Recent Amplification of the North American Winter Temperature Dipole

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SUMMARY: During the 2013-2014 and 2014-2015 winters, anomalously warm temperatures in western North America and anomalously cool temperatures in eastern North America resulted in substantial human and environmental impacts. Motivated by the impacts of these concurrent temperature extremes and the intrinsic atmospheric linkage between weather conditions in the western and eastern United States, we investigate the occurrence of concurrent “warm-West/cool-East” surface temperature anomalies, which we call the “North American Winter Temperature Dipole”. We find that, historically, warm-West/cool-East dipole conditions have been associated with anomalous mid-tropospheric ridging over western North America and downstream troughing over eastern North America. We identify atmospheric circulation anomalies in mid- and high-latitude regions, and convective anomalies in the Central Pacific, which precede NAWTD events on daily-to-weekly timescales. We also find that the occurrence and severity of “warm-West/cool-East” events has increased significantly between 1980 and 2015, driven largely by an increase in the frequency with which high-amplitude “ridge-trough” wave patterns result in simultaneous severe temperature conditions in both the West and East. Using a large single-model ensemble of climate simulations, we show that the observed positive trend in the “warm-West/cool-East” events is attributable to historical anthropogenic emissions including greenhouse gases, but that the co-occurrence of extreme western warmth and eastern cold will likely decrease in the future as winter temperatures warm dramatically across the continent, thereby reducing the occurrence of severely cold conditions in the East. Although our analysis is focused on one particular region, our analysis framework is generally transferable to the physical conditions shaping different types of extreme events around the globe.

DEFINITIONS:
North American Winter Temperature Dipole Events: Co-occurrence of warm extremes in the west (Tsurf_West > 84°C) and cool extremes in the east (Tsurf_East < 16°C) over some minimum fraction (X%) of the respective domains. (X varies from 5-30% in this analysis.)
North American Winter Temperature Dipole Intensity: Area-weighted average temperature difference between the regions experiencing extremes in the western and eastern domains. NAWTD Intensity: (Tsurf_West – Tsurf_East), where A_West > A_East


Data: NCEP-NCAR Reanalysis

- a) Composite Near-Surface (2m) Temperature Anomalies
- b) Composite Daily Mid-tropospheric (500mb) Geopotential Height Anomalies (Amplified Ridge-Trough Pattern)


- a) Seasonal Average Temperature (¹°C)
- b) Seasonal Average Fractional Area Experiencing Extremes
- c) Temperature Dipole Occurrence
- d) Temperature Dipole Intensity

3. Relationship of Temperature Extremes to Mid-Tropospheric Circulation Patterns

- Applied a clustering approach (20-node Self Organizing Maps) to daily DJF 500mb geopotential height anomalies between 1980-2015 to identify “typical” winter circulation patterns over the domain
- Identified 6 “leading” circulation patterns based on spatial correlations (C_r) between the geopotential height anomalies of the cluster composites and the NAWTD events composite.
- Quantified the fraction of occurrences of each cluster pattern that were associated with NAWTD events (indicated on the temperature composites corresponding to each cluster)

4. Role of circulation changes in driving NAWTD trends

- a) 6-node SOM frequency and percent contribution to NAWTD events
- b) Dipole events with 6-leading nodes and remaining 14 nodes

5. Attribution of trends to anthropogenic versus natural forcing

- Estimate 36-year trends in preindustrial (PIControl) and historical climate from the NCAR LENS ensemble
- Calculate likelihood of the observed trend direction in historical climate from the NCAR LENS ensemble
- Identify the fraction of “leading” patterns producing NAWTD events

6. Work In Progress

- Trends in frequency of all area dipole events
- Seasonal-average western U.S. temperatures and fraction of the western U.S. experiencing extremes

Trends in frequency of all area dipole events, seasonal-average western U.S. temperatures and fraction of the western U.S. experiencing extremes are significantly more likely in the historical climate relative to a preindustrial climate