Workshop on High-dimensional and Multivariate Extremes

Bristol, 2nd-4th July, 2014

Organised by Ioannis Papastathopoulos

Conference programme

SuSTaIn

"SuSTaIn is Statistics underpinning Science, Technology and Industry, a programme with the ambitious goal of strengthening the discipline of Statistics in the UK, by equipping it to face the challenges of future applications. Thus the focus is on rigorous and innovative new theory and methodology – core statistics for the 21st century – aimed at and stimulated by generic challenges raised by the 'data revolution', in areas as diverse as genomics, astronomy, telecommunications and finance.

It is funded principally by a 3.5million Science and Innovation award from EPSRC, and partly by the University of Bristol, and runs from 2006 to 2016."

Guy Nason, Director.

Programme

Invited and contributed talks last for 1h and 30mins, respectively, including questions.

Day 1: Wednesday 2nd July 2014

09.30 – 11.45 Registration + Breakfast
11.45 – 12.00 Welcome session
12.00 – 13.00 Sidney Resnick
13.00 – 15.00 Lunch
15.00 – 16.00 Johan Segers
16.00 – 17.00 Daniel Cooley
17.30 – 19.30 Wine reception and Poster Session

Day 2: Thursday 3rd July 2014

09.00 – 10.00 Holger Rootzén
10.00 – 10.30 Raphael Huser
10.30 – 11.00 Coffee break
11.00 – 11.30 Kirstin Strokorb
11.30 – 12.30 Martin Schlather
12.30 – 14.00 Lunch
14.00 – 15.00 Jonathan Tawn
15.00 – 15.30 Fabrizio Laurini
15.30 – 16.00 Coffee break
16.00 – 16.30 Anna Kiriliouk
16.30 – 17.00 Hugo Winter

20.00 – Dinner (riverstation)

Day 3: Friday 4th July 2014

09.00 – 10.00 Ye Liu
10.00 – 10.30 Ioannis Papastathopoulos
10.30 – 11.00 Coffee break
11.00 – 11.30 Sebastien Engelke
11.30 – 12.30 Jennifer Wadsworth
12.30 – 14.00 Lunch
14.00 – 15.00 Phillip Jonathan
15.00 – 15.30 Coffee break
15.30 – 16.00 Quentin Sebille
16.00 – 16.30 Paul Northrop
16.30 End of Workshop

Posters

Thomas Lugrin, Linda Mhalla, John O'Sullivan, Ilaria Prosdocimi, Emeric Thibaud, Ross Towe.

Titles of talks (in order of appearance)

Sidney Resnick: *Models with hidden regular variation: generation and detection.*

Johan Segers: *Extreme value theory for random upper semi-continuous processes: max-stable limits and domains of attraction.*

Daniel Cooley: *Hidden regular variation in joint tail modeling with likelihood inference via the Monte Carlo EM algorithm.*

Holger Rootzén: *Multivariate peaks over thresholds modelling.*

Raphael Huser: *A comparative study of likelihood estimators for multivariate extremes.*

Kirstin Strokorb: *Systematic co-occurrence of tail correlation functions among max-stable processes.*

Martin Schlather: *Improved simulation method of max-stable processes.*

Jonathan Tawn: *A range of new modelling approaches for multivariate extremes.*

Fabrizio Laurini: *Numerical strategies to handle extremes of high-order GARCH models.*

Anna Kiriliouk: *An M-estimator of spatial tail dependence.*

Hugo Winter: *Extreme value modelling of heatwaves under climate change.*

Ye Liu: *Statistical model for global extreme precipitation and river flow.*

Ioannis Papastathopoulos: *New representations for the conditional approach to multivariate extremes.*

Sebastien Engelke: *Max-stable processes on river networks.*

Jennifer Wadsworth: *Modelling across extremal dependence classes.*

Phillip Jonathan: *Applications of non-stationary marginal and conditional extreme value models for the ocean environment.*

Quentin Sebille: *Modelling extreme precipitation in France with a spatial hierarchical model.*

Paul Northrop: *Cross-validatory extreme value threshold selection and uncertainty with application to wave heights.*

Abstracts (in order of appearance)

Sidney Resnick, Cornell University

Models with hidden regular variation: generation and detection.

We review definitions of multivariate regular variation (MRV) and hidden regular variation (HRV) for distributions of random vectors and then summarize methods for generating models exhibiting both properties. We also discuss diagnostic techniques that detect these properties in multivariate data and indicate when models exhibiting both MRV and HRV are plausible fits for the data. We illustrate our techniques on simulated data and also two real Internet data sets.

(Joint work with **Bikramjit Das**, Singapore University of Technology and Design)

Johan Segers, Université Catholique de Louvain

Extreme value theory for random upper semi-continuous processes: max-stable limits and domains of attraction.

In the context of extreme value theory, upper semi-continuity is a natural requirement on the sample paths of a stochastic process. Extremes of upper semi-continuous processes have been investigated, among others, by Vervaat (1982), Norberg (1987), Giné et al. (1990), and Roy and Resnick (1991). Max-stability is defined via a sequence of scaling constants only, which are supposed to be the same at every ordinate of the process. In order to deal adequately with path discontinuities, weak convergence is considered with respect to the hypotopology rather than the supremum distance. Random upper semi-continuous processes are thus identified with random closed sets (Salinetti and Wets 1986, Molchanov 2005). In contrast to continuous processes, semi-continuous processes do not seem to have found their way to practical extreme value analysis yet, although they do arise in some models used for spatial extremes (Schlather 2002, Robert 2013).

We are interested in max-stable upper semi-continuous processes as well as their domains of attraction. Differently from previous work, we allow for affine normalizations of sample maxima by functions rather than by constants, allowing the normalization to depend on the ordinate. A common trick in extreme value theory is to standardize margins to a common scale (Gumbel, unit Fréchet, etc.). In the semi-continuous case, the possibility of such a standardization is not guaranteed.

(Joint work with **Anne Sabourin**, Télécom ParisTech)

Daniel Cooley, Colorado State University

Hidden regular variation in joint tail modeling with likelihood inference via the Monte Carlo EM algorithm.

A fundamental deficiency of classical multivariate extreme value theory is the inability to distinguish between asymptotic independence and exact independence. In this work, we examine multivariate threshold modeling based on the framework of regular variation on cones. Tail dependence is described by a limiting measure, which in some cases is degenerate on joint tail regions despite strong sub-asymptotic dependence in such regions. Hidden regular variation, a higher-order tail decay on these regions, offers a refinement of the classical theory. This work develops a representation of random vectors possessing hidden regular variation as the sum of independent regular varying components. The representation is shown to be asymptotically valid via a multivariate tail equivalence result, and an example is demonstrated via simulation. We develop a likelihood-based estimation procedure from this representation via a version of the Monte Carlo expectation-maximization algorithm which has been modified for tail estimation.

The methodology is demonstrated on simulated data and applied to a bivariate series of air pollution data from Leeds, UK. We demonstrate the improvement in tail risk estimates offered by the sum representation over approaches which ignore hidden regular variation in the data.

(Joint work with **Grant Weller**, Department of Statistics, Carnegie Mellon University)

Holger Rootzén, Chalmers University of Technology

Multivariate peaks over thresholds modelling.

Quite a number of different approaches to multivariate Peaks over Thresholds modelling has been proposed in the literature. Most of them are based on multivariate generalizations of the Generalized Pareto distribution, but other approaches have also been proposed. This talk will review and discuss some of these approaches. Further, work in progress on new parametric multivariate Generalized Pareto models will be presented. These models have tractable likelihoods and permit use of the entire standard maximum likelihood machinery for estimation, testing, and model checking.

Raphael Huser, King Abdullah University of Science and Technology

A comparative study of likelihood estimators for multivariate extremes.

The main approach to inference for multivariate extremes consists in approximating the joint upper tail of the observations by a parametric family arising in the limit for extreme events. The latter may be expressed in terms of componentwise maxima, high threshold exceedances, or point processes, yielding different but related asymptotic characterizations and estimators. In this talk, I will clarify the connections between the main likelihood estimators, and assess their practical performance. I will compare their ability to estimate the extremal dependence structure and to predict future extremes, using exact calculations and simulation, in the case of the logistic model.

Kirstin Strokorb, Universität Mannheim

Systematic co-occurrence of tail correlation functions among max-stable processes.

The tail correlation function (TCF) is one of the most popular bivariate extremal dependence measures that has entered the literature under various names (chi-measure, upper tail dependence coefficient function, extremal coefficient function). We study to what extent the TCF can distinguish between different classes of well-known max-stable processes and identify essentially different classes of processes sharing the same TCFs.

(Joint work with **Felix Ballani** and **Martin Schlather**)

Martin Schlather, Universität Mannheim

Improved simulation method of max-stable processes.

The simulation method for mixed moving maxima processes suggested by Schlather (2002) has the disadvantage of being exact only for bounded storm functions with compact support. Here, we present a new, exact method that does not have these restrictions. We show that the new method is to some extend optimal, and demonstrate by an example that the new, exact method can be faster than the approximation by Schlather (2002) for storm function with non-compact support. While the implementation of the former algorithm has been straightforward, the new method needs some more effort for coding. We will highlight also some of these aspects and refer to the R package RandomFields for an implementation.

Schlather, M. (2002). Models for stationary max-stable random fields. *Extremes*, **5**, 33–44.

Oesting, M., Schlather, M. & Zhou, C. (2013). On the Normalized Spectral Representation of Max-Stable Processes on a compact set. *ArXiv*: 1310.1813.

Schlather, M., Malinowski, A., Oesting, M., Boecker, D., Strokorb, K., Engelke, S., Martini, J., Ballani, F., Menck, P., Gross, S., Ober, U., Burmeister, K., Manitz, J., Singleton, R. & Pfaff, B., R Core Team (2014). *RandomFields: Simulation and Analysis of Random Fields.* R package version 3.0.13

Jonathan Tawn, Lancaster University
A range of new modelling approaches for multivariate extremes.

Methods for multivariate extreme value problems continue to be developed. Early models were based on a point process representation, or the equivalent basis of multivariate regular variation. The weakness with such methods was their inability to fully capture the tail properties of asymptotically independent variables. Since the mid 1990s methods of hidden regular variation and conditional extremes have been developed in an attempt to address this deficiency. In this talk I will look at reviewing recent advances in both of these methods, covering both probabilistic representations and statistical inference, and I will present theory which identifies some connections between them.

The talk will be based on the following papers:

Keef, C., Papastathopoulos, I. & Tawn, J. A. (2013). Estimation of the conditional distribution of a multivariate variable given that one of its components is large: additional constraints for the Heffernan and Tawn model. *J. Mult. Anal.*, **115**, 396–404.

Liu, Y. & Tawn, J. A. (2014). Self-consistent estimation of conditional multivariate extreme distributions. To appear in *J. Mult. Anal.*.

Liu, Y. & Tawn, J. A. (2014). Extreme risks of financial investments. To appear as a chapter in *Extreme Value Modeling and Risk Analysis: Methods and Applications.*

Wadsworth, J. L. & Tawn, J. A. (2013). A new representation for multivariate tail probabilities. *Bernoulli*, **19**, 2689–2714.

Fabrizio Laurini, University of Parma
Numerical strategies to handle extremes of high-order GARCH models.

Models with conditional heterosckedasticity have generated a dispute into the financial econometrics literature, with GARCH-type and pure SV process representing the cornerstone of two different classes of models. Such a dispute still holds when the extremal behaviour of these processes is of concern, and the two classes are contrasted in term of their extremal index. Broadly speaking, extremes of standard SV are like those of an IID process, whereas for GARCH-type models there is a richer structure of clustering of extremes. Available results for simpler special cases, like the ARCH(1), or the GARCH$(1, 1)$ seem hard to be generalized to higher dimensional case. Closed-form analytical expression for the extremal index of GARCH(p, q) seems hard to be usable for its numerical evaluation. A preliminary numerical strategy that handle extremes of GARCH(p, q) is presented. With the support of basic statistical independence diagnostics we provide an efficient Monte Carlo algorithm. We originally work with the squared of a GARCH(p, q), so that symmetric errors will be first considered to make simple computation, but some hints on heavy-tailed skew-distributions will be also considered.

Anna Kiriliouk, Université Catholique de Louvain

An M-estimator of spatial tail dependence.

Tail dependence models for distributions attracted to a max-stable law are fitted using observations above a high threshold. To cope with spatial, high-dimensional data, a rank-based M-estimator is proposed relying on bivariate margins only. A data-driven weight matrix is used to minimize the asymptotic variance. Empirical process arguments show that the estimator is consistent and asymptotically normal. Its finite-sample performance is assessed in simulation experiments involving popular max-stable processes perturbed with additive noise. An analysis of wind speed data from the Netherlands illustrates the method.

Hugo Winter, Lancaster University

Extreme value modelling of heatwaves under climate change.

Extreme value models that can account for dependence are vital when modelling rare weather phenomena that can cause large damages and loss of life. An important question in the climate community regards how characteristics of future rare events might change with human induced climate change. In a worst case scenario, stronger and longer events coupled with an expanding global population could lead to greater problems in the future. In this work we shall focus on analysing temperature data from the Met Office's HadGEM2 global climate model for central France. The GCM is forced with climate forcing parameters consistent with the A2 climate change scenario which produces a rapid increase in global temperatures. The aim is to better understand how the duration and intensity of future heatwaves will change in a changing climate. For this purpose we develop methods for dealing with non-stationarity in our extreme value models by incorporating covariates.

Ye Liu[*], D. Marechal[†], A. Bonazzi[†], Y. Tang[*], T. Willis[†], [*]JBA Risk Management Limited, [†]Guy Carpenter & Company

Statistical model for global extreme precipitation and river flow.

To minimise the financial losses caused by natural hazards, companies or individuals buy insurance policies to cover their assets at risk. Insurance companies then aim to balance their premium income and claim payout based on the rule of large numbers. However policies that normally generate independent claim payouts may be affected by the same natural catastrophe event, leading to a substantial aggregated payout. Typically insurance companies seek help from reinsurance companies or brokers for protection against such catastrophe events. The providers of re-insurance cover on the other hand are keen to understand and estimate the probability of such catastrophe events. Given the limited data coverage and the high quantiles the modelled results are extrapolated to, multivariate extreme value models provide an intuitive and natural approach in this case. Driven by the devastating effects of widespread floods, JBA Risk Management and Guy Carpenter have joined forces to develop a statistical model for extreme precipitation and river flow on a global scale. The proposed approach aims to capture the spatial and temporal pattern of large-scale flood events caused by excessive river flow, hurricane-induced or non-hurricane-induced extreme precipitation. A collection of different models are carefully selected to fit the distinctive nature of the underlying physical processes. Some initial results are shown to verify the performance of the proposed approach.

Key-words: catastrophe model, extremal dependence, multivariate extreme value theory, point process, widespread floods.

Ioannis Papastathopoulos, University of Bristol
New representations for the conditional approach to multivariate extremes.

Extreme meteorological events such as floods, heatwaves and windstorms can cause havoc for the people affected and typically result in large financial losses. There is a clear need to have good methods to estimate the likelihoods of such events to help in mitigating the risk. The conditional approach to multivariate extremes concerns the characterization of the limiting distribution of appropriately normalised random vectors given that at least one of their components is large. The statistical methods for the conditional approach are based on a canonical parametric family of location and scale norming functions. Recently, inverted max-stable processes have been proposed as an important new class for spatial extremes covering asymptotic independence in contrast to max-stable processes which are asymptotically dependent. We study a broad range of inverted max-stable processes and present examples where the normalisations required for non-degenerate conditioned limit laws do not belong to the canonical family. Despite such differences at an asymptotic level, we show that at practical levels, the canonical model approximates well the true conditional distributions.

Sebastien Engelke, Ecole Polytechnique Fédérale de Lausanne, Université de Lausanne
Max-stable processes on river networks

Max-stable processes are suitable models for extreme events that exhibit spatial dependencies. The dependence measure is usually a function of Euclidean distance between two locations. In this talk, we model extreme river discharges on a river network in the upper Danube catchment, where flooding regularly causes huge damage. Dependence is more complex in this case as it goes along the river flow. For non-extreme data a Gaussian moving average model on stream networks was proposed by Ver Hoef and Peterson (2010, *J. Amer. Statist. Assoc.*). Inspired by their work, we introduce a max-stable process on the river network that allows flexible modeling of flood events and that enables risk assessment even at locations without a gauging station. Recent methods from extreme value statistics are used to fit this process to a big data set from the Danube area.

Jennifer Wadsworth, University of Cambridge
Modelling across extremal dependence classes.

A number of different dependence scenarios can arise in the theory of multivariate extremes, entailing careful selection of an appropriate class of models. In the simplest case of bivariate extremes, a dichotomy arises: pairs of variables are either asymptotically dependent or are asymptotically independent. Most available statistical models are suitable for either one case or the other, but not both. The consequence is a stage in the inference that is not accounted for, but which may have large impact upon the subsequent extrapolation. Previous modelling strategies that address this problem are either applicable only on restricted parts of the domain, or appeal to multiple limit theories. We present a unified representation for multivariate extremes that encompasses a wide variety of dependence scenarios, and is applicable when at least one variable is large. The representation motivates a parametric statistical model that is able to capture either dependence class, and model structure therein. An implementation of a simple version of this model shows that it offers good estimation capability over a variety of dependence structures.

Phillip Jonathan, Shell

Applications of non-stationary marginal and conditional extreme value models for the ocean environment.

Extreme value analysis helps characterise rare environmental events. For example, reliable design and assessment of flood and coastal defences, land-based and marine structures requires estimation of both marginal and dependence characteristics of extreme environments (Davison et al. 2012, Chavez-Demoulin and Davison 2012). Careful incorporation of covariate effects is essential. By expressing parameters of extreme value model as smooth functions of covariates, more reliable inferences can be achieved (Davison and Smith 1990, Jonathan et al. 2008).

We present a general spline based (Eilers and Marx 2010) methodology to incorporate spatial, directional, seasonal, temporal and other covariate effects in extreme value models. The approach uses quantile regression to estimate a suitable extremal threshold, a Poisson process model for the rate of occurrence of threshold exceedances, and a generalised Pareto model for size of threshold exceedances. Covariate effects are incorporated at each stage by describing all model parameters as roughness-penalised linear combinations of spline basis functions, the latter constructed as tensor products of B-spline bases for individual covariates. Optimal roughness penalties are selected using cross-validation or similar, and model uncertainty is quantified using bootstrap re-sampling. The method is applied to estimate marginal return values of ocean storm severity varying with storm direction and season, incorporating intra-storm variability, for locations in the North Sea (Feld et al. 2014) and South China Sea.

Applications to large spatial neighbourhoods of locations in the Gulf of Mexico and off the North West Shelf of Australia, incorporating spatial and directional effects, are also outlined (Jonathan et al. 2014b), as is a non-stationary extension of the conditional extremes model of Heffernan and Tawn (2004) (Jonathan et al. 2014a).

Chavez-Demoulin, V., & Davison, A. C. (2012). Modelling time series extremes. *REVSTAT Statistical Journal*, **10**, 109–133.

Davison, A. C., Padoan, S. A. & Ribatet, M. (2012). Statistical modelling of spatial extremes. *Statistical Science*, **27**, 161–186.

Davison, A. C. & Smith, R. L. (1990). Models for exceedances over high thresholds. *J. R. Statist. Soc. B*, **52**, 393–442, 1990.

Eilers, P. H. C. & Marx, B. D. (2010). Splines, knots and penalties. *Wiley Interscience Reviews: Computational Statistics*, **2**, 637–653.

Feld, G., Randell, D., Wu, Y., Ewans, K. & Jonathan, P. (2014). Estimation of storm peak and intra-storm directional-seasonal design conditions in the North Sea. *Proceedings of 33nd International Conference on Ocean, Offshore and Arctic Engineering*, OMAE2014–23157. (draft at `www.lancs.ac.uk/jonathan`)

Heffernan, J. E. and Tawn, J. A. (2004). A conditional approach for multivariate extreme values. *J. R. Statist. Soc. B*, **66**, 497–546.

Jonathan, P., Ewans, K. C., & Forristall, G. Z. (2008). Statistical estimation of extreme ocean environments: The requirement for modelling directionality and other covariate effects. *Ocean Eng.*, **35**, 1211–1225, 2008.

Jonathan, P., Ewans, K. C. & Randell, D. (2014a). Non-stationary conditional extremes of northern North Sea storm characteristics. *Environmetrics*, **25**, 172–188.

Jonathan, P., Randell, D., Wu, Y. & Ewans, K. (2014b). Return level estimation from non-stationary spatial data exhibiting multidimensional covariate effects. (Submitted to *Ocean Engineering*. (draft at `www.lancs.ac.uk/jonathan`).

Quentin Sebille, Institut Camille Jordan

Modelling extreme precipitation in France with a spatial hierarchical model.

The aim of my talk is the modelling of extreme values of a random vector describing daily precipitation in n meteorological stations ($n > 3$) in France. We wish then to extrapolate on the law of extreme values on unobserved sites, given the observations we have around. In a first time, I will describe the data at my disposal and the univariate analysis I leaned on stationarity. Then, I will talk about a particular spatial hierarchical model of extreme values, the one of Reich and Shaby (2012, 2013 and 2014).

Paul Northrop, University College London

Cross-validatory extreme value threshold selection and uncertainty with application to wave heights.

Designs conditions for marine structures are typically informed by threshold-based extreme value analyses of oceanographic variables, in which excesses of a high threshold are modelled by a generalized Pareto (GP) distribution. Too low a threshold leads to bias from model misspecification; raising the threshold increases the variance of estimators: a *bias-variance trade-off*. Existing threshold selection methods do not address this trade-off directly, but rather aim to select the lowest threshold above which the GP model is judged to hold approximately. In this paper Bayesian cross-validation is used to address the trade-off by comparing thresholds based on predictive ability at extreme levels. Extremal inferences can be sensitive to the choice of a single threshold. We use Bayesian model averaging to combine inferences from many thresholds, thereby reducing sensitivity to the choice of a single threshold. The methodology is illustrated using significant wave height datasets from the North Sea and from the Gulf of Mexico.

Abstracts (posters)

Thomas Lugrin, Ecole Polytechnique Fédérale de Lausanne

Bayesian semiparametrics for modelling the clustering of extreme values.

Risk estimates for time series with short-range dependence are often obtained using the peaks over threshold method (Davison and Smith, 1990, *J. R. Statist. Soc. B*). Such estimates may be badly biased, and sensitive to how the peaks are identified. An alternative characterization of cluster maxima (Eastoe and Tawn, 2012, *Biometrika*) allows separate consideration of both the marginal distribution of exceedances over the threshold and of the extremal dependence structure. This characterization uses the extremal index at subasymptotic levels, for which a formulation can be derived from the conditional model of Heffernan and Tawn (2004, *J. R. Statist. Soc. B*), which involves specifying the conditional distribution and two stages of inference. Here we estimate this distribution by a Bayesian semiparametric approach using a dependent Dirichlet process, allowing us to fit a model for clusters of extremes in a single step. The ideas, illustrated using simulated data, can result in substantially improved estimates of high quantiles for time series.

Linda Mhalla, Ecole Polytechnique Fédérale de Lausanne

Joint estimation for extremes of aggregated data.

We consider extremes on a variable aggregated over different time intervals. Two examples are rainfall and log-returns on some stock: we might be interested in rainfall maxima at 10 minutes, 30 minutes, and 60 minutes, or in annual maxima of daily, weekly and monthly log-returns. If we fit different models separately at the different aggregation levels, the different shape parameter estimates might not be properly ordered and this can lead to inconsistencies when extrapolating to extreme quantiles. Ferreira et al. (2012) discuss this in the context of max-stable processes and show that, under certain conditions, the shape parameters are the same at different levels of aggregation. Here we jointly estimate extremes of aggregated data and assess, both theoretically and using simulations, the gain in efficiency when estimating the common shape parameter and extreme quantiles.

John O'Sullivan, University College of Dublin

Projecting Changes in Climate Extremes in Ireland.

This study plans to create an extreme climate map of Ireland. It will examine how climate extremes of temperature, precipitation and wind speed have changed in the recent past, and how they are projected to change in the future, according to output from the latest high-resolution climate models. Much current climatology analysis tends to focus on how the average value of a climate variable is projected to change. However, changes in extreme events are of more immediate import to both policymakers and the general public. But measuring changes in the frequency, intensity and duration of extreme events is quite difficult, due to the scarcity of available data. This study will compare climate model data (from the EURO–CORDEX project) to historical observations (from Met. Éireann) for the period 1951-2006. The study method involves inference on the three parameters that uniquely define a Generalised Extreme Value curve, for any given set of extremes. A thorough investigation will be undertaken into developing successful methods to overcome the difficulties in moving from model space to observational space. Focus will then move to analysing means to include the information contained in values of historical and model variables such as the North Atlantic Oscillation, global surface temperature, and the particular GCM and RCM in consideration. Bayesian inference forms the basis of the analysis, with MCMC methods used to sample from the posterior densities of the parameters. The prior distributions will be smoothed using Gaussian Processes. These techniques will then be used to analyse and learn about future projected changes in climate extremes in Ireland from climate model data for 2006-2100. The result will be the creation of a spatio-temporal map of Ireland, showing the projected changes in the distribution of the climate extremes of temperature, precipitation and wind speed.

Key-words: climate extremes, climate models, extreme value theory, temperature, precipitation

Ilaria Prosdocimi, Centre for Ecology & Hydrology, Wallingford

Non-stationarity in annual peak flow in the UK: the challenge of a spatial model.

This study investigates the presence of trends in national databases of annual maxima in both peak river flow and catchment-average daily rainfall in the UK. Assuming a two-parameter log-normal distribution for all data series, the existence of non-stationarity is investigated by relating the location parameter to two different variables: time and extreme rainfall levels. This modelling framework enables the detection of the underlying trend in the observed peak flows once the influence of the rainfall variability has been accounted for. At first, a simple non-stationary frequency model is adopted in which the location parameter is described by a standard linear regression model linking the log-transformed data series directly to time (year of occurrence). Next, a rainfall-related variable (i.e. the 99th quantile of the daily rainfall for each year) is included in the model for peak river flow to account for the influence of the rainfall variability, thereby reducing the uncertainty in the estimates of the time effect. The inclusion of the dependence of river flow maxima to a rainfall related variable allows for a straightforward handling of the temporal autocorrelation of river peak flows. The drawbacks of the simple approach taken in most trend analysis studies are then discussed, in particular with respect to the lack of a consideration of the natural spatial correlation between nearby stations. The challenges connected with the specific nature of river flow data are discussed and some basic solutions based on a mixed models approach are suggested.

Emeric Thibaud, Ecole Polytechnique Fédérale de Lausanne

Likelihood-based inference for spatial extremes.

During the last few years, Brown-Resnick and extremal-t processes have been widely used to model spatial extremes. These max-stable processes are suitable models for block maxima or random processes but they can also be used to model exceedances of high thresholds. Because of the complicated form of their distributions, inference for max-stable processes has been mostly based on maximising pairwise likelihood functions, at the price of a loss in efficiency compared to the use of full likelihoods. Recent advances in extreme value theory suggest the use of Poisson and Pareto process approaches to model threshold exceedances of random processes. We discuss inference for Pareto processes associated to extremal-t models using full likelihoods and a partial censoring scheme. Our results show that the use of full likelihoods provide a gain in efficiency compared to pairwise likelihoods, though the latter appear to be more robust to certain types of model misspecification.

Ross Towe, Lancaster University

A diagnostic tool for spatial extreme value modelling.

Max-stable processes are the most common way of modelling of a spatial extreme data set. These processes are rather restrictive as they assume that the spatial dependence between sites is either independent or asymptotically dependent. Currently, there does not exist any diagnostic tools to test whether a process is max-stable. A diagnostic tool is developed to perform the aforementioned test; this diagnostic tool is illustrated by simulating from three data sets over a regularly spaced grid, each with differing dependence structures and with the uncertainty in the classification of dependence structure determined by using a non-parametric bootstrap. The diagnostic tool correctly identifies the correct extremal dependence structure of the three data sets and the tool itself is calculated for the k-th dimensional property of the process. Particular interest lies in the case where $k = 2$ as this corresponds to the pairwise case, which is used in the composite likelihood approaches used to fit max-stable processes. Illustrations will show that considering higher order dependence is vital to identify the correct dependence structure of a spatial data set.

List of Participants

	Participant	Institution
1	Nicolas Attalides	*University College London*
2	Heather Battey	*University of Bristol*
3	Tim Cannings	*University of Cambridge*
4	Panayiota Constantinou	*University of Bristol*
5	Dan Cooley	*Colorado State University*
6	Anthony Davison	*Ecole Polytechnique Fédérale de Lausanne*
7	Sebastian Engelke	*Ecole Polytechnique Fédérale de Lausanne, Université de Lausanne*
8	Vangelis Evangelou	*University of Bath*
9	Dawei Han	*University of Bristol*
10	Janet Heffernan	*J. Heffernan Consulting*
11	Raphael Huser	*King Abdullah University of Science and Technology*
12	Anja Janßen	*University of Hamburg*
13	Philip Jonathan	*Shell, Lancaster University*
14	Tom Kealy	*University of Bristol*
15	Anna Kiriliouk	*Université Catholique de Louvain*
16	Fabrizio Laurini	*University of Parma*
17	Finn Lindgren	*University of Bath*
18	Ye Liu	*JBA Risk Management*
19	Thomas Lugrin	*Ecole Polytechnique Fédérale de Lausanne*
20	Linda Mhalla	*Ecole Polytechnique Fédérale de Lausanne*
21	Ali Yasin Mohammed	*Vrije Universiteit Brussels*
22	Paul Northrop	*University College London*
23	Ragnhild Noven	*Imperial College London*
24	John O'Sullivan	*University College of Dublin*
25	Ioannis Papastathopoulos	*University of Bristol*
26	Marcelo Pereyra	*University of Bristol*
27	Ilaria Prosdocimi	*Centre for Ecology and Hydrology, Wallingford*
28	Kanan Purkayastha	*University of Bristol*
29	David Randell	*Shell Global Solutions*
30	Sidney Resnick	*Cornell University*
31	Holger Rootzén	*Chalmers University of Technology*
32	Martin Schlather	*Universität Mannheim*
33	Quentin Sebille	*Université Claude Bernard Lyon 1*
34	Johan Segers	*Université Catholique de Louvain*
35	Claudio Semadeni	*Ecole Polytechnique Fédérale de Lausanne*
36	Kirstin Strokorb	*Universität Mannheim*
37	Jonathan Tawn	*Lancaster University*
38	Emeric Thibaud	*Ecole Polytechnique Fédérale de Lausanne*
39	Ross Towe	*Lancaster University*
40	Jennifer Wadsworth	*University of Cambridge*
41	Hugo Winter	*Lancaster University*
42	Ben Youngman	*University of Exeter*