the past several years we have proposed an alternative paradigm which we call the Self Organized Spinodal(SOS) Hypothesis. This is based on the fact that faults and fault systems have stress Greens functions that have a very long range. Such systems are known to be well approximated by meanfield. These systems have a spinodal critical point that marks the boundary betwee metastable and unstable states. Such spinodal points act in many ways like critical points, i.e. they generate scaling, however they also give rise to other phenomena such as nucleation which play a role in the earthquake cycle. The SOS picture then naturally generates an earthquake cycle and provides a physical basis for the forcasting algorithm developed by our group. In this presentation I will explain the SOS hypothesis and describe how it generates scaling as well as how it can be used as a basis for statistical forcasting.

NG32A-05 1440h INVITED

Long Range Earthquake Interaction in Iceland

Christian Goltz (+49-431-880-3881; goltz@geophysik.uni-kiel.de)

Geophysics, Kiel University, Otto-Hahn-Platz 1, Kiel 24118, Germany

It has been observed that earthquakes can be triggered by similarly sized events at large distances. The phenomenon has recently been shown to be statistically significant at a range up to several source dimensions in global earthquake data. The most appropriate explanation of the phenomenon seems to be criticality of the Earths crust as e.g. changes in static and dynamic stresses would otherwise be too small to trigger remote events. I present results for a regional (as opposed to global) study of seismicity in Iceland which is based on a high quality reprocessed catalogue. Results include the time-dependent determination of the maximum range of interaction and the correlation length and also address the question whether small events can trigger larger ones. Pitfalls such as data accuracy and geometry as well as boundary effects are thoroughly discussed. A comparison with surrogate data helps to assess the statistical significance of the results.

NG32A-06 1455h INVITED

Proximity to Criticality: Statistical Mechanics, Numerical Models and Natural Earthquake Data

Fahad Al-Kindy[1] (fahadak@glg.ed.ac.uk)

Ian Main[1] (+44 131 650 4911; ian.main@ed.ac.uk)

[1]University of Edinburgh, School of GeoSciences West Mains Road, Edinburgh EH9 3JW, United Kingdom

Complex driven threshold systems often produce statistical fluctuations that are very similar to those of equilibrium systems, with Boltzmann fluctuations in energy that can be used formally to define an entropy S and a 'temperature term' T. In this spirit we develop a mean field formulation for the frequency-magnitude distribution of earthquakes. Based on the results of numerical models for earthquakes as a complex system (averaged over several cycles), we assume a positive correlation between the distribution of potential strain energy U in the internal system and the radiated seismic energy E. The model predicts a functional relationship between S and <lnE> that can be used to answer the question: 'How close is the system to the critical point?'. We examine this question for temporal and spatial ensembles using CMT data. The answer for the temporal ensemble (annual data) is that the fluctuations represented by the earthquakes are indistinguishable from self-organised criticality, with a linear relationship between S and <logE>, but no correlation between S and <E>. Similarly <lnE> and <E> are not strongly correlated because <lnE> is determined most by intermediate-sized events on the Gutenberg-Richter trend, and <E> is dominated by the largest events. However, the spatial ensemble (with regions as defined in the Flinn-Engdahl scheme) show a systematic curvature in the plot of S v <lnE> consistent with an intermittently (but still near-critical) critical point system.

NG32A-07 1510h

Phase-locking in Coupled Non-linear Relaxation Oscillators: an Explanation for Observed Temporal and Spatial Correlation and Anti-correlation of Large Earthquakes

Charles G. Sammis[1] ((213) 740-5836; sammis@email.usc.edu)

James F. Dolan[1] ((213) 740-8599; dolan@email.usc.edu)

Stewart W. Smith[2] ((425) 823-1893; swsmith@nwlink.com)

[1]Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, United States

[2]Department of Earth and Space Sciences, University of Washington, Seattle, WA 98034, United States

There is mounting paleoseismological evidence that large earthquakes on a given fault network tend to occur in temporal clusters. Examples include the southern San Andreas system in the Imperial Valley (Rockwell et al., in prep, 2003), the Eastern California Shear Zone (Rockwell et al., BSSA, 2000), the Garlock system (Dawson et al, in prep., 2003) and the Los Angeles area (Dolan et al., in prep., 2003). This last study has also found evidence that clusters within the Los Angeles area tend to be anti-correlated with similar clusters in the Eastern California shear zone and on the Garlock fault. This clustering behavior is expected if large earthquakes behave as coupled non-linear relaxation oscillators. As a simplest case, we consider two identical faults which are loaded at constant strain rate and which fail at a prescribed stress threshold. Each thus produces the saw-tooth stress strain curve characteristic of a relaxation oscillator. The faults are non-linear oscillators because we assume the stress-strain curve is non-linear, having the negative curvature typical of laboratory experiments and regional damage mechanics models (Ben-Zion and Lyakhovsky, 2002). The two faults are coupled by symmetric stress transfer, in that we assume each fault either increases or decrease the Coulomb stress on the other by an equal amount. We find that events on the two faults phase-lock either in phase if the Coulomb stress transfer is positive or 180 degrees out of phase if the transfer is negative. This phase-lock is driven by the non-linear stress-strain relation. When a fault is close to failure, the increment of stress transfer causes a larger increment in strain. Since time is linked to strain through the assumption of constant strain rate loading, the time shift of the impending event is larger the nearer a fault is to failure. For a positive stress transfer, this shortens the interval and leads to in-phase locking. For a negative stress transfer, the interval is lengthened and the system evolves to a 180 degree out of phase lock. Preliminary models of simple faults controlled by rate- and state-dependent friction have found that non-linearity introduced by friction has a similar effect.

NG32A-08 1525h

Which Works Best, ETAS or SAM?

Geoffrey King[1] (king@ipgp.jussieu.fr)

David Bowman[2] ((714) 278-5436; dbowman@fullerton.edu)

Arnaud Mignan[1] (mignan@ipgp.jussieu.fr)

[1]Institut de Physique du Globe de Paris, 4, place Jussieu, Paris 75252, France

[2]California State University, Fullerton, 800 N. State College Blvd, Fullerton, CA 92834-6850, United States

In recent years a number of models have been proposed that describe evolutionary seismicity as an interplay between aftershocks and Coulomb stress interactions. The Epidemic-Type Aftershock Sequence (ETAS) model has in particular been proposed as a possible explanation for the widely observed phenomenon of accelerating moment release before large earthquakes. This model is based on the idea that large earthquakes are the end result of a period of self-organization in the background stress field (i.e. smaller earthquakes). In contrast to this concept is the Stress Accumulation Model, (SAM) which treats the evolution of seismicity before a large earthquake as the result of loading of the main fault primarily by creep on an extension of the fault at depth. While both of these models predict accelerating seismicity before the mainshock, they make different predictions of the spatial distribution of this activity. We demonstrate that the predictions of the Stress Accumulation model are more consistent with observed seismicity than the predictions of the ETAS model.

NG32B MCC: 3001-3003 Wednesday 1600h

Lorenz Lecture

Presiding: **S F Tebbens,** University of South Florida

NG32B-01 1605h INVITED

Wonders of Planet Earth: Complexity and Order in Earth Systems

Rafael L. Bras (617-253-2117; rlbras@mit.edu)

Department of Civil and Environmental Engineering Massachusetts Institute of Technology, Room 48-213, Cambridge, MA 02139, United States

Much of the climate, weather and landscape of the earth is mediated by the ever present water. This talk explores the non-linearities of hydrologic processes which commonly lead to chaotic-like behavior yet beautifully organized systems. Land-atmosphere interactions are discussed first. The dynamic impact on the atmosphere and climate of land surface conditions like soil moisture and vegetation are illustrated. The ideas of multiple equilibria in vegetation and soil moisture, and of maximum evaporation at all times, are discussed. Self organization in landscape forms are the next topic. Organization in geometry and in surface texture of the river basin is achieved jointly and is the result of highly nonlinear phenomena.

NG41A MCC: 3010 Thursday 0800h

Scaling in Our Fluid Earth: Chaos and Multifractals in the Atmosphere, Oceans, Hydrology, and Climate I

(joint with A, B, GP, H, OS, PP, SA, AE, C, GC)

Presiding: **S Lovejoy,** McGill University**; D Schertzer,** Laboratoire de Modélisation en Mécanique, Université Pierre et Marie Curie

NG41A-01 0800h

Deriving Spatiotemporal Fractal And Wavelet Models In Terms Of The Generalized Random Field Theory

George Christakos (919-966-1767; george_christakos@unc.edu)

Center for the Advanced Study of the Environment (CASE), Department of Environmental Science and Engineering, University of North Carolina-Chapel Hill, 111 Rosenau Hall, CB# 7431, Chapel Hill, NC 27599-7431, United States

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A powerful unified framework is suggested in terms of generalized spatiotemporal random fields (GS/TRF), which can derive well-known models as its special cases, including fractal, wavelet and heterogeneous random field models. It is worth-noticing that the development of the GS/TRF theory precedes that of its special cases above. A G-S/TRF is typically defined in terms of a functional involving a so-called test function belonging to a space D. The choice of D is made on the basis of the physics of the atmospheric situation and the goals of the analysis. Very rich classes of moments across space and time are derived by means of the corresponding GS/TRF functionals. By properly selecting the test functions, space-time heterogeneous models are generated, termed GS/TRF-n/m, where n and m are the corresponding spatial and temporal orders of heterogeneity, respectively. Well-known fractal random fields are readily obtained from the GS/TRF-n/m which, in addition, can lead to new and richer fractal representations in space-time. By assuming test functions having properties useful in the study of important field characteristics (multiscale features, singularities caused by physical laws, sharp variations etc.), continuous space-time wavelets are derived which have a wide range of earth science and image processing applications.

NG41A-02 0815h

Multifractals and Chaos, Predictability and Prediction Skills in Geophysics

Daniel JM Schertzer[1,2] (schertze@cereve.enpc.fr)

Shaun Lovejoy[3] (lovejoy@physics.mcgill.ca)

[1]CEREVE Ecole Nationale des Ponts et Chausses, 6-8, avenue Blaise Pascal Cité Descartes, Marne-la Vallée 77455 Cede, France

[2]Meteo-France, 1 quai Branly, Paris 75007, France

[3]Dept. Physics McGill U., 3600 University St., Montreal, PQ H3A 2T8, Canada

The question of prediction - from short to very long term - and its intrinsic limits is a fundamental question in Geophysics; it cross-cuts traditional discipline boundaries. The chaos revolution emphasized the fact that nonlinearity is at the core of this question. This was widely popularized as the 'butterfly effect' with the help of the celebrated Lorenz model, which was introduced as a highly simplliefied mathematical model

of convection and has the lowest possible dimensionality, i.e. three, for chaotic differential systems. Unfortunately, this success may have lead to an awkward tendency to reduce complex systems to their low dimensional caricatures including the corresponding predictibility limits. This tendency may have been reinforced by the apparent success of the rather straightforward correlation dimension algorithm to estimate the dimensionality for various complex systems. As a consequence - in spite of observed discrepancies - the existence of characteristic predictability time and a corresponding exponential fall-off of predictability were considered as the universal long-time asymptotic laws. However, for rather well known reasons, the low dimension estimates of geophysical systems turn out to be spurious. It is now rather clear that the chaos of these spatially extended systems, requires approaches dealing with very large number of degrees of freedom and that certain asymptotic behaviors correspond instead to the infinite limit. The modelling of this high number of degreees of freedom liimit can be obtained by an original blending of stochastics and scaling dynamics, e.g. multiplicative cascade processes, more generally with the help of multifractal processes. The latter do not yield characteristic times of predictability: a limited uncertainty on initial and/or boundary conditions on a given range of time and space scales rapidly grows across the scales and yields scaling (i.e. power-law) decays of the predictability, therefore we should be able to predict on the average much better and longer than previously thought. However, intermittency plays a crucial role, as it will be illustrated with the help of multifractal simulations. Decay of predictability is not homogeneous, but occurs by bursts. Some non trivial questions about multifractal prediction are related to it: it is not sufficient, although an improvement in respect to usual methods, to forecast a field with a lower and lower resolution for larger and larger time lag. Indeed, one need to take into account the interactions between the rather predictable large scales with the hihgly impredictible smaller scales. This is particularly indispensable to forecast the extreme events.

URL: http://www.multifractal.jussieu.fr

NG41A-03 0830h

Strategies for the Use of Scaling for Subgrid Parameterizations for Globbal Circulation Models of the Atmosphere

Joseph Tribbia (tribbia@ucar.edu)

NCAR, Box 3000, Boulder, CO 80307, United States

The problem of parameterization of physical process in large scale numerical models of the atmosphere will be developed first from a formal perspective of specifying sub-grid effects as distributions conditional upon resolved scales of motions. Historically, focus has been concentrated upon models of the 'average' or mean tendencies and the models have been of two classes: subgrid models which depend upon scale similarity and those which are developed from idealized process models. The Smagorinsky eddy diffusion is the most notable use of scale similarity arguments in parameterizations for large scale models. However, for many other sub-grid physical processes little use of scaling structure has been utilized in the development of parameterizations. I will describe some recent efforts and new strategies aimed at moving beyond the use of non-scaling process models for the computation of the subgrid tendencies due to subgrid effects of clouds, cumulus convection, orographic drag and radiation. The major complication in the pure scale similarity approach or the process model approach to parameterization is the spatio-temporal intermittency of meso and micro scale atmospheric motions which must be accounted for.

NG41A-04 0845h INVITED

Airborne Studies of Scale Invariance in the Polar Night Jet Stream

Adrian F Tuck[1] (3034975485; tuck@al.noaa.gov)

Susan J Hovde[1,2]

Erik C Richard[1,2]

Thao Paul Bui[3]

Max Loewenstein[3]

[1]NOAA Aeronomy Laboratory R/AL6, 325 Broadway, Boulder, CO 80305-3328, United States

[2]CIRES, University of Colorado, Boulder, CO 80309-0215, United States

[3]NASA Ames Research Center, Moffett Field, Mountain View, CA 94035-1000, United States

Airborne observations in both hemispheres of the lower stratospheric polar night jet stream revealed generalized scale invariance. The scaling exponent H_z for wind speed and temperature had systematic correlations with wind shear and temperature gradient respectively, showing persistence across-jet, anti-persistence along-jet and a canonical mean value of $H_z = 5/9$. A passive scalar, nitrous oxide, had $H_z = 0.56$ with s.d. = 0.01, while photochemically active ozone had 0.49 with the same s.d. The intermittency of temperature was 2-3 times larger than that of wind speed or ozone. The analysis appears to provide a natural connection between generalized scale invariance of high resolution observations and traditional large-scale dynamical meteorology.

NG41A-05 0900h INVITED

Mesoscale Variability, Representativeness of Meteorological Observations and Assimilation of Observations into models

Kenneth S Gage (303-497-3964; Kenneth.S.Gage@noaa.gov)

NOAA Aeronomy Laboratory, 325 Broadway, Boulder, CO 80305-3337

This review is concerned with issues related to the assimilation of meteorological observations into numerical models in the presence of mesoscale variability that may limit the representativeness of the observation on the resolution scale of the model. Models provide an essential tool for synthesizing diverse observations from many sources. They provide us with a means to specify the state of the atmosphere or ocean at any particular time and allow us to forecast the future state of the atmosphere or ocean. Observations assimilated into models may be in situ point measurements, remotely sensed direct measurements such as are provided by wind profilers, or indirect remotely Sensed measurements provided by satellites. While the issues considered in this review are very general, there is a pressing need to assimilate remotely sensed data into models. From developments in data assimilation it is well known that for optimal performance models require information on the error covariance of the parameter being measured. In general, this means information is required on the measurement error of instruments as well as the representativeness of the measurements themselves. The representativeness error is often the dominant component of error covariance. Specification of representativeness error requires knowledge of the variability of the field being measured.This review examines sources of mesoscale atmospheric variability and some means for specifying variability quantitatively.

NG41A-06 0915h INVITED

Long-term correlations in the atmosphere: Testbeds of climate models and novel extreme value statistics

Armin Bunde[1] (496419933360; bunde@physik.uni-giessen.de); Jan Eichner[1] (496419933376; eichner@physik.uni-giessen.de); Jan Kantelhardt[1] (496419933373; kantelhardt@physik.uni-giessen.de); Shlomo Havlin[2] (97235318436; havlin@ophir.ph.biu.ac.il); Stephen Brenner[2] (97235318436; havlin@ophir.ph.biu.ac.il); Dmitry Vjushin[2] (97235318436; vjushin@ory.ph.biu.ac.il)

[1]Institut fuer Theoretische Physik III, Universitaet Giessen, Heinrich-Buff-Ring 16, Giessen 35392, Germany

[2]Department of Physics, Bar-Ilan University, Ramat Gan 552900, Israel

Temperature records exhibit long-term correlations characterized by a power-law decay of the autocorrelation function, $C(s) \sim s^{-\gamma}$, with γ close to 0.7 for continental stations and γ close to 0.4 for sea surface temperatures. Here we show that these laws present a powerful test bed for the various scenarios of the state-of-the-art climate models and discuss, how the presence of long-term correlations affects the statistics of the return intervals r_q for events above a certain threshold value q. Among others, we show (i) that the distribution of r_q follows a stretched exponential, $\ln P_q(r) \sim -(r/\langle r_q\rangle)^{\gamma}$, and (ii) that the return intervals are also long-term correlated with the exponent γ, yielding clustering of both small and large intervals. We present evidence, that both features can be seen in long observational and reconstructed records.

NG41A-07 0930h INVITED

Multiscale Structure of the Heliospheric Magnetic Field Strength and Solar Wind Speed: Multifractal Structure and Distribution Functions

Leonard F. Burlaga (301 286-5956; leonard.f.burlaga@nasa.gov)

Laboratory for Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771, United States

The Sun is surrounded by a region called the 'heliosphere', which has been explored by the Voyager 1 spacecraft to 85 AU and beyond. The heliosphere is filled with magnetic fields and plasmas moving from the Sun toward the interstellar medium at supersonic speeds. The magnetic fields and have plasmas a variety of sources on the Sun and they move with a broad range of speeds, so that they interact as they move away from the Sun. The diversity of the flows and their interactions on a wide range of scales lead to a complex, evolving heliospheric structure. On scales from 1 to 26 days the magnetic field and speed variations can be described by multifractals, power spectra, and probability distribution functions on various scales. The radial evolution of the multi-scale structure of the large-scale fluctuations in the heliosphere can be described and predicted by a deterministic multi-fluid MHD model, with observations at 1 AU as input conditions.

NG41A-08 0945h INVITED

Non-homogeneity in rainfall: some considerations

Carlo De Michele (+39-0223996233; carlo.demichele@polimi.it)

DIIAR-Politecnico di milano, 32, P.zza L. da Vinci, Milano I20231, Italy

The homogeneity of rainfall as working hypothesis has widely adopted in hydrologic science. Non-homogeneity can be safely neglected when, at the relevant scales, it has small effect and the random field may be considered homogeneous; in other circumstances homogeneity and non-homogeneity co-exist within the same data set, at different range of scales (e.g. small-scale non-homogeneity and large-scale homogeneity) or in a more complex way. On the other side, it is accepted that rainfall fields exhibit scale invariance properties over a wide range of spatial and temporal windows. This aspect of rainfall is non consistent with its non-homogeneity; namely when the scaling properties are assessed over a range of scales where the homogeneity is a poor approximation, wrong conclusions are drawn. On this route, the presence of non-homogeneity in rainfall is detected through some statistical tests. It is showed how neglecting the non-homogeneity behaviour, some wrong conclusions and unreliable estimate of the scaling exponents can be obtained. Applications to observed and synthetic rainfall data are given and discussed.

NG41B MCC: Level 1 Thursday 0830h

From Microscale to Macroscale: Models for Material Damage Mechanics and Earth System Dynamics and Their Relation to Seismicity and Earthquakes II Posters

(joint with S, T, AE, GC, MR)

Presiding: **J B Rundle,** University of California, Davis**; R Shcherbakov,** University of California, Davis**; D L Turcotte,** University of California, Davis

NG41B-0057 0830h INVITED POSTER

VISCO-ELASTIC DAMAGE RHEOLOGY MODEL: THEORY AND EXPERIMENTAL TESTS

Vladimir Lyakhovsky[1] (972-2-5314265; vladi@geos.gsi.gov.il)

Yariv Hamiel[1,2] (972-2-5314265; yarivh@huji.ac.il)

Yunfeng Liu[3] (213 7406734; yunfeng@terra.usc.edu)

Yehuda Ben Zion[3] (213 7406734)

Dave Lockner[4] (dlockner@usgs.gov)

[1]The Geological Survey of Israel, Maslkhei Israel 30, Jerusalem 95501, Israel

[2]Institute of Earth Science, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

[3]Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, United States