An Ensemble-Constrained Variational Analysis of Atmospheric Forcing Data and Its Application

Research Highlight

Clouds represent one of the largest uncertainties in current General Circulation Models (GCM) simulations. Studies have shown that the model discrepancies can come from deficiencies in the physical parameterization and uncertainties in the large-scale atmospheric condition. However, it is still unclear how each of them contributes to the model errors. The ensemble ARM constrained analysis of atmospheric forcing data accurately specifies the large-scale dynamics conditions along with uncertainty range over the ARM site, thereby enabling more definitive isolation of model physics errors when the ensemble data are used to force models.

An ensemble variationally constrained objective analysis of atmospheric large-scale forcing data was developed for the March 2000 IOP at the ARM SGP site. The ensemble approach used the uncertainty information of the background data, error covariance matrices, and constraint variables in the ARM constrained variational analysis. The ensemble forcing data were applied to drive the CAM5 SCM and the simulated clouds were compared with MICROBASE cloud retrievals to diagnose the source of model biases. The results showed that most of the model biases are larger than the uncertainty from large-scale forcing data plus uncertainty from observations, pointing the simulated clouds biases to model parameterization deficiencies.

Sensitivity study showed that background data, error covariance matrix, and constraint variables all contribute to the uncertainty range of the analyzed state variables and large-scale forcing data, especially to the vertical velocity and advective tendencies. Background data had the largest impact. CAM5 simulations of clouds forced by the ARM ensemble forcing data systematically overestimated high-clouds while underestimating low-clouds when compared with ARM MICROBASE cloud retrievals. These model biases could not be explained by the uncertainty of large-scale forcing data and the uncertainty of observations, pointing to the deficiencies of physical parameterizations.

Reference(s)

Tang S, M Zhang, and S Xie. 2016. "An ensemble constrained variation alanalysis of atmospheric forcing data and its application to evaluate clouds in CAM5." Journal of Geophysical Research – Atmospheres, 121(1), doi:10.1002/2015JD024167.

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Cloud Life Cycle