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Sensitivity of Z-R relations to aggregation

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Rain radars routinely rely on power functions to retrieve rain rates based on radar reflectivities measured at widely ranging spatial and temporal resolutions. The nonlinear nature of power functions may complicate the comparison of rainfall estimates employing reflectivities measured at different scales, as transforming reflectivity Z into rain rate R using relations that have been derived for other spatial and/or temporal scales results in a bias. We investigate the sensitivity of such power functions, known as Z-R relations, to spatial and temporal aggregation using high-resolution reflectivity fields measured with an X-band radar, 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 breaks that are event-dependent in the temporal domain and nearly constant in the spatial domain. The systematic behavior of prefactors and exponents with scale can be described with prescribed functions, notably power, linear and exponential functions. The systematic error associated with aggregation bias at a given scale can be of the same order of magnitude as the corresponding random error associated with intermittent sampling. The predictable bias can be constrained by including information about the variability of Z within a certain scale of aggregation, and is captured by simple functions of the coefficient of variation. Several descriptors of spatial and temporal variability of the reflectivity field show strong links with aggregation bias. Prefactors in Z-R relations can be related to multi-fractal properties of the rainfall field whereas scale dependencies in the exponent may be interpreted as a spurious artifact of the regression procedure. Shape factors of both bounded bilinear and unbounded exponential variogram models are insensitive to aggregation for moments of order higher than unity, however, the structural analysis of spatial rainfall reveals a scaling break at spatial lags comparable with the maximum scale of aggregation imposed by the limited spatial coverage of the radar dataset analyzed. Our results support the good practice of attaching ranges of validity to nonlinear calibrations.