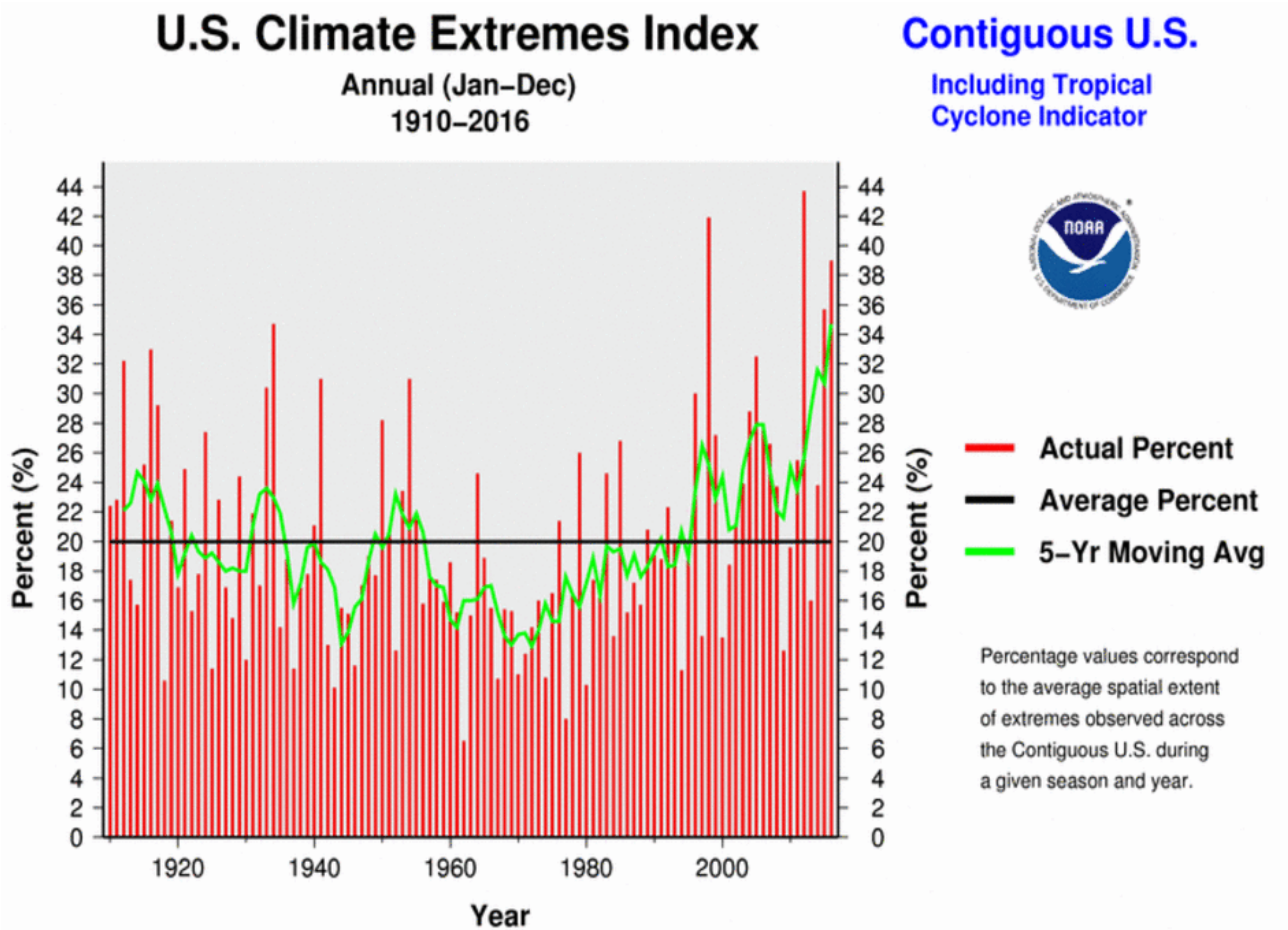
Linkage between Arctic Climate Change and Mid-Latitude Extreme Climate

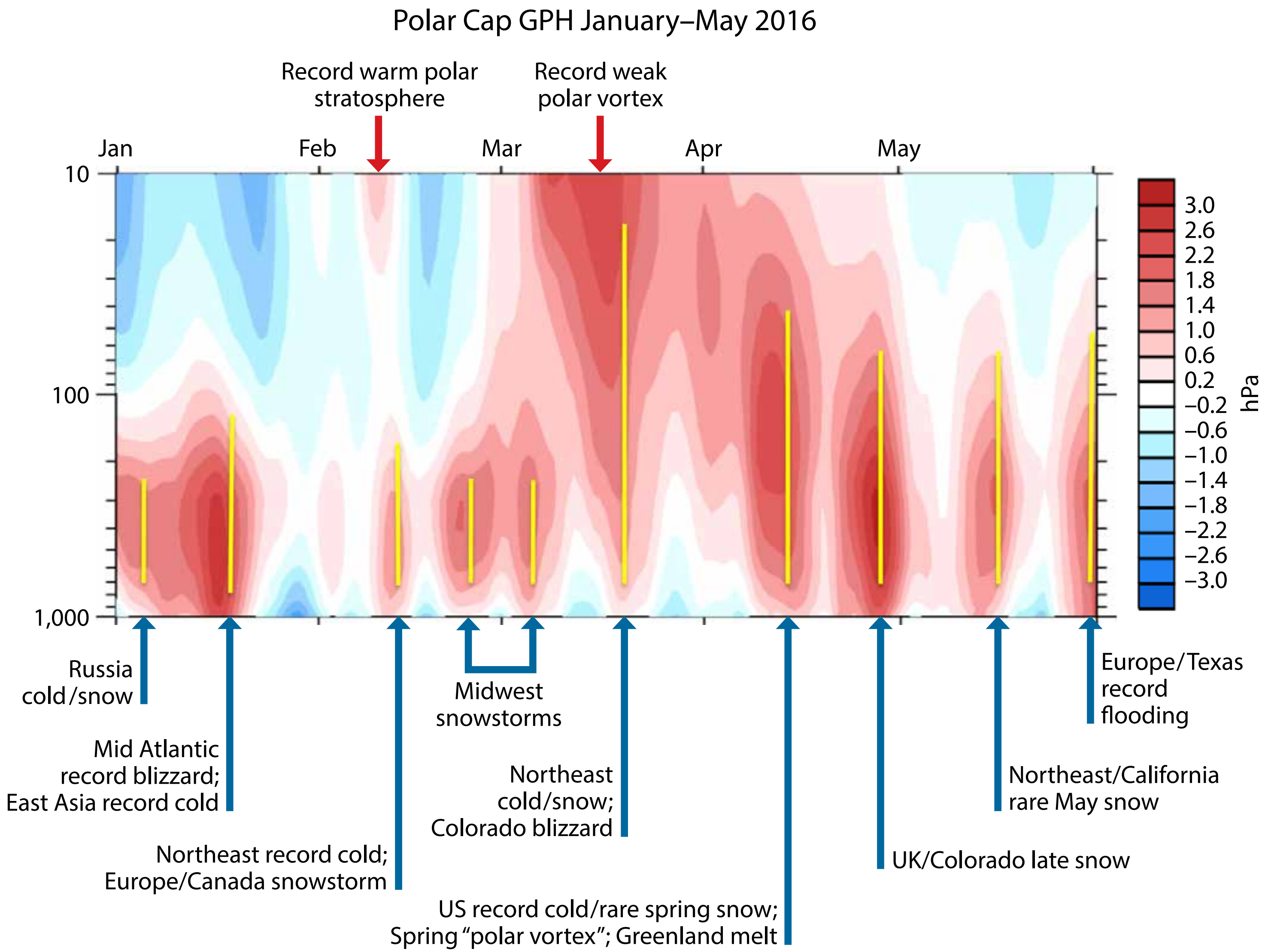
Steve Vavrus
Nelson Institute Center for Climatic Research
University of Wisconsin

(with assistance from Timo Vihma, Simon Wang, and Yannick Peings)

Increasing Trend of Extreme Weather



Extreme Weather often Coincides with Weak Polar Vortex



Cohen et al. 2017

Once Black and White . . .

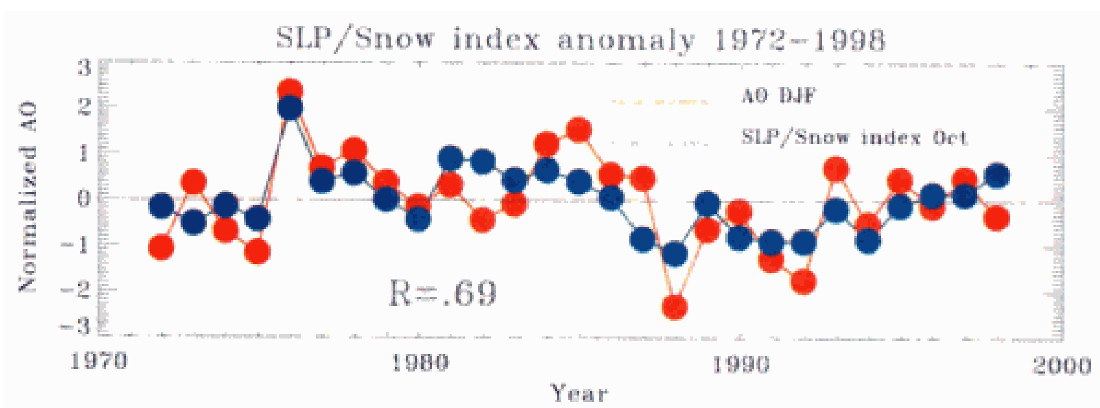
More Autumn Snow Cover = Strong Siberian High = Negative AO

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

The role of the Siberian high in Northern Hemisphere climate variability

Judah Cohen
Atmospheric and Environmental Research, Inc., Cambridge, Massachusetts

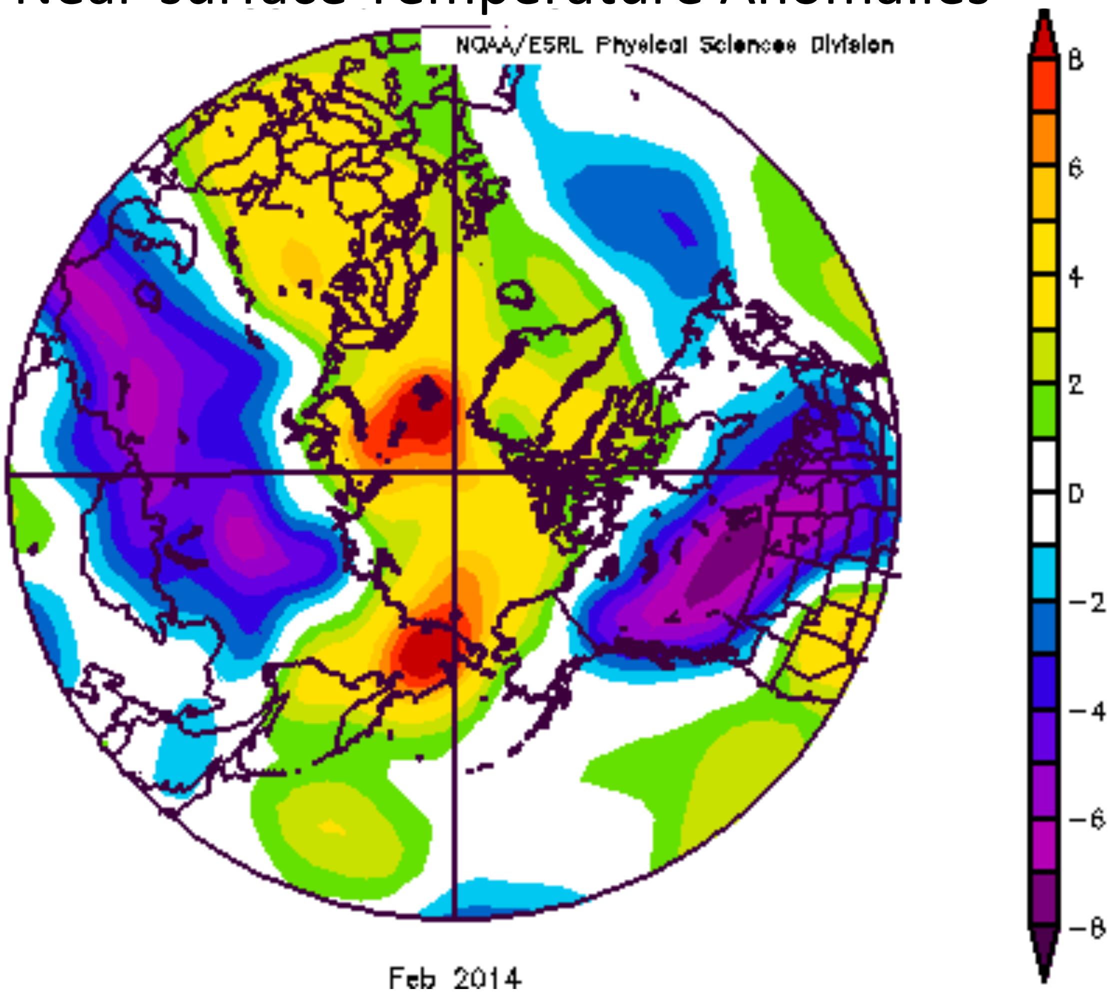
Kazuyuki Saito[1] and Dara Entekhabi
Massachusetts Institute of Technology Cambridge, Massachusetts



Once Black and White . . .

Warm Arctic-Cold Continents Pattern

Near-surface Temperature Anomalies



Arctic warms

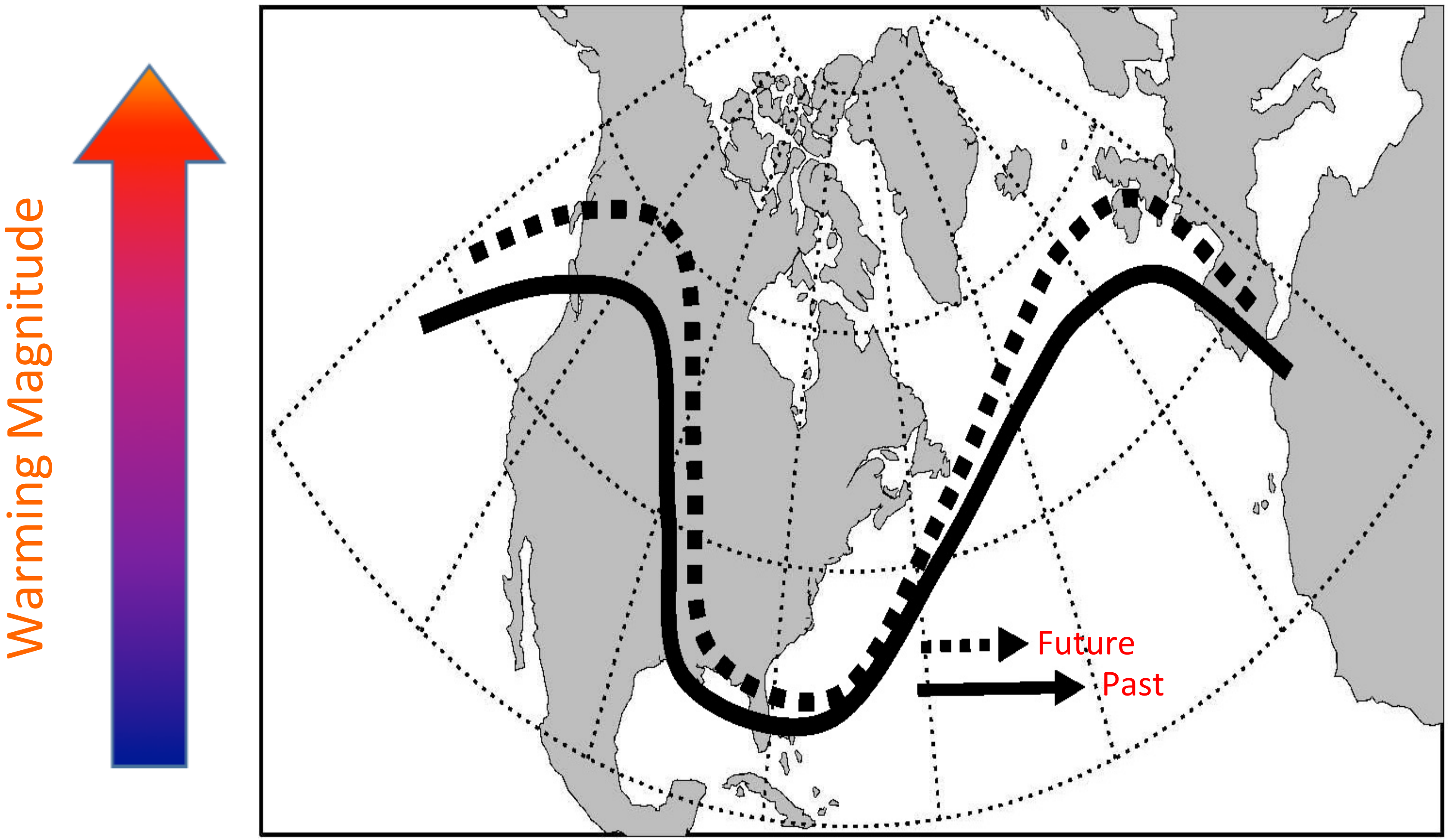
Continents cool

via
Arctic Oscillation

Overland et al. 2011

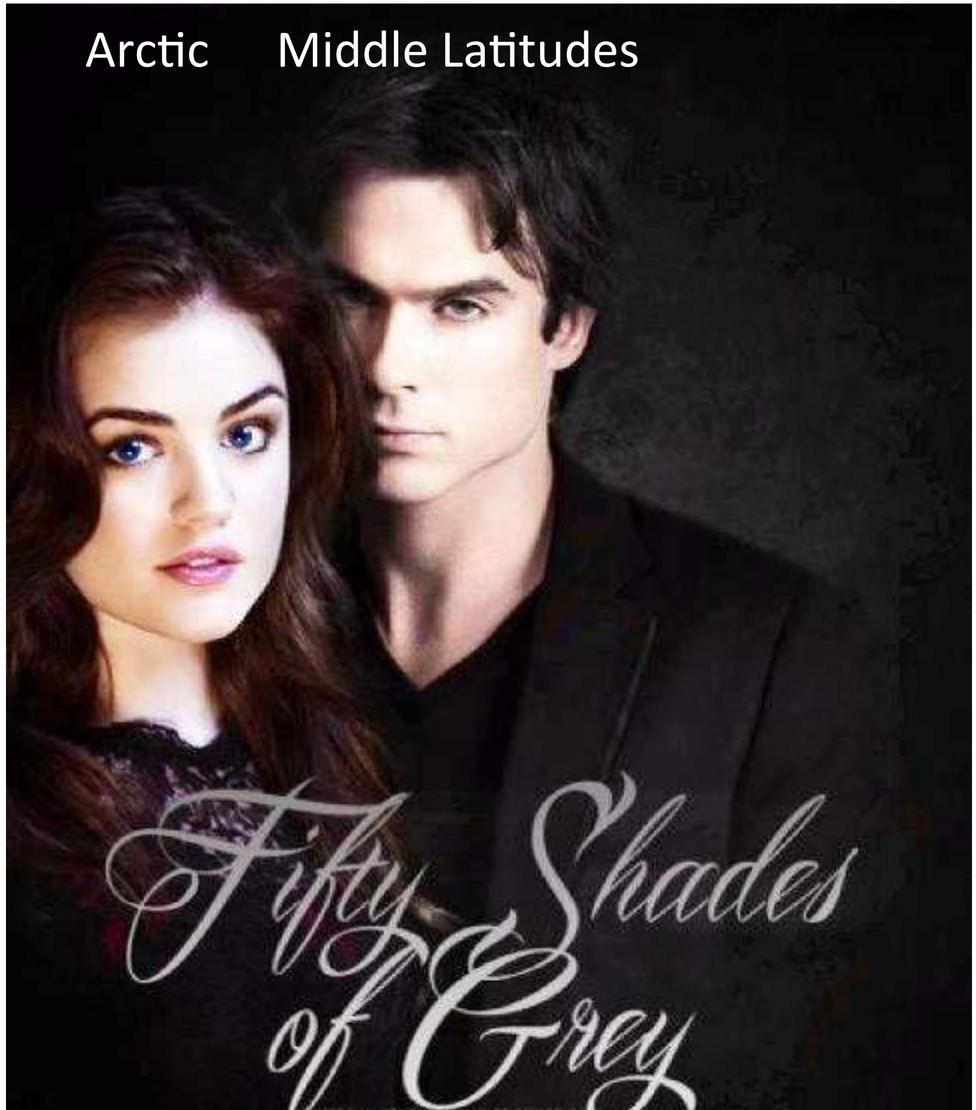
Once Black and White . . .

Warming Arctic = Weaker, Wavier Flow = More Extremes

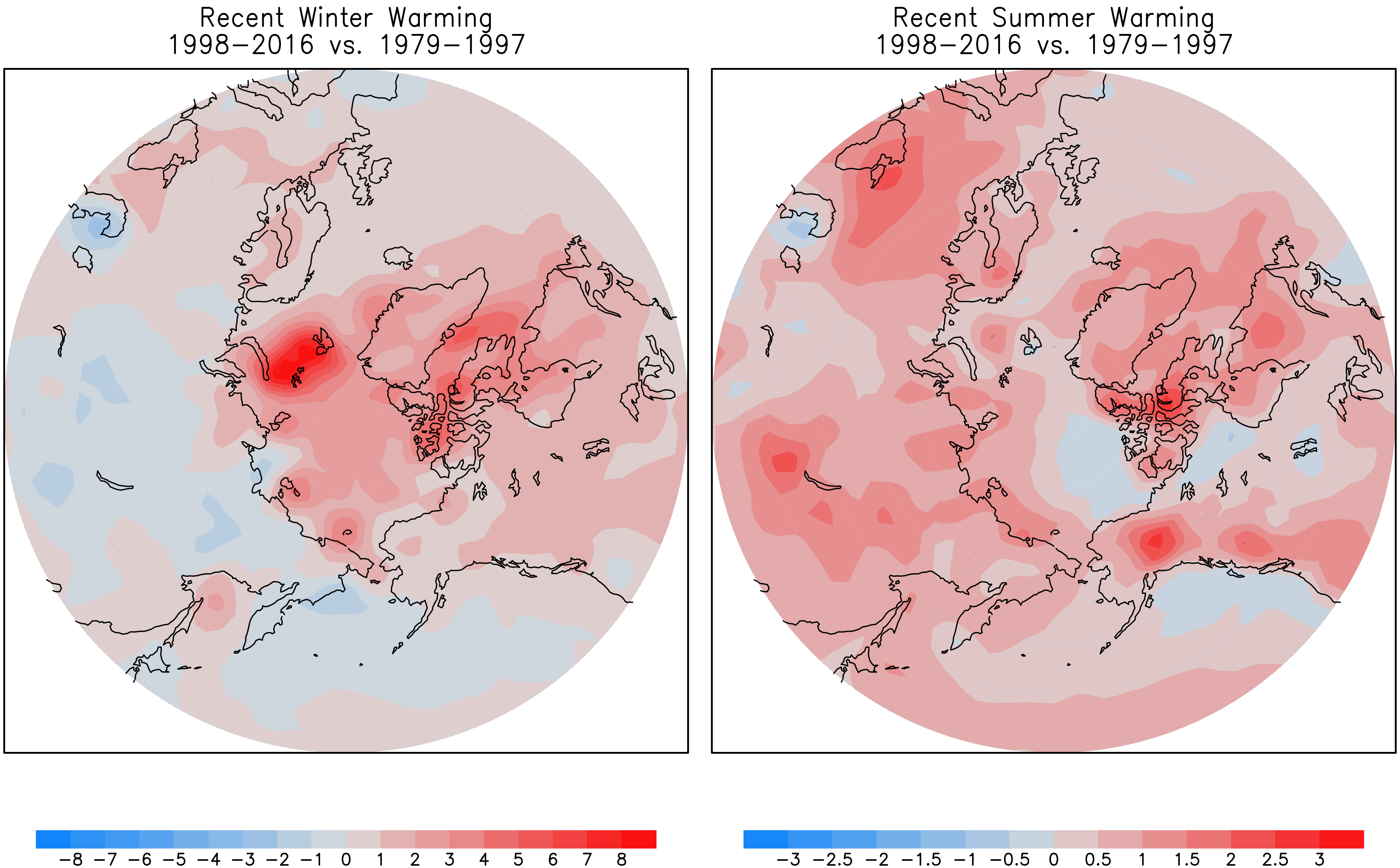


Francis & Vavrus 2012

. . . Now (at least) 50 Shades of Gray



Different Seasonal Patterns of Recent Warming

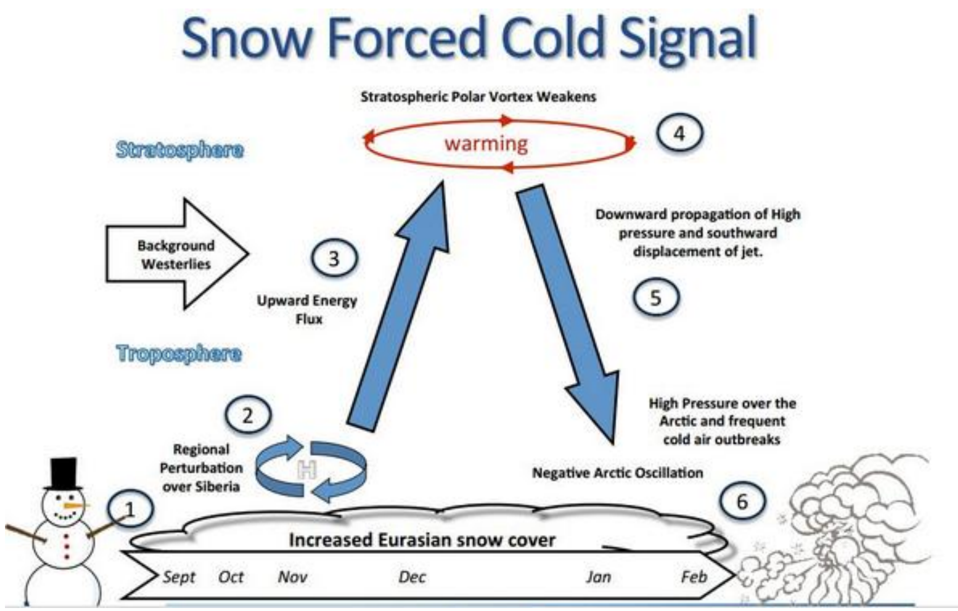


Mostly ocean-based

Mostly land-based

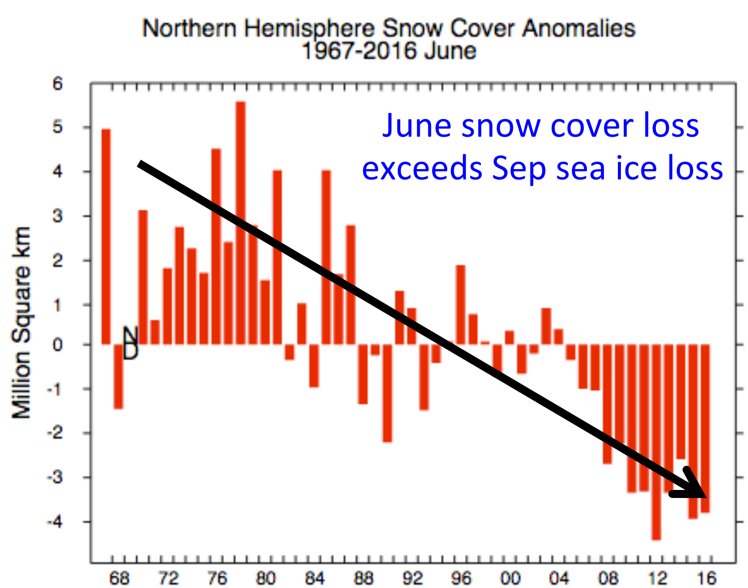
Role of Snow Cover

Autumn-Winter



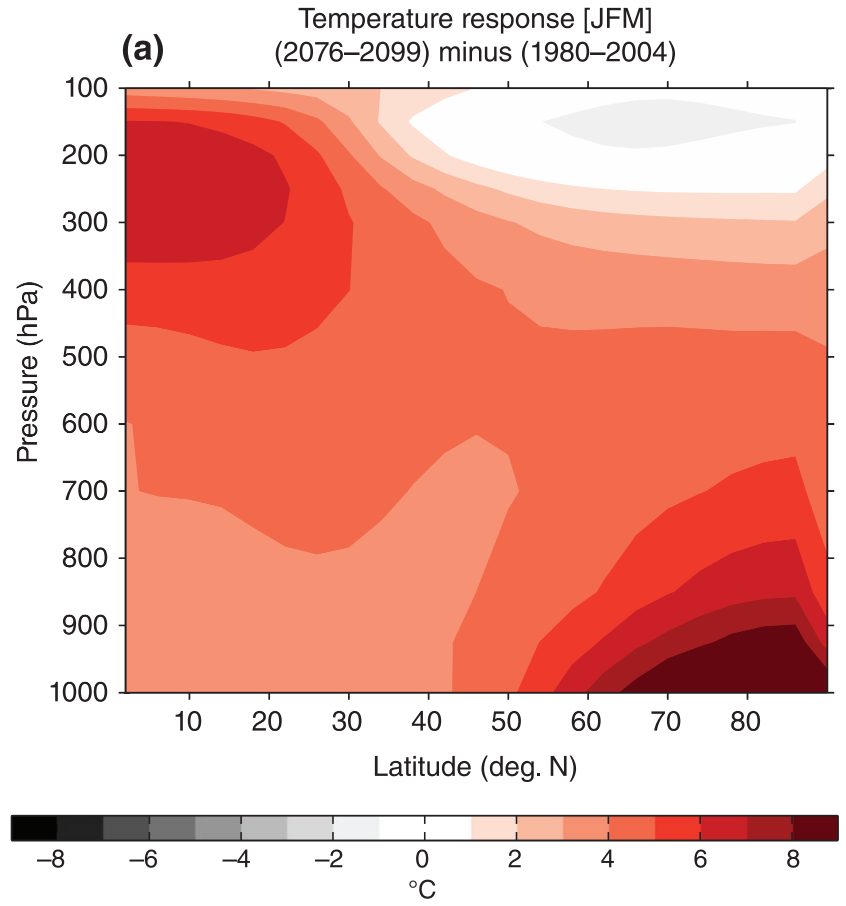
Judah Cohen

Spring-Summer



Rutgers Global Snow Lab

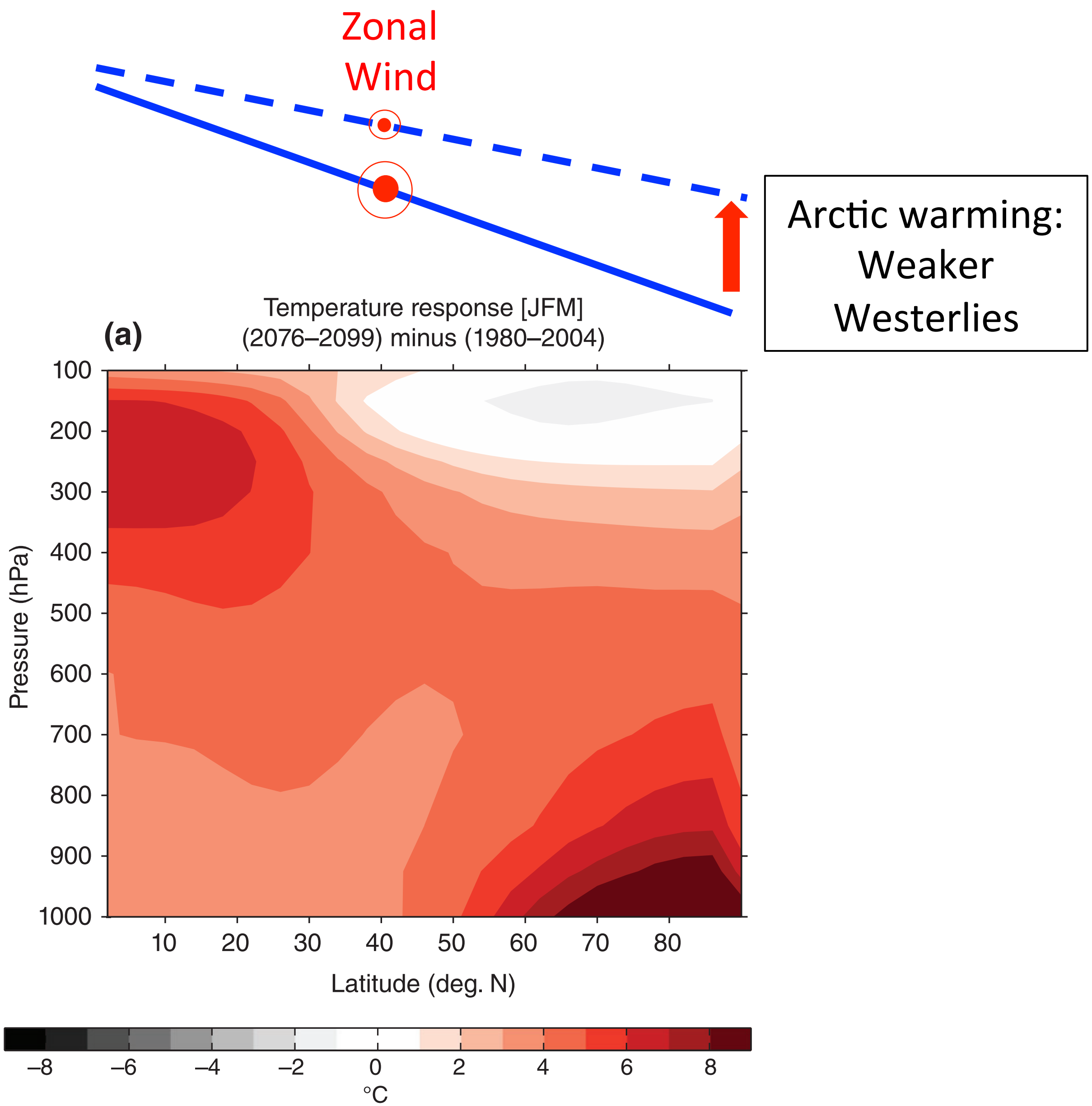
Tropical vs. Polar Tug-of-War



Projected Winter Warming, CMIP5

Barnes and Screen, 2015

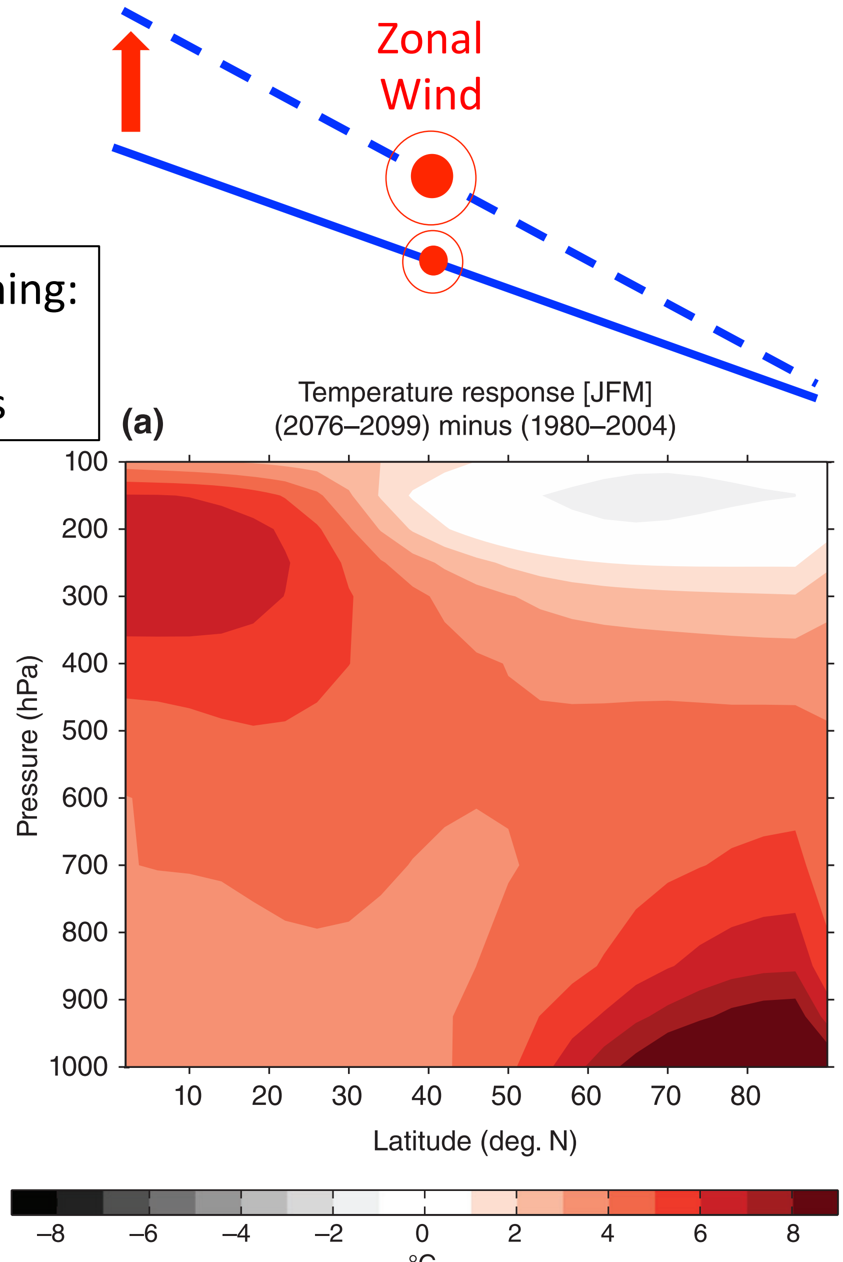
Tropical vs. Polar Tug-of-War



Barnes and Screen, 2015

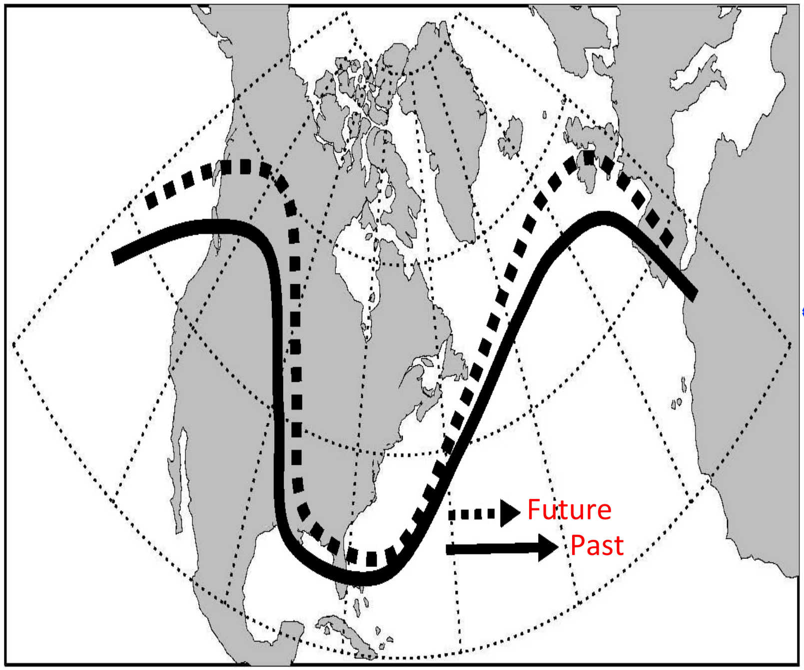
Tropical vs. Polar Tug-of-War

Tropical warming:
Stronger
Westerlies



Barnes and Screen, 2015

Weaker and Wavier Circulation Promotes Extreme Weather?



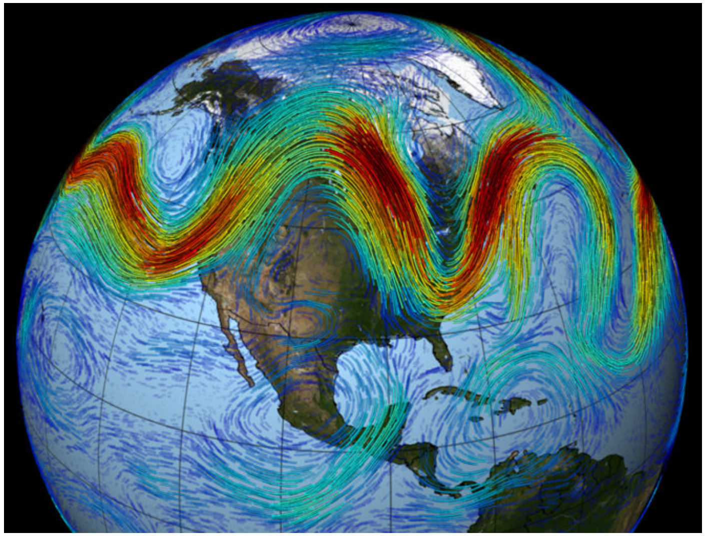
Meridional temperature gradient not sole control on mid-latitude jet (eddy-mean flow feedbacks) [*Hoskins & Woolings 2015*]

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

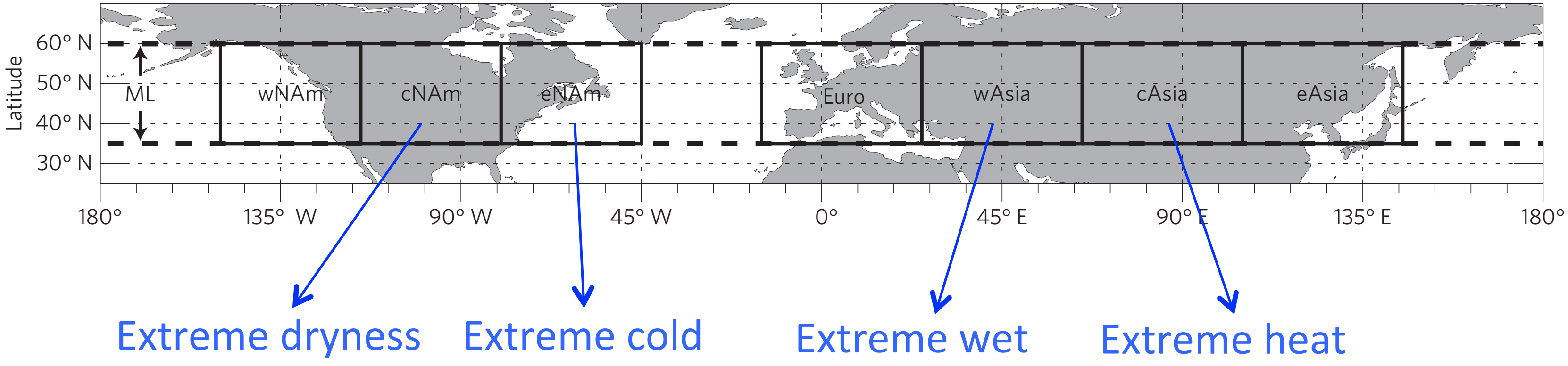
Thermal influence of wavier circulation on cold extremes is mitigated by advection of warmer upstream Arctic air [*Screen 2014*]

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



Screen & Simmonds 2014

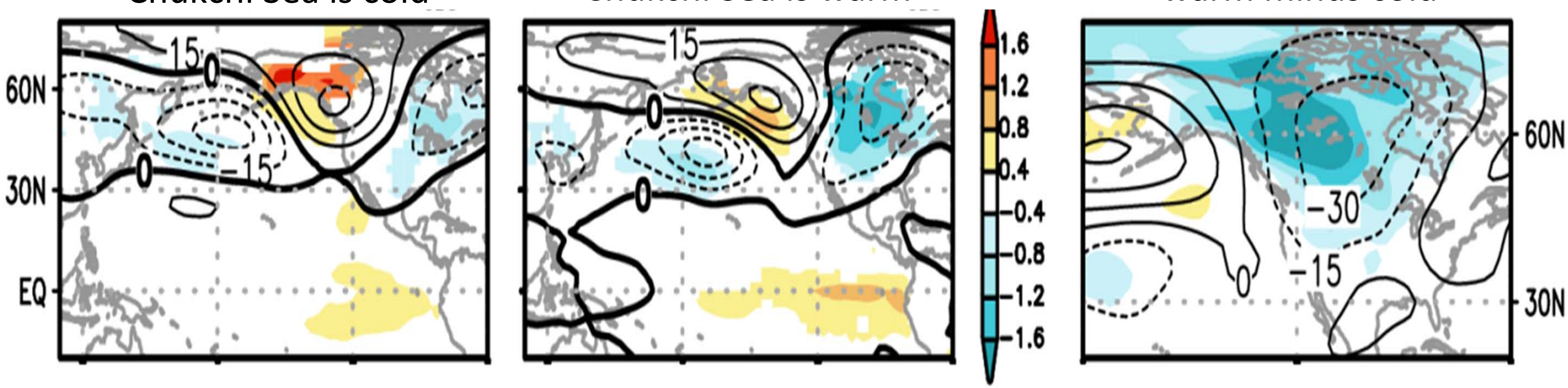
Dependence of Teleconnections on Background State

Response of Autumn-Winter 300 hPa Heights

PDO Influence when Chukchi Sea is cold

PDO Influence when Chukchi Sea is warm

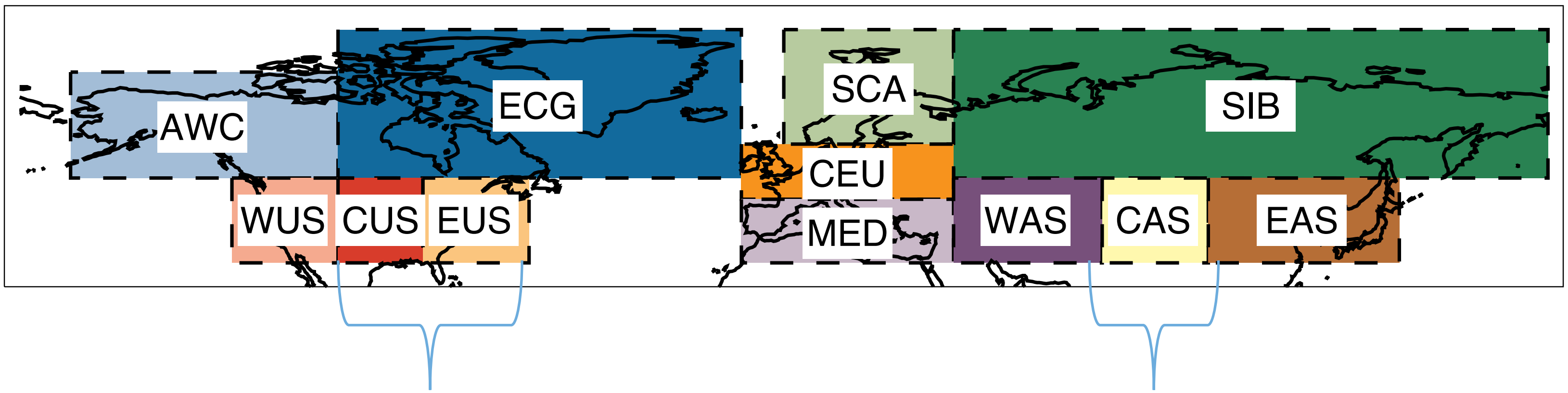
Different in PDO Influence warm minus cold



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

↓

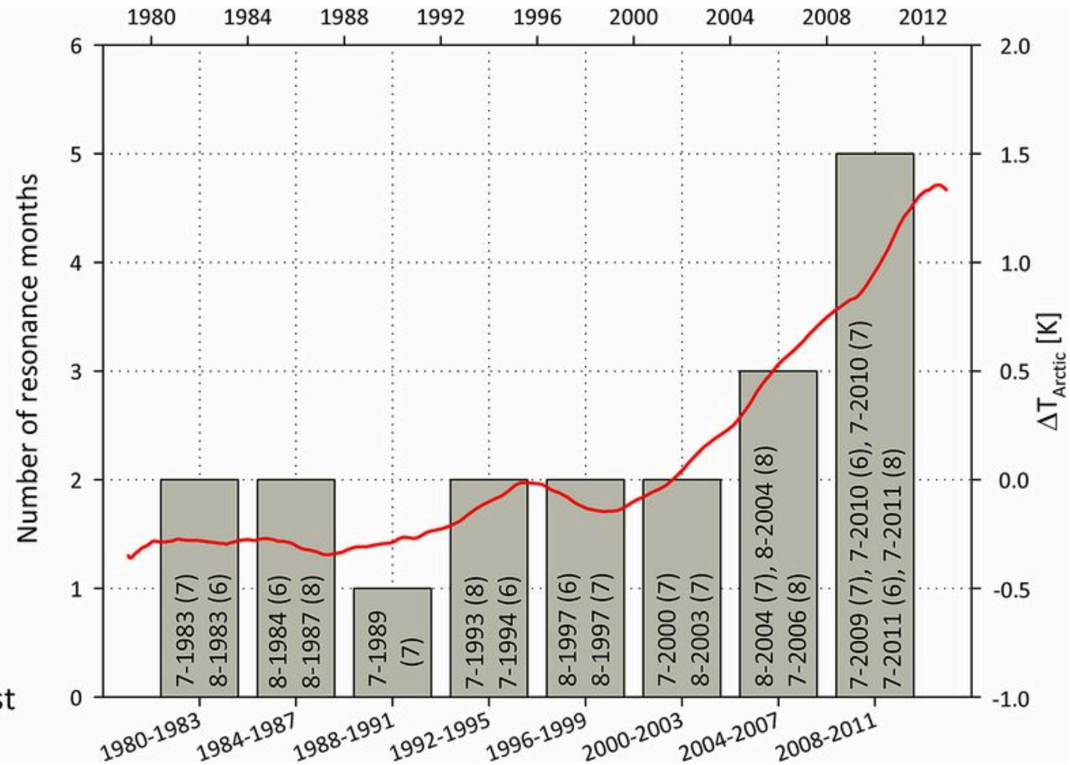
Amplification of quasi-stationary waves by resonance in middle latitudes

↓

More extreme weather events during summer

Number of observed July and August resonance months

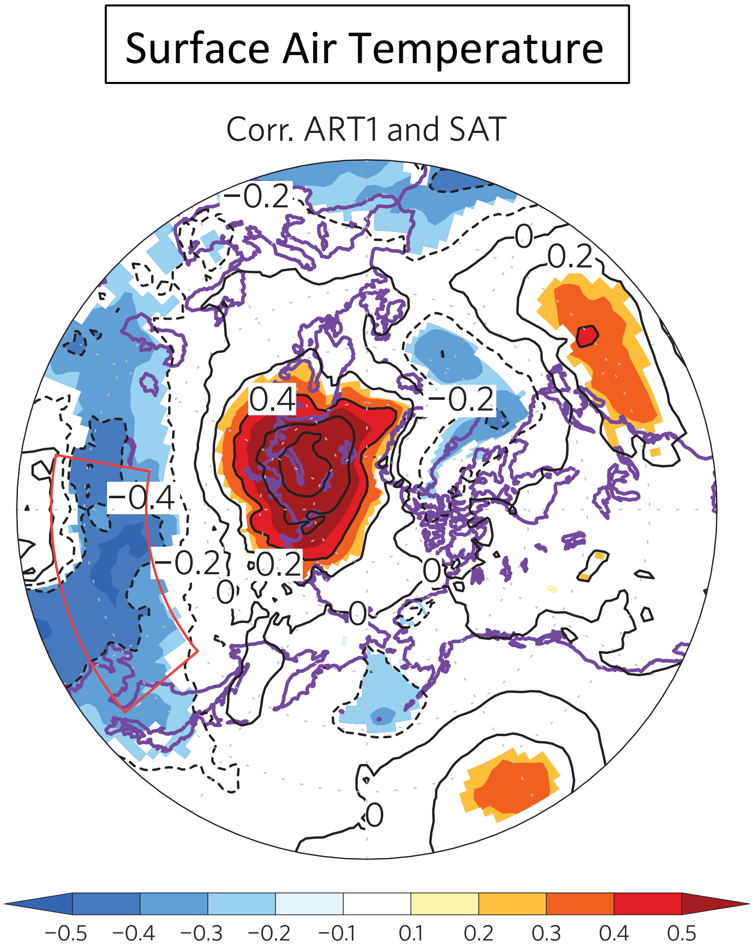
7-2011	Heat wave in the United States
7/8-2010	Russian heat wave and Pakistan flood
7-2006	European heat wave
8-2004	Winter like temperatures in Northern Europe
8-2003	European summer 2003 heat wave
8-2002	Elbe and Danube floods in Europe
7-2000	Floods in northern Italy and the Tisza basin, heat wave 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

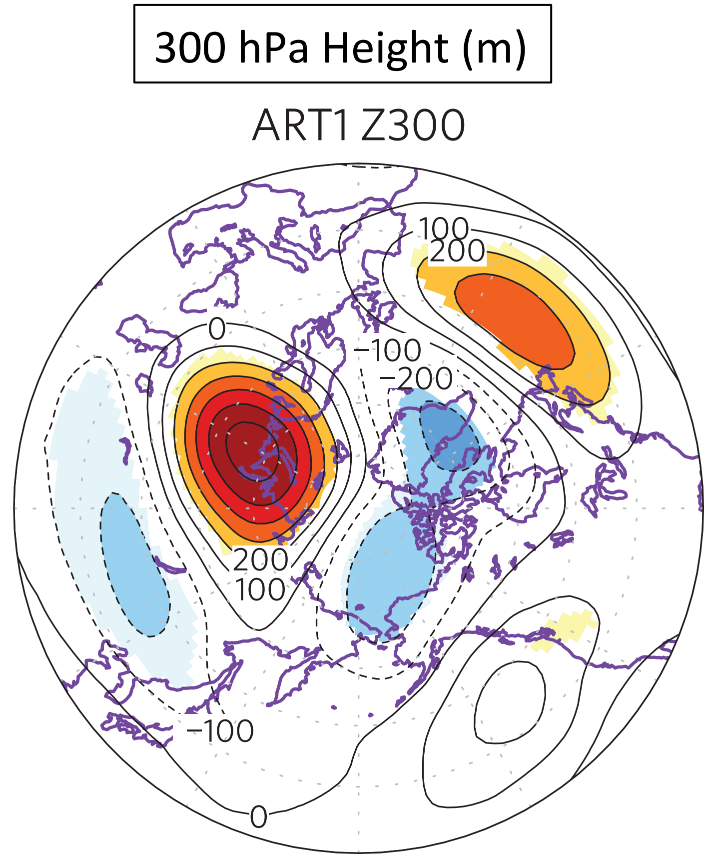


Coumou et al. 2014
Petoukhov et al. 2013

Barents/Kara Sea-Asian Winter Teleconnection

Warm Barents/Kara Seas → Cold Asia



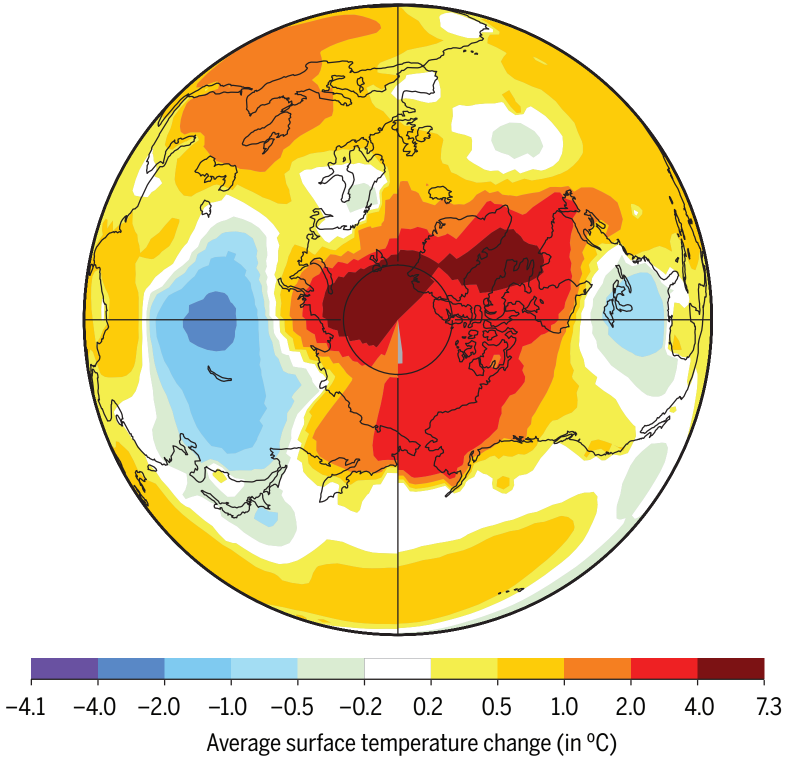


Kug et al. 2015

Barents/Kara Sea-Asian Winter Teleconnection

Warm Barents/Kara Seas → Cold Asia

Past 25 Years DJF Temps

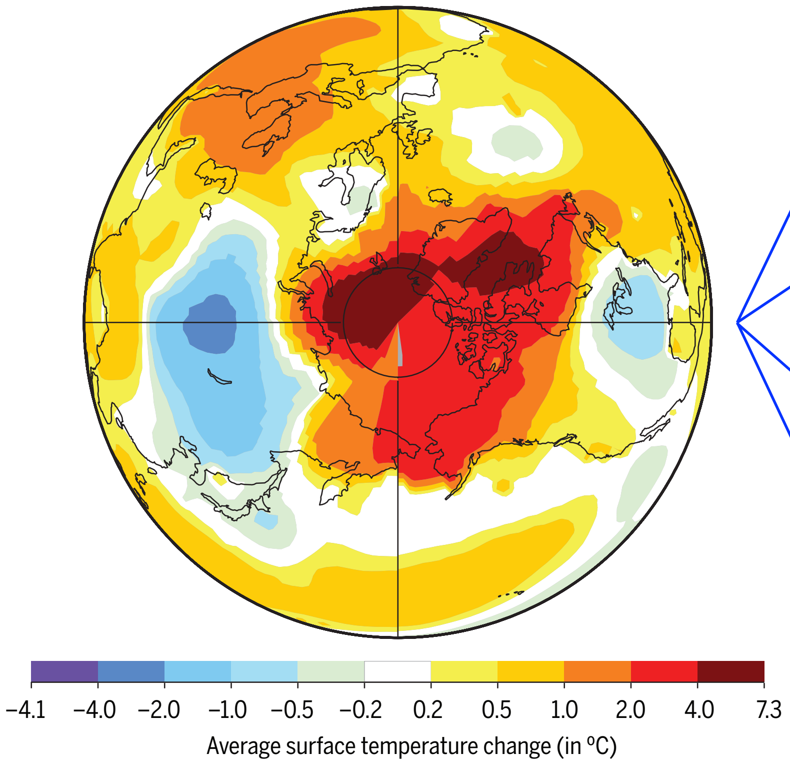


GISTEMP team 2016

Barents/Kara Sea-Asian Winter Teleconnection

Warm Barents/Kara Seas → Cold Asia

Past 25 Years DJF Temps



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*]

Is Asian cooling trend just internal variability? [*McCusker et al. 2016, Sun et al. 2016*]

GISTEMP team 2016

Where do We Stand Now?

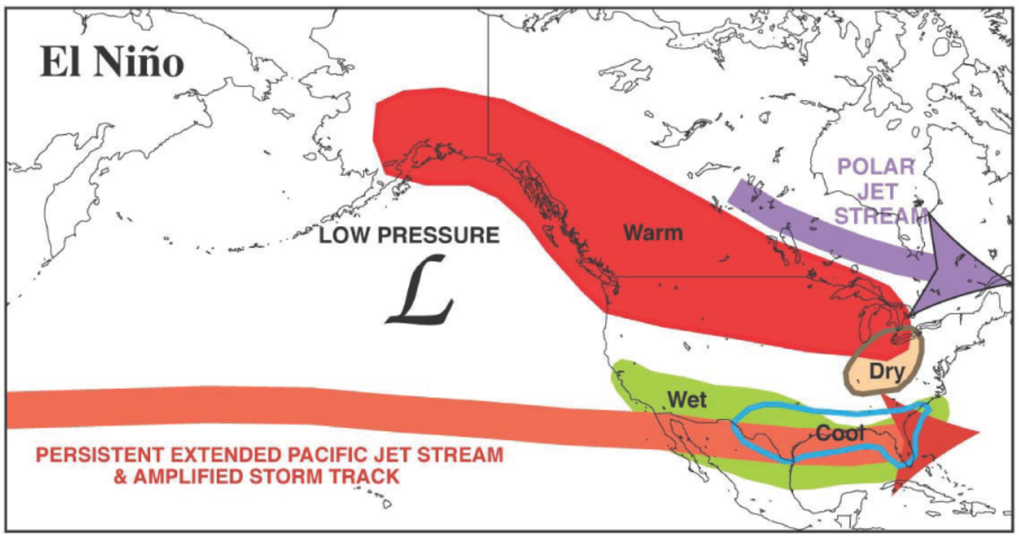
Where do We Stand Now?

We are in the "pre-consensus" stage of a theory that there are links between the rapid warming of the Arctic and some severe weather events since 2007. --Jim Overland

Where do We Stand Now?

We are in the "pre-consensus" stage of a theory that there are links between the rapid warming of the Arctic and some severe weather events since 2007. --Jim Overland

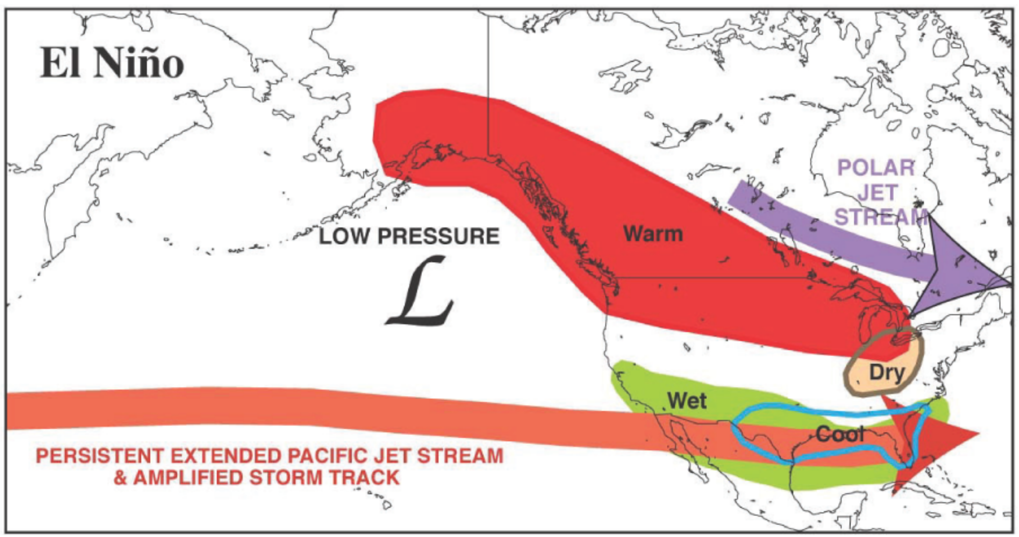
Canonical El Niño



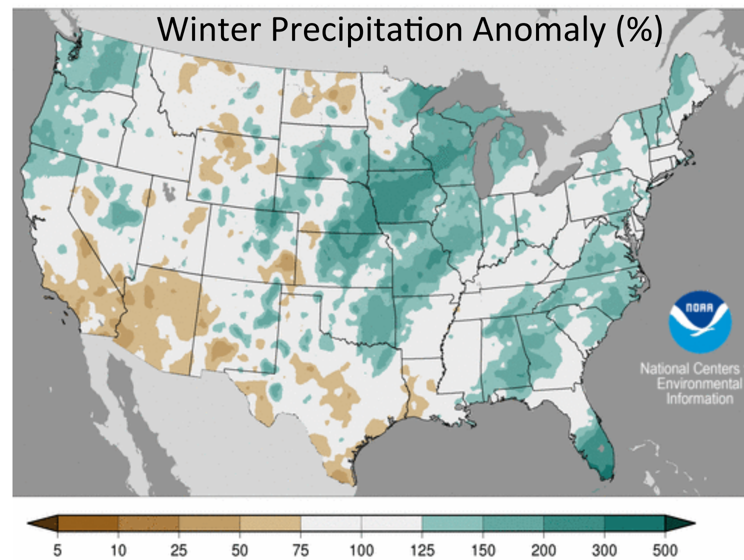
Where do We Stand Now?

We are in the "pre-consensus" stage of a theory that there are links between the rapid warming of the Arctic and some severe weather events since 2007. --Jim Overland

Canonical El Niño



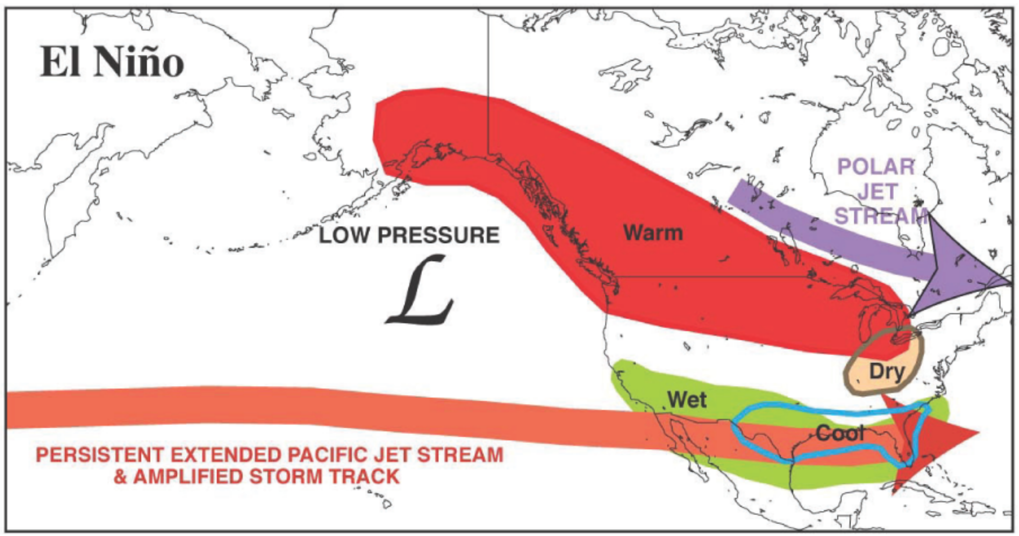
2015-16 'Godzilla' El Niño



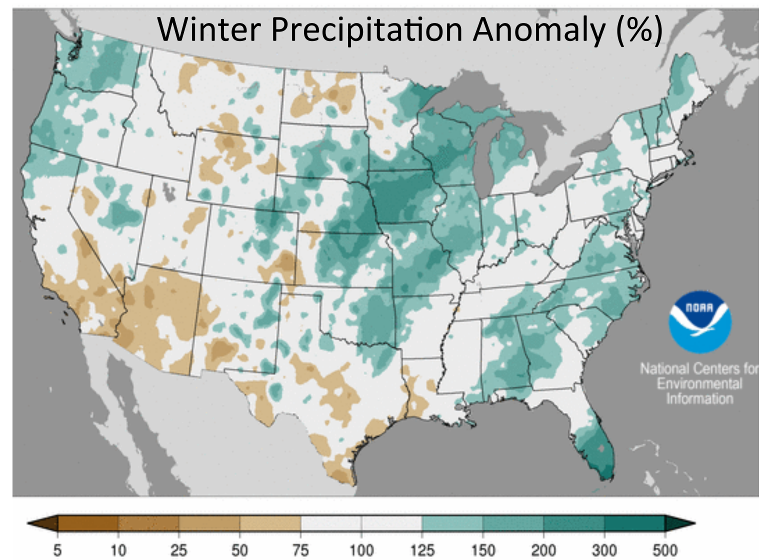
Where do We Stand Now?

We are in the "pre-consensus" stage of a theory that there are links between the rapid warming of the Arctic and some severe weather events since 2007. --Jim Overland

Canonical El Niño

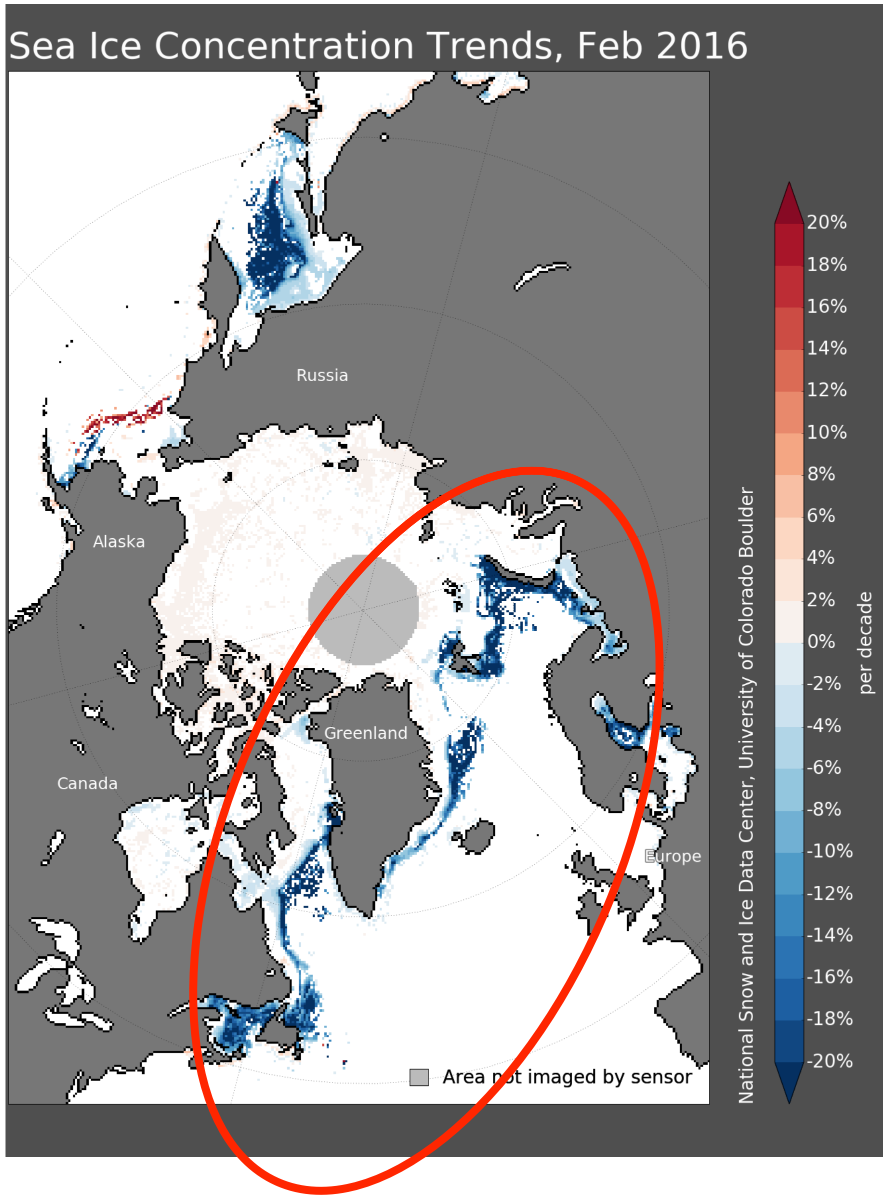


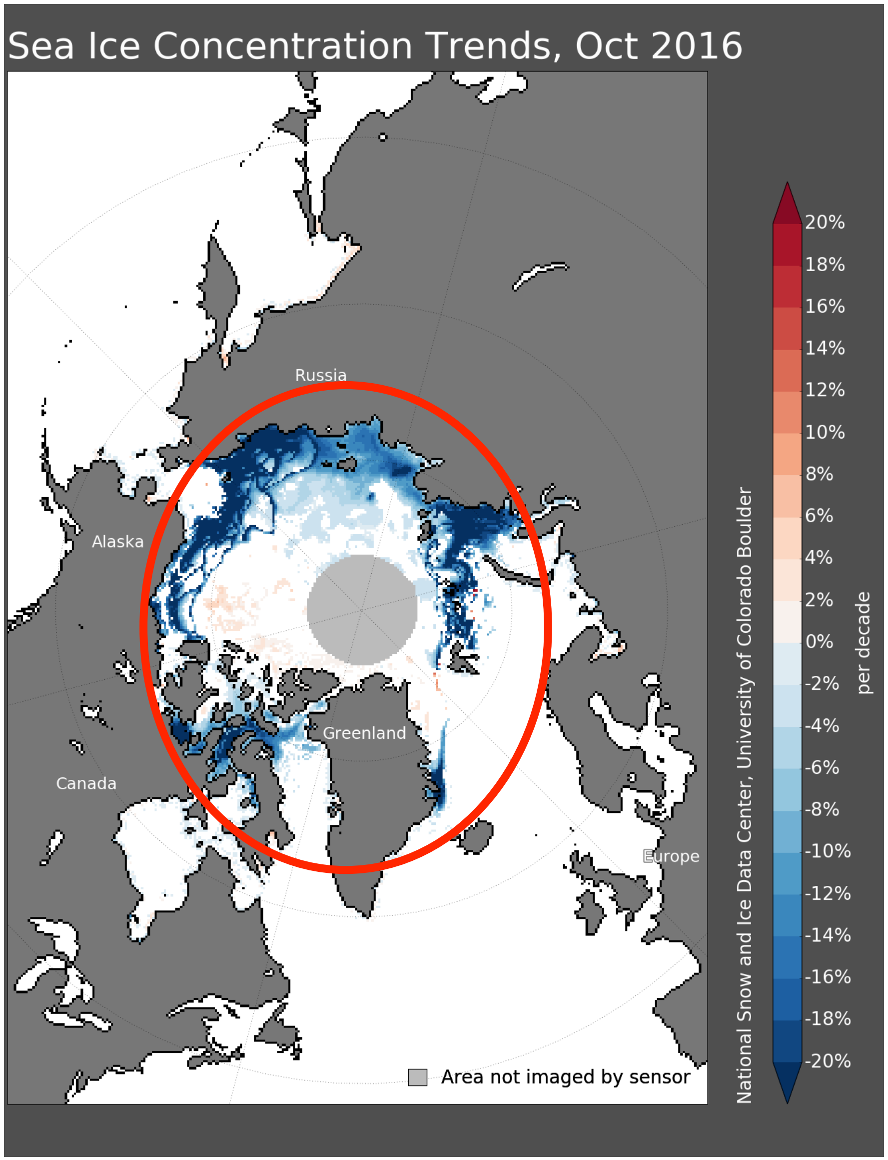
2015-16 'Godzilla' El Niño



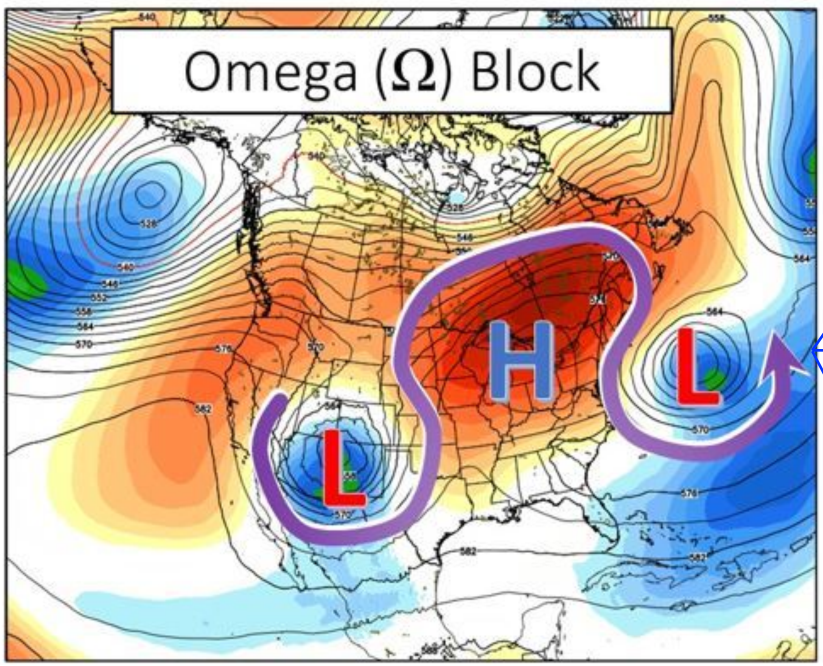
The question is not whether Arctic changes are affecting mid-latitudes but rather how and by how much. --Ted Shepherd, Science (Sep 2016)

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