<u>Synoptic Meteorology II: The Impacts of Diabatic Heating on IPV</u>

Though we do not have direct observations of diabatic heating, nor do we output enough data from operational weather prediction models to directly diagnose it, we can nevertheless use operational weather prediction model output to *infer* the presence of diabatic heating and its impacts on IPV. Here, we consider the reduction of upper-tropospheric IPV associated with diabatic warming tied to deep, moist convection associated with a midlatitude cyclone on 18 April 2019. We leverage GFS numerical model analyses from Tropical Tidbits for this illustration.

Consider the 330-K isentropic potential vorticity analyses given by Figs. 1-3. We are interested in what occurs over the central United States, roughly in the regions bounded by the purple contours in each figure (representing an 850 hPa cyclonic-vorticity maximum), over the 12-h period encompassing these figures. The gradient between blue and yellow shading depicts the 2 PVU surface, separating regions in which the 330-K isentropic surface is within the troposphere (blue) from those in which it is within the stratosphere (yellow/orange).

Note how moderate blue shading becomes more expansive ahead of the positive PV anomaly to the west. Although there is initially blue shading in the southeast United States, the flow there is directed more toward the east-northeast than toward the northeast. Thus, advection alone cannot be responsible for the reduction in 330-K isentropic potential vorticity over this period.

Next, consider the simulated IR satellite imagery given by Figs. 4-6. Note the cold cloud tops over the central United States – particularly near the Great Lakes in Fig. 4 and the south-central Plains in Figs. 5 and 6. These are indicative of deep, moist convection – in other words, thunderstorms and rainfall – forced by ascent ahead of the positive PV anomaly/upper-tropospheric trough to the west.

As discussed in the lecture notes, thunderstorms are typically associated with diabatic warming maximized at mid-levels, decreasing toward zero both near the surface and the tropopause. Thus, in the upper troposphere, diabatic heating rate decreases upward as potential temperature increases. This vertical structure is associated with a reduction in upper-tropospheric IPV following the flow, which is what we see in Figs. 1-3. Instead of being destroyed, however, IPV is redistributed toward the surface, through which it may contribute to the intensification of the surface cyclone (though we note that this cyclone maintains a quasi-steady intensity over the time period considered in Figs. 1-3). This is a complementary perspective on the influence of diabatic warming to surface cyclone development in the context of the Pettersen-Sutcliffe development equation, and we will soon revisit this idea in the IPV framework.

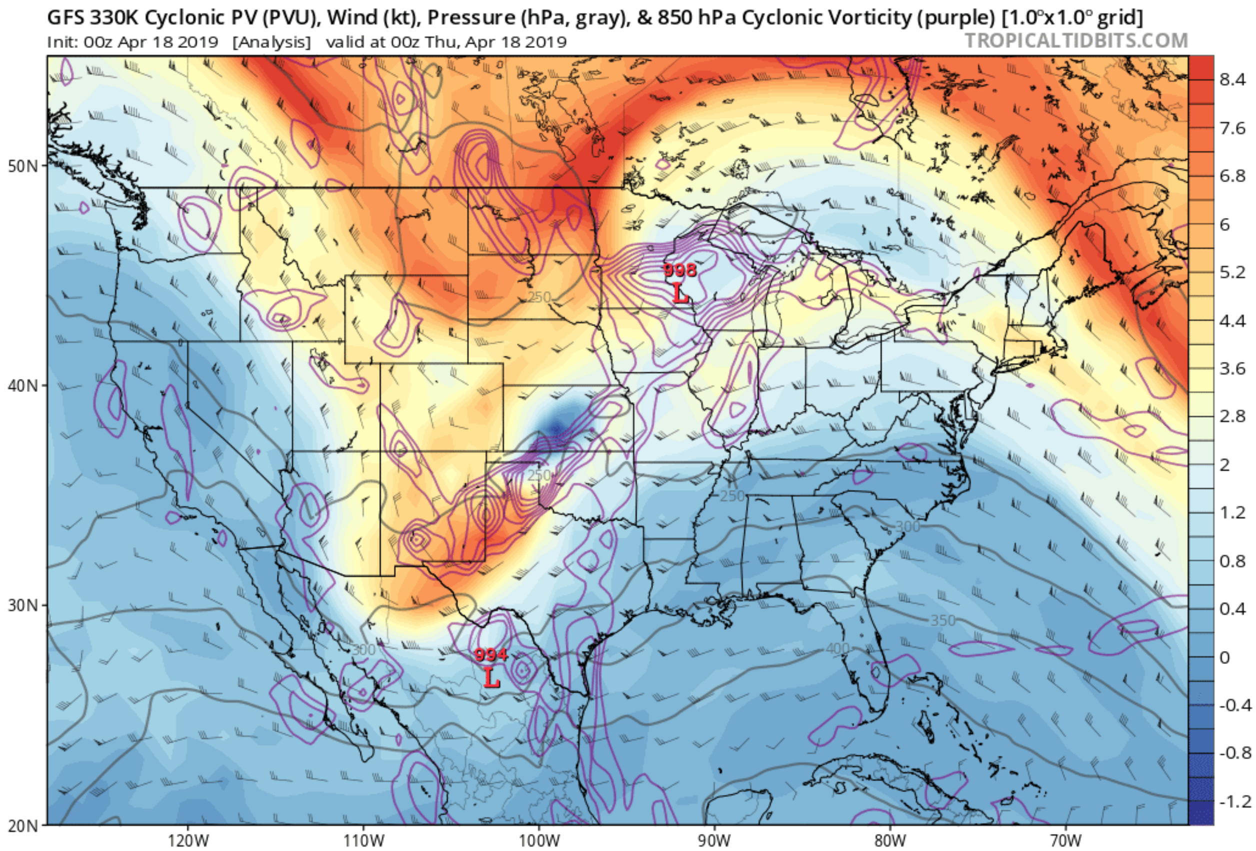

Figure 1. GFS 0-h analysis (valid 0000 UTC 18 April 2019) of 330-K potential vorticity (shaded in PVU per the color bar at right), pressure (grey contours in hPa), and wind (half-barb: 5 kt, full barb: 10 kt, pennant: 50 kt); 850 hPa cyclonic vorticity (purple contours); and cyclonic sea-level pressure anomalies (red markers). Figure obtained from Tropical Tidbits.

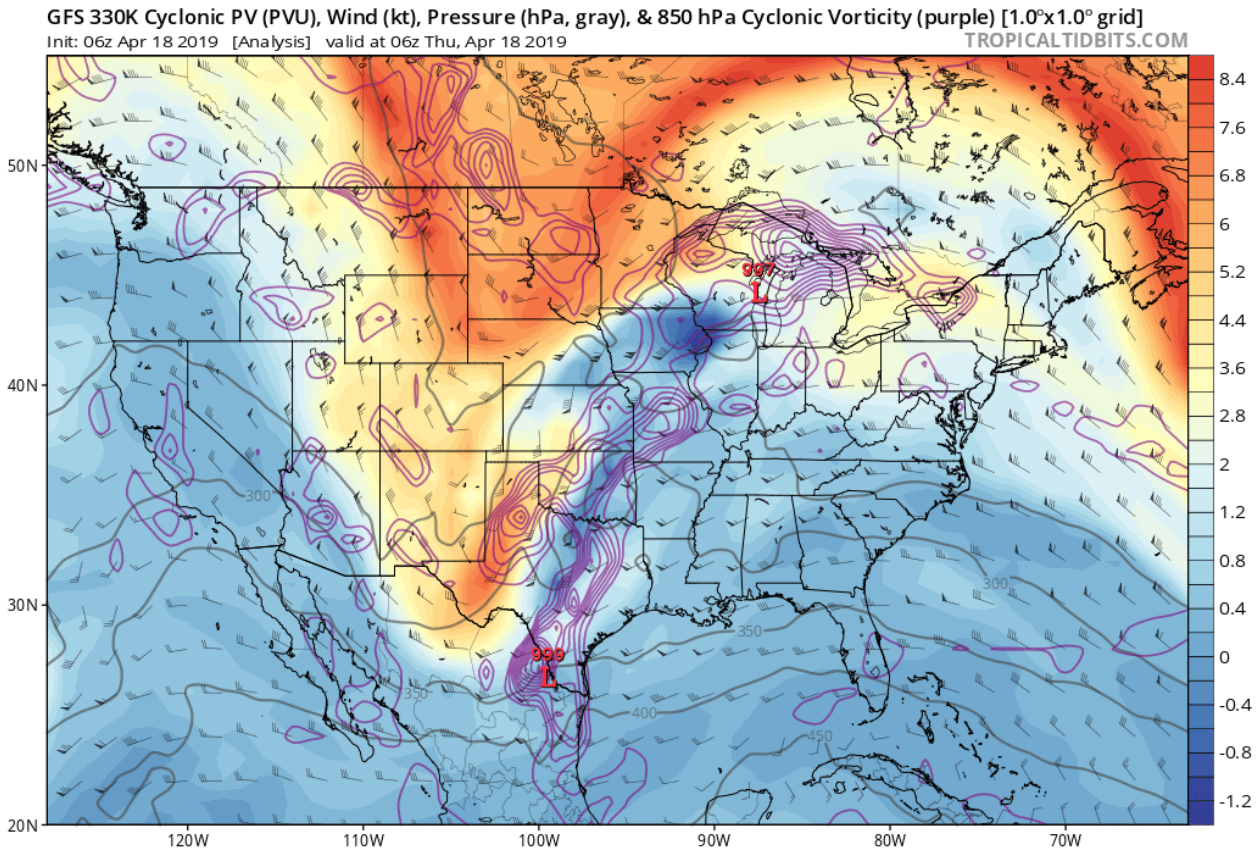

Figure 2. As in Fig. 1, except at 0600 UTC 18 April 2019.

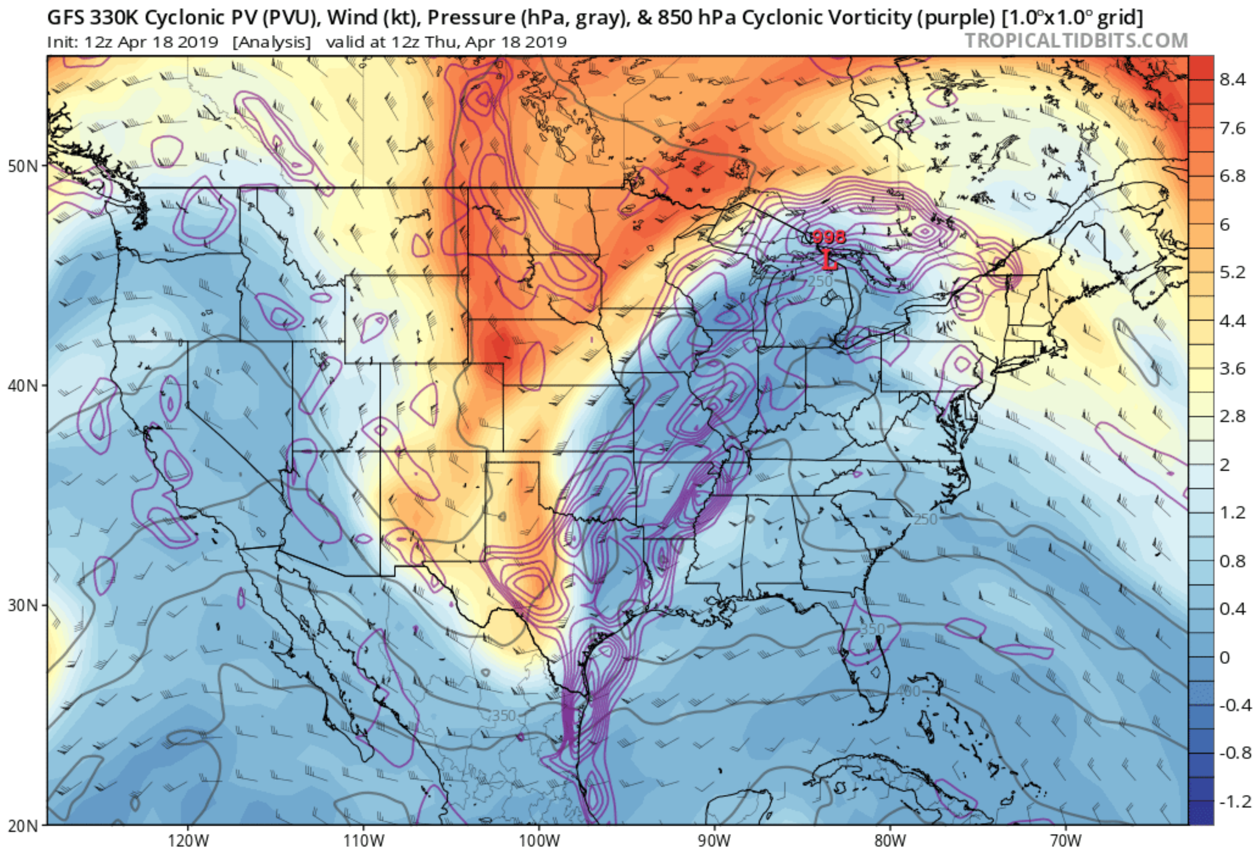

Figure 3. As in Fig. 1, except at 1200 UTC 18 April 2019.

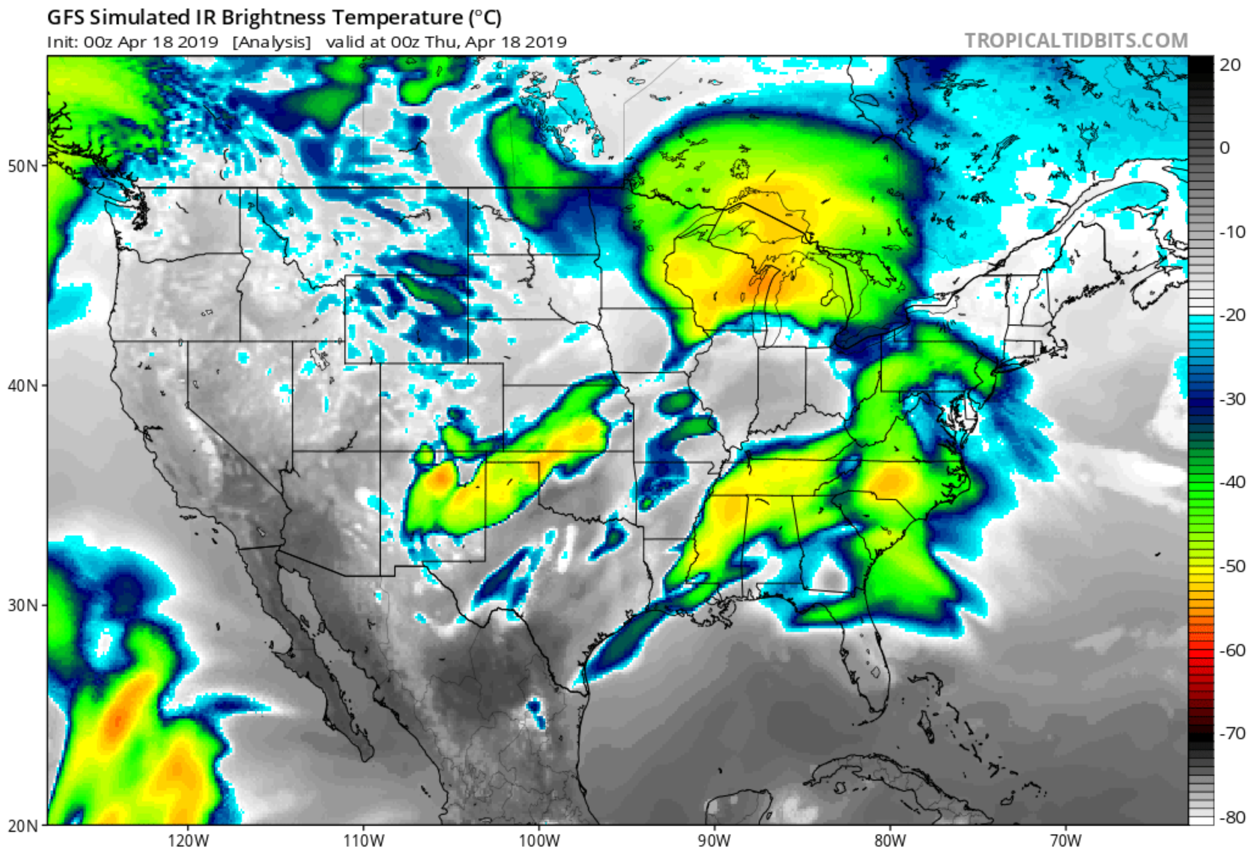

Figure 4. Simulated IR satellite image, with shading indicating cloud-top brightness temperatures (shaded in °C per the color bar at right) from the GFS 0-h analysis valid 0000 UTC 18 April 2019. Brighter colors indicate colder cloud tops, which are often associated with deep, moist convection and/or cirrus clouds. Figure obtained from Tropical Tidbits.

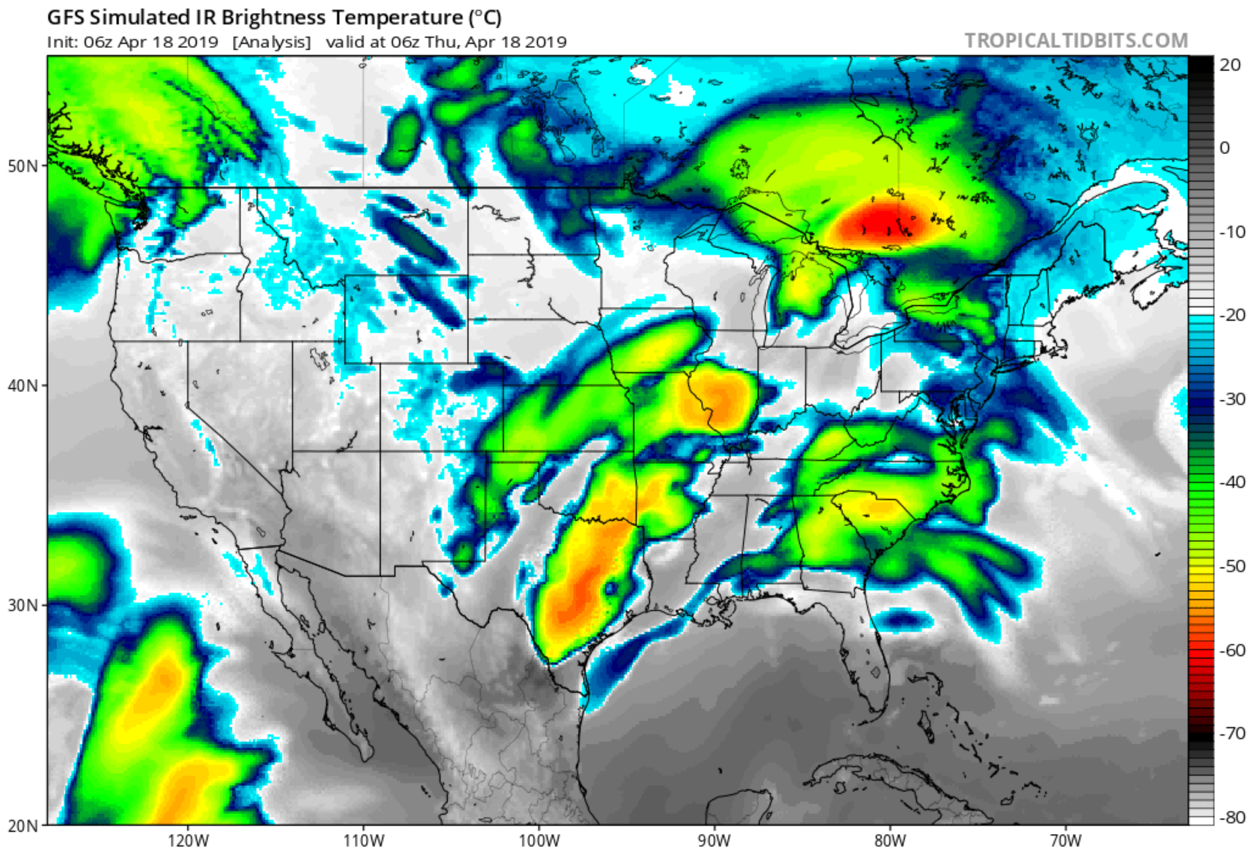

Figure 5. As in Fig. 4, except from the GFS 0-h analysis valid 0600 UTC 18 April 2019.

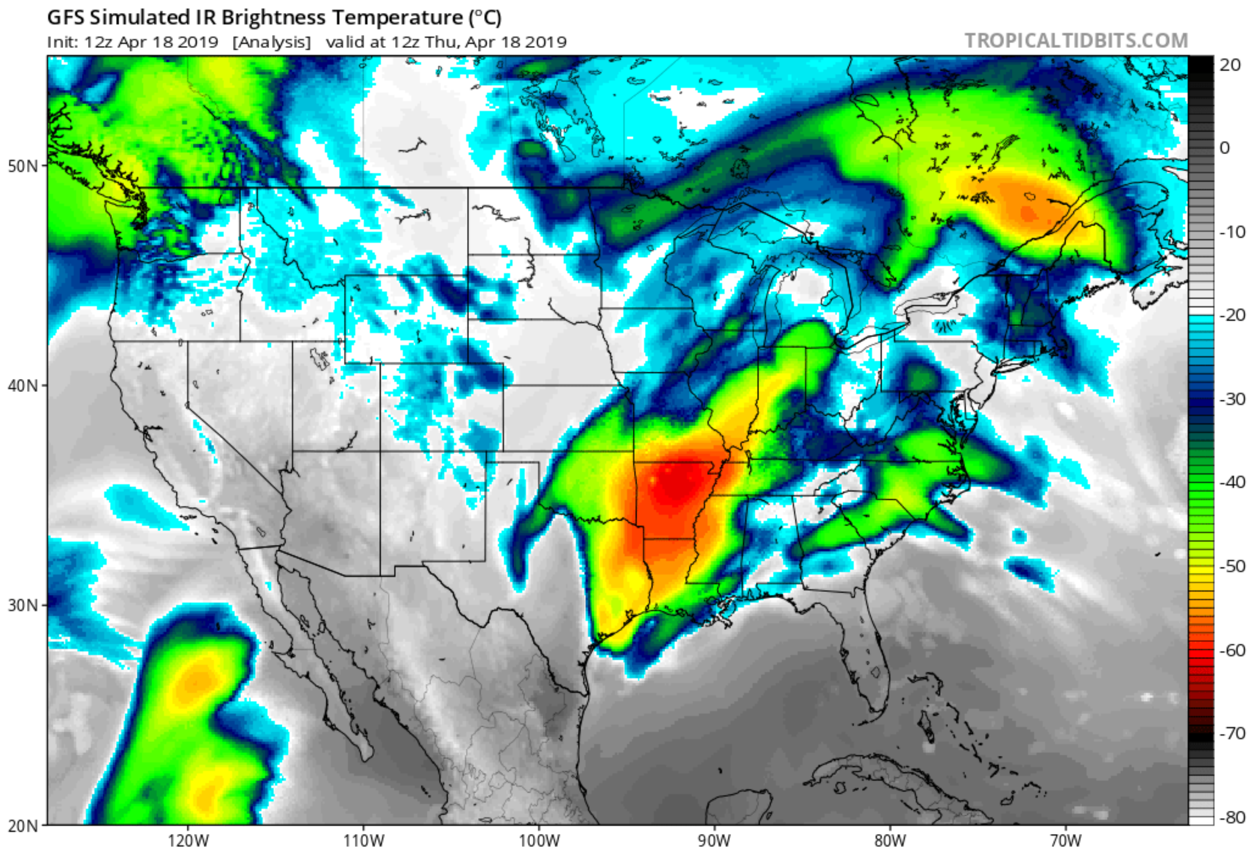

Figure 6. As in Fig. 4, except from the GFS 0-h analysis valid 1200 UTC 18 April 2019.