Assessing the Impact of the Horizontal Covariance Localization Radius When Assimilating Infrared Brightness Temperature Observations

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Introduction

In this study, results from a regional-scale Observing System Simulation Experiment (OSSE) are used to evaluate how changes in the horizontal covariance localization radius employed during the assimilation of clear and cloudy-sky infrared brightness temperatures impacts the accuracy of atmospheric analyses and short-range model forecasts. Simulated observations from the Advanced Baseline Imager (ABI) to be launched onboard the GOES-R satellite in 2015 were employed. The ABI is a 16-band imager containing two visible, four near infrared, and 10 infrared bands. Accurate radiance and reflectance measurements will provide detailed information about atmospheric water vapor, surface characteristics and cloud top properties with high spatial and temporal resolution (Schmit et al. 2005).

Model Configuration and Simulated Observations

Assimilation experiments were conducted using the Weather Research and Forecasting (WRF) model and the ensemble Kalman filter algorithm in the Data Assimilation Research Testbed (DART) system. Satellite brightness temperature observations were assimilated using the Successive Order of Interaction (SOI) forward radiative transfer model that was implemented in the DART system by Otkin (2010).

Simulated observations from the ABI sensor and from three conventional observing systems were generated using data from a high-resolution "truth" simulation. Synthetic ABI 8.5 μm infrared brightness temperatures were computed using the SOI forward model and were then coarsened to 30-km resolution prior to assimilation. Observations at this wavelength are sensitive to cloud top properties when clouds are present or to the surface when clouds are missing. Simulated METAR, radiosonde, and aircraft reports were generated for existing surface and upper air station locations and wherever real pilot reports occurred during the case study period.

Truth Simulation

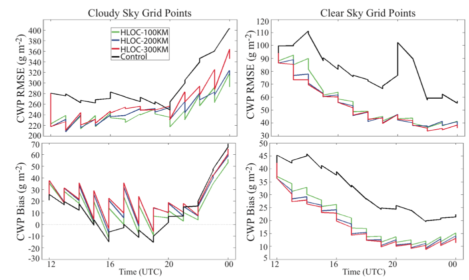
A high-resolution truth simulation tracking the evolution of several weather systems across the contiguous U.S. during 07-08 January 2008 was performed using the WRF model. The simulation was initialized using 20-km Rapid Update Cycle (RUC) analyses. The domain contained 6-km horizontal resolution and 52 vertical levels. Inspection of the simulated cloud top pressure, cloud water path, and 300 hPa height and wind fields during the truth simulation (not shown) revealed that a deep upper level trough was located across the western U.S., a seasonably strong jet streak extended across the central U.S, and a broad ridge was located over the eastern U.S. Several cloudy areas were present within the trough and also along and to the east of a strong surface thermal boundary extending across the central U.S.

Assimilation Cases

Assimilation experiments were performed for the same geographic domain as the truth simulation, but contained 18-km horizontal resolution and 37 vertical levels. Four assimilation experiments were performed. Simulated conventional observations were assimilated during all of the cases. Clear and cloudy sky 8.5 μm brightness temperatures were assimilated during the HLOC-100KM, HLOC-200KM, and HLOC-300KM cases. For these cases, the horizontal localization radius was set to 100, 200, or 300 km for the infrared observations. Observations were assimilated once per hour during a 12 hour period. Prognostic fields contained in the model state vector include the temperature, water vapor mixing ratio, horizontal and vertical wind components, surface pressure, number concentration of ice, and the mixing ratios for cloud water, rain water, pristine ice, snow, and graupel.

Cloud Time Series

The image to the right shows the evolution of the prior and posterior bias and RMSE for the cloud water path computed with respect to the cloudy and clear grid points in the truth simulation. Overall, using a larger localization radius lead to smaller errors during most of the assimilation period for the clear-sky grid points with the HLOC-300KM case containing the smallest bias and RMSE by 00 UTC; however, for the cloudy grid points, it was generally better to use a smaller localization radius. The different performance for the clear and cloudy grid points suggests that the smaller scale structure apparent in many cloud fields may require a smaller localization radius to achieve optimal results. For instance, cloud properties can vary quickly over short distances so a smaller localization radius limits the spread of information from individual cloudy observations that may not be totally representative of the larger cloud structure and also helps to preserve smaller cloud features when surrounded by clear observations.



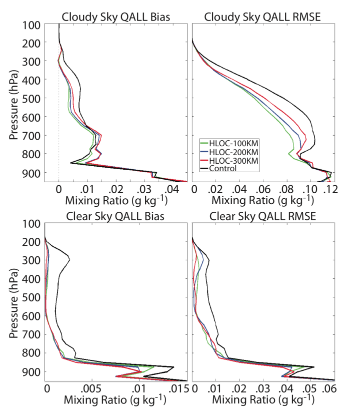
Final Analysis Accuracy

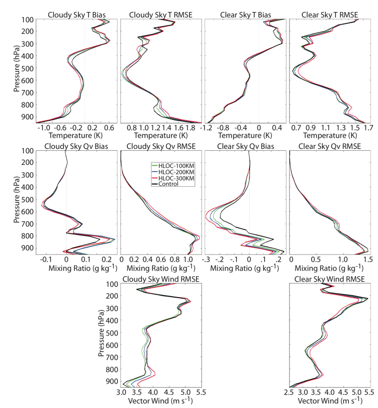
The accuracy of the final cloud analysis is shown below. Overall, the cloud analysis was greatly improved when 8.5 μm brightness temperatures were assimilated. The RMSE was much lower for both clear and cloudy grid points, with the largest error reductions occurring in the middle and upper troposphere. Comparison of the brightness temperature assimilation cases reveals that similar errors occurred for the clear-sky grid points; however, the errors consistently decreased with decreasing localization radius for the cloudy sky grid points.

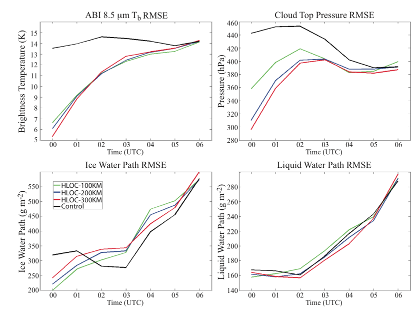
Vertical error profiles for the final temperature, water vapor, and vector wind speed analyses are shown to the lower right. In general, the RMSE for these variables was similar to or slightly better than the Control case only when the localization radius was reduced to 100 km for the 8.5 μm observations. The greatest degradation tended to occur for both clear and cloudy grid points when a larger localization radius was used. Combining these results with the final cloud analysis results indicates that although the infrared observations were able to consistently improve the cloud analysis regardless of the length of the localization radius, that it was necessary to use a smaller localization radius to maintain or improve the accuracy of the thermodynamic and moisture analyses relative to the Control case.

Forecast Accuracy

Short-range ensemble forecasts were performed for each case using the ensemble analyses at the end of the assimilation period. The figure below shows the evolution of the bias and RMSE for the ABI 8.5 μm band, cloud top pressure, ice water path (IWP), and liquid water path (LWP) fields. Overall, the positive impact of the infrared observations decreased rapidly during the forecast period and converged with the Control case within 6 hours for the cloud top pressure and 8.5 μm band and within 2 hours for the IWP and LWP fields. The rapid increase in the IWP and LWP errors indicates that improvements in the final cloud analysis quickly disappeared during the forecast period. This most likely was due to the less accurate moisture, temperature, and wind analyses at end of the assimilation period, which shows that if the moisture and thermodynamic forcing controlling the cloud evolution are not improved, that it is difficult to maintain the beneficial changes made to the final cloud analysis.







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