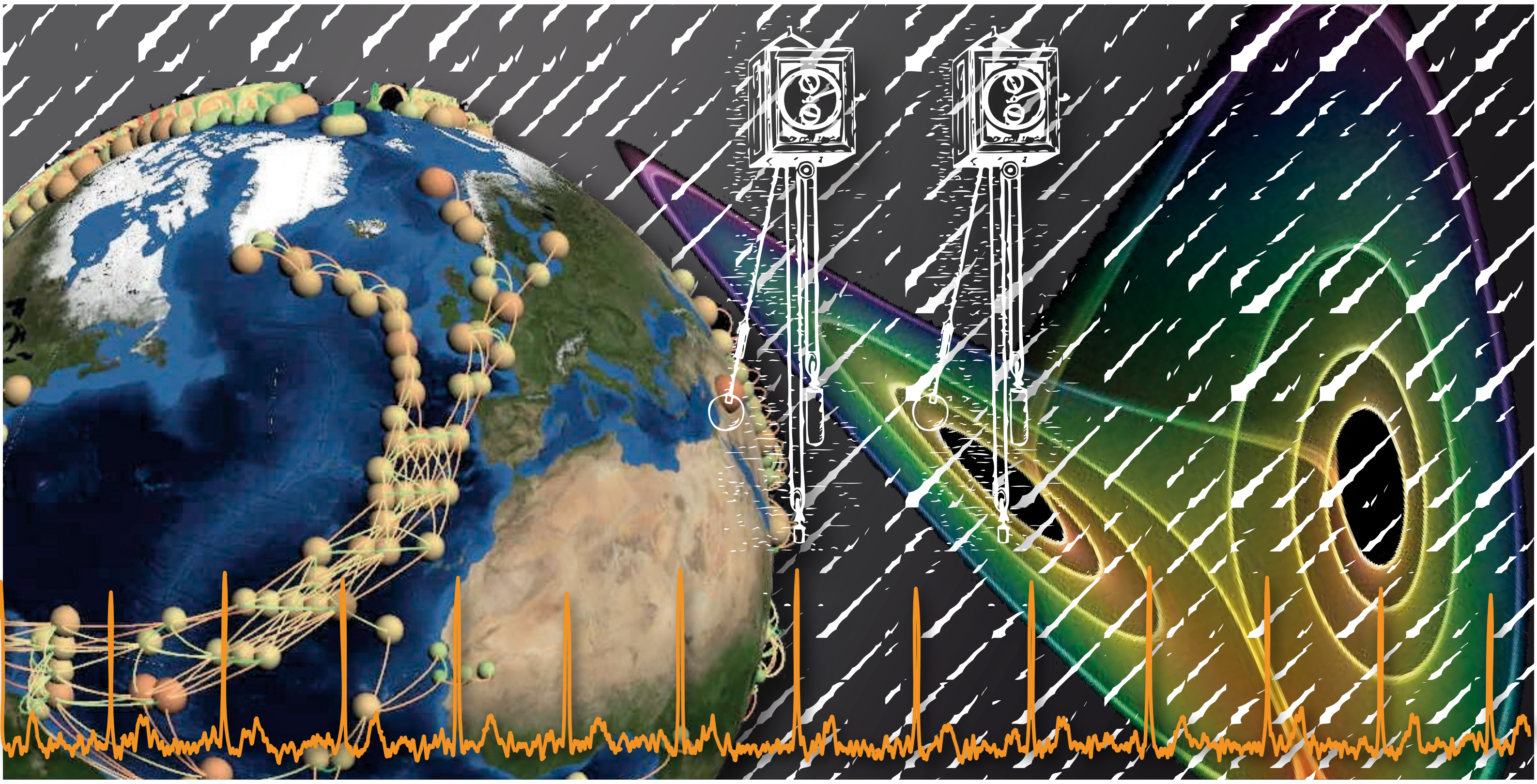
Conference Programme

Nonlinear Data Analysis and Modeling: Advances, Applications, Perspectives



Leibniz-Gemeinschaft

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Aims

The aim of this meeting is to gather scientists from various fields of complex systems science, in particular nonlinear data analysis, synchronization, complex networks, modeling, and applications in Earth system sciences, neuroscience, physiology, and astrophysics, in which Jürgen Kurths contributed. This interdisciplinary conference will be a platform to exchange ideas and knowledge, as well as discuss new directions in complex systems science and its applications from the view of different disciplines.

This conference is intended to bring together Jürgen Kurths' former and recent students, collaborators, and colleagues as well as researchers interested in this interdisciplinary field.

Location

The conference will take place at the historical science campus at the Telegrafenberg in Potsdam. The venue is in the lecture hall of building H.

Presentations

Presentations should be uploaded to the presentation computer in the lecture hall at the earliest of your convenience but not later than the last break before the session of presentation. The time for the talk is 25 min + 5 min discussion.

Both MacOS and Windows machines will be available, installed with standard presentation software (PowerPoint, Acrobat, Preview, and Keynote). You may also bring your own computer or presentation device provided that it is fitted with the appropriate VGA output and that you are capable of installing and testing the machine prior to the scheduled session time.

Note

The symposium will adhere to the rules of good scientific and ethical practice. This means that it is not allowed to copy presentations from the presentation computer. It is also forbidden to take photographs of oral presentations and presented posters without explicitely given permission of the presenter.

Social Programme

A guided tour over the Telegrafenberg campus has been organized for Thursday, March 21st, 12:00.

Prof. Jürgen Kurths invites for a reception after the conference, in the foyer of the conference venue, starting 18:15 with an opening in the lecture hall, Friday, March 22nd.

Lunch

Lunch meals are not included in the conference registration. The canteen in the 1st floor of the conference building can be used to take lunch at one's own expense.

Internet Access

Wireless internet access is available for symposium participants with the following login details:

SSID: `PIK-Visitors`
Password:

The number of simultaneous access is limited.

Financial Support

The conference was financially supported by the Potsdam Institute for Climate Impact Research, the Humboldt-Universität zu Berlin, the Carl von Ossietzky Universät Oldenburg, the EU funded Coordination Action *Global Systems Dynamics & Policy (GSDP)*, and the DFG/FAPESP funded International Research Training Group *Dynamical Phenomena in Complex Networks:Fundamentals and Applications* (IRTG 1740).

Programme

Symposium From Synchronisation to Networks of Networks

Thursday, March 21, 2013

13:00	*Welcome note*
13:10	Alexey Zaikin, University College London, UK: *Coupling, Synchronization and Noise in AGNLD*
13:40	Changsong Zhou, Hong Kong Baptist University, China: *Quantitative analysis and modeling of interacting human activities*
14:10	Stefano Boccaletti, Consiglio Nazionale delle Ricerche, Sesto Fiorentino, Italy: *Scales and topology emerge spontaneously from synchronization of adaptive networks*
14:40	Shlomo Havlin, Bar-Ilan University, Ramat Gan, Israel: *From Single Network to Network of Networks*
15:10	*Coffee break*
15:30	Arkady Pikovsky, University of Potsdam, Germany: *Reconstructing oscillator networks from multivariate data*
16:00	Ljupco Kocarev, Macedonian Academy of Sciences and Arts, Skopje, Macedonia: *Influence of the network topology on epidemic spreading*
16:30	Elbert Macau, National Institute for Space Research (INPE), Sao Jose dos Campos, Brazil: *Isochronal Synchronization in Complex Network with Propagation Delay*
17:00	Grigory Osipov, Nizhny Novgorod University, Russia: *Sequential activity in neuronal networks*
17:30	*Poster session with wine, beer, and bretzels*

Symposium Complex Natural Systems: From Cardiology to Climate

Friday, March 21, 2013

9:00	Maria Carmen Romano, University of Aberdeen, UK: *Ribosome traffic dynamics in gene expression regulation*
9:30	Klaus Lehnertz, University of Bonn, Germany: *Nonlinear dynamics and complex networks in epilepsy*
10:00	Reinhold Kliegl, University of Potsdam, Germany: *Nonlinear cognitive science*
10:30	*Coffee break*
11:00	Niels Wessel, Humboldt-University at Berlin, Germany: *The Heart of/in Physics*
11:30	Ruedi Stoop, University of Zurich and ETH Zurich, Switzerland: *A complete dynamical systems based model of the peripheral auditory system*

12:00 Holger Kantz, MPI for the Physics of Complex Systems Dresden, Germany:
Surprises when comparing data based to model based predictions

12:30 Friedrich-Wilhelm Gerstengarbe, Potsdam Institute for Climate Impact Research, Germany:
The complete non-hierarchical cluster analysis to describe climate changes

13:00 *Lunch*

Symposium Advances and Perspectives of Complex Systems

Friday, March 21, 2013

14:00 Lutz Schimansky-Geier, Humboldt-University at Berlin:
Stochastic Models for Active Particles

14:30 Guenther Ruediger, Leibniz Institute for Astrophysics Potsdam:
Why do newborn neutron stars rotate so slowly? – Magnetic instabilities in the laboratory

15:00 Leonard Smith, London School of Economics and Political Science, UK:
Unpopular Essays of Jürgen Kurths: Practicalities and Predictability

15:30 M. Lakshmanan, Bharathidasan University Tiruchirapalli:
Applications of Nonlinear Dynamics to Spintronics: STNOs and Microwave Generation

16:00 *Coffee break*

16:30 Hans Joachim Schellnhuber, Potsdam Institute for Climate Impact Research:
Unifying Complexity and Climate-Change Research

16:45 Celso Grebogi, University of Aberdeen:
Conductance Fluctuations in Graphene Systems: The Relevance of Classical Dynamics

17:15 Kazuyuki Aihara, University of Tokyo:
Complex Systems Modelling for Personalised Medicine

17:45 Michael Ghil, ENS Paris:
Boolean delay equations, networks and damage propagation

18:15 *Reception opening*

Poster

Poster 1	F. Feudel: *Convection patterns in a spherical fluid shell under microgravity conditions*
Poster 2	P. Carl: *A General Circulation Model en route to chaos*
Poster 3	Jan Schumann-Bischoff, Stefan Luther, and Ulrich Parlitz: *Optimization based state and parameter estimation employing automatic differentiation*
Poster 4	Peter Menck, Jobst Heitzig, Norbert Marwan, Jürgen Kurths: *How Basin Stability Complements the Linear-Stability Paradigm*
Poster 5	Frank Selten and Wim Wiegerinck: *Supermodels: Dynamically Coupled Ensembles of Imperfect Models*
Poster 6	A. Zakharova, A. Feoktistov, T. Vadivasova, E. Schoell: *Coherence resonance and stochastic synchronization in a nonlinear circuit near a subcritical Hopf bifurcation*
Poster 7	Pooja Rani Sharma, Manish Dev Shrimali, Awadhesh Prasad, and Ulrike Feudel: *Controlling bistability by linear augmentation*
Poster 8	Peng Ji: *Cluster Explosive Synchronization in a Power Grid model*
Poster 9	C. R. Hens, R. E. Amritkar, U. Feudel, S. K. Dana: *Extreme multistability in coupled oscillator*
Poster 10	H. Mancini: *Confined Flows Synchronization and Control in Thermo-Convective Systems*
Poster 11	Sergey Astakhov, Naoya Fujiwara, Artem Gulay and Jürgen Kurths: *The Andronov – Hopf bifurcation in a system of two phase oscillators with asymmetrical repulsive coupling.*
Poster 12	Bernd Blasius: *Marine bioinvasion in the network of global shipping connections*
Poster 13	S. Rüdiger, C. Schmeltzer: *Population firing rate in networks with degree correlations*
Poster 14	Lavneet Janagal, Sumantra Sarkar and P. Parmananda: *Synchronization in an ensemble of spatially moving oscillators*
Poster 15	D. Maza, L. Pugnaloni, R. Arevalo, I. Zuriguel: *Granular packing and complex networks*
Poster 16	Serhiy Yanchuk: *Patterns in lattices of delay coupled neurons*
Poster 17	Xiaojuan Sun, Qishao Lu, and Jürgen Kurths: *Neuronal dynamics in a network of subnetworks*
Poster 18	Reik V. Donner, Jonathan F. Donges, Yong Zou, Norbert Marwan, Jobst Heitzig, Jürgen Kurths: *A complex network perspective for time series analysis of dynamical systems*
Poster 19	A. Schlemmer, U. Parlitz, and S. Luther: *Detecting spatiotemporal patterns in excitable media using node communities*
Poster 20	M.V. Ivanchenko and T.V. Laptyeva: *Localization and wave propagation in nonlinear random and incommensurate lattices*
Poster 21	Gorka Zamora-Lopez and Tiago Pereira: *Modelling network dynamics: when do collective dynamics reflect the underlying connectivity?*
Poster 22	Stefan Schinkel, Gorka Zamora-Lopez, Olaf Dimigen, Werner Sommer and Jürgen Kurths: *Reconstruction of time-evolving functional brain networks using order patterns*
Poster 23	Yong Zou, Michael Small, Zonghua Liu, Juergen Kurths: *A complex network perspective on the maxima/minima correlations of the solar cycles from time series*
Poster 24	Norbert Marwan, Gorka Zamora-Lopez: *Prof. Jürgen Kurths world of publications*
Poster 25	A. Rheinwalt, N. Marwan, J. Kurths, P. Werner and F.-W. Gerstengarbe: *Boundary effects in network measures of spatially embedded networks*
Poster 26	Nora Molkenthin, Kira Rehfeld, Norbert Marwan, Jürgen Kurths *Networks from Flows – From Dynamics to Topology*
Poster 27	Rajat Karnatak, Ulrike Feudel, Gerrit Ansmann, Klaus Lehnertz *Extreme events in excitable systems: Two coupled units*
Poster 28	Ulrich Parlitz, Hiromichi Suetani, Stefan Luther: *Parameter and state identification using ordinal patterns*

Poster 29 G. Ambika, K. P. Harikrishnan, and R. Misra:
Characterising Hyperchaotic Attractors using nonlinear data analysis

Poster 30 Jakob Runge, J. Heitzig, V. Petoukhov, N. Marwan, and J. Kurths:
Quantifying causality from time series of complex systems

Poster 31 Linda Sommerlade, Malenka Mader, Wolfgang Mader, Jens Timmer and Björn Schelter:
Optimal detection of interactions in nonlinear dynamical systems: A study based on cross-spectral analysis

Poster 32 J. F. Donges, R. V. Donner, M. H. Trauth, N. Marwan, H. J. Schellnhuber, J. Kurths:
Nonlinear detection of paleoclimate-variability transitions possibly related to human evolution

Poster 33 George Balasis, Reik V. Donner, Jonathan F. Donges:
Towards a unified study of extreme events using universality concepts

Poster 34 L.Schaefer, A. Torick, H. Matuschek, M. Holschneider, F. Bittmann:
Synchronization of myofascial oscillations of M. triceps brachii during isometric interaction

Poster 35 A. Torick, L. Schaefer, D. Lehmann, T. Behnke, H. Matuschek, M. Holschneider, F. Bittmann:
Mechanomyography (MMG) – Measuring and data processing – An overview

Poster 36 Gerson Florence, Erich T. Fonoff, Jürgen Kurths, Manoel J. Teixeira, Koichi Sameshima:
A Computational Analysis Concerning the Transition to Different Levels of Neuronal Excitability Induced by Electrical Stimulation

Poster 37 E. J. Ngamga, C. Geier, K. Lehnertz and J. Kurths:
Evaluation of predictive skills of recurrence-based measures of complexity on epileptic EEG recorded data

Poster 38 Hans A. Braun, Aubin Tchaptchet, Christian Finke, Svetlana Postnova, Martin T. Huber:
Determinism, Randomness and the Relations between Neuronal Membrane Potentials, Ion Currents and Ion Channel Dynamics

Poster 39 Veronika Stolbova and Jürgen Kurths:
Analysis of extreme rainfall over the Indian subcontinent: insights from complex networks perspective

Poster 40 Naoki Itoh:
Application of singular spectrum transformation to Kenyan precipitation

Poster 41 Michael Flechsig, Thomas Nocke:
Sensitivity, Uncertainty and Visual Analysis in Climate Sciences

Poster 42 Kira Rehfeld, Bedartha Goswami, Norbert Marwan, Sebastian F.M. Breitenbach, Jürgen Kurths:
Paleoclimate networks: a concept meeting central challenges in the reconstruction of paleoclimate dynamics

Poster 43 Cristina Masoller:
Learning about Interacting Networks in Climate: the LINC project

Poster 44 Milan Paluš:
Nonlinear multiscale dynamics of the atmosphere and climate: Cross-frequency interactions in the air temperature

Poster 45 Peter Read, Alfonso Castrejon-Pita, Irene Moroz, Scott Osprey, Kylash Rajendran:
A Chorus of the Winds: phase-synchronized behavior between atmospheric inter annual and intra-seasonal oscillations

Poster 46 Dörthe Handorf, Klaus Dethloff:
Shortcomings of current climate and Earth system models in reproducing Northern Hemisphere atmospheric teleconnection patterns - A comparison of the CMIP5 and the CMIP3 ensembles

Poster 47 Miguel A. Bermejo and Manfred Mudelsee:
Does Climate Have Heavy Tails?

Poster 48 P. Carl:
Synchronous motions across the instrumental climate record

Poster 49 A. Müller, M. Riedl, J. F. Krämer, T. Penzel, H. Bonnemeier, J. Kurths, N. Wessel:
Steps to a coupling analysis of transient cardiovascular dynamics

Poster 50 P. Van Leeuwen, D. Geue, M. Thiel, S. Lange, D. Cysarz, M.C. Romano, J. Kurths, D. Grönemeyer:
Fetal maternal heart rate entrainment under controlled maternal breathing

Poster 51 J. Gieraltowski, D. Hoyer, U. Schneider, Jan J. Zebrowski:
Fetal development assessed by Multiscale Multifractal Analysis of heart rate variability

Poster 52 Sabrina Camargo, Maik Riedl, Jürgen Kurths, Niels Wessel:
Diminished heart beat nonstationarities in congestive heart failure

Poster 53 Stefan Luther:
Low-energy control of electrical turbulence in the heart

Poster 54 David Hansmann:
IRTG 1740 – Dynamical Phenomena in Complex Networks: Fundamentals and Applications

Abstracts

Complex Systems Modelling for Personalised Medicine

Kazuyuki Aihara

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In this talk, I review our complex systems modelling for personalised medicine. First, we formulate hybrid dynamical systems models for prostate cancer and apply them to personalised diagnosis, opitimal hormone therapy, and prognosis [1–9]. Second, we extend the concept of the conventional biomarkers to that of dynamical networks biomarkers toward detecting early-warning signals for sudden deterioration of complex diseases in a personalised way [10, 11].

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Scales and topology emerge spontaneously from synchronization of adaptive networks

R. Gutierrez, J. Almendral, M. Zanin, A. Amann, D. Papo, V. Latora, S. Assenza, J. Gomez Gardeñes and S. Boccaletti

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Synchronization is a collective phenomenon occurring in systems of interacting units, and is ubiquitous in nature, society and technology. Recent studies have enlightened the important role played by the interaction topology on the emergence of synchronized states. However, most of these studies neglect that real world systems change their interaction patterns in time. Here, we analyze synchronization features in networks in which structural and dynamical features co-evolve. The feedback of the node dynamics on the interaction pattern is ruled by the competition of two mechanisms: homophily (reinforcing those interactions with other correlated units in the graph) and homeostasis (preserving the value of the input strength received by each unit). The competition between these two adaptive principles leads to the emergence of key structural properties observed in real world networks, such as modular and scale-free structures, together with a striking enhancement of local synchronization in systems with no global order.

The complete non-hierarchical cluster analysis to describe climate changes

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Cluster analysis contains several multivariate methods for the separation of patterns (clusters). Definition of the optimum, or globally best, cluster analysis is an unresolved issue. Two methods are of special importance: 1. The statistical security of cluster separation. 2. The definition of the optimal number of clusters. On the basis of nonhierarchical minimum-distance cluster analysis a new method is described that allows a separation of clusters in a statistically well-founded way. Applying this extended nonhierarchical cluster analysis algorithm, the following additional problems need to be solved: The generation of a suitable initial partition, the estimation of the initial number of clusters, and the error reduction by delimitation of the level of significance for cluster separation. The following solutions are proposed: Random ranking of the initial partition, derivation of the cluster number using target function and Pettitt-test, and estimation of outliers including a new classification with the clusters. The complete method is tested and discussed using a theoretical and a practical example. For the practical example, a climate classification of the world and their changes are established which shows that the proposed improvements can be of great practical relevance.

Boolean delay equations, networks and damage propagation

Michael Ghil

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Boolean Delay Equations (BDEs) are semi-discrete dynamical models with Boolean-valued variables that evolve in continuous time. Systems of BDEs can be classified into conservative or dissipative, in a manner that parallels the classification of ordinary or partial differential equations. Solutions to certain conservative BDEs exhibit growth of complexity in time; such BDEs can be seen therefore as metaphors for biological evolution or human history. Dissipative BDEs are structurally stable and exhibit multiple equilibria and limit cycles, as well as more complex, fractal solution sets, such as Devil's staircases and "fractal sunbursts."

BDE systems have been used as highly idealized models of climate change on several time scales, as well as in earthquake modeling and prediction, and in genetics. BDEs with an infinite number of variables on a regular spatial grid have been called partial BDEs" and we discuss connections with other types of discrete dynamical systems, including cellular automata and Boolean networks.

We present recent BDE work on damage propagation in networks, with an emphasis on production-chain models. This formalism turns out to be well adapted to investigating propagation of an initial damage due to a climatic or other natural disaster. We concentrate on two different network structures, periodic and random, respectively; their study allows one to understand the effects of multiple, concurrent production paths, and the role played by the network topology in damage propagation. Applications to the recent network modeling of climate variability are also discussed.

Conductance Fluctuations in Graphene Systems: The Relevance of Classical Dynamics

Lei Ying, Liang Huang, Ying-Cheng Lai, and Celso Grebogi

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Conductance fluctuations associated with transport through quantum-dot systems are currently understood to depend on the nature of the corresponding classical dynamics, i.e., integrable or chaotic. However, we find that in graphene quantum-dot systems, when a magnetic field is present, signatures of classical dynamics can disappear and universal scaling behaviours emerge. In particular, as the Fermi energy or the magnetic flux is varied, both regular oscillations and random fluctuations in the conductance can occur, with alternating transitions between the two. By carrying out a detailed analysis of two types of integrable (hexagonal and square) and one type of chaotic (stadium) graphene dot system, we uncover a universal scaling law among the critical Fermi energy, the critical magnetic flux, and the dot size. We develop a physical theory based on the emergence of edge states and the evolution of Landau levels (as in quantum Hall effect) to understand these experimentally testable behaviours.

From Single Network to Network of Networks

Shlomo Havlin

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Network science have been focused on the properties of a single isolated network that does not interact or depends on other networks. In reality, many real-networks, such as power grid, protein networks, transportation and communication infrastructures interact and depend on each other. I will present a framework for studying the vulnerability of networks of interacting networks. In interdependent networks, when nodes in one network fail, they cause dependent nodes in other networks to also fail. This may happen recursively and can lead to a cascade of failures and to a sudden fragmentation of the system. I will present analytical solutions for the critical threshold and the giant component of a network of n interdependent networks. I will show, that the general theory has many novel features that are not present in classical network theory. Our results for network of n networks suggest that the classical percolation theory extensively studied in physics and mathematics is a limiting case of n=1 of the general theory of percolation in network of networks. while a failure of a fraction of nodes in a single network can lead We also show that interdependent networks embedded in space are significantly more vulnerable compared to random networks.

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Surprises when comparing data based to model based predictions

Stefan Siegert and Holger Kantz

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In this case study, we investigate the predictability of surface temperatures. We compare the output of sophisticated weather models to very simple data based statistical prediction schemes. As it turns out, the choice of the measure for success of such prediction decisively determines conclusions about predictability. Independent of that, data based predictions are not as much outperformed by dynamical weather models as one might expect when considering the difference is effort needed to produce a forecast.

Nonlinear cognitive science

Reinhold Kliegl

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The presentation reviews some of Jürgen Kurth's direct and indirect, linear and nonlinear contributions to various domains of cognitive science such as rhythm production of expert pianists, fixational movements of the eyes, covert shifts of visual attention, and language processing.

Influence of the network topology on epidemic spreading

Ljupco Kocarev

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The influence of the network's structure on the dynamics of spreading processes has been extensively studied in the last decade. Important results that partially answer this question show a weak connection between the macroscopic behavior of these processes and specific structural properties in the network, such as the largest eigenvalue of a topology relatedmatrix. However, little is known about the direct influence of the network topology on the microscopic level, such as the influence of the (neighboring) network on the probability of a particular node's infection. To answer this question, we derive both an upper and a lower bound for the probability that a particular node is infective in a susceptible-infective-susceptible model for two cases of spreading processes: reactive and contact processes.

Applications of Nonlinear Dynamics to Spintronics: STNOs and Microwave Generation

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Spintronics is a fast emerging field of nanotechnology where giant magnetoresistance (GMR) effect plays a pivotal role. Spin tansfer nano oscillators (STNOs) are fascinating entities based on GMR where the flow of spin polarized current perpendicular to thin ferromagnetic layers can induce the magnetization of the free layer either to switch its direction very fast (<200 ps) or make it to precess at GHz range, leading to potential applications in computer discs and microwave devices. The underlying dynamics is governed by the so called Landau-Lifshitz-Gilbert- Slonczewski equation for the spin, which is a patently nonlinear dynamical equation. Then the theory of synchronization and networks central to nonlinear dynamics play a major role towards development in designing potential devices based on STNOs. I will briefly review these theoretical developments in my talk.

Nonlinear dynamics and complex networks in epilepsy

Klaus Lehnertz

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Epilepsy is a complex malfunction of the brain that affects approximately 1% of the world's population. Epileptic seizures are the cardinal symptom of this multi-facetted disease and are usually characterized by an overly synchronized firing of neurons. Seizures cannot be controlled by any available therapy in about 25% of individuals, and knowledge about mechanisms underlying generation, spread, and termination of the extreme event seizure in humans is still fragmentary. Over the last decades, an improved characterization of the spatial-temporal dynamics of the epileptic process could be achieved with tools from nonlinear dynamics, statistical physics, synchronization and network theory. I will summarize these research findings that already have opened promising directions for the development of new therapeutic possibilities.

Isochronal Synchronization in Complex Network with Propagation Delay

Elbert E. N. Macau

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Isochronal synchronization is a unique phenomenon in which physically distant oscillators wired together relax into zero-lag synchronous behavior over time. Such behavior is observed in natural processes and, recently, has been considered for promising applications in communication. Towards technological development of devices that explore isochronal sync, stability issues of the phenomenon need to be considered, both in the context of a pair or a network of coupled oscillators. This study concerns such stability issues by using the Lyapunov-Krasovskii theorem to propose a framework to study synchronization stability by using accessible parameters of the network coupling setup. As a result, relations between stability and network parameters are unveiled and the comprehension of roads leading to stability is enhanced.

Sequential activity in neuronal networks

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Complex activity in neuronal networks can be represented as sequential transition between complicated metastable states. From dynamical systems theory point of view sequential activity in neuronal networks is associated with existence of stable heteroclinic contours in phase space of corresponding neuronal model. Before, conditions of existence and stability of these contours are studied in networks of only inhibitory synaptically coupled cells. In this paper the effect of excitatory neurons are studied. Conditions of existence of metastable states and sequential dynamics arising are presented.

Reconstructing oscillator networks from multivariate data

Björn Kralemann, Michael Rosenblum, Zoran Levnajic, Arkady Pikovsky

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We discuss recently developed approaches to reconstruction of the coupling structure in oscillator networks from data. Preprocessing, embeding, phase reconstruction, determining its dynamics also under phase resettings, and the final decomposition of coupling functions in forcing and phase response are the stages of the method.

Ribosome traffic dynamics in gene expression regulation

Maria Carmen Romano

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I will present an overview of different aspects of ribosome traffic dynamics and how they determine gene expression regulation. Ribosome traffic is described in terms of a paradigmatic non-equilibrium statistical physics model. This theory is then applied to the entire set of messenger RNA molecules of yeast, and important consequences can be drawn on the relationship between traffic dynamics and the biological function of the encoding proteins. Moreover, translation can be considered as a global process since the entire set of mRNAs in the cell share the same pool of resouces (tRNAs and ribosomes). A model for this sharing of resources will also be presented and the consequences for protein production will be discussed.

Why do newborn neutron stars rotate so slowly? Magnetic instabilities in the laboratory

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Newborn neutron stars and the cores of red giant stars rotate much slower than they should after the results of numerical simulations if no extra angular momentum transport is included. Obviously, there is a sort of eddy viscosity exceeding the microscopic one by a factor of about 500 which we assume as due to the instability of large-scale internal toroidal magnetic fields. Under the presence of nonuniform rotation all radial profiles of toroidal fields are found as unstable against nonaxisymmetric perturbations. Recent MHD Taylor-Couette flow experiments with fluid metals demonstrate the existence of kink-type instabilities for i) too strong uniform elec- tric currents (TI, Tayler Instability) and ii) too strong current-free (!) fields together with hydrodynamically stable differential rotation (AMRI, Azimuthal MagnetoRotational Instability). With the gallium alloy GaInSn as the conducting fluid the electric currents must exceed 2.8 kAmp to realize the TI in a resting column while minimum 10 kAmp are necessary for AMRI with a differential rotation close to the Rayleigh limit. The calculated turbulent viscosities for AMRI are much higher than for TI so that any initial differential rotation must decay and the the stellar cores will finally rotate rigidly – as it is also known from the Sun.

Stochastic Models for Active Particles

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I consider self-propelled particles under the influence of noise, a concept which was called “active Brownian motion”. First, I discuss the influence of active fluctuations, as independent stochastic processes in the direction of motion and velocity. Such description leads to an accumulation of probability at vanishing speed values. Secondly, effects of correlations in the noise and of scattering boundaries on the motion of the active particles are investigated. I present transport properties as the mean flux and the diffusion coefficient in different situations, e.g., overdamped, or with intertia, or with constant speed, and affected by additional torques etc. Furthermore, we consider interacting active Brownian agents. I focus on the problem how the onset of collective motion depends on the choice of the specific noise. Special attention is paid for the occurring large scaled spatial structures of chemotactically interacting Brownian agents.

Unpopular Essays of Jürgen Kurths: Practicalities and Predictability

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Prediction is difficult, and predicting the predictability of imperfectly known nonlinear systems triply so. Early work on the predictability of predictability is reexamined in light of recent developments; kernels of today's advances are found in early papers of Juergen Kurths. Insights from two of these papers, neither among his most popular, are reflected upon along with their predictably unpopular attributes. In 1950, Bertrand Russell published a book entitled "Unpopular Essays." After suggesting in the preface of another book that the material was of interest to the general public, Russell had been taken to task by reviewers who found the material difficult; the title of his new book effectively avoided the charge that he considered those essays "popular." Indexes to judge whether or not a modern scientific article is popular abound; in terms of such indexes the two articles considered do not rank that highly amongst their brethren; nevertheless they are shown to be interesting in a number of ways. Framing predictability through the decay of information clarifies variability in forecast skill and can aid in the design of a probabilistic forecast system. An information theoretic context may provide a popular handle on predictability, clarifying and reducing the challenges of using forecasts in risk management, challenges considered explicitly over a decade ago.

A complete dynamical systems based model of the peripheral auditory system

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Sound triggers basilar membrane oscillations in the inner ear that then are picked up by the inner hair cells (IHC). Auditory nerve neurons (ANN) transduce this information into spikes, usable by the central nervous system. We reveal the physics principles underlying this transduction. A surprisingly simple, robust and efficient computational system is revealed that artfully employs stochastic resonance to arrive at the correct psychophysical pitch sensation.

The Heart of/in Physics

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In this contribution we introduce recently developed nonlinear methods of cardiovascular physics and show their applicability to clinically relevant questions. The first part of the work describes the methods of cardiovascular physics, especially the data analysis and modeling of non-invasively measured biosignals, with the aim to improve clinical diagnostics and to improve the understanding of cardiovascular regulation. The main advantage of our methods is their potential to replace or compliment invasive diagnostic procedures by improved and cost saving non-invasive diagnostic tools. Applications of our data analysis and modeling tools are various and outlined in the second part of this contribution: monitoring-, diagnosis-, course and mortality prognoses as well as early detection of heart diseases. We show, that our data analyses and modeling methods lead to significant improvements in different medical fields. Patients as well as the whole society would benefit from a rapid use of these potentials in clinical practice.

Coupling, Synchronization and Noise in AGNLD

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AGNLD has always specialized in the study of very different applications of Systems Science in biology or medicine. Following this approach I will discuss suprising dynamics of genetic circuits and molecular biology systems based on nontrivial interplay between coupling, noise and a response to the external signalling.

Quantitative analysis and modeling of interacting human activities

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Human interactions underlie almost all social and economic events. The use of advanced communication and information technology allows precise recording of the times of interacting human activities and provides unprecedented opportunity to uncover universal patterns and to reveal underlying mechanisms through quantitative and modeling. In this talk, I will show some universal patterns in the inter-event times in interacting human activities including mobile phone short message (SMs) communication and the collaborative editing history of articles in Wikipedia. For SMs, it is found that active users form a pair of communicators who send the majority of messages to each other, and the interevent time displays a bimodal distribution with a power-law head and an exponential tail. Such a bimodal distribution also features the article editing in Wikipedia when the growing rate of the number of users or number of edits can be regarded as constant within short periods of time. However, over long time, typically the number of users and the number of events grow exponentially till saturation. The distribution of interevent time follows a universal double power-law form. This regular pattern is insensitive to the articles content, length and lasting time.

We propose to decompose collective human activities into several generic modules related to individual behavior, interaction and the growth of interacting population. Individual behavior is characterized by random initiation of activity and passive response to others with a power-law distribution of waiting time and the interaction is modeled by a cascading process. We show analytically that these two ingredients will lead to a bimodal distribution of a power-law head and an exponential tail. Integrating with the exponential growth of interacting population will result in a formula describing a double power-law distribution, with a universal exponent -2 at the tail. Strikingly, our model analysis is fully supported by empirical data from short messages and Wikipedia. For more than 600 Wikipedia articles we analyzed, the same formula can fit to the data of each article with a parameter estimated from the growing rate of the number of submits of the article.

Characterising Hyperchaotic Attractors using nonlinear data analysis

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Most of the complex systems can be understood and their complexity characterized by nonlinear analysis of the observational data of a few variables. Such studies are helpful to detect nontrivial structures and characterize them for a proper understanding of the underlying dynamics. In this talk, we present a recently proposed algorithmic scheme for correlation dimension analysis of hyper chaotic attractors. We show that the transition to hyper chaos is sudden and can be characterized using the discontinuous changes in the correlation dimension (D2) of the attractor. At the transition, the attractor breaks up into large number of local clusters combined together to form the global attractor. As a consequence, the attractor displays two scaling regions in the hyper chaotic phase, one representing the local scaling within the clusters and the other representing the inter-cluster scaling for the global attractor, with a cross over regime in between. Further confirmation of our results is provided by computing the spectrum of Lyapunov Exponents (LE). This is illustrated for two well known hyper chaotic flows and two standard time delayed hyper chaotic systems.

The Andronov – Hopf bifurcation in a system of two phase oscillators with asymmetrical repulsive coupling.

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We consider the phase reduction of two coupled van der Pol oscillators with asymmetric repulsive coupling under external harmonic force. We show that the system of phase oscillators possesses multistability and demonstrates a Hopf bifurcation on a 2π-periodic phase plane. We show the bifurcation mechanisms of multistability formation in the phase-reduced system which can lead to the coexistence of three synchronization regimes in the non-reduced system. Also we compare our results with the non-reduced system of van der Pol oscillators and show that the bifurcations found in the reduced system take place in the non-reduced one.

Towards a unified study of extreme events using universality concepts

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The dynamics of many complex systems is characterized by the same universal principles. In particular, systems which are otherwise quite different in nature show striking similarities in their behavior near tipping points (bifurcations, phase transitions, sudden regime shifts) and associated extreme events. Such critical phenomena are frequently found in diverse fields such as climate, seismology, or financial markets. Notably, the observed similarities include a high degree of organization, persistent behavior, and accelerated energy release, which are common to (among others) phenomena related to geomagnetic variability of the terrestrial magnetosphere (intense magnetic storms), seismic activity (electromagnetic emissions prior to earthquakes), solar-terrestrial physics (solar flares), neurophysiology (epileptic seizures), and socioeconomic systems (stock market crashes).

It is an open question whether the spatial and temporal complexity associated with extreme events arises from the system structural organization (geometry) or from the chaotic behavior inherent to the nonlinear equations governing the dynamics of these phenomena. On the one hand, the presence of scaling laws associated with earthquakes and geomagnetic disturbances suggests understanding these events as generalized phase transitions similar to nucleation and critical phenomena in thermal and magnetic systems. On the other hand, because of the structural organization of the systems (e.g., as complex networks) the associated spatial geometry and/or topology of interactions plays a fundamental role in the emergence of extreme events.

Here, a few aspects of the interplay between geometry and dynamics (critical phase transitions) that could result in the emergence of extreme events, which is an open problem, will be discussed.

Does Climate Have Heavy Tails?

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When we speak about a distribution with heavy tails, we are referring to the probability of the existence of extreme values will be relatively large. Several heavy-tail models are constructed from Poisson processes, which are the most tractable models. Among such processes, one of the most important are the Lévy processes, which are those process with independent, stationary increments and stochastic continuity. If the random component of a climate process that generates the data exhibits a heavy-tail distribution, and if that fact is ignored by assuming a finite-variance distribution, then there would be serious consequences (in the form, e.g., of bias) for the analysis of extreme values. Yet, it appears that it is an open question to what extent and degree climate data exhibit heavy-tail phenomena.

We present a study about the statistical inference in the presence of heavy-tail distribution. In particular, we explore (1) the estimation of tail index of the marginal distribution using several estimation techniques (e.g., Hill estimator, Pickands estimator) and (2) the power of hypothesis tests. The performance of the different methods are compared using artificial time-series by means of Monte Carlo experiments.

We have systematically applied the heavy tail inference to observed climate data, in particular we have focused on time series data. We have worked with several climate variables from the Holocene epoch.

Marine bioinvasion in the network of global shipping connections

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Transportation networks play a crucial role for the spread of invasive species. Here, we combine the network of world-wide cargo ship movements with environmental conditions and biogeography, to develop a model for marine bioinvasion. We classify marine ecoregions according to their total invasion risk and the diversity of their invasion sources. Our predictions agree with observations in the field and reveal that invasion risks are highest for intermediate geographic distances. Our findings suggest that network-based invasion models facilitate the development of targeted mitigation strategies.

Determinism, Randomness and the Relations between Neuronal Membrane Potentials, Ion Currents and Ion Channel Dynamics

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A Hodgkin-Huxley type modeling approach has been used to examine the relations of membrane potentials and ion currents to lower functional levels of ion channel dynamics. This study demonstrates that determinism only exists as a statistical measure. Already the steady-state voltage-dependencies of ion current activation, modeled as a combination of exponential transition rates, Boltzman functions or in any other form, imply physiological randomness of ion channel opening and closing. The randomness behind these curves may be called Şstatic randomnessŤ because the corresponding values could only be reached after an infinite long time or, alternatively, with an infinite high number of ion channels. Hence, in all real situations, uncertainty remains. The real values will continuously fluctuate also under steady state conditions. This Şdynamic randomnessŤ is unavoidable - in principle.

Separation of static and dynamic randomness of neural functions into deterministic and a noise terms is statistics. In reality, the underlying mechanisms are the same, namely ion channels opening and closing probabilities. Indeed, the ion channel transitions are following physiological laws – but these are probabilistic. Moreover, the dynamic component significantly changes depending on the static values. In the extremes of ion channel activation the random fluctuations may almost diminish while they increase towards the functionally relevant range of neural dynamics. Hence, basic functions of life seem to be tuned into randomness.

We will show that such ion channel "noise" does not necessarily smear out at higher functional levels but can dramatically blow up in the neighborhood of biologically relevant bifurcations. Possible functional roles of these particular properties of ion channels randomness will be illustrated and we will discuss how the interdependencies between static and dynamic components can be considered in neuron models in a physiologically appropriate way.

Major parts of the simulations to which we refer have been implemented as applets to "SimNeuron", one of the "Virtual Physiology" teaching tools for life science education (http://www.virtual-physiology.com).

Diminished heart beat nonstationarities in congestive heart failure

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It has been a long time since studies on heart rate variability (HRV) have become as popular as the many devices available to record the cardiac activity. HRV refers to heart beating signal itself as well to the time between consecutive heart beatings. As reported in literature, several diseases and conditions, as myocardial infarction, diabetic neuropathy, and myocardial disfunction, for example, are related to decreasing HRV, pointing to a connection between healthiness and complexity. Also, the effects of aging are known to present higher HRV in younger individuals, compared to elderly ones. The possibility on diagnosis based on noninvasive techniques such as HRV studies compels us to overcome the difficulties originated on the environmental changes that can affect the signal, eventually pointing out to a false disruption of the dynamics or leading to neglect a real one. Spectral analysis, for example, rely on the assumption of stationarity, but even in controlled environments, it is questionable whether the efficiency of such control ensures stable conditions.

We analyze data for 15 patients with congestive heart failure (CHF; 11 males, 4 females, age 56 ± 11 years), 15 elderly healthy subjects (EH; 10 males, 5 females, age 50 ± 9 years), and 18 young healthy subjects (YH; 13 females, 5 males, age 34 ± 8 years). By finding stationary segments we are able to analyze the size of these segments and evaluate how the signal changes from one segment to another, looking at the statistical moments given in each patch, for example, mean and variance, in what we can call the intrinsic time scale of the signal. Our results show higher variance for YH, and EH, while CHF displays diminished variance with p-values < 0.01 when compared to the healthy groups, confirming higher HRV in healthy subjects. Also, the results give the portray of the nonstationarities of the groups, and we detail the analysis in the way that it can be applied to other physiological rhythms, providing the distributions of the local moments in highly nonstationary data.

A General Circulation Model en route to chaos

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Chaotic behaviour of truncated atmospheric transport equations bears conceptual grounds in weather predictability, and low-order models of the El Niño–Southern Oscillation system show chaotic motions as well. The gap to General Circulation Models (GCMs), with their substantially higher number of degrees of freedom, has been bridged in conceptual studies using a coarse spatial resolution, but temporally and physically resolved, tropospheric GCM. Despite of its coarse numerical grid, the model shows difficult-to-obtain intraseasonal dynamics of the global boreal summer monsoon system and its regional branches, in a qualitatively and quantitatively reasonable manner.

Cross sections throughout the season of the GCM's attractor set hint at an inverse route to chaos of the major active-break monsoon cycle. This is best visible in variables closely related to global integrals of motion. The model organizes these dynamics via synchronized planetary waves with low rational frequency relationships. Extensive attractor soundings unveil a distinct climatic subregime of the seasonal cycle, borne in topological changes between bifurcations in spring and autumn. Abrupt monsoon onset may be traced back to a subcritical Hopf bifurcation in spring, bearing hard transition into a July regime of chaotic oscillations. As the season advances, the GCM's monsoon activity cycle calms down via period-two and period-one into a wrinkling torus segment, before these motions cease to exist. For a short period after this structural monsoon retreat, a slow irregular wander is found between unstable fixpoints of the summer and winter circulation. These slow dynamics show essential features of the Southern Oscillation.

Computational stability problems notwithstanding, the poster summarizes the GCM's "geometry of behaviour" and its observational analogues, and offers conclusions with a view on climate sensitivity, variability, and change. The present-day 'monsoon climate' on Earth and its 'dynamical status' are introduced as conceptions to supplement the debate on climatic change and its mitigation by the missing aspect of qualitative dynamics, and to emphasize the structural role of the hydrological cycle. Potential routes of climatic evolution are addressed.

Synchronous motions across the instrumental climate record

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The dynamical status of the climate system and of its elaborated General Circulation Models (GCMs) is largely unknown. This poses challenges when grasping the system's past evolution and/or evaluating forecasts of its future. Complex, evolving modal structures may emerge under multiple cyclic forcing in a feedback system with rich oscillatory capabilities. That a small GCM shows a route to planetary-scale chaos, calls for clarification of the role that low-dimensional dynamics may play in the real climate system.

Such type behaviour cannot arise without internal synchronizations which should be detectable from representative time series. Here, the adaptive Matching Pursuit (MP) approach to sparse time series approximation has been chosen. A large, overcomplete dictionary is used that is exclusively made of a very flexible analyzing wavelet, the frequency-modulated (FM) Gabor atom ('Gaussian logon'). The poster summarizes an exploratory, univariate study, illustrates the system's traverse through different dynamic regimes, and synthesizes externally and internally synchronized multivariate motions of different spatial scales.

Among the types of synchrony at global scale, phase-frequency ('interdomain') coalitions dominate, showing frequency drift of one (leading) MP-FM mode in parallel to the phase evolution of another one. Contemporary methods of data analysis in climate research do not uncover this sort of synchronous motion. Further types of organized dynamics include phase and envelope synchronies, common frequency drift or FM, temporary captures in the time domain, and complex, combined synchronizations. One might thus speak of an organized climate system which shows substantial hints at low-dimensional behaviour.

Predictability, waiting times and tipping points in the climate

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It is taken for granted that the limited predictability in the initial value problem, the weather prediction, and the predictability of the statistics are two distinct problems. Predictability of the first kind in a chaotic dynamical system is limited due to critical dependence on initial conditions. Predictability of the second kind is possible in an ergodic system, where either the dynamics is known and the phase space attractor can be characterized by simulation or the system can be observed for such long times that the statistics can be obtained from temporal averaging, assuming that the attractor does not change in time. For the climate system the distinction between predictability of the first and the second kind is fuzzy. On the one hand, weather prediction is not related to the inverse of the Lyapunov exponent of the system, determined by the much shorter times in the turbulent boundary layer. These time scales are effectively averaged on the time scales of the flow in the free atmosphere. On the other hand, turning to climate change predictions, the time scales on which the system is considered quasi-stationary, such that the statistics can be predicted as a function of an external parameter, say atmospheric CO2, is still short in comparison to slow oceanic dynamics. On these time scales the state of these slow variables still depends on the initial conditions. This fuzzy distinction between predictability of the first and of the second kind is related to the lack of scale separation between fast and slow components of the climate system.

The non-linear nature of the problem furthermore opens the possibility of multiple attractors, or multiple quasi-steady states. As the paleoclimatic record shows, the climate has been jumping between different quasi-stationary climates. The question is: Can such tipping points be predicted? This is a new kind of predictability (the third kind).

In a series of papers, some co-authored by Professor Kurths, the Dansgaard-Oeschger climate events observed in ice core records are analyzed in order to answer some of these questions. The result of the analysis points to a fundamental limitation in predictability of the third kind.

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Nonlinear detection of paleoclimate-variability transitions possibly related to human evolution

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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 pro- cesses 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 during the (i) Mid-Pliocene (3.35-3.15 Ma BP (before present)), (ii) Early Pleistocene (2.25-1.6 Ma BP), and (iii) Mid-Pleistocene (1.1-0.7 Ma BP). A deeper examination of these transition periods reveals potential climatic drivers, including (i) large-scale changes in ocean currents due to a spatial shift of the Indonesian throughflow in combination with an intensification of Northern Hemisphere glaciation, (ii) a global reorganization of the atmospheric Walker circulation induced in the tropical Pacific and Indian Ocean, and (iii) shifts in the dominating temporal variability pattern of glacial activity during the Mid-Pleistocene, respectively. 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.

A complex network perspective for time series analysis of dynamical systems

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In the last years, several approaches have been proposed for studying properties of dynamical systems represented by time series by means of complex network methods. Recently, two main concepts have attracted particular interest: recurrence networks and visibility graphs. This contribution presents a thorough review of the state of the art of both approaches, with a special emphasis on what kind of information about a dynamical system can be inferred from its adjoint network representations. On the one hand, recurrence networks are based on the mutual proximity of sampled state vectors in the (possibly reconstructed) phase space of a dynamical system under study. Their local as well as global properties have been proven to characterize important structural aspects of the underlying attractors. Specifically, the emergence of scale-free degree distributions highlights the presence of power-law singularities of the invariant densities, whereas the transitivity properties are related to a novel notion of fractal dimension of the system. Successful and relevant real-world applications particularly include the identification of dynamical transitions in observational time series. On the other hand, visibility graphs and related concepts characterize stochastic properties of a system such as its Hurst exponent or the absence of time-reversal symmetry indicating nonlinearity of the observed process. The potentials and possible methodological problems of both approaches are highlighted and illustrated based on some real-world geoscientific time series.

Convection patterns in a spherical fluid shell under microgravity conditions

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This work is motivated by the GeoFlow experiment, which is performed under microgravity conditions at the International Space Station. A fluid confined in a spherical shell is heated from within by a constant temperature difference and driven by buoyancy due to an central force field which is generated by a dielectrophoretic mechanism. The experiment seek to investigate thermal convection for both rotating and non-rotating spheres.

In order to predict and identify observable patterns symmetry-breaking bifurcations have been studied by simulations together with applications of path-following techniques and stability computations. The investigations confirm that multistability is a typical feature in spherical shell convection both for the rotating and non-rotating situation. Particular attention is payed to study the spatio-temporal features of the solutions, consecutive bifurcations and the route to chaos.

Extreme events in excitable systems: Two coupled units

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Networks of excitable elements of FitzHugh Nagumo type exhibit high amplitude events which are recurrent on large time scales. To understand the mechanism of the generation of such so-called extreme events we study two diffusively coupled, non-identical FitzHugh Nagumo models. These rare spikes are found for a parameter range where the coupled system is chaotic. This chaotic dynamics consists of small subthreshold oscillations with irregular spikes immersed. Possible mechanisms behind this "extreme" behavior of the system are discussed.

Sensitivity, Uncertainty and Visual Analysis in Climate Sciences

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Model development and application as well as data analysis and integration are main methodologies in climate research. On the one hand, in recent years, increasing computer resources have advanced the evaluation of model results and their uncertainty and sensitivity quantification due to the variability of model factors. Simulation environments are adequate tools to cope with this challenge. The poster describes a multi-run environment for multi input/output models that comes with a model interface. Pre-defined experiment types are based on probabilistic, Bayesian, and deterministic sampling of factor spaces and allow for flexible experimentation of analysis afterwards.

On the other hand, visualization has established as a flexible tool to analyze Earth system data. In this context, this poster introduces techniques and tools for a visual analysis of large, heterogeneous climate data, incorporating visualization examples for ensemble simulations and climate networks.

A Computational Analysis Concerning the Transition to Different Levels of Neuronal Excitability Induced by Electrical Stimulation

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The neuronal electrical activity can be changed by an abnormal raise of cellular excitability, which happens in some neurological disorders. In Parkinson's disease (PD), the discharge pattern of subthalamic nucleus presents a mixed burst-firing mode. In epilepsy, there is a paroxysmal depolarizing shift - high amplitude of depolarization, 20-40mV, with 50-200ms duration that triggers a burst of spikes. Another activity is the spreading depression (SD). SD is characterized by shifting the cellular membrane potential near to zero. In experimental studies, the electrical stimulation (ES) have been applied to induce neuronal activity or to disrupt these patterns. However, the underlying mechanisms of the transition to these oscillatory patterns are not completely understood. To study these phenomena, we simulated a model of the hippocampal region CA1. The computational simulations using different amplitude levels of ES showed three stages of neuronal excitability: 1) burst-firing mode – the ES triggered a sequence of action potentials (AP's). The AP's leaded to a continuous growth of extracellular potassium concentration ([K+]o). Then, the continuous growth of [K+]o provoked depression of K+ currents. The ES and depressed K+ currents kept the membrane potential in a high level, impairing the cellular repolarization process; 2) depolarization block – with the raise of ES, there was an unbalance between the excitatory and inhibitory currents. In this case, the depressed K+ currents caused by high [K+]o could not reduce the level of membrane potential after each AP in opposition to Na+ currents. Herewith, a new spike would initiate earlier (increasing the AP frequency) when the K+ conductance was still high (decreasing the AP amplitude). This process continued until the AP inactivation in around -34mV when Hopf bifurcation has occurred; 3) SD wave – this wave was induced by the reduction of Na-K pump activity. The transition to SD kept some similarities with the depolarization block. There was an AP inactivation by Hopf bifurcation. However, after the AP inactivation process, the Na+ currents overcame the K+ currents, producing a positive net current which would slowly depolarize the membrane potential from ~ -34mV near to zero. During this process, the SD is maintained by a positive feedback between increasing $[K+]_o$ and membrane depolarization. Thus, this analysis suggests that the increase of neuronal excitability changes the dynamics of neuronal activity, producing abnormal oscillatory patterns. Understanding this process would help to improve the DBS techniques to control different kinds of neurological disorders.FAPESP 2011/21138-5

Fetal development assessed by Multiscale Multifractal Analysis of heart rate variability

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Objectives: Very low frequencies (VLF) and ultra low frequencies (ULF) components of human heart rate variability (HRV) account for 95 % of signal total power but their physiological background is still very uncertain. The main difficulty lies in the lack of appropriate analysis methods for such low frequencies bands better than the basic power spectral analysis. Fractal methods such as DFA or MF-DFA have been used to characterize the frequencies below the LF band also regarding fetal heart rate variability [1].

Methods: We applied a new method, the Multiscale Multifractal Analysis (MMA) [2], an extension of MF-DFA in which the Hurst surface is calculated. The method is designed to analyze correlation properties at such low frequencies. We analyzed 158, 30 minute magnetocardiographic HRV recordings from fetuses 21–38 weeks of age. To analyze such short data sets using MMA, we introduced an overlapping sliding window of analysis and limited the range of the scales considered. We distinguish a quiet and an active state of the fetus (related to the developing behavioral states of quiet and active sleep) irrespective of age and also distinguish young (gestational age <29) and old (>34 week) fetuses. For every single series, we calculated the Hurst surface, which represents the properties of the scaling of heart rate fluctuations, depending on their magnitude and frequency range. To show the development stages of HRV in VLF, we calculated a contour plot showing correlations between the Hurst surface and the gestational age.

Results: A significant difference between the properties of the HRV of the young fetuses and the older ones is well visible and in agreement with [3]. We chose the most significant areas of the Hurst surface (highly correlated with age) and assessed the changes of their mean values statistically.

Conclusions: When introduced, the MMA method [2] required at least a 104 RR interval long series. We modified it and obtained a tool allowing to analyze the 4000 RR interval long fetal data (30 min) [4]. For adults that means that the requirement for data length is now slightly over 1 h. We observed a difference between the results for small amplitude fluctuations in the signal and for large amplitude fluctuations as well as differences for different scale ranges. In addition, using the results of statistical analysis of Hurst surfaces for the whole group studied, we obtained a linear statistical model which explains about 50 % of the variability of the correlation of the local Hurst exponent as a function of gestation age. Note that MMA is designed as a tool for the analysis of frequencies below the LF band of HRV.

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Shortcomings of current climate and Earth system models in reproducing Northern Hemisphere atmospheric teleconnection patterns – A comparison of the CMIP5 and the CMIP3 ensembles

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This paper evaluates the ability of current climate and Earth system models to reproduce the low-frequency variability of the mid-tropospheric winter flow of the Northern Hemisphere in terms of atmospheric teleconnection patterns. Therefore, multi-model simulations for present day conditions from the CMIP3 and CMIP5 ensembles have been analysed and compared with reanalysis data sets. The spatial patterns of atmospheric teleconnections are reproduced reasonably by most of the models for both ensembles. For the CMIP5 ensemble comprising models with higher spatial resolution, only slight improvements of the reproduction of the spatial patterns of atmospheric teleconnections have been estimated. The comparison of coupled with atmosphere-only runs confirmed that a better representation of the forcing by sea surface temperatures has the potential to slightly improve the representation of only wave train-like patterns. Due to internally generated climate variability, the models are not able to reproduce the observed temporal behaviour. Insights into the dynamical reasons for the limited skill of climate models in reproducing teleconnections have been obtained by studying the relation between major teleconnections and zonal wind variability patterns. About half of the models are able to reproduce the observed relationship. For these cases, the quality of simulated teleconnection patterns is largely determined by the quality of zonal wind variability patterns. Therefore, improvements of simulated interactions between baroclinic eddies and planetary waves have the potential to improve the atmospheric teleconnections.

Extreme multistability in coupled oscillator

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An extreme kind of multistability, where the number of coexisting attractors is infinite, has been reported in a coupled system by Sun et al. [1]. A particular choice of the coupling plays the key role. The coupling needed to obtain this extreme kind of multistability is rather unusual. It has been shown that the reason for the emergence of infinitely many attractors lies in the appearance of a conserved quantity in the long-term limit [1, 2]. In particular cases, this conserved quantity can be considered as a unique emergent parameter which governs the dynamics of the system in the long-term limit and, hence, allows for a reduction of the dimension of the system. However, in these studies of extreme multistability in coupled systems, it was not possible to find a systematic definition of the coupling type. In example systems, such as the Lorenz system or the coupled chemical oscillators, the coupling was particularly chosen to create an infinity of attractors. The question arises if there is a general principle of designing the coupling, leading to infinitely many attractors in coupled systems.

In this presentation, we address the issue of finding a general principle of defining the coupling for extreme multistability. The coupling is defined [3] in a systematic way by using the principle of partial synchronization based on the Lyapunov function stability. The method is very general in its applicability to any dynamical system and allows many alternative design options. As a result, it provides flexibility in the physical realization of extreme multistability in dynamical systems. This phenomenon is also found to be robust with respect to parameter mismatch. The result is recently extended to network of oscillators.

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Application of singular spectrum transformation to Kenyan precipitation

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In this presentation we propose a new method of change-point detection, a technique of finding an abrupt structural and dynamical change in a time series, by extending singular spectrum transformation (SST) (Id'e et al. 2005) and then monthly Kenyan precipitations, as a climate data analysis on East Africa, are analysed by using this method. SST has been developed based on singular spectrum analysis (SSA) that is defined as a nonparametric method (Elsner et al., 1996 and Golyandina et al., 2001). SSA can orthogonally decompose a time series into several representative components, such as trends, harmonics, and noise. Although the conventional SST estimated the change-point scores of the only most dominant component extracted from the time series our extended method can do all the representative components respectively. In the application the detected change points of the precipitations compare with variations in Indian Ocean Dipole (IOD) (Saji et al. 1999) influencing rainfall in East Africa. As a result, we can find that the change points of the precipitations coincide with the behaviour of the IOD.

Localization and wave propagation in nonlinear random and incommensurate lattices

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Localization of oscillations and halt of wave propagation due to spatial inhomogeniety is a fundamental phenomenon of wave physics that crucially affects charge, light, and matter transport in a variety of structured systems. Originally proposed to explain metal-insulator transition, it has recently been found to shape light propagation in waveguide arrays and dynamics of ultra-cold gases in optical lattices. While the linear case either for pure disordered lattices or for bichromatic potentials is comprehencively studied, yielding, respectively, Anderson or Aubry-Andre localization of eigenmodes, the effect of nonlinearity is far from being understood well yet.Numerical experiments demonstrated subdiffusive wave propagation in case the nonlinearity is pronounced. However, it left the problem open, what happens in the weak nonlinearity limit (also attained when the wave packet has substantially expanded and its energy density become low), raising deep and intricate questions of persistence, measure, and localization properties of KAM trajectories. To solve the problem we developed the perturbation theory for localized periodic and quasiperiodic orbits and, deriving the necessary conditions for existence, demonstrated that the localization may be broken by arbitrarily small but finite nonlinearity with finite probability. This probability grows linearly with the nonlinearity strength and becomes 1 after a certain threshold. We now confirmed the validity of these results for random and incommensurate lattices showing that the nonlinearity does restore wave transport in localizing media.

Cluster Explosive Synchronization in a Power Grid model

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The emergence of explosive synchronization has been reported as an abrupt transition in complex networks of first-order Kuramoto oscillators. In this Letter, we demonstrate that the nodes in a power grid model, equivalent to a second-order Kuramoto model, demonstrate a cascade of transitions toward a synchronous macroscopic state, a novel phenomenon that we call cluster explosive synchronization. We provide a rigorous analytical treatment using a mean-field method in uncorrelated networks.

Our findings are in good agreement with numerical simulations and fundamentally deepen the understanding of microscopic mechanisms toward synchronization.

Low-energy control of electrical turbulence in the heart

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Controlling the complex spatial-temporal dynamics underlying life-threatening cardiac arrhythmias such as fibrillation is extremely difficult, because of the nonlinear interaction of excitation waves in a heterogeneous anatomical substrate. In the absence of a better strategy, strong, globally resetting electrical shocks remain the only reliable treatment for cardiac fibrillation. Here we establish the relationship between the response of the tissue to an electric field and the spatial distribution of heterogeneities in the scale-free coronary vascular structure. We show that in response to a pulsed electric field, E, these heterogeneities serve as nucleation sites for the generation of intramural electrical waves with a source density $\rho(E)$ and a characteristic time, τ, for tissue depolarization that obeys the power law $\rho \propto E^{\alpha}$. These intramural wave sources permit targeting of electrical turbulence near the cores of the vortices of electrical activity that drive complex fibrillatory dynamics. We show in vitro that simultaneous and direct access to multiple vortex cores results in rapid synchronization of cardiac tissue and therefore, efficient termination of fibrillation. Using this control strategy, we demonstrate low-energy termination of fibrillation in vivo. Our results give new insights into the mechanisms and dynamics underlying the control of spatial-temporal chaos in heterogeneous excitable media and provide new research perspectives towards alternative, life-saving low-energy defibrillation techniques.

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Steps to a coupling analysis of transient cardiovascular dynamics

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The analysis of effects from coupling in and between systems is important in data driven investigations as practiced in many scientific fields. It allows deeper insights into the mechanisms of interaction emerging among individual smaller systems when forming complex systems as in the human circulatory system. For systems featuring various regimes usually only the epochs before and after a transition between different regimes are analysed, although relevant information might be hidden within these transitions. Transient behaviour of cardiovascular variables may emerge on the one hand from the recovery of the system after a severe disturbance or on the other hand from adaptive behaviour throughout changes of states. It contains important information about the processes involved and the relations between state variables like heart rate, blood pressure and respiration. Therefore, the analysis of time-dependant couplings during these transient epochs is an important current research problem. Hence it is essential to extend existing coupling measures for a time-variant coupling analysis. We use multiple realizations of time dependant dynamics in order to estimate existing coupling measures not over the time domain of one time series but over several realizations of the same system at a certain time point. This allows for an analysis of coupling behaviour even on very short time scales which cannot be done by using e.g. windowed methods. This method can be applied to almost any existing coupling measure, permitting us to use the scope of nonlinear, multivariate measures already developed. We chose the method of Symbolic Coupling Traces (SCT) for a first test of the ensemble method. Besides using model data we applied the method to stationary stages of a polysomnographic data set as well as to ECG and blood pressure data of several subjects during an orthostatic test. The aim of this analysis is to get new insights about the short-term nonlinear cardiovascular regulation and to better predict potential health risks.

Confined Flows Synchronization and Control in Thermo-Convective Systems.

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We will present in this poster some results obtained in experiments and numerical simulations performed to synchronize/control time-dependent (chaotic) thermo-convective structures.

Prof. Jürgen Kurths world of publications

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We present the co-authorship network of Juergen Kurth's publications.

Learning about Interacting Networks in Climate: the LINC project

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Improving our understanding of the Earth's complex climate phenomena, such as El Niño/Southern Oscillation, has a huge economic and social impact for present and future generations, and can underpin advances in areas as diverse as energy, environment, agricultural and marine sciences. Given the complexity of the interrelations between the subsystems that constitute our climate, it is important to approach the problem from an interdisciplinary perspective. However, there is a great shortage of qualified workforce to perform this task, and a major challenge is the education and training of young researchers that can approach climate phenomena from a complex systems perspective. This requires knowledge from several disciplines such as physics, dynamical systems and computer science, and also requires a good understanding of Earth sciences such as climatology and oceanography.

The Initial Training Network LINC, 'Learning about Interacting Networks in Climate' (funded by the EU FP7 Marie Curie program) aims to address these issues by training 12 early stage researchers (ESRs) and 3 young experienced researchers (ERs) in the complete set of skills required to undertake a career in physics and geosciences with expertise in climatology, networks and complex systems. The training program combines recent advances in network methodologies with state-of-the-art climate understanding.

The LINC consortium, comprising 6 academic partners and 3 SMEs, has expertise in complex systems (network construction, nonlinear time series analysis), environment and geosciences (nonlinear processes in the oceans and atmosphere) and applications (climate risk analysis, extreme events, etc).

The research training is organized in five work packages. In WP1 (Network Construction and Analysis), by assuming that climate phenomena can be represented in terms of networks (where nodes represent geographical areas and links represent couplings between their dynamics), the goal is to identify the backbone of the Earth's climate network at different time scales. In WP2 (Interacting Networks) the goal is to understand how changes in the different networks representing sub-systems composing the Earth's climate can cause inter-related dynamical changes in the other sub-systems. For WP3 (Natural Climate Variability) the goal is to understand changes in climate network properties in terms of the physics of low-frequency climate variability. To accomplish this, idealized climate models (for which the mechanisms of natural variability are known), results from General Circulation Models (GCMs), and observations will be used. The aim in WP4 (Future Climate Change) will be to study the climate networks using data bases from state-of-the-art models, to understand the main physical processes that characterize these networks, project future changes and (if possible) provide uncertainty estimates for near term climate changes. Methodologies to detect signatures of abrupt change in past climate and to identify warning signals of the closeness to future tipping points are very data-demanding, and it is not clear whether they will detect critical changes early enough. In WP5 (Tipping Points in the Climate System) the goal is to explore innovative network approaches in climatology, which have great potential to detect critical changes due to their inherent data-integrative nature.

In LINC the training of researchers will be aided by secondments at the SME partners, a series of schools, workshops, and a final conference. The second school (open to all participants) will take place in The Netherlands in April 2013. Please visit the LINC web page (climatelinc.eu) for more information.

Granular packing and complex networks

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The compaction of a tapped granular media is an ancient problem with scientific and applied interest. The fundamental properties of this kind of systems are its packing fraction and stress. Both magnitudes are subtly related by its topological properties. In this work, we analyze the complexity of the contact network behind this topology. Tuning the force threshold that determines which contacts define the network, the topology and the motif distribution (the different types of polygonal structures) are analyzed. The characterization of the structural features thus obtained, may be useful in the understanding of the macroscopic physical behaviour exhibited by this class of situation.

How Basin Stability Complements the Linear-Stability Paradigm

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The human brain, power grids, arrays of coupled lasers and the Amazon rainforest are all characterized by multistability. The likelihood that these systems will remain in the most desirable of their many stable states depends on their stability against significant perturbations, particularly in a state space populated by undesirable states. Here we claim that the traditional linearization-based approach to stability is too local to adequately assess how stable a state is. Instead, we quantify it in terms of basin stability, a new measure related to the volume of the basin of attraction. Basin stability is non-local, nonlinear and easily applicable, even to high-dimensional systems. It provides a long-sought-after explanation for the surprisingly regular topologies of neural networks and power grids, which have eluded theoretical description based solely on linear stability. We anticipate that basin stability will provide a powerful tool for complex systems studies, including the assessment of multistable climatic tipping elements.

Networks from Flows – From Dynamics to Topology

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We define a continuous analogue of the Pearson correlation in order to compute networks in a bottom-up approach directly from simple stationary flows using the fluiddynamical advection-diffusion-equation. We solved this for the case of a homogeneous and circular flow as well as an approximation for general flows and compare the resulting networks to time series networks of the equatorial counter current.

Evaluation of predictive skills of recurrence-based measures of complexity on epileptic EEG recorded data

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EEG data from seven epilepsy patients undergoing presurgical evaluation of drug-resistant epilepsy are analyzed using some recurrence time based and recurrence based network measures of complexity. Investigation on the capability of these measures of complexity to distinguish interictal periods from some assumed preictal ones are performed. When comparing the distributions of values of the considered measures of complexity for interictal and preictal periods, the Kolmogorov-Smirnov tests performed at three significance levels show that both distributions achieve significant different values for certain measures. A uniform behavior of the measures of complexity which holds for all the seizures and for all the patients has not been observed.

Nonlinear multiscale dynamics of the atmosphere and climate: Cross-frequency interactions in the air temperature

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The complex dynamics of the Earth atmosphere and climate evolve on a wide range of temporal and spatial scales. Analyses of the low-frequency variability on seasonal to decadal time scales have led to detection of oscillatory phenomena possibly possessing a nonlinear origin and exhibiting phase synchronization between oscillatory modes extracted either from different types of climate-related data or data recorded at different locations on the Earth [1-4]. We study nonlinear interactions between dynamics on different temporal scales in about a century long records of daily mean surface air temperature from various European locations using conditional mutual information together with the Fourier-transform and multifractal surrogate data methods [5]. Information transfer from larger to smaller scales has been observed as the influence of the phase of slow oscillatory phenomena with periods around 6-11 years on amplitudes of the variability characterized by smaller temporal scales from a few months to 4-5 years. The overall effect of the slow oscillations on the inter-annual temperature changes within the range 1-2 K has been observed in large areas of Europe.

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Parameter and state identification using ordinal patterns

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The frequency of occurrence of ordinal patterns in an observed (or measured) times series can be used to identify possible generating dynamical system. We demonstrate this approach for system identification and parameter estimation for dynamics that can (at least approximately) be described by one-dimensional iterated maps (obtained by means of nonlinear dimension reduction methods [1], for example).

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Synchronization in an ensemble of spatially moving oscillators

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We study synchronization in an ensemble of oscillators residing in a finite 2-dimensional space. Both phase and real oscillators are considered. The interaction between the oscillators is governed by their spatial movement. The coupling is unidirectional and is of the intermediate kind, with the spatial vision of each oscillator deciding the number of oscillators it is coupled to. We also analyze how the extent of synchronization, characterized by the order-parameter, depends upon the system parameters such as: spatial vision, spatial motion, and strength of the coupling.

A Chorus of the Winds: phase-synchronized behavior between atmospheric inter annual and intra-seasonal oscillations

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A combination of singular systems analysis and analytic phase techniques are used to investigate the possible occurrence in observations of coherent synchronization between inter annual (quasi-biennial) and intra-seasonal oscillations in the Earth's stratosphere and troposphere. Time series of observed zonal mean zonal winds near the Equator (and at other latitudes) are analysed over periods of up to 50 years and compared with current (CMIP5) comprehensive model simulations of the climate system. Clear but intermittent synchronization is found, for example, between stratospheric and tropospheric quasi-biennial oscillations and components of the seasonal cycle and semi-annual oscillations in observations, though less clearly in climate model simulations. We are also exploring simplified models of these interactions to elucidate the dynamical mechanisms that underly them, and to suggest directions for improving climate models.

Paleoclimate networks: a concept meeting central challenges in the reconstruction of paleoclimate dynamics

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Statistical analysis of dependencies amongst paleoclimate data helps to infer on the climatic processes they reflect. Three key challenges have to be addressed, however: the datasets are heterogeneous in time (i) and space (ii), and furthermore time itself is a variable that needs to be reconstructed, which (iii) introduces additional uncertainties.

To address these issues in a flexible way we developed the paleoclimate network framework, inspired by the increasing application of complex networks in climate research. Nodes in the paleoclimate network represent a paleoclimate archive, and an associated time series. Links between these nodes are assigned, if these time series are significantly similar. Therefore, the base of the paleoclimate network is formed by linear and nonlinear estimators for Pearson correlation, mutual information and event synchronization, which quantify similarity from irregularly sampled time series. Age uncertainties are propagated into the final network analysis using time series ensembles which reflect the uncertainty. We discuss how spatial heterogeneity influences the results obtained from network measures, and demonstrate the power of the approach by inferring teleconnection variability of the Asian summer monsoon for the past 1000 years.

Boundary effects in network measures of spatially embedded networks

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In studies of spatially confined networks, network measures can lead to false conclusions since most measures are boundary-affected. This is especially the case if boundaries are artificial and not inherent in the underlying system of interest (e.g. borders of countries). An analytical estimation of emphboundary effects is not trivial due to the complexity of measures. The straightforward approach we propose here is to use surrogate networks that provide estimates of boundary effects in graph statistics. This is achieved by using spatially embedded random networks as surrogates that have approximately the same link probability as a function of spatial link lengths. The potential of our approach is demonstrated for an analysis of spatial patterns in characteristics of regional climate networks. As an example networks derived from daily rainfall data and restricted to the region of Germany are considered.

Quantifying causality from time series of complex systems

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While it is an important problem to identify the existence of causal associations from multivariate time series it is even more important to assess the strength of their association in a meaningful way. Mutual information (MI) and transfer entropy (TE) are commonly used, but how meaningful are they? Our alternative: Momentary Information Transfer (MIT).

Population firing rate in networks with degree correlations

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We discuss the spike emission rates in assortative or degree-correlated neuronal networks. The network is split into populations of neurons according to their input-degree. Based on earlier mean-field theory, we derive the coupled equations for population firing rates, which allow for a self-consistent solution. Results are compared to extensive numerical simulations.

Synchronization of myofascial oscillations of M. triceps brachii during isometric interaction

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1. Introduction Various investigations using Mechanomyography (MMG) indicate, that muscles oscillate with a frequency of about 10 Hz. [1][2][3][4] But what happens with myofascial oscillations, if neuromuscular systems interact? On the basis of a case study, it is considered, whether the MMG-signals of two interacting persons are related to each other. It is hypothesized, that the neuromuscular systems are able to a mutual synchronization. In order to analyze the interaction, algorithms of nonlinear dynamics are used.

2. Methods Two male sport students (age: 24 and 23 years; body height: 180 cm, weight: 77 and 69 kg) were sitting opposite, but shifted in a way, so that the vertically positioned forearms were directly towards each other. The angles between leg and trunk, arm and trunk and the elbow angle measured 90ř. The subjects were connected through an interface proximal of the ulnar styloid process. Amongst others, the muscle oscillations of the here considered lateral head of the triceps brachii muscle were recorded using piezoelectric MMG-sensors (model: Shadow SH 4001). The subjects should perform four measurements, maintaining an isometric status at 80% MVC of the weaker subject for 15 s. The MMG-signals were analyzed concerning their interaction with algorithms of nonlinear dynamics: Cross-Wavelet- and Coherence-Analysis on the base of Continuous Wavelet Transform (CWT).

3. Results The analysis of single MMG-signals (PSD, CWT) shows, that – also during interaction – both neuromuscular systems oscillate in the known range of frequency (here around 12 Hz). The Coherence-Analysis of the MMGs of both subjects towards each other indicates a significant coherent behavior (Îś = .05) over the whole isometric status of ≈ 17 s in the known band of frequency. The Cross-Wavelet-Analysis shows, that this coherent behavior takes place with a phase shift of approximately 90 degree. These analyses reveal that both subjects are able to adjust their oscillations against each other.

4.Discussion The results indicate that the complementary neuromuscular partners potentially have the ability of mutual synchronization of their myofascial oscillations. Such a complementary system of two interacting oscillating systems requires high sensorimotor functionality of the involved neuromuscular systems. The 90ř phase shift suggests that there could be a leader-follower-mode between both subjects during isometric interaction.

The described phenomenon for this pair of subjects was reproducible over all four measurements. Thus – for the presented case example – the hypothesis can be accepted in principle: Two neuromuscular systems are able to synchronize their myofascial oscillations during interaction.

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Reconstruction of time-evolving functional brain networks using order patterns

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Complex networks provide an excellent framework for studying the function of the human brain activity. Yet estimating functional networks from measured signals is not trivial, especially if the data is non-stationary and noisy as it is often the case with physiological recordings. We propose a method that uses the local rank structure to partition the data and to define functional links in terms of identical rank structures. The method yields temporal sequences of networks which permits to trace the evolution of the functional connectivity during the time course of the observation. We demonstrate the potentials of this approach with experimental data from an electrophysiological studies on language processing.

Detecting spatiotemporal patterns in excitable media using node communities

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The dynamics of excitable media are known to exhibit pattern-formation processes such as spiral waves or spatiotemporal chaos. Node community detection employing a network of sensors is used to identify regions of different (transient) dynamics. The application of the algorithm to simulated data and to data obtained in optical-mapping-experiments of dog hearts is demonstrated.

Reference:

U. Parlitz, A. Schlemmer, S. Luther, *Phys. Rev. E* **83**, 057201 (2011).

Controlling bistability by linear augmentation

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We present a method to drive a bistable system to a desired target attractor by annihilating the another attractor by linear augmentation of the nonlinear oscillator. For a proper choice of the control function one of the attractor disappears at a critical coupling strength in an control-induced boundary crisis. This transition from bistability to monostability is demonstrated with two paradigmatic examples, the autonomous Chua oscillator and a neuronal system with periodic input signal.

Optimization based state and parameter estimation employing automatic differentiation

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An optimization based state and parameter estimation method is presented where the required Jacobian matrix of the cost function is computed via automatic differentiation. Automatic differentiation evaluates the programming code of the cost function and provides exact values of the derivatives. In contrast to numerical differentiation it is not suffering from approximation errors and compared to symbolic differentiation it is more convenient to use, because no closed analytic expressions are required. Furthermore, we demonstrate how to generalize the parameter estimation scheme to delay differential equations, where estimating the delay time requires attention.

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Supermodels: Dynamically Coupled Ensembles of Imperfect Models

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In the super modeling approach, imperfect models are combined into a single super model by either introducing connection terms in the dynamical equations allowing the models to synchronize on a single solution or by integrating the ensemble weighted-mean equations. Connnection strengths or weights are learned on the basis of a set of observations of the true system. Here we show the benefits of this approach in the context of an atmospheric model describing realistic large-scale extra-tropical atmospheric circulation variations.

Optimal detection of interactions in nonlinear dynamical systems: A study based on cross-spectral analysis

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Analysis of nonlinear dynamical systems and their interaction has gained particular interest in the past years. To this aim often linear methods such as cross-spectral analysis are applied. A crucial parameter in cross-spectral estimation is the choice of a spectral smoothing window. In order to establish an asymptotically consistent estimator, certain assumptions on the smoothing window have to be fulfilled. Under these assumptions, analytical significance levels can be derived. Especially narrow band signals, which are slowly mixing, show the importance of the time scale of mixing properties when choosing the parameters. In case the asymptotic is not reached, false positive conclusions may be drawn. For example, a significant coherence may be obtained when analyzing uncoupled sys-

tems. We present an example of two Rössler systems to uncover the relation of the choice of parameters in spectral estimation and the mixing properties of the system on the results obtained. A data driven method to choose the parameters for spectral estimation optimally is introduced. We complete our investigation with an application to nonlinear Parkinsonian tremor signals. In particular we analyze electroencephalogram (EEG) and electromyogram (EMG) data.

Analysis of extreme rainfall over the Indian subcontinent: networks perspective

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Indian monsoon is a large scale pattern in the climate system of the Earth. The motivation of our work was to reveal spatial structures in strong precipitation over the Indian subcontinent and their evolution during the year because it is crucial as for understanding of monsoon regularities as well for India's agriculture and economy. We present an analysis of extreme rainfall over the Indian peninsular and Sri Lanka. Using the method of event synchronization we constructed networks of extreme rainfalls (higher than the 90-th percentile quantile of rainfall events) during the Indian summer monsoon (ISM, June – September), Northeast monsoon (NEM, October – December, so called winter monsoon) and period before summer monsoon (January – May). Obtained networks show how extreme rainfalls for given area in India are synchronized with extreme rainfalls for other areas in India. Analysis of degree centrality of the networks reveals areas (clusters) with extreme rainfalls in India that are strongly connected with maximal number of other areas with extreme rainfalls (e.g. North Pakistan, Eastern Ghats). Additionally, betweenness centrality shows areas that are important in the sense of water transport in the networks (e.g. Himalayas, Western Ghats, Eastern Ghats etc.). By comparison of networks before summer monsoon, during summer and winter monsoons we determined how spatial patterns of rainfalls synchronization change during the year. These changes play a crucial role in the organization of the rainfall all over the Indian subcontinent.

Neuronal dynamics in a network of subnetworks

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Dynamics of neuronal networks have been studied for many years. Recently, it has been found that neuronal networks exhibit modular structures. In this work, we will discuss the dynamics of a neuronal network of subgraphs, and investigate the effects of coupling terms on burst synchronization. Moreover, we will also discuss the effects of noise on such a neuronal network.

Mechanomyography (MMG) – Measuring and data processing – An overview

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Any kind of muscle contraction has an oscillative component (Barry, 1987). An increasing interest in exploring this phenomenon is noticeable in an increasing amount of research. Considering the complexity of neurophysiological mechanisms underlying the spatial and temporal coordination of hundreds or thousands of motor units, it is expectable that measuring and analyzing the muscle oscillations will provide us with knowledge about the functionality and disorders of the neuromuscular system (McAuley & Marsden, 2000). The mechanomyography (MMG) is a mechanical physiological method to measure and analyze these oscillation patterns. The measurement systems consist of MMG sensor with amplifier, AD converter and a PC with the measurement and analysis software. Piezoelectric microphones and accelerator sensors are most used as MMG sensors to measure the muscle oscillations. In addition to known methods, such as the fast Fourier transformation (FFT), the continuous wavelet transformation (CWT) is increasingly used to analyze the frequency spectrums of the MMG signals. The wavelet transform has proven to be suitable for the analysis of non-stationary processes (Maraun, Kurths, & Holschneider, 2007; Schaefli, Maraun, & Holschneider, 2007). This non-stationarity might be caused by the modication of extrinsic parameters of the experiment as well as unobserved variations of intrinsic process parameters during the time period of the experiment. In contrast to the Fourier spectrum, which has no time-resolution at all, the wavelet transformation allows to quantify changes in the spectral properties of the process over time.

This overview shows the potential of MMG and CWT as tools to measure and understand neurophysiologic mechanisms and also neuromuscular disorders. Based on the CWT it is expected, that it will be possible to differentiate the kind and localization of degenerative changes.

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Fetal maternal heart rate entrainment under controlled maternal breathing

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There is evidence that, during pregnancy, fetal and maternal cardiac activity may coordinate over short periods of time. Aim of this work was to investigate whether controlled paced maternal respiration has an effect on the occurrence of fetal-maternal heart rate synchronization. In 6 healthy pregnant women (34th – 40th week of gestation) we obtained simultaneous 5 min. fetal and maternal magnetocardiograms (MCG) at maternal respiration rates of 10, 12, 15 and 20 cpm as well as under spontaneous breathing. Fetal and maternal RR interval time series were constructed for each MCG data set and synchrograms were obtained using the stroboscopic technique. Synchronization epochs (SE) >10 s were identified in these original data. Furthermore, "twin surrogate" data sets of the maternal MCG were constructed, combined with the fetal MCG data and SE were identified in these surrogate data. In the original data, there was a higher number of SE found at 20 cpm respiratory rate compared to other rates. This was not evident in the surrogate data. Fewer SE were found at lower rates (10 cpm) both in the original and surrogate data. Examination of the phase of fetal R peaks relative to maternal RR cycles showed that in the original data there was a clear phase preference in the 20 cpm data. This preference was not found in the surrogate data. These results were reproduced on the basis of a mathematical model incorporating the essential elements of fetal and maternal heart rates and their variability. We conclude that fetal-maternal heart rate entrainment may be induced by high maternal respiratory rates and that chance fetal-maternal heart rate coordination may be inhibited by low maternal respiratory rates.

Patterns in lattices of delay coupled neurons

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Coherence resonance and stochastic synchronization in a nonlinear circuit near a subcritical Hopf bifurcation

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We analyze noise-induced phenomena in dynamical systems near a subcritical Hopf bifurcation. We investigate qualitative transformations of probability distributions (stochastic bifurcations), coherence resonance-like effect and stochastic synchronization. These effects are found and studied in different dynamical systems for which subcritical Hopf bifurcation occurs. The investigations are carried out by means of analytical calculations, numerical simulations and experiments on electronic circuits. For the Duffing-Van der Pol model we uncover the similarities between the behavior of a self-sustained oscillator characterized by subcritical Hopf bifurcation and an excitable system. The analogy is manifested through coherence resonance-like effect and stochastic synchronization. In particular, we show both experimentally and numerically that stochastic oscillations that appear due to noise in a system with hard excitation, can be partially synchronized even outside the oscillatory region of the deterministic system.

Modelling network dynamics: when do collective dynamics reflect the underlying connectivity?

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The synchronization phenomena in networks of oscillators is a highly exploited topic of research. Most of works have aimed at determining how the synchronizability of the system depends on the topology of the underlying network. A hidden assumption, that is often taken for granted, is that the dynamical behaviour of the system reflects the network topology. We show that this assumption is in general not true and only holds for restricted choices for the oscillator and for the coupling function. One consequence of this result is that prediction of the network topology out of functional connectivity data is only possible under particular mathematical constraints.

A complex network perspective on the maxima/minima correlations of the solar cycles from time series

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We unveil a novel perspective on the long term correlations of the solar cycles by means of constructing visibility graphs, which are a special kind of complex networks, from both daily and monthly sunspot series. It is shown that the long term variation is reflected by extra large sunspots corresponding to hubs in the network which span large time intervals. The degree distribution of the derived network has clear non-Gaussian properties. Furthermore, we propose to construct the network by a negatively inverse transformed series, and the degree distribution is bimodal, clearly distinguishing the strong minima from maxima. The persistence range of the solar cycles has been identified over 15-1000 days by a power law regime of the occurrence time of two subsequent strong minima, in contrast, the persistence is not present in the maximal numbers although maxima have significant deviations from an exponential form. Our results suggest some new insights for further developing the current solar dynamo theory and evaluating existing models.

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