The Impact of Community Radiative Transfer Model Microwave Sea Surface Emissivity Improvements on Forecast Skill

David Neil Groff[abc], Quanhua Liu[cd], Paul van Delst[abc], Andrew Collard[abc], Yanqiu Zhu[abc]

[a] NOAA National Centers for Environmental Prediction, [b] I.M. Systems Group, Inc., USA, David.Groff@noaa.gov, [c] Joint Center For Satellite Data Assimilation, [d] University of Maryland, USA.

Abstract

Observation operators are needed in data assimilation systems to map forecast model space to observation space. In this regard, the accuracy of observation operators is important, because aliasing of forecast model errors and errors from the observation operator will serve to degrade analyses. For satellite-based radiance observations, the mapping to observation space requires application of a radiative transfer model that can perform sufficiently accurate satellite-based radiance simulations. Furthermore, the radiative transfer model must be sufficiently fast to satisfy time constraints imposed on operational data assimilation systems. As such, the Community Radiative Transfer Model (CRTM) is applied in the National Centers for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) data assimilation system.

A desirable feature that accompanies the latest CRTM, release 2.1.3, is a general improvement in the accuracy of sea surface field of view simulations for surface sensitive microwave channels. For example, when applied in the GSI, the variances and biases of first guess departures for AMSUA surface sensitive channels have in general been reduced relative to the application of a previous CRTM, release 2.0.5, over sea surfaces. This CRTM improvement is due to the replacement of an older Fast Microwave Emissivity Model (FASTEM), FASTEM-1, with a newer FASTEM, (FASTEM-5), in CRTM release 2.1.3. A particularly salient component of the FASTEM-5 Geometrical Optics (GO) theory is the accounting of interactions with small-scale sea surface waves (Liu et. al., 2011). This accounting of small-scale waves was absent in FASTEM-1. To estimate the forecast impact of this CRTM improvement, parallel experiments were performed using a 3dvar T254 configuration. The impact appears to be neutral for the Northern Hemisphere, but positive in both the tropics and Southern Hemisphere. In this work, we describe how reduction of model error aliasing in the GSI that can be attributed to application of the aforementioned CRTM improvements, might explain the positive forecast impact.

FASTEM Development and Two-Scale Emissivity Models

FASTEM-1 accounts for large-scale ocean waves by applying GO theory with an empirical correction to small-scale waves. The latest FASTEMs (FASTEM-4 and FASTEM-5) rigorously account for two-scales of ocean waves, and can be considered two-scale emissivity models. In addition, the latest FASTEMs account for azimuthal view geometry and salinity. The salient distinction between FASTEM-4 and FASTEM-5 is that the latter applies the same foam coverage model as FASTEM-1.

Impact on GSI Innovations

The CRTM is the observation operator for infrared and microwave satellite radiances in the GSI. In this context the objective of the CRTM is to enable the GSI to minimize differences between simulated and observed radiances (the innovation vector) that can be attributed to the mapping of the state vector to observation space. Innovations from GSI stand-alone single cycle runs are shown below. These plots are representative of the non-bias corrected AMSUA innovations over ocean surfaces when applying FASTEM-5, FASTEM-4 and FASTEM-1. The plots are for surface sensitive channels.
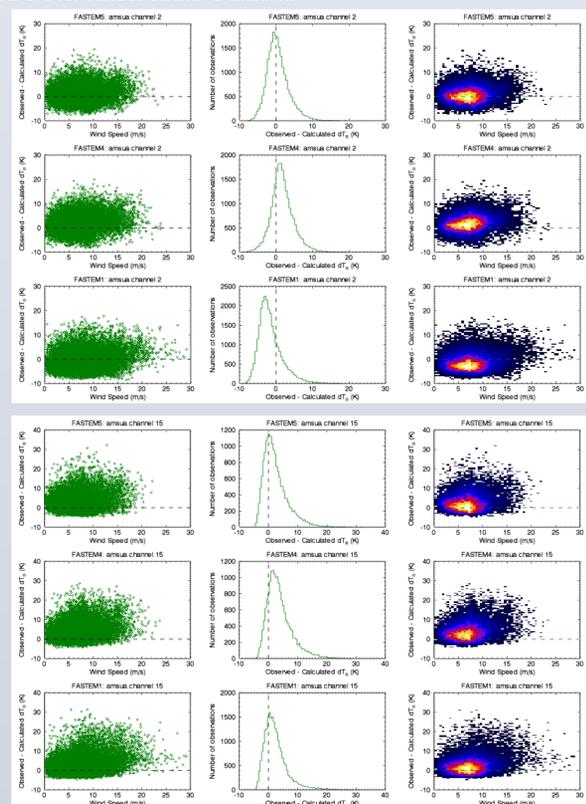
Figure 1 Non-bias corrected innovations for AMSUA channels 2 (top) and 15 (bottom) as a function of the 10m first guess wind speed . The innovations are for a stand-alone single cycle run of GSI run of January 27th, 2013 @ 00Z. The plots represent the aggregate results for all AMSUA sensors used in the GSI. From left to right scatter-plots, 1-d histograms and 2-d histograms are shown. For each channel, innovations for the application of FASTEM-1, FASTEM-4 and FASTEM-5 are shown.

Forecast Impact

To estimate the forecast impact of applying FASTEM-5 in the GSI as opposed to FASTEM-1, a two month parallel experiment was performed by running the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) for a 3dvar T254 configuration. The experiment was run for the months of July and August 2012.

The anomaly correlation scores for 3 day forecasts at 500mb are shown in figure 2. The control and experiment forecast anomaly correlation scores are with respect to their own analyses. Based on this metric the impact was positive in both the Southern Hemisphere and Tropics, and neutral in the Northern Hemisphere.

Note that 'control' hereafter refers to application of FASTEM-1 and 'test' refers to application of FASTEM-5.
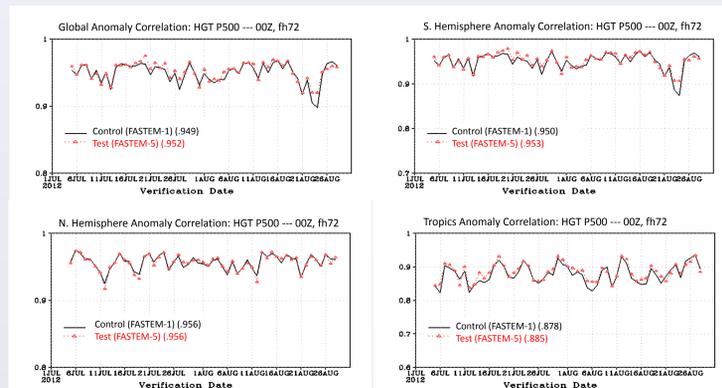
Figure 2 Three day forecast anomaly correlation (AC) scores for a GFS 3dvar T254 parallel experiment. The control AC scores are in black and the test AC scores are in red. The forecast anomaly correlation scores shown are with respect to their own analyses.

Figure 3 shows the test global anomaly correlation scores compared to the control at 500mb and 700mb for waves 1-20. The anomaly correlation scores are shown as a function of forecast hour going out to day 6. In general the positive forecast impact of applying FASTEM-5 is statistically significant for forecast days 1 through 4.
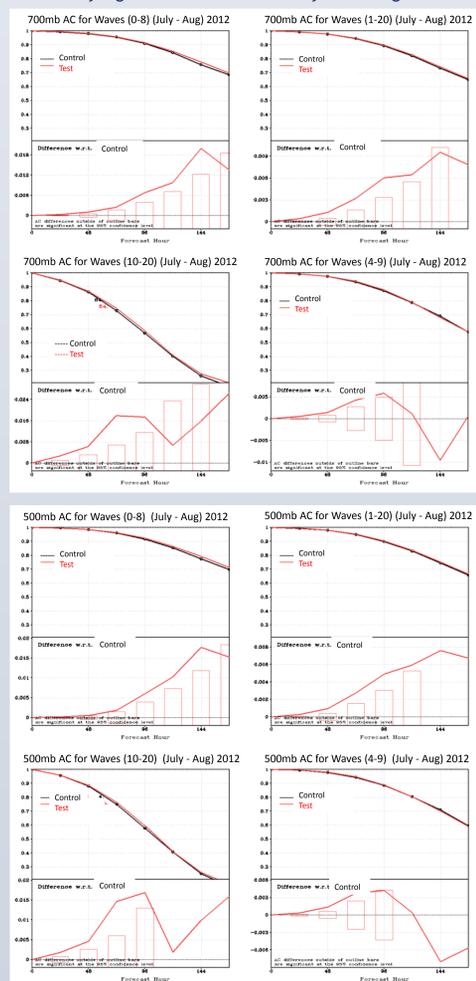
Figure 3 Anomaly correlation of the test compared to the control as a function of forecast hour for 700mb (top) and 500mb (bottom). The results for waves 1 to 20 are shown.

Discussion and Analysis

Figure 4 shows the test and control mean near surface zonal wind analysis increments for the second half of the two month parallel experiment. The differences between the test near surface zonal wind analysis increments and the control near surface zonal wind analysis increments are also plotted in figure 4. The larger differences in near surface zonal wind analysis increments are generally found along the Southern Hemisphere storm track latitudes between 60ºS and 65ºS.

Relative to the control the zonal wind analysis increments for the test tend to slacken the trade winds in the Western Tropical Pacific. In the Eastern Tropical Pacific the test zonal wind analysis increments between 5ºN and 15ºN tend to hasten the trade winds relative to the control.
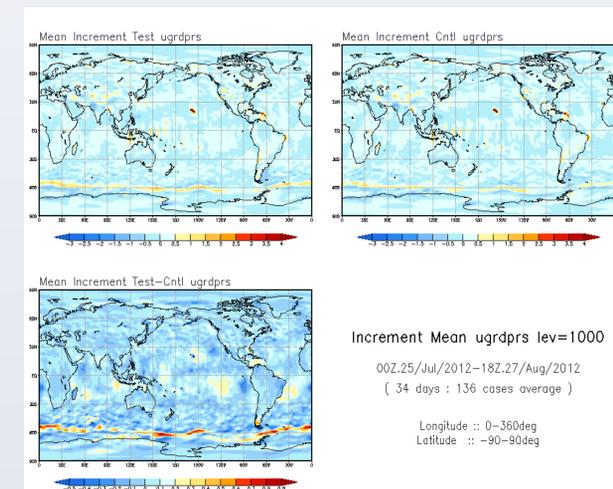
Figure 4 Near surface zonal wind analysis increments for the test are plotted in the upper left. Near surface zonal wind analysis increments for the control are plotted in the upper right. The differences between the test and control near surface zonal mean analysis increments are plotted in the bottom left . The units for all plots are m/s.

Figure 5 shows the test and control near surface temperature analysis increments for the second half of the two month parallel experiment. The differences between the test near surface temperature analysis increments and the control near surface temperature analysis increments are also plotted in figure 5. The larger near surface temperature analysis increment differences are generally found in the high latitude Polar regions.
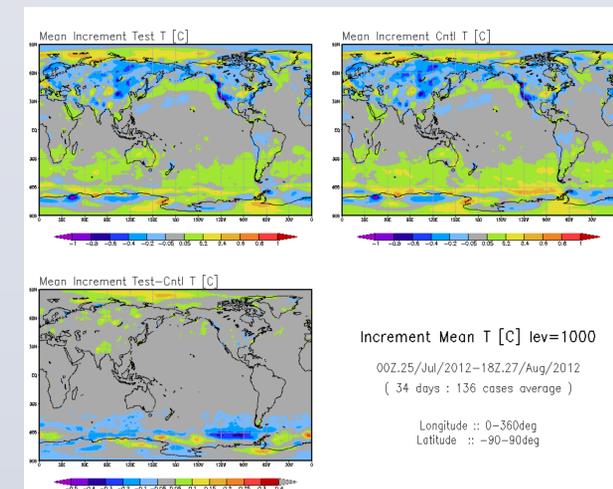
Figure 5 Near surface temperature analysis increments for the test are plotted in the upper left. Near surface temperature analysis increments for the control are plotted in the upper right. The differences between the test and control near surface temperature analysis increments are plotted in the bottom left .

References

Liu, Q., F. Weng, and S. English, 2011: An improved fast microwave water emissivity model. IEEE Trans. Geosci. Remote Sens, 49, 1238-1250

Kleist, D., D. Parrish, J. Derber, R. Treadon, R. Errico and R. Yang, 2008: Improving Incremental Balance in the GSI 3DVAR Analyisis System. Monthly Weather Review, 137, 1046-1060

Poster Contact

For questions or discussion in regards to this poster please contact david.groff@noaa.gov.