Geophysical Research Abstracts
Vol. 15, EGU2013-10572, 2013
EGU General Assembly 2013

The weather and climate: emergent laws and multifractal cascades

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Science in general and physics and geophysics in particular are hierarchies of interlocking theories and models with low level, fundamental laws such as quantum mechanics and statistical mechanics providing the underpinnings for the emergence of the qualitatively new, higher level laws of thermodynamics and continuum mechanics that provide the current bases for modelling the weather and climate. Yest it was the belief of generations of turbulence pioneers (notably Richardson, Kolmogorov, Obhukhov, Corrsin, Bolgiano) that at sufficiently high levels of nonlinearity (quantified by the Reynold's number, of the order 10**12 in the atmosphere) that new even higher level laws would emerge describing "fully developed turbulence". However for atmospheric applications, the pioneers' eponymous laws suffered from two basic restrictions - isotropy and homogeneity – that prevented them from being valid over wide ranges of scale. Over the last thirty years both of these restrictions have been overcome – the former with the generalization from isotropic to strongly anisotropic notions of scale (to account notably for stratification), and from homogeneity to strong heterogeneity (intermittency) via multifractal cascades.

In this presentation we give an overview of recent developments and analyses covering huge ranges of space-time scales (including weather, macroweather and climate time scales). We show how the combination of strong anisotropy and strong intermittency commonly leads to the "phenomenological fallacy" in which morphology is confounded with mechanism. With the help of stochastic models, we show how processes with vastly different large and small scale morphologies can arise from a unique multifractal dynamical mechanisms [Lovejoy and Schertzer, 2013].

References:

Lovejoy, S., and D. Schertzer (2013), The Weather and Climate: Emergent Laws and Multifractal Cascades, 480 pp., Cambridge University Press, Cambridge.