Conference on Nonstationarity

June 4-6, 2018

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sponsored this event and made it possible. The organisers are also very grateful to the speakers and participants of the conference

Contents

1 Aims of the Conference

The conference `http://urlz.fr/6CNu` is organized[1] by the AGM laboratory on

- June 4-5, 2018 at the **MIR, Neuville-sur-Oise**[2],
- June 6, 2018 in the **"salle des conférences", les Chênes 1** at University Cergy-Pontoise[3].

The techniques of time series are widely used for the prediction of random phenomena. Other related questions such as for example calibration, resampling or risk management are other important issues.

Stationarity is usually assumed because of a fundamental technical feature: it makes possible to use the ergodic theorem in order to derive consistent estimations. This idea of ergodicity is thus beyond any asymptotical theory for large samples.

The aim of the conference is to consider models which dont meet the stationarity condition. Indeed, the models should fit the considered data sets, and beyond the local stationarity (see e.g. Dahlhaus), possible models invoking periodicities, exogenous data or shape constraints as monotonicity need further considerations. Applications to real problems and data sets should fit the considered mathematical models.

The emblematic global warming problem[4] is of a vital importance; checking whether it really exists should rely on a test of hypothesis, and relevant models are needed; one may think of models whose dynamics is driven by a sequence of parameters $(\theta_t)_{1\le t\le n}$, for $\theta_t = (\theta_t^{(1)}, \ldots, \theta_t^{(d)})$ over a period of observation $\{1, \ldots, n\}$. In this case many $d-$periodic behaviours depend on the time scale and are given either through days and nights; in this case $d = 2$ if the sampling time is 12 hours, $d = 2 \times 12$ if this time one hour and $d = 6 \times 12 \times 60 = 4320$ is the sampling time is each minute). If seasons are considered then $d = 4$ in case of monthly observations; finally if the observed period of activity is that of the of the sun then $d = 12$ for observations sampled each year. An important question is the type of asymptotics, namely the conference is more oriented in a discrete time

[1] This workshop is sponsored by the LABEX MME-DII, the Institute for Advances Studies, the laboratory AGM, the ANR Elitisme, in University of Cergy-Pontoise, and the laboratory SAMM Paris 1 Sorbonne, CDiscount Bordeaux and the Mathamsud SaS-MoTiDep project.

[2] Train station: Neuville-Université.

[3] Train station: RER A Cergy-Préfecture.

[4] which may not affect all the countries in the world, as claimed President Trump...

asymptotic, for instance a random phenomenon Z_t is observed at epochs $k\Delta$ for a fixed $\Delta > 0$ and $X_k = Z_{k\Delta}$ for $k = 1, \ldots, n$; this scheme needs ergodic theorems. The same holds in case $\Delta = v_n \times \delta$ if $\lim_{n\to\infty} nv_n = \infty$. An alternative asymptotic is known as infills statistics and corresponds to the cas $\Delta = \frac{1}{n} \times \delta$; in this case ergodic theorems are replaced by regularity conditions on the trajectories of the process (Z_t).

Non-asymptotic results are also essential for real data analysis.

Monotonic trends or locally stationary behaviours can be considered. The use of exogenous data time series is also important: think of nebulosity in the global warming setting.

- Procedures for the estimation are given by many speakers mainly on the first day of the conference, June 4. They include distributional point-wise or uniform asymptotic behaviours of the corresponding estimations.

- The second day of the conference aims at widening the amount of models through the introduction of continuous time or point process valued models. Limit theorems and specific dependence properties for a wide variety of such models will also be considered.

- The final day of the conference, June 6, is more dedicated to specific applications. First the introduction of change point models, with stationary behaviours between unknown periods of time $n_0 = 1 < n_1 \leq \cdots \leq n_k = n$ is an important tool for the modeling of non-stationarity. Applications to economy (see e.g. commodities trading such as energy markets, online retail banking...), global warming and coral reefs, or astrophysics will be considered. As stressed in the different talks, it is possible to use a very large variety of techniques for relevant data analyses.

Note also that many further applications to financial and actuarial data, to astronomical data, or to biological, medical or genomic data sets need further considerations. This means that the conference must be viewed as an exploratory one more than a definitive consideration of non stationarity issues.

2 Schedule

- **June 4 (IEA)**

Modeling and fitting non stationary data

09:00-9:40 *Coffee*

09:40-10 Opening conference

Local stationarity

10-10:30 Rainer Dahlhaus, Heidelberg University. Towards a general theory for non-linear locally stationary processes

10:40-11:10 Stefan Richter, Heidelberg University. Bahadur representation and simultaneous inference for curve estimation in time-varying models

11:20-11:50 Suhasini Suba Rao, Texas A&M University. A test for stationarity for irregularly spaced spatial data

12:00-12:30 Guy Mélard, Université libre de Bruxelles. Time series models with time dependent coefficients

12:40-14:00 *Lunch break*
Poster session

Non stationarity

14:00-14:30 Liudas Giraitis, Queen Mary University of London. Inference on time series with changing mean and variance

14:40-15:10 Philippe Naveau, LSCE Paris. Analysis of extreme climate events by combining multivariate extreme values theory and causality theory

15:20-15:50 Coffee break

15:50-16:20 Herold Dehling, University of Bochum. Robust tests for change points in time series

16:30-17:10 Oliver Wintenberger, Sorbonne University. Contrast estimation of non-stationary infinite memory models involving coupling techniques

17:20-17:50 Konstantinos Fokianos, Cyprus and Cergy-Pontoise Universities. On integrated L^1-convergence rate of an isotonic regression estimator for multivariate observations

18:00-18:40 Round table: modeling of non stationarity

18:40 *Welcome cocktail*

- **June 5 (IEA)**

Probabilistic issues of non stationarity

09:30-10:00 *Coffee*

Continuous time non stationary models

10:00-10:30 Reinhard Höpfner, University of Mainz. Ergodicity and limit theorems for degenerate diffusions with time periodic drift

10:40-11:10 Kerlyns Martínez, Valparaiso University. Calibration on Lagrangian turbulent flow models

11:20-11:50 François Roueff, TELECOM Paris-Tech. Time-frequency analysis of locally stationary Hawkes processes

12:00-12:30 Mathieu Rosenbaum, Polytechnique, Saclay. Inhomogeneous Hawkes processes

12:40-14:00 *Lunch break*
Poster session

Limit theory for non stationary processes

14:40-15:10 Lionel Truquet, ENSAI Rennes. A perturbation analysis of some Markov chains models with time-varying parameters

15:20-15:50 Michael Neumann, Jena University. Absolute regularity of semi-contractive GARCH-type processes

16:00-16:30 *Coffee break*

16:40-17:10 Florence Merlevède, University of Marne la Vallée. On the functional CLT for non-stationary sequences in L^2

17:20-17:50 Nikolai Leonenko, Cardiff University. Non-stationary random fields with application to astrophysics

19:30 *Conference dinner*

- **June 6 (Les Chênes: salle de conférences)**

Alternatives and applications of non stationarity

09:40-10 *Coffee*

Cyclic and change point issues

10:00-10:30 Elżbieta Gajecka-Mirek, State University of Applied Sciences in Nowy Sacz. Resampling confidence intervals for the mean for the selected class of nonstationary time series with weak dependence condition

10:40-11:10 Anna Dudek, AGH University of Science and Technology, Crakow, Poland. Bootstrap for almost cyclostationary processes with jitter effect

11:20-11:50 Jean Marc Bardet, University Paris 1 - Panthéon-Sorbonne. Non-parametric estimation of time varying AR(1)-processes with local stationarity and periodicity

12:00-12:30 Emilie Lebarbier, AgroParisTech, INRA, Université Paris-Saclay. Segmentation methods for breakpoint detection in time series

12:40-14:00 *Lunch break*

Applications

14:00-14:30 Nathalie Picard, University Cergy-Pontoise. Non stationarity in HMM models

14:40-15:10 Pierre Gaillard, INRIA Paris. Online prediction of arbitrary time-series with non-stationarity with application to electricity consumption

15:20-15:50 Arnaud Belletoile, CDiscount, Bordeaux. Real life non-stationary time series from a large e-retail supply chain

16:00-16:30 *Coffee break*

16:30-17:00 Perspectives

3 Abstracts

Jean-Marc Bardet, University Paris 1, Sorbonne

Non-parametric estimation of time varying AR(1)–processes with local stationarity and periodicity

Extending the ideas of Dahlhaus (2012), this paper aims at providing a kernel based non-parametric estimation of a new class of time varying AR(1) processes (X_t), with local stationarity and periodic features (with a known period T), inducing the definition $X_t = a_t(t/nT)X_{t-1} + \xi_t$ for $t \in \mathbb{N}$ and with $a_{t+T} \equiv a_t$. Central limit theorems are established for kernel estimators $\widehat{a}_s(u)$ reaching classical minimax rates and only requiring low order moment conditions of the white noise $(\xi_t)_t$ up to the second order.

(Joint work with Paul Doukhan).

Arnaud Belletoile, CDISCOUNT Bordeaux

Real life non-stationary time series from a large e-retail supply chain

It is not an overstatement to say that the position of Cdiscount as the leading french e-retailer is largely due to the competitiveness of its logistic chain. With more than 8.6M active users and 10M pages visited each day, the efficiency of the whole supply chain is decisive to satisfy our users while maintaining a cost-effective organization. The precise knowledge of the demand for a given product allow us to reduce delivery time, save costly storage and prevent any product shortage all at once. Considering our 30M+ references, it comes as no surprise that the reduction of the uncertainty on the demand forecast is an active area of work at Cdiscount.
During this talk, I will introduce in greater details our problematic of demand and sales forecasting at Cdiscount. From the diversity of our procurement lead times to the inclusion of covariates, I will try to sketch the most accurate picture of the difficulties with have to face with concrete examples of non-stationary processes. Finally, I will present some of the tested solutions and the lessons learned while trying to tackle what remains an open problem.

David Berger, Ulm University

On non-stationary (causal) linear fields and strong mixing questions

We present some results on strong mixing properties of nonstationary (causal) linear random fields and study explicitly the rates depending on the innovations and coefficients. Furtermore, we will study some properties of the L^p

modulus of infinitely divisble densities as the mixing rate depends directly on the 1−modulus of the innovations, where we give sufficient conditions in terms of the characteristic triplet (a, γ, ν) of the Lévy-Khintchine representation of the distribution to have Hölder-continuous 1−modulus. We will also see that some of these results are optimal.

Emmanuel Caron, Centrale School, Nantes

Asymptotic distribution of least square estimators for linear models with dependent errors

We consider the usual linear regression model in the case where the error process is assumed strictly stationary. We use a result from Hannan (1973), who proved a Central Limit Theorem for the usual least square estimator under general conditions on the design and on the error process. We show that for a large class of designs, the asymptotic covariance matrix is as simple as the independent and identically distributed case. We then estimate the covariance matrix using an estimator of the spectral density whose consistency is proved under very mild conditions. As an application, we show how to modify the usual Fisher tests in this dependent context, in such a way that the type-I error rate remains asymptotically correct, and we illustrate the performance of this procedure through different sets of simulations.

(Joint work with Sophie Dede).

Imma Curato, Ulm University

On the sample autocovariance of a Lévy driven moving average process when sampled at a renewal sequences

We consider a Lévy driven continuous time moving average process X sampled at random times which follow a renewal structure independent of X. Asymptotic normality of the sample mean, the sample autocovariance, and the sample autocorrelation is established under certain conditions on the kernel and the random times. We compare our results to a classic non-random equidistant sampling method and give an application to parameter estimation of the Lévy driven Ornstein-Uhlenbeck process. We then develop our theory in the case in which the random times follow a renewal structure dependent of X.

(Joint work with Dirk Brandes).

Didier Dacunha-Castelle, University Paris-South, Orsay

Statistics and stationarity with an application to climatic problems

Considering a stochastic process, stationarity is defined by infinity of nested conditions. Thus it cannot be checked from observations. The same thing of course for cyclo-stationarity or other more or less extensions as transformation by operators as difference, linear combinations, and so on getting classical processes as Brownian, branching ones. We discuss how to choose a finite set of conditions giving an approximation of stationarity who can be tested and what kind of tests are convenient. Then we discuss when elementary operations as detrending and scaling have to be done before the study of stationarity. But what can be done for more complex non stationarities as that of correlations. We discuss this kind of situations for climatic data.

Rainer Dahlhaus, University of Heidelberg

Towards a general theory for non-linear locally stationary processes

In this paper some general theory is presented for locally stationary processes based on the stationary approximation and the stationary derivative. Strong laws of large numbers, central limit theorems as well as deterministic and stochastic bias expansions are proved for processes obeying an expansion in terms of the stationary approximation and derivative. In addition it is shown that this applies to some general nonlinear non-stationary Markov-models. In addition the results are applied to derive the asymptotic properties of maximum likelihood estimates of parameter curves in such models. The approach is also used to derive results on adaptive bandwidth selection via cross validation for local M-estimators in locally stationary processes.

(Joint work with Stefan Richter and Wei Biao Wu).

Herold Dehling, Ruhr-University Bochum

Robust tests for change-points in time series

We will present a survey of some recent results on robust tests for change-points in time series. Among others, we will cover rank tests, tests based on the empirical distribution, on ordinal patterns, and on empirical characteristic functions.

Anna Dudek, AGH University, Crakow

Bootstrap for almost cyclostationary processes with jitter effect

In this talk we consider almost cyclostationary (ACS) processes. To analyze ACS processes, Fourier analysis is often applied. Fourier expansions of the mean and the autocovariance function are used for instance to detect significant frequencies. Although, results establishing the estimators of the Fourier coefficients and their properties are well known, in practical applications one needs also a method to obtain the range of possible values of the considered parameters.
Unfortunately, the asymptotic confidence intervals cannot be constructed because the asymptotic variances of the estimators depend on the unknown parameters. Thus, to compute confidence intervals resampling methods are used. We show how the block bootstrap methods can be applied to the ACS processes, which are observed in instants that are randomly disturbed. This effect is called jitter. It appears in many signal analysis problems, e.g., receiver design in telecommunication, audio applications, optical encoders, etc. We propose a bootstrap approach based on the Moving Block Bootstrap method to construct pointwise and simultaneous confidence intervals for the Fourier coefficients of the autocovariance function of such processes. In the simulation study we show how our results can be used to detect the significant frequencies of the autocovariance function. Moreover, we present a real data application of our methodology.

Reference

D. Dehay, A.E. Dudek and M. Elbadaoui (2018). Bootstrap for almost cyclostationary processes with jitter effect, *Digital Signal Processing*, 73, 93-105.

(Joint work with Dominique Dehay and Mohamed El Badaoui).

Konstantinos Fokianos, University of Cyprus

On Integrated L^1 Convergence Rate of an Isotonic Regression Estimator for Multivariate Observations

We consider a general monotone regression estimation where we allow for independent and dependent regressors. We propose a modification of the classical isotonic least squares estimator and establish its rate of convergence for the integrated L^1-loss function. The methodology captures the shape of the data without assuming additivity or a parametric form for the regression function. Furthermore, the degree of smoothing is chosen automatically and no auxiliary tuning is required for the theoretical analysis. Some simulations complement the study of the proposed estimator.

(Joint work with Anne Leucht and Michael H. Neumann).

Pierre Gaillard, INRIA Paris
Online prediction of arbitrary time-series with non-stationarity with application to electricity consumption

Short-term electricity forecasting has been studied for years at EDF and different forecasting models were developed from various fields of statistics or machine learning (functional data analysis, time series, semi-parametric regression, boosting, bagging). We are interested in the forecasting of France's daily electricity load consumption based on these different approaches. In this talk, I will present how combining forecasts can lead to a significant improved accuracy on the data sets at hand; the improvements lie in a reduced mean squared error but also in a more robust behavior with respect to large occasional errors. We will consider the framework of prediction of arbitrary sequences and will see how to deal with non-stationarity.

Elżbieta Gajecka-Mirek, State University of Applied Sciences in Nowy Sacz, Poland
Resampling confidence intervals for the mean for the selected class of nonstationary time series with weak dependence condition

Possibility to construct sampling distributions of estimators for time series is very important in statistical studies. The traditional statistical inference based on asymptotic distributions does not always lead to effective statistical procedures. In many cases the resampling methods are the only effective technique. One can compute the confidence intervals and critical values from the resampling distributions instead of the asymptotic distributions. The attention will be focused on estimating the mean function for a class of nonstationary time series that are heavy tailed (finite at least fourth moment, e.g.: GED, t-Student) and exhibit long memory together with periodic behavior in their mean and variance.

Such a model can be naturally used in many areas like energy, vibromechanics, telecommunications, climatology and economics. The chosen resampling method is subsampling. It involves selecting from the observation all possible subsequences of some length and calculate the estimator on these subsequences. The theoretical and practical results describing the consistency of subsampling method and using them in statistical inference for the specific time series will be introduced.

Liudas Giraitis, Queen Mary University of London
Inference on time series with changing mean and variance

The paper develops point estimation and large sample statistical inference with respect to a semiparametric model for time series with moving mean and unconditional heteroscedasticity.
These two features are modelled nonparametrically, whereas autocorrelations are described by a short memory stationary parametric time series model.
We first study the usual least squares estimate of the coefficient of the first-order autoregressive model based on constant but unknown mean and variance. Allowing for both the latter to vary in a general way we establish its probability limit and a central limit theorem for a suitably normed and centred statistic, giving explicit bias and variance formulae. As expected mean variation is the main source of inconsistency and heteroscedasticity the main source of inefficiency, though we discuss circumstances in which the estimate is consistent for, and asymptotically normal about, the autoregressive coefficient, albeit inefficient.
We then consider standard Whittle estimates of a more general class of short memory parametric time series model, under otherwise more restrictive conditions.
When the mean is correctly assumed to be constant, estimates that ignore the heteroscedasticity are again found to be consistent for the dependence parameters, and asymptotically normal with parametric rate, and inefficient. Allowing a slowly time-varying mean we resort to trimming out of low frequences to achieve the same outcome. Returning to finite order autoregression, nonparametric estimates of the varying mean and variance are given asymptotic justification, and forecasting formulae developed.
Finite sample properties are studied by a small Monte Carlo simulations, and an empirical example is also included.

(Joint work with Violetta Dalla and Peter M. Robinson).

José Gomez, University of Cergy-Pontoise
Assessing Imputation of Extreme Data on Climatological Time Series

During the last few years, extreme temperature events took important relevance, specially by the conclusions of global scale studies. However, there is a lack of information and/or studies on Africa and South America where the geographical inhomogeneity of the results is mainly due to the absence of data. A special case is Uruguay, where long time series (sometimes reaching a century) are available which represent a great value for this kind of studies. However, the series are not complete, with missing records on several consecutive years, which translates in a clear inconvenient for the study of extreme events. Disposing of complete datasets has a fundamental role.

While techniques for imputation of missing data are generally well known, they are often applied and validated on non-extreme data. Even for specific approaches specialised on extreme data, the question of how to assess the imputation is raised. We propose to use known estimators of extreme value theory, such as the extremogram, which we generalised to the case of missing data and under local stationary.

In this work we present some theoretical results which establish the appropriateness of the proposition. Also we provide simulation experiments of time series with presence and absence of missing data in order to show numerically the accuracy of the method. Finally, we use a real data set of minimum temperature records for 11 meteorological stations in Uruguay. We apply our procedure to asses the reconstruction quality of the reconstructed records obtained by a new imputation scheme.

(Joint work with Jairo Cugliari).

Pierre Hodara, University of Sao Paulo

Estimation of the interaction graph of a network of neurons

In this work we present a statistical procedure proposed by Duarte, Galves Löcherbach and Ost (2016, see `https:arxiv.org/pdf/1604.00419.pdf`) to identify the interaction graph in the class of stochastic neuronal networks introduced by Galves and Lcherbach. This procedure was specially designed to deal with the small sample sizes met in actual datasets. The procedure do not require stationnarity in the sample, which is crucial since most of available recordings deal with stimulus driven activity. We evaluate the performance of the procedure on simulated data. This simulation study is also used for parameter tuning and for exploring the effect of recording only a small subset of the neurons of a network. We then apply our procedure to a recently released dataset from the first olfactory relay of the locust, which has not been analyzed so far.

(Joint work with Antonio Galves, Christophe Pouzat, Ludmilla Brochini and Guilherme Ost).

Reinhard Höpfner, University of Mainz

Ergodicity and limit theorems for degenerate diffusions with time periodic drift

We consider strongly degenerate stochastic systems: a d-dimensional diffusion $\mathbb{X} = (\mathbb{X}_t)_{t\geq 0}$ is driven by an m-dimensional Brownian motion $W = (W_t)_{t\geq 0}$

$$d\mathbb{X}_t \;=\; b(t,\mathbb{X}_t)\,dt \,+\, \sigma(\mathbb{X}_t)\,dW_t$$

where m is small in comparison to d. The state space is a Borel subset E of $\mathbb{R}^d$ with certain properties at its boundary, and we assume throughout that the coefficients are smooth ($\mathcal{C}^\infty$ on some open neighbourhood of E, or even analytic).
Time dependence is caused by some deterministic smooth T-periodic signal $t \mapsto S(t)$ which is encoded in the drift; the diffusion coefficient does not depend on time. Thus time enters the SDE only via the drift and only modulo T, the semigroup $(P_{s,t})_{0\leq s<t<\infty}$ of the process is T-periodic, and the following objects are homogeneous in time: (i) the T-grid chain $(\mathbb{X}_{kT})_{k\in\mathbb{N}_0}$; (ii) the extended process

$$\overline{\mathbb{X}} \;=\; (t,\mathbb{X}_t)_{t\geq 0} \quad \text{taking values in } \overline{E} := \mathbb{T}\times E$$

(continuous in time) where $\mathbb{T}$ is the periodicity interval $[0,T]$ viewed as a torus.
Our aim is to show that the extended process $\overline{\mathbb{X}}$ and/or the T-grid chain $(\mathbb{X}_{kT})_{k\in\mathbb{N}_0}$ are positive Harris recurrent (the assertion for one implying the assertion for the other). Once positive Harris recurrence is established, we dispose of (i) a unique invariant probability μ on E for the T-grid chain $(\mathbb{X}_{kT})_{k\in\mathbb{N}_0}$; (ii) a unique invariant probability $\overline{\mu}$ on $\overline{E}$ for the extended process $\overline{\mathbb{X}}$. Both are related by

$$\overline{\mu}(dt,dx) \;=\; \frac{1}{T}\int_0^T ds\;[\epsilon_{\{s\}}\otimes \mu P_{0,s}](dt,dx)\;, \quad t\in\mathbb{T}\,,\; x\in E\;.$$

Thus we have strong laws of large numbers for a large class of (integrable) addditive functionals, and martingale convergence theorems for martingales whose angle bracket is an (integrable) additive functional.
There are three types of assumptions. We need a Lyapunov function, forcing the grid chain to visit suitable large compacts infinitely often. We need some 'privileged' point $x^* \in \mathrm{int}(E)$ at which a weak Hoermander condition holds, and which is attainable in a sense of stochastic control from all starting positions in E.
Then weak Hoermander yields continuous transition densities locally at x^*, and attainability implies the positivity of these densities locally at x^*. This allows to write down a Nummelin minorisation condition for the T-grid chain: the 'small set' which is visited infinitely often is some open ball around x^*, and we can use Nummelin splitting to prove positive Harris recurrence for the grid chain.

In case where coefficients are analytic, control paths do transport weak Hoermander dimension, thus weak Hoermander will hold at all points in the state space.
Our work was motivated by a stochastic Hodgkin Huxley model where the above assumptions can be verified, and where 'adding noise' smoothens and simplifies a difficult and extremely complex deterministic setting. The classical deterministic Hodgkin Huxley model, well known in neuroscience, is a deterministic 4d system modelling the membrane potential in a neuron together with the behaviour of 'gating variables'. Periodic 'input' into the system results in an intricate tableau for the 'output': in most cases the output will be periodic, with 1 period of output corresponding to k periods of input and producing ℓ spikes ($k \in \mathbb{N}$, $\ell \in \mathbb{N}_0$), but also deterministic chaotic behaviour does exist, and minimal changes of the structure of the 'input' may change drastically the structure of the 'output'. We replace this by a stochastic Hodgkin Huxley system which is a 5d strongly degenerate stochastic system driven by 1d Brownian motion; the former deterministic input is replaced by a stochastic input process of OU or CIR type which is mean-reverting towards a deterministic periodic signal $t \mapsto S(t)$. Positive Harris recurrence simplifies the tableau of 'output phenomena' essentially: in the stochastic Hodgkin Huxley model, output will always be 'of simple and unified structure' in the long run, in a sense of strong laws of large numbers.

References

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(Joint work with Eva Löcherbach, and Michelle Thieullen).

Oleg Klesov, Kiev Polytechnic Institute

Extreme value theory for some non stationary time series

Let $\{X_n\}$ be a sequence of non-negative random variables. Denote

$$M_n = \max\{X_1, \dots, X_n\}, \qquad n \geq 1.$$

We say that n is a *record moment* if

$$X_n > M_{n-1}.$$

By definition, $n = 1$ is a record moment. If n is a record moment, then X_n is said to be a *record value*. The number of records up to the moment n is denoted by $N(n)$. The moment when an n^{th} record occurs is denoted by $\tau(n)$.

The almost sure and distributional behavior of $N(n)$ and $\tau(n)$ as $n \to \infty$ is of primary interest for the mathematical theory of records. In doing so, one should be convinced that there are infinitely many records in the sequence $\{X_n\}$. For simplicity, we assume that

$$\mathbb{P}(X_i = X_j \text{ infinitely often}) = 0.$$

Our main aim is to find conditions to be imposed on $\{X_n\}$ in order that

$$\mathbb{P}(\text{there are infinitely many records in the sequence } \{X_n\}) = 1. \quad (1)$$

Stationary case. Assume $\{X_n\}$ are jointly independent and identically distributed. The question on whether or not infinitely many records exist is usually deduced from the observations due to A. Rényi. Namely,

1. the random events $\{\omega : n \text{ is a record moment}\}$ are jointly independent;
2. $\mathbb{P}(n \text{ is a record moment}) = \frac{1}{n}$.

Then the second Borel–Cantelli lemma does the job.

Dependent case. It is commonly accepted that any step from the classical setting towards dependence makes many problems related to records intractable. Only a few papers is known where independence is avoided successfully. We propose another (elementary in nature) approach for the problem (1). In doing so, we an get a positive solution for pair-wise independent and m-dependent sequences. Some more technique allows us to get it for sequences with mixing.

Non-stationary case. The Rényi method does not work even for the simplest non-stationary models like $X_n + a_n$ or $b_n X_n$ if $\{X_n\}$ are independent identically distributed random variables and $\{a_n\}$ or $\{b_n\}$ are nonrandom numbers, since the events $I_n = \{\omega : n \text{ is a record moment}\}$ are not independent anymore. Moreover, the dependence structure of the sequence of record indicators $\mathbf{1}_{I_n}$, $n \geq 1$, is unknown.

The method proposed treats these two cases as well as some other more sophisticated ones.

(Joint work with Paul Doukhan).

Emilie Lebarbier, INRA MIA, France

Segmentation methods for breakpoint detection in time series

The objective of segmentation methods is to detect abrupt changes, called breakpoints, in the distribution of a signal. Such segmentation problems arise in many areas: in biology for the detection of chromosomal aberrations (Picard et al., 2005) or in geodesy for the detection of changes in GPS location series which are due either to instrumental or environmental changes, as earth's crust shifts (Williams, 2003). For this latter example, in addition to the abrupt changes, the GPS time series are corrupted by environemental effects (changes in atmospheric pressure and hydrology) that appear in the signal through periodic signals. Moreover, when dealing with time-series, it is likely that time-dependency exists. We need to take into account for the periodic signal or the dependency in order to avoid false breakpoint detection.
The inference of segmentation models requires to search over the space of all possible segmentations, which is prohibitive in terms of computational time, when performed in a naive way. The Dynamic Programming (DP) efficient strategy is the only one that gives the exact solution in a fast way but only applies when the contrast (e.g. the log-likelihood) to be optimized is additive with respect to the segments. However, this is not the case in presence of some functional or dependencies. In this talk, after presenting a simple segmentation model, the issues and solutions, we consider

(i) the segmentation case where the signal is affected by periodic signals. We propose a segmentation model in which a functional part is included. To estimate these two parts of the model, we propose an iterative procedure combining DP and a Lasso-type procedure to estimate the functional part [1]. An application to real data is done.

(ii) the segmentation case where time dependency exists. We model the time dependency with an AR(1). For the inference, we propose a two-steps procedure: first, we propose a robust estimator of the autocorrelation parameter, which is consistent. Then, we apply the classical inference approach on the decorrelated series. We show asymptotic properties of the obtained estimators [2].

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(Joint work with Karine Bertin, Xavier Collilieux, Cristian Meza, Souhil Chakar, Céline Lévy-Leduc and Stéphane Robin).

Nikolai Leonenko, Cardiff University, UK
Non-stationary random fields with application to astrophysics

Estimating of the mean and the covariance function of a Gaussian isotropic random field on the unit sphere of the 3D Euclidean space has primary importance. We assume that an observation is given and consider an estimator of the mean and the covariance function. We show that this estimator of the covariance function follows a Rosenblatt type distribution. The asymptotic distribution of the truncated version of the estimator is also given. One can substitute the usual estimator of the spectrum by estimating the covariance function first then using the Gauss-Legendre quadrature for estimation of the spectrum. The problem of cosmic variance is also considered. In practice the observations are given on a high resolution discretized sphere (for instance the Cosmic Microwave Background (CMB) data). We also discuss the Minkowski functionals of isotropic random fields on the sphere (exact formulae and the fixed domain and increasing domain asymptotics), and other problems related to applications of isotropic random fields to astrophysics.

(Joint work with Mara Dolores Ruiz Medina, Murad Taqqu, and Gyorgy Terdik).

Kerlyns Martínez, University of Valparaiso
Calibration on Lagrangian Turbulent Flow Models

There are several models and approaches concerning the modeling of the velocity in turbulent flows; for instance the Eulerian approach, which focuses attention on the properties of a flow at a given point in space as a function of time, with closure models for Reynolds Averaged Navier-Stokes equations (RANS, for short) assuming the fluid to be composed of a very large number of particles whose motion must be described, the Lagrangian setting, which is based on stochastic structures for the components of the fluid and the average of particle velocities (see for example [4], [6]).
We have special interest in the Lagrangian setting where the dynamic of the pseudo-fluid particles follow a Langevin system of Stochastic Differential Equations, firstly inspired by Pope's works. In order to specify the system of stochastic differential equations (SDEs, for short) that we are interested in, we assume that the flow is incompressible with constant mass density.

In this case, if the processes $(X_t; 0 \le t \le T)$ and $(U_t; 0 \le t \le T)$ represent the position and the velocity of a fluid particle, respectively, where T is a finite horizontal time, then the evolution of the pair (X, U) is driven by the following SDE system:

$$\begin{cases} X_t = \left[X_0 + \int_0^t U_s ds\right], \quad mod\ 1 \\ U_t = U_0 - \dfrac{1}{\varrho}\int_0^t \nabla_x \langle \mathcal{P} \rangle (s, X_s) ds \\ \qquad + \int_0^t \left(\dfrac{1}{2} + \dfrac{3}{4} C_0\right) \dfrac{\epsilon(s, X_s)}{k(s, X_s)} (\mathbb{E}[U_s | X_s] - U_s) ds \\ \qquad + \int_0^t \sqrt{C_0\, \epsilon(s, X_s)}\, dW_s, \qquad \forall\, t \in [0, T] \end{cases} \tag{2}$$

where W is a $\mathbb{R}^3$-standard Brownian motion, (X_0, U_0) are random variables whose probability law, μ_0, is given, ϱ is the mass density of the fluid, and C_0 is a *prescribed constant.* The functions $\epsilon, k : [0, T] \times \mathbb{T} \longrightarrow \mathbb{R}$ (for $\mathbb{T}$ being the torus) are the dissipation rate and the kinetic energy of the fluid, respectively, for which we consider a closure relation by mixing length parameterization of ϵ_t.

In order to overcome the obstacles given by the non-linearity of the SDE in the sense that the coefficients depend on the conditional law of the solution (i.e. non-linear in the sense of McKean-Vlasov), we chose a simplified turbulent kinetic energy model derived from the Lagrangian model through the turbulent velocity $u'_t := U_t - \mathbb{E}[U_t]$ and obtain the dynamic

$$\begin{aligned} dq_t &= (3C_0 - 2C_R) \frac{C_\epsilon}{2\sqrt{2}\, l_m} q_t^{\frac{3}{2}} dt + 2\sqrt{\frac{C_0\, C_\epsilon}{2\sqrt{2}\, l_m}} q_t{}^{\frac{5}{4}}\, dW_t, \\ q_0 &\sim \mu_0, \end{aligned} \tag{3}$$

where C_R is the so-called Rotta constant. This process has an advantageous relation with a Bessel process.

The analysis of this model constitutes a joint work with M. Bossy (INRIA, Sophia Antipolis), P. Cinnella (ENSAM, Paris) and J-F. Jabir (HSE, Moscow) and our main objective is to choose appropriately the values for the model parameters C_0, C_R, l_m and C_ϵ given some experimental data, in order to replicate as best as possible the observed data and give a realistic predictor model. This procedure is understood as calibration procedure, and is mainly inspired on the ideas exposed in the work of Cinnella *et. al* where the authors were interested in error estimation using Bayesian Inference for RANS simulations with the Launder-Sharma $k - \epsilon$ closure model for a class of flows, varying the gradient flows.

We consider observed data (observed kinetic energy) as a function of the vector parameter $\theta = (C_0, C_R, C_\epsilon, l_m)$, thus for each θ candidate we need to simulate $q_t(\theta)$ at an arbitrary time $0 \leq t \leq T$. To this aim we construct a reflected Euler-Maruyama time-discrete approximation for (3) (denoted by ES). Given an homogeneous time step $\triangle t = T/N$ from which we define the N-partition $0 = t_0 \leq t_1 \leq \cdots \leq t_N = T$ of the time interval $[0,T]$ with $t_n = nh$, $n = 0,\ldots,N$, we define the sequence of random variables $q_{t_0}, q_{t_1}, \ldots, q_{t_N}$ with $q_{t_0} = q_0 > 0$ and, for all $0 \leq n \leq N-1$,

$$q_{t_{n+1}} = q_{t_n} + \frac{(3C_0 - 2C_R)C_\epsilon}{2\sqrt{2}l_m}|q_{t_n}|^{\frac{3}{2}}\triangle t + \sqrt{\frac{\sqrt{2}C_0\,C_\epsilon}{l_m}}|q_{t_n}|^{\frac{5}{4}}\left(W_{t_{n+1}} - W_{t_n}\right), \tag{4}$$

where the Brownian increment $W_{t_{n+1}} - W_{t_n}$ is distributed according to $\mathcal{N}(0,\triangle t)$. By adding the absolute value in the drift and diffusion components in (4) ensures the well-posedness of the time-discrete approximation at each step of its construction. The main difficulty is that both coefficients in the dynamic of the kinetic process are just locally Lipschitz, thus a numerical analysis is required in order to use (4) as an accurate approximation in the calibration procedure (see references [1], [2], [3] for analysis on CIR type models).

The used experimental data is composed by the three components of the wind velocity, as well as the temperature, measured in a wind farm, with a LIDAR measurement scenario and with frequency of 1/10 seconds for 24 hours during a windy and a windless day. Thus observations correspond to different regimes of turbulent wind intensity.

In this talk we introduce the analytical model and review the calibration approaches used in our work: maximum pseudo-likelihood estimators, Bayesian estimators (defining its corresponding statistical model) using a Markov chain Monte Carlo method (McMC) and Quadratic Variation estimators [5], with their respective drawbacks and complexity. In all cases we test the calibration by simulating kinetic energy data for fixed parameters and trying to recover the inputs parameters through the calibration, to then apply the corresponding methodology to the observed data.

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(Joint work with Mireille Bossy, Paola Cinnella, and Jean-François Jabir).

Guy Mélard, Université libre de Bruxelles
Time series models with time-dependent coefficients

This paper is a follow-up to works [1], [2] where we have studied ARMA models (and vector ARMA models in the multivariate context) with time-dependent coefficients, or tdARMA (tdVARMA) models. The coefficients can also, but do not need to, depend on the time series length n. In addition, the innovation scatter, its variance or covariance matrix, can also be time-dependent. The model coefficients (and the innovation scatter as well) are supposed to be deterministic functions of time t, and possibly of n, and of a small number of parameters.
We feel that it is more realistic and useful to model time-dependency by a parametric model than to let the coefficients vary freely. A typical change with respect to classical models with constant coefficients would be to replace these coefficients by slowly varying functions of t, like linear functions. In that case, for the purpose of the asymptotic theory, the coefficients will be dependent on t/n, like in [3]. However, more generally, the coefficients (and scatter) are not necessarily smooth functions of time. For example, it is possible to cope with sudden breaks in a coefficient or with a periodic (e.g. seasonal) heteroscedasticity.
In order to obtain asymptotic results in such a context where the observations are dependent, not identically distributed and possibly multivariate with a fairly general distribution, some assumptions are required on the model (including existence of some innovation moments) in order to obtain a consistent estimator for the parameters which is also asymptotically normal. We use a quasi-maximum likelihood estimator based on an exact Gaussian likelihood. However, the assumptions do not include stationarity and ergodicity, contrarily to the usual treatment of nonlinear time series models. For example, for an tdAR(1) model, the time-varying autoregressive coefficient can even escape from the interval $[-1, 1]$ during a finite interval of time.
Besides parameter estimation, the asymptotic covariance matrix of the estimator is required with a procedure to estimate it. When the model does

not depend on n, [4] plus a law of large numbers, a central limit theorem for a martingale difference sequence, as well as a law of large numbers for a mixingale sequence are used to establish the asymptotic properties. Otherwise, similar theorems for triangular arrays are needed. With respect to [2], we provide new theoretical results: (i) a fundamental theorem for the asymptotic theory in an approach based on [5]; (ii) a lemma for reducing the assumption on moments from 8 to slightly more than 4; (iii) two theorems to establish convergence for the two matrices V and W involved in the sandwich formula that provides the asymptotic covariance matrix of the estimator; (iv) two practical methods to evaluate these matrices.
We apply these results to some time-dependent td(V)AR and td(V)MA models. In particular, we show simulation results for short time series with different types of distributions (including a multivariate Laplace and a multivariate Student) for the innovations and compare the standard errors to those deduced from the theory.

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Florence Merlevède, University Marne la Vallée
On the functional CLT for non-stationary sequences in L^2

In this talk, we will give non-stationary martingale techniques for dependent data. We shall stress the non-stationary version of the projective Maxwell-Woodroofe condition, which will be essential for obtaining maximal inequalities and functional central limit theorem for the following examples: nonstationary ρ-mixing sequences, functions of linear processes with non-stationary innovations and quenched version of the functional central limit theorem for a stationary sequence.

(Joint work with Magda Peligrad and Sergei Utev).

Philippe Naveau, LSCE Paris.
Analysis of extreme climate events by combining multivariate extreme values theory and causality theory

Multiple changes in Earth?s climate system have been observed over the past decades. Determining how likely each of these changes are to have been caused by human influence, is important for decision making on mitigation and adaptation policy. This is particularly true for extreme events, e.g. the 2003 European heatwave. To quantity these issues, we combine causal counterfactual theory (Pearl 2000) with multivariate extreme value theory. In particular, we take advantage of recent advances in the modeling of the multivariate generalized Pareto distributions to propose a conceptual framework to deal with climate-related events attribution.

(Joint work with Anna Kiriliouk and Alexis Hannart and Julien Worms).

Michael H. Neumann, Friedrich-Schiller-Universität Jena
Absolute regularity of semi-contractive GARCH-type processes

We prove existence and uniqueness of a stationary distribution and absolute regularity for nonlinear GARCH and INGARCH models of order (p, q). In contrast to previous work we impose, besides a geometric drift condition, only a semi-contractive condition which allows us to include models which would be ruled out by a fully contractive condition. This results in a subgeometric rather than the more usual geometric decay rate of the mixing coefficients. The proofs are heavily based on a coupling of two versions of the processes.
A non stationary makes use of uniform the conditions with respect to the parameters of interest. Time non-homogeneity is then taken into account and the same subgeometric bounds of the $\beta-$mixing coefficients are derived.

(Joint work with Paul Doukhan).

Nathalie Picard, University of Cergy-Pontoise
Non stationarity in HMM models

Hidden Markov chain Models are non-stationary in the sense that they assume a different distribution in each regime. The Markov chain determining the regime is hidden because the regime is not observed.
However, in the baseline model, the parameters of each regime are stationary, in the sense that they are assumed constant over time, and the distribution

of the observed variable, conditional on the regime, is also constant over time.
An autoregressive distribution for the observed variable can be considered either stationary in the sense that it only involves parameters constant over time, or non-stationary in the sense that the distribution of the observed variable, conditional on its own past, varies across time.
We consider different extensions of HMM models, involving time-varying parameters, and perform backtests to compare their predictive powers at different prediction horizons, using data on the returns of financial products.

Suhasini Subba Rao, Texas A&M University
A test for stationarity for irregularly spaced spatial data

The analysis of spatial data is based on a set of assumptions, which in practice need to be checked. A commonly used assumption is that the spatial random field is second order stationary. In this paper, a test for spatial stationarity for irregularly sampled data is proposed.
The test is based on a transformation of the data (a type of Fourier transform), where the correlations between the transformed data is close to zero if the random field is second order stationary. On the other hand, if the random field were second order nonstationary, this property does not hold. Using this property a test for second order stationarity is constructed. The test statistic is based on measuring the degree of correlation in the transformed data. The asymptotic sampling properties of the test statistic is derived under both stationarity and nonstationarity of the random field. These results motivate a graphical tool which allows a visual representation of the nonstationary features. The method is illustrated with simulations and a real data example.

Stefan Richter, University of Braunschweig
Bahadur representation and simultaneous inference for curve estimation in time-varying models

In this talk we formulate a general class of time-varying regression models which covers general linear models and popular locally stationary time series models. We estimate the regression coefficients by using local linear M-estimation. For these estimators, Bahadur representations are obtained and used to construct simultaneous confidence bands. For practical implementation, we propose a bootstrap based method to circumvent the slow logarithmic convergence of the theoretical simultaneous bands. The results naturally provide tests on stationarity and on parametric forms of the unknown parameter curves.

Our results substantially generalize and unify the treatments for several time-varying regression and auto-regression models such as linear and logistic regression and tvARMA, tvGARCH processes.

We study the performance for tvARCH and tvGARCH models in simulations and in real-life applications such as financial datasets.

(Joint work with Sayar Karmakar and Wei Biao Wu).

Mathieu Rosenbaum, Polytechnique, Saclay
Market impact can only be power law and this implies diffusive prices and rough volatilites

Market impact is the link between the volume of an order and the price move during and after the execution of this order. We show that under no-arbitrage, the market impact function can only be of power law-type. Furthermore we prove that this implies that the long term price is diffusive with rough volatility. Hence we simply explain the universal rough behavior of the volatility as a consequence of the no-arbitrage property. From a mathematical viewpoint, our study relies in particular on new results about hyper rough stochastic Volterra equations obtained using Hawkes processes.

(Joint work with Paul Jusselin).

François Roueff, Telecom Paristech
Time-frequency analysis of locally stationary Hawkes Processes

Self-exciting point processes have recently attracted a lot of interest in applications in the life sciences (seismology, genomics, neuro-science,...), but also in the modeling of high-frequency financial data. We introduce locally stationary Hawkes processes in order to generalise classical Hawkes processes away from stationarity by allowing for a time-varying second-order structure. A convenient way to reveal this interesting feature on a data set is to perform a time-frequency analysis. We introduce such a tool adapted to non-stationary point processes via non-parametric kernel estimation. Moreover, we provide a fully developed nonparametric estimation theory of both local mean density and local Bartlett spectra of a locally stationary Hawkes process. In particular we apply our kernel estimation to two data sets of transaction times exhibiting time-evolving characteristics in the data that had not been made visible by classical approaches.

Lionel Truquet, University Rennes 1 and ENSAI
A perturbation analysis of some Markov chains models with time-varying parameters

Modeling the dynamic of nonstationary time series is a challenging problem. When stationarity cannot be reached from differentiation of the series, the notion of local stationarity offers an interesting approach. However, this notion has been only studied for continuous data. In this talk, we will focus on Markov models for categorical data. Using slowly-varying and ergodic transition kernels, a perturbation approach can be used to assess how the marginal distributions deviate from that of some stationary processes. We will present some examples of such nonstationary Markov models and discuss statistical inference of the (local) transition kernel.

Olivier Wintenberger, LPSM, Sorbonne University
Contrast estimation of non-stationary infinite memory models involving coupling techniques

To be announced

(Joint work with Jean-Marc Bardet and Paul Doukhan).

Wei Biao Wu, University of Chicago
Gaussian Approximation for High Dimensional Time Series

I will talk about the problem of approximating sums of high dimensional stationary time series by Gaussian vectors, using the framework of functional dependence measure. The validity of the Gaussian approximation depends on the sample size n, the dimension p, the moment condition and the dependence of the underlying processes. We also consider an estimator for long-run covariance matrices and study its convergence properties. Our results allow constructing simultaneous confidence intervals for mean vectors of high-dimensional time series with asymptotically correct coverage probabilities. As an application, we propose a Kolmogorov-Smirnov type statistic for testing distributions of high-dimensional time series.

(Joint work with Danna Zhang).

Junho Yang, Texas A&M University

Nonparametric non-negative definite estimation of stationary and non-stationary spatial covariance

We propose a simple, computational fast method for estimating the spatial covariance function under various assumptions on the spatial random field, including isotropy, anisotropy, stationarity, local stationarity. Under certain conditions we show that the proposed estimator is consistent. The estimated covariance can be used in both model validation and prediction. We show that the estimation methodology can easily be extended to multivariate spatial random fields.

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