P3.25 A STUDY OF COHERENT TROPOPAUSE DISTURBANCES WITHIN THE NORTHERN HEMISPHERIC CIRCUMPOLAR VORTEX

Joseph R. Kravitz*, Lance F. Bosart, Daniel Keyser, and Anantha Aiyyer
Department of Earth and Atmospheric Sciences, University at Albany, SUNY

1. INTRODUCTION

Coherent tropopause disturbances (CTDs) embedded within the Northern Hemispheric (NH) large-scale circumpolar vortex (CPV) are characterized by closed potential temperature and/or pressure contours on maps of the dynamic tropopause (DT). Most commonly of arctic origin, CTDs frequently rotate through the bases of troughs at the southern extent of the CPV, corresponding to the northern margins of the most prominent jet streams in the NH. The interaction of CTDs with the polar-front jet stream (Pyle et al. 2004), particularly over North America, as well as mergers with midlatitude disturbances, may result in intense cyclogenesis (e.g., Bosart et al. 1996; Hakim et al. 1995, 1996). CTDs are of scientific interest for several reasons. Observational data limitations in arctic regions can complicate investigations of the thermodynamical and dynamical processes that govern the origin, structure, and life cycles of these features. CTDs also are of interest from a predictability standpoint because of numerical weather prediction model initialization and physics limitations.

The purpose of this study is to document the behavior of CTDs from a climatological perspective, including preferred regions of genesis and lysis, and tracks of CTDs. This study expands upon previous work (Hakim 2000; Hakim and Canavan 2003) by utilizing a high-resolution dataset interpolated to the DT in order to better capture the mesoscale structure of CTDs and their interactions with jet streams.

2. DATA AND METHODOLOGY

An initial subjective evaluation was performed utilizing pressure on DT maps for the 2002–2003 cool season (September 2002–May 2003) constructed from the twice daily National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) 2.5° × 2.5° initialized analyses. All CTDs with a 480 hPa or greater closed contour for at least two consecutive 12 h periods (24 h) were tracked. This choice of threshold was based upon a subjective determination that using the next higher contour (520 hPa) excludes many disturbances with a strong pressure gradient whereas choice of the next lower contour (440 hPa) includes many disturbances with weak pressure gradients. This subjective evaluation was performed as a means for validating an objective tracking program developed as part of the present study (to be described below), for isolating the behavior of individual CTDs for subsequent case studies, and for categorizing CTD behavior.

An objective tracking program was applied to CTDs utilizing four times daily NCEP GFS 1.0° × 1.0° final (FNL) analyses from January 2000–May 2004 (a 53 month period for which the data were continuous). Once again, a 480 hPa threshold was used. A CTD was identified if the threshold was exceeded at any grid point and there was at least a 120 hPa reduction in pressure extending outward from this grid point along at least 16 of 18 radials over a 2000 km radial distance. This criterion was established as optimal upon subjective evaluation of tracks for a 10 day period as described below. A relatively basic proximity algorithm was then employed to track each CTD wherein the track was extended if the criteria were again met at t + 6 h within 1000 km of the previous point. A track was counted if the criteria were met for four consecutive periods (24 h). In cases of two CTDs in proximity a weighting scale was utilized to determine which track to assign each point. This weighting scale considers proximity (4 points), CTD intensity (2 points for central pressure value and 2 points for radial pressure gradient), and direction of motion (2 points for zonal direction and 1 point meridional). Subjective analysis suggests that splits are very rare so these were excluded from the objective procedure. Mergers are observed more frequently, and in these cases the shorter of the two merging tracks was terminated.

This tracking methodology was checked subjectively over a 10 day period. Of 27 subjectively noted tracks, one track was not reproduced objectively and portions of three others were not reproduced (approximately 75% of one, 33% of a second and 25% of a third). This result gives a false negative rate of approximately nine percent. There were no false tracks by the objective method and only three tracks had small portions (< 10 percent of the track) that were improperly tracked. This gives a false positive rate of approximately one percent. The greatest false negative rate was for tracks near the Atlantic and Pacific jets due to the strong background flow. Attempts to scale based upon latitude decreased this rate but unduly increased the false positive rate. This latitudinal scaling procedure was, therefore, not used in the interest of consistency and reproducibility.

CTD track maps were subsequently plotted for various time periods (e.g., annual, seasonal) as well as various

---

Corresponding author address: Joseph R. Kravitz, Dept. of Earth and Atmospheric Sciences, University at Albany, SUNY, 1400 Washington Ave., Albany, NY 12222.
E-mail: kravitz@atmos.albany.edu

longevity thresholds. The location of CTD genesis and lysis points was also delineated.

3. RESULTS

Subjective evaluation for the cool season of 2002–2003 (not shown) identified various characteristic CTD life cycles. The most common categories are: 1) short-lived disturbances of three days duration or less (76 of 152 CTDs tracked) and 2) long-lived disturbances of one to six weeks duration (45 of 152). The short-lived disturbances have two distinct genesis and, given their short duration, lysis regions: 1) polar regions and 2) along cyclonic shear zones adjacent to the Atlantic and Pacific jet streams. The long-lived CTDs appear to be of greatest interest in terms of their impact on midlatitude weather events. Although some of these disturbances remain in polar regions for the duration of their life cycles, the majority originate in polar regions and subsequently migrate southward, moving into troughs at the periphery of the CPV. These CTDs frequently invigorate the adjacent jet stream as they move southward into the base of the trough. They then accelerate zonally when in proximity to the jet stream. Lysis typically occurs over the northwestern Atlantic Ocean and northwestern Pacific Ocean. In the Atlantic region, CTDs tend to dissipate as they encounter a large-scale ridge that was relatively persistent during the 2002–2003 cool season. In the Pacific region, those CTDs that rotate into the trough over eastern Asia and the western Pacific Ocean also tend to dissipate when approaching large-scale ridges.

Objective analysis of tracks of at least one week duration for all cool season months from January 2000 through May 2004 (41 months, 662 tracks) reveals significant interannual variability depending on the dominant circulation pattern, as manifested in the configuration of the periphery of the CPV. For example, the 2002–2003 cool season is dominated by a persistent trough over eastern North America with tracks concentrated within this trough (Fig. 1). During the 2000–2001 cool season, the dominant trough with its associated CTDs is located over western North America and the adjacent Pacific Ocean (Fig. 2).

Genesis sites for all five cool seasons combined (Fig. 3) are concentrated at high latitudes, particularly over the Queen Elizabeth Islands of northern Canada and over northern Siberia. Lysis sites (Fig. 4) are distributed more diffusely with minimally greater concentration over the northernmost Atlantic Ocean and the northwestern Pacific Ocean.

4. ACKNOWLEDGMENTS

I would like to thank Gregg Walters of NCAR for his help in correcting a small subset of faulty data. Financial support for this research was provided by the National Science Foundation through Grant ATM-0434189.

5. REFFERENCES

Bosart, L. F., G. J. Hakim, K. R. Tyle, M. A. Bedrick, W. E. Bracken, M. J. Dickinson, and D. M. Schultz, 1996: Large-scale antecedent conditions associated with the 12–14 March 1993 cyclone (“superstorm ‘93”) over eastern North America. *Mon. Wea. Rev.,* **124,** 1865–1891.

Hakim, G. J., 2000: Climatology of coherent structures on the extratropical tropopause. *Mon. Wea. Rev.,* **126,** 385–406.

——, and A. J. Canavan, 2003: Observed cyclone-anticyclone vortex asymmetries. *J. Atmos. Sci.,* (submitted).

——, L. F. Bosart, and D. Keyser, 1995: The Ohio Valley wave-merger cyclogenesis event of 25–26 January 1978. Part I: Multiscale case study. *Mon. Wea. Rev.,* **123,** 2663–2692.

——, D. Keyser, and L. F. Bosart, 1996: The Ohio Valley wave-merger cyclogenesis event of 25–26 January 1978. Part II: Diagnosis using quasigeostrophic potential vorticity inversion. *Mon. Wea. Rev.,* **124,** 2176–2205.

Pyle, M. E., D. Keyser, and L. F. Bosart, 2004: A diagnostic study of jet streaks: kinematic signatures and relationship to coherent tropopause disturbances. *Mon. Wea. Rev.,* **132,** 297–319.

.

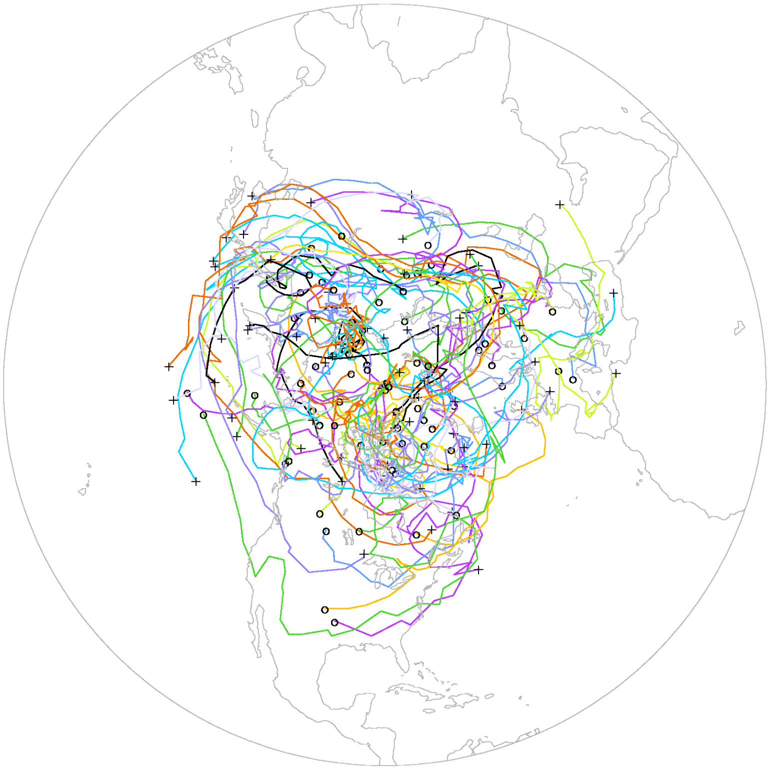

Figure 1: CTD tracks of at least one week duration for the 2002–2003 cool season. Circles represent track genesis and crosses represent track lysis. Track coloring is for visualization purposes only.

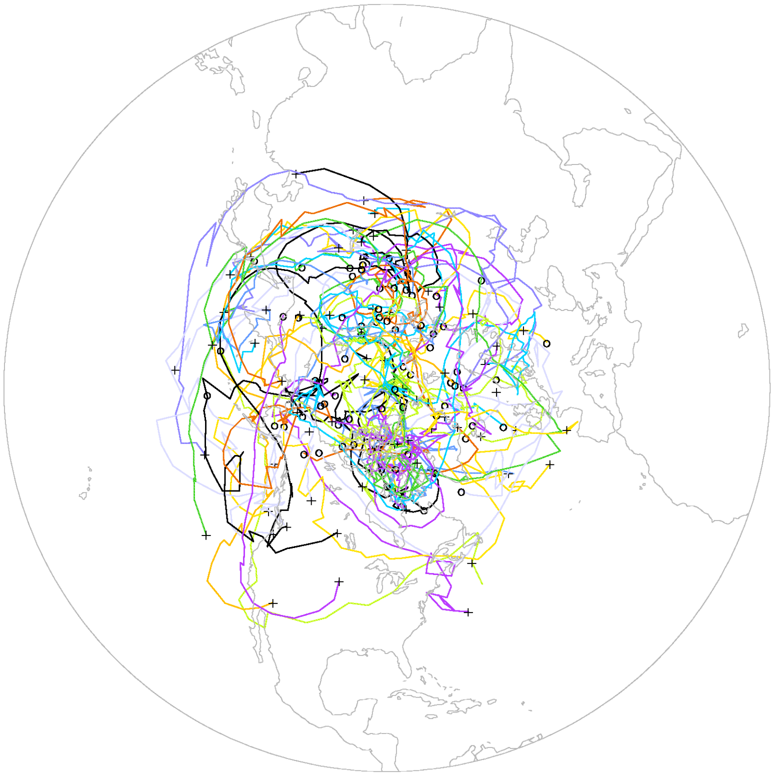

Figure 2: CTD tracks of at least one week duration for the 2000–2001 cool season. Circles represent track genesis and crosses represent track lysis. Track coloring is for visualization purposes only.

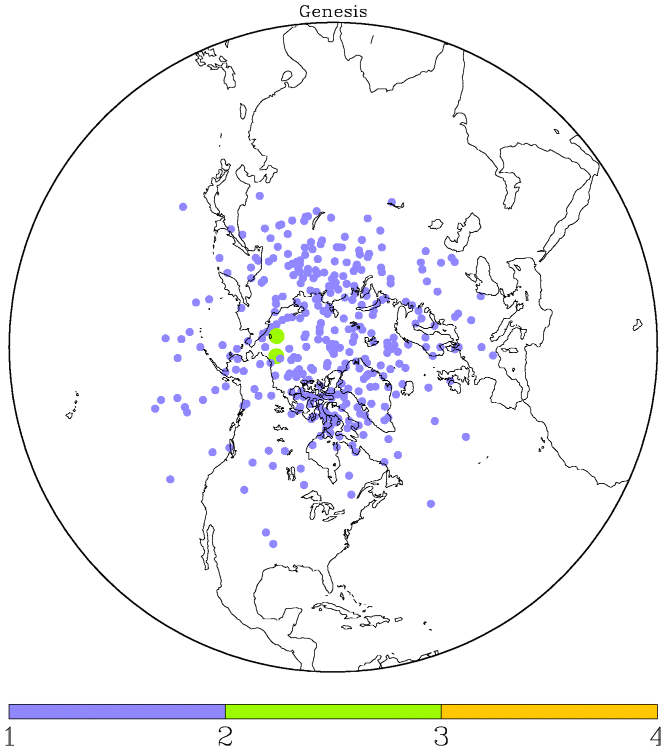

Figure 3: CTD genesis sites for all tracks of at least one week duration for the cool season months from January 2000 through May 2004 (41 months total). Dot size and color indicate number of genesis events at any given grid point.

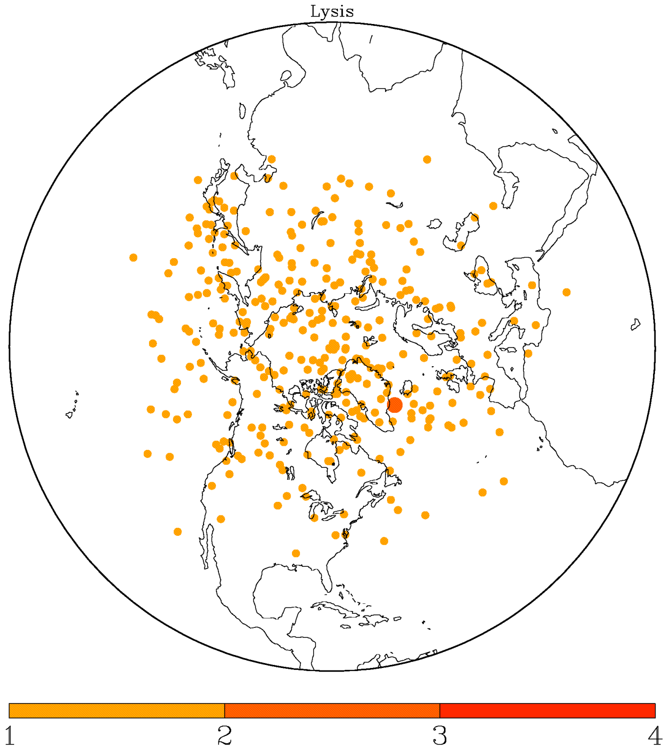

Figure 4: Same as Fig. 3 but for CTD lysis sites.