Why is radar data so difficult to assimilate properly?

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Though radar is our most important tool for identifying severe weather threats, the assimilation of its data does not yet improve the skill of numerical weather forecasting beyond that of nowcasting in the first hour. To understand why, a set of assimilation requirements, data characteristics, and common practices are documented that hinder optimum data assimilation by traditional approaches. Fundamentally, radars provide dense measurements of a few highly variable storm outcomes (precipitation, wind) in atmospherically unstable conditions where forecast errors are growing rapidly, leading to complex statistical relationships between errors of measured and unmeasured fields. In parallel, just outside of storms lie large regions for which radars give no new information, yet whose properties will soon shape the outcome of storms; any innovation over those regions must hence be projected from distant precipitating areas. This double need, specific to radar data assimilation, of correcting in-storm properties with complex errors while projecting information at unusually far distances outside of storms is at odds with many traditional assimilation approaches and implementations. Superposed on this fundamental challenge, other data characteristics and practices such as assimilating reflectivity in logarithmic units further reduces the linearity of covariance between observations and state variables, though they may help in other ways. Using a range of thought experiments and numerical examples, we illustrate how characteristics of radar measurements and common assimilation practices are incompatible with many conditions of success of assimilation. Facing these challenges may force us to consider assimilation approaches that use differently the information provided.

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