Arctic Amplification and its Possible Influence on Mid-latitude Extreme Weather

Judah Cohen (AER)

November 10, 2015

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

South Carolina governor calls deadly rain a 'thousand-year' event

CNN

'Possibly catastrophic': Texas braces for even more flooding

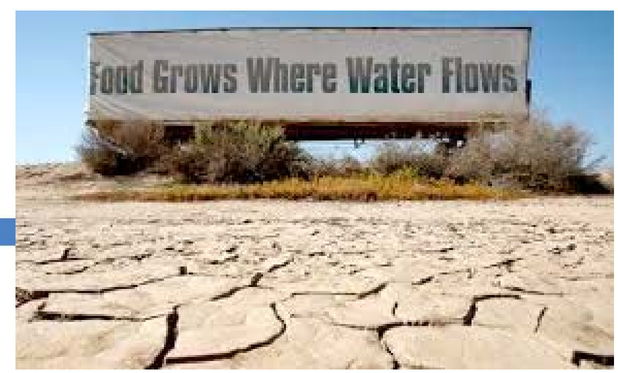
India Heat Wave, Now 5th Deadliest on Record, Kills More Than 2,300

The Weather Channel

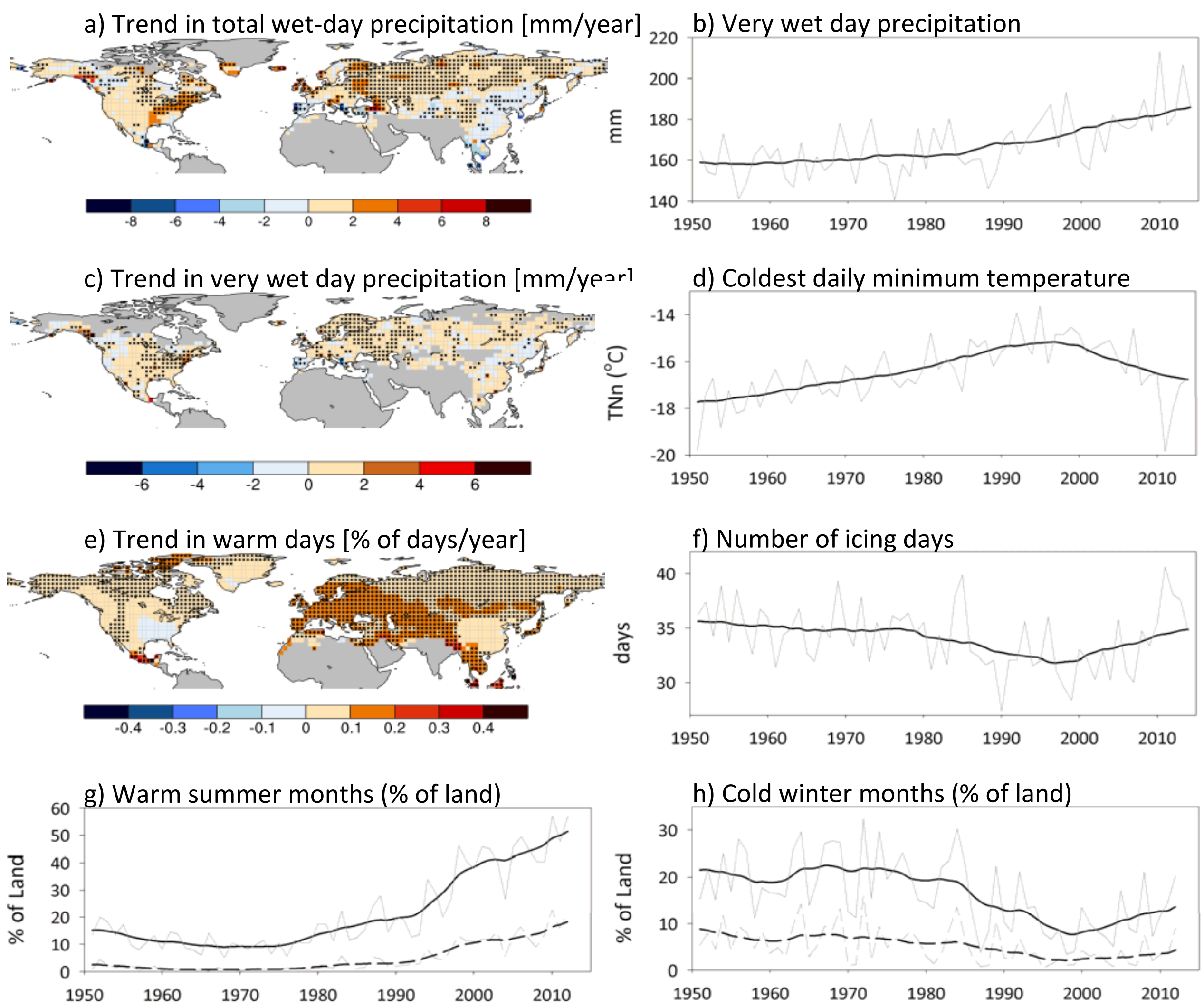
Heat Records Shattered in Germany, France, The Netherlands in June/July 2015 Europe Heat Wave

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

The New York Times

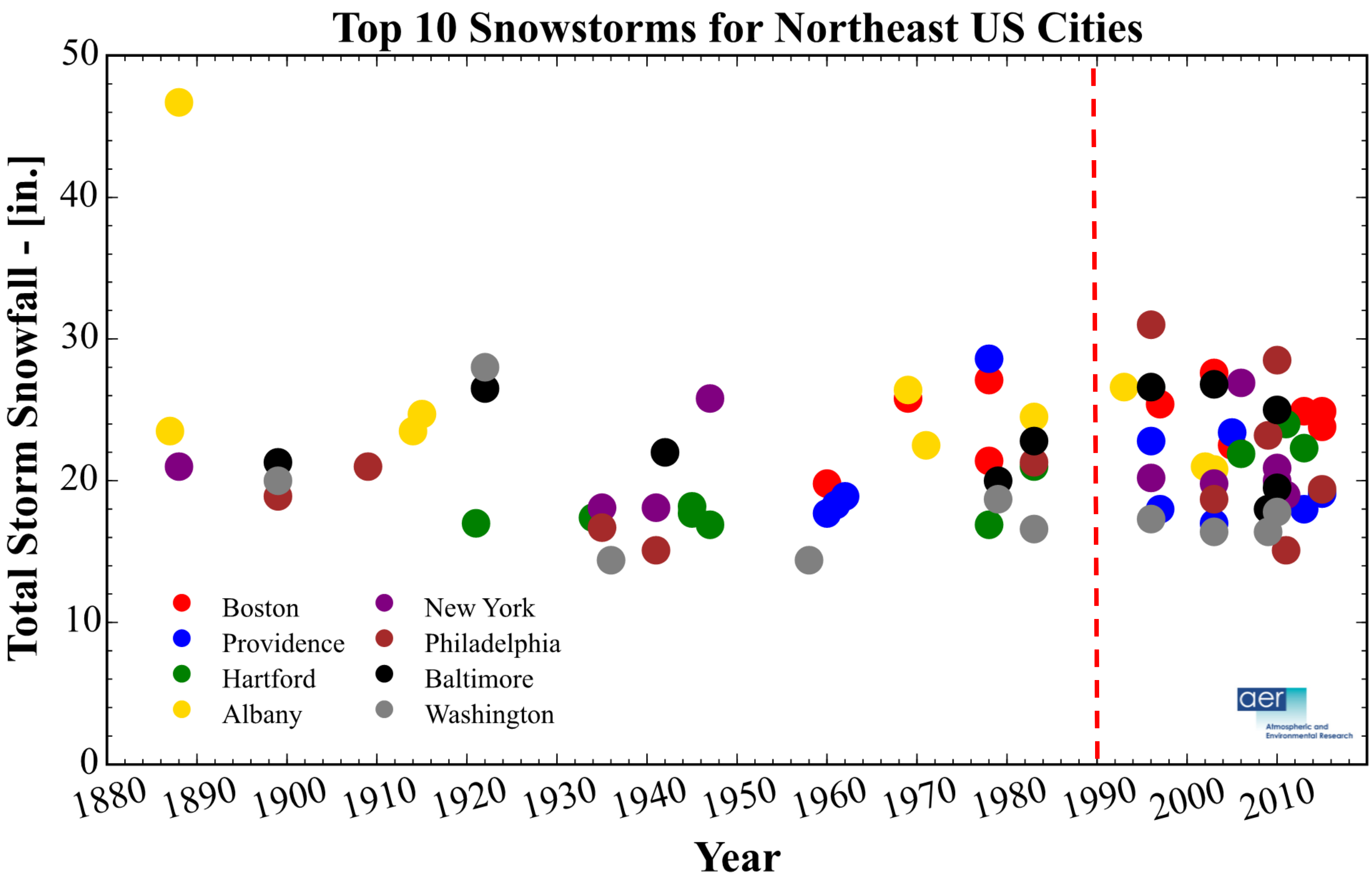


Extreme Weather



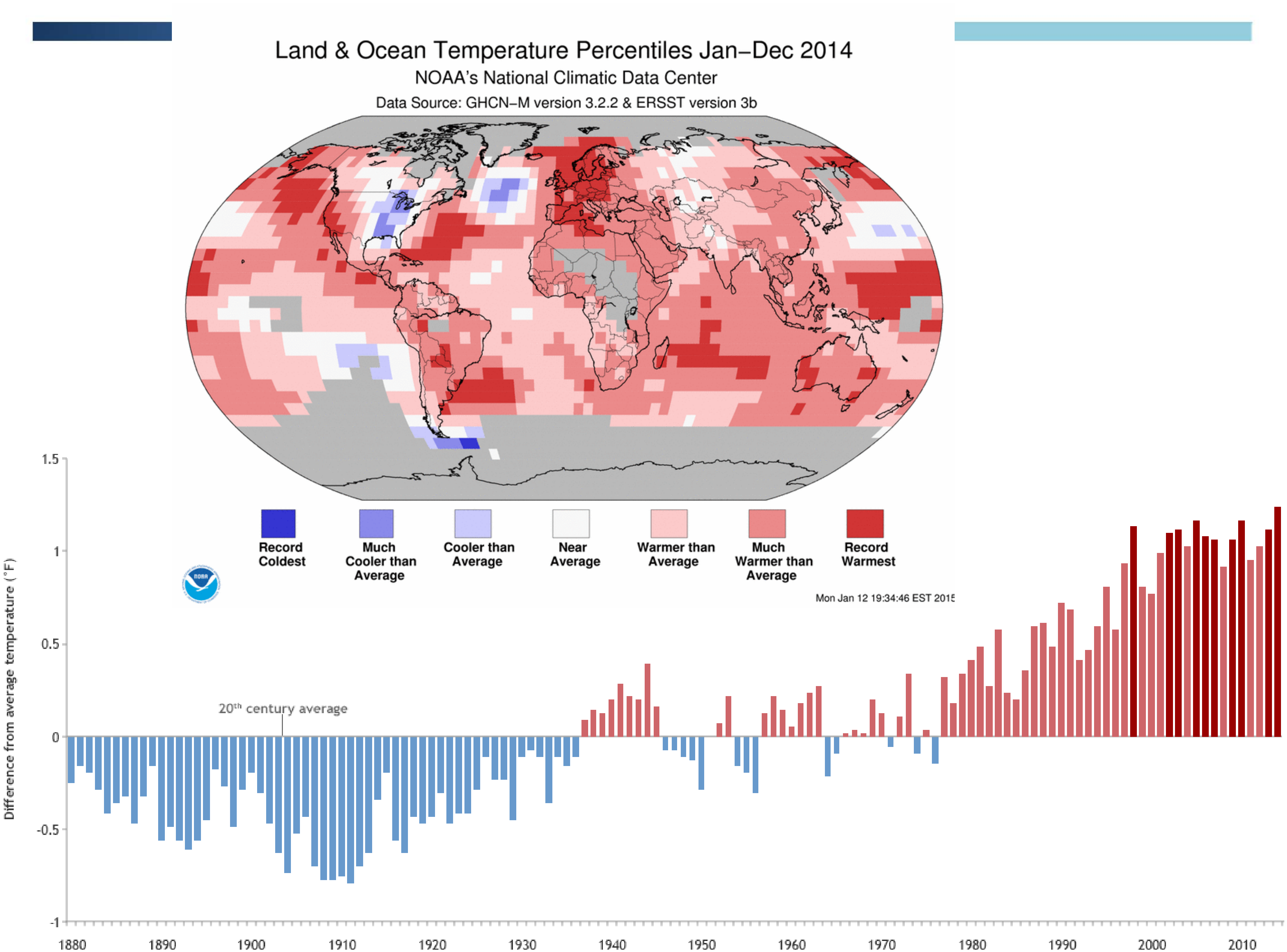
Cohen et al. 2014

Extreme Snowfall



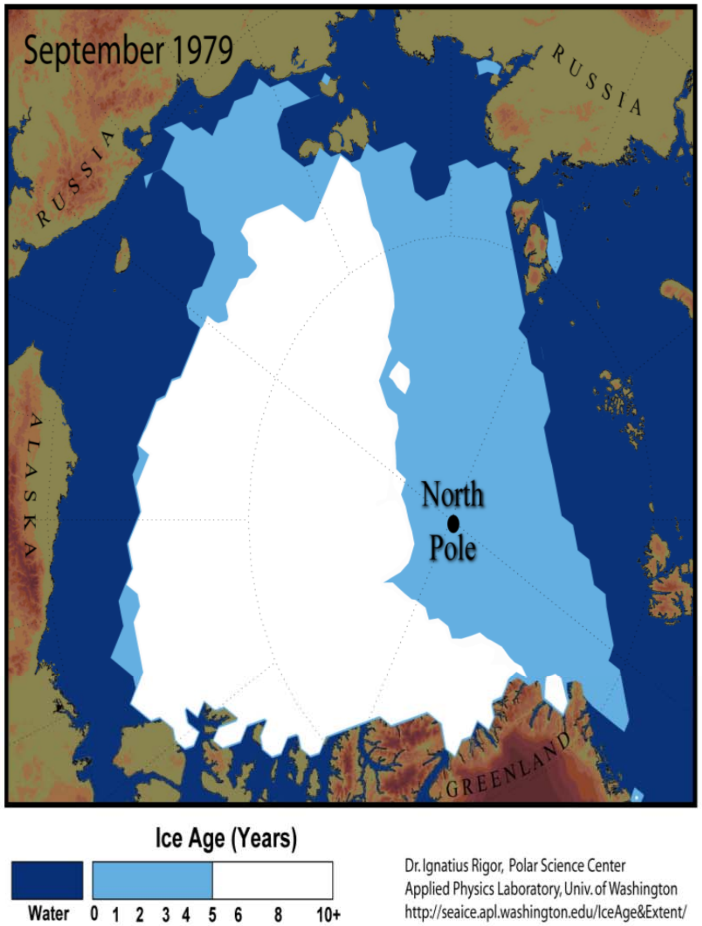
Theories linking AA to Mid-latitude Weather

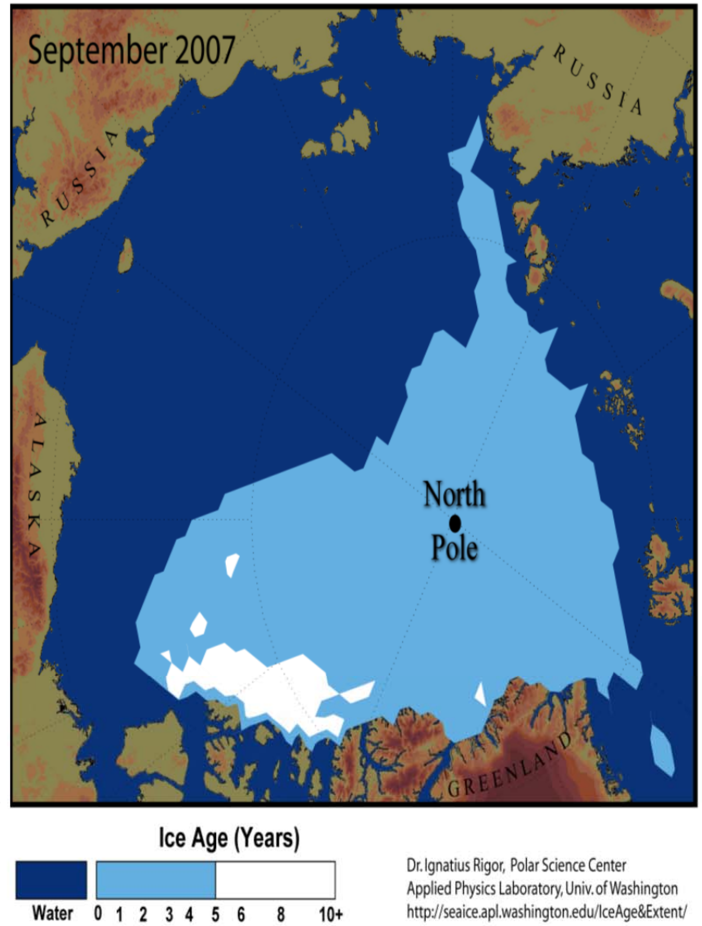
- Changes to latitudinal temperature gradient
- Changes to the Jet Stream/blocking/wave speed
- Changes to atmospheric waves:
  - Planetary waves (winter)
  - Synoptic scale waves (summer)
- Changes to troposphere-stratosphere coupling
- Support of these theories are conditional and challenged by imperfect observations and models



Land & Ocean Temperature Percentiles Jan–Dec 2014
NOAA's National Climatic Data Center
Data Source: GHCN–M version 3.2.2 & ERSST version 3b
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest
Mon Jan 12 19:34:46 EST 2015
Difference from average temperature (°F)
1.5
1
0.5
0
-0.5
-1
20th century average
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

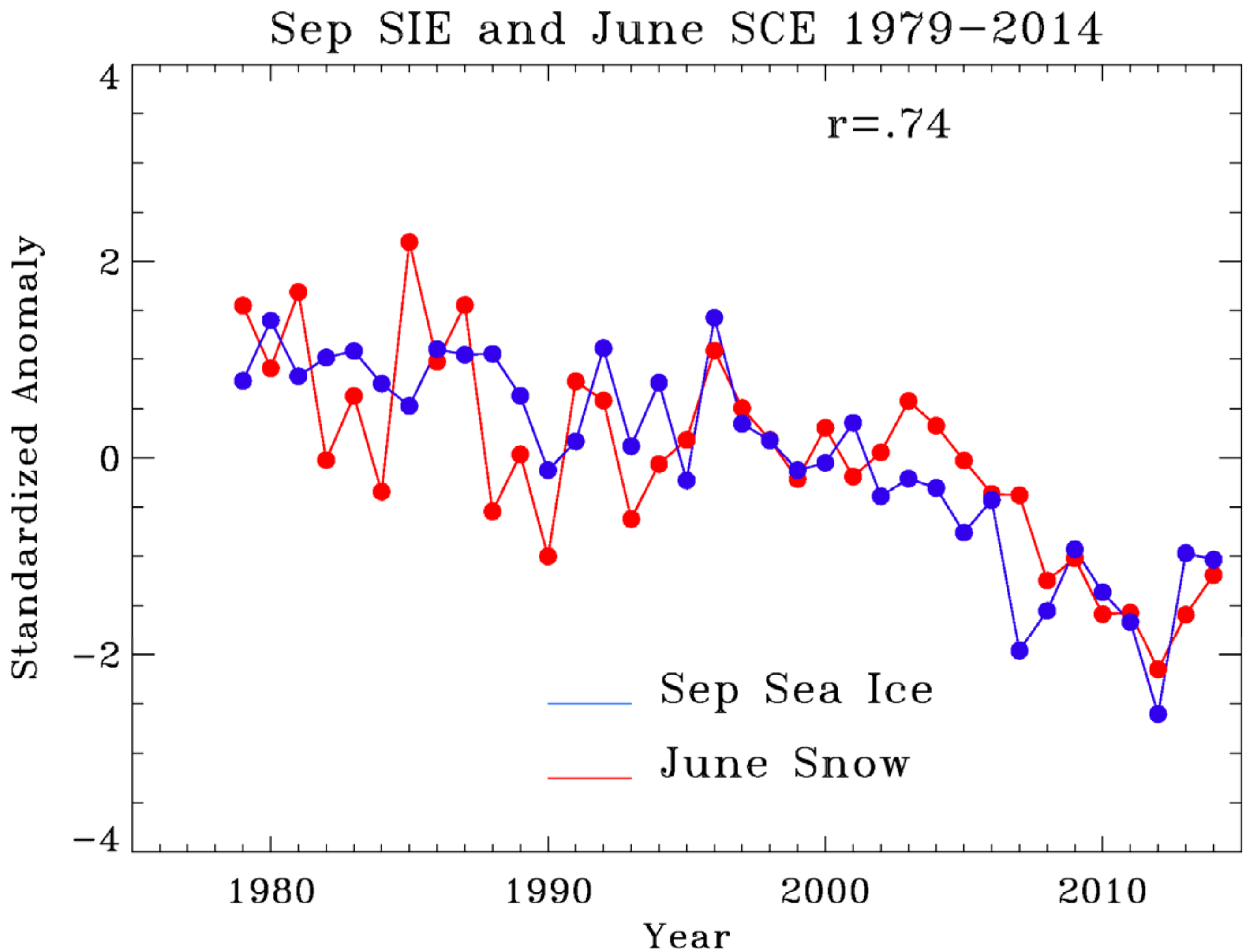
Sea Ice Melt





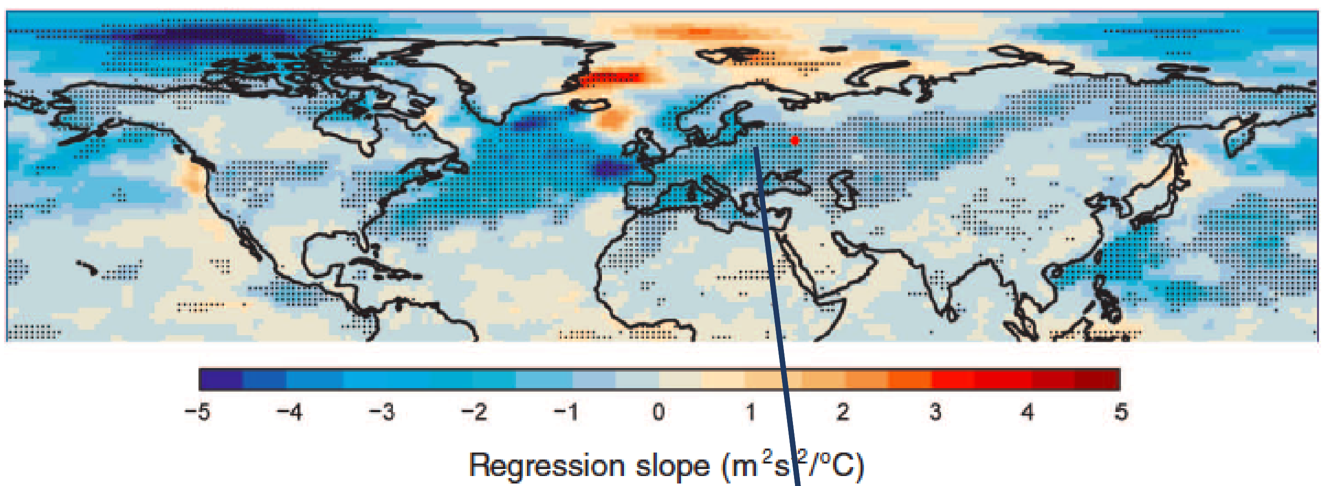
Ignatius Rigor

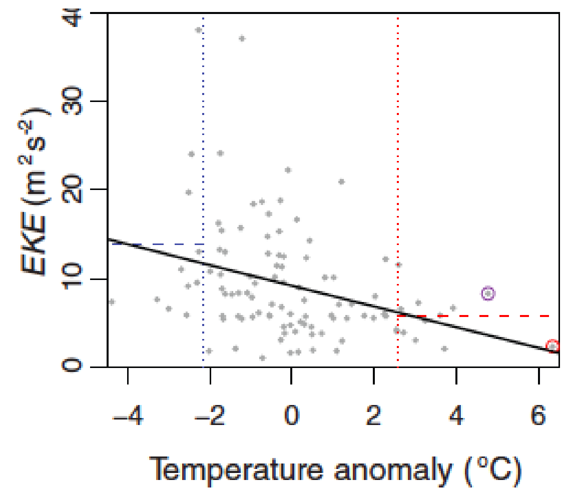
Sea Ice and Snow Cover Decline



WAVE SPEED AMPLITUDE AND SUMMER WEATHER

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

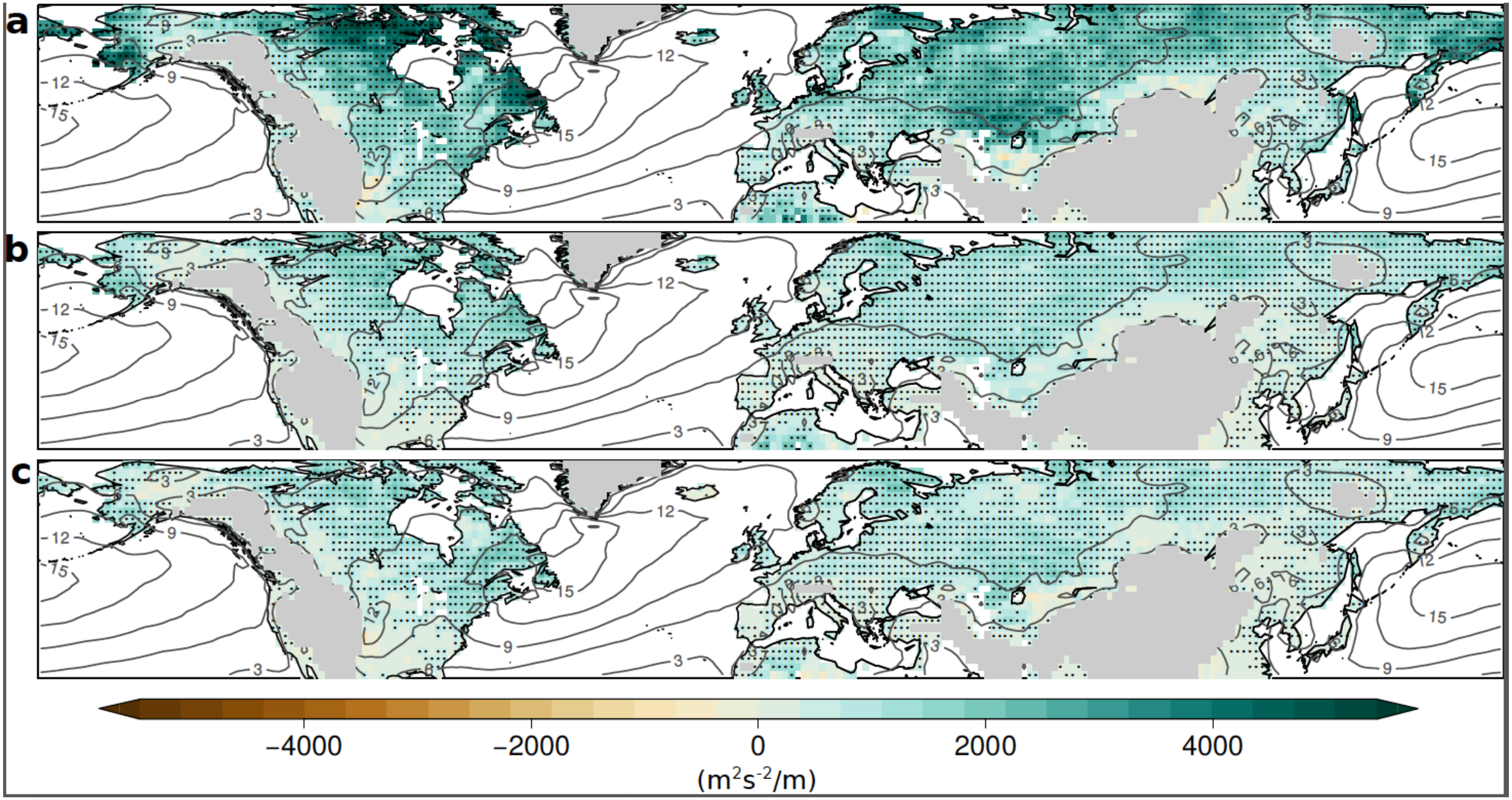




This relationship is especially strong for Europe where the penetration of maritime air is needed to keep temperatures moderate. Weakening of the westerly winds will result in warmer temperatures.

Coumou et al. 2015

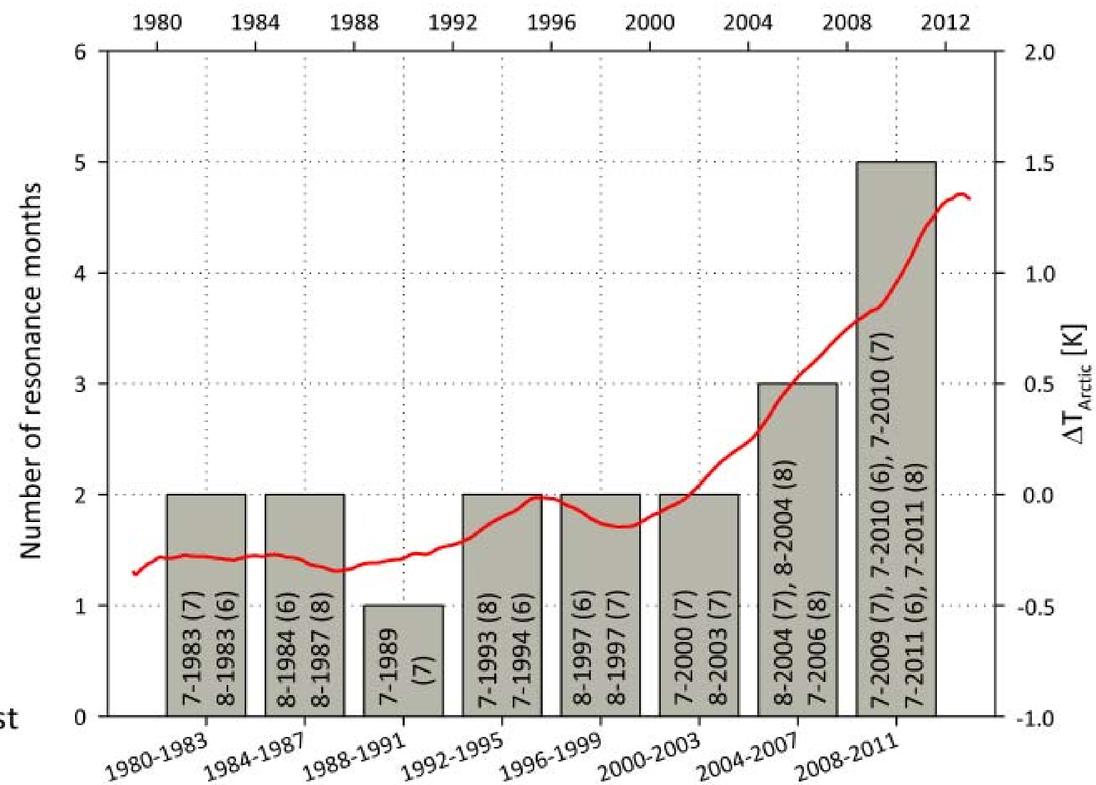
Precipitation anomalies are proportional to the speed of the wind (all year).



Coumou et al. 2015

Summer wave resonance and extreme weather

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

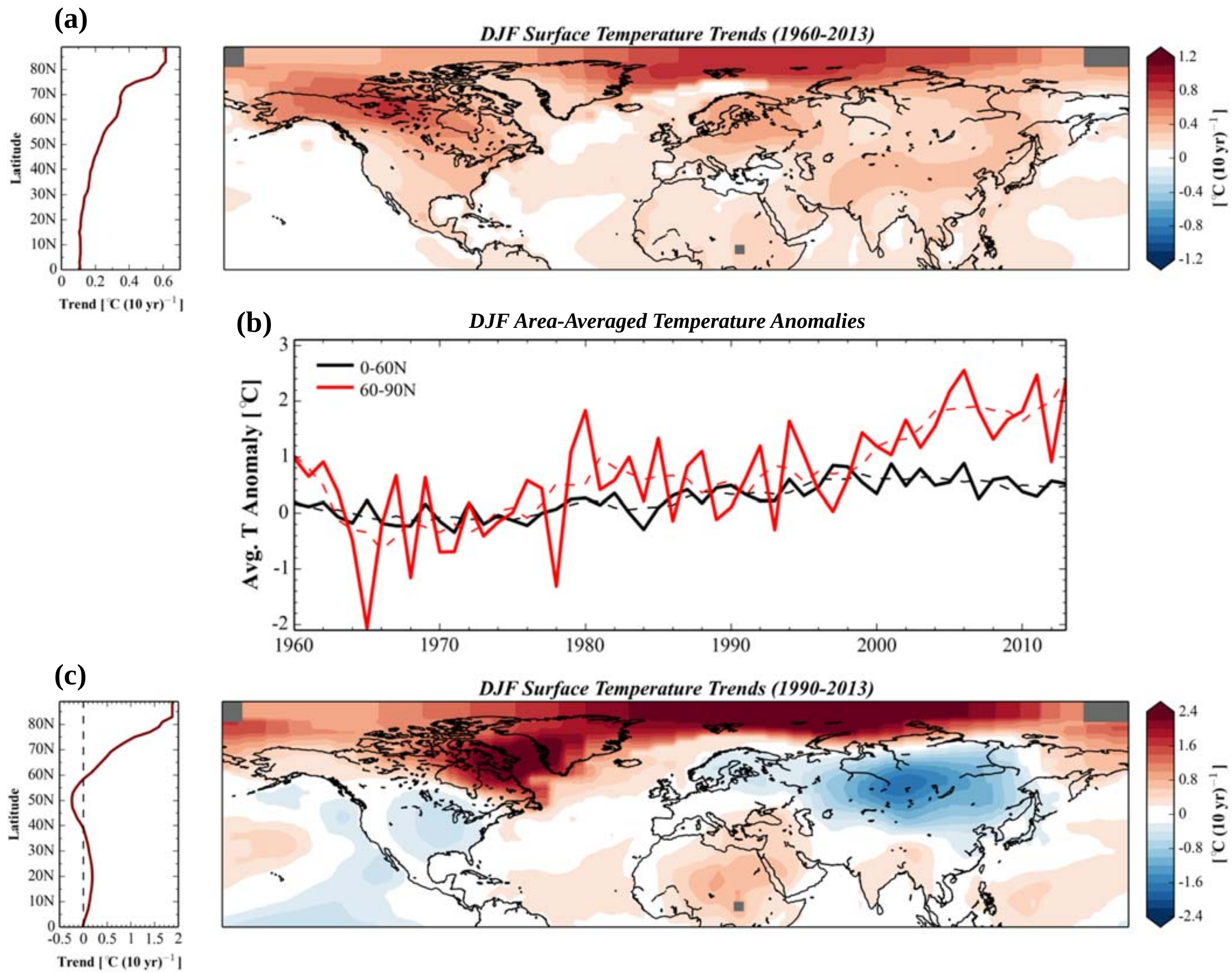


For wave numbers 6-8 we have observed an increase in the frequency of of high-amplitude quasi-stationary waves. This has coincided with an increase in summer extreme weather events.

Coumou et al. 2015

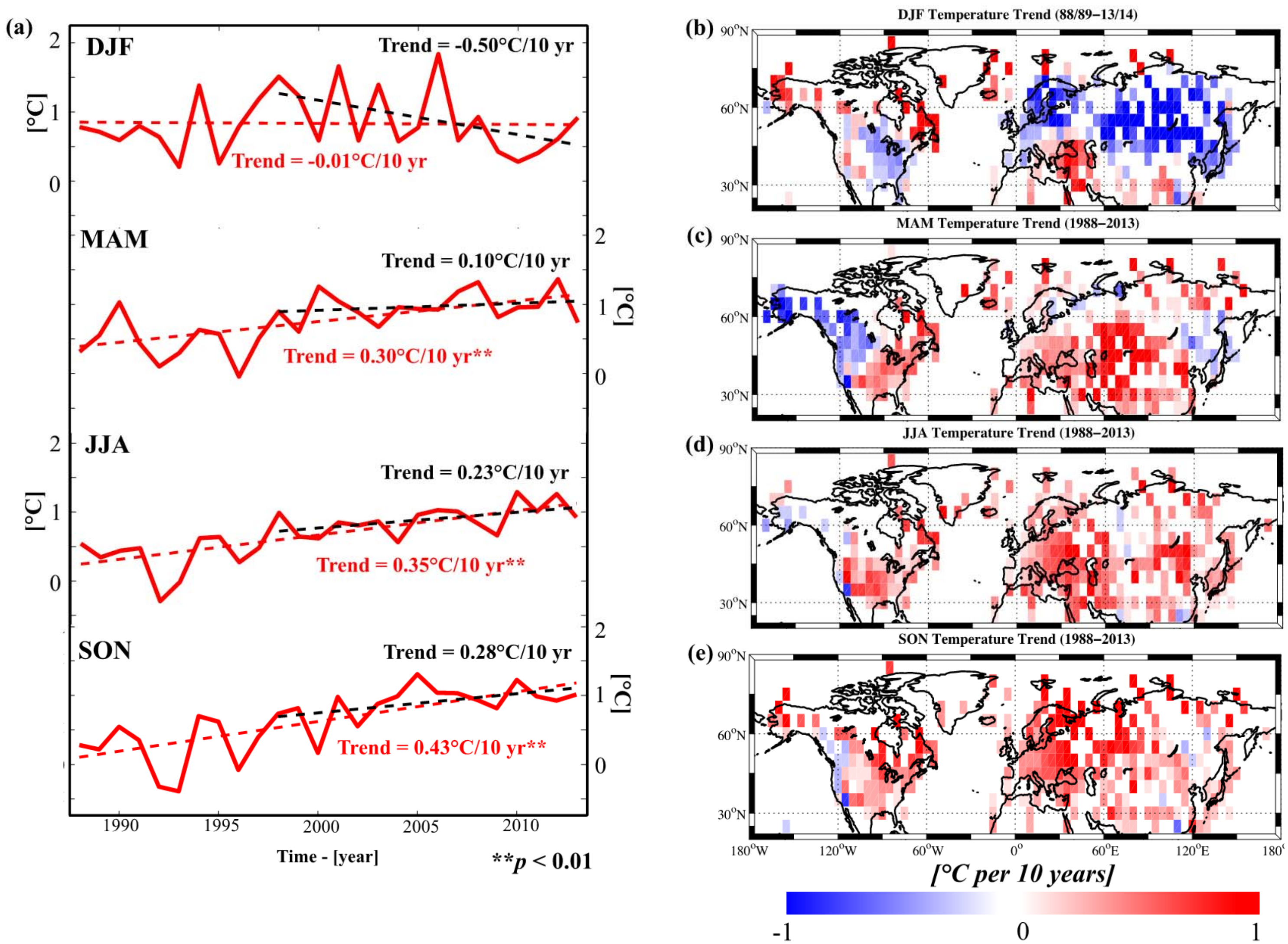
STRENGTH OF POLAR VORTEX AND WINTER WEATHER

Arctic Amplification



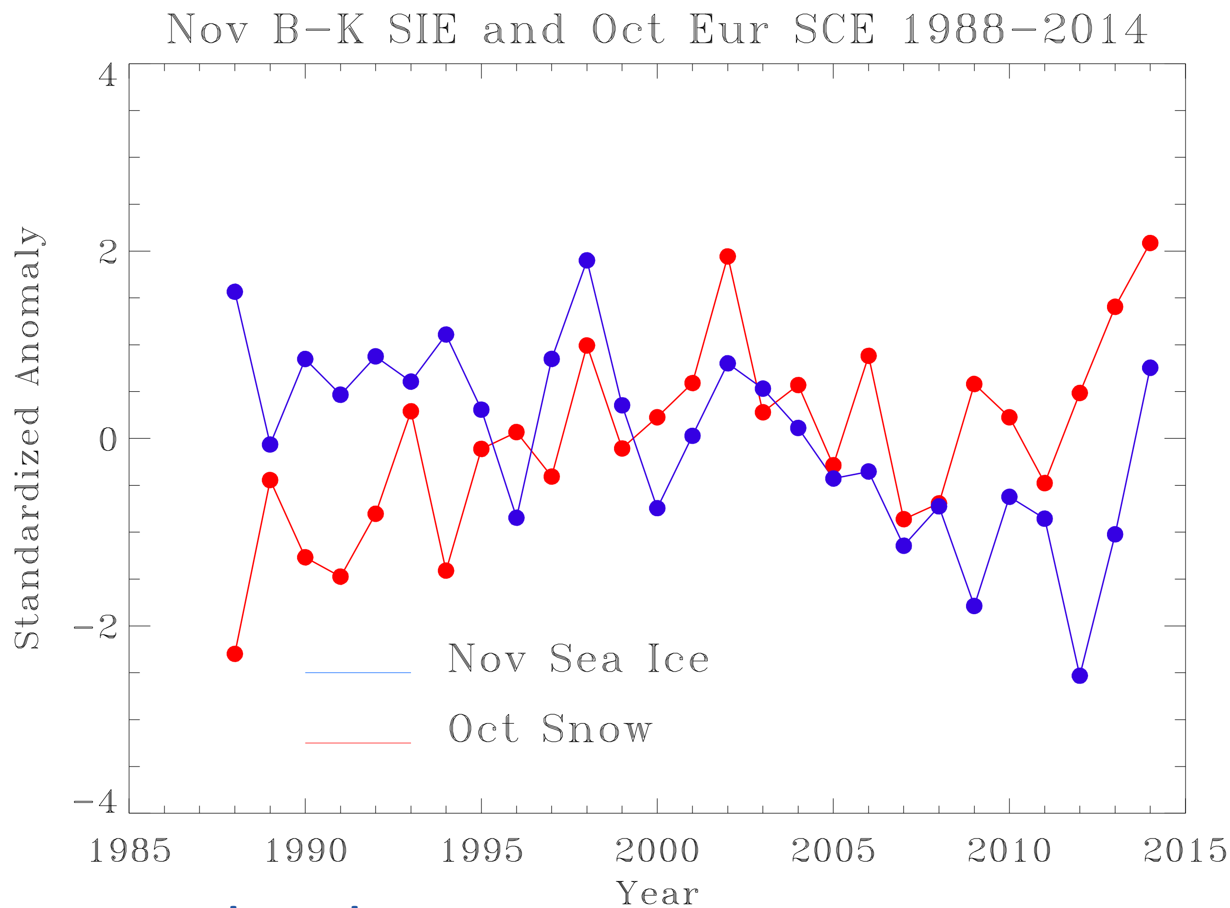
Cohen et al. 2014

Northern Hemisphere Land Temperatures 1987-2014



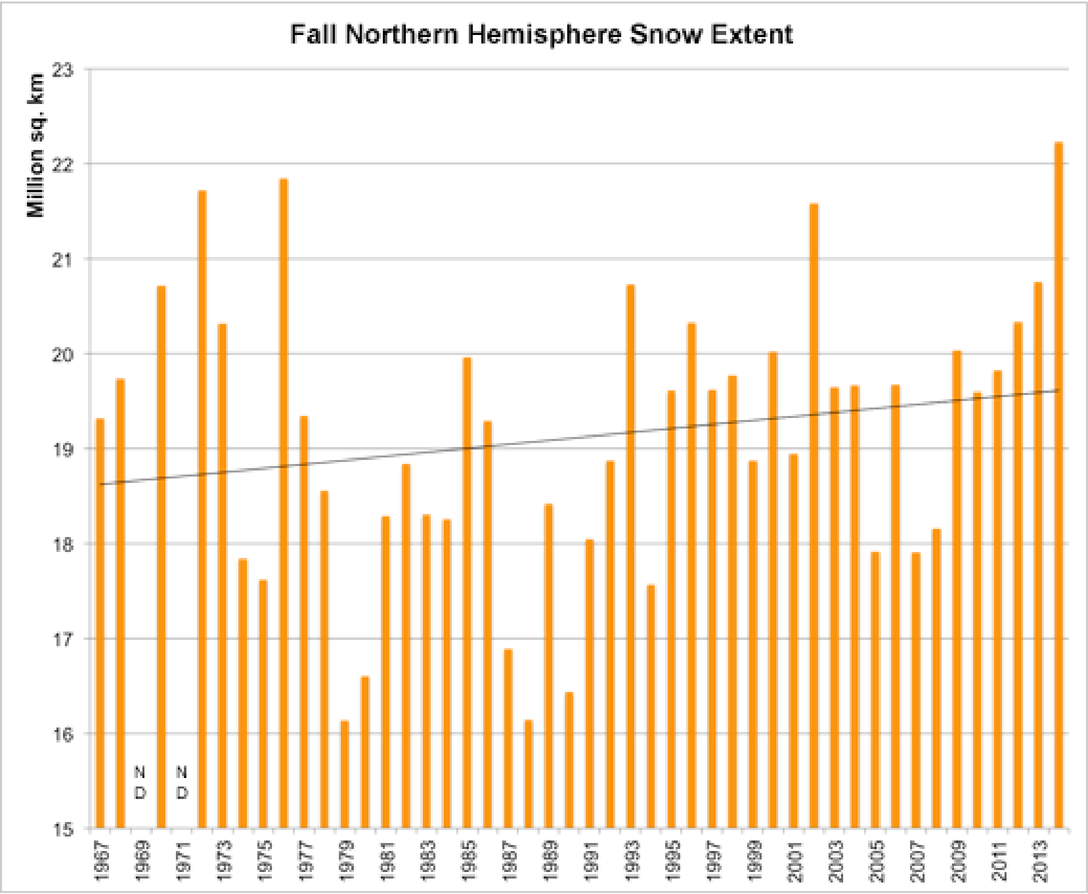
Cohen et al. 2012

Trends in Snow Cover and Sea Ice Extent



Snow cover has been increasing since 1988 and sea ice decreasing, especially since 1998.

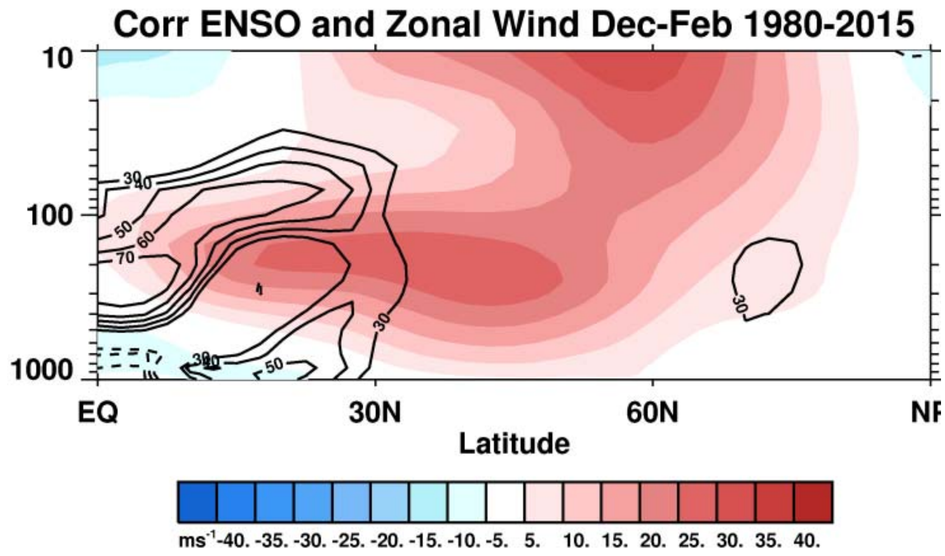
Trends in NH Fall Snow Cover Extent

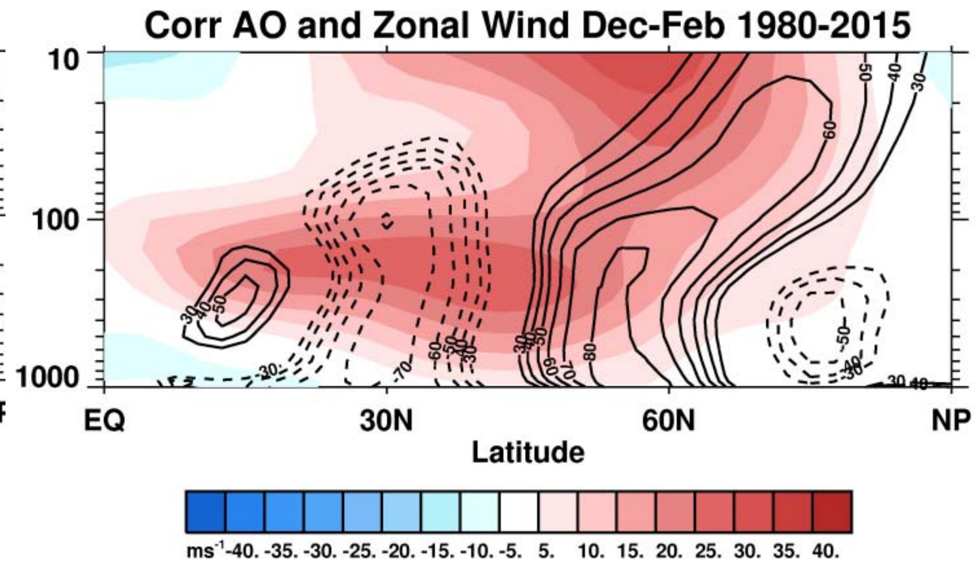


ND indicates no data for a given year

Last year was highest on record!

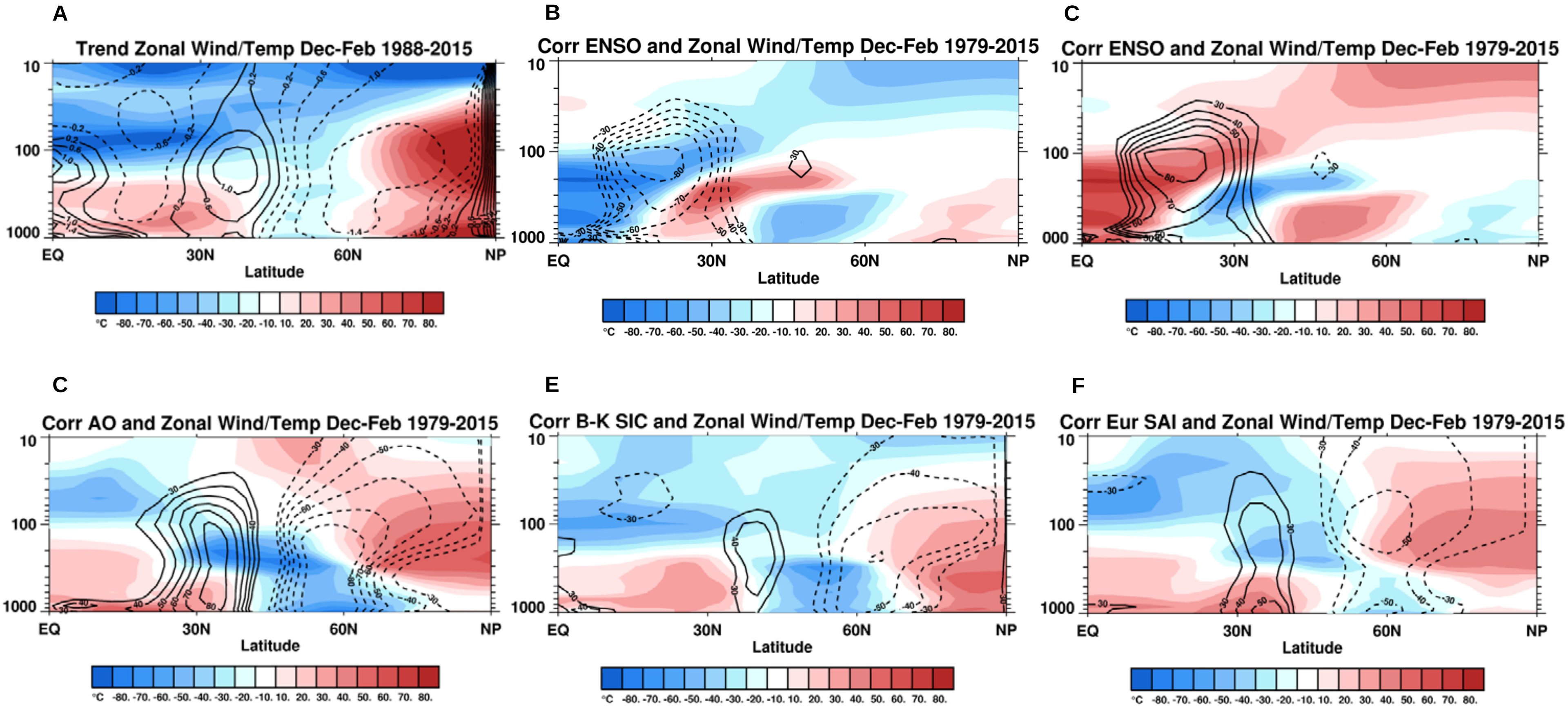
Correlations of AO with Zonal Wind (North Atlantic only)



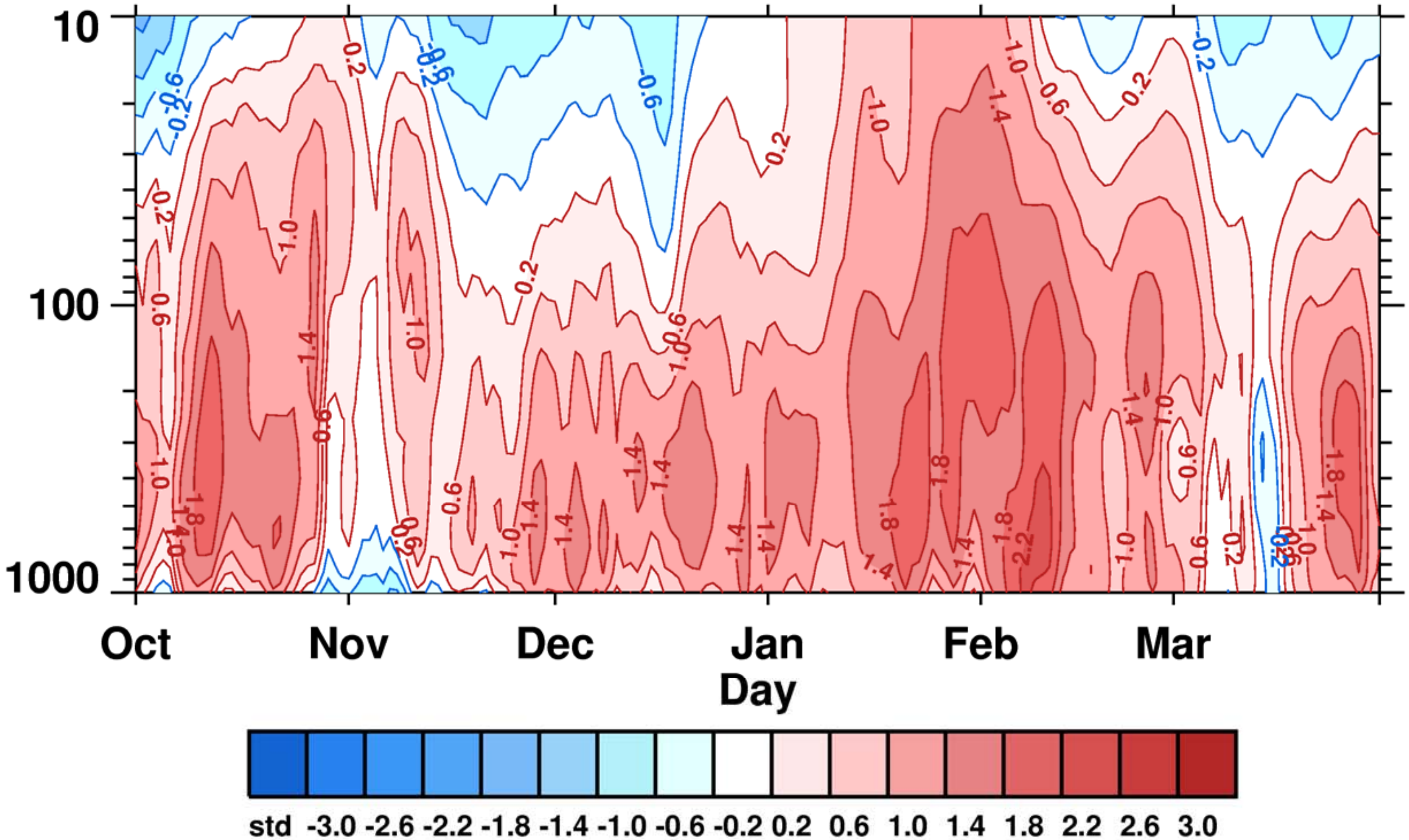


ENSO

AO

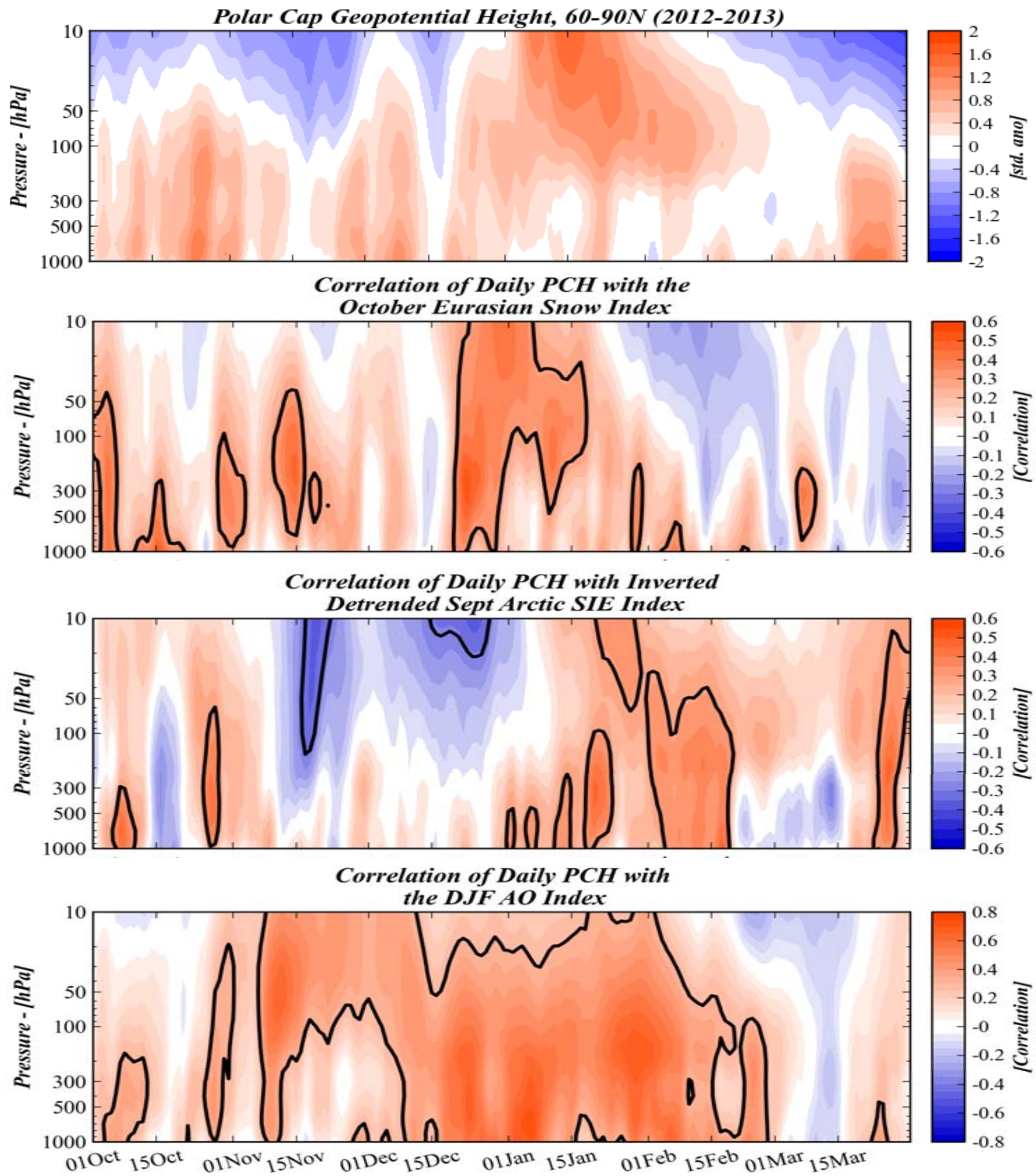

A
Trend Zonal Wind/Temp Dec-Feb 1988-2015
B
Corr ENSO and Zonal Wind/Temp Dec-Feb 1979-2015
C
Corr ENSO and Zonal Wind/Temp Dec-Feb 1979-2015
C
Corr AO and Zonal Wind/Temp Dec-Feb 1979-2015
E
Corr B-K SIC and Zonal Wind/Temp Dec-Feb 1979-2015
F
Corr Eur SAI and Zonal Wind/Temp Dec-Feb 1979-2015
10
100
1000
EQ
30N
60N
NP
Latitude
°C -80. -70. -60. -50. -40. -30. -20. -10. 10. 20. 30. 40. 50. 60. 70. 80.

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



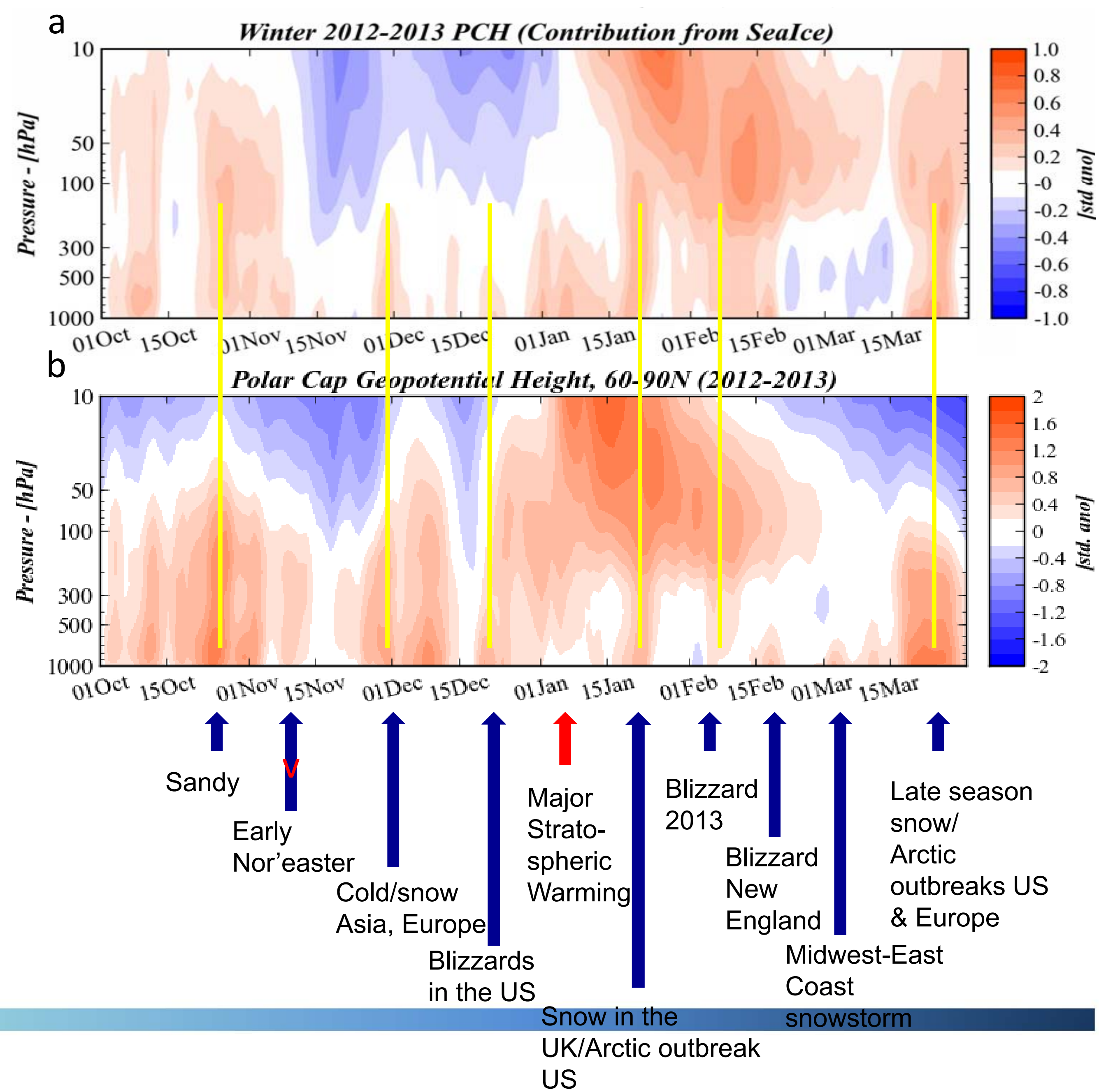
Increase in stratosphere-troposphere coupling mid-late winter that favors a warmer polar stratosphere and higher heights in the Arctic troposphere (negative AO/weak polar vortex).

PCH Oct-Mar



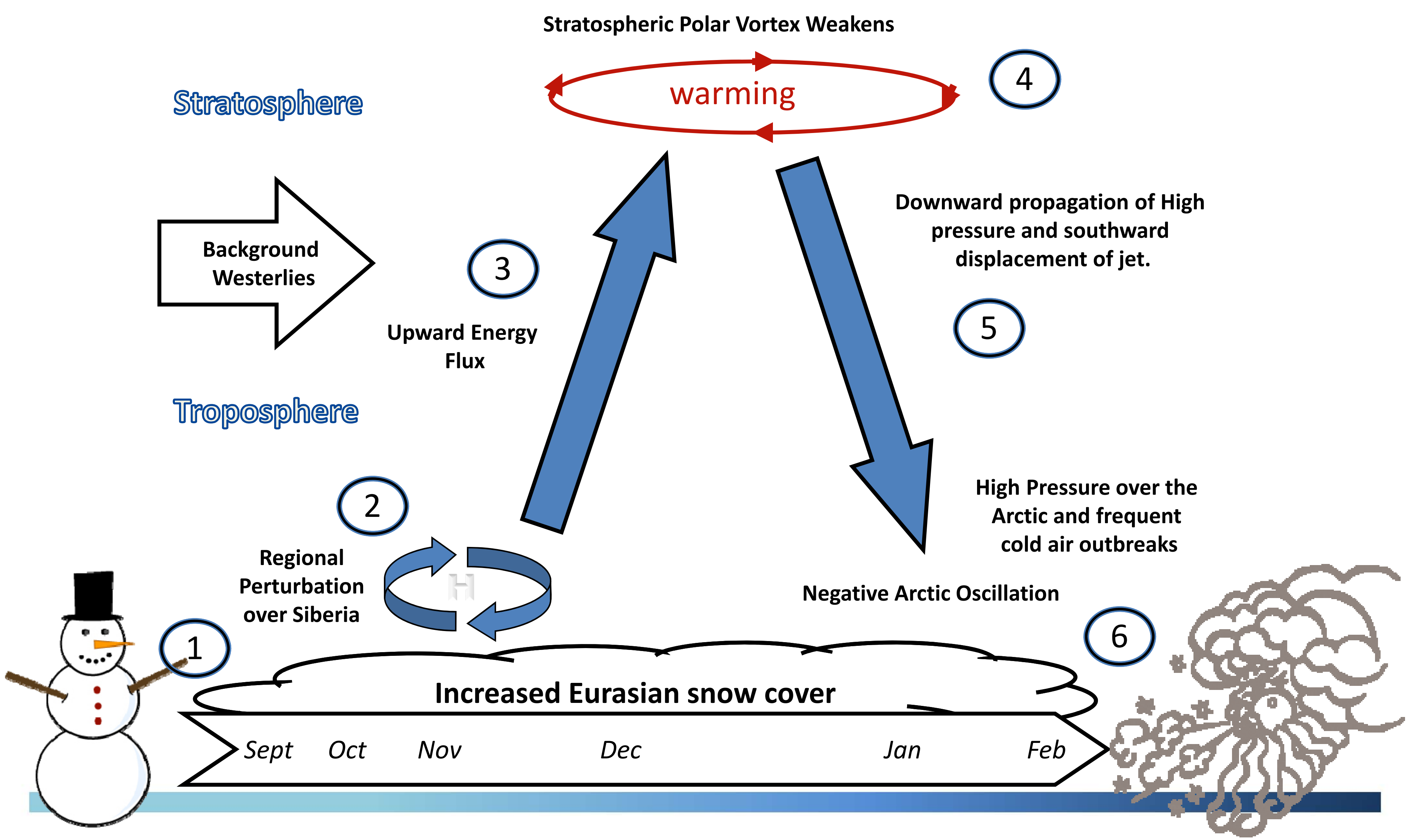
Polar Cap Geopotential Height, 60-90N (2012-2013)
Pressure - [hPa]
10
50
100
300
500
1000
[std. ano]
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
Correlation of Daily PCH with the October Eurasian Snow Index
[Correlation]
0.6
0.5
0.4
0.3
0.2
0.1
-0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Correlation of Daily PCH with Inverted Detrended Sept Arctic SIE Index
Correlation of Daily PCH with the DJF AO Index
0.8
0.6
0.4
0.2
-0
-0.2
-0.4
-0.6
-0.8
01Oct
15Oct
01Nov
15Nov
01Dec
15Dec
01Jan
15Jan
01Feb
15Feb
01Mar
15Mar

PCH
Oct-Mar

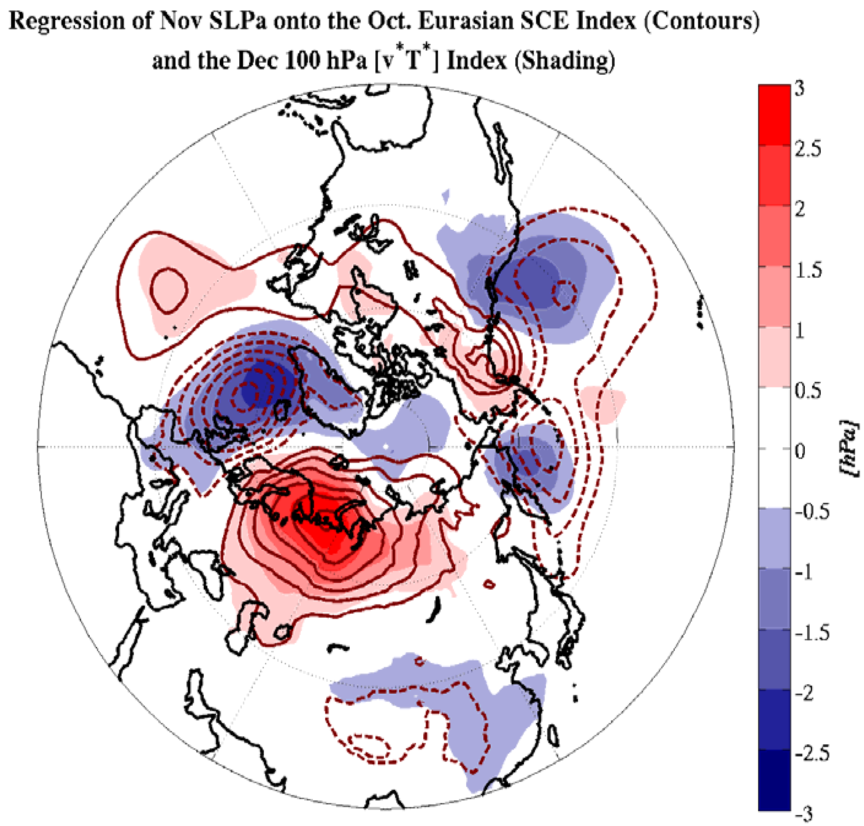


a
Winter 2012-2013 PCH (Contribution from SeaIce)
Pressure - [hPa]
[std ano]
b
Polar Cap Geopotential Height, 60-90N (2012-2013)
Pressure - [hPa]
[std. ano]
01Oct 15Oct 01Nov 15Nov 01Dec 15Dec 01Jan 15Jan 01Feb 15Feb 01Mar 15Mar
Sandy
Early Nor'easter
Cold/snow Asia, Europe
Blizzards in the US
Major Strato-spheric Warming
Snow in the UK/Arctic outbreak US
Blizzard 2013
Blizzard New England
Midwest-East Coast snowstorm
Late season snow/ Arctic outbreaks US & Europe

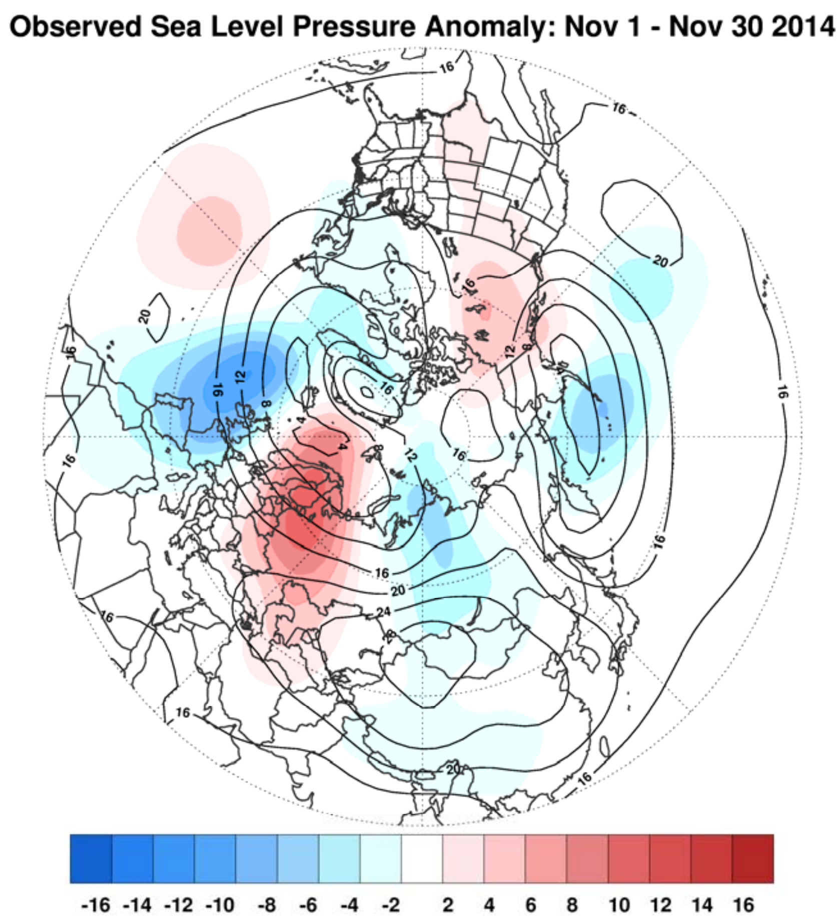
Snow Forced Cold Signal



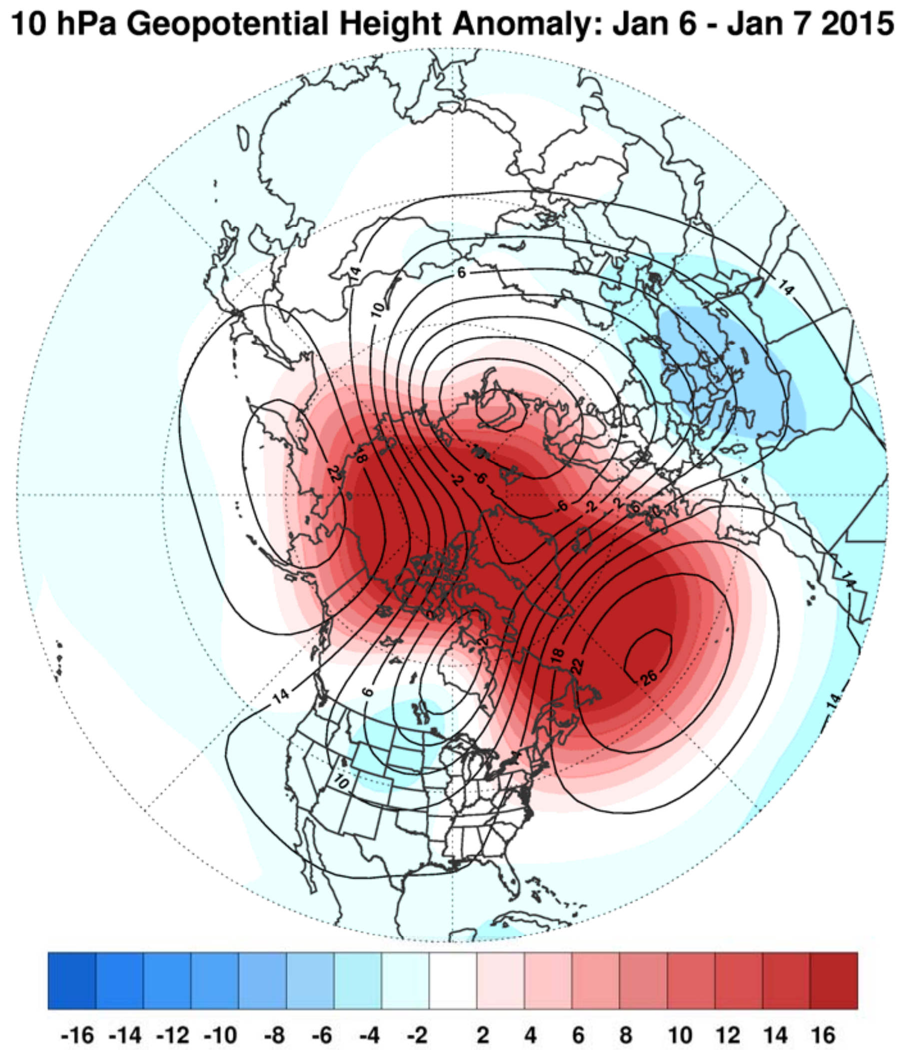
Tropospheric precursor November 2014



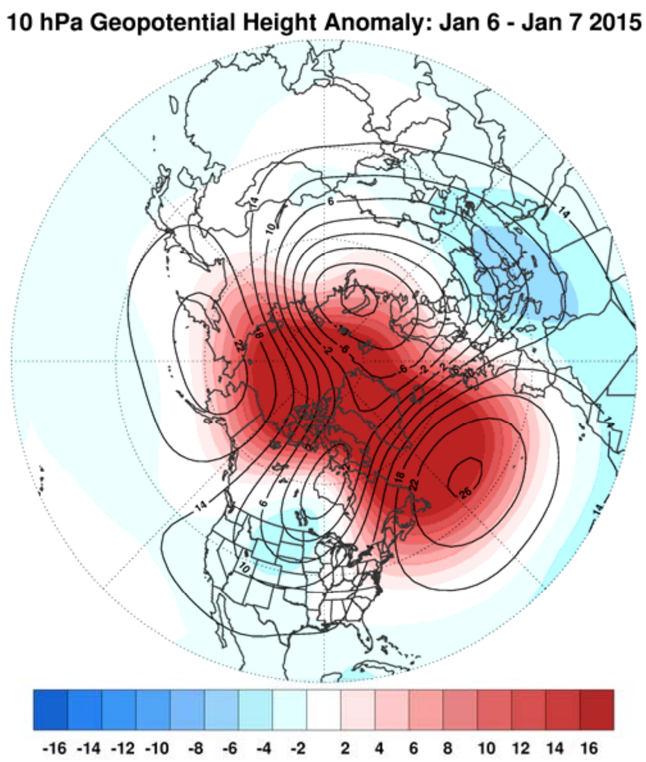
Pattern correlation = 0.93 between 40-80°N

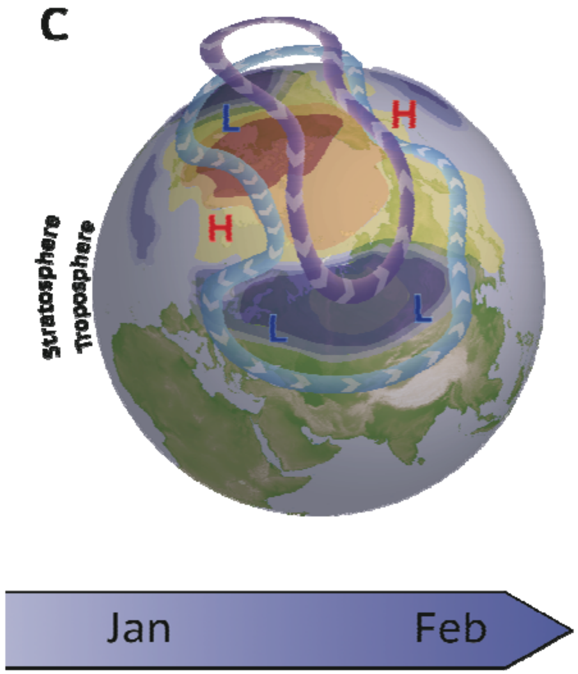


Stratospheric Warming/PV Split



Synthesis of Sea Ice and Snow Cover

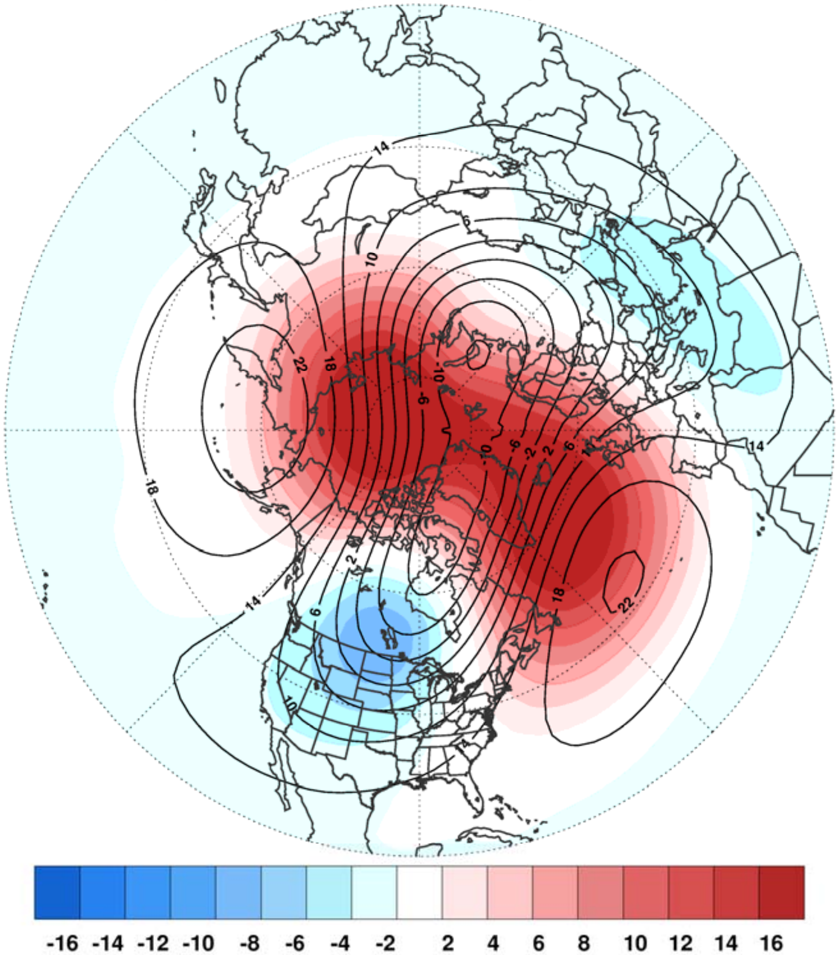




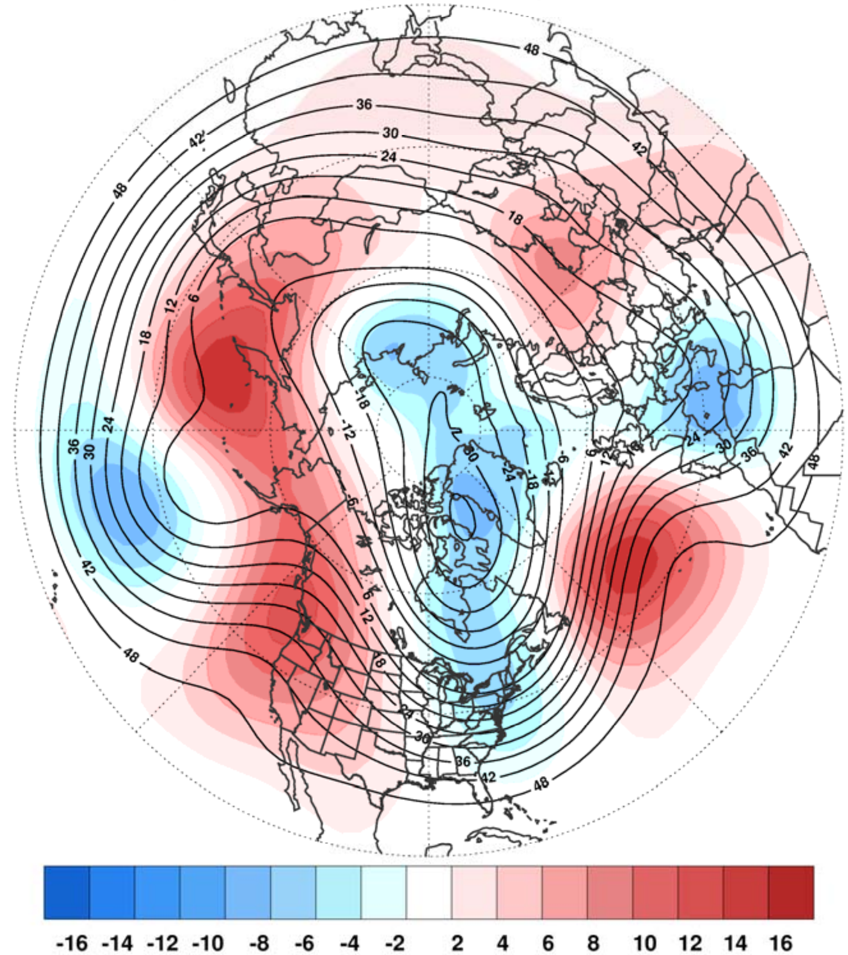
Cohen et al. 2014

Atmospheric Circulation

10 hPa Geopotential Height Anomaly: Jan 1 - Jan 10 2015

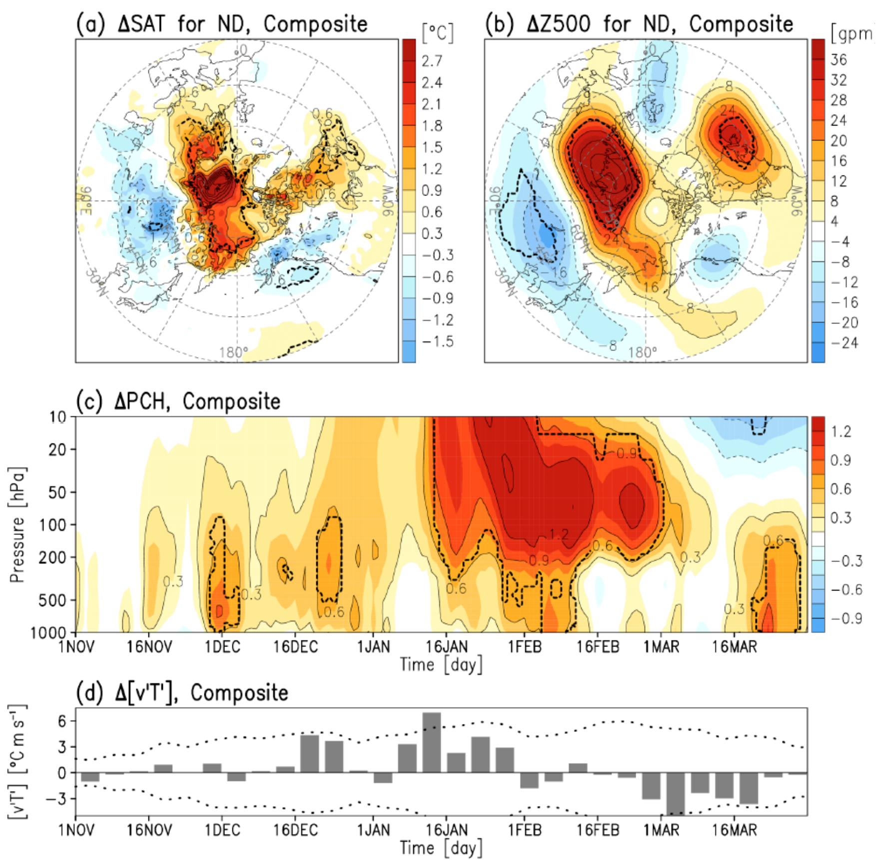


500 hPa Geopotential Height Anomaly: Jan 19 - Feb 28 2015

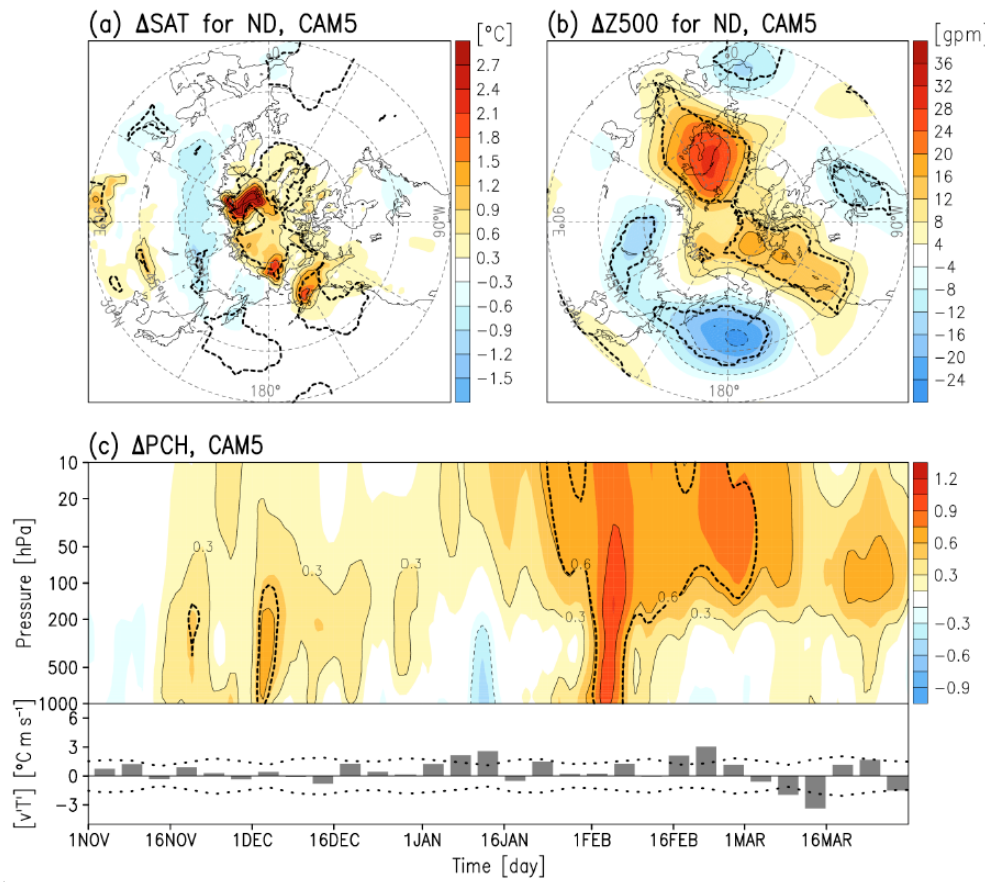


Low Sea Ice Forced Cold Signal

observations



model

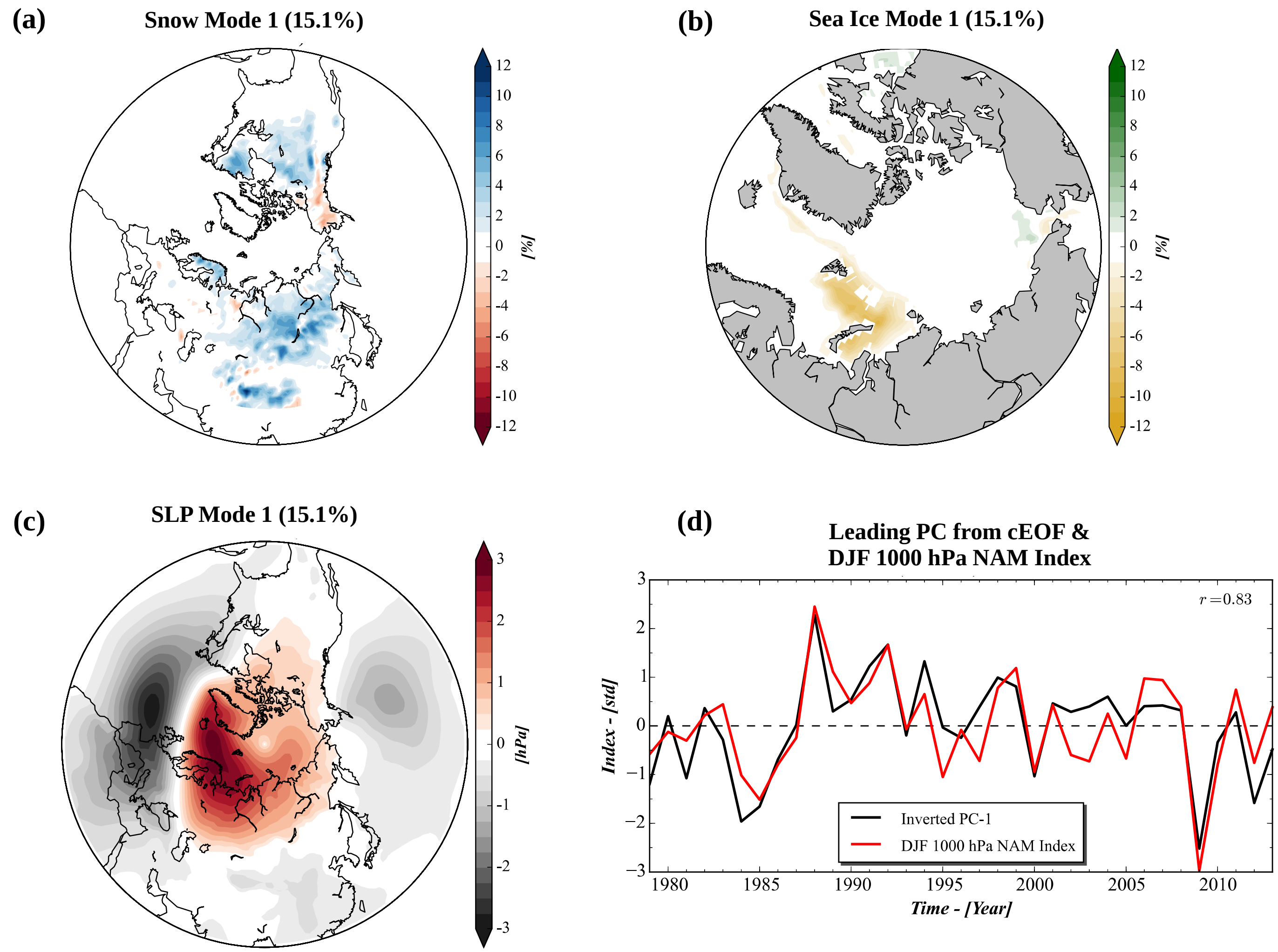


Some model runs forced with low sea ice have been able to simulate atmospheric response as observed.

Kim et al. 2014

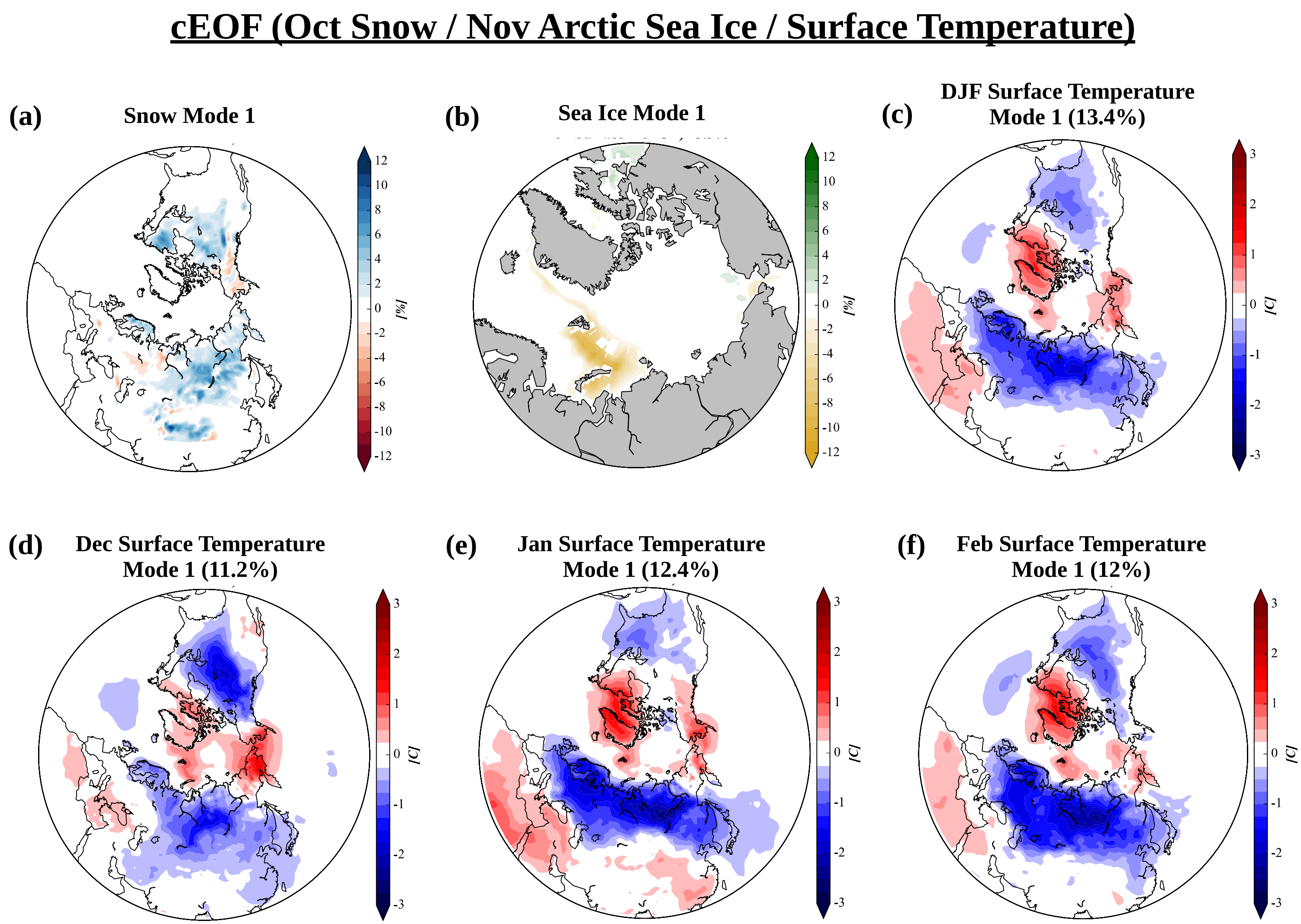
Relationship between Sea Ice, Snow Cover and the AO

cEOF (Oct Snow / Nov Arctic Sea Ice / DJF SLP)



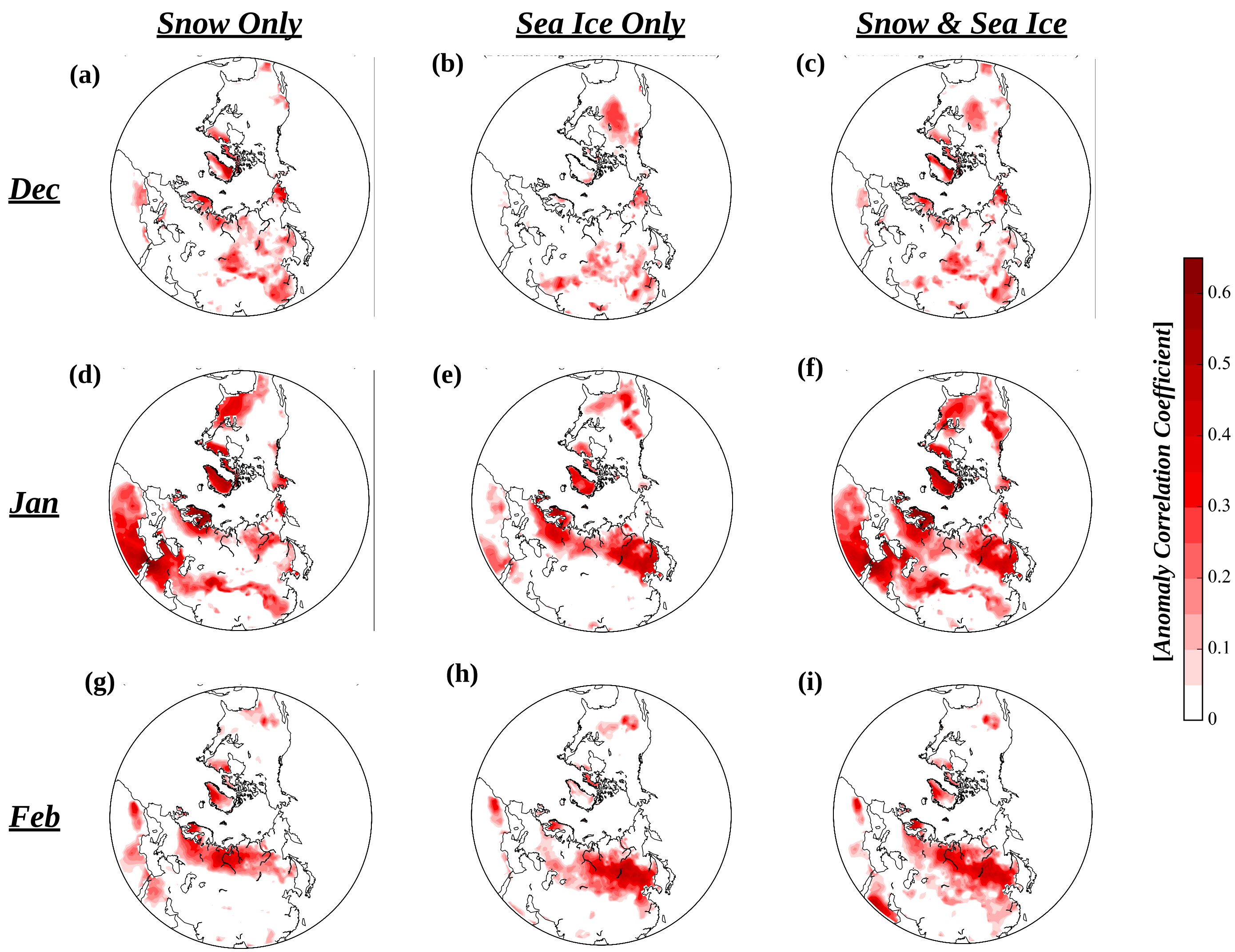
Furtado et al. in preparation

Relationship between Sea Ice, Snow Cover and Surface Temperatures



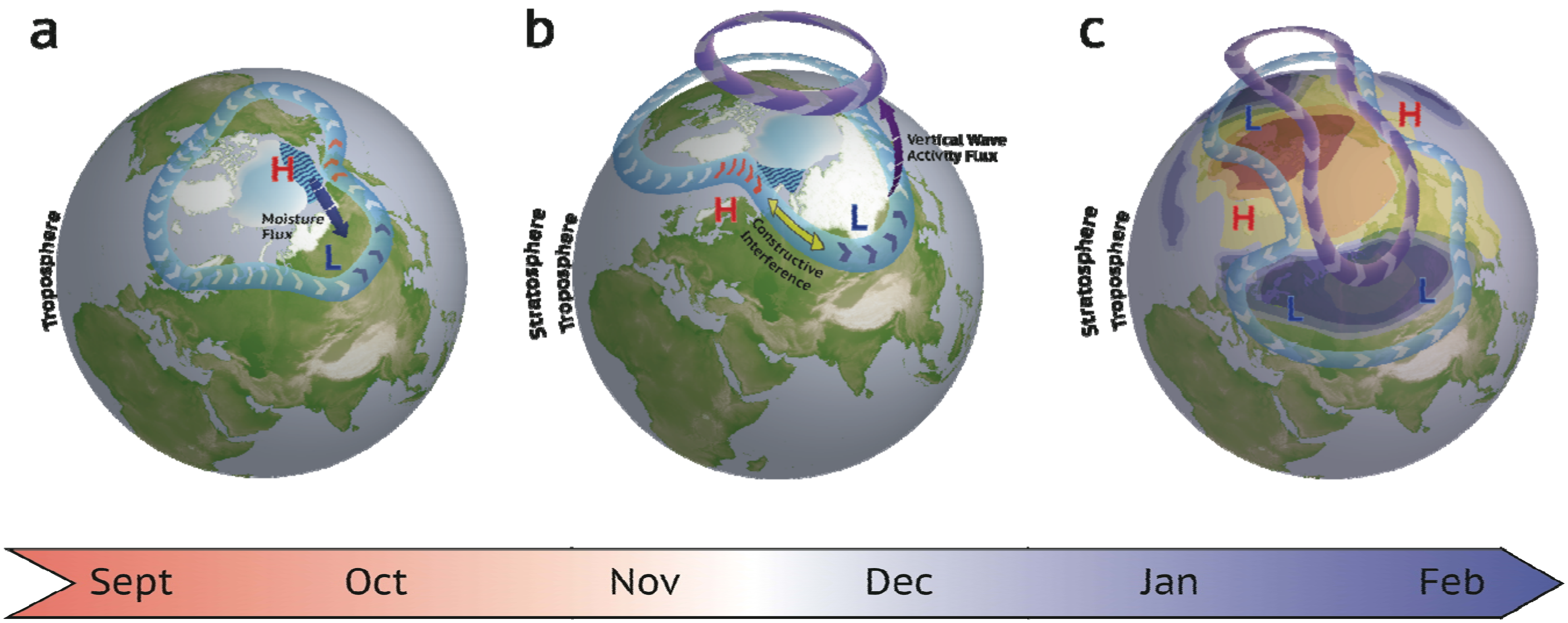
Furtado et al. in preparation

Relationship between Sea Ice, Snow Cover and Surface Temperatures



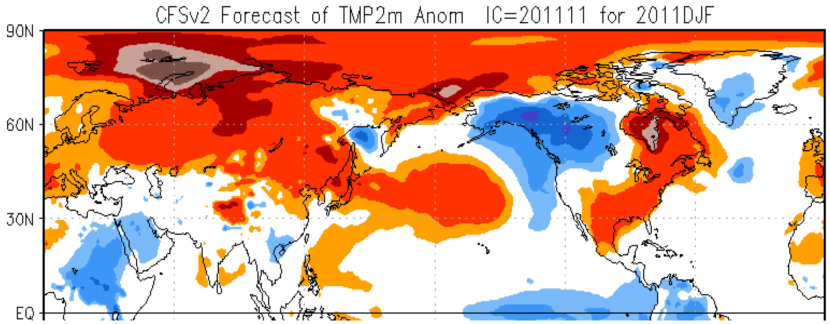
Furtado et al. in preparation

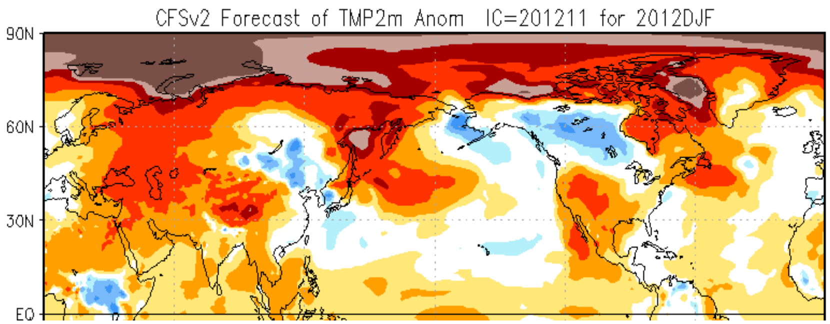
Synthesis of Sea Ice and Snow Cover

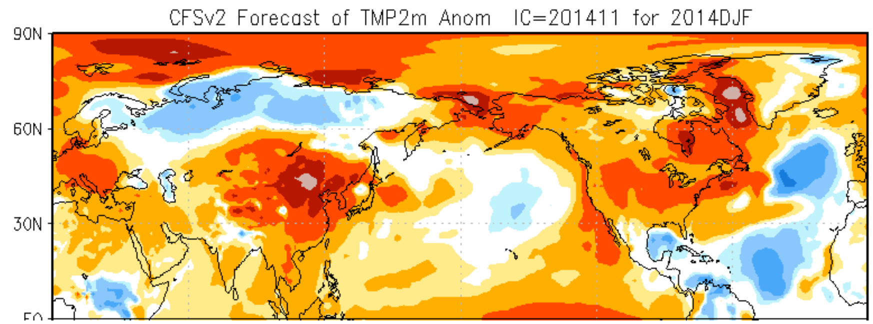


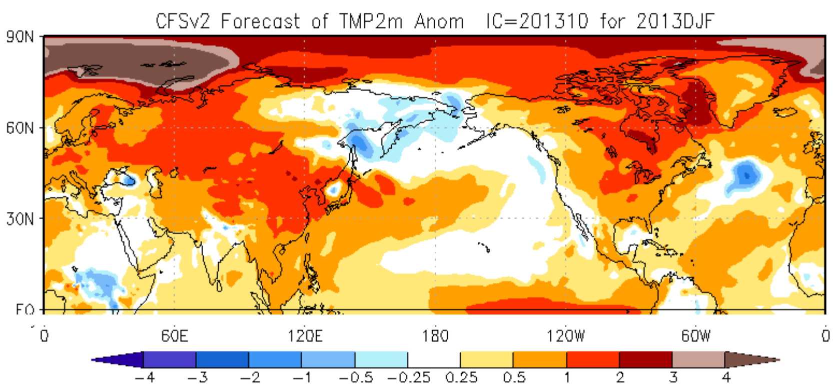
Cohen et al. 2014

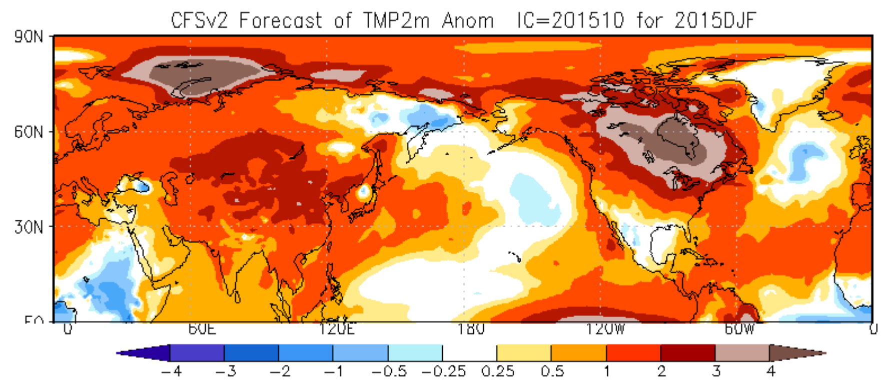
Dynamical Winter Forecasts 2010/11-15/16







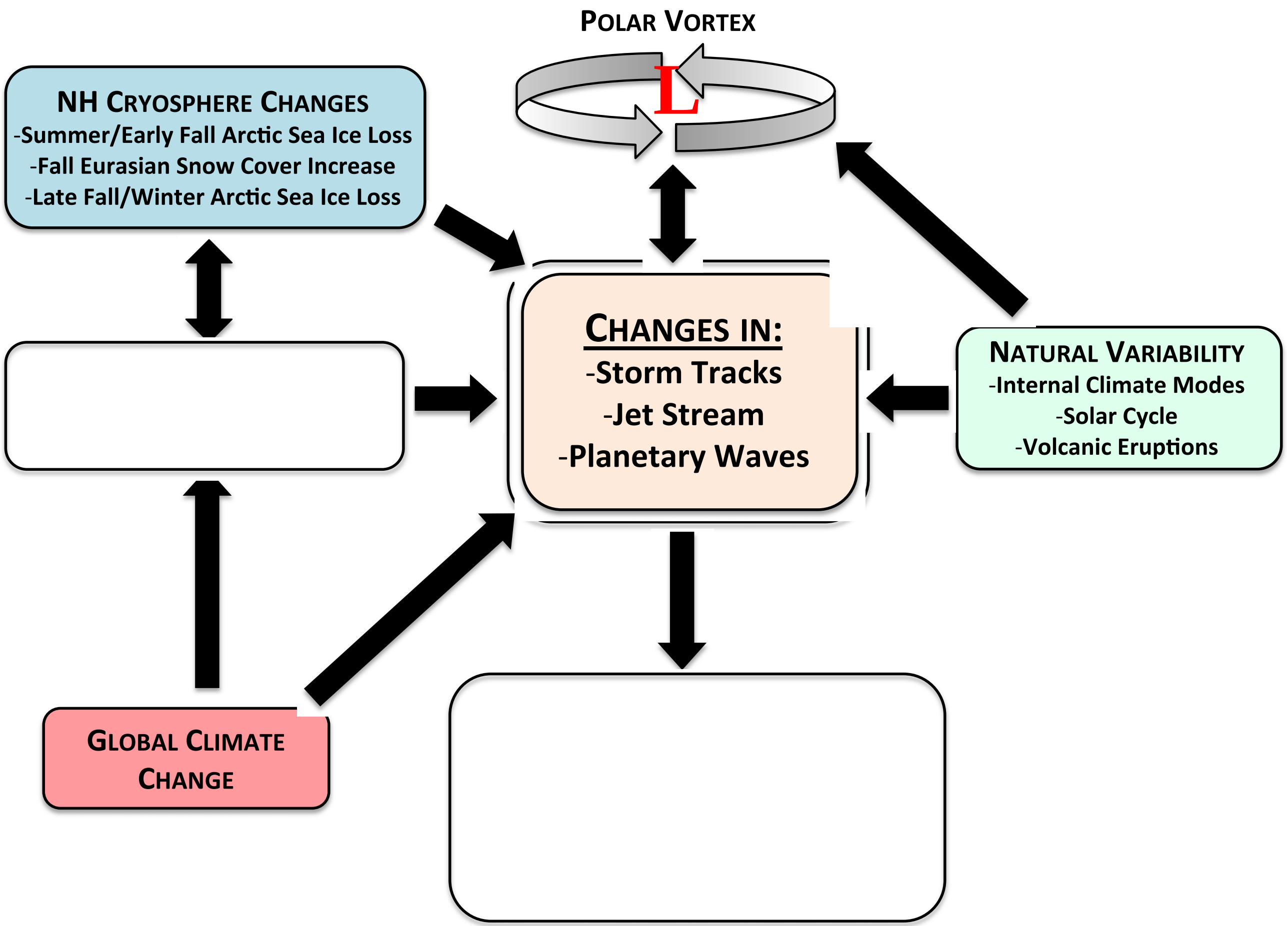




Challenges with Data and Models

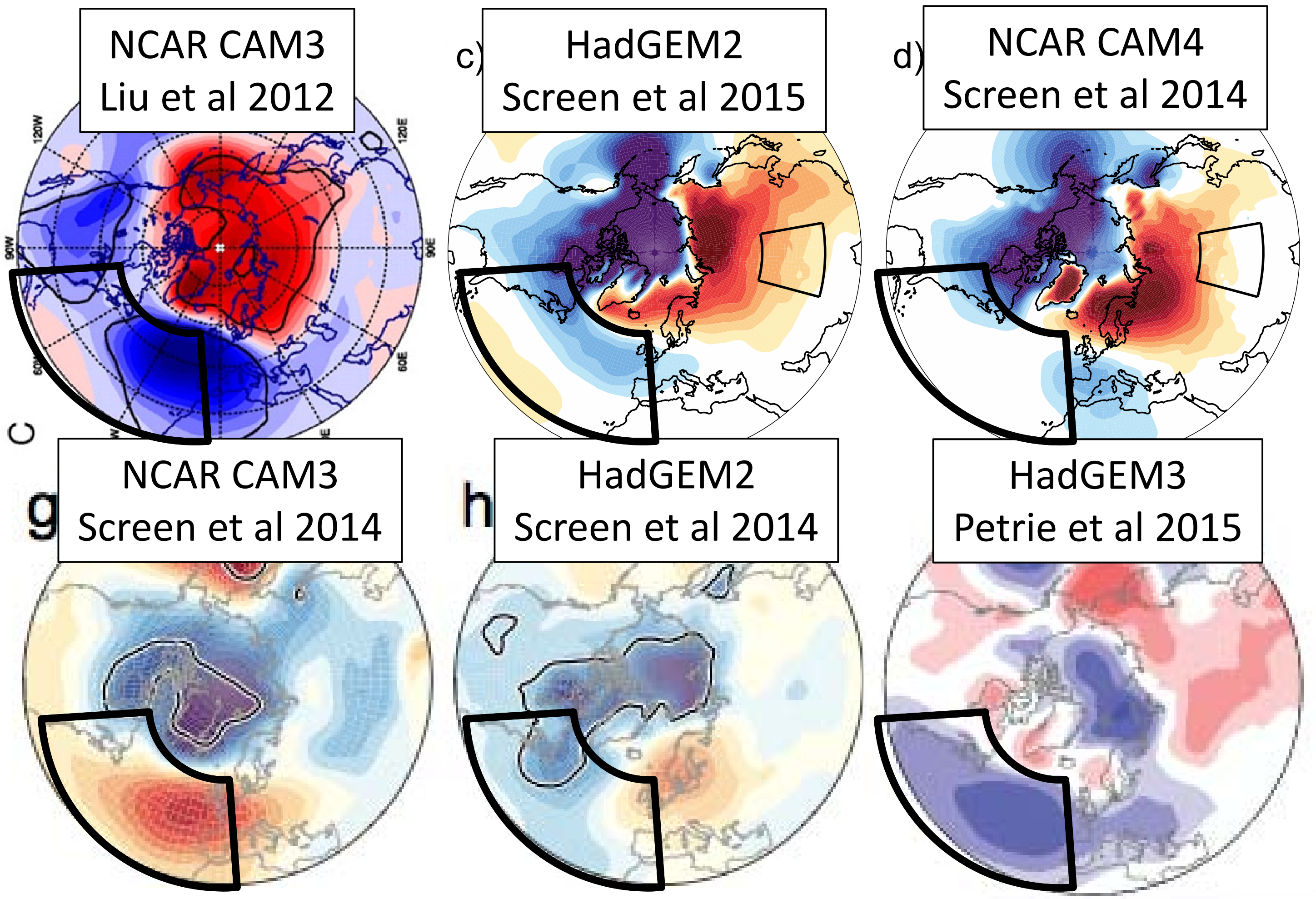
- Short time series in observations
- Model deficiencies
- Uncoordinated modeling studies
- Biases and uncertainties in matrices for quantitative analysis
- Still more and more observational and modeling studies argue that a changing Arctic is influencing mid-latitude weather

Mid-latitude Weather is Complicated



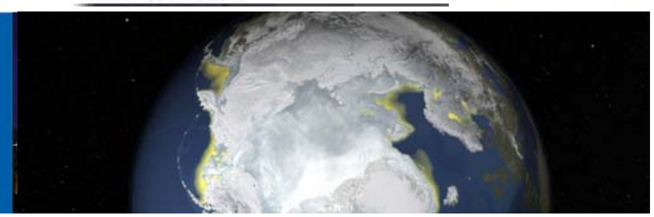
Cohen et al. 2014

Winter MSLP response to sea-ice loss

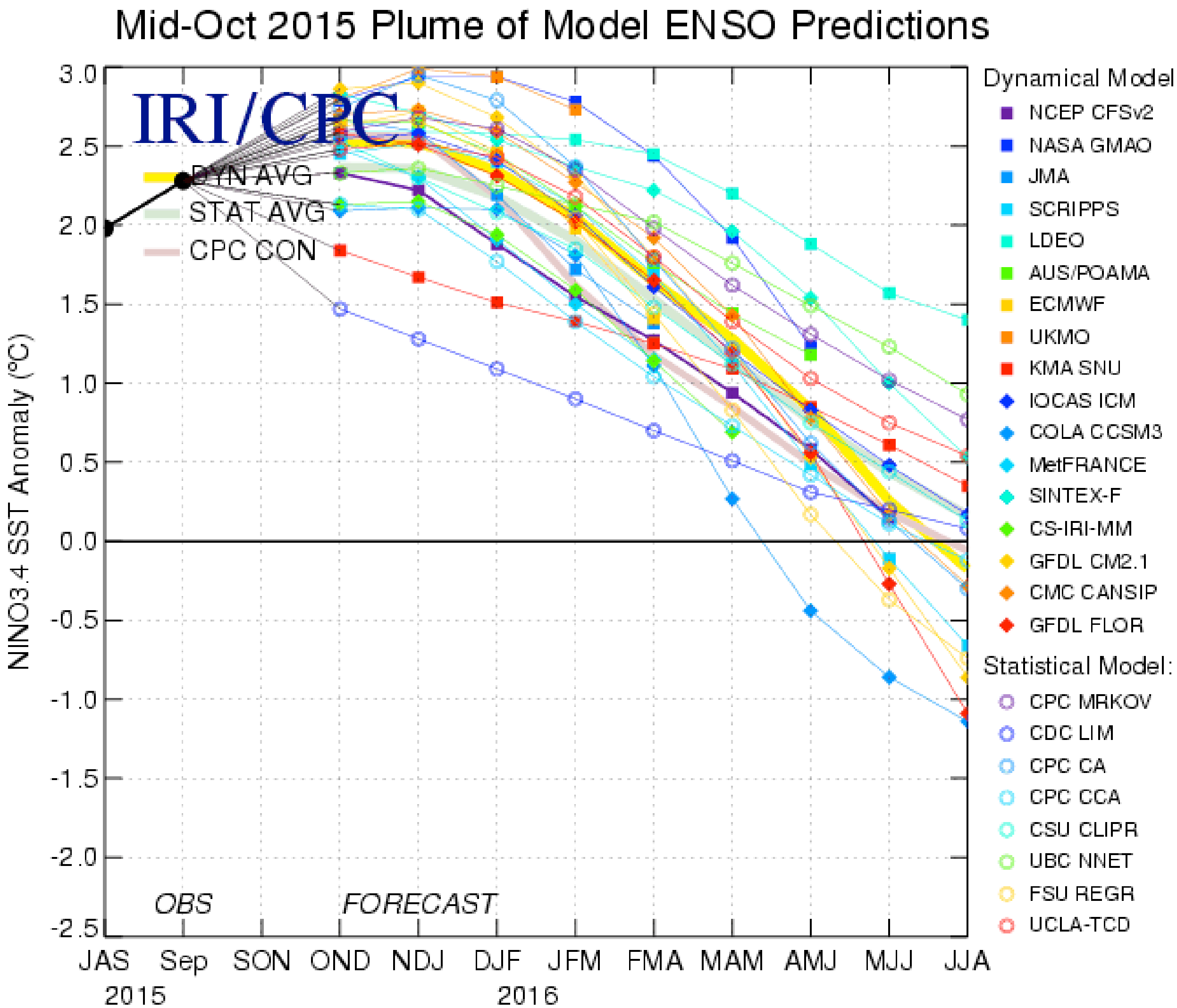


UNIVERSITY OF EXETER

j.screen@exeter.ac.uk



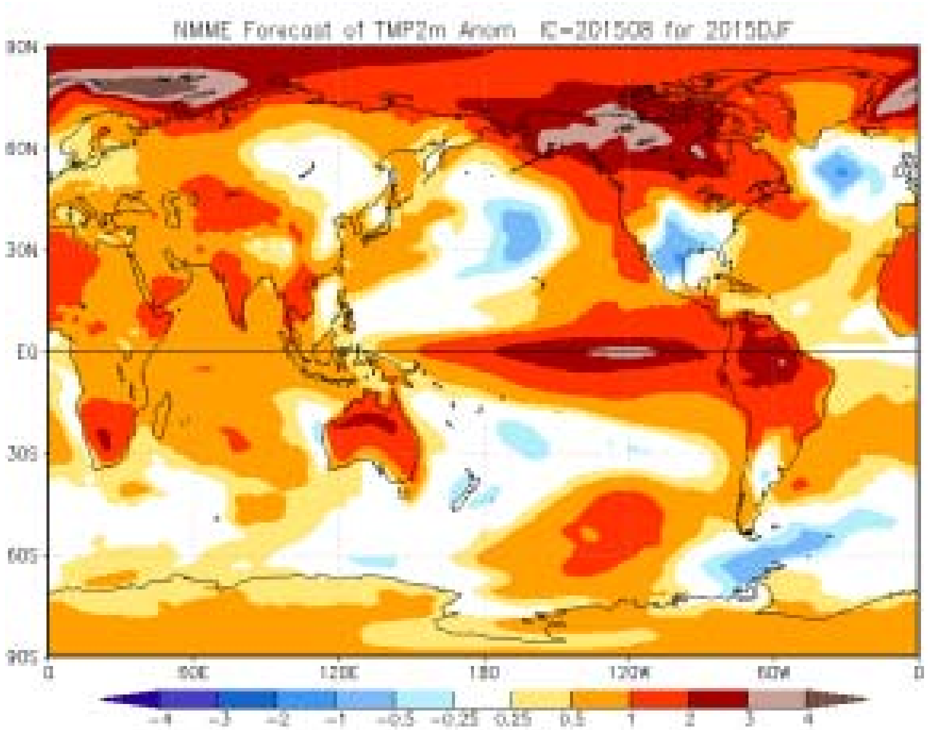
ENSO Forecast

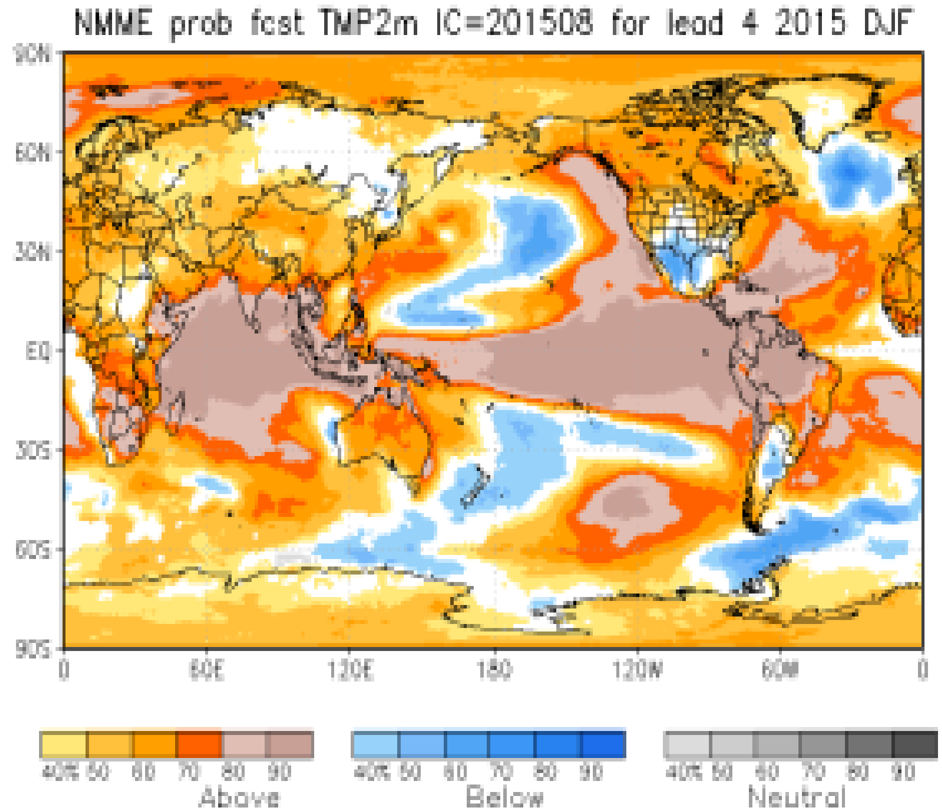


All multi-model averages suggest that Niño 3.4 will be above +1.5ºC (a "strong" El Niño) during late 2015 into early 2016.

NOAA Climate Prediction Center

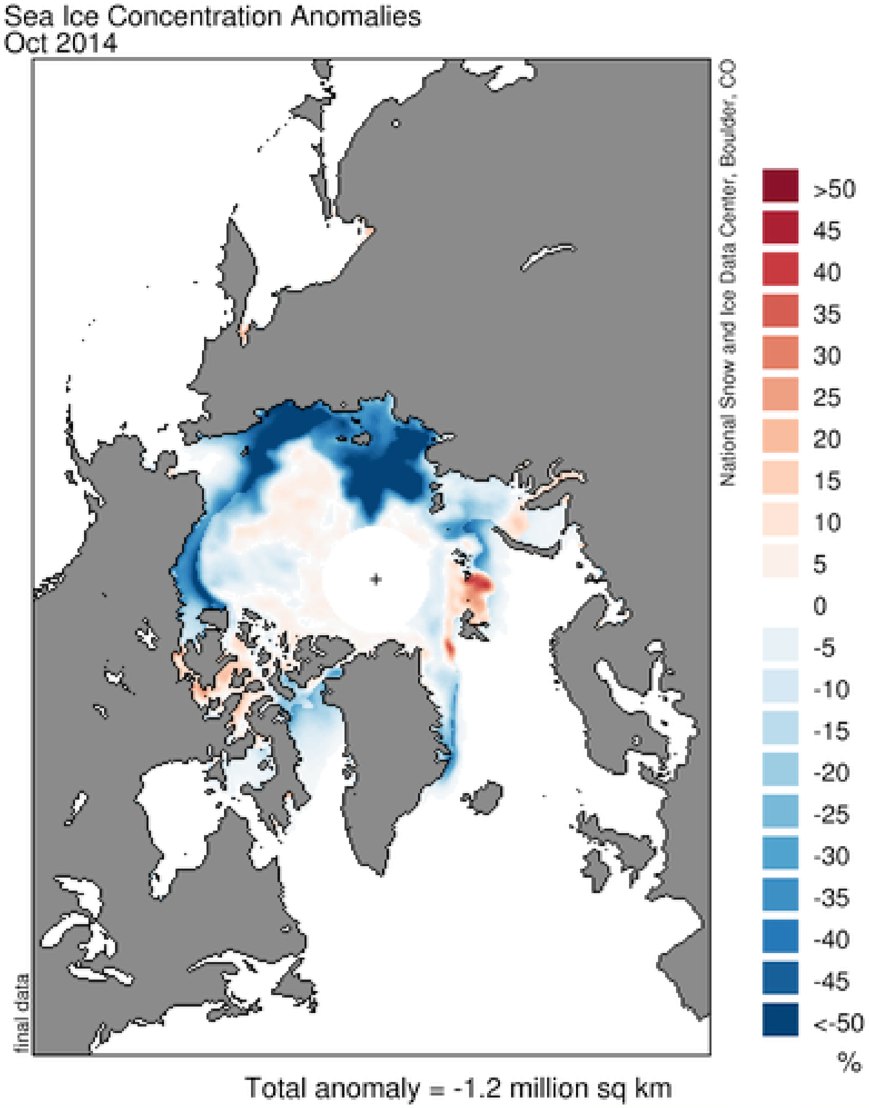
ENSO Dynamical Model Forecast

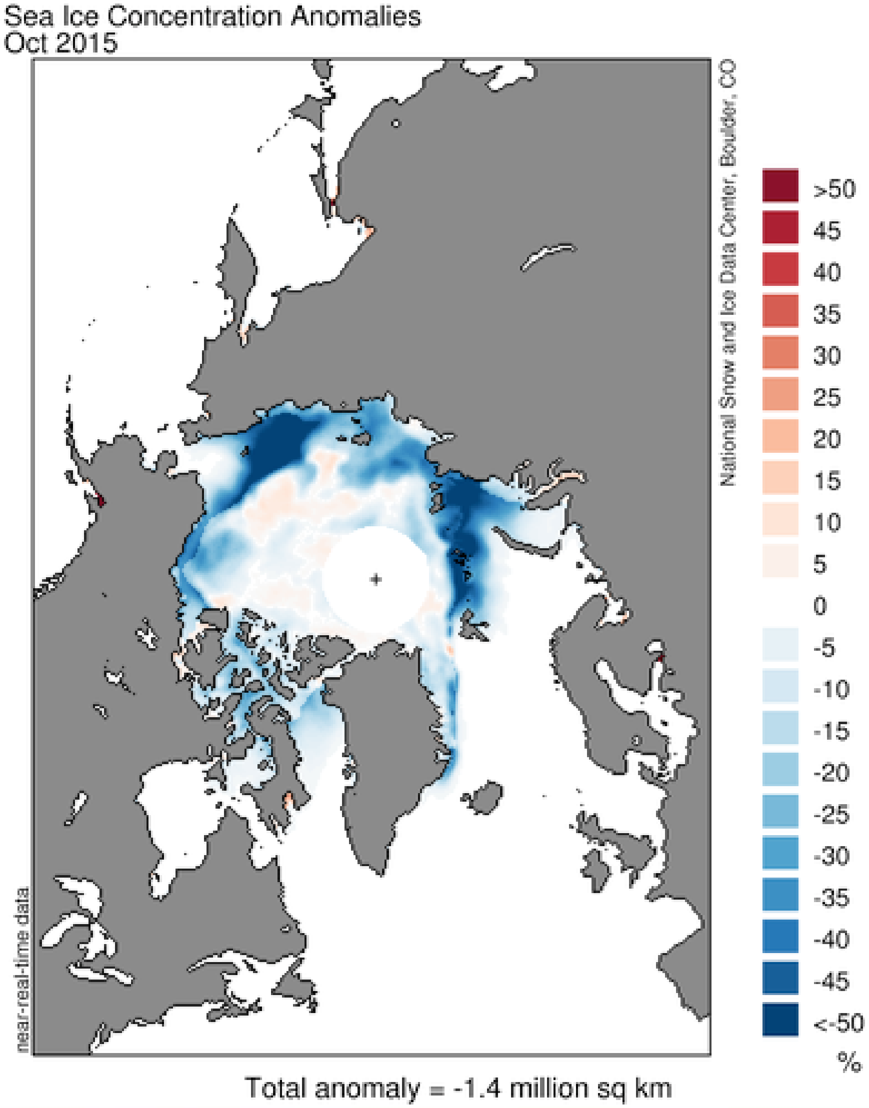




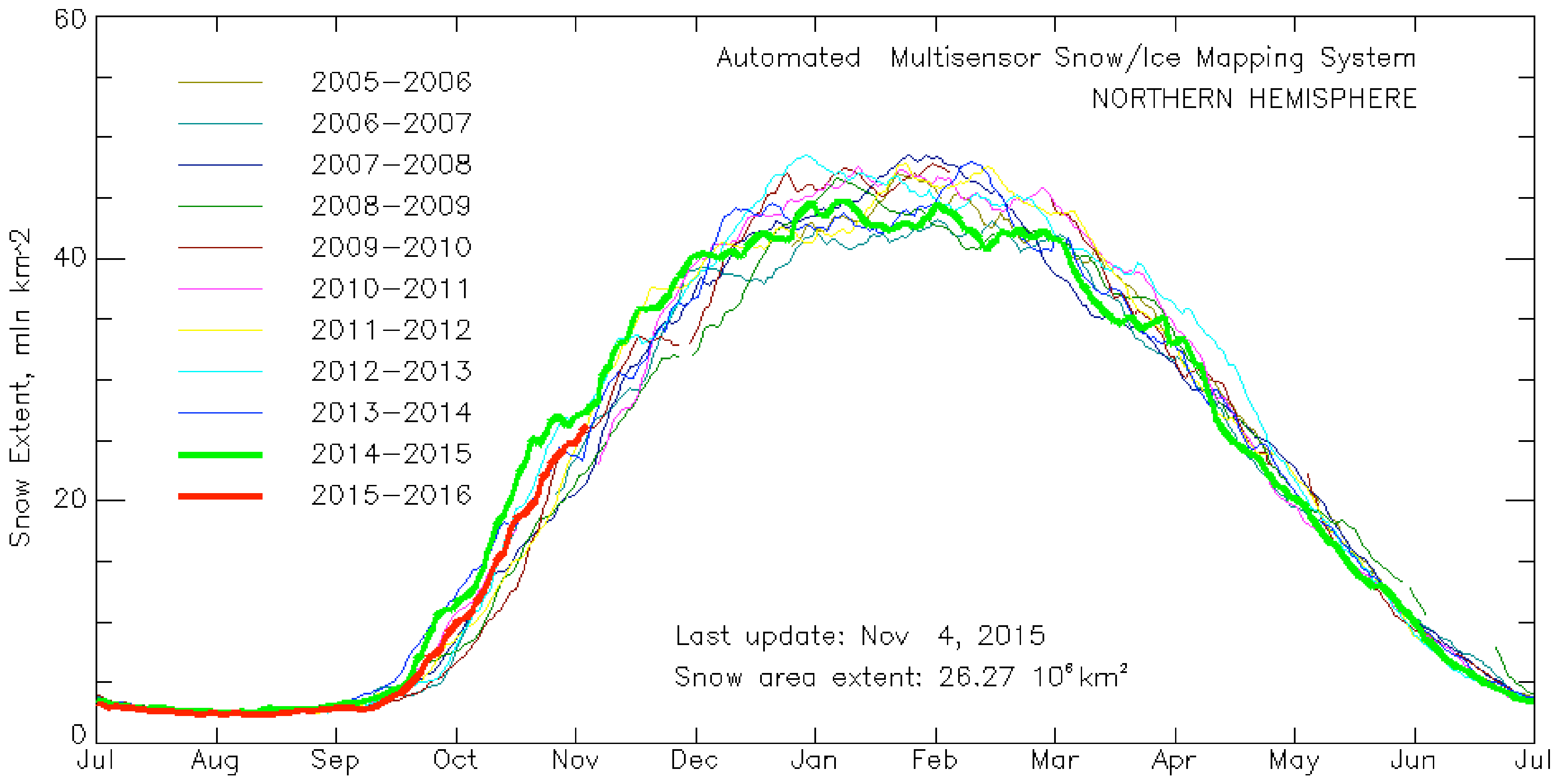
Models are confident in regions with high skill from ENSO or sea ice is melting in the Arctic

September Sea Ice Anomalies

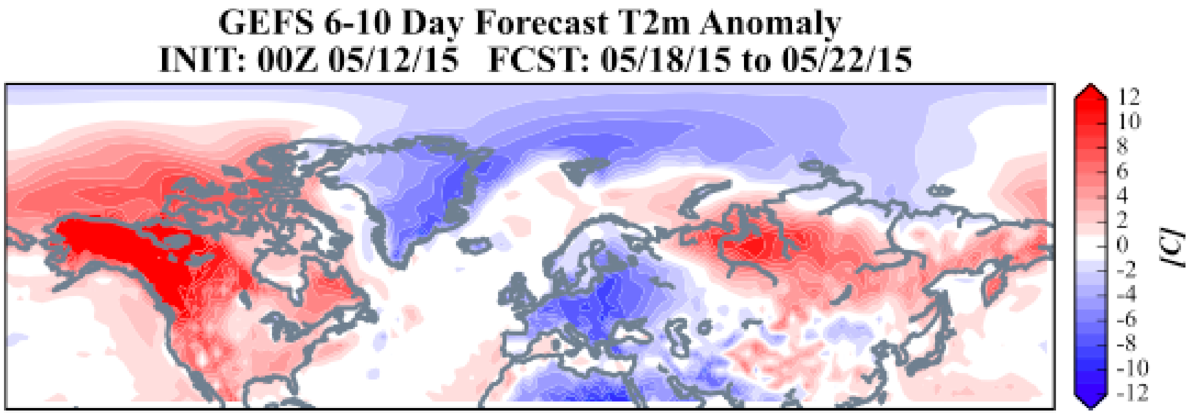


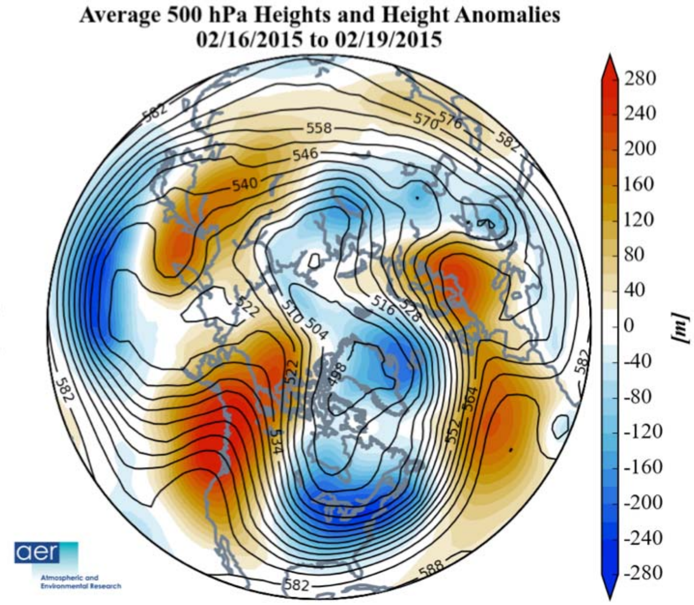


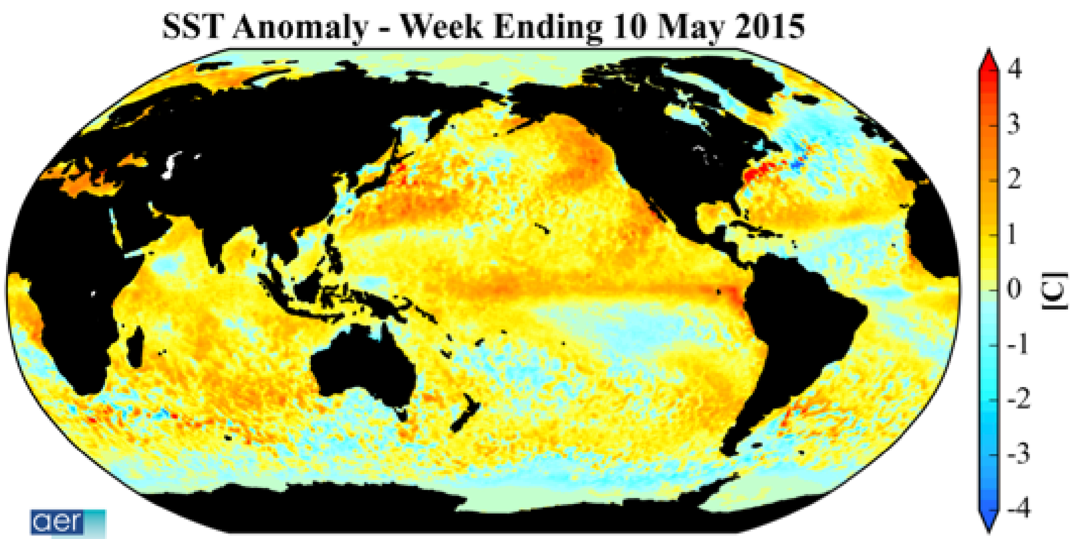
October Snow Cover Extent

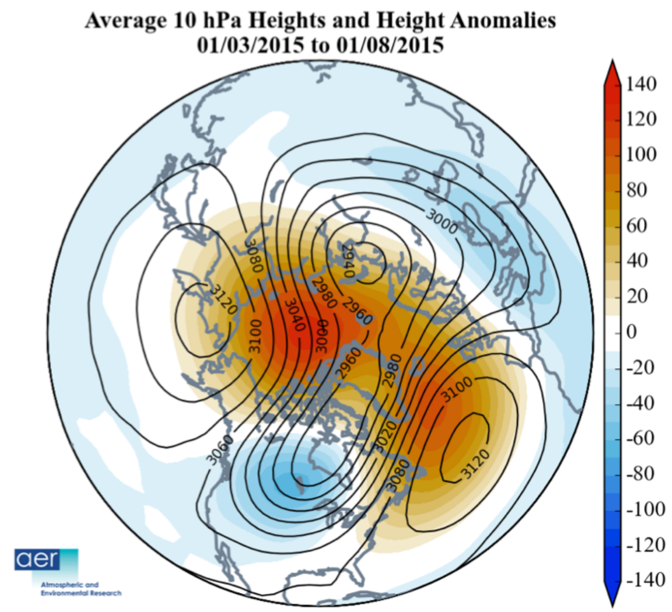


Arctic Oscillation Blog









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

Capital Weather Gang

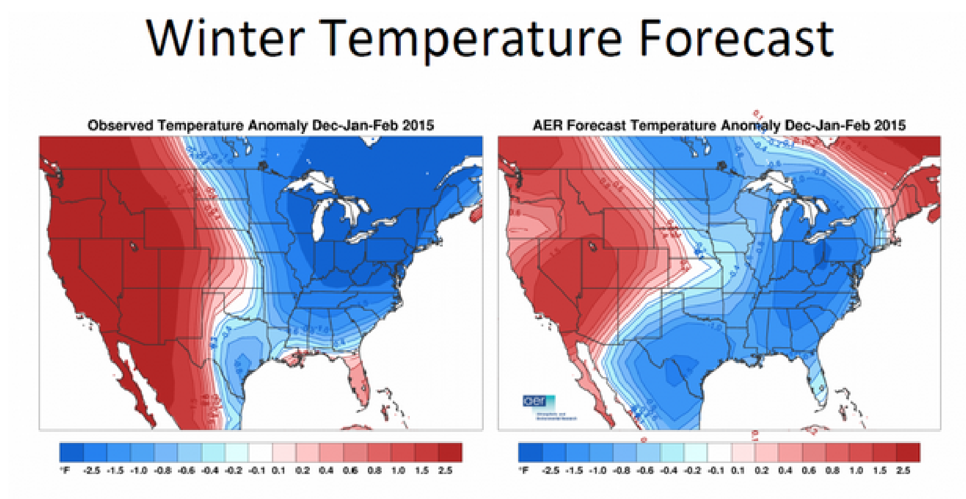
Expert: Ramp-up in Siberian snow cover hints at cold winter for eastern U.S.

A 19

By Jason Samenow October 14 at 2:08 PM Follow @ca

Based on the snow cover behavior, Cohen forecast a colder than normal winter for the eastern U.S. He was not only right that the winter would be a cold one, but also accurately forecast that the second half of winter would be significantly colder than the first half.

Cohen shared his 2014-2015 winter temperature forecast (below right) compared to what actually happened (below left) and the match is remarkable. “As far as seasonal forecasts go, that is incredibly accurate with the gross features correct and differences only in the details,” Cohen said.

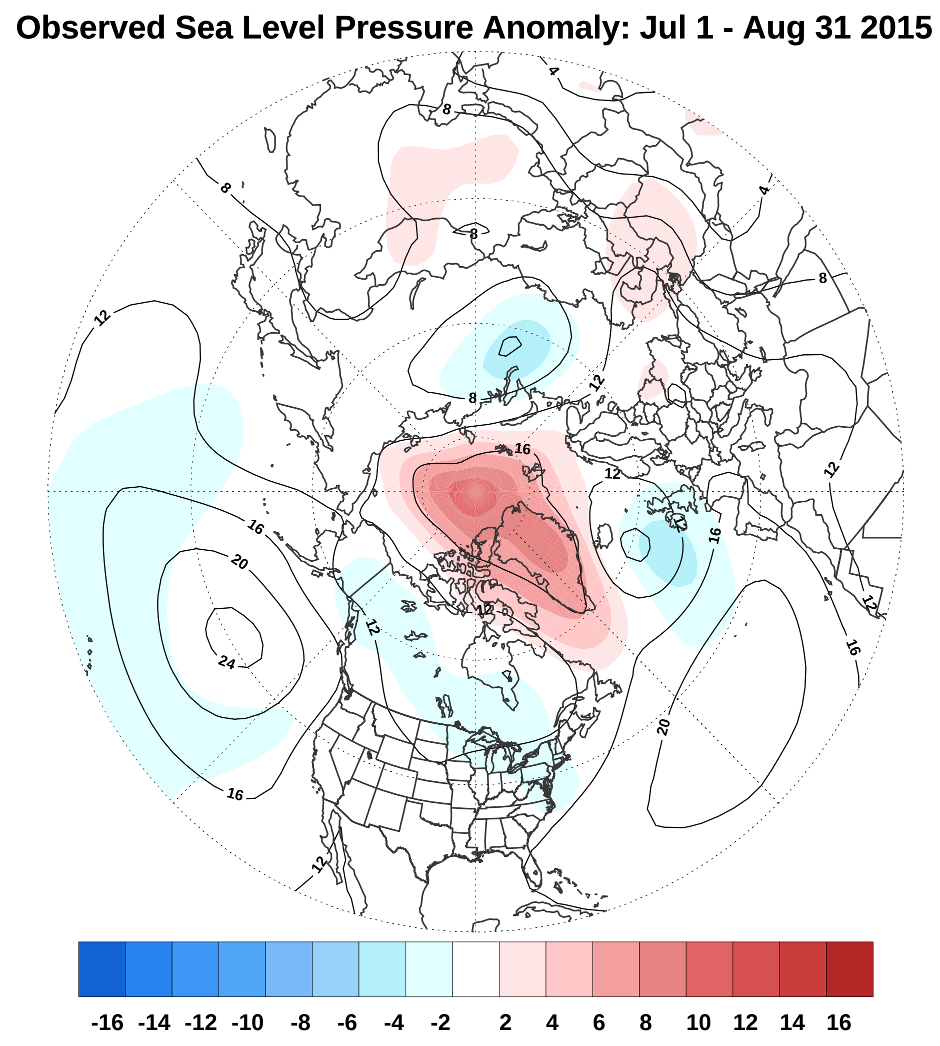


(Judah Cohen)

Summary

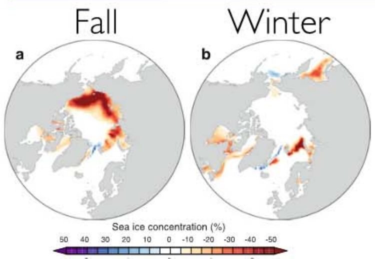
- Over the past two decades the Arctic has undergone rapid and dramatic changes.
- Strong warming and large variability in sea ice and snow cover could be influencing mid-latitude weather.
- Many theories/studies argue/show that Arctic variability influences mid-latitude weather through wave interference and/or Jet Stream characteristics.
- Skepticism remains high due to large natural variability, short observational record, inconclusive and ambiguous modeling studies and modeling deficiencies.
- The need for advance is significant and appreciated and efforts are underway to improve observational and modeling studies.

Summer Circulation



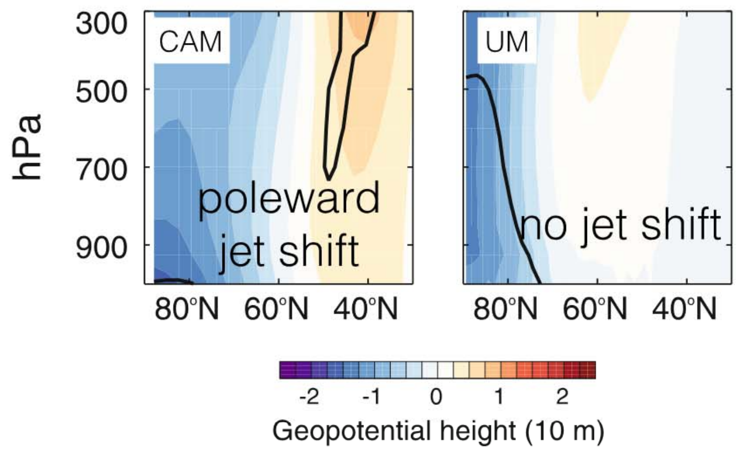
Same sea ice forcing – different model response

Internal atmospheric variability is large



perturbed sea ice minus control (similar to 2009-1979)

geopotential height response [SON]



- AMIP experiments with high and low sea-ice concentrations based on observed trends (1979-2009)
- same forcing…different response!

100 years of Unified Model
60 years of CAM
Screen, Deser et al. (2013; CDYN)

Arctic Amplification – Mid-latitude Weather

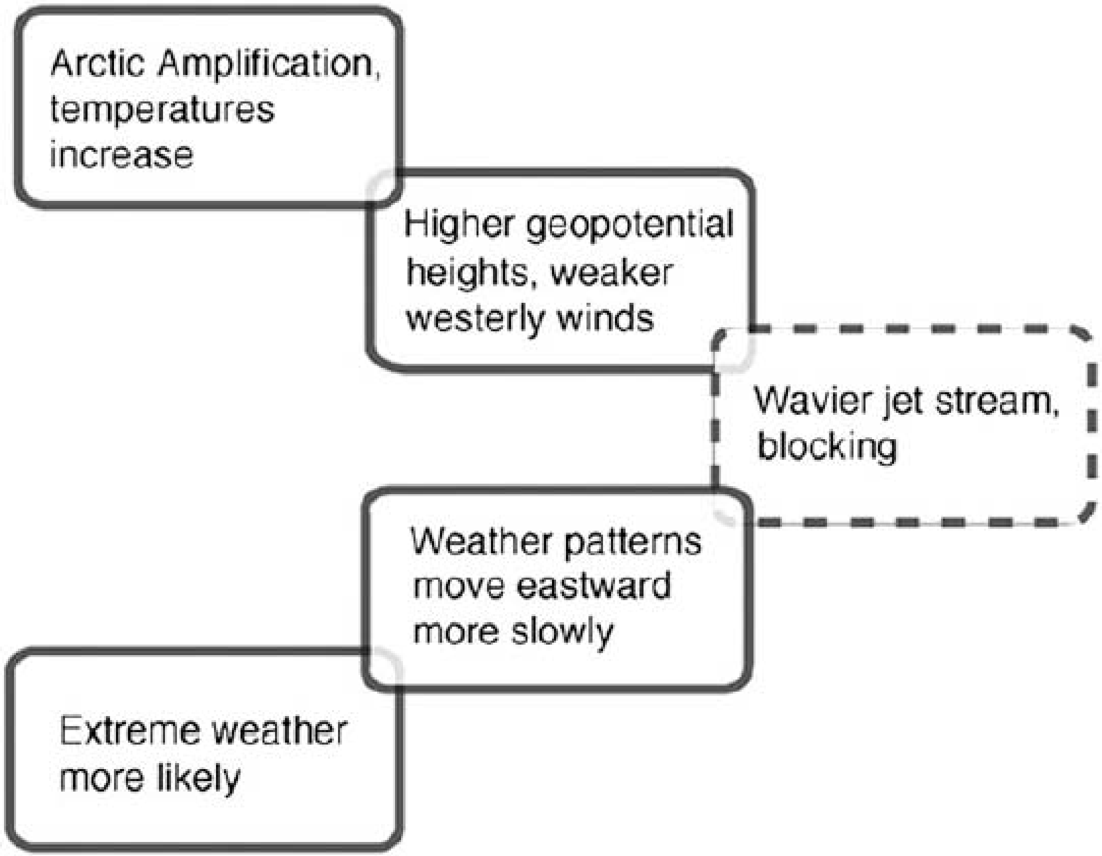


FIG. 2. Hypothesized steps linking Arctic amplification with extreme weather events in Northern Hemisphere midlatitudes.

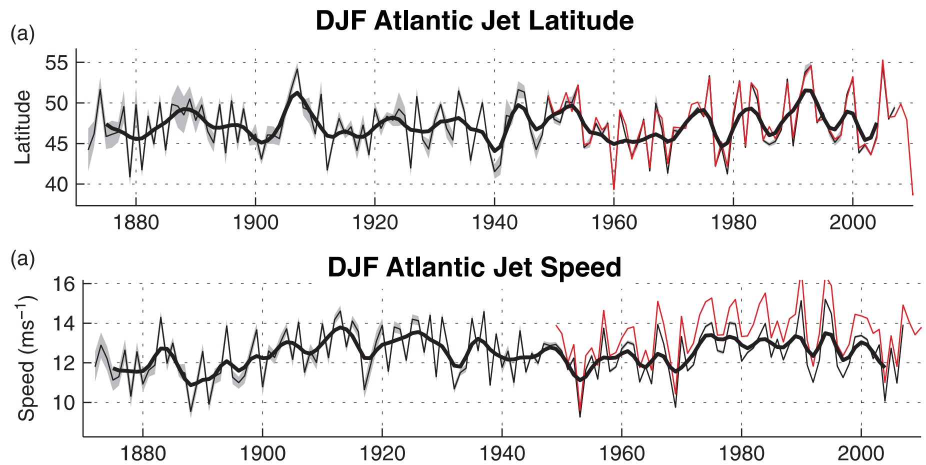
Overland et al. 2015

Natural Variability

- The role of natural variability on mid latitude weather is large and it is always a challenge to separate the signal from the noise.
- There are many factors influencing mid-latitude weather and isolating one factor is difficult.
- We know that the tropics and mid-latitudes influence the Arctic, therefore AA may be more of a response than a cause.
- This is further complicated when studying extreme events which are infrequent, may be poorly observed and definitions are subjective and my be more societal based than metric based.

Natural Variability in the Mid-latitudes

Internal atmospheric variability is large



20th Century Reanalysis jet latitude and speed
red line denote NCEP-NCAR Reanalysis
Woollings et al. (2014; QJRMS)

- Decadal variability of jet position and speed is large
- Behavior over the past decade does not appear exceptional compared to the long-term variability

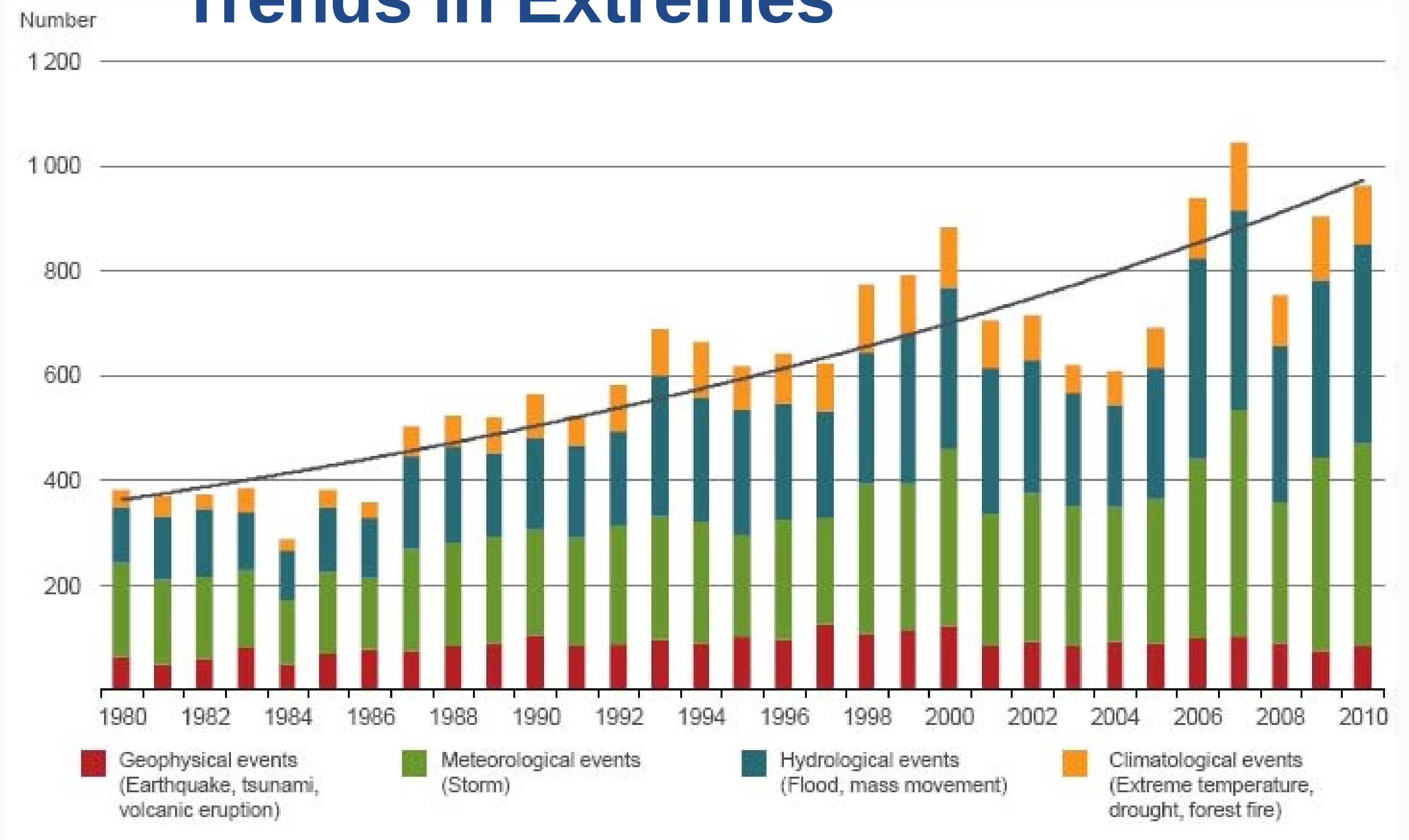
Extreme Weather

- Extreme weather is subjective and not well defined.
- Extreme weather is predicted to increase under climate change and AA is not needed to explain an increase in extreme weather.
- A challenge for the group is to identify which extremes may or may not be influenced by AA.
- We are not simply focusing on extreme weather but rather AA and linkages to changes in the atmospheric circulation. However extreme weather is what the public is most concerned about.

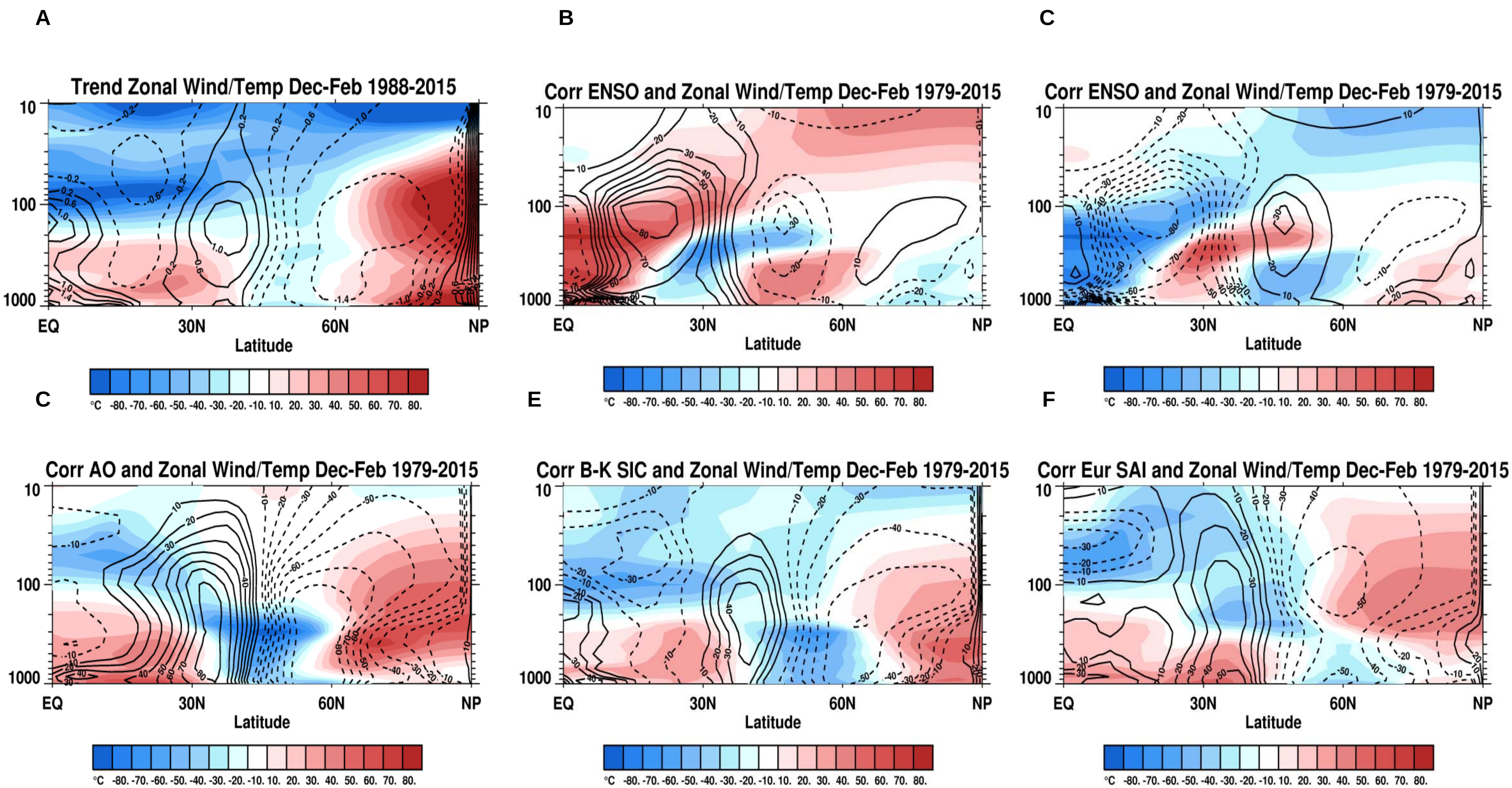
Outline

- Over the past two decades the Arctic has been warming more than twice as fast as the rest of the globe and is referred to as “Arctic Amplification” (AA)
- Concurrent with AA, extreme weather has been observed to be increasing.
- There have been numerous theories linking AA to more frequent and extreme weather/climate events, though testing these theories is challenging due to large natural variability, short observational record and model shortcomings and conflicting results.
- We have assembled the leading scientists studying this topic to move the science forward through meetings, coordinated studies and future publications.

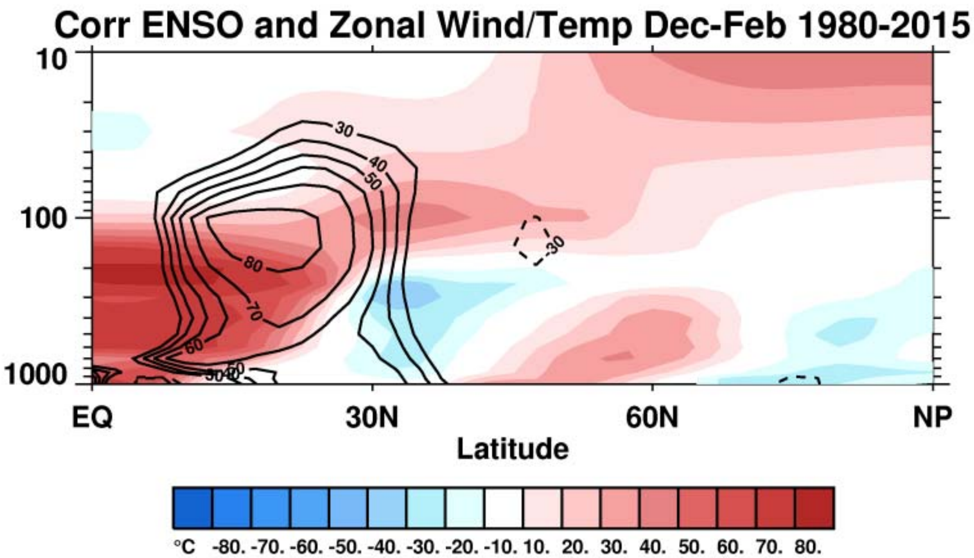
Trends in Extremes

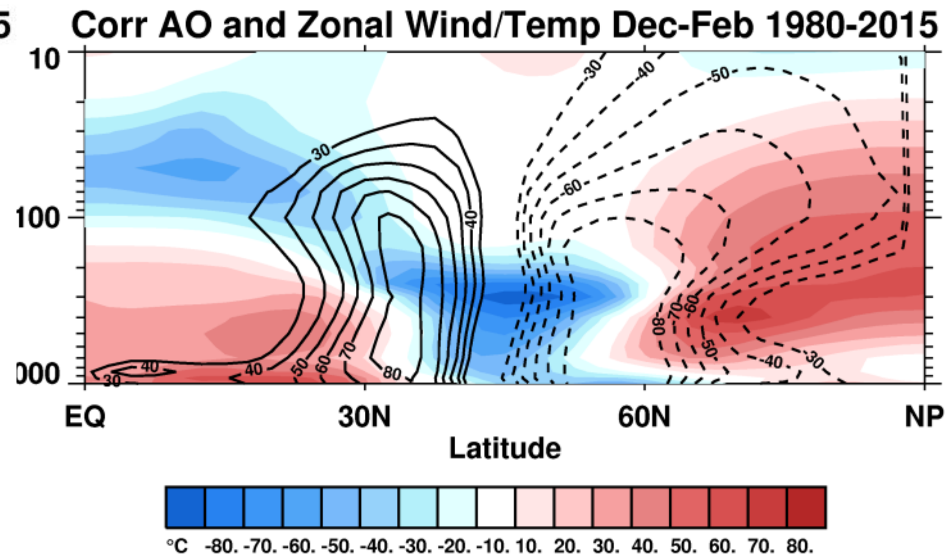


Source: MunichRe


A
Trend Zonal Wind/Temp Dec-Feb 1988-2015
B
Corr ENSO and Zonal Wind/Temp Dec-Feb 1979-2015
C
Corr ENSO and Zonal Wind/Temp Dec-Feb 1979-2015
C
Corr AO and Zonal Wind/Temp Dec-Feb 1979-2015
E
Corr B-K SIC and Zonal Wind/Temp Dec-Feb 1979-2015
F
Corr Eur SAI and Zonal Wind/Temp Dec-Feb 1979-2015
Latitude
EQ 30N 60N NP
10 100 1000
°C -80. -70. -60. -50. -40. -30. -20. -10. 10. 20. 30. 40. 50. 60. 70. 80.

Correlations of AO with Zonal Wind and Temperature

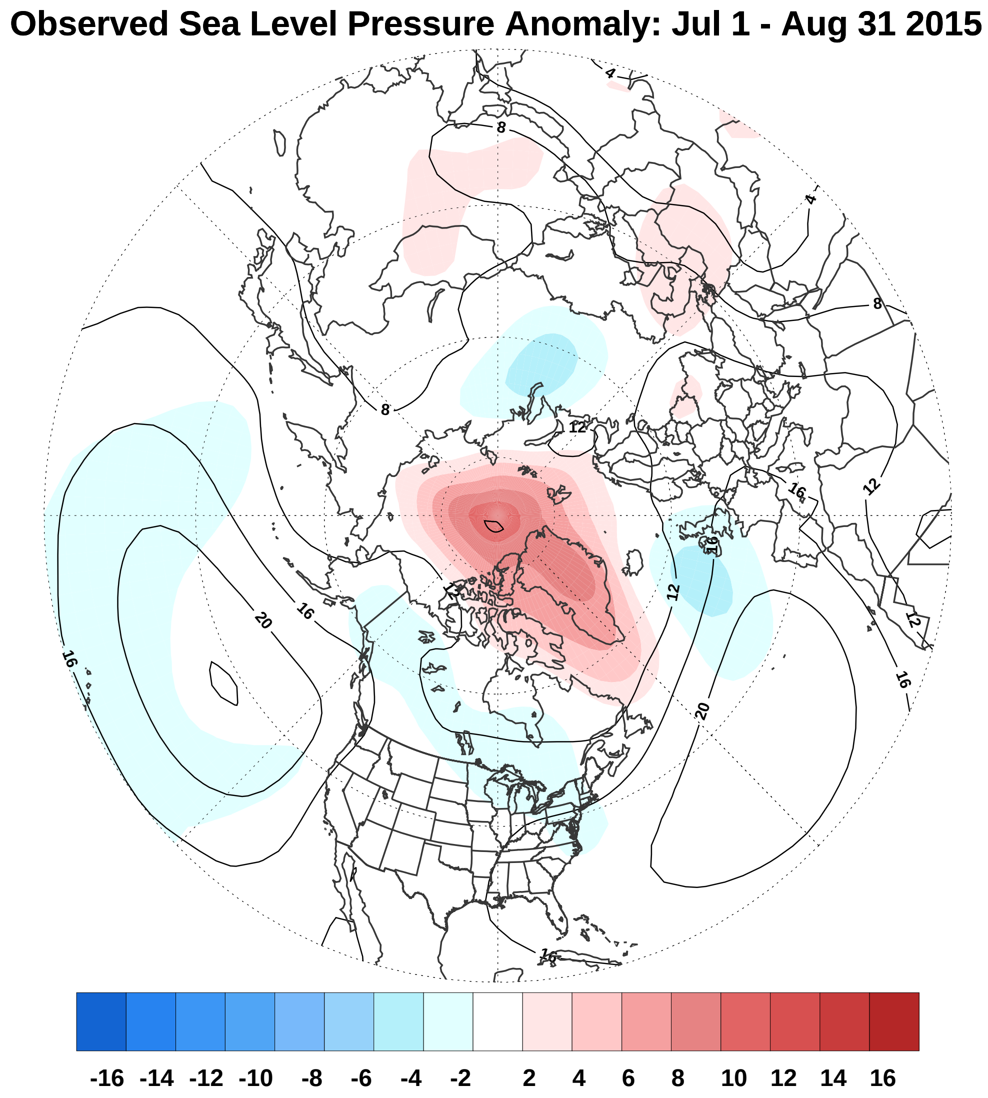




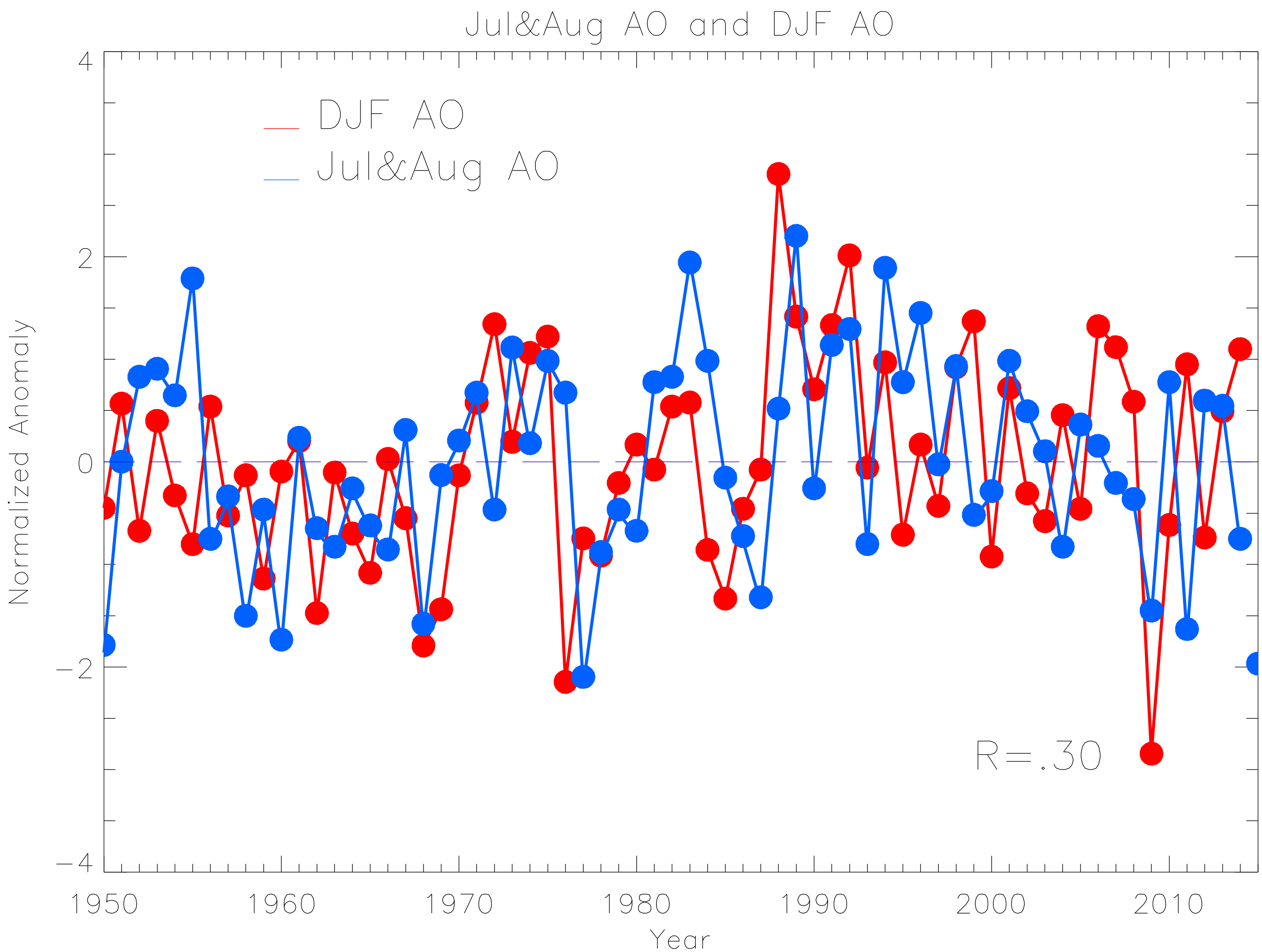
ENSO

AO

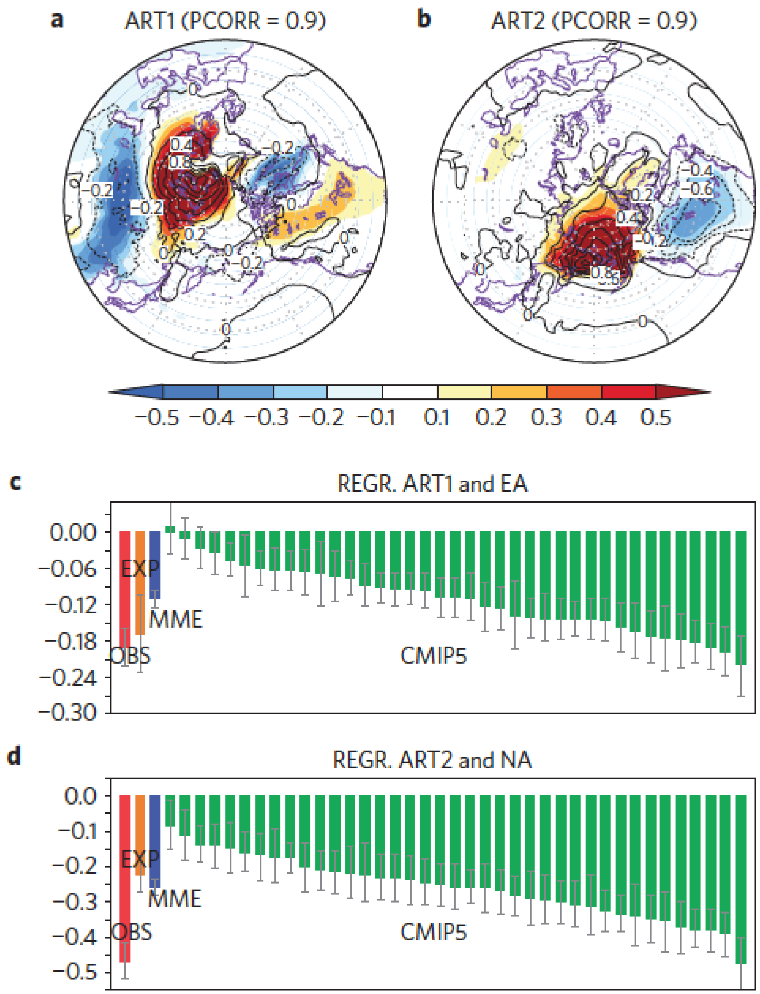
Summer Circulation



Summer and Winter AO



Warm Arctic Forced Cold Signal



Shown are both observations and models

Kug et al. 2015