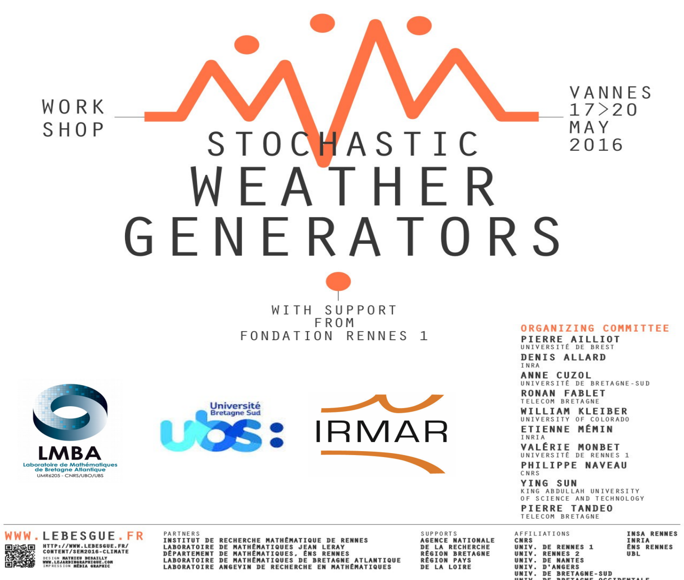
Third Workshop on Stochastic Weather Generators

Vannes May 17th-20th, 2016

CENTRE
HENRI LEBESGUE
CENTRE DE MATHÉMATIQUES



Tuesday 17th May

09h15-09h45 Registration & Welcome Coffee

Multivariate models (m*oderator: V. Monbet)*

- **09h45-10h20**William Kleiber (University of Colorado, USA). *Stochastic Weather Generators: From WGEN to BayGEN.*

- **10h20-10h55** Denis Allard (INRA, France). *A multivariate multi-site Weather Generator based on a Flexible Class of Non-separable Cross-Covariance Functions.*

10h55-11h25 Coffee break

Multivariate models *(moderator: V. Monbet)*

- **11h25-12h00** Thi Thu Huong Hoang (EDF R&D, France). *Joint simulations of temperature, precipitation, solar and wind.*

- **12h00-12h35** Vincent Cailliez (Chambre d'agriculture de la Creuse, France). *A stochastic weather generator for daily temperatures and precipitations : usability for climate change adaptation in agriculture.*

12h30-14h00 Lunch at University restaurant

Multivariate models (m*oderator: Y. Sun)*

- **14h00-14h35** Nina A. Kargapolova (Novosibirsk National Research State University, Russia). *Monthly average temperatures and precipitation stochastic simulation in the Lake Baikal region.*

- **14h35-15h10** Komlan Kpogo-Nuwoklo (Freie Universität Berlin, Berlin, Germany). *Stochastic swell events generator.*

15h10-15h40 Coffee break

Data Assimilation (m*oderator: Y. Sun)*

- **15h40-16h15** Marc Bocquet (CEREA, France). *Estimating model evidence using data assimilation.*

- **16h15-16h50** Redouane Lguensat (Telecom Bretagne, France). *Analog Data Assimilation.*

Wednesday 18th May

Downscaling (m*oderator: E. Mémin)*

- **09h00-09h35** Philipp Sommer (University of Lausanne, Switzerland). *Fundamental statistical relationships between monthly and daily meteorological variables: Temporal downscaling of weather based on a global observational dataset.*

- **09h35-10h10** Liliane Bel (INRA, France). *"Spatial Hybrid Downscaling" (SHD) for statistical spatial downscaling of extreme precipitation fields.*

- **10h10-10h45** Samuel Groyer (Ecole Nationale de la Météorologie, France). *Fine scale stochastic downscaling of re-analysis data along an elevation gradient.*

10h45-11h15 Coffee break

Stochastic climate models (m*oderator: E. Mémin)*

- **11h15-11h50** Christian Franzke (University of Hamburg, Germany). *Systematic stochastic modeling of atmospheric variability.*

- 1**1h50-12h25** Valentin Resseguier (INRIA, France). *Randomized fluid dynamics based on subgrid transport*.

12h30-14h00 Lunch at University restaurant

Simulating Precipitation (m*oderator: W. Kleiber)*

- **14h00-14h35** Clément Guilloteau (LEGOS, Toulouse). *Stochastically Generated High Resolution Precipitation Ensembles Constrained by Satellite Observations.*

- **14h35-15h10** Erwan Koch (ETH Zurich, Switzerland). *A frailty-contagion model for multi-site hourly precipitation driven by atmospheric covariates.*

15h10-15h40 Coffee break

Simulating Precipitation *(moderator: W. Kleiber)*

- **15h40-16h15** Christoph Ritshel (Freie Universität Berlin, Berlin, Germany). *Intensity-Duration relationships in a seasonal Bartlett-Lewis rectangular Pulse model.*

- **16h15-16h50** Gregoire Mariethoz (University of Lausanne, Switzerland). *Estimating local space-time properties of rainfall from a dense gauge network.*

19h00-22h00 Dinner cruise

Thursday 19th May

Space-time Models *(moderator: D. Allard)*

- **09h00-09h35** Valérie Monbet (Université de Rennes 1, France). *Time varying autoregressive models for multisite weather generators.*
- **09h35-10h10** Ying Sun (KAUST, Saudi Arabia). *Stochastic simulation models for multi-site nonstationary time series using wavelets.*
- **10h10-10h45** Pierre Pinson (Technical University of Denmark). *Generating and evaluating space-time trajectories of renewable power generation.*

10h45-11h15 Coffee break

Space-time Models *(moderator: D. Allard)*

- **11h15-11h50** Julie Bessac (Argonne National Laboratory, USA). *Stochastic simulation of predictive space-time scenarios of wind speed using observations and physical models.*
- **11h50-12h25** Dionissios Hristopulos (Technical University of Crete, Greece). *Stochastic Local Interaction Models and Space-Time Covariance Functions based on Linear Response Theory.*

12h30-14h00 Lunch at University restaurant

Extreme Events (moderator: P. Tandeo)

- **14h00-14h35** Cameron Bracken (University of Colorado, USA). *Generating gridded extreme precipitation fields for large domains with a Bayesian hierarchical model.*
- **14h35-15h10** Reik Donner (Potsdam Institute for Climate Impact Research, Germany). *Quantile regression for trend assessment of heavy rainfall events and bias correction of regional climate models.*

15h10-15h40 Coffee break

Analogues and Resampling Methods *(moderator: P. Tandeo)*

- **15h40-16h15** Pascal Yiou (LSCE, France). *Stochastic weather generators and conditional detection and attribution of singular events.*
- **16h15-16h50** Dimitris Giannakis (Courant Institute of Mathematical Sciences, USA). *Kernel methods for nonparametric analog forecasting.*
- **16h50-17h25** Aitor Atencia (McGill University, Canada). *Probabilistic comparison of the information in the rainfall field from NWP and analogue-based forecasts.*

Friday 20th May

Non-Gaussian Processes *(moderator: P. Ailliot)*

- **09h00-09h35** Anastassia Baxevani (University of Cyprus). *Use of latent Gaussian processes in certain environmental applications.*

- **09h35-10h10** Sara Martino (SINTEF Energy AS, Norway). *Spatio-temporal precipitation generator based on latent Gaussian field.*

10h10-10h40 Coffee break

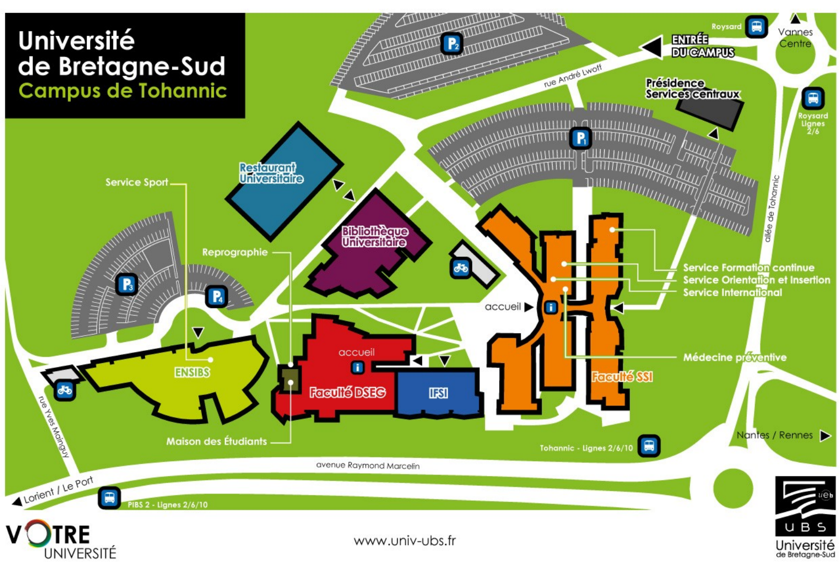
Non-Gaussian Processes *(moderator: P. Ailliot)*

- **10h40-11h15** Vasily A. Ogorodnikov (Novosibirsk National Research State University, Russia). *Numerical stochastic models of conditional meteorological fields.*

- **11h15-11h50** Marc Genton (KAUST, Saudi Arabia). *Tukey g-and-h Random Fields.*

12h00-13h00 Lunch at University restaurant

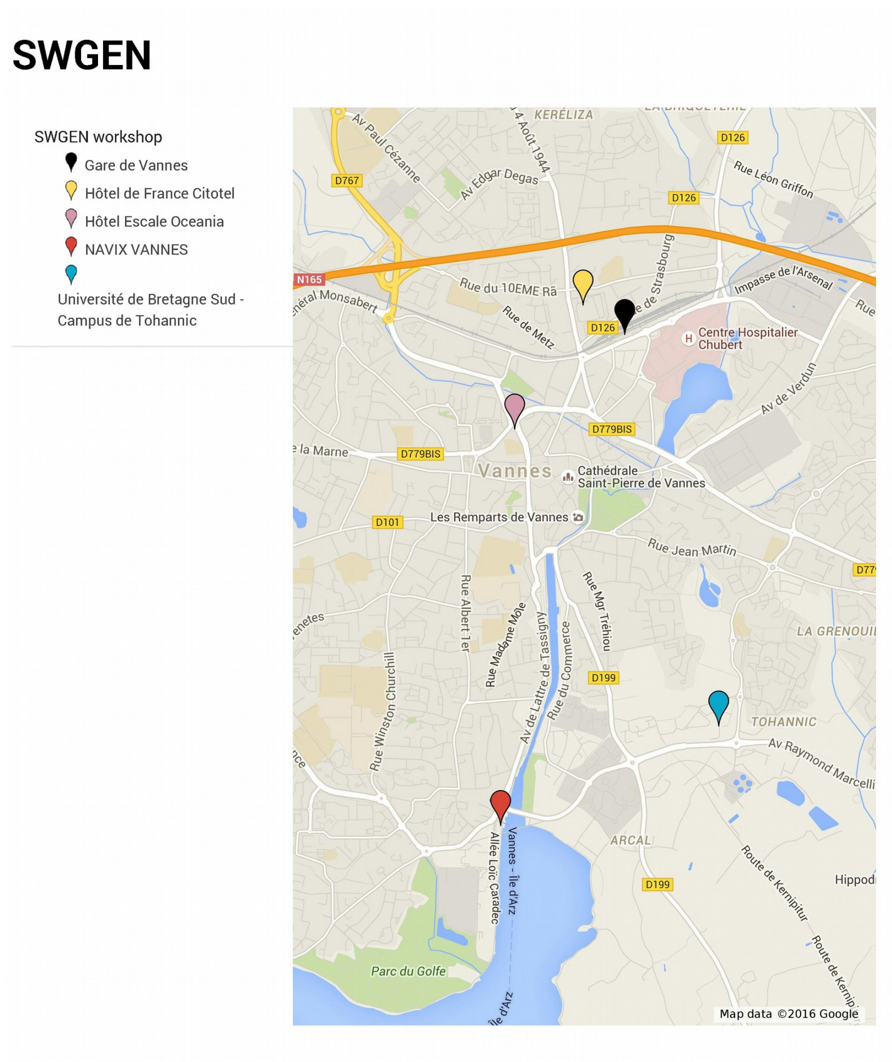
The talks will be given in the Amphithéâtre 103 in the bulding “DSEG” (red building on the map).



To get to the University of Bretagne Sud, you can take one of the city busses:

- From Vannes railway station ("Gare SNCF"): bus 6 (direction "Vannes agglo"), stop at "Université".
- From Vannes city center: bus 2 (direction "Petit Tohannic"), stop at "Université"; bus 10 (direction "Theix"), stop at "Tohannic".

The cruise dinner will start from the “Gare Maritime” (Navix flag on the map).



List of talks

1. Denis Allard. A multivariate multi-site Weather Generator based on a Flexible Class of Non-separable Cross-Covariance Functions.
2. Aitor Atencia. Probabilistic comparison of the information in the rainfall field from NWP and analogue-based forecasts.
3. Anastassia Baxevani. Use of latent Gaussian processes in certain environmental applications.
4. Liliane Bel. Spatial Hybrid Downscaling (SHD) for statistical spatial downscaling of extreme precipitation fields.
5. Julie Bessac. Stochastic simulation of predictive space-time scenarios of wind speed using observations and physical models.
6. Marc Bocquet. Estimating model evidence using data assimilation.
7. Cameron Bracken. Generating gridded extreme precipitation fields for large domains with a Bayesian hierarchical model.
8. Vincent Cailliez. A stochastic weather generator for daily temperatures and precipitations: usability for climate change adaptation in agriculture.
9. Reik Donner. Quantile regression for trend assessment of heavy rainfall events and bias correction of regional climate models.
10. Christian Franzke. Systematic stochastic modeling of atmospheric variability.
11. Marc Genton. Tukey g-and-h Random Fields.
12. Dimitris Giannakis. Kernel methods for nonparametric analog forecasting.
13. Samuel Groyer. Fine scale stochastic downscaling of re-analysis data along an elevation gradient.
14. Clément Guilloteau. Stochastically Generated High Resolution Precipitation Ensembles Constrained by Satellite Observations.
15. T.T.H Hoang. Joint simulations of temeprature, precipitation, solar and wind.
16. Dionissios T. Hristopulos. Stochastic Local Interaction Models and Space-Time Covariance Functions based on Linear Response Theory.
17. William Kleiber. Stochastic Weather Generators: From WGEN to BayGEN.

18. Erwan Koch. A frailty-contagion model for multi-site hourly precipitation driven by atmospheric covariates.
19. Komlan Kpogo-Nuwoklo. Stochastic swell events generator.
20. Nina A. Kargapolova. Monthly average temperatures and precipitation stochastic simulation in the Lake Baikal region.
21. Redouane Lguensat. Analog Data Assimilation.
22. Gregoire Mariethoz. Estimating local space-time properties of rainfall from a dense gauge network.
23. Sara Martino. Spatio-temporal precipitation generator based on latent Gaussian field.
24. Valérie Monbet. Time varying autoregressive models for multisite weather generators.
25. Vasily A. Ogorodnikov. Numerical stochastic models of conditional meteorological fields.
26. Pierre Pinson. Generating and evaluating space-time trajectories of renewable power generation.
27. Valentin Resseguier. Randomized fluid dynamics based on subgrid transport.
28. Christoph Ritshel. Intensity-Duration relationships in a seasonal Bartlett-Lewis rectangular Pulse model.
29. Philipp Sommer. Fundamental statistical relationships between monthly and daily meteorological variables: Temporal downscaling of weather based on a global observational dataset.
30. Ying Sun. Stochastic simulation models for multi-site nonstationary time series using wavelets
31. Pascal Yiou. Stochastic weather generators and conditional detection and attribution of singular events.

A multivariate multi-site Weather Generator based on a Flexible Class of Non-separable Cross-Covariance Functions

Denis Allard (1), Marc Bourotte (1) and Emilio Porcu (2)

(1) Biostatistique et Processus Spatiaux (BioSP), INRA, Avignon, France

(2) Departamento de Matemática, Universidad Técnica Federico Santa María, Valparaíso, Chile

Abstract

We propose a multivariate, multi-site stochastic weather generator for the simultaneous generation at the daily time scale of several variables, including precipitation. The model relies on two ingredients. First, adequate transforms are applied to each variable. Precipitation deserves specific attention due to the very large proportion of dry days. For precipitation, we propose to use a single latent transformed Gaussian process that controls both the occurrence as well as the intensity of the process. The second ingredient is the use of a new, flexible, parametric class of non-separable cross-covariance functions for multivariate space-time Gaussian random fields. Space-time components belong to the (univariate) Gneiting class of space-time covariance functions, with Matérn or Cauchy covariance functions in the spatial margins. The smoothness and scale parameters can be different for each variable. Sufficient conditions for positive definiteness are shown. A simulation study has shown that the parameters of this model can be efficiently estimated using weighted pairwise likelihood, which belongs to the class of composite likelihood methods. This multivariate, multi-site stochastic weather generator is illustrated on a data-set of weather variables over the Southern region of France.

Probabilistic comparison of the information in the rainfall field from NWP and analogue-based forecasts

Aitor Atencia, Isztar Zawadzki
Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, Canada

Abstract

Outputs of a state-of-the-art MWP system including radar data assimilation show that the intrinsic predictability of quantitative precipitation at scales smaller than 200 km is limited ∼10 hours. Errors in NWP further decrease the predictability to a few hours. Thus, at these scales, only probabilistic forecasts are possible. In this work we explore the added value of 17 years of historical radar data to probabilistic precipitation forecast and compare to NWP ensemble forecasting.

According to the chaos theory, similar states, also called analogues, evolve in a similar way plus an error related with the predictability of the situation. Consequently, finding these states in a historical dataset provide a way of forecasting which includes all the physical processes such as growth and decay, among others. The difficulty of this approach lies in finding these analogues. In this study, recent radar observations are compared with a 17-year radar dataset. Similar states within the dataset are selected according to their spatial rainfall patterns, temporal storm evolution and synoptic patterns. These similar situations create an ensemble of rainfall forecast.

A comparison of the probabilistic information provided by the NWP ensemble forecasting and the analogue-based ensemble forecasting is performed. The results are analysed in terms of the spatial scale, lead-time and intensity to account for the dependence of the verification on these factors. The comparison shows the weak and strong points of both techniques and provides guidelines for improving the rainfall forecasts by looking into the complimentary information on them.

Use of latent Gaussian processes in certain environmental applications

Anastassia Baxevani
Department of Mathematics and Statistics, University of Cyprus

Abstract

A methodology for modeling such environmental processes as precipitation, wind and wind power is suggested. These processes have in common densities with a mass at zero and tails heavier than the Gaussian. We propose use of a single latent transformed Gaussian process that controls both the different regimes as well as the intensity of the process. The choice of parametric model for the transformation, often called anamorphosis function, depends on the problem at hand. Different choices include the Gamma, log-normal and Beta distributions, among others, or hybrid models built by either of the previous distributions coupled with the generalized Pareto or any of the extreme value distributions when more emphasis is given at the tails of the distribution. The transformed nonnegative data follow then a distribution that is truncated normal and inference in such models can be performed at a relatively low cost. A difficulty though arises in the estimation of the covariance function due to the truncation. We suggest and study different methods to estimate the covariance function. The suggested methodology is applied to two different data sets - precipitation data from Sweden and wind power data from Denmark.

Spatial Hybrid Downscaling (SHD) for statistical spatial downscaling of extreme precipitation fields

Liliane Bel(1), Aurlien Bechler (1), (2), Mathieu Vrac (2)

1. AgroParisTech, INRA, 16 rue Claude Bernard, 75005, Paris

2. Laboratoire des Sciences du Climat et de lEnvironnement (LSCE-IPSL, CNRS), Orme des Merisiers, Gif-sur-Yvette, France

Abstract

As extreme events are inherently rare and often unexpected, society is not well prepared to face them. Therefore, it is important to evaluate the evolution of such events in the future. Global Climate Models (GCMs) allows providing future scenarios of precipitation. However, their resolution (200km) is not yet sufficient to describe efficiently what happens at local scales (e.g., a few kilometres). Therefore, downscaling models have been developed. However, both the extreme behaviours and the spatial structures are not always well described by these methods, and most of the statistical downscaling models cannot simulate values at locations where there is no observed data for calibration.

The suitable statistical framework for modelling extreme events is the extreme value theory (EVT). In this context, there is a growing effort to develop non-stationary space-time models. Max-stable processes have emerged as a powerful tool for the statistical modelling of spatial extremes. One recent development is for conditional simulations of spatial fields of maximum values, providing empirical distributions of maximum values at any location in a given region, conditioned by observed values at neighbouring locations.

We propose a two-step methodology, called Spatial Hybrid Downscaling (SHD), to tackle the problem of spatial downscaling for fields of extreme precipitation. The first step consists in a univariate statistical downscaling at some locations. Then, a conditional simulation of an extremal t process enables us to get conditional distributions and to downscale extreme precipitation values at any point of the region, even in a climate change context.

Stochastic simulation of predictive space-time scenarios of wind speed using observations and physical models

Julie Bessac (1), Emil M. Constantinescu (1), (2), Mihai Anitescu (1), (2)

(1) Mathematics and Computer Science Division, Argonne National Laboratory, Argonne, IL, USA.

(2)The University of Chicago, Chicago, IL, USA.

Abstract

We propose a statistical space-time model for predicting atmospheric wind speed based on deterministic numerical weather predictions (NWP) and historical measurements. The wind speed forecast is then represented as stochastic predictive scenarios that are targeted for power grid applications where they account for the uncertainty associated with renewable energy generation. We consider a Gaussian multivariate space-time framework that combines multiple sources of past physical model outputs and measurements along with NWP model predictions in order to produce a probabilistic wind speed forecast within the prediction window. The process is expressed hierarchically in order to facilitate the specification of cross-variances between the two datasets. We illustrate this strategy on wind speed forecast during several months in 2012 for a region near the Great Lakes in the United States. The results show that the prediction is improved in the mean-squared sense relative to the numerical forecasts as well as in probabilistic scores. Moreover, the samples are shown to produce realistic wind scenarios based on sample spectra.

Estimating model evidence using data assimilation

Marc Bocquet(1), Alberto Carrassi(2), Alexis Hannart(3) and Michael Ghil(4),(5)

(1) CEREA joint laboratory cole des Ponts ParisTech and EdF R&D, Universit Paris-Est, Champs-sur-Marne, France.

(2) Nansen Environmental and Remote Sensing Center NERSC, Bergen, Norway.

(3) IFAECI, CNRS/CONICET/UBA, Buenos Aires, Argentina.

(4) cole Normale Suprieure, Paris, France.

(5) University of California, Los Angeles, USA.

Abstract

This talk will address the problem of quantifying the performance of a state inference by estimating the so-called marginal likelihood also sometimes referred to as model evidence which quantifies the goodness-of-fit between the data and the chosen state-space model. Model evidence can be used as a general metric for model selection and comparison, relevant to many different purposes frequently faced by both scientists and practitioners: e.g. calibrating the model parameters, comparing the skill of several candidate models (or model settings, or boundary conditions) in representing the observed signal, or even evidencing the existence (or non-existence) of a causal relationship between an external forcing and an observed response.

Mathematically speaking, deriving the marginal likelihood comes with a major difficulty, as it requires, by definition, to integrate out the state vector, a daunting task that is usually intractable in high-dimensional models or in the presence of big datasets.

The present study focuses on the estimation of model evidence using data assimilation (DA) techniques expressively designed to deal with large numerical models and dataset and under partial Gaussian assumptions. It is shown how model evidence can be obtained as a side-product of the statistical inference performed by DA. Three strategies are considered: DA-based ensemble forecasting, filtering and smoothing. The theoretical rationale of this approach is explained and illustrated using numerical experiments with prototypical low-order models. Finally the potential application of this DA-based approach to estimate model parameters and for the casual attribution of climate-related events is described.

Generating gridded extreme precipitation fields for large domains with a Bayesian hierarchical model

Cameron Bracken and Balaji Rajagopalan
University of Colorado, Boulder

Abstract

In this talk we discuss the generation of gridded fields of extreme precipitation for large geographic regions using a Bayesian hierarchical model (BHM). Random fields of extreme precipitation which capture the statistical properties of observations are useful for engineering design, planning, risk assessment and mitigation. Large scale climate drives a strong organization of extremes in space; accounting for spatial dependence can lead to reduced uncertainty due to stations lending strength in space, a feature which traditional single-site methods fail to capture. Spatial extremes BHMs are typically composed of (1) a data layer assumption, either conditional independence of observations given marginal parameters or dependence which can be captured with a variety of joint distributions, (2) spatial processes to capture spatial dependence in marginal parameters and (3) priors. When a joint distribution is included in the data layer, simulation of fields of extremes becomes possible. Using a spatial extremes BHM which is designed for large regions, we detail the simulation procedure for arbitrary grid resolutions when the joint distribution of observations is captured using a Gaussian elliptical copula and the marginal distributions are generalized extreme value. A simplified version of the procedure consists of (a) simulating from the latent spatial processes via conditional simulation, (b) simulating from the copula joint distribution and (c) combining latent and data layer simulations using the inverse marginal distribution. We discuss methods for speeding up simulations which may be computationally expensive for fine grid resolutions. We demonstrate this approach by generating simulations of extreme precipitation on a 1/8th degree grid for a region covering the western United States, with about 2600 stations, an approximate area of 3,500,000 km2 and elevations ranging from below sea level to over 3,000 meters. Our results show that it is feasible to conduct a simulation of extreme precipitation for tens of thousands of grid points on a modern laptop in a matter seconds though simulations for large posterior sample sizes may require more sophisticated computing resources.

A stochastic weather generator for daily temperatures and precipitations: usability for climate change adaptation in agriculture

Vincent Cailliez
Chambre d'agriculture de la Creuse

Abstract

We decide to conceive and use a specific SWG in the network of Chambers of Agriculture in France because of a few preliminary statements. Firstly, the GCM simulations for the present and near-future show a severe incompatibility with observed real evolutions. Secondly, classical SWGs tend to concentrate on distribution (including extremes) and less on time organization. Thirdly, our agronomic point of view is relevant to monosite weather generators.

Our SWG (unofficially called Gen-CFox) is highly parametrized regarding time organization.

The general idea is to disorganize and reorganize a time serial. We separate the long-term organizations like trend or cycles from the short-term ones. Trend is studied by a regression and cycles through a periodogram. They are extracted by a simple subtraction. Next, we extract the short-term organizations by an autoregressive process, reaching order 3 to 7. Amplitudes, phases of cycles and autoregressive coefficients are not necessary constants. They can be organized themselves in trends and cycles.

The randomness of the final residual is subsequently checked by a bunch of runs tests. Its observed distribution is idealized by its mean, variance, skewness and kurtosis. This idealized distribution is used to calibrate a random number generator. The total serial is re-built by adding the short-term organizations and then the long-term ones.

Unfortunately, the complete generated serials are not perfectly consistent with the observed one. So we had to use a quantile-quantile post-simulation correction method. Fortunately, this correction do not significantly alter the chronological organization.

After this correction, the consistency between observation and simulation is excellent to a 10-years return period for temperature and to a 5-years return period for precipitations.

Noticeably, we generate the minimum and maximum temperatures together through the autoregressive process and the precipitations serials need a logarithmic transformation in order to cope with their impulse-like organization.

Toward the future, we use the very moderate hypothesis of continuation of the observed climate change rate without any acceleration. The 1980-2010 period is used for calibration and the simulations are taken into consideration on the 2010-2040 period. They are effectively used to calculate numerous agro-climatic indexes.

In the years to come, we intend to co-generate temperatures and precipitations serials and to add the potential evapotranspiration parameter in a fully multivariate approach which is needed for most agricultural questions.

Quantile regression for trend assessment of heavy rainfall events and bias correction of regional climate models

Reik Donner (1) and Christian Passow (1,2)

(1) Potsdam Institute for Climate Impact Research, Research Domain IV - Transdisciplinary Concepts & Methods, Potsdam, Germany

(2) Department of Meteorology, Free University of Berlin, Germany.

Abstract

In many cases, recent trends in the distribution of daily precipitation sums are only imperfectly retrieved by hindcast runs of state-of-the-art regional climate models. Besides the strong locality of rainfall being a recognized source of deviations of simulated precipitation from point measurements, the appropriate compensation of model biases becomes particularly challenging under changing climate conditions. Among others, this brings the problem of not sufficiently reliable statistical projections of the distribution of future precipitation extremes, which can have severe consequences if changing return levels are not properly accounted for in the design of drainage systems or dams, to mention only a few examples.

Here, we utilize quantile regression as tool for gaining a better understanding of data-model mismatches and correcting scenario runs of climate model simulations to obtain improved estimates of the future distribution of daily precipitation, with a special focus on the tails of the PDF containing heavy rainfall events. In a first step, we present a case study providing an inter-comparison between the results of classical extreme value theory and quantile regression for daily rainfall observations of the German Weather Service from 1951-2009, highlighting the capability of quantile regression to derive meaningful estimates of trends in heavy rainfall magnitudes. At the same time, quantile regression is more versatile than extreme value statistics in the sense that it can be used for obtaining trends for arbitrary quantiles of the distribution of daily precipitation and takes full account of all observations instead of restricting itself to threshold exceeding events or block maxima.

In a second step, we repeat our analysis for hindcast simulations of different regional climate models for the same period of time, allowing for a systematic comparison between the trends of each specific quantile in observed and modelled rainfall. The thus obtained knowledge can be subsequently used for systematically correcting biases in scenario runs of the same climate models. Some methodological problems like the mutual crossing of trend functions estimated for different quantiles are identified and discussed. The proposed approach can be widely applied for bias-correcting statistical and dynamical regional climate models as well as constraining distributions and non-stationarities of meteorological variables in stochastic weather generators.

Systematic stochastic modeling of atmospheric variability

Christian Franzke
Meteorological Institute, University of Hamburg

Abstract

Stochastic methods are increasingly used in numerical weather and climate prediction models. However, most of the used methods are rather ad hoc. There is a clear need for systematic approaches to stochastic modeling of atmospheric variability. In my presentation I will discuss the stochastic mode reduction strategy for the systematic derivation of stochastic climate models. I will also discuss the emergence of memory effects and heavy-tailed distributions in these models.

Tukey g-and-h Random Fields

Marc G. Genton

King Abdullah University of Science and Technology (KAUST), Saudi Arabia

Abstract

We propose a new class of trans-Gaussian random fields named Tukey g-and-h (TGH) random fields to model non-Gaussian spatial data. The proposed TGH random fields have extremely flexible marginal distributions, possibly skewed and/or heavy-tailed, and, therefore, have a wide range of applications. The special formulation of the TGH random field enables an automatic search for the most suitable transformation for the dataset of interest while estimating model parameters. An efficient estimation procedure, based on maximum approximated likelihood, is proposed and an extreme spatial outlier detection algorithm is formulated. The probabilistic properties of the TGH random fields, such as second-order moments, are investigated. Kriging and probabilistic prediction with TGH random fields are developed along with prediction confidence intervals. The predictive performance of TGH random fields is demonstrated through extensive simulation studies and an application to a dataset of total precipitation in the south east of the United States. The talk is based on joint work with Ganggang Xu.

Kernel methods for nonparametric analog forecasting

Dimitris Giannakis
Courant Institute of Mathematical Sciences, USA

Abstract

Analog forecasting is a nonparametric technique introduced by Lorenz in 1969 which predicts the evolution of observables of dynamical systems by following the evolution of samples in a historical record of observations of the system which most closely resemble the observations at forecast initialization. In this talk, we discuss a family of forecasting methods which improve traditional analog forecasting by combining ideas from kernel methods for machine learning and state-space reconstruction for dynamical systems. A key ingredient of our approach is to replace single-analog forecasting with weighted ensembles of analogs constructed using local similarity kernels. The kernels used here employ a number of dynamics-dependent features designed to improve forecast skill, including Takens' delay-coordinate maps (to recover information in the initial data lost through partial observations) and a directional dependence on the dynamical vector field generating the data.

Mathematically, the approach is closely related to kernel methods for out-of-sample extension of functions, and we discuss alternative strategies based on the Nystrom method and the multiscale Laplacian pyramids technique. We illustrate these techniques in prediction of North Pacific SST variability and arctic sea ice.

Fine scale stochastic downscaling of re-analysis data along an elevation gradient

Samuel Groyer (1), Denis Allard (2)

(1) Ecole Nationale de la Météorologie, Toulouse, France

(2) Biostatistique et Processus Spatiaux (BioSP), INRA, Avignon, France

Abstract

Beech and silver fir in Ventoux forest (Provence, France) are at their southern margin and growth of beech has recently decreased. Currently, these forests may be considered as the most endangered forests in Provence by climate change. SWGs are used to disentangle the effect of climate variables and CO2 on wood growth. On the one hand, weather variables (Precipitation, temperature, Humidity) are surveyed with automated devices since 2007 in 4 forest stands along one elevation gradient. On the other hand, SAFRAN re-analysis data are available from 1959 to 2015 at the same general location, at an 8km w 8km scale. A SWG is built in order to downscale the re-analysis data at the same forest stands. Due to the sparsity of official Meteo-France weather stations, the mountainous nature of the region and the differences between re-analysis data and measurements, the relation between re-analysis data and measured data is extremely noisy, requiring cautious modeling. For precipitation, we propose to use a single latent transformed Gaussian process that controls both the occurrence as well as the intensity of the process. For the other variables, simple transforms are applied. Residuals and Gaussian latent variables are then modeled in a multivariate Gaussian framework.

Stochastically Generated High Resolution Precipitation Ensembles Constrained by Satellite Observations

C. Guilloteau[1,3,], R. Roca[1], and M. Gosset[2]*

[1] *Laboratoire d'Etudes en Geophysique et Oceanographie Spatiales, Toulouse.*

[2] *Laboratoire Geoscience Environnement, Toulouse.*

[3] *Université Toulouse III*

Abstract

Gridded datasets of estimated precipitation from satellite measurements are affected by uncertainties that may limit some end users applications, particularly when fine scale spatio-temporal variability is involved. The magnitude of these uncertainties is depending on geographical areas, seasons and types of observed precipitating systems and is therefore hard to quantify. Many validation studies have demonstrated that the deterministic approach for the estimation of precipitation from satellite at high resolution (finer than 0.25° × 0.25° × 3h) is limited. Comparison of satellite-derived fields with radar data in West Africa confirms this assessment. This calls for using probabilistic approaches to handle the fine scale variability of rain from satellite observations.

In this work, ensembles of stochastically generated rain fields at resolution 6km × 6km × 30min are presented. These fields are obtained by spatio-temporal filtering of high resolution (3km × 3km × 15min) satellite-derived precipitation fields. The original satellite fields used here are produced by the algorithm Tropical Amount of Precipitation with Estimate of ERrors (TAPEER), developed by the Megha-Tropiques French research team. The wavelet-based spatio-temporal filtering preserves the large scale patterns observed by satellites and eliminates the fine scale variations which are known to be non-representative of actual precipitation variability. This optimal (in term of mean square error) filtering is a spatio-temporal extension of the spatial filtering method described in Turner et al. (2004). Optimal values for the filtering coefficients are determined through the wavelet-based joint analysis of satellite and radar fields.

The fine scale variability which is badly handled by the satellites is then stochastically regenerated. A random signal is added to the series of wavelet coefficients encoding the fine scale variations. The inverse wavelet transform is then applied. This method enables to constrained the spatio-temporal wavelet energy spectrum. The spectrum is considered here as a proxy of the autocorrelation function. Using the wavelet transform enables to generate ensembles of synthetic rain fields which spatio-temporal structure meets the statistical properties of real rain fields.

Because the coarse-scale patterns observed by the satellites are preserved and the fine scale variations are partially randomized, the process can be viewed as similar to a stochastic downscaling.

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Joint simulations of temeprature, precipitation, solar and wind.

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Abstract

In the current context of energy mix, the management of photovoltaic and wind production becomes important beside other types of conventional production as nuclear, thermal and hydro productions. We aim to manage jointly the various means of production and consumption forecast. These elements are closely related to the meteorology variables. By consequence, we need the joint simulations of different meteorology variables as temperature, precipitation, solar and wind. The used simulation method is based on the work of Schefzik on Ensemble Copula Coupling. Briefly, the idea is to simulate each variable independently by local marginal distributions and then use the historical ranks of observed data to guarantee the temporal coherence and coherence between variables. A preprocessing is first used to remove the trend and the seasonality. The used data are tri-hourly reanalysis ERA-Interim data on the period of 1979-2014. The model is applied to different locations with different types of climate. Different criteria are considered to validate the model.

Stochastic Local Interaction Models and Space-Time Covariance Functions based on Linear Response Theory

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Abstract

This presentation focuses on spatial and spatiotemporal models based on local interactions which aim at the generation of sparse precision matrices and novel covariance forms. In the purely spatial case, local interactions are embodied in an effective energy function that defines the joint density of a Gibbs random field. Spartan spatial random fields have been defined and investigated for a specific form of local interactions [1]. We show that covariance functions with interesting properties are generated from this formalism. We also present the recently derived Karhunen-Love expansion of Gaussian fields with SSRF covariance functions in one spatial dimension [5]. Next, we briefly discuss stochastic local interaction (SLI) models which are based on discrete analogues of SSRFs and ideas from statistical learning. The SLI models are characterized by adaptiveness to irregular sampling designs and potentially sparse precision matrices. For data distributed on regular grids, SLI models lead to Gauss-Markov random fields. For time-varying problems, we propose to use linear response theory (LRT) which was developed in statistical mechanics to treat non-equilibrium systems [3]. In LRT the non-equilibrium (time-dependent) response of a system to an external stimulus is expressed by means of the functional derivative of the equilibrium energy function. The linear response formalism provides equations of motion (EOM) for the field, obtained by perturbing the equilibrium via a stochastic term thus leading to a Langevin equation. The respective covariance EOM take the form of partial differential equations. We investigate the EOM derived from a restricted form of the SSRF energy functional in one and three spatial dimensions [2]. The solutions are quite rough at the origin (zero space and time lag) due to the so-called ultraviolet divergence. The divergence can be tamed by introducing a frequency cutoff, but the closed-form of the covariance function is then lost. We demonstrate a different approach for constructing a valid space-time covariance function in three dimensions which is based on the inverse space transform of the one-dimensional EOM solution. This procedure leads to a new, non-separable space-time covariance function.

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Monthly average temperatures and precipitation stochastic simulation in the Lake Baikal region

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Abstract

The goal of this talk is to propose stochastic spatio-temporal models for monthly average temperatures and monthly total precipitation fields in the Lake Baikal region.

Because of the complex terrain of the considered area and strong seasonal changes it is not possible to use an assumption that random fields of weather elements are spatially isotropic and temporary stationary. Suggested models are based on the hypotheses that fields are periodically correlated in time, wide-sense spatially homogeneous and parameters of one-dimensional non-Gaussian distributions depend both on spatial coordinates and time. These assumptions allow one to simulate random fields capturing the annual cycle of real processes and their heterogeneity.

In case when it is necessary to simulate considered fields not only in points, where weather stations are situated, but also in nodes of a (ir-)regular grid, weighted interpolation is used for calculation of one-dimensional distributions' parameters. For calculation of a correlation matrix in this case standard technique is used: estimated on basis of real data spatial correlation coefficients between weather stations are approximated with a correlation function of continuous variables; this function is used for calculation of correlation coefficients between nodes.

Numerical experiments show that some statistics (for example, probability distribution of the annual sum of precipitation in different subdomains, dependence between share of territory, where monthly mean temperature is below given level, and this level, etc.) are well reproduced by the models.

This work was supported by the Russian Foundation for Basis Research (grants No 15-01-01458-a, 16-31-00123-mol-a, 16-31-00038-mol-a).

Stochastic Weather Generators: From WGEN to BayGEN

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Abstract

There is a long history of models for stochastically simulating daily precipitation, temperature, and other weather variables, which have been motivated by the need for weather ensembles to model a variety of processes (e.g., hydrology, crop yield, erosion, etc.). Historical weather data can be limited in space and time, and represent a single realization of the weather process, thus weather generators are essential to quantify the variability needed for robust modeling of these processes. This presentation will trace the journey of stochastic weather generation starting from single-site precipitation and temperature models to the latest Bayesian space-time weather generator, BayGEN. The journey will cover (i) Markov chains for single-site daily precipitation occurrence and distribution functions for precipitation amount and daily temperatures; (ii) WGEN, the formal daily precipitation, maximum and minimum temperature weather generator; (iii) extensions to multisite simulation; (iv) nonparametric daily weather generators using discrete, continuous, and multivariate kernel density estimators, (v) K-nearest neighbor time series bootstrap generators for single and multisite, including flavors of the above methods. Recently, the authors have developed Generalized Linear Model (GLM) based weather generators with the illustrated ability to model and simulate daily weather at arbitrary (i.e., unobserved) locations through spatial process models. They can also be applied to simulate daily weather conditioned on large-scale climate state at seasonal and multi-decadal time scales. Future challenges include space-time modeling of other variables like relative humidity and solar radiation whose treatment within the GLM framework is not necessarily straightforward.

We conclude with BayGEN, an implementation of the GLM based generator within a Bayesian framework. BayGEN employs a hierarchical framework with data and process layers. In the data layer, precipitation occurrence at each site is assumed to be a realization from a latent Gaussian process, precipitation amounts as Gamma random variables, and minimum and maximum temperatures as Gaussian processes. In the process layer, the model parameters of the data layers are assumed to be spatially distributed as Gaussian processes, consequently enabling the simulation of daily weather at arbitrary locations. The posterior distribution of the model parameters are obtained in a Bayesian framework, wherein weakly informative priors are placed on the model parameters. The No U-Turn Sampler, an adaptive form of the Hamiltonian Monte Carlo sampler, is used to build the posterior distributions. Using the posterior distribution, uncertainty is effectively translated to weather simulations, an important feature, that makes BayGEN unique and novel compared to traditional weather generators.

A frailty-contagion model for multi-site hourly precipitation driven by atmospheric covariates

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Abstract

Accurate stochastic simulations of hourly precipitation are needed for impact studies at local spatial scales. Statistically, hourly precipitation data represent a difficult challenge. They are non-negative, skewed, heavy tailed, contain a lot of zeros (dry hours) and they have complex temporal structures (e.g., long persistence of dry episodes). Inspired by frailty-contagion approaches used in finance and insurance, we propose a multi-site precipitation simulator that, given appropriate regional atmospheric variables, can simultaneously handle dry events and heavy rainfall periods. One advantage of our model is its conceptual simplicity in its dynamical structure. In particular, the temporal variability is represented by a common factor based on a few classical atmospheric covariates like temperatures, pressures and others. Our inference approach is tested on simulated data and applied on measurements made in the northern part of French Brittany.

Stochastic Swell events generator

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Abstract

Accurate estimation and representation of long-term sea conditions is a major issue in many ocean and coastal engineering applications: design of coastal and offshore structures, preparation of marine operations, wave energy harvesting, etc. The main requirement is to estimate accurately the distribution (i.e. the probability of occurrence) of sea conditions at a location of interest. Stochastic modeling can be used to estimate these distributions because it enables to overcome the limits in duration that observations impose.

In this study, a new stochastic approach, event-based representation of sea state data, is proposed to model the wave climate in West Africa (from Ivory Coast to Namibia). An event refers to a wave system (swell or wind sea) evolving over time, that can be observed for a finite, yet significant duration and that can be linked to a single meteorological source phenomenon (e.g. low pressure systems, storms, etc.). Sea states are mostly composed of several superimposed wave systems, each with its own contribution to the total energy and time-evolving characteristics. Some existing methods allow partitioning of the sea state spectrum into its constituent wave systems. Conventionally, it is possible to identify events by tracking wave systems in time, following their dynamical evolutions. The event-based approach that we propose here involves fewer parameters and more rational dependencies between them. It provides a structure with physical meaning and temporal consistence for the representation of sea states data.

This approach is mainly used in this study for the modeling of swell climate, that contributes to more than 80% of the total energy of sea states in West Africa. Using as foundation elements the swell events, previously extracted from a time series of directional spectra, we build a stochastic generator of swell events and successfully reconstruct swell climate for durations of arbitrary length, that can be used with confidence in ocean and coastal engineering applications. The procedure we have developed for that purpose is decomposed into three following steps.

First, we have developed a new method: Time-domain of Spectral Expansion partitioning techniques (TESP)), based on the watershed algorithm in three dimensions (time, frequency, direction), to extract swell events from a time series of directional spectra. TESP uses the temporal coherence of wave systems in the partitioning and allows to extract consistent events with respect to the dynamical evolutions of wave systems. TESP ensures the continuity of any extracted event and allows for reducing the number of tuning parameters, conventionally used in existing methods, thereby reducing the computation time. We have also shown that TESP is not only suited to West Africa data, but it can also be used for spectra from different locations, having different dynamics.

We have then developed a model (Swell Event Model (SEM)) to represent each swell event by a reduced number of parameters (seven), the values of which are used as

the basis variables for the stochastic generator. SEM model is validated by the joint distribution of the significant wave heights and periods and also in an application to estimate the power extracted by a wave Energy converter. The results showed that swell events observed in West Africa can be modeled by SEM with no significant difference in the joint distribution of the significant heights and periods and for ocean and coastal engineering applications.

In the last step, we have constructed the stochastic swell events generator by modeling the joint distribution of the parameters of SEM and by modeling the occurrence process of the events. This generator allows for simulation of individual swell events and for reconstruction of swell climate over durations of arbitrary lengths. Using appropriate statistical tests, we have validated the generator at each step of its implementation. We have also compared the distribution of the global significant heights and weather windows estimated from the reconstructed swell climate with those from the reference dataset. The results showed good agreement between reconstructed climate and that of reference. These results allow to conclude that our stochastic swell events generator can reliably be used to simulate sea state data in West Africa for a large range of coastal and ocean engineering applications.

Analog Data Assimilation

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Abstract

Nowadays, ocean, atmosphere and climate sciences face a deluge of data pouring from space, in situ monitoring as well as numerical simulations. The availability of these different data sources offer new opportunities, still largely underexploited, to improve the understanding, modeling and reconstruction of geophysical dynamics. In a classical filtering or smoothing framework, data assimilation methods address the reconstruction of space-time dynamics from observations. They require multiple runs of an explicit dynamical model and may involve severe limitations including its computational cost, the lack of consistency of the model with respect to the observed data as well as modeling uncertainties. Here, we explore an alternative strategy and develop a fully data-driven assimilation. We do not require any explicit knowledge of the dynamical model. We assume that a representative catalog of trajectories of the system are available. Based on this catalog, we combine machine learning and stochastic assimilation techniques to introduce the analog data assimilation. It relies on the non-parametric sampling of the dynamical model using analog forecasts, such that no online evaluation of the physical model is exploited. We derive both ensemble Kalman and particle filtering versions of the proposed analog assimilation approach. As a proof concept, we demonstrate the relevance of our approach, including comparisons to classical model-driven assimilation, for numerical simulations of chaotic systems, namely Lorenz-63 and Lorenz-96 dynamics. We further discuss the key features of analog data assimilation and the new research avenues it opens in ocean-atmosphere science.

Estimating local space-time properties of rainfall from a dense gauge network.

Gregoire Mariethoz
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Abstract

Rain gauges provide direct and continuous observations of rain accumulation with a high time resolution (up to 1min). However the representativeness of these measurements is restricted to the funnel where rainwater is collected. Due to the high spatial heterogeneity of rainfall, this poor spatial representativeness is a strong limitation for the detailed reconstruction of rain intensity fields. Here we propose a geostatistical framework that is able to generate an ensemble of simulated rain fields based on data from a dense rain gauge network. When the density of rain gauges is high (sensor spacing in the range 500m to 1km), the spatial correlation between precipitation time series becomes sufficient to estimate both spatial and temporal parameters in order to characterize advection and track the rain patterns observed at a high sampling rate. Rain observations derived from such networks can thus be used to reconstruct the rain field with a high resolution in both space and time (i.e 1min in time, 100m in space). Our method is based on the modeling of twcorrelated random fields: one for the rainfall occurrence and another one for the rainfall intensity. Compared to the often used latent field approach, it requires the estimation of a larger number of parameters, but is able to characterize the different scales of the process, representing on the one hand the movement and intermittence of the rain cells and on the other hand the intra-cell precipitation variability. Once the estimation of spatio-temporal variograms has taken place, we use conditional geostatistical simulations to produce an ensemble of realizations that honor the rain intensities measured throughout the rain gauge network and that preserve the main features of the rain intensity field at the considered scale, i.e.: the advection and morphing properties of rain cells over time and the intermittency and the skewed distribution of rainfall. Our model also explicitly includes a decrease of the rain rate near the rain cell borders (dry drift). The reconstructed rainfall fields are continuous in space but discrete in time, and therefore can complement weather radar observations which are snapshots of the rain field. The application of this method to networks with a spatial extent comparable to the one of a radar pixel (i.e. around 1km2) could allow exploration of the rain field within a single radar pixel.

Spatio-temporal precipitation generator based on latent Gaussian field

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Abstract

We propose a daily spatio-temporal precipitation generator based on a latent Gaussian field. The mean of the latent Gaussian field governs the occurrence process, a transformation is applied in order to obtain simulated intensities. Statistical parameters are estimated from data at each observed location. Parameters at unobserved locations are obtained by assuming that the estimated parameters are a realization of a latent Gaussian field and simulating from the conditional posterior of such latent Gaussian field. The use of the SPDE approach [1] to approximate such latent Gaussian fields allow to sample over large domains in a fast way. The methodology is illustrated on a data set of daily rainfall values covering the South of Norway.

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Time-varying autoregressive models for multisite weather generators.

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Abstract

In this talk we will explore several strategies to model weather variables with time-varying dynamics using locally linear models.

Numerical stochastic models of conditional meteorological fields

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Abstract

When properties of extreme atmospheric events are studied, it may be necessary to simulate conditionally distributed meteorological random fields with fixed values at given points. For example, conditional distributions of a field (that is simulated on a regular grid) may be defined by known meteorological conditions on weather stations that are situated arbitrary. The goal of this talk is to propose approaches to the approximate numerical simulation of non-Gaussian conditional meteorological fields. Suggested method is based on the hypothesis that correlation structure of the random field is known and is given by corresponding correlation function. It is also assumed that random field is homogeneous or homogeneous isotropic. To simulate non-Gaussian fields simulation algorithms for conditionally distributed Gaussian fields and method of inverse distribution functions are used. The first method for simulation of conditional precipitation fields is based on an assumption, according to which absence of precipitation is identified with zero amount of precipitation. One-dimensional distribution function of precipitation field in this case is determined at a closed interval with the left boundary that is equal to zero. If during simulation values that are less then values that may be measured by a raingauge appear they are replaced with zeros. The second method is based on a special algorithm for modeling of conditional indicator precipitation fields.

Several examples that illustrate how conditional models may be used are given in this report. It is shown that considered models may be used for analysis of the total precipitation amount in a given area for different scenarios of rainfall at the stations.

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Generating and evaluating space-time trajectories of renewable power generation

Pierre Pinson
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Abstract

Renewable wind generation (say, wind and solar power) is highly variable and of limited predictability only. This is while the way power systems are managed require to make a number of decisions quite some time prior to actual operation. In these decision-making problems, costs functions are asymmetric, possibly nonlinear and dynamic, but also linked in space (due to the power network) and in time (due to generators' constraints and storage dynamics). Hence, space-time scenarios of renewable power generation are seen as a must-have as input to a wide range of operational decision-making problems. Besides their use in actual operations, sets of trajectories may need to be generated as input to planning and investment studies, or for risk analysis. Those scenarios are most often generated today by converting ensemble forecasts of relevant meteorological variables to power, or by joint modelling of marginal predictive densities for every location and lead time, as well as their dependence structure. We will discuss a few methods that were recently proposed, as well as their implementation as part of an open-source platform with application for the US and continental Europe. A set of current methodological and practical challenges related to the generation of high-dimensional sets of trajectories, as well as their verification, will finally be discussed.

Randomized fluid dynamics based on subgrid transport

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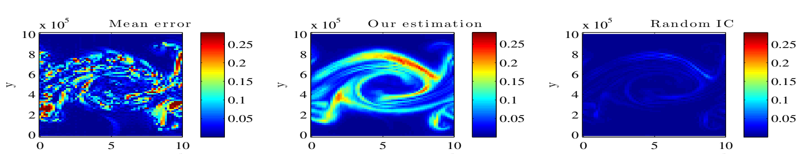
Abstract

Ensemble forecasting and filtering are widely used in geophysical sciences for numerical weather forecasting and climate projection application. In practice to be efficient these methods require an accurate physical modeling of the dynamical model errors. These errors evolve along time and strongly interact with the large-scale state variables of interest. The generic design of large-scale geophysical models incorporating errors or uncertainty is consequently far from being an easy task. To address this issue, we propose to model the unresolved velocity (the errors or uncertainties) of our fluid dynamics system by a divergence free Gaussian process, denoted $\boldsymbol{\sigma}\dot{\boldsymbol{B}}$, correlated in space but uncorrelated in time. Within this simple assumption, the material derivative, $D_t\Theta$, – the derivative along the flow trajectory $\boldsymbol{X}_t$ – of a tracer, Θ, has to be modified as:

$$0 = D_t\Theta = \underbrace{\mathrm{d}_t\Theta}_{\substack{\text{Time}\\\text{increment}}} + \underbrace{\boldsymbol{w}^\star \cdot \boldsymbol{\nabla}\Theta}_{\text{Advection}}\mathrm{d}t + \underbrace{\boldsymbol{\sigma}\mathrm{d}\boldsymbol{B}_t \cdot \boldsymbol{\nabla}\Theta}_{\text{Noise}} - \underbrace{\boldsymbol{\nabla}\cdot\left(\frac{1}{2}\boldsymbol{a}\boldsymbol{\nabla}\Theta\right)}_{\text{Diffusion}}\mathrm{d}t,$$

with, $\boldsymbol{w}$, denoting the large-scale velocity, $\boldsymbol{w}^\star = \boldsymbol{w} - \frac{1}{2}(\boldsymbol{\nabla}\cdot\boldsymbol{a})^T$ an effective drift and $\boldsymbol{a}\mathrm{d}t = \mathbb{E}\left\{\boldsymbol{\sigma}\mathrm{d}\boldsymbol{B}_t\left(\boldsymbol{\sigma}\mathrm{d}\boldsymbol{B}_t\right)^T\right\}$. Compared to a usual transport equation, three new terms appear in this expression: (*i*) a drift correction, (*ii*) an inhomogeneous and anisotropic diffusion and (*iii*) a multiplicative noise. These three terms are strongly linked together, which ensures desired properties such as energy conservation.

With this stochastic version of the transport equation, it is possible to express the fundamental conservation laws of classical mechanics and to derive stochastic versions of *a priori* any fluid dynamics models. Following this procedure, we have derived and simulated a stochastic version of the Surface Quasi-Geostrophic (SQG) model. We have shown that the realizations of this stochastic version allows us to better resolve the small-scales in comparizon to the usual SQG model. Besides, we have evidenced that an ensemble of realization was able to accurately estimate at each time step the amplitudes and positions of the model errors in both spatial and spectral domains. In comparison a classical randomization of the initial state leads though having a similar error repartition to an underestimation of one order of magnitude. The figure displays those results in the spatial domain. Our ensemble also succeeded to predict density skewness and extreme events of the tracer at small scales. The talk will explicit our stochastic version of the material derivative and comment the numerical results.



Intensity-Duration relationships in a seasonal Bartlett-Lewis rectangular Pulse model

Christoph Ritschel, Komlan Agbéko Kpogo-Nuwoklo, Henning W. Rust, Uwe Ulbrich, Peter Névir

Freie Universität Berlin, Germany

Abstract

Precipitation time series with a high temporal resolution are needed as input for sev- eral hydrological applications, e.g. river runoff or sewer system models. As adequate observational data sets are often not available, simulated precipitation series come to use. Poisson-cluster models are commonly applied to generate these series. It has been shown that this class of stochastic precipitation models is able to well reproduce important characteristics of observed rainfall. For the gauge based case study presented here, the Bartlett-Lewis rectangular pulse model (BLRPM) has been chosen.

For different seasons, we compare the intensity-duration relations from observations to those found for simulations from the BLRPM. We investigate to what extend the BLRPM captures these relations. A focus is on extreme intensities which are evaluated based on extreme value statistics.

Furthermore it has been shown that certain model parameters vary with season in a midlatitude moderate climate due to different rainfall mechanisms dominating in winter and summer, model parameters are typically estimated separately for individual seasons or individual months. Here, we suggest a simultaneous parameter estimation for the whole year under the assumption that seasonal variation of parameters can be described with harmonic functions. We use an observational precipitation series from Berlin with a high temporal resolution to exemplify the approach. We estimate BLRPM parameters with and without this seasonal extention and compare the results in terms of model performance and robustness of the estimation.

Fundamental statistical relationships between monthly and daily meteorological variables: Temporal downscaling of weather based on a global observational dataset

Philipp Sommer, Jed O. Kaplan
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Abstract

Accurate modelling of large-scale vegetation dynamics, hydrology, and other environmental processes requires meteorological forcing on daily timescales. While meteorological data with high temporal resolution is becoming increasingly available, simulations for the future or distant past are limited by lack of data and poor performance of climate models, e.g., in simulating daily precipitation. To overcome these limitations, we may temporally downscale monthly summary data to a daily time step using a weather generator. Parameterization of such statistical models has traditionally been based on a limited number of observations. Recent developments in the archiving, distribution, and analysis of big data datasets provide new opportunities for the parameterization of a temporal downscaling model that is applicable over a wide range of climates. Here we parameterize a WGEN-type weather generator using more than 50 million individual daily meteorological observations, from over 10'000 stations covering all continents, based on the Global Historical Climatology Network (GHCN) and Synoptic Cloud Reports (EECRA) databases. Using the resulting "universal" parameterization and driven by monthly summaries, we downscale mean temperature (minimum and maximum), cloud cover, and total precipitation, to daily estimates. We apply a hybrid gamma-generalized Pareto distribution to calculate daily precipitation amounts, which overcomes much of the inability of earlier weather generators to simulate high amounts of daily precipitation. Our globally parameterized weather generator has numerous applications, including vegetation and crop modelling for paleoenvironmental studies.

Stochastic simulation models for multi-site nonstationary time series using wavelets

Ying Sun
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Abstract

Many meteorological variables exhibit nonstationarity in time. In particular, the time series appears to have modulated oscillations that may correspond to the recurrent but still changing set of climate conditions. In this work, a multi-scale stochastic simulation model is developed using wavelet decomposition. The multiresolution and localization properties of wavelets make them favorable for reproducing different time-varying local features of processes at different time scales. Specifically, for a given time scale, we propose to use a stochastic model based on evolving periodic functions to model the wavelet coefficients that vary in a periodic fashion, and both periodicity and amplitude are allowed to change over time. We apply this approach to analyze the monthly southern oscillation index from 1876 to 2015, and show that the proposed simulation model can successfully reproduce the interdecadal fluctuations, which have the effect of modulating the amplitude and frequency of occurrence of El Nino events. Multi-site simulation models are also developed with an application to a minute-by-minute meteorological dataset collected at multiple monitoring locations from the Atmospheric Radiation Measurement program. This talk is based on the joint work with Xiaohui Chang from Oregon State University.

Stochastic weather generators and conditional detection and attribution of singular events

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Abstract

Detection and Attribution of singular events (DASE) consists in estimating the difference of occurrence probabilities of a rare events in two different worlds. Such worlds can be a factual world (where all anthropogenic and natural forcings are at play) and a counterfactual world (where there are only natural forcings).

DASE has required the use of huge computer resources in order to produced a large amount of model simulations, with and without anthropogenic forcings, to produce such probability estimates. This requirement somewhat hinders a systematic and quick investigation of extreme events.

In this presentation, I propose an alternative to such an approach of DASE by using a stochastic weather generator based on analogues of the atmospheric circulation. Such a weather generator can mimic trajectories of the atmospheric system from observations. In particular, this methodology can be used to decompose the probability of extreme events into contributions from atmospheric circulation changes and thermodynamical terms.

The methodology will be illustrated on a flood event that struck southern UK and northwestern France in January 2014. I will argue that the results obtained with this stochastic approach are consistent with large ensembles of model simulations.