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Statistical Extremes of Turbulence and a Cascade Generalisation of Euler's Gyroscope Equation

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Turbulence refers to a rather well defined hydrodynamical phenomenon uncovered by Reynolds. Nowadays, the word turbulence is used to designate the loss of order in many different geophysical fields and the related fundamental extreme variability of environmental data over a wide range of scales.
Classical statistical techniques for estimating the extremes, being largely limited to statistical distributions, do not take into account the mechanisms generating such extreme variability. An alternative approaches to nonlinear variability are based on a fundamental property of the non-linear equations: scale invariance, which means that these equations are formally invariant under given scale transforms. Its specific framework is that of multifractals. In this framework extreme variability builds up scale by scale leading to non-classical statistics. Although multifractals are increasingly understood as a basic framework for handling such variability, there is still a gap between their potential and their actual use. In this presentation we discuss how to dealt with highly theoretical problems of mathematical physics together with a wide range of geophysical applications.
We use Euler's gyroscope equation as a basic element in constructing a complex deterministic system that preserves not only the scale symmetry of the Navier-Stokes equations, but some more of their symmetries. Euler's equation has been not only the object of many theoretical investigations of the gyroscope device, but also generalised enough to become the basic equation of fluid mechanics. Therefore, there is no surprise that a cascade generalisation of this equation can be used to characterise the intermittency of turbulence, to better understand the links between the multifractal exponents and the structure of a simplified, but not simplistic, version of the Navier-Stokes equations. In a given way, this approach is similar to that of Lorenz, who studied how the flap of a butterfly wing could generate a cyclone with the help of a 3D ordinary differential system. Being well supported by the extensive numerical results, the cascade generalisation of Euler's gyroscope equation opens new horizons for predictability and predictions of processes having long-range dependences.