Arctic Connections to Extreme Weather: Evidence and Gaps

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Chain of Events Linking Arctic Amplification (AA) with Increased Extreme Weather in Mid-Latitudes

AA: Arctic warming 2-3 times faster than N. hemisphere

Poleward temperature gradient weakening

500 mb zonal winds decreasing where gradient weakens

Upper-level flow becoming more meridional

Amplitude of Rossby waves increasing, blocking more likely

Large-scale waves progress more slowly eastward

More persistent weather patterns, extremes more likely
The Evidence

AA: Arctic warming 2-3 times faster than N. hemisphere

1000-500mb Thickness

Winter JFM
Spring AMJ
Summer JAS
Fall OND
The Evidence

Poleward temperature gradient weakening

Trends in poleward thickness gradient (1000-500 hPa) from 1979 to 2012
500 mb zonal winds decreasing where gradient weakens

Zonal-mean zonal winds at 500 hPa, 40-60°N, N. Hem.

Anomalies in zonal winds at 500 hPa from 2000 to 2012
The Evidence

Upper-level flow becoming more meridional

CCSM4 4 x CO₂
Change in Meridional Wind Fraction @45°N
Trends in meridional component of the 500 hPa wind (1979 to 2011)

Less wavy
More wavy
The Evidence

Amplitude of Rossby waves increasing, blocking more likely

Trends in Amplitude from Barnes (2013)

JAS Northern Hemisphere

Trend in ridges

500mb heights JAS 2000–2012 from Screen and Simmonds (2013)
Amplitude of Rossby waves increasing, blocking more likely

Ridge peaks

"Blocking" (days/year)

U500 $r = -0.68$
An Artifact of the Methodology?

Wave amplitude (deg. latitude) from Barnes (2013)

1980-1995
1996-2011

500 mb height with maximum waviness
500 mb height contour used in FV12
An Artifact of the Methodology?

Typical 500 hPa pattern in Nov

Contour with max waviness has different shape from FV12's contour in max gradient
An Artifact of the Methodology?

Contour with max waviness had 15° farther north than FV12's contour in max gradient. Contour with max waviness is 15° farther north, not in max wind zone, not representative of jet stream trajectory.
Large-scale waves progress more slowly eastward.

From Barnes (2013) “We find a robust decrease in wave phase speeds in OND, which is consistent with the $u_{500}$ reductions.”

More work is needed to assess changes in speed of large wave progression.
The Evidence

More persistent weather patterns, extremes more likely

NOAA/NCDC Climate Extremes Index
US, annual
More persistent weather patterns, extremes more likely

Mean day-to-day temperature differences in Beaver City, NE before and after 1995.

Small day-to-day temperature changes becoming more common.
Upper-air Circulation Anomalies during Extreme Weather in Chicago from S. Vavrus

High-Amplitude Wave Patterns

10 Coldest Days

10 Hottest Days

10 Wettest Days

10 Driest Summers
The Evidence

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More persistent weather patterns, extremes more likely

Projected increased ridging over continents associated with higher SATs.

Ridging over N. Atlantic cools western Europe
The Evidence

In recent decades, higher summer SATs occur when 500 hPa zonal winds are weak or easterly, i.e., under dome of ridge.

Projection for 2090s suggests that light and easterly winds will become more common at the expense of west winds » higher SATs, extremes more likely.
More persistent weather patterns, extremes more likely

Regression of detrended anomalies in spring snow cover and summer sea ice extent on extreme summer heat waves.

Even though snow anomalies are twice as large, sea ice has a larger influence over the US.
Evidence for Arctic linkages to changes in mid-latitude weather patterns is piling up.

Many links in the chain are solid.

Connections strongest in fall, but AA is emerging in other seasons, response should strengthen.

More work needed to assess:

- Changing propagation of large-scale waves (speed and cause)
- Changing persistence of weather patterns
- Changing frequency of extremes
- Interactions among AA and other large-scale influences (ENSO, PDO, etc.)
Extras
Change in JJA Snow Cover Fraction 2090s – Late 21\textsuperscript{st} C (CCSM4 RCP8.5)
Band of increased $|\text{MCI}|$ across U.S. and Asia through N. Pacific, decreases over Canada and Alaska, suggesting wavier flow
Anomalies in zonal-mean heights and zonal winds for OND 2007-2012
Conditions leading up to Sandy

- Time/latitude evolution during Oct. 2012 of heights (1000 hPa and 500 hPa) and zonal wind anomalies at 500 hPa in the N. Atlantic (0 to 90°W).
- Blocking high begins ~Oct 20th with positive anomalies at 1000 hPa across the Arctic related to surface temperatures.
- 500 hPa ridge causes weakening zonal winds between 38°N-50°N.
Zonal wind anoms 700 hPa

Oct 1980-1992

Oct 2000-2012

from Barnes et al (2013)
Contours = average easterlies during Oct. 27-29, 5 m s\(^{-1}\)

Stronger easterlies in recent years of low ice extent in region where strong easterlies existed during Sandy.

ASO anomalies in 500 hPa heights

Change in Oct zonal wind -- CCSM4 -- 4 x CO\(_2\)