Configuration of All-sky Microwave Radiance Assimilation in the NCEP's GFS Data Assimilation System

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In the current operational NCEP's hybrid 3D Ensemble-Variational Global Forecast System (GFS), the clear-sky approach for radiance data assimilation is employed, in which radiances for cloud-free Field of Views (FOVs) and FOVs that include thin clouds are assimilated. For the FOVs that include thin clouds, the cloud signal is removed by applying a cloud liquid water bias term in the radiance bias correction scheme. The Advanced Microwave Sounding Unit-A (AMSU-A) microwave radiometer includes 12 sounding channels in the 60 GHz oxygen band, and 3 window channels at 24, 31 and 89 GHz that are sensitive to variability in water vapor, cloud and precipitation. Presently, AMSU-A channels 1-13 and 15 are assimilated in the operational GFS.

Improvements to the Community Radiative Transfer Model (CRTM) and the forecast model have been concurrent with all-sky radiance data assimilation development in the Gridpoint Statistical Interpolation (GSI) data assimilation system at NCEP. To date, cloud-affected AMSU-A radiance assimilation development has been limited to FOVs with non-precipitating clouds. These efforts have expanded the use of AMSU-A observations over cloud-affected regions. Furthermore, after accounting for non-precipitating cloud information in the inputs to the CRTM in the satellite-radiance observation operator, simulations of satellite radiances are more realistic over a much larger footprint of meteorologically active weather conditions. This has allowed us to improve the satellite radiance innovation (OmF) statistics for cloud affected FOVs, enabling the production of better analyses of temperature and moisture.

In the GFS, a cloud control variable is explicitly employed. Cloud water, including cloud liquid water and cloud ice, has been used in the clear-sky approach of the operational GFS. One of the benefits of the all-sky approach is that, the radiance data information is mapped onto not only the temperature and moisture fields, but also cloud fields via the brightness temperature Jacobians with respect to hydrometeors. CRTM does not produce a cloud Jacobian in cloud-free areas, but this is overcome by providing a very small cloud amount to the radiative transfer model in these cases. The background error covariance is composed of two parts, 75% from the flow-dependent ensemble and 25% from a static term. With the capability of choosing either individual hydrometeors or cloud water as cloud control variable(s) in the all-sky approach, a normalized cloud water control variable is used in this study to reduce spurious clouds generated from the static part of the background error covariance. While cloud analysis increments are produced through the background error cross-covariance in the clear-sky approach, additional analysis increments are generated from the projection of the radiance data information onto the cloud fields through the cloud background error variance for clouds and through the background error cross-covariance for temperature and moisture in the all-sky approach.

The symmetric observation error method (Geer and Bauer 2010; Bauer et al. 2010) is adopted in the all-sky approach for AMSU-A channels 1-5 and 15, i.e., the observation error is assigned based on the average value of cloud liquid water (Grody et al. 2001) calculated from the first guess and the observation, as the observation error for clear-sky radiance is basically the same as the one used in the clear-sky approach. On top of the symmetric observation error, additional quality control and situation-dependent observation error inflation are applied. Several factors are considered in the situation-dependent inflation: the cloud liquid water difference between the first guess and the observation, the large scattering index, the mismatched cloud information between the first guess and the observation, as well as the surface wind speed. Figure 1 displays the OmF after bias correction (left panel) for the used data and the difference in the cloud liquid water between the first guess and the observation (right panel) for AMSU-A channel 2. It is seen that the larger difference in cloud liquid water usually comes with a larger OmF.

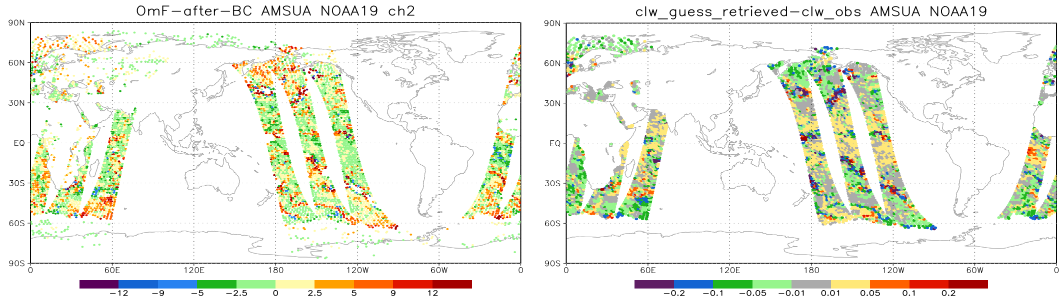

Figure 1. Used OmF after bias correction (left panel) and difference of cloud liquid water between the guess and the observation (right panel) for AMSU-A channel 2 data from NOAA19 at 00Z Oct. 27, 2013.

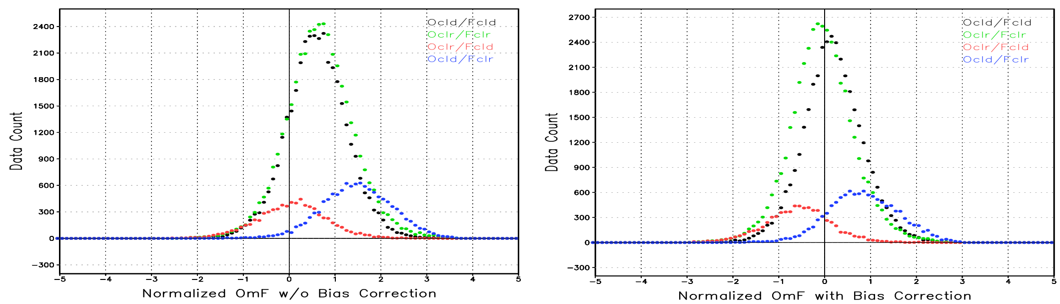

Figure 2. Histograms of OmF before (left panel) and after (right panel) bias correction for AMSU-A channel 1 data from NOAA15 for a five-days period for the four cloud catogories from first guess and observation.

As for the radiance bias correction, the cloud liquid water bias term, which is defined as the cloud liquid water difference between the guess and the observed, has been constructed in the clear-sky approach to remove the cloud signal. As this cloud liquid water bias term is no longer necessary in the all-sky approach, a new radiance bias correction strategy is formulated for the all-sky approach (Zhu et al. 2014). While all quality-controlled radiance data are used to obtain the analysis, bias correction coefficients in the all-sky approach are derived using only a selected data sample with consistent cloudy information between the first guess and the observation, and the radiance data with mismatched cloud information are bias corrected using the latest bias coefficients available. An example of histograms of OmF before (left panel) and after (right panel) bias correction for AMSU-A channel 1 data from NOAA15 is shown in Fig. 2.

The all-sky microwave radiance configuration has been tested in a T670 low-resolution hybrid 3D Ensemble-Variational GFS system. The experiment results showed a neutral impact on the forecast skill in the Northern Hemisphere but a positive impact in the Southern Hemisphere. It will soon be tested in the NCEP parallel hybrid 4D Ensemble-Variational (4D_EnVar) data assimilation system for the next implementation. Meanwhile, tests are underway on applying the averaged cloud liquid water bias term from the observation and the guess to further improve the performance of the bias correction. The balance between the analysed variables (particularly cloud, temperature and humidity) will be investigated further in the near future.

References

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