DY 28: Data Analysis Methods and Modelling of Geophysical Systems

Time: Thursday 15:00–17:45 Location: MA 144

DY 28.1 Thu 15:00 MA 144

Nonlinear detection of paleoclimate-variability transitions possibly related to human evolution — •Jonathan F. Donges[1,2], Reik V. Donner[1], Martin H. Trauth[3], Norbert Marwan[1], Hans Joachim Schellnhuber[1], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Department of Physics, Humboldt University, Berlin, Germany — [3]Department of Earth and Environmental Sciences, University of Potsdam, Potsdam, Germany

Potential paleoclimatic driving mechanisms acting on human evolution present an open problem of cross-disciplinary scientific interest. The analysis of paleoclimate archives encoding the environmental variability in East Africa during the last 5 Ma (million years) has triggered an ongoing debate about possible candidate processes and evolutionary mechanisms. In this work, we apply a novel nonlinear statistical technique, recurrence network analysis, to three distinct marine records of terrigenous dust flux. Our method enables us to identify three epochs with transitions between qualitatively different types of environmental variability in North and East Africa. A reexamination of the available fossil record demonstrates statistically significant coincidences between the detected transition periods and major steps in hominin evolution. This suggests that the observed shifts between more regular and more erratic environmental variability may have acted as a trigger for rapid change in the development of humankind in Africa.

DY 28.2 Thu 15:15 MA 144

Correlations of record events as a test for heavy-tailed distributions — •Jasper Franke, Gregor Wergen, and Joachim Krug — Institut für Theoretische Physik, Universität zu Köln, Germany

A record is an entry in a time series that is larger or smaller than all previous entries.

If the time series consists of independent, identically distributed random variables with a superimposed linear trend, record events are positively (negatively) correlated when the tail of the distribution is heavier (lighter) than exponential. Here we use these correlations to detect heavy-tailed behavior in small sets of independent random variables. The method is based on choosing ordered subsets of the data, adding a linear trend, and estimating the resulting record correlations.

DY 28.3 Thu 15:30 MA 144

Predictability of temperature exceedance events by data-driven and physical-dynamical modeling — •Stefan Siegert and Holger Kantz — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

We present a predictability study of temperature in Hannover, Germany. We issue probabilistic predictions for the event that the value of the temperature exceeds a certain threshold on the next day. The forecast probabilities are generated via two different approaches. In the data-driven approach, an autoregressive model is used to generate the exceedance probability conditional on temperature measurements from the immediate past. In the physical modeling approach, an ensemble of runs generated by an atmospheric circulation model is used. Predictions issued by these two approaches are compared by proper skill scores. A decomposition of the skill scores is used to assess different forecast attributes, namely resolution and reliability. The main conclusion of the study is that the physical modeling approach is superior to the data-driven approach, but only after the model output has been corrected by statistical post-processing.

DY 28.4 Thu 15:45 MA 144

Visibility graphs for testing reversibility of time series — •Jonathan F. Donges[1,2] and Reik V. Donner[1] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Department of Physics, Humboldt University, Berlin, Germany

Reversibility or time reversal symmetry is a fundamental property of time series. Among other applications, it can be harnessed for selecting models that are consistent with experimental time series data. We propose a novel set of statistical tests against reversibility based on visibility graphs constructed from time series as well as on time-directed variants of common graph-theoretical measures like degree and local clustering coefficient. Unlike other tests against reversibility, the technique proposed here has the advantage that it does not require the construction of surrogate time series. We investigate the performance of our statistical tests for time series from paradigmatic model systems with known time reversal properties and compare it to a traditional test against reversibility. Finally, our tests are applied to characterize the temporal structure of electroencephalogram (EEG) time series representing normal and pathological dynamics of the human brain.

DY 28.5 Thu 16:00 MA 144

State and parameter estimation for nonlinear systems — •Jan Schumann-Bischoff, Stefan Luther, and Ulrich Parlitz — Biomedical Physics, Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen

We present an efficient method for estimating variables and parameters of a given system of ordinary differential equations by adapting the model output to an observed time series from the (physical) process described by the model. The proposed method [1] is based on (unconstrained) nonlinear optimization exploiting the particular structure of the relevant cost function. For illustrating features and performance of the method simulations are presented using chaotic time series generated by the Colpitts oscillator, the three dimensional Hindmarsh-Rose neuron model and a 9-dimensional extended hyperchaotic Rössler system.

[1] J. Schumann-Bischoff and U. Parlitz, State and parameter estimation using unconstrained optimization, *Phys. Rev. E* 84, 056214 (2011)

DY 28.6 Thu 16:15 MA 144

Signal analysis and classification using ordinal patterns — •Ulrich Parlitz, Sebastian Berg, and Stefan Luther — Biomedical Physics, Max Planck Institute for Dynamics and Self-Organization, Am Fassberg 17, 37077 Göttingen

Ordinal patterns [1-5] describe the relations within short segments of a given time series. They are easy to compute and robust against noise. For this reason ordinal patterns have been used in a wide range of applications like detection of determinism in noisy time series [4], estimation of transfer entropy in epilepsy [3], or complexity analysis of time series [1,2]. In this contribution we shall present and discuss applications of ordinal pattern statistics for synchronization analysis, forecasting and signal classification. In particular very promising applications to ECG data [5] will be discussed which show that symbolic dynamics based on ordinal patterns provides a powerful tool for coping with data from life sciences.

[1] J.M. Amigo, Permutation Complexity in Dynamical Systems, Springer Series in Synergetics, Springer-Verlag Berlin Heidelberg (2010).

[2] C. Bandt and B. Pompe, Phys. Rev. Lett. 88, 174102 (2002).

[3] M. Staniek and K. Lehnertz, Phys. Rev. Lett. 100, 158101 (2008).

[4] J.M. Amigo et al., EPL 79 50001 (2007); EPL 83, 60005 (2008).

[5] U. Parlitz et al., "Classifying cardiac biosignals using ordinal pattern statistics and symbolic dynamics", to appear in: Computers in Biology and Medicine, available online 20 April 2011, doi:10.1016/j.compbiomed.2011.03.017

DY 28.7 Thu 16:30 MA 144

On bi- and multivariate extensions of recurrence network analysis — Jan H. Feldhoff[1,2], •Reik V. Donner[1], Jonathan F. Donges[1,2], Norbert Marwan[1], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germany — [2]Department of Physics, Humboldt University of Berlin, Germany

Recurrence plots (RPs) obtained from time series are known to contain all essential information on the dynamical characteristics of underlying dynamical systems. Recently, it has been suggested to reinterpret the RP as the connectivity matrix of a complex network associated with the time series under study. Statistical measures characterizing the topology of such recurrence networks on both local and global scale have already demonstrated their great potential for detecting changes in the underlying dynamics as reflected in the geometry of the corresponding attractor in phase space.

Here, we introduce two possible extensions of the recurrence network approach for studying two or more potentially coupled dynamical systems. Specifically, the established concepts of cross- and joint RPs, as well as the recently introduced graph-theoretic framework for describing the properties of interacting networks are utilized for deriving a corresponding complex network representation. We discuss the interpretation of both approaches in terms of the associated phase space properties and provide some examples highlighting their performance for studying interacting complex systems.

DY 28.8 Thu 16:45 MA 144

Similarity measures for irregularly sampled time series — •Kira Rehfeld[1,2], Norbert Marwan[1], Jobst Heitzig[1], and Jürgen Kurths[1,2] — [1]Potsdam Institute for Climate Impact Research, Potsdam, Germanyesearch, Potsdam, Germany — [2]Department of Physics, Humboldt University Berlin, Berlin, Germany

Automated and joint analysis and inter-comparison of palaeoclimatological time series from proxy archives, e.g. stalagmites, ice and sediment cores, is of much interest in the study of past climate and its changes. Due to heterogeneous archive properties, reconstructed observation times are not spaced at regular intervals. This introduces an additional, substantial, error source when applying standard linear and nonlinear measures, as necessary interpolation introduces bias, especially for high-frequency signal components. Using kernel-based approaches, we circumvent the need for interpolation and use the information contained in the time series at the different time scales directly. In benchmark tests we compare results for kernel-based Pearson correlation and mutual information to estimates obtained from standard interpolation-based methods. We illustrate robustness, reliability and superiority of the new methods using synthetic time series of known inter-sampling time distributions similar to those found in reality and show that the results we obtain from palaeo records show the same characteristics. To illustrate the capability of our approach we construct, analyze and interpret small complex networks from palaeo records of Asian Monsoon variability.

DY 28.9 Thu 17:00 MA 144

Early warning signals: a generalised modelling approach — •Steven Lade[1] and Thilo Gross[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Department of Engineering Mathematics, University Of Bristol, United Kingdom

Critical transitions, here defined as sudden and difficult to reverse changes of state that are often associated with bifurcations, occur in many systems in nature and society such as ecology, physiology, climate, and economies. Given the often catastrophic nature of these transitions, some warning of these transitions is highly desirable. Over the last decade a number of such early warning signals have been proposed based on simple analyses of time series data, for example an increasing variance or increasing autocorrelation.

These methods, however, can be limited by the amount of data they require. In this talk I will propose a new method that significantly reduces the amount of data required. It is based on combining multiple types of time series data with system-specific structural knowledge through the framework of a generalised model. I apply the method to two ecological examples, including the simulated collapse of a fishery.

Topical Talk DY 28.10 Thu 17:15 MA 144

Sensitivity and out-of-sample error in data assimilation — •Jochen Bröcker — Max-Planck-Institut für Physik komplexer Systeme

“Data Assimilation” is one of many names for the following problem: Given a history of observations as well as a dynamical model, find trajectories which are, on the one hand, consistent with the model, and on the other hand, consistent with the observations. Attaining both objectives at the same time is essentially never possible (nor in fact desired) in reality, since our models are invariably simplifications. Any data assimilation algorithm should therefore allow for deviations from the proposed model equations as well as from the observations. How we might trade off between these two is the subject of this talk. It is shown how we can still find “good” trajectories, where the measure of goodness obviously cannot be just the deviation from the observations. Rather, a measure similar to the out-of-sample error from statistical learning is considered. The connection between the out-of-sample error and the sensitivity is elucidated, including some numerical examples.

Reference:

J.B., Ivan G. Szendro, Sensitivity and out–of–sample error in continuous time data assimilation, *Quarterly Journal of the Royal Meteorological Society*, 2011.