International Workshop on
Long time stochastic and statistical approximations for turbulent dynamical systems

Organized by Professor Andrew Majda

Fudan University, Shanghai, China
May 24 - 27, 2012

VENUE:
Room 1801, East Guanghua Main Building, School of Mathematical Sciences
Fudan University, No. 220 Handan Road, Shanghai, China
TABLE OF CONTENTS

SCIENTIFIC PROGRAM ....................................................... 1
TITLES AND ABSTRACTS ..................................................... 3

INVITED SPEAKERS:

Michał Branicki (Courant, USA)
Mickael D. Chekroun (UCLA, USA)
Andrey Gritsun (RAS, Russia)
Martin Hairer (Warwick, UK)
Xuerong Mao (Strathclyde, UK)
Andrew Majda (Courant, USA)
Ricardo M. S. Rosa (UFRJ, Brasil)
Themis Sapsis (Courant, USA)
Andrew Stuart (Warwick, UK)
Eric Vanden-Eijnden (Courant, USA)
Xiaoming Wang (FSU, USA)
Djoko Wirosotisno (Durham, UK)

SCIENTIFIC COMMITTEE:

Andrew Majda (Courant, USA)
Tatsien Li (Fudan, China)
Jiaxing Hong (Fudan, China)
Xiaoming Wang (Florida State U., USA)
Jin Cheng (Fudan, China)

CO-ORGANIZED BY:

School of Mathematical Sciences, Fudan University, Shanghai, China
Shanghai Key Lab of Contemporary Applied Math, Shanghai, China
Nonlinear Mathematical Modeling and Methods Laboratory, Ministry of Education, China

SPONSORED BY:

111 Project
National Science Foundation of China
Fudan University, Shanghai, China
# Program

<table>
<thead>
<tr>
<th>Date</th>
<th>Morning Session</th>
<th>Afternoon Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 23rd</td>
<td></td>
<td>14:00PM—16:00 PM</td>
</tr>
<tr>
<td>(Wednesday)</td>
<td></td>
<td>Michal Branicki</td>
</tr>
<tr>
<td></td>
<td>09:30 AM—09:40 AM</td>
<td>14:00PM—14:50 PM</td>
</tr>
<tr>
<td></td>
<td>Opening ceremony</td>
<td>Xuerong Mao</td>
</tr>
<tr>
<td></td>
<td>09:40 AM —10:30 AM</td>
<td>14:50 PM—15:10 PM</td>
</tr>
<tr>
<td></td>
<td>Andrew Stuart</td>
<td>Tea break</td>
</tr>
<tr>
<td>May 24th</td>
<td></td>
<td>15:10 PM—16:00 PM</td>
</tr>
<tr>
<td>(Thursday)</td>
<td>10:30 AM—10:50 AM</td>
<td>Djoko Wirososetisno</td>
</tr>
<tr>
<td></td>
<td>Tea break</td>
<td>16:00 PM—16:20 PM</td>
</tr>
<tr>
<td></td>
<td>10:50 AM—11:40 AM</td>
<td>Tea break</td>
</tr>
<tr>
<td></td>
<td>Michal Branicki</td>
<td>16:20 PM—17:10 PM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Themis Sapsis</td>
</tr>
<tr>
<td>Time Slot</td>
<td>Morning Session</td>
<td>Afternoon Session</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Morning Session</td>
<td>09:30 AM—10:20 AM Andrew Stuart</td>
<td>14:00 PM—14:50 PM Michał Branicki</td>
</tr>
<tr>
<td>Afternoon Session</td>
<td>10:20 AM—10:40 AM Tea break</td>
<td>14:50 PM—15:10 PM Tea break</td>
</tr>
<tr>
<td>May 25th</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Friday)</td>
<td>10:40 PM—11:30 PM Themis Sapsis</td>
<td>15:10 PM—16:00 PM Xiaoming Wang</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17:00 PM—20:00 PM Banquet</td>
</tr>
<tr>
<td>Morning Session</td>
<td>09:30 AM—10:20 AM Andrey Majda</td>
<td></td>
</tr>
<tr>
<td>Afternoon Session</td>
<td>10:20 AM—10:40 AM Tea break</td>
<td>14:00 PM—16:00 PM Free discussion on</td>
</tr>
<tr>
<td>May 26th</td>
<td></td>
<td>challenges and trends</td>
</tr>
<tr>
<td>(Saturday)</td>
<td>10:40 PM—11:30 PM Andrey Gritsun</td>
<td></td>
</tr>
</tbody>
</table>
<Titles and abstracts>

Michal Branicki
Courant Institute of Mathematical Sciences
New York University
251 Mercer Street, New York, 10012 NY, USA
Email: branicki@cims.nyu.edu

Title:
Fundamental Limitations of Polynomial Chaos Expansions for Uncertainty Quantification in Systems with Intermittency

Abstracts:
There has been a recent growth of interest in the scientific computing and engineering communities in expansion-based methods for quantifying the uncertainty due to random or unresolved processes in predictions of complex nonlinear systems. I will discuss the suitability of two such techniques: the truncated Polynomial Chaos Expansions (PCE) and truncated Gram-Charlier Expansions (GrChE) as possible methods for uncertainty quantification (UQ) in systems with intermittency and positive Lyapunov exponents. Based on a simple, statistically exactly solvable non-linear and non-Gaussian test model, I will show in detail that these methods have significant limitations for UQ in systems with intermittent instabilities or parametric uncertainties. Intermittency and fat-tailed probability densities are hallmark features of the inertial and dissipation ranges of turbulence and it turns out that in such important dynamical regimes PCE performs, at best, similarly to the vastly simpler Gaussian moment closure technique. Moreover, I will show that the non-realizability of the GrChE approximations is linked to the onset of intermittency in the dynamics.

Title:
Quantifying Uncertainty for Long Range Forecasting Scenarios with Model Errors in Non-Gaussian Systems with Intermittency

Abstract:
Synergy between the empirical information theory and fluctuation-dissipation type approach for forced dissipative systems
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. An important theme present throughout will concern the information barriers to imperfect model improvement. The first talk will focus on the ‘single mode’ framework which will be followed by extending these concepts to spatially extended turbulent systems.
Andrey Gritsun
Institute of Numerical Mathematics
Russian academy of Sciences
8 Gubkina str., Moscow, 119333,Russia

Email: asgrit@mail.ru

Title:
Estimation of the sensitivity of atmospheric systems using fluctuation -
dissipation theorem

Abstract:
In this study we discuss one possibility to estimate response operators of the statistical characteristics of (chaotic, dissipative) atmospheric systems onto small external forcing.

The method is based on applying fluctuation-dissipation theorem (FDT) which states ([1,2,3]) that for systems with stationary quasi-Gaussian PDF a response of system statistical characteristics to weak external forcing could be expressed in terms of covariances and lag-covariances of fluctuations of the unperturbed system. C.Leith ([4]) expressed an idea that the dynamics of the Earth's atmosphere is reasonably close to the conditions required by FDT and suggested to use FDT in climate studies. The major advantage of this approach is that one may calculate climate system approximate response operator (relating changes in the system statistics with changes in the system external forcing) using observational data only.

In this study we use FDT to construct approximate response operators for the atmospheric general circulation models CCM0 and CAM3 of National Center for atmospheric research and INM-A5421 of Institute of numerical mathematics RAS. It is demonstrated that with these operators one may solve inverse problem of finding external forcing producing a prescribed response of the system average state with sufficient accuracy. Another important application is the analysis of the system sensitivity (i.e. the calculation of the external forcing that produces the maximum possible response of the system).

References.
4. Leith, C. E., Climate response and fluctuation dissipation, J. Atmos. Sci.,
Andrew Majda

Morse Professor of Arts and Science
Department of Mathematics and
Climate, Atmosphere, Ocean Science (CAOS)
Courant Institute of Mathematical Sciences
New York University
Warren Weaver Hall, 251 Mercer Street, New York, NY 10012, USA

Email: jonjon@cims.nyu.edu

Title:
TBA

Abstracts:
TBA
Xuerong Mao

Department of Mathematics and Statistics
University of Strathclyde
26 Richmond Street
Glasgow G1 1XH, UK

Email: x.mao@strath.ac.uk

Title:
Numerical Methods for Hybrid SDEs

Abstracts:
Nonlinear hybrid stochastic differential equations (SDEs) appear in many branches of science and industry. Our aim here is to discuss asymptotic properties of the numerical solutions of the hybrid SDEs. More precisely, the issue which we address in this talk is: can a numerical method reproduce the asymptotic properties of the underlying hybrid SDE? The asymptotic properties in this talk include the exponential stability and stationary distributions, while the numerical methods include the Euler-Maruyama (EM) and the backward EM. Several examples and computer simulations will be used to illustrate the theory.
Themistoklis Sapsis

New York University
251 Mercer str., New York, 10012

Email: sapsis@cims.nyu.edu

Title:
Interplay of dynamical instabilities, non-Gaussian statistics, and energy transfers in fluid flows with low-dimensional attractors

Abstracts:
We examine the geometry of the inertial manifold associated with fluid flows described by Navier-Stokes equations and we relate its nonlinear dimensionality to energy exchanges between the mean flow and stochastic modes of the flow. Specifically, we employ a stochastic framework based on the dynamically orthogonal field equations to perform efficient order reduction in terms of time-dependent modes and describe the inertial manifold in the reduced-order phase space in terms of the associated probability measure. We introduce the notion of local fractal dimensionality and we establish a connection with the finite-time Lyapunov exponents of the reduced-order dynamics. Based on this tool we illustrate in 2D Navier-Stokes equations 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 the stochastic fluctuations (containing in general smaller lengthscales) back to the mean flow (which is characterized by larger spatial scales).

Title:
Blended reduced subspace algorithms for uncertainty quantification of systems with high-dimensional attractors and strong energy cascades

Abstracts:
We study uncertainty-quantification (UQ) properties of the Quasi-linear Gaussian (QG) closure method and we compare it with the results from order-reduction based on dynamical orthogonality (DO) equations. We find that each of these approaches suffer from disadvantages that can be overcome by combining them. Specifically, the QG method is incapable to capture strong energy transfers among linearized modes. On the other hand, due to the reduced order character the DO approach is incapable to capture the full-order effect of the linearized operator which in many cases (e.g. skew systems) can be critical for the correct evolution of the statistics. We formulate a blended approach based on these two methods which can be further improved by adding empirical information.
Andrew Stuart
Mathematics Institute,
University of Warwick
Coventry CV4 7AL, UK

Email: a.m.stuart@warwick.ac.uk

Title:
How Does The EnKF Work?
Permeability Estimation in Subsurface Flow
(Joint work with MA Iglesias and K Law)

Abstracts:
Estimation of distributed parameters, such as permeability fields, is a key inverse problem in subsurface geophysics. The ensemble Kalman filter is widely used within the petroleum industry for such problems, yet it is incompletely understood as a tool for inversion. The talk will contain two components. In the first I will use the "gold standard" of MCMC-based Bayesian Inversion to evaluate the ability of EnKF to reproduce the posterior mean and covariance of the permeability. In the second I will study in detail the structure of the EnKF solution to the inverse problem and discuss some of its' properties.

Title:
How Does 3DVAR Work?
State Estimation in Navier-Stokes Equation
(Joint work with D Bloemker, K Law and K. Zygalakis)

Abstracts:
3DVAR is a basic filtering scheme used for state estimation in high dimensional systems in which an incompletely known initial condition is compensated for by partial noisy observations. The aim of this work is to demonstrate how variance inflation, which weights the data in favour of the model, works for such state estimation problems. Since 3DVAR is prototypical of many more advanced filters used in practice, analysis of its properties will serve as a useful building block. The key mechanism is to combine the squeezing property (contraction at high wave numbers) with observed data (contraction at low wave numbers) to induce an overall contraction in the filter. This mechanism is illustrated for both discrete time filtering, and a stochastic PDE which arises as the limit of 3DVAR with high frequency data.
Title:
Numerical schemes for long time statistical properties of turbulent dynamical systems

Abstracts:
We will discuss methodologies that can be used to design numerical schemes that are able to capture long time statistical properties of turbulent dynamical systems governed by dissipative partial differential equations. In particular, we will offer criterions in terms temporal, spatial, and fully discretized algorithms that guanrantee the desired convergence of long time statistical properties. Noise effect will be discussed as well.
Djoko Wirosoetisno

Mathematical Sciences
Durham University
Durham, UK

Email: djoko.wirosoetisno@durham.ac.uk

Title:
Long-time stability of timestepping schemes for convection problems

Abstracts:
Several timestepping schemes are considered for a model of convection in 2d Boussinesq fluids. Of particular interest here is when and how one can obtain global-in-time stability in a space strong enough to establish convergence of statistical properties. The curious role of the boundary conditions will be discussed.