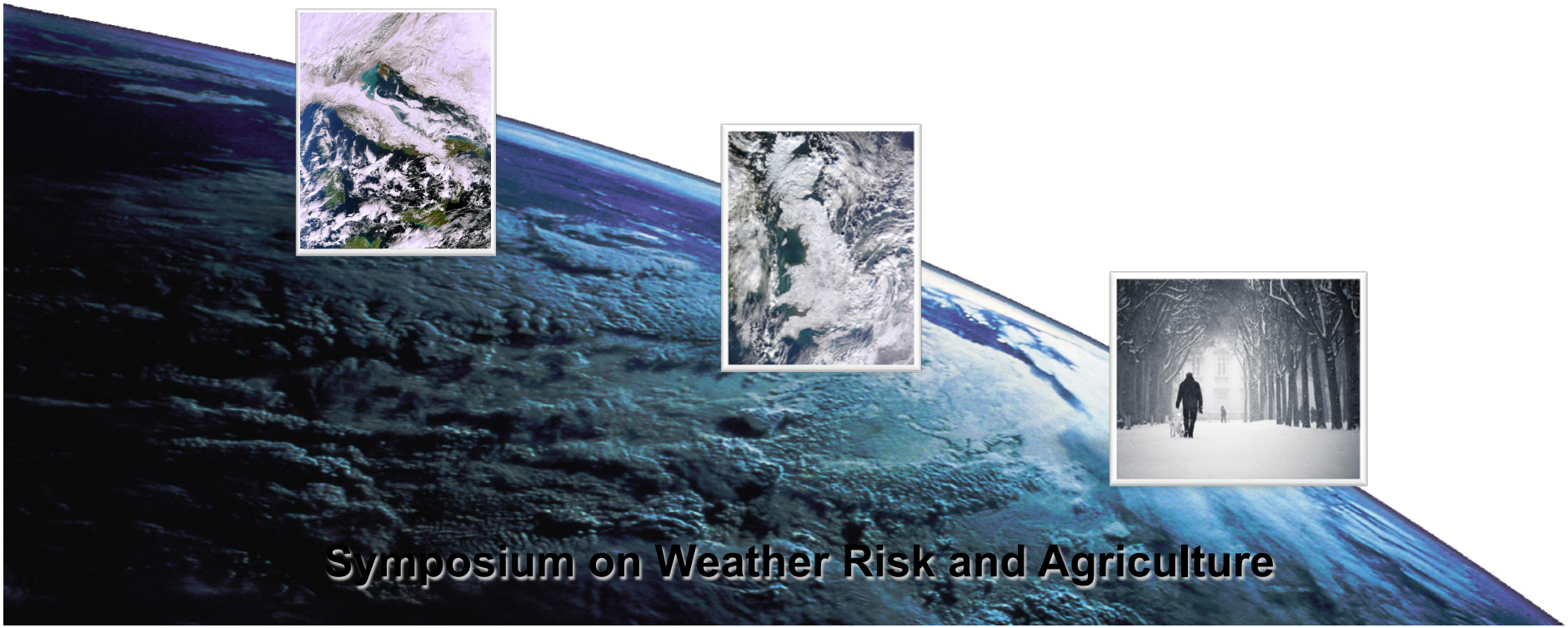
The Relationship between Recent Arctic Change and Extreme Mid-latitude Weather

Judah Cohen
AER/Dept CEE MIT
May 15, 2015



Symposium on Weather Risk and Agriculture

USA TODAY

Boston breaks seasonal snowfall record with 108.6 inches

Capital Weather Gang

How climate change may be producing more blockbuster snowstorms

The Washington Post

Energy and Environment

What the massive snowfall in Boston tells us about global warming

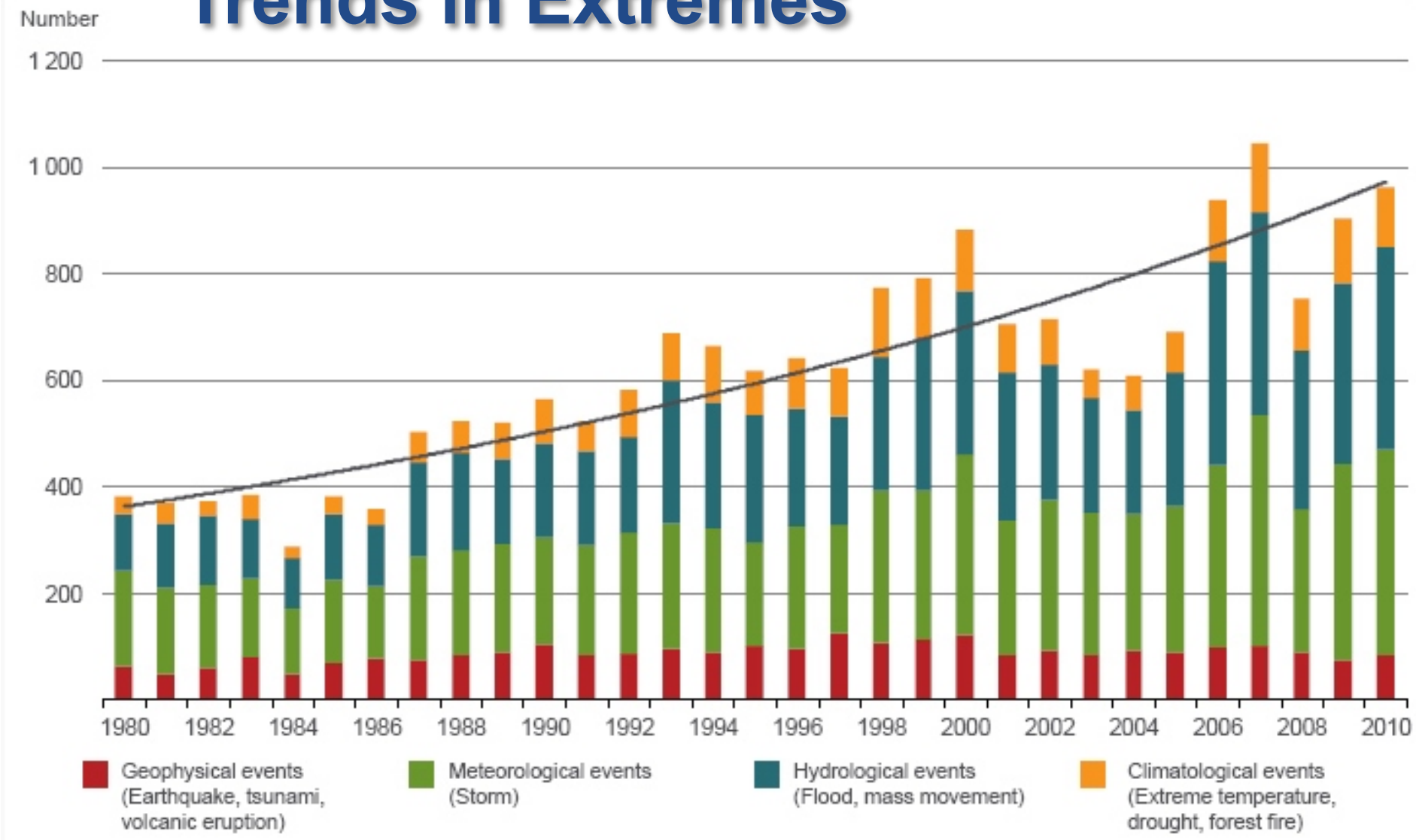
Cities in West, Northeast See Record Temperature Extremes in First Three Months of 2015

The Weather Channel

As California Drought Enters 4th Year, Conservation Efforts and Worries Increase

The New York Times

Trends in Extremes



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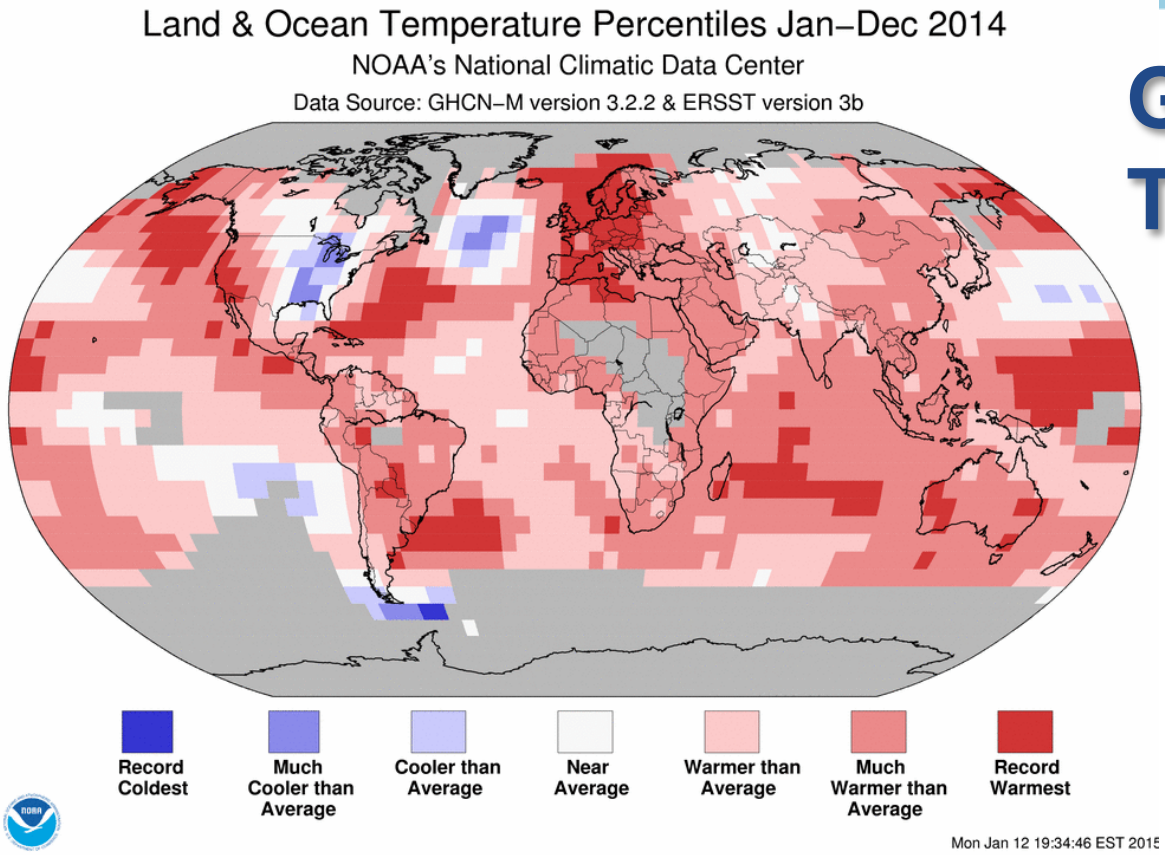
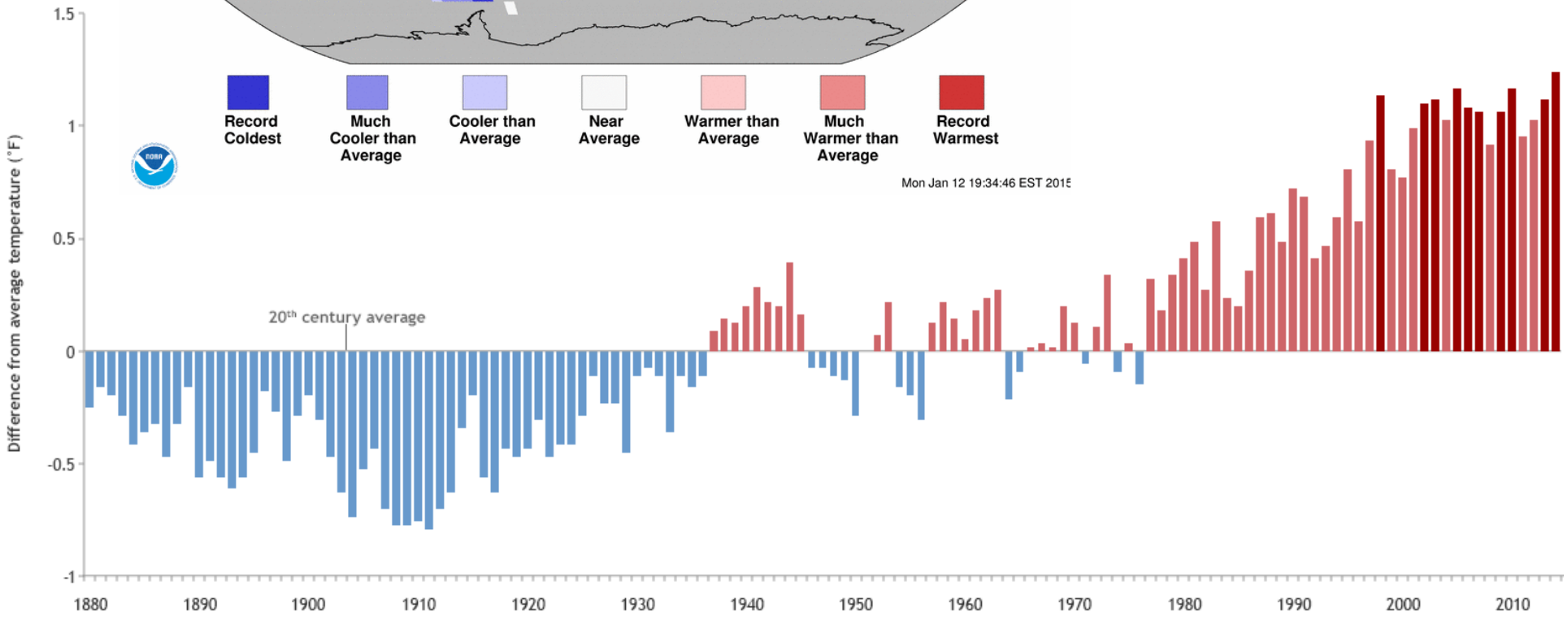
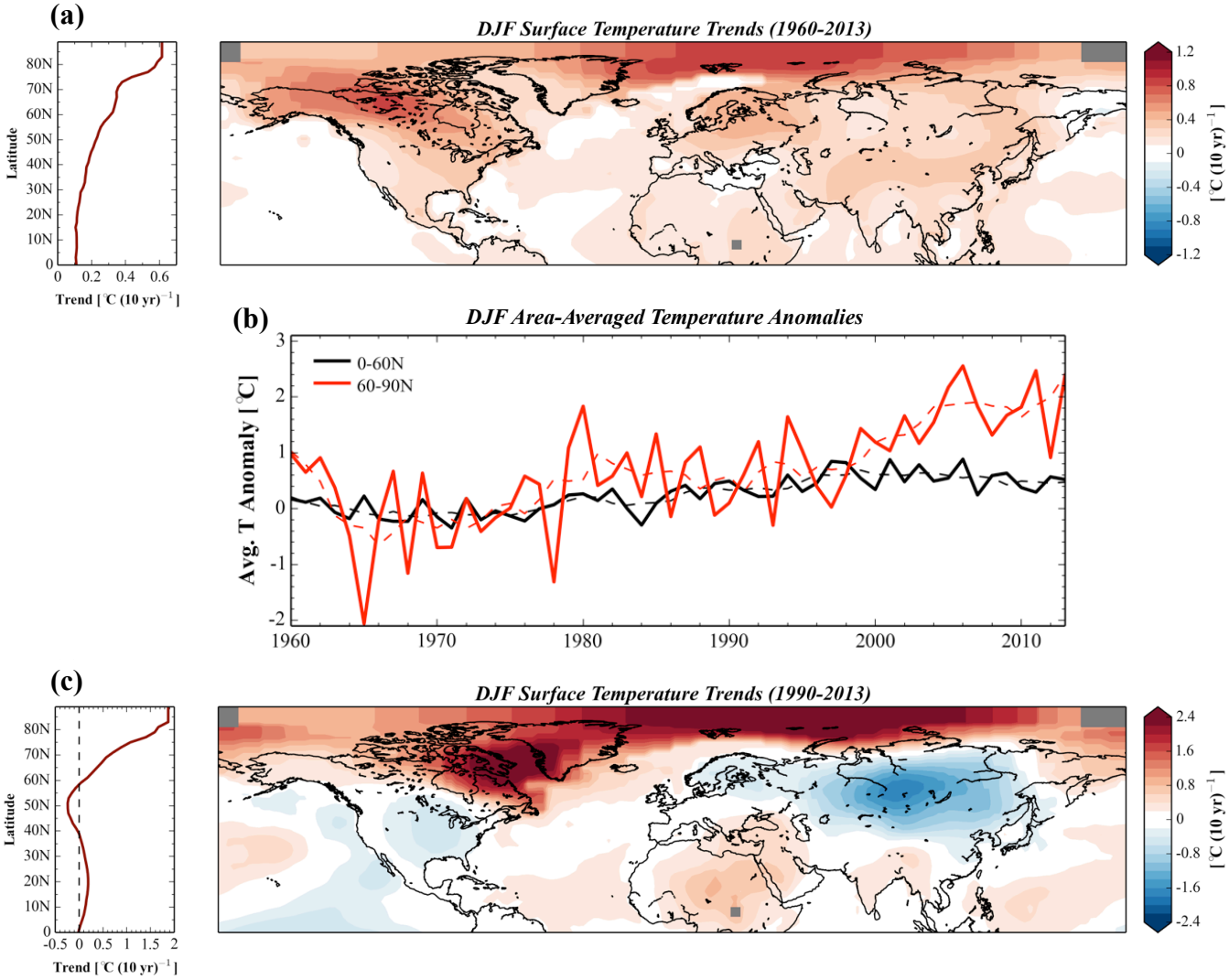
Source: MunichRe

Global Temperatures



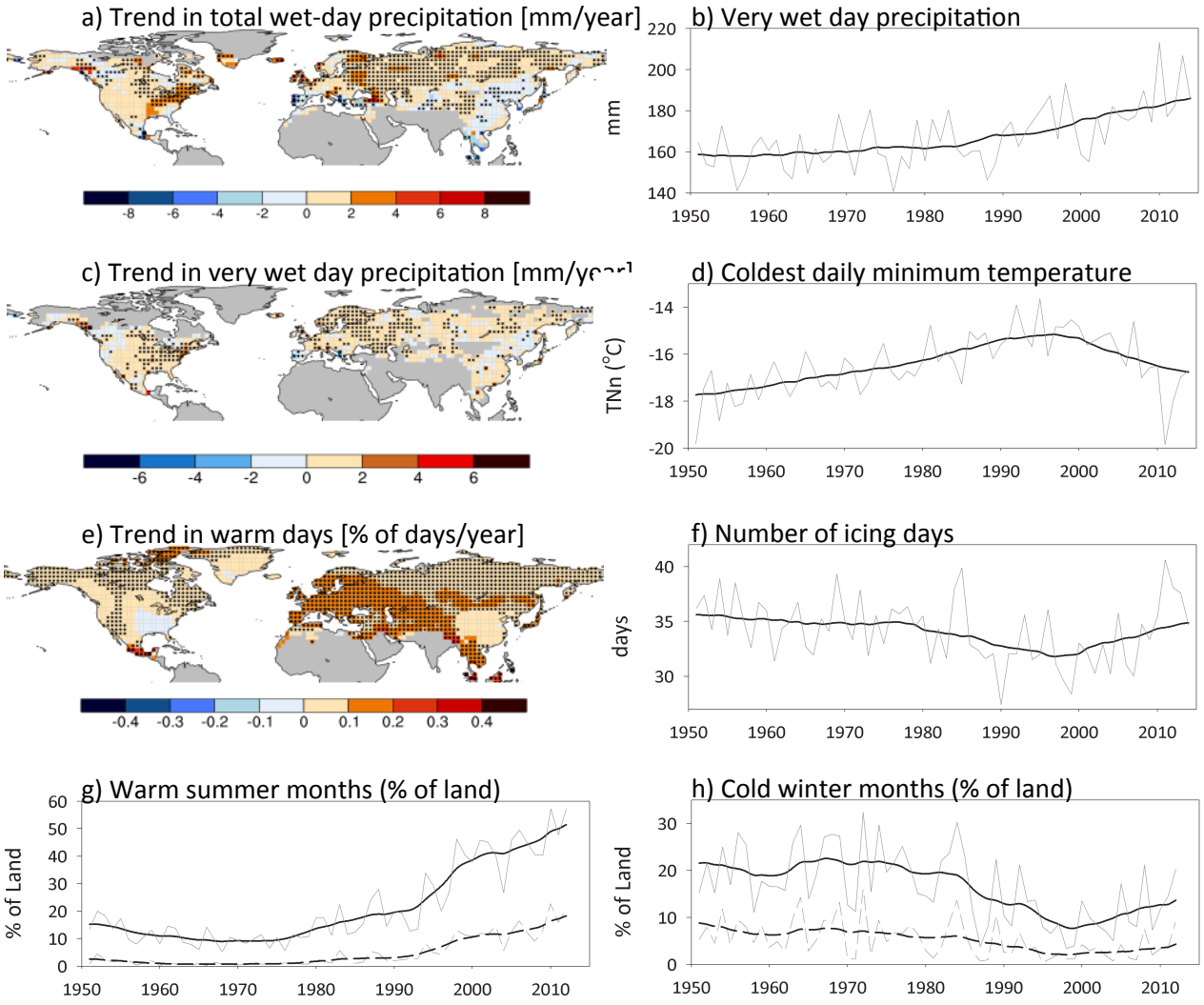


Arctic Amplification (accelerated warming)



Cohen et al. 2014

Extreme Weather



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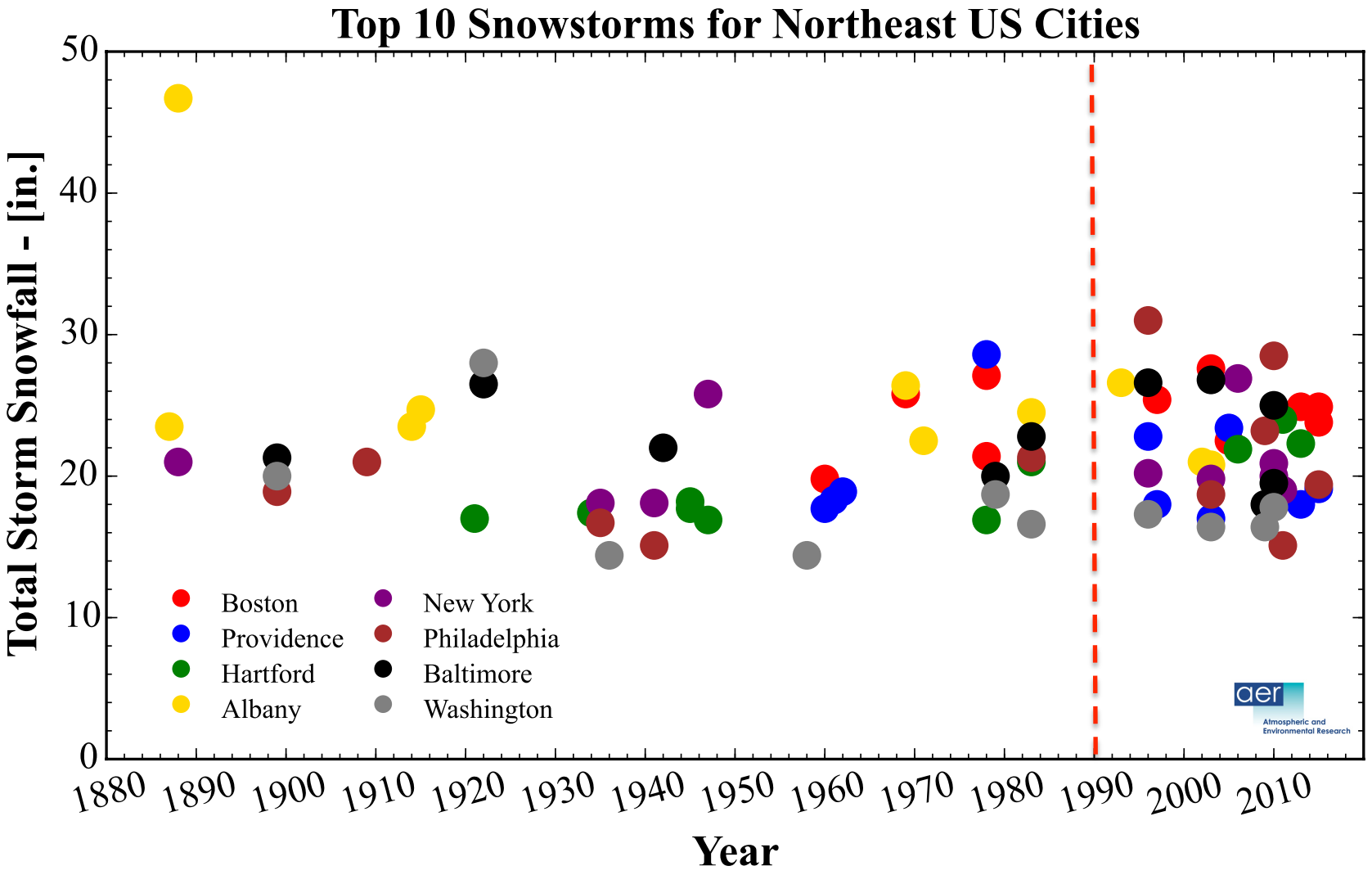
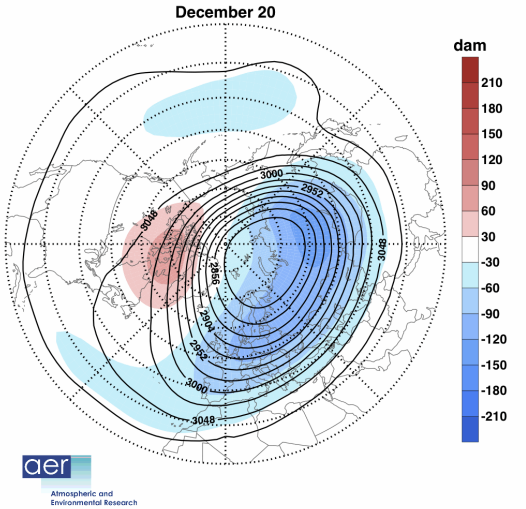
Cohen et al. 2014

Extreme Snowfall



Arctic Oscillation (AO)/Polar Vortex

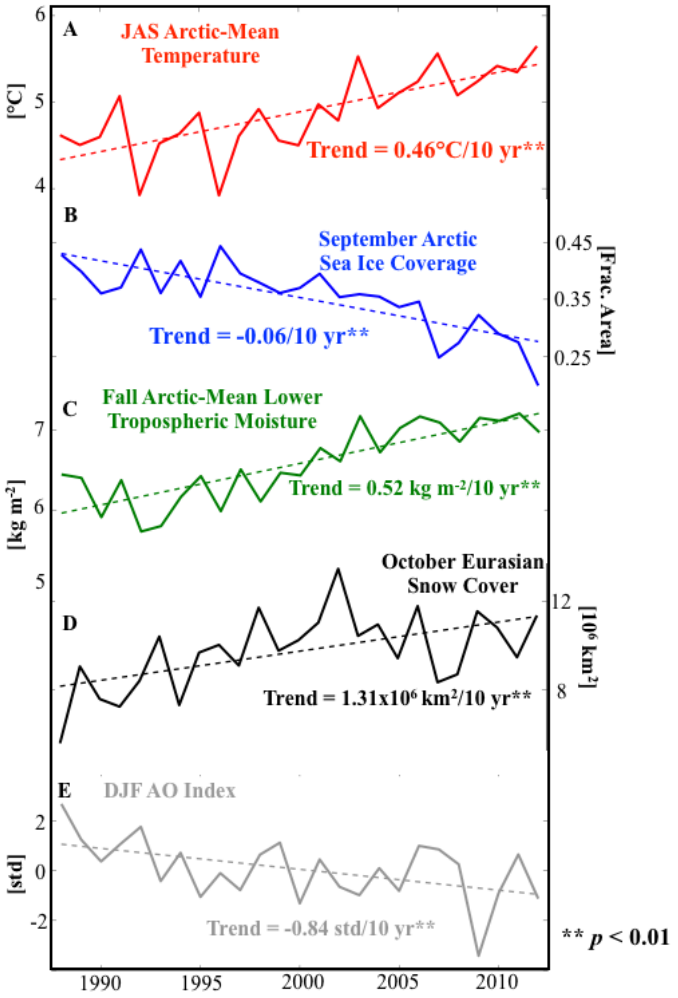
- Also known as the North Atlantic Oscillation.
- Can be thought of as a metric of how much mixing of atmospheric masses is occurring in the atmosphere.



- Positive AO/strong polar vortex – little mixing with strong low pressure/cold air sitting over the pole and higher pressure/warmer air to the south.
- Negative AO/weak polar vortex – strong mixing causes warm air to rush the Pole and Arctic south spills equatorward

Melting sea and ice and increasing snow cover are contributing to a weakening of the polar vortex (and more extreme weather).

- ✓Warming Arctic
- ✓Less sea ice
- ✓More atmospheric moisture
- ✓Increasing snow cover
- ✓Decreasing Arctic Oscillation trend/weakening of the polar vortex



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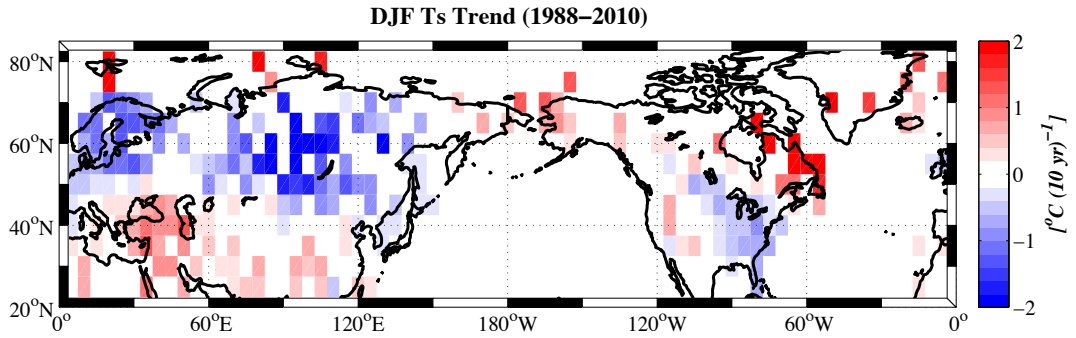
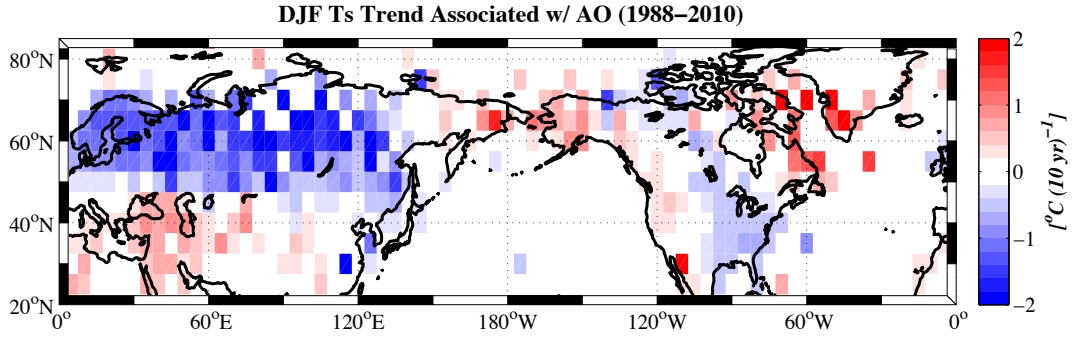
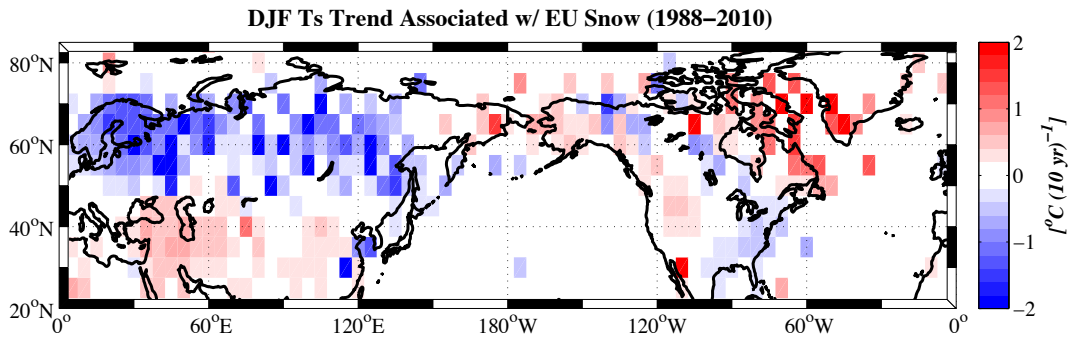
Cohen et al. 2012b

Winter Temperature Trends







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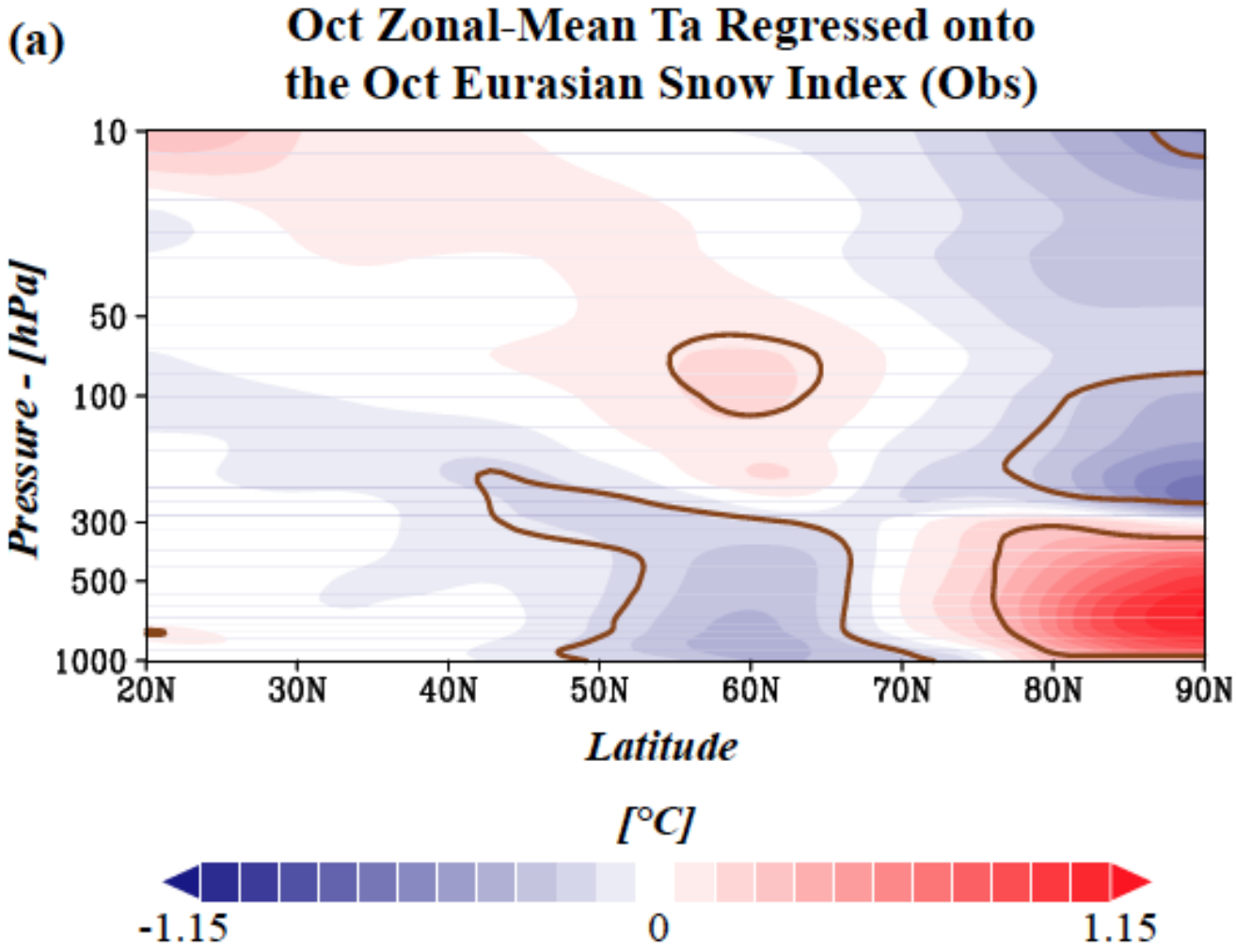
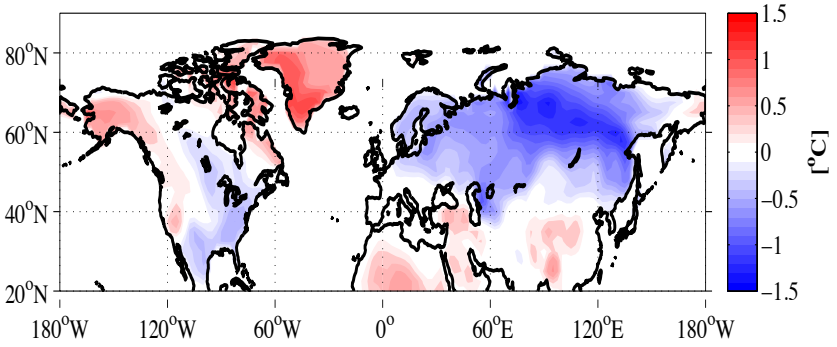
Correlations with surface temperature

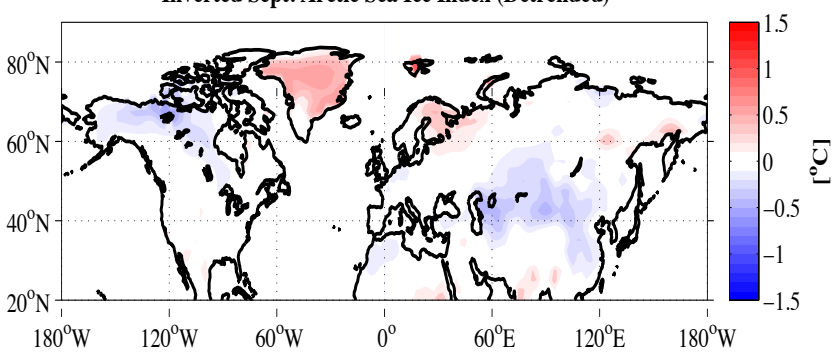


Snow and Sea Ice as Predictors of the AO Temperature Pattern

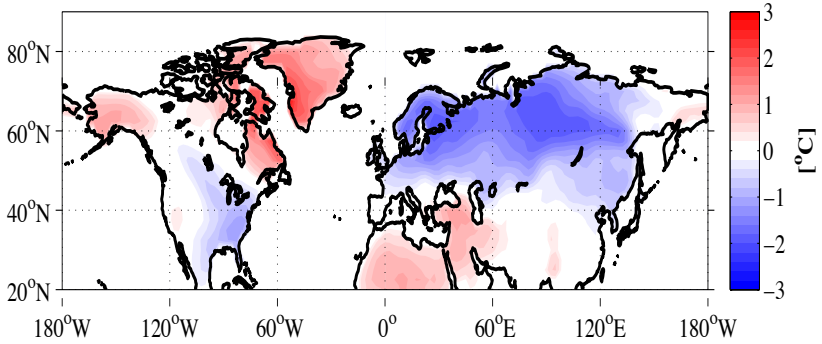
Regression of DJF Surface Temperature onto the October Snow Index (Detrended)



Regression of DJF Surface Temperature onto the Inverted Sept. Arctic Sea Ice Index (Detrended)



Regression of DJF Surface Temperature onto the −AO Index (Detrended)



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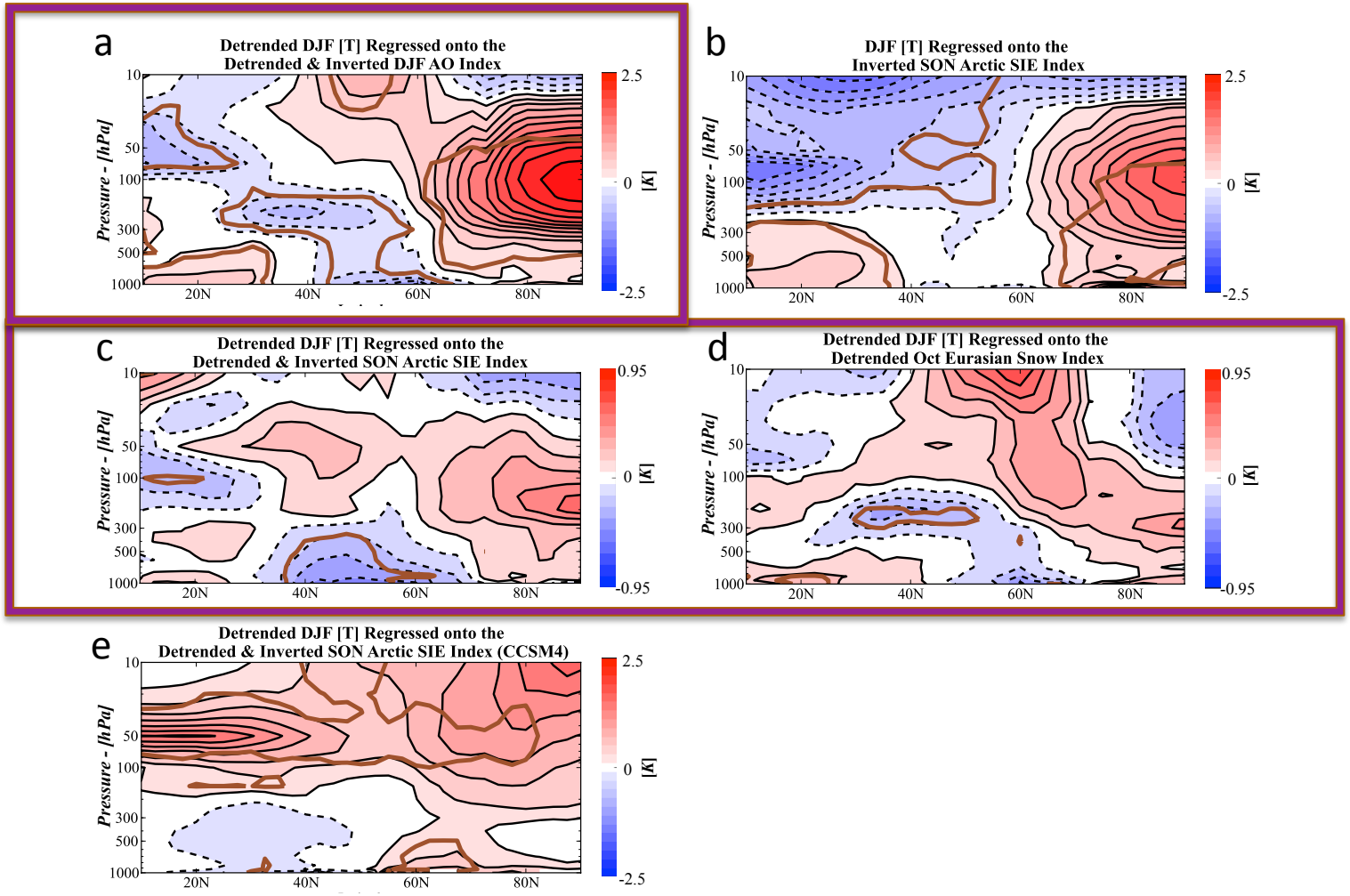
Warm Arctic-Cold Continents



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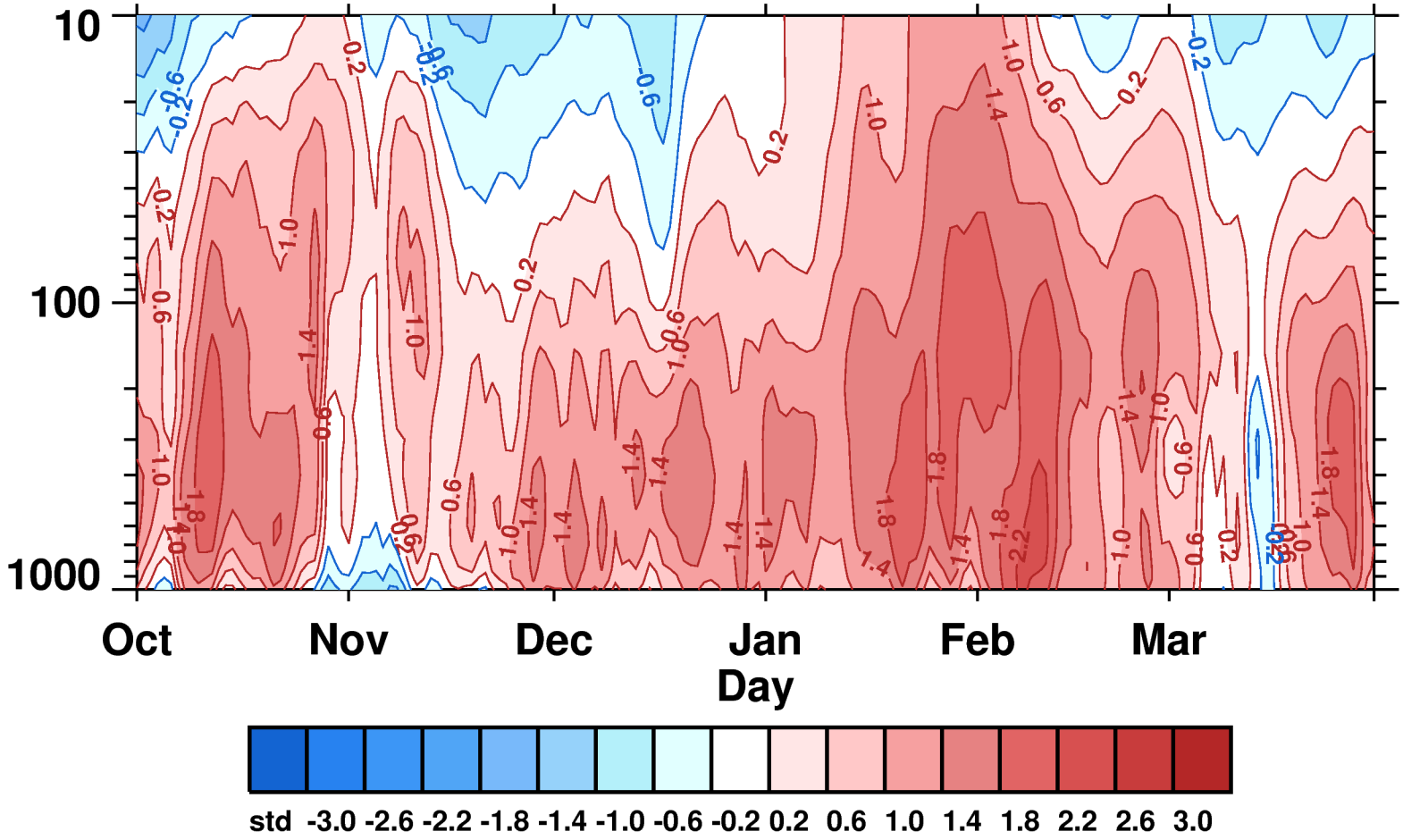
Cohen et al. 2013

Trend in Polar Cap Height 1988/89-2013/14



Increase in stratosphere-troposphere coupling mid-late winter that favors a warmer polar stratosphere and higher heights in the Arctic troposphere (negative AO).

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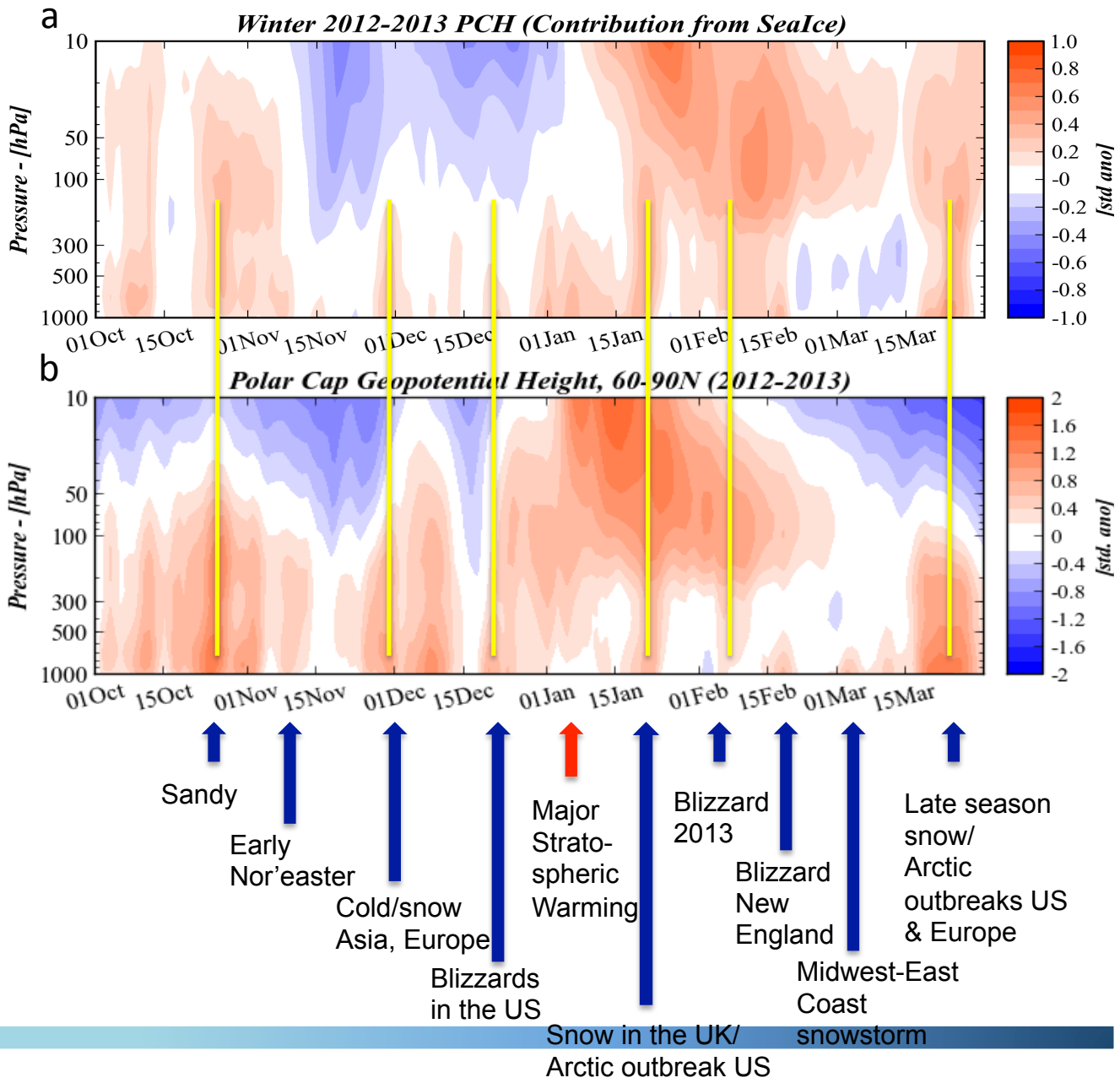
PCH Oct-Mar 2012/13



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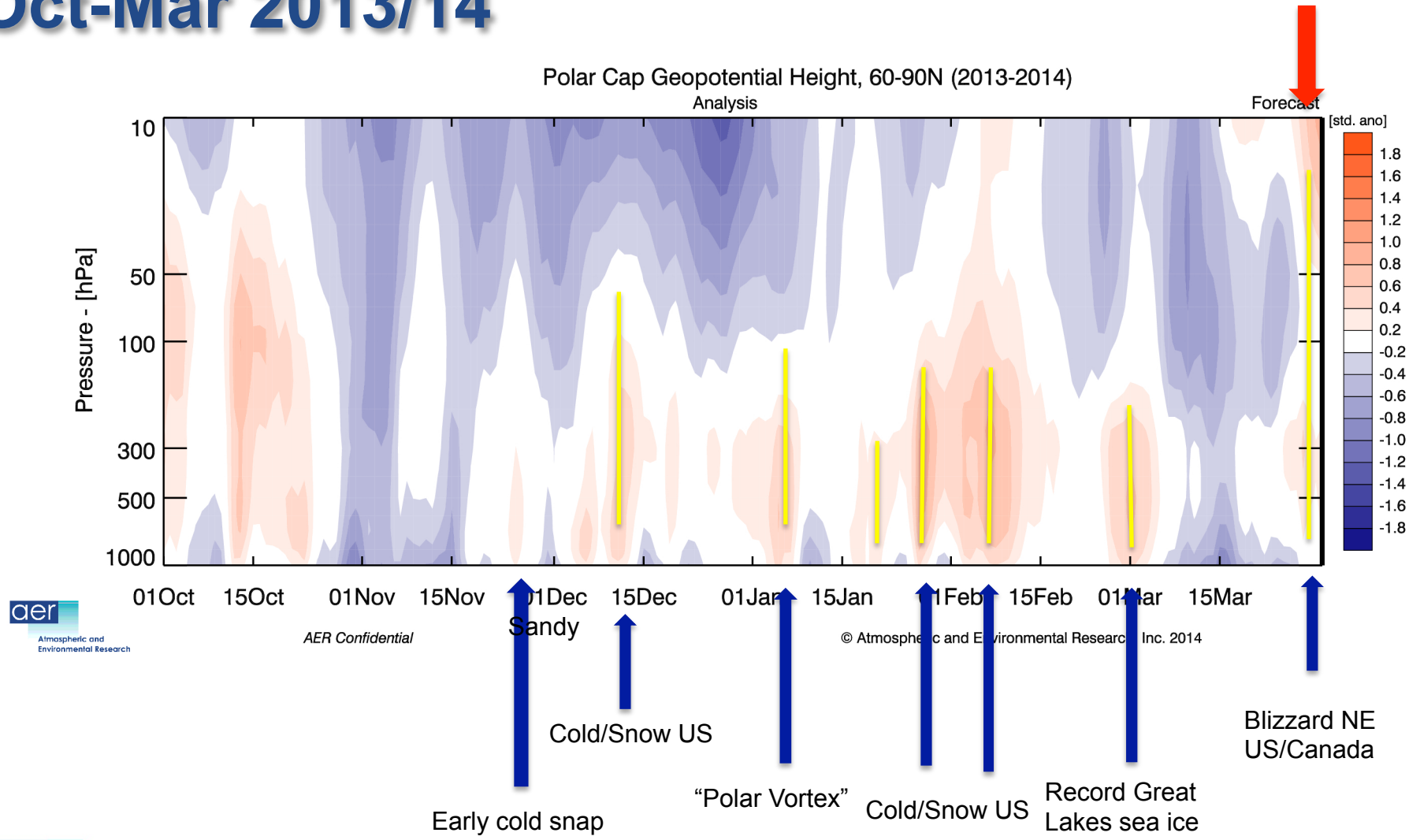
PCH
Oct-Mar 2013/14



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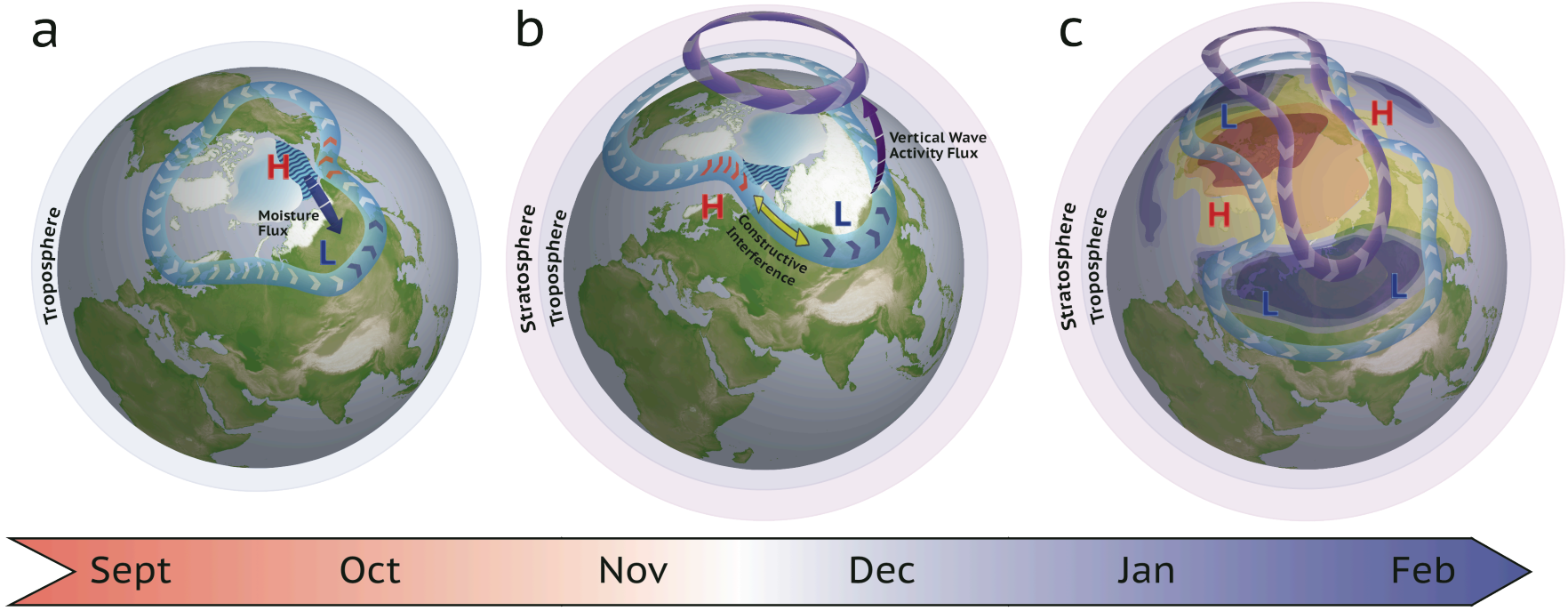
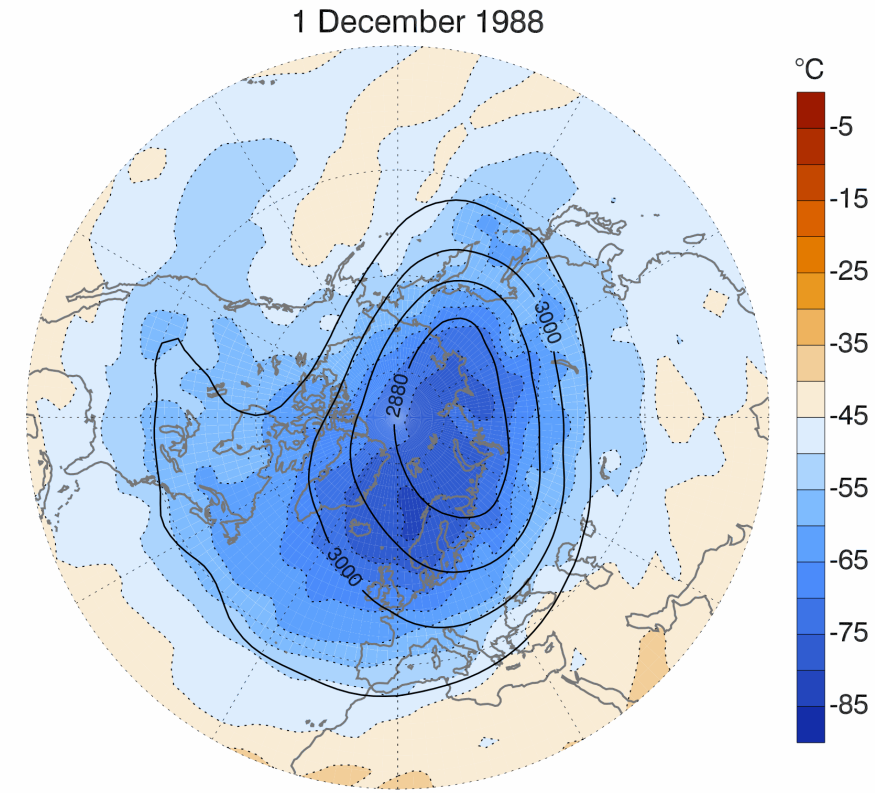
Synthesis of Sea Ice and Snow Cover

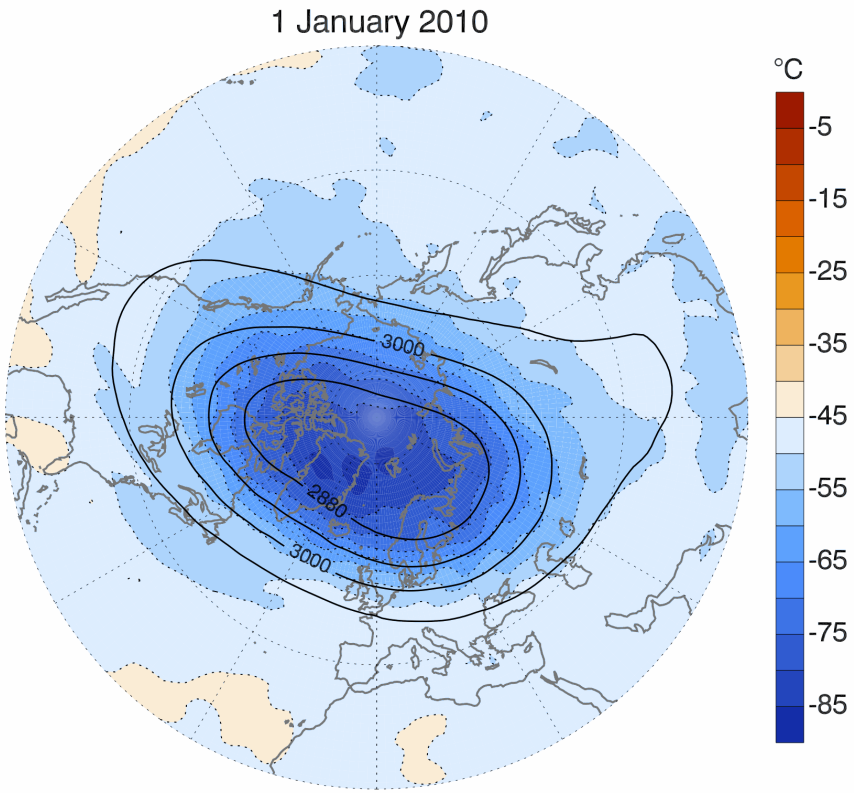


Cohen et al. 2014

Stratospheric polar vortex strong (cold)/ weak (warm)



Atmospheric and Environmental Research (AER)



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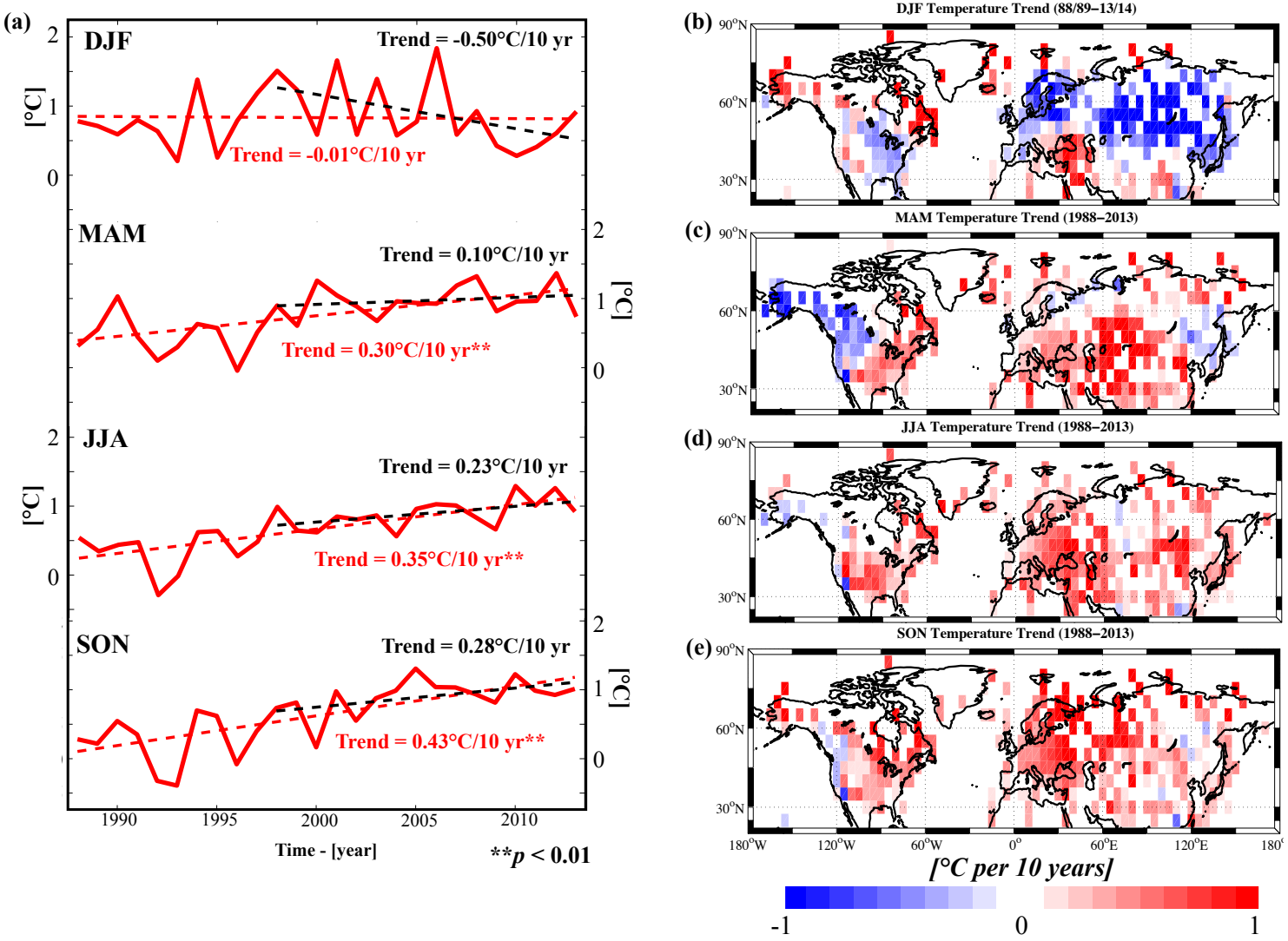
Northern Hemisphere Land Temperatures 1987-2014

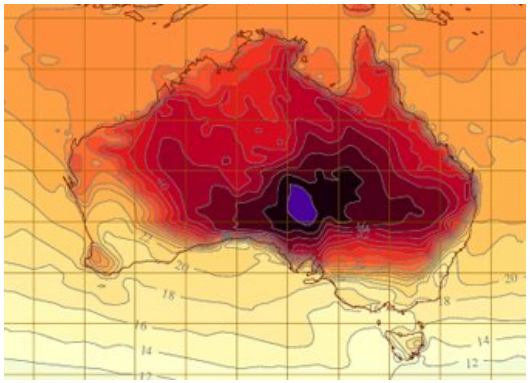


Atmospheric and Environmental Research

Cohen et al. 2012a

TIME

Heatwaves Caused By Climate Change 75% Of the Time, Study Finds



Extreme heat poses a billion-dollar threat to Australia's economy

THE CONVERSATION
Academic rigour, journalistic flair

UK Weather: English heat waves 'up to 22 times more likely' due to climate change

Mirror

Recent Heat Waves Likely Warmest Since 1500 in Europe

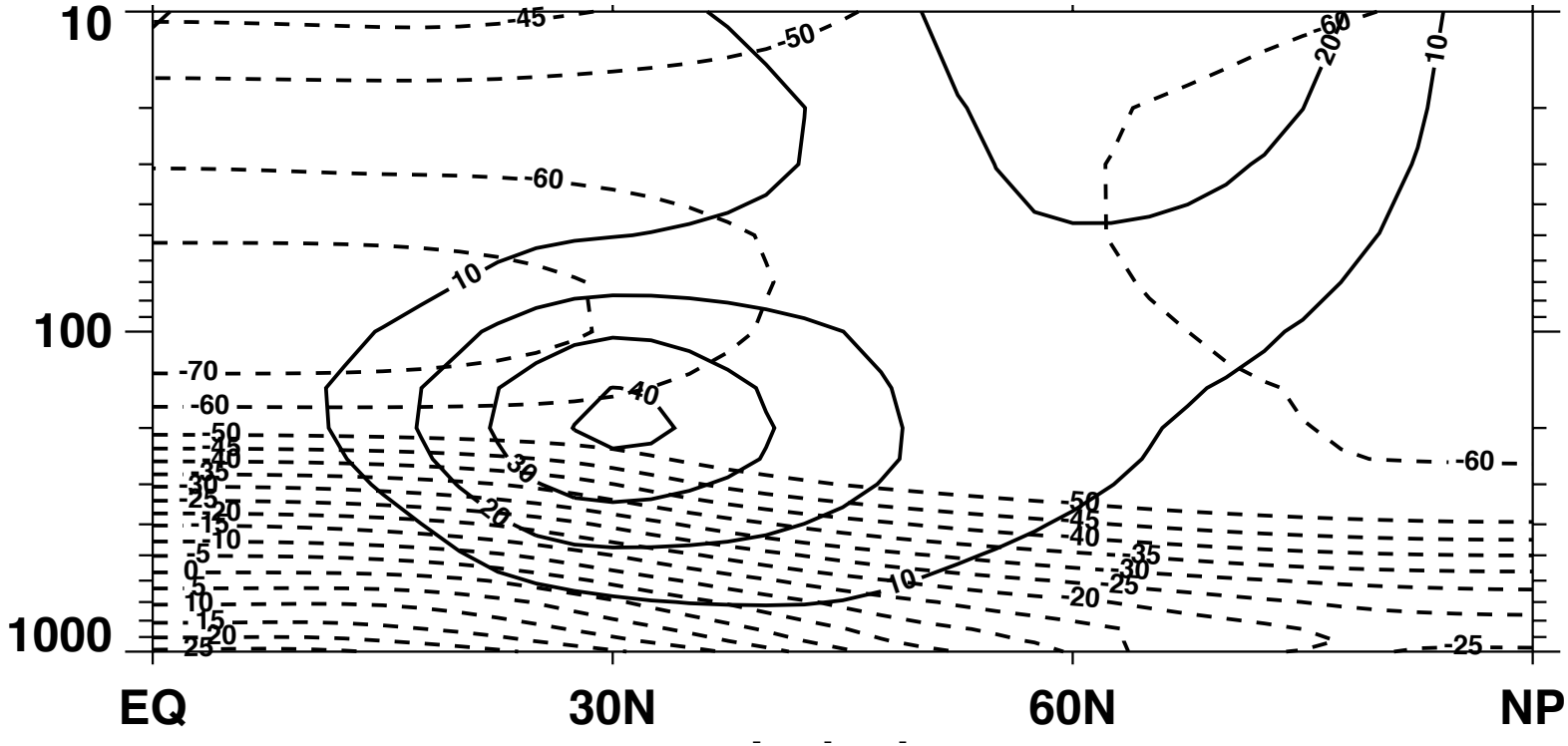
livescience

Arctic Amplification - Jet Stream

Slower jet stream results in more amplified and slower moving waves. Probably not true for most cases but may be true for summer during heat waves.

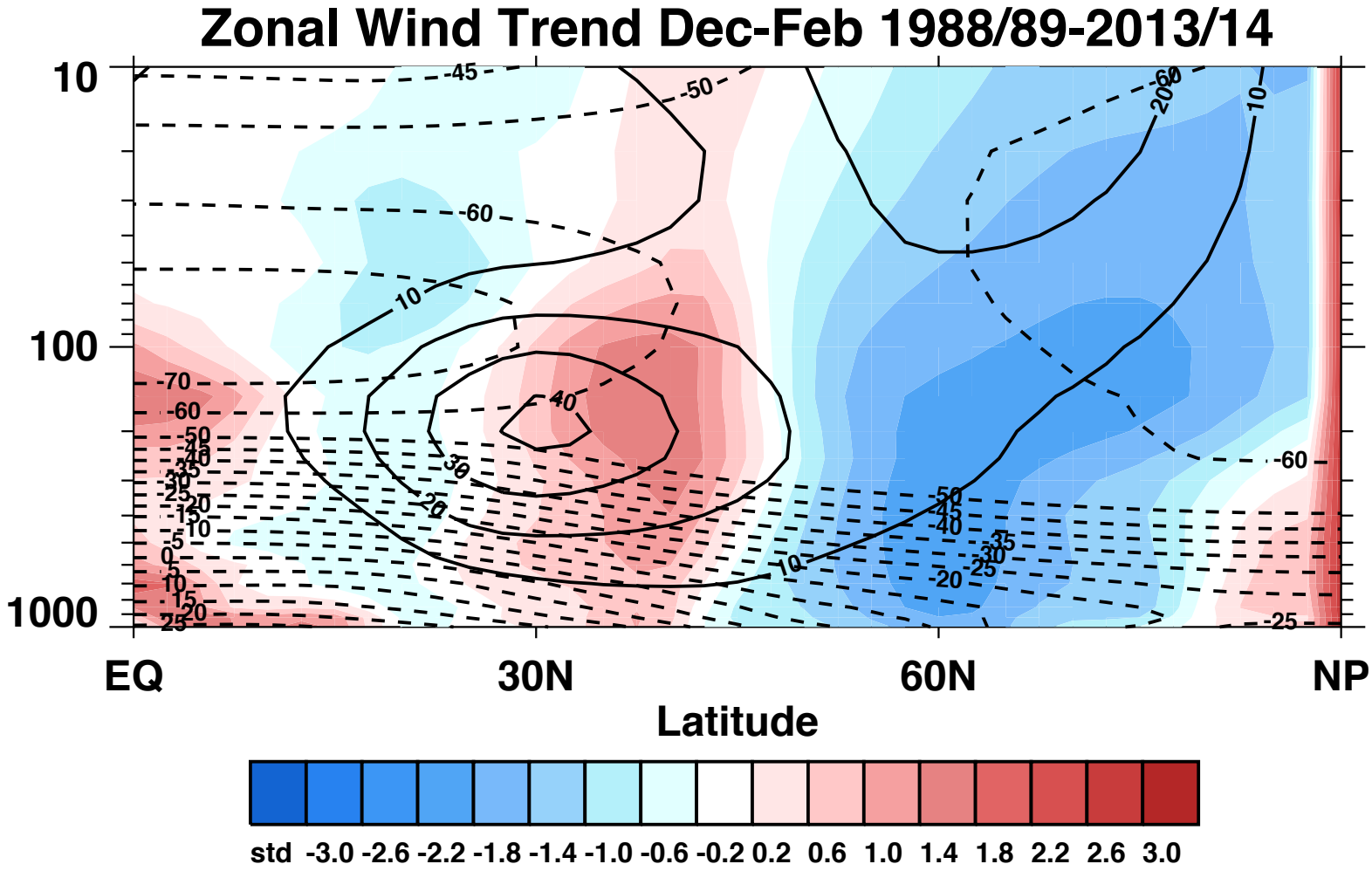
Figure 3:
Schematic of a typical jet stream trajectory (solid line) over North America and the expected elongation of ridge peaks northward (dashed line) in response to Arctic Amplification.

Jet Stream is determined by largest temperature gradient – thermal wind relationship



Solid contours are wind and dashed contours are temperature

Jet Stream is determined by largest temperature gradient – thermal wind relationship



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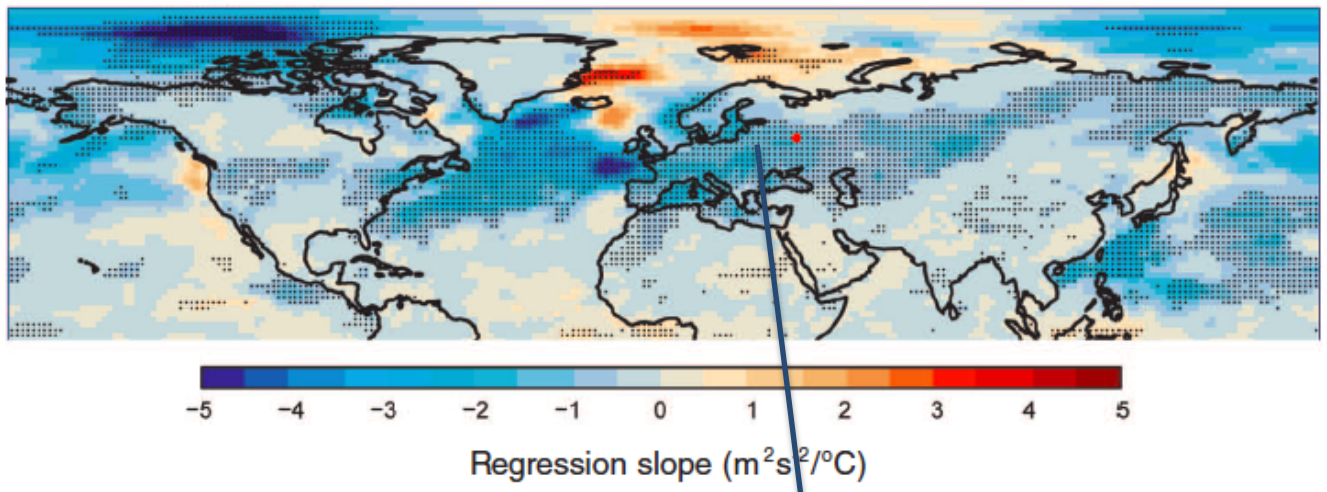
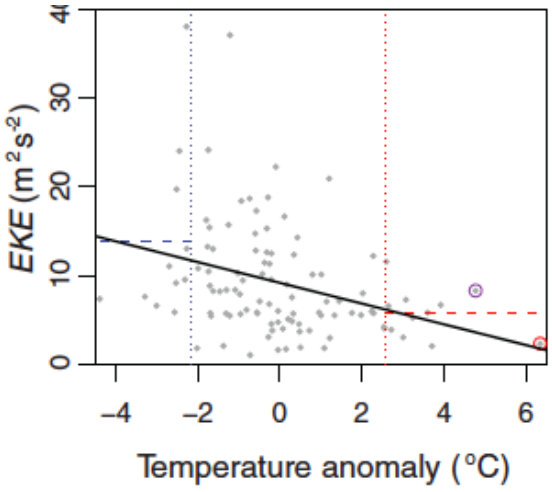
Surface temperature anomalies are inversely proportional to the speed of the wind.





This relationship is especially strong for Europe where the penetration of maritime air is needed to keep temperatures moderate. Weakening of the westerly winds will result in warmer temperatures.

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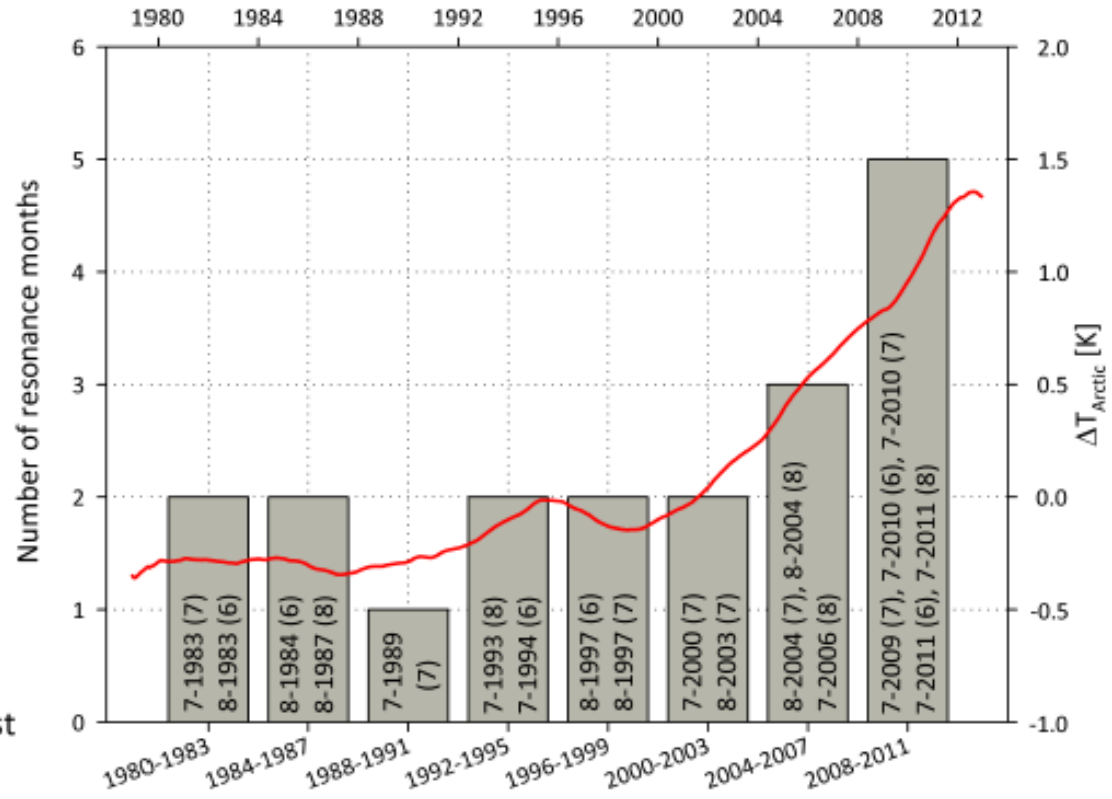
Coumou et al. 2015

Slower moving more persistent waves has resulted in greater frequency of heat waves in the era of Arctic Amplification (2000 to present)

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. 2015

Seasonal forecasting has been challenging, especially for Europe

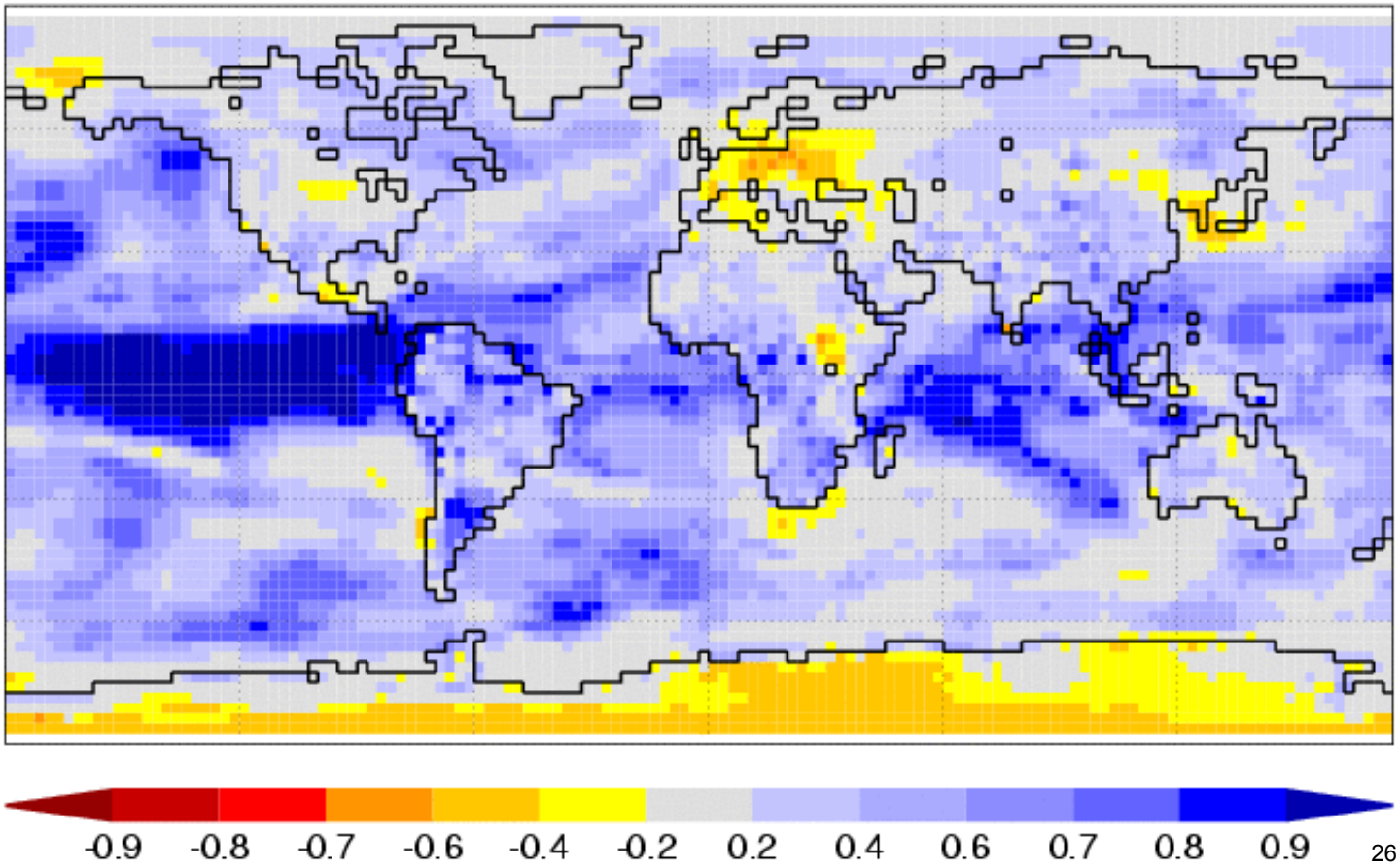
Operational ECMWF

2m-Temperature

Anomaly Correlation Coefficient: EXP(ECMWF_oper) with ERA-40 and op. analysis

Forecast start month and years: November / 1987-2002

FC period: months 2-4 (DJF), ens: 0-39



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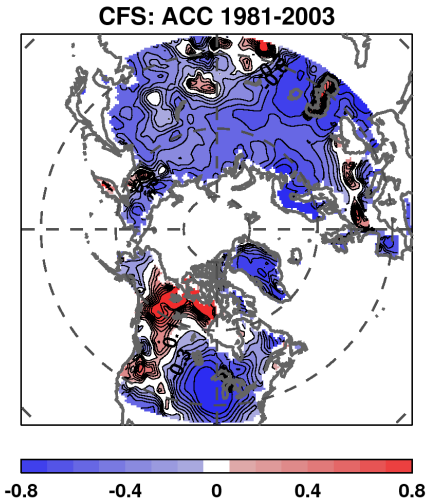
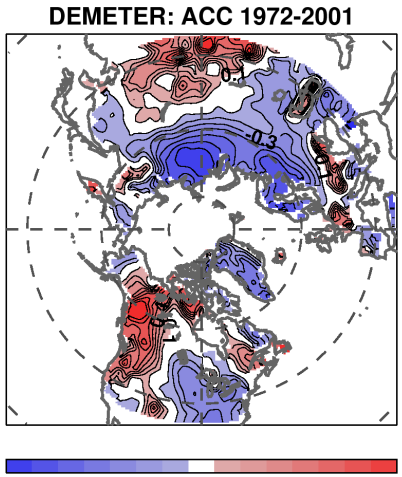
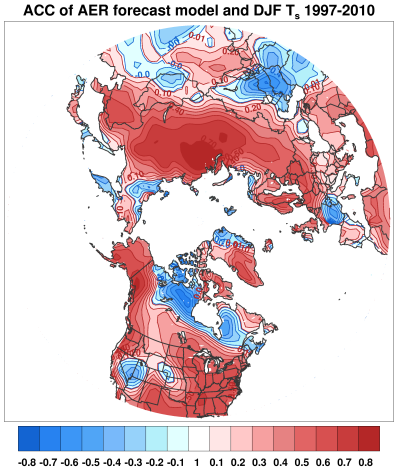
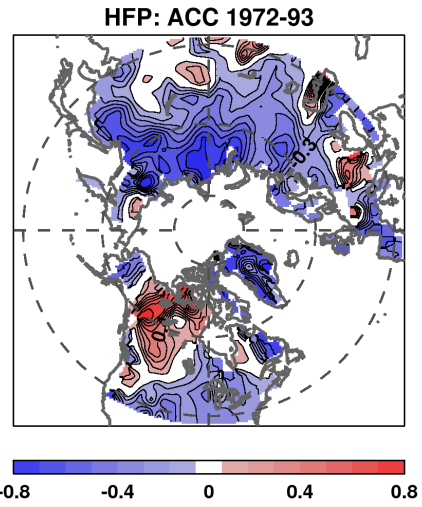
AER's model is the best performing





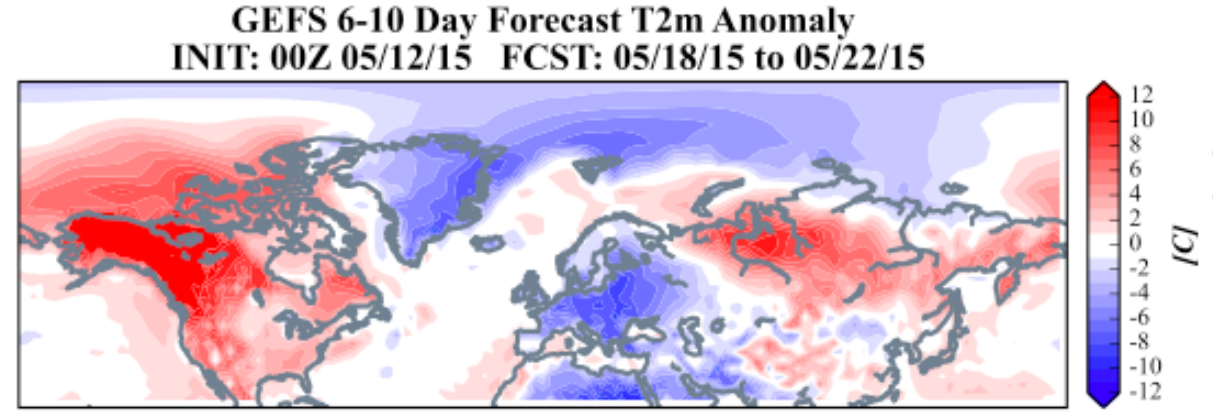


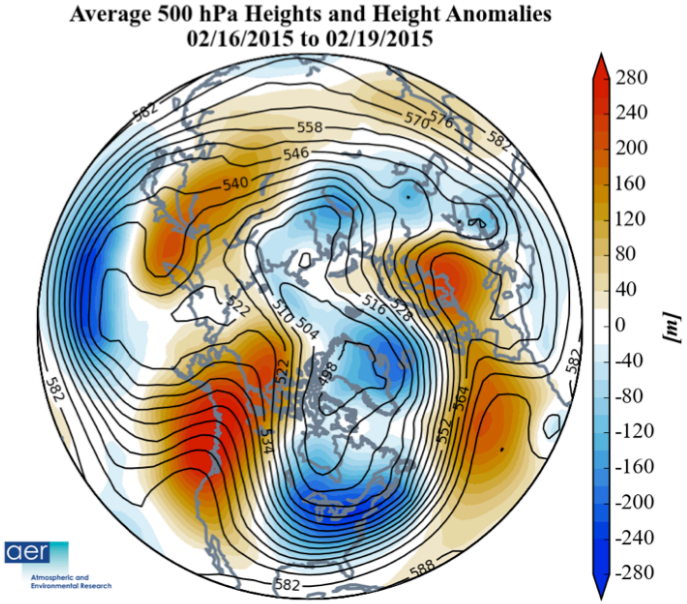


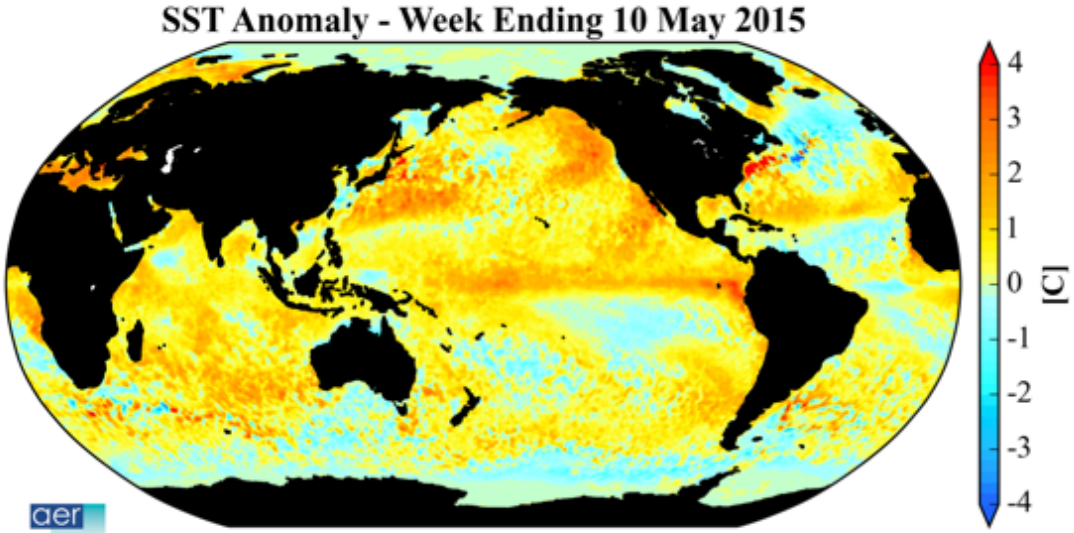
Cohen and Fletcher (2007)

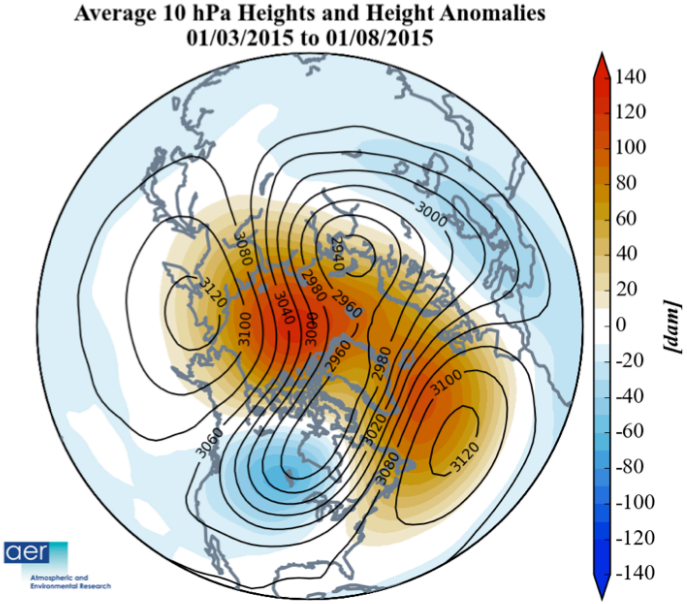
Atmospheric and Environmental Research

Arctic Oscillation Blog









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http://www.aer.com/science-research/climate-weather/arctic-oscillation

Summary

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Capital Weather Gang

The inside scoop on weather in the D.C. area and beyond

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AER's Judah Cohen produces amazingly accurate winter outlook

Posted by Jason Samenow on April 25, 2013 at 3:32 pm

Back in November, we presented the winter outlook from Judah Cohen, a meteorologis
Atmospheric and Environmental Research (AER). He sent me a verification of his outl
and my jaw dropped.

While his ideas for Washington, D.C., which favored a cold and snowy winter, didn't ex
work out, his outlooks for North America and Northern Hemisphere overall were striki
accurate – putting other seasonal forecasts to shame.

SaturdayLife

FITNESS WELLNESS TECH

THE BOSTON GLOBE SATURDAY, MARCH 21, 2015 | BOSTONGLOBE.COM/LIFESTYLE

HE SAW IT COMING

Weather consultant Judah Cohen's predictions, partly based on the rate of Siberian snowfall, bested federal forecasters on this year's brutal winter

By Bella English
GLOBE STAFF

LEXINGTON — Judah Cohen is positively giddy that we got hammered this winter. He loved the idea of a snowfall record, but more than that he loves being right.

"I'm really happy," he says with a grin, sitting in his small, neat office dominated by a huge computer screen that seems in constant motion as he pulls up this weather map or that satellite image. "I thought we did a very good job predicting it." In fact, his forecast proved better than that of the federal government.

Cohen, 52, a self-described "weather weenie," is di-

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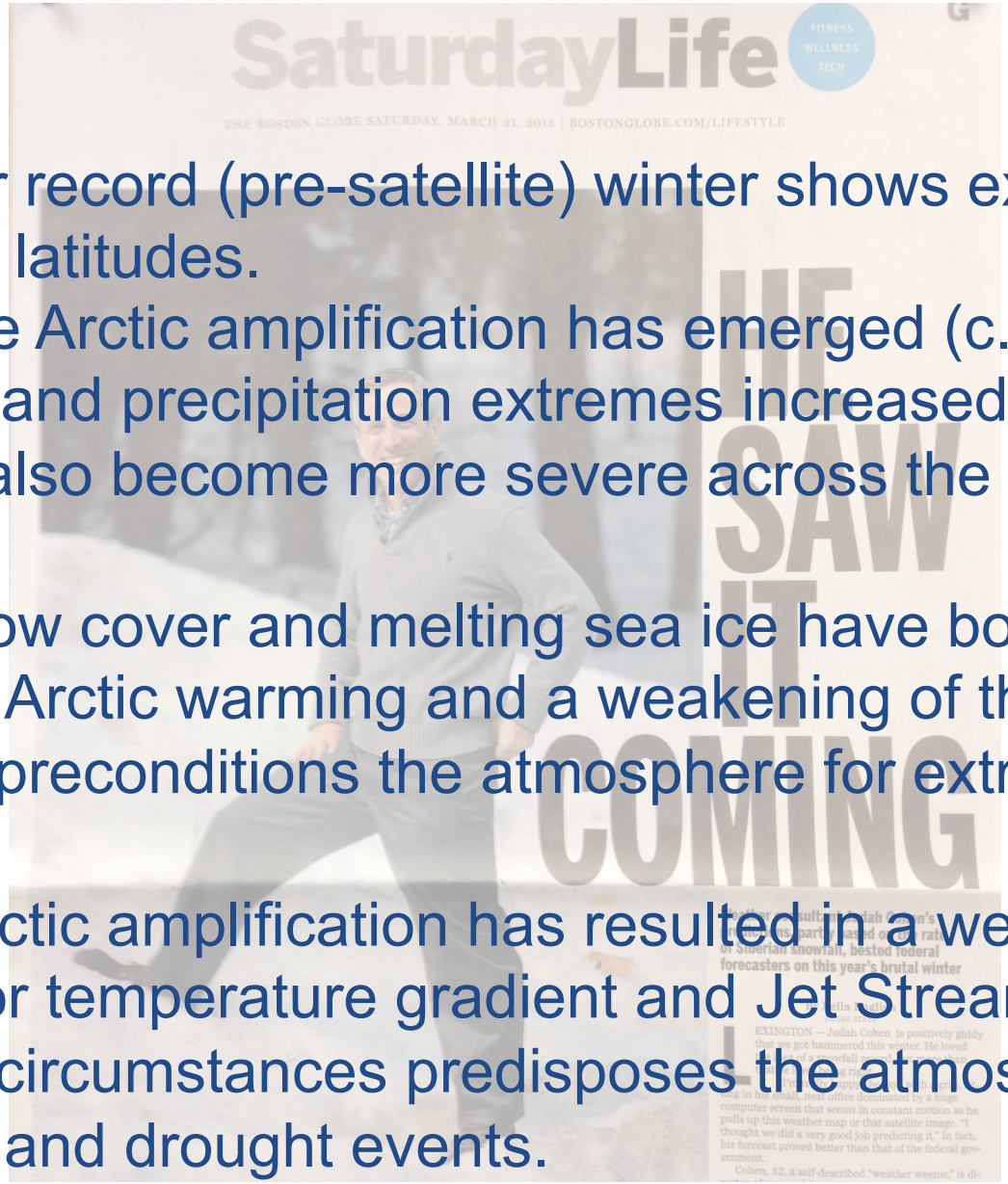
Summary



- Over the loner record (pre-satellite) winter shows expected warming at all latitudes.
- However since Arctic amplification has emerged (c. 1990), not only has heat and precipitation extremes increased but winters have also become more severe across the mid-latitudes.
- Increasing snow cover and melting sea ice have both contributed to Arctic warming and a weakening of the polar vortex, which preconditions the atmosphere for extreme events
- In summer, Arctic amplification has resulted in a weakened pole to equator temperature gradient and Jet Stream, which under certain circumstances predisposes the atmosphere to heat, flooding and drought events.

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Cohen, J., J. Furtado, M. Barlow, V. Alexeev and J. Cherry, 2012a, Asymmetric seasonal temperature trends, *Geophysical Research Letters*, 014007 doi: 10.1029/2011GL050582.

Cohen, J., J. Furtado, M. Barlow, V. Alexeev and J. Cherry, 2012b, Arctic warming, increasing snow cover and widespread winter cooling, *Environmental Research Letters*, 014007 doi: 10.1088/1748-9326/7/1/014007.

Cohen, J., J. Jones, J. Furtado, and E. Tziperman, 2013, Warm Arctic, Cold Continents: A Common Pattern Related to Arctic Sea Ice Melt, Snow Advance, and Extreme Winter Weather, *Oceanography*, 26(4), http://dx.doi.org/10.5670/oceanog.2013.70..

Cohen et al., 2014, Linking siberian snow cover to precursors of stratospheric variability, Journal of Climate, 27, 5422-5432.

Cohen, J. et al., 2014:, Recent Arctic amplification and extreme mid-latitude weather, *Nature Geoscience*, 7, 627–637.

Thank you!