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Stochastic multifractal forecasts: from theory to applications in radar meteorology

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Radar meteorology has been very inspiring for the development of multifractals. It has enabled to work on a 3D+1 field with many challenging applications, including predictability and stochastic forecasts, especially nowcasts that are particularly demanding in computation speed. Multifractals are indeed parsimonious stochastic models that require only a few physically meaningful parameters, e.g. Universal Multifractal (UM) parameters, because they are based on non-trivial symmetries of nonlinear equations.

We first recall the physical principles of multifractal predictability and predictions, which are so closely related that the latter correspond to the most optimal predictions in the multifractal framework. Indeed, these predictions are based on the fundamental duality of a relatively slow decay of large scale structures and an injection of new born small scale structures. Overall, this triggers a mulfitractal inverse cascade of unpredictability.

With the help of high resolution rainfall radar data ($\approx$ 100 m), we detail and illustrate the corresponding stochastic algorithm in the framework of (causal) UM Fractionally Integrated Flux models (UM-FIF), where the rainfall field is obtained with the help of a fractional integration of a conservative multifractal flux, whose average is strictly scale invariant (like the energy flux in a dynamic cascade). Whereas, the introduction of small structures is rather straightforward, the deconvolution of the past of the field is more subtle, but nevertheless achievable, to obtain the past of the flux. Then, one needs to only fractionally integrate a multiplicative combination of past and future fluxes to obtain a nowcast realisation.