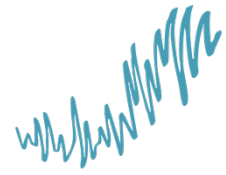


Stochastic Differential Equations:
Computation, Inference, Applications

COST Action CA24104



STOCHASTICA

STOCHASTICA Directions Workshop, April 27-29, 2026

*Aula Maxima,
University College Cork,
Ireland*

Programme and Book of Abstracts

Plenary speakers

All times are Irish Summer Time (GMT+1). All talks will be held in the Aula Maxima.

Monday April 27, 2026

09:30-10:30 *Registration and Tea/Coffee*

10:30-11:00 *Welcome from the President of UCC and Working Group introductions*

11:00-11:40 *Glenn Marion (Biomathematics and Statistics Scotland, UK)*

Opportunities and barriers in application of stochastic differential equations to agriculture and ecology

I will highlight a range of modelling applications from current work in agriculture and ecology and consider opportunities for, and barriers to, use of stochastic differential equations (SDEs) in tackling key challenges in these sectors. I will show illustrative examples where these continuous state-space stochastic processes are employed and areas where they are currently not. Examples include the dynamics of anti-microbial resistance, natural pest control, and infectious disease modelling. In doing so I will identify perceived and possibly methodological barriers to application of SDEs that I believe STOCHASTICA could address through development of novel tools, and enhanced dissemination of existing tools, results and capabilities to a wider audience.

11:40-12:20 *Susanne Ditlevsen (University of Copenhagen, Denmark)*

Estimation of tipping points in complex systems

Early warning signals for tipping are typically second order statistics, namely increasing variance (loss of resilience) and increasing autocorrelation (critical slowing down). However, it is statistically challenging to estimate these from non-stationary data, which is exactly the case for systems approaching tipping points. Moreover, the systems are typically highly non-linear and noisy, and this even more so, the closer to the tipping point. I will discuss such statistical challenges for estimating essential quantities and doing statistical inference related to tipping systems.

12:20-13:50 *Lunch*

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Monday April 27, 2026

13:50-14:30 Katie O'Brien (Health Protection Surveillance Centre, Ireland)

Infectious disease modelling: Move beyond deterministic models?

Classic compartmental models are widely used to represent infectious disease transmission in populations and have proven valuable in many settings. At the Health Protection Surveillance Centre (HPSC) within Ireland's Health Service Executive, we frequently support planning and resource allocation by producing scenario models for a range of infectious diseases—for example, anticipating larger seasonal influenza epidemics, assessing the dynamics of measles outbreaks in a highly but unevenly vaccinated population, or evaluating the potential impact of new interventions such as nirsevimab for Respiratory Syncytial Virus (RSV).

To date, our work has largely relied on deterministic modelling approaches, which offer transparency, reproducibility, and computational simplicity. However, as questions become more nuanced and as we increasingly confront smaller outbreaks, heterogeneous contact structures, or rare events, we are interested in exploring stochastic elements for our models.

In this talk, I will outline the deterministic methods currently used within HPSC, highlight the challenges we encounter, and discuss when and why it becomes important to incorporate stochastic elements into model design.

14:30-15:10 Steffen Dereich (Universität Münster, Germany)

Convergence analysis for the Adam algorithm

The talk is concerned with a mathematically rigorous analysis of one of the standard algorithms currently employed for training neural networks, the Adam algorithm, introduced by Kingma and Ba in 2014. This algorithm is an enhancement of the traditional stochastic gradient descent, incorporating a momentum approach together with a damping factor. During the presentation, I will present new error estimates for the Adam algorithm. Specifically, we demonstrate that the algorithm's effective behavior is closely connected to a particular vector field, that we call the Adam field. We will provide an error estimate for the speed of convergence for the classical Adam algorithm and a central limit theorem for an averaged Adam algorithm, both under an appropriate monotonicity assumption on the Adam vector field.

15:10-15:40 Coffee/Tea

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Monday April 27, 2026

15:40-16:20 Pawel Morkisz (Aigorithmics, Poland)

Noise, Precision, and Stochastic Differential Equations: From Numerical Analysis to Modern AI Systems

Stochastic differential equations (SDEs) play a central role in modeling uncertainty across science and engineering. In classical numerical analysis, the accuracy of approximation methods such as Euler or Milstein schemes is typically studied under the assumption that the driving noise and model evaluations are observed exactly.

In many realistic settings, however, computations are performed using inexact or noisy information. This situation naturally arises in numerical simulations with measurement errors, as well as in modern machine learning systems where aggressive low-precision arithmetic and quantization are widely used to accelerate computation.

In this talk we discuss the impact of noisy information on numerical methods for SDEs. We present recent theoretical results establishing upper and lower bounds for approximation errors in models where perturbations affect the Wiener process and evaluations of the drift and diffusion coefficients. These results quantify how different sources of noise influence achievable accuracy.

We then place these findings in a broader context by discussing emerging connections with modern machine learning systems. In particular, we highlight how stochastic differential equations appear in diffusion models and how the growing use of low-precision computation (e.g., 16-bit, 8-bit, 4-bit, and below) raises new questions about the interaction between stochastic dynamics and computational noise.

The goal of the talk is to illustrate how classical questions from information-based complexity and numerical analysis remain highly relevant in contemporary large-scale AI systems.

16:20-17:00 Wrap-up discussion

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Tuesday April 28, 2026

09:10-09:50 Miguel Munoz Zuniga (IFP Energies nouvelles, France)

Quantification and reduction of uncertainty in complex ‘black-box’ numerical models analysis using Gaussian processes

Learning from complex simulations, which are subject to uncertainties related to input data or the model, is a major challenge in the energy sector, particularly as the more accurate the quantification of uncertainties, the more relevant the decision-making process becomes. In this context, modelling using surrogates of high-fidelity simulators, which are costly to evaluate, lies at the heart of modern uncertainty quantification.

In this presentation, I will provide an overview of several such examples involving Gaussian processes for the uncertainty analysis of real numerical models, such as a wind turbine simulator or a vehicle emissions control system. I will then discuss more recent developments highlighting some links between ‘black-box’ uncertainty analysis, stochastic calculus and stochastic differential equations.

09:50-10:30 Sander Rieken (Alliander, The Netherlands)

Stochastics for Energy Distribution Systems

In this talk, I will present a selection of challenges arising in Dutch distribution grids where stochastic modeling could play a key role. Examples include load forecasting under high volatility, prediction of peak demand in increasingly congested networks, modelling of accelerated asset degradation and ageing under increased loading, and inverse problems for where asset states must be inferred from limited and noisy measurements.

10:30-11:00 Coffee/Tea

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Tuesday April 28, 2026

11:00-11:40 Yue Ying (Nansen Environmental and Remote Sensing Center, Norway)

Advancing multiscale and non-Gaussian data assimilation methodology for geophysical models

The data assimilation (DA) for geophysical models presents a fundamental conflict between computational scalability and forecast accuracy. These problems are characterized by two primary challenges: high dimensionality ($O(10^7)$ model variables) and high nonlinearity arising from chaotic dynamics at smaller scales. Currently, the Ensemble Kalman Filter (EnKF) and its variants are the workhorses for large-scale geophysical model systems thanks to their scalability and computational efficiency. However, the EnKF relies on a linear-Gaussian assumption that doesn't capture the non-Gaussian error distributions inherent in nonlinear dynamics. On the other hand, nonlinear methods such as the Particle Filter suffers from the curse of dimensionality, rendering them computationally infeasible for high-dimensional problems. To bridge this gap, the DA community has pursued scalable non-Gaussian methods, including the integration of AI techniques in the DA workflow. In this talk, I discuss the current state of these methodologies and their potential for operational ocean and sea ice forecasting. I will also highlight the objectives of the upcoming EU Horizon project, COMEDI, which investigates novel DA frameworks such as multiscale, non-Gaussian, and AI-based approaches to address the challenges in the operational ocean and sea ice forecasting within the Copernicus Marine Service.

11:40-12:20 Francesco Piazza (Università di Firenze, Italy)

Noise in Biology: Hidden States, Fate Decisions, Sensing Limits, and Self-Organized Order

Noise in biology is not only a source of variability: it can reveal hidden molecular states, trigger rare cell-fate decisions, limit the precision of sensing, and even generate macroscopic temporal order. This lecture develops a compact set of mathematically clean examples built around master equations and stochastic processes, ranging from promoter switching and bursty protein synthesis yielding super-Poisson fluctuations, excitable genetic modules, sensing bounds for cells reading chemical concentrations, and purely noise-generated quasi-cycles in systems whose deterministic dynamics are damped. The common theme is that biological noise becomes informative once it is filtered by network architecture, timescale separation, and nonequilibrium dynamics.

12:20-13:50 Lunch

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Tuesday April 28, 2026

13:50-14:30 Valerie Livina (National Physical Laboratory, UK)

Tipping point analysis of real-world complex systems

In the recent years, tipping point analysis became popular in diverse applications, from ecology to structure health monitoring. The approach helps anticipate, detect, and forecast critical transitions in dynamical systems. The methodology combines monitoring short- and long-term memory in time series with potential analysis that analyses and extrapolates the system states.

For anticipating tipping points, early warning signal (EWS) indicators utilise dynamically derived scaling properties (for example, lag-1 autocorrelation [Held & Kleinen 2004], power-law scaling exponent of Detrended Fluctuation Analysis [Livina & Lenton 2007] power-spectrum-based EWS indicator [Prettyman et al 2018]).

We will discuss various applications in engineering systems [Livina et al 2014; Livina et al, 2020; Mesa et al, 2021; Billuroglu and Livina, 2022] and demonstrate an application of potential forecasting [Livina et al, Physica A 2013] to the WISE water accounts of European river basins [Livina, Chaos 2026].

14:30-15:10 Cornelis Oosterlee (Utrecht University, The Netherlands)

The deep multi-FBSDE method: a robust deep learning method for coupled FBSDEs

We present the deep multi-FBSDE method for robust approximation of coupled forward-backward stochastic differential equations (FBSDEs), focusing on cases where the deep BSDE method of Han, Jentzen, and E (2018) may fail to converge. To overcome the convergence issues, we consider a family of FBSDEs that are equivalent to the original problem in the sense that they satisfy the same associated partial differential equation and initial value. Our algorithm proceeds in two phases: first, we approximate the initial condition jointly for a small number of FBSDEs from the FBSDE family, and second, we approximate the original FBSDE using the initial condition approximated in the first phase. Numerical experiments show that our method converges even when the standard deep FBSDE method does not.

15:10-15:40 Coffee/Tea

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Tuesday April 28, 2026

15:40-16:20 Giulia Di Nunno (University of Oslo, Norway)

BSDEs and Operator Deep BSDEs for dynamic risk evaluation

Backward SDEs (BSDEs) have been used for dynamic risk measurement, we revise the framework and value of a dynamic risk evaluation. We also indicate some shortcomings, particularly related to the evaluation of risk at different time horizon, introduced as horizon-risk. For this reason we introduce the concept of fully-dynamic risk measurement and show how it is still easily related to BSDEs. As illustration we consider variation to the entropic case as well as we introduce the h_q -entropic risk measure inspired by Tsallis general entropy. We discuss computational methods from an operator point of view, proposing an Operator Deep BSDE approach.

16:20-17:00 Wrap-up discussion

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Wednesday April 29, 2026

09:10-09:50 Joaquin Miguez (Universidad Carlos III de Madrid, Spain)

Bayesian filters for continuous-discrete dynamic models

The continuous-discrete filtering problem consists in tracking the probability distribution of a continuous-time stochastic process (the system state) conditional on a sequence of observations collected over a time grid. This setting appears very naturally in many scientific and engineering applications, e.g., numerical weather prediction, tracking of space debris, space weather forecasting, sensor networks, etc. In this talk, we discuss some of the most common numerical algorithms for continuous-discrete filtering and discuss their main shortcomings. Then we explore some recent approaches and identify research topics that may lead to improved methods, especially in high-dimensional or otherwise complex problems where current schemes underperform.

09:50-11:00 Working Groups meet

11:00-11:40 Dan Crisan (Imperial College London, UK)

Stochastic Partial Differential Equations in Fluid Dynamics

Stochastic partial differential equations (SPDEs) have become an important framework for modelling uncertainty and unresolved dynamics in fluid flows. In this talk, I will present an overview of some SPDEs arising in fluid dynamics, with particular emphasis on the rotating shallow water equation with SALT noise. I will discuss recent theoretical developments concerning their well-posedness as well as numerical approaches for their simulation and calibration. The talk concludes with a discussion of several open problems, including questions related to well-posedness, statistical inference, numerical stability, and the role of stochastic forcing in capturing the multiscale features of turbulent flows.

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Wednesday April 29, 2026

11:40-12:20 Valentin Resseguier (INRAE, France)

Stochastic fluid dynamics & skew-symmetric multiplicative noise

The talk will present some issues raised by fluid dynamics applications. The focus will be on ensemble forecasts, data assimilation/filtering, and Bayesian inverse problems in general.

The talk will begin with a modeling approach. The multiscale nature of turbulence calls for stochastic calculus frameworks. In particular, transportation noises are becoming increasingly popular. They appear from a physical interpretation of the Ito-Wentzell formula, eventually leading to SPDEs with skew-symmetric multiplicative noises or other remarkable geometric structures.

Then, going toward physics-aware machine learning, we will see how score matching can accommodate skew-symmetric multiplicative noises and transport noises in particular. Many mathematical questions remain open here.

I will conclude with some recent generalizations of transport noise where the multifractal structure of turbulence is better taken into account. The transport by fractional Q-Wiener processes or by Gaussian multiplicative chaos makes all the statistics more realistic and opens new research paths.

12:20-13:50 Lunch

13:50-14:30 Outcome of Stakeholder Consultation

14:30 Workshop closes

List of Posters

The poster session will be held from 5-6pm on **Monday April 27, 2026** in the Aula Maxima.

1. *Fatima-Ezzahrae Bahou (Université Moulay Ismail de Meknes, Morocco)*
Deep Learning Techniques for Solving Nonlinear Partial Differential Equations in High Dimensional Spaces: Application to the Landau–Lifshitz Equation
2. *Ole Cañadas (Dublin City University, Ireland)*
Long-time behaviour & stochastic stability for stochastic Volterra processes
3. *Jasmina Đorđević (University of Niš, Serbia)*
Quadratic Backward Stochastic Differential Equation in General Filtrations
4. *Dusan D. Djordjevic (University of Niš, Serbia)*
Analytical approximations of various types of stochastic differential equations via Taylor expansions
5. *Eva Leahy (University College Cork, Ireland)*
A review of numerical schemes applied to stochastic population models
6. *Marija Milošević (University of Niš, Serbia)*
Stochastic serotonin model with discontinuous drift
7. *Kasper Niss (University of Copenhagen, Denmark)*
Extracting a common signal from time series of different lengths with application to tipping in climate
8. *Maja Obradović (University of Niš, Serbia)*
Stability of the θ -Euler-Maruyama approximation ($\theta \in (1/2, 1)$) for neutral stochastic differential equations with time-dependent delay
9. *Wenshi Tang (University College Cork, Ireland)*
On splitting strategies for the numerical solution of stochastic delay differential equations with correlated noises
10. *Nataša Trišović (University of Belgrade, Serbia)*
Fundamentals of Stochastic Differential Equations in Mechanical Vibrations
11. *Daniel Velinov (Ss. Cyril and Methodius University in Skopje, North Macedonia)*
Weighted Pseudo S -Asymptotically (ω, c) -Periodic Solutions for Stochastic Differential Equations
12. *Shufun Yang (University of Leeds, UK)*
Stochastic Variance Reduction Methods for Overcoming Standard Monte Carlo Errors in Large-Scale Photon Transport Simulation
13. *Sebastian Zeng (Linnaeus University, Sweden)*
Latent-Variable Learning for SPDEs via Wiener Chaos