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# Challenges propagating innovations on precipitation and cloud to other state variables

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In the presence of clouds and precipitation, there is a greater need for information on all state variables in a context where both data assimilation and remote sensing become more complicated, because:

1) Clouds, and to a lesser extent precipitation, shut atmospheric windows at optical (UV to IR) and upper-microwave frequencies while also introducing challenges to observation simulation, limiting the number of high-quality constraints that can be obtained via many remote sensing approaches;

2) Errors grow faster in areas of atmospheric instabilities that often cause clouds and precipitation to appear and evolve, making precipitation the least predictable of atmospheric properties;

3) Clouds and precipitation fields have greater errors, especially at smaller scales, than other fields. Because smaller-scale errors dominate, they are correlated with errors in other fields over shorter distances, limiting the benefit of information propagation that is the key to successful data assimilation. In addition, fields at small scales are not as well simulated by models of limited resolution, making any observation innovation both harder to reproduce by measurement simulation and to use for assimilation;

4) The information propagation component of many common traditional assimilation approaches often assumes a linear correlation of errors, an approach that works better given small background errors, a rarer situation in precipitating areas;

5) Innovations in precipitation have the least benefit for forecasting the future evolution of the atmosphere as, by definition, precipitation quickly gets out of the atmosphere. Successful precipitation forecasting relies more on improving the other state variables than on improving precipitation fields;

All this occurs while we also have two additional categories of model state variables to characterize, cloud and precipitation properties, that are otherwise trivial to set in the absence of clouds.

This state of affairs calls for the exploration of approaches better designed to handle such difficult situations.

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