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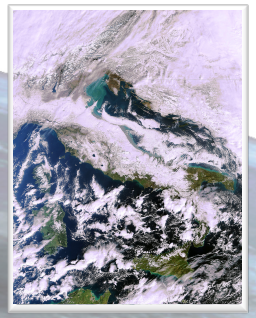
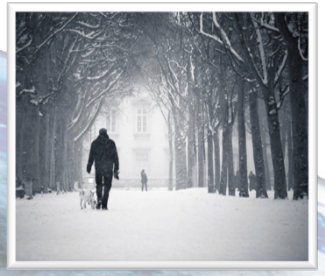
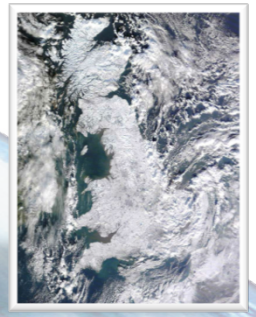
Arctic-lower latitude linkages: Implications for weather and climate predictions

J. Cohen, J. Furtado, J. Jones, M. Barlow, V. Alexeev, J. Cherry and E. Tziperman

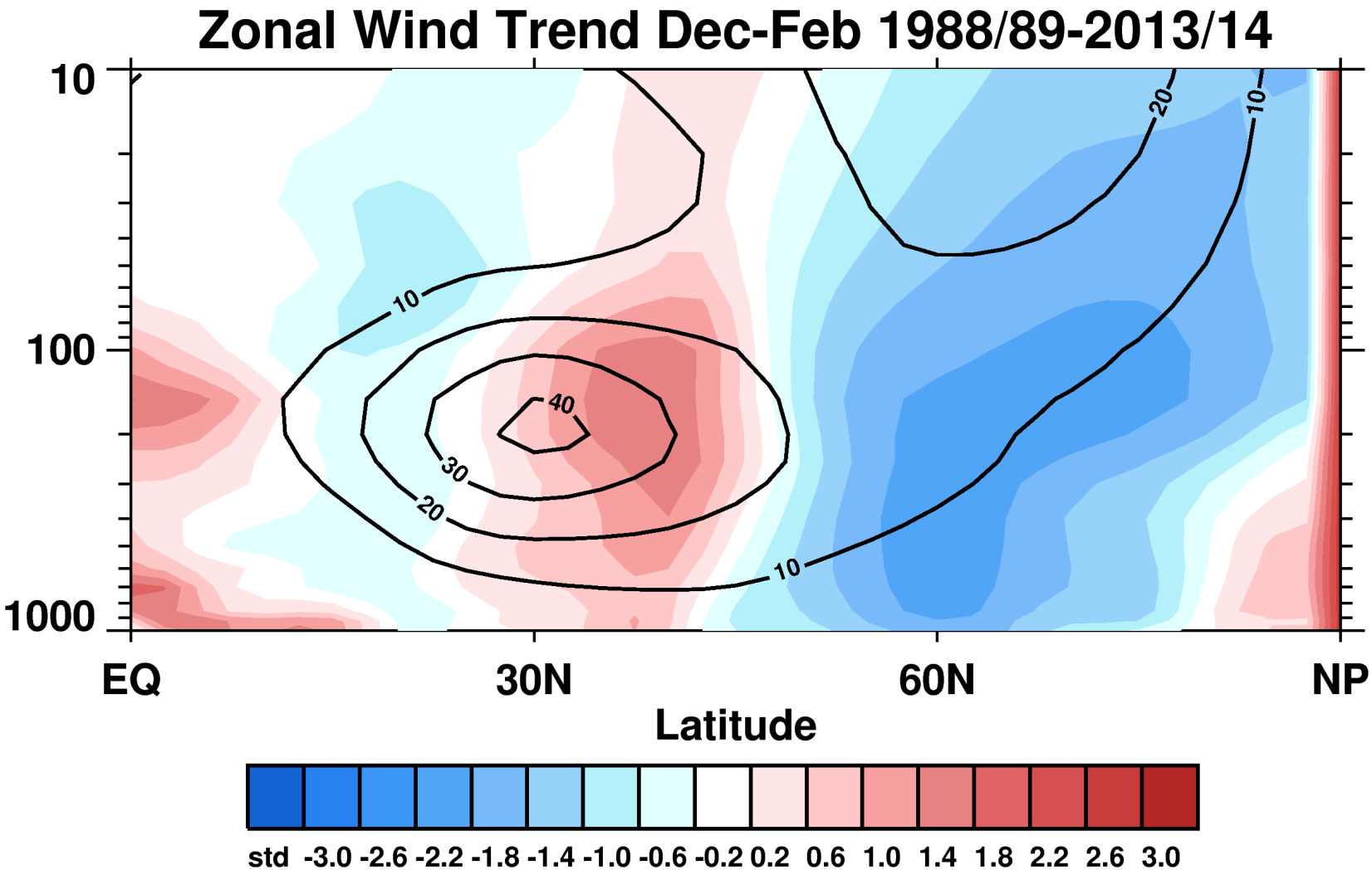
May 13, 2014







Winter Zonal Wind Trends



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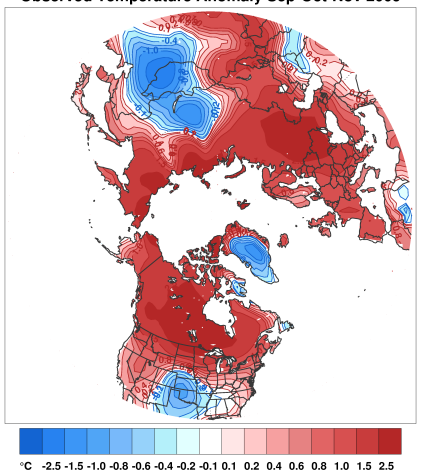
Outline

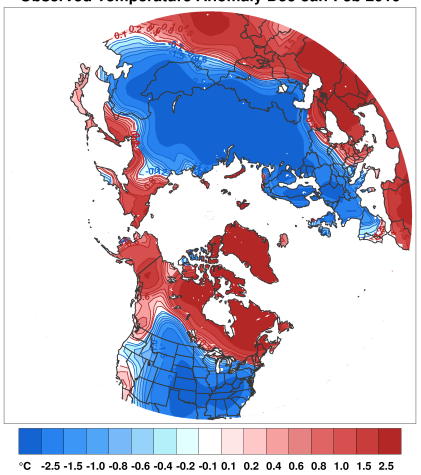
- Over the past two decades or so, robust warming has been observed for all spring, summer and fall but not winter.
- During this period the Arctic has been warming, Eurasian fall snow cover has been increasing and Arctic sea ice has been melting.
- More fall snow cover and likely less sea ice favors the negative phase of the winter Arctic Oscillation.
- Improved predictions can be gleamed by better understanding and modeling of sea ice- and snow-atmosphere coupling and stratosphere-troposphere coupling.

Northern Hemisphere Land Temperatures 2009-13

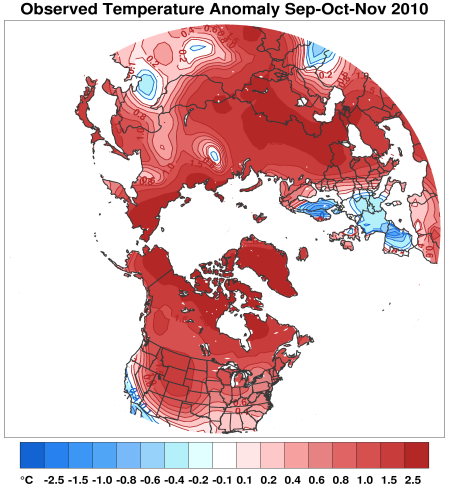
Observed Temperature Anomaly Sep-Oct-Nov 2009



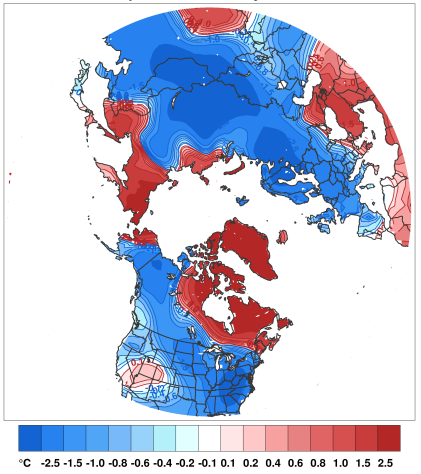
Observed Temperature Anomaly Dec-Jan-Feb 2010



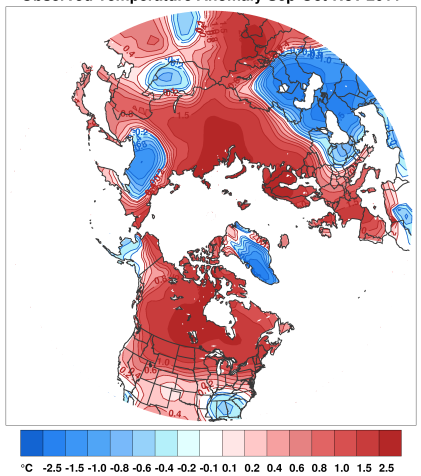
Observed Temperature Anomaly Sep-Oct-Nov 2010



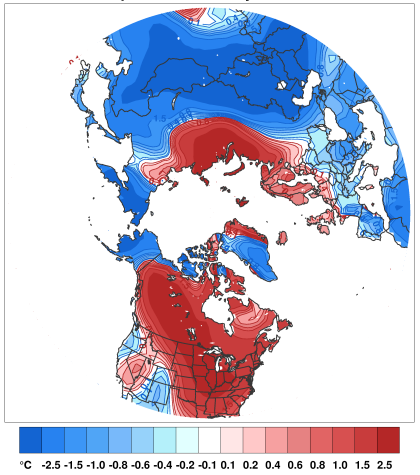
Observed Temperature Anomaly Dec-Jan-Feb 2011



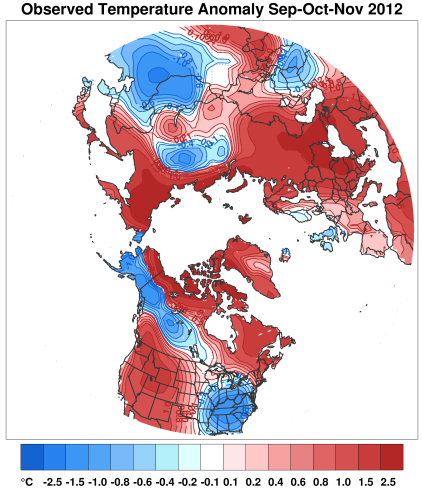
Observed Temperature Anomaly Sep-Oct-Nov 2011



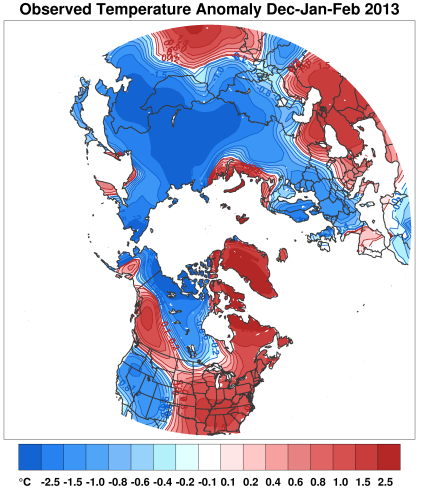
Observed Temperature Anomaly: Dec 1 - Feb 29 2012



Observed Temperature Anomaly Sep-Oct-Nov 2012



Observed Temperature Anomaly Dec-Jan-Feb 2013



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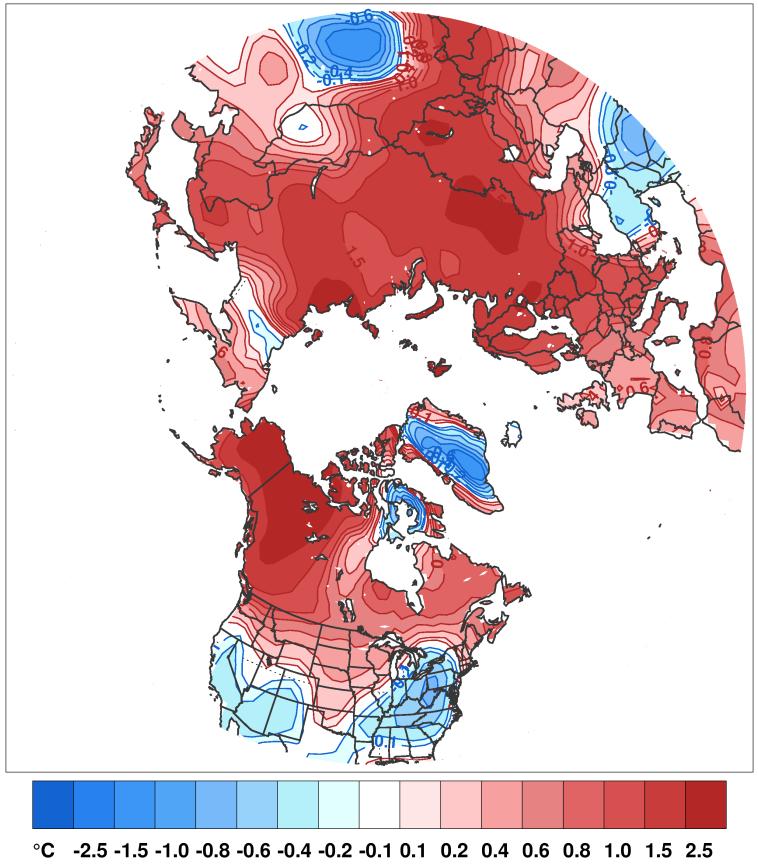
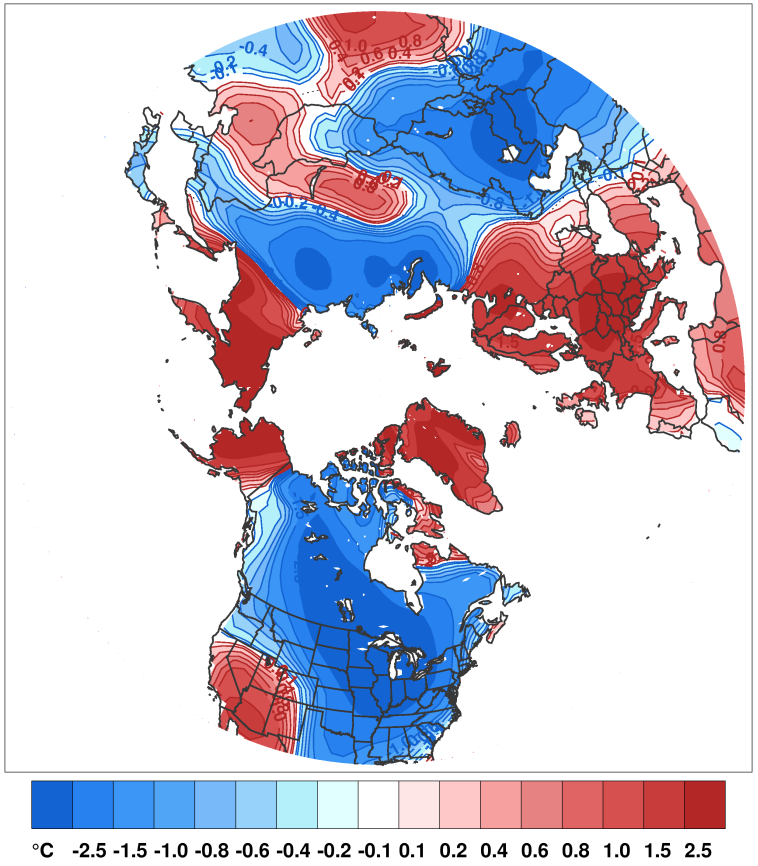
Fall-Winter 2013/14

Observed Temperature Anomaly Sep-Oct-Nov 2013



°C -2.5 -1.5 -1.0 -0.8 -0.6 -0.4 -0.2 -0.1 0.1 0.2 0.4 0.6 0.8 1.0 1.5 2.5

Observed Temperature Anomaly Dec-Jan-Feb 2014



°C -2.5 -1.5 -1.0 -0.8 -0.6 -0.4 -0.2 -0.1 0.1 0.2 0.4 0.6 0.8 1.0 1.5 2.5

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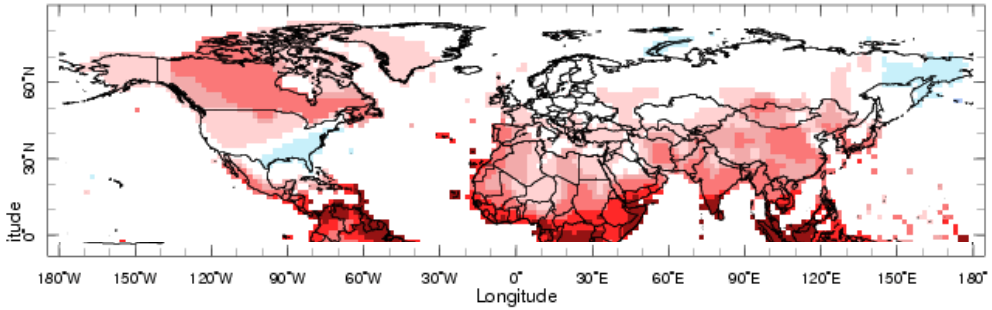
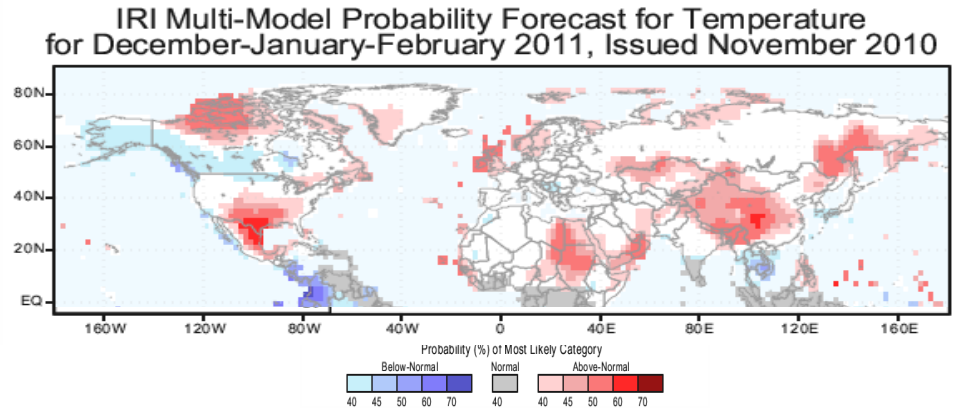
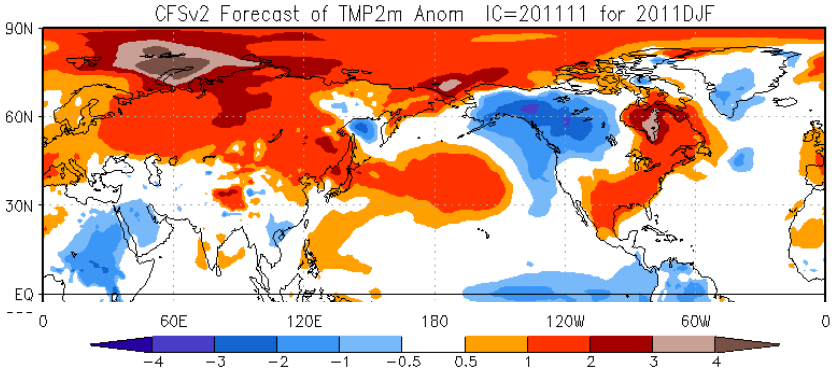
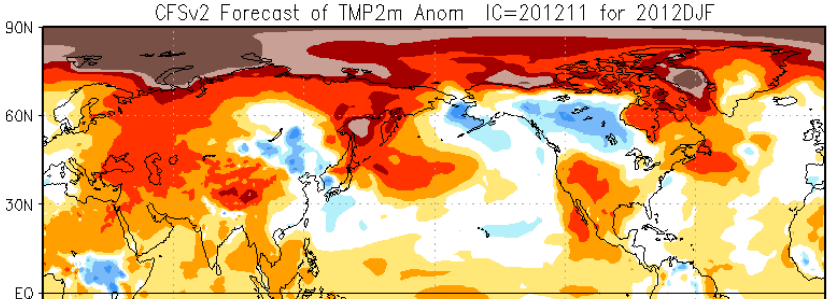
Dynamical Winter Forecasts 2009/10-13/14

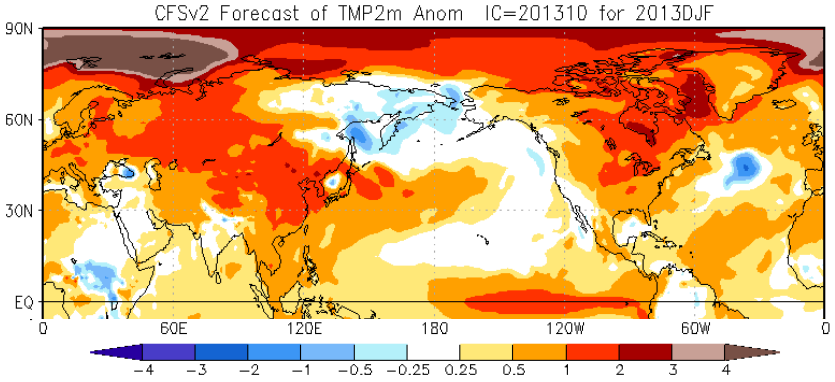


Dec 2009 - Feb 2010 IRI Seasonal Temperature Forecast issued Nov 2009









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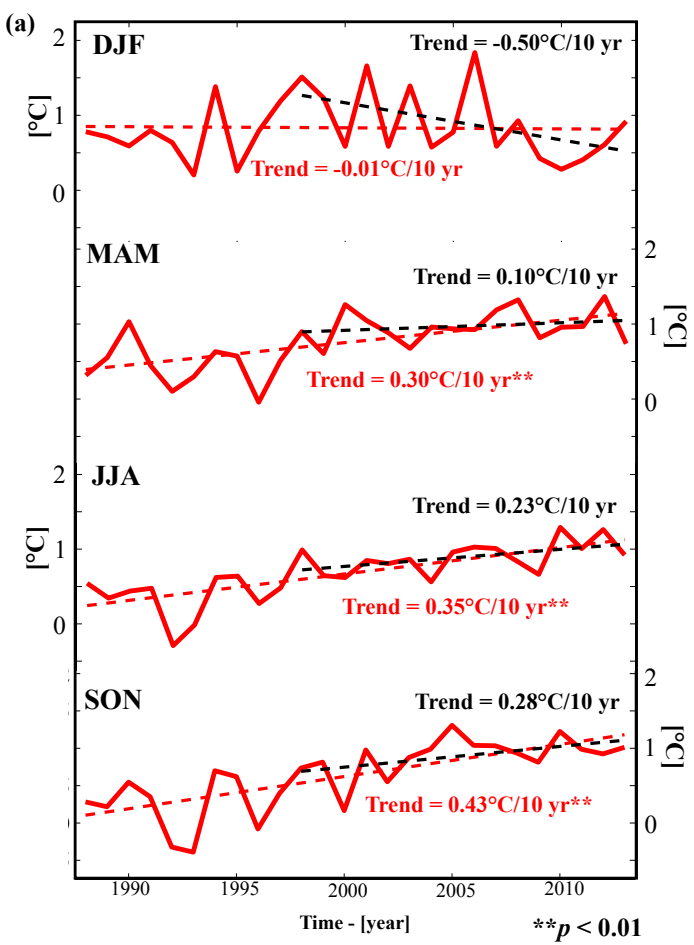
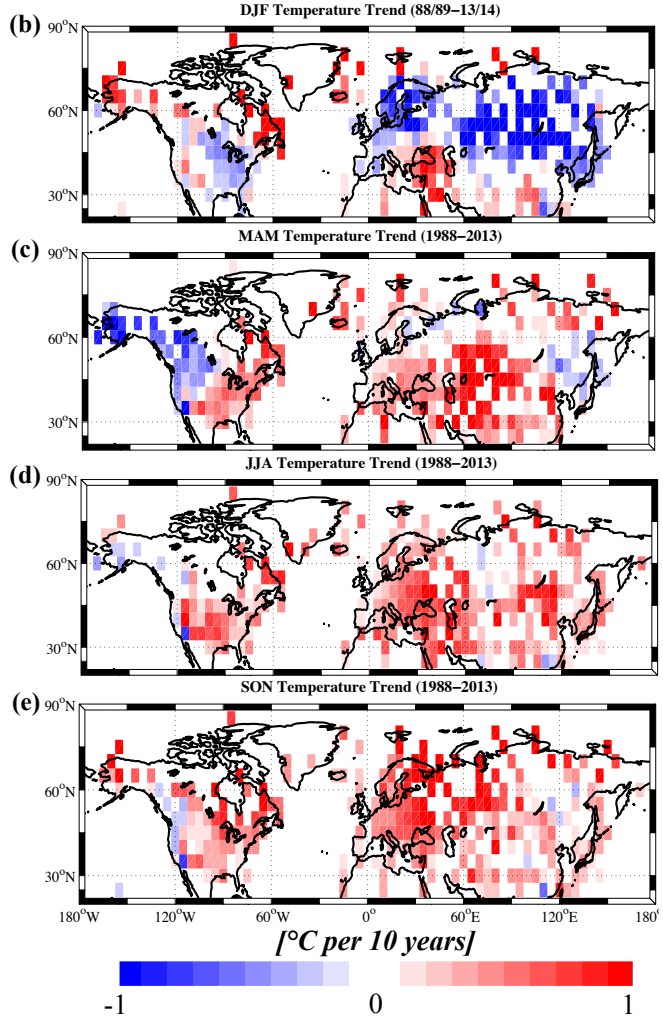
Is it Natural Variability?

- How to explain the dramatic temperature change from warm to cold from fall to winter, like an on/off switch?
- It is five years running.
- The dynamical models have incorrectly predicted all warm winters.
- There is strong radiative forcing to warm the climate and the predictions were for winter amplification.

Northern Hemisphere Land Temperatures 1988-2014





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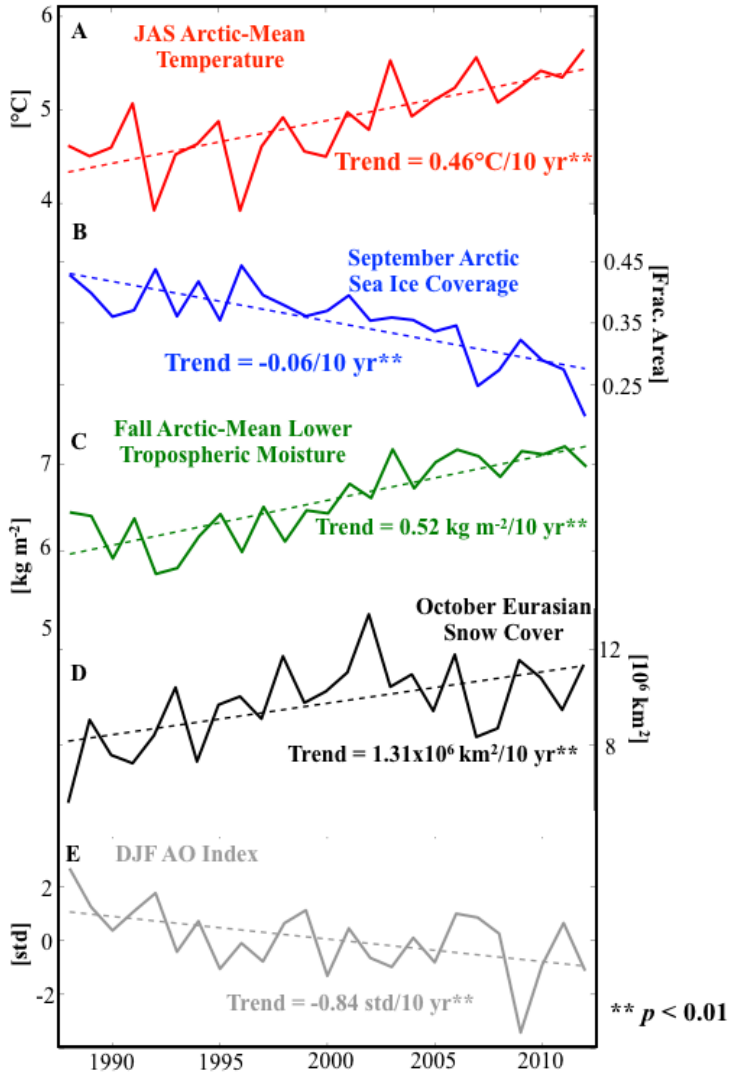
Cohen et al. 2012a

Arctic Trends 1988-2012

- ✓Warming Arctic
- ✓Less sea ice
- ✓More atmospheric moisture
- ✓Increasing snow cover
- ✓Decreasing Arctic Oscillation trend

Positive feedback loop of thermodynamic heating in the fall leads to a dynamic heating in the winter in the Arctic



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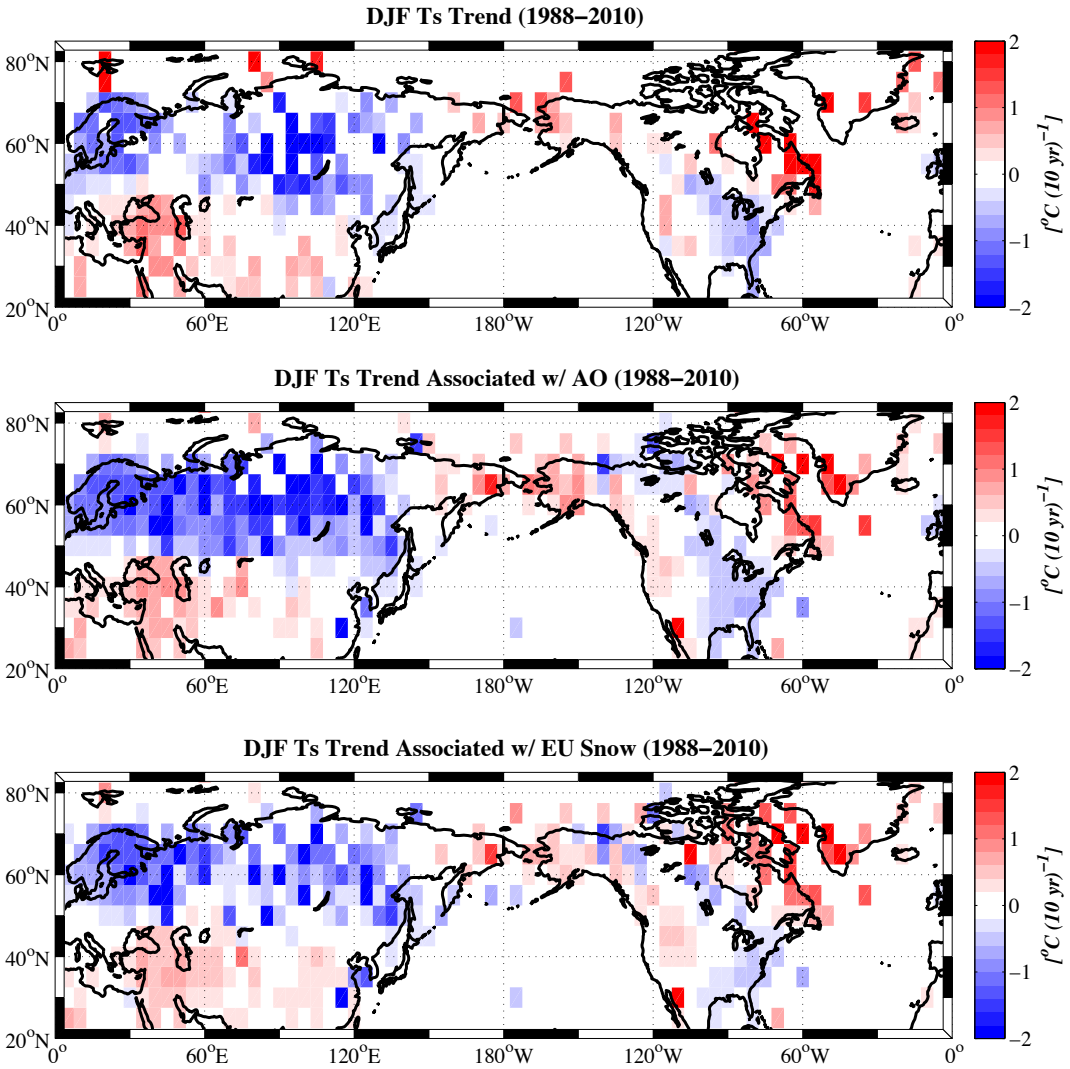
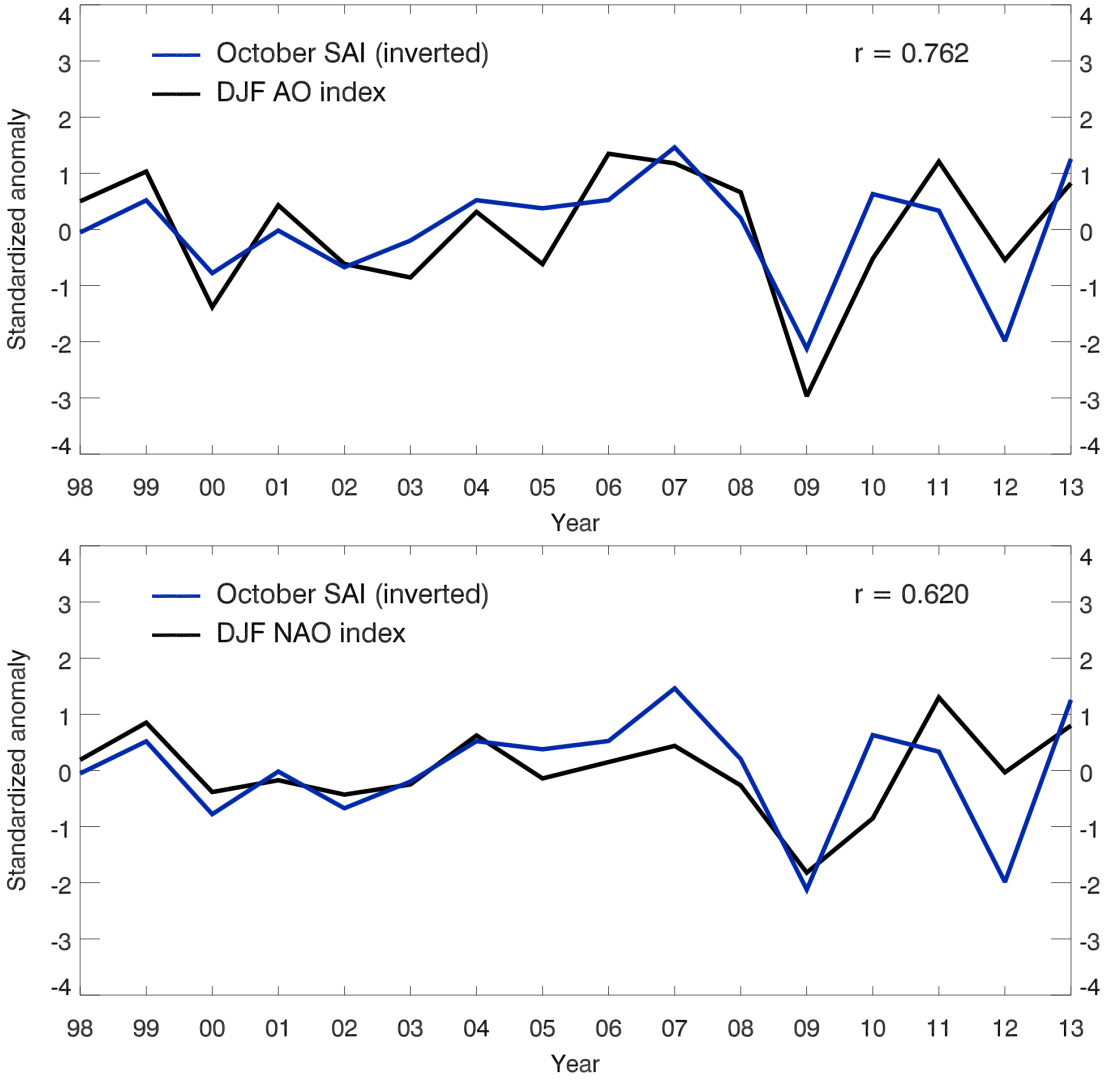
Cohen et al. 2012b

Winter Temperature Trends



SAI and the AO and NAO



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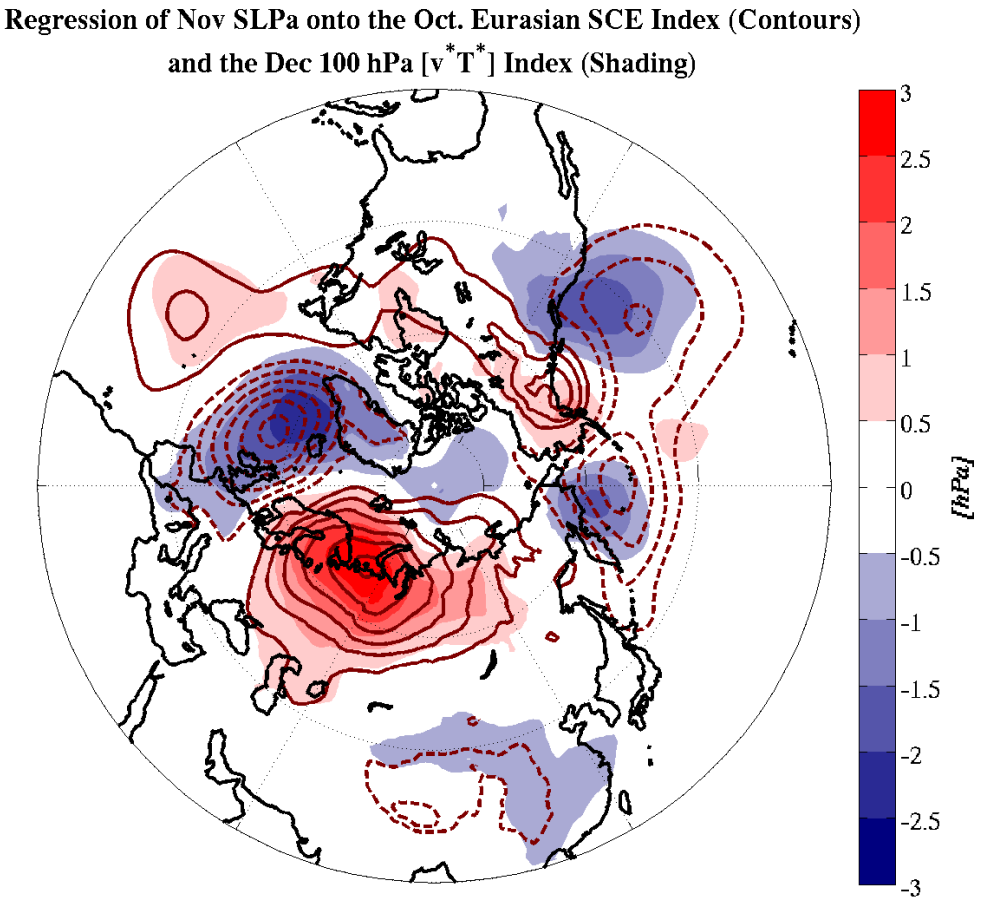
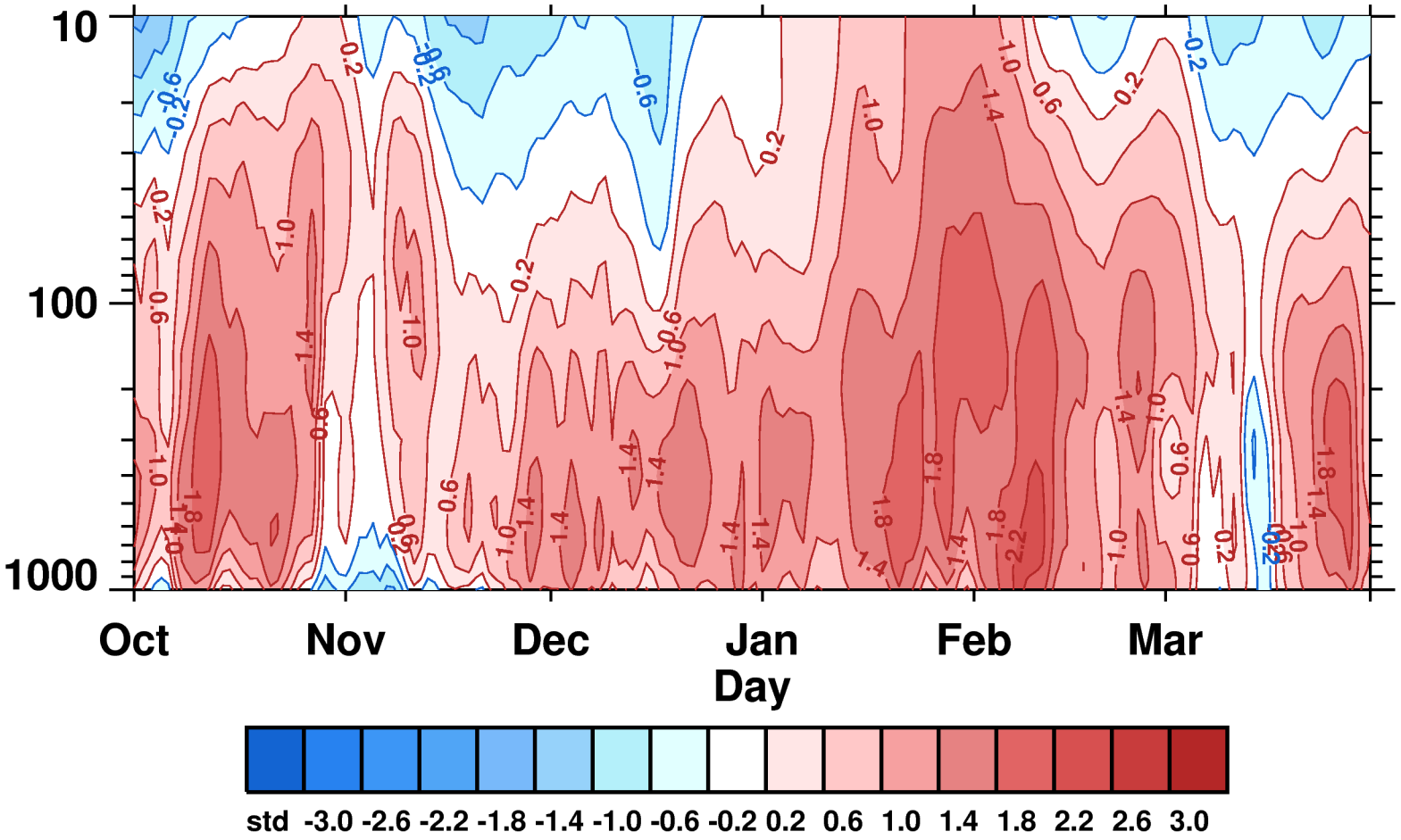
Snow Cover and 100 hPa heat flux SLP pattern



Pattern correlation = 0.93 between 40-80°N

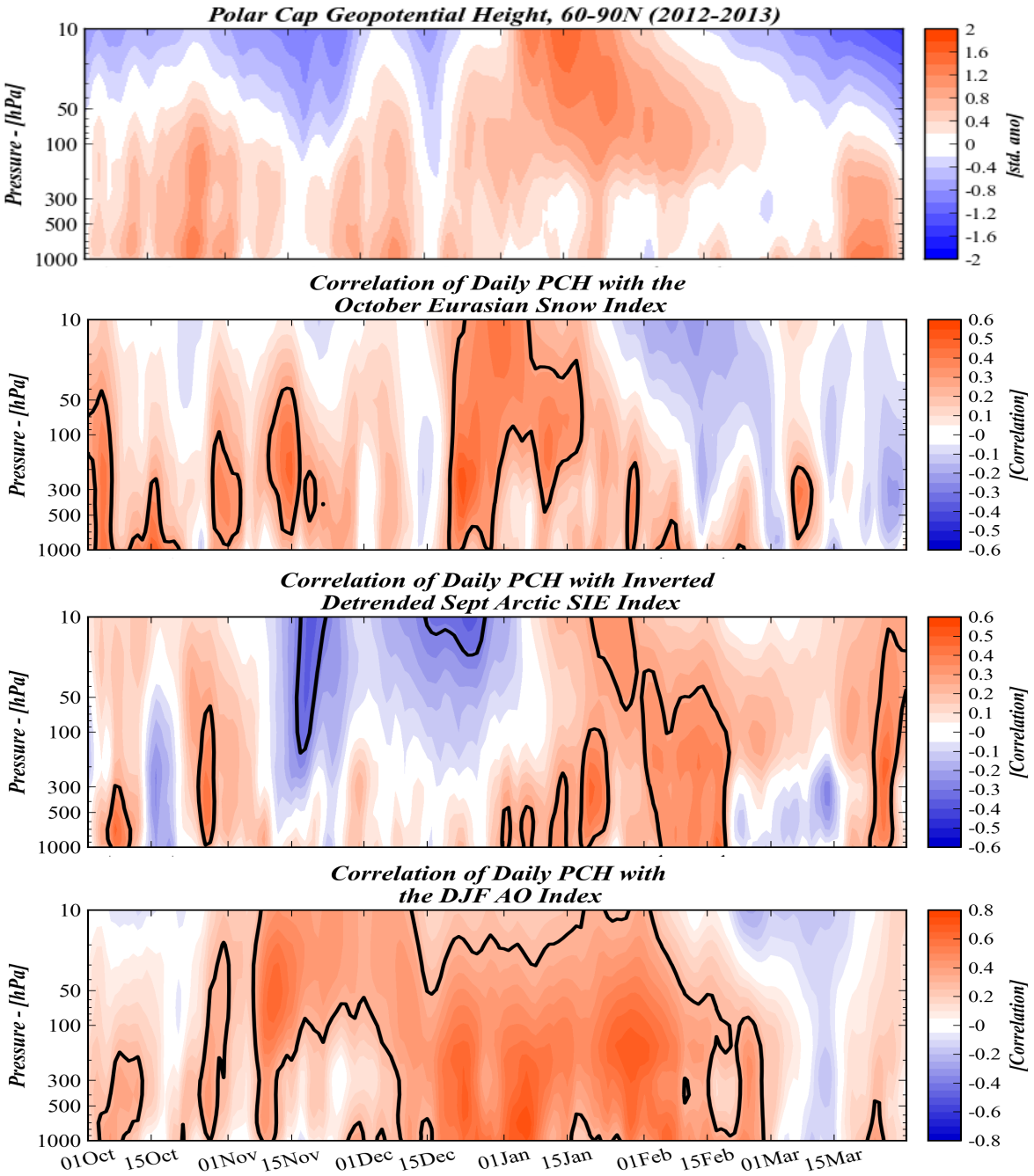
Cohen et al. 2014

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).

PCH
Oct-Mar



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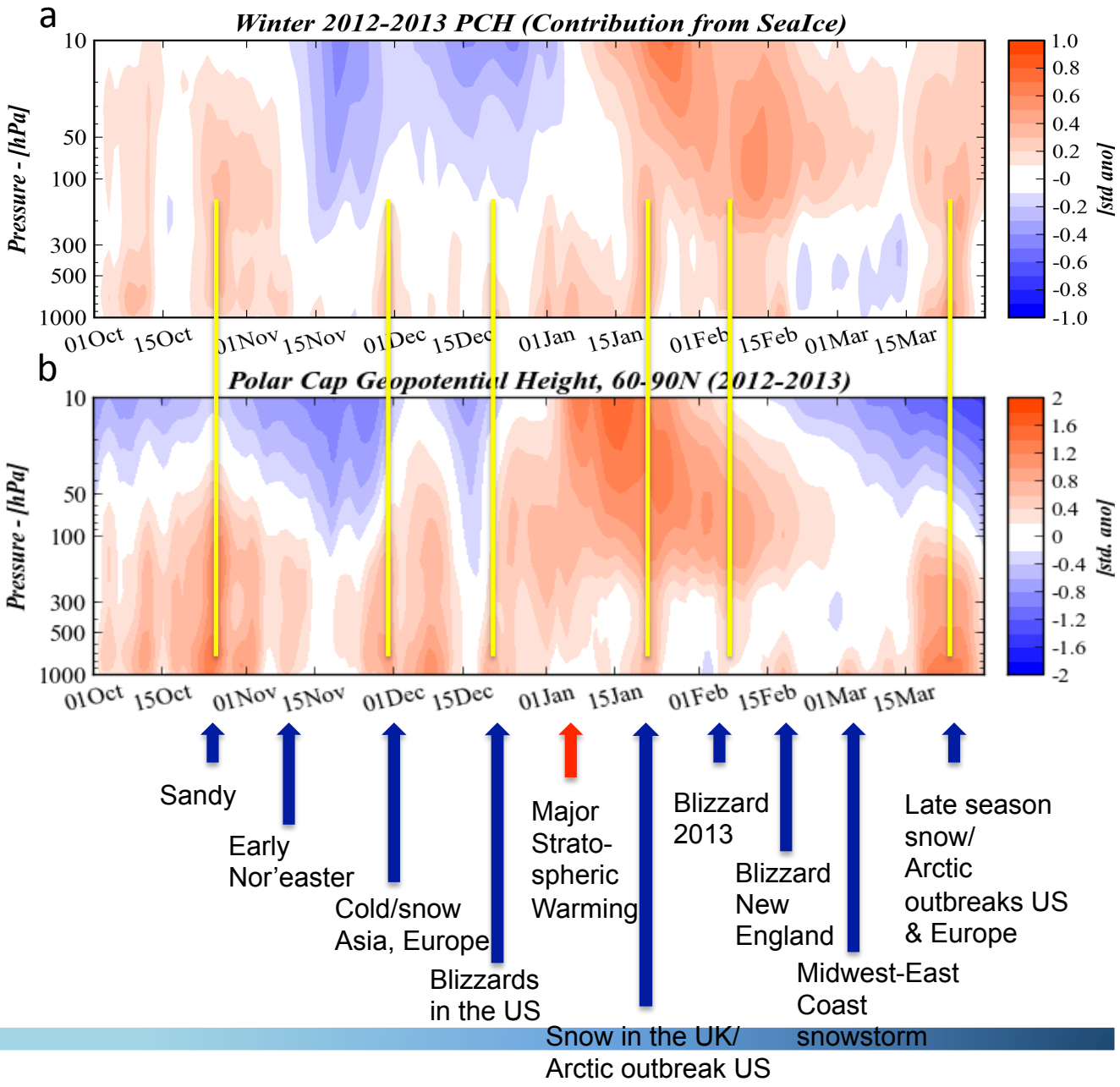
PCH Oct-Mar



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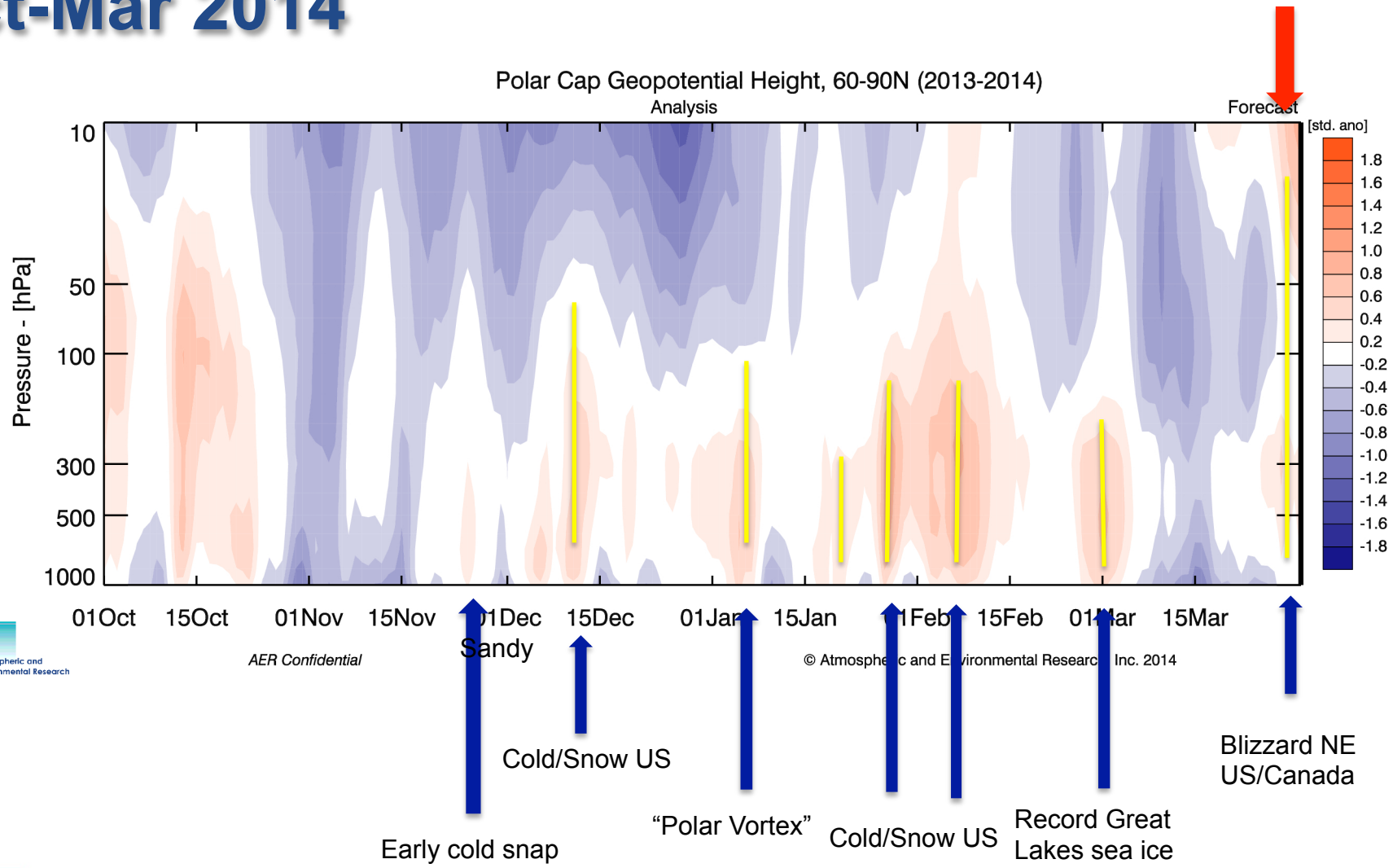
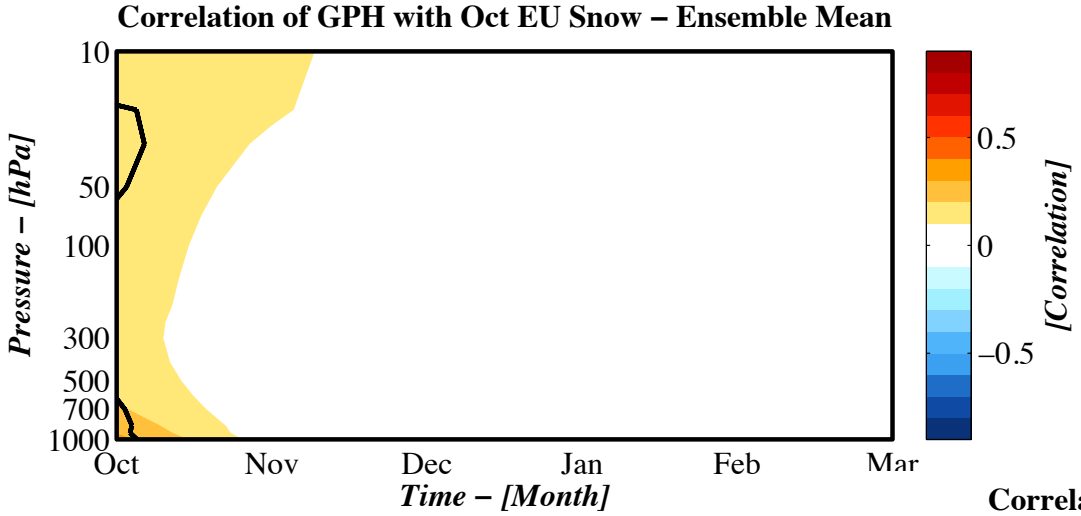
PCH
Oct-Mar 2014

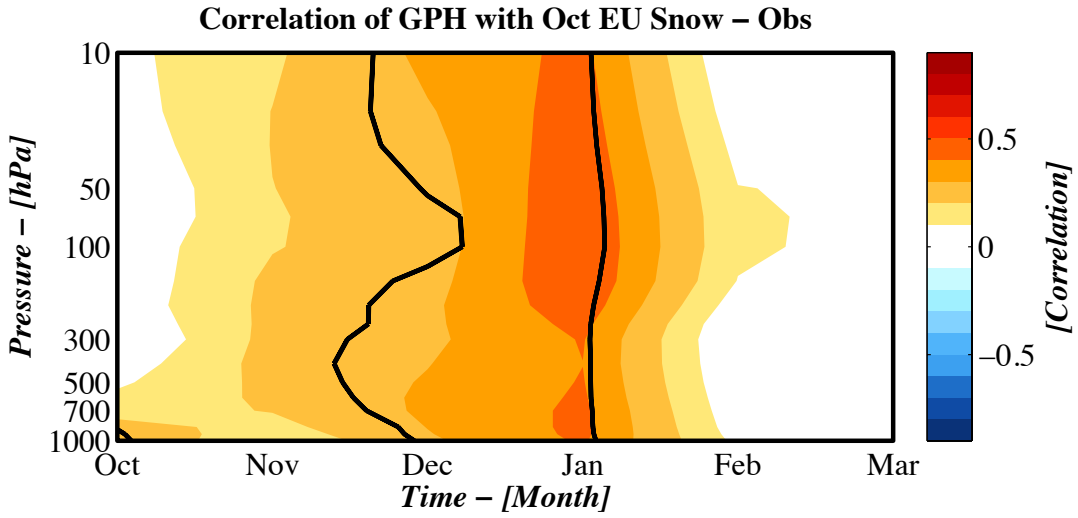


Correlation of Polar Cap GPH w/ Oct. EU Snow Observations and CMIP5



Almost no significant correlations from the models for the snow index and GPH.

Black contour = 95% significance



For the observations, the significant observations exist in December and January.

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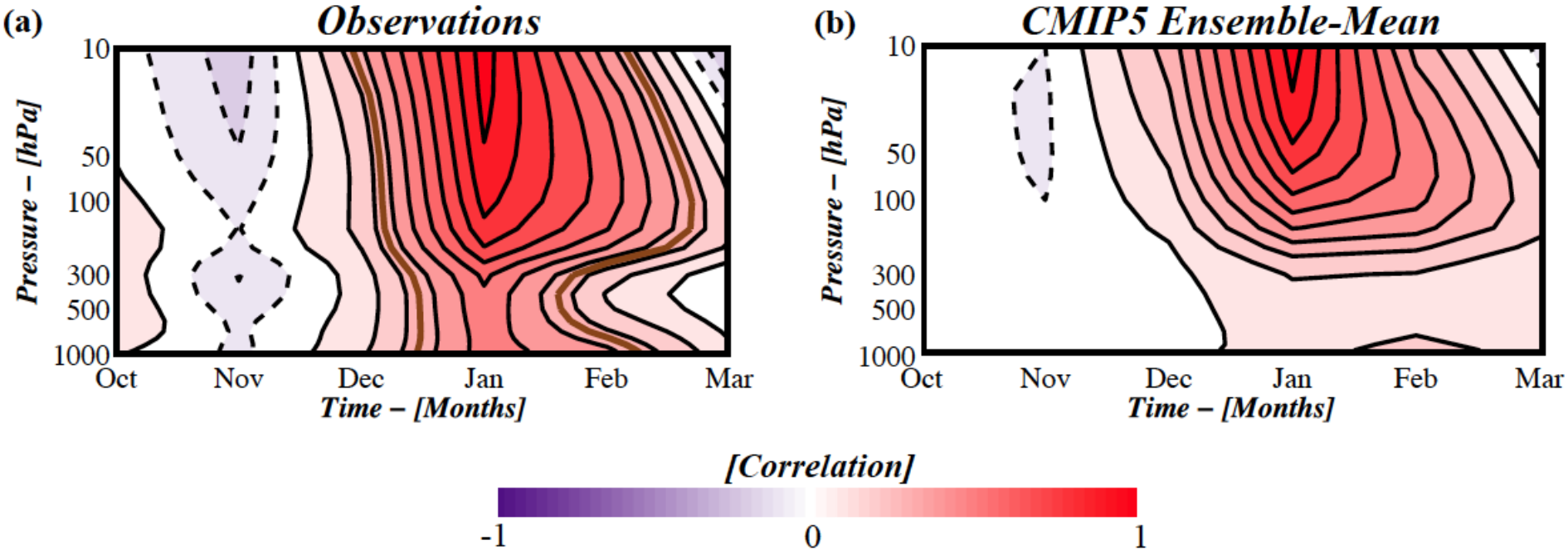
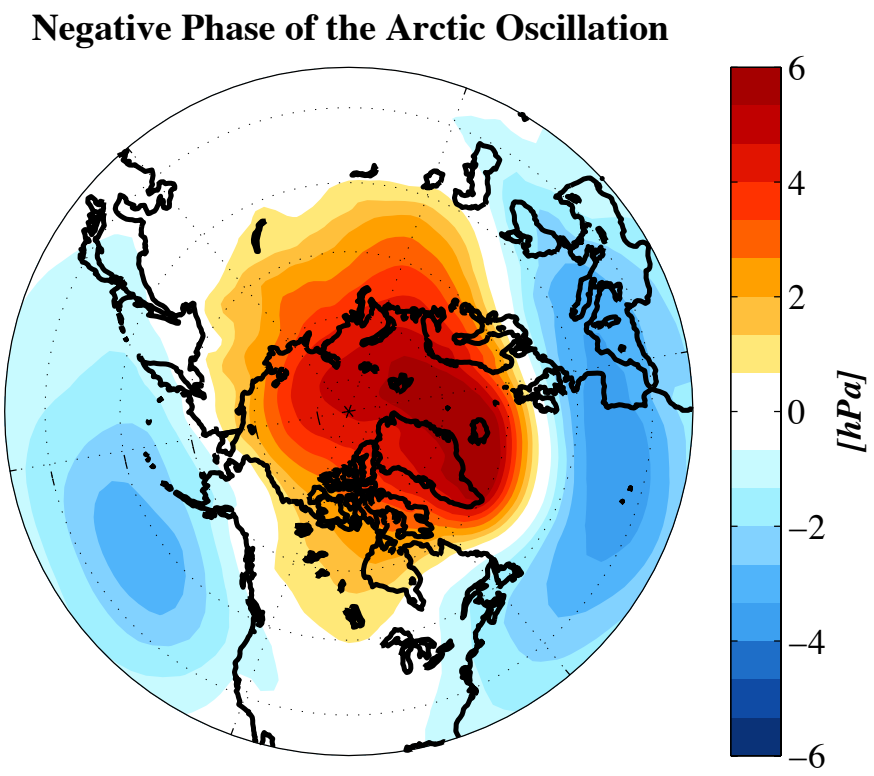
Stratosphere-troposphere coupling

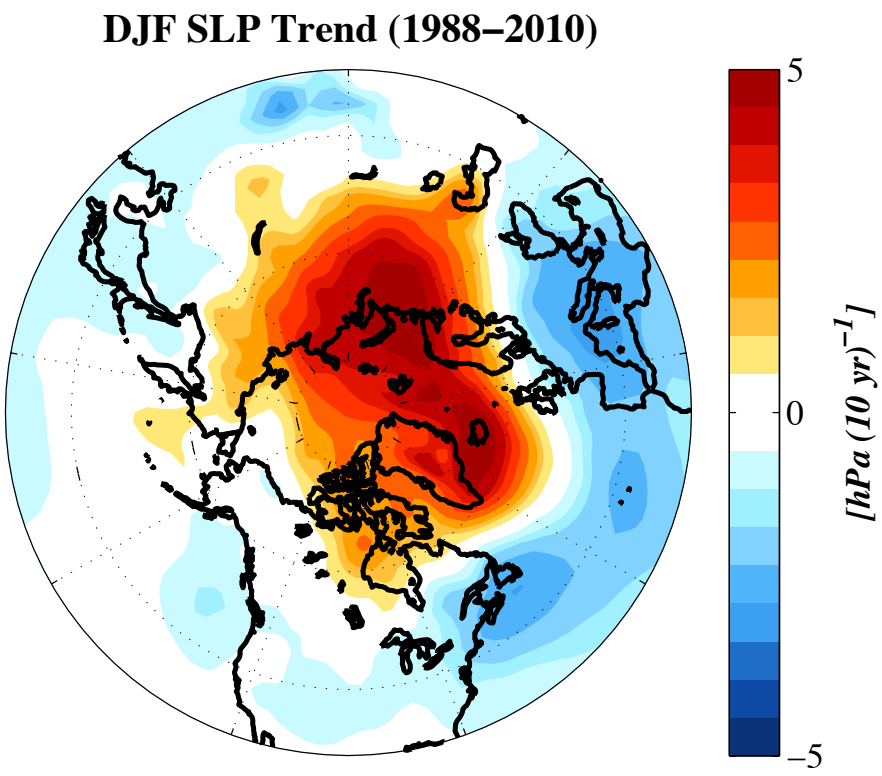
Lag Correlation of Jan AO_{10} with the AO Index at All Levels



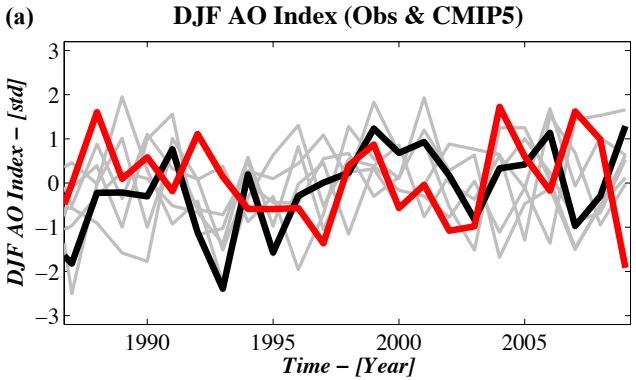
Furtado et al. 2014

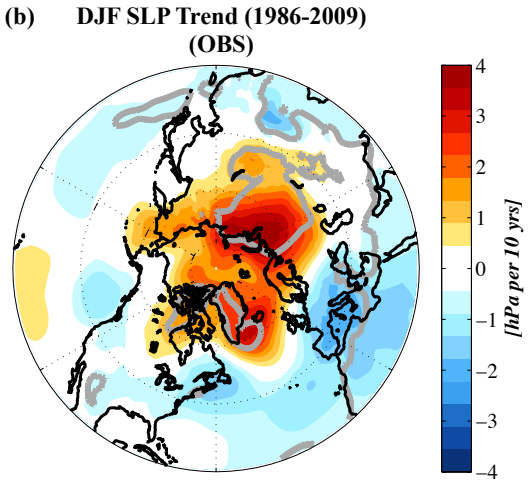
Tropospheric Winter Trends

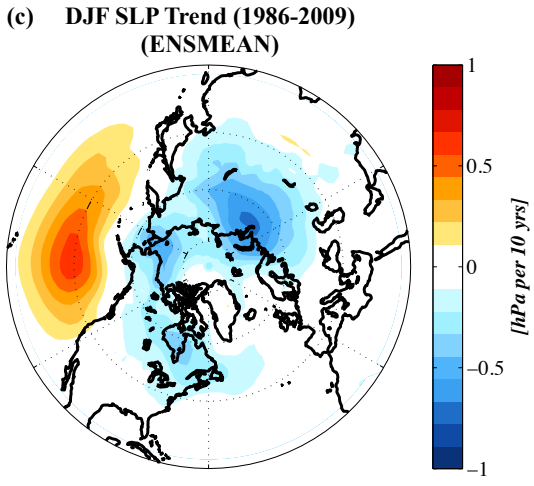




Simulated Tropospheric Winter Trends







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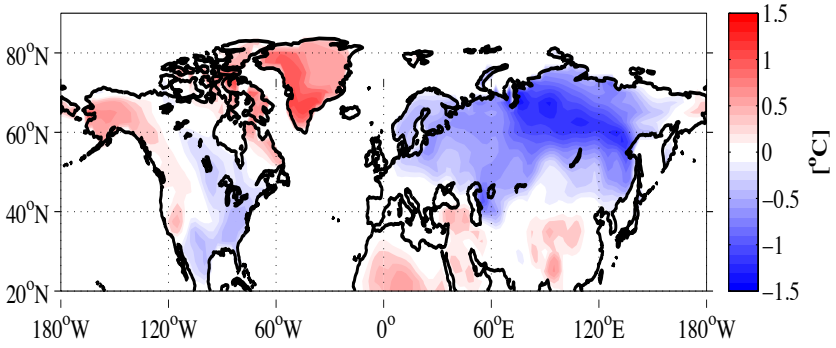
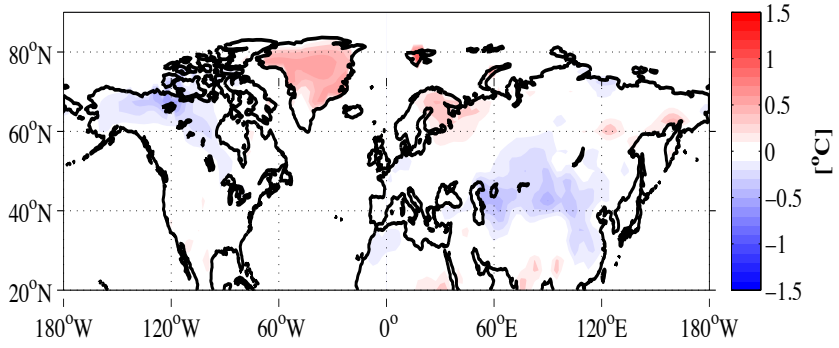
Snow and Sea Ice as Predictors of the AO Temperature Pattern

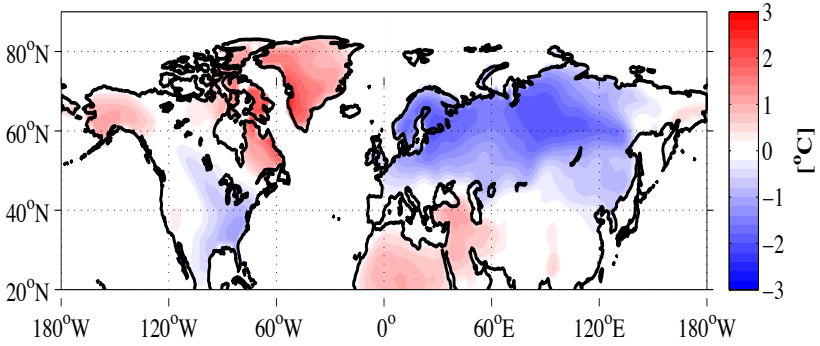
Regression of DJF Surface Temperature onto the October Snow Index (Detrended)



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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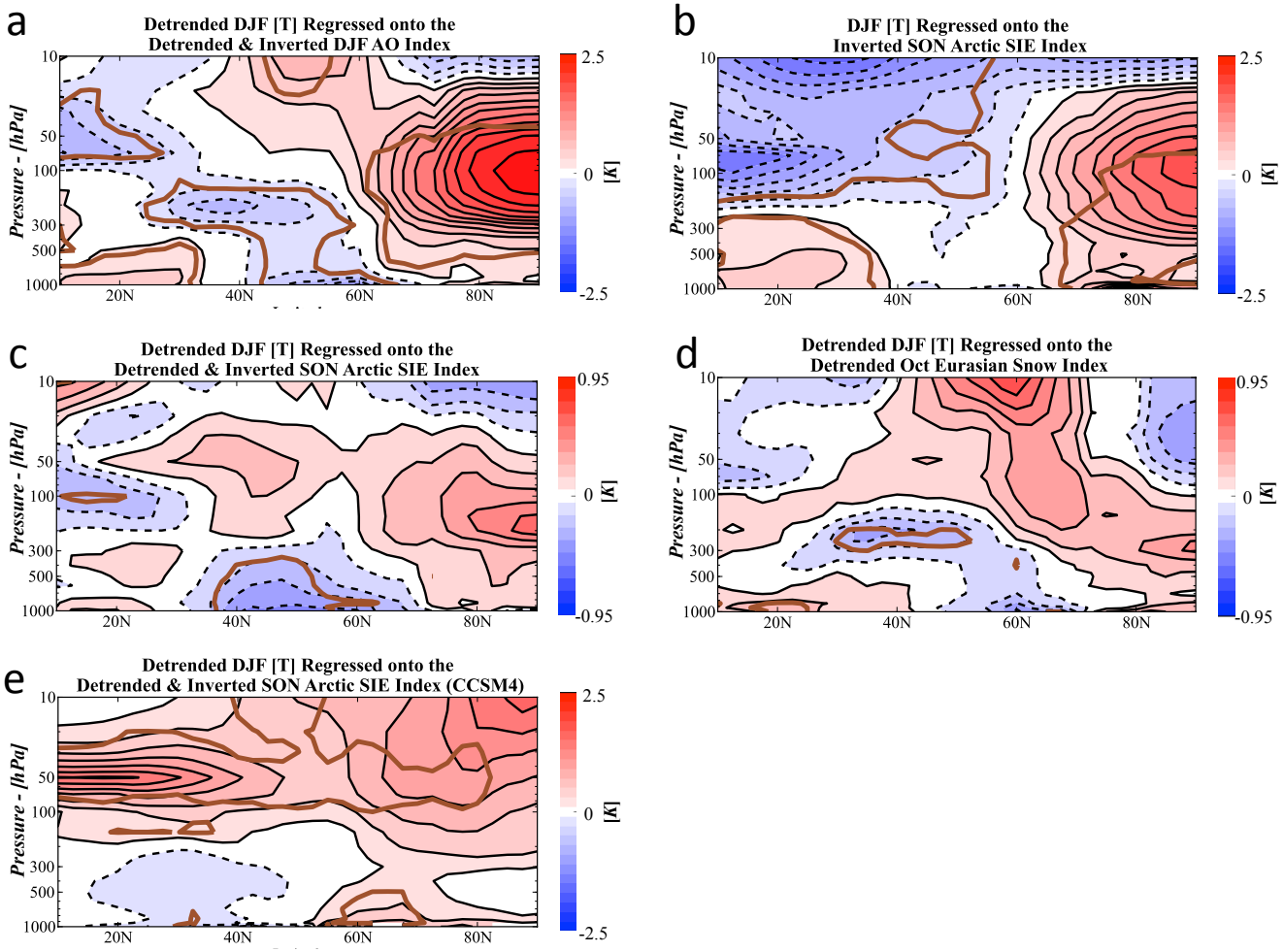
Warm Arctic-Cold Continents



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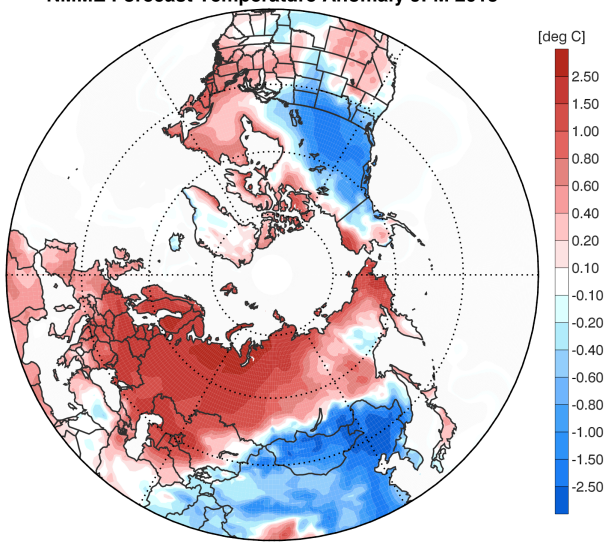
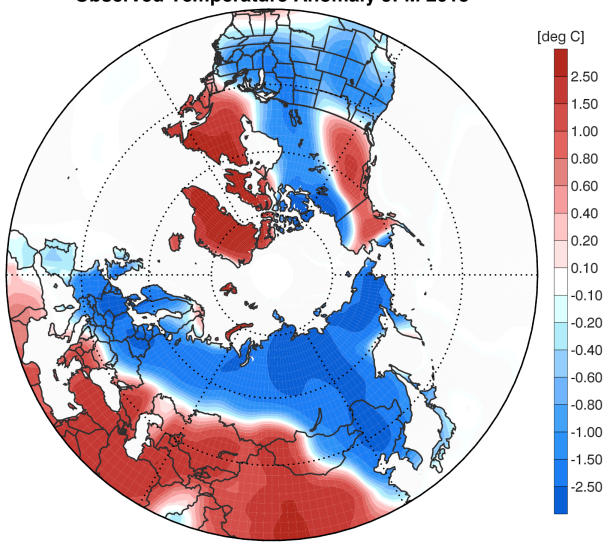
Cohen et al. 2013

Winter 2013 Temperature Forecasts

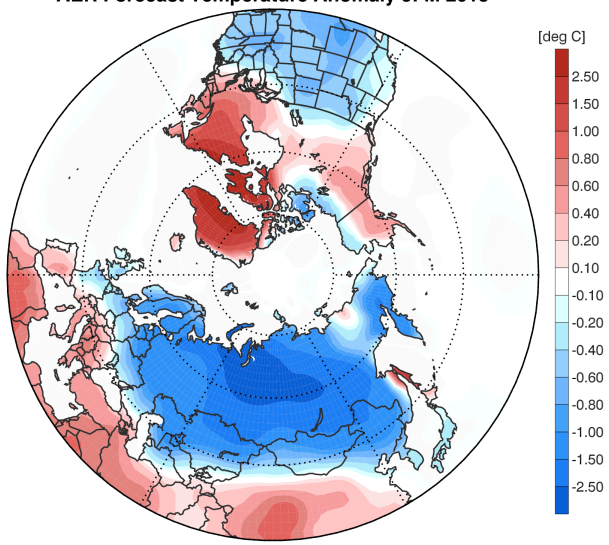
NMME Forecast Temperature Anomaly JFM 2013



Observed Temperature Anomaly JFM 2013



AER Forecast Temperature Anomaly JFM 2013



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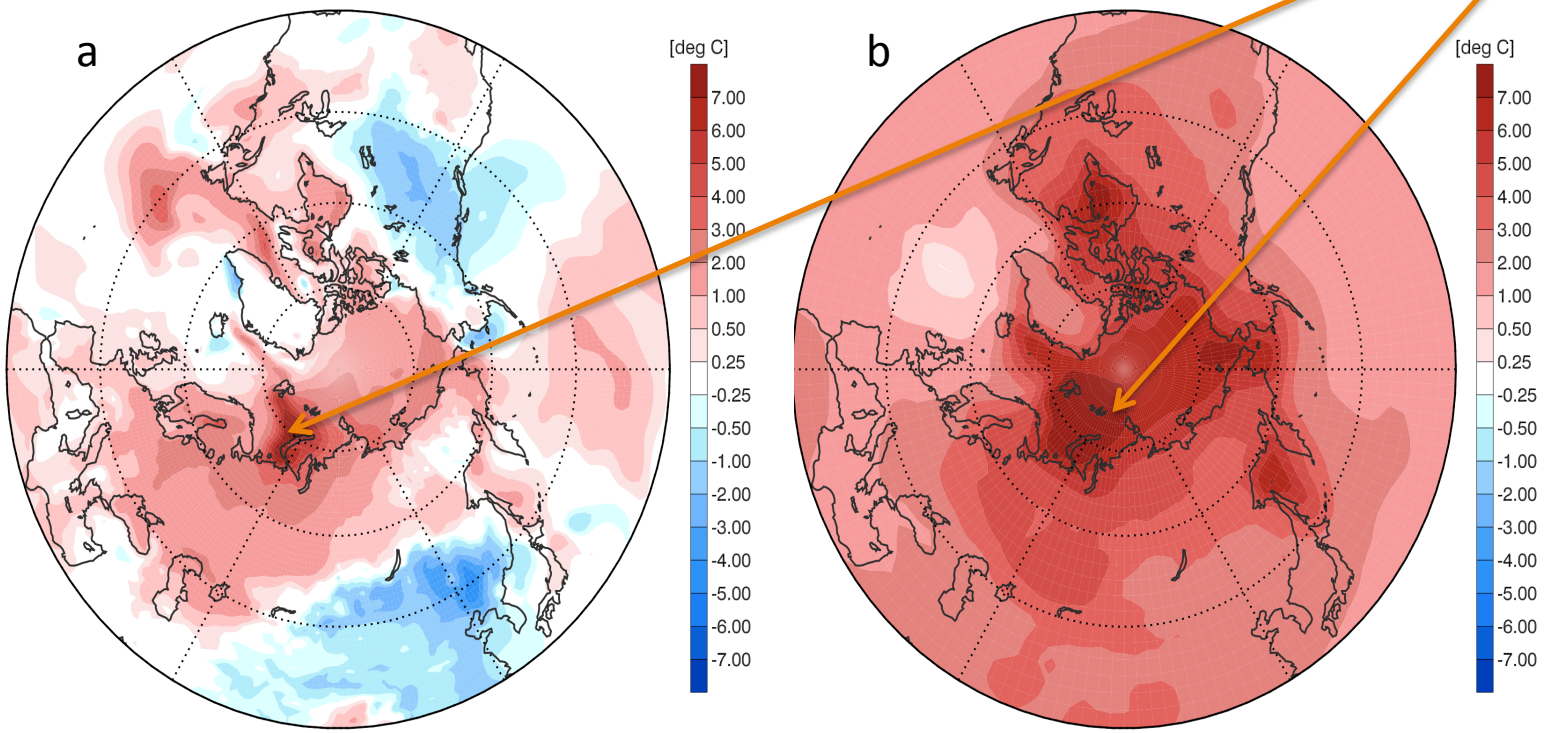
Winter 2013 Temperature Forecast/Climate Change Projections

Same bull's eye with continental warming, a cautionary tale.



January-March 2013 Dynamical model surface temperature anomaly forecast

Composite differences of surface air temperature between the periods 2079-2100 minus 1979-2000.

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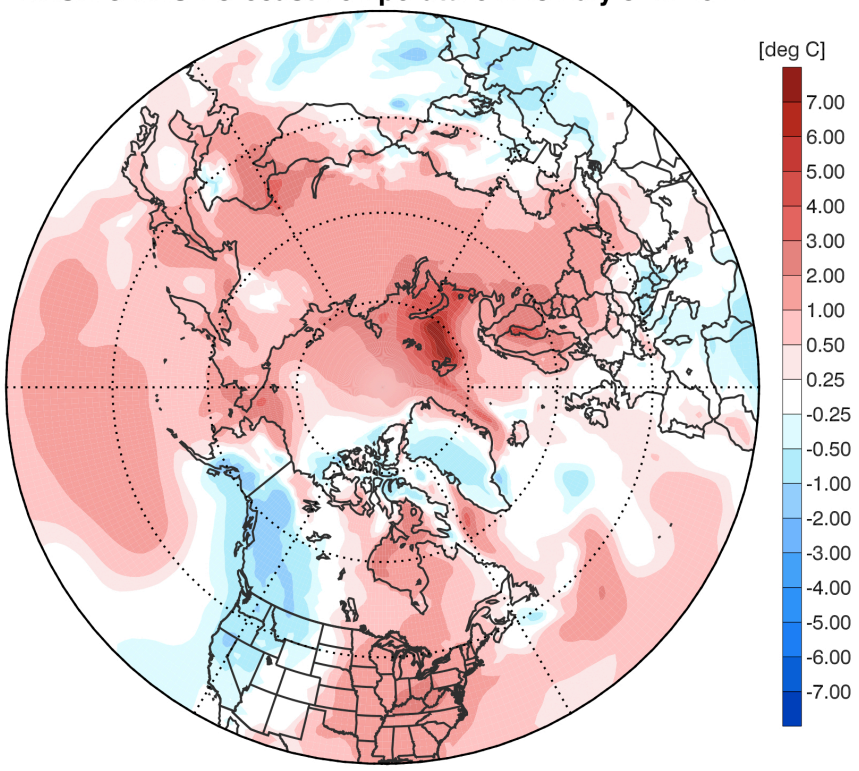
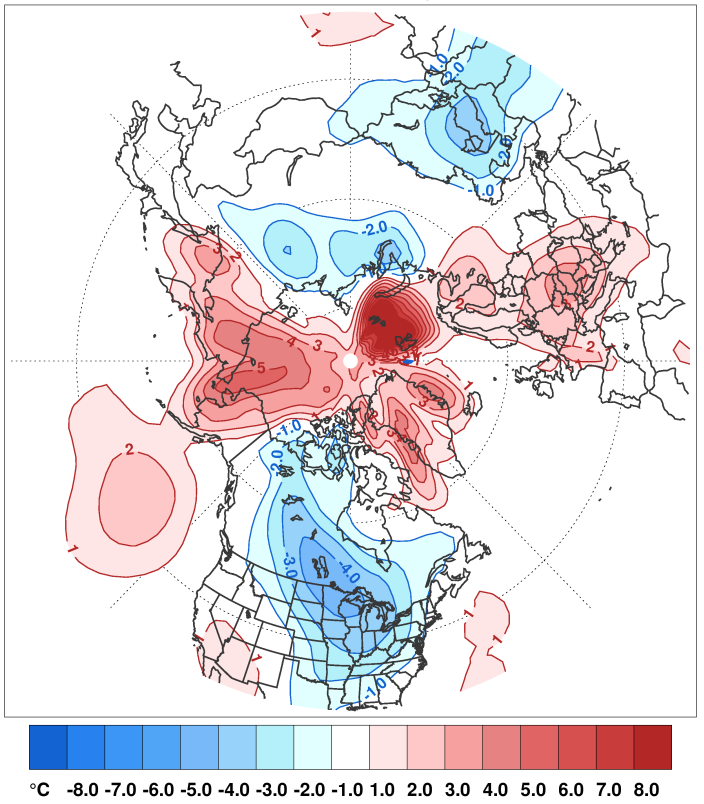
Winter 2014 Temperatures

NASA GMAO Forecast Temperature Anomaly JFM 2014



Observed Temperature Anomaly Dec-Jan-Feb 2014



In models Arctic warmth is advected ot the continents but not seen in nature.

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Summary

- Over the past two decades or so, there has been a marked asymmetry in seasonal temperature trends with cooling in winter and continued warming in the other seasons.
- The cooling is trend projects strongly on to the negative phase of the winter Arctic Oscillation (AO).
- Snow cover variability is robustly related to dynamical metrics of troposphere-stratosphere coupling and the AO pattern of variability.
- In nature “warm Arctic, cold continents” pattern is common to the negative AO, high snow cover and low sea ice but not in the dynamical models.
- Improved modeling of sea ice- and snow- atmosphere coupling and stratosphere-troposphere coupling will yield seasonal to decadal scale predictions.

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*, 014007 in press.

Cohen, J., J. Furtado, J. Jones, M. Barlow, D. Whittleston and D. Entekhabi 2014: Linking Siberian snow cover to Precursors of stratospheric variability. *Journal of Climate*, in press.

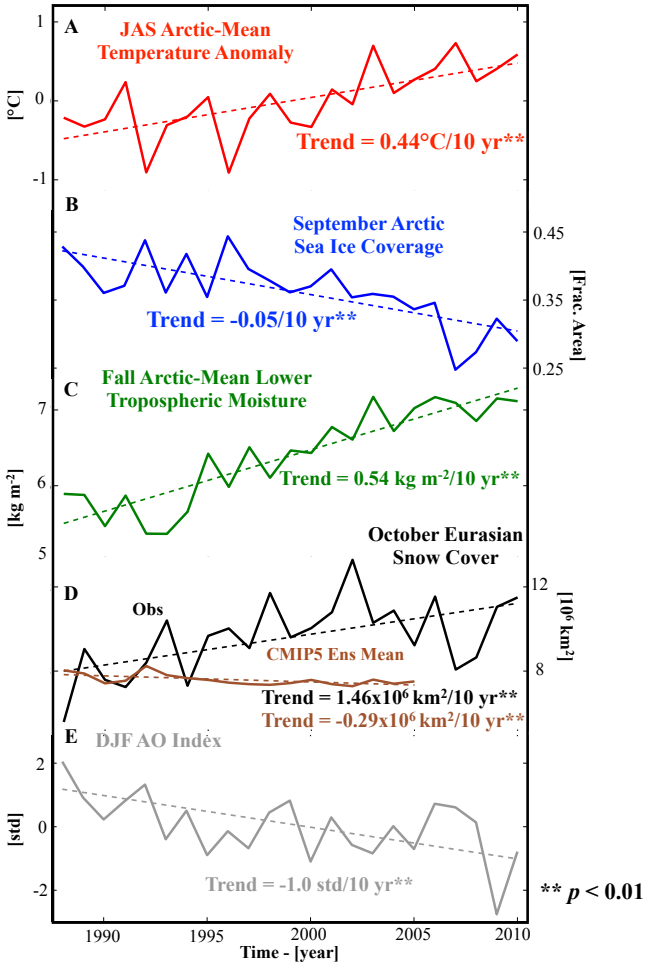
Furtado, J. C., J. L. Cohen, A. H. Butler, E. E. Riddle, and A. Kumar, 2014: Eurasian snow cover variability, winter climate, and stratosphere-troposphere coupling in the CMIP5 models. *Climate Dynamics*, in preparation.

Thank you!

Arctic Trends 1988-2010

- ✓Warming Arctic
- ✓Less sea ice
- ✓More atmospheric moisture
- ✓Increasing snow cover
- ✓Decreasing Arctic Oscillation trend

Positive feedback loop of thermodynamic heating in the fall leads to a dynamic heating in the winter in the Arctic



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Cohen et al. 2012b