involves physics on at least four interactive scales. Because of computational limitations, we inquire whether it is important to take into account the dynamics of fracture, the radiation of elastic waves, tensor stresses, the physics of nucleation and healing, the geometry of faults, three dimensionality and fault structure in modeling the full problem. We discuss the robustness of simulations to the inclusion of some of these ingredients into models to study space-time pattern formation of mainshocks.

#### NG12A-04 1415h INVITED

### The Middle Number World: A View of Complexity Theory and Methods in Ecology

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Ecosystems, like the porridge and chair that Goldilocks found in the Three Bear's house, are characterized by numbers neither too large nor too small; they belong instead to the class of middle number systems. As such, complexity theory and methods complement the web of structures and interactions which make up landscapes and ecosystems and concern the inception of "life itself" (Rosen, 1991). As a field integral to critical socio-ecological issues confronting the globe today, and one concerned with intricate scale relationships between observer (ecologist) and observed (ecosystem), ecology brings an intriguing perspective to complex systems analysis. We discuss these new findings from complexity theory within ecological research. In this overview, we describe a systematics of ecosystem dynamics (emergence, unfolding, embedding, and operational closure) which is evolving for ecological phenomena and is common to other complex adaptive systems. Further, we discuss future research directions which are emerging with the integration of complexity and social sciences theories as they develop into a new post-modern epistemology.

#### NG12A-05 1430h INVITED

### Which Chaos in Geophysics ?

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Chaos revolution has been a popular theme. Indeed, low dimensional deterministic chaos had been very helpful in order to better understand the limitations of classical methods in analyzing and modeling complex systems in Geophysics. This was achieved with the help of apparently simple caricatures of complex systems) leading nevertheless to nontrivial behaviors. The prototype example is the celebrated Lorenz model (Lorenz, 1963), which was introduced as a mathematical caricature of atmospheric convection and has the lowest possible dimensionality, i.e. three, for chaotic differential systems.

However, in the name of a very interesting extension of the classical Whitney's embedding theorem (for integer dimensional manifolds), there had been an awkward tendency to attempt to reduce complex systems to their low dimensional caricatures. We show that it corresponds to a fundamental misinterpretation of this theorem. However, this tendency was reinforced by the apparent success of a rather straightforward algorithm to estimate the dimensionality for various complex systems by its correlation dimension (Grassberger and Proccaccia, 1983). Indeed, this algorithm yielded rather low dimensionality estimates for various geophysical systems. However, these estimates turn out to be spurious for two rather well known reasons: sample size limitation, stochasticity. In the latter case, we discuss the non-classical case of (stochastic) multiplicative chaos.

We review some geophysical examples that point out the irrelevance of low dimensional chaos to Geophysics. We point out that it is rather clear that the chaos of these spatially extended systems, requires approaches dealing with very large number of degrees of freedom and that some asymptotic behavior s rather corresponds to infinite numbers. We point out that progress in that direction should result from an original blending of stochastics and dynamics, as well as a confrontation between the ergodic theory of chaos and the singularities of multifractal fields.

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

#### NG12A-06 1445h INVITED

### From Scaling to Multiscaling: Volcanoes in Anisotropic Environments

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Highly variable processes in volcanological, geophysical and environmental sciences abound. They are characteristic expressions of the highly nonlinear dynamics. A particular and prominent aspect is the ubiquity of scaling properties, implying a scaling symmetry over a wide range of scales. This is demonstrated using various examples spanning wide ranges of space and time scales including the coalescence of gas vesicles in lava and pumice, lava flow emplacement, volcanic plume dispersion, volcanic versus solar heating cooling at the terrestrial surface, etc.

Remotely sensed data are very appropriate for such kind of studies and give us the opportunity to study and describe a phenomenon from one scale to another over a large geographic area. While the existence of such scaling may reveal the continuity of a dynamic process over these scales it is also important to determine the inner and outer scales of the scaling regimes: i.e. their characteristic scales. Moreover, it is essential to consider these multifractal properties is a more general context where the (scale by scale) differential anisotropy is taken into account. In such cases, generalized scale invariance will provide new powerful insights for describing highly variable anisotropic phenomena. I will discuss this question through studied examples.

#### NG12A-07 1500h INVITED

### To what extent SOC models describe solar flares?

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We present evidences that statistical distributions of dissipative events in magnetohydrodynamic turbulence is in agreement with the statistics of solar flares. The "SOC paradigm", usually used in describing solar flares, fails to describe some of the features of real observations. The same kind of phenomena are visible also in disruptions in laboratory plasmas.

## NG12B MC: 308 Monday 1605h

### The Lorenz Lecture Series: Benoit Mandelbrot

*Presiding:* **J Rundle,** University of Colorado

#### NG12B-01 1610h INVITED

### Fractals as the Measure of Roughness in the Earth Sciences

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Centuries before our time, all but one of the major phenomena recorded by Man's senses had given rise to thriving disciplines, for example, optics and acoustics. The exception was roughness, which was well recognized but unexplored. Today, a concise and proper description of fractal and multifractal geometry is this: it promises to be a first step toward an understanding of roughness. When man was a hunter-gatherer, almost nothing was smooth and some of the most spectacular irregularities were found in the phenomena later taken up by the Earth Sciences. Roughness is equally essential in the world of non-linear dynamics and chaos. Centering the discussion around roughness, the speaker will sketch the current status of fractal geometry, with a special emphasis on its relation to the Earth and Space Sciences.

## NG21A MC: Hall D Tuesday 0830h

### Scaling Geophysics: Where We've Been, Where We're Going III *(joint with A, G, H, OS, S, SA, T, V)*

*Presiding:* **S Lovejoy,** McGill University**; V I Keilis-Borok,** Russian Ac. Sci.

#### NG21A-0402 0830h POSTER

### Alfvén Wave Generation by Multifractal Solar Magnetic Fields

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The high speed particles and magnetic fields of the solar wind form an important part of the earth's space environment. However, the energy supply driving this wind is not fully understood. The heating mechanism seems clearly to be rooted in the turbulent plasma of the solar convection zone. However, the amplitude and frequency spectrum of Alfvén waves emitted from the top of the photosphere are strongly dependent on the magnetic field strength and configuration [1]. Aside from the amplitude, the suitability of the Alfvén waves for accelerating the solar wind is strongly dependent on their frequency range. One estimate [2] requires frequencies 0.01 Hz $< \nu <$ 10 kHz. Waves below 0.01 Hz are reflected.

We have found that solar surface fields have an intermittent structure [3], pointing to generation by a multiplicative cascade process [4]. Projection to smaller scales of this observed symmetry allows us to propose a realistic photospheric magnetic flux distribution. This can be combined with a Kolmogorov photospheric velocity field [5] and the notion of flux tube impedance matching [1] for generation of Alfvén and fast mode MHD waves. The Alfvén flux depends on the cube of the magnetic field strength; for an assumed mean field of 10 G, and efficient wave excitation, we find an output flux $\sim 1.7 \times 10^5$ ergs cm$^{-2}$ s$^{-1}$ essentially all of which is produced at periods between 30 s and 80 s. Above a strong cutoff near $\nu <$ 0.01 Hz, the flux frequency spectrum is a power law $\nu^{-\beta}$ with $\beta = 3.51 \pm 0.08$. Such waves could contribute significantly to solar wind acceleration.

[1] Parker, E.N. 1992, in E. Marsch and R. Schwenn (eds.), Solar Wind Seven (COSPAR Colloquia Series, Vol. 3), Pergamon Press, Oxford, p. 79.

[2] Mckenzie, J.F., Banaszkiewicz, M. and Axford, W.I. 1995, Astron. Astrophys., 303, L45.

[3] Lawrence, J.K., Ruzmaikin, A.A. and Cadavid, A.C. 1993, Astrophys. J., 417, 805.

[4] Lawrence, J.K., Cadavid, A.C. and Ruzmaikin, A.A. 1995, Phys. Rev. E, 51, 316.

[5] Lawrence, J.K., Cadavid, A.C., Ruzmaikin, A. and Berger, T.E. 2001, Phys. Rev. Lett., 86, 5894.

#### NG21A-0403 0830h POSTER

### Fractional Differential Equations and Multifractality

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There has been a mushrooming interest in the linear Fokker-Planck Equation (FPPE) which corresponds to the generating equation of Lévy's anomalous diffusion. We already pointed out some theoretical and empirical limitations of the linear FPPE for various geophysical problems: the medium is in fact considered as homogeneous and the exponent of the power law of the pdf