Workshop on Critical Transitions in Complex Systems

Imperial College London, 19 March – 23 March 2012

Talk titles and abstracts

Christian Kühn (Technical University of Vienna)

Towards a Mathematical Framework for Critical Transitions: From Bifurcations to Complex Systems

Monday, 19 March 2012, 2.00pm–2.45pm, Huxley 139

We start by developing a basic mathematical theory for critical transitions in fast-slow stochastic systems with loss of normal hyperbolicity. It is shown that this framework encompasses various effects and requirements found in the last decade in widely disparate application areas. In particular, we will state and discuss a theorem on scaling laws of covariance matrices for all bifurcations up to codimension two. Then we apply these results to epileptic seizure data, a higher-dimensional parameter space in an ecological model and show their relevance for reduced models of a large scale adaptive epidemic network.

In the second part of my talk I will give a short proof that another mechanism for critical transitions must be considered for higher- dimensional complex systems with an example arising in evolutionary game theory. We suggest new warning signs in this context for local as well as global transitions. Thereby a first connection between network science and critical transitions is established.

The work on epileptic seizures is joint with: C. Meisel (Dresden). The work on complex systems is joint (in progress) with: G. Zschaler (Dresden) and T. Gross (Bristol).

Michael Ghil (Ecole Normale Supérieure, Paris, and University of California, Los Angeles)

The Complex Physics of Climate Change: Nonlinearity and Stochasticity

Monday, 19 March 2012, 2.45pm–3.30pm, Huxley 139

Recent estimates of climate evolution over the coming century still differ by several degrees. This uncertainty motivates in part the work presented herein.

The complex physics of climate change arises from the large number of components of the climate system, as well as from the wealth of processes occurring in each of the components and across them. This complexity has given rise to countless attempts to model each component and process, as well as to two overarching approaches to apprehend the complexity as a whole: deterministically nonlinear and stochastically linear. Call them the Ed Lorenz and the Klaus Hasselmann approach, respectively, for short.

We propose a ”grand unification” of these two approaches that relies on the theory of random dynamical systems. In particular, we apply this theory to the problem of climate sensitivity, and study the random attractors of nonlinear, stochastically perturbed systems, as well as the time-dependent invariant measures supported by these attractors.

Results are presented for several simple climate models, from the classical Lorenz convection model to El Niño–Southern Oscillation models. Their attractors support random Sinai–Ruelle–Bowen measures with nice physical properties. Applications to climate sensitivity and predictability are discussed.

This talk presents joint work with M.D. Chekroun, A. Feigin, D. Kondrashov, J.C. McWilliams, J.D. Neelin, E. Simonnet, S. Wang, and I. Zaliapin.

Didier Sornette (ETH Zürich)
Intermittent Criticality in Financial Markets
Monday, 19 March 2012, 4.00pm–4.45pm, Huxley 139

We propose two measures of activity of financial markets that provides direct access to their level of endogeneity and criticality.

The first measure, called ”crash alarm”, is based on the calibration of financial bubbles at time scales from days to years, defined as transient super-exponential stochastic price trajectories that reflect positive feedbacks. The results include advanced methods of calibration to address the quasi-degenerate or soft-mode problem in the estimation procedure, and the use of self-consistent rational expectation bubble models. The second measure, called “branching ratio”, quantifies how much price changes at high frequencies are due to endogenous feedback processes, as opposed to exogenous news. For this, we calibrate the self-excited conditional Poisson Hawkes model, which combines in a natural and parsimonious way exogenous influences with self-excited dynamics, to the E-mini S&P 500 futures contracts traded in the Chicago Mercantile Exchange from 1998 to 2010. We find that the level of endogeneity has increased significantly from 1998 to 2010, with only 70% in 1998 to less than 30% since 2007 of the price changes resulting from some revealed exogenous information. We also report evidence of intermittent criticality, as an explanation of ”flash crash” phenomena. Analogous to nuclear plant safety concerned with avoiding “criticality”, our measures provides direct quantifications of the distance of the financial market to a critical state defined precisely as the limit of diverging trading activity in absence of any external driving.

These results are part of the activities of the Financial Crisis Observatory (www.er.ethz.ch/fco) launched at ETH Zürich in 2008, which aims at testing and quantifying rigorously, in a systematic way and on a large scale the hypothesis that critical financial instabilities can diagnosed with a rigorous scientific methodology before they burst.

Sebastian Hage-Packhäuser (University of Paderborn)
Symmetry-Driven Switching & Stability of Dynamical System Networks
Monday, 19 March 2012, 4.45pm–5.15pm, Huxley 139

Since reality is a complex phenomenon which is based on the interplay of countless acting instances and crucially subject to temporal evolution, numerous real world phenomena have to be mathematically described in terms of time-varying dynamical systems networks. While the network structures stem from the interaction of various dynamic instances, time-dependence often occurs as a consequence of the instantaneous variation of these structures.

In this work, time-varying networks of dynamical systems are discussed in terms of hybrid dynamics with a special consideration of symmetries which are naturally due to the network structures involved. By means of the recent notion of hybrid symmetries, a hybrid symmetry framework is presented and symmetry-induced switching strategies are investigated. Against this background, stability-related critical transitions are encountered which are linked to the activation and termination of switching.

This is joint work with Michael Dellnitz.

Jens Rademacher (CWI Amsterdam)
Stability Boundaries of Spatial Patterns: Towards Warning Signals
Tuesday, 20 March 2012, 9.00am–9.45am, Huxley 144

In spatially extended systems a precursor to the transition from one homogeneous state (such as full vegetation) to another (such as a desert) is frequently the formation of spatial patterns (patchy vegetation). This in turn may serve as a warning signal of a critical transition. It is thus important to determine the boundary of stability of these patterns. In this talk I present analytical and numerical studies of stability boundaries and discuss some relations to the dynamics of transitions.

Katharina Krischer (Technical University Munich)
Pattern Formation in Electrochemical Systems: The role of Nonlocal and Global Coupling
Tuesday, 20 March 2012, 9.45pm–10.30pm, Huxley 144

The spontaneous formation of patterns in time and/or space occurs in many electrochemical processes, among them a variety of technological importance, such as corrosion of metals, galvanoplating of alloys, electropolishing of aluminum or silicon, or the oxidation of fuels in fuel cells. I will review experimental examples from our laboratory and discuss a general mathematical description of electrochemical pattern formation, the nonlocal complex Ginzburg–Landau equation for electrochemical systems. Employing bifurcation analysis, the role of nonlocal and global coupling for pattern formation will be highlighted, and possibilities will be discussed to manipulate dynamic instabilities by tuning the spatial coupling.

Henrik Jeldtoft Jensen (Imperial College London)
Intermittent Transformative Non-Stationary Dynamics in Complex Systems
Tuesday, 20 March 2012, 11.00am–11.45pm, Huxley 144

Non-stationary spasmodic dynamics of complex systems is reviewed through a number of models three specific models. The long time dynamics consists intermittently occurring transitions that bring about major changes to the characteristic of the system. These events are denoted quakes. They occur at a decreasing rate and are related to release of generalized intrinsic strain. Between the quakes weak fluctuations occur but no essential change in properties are induced. The accumulated effect of the quakes, however, is to induce a direct change in the probability density functions characterising the system. We discuss how the log-Poisson statistics of record dynamics may be an effective description of the long time evolution and describe how an analysis of the times at which the quakes occur enables one to check the applicability of record dynamics. We relate the discussion to models of evolutionary ecology, finance, collective dynamics in ant colonies and to several physical systems (spin glasses, magnetic relaxation in super conductors and earthquakes).

References:
P. Sibani and H.J. Jensen, Record Statistics and Dynamics, Encyclopedia of Complexity and Systems Science, Springer, 2009.
T.O. Richardson, K. Christensen, N.R. Franks, H.J. Jensen, and A.B. Sendova-Franks, Group dynamics and record signals in the ant Temnothorax albipennis, J. R. Soc Interface doi:10.1098/rsif.2010.0286 (2010).
D. Jones, H.J. Jensen and P. Sibani, Tempo and Mode of Evolution in the Tangled Nature Model, Phys. Rev. E 82, 036121, (2010).

Vasilis Dakos (Wageningen University)
Leading Indicators of Upcoming Shifts in Space
Tuesday, 20 March 2012, 2.00pm–2.45pm, Huxley 145

Predicting the risk of critical transitions such as the collapse of a population is important in order to direct management efforts. In any system that is close to a critical transition, recovery upon small perturbations becomes slow, a phenomenon known as 'critical slowing down'. It has been suggested that such slowing down may be detected indirectly through an increase in spatial and temporal correlation and variance. Here, we tested this idea in arid ecosystems, where vegetation may collapse to desert due to increasing water limitation. We used three models that describe desertification, but differ in the spatial vegetation patterns they produce. In all models, recovery rate upon perturbation decreased before vegetation collapsed. However, in one of the models, slowing down failed to translate into rising variance and correlation. This is caused by the regular self-organized vegetation patterns produced by this model. This finding implies an important limitation of variance and correlation as indicators for critical transitions. However, changes in such self-organized patterns themselves are a reliable indicator of an upcoming transition. Our results illustrate that while critical slowing down may be a universal phenomenon at critical transitions, its detection through indirect indicators may have limitations in particular systems.

Steven Lade (Max Planck Institute for the Physics of Complex Systems, Dresden)
Early Warning Signals of Intermediate Complexity
Tuesday, 20 March 2012, 2.45pm–3.30pm, Huxley 145

A mechanistic approach to anticipating critical transitions would be to design and calibrate a detailed model of the system at hand. In response to the difficulties involved with such an approach, several data-driven, model-free approaches have recently been proposed and investigated both theoretically and experimentally. In this talk I will show that there exists scope for intermediate approaches, which are driven by observations but which also incorporate available knowledge about the structure of the system. I present one such approach, which incorporates the different data and knowledge through the framework of a generalised model. I apply the generalised modelling method to two ecological examples, including the simulated collapse of a fishery.

Jose A. Capitán (Centro de Astrobiologia INTA-CSIC, Madrid)
Catastrophic Regime Shifts in Model Ecosystems as True Phase Transitions
Tuesday, 20 March 2012, 4.00pm–4.30pm, Huxley 145

Ecosystems often undergo abrupt regime shifts in response to gradual external changes [1]. These shifts are commonly explained as regime switches between alternative stable states of the ecosystem dynamical response to smooth changes in external conditions. Usual models introduce nonlinearities in the macroscopic ecosystem dynamics that lead to different stable attractors among which the shift takes place [1,2]. In this talk I will present an alternative description of ecological regime shifts as true phase transitions. This work builds on a recent model [3-5] that pictures ecological communities as systems in continuous fluctuation between different "micro-states" in the phase space of communities formed by coexisting species. Transitions between such "viable" communities are caused by the sequential arrival of rare species according to a certain immigration rate, which drives the system to a species-rich end state. The assembly process of the ecosystem is described as a finite, aperiodic Markov chain that explores the space of viable communities.

As an opposing force to the immigration rate, a spontaneous extinction rate has been introduced in the model. Species diversity in communities can decrease for reasons other than predator-prey interactions, such as habitat fragmentation, overexploitation, or fluctuations in the amount of available resources. The gradual pressure exerted by external factors affecting the ecosystem is modeled with a variable level of background extinctions. Upon variations on this control parameter the system undergoes a regime shift with similar features to those previously reported. Under this microscopic framework I will characterize, as in previous theoretical and empirical work, several precursors of the transition (anomalous variance, hysteresis cycles, trophic cascades). The model predicts a gradual loss of species in trophic levels from bottom to top near the transition. But more importantly, the spectral analysis of the transition probability matrix of the Markov chain will help to rigorously prove that we are observing the fingerprints, in a finite size system, of a true phase transition in the sense of Statistical Mechanics [6].

References:
[1] M. Scheffer et al., Nature 413, 591–596 (2001).
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[3] J.A. Capitán, J.A. Cuesta and J. Bascompte, Phys. Rev. Lett. 103, 168101 (2009).
[4] J.A. Capitán and J.A. Cuesta, J. Theor. Biol. 269, 330–343 (2011).
[5] J.A. Capitán, J.A. Cuesta and J. Bascompte, J. Theor. Biol. 269, 344–355 (2011).
[6] J.A. Capitán and J.A. Cuesta, J. Stat. Mech. P10003 (2010).

Nils Berglund (Université d'Orléans)
Sample-Path Behaviour of Noisy Systems near Critical Transitions
Wednesday, 21 March 2012, 9.00am–9.45am, Huxley 139

Noise typically has two effects on systems approaching a critical transition: (1) the variance of sample paths increases in a way characteristic for the bifurcation, and (2) transitions occur earlier than in the absence of noise. I will illustrate an approach allowing to quantify these effects by discussing in detail the case of the fold (or saddle-node) bifurcation. Then I will present a few applications of the approach to other situations (Hopf bifurcation, stochastic resonance, excitability). Based on joint work with Barbara Gentz (Bielefeld).

Sebastian Wieczorek (University of Exeter)
Novel Types of Tipping Points
Wednesday, 21 March 2012, 9.45am–10.30am, Huxley 139

Consider a system in the vicinity of a stable state. There is a general belief that sudden changes in the state of a system known as ”tipping points” are associated with ”critical ultimate magnitudes” at which the stable state disappears or destabilises in a bifurcation, causing the system to move to another state. However, in addition to critical magnitudes, there also exist ”critical rates”, above which the system is unable to keep pace with a rapidly imposed change in the stable state. Such rate-dependent tipping is conceptually different from previously studied mechanisms and very relevant to the current and future human-dominated climate epoch that may not be so much about the ultimate magnitude of warmth but its rate of change. This talk will classify different tipping mechanism and use the theory of rate-dependent tipping to explain the curious ”compost-bomb instability” observed in a climate-carbon cycle model.

This is joint work with Peter Ashwin, Peter Cox and Renato Vitolo.

Robert S. MacKay (University of Warwick)
Tipping Between Phases of Stochastic Complex Systems
Wednesday, 21 March 2012, 11.00am–11.45am, Huxley 139

Even if irreducible, spatially extended stochastic systems may exhibit more than one phase. A phase is a probability distribution for state as function of space and time. In contrast to equilibrium statistical mechanics, non-uniqueness of phase is a robust property of certain classes of non-equilibrium system. What are the situations in which a nudge or small parameter change can lead to the system flipping from one of its phases to another? Some ideas will be sketched.

Alan Hastings (University of California, Davis)
Challenges to Detection of Early Warning Signals of Regime Shifts
Wednesday, 21 March 2012, 1.15pm–2.00pm, Huxley 139

Much of the literature on early warning signals of critical transitions has focused on using summary statistics to look at saddle-node (fold) bifurcations. I will consider how views of ability to detect warning signals of regime shifts change as we consider more complex dynamical behaviors, and also what the role of more careful statistical approaches could be.

Ryan Chisholm (Smithsonian Tropical Research Institute)
Critical Slowing Down as an Indicator of Transitions in Two-Species Models
Wednesday, 21 March 2012, 2.00pm–2.45pm, Huxley 139

Transitions in ecological systems often occur without apparent warning, and may represent shifts between alternative persistent states. Decreasing ecological resilience (the size of the basin of attraction around a stable state) can signal an impending transition, but this effect is difficult to measure in practice.

Theoretical research has suggested that a decreasing rate of recovery from small perturbations (critical slowing down) is a good indicator of ecological resilience. I will present the results of a mathematical analysis that produces general conclusions about the conditions under which critical slowing down provides an early indicator of transitions in two-species predator-prey and competition models. The models exhibit three types of transition: the predator-prey model has a Hopf bifurcation and a transcritical bifurcation, and the competition model has two saddle-node bifurcations (in which case the system exhibits hysteresis) or two transcritical bifurcations, depending on the parameterisation. The findings are that critical slowing down is an earlier indicator of the Hopf bifurcation in predator-prey models in which prey are regulated by predation rather than by intrinsic density-dependent effects and an earlier indicator of transitions in competition models in which the dynamics of the rare species operate on slower timescales than the dynamics of the common species. I will describe how these results might extend to more-complex multispecies systems and I will discuss the practical implications for real-world systems in which economic factors relating to transitions must also be considered.

Simon Levin (Princeton University)
Critical Transitions in Ecosystems and Complex Adaptive Systems
Wednesday, 21 March 2012, 3.15pm–4.00pm, Huxley 139

A brief review will be given of historical interest in critical transitions in ecosystems, with an emphasis on robustness, resilience and the features of complex adaptive systems that retard critical transitions. Attention will then turn to multiple stable states, and in particular to the interplay between savannas and forests.

Jan Sieber (University of Portsmouth)
Early Escape near Tipping Points
Thursday, 22 March 2012, 9.00am–9.45am, Huxley 130

It is often known, from modelling studies, that certain climate tipping events (of the oceanic thermohaline circulation, for example) are governed by a gradual passage of a system parameter through a fold bifurcation. For such a case, we present how parameter drift speed and noise level interplay to either cause early or delayed tipping. The precise probability of tipping, which is changing over time, can be computed easily for the so-called normal form if one assumes that the noise is Gaussian.

The more difficult part, if one is given a snippet of time series that one suspects of approaching a tipping point, is to estimate the normal form parameters, especially the dominant nonlinear term. We will show some measures that permit at least the testing of presence and sign of the leading nonlinear term.

This is joint work with J.M.T. Thompson (University of Aberdeen).

Timothy Lenton (University of Exeter)
Searching for Early Warnings in Recent Climate Data
Thursday, 22 March 2012, 9.45am–10.30am, Huxley 130

A 'tipping point' occurs when a small change in forcing triggers a strongly non-linear response in the internal dynamics of a system, qualitatively changing its future state. Large-scale 'tipping elements' have been identified in the Earth's climate system that may pass a tipping point under human-induced global change this century. Such abrupt, non-linear changes are likely to have large impacts, but our capacity to forecast them has hitherto been poor. Hence the prospect that approaching tipping points carry generic early warning signals is both scientifically exciting and of great potential value to societies. Promising methods are based on detecting 'critical slowing down' in the rate a system recovers from small perturbations, and on characteristic changes in the statistical distribution of its behaviour (e.g. increasing variability). We have developed and tested such early warning methods on artificial data, in models being gradually forced past tipping points, and in paleo-climate data approaching past abrupt transitions. This has given us some confidence to start applying the methods to observational climate data, and I will show new results from this analysis. In particular, a bifurcation in Arctic sea-ice cover is detected around 2007 in which a new low ice cover state has appeared and persisted, but this was not heralded by robust early warning signals. Also, analysis of sea surface temperature datasets from the North Pacific and North Atlantic show slowing down in response to perturbations. However, this can be understood, at least partly, as a response to observed deepening of the mixed layer rather than any approach to a tipping point.

This is joint work with Valerie Livina (University of East Anglia) and Chris Boulton (University of Exeter), building on collaboration with Vasilis Dakos and Marten Scheffer (Wageningen University).

Chris Jones (University of North Carolina)
Who, or What, Will Tip the Big Climate Models?
Thursday, 22 March 2012, 11.00am–11.45am, Huxley 130

There is an accepted practice in climate science to develop an understanding of physical mechanisms in idealized conceptual models and then test them for validity in full-scale climate models. Various potential climate tipping points will be discussed in terms of this scientific approach.

Paul Valdes (University of Bristol)
Thursday, 22 March 2012, 2.00pm–2.45pm, Huxley 130

Valerie N. Livina (University of East Anglia)
Tipping Points Toolbox for Climatic Records
Thursday, 22 March 2012, 2.45pm–3.30pm, Huxley 130

We develop and apply a set of novel techniques of time series analysis to studying transitions and bifurcations in climatic records. The techniques are degenerate fingerprinting (indicators based on lag-1 autocorrelation and detrended fluctuation analysis) and potential analysis (derivation of underlying system potential and its dynamics). The techniques allow one to distinguish transitions and bifurcations in the climate system and to detect approaching critical behaviour (early warning). We test the toolbox on artificial data with known properties and then apply to case studies of geophysical data.

This is joint work with Timothy Lenton (University of Exeter).

References:
[1] Lenton et al, PNAS 2008
[2] Livina & Lenton, GRL 2007
[3] Livina et al, Climate of the Past 2010
[4] Livina et al, Climate Dynamics 2011
[5] Livina et al, Physica A 2011
[6] Lenton et al, Phil Trans Royal Soc A 2012
[7] Livina and Lenton, submitted

Peter Ditlevsen (Niels Bohr Institute Copenhagen)
Are Abrupt Climate Changes Predictable?
Thursday, 22 March 2012, 4.00pm–4.45pm, Huxley 130

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. Lorenz (1975) dubbed this predictability of the first and the second kind respectively. Predictability of the first kind in a chaotic dynamical system is limited due to the well-known 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, the predictability horizon for a weather forecast is not related to the inverse of the Lyapunov exponent of the system. These are rather associated with the much shorter times in the turbulent boundary layer and so on. These time scales are effectively averaged on the time scales of the flow in the free atmosphere. Thus, when forecasting, say, showers in the afternoon, this is really a forecast of the second kind giving a statistical probability of convection and precipitation at a specific location at a specific time as a function of a large scale flow pattern predicted from initial conditions. On the other hand, turning to climate change predictions, the time scales on which the system is considered quasi-stationary, such that the statistics, say mean surface temperature, can be predicted as a function of an external parameter, say atmospheric greenhouse gas concentration, is still short in comparison to slow dynamics such as the oceanic overturning. 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. Such a jump happens very fast when a critical tipping point has been reached. The question is: Can a tipping point be predicted? This is a new kind of predictability (the third kind). If the tipping point is reached through a bifurcation, where the stability of the system is governed by some control parameter, changing in a predictable way to a critical value, the tipping is predictable. If the sudden jump occurs because internal chaotic fluctuations, noise, push the system across a barrier, the tipping is as unpredictable as the triggering noise. In order to hint at an answer to this question, an analysis of the Dansgaard–Oeschger climate events observed in ice core records is presented. The result of the analysis points to a fundamental limitation in predictability of the third kind.

Marten Scheffer (Wageningen University)
Critical Transitions in Nature and Society
Thursday, 22 March 2012, 6.30pm–7.30pm, Huxley 311

The lecture will be about the question how we may explain the remarkably abrupt changes that sometimes occur in nature and society – and whether we can predict why and when they happen.

Alexander Feigin (University of Nizhny Novgorod)

Stochastic Reconstruction of a Dynamical System for Early Prediction of Critical Transitions

Friday, 23 March 2012, 9.00am–9.45am, Huxley 340

The majority of natural systems, including the climate system, have a high-dimensional phase-space and are open, i.e. subject to numerous external forcings. Hence they often produce complex multi-scale behavior that cannot be modeled deterministically based on a direct distillation of the observed processes. A widespread basic idea is that the robust dynamic properties of the systems evolution can be described by a few variables, while other features may be considered as stochastic perturbations thereof. Random dynamical systems (RDS) present a nice mathematical framework for reconstructing the observed systems when ab initio, first-principle mathematical models are known only poorly or not at all.

We report here on an approach to constructing an optimal model that reproduces basic dynamical properties of the system underlying an observed time series. In this approach, the systems evolution operator is represented in RDS form, including a deterministic and a stochastic term; both are formulated as artificial neural networks. A Bayesian information criterion is used to estimate the models optimal complexity, i.e. the number of parameters as well as the phase-space dimension that correspond to the most probable model generating the analyzed process.

We show on hand of a number of examples that the model with a non-uniformly distributed stochastic term – which corresponds to non-Gaussian perturbations of the deterministic evolution operator – is optimal. It appears that, even for a purely deterministic but high-dimensional system, a simple stochastic model with but a few variables is best adapted for the reconstruction of the evolution operator underlying the observed dynamics.

Finally, the ability of our reduced-order stochastic models to predict regime transitions within times longer than the observation time interval is illustrated on time series of the sea surface temperature field. These time series are taken from El-Niño/Southern Oscillation (ENSO) simulations with the intermediate-complexity model of Jin & Neelin ([1,2]; JN hereafter). The JN model uses partial differential equations in time and longitude along the Equator and was derived as a simplification of the spatially multi-dimensional Cane–Zebiak coupled ocean-atmospheric model [3].

Slow changes in the model parameters were introduced into the JN model to simulate slowly changing external conditions of the Tropical Pacifics ocean-atmosphere system, such as global warming. Given only scalar time series from the JN simulations, we show that jumps in qualitative behavior can be predicted by our stochastic, data-based model many years in advance. The predictable aspects include evolution of the probability density function and of the spectral density, including critical transitions from chaotic to regular (periodic or quasi-periodic) behavior and vice versa. The predictability time here exceeds the duration of the observed time series, while operational ENSO predictions are only useful for less than a year [4].

This is joint work with D. Mukhin (University of Nizhny Novgorod), A. Gavrilov (University of Nizhny Novgorod), D. Kondrashov (UCLA), E. Loskutov (University of Nizhny Novgorod), and M. Ghil (UCLA and Ecole Normale Supérieure, Paris).

References:

[1] Jin, F.-F., and J D. Neelin, 1993: Journal of the Atmospheric Sciences, 50, 3477–3503.
[2] F.-F. Jin, J.D. Neelin, and M. Ghil, 1994: Science, 264, 70–72.
[3] Zebiak, S.E., and M.A. Cane, 1987: Monthly Weather Review, 115, 2262–2278.
[4] IRI forecast plume, http://iri.columbia.edu/climate/ENSO/currentinfo/SST_table.html.

Mickael Chekroun (University of California, Los Angeles)
Friday, 23 March 2012, 9.45am–10.30am, Huxley 340

Eyad H. Abed (United Arab Emirates University and University of Maryland)
Monitoring Complex Systems to Avoid Sudden Instability
Friday, 23 March 2012, 11.00am–11.45am, Huxley 340

Many complex systems, be they man-made or naturally occurring, can lose stability without warning, sometimes with great economic or human cost. For engineered systems, this is typically related to system operation at levels of stress and with degrees of uncertainty that drastically reduce the capability of standard modeling and prediction methodologies. Thus, system operators might predict that a system will continue to function in an acceptable manner, while in fact the system is on the verge of complete collapse due to an impending instability. In this lecture, several existing approaches to monitoring the vulnerability of complex uncertain systems under stressed operation are discussed, and new contributions are given. The benefits and limitations of using exogenous probe signals are pointed out. Techniques for determining areas within a system that are of most value in system monitoring are developed, and these techniques are shown to provide a means both for detecting and localizing the vulnerability of a complex system to disturbances and to collapse. Power system applications are used to illustrate the concepts.