# ABSTRACTS

**Alberto Carrassi,** *Institut Catala de Ciencies del Clima, Barcelona Spain*

**Data Assimilation in Geoscience: From Weather to Climate Prediction (1 lecture)**

The objective of the talk is to give an overview of the Data Assimilation (DA) problem in environmental science. DA is the procedure through which observations and model are merged to get an improved and homogeneous estimate of a system. In numerical weather and oceanic predictions DA has dramatically contributed to enhance the forecast skill and its application to coupled Earth System Simulators (ESS) is nowadays regarded with strong interest as a unified initialization approach across all forecast horizons from NWP to seasonal and decadal. The talk will provide an introduction of the context and rationale behind DA theory and will describe the main methodological options arisen in geosciences in the last decades with a focus on the theoretical and mathematical challenges encountered. The Assimilation in the Unstable Subspace (AUS) to control chaotic error growth, and the deterministic treatment of model error will be also overviewed. The state-of-the-art in the new frontier of the coupled-DA for long-term (seasonal-to-decadal) predictions will be described at the end along with the results using a nudging approach in the framework of a realistic climate model.

**Dan Crisan,** *Imperial College, London UK*

**Convergence of particle filters and relation to data assimilation (3 lectures)**

Both stochastic filtering and data assimilation are dealing with the problem of merging models with partial observations. Data assimilation has stronger focus on algorithms for large scale problems and large data sets whilst stochastic filtering has stronger focus on asymptotic behaviour and consistency. Both fields are moving towards each other in a manner similar to that of machine learning versus statistics. One of the most successful classes of numerical methods for solving the stochastic filtering problem is that of sequential Monte Carlo methods, also known as particle filters. The aim of the mini-course is to present a bird's-eye view of the topic of particle filters, including the standard bootstrap (SIR) algorithm and branching algorithms, with emphasis on classical convergence results. Various parallels between particle filters and data assimilation will be emphasized.

**Elaine Spiller,** *Marquette University, Milwaukee WI USA*

**Importance sampling (1 lecture)**

Importance sampling is a ubiquitous tool under the umbrella of Monte Carlo simulations. I will outline ideas behind importance sampling in a general framework and discuss how it is commonly utilized in sequential Monte Carlo/particle filtering methods. Then I will present some examples using importance sampling with particle filters in the context of Lagrangian data assimilation.

**N. Sri Namachchivaya,** *University of Illinois at Urbana-Champaign, IL USA*

**Dimensional reduction and data assimilation in random dynamical systems**

Non-linearities of the governing physical processes in complex systems allow energy transfer between different scales, and many aspects of this complex behavior can be represented by stochastic models. An understanding of how scales interact with information can lead to the development of rigorous reduced-order data assimilation techniques for high-dimensional problems. This series of lectures combines stochastic dimensional reduction and nonlinear filtering to provide a theoretical framework for the development of lower dimensional particle filters, which are specifically adapted to the complexities of multi-scale signals. The lectures are organized as follows:
1) stochastic dimensional reduction;
2) dimensional reduction in nonlinear filtering;
3) reduced-order nonlinear filtering algorithm with application to a chaotic system.

**Ramon van Handel,** *Princeton University, Princeton NJ USA*

**Filtering in high dimension (3 lectures)**

Broadly speaking, the goal of filtering theory is to understand the properties of conditional distributions of stochastic models given observed data. While filtering problems have been studied in probability theory for more than half a century, conditional phenomena that arise in high dimension are only beginning to be explored. In these lectures I will aim to give an overview of some new questions and probabilistic phenomena that arise in high-dimensional filtering problems, and to develop some basic mathematical tools for this purpose. I will also explain potential implications of these ideas for the design and analysis of algorithms for data assimilation in complex systems, and outline some open problems that could merit further investigation.

**Rajeeva Karandikar,** *Chennai Mathematical Institute, Kelambakkam India*

**Introduction to Non-linear Filtering**

In this talk we will give an introduction to Stochastic Filtering theory. We will discuss the Zakai equation, Fujisaki-Kallianpur-Kunita (FKK) equation, Kushner-Stratenovich equation. We will also discuss the Characterisation of the filter as unique solution to these equations and Robustness

**Sanjoy Mitter,** *Massachusetts Institute of Technology, Cambridge MA USA*

**Variational approach to Nonlinear Estimation**

In this talk I give a Variational Interpretation of Bayesian Inference as Free Energy Minimization in analogy with the characterization of Gibbs Distributions as Free Energy Minimization. In the case that the estimand is a Markov Diffusion Process the Free Energy Minimization Problem has a stochastic control interpretation. This solves the longstanding open problem of the Duality between Estimation and Control. Joint work with Nigel Newton, University of Essex.

## SHORT TALKS

**Alejandro Aceves**, *Southern Methodist University, Dallas TX USA*

Modeling the Atlantic Meridional Overturning Circulation and its impact on Climate: A dynamical systems approach

**Gopal Basak**, *Indian Statistical Institute, Kolkata, India*

**Diffusion Approximation to Adaptive MCMC**

Adaptive MCMC algorithms are designed to tune the chain properly to decrease the time to convergence to stationary. However since the transition kernel is changed at each step of iteration proper ergodicity conditions has to be ensured. Here we define a discrete time Adaptive MCMC algorithm and study its convergence properties. We apply the diffusion approximation method to a discrete time Adaptive MCMC procedure to obtain the limiting stochastic differential equation governing the dynamics of the adaptation parameter $\theta$ and the state space variable $X$. The solution to the coupled equation will give the stationary distribution of the chain. Comparison of rates of convergence between the standard and the adaptive method will be of interest.

**Gugan Thoppe**, *Tata Institute of Fundamental Research, Mumbai*

**Optimization in Very High Dimensions.**

Optimization in or more variables is now common in many machine learning and Internet applications. But solving them using traditional gradient based sequential algorithms will mean an enormous main memory requirement and a prohibitively large waiting time per iteration. In this talk, we propose an alternative approach: in each iteration, the new estimate is the optimum of the objective function restricted to a random dimensional affine space, passing through the old estimate. Cleverly chosen affine spaces will give the ability of varying to trade-off the computational effort and program data required per iteration with the convergence rate; enable parallelization as well as a distributed storage of program data. We demonstrate this by giving a novel algorithm, with serial and parallel versions, for unconstrained quadratic programming. For a chosen d, the program data is partitioned in to blocks and only one of them, picked randomly, is used per iteration. The serial version has a preprocessing time of and a per iteration running time of The parallel scheme uses processors and cuts these down to and respectively. Both have an expected convergence rate of  The parallel version, under certain conditions, is faster than the sequential conjugate gradient scheme. This is joint work with Dinesh Garg, IBM-Research India, Delhi; and Vivek Borkar, Indian Institute of Technology Bombay, Mumbai.

**Jesse Berwald**, *Institute for Mathematics and Its Applications, University of Minnesota, USA*

**Localized Parameter Estimation**

We study parameter estimation for non-global parameters in a low-dimensional chaotic model using the local ensemble transform Kalman filter (LETKF). By modifying existing techniques for using observational data to estimate global parameters, we present a methodology whereby spatially-varying parameters can be estimated using observations only within a localized region of space. This talk will constitute a brief overview of this work.

**Neeraj Sharma**, *Indian Institute of Science, Bangalore India*

**Detect and Sample: Event-triggered sampling and reconstruction of sparse real trigonometric polynomials**

Given a continuous-time signal data-acquisition for storage and processing can be carried out in regular or irregular time intervals. Regular (also called uniform) sampling in time is a classical method of data-acquisition, thanks to the bandlimited (in frequency content) structure of natural signals. We examine an event-triggered approach for data-acquisition from a continuous-time signal. This approach enables data-acquisition only when a preset event occurs in the signal. The samples are now irregularly acquired in time. We highlight robustness of such samples for jitter and additive noise, and address reconstruction of the underlying continuous-time signal using an additional structure of sparsity in bandlimited frequency content of the signal. Here, we will focus on level crossing (LC), close to extrema LC, and extrema events. In the proposed approach both data-acquisition and signal reconstruction are non-linear operations which contrasts with classical Shannon sampling and reconstruction approach. We will highlight the implications of this from data analysis perspective.