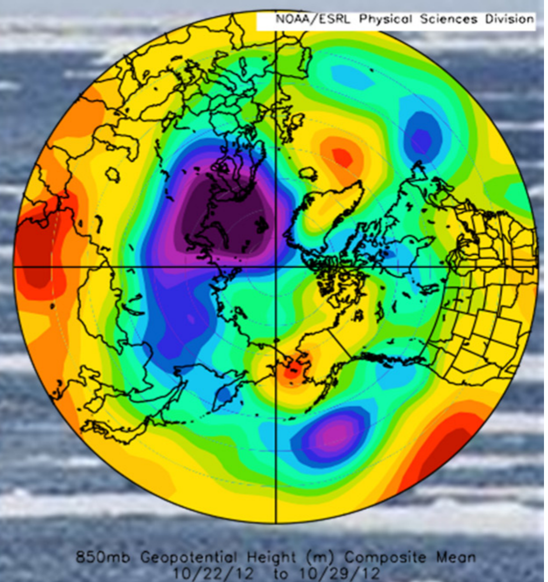
A Warming Arctic and Potential Shifts in Mid-latitude Weather: Faster than Expected

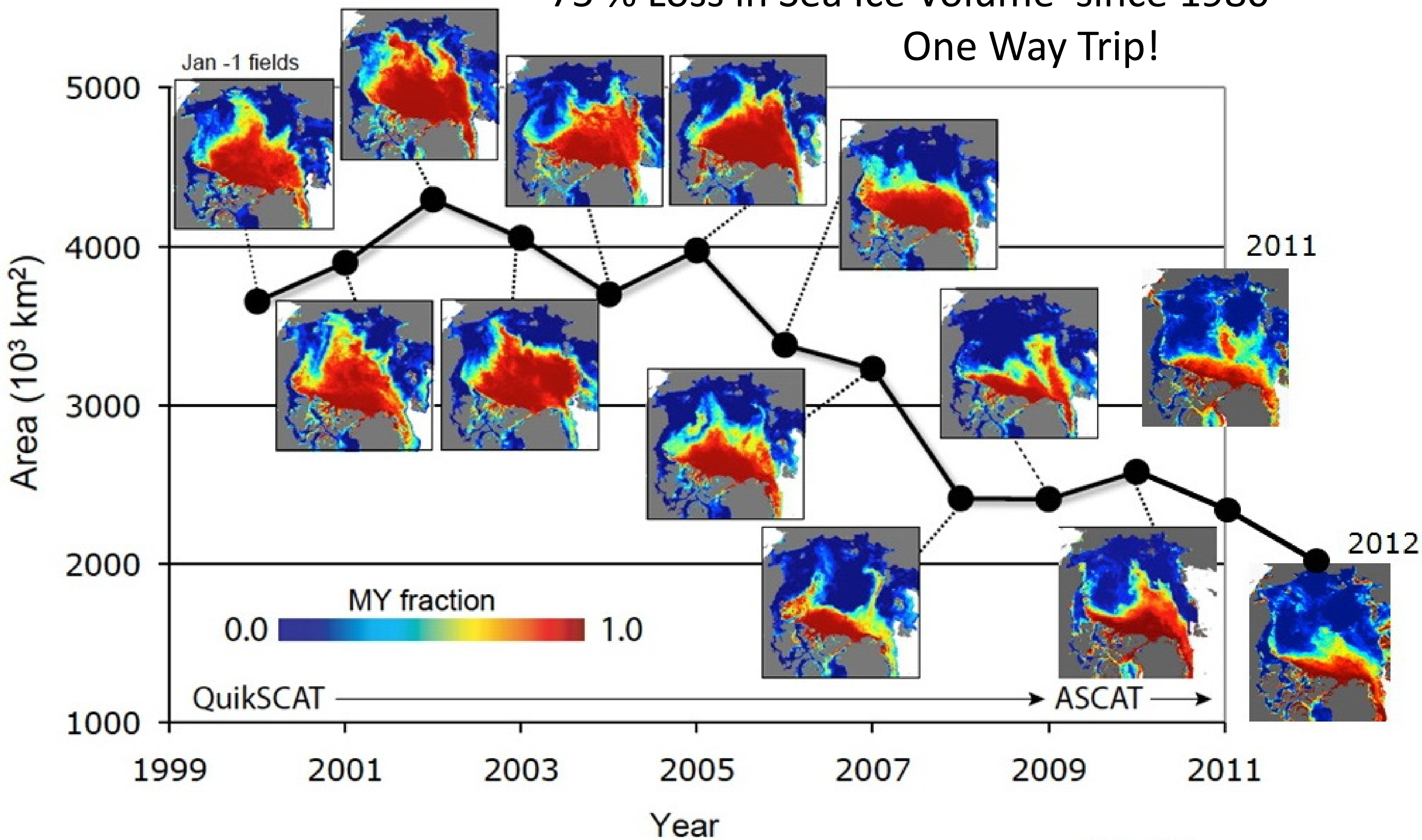


James Overland
NOAA
Pacific Marine Environmental Laboratory
Seattle

50 % Decline in Arctic Ocean Multiyear Sea Ice Coverage

75 % Loss in Sea Ice Volume since 1980

One Way Trip!



(Kwok, 2010)

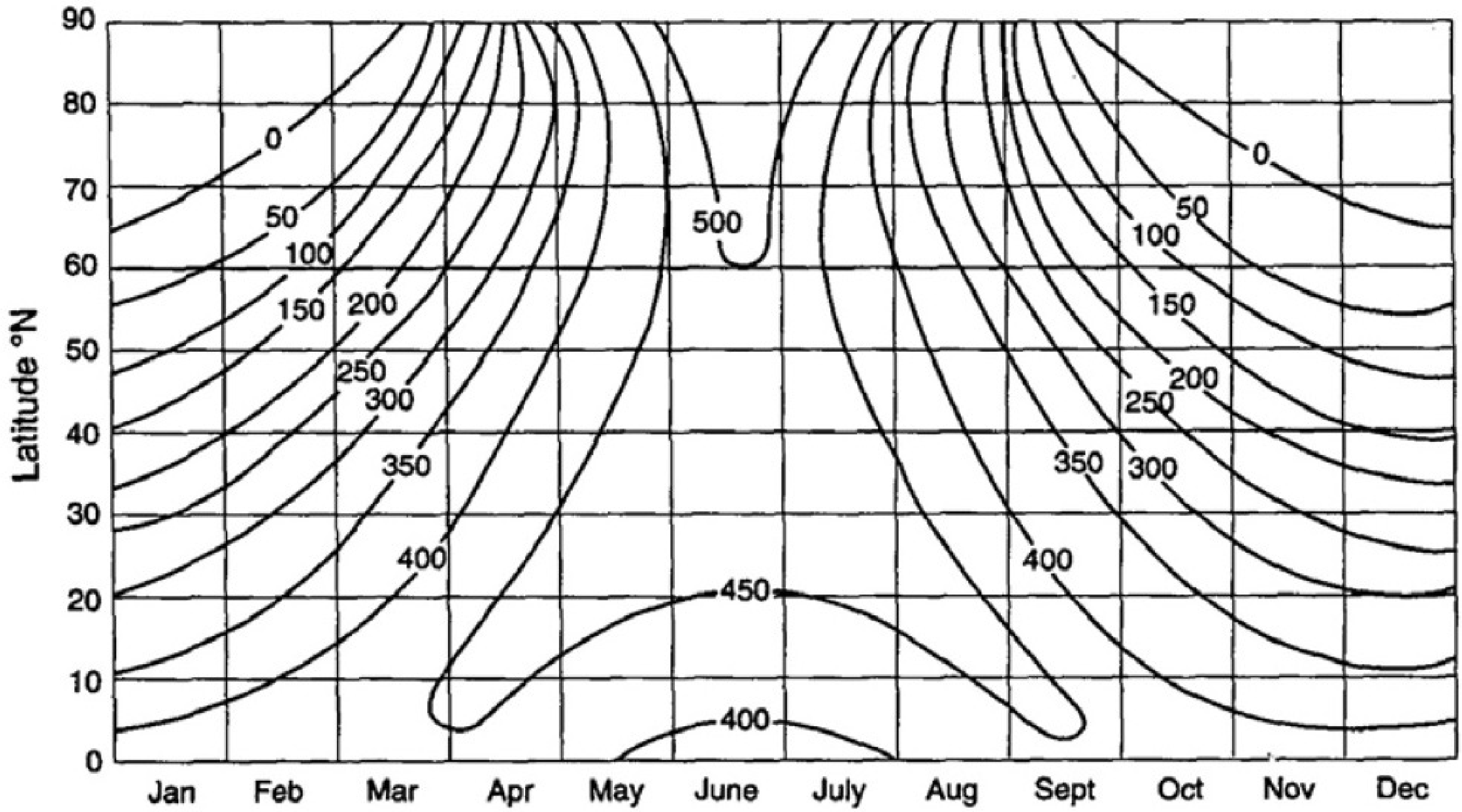
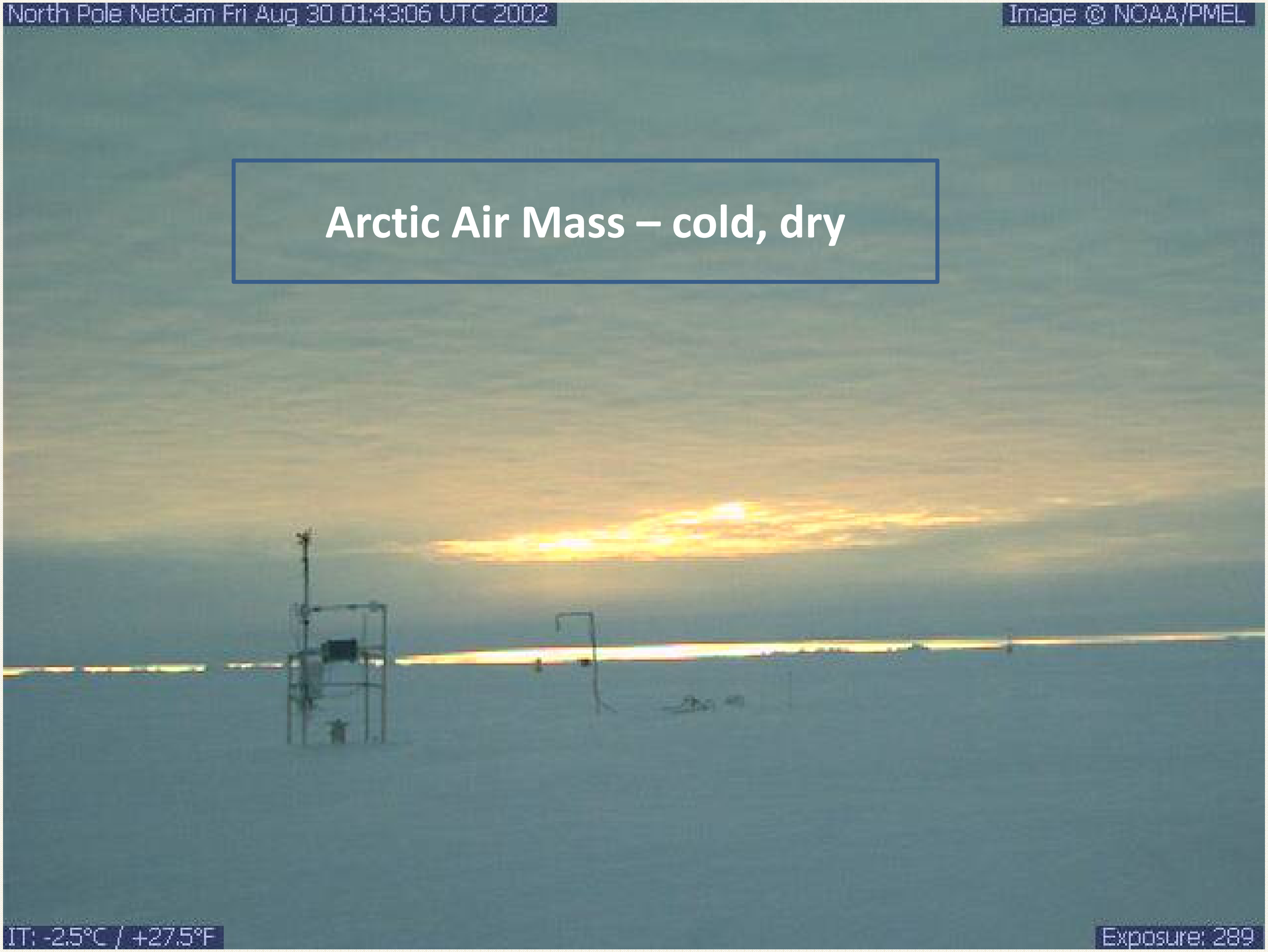


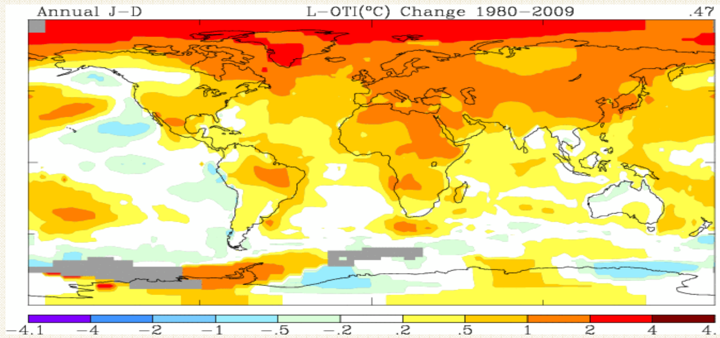
Figure 1. Latitudinal distribution of potential insolation for the Northern Hemisphere. Units are in W/m^2.


North Pole NetCam Fri Aug 30 01:43:06 UTC 2002
Image © NOAA/PMEL
Arctic Air Mass – cold, dry
IT: -2.5°C / +27.5°F
Exposure: 289


Maritime Air Mass- warm, moist

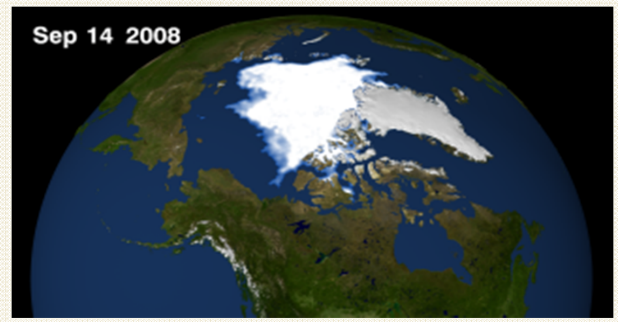
“Arctic Amplification”: Global Warming +Multiple Feedbacks

Global Warming



Arctic amplification

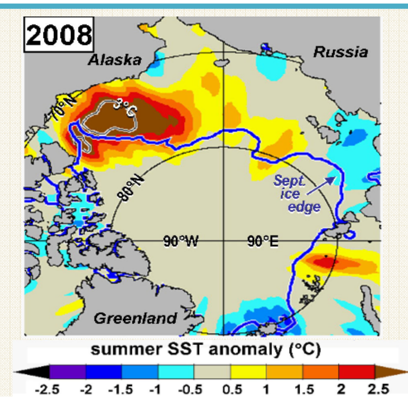
Reduction of Arctic sea Ice



Sept Sea Ice Extent

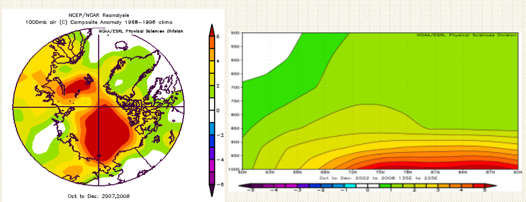
Surface albedo decrease

Ocean absorbs more heat



Heat releases to atmosphere in the fall.

Atmosphere warming

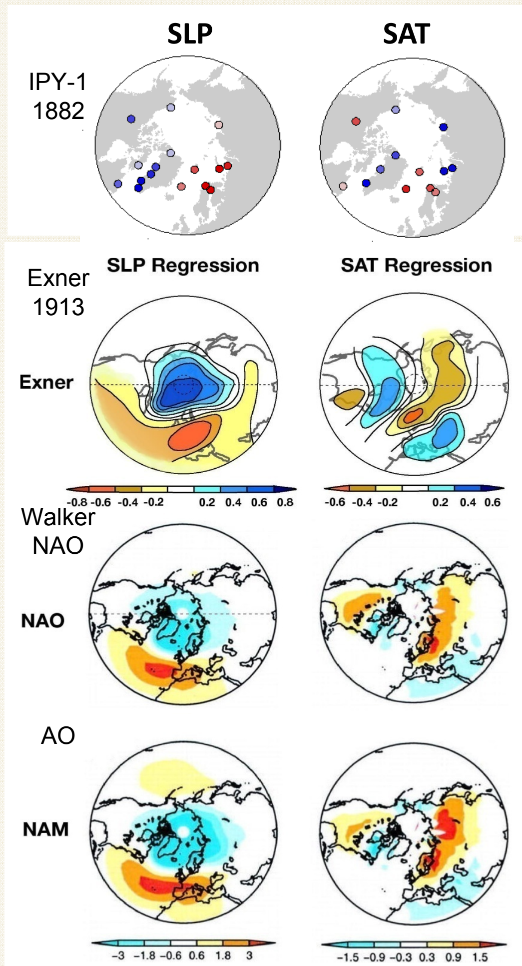


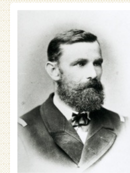
OND Temp Anomaly

Teleconnection and circulation pattern change

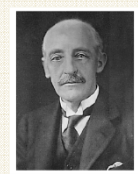
Variation in general circulation

F.M. Exner
(1876-1930)



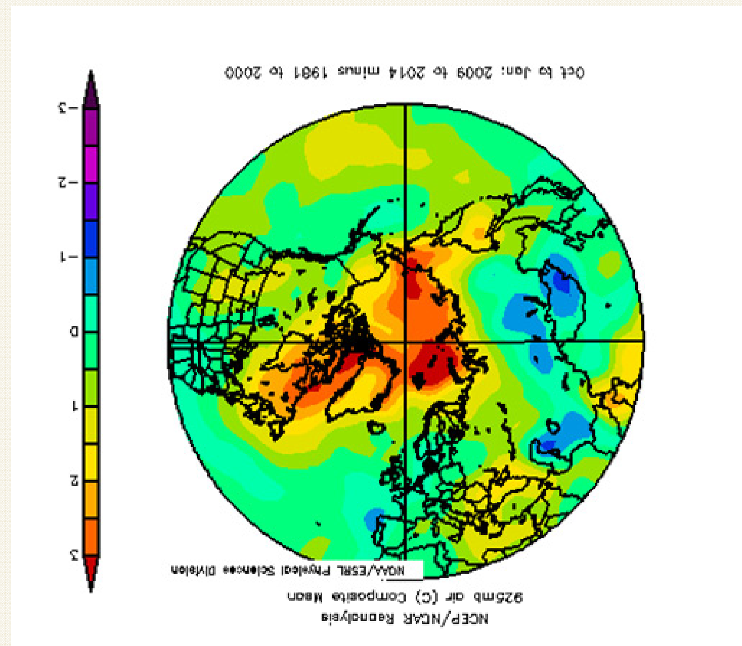


K. Weyprecht
(1838-1881)



G.T. Walker
(1868-1958)

Arctic Warming Pattern
3X faster than Mid-Latitude

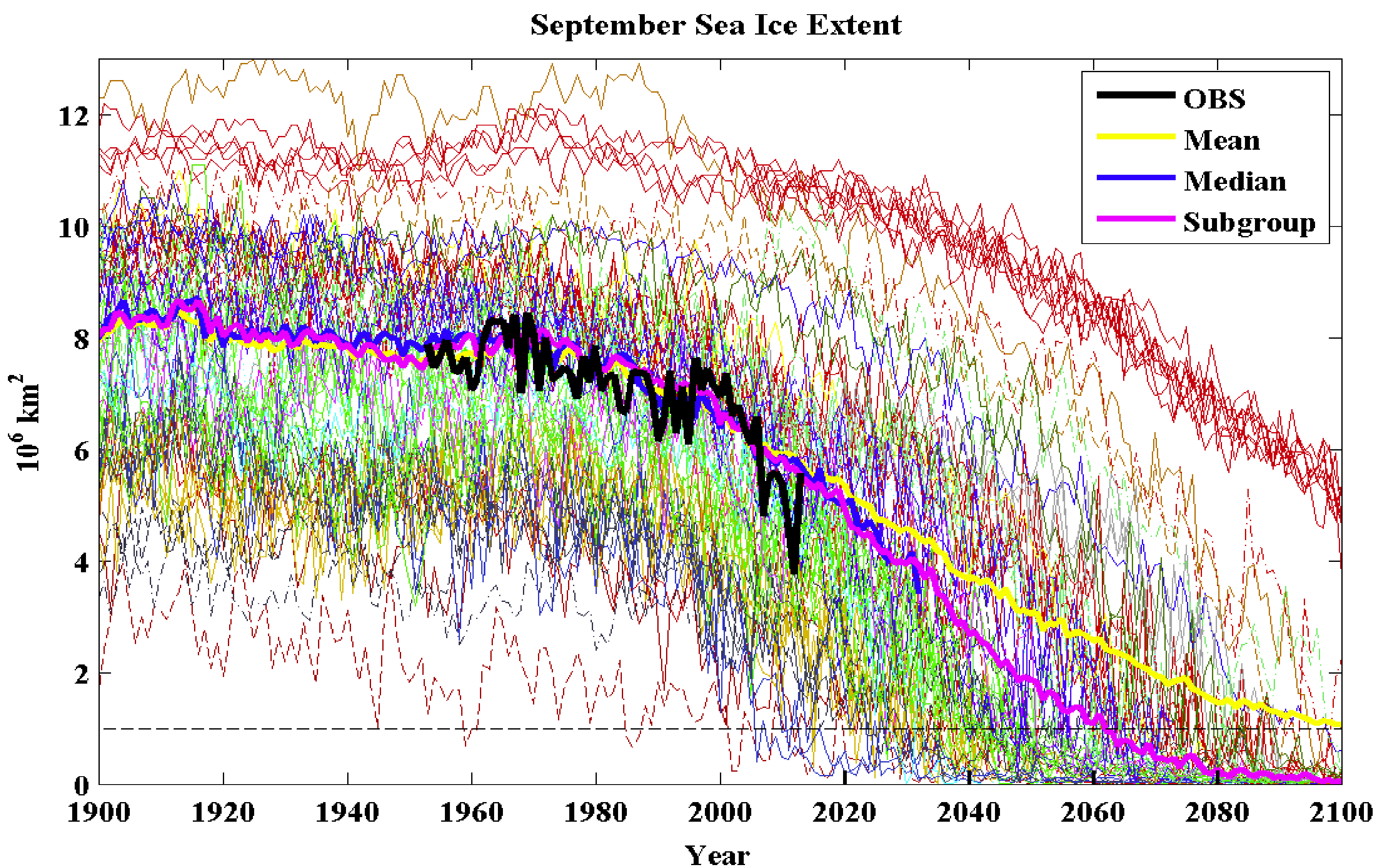


Adapted from Wood & Overland (2006), F.M. Exner (1913) *Über monatliche Witterunganomalien auf der Nördiche Erdhälfte im Winter*; NAO & AO/NAM courtesy of J.M. Wallace

Warming Pattern is Different from Natural Variability (Arctic Oscillation) Pattern

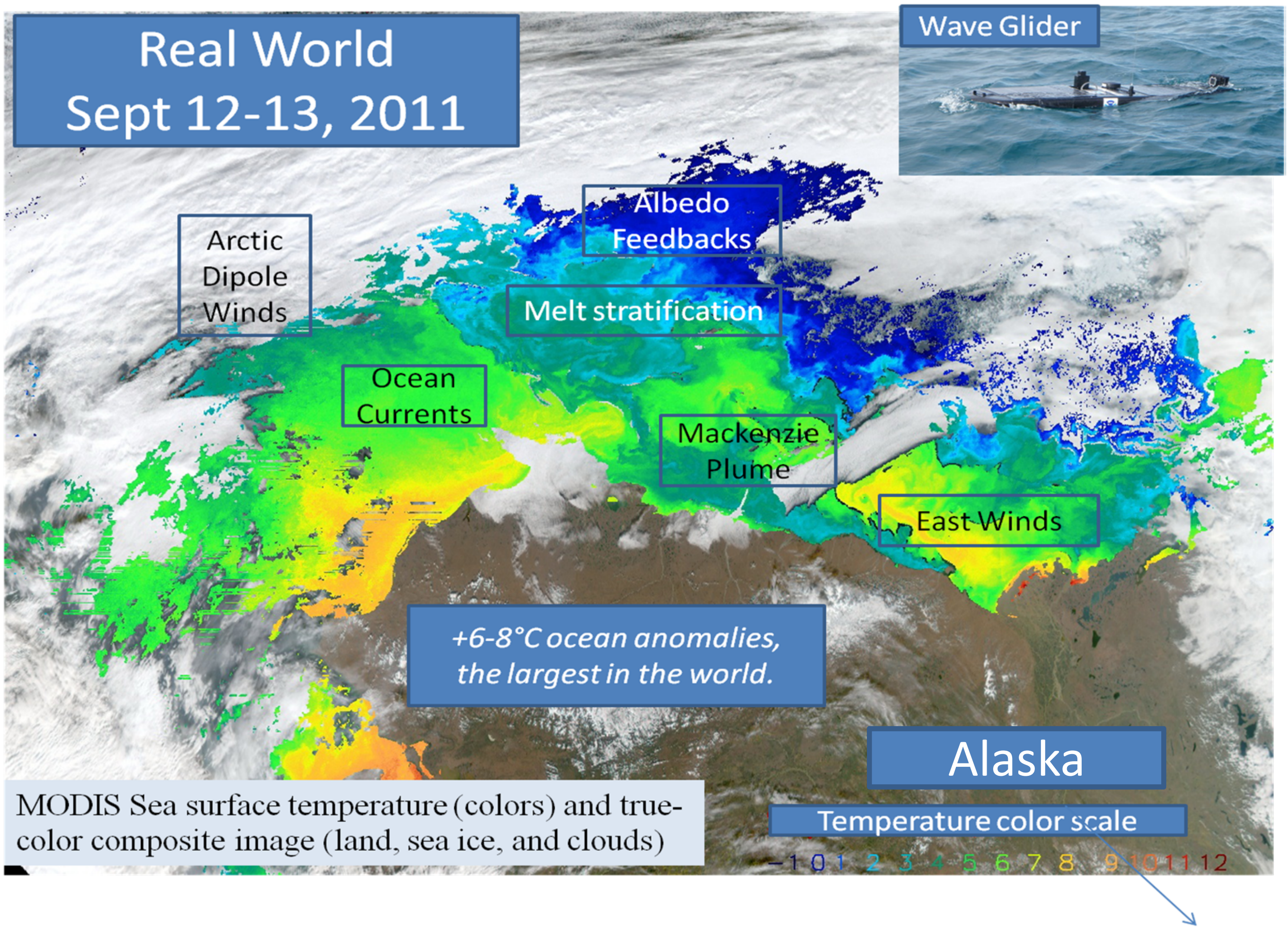
Wide Range of September Sea Ice Extent Hindcasts and Predictions

89 ensemble members from 36 CMIP5 (IPCC) models under strongest (RCP8.5) emissions scenario



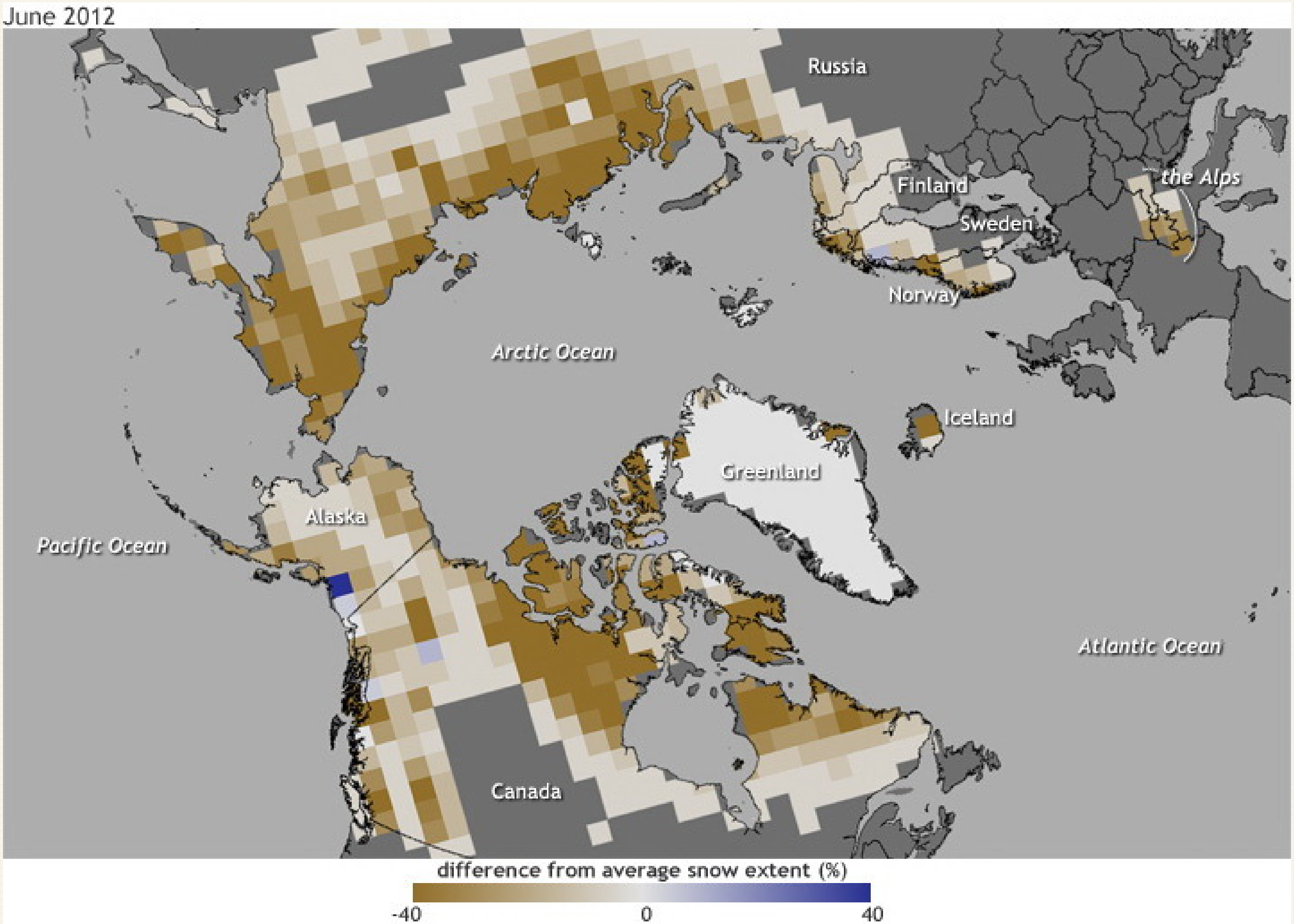
Muyin Wang

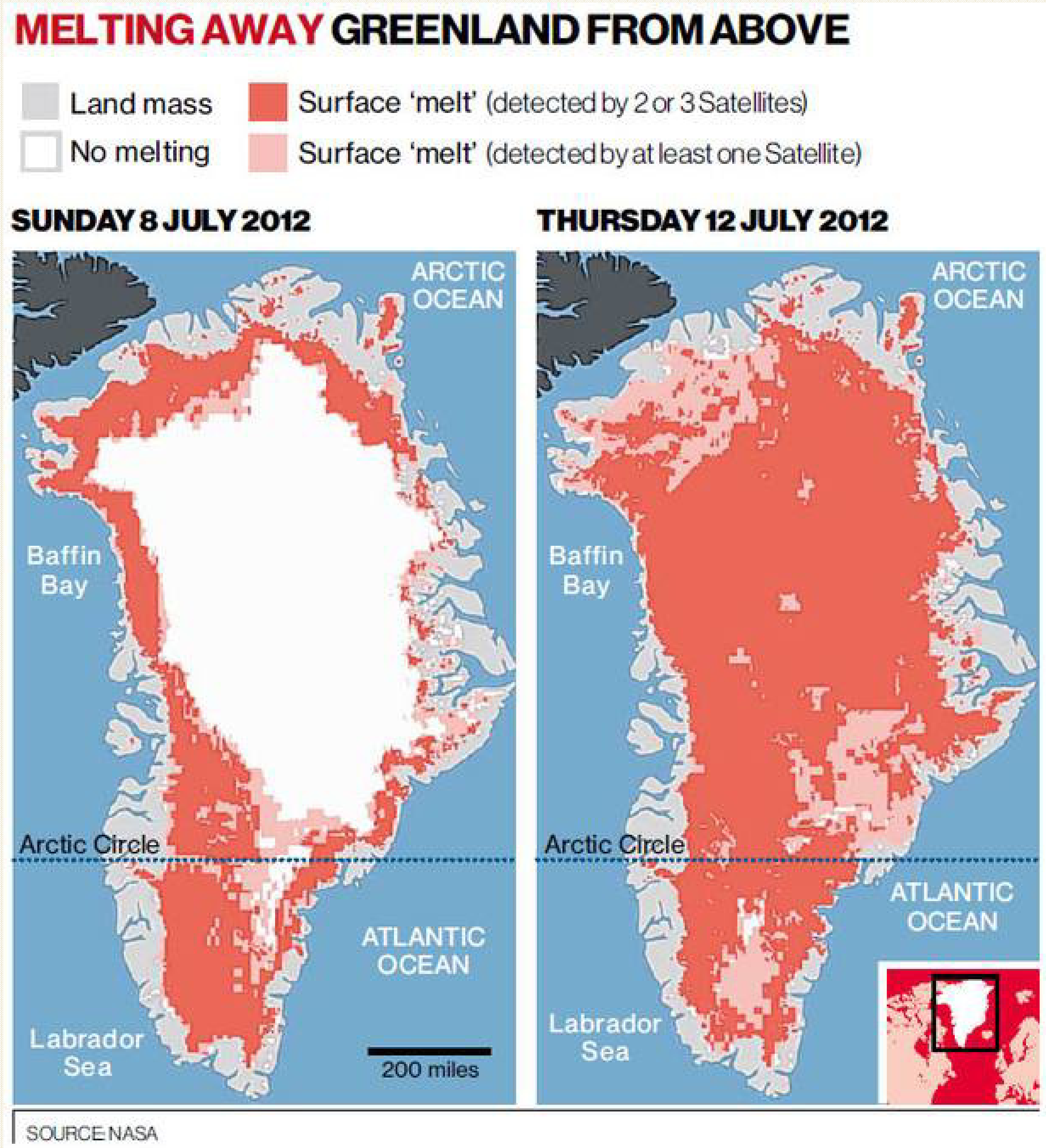
Pacific Arctic Ocean Heat Storage

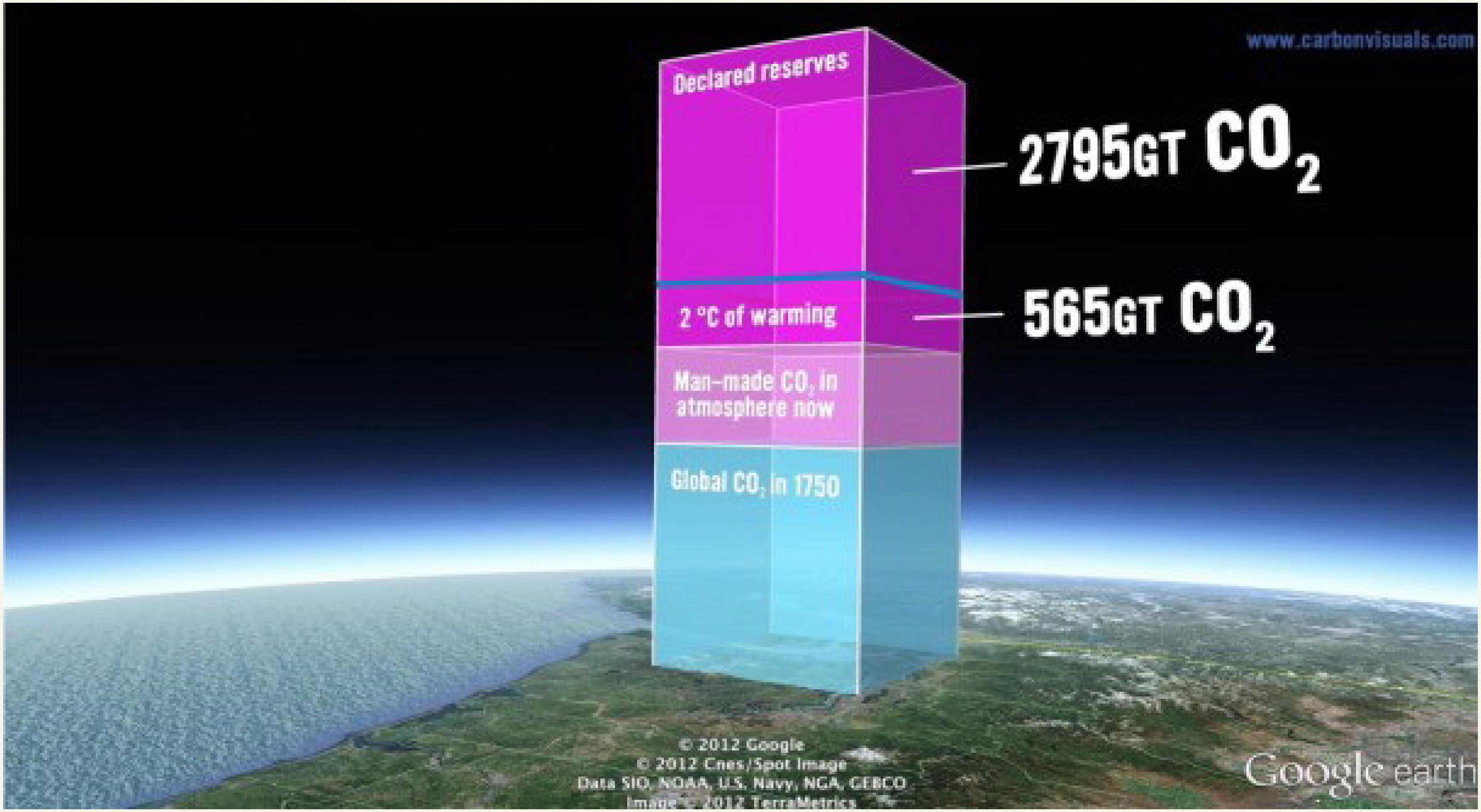


MODIS Sea surface temperature (colors) and true-color composite image (land, sea ice, and clouds)

June Snow Cover 2012 relative to 1971-2000



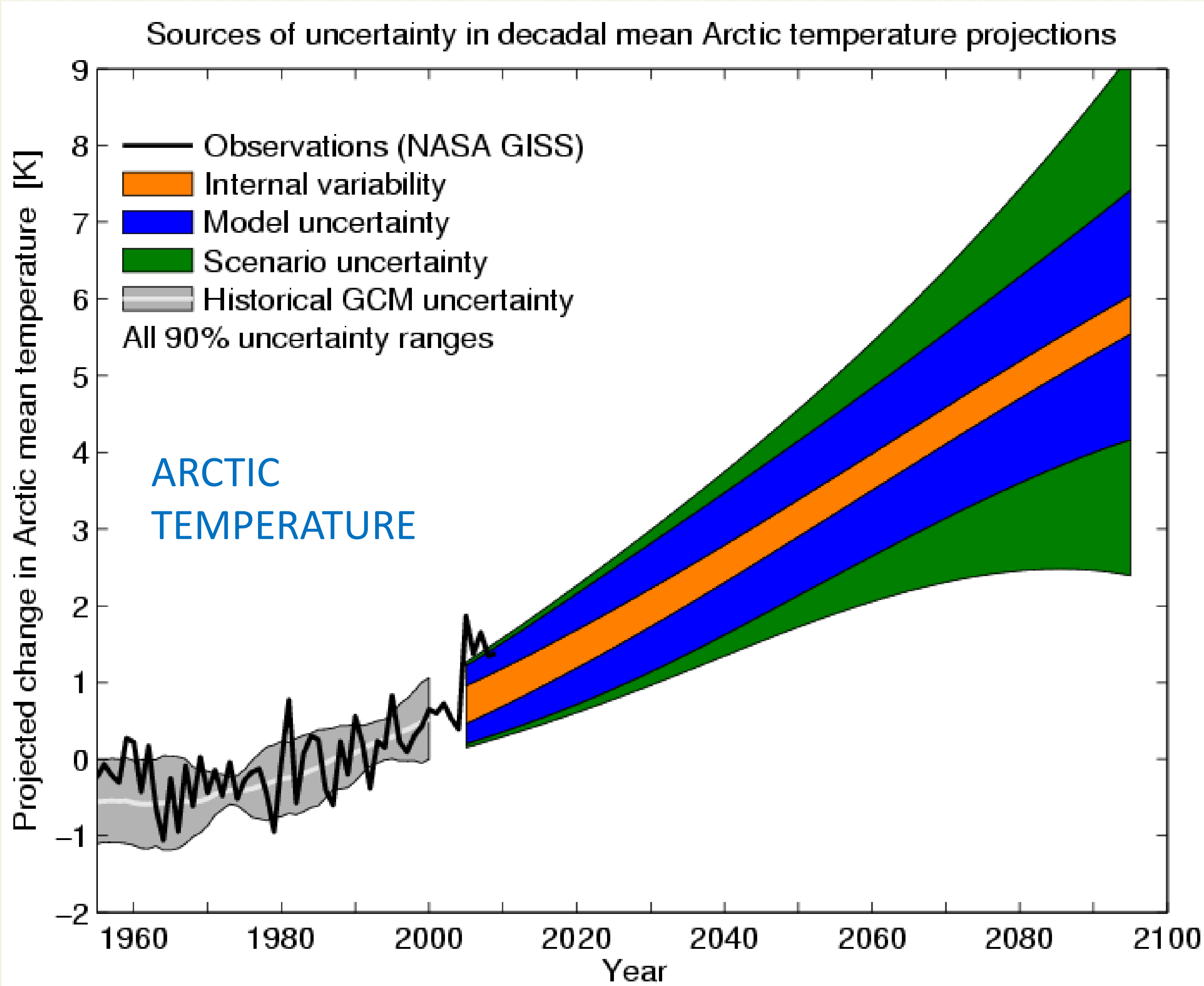

MELTING AWAY GREENLAND FROM ABOVE
Land mass
No melting
Surface 'melt' (detected by 2 or 3 Satellites)
Surface 'melt' (detected by at least one Satellite)
SUNDAY 8 JULY 2012
THURSDAY 12 JULY 2012
ARCTIC OCEAN
Baffin Bay
Arctic Circle
ATLANTIC OCEAN
Labrador Sea
200 miles
ARCTIC OCEAN
Baffin Bay
Arctic Circle
ATLANTIC OCEAN
Labrador Sea
SOURCE: NASA



www.carbonvisuals.com
Declared reserves
2795GT CO_2
565GT CO_2
2 °C of warming
Man-made CO_2 in atmosphere now
Global CO_2 in 1750
© 2012 Google
© 2012 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
Google earth

Sources of uncertainty in Arctic temperature projections

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL



Hodson et al. 2012, Clim. Dyn.

Predictions

One-Way Trip!

Human forcing is already in the climate system. Arctic amplifies the changes

Summer Arctic-wide sea ice loss is likely to occur within a decade or two.

Cutting Greenhouse gases can reduce Arctic temperature increases in 2090 by half.

A Smörgåsbord of Wacky Weather…

What do these events have in common?
“Stuck” weather patterns

J. Francis

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

Attribution is Controversial

Length of time series (<10 Years) is too short to robustly differentiate Arctic forcing from random events

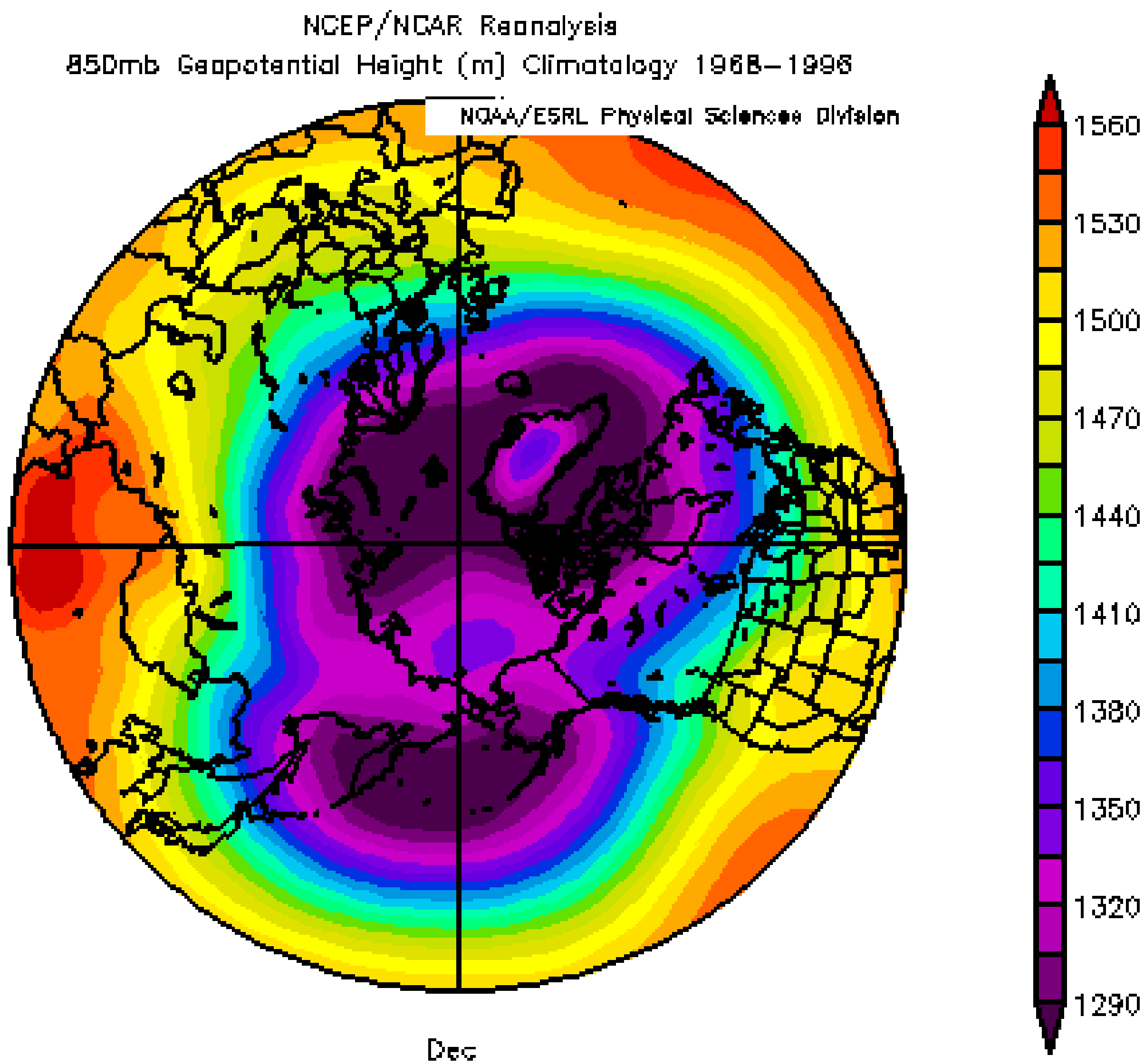
Complex interaction of Arctic forcing with chaotic mid-latitude flow; will not happen the same way in every year

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

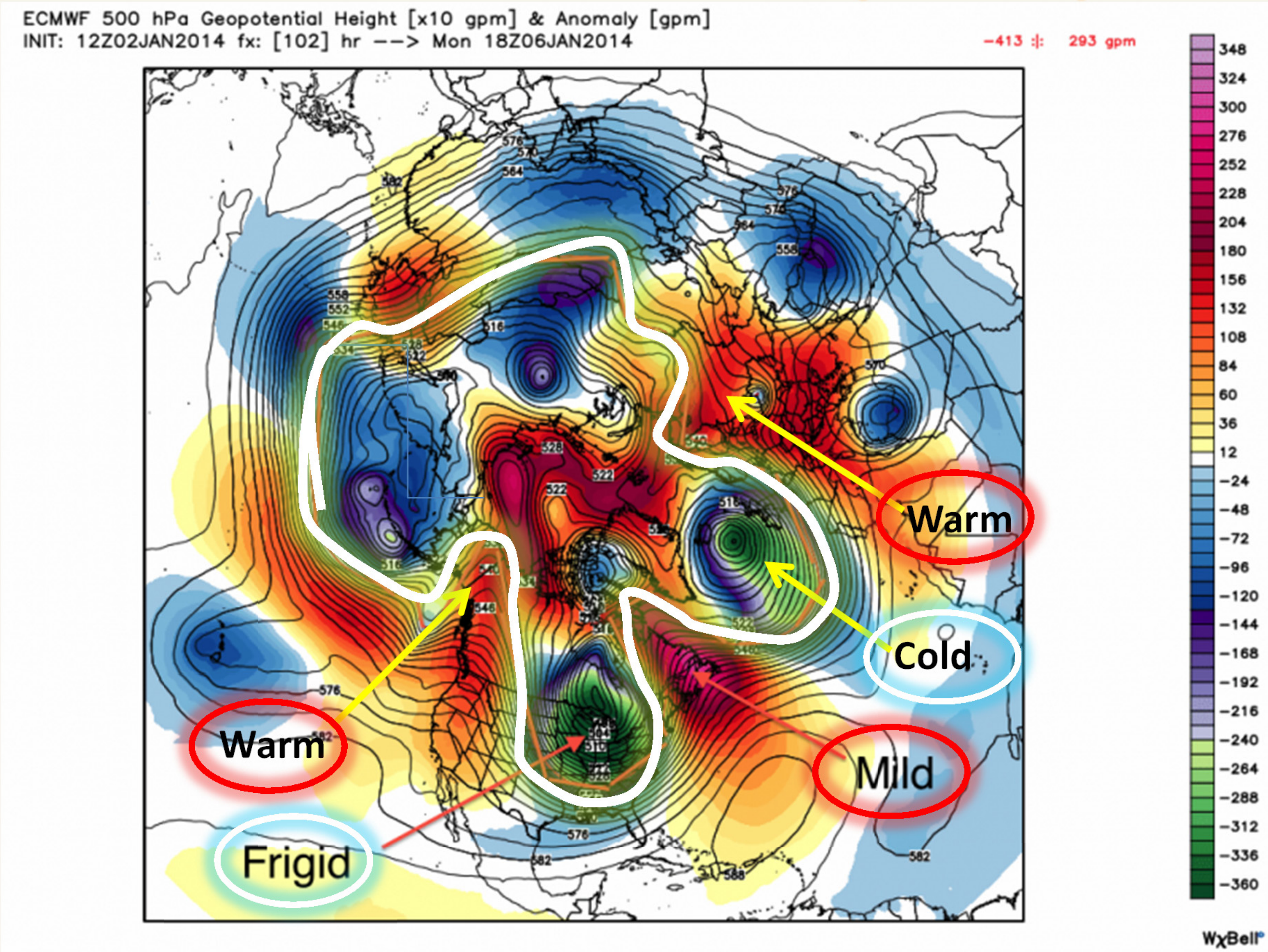
Normal "POLAR VORTEX" of west to east flowing winds traps cold air in the Arctic:

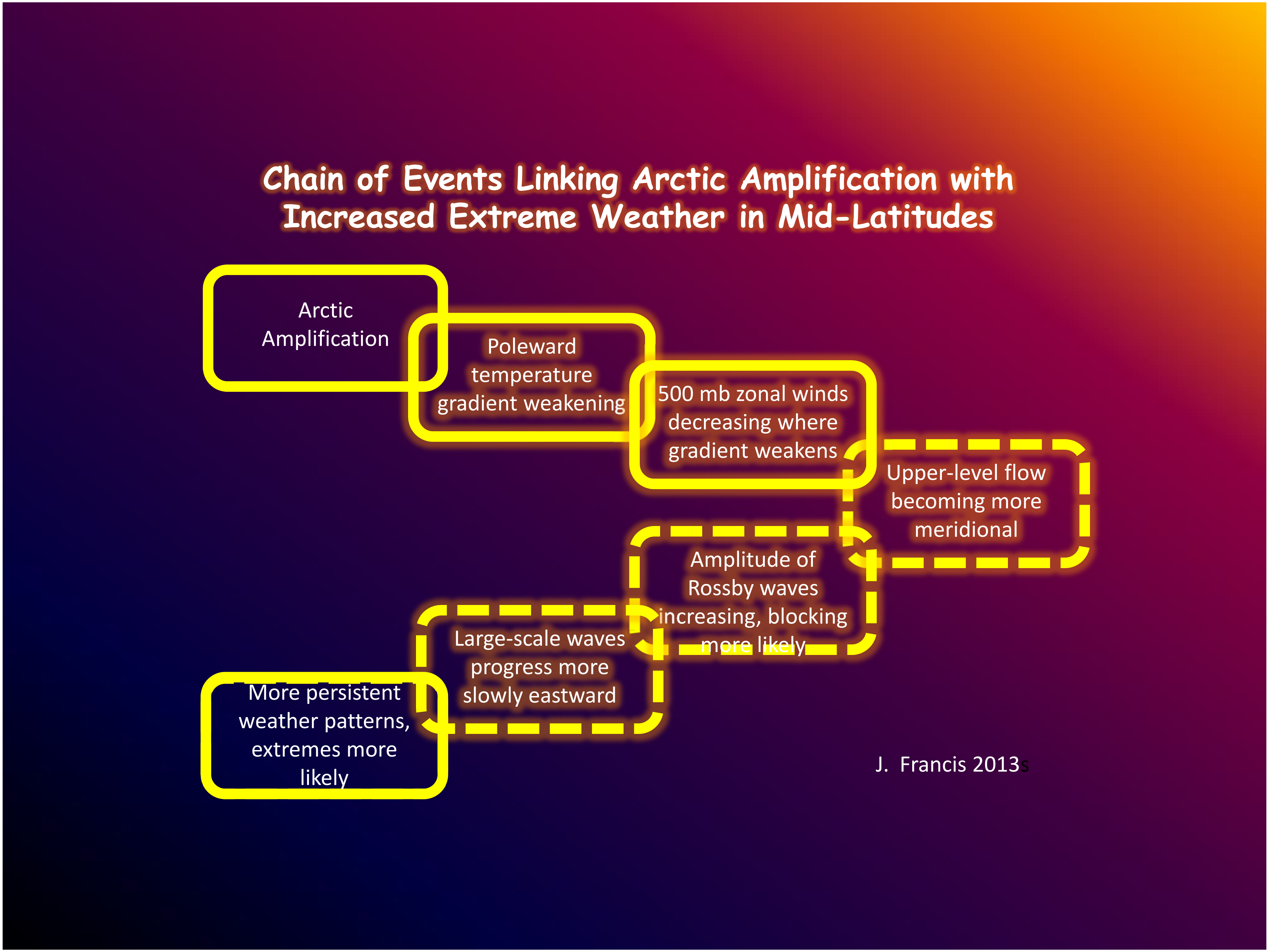
Positive Arctic Oscillation

850 GEO HGT
DEC Climatology

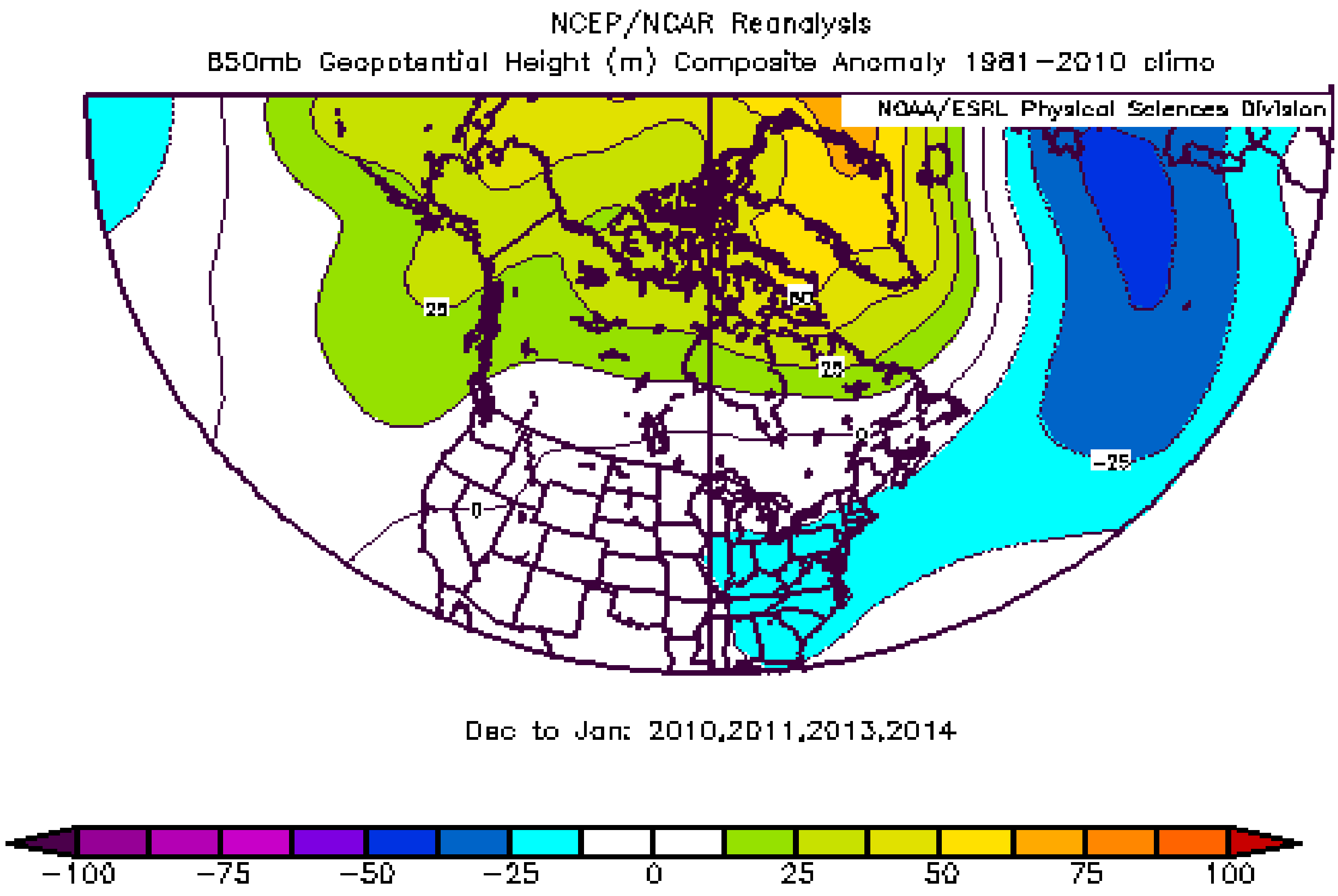


Attack of the Polar Vortex – Early January 2014

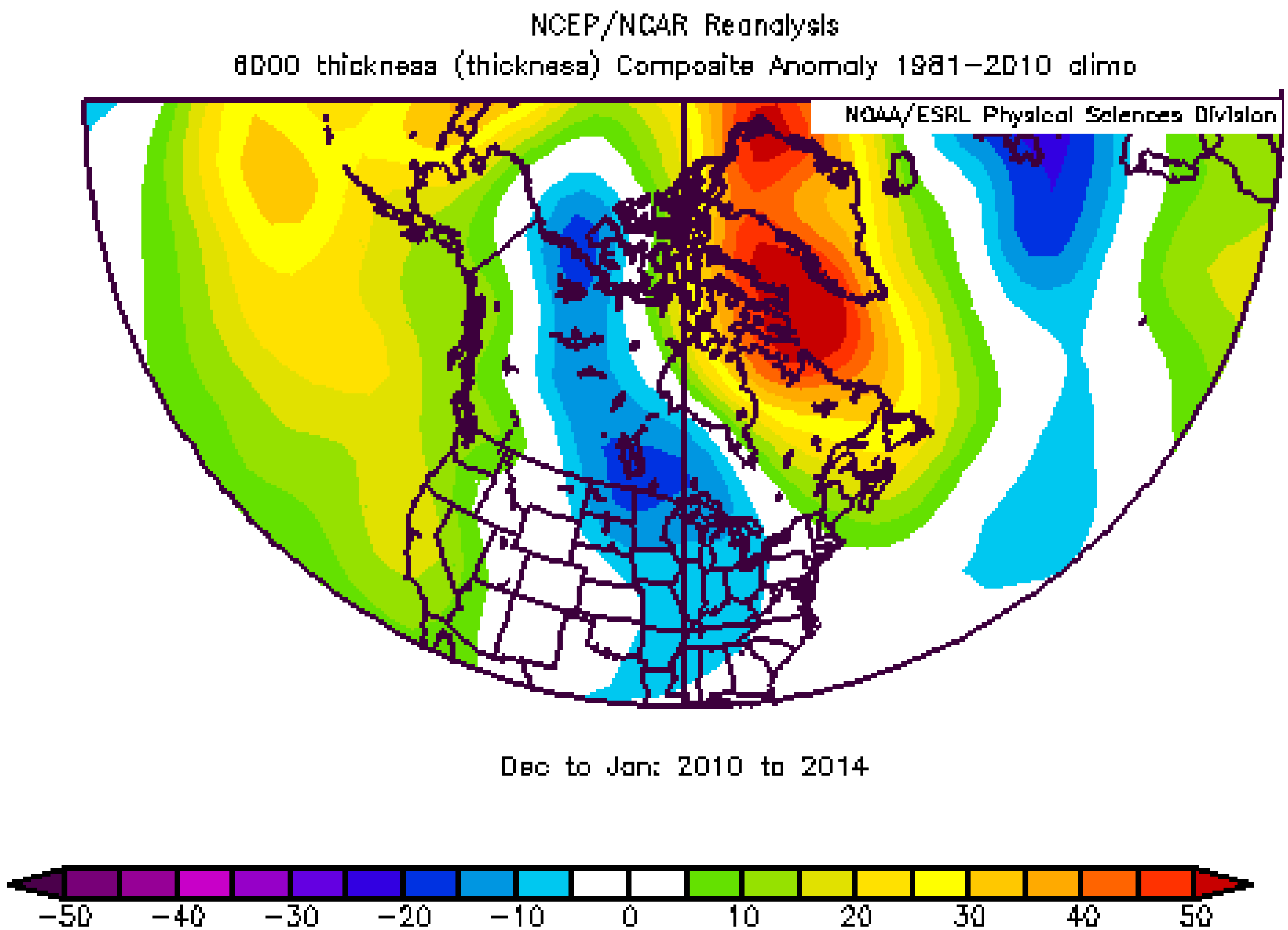



Chain of Events Linking Arctic Amplification with Increased Extreme Weather in Mid-Latitudes
Arctic Amplification
Poleward temperature gradient weakening
500 mb zonal winds decreasing where gradient weakens
Upper-level flow becoming more meridional
Amplitude of Rossby waves increasing, blocking more likely
Large-scale waves progress more slowly eastward
More persistent weather patterns, extremes more likely
J. Francis 2013

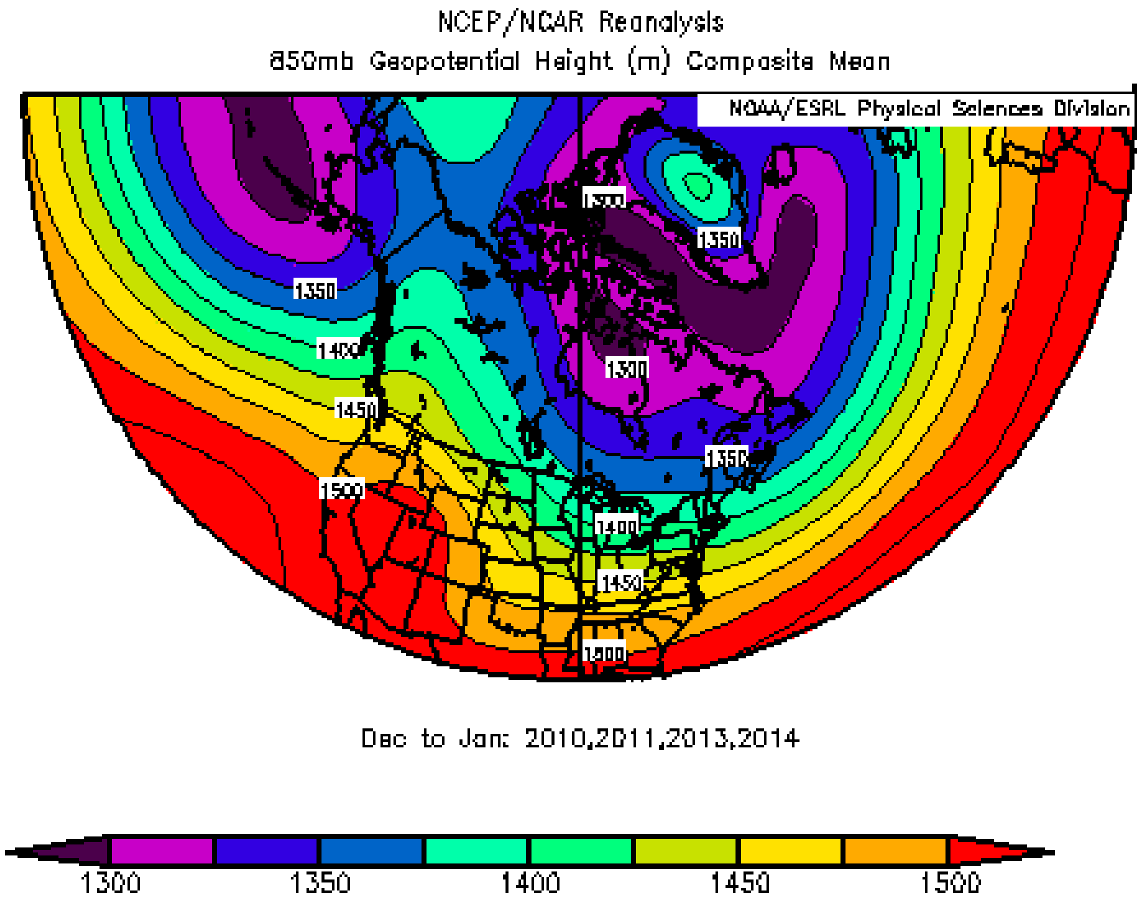
Greenland Blocking for December-January for 2009-10, 2010-11, 2012-13 and 2013-14.

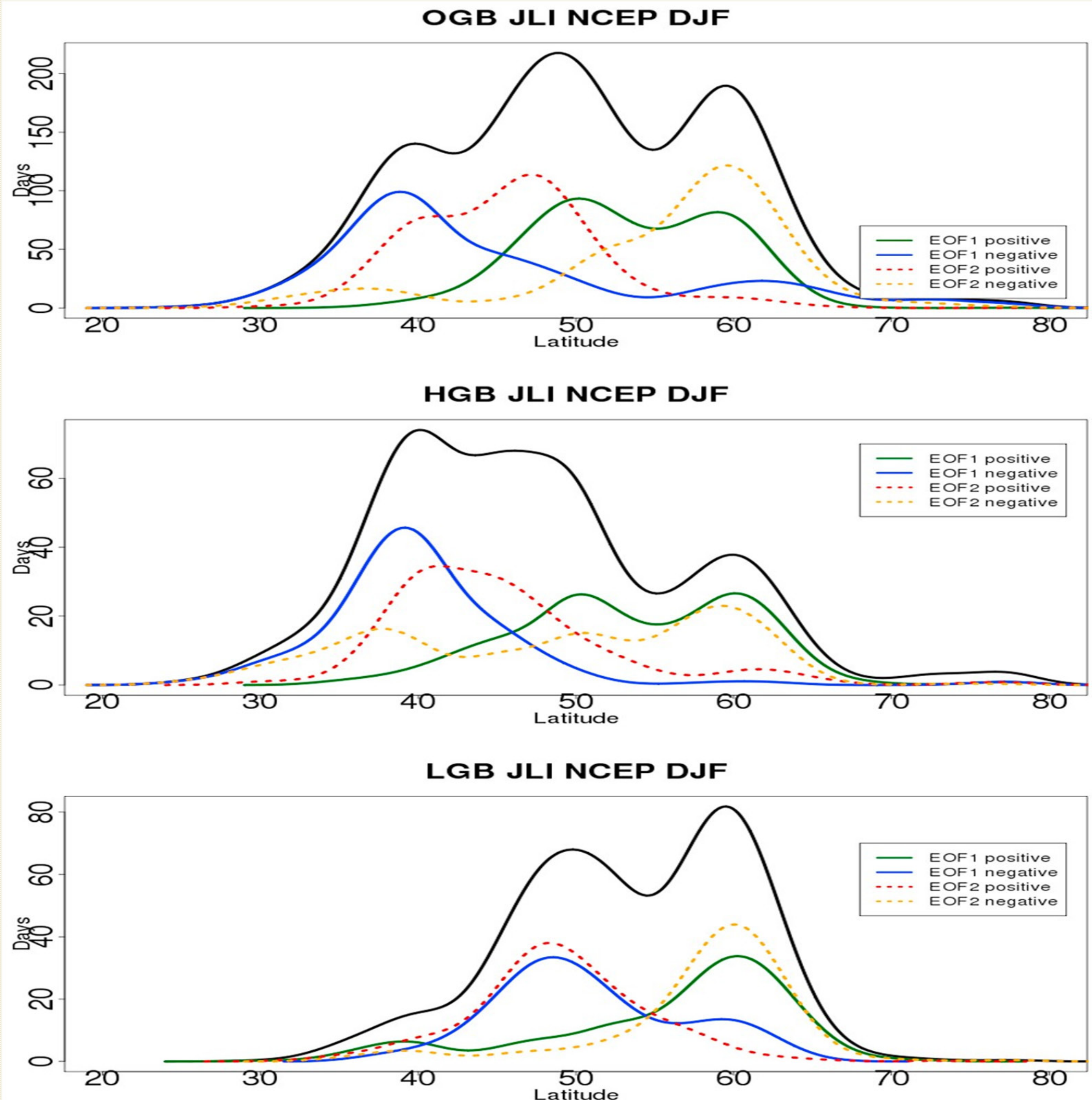


Composite 1000-500 hPa geopotential thickness anomaly field (proportional to air temperature) for December-January 2009-10, 2010-11, 2012-13 and 2013-14.



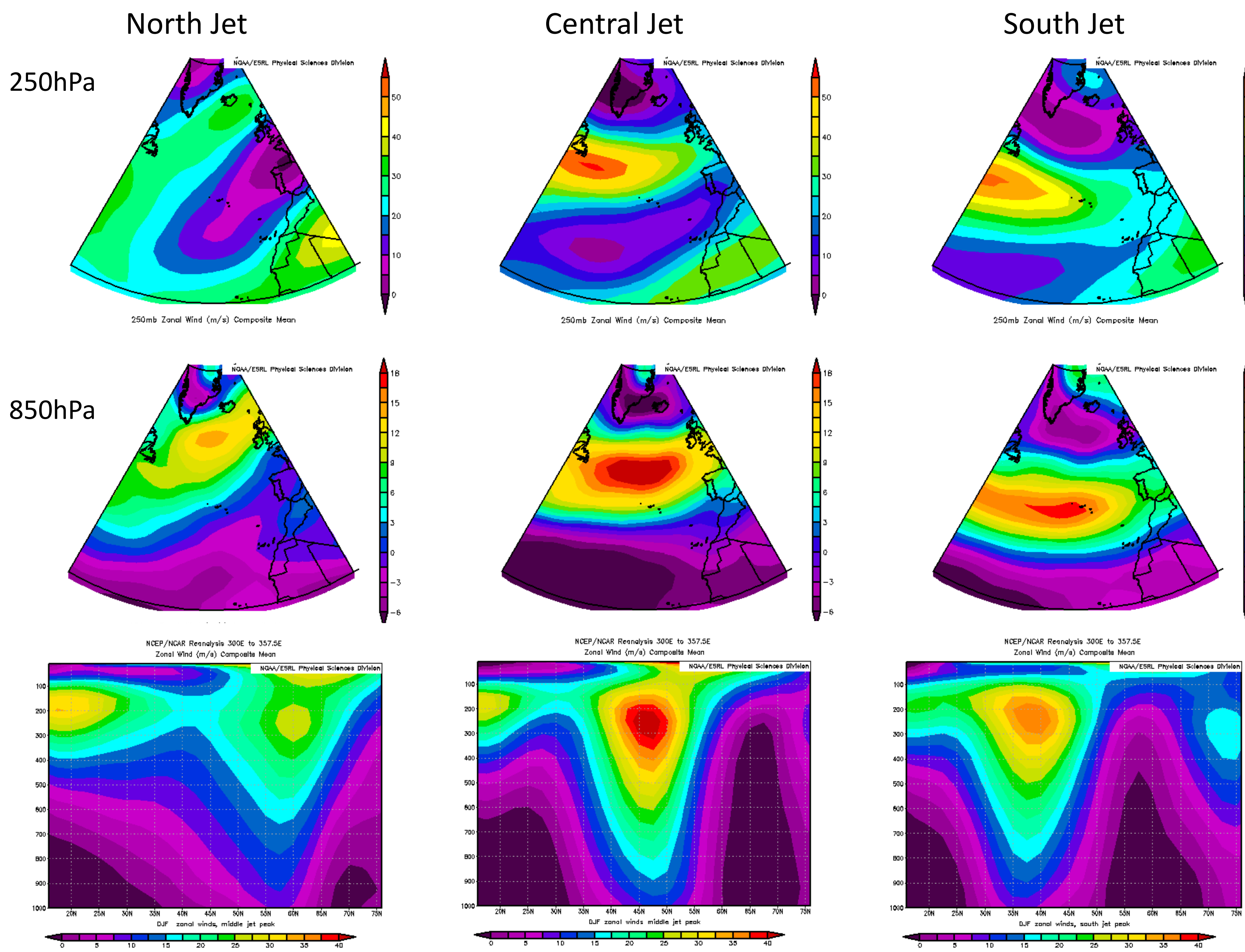
Atmospheric Wind flow, Greenland Blocking and southern N Atlantic Jet Stream for December-January for 2009-10, 2010-11, 2012-13 and 2013-14.

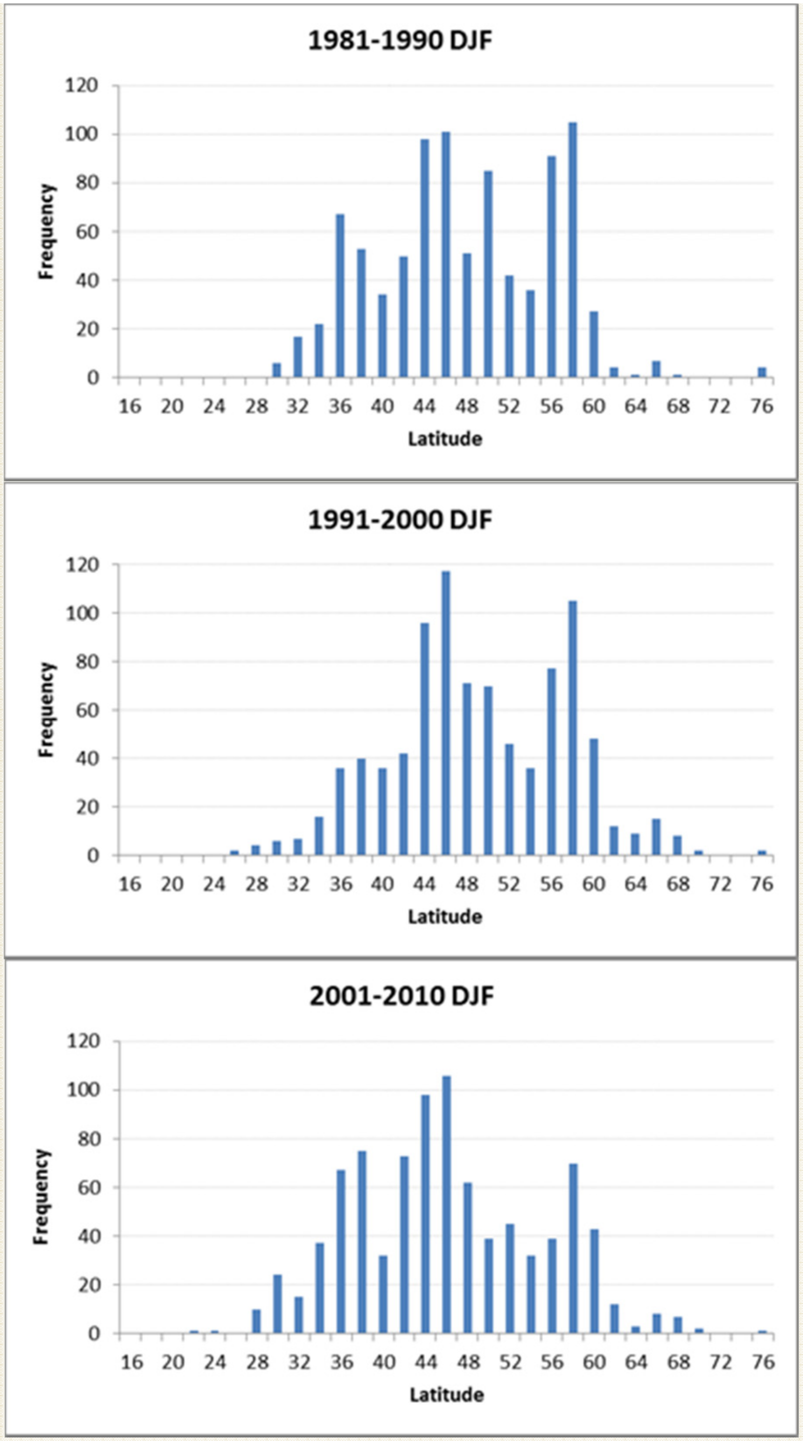




OGB JLI NCEP DJF
Days
Latitude
EOF1 positive
EOF1 negative
EOF2 positive
EOF2 negative
HGB JLI NCEP DJF
Days
Latitude
EOF1 positive
EOF1 negative
EOF2 positive
EOF2 negative
LGB JLI NCEP DJF
Days
Latitude
EOF1 positive
EOF1 negative
EOF2 positive
EOF2 negative

Davani
2012

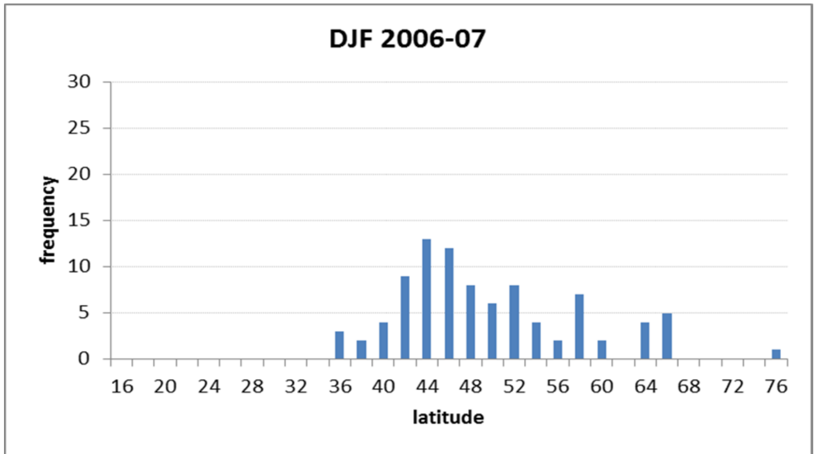

North Jet
Central Jet
South Jet
250hPa
850hPa
NOAA/ESRL Physical Sciences Division
250mb Zonal Wind (m/s) Composite Mean
NCEP/NCAR Reanalysis 300E to 357.5E
Zonal Wind (m/s) Composite Mean
DJF zonal winds, middle jet peak
DJF zonal winds middle jet peak
DJF zonal winds, south jet peak



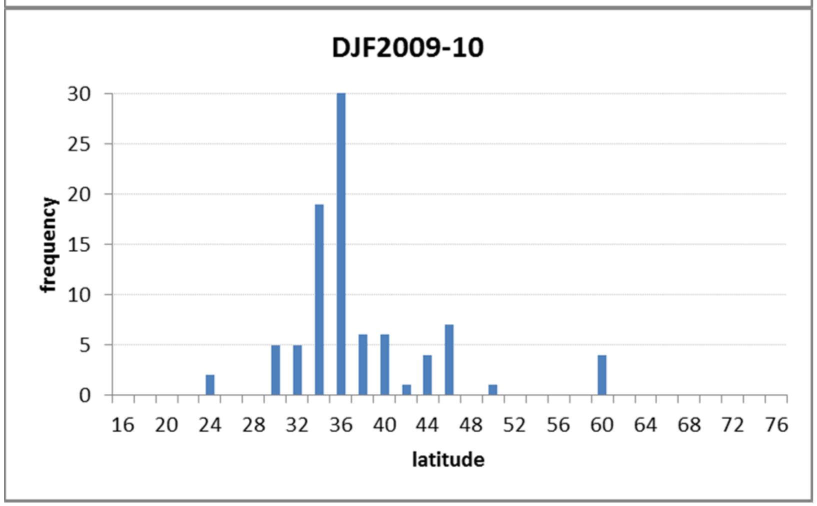
Pattern of preferred latitudes is robust over time, but with changing proportions for each peak.

0-60°W, 16-76°N, 900-700hPa, zonal winds,from 20CR

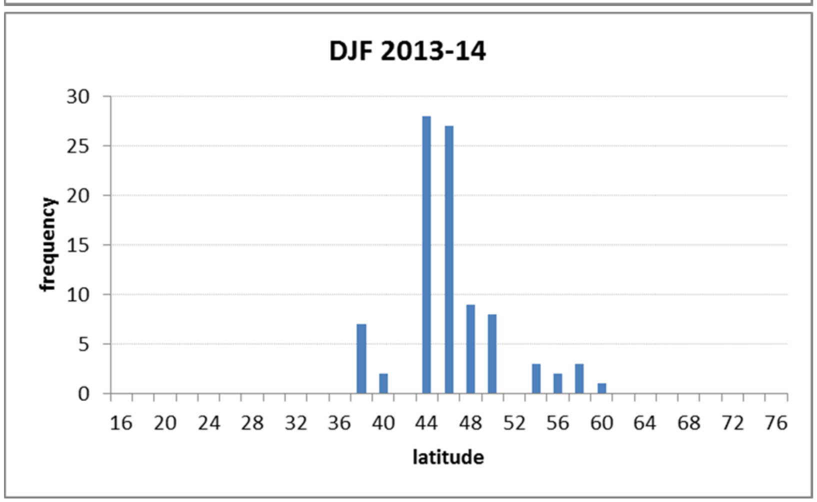
R Hall



All regimes are not necessarily represented in an individual season.



2009-10 an extreme example with a large number of days representing the southern regime. Cold winter in W Europe and E USA.
A negative NAO prevalent



2013-14 an extreme example with a large number of days representing the northern regime. Mild, very wet and Stormy in UK(but not the US!)
A positive NAO prevalent

Warm Arctic-Cold Continents

Loss of sea ice and snow pushes toward a wavy jet stream and greater chance for north-south wind flow over N. America. Negative AO

BUT Complexity: chaotic jet stream; it will not happen the same way in every year and location

NAO is a resulting Indicator; Greenland Blocking is primary dynamic indicator, resulting in more southern shift to North Atlantic wind jet