GOESR3 Periodic Reporting

Reporting Period: July 2017 – December 2017 (1st half of FY17 funding cycle)

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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 period, the cycled GSI EnKF DA system extended with convective scale radar DA capability is further extended with the assimilation of the ABI radiances. A high impact severe weather event was selected as a case study due to the challenges of forecasting the initiation and early stages of the event. The case study is used to demonstrate the progress made in code development for assimilating clear and cloudy GOES-16 ABI radiances and applying bias correction to the raw data. An experiment of the impact of assimilating clear air radiances for this case has also been conducted to demonstrate proper function of the integrated GSI-EnKF cycled DA system with ABI observations.

Progress toward FY17 Milestones

The project progresses as planned. Specifically, significant progresses for the first three items from the 5-item year one list of proposed milestones are made. These milestones were:
(1) Extends the GSI-EnKF/EnVar DA system for GOES-R water vapor and cloud sensitive radiances
(2) Refines GSI QC and preprocessing for GOES-R water vapor and cloud sensitive radiances
(3) Conducts baseline DA experiments using the extended GSI DA system.

Specific progresses are summarized below.

CASE SELECTION

A case study from 18 May 2017 is selected for an initial evaluation of the impacts of assimilating GOES ABI data into a convective scale model. The SPC severe reports from this case (Fig. 1) show that this was a high impact event with numerous tornado reports and severe weather occurring over much of the Southern Plains. Of particular interest for this study is the cluster of supercells in northern Texas and southwestern Oklahoma (Figure 2). At 1800 UTC the first weak radar reflectivity echoes are starting to appear in northern Texas (Fig. 2a). Once convective initiation (CI) occurs, the storms develop very rapidly. By 1900 UTC (Fig. 2b) there are several well-established supercells where there were not any high reflectivity values an hour earlier. Between 1900 and 2000 UTC the coverage of storms continues to increase (Fig. 2c) and a few of the stronger cells first become tornadic during this time. By 2330 UTC, the first wave of storms has weakened and moved east into central OK, while a new wave of strong convection occurs along the Red River in southwest OK and north TX (Fig. 2d).

The forecast initialization time for the experiments is selected as 1800 UTC, just before CI. At later initialization times, radar reflectivity observations can help initialize the developing storms into the model. We hypothesize that the high time and space resolution GOES ABI radiances will provide the model with previously unavailable information about not only the mesoscale environment around the incipient storms, but also the convective scale details of the incipient storms even before a clear radar signature appears. Due to the explosive convective development in cases like this, and the rapid organization into tornadic supercells, even small improvements to the CI forecast lead time and the early storm evolution forecast could provide large societal benefits by directly improving NWS warnings and watches.

CODE DEVELOPMENT

Significant code development and testing was undertaken during this reporting period to:

(a) ingest pre-processed netcdf format GOES ABI observations into GSI

(b) treat the ABI observations as a new observation type, distinct from previous satellite observations

- (i) satinfo and satbias files modified for ABI channels
- (ii) add "abi" variables mainly to setuprad.f90 for book-keeping within GSI (crtm_interface.f90, radiance_mod.f90, radinfo.f90 are also slightly modified for consistency).
- (iii) add ability to use cloudy ABI radiance in clw_mod.f90
- (iv) add ability to QC ABI radiances in qcmod.f90
- (v) update satbias_in/satbias_pc, and GSI/EnKF namelists for appropriate bias correction procedure and initial bias coefficients.

(c) properly link to the latest CRTM version 2.3.0.

The results of this development effort are demonstrated with the ABI radiance observations[1] from the 6.93 micron channel (channel 9) from the 18 May 2017 case at 1710 UTC in Figure 3. This is output from GSI diag file suggesting the development (a) of ingesting the ABI data functions properly. The observations show a large area of brightness temperatures (Tb) above 240 K extending northeastward from Mexico and south Texas corresponding to a plume of dry upper level air. Cooler Tbs are seen over the Gulf of Mexico and the central plains where stratocumulus and stratus clouds

[1] Note that, in this document, all observations have been thinned to a 6km resolution equal to two times the model grid spacing as commonly done for convective scale data assimilation.

predominate, respectively. Of particular interest for this work, localized areas of colder Tb in the region of CI are already seen in northern TX and western OK. The colder Tb corresponds to the moistening and shallow cumulus development that preceded deeper CI. It should be emphasized that this is about an hour before the first radar indication of CI in this area.

To illustrate additional development made to GSI including (b) modifying GSI to add functionalities to assimilate ABI and (c) linking with the latest CRTM 2.3.0, also shown are the bias-corrected model first guess of the observations considering (Fig. 4) only the clear air component of radiance and (Fig. 5) including the impact of cloud hydrometeors on the radiance first guess. Figure 4 demonstrates that the large scale pattern (e.g., the dry plume extending northeastward from Mexico) is fairly well represented and the bias-correction code in modified GSI is interfacing properly with the ABI data. Figure 5 demonstrates that the modified GSI code is also properly handling the cloudy radiances from the ABI. Figure 5 also shows that even without yet assimilating the ABI data into the model, the model correctly represents the cooler cloudy radiances over the Gulf of Mexico and the central Plains. The cool Tb over western OK and north TX are more expansive in the model first guess than in the observations, despite the fact that storms were slower to develop. This is likely related to the Thompson microphysics scheme, which is known to produce large amounts of thin cirrus at high levels near deep convection. This typically does not negatively impact the overall good forecast performance of the Thompson scheme for convective storms. Part of our work in the next reporting period will involve investigating how this thin cirrus affects the ability to optimally assimilate the ABI radiances.

DATA ASSIMILATION BASELINE EXPERIMENT

For these experiments, the ensemble is initialized from GEFS and SREF member analyses and 3-h forecasts, respectively at 0000 UTC 18 May 2017. Conventional surface and upper air observations from the NDAS data stream are assimilated hourly from 0100 UTC to 1700 UTC. Convective scale assimilation is then cycled every 10 minutes from 1710 to 1800 UTC. For the “RADAR” experiment, only NEXRAD radar reflectivity (as well as the conventional observations) are assimilated during this one-hour period. As a first test of the new development, an experiment assimilating ABI clear air radiance is designed and performed. For the “GOES_CLEAR_ch9” experiment, the configuration from RADAR is kept the same, except for adding clear air radiances from GOES ABI channel 9 (6.93 micron).

The forecast (initialized at 1800 UTC) from the RADAR experiment is summarized by the 6-hourly ensemble maximum updraft helicity in Figure 6. This figure shows that the baseline experiment without ABI data assimilated does have a reasonable depiction of the regional and mesoscale areas where rotating updrafts, and correspondingly severe weather, were likely. However, as anticipated there are still some notable errors in both the mesoscale organization (e.g., lack of strong helicity in far western Oklahoma due to time it takes model to spin up CI) and the convective scale details (e.g., individual storm tracks and times) that may be improved by assimilating the ABI radiances.

The GOES_CLEAR_ch9 (Figure 7) experiment shows a general increase in helicity values and an extension of the higher helicities southwestward into north Texas. This indicates that even just assimilating the clear air data can improve the mesoscale environment enough to increase the intensity of the forecasted event, which is more consistent with the very intense observed storms. However, further improvement to this forecast is clearly possible. This experiment emphasizes the importance of the cloudy radiances that were omitted, because without the cloud observations included there is no way to initialize the incipient clouds/storms into the model forecast to improve the convective scale details of the individual storm cells.

Plans for Next Reporting Period

During the next reporting period, assimilation of the cloudy radiances for this (and other) case(s) will be the focus. This will involve significant efforts to properly bias correct and quality control the cloudy radiances for various ABI channels, as well as to improve the surface emissivity contribution to the model first-guess radiances during data assimilation. In particular, during the next reporting period the UW team will upgrade the version of the GSI used during this project so that it includes the Community Surface Emissivity Model (CSEM) and the University of Wisconsin (UW) surface infrared emissivity database. Ming Chen (IMSG@NCEP/EMC) has recently implemented the UW emissivity database within the CSEM that will be included in future versions of the CRTM. He is currently testing the integration of the combined CRTM-CSEM package within the GSI. We will assist his efforts by being beta testers of the new integrated system. In addition, we will begin exploring the use of new bias correction methods when assimilating all-sky infrared brightness temperatures. This will be accomplished initially through passive monitoring of the observation-minus-background (OMB) brightness temperature departures from the control experiments performed during the current reporting period. Sensitivity tests will be performed to identify suitable quantities (such as the cloud top height or integrated water content over some vertical layer) that are able to effectively identify and remove biases from the all-sky brightness temperatures departures prior to their assimilation. The OU team will then repeat the baseline experiments using high-resolution infrared surface emissivity databases and assesses its impact with assistance from UW

Additional Information

1. Interaction with operational partners

The proposing team interacted with NCEP/EMC collaborator Yanqiu Zhu through teleconferencing during the extension of the GSI EnKF system with the ABI clear air and cloudy radiance assimilation capability. The proposing team also interacts with NCEP/EMC collaborator Ming Chen on the implementation of UW emissivity with CRTM-CSEM.

2. Conference/workshop participation

We participate the bi-weekly GSI developers meeting hosted by NCEP/EMC as the primary effort during this project period is to extend the GSI with ABI radiance assimilation. 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. Papers including scientific results will be submitted in the future.

Key Graphics

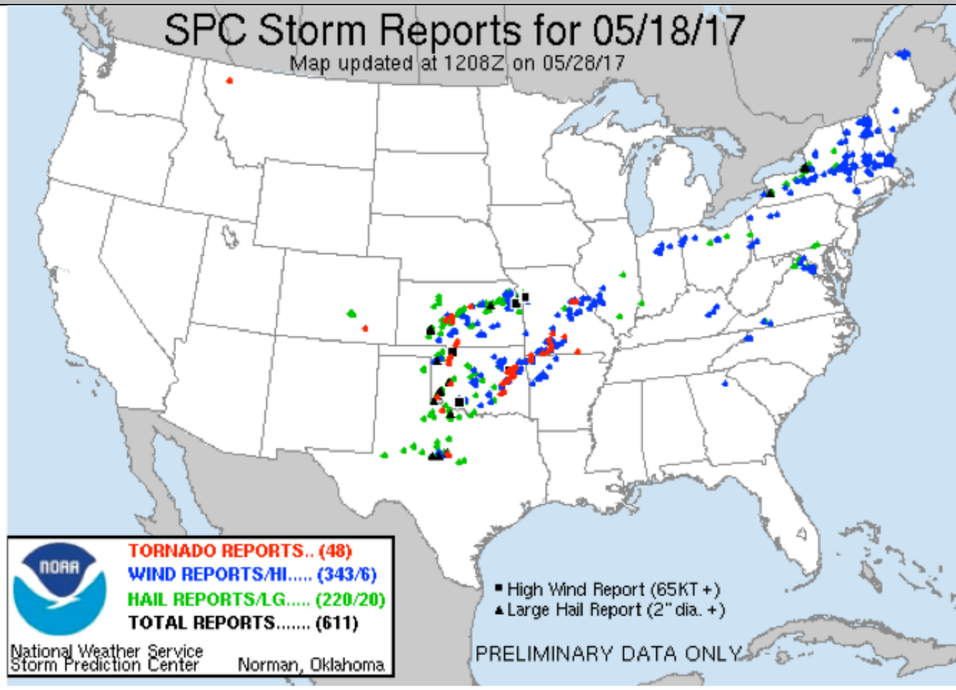

Figure 1: Severe Storm Reports from the Storm Prediction Center (SPC) for 18 May 2017.

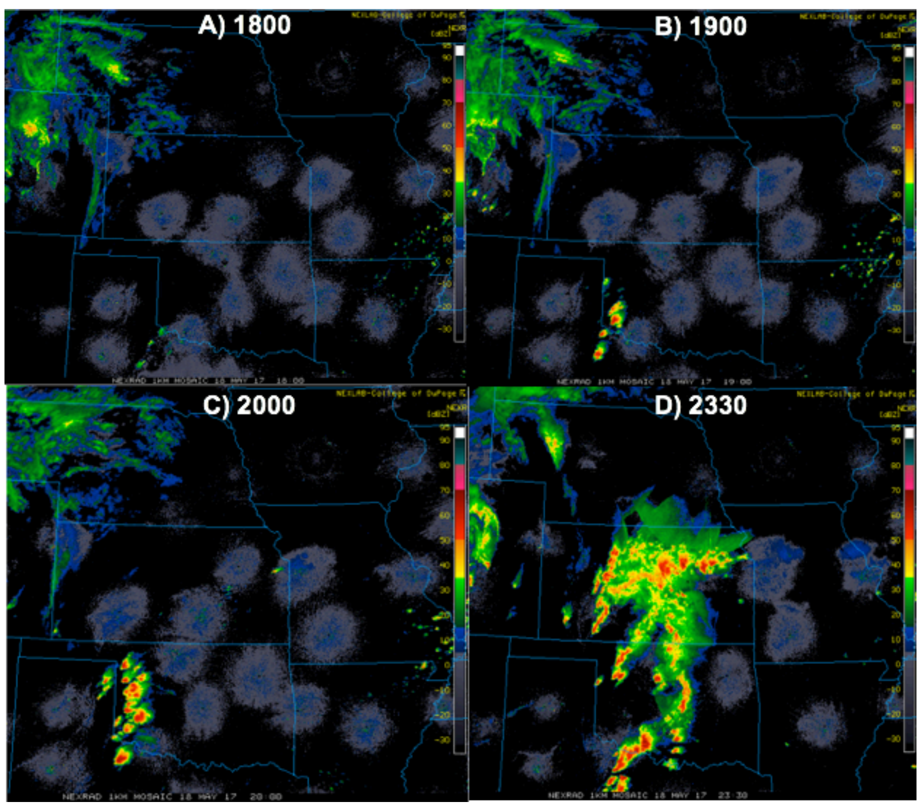

Figure 2: NEXRAD composite reflectivity mosaic on 18 May 2017 at (a) 1800 UTC, (b) 1900 UTC, (c) 2000 UTC and (d) 2330 UTC.

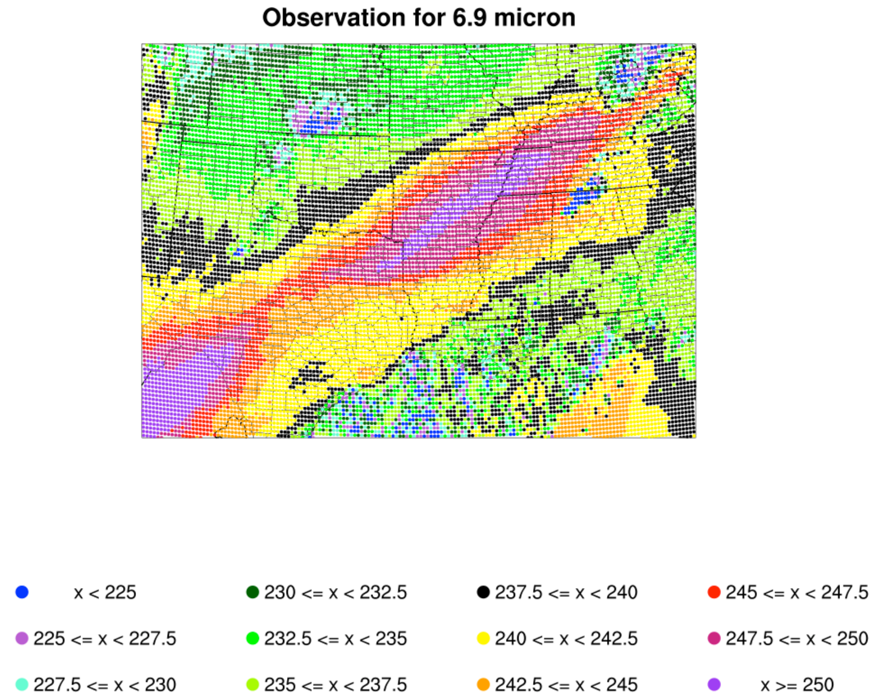

Figure 3. Brightness temperature from Channel 9 (6.93 micron) of the GOES-16 ABI at 1710 UTC 18 May 2017 output from GSI.

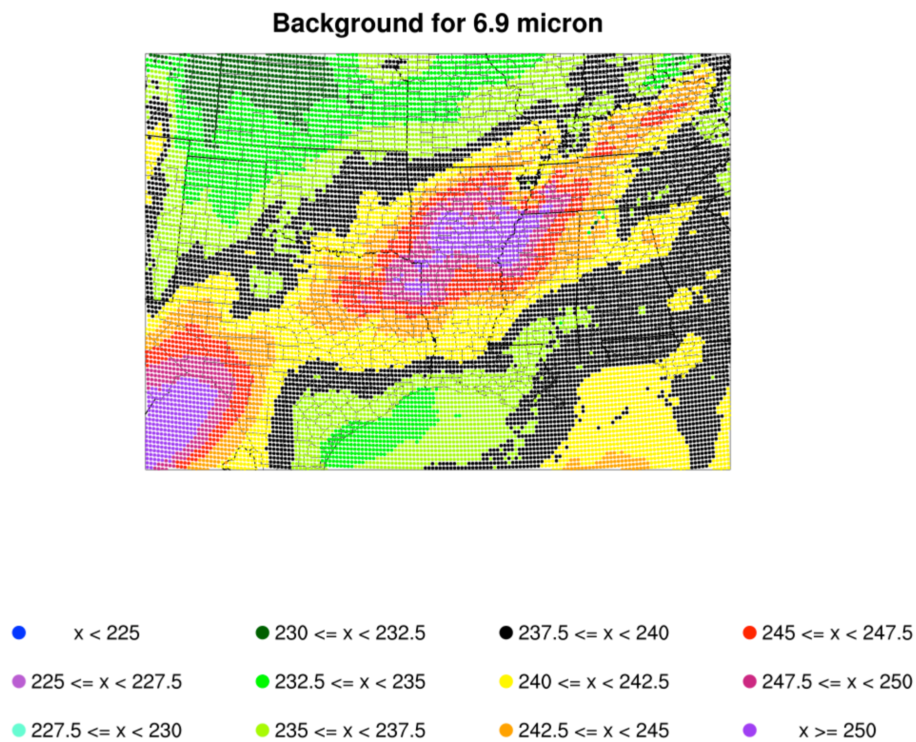

Figure 4. Bias-corrected model first guess of the radiance observations in Fig. 3, showing only the clear air component.

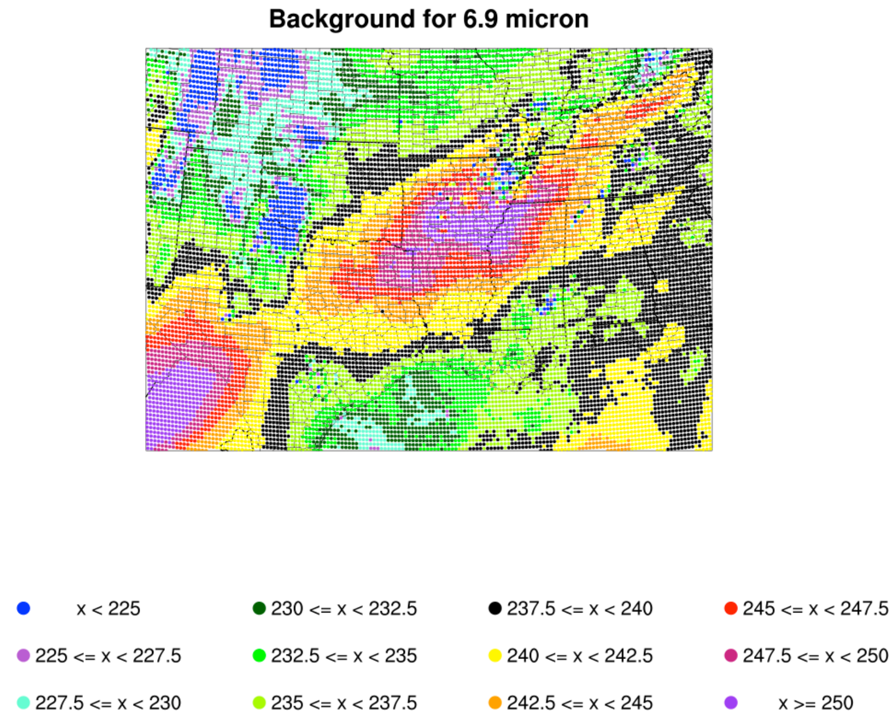

Figure 5. Bias-corrected model first guess of the radiance observations in Fig. 3, including the cloudy radiance component.

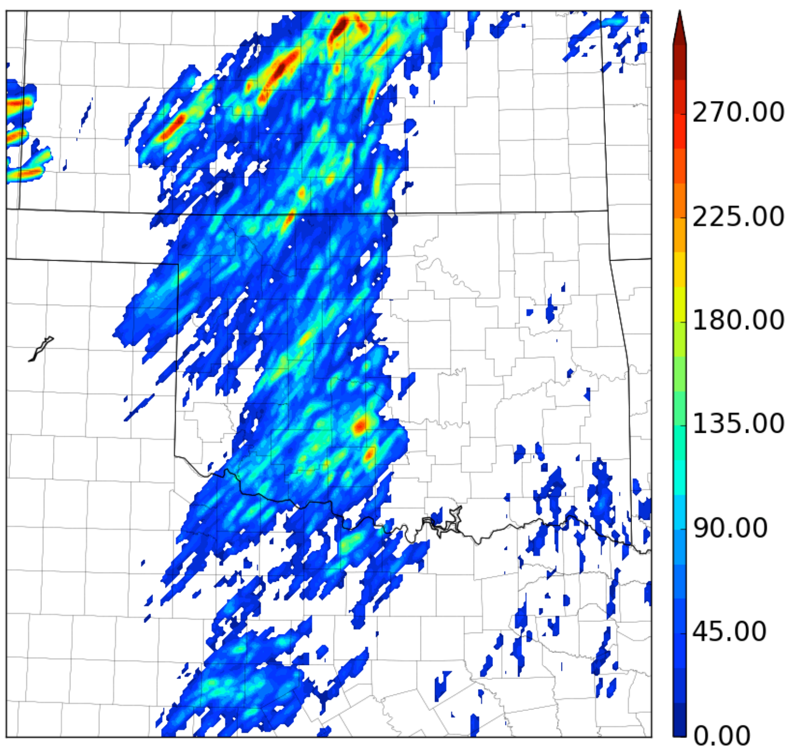

Figure 6. 6-hourly (1800-0000 UTC) ensemble (10 forecast members) maximum of updraft helicity from the baseline forecast without ABI data assimilated.

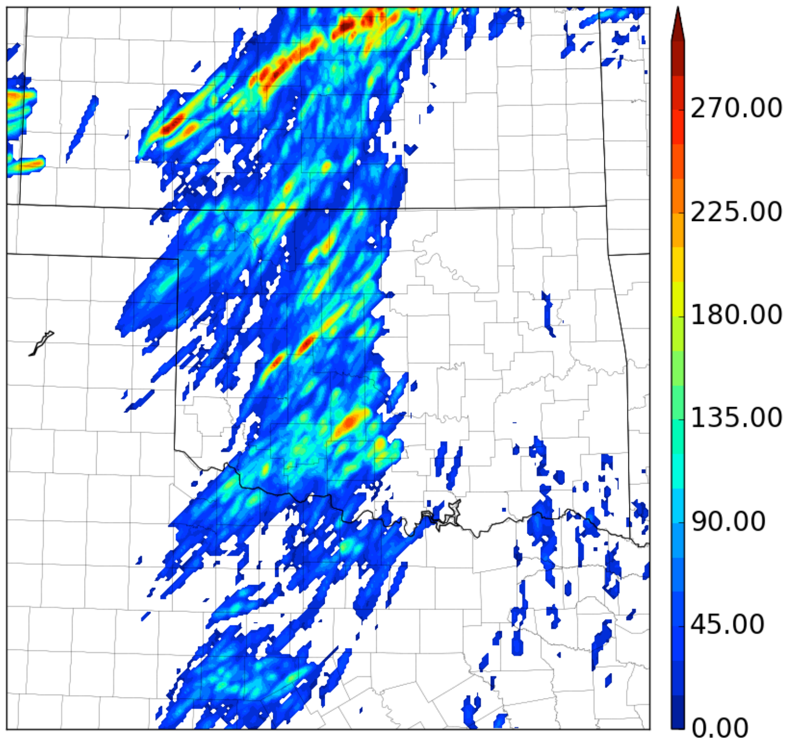

Figure 7. As in Fig. 6, except for the GOES_CLEAR_ch9 experiment with ABI clear air radiances assimilated.