CIRES

NCAR
National Center for Atmospheric Research
Boulder, Colorado

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

NSF

Environmental Impacts of a Shrinking Arctic Sea Ice Cover

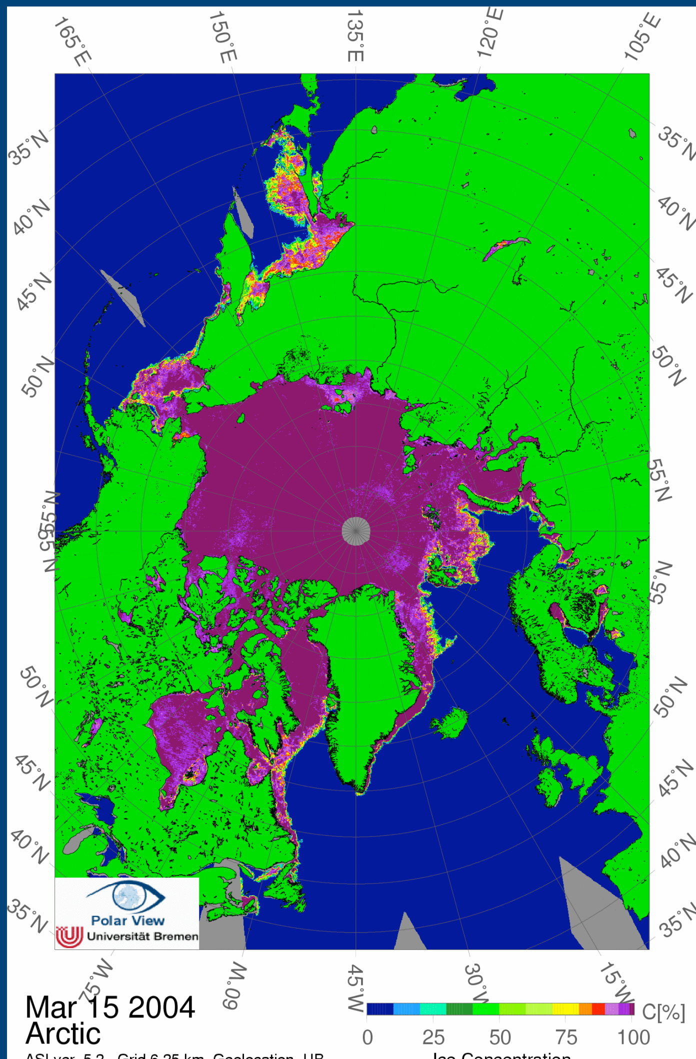
Mark Serreze, Andy Barrett, John Cassano, Julienne Stroeve and Andrew Slater
Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder

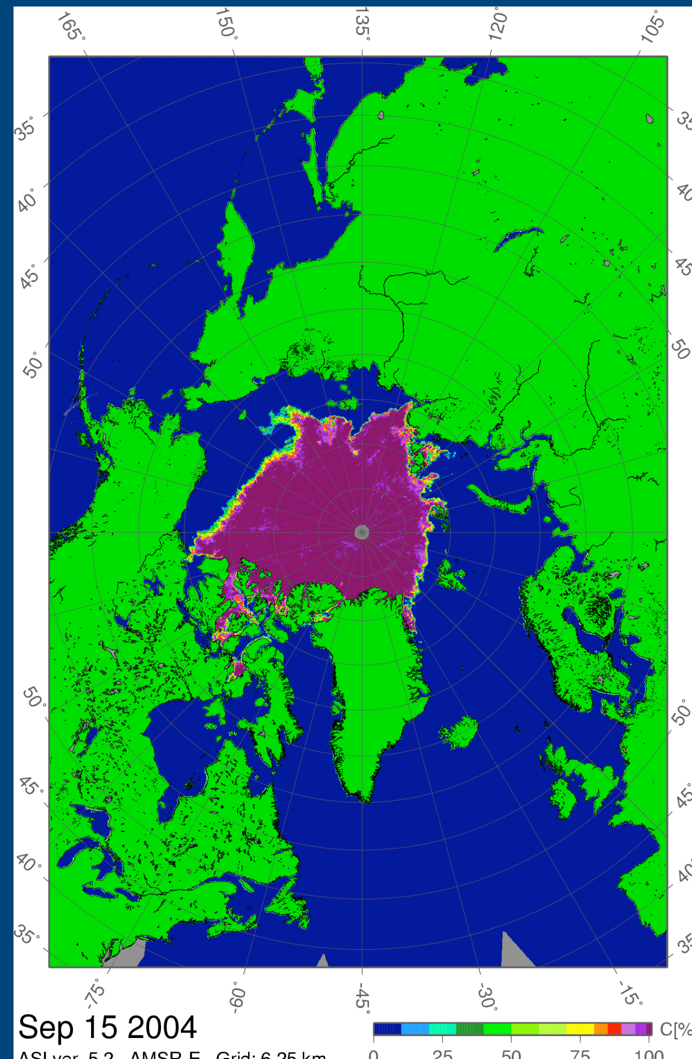
NSIDC

The National Snow and Ice Data Center (NSIDC)

The view from NSIDC

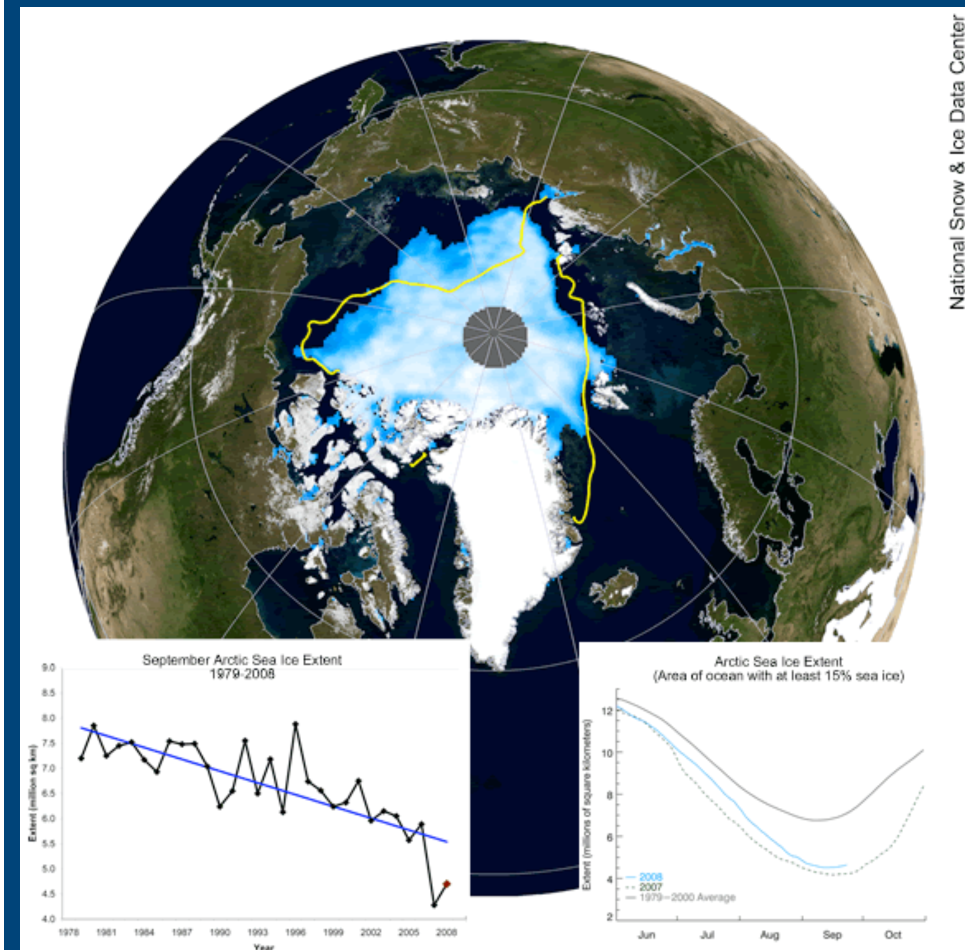
The Arctic sea ice cover





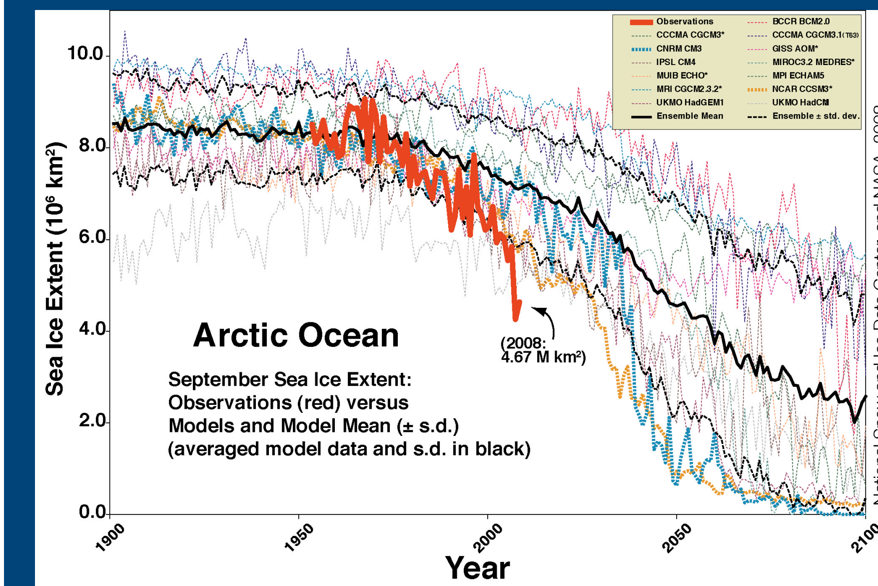
Univ. Bremen

End of summer ice extent is rapidly declining



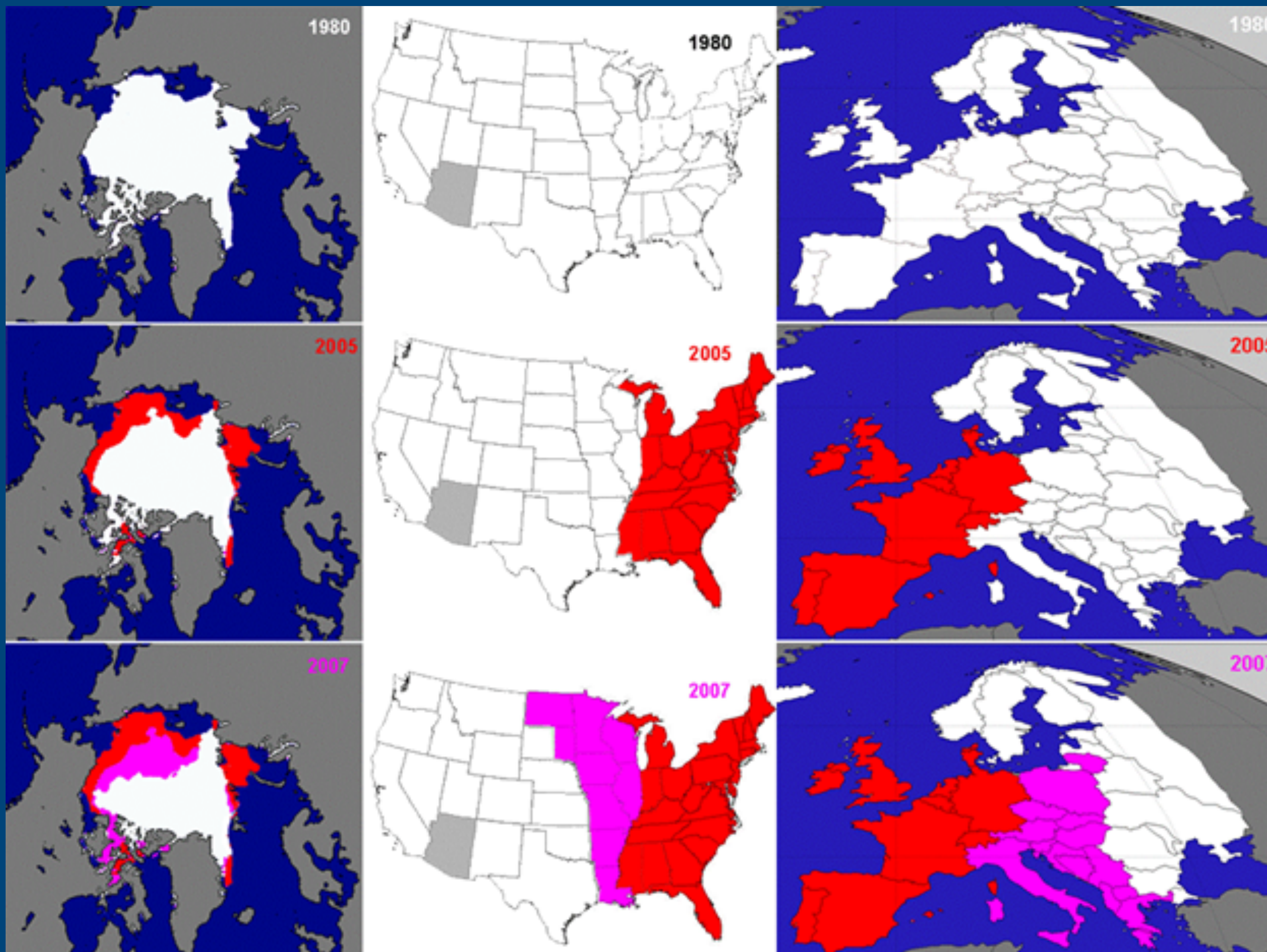
Sept 14, 2008: 4.51 million sq. km

Sept 16, 2007: 4.13 million sq. km

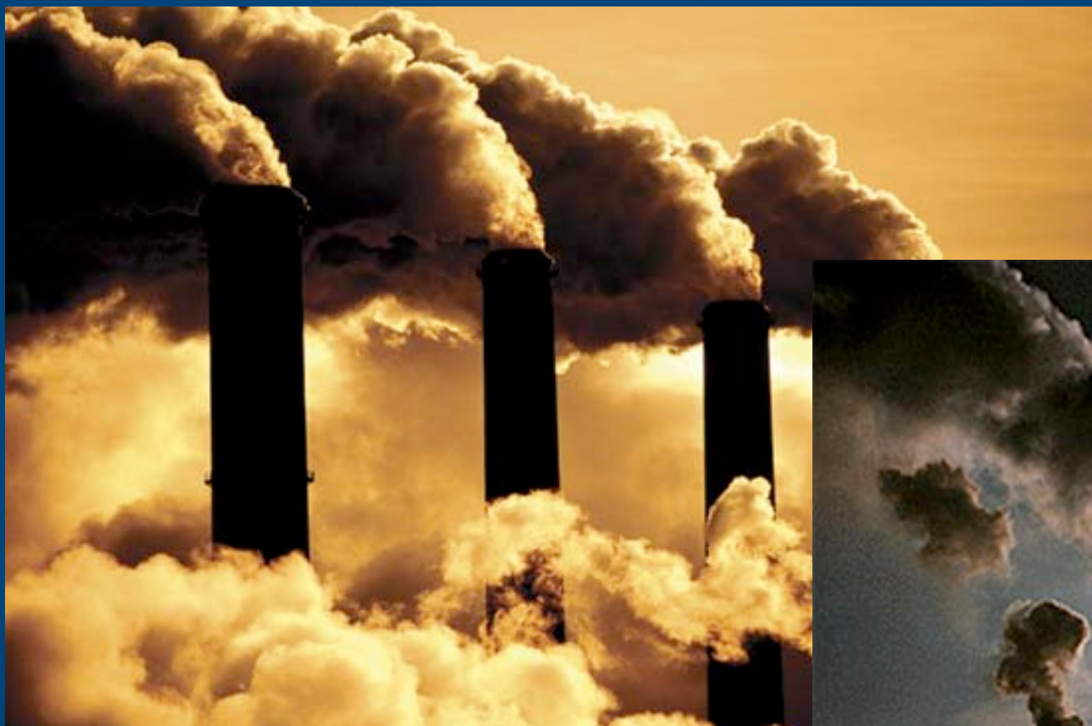


Left: From Serreze et al. (2008); Right: Updated from Stroeve et al. (2007)

Some useful comparisons



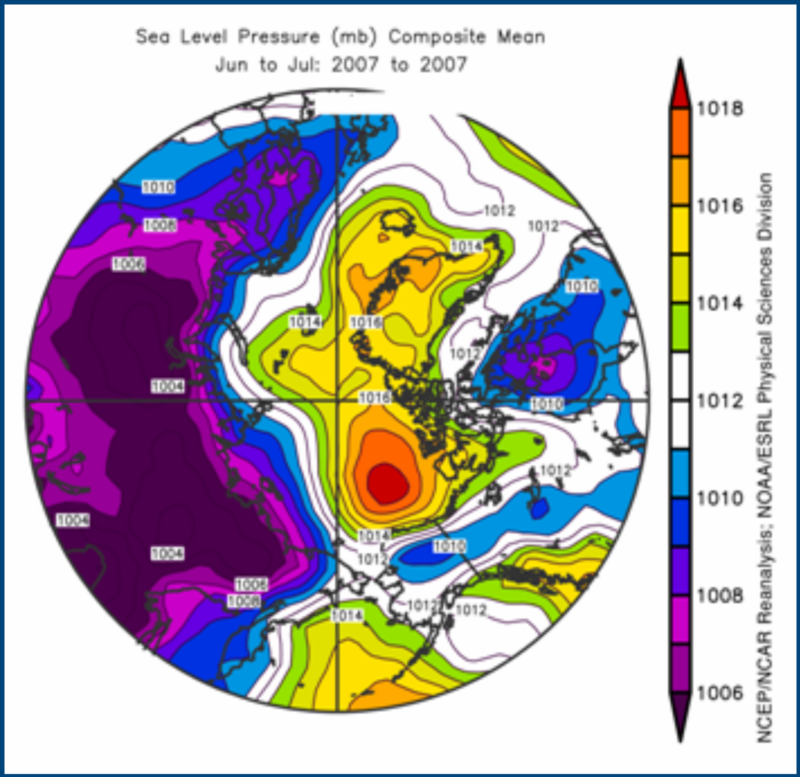
Black carbon from incomplete combustion

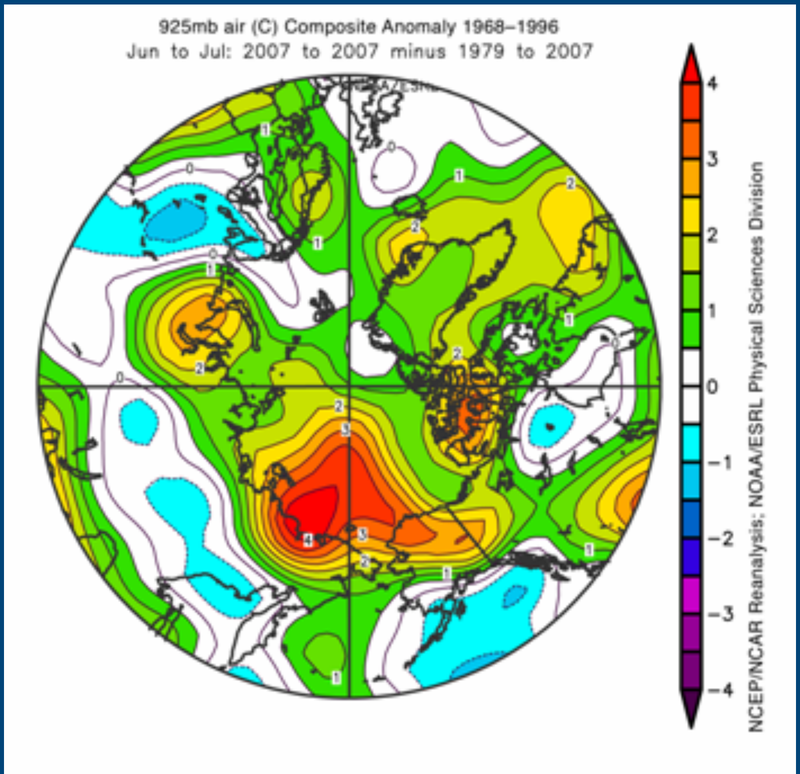


Reduction in surface albedo

newsbusters.org (left), blogs.tnr.com (right)

The summer “Dipole”





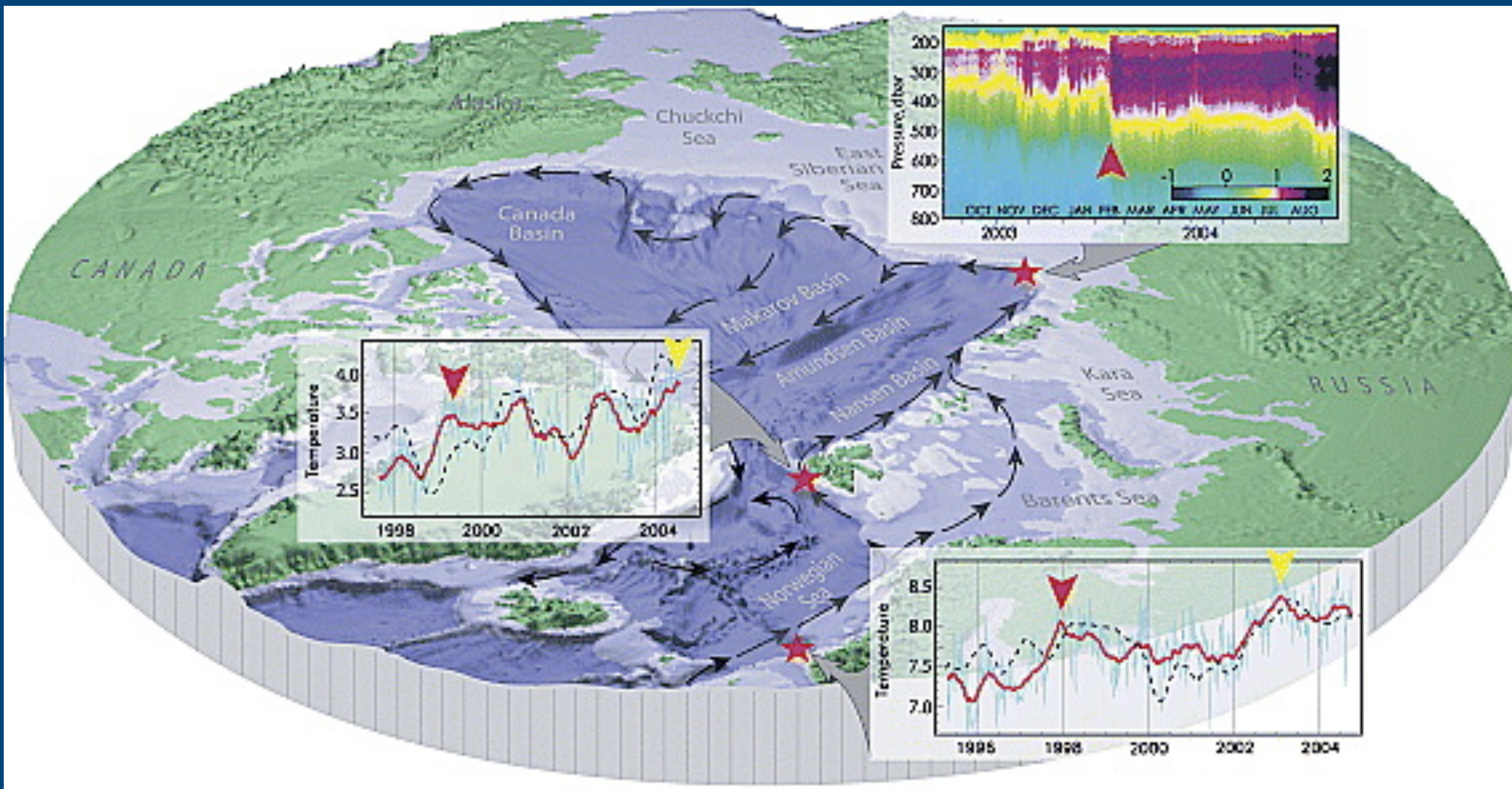
- High pressure over central Arctic Ocean
- Low pressure over Siberia

A very warm Arctic

NCEP/NCAR Reanalysis; NOAA/ESRL Physical Sciences Division

A puzzle: enhanced Atlantic inflow

Moorings at Svinoy and Fram Strait



I. Polyakov et. al, 2005

The problem of coastal erosion

Courtesy IARC, Dave Sanches

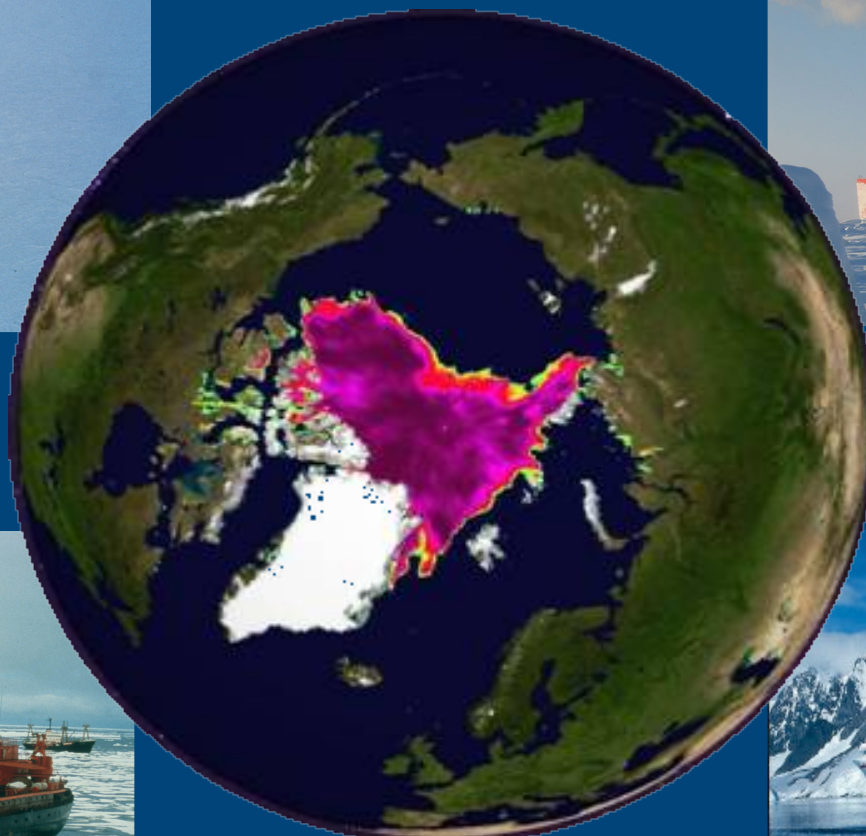
Polar bears and other charismatic megafauna

Globalization, Climate Change & Governance Implications for a New Maritime Arctic

DNV Workshop on Ice Scenarios

DNV ~ Sandvika

9-10 December 2008



Lawson W. Brigham, PhD

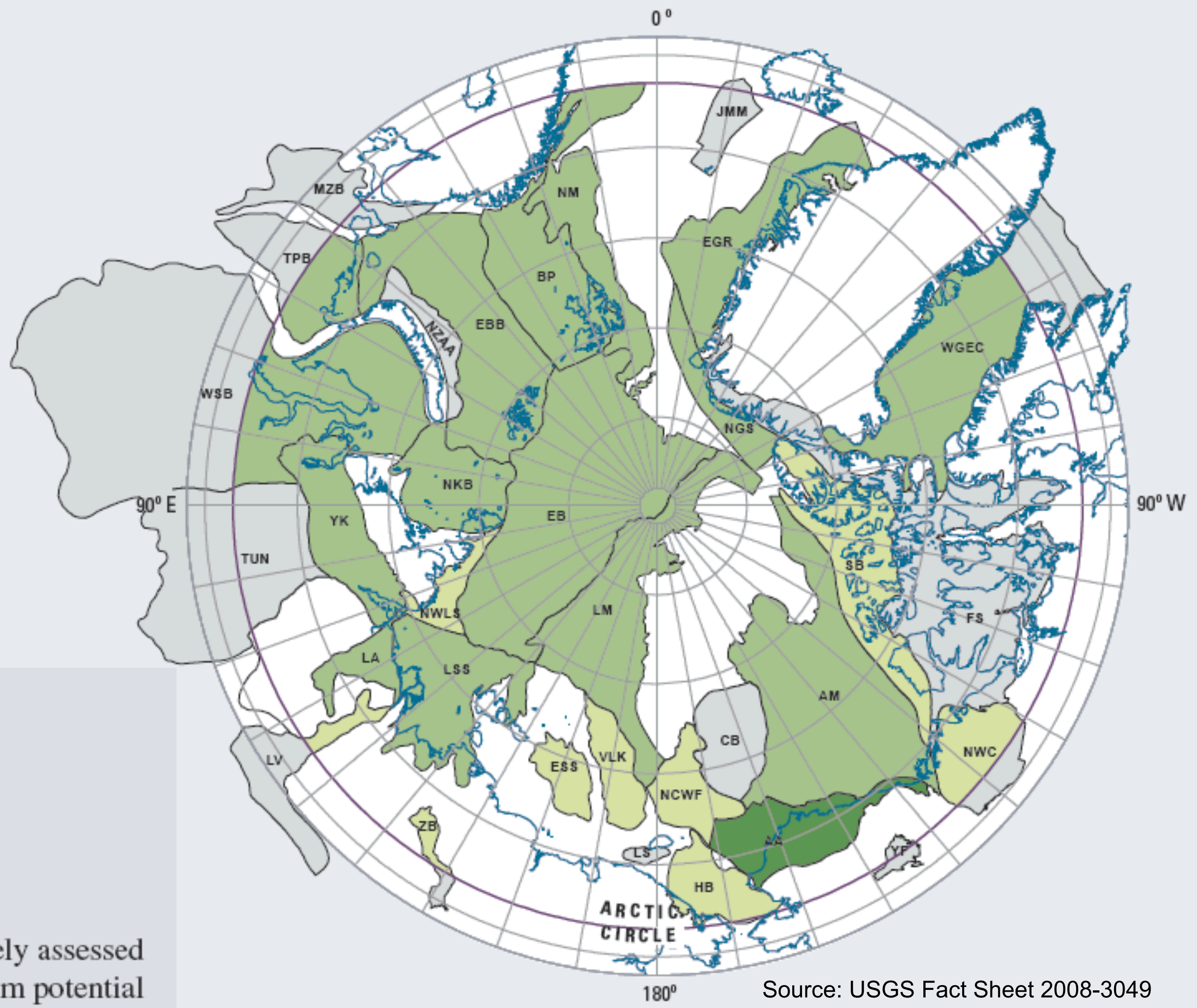
Vice Chair, PAME & Chair, AMSA

U.S. Arctic Research Commission ~ Anchorage

USGS Circum-Arctic Resource Assessment (2008)

Undiscovered oil

90 BBO



UNDISCOVERED OIL
(billion barrels)

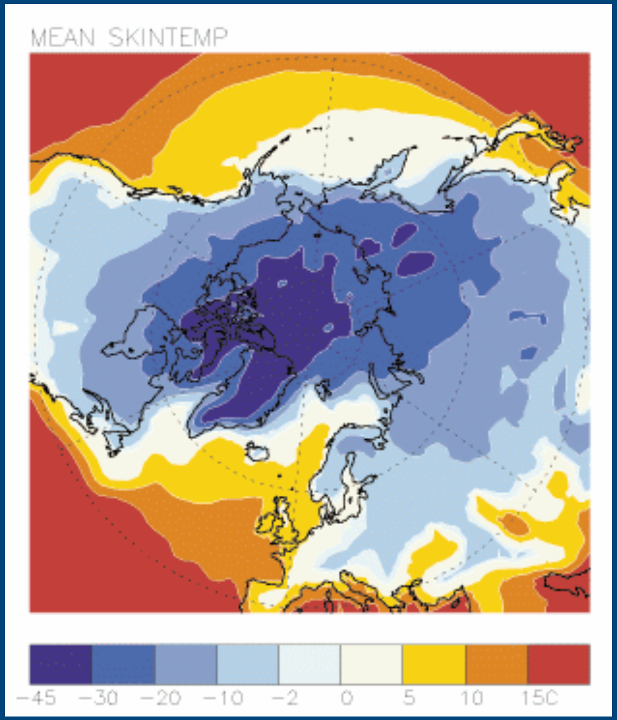
- >10
- 1-10
- <1
- Area not quantitatively assessed
- Area of low petroleum potential

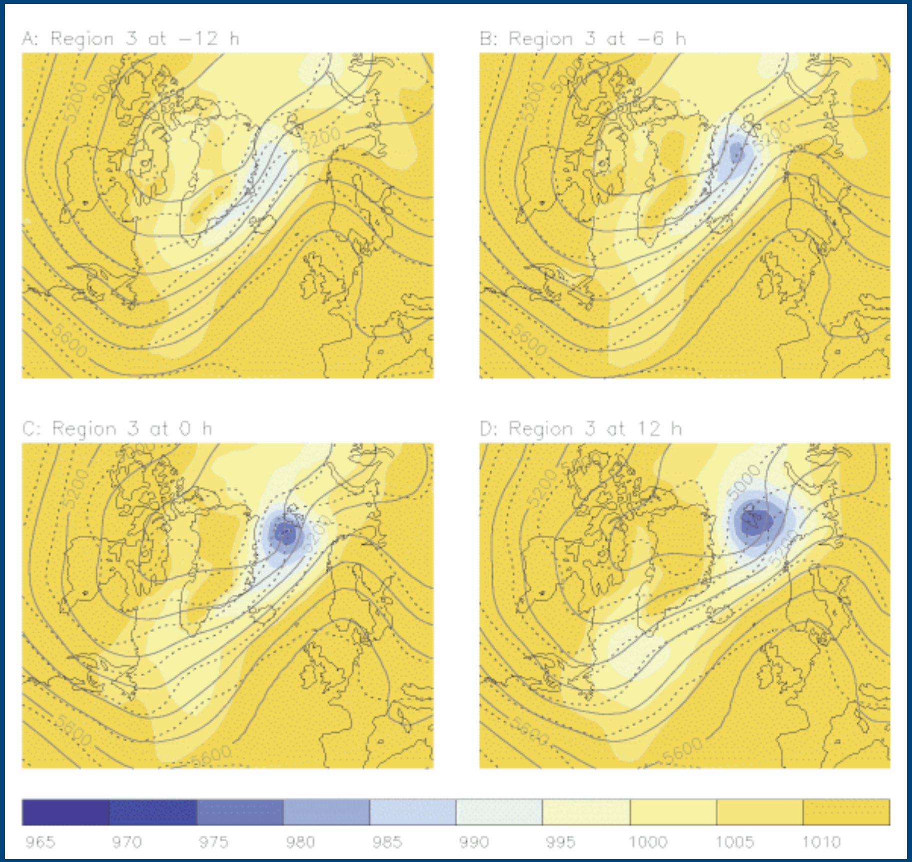
Source: USGS Fact Sheet 2008-3049

Courtesy Steven Sawhill

NSIDC

Impacts on atmospheric circulation



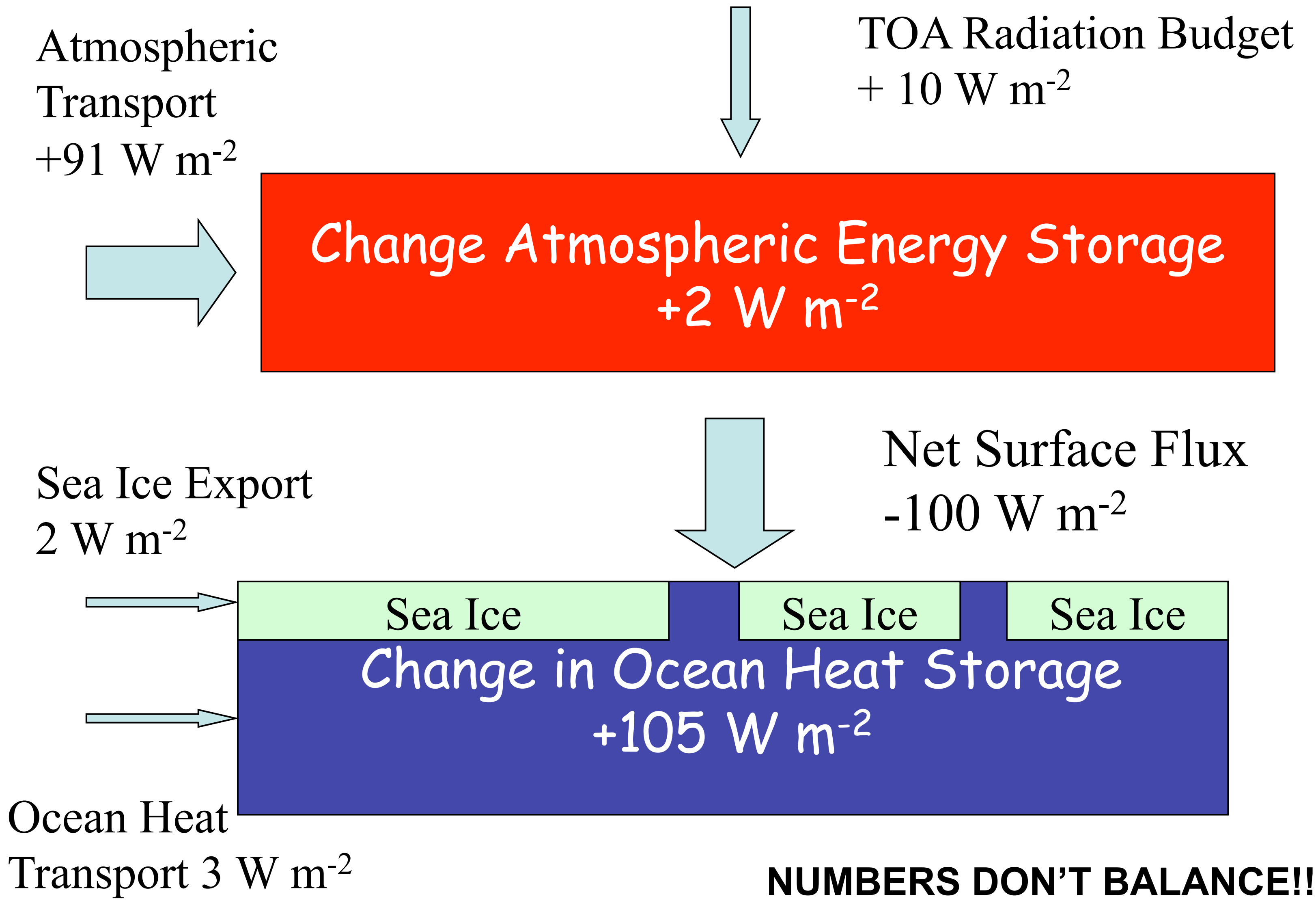


Strong temperature gradients along the sea ice margin influence the development and tracks of extra-tropical cyclones and hence regional precipitation and atmospheric energy transports

From Tsukernik et al., 2006

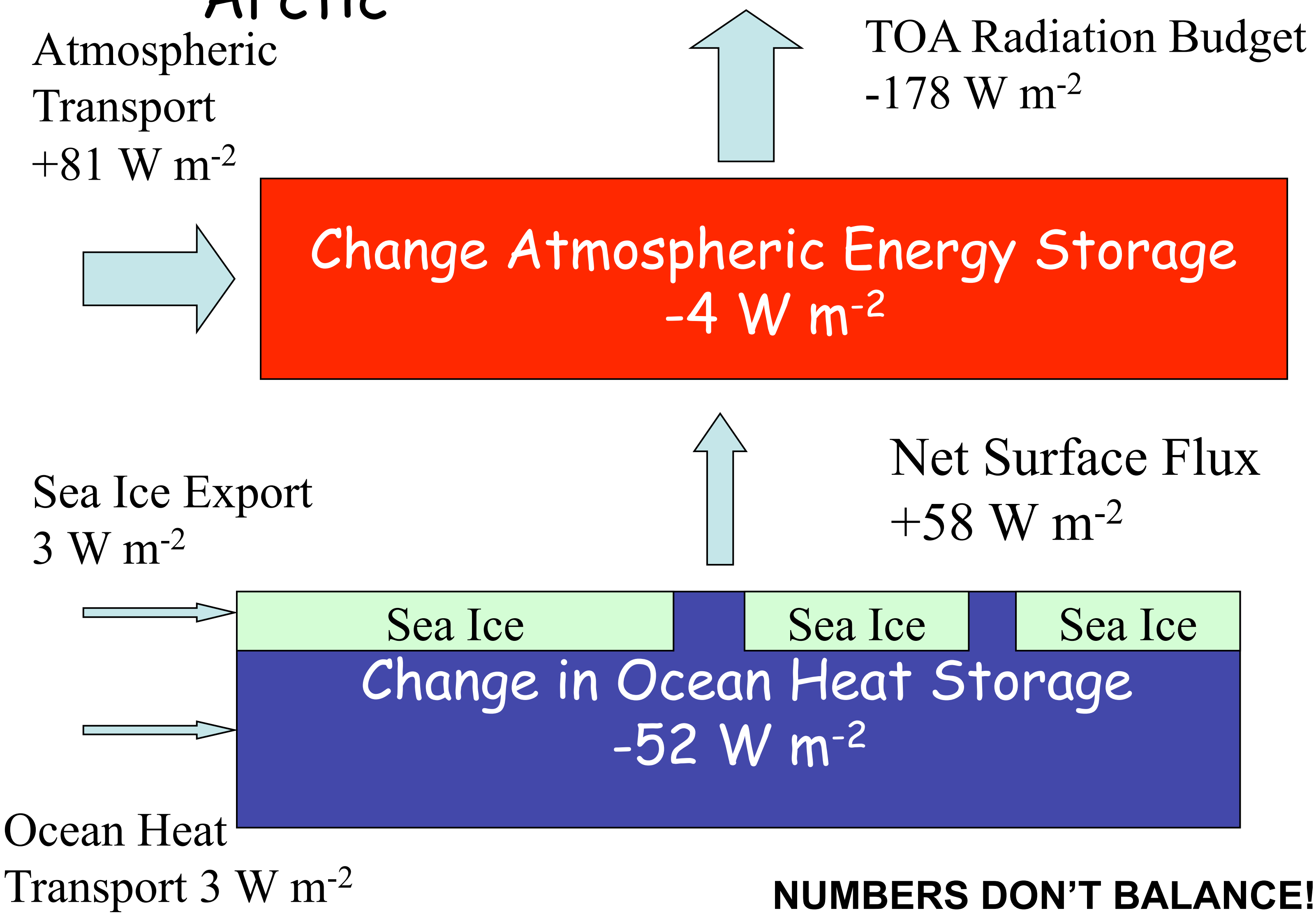
A Summer View of Svalbard

July Energy Budget of the Arctic



NUMBERS DON'T BALANCE!!

January Energy Budget of the Arctic

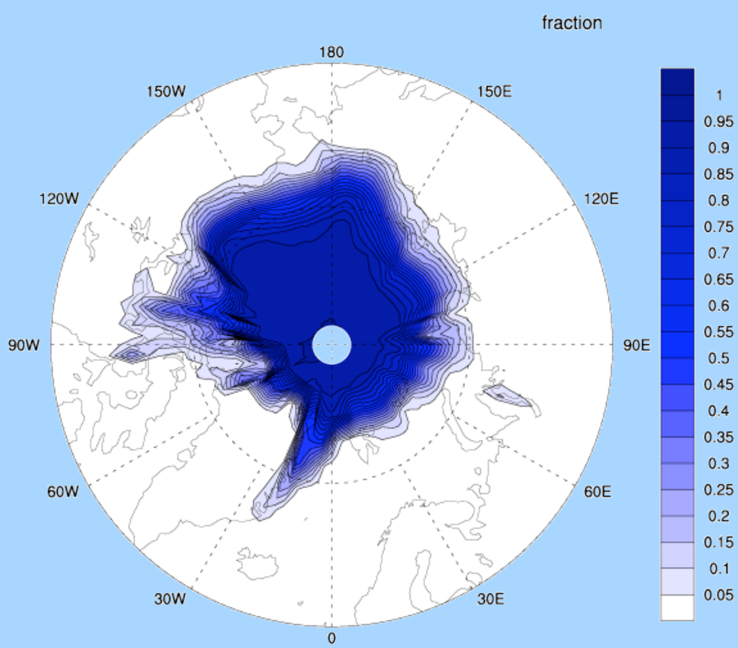


NUMBERS DON'T BALANCE!!

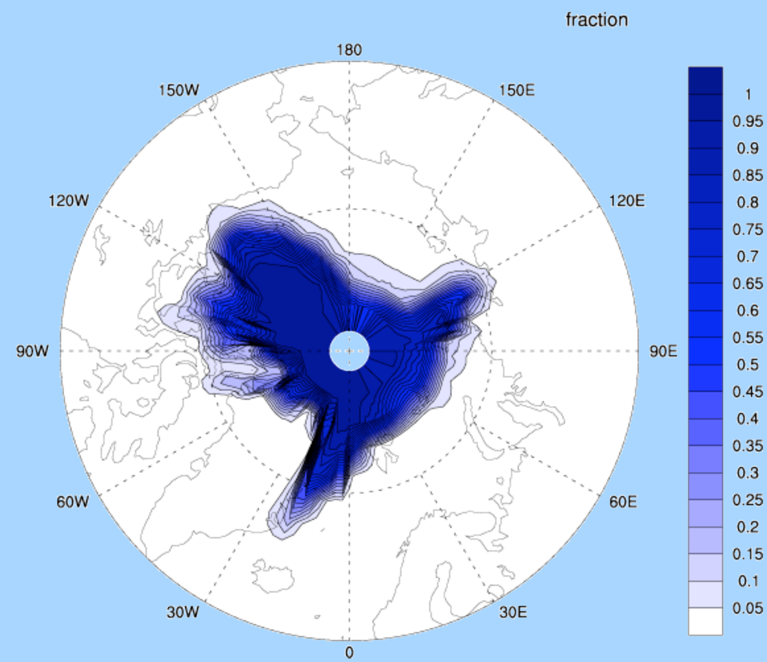
A model experiment

The NCAR Community Atmospheric Model (CAM) was used to perform two 30-year simulations, one with a climatological late 20th century seasonal cycle in sea ice fraction, and one using the 2007 seasonal cycle.

Average September sea ice fraction - Control run



Average September sea ice fraction - 2007 run

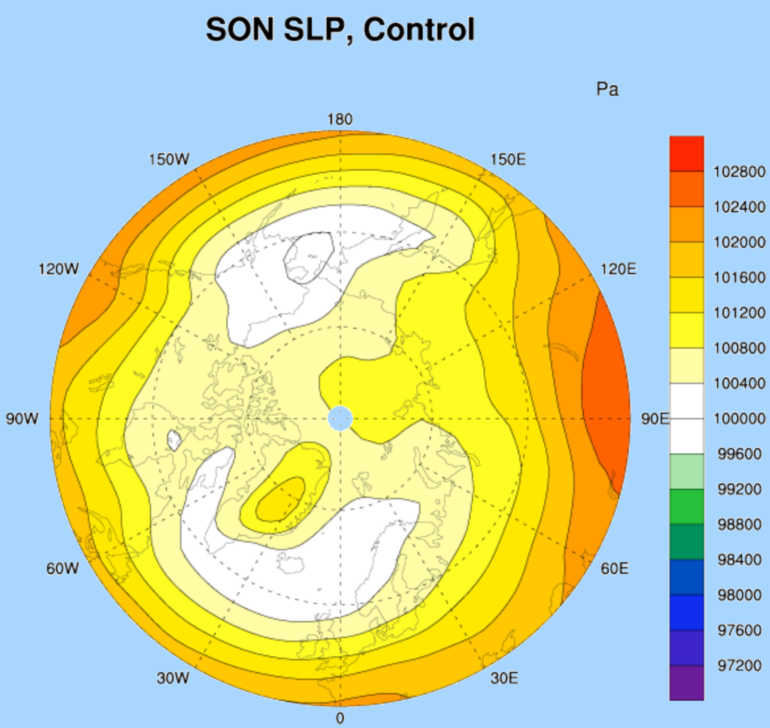


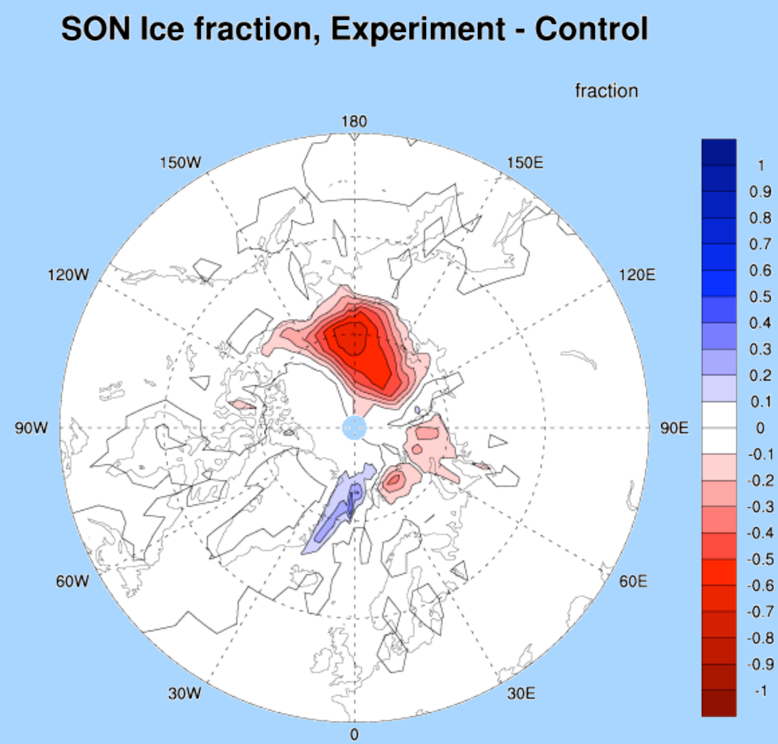
E. Cassano, J. Cassano and M. Higgins

NSIDC

Results – circulation differences

Circulation differences were most prominent in **autumn (SON)** and winter (DJF)

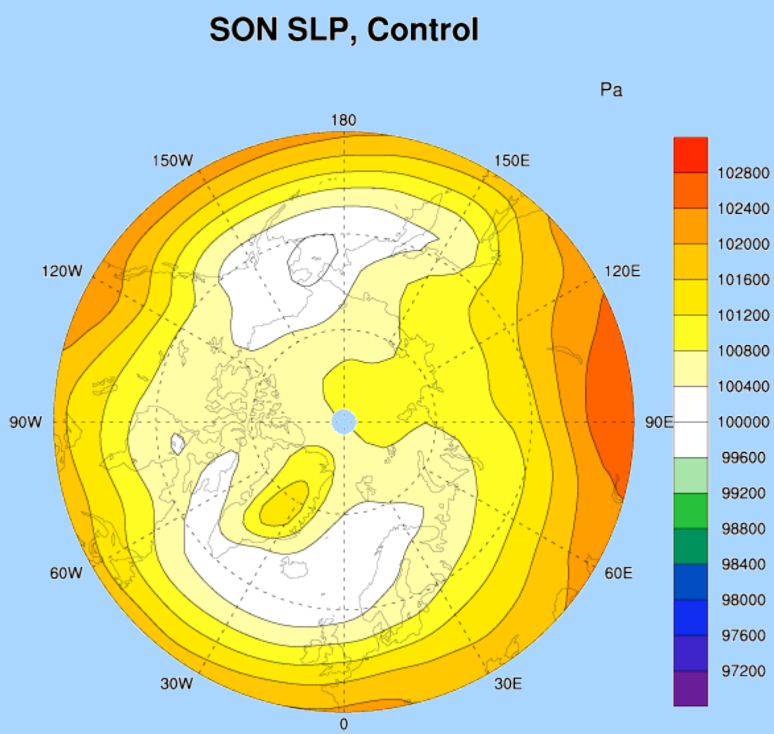


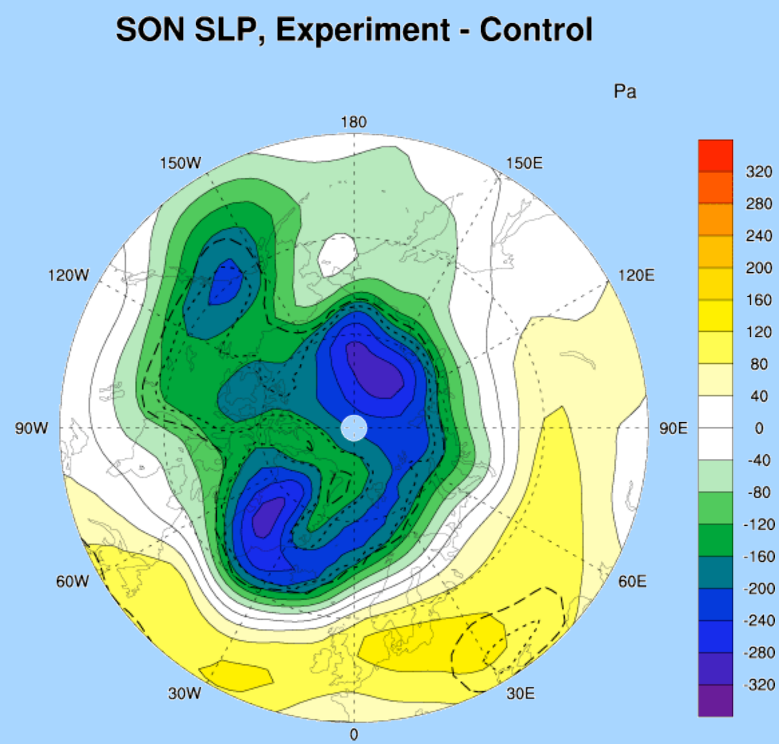


E. Cassano, J. Cassano and M. Higgins

Results – circulation differences

Circulation differences were most prominent in **autumn (SON)** and winter (DJF)



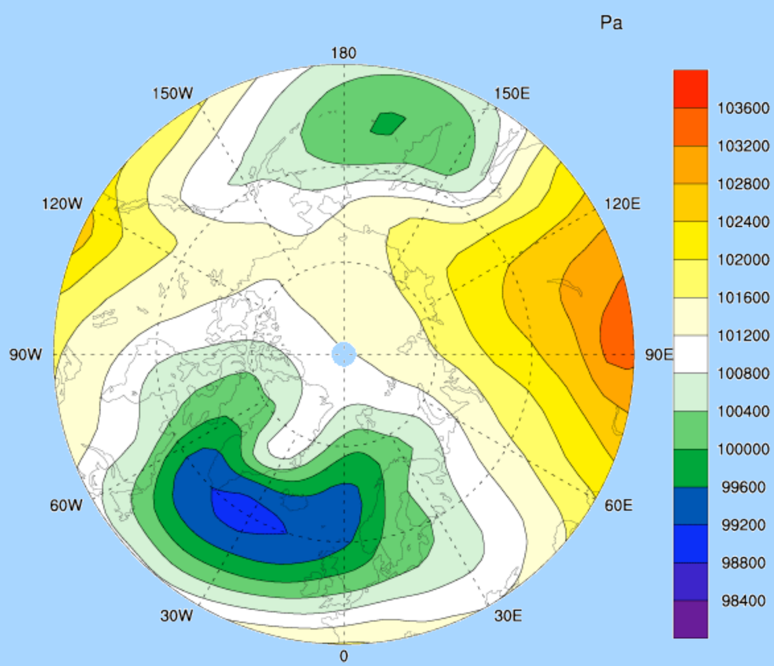


E. Cassano, J. Cassano and M. Higgins

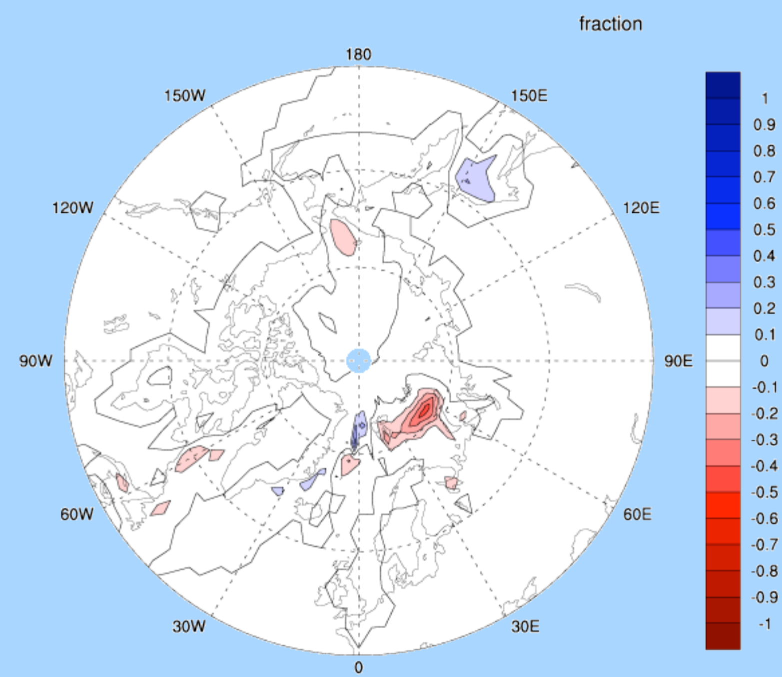
Results – circulation differences

Circulation differences were most prominent in autumn (SON) and **winter (DJF)**

DJF SLP, Control



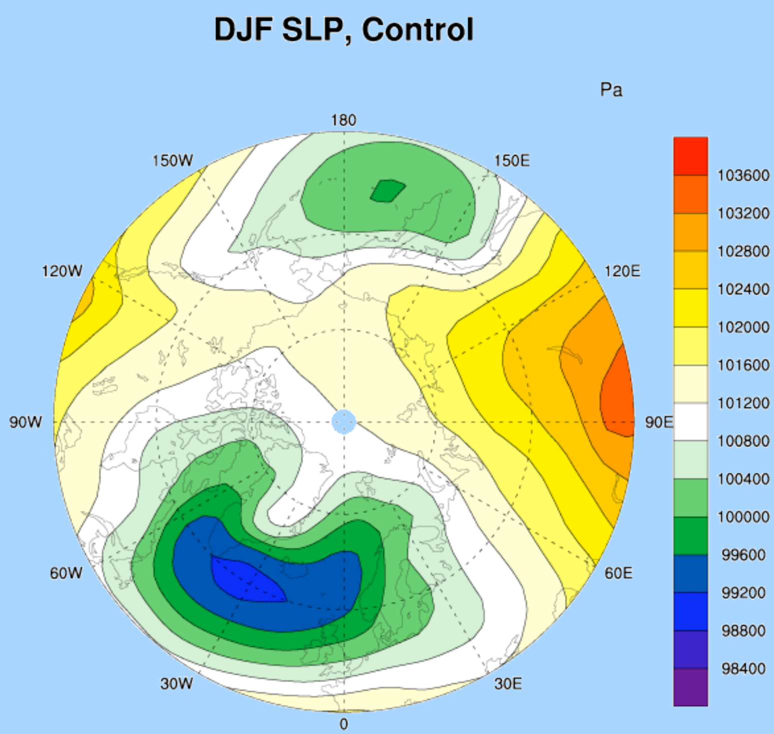
DJF Ice fraction, Experiment - Control

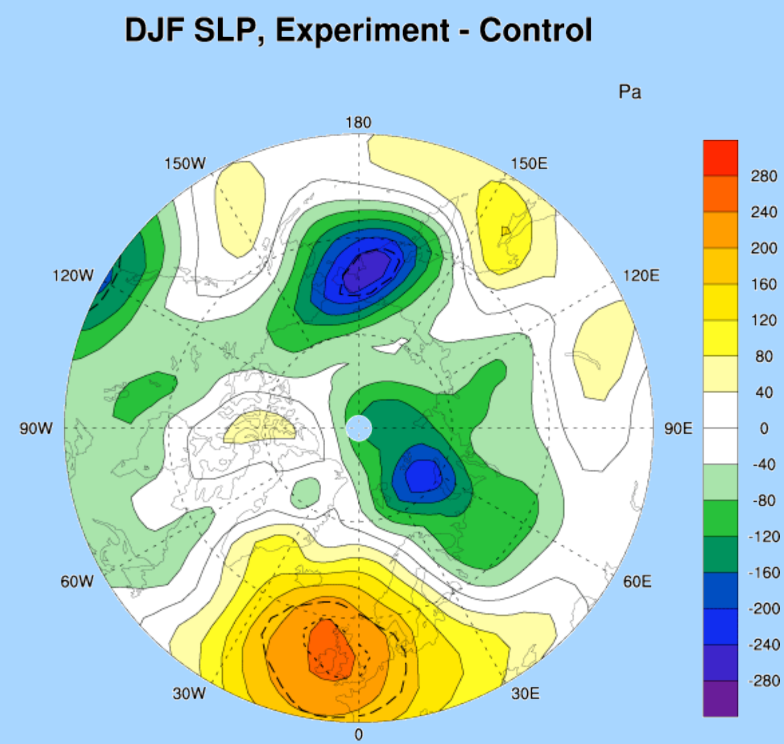


E. Cassano, J. Cassano and M. Higgins

Results – circulation differences

Circulation differences were most prominent in autumn (SON) and **winter (DJF)**

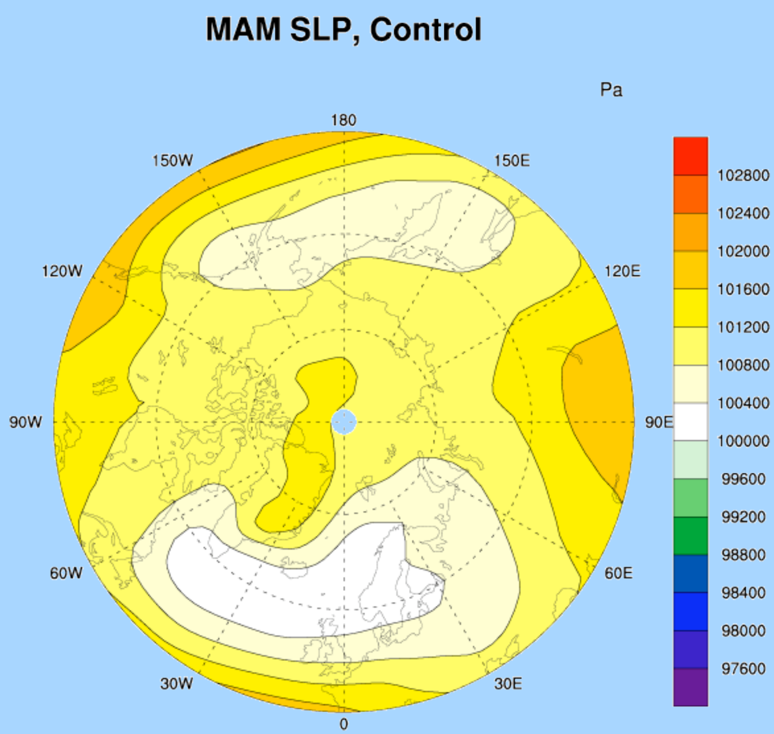


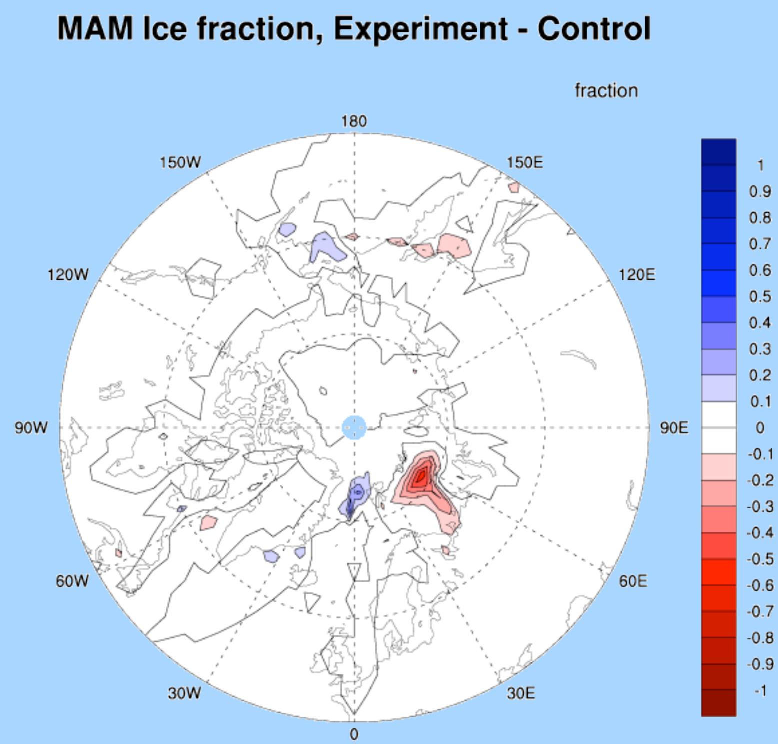


E. Cassano, J. Cassano and M. Higgins

Results – circulation differences

Circulation differences were also prominent in **spring (MAM)**





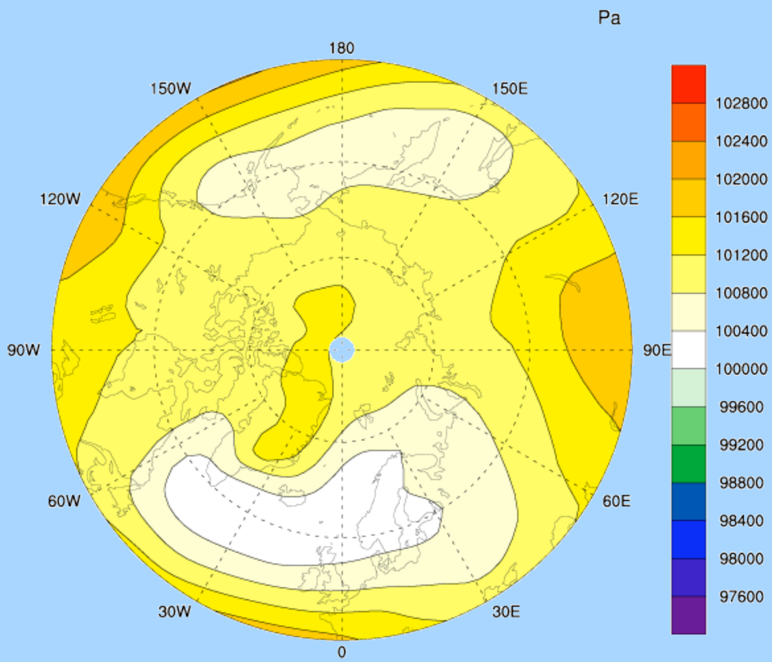
E. Cassano, J. Cassano and M. Higgins

NSIDC

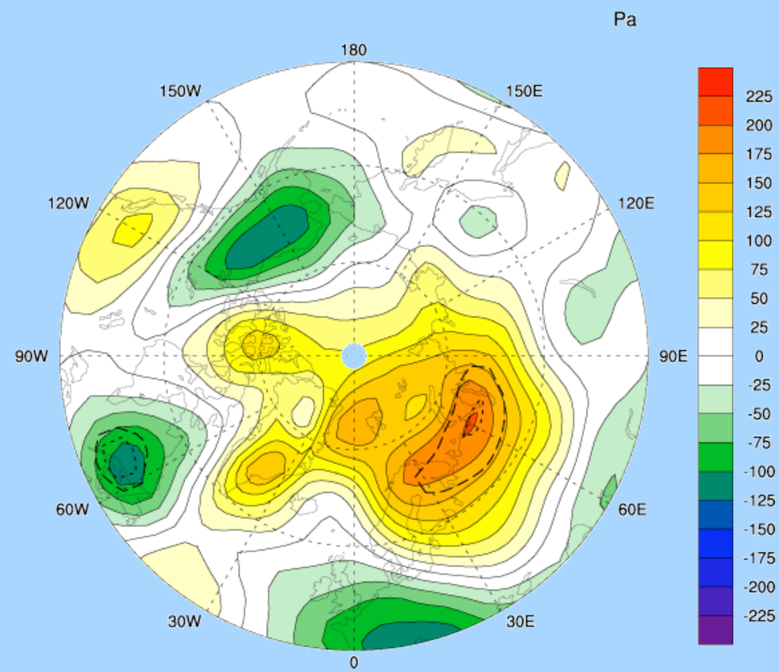
Results – circulation differences

Circulation differences were also prominent in **spring (MAM)**

MAM SLP, Control



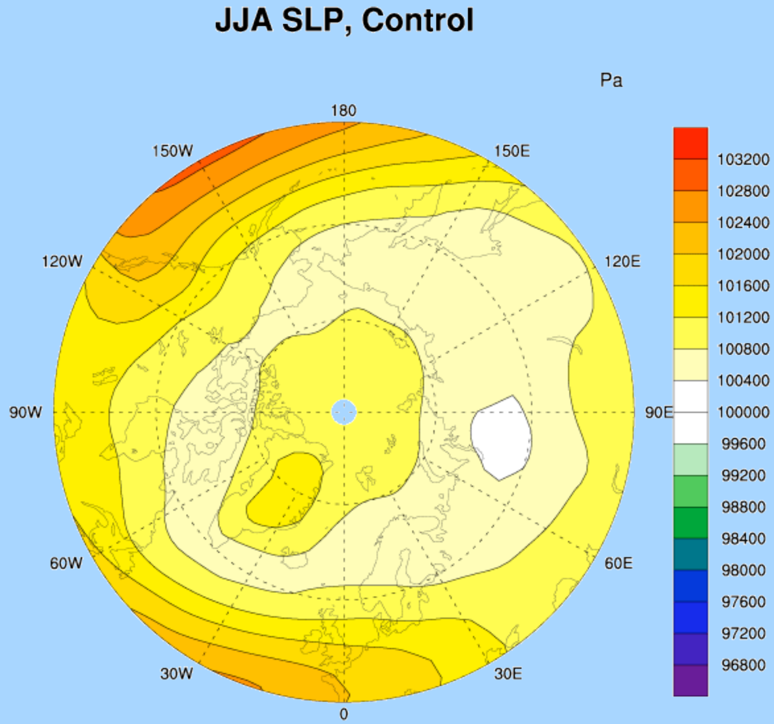
MAM SLP, Experiment - Control

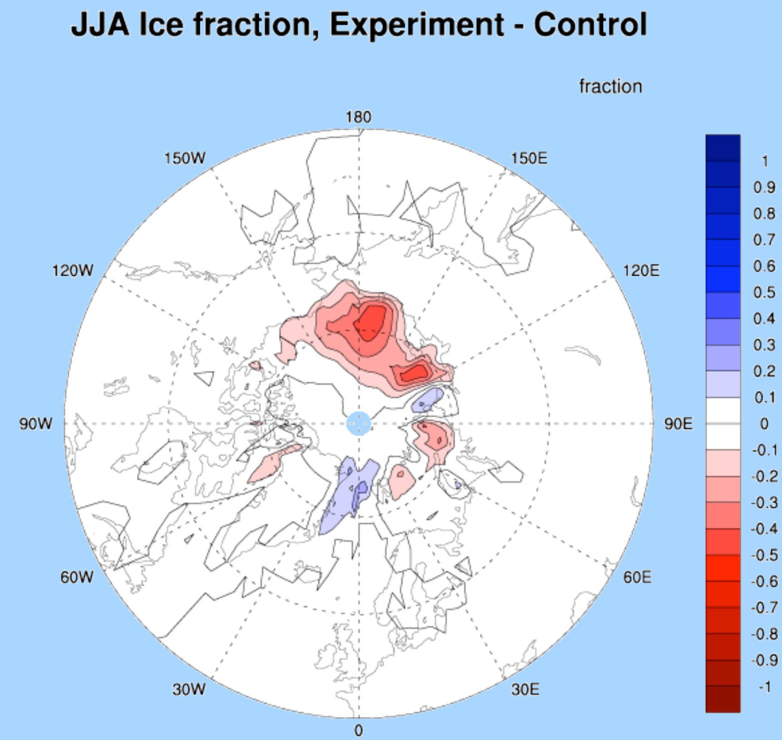


E. Cassano, J. Cassano and M. Higgins

Results – circulation differences

Circulation differences were weaker during JJA

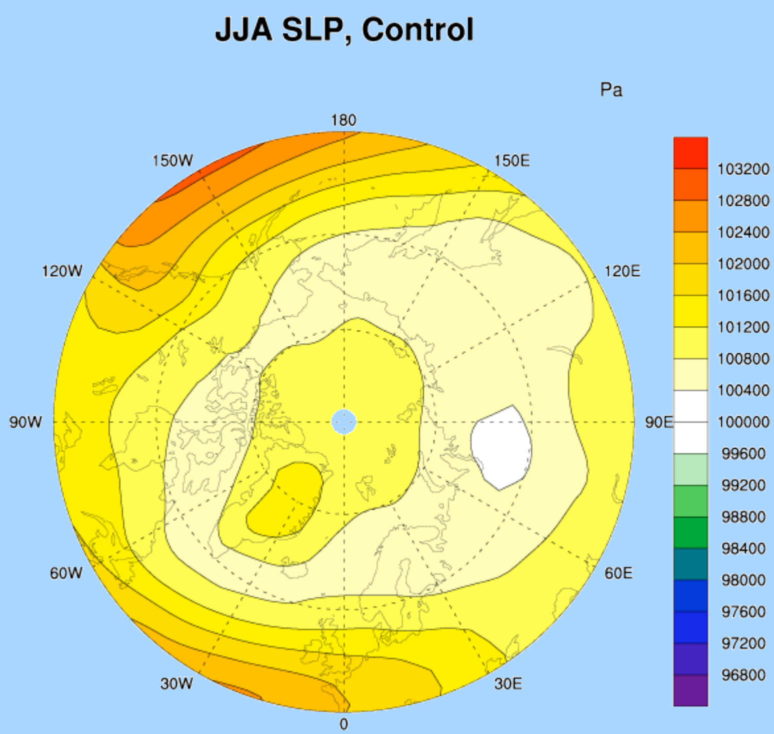


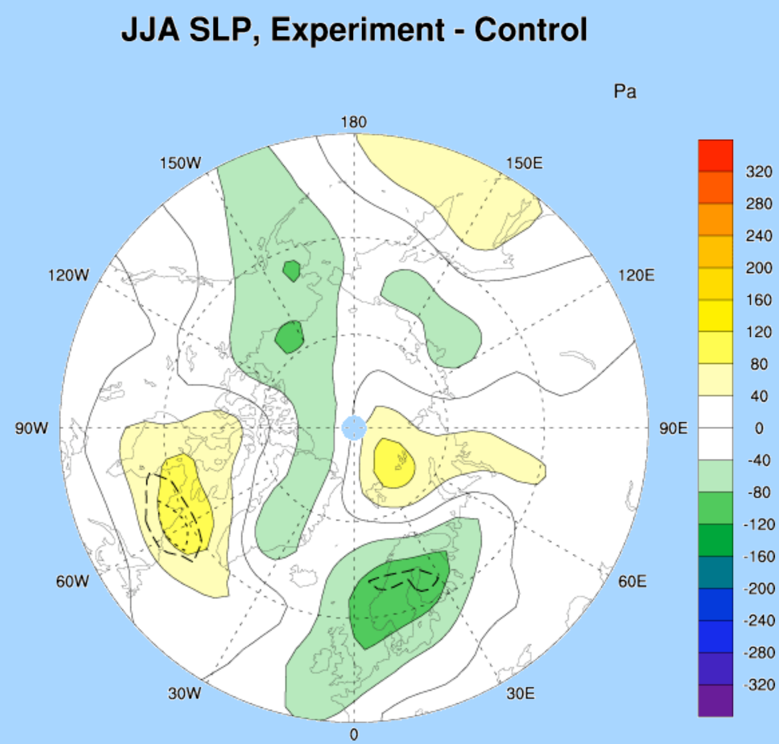


E. Cassano, J. Cassano and M. Higgins

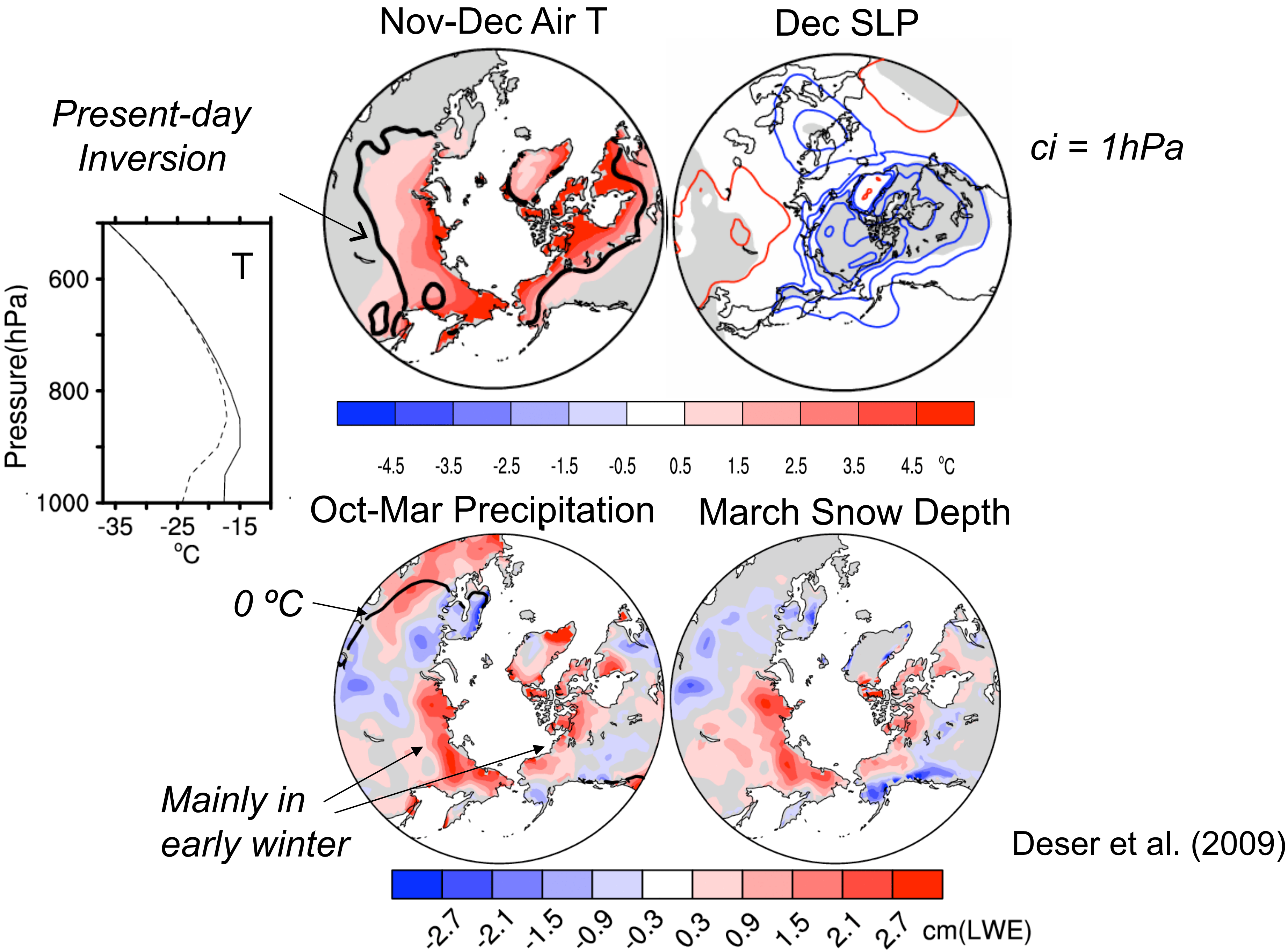
Results – circulation differences

Circulation differences were weaker during JJA





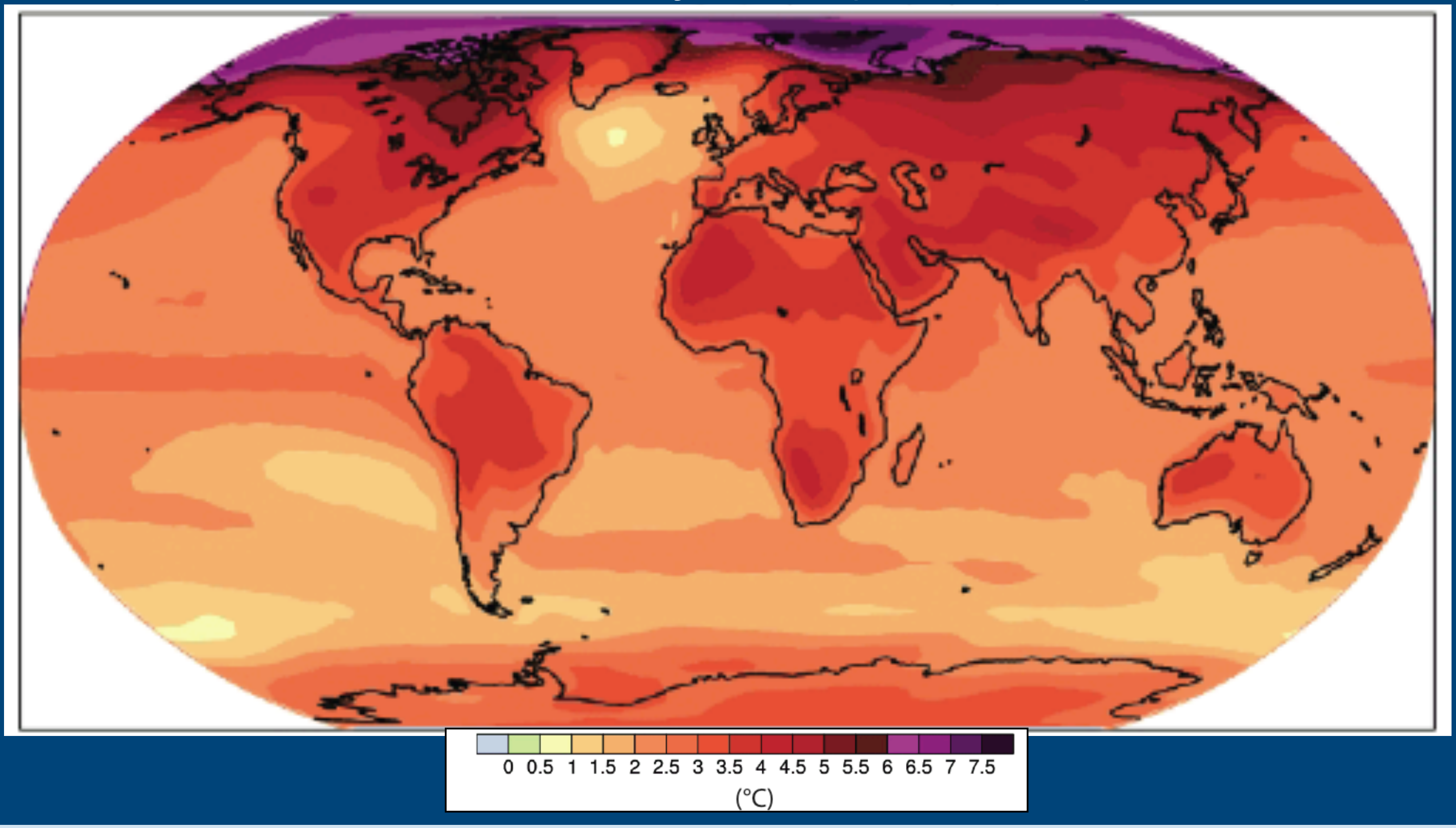
E. Cassano, J. Cassano and M. Higgins



Nov-Dec Air T
Dec SLP
ci = 1hPa
Present-day Inversion
T
Pressure(hPa)
600
800
1000
-35
-25
-15
ºC
-4.5
-3.5
-2.5
-1.5
-0.5
0.5
1.5
2.5
3.5
4.5
ºC
Oct-Mar Precipitation
March Snow Depth
0 ºC
Mainly in early winter
-2.7
-2.1
-1.5
-0.9
-0.3
0.3
0.9
1.5
2.1
2.7
cm(LWE)
Deser et al. (2009)

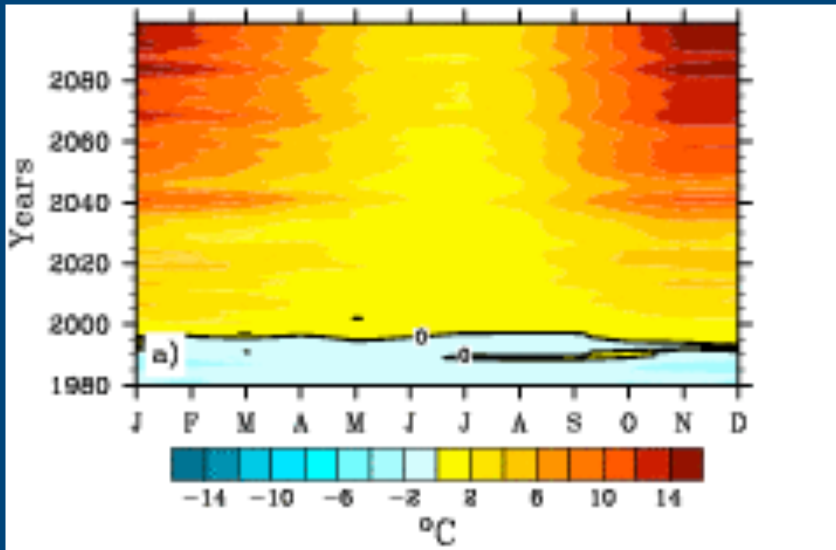
Air temperature: A1B scenario by 2100

Global mean warming of ~2.8°C (or ~5F);
Much of land area warms by ~3.5°C (or ~6.3F)
Arctic warms by ~7°C (or ~12.6F)

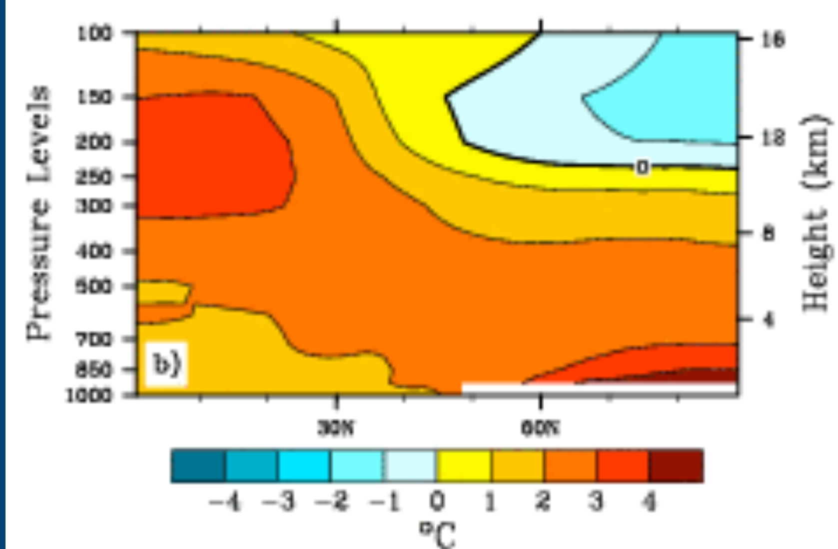


IPCC-AR4 ensemble mean, A1B Scenario, courtesy M. Holland

Model-projected Arctic amplification

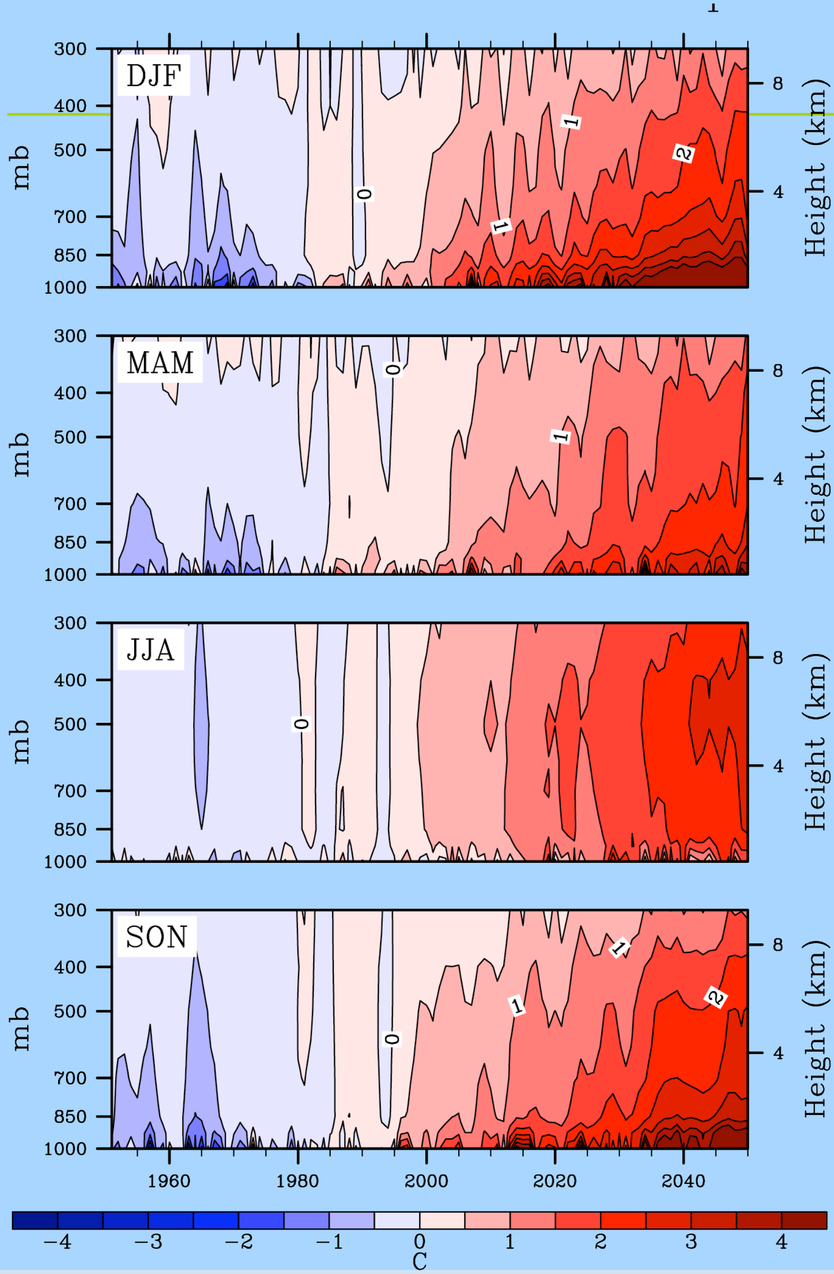


NCAR CCSM3 projection of 2-meter temperature anomalies by month and year over the Arctic Ocean, compared to 1979–2007 means



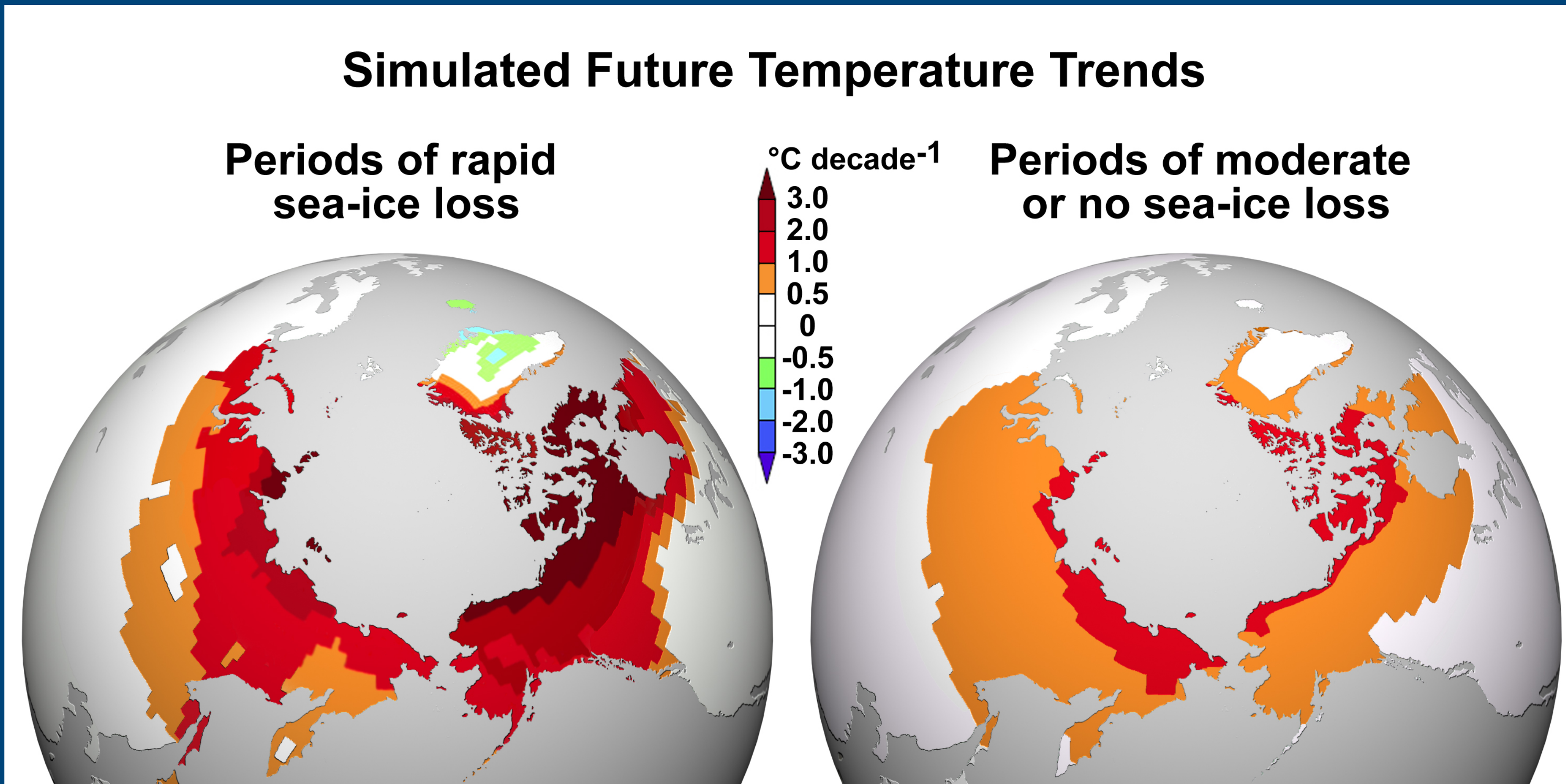
Latitude by height dependence of zonally averaged October–March temperature anomalies for 2050–2059, compared to 1979–2007 means (NCAR CCSM3)

Serreze et al., 2009



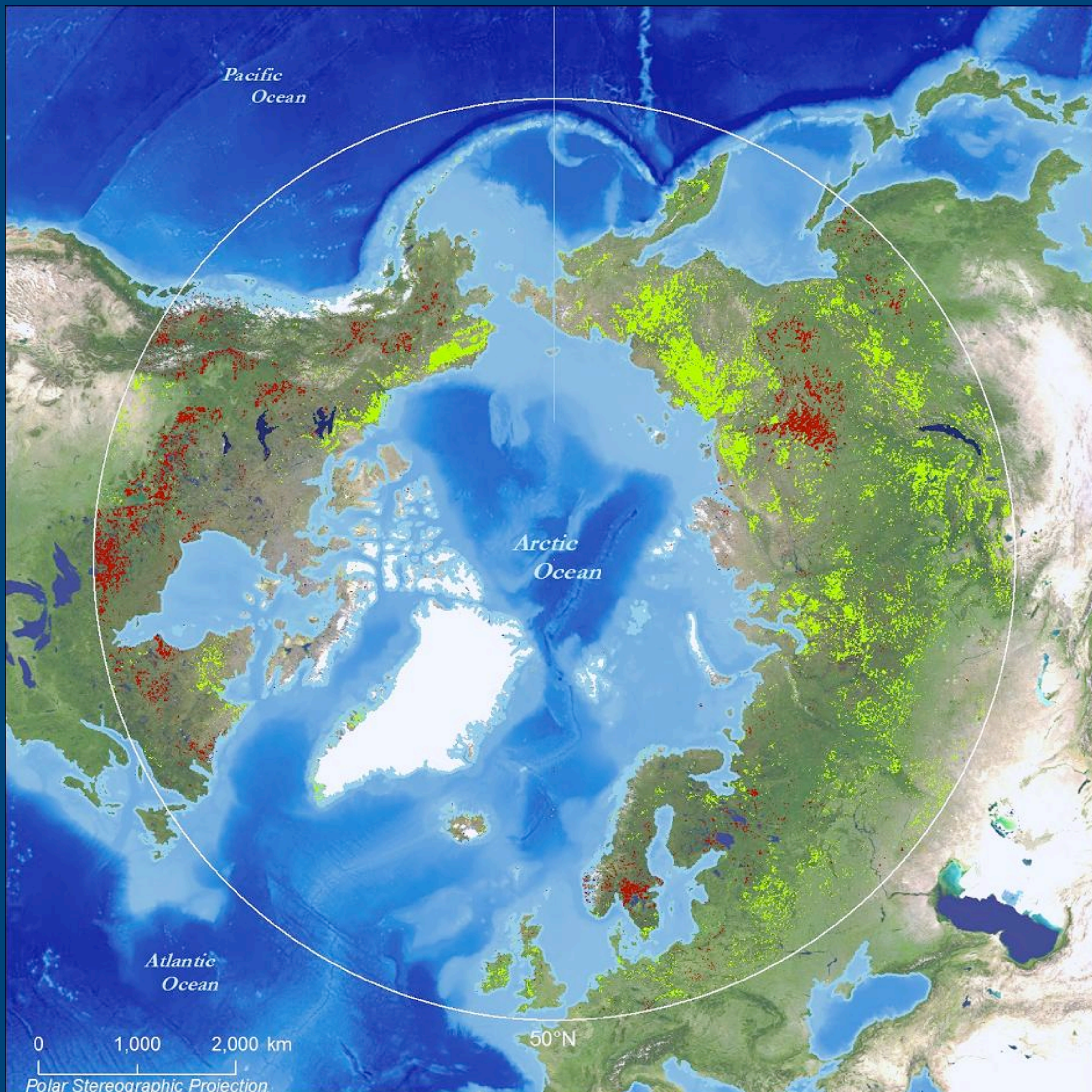
Evolution of Arctic Ocean temperature anomalies, 1950-2050, from a multi-model ensemble (CCSM3, PCM1, HADCM3 MIROC3.2-HIRES) based on observed climate forcing through 2000 and the A1B emissions scenario for the 21st century. Values are expressed as temperature anomalies with respect to 1970-1999 means. There are 15 ensemble members for the 20th century (8 CCSM3, 4 PCM1, 2 HADCM3 and 1 MIROC3.2-HIRES) and 11 for the 21st century (7 CCSM3, 2 PCM1, 1 HADCM3, 1 MIROC3.2-HIRES).

Ice loss leads to terrestrial warming



Courtesy D. Lawrence and A. Slater

Regional "greening" of the Arctic



Trends in vegetation synthetic activity from 1982–2005
(GIMMS-G AVHRR Vegetation indices)

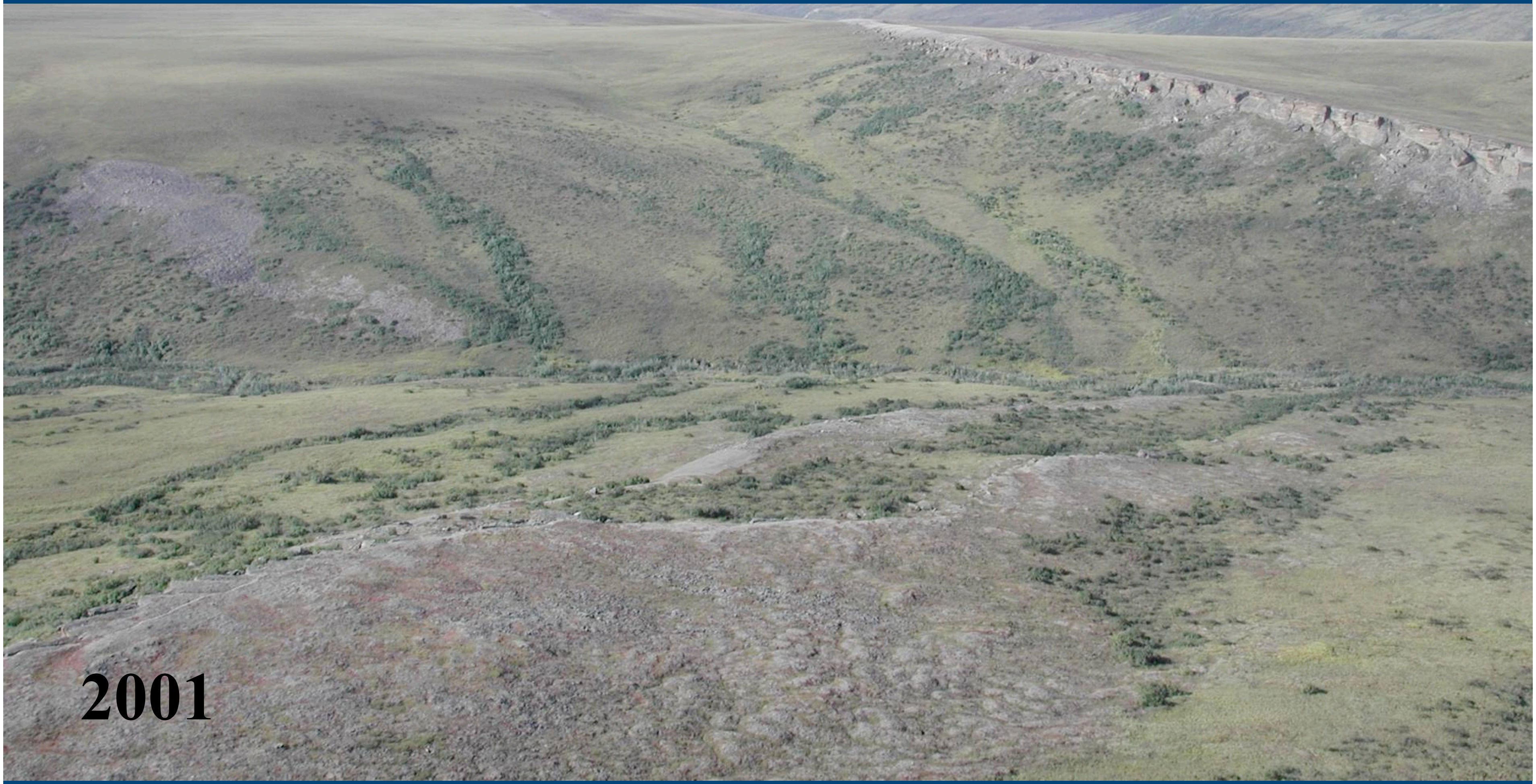
Significant positive trends

Significant negative trends

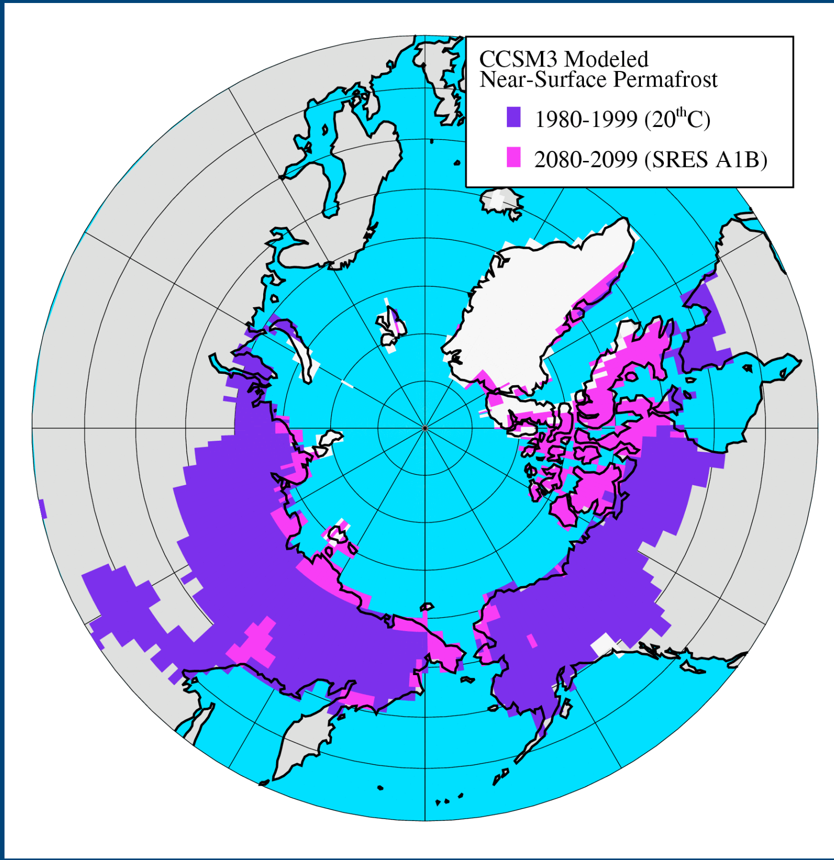
Courtesy Scott Goetz, Woods Hole

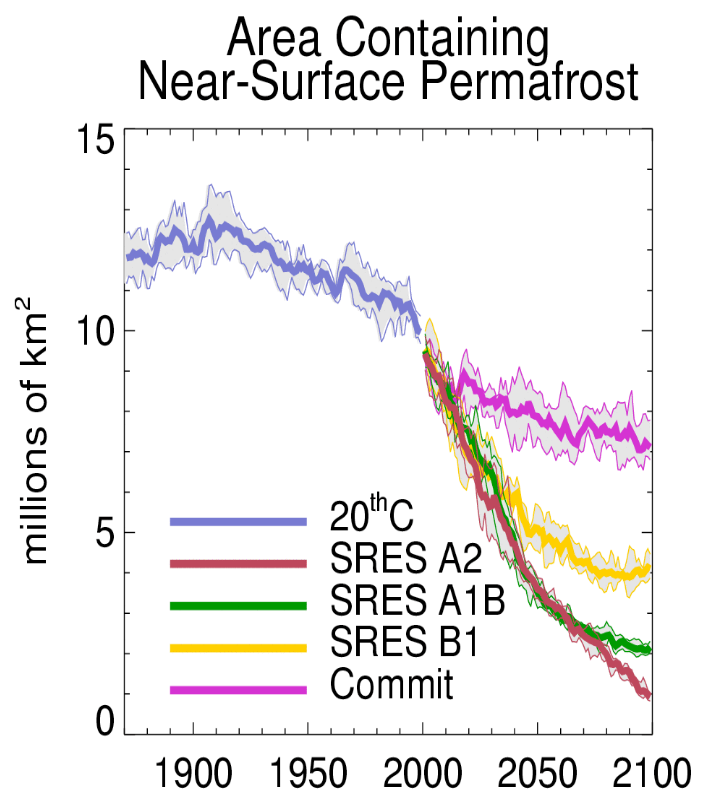
Changes in Shrub Abundance: Chandler River, AK

Chandler River, 50 miles S. of Umiat: Sturm, Racine and Tape: Fifty Years of Change in Arctic Alaskan Shrub Abundance


2001

Accelerated thawing of permafrost



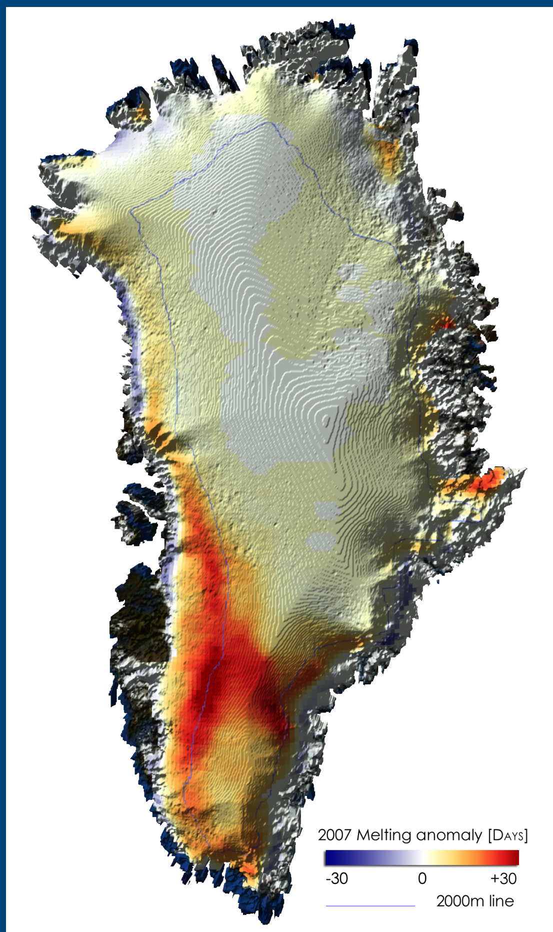


Permafrost contains about 950 Gt of carbon (Zimov et al., 2006: *Science*). For comparison, carbon content of Earth's atmosphere: ~730 Gt today.

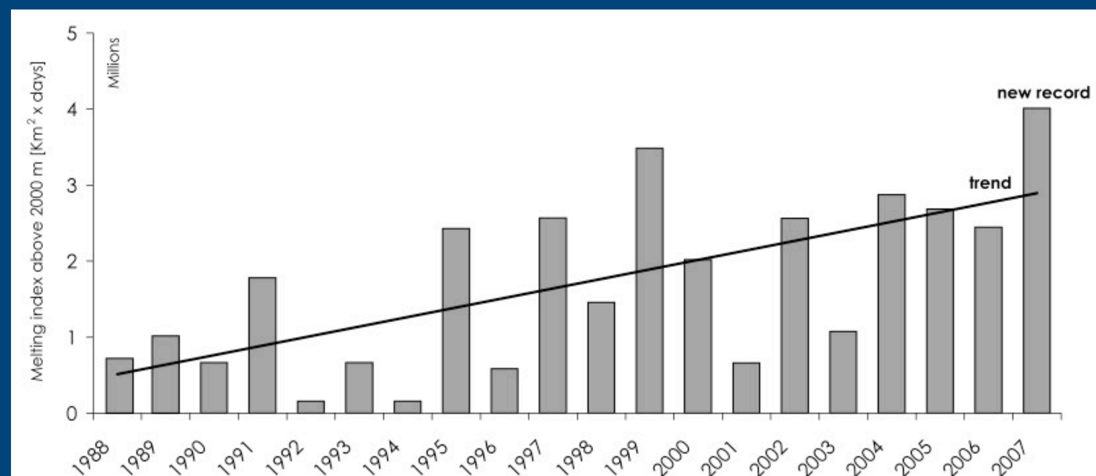
Lawrence and Slater, 2005

Impacts on the mass balance of greenland?

2007 Melting Day Anomalies

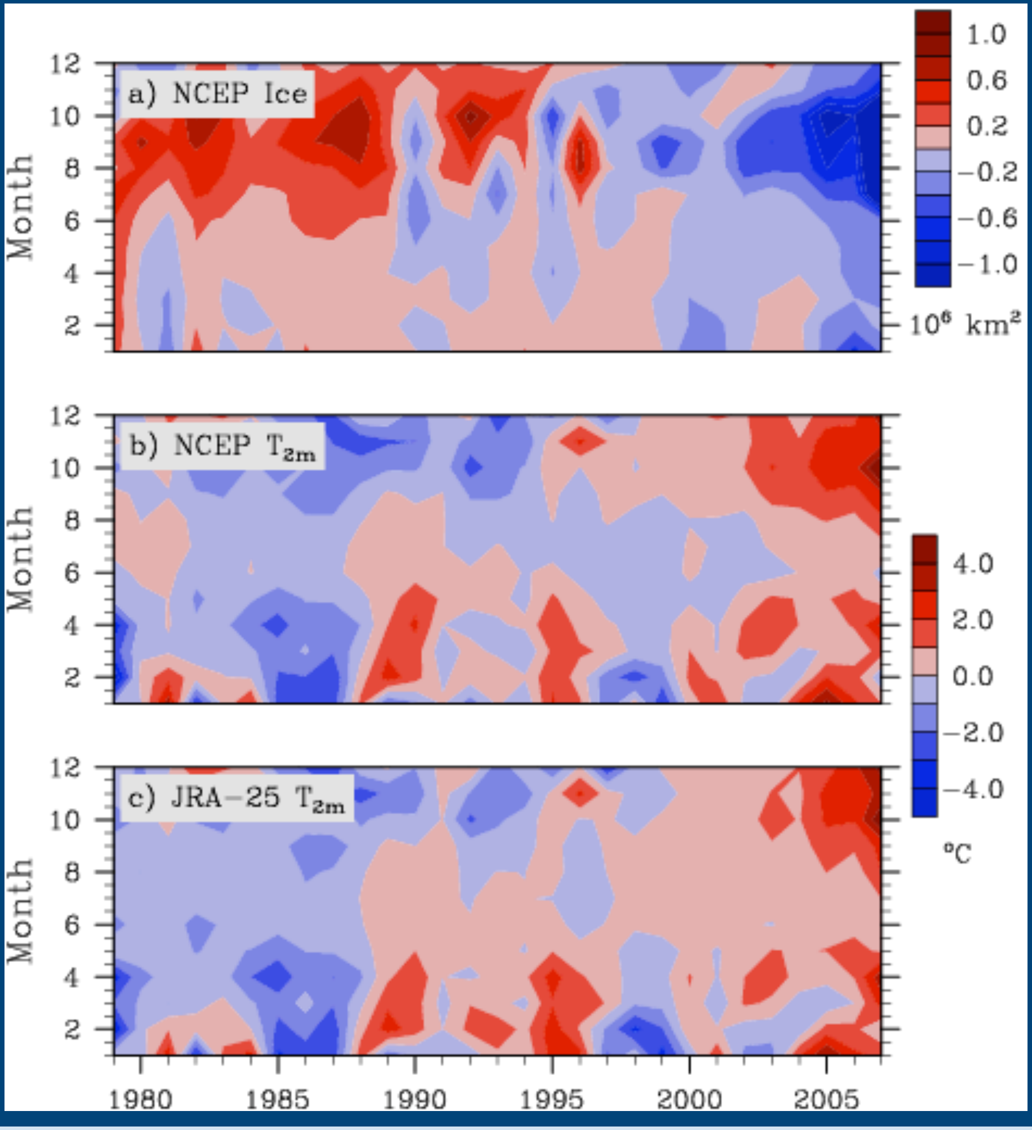


Melting Index Time Series



Marco Tedesco, City College of New York-CUNY

Sea ice extent and SAT anomalies over Arctic Ocean

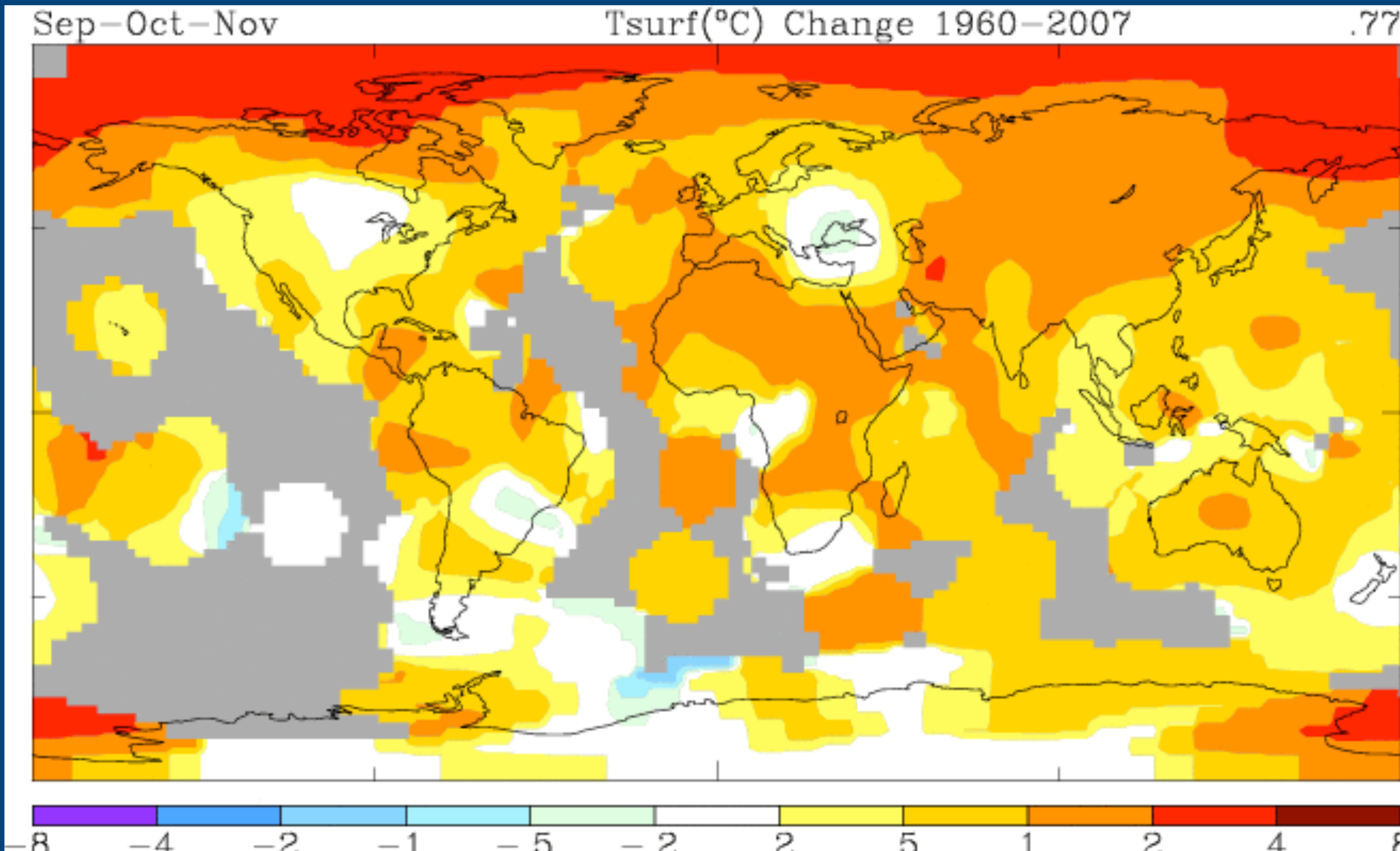


Strongest decline in sea ice extent during September

Strongest rise in surface air temperature during October

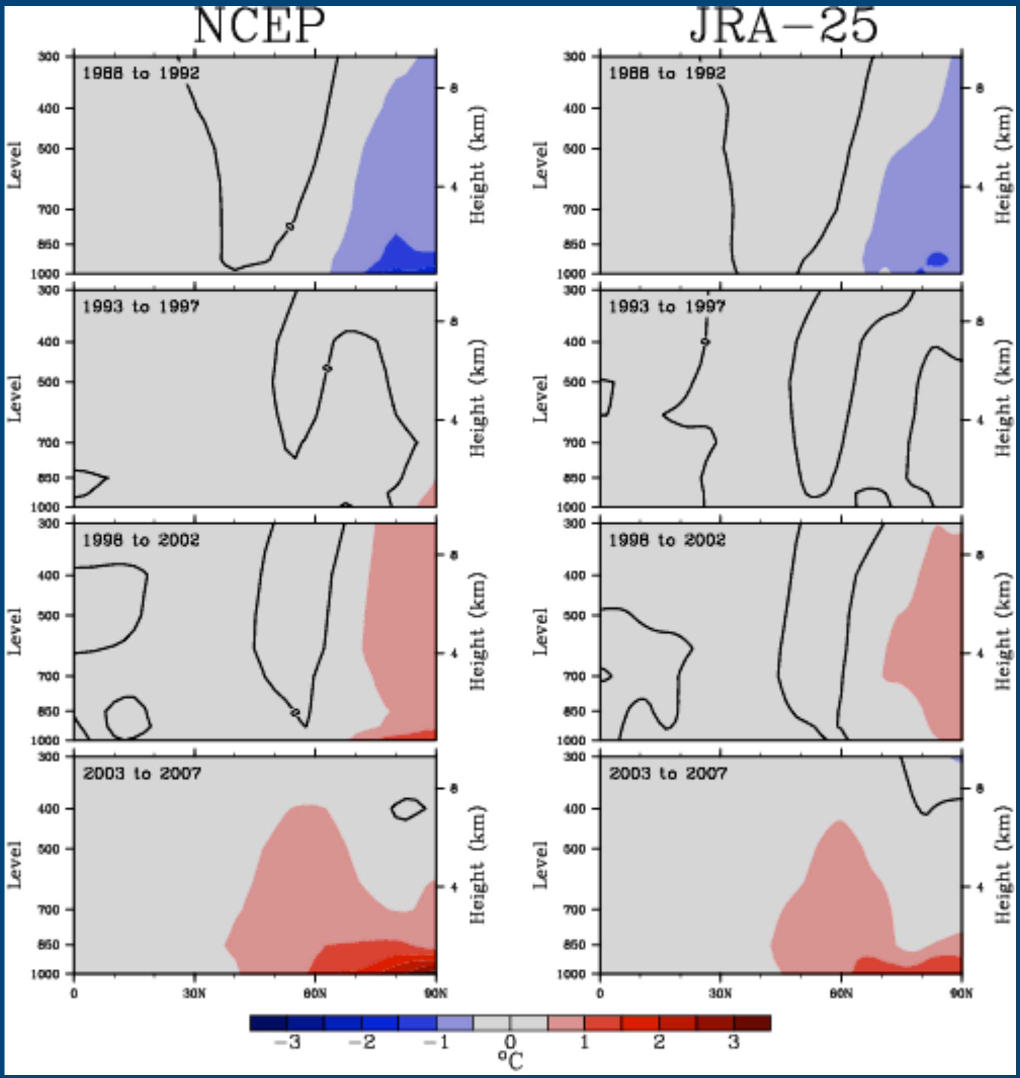
From Serreze et al., 2008

Observed autumn temperature trends, 1960-2007



GISS Analysis

Emerging autumn signal has a surface maximum



Variability aloft linked to variability in atmospheric circulation

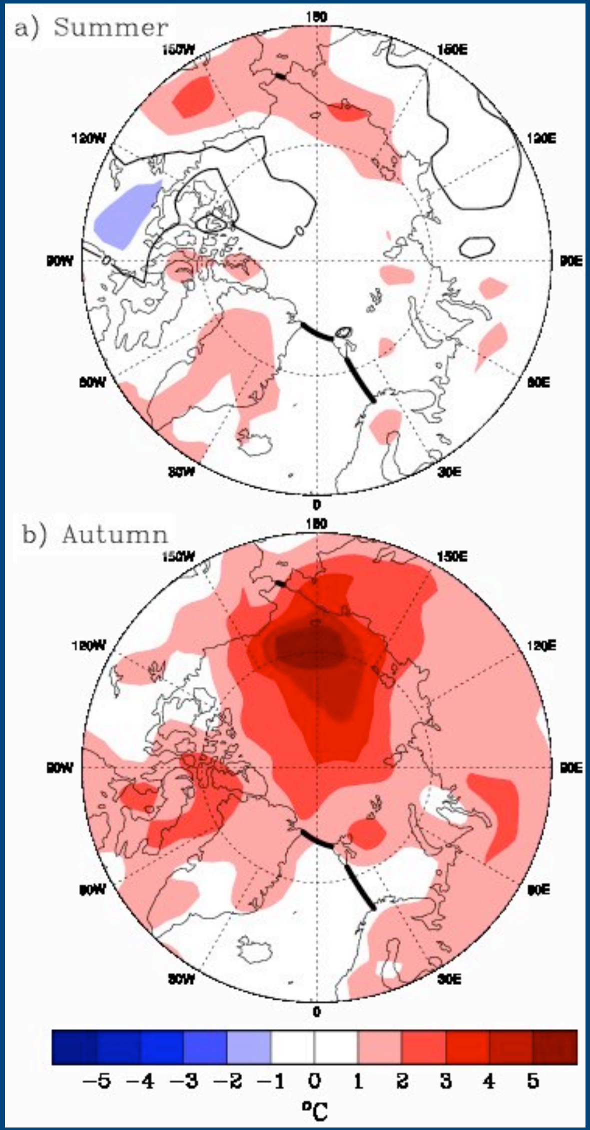
An emerging surface signal consistent with a growing surface heat source

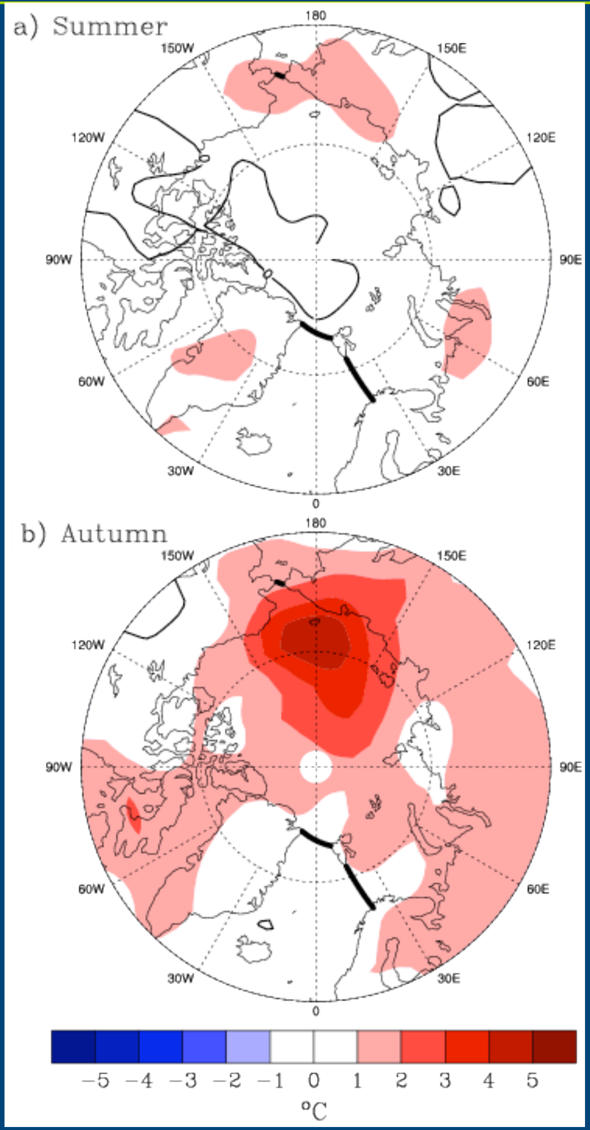
Patterns are similar in NCEP and JRA-25, stronger anomalies in NCEP

Serreze et al., 2008

SAT anomalies: 2003-2007 minus 1979-2007

NCEP

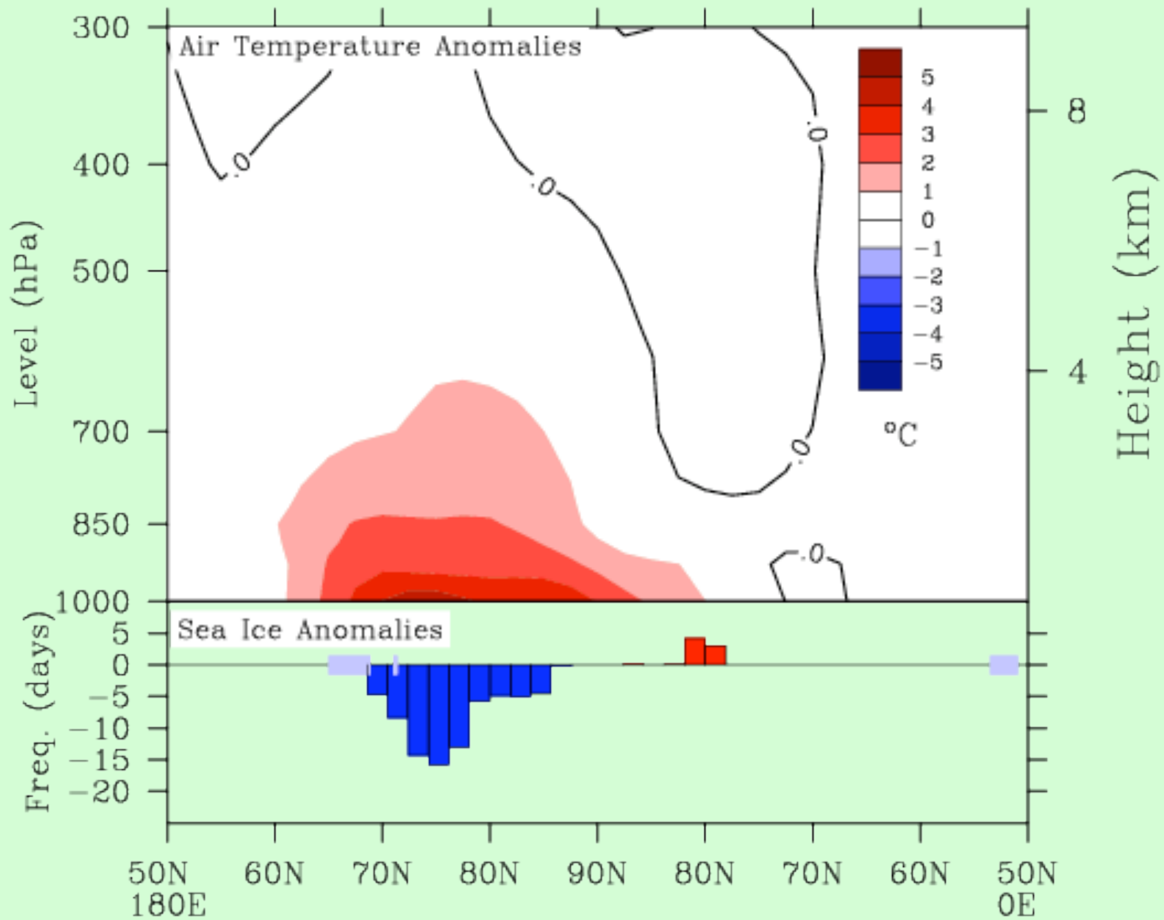




JRA-25

Serreze et al., 2008

Temperature anomalies linked to declining sea ice



NCEP temperature anomalies, 2003–2007 minus 1979–2007

Anomalies in ice-covered days from 2003–2007 minus 1979–2007

Serreze et al., 2009

Conclusions

- We are quickly losing the ice cover
  - Impacts are already being felt
- Ice-free summers by 2030? Earlier?
  - We seem to be in the fast lane
- Arctic amplification will be a big issue
  - Impacts on atmospheric circulation
  - Impacts on terrestrial warming and carbon cycle

Thank You