Synoptic Meteorology II: Potential Vorticity Anomaly Examples

Upper-tropospheric potential-vorticity and surface potential-temperature anomalies are not merely theoretical constructs; rather, they exist in the real atmosphere! In this set of examples, we leverage GFS numerical model analysis and forecast data from Tropical Tidbits to provide real-world documentation of these features.

Positive Isentropic Potential-Vorticity (IPV) Anomalies

Consider the 330-K IPV analysis in Fig. 1. If the dynamic tropopause is given by the 2 PVU isosurface, then the 330-K isentropic surface is within the troposphere wherever there is blue shading and within the stratosphere wherever there is yellow or orange shading.

We are interested in the positive IPV anomaly over the southern Mississippi River valley. A vertical cross-section through this anomaly is given in Fig. 2. Between 500-200 hPa, isentropes are tightly packed in the vertical in the center of the cross-section and less tightly packed in the vertical elsewhere. Further, there is strong cyclonic flow around the region of greater static stability: dashed contours toward B indicate flow into the page, whereas solid contours near A indicate flow out of the page. Together, these match expectations from theory: the positive IPV anomaly is associated with locally large static stability *and* cyclonic rotation.

Negative IPV Anomalies

Consider the 330-K IPV analysis in Fig. 3. We are interested in the negative IPV anomaly over the north-central Atlantic Ocean. A vertical cross-section through this anomaly is given in Fig. 4. Between 400-200 hPa, isentropes are loosely packed in the vertical on the left side of the cross-section and are tightly packed in the vertical on the right side of the cross-section. Further, there is strong flow out of the page – here, indicating westerly flow – in the middle of the cross-section, with very weak flow on the left side of the cross-section. This implies anticyclonic curvature to the flow. Together, these match expectations from theory: the negative IPV anomaly is associated with locally small static stability *and* anticyclonic rotation.

Surface Potential-Temperature Anomalies

Consider the 2-m temperature analysis in Fig. 5. If we assume an approximately flat ground, then the region of warm 2-m temperature in western Africa can be viewed as akin to a warm surface potential-temperature anomaly. A vertical cross-section through this anomaly is given in Fig. 6. Note the absence of isentropes near the surface in the middle of the figure, with tighter packing above ~600 hPa. This implies weak static stability, with a nearly constant potential temperature with height, above the immediate surface. Further in the 800-600 hPa layer, there is flow out of the page to the east, indicating northerly flow, and flow into the page to the west, indicating southerly flow. Together, these match expectations from theory: *above* a warm surface potential-temperature anomaly, the static stability is reduced and the rotation becomes increasingly anticyclonic.

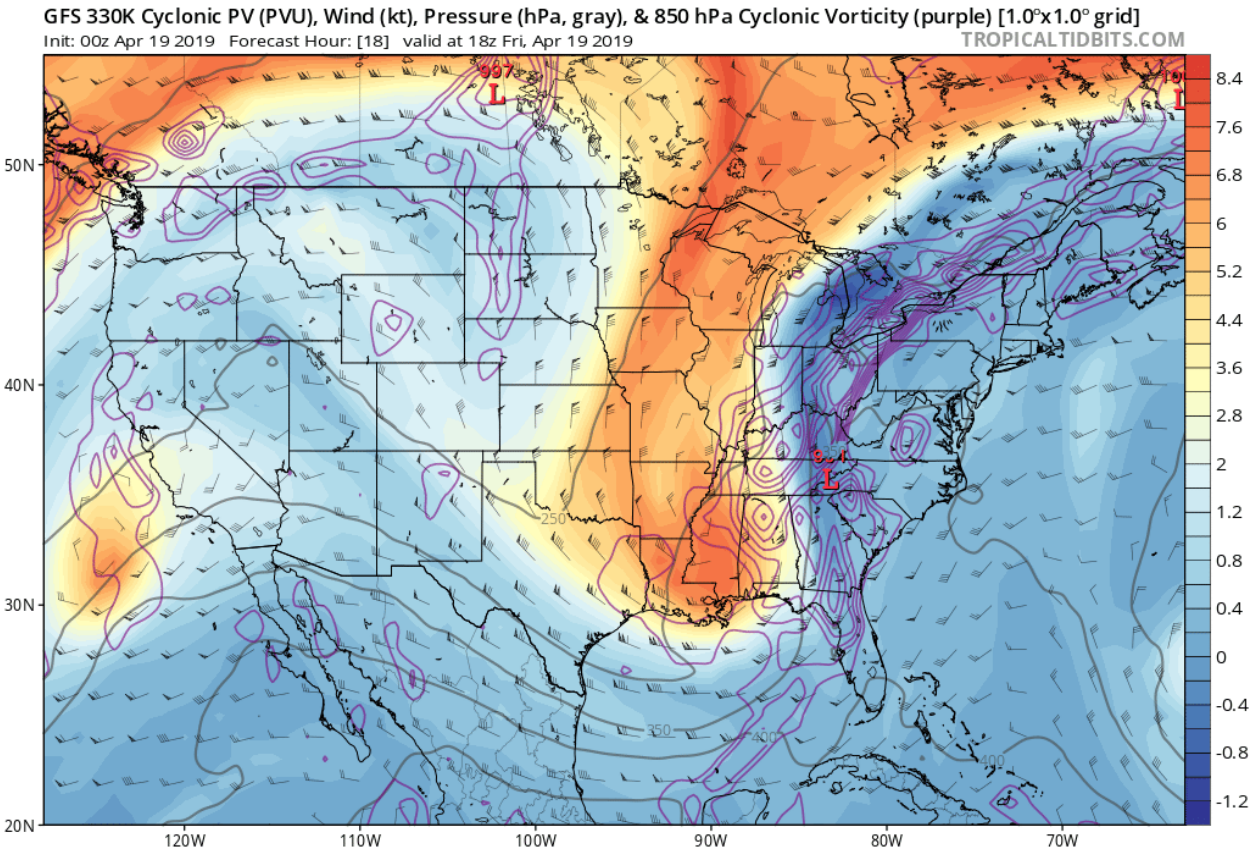

Figure 1. GFS 18-h forecast (valid 1800 UTC 19 April 2019) of 330-K potential vorticity (shaded in PVU per the color bar at right), pressure (grey contours in hPa), and wind (half-barb: 5 kt, full barb: 10 kt, pennant: 50 kt); 850 hPa cyclonic vorticity (purple contours); and cyclonic sea-level pressure anomalies (red markers). Figure obtained from Tropical Tidbits.

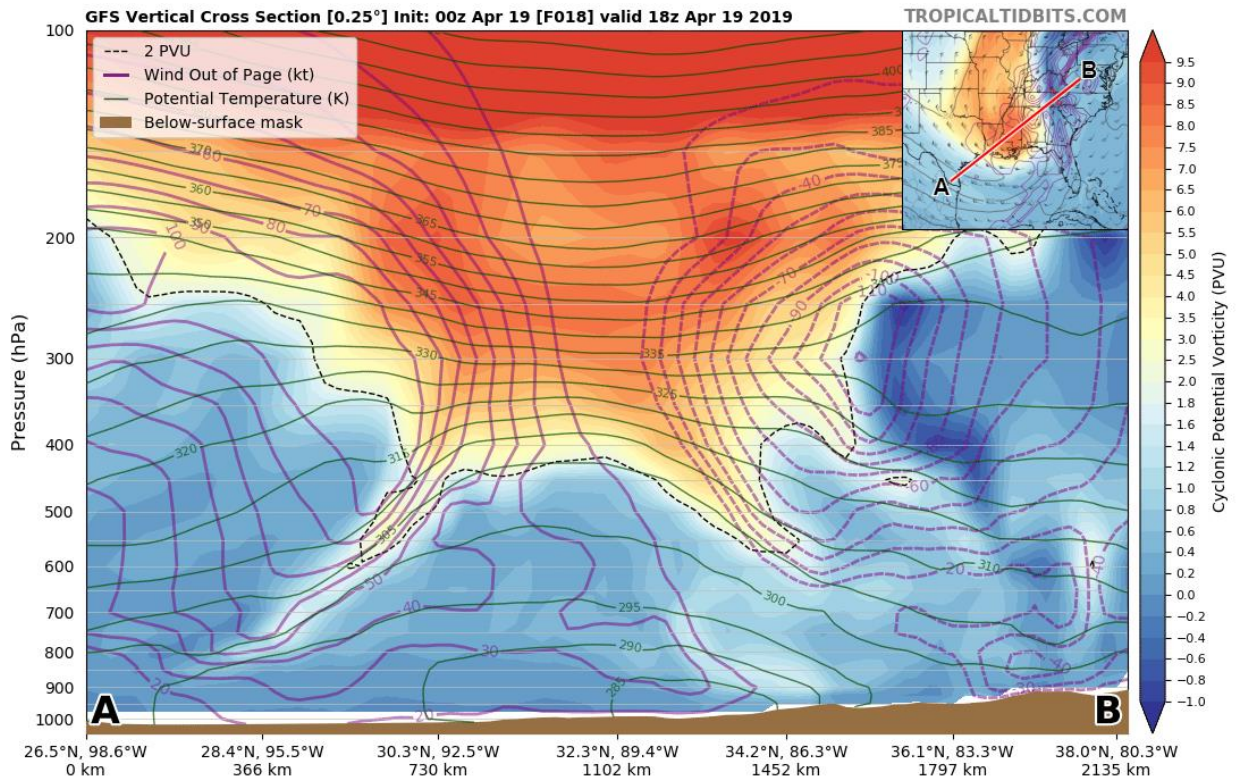

Figure 2. Vertical cross-section along the axis A–B marked in the inset at upper right (which is a zoomed-in view of Fig. 1) of potential vorticity (shaded in PVU per the color bar at right), potential temperature (green contours every 5 K), and the velocity normal to the page (purple contours every 10 kt; positive values indicate flow out of the page and negative values indicate flow into the page) from the GFS 18-h forecast valid 1800 UTC 19 April 2019. The dynamic tropopause, given by the 2 PVU surface, is denoted by the dashed black line. Brown shading at the bottom indicates terrain. Figure obtained from Tropical Tidbits.

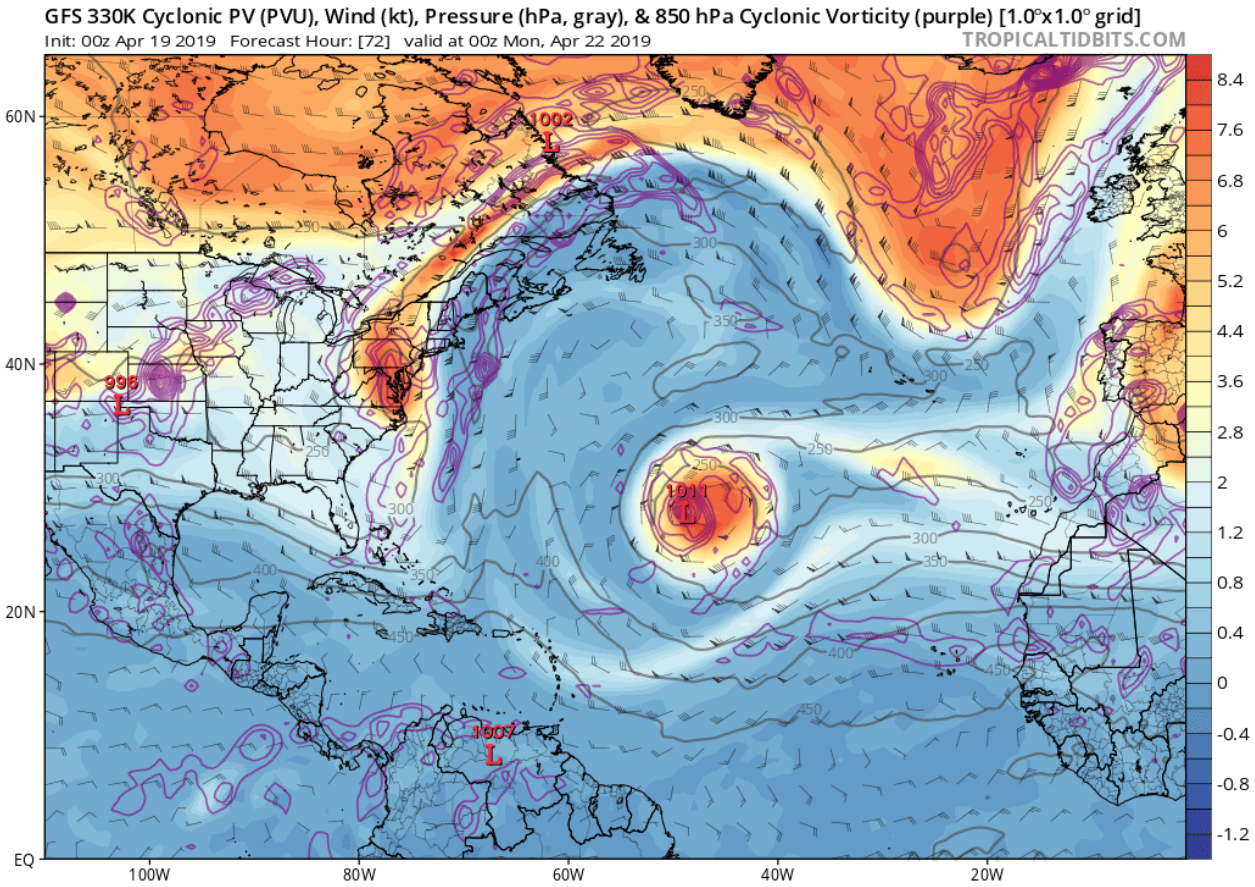

Figure 3. As in Fig. 1, except for the GFS 72-h forecast valid 0000 UTC 22 April 2019.

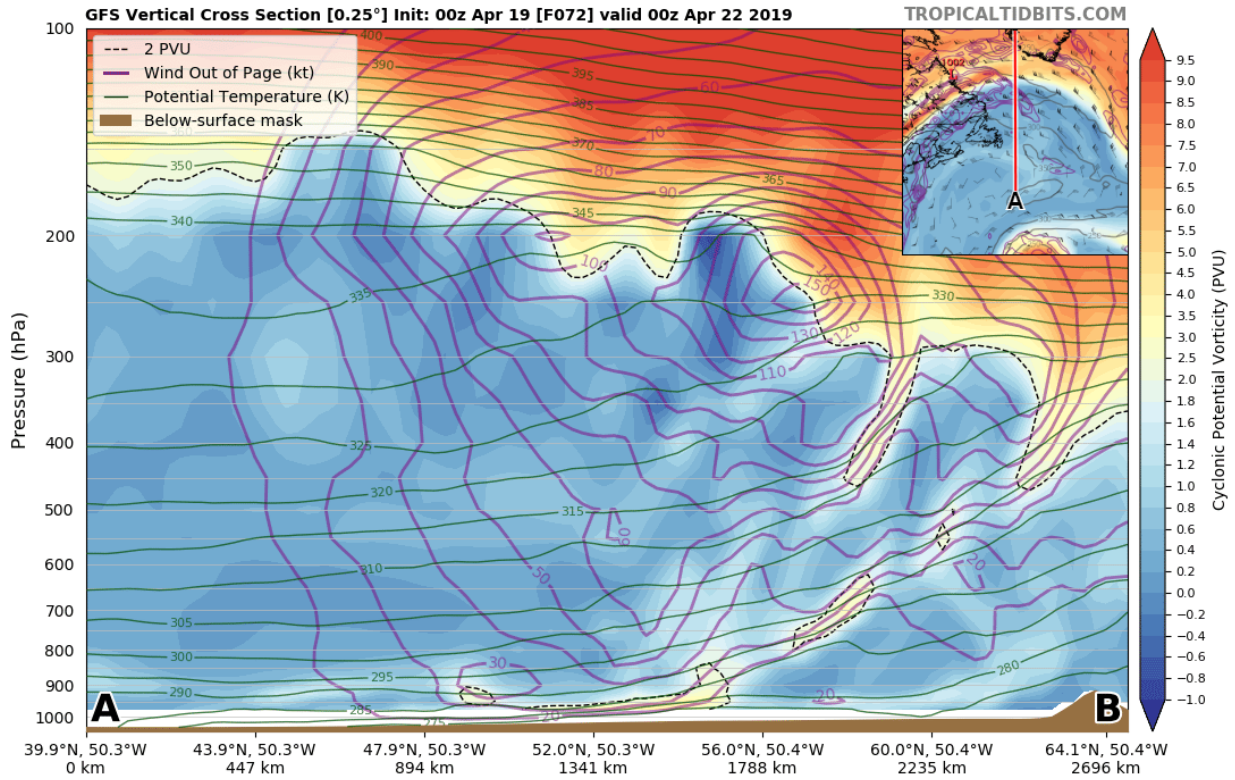

Figure 4. As in Fig. 2, except for the GFS 72-h forecast valid 0000 UTC 22 April 2019 along the axis A–B denoted in the inset at upper right (which is a zoomed-in view of Fig. 3).

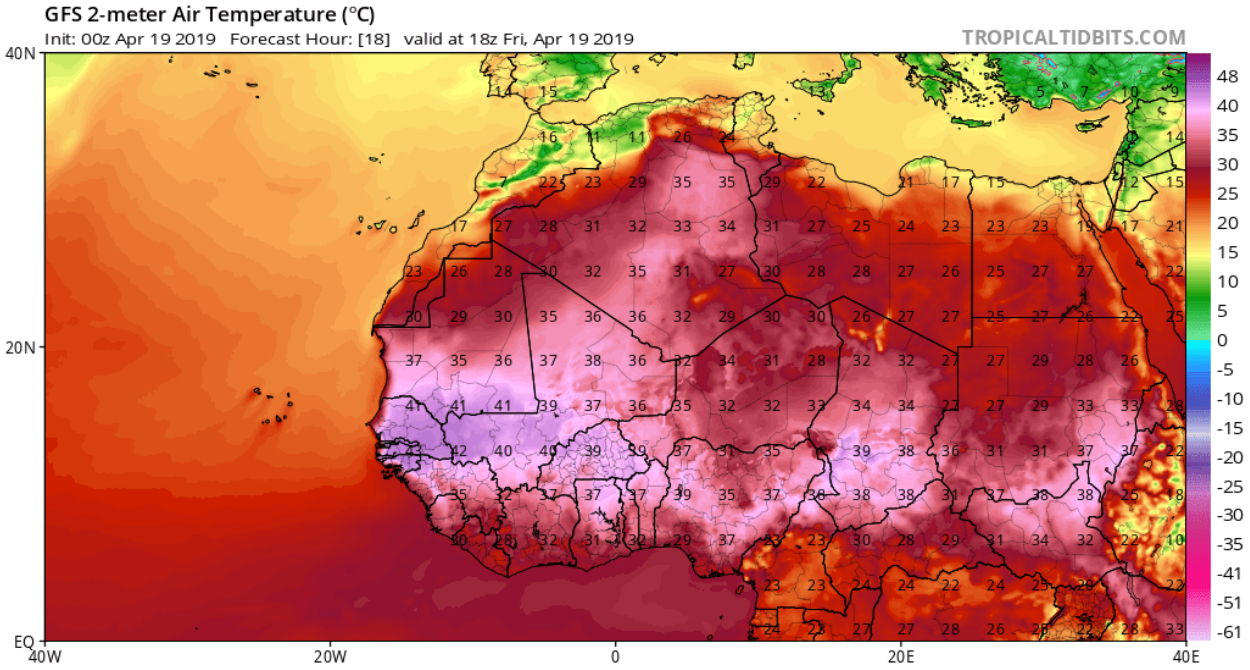

Figure 5. 2-m temperature (shaded in °C per the color bar; values every 3°lat/lon annotated on the figure in black text) from the GFS 18-h forecast valid 1800 UTC 19 April 2019. Figure obtained from Tropical Tidbits.

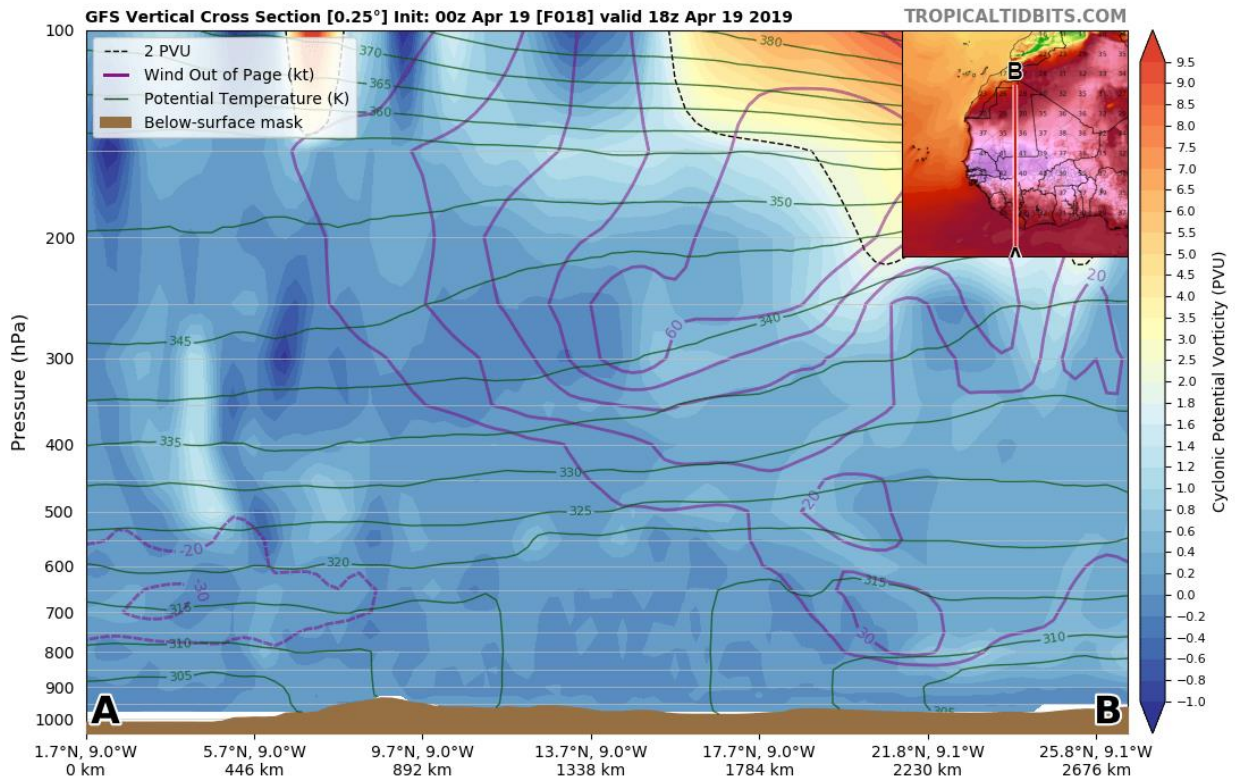

Figure 6. As in Fig. 2, except along the axis A–B denoted in the inset at upper right (which is a zoomed-in view of Fig. 5).