



An Increase in Extreme-Weather Winters for the United States

Background

In the United States, the winters of 2013-14 and 2014-15 were characterized by severe meteorological events. Much of the western U.S. experienced persistent warm temperatures, which led to record-low snowpack and record-low soil moisture. These conditions aggravated the region's multi-year drought and increased wildfire risk. Eastern states on the other hand experienced frequent cold Arctic air outbreaks and intense winter storms. Heavy snowfalls and blizzards crippled several major cities.

In the U.S., insured losses in the 2014-15 winter amounted to 2.4 billion USD, which is double the average of the last decade (according to Yoon et al). Simultaneous occurrence of extreme climate events in both the West and East proved particularly challenging. Impacts to the economy are accompanied by impacts to natural resources and the ability to deploy emergency services. Understanding the causes of such extremes can inform disaster preparation, early warning, and risk management systems.



About the Researchers

This research was led by **Deepti Singh**, a former Stanford Earth System Science graduate student; in partnership with **Noah Diffenbaugh**, Professor in Stanford University's School of Earth, Energy & Environmental Sciences and Senior Fellow at the Stanford Woods Institute for the Environment; **Leif N. Thomas**, Associate Professor of Earth System Science at Stanford University's School of Earth, Energy & Environmental Sciences and an affiliate of the Stanford Woods Institute for the Environment; **Bala Rajaratnam**, Assistant Professor of Statistics and Earth System Science at Stanford University and an affiliate of the Stanford Woods Institute of the Environment; and former members of Diffenbaugh's research group **Justin Mankin**, **Daniel Horton** and **Daniel Swain**.

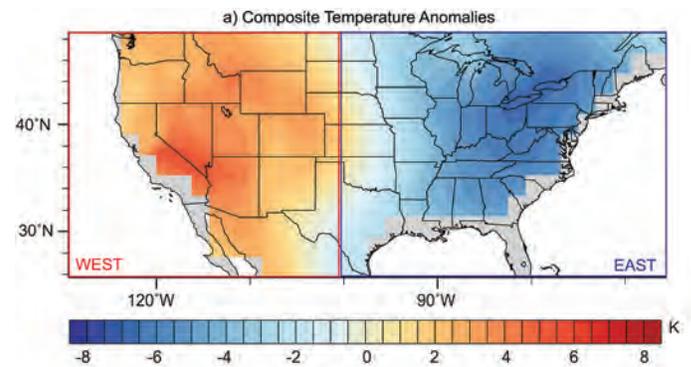
New research from Stanford University analyzes the phenomenon of co-occurring daily temperature extremes in both the western and eastern U.S., which the researchers refer to as the "North American winter temperature dipole" (NAWTD) or simply "the dipole". The findings suggests that the occurrence and severity of warm-West and cool-East events have increased significantly between 1980 and 2015, and that the trend is likely attributable to anthropogenic (human-caused) emissions of the greenhouse gases fueling climate change.



A Significant Increase in Extremes in Recent Decades

The analysis focuses on weather events in North America between 1980-2015. To discern the East from the West, the research divides the U.S. into two domains, approximately divided by the eastern edge of the Rockies. The simultaneous occurrence of warm winters in the West and cold winters in the East, NAWTD, has significantly increased in recent decades, with the following observations:

- During the 2013-14 and 2014-15 winters, North America frequently experienced a similar warm-West and cool-East surface temperature dipole pattern associated with notable daily extremes (Hartmann, 2015; S.-Y. Wang et al., 2015).
- The coolest Eastern winter and warmest Western winters on record since at least 1980 occurred during 2013-14 and 2014-15, along with unprecedented temperature differences between West and East.
- In 2013-14, around 28 percent of the eastern U.S. experienced daily minimum temperatures well below historical averages, the greatest percentage since at least 1980.
- In 2014-15, around 40 percent of the western U.S. experienced daily maximum temperatures well above historical averages, which has also not occurred since at least 1980.

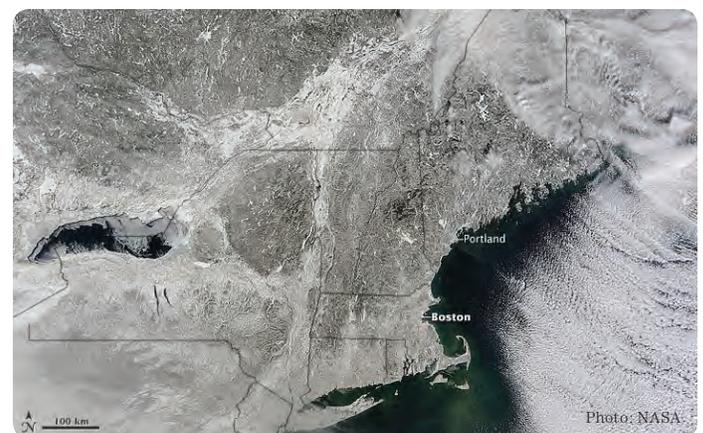


The eastern and western dipole regions defined.

Long-Term Trends For Warm-West/Cool-East Temperature Extremes

Long-term trends related to the NAWTD were also considered in the research:

- The research suggests that there has been a large and statistically significant increase in the co-occurrence of warm-West/cool-East temperature extremes.
- The seasonal temperature difference between the West and East shows an increasing trend over the period of observation, particularly due to warming temperatures in the West and slightly decreasing temperatures in the East.
- There is an increasing trend in the number of areas of the western U.S. experiencing warm extremes, however,



no noticeable trend in the number of areas in the eastern U.S. experiencing cold extremes.

Associated Trends in Atmospheric Circulation Patterns

Despite long-term warming across most of the world, some regions can experience colder temperatures due to abnormal circulation patterns that drive cold air from the poles to mid-latitudes. The study shows that, historically, warm-West/cool-East dipole conditions have been associated with abnormal atmospheric conditions: “ridging” — or areas of high-pressure — over western North America, and “troughing” — or areas of low-pressure — over eastern North America. The study finds no change in how often these atmospheric patterns have occurred. However, the study does find that these atmospheric patterns have become more likely to produce warm-West/cool-East temperature extremes, leading to the increase in total dipole temperature occurrences.

The Role of Anthropogenic Warming

The study also sought to address whether the observed trends in NAWTD events occurred by chance or were influenced by human activities. According to the study’s climate simulations, the increased positive trend in the warm-West and cool-East events is far more likely to occur in a climate that has been altered by historical anthropogenic emissions of greenhouse gases. However, the phenomenon 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. Nonetheless, even with the increased global warming, extreme cold events are still likely to occur from time to time.

Considerations for Policymakers

1. The physical factors driving extreme weather events should be considered when developing and managing infrastructure that may be affected by extreme weather events.

2. To improve prediction of extreme events, more investigations into the interactions between daily and seasonal weather patterns are needed.
3. The Stanford researchers’ extreme event analysis framework could be applied generally for understanding the physical mechanisms driving changes in extremes in other regions of the world.

Conclusions

This new research suggests that there have been robust changes in the warm-West/cool-East pattern over North America during the last 35 years, related primarily to historical warming of the earth’s surface. Understanding the extremes that occur in both regions simultaneously is essential as these are likely to have greater national-scale impacts and impose greater stress on disaster management efforts. Given the billions in economic costs, threats to infrastructure and the ability of emergency services to respond to extreme weather events of the past, the results of the research are relevant for policy and decision-makers at the national and sub-national levels.

This brief is based on the paper “[Recent Amplification of the North American Winter Temperature Dipole](#)” by Deepti Singh, Daniel L. Swain, Justin S. Mankin, Daniel E. Horton, Leif N. Thomas, Bala Rajaratnam, and Noah S. Diffenbaugh, published in AGU Publications, September 2016.

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