GOES Cloud-top cooling rate assimilation in RAP and HRRR

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GOES cloud top cooling rate data provided by UAHuntsville are being assimilated into an experimental Rapid Refresh (RAP) version at the Global Systems Division of the Earth Systems Research Laboratory. Within this RAP modeling framework, the cloud-top cooling rate data are mapped to latent heating profiles and are applied as prescribed heating during the diabatic forward model integration part of the RAP digital filter initialization (DFI). For the HRRR, the satellite-derived latent heating profile is prescribed during a one-hour pre-forecast spin-up cycle with no application of the digital filter. For both the RAP and the HRRR, the GOES-satellite-based cloud-top cooling-rate information is blended with data from radar reflectivity and lightning flash density to create a unified convective heating rate field. In the current HRRR configuration, four 15-min cycles of latent heating are applied during a pre-forecast hour of integration. This is followed by a final application of GSI at 3-km to fit the latest conventional observation data.

Previous work using an older retrospective experiment and GOES-R CI data from an older version of the algorithm (not shown) demonstrated that these cloud-top cooling rates help refine the location of analyzed storms in the RAP system, however, retention of the assimilated cloud-top-cooling-rate data was minimal. A new retrospective period of June 15-22, 2014 was selected to continue investigation of the use of cloud top cooling rates in conjunction with an improved version of the GOES-R CI algorithm and an improved version of the RAP/HRRR system. This period was quite active with severe storms, especially in the northern Plains states. In addition to the RAP tests, we are including experiments that test the impact of the derived cloud-top cooling rates in a HRRR model formulation that uses the RAP (with and without the GOES-R CI assimilation) for background and boundary fields. During this period, an initial set of RAP and HRRR retrospective runs were completed using a real-time feed of GOES-R CI data transferred from UAHuntsville to ESRL GSD. Subsequent to these experiments the GOES-R CI datasets were reprocessed by UAHuntsville and a new set of data transferred to ESRL GSD.

Using the new GOES-CI data a new RAP retrospective experiment was completed. Some results of this experiments Fig. 1. The top row shows CSI and bias scored for the 25 dBZ RAP forecast reflectivity. It should be noted that the 13-km RAP uses a cumulus parameterization scheme, so the derived reflectivity is derived as a function of both the grid-scale hydrometerors and the convective precipitation from the cumulus scheme. While this aspect combined with the 13-km scale complicates comparison against the MRMS observed reflectivity mosaic, this type of verification can still provide some information on the effectiveness of the assimilation. Despite higher CSI and bias in the analsysis (included the forward model portion of the diabatic digital filter), there is little retension of the GOES cloud-top-cooling-rate (CTCR) information in the RAP forecasts. This can be seen in the nearly identical CSI scores for the +1h forecast and beyond, and the very similar bias scores (slightly lower for the CTCR experiment). The bottom panel provides a sample illustration of the changes in the CTCR assimilation run from the analysis to the +1h forecast (note a similar comparison has not been included for the RAP run with no CTCR assimilation). There is clearly a loss of the "signal" for some of the analyzed convection (green hits at 0h changing to blue misses at +1h), while at the same time certain spurious storms begin to develop (new red false alarm areas appearing in the +1h forecast). In the first case, this can generally be interpreted as an inability of the CTCR data to overcome a HRRR background atmospheric state that is hostile to convection. In the latter case, the CTCR data have no direct way to inhibit model convective development in regions where the HRRR fields are favorable to convective development. We have considered this "convective suppression" problem for radar data assimilation, but lack of a CTCR signal cannot be interpreted as an indicator of no convection.

Subsequent recent work has focused on testing the CTCR assimilation directly in the HRRR. While RAP CTCR assimilation efforts will continue, given initial RAP results and the small-scale nature of the

CTCR information (more consistent with HRRR gridlengths), exploration of HRRR assimilation impacts was deemed the highest priority. Using a more recent RAP and HRRR configuration, code modification for CTCR assimilation within the HRRR were completed. The procedure is different in the HRRR, using four 15-min cycles of forward assimilation and no digital filter application. Following completion and testing of these code modifications, a new RAP control with no CTCR assimilation was completed and initial HRRR tests have been completed., both with and without use of the strength of signal (SOS) field. In general SOS results have been better, but again only show very slight improvement over the control. Fig. 2 shows comparison of single forecast time plots in the top row (+2 h forecast from 19z June 19, 2014) and a time series of +3h forecast CSI scores for three successive HRRR forecasts. We are examining several hypothesis for increasing the so-far minimal forecast impact for the HRRR, including increasing the strength of heating, testing to see if the radar DA is too influential compared to CTCR assimilation, and increasing the area of the heating. We are also examining the high 0-h bias, to understand how that is occurring. In addition to these followup experiments and analyses, we are planning to test a the real-time feed of the CI field in a real-time parallel HRRR version in the near future.

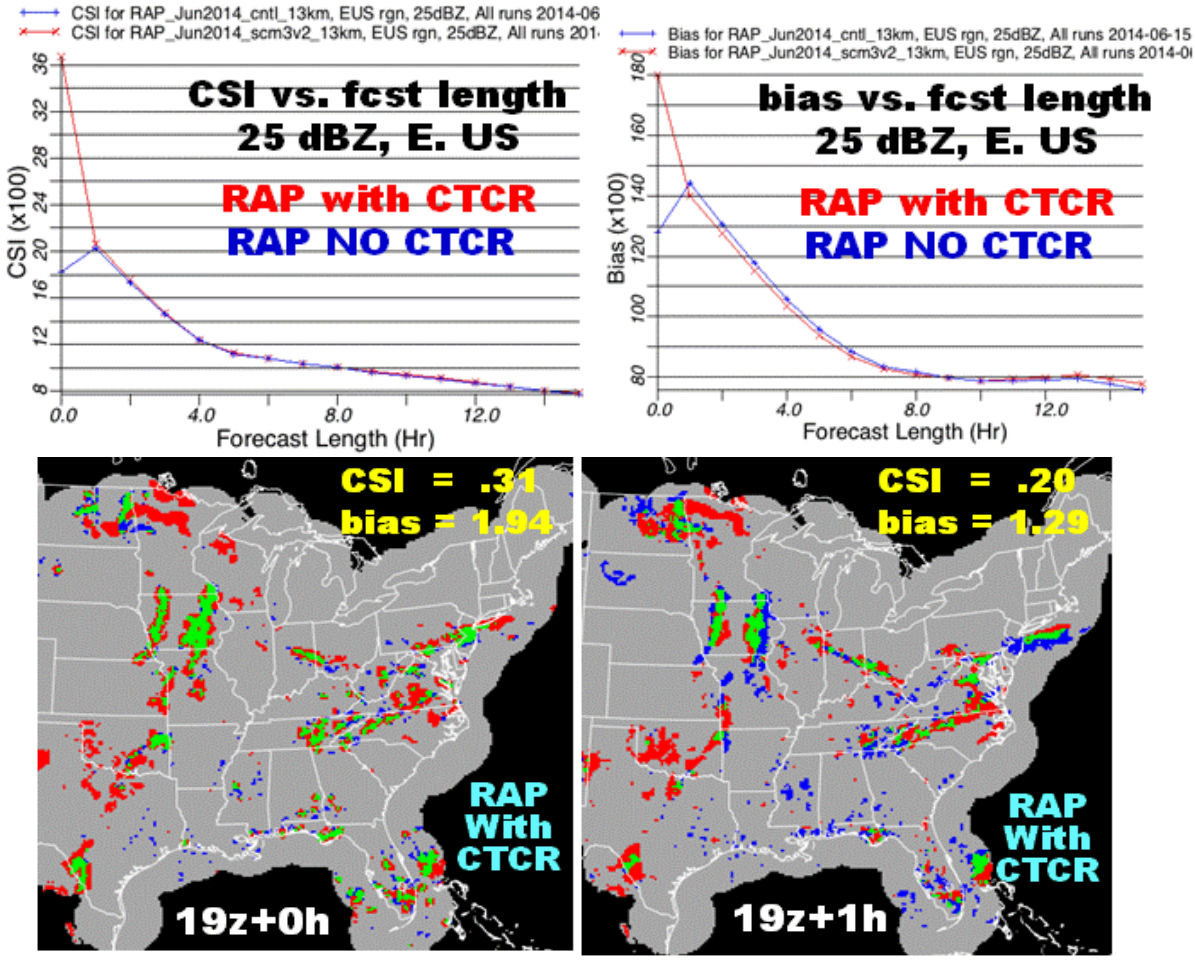

Figure 1: Top row – CSI and bias scores as function of lead-time from 2014 RAP retrospective experiment. Bottom row – HIT-MISS-FALSE ALARM (Green-Blue-Red) plots for RAP 0-h analysis and 1-h forecast from 19 June 2014, illustrating the evolution of the HRRR depiction from 0-h analysis to 1-h forecast.

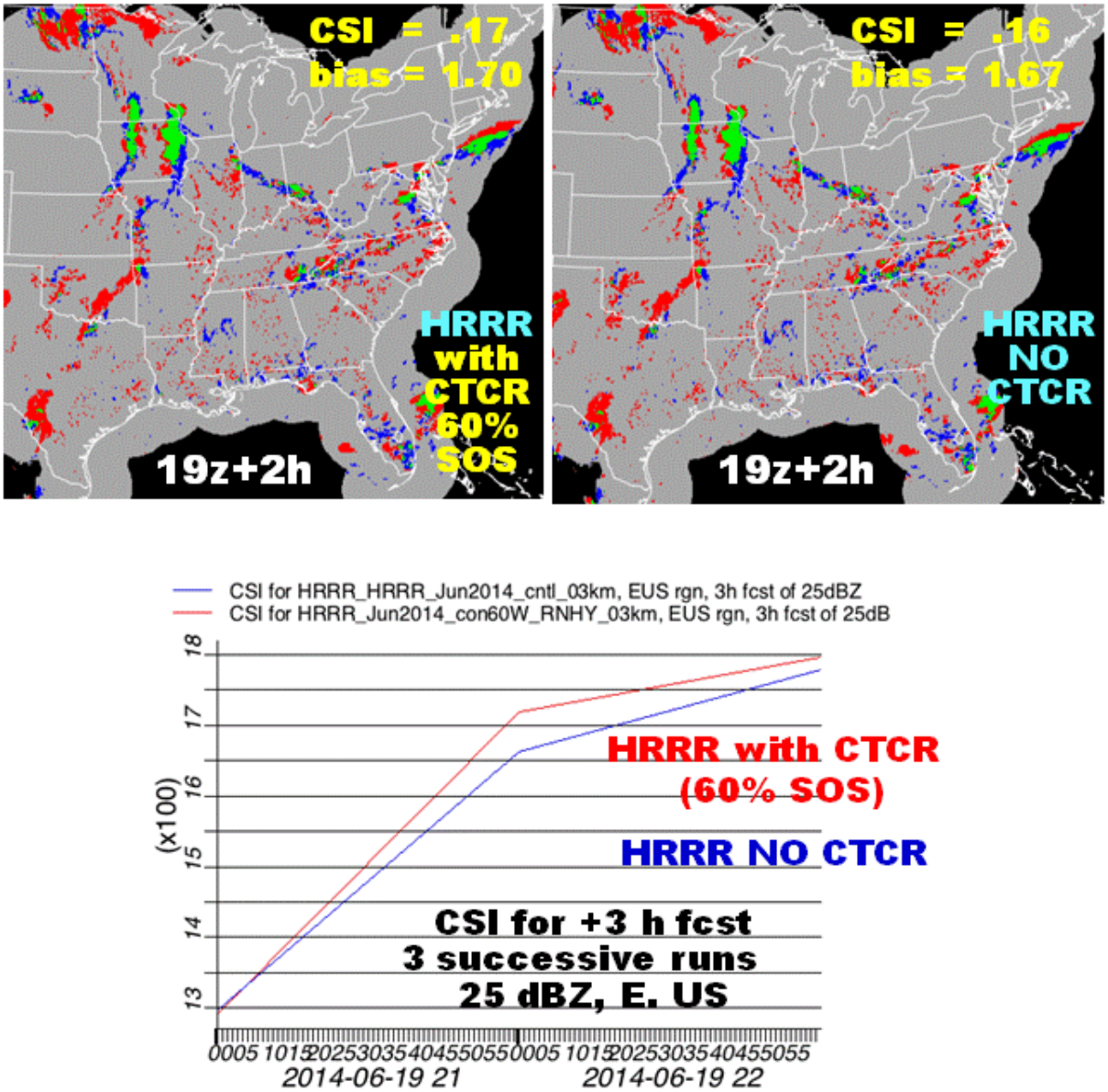

Figure 2: Top row – HIT-MISS-FALSE ALARM (Green-Blue-Red) plots of HRRR for 19z 19 June 2014 + 2h with and without CTCR (with 60% SOS) assimilation), illustrating the similarity of the forecast fields. Bottom row – Time series of HRRR 3-h forecast CSI for 3 successive runs with and without CTCR assimilation with 60% SOS filtering, illustrating similarity of scores.