Nonlinear Network Dynamics: Complexity and Control

Conference on the Occasion of the 75th Birthday of Eckehard Schöll

Berlin, 4–6 May 2026

DOOCN-XVII Dynamics On and Of Complex Networks Conference Series

Conference Booklet

Venue	Hermann-von-Helmholtz Auditorium of the Berlin Institute of the Physikalisch-Technische Bundesanstalt (PTB, National Metrology Institute), Abbestrasse 2-12, 10587 Berlin
Website	https://doocn.org/

Venue: Hermann-von-Helmholtz Building, PTB Berlin

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Sponsors

Physikalisch-Technische Bundesanstalt
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Berlin Center for Studies of Complex Chemical Systems
Germany

Conference overview

Aim and scope

The DOOCN workshop series explores nonlinear dynamics on and of complex networks. The 2026 meeting focuses on cooperative phenomena on networks, including spreading, diffusion, and synchronization, as well as complex collective behavior in networks of oscillators, typically composed of many subsystems like photons, cells, neurons, and other interacting subsystems. Topics in the present program range from socioeconomics and climate, power-grid stability, and synchronization phenomena to network physiology, brain dynamics, laser dynamics, and artificial intelligence/reservoir computing. **The conference is organized on the occasion of the 75th birthday of Eckehard Schöll who is a pioneer in the field.**

Organizing Committee

Simona Olmi (Chair), ISC-CNR, Florence, Italy	Roland Aust, Berlin, Germany
Fenja Drauschke, FU Berlin, Germany	Johanne Hizanidis, FORTH, Crete, Greece
Philipp Hövel, ZBP, Saarbrücken, Germany	Kathy Lüdge, TU Ilmenau, Germany
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Serhiy Yanchuk, UCC, Cork, Ireland	Dan Zhao, PIK, Potsdam, Germany

Practical notes

Venue: Hermann-von-Helmholtz Auditorium, PTB Berlin, Abbestrasse 2-12, 10587 Berlin..

- All times are in Central European Summer Time (CEST).
- Talk duration: 25 minutes + 5 minutes Q&A.
- Lunch: Culinary Circus, Abbestr. 2-12, 10587 Berlin, or Mensa TU Marchstr.23 (MAR)

Site Plan of Conference Venue

Scientific program overview

Time	Monday, 04/05/2026	Tuesday, 05/05/2026	Wednesday, 06/05/2026
08:45–09:00	Opening		
09:00–09:30	Jürgen Kurths	Plamen Ch. Ivanov	Cristina Masoller
09:30–10:00	Natasa Djurdjevac Conrad	Igor Franović	Arkady Pikovsky
10:00–10:30	Serhiy Yanchuk	Willian Trevizan Fred Costa	Hildegard Meyer-Ortmanns
10:30–11:00	Jens Christian Claussen	Ulrich Parlitz	Marc Timme
11:00–11:30	Coffee break	Coffee break	Coffee break
11:30–12:00	Cornelia Denz	Svetlana Gurevich	Peter Tass
12:00–12:30	Christian Beck	Philipp Hövel	Alessandro Torcini
12:30–13:00	Dirk Witthaut	Andreas Amann	Closing
13:00–14:00	Lunch	Lunch	Lunch
14:00–14:30	Rene Lozi	Theo Geisel	
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15:00–15:30	Yong Xu	Klaus Obermayer	
15:30–16:00	Michael Rosenblum	Yuliya Kyrychko	
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16:30–17:00	Aneta Koseska	Karoline Wiesner	
17:00–17:30	Ulrike Feudel	Jun Jiang	
17:30–18:00	Fakhteh Ghanbarnejad	Vitaly Belik	
18:00–18:30	Bernold Fiedler		
18:30–19:00			
19:00–20:00	Poster Session	Eckehard Schöll: Personal Remarks	
20:00–21:00			

Session color legend: Socioeconomics and climate; **Power grids**; **Synchronization of networks**; **Network physiology**; **Laser dynamics and delay**; **Brain dynamics**; **Artificial intelligence/reservoir computing**

Detailed program

Monday, 04 May 2026

Time	Speaker	Title
08:45–09:00	Opening	Simona Olmi, Eckehard Schöll, and Cornelia Denz
09:00–09:30	Jürgen Kurths	Climate Tipping Points and Extreme Events: On their Formation and Forecasting
09:30–10:00	Natasa Djurdjevac Conrad	Co-evolving Networks for Opinion and Social Dynamics in Agent-Based Models
10:00–10:30	Serhiy Yanchuk	Tipping in an adaptive climate network model
10:30–11:00	Jens Christian Claussen	Cyclic coevolutionary dynamics: from stochasticity to control
11:00–11:30	Coffee break	Coffee break
11:30–12:00	Cornelia Denz	Nonlinear networks metrology: from electricity grids to sensor networks
12:00–12:30	Christian Beck	Power grid stability: From the Kuramoto model with inertia and noise to realistic measurements
12:30–13:00	Dirk Witthaut	Synchronization and Multistability via Convex Optimization
13:00–14:00	Lunch	Lunch
14:00–14:30	Rene Lozi	Peculiarities of the spatio-temporal dynamics of a Hénon–Lozi map network in the presence of Lévy noise
14:30–15:00	Jin Yan	Coherence and Transients in Coupled Map Lattices
15:00–15:30	Yong Xu	Stochastic-resonance and coherence-resonance chimeras in coupled neurons with α-stable Lévy noise
15:30–16:00	Michael Rosenblum	Second-order Kuramoto-Sakaguchi model: what can it explain?
16:00–16:30	Coffee break	Coffee break
16:30–17:00	Aneta Koseska	Processing information with ghost scaffolds

17:00–17:30	Ulrike Feudel	The constructive role of transient chaos in complex systems
17:30–18:00	Fakhteh Ghanbarnejad	Infectious Diseases and Mobility Reshape Stability in Three-Level Food Chains
18:00–18:30	Bernold Fiedler	Classical Kuramoto oscillators: global dynamics
19:00–21:00	Poster Session	

Tuesday, 05 May 2026

Time	Speaker	Title
09:00–09:30	Plamen Ch. Ivanov	The new field of Network Physiology: Building the Human Physiolome
09:30–10:00	Igor Franović	Coherence-incoherence patterns in nonlocally coupled excitable systems
10:00–10:30	Willian Trevizan Fred Costa	External synchronization of cellular rhythms by electromagnetic fields can selectively target cancer cells
10:30–11:00	Ulrich Parlitz	Transient chaos and fibrillation in cardiac excitable media
11:00–11:30	Coffee break	Coffee break
11:30–12:00	Svetlana Gurevich	Multistable Kuramoto splay states and coherent pulse interactions in mode-locked semiconductor lasers
12:00–12:30	Philipp Hövel	Do you remember? Latency effects in time-delay feedback control of chaos
12:30–13:00	Andreas Amann	Lasing Modes in Open Multisection Lasers
13:00–14:00	Lunch	Lunch
14:00–14:30	Theo Geisel	Timeseries Analysis for Empirical Musicology
14:30–15:00	Deniz Eroğlu	Reconstructing Brain Network Dynamics: Predicting and Preventing Malfunctions
15:00–15:30	Klaus Obermayer	Computational Models of Adaptation-driven Slow Oscillations
15:30–16:00	Yuliya Kyrychko	From Gut to Brain: Modelling Microbiota-Driven Neuroinflammation in Alzheimer’s Disease
16:00–16:30	Coffee break	Coffee break
16:30–17:00	Karoline Wiesner	Nonlinear Dynamics of Deep Learning: Phase Transitions and Landscape Geometry in Neural Networks

17:00–17:30	Jun Jiang	Understanding global structure of nonlinear dynamical systems by approach of state space discretization and deep learning
17:30–18:00	Vitaly Belik	Inferring transmissibility of new variants of respiratory viruses using human mobility data
18:30–21:00	Eckehard Schöll	Personal Remarks / Social event - Get together with food and drinks

Wednesday, 06 May 2026

Time	Speaker	Title
09:00–09:30	Cristina Masoller	Synchronization transitions in networks of Hodgkin–Huxley neurons
09:30–10:00	Arkady Pikovsky	Coherence properties of global modes in oscillatory networks
10:00–10:30	Hildegard Meyer-Ortmanns	Metastable dynamics in oscillatory systems from deterministic equations
10:30–11:00	Marc Timme	Tipping to Failure? – Strongly Perturbed Nonlinear Network Dynamics
11:00–11:30	Coffee break	Coffee break
11:30–12:00	Peter Tass	Vibrotactile Coordinated Reset Fingertip Stimulation for the Treatment of Parkinson's Disease
12:00–12:30	Alessandro Torcini	A theory for self-sustained balanced states in absence of strong external currents
12:30–13:00	Closing	
13:00–14:00	Lunch	Lunch

Abstracts of invited talks

Andreas Amann

University College Cork, Ireland

Lasing Modes in Open Multisection Lasers

12:30–13:00 • Tuesday, 05 May 2026

We develop a one-dimensional formalism to describe stationary lasing modes in the case of mutliple coupled cavities, which can be either active or absorbing. Importantly, we allow the modes to radiate to infinity. Our formalism translates the electromagnetic modes onto curves on the Riemann sphere. Each section of the curve is associated with a section of a "loxodrome", which is mathematically defined as Möbius transformation of a logarithmic spiral. The individual loxodromes are concatenated to a continuous curve, which starts and finishes at two special points on the Riemann sphere corresponding to left and right moving plane waves, respectively. The interpretation of the lasing modes in this fashion provides a useful tool for the intuitive understanding of lasing modes. This allows us to conveniently explore the energy transfer between individual sections, as well as the overall output of the laser.

[1] CPJ O'Connor, S Wieczorek, A Amann Phys. Rev. A 107, 053520 (2023).

Christian Beck

Queen Mary University of London, UK

Power grid stability: From the Kuramoto model with inertia and noise to realistic measurements

12:00–12:30 • Monday, 04 May 2026

The Kuramoto model with inertia and noise is a beautiful theoretical model to theoretically study different possible synchronization states of power grids with a given network structure, see e.g. [1]. However, the question remains what type of noise and complex behaviour is actually observed in real power grids. In this talk I will present recent results for measured frequency signals that are based on real-time measurements in power grids in the UK, Europe, and South Africa [2,3,4]. A spectrum of highly complex non-Gaussian stochastic processes is seen for the tiny deviations of the frequency from the mean 50Hz, as well as for the fluctuations of the phase angle dynamics. The stochastic signal is influenced by trading on the energy markets [2], by fluctuations in the electricity consumption processes [3], by fluctuations of renewable energy generation and by control processes [4]. I will talk about suitable superstatistical modelling approaches to understand this complexity.

References

[1] L. Tumash, S. Olmi, and E. Schoell, Effect of disorder and noise in shaping the dynamics of power grids, EPL 123, 20001 (2018)

[2] B. Schaefer, C. Beck, K. Aihara, D. Witthaut, M. Timme, Non-Gaussian power grid frequency fluctuations characterized by Lévy-stable laws and superstatistics, Nature Energy 3, 119 (2018)

[3] M. Anvari, E. Proedrou, B. Schaefer, C. Beck, H. Kantz, and M. Timme, Data-driven load profiles and the dynamics of residential electricity consumption, Nature Commun. 13, 4593 (2022)

[4] X. Wen, U. Oberhofer, L. Rydin Gorjao, C. Beck, V. Hagenmeyer, and B. Schaefer, Analyzing deterministic and stochastic influences on the power grid frequency dynamics with explainable artificial intelligence, Chaos 35, 033153 (2025)

Vitaly Belik

Freie Universität Berlin, Germany

Inferring transmissibility of new variants of respiratory viruses using human mobility data

10:30–11:00 • Monday, 04 May 2026

Large-scale GPS traces from 1%L of the German population allow us to observe where people are moving and who comes close to whom. By counting how many phones end up in the same 8 m × 8 m square for at least two minutes, we can build a “contact index” (Ct) [1] that tells us how often people are in contact each day. We matched this contact index to the effective reproduction number (Rt) of SARS-CoV-2 – the average number of people that one infected person will infect – using a Bayesian model. The model adds a small lag (about 2–3 weeks) to Ct to account for the virus’s incubation period and reporting delays, and a trend term that captures other factors that affect spread, in particular, the emergence of new variants, and the effect of vaccination. Estimated averaged delays were: 17 days (wild type), 15.5 (Alpha), 16.5 (Delta), 14 (Omicron). We found that Alpha, Delta and Omicron variants had 29%, 63% and 108% increased fitness (transmissibility) than wild-type respectively. A full primary vaccination program cut transmissibility by about 246 % compared with natural immunity alone. Thus the contact-index approach can detect a more transmissible strain long before genomic sequencing reports it. The method only needs mobile phone data and the existing surveillance pipeline, so it can be adapted to other countries, even low-and middle-income countries where sequencing capacity is limited. In short, monitoring how often people come into contact can serve as a low-cost, rapid methods to detect changes in viral spread and to evaluate the impact of vaccines or other interventions.

[1] Rüdiger et al. (2021) PNAS https://doi.org/10.1073/pnas.2026731118

Jens Christian Claussen

University of Birmingham, UK

Cyclic coevolutionary dynamics: from stochasticity to control

10:30–11:00 • Monday, 04 May 2026

Coevolutionary dynamics is conveniently based on a game-theoretic dilemma situation which could reflect socio-economic interactions as well as biological interactions, including mutualisms, exclusion, dominance, and cyclic dominance eventually supporting coexistence. In finite populations, any model of the (2 or more players) interaction comprises a stochastic process leading to Fokker-Planck equations - and in the infinite population size limit - replicator (differential) equations of various types. Stability of their coexistence fixed points is lost at a critical population size through a drift-reversal scenario. Hence coexistence, or diversity can be supported by a sufficiently large population size, as well as by spatial and networked interactions. It alternatively can also be enforced by feedback control. Finally, we are investigating multiple-strategy games and how they are composite of elementary games.

Natasa Djurdjevac Conrad

Zuse Institute Berlin, Germany

Co-evolving Networks for Opinion and Social Dynamics in Agent-Based Models

09:30–10:00 • Monday, 04 May 2026

The coevolution between opinion formation and social dynamics plays a central role in the emergence of collective patterns. In this talk, we introduce a stochastic agent-based model that captures this coevolution. Our model considers agents that move in a social space governed by the social proximity and stances of others: opinion similarity fosters social closeness, while dissimilarity reinforces distancing. Similarly, opinions are shaped by both social and attitudinal proximity. By analyzing the underlying temporal interaction networks, we characterize emergent phenomena such as consensus, polarization and echo chambers. We study the empirical distribution and in the limit of infinite number of agents, we derive a corresponding reduced model given by a PDE. We apply our model to General Social Survey Data (GSS), demonstrating its ability to capture the coevolution of political identity and individual opinions regarding governmental issues. Our findings highlight the crucial role of coevolution in shaping collective social outcomes.

This is a joint work with S. Nagel, A. Djurdjevac, J.Köppl and N. Quang Vu.

Willian Trevizan/ Frederico Costa

Oncology Department, Hospital Sírio-Libanês, São Paulo, Brazil / AutEM Therapeutics, Hanover, NH, USA

External synchronization of cellular rhythms by electromagnetic fields can selectively target cancer cells

10:00–10:30 • Tuesday, 05 May 2026

Network physiology conceptualizes human biology as an integrated hierar- chy of interacting oscillatory systems coupled through bioelectrical signaling. In this study, using a paradigmatic FitzHugh–Nagumo single-cell model, we investigate whether weak externally applied electromagnetic fields (EMF) can selectively entrain endogenous cellular rhythms. We demonstrate that amplitude-modulated EMF inputs induce phase-dependent shifts in action-potential timing, resulting in either acceleration or delay of cellular oscillations depending on the resting membrane poten- tial. Cells with higher resting potentials, representative of normal excitable tissue, exhibit a complex band structure of frequency accelerations and de- celerations, with a predominance of slowing dynamics. In contrast, cells with lower resting potentials, characteristic of malignant phenotypes, dis- play predominantly accelerated oscillatory behavior across a broad range of modulation frequencies. Resonant responses near integer multiples of the intrinsic oscillation frequency further enhance this acceleration. These findings suggest that EMF exposure can modulate spike timing and oscillatory frequency through phase-sensitive mechanisms, promoting ionic influx associated with accelerated firing patterns in cancer-like cellular states. The strongest effects occur near the system’s fundamental frequency, consistent with a resonance-like interaction between external electromagnetic forcing and intrinsic excitable dynamics.

Cornelia Denz

PTB National Metrology Institute Braunschweig, Germany

Nonlinear networks metrology: from electricity grids to sensor networks

11:30–12:00 • Monday, 04 May 2026

Nonlinear dynamics and emergent collective behavior are defining features of both continuous and discrete networks in metrology, largely driven by their complex spatio-temporal structure. Such cooperative phenomena arise in large-scale technical infrastructures as well as in distributed sensing systems, posing significant challenges for modeling, measurement, and data interpretation, especially for complex topology networks [1]. In critical infrastructures such as gas and power grids - the backbone of modern society - the demand for advanced monitoring is steadily increasing to ensure high quality and stability also for distributed generation or injections. Reliable grid control, particularly under extreme or near-critical conditions, requires high-resolution data acquisition, the integration of large, heterogeneous datasets, and a fundamental understanding of the complex network structure [2]. Discrete sensor networks in turn represent a rapidly evolving domain of systems metrology [3]. Applications range from smart metering and environmental monitoring to heterogeneous sensing architectures in the Internet of Things or future urban environments. Systems metrology thus encompasses not only measurement but also the coordinated control of spatially and temporally distributed sensors. Key challenges include nonlinear sensor interactions, time-delayed coupling, synchronization, and strategies for self- and co-calibration. In addition, the inherent sparsity of measurements necessitates advanced methods as sensor fusion to reconstruct continuous representations of the measured values. In this presentation I will show by several examples how monitoring such complex networks by advanced metrology opens new avenues for controlling dynamics and developing robust, adaptive, and scalable network applications.

References:

[1] S. Strogatz, Exploring complex networks, Nature 410 (2001) 268-276.

[2] G. A. Pagani, M. Aiello, The Power Grid as a complex network: A survey, Physica A 392 (2013) 2688-2700.

[3] S. Tabandeh et al., Sensor network metrology: Current state and future directions, Measurement: Sensors 38 (2025) 101798; S. Eichstädt, M. Gruber, A. P. Vedurmudi, D. Hutzschenreuter, Fundamental aspects in sensor network metrology, Acta Imeko 12 (2023) 1-6.

Deniz Eroğlu

Kadir Has University, Istanbul, Turkey, and Imperial College, London, UK

Reconstructing Brain Network Dynamics: Predicting and Preventing Malfunctions

14:30–15:00 • Tuesday, 05 May 2026

Reconstructing complex network dynamics from data is crucial for predicting critical transitions in systems like neuronal networks, where sudden changes in dynamics can have significant consequences. In this work, we propose a novel approach that combines model reduction and machine learning techniques to address the challenge of identifying the interactions and governing equations of weakly coupled chaotic networks. By focusing on stochastic fluctuations—often discarded as noise—we uncover key insights into the interaction structure of the system. Our method, which builds an effective network model consisting of local dynamics and statistical interactions, is applied to synthetic neuronal data from the cat cerebral cortex. We demonstrate how this approach can predict critical transitions for coupling parameters outside the observed range [1]. Furthermore, we showed that, under certain assumptions, our technique can reconstruct true network dynamics with sparse data, alleviating the need for lengthy time series or small system sizes. By leveraging sparse recovery methods, we can learn both the dynamics and connectivity of realistic neuronal systems, such as those in the mouse neocortex [2]. This enables us to detect critical transitions with fewer data points, making the approach highly applicable to real-world systems. Finally, we explore future directions, including the development of black-box models for network dynamics and coupling, which could help uncover unexpected network structures and provide deeper insights into the fundamental behavior of complex systems [3].

References

[1] D. Eroglu, M. Tanzi, S. van Strien, T. Pereira, Physical Review X, 10 (2020), 021047.

[2] I. Topal, D. Eroglu, Physical Review Letters, 130 (2023) 117401.

[3] E Nijholt, JL Ocampo-Espindola, D Eroglu, IZ Kiss, T Pereira, Nature Communications 13 (2022), 4849.

Ulrike Feudel

University of Oldenburg, Germany

The constructive role of transient chaos in complex systems

17:00–17:30 • Monday, 04 May 2026

Permanent and transient chaotic dynamics has been found in many applications like mechanical oscillators, laser physics, neuroscience, ecology and coupled systems of different kind to name only a few. Recently, the focus has shifted to transient chaos on chaotic saddles as a phenomenon which provides new opportunities for complex dynamics. We show how unstable, and hence, transient chaotic dynamics can lead to extraordinary long chaotic transients or even permanent chaos in coupled oscillatory systems. We discuss the role of chaotic saddles in complex networks where a single perturbation in one node can lead to desynchronization of the whole network, which can either be destructive or constructive depending on the system under consideration. Thereby also transient chimeras can be observed. Finally, we discuss the role of transient chaos for the control of swarms of oscillators transitioning from translational motion to rotational motion and vice versa.

Bernold Fiedler

FU Berlin, Germany

Classical Kuramoto oscillators: global dynamics

18:00–18:30 • Monday, 04 May 2026

Stable synchrony for the most classical all-to-all coupling of identical Kuramoto oscillators

$$\dot{\vartheta}_j = \frac{1}{N}\sum_{k=1}^{N} \sin(\vartheta_k - \vartheta_j)$$

has been known for half a century. Transients, however, involve many metastable 2-cluster states, and shift-type heteroclinic dynamics among them. We present a mathematical description of the resulting global dynamics. Strong structural stability properties imply robustness under (small) perturbations of much more general type.

This is recent joint work with Jia-Yuan Dai and Alejandro López-Nieto. We promise a gentle introduction, for physicists and friends.

Igor Franović

University of Belgrade, Serbia

Coherence-incoherence patterns in nonlocally coupled excitable systems

09:30–10:00 • Tuesday, 05 May 2026

While coherence-incoherence patterns have exhaustively been studied in systems of coupled oscillators, much less is known about the generic mechanisms of onset and the character of chaos associated with such patterns in coupled excitable systems. In this talk, we first report on the mechanisms of emergence and the link between two types of symmetry-broken states, namely the unbalanced periodic two-cluster states and solitary states, in nonlocally coupled excitable systems, considering as an example arrays of FitzHugh-Nagumo units with attractive and repulsive interactions. We show that there exist two classes of solitary states that inherit their dynamical features from unbalanced cluster states in globally coupled networks, but that the interplay of local excitability and nonlocal interactions can also give rise to a class of solitary states unrelated to unbalanced clusters. We further introduce a new class of patterns, called patched patterns, whose self-organization involves the formation of spatially continuous domains, called patches, consisting of units locked by a 1:2 ratio by their average spiking frequencies. Patched patterns can be temporally periodic, quasiperiodic or chaotic, depending on the control parameter that modifies the prevalence of attraction vs repulsion, whereby chaotic patterns may further display interfaces, the regions comprised of units whose frequencies are intermediate between the frequencies of the patches. Finally, I will demonstrate that bumps, a typical type of patterns in coupled excitable systems, can emerge in a supercritical scenario, following a localized bifurcation on a type of Turing patterns.

Theo Geisel

MPI for Dynamics and Self-Organization, Göttingen, Germany

Timeseries Analysis for Empirical Musicology

14:00–14:30 • Tuesday, 05 May 2026

Music philosophers and psychologists have argued that emotions and meaning in music depend on an interplay of expectation and surprise. We aimed to quantify the variability of musical pieces empirically by considering them as correlated dynamical processes. Using a multi-taper method we determined power spectral density (PSD) estimates for more than 550 classical compositions and jazz improvisations down to the smallest possible frequencies [1]. The PSDs typically follow inverse power laws (1/f -noise) with exponents near $\beta=1$ for classical compositions, yet only down to a cutoff frequency, where they end in a plateau. Correspondingly the pitch autocorrelation function exhibits slow power law decays only up to a cutoff time, beyond which the correlations vanish abruptly. We determined cutoff times between 4 and 100 quarter note units serving as a measure for the degree of persistence and predictability in music. They tend to be larger in Mozart's compositions than in Bach's, which implies that the anticipation and expectation of the musical progression typically tends to last longer in Mozart's than in Bach's compositions.

Reference:

[1] C. Nelias and T. Geisel, Nature Comm. 15, 9280 (2024)

Fakhteh Ghanbarnejad

SRH University of Applied Sciences, Leipzig, Germany

Infectious Diseases and Mobility Reshape Stability in Three-Level Food Chains

17:30–18:00 • Monday, 04 May 2026

Food webs have been extensively studied from both ecological and mathematical perspectives, yet most existing models do not simultaneously account for the influence of infectious diseases. Recent research has begun integrating epidemiological dynamics into such systems. In this work, we examine a three-level food chain composed of prey, predators, and apex predators, governed by generalized Lotka–Volterra equations combined with a Susceptible–Infected–Recovered (SIR) framework applied to a single species at a time. To capture the biological consequences of infection on interactions, we introduce a parameter w that increases the predation rate and decreases the hunting efficiency of infected individuals.

We first show that when predators become infected, they do not go extinct across the tested parameter ranges, though infection can induce population oscillations not observed in either the classical SIR model or the generalized Lotka–Volterra system alone. In contrast, when the infectious disease affects apex predators, population oscillations do not arise, but extinction may occur within specific parameter regimes, reducing community persistence. We also incorporate mobility, modeled using a gravity framework that accounts for environmental factors, to examine how movement patterns influence our earlier observations. These results highlight how environmental factors shape mobility and, as a consequence, affect extinction risk and overall community persistence.

Svetlana Gurevich

University of Münster, Germany

Multistable Kuramoto splay states and coherent pulse interactions in mode-locked semiconductor lasers

11:30–12:00 • Tuesday, 05 May 2026

We discuss the dynamics of multipulse solutions in mode-locked lasers in presence of time-delayed feedback stemming, e.g., from reflections upon optical elements, and carrier dynamics. We demonstrate that the dynamics of such a high dimensional problem can be successfully described by some effective equations of motion for the pulses' phases and positions. In particular, we demonstrate the existence of multistable frequency combs that could be lined to the splay phases of the Kuramoto model with short range interactions.

Philipp Hövel
Saarland Universität, Saarbrücken, Germany

Do you remember? Latency effects in time-delay feedback control of chaos

12:00–12:30 • Tuesday, 05 May 2026

Once upon a time... Unstable periodic orbits can be controlled by time-delay feedback methods. We present a stability analysis in the case of extended time-delay autosynchronization. Our analysis includes effects of non-zero latency time, i.e., the time associated with the generation and injection of the feedback signal. We derive a theoretical explanation for experimentally observed, nontrivial features of the domain of control, e.g., gaps, maximum latency times. The explanation is done in the background of Floquet theory and we take both the unstable eigenmode and a single stable eigenmode into account... and they lived happily ever after.

Plamen Ch. Ivanov
Keck Laboratory for Network Physiology, Boston University, USA

The new field of Network Physiology: Building the Human Physiolome

09:00–09:30 • Tuesday, 05 May 2026

The human organism is an integrated network where complex physiological systems, each with its own regulatory mechanism, continuously interact to optimize and coordinate their function. Organ-to-organ interactions occur at multiple levels and spatiotemporal scales to produce distinct physiologic states: wake and sleep; light and deep sleep; consciousness and unconsciousness. Disrupting organ communications can lead to dysfunction of individual systems or to collapse of the entire organism (coma, multiple organ failure). Yet, we know almost nothing about the nature of interactions among diverse organ systems and sub-systems, and their collective role as a network in maintaining health. The emerging multidisciplinary field of Network Physiology aims to address these fundamental questions. In addition to defining health and disease through structural, dynamical and regulatory changes in individual systems, the network physiology approach focuses on the coordination and interactions among diverse organ systems as a hallmark of physiologic state and function. Through the prism of concepts and approaches originating in statistical and computational physics and nonlinear dynamics, we will present basic characteristics of individual organ systems, distinct forms of pairwise coupling between systems, and a new framework to identify and quantify dynamic networks of organ interactions. We will demonstrate how physiologic network topology and systems connectivity lead to integrated global behaviors representative of distinct states and functions. We will also show that universal laws govern physiological networks at different levels of integration in the human body (brain-brain, brain-organ and organ-organ), and that transitions across physiological states are associated with specific modules of hierarchical network reorganization. We will outline implications for new theoretical developments, basic physiology and clinical medicine, novel platforms of integrated biomedical devices, robotics and cyborg technology. The presented investigations are initial steps in building a first Atlas of dynamic interactions among organ systems and the Human Physiolome, a new kind of BigData of blue-print reference maps that uniquely represent physiologic states and functions under health and disease.

Jun Jiang
Xi'an Jiaotong University, China

Understanding global structure of nonlinear dynamical systems by approach of state space discretization and deep learning

17:30–18:00 • Tuesday, 05 May 2026

The global structure of nonlinear systems and its evolution with system parameters constitute the fundamental origin of complex dynamical phenomena. Efficiently solving and analyzing the global structure of high-dimensional nonlinear dynamical systems remains a challenging problem, which holds significant theoretical importance for gaining deeper insights into nonlinear dynamical phenomena and revealing their underlying mechanisms. The global structure of nonlinear dynamical systems refers to invariant sets including attractors with their basins of attraction, saddle-type unstable invariant sets with their stable and unstable manifolds, as well as quantitative measures characterizing system response properties on these invariant sets (such as invariant measures, probability densities, or membership functions). The methods of state space discretization are numerical approaches and cover the topological structure (invariant sets) of nonlinear systems through the subsets of the state space (referred to as "cells"), which benefit from the characteristics cells for information collecting and noise/error tolerance. This talk will introduce the methods that combine the idea of state space discretization with deep learning to develop efficient techniques for determining the attraction basins of high-dimensional nonlinear dynamical systems and solving the parameter- dependent evolution of nonlinear global structures. Several concrete numerical examples will be presented to demonstrate the effectiveness of the proposed approaches, while highlighting the significant potential of machine learning methods in the research of nonlinear dynamical systems.

Aneta Koseska
MPI for Neurobiology of Behavior, Bonn, Germany

Processing information with ghost scaffolds

16:30–17:00 • Monday, 04 May 2026

A growing body of empirical evidence suggests that neuronal and biochemical networks are often characterized by long transients which are quasi-stable, with fast switching between them. The duration of the quasi-stable patterns is much longer than one would expect from the characteristic elementary processes of the system, whereas the switching is triggered by external signals or system-autonomously, and occurs on a timescale much shorter than the one of the preceding dynamical pattern. Generalizing the concept of ghost states, we provide a theoretical framework that accounts for emergence of transiently stable phase-space flows generated by ghost scaffolds. We demonstrate that ghost-based phase space objects such as ghost channels and cycles account for emergence of advanced information processing capabilities, including on-the-fly signal classification, temporal integration and context-dependent responses.

Jürgen Kurths
Potsdam Institute for Climate Impact Research, Germany

Climate Tipping Points and Extreme Events: On their Formation and Forecasting

09:00–09:30 • Monday, 04 May 2026

The Earth system is a very complex and dynamical one basing on various feedbacks. This makes predictions and risk analysis even of very strong (sometime extreme) events as floods, landslides, heatwaves, and earthquakes etc. a challenging task. After introducing physical models for weather forecast already in 1922 by L.F. Richardson, a fundamental open problem has been the understanding of basic physical mechanisms and exploring anthropogenic influences on climate. A highlight was the pioneering studies by Hasselmann and Manabe who got the Physics Nobel Price in 2021. I will shortly review their main seminal contributions and discuss most recent challenges concerning climate change.

Next, I will introduce a recently developed approach via complex networks mainly to analyze long-range interactions in the climate system. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? To treat this problem, we have proposed a method to reconstruct and analyze a complex network from spatio-temporal data. This approach enables us to uncover teleconnections among tipping elements, in particular between Amazon Rainforest and the Tibetan Plateau, but also between the Arctic and Southwest China and California. Implications of these findings in particular for forecasting extreme events are discussed.

Yuliya Kyrychko

University of Sussex, UK

From Gut to Brain: Modelling Microbiota-Driven Neuroinflammation in Alzheimer's Disease

15:30–16:00 • Tuesday, 05 May 2026

Alzheimer's Disease (AD) is a multifaceted neurodegenerative condition shaped by a combination of pathogenic pathways. Genetic susceptibility, metabolic imbalance, and lifestyle-related influences all play important roles in shaping both vulnerability to the disease and its progression. Among the various mechanisms linked to AD, the gut-brain axis has emerged as a particularly influential factor. Shifts in the composition of gut microbiota - broadly termed gut dysbiosis - can drive systemic inflammation, alter gut permeability, and weaken the blood–brain barrier (BBB). These changes contribute to heightened inflammation within the central nervous system (CNS) and can hasten amyloid-beta (Aβ) accumulation. In this talk, I will concentrate on modelling how interactions within the gut microbiome, especially between bacterial groups with pro- and anti-inflammatory effects, regulate intestinal inflammation and subsequently influence neuroinflammatory and neurodegenerative events in the brain. I will begin by outlining the mechanisms underlying inflammation within the gut as shaped by these microbial dynamics. The discussion then moves to the development of a "leaky gut," examining how inflammation affects both gut and BBB permeability. Although AD pathology includes abnormalities in both Aβ and tau proteins, our brain-level modelling will focus on Aβ, whose buildup is widely viewed as an early and potentially initiating driver of the disease. We explore the behaviour of Aβ oligomers and amyloid plaques, each associated with neurotoxic consequences. I will finish by considering the potential clinical relevance of the findings and outlining future directions for advancing AD modelling.

Rene Lozi
Université Cote d'Azur, Nice, France

Peculiarities of the spatio-temporal dynamics of a Hénon–Lozi map network in the presence of Lévy noise

14:00–14:30 • Monday, 04 May 2026

In this common work with Galina Strelkova and her team, we explore numerically the dynamics of a single Hénon–Lozi map and networks of nonlocally coupled Hénon–Lozi maps. It is shown that due to a complicated behavior of the individual map which combines the dynamical peculiarities of the Lozi map and the Hénon map, both solitary states and chimera structures can be observed in networks of coupled Hénon–Lozi maps. These spatio-temporal structures exhibit different degrees of robustness against external noise sources. It is established that additive Lévy noise suppresses solitary states while induces chimera states, and the chimera resonance is realized.

Cristina Masoller
Universitat Politecnica de Catalunya, Barcelona, Spain

Synchronization transitions in networks of Hodgkin–Huxley neurons

09:00–09:30 • Wednesday, 06 May 2026

Cascades of neuronal activity, during which a large proportion of neurons fire synchronously, have been observed in in-vitro neural networks and in neuronal models, but the mechanisms that trigger this synchronized activity are still poorly understood. Recently, we characterized the dynamics of globally coupled, identical Hodgkin-Huxley neuronal networks and found that global neuronal activity arises from two distinct transitions: a smooth, continuous one driven by the strength of coupling, and a sharp, abrupt one driven by the intensity of noise [1]. In this presentation, we will analyze the role of heterogeneity, both in neuronal parameters and in their coupling topology. We will show that complex network structures facilitate the emergence of cascades of synchronized activity by expanding the region of parameters where they occur, while small heterogeneities in neuronal parameters leave the region where synchronized neuronal activity occurs virtually unchanged.

Reference: [1] Bruno R.R. Boaretto, Elbert E.N. Macau, Cristina Masoller, "Noise-induced extreme events in Hodgkin–Huxley neural networks", Chaos, Solitons and Fractals 194 (2025) 116133

Hildegard Meyer-Ortmanns
Constructor University, Bremen, Germany

Metastable dynamics in oscillatory systems from deterministic equations

10:00–10:30 • Wednesday, 06 May 2026

Metastability is a typical feature of brain dynamics. We present two mechanisms to generate metastable states, such that the system keeps on switching between these states in a cyclic or acyclic way. The first mechanism is realized in generalized Kuramoto models with non-reciprocal adaptive couplings. The non-reciprocity refers to the type of coupling according to Hebbian or anti-Hebbian rules and to different time scales on which the couplings evolve. The main effect of this specific combination of deterministic dynamics is an induced metastability of anti-phase synchronized clusters of oscillators. The mechanism behind sudden irregular changes in the order parameters is individual oscillators which change their cluster affiliation from time to time.

This way they provide “weak ties” between clusters of synchronized oscillators, where an individual oscillator may represent an entire brain area. The second mechanism is based on heteroclinic dynamics. Here we summarize results of earlier work on how to design the attractor space in order to observe heteroclinic cycles of heteroclinic cycles, modulating fast oscillations by slow oscillations. We also indicate how heteroclinic units can act as pacemakers, leading to entrained dynamics and providing a way of processing information over the grid, when information is encoded in the generated spatiotemporal patterns.

Klaus Obermayer
TU Berlin, Germany

Computational Models of Adaptation-driven Slow Oscillations

15:00–15:30 • Tuesday, 05 May 2026

Slow Oscillations are an adaptation driven phenomenon and are generated by cortical populations of neurons. They are prevalent during deep sleep and correlate with the consolidation of freshly acquired memories in concert with thalamic sleep spindles and hippocampal sharp-wave ripples. In my talk I will first investigate the emergence of Slow Oscillations in a mesoscopic Wilson-Cowan field model of interacting excitatory and inhibitory populations of neurons, where the excitatory population is equipped with a slow, activity-dependent feedback process. I will show, t hat positive and negative feedback processes, which both have been suggested to cause Slow Oscillations, are dynamically equivalent, and I will characterize the state space of the model with focus on multistability and spatio-temporal activity patterns.

Second, I will study the effects of a (negative) feedback process on the macroscopic level in a whole-brain model of the human brain. Each node is equipped with an adaptive excitatory and an inhibitory population in a mean-field description, which is derived from adaptive exponential integrate-and-fire model neurons. Fitting simulated brain activity to resting state fMRI and sleep EEG data provides evidence for a parametrization, which brings the operating point of the model close to a bifurcation. At this point, the model produces a balance between local and global Slow Oscillation events with a realistic spatiotemporal statistic and reacts quite sensitive to external perturbations. Global oscillations preferentially spread as waves of silence across the brain, which travel from anterior to posterior regions and which are caused by an anterior-posterior gradient of node in-degrees.

Ulrich Parlitz
MPI for Dynamics and Self-Organization, Göttingen, Germany

Transient chaos and fibrillation in cardiac excitable media

10:30–11:00 • Tuesday, 05 May 2026

The heart muscle is a complex network of electrically and mechanically excitable cardiomyocytes, whose synchronized contraction ensures the vital pumping function. However, the coherent contraction can be (significantly) impaired by the occurrence of stable or unstable spiral waves, leading to (life-threatening) arrhythmias such as atrial fibrillation or ventricular fibrillation, which, however, are often not permanent but only occur for a certain period of time. In this contribution, we discuss characteristics of this type of spatiotemporal transient chaos and the influence of heterogeneities, stochastic disturbances and control on the mean lifetime of chaotic transients. Using simulations with the Aliev-Panfilov and Fenton-Karma models, we show that such disturbances can prolong or shorten the duration of chaotic transients or even lead to persistent chaos or stable periodic wave patterns.

Arkady Pikovsky
University of Potsdam, Germany

Coherence properties of global modes in oscillatory networks

09:30–10:00 • Wednesday, 06 May 2026

Synchronization transition manifests itself as an appearance of a global oscillatory mode. In the thermodynamic limit, such a mode oscillates periodically, but for a finite system there are fluctuations. We study phase diffusion of the periodic mode and demonstrate that depending on the dynamics of an individual system, different scaling behaviors in dependence on the network size are observed.

Michael Rosenblum
University of Potsdam, Germany

Second-order Kuramoto-Sakaguchi model: what can it explain?

15:30–16:00 • Monday, 04 May 2026

We apply the second-order phase reduction to obtain the phase approximation for a network of nonidentical Stuart-Landau oscillators coupled pairwisely via an arbitrary coupling matrix. The derived model contains different triplet terms as well as pairwise terms for non-connected units. In contradistinction to the standard Kuramoto-Sakaguchi model, the coefficients of high-order terms depend on their frequencies. We concentrate on qualitative effects provided by the second approximation: (i) explanation of remote synchrony, (i) reproduction of the chimera shape's dependence on the coupling strength, and (iii) synchronization and clustering in the two-group Stuart-Landau network with neutral coupling.

Peter Tass
Stanford University, USA

Vibrotactile Coordinated Reset Fingertip Stimulation for the Treatment of Parkinson’s Disease

11:30–12:00 • Wednesday, 06 May 2026

The motor symptoms of Parkinson’s disease (PD) are linked to the loss of dopaminergic neurons. Following dopamine depletion (DD) in the basal ganglia (BG), there is extensive synaptic reorganization and alterations in neural activity, which include heightened beta oscillations and bursting activity. In patients with medically refractory Parkinson’s disease (PD), standard deep brain stimulation (DBS) effectively reduces specific symptoms during stimulus delivery. Coordinated Reset (CR)-DBS is a computationally developed technique that employs targeted patterns of electrical stimuli to counteract abnormal neuronal synchronization through desynchronization. The primary goal of CR stimulation is to enable neuronal populations to "unlearn" abnormal synaptic connectivity patterns, thereby inducing long-lasting relief. Long-lasting therapeutic and desynchronizing effects of CR-DBS have been demonstrated in Parkinsonian monkeys (MPTP) and in patients with externalized PD. To provide a non-invasive alternative to DBS, we developed vibrotactile Coordinated Reset (vCR) fingertip stimulation. Instead of delivering electrical bursts through depth electrodes, we noninvasively apply weak vibratory bursts in a CR mode to the patients' fingertips. Based on encouraging results from a first-in-human study and pilot studies, we have further optimized the vCR algorithm and the fundamental vibrotactile stimulus. This talk will present the promising results of the optimized vCR therapy, along with the underlying principles of dynamical systems and self-organization.

Marc Timme
TU Dresden, Germany

Tipping to Failure? – Strongly Perturbed Nonlinear Network Dynamics

10:30–11:00 • Wednesday, 06 May 2026

Most complex networked systems across biology and engineering are externally driven by perturbations, imposing non-equilibrium and sometimes non-stationary response dynamics. Strong external driving may induce tipping and cascading failure, yet state-of-the-art methods from network dynamics have focused on linear response theory suitable for weak driving signals only. Here we report nonlinear responses emerging generically in driven nonlinear dynamical systems yet are absent from most text book examples. Moreover, at some critical (large) driving amplitude, responses cease to stay close to a given operating point and may diverge – the system tips. As standard response theory fails to predict tipping amplitudes, even at arbitrarily high orders, we propose self-consistency conditions that capture the genuinely nonlinear response dynamics. Our novel approach uncovers a generic pondermomotive route to tipping. It may help to quantitatively predict intrinsically nonlinear response dynamics as well as bifurcations emerging at large driving amplitudes in non-autonomous dynamical systems. We highlight several application directions and a broad field of open theoretical and methodogical questions.

Alessandro Torcini
CY Cergy Paris Université, France

A theory for self-sustained balanced states in absence of strong external currents

12:00–12:30 • Wednesday, 06 May 2026

The human brain is constantly active. This ongoing activity is not random but follows complex patterns that emerge from the interactions between billions of neurons. Understanding how these patterns arise is a fundamental question in neuroscience. One influential idea is that the brain maintains a delicate balance between excitatory and inhibitory signals, preventing runaway activity while allowing rich, flexible dynamics.

However, classic models of this balance often require an external input to sustain realistic firing rates, which may not align with biological observations. In this work, we propose an alternative mechanism based on a process called short-term synaptic depression. This process weakens excitatory connections when neurons fire too much, acting as a natural self-regulating mechanism.

Using Dynamical Mean Field Theory and computer simulations, we show that this mechanism can maintain stable and irregular activity without external input. Furthermore, we identify different ways in which the system transitions from stable activity to chaotic dynamics, similar to what is observed in the brain. Our findings suggest that internal synaptic adaptation may play a key role in shaping neural activity, offering new perspectives on how the brain organizes its complex dynamics.

Karoline Wiesner
University of Potsdam, Germany

Nonlinear Dynamics of Deep Learning: Phase Transitions and Landscape Geometry in Neural Networks

17:00–17:30 • Tuesday, 05 May 2026

Deep neural networks exhibit rich nonlinear dynamics during training, yet the geometric and statistical principles underlying their behavior remain only partially understood. In this talk, we present a unified framework that connects several key phenomena in deep learning—phase transitions, saddle points, and mode connectivity—through the geometry of high-dimensional loss landscapes. We show that training dynamics can be interpreted in terms of transitions between hierarchically organized basins in the error landscape, analogous to phases in statistical physics. In particular, phase transitions observed during training are governed by saddle points, which act as critical boundaries separating models with distinct predictive structure. These transitions give rise to an implicit hierarchy of accuracy regimes, reflecting the progressive incorporation of structure from the data. Using analytically tractable models, we further demonstrate a direct link between data complexity and cascades of phase transitions in network performance. To probe these phenomena in practical settings, we introduce a simple and efficient method based on L2 regularization to explore loss landscape geometry and identify low-loss paths connecting distinct minima. This provides insight into mode connectivity and the organization of solution space in modern neural networks. Together, these results highlight how concepts from statistical physics and nonlinear dynamics can uncover organizing principles of deep learning, with implications for model interpretability, optimization, and control.

Dirk Witthaut
Forschungszentrum Jülich, Germany

Synchronization and Multistability via Convex Optimization

12:30–13:00 • Monday, 04 May 2026

Synchronization is a fundamental requirement for the stable operation of many natural and engineered networked systems, including electric power grids. In this contribution, I introduce a novel edge-based framework for analyzing phase locking in finite oscillator networks. I show that stable phase locked states can be obtained in two steps: First a subspace of solution candidates in constructed from nodal balance equations. Then the actual solutions are determined by the solution of a convex optimization problem. This two-step method provides both necessary and sufficient conditions for the existence of synchronized states and enables a systematic characterization of multistability. The framework is versatile and applies to both ordinary and topological Kuramoto models as well as to power-grid dynamics.

Yong Xu

Northwestern Polytechnical University, Xi'an, China

Stochastic-resonance and coherence-resonance chimeras in coupled neurons with α-stable Lévy noise

15:00–15:30 • Monday, 04 May 2026

Chimeras are the coexistence of coherence and incoherence, and is closely related to a variety of neuronal diseases, such as Alzheimer, Parkinson, and schizophrenia. The study of chimeras of neuronal system has very important practical significance. Research on chimeras has so far mainly concentrated on deterministic systems. The few studies that have considered stochastic systems have only explored the impacts of Gaussian noise on chimeras. However, various systems are disturbed by small perturbations, always combined with discontinuously unpredictable jumps. The α-stable Lévy noise is a kind of general random noise which can model both small and big random fluctuations with its distribution having the property of heavy tails. Thus, we investigate the chimeras in coupled neuronal networks with α-stable Lévy noise. First, we investigate the influences of α-stable Lévy noise, particularly in terms of noise intensity (D) and stability parameter (α), on typical chimera phenomena. Secondly, we explore the impact of α -stable Lévy noise on the coherence-resonance chimera phenomenon, as described by Semenova et al., which demonstrates coherence resonance in time and chimera in space. Furthermore, we report a novel type of chimera pattern called stochastic-resonance chimera that combines the stochastic resonance and chimeras. Unlike coherence-resonance chimera, the stochastic-resonance chimera strongly depends on the amplitudes of periodic forcing and noise. Stochastic-resonance chimeras are expected to have wide applications in neural networks and offer a new direction for chimera control.

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[2] Zhanqing Wang, Yongge Li, Yong Xu, Tomasz Kapitaniak, and Jürgen Kurths. Coherence-resonance chimeras in coupled HR neurons with alpha-stable Lévy noise. Journal of Statistical Mechanics: Theory and Experiment, 2022(5):053501, 2022.

[3] Zhanqing Wang, Yong Xu, Yongge Li, Tomasz Kapitaniak, and Jürgen Kurths. Chimera states in coupled Hindmarsh-Rose neurons with alpha-stable noise. Chaos, Solitons & Fractals, 148:110976, 2021

Jin Yan

WIAS Berlin, Germany

Coherence and Transients in Coupled Map Lattices

14:30–15:00 • Monday, 04 May 2026

Coupled map lattices (CMLs) provide simple yet powerful models for exploring high-dimensional nonlinear dynamics. In this talk, we begin with a brief overview of key developments in the study of CMLs. We then focus on a specific model of nonlocally coupled dissipative kicked rotors, demonstrating transitions from homogeneous stationary to spatiotemporal periodic patterns and to incoherence under variations of the coupling parameters. Interestingly, this transition scenario differs qualitatively from that of well-studied systems such as coupled logistic maps, where the coherence occurs in a series of tongue-shaped regions in the parameter space. This raises the broader question of under which conditions such tongue structures emerge. Beyond coherence, we consider transient dynamics: starting from a half-chaotic, half-regular initial condition, coupling can induce a long-lived interface between the two clusters. Even when the final attractor is fully chaotic, this interface state persists extremely long up to a critical threshold, beyond which the transient time drops abruptly.

On this special occasion, observations of chimera states in CMLs and related open questions will also be discussed.

Serhiy Yanchuk
University College Cork, Ireland

Tipping in an adaptive climate network model

10:00–10:30 • Monday, 04 May 2026

With rising global temperatures, Earth's tipping elements are becoming increasingly more vulnerable to crossing their critical thresholds. The reaching of such tipping points does not only impact other tipping elements through their connections but can also have further effect on the global mean surface temperature (GMT) itself, either increasing or decreasing the probability of further tipping points being reached.

Recently, a numerical study analyzing the risk of tipping cascades has been conducted, using a conceptual model describing the dynamics of a tipping element with its interactions with other tipping elements taken into account. Here, we extend the model substantially by including adaptation so that the GMT feedback induced by the crossing of a tipping point is incorporated as well.

We find that although the adaptive mechanism does not impact the risk for the occurrence of tipping events, large tipping cascades are less probable due to the negative GMT feedback of the ocean circulation systems. Furthermore, several tipping elements can play a different role in cascades in the adaptive model. In particular, the Amazon rainforest could be a trigger in a tipping cascade. Overall, the adaptation mechanism tends to slightly stabilize the network.

Poster list

Presenter	Affiliation	Poster title
Fatemeh Aghaei	MPI for Physics of Complex Systems, Dresden, Germany	A Conceptual Model for GHG-Temperature Feedback in the Climate System
Bahar Hamzehei	University of Bologna, Italy	Spatial Decoding of Lateralized Pain Anticipation from EEG Using Deep Temporal Neural Networks
Jobst Heitzig	Potsdam Institute for Climate Impact Research, Germany	AI systems that empower humans in a complex world
Ali Rana Atilgan	Sabanci University, Istanbul, Turkey	Trajectory Ensembles to Elucidate Mutant-Induced Kinetic Modulation of Proteins
Wolfgang Renz Juri Backes	University of Applied Sciences, Hamburg, Germany	Combining machine learning and dynamic network models for sepsis prediction
Georg Reich Julius Rosenberg	TU Berlin, Germany	CA3 Network Model Learns to Replay Hundreds of Chaotic Attractor Dynamics via Global Remapping and Synaptic Delays
Rossella Rizzo	University of Palermo, Italy	Stationary and oscillatory patterns in a FitzHugh-Nagumo model with anomalous diffusion
Merten Stender, Manish Yadav	TU Berlin, Germany	Understanding Structure-Function Relationships through Performance-Dependent Network Evolution
Ronja Strömsdörder	TU Berlin, Germany	Spike-frequency and h-current based adaptation as candidate modulators of the propagation of traveling waves
Simon Vock	Charité Berlin, Germany	Criticality governs deep learning: enhancing performance, enabling continual learning, mitigating model collapse
Yu Wang	Potsdam Institute for Climate Impact Research, Germany	Universal dynamic phenomena in delay systems: fundamentals and applications
Dan Zhao	Potsdam Institute for Climate Impact Research, Germany	Synchronization transitions and spike dynamics in a higher-order Kuramoto model with Lévy noise

Poster abstracts

Fatemeh Aghaei A.

MPI Physics of Complex Systems, Dresden, Germany

A Conceptual Model for GHG-Temperature Feedback in the Climate System

The interaction between greenhouse gas (GHG) emissions—particularly carbon dioxide—and global temperature is central to climate dynamics. In recent decades, processes such as permafrost thaw, ice sheet melt, and large-scale biomass burning have demonstrated that temperature and GHGs form a bidirectionally coupled system, creating a reinforcing loop: GHG emissions drive warming, and warming in turn increases GHG emissions.

Despite well-established concept, the complexity of the system—combined with distinct temperature thresholds and timescales— the mechanisms behind massive GHG releases are not fully understood. Here, focusing on two different tipping elements We find that feedback can either accelerate warming beyond a trend change point or to multistability and tipping. From this perspective, the first type may increase the risk of the second.

Bahar Hamzehei

University of Bologna, Italy

Spatial Decoding of Lateralized Pain Anticipation from EEG Using Deep Temporal Neural Networks

Networks We present a deep learning framework to decode spatially specific pain anticipation from electroencephalography (EEG) signals recorded during a Pavlovian threat conditioning paradigm. Beyond binary classification of threat versus safety, our primary objective is to determine whether anticipatory neural activity contains sufficient information to distinguish the predicted spatial location of pain (left vs. right arm) prior to stimulus delivery. This approach aims to characterize lateralized anticipatory brain dynamics and evaluate whether data-driven temporal models can capture structured, spatially organized predictive states in cortical activity. MATERIALS Thirty healthy adult participants underwent a threat conditioning paradigm comprising acquisition and reversal phases. During acquisition, two visual cues predicted a painful shock to either the left (CS+L) or right (CS+R) arm, while a third cue (CS−) signaled safety. In the reversal phase, contingencies were swapped, requiring flexible updating of spatial predictions. This design enabled assessment of both stability and adaptability of anticipatory neural representations. Peripheral physiological measures (SCR, MEPs) were recorded but analyzed separately. METHOD EEG was recorded from 64 scalp electrodes at 5 kHz. Data were artifact-corrected, filtered (0.5– 50 Hz), downsampled (500 Hz), baseline-corrected, and z-scored per participant. Epochs included a pre-cue baseline (−1–0 s) and cue interval (0–4.5 s). We trained a Temporal Convolutional Network (TCN) with stacked 1D convolutional layers and global pooling for multi- class classification (CS+L, CS+R, CS−). In parallel, time–frequency representations (STFT spectrograms) were evaluated as model inputs. Training followed a participant-level split (70/15/15%) to ensure generalization across individuals. RESULTS Model optimization is ongoing. Preliminary analyses indicate above-chance classification of lateralized pain anticipation during the cue period, suggesting that EEG signals encode spatially organized predictive states prior to nociceptive input. Comparative analyses across raw and time–frequency inputs are in progress. DISCUSSION These findings support the hypothesis that anticipatory brain states exhibit structured, lateralized dynamics detectable through deep temporal modeling. The paradigm further allows investigation of neural flexibility during contingency reversal, linking predictive coding and adaptive learning mechanisms. CONCLUSIONS This framework demonstrates the feasibility of decoding spatial pain anticipation from EEG and provides a foundation for integrating explainable AI approaches to identify neural features underlying predictive brain dynamics.

Jobst Heitzig

Potsdam Institute for Climate Impact Research, Germany

AI systems that empower humans in a complex world

We present results from experiments where AI systems are tasked to empower human agents in multi-agent environments with complex dynamics.

Ali Rana Atilgan

Sabanci University, Istanbul, Turkey

Trajectory Ensembles to Elucidate Mutant-Induced Kinetic Modulation of Proteins

Many experiments and coarse-grained models of protein conformational change report only a single rate, while the underlying dynamics are high-dimensional, contact-structured, and heterogeneous. We develop a two-layer sequence–structure framework that uses Maximum Caliber (MaxCal) to lift such coarse kinetic information into an explicit trajectory ensemble on a structurally defined path, and to quantify how mutations reshape that ensemble.

In the first layer, a compact sequence–structure theory estimates mutation-induced changes in gating rates. A Potts model inferred from a multiple-sequence alignment (MSA) is blended with a Gaussian Network Model built on the closed conformation; Potts couplings modulate effective spring constants, deforming the Kirchhoff matrix in a sequence-dependent manner. A gating contribution is extracted from the lowest-frequency mode that best aligns with the closed → occluded displacement, and an Arrhenius-like barrier factor accounts for non-harmonic reorganization. Applied to E. coli DHFR, this layer predicts mutant-to-wild-type rate ratios in close agreement with experiment and yields a target closed ↔ occluded rate for each sequence.

In the second layer, we use two endpoint structures and the target rate to construct a one-dimensional structural path, a contact-breaking barrier profile, and an effective free-energy landscape. MaxCal then infers nearest-neighbor transition rates that obey local detailed balance and reproduce the prescribed mean first-passage time (FPT), yielding the maximum-entropy Markov dynamics consistent with the structural and kinetic constraints. From the resulting ensemble we obtain dwell-time maps, state-resolved fluxes, path-length and FPT distributions, and path entropies that quantify route diversity, kinetic bottlenecks, and gating robustness. Whenever two structures, an MSA, and a few kinetic observables are known, the framework furnishes a minimally biased non-equilibrium process on a constrained graph.

Juri Backes, Artyom Tsanda, Tobias Knopp, Wolfgang Renz, Eckehard Schöll

University of Applied Sciences Hamburg and TU Hamburg and TU Berlin, Germany

Combining Machine Learning and Dynamic Network Models for Sepsis Prediction

We enhance short-term sepsis predictions by integrating machine learning technique

es like Auto-Encoders and Gated Recurrent Units with a dynamical 2-layer network model of adaptive phase oscillators [1,2] representing the interaction between parenchymal cells (functional organ cells) and the immune system via cytokines. The model trajectories determined by machine learning are used for detection and prediction of critical infection states and mortality. The model-based predictions are compared with those of purely data-based approaches in terms of predictive power and interpretability. To this end we project real high-dimensional medical patient data into the low-dimensional parameter space of the model.

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[2]. J. Backes: Combining Machine-Learning and Dynamic Network Models to Improve Sepsis Prediction. Master's Thesis (2026). Available at:https://github.com/unartig/sepsis osc/blob/main/main thesis.pdf

Georg Reich, Julius Rosenberg

TU Berlin, Germany

CA3 Network Model Learns to Replay Hundreds of Chaotic Attractor Dynamics via Global Remapping and Synaptic Delays

Place cells in the hippocampus are thought to provide a sparse code of locations and abstract variables, and during rest or sleep replay their previous activation sequences for memory consolidation and planning. Animals can encounter many different environments in their life, and learn to predict complex spatiotemporal patterns in different contexts. Global remapping refers to the observation that place field representations are decorrelated between different contextual environments. It has been previously found that delays can provide a powerful embedding of chaotic dynamical systems and enable an "unprecedented memory capacity" in neural circuits. In this work we make use of such transmission delays in a single network of place cells. For a given chaotic system and delay, synaptic weights are learned through the Ulam-Galerkin method where the basis is given by disjoint place fields on the attractor. This learning rule is local and online, and thus biologically plausible. In our contribution, we extend this approach to multiple delays and multiple learned systems. As a result, our model can learn the attractor dynamics of hundreds of systems and selectively replay each system in response to an initial stimulus. We empirically measure the memory capacity of our model on permutations of place fields on the Lorenz attractor, and make first steps towards an analytical treatment.

Rossella Rizzo

University of Palermo, Italy

Stationary and oscillatory patterns in a FitzHugh-Nagumo model with anomalous diffusion

Anomalous diffusion phenomena frequently occur in natural systems. Interesting examples include autocatalytic chemical reactions on porous media, the preferential movement of species driven by safety or hunting strategies, and long-range interactions in ion channels within the plasma membrane. Cross-diffusion is a kind of nonlinear diffusion used to describe population dynamics where the gradient of one species induces the flux of the other species [1, 2]. On the other hand, super-diffusive processes, such as L´evy flights, can describe the mass diffusion in plasmas or foraging dynamics of birds and oceanic predators for randomly located resources and lead to fractional derivative modeling [3, 4]. In this talk, we investigate how anomalous diffusion influences the formation of stationary patterns in the FitzHugh-Nagumo model, which represents the paradigm system to describe excitable dynamics both in chemical reactions and population dynamics [5, 6]. We find that introducing anomalous diffusion terms allows for pattern formation in both short-range activation/long-range inhibition or long-range activation/short-range inhibition, relaxing the typical requirement for a rapidly diffusing inhibitor in the case of classical diffusion [7]. Moreover, in the presence of cross-diffusion, the spatial structures induced by long-range activation/short-range inhibition mechanisms are always out of phase (cross- Turing patterns) and subcritical in most of the instability regions [8]. Finally, using the formalism of amplitude equations, we derive the asymptotic profiles of the stationary solutions and classify the bifurcation, distinguishing between super- and subcritical transitions. Moreover, we investigate the dynamics near a co-dimension 2 Turing- Hopf bifurcation point, and find the conditions under which we can have oscillatory Turing patterns.

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Merten Stender, Manish Yadav

TU Berlin, Germany

Understanding Structure-Function Relationships through Performance-Dependent Network Evolution

How do network Structure and Function co-emerge under performance pressure? We address this through the Performance-Dependent Network Evolution (PDNE) framework, a biologically inspired mechanism that grows reservoir computing networks from minimal seed topologies via iterative, performance-gated node addition and deletion. Rather than fixing architecture before training, PDNE evolves structure alongside function, producing compact, task-specialized networks that consistently outperform Erdős–Rényi random networks and uninformed growth strategies, while revealing emergent scaling laws, self-organized symmetry-breaking distributions, and a task-complexity quantifier encoded in evolved network size and density. To illuminate how structural organization encodes functional capacity, we present two complementary results: task-specific node pruning identifies functionally critical sub-networks by eliminating redundant dynamical pathways, improving efficiency and interpretability; and applying PDNE to Wilson-Cowan excitatory-inhibitory (E-I) neuronal dynamics shows that evolved reservoirs spontaneously recover the correct E-I sign structure of the target system at the population level, without this being imposed by design and generalize zero-shot to novel stimulus configurations. Together, these results establish PDNE as a principled framework for uncovering structure-function relationships in evolving networks, with implications for complex dynamical systems, network science, neuromorphic computing, and interpretable machine learning.

Ronja Strömsdörder

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Spike-frequency and h-current based adaptation as candidate modulators of the propagation of traveling waves

traveling waves During non-REM sleep, the brain shows repetitive patterns of slow oscillations (SOs, <1 Hz) between periods of active (up-state) and silent (down-state) neuronal activity, which are assumed to play a crucial role in memory consolidation (Rasch and Born, 2013). Cortical whole-brain modeling studies found the connectome to be a key driver of propagation features (e.g., directionality) of these waves (Koller et al., 2024; Cakan et al., 2022) while intrinsic mechanisms are also candidate modulators of propagation features (see Alegre-Cortés et al. (2025), who showed in-silico that changes in adaptation affected neighboring neuronal populations). Both spike-frequency adaptation (SFA) and hyperpolarization-activated (h-)current based adaptation were experimentally and computationally shown to drive traveling waves of SO- like dynamics (Dalla Porta et al., 2024; Mehrotra et al., 2024) while their modulatory contribution to propagation features remains unclear. Mechanistically contrary, meaning reduced to their canonical roles as negative feedback activated in high-activity states (SFA) vs. positive feedback activated in low-activity states (h-currents), they are dynamically equivalent under transformation and compensation (Strömsdörfer and Obermayer, 2025).

Building on the publication of Strömsdörfer and Obermayer (2025), we implement an adaptive Wilson–Cowan field model incorporating both mechanisms with equivalency-breaking properties on a two-dimensional spatial domain. We investigate how these equivalency-breaking properties differentially affect propagation features of traveling waves, and how their effects compare to recurrence weights. Preliminary results indicate that spatial gradients in adaptation strength induce directionality independent of initialization, and that gradient steepness increases wave speed.

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Simon Vock

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Criticality governs deep learning: enhancing performance, enabling continual learning, mitigating model collapse

The rapid advances in artificial intelligence (AI) have largely been driven by scaling deep neural networks (DNNs) - increasing model size, data, and computational resources. However, performance is ultimately governed by network dynamics. The lack of a principled understanding of DNN dynamics beyond heuristic-based design has contributed to challenges with their robustness, suboptimal performance, high energy consumption and pathologies in continual and AI-generated content learning. Increasing evidence suggests that the human brain may avoid these problems by operating at a critical phase transition. Inspired by this principle, we here propose that criticality may provide a unifying framework linking structure, dynamics, and function also in DNNs. First, by analyzing more than 80 state-of-the-art DNN models and well established benchmark datasets (ImageNet, MNIST), we report that a decade of AI progress has implicitly driven successful networks towards criticality, as measured by largest Lyapunov exponents λ_0 (Spearman $r = -0.5$, $p < 10^{-4}$), explaining why certain architectures succeeded while others failed. Second, incorporating criticality explicitly into training improves even highly optimized models by more than 0.4 percentage points ($p < 0.001$) and establishes robustness across weight initializations, preventing key limitations of current models. Third, we show that catastrophic AI pathologies, including continual learning degradation and model collapse from AI-generated training data, constitute a loss of critical dynamics. By keeping networks critical, we provide the first principled solution to these fundamental AI problems by mitigating performance degradation and model collapse. This work confirms criticality as substrate-independent principle of intelligence, connecting AI advancement with core principles of brain function. For systems neuroscience, this work offers a link between optimal function in biological and artificial neural networks. For AI, it provides profound theoretical insights along with immediate practical value solving major challenges to ensure long-term DNN performance and resilience as models grow in scale and complexity.

Yu Wang

Potsdam Institute for Climate Impact Research, Germany

Universal dynamic phenomena in delay systems: fundamentals and applications

The majority of delay differential equations (DDEs) with one delay have only a few bifurcation scenarios, which can be explicitly described. We explore absolute stability and universal bifurcation scenarios in DDEs using asymptotic continuous spectrum (ACS) theory. We then combine the Master Stability Function (MSF) method for discussing the dynamics of active-agent systems. First, we present how universality classes and Hopf bifurcation sequences in single-delay DDEs can be characterized through the ACS, reveal general transversality results in the large-delay regime, and consider the three most common universality classes. For each of them, we explicitly describe the sequence of stabilizing and destabilizing bifurcations. Then, we apply the above framework to active-agent systems with inertia and delayed feedback, analyzing stability conditions for formation patterns in both uncoupled and coupled settings. These results provide a unified perspective on stable coordination, pattern formation, and universal delay-induced dynamics in complex systems. Additionally, we investigate interactions in the large-delay limit, where delays affect inter-agent coupling, while local feedback remains instantaneous. In this limit, we prove rigorously that the stability region in the complex plane of the eigenvalues of the Laplacian matrix converges to a circle centered at the origin, a phenomenon previously observed in delay-coupled networks. Our findings provide a universal framework for understanding stable formations and motions of active agents with delayed interactions.

Dan Zhao

Potsdam Institute for Climate Impact Research, Germany

Synchronization transitions and spike dynamics in a higher-order Kuramoto model with Lévy noise

Synchronization in complex networks is influenced by higher-order interactions and non-Gaussian perturbations, yet their mechanisms remain unclear. We investigate the synchronization and spike dynamics in a higher-order Kuramoto model subjected to Lévy noise. Using the mean order parameter, mean first-passage time, and basin stability, we identify boundaries distinguishing synchronization and incoherence. The stability index governs the tail heaviness of the probability density function for Lévy noise, while the scale parameter affects the magnitude. Synchronization weakens as the stability index decreases, and even completely disappears when the scale parameter exceeds a critical threshold. By varying coupling, we find bifurcations and hysteresis. Lévy noise smooths the synchronization transitions and requires stronger coupling compared to Gaussian white noise. We then define spikes as extreme excursions of the order parameter and study their statistical and spectral properties. The maximum number of spikes is observed at small scale parameters. A generalized spectral analysis based on an edit distance algorithm measures the similarity between spike sequences and identifies spike patterns. These findings deepen the understanding of synchronization and extreme events in complex networks driven by non-Gaussian noise.

Practical information

Venue	The International Conference on Nonlinear Network Dynamics: Complexity and Control will take place in the Hermann-von-Helmholtz Auditorium, Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2–12, 10587 Berlin
Conference Center	The registration desk will be open from 8:00 am in front of the lecture hall on Monday, and from 8:45 am on Tuesday and Wednesday. Of course, you may contact the organizers during the breaks.
Talk format	All invited presentations will last 25 minutes speaking time plus 5 minutes for questions and discussion. It is recommended that all speakers bring their presentation on a USB stick during the coffee breaks and test their presentation on the laptop provided. The projector will be equipped with HDMI input.
Poster Presentations	The poster session on Monday evening will take place in the foyer next to the auditorium. To mount the posters, magnets will be provided. Posters should be in DIN A0 format (84 cm wide and 120 cm high) and should remain on display during the whole conference. Please remove the posters by the end of the conference.
Lunch	Lunch break is 13:00–14:00 on Monday and Tuesday; Wednesday ends with Closing + Lunch at 13:00–14:00. For lunch we recommend Culinary Circus, Abbestr. 2–12, 10587 Berlin, entrance via Marchstr./corner Fraunhoferstr., or Mensa TU Marchstraße 23 (MAR).
Poster session	Monday, 04 May 2026: 19:00-21:00
Sponsors	Physikalisch-Technische Bundesanstalt (PTB), Germany; Berlin Center for Studies of Complex Chemical Systems (BCSCCS), Germany.

Transport and access information

Transport

Venue address: Hermann-von-Helmholtz Auditorium, Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2–12, 10587 Berlin.

By public transport

The PTB Charlottenburg campus is about a 15-minute walk from Bahnhof Zoologischer Garten and is located close to Ernst-Reuter-Platz. PTB lists the following nearby public-transport stops for visitors:

- Bus M45, Otto-Suhr-Allee bus stop
- Bus 245, Marchstraße bus stop
- U-Bahn: Ernst-Reuter-Platz station

From BER Airport

From BER Airport, PTB recommends taking the S9 towards Spandau to Zoologischer Garten and then the U2 towards Theodor-Heuss-Platz to Ernst-Reuter-Platz.

From Berlin Central Railway Station (Berlin Hauptbahnhof)

From Berlin Hauptbahnhof, PTB indicates one convenient option: S-Bahn lines S3, S5, S7, or S9 to Zoologischer Garten, followed by the U-Bahn to Ernst-Reuter-Platz or a local bus connection (Bus 245).

Parking

Parking is not available at the conference site. We recommend arrival by public transport.

Registration

Conference registration is handled online via the registration link on the conference website. The on-site registration desk is open in front of the lecture hall from 8:00 am on Monday, and from 8:45 am on Tuesday and Wednesday.

Wi-Fi / WLAN

Network access details will be announced at the registration desk. Guest WLAN (SSID:PTB-Gast) will be available.

List of participants

Fatemeh Aghaei A. MPI for Physics of Complex Systems, Dresden, Germany Poster Presentert	Yingyue Lyu PIK, Potsdam, Germany Participant
Andreas Amann University College Cork, Ireland Invited speaker	Anna Mandel-Zakharova BCCN Berlin, Germany Participant
Mehrnaz Anvari Fraunhofer Institute for Algorithms and Scientific Computing, Sankt Augustin, Germany Participant	Cristina Masoller Universitat Politecnica de Catalunya, Barcelona, Spain Invited speaker
Ali Rana Atilgan Sabanci University, Istanbul, Turkey Poster presenter	Volker Mehrmann TU Berlin, Germany Organizer
Roland Aust Berlin, Germany Organizer	Hildegard Meyer-Ortmanns Constructor University, Bremen, Germany Invited speaker
Juri Backes University of Applied Sciences, Hamburg, Germany Poster presenter	Andreas E. A. Mobron Mobron Consulting, Berlin Germany Participant
Markus Bär PTB Berlin, Germany Participant	Sören Nagel Zuse Institute Berlin, Germany Participant
Christian Beck Queen Mary University of London, UK Invited speaker	Klaus Obermayer TU Berlin, Germany Invited speaker
Vitaly Belik FU Berlin Invited speaker	Simona Olmi ISC-CNR, Florence, Italy Organizer
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Jens Christian Claussen University of Birmingham, UK Invited speaker	Arkady Pikovsky University of Potsdam, Germany Invited speaker
Natasa Djurdjevac Conrad Zuse Institute Berlin, Germany Invited speaker	Georg Reich TU Berlin, Germany Poster presenter

Frederico Costa Oncology Department, Hospital Sírio-Libanês, São Paulo, Brazil Invited speaker	Wolfgang Renz University of Applied Sciences, Hamburg, Germany Poster presenter
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Sabine Dietrich Berlin, Germany Participant	Julius Rosenberg TU Berlin, Germany Poster presenter
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Sebastian Heidenreich PTB Berlin, Germany Participant	Alessandro Torcini CY Cergy Paris Université, France Invited speaker
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Philipp Hövel University of Saarbrücken, Germany Organizer. Invited speaker	Simon Vock Charité Berlin, Germany Poster presenter

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Jun Jiang Xi'an Jiaotong University, China Invited speaker	Yu Wang Potsdam Institute for Climate Impact Research, Germany Poster presenter
Oliver Kamps University of Münster, Germany Participant	Karoline Wiesner University of Potsdam, Germany Invited speaker
Lucas Kluge d-fine GmbH (former: TU Berlin & PIK) Participant	Dirk Witthaut Forschungszentrum Jülich, Germany Invited speaker
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Jürgen Kurths Potsdam Institute for Climate Impact Research, Germany Invited speaker	Yong Xu Northwestern Polytechnical University, Xi’an, China Invited speaker
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Kathy Lüdge TU Ilmenau, Germany Organizer	