Multifractals and Resolution Dependence in Remote Sensing:
The Example of Ocean Colour

S. Lovejoy (Physics Department and GIROQ, McGill University)
lovejoy@physics.mcgill.ca
D. Schertzer and H. Gaonac'h

Abstract

We argue that geophysical and geographical fields are generally characterized by wide range scaling implying systematic, strong (power law) resolution dependencies when they are remotely sensed. The corresponding geometric structures are fractal sets, the corresponding fields are multifractals. Mathematically, multifractals are measures which are singular with respect to the standard Lebesgue measures, they therefore are outside the scope of many of the methods of classical geostatistics. Because the resolution of a measurement is generally (due to technical constraints) much larger than the inner scale of the variability/scaling, the observations will be fundamentally observer dependent and hence standard remote sensing algorithms which do not explicitly take this dependence into account will depend on subjective resolution dependent parameters. We argue that on the contrary the resolution dependence must be systematically removed so that scale invariant algorithms independent of the observer can be produced.

We illustrate these ideas in various ways with the help of eight channel, 7m resolution remote ocean colour data (from the MIES II sensor) over the St. Lawrence estuary. First we show that the data is indeed multiscaling over nearly four orders of magnitude in scale, and we quantify this using universal multifractal parameters. With the help of conditional multifractal statistics we then show how to use multifractals in various practical ways such as for extrapolating from one resolution to another or from one location to another, or to correcting biases introduced when studying extreme, rare phenomena. We also show how the scaling interrelationship of surrogate and in situ data can be handled using vector multifractals and examine the resolution dependence of principle components in dual wavelength analyses. Finally, we indicated why the standard ocean colour algorithms have hidden resolution dependencies, and we show how they can (at least in principle) be removed.