Linkage between Arctic Climate Change and Mid-Latitude Extreme Climate

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Increasing Trend of Extreme Weather

U.S. Climate Extremes Index
Annual (Jan–Dec)
1910–2016

Contiguous U.S.
Including Tropical Cyclone Indicator

Percentage values correspond to the average spatial extent of extremes observed across the Contiguous U.S. during a given season and year.
Extreme Weather often Coincides with Weak Polar Vortex

Polar Cap GPH January–May 2016

Record warm polar stratosphere
Record weak polar vortex

Jan Feb Mar Apr May

Russia cold/snow
Mid Atlantic record blizzard; East Asia record cold
Northeast record cold; Europe/Canada snowstorm
Midwest snowstorms
Northeast cold/snow; Colorado blizzard
US record cold/rare spring snow; Spring “polar vortex”; Greenland melt

Europe/Texas record flooding
Northeast/California rare May snow
UK/Colorado late snow

Cohen et al. 2017
Once Black and White . . .

More Autumn Snow Cover = Strong Siberian High = Negative AO

The role of the Siberian high in Northern Hemisphere climate variability

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GEOPHYSICAL RESEARCH LETTERS. VOL 28, NO 2, PAGES 299-302, JANUARY 15, 2001
Once Black and White . . .

Warm Arctic-Cold Continents Pattern

Near-surface Temperature Anomalies

Arctic warms

Continents cool

via

Arctic Oscillation

Overland et al. 2011
Once Black and White . . .

Warming Arctic = Weaker, Wavier Flow = More Extremes

Francis & Vavrus 2012
. . . Now (at least) 50 Shades of Gray

Arctic  Middle Latitudes
Different Seasonal Patterns of Recent Warming

Recent Winter Warming

Recent Summer Warming

Mostly ocean-based

Mostly land-based
Role of Snow Cover

Snow Forced Cold Signal

Autumn-Winter

Spring-Summer

June snow cover loss exceeds Sep sea ice loss

Judah Cohen

Rutgers Global Snow Lab
Tropical vs. Polar Tug-of-War

Projecting the Arctic warming on the midlatitude jet-stream is of great interest—and important climate consequences for weather in lower latitudes? The jury is still out.

While there is a growing consensus in the model-based literature that Arctic warming may reduce the magnitude of Arctic amplification, there is no indication that it will be the dominant factor in driving future climate change. Nonetheless, the net response of the midlatitude jet-stream over the North America/North Atlantic jet-stream will speed up or slow down by 2100 (Figure 5(b)), the model response of the poleward shift driven by the tropical warming negatively correlated with the degree of Arctic warming in modulating this response, all of these influences must be considered if one is not to be explicitly determined from correlation analysis.

While the latest nonlinear interaction of many factors, only one of 21st century will ultimately be determined by the house gas emissions. Nonetheless, the net response of the circulation—i.e., our best estimate of what will occur—may not be what is expected.

FIGURE 4

2076–2099 and 1980–2004 under RCP8.5 for 21 CMIP5 models in (a) winter (January–February–March) and (b) summer (July–August–September).

Barnes and Screen, 2015
The horizontal and vertical pattern of projected warming. Zonal-mean, multimodel mean air temperature response (shading) between 2076–2099 minus 1980–2004 under RCP8.5 for 21 CMIP5 models in (a) winter (January–February–March) and (b) summer (July–August–September).
Tropical vs. Polar Tug-of-War

Tropical warming: Stronger Westerlies

Zonal Wind


Pressure (hPa)

Temperature response [JAS]

Latitude (deg. N)

Latitudes

Pressure (hPa)

-8 -6 -4 -2 0 2 4 6 8

°C

Barnes and Screen, 2015
Weaker and Wavier Circulation Promotes Extreme Weather?

Meridional temperature gradient not sole control on mid-latitude jet (eddy-mean flow feedbacks) [Hoskins & Woolings 2015]

Not all studies find sufficient Arctic heating from sea ice loss to cause significantly weaker/wavier flow [Perlwitz et al. 2015]

Thermal influence of wavier circulation on cold extremes is mitigated by advection of warmer upstream Arctic air [Screen 2014]

A weaker, wavier circulation might require a stratospheric pathway [Kim et al. 2014]
Impact of Amplified Planetary Waves Differs by Region

Impact of amplified planetary waves on extreme weather differs by region

Extreme dryness  Extreme cold  Extreme wet  Extreme heat
Dependence of Teleconnections on Background State

Response of Autumn-Winter 300 hPa Heights

PDO Influence when Chukchi Sea is cold

PDO Influence when Chukchi Sea is warm

Different in PDO Influence warm minus cold

Sung et al. 2016,
Overland et al. 2016
Different *Regional Responses* to Sea Ice Loss

**Regional Wintertime Sensitivity to Projected Future Sea Ice Loss:**

- Fewer and shorter-lived cold extremes
- More and longer-lived cold extremes

*Screen et al. 2015*
Different *Seasonal* Responses to Sea Ice Loss

*Enhanced Arctic warming changes summertime mid-latitude circulation*

*Amplification of quasi-stationary waves by resonance in middle latitudes*

*More extreme weather events during summer*

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**Number of observed July and August resonance months**

- 7-2011 Heat wave in the United States
- 7/8-2010 Russian heat wave and Pakistan flood
- 7-2006 European heat wave
- 8-2004 Winter like temperatures in Northern Europe
- 8-2003 European summer 2003 heat wave
- 8-2002 Elbe and Danube floods in Europe
- 7-2000 Floods in northern Italy and the Tisza basin, heat wave in the southern U.S.
- 7/8-1997 Great European Flood, floods in Pakistan and western U.S.
- 7-1994 Heat wave in southern Europe
- 7-1993 Unprecedented flood in the U.S.
- 7-1989 Widespread drought in U.S.
- 8-1987 Severe drought in the southeastern U.S.
- 8-1984 Severe heat and drought in the U.S.
- 7/8-1983 Severe heat and drought in U.S. mid-west

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*Coumou et al. 2014*
*Petoukhov et al. 2013*
Barents/Kara Sea-Asian Winter Teleconnection

**Warm Barents/Kara Seas → Cold Asia**

**Surface Air Temperature**

Corr. ART1 and SAT

**300 hPa Height (m)**

ART1 Z300

Kug et al. 2015
Over the past 50 years, average winter temperatures (December, January, and February) show the warming over land and enhanced warming over the Arctic expected from climate change. Departures from this behavior in the past 25 years may be due to natural variability, an altered climate-change response caused by sea ice declines, or a combination of the two. Data and graphics from (a).
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**Barents/Kara Sea-Asian Winter Teleconnection**

**Warm Barents/Kara Seas → Cold Asia**

Is Barents-Kara warming due simply to local sea ice loss or upstream Atlantic SSTs? [Sato et al. 2014]

Or is atmosphere heating driving the ice loss? [Sorokina et al. 2016]

Is teleconnection caused by tropospheric Rossby waves or via stratosphere? [Kim et al. 2014]


**Past 25 Years DJF Temps**

**Average surface temperature change (in °C)**

GISTEMP team 2016
Where do We Stand Now?
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The question is not whether Arctic changes are affecting mid-latitudes but rather how and by how much. --Ted Shepherd, *Science* (Sep 2016)
Different Seasonal Patterns of Sea Ice Loss
What about Atmospheric Blocking?

Greenhouse forcing generally leads to less blocking in models [Barnes and Polvani 2015]

But increasing waviness has been detected [Francis-Vavrus 2015, Di Capua-Coumou 2016]

Also evidence of more high-latitude blocking [Hanna et al. 2013, 2014]
Warm Arctic-Cold Continents Pattern
November 17, 2016

Air temperature anomaly (K)