Synoptic Meteorology I: Thermal Wind Applications

The thermal wind allows us to state that a geostrophic wind that turns counterclockwise (or backs) with increasing height represents *cold air advection*, whereas a geostrophic wind that turns clockwise (or veers) with increasing height represents *warm air advection*. We now wish to apply this theory to some selected real-world examples. Note that in the following we make two common approximations:

- We approximate virtual temperature with temperature. This does not generally change the qualitative interpretation and only has a significant quantitative impact near the surface if water vapor mixing ratio is large.
- We approximate the geostrophic wind with the full wind. This may not be appropriate near the surface or in strongly curved flow, but this generally does not impact the qualitative interpretation except in extreme cases.

We first examine two soundings from the southeastern United States, one at Nashville, TN (BNA; Fig. 1) and one at Charleston, SC (CHS; Fig. 2). Below 800 hPa, both soundings exhibit strongly veering wind profiles, where the wind direction turns clockwise with increasing height. This implies warm air advection from the surface to 800 hPa. To verify this, we look at a 925 hPa analysis valid at the same time as the observations (Fig. 3).

At Nashville, the 925 hPa wind is out of the southwest at approximately 50 kt. It is nearly parallel to the 925 hPa height contours, suggesting that the full wind is a good proxy for the geostrophic wind at this level. The wind is nearly perpendicular to the isotherms, with the wind blowing from warm toward cold air. This signifies warm air advection, responsible in part for the near-surface inversion on the observed Nashville sounding.

At Charleston, the 925 hPa wind is out of the south-southeast at approximately 15 kt. It is not as well aligned with the 925 hPa height contours as at Nashville, although the contour analysis over water is dubious at best (and entirely model-derived) given a lack of rawinsonde observations to support the analysis. Regardless, the wind is again nearly perpendicular to the isotherms, with the wind blowing from warm toward cold air. This signifies warm air advection. Here, too, there is a near-surface inversion present on the observed Charleston sounding, although it is not as strong as at Nashville.

We now examine two soundings from the northeastern United States and southeastern Canada, one at Albany, NY (ALB; Fig. 4) and one at Maniwaki, Quebec (CWMW; Fig. 5). In the 850-700 hPa layer, both soundings exhibit subtly backing wind profiles, where the wind direction turns counterclockwise with increasing height. This implies cold air advection in this layer. To verify this, we look at an 850 hPa analysis (Fig. 6) valid at the same time as the sounding observations.

At Albany, the 850 hPa wind is out of the northwest at approximately 30 kt. It is nearly parallel to the 850 hPa height contours, suggesting that the full wind is a good proxy for the geostrophic wind. The wind is nearly perpendicular to the isotherms, with the wind blowing from cold toward warm air, signifying cold air advection. At Maniwaki, the 850 hPa wind is out of the west-northwest at approximately 30 kt. It is also nearly parallel to the 850 hPa height contours, suggesting that the full wind is a good proxy for the geostrophic wind. The temperature gradient in this region is light; however, the wind is directed from cold toward warm air, signifying weak cold air advection.

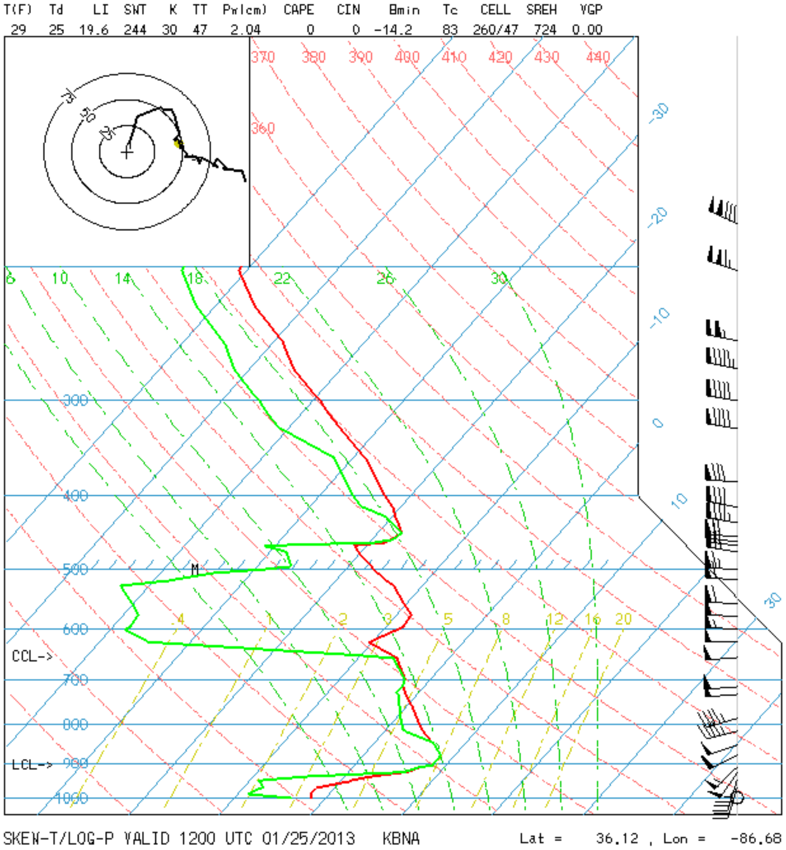

Figure 1. Nashville, TN (BNA) skew-*T*, ln-*p* diagram valid at 1200 UTC 25 January 2013. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.

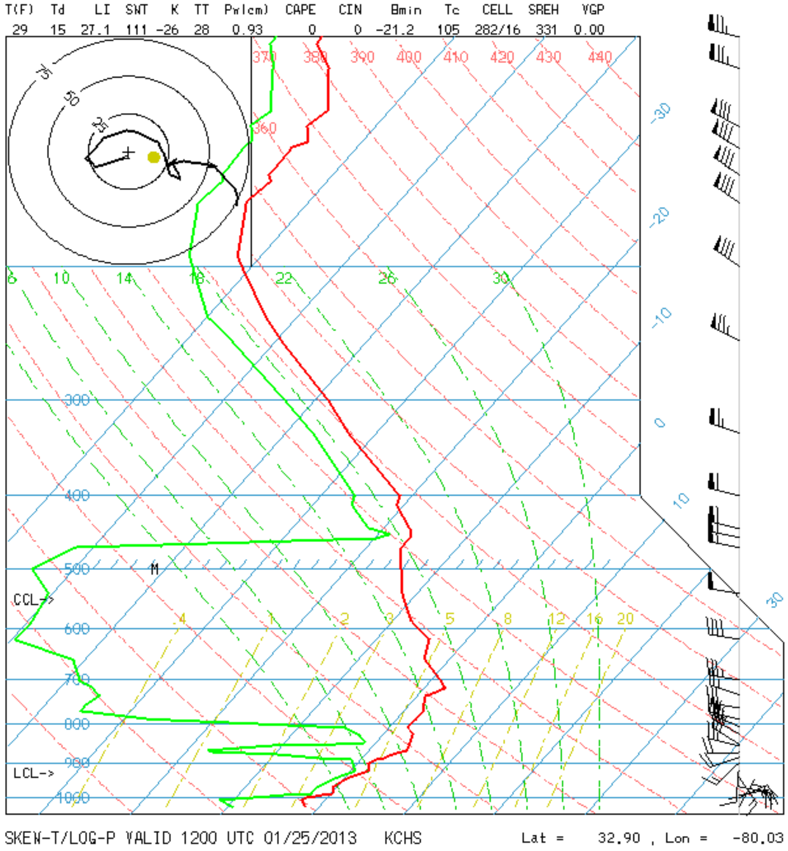

Figure 2. Charleston, SC (CHS) skew-*T*, ln-*p* diagram valid at 1200 UTC 25 January 2013. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.

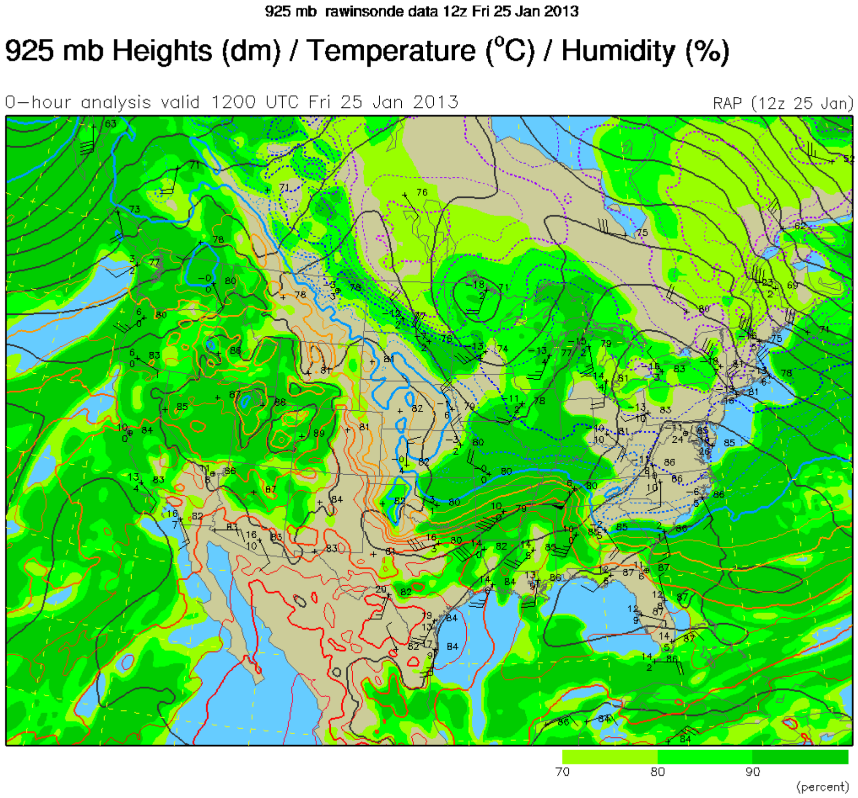

Figure 3. 925 hPa 0-h RAP analysis valid at 1200 UTC 25 January 2013. Depicted: height (black contours, dam), isotherms (colored contours, °C), and relative humidity (shaded, %). Observed upper air observations are depicted by the station plots. The station plot convention used in this image has temperature (°C) at upper left, dew point depression (°C) at lower left, height (dam) at upper right, and winds (barb; half: 5 kt, full: 10 kt, flag: 50 kt) at the origin. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.

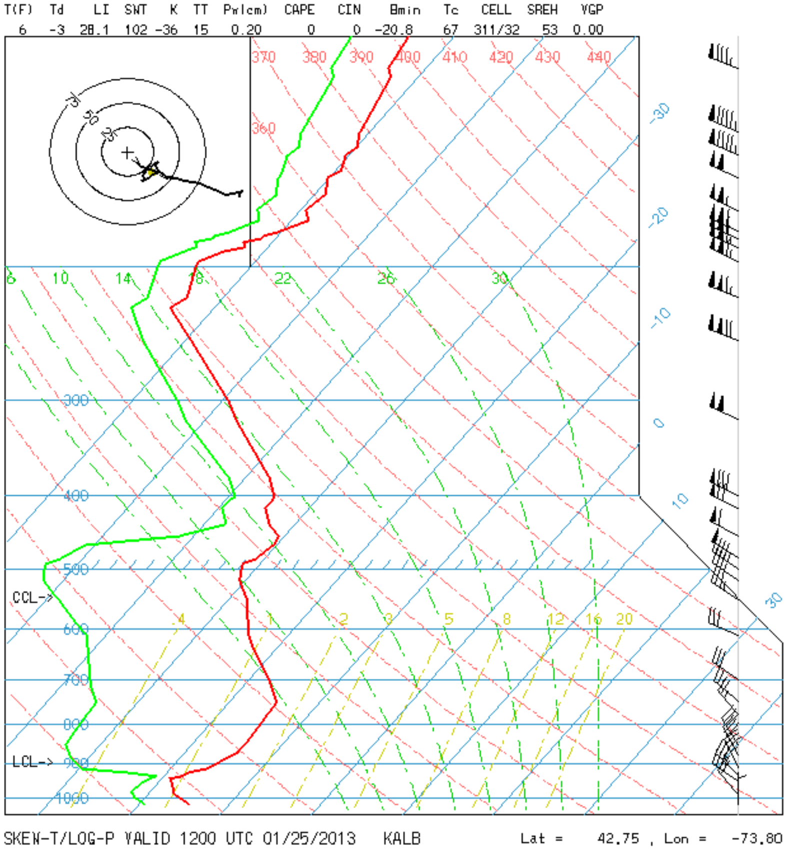

Figure 4. Albany, NY (ALB) skew-*T*, ln-*p* diagram valid at 1200 UTC 25 January 2013. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.

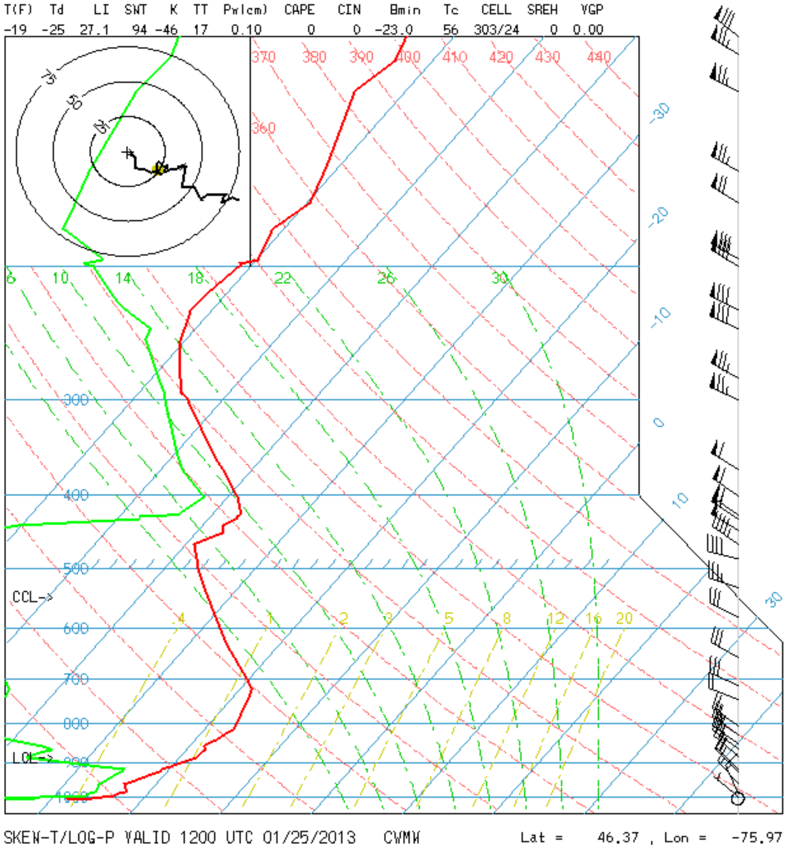

Figure 5. Maniwaki, QC (CWMW) skew-*T*, ln-*p* diagram valid at 1200 UTC 25 January 2013. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.

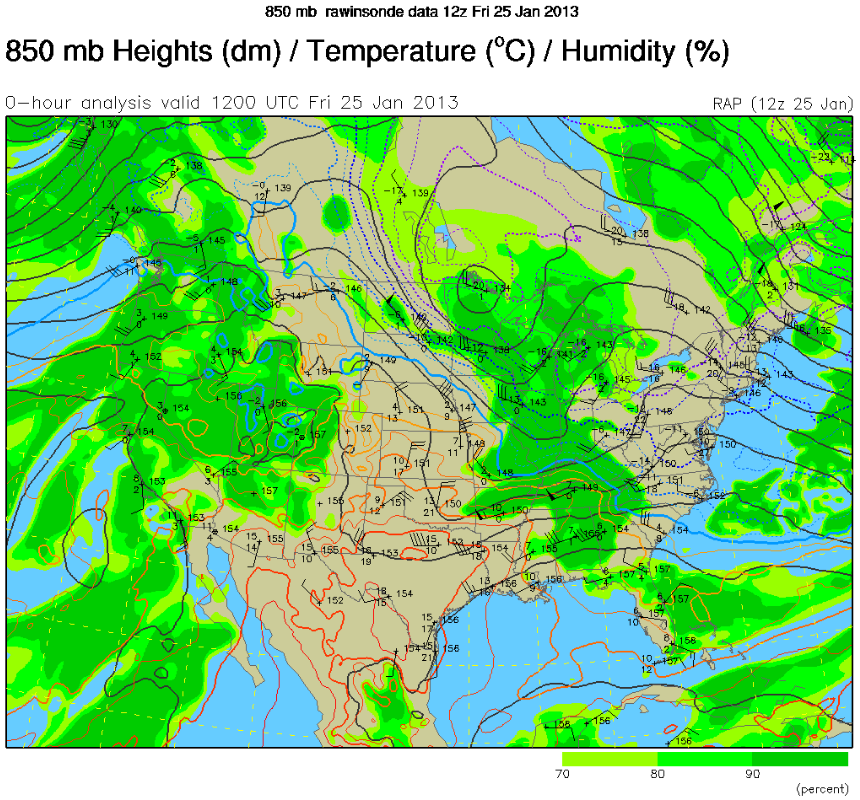

Figure 6. 850 hPa 0-h RAP analysis valid at 1200 UTC 25 January 2013. Depicted: height (black contours, dam), isotherms (colored contours, °C), and relative humidity (shaded, %). Observed upper air observations are depicted by the station plots. The station plot convention used in this image has temperature (°C) at upper left, dew point depression (°C) at lower left, height (dam) at upper right, and winds (barb; half: 5 kt, full: 10 kt, flag: 50 kt) at the origin. Image Credit: NCAR/RAL Real-Time Weather Page, http://weather.rap.ucar.edu/upper/.