choice. The generic multifractal process is a multiplicative cascade. From the point of view of multifractals, there is an enormous difference between low but finite rain rates and exactly zero rates. This leads to a fundamental modeling question: is a single rain process adequate to model rain (perhaps with a very low rate cut-off to zero) or does one require separate processes for determining where and when it rains and another for the rates in the raining regions? In more mathematical terms, is the support of the rain process a fractal subset of space-time? On the other hand, the low and zero rain rates are particularly difficult to measure; for example, a tipping-bucket type rain gauge does not have a fixed temporal resolution, but rather a fixed depth resolution so that at the low rain rate limit, the temporal resolution becomes infinite. We show that this problem leads to spurious breaks in the scaling at scales which can be of the order of an hour even though the depth resolution can be very small (0.1 mm). In order to overcome these problems an alternative is explored, which analyses the rain as a function of total rain-depth rather than time. This method is particularly suitable for tipping-bucket rain data, because it uses the raw data rather than reconstructed time-series. By comparing results from two climatological regions we show that whereas the statistics from reconstructed series are very different, those with the new depth based series are almost identical (since they are insensitive to the low/zero rain rate problem). In addition, it eliminates the scale breaks so that rain is clearly seen to be scaling from the smallest resolvable scales to the synoptic maximum (roughly 2 weeks).

NG41E MCC: 3010 Thursday 1120h

Funding Agency Perspectives on Nonlinear Approaches in Data Analysis and Simulations: Public Forum

Presiding: **D L Turcotte,** University of California, Davis**; C C Barton,** U.S. Geological Survey

NG41E-01 1125h

Funding Agency Perspectives on Nonlinear Approaches in Data Analysis and Simulations: Public Forum

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This session will be a panel discussion.

NG51A MCC: Level 2 Friday 0830h

Scaling in Our Fluid Earth: Chaos and Multifractals in the Atmosphere, Oceans, Hydrology, and Climate III Posters *(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

NG51A-0822 0830h POSTER

Study of the Space-Time Variability of the Precipitations in the semi Arid Tropics Areas like African Sahel

Philippe Ladoy

ACMAD, BP 13184, Niamey Niger, Niger

One of the difficulty of decision making in the matter of climate in semi arid tropics areas like African Sahel, is to manage the high time space variability of the atmospheric fields. For example, the high time space variability of the rain fields (intermittency) is explained by the multiplicity of time space scales which involves. A multifractal approach of the field is assumed. Some aspects of the study are related to : o Down scaling adaptations of the outputs of global climate models to regional and local scales; o Prediction of extremes events : floods, droughts or "dry spells"... Studies are developed by the African Centre for Meteorological Application for Development (ACMAD) This Centre, located in Niamey, Niger, acts as an African institution for weather and climate. Its long term goals are to : - reduce the dryness effects or any other catastrophe related to the climatic conditions such as the tropical cyclone, the floods and the storms; - to develop methodologies and techniques for weather and climate application at the national and sub-regional level; The basic activities to realize this objectives are: - the collection and analysis of hydrometeorological data; - the dissemination of climatic information for the early alarm in the fields related to the agriculture or the management of resources in water and energy; - the dissemination in due time of useful information on the weather and climate; - the connected of the variability and of the climatic change, and such as their impact upon the economy, - the development of strategies of appropriate responses to the impact of the desertification, floods, tropical cyclones,

URL: http://www.acmad.ne

NG51A-0823 0830h POSTER

Multifractal Large particle limit in rain: implications for radar rain measurements

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Raindrop size and position data - from eighteen scenes of a = 8 m**3 region each containing 5,000 to 15,000 rain drops - obtained for 5 different storms in the HYDROP (HYdrometeor Detection and Ranging using stereO-Photography) experiment - was systematically statistically analyzed in spheres ranging from 10 cm to 2m in diameter. In four of the five storms, we found convincing evidence for the convergence to a multifractal scaling large N limit; the observed scaling exponents were quite close to those reported in the rain literature at much larger scales. By randomizing the positions of the drops, we could compare directly the true fluctuation statistics with those of the classical theory; the latter were significantly smaller. By carefully considering the meteorological conditions, in particular the turbulence intensity and the drop size distributions, we could explain the observed variations in the inner scale. In the multifractal large N limit, the drop size distribution is of secondary importance, it is the drop number, liquid water content, and other densities which tend to universal multifractal scaling limits. These results are related to the often invoked log-normal behavior of rain, but with important differences. We also show that if the densities are multifractal with the same universal multifractal index a, that we recover power law relations between their statistics, for example mean(R)=a*Mean(Z)**b (c.f. the usual deterministic relations R=a*Z**b where R, Z are random variables).

NG51A-0824 0830h POSTER

Multifractal downscaling of a GCM rainfield

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In order to get a more efficient production management of reservoirs, it would be helpful to apply long-term meteorological forecasts to hydrological models. Unfortunately, the explicit scales of present GCM's are quite larger (e.g. 243kmx243kmx32 days) than those of hydrological models (e.g. 1 kmx1kmx1day). Therefore it is indispensable to proceed to a downscaling of the output of the former in order to obtain an input for the latter. In this paper, we present a multifractal downscaling procedure. The site of the study is the area of Doubs river, with the help of a dense local hydrological network, but in order to get a larger spatial scale ratio we extend our multifractal analysis to France, with the help of Météo-France PRECIP data base. We first argue that it is indispensable to consider a multifractal downscaling procedure in order to respect the scaling properties of the hydro-meteorological fields. We performed time, scale and time-space multifractal analysis of the available data and evaluate the corresponding universal exponents, as well as the anisotropy/dynamical exponent of the time-space generalized scale. We show that these exponents are quite robust. We compare our analysis to similar works, but restricted to the use of Log-Poison cascade and space-time isotropy. We show both theoretically and empirically that these restrictions are untenable, in particular with respect to the extremes. We also show simulations should be done with the help of continuous (in scale) and causal cascade models, not with ad-hoc time-space cascades, and present the corresponding numerical simulations. of space-time downscaling of (meso-scale) GCM data down to (micro-scale) hydrological scales. We greatly acknowledge the financial support from Electricité de France, as well as Météo-France for providing access to its PRECIP data base.

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

NG51A-0825 0830h INVITED POSTER

Potential of Multifractals for Water Resources Planners

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The natural variability of water resources and the augmenting demand for water leads mankind to strongly interfere with the hydrologic cycle in attempts too ensure that water will be available in adequate quantity and quality, with a proper distribution in space and time. So, engineers will be often concerned with ambitious plans of flood control. Runoff predictions, such as the estimates of peak flows that are associated with a particular exceedence probability, form the basis for the design of most civil engineering works. Since river runoff phenomena reflect many complex interactions at different scales between diverse basin factors as well as meteorological and climatic fluctuations, that strongly modify the precipitation input, the prediction of a maximum expected water flow remain a rather unsolved issue. Indeed, as hydrologists often observed it, the probabilistic distribution of runoff is skew; however its mathematical form is far from being known, in particular its tails. As a consequence, the insufficient spillway capacity remains worldwide the second commonest cause of dam failure (after the foundation failure). Present communication demonstrates how the multifractal framework overcomes some present difficulties in the flood predictions within space and time domains. Moreover, our multifractal results reflect crucial changes in river regimes after dam construction, that may have drastic consequences for the spillway capacity. To consolidate our results, we use few millions of flow measurements at very different hydrological locations all over the World. The time-scale of the data ranges from a day to several centuries.

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

NG51A-0826 0830h POSTER

Characterization of Monthly Streamflow Dynamics in the Western United States

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The present study attempts to characterize the dynamics of monthly streamflow in the western United States. Specifically, the question of whether the streamflow dynamics are (dominantly) governed by a large number of parameters (i.e., high-dimensional) or only a very few parameters (i.e., low-dimensional) is addressed. The analysis follows two important steps: (1) Representation of the underlying dynamics through reconstruction of the single-dimensional streamflow series in a multi-dimensional phase-space (i.e., phase-space reconstruction); and (2) Determination of the number of dominant parameters through a (neighbor searching) dimension algorithm (i.e., parameter estimation). Monthly streamflow series over a period of 62 years observed at 79 stations across 11 states in the western United States are analyzed. The outcomes are mixed in regards to the number of dominant parameters, as some series suggest low-dimensionality while others suggest high-dimensionality. An attempt to determine the dimensionality of flow series in terms of different flow regimes (i.e., low-flow, medium-flow, and high-flow), based on the magnitude of mean flow, also yields similar mixed interpretations. Efforts towards verification of the present results and investigation of the forecastability of these streamflow series are underway.

NG51A-0827 0830h POSTER

Space-time multifractal models of rain, predictability and nowcasting

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Rainfall nowcasting is currently performed with the help of sequences of radar or satellite derived rainfall surrogate fields, the usual assumption being that the field is "frozen" and is simply advected i.e. without any development. In this talk, we argue that space-time multifractal processes provide appropriate frameworks for modeling rain and that this can be used to forecast both the advection and the development. Necessary ingredients include the correct degree of space-time stratification, vertical-horizontal stratification as well as estimates of the basic (universal mulitfractal) parameters. In addition, special care must be given to numerical stability, and to structures larger than the model domain, and to small subpixel scale structures. We show theoretically and numerically that states with a shared past diverge algebraically (rather than exponentially) in time, and study the dependence on spatial scale. We also show how forecasts can be made using conditional expectations and quantify the error growth.

NG51A-0828 0830h POSTER

Scaling Investigation of High-Resolution Data from Two Vertically Pointing Radars

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The authors operated two vertically pointing radars collocated at the Iowa City Municipal Airport in Iowa, for eight months. The collected high-resolution data set was analyzed to obtain information about the fractal behavior of rainfall. The two radars are an X-band Doppler radar of The University of Iowa and an S-band Doppler radar of the NOAA Aeronomy Laboratory. The authors applied a power spectrum, wavelet analysis and the box-counting method to investigate the scaling in the rainfall time series. The rainfall time series was extracted from the radar data for three different heights: close to the ground and just below and above of the melting layer. The results indicate many differences and similarities of the underlying process at these three different heights. The authors also investigated the instrumental effect on this analysis by comparing the results from the two different radars.

NG51A-0829 0830h POSTER

Thickness distribution scaling in large scale sea ice mechanics

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This research builds on recent advances in large scale sea ice modelling that account for quasi-fractal oriented fractures in sea ice. It investigates the possibility that some mechanical features of sea ice also scale with its thickness. It is suggested geophysical scale strain rates in sea ice may obey a law that derives from scaling internal stress with the thickness of individual floes. Results from invariant analysis of established sea ice mechanics laws, together with model simulations over the Southern Ocean suggest that scaling of internal stress with thickness is very weak. However an unexpected outcome of the analysis shows that even very weak scaling produces strain rates that vary strongly through the thickness spectrum of sea ice thickness distributions. Whilst this result is interesting in its own right, it has direct practical application in short term forecasting and assimilation using multiple thickness models. Details are provided of the scaling parameterisation as it may be applied to both medium range sea ice forecast models and coupled climate model sea ice components alike. Model results are presented that demonstrate this scheme can be used to reproduce observed features of the Southern Ocean sea ice zone.

NG51A-0830 0830h POSTER

Multifractal Thermal Characteristics of the Southwestern GIN Sea Upper Layer

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Multifractal characteristics of the upper layer thermal structure in the southwestern Greenland Sea, Iceland Sea, and Norwegian Sea (GIN Sea) are analyzed using high-resolution, digital thermistor chain data. The energy spectrum at 20 m depth (cold sublayer) shows the existence of a spike at the scale of approximate 3 km representing the chimney scale. The graph dimension varies from higher values such as 1.89 at the surface to 1.44-1.50 in the warm intermediate layer. The stationarity decreases from the ocean surface to the warm intermediate layer. However, the information dimension varies slightly (0.92 to 0.90) that indicates low singularity. Reference Chu, P.C. 2003: Multifractal thermal characteristics of the Southwestern GIN Sea upper layer. Chaos, Solitons and Fractals, 19 (2), 275-284.

URL: http://www.oc.nps.navy.mil/~chu

NG51A-0831 0830h POSTER

Synthetic Turbulence, Fractal Interpolation and Large-Eddy Simulation

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Direct Numerical Simulation (DNS) of the Navier-Stokes equation at high Reynolds number is virtually impossible with today's computational capabilities. As a consequence, our only resorts of gaining insight into the small-scale statistical and dynamical properties in three-dimensional fully developed turbulence are: extensive experimentation and turbulence emulation by relatively simple mathematical constructs. The latter approach, also known as the synthetic turbulence generation, has received considerable attention in recent years. This work extends previous efforts of synthetic turbulence generation based on the concept of fractal interpolation. Specifically, it proposes a method that, in addition to capturing the fractal dimension of the turbulent velocity field, also preserves other essential small-scale properties of turbulence, such as multiaffinity and non-Gaussian characteristics of the probability density functions of velocity increments. We also show the applicability of this method in emulating passive-scalar fields. Simplicity and low computational complexity makes this approach an attractive candidate for subgrid scale modeling of Large-Eddy Simulation (LES).

NG51A-0832 0830h POSTER

Fluctuations of Cloud Properties and Application of Nonextensive Statistical Physics

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Microphysical properties of clouds in a turbulent atmosphere fluctuate over a wide range of scales. Knowledge of the probability density function (PDF) of the climatically important variables (e.g., liquid water content, cloud droplet number concentration and relative dispersion of the cloud droplet size distribution) is crucial for treating subgrid cloud variability in various models such as global climate models (GCMs) and for understanding the role of fluctuations in the formation and development of clouds. A Gaussian-type PDF has been traditionally applied to describe the fluctuation of cloud properties. A number of studies have recently shown that turbulent fluctuations often deviate from the "norm", exhibiting heavy-tailed PDFs, and that the PDF is scale-dependent. In this work we examine the fatness of the PDF tail and the scale-dependence of cloud microphysical data collected under different dynamical conditions. We also apply the theory of the Tallis nonextensive statistical physics to the characterization of the fluctuation PDF, and integrate the results with the systems theory that we have proposed for describing cloud droplet size distributions.. The results of this research have applications for representations of clouds in GCMs and for validation of remote sensing with in-situ measurements.

NG51A-0833 0830h POSTER

Radiative Transfer Through Stratified Multifractal Clouds

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Analysis of nearly 1000 satellite and in situ cloud radiances has shown in both infrared and visible wavelengths, over ranges spanning thousands of kilometers down to less than a meter, that the radiances are multifractal to within 1.5% per octave in scale (or better). In order to model this, we need reliable multifractal models of the liquid water density. We first discuss some technical points needed to obtain accurate mulitfractal statistics: these include the issues of numerical stability and the need to make corrections both for structures

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larger than the simulation region and smaller than a pixel. We then use a variety of techniques (e.g., Monte Carlo, and Green's function) to simulate the radiative transfer in the clouds and we relate (scale by scale) the resulting radiation fields and the (anomalous) scattering statistics to those of the cloud. We compare and contrast our results with those of the low variability "bounded cascade" model in which the multifractality is essentially destroyed by successive truncation of singularities as the cascade proceeds to smaller scales.

NG51A-0834 0830h POSTER

On the Weibull Distribution as a Statistical Model for Surface Wind Timeseries in Reanalyses

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The Weibull distribution has been identified as a statistical model for timeseries samples of surface station windspeed measurements. Previous studies have shown that near-surface winds from General Circulation Models can exhibit non-Weibull behavior. In this study we examine 10-meter windspeed data from the National Center for Environmental Prediction 50-year Reanalysis. We provide maximum-likelihood estimates of Weibull distribution shape and scale parameters γ and β respectively, as well as estimates in the uncertainties in these parameters. We then use these estimates of γ and β with the Weibull distribution to create reference distribution functions for each timeseries sample and 1) estimate the mean and standard deviation and compare them with estimates computed from the sample, and 2) compare them with the sample using a one-sample Kolmogorov-Smirnov Test. Finally, we discuss possible reasons for non-Weibull behavior in the reanalyses, and describe how our results may be used in climate model validation.

NG51A-0835 0830h POSTER

Duration Multiscaling in a Simple Model of Atmospheric Convection

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Recently, Nordstrom and Gupta (2003) developed a simple model based on a qualitative representation of the physical processes underlying atmospheric convection in the tropics. This model exhibited a high degree of variability, and its spatial moments displayed multiscaling behavior at a critical point in a parameter corresponding to the Convective Inhibition (CIN). In order to estimate the statistical moments, we subject model output to the duration scaling analysis first performed by Pavlopoulos and Gupta (2002).

NG51A-0836 0830h POSTER

Lidar Investigation of Atmospheric Stratification: $D_el = 2$, 7/3, 23/9 or 3?

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Practically all theories of turbulence assume isotropy or at least local isotropy. In buoyancy driven flows the justification is not obvious because gravity breaks the isotropy and acts at all scales. The classical assumption is that gravity leads to a basic stably stratified state while simultaneously postulating that the perturbations are nevertheless statistically isotropic. In the atmosphere, the scale height (about 10km) presents a further challenge: isotropic three dimensional turbulence cannot extend to very large scales. The standard model postulates an intermediate "meso-scale gap" followed at larger scales by two dimensional horizontally isotropic turbulence. Today, although we still lack a consensus about the full horizontal atmospheric statistics, the meso-scale gap separating these D=3, D=2 regimes has not been observed and there is wide consensus that the horizontal wind is scaling in the horizontal with spectral exponent $\beta_h = 5/3$ out to at least several hundred km. In the vertical direction, the spectral exponent $\beta_v > \beta_h$ implying scaling stratification with the volume of structures growing at a rate $D_el = 2 + (\beta_h - 1)/(\beta_v - 1)$. The two main contending proposals being $\beta_v = 11/5$ (buoyancy driven, Bolgiano-Obhukov) and $\beta_v = 3$ (gravity waves, Lumley-Shur) implying $D_el = 7/3$, 23/9 respectively. In this talk we describe some recent results using state-of-the-art lidar data of passive scalars, over the range 3 m to 4.5 km in the vertical and 100 m to 120 km in the horizontal, we directly estimate $D_el = 2.56 \pm 0.05$ supporting the 23/9 dimensional "unified scaling" model . We discuss this in relation to other measurement campaigns, and also the implications for modelling the atmosphere. Finally, we show how to make multifractal models of vertical cross-sections which are very close to the data.

NG51A-0837 0830h POSTER

Global and Multi-scale Phenomena in Geospace: Solar Wind - Magnetosphere Coupling

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Many systems in geospace exhibit global and multiscale phenomena, characterized by processes with a wide range of spatial and temporal scales. The solar wind - magnetosphere coupling is such a system in which large scale features such as plasmoid formation, co-exists with multi-scale features such as turbulence. Although the co-existence of these features in the magnetosphere is well recognized, isolating them and understanding their relative roles have been long standing problems. To separate and model the global features of the magnetosphere a new approach for data-derived modeling based on the concept of mean-filed dimension is used. For a given level of averaging in the system the mean-field dimension determines the minimum dimension of the embedding space in which the averaged dynamical system approximates the actual dynamics with the given accuracy. It is found that the minimum embedding dimension of magnetospheric time series is a function of the level of ensemble averaging and the specified accuracy of the method. To extract the global component from the observed time series the ensemble averaging is carried out over the range of scales populated by high-dimensional multi-scale constituent. The multi-scale aspects are then described in terms of conditional probabilities computed from the solar wind and magnetospheric data. Its analysis shows that some important multi-scale properties of magnetospheric response to the solar wind activity are mainly attributed to the scale-invariance of the solar wind driver rather than to the complexity of the magnetospheric dynamics itself. These results have important implications for space weather forecasting.

NG51A-0838 0830h POSTER

Symbolic Dynamics of Reanalysis Data

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Symbolic dynamics[1] is the study of sequences of symbols belonging to a discrete set of elements, the most commmon example being a sequence of ones and zeroes. Often the set of symbols is derived from a timeseries of a continuous variable through the introduction of a *partition function*–a process called *symbolization*. Symbolic dynamics has been used widely in the physical sciences; a geophysical example being the application of C^1 and C^2 complexity[2] to hourly precipitation station data[3]. The C^1 and C^2 complexities are computed by examining subsequences–or *words*–of fixed length L in the limit of large values of L. Recent advances in information theory have led to techniques focused on the growth rate of the Shannon entropy and its asymptotic behavior in the limit of long words–*levels of entropy convergence*[4]. The result is a set of measures one can use to quantify the amount of memory stored in the sequence, whether or not an observer is able to synchronize to the sequence, and with what confidence it may be predicted. These techniques may also be used to uncover periodic behavior in the sequence. We are currently applying complexity theory and levels of entropy convergence to gridpoint timeseries from the NCAR/NCEP 50-year reanalysis[5]. Topics to be discussed include: a brief introduction to symbolic dynamics; a description of the partition function/symbolization strategy; a discussion of C^1 and C^2 complexity and entropy convergence rates and their utility; and example applications of these techniques to NCAR/NCEP 50-reanalyses gridpoint timeseries, resulting in maps of C^1 and C^2 complexities and entropy convergence rates. Finally, we will discuss how these results may be used to validate climate models.

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Froude-number based spatio-temporal scaling of braided stream channels

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The lifetimes, t, of individual channels in braided streams are known to be proportional to the square root of their lengths. Since the acceleration due to gravity, g, is constant, this combination L/t*t is clearly the same as obtained from the physically-based constraint that the Froude number, Fr, be a constant. Both observation and theory imply that bed mobility tends to limit supercritical flow, i.e., to reduce Fr to 1. This is associated with a tendency to optimize dissipation. A new result for the downstream particle flux as a function of particle size appears to give a concrete way to relate the length and time scales of Fr to channel lengths and lifetimes. Thus the basis for the channel scaling appears to be the tendency to optimize dissipation, and therefore sediment transport, in steep gradient channels with mobile beds.