966

A Statistical Analysis and Synoptic Climatology of Cold Air Outbreaks in the United States

Zachary B. Murphy*, Daniel Keyser, and Lance F. Bosart

Department of Atmospheric and Environmental Sciences, University at Albany, SUNY, Albany, NY

*Corresponding author email: zbmurphy@albany.edu

1. Motivation

- Cold air outbreaks (CAOs) are associated with abnormally low temperatures that can adversely impact human life and a wide range of economic activities.
- Climatological studies of CAOs have been limited to only a few regions with only a small sample size of events.

2. CAO Identification

Dataset: Global Historical Climatology Network-Daily minimum temperature data.
Period of study: 1948–2015
Stations: 53 stations in nine National Centers for Environmental Information (NCEI) Standard Regions (Fig. 1).
Regional CAO Definition: Two or more stations within an NCEI region experience three or more consecutive days where minimum temperatures fall below the 31-day centered moving average of the 5th percentile minimum temperature for those days and share at least one overlapping day.

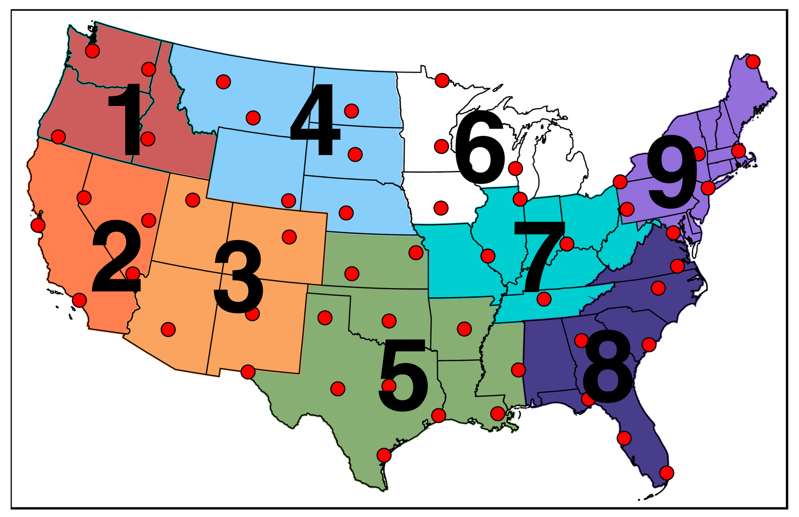


Fig. 1: Map denoting the 53 stations (markers) and the nine NCEI Standard Regions.

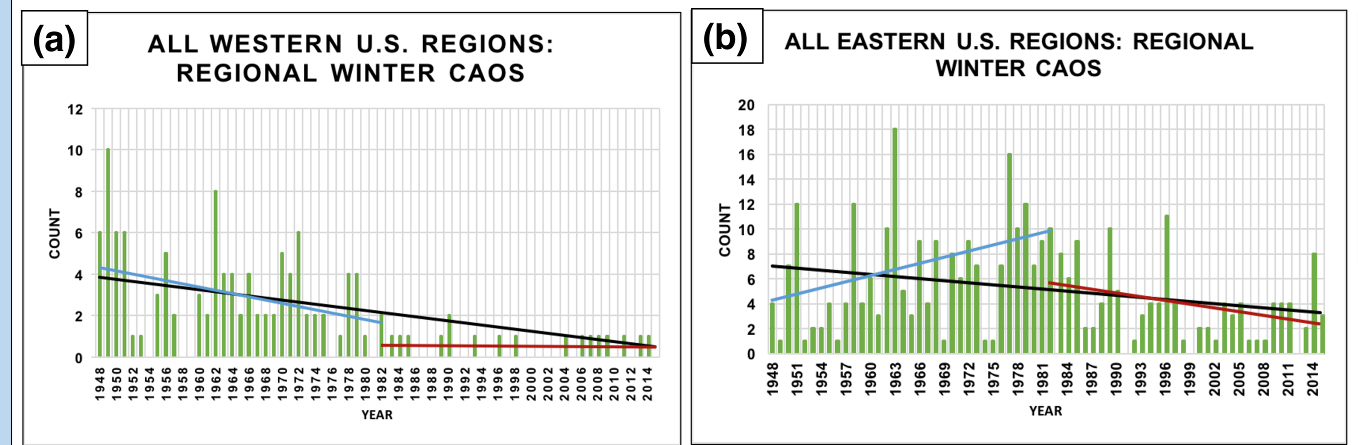
3. Time Series Methodology

- Time series were constructed for all CAOs for each region to identify CAOs and their overall trends.
- Composite time series were constructed for regions 1–3 and 4–9 to determine nationwide frequency trends. The grouping of regions 1–3 and 4–9 yielded similarities in the time series for these respective regions.
- Composite time series were constructed for the Northeast (region 9) to illustrate regional frequency trends.
- Linear regressions computed using least squares for 1948–2015, 1948–1982, and 1982–2015.
- Statistical significance assessed via the calculation of *t*-values and *p*-values using a two-tailed Student's t-test.

4. Compositing Methodology

Dataset: 2.5° × 2.5° NCEP–NCAR Reanalysis
Region: Northeast U.S.
Season: Winter (December–February)
Times: D_{-6}, D_{-4}, D_{-2}, D_0 (first day of CAO onset)
Classification methodology: Sixty-one CAOs were identified. The CAOs were binned subjectively based on similarities in the 500-hPa geopotential height pattern at the midpoint of the CAO. Those CAOs that were accompanied by a closed-off 500-hPa geopotential height minimum over the Northeast during the midpoint of the CAO were composited. This procedure resulted in 38 out of 61 CAOs being chosen for compositing.

5. U.S. Winter CAO Time Series

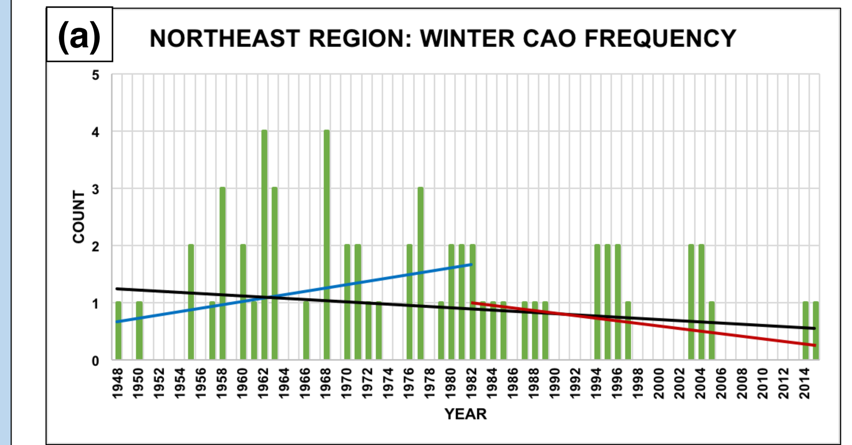


(c)

West	East
$t = -4.34$	$t = -2.29$
$p = 4.9 \times 10^{-5}$	$p = 0.02$

Fig. 2: (a) Time series analysis for all winter CAOs for regions 1–3 depicted in Fig. 1, with trendlines for 1948–1982, 1982–2015, and 1948–2015. **(b)** As in Fig. 2a, but for regions 4–9 depicted in Fig. 1. **(c)** *t*-values and *p*-values for each of the 1948–2015 regressions in Figs. 2a,b. A 95% confidence level is assumed. Statistically significant values are $t > 2.00$ or $t < -2.00$, and $p < 0.05$.

6. Northeast Winter CAO Time Series



(b)

Northeast Region
$t = -1.61$
$p = 0.11$

Fig. 3: (a) As in Fig. 2a, but for the Northeast (region 9). **(b)** As in Fig. 2c, but for the Northeast. Statistically significant values are $t > 2.00$ or $t < -2.00$, and $p < 0.05$.

7. Composites for Northeast Winter CAOs (N=38)

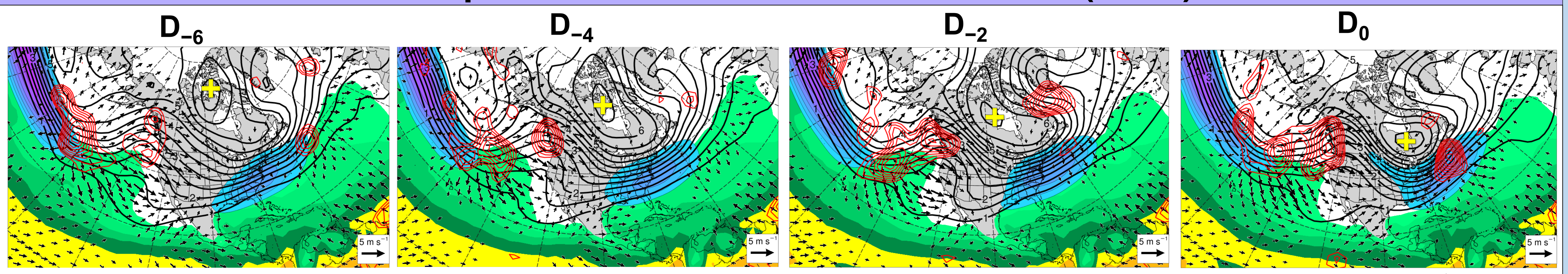


Fig. 4: 300–200-hPa layer-averaged potential vorticity (black contours, every 0.5 PVU starting at 1.0 PVU), 300–200-hPa irrotational wind (arrows), 250-hPa wind speed (fills, contoured every 5 m s^{-1} starting at 40 m s^{-1}), 500-hPa ascent (red, every −0.01 Pa s^{-1} starting at −0.05 Pa s^{-1}), precipitable water (green fills, every 5 mm starting at 20 mm). Yellow "+" denotes PV maximum.

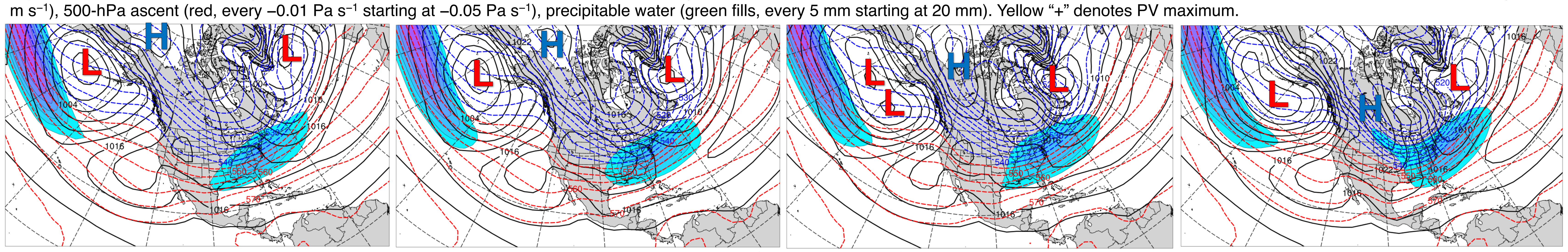


Fig. 5: Mean sea-level pressure (black contours, every 3 hPa), 250-hPa wind speed (fills, every 5 m s^{-1} starting at 40 m s^{-1}), 1000–500-hPa thickness (red and blue dashed contours, every 5 dam; blue represents values less than 540 dam.)

8. Discussion

Climatological Results

- In the regions both west and east of the Rockies, the CAO trends exhibited decreases during 1948–2015 (Figs. 2a,b). These trends are statistically significant (Fig. 2c).
- The Northeast (Fig. 3a) exhibited a similar trend during 1948–2015 as the regions west and east of the Rockies (Figs. 2a,b), but the trend is not statistically significant (Fig. 3b).
- In the regions east of the Rockies and the Northeast, the CAO trends exhibited an increase during 1948–1982 and a decrease during 1982–2015 (Figs. 2b and 3a). The trend in the regions east of the Rockies is statistically significant (Fig. 2b), whereas the trend in the Northeast is not statistically significant (Fig. 3b).

Composite Results

- Six days prior to CAO onset, a PV maximum has begun to form over Baffin Island (Fig. 4).
- Four-to-two days prior to CAO onset, ridge amplification over the eastern North Pacific is associated with low-level warm air advection and midlevel ascent (Figs. 4 and 5).
- Concurrently, ridge amplification over the North Atlantic occurs downstream of a deep trough. The concurrent ridge amplification over the eastern North Pacific and North Atlantic occurs in conjunction with the equatorward movement of the PV maximum (Fig. 4).
- Six days prior to CAO onset, an Arctic anticyclone located north of Alaska moves southward into the Northern Plains in association with upper-level convergence in the irrotational wind field (Figs. 4 and 5).
- The Arctic anticyclone is accompanied by low thickness values along its eastern flank. These low thickness values correspond to cold air at low levels; northerly flow along the eastern flank of the anticyclone transports this cold air into the Northeast (Fig. 5).

Acknowledgments: Alicia Bentley, Kevin Biernat, and Scott Runyon for their advice and assistance.