Nonlinear Geophysics

NG11A CC: 516 B Monday 0830h

Scaling and Fractals in the Earth, Atmosphere, and Hydrosphere: Resolution Dependence and Nonlinear Variability I

Presiding: **H Gaonach,** GEOTOP, Iniversite du Quebec a Montreal**; Q Cheng,** York University

NG11A-01 0830h INVITED

Multifractal Modeling and the Pareto Distribution

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The high-value tails of the sizes of mineral deposits and oil pools often can be modeled as Pareto distributions plotting as straight lines on log-log paper. However, except in their high-value tails, the central parts of the frequency distributions for these resources tend to satisfy the lognormal model with clearly developed peak and zero frequency density at the origin. Some types of multifractal cascade models result in approximately lognormal distributions but with tails controlled by the hyperbolic law. Depending on type of multifractal model used, the high-value Pareto tail is either weaker or stronger than the lognormal outward extension from the central, approximately lognormal, distribution. The multifractal cascade model corresponding to the model of De Wijs for geochemical data results in an approximately hyperbolic tail that is weaker than the lognormal extension. Hyperbolic tails stronger than lognormal can be generated if the highest concentration values are controlled by enrichment processes that are stronger than those controlling the lognormal background. For example, case history studies will be reviewed for large gold and hydrocarbon deposits.

NG11A-02 0845h

Multifractal Predictability

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The "chaos revolution" clearly emphasized that strong nonlinearity generates sensitive dependence to initial conditions and drastic predictability limits. This was achieved with the help of apparently simple caricatures of complex systems leading nevertheless to non-trivial behaviors. This was widely popularised as the 'butterfly effect', i.e. the existence of an exponential error growth and therefore of a characteristic predictability time. This became considered as the universal law of predictability limits, in spite of observed discrepancies. Spatially extended systems, like turbulent dynamics of the atmosphere and the oceans or the rain field, are extremely variable over a wide range of scales. These systems 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. Secondly, the predictability decay is highly inhomogeneous: intermittency plays a fundamental role and the loss of information occurs by intermittent puffs. As a consequence, predictability limits are much more complex than those foreseen with homogeneous theories: instead of a unique exponent relating time and space scales, an infinite hierarchy of power-law exponents is required to characterize the predictability decay from average to extreme events. Nevertheless, contrary to those of simple chaotic systems, these scaling predictability decay laws are not only asymptotic, but they are meaningful over the whole range from short to long term. We give an explicit expression of these laws, to which our current effective prediction skills should be compared. In this respect, we confirm the necessity to proceed to stochastic sub-grid modeling rather than deterministic ones, as well as the possibility to directly proceed to stochastic forecasts.

URL: http://www.enpc.fr/cereve/~schertze

NG11A-03 0900h

Detecting Lévy and fractal Gaussian Intermittencies in Geophysical Phenomena

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Time series from complex phenomena are characterized by complicated memory and/or distribution patterns. We discuss models of different statistics and explore the relationship between the statistical properties of time series and observed patterns in various phenomena. In particular, we discuss the difference between Lévy-walk intermittent noise and fractal Gaussian intermittent noise. We show that two complementary scaling analysis techniques (Diffusion Standard Deviation Analysis and Diffusion Entropy Analysis), when used together, can distinguish between the two kinds of intermittent statistics. Finally, we apply these methodologies to geophysical phenomena: (a) the stochastic coupling of solar flare intermittency with the total solar irradiance and global temperature anomalies can be modeled [1]; (b) the earthquake occurrences in California are modeled by a long-range correlated Generalized Poisson model [2]. [1] N. Scafetta and B.J. West, Solar Flare Intermittency and the Earth's Temperature Anomalies, Physical Review Letters 90, 248701-1 (2003). [2] N. Scafetta and B.J. West, Multi-Scaling Comparative Analysis of Time Series and a Discussion on "Earthquake Conversations" in California, accepted by Physical Review Letter

NG11A-04 0915h INVITED

On Why Fractals Everywhere

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Fractal is a ubiquitous phenomenon. It can be classified as deterministic or stochastic. Deterministic fractals have been commonly generated by iterative function systems (e.g., Cantor set, Sierpinski carpet and Koch snowflake) or recurrence relation (e.g., Lyapunov fractal). Stochastic fractals involve random processes and they have been used to describe some highly irregular real-world phenomena (e.g., clouds and turbulence). Stochastic fractals have been investigated with local models (e.g., Diffusion Limited Aggregation, and Percolation), as well as non-local models (e.g., Dielectric Breakdown Model and Self Organization). The objective of this study is to construct a universal non-local model to provide a plausible explanation of the origination of fractal characteristic in a wide variety of natural phenomena, without taking into account the underlying microscopic physics on a detailed level. The natural phenomena under consideration include turbulence, river networks, soil hydrology, lightning, avalanches, earthquakes, volcanic activities and distribution of leaves, updrafts/downdrafts, rain areas, clouds, interstellar clouds, sunspots or galaxies.

NG11A-05 0930h

Third Generation Multifractal Models and Geophysics

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Geophysical fields typically display extreme variability over huge ranges of scale. The simplest assumption about the corresponding dynamical mechanism is that it respects a scaling symmetry; the process is multifractal. In such processes, the variability is produced by the scale by scale repetition of a cascade-like mechanism. This is the phenomenological basis of the cascade models. In some cases, notably for cloud radiances and for the topography, the isotropic horizontal statistics can be shown to be multiscaling from planetary scales down kilometers or less to within 1-2% per octave in scale. The first generation multifractal models were the discrete (in scale) models introduced in the turbulence literature in the 1960's and 1970's. While these were useful in advancing research into scaling and intermittency, they had ugly (and unrealistic) construction lines, artifacts of the fact that that their scaling was only exactly valid for integer powers of integer scale ratios. The second generation models were introduced in the 1980's: these were continuous in scale (their generators were infinitely divisible processes), in the 1990's they were rendered anisotropic and causal (for space-time modeling). Since they were based on the exponentiation of fractionally integrated Levy noises, they are very sensitive to problems of numerical stability; this is particulary true of the strongly anisotropic models of geophysical interest. Such strong anisotropy is needed for example in modeling stratification in flows and rock strata as well as filamentary and rotating structures such as those commonly observed in clouds, or highly elongated structures such as mountain ranges. In this talk, we describe a series of technical improvements which promise to make multifractal models a standard element in the geophysicists' toolbox.

NG11A-06 0945h INVITED

Self-stabilized Fractality of Sea-coasts Through Damped Erosion

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Coastline morphology is of current interest in geophysical research and coastline erosion has important economic consequences. At the same time, although the geometry of seacoasts is often used as an introductory archetype of fractal morphology in nature there has been no explanation about which physical mechanism could justify that empirical observation. The present work propose a minimal, but robust, model of evolution of rocky coasts towards fractality. The model describes how a stationary fractal geometry arises spontaneously from the mutual self-stabilization of a rocky coast morphology and sea eroding power. If, on one hand, erosion generally increases the geometrical irregularity of the coast, on the other hand this increase creates a stronger damping of the sea and a consequent diminution of its eroding power. The increased damping argument relies on the studies of fractal acoustical cavities, which have shown that viscous damping is augmented on a longer, irregular, surface. A minimal two-dimensional model of erosion is introduced which leads to the through a complex dynamics of the earth-sea interface, to the appearance of a stationary fractal seacoast with dimension close to 4/3. Fractal geometry plays here the role of a morphological attractor directly related to percolation geometry. The model reproduces at least qualitatively some of the features of real coasts using only simple ingredients: the randomness of the lithology and the decrease of the erosion power of the sea. B. Sapoval, Fractals (Aditech, Paris, 1989). B. Sapoval, O. Haeberlé, and S.Russ, J. Acoust. Soc. Am., 2014 (1997). B. Hébert B., B. Sapoval, and S.Russ , J. Acoust. Soc. Am., 1567 (1999).

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NG12A CC: 516 B Monday 1030h

Nonlinear Phenomena in Fluid Dynamics With Implications for Climate I

Presiding: **M Stastna,** University of Toronto**; F Poulin,** Scripps Institution of Oceanography

NG12A-01 1030h INVITED

The Nonlinear Dynamics of Antarctic Intermediate Water Formation

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Recently, there has been considerable interest in the properties and formation of the oceans' intermediate waters. These waters are a complex and essential part of the role the ocean plays in modulating and driving climate change. The Antarctic Intermediate Water (AAIW) is the largest body of intermediate water. AAIW forms in the Southern Ocean in the region of the worlds strongest current, the Antarctica Circumpolar Current (ACC). However the exact details