A Difficult Arctic Science Issue: Mid-latitude Weather Linkages

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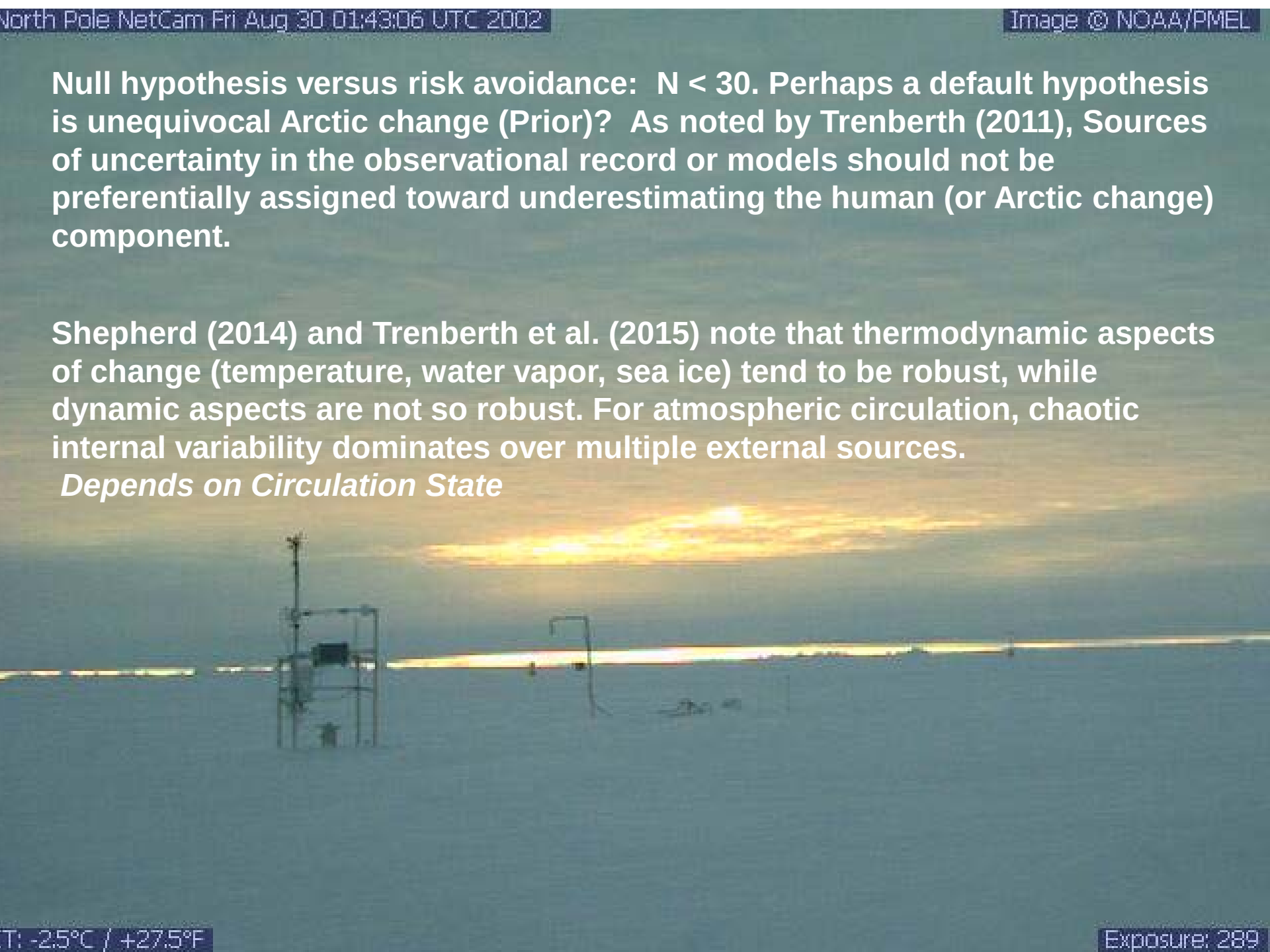
Will Arctic changes lead to mid-latitude weather extremes in the coming decades?

60 % of the public in the NE United States believe that Arctic warming will impact their weather (Hamilton and Lemcke-Stampone, 2014).

Irresolvable uncertainty:
Length of data series (<10 Years) is short; weather is chaotic; Tropical and mid-latitude sources of Arctic impacts.

Recent Consensus:
There will be no net mid-latitude cooling.
Linkages will be small, regional, episodic and based on amplification of existing weather patterns in some years

Worth further investigation for potential of improving seasonal forecasts, especially with continued Arctic external forcing

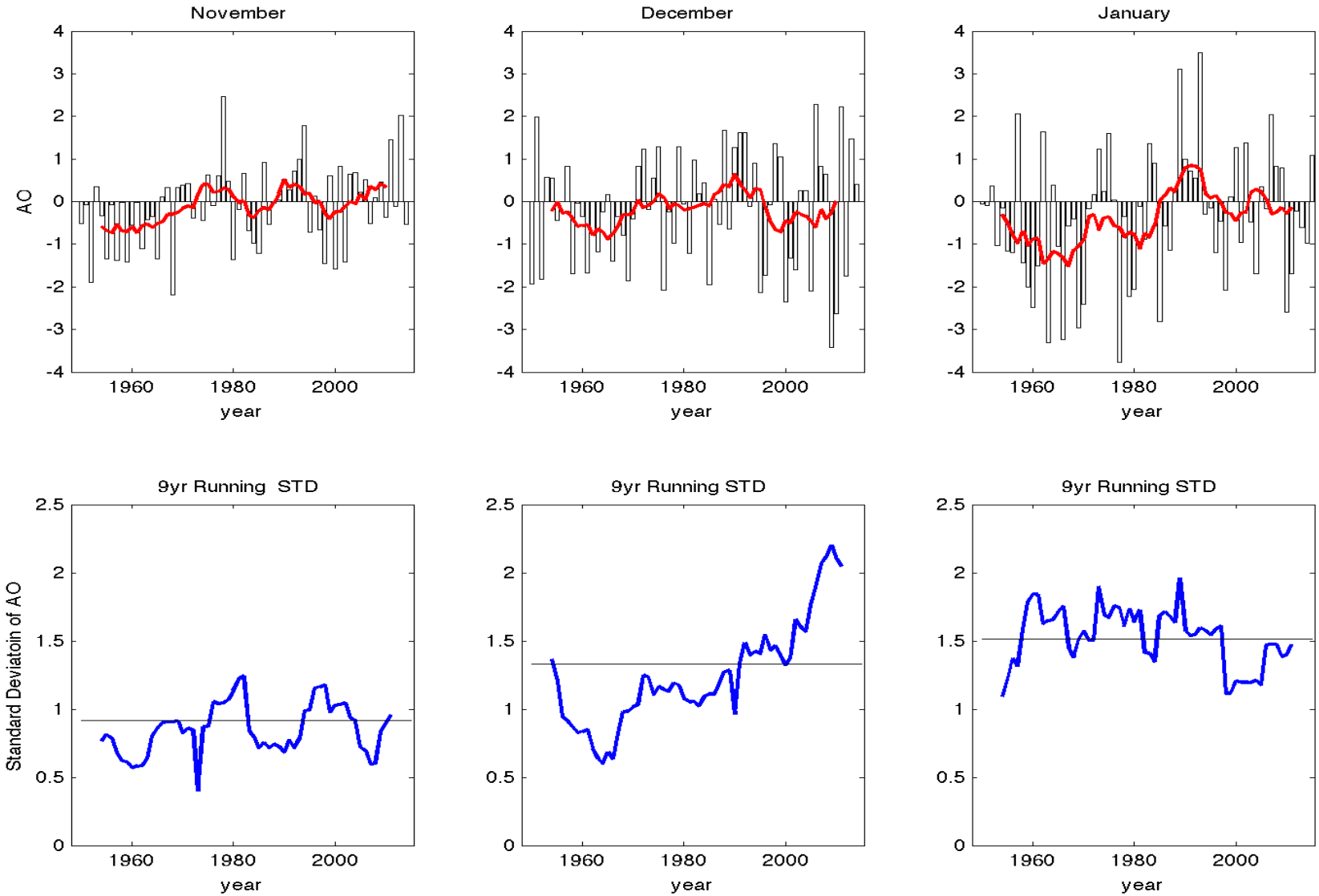


Null hypothesis versus risk avoidance: N < 30. Perhaps a default hypothesis is unequivocal Arctic change (Prior)? As noted by Trenberth (2011), Sources of uncertainty in the observational record or models should not be preferentially assigned toward underestimating the human (or Arctic change) component.

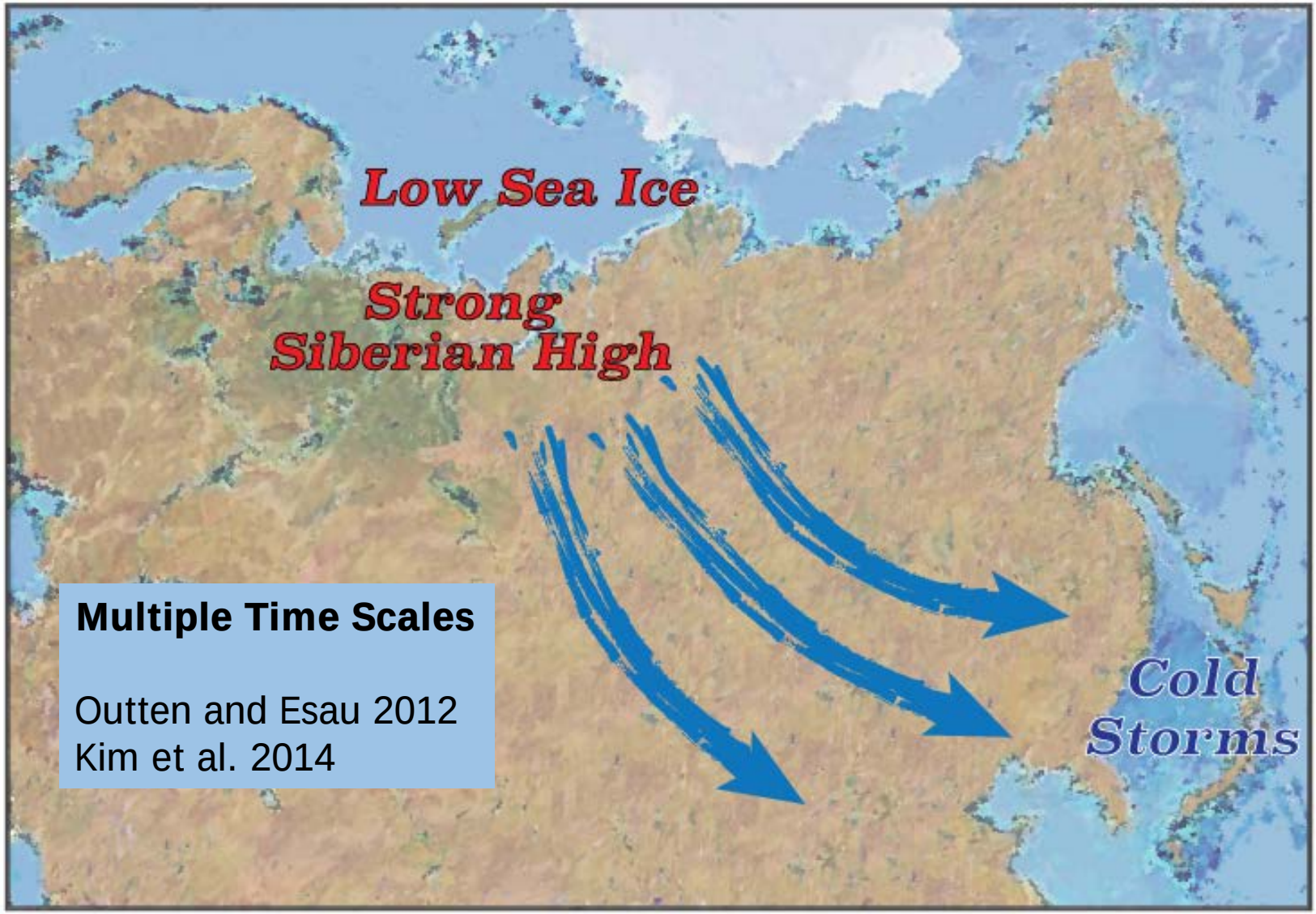
Shepherd (2014) and Trenberth et al. (2015) note that thermodynamic aspects of change (temperature, water vapor, sea ice) tend to be robust, while dynamic aspects are not so robust. For atmospheric circulation, chaotic internal variability dominates over multiple external sources.

Depends on Circulation State

Increased December Arctic Oscillation (AO) index Variability
Lower curves are 9 year running standard deviation
AO- in 2009, 2010, 2012; AO+ in 2006, 2011, 2103



Asia: Arctic-Midlatitude Weather Linkages

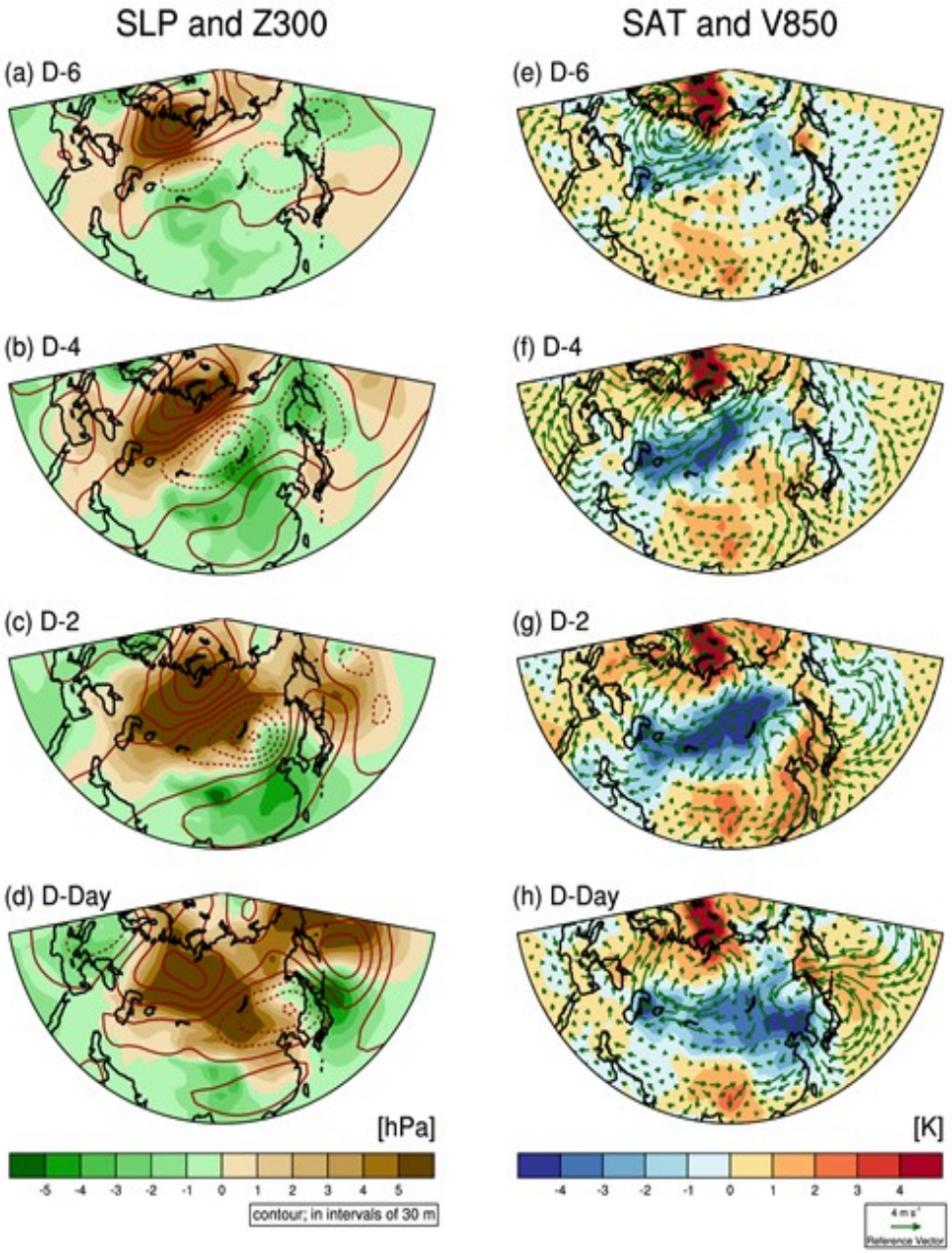


Multiple Time Scales

Outten and Esau 2012
Kim et al. 2014

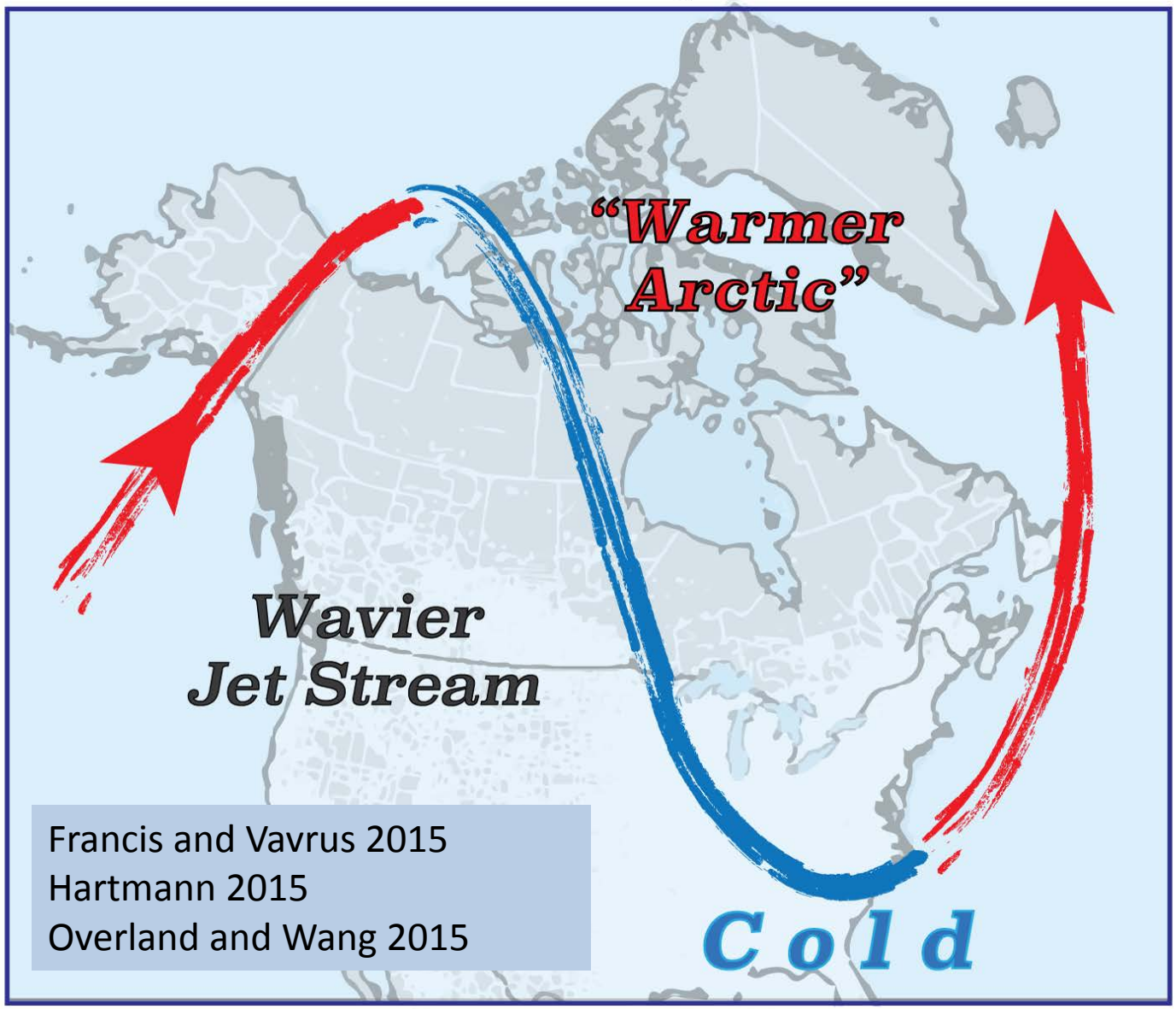
Wave Train Movement of Cold Air into Eastern Asia: Monthly to Synoptic Scale

Kim et al. 2014;
Overland et al. 2015



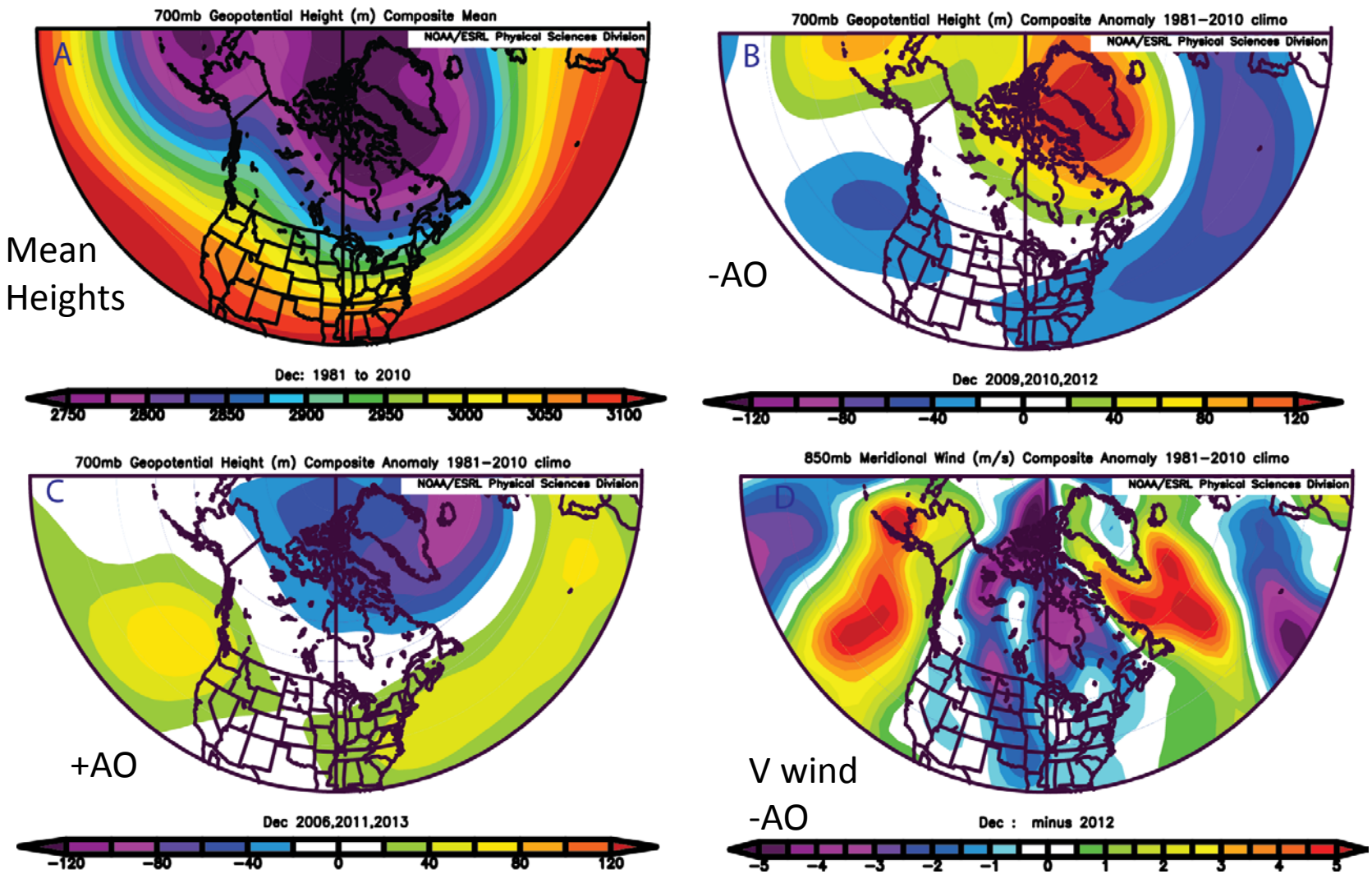
More Speculative

North America: Warmer Arctic Temperatures Can Reinforce Wavy Jet Stream



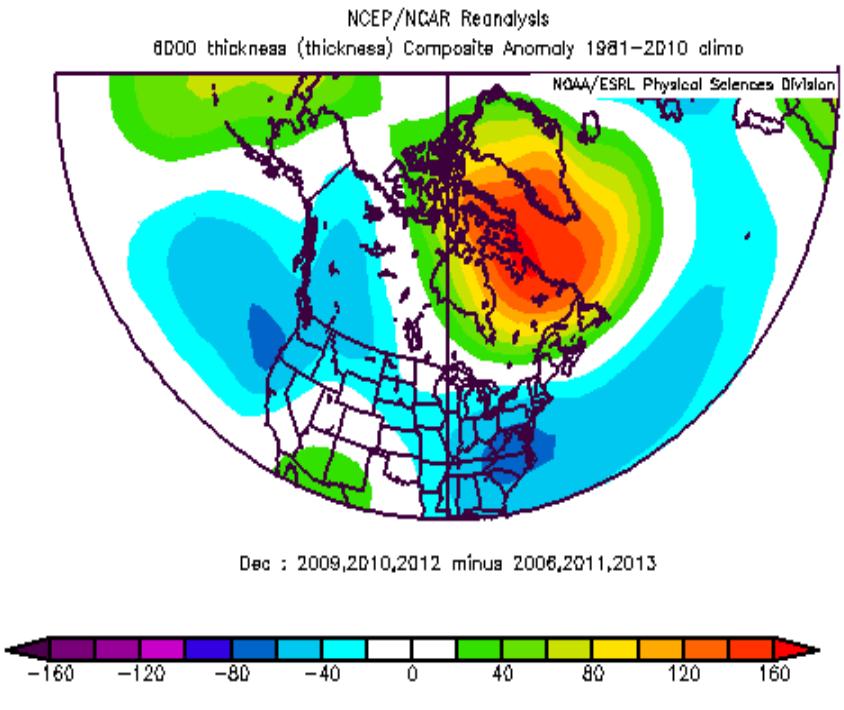
Francis and Vavrus 2015
Hartmann 2015
Overland and Wang 2015

A) December climatic mean of 700 hPa geopotential heights over North America.
(B &C) Composite of height anomalies for three months of recent AO- (Dec. 2009, 2010 and 2012) and AO+ (Dec. 2006, 2011, 2013).
(D) Meridional 850 hPa wind component showing a “wavy” pattern for Dec 2012

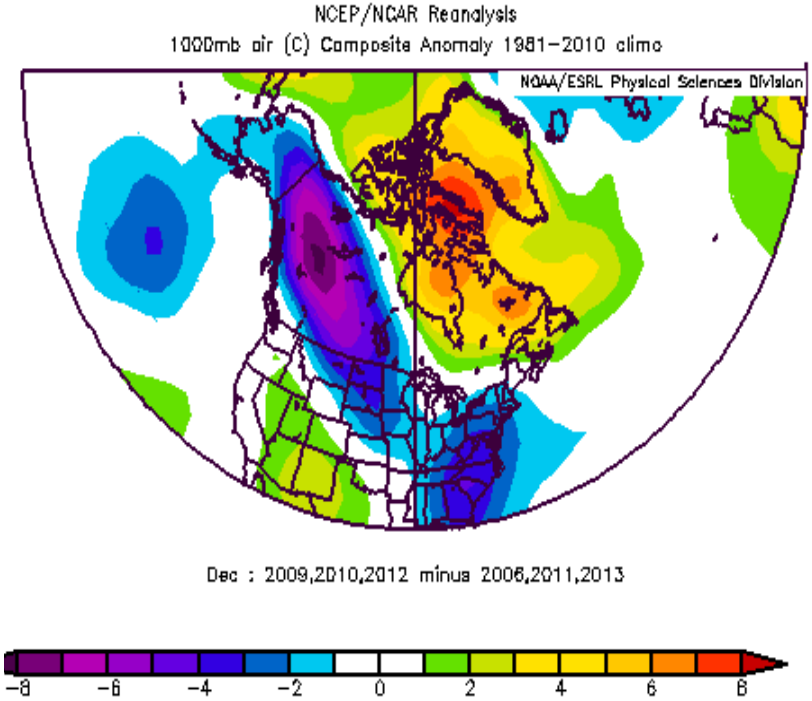


Composite of geopotential thickness (m) and near surface (1000 hPa) air temperature anomalies and for three -AO –(+AO) Decembers. Maximums are over Baffin Bay and Hudson Bay in excess of +4°C.

Thickness



Near Surface Temperature



Geopotential Tendency Equation in pressure coordinates
(notation after Holton 1979)

$$\chi \propto f_0 \boldsymbol{V_g} \cdot \nabla \left(\frac{1}{f_0} \nabla^2 \Phi + f \right) + \frac{f_0^2}{\sigma} \frac{\partial}{\partial p} \left[\boldsymbol{V_g} \cdot \left(\frac{\partial \Phi}{\partial p} \right) \right] + \frac{f_0^2 R_d}{\sigma c_p} \frac{\partial}{\partial p} \left(\frac{dQ/dt}{p} \right)$$

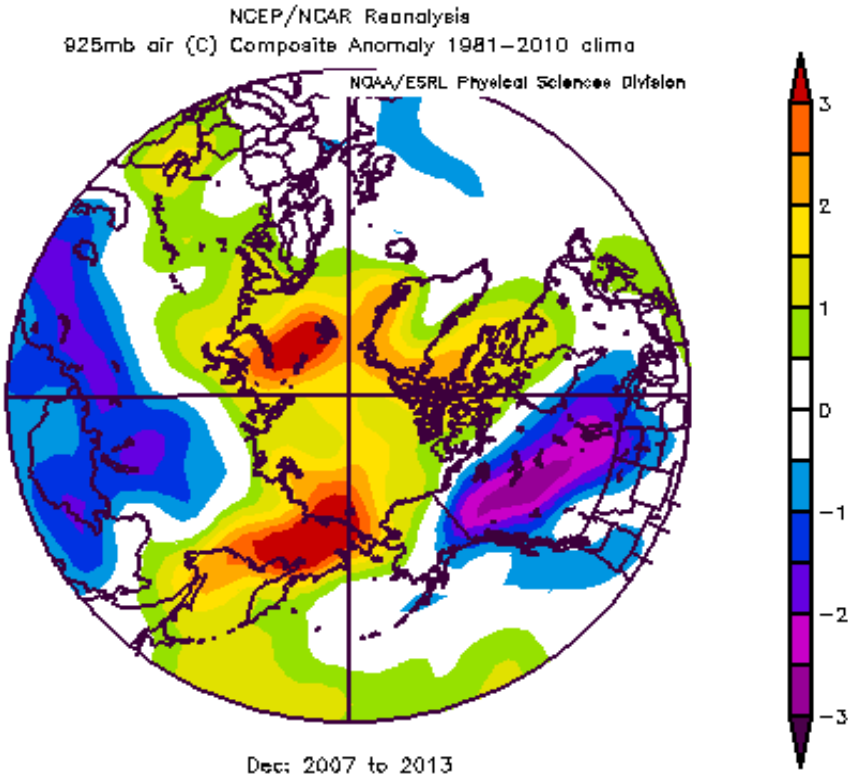
+Height 500 hPa — Vorticity advection — decrease with height of Thickness Advection and Heating

where

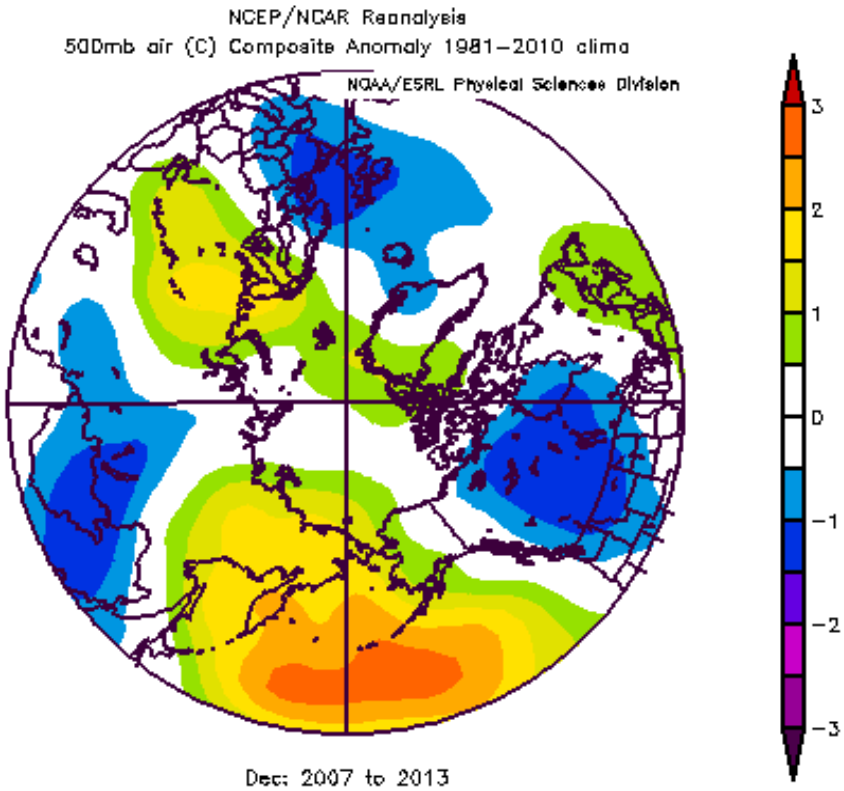
$$\chi = \frac{\partial \Phi}{\partial t}$$

is the geopotential tendency

925 hPa

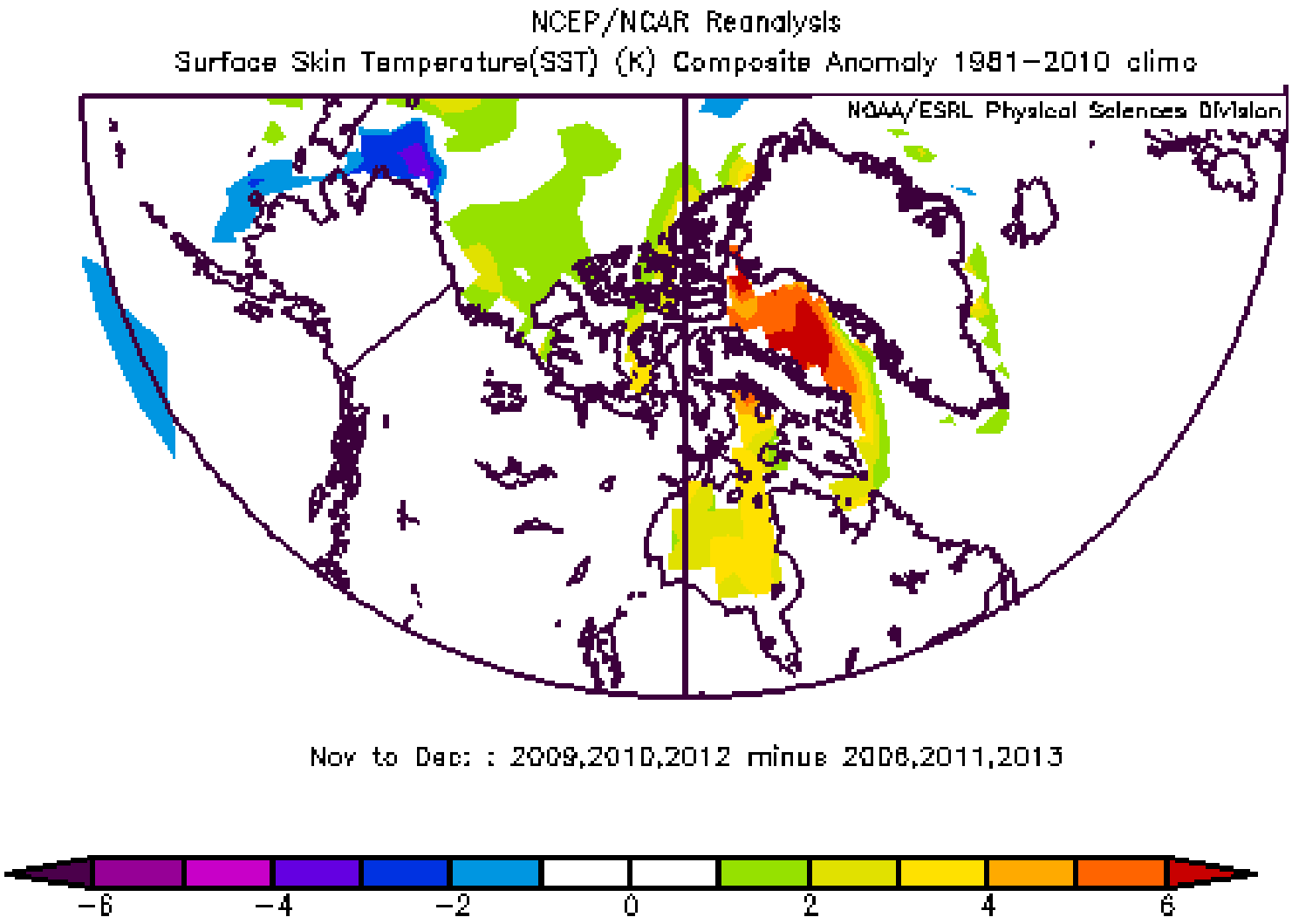


500 hPa



Decrease of Arctic temperature anomalies with height
DEC 2007-2013

Increased Surface Temps over sea ice areas in Negative AO Years



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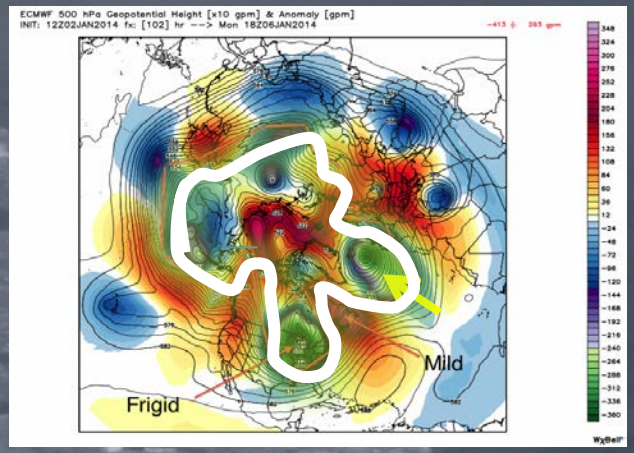

Wavy Jet Stream

Recent Consensus

No long term trends.

From Case Studies: Early winter Linkage events will be small, regional (E Asia and speculatively in E North America), and based on amplification of existing weather patterns in some years, especially in -AO years (*Circulation State Dependent*).

Linkages are a combination of internal variability, two-way mid-latitude teleconnections, and lower-tropospheric Arctic temperature anomalies *All are important*

Way forward: improving seasonal forecasts by increasing Arctic observations and improving Arctic-specific physics in the models.

How do we communicate uncertainties to a broad public?