Assimilation of Simulated Infrared Brightness Temperatures Using An Ensemble Kalman Filter

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Data Assimilation System

- Regional-scale OSSEs are used to evaluate how the assimilation of infrared brightness temperature observations from the Advanced Baseline Imager (ABI) impacts the accuracy of atmospheric analyses and affects the skill of short-range model forecasts
    - ABI will be launched onboard GOES-R in 2016
- Assimilation experiments were performed using the WRF-ARW model and the parallel EAKF algorithm implemented in the DART data assimilation system
- Successive Order of Interaction (SOI) forward radiative transfer model was implemented within the DART framework
    - Accurate and fast forward model that can be used for both infrared and microwave radiance assimilation
    - Simulated fields used by the forward model include T, q_v, T_{skin}, 10-m wind speed, and the mixing ratios and effective diameters for five hydrometeor species (cloud water, rain water, ice, snow, and graupel)

OSSE Details

- OSSE case study tracks the evolution of an extratropical cyclone across the central U.S. during 04-05 June 2005
    - Case contains a wide assortment of cloud types and extensive clear-sky regions
- High-resolution (6-km) truth simulation performed for this case using the WRF model
- Simulated ABI brightness temperatures and conventional observations generated using data from the truth simulation
    - Conventional observations include radiosondes, surface METARs, and aircraft pilot reports; these observations were only produced at existing station locations and where real pilot reports occurred
    - ABI data was remapped to a representative ABI projection and then coarsened to ~60-km resolution prior to assimilation

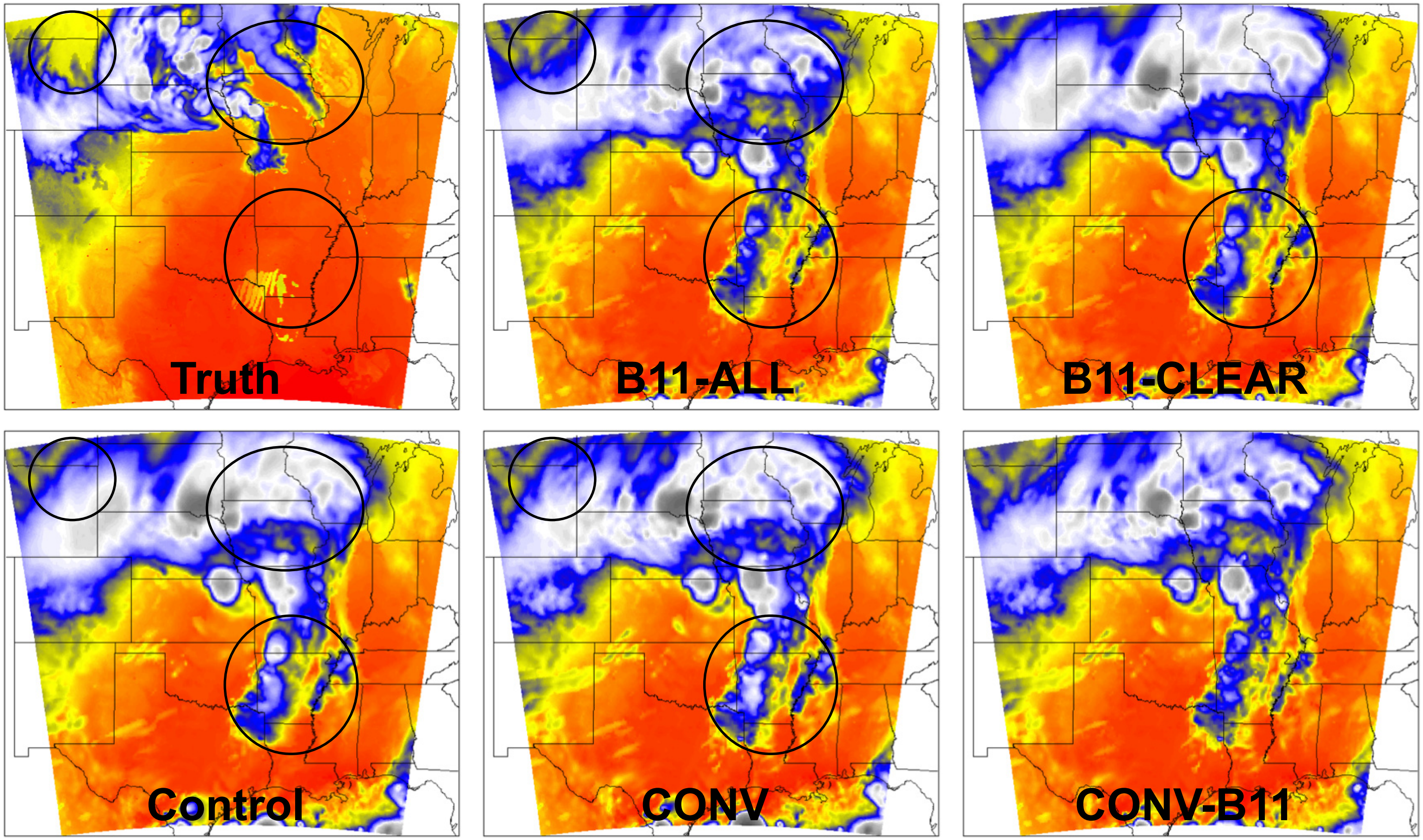
OSSE Configuration

Observations assimilated during each experiment:

- B11-ALL – both clear and cloudy sky ABI 8.5 mm (band 11) T_b
- B11-CLEAR – clear-sky only ABI 8.5 mm T_b
- CONV – conventional observations only
- CONV-B11 – both conventional observations and ABI 8.5 mm T_b
- Control – no observations assimilated

- Assimilation experiments were conducted using a 40-member ensemble containing 12-km horizontal resolution and 37 vertical levels
- Observations were assimilated once per hour during a 12-hr period

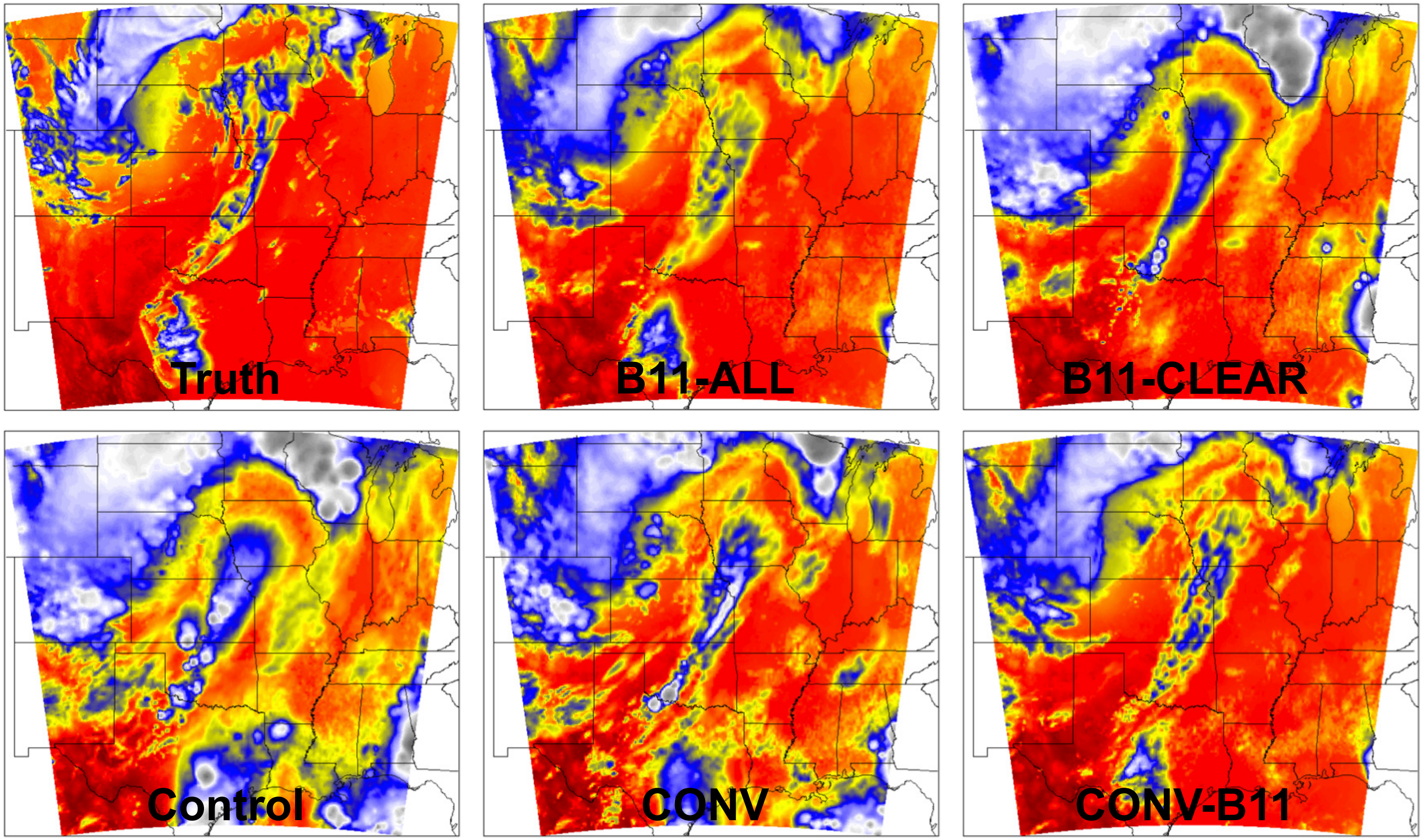
Ensemble-Mean ABI 11.2 mm Brightness Temperatures



Images valid after first data assim-ilation cycle at 12 UTC

• Compared to the conventional-only case, the assimilation of 8.5 mm brightness temperatures had a larger and more immediate impact on the erroneous cloud cover across the southern portion of the domain and also improved the structure of the cloud shield further north

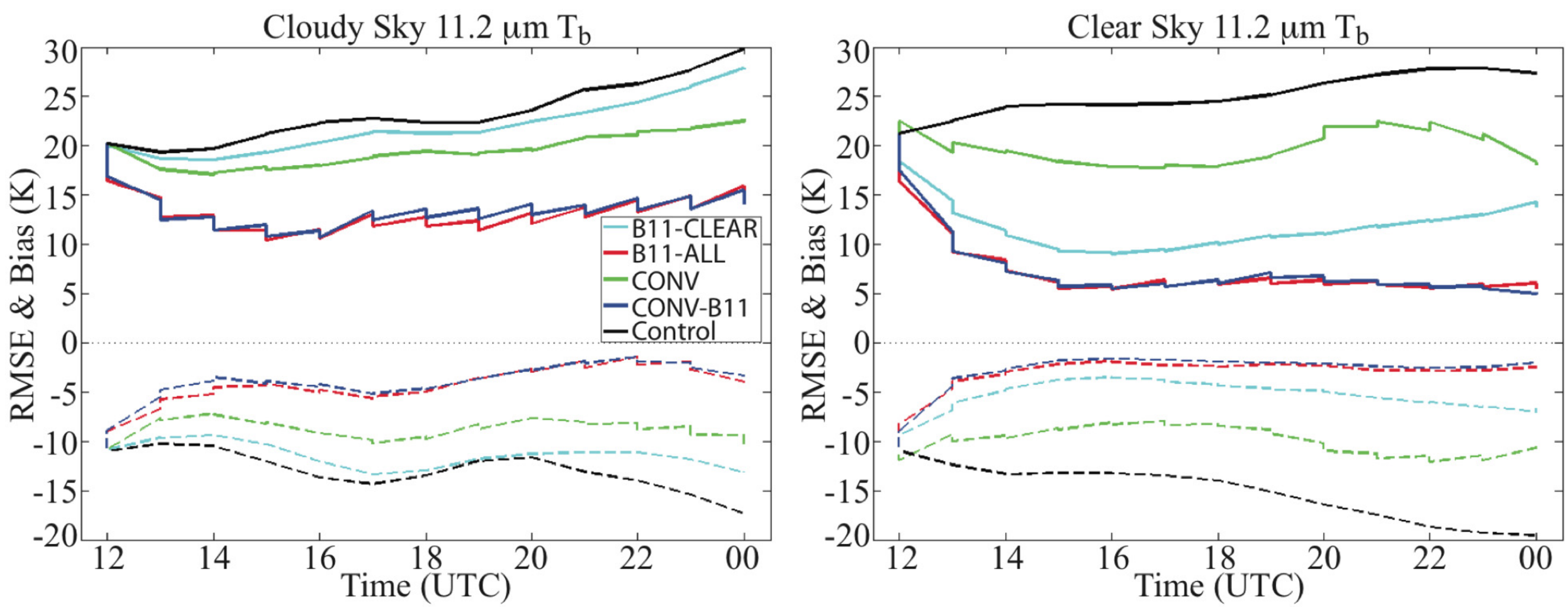
Ensemble-Mean ABI 11.2 mm Brightness Temperatures



Images valid after final data assimilation cycle at 00 UTC

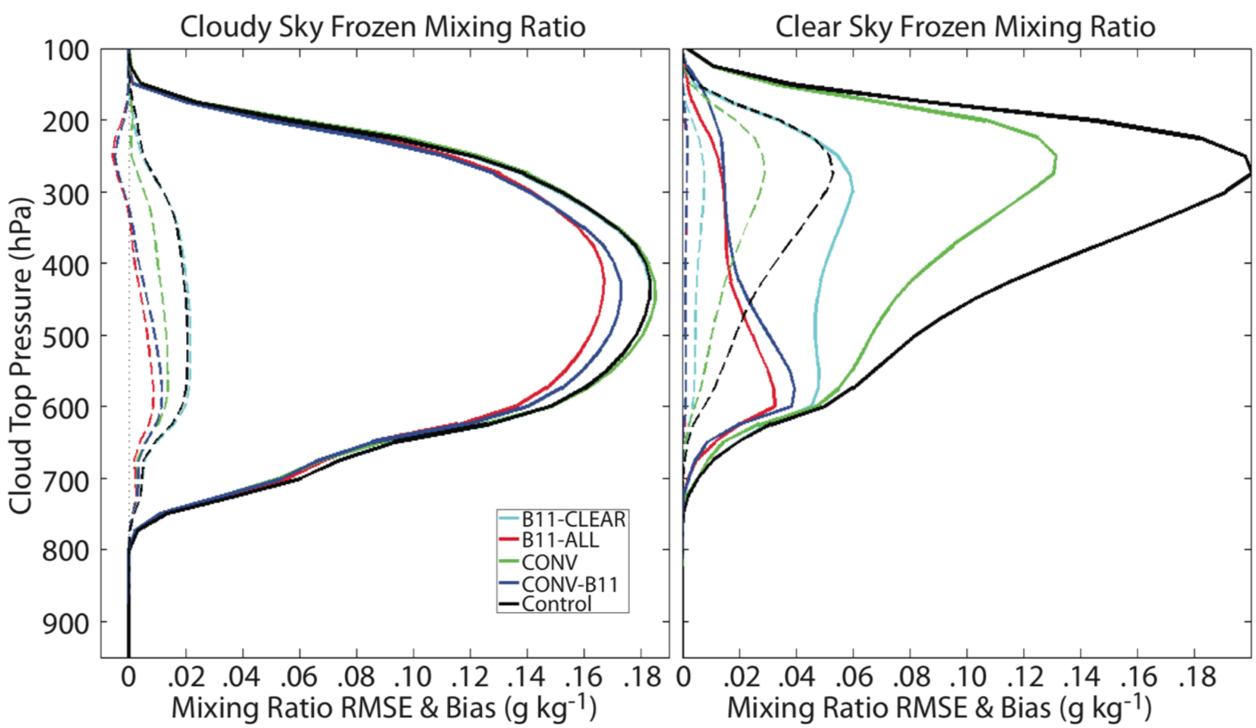
- By the end of the assimilation period, the most accurate analysis is achieved when both conventional and 8.5 mm T_b are assimilated
- Comparison of the CONV and B11-ALL images shows that the 8.5 mm Tb have a larger impact than the conventional observations

ABI 11.2 mm Brightness Temperatures Time Series



- Statistics computed with respect to clear and cloudy grid points in the truth simulation
- B11-ALL and CONV-B11 cases contain the smallest bias and RMSE for both clear and cloudy grid points during 12-hr assimilation period
- Largest improvements occur during first several assimilation cycles with nearly constant errors after 15 UTC

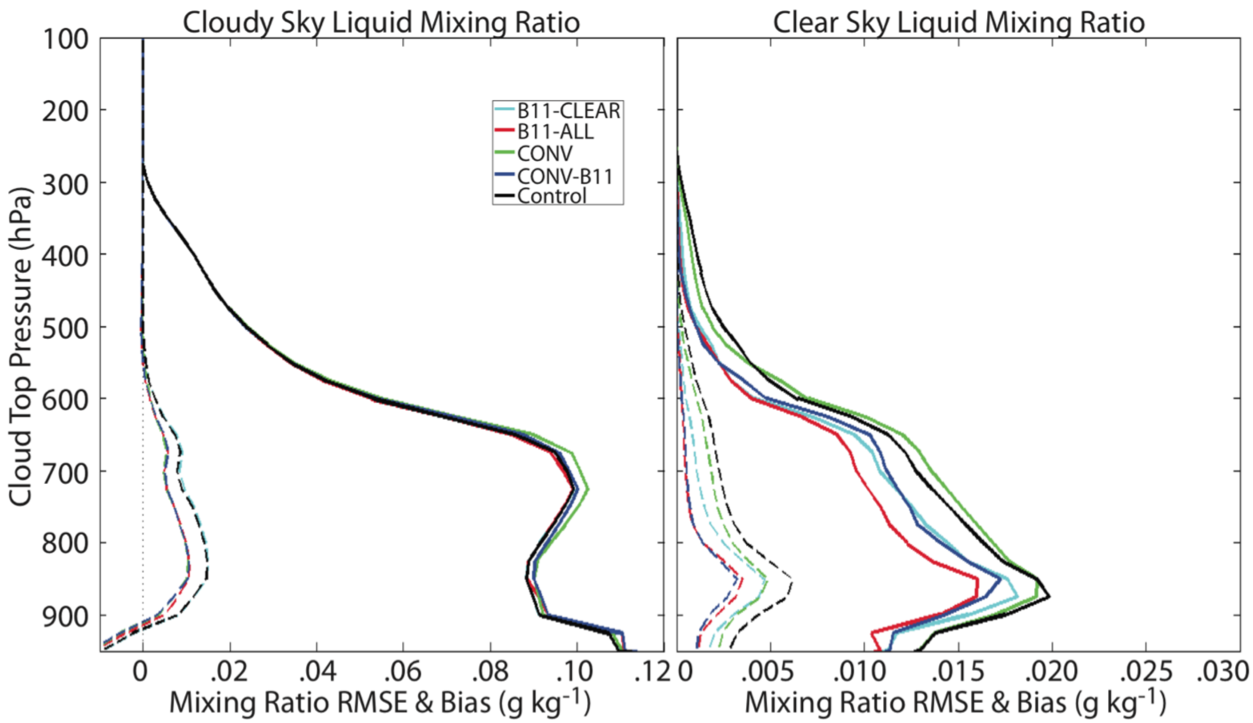
Frozen Hydrometeor Error Profiles



Vertical profiles of bias and RMSE for the “frozen” cloud hydrometeor mixing ratio (sum of cloud ice, snow, and graupel) for clear and cloudy grid points in the truth simulation

- Assimilation of both clear and cloudy-sky 8.5 mm radiances (red line) generally reduces the RMSE for cloudy grid points, particularly in the upper troposphere. The smaller errors are primarily due to a better representation of the snow mixing ratio.
- Radiance assimilation has an even larger positive impact on the clear grid points, where there is a substantial reduction in the RMSE at all levels relative to the conventional only case.

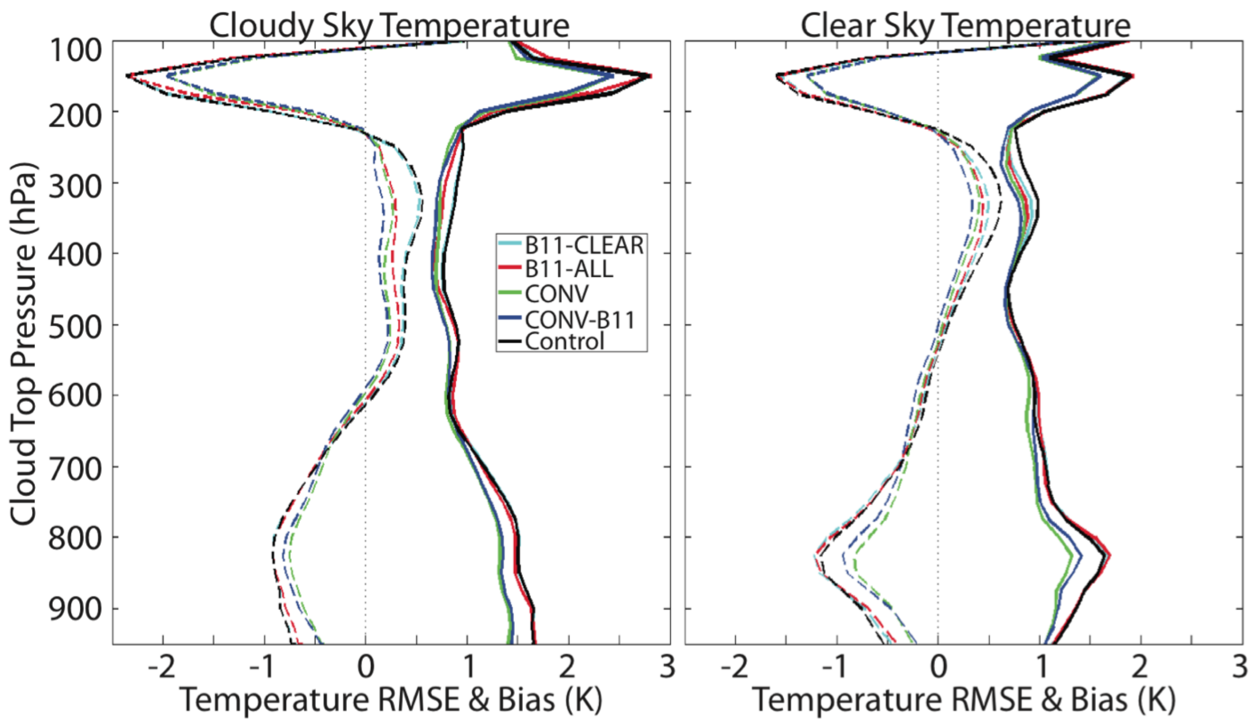
Liquid Hydrometeor Error Profiles



Vertical profiles of bias and RMSE for the “liquid” cloud hydrometeor mixing ratio (sum of cloud and rain water) for clear and cloudy grid points in the truth simulation

- Conventional observations have tendency to degrade analysis for both clear and cloudy grid points
- 8.5 mm brightness temperatures only have a minimal impact in cloudy areas and a slightly positive impact for clear grid points
- 8.5 mm brightness temperatures have much smaller impact on the liquid profiles than they did on the frozen profiles

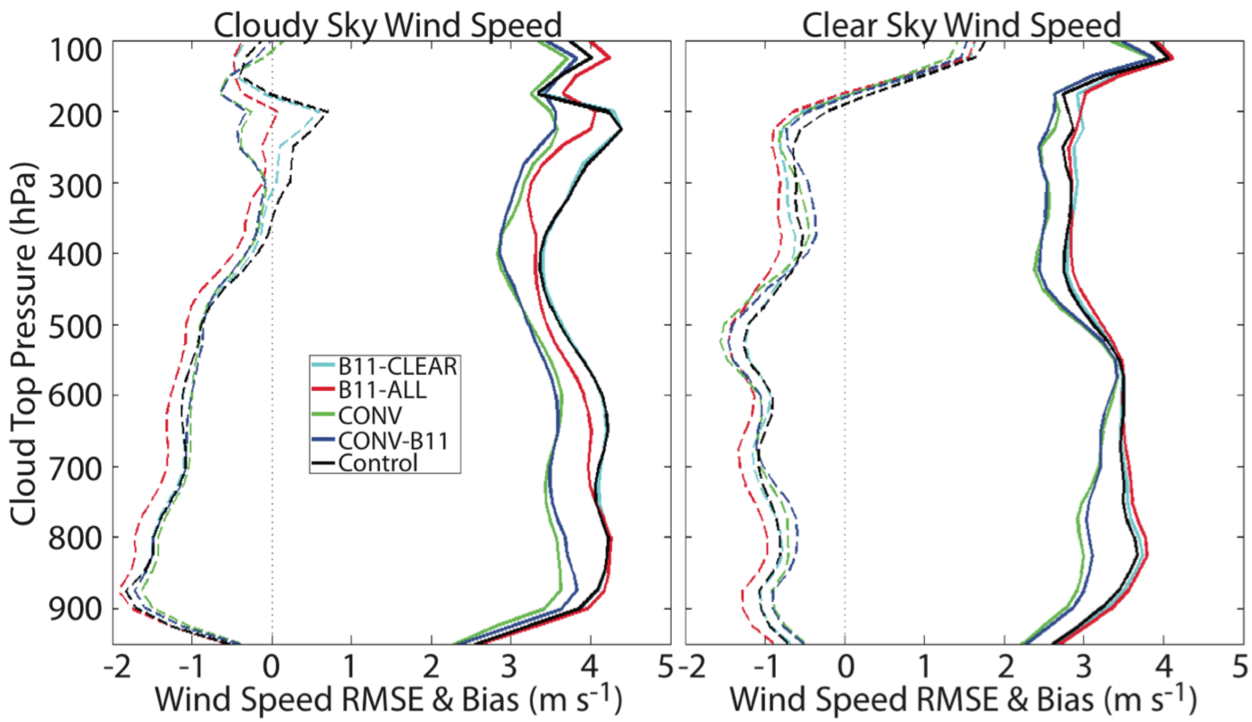
Temperature Error Profiles



Vertical profiles of temperature bias and RMSE with respect to the clear and cloudy grid points in the truth simulation

- Large error spike at 150 hPa caused by different locations in the tropopause due to use of different initialization datasets
- CONV case generally contains the smallest errors for both clear and cloudy grid points, though CONV-B11 case contains slightly smaller errors in the upper troposphere

Wind Magnitude Error Profiles



Vertical profiles of wind magnitude bias and RMSE with respect to the clear and cloudy grid points in the truth simulation

- CONV and CONV-B11 cases generally contain the smallest errors for both clear and cloudy grid points
- Accuracy was somewhat degraded in the B11-ALL and B11-CLEAR cases for the clear grid points, but improvements were made to the cloudy grid points during the B11-ALL case

Conclusions

- ABI 8.5 mm brightness temperatures had a large positive impact on the simulated cloud field with the best results achieved when both clear and cloudy sky observations were assimilated
    - Largest error reductions occurred for the clear grid points due to the removal of much of the erroneous cloud cover
    - Cloudy 8.5 mm Tb were the only observations that reduced the cloud condensate errors for the cloudy grid points
- Conventional surface and upper air observations produced more accurate temperature and wind analyses especially for clear grid points
- When both cloud-affected and thermodynamic fields are considered, the best results were obtained when both conventional and clear and cloudy sky 8.5 mm Tb were assimilated
    - CONV-B11 errors were similar to the B11-ALL errors for cloud-affected fields and similar to the CONV errors for thermodynamic fields