The Relationship between Stratospheric Polar Vortex Distortions and Tropospheric Cold-Air Surges

Stephen J. Colucci

Cornell University

Lower tropospheric cold-air anomalies can precede (Eurasia) and follow (North America) Stratospheric Sudden Warming (SSW) onsets (Kolstad et al., QJRMS, 2010)

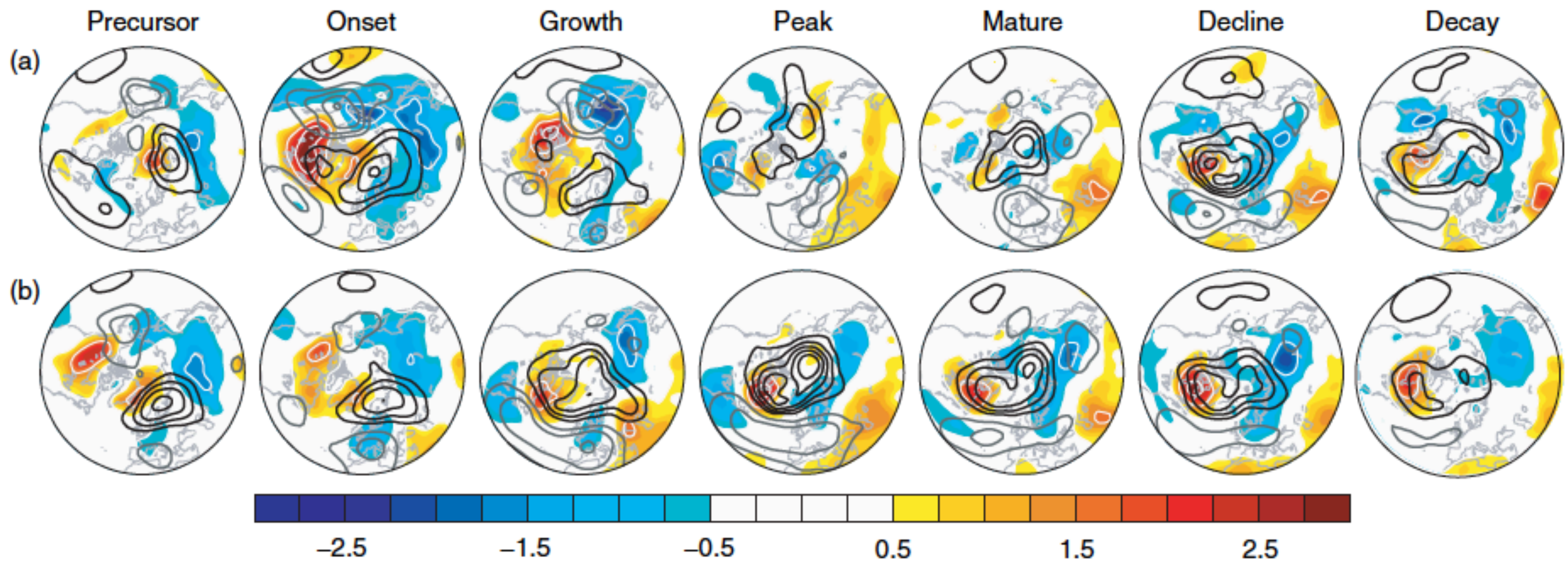


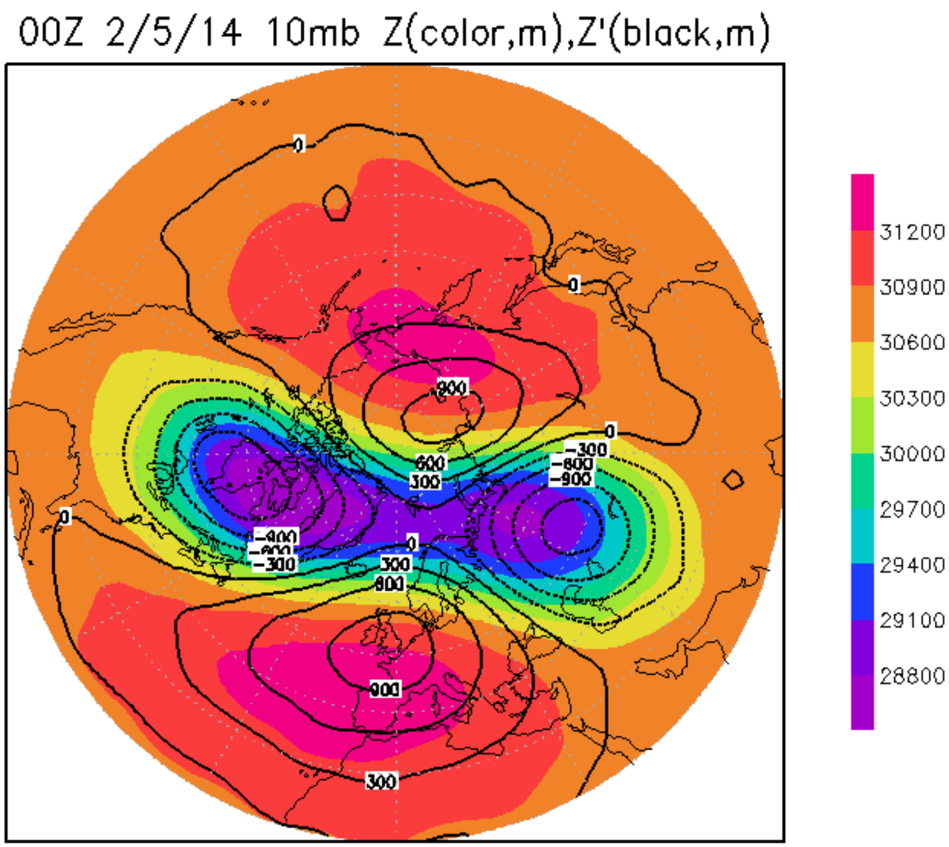
Figure 2. Composites of 850 hPa geopotential height anomalies (in m with solid contours, positive in black, negative in grey, contour interval 10 m, zero contour omitted) and 850 hPa temperature anomalies (in K with filled contours, with white contours along the values specified on the colour bar) relative to (a) SSW central dates and (b) WVDs, averaged over the specified time intervals. The region shown is the Northern Hemisphere north of 30°N, with Eurasia to the right and North America to the left.

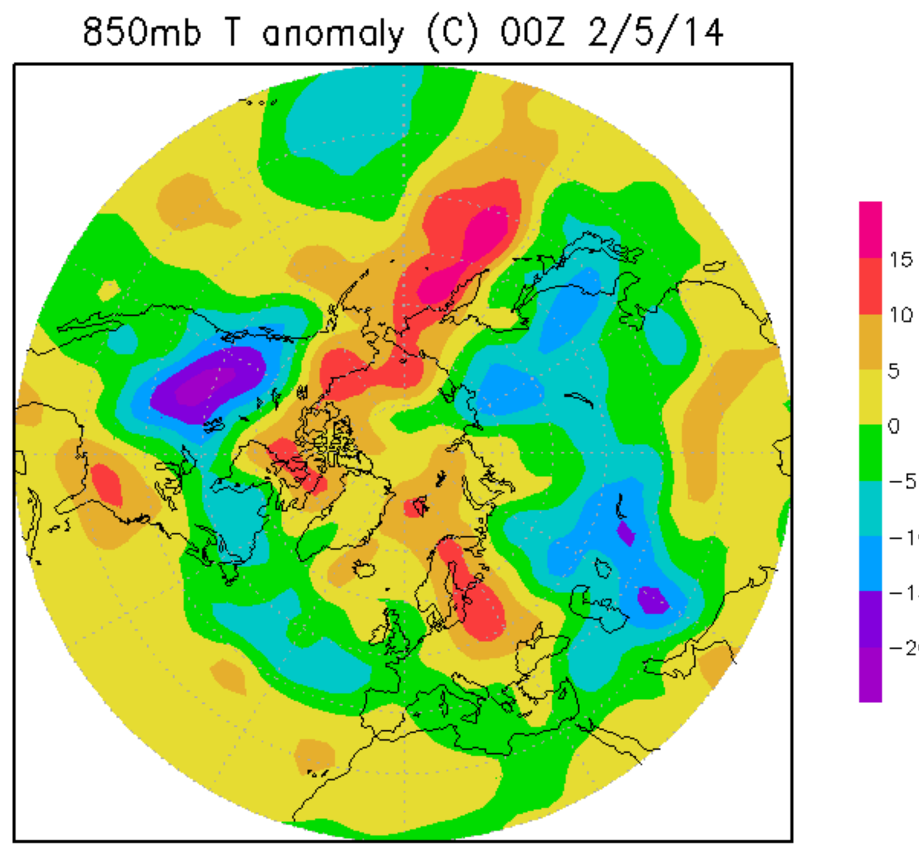
With SSW central (onset) date defined as Day 0, the Growth period is an average over days -1 through -15, while the Peak period is an average over days 0 through 14.

Observation and a Question

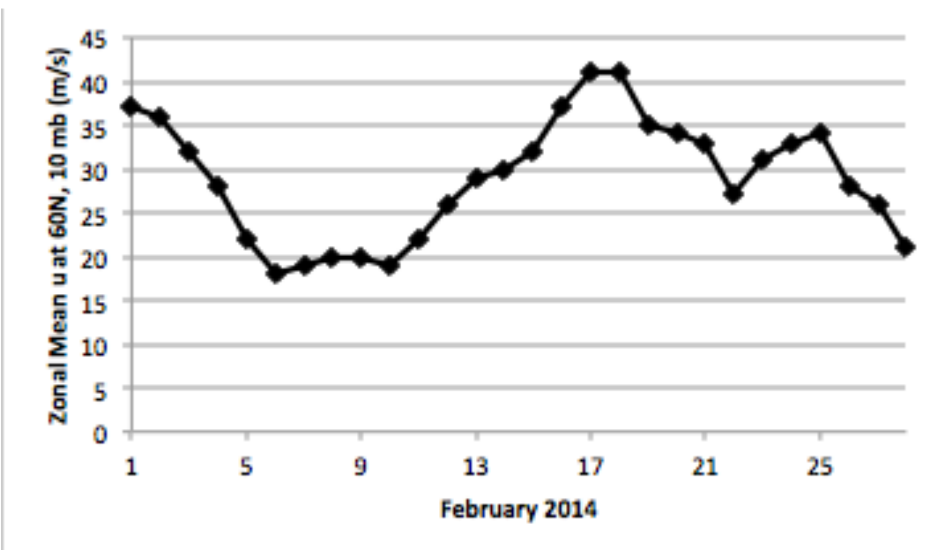
- High-latitude, stratospheric warming can force stratospheric polar vortex distortions, such as SSWs (e.g. Colucci and Kelleher, JAS 2015 and references therein).
- Can lower latitude, tropospheric cooling also force stratospheric polar vortex distortions?
- Examine processes during the winter of 2013-2014 as a pilot study.

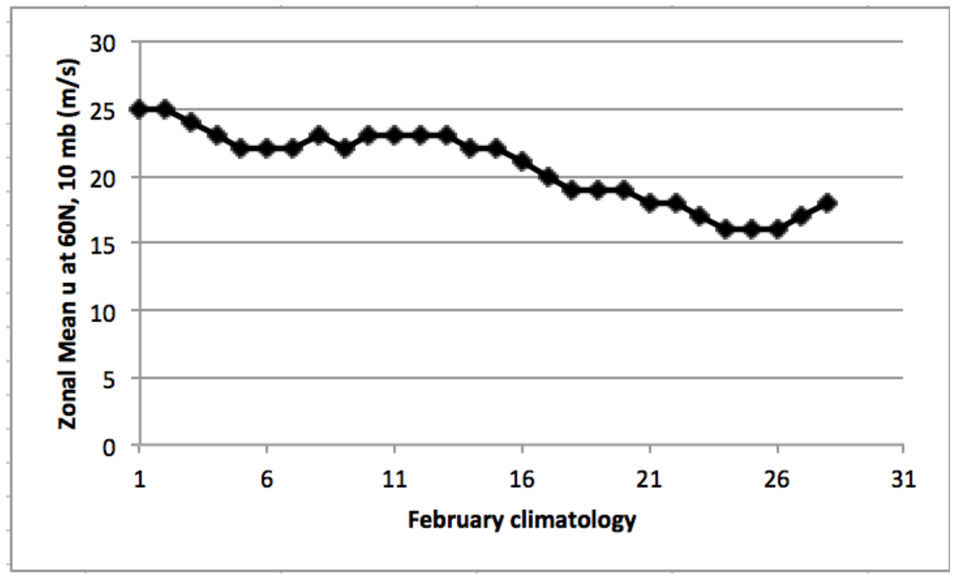
Near-split 10-mb polar vortex and anomalously cold 850-mb temperatures over North America on 0000 UTC 5 February 2014



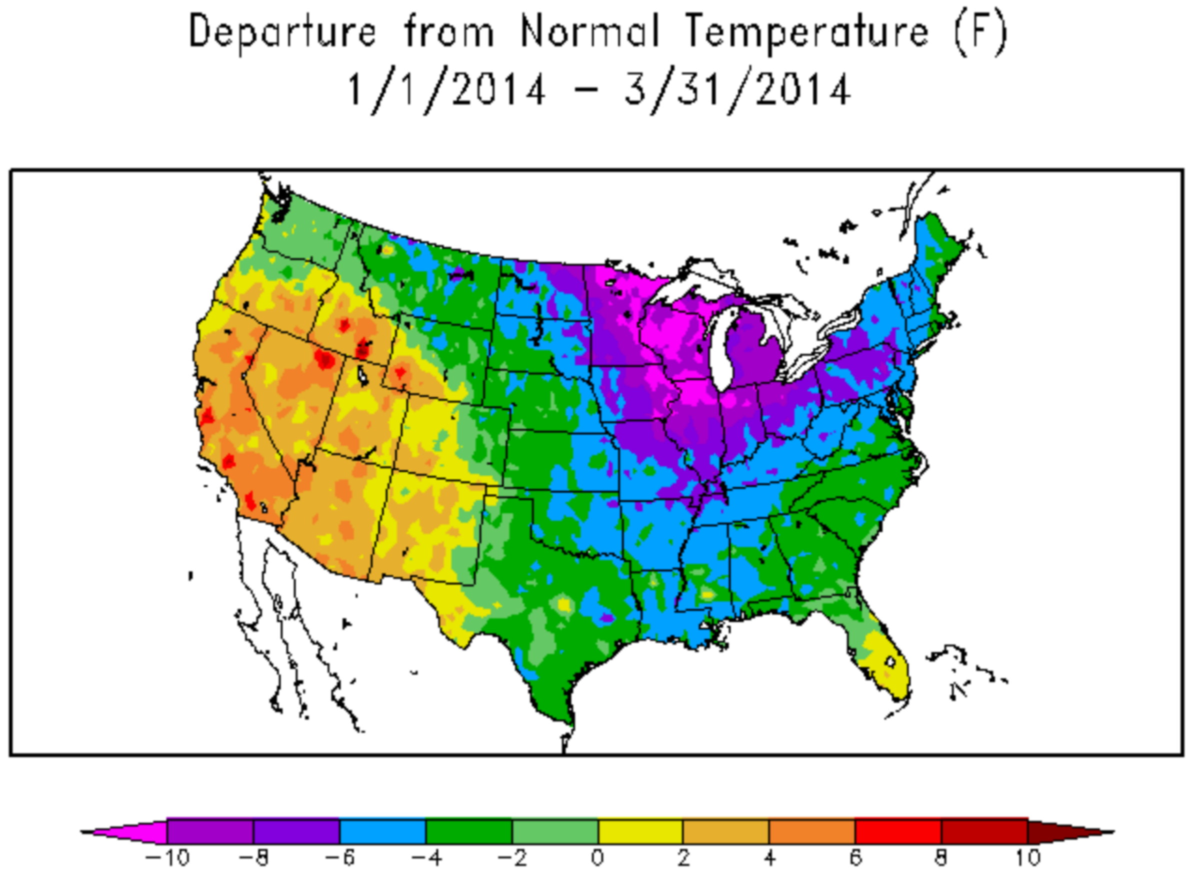


Below normal zonal mean westerlies at 60N, 10mb
6 - 10 February 2014
(but does not meet criterion for a SSW)

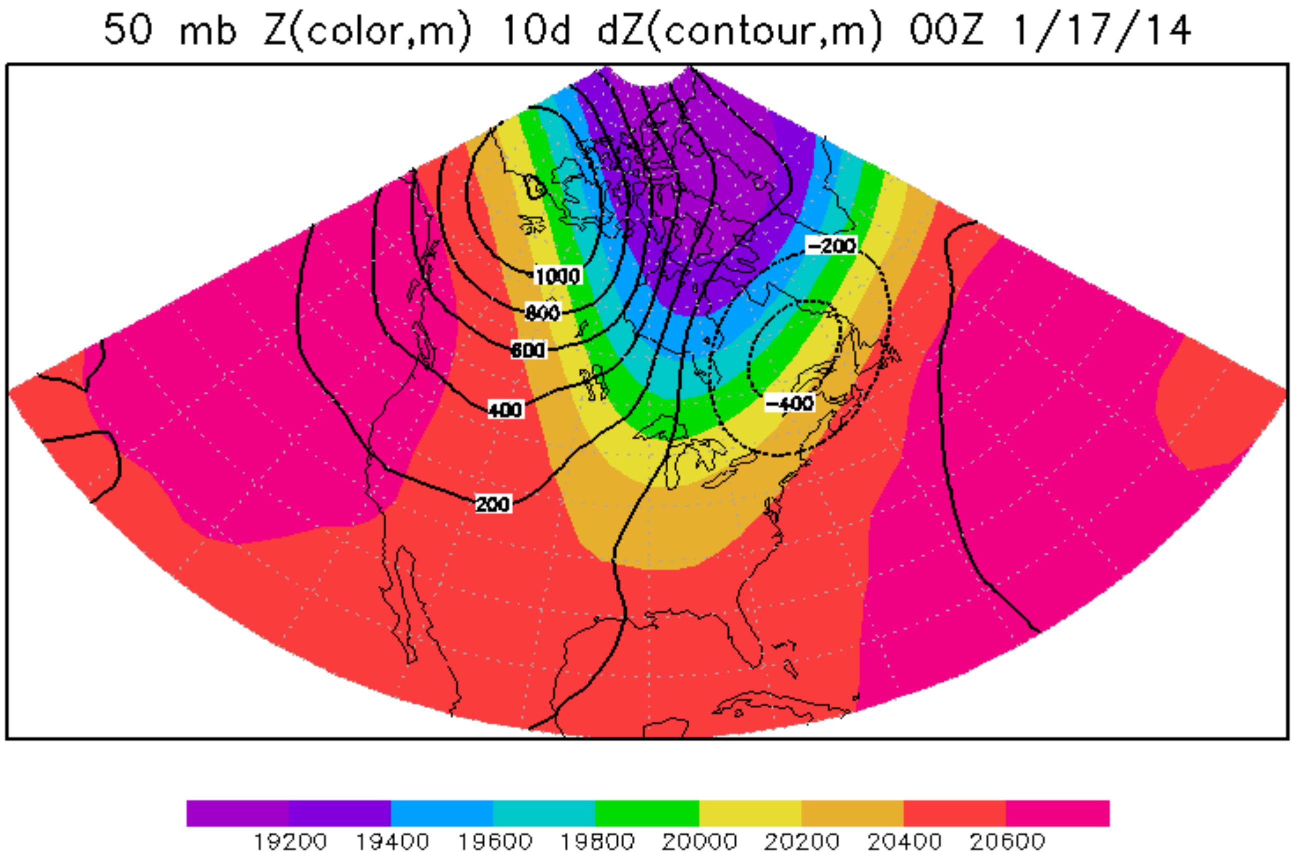




Surface temperature anomaly (F) averaged over 1 January – 31 March 2014



Geopotential height at 50 mb (colors, m) on 0000 UTC 17 January 2014 and change in 50-mb height from 12 – 22 January 2014 (contours, m)



Investigate stratospheric geopotential height changes with potential vorticity inversion applied to NCEP/NCAR Reanalysis data

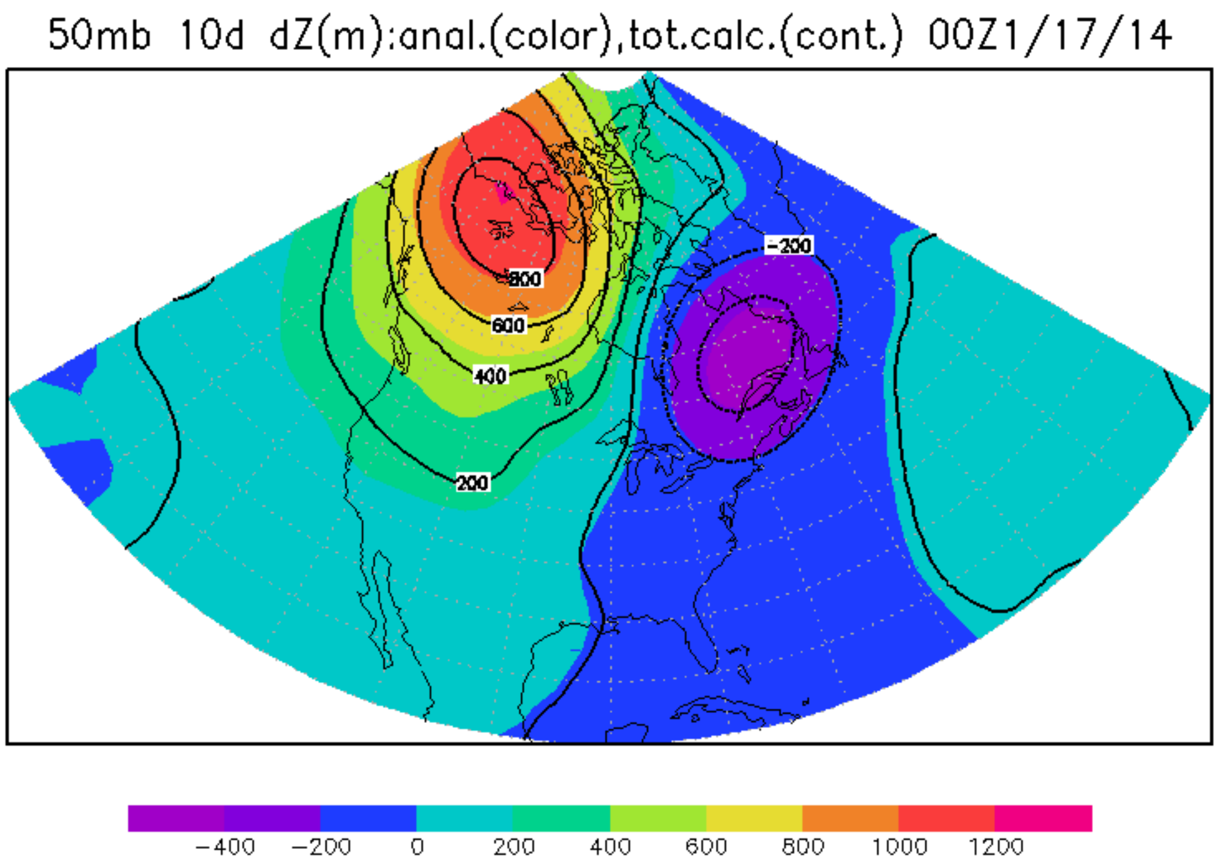
$$q = \eta_g + \frac{\partial}{\partial P}\left[\frac{f_0 g}{\sigma}\left(\frac{\partial Z}{\partial P}\right)\right] = q_V + q_T$$

$$= \frac{g}{f_0}\nabla^2 Z + f - \frac{\partial}{\partial P}\left[\frac{f_0 RT}{\sigma P}\right]$$

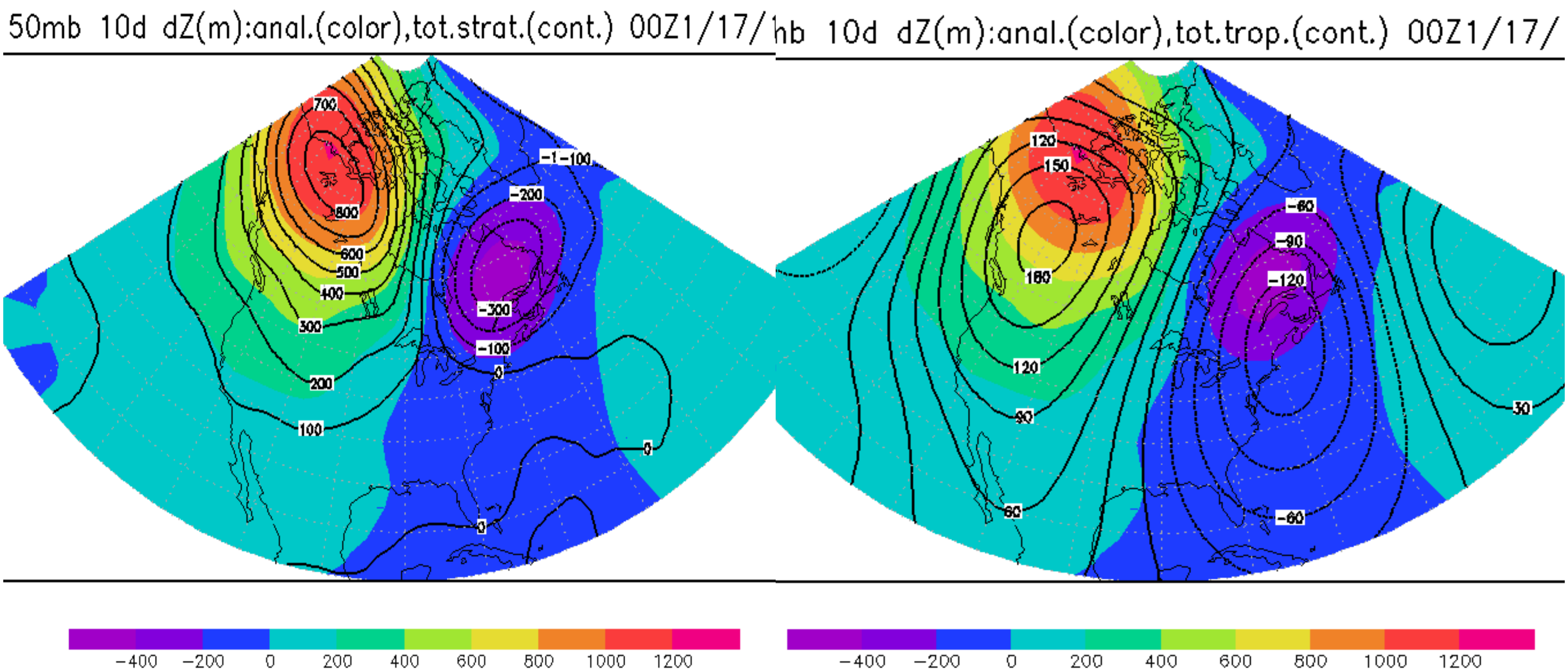
$$\therefore \left\{\nabla^2 + \frac{\partial}{\partial P}\left[\frac{f_0^2}{\sigma}\frac{\partial}{\partial P}\right]\right\}\frac{\partial Z}{\partial t} = \frac{f_0}{g}\left[\frac{\partial q_{V,Trop}}{\partial t} + \frac{\partial q_{V,Strat}}{\partial t} + \frac{\partial q_{T,Trop}}{\partial t} + \frac{\partial q_{T,Strat}}{\partial t}\right]$$

- Solve for height change ($\frac{\partial Z}{\partial t}$) due to each term on the right-hand side of the above equation by setting the other terms to zero, where “trop” =1000 - 200 mb and “strat” = 150 – 10 mb.

Analyzed (colors) and total calculated (contours) change in 50-mb geopotential height (m) from 12 – 22 January 2014



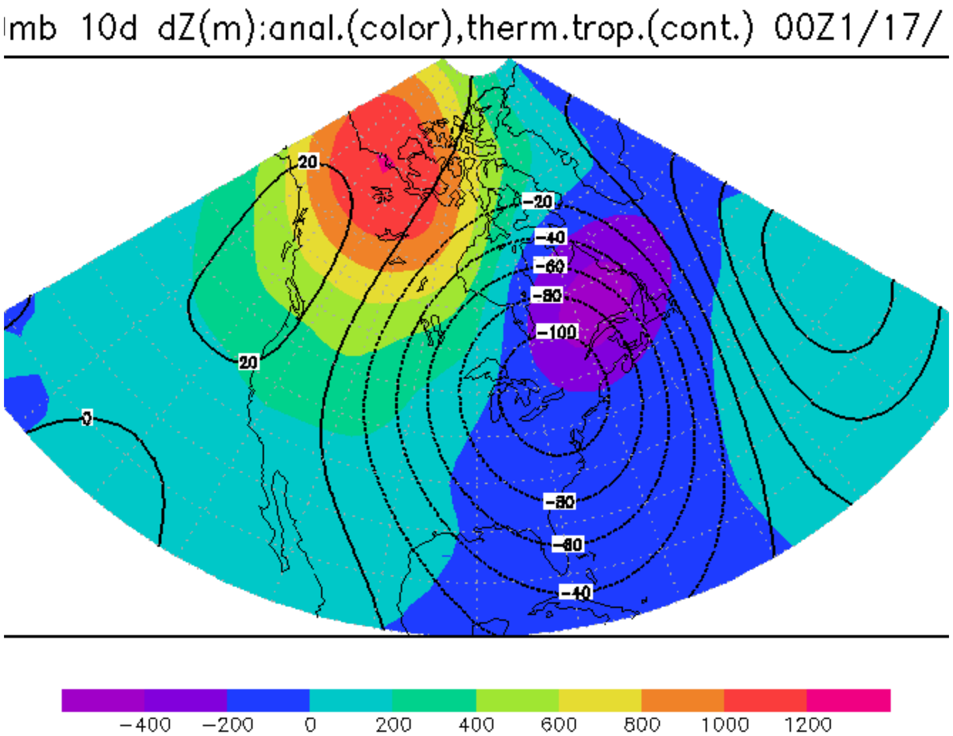
Analyzed change (colors) in 50-mb height (m) and its contribution (contours) from the stratosphere (left) and troposphere (right), 12 – 22 January 2014

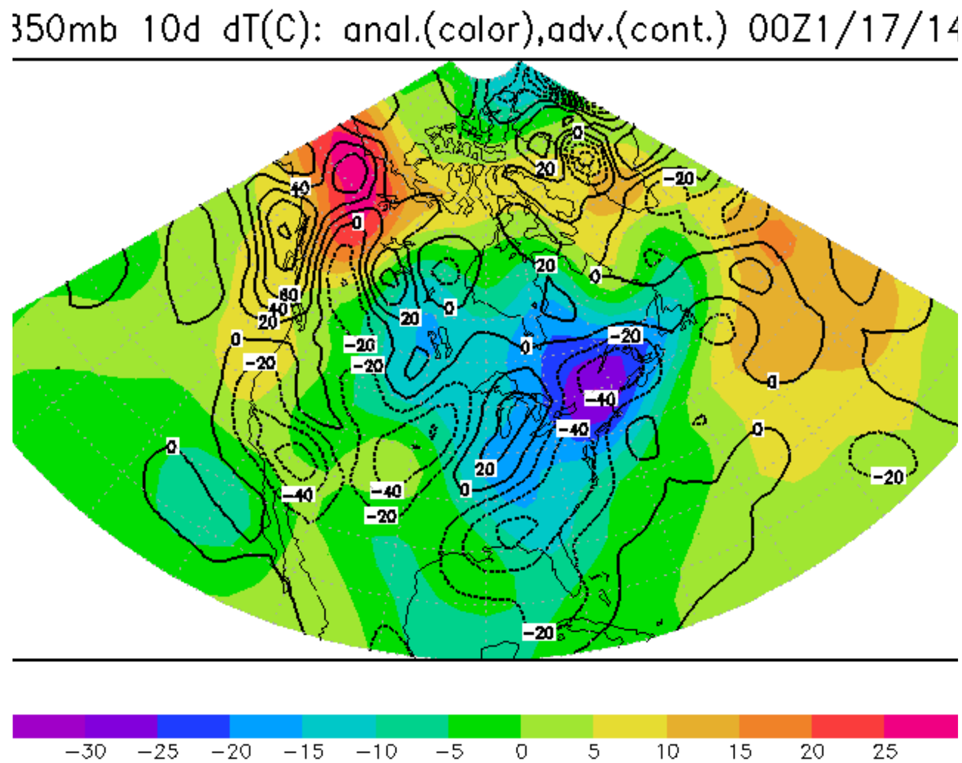


12 – 22 January 2014

Analyzed (colors) and tropospheric thermal (contours) change in 50-mb height (m)

Analyzed (colors) and advective (contours) change in 850-mb temperature (C)





Conclusions and Work in Progress

- Stratospheric geopotential height falls associated with an equatorward extension of the polar vortex during January 2014 may have been forced in part by lower tropospheric advective cooling over middle latitudes.
- The generality of this finding is being investigated in a larger (35-year) sample of stratospheric polar vortex distortions.