Characterizing Background Error with the NASA/GMAO OSSE

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The GMAO OSSE Framework

The Global Modeling and Assimilation Office (GMAO) has developed an Observing System Simulation Experiment (OSSE) framework. This includes a Nature Run from a 2-year simulation using the GEOS-5 forecast model at 7 km/72L. Synthetic observations have been generated based on the G5NR fields, including conventional observations, GPS, and satellite radiances, using methods described in Errico et al. (2013). These synthetic observations are ingested using the Gridpoint Statistical Interpolation data assimilation system, with forecasts performed by the GEOS-5 model at 55 km/72L.

Synthetic errors have been added to the synthetic observations generated from the G5NR. The synthetic errors include both a random component, and a correlated component for certain observation types (vertically correlated errors for rawinsondes, horizontally correlated errors for AMSU-A, HIRS4, and MHS; and channel correlated errors for AIRS and IASI). These errors are calibrated so that the statistics of observation innovations and analysis increments found in the OSSE match those from real data experiments.

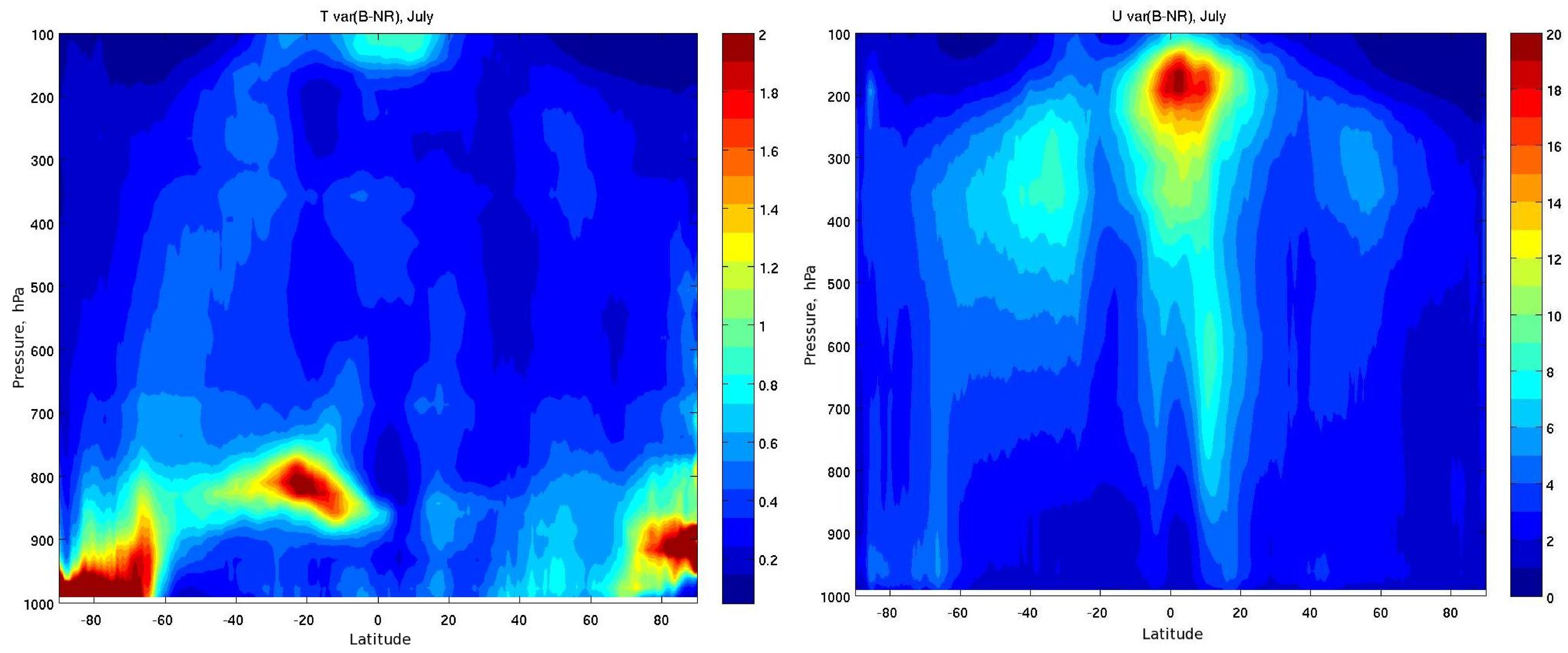

Figure 1. Zonal mean temporal variance of background errors for the month of July. Left panel, temperature (K^2); right panel, zonal wind ($m^2 s^{-2}$).

Background Error Variance

One of the most powerful aspects of OSSEs is the ability to explicitly verify the analysis and background states, as the true state is known completely in the form of the Nature Run. The above panels show the zonal mean temporal variance of background error in the GMSO OSSE for the month of July. The regions of high background error variance tend to have some combination of significant model error and limited observations. For temperature, the greatest background error variance is found in the lower troposphere, particularly near the poles. Wind has the maximum background error variance in the deep tropics near the tropopause, with secondary maxima near the midlatitude jets.

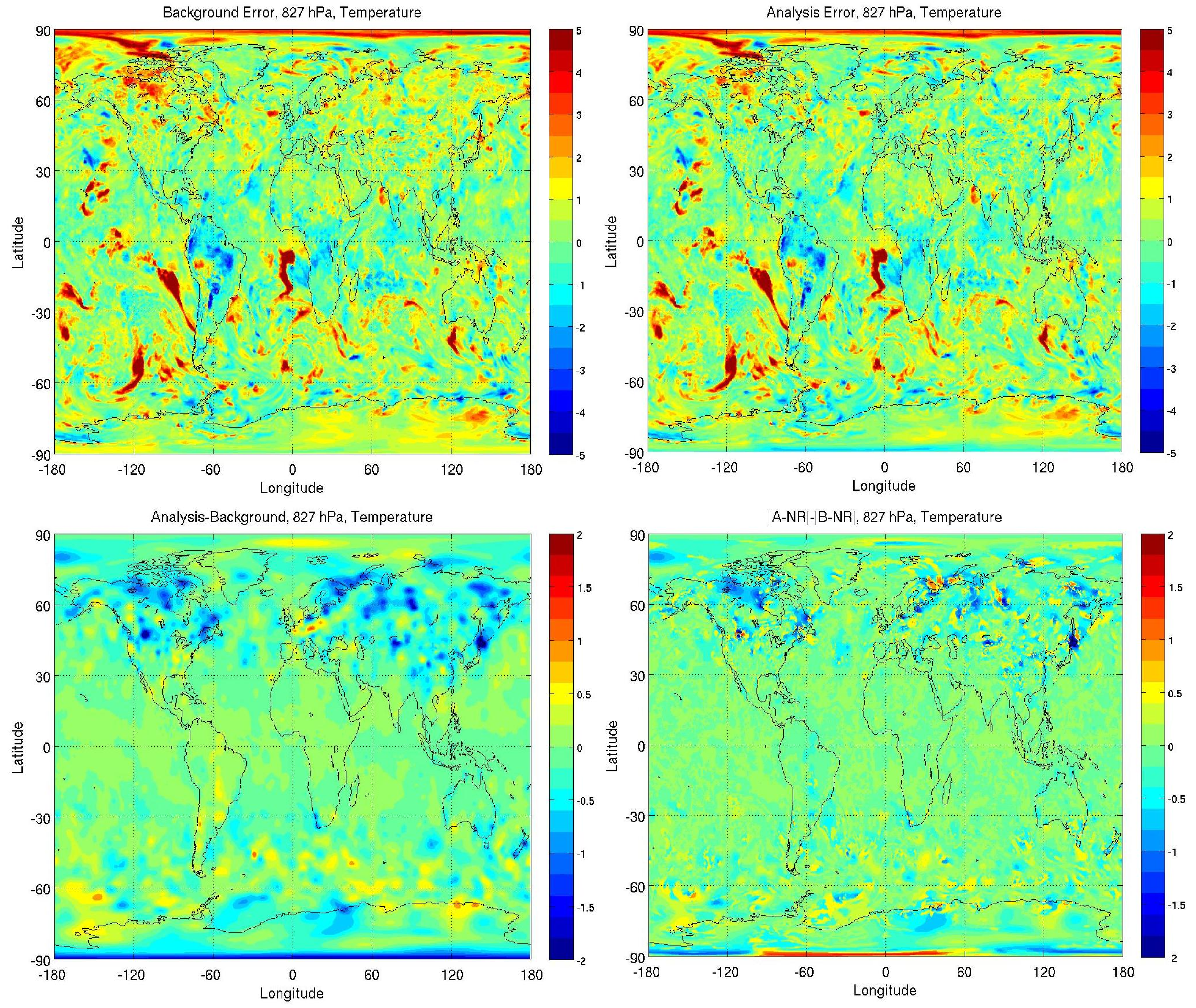

Figure 2. Snapshot of temperature fields (K) at 827 hPa equivalent eta level, 10 July 0000 UTC. Top left, background error; top right, analysis error; bottom left, (A-B); bottom right, |A-NR|-|B-NR| (positive values mean analysis has more error than background).

Background Error Snapshots

Snapshots of background error, analysis error, and analysis increment at 10 July 0000 UTC are shown in Figure 2 for temperature on the 827 hPa eta surface, and in Figure 3 for zonal wind on the 312 hPa eta surface. These surfaces were selected to sample the levels with maxima in zonal mean background error variance.

The background error has complex, anisotropic structure, with regions of error showing a variety of spatial scales and shapes. In contrast, the analysis increment has very different structure from the actual background error, as well as weaker magnitude. Although substantial background errors are found in the tropics, particularly for the wind field, the analysis increment has greater magnitude in the midlatitudes. As a result, the analysis error field appears largely unchanged in comparison to the background error field.

This result is not unexpected - the spatial scales and strength of the analysis increments are determined by the specifications of the background error covariance used by the GSI. In this case, the characteristics of the actual background error and the background error assumed by the data assimilation are very different. The background temperature errors assumed by the GSI have also been chosen to weaken the influence of the observations, resulting in especially weak analysis increments of temperature.

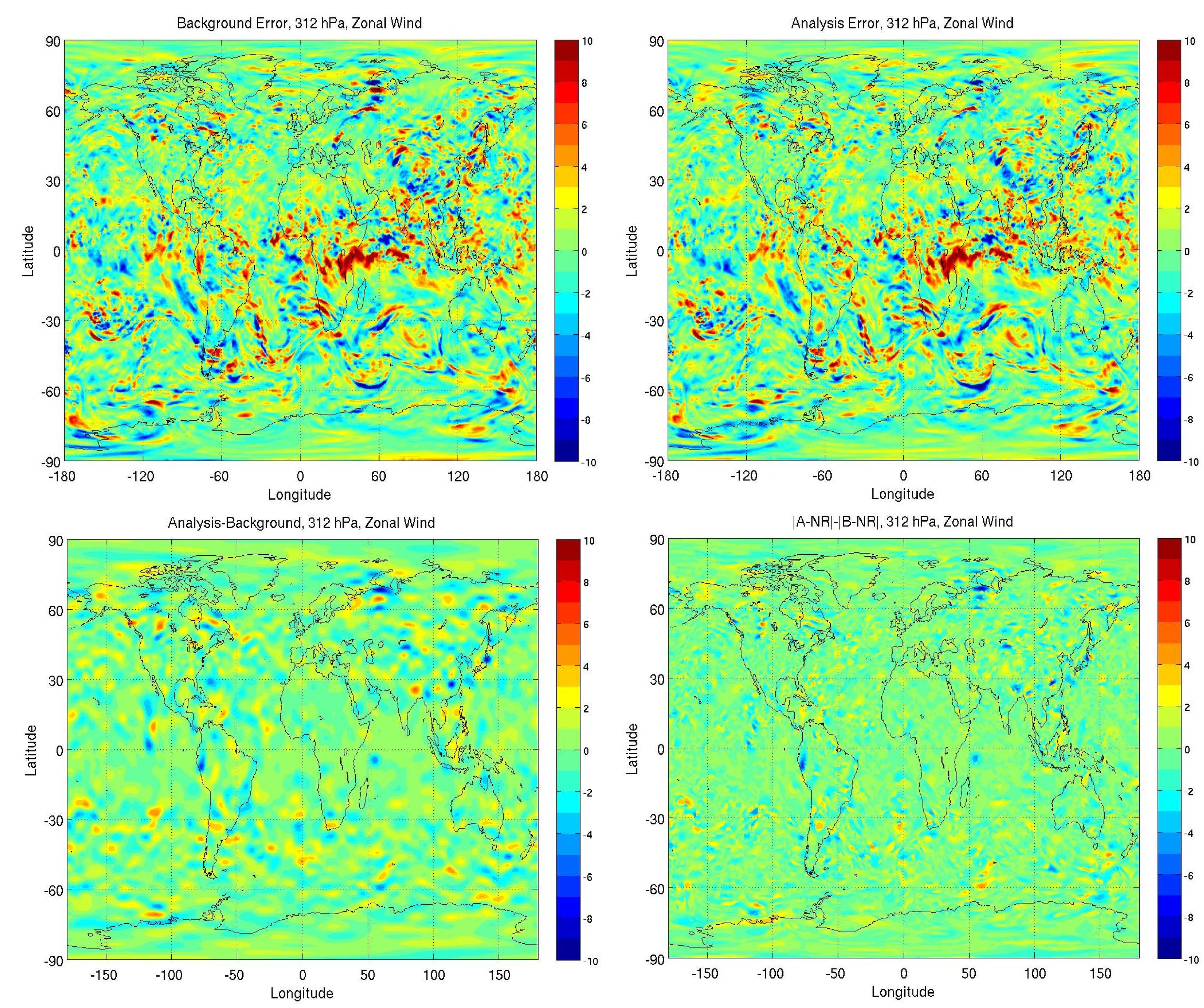

Figure 3. As for Figure 2, but for zonal wind on the 312 hPa equivalent eta level, 10 July 0000 UTC ($m\ s^{-1}$).

Also shown in Figures 2 and 3 is the metric |A-NR|-|B-NR|, which is positive (negative) when the analysis has greater (smaller) error than the background. This metric shows that while the analysis increment acts to reduce analysis error in some regions, there are many other areas where the spreading of information from observations may result in a degradation of the analysis compared to the background.

The meridional correlation lengths for the background errors are shown in Figure 4 for three regions for both temperature and meridional wind fields, calculated over the month of July. The tropics have length scales approximately twice as large as the midlatitudes.

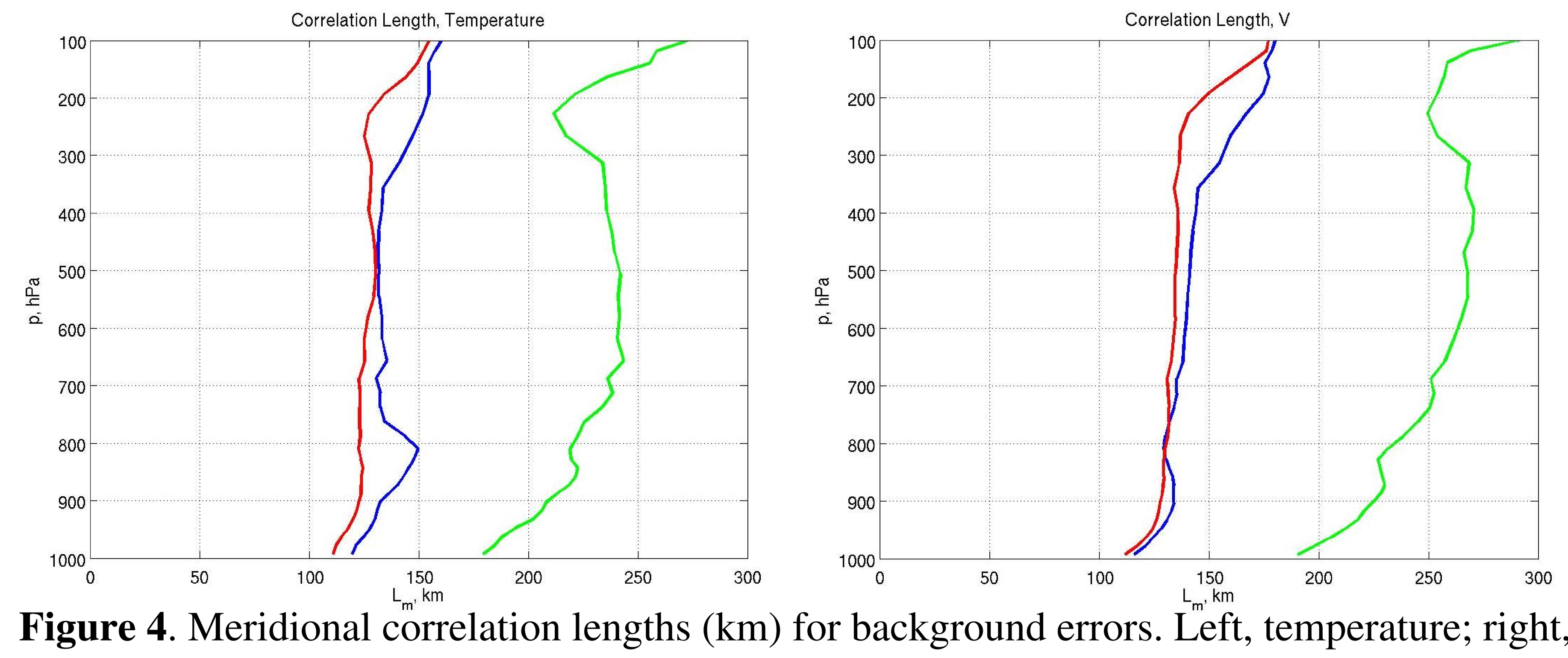

Figure 4. Meridional correlation lengths (km) for background errors. Left, temperature; right, meridional wind. Red line, 18N-54N; blue line, 54S-18S; green line, 18S-18N.