The Book of Abstracts

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Modeling load-at-risk (LaR) for computing systems: an extreme value approach

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Joint work with: Valerie Chavez-Demoulin

Type: Contributed Talk

Abstract. Sudden upticks in load may result in low quality of service for computing systems. Therefore, a common practice is to build and operate facilities aiming at satisfying peaks in demand (e.g. load). This leads to high investment and operational costs. In this paper, we use high frequency data of computing systems, such as data centers, to calculate their load-at-risk (LaR). We investigate different extreme value (EV) models in a context of contaminated data. Datasets from different major scientific data centers (e.g. CERN) as well as data from industry (web requests) are used.
Keywords: risk management; computing systems.

On the distribution of maximum of multivariate normal random vectors

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Joint work with: Saralees Nadarajah and Stephen Chan

Type: Contributed Talk

Abstract. Let $(X_1, \cdots, X_k)$ be a multivariate normal random vector. For the first time, we derive explicit expressions for the cumulative distribution function, probability density function and moments of $\max(X_1, \cdots, X_k)$. Each expression is a single infinite sum of known special functions.
Keywords: maximum of Normal vectors; moments; multivariate Normal distribution.

Pricing participating products with semi-heavy tailed risks: The case of Meixner process

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Joint work with: Brett Shanahan, John Van der Hoek

Type: Contributed Talk

Abstract. We propose a model for the valuation of participating life insurance products under the Meixner process, which belongs to the family of semi-heavy tailed processes.

This particular model assumption is extremely desirable as it captures the stylized features of the return distribution, with existing moment generating functions. The market, in this setup, is incomplete, so the minimum entropy martingale measure is used to determine the equivalent martingale measure. We employ the rejection algorithms to conduct a simulation experiment and illustrate the practical implementation of the model.
Keywords: Meixner Process, MEMM.

Model identification for infinite variance autoregressive processes

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Joint work with: Richard A. Davis

Type: Contributed Talk

Abstract. We consider model identification for infinite variance autoregressive time series processes. It is shown that a consistent estimate of autoregressive model order can be obtained by minimizing Akaike's information criterion, and we use all-pass models to identify noncausal autoregressive processes and estimate the order of noncausality (the number of roots of the autoregressive polynomial inside the unit circle in the complex plane). We examine the performance of the order selection procedures for finite samples via simulation, and use the techniques to fit a noncausal autoregressive model to stock market trading volume data.
Keywords: autoregressive; infinite variance; noncausal.

Bayesian inference for multivariate dependence structures in Extreme Value Theory

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Joint work with: Giulia Marcon; Simone A. Padoan

Type: Poster

Abstract. In recent years, interest in high-dimensional and multivariate problems concerning extreme events has increased. In fields such as environmental and economical sciences, analysis of dependence structures is often required. Current dependence models for multivariate maxima are based upon max-stable distributions, characterized by the exponent measure function governing the dependence structure among the data. A change of variable allows an alternative characterization in terms of the Pickands dependence function, defined on a unit simplex of adequate dimension. A Pickands dependence function must satisfy certain conditions in order to properly define a max-stable distribution. In particular, it must be convex over its domain. A recent proposal exploits the shape-preserving properties of multivariate Bernstein polynomials in order to represent the projection of an

initial, possibly non-convex estimate, onto the space of convex functions, thus constructing an estimator with improved theoretical properties. Two potential limitations of this method regard the choices of the initial estimation and the order of the Bernstein polynomials involved in the representation. In the present work, we propose a Bayesian approach in order to overcome the first issue, and briefly discuss a non-parametric extension for dealing with the second.

Keywords: Pickands dependence function; Bernstein polynomials; Bayesian nonparametrics.

Extreme Values modeling of wind speeds in Zahedan using maximal Generalized Extreme Value Distribution

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Joint work with: Ebrahimpour, M; Gharib, A

Type: Poster

Abstract. Distribution of maximum or minimum values (extreme values) of a data set is especially used in natural phenomena including sea waves, flow discharge, wind speeds, precipitation and it is also used in many other applied sciences such as reliability studies and analysis of environmental extreme events. So if we can explain the extremal behavior via statistical formulas, then we can estimate their behavior in the future. This article is devoted to study extreme values of wind speeds in Zahedan using two models. First method is based on maximal generalized extreme value distribution which all maxima of a data set are modeled using it. Second method is based on excesses which has been studied by Pickands (1975) which all excesses over high threshold are modeled using maximal generalized Pareto distribution, that it has more accuracy in comparison to previous method. In this article, we apply four methods to estimate distribution parameters including maximum likelihood estimation, method of moments, probability weighted moments, elemental percentile and quantile least squares then compare estimates by average scaled absolute error criterion. We also obtain quantiles estimates and confidence intervals. In addition goodness-of-fit tests are described. As a part of result, return period of maximum wind speeds are computed.

Keywords: Generalized Extreme Value distribution; Generalized Pareto Distribution; wind speeds.

Asymptotic formula for the tail of the maximum of smooth Gaussian fields on non locally convex sets

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Joint work with: Pham, Viet-Hung

Type: Invited Talk

Abstract. In this talk we consider the distribution of the maximum of a Gaussian field defined on non locally convex sets. Adler and Taylor or Azaïsand Wschebor give the expansions in the locally convex case. The present paper generalizes their results to the non locally convex case by giving a full expansion in dimension 2 and some generalizations in higher dimension. For a given class of sets, a Steiner formula is established and the correspondence between this formula and the tail of the maximum is proved. The main tool is a recent result of Azaïs and Wschebor that shows that under some conditions the excursion set is close to a ball with a random radius. Examples are given in dimension 2 and higher.
Keywords: stochastic processes; Gaussian fields; distribution of the maximum.

Selecting the Number of Largest Order Statistics in Extreme Value Analysis

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Joint work with: Jun Yan; Xuebin Zhang

Type: Poster

Abstract. The r largest order statistics approach is widely used in extreme value analysis because it may use more information from the data than just the block maxima. In practice, the choice of r is critical. If r is too large, bias can occur; if too small, the variance of the estimator can be high. The limiting distribution of the r largest order statistics, denoted by GEV_r, extends that of the block maxima. Two specification tests are proposed to select r sequentially. The first is a score test for the GEV_r distribution. Due to the special characteristics of the GEV_r distribution, the classical chi-square asymptotics cannot be used. The simplest approach is to use the parametric bootstrap, which is straightforward to implement but computationally expensive. An alternative fast weighted bootstrap or multiplier procedure is developed for computational efficiency. The second test uses the difference in estimated entropy between the GEV_r and GEV_{r-1} models, applied to the r largest order statistics and the $r-1$ largest order statistics, respectively. The asymptotic distribution is derived with the central limit theorem. In a large scale simulation study, both tests held their size and had substantial power to detect various misspecification schemes. The utility of the tests is demonstrated with environmental and financial applications.
Keywords: Generalized Extreme Value distribution; goodness-of-fit; multiplier bootstrap.

On extremes of random variables observed at random times

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Joint work with: Drago Špoljarić

Type: Contributed Talk

Abstract. We consider i.i.d. random variables $X_1, X_2, \ldots$ observed at arrival times of a renewal process $\tau(t)$, possibly dependent on X_i's. Under some restrictions, the running maximum of these observations

$$M(t) = \max_{i \leq \tau(t)} X_i \,,$$

has been thoroughly studied. We will show how one can characterize asymptotic behavior of all upper order statistics in the sequence X_i until time $\tau(t)$ using convergence of point processes. This method allows one to generalize previously published results under various types of dependence between the observations and the renewal process. As an important special case, we present an interesting invariance principle for renewal processes with regularly varying steps.
Keywords: regular variation; point processes; renewal processes.

Tail fitting of Pareto-type tails truncated at intermediate levels

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Joint work with: Fraga Alves, M.I.; Gomes, M.I.; Meerschaert, M.M.

Type: Contributed Talk

Abstract. Recently some papers, such as Aban, Meerschaert and Panorska (2006), Nuyts (2010) and Clark (2013), have drawn attention to possible truncation in Pareto tail modelling. Sometimes natural upper bounds exist that truncate the probability tail, such as the Maximum Possible Loss in insurance treaties. At other instances at the ultimate large data values deviations from a Pareto tail behaviour become apparent. This matter is especially important when extrapolation outside the sample is required. Given that in practice one does not always know whether the distribution is truncated or not, we consider estimators for extreme quantiles both under truncated and non-truncated Pareto-type distributions. Hereby we make use of the estimator of the tail index for the truncated Pareto distribution first proposed in Aban *et al.* (2006). We also propose a truncated Pareto QQ-plot and a formal test for truncation in order to help deciding between a truncated and a non-truncated case. In this way we enlarge the possibilities of extreme value modelling using Pareto tails, offering an alternative scenario by adding a truncation point T that is large with respect to the available data. In the mathematical modelling we hence let $T \to \infty$ at different speeds compared to the limiting fraction ($k/n \to 0$) of data used in the extreme value estimation. This work is motivated using practical examples from different fields of applications, asymptotics and simulation results.
Keywords: Pareto-type distributions; truncation; extreme quantile.

Extremal properties of Liouville copulas

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Joint work with: Johanna G. Neslehova

Type: Poster

Abstract. Liouville copulas are a generalization of Archimedean copulas introduced by McNeil and Nešlehová (2010) that allows modelling beyond exchangeability. We focus on the copula domain of attraction of Liouville vectors, that is the copula of the limiting max-stable distributions of maxima. Interestingly, the asymmetry carries over in the limit case but the attractor is unwieldy even in the bivariate case. Contrary to the Archimedean case, the Gumbel–Hougaard model is not an extreme–value copula when asymmetry is introduced. The extremal attractor of the survival copula is also derived and turns out to be a scaled version of the Dirichlet multivariate extreme–value distribution, which is flexible and allows for efficient inference. The findings are illustrated on flow data for the Tyne river in the UK.
Keywords: Liouville copulas; extremal attractor; Dirichlet extreme-value distribution.

Exploratory data analysis of extreme values using non-parametric kernel methods

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Joint work with: Tarn Duong; Michel Broniatowski; Scott Sisson;

Type: Contributed Talk

Abstract. In environmental fields such as climatology or hydrology the study of extreme events (e.g. heat waves, storms, floods) is of high importance. These extreme events are those whose observed values exceed a threshold and lie in the tails of the distribution function. We investigate some non-parametric methods to analyze these tail distributions by introducing a modification of classical kernel estimators which focuses directly on the tail density. Given the mild distributional assumptions required to compute these kernel estimators, we can consider them to be the closest smooth representation of the discretized data sample. This allows us to visualize the tail behavior without the gaps in the observed data and without having to impose the stronger assumptions of a parametric model. In more quantitative terms, computing the divergences of a suite of parametric models to the kernel tail density estimator serves as a proxy for selecting which of these parametric models most closely fits the data sample. Moreover our proposed approach, being kernel-based, is straightforward to extend to the exploratory analysis of multivariate extremes. We illustrate the applicability of our non-parametric analysis on a range of simulated and experimental environmental extreme values data.
Keywords: tail density; smoothing; multivariate extremes.

Point process convergence for branching random walks with regularly varying steps

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Type: Contributed Talk

Abstract. We consider the limiting behavior of the point processes associated with a branching random walk with supercritical branching mechanism and balanced regularly varying step size. Assuming that the underlying branching process satisfies Kesten-Stigum condition, it is shown that the point process sequence of properly scaled displacements coming from the n^{th} generation converges weakly to a Cox cluster process. In particular, we establish that a conjecture of Brunet and Derrida (2011) remains valid in this setup, investigate various other issues mentioned in their paper and recover a slightly improved version of a result of Durrett (1983) in our framework.
Keywords: branching random walk; Galton-Watson tree; point processes.

Conditional simulation of max-stable processes and insurance applications

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Joint work with: Zhipeng Liu; Ton Dieker; Thomas Mikosch.

Type: Invited Talk

Abstract. Max-stable processes are of great importance in extreme value analysis because of their ability to model extremes under spatial dependence. Predictive inference in the context of these models, clearly of importance in insurance applications, requires access to conditional distributions given observed values at some space-time locations. Unfortunately, such conditional distributions are challenging to compute explicitly. We provide the first class of unbiased estimators for conditional expectations for a large class of max-stable processes, namely, so-called Brown-Resnick fields. Our results built upon optimal-running time algorithms for exact sampling (simulation without bias) of Brown-Resnick processes.
Keywords: max-stable process; conditional simulation; optimal running times.

The topology of noise

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Joint work with: Robert Adler; Shmuel Weinberger

Type: Invited Talk

Abstract. Let $X_1, ..., X_n$ be a set of iid data points in $\mathbb{R}^d$ generated by a spherically symmetric density function f, and let U_n be the union of d-dimensional unit balls around

the data. We are interested in studying the topological features of this random space. In particular, we are interested in the homology of this space, which is an algebraic structure that describes features such as connected components and holes (or cycles) of different dimensions.

In this talk we will discuss the extremal behavior of topology, i.e. the topological features that appear far away from the origin. We will show that these features demonstrate an organized 'layered' behavior, where features of different types are formed at different distances from the origin. This behavior depends on the underlying distribution and its tail and we will discuss that as well.

Keywords: random complexes; stochastic topology; Extreme Value Theory.

Estimation for models defined by conditions on their L-moments

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Joint work with: A. Decurnunge

Type: Contributed Talk

Abstract. This talk extends the empirical minimum divergence approach for models which satisfy linear constraints with respect to the probability measure of the underlying variable (moment constraints) to the case where such constraints pertain to its quantile measure (called here semi parametric quantile models). The case when these constraints describe shape conditions as handled by the L-moments is considered and both the description of these models as well as the resulting non classical minimum divergence procedures are presented. These models describe neighborhoods of classical models used mainly for their tail behavior, for example neighborhoods of Pareto or Weibull distributions, with which they may share the same first L-moments. A parallel is drawn with similar problems held in optimal transportation problems. The properties of the resulting estimators are illustrated by simulated examples comparing Maximum Likelihood estimators on Pareto and Weibull models to the minimum Chi-square empirical divergence approach on semi parametric quantile models, and others.

Keywords: L-moments; divergences; tail conditions.

Estimation and assessment of anisotropic Brown-Resnick space-time models

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Joint work with: Claudia Klüppelberg

Type: Poster

Abstract. Max-stable processes can be viewed as the natural infinite-dimensional generalization of multivariate extreme value distributions. We focus on the Brown-Resnick

space-time process, a prominent max-stable model. We extend existing spatially isotropic models to more general anisotropic versions and use pairwise likelihood to estimate the model parameters. For regular grid observations we prove strong consistency and asymptotic normality of the estimators for fixed and increasing spatial domain, when the number of observations in time tends to infinity. We also present a statistical test for spatial isotropy versus anisotropy, which is based on asymptotic confidence intervals of the pairwise likelihood estimators and carried out using a subsampling procedure. We fit the spatially anisotropic Brown-Resnick model and apply the proposed test to precipitation measurements in Florida. In addition, we present some recent diagnostic tools for model assessment.

Keywords: Brown-Resnick space-time process; hypothesis test for spatial isotropy; max-stable model check.

Spatial dependence structure for flood-risk rainfall

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Joint work with: Gwladys Toulemonde

Type: Contributed Talk

Abstract. In this work, we focused on the comparison of stochastic rainfall generators for rainfall that can potentially lead to flooding, the so-called *flood-risk rainfall*. We defined flood-risk rainfall as events whose spatial average is above a threshold meaningful for the catchment under study. Misspecification of the spatial structure in the flood-risk rainfall generator might have important consequences on the estimation of high return levels of runoff. This is especially true for small mediterranean catchments subject to flash floods such as the Gardon at Anduze on which we conducted our comparison study. We use daily rainfall from eight stations over the catchment.

The motivation behind this work is twofold. On one hand, we found out that most existing multi-site rainfall generators rely on the Gaussian dependence structure and there is no or little evaluation of the consequences of this assumption. On the other hand, since we are interested in intense rainfall events, it would seem natural to use models from multivariate extreme value (MEV) theory that are based on a sound theoretical framework.

In the first part, we compared *off-the-shelf* models of spatial dependence structures to model flood-risk rainfall in dimension 8. Namely, we considered, in addition to the Gaussian, the Student t, the Skew Normal and the Skew t multivariate dependence structures. Margins are either modelled with a parametric or semi-parametric distribution. In the second part, we explored how MEV models can be used in our application. The most accessible 8-d MEV models such as the Gumbel copula are too simplistic. We followed the proposition of Salvadori & De Michele (2011) and combined two MEV copulas. The resulting copula belongs also to the MEV copula family. We put forward some new developments in terms of its application in a spatial context.

Keywords: return levels; multivariate extremes; copula.

Probabilistic tail dependence of intense precipitation on spatiotemporal scale in observations, reanalyses, and GCMs

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Joint work with: Alexander Gershunov; Anna Panorska; Tomasz Kozubowski

Type: Contributed Talk

Abstract. Daily precipitation variability as observed from weather stations is heavy tailed at most locations around the world. It is thought that diversity in precipitation-causing weather events is fundamental in producing heavy-tailed distributions, and it arises from theory that at least one of the precipitation types contributing to a heavy-tailed climatological record must also be heavy-tailed. Precipitation is a multi-scale phenomenon with a rich spatial structure and short decorrelation length and timescales; the spatiotemporal scale at which precipitation is observed is thus an important factor when considering its statistics and extremes. In this study, we examine the spatiotemporal scaling behavior of intense precipitation from point-scale to large grid cells and from one day to four weeks over the entire globe. We go on to validate the current generation of historically-forced climate models and reanalyses against observational data at consistent spatial scales. Our results demonstrate that the prevalence and magnitude of heavy tails in observations decrease when moving to lower spatiotemporal resolutions, as is consistent with stochastic theory. Reanalyses and climate models generally reproduce large, synoptic scale distribution classifications, but struggle to reproduce the statistics in regions that are strongly affected by mesoscale phenomena. We discuss these results in relation to physically consistent atmospheric regimes. We conclude with a global view of precipitation distribution type at daily resolution as calculated from the best-performing reanalysis, the Climate Forecast System Reanalysis.
Keywords: precipitation; Pareto; GCM.

Extreme value analysis of electricity demand in the UK.

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Joint work with: Saralees Nadarajah

Type: Contributed Talk

Abstract. For the first time, an extreme value analysis of electricity demand in the UK is provided. The analysis is based on the generalized Pareto distribution. Its parameters are allowed to vary linearly and sinusoidally with respect to time to capture patterns in the electricity demand data. The models are shown to give reasonable fits. Some useful predictions are given for the value at risk of the returns of electricity demand.
Keywords: Generalized Pareto Distribution; Value-at-Risk.

Bound for the discretization error for the maximum of a Gaussian stationary random field

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Joint work with: Jean-Marc Azaïs ; Guillaume Buscarlet ; Norbert Suard ; Sebastien Trilles

Type: Contributed Talk

Abstract. The objective of this work is to find and to experience some new techniques to evaluate the discretization error for the maximum of a random field observed on a grid. This work is funded by CNES, the French Space Agency and TAS France.

In satellite positioning, a Satellite Based Augmentation System, such as EGNOS (European Geostationary Navigation Overlay Service), disposes of data enabling the correction of estimated position. We work with the GIVDe (Grid Ionospheric Vertical Delay error). This variable is given for a virtual grid: the IGPs grid (Ionospheric Grid Point). This grid is large (a point every 5° in latitude and longitude, about 500km in the equatorial region). In this paper, we are interested in evaluating the difference between the GIVDe maximum on the IGPs grid and the unknown GIVDe maximum over the area covered by the grid (discretization error). To do so, we first apply a Kriging model and compute a bound for the maximum using the the Kriging estimator variance. The Kriging results are used as a reference for comparison with our innovative approach. This new method is based on the Slepian model and gives a local approximation of the random field close to its global maximum. This paper presents two important results: we first prove that asymptotically (when the grid gets finer), the point of the real maximum is uniformly distributed around the closest point of the grid. We also give the asymptotic distribution of the discretization error for a Gaussian stationary random field.
Keywords: discretization error; Kriging; Slepian model.

Extreme values for random tessellations

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Type: Invited Talk

Abstract. A random tessellation in $\mathbf{R}^d$ is a partition of the space into polytopes that are called cells. Such a structure appears in many domains such as cellular biology, telecommunications and image segmentation. Many results were established on the typical cell i.e. a cell which is "chosen uniformly" in the tessellation. However, these works do not deal with the regularity of the tessellation and the pathology of several cells (e.g. elongated or big cells).

In this talk, we investigate the random tessellations by a new approach: Extreme Value Theory. In practice, we observe the random tessellation in a window $\mathbf{W}_\rho = \rho^{1/d} W$, where W is a convex body and $\rho > 0$, and we consider a geometric characteristic (e.g. the volume, the number of vertices or the diameter of the cells). Our problem is to investigate

the behaviour of the order statistics of this characteristic for the cells in $\mathbf{W}_\rho$ when ρ to infinity. Such an approach leads to a better description of the regularity of the tessellation and could provide applications for statistics of point processes.

Our results concern mainly limit theorems on the extremes. Under suitable conditions, we show that it is enough to investigate the geometric characteristic of the typical cell. Besides, in order to study the repartition of the exceedance cells, we are interested by the convergence of underlying point processes and by the mean size of a cluster of exceedances. Many examples, with rate of convergence, are also provided for various geometric characteristics and various random tessellations.

Keywords: Extreme Value Theory; stochastic geometry; random tessellation.

Distribution of the height of local maxima of Gaussian random fields

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Joint work with: Armin Schwartzman

Type: Invited Talk

Abstract. Let $\{f(t) : t \in T\}$ be a smooth Gaussian random field over a parameter space T, where T may be a subset of Euclidean space or, more generally, a Riemannian manifold. We provide a general formula for the distribution of the height of a local maximum $\mathbb{P}\{f(t_0) > u | t_0$ is a local maximum of $f(t)\}$ when f is non-stationary. Moreover, we establish asymptotic approximations for the overshoot distribution of a local maximum

$$\mathbb{P}\{f(t_0) > u + v | t_0 \text{ is a local maximum of } f(t) \text{ and } f(t_0) > v\},$$

as $v \to \infty$. Assuming further that f is isotropic, we apply techniques from random matrix theory related to the Gaussian orthogonal ensemble to compute such conditional probabilities explicitly when T is Euclidean or a sphere of arbitrary dimension. Such calculations are motivated by the statistical problem of detecting peaks in the presence of smooth Gaussian noise.

Keywords: isotropic fields; Euler characteristics; sphere.

A note on "Moment-based density approximations for aggregate losses".

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Joint work with: Saralees Nadarajah; Xiao Jiang

Type: Poster

Abstract. Jin et al. [Scandinavian Actuarial Journal, 2015] proposed a novel moment based approximation based on the Gamma distribution for the compound sum of independent and identical random variables using the example of total insurance claims over a fixed

time period. Closed form expressions for the distribution of this compound sum are difficult to find; Jin et al. illustrated their approximation using six examples. In our analysis, we revisit four of their examples. We look at how the gamma approximation compares to four other moments based approximations based on the exponentiated exponential, Weibull, inverse Gaussian and log normal distributions, for a wide range of parameter values. We show that moment based approximations based on simpler distributions, in particular the Weibull and exponentiated exponential distributions, can be good competitors.
Keywords: Gamma distribution; moments; Weibull distribution.

Extremely dangerous events: modeling terrorist attacks

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Type: Contributed Talk

Abstract. Using a special inhomogeneous marked Poisson process we model terrorist attacks over time in different areas. The intensity of the process varies over time, it is a function of a set of economic and geographical covariates, and it incorporates random effects at the country level. The marks of the process, indicating the magnitude of the attacks in terms of victims, are dependent on another set of societal and technical (e.g. type of weapon used) covariates. The distribution of the marks allows for a fat right tail, thus taking into account extremely destructive attacks. In the talk we first present the theoretical framework, and we then show our estimates and forecasts for some Western countries, using data coming from the Global Terrorism Database.
Keywords: Poisson processes; terrorist attacks.

Large deviation estimates describing the extremal path behavior of matrix recursions

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Joint work with: Sebastian Mentemeier

Type: Invited Talk

Abstract. We study the matrix recursion

$$V_n = A_n V_{n-1} + B_n, \quad n = 1, 2, \ldots,$$

where V_n and B_n are d-dimensional random vectors and A_n is a $d \times d$ random matrix. Early work related to this recursion dates to the seminal paper of Kesten (1973), motivated by an application to multi-type branching processes. Other applications arise in financial time series modeling (connected to the study of the GARCH(p, q) processes) and in physics, and this recursive sequence has also been the focus of extensive work in the recent probability

literature. Our objective is to establish certain extremal estimates describing the path properties of $\{V_n\}$. In particular, we study the first passage time of $\{V_n\}$ into a region $uE \subset \mathbb{R}^d$, showing that this quantity grows roughly like $\gamma \log u$ for a specified constant γ, and showing that the path behavior during a large exceedance mimics that of a certain Markov random walk. Applying our techniques in a more classical setting, we also revisit Kesten's estimate for the decay of the probability $\mathbf{P}\{V_\infty \in uE\}$, $u \to \infty$, providing a refinement of this formula and a new characterization for the extremal index.
Keywords: random recursive sequences; Harris recurrent Markov chains; GARCH financial time series models.

Assessing Regional Climate Models Ability to Produce Extreme Precipitation

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Joint work with: Grant Weller

Type: Invited Talk

Abstract. In this applied talk, we present a methodology for assessing climate models' ability to simulate extreme events. Assessing model output is not straightforward, due to the different spatial and temporal scales between climate model output and observations; and this difference is exacerbated when assessing extreme behavior. There has been some work on downscaling the extremes of model output. We ask a more fundamental question of does downscaling make sense by examining the tail dependence between model output and observations. We employ bivariate extremes methods to examine the strength of daily correspondence of extreme precipitation events between observations and the output of both regional climate models (RCMs) and the driving reanalysis product. We analyze winter precipitation on the Pacific Coast and summer precipitation in the US Midwest.

Further focusing on the Pacific Coast and one particular RCM, we construct a bivariate model of the dependence between precipitation from the RCM output and observations. In an attempt to better understand and quantify the processes which lead to Pineapple Express events, we develop a daily 'PE index' based on mean sea-level pressure fields. We show this index to be tail dependent to the observed precipitation data. We investigate the possible behavior of Pineapple Express events as produced by climate models' future projections.
Keywords: bivariate extremes; asymptotic dependence; Pineapple Express.

Hidden Large Deviations for regularly varying Lévy processes

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Joint work with: Parthanil Roy

Type: Invited Talk

Abstract. We discuss (hidden) large deviations in regularly varying Lévy processes. It is well-known that large deviations of such processes are related to one large jump. We exhibit that by stripping away appropriate spaces, we can see subsequent jumps of the process under proper scaling. The results concentrate on the α-stable Lévy process. We work under the notion of M-convergence which is useful in defining regular variation on a wide variety of spaces.
Keywords: large deviations; regular variation; Lévy processes.

Predictor-dependent multivariate extremes at work

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Pontificia Universidad Catolica de Chile

Type: Invited Talk

Abstract. In this talk, I will discuss some recently developed regression methods for the spectral density of a multivariate extreme value distribution. A major goal of these approaches is on understanding how extremal dependence can evolve over a covariate. While modeling nonstationarity in marginal distributions has been the focus of much recent literature in applied extreme value modeling, approaches to modeling nonstationarity in the extremal dependence structure have received relatively little attention. In addition to overviewing methods under development, and other recent approaches, I will shed some light on directions towards which further research should be headed.
Keywords: multivariate extremes; predictor-dependent probability measures; spectral measure.

Scoring extremes

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EPFL

Joint work with: Philippe Naveau; Dan Cooley

Type: Poster

Abstract. Scoring rules are a very useful tool to assess the quality of statistical models when the sample size is small or when the likelihood is intractable or impossible to compute. Few applications have been developed for extreme values (Friederichs, 2012, Yuen & Stoev, 2014) and the theoretical properties of scoring rules are still not completely understood in this context. We review classical proper scoring rules and derive some results on their general behaviour with regard to the tail of a distribution. We focus on the Continuous Ranked Probability Score (CRPS) (Gneiting, 2007 & 2011), which is commonly used for forecast evaluation of climatological ensemble models. Properties of non-parametric estimators of this score are studied in a univariate framework and for finite samples. We

investigate possibilities for the derivation of multivariate proper scoring rules. This work was done under the supervision of P. Naveau (CNRS) and D. Cooley (CSU).
Keywords: CRPS; forecast evaluation; proper scores.

A large deviations approach to estimation of very small probabilities of multivariate extreme events

de Valk, Cees (ceesfdevalk@gmail.com)
CentER, Tilburg University

Type: Contributed Talk

Abstract. This presentation discusses the multivariate generalization of the GW (Generalized Weibull) and log-GW tail limits (de Valk, C.F., Submitted, 2014; see http://arxiv.org/abs/130 and its application to estimation of the probability of a multivariate extreme event from a sample of n iid random vectors, with the probability bounded by powers of n with exponents lower than -1. A log-GW limit is reduced to a GW limit by taking the logarithm of the random variable concerned, so only the latter is considered. Its multivariate generalization is a Tail Large Deviation Principle (LDP), which can be regarded as the analogue for very small probabilities of classical multivariate extreme value theory based on weak convergence of measures. After standardizing the marginals to a distribution function with a Weibull tail limit, dependence is represented by a homogeneous rate function. An interesting connection exists between the tail LDP and residual tail dependence (RTD), and leads to a new limit for probabilities of a wide class of tail events, generalizing the recent extension of RTD (Wadsworth, J.L. & J.A. Tawn, Bernoulli 19(5B), 2013). Based on the tail LDP, simple estimators for very small probabilities of extreme events are formulated. These avoid estimation of the rate function by making use of its homogeneity, and employ marginal tail estimation and stretching of the data cloud following a normalization of their sample marginals. Strong consistency of the estimators is proven. Some applications are shown as examples.
Keywords: multivariate extremes; large deviations; residual tail dependence.

Ruin probability for vector-valued Gaussian processes

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Joint work with: Enkelejd Hashorva; Lanpeng Ji; Tomasz Rolski

Type: Invited Talk

Abstract. Consider a vector-valued factional Brownian motion $\{\mathbf{B}_H(t) : t \geq 0\}$, where $\mathbf{B}_H(t) = (B_H^{(1)}(t), ..., B_H^{(n)}(t))$ with $\{B_H^{(i)}(t) : t \geq 0\}$, $1 \leq i \leq n$, $n \in \mathbb{N}$ being mutually independent fractional Brownian motions with Hurst index $H \in (0, 1)$.

Let, for $c_1, ..., c_n > 0$,

$$\mathcal{P}(u, \mathcal{T}) = \mathbb{P}\left(\exists_{t\in\mathcal{T}} \forall_{i=1,...,n} (B_H^{(i)}(t) - c_i t) > u\right).$$

We derive the exact asymptotics, as $u \to \infty$, both of the finite-time ruin probability $\mathcal{P}(u, [0, T])$ and the infinite-time ruin probability $\mathcal{P}(u, [0, \infty))$.

Additionally, we analyze properties of multidimensional counterparts of Pickands and Piterbarg constants that appear in the derived asymptotics.

Keywords: Extact asymptotics; fractional Brownian motion; ruin probability.

Comparison of point processes and applications to random geometric networks

Dhandapani, Yogeshwaran (d.yogesh@gmail.com)
Indian Statistical Institute

Joint work with: Bartek Blaszczyszyn

Type: Contributed Talk

Abstract. In this talk, I shall review some examples, methods, and recent results involving comparison of clustering properties of point processes. We will firstly see different comparison tools between point processes of same intensity as well as local and global geometric network functionals that can be compared using these tools. In particular, some of the functionals concern percolation, coverage properties and subgraph counts in geometric networks and even Betti numbers of some random complexes. Many results previously derived for the Poisson point process can be extended to determinantal point processes and some perturbed lattices under this framework.

Keywords: point processes; stochastic order; random geometric networks.

Random geometric complexes in the thermodynamic regime

Dhandapani, Yogeshwaran (d.yogesh@gmail.com)
Indian Statistical Institute

Joint work with: Eliran Subag, Robert Adler

Type: Invited Talk

Abstract. I shall consider the topology of simplicial complexes with vertices the points of a random point process and faces determined by distance relationships between the vertices. In particular, we study the Betti numbers of these complexes as the number of vertices becomes large, obtaining limit theorems for means and strong laws when the underlying points are from an Ergodic point process. Further, restricting to Poisson/Binomial point processes, we shall show concentration inequalities and central limit theorems for Betti numbers.

Keywords: random complexes; Betti numbers; limit theorems.

Exact simulation of max-stable distributions and max-stable random fields

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Joint work with: Sebastian Engelke; Marco Oesting

Type: Contributed Talk

Abstract. Max-stable processes have become a popular tool to model extreme events. Occurring naturally in the context of extremes as limits of maxima of independent copies of stochastic processes, they have frequently found applications in various areas. Due to the complex structure of max-stable processes, in many cases, analytical expressions are available for lower-dimensional distributions only. Thus, many characteristics need to be assessed by simulations.

As the spectral representation involves an infinite number of functions, exact simulation is in general not straightforward. Schlather (2002) proposed an algorithm that is based on some stopping rule and applies in the case of uniformly bounded spectral functions. Dieker & Mikosch (2015) recently proposed a representation of the Brown-Resnick process that allows for an exact simulation at a finite-number of locations.

The purpose of this talk is to present a general and performant algorithm for exact simulation of multivariate max-stable distributions or max-stable random fields. The main idea is to simulate only the spectral functions that actually play a role in the maximum. The complexity of our algorithm is estimated.
Keywords: max-stable distributions; exact simulation.

Non-stationary point processes and their extremes: an exploration of electricity demand in South Africa

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Joint work with: Caston Sigauke

Type: Contributed Talk

Abstract. In this paper we explore the modelling, and particularly the extreme behaviour, of aggregate electricity demand via a non-stationary point process (allowing for the inclusion of covariates in the parameters). A possible advantage of this modelling framework is that the parameterization of the process is invariant to different choices of the thresholds. Data from 1997-2013 for South Africa, where the national grid is presently highly constrained, are used.
Keywords: electricity demand; Extreme Value Theory; point processes.

Analysis of residuals in boundary regression

Drees, Holger (drees@math.uni-hamburg.de)
University of Hamburg

Joint work with: Natalie Neumeyer, Leonie Selk

Type: Invited Talk

Abstract. We consider a nonparametric endpoint regression model

$$Y_i = g(X_i) + \varepsilon_i, \quad 1 \le i \le n,$$

where g is an unknown smooth function and the errors ε_i are iid with cdf

$$F(y) = 1 - c|y|^\alpha + o(|y|^\alpha) \quad \text{as } y \uparrow 0.$$

Rate optimal estimators of the regression function g can be defined as functions of local extremes. We will discuss the asymptotic behavior of the empirical process of residuals and applications to goodness-of-fit tests for the error distribution.
Keywords: nonparametric endpoint regression; residual process; local extremes.

An M-estimator of spatial tail dependence

Einmahl, John (j.h.j.einmahl@uvt.nl)
Tilburg University

Joint work with: Anna Kiriliouk; Andrea Krajina; Johan Segers

Type: Invited Talk

Abstract. 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.
Keywords: Brown-Resnick process; spatial statistics; stable tail dependence function.

Extreme versions of Wang risk measures and their estimation

El Methni, Jonathan (jonathan.el-methni@parisdescartes.fr)
University Paris Descartes

Joint work with: Gilles Stupfler

Type: Contributed Talk

Abstract. Among the many possible ways to study the behavior of a real-valued random variable in its right tail, a particularly general one is given by considering the family of its Wang distortion risk measures. This class of risk measures encompasses various

interesting risk measures, such as the widely used Value-at-Risk and Tail-Value-at-Risk, which are especially popular in actuarial science, for instance. In this communication, we first build simple extreme analogues of Wang distortion risk measures. Special cases of the risk measures of interest include the extreme Value-at-Risk, extreme Tail-Value-at-Risk as well as the recently introduced extreme Conditional Tail Moment. We then introduce adapted estimators and give their asymptotic normality. The finite sample performance of our estimators is assessed on a simulation study and we showcase our technique on a set of real data.

Keywords: Wang distortion risk measure; conditional tail moment; heavy-tailed distribution.

A Generalized Additive Model for non-stationary Generalized Extreme Value distributions.

El-Bachir, Yousra (yousra.elbachir@epfl.ch)
EPFL

Joint work with: Anthony C. Davison

Type: Poster

Abstract. We propose a simple model to deal with temporal non-stationarity of extreme data. For instance, we combine a Generalized Additive Model (GAM) to capture trend and seasonality, and a Generalized Extreme Value (GEV) distribution to model the extremal behaviour. This mixture is based on setting a GAM form to the parameters of the GEV, and use a Backfitting algorithm for their estimation. In this new framework, the functional parameters may be correlated and to guarantee convergence of the optimization, we adopt a diagonalization feature in the estimation. We illustrate the performance of this model with an application to environmental data.

Keywords: Generalized Additive Model; Generalized Extreme Value distribution; Backfitting algorithm.

An application of extreme value analysis in hurricane and tornado research

Elsner, James (jelsner@fsu.edu)
Florida State University

Type: Contributed Talk

Abstract. Hurricanes and tornadoes are nature's most violent storms. Records from past storms provide us with information about what they might be like in the future. In this talk I show how a parameter from an extreme-value model can be used as a proxy for a limit imposed by the physical theory of hurricane intensity. I also demonstrate a spatial model for tornado activity across the U.S. Great Plains.

Keywords: hurricanes; tornadoes; applied statistics.

Extremes on River Networks

Engelke, Sebastian (sebastian.engelke@epfl.ch)
Ecole Polytechnique Federale de Lausanne / Universite de Lausanne

Joint work with: Peiman Asadi; Anthony C. Davison

Type: Invited Talk

Abstract. 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). 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.
Keywords: max-stable process; hydrological distance; network dependence.

Bias-corrected estimation of stable tail dependence function

Escobar-Bach, Mikael (escobar@sdu.dk)
University of Southern Denmark

Joint work with: Jan Beirlant; Yuri Goegebeur; Armelle Guillou

Type: Contributed Talk

Abstract. Many problems involving extreme events are inherently multivariate. In this context, a fundamental question is that of extremal dependence. Similarly to classical statistics one can summarize extremal dependency in a number of well-chosen coefficients that give a representative picture of the dependency structure. The prime example of such a dependency measure is the coefficient of tail dependence. Alternatively, a full characterization of the extremal dependence between variables can be obtained from functions like e.g. the stable tail dependence function, the spectral distribution function or the Pickands dependence function. In this talk we will focus on bias-corrected estimation of the stable tail dependence function. We propose a bias-corrected estimator and we establish its asymptotic behavior under suitable assumptions. In the univariate framework, the bias reduction of estimators for tail parameters is obtained by taking the second order structure of an extreme value model explicitly into account in the estimation stage. In the bivariate framework some attention has been paid to bias-corrected estimation of the coefficient of tail dependence. Goegebeur and Guillou (2013) obtained the bias correction by a properly weighted sum of two biased estimators, whereas Beirlant et al. (2011) fitted the extended Pareto distribution to properly transformed bivariate observations. Recently, a robust and bias-corrected estimator for the coefficient of tail dependence was introduced by Dutang et al. (2014). For what concerns the stable tail dependence function we are only aware of the

estimator recently proposed by Fougeres et al. (2015). In this talk, we illustrate the finite sample performance of our proposed estimator by means of an extensive simulation study and we compare it with the estimators of Fougeres et al. (2015) and the empirical one.
Keywords: multivariate extreme value statistics; stable tail dependence function; bias correction.

A recurrence-based technique for detecting genuine extremes in instrumental records

Faranda, Davide (davide.faranda@cea.fr)
LSCE - CEA Saclay

Joint work with: Pascal Yiou, Sandro Vaienti, Berengere Dubrulle

Type: Invited Talk

Abstract. We analyze several instrumental records of different datasets (air temperatures, blood pressure data, etc) by using new techniques originally developed for the analysis of extreme values of dynamical systems. We show that for such datasets we found the same recurrence time statistics as a chaotic dynamical system perturbed with dynamical noise and by instrument errors. The technique provides a criterion to discriminate whether the recurrence of a certain value belongs to the normal variability or can be considered as a rare event with respect to a specific timescale fixed as parameter. The method gives a self-consistent estimation of the convergence of the statistics of recurrences toward the theoretical extreme value laws.
Keywords: recurrences; dynamical systems; climate.

Stable random fields, point processes and large deviations

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Karlsruhe Institute of Technology

Joint work with: Parthanil Roy

Type: Contributed Talk

Abstract. We investigate the large deviation behaviour of a point process sequence based on a stationary symmetric α-stable ($0 < \alpha < 2$) discrete-parameter random field using the framework of Hult and Samorodnitsky (2010). Depending on the ergodic theoretic and group theoretic structures of the underlying nonsingular group action, we observe different large deviation behaviours of this point process sequence. We use our results to study the large deviations of various functionals (e.g., partial sum, maxima, etc.) of stationary symmetric stable fields.
Keywords: large deviations; point processes; stable random field.

Revisiting the Draupner freak wave

Fedele, Francesco (fedele@gatech.edu)
Georgia Institute of Technology

Type: Contributed Talk

Abstract. In this talk, I will revisit the extreme wave predictions for the 1993's Draupner freak wave event based on hindcasts from the ERA reanalysis database. In particular, following Fedele (2012) I exploit Adler-Taylor's theory on Euler-Characteristics of random fields to predict the maximum wave and crest heights that occurred over the Draupner platform's area during the storm. Drawing on the ECMWF freak wave warning system, I also revisit the influence of nonlinear effects due to quasi-resonant interactions and the associated kurtosis formulation (Fedele 2014). This study provides evidence that space-time extremes explain the observed rogue wave behavior.
Keywords: space-time extreme; rogue wave; Euler characteristics.

Precipitation extremes via pattern scaling from an initial condition ensemble of the CESM

Fix, Miranda (miranda.fix@gmail.com)
Colorado State University/ National Center for Atmospheric Research

Joint work with: Dan Cooley; Stephan Sain; Claudia Tebaldi

Type: Poster

Abstract. In this study, we employ pattern scaling to investigate future extreme precipitation under two climate scenarios over the contiguous United States. We fit a non-stationary generalized extreme value (GEV) model to annual maximum precipitation from a 30-member initial condition ensemble of transient climate model runs under the higher emission scenario RCP8.5. Our pattern scaling approach models the location and log-scale GEV parameters as a linear function of the global mean temperature. This allows us to create a predictive distribution of annual maxima for any global mean temperature of interest, in particular for global mean temperatures under the lower emission scenario RCP4.5. We find that these predictive distributions are well calibrated with the annual maxima actually produced by the RCP4.5 runs. Our model shows clearly that the 1%-probability maximal event level increases with global mean temperature. Under RCP8.5, the 1%-probability maximal event level estimate increases 21.4% on average between 2015 and 2100; and up to 43.3% at some locations. Compared to RCP8.5, RCP4.5 reduces the 1%-probability maximal event level by 6% on average, with reductions as large as 12.6% in some locations. We also compare parameter estimates produced using the data from a single ensemble member to those which we obtained using all members. We demonstrate that utilizing the annual maxima of all the ensemble members results in parameter estimates which are more precise than one would achieve from individual runs, thus allowing us to fit each location individually without needing to employ spatial smoothing methods.
Keywords: extreme precipitation; pattern scaling; GEV.

Bias correction in multivariate extremes

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Institut Camille Jordan, Université Lyon 1

Joint work with: Laurens de Haan; Cécile Mercadier

Type: Invited Talk

Abstract. The estimation of the extremal dependence structure of a multivariate extreme value distribution is spoiled by the impact of the bias, which increases with the number of observations used for the estimation. Already known in the univariate setting, the bias correction procedure is studied in this talk under the multivariate framework. New families of estimators of the stable tail dependence function are obtained. They are asymptotically unbiased versions of the empirical estimator introduced by Huang (1992). Since the new estimators have a regular behaviour with respect to the number of observations, it is possible to deduce aggregated versions so that the choice of the threshold is substantially simplified. An extensive simulation study is provided as well as an application on real data.
Keywords: multivariate extreme value theory; tail dependence; bias correction.

A general estimator for the extreme value index: applications to conditional and heteroscedastic extremes

Gardes, Laurent (gardes@unistra.fr)
University of Strasbourg

Type: Contributed Talk

Abstract. It is well known that the tail behavior of a survival function is controlled by the so-called extreme value index. The aim of this paper is the estimation of this extreme value index in the case where the observations are not necessarily distributed from the same distribution. A general procedure of estimation is proposed. The idea is to estimate in a consistent way the survival function and to apply a general functional to obtain a consistent estimator for the extreme value index. The procedure of estimation presented in this paper permits to deal with a large set of models such as *conditional extremes* and *heteroscedastic extremes*. The consistency of the obtained estimator is established under general conditions and its finite sample behavior is investigated through a simulation study.
Keywords: extreme value index; conditional extremes; heteroscedastic extremes.

Severe storm environments and Extreme Value Analysis

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National Center for Atmospheric Research

Joint work with: Matthew J. Heaton; Elizabeth Mannshardt; Barbara G. Brown; Caspar Ammann

Type: Contributed Talk

Abstract. Climate change science has historically considered the mean atmospheric state to be the definition of climate. However, it is the extreme weather conditions that are of the most importance because of their potential for loss of life, large economic damage, and environmental destruction. Assessing the mean is insufficient to know anything about extreme weather conditions, but analyzing extreme weather conditions is hampered by the relatively fine scales where extreme events occur. One approach to making inferences about severe weather in a climate setting is to investigate variables that occur on a large scale and provide information about environments where severe weather is likely (or not) to occur. One such indicator is concurrently high values of convective available potential energy and 0 - 6 km vertical wind shear. The extremes of this indicator from a global reanalysis "observation" series are analyzed spatially in different contexts, and using different EVA approaches. It is found that the particular method chosen to analyze the extremes makes a difference in terms of the resulting conclusions, but that generally no significant changes are found in terms of the extremes; though important changes may occur in the less extreme values. One promising technique utilizes the conditional EVA model proposed by Heffernan and Tawn whereby patterns of severe storm environments conditioned on having extreme energy in the field are found to be physically meaningful. Assessing the uncertainty under this paradigm is the main challenge, and is ongoing work.
Keywords: severe storm environments; spatial extreme value analysis; conditional model.

Max-linear models represented by directed acyclic graphs

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Joint work with: Claudia Klüppelberg

Type: Poster

Abstract. Graphs are popular mathematical objects to visualize the conditional independence restrictions of a family of random variables. Each node in the graph represents a random variable and edges represent statistical dependencies between these variables. Despite many domains of applications such as medicine, biology, genetic, finance, and engineering, the distributions of the random variables are mainly restricted to discrete and Gaussian distributions. In the context of risk assessment the assumption of Gaussianity leads invariably to severe underestimation of large risks and therefore to unsuitable models. We suggest a new max-linear structural equation model, where all random variables can be written as a max-linear function of their parents and noise variables, which are assumed to be jointly independent. As for each structural equation model there is a graph describing the relationships between the random variables. We assume that this graph is a directed acyclic graph and that the noise variables are max-stable, resulting in a max-stable distribution of the corresponding random vector. We present basic probabilistic results of our model and prove the directed Markov property relative to the graph by means of the corresponding regular conditional distributions. We also investigate statistical issues, identifiability questions, and algorithms to apply the new model to data.

Keywords: directed acyclic graph; max-linear distribution; structural equation model.

Limit distributions of partial maxima in the uniform AR(1) processes

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University of Belgrade, Faculty of Mathematics

Joint work with: Pavle Mladenović

Type: Contributed Talk

Abstract. Two types of the uniform $AR(1)$ process $(X_n)_{n\geq 1}$ are considered: one with positive, and the other with negative lag one correlation. Let $r \geq 2$ be parameter of this process, and $(c_n)_{n\geq 1}$ is a non-random 0-1 sequence such that the limit $\lim_{n\to\infty} \frac{1}{n}\sum_{k=1}^{n} c_k = p$ exists. Let $\widetilde{M}_n$ be the maximum of those X_k's for which $k \leq n$ and $c_k = 1$, and $M_n = \max\{X_1, \ldots, X_n\}$. Several specific sequences (c_n) are used. We prove that the limit distribution of the random vector $(\widetilde{M}_n, M_n)$, as $n \to \infty$, is not uniquely determined by the limit value p. A simulation study and analysis of a simulated data set are also presented.
Keywords: Partial samples; uniform AR(1) processes.

Confidence intervals for exceedance probabilities with application to extreme ship motions

Glotzer, Dylan (dglotzer@live.unc.edu)
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Joint work with: Dylan Glotzer; Vladas Pipiras

Type: Poster

Abstract. Statistical inference of a probability of exceeding a large critical value is studied in the peaks-over-threshold (PoT) approach. The focus is on assessing the performance of the various confidence intervals for the exceedance probability, both for the generalized Pareto distribution used above a selected threshold and in the POT setting for general distributions. The developed confidence intervals perform well in an application to extreme ship motion data. Finally, several approaches to uncertainty reduction are also considered.
Keywords: exceedance probability; quantiles; confidence intervals.

Reduced-bias Value-at-Risk semi-parametric estimation

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Universidade de Lisboa

Joint work with: Frederico Caeiro; Fernanda Figueiredo; Dinis Pestana

Type: Contributed Talk

Abstract. For any level q, $0 < q < 1$, and on the basis of a sample of either independent, identically distributed or possibly weakly dependent and stationary random variables from an unknown model F with a heavy right-tail function, the value-at-risk at the level q, the size of the loss that occurred with a small probability q, is estimated by new semi-parametric reduced-bias procedures based on the mean-of-order-p of a set of k quotients of top order statistics, with p any real number. These new VaR-estimators are compared with the classical ones, not only asymptotically, but also for finite samples, through Monte-Carlo techniques.
Keywords: Bias estimation; heavy right tails; Value-at-Risk semi-parametric estimation.

Robust and bias-corrected estimation in multivariate extremes

Guillou, Armelle (armelle.guillou@math.unistra.fr)
Strasbourg University and CNRS

Type: Invited Talk

Abstract. Multivariate extreme value statistics deals with the estimation of the tail of a multivariate distribution function based on a random sample. Of particular interest is the estimation of the extremal dependence between two or more variables. Modelling tail dependence is a crucial issue in actuarial science (see e.g. Joe, 2011), firstly, because of the forthcoming Solvency II regulation framework which will oblige insurers and mutuals to compute 99.5% quantiles. Secondly, tail dependence can be used in the daily work of actuaries, for instance for pricing an excess-of-loss reinsurance treaty (see Cebrian et al., 2003, and the references therein), and for approximating very large quantiles of the distribution of the sums of possibly dependent risks (Barbe et al., 2006). In finance, obvious applications also arise, see e.g. Charpentier and Juri (2006), and Poon et al. (2004). Therefore, accurate modelling of extremal events is needed to better understand the relationship of possibly dependent risks at the tail. A full characterization of the extremal dependence between variables can be obtained from functions like the spectral distribution function or the Pickands dependence function. We refer to Beirlant et al. (2004), and de Haan and Ferreira (2006), and the references therein, for more details about this approach. Alternatively, similar to classical statistics one can try and summarize the extremal dependency in a number of well-chosen coefficients that give a representative picture of the full dependency structure. In this talk, we will consider the estimation of such dependency coefficients/functions. Robust and asymptotically unbiased estimators will be derived from a second order model using the minimum density power divergence (MDPDE) criterion. The performance of the resulting estimators will be illustrated on a simulation study. This talk is based on several projects written in collaboration with C. Dutang, Mikael Escobar-Bach, Yuri Goegebeur and Alexandre You.
Keywords: robustness; bias-correction; multivariate extremes.

Comparison between constant-stress and step-stress accelerated life tests with extreme value regression

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University of Texas

Type: Poster

Abstract. By running life tests at higher stress levels than normal operating conditions, accelerated life testing (ALT) quickly yields information on the lifetime distribution of a test unit. The lifetime at the design stress is then estimated through extrapolation using a regression model. In constant-stress testing, a unit is tested at a fixed stress level until failure or the termination time point of test, whereas step-stress testing allows the experimenter to gradually increase the stress levels at some prefixed time points during the test. In this work, the optimal multi-level constant-stress and step-stress ALT are compared when an extreme value regression model is used for statistical analysis under complete sampling and Type-I censoring. The objective is to quantify the advantage of using the step-stress testing relative to the constant-stress one. Assuming a log-linear life-stress relationship with the cumulative exposure model for the effect of changing stress in step-stress testing, the optimal design points are determined under C/D/A-optimality criteria. The efficiency of step-stress testing to constant-stress one is then discussed in terms of the ratio of optimal objective functions based on the information matrix.
Keywords: accelerated life tests; extreme value regression; optimal designs.

Pickands' constant H_α does not equal $1/\Gamma(1/\alpha)$, for small α

Harper, Adam (ajh228@cam.ac.uk)
Jesus College, University of Cambridge

Type: Invited Talk

Abstract. Pickands' constants H_α appear in various classical limit results about tail probabilities of suprema of Gaussian processes. There is a conjecture that perhaps $H_\alpha = 1/\Gamma(1/\alpha)$ for all $0 < \alpha \leq 2$, and this is true when α is 1 or 2, which are the only cases where the exact value of H_α is known. It seems difficult to obtain much information about H_α, either theoretically or by simulation, but recent simulations suggest quite strongly that the conjecture about H_α is false.

I will try to explain my work showing rigorously that the conjecture is false for small α. This result is a byproduct of a general "conditioning and comparison" method, that gives quite strong lower bounds for tail probabilities of suprema of certain processes. If time permits I will also discuss other applications of the method, which come from number theory.
Keywords: Pickands' constants; suprema of Gaussian processes; conditioning and comparison.

Extremes of a class of non-homogeneous Gaussian random fields

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Joint work with: Krzysztof Dębicki; Lanpeng Ji

Type: Invited Talk

Abstract. This contribution establishes exact tail asymptotics of $\sup_{(s,t)\in E} X(s,t)$ for a class of non-homogeneous Gaussian random fields X on a bounded convex set $E \subset \mathbb{R}^2$, with variance function that attains its maximum on a segment on E. Our findings extend the classical results for homogeneous Gaussian random fields and Gaussian random fields with unique maximum point of the variance. The applications that will be discussed concern extremes of Shepp statistics, expansions for the maximum loss and span of stationary Gaussian processes.
Keywords: Gaussian random fields; Shepp statistics; span of stationary Gaussian processes.

Estimation of extreme depth-based quantile regions

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Tilburg University

Joint work with: Yi He; John H.J. Einmahl

Type: Contributed Talk

Abstract. Consider the extreme quantile region, induced by the halfspace depth function HD, of the form $\mathcal{Q} = \{\boldsymbol{x} \in \mathbb{R}^d : HD(\boldsymbol{x}, P) \leq \beta\}$, such that $P\mathcal{Q} = p$ for a given, very small $p > 0$. This region can hardly be estimated through a fully nonparametric procedure since the sample halfspace depth is 0 outside the convex hull of the data. Using Extreme Value Theory, we construct a natural, semiparametric estimator of this quantile region and prove a refined consistency result. A simulation study clearly demonstrates the good performance of our estimator. We use the procedure for risk management by applying it to stock market returns. An asymptotic theory is also established recently.
Keywords: extreme value statistics; halfspace depth; multivariate quantile.

Heavy tail robust and optimally bias-corrected GMM

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University of North Carolina

Type: Invited Talk

Abstract. This paper develops a heavy tail robust GMM estimator with automatic optimal bias correction. In order to ensure identification, existing robust GMM estimators

require either an underlying process to have a symmetric distribution; or assumed identification based on different trimming quantities in the left and right tails which are generally difficult to pick; or a model of the bias exists by assuming an underlying error distribution; or a simulation step based on indirect inference in order to remove the bias, which requires knowledge of an underlying distribution. In this paper, we use Karamata theory to approximate the bias using minimal information about the equation tails, resulting in a bias corrected tail trimmed estimation equation. The bias is optimally fitted such that the trimmed equation mean is, asymptotically, arbitrarily close to the untrimmed equation mean, ensuring minimal bias that vanishes in the limit distribution. Our GMM estimator is therefore asymptotically normal and unbiased in its limit distribution, irrespective of how trimming is done, as long as trimming is negligible. Indeed, our estimator has these limiting properties even if Karamata theory does not apply, that is when equation tails are not heavy in the sense that they decay faster than a power law. We give examples of the use of our estimator for robust excess shortfall estimation, AR and GARCH models estimation, and variance targeting for GARCH estimation in which tail trimming with bias correction is used in the first and second stages of estimation. A simulation study demonstrates the performance of our estimator, and its advantages over existing estimators.
Keywords: GMM; tail trimming; bias correction.

One-component regular variation for multivariate extremes

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Type: Contributed Talk

Abstract. Extreme value theory aims at describing the tails of distributions. In that context, the notion of regular variation is essential and we suggest a new definition in the multivariate case. A random vector $(X, \boldsymbol{Y})$ on $E = [1, \infty) \times \mathbb{R}^{d-1}$ is said to be *regularly varying in its first component* if

$$(t^{-1}X, \boldsymbol{Y}) \mid X \geq t \underset{t\to\infty}{\overset{w}{\Rightarrow}} \nu,$$

for a probability distribution ν on E. This coincides with the standard regular variation in the following case: if $\boldsymbol{Z}$ is a non-negative random vector, then $(||\boldsymbol{Z}||, \boldsymbol{Z}_{1:d-1}/||\boldsymbol{Z}||)$ is regularly varying in its first component if and only if

$$t^{-1}\boldsymbol{Z} \mid ||\boldsymbol{Z}|| \geq t \underset{t\to\infty}{\overset{w}{\Rightarrow}} \mu,$$

for a probability distribution μ on $\{||\boldsymbol{z}|| \geq 1\}$.

Our contribution is to generalize Karamata's theorem for one-component regular variation and to propose a model for the limiting distribution ν. It is known that $\nu(A, B) = P_\alpha(A)\, H(B)$ where P_α is the Pareto distribution of index $\alpha > 0$ and H is a probability distribution on $\mathbb{R}^{d-1}$. A major issue resides in finding a flexible model for H in high-dimension. Graphical models offer a powerful framework to specify the dependence structure of a random vector. We introduce the notion of *asymptotic conditional independence* relations among the components of the vector, which arise when the limiting probability density $d\nu$

factorizes with respect to a graphical model. This determines a valid angular distribution for $\boldsymbol{Z}/||\boldsymbol{Z}||$ and we explain how to perform the inference in that case.
Keywords: multivariate; regular variation; graphical models.

An extreme value approach for modeling Operational Risk losses depending on covariates

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Joint work with: Valerie Chavez-Demoulin; Paul Embrechts

Type: Invited Talk

Abstract. A general methodology for modeling loss data depending on covariates is developed. The parameters of the frequency and severity distributions of the losses may depend on covariates. The loss frequency over time is modeled with a non-homogeneous Poisson process with rate function depending on the covariates. This corresponds to a generalized additive model which can be estimated with spline smoothing via penalized maximum likelihood estimation. The loss severity over time is modeled with a non-stationary generalized Pareto distribution (alternatively, a generalized extreme value distribution) depending on the covariates. Since spline smoothing can not directly be applied in this case, an efficient algorithm based on orthogonal parameters is suggested. The methodology is applied both to simulated loss data and a database of operational risk losses collected from public media. Estimates, including confidence intervals, for risk measures such as Value-at-Risk as required by the Basel II/III framework are computed. Furthermore, an implementation of the statistical methodology in R is provided.
Keywords: operational risk; Value-at-Risk; covariates.

Tests for a change in extreme quantiles for beta-mixing random variables

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Type: Poster

Abstract. Under general assumptions change point tests for extreme quantiles are derived. The extreme quantile estimators used here allow us to extrapolate outside the range of available data. This is particularly important as our procedure requires the sample to be split in smaller subsamples, thus making estimation of extreme quantiles infeasible using non-parametric techniques. A simulation study is conducted to illustrate the performance of the tests in nite samples. Two empirical examples illustrate the wide applicability of the tests.
Keywords: change point test; beta-mixing; extreme quantile.

On high conditional quantile for extremes

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Type: Contributed Talk

Abstract. Quantile regression has wide applications in many fields. For extreme events, we use multivariate heavy tailed distributions, then estimating of conditional quantiles at very high or low tails is interest and difficult problem. Quantile regression uses an L1-loss function, and the optimal solution of linear programming for estimating coefficients of regression. This paper proposes a weighted quantile regression method on high quantile regression for certain extreme value sets. The Monte Carlo simulations show good results of the proposed weighted method. Comparisons of the proposed method and existing methods are given. The paper also investigates a real-world example of application on extreme events by using the proposed method.
Keywords: bivariate Pareto distribution; linear programming; weighted loss function.

Temperature Extremes in climate model simulations under increased CO2 concentrations

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Joint work with: Michael Stein; Elisabeth Moyer; David McInerney; Shanshan Sun

Type: Contributed Talk

Abstract. It is of great interest to determine how the tail behavior of temperature may change in a changing climate. However, this inquiry is complicated by the fact that the observational data records are not adequate to reliably detect possible changes in this behavior that may have already occurred. It is thus of interest to see what climate models forecast for changes in extremes. In this study we focus on the last 1000 years of three multi-millennial runs from the Community Climate System Model version 3 (CCSM3) under different CO2 concentration namely, 289 ppm (corresponding to pre-industrial values), 700 ppm and 1400 ppm. By using only the last 1000 years of each run, we can assume that the process is effectively in equilibrium and that a time series of annual extremes forms a stationary sequence. The Generalized Extreme Value (GEV) distribution is fitted to winter (December, January, and February) minimum and summer (June, July, and August) maximum temperature using the block maxima approach. A comparison of quantile functions of the fitted extreme value distributions for these three CO2 levels was performed for each pixel over the contiguous United States. The results suggest that changes in warm extremes generally follow the changes in the mean summer temperature, while cold extremes warm faster than the mean changes of winter temperature nearly everywhere in the contiguous United States. In addition, there is some evidence indicating that tail behavior may change, especially for those high latitude pixels during winter with increased atmospheric CO2 concentration.
Keywords: GEV; temperature extremes; climate change.

Urn-based bivariate extreme shock models

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Joint work with: Pasquale Cirillo

Type: Invited Talk

Abstract. A class of generalized extreme shock models based on urn processes has been recently introduced in the literature, allowing for a rather flexible modeling of risk events. The use of urns also permits to introduce some prior knowledge in those models. Analytic results can be derived under certain restrictions, regarding the initial composition and the reinforcement matrix of the urn process.

In this talk we plan to discuss the extension of such models to the multivariate case. Because of the possible complexity - and to keep the notation as simple as possible, we will restrict our attention to the bivariate case. Even in this case analytical results can be obtained under some given conditions. Moreover, in the case in which an analytical solution is not feasible, the intuitive urn construction guarantees that bivariate risk events can be easily simulated and their probabilistic properties thus studied.
Keywords: extreme risk; multivariate risk; urn models.

A comparative study of likelihood estimators for multivariate extremes

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KAUST

Joint work with: Anthony C. Davison; Marc G. Genton

Type: Invited Talk

Abstract. The main approach to inference for multivariate extremes loosely consists in approximating the joint upper tail of the observations by a parametric family of extreme-value distributions. Extreme events may be defined in terms of componentwise maxima, high threshold exceedances, or point processes, yielding different but related asymptotic characterizations and estimators. In this talk, I will remind the connections between the main likelihood estimators for extremes, and assess their practical performance. Their ability to estimate the extremal dependence structure and to predict future extremes will be compared using exact calculations and simulation, focusing on the logistic model.
Keywords: asymptotic relative efficiency; likelihood inference; multivariate extremes.

Joint extremal behavior of power products

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University of Hamburg

Joint work with: Holger Drees, University of Hamburg

Type: Contributed Talk

Abstract. For independent and non-negative random variables $X_i, 1 \leq i \leq n, n \in \mathbb{N}$, which are all assumed to be regularly varying with the same index $-\alpha, \alpha > 0$, we analyze the joint extremal behavior of the $j \in \mathbb{N}$ power products $\prod_{i=1}^{n} X_i^{\beta_{k,i}}, 1 \leq k \leq j$, with $\beta_{k,i} \in \mathbb{R}$. More precisely, we give asymptotics for the exceedance probabilities

$$P\left(\prod_{i=1}^{n} X_i^{\beta_{k,i}} > c_k x, \;\; 1 \leq k \leq j\right) \tag{1}$$

for $c_k > 0, 1 \leq k \leq j$, as $x \to \infty$. We show that under relatively mild assumptions about the matrix $(\beta_{k,i})$, the asymptotic behavior of (1) is closely linked to the solution of the linear optimization problem given by

$$\text{find } (x_1, \ldots, x_n) \in [0, \infty)^n \text{ such that } \sum_{i=1}^{n} \beta_{k,i} x_i \geq 1, \;\; 1 \leq k \leq j, \text{ and } \sum_{i=1}^{n} x_i \to \min!$$

For the derivation of our result, we make use of the concept of regular variation on cones, cf. Lindskog, Resnick and Roy (2014).

By extending the aforementioned results to an infinite number of factors we are able to apply our analysis for the derivation of joint exceedance probabilities of lagged observations $(Y_t, Y_{t+h_1}, \ldots, Y_{t+h_n}), 0 < h_1 < \ldots < h_n$, from a particular class of stochastic volatility models introduced in Janßen and Drees (2015).

Literature

Janßen, A. and Drees, H.: A stochastic volatility model with flexible extremal dependence structure. Bernoulli, forthcoming, 2015.

Lindskog, F., Resnick, S.I. and Roy, J.: Regularly varying measures on metric spaces: Hidden regular variation and hidden jumps. Probab. Surveys **11**, 270–314, 2014.

Keywords: regular variation on cones; exceedance probabilities; Breiman's Lemma.

Scale mismatch problem in the analysis of Central U.S. Temperature Anomaly

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Joint work with: Christopher Paciorek; Michael F. Wehner

Type: Invited Talk

Abstract. Analyses of extreme event attribution provide characterization of how the attributing risk of extreme events to anthropogenic climate change has increased, by quantifying the fraction of attributable risk (FAR) or the risk ratio (RR). We consider with the role of anthropogenic factors in a specific extreme event, the 2011 Texas heatwave. However, as noted in earlier paper by Smith and Wehner (2013), variances of the observational

and modeled temperature anomalies for all forcings and natural forcings have different scales, which implies that the model outputs cannot represent extremes in observed values. Our study focuses on the analysis of central United States temperature anomaly from CRUTS observational data products and CCSM4 (the fourth version of the Community Climate System Model) with multi-ensembles using extreme value modeling. In particular, we attempt to lay an intuitive framework, the so-called quantile bias correction, to solve the scale mismatch problem and estimate a corrected risk ratio based on the adjustment of probabilities of extreme events in different datasets: observational and climate model data under anthropogenic and natural forcing scenarios. We also investigate various components of uncertainties in estimation of the risk ratio based on our method, and discuss a framework to construct an one-side confidence interval of the event when the estimated probability of event is zero in the model with natural forcing, which results in a risk ratio of infinity.
Keywords: event attribution; extreme value modeling; temperature extremes.

Comparisons of smallest order statistics from Pareto distributions with different scale and shape parameters

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Joint work with: Saralees Nadarajah; Jeffrey Chu

Type: Poster

Abstract. Pareto distribution, is one of the most important distributions in Extreme Value Theory. In this case, we mainly derive conditions for stochastic, hazard rate, likelihood ratio, reversed hazard rate, increasing convex and mean residual life orderings from two independent but non-identical Pareto random variables with different shape and scale parameters. A real data application of the conditions is presented.
Keywords: Pareto type I distribution; Pareto type II distribution; stochastic order.

Tail index estimation: a generalization of Hill's estimator and some optimization problems

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Joint work with: Pavle Mladenović

Type: Contributed Talk

Abstract. Distributions with regularly varying (right) tail are often applied in statistical modelling of real data. Estimating the tail index play an important role in that procedure. In this paper we deal with a class of tail index estimators, which is a generalization of the well known Hill's estimator.

Let $X_1, X_2, \ldots, X_n$ be random variables, with common distribution function $F(x) = P\{X_k \le x\}$, and the tail $1 - F(x) = P\{X_k > x\}$ regularly varying at ∞, that is, for all $x > 0$,

$$\lim_{t\to\infty} \frac{1 - F(tx)}{1 - F(t)} = x^{-\alpha},$$

where $\alpha > 0$ is the tail index.

Hill's estimator of the tail index α is the average of log-exceedances, given by

$$H_n^{-1} = \frac{1}{m}\sum_{k=1}^{m} \ln \frac{X_{(k)}}{X_{(m+1)}} = \frac{1}{m}\sum_{k=1}^{m} \left(\ln X_{(k)} - \ln X_{(m+1)}\right).$$

As possible estimators of the tail index α, we propose all convex combinations of these exceedances , that is

$$\widetilde{H}_n^{-1} = \sum_{k=1}^{m} c_k \ln \frac{X_{(k)}}{X_{(m+1)}} = \sum_{k=1}^{m} c_k \left(\ln X_{(k)} - \ln X_{(m+1)}\right), \tag{2}$$

where $c_k \ge 0$ for $k \in \{1, 2, \ldots, m\}$ and $c_1 + c_2 + \cdots + c_m = 1$.

In this paper we consider the optimization problem, that is obtaining such values of the coefficients $c_1, c_2, \ldots, c_m \ge 0,\ c_1 + \cdots + c_m = 1$, that minimize the mean squared error

$$E\left(\widetilde{H}_n - \frac{1}{\alpha}\right)^2 = E\left(\sum_{k=1}^{m} c_k \ln \frac{X_{(k)}}{X_{(m+1)}} - \frac{1}{\alpha}\right)^2$$

of the estimator given by (2).

We propose the values of the coefficients $c_1, c_2, \ldots, c_m$, such that the corresponding estimator, in several cases, has smaller mean squared error than commonly used estimators (obtained by Hill (1975), Pickands (1975), Dekkers, Einmahl and de Haan (1989) and C. de Vries). We confirm these findings in a simulation study, and obtain some related properties.

Keywords: tail index; Hill's estimator; mean squared error.

Extreme average regression quantile: Its asymptotic and finite sample properties

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Charles University in Prague, Czech Republic

Type: Contributed Talk

Abstract. Consider the linear regression model $Y_{ni} = \beta_0 + \mathbf{x}_{ni}^\top \boldsymbol{\beta} + e_{ni}$, with i.i.d. model errors and with covariates $\mathbf{x}_{ni} \in \mathbb{R}^p,$, $i = 1, \ldots, n$. The *maximal regression quantile* is any solution to the linear program:

$$\min_{b_0\in\mathbb{R}^1, \mathbf{b}\in\mathbb{R}^p} b_0 + \sum_{i=1}^{n} \mathbf{x}_i^\top \mathbf{b} \qquad \text{s.t.} \quad Y_i \le b_0 + \mathbf{x}_i^\top \mathbf{b}, \quad i = 1, \ldots, n.$$

Alternatively, it can be defined in a two-step procedure, estimating the slope components of the regression parameter by a specific R-estimator $\boldsymbol{\beta}_{nR}^{+}$ and then characterizing the intercept component $\widehat{\beta}_{n0}(1)$ as the maximum among the residuals of Y_i's from $\boldsymbol{\beta}_{nR}^{+}$. Using this form, we shall illustrate the convergence of $\widehat{\beta}_{n0}(1)$, depending on the domain of attraction of distribution of the e_{ni}, under a moderate condition on the regressors. We shall also consider the *average extreme regression quantile* with the regressors as weights, and characterize its finite-sample and asymptotic behavior.

Keywords: extreme regression quantile; average extreme regression quantile; R-estimator.

Parsimonious and flexible models for spatial extremes

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Joint work with: Jonathan Tawn; Philip Jonathan

Type: Contributed Talk

Abstract. Offshore structures must be designed to have very low probabilities of failure due to extreme weather conditions. Inadequate design can lead to structural damage, lost revenue, danger to operating staff and environmental pollution. Design codes demand that all offshore structures exceed specific levels of reliability, most commonly expressed in terms of an annual probability of failure or return period. Hence, we want to estimate the rate and size of future occurrences of rare environmental phenomena.

Interest lies in multiple oceanographic locations, thus extremal dependence between the different sites must be taken into account, warranting a spatial modelling framework. There exist two types of extremal dependence asymptotic independence (AI) and asymptotic dependence (AD). Determining the type of extremal dependence can prove difficult, particularly when sample size is small and dependence levels are reasonably low. We will suggest new methods for estimating measures of dependence that may improve accuracy in these cases.

In practice, often AD models are used by default, as they are considered more conservative; i.e. they overestimate the extremes rather than underestimate them, which is generally preferred for safety reasons. However, data often suggests that AI models might be more appropriate for sites located further apart. Most existing models for spatial extremes form part of the family of max-stable processes, which can only capture perfect independence and AD. There have been some attempts made at modelling AI, but these models are complex and do not scale well to the size of practical applications. This is even more so the case for hybrid models that attempt to capture both AI and AD structure.

Our work focuses on building a model that can capture AD structure over short distances and AI structure for larger distances, but is simple to implement and do inference for.

Keywords: spatial extremes; extremal dependence; waves.

A test for abrupt change in hazard regression models with Weibull baselines

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Joint work with: Matthew Williams

Type: Contributed Talk

Abstract. We develop a likelihood-ratio test for an abrupt change point in Weibull hazard function with covariates, including the two-piece constant hazard as a special case. We first define the log-likelihood ratio test statistics as the supremum of the profile log-likelihood ratio process over the interval which may contain an unknown change point. Using local asymptotic normality (LAN) and empirical measure, we show that the profile log-likelihood ratio process converges weakly to a quadratic form of Gaussian process. We determine the critical values of the test and discuss how the test can be used for model selection. We also illustrate the method using the Chronic Granulomatous Disease (CGD) data.
Keywords: change point; likelihood ratio test; local asymptotic normality.

Estimating tail dependence parameters by least-squares fitting of extremal coefficients.

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Université Catholique de Louvain

Joint work with: John H.J. Einmahl; Johan Segers

Type: Contributed Talk

Abstract. We start with a random sample that is in the max-domain of attraction of a multivariate extreme value distribution, and we assume that the stable tail dependence function of the attractor belongs to a parametric model. Inspired by Einmahl et al. (2014), we propose a novel estimator constructed as the minimizer of the distance between a vector of parametric extremal coefficients and the vector of their empirical counterparts. This leads to a consistent and asymptotically normal estimator. In addition, the asymptotic variance of the estimator can be minimized by replacing the Euclidian distance by a quadratic form based on a weight matrix estimated from the data. Its computation is very fast since the extremal coefficients have a simple analytical expression for most popular parametric models. Moreover, this estimator is particularly flexible because it is not limited to pairwise inference. We will demonstrate its good performance and propose possible applications.

Einmahl, J.H.J., Kiriliouk, A., Krajina, A., & Segers, J. (2014). An M-estimator of spatial tail dependence. To be published in the Journal of the Royal Statistical Society: Series B (Statistical Methodology).
Keywords: extremal coefficient; multivariate extremes; stable tail dependence function.

A simple but enhanced test for detecting the occurrence difference in past and future climates

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Nagoya Institute of Technology

Type: Contributed Talk

Abstract. Two-sample problem for excess numbers over a threshold is discussed. In effect we focus on the tail properties to detect the differences of two samples. Most of two-sample problems have dealt with the central tendency of population by sampling, for example, t-test in parametric method, Wilcoxon test and Kolmogorov-Smirnov test in non-parametric method. Even model selection based on the likelihoods by means of AIC etc., should be considered as to be compared in the central part of population, where the data are concentrated into. Just because the null hypothesis cannot be rejected that the populations of annual maxima are equivalent, the tails of two populations, for example the properties of once per 30 years, are not always of same behavior. It seems to contradict the extreme value theory, but we discuss here a certain problem of inference accompanied with the uncertainties, which becomes larger as the sample size is small. The tail looks blurred in general, which is unavoidable for the sparseness. Thus we employ a frame of poisson test, and extend it by an extrapolation technique based on the extreme value theory. The poisson test is similar to the fisher exact test of two-sample test for equality of proportions. The propose method based on replacing the actual exceedance numbers with the values of degree of experience which indicate the effective numbers containing the transferred information of non-exceedance sample by extrapolation and are derived from the likelihoods of sample extremes. Finally we will demonstrate a simple application of comparing the level exceedance frequencies of heavy precipitations in past and future climates.
Keywords: Poisson test; occurrence rate; climate change.

Extremes on directed acyclic graphs

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Joint work with: Nadine Gissibl

Type: Invited Talk

Abstract. We consider a new max-linear structural equation model, where all random variables can be written as a max-linear function of their parents and noise terms. For the corresponding graph we assume that it is a directed acyclic graph. Leading example are max-stable noise variables, resulting in a max-linear directed acyclic graph. We present basic probabilistic results of our model and prove the directed Markov property relative to the graph by means of the corresponding regular conditional distributions. We also address statistical issues, identifiability questions, and algorithms to apply the new model to data.
Keywords: structural equation model; max-linear distribution; directed acyclic graph.

Spatial risk measures and applications to max-stable processes

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ETH Zürich, Department of Mathematics (RiskLab)

Type: Contributed Talk

Abstract. The risk of extreme environmental events is of great importance for both the authorities and the insurance industry. This paper concerns risk measures in a spatial setting, in order to introduce the spatial features of damages stemming from environmental events in the measure of the risk. We develop a new concept of spatial risk measure, based on the spatially aggregated loss over the region of interest, and propose an adapted set of axioms for these spatial risk measures. These axioms quantify the sensitivity of the risk measure with respect to the space and are especially linked to spatial diversification. In order to model the loss underlying our definition of spatial risk measure, we apply a damage function to the environmental variable considered. The latter is assumed to follow a max-stable process, very well suited for the modeling of extreme spatial events. Two damage functions are considered, respectively adapted to temperatures and wind speeds. The theoretical properties of the resulting examples of spatial risk measures are studied and some interpretations in terms of insurance are provided.
Keywords: max-stable process; risk measures; spatial dependence.

An Erdös–Révész type law of the iterated logarithm for Gaussian storage processes.

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Joint work with: Krzysztof Dębicki

Type: Contributed Talk

Abstract. Let $B_H = \{B_H(t) : t \in \mathbb{R}\}$ be a fractional Brownian motion with Hurst parameter $H \in (0,1)$ and $Q_{B_H} = \{Q_{B_H}(t) : t \geq 0\}$ be the stationary storage process describing the stationary buffer content process of a fluid queue fed by B_H. The process Q_{B_H} can be given the following representation

$$Q_{B_H}(t) = \sup_{-\infty < s \leq t} \left(B_H(t) - B_H(s) - (t-s)\right).$$

Let $\xi = \{\xi(t) : t \geq 0\}$ be defined as the last passage before time t of the process Q_{B_H} above the level given by some properly chosen function $f(\cdot)$, i.e.,

$$\xi(t) = \sup\{s : 0 \leq s \leq t, Q_{B_H}(s) \geq f(s)\}.$$

In this talk we show that there exist functions g, f such that an Erdös-Révész type law of the iterated logarithm

$$\liminf_{t\to\infty} \frac{\xi(t) - t}{g(t)} = -\mathscr{C} \text{ a.s.}$$

holds for some constant $\mathscr{C} > 0$, which can be given explicitly.
Keywords: extremes of Gaussian fields; storage processes; fractional Brownian motion.

Time-changed extremal process as a random sup measure

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IECL & INRIA

Joint work with: Gennady Samorodnitsky

Type: Invited Talk

Abstract. Starting with a stationary symmetric α-stable sequence $(X_1, X_2, \dots,)$ with a length of memory parametrized by $\beta \in (1/2, 1)$, T. Owada and G. Samorodnitsky recently establish the following functional extremal limit theorem: for a properly chosen sequence (b_n), in the space $D([0,\infty))$,

$$\left(\frac{\max_{1\le k\le [nt]} |X_k|}{b_n},\ t \ge 0\right) \Rightarrow (Z_{\alpha,\beta}(t),\ t \ge 0) \tag{3}$$

where $Z_{\alpha,\beta}(t) = Z_\alpha(t^\beta)$, the process Z_α being the standard α-extremal Fréchet process. This power time change in the classical Fréchet process is both surprising and misleadingly simple. It hides a more delicate structure of random sup measure that we uncover : for any $\beta \in (0,1)$, the stochastic process $Z_{\alpha,\beta}$ is self-similar, has stationary max-increments and can be interpreted as a random sup measure $W_{\alpha,\beta}$ evaluated on intervals $[0,t]$, $t \ge 0$. We also extend (3) seeing the random measure $W_{\alpha,\beta}$ as itself a limit of a partial maxima of the sequence $(X_1, X_2, \dots,)$. More precisely, setting for any Borel set $A \subset [0,\infty)$,

$$M_n(|X|)(A) = \max_{k:k/n\in A} |X_k|$$

we prove that

$$\frac{M_n(|X|)}{b_n} \Rightarrow W_{\alpha,\beta}.$$

in the space of random sup measure. This also opens a way to construct new class of self-similar Fréchet processes with stationary max-increments, using range of γ-subordinators.
Keywords: extremal process; random sup measure; stationary max-increments.

Extreme Value Theory for space-time Gaussian fields

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Joint work with: Debashis Mondal; Parthanil Roy

Type: Contributed Talk

Abstract. This talk will concentrate on the extreme value theory of spatial-temporal Gaussian random fields which constitute the error part of a space-time model arising in climate studies. For increasing domain case, under Berman (1964) type conditions, we show that the vectors of suitably normalized time-maxima for finitely many locations converge weakly to a vector of independent standard Gumbel random variables. Based on the

seminal works of Hsing, Hüsler and Reiss (1996) and French and Davis (2013), we extend this result to mixed domain case and obtain the limiting distribution of the vector of normalized time-maxima under certain conditions. Some standard correlation functions are checked and found to satisfy our conditions. Based on these results, we obtain maximum pseudo-likelihood estimator of model parameters in a space-time linear model when only the maximum values of the observations are present.
Keywords: Gaussian random fields; spatial-temporal data; Extreme Value Theory.

Tail index of an AR(1) model with ARCH(1) errors

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Joint work with: Ngai Hang Chan; Liang Peng; Rongmao Zhang

Type: Contributed Talk

Abstract. Relevant sample quantities such as the sample autocorrelation function and extremes contain useful information about autoregressive time series with heteroskedastic errors. As these quantities usually depend on the tail index of the underlying heteroskedastic time series, estimating the tail index becomes an important task. Since the tail index of such a model is determined by a moment equation, one can estimate the underlying tail index by solving the sample moment equation with the unknown parameters being replaced by their quasi-maximum likelihood estimates. To construct a confidence interval for the tail index, one needs to estimate the complicated asymptotic variance of the tail index estimator, however. In this paper the asymptotic normality of the tail index estimator is first derived, and a profile empirical likelihood method to construct a confidence interval for the tail index is then proposed. A simulation study shows that the proposed empirical likelihood method works better than the bootstrap method in terms of coverage accuracy, especially when the process is nearly nonstationary.
Keywords: tail index; AR(1) model; dependent errors.

Level crossing of random functions

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Columbia University

Joint work with: Jingchen Liu; Zhiliang Ying

Type: Contributed Talk

Abstract. We deal with the problem of computing level crossing probabilities for various random functions. In general, we use a change of measure technique and transform the problem of computing level crossing probabilities to the problem of assessing the size of excursion sets. The latter are usually determined by the smoothness of the random functions. In this talk, we present two applications in statistical testing problems. First, we

compute the Chernoff index of Cox's test for separate families of hypotheses. Furthermore, we establish the asymptotic efficiency of generalized sequential probability ratio test.
Keywords: level crossing; generalized likelihood ratio test; sequential test.

Rare-event simulation for the stochastic Korteweg-de Vries equation

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Joint work with: Gongjun Xu; Guang Lin

Type: Invited Talk

Abstract. An asymptotic analysis of the tail probabilities for the dynamics of a soliton wave $U(x,t)$ under a stochastic time-dependent force is developed. The dynamics of the soliton wave $U(x,t)$ is described by the Korteweg-de Vries (KdV) equation with homogeneous Dirichlet boundary conditions under a stochastic time-dependent force, which is modeled as a time-dependent Gaussian noise with amplitude ϵ. The tail probability considered is $w(b) := P(\sup_{t\in[0,T]} U(x,t) > b)$, as $b \to \infty$, for some constant $T > 0$ and a fixed x, which can be interpreted as tail probability of the amplitude of a water wave on the shallow surface of a fluid or long internal wave in a density-stratified ocean. Our goal is to characterize the asymptotic behaviors of $w(b)$ and evaluate the tail probability of the event that the soliton wave exceeds a certain threshold value under a random force term. Such rare-event calculation of $w(b)$ is especially useful for fast estimation of the risk of the potential damage that could be caused by the water wave in a density-stratified ocean modeled by the stochastic KdV equation. In this work, the asymptotic approximation of the probability that the soliton wave exceeds a high-level b is derived. In addition, we develop a provably efficient rare-event simulation algorithm to compute $w(b)$ that runs in polynomial time of $\log b$ with a prescribed relative accuracy.
Keywords: rare-event analysis; Korteweg-de Vries equation; Gaussian process.

Spatial Extreme Value Analysis using conditional modeling approach

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Joint work with: Elizabeth Mannshardt; Montserrat Fuentes

Type: Poster

Abstract. The 2014 Intergovernmental Panel on Climate Change (IPCC) reports increasing trends in heavy precipitation events over many areas of the globe. Extreme value methods can be used to model the tail of the precipitation distribution to assess the behavior of such rare events. Due to limited temporal data, it is difficult to fit these methods due to high variability for extrapolation and lack of convergence. Existing methods in spatial extremes show that incorporating spatial dependence we can improve estimates by

increasing precision. The increase in model complexity leads to computational cost and intractable forms for high dimensionality. To capitalize on the spatial information in surrounding sites, we propose computationally efficient methods to incorporate neighboring observations in a Conditional Autoregressive (CAR) model framework using the Generalized Extreme Value distribution (GEV) assumptions for extremes. Using this approach the model gains strength from additional data, computational costs can be reduced, and a tractable solution is derived. We apply our model to 12 years of precipitation data focusing on the North-East region of the U.S.

Keywords: spatial extremes; precipitation; conditional model.

Flexible modelling of extremal dependence in environmental time series

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Joint work with: Anthony C. Davison; Jonathan A. Tawn

Type: Poster

Abstract. Accuracy in measuring the risk of flooding can help prevent rare but massive damages and save costs in the long run by building appropriate water defenses. Risk estimates for time series with short-range dependence are often obtained using the peaks over threshold method (Davison and Smith, 1990, JRSSB). Such estimates can be badly biased, and sensitive to how the peaks are identified. We propose an alternative approach based on the conditional model of Heffernan and Tawn (2004, JRSSB) which allows modelling the extremal structure of dependence of the series. Here we estimate this structure of dependence in time by a Bayesian approach using a dependent Dirichlet process, yielding natural estimation of uncertainty for the risk measures of interest. These ideas are carried out on real data and supported by a simulation study, where risk estimates are substantially improved.

Keywords: Bayesian semiparametrics; extremal clustering in time; risk analysis.

Non-parametric estimation and simulation of multivariate max-stable random vectors

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Joint work with: Simone A. Padoan; Philippe Naveau; Pietro Muliere

Type: Contributed Talk

Abstract. Modelling dependence structures of high-dimensional extreme values is of increasing interest in many fields and in particular in environmental sciences. However, in multivariate problems, the estimation of the dependence and the simulation of extremes are not easy tasks. On one hand, this work concerns the estimation of the extremal dependence

structure and specifically the Pickands dependence function. In the bivariate case several non-parametric estimators exist, while in the multivariate case only few proposals are available. We consider a non-parametric estimation method based on the Bernstein-Bézier polynomial representation of the Pickands dependence function. The proposed technique formulates the estimation of the dependence as a constrained optimization problem. On the other hand, our formulation also allows to address non-parametrically the simulation of extremes. The key aspect is the relationship between Bernstein polynomial basis and the Beta or Dirichlet distributions. A non-parametric simulation scheme is proposed in order to generate max-stable random vectors with non-parametric dependence structures. The benefit of this framework is to be able to reproduce extremes with flexible dependencies. The estimation and simulation tasks are first illustrated through a simulation study and then a real-data analysis of heavy rainfall in France is applied.
Keywords: Bernstein polynomials; non-parametric estimation; Pickands dependence function.

Extensions and analysis of a state-space approach to optimal level-crossing prediction for linear Gaussian processes

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Type: Contributed Talk

Abstract. This talk presents an overview of recent contributions to the literature on optimal level-crossing prediction for linear Gaussian processes. There have been many pioneering efforts on this topic from the area of extreme value analysis beginning in the late 70s and early 80s, and a small subset of researchers from that community have continued on with this research track, considering many different applications and extensions of the basic idea. In this talk, an overview of four different papers on a state-space approach to optimal level-crossing prediction for linear Gaussian processes will be presented, which span a range of topics from extreme value analysis to providing motivation for a control theoretic perspective. A common theme among all of the papers is advocacy for use of the AUC, or area under the ROC (Receiver Operating Characteristic) curve to characterize the ability accurately predict the level-crossing event. More formally, it quantifies the Mann-Whitney-Wilcoxon U test statistic, which is equivalent to the probability of correctly ranking two randomly selected data points, one belonging to the level-crossing event class, the other not. The AUC has been deemed as a theoretically legitimate metric for model selection and algorithmic comparison. This metric of performance is used ubiquitously in the fields of machine learning, medical diagnostics, signal processing, among others. As such, the insights derived from the findings to be presented here have implications that span all of these fields, both from a theoretical and practical perspective.
Keywords: level-crossing prediction; alarm systems; Kalman filtering.

Risk of exceedances over threshold events for the air -pollution index in the urban areas of Peninsular Malaysia

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Joint work with: N. Masseran; A. M. Razali

Type: Poster

Abstract. The data of air-pollution index (API) is an important measurement for the quality of environmental status in Malaysia. API have been calculated in terms of highest averaging sub-index values which include sulphur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO), ozone (O3) and suspended particulate matters (PM10) at a particular time. The values of API that are found to exceed the index limit of 100 indicate an unhealthy status for the exposed environment. This study investigates the risk of occurrences for the event of API>100 for several urban areas in Malaysia. The extreme value model known as Generalized Pareto distribution (GPD) has been fitted to the data of API. Based on GPD, the probability of return value as an indicator of risk has been computed to describe the phenomenon of occurrences. In fact, several graphical representations have been used to support the results of this study.
Keywords: Air-pollution assessment; Extreme events; Generalized Pareto Model.

Adapting extreme value statistics to financial time series: dealing with bias and serial dependence

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Joint work with: Laurens de Haan; Chen Zhou

Type: Contributed Talk

Abstract. We handle two major issues in applying extreme value analysis to financial time series, bias and serial dependence, jointly. This is achieved by studying bias correction method when observations exhibit weakly serial dependence, namely the β-mixing series. For estimating the extreme value index, we propose an asymptotically unbiased estimator and prove its asymptotic normality under the β-mixing condition. The bias correction procedure and the dependence structure have an interactive impact on the asymptotic variance of the estimator. Then, we construct an asymptotically unbiased estimator of high quantiles. Simulations show that finite sample performance of the estimators reflects their theoretical properties.
Keywords: Hill's estimator; bias correction; β-mixing condition.

Changes in extreme daily precipitation and temperatures observed in a locality of southeast Brazil

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Joint work with: Blain, Gabriel Constantino

Type: Poster

Abstract. Extreme events such as floods, heat waves and frost, deeply affect the society due to its adverse impacts on human health, urban infrastructure, agricultural production and economy. Statistical Extreme Value Theory can be used to estimate the probability of occurrence of such events, helping disaster prevention and urban planning in general. However, the probability estimation based on the assumption of temporal independence may be invalidated due to the presence of climate change. In this context, this study aimed at detecting the presence of climate trends in extreme daily maximum precipitation and maximum and minimum temperature (Pre, Tmax and Tmin; 1951-2013) observed in Campinas, State of São Paulo, Brazil. The study was based on the Generalized Extreme Value distribution (GEV) calculated on the following proposed models: SGEV (stationary form); NSGEV1 (homoscedastic model for which the location parameter is a linear function of time) and NSGEV2 (non stationary; location and scale parameters are linear time-dependent). The Generalized Maximum Likelihood (GML) was formulated in a Bayesian framework and adopted in the present study for parameter and confidence intervals estimations along with the Lilliefors and Anderson-Darling goodness of fit tests. The Akaike information criteria was used to select the best fit and the Likelihood Ratio test was used to check the statistical difference between two or more models previously selected. The SGEV model was adopted to describe the probabilistic structure of Pre and Tmax indicating the presence of no significant trends. For the Tmin the NSGEV2 model was adopted. This model describes an increasing trend in the average of the observed values of Tmin and a decrease in the dispersion of such distribution.
Keywords: Generalized Extreme Value distribution; climate trends; generalized maximum likelihood.

Asymptotic behavior of point processes associated with coupon collector's problem

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Joint work with: Lenka Glavaš

Type: Contributed Talk

Abstract. We study point processes associated with coupon collector's problem, that is defined as follows. We draw with replacement from the set $\mathbb{N}_n$ of the first n positive integers until all elements or some other patterns are sampled, assuming that all elements have equal probability of being drawn. Let M_n be the stoping time, i.e. the number of experiments, until all elements or patterns are sampled. Among the main questions concerning this waiting time is the following one: What is the limiting distribution of the random variable M_n? Some of the most popular cases for M_n are the following:

(A1) M_n is the waiting time until all elements of $\mathbb{N}_n$ are sampled.

(A2) M_n is the waiting time until all elements of $\mathbb{N}_n$ are sampled at least r times, where $r \geq 1$ is a positive integer. For $r = 1$ this case reduces to the previous one.

(B) M_n is the waiting time until all pairs jj, $j \in \mathbb{N}_n$ are sampled.

It is well known that the normalized random variables M_n in the above mentioned cases have asymptotically *the Gumbel extreme value distribution.*

The point process we are interested in is determined by ordinal numbers of experiments that give elements we are waiting for. The set of real numbers is considered as the state space. We prove that the point process obtained after a suitable linear transformation of the state space converges weakly to the limiting Poisson random measure whose mean measure is determined. Some numerical examples are provided.

Keywords: point processes; Coupon collector's problem; Gumbel distribution.

Modelling summer daily peak load demands in South Africa using discrete time Markov chain analysis

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Joint work with: Dr. Caston Sigauke

Type: Contributed Talk

Abstract. Electricity demand exhibit a large degree of randomness in South Africa, particularly in summer. Its description requires a detailed analysis using statistical methodologies, in particular stochastic processes. The paper presents a Markov chain analysis of peak electricity demand. The data used is from South Africa's utility company Eskom, for the period 2000 to 2011. This modelling approach is important to decision makers in the electricity sector particularly in scheduling maintenance and refurbishments of power-plants. The randomness effect is accountable to meteorological factors and major electricity appliances usage. An aggregated data on daily electricity peak demand was used to develop the transition and steady-state probabilities. April was found to be the most and risky time to undertake maintenance and December was found to be an appropriate time. Such analysis is important to Eskom and other energy companies in planning load shifting, load of analysis and scheduling of electricity particularly during peak period in summer.

Keywords: Daily peak electricity demand (DPED); steady state probability; transition matrix.

Tail probabilities of infinite series of regularly varying random sums - Exact and efficient simulation

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Joint work with: Henrik Hult; Sandeep Juneja

Type: Contributed Talk

Abstract. We present an algorithm that estimates the tail probabilities of an infinite series with uniformly bounded computational effort. The components in the infinite series

are assumed to possess regularly varying tails. The problem considered is challenging in the sense that any algorithm that stops after generating only finitely many increments is likely to introduce bias. Apart from the task of eliminating bias, we are faced with an additional challenge of estimating the rare probability just with bounded number of realizations. We use randomization techniques and heavy-tailed heuristics to arrive at a simulation algorithm that efficiently estimates such probabilities without any bias.
Keywords: infinite series; heavy-tailed sums; Monte Carlo.

Bayesian B-Spline quantile regression model

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Joint work with: André St-Hilaire, Taha Ouarda

Type: Poster

Abstract. The stationarity hypothesis is essential in hydrological frequency analysis and statistical inference. This assumption is often not fulfilled for large observed datasets, especially in the case of hydro-climatic variables (streamflow, precipitations, etc.) because of low frequency climate variability or climate change. The B-Spline regression quantile with covariates allows to model data in the presence of non-stationarity and/or dependence on covariates. Linear and non-linear dependence structures have been proposed with the corresponding fitting approach. The objective of the present study is to develop the B-Spline regression quantile in a Bayesian framework. A Markov Chain Monte Carlo algorithm has been developed to estimate quantiles and their posterior distributions. The methods are tested using simulated data and applied on annual maximum and minimum streamflow records in Ontario, Canada. Results indicate an important differences between the non-linear quantiles and their unconditional and linear equivalents especially for high return period events.
Keywords: quantile regression; B-spline; Bayesian.

Return periods and attributable risks for climate extremes

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Joint work with: Alexis Hannart; Aurelien Ribes; Francis Zwiers

Type: Invited Talk

Abstract. In climatology, the field of statistics has become one of the mathematical foundations in Detection and Attribution (D&A) studies (Detection is the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change and Attributionis the process of establishing the most likely causes for the detected change with some defined level of confidence, see the IPCC definition). In

this context, we will give a brief overview on the main concepts underpinning the causality theory and proposes some methodological extensions for the causal attribution of weather and climate-related events that are rootedinto the latter. Implications for the formulation of causal claims and their uncertainty are finally discussed. A strong emphasis will be put on the treatment of extremes, in particular the definition and the inference of FAR (Fraction of Attributable Risk), and how the framework of multivariate extreme value theory could help defining and understanding the FAR.
Keywords: causality; max-stable; numerical experiments.

Multivariate Archimax copulas

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Joint work with: Arthur Charpentier; Anne-Laure Fougères; Christian Genest

Type: Contributed Talk

Abstract. Multivariate Archimax copulas extend the class of bivariate distributions with given extreme-value attractor proposed by Capéraà, Fougères, and Genest (2000). In this talk, I will provide an analytic characterization of Archimax copulas in any dimension and a stochastic representation thereof. This representation links these distributions to the well-known class of Archimedean copulas, while shedding new light on multivariate extreme-value copulas. These insights can be particularly useful for estimation and simulation purposes. Properties of Archimax copulas will be discussed, and their minimum and maximum domains of attraction will be determined. The talk is based on joint work with A. Charpentier, A.-L. Fougères, and C. Genest.
Keywords: copula; extreme-value attractor; stable tail dependence function.

Estimation for multivariate extreme value distributions using max projections

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Joint work with: Anne-Laure Fougères, Cécile Mercadier

Type: Contributed Talk

Abstract. We present a new way to estimate multivariate extreme value distributions (MEVD) from data using max projections. The approach works in any dimension, though computation time increases quickly as dimension increases. The procedure requires tools from computational geometry and multivariate integration techniques. An R package `mevd` is being developed to implement the method for several semi-parametric classes of MEVDs: discrete angular measure, generalized logistic, piecewise linear angular measures, and Dirichlet mixture models.

Keywords: multivariate extreme value distributions; max projections; estimation.

The effect of aggregation on extremes from asymptotically independent light-tailed risks

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Type: Invited Talk

Abstract. Portfolio risk diversification is a well-established concept in finance and insurance. While aggregation of several risky assets generally reduces the overall investment risk, the effectiveness of diversification depends on the stochastic properties of the assets comprising the portfolio. A new approach to quantifying the effect of portfolio tail diversification is proposed under the assumption of existence of a limit set. This property is satisfied by a number of distributions commonly used in financial applications. Several analytical examples are given to illustrate the proposed asymptotic diversification index as a measure of the effect of risk aggregation on extremes as well as to quantify the impact of dimension on diversification and as a tool in optimal portfolio selection.
Keywords: risk diversification; limit set; weak tail dependence coefficient.

A latent trawl process model for extreme values

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Joint work with: Almut E.D. Veraart; Axel Gandy

Type: Poster

Abstract. Trawl processes are a class of stationary, continuous-time stochastic processes driven by an independently scattered random measure. They belong to the wider class of so-called Ambit fields, a modelling framework originally developed for applications that require flexible (spatio)–temporal models, including turbulence and finance. We explore a purely temporal, hierarchical model for exceedances over a threshold, based on a mixture decomposition of the generalized Pareto distribution. This model uses a trawl process as a latent component, which allows for a flexible temporal correlation structure in the exceedances. We discuss parameter estimation methods for the model and investigate the clustering behaviour of the exceedances. Finally, we explore the possibility of extending the model to the spatio–temporal case.
Keywords: Generalized Pareto Distribution; extremal dependence; hierarchical model.

Min-max representations of viscosity solutions of Hamilton-Jacobi equations and applications in rare-event simulation

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Joint work with: Boualem Djehiche; Henrik Hult

Type: Contributed Talk

Abstract. When one is interested in quantities determined mainly by extreme events, the problem of rare-event sampling is a hindrance for using standard methods of stochastic simulation. One of the more successful ways to overcome this is importance sampling, a technique used to reduce the variance of standard Monte Carlo. In the last decade, by the works of Dupuis, Wang and collaborators (2004 and onwards), it has been understood that the design of efficient algorithms is intimately connected to subsolutions of the Hamilton-Jacobi equation associated with the large deviation properties of the underlying stochastic system. We will discuss a duality relation between the Mañé potential and Mather's action functional in the context of convex and state-dependent Hamiltonians. The duality is used to obtain min-max representations of viscosity solutions of first order Hamilton-Jacobi equations. The representations suggest a way to construct viscosity subsolutions, which in turn are good candidates for designing efficient rare-event simulation algorithms. The application to rare-event simulation is illustrated by the problem of computing escape probabilities for small-noise diffusions and Markov jump processes with state-dependent jumps.
Keywords: rare-event simulation; large deviations; Monte Carlo.

Conditional modeling of extreme wind gusts by bivariate Brown-Resnick processes

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Joint work with: Martin Schlather (University of Mannheim); Petra Friederichs (University of Bonn)

Type: Invited Talk

Abstract. In order to incorporate the dependence between the spatial random fields of observed and forecasted maximal wind gusts, we propose to model them jointly by a bivariate Brown-Resnick process. The one-to-one correspondence between bivariate Brown-Resnick processes and pseudo cross-variograms allows to characterize stationary Brown-Resnick processes by properties of the underlying pseudo cross-variogram. We particularly focus on the investigation of their asymptotic behavior and introduce a flexible parametric model both of them being interesting in classical geostatistics on their own. The model is applied to real observation and forecast data for 119 stations in Northern Germany. The resulting post-processed forecasts are verified.
Keywords: bivariate random field; max-stable process; statistical post-processing.

Limit theorems for point processes under geometric constraints (and Topological Crackle)

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Technion - Israel Institute of Technology

Joint work with: Robert J. Adler

Type: Invited Talk

Abstract. We study the asymptotic nature of geometric structures formed from the point cloud of i.i.d. observations in a Euclidean space of dimension greater than one. A typical example is given by the Betti numbers of Čech complexes built over the cloud. The structure of dependence and sparsity (away from the origin) generated by these distributions leads to limit laws expressible via non-homogeneous, random, Poisson measures. The parameterization of the limits depends on both the tail decay rate of the observations and the particular geometric constraint being considered.

The main theorems of the paper generate a new class of results in the well established theory of extreme values, while their applications are of significance for the fledgling area of rigorous results in topological data analysis. In particular, they provide a broad theory for the empirically well-known phenomenon of homological 'crackle'; the continued presence of spurious homology in samples of topological structures, despite increased sample size.
Keywords: point processes; topological data analysis; Geometric graph.

Extremes of Skew-Symmetric Distributions

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Joint work with: Boris Beranger; Scott Sisson

Type: Invited Talk

Abstract. In environmental, economic or financial fields, the data of real applications can exhibit highly asymmetric distributions. In risk management it is important to analyze the frequency that extreme events such as heat waves, market crashes, etc., occur. Such real processes are high-dimensional by nature. Estimating the dependence of extreme events is crucial for predicting future phenomena, that can have a large impact on real life. A simple way of dealing with asymmetrically distributed data is to use the so-called Skew-Symmetric distributions. If the interest is analyzing the extremes of such data types, then probabilistic models and statistical methods based on the paradigms of the extreme value theory are required. We illustrate different types of dependence models, the so-called extremal-skew models, which can be useful for describing the extremal behavior of asymmetrically distributed data and we show their properties. We discuss the case of random vectors and processes. Finally we describe some statistical inferential methods for estimating the dependence structure of these models.
Keywords: max-stable process; skew-normal process; extremal dependence.

Diagnosing Possible Anthropogenic Contributions to Heavy Colorado Rainfall in September 2013

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Joint work with: Christina Patricola; Michael Wehner; Dáithí Stone; Christopher Paciorek; William Collins.

Type: Invited Talk

Abstract. Unusually heavy rainfall occurred over the Colorado Front Range during early September 2013, with record or near-record totals in several locations. It was associated with a stationary large-scale weather pattern (akin to the North American Monsoon, which occurs earlier in the year) that drove a strong plume of deep moisture inland from the Gulf of Mexico. The resulting floods impacted several thousand people and many homes, businesses and infrastructure. To diagnose possible anthropogenic contributions to the odds of such heavy rainfall occurring, we adapt an existing event attribution paradigm of modelling the climate for the world that was in September 2013 and comparing it to a modelled climate for the world that might have been at that same time but for the absence of historical anthropogenic climate drivers. Specifically, we first perform world that was weather simulations with the regional WRF model at 12 km resolution over North America, driven by NCEP2 re-analysis. We then re-simulate, having adjusted the re-analysis to world that might have been conditions by modifying atmospheric greenhouse gas and other pollutant concentrations, temperature, humidity, and winds, as well as sea ice coverage, and sea-surface temperatures all according to estimates from global climate model simulations. We generate 100-member ensembles of weather simulations for both the world that was and world that might have been. Our findings are highly conditional on the driving re-analysis, but the setup allows us to elucidate possible mechanisms responsible for any heavy rainfall. Analysis suggests that, given the pattern of large-scale driving weather and adjustments therein, there is about a doubling in the odds of occurrence of heavy Colorado Front Range rainfall during September 2013 due to anthropogenic climate drivers. This increase appears to be a result of a combination of increased atmospheric water vapour and change in atmospheric circulation.
Keywords: event attribution; floods; Colorado.

Maximal Moments and Modulus of Continuity of Stable Random Fields

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Joint work with: Parthanil Roy; Yimin Xiao

Type: Contributed Talk

Abstract. Based on the seminal works of [Rosiński(1995), Rosiński(2000)] and [Samorodnitsky(2004a), Samorodnitsky(2004b)], we partially solve an open problem mentioned in a paper of [Xiao(2010)] and give sharp upper bound on the rate of growth of maximal moments for many stationary symmetric stable random fields. We also investigate the relationship between this rate of growth and the path properties of self-similar stable random fields whose first order increments are stationary and give sharper results on uniform modulus of continuity of such fields.
Keywords: stable random field; uniform modulus of continuity; nonsingular group actions.

Dynamic bivariate Normal copula

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Joint work with: Xin Liao, Zuoxiang Peng,Yanting Zheng

Type: Invited Talk

Abstract. Normal copula with a correlation coefficient between -1 and 1 is tail independent and so it severely underestimates extreme probabilities. By letting the correlation coefficient in a normal copula depend on the sample size, Husler and Reiss (1989) showed that the tail can become asymptotically dependent. In this paper, we extend this result by deriving the limit of the normalized maximum of n independent observations, where the i-th observation follows from a normal copula with its correlation coefficient being either a parametric or a nonparametric function of i/n. Furthermore, both parametric and nonparametric inference for this unknown function are studied, which can be employed to test the condition in Husler and Reiss (1989). A simulation study is presented too.
Keywords: estimation; Normal copula; tail dependence/independence.

Testing max-domains of attractions under nuisance regression

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Type: Contributed Talk

Abstract. The contribution deals with testing of the Gumbel domain of attraction against Frechet or Weibull domains under nuisance regression. We use averaged regression quantiles as the main tool for construction of tests. Jureckova and Picek (2014) showed that averaged regression quantile is asymptotically equivalent to the location quantile. We therefore propose a generalization of known tests (for example Hasofer and Wang (1992), Segers and Teugels, (2001), Neves, Picek and Alves (2006)) using the averaged regression quantiles. The used methods will be illustrated on simulated and climatological data.
Keywords: domain of attraction; averaged regression quantile; nuisance regression.

A comparative review of generalizations of the extreme value distribution

Pinheiro, Eliane (elianecpinheiro@gmail.com)
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Joint work with: Ferrari, S. L. P.

Type: Poster

Abstract. The extreme value distribution, also known as the Gumbel distribution, is widely applied for extreme value analysis but has certain drawbacks in practice because it is a non heavy-tailed distribution and is characterized by constant skewness and kurtosis. Our goal is to present a literature review of the distributions that contain the extreme value distribution embedded in them and to identify those that have flexible skewness and kurtosis and those that are heavy-tailed. The generalizations of the extreme value distribution are described and compared using an application to a wind speed data set and Monte Carlo simulations. We show that some distributions suffer from over-parameterization and coincide with other generalized Gumbel distributions with a smaller number of parameters, i.e., are non-identifiable. Our study suggests that the generalized extreme value distribution and a mixture of two extreme value distributions should be considered in practical applications.
Keywords: Generalized Extreme Value distribution; Gumbel distribution; heavy-tailed distribution.

Inverse Problem for Weighted Sums with Dependent Weights and Regularly Varying Tails

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Joint work with: Krishanu Maulik, Indian Statistical Institute, Kolkata

Type: Contributed Talk

Abstract. Consider a sequence $\{(X_i, Y_i)\}$ of independent and identically distributed random vectors such that (X_i, Y_i) is jointly distributed as bivariate Sarmanov, with marginals F and G respectively, and X_i nonnegative. If now we are given that $Z = \sum_{k=1}^{\infty} X_k \prod_{j=1}^{k} Y_j$ is regularly varying with index $-\alpha$, then under extra moment and non-vanishing Mellin transform conditions similar to those in Jacobsen et al. (2009) we can conclude that $F \in RV_{-\alpha}$ and

$$P[Z > x] = \frac{E(Y_1^{\alpha}) + \theta d_1 E[\phi_2(Y_1) Y_1^{\alpha}]}{1 - E[Y_1^{\alpha}]} \overline{F}(x) \quad \text{as } x \to \infty,$$

where ϕ_2 and d_1 are quantities we get from the Sarmanov distribution.
Keywords: inverse problem; regular variation; bivariate Sarmanov.

Resampling techniques working (hard) to improve estimation of parameters of rare events in a dependent set-up

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Joint work with: Manuela Neves

Type: Poster

Abstract. Extreme value theory (EVT) has emerged as one of the most important statistical areas for the applied sciences such as biology, environment, finance, hydrology and telecommunications, to mention only a few. The distinguishing feature of EVT is to quantify the stochastic behavior of a process at unusually large or small levels. Among the key parameters in EVT we refer to the extreme value index (EVI) and the extremal index (EI). Under a framework related to large values, the EVI measures the right tail-weight of the underlying distribution and the EI characterizes the degree of local dependence in the extremes of a stationary sequence. Many authors have worked with the EVI estimation but the EI has received less attention This parameter needs to be adequately estimated, not only by itself but because its influence on other parameters, such as, a high quantile, the return period, the expected shortfall. Like other semi-parametric estimators, EI estimators show nice asymptotic properties, but a high variance for small values of k, the number of upper order statistics used in the estimation, and a high bias for large values of k. This brings a real need for the choice of k. The main goal of this paper is to enhance the role of two well-known resampling methodologies, the Bootstrap and the Jackknife in EVT. An adaptive choice algorithm for the block size for the resampling Bootstrap procedure as well as for the choice of the more adequate number of upper order statistics for the estimation of EI is studied. Results from an intensive simulation study are shown. Applications of these procedures to the analysis of environmental and financial data are undertaken. This work was partially supported by the Fundação para a Ciência e a Tecnologia (Portuguese Foundation for Science and Technology) through the projects PEst-OE/MAT/UI0006/2014 (CEAUL) and UID/MAT/00297/2013 (Centro de Matemática e Aplicações)
Keywords: bootstrap and Jackknife; dependent set-up; Extreme Value Theory.

A point process analysis of the impact of increasing urbanization on flood risk

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Centre for Ecology & Hydrology

Joint work with: Thomas Kjeldsen; James Miller

Type: Contributed Talk

Abstract. This study investigates whether long-term changes in observed series of high flows can be attributed to changes in land-use via non-stationary flood frequency analyses. A point process characterization of threshold exceedances is used, which allows for the direct inclusion of covariates in the model and for simultaneous inference on both the magnitude and the frequency of high flows. In particular, changes in annual, winter and summer block maxima and peaks over threshold, extracted from gauged instantaneous flows records in two hydrologically similar catchments located in close proximity to one another in northern England, are investigated. The study catchment is characterized by large increases in urbanization in recent decades, while the paired control catchment has remained undeveloped during the study period (1970-2010). To avoid the potential confounding effect of natural variability, a covariate which summarizes key climatological properties is included in the flood frequency model. A significant effect of the increasing urbanization levels on high flows is detected in the case study catchment and attributed to land-use changes. The

challenges involved in attributing the detected change to a specific external variable are presented and discussed.
Keywords: point processes; floods; non-stationary.

A depth-duration-frequency model for short-duration rainfall extremes

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Centre for Ecology & Hydrology

Joint work with: Gianni Vesuviano; Lisa Stewart

Type: Poster

Abstract. Reliable estimates of extreme rainfall frequency for events of different durations (e.g. 1-hour, 1-day and 1-week) are needed for the design and managing of built structures and to assess flood risk. Depth-duration-frequency (DDF) models are generally used to estimate rainfall depths associated with key return periods for different event durations. DDF models are designed to ensure consistent estimates for different event durations, which is to say that the estimated T-year event of a longer accumulation period should not be smaller than the T-year event of a shorter accumulation period.

Small catchments tend to have a fast hydrological response to rainfall and are more susceptible to floods caused by storms of short duration (e.g. 15-minutes). The current standard rainfall DDF model in the UK is based on rain gauges data measured at hourly intervals and, although it has been extrapolated to 30-minutes durations, its use at shorter duration is discouraged. At present it is then unclear for practitioners how short-duration rainfall frequencies should be estimated. A preliminary study to investigate the relationship between event duration, event depth and event rarity for sub-hourly accumulations has been carried out, using data from selected rain gauges across England and Wales and a new DDF model for the analysis of at-site data has been developed. The proposed DDF model stems from the standard assumption that the block maxima are GEV distributed. Enforcing some basic relationships between the distribution parameters ensures that the estimated return curves are consistent across all durations. The proposed model is fitted to the annual and seasonal maxima for the selected stations giving satisfactory results. Return levels estimated by the proposed DDF model and the standard DDF models used in the UK are then compared.
Keywords: rainfall frequency; DDF model; small catchments.

Bayesian inference for non-stationary extremes

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Joint work with: Kathryn Turnbull; Philip Jonathan

Type: Contributed Talk

Abstract. Specification of realistic environmental design conditions for marine structures is of fundamental importance to their reliability over time. Design conditions for extreme waves and storm severity are typically estimated by extreme value analysis of time series of measured or hind-cast significant wave height, H_S. This analysis is complicated by two effects. Firstly, H_S exhibits temporal dependence. Secondly, the characteristics of H_S^{sp} are non-stationary with respect to multiple covariates, particularly wave direction and season.

We develop directional-seasonal return values for storm peak significant wave height (H_S^{sp}) for a location in the South China Sea by estimation of, and simulation under a non-stationary extreme value model. Extreme value model parameters vary with direction and season, and are parameterized in terms of (tensor products of) B-spline bases for direction and season. Inference is carried out using MCMC, exploiting the Manifold Metropolis Adjusted Langevin Algorithm (mMALA) for improved convergence and mixing of chains. Return value estimates from Bayesian inference are compared with those from maximum penalized likelihood estimation.
Keywords: covariate modelling; environmental; Bayesian.

Value at Risk (VaR) and Conditional Value at Risk (CVaR) Models Based on Extreme Value Theory

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Joint work with: A. M. Razali; M. A. Mohamed; N. Ismail; N. Masseran

Type: Poster

Abstract. Extreme value theory (EVT) provides a framework to study the behavior in the tails of a distribution. In other words, it provides a theoretical framework for analyzing rare events. Recent studies focus on the financial applications due to the fact that extreme data is readily available in various international financial databases. The prediction of one-day value at risk (VaR) and conditional value at risk (CVaR) based on the performance peaks over the threshold (POT) model were presented. Time series of this index has been applied from 1st August 2001 to 31st July 2012 with a total of 2,950 observations. POT model of EVT and Generalized Pareto distribution (GPD) were utilized in order to obtain a more accurate description on tail distribution of financial returns or losses. The focus is on the proposed methods which are utilized to assess tail related risk by providing a modelling tool for modern risk management. The finding of this paper is that POT model can be an alternative in modelling volatility and in estimating VaR and CVaR.
Keywords: Extreme Value Theory; Generalized Pareto Distribution; Peaks over Threshold.

A hierarchical model for serially-dependent extremes

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Joint work with: Ben Shaby; Dan Cooley

Type: Invited Talk

Abstract. Heat waves take a major toll on human populations, with negative impacts on the economy, agriculture, and human health. As a result, there is great interest in studying the changes over time in the probability and magnitude of heat waves. In this paper we propose a hierarchical Bayesian model for serially-dependent extreme temperatures. We assume the marginal temperature distribution follows the generalized Pareto distribution (GPD) above a location-specific threshold, and capture dependence between subsequent days using a transformed max-stable process. Our model allows both the parameters in the marginal GPD and the temporal dependence function to change over time. This allows Bayesian inference on the change in likelihood of a heat wave. We apply this methodology to daily high temperatures in nine cities in the western US for 19792010. Our analysis reveals increases in the probability of a heat wave in several US cities.
Keywords: Bayesian model; heat wave; max-stable process.

Tauberian theory for multivariate regularly varying distributions with application to preferential attachment networks

Resnick, Sidney (sidresnick@gmail.com)
Cornell

Joint work with: Gennady Samorodnitsky

Type: Invited Talk

Abstract. Abel-Tauberian theorems relate power law behavior of distributions and their transforms. We formulate and prove a multivariate version for non-standard regularly varying measures on the positive p-dimensional quadrant and then apply it to prove that the joint distribution of in- and out-degree in a directed edge preferential attachment model has jointly non-standard regularly varying tails.
Keywords: regular variation; preferential attachment; Tauberian theorem.

Hunting for Black Swans in the European Banking Sector using Extreme Value Analysis

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KU Leuven

Joint work with: Jan Beirlant; Wim Schoutens; Jan De Spiegeleer; Klaus Herrmann

Type: Contributed Talk

Abstract. In the recent financial crisis, many banks got into problems and needed government support. We propose to use extreme value techniques to investigate the severity of the crisis for European banks. More specifically, we look at the tail behaviour of the weekly

log-returns of European banks which are member of the Euro Stoxx Banks Index where we split the period into two parts: pre-Crisis (January 1994 until August 2007) and post-crisis (August 2007 until September 2014). We propose a methodology to evaluate if the crisis did constitute a Black Swan event for a given bank, i.e. if the tail behaviour changes drastically between the two periods. Differences in the tail behaviour can be observed in the shape and scale parameters. To evaluate these differences, both graphical methods such as QQ-plots, and estimators for the Extreme Value Index such as the Hill estimator and bias reduced estimators are considered. Unlike daily returns, weekly returns might not necessarily exhibit heavy tails. We therefore also need to consider graphical methods and estimators that are also consistent over the Gumbel domain. Moreover, it is well known that financial time series exhibit serial dependence and volatility clustering. We propose some tests for differences in scale and shape taking this into account. Additionally, we consider GARCH modelling and compare the results between the extreme value and the GARCH methodology. We evaluate the performance of both approaches using GARCH simulations.

Keywords: extreme value index; European banks; GARCH.

Probabilities of concurrent extremes

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University of Montpellier

Joint work with: Clément Dombry and Stilian Stoev

Type: Invited Talk

Abstract. Extreme value theory is widely used as soon as the focus is on rare events. Most often extreme value analysis aim at modelling the magnitude of such events but little attention has been paid to the way these events are generated. In this paper we introduce the notion of extremal concurrence, i.e., a given observation is a realization of a single extreme event and not a mixture of several extreme events, and define the related notion of extremal concurrence probability. We establish that the probability of extreme concurrence can be seen as a limiting sample concurrence probability and that it is closely related to the extremal coefficient. Explicit forms of these probabilities are given for various max-stable models and several estimators are proposed and analyzed on a simulation study. An application on extreme US temperatures is given. Results indicate that the notion of concurrence probability appears to be extremely helpful in characterizing the areal impact of extreme events. As an aside, as a probability, concurrence probabilities appear to be more interpretable than extremal coefficients.

Keywords: max-stable process; concurrence; temperature.

Expert elicitation and extreme events

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McGill University/Banco de Mexico

Type: Contributed Talk

Abstract. In this study, an analysis of extreme data is performed by using a Bayesian approach that combines a parametric form for the center and a Generalized Pareto Distribution (GPD) for the tail of the distribution. We show how to construct a prior distribution based on measures that experts are familiar with, including the value-at-risk (Var) and the expected shortfall (ES). The purpose is to facilitate prior elicitation and reproduce expert judgment faithfully. We also implement techniques for the combination of expert opinions and examine how their opinions may influence the posterior distribution and how to build a prior distribution based on expert judgment rather than using non-informative priors. While this issue has been addressed in other fields, it is relatively recent in our context. Results are presented on simulated and real data.
Keywords: Bayesian; extremes; elicitation.

Asymptotic tail behavior of phase-type scale mixture distributions

Rojas-Nandayapa, Leonardo (l.rojas@uq.edu.au)
School of Mathematics and Physics, The University of Queensland

Joint work with: Wangyue Xie

Type: Contributed Talk

Abstract. We consider phase-type scale mixture distributions which correspond to distributions of random variables obtained as the product of two random variables: a phase-type random variable Y and a nonnegative but otherwise arbitrary random variable S called the scaling random variable. We prove that the distribution of $X := SY$ is heavy-tailed iff the distribution of the scaling random variable S has unbounded support. In addition, we prove that phase-type scale mixtures preserve the maximum domain of attraction of the distribution of the scaling random variable S. For the Fréchet case, we prove a converse of Breiman's lemma which provides the exact asymptotics of the tail distribution of X. Finally, we explore subexponentiality for some important cases of phase-type scale mixtures.
Keywords: phase–type; MDA; product; subexponential.

Multivariate Peaks over Thresholds modelling

Rootzén, Holger (hrootzen@chalmers.se)
Chalmers

Type: Contributed Talk

Abstract. This talk is an overview over ongoing work on multivariate Peaks over Thresholds modeling. Topics include relations between multivariate generalized Pareto distribution and the spectral representations used in generalized Pareto processes; connection between statistical methods based on multivariate point processes models and based on

multivariate generalized Pareto models; time series Peaks over Thresholds modelling without declustering; and spatial extreme value models. Joint work with Holger Drees, Anja Janssen, Anna Kirilouk, Nader Tajvidi, Jennifer Wadsworth.
Keywords: models for excesses; time series dependence; nuggets.

Extreme value methods as decision support for high throughput screening

Rootzén, Holger (hrootzen@chalmers.se)
Chalmers

Joint work with: Dimitrii Zholud

Type: Poster

Abstract. Very large efforts are devoted to follow-up of results from high throughput screening experiments in bioscience and other areas of science. To make good decisions on allocation of these efforts requires reliable understanding of false positives. Standard methods focus on the entire distributions of p-values in tests, even though false positives only depend on the extreme lower tail of the distributions. This poster advertises the fact that tail estimation methods from extreme value statistics provide an efficient way to estimate the number of false positives, and the risk that a positive is false. We describe a Matlab tool, SmartTail `http:///www.smarttail.se`, which contains an easy to use implementation of such methods. We also provide new asymptotics which apply under weak and non-linear dependence restrictions, and which in dependent cases lead to sandwich estimators of the uncertainty of estimates.
Keywords: correction of p-values; multiple testing; SmartTail.

Extremes and large deviations for heavy-tailed random fields with strong dependence

Roy, Parthanil (parthanil.roy@gmail.com)
Indian Statistical Institute Kolkata

Type: Invited Talk

Joint work with: Ayan Bhattacharya; Vicky Fasen; Rajat Subhra Hazra; Sourav Sarkar.

Abstract. Investigation of extremal properties and large deviation issues for stochastic processes becomes very challenging in presence of strong dependence among observations. In this talk, we shall discuss how we can overcome this challenge for heavy-tailed random fields having long memory.
Keywords: large deviations; heavy tails; long-range dependence.

Data Mining for Extreme Behavior with Application to Ground Level Ozone

Russell, Brook (brooktrussell@yahoo.com)
Colorado State University Department of Statistics

Joint work with: Daniel Cooley; William Porter; Brian Reich; Colette Heald

Type: Invited Talk

Abstract. This project aims to increase understanding of the meteorological conditions which lead to extreme ground level ozone conditions. Our approach focuses only on the tail behavior by utilizing the framework of regular variation. Our approach has two parts. The first is an optimization problem: given a set of meteorological covariates, we aim to find the linear combination of these covariates which has the highest degree of tail dependence with ozone. The second is a data mining problem: given a long list of possible meteorological covariates, we seek to find the ones which are linked to extreme ozone.

We use a constrained optimization procedure which maximizes a measure of tail dependence and whose constraint enforces a requirement on the marginal distribution. Our optimization procedure requires that we consider tail dependence estimators with a smooth threshold, rather than the hard threshold typical of extremes. Data mining is performed within the model selection context, and because the model space cannot be explored completely, we employ an automated model search procedure. We present a simulation study which shows that the method can detect complicated conditions leading to extreme responses. We apply the method to ozone data for Atlanta and Charlotte and find similar meteorological drivers for these two Southeastern US cities. We identify several covariates which may help to differentiate the meteorological conditions which lead to extreme ozone levels from those which lead to merely high levels. Our current work includes a spatial extension of our modeling procedure.
Keywords: tail dependence; multivariate regular variation; cross validation.

Dependence based dimension reduction in multivariate extremes

Sabourin, Anne (anne.sabourin@telecom-paristech.fr)
Telecom ParisTech, Institut Mines-Telecom, CNRS-LTCI.

Joint work with: Nicolas Goix, Stéphan Clémençon

Type: Invited Talk

Abstract. How to analyze large dimensional problems generates an increasing interest in the statistical community. In a multivariate 'Peak-over-threshold' setting, one observes realizations of a d-dimensional random vector $\mathbf{Y} = (Y_1, \ldots, Y_d)$ and wants to learn the conditional distribution of excesses, $[\mathbf{Y} \,|\, \|\mathbf{Y}\| \geq u]$, above some large threshold u. The dependence structure of such excesses is described *via* the distribution of the 'directions' formed by the most extreme observations - the so-called *angular probability measure*. The latter is defined on the positive orthant of the $d-1$ dimensional hyper-sphere. Some probability mass may be present on any sub-sphere of dimension $k < d$, the k-faces of

an hyper-cube if we use the infinity norm, which complicates inference when d is large. However, in a wide range of applications, one may expect that only *some* 'small' groups of components may be concomitantly extreme (*e.g.* nearest neighbors on the grid of a climate model), so that only the corresponding hyper-cubes have non zero mass. In this talk, we present ongoing work aiming at identifying such faces, so as to reduce the dimension of the problem. One major issue is that real data generally have no coordinate equal to zero. This is circumvented by setting to zero any coordinate less than ϵ, so that the corresponding 'angle' is assigned to a lower-dimensional face. Consistency is achieved under regularity assumptions on the angular measure, by establishing concentration inequalities borrowed from Vapnik-Chervonenkis theory. This opens the road to modeling strategies that take advantage of the flexibility of multivariate models, while escaping the curse dimensionality.
Keywords: high-dimensional problems; unsupervised learning; anomaly detection.

Nonstandard regular variation of in-degree and out-degree in the preferential attachment model.

Samorodnitsky, Gennady (gs18@cornell.edu)
Cornell University

Joint work with: Sidney Resnick; Don Towsley; Richard David; Amy Willis; Phyllis Wan

Type: Invited Talk

Abstract. For the directed edge preferential attachment network growth model studied by Bollobas et al. (2003) and Krapivsky and Redner (2001), we prove that the joint distribution of in-degree and out-degree has jointly regularly varying tails. Typically the marginal tails of the in-degree distribution and the out-degree distribution have different regular variation indices and so the joint regular variation is non-standard. Only marginal regular variation has been previously established for this distribution in the cases where the marginal tail indices are different.
Keywords: multivariate heavy tails; preferential attachment model; scale free networks.

Implicit Extremes and Implicit Max-Stable Laws

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University of Siegen

Joint work with: Stilian Stoev

Type: Contributed Talk

Abstract. Let $X_1, \cdots, X_n$ be iid random vectors and $f \geq 0$ be a non–negative function. Let also $k(n) = \text{Argmax}_{i=1,\cdots,n} f(X_i)$. We are interested in the distribution of $X_{k(n)}$ and their limit theorems. In other words, what is the distribution the random vector where a function of its components is extreme. This question is motivated by a kind of inverse problem where one wants to determine the extremal behavior of X when only explicitly

observing $f(X)$. We shall refer to such types of results as to *implicit extremes*. It turns out that, as in the usual case of explicit extremes, all limit *implicit extreme value* laws are *implicit max–stable*. We characterize the regularly varying implicit max–stable laws in terms of their spectral and stochastic representations. We also establish the asymptotic behavior of *implicit order statistics* relative to a given homogeneous loss and conclude with several examples drawing connections to prior work involving regular variation on general cones.

Keywords: implicit extremes; implicit max-stable laws;regular variation on cones.

Functional Poisson approximation in Kantorovich-Rubinstein distance with applications to U-statistics and stochastic geometry

Schulte, Matthias (matthias.schulte@kit.edu)
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Joint work with: Laurent Decreusefond; Christoph Thäle

Type: Invited Talk

Abstract. A Poisson or a binomial process on an abstract state space and a symmetric function f acting on k-tuples of its points are considered. They induce a point process on the target space of f. The main result is a functional limit theorem which provides an upper bound for an optimal transportation distance between the image process and a Poisson process on the target space. The technical background are a version of Stein's method for Poisson process approximation, a Glauber dynamic representation for the Poisson process and the Malliavin formalism. The main result can be used to obtain Weibull limit theorems and error bounds for approximations of U-statistics by Poisson, compound Poisson and stable random variables. This is illustrated by examples from stochastic geometry like random geometric graphs.

Keywords: Poisson process approximation; Stein's method; stochastic geometry.

Extreme value copula estimation based on block maxima of a multivariate stationary time series

Segers, Johan (johan.segers@uclouvain.be)
Université catholique de Louvain

Joint work with: Axel Bücher

Type: Invited Talk

Abstract. The core of the classical block maxima method consists of fitting an extreme value distribution to a sample of maxima over blocks extracted from an underlying series. In asymptotic theory, it is usually postulated that the block maxima are an independent random sample of an extreme value distribution. In practice however, block sizes are finite, so that the extreme value postulate will only hold approximately. A more accurate asymptotic framework is that of a triangular array of block maxima, the block size depending on

the size of the underlying sample in such a way that both the block size and the number of blocks within that sample tend to infinity. The copula of the vector of component-wise maxima in a block is assumed to converge to a limit, which, under mild conditions, is then necessarily an extreme value copula. Under this setting and for absolutely regular stationary sequences, the empirical copula of the sample of vectors of block maxima is shown to be a consistent and asymptotically normal estimator for the limiting extreme value copula. Moreover, the empirical copula serves as a basis for rank-based, nonparametric estimation of the Pickands dependence function of the extreme value copula. The results are illustrated by theoretical examples and a Monte Carlo simulation study.
Keywords: copula; maxima; time series.

A coefficient of extremal asymmetry

Semadeni, Claudio (claudio.semadeni@epfl.ch)
EPFL

Joint work with: Anthony C. Davison

Type: Contributed Talk

Abstract. Many bivariate extreme value distributions have been proposed in the literature, some of which can accommodate asymmetry. However, the quantification of the latter at extreme levels has been overlooked so far. We introduce a coefficient of extremal asymmetry to address this; it might also be used as non-parametric diagnostic tool prior to inference. For the class of max-stable distributions, this coefficient can be nicely expressed in terms of the corresponding Pickands' dependence function. We propose a non-parametric estimator of the coefficient of extremal asymmetry based on maximum empirical likelihood estimation of the spectral distribution and provide corresponding confidence intervals. If time permits, we will discuss generalization to arbitrary dimensions. The approach will be illustrated with applications to environmental and financial datasets.
Keywords: empirical maximum likelihood; extremal asymmetry; multivariate extremes.

Downscaling Extremes for Fire Risk Assessment

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Type: Invited Talk

Abstract. Wildfires have the potential to inflict huge losses of life, infrastructure, and habitat. High-resolution climate models can simulate weather variables that influence ignition probability and spread potential, but these models produce distributions for these variables that unrealistic tails. We use spatial max-stable models to extract meaningful information about extreme fire weather in California from high-resolution weather model output. We construct a spatial downscaling model within the max-stable framework. This

allows us to treat climate model output as covariates, rather than as future weather variables, in a spatial extreme value regression model fit to observed data.
Keywords: max-stable; hierarchical; spatial.

Spatio-temporal modelling of extremes arising from extratropical cyclones

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Lancaster University

Joint work with: Simon Brown; Jonathan Tawn

Type: Poster

Abstract. Extratropical cyclones are dominant features of the European weather landscape that are responsible for strong winds and heavy rainfall. In the United Kingdom, they are often associated with major flood events, damaging windstorms and other events that have caused mass infrastructural damage, transport chaos and, in some instances, even human fatalities. Accurate statistical modelling of weather extremes related to cyclones is essential to aid the design of robust infrastructure and develop suitable response strategies to limit the social and economic difficulties such extremes may cause.

Extreme value analysis has long been used to model severe wind and rain events, but largely in a context which ignores the spatial and temporal aspects of the cyclone itself and the physics that generate the extremes of interest. We present a statistically consistent framework for cyclones and the rain and wind extremes they produce that incorporates various aspects of cyclone evolution, movement and structure, and large scale modes of atmospheric variability. In particular, we present a comprehensive covariate analysis of extreme rainfall in the United Kingdom by means of a Poisson process model for extremes, which reveals the spatial and temporal impact of North Atlantic storms. Theoretical advancements in the Poisson process model are also presented, which are aimed at improving model estimation and efficiency.
Keywords: climate extremes; Poisson processes; covariate modelling.

Distribution of the supremum location of self-similar processes with stationary increments

Shen, Yi (yi.shen@uwaterloo.ca)
University of Waterloo

Type: Contributed Talk

Abstract. We consider the location of the path supremum over a fixed interval of self-similar processes with stationary increments. It has been shown that for a general stationary increment process, the distribution of its path supremum is absolutely continuous in the interior of the interval, and its density function satisfies a group of conditions. In this work we prove that when the process is self-similar, the density function has many stronger

properties. For example, the density function is continuous, with explicit bounds for its Dini derivatives. As a result, a sharper upper bound for the density function is established. Moreover, we show that the distribution admits a spectral-type representation. Finally, the self-similar Lévy processes are discussed as an example.
Keywords: supremum location; self-similar processes; stationary increments.

Practical conditions for weak convergence of tail empirical processes

Soulier, Philippe (philippe.soulier@u-paris10.fr)
Université Paris Ouest Nanterre

Joint work with: Rafal Kulik; Olivier Wintenberger

Type: Invited Talk

Abstract. We consider a stationary regularly varying time series and study multivariate weighted versions of the usual tail empirical process. We prove a functional central limit theorem under abstract conditions. We prove that these conditions hold for a variety of Markovian models.
Keywords: regularly varying time series; tail empirical processes; Markov models.

Rare event simulation in the neighborhood of a rest point

Spiliopoulos, Konstantinos (kspiliop@math.bu.edu)
Boston University

Joint work with: Paul Dupuis; Xiang Zhou

Type: Contributed Talk

Abstract. We construct efficient importance sampling Monte Carlo schemes for finite time exit probabilities in the presence of rest points. We focus on reversible diffusion processes with small noise that have an asymptotically stable equilibrium point. The main novelty of the work is the inclusion of rest points in the domain of interest. We motivate the construction of schemes that perform well both asymptotically and non-asymptotically. We concentrate on the regime where the noise is small and the time horizon is large. Examples and simulation results are provided.
Keywords: importance sampling; large deviations; sub-solutions.

On the maximum distribution of Gaussian non centered fields

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Joint work with: Biljana Stamatovic

Type: Contributed Talk

Abstract. The double-sum method is one of the main tools in studying asymptotic behaviour of maxima distribution of Gaussian processes and fields, see for example Piterbarg (1996) and references therein. Technique of the double sum method has to include a way of obtaining of exact asymptotics of the high excursion on a small set and also an evaluation of probability of the excursion on two sets simultaneously. At present time, the method is extended on Gaussian fields indexed on infinite-dimensional parametric sets. Until recently centered processes have mainly been considered. It can been seen from Piterbarg (1996) and Piterbarg & Stamatovich (2001) that the investigation of non-centered Gaussian fields can be performed with similar techniques, which, however, are far from trivial. In Piterbarg & Tyurin (1993, 2000) statistical procedures have been introduced to test a hypothesis of homogeneity of two multidimensional samples. In order to estimate power of the procedures one might have to have asymptotic behaviour of tail maxima distributions for non-centered Gaussian fields.

We consider a Gaussian field indexed on a finite-dimensional, smooth, compact manifold, with the mean attaining its maximum on a submanifold. Asymptotic behaviour of the tail is evaluated.
Keywords: Gaussian fields; smooth manifolds; maximum tail distribution.

Comonotonic max-stable processes

Strokorb, Kirstin (strokorb@math.uni-mannheim.de)
University of Mannheim

Joint work with: Ilya Molchanov

Type: Invited Talk

Abstract. (joint work with Ilya Molchanov) It is well-known that, under very mild conditions, max-stable processes can be represented as the maximum of the points of a Poisson process whose intensity measure satisfies some scaling properties. We shall single out a subfamily of max-stable laws that arises from a particular (but very natural) choice of the intensity of the underlying Poisson process. We adopt the viewpoint that max-stable processes are stable random sup measures. It is shown how to associate a general stable random sup-measures with a special one, whose principal feature is the comonotonic additivity of its tail dependence functional.
Keywords: comonotonic additivity; extremal coefficient; max-stable process.

On the asymptotic behaviour of extreme geometric quantiles

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Aix Marseille Université

Joint work with: Stéphane Girard

Type: Invited Talk

Abstract. Central properties of geometric quantiles have been well-established in the recent statistical literature. In this study, we try to get a grasp of how extreme geometric quantiles behave. Their asymptotics are provided, both in direction and magnitude, under suitable moment conditions, when the norm of the associated index vector tends to one. Some intriguing properties are highlighted: in particular, it appears that if a random vector has a finite covariance matrix, then the magnitude of its extreme geometric quantiles grows at a fixed rate. The case when the random vector of interest does not have a finite covariance matrix is tackled in a multivariate regular variation framework. We illustrate our results on a simulation study.
Keywords: extreme quantile; geometric quantile; asymptotic behaviour.

Temperature Extremes in the Community Atmosphere Model with Model Error Representation

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Cornell University

Joint work with: Gennady Samorodnitsky; Mircea Grigoriu; Natalie Mahowald; Judith Berner

Type: Poster

Abstract. Observational evidence gathered during the 20th century point to an overall global increase in warm temperature extremes, and likely increases in the number of heavy precipitation events in more regions than there have been statistically significant decreases. Simulations from global climate models project further increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes in 21st century. Because of the severe impact that climate extremes can have on human and economic systems, it is important to evaluate the ability of climate models to reproduce observed extreme climate events in order assess the reliability of future projections. In this work, we evaluate the performance of the Community Atmosphere Model version 4 (CAM4) in simulating observed temperature extremes, as measured by 20-yr return levels, and compare them to estimates derived from the ERA Interim reanalysis product and the HadEX2 observational dataset. Moreover, we quantify to which degree the differences are the result of differences in the climatology of temperature extremes. In addition, we examine whether introducing a stochastic parameterization in CAM4 improves the agreement of simulated extremes with those from the verification datasets. In particular, we consider the stochastic kinetic energy backscatter scheme, whose origin lies in large-eddy simulation modeling and has recently been extended to weather and climate scales. Our results indicate that CAM4 tends to overestimate both cold and warm extremes over land relative to the verification datasets, but much of the difference is explained by climatological discrepancies. SKEBS improves the simulation of cold extremes, but further enhances the overestimation of warm extremes.

Keywords: temperature extremes; stochastic parameterization; community atmosphere model.

Extreme Risks in Insurance and Finance with Multivariate Regular Variation

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Joint work with: Zhongyi Yuan

Type: Contributed Talk

Abstract. In this talk, after a brief introduction of multivariate regular variation I shall illustrate its versatility in quantitative risk management by presenting its applications to various topics in the interdisciplinary area of insurance and finance. These topics include losses given default, capital allocation, and interplay of insurance and financial risks.
Keywords: multivariate regular variation; quantitative risk management; asymptotic dependence.

Bayesian hierarchical modelling of extreme low temperatures in Northern Finland

Thibaud, Emeric (emeric.thibaud@colostate.edu)
Colorado State University

Joint work with: Anthony Davison

Type: Invited Talk

Abstract. Brown-Resnick and extremal-t models have proven to be well-suited for modelling extremes of complex environmental processes, but their full density function cannot be calculated in general, preventing the widespread use of these models in Bayesian inference. In this talk we consider one particular case for which the full likelihoods of Brown-Resnick and extremal-t processes can be calculated, using the approach of Stephenson and Tawn (2005, Biometrika) that exploit the occurrence times of component-wise maxima. We propose the construction of a Bayesian hierarchical model for extreme low temperatures in Northern Finland. The resulting approach, potentially more efficient than classical approaches based on composite likelihoods, allows both the complex modelling of marginal distributions of extremes and an appropriate treatment of extremal dependence.
Keywords: max-stable process; occurrence times; likelihood inference.

Tail index estimation, concentration and adaptivity

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Université Paris-Diderot

Joint work with: Stephane Boucheron

Type: Contributed Talk

Abstract. This paper proposes an adaptive version of the Hill estimator based on Lespki's model selection method. This data-driven index selection method is shown to satisfy an oracle inequality and is checked to achieve the lower bound recently derived by Carpentier and Kim. In order to establish the oracle inequality, we establish non-asymptotic variance bounds and concentration inequalities for Hill estimators. These concentration inequalities are derived from Talagrand's concentration inequality for smooth functions of independent exponentially distributed random variables combined with three tools of Extreme Value Theory: the quantile transform, Karamata's representation of slowly varying functions, and Rényi's characterization of the order statistics of exponential samples. The performance of this computationally and conceptually simple method is illustrated using Monte-Carlo simulations.
Keywords: Hill's estimator; adaptivity; concentration.

Multivariate tail estimation under extremal dependence and independence

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University of Ottawa

Joint work with: Rafal Kulik

Type: Contributed Talk

Abstract. We consider regularly varying random vectors and non-parametric estimation for some characteristics related to conditioning on an extreme event, like the tail dependence coefficient (TDC) and expected shortfall (ES). We will distinguish between two cases: extremal independence (that is, when the exponent measure is concentrated on the axes) and extremal dependence. In the first case we consider conditional extreme value approach and introduce a conditional scaling exponent that allows to estimate the expected shortfall. In the latter case, we introduce a quasi-spectral decomposition that allows to improve efficiency of estimators of TDC and ES. Asymptotic normality of estimators is based on weak convergence of tail empirical processes. Theoretical results are supported by simulation studies.
Keywords: tail estimation; extremal dependence; extremal independence.

A directional multivariate extremes identification

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Universidad Carlos III de Madrid

Joint work with: Rosa E. Lillo; Carlo De Michele; Henry Laniado

Type: Contributed Talk

Abstract. Extreme value theory has been commonly applied in insurance, finance, economy and environmental science. It has been widely developed in the univariate setting but events such as economic crisis and environmental disasters suggest that it is necessary to analyze extreme values considering the joint information among all the variables implied in the problems. Therefore, researchers have tried to extend some typical concepts of the extreme value theory to the multivariate framework. Specifically, the quantile notion is of special interest as a way to generalize the methodology to recognize extremes. However, this is a difficult task due to the lack of a total order in the multivariate setting. Some definitions of multivariate quantiles have been introduced in the literature through partial orders or as generalizations of theoretical properties of the univariate quantile notion and these definitions are usually based on the level sets related to the joint cumulative distribution or to the survival distribution, but it can be shown that this consideration is not enough to recognize extreme events. In this work, we introduce a directional approach for studying multivariate quantiles and therefore, we try to find extreme values considering other directions of interest different from those given for the cumulative distribution or the survival distribution. We use the extremality level sets recently introduced in the literature to define a directional multivariate quantile notion. We provide analytical properties of this approach and a non-parametric estimation procedure, which is feasible in high dimensions. Finally, we propose and illustrate the methodology with simulated examples and a real data set in Hydrology, highlighting the relationships and differences between our proposal and some methods implemented in the literature which are based on copulas.
Keywords: multivariate quantile; copula; oriented orthants.

Predicting the future extreme wave climate of the North Sea

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Joint work with: Jonathan Tawn, Lancaster University; Emma Eastoe, Lancaster University; Philip Jonathan, Shell Global Solutions

Type: Contributed Talk

Abstract. For safe offshore operations accurate knowledge is required of the extreme oceanographic conditions that might be experienced. The distribution of the largest waves during the operating period is the most critical. We develop a multi-step statistical downscaling algorithm to use data from large-scale (low resolution) climate models and local-scale hindcast data to make predictions of the extreme wave climate in 2040-50 at locations in the North Sea.

To account for the effects of climate change, both historical and future predictions from the HADGEM2 global climate model (GCM) are used. The GCM only provides aggregated wave height data at a monthly scale and without information about wave direction. This information is not sufficient to tell us about extreme waves as storms typically last only a couple of days. Instead, we use 3-hourly wind speed and direction variables from the GCM. Exploiting the graphical structure of these variables and their inter-relationship with wave heights and direction, a probabilistic downscaling approach is used to relate the large and local-scale data sets, with parametric models for the inter-relationships derived from the

hindcast data. The estimated downscaled distributions of wave height are compared with waves observations over 2000-2009 to assess the performance of the method.

The framework is developed first for an individual site, but then extended to cover the North Sea. The application on the larger region provides a clear visual assessment of the effectiveness of the methodology at capturing the spatial impact of climate change on extreme values.

Keywords: covariate modelling; statistical downscaling; oceanography.

CLT of Lipschitz-Killing curvatures of excursion sets of Gaussian random fields

Vadlamani, Sreekar (sreekar@math.tifrbng.res.in)
TIFR-CAM

Joint work with: Marie Kratz

Type: Invited Talk

Abstract. Consider a Gaussian random field f defined on the d-dimensional Euclidean space, and define f_T as the restriction of f to a convex subset T of $\mathbb{R}^d$.

We study the asymptotic behavior of some global geometric functionals called the Lipschitz-Killing curvatures of the excursion sets $A_u(f_T)$ of f_T above the threshold u.

In particular, we show, after appropriate normalization, that, as the parameter space of the random field increases to the full Euclidean space, the Lipschitz-Killing curvatures of $A_u(f_T)$ converge weakly to a Gaussian random variable, thus exhibiting a central limit theorem for the geometric functionals.

Keywords: chaos expansion; CLT; excursion sets; Gaussian fields; Lipschitz-Killing curvatures.

Estimation of continuous 24-h precipitation extremes

Van de Vyver, Hans (hvijver@meteo.be)
Royal Meteorological Institute

Type: Poster

Abstract. Extreme value analysis of precipitation is of great importance for several types of engineering studies and policy decisions. For return level estimation of extreme 24-h precipitation, practitioners often use daily measurements (usually 08:00–08:00 local time) since high-frequency measurements are scarce. Annual maxima of daily series are smaller or equal to continuous 24-h precipitation maxima such that the resulting return levels may be systematically underestimated. In this paper we use a rule, derived earlier, on the conversion of the generalized extreme value (GEV) distribution of daily to 24-h maxima. We develop an estimator for the conversion exponent by combining daily maxima and high-frequency sampled 24-h maxima in one joint log-likelihood. Once the conversion exponent has been estimated, GEV-parameters of 24-h maxima can be obtained at sites where only

daily data is available. The new methodology has been extended to spatial regression models.
Keywords: extremal index; rainfall; sampling frequency.

On Parametric and Non-Parametric Estimation of the Dependence Function in Multivariate Extremes

Vettori, Sabrina (sabrina.vettori@kaust.edu.sa)
KAUST

Joint work with: Raphael Huser; Marc G. Genton

Type: Contributed Talk

Abstract. In a wide range of environmental applications it is of interest to model the behaviour of several variables at high levels, such as extremes of natural phenomena observed at distinct locations. Various non-parametric and parametric estimators of the dependence structure for multivariate maxima have been proposed. In this paper we investigate, through an extensive simulation study, the performance of some of these estimators under different dependence scenarios, focusing on the comparison between non-parametric and parametric approaches. In particular, we assess the performance of several non-parametric estimators, considering two different ways to make them satisfy the necessary constraints: either by naive modifications proposed in the literature or by projecting them onto the subspace of valid dependence functions. Non-parametric methods are then compared with parametric methods within the asymmetric logistic family of dependence structures.
Keywords: non-parametric and parametric estimators; asymmetric logistic family; Bernstein-Bezier polynomial.

Modelling across (bivariate) extremal dependence classes

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Lancaster University, UK

Joint work with: Jonathan Tawn; Anthony Davison; Daniel Elton

Type: Invited Talk

Abstract. 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 bivariate 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. We implement a simple version of this model, now written in an R package, and show that it offers good estimation capability over a variety of dependence structures.
Keywords: asymptotic independence; dependence modelling; censored likelihood.

Semiparametric Exponential Families for Heavy-Tailed Data

Wager, Stefan (swager@stanford.edu)
Stanford University

Joint work with: William Fithian

Type: Invited Talk

Abstract. We propose a semiparametric method for fitting the tail of a heavy-tailed population given a relatively small sample from that population and a larger sample from a related background population. We model the tail of the small sample as an exponential tilt of the better-observed large-sample tail, using a robust sufficient statistic motivated by extreme value theory. In particular, our method induces an estimator of the small-population mean, and we give theoretical and empirical evidence that this estimator outperforms methods that do not use the background sample. We demonstrate substantial efficiency gains over competing methods in simulation and on data from a large controlled experiment conducted by Facebook.
Keywords: Exponential family; Extreme Value Theory; semi-parametric estimation.

Heavy-Tailed Distributions and Robustness in Economics and Finance

Walden, Johan (walden@haas.berkeley.edu)
Haas School of Business, Berkeley

Joint work with: Marat Ibragimov; Rustam Ibragimov

Type: Invited Talk

Abstract. We analyze the implications of the presence of heavy-tailed risk distributions in economics, finance and insurance. Specifically, we show that depending on the degree of heavy-tailedness the implications of a number of models in these fields can either be reinforced or reversed. A key force behind our results is the failure of diversification that arises with heavy-tailed risks. Our conclusions on (non-)robustness of economic and financial models motivate the development and applications of robust inference approaches under heavy tails, heterogeneity and dependence in observations.
Keywords: heavy-tailed distribution; diversification; robustness.

Choice of Threshold With a View Towards Inference on Angular Distribution of Regularly Varying Data

Wan, Phyllis (phyllis@stat.columbia.edu)
Columbia University

Joint work with: Richard A. Davis

Type: Contributed Talk

Abstract. Regular variation is often used as the starting point for modelling heavy-tailed multivariate data. A random vector is regularly varying if and only if the radial part R is regularly varying and independent of the angular part Θ as R goes to infinity. In many applications, the primary goal is to estimate the limit distribution of the angular component; this could be either parametric, if there is a known parametric form of the limit distribution, or non-parametric. A typical strategy for carrying out this inference is based on the angular components of the data for which the radial parts exceed some threshold. So choosing a large threshold for which the angular and radial parts are nearly independent is an important piece of the inference procedure. In this talk, we would discuss a procedure for choosing the threshold that is based on distance correlation, a measure of independence. We provide some background theory for this procedure and illustrate its performance on both simulated and real data.
Keywords: multivariate regular variation; threshold for heavy-tailed data; distance correlation.

Invariance principles for operator-scaling Gaussian random fields

Wang, Yizao (yizao.wang@uc.edu)
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Joint work with: Hermine Biermé; Olivier Durieu

Type: Contributed Talk

Abstract. Recently, Hammond and Sheffield introduced a model of correlated random walks that scale to fractional Brownian motions with long-range dependence. In this paper, we consider a natural generalization of this model to dimension $d \geq 2$. We define a $\mathbb{Z}^d$-indexed random field with dependence relations governed by an underlying random graph with vertices $\mathbb{Z}^d$, and we study the scaling limits of the partial sums the random field over rectangular sets. An interesting phenomenon appears: depending on how fast the rectangular sets increase along different directions, different random fields arise in the limit. In particular, there is a critical regime where the limit random field is operator-scaling and inherits the full dependence structure of the discrete model, whereas in other regimes the limit random fields have at least one direction that has either invariant or independent increments, no longer reflecting the dependence structure in the discrete model.
Keywords: partition by random sampling; fractional Brownian motion; self-similar processes.

Statistics for Tail Processes

Warchol, Michal (michal.warchol@uclouvain.be)
Universite catholique de Louvain

Joint work with: Holger Drees; Johan Segers

Type: Contributed Talk

Abstract. At high levels, the asymptotic distribution of a stationary, regularly varying time series is given by its tail process. In the special case of Markov chains the latter takes the form of a geometric random walk, the increment distribution depending on the sign of the process at the current state and on the flow of time, either forward or backward. Estimation of the spectral tail process provides a nonparametric approach to analyze serial extremal dependence and the magnitude of extreme values independently. A duality between the distributions of the forward and backward increments provides additional information that can be exploited in the construction of more efficient estimators. The large-sample distribution of such estimators is derived via empirical process theory for cluster functionals. Their finite-sample performance is evaluated via Monte Carlo simulations. The estimators are applied to stock price data to study the absence or presence of symmetries in the succession of large gains and losses.
Keywords: regular variation; stationary time series; tail process.

Floods - Some statistical considerations and realities

Whitfield, Paul (paul.whitfield@ec.gc.ca)
Environment Canada / University of Saskatchewan

Type: Contributed Talk

Abstract. Flood events in Canada, as in the US, result in larger costs, in terms of property damage, than any other natural disaster. As an extreme event, floods are particularly difficult to study. Floods in Canada are caused by a range of processes or mixtures of processes: snowmelt runoff; rain-on-snow, and rainfall; ice jams during ice formation or spring break-up; failure of natural dams; and coastal flooding from storm surges, hurricanes and tsunamis. Urban flooding can be caused by storm water runoff, riverine flooding and structural failure when engineered flood management structures, including dams and levees, prove inadequate to manage the quantities and force of flood waters. Any of these processes alone or in combination can produce inundation: an area becoming covered in water and sediment. Frequently, extreme floods are not from a well sampled frequency distribution particularly using point data. Some important aspects of the statistical study of floods will be addressed; nonstationarity, mixed processes, suitable data, separating floods from flood damages. In addition, changes in land use, and more recently the impacts of climate change, can lead to changes in the flood regime.
Keywords: floods; generation processes.

A large deviations approach to limit theory for heavy-tailed time series

Wintenberger, Olivier (olivier.wintenberger@upmc.fr)
Université Pierre et Marie Curie

Joint work with: Thomas Mikosch

Type: Invited Talk

Abstract. A large deviations approach for proving limit theory for (generally) multivariate time series with heavy tails is described assuming regular variations. We provide general large deviation results for functionals acting on a sample path and vanishing in some neighborhood of the origin. We study a variety of such functionals, including large deviations of random walks, their suprema, the ruin functional, and further derive weak limit theory for maxima, point processes, cluster functionals and the tail empirical process. One of the main results of this paper concerns bounds for the ruin probability in various heavy-tailed models including GARCH, stochastic volatility models and solutions to stochastic recurrence equations.
Keywords: large deviations; ruin probability; tail empirical processes; GARCH.

Assessing the risk of heatwaves using extreme value theory

Winter, Hugo (h.winter@lancaster.ac.uk)
Lancaster University

Joint work with: Jonathan Tawn; Simon Brown

Type: Invited Talk

Abstract. Since the turn of the century record temperatures have been observed in at least 20 different countries across Europe. Climate change is now widely regarded as a driving force behind these higher temperatures. Isolated hot days are not often an issue; many more deaths occur when hot temperatures persist over many days. For example, the 2003 heatwave over Europe caused 40,000 deaths over a four week period. These prolonged periods of hot temperatures reduce the capacity of the human body for heat regulation and cause the body to overheat. This in turn can increase blood pressure, lead to cardiovascular stress and death.

Heatwaves are a type of extreme event defined as a period of persistent hot temperatures. Many previous extreme value studies have focused the maximum intensity of an event without considering the effect that the duration and spatial extent might have. From a modelling perspective this represents a focus on the marginal distribution while ignoring the extremal dependence structure. The conditional extremes approach (Heffernan and Tawn (2004)) provides a framework to model the spatial and temporal dependence of extreme values. We extend this approach to create space-time models which permit the simulation of replicate heatwave events. Covariates are included in the marginal and dependence structures, allowing our models to be used to predict whether the duration, severity and spatial extent of heatwaves will alter with climate change.

We investigate the behaviour of heatwaves for daily maximum temperature observations and a selection of global climate models forced under the A2 climate scenario (large local

growth with heavy reliance on fossil fuels). We aim to observe whether there are any changes in the spatial and temporal dependence structures of consecutive extreme events with climate change and see whether they are consistent across an ensemble of climate models. We then aim to answer questions such as 'How will a 1°C warming in the global temperature increase the chance of a 2003 style event? and estimate probabilities of an event that causes a specified increase in mortality.
Keywords: extremal dependence; conditional extremes; heatwaves.

Excursion Probability of Gaussian Random Fields on Sphere

Xiao, Yimin (xiao@stt.msu.edu)
Michigan State University

Joint work with: Dan Cheng

Type: Invited Talk

Abstract. Let $X = \{X(x) : x \in \mathbb{S}^N\}$ be a real-valued, centered Gaussian random field indexed on the N-dimensional unit sphere $\mathbb{S}^N$. Approximations to the excursion probability $\mathbb{P}\{\sup_{x\in\mathbb{S}^N} X(x) \geq u\}$, as $u \to \infty$, are obtained for two cases: (i) X is locally isotropic and its sample functions are non-smooth and; (ii) X is isotropic and its sample functions are twice differentiable. For case (i), the excursion probability can be studied by applying the results in Piterbarg (1996), Mikhaleva and Piterbarg (1997) and Chan and Lai (2006). It is shown that the asymptotics of $\mathbb{P}\{\sup_{x\in\mathbb{S}^N} X(x) \geq u\}$ is similar to Pickands' approximation on the Euclidean space which involves Pickands' constant. For case (ii), we apply the expected Euler characteristic method to obtain a more precise approximation such that the error is super-exponentially small.
Keywords: Gaussian random field on the sphere; the double sum method; the mean Euler characteristic method.

Rare-event Analysis for Extremal Eigenvalues of the Beta-Laguerre Ensemble

Xu, Gongjun (xuxxx360@umn.edu)
University of Minnesota

Joint work with: Tiefeng Jiang; Kevin Leder

Type: Invited Talk

Abstract. In this talk we consider the extreme behavior of the largest eigenvalue coming from the beta-Laguerre ensemble, which is a generalization of the Wishart matrix and plays an important role in Multivariate Analysis. In particular, we focus on the case when the dimension of the feature p is much larger than or comparable to the number of observations n, a common situation in modern data analysis. We provide asymptotic approximations and bounds for the tail probabilities of the largest eigenvalue. In addition, we construct

efficient Monte Carlo simulation algorithms to compute the tail probabilities. Simulation results show that our method has the best performance amongst known approximation approaches, and furthermore provides an efficient and accurate way for evaluating the tail probabilities in practice.
Keywords: importance sampling; extremal eigenvalues; beta-Laguerre ensemble.

Risk Concentration based on Expectiles for Extreme Risks under FGM Copula

Yang, Fan (fan.yang@uwaterloo.ca)
University of Waterloo

Joint work with: Tiantian Mao

Type: Contributed Talk

Abstract. Risk concentration is used as a measurement of diversification benefits in the context of risk aggregation. Expectiles, which are known to possess many good properties, have attracted increasing interests in recent years. In this talk, we aim to study the asymptotic properties of risk concentration based on Expectiles. Firstly, we extend the results on the second-order asymptotics of Expectiles in Mao et al. (2014). Secondly, we investigate the second-order asymptotics of tail probabilities and then apply them to risk concentrations based on Expectiles as well as on VaR. The risk random variables are assumed to have identical margins with regularly varying tails and their dependence structure is modeled by two types of generalized FGM copulas. Through numerical examples, we show that the second-order asymptotics are better than the first-order for capturing the diversification benefits of extreme risks.
Keywords: risk concentration; Expectiles; FGM copula.

Vector generalized linear and additive extreme value models

Yee, Thomas (t.yee@auckland.ac.nz)
University of Auckland

Joint work with: Alec G. Stephenson

Type: Contributed Talk

Abstract. A paper published in 2007 in Extremes under the same title demonstrated how regression models may be fitted to extremes in a similar manner as generalized linear and additive models can to distributions in the exponential family. In this talk we try to give a flavour of such analyses using the VGAM R package and family functions `gev()` and `gpd()`. We raise the important issue about software defaults. It is an unfortunate reality that most users blindly accept the default settings of software functions (and many do not even read the online help). Consequently, they suffer the real possibility of fitting poor quality models to data. The paper Withers C. S. and Nadarajah, S. (2009), Random Operators and

Stochastic Equations 17(1): 55–60, shows that, at the upper tail of power-type or gamma-type distributions, the variability trend, not the mean trend, drives extremes. Given a set of explanatory variables, the software default for `gev()` currently makes the scale and shape parameters intercept-only, i.e., only the location parameter is modelled by the covariates. Possibly, the scale parameter should be allowed to be a function of the covariates too, by default. It is hoped that this talk will invoke discussion about this practically important topic.

Keywords: Vector generalized linear and additive models; VGAM R package; software defaults.

Pointwise Tolerance Intervals for Non-Stationary Generalized Extreme Value Regression Models

Young, Derek (derek.young@uky.edu)
University of Kentucky

Type: Contributed Talk

Abstract. Important information is often found in the extremes of a measured characteristic of interest. When additional explanatory variables are also available, generalized extreme value (GEV) regression models can provide a flexible modeling paradigm to describe possible relationships. Just like other regression settings, there may be extreme values under the specified GEV regression model. Such values could signal a critical threshold in the underlying process being characterized. Essentially, we are interested in identifying the extremes of the extremes. One approach for identifying such thresholds is statistical tolerance intervals, which are designed to characterize a certain proportion of the sampled population at a given confidence level. Statistical tolerance intervals have been used successfully for many years, including in traditional regression contexts. In this talk, we develop pointwise tolerance intervals for non-stationary GEV regression models as a way to set thresholds for identifying the extreme values. Simulation results will be discussed to assess general coverage properties. An application to an extreme temperature dataset will also be presented.

Keywords: GEV regression; outliers; tolerance intervals.

Universal bounds on extreme value-at-risk under fixed extremal coefficients

Yuen, Robert (bobyuen@umich.edu)
University of Michigan

Joint work with: Stilian Stoev; Dan Cooley

Type: Invited Talk

Abstract. When estimating extreme value-at-risk for the sum of dependent losses, it is imperative to determine the nature of dependencies in the tails of said losses. Characterizing

the tail dependence of regularly varying losses involves working with the spectral measure, an infinite dimensional parameter that is difficult to infer and in many cases intractable. Conversely, various summary statistics of tail dependence such as extremal coefficients are manageable in the sense that they are finite dimensional and efficient estimates are obtainable. While extremal coefficients alone are not sufficient to characterize tail dependence, it was not previously known how they constrain the theoretical range of Value-at-Risk. The answer involves optimization over an infinite dimensional space of measures. In this work, we establish the solution and determine exact bounds on the asymptotic value-at-risk for the sum of regularly varying dependent losses when given full or partial knowledge of the extremal coefficients. We show that in-practice, the theoretical range of value-at-risk can be reduced significantly when relatively few, low dimensional extremal coefficients are given.
Keywords: semi-infinite linear programming; Tawn-Molchanov model; Value-at-Risk; extremal coefficient; spectral measure.

Estimation of Extreme Return Levels of Maximum Temperature over Southern Pakistan

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Meteorological Institute, University of Hamburg, Germany

Joint work with: Maida Zahid ; Valerio Lucarini

Type: Poster

Abstract. This study aims to estimate the maximum temperature extreme return levels for various return periods in different cities of Southern Pakistan (Sindh Province). This region is recently becoming exposed to climate extremes and has emerged as a hot spot of climate change due to its vulnerability to high population density, poor infrastructures and high dependence of the agriculture on climatic factor. This area also embraces the widespread cultivation of cotton i.e. cash crop of the country. Extremely high and consistent temperature events may lead to gigantic crop yield fiasco and economic losses to the country. Hence, this study will be significant for a variety of stakeholders both public and private, particularly for local administrations for timely planning and adaptations in water and agriculture sectors. The precise evaluation of magnitude and frequency of extreme temperature is of fundamental importance in this context. The extreme value theory (EVT) is a quite popular statistical approach in scientific community for risk assessment. Therefore, peak over threshold (POT) method has been used to estimate the return levels (RL) of extreme maximum temperature at nine meteorological stations over Southern Pakistan from 1980-2013. The choice of threshold results in very good model fits. The shape of the GPD model fits is quite homogenous; they all have an upper bound. The return levels showed that warming is consistent in most of the cities over the next fifty years with the exception of Badin and Chhor, due to negligible return levels. The 50 years return levels for the hottest stations like Jacobabad, Mohenjo-daro and Padidan comprised between 51°C - 53.6°C. However, Nawabshah, Rohri, Hyderabad and Karachi showed return levels between 47°C - 52.1°C. In nutshell, high RL of maximum temperature in the region may adversely effect the production of wheat, cotton and sugarcane in near future.

Keywords: extreme maximum temperature; return levels; Peaks over Threshold.

Modelling non-stationary environmental extremes

Zanini, Elena (e.zanini1@lancaster.ac.uk)
University of Lancaster

Joint work with: E. Eastoe; P. Jonathan; D. Randell; J. Tawn

Type: Poster

Abstract. Safety is a key concern for offshore structures and operations. Insight into these extreme sea states can be inferred from an historical or hind-cast data set by using Extreme Value Analysis. However, non-stationarity strongly affects oceanographic variables such as wave height. Developing reliable and accurate methods to account for the presence of factors such as wave direction and seasonal pattern is then essential.

The long term aim of the project is to address a variety of issues that arise in the non-stationary case, and investigate the performance of existing threshold models in such a context. Of these models, the two most common methods are the generalized Pareto distribution model and a Poisson point process approach. An overview of some of the issues arising in model inference in the presence of covariates is given, as well as some possible re-parametrisations of the models to address them. Simulated data is used to better illustrate both these issues and the model performance under controlled conditions.
Keywords: non-stationary; offshore design; model inference.

The integrated periodogram of a dependent extremal event sequence

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Ulm University

Joint work with: Thomas Mikosch

Type: Contributed Talk

Abstract. We investigate the asymptotic properties of the integrated periodogram calculated from a sequence of indicator functions of dependent extremal events. An event in Euclidean space is extreme if it occurs far away from the origin. We use a regular variation condition on the underlying stationary sequence to make these notions precise. Our main result is a functional central limit theorem for the integrated periodogram of the indicator functions of dependent extremal events. The limiting process is a continuous Gaussian process whose covariance structure is in general unfamiliar, but in the iid case a Brownian bridge appears. In the general case, we propose a stationary bootstrap procedure for approximating the distribution of the limiting process. The developed theory can be used to construct classical goodness-of-fit tests such as the Grenander-Rosenblatt and Cramér-von Mises tests which are based only on the extremes in the sample. We apply the test statistics to simulated and real-life data.

Keywords: spectral analysis; functional central limit theorem; stationary bootstrap.

Tail Estimation for Window Censored Processes

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Chalmers University of Technology

Joint work with: Holger Rootzén

Type: Invited Talk

Abstract. We develop methods to estimate the tail distribution of the lengths of the 0-intervals in a continuous time stationary ergodic stochastic process which takes the values 0 and 1 in alternating intervals. The key assumption is that many of such 0-1 processes have been observed during a short time window, and thus the observed 0-intervals could be non-censored, left-censored, right-censored, or double-censored. We develop maximum likelihood tail estimation methods based on a semi-parametric generalized Pareto model, study asymptotic normality property of the estimators, and apply our methods to estimation of the length of off-road glances in a big naturalistic driving experiment.
Keywords: tail estimation; censored data; traffic safety.

Tail beta

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Joint work with: Maarten van Oordt

Type: Invited Talk

Abstract. This talk covers two recent papers on applying multivariate Extreme Value Theory to analyze systematic tail risks in stock returns. We first consider the problem of estimating a linear model between two heavy-tailed variables if the explanatory variable has an extremely low (or high) value. We propose an estimator for the model coefficient by exploiting the tail dependence between the two variables. Then this method is applied for analyzing the systematic tail risk of stock returns. In the context of finance, we call the model coefficient, the "tail beta". This talk shows two applications of the tail beta. First, the tail beta approach performs better than the conditional regression approach in projecting the losses of industry-specific stock portfolios in the event of a market crash. Second, the tail beta is not priced in the expected stock returns in the cross-section. The combination of the two results show the existence of a potentially free insurance against large market shocks.
Keywords: risk management; asset pricing; systematic risk.

On records and champions in higher dimensions

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Joint work with: Clément Dombry; Michael Falk

Type: Contributed Talk

Abstract. Let $\boldsymbol{X}^{(1)}, \ldots, \boldsymbol{X}^{(n)}$ be a set of iid random vectors (rv) in $\mathbb{R}^d$ with a continuous distribution function F. The rv $\boldsymbol{X}^{(i)}$ is said to be the champion among $\boldsymbol{X}^{(1)}, \ldots, \boldsymbol{X}^{(n)}$ if $\boldsymbol{X}^{(i)} > \boldsymbol{X}^{(j)}$ for $j \neq i$, where this is meant to hold for all components. Different to that, $\boldsymbol{X}^{(i)}$ is called a record if $\boldsymbol{X}^{(i)} > \boldsymbol{X}^{(j)}$ for $j = 1, \ldots, i-1$. Note that there might be several records among $\boldsymbol{X}^{(1)}, \ldots, \boldsymbol{X}^{(n)}$, but only one champion.

In the univariate case $d = 1$ there clearly is a champion with probability one. In the case $d \geq 2$, however, this is no longer true. The probability of having a champion among $\boldsymbol{X}^{(1)}, \ldots, \boldsymbol{X}^{(n)}$ does only depend on the copula of F and we show that this probability converges as n tends to infinity, if the copula of F is in the max-domain of attraction of a multivariate extreme value distribution. This limit can be characterized in terms of D-norms. We also derive the survivor function of a champion, given that there is a champion. The results are extended to the functional case $\boldsymbol{X}^{(i)} \in C([0,1]^k)$.

Keywords: max-stable distributions; max-domain of attraction; D-norm.

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