A Predictability Study of a Polar Low Linked to a Tropopause Polar Vortex

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Presented at AGU 2018 Fall Meeting on 14 December 2018

1) Background

- Tropopause polar vortices (TPVs) are tropopause-based vortices of high-latitude origin and are material features (e.g., Cavallo and Hakim 2010).
- Polar lows are small, intense cyclones characterized by horizontal scales from 10s to 100s of km, short lifetimes, and rapid evolution, and often form within, or at the leading edge of, a cold air mass moving over warmer sea surfaces in high latitudes (e.g., Rasmussen and Turner 2003).
- Polar lows may be associated with strong surface winds and heavy precipitation, posing hazards to ships and infrastructure (e.g., Rasmussen and Turner 2003).
- TPVs may act as precursors for the development of polar lows (e.g., Kostad 2011)
- This study investigates physical processes that influence the evolution and predictability of a polar low linked to a TPV.

2) Data and Methods

- Obtained polar lows from the Sea Surface Temperature and Altimeter Synergy for Improved Forecasting of Polar Lows (STARS) database of polar lows over the Norwegian and Barents Sea during 2002–2011 (Sætra et al. 2010).
- Compared STARS database to a 1979–2015 database of TPVs constructed using the ERA-Interim (Dee et al. 2011) and a TPV tracking algorithm (Szapiro and Cavallo 2016), and identified polar lows linked to TPVs.
- Conducted a multiscale analysis of a Barents Sea polar low linked to a TPV occurring during 1800 UTC 10–1200 UTC 11 February 2011 using the ERA5 (Hersbach and Dee 2016).
- Used the ECMWF Ensemble Prediction System (Buzzi et al. 2007) initialized at 1200 UTC 9 February 2011 (30 h prior to polar low genesis) to evaluate the forecast skill of the polar low, with the ERA5 used as the verification.
- Assessed forecast skill of polar low in terms of a metric adapted from Lamberson et al. (2016) that combines forecast track and intensity error of polar low based on 850-hPa relative vorticity.
- Separated ensemble members into two groups: the eight most accurate and the eight least accurate members in terms of aforementioned metric.

3) Climatology and Case Tracks

- Figure 1 (left): Tracks of STARS polar lows linked to TPVs (red) and STARS polar lows not linked to TPVs (blue). Dots indicate the genesis locations of the polar lows. 54% out of a total 140 polar lows, or 74.3%, are linked to TPVs.

4) Polar Low and TPV Evolution

- Figure 3 (left): 2D (2PV) surface (K, shaded), wind speed (black, every 10 m s−1; shading, 35 m s−1); and 3D (3PV) surface (K, shaded), wind speed (black, every 1.5 × 10−4 m s−1; shading, 10 × 10−4 m s−1). L1 and TPV denote positions of a predecessor cyclone (L1) and the TPV, respectively.

5) Ensemble Differences at 1800 UTC 10 Feb 2011 (30-h Forecast)

- Figure 4: Ensembles mean (red), most accurate group A (green), and least accurate group B (blue). Shading indicates the difference between the most accurate and least accurate group.

6) Discussion

- A large percentage, 74.3%, of the STARS polar lows are linked to TPVs (Fig. 1).
- The evolution of the polar low appears to be related to the interaction between the TPV and a tropospheric-deep baroclinic zone (Figs. 2a and Figs. 3a–f).
- Forcing for ascent associated with the TPV (Fig. 4a) and a favorable thermodynamic environment (Fig. 4b) likely support the intensification of the polar low (Figs. 3b,d).
- The polar low is stronger and positioned farther northeastward in the most accurate group compared to the least accurate group (Figs. 5a,b).
- Composite differences between the most and least accurate groups suggest that the TPV and a predecessor cyclone (L1; Figs. 3b,d) are positioned farther northeastward (Figs. 6a–c and Figs. 7a,b) and the tropospheric-deep baroclinic zone is positioned farther eastward (Figs. 6a and Fig. 7b) in the most accurate group.
- These position differences may be tied to the ridges flanking the TPV (R1 and R2) being less amplified (Fig. 6a).
- These position differences likely contribute to the polar low position differences between the groups (Figs. 5a,b).

7) References