DY 4: Focus Session: Atmospheric and Climate Complexity

This focus session is devoted to modern methods to analyze complex systems which are applied to climate and atmospheric physics. This is also in the context of the initiative "Mathematics of Planet Earth 2013", which is supported by many different science organisations. (Organizer Christian Beck)

Time: Monday 15:00–17:30 Location: H47

Invited Talk DY 4.1 Mon 15:00 H47

Environmental Superstatistics — •Christian Beck — School of Mathematical Sciences, Queen Mary, University of London, London E1 4NS, UK

Complex systems in driven nonequilibrium situations often consist of a superposition of various dynamics on well-separated time scales. Often one or several parameters (such as e.g. the local inverse temperature beta) fluctuate on a rather large time scale, much larger than the relaxation time of the local system, and one can then apply so-called superstatistical techniques. The basic idea is to have a superposition of two statistics, one given by ordinary statistical mechanics and the other one by that of the fluctuating parameter. The resulting marginal distributions typically have fat tails, which can be understood by methods borrowed from large deviation theory. The superstatistics concept has been recently applied to a variety of complex systems, in particular to the dynamics of tracer particles in turbulent flows, to traffic delay statistics, cancer survival statistics, and share price fluctuations. After a short review of the field I will describe some new results on environmentally relevant superstatistics, dealing with typical temperature distributions observed on Planet Earth, wind velocity fluctuations, as well as rainfall/flooding statistics.

Invited Talk DY 4.2 Mon 15:30 H47

Statistical decomposition of atmospheric turbulence — •Matthias Wächter, Allan Morales, Tanja Mücke, Nico Reinke, and Joachim Peinke — ForWind - Institut für Physik, Universität Oldenburg

Atmospheric turbulence shows pronounced intermittency in the probability density functions of wind velocity increments $u_r = u(t+\tau) - u(t)$, in the sense of very high probabilities of extreme events, over a wide range of scales τ. This intermittency is commonly observed to be significantly stronger and covering a wider range of scales than that found in homogeneous isotropic turbulence (HIT) in laboratory experiments.

We present a superposition approach which allows for a decomposition of atmospheric turbulence into subsets obeying statistics similar to HIT in the sense of Kolmogorov's theory of 1962. The practical relevance of atmospheric intermittency is demonstrated for the example of wind energy converters. Furthermore, we give an outlook to the application of our approach in wind tunnel experiments with the aim of generating wind tunnel flows similar to atmospheric turbulence.

Invited Talk DY 4.3 Mon 16:00 H47

Quantitative approaches to the statistics of extreme events in atmospheric dynamics — •Holger Kantz[1], Jochen Broecker[2], Leo Granger[1], and Julia Gundermann[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Dept. Mathematics and Statistics, University of Reading, UK

We discuss various statistical aspects of extreme events based on empirical and theoretical grounds. We consider specifically extreme events caused by the dynamics of the atmosphere such as wind gusts, precipitation events and large temperature anomalies. Relevant quantities are the event rate/return time as a function of event magnitude for very rare events. Whereas data analysis shows that marginal distributions of most types of extremes do not have fat tails and hence extremes are not by orders of magnitudes larger than the standard deviation, correlations in the succession of extremes render large deviation results invalid. One potential theoretical approach to the estimation of the frequency of very rare events is offered by non-equilibrium fluctuation theorems, and we present preliminary results of a study of a two-dimensional hydrodynamical flow. Finally, we discuss predictability and performance of extreme event prediction and show that conclusions depend much stronger on the choice of the performance criterion than anticipated.

Invited Talk DY 4.4 Mon 16:30 H47

Climate as a Problem of Non-equilibrum Statistical Mechanics — •Valerio Lucarini — Klimacampus, Institute of Meteorology, University of Hamburg, Hamburg, Germany — Department of Mathematics and Statistics, University of Reading, Reading, UK

The investigation of the climate system is one of the grand challenges of contemporary science. Such a problem is gaining more and more relevance as exoplanets are being discovered at an accelerating rate and rather exotic atmospheric circulations are being conjectured, due to the vast variety of possible astronomical and astrophysical configurations. In this contribution we will discuss how non-equilibrium statistical mechanics (and, specifically the adoption of the mathematical framework provided by Axiom A dynamical systems) allows framing in a rigorous and efficient way classical problems of climate science such as the understanding of the climatic response to forcings of general nature and the parametrization of unresolved processes.

DY 4.5 Mon 17:00 H47

Rain in a test-tube! — •Martin Rohloff[1,2] and Jürgen Vollmer[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization (MPIDS), 37077 Göttingen, Germany — [2]Faculty of Physics, University of Göttingen, 37077 Göttingen, Germany

Demixing of multiphase fluids is important for precipitation in the atmosphere of the earth and other planets. The mechanisms of droplet growth that lead to precipitation are under vivid discussion.

We present a lab experiment in which repeated precipitation cycles can be observed. Binary mixtures of liquids are used as model systems. They undergo demixing when subjected to a shallow temperature ramp. We perform measurements of the droplet size distribution and turbidity measurements. Having access to the droplet size distribution for many oscillations and different types of binary mixtures, we identify the dependence on different material parameters like density, viscosity, surface tension, as well as the influence of heating rate and sample geometry.

DY 4.6 Mon 17:15 H47

Disentangling different types of El Niño episodes by evolving climate network analysis — Alexander Radebach[1,2,3], •Reik V. Donner[1], Jonathan F. Donges[1,2], Jakob G.B. Runge[1,2], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Germany — [2]Department of Physics, Humboldt University, Berlin, Germany — [3]Mercator Research Institute on Global Commons and Climate Change, Berlin, Germany

Complex network theory provides a powerful toolbox for studying the backbone of statistical interrelationships between multiple time series in various scientific disciplines. In this work, we apply the recently proposed climate network approach for characterizing the evolving correlation structure of the Earth's climate system based on reanalysis data of surface air temperatures. We provide a detailed study on the temporal variability of several global climate network characteristics, which allows deriving results that go significantly beyond recent findings. Based on a simple conceptual view on sparse climate networks, we are able to give a thorough interpretation of our evolving climate network characteristics, which allows a functional discrimination between recently recognized different types of El Niño episodes (so-called cold-tongue and warm pool events). In this respect, our analysis provides deep insights into the Earth's climate system, particularly its response to strong volcanic eruptions and large-scale impacts of different types of El Niño episodes, and thus contributes to the understanding of the global signatures of distinct phases of the El Niño Southern Oscillation (ENSO).