An Examination of the New PTOSIG within the GEOS-DAS

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The new interpolation technique which was implemented into the GEOS-3.12 system is designed to produce a sigma-level model state which is capable of reproducing the analyzed fields of height, wind, moisture and sea-level pressure. This is accomplished by performing a variational analysis on the sigma-level *model* fields using the contraint of matching the mandatory-level *analyzed* fields through SIGTOP interpolation. Using off-line static tests, the new algorithm was developed and shown to reproduce the analyzed fields very well.

In-line validation tests were then performed by comparing the previously validated system (geos b290_o3_w98) to a version using the new interpolation (geos b312_o1_w98). The test date of January 1998 was used for this comparison. Since the GEOS-DAS incorporates analysis changes throuth the use of the Incremental Analysis Update (IAU), it is not straight-forward to assess whether the after-analysis sigma-level state can reproduce the after-analysis pressure-level fields. In fact, the model never sees the after-analysis sigma-level state directly but only feels its influence through the IAU forcing. A key factor to the success of IAU, however, is the linear nature of the assimilation system to small but frequent adjustments. We can use this quasi-linear response to assess the impact of the new interpolation technique.

We shall define the following terms:

$$
\begin{aligned}
RS &= \text{Sigma-Level Model State at the mid-synoptic time} \\
FG &= \text{First-Guess State at the synoptic analysis time} \\
AA &= \text{After-Analysis State on Sigma} \\
IAU &= \text{Incremental Analyis Update Tendency} \\
AS &= \text{Assimilated Sigma-Level State at the synoptic analysis time}
\end{aligned}
$$

We may then write:

$$
\begin{aligned}
FG &= RS + \Delta_M \\
AA &= FG + \Delta_A \\
&= RS + \Delta_M + \Delta_A
\end{aligned}
$$

where Δ_M is the change made by the model from the mid-synoptic restart RS, and Δ_A is the change made by the analysis from the synoptic time first guess FG.

The IAU and assimilated states may then be expressed as:

$$
\begin{aligned}
IAU &= \frac{AA - FG}{6hrs} \\
&= \frac{\Delta_A}{6hrs} \\
\\
AS &= RS + \Delta_M + 3hr * IAU \\
&= RS + \Delta_M + \frac{\Delta_A}{2}
\end{aligned}
$$

Note that at the synoptic analysis time only 1/2 of the analysis adjustment has been incorporated. As a result, we may write:

$$
\begin{aligned}
2 * (AS - FG) &= 2 * \left[(RS + \Delta_M + \frac{\Delta_A}{2}) - (RS + +\Delta_M) \right] \\
&= \Delta_A
\end{aligned}
$$

Therefore, if the system were perfectly linear the quantity $2 * (AS - FG)$ interpolated to the mandatory pressure levels would be exactly equal to the analysis increment Δ_A on pressure. How well these two terms agree is a measure of how well the interpolation technique is able to reproduce the analyzed fields on pressure levels, in addition to how well the system is responding in a linear fashion.

Results

All results shown are derived for the monthly mean. Figure 1 shows the analyis increment of sea-level pressure (top panel), the corresponding term from the assimilation cycle $2 * (AS - FG)$ (center panel), and the difference (bottom panel). The new interpolation is shown in the left column, while the control case is shown in the right column. In the extra-tropics, the new interpolation technique is much better able to reproduce the analysis increment than the control case. The large errors seen over most land masses in the control case have been significantly reduced or eliminated using the new algorithm. Some errors still exist over the highest mountains (Himalayas) as well as over areas in the tropics.

Figure 2 depicts the same metric for the zonal mean heights. We again see that, in the extra-tropics, the new algorithm has significantly reduced the differences between the adjustments the analysis *wanted* to make and the *actual* adjustments that were made during the assimilation cycle. We again note systematic errors in the tropics for both algorithms.

The largest differences seen are associated with high mountains in the northern hemisphere. Therefore, Figure 3 shows vertical profiles of Height Increments at 45 degrees North for various longitude points. The solid lines correspond to the analysis increments, while the dashed lines correspond the the assimilation term $2 * (AS - FG)$. For a perfect, linear system, the solid and dashed lines for each experiment would coincide. We again see a clear improvement associated with the new interpolation technique. The last bottom two panels of Figure 3 show results for regions in the tropics. It is clear that the tropics are not behaving in a manner predicted by the linear analysis. It should be noted that off-line test using the new algorithm had no problem reproducing the analyzed fields in the tropical regions.

Figures 4 and 5 show the Height Increments at 500-mb and 50-mb, respectively. We see significant errors over most of Asia using the control algorithm, while very good agreement is seen with the new algorithm. In the tropics, comparable errors are being made in both. Figures 6 and 7 show the same for the U-Wind Increments. Generally the wind increments, being local in nature, are resonably reproduced by the control case, although improvements can still be seen using the new algorithm.

Conclusion

The new interpolation algorithm has been shown to produce an assimilated state which is being forced by increments which are in better agreement with the increments produced by the analyis. As a result, the climatology of the assimilated state, as well as the first guess, is closer to the climatology of the analysis than in the control run. The new interpolation had the most impact in the extra-tropics. Both techniques have serious deficiencies in the tropics. Since off-line tests showed no problem in this area, other possible explanations need to be explored.

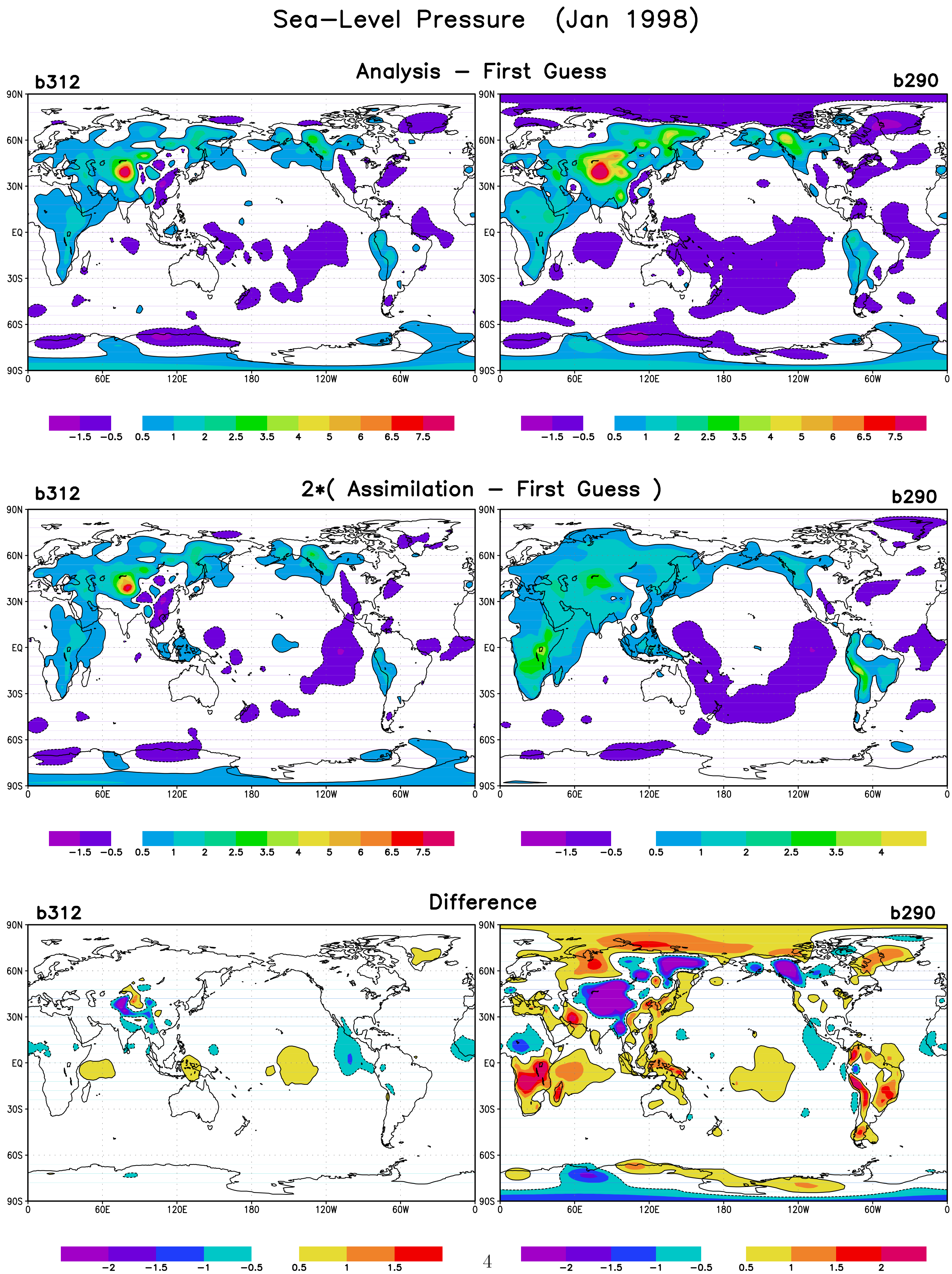

Figure 1: Sea-Level Pressure Increments

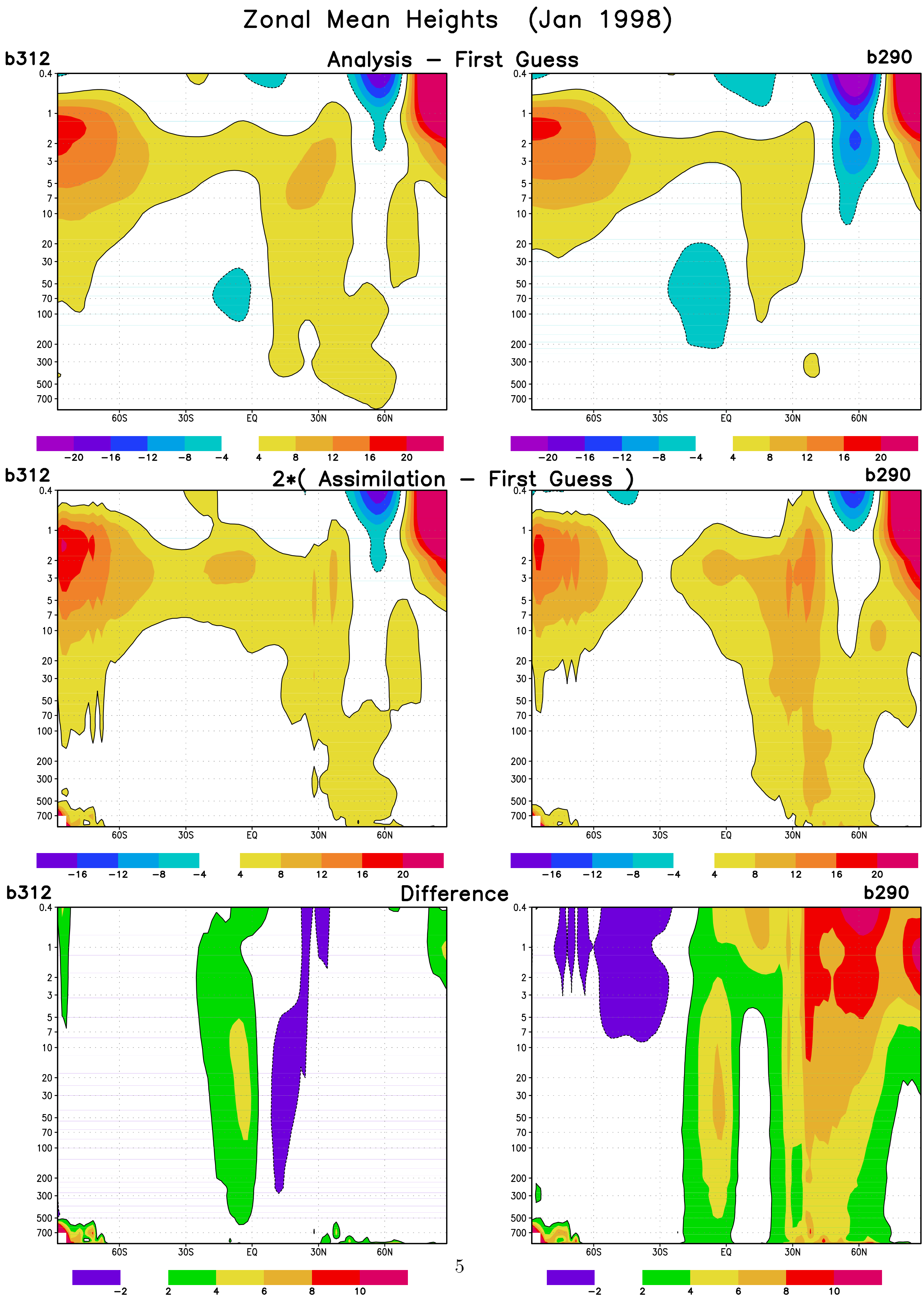

Figure 2: Zonal Mean Height Increments

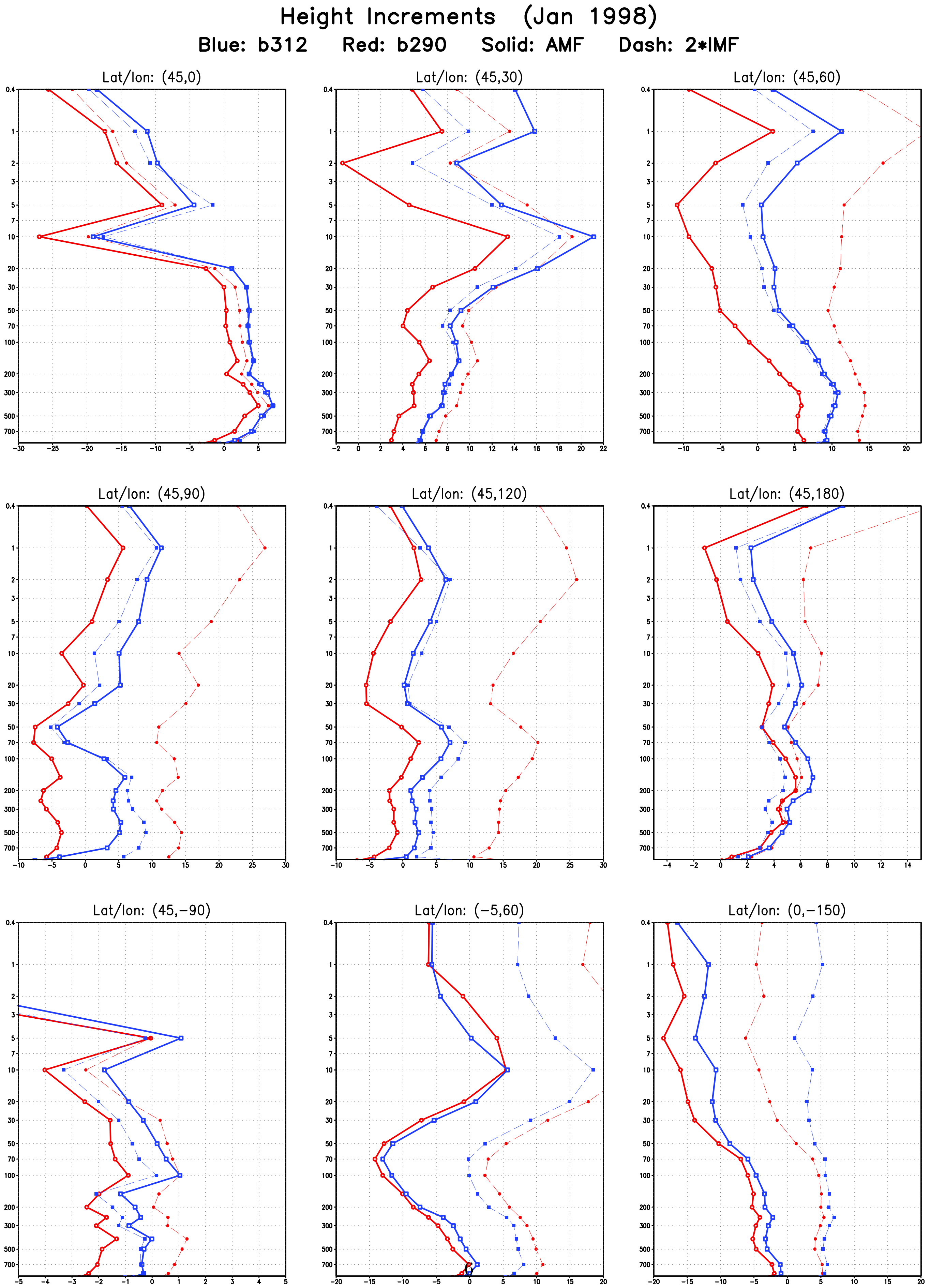

Figure 3: Profile Height Increments

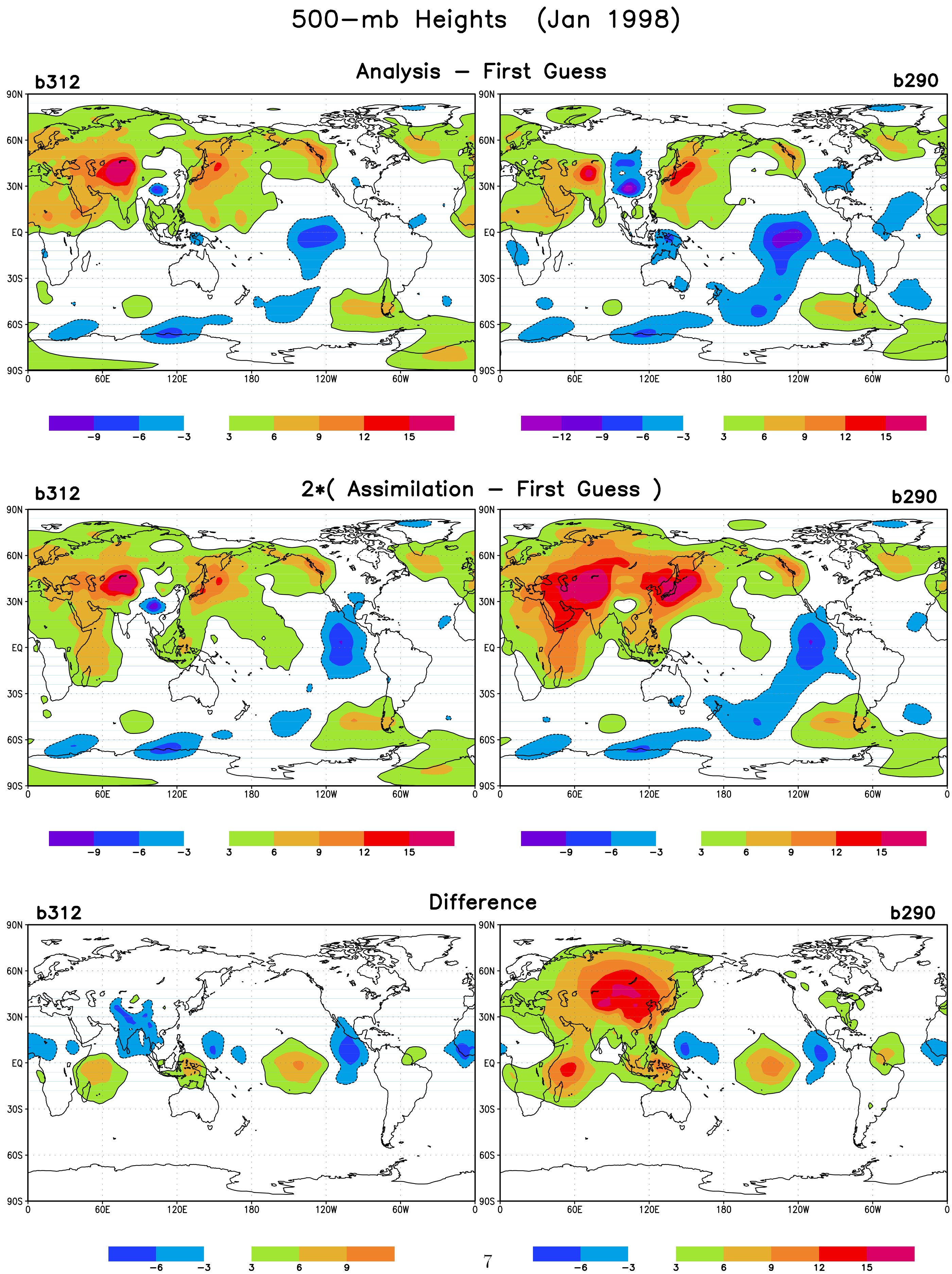

Figure 4: 500-mb Heights

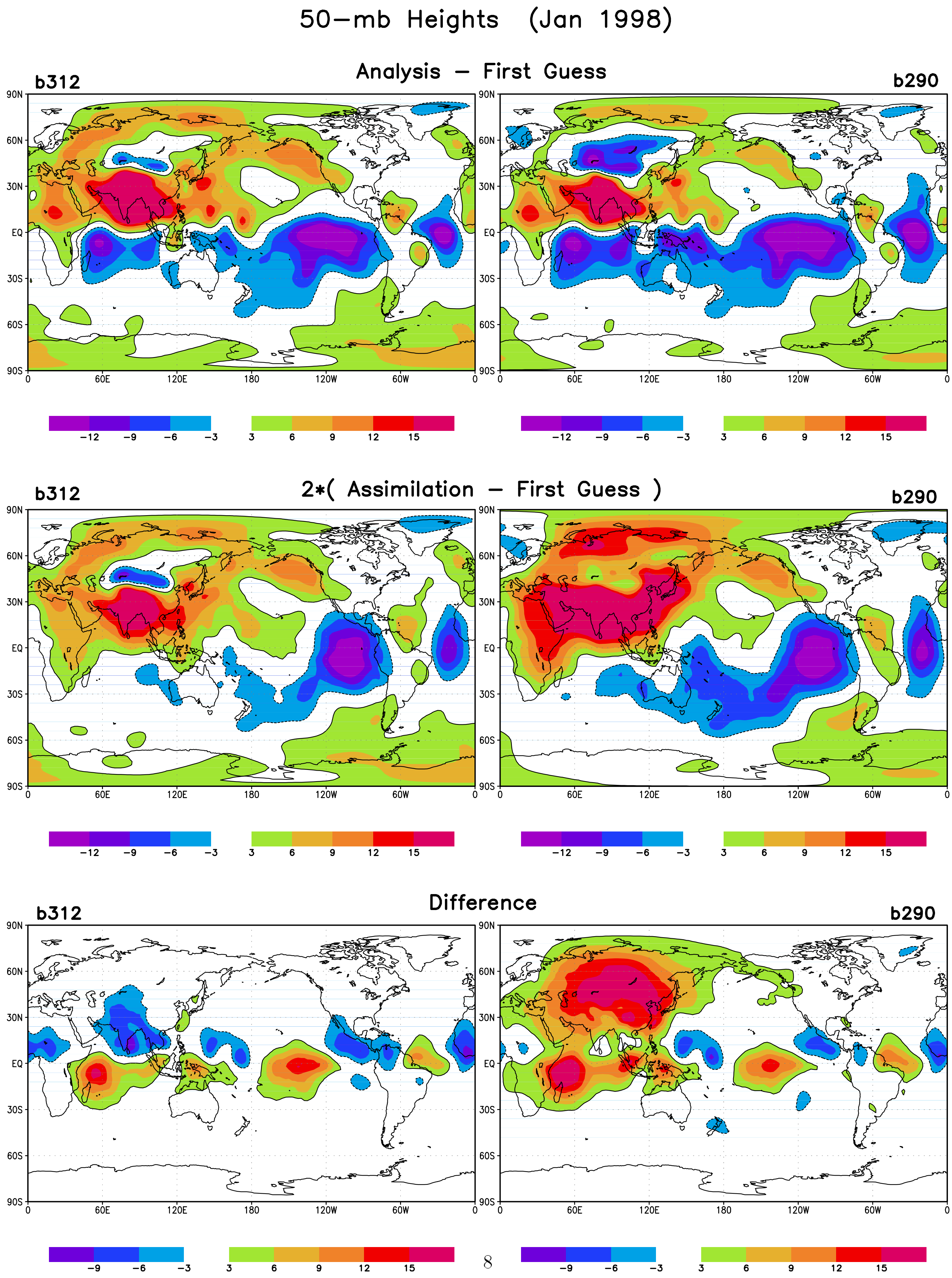

Figure 5: 50-mb Heights

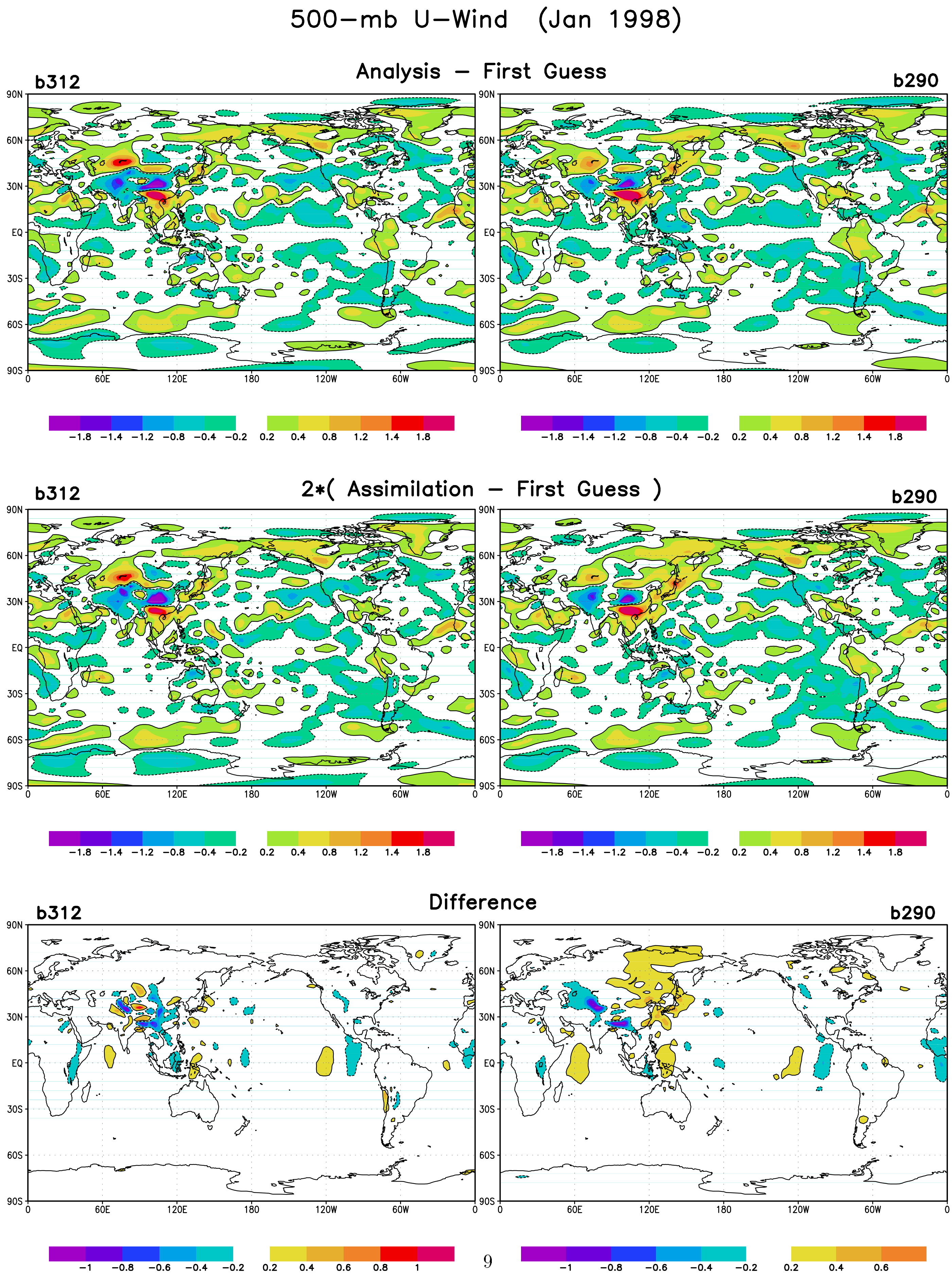

Figure 6: 500-mb U-Wind

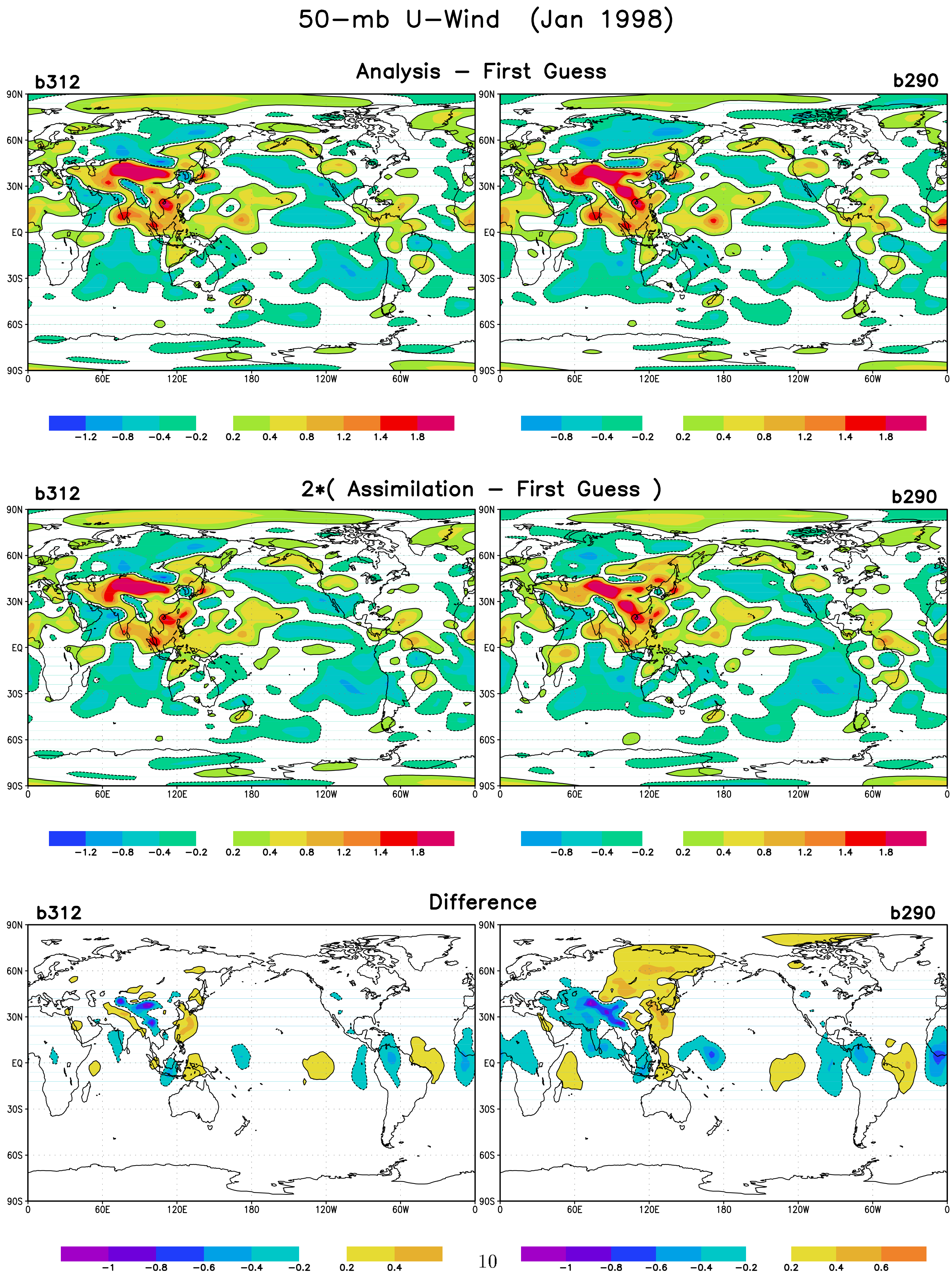

Figure 7: 50-mb U-Wind