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Cloud-Resolving Ensemble Data Assimilation

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Cloud microphysics represents one of the most challenging obstacles for development of data assimilation, for both theoretical and practical reasons. From theoretical point of view, the difficulty originates from nonlinearity of cloud processes and observation operators for cloud observations. In addition cloud processes are often represented by non-differentiable operators, which further complicates their proper assimilation. From practical point of view, modeling of cloud processes requires fine spatio-temporal resolution, dramatically increasing the dimension of the control variable and consequently making algorithmic development more difficult.

On the other hand, clouds are at the crossroads of weather, climate and hydrology. As such, their proper representation can have a dramatic positive impact in all of these disciplines, prompting a considerable need for mastering data assimilation with cloud microphysics.

In this work we address the problem of assimilation of cloud microphysical variables in ensemble data assimilation. We discuss theoretical and practical issues of assimilation of cloud microphysics and offer means for resolving these issues. In particular we focus on using the Maximum Likelihood Ensemble Filter (MLEF), developed with components of both ensemble and variational data assimilation methods. We show recent MLEF results with the Weather Research and Forecasting (WRF) model in applications to intensive precipitation, severe weather and tropical cyclones.

Our results indicate that inclusion of cloud microphysical variables and cloudy satellite radiance observations in data assimilation is beneficial, and most likely necessary for proper analysis and prediction of clouds. The relevance of cloud microphysical variables in cloud-scale data assimilation is also confirmed by information content analysis of assimilated observations, which indicates an increased information content of cloud-sensitive observations.