<u>Synoptic Meteorology II: Isentropic Analysis Examples</u>

Potential Temperature as a Vertical Coordinate

On the following pages are three skew *T*, ln *p* diagrams valid at 1200 UTC 1 April 2019 from Green Bay, WI (GRB), Springfield, MO (SGF), and Brownsville, TX (BRO). We can envision potential temperature as the vertical coordinate by choosing an isentropic surface of interest and interpolating the data from the skew *T*, ln *p* diagrams to that surface.

Let us consider the 300 K isentropic surface. By definition, a potential temperature of 300 K means that the 1000 hPa temperature must be 300 K = 27°C. Thus, we start at a temperature of 27°C at 1000 hPa. Next, we ascend along a dry adiabat, along which potential temperature is constant, until intersecting the observed temperature trace. This occurs at approximately 550 hPa, 650 hPa, and 800 hPa at GRB, SGF, and BRO, respectively. Thus defines the altitude of the 300-K isentropic surface at these locations. The wind and the mixing ratio of the sounding at these altitudes thus corresponds to their respective values on the 300-K isentropic surface.

If we follow this process at a wide range of locations, whether using observations or model data, we can construct the 300 K isentropic surface.

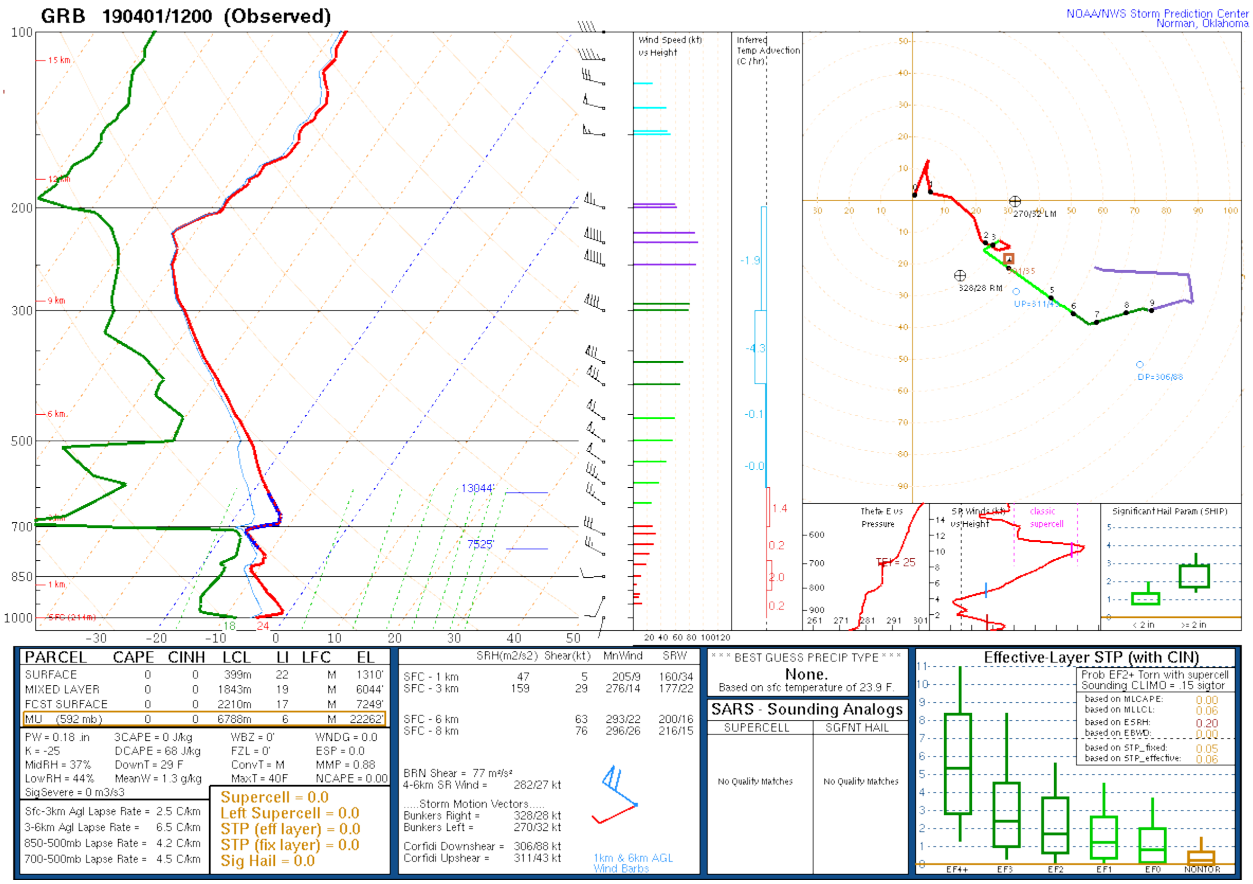

Figure 1. Skew *T*, ln *p* diagram at 1200 UTC 1 April 2019 from Green Bay, WI (GRB), obtained from the Storm Prediction Center (https://www.spc.noaa.gov/exper/soundings/).

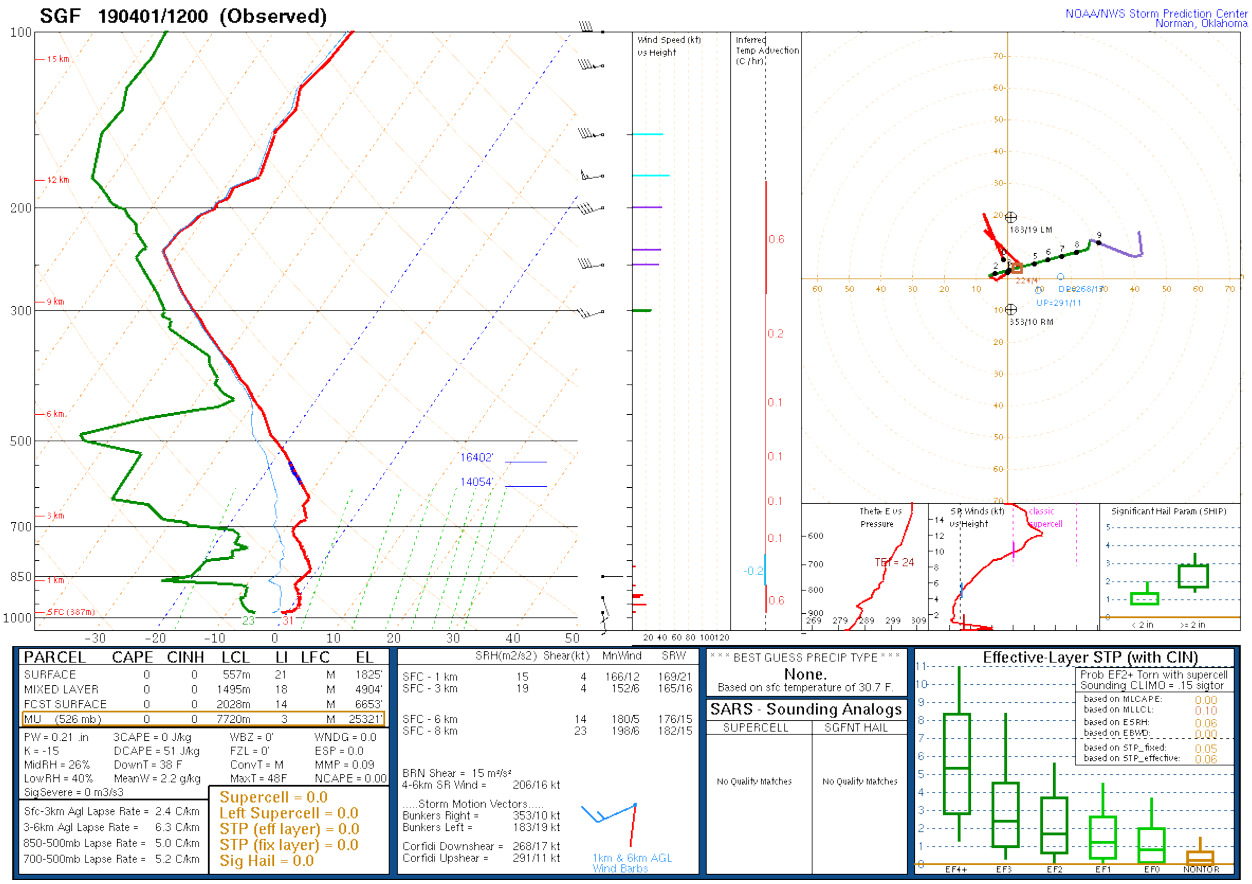

Figure 2. As in Fig. 1, except from Springfield, MO (SGF).

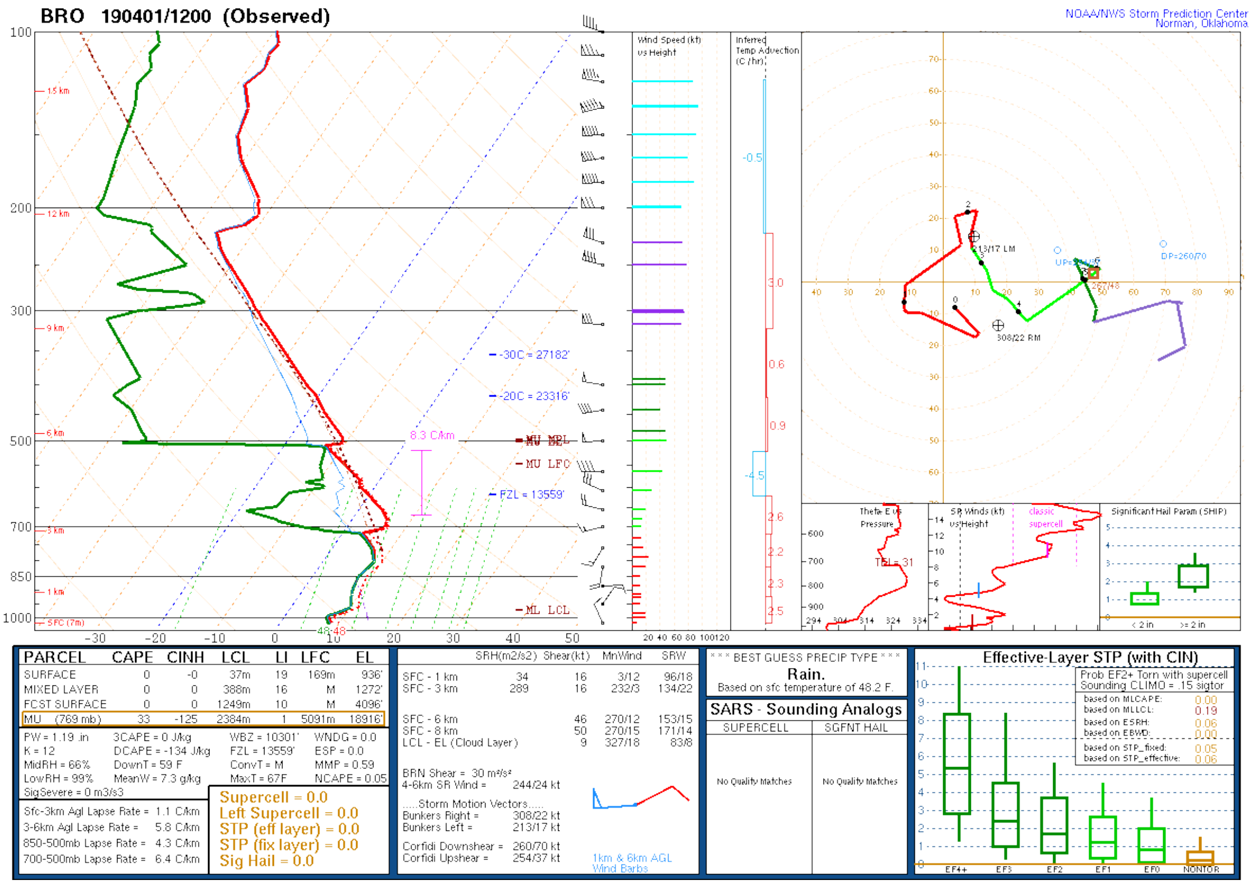

Figure 3. As in Fig. 1, except from Brownsville, TX (BRO).

General Comments

There are a few basic tenets of note when it comes to potential temperature as a vertical coordinate:

- Except in the rare instances where the observed lapse rate exceeds the dry adiabatic lapse rate, potential temperature either increases or remains constant with increasing height. We can see this in Figs. 1-3 above.
- Potential temperature increases most rapidly with height through an inversion. We can see this near 700 hPa at GRB (Fig. 1) and near 500 hPa and 700 hPa at BRO (Fig. 3).
- Potential temperature slowly increases or remains constant with increasing height when the lapse rate is nearly dry adiabatic. We can see this in the 950-850 hPa layer at GRB (Fig. 1) and in the 650-525 hPa layer at BRO (Fig. 3).
- At any given *pressure*, potential temperature is largest where it is warm and smallest where it is cold. For instance, consider 850 hPa in Figs. 1-3 above. The observed temperatures are -10°C, -1.5°C, and 8.5°C at GRB, SGF, and BRO, respectively. These lead to potential temperatures of approximately 276 K, 285 K, and 295 K, respectively.
- At any given *potential temperature*, pressure is largest where it is warm and smallest where it is cold. This is illustrated for Figs. 1-3 on the first page of these notes.

Correspondence between Adiabatic Omega and QG Omega

The following images from 1200 UTC 1 April 2019 document the correspondence between the adiabatic omega obtained from isentropic analysis principles and the omega obtained from quasi-geostrophic principles. In each, focus just offshore from Washington and Oregon.

The 298 K isentropic surface (Fig. 4) is found at increasingly low pressure as you move northward along the United States west coast; west of Oregon, it is at 775-675 hPa. Here, the wind is partially directed across the isobars with a component from high toward low pressure, implying adiabatic forcing for ascent. Similarly, if we look at the total right-hand-side forcing from the QG omega equation (Fig. 5) or the Q-vector formulation thereof (Fig. 6), we find forcing for ascent as well. Given the presence of an upstream shortwave trough (Figs. 5-6) with geostrophic flow from warm toward cold air (Fig. 6), we can infer that both differential cyclonic vorticity advection and warm potential temperature advection contribute to the quasi-geostrophic forcing for ascent.

It should be emphasized, though, that these are *not* different forcings for ascent – rather, they are different ways of *conceptualizing* a single forcing for ascent!

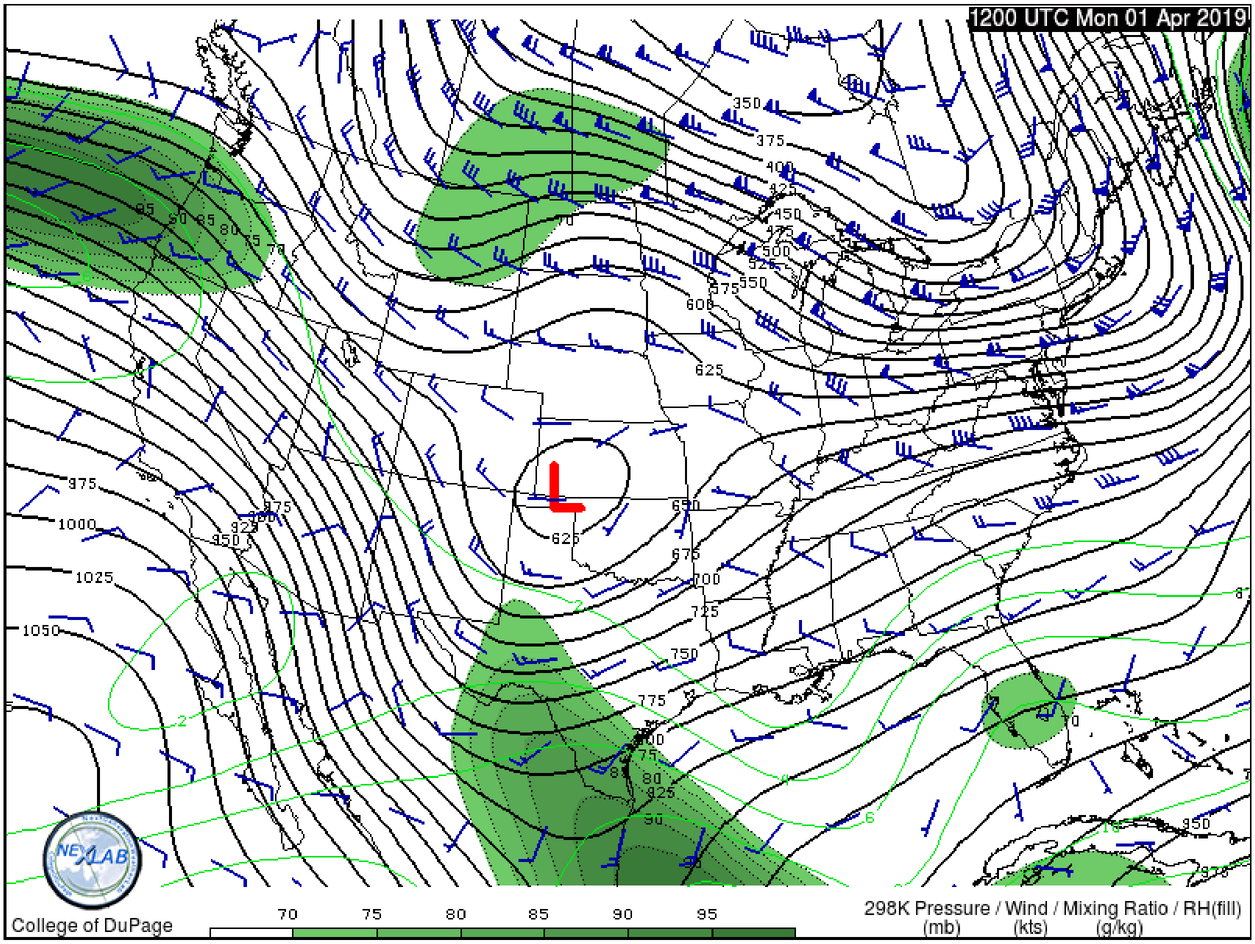

Figure 4. 298-K pressure (black contours every 25 hPa), wind (barbs; half-barb: 5 kt, full barb: 10 kt, pennant: 50 kt), mixing ratio (green contours every 1 g kg^{-1} starting at 2 g kg^{-1}), and relative humidity (shaded in % per the color bar) at 1200 UTC 1 April 2019, obtained from the College of DuPage (https://weather.cod.edu/analysis/).

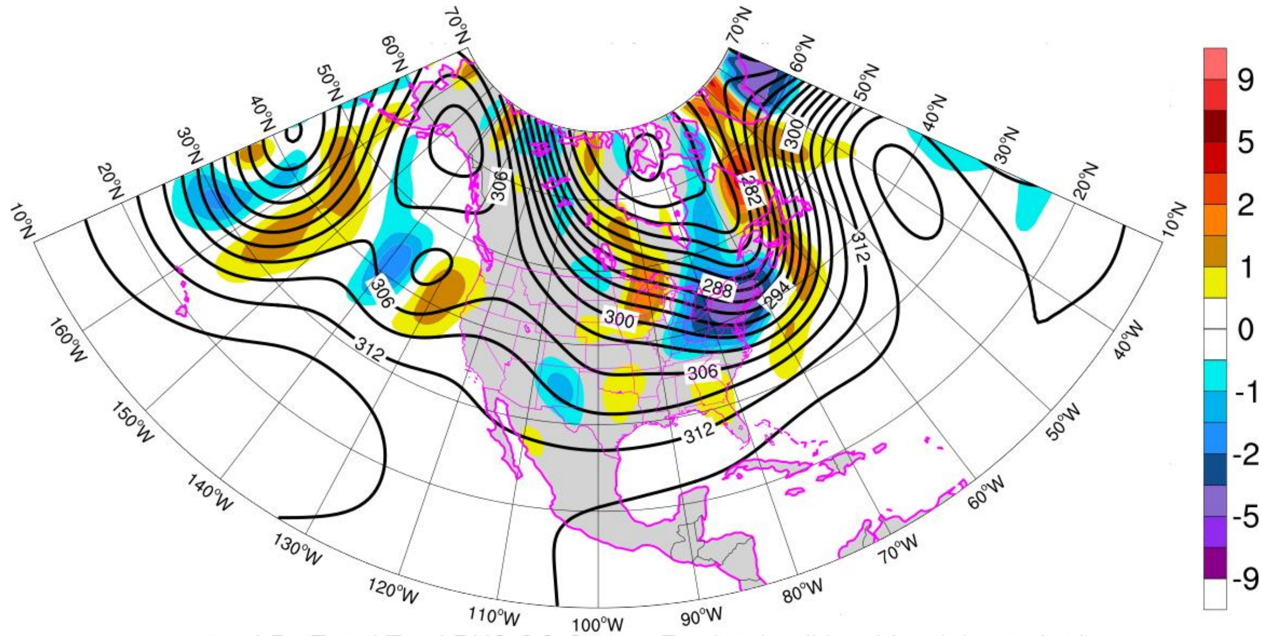

Figure 5. 700 hPa geopotential height (black contours every 30 m = 3 dam) and total forcing from the right-hand-side of the quasi-geostrophic omega equation (shaded per the color bar at right, with positive values indicating forcing for ascent; units: x10^{-12} Pa m^{-2} s^{-1}) at 1200 UTC 1 April 2019, obtained from https://inside.nssl.noaa.gov/tgalarneau/real-time-qg-diagnostics/.

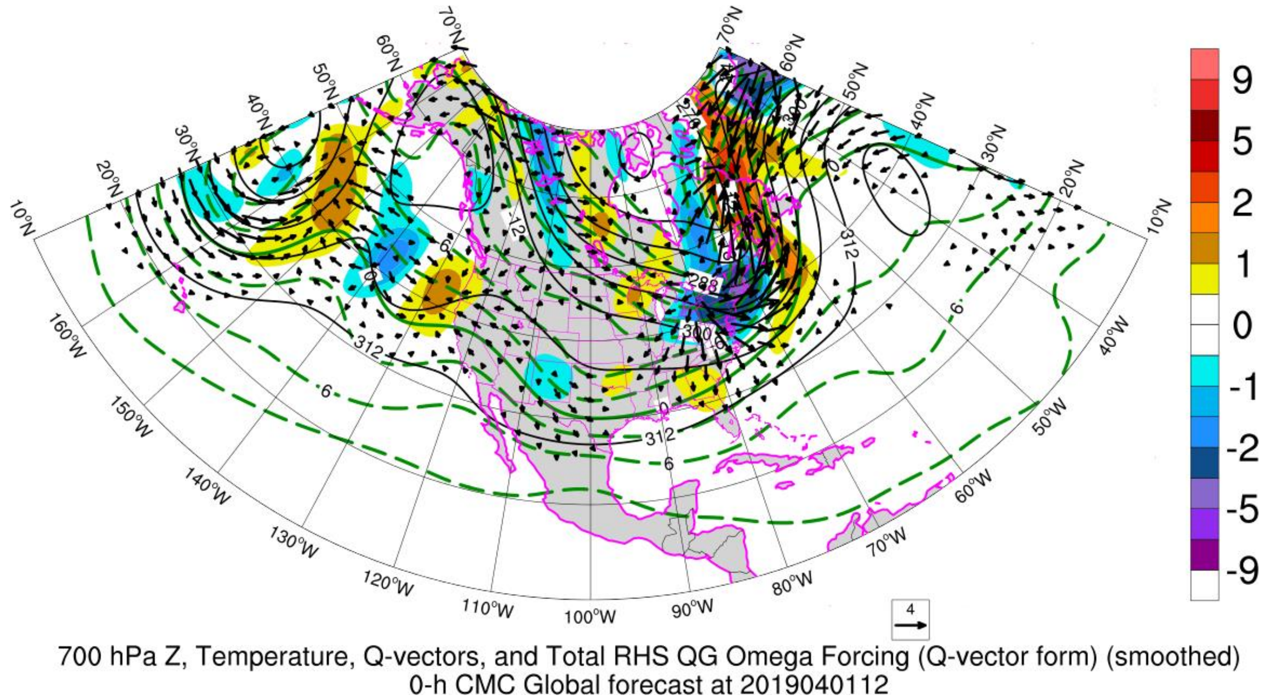

Figure 6. 700 hPa geopotential height (black contours every 30 m = 3 dam), temperature (green contours every 3°C), Q-vectors (black vectors; reference vector at bottom; units: x10^{-7} Pa m^{-1} s^{-1}), and Q-vector convergence (shaded per the color bar at right, with positive values indicating forcing for ascent; units: x10^{-12} Pa m^{-2} s^{-1}) at 1200 UTC 1 April 2019, obtained from obtained from https://inside.nssl.noaa.gov/tgalarneau/real-time-qg-diagnostics/.