Maths Foresees General Assembly

5th-7th September 2016, St Leonard's Hall, Edinburgh EH16 5AY

Programme

Monday 5th September		
1230 - 1330	Lunch	
1330 - 1345	Introduction and opening	Onno Bokhove (University of Leeds)
1345 - 1415	The art of the science of getting maths into practice: an Environment Agency perspective	Andy Moores (Environment Agency)
1415 - 1445	TBC (research talk)	Gavin Esler (UCL)
1445 - 1515	Convection problem in a single column - modelling, algorithm and analysis	Matt Turner (University of Surrey)
1515 - 1545	Tea & coffee	
1545 - 1745	Mini-workshop 1: Data assimilation to improve weather and flooding predictions	Sarah Dance (University of Reading) and Gordon Inverarity (Met Office)
1745 - 1815	Discussions	
1900 - late	Network dinner at Blonde (EH8 9QR)	

Tuesday 6th September		
0845 - 0900	Introduction	Onno Bokhove (University of Leeds)
0900 - 0930	An introduction to the Flooding & Coastal Erosion Risk Management Network (FCERM.net)	Garry Pender (Heriot-Watt University)
0930 - 1000	The impact of extreme events on air travel under climate change	Paul Williams (University of Reading)
1000 - 1030	Feasibility study progress: Modelling wave dynamics on jet currents in a flume	Victor Shrira (Keele University) and Sergei Lukaschuk (University of Hull)
1030 - 1100	Tea & coffee	
1100 - 1130	Feasibility study progress: A prototype vortex-in-cell algorithm for modelling moist convection	David Dritschel (University of St Andrews) and Steven Böing (University of Leeds)
1130 - 1200	Feasibility study progress: The effects of	Mark Woodhouse (University of Bristol)

	topographic uncertainty on flood and debris flow modelling	
1200 - 1230	Feasibility study progress: A multiscale model of urban dispersion	Jacques Vanneste (University of Edinburgh)
1230 - 1330	Lunch (JMCC)	
1330 - 1530	Mini-workshop 2: Flood demonstrator Wetropolis: the design of a public engagement project on extreme rainfall and river flooding	Onno Bokhove and Tom Kent (University of Leeds) with Wout Zweers (Wowlab at Roombeek Studios, The Netherlands)
1530 - 1600	Discussion	
1600 - 1630	Tea & coffee	
1630 - 1700	Firedrake: a system for automating the finite element method	David Ham (Imperial College London)
1700 - 1730	Quantifying the time dynamics of the full local distribution of daily precipitations and its uncertainties	Nick Watkins (LSE, University of Warwick and The Open University)
1730	Close (evening meal not covered by network)	

Wednesday 7th September		
0845 - 0900	Introduction	Onno Bokhove (University of Leeds)
0900 - 0930	Feasibility study progress: Multilevel Monte Carlo methods for flood risk assessment	Colin Cotter and Alastair Gregory (Imperial College London)
0930 - 1030	Leeds Flood Alleviation Scheme	Katy Bullock (Leeds City Council) and Mark Garford (Environment Agency)
1030 - 1100	Tea & coffee	
1100 - 1200	Flood forecasting using data assimilation	Arnold Heemink (TU Delft)
1200 - 1330	Closing remarks, lunch and announcement of bid outcomes	Onno Bokhove (University of Leeds)

Abstracts available overleaf.

Abstracts

THE ART OF THE SCIENCE OF GETTING MATHS INTO PRACTICE: AN ENVIRONMENT AGENCY PERSPECTIVE

Andy Moores (Environment Agency)

The talk will focus on (i) the role of the Environment Agency, (ii) how we deliver our research needs, (iii) where we use mathematics, (iv) uptake and enhancing research impact, and (v) some challenges where alternative mathematics-based approaches may help us.

CONVECTION PROBLEM IN A SINGLE COLUMN - MODELLING, ALGORITHM AND ANALYSIS

Matt Turner (University of Surrey)

This was a project which came from the Environmental Modelling in Industry Study Group 2015 held in Cambridge. This talk is based around the work of the group who focused on a model problem of idealised moist air convection in a single column of atmosphere. This talk lays out the model problem and discusses the numerical algorithm proposed to best model the problem. Results are presented showing the algorithm converging to a weak solution of the PDE system as the resolution of the model is increased.

MINI-WORKSHOP

DATA ASSIMILATION TO IMPROVE WEATHER AND FLOODING PREDICTIONS

Gordon Inverarity (Met Office) and Sarah Dance (University of Reading)

The accuracy and usefulness of environmental prediction models, such as for the weather and flooding, depends on the quality of the forecast model and of the observations used to estimate the initial conditions used to start each forecast. Data assimilation is the process whereby information contained in the model formulation and recent observations is blended to provide the best estimate of the state of the system at the start of each forecast. The Bayesian statistical nature of the underlying algorithm and solution approaches will be described along with the practical constraints imposed by an operational forecasting environment, namely the Met Office.

Three topical problems will be described for small groups to consider and propose solutions. These are (i) how to estimate source inputs driving the governing equations, such as rainfall for flooding and pollution emissions for air quality forecasting, (ii) how to ensure that certain quantities, such as tracer concentrations or humidity, remain positive and (iii) how to implement a parallel optimisation algorithm to solve the problem as quickly as possible.

THE IMPACT OF EXTREME EVENTS ON AIR TRAVEL UNDER CLIMATE CHANGE

Paul Williams (University of Reading)

The climate is changing, not just where we live at ground level, but also where we fly at 35,000 feet. We know that air travel contributes to climate change through its emissions. However, we are only now realising that climate change could have significant consequences for air travel. For example, warmer air at ground level reduces the lift force on departing aircraft, and we know that extreme heat episodes are already causing take-off weight restrictions to become more frequent. There is evidence that clear-air turbulence is becoming up to 40% stronger and twice as common. Transatlantic flights may take significantly longer because of changes to the jet stream, adding millions of dollars to airline fuel costs. This talk will summarise and discuss the evidence for these and other impacts of climate change on air travel.

FEASIBILITY STUDY PROGRESS: MODELLING WAVE DYNAMICS ON JET CURRENTS IN A FLUME

Sergei Lukaschuk (University of Hull) and Victor Shrira (Keele University)

Most of oceanic currents are jets, a pattern which is notoriously difficult to reproduce in a flume. On the other hand it is well known that rogue waves are much more frequent on such currents.. The aim of the project is to examine feasibility of laboratory studies of key aspects of wave dynamics upon jet currents. There were two open fundamental questions we had to resolve: (i) Is it possible to create almost uniform strong jet in a flume over the whole length of the flume? (ii) How to model trapped modes on jet currents? The experiments carried out in the Hull flume resulted in the following conclusions. It proved to be impossible to create strong longitudinally uniform jet current in the flume. However, we found a way to create a well pronounced strong jets with a moderate longitudinal weakening and divergence which was sufficient to observe trapped waves and to study their dynamics. We report these observations. Among a number of `first ever' observations we highlight the first observation of blockage for the trapped waves.

FEASIBILITY STUDY PROGRESS: A PROTOTYPE VORTEX-IN-CELL ALGORITHM FOR MODELLING MOIST CONVECTION

David Dritschel[1], Steven Böing[2], Doug Parker[2], Alan Blyth[2]

[1]University of St Andrews, [2]University of Leeds

Climate Models are highly sensitive to the representation of cumulus clouds. These models depend crucially on a statistical representation (parametrisation) of cumulus convection, which involve a large number of assumptions on the behaviour of the convective clouds. Convection-Permitting Models (CPMs) go further by attempting to explicitly resolve the moist dynamics of clouds. CPMs are increasingly used for Numerical Weather Prediction and climate applications. Nevertheless, even these computationally expensive models are only marginally resolving convective clouds, which leads to biases such as too intense deep convection and a poor representation of the non-linear processes that lead to rainfall. We are developing a potentially revolutionary approach to this problem, namely to model both dynamics and processes explicitly using Lagrangian particles. These particles represent miniature "cloud parcels/cloud circulations", and each carries a number of attributes such as liquid water content, buoyancy anomaly, and circulation. We have explored the potential of this approach in a framework using simplified moist dynamics. Our first results compare the fully Lagrangian model to a pseudo-spectral model and the Met Office NERC Cloud model (MONC) in the same framework. We show that the fully Lagrangian model provides a computationally affordable alternative for the simulation of moist physics.

FEASIBILITY STUDY PROGRESS: THE EFFECTS OF TOPOGRAPHIC UNCERTAINTY ON FLOOD AND DEBRIS FLOW MODELLING

Mark Woodhouse[1], Andrew Hogg[1], Jonathan Rougier[1], Paul Bates[1], Rob Lamb[2]

[1]University of Bristol, [2]JBA Trust

Earth surface flows such as floods, debris flows and lahars pose a major hazards to populations and infrastructure. Modelling these flows is essential to mitigating the hazards. We present a shallow-water model that can be used to predict the dynamics of floods, debris flows and lahars.

The flows are primarily driven by gravitational acceleration and so are strongly influenced by the surface topography. Consequently, the accuracy of model predictions is tied to the accuracy of the representation of the topography. Topographic data used in model is not free from error, and quantifying the uncertainty due to the imperfect topography is an essential component of a hazard assessment.

Modern statistical methods allow us to treat the digital elevation map (DEM) as an imperfect observation on the underlying true elevation, and in this way to generate a set of spatially coherent candidates for the true elevation, representing the uncertainty in the DEM. We show modelling the error process in the elevation data as a Gaussian Markov Random Field allows us to efficiently generate candidate DEMs that are consistent with the observed elevation.

The candidate DEMs are used in the flow model to explore the uncertainty in the model predictions due to imprecise topographic data.

FEASIBILITY STUDY PROGRESS: A MULTISCALE MODEL OF URBAN DISPERSION

Jacques Vanneste[1], Ruth Doherty[1], Alexandra Tzella[2]

[1] University of Edinburgh, [2]University of Birmingham

A simple mathematical model of the dispersion of pollutants released in an urban environment represents a (densely built) city centre by a network of one-dimensional streets along which a passive scalar is advected and diffused. For a regular network, the techniques of homogenisation and large deviations make it possible to obtain a coarse-grained description of the dispersion. We discuss the relevance of this description to real cities by comparing it with a numerical solution of the advection-diffusion problem in a realistic street network, here taken that of Manhattan. An extension of the model to account for the entrainment and detrainment of the scalar above the urban canopy is also discussed.

MINI-WORKSHOP

FLOOD DEMONSTRATOR WETROPOLIS: THE DESIGN OF A PUBLIC ENGAGEMENT PROJECT ON EXTREME RAINFALL AND RIVER FLOODING

Onno Bokhove[1], Wout Zweers[2], Tom Kent[1]

[1]University of Leeds, [2]Wowlab at Roombeek Studios, The Netherlands

We will showcase our table-top flood demonstrator "Wetropolis": a public outreach project funded by Maths Foresees. It conceptualises the science of flooding, to make it concrete and accessible to the public. It is a simplified flooding set-up consisting of a river, a porous flow cell with observable ground water flow representing a watershed, a reservoir, canal sections parallel to the river, (controllable) weirs, river inflow and "rainfall". The rainfall is supplied randomly in location (with four choices: rain at either of two locations or at both locations, or no rain) and in volume (with four choices per location) during the equivalent of a 24-hour rainfall period (10s in our flood demonstrator). The rainfall amount is determined by draws from a discrete probability density function in the form of an asymmetric Galton board with four outcomes, including a "rare event". This mimics the situation in flood risk analysis regarding specified rainfall uncertainty. Its design is based on simulations of a one-dimensional numerical model of the dynamics. After discussing extreme rainfall and flooding events, the mathematics of this model will be explained before four mini-workshop challenges, inspired by Wetropolis, will be introduced. To conclude, we will show a live demonstration.

Photos & movies of Wetropolis: www.facebook.com/resurging.flows
Updates: www1.maths.leeds.ac.uk/mathsforesees/projects.html

FIREDRAKE: A SYSTEM FOR AUTOMATING THE FINITE ELEMENT METHOD

David Ham (Imperial College London)

The creation of advanced simulation tools requires the composition of expertise from diverse fields of mathematics and computer science. As a consequence, simulation software is often complex, hard to develop and even harder to maintain. In this talk I will present Firedrake, a system for creating finite element simulations which works by generating the implementation code from a high-level mathematical language. This enables researchers in these various fields to directly leverage each other's expertise to produce sophisticated high performance finite element solvers. I will particularly focus on Firedrake features of interest to the environmental mathematics community, such as extruded meshes and the automated adjoint facility provided by dolfin-adjoint.

QUANTIFYING THE TIME DYNAMICS OF THE FULL LOCAL DISTRIBUTION OF DAILY PRECIPITATIONS AND ITS UNCERTAINTIES

Sandra Chapman[1], David Stainforth[2], Nick Watkins[1,2,3]

[1]University of Warwick, [2]LSE, [3]The Open University

A characteristic feature of how our climate is changing is that it varies locally. This requires quantifying the geographical patterns in changes at specific thresholds or quantiles of distributions

of daily precipitation, and their uncertainties. A range of indices have been developed which focus on high percentiles (e.g. rainfall falling on days above the 99th percentile) and on absolute extremes (e.g. maximum annual one day precipitation) but climate-vulnerable policy decisions, adaptation planning and impact assessments all have different relevant thresholds and sensitivities. We present a methodology which maintains the flexibility to provide information at different thresholds for different downstream users, both scientists and decision makers. Our method analyses local climatic time series to assess which quantiles of the local climatic distribution show the greatest and most robust changes, to specifically address the challenges presented by daily precipitation data which has 'fat tailed' distributions. We extract from the data quantities that characterize the changes in time of the likelihood of daily precipitation above a threshold and of the relative amount of precipitation in those days. This involves not only determining which quantiles and geographical locations show the greatest change, but also those at which any change is highly uncertain. We demonstrate this approach using E-OBS gridded data which are time series of local daily precipitation from specific locations across Europe over the last 60 years. We treat geographical location and precipitation as independent variables and thus obtain as outputs the pattern of change at a given threshold of precipitation and with geographical location. This is model- independent, thus providing data of direct value in model calibration and assessment. Our results show regionally consistent patterns of systematic increase in precipitation on the wettest days, and of drying across all days, which are of potential value in adaptation planning.

FEASIBILITY STUDY PROGRESS: MULTILEVEL MONTE CARLO METHODS FOR FLOOD RISK ASSESSMENT

[1]Colin Cotter, [1]Alastair Gregory, [1]David Ham, [2]Rob Lamb

[1]Imperial College London, [2]JBA Trust

Flood risk quantification requires Monte Carlo simulation to calculate flooding probabilities under uncertainty in rainfall, topography, absorption coefficients etc. This is currently challenging to do with shallow water models since Monte Carlo requires many model runs and each model run is time consuming. The multilevel Monte Carlo (MLMC) algorithm attempts to address this type of issue by combining model runs on a hierarchy of grids of different resolutions, trading off estimator variance with model error. In this feasibility study, we are investigating the application of MLMC to flood risk quantification. We will report progress in this study and present some results.

LEEDS FLOOD ALLEVIATION SCHEME

Katy Bullock (Leeds City Council) and Mark Garford (Environment Agency)

The £45million Leeds Flood Alleviation Scheme (FAS) is one of the largest river flood defence schemes in the country. It will see major construction work along the River Aire in the city centre and Holbeck extending 4.3km between Leeds train station and Thwaite Mills. Flood risk is increasing throughout the UK and in recent years Leeds city centre has come close to flooding several times. Unfortunately on Boxing Day 2015 this flood risk was experienced with hundreds of properties flooding in the city. There are no formal flood defences in Leeds along the River Aire. The scheme includes the installation of innovative moveable weirs at Crown Point and at Knostrop that can be lowered in flood conditions to reduce river levels and the threat of river flooding. This is the first time that these moveable weirs will have been installed in the UK for flood alleviation purposes. The main construction works started in January 2015 and the project end date is May 2017. The defences will provide the city centre and over 3,000 homes and 500 businesses with protection against flood events from the River Aire and the Hol Beck. It will also protect 300 acres of development land and open up key regeneration opportunities in the South Bank area. The scheme will also help safeguard 22,000 jobs over the next 10 years and create 150 jobs and apprenticeships to work on the project. Initial work on the Leeds Flood Alleviation Scheme saw defences constructed at Woodlesford during 2014, providing residents with protection against a one in 200 year flood event from the River Aire.

FLOOD FORECASTING USING DATA ASSIMILATION

Arnold Heemink (TU Delft)

Data assimilation methods can be used to combine the results of a large-scale numerical tidal model with the measurement information available in order to obtain accurate forecasts. Many data assimilation schemes are based on the well-known Kalman filtering algorithm. In the last 20 years a number of ensemble-based algorithms have been proposed, e.g. the Ensemble Kalman filter (EnKF), the Reduced Rank Square Root filter (RRSQRT), the Ensemble Square Root filter (ESRF) and – especially for tidal assimilation problems – the two sample Kalman filter. Variational data assimilation of “the adjoint model” can also be used for data assimilation. This approach is especially attractive for model calibration problems. Variational data assimilation however requires the implementation of the so-called adjoint model. Even with the use of the adjoint compliers that have become available this is a tremendous programming effort that hampers application of the method. Therefore an ensemble approach to variational data assimilation using model reduction has been proposed. This methos does not require the implementation of the adjoint model and is very efficient for the calibration of tidal models. In this presentation the various ensemble approaches for solving data assimilation problems will be summarised. The characteristics and performance of the methods will be illustrated with real-life data assimilation applications:

- Operation storm surge forecasting in the Netherlands using Kalman filtering
- Calibration of the tidal model used for storm surge forecasting