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On scaling in spatial precipitation from radar

Athanasios Paschalis, Peter Molnar, and Paolo Burlando
Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland (molnar@ifu.baug.ethz.ch)

The topic of self-similarity in precipitation in time and space has been prominent in precipitation research for at least the last 3 decades. Data analysts have explored evidence for self-similarity and reported departures from it. Modellers have developed stochastic models that are based on self-similarity concepts or at least reproduce the observed scaling behaviour. Physicists and meteorologists have argued why scale invariance should, or should not, exist in precipitation. Although there appears to be consensus between these communities that precipitation may exhibit scale invariance in some range of scales, most of us would probably also agree that the scaling properties are connected to the precipitation generation mechanisms (e.g. convection, orographic enhancement, etc.) and are not generally valid. The demonstration of this variability in scaling properties of precipitation and their relation to possible precipitation generating mechanisms is the focus of this paper.

We analyse the spatial structure of radar precipitation for the orographically complex environment of the Swiss Alps as a multi-scaling process. A reliable 7 year long, high quality precipitation radar dataset, derived from the operational weather radars of MeteoSwiss is used to conduct a comprehensive data analysis and to reveal potential connections of the scaling processes of the precipitation structure and its respective generating mechanisms. We use different analysis techniques to quantify scale-dependent properties, from spectral analysis to multiplicative random cascades, employing estimation techniques spanning from traditional moment scaling to wavelet based estimators. We compare the results seasonally for radars in two different locations, one north and one south of the main Alpine divide, with very different topography.

The main result is that distinct seasonal and spatial patterns in precipitation scaling properties exist which highlight the effect of topography on precipitation formation. Our key findings are: (1) Topography and dominant wind flow patterns can affect the isotropic/anisotropic structure of the precipitation fields. (2) Distinct seasonal patterns for the scaling parameters of spatial precipitation exist, and some analysis techniques are better than others to quantify those. (3) Scaling parameters are related to precipitation large scale forcing, e.g. mean precipitation intensity, and this relationship is seasonally dependent. (4) Our data suggest that precipitation scaling in a topographically complex environment cannot be easily associated with the thermodynamic descriptors of the state of the atmosphere, in contradiction to what has been found in previous studies. (5) Topography and in particular different enhancing/shadowing mechanisms at the two radar sites strongly influence the scaling properties and spatial distribution of the precipitation fields. All of these findings demonstrate that scaling properties in spatial rainfall should in fact be expected to be variable, and the source of this variability is likely to be found in precipitation generating mechanisms and the stochasticity in precipitation formation in general.