CIRES

NCAR
National Center for Atmospheric Research
Boulder, Colorado

NSIDC
National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

NSF

Impacts on Arctic Sea Ice Predictions of Extreme Weather and Natural Variability

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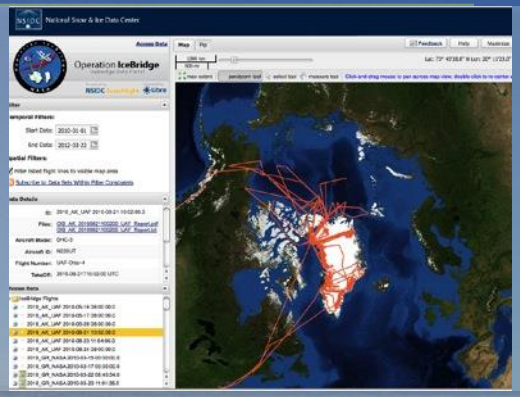
NSIDC

The National Snow and Ice Data Center…

Manages and distributes scientific data

Provides tools for data access



Researches the cryosphere and data science

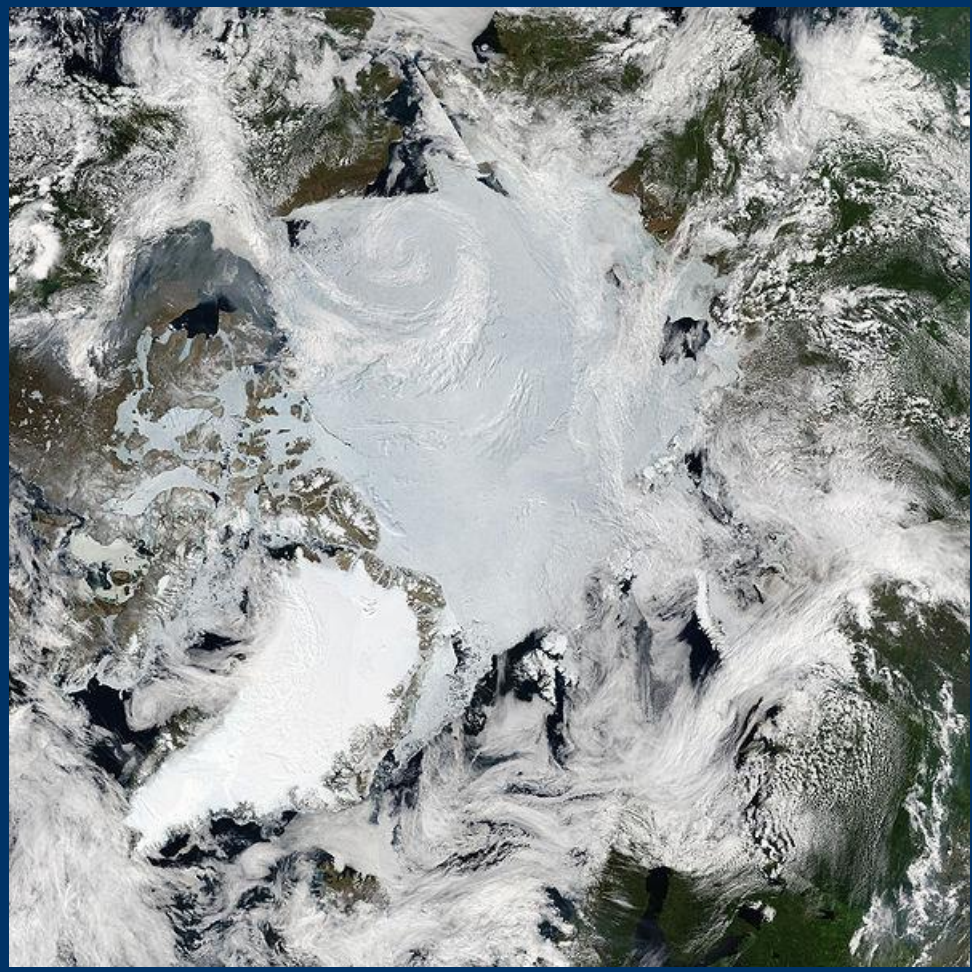
Supports local and traditional knowledge

Supports data users

Educates the public about the cryosphere

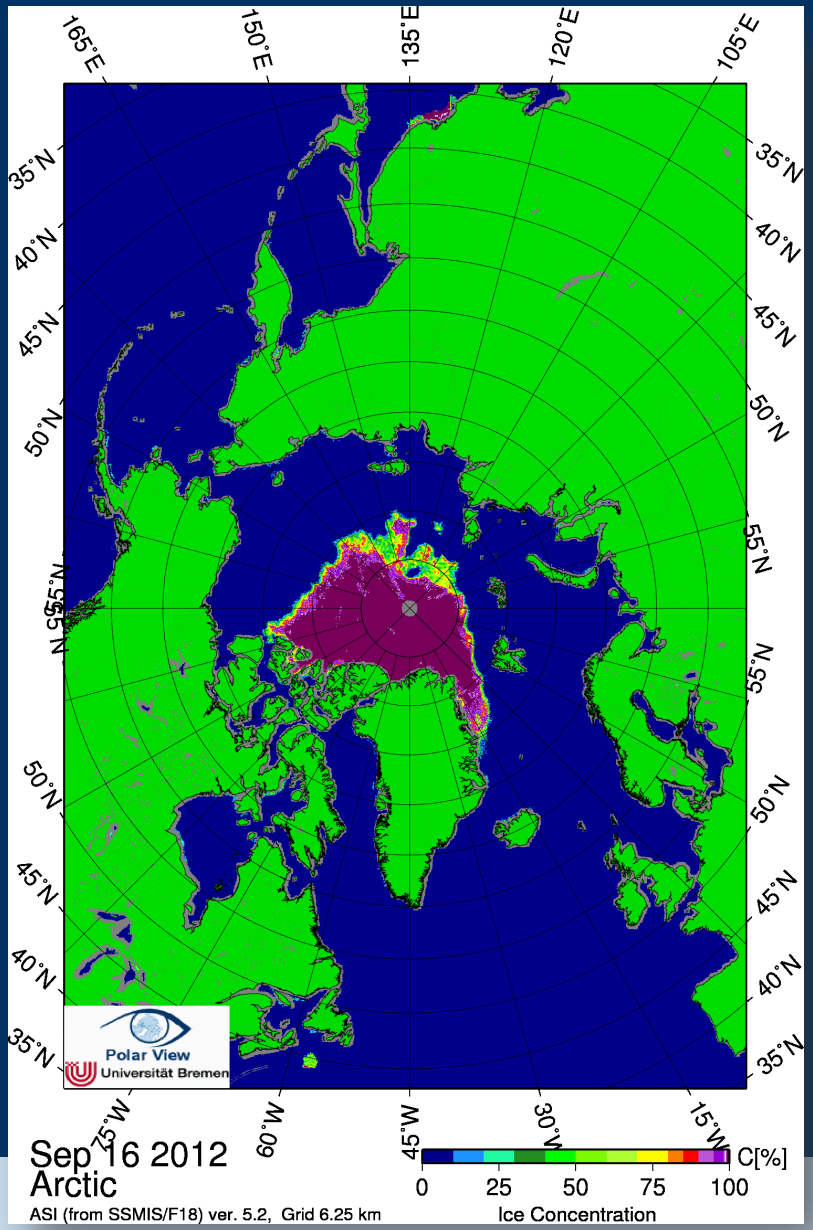
CIRES

Two views of the Arctic

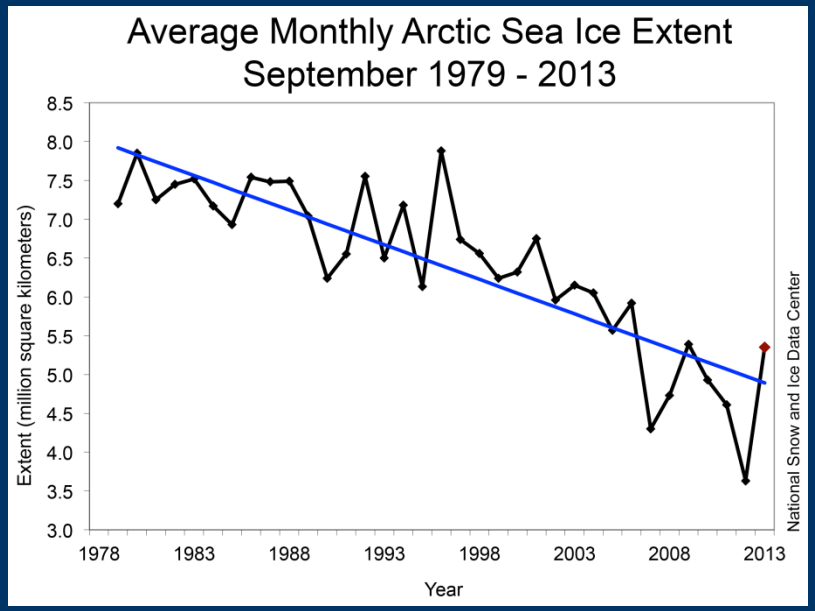


[NSIDC (left) and (right), http://lance.nasa.gov/imagery/rapid-response/]

We are losing the perennial sea ice cover



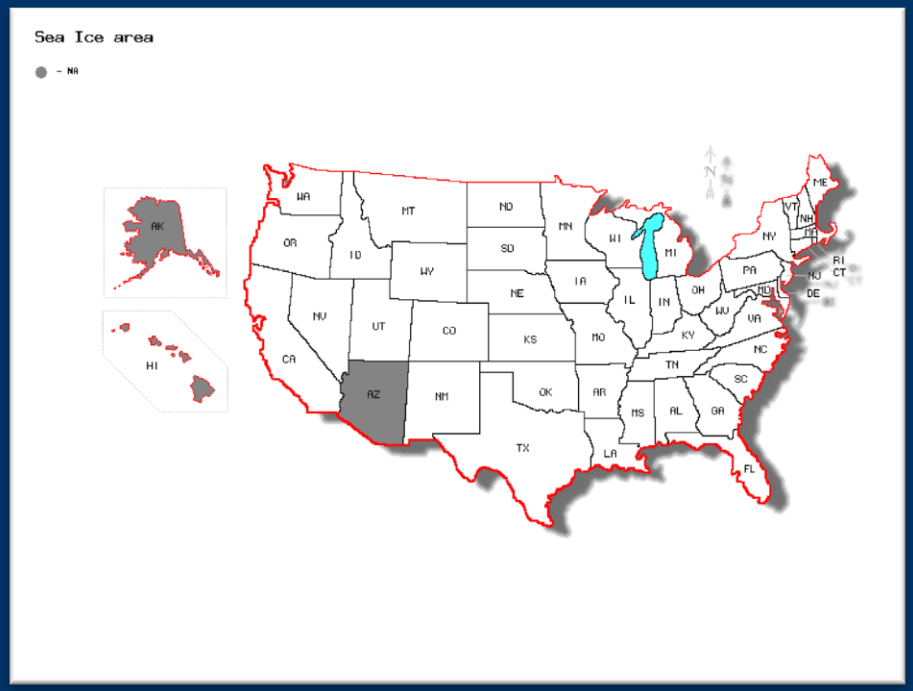
1) Sept 16, 2012: 3.41 million sq. km
2) Sept 16, 2007: 4.17 million sq. km
3) Sept 9, 2011: 4.33 million sq. km
4) Sept 14, 2008: 4.51 million sq. km
5) Sept 19, 2010: 4.60 million sq. km



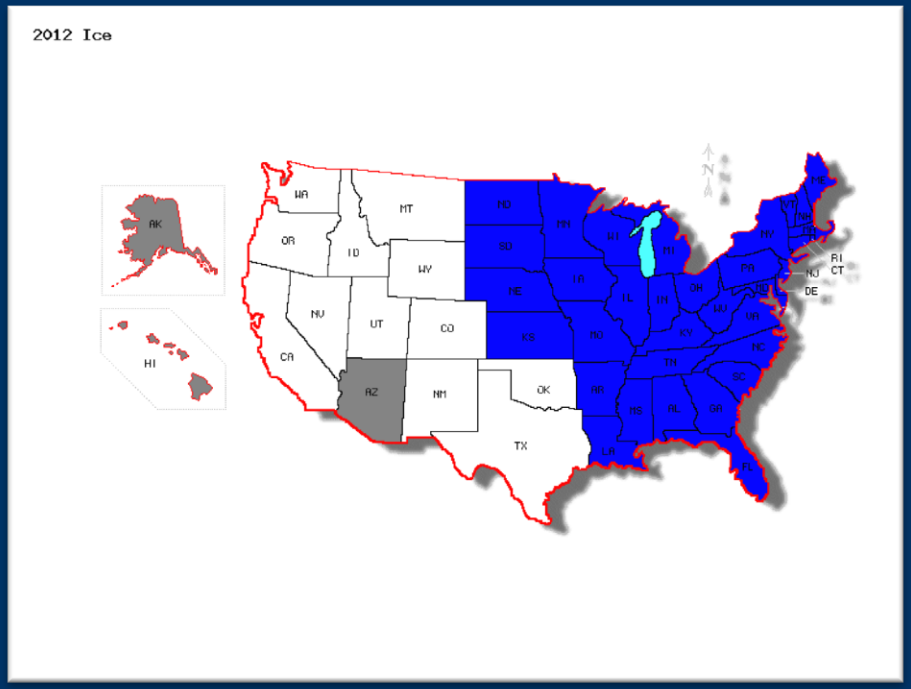
Left: Univ. Bremen; right: NSIDC

Putting September 2012 into perspective

September 1980



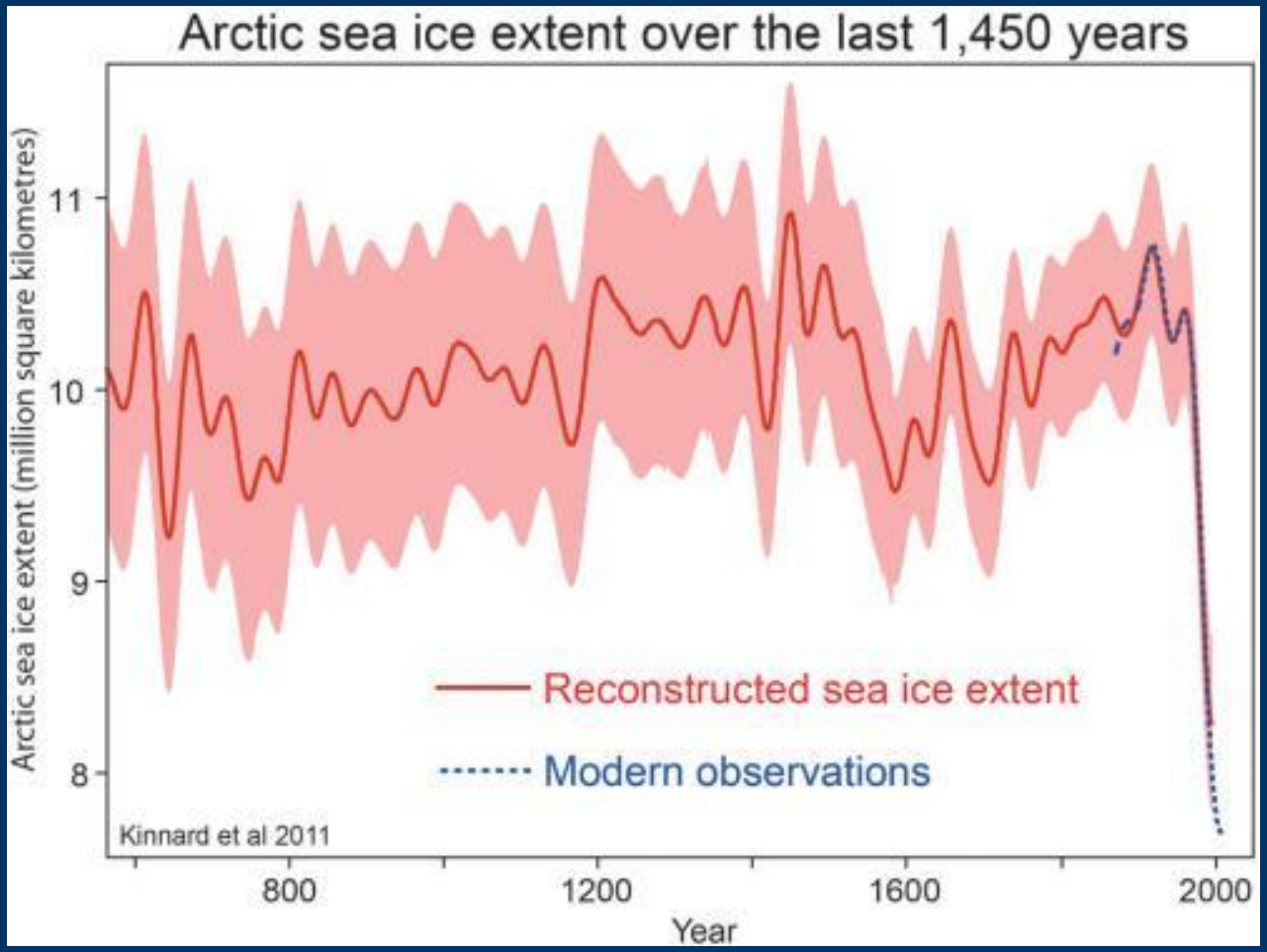
September 2012



More than a 40% reduction compared to the late 1970s

Courtesy Walt Meier, NSIDC

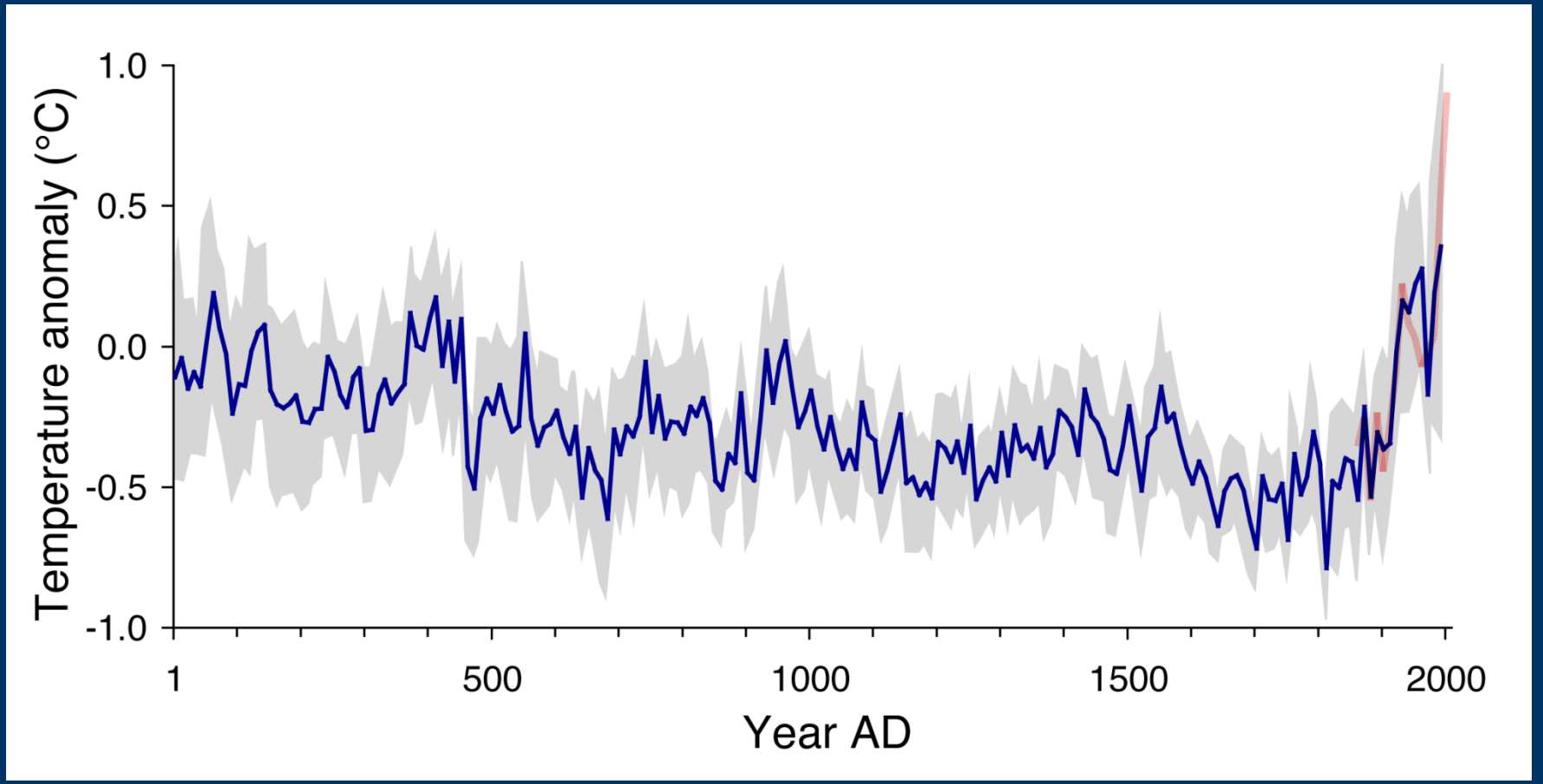
Putting the satellite record into a longer perspective



Summer average extent based on paleoclimate records compared to modern observations – a “hockey stick”, but with the blade pointing down

Kinnard et al., 2011

Arctic summer temperatures for the past 2000 years

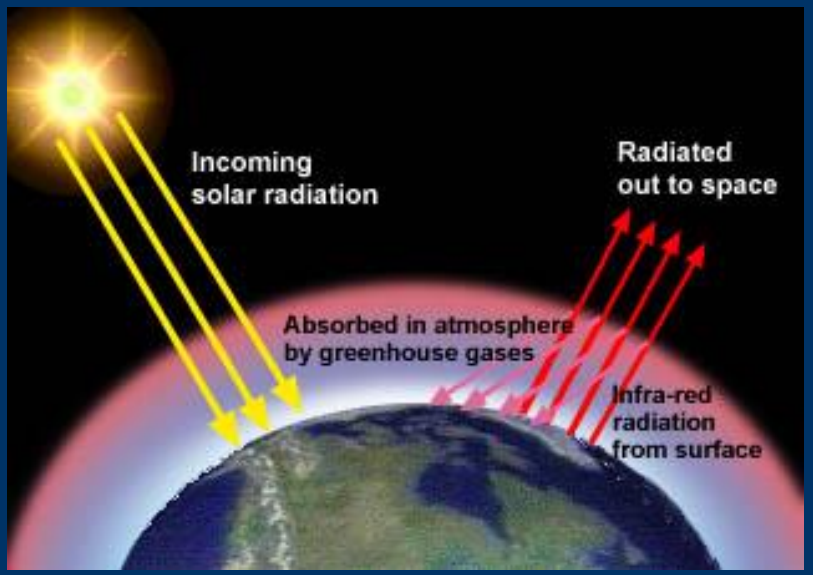


A composite of 23 proxy records from lake sediments, ice cores, and tree rings. relative to 1961-1990 reference period. The red line shows recent Arctic temperatures based on instrumental observations. Another “hockey stick”

Adapted from Kaufman et al. [2009]

Svante Arrhenius

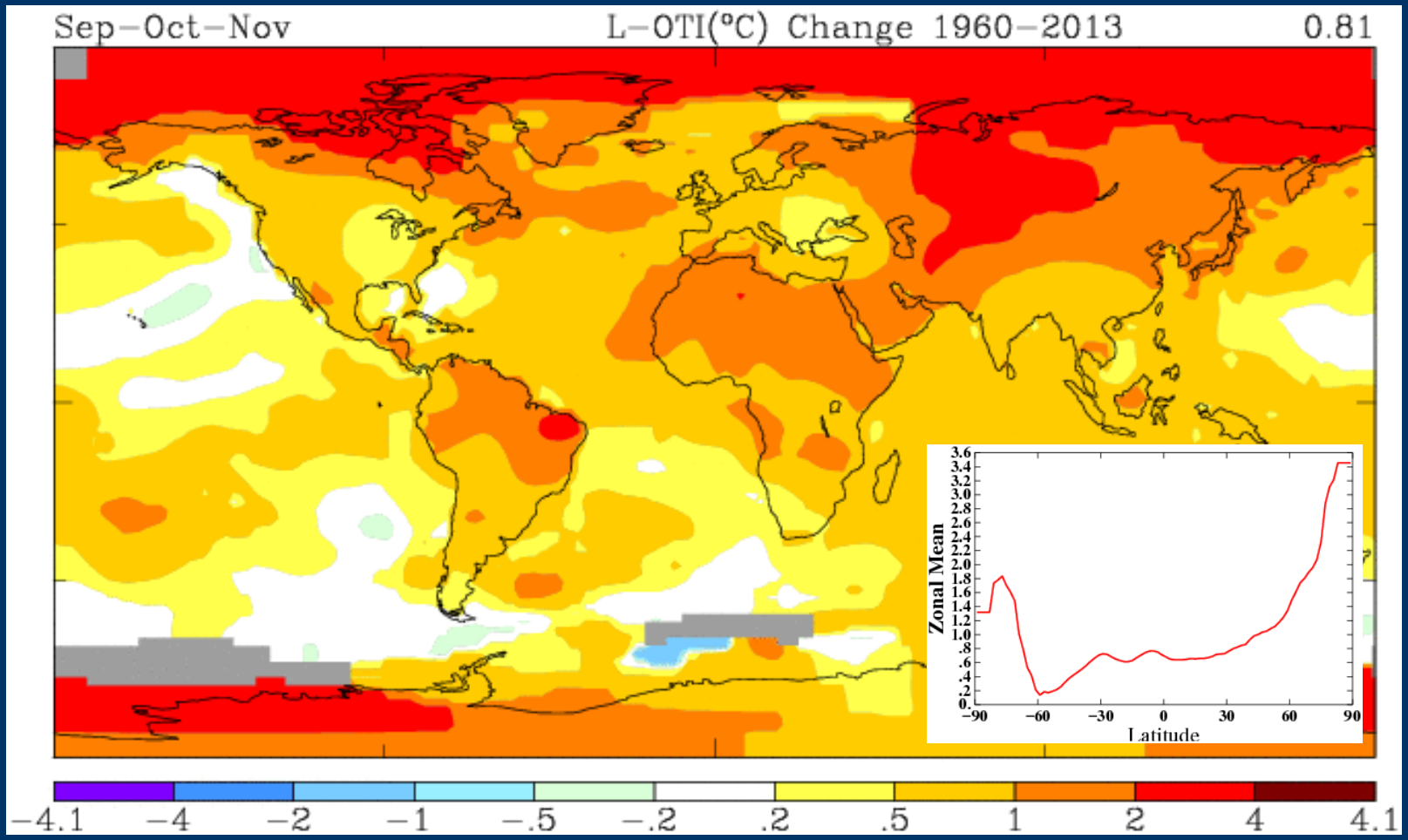
Back in 1896, the Swedish scientist Svante Arrhenius (winner of the Nobel Prize in chemistry) argued that rises in the concentration of carbon dioxide in the atmosphere would warm Earth's surface and that the warming would be especially large in the polar regions (Arrhenius, 1896).



Courtesy Tufts University

http://nobelprize.org/nobel_prizes/chemistry/laureates/1903/arrhenius-bio.html

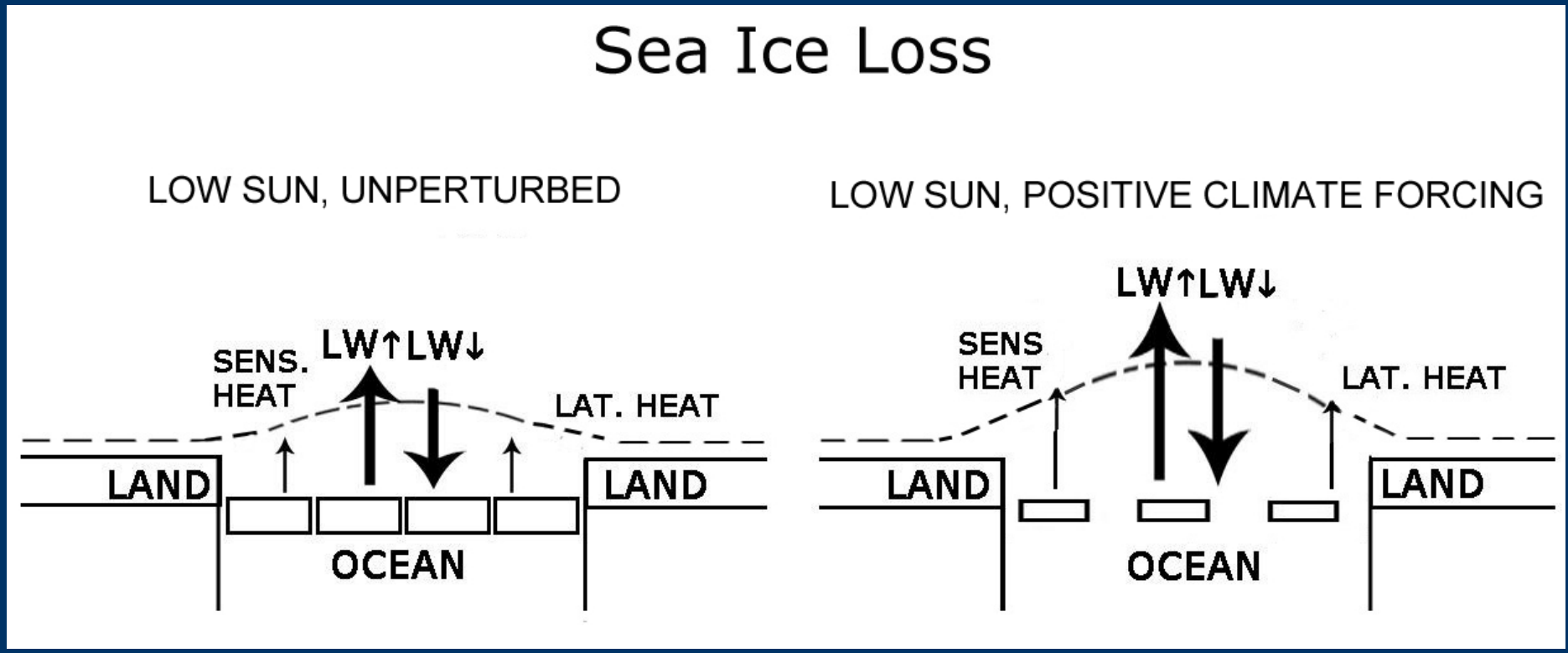
Observed autumn temperature trends, 1960-2013



Recent Arctic warming is greater than for the globe as a whole, best expressed in autumn and winter. Arctic Amplification is here.

GISS Analysis

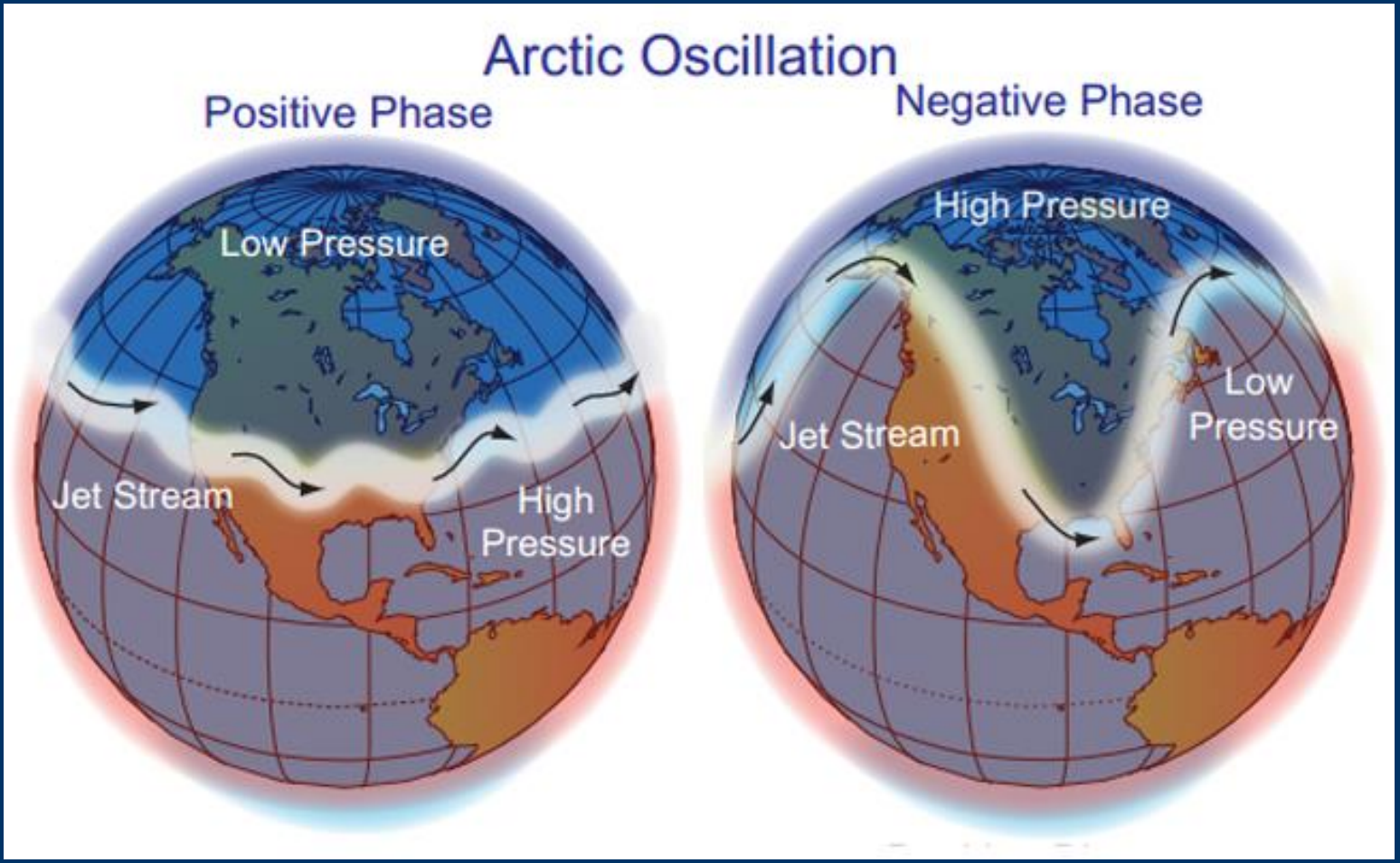
Sea ice loss and Arctic amplification



- Ocean picks up more heat in summer
- Releases more heat back to the atmosphere in autumn and winter
- Albedo feedback signal on temperature is seasonally delayed

Serreze and Barry, 2011

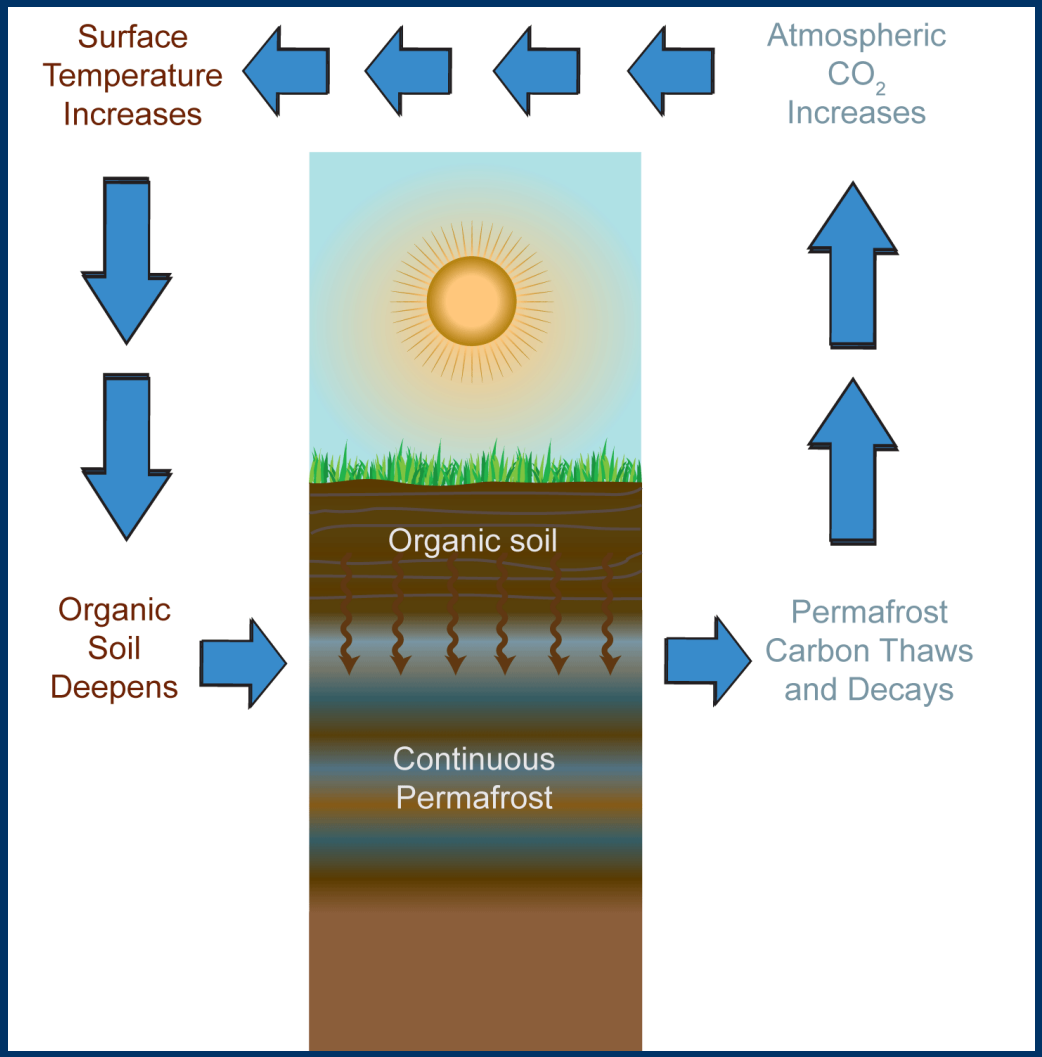
Impacts on mid-latitude weather patterns?



A big science question and VERY controversial

http://frontierscientists.com/2013/06/under-pressure-arctic-extreme-weather/

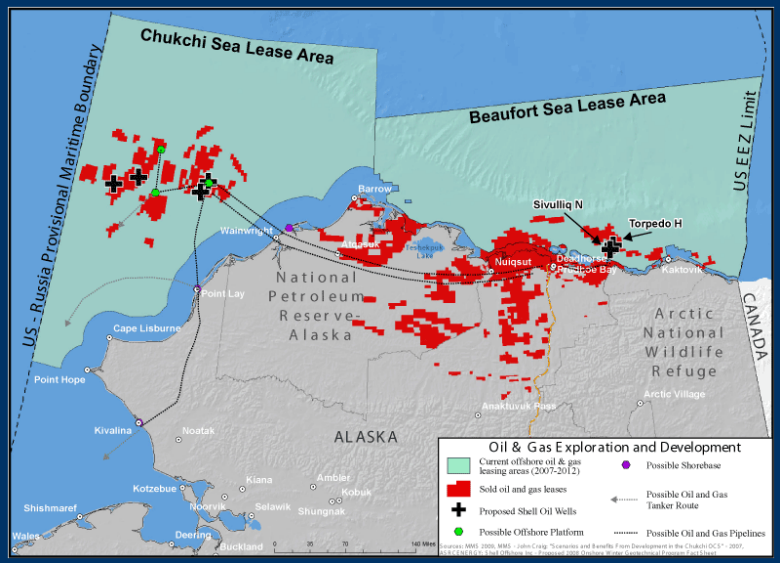
The permafrost carbon cycle feedback



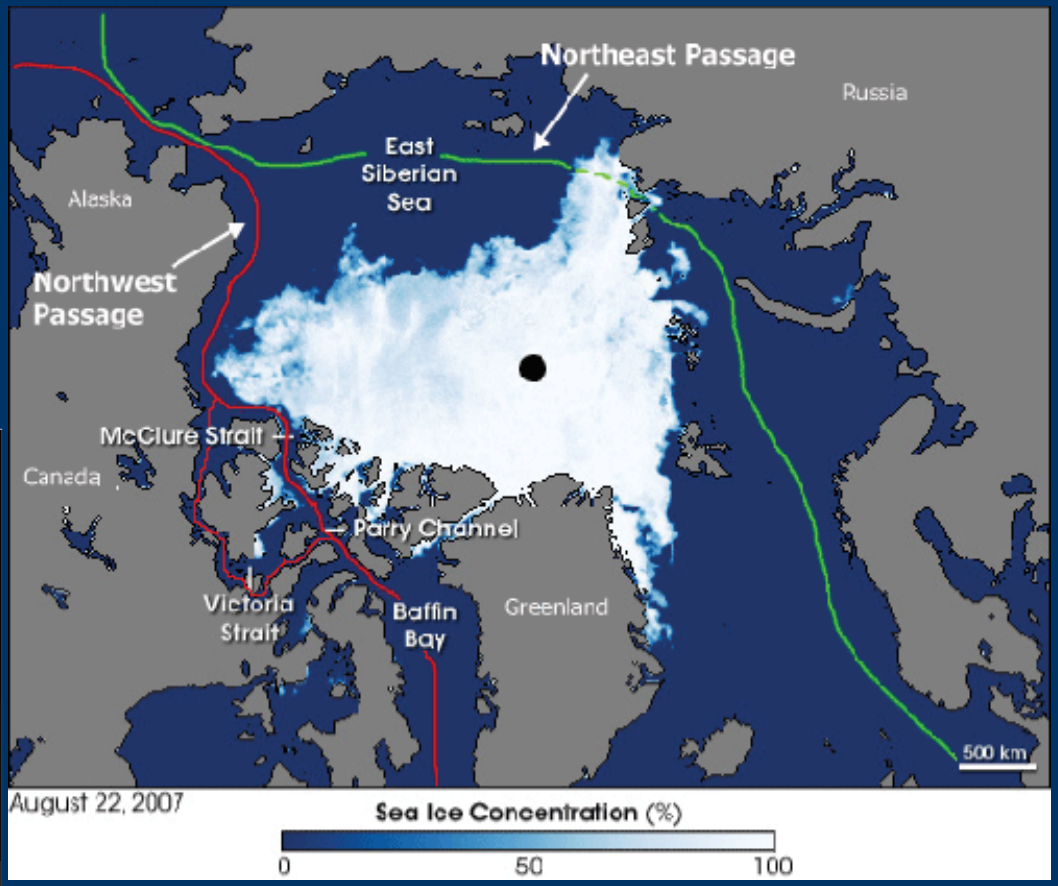
http://na.unep.net/geas/newsletter/Mar_11.html

NSIDC

Charismatic megafauna, commercial shipping, oil and gas

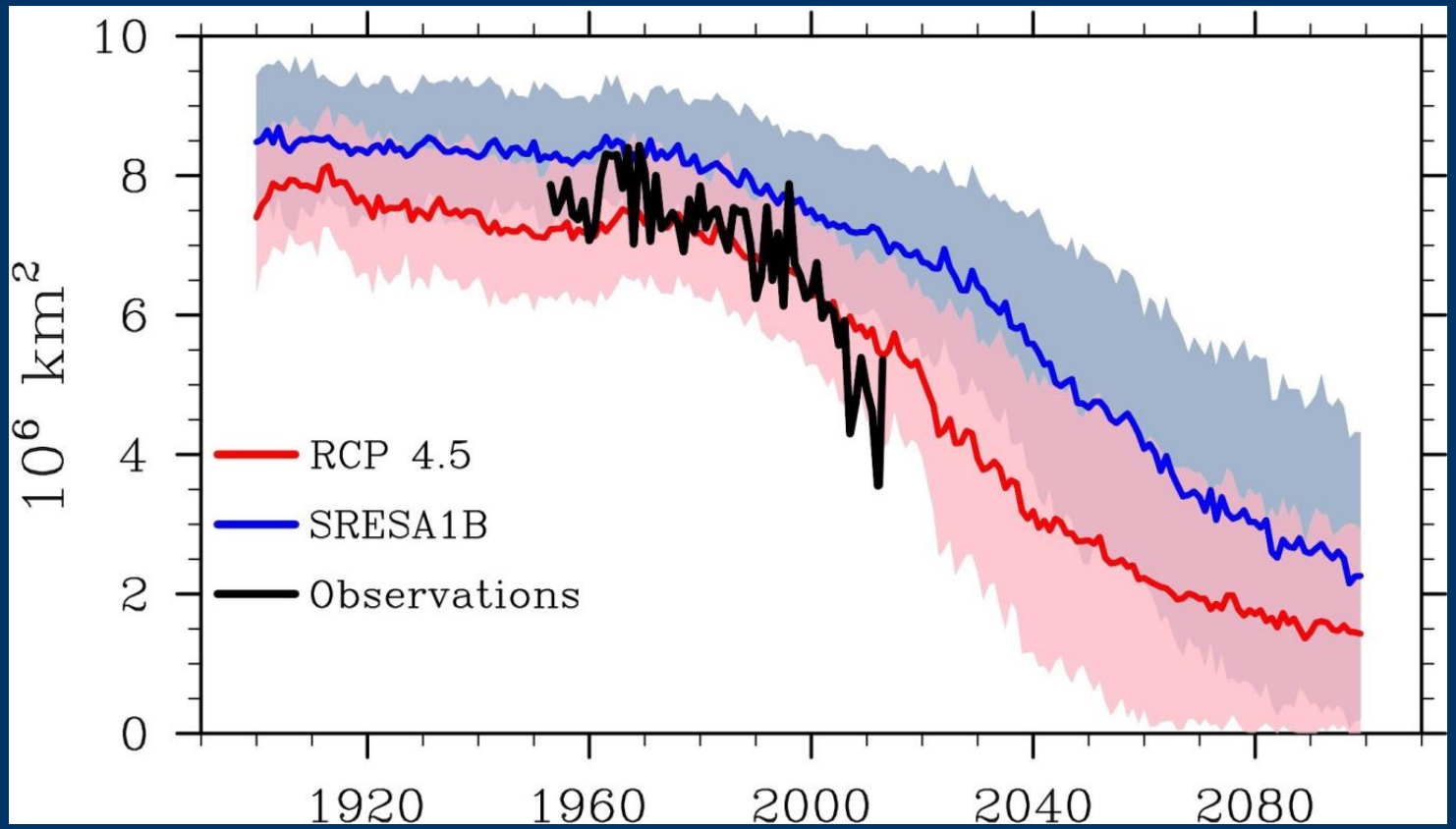


http://arcticoceanforever.com/the-risks/



http://www.wunderground.com/climate/NorthernPassages.asp

Conservative climate models and an uncertain future

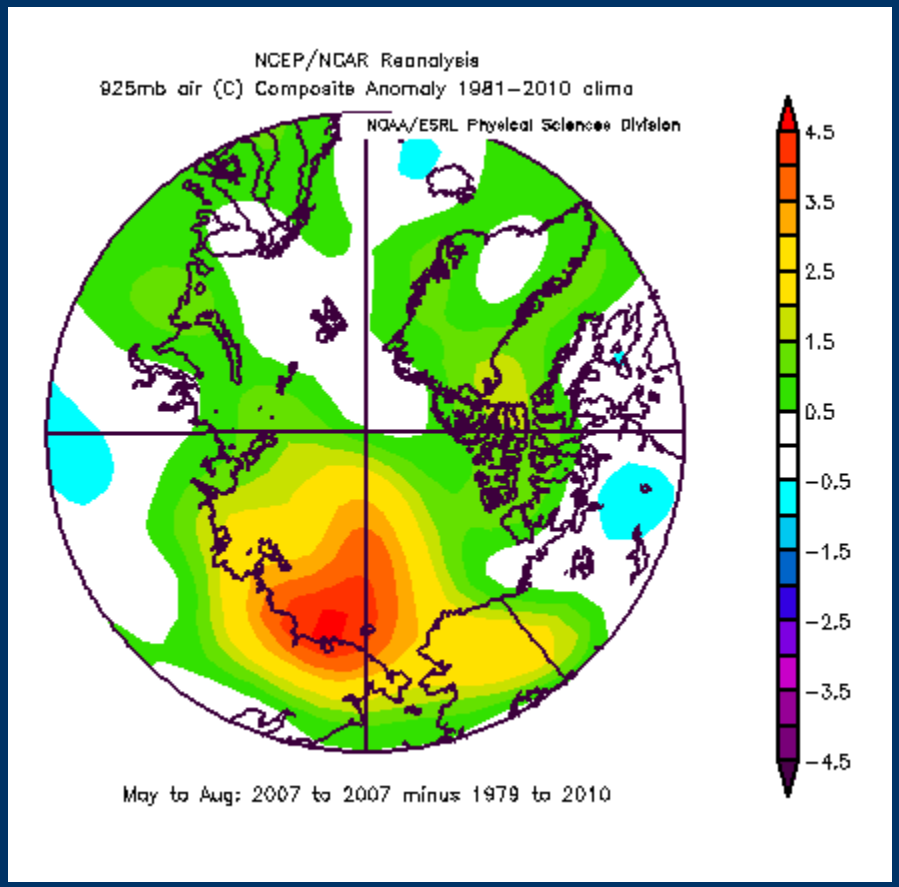


- Model architecture and physical treatments
- Uncertainties in future greenhouse gas emissions
- Natural climate variability (atmosphere and ocean)

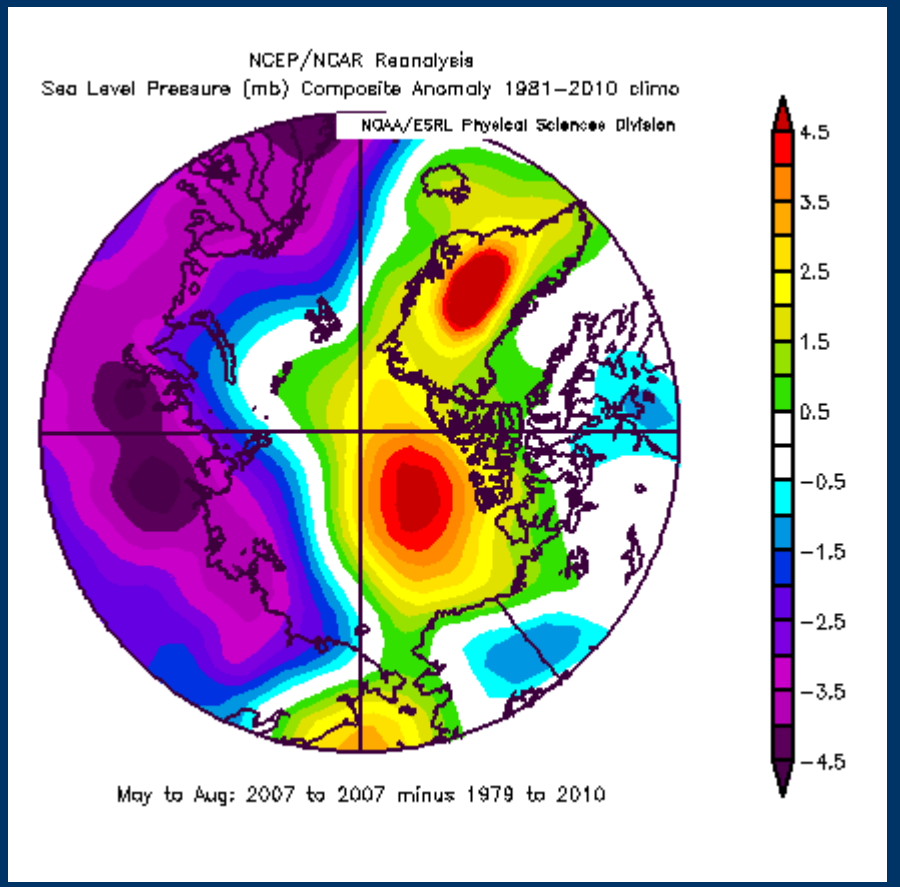
Adapted from Stroeve et al. (2012)

Summer 2007: The “Dipole Anomaly”

May to Aug. 925 hPa temp. anomaly



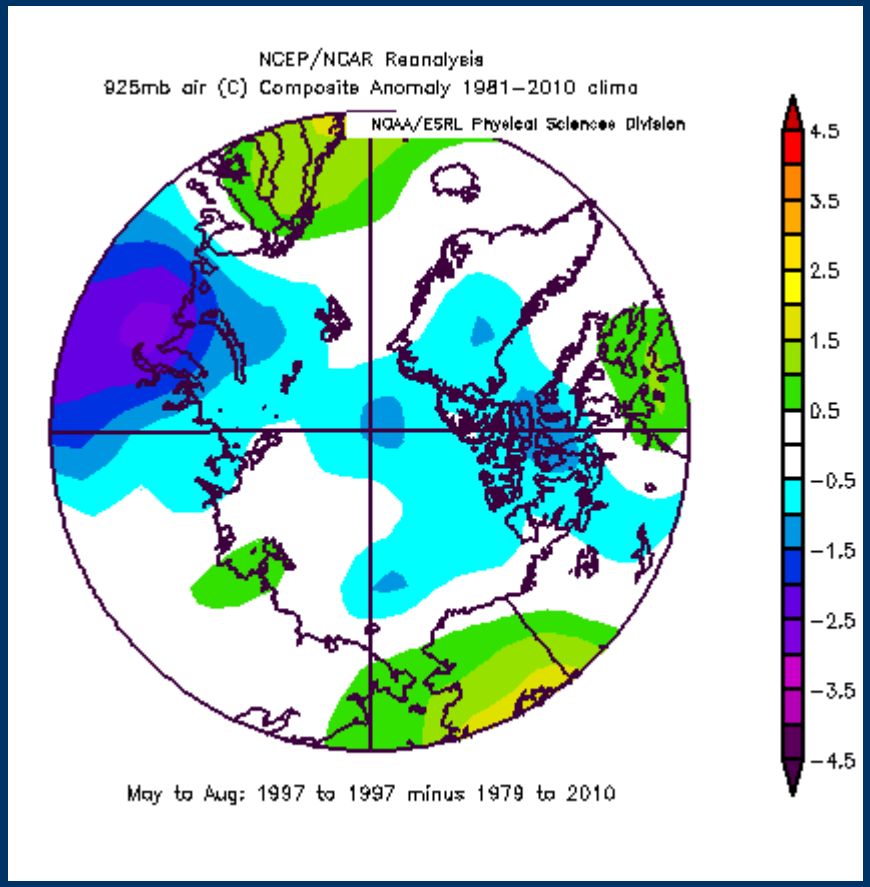
May to Aug. SLP anomaly



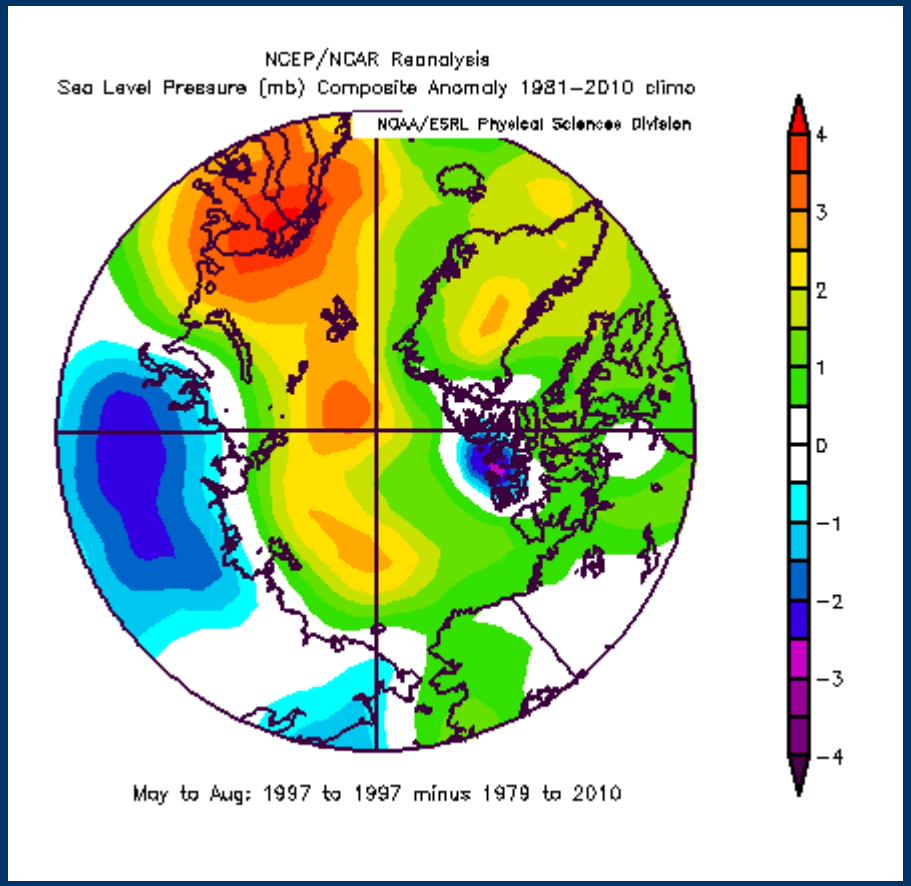
- At the time, 2007 had the lowest September extent on record
- Atmospheric conditions were highly conducive to summer ice loss

Summer 1997: A different pattern

May to Aug. 925 hPa temp. anomaly

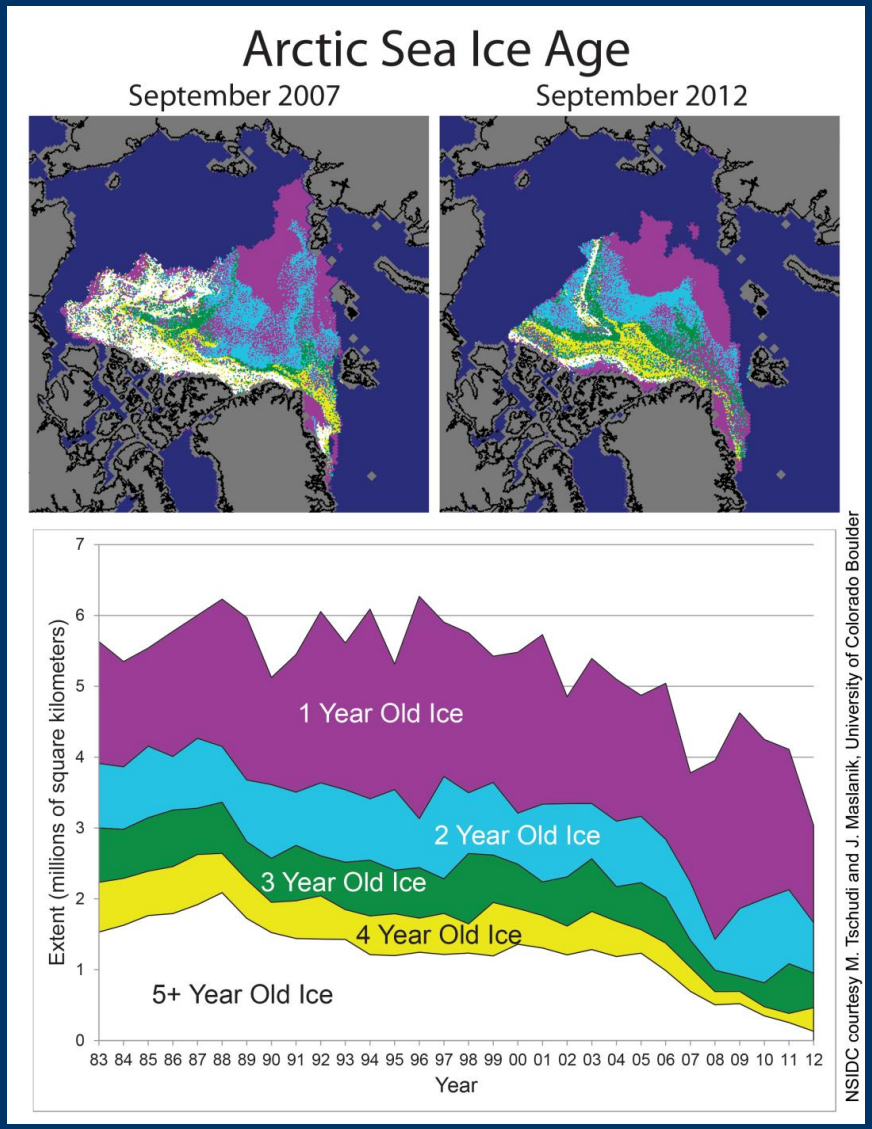


May to Aug. SLP anomaly



- The year 1997 has the highest September extent on record
- It was a relatively cool summer, with no pronounced “dipole anomaly”

The ice cover is getting younger and thinner



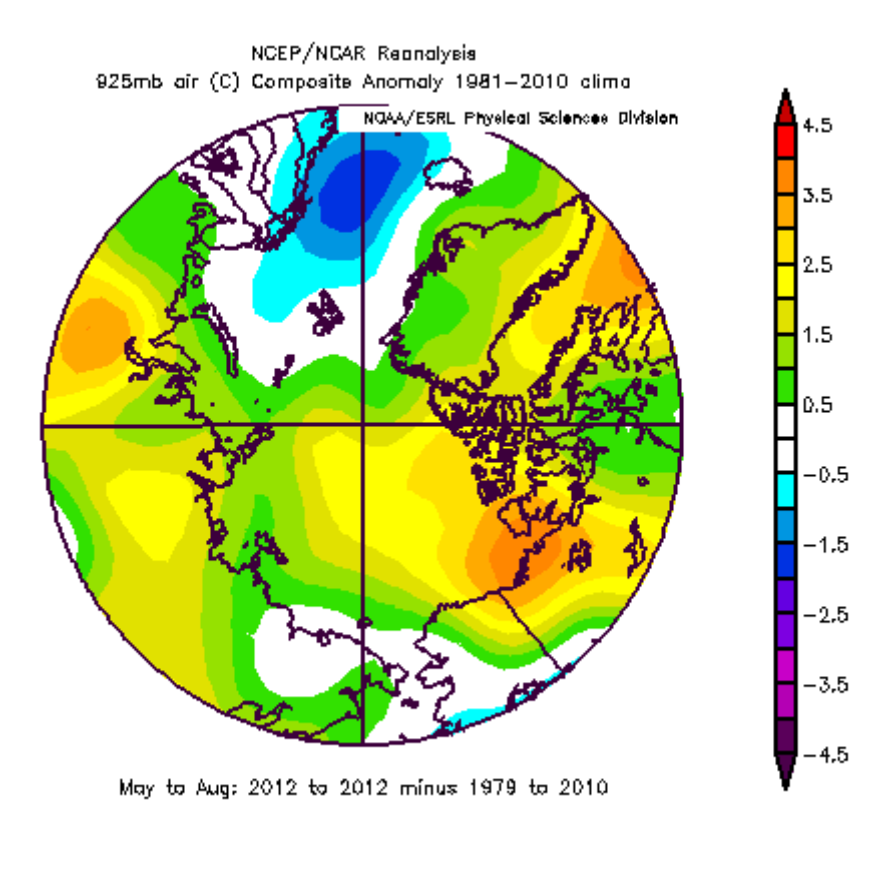
Ice age based on a tracking algorithm applied to satellite data. The top panel shows the spatial pattern of ice age classes for September 2012 and September 2007, while the bottom panel shows the time history of September age classes for the Arctic Ocean as a whole back to 1983.

Key point: Effects of natural variability are superposed upon the effects of thinning – ways in which the ice cover responded to atmospheric forcing in the past may no longer hold.

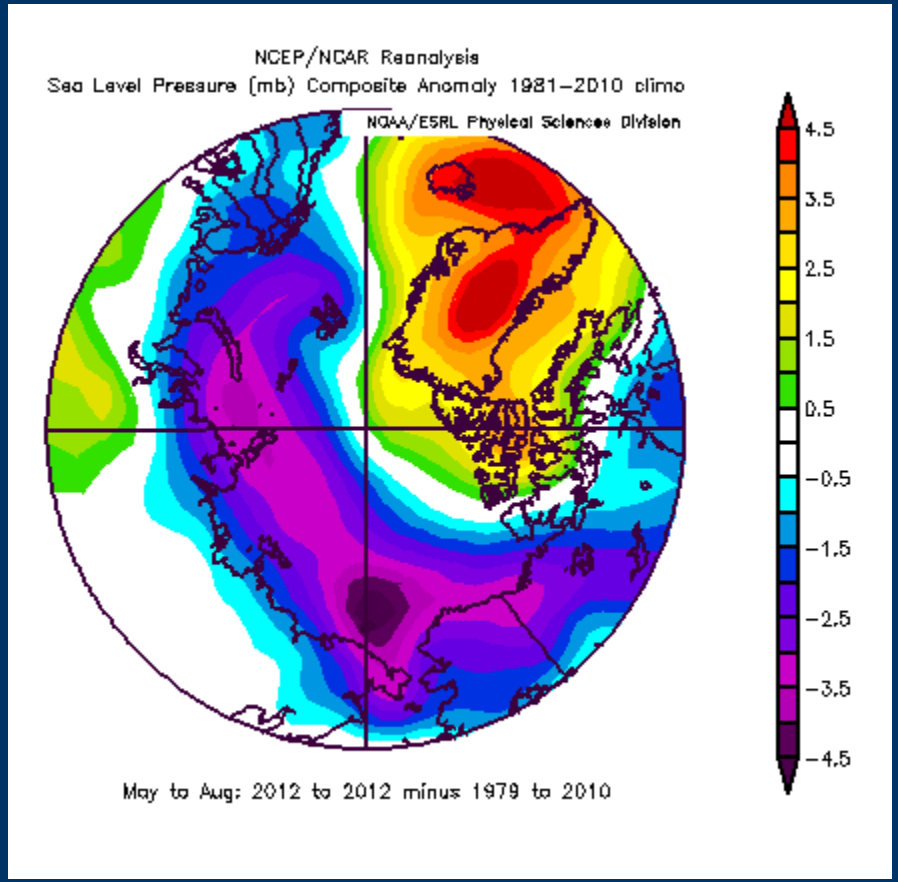
NSIDC, courtesy J. Maslanik and M. Tschudi

Summer of 2102: Ho hum atmospheric forcing

May to Aug. 925 hPa temp. anomaly



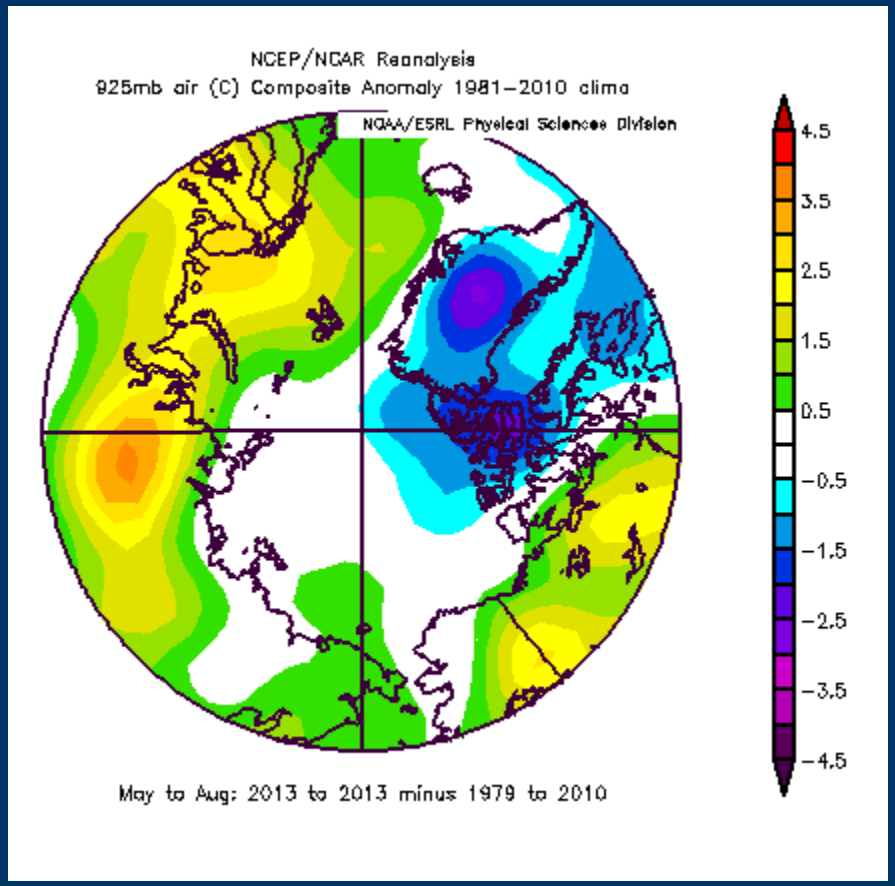
May to Aug. SLP anomaly



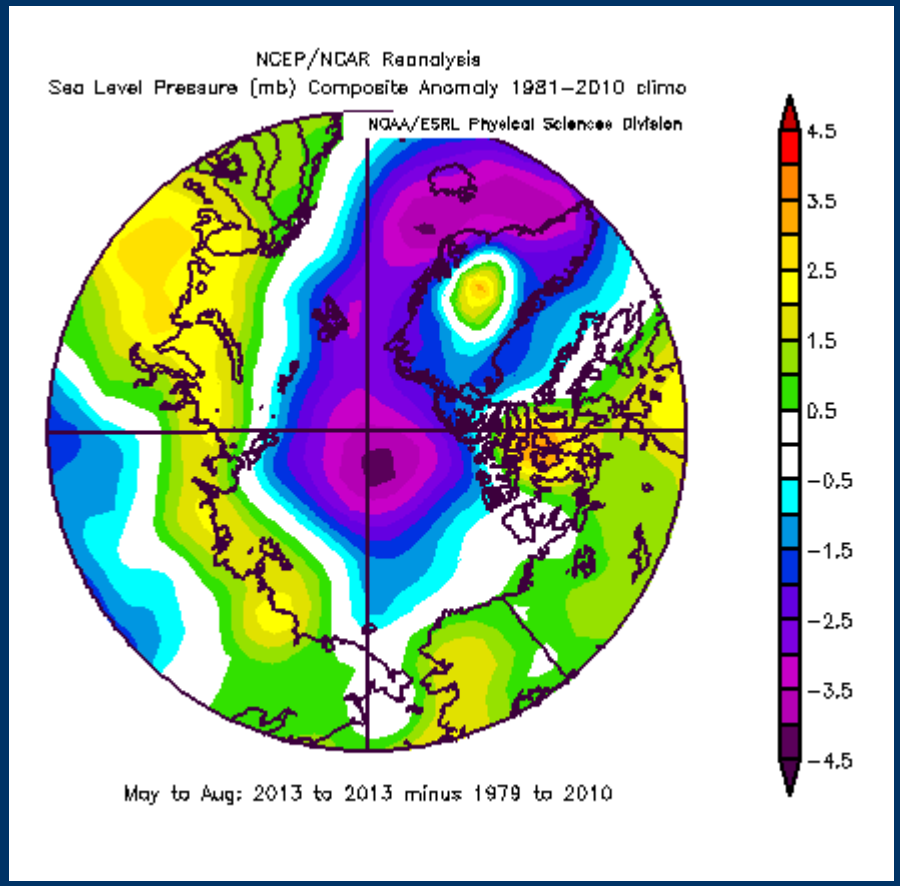
- September 2012 had the lowest September extent on record
- Unremarkable atmospheric conditions – effects of thinning taking over?

Summer of 2013: A cool cyclonic pattern

May to Aug. 925 hPa temp. anomaly

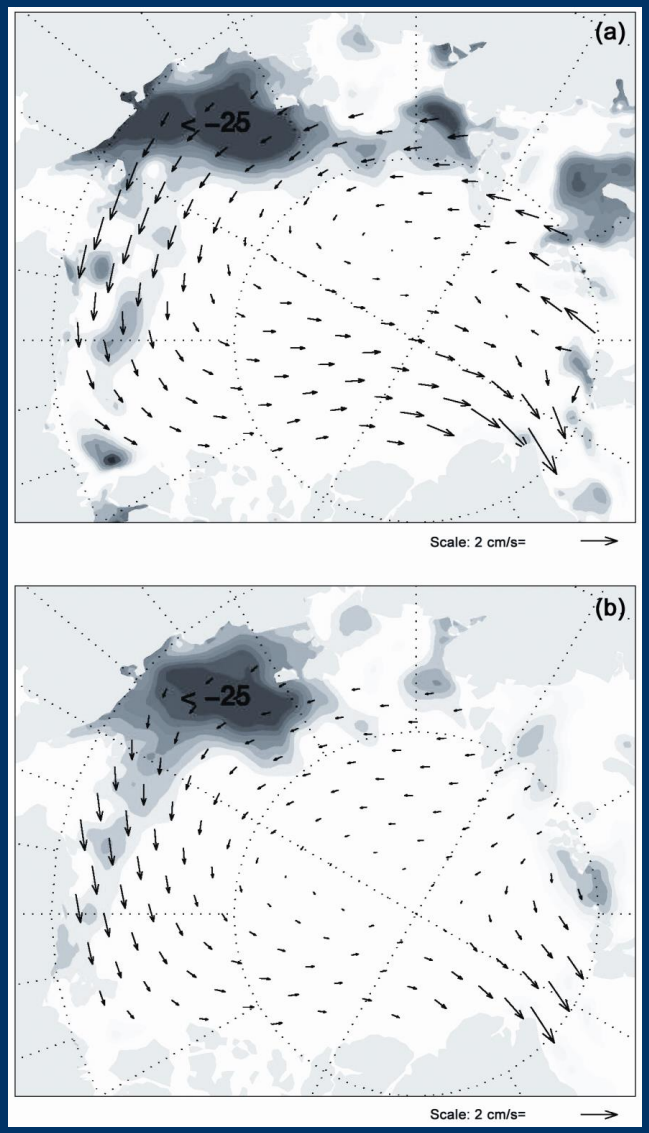


May to Aug. SLP anomaly



- A big recovery from 2012, but still the sixth lowest extent on record
- Again, effects of thinning taking over?

Winter conditions are also important



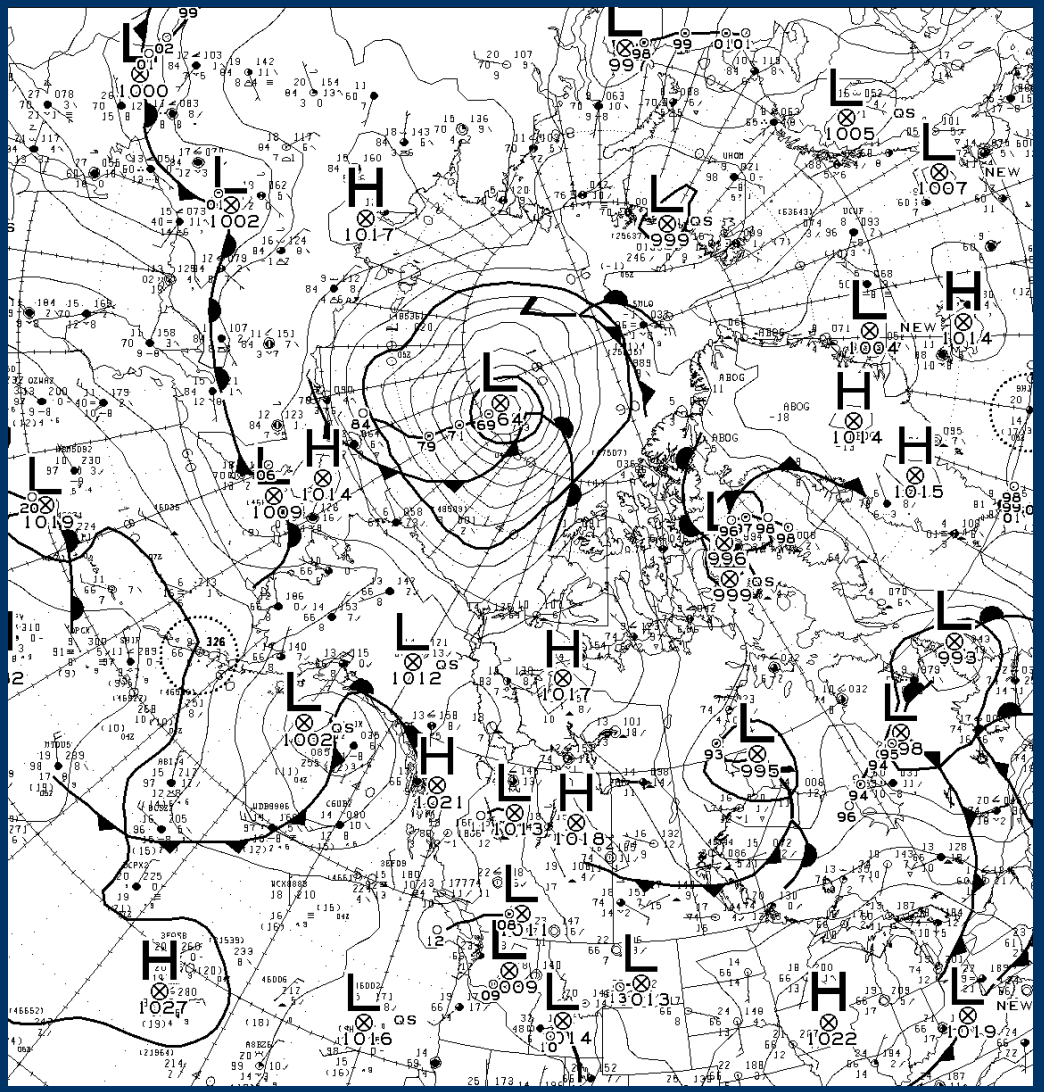
Large scale trends in winter sea ice motion and summer sea ice concentration (a) and regressions on the prior winter AO index (b). Results are based on the period 1979-1998. Shading is proportional to the magnitude of the ice concentration trends. The two panels look very similar to each other. Positive AO winters invoke a counterclockwise anomaly in sea ice motion, pulling ice away from the Eurasian coast and promoting growth of thin ice in these regions. This thin ice then readily melts in summer, leading to negative anomalies in summer ice concentration. The ice circulation pattern associated with the positive AO also works to “flush” thick ice out of the Arctic Ocean into the North Atlantic via Fram Strait.

Adapted from Rigor et al., 2002

Individual extreme weather events

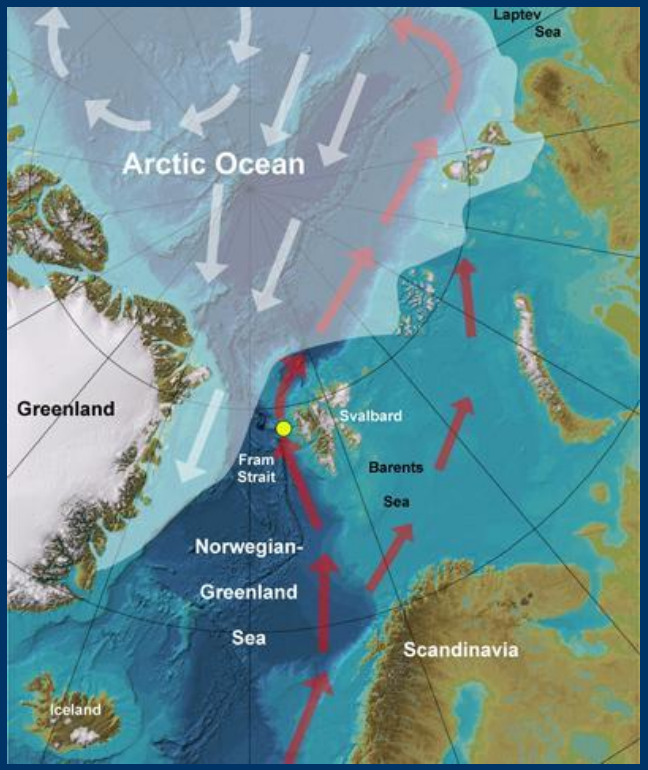
The great Arctic cyclone of August 2012 was an impressive event (central pressures dropped to as low as 964 hPa) but its impact on sea ice extent was nothing to write home about. Modeling studies indicate that even without it, we would have had a record low extent in September,

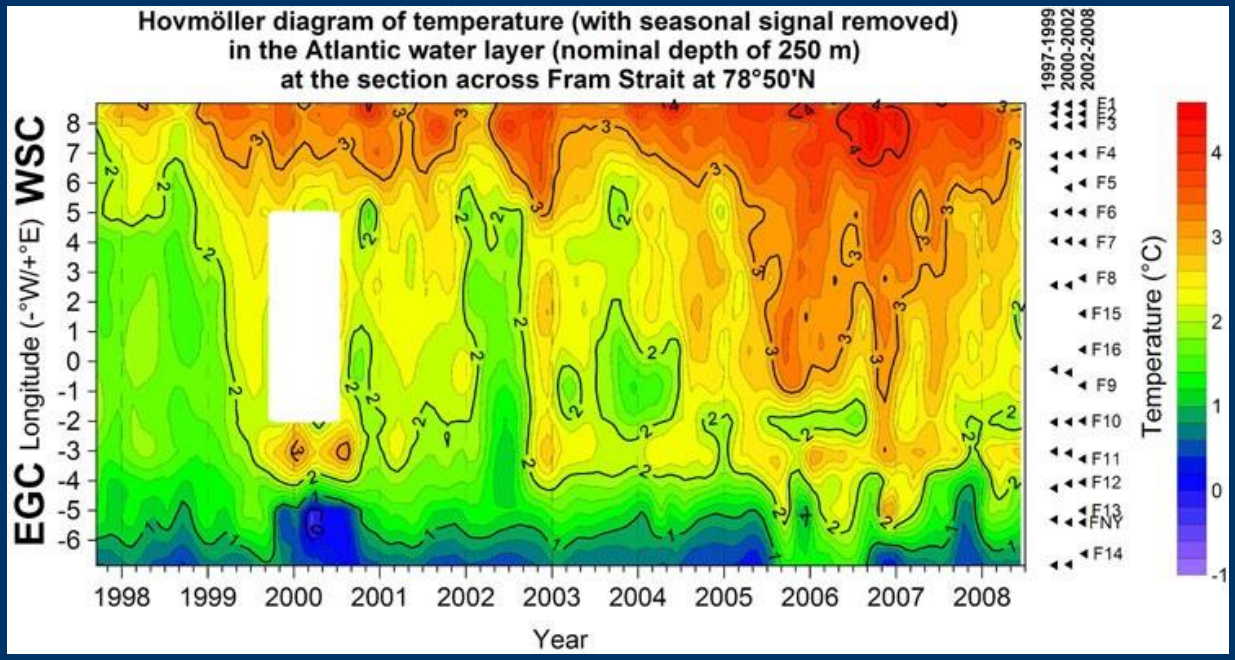
What happens over the *season* is more important



CMC Analysis, August 6, 2012

Let's not forget the ocean





- Atlantic layer inflow (approximately 250 depth) is warming, paleoclimate evidence suggest that Atlantic-layer water temperatures are now the highest of the past 2000 years.
- Natural variability or an anthropogenic influence?
- How is this influencing the ice cover? There are unknowns

arctic-roos.org (right), www.nature.com (left)

Conclusions

We are quickly losing the perennial ice cover

- Some impacts are already being felt
- Impacts on mid-latitude weather? Controversial

When do we go essentially seasonally ice free?

- There is much uncertainty
  - Model architecture and physical treatments
  - Greenhouse gas emissions
  - Natural climate variability

Summer weather patterns are very important

Effects of changes in ocean heat transport are unclear

Impacts of a single extreme event (e.g., 2012 cyclone) seem to be overblown

But as the ice thins, the rules change


Thank You
04.10.2008