Final Program and Abstracts

SIAM Conference on

Uncertainty Quantification

Raleigh Marriott City Center Hotel
Raleigh, North Carolina, USA
April 2-5, 2012

This conference is being held in cooperation with the American Statistical Association (ASA), the Statistical and Applied Mathematical Sciences Institute (SAMSI), and the United States Association for Computational Mechanics (USACM).

Sponsored by the SIAM Activity Group on Uncertainty Quantification (SIAG/UQ)

The SIAM Activity Group on Uncertainty Quantification (SIAG/UQ) fosters activity and collaboration on all aspects of the effects of uncertainty and error on mathematical descriptions of real phenomena. It seeks to promote the development of theory and methods to describe quantitatively the origin, propagation, and interplay of different sources of error and uncertainty in analysis and predictions of the behavior of complex systems, including biological, chemical, engineering, financial, geophysical, physical and social/political systems. The SIAG/UQ serves to support interactions among mathematicians, statisticians, engineers, and scientists working in the interface of computation, analysis, statistics, and probability.

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Sunday, April 1
5:00 PM - 8:00 PM

Monday, April 2
7:00 AM - 5:00 PM

Tuesday, April 3
7:45 AM - 5:00 PM

Wednesday, April 4
7:45 AM - 5:00 PM

Thursday, April 5
7:45 AM - 1:30 PM

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Raleigh, North Carolina 27601 USA
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Funding Agency

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- Admission to all technical sessions
- Business Meeting (open to SIAG/UQ members)
- Coffee breaks daily
- Room set-ups and audio/visual equipment
- Welcome Reception and Poster Session

Job Postings

Please check with the SIAM registration desk regarding the availability of job postings or visit *http://jobs.siam.org.*

Important Notice to Poster Presenters

The poster session is scheduled for Sunday, April 1 from 6:00 PM – 8:00 PM. Poster presenters are requested to set up their poster material on the provided 4' x 8' poster boards in State DEF between the hours of 2:00 PM and 6:00 PM. All materials must be posted by Sunday, April 1 at 6:00 PM, official start time of the session. Posters will remain on display through 8:00 PM. Poster displays must be removed by 8:00 PM on Sunday, April 1. Posters remaining after this time will be discarded. SIAM is not responsible for discarded posters.

SIAM Books and Journals

Display copies of books and complimentary copies of journals are available on site. SIAM books are available at a discounted price during the conference. If a SIAM books representative is not available, completed order forms and payment (credit cards are preferred) may be taken to the SIAM registration desk. The books table will close at 9:30 AM on Thursday, April 5.

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Sven Leyffer, SIAM Vice President for Programs (*vpp@siam.org*)

Get-togethers

- Sunday, April 1, 6:00 PM
  Welcome Reception
  and Poster Session
- Monday, April 2, 8:00 PM
  Business Meeting
  (open to SIAG/UQ members)

  Complimentary beer and wine will be served.

Please Note

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Minitutorials

** All Minitutorials will take place in State C**

Analysis of SPDEs and Numerical Methods for Uncertainty Quantification

This tutorial explores numerical and functional analysis techniques for solving PDEs with random input data, such as model coefficients, forcing terms, initial and boundary conditions, material properties, source and interaction terms or geometry. The resulting stochastic systems will be investigated for well-posedness and regularity. We will present detailed convergence analysis of several intrusive and non-intrusive methods for quantifying the uncertainties associated with input information onto desired quantities of interest, forward and inverse UQ approaches, and necessary theoretical results from stochastic processes and random fields, error analysis, anisotropy, adaptive methods, high-dimensional approximation, random sampling and sparse grids.

MT1 Part I: Monday, April 2, 9:30 AM - 12:30 PM
MT4 Part II: Tuesday, April 3, 9:30 AM - 12:30 PM

Organizer:

Clayton G. Webster, Oak Ridge National Laboratory, USA

Co-author:

Max Gunzburger, Florida State University, USA

Speakers:

John Burkardt, Florida State University, USA

Clayton G. Webster, Oak Ridge National Laboratory, USA

Emulation, Elicitation and Calibration

This minitutorial concerns statistical approaches to UQ based on Bayesian statistics and the use of emulators. It is organised as three 2-hour sessions. The first begins with an overview of UQ tasks (uncertainty propagation, sensitivity analysis, calibration, validation) and of how emulation (a non-intrusive technique) tackles those tasks efficiently. It continues with an introduction to elicitation, a key component of input uncertainty quantification in practice. The second session presents the basic ideas of emulation and illustrates its power for uncertainty propagation, etc. The third session is about calibration, including the importance of model discrepancy and history matching.

MT2 Part I: Monday, April 2, 2:00 PM - 4:00 PM
MT5 Part II: Tuesday, April 3, 2:00 PM - 4:00 PM
MT8 Part III: Wednesday, April 4, 2:00 PM - 4:00 PM

Organizer:

Anthony O’Hagan, University of Sheffield, United Kingdom

Speakers:

Peter Challenor, National Oceanography Centre, Southampton, United Kingdom
Anthony O’Hagan, University of Sheffield, United Kingdom
Ian Vernon, University of Durham, United Kingdom

SIAM Activity Group on Uncertainty Quantification (SIAG/UQ)

www.siam.org/activity/uq

A GREAT WAY TO GET INVOLVED!

Collaborate and interact with mathematicians and applied scientists whose work involves uncertainty quantification.

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Raleigh Marriott City Center Hotel
Raleigh, North Carolina, USA
April 2-5, 2012

ACTIVITES INCLUDE:

- Special sessions at SIAM Annual Meetings
- Biennial conference
- Website

BENEFITS OF SIAG/UQ MEMBERSHIP:

- Listing in the SIAG's online-only membership directory
- Additional $10 discount on registration at the SIAM Conference on Uncertainty Quantification (excludes student)
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- Participation in the selection of SIAG/UQ officers

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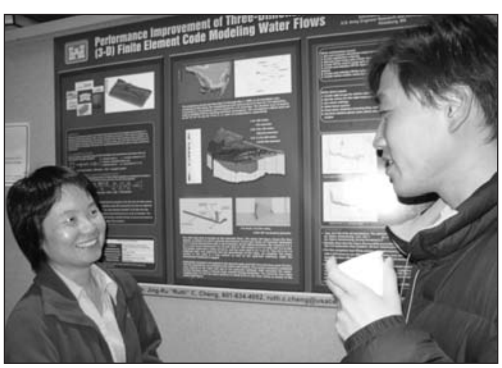

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Minitutorials

* *All minitutorials will take place in State C**

Uncertainty Quantification: Foundations and Capabilities for Model-Based Simulations

The minitutorial will present the physical motivation and mathematical foundations necessary for the formulation of well-posed UQ problems in computational science and engineering. In particular, the minitutorial will cover 1) aspects of probabilistic modeling and analysis, 2) polynomial chaos representations, 3) stochastic processes and Karhunen-Loeve expansions, 4) forward UQ including sampling, sparse-grid, stochastic Galerkin and collocation, 5) inverse problems in UQ, 6) overview of software resources, 7) summary of advanced topics.

MT3 Part I: Monday, April 2, 4:30 PM - 6:30 PM
MT6 Part II: Tuesday, April 3, 4:30 PM - 6:30 PM
MT9 Part III: Wednesday, April 4, 4:30 PM - 6:30 PM

Organizer:

Roger Ghanem, University of Southern California, USA

Speakers:

Roger Ghanem, University of Southern California, USA

Bert Debusschere, Sandia National Laboratories, USA

Introduction to Statistical Analysis of Extremes

This minitutorial will introduce the ideas and techniques involved in the analysis of both univariate and multivariate extremes. Statistical practice relies on fitting distributions suggested by asymptotic theory to a subset of data considered to be extreme. The minitutorial will introduce the fundamental asymptotic results which underlie extremes analysis via demonstrations and examples. Both block maximum and threshold exceedance approaches will be presented for both the univariate and multivariate cases. The multivariate portion of the course will largely focus on how dependence is described for extremes: via an angular measure rather than via correlation.

MT7 Wednesday, April 4, 9:30 AM - 12:30 PM

Organizer and Speaker:
Dan Cooley, Colorado State University, USA

A Tutorial on Uncertainty Quantification and Data Analysis for Inverse Problems

We will start with a brief overview of ill-posed inverse problems and regularization that includes a quick review of the necessary results from functional analysis. We then focus on uncertainty quantification for a particular class of regularization procedures using frequentist and Bayesian frameworks. We describe basic methods to assess uncertainty in each of these frameworks. This will include a review of the basic statistics and probability tools needed. We end with an introduction to exploratory data analysis methods that can be used for model validation.

MT10 Thursday, April 5, 9:30 AM - 12:30 PM

Organizer and Speaker:

Luis Tenorio, Colorado School of Mines, USA

Invited Plenary Speakers

* *All Invited Plenary Presentations will take place in State C/D **

Monday, April 2

8:15 AM - 9:00 AM

IP1 Sparse Tensor Algorithms in Uncertainty Quantification

Christoph Schwab, *ETH Zürich, Switzerland*

1:00 PM - 1:45 PM

IP2 Integrating Data from Multiple Simulation Models - Prediction and Tuning

Derek Bingham, *Simon Fraser University, Canada*

Tuesday, April 3

8:15 AM - 9:00 AM

IP3 Polynomial Chaos Approaches to Multiscale and Data Intensive Computations

Omar M. Knio, *Duke University, USA*

Invited Plenary Speakers

Wednesday, April 4

8:15 AM - 9:00 AM

IP4 Large Deviation Methods for Quantifying Uncertainty

George C. Papanicolaou, *Stanford University, USA*

1:00 PM - 1:45 PM

IP5 Model Reduction for Uncertainty Quantification of Large-scale Systems

Karen E. Willcox, *Massachusetts Institute of Technology, USA*

Thursday, April 5

8:15 AM - 9:00 AM

IP6 Statistical Approaches to Combining Models and Observations

Mark Berliner, *Ohio State University, USA*

UQ12 Program

SIAM Conference on

Uncertainty Quantification

Raleigh Marriott City Center Hotel
Raleigh, North Carolina, USA
April 2-5, 2012

Sunday, April 1

Registration

5:00 PM-8:00 PM

Room:Chancellor and Pre-Function Area

Sunday, April 1

PP1

Welcome Reception and Poster Session

6:00 PM-8:00 PM

Room:State DEF

A Statistical Decision-Theoretic Approach to Dynamic Resource Allocation for a Self-Aware Unmanned Aerial Vehicle

Doug Allaire and Karen E. Willcox, Massachusetts Institute of Technology, USA

Computational Reductions in Stochastically Driven Neuronal Models with Adaptation Currents

Victor Barranca and Gregor Kovacic, Rensselaer Polytechnic Institute, USA; David Cai, New York University, USA

A Predictive Model for Geographic Statistical Data

Jorge Diaz-Castro, University of Puerto Rico, Puerto Rico

A Stochastic Collocation Method Combined with a Reduced Basis Method to Compute Uncertainties in the Sar Induced by a Mobile Phone

Mohammed Amine Drissaoui, Laboratoire AMPERE, France

Random and Regular Dynamics of Stochastically Driven Neuronal Networks

Pamela B. Fuller, Rensselaer Polytechnic Institute, USA

Calibration of Computer Models for Radiative Shock Experiments

Jean Giorla, Commissariat à l'Energie Atomique, France; E. Falize, CEA/DAM/DIF, F-91297, Arpajon, France; C. Busschaert and B. Loupias, CEA, DAM, DIF-Bruyeres, France; M. Koenig, A. Ravasio, and A. Dizière, Ecole Polytechnique, Palaiseau, France; Josselin Garnier, Université Paris VII, France; C. Michaut, Observatoire de Paris, Meudon, France

Regional Climate Model Ensembles and Uncertainty Quantification

Tamara A. Greasby, National Center for Atmospheric Research, USA

Multiple Precision, Spatio-Temporal Computer Model Validation using Predictive Processes

Matthew J. Heaton, Stephan Sain, William Kleiber, and Michael Wiltberger, National Center for Atmospheric Research, USA; Derek Bingham, Simon Fraser University, Canada; Shane Reese, Brigham Young University, USA

Variance Based Sensitivity Analysis of Epidemic Size to Network Structure

Kyle S. Hickmann, Tulane University, USA; James (Mac) Hyman, Los Alamos National Laboratory, USA; John E. Ortmann, Tulane University, USA

Autoregressive Model for Real-Time Weather Prediction and Detecting Climate Sensitivity

Emily L. Kang, University of Cincinnati, USA; John Harlim, North Carolina State University, USA

A Split Step Adams Moulton Milstein Method for Stiff Stochastic Differential Equations

Abdul M. Khaliq, Middle Tennessee State University, USA; David A. Voss, Western Illinois University, USA

Computer Model Calibration with High and Low Resolution Model Output for Spatio-Temporal Data

William Kleiber, Stephan Sain, and Michael Wiltberger, National Center for Atmospheric Research, USA; Derek Bingham, Simon Fraser University, Canada; Shane Reese, Brigham Young University, USA

Propagating Arbitrary Uncertainties Through Models Via the Probabilistic Collocation Method

Matthew Cherry, University of Dayton, USA; Jeremy Knopp, Air Force Research Laboratory, USA

Goal-Oriented Statistical Inference

Chad E. Lieberman and Karen E. Willcox, Massachusetts Institute of Technology, USA

Uncertainty in Model Selection in Remote Sensing

Anu Määttä, Marko Laine, and Johanna Tamminen, Finnish Meteorological Institute, Helsinki, Finland

Multifidelity Approach to Variance Reduction in Monte Carlo Simulation

Leo Ng, and Karen E. Willcox, Massachusetts Institute of Technology, USA

Local Sensitivity Analysis of Stochastic Systems with Few Samples
John E. Ortmann, Tulane University, USA; James (Mac) Hyman, Los Alamos National Laboratory, USA; Kyle S. Hickmann, Tulane University, USA

Worst Case Scenario Analysis Applied to Uncertainty Quantification in Electromagnetic Simulations
Ulrich Roemer, Stephan Koch, and Thomas Weiland, Technical University Darmstadt, Germany

Constructive and Destructive Correlation Dynamics in Simple Stochastic Swimmer Models
Kajetan Sikorski, Rensselaer Polytechnic Institute, USA

Preserving Positivity in Pc Approximations Via Weighted Pc Expansions
Faidra Stavropoulou and Josef Obermaier, Helmholtz Zentrum München, Germany

Visualization of Uncertainty: Standard Deviation and Pdf's
Richard A. Strelitz, Los Alamos National Laboratory, USA

How Typical Is Solar Energy? A 6 Year Evaluation of Typical Meteorological Year Data (TMY3)
Matthew K. Williams and Shawn Kerrigan, Locus Energy, USA

Second-Order Probability for Error Analysis in Numerical Computation
Hua Chen, Yingyan Wu, Shudao Zhang, *Haibing Zhou*, and Jun Xiong, Institute of Applied Physics and Computational Mathematics, China

Uncertainty Quantification for Hydromechanical Coupling in Three Dimensional Discrete Fracture Network
Souheil M. Ezzedine, and Frederick Ryerson, Lawrence Livermore National Laboratory, USA

Monday, April 2

Registration

7:00 AM-5:00 PM

Room:Chancellor and Pre-Function Area

Opening Remarks

8:00 AM-8:15 AM

Room:State C/D

Monday, April 2

IP1

Sparse Tensor Algorithms in Uncertainty Quantification

8:15 AM-9:00 AM

Room:State C/D

Chair: Olivier P. Le Maitre, LIMSI-CNRS, France

We survey recent mathematical and computational results on sparse tensor discretizations of Partial Differential Equations (PDEs) with random inputs. The sparse Tensor discretizations allow, as a rule, to overcome the curse of dimensionality in approximating infinite dimensional problems. Results and Methods surveyed include a) regularity and N-term gpc approximation results and algorithms for elliptic and parabolic PDEs with random coefficients [joint work with A. Cohen, R. DeVore and V.H.Hoang] and b) existence and regularity results for solutions of classes of certain hyperbolic PDEs from conservation and balance laws. Multi-Level Monte-Carlo (MLMC) [joint with A. Barth] and Multi-Level Quasi-Monte-Carlo (MLQMC) [joint with I. Graham, R. Scheichl, F.Y.Kuo and I.M. Sloan] methods can be viewed as particular classes of sparse tensor discretizations. Numerical MLMC and MLQMC results for elliptic PDEs with random coefficients and for nonlinear systems of hyperbolic conservation laws are presented [joint work with S. Mishra and J. Sukys (ETH)]. We compare the performance of these methods with that of adaptive generalized polynomial chaos discretizations.

Christoph Schwab
ETH Zürich, Switzerland

Coffee Break

9:00 AM-9:30 AM

Room:Pre-Function Area

Monday, April 2

MT1

Analysis of SPDEs and Numerical Methods for Uncertainty Quantification - Part I of II

9:30 AM - 12:30 PM

For Part 2 see MT4

Room: State C

This tutorial explores numerical and functional analysis techniques for solving PDEs with random input data, such as model coefficients, forcing terms, initial and boundary conditions, material properties, source and interaction terms or geometry. The resulting stochastic systems will be investigated for well-posedness and regularity. We will present detailed convergence analysis of several intrusive and non-intrusive methods for quantifying the uncertainties associated with input information onto desired quantities of interest, forward and inverse UQ approaches, and necessary theoretical results from stochastic processes and random fields, error analysis, anisotropy, adaptive methods, high-dimensional approximation, random sampling and sparse grids.

Organizer:

Clayton G. Webster, Oak Ridge National Laboratory, USA

Speakers:

John Burkardt, Florida State University, USA

Clayton Webster, Oak Ridge National Laboratory, USA

Monday, April 2

MS1

Frontiers in Emulation

9:30 AM-11:30 AM

Room:State D

The area of computer models is an emerging and highly topical field of statistical research, with many challenges and an enormous range of applications. Full uncertainty quantification regarding the complex physical system centres around the use of an emulator: a fast stochastic function which replaces the complex and expensive physical model. Despite their successes, emulators still face several challenges both in terms of their construction and their use in various applications. Here, recent developments at the frontiers of emulation methodology are discussed including efficient calibration techniques, super-parameterisation and solutions to ill-conditioning. Applications in Oceanic, Galaxy formation and Natural History models will be discussed.

Organizer: Ian Vernon
University of Durham, United Kingdom

9:30-9:55 History Matching: An alternative to Calibration for a Galaxy Formation Simulation
Ian Vernon, University of Durham, United Kingdom

10:00-10:25 Emulation of Count Data in Healthcare Models
Ben Youngman, University of Sheffield, United Kingdom

10:30-10:55 Effective and Efficient Handling of Ill-Conditioned Correlation Matrices in Kriging and Gradient Enhanced Kriging Emulators through Pivoted Cholesky Factorization
Keith Dalbey, Sandia National Laboratories, USA

11:00-11:25 Super-parameterisation of Oceanic Deep Convection using Emulators
Yiannis Andrianakis, University of Southampton, United Kingdom

Monday, April 2

MS2

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part I of V

9:30 AM-11:30 AM

Room:State A

For Part 2 see MS11

Uncertainty quantification in computational science and engineering has two main components: (i) modeling of the uncertainty in the input parameters, consistent with available information, physical constraints, and prior knowledge; (ii) the forward propagation of input uncertainty to the output quantities used in engineering design and regulatory requirements. This minisymposium focuses on the stochastic approach to uncertainty quantification in computational science and engineering; it aims to showcase emerging methodologies for building parametric and nonparametric stochastic models for uncertain input parameters, eventually involving the solution of stochastic inverse problems, as well as innovative techniques for propagating input stochasticity through complex differential models and computing statistics of the output quantities of interest.

Organizer: Youssef M. Marzouk
Massachusetts Institute of Technology, USA

Organizer: Olivier LeMaitre
LIMSI-CNRS, France

Organizer: Fabio Nobile
EPFL, Switzerland

9:30-9:55 Bayesian Inference with Optimal Maps
Tarek El Moselhy and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

10:00-10:25 Nonparametric Bayesian Inference for Inverse Problems
Andrew Stuart, University of Warwick, United Kingdom

10:30-10:55 Sample-based UQ via Computational Linear Algebra (Not MCMC)
Colin Fox, University of Otago, New Zealand

continued on next page

Monday, April 2

MS2

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part I of V

continued

11:00-11:25 Toward Extreme-scale Stochastic Inversion

Tan Bui, University of Texas at Austin, USA; Carsten Burstedde, Universitaet Bonn, Germany; *Omar Ghattas*, James R. Martin, Georg Stadler, and Lucas Wilcox, University of Texas at Austin, USA

Monday, April 2

MS3

Stochastic Sensitivity Analysis for Correlated Inputs

9:30 AM-11:30 AM

Room:State B

Many mathematical models use a large number of poorly-known parameters as inputs. Quantifying the influence of each of these parameters is one of the aims of sensitivity analysis. Stochastical approaches in the case of independent inputs have been widely developed. This session focus on the recent results derived in the more realistic case where input parameters may be correlated. The main difficulty is then to take into account the joint inputs distribution which is often unknown in practice. Various measures and computation tools will be described in the four next talks.

Organizer: Clémentine Prieur

Université Joseph Fourier and INRIA, France

9:30-9:55 Sensitivity Indices Based on a Generalized Functional ANOVA

Clémentine Prieur, Université Joseph Fourier and INRIA, France; Gaelle Chastiang, INRIA, France; Fabrice Gamboa, University of Toulouse, France

10:00-10:25 Global Sensitivity Analysis for Systems with Independent and/or Correlated Inputs

Herschel Rabitz and Genyuan Li, Princeton University, USA

10:30-10:55 Variance-based Sensitivity Indices for Models with Correlated Inputs Using Polynomial Chaos Expansions

Bruno Sudret, Université Paris-Est, France; Yann Caniou and Alexandre Micol, Phimeca, France

11:00-11:25 Global Sensitivity Analysis with Correlated Inputs: Numerical Aspects in Distribution-Based Sensitivity Measures

Emanuele Borgonovo, Bocconi University, Italy

Monday, April 2

MS4

Kriging-based Surrogate Models for Expensive Computer Codes

9:30 AM-11:30 AM

Room:State E

Kriging-based surrogate models have been widely developed in computer experiments. The objective of this mini-symposium is to present recent advances in kriging to perform optimization, statistical prediction, and risk analysis. In particular, the case of codes with tunable precision and their exploitation – with stochastic simulators and partial converged simulations – are presented. To conclude the symposium, a presentation describing a problem with complex inputs is given. It will be the opportunity to exchange on different methodologies and to consider how they can benefit mutually.

Organizer: Loic Le Gratiet

Université Paris VII, France

9:30-9:55 Sampling Strategy for Stochastic Simulators with Heterogeneous Noise

Loic Le Gratiet and Josselin Garnier, Université Paris VII, France

10:00-10:25 Optimization of Expensive Computer Experiments Using Partially Converged Simulations and Space-time Gaussian Processes

Victor Picheny, CERFACS, France

10:30-10:55 Quantifying and Reducing Uncertainties on a Set of Failure Using Random Set Theory and Kriging

Chevalier Clément, IRSN and UNIBE, France; David Ginsbourger, University of Berne, Switzerland; Julien Bect, SUPELEC, France; Ilya Molchanov, University of Berne, Switzerland

11:00-11:25 Models with Complex Uncertain Inputs

David M. Steinberg, Tel Aviv University, Israel

Monday, April 2

MS5

A Posteriori Error Estimation for Reliable Uncertainty Quantification - Part I of II

9:30 AM-11:30 AM

Room:State F

For Part 2 see MS14

A posteriori error estimation has a rich history in the analysis of partial differential equations and is a standard verification technique for deterministic models. The extension of error estimation techniques to stochastic models has been the subject of increasing interest in recent years. Themes of this minisymposium include theoretical and numerical analysis of errors in the propagation of uncertainty through computational models resulting from discretization, the use of surrogate models/emulators, and sampling. Both forward and inverse/inference problems may be considered. The intent of this minisymposium is to bring together researchers to report on recent developments and to facilitate discussion and collaboration.

Organizer: Tim Wildey
Sandia National Laboratories, USA

Organizer: Troy Butler
University of Texas at Austin, USA

9:30-9:55 A Posteriori Error Analysis and Adaptive Sampling for Probabilities using Surrogate Models
Tim Wildey, Sandia National Laboratories, USA; Troy Butler, University of Texas at Austin, USA

10:00-10:25 Approximation and Error Estimation in High Dimensional Stochastic Collocation Methods on Arbitrary Sparse Samples
Rick Archibald, Oak Ridge National Laboratory, USA

10:30-10:55 Spatially Varying Stochastic Expansions for Embedded Uncertainty Quantification
Eric C. Cyr, Sandia National Laboratories, USA

11:00-11:25 Simultaneous Local and Dimension Adaptive Sparse Grids for Uncertainty Quantification
John D. Jakeman, Sandia National Laboratories, USA; Stephen G. Roberts, Australian National University, Australia

Monday, April 2

MS6

Data Analysis and Inference in Functional Spaces; Statistical and Numerical Approaches to Uncertainty Estimation - Part I of II

9:30 AM-11:30 AM

Room:Congressional A

For Part 2 see MS15

This minisymposium considers models at the interplay between statistics and numerical analysis, dealing with uncertainty quantification and variability estimation in functional space settings. The analysis of complex and high-dimensional data and problems (images, functional signals and dynamics, shapes, etc) calls in fact for the merging of advanced statistical and numerical expertise. The minisymposium aims in particular at showcasing recent and innovative techniques for functional data analysis, including penalized smoothing with differential regularizations, statistical inference and functional parameter estimation in differential models.

Organizer: Fabio Nobile
EPFL, Switzerland

Organizer: Laura M. Sangalli
Politecnico di Milano, Italy

Organizer: Piercesare Secchi
Politecnico di Milano, Italy

9:30-9:55 Spatial Spline Regression Models
Laura M. Sangalli, Politecnico di Milano, Italy; Laura Azzimonti, Politecnico di Milano, Italy; James O. Ramsay, McGill University, Canada; Piercesare Secchi, Politecnico di Milano, Italy

10:00-10:25 Sparse Grids for Regression
Jochen Garcke, University of Bonn, Germany

10:30-10:55 Heat Kernel Smoothing on an Arbitrary Manifold Using the Laplace-Beltrami Eigenfunctions
Moo Chung, University of Wisconsin, Madison, USA

11:00-11:25 Second-Order Comparison of Random Functions
Victor M. Panaretos, EPFL, Switzerland

Monday, April 2

MS7

Scalable Methods for Uncertainty Quantification

9:30 AM-11:30 AM

Room:Congressional B

Uncertainty Quantification (UQ) in complex dynamic networks is essential for robust operation of commercial and defense systems. This session presents recent advances in fast UQ methods for high dimensional dynamical systems that arise in industry. In particular we will present a new iterative scheme for scalable propagation of uncertainty through networks of switching systems and methods for uncertainty quantification utilizing sensitivity analysis and model reduction. We will also demonstrate how scalable UQ can be used to design energy efficient building systems and discuss recent advances in wide usability of non-intrusive polynomial chaos methods for high dimensional problems.

Organizer: Tuhin Sahai
United Technologies Research Center, USA

9:30-9:55 Global Sensitivity and Reduction of Very High-Dimensional Models with Correlated Inputs
Vladimir Fonoberov, AIMdyn, Inc., USA; Igor Mezic, University of California, Santa Barbara, USA

10:00-10:25 NIPC: A MATLAB GUI for Wider Usability of Nonintrusive Polynomial Chaos
Kanali Togawa and Antonello Monti, RWTH Aachen University, Germany

10:30-10:55 Iterative Methods for Propagating Uncertainty through Networks of Switching Dynamical Systems
Tuhin Sahai, United Technologies Research Center, USA

11:00-11:25 Uncertainty Quantification in Energy Efficient Building Retrofit Design
Slaven Peles, United Technologies Research Center, USA

Monday, April 2

MS8

Sensitivity Analysis for Investigating Uncertainty in Model Predictions

9:30 AM-11:30 AM

Room:University A

In most computer model predictions, there will be two sources of uncertainty: uncertainty in the choice of model input parameters, and uncertainty in how well the computer model represents reality ("model discrepancy"). We consider using sensitivity analysis tools to investigate both sources of uncertainty. Such analyses can be used to understand how best to reduce prediction uncertainty, either by learning more about particular input parameters, or by improving the structure of the model to better represent reality. Tools for computationally expensive models are presented, and applications are given in aerosol modelling, infectious disease modelling, and health economics.

Organizer: Jeremy Oakley
University of Sheffield, United Kingdom

9:30-9:55 Sensitivity Analysis for Complex Computer Models
Jeremy Oakley, University of Sheffield, United Kingdom

10:00-10:25 Sensitivity Analysis of a Global Aerosol Model to Quantify the Effect of Uncertain Model Parameters
Lindsay Lee and Kenneth Carslaw, University of Leeds, United Kingdom

10:30-10:55 Speeding up the Sensitivity Analysis of an Epidemiological Model
John Paul Gosling, University of Leeds, United Kingdom

11:00-11:25 Managing Model Uncertainty in Health Economic Decision Models
Mark Strong and *Jeremy Oakley*, University of Sheffield, United Kingdom

Monday, April 2

MS9

Hybrid Uncertainty Quantification Methods for Multi-physics Application

9:30 AM-11:30 AM

Room:University B

Uncertainty quantification (UQ) for multi-physics applications is challenging for both intrusive and non-intrusive methods. A question naturally arises: "Can we take the best of both worlds to introduce a 'hybrid' UQ methodology for multi-physics applications?" This minisymposium brings together researchers who are exploring hybrid UQ methods. In particular, we emphasize techniques that propagate global uncertainties yet allow individual physics components to use their local intrusive or non-intrusive UQ methods. Relevant issues for discussions are: hybrid uncertainty propagation algorithms, dimension reduction, Bayesian data fusion techniques, design of hybrid computational framework, and scalable algorithms for hybrid UQ.

Organizer: Charles Tong
Lawrence Livermore National Laboratory, USA

Organizer: Gianluca Iaccarino
Stanford University, USA

9:30-9:55 A High Performance Hybrid pce Framework for High Dimensional UQ Problems
Akshay Mittal, Stanford University, USA

10:00-10:25 Hybrid UQ Method for Multi-Species Reactive Transport
Xiao Chen, Brenda Ng, Yunwei Sun, and Charles Tong, Lawrence Livermore National Laboratory, USA

10:30-10:55 Stochastic Dimension Reduction Techniques for Uncertainty Quantification of Multiphysics Systems
Eric Phipps, Sandia National Laboratories, USA; Maarten Arnst, Université de Liege, Belgium; Paul Constantine, Stanford University, USA; Roger Ghanem, University of Southern California, USA; John Red-Horse and Tim Wildey, Sandia National Laboratories, USA

11:00-11:25 Preconditioners/Multigrid for Stochastic Polynomial Chaos Formulations of the Diffusion Equation
Barry Lee, Pacific Northwest National Laboratory, USA

Monday, April 2

Lunch Break

11:30 AM-1:00 PM

Attendees on their own

IP2

Integrating Data from Multiple Simulation Models - Prediction and Tuning

1:00 PM-1:45 PM

Room:State C/D

Chair: James Berger, Duke University, USA

Simulation of complex systems has become commonplace in most areas of science. In some settings, several simulators are available to explore the system, each with varying levels of fidelity. In this talk, Bayesian methodology for integrating outputs from multi-fidelity computer models, and field observations, to build a predictive model of a physical system is presented. The problem is complicated because inputs to the computer models are not all the same and the simulators have inputs (tuning parameters) that must be estimated from data. The methodology is demonstrated on an application from the University of Michigan's Center for Radiative Shock Hydrodynamics.

Derek Bingham
Simon Fraser University, Canada

Intermission

1:45 PM-2:00 PM

Monday, April 2

MT2

Emulation, Elicitation and Calibration - Part I of III

2:00 PM - 4:00 PM

For Part 2 see MT5

Room: State C

This minitutorial concerns statistical approaches to UQ based on Bayesian statistics and the use of emulators. It is organised as three 2-hour sessions. The first begins with an overview of UQ tasks (uncertainty propagation, sensitivity analysis, calibration, validation) and of how emulation (a non-intrusive technique) tackles those tasks efficiently. It continues with an introduction to elicitation, a key component of input uncertainty quantification in practice. The second session presents the basic ideas of emulation and illustrates its power for uncertainty propagation, etc. The third session is about calibration, including the importance of model discrepancy and history matching.

Organizer:

Anthony O'Hagan, University of Sheffield, United Kingdom

Speakers:

Peter Challenor, National Oceanography Centre, Southampton, United Kingdom

Anthony O'Hagan, University of Sheffield, United Kingdom

Ian Vernon, University of Durham, United Kingdom

Monday, April 2

CP1

UQ in Material Science

2:00 PM-4:00 PM

Room:University A

Chair: Sourish Chakravarty, State University of New York at Buffalo, USA

2:00-2:15 Capturing Signatures of *microcracks* from *macrolevel* Responses

Sonjoy Das and *Sourish Chakravarty*, State University of New York at Buffalo, USA

2:20-2:35 Uncertainty Quantification in Image Processing

Torben Pätz, University of Bremen, Germany; Michael Kirby, University of Utah, USA; Tobias Preusser, University of Bremen, Germany

2:40-2:55 Identification of Uncertain Time-Dependent Material Behavior with Artificial Neural Networks

Steffen Freitag and Rafi L. Muhanna, Georgia Institute of Technology, USA

3:00-3:15 Statistics of Mesoscale Conductivities and Resistivities in Polycrystalline Graphite

Shivakumar I. Ranganathan, American University of Sharjah, United Arab Emirates; Martin Ostoja-Starzewski, University of Illinois at Urbana-Champaign, USA

3:20-3:35 Random Fields for Stochastic Mechanics of Materials

Martin Ostoja-Starzewski, University of Illinois at Urbana-Champaign, USA; Luis Costa, US Army ARL-ARDEC, USA; Emilio Porcu, Georg-August-Universität Göttingen, Germany

3:40-3:55 Uncertainty Quantification of Discrete Element Micro-Parameters Conditioned on Sample Preparation of Homogeneous Particle Materials

Patrick R. Noble, Tam Doung, and Zenon Medina-Cetina, Texas A&M University, USA

Monday, April 2

CP2

Model Validation & Discrepancy

2:00 PM-4:00 PM

Room:University B

Chair: Ajaykumar Rajasekharan, Seagate Technology International, USA

2:00-2:15 Quantifying Uncertainty and Accounting Model Discrepancy in Slider Air Bearing Simulations for Calibration and Prediction

Ajaykumar Rajasekharan and Paul J Sonda, Seagate Technology International, USA

2:20-2:35 Model Inadequacy Quantification for Simulations of Structures Using Bayesian Inference

Richard Dwight and Hester Bijl, Delft University of Technology, Netherlands

2:40-2:55 Model Discrepancy and Uncertainty Quantification

Jenny Brynjarsdottir, Statistical and Applied Mathematical Sciences Institute, USA; Anthony O'Hagan, University of Sheffield, United Kingdom

3:00-3:15 Quantitative Model Validation Techniques: New Insights

You Ling and Sankaran Mahadevan, Vanderbilt University, USA

3:20-3:35 Integration of Verification, Validation, and Calibration Activities for Overall Uncertainty Quantification

Shankar Sankararaman and Sankaran Mahadevan, Vanderbilt University, USA

3:40-3:55 Dynamic Model Validation of a 160 Mw Steam Turbine Lp Last Stage (L-0) Blade

Sadegh Rahrovani and Thomas Abrahamsson, Chalmers University of Technology, Sweden

Monday, April 2

MS10

Numerical Methods for High-Dimensional Uncertainty Quantification - Part I of V

2:00 PM-4:00 PM

Room:State D

For Part 2 see MS17

There has been a growing interest in developing scalable numerical methods for stochastic computation in the presence of high-dimensional random inputs. This is motivated by the need to reduce the issue of curse-of-dimensionality, i.e., exponential increase of computational complexity, in predictive simulation of physical systems where accurate description of uncertainties entails a large number of random variables. To this end, several novel approaches based on multi-level, reduced order, sparse, and low-rank approximations have been recently developed. This minisymposium presents state-of-the-art in such developments for various aspects of high-dimensional stochastic computation, including analysis, algorithms, implementation, and applications.

Organizer: Dongbin Xiu
Purdue University, USA

Organizer: Alireza Doostan
University of Colorado at Boulder, USA

2:00-2:25 Stochastic Collocation Methods in Unstructured Grids

Akil Narayan and Dongbin Xiu, Purdue University, USA

2:30-2:55 First Order k-th Moment Finite Element Analysis of Nonlinear Operator Equations with Stochastic Data

Alexey Chernov, University of Bonn, Germany; Christoph Schwab, ETH Zürich, Switzerland

3:00-3:25 An Adaptive Iterative Method for High-dimensional Stochastic PDEs

Tarek El Moselhy and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

3:30-3:55 Adjoint Enhancement Within Global Stochastic Methods

Michael S. Eldred, Eric Phipps, and Keith Dalbey, Sandia National Laboratories, USA

Monday, April 2

MS11

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part II of V

2:00 PM-4:00 PM

Room:State A

For Part 1 see MS2
For Part 3 see MS18

Uncertainty quantification in computational science and engineering has two main components: (i) modeling of the uncertainty in the input parameters, consistent with available information, physical constraints, and prior knowledge; (ii) the forward propagation of input uncertainty to the output quantities used in engineering design and regulatory requirements. This minisymposium focuses on the stochastic approach to uncertainty quantification in computational science and engineering; it aims to showcase emerging methodologies for building parametric and nonparametric stochastic models for uncertain input parameters, eventually involving the solution of stochastic inverse problems, as well as innovative techniques for propagating input stochasticity through complex differential models and computing statistics of the output quantities of interest.

Organizer: Youssef M. Marzouk
Massachusetts Institute of Technology, USA

Organizer: Olivier LeMaitre
LIMSI-CNRS, France

Organizer: Fabio Nobile
EPFL, Switzerland

2:00-2:25 Data Analysis Methods for Inverse Problems

Luis Tenorio, Colorado School of Mines, USA

2:30-2:55 A Dynamic Programming Approach to Sequential and Nonlinear Bayesian Experimental Design

Xun Huan, and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

continued in next column

3:00-3:25 Identification of Polynomial Chaos Representations in High Dimension

Guillaume Perrin, Christian Soize, and Denis Duhamel, Université Paris-Est, France; Christine Funfschilling, SNCF, France

3:30-3:55 Inverse Problems for Nonlinear Systems via Bayesian Parameter Identification

Bojana V. Rosic, Oliver Pajonk, Alexander Litvinenko, and Hermann G. Matthies, Technical University Braunschweig, Germany; Anna Kucerova and Jan Sykora, Czech Technical University, Prague, Czech Republic

Monday, April 2

MS12

Optimization Methods for Stochastic Inverse Problems - Part I of II

2:00 PM-4:00 PM

Room:State B

For Part 2 see MS19

A stochastic inverse problem is a general framework used to convert uncertainties in observed measurements into useful information about a physical system of interest. The transformation from statistical data to random model parameters is a result of the interaction of a physical system with the object that we wish to infer properties about. As such, this minisymposium focuses on optimization methods for stochastic identification/control of input random data constrained by systems partial differential equations. The optimization approaches presented in this session allow for the optimal identification of statistical moments or even the whole probability distribution of the input random fields, given the probability distribution of some responses of the system.

Organizer: Clayton G. Webster
Oak Ridge National Laboratory, USA

Organizer: Max Gunzburger
Florida State University, USA

Organizer: Hyung-Chun Lee
Ajou University, South Korea

2:00-2:25 Analysis and Finite Element Approximations of Optimal Control Problems for Stochastic PDEs
Hyung-Chun Lee, Ajou University, South Korea

2:30-2:55 Generalized Methodology for Inverse Modeling Constrained by SPDEs
Catalin S. Trenchea, University of Pittsburgh, USA; Max Gunzburger, Florida State University, USA; Clayton G. Webster, Oak Ridge National Laboratory, USA

continued in next column

3:00-3:25 Least-Squares Estimation of Distributed Random Diffusion Coefficients
Hans-Werner van Wyk and Jeff Borggaard, Virginia Polytechnic Institute & State University, USA

3:30-3:55 Stochastic Inverse Problems via Probabilistic Graphical Model Techniques
Nicholas Zabaras and Peng Chen, Cornell University, USA

Monday, April 2

MS13

UQ for Model Calibration, Validation and Predictions - Part I of II

2:00 PM-4:00 PM

Room:State E

For Part 2 see MS20

The ultimate purpose of computational models is to predict quantities of interest (QoIs) to decision makers. The incorporation of uncertainty in computational models is key for predicting QoIs more realistically, improving the chances for more informed and better decisions. The whole prediction process might involve not only the forward propagation of uncertainties, but also model calibration, data assessment (which data is more informative?), and model ranking (which models are “better”?). This minisymposium targets scientists that develop and use UQ for model calibration, validation and predictions. The participation of a wide variety of algorithms and applications is encouraged.

Organizer: Gabriel A. Terejanu
University of Texas at Austin, USA

Organizer: Ernesto E. Prudencio
Institute for Computational Engineering and Sciences, USA

2:00-2:25 Challenges on Incorporating Uncertainty in Computational Model Predictions
Ernesto E. Prudencio, Institute for Computational Engineering and Sciences, USA; Gabriel A. Terejanu, University of Texas at Austin, USA

2:30-2:55 A Randomized Iterative Proper Orthogonal Decomposition (RI-POD) Technique for Model Identification
Dan Yu and Suman Chakravorty, Texas A&M University, USA

3:00-3:25 Sparse Bayesian Techniques for Surrogate Creation and Uncertainty Quantification
Nicholas Zabaras and Ilias Bilionis, Cornell University, USA

3:30-3:55 A Stochastic Collocation Approach to Constrained Optimization for Random Data Estimation Problems
Max Gunzburger, Florida State University, USA; *Catalin S. Trenchea*, University of Pittsburgh, USA; Clayton G. Webster, Oak Ridge National Laboratory, USA

Monday, April 2

MS14

A Posteriori Error Estimation for Reliable Uncertainty Quantification - Part II of II

2:00 PM-3:30 PM

Room:State F

For Part 1 see MS5

A posteriori error estimation has a rich history in the analysis of partial differential equations and is a standard verification technique for deterministic models. The extension of error estimation techniques to stochastic models has been the subject of increasing interest in recent years. Themes of this minisymposium include theoretical and numerical analysis of errors in the propagation of uncertainty through computational models resulting from discretization, the use of surrogate models/emulators, and sampling.
Both forward and inverse/inference problems may be considered. The intent of this minisymposium is to bring together researchers to report on recent developments and to facilitate discussion and collaboration.

Organizer: Tim Wildey
Sandia National Laboratories, USA

Organizer: Troy Butler
University of Texas at Austin, USA

2:00-2:25 Estimating and Bounding Errors in Distributions Propagated via Surrogate Models

Troy Butler and Clint Dawson, University of Texas at Austin, USA; Tim Wildey, Sandia National Laboratories, USA

2:30-2:55 An Adjoint Error Estimation Technique Using Finite Volume Methods for Hyperbolic Equations

Jeffrey M. Connors, University of Pittsburgh, USA; Jeffrey W. Banks, Lawrence Livermore National Laboratory, USA; Jeffrey A. Hittinger and Carol S. Woodward, Lawrence Livermore National Laboratory, USA

3:00-3:25 Application of Goal-Oriented Error Estimation Methods to Statistical Quantities of Interest

Corey Bryant and Serge Prudhomme, University of Texas at Austin, USA

Monday, April 2

MS15

Data Analysis and Inference in Functional Spaces; Statistical and Numerical Approaches to Uncertainty Estimation - Part II of II

2:00 PM-4:00 PM

Room:Congressional A

For Part 1 see MS6

This minisymposium considers models at the interplay between statistics and numerical analysis, dealing with uncertainty quantification and variability estimation in functional space settings. The analysis of complex and high-dimensional data and problems (images, functional signals and dynamics, shapes, etc) calls in fact for the merging of advanced statistical and numerical expertise. The minisymposium aims in particular at showcasing recent and innovative techniques for functional data analysis, including penalized smoothing with differential regularizations, statistical inference and functional parameter estimation in differential models.

Organizer: Fabio Nobile
EPFL, Switzerland

Organizer: Laura M. Sangalli
Politecnico di Milano, Italy

Organizer: Piercesare Secchi
Politecnico di Milano, Italy

2:00-2:25 Nonparametric Estimation of Diffusions: A Differential Equations Approach

Omiros Papaspiliopoulos, Universitat Pompeu Fabra, Spain; Yvo Pokern, University College, London, United Kingdom; Gareth O. Roberts, Warwick University, United Kingdom; Andrew M. Stuart, University of Warwick, United Kingdom

2:30-2:55 Large-scale Seismic Inversion: Elastic-acoustic Coupling, DG Discretization, and Uncertainty Quantification

Tan Bui, University of Texas at Austin, USA; Carsten Burstedde, Universitaet Bonn, Germany; Omar Ghattas, Georg Stadler, James R. Martin, and Lucas Wilcox, University of Texas, Austin, USA

continued in next column

3:00-3:25 Computation of Posterior Distribution in Ordinary Differential Equations with Transport Partial Differential Equations

Nicolas J-B Brunel and Vincent Torri, Université Evry Val d'Essonne, France

3:30-3:55 A Statistical Approach to Data Assimilation for Hemodynamics

Alessandro Veneziani, Emory University, USA; Marta D'Elia, Emory University, USA

Monday, April 2

MS16

Statistical Surrogates and Functional Output

2:00 PM-4:00 PM

Room:Congressional B

UQ of large complex computer models requires use of fast surrogates or approximations, which are fitted with relatively few runs of the model. Statistical surrogates provide a distribution for the prediction of model output at each input; this full distribution is useful in complex UQ tasks that require combination of all sources of uncertainty, since the distributions can be coherently combined through probability theory. The most used statistical emulators for UQ are Gaussian Processes (GPs). This session presents recent perspectives on GPs, suggests improved methods of fitting GPs, and addresses propagation through the dynamics of the model.

Organizer: M.J. Bayarri
University of Valencia, Spain

Organizer: James Berger
Duke University, USA

2:00-2:25 Statistical Approximation of Computer Model Output aka Emulation of Simulation

Jerry Sacks, National Institute of Statistical Sciences, USA

2:30-2:55 Improving Gaussian Stochastic Process Emulators

Danilo Lopes, SAMSI, USA

3:00-3:25 Emulating Dynamic Models: An Overview of Suggested Approaches

Peter Reichert, Swiss Federal Institute of Aquatic Science and Technology, Switzerland

3:30-3:55 Toward Improving Statistical Components of Multi-scale Simulation Schemes

Peter R. Kramer, Rensselaer Polytechnic Institute, USA; Sorin Mitran, University of North Carolina at Chapel Hill, USA; Sunli Tang, Rensselaer Polytechnic Institute, USA; M.J. Bayarri, University of Valencia, Spain; James Berger, Duke University, USA; Murali Haran, Pennsylvania State University, USA; Hans Rudolf Kuensch, ETH Zürich, Switzerland

Monday, April 2

Coffee Break

4:00 PM-4:30 PM

Room:Pre-Function Area

MT3

Uncertainty Quantification: Foundations and Capabilities for Model-Based Simulations - Part I of III

4:30 PM - 6:30 PM

For Part 2 see MT6

Room: State C

The minitutorial will present the physical motivation and mathematical foundations necessary for the formulation of well-posed UQ problems in computational science and engineering. In particular, the minitutorial will cover 1) aspects of probabilistic modeling and analysis, 2) polynomial chaos representations, 3) stochastic processes and Karhunen-Loeve expansions, 4) forward UQ including sampling, sparse-grid, stochastic Galerkin and collocation, 5) inverse problems in UQ, 6) overview of software resources, 7) summary of advanced topics.

Organizer:

Roger Ghanem, University of Southern California, USA

Speakers:

Roger Ghanem, University of Southern California, USA

Bert Debusschere, Sandia National Laboratories, USA

Monday, April 2

CP3

Multi-fidelity UQ

4:30 PM-6:10 PM

Room:Congressional B

Chair: Matthew Parno, Massachusetts Institute of Technology, USA

4:30-4:45 Contour Estimation Via Two Fidelity Computer Simulators under Limited Resources

Ray-Bing Chen, National Cheng Kung University, Taiwan; Ying-Chao Hung, National Chengchi University, Taiwan; Weichung Wang and Sung-Wei Yen, National Taiwan University, Taiwan

4:50-5:05 Dimension Reduction and Measure Transformation in Stochastic Multiphysics Modeling

Maarten Arnst, Université de Liege, Belgium; Roger Ghanem, University of Southern California, USA; Eric Phipps and John Red-Horse, Sandia National Laboratories, USA

5:10-5:25 Improvement in Multifidelity Modeling Using Gaussian Processes

Celine Helbert and Federico Zertuche, Université de Grenoble I, France

5:30-5:45 A Multiscale Framework for Bayesian Inference in Elliptic Problems

Matthew Parno and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

5:50-6:05 An Uncertainty Quantification Approach to Assess Geometry-Optimization Research Spaces through Karhunen-Loève Expansion

Matteo Diez, CNR-INSEAN, Italy; Daniele Peri, INSEAN, Italy; Frederick Stern, University of Iowa, USA; Emilio Campana, INSEAN, Italy

Monday, April 2

CP4

UQ & Computation

4:30 PM-6:30 PM

Room:University A

Chair: Jeroen Witteveen, Stanford University, USA

4:30-4:45 Efficient Evaluation of Integral Quantities in Rdo by Sequential Quadrature Formulas

Daniele Peri, INSEAN, Italy; Matteo Diez, CNR-INSEAN, Italy

4:50-5:05 Robust Approximation of Stochastic Discontinuities

Jeroen Witteveen and Gianluca Iaccarino, Stanford University, USA

5:10-5:25 Super Intrusive Polynomial Chaos for An Elliptic Pde for Heat Transfer

Andrew Barnes, GE Global Research, USA; Jose Cordova, General Electric Global Research Center, USA

5:30-5:45 Adjoint Error Estimation for Stochastic Collocation Methods

Bettina Schieche, and Jens Lang, Technical University Darmstadt, Germany

5:50-6:05 A Library for Large Scale Parallel Modeling and Simulation of Spatial Random Fields

Brian Carnes and John Red-Horse, Sandia National Laboratories, USA

6:10-6:25 Application of a Novel Adaptive Finite Difference Solution of The Fokker-Planck Equation for Uncertainty Quantification

Mani Razi, Peter Attar, and Prakash Vedula, University of Oklahoma, USA

Monday, April 2

CP5

Emulation

4:30 PM-6:30 PM

Room:University B

Chair: Alex A. Gorodetsky, Massachusetts Institute of Technology, USA

4:30-4:45 A Learning Method for the Approximation of Discontinuous Functions in High Dimensions

Alex A. Gorodetsky and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

4:50-5:05 Svr Regression with Polynomial Kernel and Monotonicity Constraints

Francois Wahl, IFPEN, USA

5:10-5:25 Constrained Gaussian Process Modeling

Sebastien Da Veiga, IFP, France; Amandine Marrel, CEA, France

5:30-5:45 Shape Invariant Model Approach to Functional Outputs Modelling

Ekaterina Sergienko and Fabrice Gamboa, University of Toulouse, France; Daniel Busby, IFP Energies Nouvelles, France

5:50-6:05 Reduced Basis Surrogate Models and Sensitivity Analysis

Alexandre Janon, Maelle Nodet, and Clémentine Prieur, Université Joseph Fourier and INRIA, France

6:10-6:25 Improvement of the Accuracy of the Prediction Variance Using Bayesian Kriging: Application to Three Industrial Case Studies

Celine Helbert, Université de Grenoble I, France

Monday, April 2

MS17

Numerical Methods for High-Dimensional Uncertainty Quantification - Part II of V

4:30 PM-6:30 PM

Room:State D

For Part 1 see MS10
For Part 3 see MS23

There has been a growing interest in developing scalable numerical methods for stochastic computation in the presence of high-dimensional random inputs. This is motivated by the need to reduce the issue of curse-of-dimensionality, i.e., exponential increase of computational complexity, in predictive simulation of physical systems where accurate description of uncertainties entails a large number of random variables. To this end, several novel approaches based on multi-level, reduced order, sparse, and low-rank approximations have been recently developed. This minisymposium presents state-of-the-art in such developments for various aspects of high-dimensional stochastic computation, including analysis, algorithms, implementation, and applications.

Organizer: Alireza Doostan
University of Colorado at Boulder, USA

Organizer: Dongbin Xiu
Purdue University, USA

4:30-4:55 A Compressive Sampling Approach for the Solution of High-dimensional Stochastic PDEs

Alireza Doostan, University of Colorado at Boulder, USA

5:00-5:25 PDE with Random Coefficient as a Problem in Infinite-dimensional Numerical Integration

Ian H. Sloan, University of New South Wales, Australia

5:30-5:55 Adaptive Sparse Grids for Stochastic Collocation on Hybrid Architectures

Rick Archibald, Oak Ridge National Laboratory, USA

6:00-6:25 Tensor-based Methods for Uncertainty Propagation: Alternative Definitions and Algorithms

Anthony Nouy, Billaud Marie, Mathilde Chevreuil, Rai Prashant, and Zahm Olivier, Université de Nantes, France

Monday, April 2

MS18

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part III of V

4:30 PM-6:30 PM

Room:State A

For Part 2 see MS11
For Part 4 see MS24

Uncertainty quantification in computational science and engineering has two main components: (i) modeling of the uncertainty in the input parameters, consistent with available information, physical constraints, and prior knowledge; (ii) the forward propagation of input uncertainty to the output quantities used in engineering design and regulatory requirements. This minisymposium focuses on the stochastic approach to uncertainty quantification in computational science and engineering; it aims to showcase emerging methodologies for building parametric and nonparametric stochastic models for uncertain input parameters, eventually involving the solution of stochastic inverse problems, as well as innovative techniques for propagating input stochasticity through complex differential models and computing statistics of the output quantities of interest.

Organizer: Youssef M. Marzouk
Massachusetts Institute of Technology, USA

Organizer: Olivier LeMaitre
LIMSI-CNRS, France

Organizer: Fabio Nobile
EPFL, Switzerland

4:30-4:55 Optimized Polynomial Approximations of PDEs with Random Coefficients

Joakim Beck, KAUST Supercomputing Laboratory, Saudi Arabia; *Fabio Nobile*, EPFL, Switzerland; Lorenzo Tamellini, Politecnico di Milano, Italy; Raul F. Tempone, King Abdullah University of Science & Technology (KAUST), Saudi Arabia

continued in next column

5:00-5:25 A Multiscale Domain Decomposition Method for the Solution of Stochastic Partial Differential Equations with Localized Uncertainties

Mathilde Chevreuil, and Anthony Nouy, Université de Nantes, France; Safatly Elias, Ecole Centrale de Nantes, France

5:30-5:55 Solving Saddle Point Problems with Random Data

Catherine Powell, University of Manchester, United Kingdom

6:00-6:25 Greedy Algorithms for Non Symmetric Linear Problems with Uncertainty

Virginie Ehrlacher, CERMICS, France

Monday, April 2

MS19

Optimization Methods for Stochastic Inverse Problems - Part II of II

4:30 PM-6:30 PM

Room:State B

For Part 1 see MS12

A stochastic inverse problem is a general framework used to convert uncertainties in observed measurements into useful information about a physical system of interest. The transformation from statistical data to random model parameters is a result of the interaction of a physical system with the object that we wish to infer properties about. As such, this minisymposium focuses on optimization methods for stochastic identification/control of input random data constrained by systems partial differential equations. The optimization approaches presented in this session allow for the optimal identification of statistical moments or even the whole probability distribution of the input random fields, given the probability distribution of some responses of the system.

Organizer: Clayton G. Webster
Oak Ridge National Laboratory, USA

Organizer: Max Gunzburger
Florida State University, USA

Organizer: Hyung-Chun Lee
Ajou University, South Korea

4:30-4:55 Optimization and Model Reduction for Parabolic PDEs with Uncertainties

Matthias Heinkenschloss, Rice University, USA

5:00-5:25 An Efficient Sparse-Grid-Based Method for Bayesian Uncertainty Analysis

Guannan Zhang, Max Gunzburger, and Ming Ye, Florida State University, USA

5:30-5:55 Optimal Control of Stochastic Flow Using Reduced-order Modeling

Ju Ming and Max Gunzburger, Florida State University, USA

6:00-6:25 A Stochastic Galerkin Method for Stochastic Control Problems

Jangwoon Lee, University of Mary Washington, USA; Hyung-Chun Lee, Ajou University, South Korea

Monday, April 2

MS20

UQ for Model Calibration, Validation and Predictions - Part II of II

4:30 PM-6:30 PM

Room:State E

For Part 1 see MS13

The ultimate purpose of computational models is to predict quantities of interest (QoIs) to decision makers. The incorporation of uncertainty in computational models is key for predicting QoIs more realistically, improving the chances for more informed and better decisions. The whole prediction process might involve not only the forward propagation of uncertainties, but also model calibration, data assessment (which data is more informative?), and model ranking (which models are "better"?). This minisymposium targets scientists that develop and use UQ for model calibration, validation and predictions. The participation of a wide variety of algorithms and applications is encouraged.

Organizer: Gabriel A. Terejanu
University of Texas at Austin, USA

Organizer: Ernesto E. Prudencio
Institute for Computational Engineering and Sciences, USA

4:30-4:55 Physics-based Auto- and Cross-Covariance Models for Gaussian Process Regression

Emil M. Constantinescu, and Mihai Anitescu, Argonne National Laboratory, USA

5:00-5:25 Covariance Approximation Techniques in Bayesian Non-stationary Gaussian Process Models

Bledar Konomi and Guang Lin, Pacific Northwest National Laboratory, USA

5:30-5:55 Fundamental Limitations of Polynomial Chaos Expansions for Uncertainty Quantification in Systems with Intermittent Instabilities

Michal Branicki, New York University, USA; Andrew Majda, Courant Institute of Mathematical Sciences, New York University, USA

6:00-6:25 Inertial Manifold Dimensionality & Finite-time Instabilities in Fluid Flows

Themistoklis Sapsis, New York University, USA

Monday, April 2

MS21

Statistical Design and Modeling of Computer Experiments- Part I of II

4:30 PM-6:30 PM

Room:State F

For Part 2 see MS27

Computer models are now used ubiquitously in sciences and engineering. This minisymposium aims to showcase recent methodological advances in the statistical design and modeling of computer experiments and illustrate them with diverse applications. The minisymposium invites eight speakers from various universities and national labs. Topics to be discussed include new classes of space-filling and sequential designs, alternatives to Gaussian process models, modeling computer experiments with nonstationary output or massive data, statistical model-reduction and variable selection for large-scale problems and the interplay between design and modeling in computer experiments.

Organizer: Peter Qian
University of Wisconsin, Madison, USA

Organizer: Jeff Wu
Georgia Institute of Technology, USA

4:30-4:55 A Matrix-Free Approach for Gaussian Process Maximum Likelihood Calculations

Jie Chen, Argonne National Laboratory, USA

5:00-5:25 Sequential Optimization of a Computer Model: What's So Special about Gaussian Processes Anyway?

Hugh Chipman and Pritam Ranjan, Acadia University, Canada

5:30-5:55 Extracting Key Features of Physical Systems for Emulation and Calibration

Nicolas Hengartner, Los Alamos National Laboratory, USA

6:00-6:25 Sliced Cross-validation for Surrogate Models

Peter Qian, and Qiong Zhang, University of Wisconsin, Madison, USA

Monday, April 2

MS22

Simulation Informatics: Applying Machine Learning Techniques To Simulation Databases

4:30 PM-6:30 PM

Room:Congressional A

As computing power for simulation-based analysis approaches the exascale, the need will arise for practical, efficient, and robust exascale data management. Modern physical simulations produce prodigious amounts of data that must be compared to experiments, theory, and other simulations. Moreover, simulation results contain uncertainties that typically require an ensemble of runs to characterize. In this minisymposium, we will explore the application of scalable informatics and machine learning methods to the outputs of physical simulations, where theoretical insights from the physical models inform the choice of learning methods. These methods will be used to quantify the uncertainty associated with model predictions.

Organizer: Paul Constantine
Stanford University, USA

Organizer: David F. Gleich
Purdue University, USA

4:30-4:55 Simulation Informatics

David F. Gleich, Purdue University, USA

5:00-5:25 Extracting Non-conventional Information in Simulation of Chaotic Dynamical Systems

Qiqi Wang, Massachusetts Institute of Technology, USA

5:30-5:55 Machine Learning to Recognize Phenomena in Large Scale Simulations

Barnabas Poczos, Carnegie Mellon University, USA

6:00-6:25 Scientific Data Mining Techniques for Extracting Information from Simulations

Chandrika Kamath, Lawrence Livermore National Laboratory, USA

Monday, April 2

Dinner Break

6:30 PM-8:00 PM

Attendees on their own

SIAG/UQ Business Meeting

8:00 PM-8:45 PM

Room:State C/D

Complimentary beer and wine will be served.

Tuesday, April 3

Registration

7:45 AM-5:00 PM

Room:Chancellor and Pre-Function Area

Remarks

8:10 AM-8:15 AM

Room:State C/D

IP3

Polynomial Chaos Approaches to Multiscale and Data Intensive Computations

8:15 AM-9:00 AM

Room:State C/D

Chair: Nicholas Zabaras, Cornell University, USA

Prediction of multiscale systems is increasingly being based on complex physical models that depend on large uncertain data sets. In this talk, we will outline recent developments in polynomial chaos (PC) methods for uncertainty quantification in such systems. Implementations will be illustrated in light of applications to chemical kinetics, and geophysical flows. Conclusions are in particular drawn concerning the potential of parallel databases in providing a platform for discovery, assessing prediction fidelity, and decision support.

Omar M. Knio
Duke University, USA

Coffee Break

9:00 AM-9:30 AM

Room:Pre-Function Area

Tuesday, April 3

MT4

Analysis of Spdes and Numerical Methods for Uncertainty Quantification - Part II of II

9:30 AM - 12:30 PM

For Part 1 see MT1
Room: State C

This tutorial explores numerical and functional analysis techniques for solving PDEs with random input data, such as model coefficients, forcing terms, initial and boundary conditions, material properties, source and interaction terms or geometry. The resulting stochastic systems will be investigated for well-posedness and regularity. We will present detailed convergence analysis of several intrusive and non-intrusive methods for quantifying the uncertainties associated with input information onto desired quantities of interest, forward and inverse UQ approaches, and necessary theoretical results from stochastic processes and random fields, error analysis, anisotropy, adaptive methods, high-dimensional approximation, random sampling and sparse grids.

Organizer:

Clayton G. Webster, Oak Ridge National Laboratory, USA

Speakers:

John Burkardt, Florida State University, USA

Clayton Webster, Oak Ridge National Laboratory, USA

Tuesday, April 3

CP6

Design and Control

9:30 AM-10:50 AM

Room:University A

Chair: Khanh D. Pham, Air Force Research Laboratory, USA

9:30-9:45 Risk-Averse Control of Linear Stochastic Systems with Low Sensitivity: An Output-Feedback Paradigm

Khanh D. Pham, Air Force Research Laboratory, USA

9:50-10:05 Path Variability Due To Sensor Geometry

Timothy Hall, PQI Consulting, USA

10:10-10:25 Quantification of Uncertainty of Low Fidelity Models and Application to Robust Design

Jessie Birman, Airbus Operation S.A.S., France

10:30-10:45 An Information-Based Sampling Scheme with Applications to Reduced-Order Modeling

Raphael Sternfels and Christopher J. Earls, Cornell University, USA

Tuesday, April 3

CP7

Dynamic Systems

9:30 AM-11:10 AM

Room:University B

Chair: Mircea Grigoriu, Cornell University, USA

9:30-9:45 A Method for Solving Stochastic Equations by Reduced Order Models

Mircea Grigoriu, Cornell University, USA

9:50-10:05 Effect of Limited Measurement Data on State and Parameters Estimation in Dynamic Systems

Sonjoy Das, and *Reza Madankan*, and Puneet Singla, State University of New York, Buffalo, USA

10:10-10:25 Managing Uncertainty in Complex Dynamic Models

Ufuk Topcu, California Institute of Technology, USA; Peter Seiler, University of Minnesota, USA; Michael Frenklach, University of California, Berkeley, USA; Gary Balas, University of Minnesota, USA; *Andrew Packard*, University of California, Berkeley, USA

10:30-10:45 On-Line Parameter Estimation and Control of Systems with Uncertainties

Faidra Stavropoulou, Helmholtz Zentrum München, Germany; Johannes Mueller, TU München, Germany

10:50-11:05 Estimation and Verification of Curved Railway Track Geometry Using Monte Carlo Particle Filters

Akiyoshi Yoshimura, Tokyo University of Technology, Japan

Tuesday, April 3

MS23

Numerical Methods for High-Dimensional Uncertainty Quantification - Part III of V

9:30 AM-11:30 AM

Room:State D

For Part 2 see MS17
For Part 4 see MS31

There has been a growing interest in developing scalable numerical methods for stochastic computation in the presence of high-dimensional random inputs. This is motivated by the need to reduce the issue of curse-of-dimensionality, i.e., exponential increase of computational complexity, in predictive simulation of physical systems where accurate description of uncertainties entails a large number of random variables. To this end, several novel approaches based on multi-level, reduced order, sparse, and low-rank approximations have been recently developed. This minisymposium presents state-of-the-art in such developments for various aspects of high-dimensional stochastic computation, including analysis, algorithms, implementation, and applications.

Organizer: Dongbin Xiu
Purdue University, USA

Organizer: Alireza Doostan
University of Colorado at Boulder, USA

9:30-9:55 Stochastic Basis Reduction by QoI Adaptation

Roger Ghanem and Ramakrishna Tippireddy, University of Southern California, USA

10:00-10:25 Distinguishing and Integrating Aleatoric and Epistemic Variation in UQ

Kenny Chowdhary and Jan S. Hesthaven, Brown University, USA

10:30-10:55 Adaptive Basis Selection and Dimensionality Reduction with Bayesian Compressive Sensing

Khachik Sargsyan, Cosmin Safta, Robert D. Berry, Bert J. Debusschere, and Habib N. Najm, Sandia National Laboratories, USA; Daniel Ricciuto and Peter Thornton, Oak Ridge National Laboratory, USA

11:00-11:25 Stochastic Collocation Methods for Stochastic Differential Equations Driven by White Noise

Zhongqiang Zhang, George E. Karniadakis, and Boris Rozovsky, Brown University, USA

Tuesday, April 3

MS24

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part IV of V

9:30 AM-11:30 AM

Room:State A

For Part 3 see MS18
For Part 5 see MS32

Uncertainty quantification in computational science and engineering has two main components: (i) modeling of the uncertainty in the input parameters, consistent with available information, physical constraints, and prior knowledge; (ii) the forward propagation of input uncertainty to the output quantities used in engineering design and regulatory requirements. This minisymposium focuses on the stochastic approach to uncertainty quantification in computational science and engineering; it aims to showcase emerging methodologies for building parametric and nonparametric stochastic models for uncertain input parameters, eventually involving the solution of stochastic inverse problems, as well as innovative techniques for propagating input stochasticity through complex differential models and computing statistics of the output quantities of interest.

Organizer: Youssef M. Marzouk
Massachusetts Institute of Technology, USA

Organizer: Olivier LeMaitre
LIMSI-CNRS, France

Organizer: Fabio Nobile
EPFL, Switzerland

9:30-9:55 Proper Generalized Decomposition for Stochastic Navier-Stokes Equations
Olivier LeMaitre, LIMSI-CNRS, France

continued in next column

10:00-10:25 Computation of the Second Order Wave Equation with Random Discontinuous Coefficients
Mohammad Motamed, King Abdullah University of Science & Technology (KAUST), Saudi Arabia; Fabio Nobile, EPFL, Switzerland; Raul F. Tempone, King Abdullah University of Science & Technology (KAUST), Saudi Arabia

10:30-10:55 Probabilistic UQ for PDEs with Random Data: A Case Study
Oliver G. Ernst, TU Bergakademie Freiberg, Germany

11:00-11:25 A Predictor-corrector Method for Fluid Flow Exhibiting Uncertain Periodic Dynamics
Michael Schick and Vincent Heuveline, Karlsruhe Institute of Technology, Germany; Olivier LeMaitre, LIMSI-CNRS, France

Tuesday, April 3

MS25

Uncertainty Quantification Techniques and Applications for Engineering Problems in the Geosphere - Part I of II

9:30 AM-11:30 AM

Room:State B

For Part 2 see MS33

Geologic experience and data along with geophysical models are often used as input to engineering designs. Limited sampling of geologic properties and the potentially large discrepancy in temporal and spatial scales between different types of information often serves as sources of uncertainty in predicting the performance of the engineered system. Probabilistic techniques can be used to estimate unknown model parameters conditional on varying initial and boundary conditions, constitutive and even intrinsic numerical parameters. These serve as the basis for predicting performance of the engineered system. This minisymposium aims at discussing research developments to engineered systems that interface with the geosphere.

Organizer: Zenon Medina-Cetina
Texas A&M University, USA

Organizer: Sean A McKenna
Sandia National Laboratories, USA

9:30-9:55 Quantifying and Reducing Uncertainty through Sampling Design
Sean A McKenna, Jaideep Ray, and Bart G. Van Bloemen Waanders, Sandia National Laboratories, USA

10:00-10:25 Uncertainty Analysis in the Florida Public Hurricane Loss Model
Sneh Gulati, Shahid S. Hamid, and Golam Kibria, Florida International University, USA; Steven Cocke, Florida State University, USA; Mark D. Powell, National Oceanic and Atmospheric Administration, USA; Jean-Paul Pinelli, Florida Institute of Technology, USA; Kurtis R. Gurley, University of Florida, USA; Shu-Ching Chen, Florida International University, USA

continued on next page

Tuesday, April 3

MS25

Uncertainty Quantification Techniques and Applications for Engineering Problems in the Geosphere - Part I of II

9:30 AM-11:30 AM

continued

10:30-10:55 Uncertainty Quantification of Shallow Groundwater Impacts due to CO2 Sequestration

Daniel M. Tartakovsky, University of California, San Diego, USA; *Hari Viswanathan*, Elizabeth Keating, Zhenxue Dai, and Rajesh Pawar, Los Alamos National Laboratory, USA

11:00-11:25 Toward Transparency and Refutability in Environmental Modeling

Mary Hill, U.S. Geological Survey, USA; Dmitri Kavetski, University of Newcastle, Australia; Martyn Clark, University of Colorado, Boulder, USA; Ming Ye, Florida State University, USA; Mazdak Arabi, Colorado State University, USA; Laura Foglia, University of California, Davis, USA; Steffen Mehl, California State University, Chico, USA

Tuesday, April 3

MS26

Predictive Fidelity in Multiscale Simulations - Part I of III

9:30 AM-11:30 AM

Room:State E

For Part 2 see MS41

In many applications, the overall system dynamics are affected by coupled physical phenomena, occurring over a wide range of time and length scales. Multiscale physics simulations employ the requisite models that represent the relevant physics on each time and length scale level, and couple the various models across the scales in order to resolve the overall system behavior. Assessing the predictive fidelity of multiscale simulations requires careful quantification and propagation of uncertainties on all scales, as well as in the coupling between scales. This minisymposium covers research topics in this general area.

Organizer: Bert J. Debusschere
Sandia National Laboratories, USA

Organizer: Habib N. Najm
Sandia National Laboratories, USA

Organizer: Allen C. Robinson
Sandia National Laboratories, USA

9:30-9:55 Quantifying Sampling Noise and Parametric Uncertainty in Coupled Atomistic-Continuum Simulations

Maher Salloum, Khachik Sargsyan, Reese Jones, Bert J. Debusschere, Habib N. Najm, and Helgi Adalsteinsson, Sandia National Laboratories, USA

10:00-10:25 UQ in MD Simulations: Forward Propagation and Parameter Inference

Francesco Rizzi, Johns Hopkins University, USA; Omar M. Knio, Duke University, USA; Habib N. Najm, Bert J. Debusschere, Khachik Sargsyan, Maher Salloum, and Helgi Adalsteinsson, Sandia National Laboratories, USA

continued in next column

10:30-10:55 Random Fluctuations in Homogenization Theory; How Stochasticity Propagates Through Scales

Guillaume Bal, Columbia University, USA

11:00-11:25 Uncertainty Quantification in Multi-Scale, Multi-Physics MEMS Performance Prediction

Sankaran Mahadevan, You Ling, Joshua Mullins, and Shankar Sankararaman, Vanderbilt University, USA

Tuesday, April 3

MS27

Statistical Design and Modeling of Computer Experiments - Part II of II

9:30 AM-11:30 AM

Room:State F

For Part 1 see MS21

Computer models are now used ubiquitously in sciences and engineering. This minisymposium aims to showcase recent methodological advances in the statistical design and modeling of computer experiments and illustrate them with diverse applications. The minisymposium invites eight speakers from various universities and national labs. Topics to be discussed include new classes of space-filling and sequential designs, alternatives to Gaussian process models, modeling computer experiments with nonstationary output or massive data, statistical model-reduction and variable selection for large-scale problems and the interplay between design and modeling in computer experiments.

Organizer: Peter Qian
University of Wisconsin, Madison, USA

Organizer: Jeff Wu
Georgia Institute of Technology, USA

9:30-9:55 Evaluation of Mixed Continuous-Discrete Surrogate Approaches

Patricia D. Hough, Sandia National Laboratories, USA

10:00-10:25 Large-scale Surrogate Models

Matthew Pratola, Los Alamos National Laboratory, USA

10:30-10:55 High Performance Bayesian Assessment of Earthquake Source Models for Ground Motion Simulations

Ernesto E. Prudencio, Institute for Computational Engineering and Sciences, USA

11:00-11:25 Use of Gaussian Process Modeling to Improve the Perez Model in the Study of Surface Irradiance of Buildings

Heng Su, Georgia Institute of Technology, USA

Tuesday, April 3

MS28

Efficiency in an Uncertain World, UQ in High Performance Buildings

9:30 AM-12:00 PM

Room:Congressional A

Buildings are the largest single source of energy consumption and pollution in the US, and because of this, efficient design and operation of buildings is needed for energy security, economic prosperity, and environmental stability. The objective of this symposium is to bring together experts and practitioners to share state-of-the-art methods in UQ with focus on the underlying mathematics, simulation methods and the characteristics of UQ analysis for buildings. The intent is to articulate problems in building design and operation that require UQ capability, the current barriers to deploying UQ analysis at scale, and benefits of deploying such capabilities.

Organizer: Bryan Eisenhower
University of California, Santa Barbara, USA

Organizer: Satish Narayanan
United Technologies Research Center, USA

Organizer: Clas Jacobson
United Technologies Research Center, USA

9:30-9:55 An Integrated Approach to Design and Operation of High Performance Buildings in the Presence of Uncertainty

Bryan Eisenhower, University of California, Santa Barbara, USA

10:00-10:25 Sensitivity of Building Parameters with Building Type, Climate, and Efficiency Level

John Kennedy, Autodesk, Inc., USA

10:30-10:55 Uncertainty Quantification Methods for Multi-physics Applications

Charles Tong, Lawrence Livermore National Laboratory, USA

11:00-11:25 Uncertainty Quantification of Building Energy Models

Godfried Augenbroe, Georgia Institute of Technology, USA

11:30-11:55 UQ for Better Commercial Buildings: From Design to Operation

Gregor Henze, University of Colorado at Boulder, USA

Tuesday, April 3

MS29

Implicit Sampling: Theory and Application to Data Assimilation

9:30 AM-11:30 AM

Room:Congressional B

The effective sampling of multidimensional probability densities is one of the key problems in computational science. The difficulty lies in the fact that there are too many states to be listed, and the fraction of states that has a significant probability is too small for standard sampling methods. Implicit sampling is a new methodology for finding high probability samples by solving a random equation. This minisymposium focuses on the theory of implicit sampling applied to data assimilation. Two of the talks have a theoretic emphasis; the other two present applications of implicit sampling to data assimilation in geophysics.

Organizer: Matthias Morzfeld
Lawrence Berkeley National Laboratory, USA

9:30-9:55 A Tutorial on Implicit Particle Filtering for Data Assimilation

Xuemin Tu, University of Kansas, USA

10:00-10:25 Implicit Particle Filtering for Geomagnetic Data Assimilation

Matthias Morzfeld, Lawrence Berkeley National Laboratory, USA

10:30-10:55 Application of the Implicit Particle Filter to a Model of Nearshore Circulation

Robert Miller, Oregon State University, USA

11:00-11:25 An Application of Rare Event Tools to a Bimodal Ocean Current Model

Jonathan Weare, University of Chicago, USA; Eric Vanden-Eijnden, Courant Institute of Mathematical Sciences, New York University, USA

Lunch Break

11:30 AM-2:00 PM

Attendees on their own

Tuesday, April 3

MS30: Cancelled

1:00 PM-1:45 PM

Tuesday, April 3

MT5

Emulation, Elicitation and Calibration - Part II of III

2:00 PM - 4:00 PM

For Part 1 see MT2

For Part 3 see MT8

Room: State C

This minitutorial concerns statistical approaches to UQ based on Bayesian statistics and the use of emulators. It is organised as three 2-hour sessions. The first begins with an overview of UQ tasks (uncertainty propagation, sensitivity analysis, calibration, validation) and of how emulation (a non-intrusive technique) tackles those tasks efficiently. It continues with an introduction to elicitation, a key component of input uncertainty quantification in practice. The second session presents the basic ideas of emulation and illustrates its power for uncertainty propagation, etc. The third session is about calibration, including the importance of model discrepancy and history matching.

Organizer:

Anthony O'Hagan, University of Sheffield, United Kingdom

Speakers:

Peter Challenor, National Oceanography Centre, Southampton, United Kingdom

Anthony O'Hagan, University of Sheffield, United Kingdom

Ian Vernon, University of Durham, United Kingdom

Tuesday, April 3

CP8

Sensitivity Analysis I

2:00 PM-3:40 PM

Room:University A

Chair: Kyle S. Hickmann, Tulane University, USA

2:00-2:15 Global Sensitivity Analysis for Disease and Population Models

Kyle S. Hickmann, Tulane University, USA; James (Mac) Hyman, Los Alamos National Laboratory, USA; John E. Ortmann, Tulane University, USA

2:20-2:35 Locality Aware Uncertainty Quantification and Sensitivity Algorithms

Steven F. Wojtkiewicz, University of Minnesota, USA; Erik A. Johnson, University of Southern California, USA

2:40-2:55 Fast and Rbd Revisited

Jean-Yves Tissot, Université de Grenoble I, France; Clémentine Prieur, Université Joseph Fourier and INRIA, France

3:00-3:15 A Global Sensitivity Analysis Method for Reliability Based Upon Density Modification

Paul Lemaître, INRIA Bordeaux Sud-Ouest, France; Ekaterina Sergienko and Fabrice Gamboa, University of Toulouse, France; Bertrand Iooss, Institut Mathématique de Toulouse, France

3:20-3:35 Investigations on Sensitivity Analysis of Complex Final Repository Models

Dirk-Alexander Becker, Gesellschaft für Anlagen- und Reaktorsicherheit mbH, Germany

Tuesday, April 3

CP9

Dynamical Systems & EnKF

2:00 PM-3:40 PM

Room:University B

Chair: Yuefeng Wu, University of California, Santa Cruz, USA

2:00-2:15 Collocation Inference for Nonlinear Stochastic Dynamic Systems with Noisy Observations

Yuefeng Wu, University of California, Santa Cruz, USA; Giles Hooker, Cornell University, USA

2:20-2:35 Uncertainty Quantification in the Ensemble Kalman Filter

Jon Saetrom, Statoil ASA, Norway; Henning Omre, Norwegian University of Science and Technology, Norway

2:40-2:55 A Spectral Approach to Linear Bayesian Updating

Oliver Pajonk, Technische Universität Braunschweig, Germany; Bojana V. Rosic and Alexander Litvinenko, TU Braunschweig, Germany; Hermann G. Matthies, Technical University Braunschweig, Germany

3:00-3:15 Multi-Modal Oil Reservoir History Matching Using Clustered Ensemble Kalman Filter

Ahmed H. ElSheikh, Imperial College London, United Kingdom

3:20-3:35 Emulating Dynamic Models -- Numerical Challenge

Carlo Albert, Eawag, Switzerland

Tuesday, April 3

MS31

Numerical Methods for High-Dimensional Uncertainty Quantification - Part IV of V

2:00 PM-4:00 PM

Room:State D

For Part 3 see MS23
For Part 5 see MS38

There has been a growing interest in developing scalable numerical methods for stochastic computation in the presence of high-dimensional random inputs. This is motivated by the need to reduce the issue of curse-of-dimensionality, i.e., exponential increase of computational complexity, in predictive simulation of physical systems where accurate description of uncertainties entails a large number of random variables. To this end, several novel approaches based on multi-level, reduced order, sparse, and low-rank approximations have been recently developed. This minisymposium presents state-of-the-art in such developments for various aspects of high-dimensional stochastic computation, including analysis, algorithms, implementation, and applications.

Organizer: Alireza Doostan
University of Colorado at Boulder, USA

Organizer: Dongbin Xiu
Purdue University, USA

2:00-2:25 An Adaptive Sparse Grid Generalized Stochastic Collocation Method for High-dimensional Stochastic Simulations

Clayton G. Webster, Oak Ridge National Laboratory, USA; Max Gunzburger, Florida State University, USA; Fabio Nobile, EPFL, Switzerland; Raul F. Tempone, King Abdullah University of Science & Technology (KAUST), Saudi Arabia

continued in next column

2:30-2:55 Multiple Computer Experiments: Design and Modeling

Youngdeok Hwang, Xu He, and Peter Qian, University of Wisconsin, Madison, USA

3:00-3:25 Uncertainty Quantification for Overcomplete Basis Representation in Computer Experiments

Jeff Wu, Georgia Institute of Technology, USA

3:30-3:55 Efficient Analysis of High Dimensional Data in Tensor Formats

Alexander Litvinenko, TU Braunschweig, Germany

Tuesday, April 3

MS32

Stochastic Uncertainty: Modeling, Forward Propagation, and Inverse Problems - Part V of V

2:00 PM-4:00 PM

Room:State A

For Part 4 see MS24

Uncertainty quantification in computational science and engineering has two main components: (i) modeling of the uncertainty in the input parameters, consistent with available information, physical constraints, and prior knowledge; (ii) the forward propagation of input uncertainty to the output quantities used in engineering design and regulatory requirements. This minisymposium focuses on the stochastic approach to uncertainty quantification in computational science and engineering; it aims to showcase emerging methodologies for building parametric and nonparametric stochastic models for uncertain input parameters, eventually involving the solution of stochastic inverse problems, as well as innovative techniques for propagating input stochasticity through complex differential models and computing statistics of the output quantities of interest.

Organizer: Youssef M. Marzouk
Massachusetts Institute of Technology, USA

Organizer: Olivier LeMaitre
LIMSI-CNRS, France

Organizer: Fabio Nobile
EPFL, Switzerland

2:00-2:25 Hierarchical Multi-output Gaussian Process Regression for Uncertainty Quantification with Arbitrary Input Probability Distributions
Ilias Bilionis and *Nicholas Zabaras*, Cornell University, USA

continued in next column

2:30-2:55 Efficient Algorithm for Computing Rare Failure Probability
Jing Li and *Dongbin Xiu*, Purdue University, USA

3:00-3:25 Pink and $1/f^{\alpha}$ Noise Inputs in Stochastic PDEs
John Burkardt, Max Gunzburger, and *Miroslav Stoyanov*, Florida State University, USA

3:30-3:55 Computational Nonlinear Stochastic Homogenization Using a Non-concurrent multiscale Approach for Hyperelastic Heterogeneous Microstructures Analysis
Alexandre Clément and Christian Soize, Université Paris-Est, France

Tuesday, April 3

MS33

Uncertainty Quantification Techniques and Applications for Engineering Problems in the Geosphere - Part II of II

2:00 PM-4:00 PM

Room:State B

For Part 1 see MS25

Geologic experience and data along with geophysical models are often used as input to engineering designs. Limited sampling of geologic properties and the potentially large discrepancy in temporal and spatial scales between different types of information often serves as sources of uncertainty in predicting the performance of the engineered system. Probabilistic techniques can be used to estimate unknown model parameters conditional on varying initial and boundary conditions, constitutive and even intrinsic numerical parameters. These serve as the basis for predicting performance of the engineered system. This minisymposium aims at discussing research developments to engineered systems that interface with the geosphere.

Organizer: Zenon Medina-Cetina
Texas A&M University, USA

Organizer: Sean A McKenna
Sandia National Laboratories, USA

2:00-2:25 Causality and Stochastic Processes with Varying Evidence Conditions
Zenon Medina-Cetina, Texas A&M University, USA

2:30-2:55 Uncertainty in Geotechnical Engineering
Gabriel Auvinet-Guichard, Universidad Nacional Autonoma de Mexico, Mexico

3:00-3:25 Modelling Uncertainty in Risk Assessment for Natural Hazards
Farrokh Nadim, Norwegian Geotechnical Institute, Norway

3:30-3:55 Estimation of Multiscale Fields Representing Anthropogenic CO2 Emissions from Sparse Observations
Jaideep Ray, Bart G. Van Bloemen Waanders, and Sean A McKenna, Sandia National Laboratories, USA

Tuesday, April 3

MS34

Code Verification: Practices and Problem Development - Part I of II

2:00 PM-4:00 PM

Room:Congressional B

For Part 2 see MS39

For scientific simulation codes, rigorous code verification is essential to provide confidence in code correctness and as a foundation for subsequent validation and uncertainty quantification activities. While a consensus theory of code verification has emerged, many issues remain in its practice. In Session I speakers will address considerations such as criteria of completeness, effective conveyance of results, and use of verification to improve code development. Furthermore, the availability of effective test problems is critical to success of any code verification effort, and speakers in Session II will discuss informative test problems developed for their applications.

Organizer: Carol S. Woodward
Lawrence Livermore National Laboratory, USA

Organizer: V. Gregory Weirs
Sandia National Laboratories, USA

2:00-2:25 Code Verification: Practices and Perils
Carol S. Woodward, Lawrence Livermore National Laboratory, USA

2:30-2:55 Challenges in Devising Manufactured Solutions for PDE Applications
Patrick M. Knupp, Sandia National Laboratories, USA

3:00-3:25 Tools and Techniques for Code Verification using Manufactured Solutions
Nicholas Malaya, Roy Stogner, and Robert D. Moser, University of Texas at Austin, USA

3:30-3:55 The Requirements and Challenges for Code Verification Needed to Support the Use of Computational Fluid Dynamics for Nuclear Reactor Design and Safety Applications
Hyung B. Lee, Bettis Laboratory, USA

Tuesday, April 3

MS35

UQ Solutions for Design and Manufacturing Process Engineering - Part I of II

2:00 PM-4:00 PM

Room:State F

For Part 2 see MS42

This minisymposium convenes leaders of several concurrent development efforts in uncertainty quantification (UQ) methodologies, techniques, and tools for design and manufacturing process engineering. The emphasis is on practical methodologies and techniques that are effectively implemented by mathematically rigorous, computationally efficient, and engineer-friendly tools. The solutions should advance systems engineering and/or concurrent engineering approaches. The target audience is engineering practitioners who would like to better solve their UQ problems, as well as researchers who would like to understand the scope of, and relationship between, existing state-of-the-art UQ solutions in design and manufacturing process engineering.

Organizer: Mark Campanelli
National Institute of Standards and Technology, USA

2:00-2:25 Exact Calculations for Random Variables in Uncertainty Quantification Using a Computer Algebra System
Lawrence Leemis, College of William & Mary, USA

2:30-2:55 HPD Liberates Applied Probability AND Enables Comprehensively Tackling Design Engineering
Jean Parks and Chun Li, Variability Associates, USA

3:00-3:25 Practical UQ for Engineering Applications with DAKOTA
Brian M. Adams, Laura Swiler, and Michael S. Eldred, Sandia National Laboratories, USA

3:30-3:55 Open TURNS: Open source Treatment of Uncertainty, Risk 'N Statistics
Anne-Laure Popelin, EDF, France; Anne Dutfoy, EDF, Clamart, France; *Paul Lemaître*, INRIA Bordeaux Sud-Ouest, France

Tuesday, April 3

MS36

Data Assimilation in Large-scale Weather and Climate Models

2:00 PM-4:00 PM

Room:Congressional A

Data assimilation is concerned with quantifying the uncertainty in state estimates used for initializing large models. An emerging technique to the challenge of refining large models is using low-dimensional solutions in data assimilation methods. Approaches such as local low dimensionality and the Local Ensemble Transform Kalman Filter are promising for improving existing data assimilation schemes for difficult computational problems. This minisymposium will survey how current ensemble, variational, and hybrid data assimilation methods quantify uncertainty in weather and climate models, from low-dimensional theoretical models to large-scale operational models. Talks will examine both analytical and numerical approaches in such models.

Organizer: Lewis Mitchell
University of Vermont, USA

Organizer: Thomas Bellsky
Arizona State University, USA

2:00-2:25 Local-Low Dimensionality of Complex Atmospheric Flows
Thomas Bellsky, Arizona State University, USA

2:30-2:55 Uncertainty Quantification and Data Assimilation in Multiscale Systems Using Stochastic Homogenization
Lewis Mitchell, University of Vermont, USA; Georg A. Gottwald, University of Sydney, Australia

3:00-3:25 Assimilation of Thermodynamic Profiler Retrievals in the Boundary Layer: Comparison of Methods and Observational Error Specifications
Sean Crowell and Dave Turner, National Severe Storms Laboratory, USA

3:30-3:55 Lagrangian Data Assimilation and Control: Hide and Seek
Damon Mcdougall, University of Warwick, United Kingdom

Tuesday, April 3

MS37

Uncertainty Quantification for Volcanic Hazard Assessment

2:00 PM-4:00 PM

Room:State E

Large granular volcanic events -- pyroclastic flows -- are rare yet potentially devastating for communities situated near volcanoes. Proper assessment of such hazards must include scenarios that are larger in volume than any previous events. This task inherently requires a combination of physical and statistical modeling as well as large scale computations. Accounting for these multiple sources of uncertainty is crucial in the hazard assessment process. Furthermore, one must carefully handle the rare nature of the most dangerous events to keep probability calculations computationally feasible. To this end, model surrogates prove a useful powerful tool in developing probabilistic hazard maps.

Organizer: Elaine Spiller
Marquette University, USA

2:00-2:25 Overview of Volcanic Hazard Assessment
M.J. Bayarri, University of Valencia, Spain

2:30-2:55 Modeling Large Scale Geophysical Flows: Physics and Uncertainty
E. Bruce Pitman, State University of New York, Buffalo, USA; M.J. Bayarri, University of Valencia, Spain; James Berger, Duke University, USA; Eliza Calder, University of Buffalo, USA; Abani K. Patra, State University of New York, Buffalo, USA; Elaine Spiller, Marquette University, USA; Robert Wolpert, Duke University, USA

3:00-3:25 Design and Use of Surrogates in Hazard Assessment
Elaine Spiller, Marquette University, USA

3:30-3:55 Combining Deterministic and Stochastic Models For Hazard Assessment
Robert Wolpert, Duke University, USA; Elaine Spiller, Marquette University, USA

Coffee Break

4:00 PM-4:30 PM

Room:Pre-Function Area

Tuesday, April 3

MT6

Uncertainty Quantification: Foundations and Capabilities for Model-Based Simulations - Part II of III

4:30 PM - 6:30 PM

For Part 1 see MT3
For Part 3 see MT9

Room: State C

The minitutorial will present the physical motivation and mathematical foundations necessary for the formulation of well-posed UQ problems in computational science and engineering. In particular, the minitutorial will cover 1) aspects of probabilistic modeling and analysis, 2) polynomial chaos representations, 3) stochastic processes and Karhunen-Loeve expansions, 4) forward UQ including sampling, sparse-grid, stochastic Galerkin and collocation, 5) inverse problems in UQ, 6) overview of software resources, 7) summary of advanced topics.

Organizer:

Roger Ghanem, University of Southern California, USA

Speakers:

Roger Ghanem, University of Southern California, USA

Bert Debusschere, Sandia National Laboratories, USA

Tuesday, April 3

CP10

Inverse Problems I

4:30 PM-6:30 PM

Room:University A

Chair: Cranos M. Williams, North Carolina State University, USA

4:30-4:45 Langevin Based Inversion of Pressure Transient Testing Data
Richard Booth and Kirsty Morton, Schlumberger Brazil Research and Geoengineering Center, Brazil; Mustafa Onur, Istanbul Technical University, Turkey; Fikri Kuchuk, Schlumberger Riboud Product Center, France

4:50-5:05 Inverse Problem: Information Extraction from Electromagnetic Scattering Measurement
Pierre Minvielle-Larrousse, Marc Sancandi, Francois Giraud, and Pierre Bonnemason, CEA/CESTA, France

5:10-5:25 Bayesian Acoustic Wave-Field Inversion of a 1D Heterogeneous Media
Saba S. Esmailzadeh and Zenon Medina-Cetina, Texas A&M University, USA; Jun Won Kang, New Mexico State University, USA; Loukas F. Kallivokas, University of Texas at Austin, USA

5:30-5:45 Some Inverse Problems for Groundwater
Nicholas Dudley Ward, Otago Computational Modelling Group, New Zealand; Tiangang Cui, University of Auckland, New Zealand; Jari P Kaipio, University of Eastern Finland, Finland and University of Auckland, New Zealand

5:50-6:05 Set-Based Parameter and State Estimation in Nonlinear Differential Equations Using Sparse Discrete Measurements
Cranos M. Williams and Skylar Marvel, North Carolina State University, USA

6:10-6:25 Probabilistic Solution of Inverse Problems under Varying Evidence Conditions
Zenon Medina –Cetina and *Negin Yousefpour*, Texas A&M University, USA; Hans Petter Langtangen, Are Magnus Bruaset, and Stuart Clark, Simula Research Laboratory, Norway

Tuesday, April 3

CP11

Inverse Problems II

4:30 PM-6:10 PM

Room:University B

Chair: Nikhil Galagali, Massachusetts Institute of Technology, USA

4:30-4:45 Chemical Reaction Mechanism Generation Using Bayesian Variable Selection

Nikhil Galagali and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

4:50-5:05 Inferring Bottom Bathymetry from Free-Surface Flow Features

Sergey Koltakov, Gianluca Iaccarino, and Oliver Fringer, Stanford University, USA

5:10-5:25 Bayesian Updating of Uncertainty in the Description of Transport Processes in Heterogeneous Materials

Jan Sykora and Anna Kucerova, Czech Technical University, Prague, Czech Republic; Bojana V. Rosic, and Hermann G. Matthies, Technical University Braunschweig, Germany

5:30-5:45 Adaptive Error Modelling in Mcmc Sampling for Large Scale Inverse Problems

Tiangang Cui, University of Auckland, New Zealand; Nicholas Dudley Ward, Otago Computational Modelling Group, New Zealand; Colin Fox, University of Otago, New Zealand; Mike O'Sullivan, University of Auckland, New Zealand

5:50-6:05 Scalable Methods for Large-Scale Statistical Inverse Problems, with Applications to Subsurface Flow

H. Pearl Flath, Tan Bui-Thanh, and Omar Ghattas, University of Texas at Austin, USA

Tuesday, April 3

MS38

Numerical Methods for High-Dimensional Uncertainty Quantification - Part V of V

4:30 PM-6:30 PM

Room:State D

For Part 4 see MS31

There has been a growing interest in developing scalable numerical methods for stochastic computation in the presence of high-dimensional random inputs. This is motivated by the need to reduce the issue of curse-of-dimensionality, i.e., exponential increase of computational complexity, in predictive simulation of physical systems where accurate description of uncertainties entails a large number of random variables. To this end, several novel approaches based on multi-level, reduced order, sparse, and low-rank approximations have been recently developed. This minisymposium presents state-of-the-art in such developments for various aspects of high-dimensional stochastic computation, including analysis, algorithms, implementation, and applications.

Organizer: Alireza Doostan

University of Colorado at Boulder, USA

Organizer: Dongbin Xiu

Purdue University, USA

4:30-4:55 Numerical Strategies for Epistemic Uncertainty Analysis

Xiaoxiao Chen, Purdue University, USA; Eun-Jae Park, Yonsei University, South Korea; Dongbin Xiu, Purdue University, USA

5:00-5:25 Uncertainty Quantification with High Dimensional, Experimentally Measured Inputs

Ilias Bilionis and *Nicholas Zabaras*, Cornell University, USA

5:30-5:55 Stochastic Integration Methods and their Application to Reliability Analysis

Utz Wever and Albert B. Gilg, Siemens AG Corporate Technology, Germany; Meinhard Paffra, Siemens AG, Germany

6:00-6:25 A Localized Strategy for Generalized Polynomial Chaos Methods

Yi Chen and Dongbin Xiu, Purdue University, USA

Tuesday, April 3

MS39

Code Verification: Practices and Problem Development - Part II of II

4:30 PM-6:30 PM

Room:Congressional B

For Part 1 see MS34

For scientific simulation codes, rigorous code verification is essential to provide confidence in code correctness and as a foundation for subsequent validation and uncertainty quantification activities. While a consensus theory of code verification has emerged, many issues remain in its practice. In Session I speakers will address considerations such as criteria of completeness, effective conveyance of results, and use of verification to improve code development. Furthermore, the availability of effective test problems is critical to success of any code verification effort, and speakers in Session II will discuss informative test problems developed for their applications.

Organizer: Carol S. Woodward

Lawrence Livermore National Laboratory, USA

Organizer: V. Gregory Weirs

Sandia National Laboratories, USA

4:30-4:55 Several Interesting Parabolic Test Problems

Jeffrey A. Hittinger, and Jeffrey W. Banks, Lawrence Livermore National Laboratory, USA; Jeffrey M. Connors, University of Pittsburgh, USA; Carol S. Woodward, Lawrence Livermore National Laboratory, USA

5:00-5:25 Exact Error Behavior of Simple Numerical Problems

Daniel Israel, Los Alamos National Laboratory, USA

5:30-5:55 Verification and Validation in Solid Mechanics

Krishna Kamojjala and Rebecca Brannon, University of Utah, USA

6:00-6:25 Cross-Application of Uncertainty Quantification and Code Verification Techniques

V. Gregory Weirs, Sandia National Laboratories, USA

Tuesday, April 3

MS40

Methods for Uncertainty Quantification in Inverse Problems and Data Assimilation - Part I of II

4:30 PM-6:30 PM

Room:State B

For Part 2 see MS47

In an inverse problem, estimates of unknown parameters in a physical model are sought from measured data assumed to have been output from the model. Due to random noise in the measurement process, parameter estimates are also random, and hence quantifying uncertainty in estimators is an important task. In this minisymposium, we focus on techniques for uncertainty quantification in inverse problems. The inverse problems considered range from classical high-dimensional applications in image deblurring and tomography, to time varying data assimilation problems in weather prediction and process tomography, to lower-dimensional parameter estimation problems in climate modeling, biology, and chemistry.

Organizer: Johnathan M. Bardsley
University of Montana, USA

4:30-4:55 Sampling and Inference for Large-scale Inverse Problems Using an Optimization-based Approach

Johnathan M. Bardsley, University of Montana, USA

5:00-5:25 Approximate Marginalization of Uninteresting Distributed Parameters in Inverse Problems

Ville P. Kolehmainen, University of Kuopio, Finland; Jari P Kaipio, University of Eastern Finland, Finland and University of Auckland, New Zealand; Tanja Tarvainen, University of Eastern Finland, Finland; Simon Arridge, University College London, United Kingdom

continued in next column

5:30-5:55 Recovery from Modeling Errors in Non-stationary Inverse Problems: Application to Process Tomography

Aku Seppanen, and Antti Lipponen, University of Eastern Finland, Finland; Jari P. Kaipio, University of Eastern Finland, Finland and University of Auckland, New Zealand

6:00-6:25 Variational Approximations in Large-scale Data Assimilation: Experiments with a Quasi-Geostrophic Model

Antti Solonen, Lappeenranta University of Technology, Finland

Tuesday, April 3

MS41

Predictive Fidelity in Multiscale Simulations - Part II of III

4:30 PM-6:30 PM

Room:State E

For Part 1 see MS26
For Part 3 see MS48

In many applications, the overall system dynamics are affected by coupled physical phenomena, occurring over a wide range of time and length scales. Multiscale physics simulations employ the requisite models that represent the relevant physics on each time and length scale level, and couple the various models across the scales in order to resolve the overall system behavior. Assessing the predictive fidelity of multiscale simulations requires careful quantification and propagation of uncertainties on all scales, as well as in the coupling between scales. This minisymposium covers research topics in this general area.

Organizer: Bert J. Debusschere
Sandia National Laboratories, USA

Organizer: Habib N. Najm
Sandia National Laboratories, USA

Organizer: Allen C. Robinson
Sandia National Laboratories, USA

4:30-4:55 A Spectral Uncertainty Quantification Approach in Ocean General Circulation Modeling

Alen Alexanderian, Johns Hopkins University, USA; Justin Winokur and Ihab Sraj, Johns Hopkins University, USA; Ashwanth Srinivasan, and Mohamed Iskandarani, University of Miami, USA; WilliamCarlisle Thacker, National Oceanic and Atmospheric Administration, USA; Omar M. Knio, Duke University, USA

5:00-5:25 Uncertainty Quantification of Equation-of-state Closures and Shock Hydrodynamics

Allen C. Robinson, Robert D. Berry, John H. Carpenter, Bert J. Debusschere, Richard R. Drake, Ann E. Mattsson, and William J. Rider, Sandia National Laboratories, USA

continued on next page

5:30-5:55 Optimal Uncertainty Quantification and (Non-) Propagation of Uncertainties Across Scales

Tim Sullivan, Michael McKerns, Michael Ortiz, and Houman Owhadi, California Institute of Technology, USA; Clint Scovel, Los Alamos National Laboratory, USA; Florian Theil, University of Warwick, United Kingdom

6:00-6:25 Coarse Graining with Uncertainty: A Relative Entropy Framework

Nicholas Zabaras and Ilias Bilionis, Cornell University, USA

Tuesday, April 3

MS42

UQ Solutions for Design and Manufacturing Process Engineering - Part II of II

4:30 PM-6:00 PM

Room:State F

For Part 1 see MS35

This minisymposium convenes leaders of several concurrent development efforts in uncertainty quantification (UQ) methodologies, techniques, and tools for design and manufacturing process engineering. The emphasis is on practical methodologies and techniques that are effectively implemented by mathematically rigorous, computationally efficient, and engineer-friendly tools. The solutions should advance systems engineering and/or concurrent engineering approaches. The target audience is engineering practitioners who would like to better solve their UQ problems, as well as researchers who would like to understand the scope of, and relationship between, existing state-of-the-art UQ solutions in design and manufacturing process engineering.

Organizer: Mark Campanelli
National Institute of Standards and Technology, USA

4:30-4:55 UQ Practices and Standards for Design and Manufacturing Process Engineering

Mark Campanelli, National Institute of Standards and Technology, USA

5:00-5:25 Systematic Integration of Multiple Uncertainty Sources in Design Process

Sankaran Mahadevan, Vanderbilt University, USA

5:30-5:55 Generalized Chapman-Kolmogorov Equation for Multiscale System Analysis

Yan Wang, Georgia Institute of Technology, USA

Tuesday, April 3

MS43

Random Media: Models, Simulations, and Applications

4:30 PM-7:00 PM

Room:Congressional A

The understanding of uncertainty quantitfication is a current thrust in many applied sciences, in particular geosciences. A crucial component is the construction of stochastic models of uncertainty and the understanding of subsequent properties. Questions abound: What distributional properties are desired? How should parameters be selected? How well does the behavior of subsequent models reflect physical reality? Is numerical simulation feasible? The ensemble of talks in this session give some insight in model selection, simulation, and evaluation in the context of modeling physical processes in random media.

Organizer: Mina E. Ossiander
Oregon State University, USA

Organizer: Malgorzata Peszynska
Oregon State University, USA

Organizer: Nathan L. Gibson
Oregon State University, USA

4:30-4:55 Stochastic Models, Simulation and Analysis in Subsurface Flow and Transport

Mina E. Ossiander, Malgorzata Peszynska, and Veronika S. Vasylkivska, Oregon State University, USA

5:00-5:25 Macroscopic Properties of Isotropic and Anisotropic Fracture Networks from the Percolation Threshold to Very Large Densities

Pierre Adler, Université Pierre et Marie Curie, France; Jean Francois Thovert and Valeri Mourzenko, PPRIME, France

5:30-5:55 A Comparative Study on Reservoir Characterization using Two Phase Flow Model

Victor E. Ginting, Felipe Pereira, and Arunasalam Rahunanthan, University of Wyoming, USA

continued on next page

Tuesday, April 3

MS43

Random Media: Models, Simulations, and Applications

4:30 PM-7:00 PM

continued

6:00-6:25 Uncertainty Quantification Methods for Unsaturated Flow in Porous Media

David A. Barajas-Solano, University of California, San Diego, USA

6:30-6:55 Adaptive AMG for Diffusion Equations with Stochastic Coefficients

Christian Ketelsen and Panayot Vassilevski, Lawrence Livermore National Laboratory, USA

Tuesday, April 3

MS44

Spatial UQ

4:30 PM-6:30 PM

Room:State A

This session is devoted to computer models in which the spatial dimension is key to the uncertainty quantification. Open questions are: (1) Where should we collect information to efficiently calibrate parameterizations? (2) What spatial covariance should we employ to model the spatial uncertainty of the outputs in emulators? (3) What levels of spatial resolution will achieve low predictive uncertainty? Various Bayesian formulations are developed to address these issues. Applications presented in this symposium are: geophysical model for pressure wave attenuation; spatial distribution of fish species; air pollution on streets; energy consumption by buildings in cities.

Organizer: Ruchi Choudhary

University of Cambridge, United Kingdom

4:30-4:55 Spatial Analysis of Energy Consumption by Non-Domestic Buildings in Greater London

Ruchi Choudhary and Wei Tian, University of Cambridge, United Kingdom

5:00-5:25 Adding Spatial Dependence Constraints to a Geophysical Inverse Problem

Eugene Morgan, Duke University, USA

5:30-5:55 Spatial Statistical Calibration of a Turbulence Model

Nina Glover, Serge Guillas, and Liora Malki-Epshtein, University College London, United Kingdom

6:00-6:25 Asessing the Spatial Distribution of Fish Species Using Bayesian Latent Gaussian Models

Facundo Muñoz, University of Valencia, Spain; María Pennino, Spanish Institute of Oceanography, Spain; David Conesa and Antonio López-Quílez, University of Valencia, Spain

Dinner Break

6:30 PM-8:00 PM

Attendees on their own

Tuesday, April 3

PD1

Forward Looking Panel Discussion

8:00 PM-9:00 PM

Room:State C/D

Chair: James Berger, Duke University, USA

The Committee on Mathematical Foundations of Verification, Validation, and Uncertainty Quantification was formed by the National Research Council with several charges, including (i) identifying mathematical sciences research needed to establish a foundation for building a science of V&V and for improving the practice of VVUQ, and (ii) recommending educational changes needed in the mathematical sciences community and mathematical sciences education needed by other scientific communities to most effectively use VVUQ. The report of the committee will just have been released by the time of the conference, and the co-chairs of the committee will open the forward looking session by summarizing relevant aspects of the report.

Panelists:

Marvin Adams
Texas A&M University, USA

David Higdon
Los Alamos National Laboratory, USA

Wednesday, April 4

Registration

7:45 AM-5:00 PM

Room:Chancellor and Pre-Function Area

Remarks

8:10 AM-8:15 PM

Room:State C/D

IP4

Large Deviation Methods for Quantifying Uncertainty

8:15 AM-9:00 AM

Room:State C/D

Chair: Andrew Stuart, University of Warwick, United Kingdom

Large deviation methods have been particularly successful in assessing small probabilities of rare events, which are difficult to compute. They are also at the center of many importance sampling methods that aim to estimate probabilities of rare events by Monte Carlo methods. Since probabilities of rare events are an important part of the emerging field of uncertainty quantification in complex scientific problems, the question arises as to how effective they are. This is because the results of large deviation theory depend sensitively on details of the probabilistic model used, and such details may not be available or may themselves be subject to uncertainty. I will address these issues with some examples using mean-field models and conservation laws and attempt to draw some broader conclusions.

George C. Papanicolaou
Stanford University, USA

Coffee Break

9:00 AM-9:30 AM

Room:Pre-Function Area

Wednesday, April 4

MT7

Introduction to Statistical Analysis of Extremes

9:30 AM - 12:30 PM

Room: State C

This minitutorial will introduce the ideas and techniques involved in the analysis of both univariate and multivariate extremes. Statistical practice relies on fitting distributions suggested by asymptotic theory to a subset of data considered to be extreme. The minitutorial will introduce the fundamental asymptotic results which underlie extremes analysis via demonstrations and examples. Both block maximum and threshold exceedance approaches will be presented for both the univariate and multivariate cases. The multivariate portion of the course will largely focus on how dependence is described for extremes: via an angular measure rather than via correlation.

Organizer and Speaker:
Dan Cooley, Colorado State University, USA

Wednesday, April 4

CP12

Calibration & Inverse Problems

9:30 AM-10:50 AM

Room:University A

Chair: Benjamin P. Smarslok, Air Force Research Laboratory, USA

9:30-9:45 Bayesian Models for the Quantification of Model Errors in Pde-Based Systems
Phaedon S. Koutsourelakis, Heriot-Watt University, Scotland

9:50-10:05 Investigating Uncertainty in Aerothermal Model Predictions for Hypersonic Aircraft Structures
Benjamin P. Smarslok, Air Force Research Laboratory, USA; Sankaran Mahadevan, Vanderbilt University, USA

10:10-10:25 Predictive Simulation for CO_2 Sequestration in Saline Aquifers
Victor E. Ginting, Marcos Mendes, Felipe Pereira, and *Arunasalam Rahunanthan*, University of Wyoming, USA

10:30-10:45 The Effect of Prediction Error Correlation on Bayesian Model Updating
Ellen Simoen, K.U. Leuven, Belgium; Costas Papadimitriou, University of Thessaly, Greece; Guido De Roeck and Geert Lombaert, K.U. Leuven, Belgium

Wednesday, April 4

CP13

Propagation & Estimation

9:30 AM-11:30 AM

Room:University B

Chair: Patrick R. Conrad, Massachusetts Institute of Technology, USA

9:30-9:45 Multilevel Monte Carlo for Uncertainty Quantification in Subsurface Flow

Robert Scheichl, University of Bath, United Kingdom; Andrew Cliffe, University of Nottingham, United Kingdom; Michael B. Giles, University of Oxford, United Kingdom; Minho Park, University of Nottingham, United Kingdom; Aretha Teckentrup and *Elisabeth Ullmann*, University of Bath, United Kingdom

9:50-10:05 Comparison of Stochastic Methods for Bayesian Updating of Uncertainty in Parameters of Nonlinear Models

Anna Kucerova and Jan Sykora, Czech Technical University, Prague, Czech Republic; Bojana V. Rosic, TU Braunschweig, Germany; Hermann G. Matthies, Technical University Braunschweig, Germany

10:10-10:25 Adaptive Smolyak Pseudospectral Expansions

Patrick R. Conrad and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

10:30-10:45 Reservoir Uncertainty Quantification Using Clustering Methods

Asaad Abdollahzadeh, Heriot-Watt University, Scotland; Mike Christie and David W. Corne, Heriot-Watt University, United Kingdom

10:50-11:05 Stochastic Anova-Galerkin Projection Schemes

Prasanth B. Nair, University of Toronto, Canada; Christophe Audouze, Université Paris-Sud, France

11:10-11:25 Uncertainty and Differences in Global Climate Models

Joshua P. French, University of Colorado, Denver, USA; Stephan Sain, National Center for Atmospheric Research, USA

Wednesday, April 4

MS45

Climate Uncertainty Quantification - Part I of IV

9:30 AM-11:30 AM

Room:State D

For Part 2 see MS52

Uncertainty quantification of climate predictions is challenging. Climate models used for making predictions contain not only many aleatoric sources of uncertainty, many of their epistemological aspects are not well defined. How can we test model responses to a forcing for which we do not have observations? How do we separate observations used to drive model development from those used for model evaluation? Climate models simulate non-linear processes that interact on many time and space scales, so representing, sampling, and computing aleatoric uncertainties alone is a major challenge. We welcome contributions that address any challenges in climate uncertainty quantification.

Organizer: Guang Lin
Pacific Northwest National Laboratory, USA

Organizer: Charles Jackson
University of Texas at Austin, USA

Organizer: Donald D. Lucas
Lawrence Livermore National Laboratory, USA

9:30-9:55 Quantifying Uncertainties in Fully Coupled Climate Models

Donald D. Lucas, Scott Brandon, Curt Covey, Davlid Domyancic, Gardar Johannesson, Stephen Klein, John Tannahill, and Yuying Zhang, Lawrence Livermore National Laboratory, USA

10:00-10:25 Upper Ocean Singular Vectors of the North Atlantic: Implications for Linear Predictability and Observational Requirement

Patrick Heimbach, Massachusetts Institute of Technology, USA; Laure

continued in next column

Zanna, University of Oxford, United Kingdom; Andrew M. Moore, University of California, Santa Cruz, USA; Eli Tziperman, Harvard University, USA

10:30-10:55 Uncertainty Quantification for Large Multivariate Spatial Computer Model Output with Climate Applications

K. Sham Bhat, Los Alamos National Laboratory, USA

11:00-11:25 Quantifying Uncertainty for Climate Change Predictions with Model Error in non-Gaussian Systems with Intermittency

Michal Branicki, New York University, USA; Andrew Majda, Courant Institute of Mathematical Sciences, New York University, USA

Wednesday, April 4

MS46

Recent Advances in Numerical SPDES - Part I of II

9:30 AM-11:30 AM

Room:State A

For Part 2 see MS53

It is well understood that effective numerical methods for stochastic partial differential equations (SPDES) are essential for uncertainty quantification. In the last decade much progress has been made in the construction numerical algorithms to efficiently solve SPDES with random coefficients and white noise perturbations. However, high dimensionality and low regularity is still the bottleneck in solving real world applicable SPDES with efficient numerical methods. This mini-symposium is intended to address the mathematical aspects of numerical approximations of SPDES, including error analysis and complexity analysis and development of new efficient numerical algorithms.

Organizer: Yanzhao Cao
Auburn University, USA

Organizer: Clayton G. Webster
Oak Ridge National Laboratory, USA

9:30-9:55 Efficient Nonlinear Filtering of a Singularly Perturbed Stochastic Hybrid System
Boris Rozovski, Brown University, USA

10:00-10:25 Efficient Spectral Garlerkin Method with Orthgonal Polynomials for SPDES
Yanzhao Cao, Auburn University, USA

10:30-10:55 Two Stochastic Modeling Strategies for Elliptic Problems
Xiaoliang Wan, Louisiana State University, USA

11:00-11:25 Adaptive Methods for Elliptic Partial Differential Equations with Random Operators
Claude Gittelson, Purdue University, USA

Wednesday, April 4

MS47

Methods for Uncertainty Quantification in Inverse Problems and Data Assimilation - Part II of II

9:30 AM-11:30 AM

Room:State B

For Part 1 see MS40

In an inverse problem, estimates of unknown parameters in a physical model are sought from measured data assumed to have been output from the model. Due to random noise in the measurement process, parameter estimates are also random, and hence quantifying uncertainty in estimators is an important task. In this mini-symposium, we focus on techniques for uncertainty quantification in inverse problems. The inverse problems considered range from classical high-dimensional applications in image deblurring and tomography, to time varying data assimilation problems in weather prediction and process tomography, to lower-dimensional parameter estimation problems in climate modeling, biology, and chemistry.

Organizer: Johnathan M. Bardsley
University of Montana, USA

9:30-9:55 Putting Computational Inference into an FPGA
Colin Fox, University of Otago, New Zealand

10:00-10:25 Model Reductions by MCMC
Heikki Haario, Lappeenranta University of Technology, Finland

10:30-10:55 Advanced Uncertainty Evaluation of Climate Models by Monte Carlo Methods
Marko Laine, Finnish Meteorological Institute, Helsinki, Finland

11:00-11:25 Covariance Estimation Using Chi-squared Tests
Jodi Mead, Boise State University, USA

Wednesday, April 4

MS48

Predictive Fidelity in Multiscale Simulations - Part III of III

9:30 AM-11:00 AM

Room:State E

For Part 2 see MS41

In many applications, the overall system dynamics are affected by coupled physical phenomena, occurring over a wide range of time and length scales. Multiscale physics simulations employ the requisite models that represent the relevant physics on each time and length scale level, and couple the various models across the scales in order to resolve the overall system behavior. Assessing the predictive fidelity of multiscale simulations requires careful quantification and propagation of uncertainties on all scales, as well as in the coupling between scales. This minisymposium covers research topics in this general area.

Organizer: Bert J. Debusschere
Sandia National Laboratories, USA

Organizer: Habib N. Najm
Sandia National Laboratories, USA

Organizer: Allen C. Robinson
Sandia National Laboratories, USA

9:30-9:55 Heterogeneous Deformation of Polycrystalline Metals and Extreme Value Events
Curt Bronkhorst, Los Alamos National Laboratory, USA

10:00-10:25 Coupled Chemical Master Equation - Fokker Planck Solver for Stochastic Reaction Networks
Khachik Sargsyan, Cosmin Safta, *Bert J. Debusschere*, and Habib N. Najm, Sandia National Laboratories, USA

10:30-10:55 A New Approach for Solving Multiscale SPDEs using Probabilistic Graphical Models
Nicholas Zabaras and *Jiang Wan*, Cornell University, USA

Wednesday, April 4

MS49

UQ in Engineering Applications - Part I of III

9:30 AM-11:30 AM

Room:State F

For Part 2 see MS56

Uncertainty quantification plays a critical role in model validation and system design, reducing risks associated with computations in engineering practice. A variety of UQ algorithms address limitations of existing methodologies: the curse of dimensionalitgy, discontinous response surfaces, expensive function evaluations, etc. It is important to assess the impact of UQ on industrial applications in view of these issues and to identify further opportunities and remaining bottlenecks. The minisymposium will address these questions through a discussion of recent innovations in UQ algorithms and specific UQ engineering applications in a variety of fields.

Organizer: James G. Glimm
State University of New York, Stony Brook, USA

Organizer: Gianluca Iaccarino
Stanford University, USA

9:30-9:55 Uncertainty Quantification for Turbulent Mixing and Turbulent Combustion

James G. Glimm, State University of New York, Stony Brook, USA

10:00-10:25 Criteria for Optimization Under Uncertainty

Domenico Quagliarella, Centro Italiano Ricerche Aerospaziali, Italy; G. Petrone, Università degli Studi di Napoli Federico II, Italy; Gianluca Iaccarino, Stanford University, USA

10:30-10:55 Chemical Kinetic Uncertainty Quantification for High-Fidelity Turbulent Combustion Simulations

Michael Mueller, Gianluca Iaccarino, and Heinz Pitsch, Stanford University, USA

11:00-11:25 A Reduced Order Model for a Nonlinear, Parameterized Heat Transfer Test Case

Paul Constantine and Jeremy Templeton, Sandia National Laboratories, USA; Joe Ruthruff, Lawrence Livermore National Laboratory, USA

Wednesday, April 4

MS50

Uncertainty Quantification and Prediction with Applications in Geoscience

9:30 AM-11:30 AM

Room:Congressional A

Characterization of the uncertainties for high-dimensional parameter spaces and expensive forward simulations remains a tremendous challenge for many problems today. Many problems in geoscience and environmental engineering are described by computationally expensive models. Multiple types of uncertainty need to be incorporated, including data error, model error, parameter error, randomness in model input (static and dynamic). The invited session is being proposed to highlight recent advances in this field.ncluding determination of spatial distribution of geologic materials in the subsurafce, determination of location of oil reservoirs or underground water based on exploratory drilling (few spatial points, high accuracy), forecast of contaminant transport.

Organizer: Bani Mallick
Texas A&M University, USA

9:30-9:55 Bayesian Uncertainty Quantification for Flows in Highly Heterogeneous Media

Yalchin Efendiev, Texas A&M University, USA

10:00-10:25 Uncertainty Quantification for Reactive Transport of Contaminants

Gowri Srinivasan, Los Alamos National Laboratory, USA

10:30-10:55 A Framework for Experimental Design for Ill-posed Inverse Problems

Luis Tenorio, Colorado School of Mines, USA

11:00-11:25 Emulators in Large-scale Spatial Inverse Problems

Anirban Mondal, Quantum Reservoir Impact, USA

Wednesday, April 4

MS62

Recent Advances and Applications of Stochastic Partial Differential Equations- Part I of III

9:30 AM-11:30 AM

Room:Congressional B

For Part 2 see MS69

Stochastic partial differential equations have been used in numerous physical phenomena to incorporate random effects arising from uncertainties in the system. In order to properly apply these equations in physical models, it is imperative to understand the mathematical structure and properties of these stochastic models and to study how they can be used to quantify the uncertainty in the physical systems. This minisymposium is intended to bring together both theoreticians and practitioners to address a range of applications of SPDEs, including fluid dynamics, optics and statistical inference of SPDE.

Organizer: Xiaoying Han
Auburn University, USA

Organizer: Chia Ying Lee
University of North Carolina, USA

9:30-9:55 Perspectives on Quantifying Uncertain Mechanisms in Dynamical Systems

Jinqiao Duan, University of California, Los Angeles, USA

10:00-10:25 Stochastic Integrable Dynamics of Optical Pulses Propagating through an Active Medium

Gregor Kovacic, Rensselaer Polytechnic Institute, USA; Ethan Atkins, Courant Institute of Mathematical Sciences, New York University, USA; Peter R. Kramer, Rensselaer Polytechnic Institute, USA; Ildar R. Gabitov, University of Arizona and Los Alamos National Laboratory, USA

continued on next page

10:30-10:55 Reduced Models for Mode-locked Lasers with Noise

Richard O. Moore, New Jersey Institute of Technology, USA; Daniel S. Cargill, New Jersey Institute of Technology, USA; Tobias Schaefer, City University of New York, Staten Island, USA

11:00-11:25 Analysis and Simulations of a Perturbed Stochastic Nonlinear Schrödinger Equation for Pulse Propagation in Broadband Optical Fiber Lines

Avner Peleg, State University of New York, Buffalo, USA; Yeojin Chung, Southern Methodist University, USA

Lunch Break

11:30 AM-1:00 PM

Attendees on their own

Wednesday, April 4

IP5

Model Reduction for Uncertainty Quantification of Large-scale Systems

1:00 PM-1:45 PM

Room:State C/D

Chair: Omar Ghattas, University of Texas at Austin, USA

Uncertainty quantification is becoming recognized as an essential aspect of development and use of numerical simulation tools, yet it remains computationally intractable for large-scale complex systems characterized by high-dimensional uncertainty spaces. In such settings, it is essential to generate surrogate models -- low-dimensional, efficient models that retain predictive fidelity of high-resolution simulations. This talk will discuss formulations of projection-based model reduction approaches for applications in uncertainty quantification. For systems governed by partial differential equations, we demonstrate the use of reduced models for uncertainty propagation, solution of statistical inverse problems, and optimization under uncertainty.

Karen E. Willcox
Massachusetts Institute of Technology, USA

Intermission

1:45 PM-2:00 PM

Wednesday, April 4

MT8

Emulation, Elicitation and Calibration - Part III of III

2:00 PM - 4:00 PM

For Part 2 see MT5

Room: State C

This minitutorial concerns statistical approaches to UQ based on Bayesian statistics and the use of emulators. It is organised as three 2-hour sessions. The first begins with an overview of UQ tasks (uncertainty propagation, sensitivity analysis, calibration, validation) and of how emulation (a non-intrusive technique) tackles those tasks efficiently. It continues with an introduction to elicitation, a key component of input uncertainty quantification in practice. The second session presents the basic ideas of emulation and illustrates its power for uncertainty propagation, etc. The third session is about calibration, including the importance of model discrepancy and history matching.

Organizer:
Anthony O'Hagan, University of Sheffield, United Kingdom

Speakers:
Peter Challenor, National Oceanography Centre, Southampton, United Kingdom
Anthony O'Hagan, University of Sheffield, United Kingdom
Ian Vernon, University of Durham, United Kingdom

Wednesday, April 4

CP14

Propagation & Prediction

2:00 PM-3:40 PM

Room:University A

Chair: Nathan L. Gibson, Oregon State University, USA

2:00-2:15 Hybrid Stochastic Collocation - Stochastic Perturbation Method for Linear Elastic Problems with Uncertain Material Parameters

Boyan S. Lazarov, Technical University of Denmark, Denmark; Mattias Schevenels, K.U. Leuven, Belgium

2:20-2:35 Stochastic Analysis of the Hydrologic Cascade Model, a Polynomial Chaos Approach

Franz Konecny and Hans-Peter Nachtnebel, University of Natural Resources and Applied Life Sciences, Austria

2:40-2:55 Likelihood-Based Observability Analysis and Confidence Intervals for Model Predictions

Clemens Kreutz, Andreas Raue, and Jens Timmer, University of Freiburg, Germany

3:00-3:15 Toward Reduction of Uncertainty in Complex Multi-Reservoir River Systems

Nathan L. Gibson, Arturo Leon, and Christopher Gifford-Miears, Oregon State University, USA

3:20-3:35 A Comparison Of Uncertainty Quantification Methods Under Practical Industry Requirements

Liping Wang, Gulshan Singh, and Arun Subramaniyan, GE Global Research, USA

Wednesday, April 4

CP15

Reliability & Rare Events

2:00 PM-3:00 PM

Room:University B

Chair: Aparna V. Huzurbazar, Los Alamos National Laboratory, USA

2:00-2:15 Glimpses of Uq, Qmu, and Reliability

Aparna V. Huzurbazar and David Collins, Los Alamos National Laboratory, USA

2:20-2:35 Bayesian Subset Simulation

Konstantin M. Zuev, University of Southern California, USA; James Beck, California Institute of Technology, USA

2:40-2:55 Rare Events Detection and Analysis of Equity and Commodity High-Frequency Data

Dragos Bozdog, Ionut Florescu, Khaldoun Khashanah, and Jim Wang, Stevens Institute of Technology, USA

Wednesday, April 4

MS52

Climate Uncertainty Quantification - Part II of IV

2:00 PM-4:00 PM

Room:State D

For Part 1 see MS45
For Part 3 see MS59

Uncertainty quantification of climate predictions is challenging. Climate models used for making predictions contain not only many aleatoric sources of uncertainty, many of their epistemological aspects are not well defined. How can we test model responses to a forcing for which we do not have observations? How do we separate observations used to drive model development from those used for model evaluation? Climate models simulate non-linear processes that interact on many time and space scales, so representing, sampling, and computing aleatoric uncertainties alone is a major challenge. We welcome contributions that address any challenges in climate uncertainty quantification.

Organizer: Guang Lin
Pacific Northwest National Laboratory, USA

Organizer: Charles Jackson
University of Texas at Austin, USA

Organizer: Donald D. Lucas
Lawrence Livermore National Laboratory, USA

2:00-2:25 Spatial ANOVA Modeling of High-resolution Regional Climate Model Outputs from NARCCAP

Emily L. Kang, University of Cincinnati, USA; Noel Cressie, Ohio State University, USA

2:30-2:55 Quantifying Uncertainties in Hydrologic Parameters in the Community Land Model

Ruby Leung, Zhangshuan Hou, Maoyi Huang, Yinghai Ke, and Guang Lin, Pacific Northwest National Laboratory, USA

3:00-3:25 Uncertainty Propagation in Land-Crop Models

Xiaoyan Zeng, Mihai Anitescu, and Emil M. Constantinescu, Argonne National Laboratory, USA

3:30-3:55 Statistical Issues in Catchment Scale Hydrological Modeling

Cari Kaufman, University of California, Berkeley, USA

Wednesday, April 4

MS53

Recent Advances in Numerical SPDES - Part II of II

2:00 PM-4:00 PM

Room:State A

For Part 1 see MS46

It is well understood that effective numerical methods for stochastic partial differential equations (SPDES) are essential for uncertainty quantification. In the last decade much progress has been made in the construction numerical algorithms to efficiently solve SPDES with random coefficients and white noise perturbations. However, high dimensionality and low regularity is still the bottleneck in solving real world applicable SPDES with efficient numerical methods. This mini-symposium is intended to address the mathematical aspects of numerical approximations of SPDES, including error analysis and complexity analysis and development of new efficient numerical algorithms.

Organizer: Yanzhao Cao
Auburn University, USA

Organizer: Clayton G. Webster
Oak Ridge National Laboratory, USA

2:00-2:25 Basis and Measure Adaptation for Stochastic Galerkin Projections

Roger Ghanem and Bedřich Sousedík, University of Southern California, USA; Eric Phipps, Sandia National Laboratories, USA

2:30-2:55 Adaptive Sparse Grid Generalized Stochastic Collocation Using Wavelets

Clayton G. Webster, Oak Ridge National Laboratory, USA; Max Gunzburger and John Burkardt, Florida State University, USA

continued in next column

3:00-3:25 Error Analysis of a Stochastic Collocation Method for Parabolic Partial Differential Equations with Random Input Data

Guannan Zhang and Max Gunzburger, Florida State University, USA

3:30-3:55 A Stochastic Collocation Method Based on Sparse Grid for Stokes-Darcy Model with Random Hydraulic Conductivity

Max Gunzburger, Florida State University, USA; *Xiaoming He* and Xuerong Wen, Missouri University of Science and Technology, USA

Wednesday, April 4

MS54

Uncertainty Characterization and Management in Models of Dynamical Systems - Part I of IV

2:00 PM-4:00 PM

Room:State B

For Part 2 see MS61

Uncertainty in models of complex dynamical systems affect their use in prediction and control. Most current methods for addressing uncertainty either rely on a linear Gaussian assumption or suffer from the “curse-of-dimensionality” and become increasingly infeasible for high-dimensional nonlinear systems. This necessitates novel approaches for model reduction/refinement, statistical analysis of model performance, uncertainty-based design, model-data fusion, and control of systems in the presence of uncertainty. The aim of this invited session is to bring together researchers working in this area and present their recent results to the SIAM community.

Organizer: Abani K. Patra
State University of New York, Buffalo, USA

Organizer: Puneet Singla
State University of New York, Buffalo, USA

Organizer: Sonjoy Das
State University of New York, Buffalo, USA

2:00-2:25 Uncertainty Analysis of Dynamical Systems -- Application to Volcanic Ash Transport

Abani K. Patra, Puneet Singla, Marcus Bursik, E. Bruce Pitman, Matthew Jones and Tarunraj Singh, State University of New York, Buffalo, USA

2:30-2:55 Retrospective-Cost-Based Model Refinement of Systems with Inaccessible Subsystems

Dennis Bernstein, Anthony D’Amato, and Asad Ali, University of Michigan, USA

3:00-3:25 Multiscale Methods for Flows in Heterogeneous Stochastic Porous Media

Yalchin Efendiev, Texas A&M University, USA

3:30-3:55 Feedback Particle Filter: A New Formulation for Nonlinear Filtering Based on Mean-field Games

Tao Yang, *Prashant G. Mehta*, and Sean Meyn, University of Illinois at Urbana-Champaign, USA

Wednesday, April 4

MS55

Gradient-based Intrusive Uncertainty Quantification

2:00 PM-4:00 PM

Room:State E

Gradient-based uncertainty quantification holds the promise of more accurate assessment for lower computational cost, due to the favorable computational properties of adjoint calculations. Nevertheless, obtaining gradient information has its own theoretical, practical, and methodological complexities. In this minisymposium we discuss theoretical and practical issues in obtaining and using gradient information in the context of uncertainty quantification. Speakers in the workshop will discuss methods to efficiently compute sensitivity information for select applications, uncertainty models that are suitable for use with derivative information, and computational patterns that are enhanced by gradient information.

Organizer: Mihai Anitescu
Argonne National Laboratory, USA

2:00-2:25 Gradient-based Optimization for Mixed Epistemic and Aleatory Uncertainty

Brian Lockwood and Dimitri Mavriplis, University of Wyoming, USA

2:30-2:55 Gradient-based Data Assimilation in Atmospheric Applications

Adrian Sandu, and Mihai Alexe, Virginia Polytechnic Institute & State University, USA

3:00-3:25 Optimal Use of Gradient Information in Uncertainty Quantification

Mihai Anitescu, Argonne National Laboratory, USA; Fred J. Hickernell and Yiou Li, Illinois Institute of Technology, USA; Oleg Roderick, Argonne National Laboratory, USA

3:30-3:55 Sensitivity Analysis and Error Estimation for Differential Algebraic Equations in Nuclear Reactor Applications

Hayes Stripling, Texas A&M University, USA; Mihai Anitescu, Argonne National Laboratory, USA; Marvin Adams, Texas A&M University, USA

Wednesday, April 4

MS56

UQ in Engineering Applications - Part II of III

2:00 PM-4:00 PM

Room:State F

For Part 1 see MS49
For Part 3 see MS63

Uncertainty quantification plays a critical role in model validation and system design, reducing risks associated with computations in engineering practice. A variety of UQ algorithms address limitations of existing methodologies: the curse of dimensionalitgy, discontinous response surfaces, expensive function evaluations, etc. It is important to assess the impact of UQ on industrial applications in view of these issues and to identify further opportunities and remaining bottlenecks. The minisymposium will address these questions through a discussion of recent innovations in UQ algorithms and specific UQ engineering applications in a variety of fields.

Organizer: James G. Glimm
State University of New York, Stony Brook, USA

Organizer: Gianluca Iaccarino
Stanford University, USA

2:00-2:25 Uncertainty Quantification with Incomplete Physical Models

Gianluca Iaccarino, and Gary Tang, Stanford University, USA

2:30-2:55 Numerical Methods for Polynomial Chaos in Uncertain Flow Problems

Mass Per Pettersson, Stanford University, USA

3:00-3:25 A Semi-Intrusive Deterministic Approach to Uncertainty Quantifications

Remi Abgrall, INRIA and University of Bordeaux, France; James G. Glimm, State University of New York, Stony Brook, USA

3:30-3:55 Evidence Based Multiciplinary Robust Design

Massimilian Vasile, University of Strathclyde, United Kingdom

Wednesday, April 4

MS57

Uncertainty Quantification for Ice Sheet Models

2:00 PM-4:00 PM

Room:Congressional A

Understanding the dynamics of polar ice sheets is critical for projections of future sea level rise. Yet, there remain large uncertainties in the inputs of models that describe present and future evolutions of ice sheets, ice shelves or glaciers. These uncertainties can be due to unknown model parameters, noise in the observations, uncertain initial and boundary conditions, or uncertain geometry. This session is intended to present recent developments in uncertainty quantification methods for forward propagation of uncertainty in ice sheet models, as well as for the solution of inverse ice sheet problems.

Organizer: Noemi Petra
University of Texas at Austin, USA

Organizer: Omar Ghattas
University of Texas at Austin, USA

Organizer: Georg Stadler
University of Texas at Austin, USA

2:00-2:25 Quantification of the Uncertainty in the Basal Sliding Coefficient in Ice Sheet Models

Noemi Petra, Hongyu Zhu, Georg Stadler, and Omar Ghattas, University of Texas at Austin, USA

2:30-2:55 Toward Estimation of Sub-ice Shelf Melt Rates to Ocean Circulation Under Pine Island Ice Shelf, West Antarctica

Patrick Heimbach, Massachusetts Institute of Technology, USA; Martin Losch, Alfred Wegener Institute, Germany

3:00-3:25 Ice Bed Geometry: Estimates of Known Unknowns

Charles Jackson, Chad Greene, John Goff, Scott Kempf, and Duncan Young, University of Texas at Austin, USA; Evelyn Powell, Institute for Geophysics, USA; Don Blankenship, University of Texas at Austin, USA

3:30-3:55 Bayesian Calibration via Additive Regression Trees with Application to the Community Ice Sheet Model

Matthew Pratola, Stephen Price, and David Higdon, Los Alamos National Laboratory, USA

Wednesday, April 4

MS58

Model Reduction for Nonlinear Dynamical Systems

2:00 PM-4:00 PM

Room:Congressional B

Model reduction methods have been successfully applied to linear dynamical systems to drastically reduce the cost of computing the system's time-history using a set of reduced coordinates. Such reduction enables (1) real-time analysis and control for large-scale systems and (2) parameter studies (e.g., uncertainty quantification, sensitivity analysis, and design optimization), where simulations are run for many input-parameter values. One challenge facing model reduction methods is application to nonlinear dynamical systems, where complexity reduction requires more sophisticated approaches. This minisymposium will explore state-of-the-art methods for nonlinear model reduction and their application to problems in uncertainty quantification.

Organizer: Kevin T. Carlberg
Stanford University, USA

Organizer: Paul Constantine
Stanford University, USA

2:00-2:25 Linearized Reduced-order Models for Optimization and Data Assimilation in Subsurface Flow
Jincong He and Lou J. Durlofsky, Stanford University, USA

2:30-2:55 Decreasing the Temporal Complexity in Nonlinear Model Reduction
Kevin T. Carlberg, Stanford University, USA

3:00-3:25 Reduced Basis, the Discrete Interpolation Method and Fast Quadratures for Gravitational Waves
Harbir Antil, University of Maryland, USA

3:30-3:55 Error Analysis for Nonlinear Model Reduction Using Discrete Empirical Interpolation in the Proper Orthogonal Decomposition Approach
Saifon Chaturantabut, Virginia Polytechnic Institute & State University, USA; Danny C. Sorensen, Rice University, USA

Coffee Break

4:00 PM-4:30 PM

Room:Pre-Function Area

Wednesday, April 4

MT9

Uncertainty Quantification: Foundations and Capabilities for Model-Based Simulations - Part III of III

4:30 PM - 6:30 PM

For Part 2 see MT6

Room: State C

The minitutorial will present the physical motivation and mathematical foundations necessary for the formulation of well-posed UQ problems in computational science and engineering. In particular, the minitutorial will cover 1) aspects of probabilistic modeling and analysis, 2) polynomial chaos representations, 3) stochastic processes and Karhunen-Loeve expansions, 4) forward UQ including sampling, sparse-grid, stochastic Galerkin and collocation, 5) inverse problems in UQ, 6) overview of software resources, 7) summary of advanced topics.

Organizer:

Roger Ghanem, University of Southern California, USA

Speakers:

Roger Ghanem, University of Southern California, USA

Bert Debusschere, Sandia National Laboratories, USA

Wednesday, April 4

CP16

Modeling Structured Systems

4:30 PM-5:10 PM

Room:University A

Chair: Yan Sun, Utah State University, USA

4:30-4:45 Delay in Neuronal Spiking
Mikhail M. Shvartsman, University of St. Thomas, USA

4:50-5:05 A Gaussian Hierarchical Model for Random Intervals
Yan Sun, Utah State University, USA; Dan Ralescu, University of Cincinnati, USA

Wednesday, April 4

MS51

PDE Constrained Optimization with Uncertain Coefficients

4:30 PM-6:30 PM

Room:State E

The appropriate treatment of uncertainty in optimization problems governed by partial differential equations (PDEs) with random coefficients raises many modeling, analytical, and computational challenges. The talks in this minisymposium present recent advances in the computational modeling of risk in PDE constrained optimization, techniques to efficiently sample the random parameters in the context of PDE constrained optimization, and optimization algorithms tailored to stochastic PDE constrained optimization. The theoretic and algorithmic advances are illustrated using a variety of applications from optimal control and shape optimization.

Organizer: Matthias Heinkenschloss
Rice University, USA

4:30-4:55 Uncertainty Quantification using Nonparametric Estimation and Epi-Splines

Johannes O. Royset, Naval Postgraduate School, USA

5:00-5:25 An Approach for the Adaptive Solution of Optimization Problems Governed by PDEs with Uncertain Coefficients

Drew Kouri, Rice University, USA

5:30-5:55 Risk Neutrality and Risk Aversion in Shape Optimization with Uncertain Loading

Ruediger Schultz, University of Duisburg-Essen, Germany

6:00-6:25 Numerical Methods for Shape Optimization under Uncertainty

Claudia Schillings and Volker Schulz, University of Trier, Germany

Wednesday, April 4

MS59

Climate Uncertainty Quantification - Part III of IV

4:30 PM-6:30 PM

Room:State D

For Part 2 see MS52
For Part 4 see MS66

Uncertainty quantification of climate predictions is challenging. Climate models used for making predictions contain not only many aleatoric sources of uncertainty, many of their epistemological aspects are not well defined. How can we test model responses to a forcing for which we do not have observations? How do we separate observations used to drive model development from those used for model evaluation? Climate models simulate non-linear processes that interact on many time and space scales, so representing, sampling, and computing aleatoric uncertainties alone is a major challenge. We welcome contributions that address any challenges in climate uncertainty quantification.

Organizer: Guang Lin
Pacific Northwest National Laboratory, USA

Organizer: Charles Jackson
University of Texas at Austin, USA

Organizer: Donald D. Lucas
Lawrence Livermore National Laboratory, USA

4:30-4:55 Uncertainty in Regional Climate Experiments

Stephan Sain, National Center for Atmospheric Research, USA

5:00-5:25 Efficient Surrogate Construction for High-Dimensional Climate Models

Cosmin Safta and Khachik Sargsyan, Sandia National Laboratories, USA; Daniel Ricciuto, Oak Ridge National Laboratory, USA; Robert D. Berry and Bert J. Debusschere, Sandia National Laboratories, USA; Peter Thornton, Oak Ridge National Laboratory, USA; Habib N. Najm, Sandia National Laboratories, USA

continued in next column

5:30-5:55 An Overview of Uncertainty Quantification in the Community Land Model

Daniel Ricciuto and Dali Wang, Oak Ridge National Laboratory, USA; Cosmin Safta, Khachik Sargsyan, and Habib N. Najm, Sandia National Laboratories, USA; Peter Thornton, Oak Ridge National Laboratory, USA

6:00-6:25 Testbeds for Ocean Model Calibration

James Gattiker and Matthew Hecht, Los Alamos National Laboratory, USA

Wednesday, April 4

MS60

From Model Calibration and Validation to Reliable Extrapolations - Part I of III

4:30 PM-6:30 PM

Room:State A

For Part 2 see MS67

Computational models serve the ultimate purpose of predicting the behavior of systems under scenarios of interest. Due to various limitations, models are usually calibrated and validated with data collected in scenarios other than the scenarios of interest, and model extrapolation is thus required. What are the necessary conditions to claim that a model has predictive capability and on how to quantify its credibility? There is no agreement in the scientific community today on what are the best validation practices. This mini-symposium targets scientists that develop and use calibration, validation, and uncertainty quantification methodologies to build confidence in model predictions.

Organizer: Gabriel A. Terejanu
University of Texas at Austin, USA

Organizer: Ernesto E. Prudencio
Institute for Computational Engineering and Sciences, USA

4:30-4:55 Towards Finding the Necessary Conditions for Justifying Extrapolations

Gabriel A. Terejanu, University of Texas at Austin, USA; Ernesto E. Prudencio, Institute for Computational Engineering and Sciences, USA

5:00-5:25 Calibration, Validation and the Importance of Model Discrepancy

Anthony O'Hagan, University of Sheffield, United Kingdom; Jenny Brynjarsdottir, Statistical and Applied Mathematical Sciences Institute, USA

continued in next column

5:30-5:55 Calibration, Model discrepancy and Extrapolative Predictions

Dave Higdon, Los Alamos National Laboratory, USA

6:00-6:25 "Experiment" and "Traveling" Models, Extrapolation Risk from Undetected Model Bias, and Data Conditioning for Systematic Uncertainty in Experiment Conditions

Vicente J. Romero, Sandia National Laboratories, USA

Wednesday, April 4

MS61

Uncertainty Characterization and Management in Models of Dynamical Systems - Part II of IV

4:30 PM-6:30 PM

Room:State B

For Part 1 see MS54
For Part 3 see MS68

Uncertainty in models of complex dynamical systems affect their use in prediction and control. Most current methods for addressing uncertainty either rely on a linear Gaussian assumption or suffer from the "curse-of-dimensionality" and become increasingly infeasible for high-dimensional nonlinear systems. This necessitates novel approaches for model reduction/refinement, statistical analysis of model performance, uncertainty-based design, model-data fusion, and control of systems in the presence of uncertainty. The aim of this invited session is to bring together researchers working in this area and present their recent results to the SIAM community.

Organizer: Puneet Singla
State University of New York, Buffalo, USA

Organizer: Abani K. Patra
State University of New York, Buffalo, USA

Organizer: Sonjoy Das
State University of New York, Buffalo, USA

4:30-4:55 Conjugate Unscented Transformation -- "Optimal Quadrature"

Nagavenkat Adurthi, *Puneet Singla*, and Tarunraj Singh, State University of New York, Buffalo, USA

5:00-5:25 A New Approach to Uq Based on the Joint Excitation-Response Pdf: Theory and Simulation

Heyrim Cho, Daniele Venturi, and George E. Karniadakis, Brown University, USA

5:30-5:55 A Random Iterative Proper Orthogonal Decomposition Approach with Application to the Filtering of Distributed Parameter Systems

Suman Chakravorty, Texas A&M University, USA

6:00-6:25 Bayesian UQ on Infinite Dimensional Spaces with Incompletely Specified Priors

Houman Owhadi, California Institute of Technology, USA

Wednesday, April 4

MS63

UQ in Engineering Applications - Part III of III

4:30 PM-6:00 PM

Room:State F

For Part 2 see MS56

Uncertainty quantification plays a critical role in model validation and system design, reducing risks associated with computations in engineering practice. A variety of UQ algorithms address limitations of existing methodologies: the curse of dimensionalitgy, discontinous response surfaces, expensive function evaluations, etc. It is important to assess the impact of UQ on industrial applications in view of these issues and to identify further opportunities and remaining bottlenecks. The minisymposium will address these questions through a discussion of recent innovations in UQ algorithms and specific UQ engineering applications in a variety of fields.

Organizer: James G. Glimm

State University of New York, Stony Brook, USA

Organizer: Gianluca Iaccarino

Stanford University, USA

4:30-4:55 Case Studies in Uncertainty Quantification for Aerodynamic Problems in Turbomachinery

Sriram Shankaran, General Electric, USA

5:00-5:25 Quantification of Uncertainty in Wind Energy

Karthik Duraisamy, Stanford University, USA

5:30-5:55 Uncertainty Quantification for Rayleigh-Taylor Turbulent Mixing

Tulin Kaman and James Glimm, State University of New York, Stony Brook, USA

Wednesday, April 4

MS64

Uncertainty in Inverse Problems

4:30 PM-6:30 PM

Room:Congressional A

The solution of inverse problems is used in applications ranging from oil and mineral exploration to medical imaging and surgery planning. Typically, a solution is presented to the practitioner without any assessment of the errors that may be involved with it. In this minisymposium we discuss how to quantify, compute and display a measure of uncertainty.

Organizer: Eldad Haber

University of British Columbia, Canada

Organizer: Lior Horesh

Emory University, USA

4:30-4:55 Prior Modelling for Inverse Problems Using Gaussian Markov Random Fields

Johnathan M. Bardsley, University of Montana, USA

5:00-5:25 Challenges in Uncertainty Quantification for Dynamic History Matching

Lior Horesh, Emory University, USA; Andrew R. Conn, IBM T.J. Watson Research Center, USA; Gijs van Essen and Eduardo Jimenez, Shell Innovation Research & Development, USA; Sippe Douma, Shell, USA; Ulisses Mello, IBM T.J. Watson Research Center, USA

5:30-5:55 Title Not Available at Time of Publication

Luis Tenorio, Colorado School of Mines, USA

6:00-6:25 Evaluation of Covariance Matrices and their use in Uncertainty Quantification

Eldad Haber, University of British Columbia, Canada

Wednesday, April 4

MS65

Modeling Networks in Dynamic Systems

4:30 PM-6:30 PM

Room:Congressional B

Many physical systems rely on complex and intricate network structures for their proper function. Understanding the interaction between the network structure and the global properties of the system is a crucial yet often difficult problem to solve as the network may be hard to experimentally determine and/or requires a large number of variables to characterize. The talks in this mini- symposium will discuss the statistical features of networks from various physical systems and their level of importance in determining global responses of the full physical system.

Organizer: Katherine Newhall

Rensselaer Polytechnic Institute, USA

4:30-4:55 Size of Synchronous Firing Events in Model Neuron Systems

Katherine Newhall, Rensselaer Polytechnic Institute, USA

5:00-5:25 The Influence of Topology on Sound Propagation in Granular Force Networks

Danielle S. Bassett, University of California, Santa Barbara, USA; Eli Owens and Karen Daniels, North Carolina State University, USA; Mason A. Porter, University of Oxford, United Kingdom

5:30-5:55 Asymptotically Inspired Moment-Closure Approximation for Adaptive Networks

Maxim S. Shkarayev, Rensselaer Polytechnic Institute, USA; Leah Shaw, College of William & Mary, USA

6:00-6:25 Network Analysis of Anisotropic Electrical Properties in Percolating Sheared Nanorod Dispersions

Feng B. Shi, and Mark Forest, University of North Carolina, Chapel Hill, USA; Peter J. Mucha, University of North Carolina, USA; Simi Wang, University of North Carolina, Chapel Hill, USA; Xiaoyu Zheng, Kent State University, USA; Ruhai Zhou, Old Dominion University, USA

Thursday, April 5

Registration

7:45 AM-1:30 PM

Room:Chancellor and Pre-Function Area

Closing Remarks

8:10 AM-8:15 PM

Room:State C/D

IP6

Statistical Approaches to Combining Models and Observations

8:15 AM-9:00 AM

Room:State C/D

Chair: Anthony O'Hagan, University of Sheffield, United Kingdom

Numerical models and observational data are critical in modern science and engineering. Since both of these information sources involve uncertainty, the use of statistical, probabilistic methods play a fundamental role. I discuss a general Bayesian framework for combining uncertain information and indicate how various approaches (ensemble forecasting, UQ, etc.) fit in this framework. A paleoclimate analysis illustrates the use of simple physics and statistical modeling to produce inferences. A second example involves glacial dynamics and illustrates how updating models and data can lead to estimates of model error. A third example involves the extraction of information from multi-model ensembles in climate projection studies.

Mark Berliner
Ohio State University, USA

Coffee Break

9:00 AM-9:30 AM

Room:Pre-Function Area

Thursday, April 5

MT10

A Tutorial on Uncertainty Quantification and Data Analysis for Inverse Problems

9:30 AM - 12:30 PM

Room: State C

We will start with a brief overview of ill-posed inverse problems and regularization that includes a quick review of the necessary results from functional analysis. We then focus on uncertainty quantification for a particular class of regularization procedures using frequentist and Bayesian frameworks. We describe basic methods to assess uncertainty in each of these frameworks. This will include a review of the basic statistics and probability tools needed. We end with an introduction to exploratory data analysis methods that can be used for model validation.

Organizer and Speaker:

Luis Tenorio, Colorado School of Mines, USA

Thursday, April 5

CP17

Theory & Foundations

9:30 AM-11:30 AM

Room:University A

Chair: Rafi L. Muhanna, Georgia Institute of Technology, USA

9:30-9:45 Interval-Based Inverse Problems with Uncertainties

Rafi L. Muhanna and Francesco Fedele, Georgia Institute of Technology, USA

9:50-10:05 Cramer-Rao Bound for Models of Fat-Water Separation Using Magnetic Resonance Imaging

Angel R. Pineda and Emily Bice, California State University, Fullerton, USA

10:10-10:25 Automated Exact Calculation of Test Statistics in Hypothesis Testing

Lawrence Leemis and *Vincent Yannello*, College of William & Mary, USA

10:30-10:45 Probability Bounds for Nonlinear Finite Element Analysis

Rafi L. Muhanna, Georgia Institute of Technology, USA; *Robert Mullen*, University of South Carolina, USA

10:50-11:05 A Complete Closed-Form Solution to Stochastic Linear Systems with Fixed Coefficients

Elmor L. Peterson, Systems Science Consulting, USA

11:10-11:25 Evidence-Based Approach for the Probabilistic Assessment of Unknown Foundations of Bridges

Negin Yousefpour, Zenon Medina –Cetina, and Jean-Louis Briaud, Texas A&M University, USA

Thursday, April 5

CP18

Sensitivity & Stochastic Representations

9:30 AM-10:50 AM

Room:University B

Chair: Jemin George, U.S. Army Research Laboratory, USA

9:30-9:45 Analysis of Quasi-Monte Carlo FE Methods for Elliptic PDEs with Lognormal Random Coefficients

Robert Scheichl, and Ivan G. Graham, University of Bath, United Kingdom; Frances Y. Kuo and James Nichols, University of New South Wales, Australia; Christoph Schwab, ETH Zürich, Switzerland; Ian H. Sloan, University of New South Wales, Australia

9:50-10:05 An Approach to Weak Solution Approximation of Stochastic Differential Equations

Jemin George, U.S. Army Research Laboratory, USA

10:10-10:25 Frechet Sensitivity Analysis for the Convection-Diffusion Equation

Vitor Leite Nunes, Virginia Polytechnic Institute & State University, USA

10:30-10:45 Asymptotic Normality and Efficiency for Sobol Index Estimator

Alexandre Janon, Université Joseph Fourier and INRIA, France; *Thierry Klein*, Universite de Toulouse, France; Agnes Lagnoux, CNRS, France; Maëlle Nodet, Université Joseph Fourier, France and INRIA, France; Clémentine Prieur, Université Joseph Fourier and INRIA, France

Thursday, April 5

MS66

Climate Uncertainty Quantification - Part IV of IV

9:30 AM-11:30 AM

Room:State D

For Part 3 see MS59

Uncertainty quantification of climate predictions is challenging. Climate models used for making predictions contain not only many aleatoric sources of uncertainty, many of their epistemological aspects are not well defined. How can we test model responses to a forcing for which we do not have observations? How do we separate observations used to drive model development from those used for model evaluation? Climate models simulate non-linear processes that interact on many time and space scales, so representing, sampling, and computing aleatoric uncertainties alone is a major challenge. We welcome contributions that address any challenges in climate uncertainty quantification.

Organizer: Guang Lin
Pacific Northwest National Laboratory, USA

Organizer: Charles Jackson
University of Texas at Austin, USA

Organizer: Donald D. Lucas
Lawrence Livermore National Laboratory, USA

9:30-9:55 Propagating Uncertainty from General Circulation Models through Projected Local Impacts

Peter Guttorp, University of Washington, USA

10:00-10:25 Covariance Approximation for Large Multivariate Spatial Datasets with An Application to Multiple Climate Models

Huiyan Sang, Texas A&M University, USA

10:30-10:55 Measures of Model Skill and Parametric Uncertainty Estimation for Climate Model Development

Gabriel Huerta, Indiana University, USA; Charles Jackson, University of Texas at Austin, USA

11:00-11:25 Optimal Parameter Estimation in Community Atmosphere Models

Guang Lin, Ben Yang, Yun Qian, and Ruby Leung, Pacific Northwest National Laboratory, USA

Thursday, April 5

MS67

From Model Calibration and Validation to Reliable Extrapolations - Part II of III

9:30 AM-11:30 AM

Room:State A

For Part 1 see MS60
For Part 3 see MS75

Computational models serve the ultimate purpose of predicting the behavior of systems under scenarios of interest. Due to various limitations, models are usually calibrated and validated with data collected in scenarios other than the scenarios of interest, and model extrapolation is thus required. What are the necessary conditions to claim that a model has predictive capability and on how to quantify its credibility? There is no agreement in the scientific community today on what are the best validation practices. This minisymposium targets scientists that develop and use calibration, validation, and uncertainty quantification methodologies to build confidence in model predictions.

Organizer: Gabriel A. Terejanu
University of Texas at Austin, USA

Organizer: Ernesto E. Prudencio
Institute for Computational Engineering and Sciences, USA

9:30-9:55 Model Selection and Inference for a Nuclear Reactor Application

Laura Swiler, Sandia National Laboratories, USA; Brian Williams and Rick Picard, Los Alamos National Laboratory, USA

10:00-10:25 Validation Experience for Stochastic Models of Groundwater Flow and Radionuclide Transport at Underground Nuclear Test Sites and the Shift Away from Quantitative Measures and Toward Iterative Improvement

Jenny Chapman, Desert Research Institute, USA; Ahmed Hassan, Cairo University, Egypt; Karl Pohlmann, Desert Research Institute, USA

continued on next page

Thursday, April 5

MS67

From Model Calibration and Validation to Reliable Extrapolations - Part II of III

9:30 AM-11:30 AM

continued

10:30-10:55 Validation and Data Assimilation of Shallow Water Models

Clint Dawson, Jennifer Proft, J. Casey Dietrich, Troy Butler, and Talea Mayo, University of Texas at Austin, USA; Joannes Westerink, University of Notre Dame, USA; Ibrahim Hoteit and M.U. Altaf, King Abdullah University of Science & Technology (KAUST), Saudi Arabia

11:00-11:25 Quantifying Long-Range Predictability and Model Error through Data Clustering and Information Theory

Dimitris Giannakis, New York University, USA

Thursday, April 5

MS68

Uncertainty Characterization and Management in Models of Dynamical Systems - Part III of IV

9:30 AM-11:30 AM

Room:State B

For Part 2 see MS61
For Part 4 see MS76

Uncertainty in models of complex dynamical systems affect their use in prediction and control. Most current methods for addressing uncertainty either rely on a linear Gaussian assumption or suffer from the "curse-of-dimensionality" and become increasingly infeasible for high-dimensional nonlinear systems. This necessitates novel approaches for model reduction/refinement, statistical analysis of model performance, uncertainty-based design, model-data fusion, and control of systems in the presence of uncertainty. The aim of this invited session is to bring together researchers working in this area and present their recent results to the SIAM community.

Organizer: Abani K. Patra
State University of New York, Buffalo, USA

Organizer: Puneet Singla
State University of New York, Buffalo, USA

Organizer: Sonjoy Das
State University of New York, Buffalo, USA

9:30-9:55 New Positive-definite Random Matrix Ensembles for Stochastic Dynamical System with High Level of Heterogeneous Uncertainties

Sonjoy Das, State University of New York, Buffalo, USA

continued in next column

10:00-10:25 Uncertainty Quantification and Model Validation in Flight Control Applications

Raktim Bhattacharya, Texas A&M University, USA

10:30-10:55 Existence and Stability of Equilibria in Stochastic Galerkin Methods

Roland Pulch, University of Wuppertal, Germany

11:00-11:25 A Nonlinear Dimension Reduction Technique for Random Fields Based on Topology-Preserving Transformations

Daniele Venturi, Brown University, USA; Guang Lin, Pacific Northwest National Laboratory, USA; George E. Karniadakis, Brown University, USA

Thursday, April 5

MS69

Recent Advances and Applications of Stochastic Partial Differential Equations - Part II of III

9:30 AM-12:00 PM

Room:Congressional B

For Part 1 see MS62
For Part 3 see MS77

Stochastic partial differential equations have been used in numerous physical phenomena to incorporate random effects arising from uncertainties in the system. In order to properly apply these equations in physical models, it is imperative to understand the mathematical structure and properties of these stochastic models and to study how they can be used to quantify the uncertainty in the physical systems. This minisymposium is intended to bring together both theoreticians and practitioners to address a range of applications of SPDEs, including fluid dynamics, optics and statistical inference of SPDE.

Organizer: Xiaoying Han
Auburn University, USA

Organizer: Chia Ying Lee
University of North Carolina, USA

9:30-9:55 Asymptotic Behavior of Stochastic Lattice Differential Equations
Xiaoying Han, Auburn University, USA

10:00-10:25 Generalized Malliavin Calculus and Spdes in Higher-Order Chaos Spaces
Sergey Lototsky, University of Southern California, USA; Boris Rozovskii, Brown University, USA; Dora Selesi, University of Novi Sad, Serbia

10:30-10:55 New Results for the Stochastic PDEs of Fluid Dynamics
Nathan Glatt-Holtz, Indiana University, USA

continued in next column

11:00-11:25 Stochastic-Integral Models for Propagation-of-Uncertainty Problems in Nondestructive Evaluation
Elias Sabbagh, Kim Murphy, and *Harold Sabbagh*, Victor Technologies, USA; John Aldrin, Computational Tools, USA; Jeremy Knopp and Mark Blodgett, Air Force Research Laboratory, USA

11:30-11:55 Unbiased Perturbations of the Navier-Stokes Equation
Chia Ying Lee, University of North Carolina, USA; Boris Rozovsky, Brown University, USA

Thursday, April 5

MS70

Data Assimilation and Inverse Problems - Part I of II

9:30 AM-11:30 AM

Room:State F

For Part 2 see MS78

Data assimilation is the process of fusing information from imperfect models, noisy measurements, and priors, to produce an optimal representation of the state of a physical system. Inverse problems infer parameter values from measurements of reality. This minisymposium focuses on important problems related to data assimilation and inverse problems, including: new computational algorithms for large scale systems, both variational and ensemble based; sensitivity analysis; adjoint model development; modeling of model errors; impact of observations; quantification of the posterior uncertainty.

Organizer: Adrian Sandu
Virginia Polytechnic Institute & State University, USA

Organizer: Dacian N. Daescu
Portland State University, USA

Organizer: Humberto C. Godinez
Los Alamos National Laboratory, USA

Organizer: Ralph C. Smith
North Carolina State University, USA

9:30-9:55 The Estimation of Functional Uncertainty using Polynomial Chaos and Adjoint Equations
Michael Navon, Florida State University, USA

10:00-10:25 FATODE: A Library for Forward, Tangent Linear, and Adjoint ODE Integration
Hong Zhang, and Adrian Sandu, Virginia Polytechnic Institute & State University, USA

10:30-10:55 Model Covariance Sensitivity as a Guidance for Localization in Data Assimilation
Humberto C. Godinez, Los Alamos National Laboratory, USA; Dacian N. Daescu, Portland State University, USA

11:00-11:25 Hybrid Methods for Data Assimilation
Haiyan Cheng, Willamette University, USA; Adrian Sandu, Virginia Polytechnic Institute & State University, USA

Thursday, April 5

MS71

Ensembles of Random Points for Uncertainty Quantification

9:30 AM-12:00 PM

Room:Congressional A

We introduce random point and mesh algorithms, and how they are used for fracture mechanics uncertainty quantification. We also discuss how random point cloud techniques might be extended to generate experimental designs. Some physics simulations are inherently dependent on the mesh or point cloud. For example, in some fracture simulations cracks can only propagate along mesh edges. Further, mesh variability models some of the natural material strength variability. In this sense, a mesh is a multi-dimensional uncertain input parameter to the simulation. Simulations over an ensemble of (random) meshes can help quantify the range of outcomes.

Organizer: Scott A. Mitchell
Sandia National Laboratories, USA

9:30-9:55 Random Poisson-Disk Samples and Meshes
Scott A. Mitchell and Mohamed S. Ebeida, Sandia National Laboratories, USA

10:00-10:25 Upscaling Micro-scale Material Variability Through the use of Random Voronoi Tessellations
Joseph Bishop, Sandia National Laboratories, USA

10:30-10:55 Simplex Stochastic Collocation Approach
Gianluca Iaccarino and Jeroen Witteveen, Stanford University, USA

11:00-11:25 Discrete Models of Fracture and Mass Transport in Cement-based Composites
John Bolander, University of California, Davis, USA; Peter Grassl, University of Glasgow, Scotland, UK

11:30-11:55 Maximal Poisson-disk Sampling for UQ Purposes
Mohamed S. Ebeida, Sandia National Laboratories, USA

Thursday, April 5

MS72

Integrating Simulation, Emulation and Extreme Value Methods for Rare Events

9:30 AM-11:30 AM

Room:State E

Quantitative risk assessment usually involves estimating small probabilities of rare, high consequence events. Relative uncertainty is high due to extremely limited data. Computer simulations can provide additional information but realistic stochastic models require massive run times to generate useful information, so efficient methods are required. In many applications, the level of the extreme quantity is also important, so the distribution tail becomes important. Extensions/combinations of computer model emulation and extreme value techniques are required to deal with stochastic outputs and quantify uncertainty in the output distribution tail. We'll discuss recent theoretical and computational developments, open research questions, and example applications.

Organizer: Marc C. Kennedy
The Food and Environment Research Agency, United Kingdom

9:30-9:55 Sensitivity Analysis and Estimation of Extreme Tail Behaviour in Two-dimensional Monte Carlo Simulation (2DMC)
Marc C. Kennedy and Victoria Roelofs, The Food and Environment Research Agency, United Kingdom

10:00-10:25 Methods for Assessing Chances of Rare, High-Consequence Events in Groundwater Monitoring
Dave Higdon, Elizabeth Keating, Zhenxue Dai, and James Gattiker, Los Alamos National Laboratory, USA

10:30-10:55 Quantile Emulation for Non-Gaussian Stochastic Models
Remi Barillec, Alexis Boukouvalas, and Dan Cornford, University of Aston, United Kingdom

continued in next column

11:00-11:25 An Investigation of the Pineapple Express Phenomenon via Bivariate Extreme Value Theory
Grant Weller and Dan Cooley, Colorado State University, USA; Stephan Sain, National Center for Atmospheric Research, USA

Lunch Break

11:30 AM-1:00 PM

Attendees on their own

Thursday, April 5

CP19

Modeling & Estimation

1:00 PM-2:20 PM

Room:University A

Chair: Hadi Meidani, University of Southern California, USA

1:00-1:15 Maximum Entropy Construction for Data-Driven Analysis of Diffusion on Random Manifolds

Hadi Meidani and Roger Ghanem, University of Southern California, USA

1:20-1:35 Multiple Signal Classification in Covariance Space of EEG Data

Deepashree Sengupta and *Aurobinda Routray*, Indian Institute of Technology Kharagpur, India

1:40-1:55 Random Matrix Based Approach for Adaptive Estimation of Covariance Matrix

Sonjoy Das, and *Kumar Vishwajeet*, State University of New York, Buffalo, USA; Puneet Singla, State University of New York, Buffalo, USA

2:00-2:15 Dynamic Large Spatial Covariance Matrix Estimation in Application to Semiparametric Model Construction Via Variable Clustering: the Sce Approach

Song Song, University of Texas, Austin, USA

Thursday, April 5

CP20

Representing Uncertainty & Structure

1:00 PM-2:20 PM

Room:University B

Chair: Marylesa Howard, University of Montana, USA

1:00-1:15 Computational Methods for Statistical Learning Using Support Vector Machine Classifiers

Marylesa Howard, University of Montana, USA

1:20-1:35 A Comparison of Dimensionality Reduction Techniques in Scientific Applications

Ya Ju Fan, and Chandrika Kamath, Lawrence Livermore National Laboratory, USA

1:40-1:55 Determining Critical Parameters of Sine-Gordon and Nonlinear Schrödinger Equations with a Point-Like Potential Using Generalized Polynomial Chaos Methods

Debananda Chakraborty and Jae-Hun Jung, State University of New York, Buffalo, USA

2:00-2:15 A Hidden Deterministic Solution to the Quantum Measurement Problem

Pabitra Pal Choudhury, ISI Kolkata, India; Swapan Kumar Dutta, Retired

Thursday, April 5

MS73

Uncertainty Quantification for Large Climate Models

1:00 PM-3:00 PM

Room:State C

Climate science depends on large, computationally intensive simulators. These include coupled simulators of the atmosphere, the ocean, sea ice and increasingly, the terrestrial and oceanic biosphere and land ice. Because of the political importance of the projections from such simulators it is important that we quantify the uncertainty in them. This mini-symposium looks at how we can use emulator based methods to look at these problems. The size of these models pose particular challenges to the methods and these will be discussed along with sensitivity analysis and how we can use data to constrain and calibrate the simulators.

Organizer: Peter Challenor

National Oceanography Centre, United Kingdom

1:00-1:25 An Introduction to Emulators and Climate Models

Peter Challenor, National Oceanography Centre, United Kingdom

1:30-1:55 Uncertainty in Modeled Upper Ocean Heat Content Change using a Large Ensemble

Robin Tokmakian, Naval Postgraduate School, USA

2:00-2:25 Calibration of Gravity Waves in WACCM

Serge Guillas, University College London, United Kingdom; Hanli Liu, National Center for Atmospheric Research, USA

2:30-2:55 Emulating Time Series Output of Climate Models

Danny Williamson, Durham University, United Kingdom

Thursday, April 5

MS74

Inference for Models Using Set-valued Inverses

1:00 PM-3:00 PM

Room:State D

This minisymposia will explore the use of set-valued inverses of models for inference. Topics will include approximation of set-valued inverses, computation of inverse measures in parameter spaces for models, relation to fiducial inference and Dempster and Shafer calculus, convergence and accuracy of computed inverse measures, inversion using multiple observations, and intrusive and non-intrusive computational methods.

Organizer: Donald Estep
Colorado State University, USA

1:00-1:25 A Computational Approach for Inverse Sensitivity Problems using Set-valued Inverses and Measure Theory

Donald Estep, Colorado State University, USA

1:30-1:55 A Non-intrusive Alternative to a Computational Measure Theoretic Inverse

Troy Butler, University of Texas at Austin, USA

2:00-2:25 Inverse Problem and Fisher's View of Statistical Inference

Jan Hannig, University of North Carolina, USA

2:30-2:55 Inverse Function-based Methodology for UQ

Jessi Cisewski, University of North Carolina at Chapel Hill, USA

Thursday, April 5

MS75

From Model Calibration and Validation to Reliable Extrapolations - Part III of III

1:00 PM-3:00 PM

Room:State A

For Part 2 see MS67

Computational models serve the ultimate purpose of predicting the behavior of systems under scenarios of interest. Due to various limitations, models are usually calibrated and validated with data collected in scenarios other than the scenarios of interest, and model extrapolation is thus required. What are the necessary conditions to claim that a model has predictive capability and on how to quantify its credibility? There is no agreement in the scientific community today on what are the best validation practices. This minisymposium targets scientists that develop and use calibration, validation, and uncertainty quantification methodologies to build confidence in model predictions.

Organizer: Gabriel A. Terejanu
University of Texas at Austin, USA

Organizer: Ernesto E. Prudencio
Institute for Computational Engineering and Sciences, USA

1:00-1:25 Variable Selection and Sensitivity Analysis via Dynamic Trees with an application to Computer Code Performance Tuning

Robert Gramacy, University of Chicago, USA

1:30-1:55 On Data Partitioning for Model Validation

Rebecca Morrison, Corey Bryant, Gabriel A. Terejanu, Serge Prudhomme, and Kenji Miki, University of Texas at Austin, USA

continued in next column

2:00-2:25 Validation of a Random Matrix Model for Mesoscale Elastic Description of Materials with Microstructures

Arash Noshadravan and Roger Ghanem, University of Southern California, USA; Johann Guilleminot, Université Paris-Est, France; Ikshwaku Atodaria and Pedro Peralta, Arizona State University, USA

2:30-2:55 Bayesian Filtering in Large-Scale Geophysical Systems and Uncertainty Quantification

Ibrahim Hoteit, King Abdullah University of Science & Technology (KAUST), Saudi Arabia; Bruce Cornuelle and Aneesh Subramanian, University of California, San Diego, USA; Hajoon Song, University of California, Santa Cruz, USA; Xiaodong Luo, King Abdullah University of Science & Technology (KAUST), Saudi Arabia

Thursday, April 5

MS76

Uncertainty Characterization and Management in Models of Dynamical Systems - Part IV of IV

1:00 PM-2:30 PM

Room:State B

For Part 3 see MS68

Uncertainty in models of complex dynamical systems affect their use in prediction and control. Most current methods for addressing uncertainty either rely on a linear Gaussian assumption or suffer from the "curse-of-dimensionality" and become increasingly infeasible for high-dimensional nonlinear systems. This necessitates novel approaches for model reduction/refinement, statistical analysis of model performance, uncertainty-based design, model-data fusion, and control of systems in the presence of uncertainty. The aim of this invited session is to bring together researchers working in this area and present their recent results to the SIAM community.

Organizer: Puneet Singla
State University of New York, Buffalo, USA

Organizer: Abani K. Patra
State University of New York, Buffalo, USA

Organizer: Sonjoy Das
State University of New York, Buffalo, USA

1:00-1:25 Characterization of the Effect of Uncertainty in Terrain Representations for Modeling Geophysical Mass Flows

Ramona Stefanescu, Abani K. Patra, and Marcus Bursik, State University of New York, Buffalo, USA

1:30-1:55 Toward Analysis of Uncertainty in Chaotic Systems

Eleanor Deram, Todd Oliver, and Robert D. Moser, University of Texas at Austin, USA

2:00-2:25 A Dynamically Weighted Particle Filter for Sea Surface Temperature Modeling

Faming Liang, Texas A&M University, USA; Duchwan Ryu, Medical College of Georgia, USA; Bani Mallick, Texas A&M University, USA

Thursday, April 5

MS77

Recent Advances and Applications of Stochastic Partial Differential Equations - Part III of III

1:00 PM-3:00 PM

Room:Congressional B

For Part 2 see MS69

Stochastic partial differential equations have been used in numerous physical phenomena to incorporate random effects arising from uncertainties in the system. In order to properly apply these equations in physical models, it is imperative to understand the mathematical structure and properties of these stochastic models and to study how they can be used to quantify the uncertainty in the physical systems. This minisymposium is intended to bring together both theoreticians and practitioners to address a range of applications of SPDEs, including fluid dynamics, optics and statistical inference of SPDE.

Organizer: Xiaoying Han
Auburn University, USA

Organizer: Chia Ying Lee
University of North Carolina, USA

1:00-1:25 Adaptive Construction of Surrogates for Bayesian Inference

Jinglai Li and Youssef M. Marzouk, Massachusetts Institute of Technology, USA

1:30-1:55 Statistical Inference Problems for Nonlinear SPDEs

Igor Cialenco, Illinois Institute of Technology, USA

2:00-2:25 Filtering the Navier Stokes Equations

Kody Law, University of Massachusetts, Amherst, USA

2:30-2:55 Reimagining Diffusion Monte Carlo for Quantum Monte Carlo, Sequential Importance Sampling, Rare Event Simulation and More

Jonathan Weare, University of Chicago, USA; Martin Hairer, University of Warwick, United Kingdom

Thursday, April 5

MS78

Data Assimilation and Inverse Problems - Part II of II

1:00 PM-3:00 PM

Room:State F

For Part 1 see MS70

Data assimilation is the process of fusing information from imperfect models, noisy measurements, and priors, to produce an optimal representation of the state of a physical system. Inverse problems infer parameter values from measurements of reality. This minisymposium focuses on important problems related to data assimilation and inverse problems, including: new computational algorithms for large scale systems, both variational and ensemble based; sensitivity analysis; adjoint model development; modeling of model errors; impact of observations; quantification of the posterior uncertainty.

Organizer: Adrian Sandu
Virginia Polytechnic Institute & State University, USA

Organizer: Dacian N. Daescu
Portland State University, USA

Organizer: Humberto C. Godinez
Los Alamos National Laboratory, USA

Organizer: Ralph C. Smith
North Carolina State University, USA

1:00-1:25 Error Covariance Sensitivity and Impact Estimation with Adjoint 4D-Var

Dacian N. Daescu, Portland State University, USA

1:30-1:55 Uncertainty Quantification and Data Assimilation Issues for Macro-Fiber Composite Actuators

Ralph C. Smith and Zhengzheng Hu, North Carolina State University, USA; Nathanial Burch, SAMSI, USA

2:00-2:25 Computing and Using Observation Impact in 4D-Var Data Assimilation

Alexandru Cioaca, and Adrian Sandu, Virginia Polytechnic Institute & State University, USA

2:30-2:55 Lagrangian Data Assimilation

Christopher Jones, University of North Carolina at Chapel Hill and University of Warwick, United Kingdom

Thursday, April 5

MS79

Modeling Consequences of Parameter Uncertainty

1:00 PM-3:00 PM

Room:Congressional A

Uncertainty in model parameters and simplification of complex models can be used advantageously to regularize ill-posed inverse problems, and to analyze predictive uncertainty. The speakers in this minisymposium will discuss approaches to model simplification and the effects of simplification on model predictions. In addition, they will discuss efficient algorithms for the direct evaluation of uncertainty propagation. The applications will include electrochemical impedance spectroscopy, groundwater, and soil moisture modeling.

Organizer: Jodi Mead
Boise State University, USA

1:00-1:25 Modeling Spatial Variability as Measurement Uncertainty
Jodi Mead, Boise State University, USA

1:30-1:55 Analyzing Predictive Uncertainty using Paired Complex and Simple Models
John Doherty, Flinders University and Watermark Numerical Computing, Australia

2:00-2:25 Quantifying Simplification-induced Error using Subspace Techniques
Jeremy White, U. S. Geological Survey, USA; Joseph Hughes, U.S. Geological Survey, USA

2:30-2:55 Using Electrochemical Impedance Spectroscopy for Studying Respiration of Anode Respiring Bacteria for Solid Oxide Fuel Cells
Rosemary A. Renaut, Arizona State University, USA

Thursday, April 5

MS80

Reduced Order Modeling for High Dimensional Nonlinear Models

1:00 PM-2:30 PM

Room:State E

The trade-off between accuracy and computational efficiency has always played an essential role in real world engineering calculations. The complexity of the models often increases at a higher rate than the increase in computer power which renders their repeated execution for engineering purposes computationally inefficient or impractical. To combat this challenge, scientists have invested into strategies to develop computationally efficient models with reduced complexity and acceptable accuracy. This approach is referred to as ‘reduced order modeling’ (ROM) which represents the subject of this session. The focus will be on obtaining solutions and completing uncertainty quantification efficiently.

Organizer: Hany S. Abdel-Khalik
North Carolina State University, USA

1:00-1:25 Hybrid Reduced order Modeling for Uncertainty Management in Nuclear Modeling
Hany S. Abdel-Khalik, North Carolina State University, USA

1:30-1:55 Intrusive Analysis for Uncertainty Quantification of Simulation Models
Oleg Roderick, Argonne National Laboratory, USA

2:00-2:25 Sparse Interpolatory Reduced-Order Models for Simulation of Light-Induced Molecular Transformations
Carl T. Kelley and David Mokrauer, North Carolina State University, USA

UQ12 Abstracts

SIAM Conference on

Uncertainty Quantification

Raleigh Marriott City Center Hotel
Raleigh, North Carolina, USA
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IP1

Sparse Tensor Algorithms in Uncertainty Quantification

We survey recent mathematical and computational results on sparse tensor discretizations of Partial Differential Equations (PDEs) with random inputs. The sparse Tensor discretizations allow, as a rule, to overcome the curse of dimensionality in approximating infinite dimensional problems. Results and Methods surveyed include a) regularity and N-term gpc approximation results and algorithms for elliptic and parabolic PDEs with random coefficients [joint work with A. Cohen, R. DeVore and V.H.Hoang] and b) existence and regularity results for solutions of classes of certain hyperbolic PDEs from conservation and balance laws. Multi-Level Monte-Carlo (MLMC) [joint with A. Barth] and Multi-Level Quasi-Monte-Carlo (MLQMC) [joint with I. Graham, R. Scheichl, F.Y.Kuo and I.M. Sloan] methods can be viewed as particular classes of sparse tensor discretizations. Numerical MLMC and MLQMC results for elliptic PDEs with random coefficients and for nonlinear systems of hyperbolic conservation laws are presented [joint work with S. Mishra and J. Sukys (ETH)]. We compare the performance of these methods with that of adaptive generalized polynomial chaos discretizations.

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IP2

Integrating Data from Multiple Simulation Models - Prediction and Tuning

Simulation of complex systems has become commonplace in most areas of science. In some settings, several simulators are available to explore the system, each with varying levels of fidelity. In this talk, Bayesian methodology for integrating outputs from multi-fidelity computer models, and field observations, to build a predictive model of a physical system is presented. The problem is complicated because inputs to the computer models are not all the same and the simulators have inputs (tuning parameters) that must be estimated from data. The methodology is demonstrated on an application from the University of Michigans Center for Radiative Shock Hydrodynamics.

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IP3

Polynomial Chaos Approaches to Multiscale and Data Intensive Computations

Prediction of multiscale systems is increasingly being based on complex physical models that depend on large uncertain data sets. In this talk, we will outline recent developments in polynomial chaos (PC) methods for uncertainty quantification in such systems. Implementations will be illustrated in light of applications to chemical kinetics, and geophysical flows. Conclusions are in particular drawn concerning the potential of parallel databases in providing a platform for discovery, assessing prediction fidelity, and decision support.

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IP4

Large Deviation Methods for Quantifying Uncertainty

Large deviation methods have been particularly successful in assessing small probabilities of rare events, which are difficult to compute. They are also at the center of many importance sampling methods that aim to estimate probabilities of rare events by Monte Carlo methods. Since probabilities of rare events are an important part of the emerging field of uncertainty quantification in complex scientific problems, the question arises as to how effective they are. This is because the results of large deviation theory depend sensitively on details of the probabilistic model used, and such details may not be available or may themselves be subject to uncertainty. I will address these issues with some examples using mean-field models and conservation laws and attempt to draw some broader conclusions.

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IP5

Model Reduction for Uncertainty Quantification of Large-scale Systems

Uncertainty quantification is becoming recognized as an essential aspect of development and use of numerical simulation tools, yet it remains computationally intractable for large-scale complex systems characterized by high-dimensional uncertainty spaces. In such settings, it is essential to generate surrogate models – low-dimensional, efficient models that retain predictive fidelity of high-resolution simulations. This talk will discuss formulations of projection-based model reduction approaches for applications in uncertainty quantification. For systems governed by partial differential equations, we demonstrate the use of reduced models for uncertainty propagation, solution of statistical inverse problems, and optimization under uncertainty.

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IP6

Statistical Approaches to Combining Models and Observations

Numerical models and observational data are critical in modern science and engineering. Since both of these information sources involve uncertainty, the use of statistical, probabilistic methods play a fundamental role. I discuss a general Bayesian framework for combining uncertain information and indicate how various approaches (ensemble forecasting, UQ, etc.) fit in this framework. A paleoclimate analysis illustrates the use of simple physics and statistical modeling to produce inferences. A second example involves glacial dynamics and illustrates how updating models and data can lead to estimates of model error. A third example involves the extraction of information from multi-model ensembles in climate projection studies.

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CP1

Capturing Signatures of *microcracks* from *macrolevel* Responses

The current work considers the problem of characterizing microcracks that are typically at 10–100 μm level (depending on the material). These microcracks are invisible to naked eyes, and can cause catastrophic failure once they grow to a certain critical length. A stochastic upscaling scheme based on previous work by Das is extended in the present work to include the effects of microcracks. The uncertainty (due to microstructural heterogeneities, and random size, orientation, and distribution of microcracks) is accounted for in the macroscopic (continuum) constitutive elasticity matrices by modeling them as bounded positive-definite random matrices. Distinct difference in probabilistic characteristics of macrolevel response variables is observed depending on the presence or absence of microcracks. This finding opens up a new way of capturing signatures of microcracks from macrolevel experimental response measurements.

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CP1

Identification of Uncertain Time-Dependent Material Behavior with Artificial Neural Networks

Reliability assessment of structures requires knowledge of the structural behavior. In case of new materials, tests are required to investigate structural behavior. Obtained measurements are usually limited and imprecise, which leads to difficulties in selecting or developing material models (stress-strain-time dependencies) and determine their parameters. In this work, we will present an alternative approach that is based on artificial neural networks. Recurrent neural networks are used to construct relationships between material-loads, and material-responses under uncertainty.

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CP1

Uncertainty Quantification of Discrete Element Micro-Parameters Conditioned on Sample Preparation of Homogeneous Particle Materials

This lecture analyzes the effect of varying micro-parameters of a Discrete Element Model (DEM) developed to analyze the effect of homogeneous particle materials. An experimental database is populated using steel spheres of constant diameter to build cylindrical specimens under controlled experimental conditions. Specimens vary from the loosest to the densest conditions. A 3D-DEM model is built to reproduce the same experimental sample preparation conditions, which is used to explore all varying micro-parameters combinations that lead to the reference experimental samples. X-Ray Computer Tomography is used to validate the numerical simulations.

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CP1

Random Fields for Stochastic Mechanics of Materials

An approach based on a Hill-Mandel condition allows determination of scaling laws and mesoscale random fields with continuous realizations from the microstructural properties described by random fields with discontinuous realizations, typically given by image analyses of just about any microstructure. We discuss one- and two-point statistics of such fields, the (an)isotropy of realizations versus (an)isotropy of correlation functions, as well as their unavoidable scale-dependence, non-uniqueness, and correspondence with specific variational principles of solid mechanics.

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CP1

Uncertainty Quantification in Image Processing

Based on the polynomial chaos and stochastic finite elements we construct stochastic extensions of image processing operators like Perona-Malik smoothing and Mumford-Shah resp. Ambrosio-Tortorelli segmentation and of the level set method. The stochastic extensions allow propagating information about the image noise from the acquisition step to the result, thus equipping the image processing results with reliability estimates. This modeling is important in medical applications where treatment decisions are based on quantitative information extracted from the images.

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CP1

Statistics of Mesoscale Conductivities and Resistivities in Polycrystalline Graphite

We consider mesoscale heat conduction in random polycrystalline graphite under uniform essential (Dirichlet) and uniform natural (Neumann) boundary conditions. Using numerical experiments, we obtain rigorous bounds on all the six independent components of the mesoscale conductivity (and resistivity) tensor and thereby the three invariants. The bounds on conductivity obtained using the proposed approach are the tightest when compared to the Voigt, Reuss, upper and the lower Hashin-Shtrikman bounds and incorporate the effects of scaling unlike the other bounds. The scale-dependent probability densities of the invariants of the mesoscale conductivities (resistivities) are also determined.

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CP2

Model Discrepancy and Uncertainty Quantification

When quantifying uncertainty in computer models it is important to account for all sources of uncertainty. One important source of uncertainty is model discrepancy; the difference between reality and the computer model output. However, the challenge with incorporating model discrepancy in a statistical analysis of computer models is the confounding with calibration parameters. In this talk we explore, through examples, ways to include model discrepancy in a Bayesian setting.

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CP2

Model Inadequacy Quantification for Simulations of Structures Using Bayesian Inference

We quantify the level of model inadequacy (aka model structure uncertainty) in simulations of the eigenfrequencies of a simple metal structure. Starting with a statistical model of the system, including parametric uncertainty, discretization error, as well as a generic representation of model inadequacy, we calibrate against an extensive experimental data-set, which includes attempts to identify and estimate sources of measurement noise and bias. A reliable estimate of model inadequacy for this simple situation is obtained.

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CP2

Quantitative Model Validation Techniques: New Insights

This research develops new insights into quantitative model validation techniques. Traditional Bayesian hypothesis testing is extended based on interval hypotheses on distribution parameters and equality hypotheses on probability distributions. Two types of validation experiments (well characterized and partially characterized) are considered. It is shown that under some specific conditions, the Bayes factor metric in Bayesian equality hypothesis testing and the reliability-based metric can both be mathematically related to the p-value metric in classical hypothesis testing.

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CP2

Dynamic Model Validation of a 160 Mw Steam Turbine Lp Last Stage (L-0) Blade

Laboratory vibration testing of turbine blades has always provided a major contribution to the understanding, detection and the possibility to predict the probable failures encountered under real operation conditions. The importance of testing for large steam turbines, with long slender blades with increased risk of fatal vibrations, is higher due to cost and safety. In this regard, the main focus of this work is to identify the Siemens Co. benchmark blade modal model based on experimental test data, using SDOF and MDOF methods. The accuracy of the Circle and line fit methods were compared with a state-space subspace method called N4SID. Furthermore, in order to validate the smaller size model with capability to capture main features of the full model, SVD-based model approximation methods are used to achieve a minimal state space representation of the original model. Finally the accuracy and efficiency of a Hankel-norm based reduction and a balanced truncation method are compared and the results are presented.

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CP2

Quantifying Uncertainty and Accounting Model Discrepancy in Slider Air Bearing Simulations for Calibration and Prediction

Coupled multiphysics simulation of a slider air-bearing is routinely performed during a hard disk design process to achieve various critical performance requirements. Characterizing uncertainty through these simulations is critical to predict variation in outputs of interest and to drive sigma reduction of main contributing inputs. A non-intrusive sparse stochastic collocation scheme is used to propagate uncertainty here and its efficiency compared to the Latin hyper-cube Monte Carlo sampling approach. Experimental results are used to update unknown functions in the model inputs using a Bayesian formulation and Markov Chain Monte Carlo approach. In another specific application, the discrepancy between the simulation and the experimental results is accounted for by augmenting the model with discrepancy term and specifying a Gaussian Process model for the same. Two examples of applications in active fly height loss during environmental conditions and operational shock survival is presented here.

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CP2

Integration of Verification, Validation, and Calibration Activities for Overall Uncertainty Quantification

This talk presents a Bayesian methodology to integrate information from verification, validation, and calibration activities for overall prediction uncertainty quantification. Multi-level systems are considered, with two types of information flow - (1) lower-level output becomes higher-level input, and (2) parameters calibrated with lower-complexity models and experiments are applied to full system simulation. The various sources of uncertainty, multiple levels of models and experiments are connected through a Bayes network, to quantify the uncertainty in system-level prediction.

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CP3

Dimension Reduction and Measure Transformation in Stochastic Multiphysics Modeling

We present a computational framework based on stochastic expansion methods for the efficient propagation of uncertainties through multiphysics models. The framework leverages an adaptation of the Karhunen-Loeve decomposition to extract a low-dimensional representation of information passed from component to component in a stochastic coupled model. After a measure transformation, the reduced-dimensional interface thus created enables a more efficient solution in a reduced-dimensional space. We demonstrate the proposed approach on an illustration problem from nuclear engineering.

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CP3

Contour Estimation Via Two Fidelity Computer Simulators under Limited Resources

In this work, we study the contour estimation problem for complex systems with two fidelity simulators. Using Gaussian process for surrogate construction, the sequential procedure is designed to choose the best suited simulator and input location for each simulation trial so that the overall estimation of the desired contour can be as good as possible under limited resources. Finally, the methodology is illustrated on a queueing system and its efficiency evaluated via a simulation study.

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CP3

An Uncertainty Quantification Approach to Assess Geometry-Optimization Research Spaces through Karhunen-Loève Expansion

UQ is exploited to assess geometry-optimization research spaces and support the design of the optimization task. A set of prescribed geometries defines the research space through morphing. Karhunen-Loève Expansion gives the total geometric variance and the geometric variability of each principal direction. This is used to compare different spaces and reduce their dimension and the computational costs. Finally, UQ methods identify the statistical properties of the relevant objectives. Hydrodynamic application in ship design is presented.

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CP3

Improvement in Multifidelity Modeling Using Gaussian Processes

Using different types of fidelity measurements can result in a large improvement of predictions by surrogate modeling in terms of computing time and precision. O'Hagan proposed an autoregressive Gaussian process to model the relationship between high and low accurate responses. However, we show that in practice the linearity is not always observed. Therefore in the present work the estimation of the relationship between the cheap and expensive responses by using smoothing splines is studied.

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CP3

A Multiscale Framework for Bayesian Inference in Elliptic Problems

Motivated by applications in hydrology, we present a multiscale framework for efficient sampling of Bayesian posteriors. The method is broadly applicable, but we concentrate on length scales and a conditional independence structure defined by the multiscale finite element method. The problem has two key components: construction of a coarse-scale prior, and an iterative method for conditioning fine-scale realizations on coarse-scale constraints. Theoretical justification and numerical examples show that the framework can strongly decouple scales and lead to more efficient inference.

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CP4

Super Intrusive Polynomial Chaos for An Elliptic Pde for Heat Transfer

We study uncertainty quantification via an elliptic partial differential equation for certain heat transfer problems. We use a polynomial chaos formulation that is super intrusive – we use the structure of the equations to derive exact closed form expressions for the mean and standard deviation of a random field (verified via Monte Carlo simulation). We harness the problem specific stochastic dependence structure in a way that could be useful in a variety of other applications with a similar mathematical structure.

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CP4

A Library for Large Scale Parallel Modeling and Simulation of Spatial Random Fields

Spatial random fields (RFs) model heterogeneous fields in computational simulations, including material properties, boundary/initial conditions, and geometric properties. We present a parallel API/library for modeling spatial RFs using either Karhunen-Loeve (KL) or Polynomial Chaos (PC) expansions. In addition to generating KL/PC realizations, the library includes a preprocessor to solve KL eigenproblems and a posteriori error estimators for the resulting approximate solutions. Finally we describe several applications, including structural mechanics and flow in porous media.

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CP4

Efficient Evaluation of Integral Quantities in Rdo by Sequential Quadrature Formulas.

Accuracy of the computation of the integral quantities involved in RDO represents a key element for the success of the optimization. If numerical quadrature is adopted, a convergence study of a benchmark UQ may be not sufficient, due to the changing characteristics of the objective function thru the optimization process. To preserve accuracy, different sequential quadrature formulas are here applied to a practical application for ship design, comparing their efficiency and the associated numerical effort.

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CP4

Application of a Novel Adaptive Finite Difference Solution of The Fokker-Planck Equation for Uncer-

tainty Quantification

An accurate and computationally efficient intrusive approach for UQ is introduced. It utilizes the diffusionless Fokker-Planck equation for the time evolution of the PDF. This equation is solved numerically using a TVD finite difference scheme and a novel method for obtaining the grid distribution. The results for some time-dependent problems will be compared with exact solutions or other computational UQ methodologies to demonstrate the method's ability to accurately and efficiently obtain statistical quantities of interest.

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CP4

Adjoint Error Estimation for Stochastic Collocation Methods

We use stochastic collocation on sparse grids for solving partial differential equations with random parameters. Our aim is to combine the method with an adjoint approach in order to estimate and control the error of some stochastic quantity, such as the mean or variance of a solution functional. Therefore, our major goal is to provide appropriate error estimates that require less computational effort then the collocation procedure itself.

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CP4

Robust Approximation of Stochastic Discontinuities

The robust approximation of discontinuities in stochastic problems is important, since they can lead to high sensitivities and oscillatory interpolations. To that end, we introduce finite volume robustness concepts from computational fluid dynamics into uncertainty quantification. The application of these new uncertainty propagation algorithms to engineering problems shows that they require a minimal number of samples to resolve discontinuities, for example, in transonic airfoil flow simulations with uncertain free stream conditions.

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CP5

Constrained Gaussian Process Modeling

In this paper, we introduce a new framework for incorporating constraints in Gaussian process modeling, including bound, monotony and convexity constraints. This new methodology mainly relies on conditional expectations of the truncated multinormal distribution. We propose several approximations based on correlation-free assumptions, numerical integration tools and sampling techniques. From a practical point of view, we illustrate how accuracy of Gaussian process predictions can be enhanced with such constraint knowledge.

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CP5

A Learning Method for the Approximation of Discontinuous Functions in High Dimensions

Tractable uncertainty quantification in high dimensions requires approximating computationally intensive functions with fast and accurate surrogates. Functions exhibiting discontinuities or sharp variations with respect to their inputs cause significant difficulty for traditional approximation methods. We have developed an unstructured and sampling-based method to address such problems. First we locate discontinuities via a kernel SVM classifier and uncertainty sampling. Then we map each resulting smooth region to a regular domain on which to build sparse polynomial approximations utilizing existing theory.

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CP5

Improvement of the Accuracy of the Prediction Variance Using Bayesian Kriging. Application to Three Industrial Case Studies.

Kriging is often used in computer experiments, in particular because it quantifies the variance of prediction which plays a major role in many applications (Efficient Global Optimization, Uncertainty Quantification, Sensitivity Analysis,...). In this talk we present three industrial case studies from different application fields (reservoir engineering, nuclear security, optics) where we show how bayesian kriging provides an accurate variance of prediction especially when prior information is available, for example when derived from less accurate but faster simulations.

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CP5

Reduced Basis Surrogate Models and Sensitivity Analysis

Computation of Sobol indices requires a large number of runs of the considered model. These runs often take too much time, and one has to approximate the model by a surrogate model which is faster to run. We present a reduced basis method, a way to build efficient surrogate models, coming with a rigorous error bound certifying the model approximation, which can be used to provide an error estimation on the estimated Sobol indices.

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CP5

Shape Invariant Model Approach to Functional Outputs Modelling

To tackle the problem of uncertainty propagation in dynamic simulators such as multiphase flow transport we propose a response surface method based on Gaussian Process. To reduce the dimension a shape invariant model approach is proposed. Multiple runs from the experimental design are modelled by a parametrical transformation applied to a template curve. The response surface model is then applied to the reduced set of transformation parameters from which the functional output is reconstructed.

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CP5

Svr Regression with Polynomial Kernel and Monotonicity Constraints

Very often, regression models have to respect some additionnal constraints like monotonicity constraints. We present here a new method based on Support Vector Regression and Polynomial Kernel. As a major feature this method produces an equation valid in the whole domain of interest, which can be used without any additionnal work by engineers. Avoiding any discretization of the domain, this method can be applied up to 10 regressions variables.

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CP6

Quantification of Uncertainty of Low Fidelity Models and Application to Robust Design

One of the major difficulties concerning uncertainty propagation techniques is to identify and quantify the sources of uncertainty. Predictive uncertainty of models has been defined as the main source of uncertainty in aircraft preliminary design. Moreover, its quantification is made more complex by model interdependencies. The aim of this study is to propose a way to quantify model predictive uncertainty and propagate it through an overall design process to figure out the robustness of its result.

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CP6

Path Variability Due To Sensor Geometry

The concept of Path Variability Due To Sensor Geometry (PVDSG) is fundamental to geomatic engineering. The PVDSG is a measure of the variability "built into' a statistic based on the distances from a target to the elements of a sensor array, due to the particular geometry of that array, as the target traverses a given path. This paper documents PVDSG measures as functions of the covariance matrix of the proportional target/sensor separations.

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CP6

Risk-Averse Control of Linear Stochastic Systems with Low Sensitivity: An Output-Feedback Paradigm

The research investigation treats the problem of controlling stochastic linear systems with quadratic criteria, including sensitivity variables is investigated, when noisy measurements are available. It is proved that the low sensitivity control strategy with risk aversion can be realized by the cascade of: i) the conditional-mean estimates of the current states using a Kalman filter and ii) optimally feedback, which is comprised of a custom set of mathematical statistics associated with the finite-horizon quadratic random cost. In other words, the certainty equivalence principle still holds for this class of optimal statistical control problem.

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CP6

An Information-Based Sampling Scheme with Applications to Reduced-Order Modeling

This work presents a novel methodology to sample effectively relevant points in the parameter space when designing computer experiments, or collecting snapshots for reduced-order models from an expensive to evaluate computer model. Principles from *information geometry* are employed, where the parameter space is interpreted as a Riemannian manifold equipped with a sensitivity related metric. An adaptive Sequential Monte Carlo scheme enables an effective sampling of such points, while allowing a controlled computational cost related to the evaluations of the computer model. Numerical examples, in the context of reduced order modeling, are provided.

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CP7

A Method for Solving Stochastic Equations by Reduced Order Models

A method is developed for calculating statistics of the solution U of a stochastic equation depending on an R^d-valued random variable Z. The method is based on two recent developments. The first approximates the mapping $Z \mapsto U(Z)$ by a finite family of hyperplanes tangent to $U(Z)$ at points selected by geometrical considerations. The second represents Z by a simple random vector $\tilde{Z}$ delivered by an optimization algorithm minimizing the discrepancy between properties of Z and $\tilde{Z}$. The methods uses samples of $\tilde{Z}$ to construct approximate representations for $U(Z)$, so that these representations account for the probability law of Z.

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CP7

Effect of Limited Measurement Data on State and Parameters Estimation in Dynamic Systems

This work characterizes the effect of data uncertainty on estimates of state and parameters of dynamic systems. The sample moments of state and parameters of dynamic system based on limited available measurements are treated as random variates that characterize the effects of uncertainty due to limited measurement data. The Hankel matrices associated with each sample moment estimator (that arises in the context of corresponding Hamburger moment problem) and the covariance matrix (that characterizes statistical dependencies among the sample moment estimators), thus, turn out to be random positive-definite matrices. An array of methodologies (Bayes' theorem, random matrix theory, maximum entropy principle, and polynomial chaos expansion) are employed to estimate the probability density functions of these positive-definite random matrices. Efficient sampling schemes are also presented to sample from these pdfs.

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CP7

Managing Uncertainty in Complex Dynamic Models

Various fields of science/engineering have developed application specific formulations of uncertainty quantification with computational approaches. Such efforts in control system analysis employ functional analysis and semidefinite programming, yielding tractable algorithms for quantifying the effect of individual component uncertainty and unknown external influences on behavior of large, heterogeneous interconnections of components. This talk will review the formalism, its use in practice, and explore the potential connections across other areas to better exploit each other's successes.

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CP7

On-Line Parameter Estimation and Control of Systems with Uncertainties

We present a method for parameter estimation and control of dynamical systems with uncertainties in real time. The method combines the polynomial chaos (PC) theory for uncertainty propagation and the Bayesian framework for parameter estimation in a novel way. The recursive nature of the algorithm requires the estimation of the PC coefficients of the parameters from their posterior distribution. We present methods for estimating these coefficients. The problem is motivated by a biological application.

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CP7

Estimation and Verification of Curved Railway Track Geometry Using Monte Carlo Particle Filters

A railway track geometry differs from the pre-designed one. It has track irregularities due to the frequent traffic of the train. A railway track geometry of level and alignment is measured based on the principle of three-point chord measurement, called 10m chord versine. Reconstructing the true track geometry from the measured data is a kind of the inverse problem. In this study a method of estimating

and verifying the true track geometry in the curved section from measured data using Monte Carlo particle filters is described.

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CP8

Investigations on Sensitivity Analysis of Complex Final Repository Models

The complex computation models for assessing the long-term safety of final repositories for radioactive waste typically show a number of particularities that can cause problems when a probabilistic sensitivity analysis is performed, such as skewed output distributions over many orders of magnitude, including the possibility of zero-output, or non-continuous behavior. Several numerical experiments are presented, demonstrating these problems and some ideas to deal with them. Different correlation-based and variance-based techniques of sensitivity analysis are applied and compared.

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CP8

Global Sensitivity Analysis for Disease and Population Models

Variance based sensitivity measures are used to examine the structure of biological models. To limit expensive model evaluations we use a Gaussian process emulator to estimate sensitivity indices. The use of a stochastic surrogate model allows us to quantify the uncertainty due to lack of data in sensitivity estimates. Our methods are applied to an ODE based model for the spread of an epidemic on a network and to an agent based model of disease in a metropolitan region.

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CP8

A Global Sensitivity Analysis Method for Reliability Based Upon Density Modification

For global sensitivity analysis of numerical models, variance decomposition is widely applied. However, when the quantity of interest is a failure probability this method requires numerous function evaluations and does not always provide relevant information . We propose a new importance sampling method based upon modification of the distribution of inputs controlled by Kullback-Leibler divergence. The function sample is evaluated only once, resulting in significant time saving.

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CP8

Fast and Rbd Revisited

This is a new introduction to the existing ANOVA-based global sensitivity analysis methods: Fourier Amplitude Sensitivity Test (FAST) and Random Balance Design (RBD). First this work consists in clarifying the underlying mathematical theory, then in performing a rigorous error analysis and last in suggesting some improvements and generalizations of both these methods. Numerical examples are also provided to illustrate this work.

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CP8

Locality Aware Uncertainty Quantification and Sensitivity Algorithms

A need exists for UQ and sensitivity analysis algorithms that leverage information from one system realization to another. Although the size of the computational models used in many engineering and scientific simulations is extremely large, *i.e.* millions of equations, the uncertainty present is oftentimes very localized to small regions of the model. Here, recent efforts to develop computational methods that exploit this localization and the ensemble nature of the requisite iterative analyses will be discussed.

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CP9

Emulating Dynamic Models - Numerical Challenge

Dynamic models can be emulated by linearizing its equations and compensating for the non-linearities with Gaussian white noise. Coupling replica of the resulting linear stochastic system according to the distance between their inputs and conditioning the coupled system on off-line simulation outputs results in a mechanistic emulator. For piece-wise constant inputs, the covariance matrix of the coupled system can be derived explicitly. Conditioning of the emulator boils down to an (off-line) inversion of this covariance matrix and the emulation to mere (on-line) multiplications of matrices of the dimension of the state space. This approach is compared with Kalman filtering and smoothing.

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CP9

Multi-Modal Oil Reservoir History Matching Using Clustered Ensemble Kalman Filter

A multi-modal history-matching algorithm using Regularized Ensemble Kalman Filter was developed. The EnKF algorithm is augmented with k-means clustering algorithm to form sub-ensembles that explore different parts of the search space. Clusters are updated at regular intervals to merge clusters approaching the same local minima. The resulting mean of each sub-ensemble is used for robust production optimization. The proposed algorithm provides an efficient method for parameter estimation, uncertainty quantification and robust optimization of oil production.

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CP9

A Spectral Approach to Linear Bayesian Updating

The linear Bayesian methods of the family of low-rank Kalman filters have become popular for the solution of inverse and data assimilation problems, with one example being the ensemble Kalman filter. In this work we present a related approach which is based on well-known spectral expansions of the stochastic space, like the polynomial chaos expansion. The connection of this 'Bayes linear' approach with the original Bayes formula is highlighted, an it is demonstrated that spectral expansions can be used directly in the update equation without any detour to sampling. Numerical examples show the advantages and challenges of this approach. Examples will be given involving the well-known Lorenz systems and the estimation of a diffusion coefficient.

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CP9

Uncertainty Quantification in the Ensemble Kalman Filter

The Ensemble Kalman Filter (EnKF) is a data assimilation algorithm that over the last decade has been applied to numerous fields. However, it is well known that the standard implementation of the EnKF will lead to an underrepresentation of the prediction uncertainty. In this talk we will explain, using classical results from statistics, why the EnKF is not able to quantify the uncertainty correctly, and present statistical methods that can resolve this issue.

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CP9

Collocation Inference for Nonlinear Stochastic Dynamic Systems with Noisy Observations

Collocation-based methods are proposed for estimating parameters and performing inference for nonlinear stochastic continuous-time dynamic systems with noisy observations. EM algorithm is applied to handle the systematic stochastic input and the observational error simultaneously. The approaches use collocation method to avoid the computational intensity. Two computation algorithms: Laplace approximations and Monte Carlo integration are examined. The convergence rates are h^p, where h is the bandwidth of the approximation scheme for stochastic Ronge-Kutta type penalty.

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CP10

Langevin Based Inversion of Pressure Transient Testing Data

In the oilfield, pressure transient testing is an ideal tool for determining average reservoir parameters, but this technique does not fully quantify the uncertainty in the spatial distribution of these parameters. We wish to determine plausible parameter distributions, consistent with both the pressure transient testing data and prior geological knowledge. We used a Langevin-based MCMC technique, adapted to the large number of parameters and data, to identify geological features and characterize the uncertainty.

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CP10

Some Inverse Problems for Groundwater

Perhaps the most appealing aspect of Bayesian inference in the context of groundwater engineering is that it makes proper use of data, and provides the engineer with a tool that may be used to inform the judicious design of pump tests so that quantities of interest are determined within acceptable bounds. Low dimensional inverse problems for groundwater may capture the essential physics and provide guidance on what is important in the solution of their higher dimensional cousins; we present some recent work on low and high dimensional inverse problems for groundwater.

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CP10

Bayesian Acoustic Wave-Field Inversion of a 1D Heterogeneous Media

We discuss a Bayesian parameter estimation scheme to reconstruct the distribution of the subsurface elastic characteristics of a 1D heterogeneous earth model, given the probed medium's response to interrogating acoustic waves measured at the surface. We consider a generic multilayer media where the number of layers along with their velocities and thicknesses are treated as random variables, where the solution's non-uniqueness is fully accounted for by the posterior probability density of the unknowns. A synthetic study is provided to indicate the applicability of the technique.

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CP10

Inverse Problem: Information Extraction from Electromagnetic Scattering Measurement

The estimation of local radioelectric properties of materials from the global electromagnetic scattering measurement is a challenging ill-posed inverse problem. It is intensively explored on High Performance Computing machines by a Maxwell solver and statistically reduced to a simpler probabilistic metamodel. Considering the properties as a dynamic stochastic process, it is shown how advanced Markov Chain Monte Carlo methods, called interacting Kalman filters, can perform Bayesian inference to estimate the properties and their associated uncertainties.

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CP10

Set-Based Parameter and State Estimation in Nonlinear Differential Equations Using Sparse Discrete Measurements

Bounded experimental uncertainty and sparse measurements limit our ability to generate estimates of component concentrations and kinetic parameters in biological models because of algorithm instability and computational intractability. We present a set-based approach for producing estimates that address these issues. We use first-principles and a-priori knowledge to generate stabilizing bounds that maintain algorithm stability while removing spurious solutions that occur due to limited measurements. This is implemented in a multithreaded architecture to address computational limitations.

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CP10

Probabilistic Solution of Inverse Problems under Varying Evidence Conditions

Results of the impact of varying evidence conditions on the probabilistic calibration of model parameters are presented. A synthetic case study is populated where data is fully controlled, including the effect of location, number, variance and correlation, when used to calibrate a simple differential equation used to simulate diffusion problems. Since the calibration follow a Bayesian approach, it is thus possible to describe the uncertainty changes on the model parameters as the evidence conditions vary, as this is reflected on independent analyses of the posterior distribution.

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CP11

Adaptive Error Modelling in Mcmc Sampling for Large Scale Inverse Problems

We present a new adaptive delayed-acceptance MCMC algorithm (ADAMH) that adapts to the error of a reduced order model to enable efficient sampling from the posterior distribution arising in large scale inverse problems. This use of adaptivity differs from existing algorithms that tune the proposals, though ADAMH also implements that. Conditions given by Roberts and Rosenthal (2007) are used to give constructions that are provably convergent. We applied ADAMH to several large scale groundwater studies.

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CP11

Scalable Methods for Large-Scale Statistical Inverse Problems, with Applications to Subsurface Flow

We address the challenge of large-scale nonlinear statistical inverse problems by developing an adaptive Hessian-based non-stationary Gaussian process response surface method to approximate the posterior pdf solution. We employ an adaptive sampling strategy for exploring the parameter space efficiently to find interpolation points and build a global analytical response surface far less expensive to evaluate than the original. The accuracy and efficiency of the response surface is demonstrated with examples, including a subsurface flow problem.

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CP11

Chemical Reaction Mechanism Generation Using Bayesian Variable Selection

The generation of detailed chemical reaction mechanisms, for applications ranging from electrochemistry to combustion, must often rely on noisy and indirect system-level data. We present a novel approach to mechanism generation based on Bayesian variable selection and a PDE-based physical model. Adaptive Markov chain Monte Carlo methods are used to efficiently explore a posterior that encompasses models comprised of subsets of elementary reactions. In contrast to conventional techniques, our approach provides a statistically rigorous assessment of uncertainty in reaction mechanism structure and in reaction rate parameters.

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CP11

Inferring Bottom Bathymetry from Free-Surface Flow Features

We are solving an inverse problem of determining bathymetry of a channel from the mean flow features at the free surface. Our approach is optimization-based operating on a database of simulations with parameterized bedforms. Sensitivity of the inversion process to noise (e.g., instrument error, turbulence) is investigated. In the present framework, we rely on the time-averaged surface flow features, although also consider a more complex problem of using multiple free-surface snapshots of the unsteady flow.

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CP11

Bayesian Updating of Uncertainty in the Description of Transport Processes in Heterogeneous Materials

The prediction of thermo-mechanical behaviour of heterogeneous materials such as heat and moisture transport is strongly influenced by the uncertainty in parameters. Such materials occur e.g. in historic buildings, and the durability assessment of these therefore needs a reliable and probabilistic simulation of transport processes, which is related to the suitable identification of material parameters. In order to include expert knowledge as well as experimental results, we employ a Bayesian updating procedure.

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CP12

Bayesian Models for the Quantification of Model Errors in Pde-Based Systems

Bayesian formulations offer a unified statistical treatment for the solution of model-based inverse problems. Apart from the noise in the data, another source of uncertainty, which is largely unaccounted for, is model uncertainty.In general, there will be deviations between the physical reality where measurements are made, and the idealized mathematical/computational description (in our case a system of PDEs consisting of conservation laws and constitutive equations). We propose an intrusive Bayesian strategy and efficient inference tools that are capable of quantifying model errors in the governing equations.

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CP12

Predictive Simulation for CO2 Sequestration in Saline Aquifers

One of the most difficult tasks in CO2 sequestration projects is the reliable characterization of properties of the subsurface. A typical situation employs dynamic data integration such as sparse CO2 measurement data in time and sparse measurements of permeability and porosity in space to be matched with simulated responses associated with a set of permeability and porosity fields. Among the challenges found in practice are proper mathematical modeling of the flow, persisting heterogeneity in porosity and permeability, and the uncertainties inherent in them. In this talk, we propose a Bayesian framework Monte Carlo Markov Chain simulation (MCMC) to sample a set of characteristics of the subsurface from the posterior distribution that are conditioned to the measured CO2 data. This process requires obtaining the simulated responses over many iterations. We use the model proposed in Obi and Blunt [Water Resources Research, 2006] to perform numerical simulations of the injection of CO2 in saline aquifers, and illustrate the MCMC procedure and its use in predictive simulation for CO2 sequestration.

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CP12

The Effect of Prediction Error Correlation on Bayesian Model Updating

In this contribution, a Bayesian inference framework is adopted to quantify uncertainties due to measurement and modeling errors in vibration-based model updating. In most cases, independent normal distributions are assumed for the observed prediction errors on natural frequencies and mode shape components. However, such an assumption is not expected to hold in case of mode shape components identified from dense sensor networks. A correlated prediction error is therefore introduced and its effect on the identification is investigated.

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CP12

Investigating Uncertainty in Aerothermal Model Predictions for Hypersonic Aircraft Structures

Validating computational models of fluid-thermal-structural interactions in hypersonic aircraft structures remains a challenge due to limited experimental data. This research investigates uncertain model parameters and model errors in aerodynamic pressure and heating predictions. The modeled conditions correspond to aerothermal test data from hypersonic wind tunnel experiments of a spherical dome protuberance on a flat plate. Bayesian calibration and sensitivity analysis are used with the test data to improve understanding of model and experimental uncertainty.

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CP13

Reservoir Uncertainty Quantification Using Clustering Methods

Quantifying uncertainty in reservoir predictions is important in the petroleum industry, since more accurate quantification of the uncertainty contributes to prudent multimillion dollar decision makings. Nowadays predictions are made from conditioned multi-model ensembles obtained in history-matching using optimisation with evolutionary algorithms. These ensembles are usually multi-modal and different models will result in different forecasts. We use k-mean, probabilistic distance, and agglomerate clustering methods to locate and track multiple distinct optima representing uncertainties of the reservoir.

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CP13

Adaptive Smolyak Pseudospectral Expansions

Smolyak pseudospectral expansions provide an efficient and accurate approach for computing sparse polynomial chaos approximations of functions with weak coupling between the input dimensions. We rigorously develop the Smolyak algorithm and show that it is well behaved. This behavior stands in contrast to the traditional sparse quadrature approach for building polynomial expansions, which is either inaccurate or inefficient in almost all cases. Furthermore, we tailor the Smolyak algorithm to individual functions at run-time through an adaptive strategy.

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CP13

Uncertainty and Differences in Global Climate Models

Climate models have greatly aided investigation of global climate change. The uncertainty, similarities, and differences between climate models can be examined using exceedance regions. We propose methodology for drawing conclusions about entire exceedance regions with known confidence. The methodology uses kriging and conditional simulation to create confidence regions having the necessary statistical properties. Discussion will include assessment of future climate change for several regions of North America and highlight differences between various climate models.

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CP13

Comparison of Stochastic Methods for Bayesian Updating of Uncertainty in Parameters of Nonlinear Models

An extensive development of efficient methods for stochastic modelling enabled uncertainty propagation through complex models. In this contribution, we present a review and comparison of several approaches such as stochastic Galerkin method or stochastic collocation method in context of Bayesian uncertainty updating.

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CP13

Stochastic Anova-Galerkin Projection Schemes

We present numerical schemes based on ANOVA-Galerkin projection for stochastic PDEs with large number of random variables. The central idea is to represent the solution using a functional ANOVA decomposition supplemented by appropriate orthogonality constraints so that the weak form can be decoupled into a set of independent low-dimensional subproblems. Numerical studies will be presented for the steady-state and time-dependent stochastic diffusion equation with more than 500 variables.

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CP13

Multilevel Monte Carlo for Uncertainty Quantification in Subsurface Flow

Multilevel Monte Carlo is an efficient variance reduction technique to quantify uncertainties in simulations of subsurface flows with highly varying, rough coefficients, e.g. in radwaste disposal. We study model elliptic problems of single phase flow in random media described by correlated lognormal distributions, discretized in space via (standard and mixed) finite elements. We will demonstrate (theoretically and numerically) significant gains with respect to standard Monte Carlo, leading (in the best case) to an asymptotic cost that is proportional to solving one deterministic PDE.

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CP14
Toward Reduction of Uncertainty in Complex Multi-Reservoir River Systems

Uncertainties are inherent in the operation of any system, however assuming that they are all purely stochastic and independent, both spatially and temporally, may result in unnecessarily large uncertainties that may not be useful for the operation of a system. In this paper we present a novel framework for better modeling uncertainty in complex systems and demonstrate the approach applied to regulated river systems. This framework aims to combine "purely stochastic processes' (not well understood or unpredicted at this stage) with the physical description of the system (e.g., flow dynamics in the case of complex regulated river systems) with the goal of better modeling uncertainties and hence reduce the ranges of the confidence intervals. In this framework, only the stream inflows (external source) are assumed to be purely stochastic. Other uncertain quantities are correlated to the uncertainty of the stream inflows using the dynamics of the river as the physical description of the system. In this framework the dynamics of the river is simulated using the performance graphs approach. For the quantification of uncertainty, rather than doing sampling of the input distributions, we explicitly model the random space (via random variables and processes). We represent uncertainty in stream inflows via an error term modeled as a stochastic process. The resulting system is discretized (in random space) using stochastic collocation, which is distinct from random sampling methods in that the Gaussian nodes are deterministic. By recycling existing deterministic codes, this non-intrusive approach is both more efficient than Monte-Carlo methods and as flexible in their application.

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CP14
Stochastic Analysis of the Hydrologic Cascade Model, a Polynomial Chaos Approach

In this talk we analyse a Nash cascade of linear reservoirs representing a watershed. It is specified by a system of coupled linear differential equations with random coefficients. A stochastic spectral representation of these parameters is used, together with a polynomial chaos expansion. A system of differential equations is obtained which describe the evolution of the mean and higher-order moments with respect to time.

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CP14
Likelihood-Based Observability Analysis and Confidence Intervals for Model Predictions

Nonlinear dynamic models of biochemical networks contain a large number of parameters. This renders classical approaches for the calculation of confidence regions for parameter estimates and model predictions hardly feasible. We present the so-called prediction profile likelihood which is utilized to generate reliable confidence intervals for model predictions and for a data-based observability analysis. The presented approach constitutes a general concept and is therefore applicable for any kind of prediction model.

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CP14
Hybrid Stochastic Collocation - Stochastic Perturbation Method for Linear Elastic Problems with Uncertain Material Parameters

We propose a hybrid formulation combining the stochastic collocation (SC) and stochastic perturbation (SP) methods to obtain the response of a linear elastic system with material uncertainties. The material properties are modelled as a memory-less transformation of a Gaussian field, which discretized by a series expansion method. The response of the system is estimated using SC to account for the most important (lower) modes in the series expansion and SP for the other (higher) modes.

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CP14
A Comparison Of Uncertainty Quantification Methods Under Practical Industry Requirements

The objective of this paper is to establish comprehensive guidelines for engineers to effectively perform probabilistic design studies through a systematically comparison of uncertainty quantification or probabilistic methods. These methods include 1) Simulation-based approaches such as

Monte Carlo simulation, importance sampling and adaptive sampling, 2) Local expansion-based methods such as Taylor series method or perturbation method, 3) First Order Second Moment (FOSM) based methods, 4) Stochastic expansion-based methods, such as Neumann expansion and polynomial chaos expansion, 5) Numerical integration-based or moments-based methods, such as Point Estimate Method, Eigenvector Dimension Reduction, 6) Regression- or metamodel-based methods, 7) Bayesian methods, and 8) Data classification methods. Both aleatory & epistemic uncertainty will be addressed in the paper. A set of benchmark problems representing different levels of dimensionality, non-linearity and noise level will be used for the comparison.

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CP15

Rare Events Detection and Analysis of Equity and Commodity High-Frequency Data

We present a methodology to detect unusual trading activity defined as high price movement with relatively little volume traded. The analysis is applied to high-frequency transactions of thousands of equities and the probability of price recovery in the proximity of these rare events is calculated. Similar results are obtained when analyzing commodities with different expiration dates. The propagation of rare events in the commodity structure and the liquidity problems are addressed.

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CP15

Glimpses of Uq, Qmu, and Reliability

We will provide an introduction to quantification of margins and uncertainties (QMU) and reliability. QMU is a summary number that is relatively easy to interpret for decision-making. Reliability is defined as the probability that a given item will perform its intended function for a given period of time under a given set of conditions. The underlying concepts in this definition are probability, intended function, time, and conditions. Reliability is a quantity that can be very difficult to compute for complex systems, and viewed rigorously, is inherently a statistical distribution on the probability of success (or failure) of a system. Both concepts are concerned with uncertainty quantification. We will illustrate with examples from complex systems from our work at Los ALamos National Laboratory.

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CP15

Bayesian Subset Simulation

One of the most important and computationally challenging problems in reliability engineering is to estimate the failure probability of a dynamic system. In cases of practical interest, the failure probability is given by an integral over a high-dimensional uncertain parameter space. Subset Simulation method, provides an efficient algorithm for computing failure probabilities for general high-dimensional reliability problems. In this work, a Bayesian counterpart of the original Subset Simulation method is developed.

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CP16

Delay in Neuronal Spiking

We study how some delay mechanisms influence interaction between a neuron and its network. Specifically, we look at conduction delay, spike-timing dependent plasticity, and time delay induced by the partial differential equation describing a particular neuron. We further compare the contribution of different delay mechanisms to numerical solutions of the governing cable equation. We study two cases: the case of passive electrical activity and the case of propagating action potential.

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CP16

A Gaussian Hierarchical Model for Random Intervals

Many statistical data are imprecise due to factors such as measurement errors, computation errors, and lack of information. In such cases, data are better represented by intervals than single-valued numbers. To model both randomness and imprecision, we propose a Gaussian hierarchical model for random intervals, and develop a minimum contrast estimator that we show is both consistent and asymptotically normal. We extend this model to the time series context and build an interval-valued GARCH model.

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CP17

Interval-Based Inverse Problems with Uncertain-

ties

Inverse problems in science and engineering aim at estimating model parameters of a physical system using observations of the models response. However, response measurements are usually associated with uncertainties, and deterministic inverse algorithms hardly provide the associated error estimates for the model parameters. In this work, we will present an interval-based iterative solution that predicts such error exploiting an adjoint -based optimization and the containment-stopping criterion.

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CP17
Probability Bounds for Nonlinear Finite Element Analysis

A set of possible cumulative probability distributions defined by its bounding functions is one way for representing epistemic and aleatory uncertainty separately. Such sets are known as a probability box (P-box). In this work we will present an interval Monte Carlo method for calculating the non-linear response of structures in terms of P-boxes when system parameters and loading are described as P-boxes. Results obtained show very tight enclosures even for large uncertainties.

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CP17
A Complete Closed-Form Solution to Stochastic Linear Systems with Fixed Coefficients

Given a fixed but arbitrary coefficient matrix A and a meaningful input probability density d(b) that stochastically describes the other input data b for the system Ax = b, this paper: (1) derives explicit formulas for numerically computing the induced probability that this system has at least one solution x, (2) formulates and then describes the important properties of the optimization problem whose solutions b* (if any) maximize d(b) over all b for which Ax = b has at least one solution x, (3) formulates and then describes the important properties of a general optimization problem whose solutions x* (if any) optimize a given function g(x) over all x for which Ax = b*. This methodology can numerically compete with both the simulation approaches and the simplified deterministic approaches based on expected values and other moment information. In modified form, it might also provide new approaches to systems Ax = b with "fuzzy" data b.

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CP17
Cramer-Rao Bound for Models of Fat-Water Separation Using Magnetic Resonance Imaging

Magnetic resonance images typically contain both water and fat but most of the information is in the water signal. Different assumptions about the imaging conditions result linear and non-linear models of the image generation. The multiple parameters and non-linearity lead to a version of the Cramer-Rao bound for a parameter if all other parameters were known. We study how the choice in model affects the optimal data acquisition based on minimizing this Cramer-Rao bound.

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CP17
Automated Exact Calculation of Test Statistics in Hypothesis Testing

Many classical statistical tests rely on large-sample approximations for determining appropriate critical values. We use a computer algebra system to compute the exact distribution of test statistics under the null hypothesis for the Wilcoxon signed-rank test and the chi-square goodness of fit test, which gives the exact critical value for small sample sizes.

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CP17
Evidence-Based Approach for the Probabilistic Assessment of Unknown Foundations of Bridges

As of 2005, there were approximately sixty thousand bridges throughout the US identified as having Unknown Foundations. Missing substructure information has made safety monitoring of bridges very difficult for departments of transportation, especially for over-river bridges which are susceptible to scour. An evidence-based methodology is proposed in this paper to determine the unknown characteristics of bridge foundations conditional on information collected from existing bridges. The proposed approach combines the use of a Neural-Network model to compute the foundations bearing capacity, with a Bayesian formulation that allows for defining probability distributions of the foundation type, size and embedment depth, as well as of the soil properties supporting the foundation.

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CP18
An Approach to Weak Solution Approximation of Stochastic Differential Equations

This paper presents an approach to approximate the weak solution of nonlinear stochastic differential equations. Utilizing the results from the Radon-Nikodym theorem and the Girsanov theorem, the proposed approach introduces a measure transformation so that the Itô process under consideration becomes a Wiener process under the transformed measure. Here we propose the Euler-Maruyama scheme to approximate the stochastic integral involved in calculating the Radon-Nikodym derivative associated with the measure transformation. A detailed analysis of the proposed approximation scheme reveals that the proposed approach is exactly the same as calculating the weak solution using the traditional Euler-Maruyama scheme and thus the proposed approach is weakly convergent with a convergence rate of $\gamma = 1$. A numerical example is presented to validates the proposed approach and illustrate its capability.

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CP18

Asymptotic Normality and Efficiency for Sobol Index Estimator

In this talk we will study the convergence and the efficiency of Sobol index estimators. More precisely, we will consider the following model

$$Y = f(X, Z)$$

where X and Z are independent random vectors. The importance of each input variable can be measured by $S = \left(\frac{\text{Var}(\text{E}(\text{Y}|\text{X}))}{\text{Var}(\text{Y})}, \frac{\text{Var}(\text{E}(\text{Y}|\text{Z}))}{\text{Var}(\text{Y})}\right)$. We will construct an estimator S_n of S and show that it is asymptotically normal and efficient. At the end of the talk, we will give similar results when f is replaced by some approximation $\tilde{f}$.

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CP18

Frechet Sensitivity Analysis for the Convection-Diffusion Equation

In this work, we consider Frchet derivatives of solutions to the convection-diffusion equation with respect to distributed parameters and demonstrate their applicability in parameter estimation. Under certain conditions, the Frchet derivative operator is Hilbert-Schmidt and thus there are parametric variations that have more impact on the solution than others. These variations can be used to identify locations for new measurements or data samples. We also analyze an algorithm for approximating these parametric variations.

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CP18

Analysis of Quasi-Monte Carlo FE Methods for Elliptic PDEs with Lognormal Random Coefficients

We devise, implement and analyse quasi-Monte Carlo methods for computing the expectations of (nonlinear) functionals of solutions of a class of elliptic partial differential equations with lognormal random coefficients. Our motivation comes from fluid flow in random porous media, where a very large number of random variables is usually needed to give a realistic model of the coefficient field. By using deterministically chosen sample points in an appropriate (usually high-dimensional) parameter space, quasi-Monte Carlo methods can obtain substantially higher convergence rates than classical Monte Carlo. An analysis in appropriate function spaces confirms this also theoretically. The analysis is particularly challenging since in the lognormal case the PDE is neither uniformly elliptic nor uniformly bounded and the parametrisation of the coefficient is nonlinear.

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CP19

Maximum Entropy Construction for Data-Driven Analysis of Diffusion on Random Manifolds

A data-driven approach is developed for the diffusion on manifolds with unknown geometry. Given limited number of samples drawn from the manifold, our objective is to characterize the geometry, while accounting for inevitable uncertainties due to measurement noise and scarcity of samples. We will present a MaxEnt construction for uncertainty representation of the graph Laplacian used to approximate the Laplace-Beltrami operator. We also discuss the adaptation of this formulation for information diffusion in social networks.

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CP19

Multiple Signal Classification in Covariance Space of EEG Data

The objective is to find discriminative features in the EEG signals to mark various stages of drowsiness in vehicle operators. Existing methods are only able to distinguish between extreme stages. In this research, we are trying to use metrics on the covariance space of EEG data to identify the evolution of the state of fatigue from low to high. We have conducted experiments to induce continuous fatigue in human subjects while keeping them awake for about 36 hours. The EEG data has been recorded over 3-hours interval. Eventually we intend to build a spatio-temporal model of evolution of fatigue in the covariance space of EEG data.

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CP19

Dynamic Large Spatial Covariance Matrix Estimation in Application to Semiparametric Model Construction Via Variable Clustering: the Sce Approach

We consider estimating a large spatial covariance matrix of the high-dimensional time series by thresholding, quantify the interplay between the spatial estimators' consistency and the temporal dependence level, and prove a CV result for threshold selection. Given a consistently estimated matrix and its natural links with semiparametrics, we screen, cluster the explanatory variables and construct the corresponding semiparametric model to be further estimated with sign constraints. We call this the SCE approach.

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CP19

Random Matrix Based Approach for Adaptive Estimation of Covariance Matrix

The work considers the problem of estimating unknown covariance matrix, $\mathbf{Q}$, of process noise in linear dynamic system based on corrupted state measurements data. Here, $\mathbf{Q}$ is *directly* treated as a symmetric, positive-definite random matrix unlike other approaches where each element of $\mathbf{Q}$ is treated as random variable or $\mathbf{Q}$ is itself parameterized by a set of scalar-valued random variables. The probability density function (pdf) of $\mathbf{Q}$ is estimated by employing maximum entropy principle. The theory of multiple model and Kalman Filter are then used to update this pdf over time, resulting in a pdf with sharp peak around the true covariance matrix once sufficient number of measurements are made.

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CP20

Determining Critical Parameters of Sine-Gordon and Nonlinear Schrödinger Equations with a Point-Like Potential Using Generalized Polynomial Chaos Methods

We consider the sine-Gordon and nonlinear Schrödinger equations with a point-like singular source term. The soliton interaction with such a singular potential yields a critical solution behavior. That is, for the given value of the potential strength or the soliton amplitude, there exists a critical velocity of the initial soliton solution, around which the solution is either trapped by or transmitted through the potential. In this talk, we propose an efficient method for finding such a critical velocity by using the generalized polynomial chaos (gPC) method. For the proposed method, we assume that the soliton velocity is a random variable and expand the solution in the random space using the orthogonal polynomials. We consider the Legendre and Hermite chaos with both the Galerkin and collocation formulations. The proposed method finds the critical velocity accurately with spectral convergence. Thus the computational complexity is much reduced. The very core of the proposed method lies in using the mean solution instead of reconstructing the solution. The mean solution converges exponentially while the gPC reconstruction may fail to converge to the right solution due to the Gibbs phenomenon in the random space. Numerical results confirm the accuracy and spectral convergence of the method.

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CP20

A Comparison of Dimensionality Reduction Techniques in Scientific Applications

High-dimensional data sets, where each data item is represented by many attributes or features, are a challenge in data mining. Irrelevant attributes can reduce the accuracy of classification algorithms, while distance-based clustering algorithms suffer from a loss of meaning of the term "nearest neighbors". Using data sets from scientific applications, we present a comparison of different dimensionality reduction methods, including various feature selection techniques, as well as linear and non-linear feature transform methods.

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CP20

Computational Methods for Statistical Learning Using Support Vector Machine Classifiers

An augmented Lagrangian algorithm for solving equality and bound constrained quadratic problems will be presented for use in support vector machine (SVM) classification. Examples will include images and a diabetes data set. The algorithm will be compared with existing optimization techniques and the SVM method will be compared with quadratic discriminant analysis, as well as a general linearized model for the diabetes data set.

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CP20

A Hidden Deterministic Solution to the Quantum Measurement Problem

In this paper we present a nonconventional method of establishing a hidden but computationally realizable deterministic solution to quantum measurement problems in the non-infinite, non-zero quantized energy limits. Our approach is not in contradiction with Heisenberg's Uncertainty Principle, rather it determines energy (E) and momentum (p) of a quantum particle as functions of uncertainties,viz $E = f(\Delta E)$ and $p = f(\Delta p)$. Thus an observer gets $E \pm \triangle E$ and $p \pm \triangle p$ as the observed values of the energy and momentum of the said particle.

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MS1

Super-parameterisation of Oceanic Deep Convection using Emulators

Misrepresentation of sub-grid scale processes can increase the uncertainty in the results of large scale models. Despite the existence of detailed numerical models that resolve subgrid scale processes, embedding these in a large scale model is often computationally prohibitive. A viable alternative is to encapsulate our knowledge about the sub-grid scale model in an emulator and use this as a surrogate. We apply this paradigm of 'super-parameterisation' to an oceanic deep convection problem.

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MS1

Effective and Efficient Handling of Ill-Conditioned Correlation Matrices in Kriging and Gradient Enhanced Kriging Emulators through Pivoted Cholesky Factorization

Kriging or Gaussian Process emulators are popular because they interpolate build data if the correlation matrix is R.S.P.D. and produce a spatially varying error estimate. However, handling ill-conditioned correlation matrices can be challenging. The rows/columns of an ill-conditioned matrix substantially duplicate information. Pivoted Cholesky ranks points by their new information content; then low information points are discarded. Since discarded points contain the least new information, they best remediate ill-conditioning and are the easiest to predict.

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MS1

History Matching: An alternative to Calibration for a Galaxy Formation Simulation

In the context of computer models, calibration is a vital technique whereby an emulator is used to obtain a posterior distribution over the input space of the computer simulator. However, this process can be extremely challenging. We discuss a powerful alternative known as history matching that can either serve as a prelude to a full calibration to greatly improve efficiency, or that can in several cases replace calibration entirely. Work from Mitchell Prize winning paper.

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MS1

Emulation of Count Data in Healthcare Models

Natural History Models are simulators used in healthcare applications to simulate patients' outcomes from certain illnesses. Their output is typically count data and for rare illnesses zeros are common. The simulators rely on many unknown parameters, but calibration using Monte Carlo methods is impractical due to computational expense. Instead we calibrate using an emulator as a surrogate for the simulator, showing how appropriate regions of parameter space are identified for the emulator to perform well.

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MS2

Bayesian Inference with Optimal Maps

We present a new approach to Bayesian inference that entirely avoids Markov chain simulation, by constructing a map that *pushes forward* the prior measure to the posterior measure. Existence and uniqueness of a suitable measure-preserving map are established by formulating the problem in the context of optimal transport theory. We discuss various means of explicitly parameterizing the map and computing it efficiently through solution of a stochastic optimization problem, exploiting gradient information from the forward model. The resulting algorithm overcomes many of the computational bottlenecks associated with Markov chain Monte Carlo. Advantages of a map-based representation of the posterior include analytical expressions for posterior moments and the ability to generate arbitrary numbers of independent posterior samples without additional likelihood evaluations or forward solves. The optimization approach also provides clear convergence criteria for posterior approximation and facilitates model selection through automatic evaluation of the marginal likelihood. We demonstrate the accuracy and efficiency of the approach on nonlinear inverse problems of varying dimension, involving the inference of parameters appearing in ordinary and partial differential equations.

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MS2

Sample-based UQ via Computational Linear Algebra (Not MCMC)

Sample-based inverse and predictive UQ has proven effective, though MCMC sampling is expensive. Several groups are now developing links between computational linear algebra and sampling algorithms with the aim of reducing the cost of sampling. Currently these links are exact for Gaussian distributions, only, but do indicate how the more general case should look.

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MS2

Toward Extreme-scale Stochastic Inversion

We are interested in inferring earth models from global seismic wave propagation waveforms. This inverse problem is most naturally cast as a large-scale statistical inverse wave propagation problem in the framework of Bayesian inference. The complicating factors are the high-dimensional parameter spaces (due to discretization of infinite-dimensional parameter fields) and very expensive forward problems (in the form of 3D elastic-acoustic coupled wave propagation PDEs). Here we present a so-called stochastic Newton method in which MCMC is accelerated by constructing and sampling from a proposal density that builds a local Gaussian approximation based on local gradient and Hessian (of the log posterior) information. Hessian manipulations (inverse, square root) are made tractable by a low rank approximation that exploits the compact nature of the data misfit operator. This amounts to a reduced model of the parameter-to-observable map. We apply the method to 3D seismic inverse problems with several million parameters, illustrating the efficacy and scalability of the low rank approximation.

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MS2

Nonparametric Bayesian Inference for Inverse Problems

I will consider the Bayesian approach to inverse problems in the setting where Gaussian random field priors are adopted. I will study random walk type Metropolis algorithms and demonstrate how small modifications in the standard algorithm can lead to an order of magnitude speed up, in terms of the size of the discretization used.

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MS3

Global Sensitivity Analysis with Correlated Inputs: Numerical Aspects in Distribution-Based Sensitivity Measures

In this work, we address the sensitivity of model output utilizing density-based importance measures and a recently introduced sensitivity measures based on repeated Kolmogorov-Smirnov Test. We offer a comparison of the two statistics which, as we are to see, are closely related. We show that they hare closely related. We then show that they can be estimated from given samples. We use this fact to study their estimation in the presence of correlations. Numerical results for examples in which the analytical solution is known are discussed.

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MS3

Sensitivity Indices Based on a Generalized Functional ANOVA

Functional ANOVA allows defining variance based sensitivity indices of any order in the case of independent inputs. Under a dependence-type condition on the joint inputs distribution, we derive a generalization of Hoeffding decomposition, from which we introduce sensitivity indices of any order even for correlated inputs. We also propose an algorithm to compute these indices in the particular case where inputs are correlated two by two.

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MS3

Global Sensitivity Analysis for Systems with Independent and/or Correlated Inputs

Structural and Correlative Sensitivity Analysis (SCSA) provides a new unified framework of global sensitivity analysis for systems with independent and correlated variables based on a covariance decomposition of the output variance. Three sensitivity indices were defined to give a full description, respectively, of the total, structural and correlative contributions of the inputs upon the output. For independent inputs, these indices reduce to a single index consistent with the variance-based method as a special case of the new treatment.

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MS3

Variance-based Sensitivity Indices for Models with Correlated Inputs Using Polynomial Chaos Expansions

The variance decomposition techniques used for global sensitivity analysis are well established as a means for quantifying the uncertainty of the output of a computer model that may be attributed to each input parameter. The classical framework only holds for independent input parameters. In this paper the covariance decomposition proposed by Rabitz is adapted to polynomial chaos expansions of the model response in order to estimate the structural and correlative importance of each input parameter.

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MS4

Quantifying and Reducing Uncertainties on a Set of Failure Using Random Set Theory and Kriging

In computer-assisted robust design and safety studies, calculating probability of failures based on approximation models of the objective function is a problem of growing interest, and has recently inspired several strategies relying on Kriging (e.g., Stepwise Uncertainty Reduction strategies). An even more challenging problem is to describe the set of all dangerous configurations, i.e. the set of input parameters such the output of interest exceeds a given threshold T. Mathematically, if f is the response, such set of failure is denoted by $G = \{x : f(x) \geq T\}$. Estimating G in a severely limited budget of evaluations of f is a difficult problem, and a suitable use of Kriging may help solving it in practice. Starting from an initial set of evaluations of f at an initial Design of Experiments, one can indeed calculate coverage probabilities and/or simulate Gaussian Field realizations conditionally on the available information. We propose to use such notions to sum up the current knowledge on the excursion set, and also to define new SUR strategies based on decreasing some measure of variability of the excursion set distribution. We recently revisited classical notions of random set theory to obtain candidate "expectations' for random sets of excursion, as well as candidate quantifications of uncertainty related to the investigated expectation notions. In this talk we focus on the so called Vorob'ev expectation (for which there is a candidate quantification of uncertainty naturally associated) and derive a new SUR sampling criterion associated to this uncertainty. Implementation issues are discussed and the criterion is illustrated on mono and multi-dimensional examples.

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MS4

Sampling Strategy for Stochastic Simulators with Heterogeneous Noise

Kriging-based approximation is a useful tool to approximate the output of a Monte-Carlo simulator. Such simulator has the particularity to have a known relation between its accuracy and its computational cost. Our objective is to find a sampling strategy optimizing the tradeoff between the fidelity and the number of simulation given a limited computational budget when the fidelity of the M-C simulator depends on the value of the input space parameter. The presented strategies are illustrated on an industrial example of neutron transport code.

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MS4

Optimization of Expensive Computer Experiments Using Partially Converged Simulations and Space-time Gaussian Processes

To alleviate the cost of numerical experiments, it is sometimes possible to stop at early stage the convergence of a simulation and exploit the obtained response, the gain in time being at the price of convergence error. We propose to model such data using a GP model in the joint space of design parameters and computational time, and perform optimization using an EGO-like strategy with the help of a new statistic: the Expected Quantile Improvement.

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MS4

Models with Complex Uncertain Inputs

We consider the problem of investigating the consequences of an event that releases contamination into the atmosphere. Simulators for such events depend on atmospheric and meteorological conditions over at least a six-hour time span. For example, wind strength and direction will be influential in assessing the severity of contamination across a spatial window. The common strategy for simulating these conditions is to sample observed stretches of data. We consider how to generate an informative sample and how to carry out the subsequent analysis.

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MS5

Approximation and Error Estimation in High Dimensional Stochastic Collocation Methods on Arbitrary Sparse Samples

Stochastic collocation methods are an attractive choice to characterize uncertainty because of their non-intrusive nature. High dimensional stochastic spaces can be approximated well for smooth functions with sparse grids. There has been a focus in extending this approach to non-smooth functions using adaptive sparse grids. This presentation will present both adaptive approximation methods and error estimation techniques for high dimension functions.

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MS5

Spatially Varying Stochastic Expansions for Embedded Uncertainty Quantification

Existing discretizations for stochastic PDEs, based on a tensor product between the deterministic basis and the stochastic basis, treat the required resolution of uncertainty as uniform across the physical domain. However, solutions to many PDEs of interest exhibit spatially localized features that may result in uncertainty being severely over or under-resolved by existing discretizations. In this talk, we explore the mechanics and accuracy of using a spatially varying stochastic expansion. This is achieved through an adaptive refinement algorithm where simple error estimates are used to independently drive refinement of the stochastic basis at each point in the physical domain. Results will be presented comparing the performance of this method with other embedded UQ techniques.

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MS5

Simultaneous Local and Dimension Adaptive Sparse Grids for Uncertainty Quantification

Polynomial methods, such as Polynomial Chaos, are often used to construct surrogates of expensive numerical models. When the response surface is smooth these techniques accurately reproduce the model variance. However when discontinuities are present or local metrics, such as probability of failure, are of interest the utility of these methods decreases. Here we propose a greedy, locally and dimension adaptive sparse grid interpolation method which restricts function evaluations to dimensions and regions of interest. The adaptivity is guided by a weighted local interpolation error estimate. The proposed method is highly efficient when only a sub-region of a high-dimensional input space is important.

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MS5

A Posteriori Error Analysis and Adaptive Sampling for Probabilities using Surrogate Models

Surrogate methods have grown in popularity in recent years for stochastic differential equations due to their high-order convergence rates for moments of the solution. Oftentimes, however, the objective is to compute probabilities of certain events, which is performed by sampling the surrogate model. Unfortunately, each of these samples contains discretization error which affects the reliability. We apply adjoint techniques to quantify the accuracy of statistical quantities by estimating the error in each sample and seek to improve the surrogate model through drive adaptive refinement.

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MS6

Heat Kernel Smoothing on an Arbitrary Manifold Using the Laplace-Beltrami Eigenfunctions

We present a novel kernel smoothing framework on curved surfaces using the Laplace-Beltrami eigenfunctions. The

Green's function of an isotropic diffusion equation is analytically represented using the Laplace-Beltrami eigenfunctions. The Green's function is then used in explicitly constructing heat kernel smoothing as a series expansion. Our analytic approach offers many advantages over previous filtering methods that directly solve diffusion equations using FEM. The method is illustrated with various surfaces obtained from medical images.

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MS6

Sparse Grids for Regression

We consider the sparse grid combination technique for regression, which we regard as a problem of function reconstruction in some given function space. We use a regularised least squares approach, discretised by sparse grids and solved using the so-called combination technique, where a certain sequence of conventional grids is employed. The sparse grid solution is then obtained by the addition of these partial solutions with certain predefined combination coefficients. We show why the original combination technique is not guaranteed to converge with higher discretisation levels in this setting, but that a so-called optimised combination technique can be used instead.

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MS6

Second-Order Comparison of Random Functions

Given two samples of random square-integrable functions, we consider the problem of testing whether they share the same second-order structure. Our study is motivated by the problem of determining whether the mechanical properties of short DNA loops are significantly affected by their base-pair sequence. The testing problem is seen to involve aspects of ill-posed inverse problems and a test based on a Karhunen-Love approximation of the Hilbert-Schmidt distance of the empirical covariance operators is proposed and investigated. More generally, we develop the notion of a dispersion operator and construct a family of tests. Our procedures are applied to a sample of DNA minicircles obtained via the electron microscope.

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MS6

Spatial Spline Regression Models

We deal with the problem of surface estimation over irregularly shaped domains, featuring complex boundaries, strong concavities and interior holes. Adopting an approach typical of Functional Data Analysis, we propose a Spatial Spline Regression model that efficiently handle this problem; the model also accounts for covariate information, can comply with general conditions at the domain boundary and has the capacity to incorporate a priori information about the surface shape.

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MS7

Global Sensitivity and Reduction of Very High-Dimensional Models with Correlated Inputs

Models originating from observed data or from computer code can be very high-dimensional. Total contribution from model input X_i to variance of model output Y is defined as $V_{T_i} = \text{Var}(Y) - \text{Var}[E(Y|\mathbf{X}_{-i})]$, where $\mathbf{X}_{-i}$ corresponds to all inputs except X_i. We develop an efficient algorithm to compute V_{T_i} for models with thousands of possibly correlated inputs with arbitrary distributions. The number of required model samples is independent of the number of inputs. The resulting global sensitivities $V_{T_i}/\text{Var}(Y)$ can be used to create a reduced model for fast output prediction and uncertainty quantification. The developed algorithms are implemented in our software GoSUM (Global Optimizations, Sensitivity and Uncertainty in Models).

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MS7

Uncertainty Quantification in Energy Efficient Building Retrofit Design

One area of engineering where uncertainty quantification and mitigation is not only desired, but actually necessary is energy efficient building retrofit design. Buildings are complex systems with large number of parameters that are often not properly measured and recorded (e.g. equipment efficiencies) or that have inherently large uncertainties associated with them (e.g. occupancy patterns). In this talk we discuss mathematical methods and technical challenges involved with UQ for retrofit design.

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MS7

Iterative Methods for Propagating Uncertainty through Networks of Switching Dynamical Systems

Networks of switching dynamical systems arise naturally in a vast variety of applications. These systems can be challenging for analysis due to non-smooth dynamics. Here, we develop methods to perform uncertainty quantification on switching systems using polynomial chaos based on wavelet expansions. Since the number of equations required scales exponentially, we develop novel iterative methods to simulate networks of switching dynamical systems. We demonstrate these methods on a large network of switching oscillators.

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MS7

NIPC: A MATLAB GUI for Wider Usability of Nonintrusive Polynomial Chaos

Polynomial Chaos theory is a sophisticated method for a fast stochastic analysis of dynamic systems with few random parameters. Classically, all system laws are reformulated into deterministic equations, but recently, a nonintrusive variation has been developed for application with black boxes. After a brief introduction of this concept, we would like to present a tool which makes the numerous adjustments and the understanding of the advanced mathematical roots of Polynomial Chaos irrelevant for the user.

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MS8

Speeding up the Sensitivity Analysis of an Epidemiological Model

This presentation describes a probabilistic sensitivity analysis of an epidemiological simulator of rotavirus. We used both advanced input screening techniques and emulator-based methods to make the process more efficient and focussed on the relevant regions of the input space. The key to successfully applying these methods was the quantification of expert uncertainty about the input parameters. The methods for expert elicitation will be described and their use in the sensitivity analysis will be illustrated.

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MS8

Sensitivity Analysis of a Global Aerosol Model to Quantify the Effect of Uncertain Model Parameters

We present a sensitivity analysis of a global aerosol model using Gaussian process emulation. We present results for the sensitivity of global cloud condensation nuclei to 37 uncertain process parameters and emissions. We show global maps of the total uncertainty in several aerosol quantities as well as a breakdown of the main factors controlling the uncertainty. These results provide a very clear guide for the reduction in model uncertainty through targeted model development.

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MS8

Sensitivity Analysis for Complex Computer Models

We discuss the problem of quantifying the importance of uncertain input parameters in a computer model; which input parameters should we learn about to best reduce output uncertainty? Two standard tools are reviewed: variance-based sensitivity analysis, and decision theoretic measures based on the value of information. For computationally expensive models, computational methods are presented for calculating these measures using Gaussian-process surrogate models. These tools will be applied in the remaining three talks.

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MS8

Managing Model Uncertainty in Health Economic Decision Models

Health economic models predict the costs and health effects associated with competing decision options (e.g. recommend drug X versus Y). Current practice is to quantify input uncertainty, but to ignore uncertainty due to deficiencies in model structure. Given a relatively simple but imperfect model, is there value in incorporating additional complexity to better describe the decision problem? We derive the 'expected value of model improvement' via a decision theoretic sensitivity analysis of model discrepancy.

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MS9

Hybrid UQ Method for Multi-Species Reactive Transport

Uncertainty quantification (UQ) for multi-physics applications is challenging for both intrusive and non-intrusive methods. A question naturally arises: Can we take the best of both worlds to introduce a 'hybrid' UQ methodology for multi-physics applications? This minisymposium brings together researchers who are exploring hybrid UQ methods. In particular, we emphasize techniques that propagate global uncertainties yet allow individual physics components to use their local intrusive or non-intrusive UQ methods. Relevant issues for discussions are: hybrid uncertainty propagation algorithms, dimension reduction, Bayesian data fusion techniques, design of hybrid computational framework, and scalable algorithms for hybrid UQ.

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MS9

Preconditioners/Multigrid for Stochastic Polynomial Chaos Formulations of the Diffusion Equation

This talk presents (parallel) preconditioners and multigrid solvers for solving linear systems of equations arising from stochastic polynomial chaos (PC) formulations of the diffusion equation with random coefficients. These preconditioners/solvers are an extension of the preconditioner developed in [?] for strongly coupled systems of elliptic partial equations that are norm equivalent to systems that can be factored into an algebraic coupling component and a diagonal differential component, as is the case for the systems produced by PC formulations of the diffusion equation.

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MS9

A High Performance Hybrid pce Framework for High Dimensional UQ Problems

In the domain of stochastic multi-physics problems, traditional non-intrusive and intrusive UQ methods are expensive and preclude a much-needed modular plug and play solver infrastructure. We present a hybrid UQ methodology to tackle these challenges. A conditional polynomial representation of the stochastic solution vector is used to track local and global uncertainty propagation between modules. The frameworks parallel efficiency and spectral accuracy is shown using a multi-species reaction-flow problem modeled as a non-linear PDE system.

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MS9

Stochastic Dimension Reduction Techniques for Uncertainty Quantification of Multiphysics Systems

Uncertainty quantification of multiphysics systems represents numerous mathematical and computational challenges. Indeed, uncertainties that arise in each physics in a fully coupled system must be captured throughout the whole system, the so-called curse of dimensionality. We present techniques for mitigating the curse of dimensionality in network-coupled multiphysics systems by using the structure of the network to transform uncertainty representations as they pass between components. Examples from the simulation of nuclear power plants will be discussed.

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MS10

First Order k-th Moment Finite Element Analysis of Nonlinear Operator Equations with Stochastic Data

We develop and analyze a class of efficient algorithms for uncertainty quantification of nonlinear operator equations. The algorithms are based on sparse Galerkin discretizations of tensorized linearizations at nominal parameters. Specifically, we analyze a class of abstract nonlinear, parametric operator equations

$$J(\alpha, u) = 0$$

for random parameters α with realizations in a neighborhood of a nominal parameter α_0. Under some structural assumptions on the parameter dependence, random parameters $\alpha(\omega) = \alpha_0 + r(\omega)$ are shown to imply a unique random solution $u(\omega) = S(\alpha(\omega))$. We derive an operator equation for the deterministic computation of k-th order statistical moments of the solution fluctuations $u(\omega) - S(\alpha_0)$, provided that statistical moments of the random parameter perturbation $r(\omega)$ are known. This formulation is based on the linearization in a neighborhood of a nominal parameter α_0. We provide precise bounds for the linearization error by means of a Newton-Kantorovich-type theorem. We present a sparse tensor Galerkin discretization for the tensorized first order perturbation equation and deduce that sparse tensor Galerkin discretizations of this equation converge in accuracy vs. complexity which equals, up to logarithmic terms, that of the Galerkin discretization of a single instance of the mean field problem.

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MS10

An Adaptive Iterative Method for

High-dimensional Stochastic PDEs

A new approach for constructing low-rank solutions to stochastic partial differential equations is presented. Our algorithm exploits the notion that the stochastic solution and functionals thereof may live on low-dimensional manifolds, even in problems with high-dimensional stochastic inputs. We use residuals of the stochastic PDE to sequentially and adaptively build bases for both the random and deterministic components of the solution. By tracking the norm of the residual, meaningful error measures are provided to determine the quality of the solution. The approach is demonstrated on Maxwell's equations with uncertain boundaries and on linear/nonlinear diffusion equations with log-normal coefficients, characterized by several hundred input dimensions. In these problems, we observe order-of-magnitude reductions in computational time and memory compared to many state-of-the-art intrusive and non-intrusive methods.

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MS10

Adjoint Enhancement Within Global Stochastic Methods

This presentation will explore the use of local adjoint sensitivities within global stochastic approximation methods for the purposes of improving the scalability of uncertainty quantification methods with respect to random dimension. Methodologies of interest include generalized polynomial chaos, based on regression over unstructured grids; stochastic collocation, based on gradient-enhanced interpolation polynomials on structured grids; and global reliability methods, using gradient-enhanced kriging on unstructured grids. Efficacy of these gradient-enhanced approaches will be assessed based on relative efficiency (speed-up with adjoint gradient inclusion) and numerical robustness (ill-conditioning of solution or basis generation).

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MS10

Stochastic Collocation Methods in Unstructured Grids

We present a framework for stochastic collocation method on arbitrary grids. The method utilizes a newly developed least orthogonal interpolation theory to construct high-order polynomial approximations of the stochastic solution, based on the collocation results of any type of grids in arbitrary dimensions. We present both the mathematical theory and numerical implementation. Examples are provided to demonstrate the flexibility of the methods.

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MS11

A Dynamic Programming Approach to Sequential and Nonlinear Bayesian Experimental Design

We present a framework for optimal sequential Bayesian experimental design, using information theoretic objectives. In particular, we adopt a "closed-loop" approach that uses the results of intermediate experiments to guide subsequent experiments in a finite horizon setting. Direct solution of the resulting dynamic programming problem is computationally impractical. Using polynomial chaos surrogates, stochastic optimization methods, and value function approximations, we develop numerical tools to identify sequences of experiments that are optimal for parameter inference, in a computationally feasible manner.

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MS11

Identification of Polynomial Chaos Representations in High Dimension

The usual identification methods of polynomial chaos expansions in high dimension are based on the use of a series of truncations that induce numerical bias. We first quantify the detrimental influence of this numerical bias, we then propose a new decomposition of the polynomial chaos coefficients to allow performing relevant convergence analysis and identification with respect to an arbitrary measure for the high dimension case.

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MS11

Inverse Problems for Nonlinear Systems via Bayesian Parameter Identification

Inverse problems are important in engineering science and appear very frequently such as for example in estimation of material porosity and properties describing irreversible behaviour, control of high-speed machining processes etc. At present, most of identification procedures have to cope with ill-possedness as the problems are often considered in a deterministic framework. However, if the parameters are modelled as random variables the process of obtaining more information through experiments in a Bayesian setting becomes well-posed. In this manner the Bayesian information update can be seen as a minimisation of variance. In this work we use the functional approximation of uncertainty and develop a purely deterministic procedure for the updating process. This is then contrasted to a fully Bayesian update based on Markov chain Monte Carlo sampling on a few numerical nonlinear examples. Examples are based on plasticity and nonlinear diffusion models.

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MS11

Data Analysis Methods for Inverse Problems

We present exploratory data analysis methods to assess inversion estimates using examples based on l2- and l1-regularization. These methods can be used to reveal the presence of systematic errors s and validate modeling assumptions. The methods include: confidence intervals and bounds for the bias, resampling methods for model validation, and construction of training sets of functions with controlled local regularity.

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MS12

Analysis and Finite Element Approximations of Optimal Control Problems for Stochastic PDEs

In this talk, we consider mathematically and computationally optimal control problems for stochastic partial differential equations. The control objective is to minimize the expectation of a cost functional, and the control is of the deterministic distributed and/or boundary value type. The main analytical tool is the Karhunen-Loeve (K-L) expansion. Mathematically, we prove the existence of an optimal solution and derive optimality system. Computationally, we approximate the optimality system through the discretizations of the probability space and the spatial space by the finite element method; we also derive error estimates in terms of both types of discretizations. Some numerical experiments are given.

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MS12

Generalized Methodology for Inverse Modeling Constrained by SPDEs

We formulate several stochastic inverse problems to estimate statistical moments (mean value, variance, covariance) or even the whole probability distribution of input data, given the PDF of some response (quantities of physical interest) of a system of SPDEs. The identification objectives minimize the expectation of a tracking cost functional or minimize the difference of desired statistical quantities in the appropriate norms. Numerical examples illustrate the theoretical results and demonstrate the distinctions between the various objectives.

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MS12

Stochastic Inverse Problems via Probabilistic Graphical Model Techniques

We build a graphical model for learning the probabilistic relationship between the input and output of a multiscale problem (e.g. crystal plasticity based deformation). The graphical model is first learned (parameters in potential functions) using a set of training data and suitable optimization strategies (e.g. MLE, EM, etc.). After that, by applying belief propagation algorithm, we can solve the coarse to fine scale inverse problem (e.g. find the initial microstructure given desired properties) or the forward problem (e.g. find the properties resulting from a given initial microstructure).

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MS12

Least-Squares Estimation of Distributed Random Diffusion Coefficients

We formulate a stochastic inverse problem, estimating the random diffusion coefficient in an elliptic PDE, as a least squares problem in the space of functions with bounded mixed derivatives. We prove existence and define the necessary optimality conditions using techniques from optimization theory. In addition, the regularization of the problem connects the infinite dimensional problem with its finite noise discretization. Numerical results that validate our theory will be presented.

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MS13

Challenges on Incorporating Uncertainty in Computational Model Predictions

Bayes' theorem allows for the treatment of uncertainties in the whole model prediction process. It can be used for model calibration (either batch or real-time), ranking of scientific hypotheses formulated as mathematical models, ranking of data sets according to information content, and averaging of predictions made by competing models. We discuss the uncertainty quantification research we have been pursuing in the context of realistic models, including sampling with MCMC algorithms and emulation with Gaussian processes.

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MS13

A Stochastic Collocation Approach to Constrained Optimization for Random Data Estimation Problems

We present a scalable, parallel mechanism for identification of statistical moments of input random data, given the probability distribution of some response of a system of stochastic partial differential equations. To characterize data with moderately large amounts of uncertainty, we introduce a stochastic parameter identification algorithm that integrates an adjoint-based deterministic algorithm with the sparse grid stochastic collocation FEM. Rigorously derived error estimates are used to compare the efficiency of the method with other techniques.

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MS13

A Randomized Iterative Proper Orthogonal Decomposition (RI-POD) Technique for Model Identification

In this talk, we shall present a data based technique for the identification of the eigenmodes of very high dimensional linear systems. Our technique is based on the snapshot proper orthogonal decomposition (POD) method. We show that using the snapshot POD with randomized forcing or initial conditions, in an iterative fashion, we can extract as many of the eigenmodes of the linear system as required. The technique works for symmetric as well as non-symmetric systems.

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MS13

Sparse Bayesian Techniques for Surrogate Creation and Uncertainty Quantification

We develop a multi-output, Bayesian, generalized linear regression model with arbitrary basis functions. The model automatically excludes redundant basis functions while providing access to the full Bayesian predictive distribution of the statistics. By employing a sequentially built tree structure, we are able to demonstrate that it is capable of identifying discontinuities in the response surface. We demonstrate our claims numerically using various basis functions that vary from localized kernels to numerically build Generalized Polynomial Chaos basis.

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MS14

Application of Goal-Oriented Error Estimation Methods to Statistical Quantities of Interest

The objective here is to present an extension of goal-oriented methods for a posteriori error estimation to the case of stochastic problems with random parameters. We shall consider the stochastic collocation method, for which estimates of statistical moments of the error in a quantity of interest have been proposed in the past, but will focus on estimating the error in these moments themselves and on accurately representing the posterior distribution of the quantity of interest.

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MS14

Estimating and Bounding Errors in Distributions Propagated via Surrogate Models

We consider the problem of propagating distributions through quantities of interest to differential equations with parameters modeled as random processes. Polynomial chaos expansions approximate random processes, and the differential equations are solved numerically. We estimate discretization error, bound truncation error, and consider the effect of finite sampling in the computed distribution functions for both forward and inverse problems. The results are computable error bounds for distribution functions that we demonstrate with numerical examples.

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MS14

An Adjoint Error Estimation Technique Using Finite Volume Methods for Hyperbolic Equations

Many codes exist for hyperbolic equations that employ finite volume methods, which are often nonlinear. A method is presented for adjoint-based *a posteriori* error calculations with finite volume methods. Conditions are derived under which the error in a quantity of interest may be recovered with guaranteed asymptotic accuracy, including for nonlinear forward solvers and weak solutions. We demonstrate the flexibility in implementation of this post-processing technique and accuracy with smooth and discontinuous solutions.

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MS15

Computation of Posterior Distribution in Ordinary Differential Equations with Transport Partial Differential Equations

We consider the estimation of the initial conditions of an Ordinary Differential Equation from a noisy trajectory in a Bayesian setting. The posterior distribution is computed by exploiting the fact that it is transported by the vector field defining the ODE. As a consequence, one can design an iterative computation based on the transport of probability. This transported probability is the solution of a PDE, which is solved by an Eulerian-Lagrangian scheme with bi-orthogonal wavelets.

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MS15

Large-scale Seismic Inversion: Elastic-acoustic Coupling, DG Discretization, and Uncertainty Quantification

We present our recent efforts on solving globally large-scale seismic inversion. We begin by a unified framework for elastic-acoustic coupling together with an hp-nonconforming discontinuous Galerkin (DG) spectral element method. Next, consistency, stability, and hp-convergence of the DG method as well as its scalability up to 224k cores are presented. Finally, a method for uncertainty quantification based on the compactness of the data mistfit is presented, followed by a brief discussion on a variance-driven adaptivity.

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MS15

Nonparametric Estimation of Diffusions: A Differential Equations Approach

We consider estimation of scalar functions that determine the dynamics of diffusion processes. It has been recently shown that nonparametric maximum likelihood estimation is ill-posed in this context. We adopt a probabilistic approach to regularize the problem by the adoption of a prior distribution for the unknown functional. A Gaussian prior measure is chosen in the function space by specifying its precision operator as an appropriate differential operator. We establish that a Bayesian Gaussian conjugate analysis for the drift of one-dimensional non-linear diffusions is feasible using high-frequency data, by expressing the log-likelihood as a quadratic function of the drift, with sufficient statistics given by the local time process and the end points of the observed path. Computationally efficient posterior inference is carried out using a finite element method.

We embed this technology in partially observed situations and adopt a data augmentation approach whereby we iteratively generate missing data paths and draws from the unknown functional. Our methodology is applied to estimate the drift of models used in molecular dynamics and financial econometrics using high and low frequency observations. We discuss extensions to other partially observed schemes and connections to other types of nonparametric inference.

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MS15

A Statistical Approach to Data Assimilation for Hemodynamics

We discuss a Data Assimilation (DA) technique for hemodynamics based on a Bayesian approach. DA is formulated as a control problem minimizing a weighted misfit between data and velocity under the constraint of the Navier-Stokes equations. The control variable is the probability density function of the normal stress at the inflow; we derive statistical estimators (maximum a posteriori and maximum likelihood) and confidence intervals for the velocity. We compare statistical and deterministic estimators.

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MS16

Toward Improving Statistical Components of Multi-scale Simulation Schemes

I will describe an ongoing collaboration with Sorin Mitran and a group of statisticians to develop more sophisticated approaches to handling some issues concerning representation of and communication between kinetic mesoscale PDFs and stochastically simulated microscale data in Mitran's novel time-parallel Continuum-Kinetic-Molecular (tpCKM) method. The mesoscale component of this method can be viewed as an emulator for the microscale dynamics, and our research regards offline and online control of its quality.

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MS16

Improving Gaussian Stochastic Process Emulators

Gaussian Stochastic Process (GASP) emulators are fast surrogates to the output of computationally expensive simulators of complex physical processes used in many scientific applications. They have many advantages, but some improvements are still needed. The talk will present several methods in a Bayesian context for improving the implementation of GASP emulators under computational constraints (including the use of large data sets) and obtaining statistical approximations to the computer model that are closer to the reality.

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MS16

Emulating Dynamic Models: An Overview of Suggested Approaches

Dynamic models are characterized by a large number of outputs in the time domain and by a strong dependence of outputs conditional on recent past outputs. This makes it difficult to apply standard emulation techniques to such models. Several approaches have been suggested to overcome these problems. The talk will give an overview of these concepts, try to analyze which approach may be most promising under which circumstances, and identify needs for further research.

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MS16

Statistical Approximation of Computer Model

Output aka Emulation of Simulation

Computer model data can be used to construct a predictor of the computer model output at untried inputs. Such construction combined with assessment of prediction uncertainty is an emulator or surrogate of the computer model. A key strategy uses the Bayes paradigm to produce predictors and quantify uncertainties. An overview of this strategy which uses gaussian stochastic processes as priors will include comments on connections with approaches such as polynomial chaos.

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MS17

Adaptive Sparse Grids for Stochastic Collocation on Hybrid Architectures

We discuss the algorithmic developments required to build a scalable adaptive sparse grid library tailored for emerging architectures that will allow the solution of very large stochastic problems. We demonstrate the first results of adaptive sparse grids for hybrid systems and detail the algorithmic challenges that were overcome to get these techniques to work on these novel systems.

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MS17

A Compressive Sampling Approach for the Solution of High-dimensional Stochastic PDEs

We discuss a non-intrusive sparse approximation approach for uncertainty propagation in the presence of high-dimensional random inputs. The idea is to exploit the sparsity of the quantities of interest with respect to a suitable basis in order to estimate the dominant expansion coefficients using a number of random samples that is much smaller than the cardinality of the basis.

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MS17

Tensor-based Methods for Uncertainty Propagation: Alternative Definitions and Algorithms

Tensor approximation methods have recently received a growing attention in scientific computing for the solution of high-dimensional problems. These methods are of particular interest in the context of uncertainty quantification with functional approaches, where they are used for the representation of multiparametric functionals. Here, we present different alternatives, based on projection or statistical methods, for the construction of tensor approximations, in various tensor formats, of the solution of parameterized stochastic models.

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MS17

PDE with Random Coefficient as a Problem in Infinite-dimensional Numerical Integration

This talk is concerned with the use of quasi-Monte Carlo methods combined with finite-element methods to handle an elliptic PDE with a random field as a coefficient. A number of groups have considered such problems (under headings such as polynomial chaos, stochastic Galerkin and stochastic collocation) by reformulating them as deterministic problems in a high di- mensional parameter space, where the dimensionality comes from the num- ber of random variables needed to characterise the random field. In recent joint work with Christoph Schwab (ETH) and Frances Kuo (UNSW) we have treated a problem of this kind as one of infinite-dimensional integration - where integration arises because a multi-variable expected value is a multidimensional integral - together with finite-element approximation in the physical space. We use recent developments in the theory and practice of quasi-Monte Carlo integration rules in weighted Hilbert spaces, through which rules with optimal properties can be constructed once the weights are known. The novel feature of this work is that for the first time we are able to design weights for the weighted Hilbert space that achieve what is believed to be the best possible rate of convergence, under conditions on the random field that are exactly the same as in a recent paper by Cohen, DeVore and Schwab on best N-term approximation for the same problem.

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MS18

A Multiscale Domain Decomposition Method for the Solution of Stochastic Partial Differential Equations with Localized Uncertainties

The presence of numerous localized sources of uncertainties in physical models leads to high dimensional and complex multiscale stochastic models. A numerical strategy is here proposed to propagate the uncertainties through such models. It is based on a multiscale domain decomposition method that exploits the localized side of uncertainties. The separation of scales has the double benefit of improving the conditioning of the problem as well as the convergence of tensor based methods (namely Proper Generalized Decomposition methods) used within the strategy for the separated representation of high dimensional stochastic parametric solutions.

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MS18

Greedy Algorithms for Non Symmetric Linear Problems with Uncertainty

Greedy algorithms, also called Progressive Generalized Decomposition algorithms, are known to give very satisfactory results for the approximation of the solution of symmetric uncertain problems with a large number of random parameters. Indeed, their formulation leads to discretized problems whose complexity evolves linearly with respect to the number of parameters, while avoiding the curse of dimensionality. However, naive adaptations of these methods to non-symmetric problems may not converge towards the desired solution. In this talk, different versions of these algorithms will be presented, along with convergence results.

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MS18

Optimized Polynomial Approximations of PDEs with Random Coefficients

We consider the problem of numerically approximating statistical moments of the solution of a partial differential equation (PDE), whose input data (coefficients, forcing terms, boundary conditions, geometry, etc.) are uncertain and described by a finite or countably infinite number of random variables. This situation includes the case of infinite dimensional random fields suitably expanded in e.g Karhunen-Loève or Fourier expansions. We focus on polynomial chaos approximations of the solution with respect to the underlying random variables by either Galerkin projection; Collocation on sparse grids of Gauss points or discrete projection using random evaluations. We discuss in particular the optimal choice of the polynomial space for linear elliptic PDEs with random diffusion coefficient, based on a-priori estimates. Numerical results showing the effectiveness and limitations of the approaches will be presented.

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MS18

Solving Saddle Point Problems with Random Data

Stochastic Galerkin and stochastic collocation methods are becoming increasingly popular for solving (stochastic) PDEs with random data (coefficients, sources, boundary conditions, domains). The former usually require the solution of a large, coupled linear system of equations while the latter require the solution of a large number of small systems which have the dimension of the corresponding deterministic problem. Although many studies on positive definite problems with random data can be found in the literature, there is less work on stochastic saddle point problems, both in terms of approximation theory, and solvers. In this talk, we discuss some of the approximation theory and linear algebra issues involved in applying stochastic Galerkin and collocation schemes to saddle point problems with random data. Model problems that will be used to illustrate the main points, include: 1) a mixed formulation of a second-order elliptic problem (with random diffusion coefficient), 2) the steady-state Navier-Stokes equations (with random viscosity) and 3) a second-order elliptic PDE on a random domain, solved via the fictitious domain method.

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MS19

Optimization and Model Reduction for Parabolic PDEs with Uncertainties

Optimization of time-dependent PDEs with uncertain coefficients is expensive, because the problem size depends on the spatial and temporal discretization, and on sampling of the uncertainties. I analyze an approach based on stochastic collocation and model reduction, which are used to decouple the subproblems and reduce their sizes. For a class of problems and methods, I prove an estimate for the error between the full and the reduced order optimization problem. Numerical illustrations are provided.

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MS19

A Stochastic Galerkin Method for Stochastic Control Problems

We examine a physical problem, fluid flow in porous media, which is represented by a stochastic PDE. We first give a priori error estimates for an optimization problem constrained by the physical model. We then use the concept of Galerkin finite element methods to establish a numerical algorithm to give approximations for our stochastic problem. Finally, we develop original computer programs based on the algorithm and present several numerical examples

of various situations.

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MS19

Optimal Control of Stochastic Flow Using Reduced-order Modeling

We explore an stochastic optimal control problem for incompressible flow by using reduced-order modeling (ROM) based on proper orthogonal decomposition (POD). The POD basis is constructed via a set of "snapshots' obtained by sampling the solution of the Navier-Stokes system at several time instants and over several independent realizations of the random data. Then, the stochastic ROM is constructed via a Galerkin method with respect to the POD basis.

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MS19

An Efficient Sparse-Grid-Based Method for Bayesian Uncertainty Analysis

We develop an efficient sparse-grid (SG) Bayesian approach for quantifying parametric and predictive uncertainty of physical systems constrained by stochastic PDEs. An accurate surrogate posterior density is constructed as a function of polynomials using SG interpolation and integration. It improves the simulation efficiency by accelerating the evaluation of the posterior density without losing much accuracy, and by determining an appropriate alternative density which is easily-sampled and captures the main features of the exact posterior density.

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MS20

Fundamental Limitations of Polynomial Chaos Expansions for Uncertainty Quantification in Systems with Intermittent Instabilities

Methods based on truncated Polynomial Chaos Expansion (PCE) have been a popular tool for probabilistic uncertainty quantification in complex nonlinear systems. We show rigorously that truncated PCE have fundamental limitations for UQ in systems with intermittently positive Lyapunov exponents, leading to non-realizability of probability densities and even a blow-up at short times of the second-order statistics. Simple unambiguous examples are used to illustrate these limitations.

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MS20

Physics-based Auto- and Cross-Covariance Models for Gaussian Process Regression

Gaussian process analysis of systems with multiple outputs is limited by the fact that far fewer good classes of covariance functions exist compared with the single-output case. We propose analytical and numerical auto- and cross-covariance models, which take a form consistent with physical laws governing the underlying simulated process, and are suitable when performing uncertainty quantification or inferences on multidimensional processes (co-kriging). High-order closures are also derived for nonlinear dependencies among the observables.

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MS20

Covariance Approximation Techniques in Bayesian Non-stationary Gaussian Process Models

Bayesian Gaussian processes have been widely used in spatial statistics but face tremendous computational challenges for very large data sets. The full rank approximation is among the best approximation techniques used recently in statistics to deal with large spatial dataset. This technique is successfully applied in stationary spatial processes where the data are reasonably considered stationary but been tried with real non-stationary large spatial datasets. The goal of this presentation is to generalize this method.

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MS20

Inertial Manifold Dimensionality Finite-time Instabilities in Fluid Flows

We examine the geometry of the inertial manifold associated with fluid flows and relate its nonlinear dimensionality to energy exchanges among different dynamical components. Using dynamical orthogonality we perform efficient order-reduction and we prove and illustrate in 2D Navier-Stokes that the underlying mechanism responsible for the finite dimensionality of the inertial manifold is, apart from

the viscous dissipation, the reverse flow of energy from large to small scales. We discuss implications on data assimilation schemes.

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MS21

A Matrix-Free Approach for Gaussian Process Maximum Likelihood Calculations

In Gaussian processes analysis, the maximum likelihood approach for parameter estimation is limited by the use of the Cholesky factorization on the covariance matrix in computing the likelihood. In this work, we present a stochastic programming reformulation with convergence estimates for solving the maximum likelihood problem for large scale data. We demonstrate that the approach scales linearly with an increase in the data size on a desktop machine, and show some preliminary results on supercomputers with parallel processing.

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MS21

Sequential Optimization of a Computer Model: Whats So Special about Gaussian Processes Anyway?

In computer experiments, statistical models are commonly used as surrogates for slow-running codes. In this talk, the usually ubiquitous Gaussian process models are nowhere to be seen, however. Instead, an adaptive nonparametric regression model (BART) is used to deal with nasty nonstationarities in the response surface. By providing both point estimates and uncertainty bounds for prediction, BART provdes a basis for sequential design criteria to find optima with few function evaluations.

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MS21

Extracting Key Features of Physical Systems for Emulation and Calibration

Many physical models, such as material strength models, rely on a large number of parameters describe the physical system over a large range of possible input settings. However, for particular model based prediction, the physical complexity of the system is much reduced, and as a result, the effective physical model needed to make predictions may be described by a few functions of the parameters (which we call feature).We present an example where physical understanding and its implementation in the predictive computer code suggest a particular function of material strength to focus on. This allows us to greatly reduce the dimensionality and non-linearity of the problem, making emulation and calibration a much simpler task.

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MS21

Sliced Cross-validation for Surrogate Models

Multi-fold cross-validation is widely used to assess the accuracy of a surrogate model. Despite its popularity, this method is known to have high variability. We propose a method, called sliced cross-validation, to mitigate this drawback. It uses sliced space-filling designs to construct structured cross-validation samples such that the data for each fold are space-filling. Numerical examples and theoretical results will be given to illustrate the proposed method.

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MS22

Simulation Informatics

Modern physical simulations produce large amounts of data. Proper uncertainty quantification on such data sets requires scalable, fault tolerant methods for feature extraction and machine learning. We frame the statistical questions arising from uncertainty quantification as a machine learning problem, which leverages existing work in informatics. We focus particularly on scalable model reduction and surrogate modeling for parameterized simulations – a common scenario in uncertainty quantification.

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MS22

Scientific Data Mining Techniques for Extracting Information from Simulations

Techniques from scientific data mining have long been used for the analysis of data from various domains including astronomy, remote sensing, materials science, and simulations of turbulence in fluids and plasma. In this talk, I will present some of my work in classification of orbits in Poincare plots in fusion simulations, analysis of coherent structures in Rayleigh-Taylor instability, and comparison of experiments and simulations in Richtmyer-Meshkov instability.

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MS22

Machine Learning to Recognize Phenomena in Large Scale Simulations

Clustering, classification, and anomaly detection are among the most important problems in machine learning. The existing methods usually treat the individual data points as the object of consideration. Here we consider a different setting. We assume that each instance corresponds to a group of data points. Our goal is to estimate the distances between these groups and use them to create new clustering and classification algorithms, and recognize phenomena in large scale simulations.

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MS22

Extracting Non-conventional Information in Simulation of Chaotic Dynamical Systems

Many state-of-the-art large scale simulations are chaotic. Examples include turbulent fluid flows using techniques such as direct numerical simulation or large eddy simulation, protein folding using molecular dynamics, and nuclear fusion engineering using plasma dynamics simulation. Performing these simulations often produces very large amounts of data; however, to extract physical insight and understanding from the result of the simulation is nontrivial. This talk focuses on a method of extracting non-conventional information, such as robustness, sensitivity and quantified uncertainty, from the data produced by chaotic simulations. We will discuss methods for identifying the attractor of the chaotic simulation, and introduce the attractor-Fokker-Planck equation that governs the ergodic density on the attractor. We then will introduce our Monte Carlo solver for the adjoint of the Fokker-Planck equation, which can be used to compute the robustness and sensitivity of the chaotic simulation with respect to possible parameter changes. Finally, we will show how the resulting sensitivity can be used for uncertainty quantification.

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MS23

Distinguishing and Integrating Aleatoric and Epistemic Variation in UQ

Much of UQ to date has focused on determining the effect of variables modeled probabilistically, with known distributions. We develop methods to obtain information on a system when the distributions of some variables are known exactly, while others are known only approximately. We use the duality between risk-sensitive integrals and relative entropy to obtain bounds on performance measures over families of distributions. These bounds are computed using polynomial chaos techniques.

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MS23

Stochastic Basis Reduction by QoI Adaptation

We describe a new stochastic model reduction approach that characterizes the uncertainty in predictive models by relying on the dominant subspace occupied by a Quantity of Interest. Orders of magnitude reduction in requisite representation and associated computational costs are achieved in this manner. We demonstrate the methodology on an elliptic problem describing an elastically deforming body.

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MS23

Adaptive Basis Selection and Dimensionality Reduction with Bayesian Compressive Sensing

Bayesian inference is implemented to obtain a polynomial chaos expansion for the response of a complex model, given a sparse set of training runs. For polynomial basis reduction, Bayesian compressive sensing is employed to detect basis terms with strong impact on model output via relevance vector machine. Furthermore, a recursive algorithm is proposed to determine the optimal set of basis terms. The methodology is applied to global sensitivity studies of the Community Land Model.

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MS23

Stochastic Collocation Methods for Stochastic Differential Equations Driven by White Noise

We propose stochastic collocation methods for time-dependent stochastic differential equations (SDEs) driven by white noise. To control the increasing dimensionality in random space generated by the increments of Brownian motion, we approximate Brownian motion with its spectral expansion. We also use sparse grid techniques to further reduce the computational cost in random space. Numerical examples shows the efficiency of the proposed methods. In particular, our proposed methods can run up to moderately large time with proper schemes in physical space and time.

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MS24

Probabilistic UQ for PDEs with Random Data: A Case Study

We present a case study for probabilistic uncertainty quantification (UQ) applied to groundwater flow in the context of site assessment for radioactive waste disposal based on data from the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico. In this context, the primary quantity of interest is the time it takes for a particle of radioactivity to be transported with the groundwater from the repository to man's environment. The mathematical model consists of a stationary diffusion equation for the hydraulic head in which the hydraulic conductivity coefficient is a random field. Once the (stochastic) hydraulic head is computed, contaminant transport can be modelled by particle tracing in the associated velocity field. We compare two approaches: Gaussian process emulators and stochastic collocation combined with geostatistical techniques for determining the parameters of the input random field's probability law. The second approach involves the numerical solution of the PDE with random data as a parametrized deterministic system. The calculation of the statistics of the travel time from the solution of the stochastic model is formulated for each of the methods being studied and the results compared.

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MS24

Proper Generalized Decomposition for Stochastic Navier-Stokes Equations

We propose an application of the Proper Generalized Decomposition to the stochastic Navier-Stokes equations in the incompressible regime. The method aims at determining the dominant components of the stochastic flow by means of suitable reduced bases approximations. The deterministic reduced basis is here constructed using Arnoldi-type iterations, which involve the resolution of a series of deterministic problems whose structure is similar to the original deterministic Navier-Stokes equations such that classical solvers can be re-used. The stochastic solution is then approximated in the reduced space of deterministic modes by means of a Galerkin projection, yielding a low dimensional set of coupled quadratic equations for the stochastic coefficients. The efficiency of the method will be illustrated and its computational complexity will be contrasted with the classical Galerkin Polynomial Chaos method. Computation of the reduced solution residual and of the stochastic pressure field will also be discussed.

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MS24

Computation of the Second Order Wave Equation with Random Discontinuous Coefficients

In this talk we propose and analyze a stochastic collocation method for solving the second order wave equation with a random wave speed and subjected to deterministic boundary and initial conditions. The speed is piecewise smooth in the physical space and depends on a finite number of random variables. The numerical scheme consists of a finite difference or finite element method in the physical space and a collocation in the zeros of suitable tensor product orthogonal polynomials (Gauss points) in the probability space. This approach leads to the solution of uncoupled deterministic problems as in the Monte Carlo method. We consider both full and sparse tensor product spaces of orthogonal polynomials. We provide a rigorous convergence analysis and demonstrate different types of convergence of the probability error with respect to the number of collocation points for full and sparse tensor product spaces and under some regularity assumptions on the data. In particular, we show that, unlike in elliptic and parabolic problems, the solution to hyperbolic problems is not in general analytic with respect to the random variables. Therefore, the rate of convergence may only be algebraic. An exponential/fast rate of convergence is still possible for some quantities of interest and for the wave solution with particular types of data. We present numerical examples, which confirm the analysis and show that the collocation method is a valid alternative to the more traditional Monte Carlo method for this class of problems. We also present extensions to the elastic wave equation.

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MS24

A Predictor-corrector Method for Fluid Flow Exhibiting Uncertain Periodic Dynamics

Generalized Polynomial Chaos (gPC) is known to exhibit computational difficulties in context of dynamical systems involving random coefficients. This can in particular be attributed to the broadening of the solution spectrum as time evolves. In this work, an iterative numerical method is developed to the computation of almost surely stable limit cycles for the incompressible Navier-Stokes equations subject to random inflow boundary conditions. It relies on the reformulation of the model equations in terms of an uncertain period, which involves a rescaling of the physical time variable. Based on the scaled version, a predictor step estimates the period with respect to a deterministic reference solution. Afterwards, a convex optimization problem is solved to obtain a stochastic correction term to ensure a minimal distance between an initial and terminal state of the trajectory almost surely. An inexact Newton method provides a correction for the initial state such the distance can be decreased even further. The developed numerical method is applied to a benchmark problem given by a flow around a circular domain subject to uniformly distributed inflow boundary conditions. The numerical results demonstrate the ability of capturing almost surely stable limit cycles with high accuracies, characterized by a vortex shedding scheme with an uncertain period.

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MS25

Uncertainty Analysis in the Florida Public Hurricane Loss Model

The Florida Public Hurricane Loss Model was developed for the purpose of predicting annual insured hurricane loss in the state of Florida. The model is an open public model comprised of atmospheric science, engineering, and actuarial science components and it serves as a benchmark against existing proprietary commercial models. This talk will present statistical techniques used to validate the model with a focus on the uncertainty and sensitivity analysis for the loss costs.

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MS25

Toward Transparency and Refutability in Environmental Modeling

Environmental models would be made more effective by establishing a base set of model fit, sensitivity, and uncertainty measures. Reporting the results of this base set of methods consistently, along with any other methods considered and as innovations in model analysis continue, would improve model transparency and refutability. This work proposes two base set of methods: base set I for all models; base set II for models with shorter execution times

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MS25

Quantifying and Reducing Uncertainty through Sampling Design

Uncertainty reduction for geo-sphere based projects relies on data collection. A variety of performance measures and associated sample-designs have been proposed. These designs are evaluated on a test problem with a focus on adaptive sampling where information from previous samples is used to identify future sample locations. Example applications of sampling design in from CO2 sequestration and ground water contaminant detection are presented.

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MS25

Uncertainty Quantification of Shallow Groundwater Impacts due to CO2 Sequestration

A suite of numerical tools including multi-phase and multi-component reactive transport modeling, uncertainty quantification and risk assessment are used to develop risk profiles for the National Risk Assessment Program for CO2 Sequestration. Two quantities, pH and total dissolved solids, were chosen as proxies for assessing shallow groundwater impacts due to CO2 and brine leakage in to the shallow aquifer. A 3D flow and transport model of the Edwards aquifer is used as a site example.

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MS26

Random Fluctuations in Homogenization Theory; How Stochasticity Propagates Through Scales

The influence of small scale fluctuations on the solutions of partial differential equations (PDE) is relatively well understood at the most macroscopic level, ie the homogenization level describing the ensemble average of the PDE solution. Many uncertainty quantification contexts require that we understand, at least qualitatively, the random fluctuations of the PDE solution. Much less is known from the theoretical standpoint. This talk will review some existing theories.

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MS26

Uncertainty Quantification in Multi-Scale, Multi-Physics MEMS Performance Prediction

This presentation describes a Bayes network approach to perform comprehensive uncertainty quantification in multi-scale, multi-physics model prediction for a MEMS device. The device performance is related to membrane deflection, affected by multiple physics: creep, damping, contact, and dielectric charging. The Bayes network is able to integrate epistemic and aleatory uncertainty information from multiple sources and activities (modeling, experiments, experts, calibration, verification, validation) and multiple formats (full distributions, sparse data, imprecise data, noise, error estimates).

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MS26

UQ in MD Simulations: Forward Propagation and Parameter Inference

This work focuses on quantifying uncertainty in molecular dynamics (MD) simulations of TIP4P water accounting for intrinsic noise and parametric uncertainty. A functional relationship between selected macroscale observables and uncertain atomistic model parameters is constructed via polynomial chaos expansions using a non-intrusive spectral projection and a Bayesian inference approach. These PC representations are then exploited in an inverse problem involving the estimation of force-field parameters of the TIP4P model using bulk-phase properties of water.

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MS26

Quantifying Sampling Noise and Parametric Uncertainty in Coupled Atomistic-Continuum Simu-

lations

We perform a coupled atomistic-to-continuum simulation in a model operating under uncertainty. This latter has the form of parametric uncertainty and sampling noise intrinsic in atomistic simulations. We present mathematical formulations that enable the propagation of uncertainty between the discrete and continuum components and the solution of the exchanged variables in terms of polynomial chaos expansion. We consider a simple Couette flow model where the variable of interest is the wall velocity. Results show convergence of the exchanged variables at a reasonable computational cost.

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MS27

Evaluation of Mixed Continuous-Discrete Surrogate Approaches

Evaluating the performance of surrogate modeling approaches is essential for determining their viability in uncertainty analysis. To this end, we evaluated categorical regression, ACOSSO splines, Gaussian processes (GPs) with specialized covariance models, and treed GPs on a set of test functions. We describe our evaluation principles and metrics, the characteristics of the test functions considered, and our software testbed. Additionally, we present our numerical results and discuss our observations regarding the merits of each approach.

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MS27

Large-scale Surrogate Models

The Bayesian Additive Regression Tree (BART) is a statistical model that represents observed data as a sum of weak learners. Each tree represents a weak learner, and the overall model is a sum of such trees. In this work, we extend the BART model to handle massive datasets using a parellelized MCMC algorithm. Our approach handles datasets too massive to fit on any single data repository, and scales linearly in the number of processor cores.

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MS27

High Performance Bayesian Assessment of Earthquake Source Models for Ground Motion Simulations

Reliable ground motion predictions, with quantified uncertainty, are very important for designing large civil structures. Using Bayesian analysis, we rank candidate kinematic earthquake model classes by comparing their computed quantities of interest (e.g. peak ground velocity, spectral acceleration) against reference attenuation relations. The candidate model classes differ on hypotheses about the physical parameters involved. We report results and give an overview of state of the art parallel statistical algorithms we have been researching.

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MS27

Use of Gaussian Process Modeling to Improve the Perez Model in the Study of Surface Irradiance of Buildings

In building energy simulations, a model due to Perez is used to calculate the irradiance received by a tilted surface of a building based on the measurements of the irradiance on a horizontal surface. However, it is known that the prediction from this model can have a substantial discrepancy from the real measurement on a tilted surface. We treat this discrepancy as an integral of an unknown function over the space of the sky dome, and use Gaussian Process to model the integrated values in each small rectangular grid of the sky dome. Nugget is used to stabilize the parameter estimation. Results from different scales of the grid are presented to illustrate this new approach.

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MS28

Uncertainty Quantification of Building Energy Models

We discuss the NSF funded EFRI-SEED project for risk conscious methods in the design and retrofit of buildings focusing on the quantification of parameter uncertainty in building energy models, at different system scales and different model fidelities. The UQ of the most sensitive parameters is discussed and their influence on building performance predictions is demonstrated. A discussion of how the translation of uncertainties in risk measures will inform design and retrofit decisions concludes the presentation.

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MS28

An Integrated Approach to Design and Operation of High Performance Buildings in the Presence of Uncertainty

In this talk we introduce how to use uncertainty quantification to leverage the design and operation of high performance buildings. As buildings contain thousands of parameters (from the way they are designed to the way they are occupied and operated), efficient parameter management and identification of critical parameters is the key. We discuss uncertainty and sensitivity analysis in the context of an integrated design process including model calibration, optimization, and failure mode analysis.

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MS28

UQ for Better Commercial Buildings: From Design to Operation

Commercial buildings are expensive assets characterized by long lives and significant environmental and economic impact; demanding great care in both their design as well as ongoing operation. This talk discusses UQ for the robust design of high-performance buildings, their improved operation using model based predictive control that relies on reduced order models and extracted near optimal rule sets in the face of uncertainty in human behavior, and fault detection and diagnosis for existing buildings.

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MS28

Sensitivity of Building Parameters with Building Type, Climate, and Efficiency Level

As one embarks on building an energy model of an existing building there are parameters that are known, somewhat unknown, and very unknown. Based on the type of building, the climate it is operating in, and its energy use intensity, the uncertainty of the simulations energy results based on the results sensitivity to the known and unknown parameters variations. Results will be presented of several hundred thousand simulations showing these uncertainties and their corresponding parameter sensitivities.

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MS28

Uncertainty Quantification Methods for Multiphysics Applications

Uncertainty quantification is increasingly recognized as a key component in modeling and simulation-based science and engineering. There are, however, many UQ challenges for large-scale applications including expensive model evaluation, large parameter space with complex correlations, highly nonlinear models, diverse data sources for calibration, model-form uncertainties, etc. This talk surveys current techniques for these challenges and also describes a LLNL software package called PSUADE that captures many such techniques, may be applicable to energy efficiency applications.

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MS29

Application of the Implicit Particle Filter to a Model of Nearshore Circulation

Data assimilation is properly viewed as an exercise in conditional probabilities. Models of the ocean and atmosphere have typical state dimensions of $O(10^5 - 10^7)$, so direct calculation of the relevant pdfs is not practical and we must apply Monte-Carlo methods. We present results from an efficient Monte-Carlo method in which the conditional pdf is sampled directly. We show applications of the method to high dimensional systems.

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MS29

Implicit Particle Filtering for Geomagnetic Data Assimilation

A large amount of data of the earths magnetic field has recently become available due to satellite missions. This data can be used to improve the predictions of geomagnetic models and the interest in data assimilation techniques has thus grown in this field. Thus far, a 4D-Var approach and a Kalman filter have been considered. Here, the implicit particle filter is applied and its performance is compared to two competing Monte Carlo algorithms.

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MS29

A Tutorial on Implicit Particle Filtering for Data Assimilation

I will give an introduction to implicit sampling, a new methodology that finds high-probability samples of multidimensional probability densities by solving equations with a random input. The implicit sampling strategy focuses attention on regions of high probability and, thus, is applicable even if the state dimension is large. I will present details of implicit sampling in connection with data assimilation and will provide several examples to illustrate the efficiency and accuracy of the algorithm.

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MS29

An Application of Rare Event Tools to a Bimodal Ocean Current Model

I will review some recent results on importance sampling methods for rare event simulation as well as discuss their application to the filtering problem for a simple model of the Kuroshio current. Assuming a setting in which both observation noise and stochastic forcing are present but small, I will demonstrate numerically and theoretically that sophisticated importance sampling techniques can achieve very small statistical error. Standard filtering methods deteriorate in this small noise setting.

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MS31

Multiple Computer Experiments: Design and Modeling

A growing trend in uncertainty quantification is to use multiple computer experiments to study the same complex system. We construct a new type of design, called a sliced orthogonal array based Latin hypercube design, intended for efficiently running such experiments. Such a design itself achieves attractive uniformity and can be sliced into Latin hypercube designs. This sliced structure also leads to a two-stage modeling strategy for integrating data from multiple computer experiments.

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MS31

Efficient Analysis of High Dimensional Data in Tensor Formats

In this article we introduce new methods for the analysis of high dimensional data in tensor formats, where the underling data come from the stochastic elliptic boundary value problem. We approximate the high dimensional operator via sums of elementary tensors. This tensors representation can be effectively used for computing different values of interest, such as maximum norm, level sets and cumulative distribution function. As an intermediate step we describe efficient iterative algorithms for computing the characteristic and sign functions as well as pointwise inverse in the canonical tensor format.

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MS31

An Adaptive Sparse Grid Generalized Stochastic Collocation Method for High-dimensional Stochastic Simulations

Our modern treatment of predicting the behavior of physical and engineering problems relies on approximating solutions in terms of high dimensional spaces, particularly in the case when the input data (coefficients, forcing terms, boundary conditions, geometry, etc) are affected by large amounts of uncertainty. To approximate these higher dimensional problems we present an adaptive sparse grid generalized stochastic collocation technique constructed from both global polynomial approximations and local multiresolution decompositions. Rigorously derived error estimates, for the fully discrete problem, will be used to show the efficiency of the methods at predicting the behavior of both smooth and/or discontinuous solutions.

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MS31

Uncertainty Quantification for Overcomplete Basis Representation in Computer Experiments

Overcomplete basis representation is a surrogate model formed by a linear combination of overcomplete basis functions. The method can be effectively used to mimic complicated and non-stationary response surfaces in computer experiments or numerical approximation. The coefficients in the model are inferred via the matching pursuit technique based on a sparse model assumption. Prediction is made based on the fitted model. Because it is a numerical method without a stochastic structure, it cannot readily give an assessment of the prediction uncertainty. We use a Bayesian approach to impose a multivariate normal prior on the collection of the coefficients in the overcomplete basis representation. Since this is a large dictionary, the prior is over a very large space. But the number of significant coefficients in the representation is usually much smaller (called effect sparsity in design of experiments). For a given data, we can thus collapse the large space to a manageable size. This collapsing is achieved by using a Bayesian variable selection technique called stochastic search variable selection. Once the Bayesian framework is formulated, UQ can be readily implemented but the computational details need to be worked out. The proposed UQ approach can be used to simulate posterior samples for the predicted model, from which Bayesian credible intervals are constructed. Numerical study in two cases demonstrates the success of the approach. (Based on joint work with R. B. Chen, W. C. Wang, and Rui Tuo.)

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MS32

Computational Nonlinear Stochastic Homogenization Using a Non-concurrent multiscale Approach

for Hyperelastic Heterogeneous Microstructures Analysis

We present an analysis of the effects of stochastic dimension on a solver based on a tensorial product decomposition for studying propagation of uncertainties in nonlinear boundary value problems. An application to computational nonlinear stochastic homogenization for hyperelastic heterogeneous materials, where the geometry of the microstructure is random, is proposed.

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MS32

Pink and $1/f^{\alpha}$ Noise Inputs in Stochastic PDEs

We consider colored noise having a power spectrum that decays as $1/f^{\alpha}$, where f denotes the frequency and $\alpha \in (0, 2]$. We study, in the context of both 1-D and 2-D differential equations, methods for modeling random inputs as $1/f^{\alpha}$ random fields. We show that the solutions to differential equations exhibit a strong dependence on α, indicating that further examination of how randomness in differential equation is modeled and simulated is warranted.

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MS32

Efficient Algorithm for Computing Rare Failure Probability

Evaluation of failure probability is a fundamental task in many important applications such as aircraft design, risk management, etc. Mathematically it can be formulated easily as integrals. The difficulty lies in the fact that the integrals are usually of high dimensions and more importantly the geometry is irregular and known only through simulations of some complex systems under consideration. In practical applications when full-scale simulations are time consuming, there exists no effective methods to accurately compute failure probability. The situation is more severe when dealing with rare failure probability, i.e, failure probability less than 10^{-5}. In this work we discuss the strength and limitation of the existing popular methods. We further present an efficient algorithm to simulate failure probability accurately at very low simulation cost. The algorithm is able to capture rare failure probability with only a few hundreds simulations and is suitable for practical complex system. Both mathematical analysis and numerical examples are provided.

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MS32

Hierarchical Multi-output Gaussian Process Regression for Uncertainty Quantification with Arbitrary Input Probability Distributions

We develop an efficient, fully Bayesian, non-intrusive framework for uncertainty quantification of computer codes. A hierarchical treed Gaussian process surrogate is built by adaptively decomposing the stochastic space in a sequential manner that calls upon Bayesian Experimental Design techniques for data gathering. The resulting surrogate provides point estimates as well as error-bars for the statistics of interest. We demonstrate numerically that the suggested framework can resolve local, non-isotropic features, e.g., discontinuities, slowly varying dimensions, etc.

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MS33

Uncertainty in Geotechnical Engineering

The lecture will focus on the applications of probabilistic techniques to different problems in Geotechnical engineering. The theoretical background, including representation of uncertainty on soil properties by means of random fields will be briefly presented. A number of examples will illustrate the important contribution of probabilistic techniques to the assessment of geotechnical structures safety and reliability and to decision taking in Geotechnical Engineering, including earth and rockfill dams, foundations, tunnels and shafts.

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MS33

Causality and Stochastic Processes with Varying Evidence Conditions

A methodology for introducing Causality and Stochastic Processes into the probabilistic solution of inverse problems is presented. This is based on the representation on causal events by the use of Bayesian Networks when coupled to different schemes of evidence availability. Particularly when evidence varies (data, model predictions and even expert's beliefs) and this can be represented as stochastic processes. Illustrative cases including Multi-Physics Geomechanics, Natural Hazards and Energy-Based Developments are discussed.

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MS33
Modelling Uncertainty in Risk Assessment for Natural Hazards

Optimal strategies for natural hazards risk mitigation, risk analysis professionals must assess and quantify hazard, vulnerability and risk in the context of safety. These are subject to major uncertainties. Uncertainty in different steps of the analysis is often categorized into alreatory (natural variability) and epistemic (due to lack of knowledge). Examples that illustrate how the uncertainty is modeled in quantitative risk analysis, and the shortcomings of the existing methods, will be presented.

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MS33
Estimation of Multiscale Fields Representing Anthropogenic CO2 Emissions from Sparse Observations

We investigate spatial models of anthropogenic CO2 emissions for use in inverse problems. Socioeconomic methods of CO2 emissions estimation show that their spatial distribution is strongly multiscale. We investigate the use of easily observed proxies e.g., images of nightlights and population density for emission modeling. We consider bases drawn from them e.g. bivariate Gaussian kernels, or combine them to develop reduced wavelet representations. We perform trade-offs between model complexity, reconstruction accuracy and the uncertainty.

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MS34
Challenges in Devising Manufactured Solutions for PDE Applications

We describe some challenges we've encountered in devising manufactured solutions to specific PDE applications and the ways in which the challenges were met. The applications are Darcy flow with discontinuous permeability coefficient, free surface flow with kinematic boundary condition, the solute transport equations, and the drift-diffusion equations. The examples demonstrate the flexibility and wide applicability of manufactured solutions, along with some limitations.

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MS34
The Requirements and Challenges for Code Verification Needed to Support the Use of Computational Fluid Dynamics for Nuclear Reactor Design and Safety Applications

Today, computational fluid dynamics (CFD) is being used extensively in support of nuclear reactor design and safety analysis. Verification and Validation (VV) are the technical tools (processes) by which CFD simulation credibility is quantified. In particular, code verification, solution verification, and validation are coupled into an overall process for assessing the accuracy of the computed CFD solution. This presentation will discuss some of the specific requirements, as well as challenges, for code verification needed to support of the use of CFD for nuclear reactor design and safety applications.

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MS34
Tools and Techniques for Code Verification using Manufactured Solutions

Verifying computational science software using manufactured solutions requires the generation of the solutions with associated forcing terms and their reliable implementation in software. There are several issues that arise in generating solutions, including ensuring that they are meaningful, and the algebraic complexity of the forcing terms. Addressing these issues within the open source Manufactured Analytical Solution Abstraction (MASA) library, which is designed to provide a reliable platform for verification with manufactured solutions, will be discussed.

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MS34
Code Verification: Practices and Perils

As scientific codes become more complex through use of sophisticated algorithms, parallelization procedures and layers of interfaces, probability for implementation mistakes that affect the computed solution increases. In this environment, rigorous code verification through use of order-of-accuracy studies becomes essential to provide confidence that the intended code solves its governing equations correctly. We will discuss a set of best practices for code verification and some common issues that arise in their use.

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MS35
Practical UQ for Engineering Applications with DAKOTA

Through DAKOTA, we strive to deploy general-purpose UQ software to a broad range of engineering applications, supporting risk-informed design. Practical engineering UQ methods must manage simulation cost, nonlinearity, non-smoothness, and potentially large parameter spaces. Emerging reliability, stochastic expansion, and interval estimation algorithms in DAKOTA address these challenges. These can be employed in mixed deterministic/probabilistic analyses such as optimization under uncertainty. This talk will highlight application and environment complexities that can limit efficient uncertainty quantification.

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MS35

Exact Calculations for Random Variables in Uncertainty Quantification Using a Computer Algebra System

The Maple-based APPL language performs exact probability calculations involving random variables. This talk introduces the langauge and presents several applications, including bootstrapping, goodness-of-fit, reliability, probability distribution selection, stochastic activity networks, time series analysis, and transient queueing analysis.

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MS35

Open TURNS: Open source Treatment of Uncertainty, Risk 'N Statistics

The needs to assess robust performances for complex systems have lead to the emergence of a new industrial simulation challenge: to take into account uncertainties when dealing with complex numerical simulation frameworks. Open TURNS is an Open Source software platform dedicated to uncertainty propagation by probabilistic methods, jointly developed since 2005 by EDF RD, EADS Innovation Works, and PhiMECA. This talk gives an overview of the main features of the software from a user's viewpoint.

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MS35

HPD Liberates Applied Probability AND Enables Comprehensively Tackling Design Engineering

HPD, which stands for *Holistic Probabilistic Design*, consists of a *methodology* and two breakthrough *software suites* for probabilistically tackling problems of any complexity in Design Engineering. Initially developed at Xerox Corporation where variability of thousands of characteristics affecting system performance dominated product development efforts, the HPD software, in fact, *liberates Applied Probability* and has *exposed shortfalls* of existing techniques! As importantly, *HPD revolutionizes Stochastic Analysis and Optimization* for manufacturing industries!

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MS36

Local-Low Dimensionality of Complex Atmospheric Flows

We are investigating complex atmospheric flows in Owens Valley, California, using the Weather Research and Forecasting (WRF) Model. Owens Valley is particularly interesting since it displays complex flows, including clear-air turbulence and atmospheric rotors. We are exploring whether a Local Ensemble Transform Kalman Filter (LETKF) data assimilation scheme works well in such a geographical setting. This work determines how small of an effective dimension the atmospheric dynamics reduce to over such a terrain.

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MS36

Assimilation of Thermodynamic Profiler Retrievals in the Boundary Layer: Comparison of Methods and Observational Error Specifications

A 2009 National Research Council report recommended investing in a nationwide network of thermodynamic profiling instruments for the atmospheric boundary layer to better forecast mesoscale storm and rainfall events. In this work, we complement the efforts of *Otkin et al* (2011) and *Hartung et al* (2011) by considering variational and hybrid data assimilation frameworks, and different approximations of the retrieved observation error covariance matrices.

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MS36

Lagrangian Data Assimilation and Control: Hide and Seek

Data Assimilation is the act of merging observed quantities of a physical system into a Mathematical model to provide an estimate of the state. The Lagrangian framework is utilised when the observations are of positions of underwater autonomous vehicles that move with the flow field. In this talk I will incorporate the Data Assimilation framework with techniques developed in control theory to provide a novel approach in inferring on important structures of the flow field.

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MS36

Uncertainty Quantification and Data Assimilation in Multiscale Systems Using Stochastic Homogenization

We study ensemble Kalman filtering on a low-dimensional multiscale system with fast and slow metastable regimes. We find that, surprisingly, a reduced forecast model with stochastic parametrization of the fast dynamics can better capture transitions between slow metastable states than when using the higher-dimensional, perfect deterministic model. This is explained in terms of greater reliability of the ensemble or improved ensemble spread using the stochastic model. Implications for stochastic parametrizations in data assimilation are discussed.

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MS37

Overview of Volcanic Hazard Assessment

Straight Monte-Carlo determination of the probability of rare catastrophic volcanic events is not possible. Our strategy uses a GaSP emulator to determine the region of the input space defining the catastrophic event. A suitable distribution on the inputs is then used to determine the probability of this region. Adequate handling of the many uncertainties present is possible by quantifying all uncertainties in terms of probability distributions and combining them in a Bayesian analysis.

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MS37

Modeling Large Scale Geophysical Flows: Physics and Uncertainty

Mathematical simulations of volcanic mass flows supplement field deposit studies, providing data from which to make predictions of volcanic hazards. Several parameters and functions must be specified upon input, in order to start the simulation. These inputs include the total volume of the mass flow, the initial direction of the flow, friction and dissipation factors, and the terrain over which the mass moves. These inputs are often poorly characterized, or are known to be inaccurate, and these inaccuracies affect the simulation outputs. Here we study the interplay between the physics of geophysical flows and the uncertain inputs, and examine the effect of uncertainty on outputs, in order to provide a quantitative measure of hazard at locations downstream from the volcano. This approach draws on insight from the geo-science community, methods of high performance computing, and novel use of Bayesian statistics and mathematical modeling.

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MS37

Design and Use of Surrogates in Hazard Assessment

It is the rare, but large volume events that will cause some location of interest to be inundated by a volcanic flow. Standard statistical sampling techniques would focus too many samples (e.g. volcanic flow simulations) on small volume events. Using a statistical emulator of flow simulations, we can focus attention on these infrequent but high-consequence events and construct a boundary in parameter space at the smallest volume events that would inundate a location of concern.

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MS37

Combining Deterministic and Stochastic Models For Hazard Assessment

The deterministic flow model "TITAN-2D" predicts course, depth, and velocity for pyroclastic flows following a dome collapse events of specified volumes and initial directions, for a region whose topography is available as digital elevation maps (DEMs). I describe how to combine evidence from TITAN-2D, a rapid stochastic emulator, and heavy-tailed stochastic models of flow volumes and directions, to quantify the hazard of a catastrophic inundation at specified locations, reflecting uncertainty about the models and data.

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MS38

Numerical Strategies for Epistemic Uncertainty Analysis

Most of the existing UQ analysis tools rely on the knowledge of the probability distribution of the uncertain inputs, also known as aleatory uncertainty. In practice, more often one does not possess sufficient amount of knowledge to completely specify the distributions of the input uncertainty — epistemic uncertainty. And most of the existing tools of UQ do not readily apply. In this talk we discuss some numerical strategies to efficiently quantify the impacts of epistemic uncertainty. The methods are based on numerically creating accurate surrogate of the problem, without the need of input probability distributions. And probabilistic analysis can then be conduct in a post-processing step, without incurring additional simulation effort. We present the numerical algorithms, their convergence analysis, and examples to demonstrate the effectiveness of the strategies.

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MS38

A Localized Strategy for Generalized Polynomial Chaos Methods

We present a numerical strategy to treat stochastic differential equations in high dimensions. The approach utilizes a local generalized polynomial chaos (gPC) expansion to approximate the solution in ”elements”. And such a local expansion can be low dimensional. Then connecting conditions are imposed to enforce the solution to satisfy the desired mathematical properties of the original differential equations. When properly implemented, the method can reduce a high-dimensional SPDE in the global domain into a group of much lower dimensional SPDEs in elements. And the simulation speed-up could be highly significant. We will discuss the technical details of the approach and use examples to demonstrate its efficiency.

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MS38

Stochastic Integration Methods and their Application to Reliability Analysis

Among the most popular methods for computing failure probabilities is FORM. If the curvature of the failure function is large, FORM is known to become inaccurate. Under certain conditions the failure integral may be carried over to an expectation value. The computation of this integrals leads to high dimensional integration over the random space. Several sparse grid integration methods are considered and compared on test examples from literature. The complete method is applied to the life cycle of a wheel set of a train.

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MS38

Uncertainty Quantification with High Dimensional, Experimentally Measured Inputs

In this work, we tackle in a holistic manner the problem of uncertainty quantification in the presence of high-dimensional, experimentally measured inputs. Non-linear model reduction techniques are used to reduce the dimensionality of the experimentally observed input and estimate its probability density. A surrogate of the underlying system is created via interplay of High Dimensional Model Reduction (HDMR/ANOVA) and the treed Bayesian regression frameworks developed recently by our group. Numerical emphasis is given in uncertainty quantification of flow through porous media.

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MS39

Several Interesting Parabolic Test Problems

An important consideration for a posteriori error estimation methods is their performance on nonlinear PDEs for problems that involve weak solution features or other degeneracies. Typically, the errors in such regions are large, and nonlinear aspects of the error evolution cannot be neglected. To test error estimation techniques in this regime, we have formulated several problems based on nonlinear, parabolic PDEs. We will discuss these problems and demonstrate results from the nonlinear error transport method.

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MS39

Exact Error Behavior of Simple Numerical Problems

Although there is significant mathematical literature regarding convergence analysis, actual testing of codes is done by numerical experiment. The gap between numerical results and mathematical theory leaves many questions unanswered. The most important being, how do we know the observed convergence rate is the asymptotic one? In this paper we outline a class of exact solutions for the modified equation that allow us to explore this and other questions in a more rigorous manner.

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MS39

Verification and Validation in Solid Mechanics

Verification and validation in solid mechanics lags behind other disciplines, possibly because of the larger number of variables involved. Verification in solid mechanics must extend from small deformations using simple constitutive models to large deformations using complicated constitutive models. Innovative large-deformation manufactured solutions, applicable to history-dependent materials, are presented. Also, novel visualizations of stress states actually reached in applications are used to expose the need for experiments involving transient loading under massive deformations.

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MS39

Cross-Application of Uncertainty Quantification and Code Verification Techniques

In most applications, sensitivity analysis (SA) and uncertainty quantification (UQ) ignore numerical error when applied to data from computer simulations, but in this work, numerical error is the focus. The differences in SA results for models with and without numerical error are examined, with implications for SA and UQ consumers. Then, UQ techniques are used to directly investigate the truncation error of numerical methods.

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MS40

Sampling and Inference for Large-scale Inverse Problems Using an Optimization-based Approach

In the Bayesian approach to inverse problems, a posterior probability density function is written down that depends upon the likelihood and prior probability density functions. Estimators for unknown parameters can then be computed, and uncertainty quantification performed, using output from an MCMC method which samples from the posterior. In this talk, the focus is on efficient MCMC sampling techniques for large-scale inverse problems that make using of optimization algorithms.

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MS40

Approximate Marginalization of Uninteresting Distributed Parameters in Inverse Problems

In the Bayesian inversion framework, all unknowns are treated as random variables and all uncertainties can be modeled systematically. Recently, the approximation error approach was proposed for handling model errors due to unknown nuisance parameters and model reduction. In this approach, approximate marginalization of these errors is carried out before the estimation of the interesting variables. We discuss the adaptation of the approximation error approach for approximate marginalization of uninteresting distributed parameters in inverse problems.

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MS40

Recovery from Modeling Errors in Non-stationary Inverse Problems: Application to Process Tomography

In non-stationary inversion, time-varying targets are estimated based on measurements collected during the evolutions of the targets. In the reconstructions, evolution models of the targets are utilized. The solutions of inverse problems are sensitive to errors in the models. We demonstrate that in some cases, however, it is possible to recover from modeling errors by statistical modeling of the error sources. As an example case, we consider imaging of moving fluids in industrial process tomography.

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MS40

Variational Approximations in Large-scale Data Assimilation: Experiments with a Quasi-Geostrophic Model

The extended Kalman filter (EKF) is one of the most widely used data assimilation methods. However, EKF is computationally infeasible in large-scale problems, due to the need to store full covariance matrices. Recently, approximations to EKF have been proposed, where the covariance matrices are computed via Limited Memory Broyden-Fletcher-Goldfarb-Shanno (LBFGS) and Conjugate Gradient (CG) optimization methods. In this talk, we review the proposed methods and present data assimilation results using a nonlinear Quasi-Geostrophic benchmark model.

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MS41

A Spectral Uncertainty Quantification Approach in Ocean General Circulation Modeling

We address the impact of uncertain model parameters on simulations of the oceanic circulation. We focus on high-resolution simulations in Gulf of Mexico during the passage of hurricane Ivan. Uncertainties in subgrid mixing and wind drag parametrizations for HYCOM are propagated using Polynomial Chaos (PC) expansions. A non-intrusive, sparse spectral projection is used to quantify the stochastic model response. A global sensitivity analysis is finally presented that reveals the dominant contributors to prediction uncertainty.

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MS41

Uncertainty Quantification of Equation-of-state Closures and Shock Hydrodynamics

We seek to propagate uncertainties in the experimental and numerical atomistic data used to define multiphase equation-of-state (EOS) models to output quantities of interest computed by the equations of shock hydrodynamics. A Bayesian inference approach for characterizing and representing the EOS parametric uncertainty and model discrepancy information is presented. Given the model uncertainty representation, we explicitly demonstrate a viable approach for tabular delivery of uncertain EOS information to the shock hydrodynamics modeling community. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

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MS41

Optimal Uncertainty Quantification and (Non-)Propagation of Uncertainties Across Scales

Posing UQ problems as optimization problems — over infinite-dimensional spaces of probability measures and response functions — gives a method for obtaining sharp bounds on output uncertainties given generic information about input uncertainties. These problems can be solved computationally and sometimes in closed form. Surprisingly, our results show that input uncertainties may fail to propagate across scales if the probabilities and response functions are imperfectly known.

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MS41

Coarse Graining with Uncertainty: A Relative Entropy Framework

In this work, we develop a generic framework for uncertainty propagation from an all-atom (AA) system to a coarse-grained (CG) system. The AA system is assumed to follow a probability law that depends on some uncertain parameters. The question we explore is how this uncertainty affects the induced probability law of the CG system. Our solution is posed as a stochastic optimization problem in terms of relative entropies and an efficient solution scheme is developed. The efficacy of the framework is demonstrated numerically.

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MS42

UQ Practices and Standards for Design and Manufacturing Process Engineering

Design and manufacturing process engineering have always necessitated some degree of uncertainty management. Increasingly complicated systems, with greater performance requirements/constraints, require corresponding advances in uncertainty quantification (UQ) practices. To make effective engineering decisions, these practices are typically implemented with software tools that must address multiple types of uncertainty across a spectrum of models, measurements, and simulations. This talk discusses the present evolution of UQ practices and the potential for improvement through standards development.

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MS42

Systematic Integration of Multiple Uncertainty Sources in Design Process

A design optimization methodology is presented that systematically accounts for various sources of uncertainty physical variability (aleatory uncertainty), data uncertainty (epistemic) due to sparse or imprecise data, and model uncertainty (epistemic) due to modeling errors/approximations. A Bayes network approach effectively integrates both aleatory and epistemic uncertainties, and fuses multiple formats of information from models, experiments, expert opinion, and model error estimates. The methodology is illustrated using a three-dimensional wing design problem involving coupled multi-disciplinary simulation.

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MS42

Generalized Chapman-Kolmogorov Equation for Multiscale System Analysis

In multiscale system analysis, the effect of incertitude due to lack of knowledge may become significant such that it needs to be quantified separately from inherent randomness. A generalized Chapman-Kolmogorov equation based on generalized interval probability is proposed to describe drift-diffusion and reaction processes under aleatory and epistemic uncertainties. Numerical algorithms are developed to solve the generalized Fokker-Planck equation and interval master equation, where the respective evolutions of the two uncertainty components are distinguished.

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MS43

Macroscopic Properties of Isotropic and Anisotropic Fracture Networks from the Percolation Threshold to Very Large Densities

Some recent studies of fracture networks are summarized. They are made possible by a very versatile numerical technique based on a three-dimensional discrete description of the fractures. Systematic calculations have been made up to very large densities for isotropic, anisotropic networks consisting of fractures distributed according to a power law. The percolation threshold and the macroscopic permeability are shown to be almost independent of the fracture shape when displayed as functions of a dimensionless density calculated by means of the excluded volume.

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MS43

Uncertainty Quantification Methods for Unsaturated Flow in Porous Media

We present a stochastic collocation (SC) method to quantify epistemic uncertainty in predictions of unsaturated flow in porous media. SC provides a non-intrusive framework for uncertainty propagation in models based on the non-linear Richards' equation with arbitrary constitutive laws describing soil properties (relative conductivity and retention curve). To illustrate the approach, we use the Richards' equation with the van Genutchen-Mualem model for water retention and relative conductivity to describe infiltration into an initially dry soil whose uncertain parameters are treated as random fields. These parameters are represented using a truncated Karhunen-Lovve expansion; Smolyak algorithm is used to construct a structured set of collocation points from univariate Gauss quadrature rules. A resulting deterministic problem is solved for each collocation point, and together with the collocation weights, the statistics of hydraulic head and infiltration rate are computed. The results are in agreement with Monte Carlo simulations. We demonstrate that highly heterogeneous soils (large variances of hydraulic parameters) require cubature formulas of high degree of exactness, while their short correlation lengths increase the dimensionality of the problem. Both effects increase the number of collocation points and thus of deterministic problems to solve, affecting the overall computational cost of uncertainty quantification.

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MS43

A Comparative Study on Reservoir Characterization using Two Phase Flow Model

We consider the problem of characterization of porosity and permeability of reservoir using a two phase flow model. We use a Bayesian MCMC framework to sample these parameters conditioned to available dynamic measurement data. A prefetching procedure to parallelize the MCMC is studied and compared with the multistage MCMC. A set numerical examples are presented to illustrate the comparison.

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MS43

Adaptive AMG for Diffusion Equations with Stochastic Coefficients

We are interested in solving a 2nd-order diffusion equation where there is uncertainty in the conductivity field. Conditioning conductivity fields to dynamic data using Markov Chain Monte Carlo requires repeated solution of the forward problem for many thousands of realizations of the field. We present an adaptive algebraic multigrid method which automatically adapts to the changing conductivity field in an inexpensive manner. Numerical experiments are discussed for an interesting model problem.

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MS43

Stochastic Models, Simulation and Analysis in Subsurface Flow and Transport

We discuss stochastic models for heterogeneous random media in the context of numerically computing subsurface flow and transport of fluids. Simulated models are based on series expansions in a variety of bases as well as using geostatistical libraries. The parameterizations employed allow integration of prior observations of the random substrate. Pressures and fluxes are computed numerically and transport curves are compared under different stochastic regimes.

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MS44

Spatial Analysis of Energy Consumption by Non-Domestic Buildings in Greater London

This research investigates the influence of local temperatures, building shapes, and mix of buildings across districts on heating energy consumed by non-domestic buildings in London. The goal is to reduce the uncertainty in energy simulation model outputs of buildings by accounting for spatial variations of energy consumption across the city. We explore (and compare) three statistical formulations to quantify the spatial autocorrelations: spatial autoregressive error model, Bayesian geographically weighted regression, and Bayesian CAR model.

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MS44

Spatial Statistical Calibration of a Turbulence Model

The k-ε turbulence model is widely used in CFD modeling. However, it has problems predicting flow separation as well as unconfined and transient flows. We calibrate its parameters against wind tunnel observations of turbulent kinetic energy (TKE) distributed over a two-dimensional cross section of a street canyon. We use a sequential design to pick optimal spatial locations. We then build an emulator to quantify the uncertainty of the modeled TKEs.

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MS44

Adding Spatial Dependence Constraints to a Geo-

physical Inverse Problem

Given a geophysical model of seismic pressure wave attenuation, measurements of this attenuation at points in space, and partial information on subsurface soil properties (model parameters), I am interested in estimating the unknown soil properties. This inversion has been done via a stochastic optimization routine because of the complexity of the geophysical model. The goal here is to reduce uncertainty in these estimates by incorporating spatial dependency constraints in the model inversion.

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MS44

Asessing the Spatial Distribution of Fish Species Using Bayesian Latent Gaussian Models

We describe the use of the integrated nested Laplace approximation (INLA) approach to infer the spatial distribution of fish species, taking into account the spatial autocorrelation, and quantifying the uncertainty. The type of data available (and the methodology used to gather it) will determine the appropriate modelling scheme. In the first example, binary data has been collected that can be regarded as randomly sampled. In the second example, we analyze quantitative data with preferential sampling.

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MS45

Uncertainty Quantification for Large Multivariate Spatial Computer Model Output with Climate Applications

Characterizing uncertainty in climate predictions and models is crucial for climate decision-making. One uncertainty source is due to inability to resolve complex physical processes, which is approximated using a parameterization. We characterize parameter uncertainty by calibrating the model to physical observations. Both model output and observations are large multivariate space-time fields. We use Bayesian methods to infer these parameters while incorporating space-time dependence and other uncertainty sources using a Gaussian process emulator and dimension reduction.

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MS45

Quantifying Uncertainty for Climate Change Predictions with Model Errorin non-Gaussian Systems with Intermittency

Synergy between empirical information theory and fluctuation-dissipation theorem provides a systematic framework for improving sensitivity and predictive skill for imperfect models of complex natural systems. We utilize a suite of increasingly complex nonlinear models with intermittent hidden instabilities and time-periodic features to illustrate the advantages of such an approach, as well as the role of model errors due to coarse-graining, moment closure approximations, and the memory of initial conditions in imperfect prediction.

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MS45

Upper Ocean Singular Vectors of the North Atlantic: Implications for Linear Predictability and Observational Requirement

Recent interest in decadal prediction in the Atlantic sector presumes that the ocean carries sufficient low-frequency predictive skill. We explore the limits of predictability in sea surface temperature and meridional overturning circulation from singular vector calculations with combined tangent linear and adjoint versions of an ocean general circulation model.

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MS45

Quantifying Uncertainties in Fully Coupled Climate Models

Fully coupled climate models are the most realistic tools used to simulate climate change. They incorporate highly detailed, interacting components for the atmosphere, ocean, and sea ice. There is a dire need to quantify their uncertainties, but coupled climate models are computationally very demanding and contain many sources of uncertainty. We describe efforts to quantify uncertainties of the coupled climate system using perturbed-parameter ensembles of the Community Earth System Model.

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MS46

Efficient Spectral Garlerkin Method with Orthgonal Polynomials for SPDES

In this talk we first develop a fast algorithm to evaluate orthogonal polynomial expansions for d-variable functions in on sparse grids. Then we apply this fast algorithm to develop an efficient spectral method to approximate the solutions of stochastic partial differential equations with random input data. Three aspects distinguishes work from the existing ones: 1. Our algorithm is applicable L^2 functions with arbitrary probability density weight; 2. The use of orthogonal polynomials results in matrix sparsity; 3. Exponential rate of convergence of the numerical algorithm is rigorously proved.

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MS46

Adaptive Methods for Elliptic Partial Differential Equations with Random Operators

Solutions of random elliptic boundary value problems admit efficient approximations by polynomials on the parameter domain, but it is not clear a priori which polynomials are most significant. I will present numerical methods that adaptively construct suitable spaces of polynomials. These methods are based on adaptive finite elements and adaptive wavelet algorithms, with orthonormal polynomial systems in place of wavelet bases. They construct efficient sparse representations of the approximate solution.

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MS46

Efficient Nonlinear Filtering of a Singularly Perturbed Stochastic Hybrid System

Astract not available at time of publication.

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MS46

Two Stochastic Modeling Strategies for Elliptic Problems

In this talk, we compare two stochastic elliptic models: $-\nabla \cdot (a(x,\omega) \cdot \nabla u(x,\omega)) = f(x)$ and $-\nabla \cdot \left(\left(a^{-1}\right)^{\diamond(-1)} \diamond \nabla u(x,\omega) \right) = f(x)$, where $a(x,\omega)$ is a lognormal random field, with respect to the two characteristic parameters of the underlying Gaussian random field, i.e., the standard deviation and the correlation length. Some related numerical issues and numerical results will be discussed.

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MS47

Putting Computational Inference into an FPGA

We are building a compiler to map large numerical computations into FPGAs (Field Programmable Gate Array). Our target application is MCMC (Markov chain Monte Carlo) based inference for ECT (Electrical Capacitance Tomography). We aim to realize the good compute throughput of FPGAs, both in terms of performance-per-dollar and performance-per-Watt, to perform real-time UQ embedded into industrial sensors.

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MS47

Model Reductions by MCMC

Identification of models is often complicated by the fact that the available experimental data from field measurements is noisy or incomplete. Moreover, models may be complex, and contain a large number of correlated parameters. As a result, the parameters are poorly identified by the data, and the reliability of the model predictions is questionable. We consider a general scheme for reduction and identification of dynamic models using two modern approaches, Markov chain Monte Carlo sampling methods together with asymptotic model reduction techniques. The ideas are illustrated with examples related to bio-medical applications and epidemiology.

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MS47

Advanced Uncertainty Evaluation of Climate Models by Monte Carlo Methods

Uncertainties in future climate projections are often evaluated based on the perceived spread of ensembles of multimodel climate projections. Here we focus on the uncertainties related to a single climate model and its closure parameters that are used in physical parameterization schemes and cover topics such as specification of the cost function and parameter identification by Monte Carlo methods.

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MS47

Covariance Estimation Using Chi-squared Tests

Regularized solutions of ill-posed inverse problems can be viewed as solutions of the original problem when the problem is regularized by adding statistical information to it. The discrepancy principle finds a regularization parameter by applying a chi-square test, and we extend and improve the approach to estimate a regularization matrix. This regularization matrix can be viewed as an estimate of an error covariance matrix. Results will be shown from an event reconstruction problem.

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MS48

Heterogeneous Deformation of Polycrystalline Metals and Extreme Value Events

Astract not available at time of publication.

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MS48

Coupled Chemical Master Equation - Fokker Planck Solver for Stochastic Reaction Networks

Stochastic reaction networks are generally governed by the Chemical Master Equation (CME). While the CME, as a high-dimensional ODE system, is hard to solve in general, its continuum approximations, e.g. Focker-Planck equations (FPE), are reliable alternatives when the species count is large enough. We present a proof-of-concept methodology for a hybrid construction that effectively combines CME and FPE, employing a discrete scale CME solution in regions where the continuum FPE is inaccurate.

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MS48

A New Approach for Solving Multiscale SPDEs using Probabilistic Graphical Models

We propose a hierarchical representation of random fields by capturing the stochastic input at fine scale with locally reduced models and combining them with graphical models on the coarse scale. Regression models are constructed such that local features are taken as input and multiscale basis functions as output. In this way, we can make samples of coarse scale properties from the graphical probabilistic model, obtain multiscale basis functions with regression models and solve SPDEs on the coarse scale.

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MS49

A Reduced Order Model for a Nonlinear, Parameterized Heat Transfer Test Case

We present a reduced order model (ROM) for heat transfer through a composite fiber with two material properties. The ROM is constructed by interpolating the components of a modal decomposition (SVD) of a sampling of high-fidelity models – each computed with different material properties. We are able to scale the SVD using a novel implementation in MapReduce. We then use the ROM as a cheap surrogate to study the probability of failure of the system.

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MS49

Uncertainty Quantification for Turbulent Mixing and Turbulent Combustion

Large eddy simulations of mixing and combustion with finite rate chemistry eliminate a major source of chemistry model related (epistemic)uncertainty. The method is a notion of stochastic convergence, to generate space-time dependent PDFs (Young's measures) out of a single simulation via coarse graining with the multiple mesh values in a supercell to generate the PDF. Comparison to experimental data related to a Scram jet is included. Comparison to RANS and other simulations allows model related error assessment and uncertainty quantification.

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MS49

Chemical Kinetic Uncertainty Quantification for High-Fidelity Turbulent Combustion Simulations

Detailed chemical mechanisms consist of hundreds or thousands of chemical reactions with an uncertain rate for each. Direct propagation of this very high-dimensional uncertainty through high-fidelity Large Eddy Simulation (LES) of turbulent reacting flows is computationally intractable. Instead, a method is presented in which the pre-processing portion of the turbulent combustion model is used to condition this very high-dimensional uncertainty, resulting in a lower-dimensional uncertainty space that is efficiently propagated through the LES. The approach is demonstrated with a laboratory-scale turbulent nonpremixed jet flame.

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MS49
Criteria for Optimization Under Uncertainty

In this work different criteria for robust optimization under uncertainty are compared. In particular, a framework proposed by the authors and characterized by the use of all the possible information in the probabilistic domain, namely the Cumulative Distribution Function (CDF), is compared to more classical approaches that rely on the usage of classical statistical moments as deterministic attributes that define the objectives of the optimization process. Furthermore, the use of an area metric leads to a multi-objective methodology which allows an a posteriori selection of the candidate design based on risk/opportunity criteria defined by the designer. A comparison with another new technique based on Evidence Theory, proposed by different authors, is also introduced.

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MS50
Bayesian Uncertainty Quantification for Flows in Highly Heterogeneous Media

Abstract not available at time of publication.

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MS50
Emulators in Large-scale Spatial Inverse Problems

We consider a Bayesian approach to nonlinear inverse problems in which the unknown quantity (input) is a random field (spatial or temporal). The forward model is complex and non linear, therefore computationally expensive. We develop an emulator based approach where the Bayesian multivariate adaptive splines (BMARS) has been used to model unknown functions of the model input. We consider discrete cosine transformation (DCT) for dimension reduction of the input field. The estimation is carried out using trans dimensional Markov chain Monte Carlo. Numerical results are presented by analyzing simulated as well as real data for reservoir characterization.

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MS50
Uncertainty Quantification for Reactive Transport of Contaminants

The fate and transport of contaminants in the subsurface is strongly influenced by bio-geochemical reactions. Predictions are routinely compromised by both model (structural) and parametric uncertainties. I will first present a set of computational tools for quantifying these two types of uncertainties for multi-component nonlinear chemical reactions. The second part of the talk will deal with the combined effects of uncertainty in reactions and heterogeneity of the medium on the transport of reactive contaminants.

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MS50
A Framework for Experimental Design for Ill-posed Inverse Problems

A fremework for experimental design for ill-posed inverse problems We consider the problem of experimental design for ill-posed inverse problems. The main difficulties we have to address are: the bias introduced by the regularization of the inverse problem, and the parameter selection required by the regularization. We propose a Bayesian approach based on a hierarchical sequence of prior moment conditions. The methodology applies also to a non-Bayesian mathod based on training models. We provide generalization of the usual equivalence theorems and propose numerical methods to tackle large-scale problems.

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MS51
An Approach for the Adaptive Solution of Optimization Problems Governed by PDEs with Uncertain Coefficients

Using derivative based numerical optimization routines to solve optimization problems governed by partial differential equations (PDE) with uncertain coefficients is computationally expensive due to the large number of PDE solves required at each iteration. I propose a framework for the adaptive solution of such optimization problems based on the retrospective trust region algorithm. I prove global convergence of the retrospective trust region algorithm under weak assumptions on gradient inexactness. If one can bound the error between actual and modeled gradients using reliable and efficient a posteriori error estimators, then the global convergence of the proposed algorithm follows. I present a stochastic collocation finite element method for the solution of the PDE constrained optimization. In the stochastic collocation framework, the state and adjoint equations can be solved in parallel. Initial numerical results for the adaptive solution of these optimization problems are presented.

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MS51
Uncertainty Quantification using Nonparametric

Estimation and Epi-Splines

We address uncertainty quantification in complex systems by a flexible, nonparametric framework for estimation of density and performance functions. The framework systematically incorporates hard information derived from physics-based sensors, field test data, and computer simulations as well as soft information from human sources and experiences. The framework is based on epi-splines for consistent approximation of infinite-dimensional optimization problems arising in the estimation process. Preliminary numerical results indicate that the framework is highly promising.

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MS51

Numerical Methods for Shape Optimization under Uncertainty

The proper treatment of uncertainties in the context of aerodynamic shape optimization is a very important challenge to ensure a robust performance of the optimized airfoil under real life conditions. This talk will propose a general framework to identify, quantize and include stochastic distributed, aleatory uncertainties in the overall optimization procedure. Appropriate robust formulations of the underlying deterministic problem and uncertainty quantification techniques in combination with adaptive discretization approaches are investigated in order to measure the effects of the uncertainties in the input data on quantities of interest in the output. Finally, algorithmic approaches based on multiple-setpoint ideas in combination with one-shot methods as well as numerical results are presented.

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MS51

Risk Neutrality and Risk Aversion in Shape Optimization with Uncertain Loading

Conceptually inspired by finite-dimensional stochastic programming with recourse we propose infinite-dimensional two-stage stochastic models for shape optimization of elastic bodies with linearized elasticity and stochastic loading. Risk neutral and risk averse approaches, the latter involving suitable risk measures or dominance relations, will be discussed. Reporting illustrative computational experiments concludes the talk.

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MS52

Spatial ANOVA Modeling of High-resolution Regional Climate Model Outputs from NARCCAP

The differences between future (2041-2070) and current (1971-2000) average seasonal temperature fields, from two regional climate models (RCMs) driven by the same atmosphere-ocean general circulation model in the North American Regional Climate Change Assessment Program (NARCCAP), are analyzed using a hierarchical two-way ANOVA model with the factors of season, RCM, and their interaction. The spatial variability across the domain is modeled through the Spatial Random Effects (SRE) model, which allows for efficient computation.

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MS52

Statistical Issues in Catchment Scale Hydrological Modeling

Many uncertainty quantification methods currently in use by the hydrological community make the mistake of implicitly conflating the hydrological model with the true physical system. Rather than using a framework with an additive discrepancy term, I will argue for making the hydrological model itself stochastic, expressed using a system of stochastic differential equations. I will discuss Bayesian inference under this model, which falls under the difficult category of dynamic models with non-time-varying parameters.

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MS52

Quantifying Uncertainties in Hydrologic Parameters in the Community Land Model

Uncertainties in hydrologic parameters could have significant impacts on the simulated water and energy fluxes and land surface state, which can affect carbon cycle and atmospheric processes in coupled earth system simulations. In this study, we introduce an uncertainty quantification (UQ) framework for sensitivity analyses and uncertainty quantification of selected parameters related to hydrologic processes in the Community Land Model. Ten flux tower sites and over fifteen watersheds spanning a wide range of climate and site conditions were selected to perform sensitivity analyses by perturbing the parameters identified. An Entropy-based approach was used to derive prior PDF for each input parameter and the Quasi-Monte Carlo (QMC) approach was used to generate samples of parameters from the prior PDFs. A simulation for each set of sampled parameters was performed to obtain response curves. Based on statistical tests, the parameters were ranked for their significance depending on the simulated latent heat flux, sensible heat flux, and total runoff. The study provides the basis for parameter dimension reduction and guidance on parameter calibration framework design, under different hydrologic and climatic regimes.

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MS52
Uncertainty Propagation in Land-Crop Models

Crop models were recently included in the land model of the Community Earth System Model (CESM). Good estimates of physiology parameters for crops are essential to get accurate outputs, particularly carbon cycle ones. To that end, we investigate the potential of intrusive uncertainty quantity approaches when used in combination with maximum likelihood/ regression models for calibrating the crop model parameters from Ameriflux data. Numerical tests for this approach using soybean data from the Bondville, IL site produced very promising initial results.

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MS53
Basis and Measure Adaptation for Stochastic Galerkin Projections

Use of the stochastic Galerkin finite element methods leads to large systems of linear equations.These systems are typically solved iteratively.We propose a preconditioner which takes advantage of the recursive hierarchy in the structure of the global system matrices. Neither the global matrix, nor the preconditioner need to be formed explicitly.The ingredients include only the number of stiffness matrices from the truncated Karhunen-Loève expansion and a preconditioner for the mean-value problem.The performance is illustrated by numerical experiments.

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MS53
A Stochastic Collocation Method Based on Sparse Grid for Stokes-Darcy Model with Random Hydraulic Conductivity

The Stokes-Darcy model has attracted significant attention since its higher fidelity than either Darcy or Stokes system is important for many applications, but uncertainties and coupling issues lead to a rather complex system. We present a stochastic collocation method based on sparse grid for the Stokes-Darcy model with random hydraulic conductivity. This method is natural for parallel computation and some numerical results are presented to illustrate the features of this method.

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MS53
Adaptive Sparse Grid Generalized Stochastic Collocation Using Wavelets

Accurate predictive simulations of complex real world applications require numerical approximations to first, oppose the *curse of dimensionality* and second, converge quickly in the presence of steep gradients, sharp transitions, bifurcations or finite discontinuities in high-dimensional parameter spaces. In this talk we present a novel multidimensional multiresolution adaptive (MdMrA) sparse grid stochastic collocation method, that utilizes hierarchical multiscale piecewise Riesz basis functions constructed from interpolating wavelets. The basis for our non-intrusive method forms a stable multiscale splitting and thus, optimal adaptation is achieved. Error estimates and numerical examples will used to compare the efficiency of the method with several other techniques.

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MS53
Error Analysis of a Stochastic Collocation Method for Parabolic Partial Differential Equations with Random Input Data

A stochastic collocation method for solving linear parabolic PDEs with random input data is analyzed. The input data are assumed to depend on a finite number of random variables. Unlike previous analysis, a wider range of situations is considered including input data that depend nonlinearly on the random variables and random variables that are

correlated or even unbounded. We demonstrate exponential convergence of the interpolation error for both a semi-discrete and a fully-discrete scheme.

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MS54

Retrospective-Cost-Based Model Refinement of Systems with Inaccessible Subsystems

Spatially discretized models are typically constructed based on physical laws and parameter estimates. These models may be erroneous, however, due to unmodeled physics and numerical errors. These discrepancies become apparent when model predictions disagree with measurements. The goal of this research is to use data to improve the fidelity of an initial model. The approach we take is based on retrospective-cost-based optimization of subsystems that are inaccessible, that is, whose inputs and outputs are not measured. Applications to space weather modeling will be presented.

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MS54

Multiscale Methods for Flows in Heterogeneous Stochastic Porous Media

In this talk, I will discuss multiscale methods for stochastic problems. The main idea of our approach is to construct local basis functions that encode the local features present in the coefficient to approximate the solution of parameter-dependent flow equation. Constructing local basis functions involves (1) finding initial multiscale basis functions and (2) constructing local spectral problems for complementing the initial coarse space. We use the Reduced Basis (RB) approach to construct a reduced dimensional local approximation that allows quickly computing the local spectral problem. I will present the details of the algorithm, numerical results, and computational cost. Applications to Bayesian Uncertainty Quantification will be discussed. This is a joint work with Juan Galvis (TAMU) and Florian Thomines (ENPC).

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MS54

Feedback Particle Filter: A New Formulation for Nonlinear Filtering Based on Mean-field Games

A new formulation of the particle filter for nonlinear filtering is presented, based on concepts from optimal control, and from mean-field game theory. The feedback particle filter admits an innovations error-based feedback control structure: The control is chosen so that the posterior distribution of any particle matches the posterior distribution of the true state given the observations. The feedback particle filter is shown to have significant advantages over the conventional particle filter in the numerical examples considered. Application to Bayesian inference in neural circuits is briefly discussed with the aid of coupled oscillator models.

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MS54

Uncertainty Analysis of Dynamical Systems – Application to Volcanic Ash Transport

Uncertainty analysis of a number of societally important physical systems may be posed in the dynamic systems framework. In this leadoff talk we will overview this minisymposium on this topic and frame issues using our group's work on transport of volcanic ash transport. Basic approaches and results of application of these methods to recent eruption events will be presented.

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MS55

Optimal Use of Gradient Information in Uncertainty Quantification

We discuss methods that use derivative information for probabilistic uncertainty propagation in models of complex system. We demonstrate that such methods needs less sampling information compared to their derivative-free version. Here we discuss the importance of several algorithmic choices, such as the choice of basis in regression with derivative information, the choice of error model by means of Gaussian processes, and the choice of sampling points based on optimal design considerations. We demonstrate in particular that standard choices originating from derivative-free methods are not suitable in this circumstance, and we define criteria adapted to the use of derivative information that result in novel designs and bases. We demonstrate our findings on models from nuclear engineering.

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MS55

Gradient-based Optimization for Mixed Epistemic and Aleatory Uncertainty

Within this talk, a novel sampling/optimization approach to mixed aleatory/epistemic uncertainty quantification is presented for hypersonic computational fluid dynamic simulations. This approach uses optimization to propagate epistemic uncertainty to simulation results while sampling of these optimization results is used to characterize the distribution due to aleatory variables. To reduce the required number of optimizations, a Kriging surrogate is employed. For this talk, this combined sampling/optimization approach will be demonstrated for analytic functions and simulations drawn from hypersonic fluid flows. Additionally, the performance of a similar uncertain optimization approach is tested for this application.

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MS55

Gradient-based Data Assimilation in Atmospheric Applications

Adaptivity in space and time is ubiquitous in modern numerical simulations. To date, there is still a considerable gap between the stateoftheart techniques used in direct (forward) simulations, and those employed in the solution of inverse problems, which have traditionally relied on fixed meshes and time steps. This talk describes a framework for building a space-time consistent adjoint discretization for a general discrete forward problem, in the context of adaptive mesh, adaptive time step models.

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MS55

Sensitivity Analysis and Error Estimation for Differential Algebraic Equations in Nuclear Reactor Applications

We develop a general framework for computing the adjoint variable to nuclear engineering problems governed by a set of differential-algebraic equations. We use an abstract variational approach to develop the framework, which provides flexibility in modification and expansion of the governing equations. Using both a simplex example with known solution and a dynamic reactor model, we show both theoretically and numerically that the framework can be used for both parametric uncertainty quantification and the estimation of global time discretization error.

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MS56

A Semi-Intrusive Deterministic Approach to Uncertainty Quantifications

This paper deals with the formulation of a semi-intrusive (SI) method allowing the computation of statistics of linear and non linear PDEs solutions. This method shows to be very efficient to deal with probability density function of whatsoever form, long-term integration and discontinuities in stochastic space. The effectiveness of this method is illustrated for a modified version of Kraichnan-Orszag three-mode problem where a discontinous pdf is associated to the stochastic variable, and for a nozzle flow with shocks. The results have been analyzed in terms of accuracy and probability measure flexibility. Finally, the importance of the probabilistic reconstruction in the stochastic space is shown up on an example where the exact solution is computable, in the resolution of the viscous Burgers equations. We expect some more applications by the time of the conference.

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MS56

Uncertainty Quantification with Incomplete Physical Models

The emergence of uncertainty quantification (UQ) has been a critical development towards the goal of predictive science. The many efficient, non-intrusive, intuitive approaches of probabilistic uncertainty have accelerated the widespread adoption of the methodology. The additional uncertainty arising from incomplete physical models makes the analysis much less obvious. This work examines how optimization over a restricted class of functionals can bound the analysis of the true model if it were available. Furthermore, these bounds provide insight into the sensitivity of this knowledge-gap relative to the overall prediction.

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MS56

Numerical Methods for Polynomial Chaos in Uncertain Flow Problems

The Euler equations subject to input uncertainty are investigated via the stochastic Galerkin approach. We present a fully intrusive method based on a variable transformation of the continuous equations. Roe variables are employed to get quadratic dependence in the flux function. The Roe formulation saves computational cost compared to the formulation based on expansion of conservative variables, and can handle cases of supersonic flow, for which the conservative variable formulation leads to instability.

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MS56

Evidence Based Multiciplinary Robust Design

Abstract not available at time of publication.

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MS57

Toward Estimation of Sub-ice Shelf Melt Rates to Ocean Circulation Under Pine Island Ice Shelf, West Antarctica

Increased melt rates under ice shelves around Antarctica have been suggested as a dominant cause for observed acceleration of the ice sheet near its marine margin. The melt rates are difficult to observe directly. We present first steps towards estimating the melt rates from accessible hydrography and optimal control methods. We address to which extent hydrographic observations away from the ice-ocean boundary can be used to constrain melt rates. We derive sensitivity patterns of melt rates to changes in ocean circulation underneath the Pine Island Ice-Shelf. The sensitivity patterns are computed with an adjoint model of an ocean general circulation model that resolves the sub-ice shelf circulation. Inverting for best-estimate melt rates presents a first step towards backward propagation of uncertainties.

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MS57

Ice Bed Geometry: Estimates of Known Unknowns

For ice sheets, kilometer scale features in bed geometry may dominate scenarios of ice mass loss. We developed a radar sensor model for Thwaites basin in West Antarctica and use conditional simulations of off-track features to characterize unknown knowns of its bed geometry. We shall discuss the observational, scientific, and statistical strategies for quantifying effects of bed geometry uncertainties on estimates of sea level rise.

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MS57

Quantification of the Uncertainty in the Basal Slid-

ing Coefficient in Ice Sheet Models

The estimation of uncertainty in the solution of ice sheet inverse problems within the framework of Bayesian inference is considered. We exploit the fact that for Gaussian noise and prior probability densities and linearized parameter-to-observable map the posterior density (i.e., the solution of the statistical inverse problem) is Gaussian and hence is characterized by its mean and covariance. The method is applied to quantify uncertainties in the inference of basal boundary conditions for ice sheet models.

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MS57

Bayesian Calibration via Additive Regression Trees with Application to the Community Ice Sheet Model

Quantifying uncertainties in calibration experiments involving complex computer models with high dimensional input spaces and large outputs is often infeasible. We develop a non-parametric Bayesian trees model that scales to challenging calibration problems. Here, each tree represents a weak learner and the overall model is a sum-of-trees. The idea is to learn locally-adaptive bases while retaining efficient MCMC sampling of the posterior distribution. We demonstrate our method by calibrating the Community Ice Sheet Model.

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MS58

Reduced Basis, the Discrete Interpolation Method and Fast Quadratures for Gravitational Waves

Finding gravitational waveforms (GWs) is potentially going to open a new window to the universe. Einstein's equations are nonlinear parameter dependent (mass, spin etc.) PDEs that approximate the post-Newtonian equations (PN). PN without spin gives stationary phase approximations (SPA) to waveforms. Using matched filtering techniques, a LIGO search to find GWs, requires about 10,000 SPA templates and several months on supercomputers. Reduced basis and using DEIM points as quadrature nodes leads to significant savings.

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MS58

Decreasing the Temporal Complexity in Nonlinear Model Reduction

UQ for nonlinear dynamical systems presents a challenge: uncertainty-space sampling requires thousands of large-scale simulations. To mitigate this burden, researchers have developed model-reduction techniques that decrease the model's 'spatial complexity' by decreasing 1) the number of degrees of freedom and 2) the complexity of nonlinear functions evaluations. However, when an implict time integrator is used, the number of time steps remains very large. This talk presents a strategy for decreasing the model's 'temporal complexity'.

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MS58

Error Analysis for Nonlinear Model Reduction Using Discrete Empirical Interpolation in the Proper Orthogonal Decomposition Approach

Discrete Empirical Interpolation Method (DEIM) is an efficient technique for resolving the complexity issue of the standard projection-based model reduction methods, such as the popular Proper Orthogonal Decomposition (POD) approach, due to nonlinearities of dynamical systems. Recently, the hybrid approach combining POD with DEIM has been successfully used to obtain accurate low-complexity reduced systems in many applications. However, error analysis for this approach has not been investigated yet. This work provides state space error bounds for the solutions of reduced systems constructed from this POD-DEIM approach. The analysis is particularly relevant to ODE systems arising from spatial discretizations of parabolic PDEs. The resulting error bounds reflect the POD approximation property through the decay of singular values, as well as explain how the DEIM approximation error involving the nonlinear term comes into play. The conditions under which the stability of the original system is preserved and the reduction error is uniformly bounded will be discussed.

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MS58

Linearized Reduced-order Models for Optimization and Data Assimilation in Subsurface Flow

Trajectory piecewise linearization (TPWL) is a reduced-order modeling approach where new solutions for nonlinear problems are represented using linear expansions around previously simulated (and saved) solutions. The high-dimensional representation is projected into a low-dimensional subspace using proper orthogonal decomposition, which results in very large runtime speedups. We describe the application of TPWL for the optimization of well settings in oil reservoir simulation and for inverse problems involving the determination of geological parameters.

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MS59

Testbeds for Ocean Model Calibration

Tuning and uncertainty quantification in ocean models is challenging particularly because of the lack of suitable observation datasets, and the computational expense in running full-Earth simulations. Ocean models can be run in limited instances at an eddy-resolving resolution, so high-resolution runs can be a target response for lower-resolution parameterization. Testbed configurations are then sufficient to expose effects of concern. We show results from a channel model representative of the Antarctic Circumpolar Current (ACC), emphasizing eddy heat transport.

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MS59

An Overview of Uncertainty Quantification in the Community Land Model

The Community Land Model (CLM) is the terrestrial component of the Community Earth System Model (CESM), which is used extensively for projections of the future climate system. CLM has over 100 uncertain parameters, contains multiple nonlinear feedbacks, and is computationally demanding, presenting a number of challenges for UQ efforts. CLM modeling has benefitted from our initial UQ efforts through a new ability to rank parameters by relative importance and to identify unrealistic parameter combinations.

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MS59

Efficient Surrogate Construction for High-Dimensional Climate Models

In this study we explore the use of non-intrusive methods to construct surrogate approximations for the Community Land Model (CLM). Relevant vector machine techniques are used to reduce the dimensionality of the input space. This approach is used in conjunction with adaptive constrained sparse quadrature to construct the surrogate model coefficients. Domain clustering methodologies are also employed to properly model plateaus and sharp discontinuities in the climate model observables.

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MS59

Uncertainty in Regional Climate Experiments

climate models are subject to a number of different sources of uncertainty. Regional climate modeling introduce additional uncertainties associated with the boundary conditions and resolution of the models. In this talk, based on the ensemble being generated as part of the North American Regional Climate Assessment Program (NARCCAP), we will present statistical methodology for the analysis of the spatial-temporal output in the ensemble and quantifying the uncertainties associated with the NARCCAP experiment.

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MS60

Calibration, Model discrepancy and Extrapolative Predictions

In the presence of relevant physical observations, one can usually calibrate a computer model, and even estimate systematic discrepancies of the model from reality. Estimating and quantifying the uncertainty in this model discrepancy can lead to reliable predictions - so long as the prediction is "similar" to the available physical observations. Exactly how to define "similar" has proven difficult. Clearly it depends on how well the computational model captures the relevant physics in the system, as well as how portable the model discrepancy is, going from the available physical data to the prediction. This talk will discuss these concepts using computational models ranging from simple to very complex.

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MS60

Calibration, Validation and the Importance of Model Discrepancy

Extrapolation is inevitably accompanied by substantial uncertainty. To manage and quantify that uncertainty, calibration and validation are important tasks. But a fundamental feature underlying all these activities is model discrepancy, which is the difference between reality and the simulator output with "best" or "true" input values. This talk will show, both conceptually and through examples, that unless model discrepancy is acknowledged and carefully modeled calibration and extrapolations will be biased and over-confident.

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MS60

"Experiment" and "Traveling" Models, Extrapolation Risk from Undetected Model Bias, and Data Conditioning for Systematic Uncertainty in Experiment Conditions

This talk will discuss some fundamental concepts and issues related to extrapolative prediction risk associated with model validation and conditioning. Topics will include: "traveling model" which travels to predictions beyond the validation or conditioning setting as a subset of the larger "experiment model" of the experiments; handling uncertainties accordingly; consistent and non-consistent bias and uncertainty in extrapolation; Type X validation or conditioning error from neglected systematic experimental uncertainty; data conditioning to mitigate associated prediction risk.

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MS60

Towards Finding the Necessary Conditions for Justifying Extrapolations

A comprehensive approach is proposed to justify extrapolative predictions for models with known sources of error. The connection between model calibration, validation and prediction is made through the introduction of alternative uncertainty models used to model the localized errors. In addition a validation metric is introduced to provide a quantitative characterization of consistency of model predictions when compared with validation data. The talk will discuss the challenges in caring out the proposed methodology.

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MS61

A Random Iterative Proper Orthogonal Decomposition Approach with Application to the Filtering of Distributed Parameter Systems

We consider the problem of filtering systems governed by partial differential equations. We propose a randomly perturbed iterative version of the snapshot proper orthogonal decomposition (POD) technique, termed RI-POD, to construct an ROM to capture the systems global behaviour. The technique is data based, and is applicable to forced as well as unforced systems. The ROM generated is used to construct reduced order Kalman filters to solve the filtering problem.

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MS61

A New Approach to Uq Based on the Joint Excitation-Response Pdf: Theory and Simulation

We study the evolution equation of joint excitation-response PDF obtained by Hopf functional approach for various stochastic systems. Some issues arising in this formulation are examined including, multiple available equations, representation of correlated random process, and etc. This approach is tested with Nonlinear Advection equation, Tumor cell model, Duffing Oscillator, and Limit Cycle Oscillator, and the results are compared.

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MS61

Bayesian UQ on Infinite Dimensional Spaces with Incompletely Specified Priors

The Bayesian framework is popular way of handling data in UQ. This is done by defining priors on (possibly infinite dimensional) spaces of measures and functions and conditioning those priors after the observation of the sample data. It has been known since the earlier work of Diaconis and Freedman that, when the probability space allows for an infinite number of outcomes, the Bayesian posteriors, in general, do not converge towards the "true distribution.' In this work we compute optimal bounds on posteriors when priors in incompletely specified (through finite-dimensional marginals for instance). These bounds show that: (1) priors sharing the same finite dimensional marginals may lead to diverging posteriors under sample data (2) any desired posterior can be achieved by a prior satisfying pre-specified finite-dimensional constraints (3) the measurement of sample data (in general) increases uncertainty instead of decreasing it if the classical Bayesian framework is applied ("as is') to an infinite (possibly high-dimensional) space. Finally, we develop a (OUQ) variant of the Bayesian framework that (1) allows to work with incompletely specified priors (2) remains consistent in infinite-dimensional spaces (whose posteriors converge towards the "true distribution') (3) provides optimal bounds on posteriors (4) leads to sharper estimates than those associated with the vanilla frequentist framework if the (incomplete) information on priors is accurate. This is a joint work with Clint Scovel (LANL) and Tim Sullivan (Caltech) and a sequel to an earlier work on Optimal Uncertainty Quantification (OUQ, http://arxiv.org/abs/1009.0679, joint with C. Scovel, T. Sullivan, M. McKerns (Caltech) and M. Ortiz (Caltech)).

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MS61

Conjugate Unscented Transformation – "Optimal Quadrature"

This talk will introduce a recently developed Conjugate Unscented Transformation (CUT) to compute multi-dimensional expectation integrals. An extension of popular unscented transformation will be presented to find a minimal number of quadrature points that is equivalent to the Gaussian quadrature rule of same order. Equivalent to same order implies that both the new reduced quadrature point set and the Gaussian quadrature product rule exactly reproduce the expectation integral involving a polynomial function of order d.

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MS62

Perspectives on Quantifying Uncertain Mechanisms in Dynamical Systems

Due to lack of scientific understanding, some mechanisms are not always well-represented in mathematical models for complex systems. The impact of these uncertain mechanisms on the overall system evolution may be delicate or even profound. These uncertain mechanisms are sometimes microscopic, and it is desirable to examine how they affect the system at the macroscopic level since we are often mainly interested in macroscopic dynamics. The speaker presents an overview of several available analytical and computational techniques for extracting macroscopic dynamics, while taking uncertain microscopic mechanisms into account. The issues include quantifying uncertain mechanisms via probability distributions, dynamical averaging of random slow-fast microscopic mechanisms, ensemble averaging of fluctuating driving forces, and especially, data-driven quantification of uncertain mechanisms in water vapor dynamics.

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MS62

Stochastic Integrable Dynamics of Optical Pulses Propagating through an Active Medium

Resonant interaction of light with a randomly-prepared, lambda-configuration active optical medium is described by exact solutions of a completely-integrable, stochastic partial differential equation, thus combining the opposing concepts of integrability and disorder. An optical pulse passing through such a material will switch randomly between left- and right-hand circular polarizations. Exact probability distributions of the electric-field envelope variables describing the light polarization and their switching times will be presented .

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MS62

Reduced Models for Mode-locked Lasers with Noise

We explore the impact of spontaneous emissions noise on mode-locked laser linewidth by using a variational technique to reduce the original model, a stochastic partial differential equation, to a low-dimensional stochastic ordinary differential equation. The joint distribution of the parameters is mapped to a full-width half-maximum measure of the output laser linewidth, i.e., frequency uncertainty. Events causing the linewidth to exceed a prescribed uncertainty level are rare, requiring the application of large deviations theory or importance sampling approaches.

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MS62

Analysis and Simulations of a Perturbed Stochastic Nonlinear Schrödinger Equation for Pulse Propagation in Broadband Optical Fiber Lines

We study the interplay between bit pattern randomness, Kerr nonlinearity, and delayed Raman response in broadband multichannel optical fiber transmission lines. We show that pulse propagation can be described by a perturbed stochastic nonlinear Schrödinger equation, which takes into account changes in pulse amplitude, group velocity, and position. Numerical simulations with the stochastic PDE along with analysis of the corresponding stochastic reduced ODE model are used to calculate the bit-error-rate and to identify the major error-generating processes in the fiber line.

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MS63

Quantification of Uncertainty in Wind Energy

Abstract not available at time of publication.

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MS63

Uncertainty Quantification for Rayleigh-Taylor Turbulent Mixing

We present two main results. First: a reformulation of convergence for simulations of turbulent flow, through binning solution values from neighboring points (in a "supercell") to define a finite approximation to a space-time dependent probability density function. We thereby obtain convergence of fluctuations, and of nonlinear functions of the solution. Second: to reconstruct initial conditions (often not recorded) from early time data with uncertainty bounds on the reconstruction and on the entire solution.

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MS63

Case Studies in Uncertainty Quantification for Aerodynamic Problems in Turbomachinery

In this study, we study the use of common UQ methods for problems of importance in practical engineering designs. In particular, we assess the efficiency of common polynomial chaos basis functions and sampling techniques like Smolyak-grids. The computational frame-work will be first validated against Monte-Carlo simulations to assess convergence of pdfs. It will then be used to assess the variability in compressor blade efficiency and turbine vane loss due to uncertainty in inflow conditions. The results will be used to answer the following questions: Do we need new probabilistic algorithms to quantify the impact of uncertainty? What is the optimal basis for standard performance metrics in turbomachinery? What are the computational and accuracy requirements of this probabilistic approach? Are there alternate (more efficient) techniques? We believe that the answers to the above questions will provide a quantitative basis to assess the usefulness of non-intrusive (and possibly intrusive) probabilistic methods to analyze variability in engineering designs.

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MS64

Prior Modelling for Inverse Problems Using Gaussian Markov Random Fields

In inverse problems, regularization functions are often chosen to incorporate prior information about a spatially distributed parameter, such as differentiability. In contrast, a standard Bayesian approach assumes that the value of each parameter is Gaussian with mean and variance dependent upon the values of its neighbors. This approach leads to a so-called Gaussian Markov random field prior. We will explore the interesting connections between these two approaches, which in many cases yield equivalent variational problems.

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MS64

Evaluation of Covariance Matrices and their use in Uncertainty Quantification

Abstract not available at time of publication.

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MS64

Challenges in Uncertainty Quantification for Dynamic History Matching

The inversion of large scale ill-posed problems introduces multiple challenges. Examples would be: how to prescribe a suitable regularizer, design an informative experiment, quantify uncertainty, exploit supplementary information from multiple sources, or even how to define an appropriate optimization scheme. In the context of flow in porous medium, subsurface parameters are inferred through inversion of oil production data in a process called history matching. In this talk the inherent uncertainty of the problem is tackled in terms of prior sampling. Despite meticulous efforts to minimize the variability of the solution space, the distribution of the posterior may remain rather intrusive. In particular, geo-statisticians often propose large sets of prior samples that regardless of their apparent geological distinction are almost entirely flow equivalent. As an antidote, a reduced space hierarchical clustering of flow-relevant indicators is proposed for aggregation of these samples. The effectiveness of the method is demonstrated both with synthetic and real field data. This research was performed as part of IBM-Shell joint research project.

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MS64
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MS65
The Influence of Topology on Sound Propagation in Granular Force Networks

Granular materials have been modelled using both continuum and particulate perspectives but neither approach can capture complex behaviours during sound propagation. A network representation provides an intermediate approach that allows one to directly consider microscopic features and longer-range interactions, e.g. force chains. In experiments on granular materials composed of photoelastic particles, we characterise the internal force structure and show that weighted meso-scale network diagnostics are crucial for quantifying sound propagation in this heterogeneous medium.

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MS65
Size of Synchronous Firing Events in Model Neuron Systems

We investigate the interaction of synchronous dynamics and the network topology in simple pulse-coupled Markov chain models for neuron dynamics. Theories for predicting the size of synchronous firing events are presented, in which the probabilistic dynamics between these events are taken into account. We use the theories to find different model networks that preserve the global dynamics on these networks.

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MS65
Network Analysis of Anisotropic Electrical Properties in Percolating Sheared Nanorod Dispersions

Percolation in nanorod dispersions induces extreme properties, with large variability near the percolation threshold. We investigate electrical properties across the dimensional percolation phase diagram of sheared nanorod dispersions [Zheng et al., Adv. Mater. 19, 4038 (2007)]. We quantify bulk average properties and corresponding fluctuations over Monte Carlo realizations, including finite size effects. We also identify fluctuations within realizations, with special attention on the tails of current distributions and other rare nanorod subsets which dominate the electrical response.

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MS65
Asymptotically Inspired Moment-Closure Approximation for Adaptive Networks

Adaptive social networks, in which nodes and network structure co-evolve, are often described using a mean-field system of equations for the density of node and link types. These equations constitute an open system due to dependence on higher order topological structures. We propose a moment-closure approximation based on the analytical description of the system in an asymptotic regime. We show a good agreement between the improved mean-field prediction and simulations of the full network system.

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MS66

Propagating Uncertainty from General Circulation Models through Projected Local Impacts

We develop statistical methodologies for impact analysis of climate change for economically important sectors, and transfer this development to the design of decision-support tools. Our approach is to implementin the context of specific regions and sensitive sectors of high economic and social importancetools that allow a coherent characterization of the propagation of uncertainty all the way to projected impacts, appropriately equipped with confidence or credibility statements relevant to the quantification of risks.

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MS66

Measures of Model Skill and Parametric Uncertainty Estimation for Climate Model Development

Measures of model skill and parametric uncertainty estimation for climate model development.

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MS66

Optimal Parameter Estimation in Community Atmosphere Models

The current tuning process of parameters in global climate models is often performed subjectively or treated as an optimization procedure to minimize model biases based on observations. In this study, a stochastic important-sampling algorithm, Multiple Very Fast Simulated Annealing (MVFSA) was employed to efficiently sample the input parameters in the KF scheme based on a skill score so that the algorithm progressively moved toward regions of the parameter space that minimize model errors.

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MS66

Covariance Approximation for Large Multivariate Spatial Datasets with An Application to Multiple Climate Models

In this work we investigate the cross-correlations across multiple climate model errors. We build a Bayesian hierarchical model that ac- counts for the spatial dependence of individual models as well as cross-covariances across different climate models. Our method allows for a non-separable and non-stationary cross-covariance structure. We also present a covariance approximation approach to facilitate the computation in the modeling and analysis of very large multivariate spatial data sets. The covariance approximation consists of two parts: a reduced-rank part to capture the large-scale spatial dependence, and a sparse covariance matrix to correct the small-scale dependence error induced by the reduced rank approximation. Simulation results of model fitting and prediction show substantial improvement of the proposed approximation over the predictive process approximation and the independent blocks analysis. We then apply our computational approach to the joint statistical modeling of multiple climate model errors.

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MS67

Validation Experience for Stochastic Models of Groundwater Flow and Radionuclide Transport at Underground Nuclear Test Sites and the Shift Away from Quantitative Measures and Toward Iterative Improvement

Several groundwater models of underground nuclear tests, incorporating uncertainty, were subjected to validation processes. There were failures in balancing readily quantifiable and measurable model attributes against harder-to-measure conceptual issues, in gaining decision-maker acceptance of statistically based conclusions, and ultimately in the quality and quantity of data forming the foundation of the original models. From this experience, the regulatory framework has shifted away from validation and toward a model evaluation approach with an emphasis on iterative improvement.

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MS67

Validation and Data Assimilation of Shallow Water Models

We will discuss the validation of large-scale coupled wave-current models for simulating hurricane storm surge. We will demonstrate that by including the appropriate physics, discretizations, and parameters, one can consistently match measured data from a wide range of hurricanes. However, we will also point out where the models have significant uncertainty and describe a new data-assimilation framework for real-time hurricane surge forecasts.

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MS67

Quantifying Long-Range Predictability and Model Error through Data Clustering and Information Theory

We present a framework blending data clustering and information theory to quantify long-range initial-value predictability and forecast error with imperfect models in complex dynamical systems. With reference to wind-driven ocean circulation, we demonstrate that the pertinent information for long-range forecasting can be represented via a coarse-grained partition of the set of initial data available to a model. A related formalism is applied to assess the forecast skill of Markov models of ocean circulation regimes.

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MS67

Model Selection and Inference for a Nuclear Reactor Application

We compare statistical techniques for model selection, with a focus on information theoretic approaches, applied in a statistical framework for calibration of computer codes. Additionally, we propose a sequential strategy for iterative refinement of importance distributions used to sample uncertain model inputs to estimate the probability that a calibrated model exceeds a fixed or random threshold. We demonstrate these methods on a nuclear reactor application involving calculation of peak coolant temperature with the R7 code.

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MS68

Uncertainty Quantification and Model Validation in Flight Control Applications

Models derived from physics or data are often too complicated for analysis or controller design. This is leads to reduced order modeling. However, it is important to assess the quality of such models. Often, for nonlinear systems in particular, model validation is performed using Monte-Carlo simulations. Two systems are qualified to be similar if the variance of the trajectories are small. In this paper, we present a new paradigm where two systems are qualified to be similar if the density function of the output is similar, when excited by the same random input. This is more general than comparing few moments or the support of the trajectories. We use Wasserstein distance to compare density functions and also argue why the commonly use Kullback-Liebler metric is unsuitable for model validation. Examples based on flight control problems are presented to illustrate model validation in this framework.

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MS68

New Positive-definite Random Matrix Ensembles for Stochastic Dynamical System with High Level of Heterogeneous Uncertainties

The scientific community has seen an increasing surge of applications of positive-definite random matrix ensembles in the fields of mechanics and multiscale mechanics in recent years. These ensembles are employed to *directly* model several positive-definite matrix-valued objects, e.g., mass matrices, stiffness matrices, constitutive elasto-plasticity tensor, etc. Matrix variate distributions, e.g., Wishart/Gamma distribution, Beta Type 1 distribution, Kummer-Beta distribution, or distributions derived from them, are currently considered for this modeling purpose. These distributions are, however, parameterized such that they induce specific mean and covariance structures that do not allow sufficient flexibility in modeling high level of uncertainties. The current work will discuss two new positive-definite random matrix ensembles that are likely to provide more flexibility in modeling high level of uncertainties.

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MS68

Existence and Stability of Equilibria in Stochastic Galerkin Methods

We consider dynamical systems in form of nonlinear autonomous ordinary differential equations including random parameters. Thus the corresponding solutions represent random processes. The existence of a unique stable equilibrium is assumed for each sample of the parameters. Thereby, the equilibria depend on the random parameters. We apply the polynomial chaos expansion of the unknown random process to solve the stochastic dynamical system. The stochastic Galerkin method yields a larger coupled system of nonlinear ordinary differential equations satisfied by an approximation of the random process. The existence of equilibria is investigated for the coupled system. Moreover, we analyze the stability of these fixed points, where the spectrum of a Jacobian matrix has to be examined. Numerical simulations of test examples are presented.

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MS68

A Nonlinear Dimension Reduction Technique for Random Fields Based on Topology-Preserving Transformations

The intrinsic dimensionality of a random field may be defined as the minimum number of degrees of freedom which is neccessary to account for its relevant statistical information. In this talk we will present a new nonlinear dimension reduction technique for random fields based on latent variable models and topology-preserving transformations. The low-dimensional embedding will be explicitly constructed together with the probability measure associated with the reduced-order probability space.

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MS69

New Results for the Stochastic PDEs of Fluid Dynamics

The addition of white noise driven terms to the fundamental equations of physics and engineering are used to model numerical and empirical uncertainties. In this talk we will discuss some recent results for the Stochastic Navier-Stokes and Euler Equations as well as for the Stochastic Primitive Equations, a basic model in geophysical scale fluid flows. For all of the above systems our results cover the case of a general nonlinear multiplicative stochastic forcing.

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MS69

Asymptotic Behavior of Stochastic Lattice Differential Equations

Random attractor is an important concept to describe long-term behavior of solutions for a given stochastic system. In this talk we will first provide sufficient conditions for the existence of a global compact random attractors for general dynamical systems in weighted space of infinite sequences. We then apply the result to show the existence of a unique global compact random attractor for first order, second order and partly dissipative stochastic lattice differential equations with random coupled coefficients and multiplicative/additive white noise in weighted spaces.

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MS69

Unbiased Perturbations of the Navier-Stokes Equation

We consider a new class of stochastic perturbations of the Navier-Stokes equation. Its unique feature is the preservation of the mean dynamics of the deterministic equation, hence it is an unbiased random perturbation of the equation. We will discuss results for the steady state solutions and the convergence to steady solutions, and show sufficient conditions which are very similar to analogous results for the unperturbed equation. Numerical simulations comparing this unbiased perturbation with the usual stochastic Navier-Stokes will be shown.

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MS69

Generalized Malliavin Calculus and Spdes in Higher-Order Chaos Spaces

The Malliavin derivative, divergence operator (Skorokhod integral), and the Ornstein-Uhlenbeck operator are extended from the traditional Gaussian setting, or first-order chaos space, to nonlinear generalized functionals of white noise, which are elements of the full chaos space. These extensions are then applied to study stochastic elliptic and parabolic equations driven by noise from higher-order chaos spaces.

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MS69

Stochastic-Integral Models for Propagation-of-Uncertainty Problems in Nondestructive Evaluation

Generalized polynomical chaos (gPC) and the probabilistic collocation method (PCM) are finding considerable application to problems of interest to engineers in which random parame- ters are an essential feature of the mathematical model. So far the applications have been mainly to stochastic partial differential equations, but we extend the method to volume-integral equations, which have met great success in electromagnetic nondestructive evaluation (NDE), especially with eddy-currents. The problems of main interest to the NDE community in this connection are concerned with the issue of propagation of uncertainty when the relevant parameters are not well characterized, or are known simply as random variables. We demonstrate the ideas by considering a metallic surface that has undergone a shot-peening treatment to reduce residual stresses, and has, therefore, become a random conductivity field.

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MS70

Hybrid Methods for Data Assimilation

I present a theoretical comparison of two widely used data assimilation methods: the ensemble Kalman filter (EnKF) approach and the four dimensional variational (4D-Var) approach. Then I propose a suboptimal hybridization scheme to combine the advantages of the EnKF and the 4D-Var. This new hybrid technique is computationally less expensive than the full 4D-Var and, in simulations, performs better than EnKF for both linear and nonlinear test problems.

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MS70

Model Covariance Sensitivity as a Guidance for Localization in Data Assimilation

In this talk we present how to use model covariance sensitivity information to guide, in a more precise manner, the selection of appropriate cross-correlation length-scale parameters for model covariance localization techniques. Covariance sensitivities are obtained using adjoint-based methods. Numerical experiments are presented for the ensemble Kalman filter data assimilation applied to the Lorenz 40-variable model. The relevance of the technique, as well as its utility, for operational data assimilation systems will be presented and discussed.

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MS70

The Estimation of Functional Uncertainty using Polynomial Chaos and Adjoint Equations

The combined use of nonintrusive polynomial chaos (PC) and adjoint equations (yielding the gradient) is addressed aimed at the estimation of uncertainty of a valuable functional subject to large errors in the input data. Random variables providing maximum impact on the result (leading values) may be found using the gradient information that allows reduction of the problem dimension. The gradient may be also used for the calculation of PC coefficients, thus enabling further acceleration of the computations. Using gradient information for the estimation of polynomial coefficients (APC) also provides a significant reduction of the computation time. The adjoint Monte VCarlo (AMC)is highly efficient from a computational viewpoint and accurate for moderate amplitude of errors. For a large number of random variables, the accuracy of AMC is close (or even superior) to PC results even under large error.

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MS70

FATODE: A Library for Forward, Tangent Linear, and Adjoint ODE Integration

FATODE is a FORTRAN library for the integration of ordinary differential equations with direct and adjoint sensitivity analysis capabilities. The paper describes the capabilities, implementation, code organization, and usage of this package. FATODE implements the forward, adjoint, and tangent linear models for four families of methods — ERK, FIRK, SDIRK, and Rosenbrock. A wide range of applications are expected to benefit from its use; examples include parameter estimation, data assimilation, optimal control, and uncertainty quantification.

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MS71

Upscaling
Micro-scale Material Variability Through the use

of Random Voronoi Tessellations

A randomly seeded Voronoi tessellation is used to model the microscale grain structure of a thin ductile ring. Each grain is assigned an elastic stiffness tensor with cubic symmetry but with randomly oriented principal directions. The ring is subjected to internal pressure loading and deformed elastically. The displacement and stress response of the ring is studied from the perspective of homogenization theory as the ratio of the grain size to ring diameter is varied.

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MS71
Discrete Models of Fracture and Mass Transport in Cement-based Composites

The life-cycle performance of structural concrete is affected by material features and internal processes that span several length scales. This presentation regards the discrete lattice modeling of such features, fracture, and crack-assisted mass transport in concrete. Domain discretization is based on Voronoi/Delaunay tessellations of semi-random point sets. Lack of scale separation complicates the modeling efforts. Variability is quantified by simulating multiple, random realizations of nominally identical structures.

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MS71
Maximal Poisson-disk Sampling for UQ Purposes

We describe a new approach to solve the maximal Poisson-disk sampling in d-dimensional spaces for UQ purposes. In contrast to existing methods, our technique tracks the remaining voids after a classical dart throwing phase by constructing the associated convex hulls. This provides a mechanism for termination with bounded time complexity. We also show how to utilize this sampling techniques to achieve better estimations of probability of failure and detection of discontinuities. We demonstrate application examples.

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MS71
Simplex Stochastic Collocation Approach

The Simplex Stochastic Collocation method is introduced as an non-intrusive, adaptive un- certainty quantification method for computational problems with random inputs. The effectiveness of adaptive formulation is determined by both h- and p-refinement measures and a stopping criterion derived from an error estimate based on hierarchical surpluses. A p-criterion for the polynomial degree p is formulated to achieves a constant order of convergence with dimensionality. Numerical results show that the stopping criterion is reliable owing to the accurate and conservative error estimate, and that the refinement measures outperform uniform refinement.

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MS71
Random Poisson-Disk Samples and Meshes

Maximal Poisson-disk sampling produces random point clouds of uniform density. Every part of the domain is within distance r of a sample, yet no two samples are closer than r to each other. I will describe an optimal algorithm for generating samples, and how we sample the domain boundary differently to get a Delaunay triangle or Voronoi polyhedral mesh. These meshes have provable quality similar to determinist meshes, but with uniform random orientations.

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MS72
Quantile Emulation for Non-Gaussian Stochastic Models

Stochastic models often require a large number of expensive runs for practical applications. In the emulator framework, the model is replaced with a faster surrogate (a Gaussian process) which captures prediction uncertainty under the assumption of Gaussianity. If the simulator response is non-Gaussian however, alternative approaches have to be sought. We investigate emulation of quantiles and discuss how to perform Bayesian inference for this class of models. A real world example application is provided.

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MS72
Methods for Assessing Chances of Rare, High-Consequence Events in Groundwater Monitoring

This talk looks at multiple approaches for assessing uncertainty in high-consequence, low probability events related to groundwater monitoring. We consider Monte Carlo, Markov chain Monte Carlo, and null-space Monte Carlo, all of which have difficulty estimating the chance of low probability events. We also look at modifications to these approaches that help address this issue. We focus on a synthetic application in 3d solute transport.

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MS72

Sensitivity Analysis and Estimation of Extreme Tail Behaviour in Two-dimensional Monte Carlo Simulation (2DMC)

Two-dimensional Monte Carlo simulation is frequently used to implement risk models, comprising mechanistic and probabilistic components, to separately quantify uncertainty and variability within a population. Risk managers must assess the proportion exceeding a critical threshold, and the levels of exceedence. We describe an efficient method combining Bayesian model emulation and extreme value theory, which can also be used to quickly identify those model parameters having the greatest impact on the probabilities of rare events.

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MS72

An Investigation of the Pineapple Express Phenomenon via Bivariate Extreme Value Theory

We apply bivariate extreme value methods in an examination of extreme winter precipitation events produced by a regional climate model. We first assess the model's ability to reproduce these events in the US Pacific coast region. We then link these events to large-scale process dynamics, with a particular focus on the pineapple express (PE), a special type of winter event. Finally, we examine extreme events produced by the model in a future climate scenario.

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MS73

An Introduction to Emulators and Climate Models

State of the art climate simulators pose particular problems for UQ methods. They have very large state spaces ($o10^{12}$) and are computationally expensive. In this talk I will introduce climate models, what they do, how they work and the problems that arise when we quantify their uncertainty, identify its source and use data to reduce it. I will outline some solutions to these , where the current challenges lie and outline future research.

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MS73

Calibration of Gravity Waves in WACCM

The Whole Atmosphere Community Climate Model (WACCM) is a comprehensive numerical model, spanning the range of altitude from the Earth's surface to the thermosphere. Gravity waves are a key component of the dynamics, and are parametrized. However, the current parametrization does not result in fully realistic features such as the period of the quasi-biennial oscillation. We carry out a Bayesian calibration of the gravity waves scheme using efficient sequential design of experiments.

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MS73

Uncertainty in Modeled Upper Ocean Heat Content Change using a Large Ensemble

We evaluate the uncertainty in the heat content change (ΔQ) in the top 700 meters in the ocean component of the CCSM3.0 model using an emulator created from a large member ensemble. A large ensemble of the CCSM3.0 ocean/ice system at a 3 degree resolution was created by varying parameters related to ocean mixing and advection. The outcomes are compared to four estimates using observational data. We explore how other modeled estimates of ΔQ from the CMIP3 ensemble can be understood in the context of this large ensemble.

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MS73

Emulating Time Series Output of Climate Models

The RAPIT project is concerned with the risk, probability and impacts of future changes to the Atlantic Meridional Overturning Circulation (AMOC) under anthropogenic forcing. Our principle resource is an unprecedented perturbed parameter ensemble, (order 10,000 runs), of the fully coupled, un-flux-adjusted climate model, HadCM3. We present dynamic methods for emulating the AMOC time series output by the model and explore the use of these emulators in helping to constrain future AMOC projections using different data sources and ocean monitoring systems.

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MS74

A Non-intrusive Alternative to a Computational

Measure Theoretic Inverse

We develop a non-intrusive technique for extending the computational measure-theoretic methodology to problems where it is either infeasible or impractical to obtain derivative information from the map. We discuss various sources of errors in the methodology and how to address these.

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MS74

Inverse Function-based Methodology for UQ

There is a growing need of statistical methodology for problems addressing inverse sensitivity analysis in which there are one or multiple quantities of interest connected to the input space through a system of partial differential equations. Though Bayesian methodology has become quite popular in this setting, we explore potential non-Bayesian solutions using some newer ideas related to inverse function-based inference. The goal is to understand the distribution on the parameter space without use of priors.

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MS74

A Computational Approach for Inverse Sensitivity Problems using Set-valued Inverses and Measure Theory

We discuss a numerical method for inverse sensitivity analysis of a deterministic map from a set of parameters to a randomly perturbed quantity of interest. The solution method has two stages: (1) approximate the unique set-valued solution to the inverse problem and (2) apply measure theory to compute the approximate probability measure on the parameter space that solves the inverse problem. We discuss convergence and analysis of the method.

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MS74

Inverse Problem and Fisher's View of Statistical Inference

R. A. Fisher's fiducial inference has been the subject of many discussions and controversies ever since he introduced the idea during the 1930's. The idea experienced a bumpy ride, to say the least, during its early years and one can safely say that it eventually fell into disfavor among mainstream statisticians. However, it appears to have made a resurgence recently under various guises. For example under the new name generalized inference fiducial inference has proved to be a useful tool for deriving statistical procedures for problems where frequentist methods with good properties were previously unavailable. Therefore we believe that the fiducial argument of R.A. Fisher deserves a fresh look from a new angle. In this talk we first generalize Fisher's fiducial argument and obtain a fiducial recipe applicable in virtually any situation. We demonstrate this fiducial recipe on examples of varying complexity. We also investigate, by simulation and by theoretical considerations, some properties of the statistical procedures derived by the fiducial recipe showing they often posses good repeated sampling, frequentist properties. As an example we apply the recipe to interval observed mixed linear model. Portions of this talk are based on a joined work with Hari Iyer, Thomas C.M. Lee and Jessi Cisewski

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MS75

Variable Selection and Sensitivity Analysis via Dynamic Trees with an application to Computer Code Performance Tuning

We introduce a new response surface methodology, dynamic trees, with an application to variable selection and an input sensitivity analysis. These methods are used to analyze automatic computer code tuning that combines classification and regression elements on large data sets. The talk will also highlight an R package implementing the methods, called dynaTree, which is available on CRAN.

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MS75

Bayesian Filtering in Large-Scale Geophysical Systems and Uncertainty Quantification

Bayesian filters compute the probability distribution of the system, thus readily provide a framework for uncertainty quantification and reduction. In geophysical applications, filtering techniques are designed to produce a small sample of state estimates, as a way to reduce computational burden. This, coupled with poorly known model-observation deficiencies, would lead to distribution estimates that are far from optimal, yet still provide meaningful estimates. We present this problem and discuss possible approaches to produce improved uncertainty estimates.

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MS75
On Data Partitioning for Model Validation

Validation processes usually require that experimental data be split into calibration and validation datasets. As this choice is often subjective, we introduce an approach based on the concept of cross-validation. The proposed method allows one to systematically determine the optimal partition and to address fundamental issues in validation, namely that the model 1) be evaluated with respect to the data and to predictions of quantities of interest; 2) be highly challenged by the validation set.

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MS75
Validation of a Random Matrix Model for Mesoscale Elastic Description of Materials with Microstructures

We present validation of a bounded random matrix model defining the constitutive elastic behavior of heterogeneous material. Using an experimental database of microstructures, we first construct a surrogate model in order to further the data, required for calibration and validation. We then recall the construction of the random matrix model characterizing the mesoscale apparent elasticity tensor of the material. Finally a procedure is presented to validate the model using observations resulting from fine scale simulations.

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MS76
Toward Analysis of Uncertainty in Chaotic Systems

Due to the exponential growth of small disturbances, uncertainty analysis in chaotic systems is challenging. For example, even for mean quantities, sensitivity analysis using a standard adjoint-based approach fails because the adjoint variables diverge. In this talk, recent work on uncertainty quantification for chaotic systems is described. In particular, several methods, including polynomial chaos expansions, are evaluated for capturing uncertainty in mean quantities using the Lorenz equations as a model problem.

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MS76
A Dynamically Weighted Particle Filter for Sea Surface Temperature Modeling

The sea surface temperature (SST) is an important factor of the earth climate system. We analyze the SST data of Caribbean Islands area after a hurricane using the radial basis function network-based dynamic model. Comparing to the traditional grid-based approach, our approach requires much less CPU time and makes the real-time forecast of SST doable on a personal computer.

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MS76
Characterization of the Effect of Uncertainty in Terrain Representations for Modeling Geophysical Mass Flows

In modeling flow on natural terrains a persistent and difficult problem is the effect of errors and uncertainties in the representation of the terrain. In this talk we will discuss the effect of such uncertainty on outputs from a geophysical mass flow model. We will then introduce methodology to systematically account for these uncertainties by using a model of the error and sampling it to create ensembles of possible elevations.

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MS77

Statistical Inference Problems for Nonlinear SPDEs

We consider a parameter estimation problem to determine the drift coefficient for a large class of parabolci Stochastic PDEs driven by additive or multiplicative noise. We derive several different classes of estimators based on the first N Fourier modes of a sample path observed continuously on a finite time interval. We study the consistency and asymptotic normality of these estimators as number of Fourier coefficients increases, and we present some numerical simulation results.

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MS77

Filtering the Navier Stokes Equations

Data assimilation refers to methodologies for the incorporation of noisy observations of a physical system into an underlying model in order to infer the properties of the state of the system (possibly including parameters). The model itself is typically subject to uncertainties, in the input data and in the physical laws themselves. This leads naturally to a Bayesian formulation in which the posterior probability distribution of the system state, given the observations, plays a central conceptual role. The aim of this paper is to use this Bayesian posterior probability distribution as a gold standard against which to evaluate various commonly used data assimilation algorithms. We study the 2D Navier-Stokes equations in a periodic geometry and evaluate a variety of sequential filtering approximations based on 3DVAR and on extended and ensemble Kalman filters. The performance of these data assimilation algorithms is quantified by comparing the relative error in reproducing moments of the posterior probability distribution. The primary conclusions of the study are that: (i) with appropriate parameter choices, approximate filters can perform well in reproducing the mean of the desired probability distribution; (ii) however these filters typically perform poorly when attempting to reproduce information about covariance; (iii) this poor performance is compounded by the need to modify the filters, and their covariance in particular, in order to induce filter stability and avoid divergence. Thus, whilst filters can be a useful tool in predicting mean behaviour, they should be viewed with caution as predictors of uncertainty. We complement this study with (iv) a theoretical analysis of the ability of the filters to estimate the mean state accurately, and we derive a non-autonomous (S)PDE for this estimate in the continuous-time limit.

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MS77

Adaptive Construction of Surrogates for Bayesian Inference

Surrogate models are often used to accelerate Bayesian inference in statistical inverse problems. Yet the construction of globally accurate surrogates for complex models can be prohibitive and in a sense unnecessary, as the posterior distribution typically concentrates on a small fraction of the prior support. We present a new adaptive approach that uses stochastic optimization (the cross-entropy method) to construct surrogates that are accurate over the support of the posterior distribution. Efficiency and accuracy are demonstrated via parameter inference in nonlinear PDEs.

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MS77

Reimagining Diffusion Monte Carlo for Quantum Monte Carlo, Sequential Importance Sampling, Rare Event Simulation and More

Diffusion Monte Carlo was developed forty years ago within the Quantum Monte Carlo community to compute ground state energies of the Schrodinger operator. Since then the basic birth/death strategy of DMC has found its way into a wide variety of application areas. For example efficient resampling strategies used in sequential importance sampling algorithms (e.g. particle filters) are based on DMC. As I will demonstrate, some tempting generalizations of the basic DMC framework lead to an instability in the time discretization parameter. This instability has important consequences in, for example, applications of DMC in sequential importance sampling and rare event simulation. We suggest a modification of the basic DMC algorithm that eliminates this instability. In fact, the new algorithm is more efficient than DMC under any condition (parameter regime). We prove this as well as show numerically and analytically that it is stable in unstable regimes for DMC.

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MS78

Computing and Using Observation Impact in 4D-Var Data Assimilation

Data assimilation combines information from an imperfect model, sparse and noisy observations, and error statistics, to produce a best estimate of the state of a physical system. Different observational data points have different contributions to reducing the uncertainty with which the state is estimated. In this paper we present a computational ap-

proach to quantify the observation impact for analyzing the effectiveness of the assimilation system, for data pruning, and for designing future sensor networks.

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MS78

Error Covariance Sensitivity and Impact Estimation with Adjoint 4D-Var

The adjoint-data assimilation system (DAS) is presented as a feasible approach to evaluate the forecast sensitivity with respect to the specification of the observation and background error covariances in a four-dimensional variational DAS. A synergistic link is established between various techniques to analyze the DAS performance: observation sensitivity, error covariance sensitivity and impact estimation, and a posteriori diagnosis. Applications to atmospheric modeling and the current status of implementation at numerical weather prediction centers are discussed.

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MS78

Lagrangian Data Assimilation

Abstract not available at time of publication.

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MS78

Uncertainty Quantification and Data Assimilation Issues for Macro-Fiber Composite Actuators

Macro-fiber composites (MFC) are being considered for a range of present and emerging applications, such as flow control and remote configuration of large space structures, due to their large bandwidth, moderate power requirements, and moderate stain capabilities. However, they also exhibit hysteresis and constitutive nonlinearities due to their PZT components. In this presentation, we will discuss uncertainty quantification and data assimilation techniques for these actuators within the context of the homogenized energy modeling framework. This will utilize data collected under a variety of operating regimes.

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MS79

Analyzing Predictive Uncertainty using Paired Complex and Simple Models

In analyzing the uncertainty of environmental model predictions a tension exists between the prior information and likelihood terms of Bayes Equation. The first requires a complex model that reflects the complexity of earth processes. The second requires a simple, fast-running model that can capture information from historical data. Use of a single model to achieve both erodes its ability to achieve either. A paired model approach can achieve the same ends with fewer compromises.

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MS79

Modeling Spatial Variability as Measurement Uncertainty

Direct evaluation of uncertainty in models, parameters and measurements will be viewed through an ill-posed inverse problem and we will demonstrate how incorporating uncertainty can regularize the problem. In particular, we will estimate soil hydraulic properties using two different types of measurements, and incorporate uncertainty due to spatial variation. These estimates can be used over larger scales than those that were measured, and their corresponding uncertainty indicates areas where measurement uncertainty needs to be reduced.

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MS79

Using Electrochemical Impedance Spectroscopy for Studying Respiration of Anode Respiring Bacteria for Solid Oxide Fuel Cells

Electrochemical impedance spectroscopy (EIS) is a powerful diagnostic technique that involves applying a small AC voltage to an electrode for a range of frequencies. EIS for estimating anode resistances in the study of anode bacteria respiration is of interest. Respiration of the bacteria leads to an electrical current that can be used for various bioenergy applications. Here the focus is on the inverse problem for practical data obtained in solid-oxide fuel cell research.

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MS79

Quantifying Simplification-induced Error using Subspace Techniques

All geophysical models represent a simplification of reality. As a result, the history-matching process can lead to surrogate parameters that compensate for model simplification. This parameter surrogacy may or may not create predictive bias, depending on prediction sensitivity to null and solution space parameter components. The potential for bias indicates the role of history matching is prediction dependent. History-matching-induced predictive bias is analyzed and quantified from a subspace perspective for a physics-based water resource model.

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MS80

Hybrid Reduced order Modeling for Uncertainty Management in Nuclear Modeling

The speaker will overview reduced order modeling techniques currently used in nuclear reactor design calculations. Reactor calculations are very complex given that nature of the physics governing their behavior and their heterogeneous design. Reduced order modeling is therefore required to allow engineers to carry out design calculations on a routine basis. In doing so, the fidelity of the calculations must be preserved. When used to perform uncertainty quantification, sensitivity analysis, or data assimilation, additional reduction is necessary since these analyses require many executions of the models. The speaker has developed hybrid statistical deterministic reduction techniques to enable the execution of these analysis on a routine basis. He will give a quick overview of reduction techniques used in best-estimate reaction calculations, then focus in depth on reduction algorithms he developed to perform sensitivity and uncertainty analyses.

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MS80

Sparse Interpolatory Reduced-Order Models for Simulation of Light-Induced Molecular Transformations

We describe an efficient algorithm for using a quantum-chemistry simulator to drive a gradient descent algorithm. Our objective is to model light-induced molecular transformations. The simulator is far too expensive and the design space too high-dimensional for the simulator to be used directly to drive the dynamics. We begin by applying domain-specific knowledge to reduce the dimension of the design space. Then we use sparse interpolation to model the energy from the quantum code on hyper-cubes in configuration space, controlling the volume of the hyper-cubes both to maintain accuracy and to avoid failure of the quantum codes internal optimization. We will conclude the presentation with some examples that illustrate the algorithm's effectiveness.

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MS80

Intrusive Analysis for Uncertainty Quantification of Simulation Models

We develop intrusive, hybrid uncertainty quantification methods applicable to modern, high-resolution simulation models. We seek to construct surrogate models of uncertainty by augmenting knowledge of the model with results of intrusive analysis, such as Automatic Differentiation. Our toolset now includes a gradient-enhanced regression, stochastic-processes based analysis that provides error bounds and statistical metrics for the prior regression model, and a framework for the use of reduced, lower-fidelity approximations to effectively describe uncertainties in the model.

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PP1

A Statistical Decision-Theoretic Approach to Dynamic Resource Allocation for a Self-Aware Unmanned Aerial Vehicle

For inference and prediction tasks, it is typical for decision-makers to have available to them several different numerical models as well as experimental data. Our statistical decision-theoretic approach to dynamic resource allocation seeks to exploit optimally all available information by selecting models and data with the appropriate fidelity for the task at hand. We demonstrate our approach on the online prediction of flight capabilities for a self-aware unmanned aerial vehicle.

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PP1

Computational Reductions in Stochastically Driven Neuronal Models with Adaptation Currents

The complexity of stochastic, conductance-based neuronal network dynamics has motivated several computational reductions to the Hodgkin-Huxley neuron model. These reductions, however, rarely generalize to neurons containing realistic adaptive ionic currents. Using several measures of robustness and network simulations, we show the modeling algorithm described in this talk achieves the goals of attaining accuracy and efficiency while producing a modeling scheme general enough for modeling a wide array of specialized neuronal dynamics.

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PP1
Propagating Arbitrary Uncertainties Through Models Via the Probabilistic Collocation Method

Nonintrusive methods for propagating uncertainty in simulations have been introduced in recent times. Some of these methods use polynomial chaos expansions which can be used with many standard statistical distributions based on the Askey scheme. This work describes an efficient method for propagating arbitrary distributions through forward models based on application of the standard recurrence relation for generating orthogonal polynomials. The method is demonstrated in the context of eddy-current nondestructive evaluation.

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PP1
A Predictive Model for Geographic Statistical Data

Any planar map may be transformed into a graph. If we consider each country to be represented by a vertex (or node), if they are adjacent they will be joined by an edge. To consider how trends migrate across boundaries, we obtain relevant measures of the statistic we want to consider; namely, the index of prevalence, and the index of incidence. We define a cycle by a given unit of time, usually a year. We then propose various alternate equations whereby, by parametrizing various variables, such as population size, birth rate, death rate, and rate of immigration/emigration, we calculate a new index of prevalence/index of incidence, for the next cycle. For a given data set, each statistic we consider may propagate by a different equation, and/or a different set of parameters; this will be determined empirically. What we are proposing is, technically, to model how a discrete stochastic process propagates geographically, according to geographical proximity. Very often, statistics that depend on geographical proximity are tabulated by variables that are not; i.e., alphabetically. Such a predictive model would be relevant in areas such as public health; and/or crime mapping, for law enforcement purposes. We present an application using a GIS (geographic information system).

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PP1
A Stochastic Collocation Method Combined with a Reduced Basis Method to Compute Uncertainties in the Sar Induced by a Mobile Phone

A reduced basis method is introduced to deal with a stochastic problem in a numerical dosimetry application in which the field solutions are computed using an iterative solver. More precisely, the computations already performed are used to build an initial guess for the iterative solver. It is shown that this approach significantly reduces the computational cost.

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PP1
Uncertainty Quantification for Hydromechanical Coupling in Three Dimensional Discrete Fracture Network

Fractures and fracture networks are the principle pathways for migration of water, heat and mass in geothermal systems, oil/gas reservoirs, sequestrated CO2 leakages. We investigate the impact of parameter uncertainties of the PDFs that characterize discrete fracture networks on the hydromechanical response of the system. Numerical results of first, second and third moments, normalized to a base case scenario, are presented and integrated into a probabilistic risk assessment framework. (Prepared by LLNL under Contract DE-AC52-07NA27344)

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PP1
Random and Regular Dynamics of Stochastically Driven Neuronal Networks

Dynamical properties of and uncertainty quantification in Integrate-and-Fire neuronal networks with multiple time scales of excitatory and inhibitory neuronal conductances driven by random Poisson trains of external spikes will be discussed. Both the asynchronous regime in which the network spikes arrive at completely random times and the synchronous regime in which network spikes arrive within periodically repeating, well-separated time periods, even though individual neurons spike randomly will be presented.

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PP1
Calibration of Computer Models for Radiative Shock Experiments

POLAR experiments aimed to mimic the astrophysical accretion shock formation in laboratory using high-power laser facilities. The dynamics and the main physical properties of the radiative shock produced by the collision of the heated plasma with a solid obstacle have been characterised on recent experiments and compared to radiation hydrodynamic simulations. This poster will present the statistical method based on Bayesian inference used to calibrate the main unknown parameters of the simulation and to quantify the model uncertainty.

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PP1

Regional Climate Model Ensembles and Uncertainty Quantification

One goal of the North American Regional Climate Change Assessment Program (NARCCAP) is to better understand regional climate model output and the impact of the boundary conditions provided by the global climate model, the regional climate model itself, and interaction between the two. This poster will outline a statistical framework for quantifying temperature output and the associated uncertainty both spatially and temporally. The aim is to understand the contributions of each model type and how those contributions vary over space.

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PP1

Multiple Precision, Spatio-Temporal Computer Model Validation using Predictive Processes

The Lyon-Fedder-Mobarry (LFM) global magnetosphere model is a computer model used to study physical processes in the magnetosphere and ionosphere. Given a set of input values and solar wind data, the LFM model numerically solves the magnetohydrodynamic equations and outputs a spatio-temporal field of ionospheric energy. The LFM model has the benefit of being able to be run at multiple precisions (with higher precisions more closely representing true ionospheric conditions at the cost of computation). This work focuses on relating the multiple precision output from the LFM model to field observations of ionospheric energy. Of particular interest here are the input settings (and their uncertainties) of the LFM model which most closely match the field observations. A low rank spatio-temporal statistical LFM model emulator is constructed using predictive processes. The emulator borrows strength across the multiple precisions of the LFM model to calibrate the input variables to field observations. In this way, the less computationally demanding yet lower precision models are leveraged to provide estimates of the higher precision LFM model output.

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PP1

Variance Based Sensitivity Analysis of Epidemic Size to Network Structure

I demonstrate the use of global sensitivity analysis to study the dependence of epidemic growth on the structure of the underlying network. These networks model the social interactions and migration patterns of individuals susceptible to a disease. Variance based sensitivity indices are shown to indicate quantities in the structure of these networks that determine the behaviour of epidemics.

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PP1

Autoregressive Model for Real-Time Weather Prediction and Detecting Climate Sensitivity

We propose reduced stochastic models with nonlinear terms replaced by autoregressive linear stochastic model in Fourier space for filtering and for climate modeling. Using the Lorenz-96 model as a test bed, we show that this reduced filtering strategy is computationally cheap and provides more accurate filtered solutions than current methods. The potential of application of this autoregressive model to study climate sensitivity using the Fluctuation-Dissipation Theorem (FDT) is also addresses.

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PP1

A Split Step Adams Moulton Milstein Method for

Stiff Stochastic Differential Equations

A split-step method for solving Itō stochastic differential equations (SDEs) is presented. The method is based on Adams Moulton Formula for stiff ordinary differential equations and modified for use on stiff SDEs which are stiff in both the deterministic and stochastic components. Its order of convergence is proved and stability regions are displayed. Numerical results show the effectiveness of the method in the path-wise approximation of SDEs and its' capability to deal with uncertainty.

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PP1

Computer Model Calibration with High and Low Resolution Model Output for Spatio-Temporal Data

We discuss a framework for computer model calibration based on low and high resolution model output for large spatio-temporal datasets. The physical model in use is a coupled magnetohydrodynamical model for solar storms occurring in Earth's upper atmosphere. The statistical model is informed by known physical equations and is tailored to large datasets. Given initial runs of the computer model, we propose a sequential design based on Expected Improvement.

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PP1

Goal-Oriented Statistical Inference

In many applications statistical inference is utilized for model identification before simulations are conducted to predict outputs of interest. Our goal-oriented approach to inference automatically targets parameter modes required to make predictions. In the linear Gaussian case, the mean and covariance of the posterior predictive are obtained by inferring many fewer parameter modes than an unmodified approach. This method could pave the way for efficient Markov chain Monte Carlo in the high-dimensional parameter setting.

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PP1

Uncertainty in Model Selection in Remote Sensing

The model choice problem arise in the context of estimating the total amount of atmospheric aerosols using satellite measurements. Modeling uncertainty related to unknown aerosol type is taken into account when assessing uncertainty in aerosol products using Bayesian model selection tools. In this work, uncertainty modeling is comprised of measurement uncertainty estimates, uncertainty in aerosol models, and uncertainty in model selection. Illustrating and quantifying modeling uncertainty gives valuable information to algorithm developers and users.

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PP1

Multifidelity Approach to Variance Reduction in Monte Carlo Simulation

Engineers often have a suite of numerical models at their disposal to simulate a physical phenomenon. For uncertainty propagation, we present an approach that utilizes information from inexpensive, low-fidelity models to reduce the variance of the Monte Carlo estimator of an expensive, high-fidelity model. For a given computational budget, we demonstrate that our approach can produce more accurate estimation of the statistics of interest than regular Monte Carlo simulation.

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PP1

Local Sensitivity Analysis of Stochastic Systems with Few Samples

We estimate local sensitivity of predicted quantities in stochastic models with respect to input parameters by minimizing the Lp residual of linear hyperplanes fit through sparse multidimensional output. We analyze how the number of function evaluations necessary for reliable estimates for the sensitivity indices depends upon the Lp norm ($0 < p < 2$) used and how the optimal Lp norm can reduce the number of function evaluations necessary for the sensitivity analysis. We apply this method to an epidemic model.

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PP1

Worst Case Scenario Analysis Applied to Uncertainty Quantification in Electromagnetic Simulations

The input parameters of models used for the simulation of technical devices exhibit uncertainties, e.g., due to the manufacturing process. Whenever their probability distribution is unknown, a worst case scenario analysis [Babuška et al. (2005)] is appealing, potentially requiring little numerical effort. Based on sensitivity analysis techniques, the quantification of uncertainty due to variations in geometry, material distribution and sources will be discussed for electromagnetic problems within the finite element method.

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PP1

Constructive and Destructive Correlation Dynamics in Simple Stochastic Swimmer Models

Micro-swimming organisms usually can be classified into two groups based on their method of propulsion: pushers and pullers. Experimental data as well as numerical simulations point towards much larger orientational correlations for suspensions of pushers compared to pullers. I will discuss an analytical mean field theory for a simplified swimmer model that captures two body interactions and can help lead to an understanding of the above observations.

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PP1

Preserving Positivity in Pc Approximations Via Weighted Pc Expansions

The preservation of the positivity of the solution in dynamical systems is important in a wide range of applications. When working with polynomial chaos (PC) approximations, the positivity can be lost after the truncation of the PC expansion. We show that the introduction of weights in the PC approximations solves this problem for a wide range of polynomial systems. We present sufficient conditions for the weights and an algorithm that allows determining these weights.

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PP1

Visualization of Uncertainty: Standard Deviation and Pdf's

Uncertainty can be expressed as an error bar (ie standard deviation) or a distribution. Except for the simplest cases, concurrent visualization of uncertainty and underlying value, uncertainty remains un-visualized. We present a method to display scalar uncertainty based on tessellating the field of uncertainty density into cells containing nearly equal uncertainty. We present a method for segmenting a field of node based probability distributions into meaningful features. We use climate data to illustrate the concepts.

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PP1

How Typical Is Solar Energy? A 6 Year Evaluation of Typical Meteorological Year Data (TMY3)

The US solar industry makes bets on system performance using NRELs typical meteorological year data (TMY3). TMY3 is a 1-year dataset of typical solar irradiance and other meteorological elements used for simulation of solar power production. Irradiance naturally varies from TMY3 temporally and geographically, thus creating risk. Using data from NOAAs Surface Radiation Network (SurfRad), 6-years of irradiance observations were analyzed. Statistically comparing SurfRad against TMY3 quantified temporal and geographic uncertainty in typical solar irradiance.

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PP1

Second-Order Probability for Error Analysis in Numerical Computation

It is difficult to quantify the uncertainty for numerical computation because computational error are deeply affected by many epistemic uncertainty variables. The best known methods for estimating computational error are Richardson extrapolation(RE) and generalized RE. However, it only estimate descretization error. In this paper we propose second-order probability method for error analysis in numerical computation. This method can provide integrated error analysis for all error sources and quantify measurement uncertainty of numerical computation error.

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Organizer and Speaker Index

SIAM Conference on

Uncertainty Quantification

Raleigh Marriott City Center Hotel
Raleigh, North Carolina, USA
April 2-5, 2012

Italicized names indicate session organizers.

D

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Notes

UQ12 Budget

Conference Budget

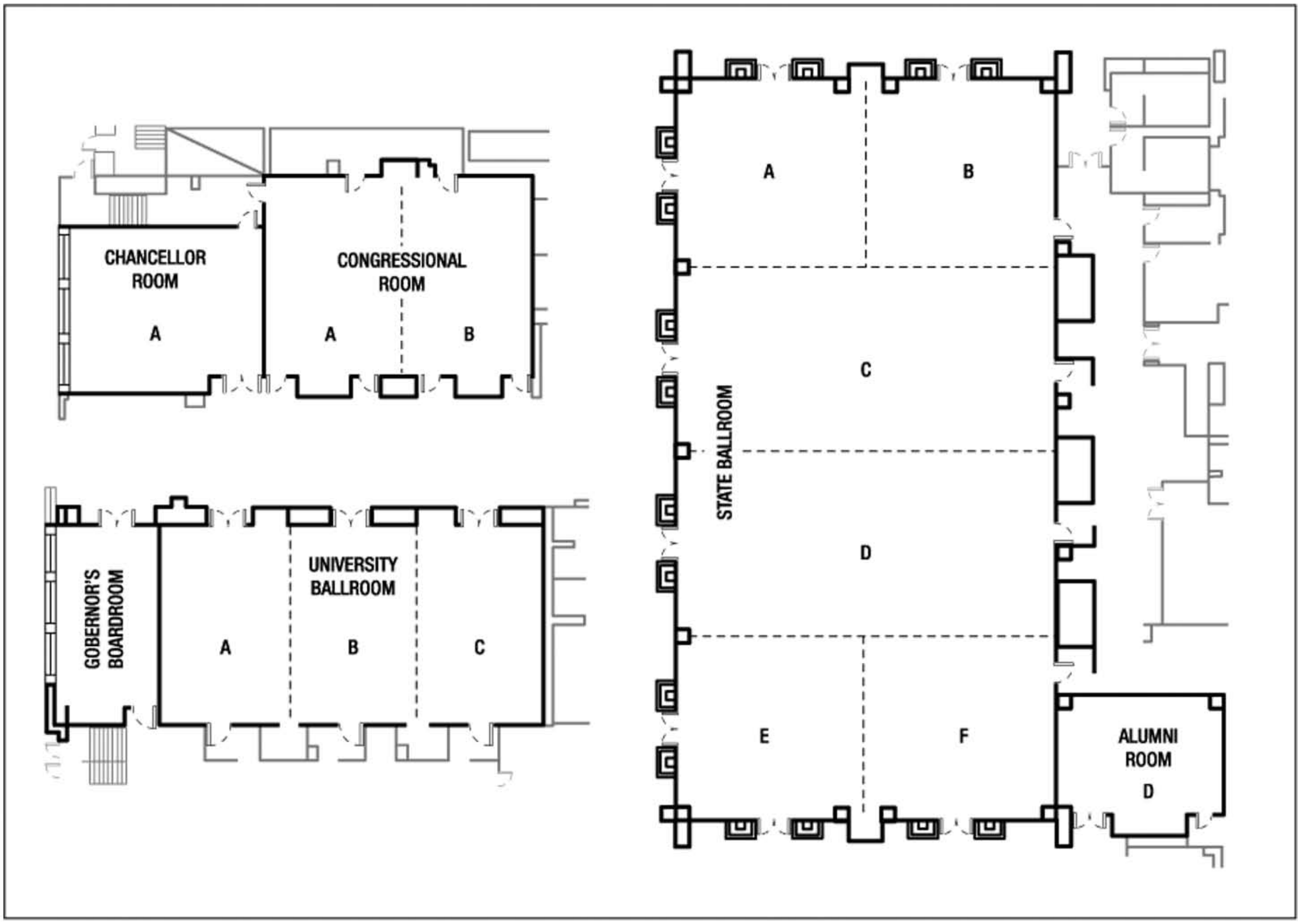
SIAM Conference on Uncertainty Quantification
April 2 - 5, 2012
Raleigh, NC

Expected Paid Attendance: 400

Revenue		
Registration		$130,780
Total		$130,780
Direct Expenses		
Printing		$2,700
Organizing Committee		$2,100
Invited Speaker		$12,750
Food and Beverage		$22,000
Telecomm		$1,500
AV and Equipment (rental)		$17,325
Room (rental)		$5,500
Advertising		$3,800
Conference Staff Labor		$23,600
Other (supplies, staff travel, freight, exhibits, misc.)		$3,200
	Total Direct Expenses:	$94,475
Support Services: *		
Services covered by Revenue		$36,305
Services covered by SIAM		$33,014
	Total Support Services:	$69,319
	Total Expenses:	$163,794

* Support services includes customer service, accounting, computer support, shipping, marketing and other SIAM support staff. It also includes a share of the computer systems and general items (building expenses in the SIAM HQ).

Raleigh Marriott City Center Hotel Map



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