Sensitivity of power functions to aggregation: bias and uncertainty in radar rainfall retrieval

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Rainfall retrieval using weather radar relies on power functions between radar reflectivity $Z$ and rain rate $R$. The nonlinear nature of these relations complicates the comparison of rainfall estimates employing reflectivities measured at different scales. Transforming $Z$ into $R$ using relations that have been derived for other scales results in a bias and added uncertainty. We investigate the sensitivity of $Z$-$R$ relations to spatial and temporal aggregation using high-resolution reflectivity fields for five rainfall events. Existing $Z$-$R$ relations were employed to investigate the behavior of aggregated $Z$-$R$ relations with scale, the aggregation bias and the variability of the estimated rain rate. The prefactor and the exponent of aggregated $Z$-$R$ relations systematically diverge with scale, showing a break that is event-dependent in the temporal domain and nearly constant in space. The systematic error associated with the aggregation bias at a given scale can become of the same order as the corresponding random error associated with intermittent sampling. The bias can be constrained by including information about the variability of $Z$ within a certain scale of aggregation, and is largely captured by simple functions of the coefficient of variation of $Z$. Several descriptors of spatial and temporal variability of the reflectivity field are presented, to establish the links between variability descriptors and resulting aggregation bias. Prefactors in $Z$-$R$ relations can be related to multi-fractal properties of the rainfall field. We find evidence of scaling breaks in the structural analysis of spatial rainfall with aggregation.