

GOESR3 Periodic Reporting

Reporting Period: Jan 2019 – July 2019 (2nd half of FY18 funding cycle)

Team Lead: Xuguang Wang (PI, OU)

Team Members: co-PIs Aaron Johnson (OU), Thomas Jones (OU), Jason Otkin (WI), Yanqiu Zhu (EMC)

Project Title: Assimilation of high resolution GOES-R ABI infrared water vapor and cloud sensitive radiances using the GSI-based hybrid ensemble-variational data assimilation system to improve convection initiation forecast.

Project Number: NA16OAR4320115

Executive Summary

The primary objectives of the project include (a) further extend the GSI EnKF/EnVar DA system for assimilating high resolution GOES-R ABI infrared water vapor and cloud sensitive radiance observations by ingesting convection resolving model's own high-resolution EnKF ensemble rather than the GFS ensemble and by directly updating cloud hydrometeor variables; (b) improve the usage of GOES-R ABI water vapor and cloud sensitive radiances for rapidly updated DA by refining data quality control, using high-resolution infrared land surface emissivity databases and exploring all-sky bias correction and observation error methods, and (c) test different DA configurations and evaluate the impact of assimilating GOES-R water vapor and cloud sensitive radiance observations for the prediction of diverse CI events when combined with ground based observation networks.

During this reporting period, work has focused on comparing forecasts of CI that assimilate channel 9 (mid-level water vapor) ABI radiances with GSI-EnKF default method of bias correction (shown in previous report) to forecasts with no bias correction at all, bias correction with a simulated brightness temperature predictor for the non-linear bias correction method, and bias correction with observed brightness temperature as the predictor. These comparisons are helping to understand the relative advantages and disadvantages of different aspects of the bias correction procedure. Furthermore, experiments are conducted to determine added benefits of adding a slightly lower level water vapor channel (channel 10).

Progress toward FY19 Milestones

The project progresses as planned in general. Progress during this reporting period have led to a better understanding of the important issues for bias correction of all-sky IR radiance in the context of CI forecasts.

Specific progresses are described below.

A) IMPROVEMENT TO DA CONFIGURATION FOR THIS CASE

Previously reported results followed the default GSI-EnKF settings, which allow infrared radiance observations to update cloud liquid water and cloud ice. One optimization that has been added to the data assimilation configuration is to let the ABI IR radiances update precipitating hydrometeors. This was particularly important for helping to remove spurious convection at the start of the data assimilation period for this case because of the large upper level convective anvil that the ABI radiances could only help to remove if they are able to update the snow hydrometeor mixing ratio. In the updated configuration, in order to have a complete representation of cloudy brightness temperature, we have modified the GSI source code to accommodate different hydrometeor mixing ratios like cloud, rain, ice, snow and graupel for CRTM calculation.

For this particular case study, the ability to suppress the initial spurious convection was dominating the initial comparison of the impacts of assimilating different channels of ABI radiance with different bias correction techniques. While the impacts on suppressing spurious convection are themselves interesting, we are also interested specifically in how well the newly initiating storms are added to the analysis, and maintained in the forecast, during the earliest stages of storm development. To see the full benefit of different ABI assimilation methods in this regard, we also optimized the data assimilation for this case by beginning radar-only assimilation an hour earlier to make sure the spurious convection earlier in the day has minimal impact on the mesoscale environment that is to be supporting the analyzed initiating storms. Other changes to the frequency of DA cycling have much less impact on this case than just starting radar-only assimilation an hour before the 1710-1830 UTC data assimilation cycles for all experiments. This change is now adopted for a second set of comparisons. The experiments and diagnostics on their results are still in progress. A few selected results are highlighted below.

B) IMPACTS OF DIFFERENT ABI CHANNELS AND DEFAULT BIAS CORRECTION IN GSI-ENKF

For brevity, the baseline forecasts that only assimilate radar reflectivity observations, valid at 1830 UTC 18 May 2017, for forecasts initialized at 1800, 1810, 1820 and 1830 UTC are similar to that shown in the last report. Fig. 1 shows the 3 experiments with ABI included. As previously reported, for the baseline forecasts, the forecasts do not start picking up on the storm in southeastern Oklahoma until the 1830 UTC initialization when the storm is already well-established in the reflectivity observations. When no bias correction is applied (Figure 1, first row), assimilating the ABI channel 9 infrared radiance provides very limited improvement in the forecast, although the analyses (not shown here) do reflect the incipient storms a little better with the inclusion of the ABI radiances. The 2nd row of Figure 1 shows the forecasts when the default bias correction procedure within GSI-EnKF is applied. The bias correction adds about 10 minutes of lead time to the northern storm but does not help to add the southern storm to the forecast, even at the 1830 lead time.

Additional experiments are also started to compare the impacts of assimilating different ABI radiance channels. The hypothesized advantage of adding channel 10 is that it is sensitive to a lower altitude layer of water vapor so it may provide a better analysis of both the mesoscale moisture field in the pre-storm and near-storm environment, as well as picking up on the upward growing storm clouds sooner than the higher level water vapor channel (channel 9). Figure 1 (bottom row) shows that even without applying bias correction, assimilating ABI channel 10 together with the radar reflectivity and channel 9 observations significantly improves both the forecasts and analyses (not shown) and adds more forecast lead time to these high impact supercells.

C) EFFECT OF DIFFERENT BIAS CORRECTION PREDICTORS in NON-LINEAR BIAS CORRECTION

In the last report, the nonlinear bias correction method was implemented in GSI. Two predictors were included: simulated vs. observed brightness temperature. In this report period, experiments and diagnostics were performed to compare the effects of these two predictors.

The non-linear bias correction technique which represents O-B departures as a third order polynomial function of a predictor has been used in this experiment. The effect of non-linear bias correction on the analysis and forecast state is studied with two different predictors namely (i) Observed brightness temperature and (ii) Simulated brightness temperature. The bias which was removed from O-B using two different predictors at each cycle of assimilation is shown in figure 2. From figure 2 it can be seen that the observed brightness temperature predictor removes bias mostly from the cold observed BT (Brightness Temperature) region which corresponds to high top clouds. The simulated BT predictor on the other hand, removes considerable bias from the spurious cloud region. The analysis states from two different bias predictor experiments is compared to the observation as shown in figure 3. It should be noted that the spurious cloud region has been removed very effectively in both of the experiments. However, the non-cloudy regions are not well represented when the observed brightness temperature was used as a predictor. When simulated brightness temperature is used as a predictor, the degradation of non-cloudy regions in the analysis is reduced substantially. This is due to the magnitude of bias which was removed by two different predictors. In the non-cloudy regions, the constant offset term in the non-linear bias correction dominates. Therefore both bias corrections remove more bias from the non-cloudy region which results in the degradation.

The forecast valid at 1900UTC initialized from different times is shown in figure 4 for two different bias predictor experiments. It can be seen that compared with the baseline radar only experiments (last report), assimilating ABI with nonlinear bias correction improved the forecasts initialized at 1820 UTC. Using the simulated BT predictor slightly improved the forecasts initialized at 1820UTC compared to using the observed BT predictor.

The analysis at 1830UTC from both bias predictor experiments is compared to the channel 9 ABI observation as shown in figure 5. The simulated BT predictor adds more clouds in the analysis, thereby creating cold BTs at the storm location compared to the analysis from the observation BT predictor experiment. This addition of cloud in the analysis at storm location has translated well in the forecast as well.

D) SUMMARY OF CONCLUSIONS SO FAR

In summary, in this report period we further optimize the data assimilation configuration to improve the update of precipitation hydrometeors (especially snow) and to better suppress spurious convection before the experiment period. We find that assimilating the bias corrected ABI channel 9 radiance adds more forecast lead time. More pronounced advantages are seen when also assimilating a lower level water vapor channel (channel 10). The results also suggest the success of bias correction can be dependent on the selected predictors.

Plans for Next Reporting Period

Experiments described in part (b) above are planned to be completed and written up for a peer-reviewed manuscript during the next reporting period after comprehensive diagnostics and optimally tuned the DA

parameters. The impacts of nonlinear bias correction with different predictors (part c above) are also being expanded to the other channels and will be more comprehensively compared with the default bias correction approach.

Additional Information

1. Interaction with operational partners –

The proposing team interacted with NCEP/EMC collaborator Yanqiu Zhu during the extension and testing of the GSI EnKF system with the ABI clear air and cloudy radiance assimilation including pre-processing, QC, code modifications. The proposing team also interacts with NCEP/EMC collaborator Ming Chen on the implementation of high resolution surface emissivity with CRTM-CSEM.

2. Conference/workshop participation –

We continue participating the bi-weekly GSI developers meeting hosted by NCEP/EMC. Scientific results with more experiments will be presented in future workshops and conferences.

3. Outside project publicity –

N/A during this project period.

4. Journal articles –

N/A during this project period as the primary effort is system development and diagnostics. Papers including scientific results will be submitted in the future.

Key Graphics

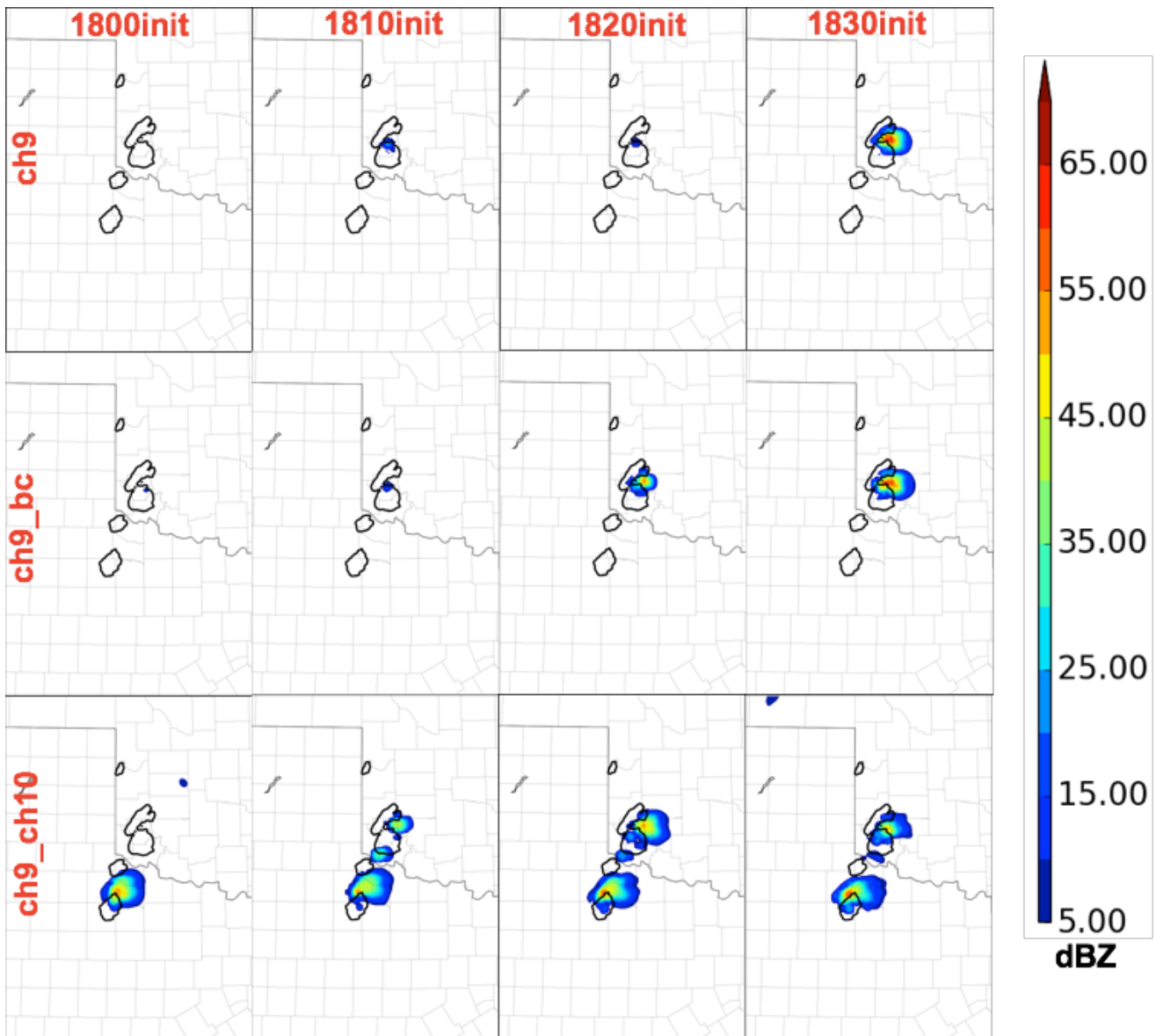


Figure 1. Forecasts of composite reflectivity from different experiments (top row: assimilated radar only; middle row: assimilated radar and ABI ch. 9 without bias correction; bottom row: assimilated radar and ABI ch9 with bias correction, with observed 35 dBZ contour overlaid. All forecasts are valid at 1900 UTC. Columns are initialized at different times.

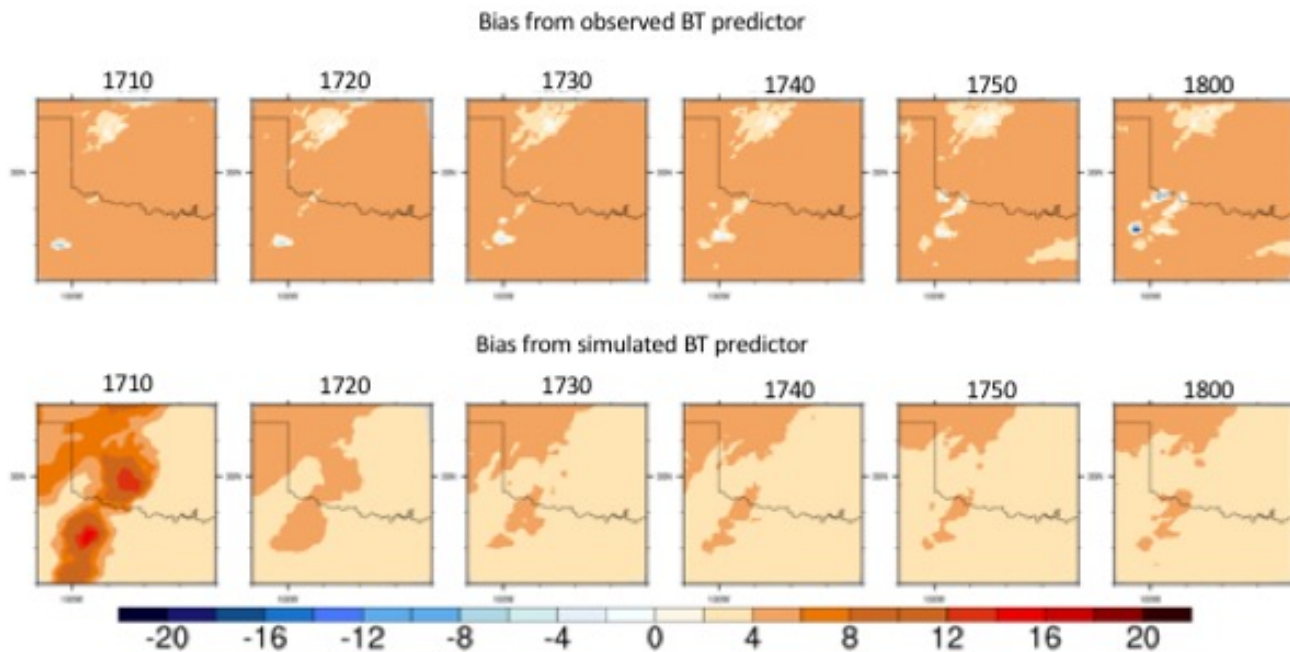


Figure 2: Spatial distribution of estimated bias (in K) from two different bias predictors at different analysis times from 1710 to 1800 UTC.

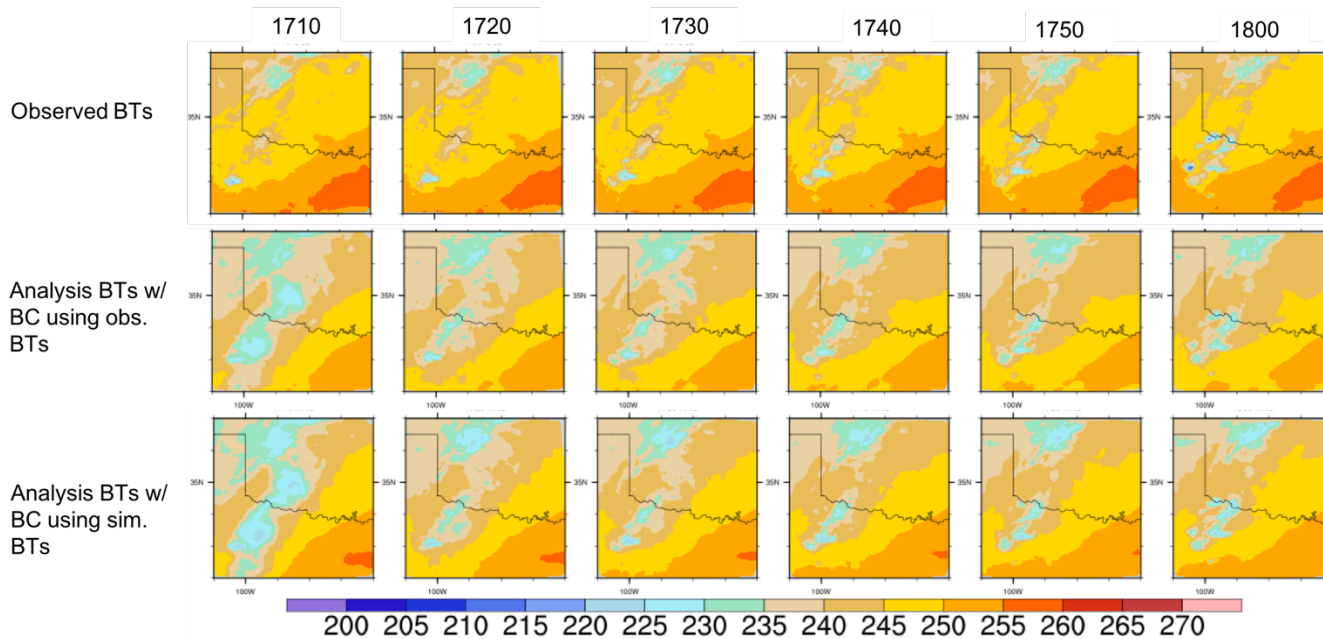


Figure 3: Comparison of observed BTs (in K) with analysis BTs (in K) from two bias correction experiments

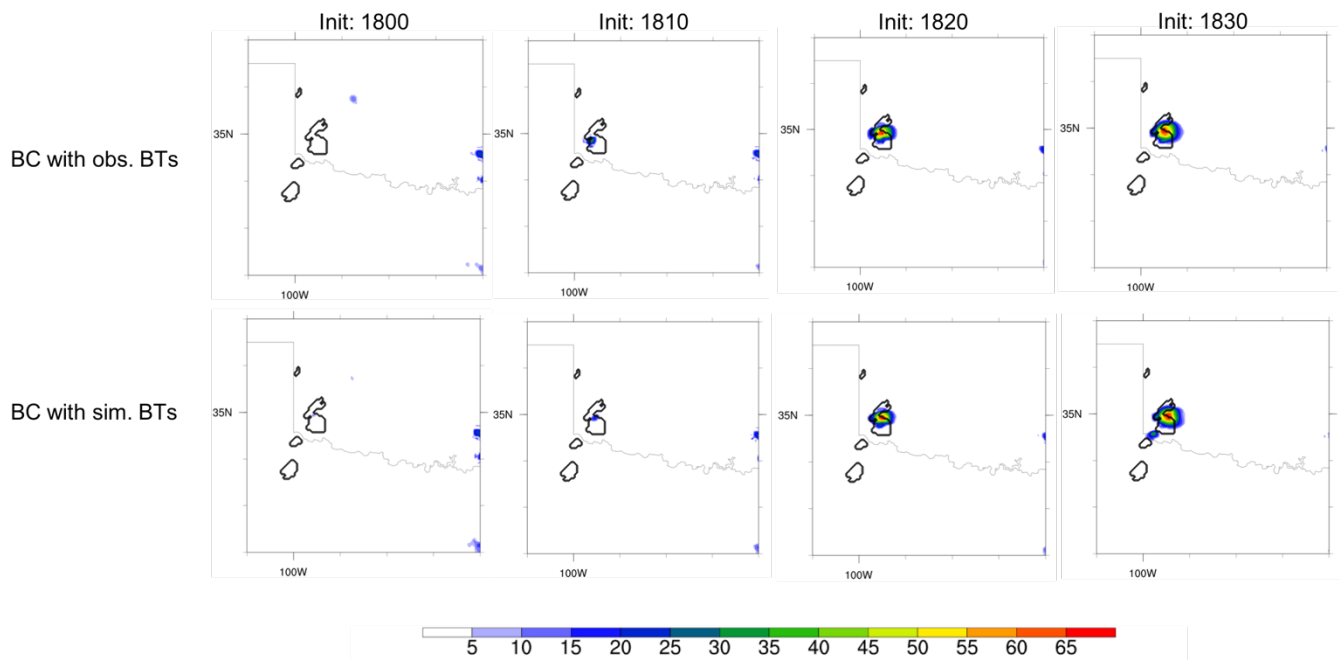


Figure 4: Column maximum reflectivity (in dbz) forecast valid at 1900 UTC initialized from different analysis times for two bias predictor experiment (Colored contour represents the model forecast and black line contour represents the observation above 30 dbz threshold)

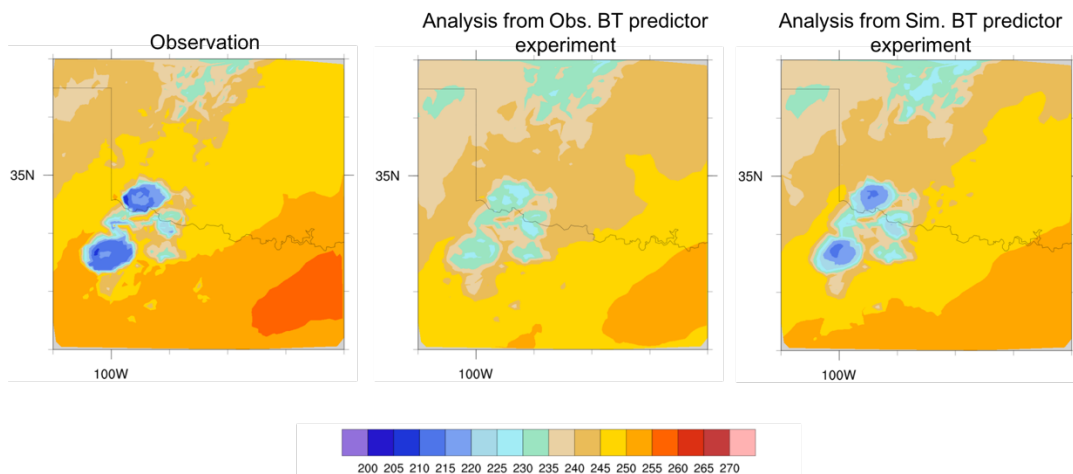


Figure 5: Comparison of analysis channel 9 BTs at 1830 UTC from observed BT predictor and simulated BT predictor experiment.