A global view of large-scale atmospheric circulation variability over the last 60 years

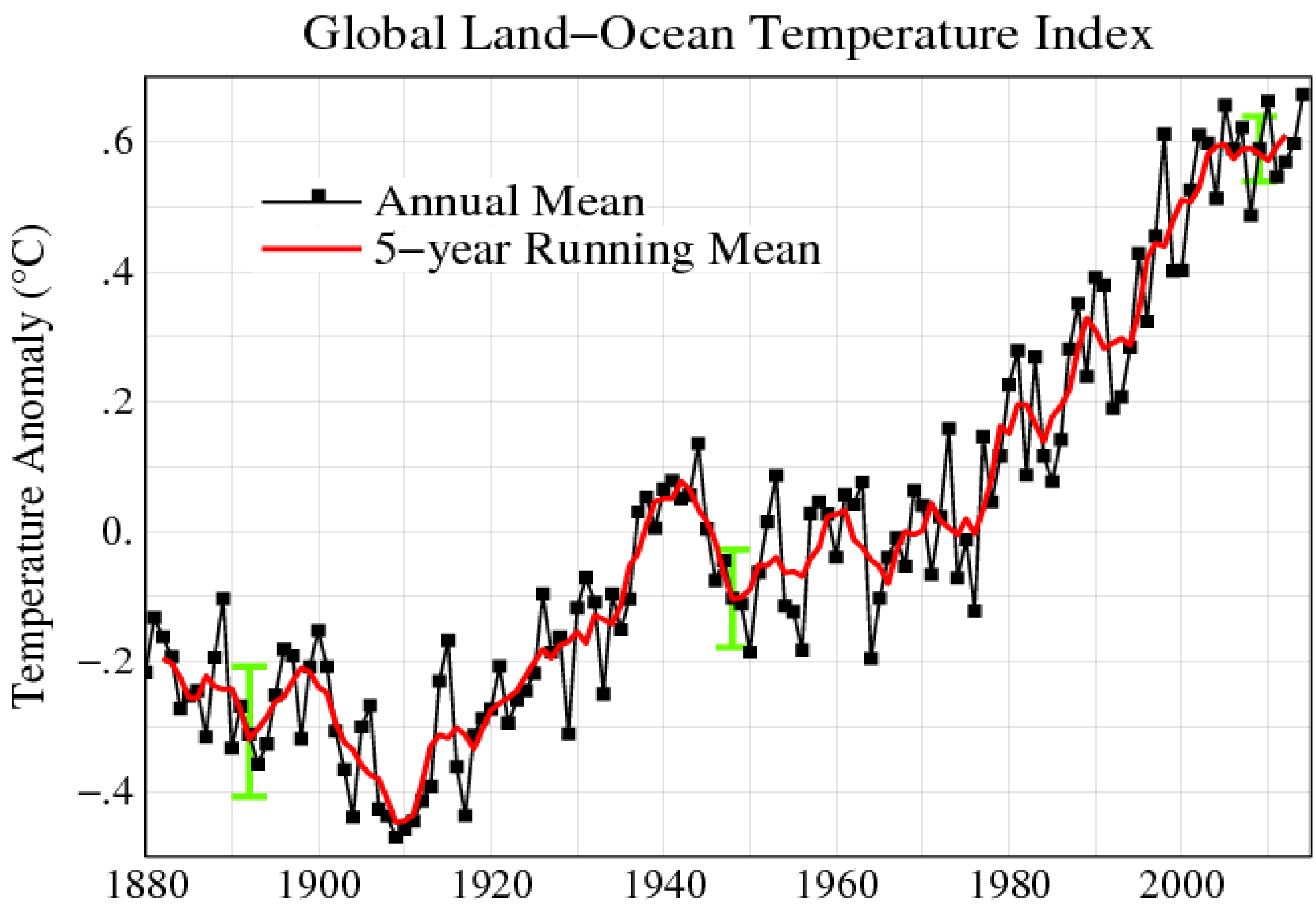
Qinghua Ding

Polar Science Center Applied Physics Lab
University of Washington

Acknowledgement:
John Wallace, David Battisti, Eric Steig, Ailie Gallant, HyungJin Kim & Lei Geng

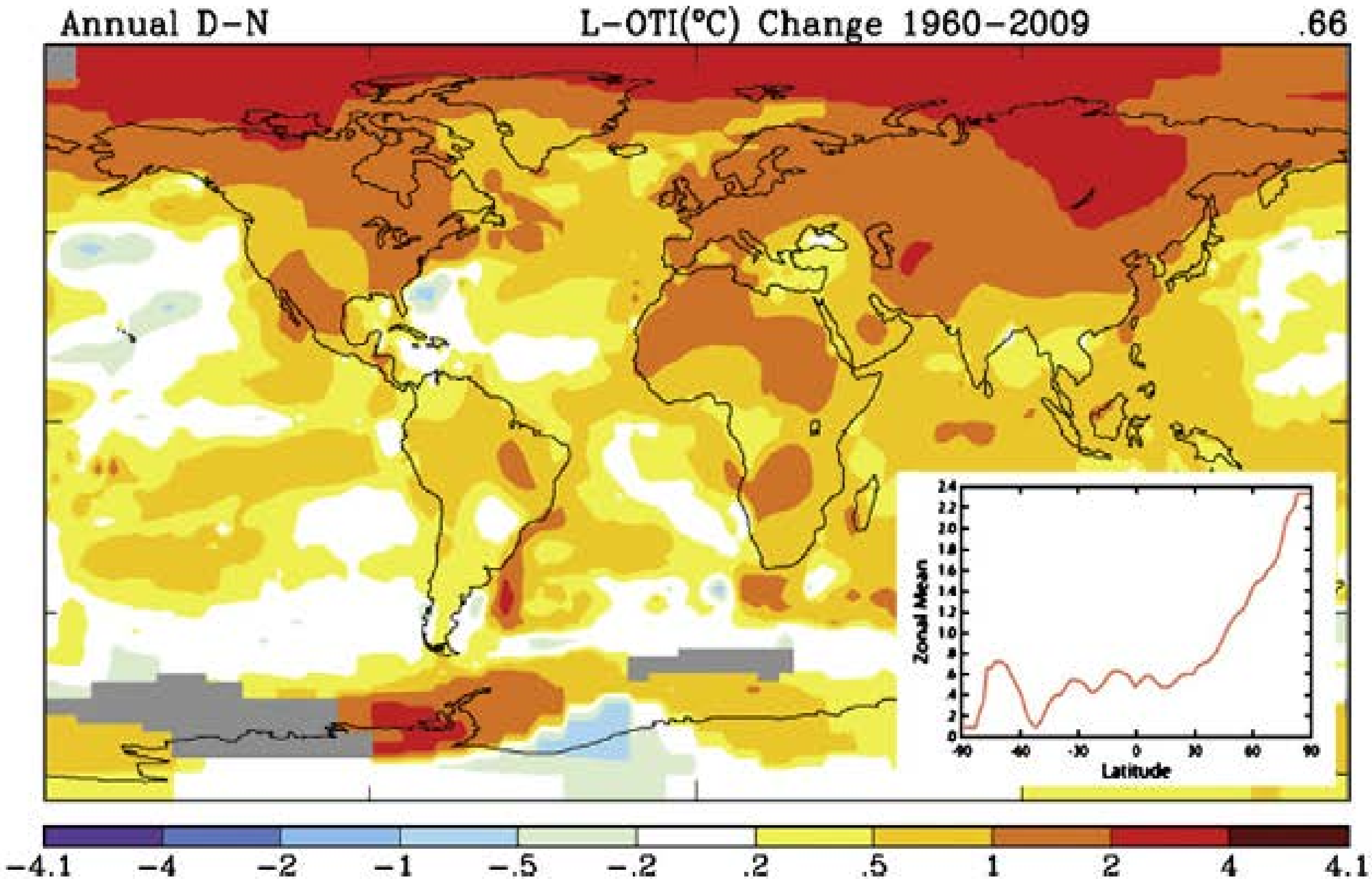
MODES workshop, August, 28, 2015

Photo: NASA



Hansen et al. 2010

The fastest warming rate in the Arctic and Antarctic Peninsula



Serreze and Barry 2011

Warming trend is sensitive to start/end of a period

Surf-T poleward of 59N

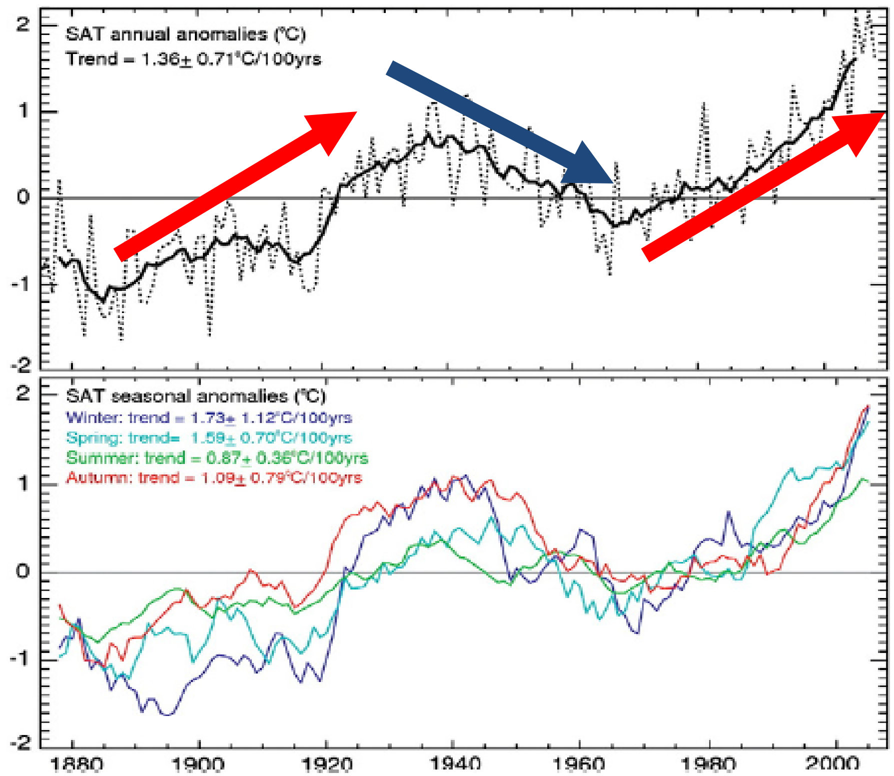
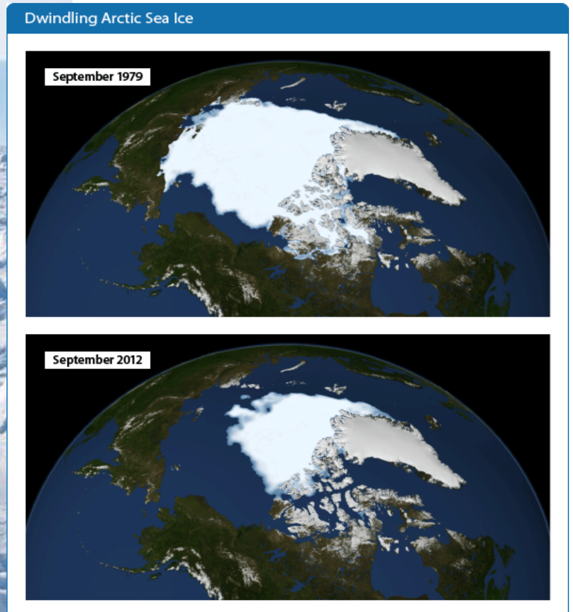


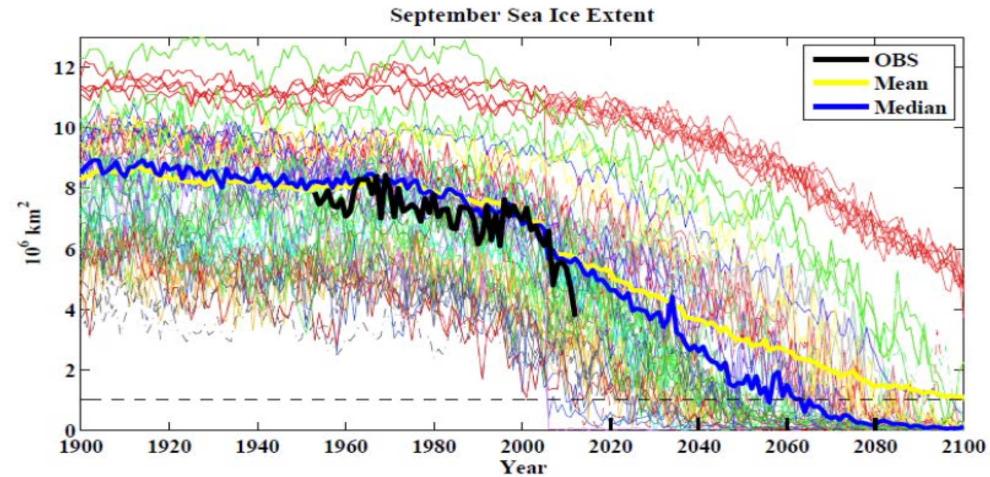
Fig. 3. Composite time series of the (top) annual and (bottom) seasonal surface air temperature anomalies (°C) for the region poleward of 59°N. The dotted lines show unsmoothed values, the solid lines are seven year running means. The liner trends listed in the legend are computed using data for the period 1900–2008 (from Bekryaev et al., 2010). Note the strong warming, from about 1920–1940, strong cooling until about 1970, and renewed warming through the end of the record.

Serreze and Barry 2011

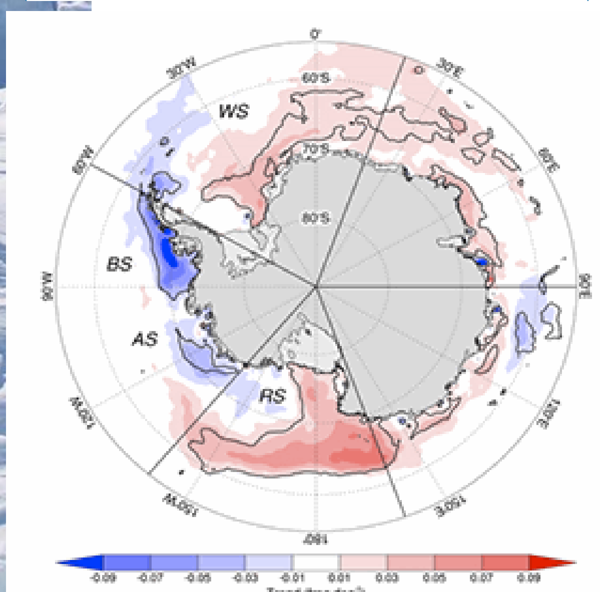
Sea ice change in the Arctic and Antarctic



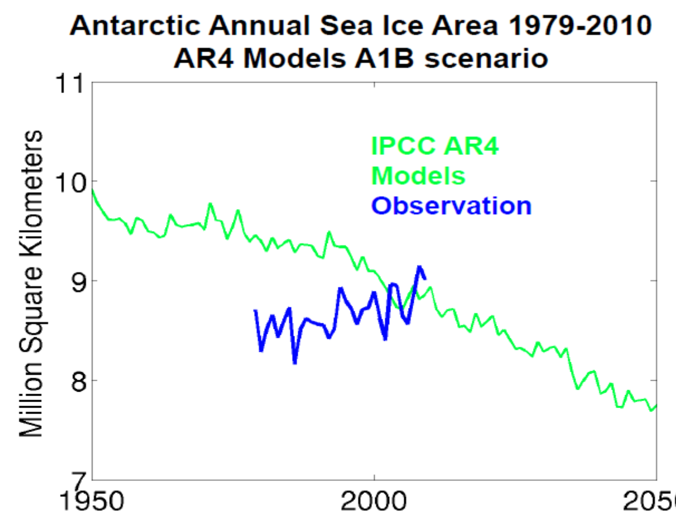
NASA



Overland and Wang 2013

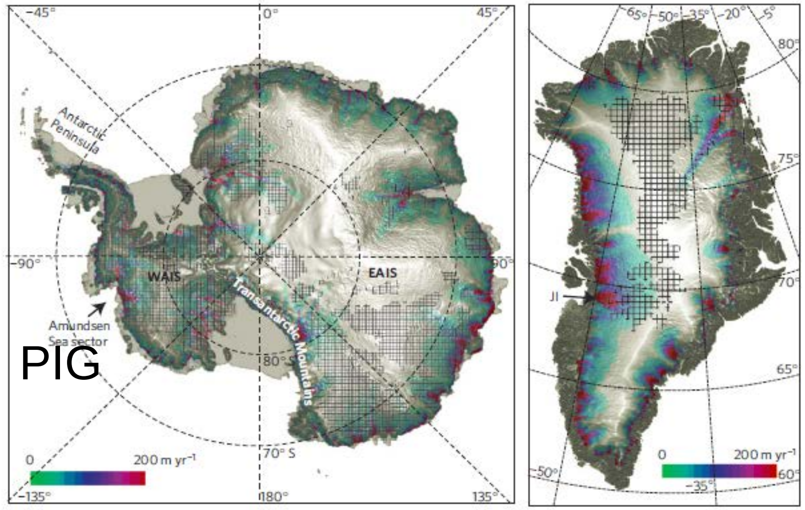


BAS

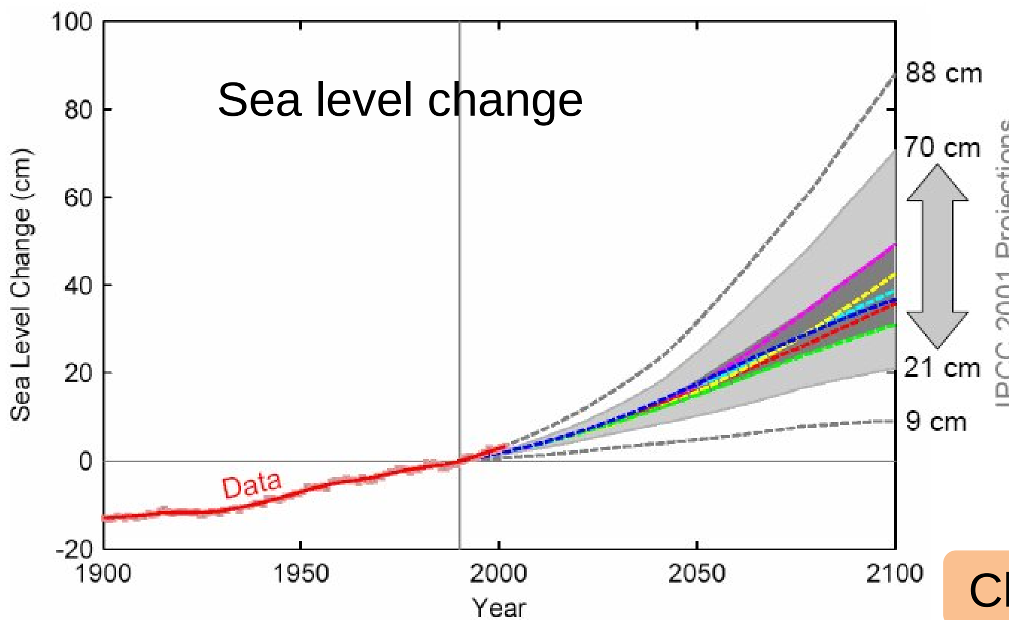


C. Bitz

Rapid Ice sheet melt in the Arctic and Antarctic

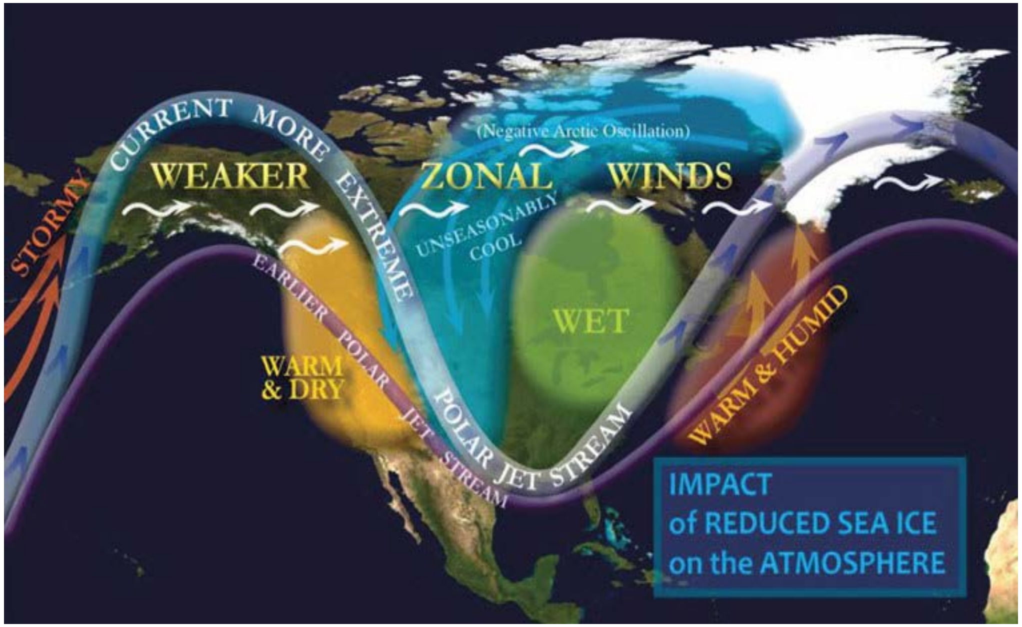


Bamber and Aspinall 2013



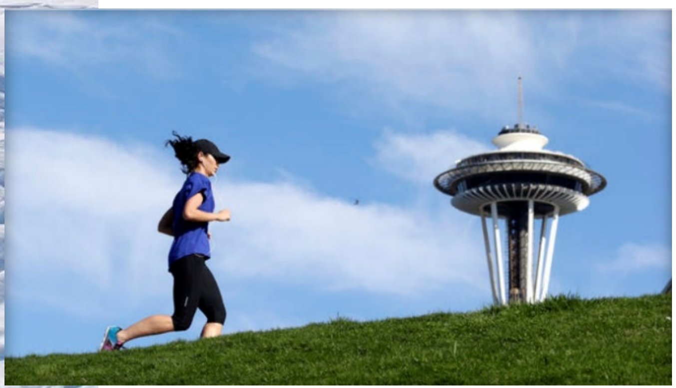
Church and White 2006

Arctic warming and extreme events



Francis and Vavrus 2012

Seattle in Feb, 2015



2014/15 brutal Winter in New England

Arctic amplification

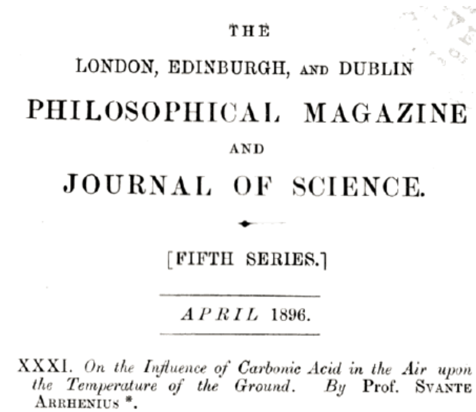
Local causes (anthropogenic)

- Sea ice loss
- Albedo feedback
- Cloud cover and water vapor
- Black carbon aerosol
- Local thermal inversion
- Vegetation feedback

Remote causes (anthropogenic)

- Poleward heat and moisture transport by atmosphere and ocean

Svante Arrhenius
(1859 – 1927)



THE

LONDON, EDINBURGH, AND DUBLIN

PHILOSOPHICAL MAGAZINE

AND

JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

Key Questions

- What are relative contributions of the external (thermodynamics) and internal (dynamics) forcing in the recent climate change in the Arctic and Antarctic?

- How is the internal forcing causing these changes?

- Can we predict the primary internal forcing of polar regions in the next two-three decades?

Contents

Recent three decades

Past 60-70 years

Data and Method

DATA

- **Atmospheric reanalysis**
  1979-2013: ERA-interim, NCEPII, MERRA, CFS2
  1948-2013: ERA40, NCEP1, JRA55
  1900-2010: ERA-20C, NOAA 20^{th}
- **SST & sea ice**
  ERSST3, HADISST, Kaplan, COBE
- **Surface temperature**
  GISS-TEMP, Delaware, CRU, ERA-interim, MERRA, AVHRR
- **IPCC AR5 historical run** (1958-2004)

Model

- ECHAM4.6 model (T42L19)+ slab ocean/sea ice
- CESM1.2 (POP2+CICE2)
- PIOMAS

Method

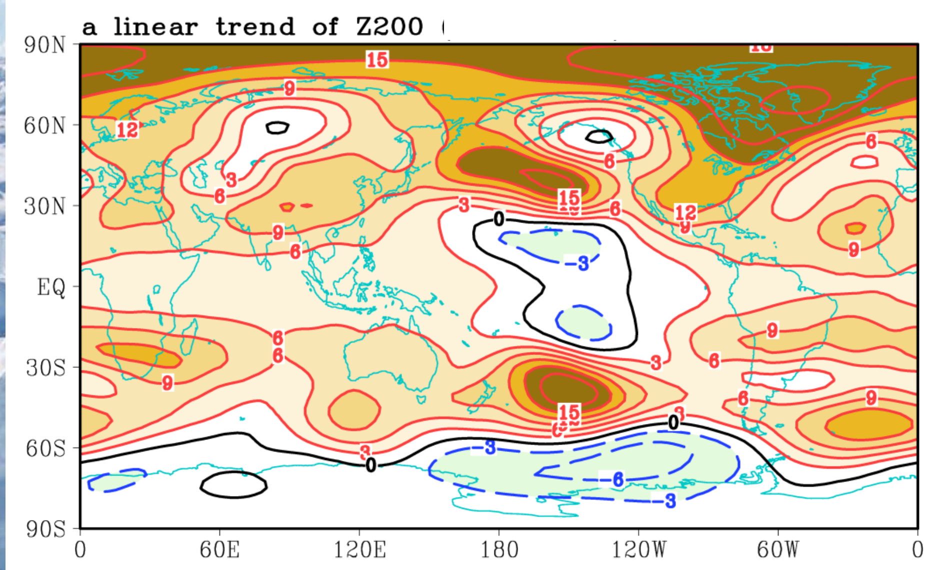
- Annual mean (June- May)
- Trend: epochal difference or linear trend
- Trend significance (signal to noise ratio, Mann-kendall test)
- Upper level circulation

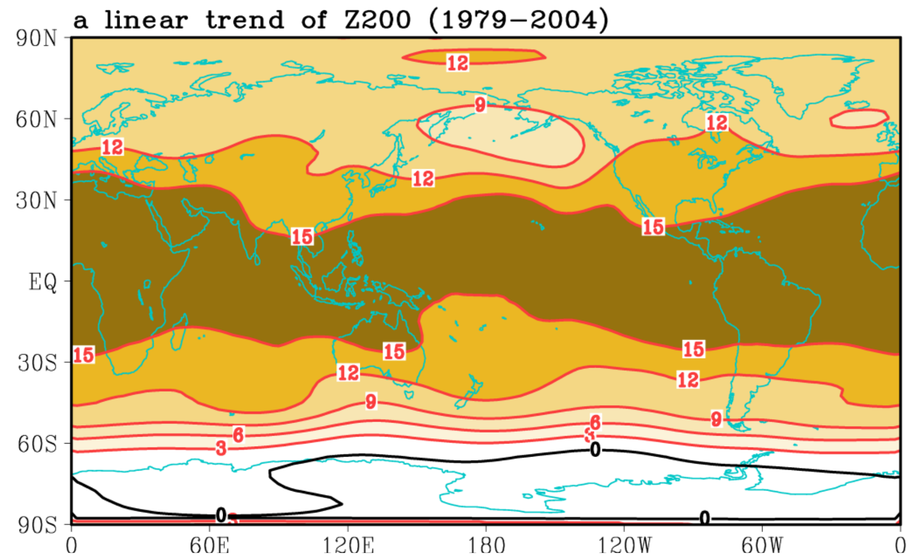
Internal variability vs forced response

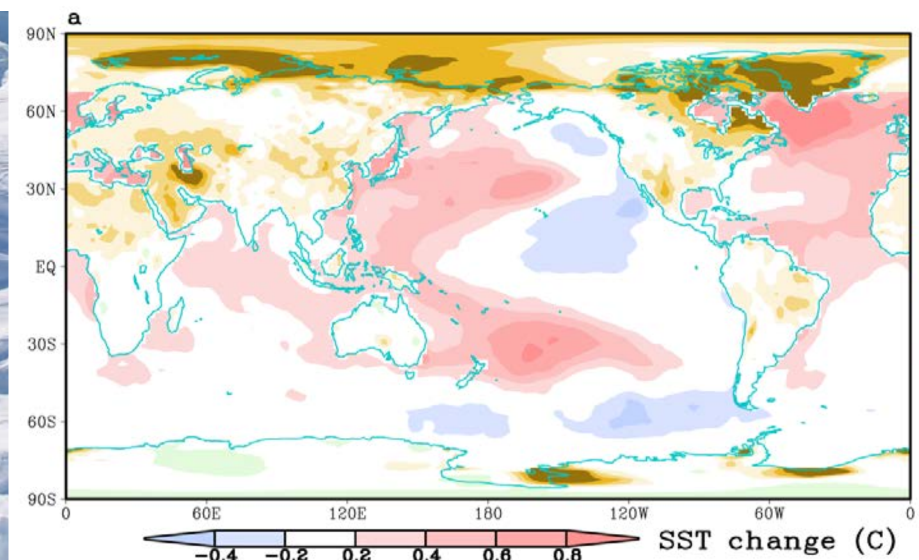
Annual mean
m/decade

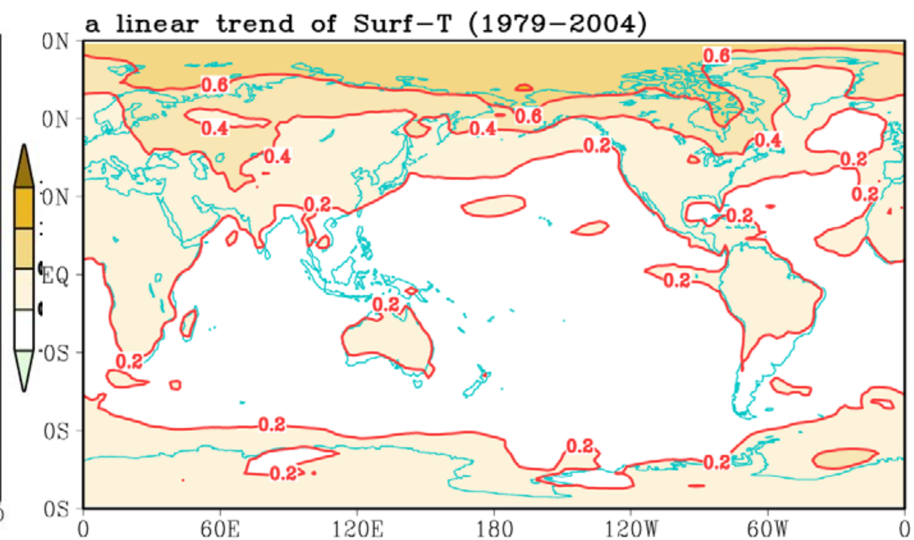
Reanalysis (1979-2013)

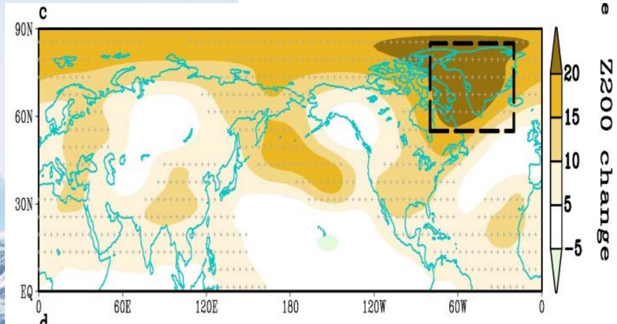
IPCC AR5 historical run
(ensemble mean of 40 model)

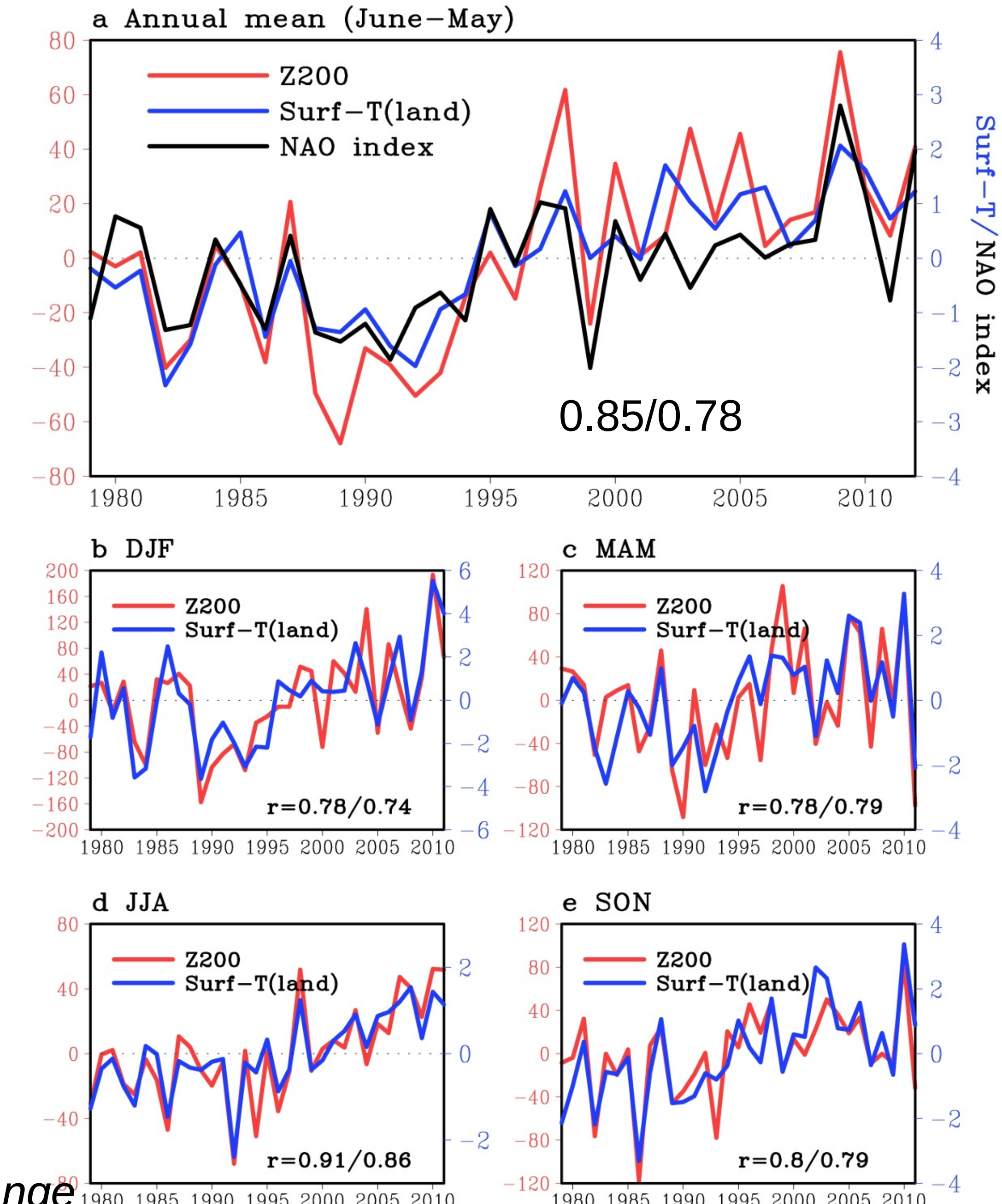






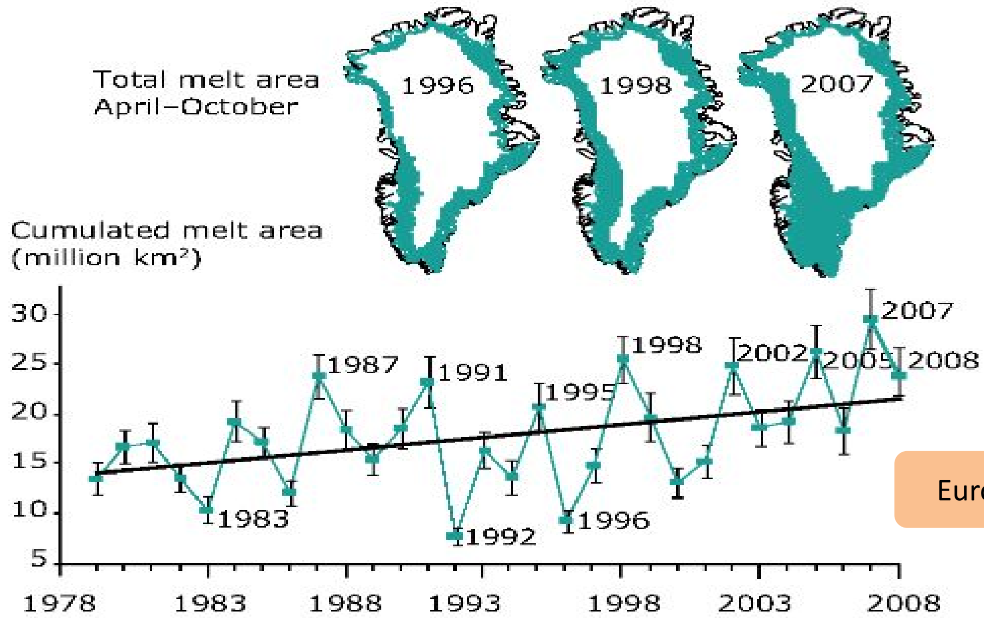






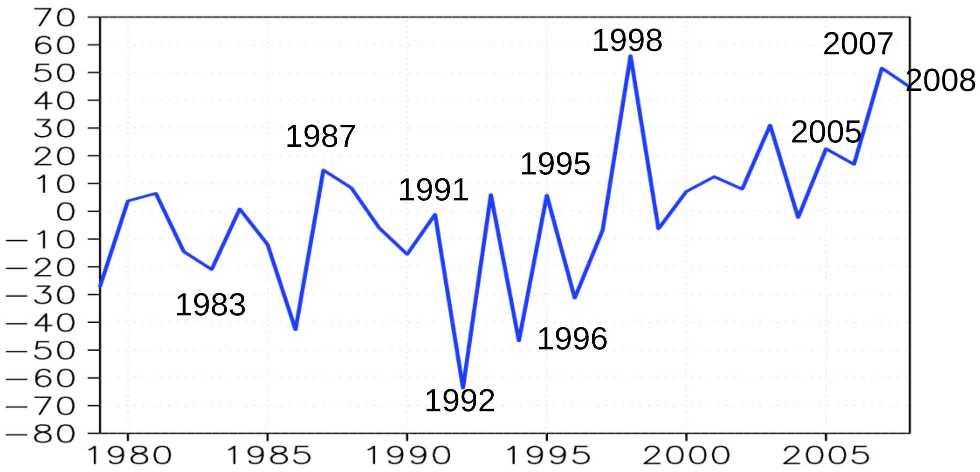
Interdecadal-like change

Greenland ice sheet melt extent



European Environment Agency

JJA Z200 change in Greenland

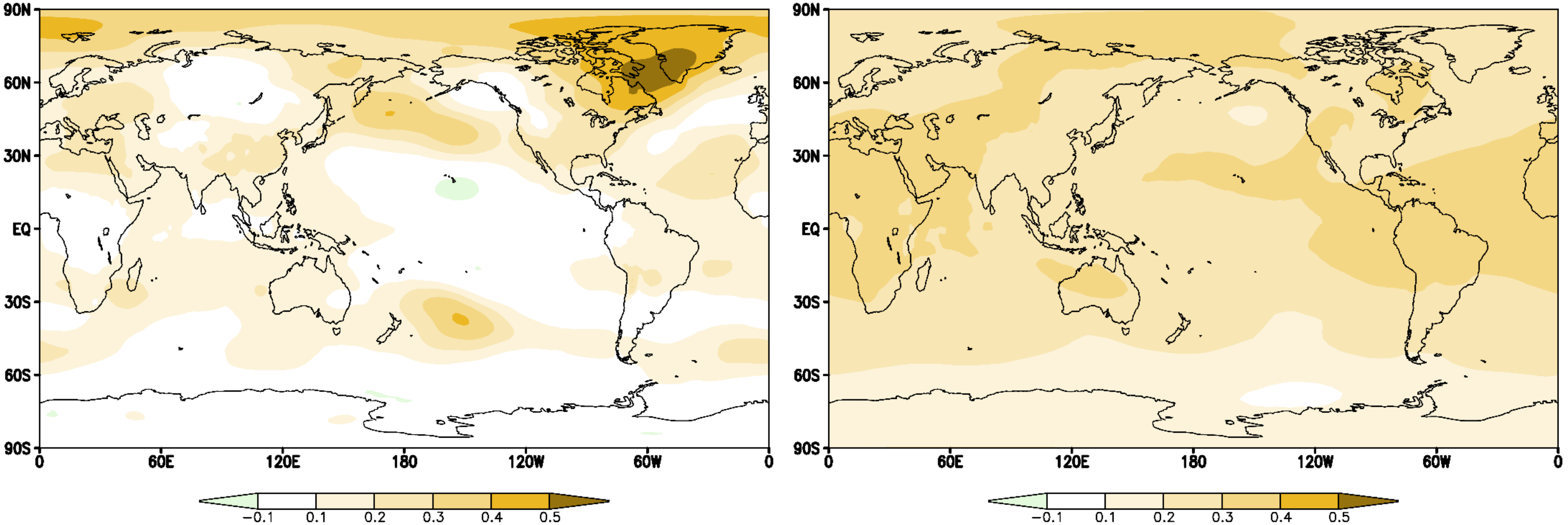


Internal variability vs forced response

Linear trend of annual mean 300-850hPa temperature 1979-2013

Reanalysis

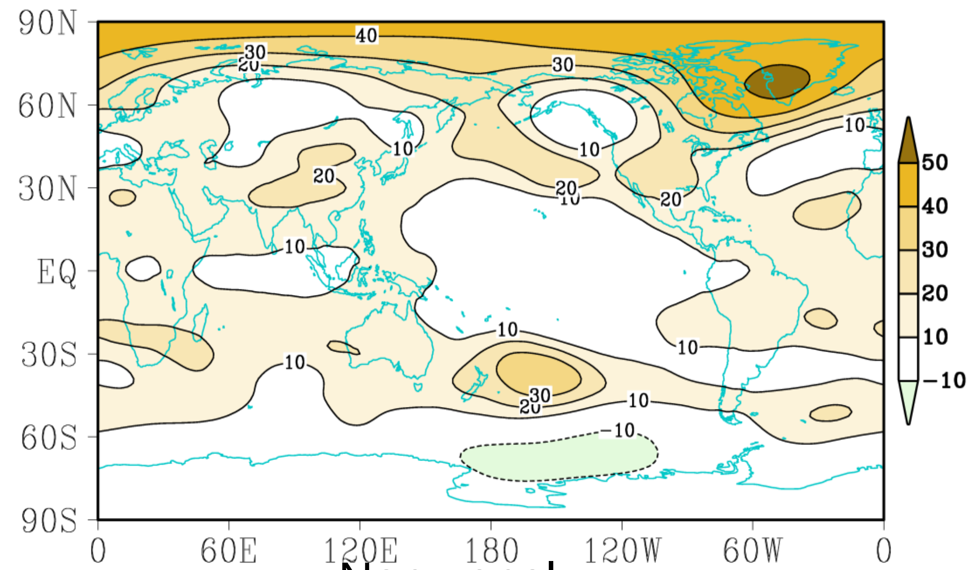
CMIP5



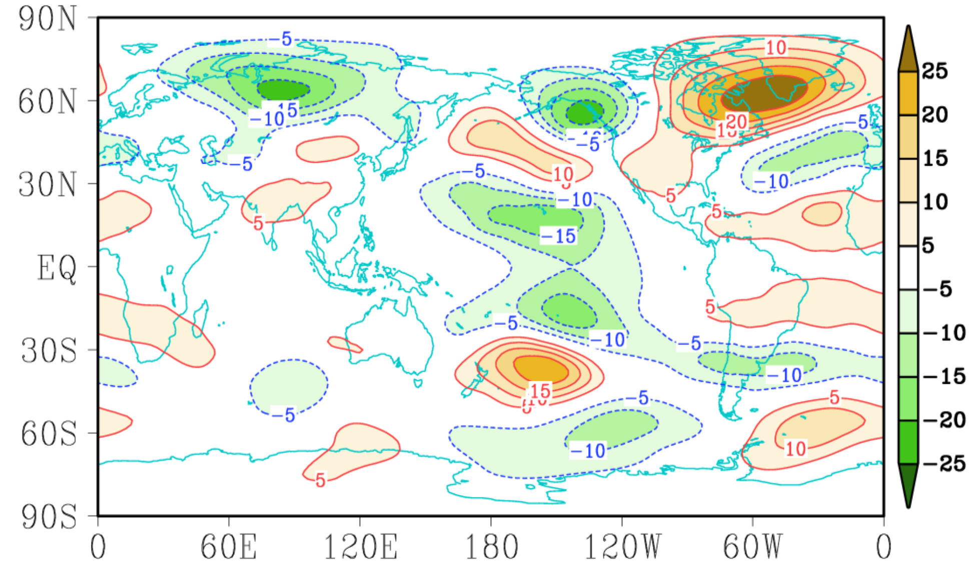
c/decade

Annual mean SST and Z200 change (1996-2013 minus 1979-1995)

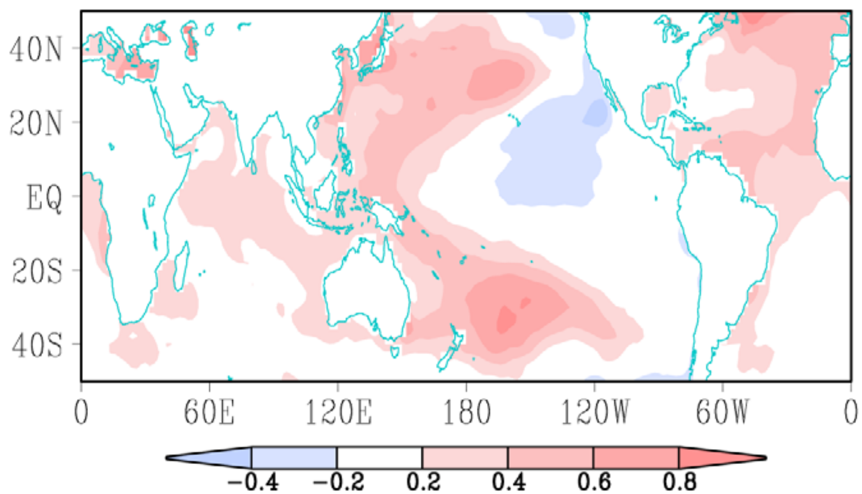
Z200 change



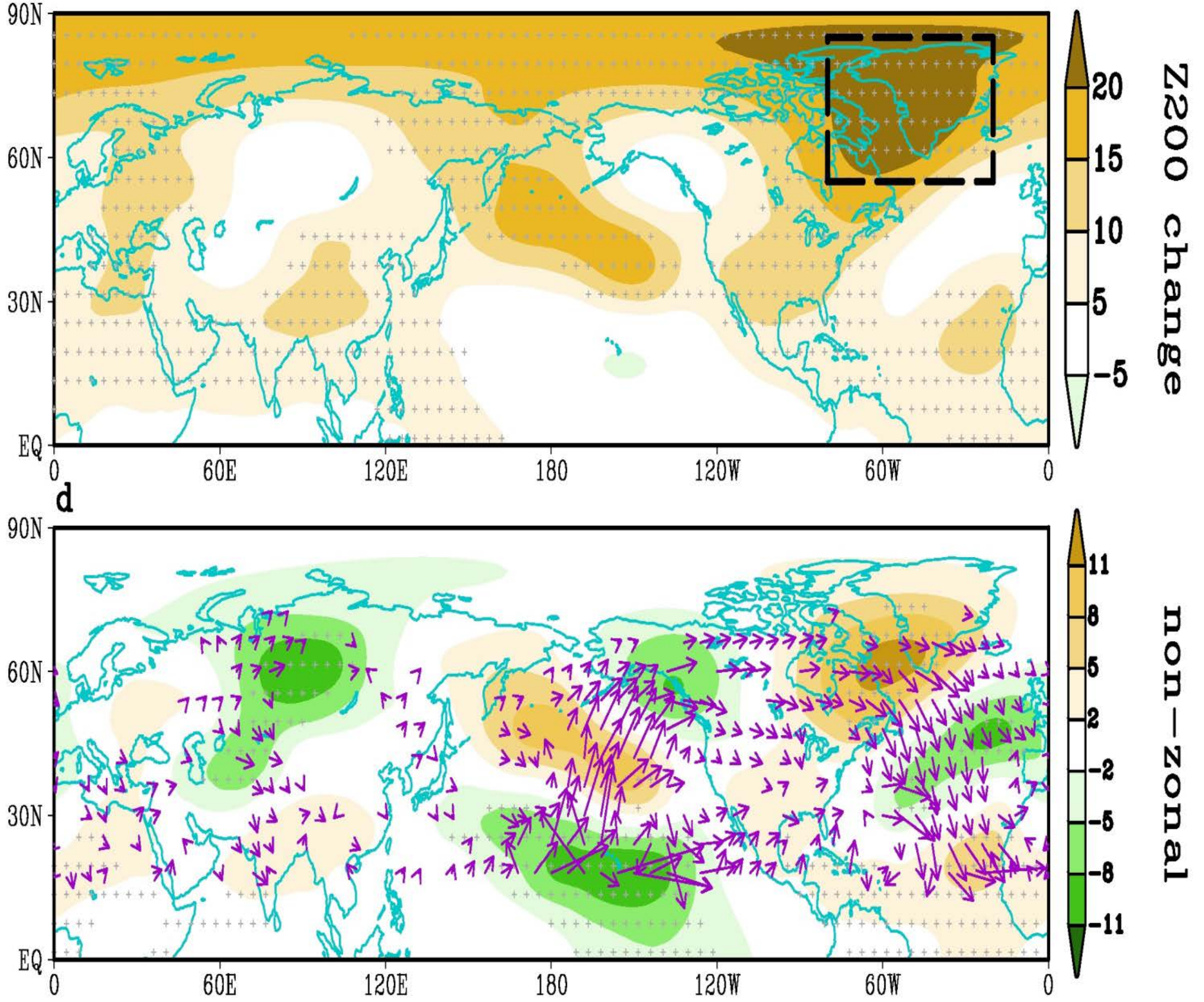
Non-zonal



SST change



Annual mean Z200 trend (1979-2013)

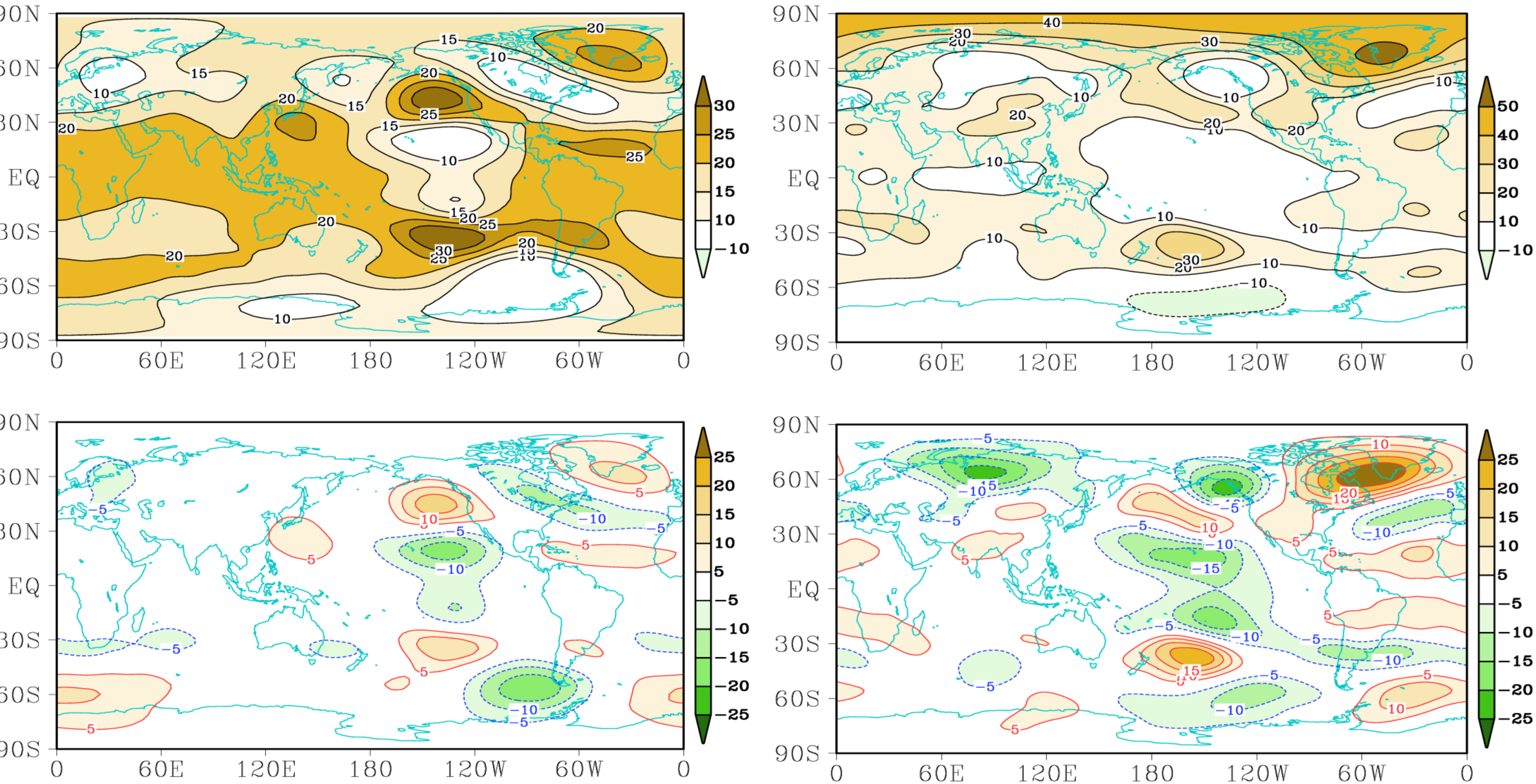


the Arctic is running a tropical fever

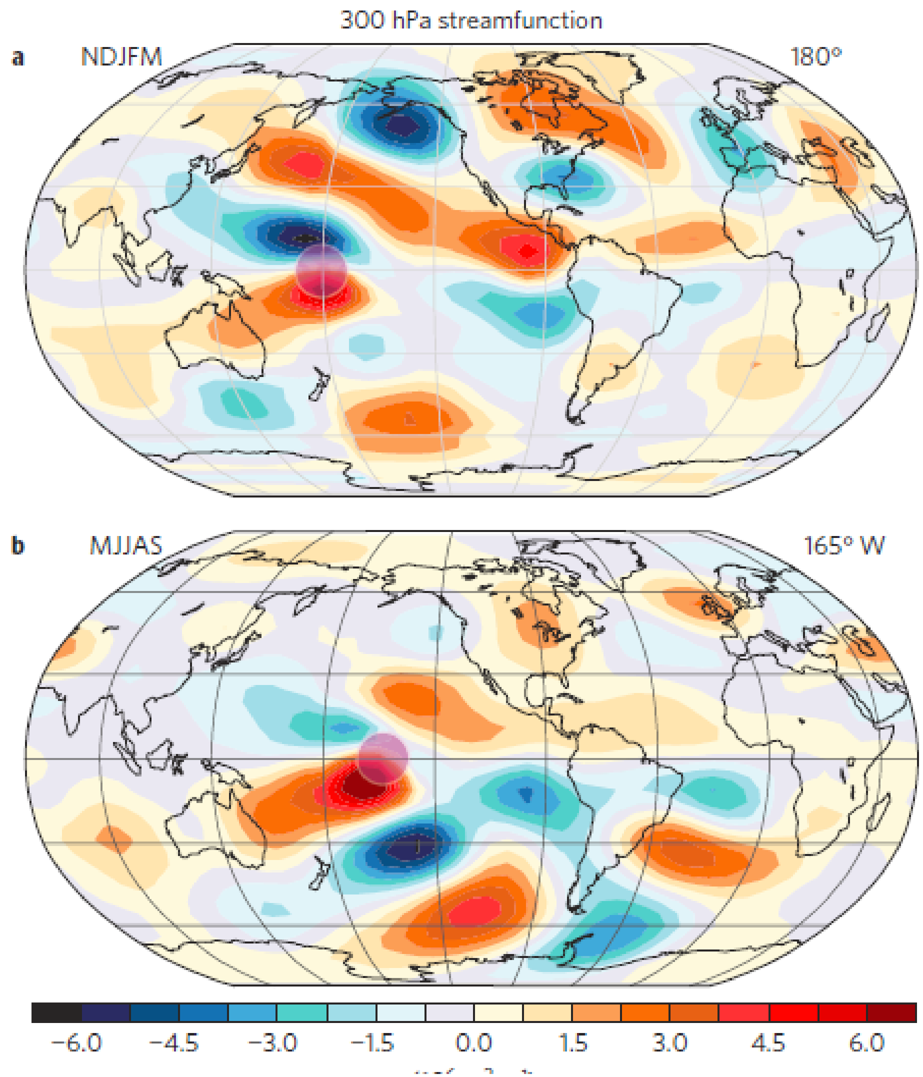
Plumb flux 1985

Annual mean Z200 change (1996-2013 minus 1979-1995)

ECHAM4 Simulation | observation

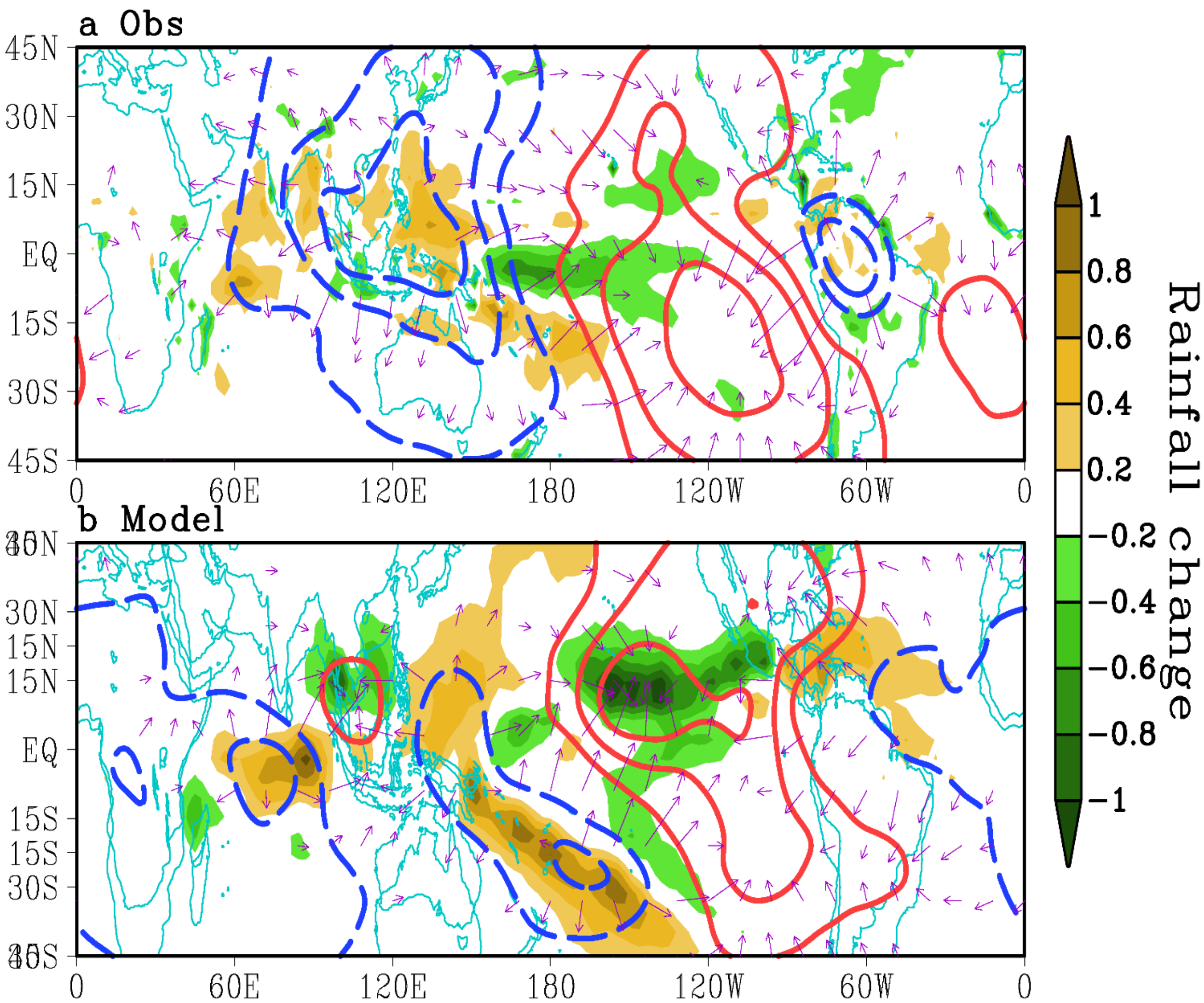


CAM model response to tropical heating anomalies

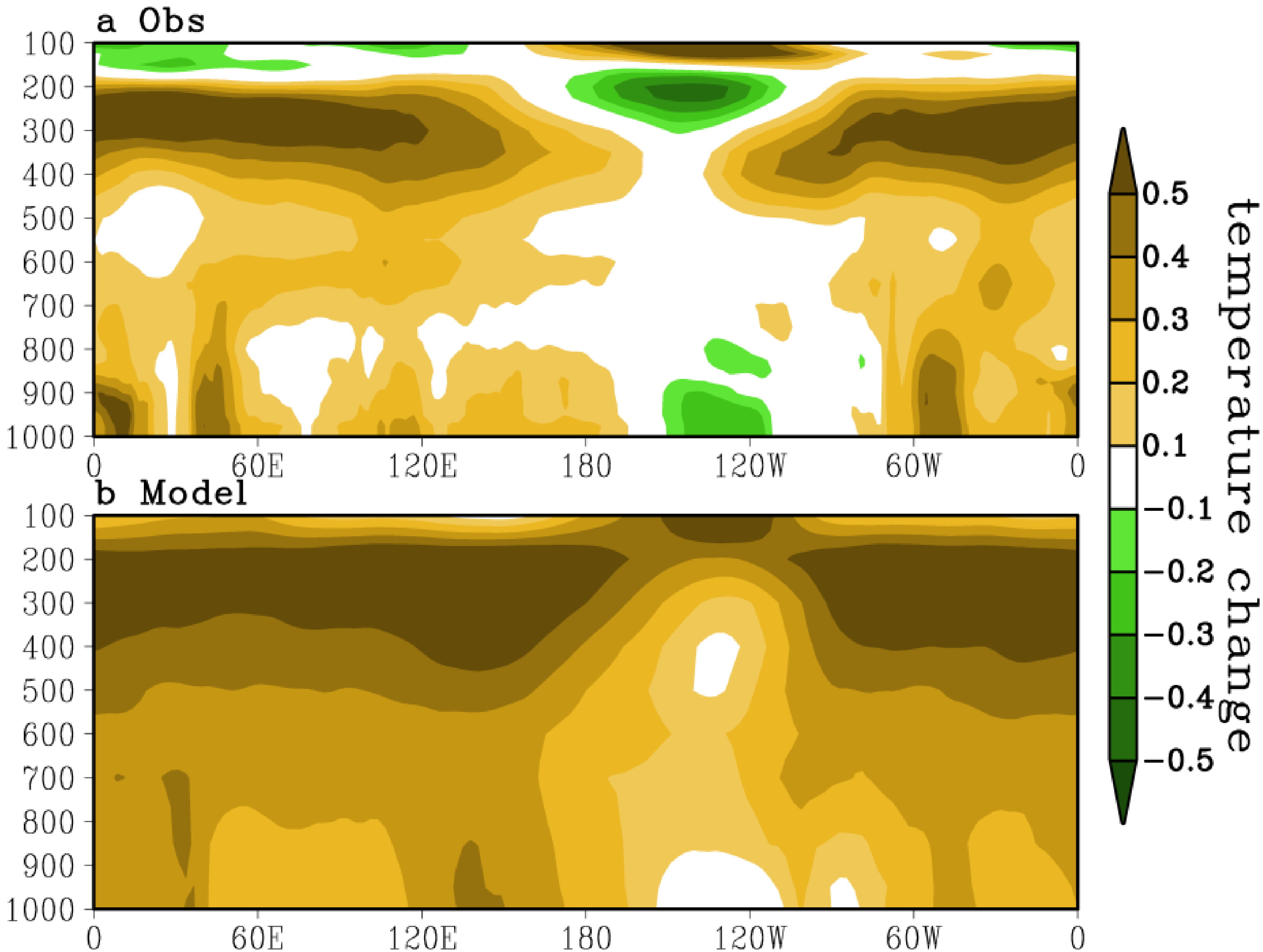


Trenberth et al. 2014

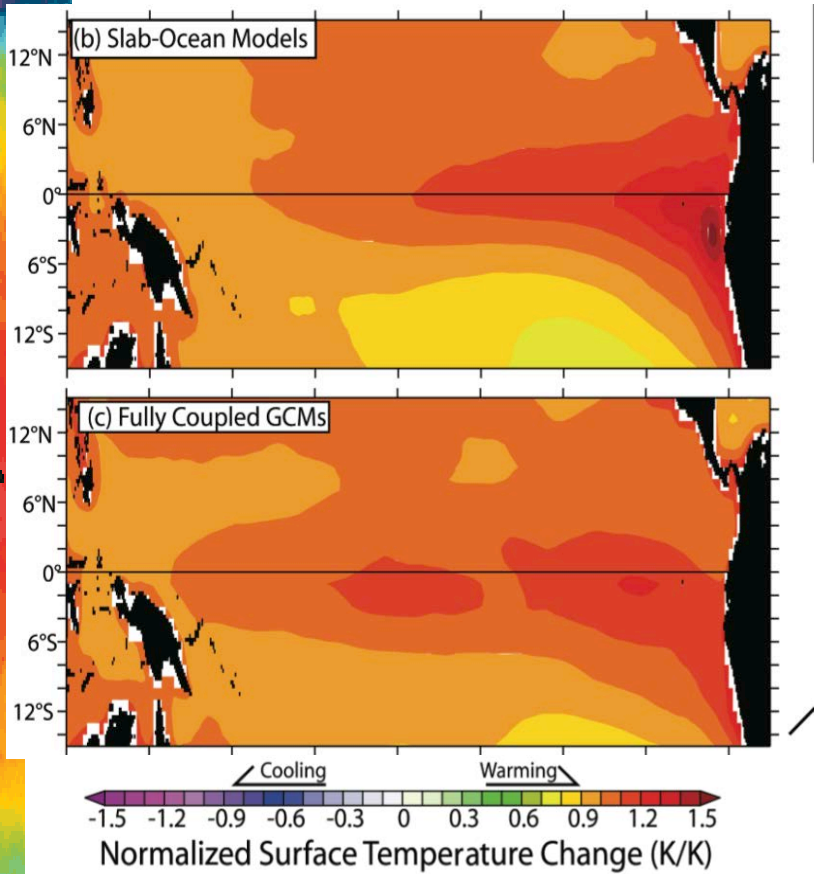
Annual mean rainfall trend in 1979-2013

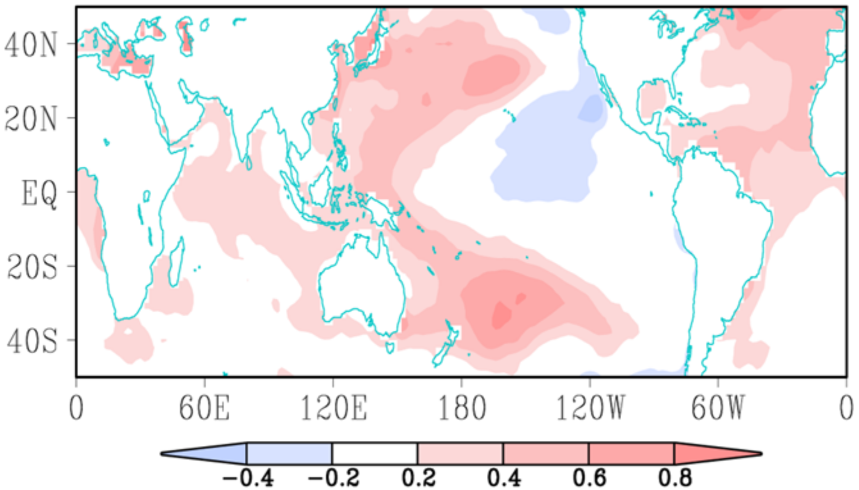


Annual mean tropical temperature trend in 1979-2013



Tropical SST response to warming climate





Cobb et al. 2011

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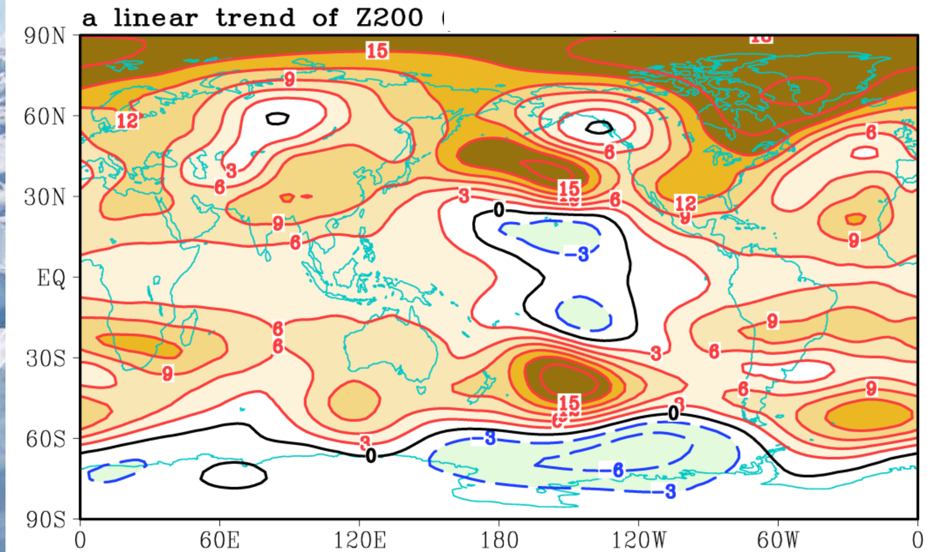
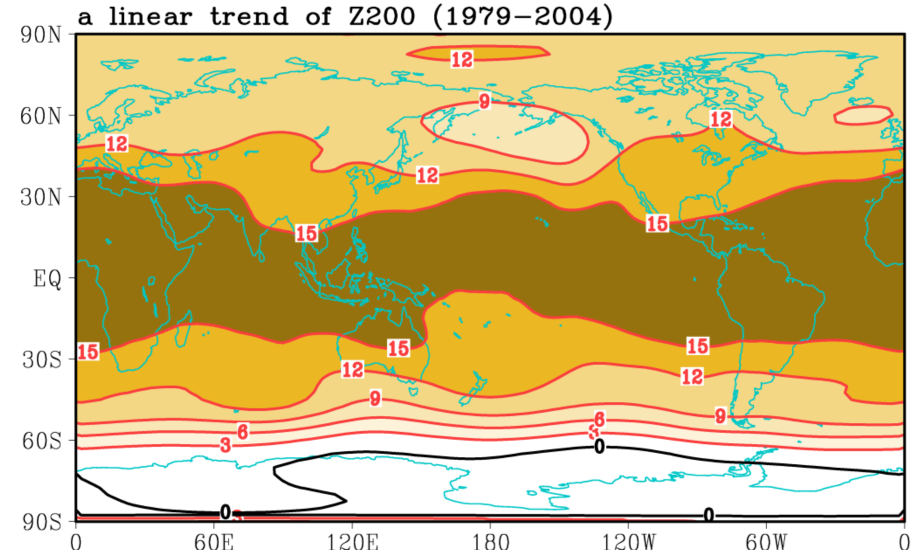
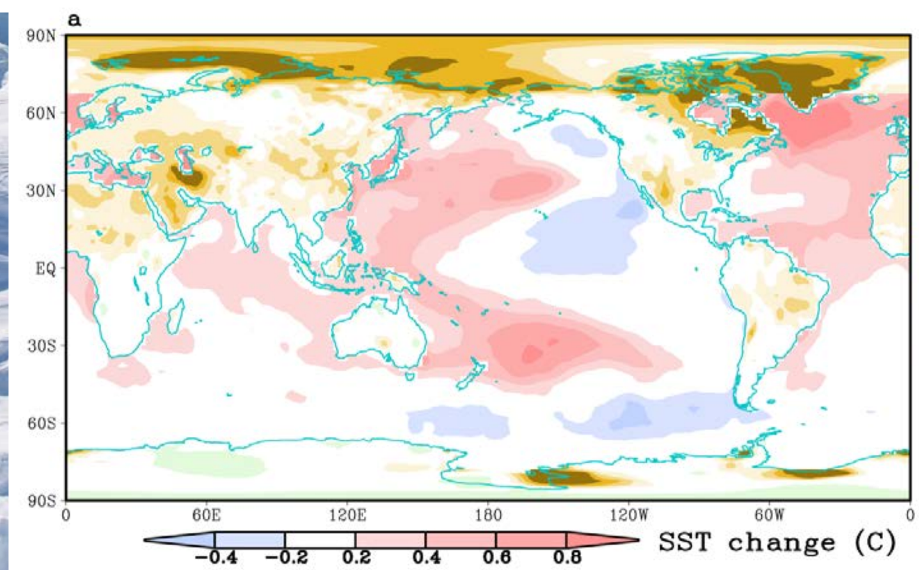
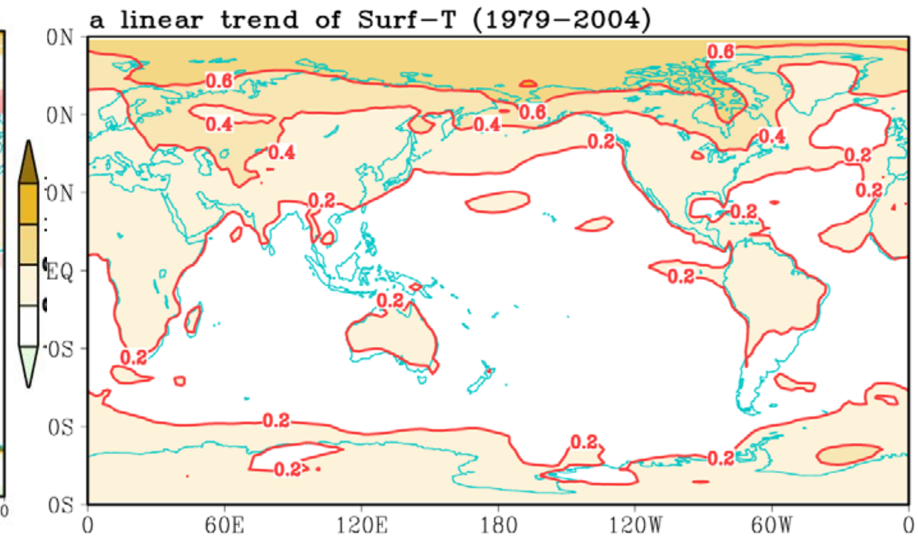
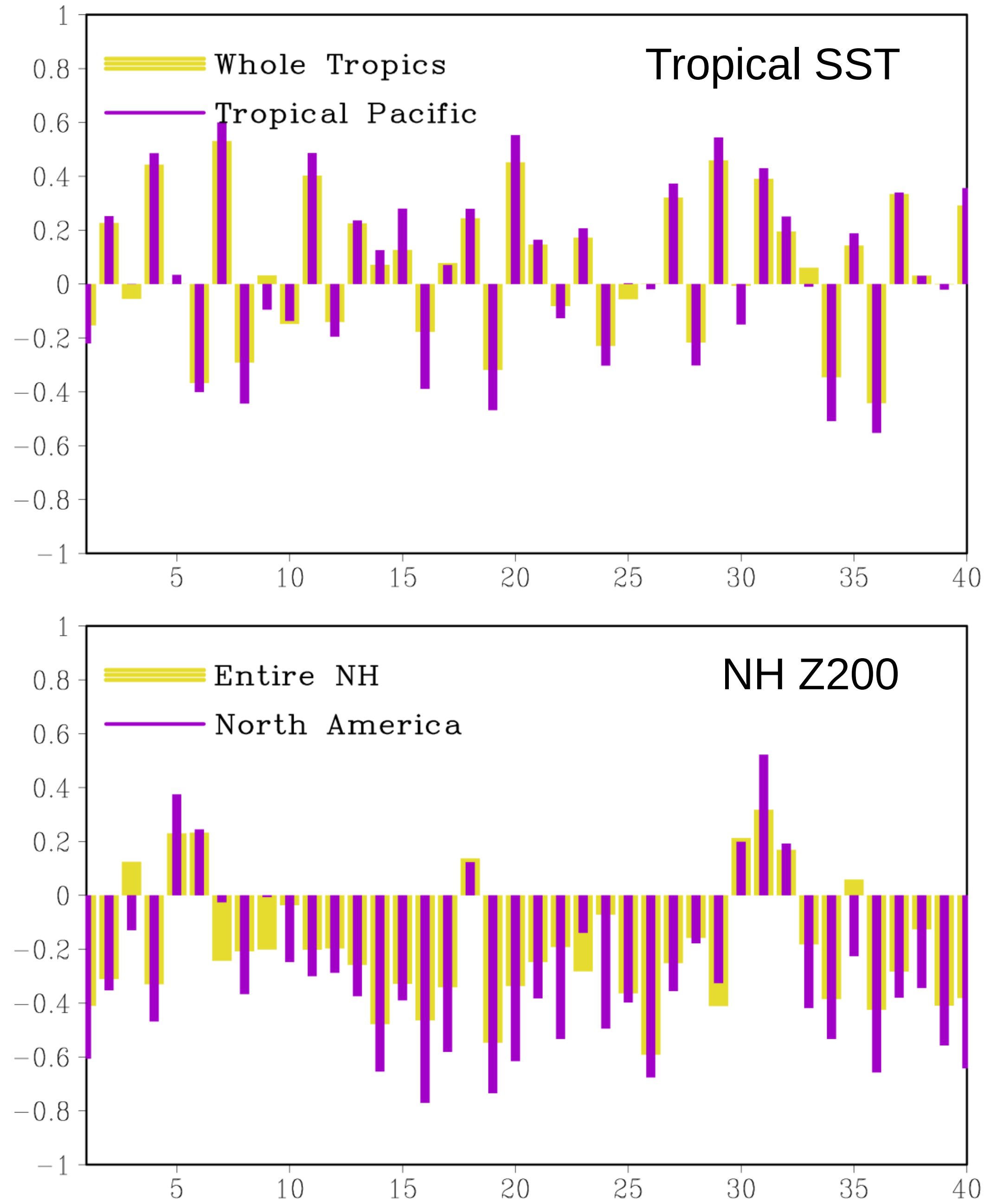




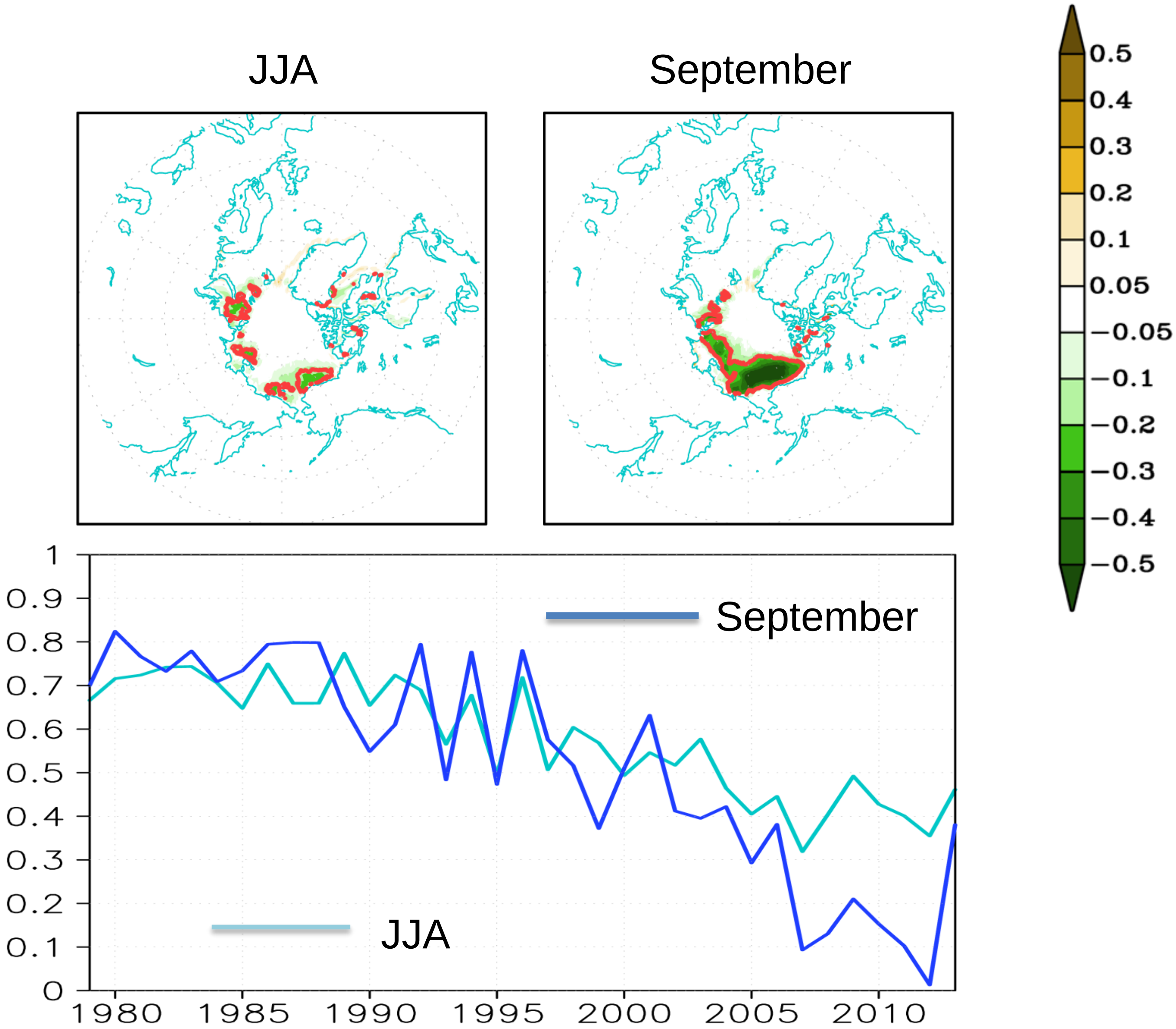




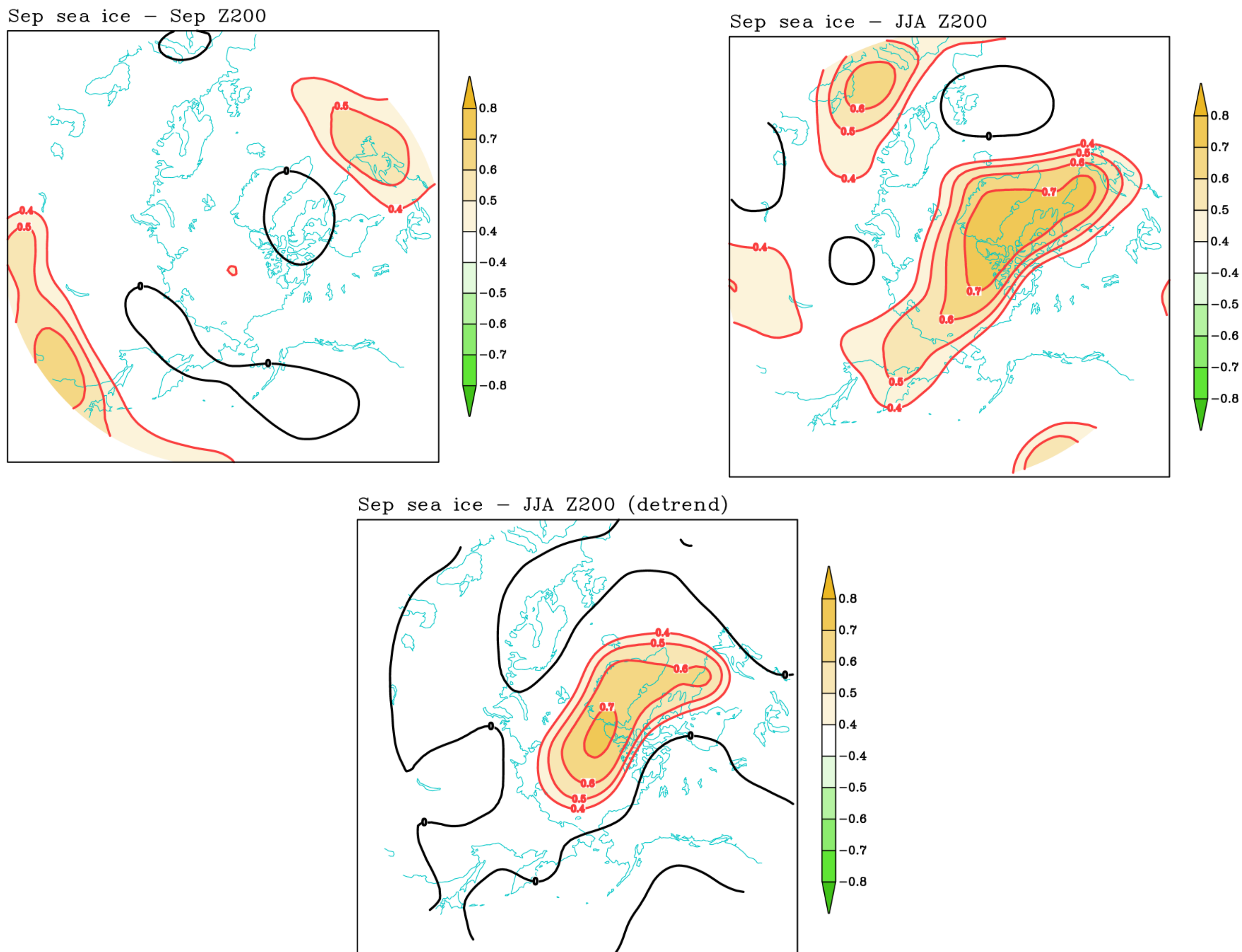
Is there a best-fit model in CMIP5?



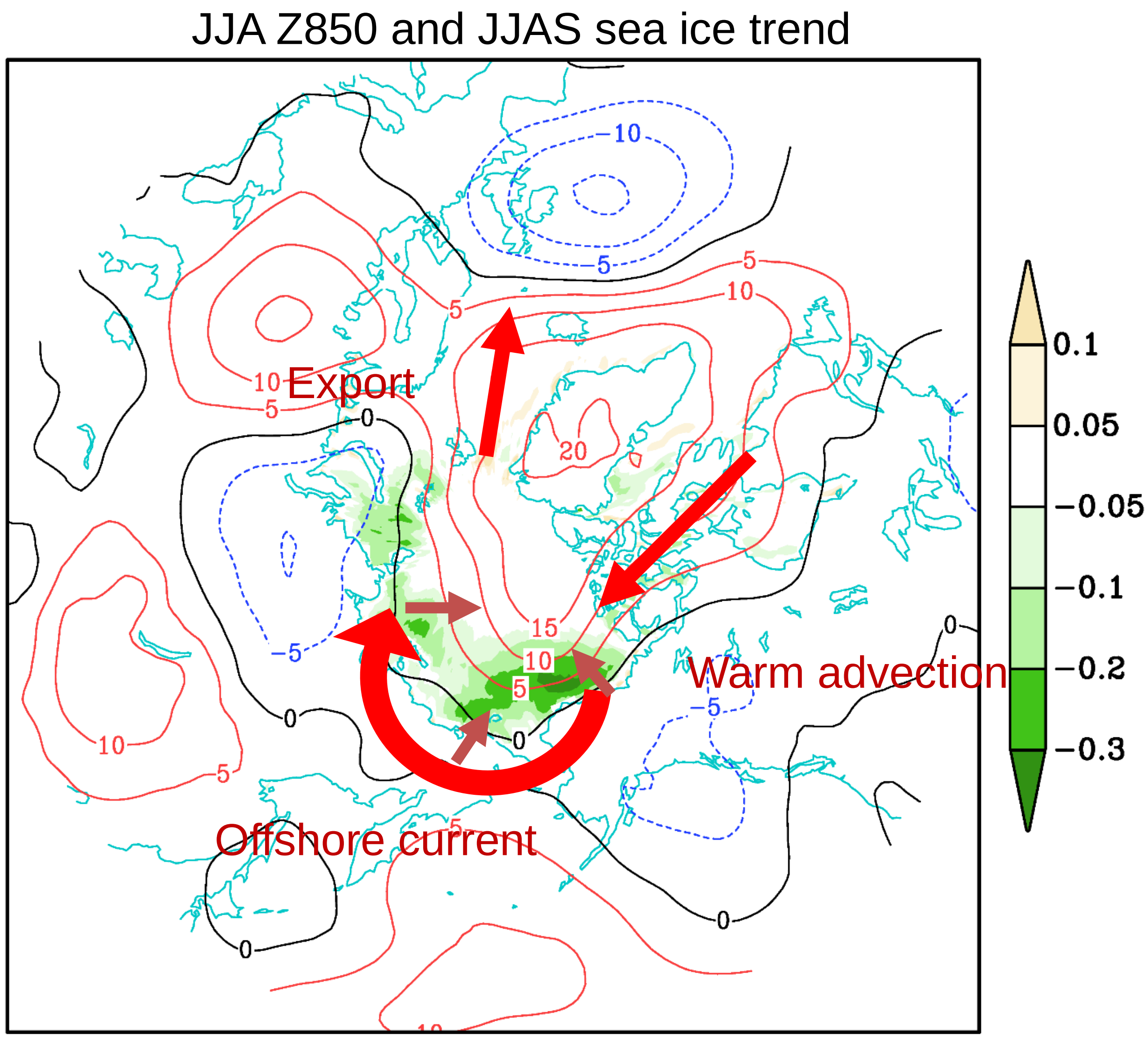
Decreasing trend of the Arctic sea ice (1979-2013)



September sea ice change is related to JJA Z200 variability

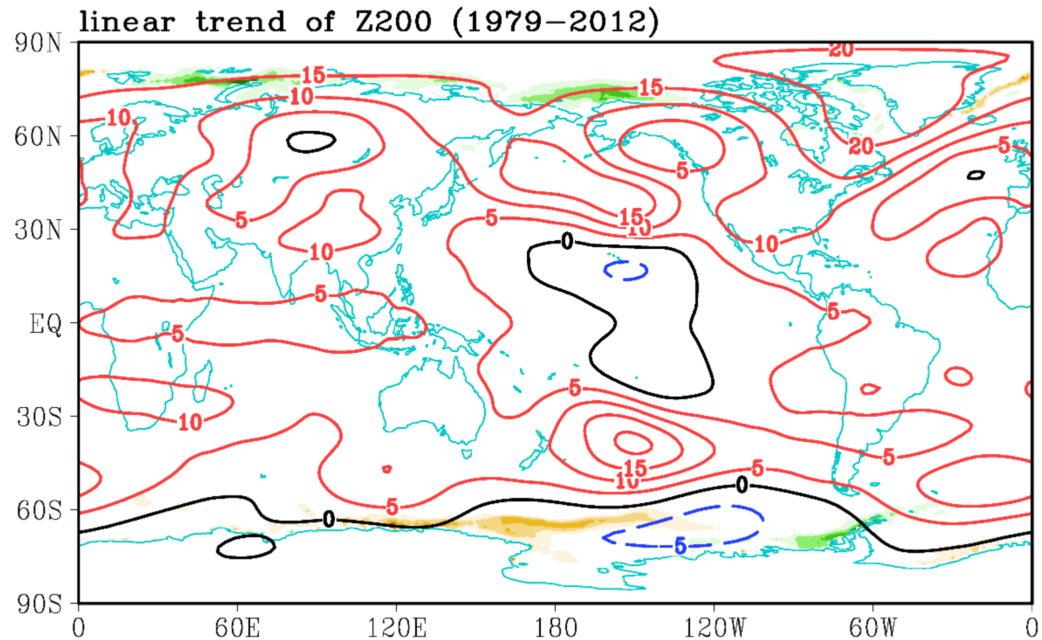


Circulation change may reduce the Arctic sea ice



Tropical related global circulation change is linking sea ice changes in the Arctic and Antarctic

Annual mean



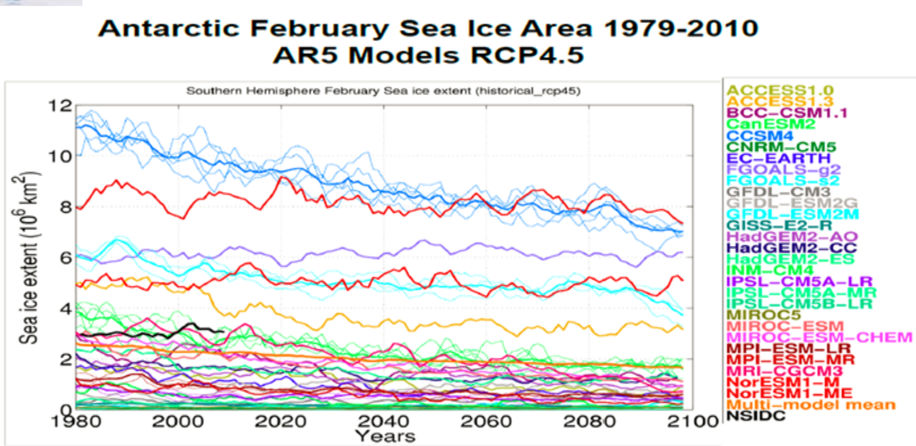
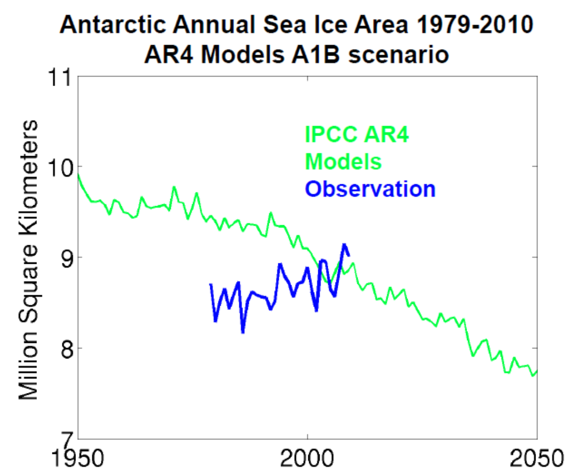
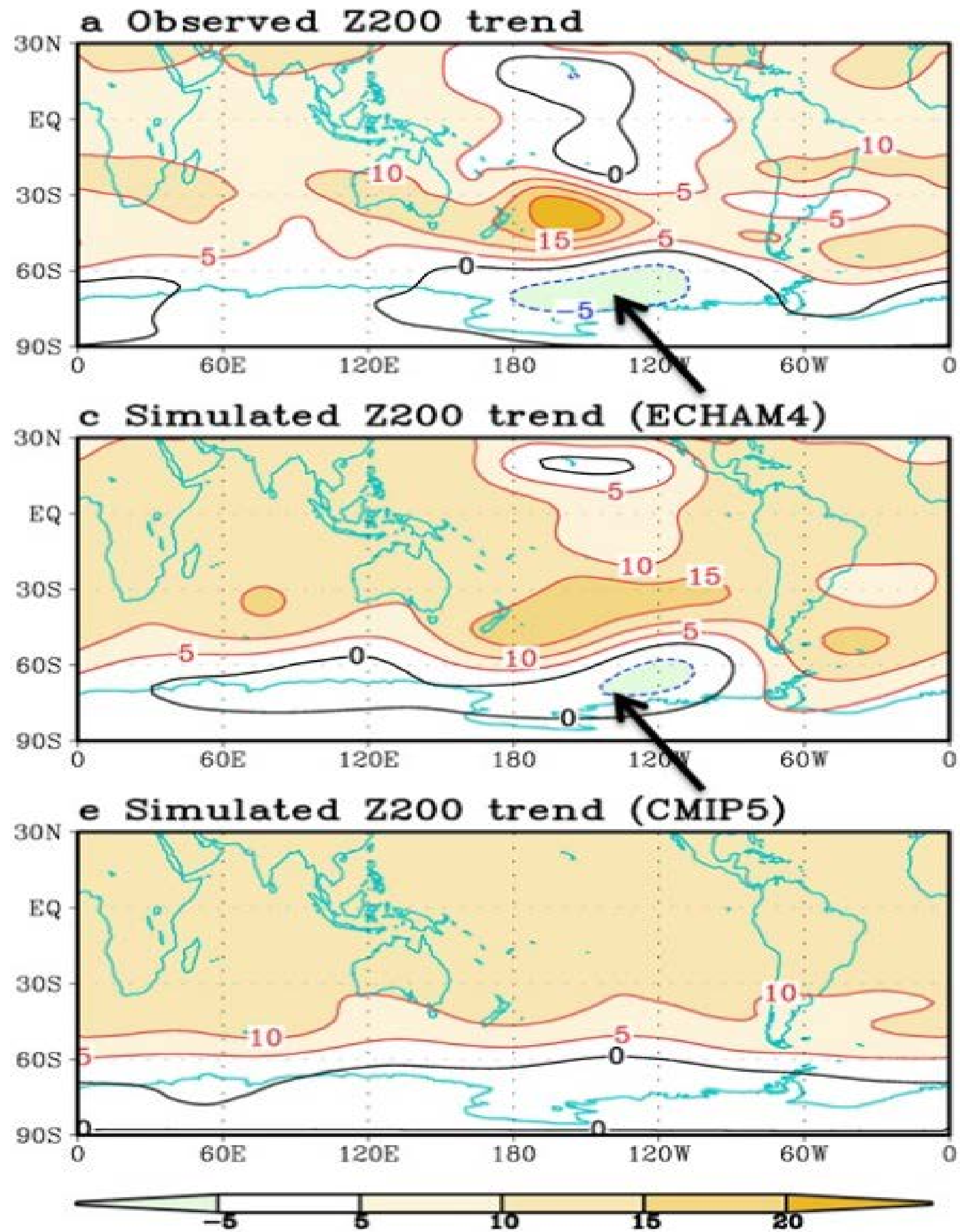
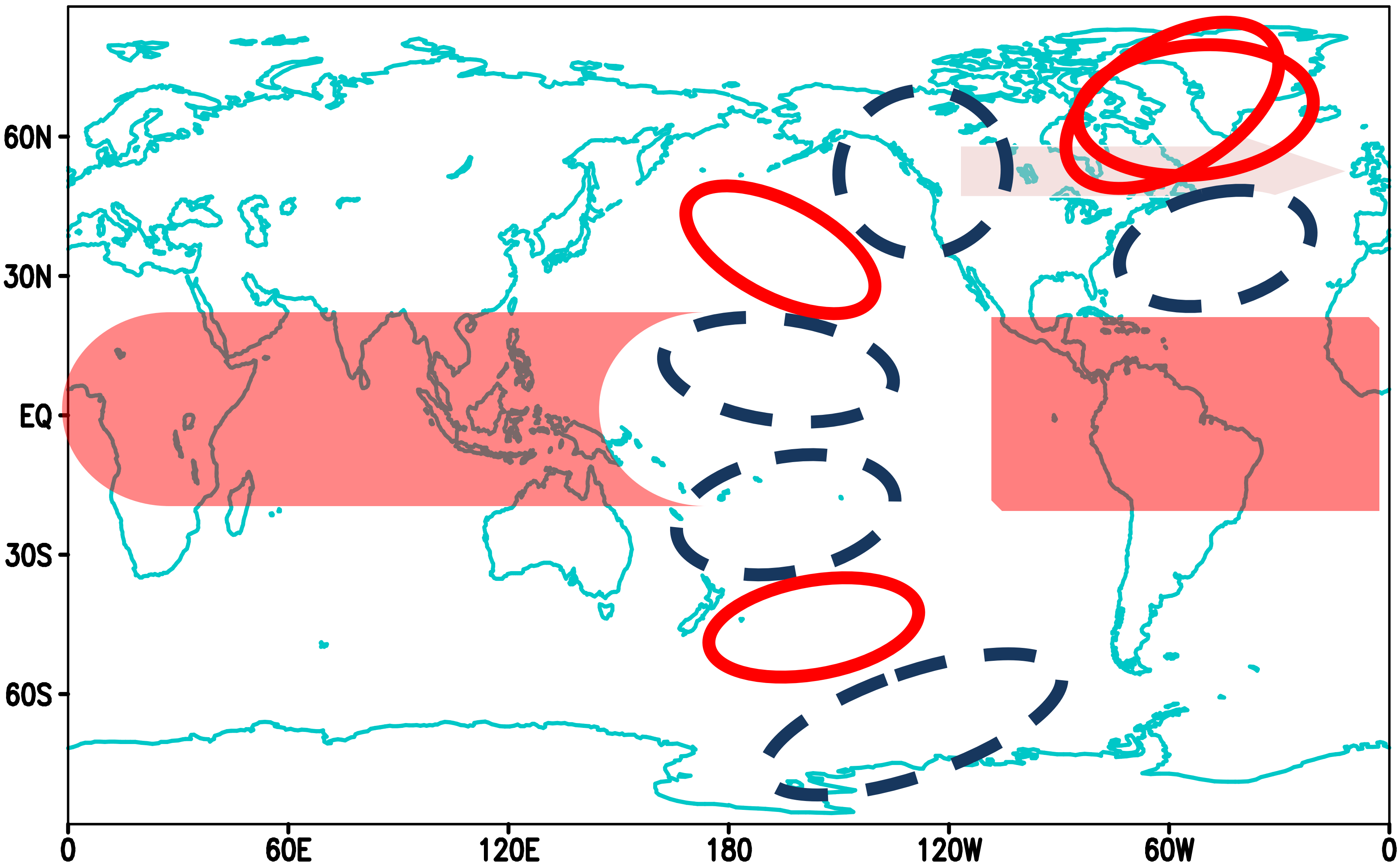


Figure by F Massonet

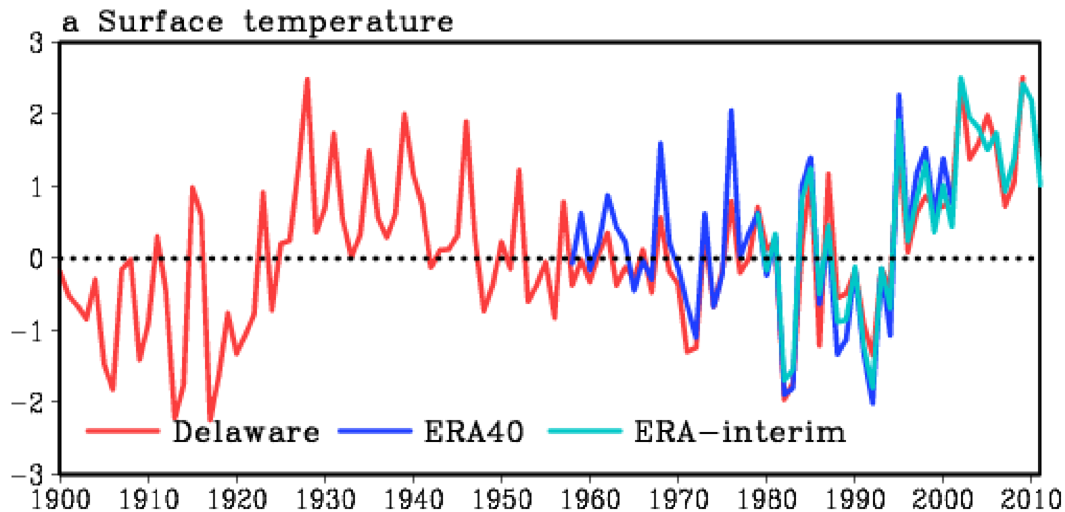


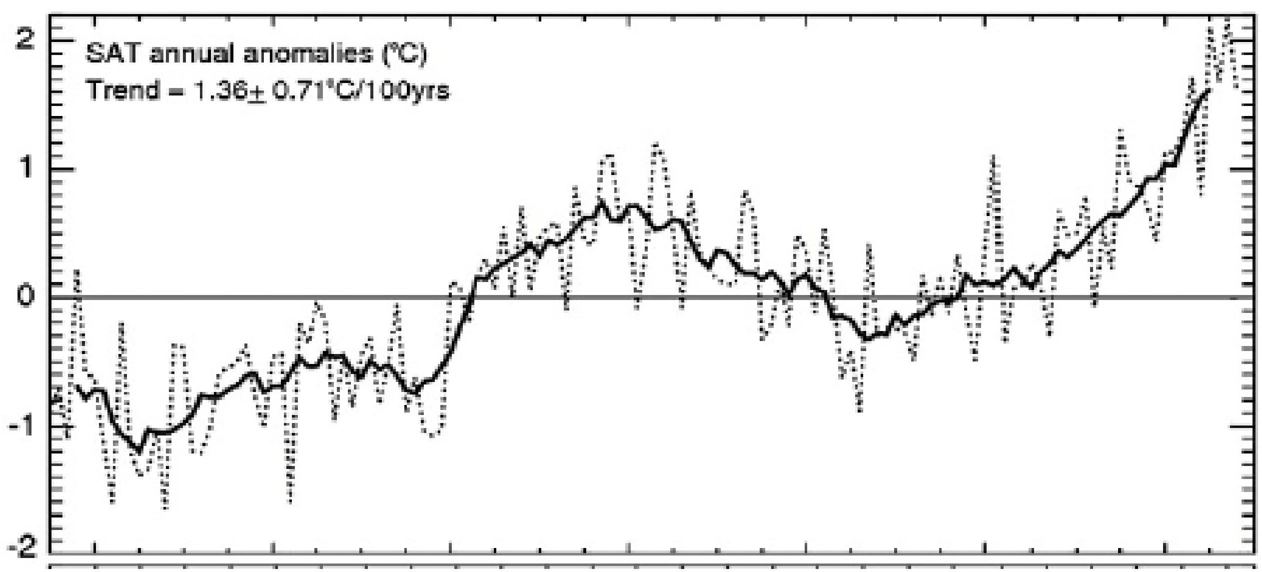

a Observed Z200 trend
c Simulated Z200 trend (ECHAM4)
e Simulated Z200 trend (CMIP5)
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
-5
5
10
15
20

How is the tropical forcing linking recent changes in the two poles?



Multi-decadal variability of surface temperature in Greenland



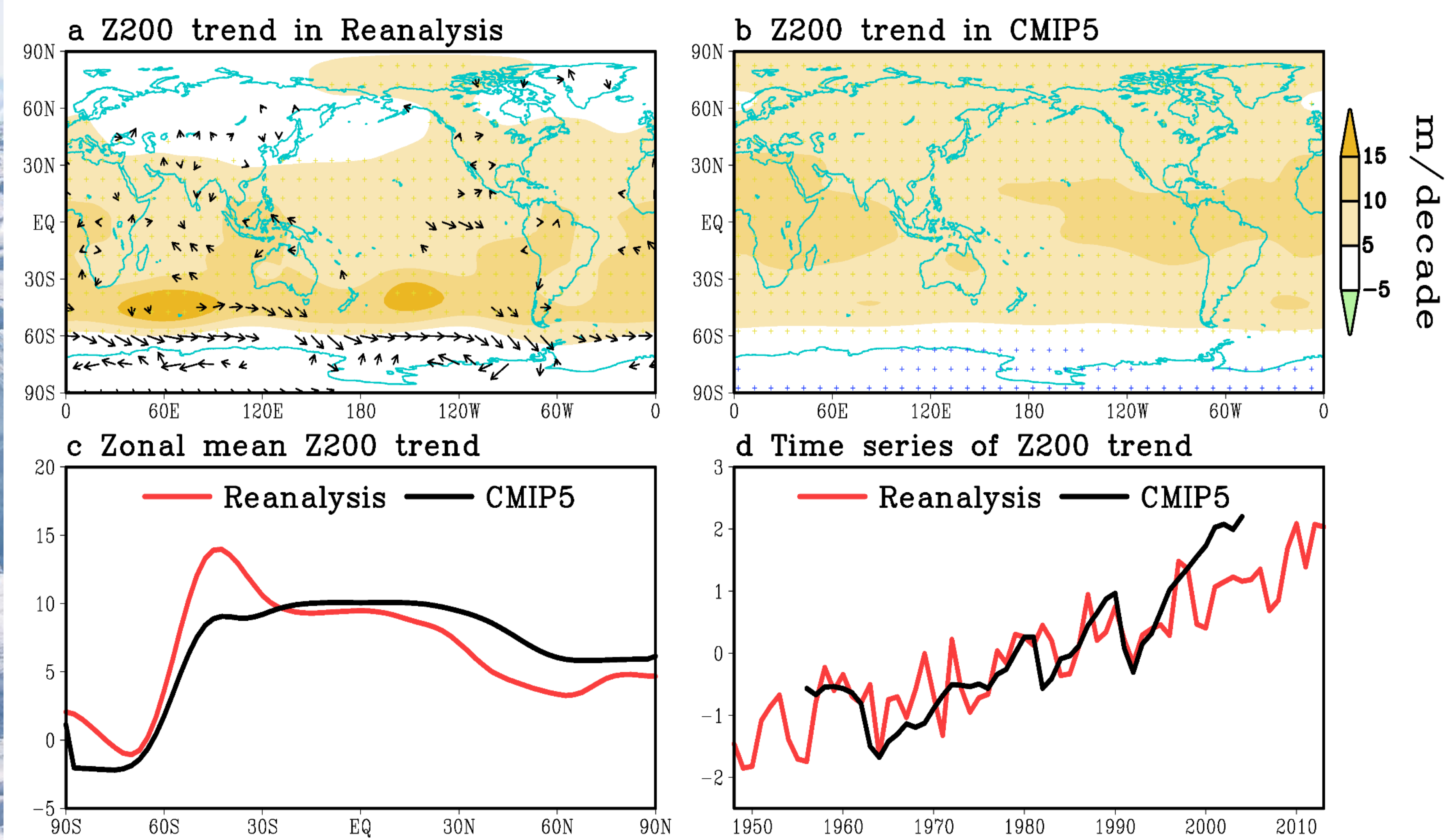


1880

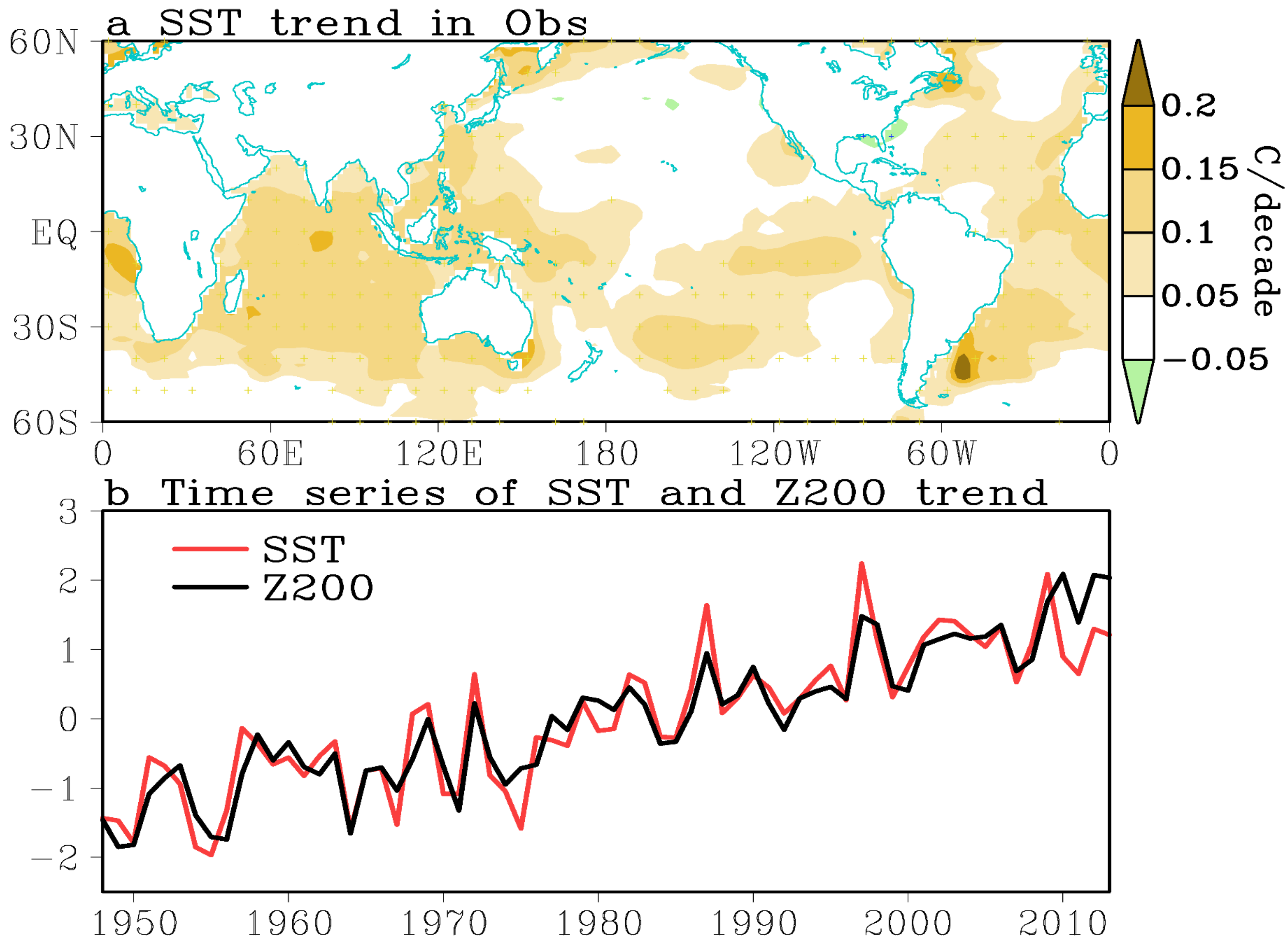
2008

Serreze and Barry 2011

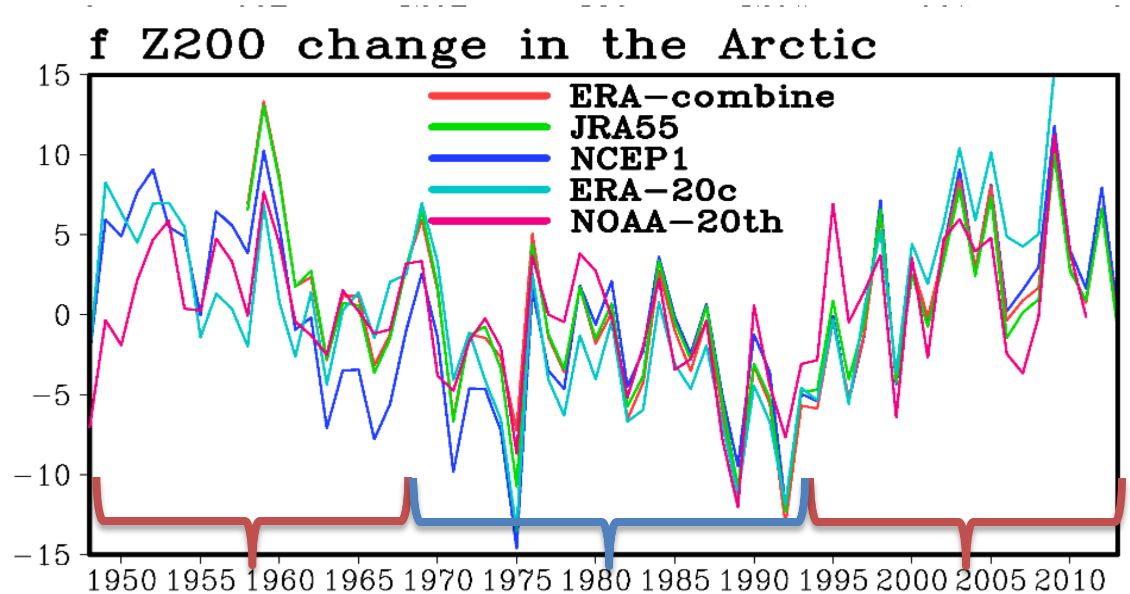
Linear trend of Z200 over the last 66 years (1948-2013)

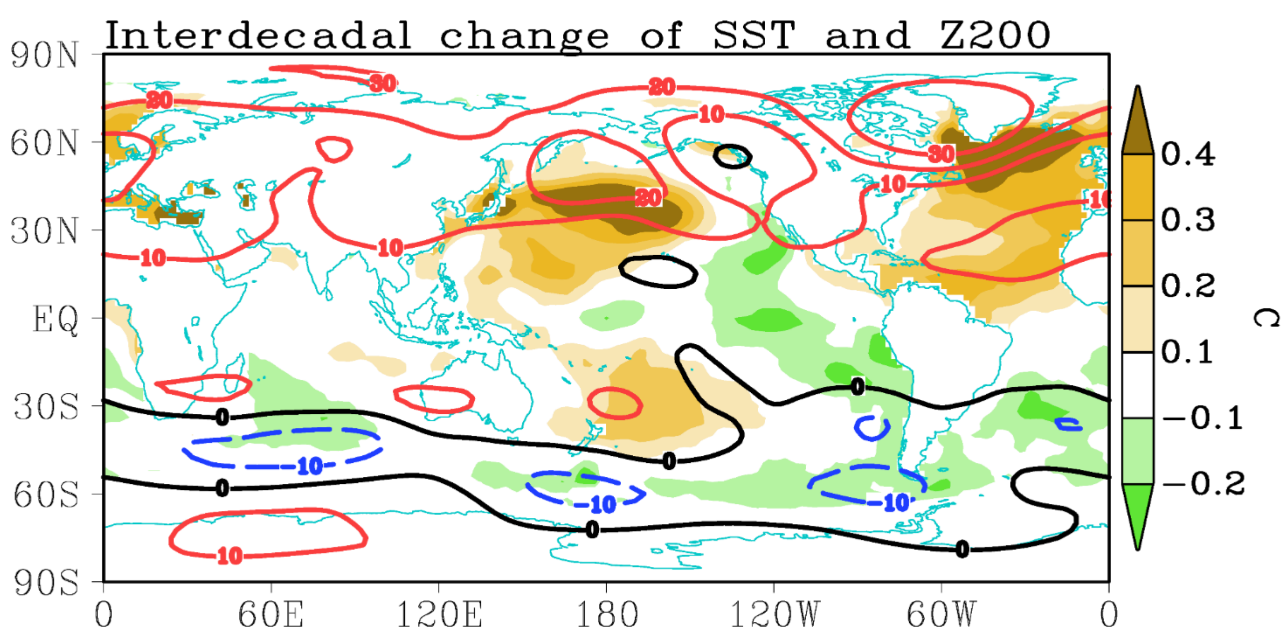


Linear trend of SST over the last 66 years (1948-2013)

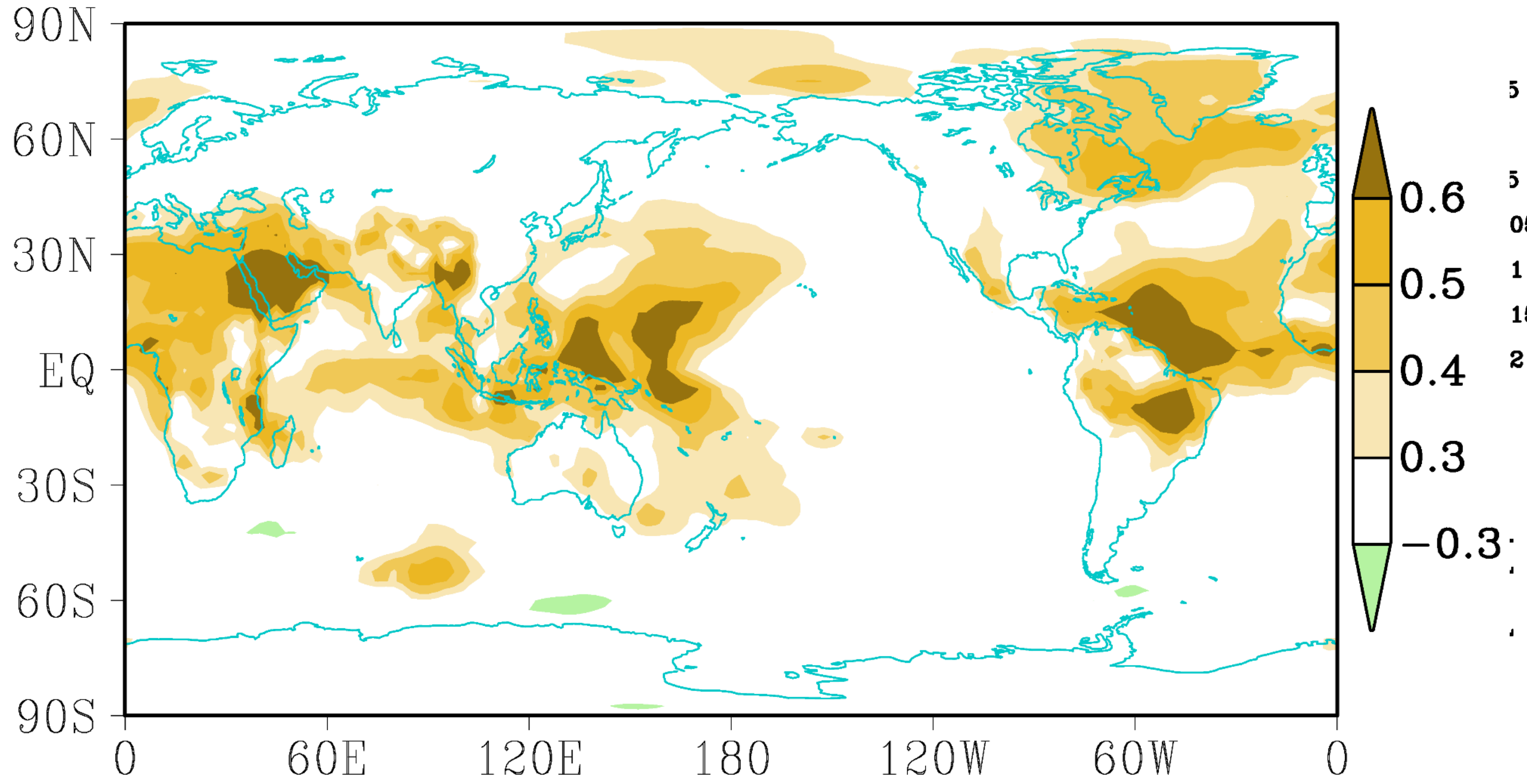


Interdecadal changes of the global circulation and SST





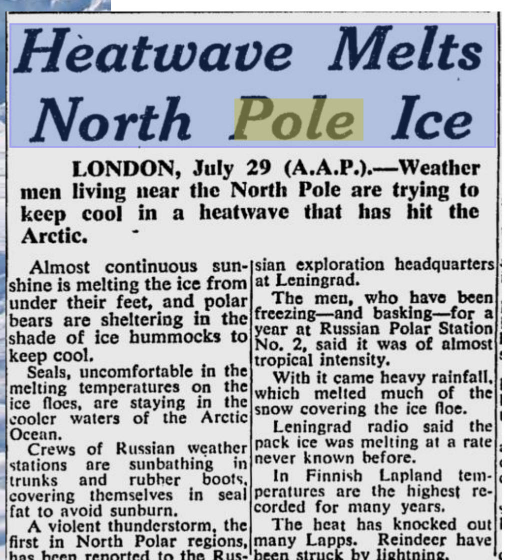
Maximum Covariance analysis (Z200 and tropical SST) 1948-2013



The Arctic warming in 1958

by [Steven Goddard](#) on real Science

USS Skate at the North Pole, 11 August 1958



Heatwave Melts North Pole Ice

LONDON, July 29 (A.A.P.).—Weather men living near the North Pole are trying to keep cool in a heatwave that has hit the Arctic.

Almost continuous sunshine is melting the ice from under their feet, and polar bears are sheltering in the shade of ice hummocks to keep cool.

Seals, uncomfortable in the melting temperatures on the ice floes, are staying in the cooler waters of the Arctic Ocean.

Crews of Russian weather stations are sunbathing in trunks and rubber boots, covering themselves in seal fat to avoid sunburn.

A violent thunderstorm, the first in North Polar regions, has been reported to the Russian exploration headquarters at Leningrad.

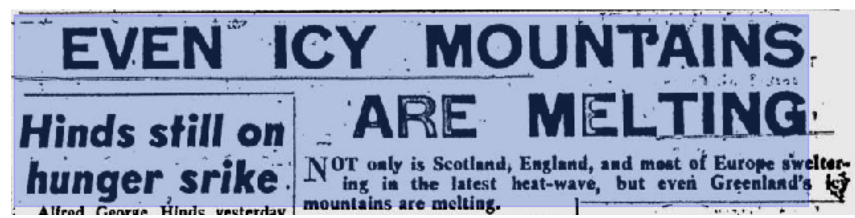
The men, who have been freezing—and basking—for a year at Russian Polar Station No. 2, said it was of almost tropical intensity.

With it came heavy rainfall, which melted much of the snow covering the ice floe.

Leningrad radio said the pack ice was melting at a rate never known before.

In Finnish Lapland temperatures are the highest recorded for many years.

The heat has knocked out many Lapps. Reindeer have been struck by lightning.



EVEN ICY MOUNTAINS ARE MELTING

Hinds still on hunger srike

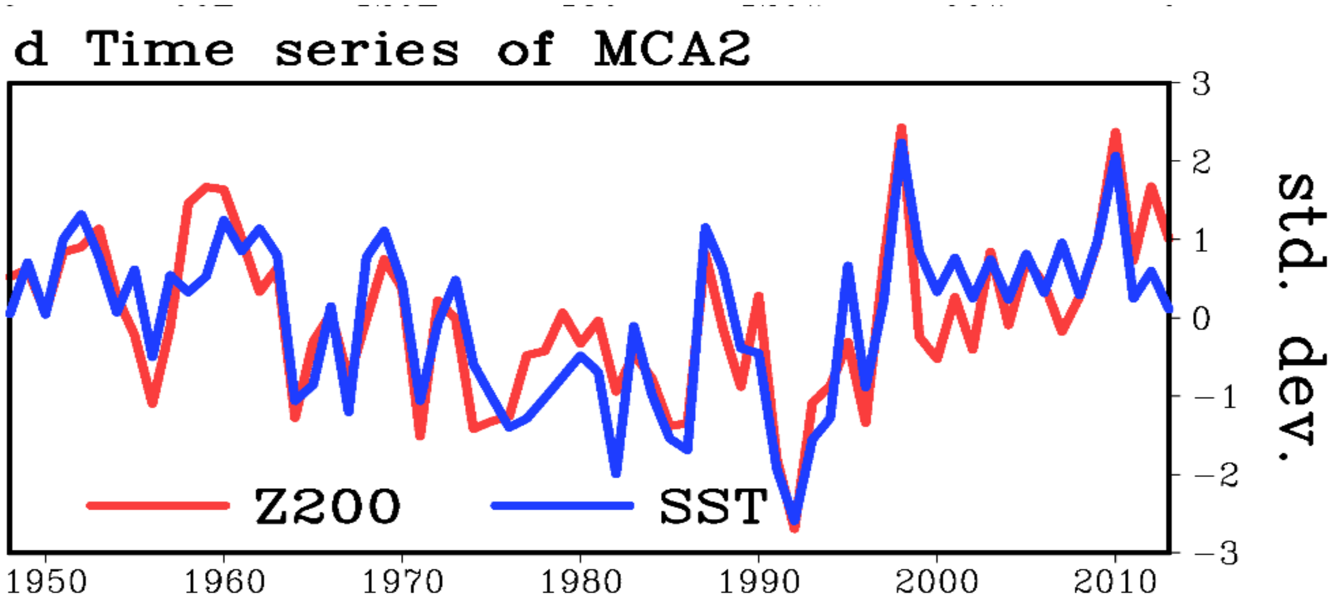
NOT only is Scotland, England, and most of Europe sweltering in the latest heat-wave, but even Greenland's icy mountains are melting.

Alfred George Hinds yesterday

The Bulletin July, 1, 1957

[**The Sydney Morning Herald - Jul 30, 1957**](#)

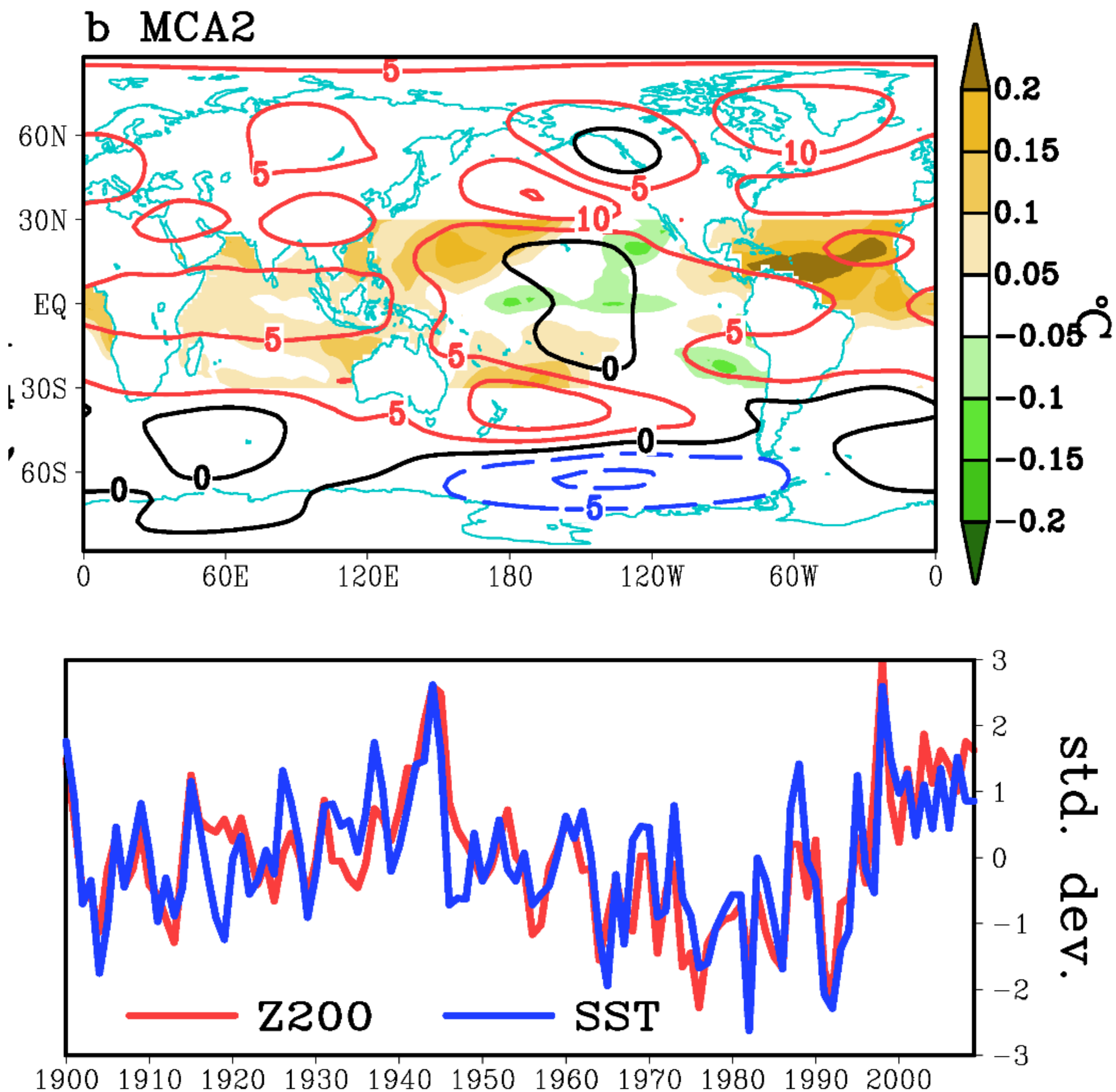
Global cooling vs global warming



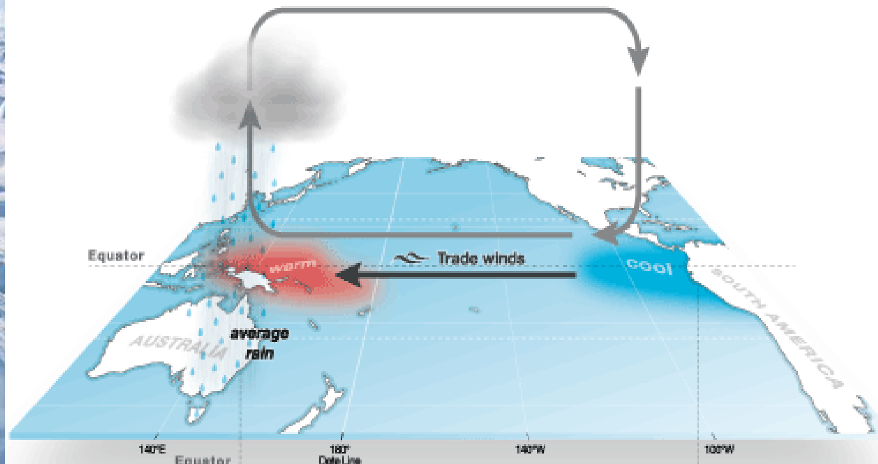
1980s

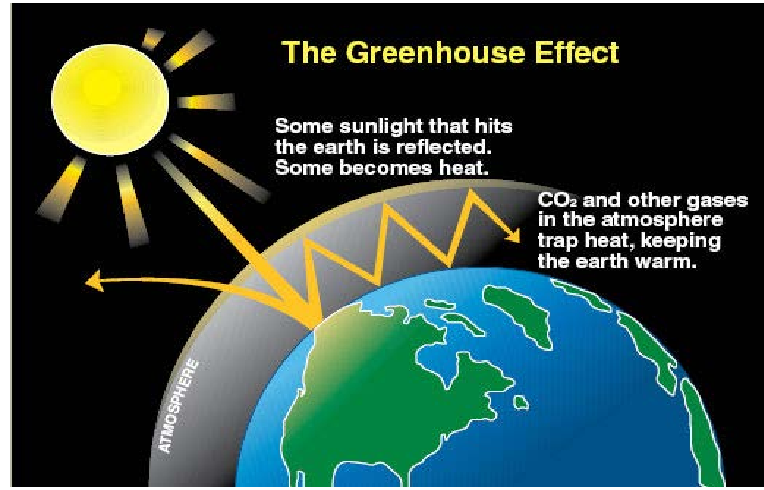
2000s

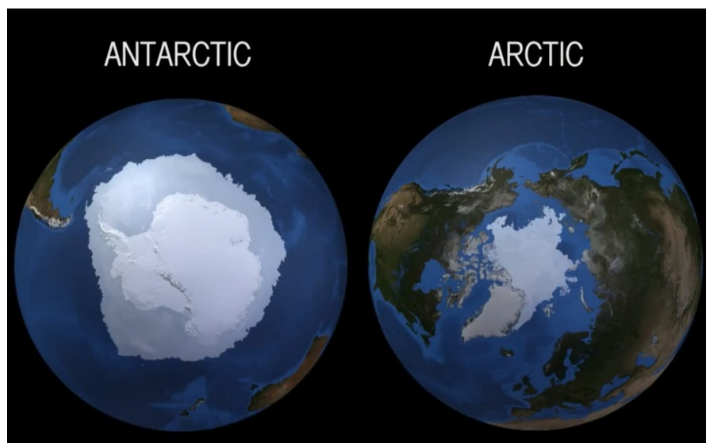
Interdecadal changes of the global circulation and SST since 1900



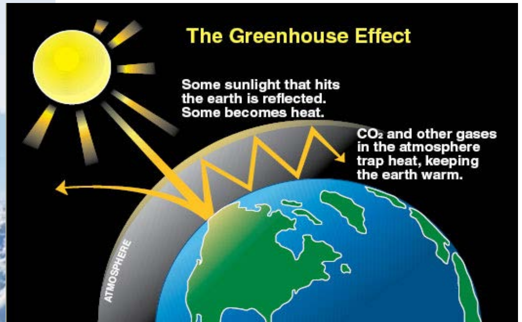
Both anthropogenic and natural forcings are important for the recent rapid Arctic warming







Arctic warming vs tropical forcing



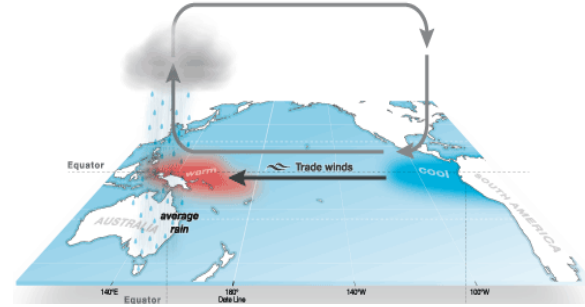
Global warming

Artic warming

Midlatitude wavy flow

Extreme events

Francis and Vavrus 2012



Tropical internal

Midlatitude wavy flow

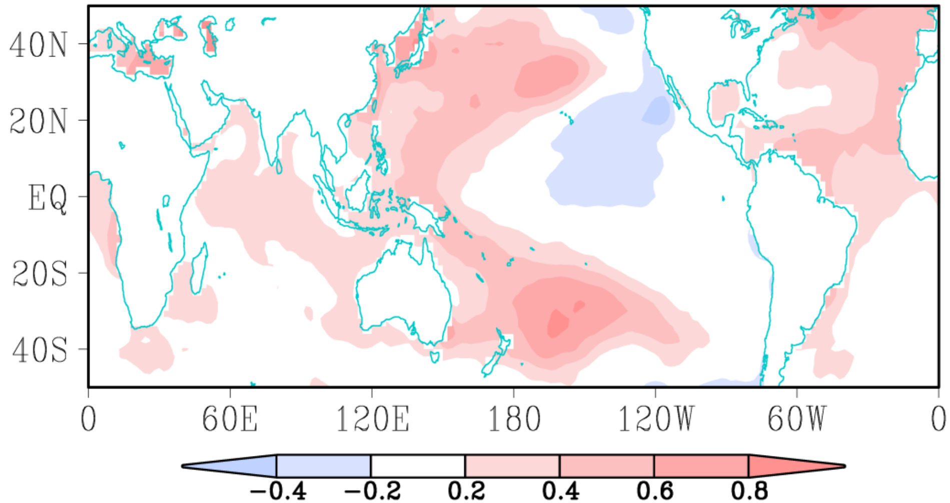
Extreme events

Artic change

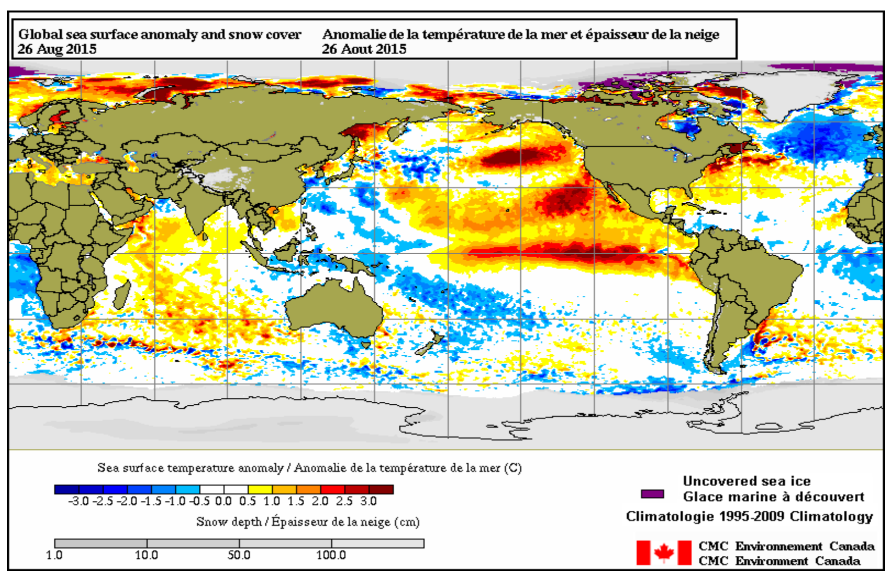
Global warming

Can we predict this interdecadal mode?

SST trend 1979-2013

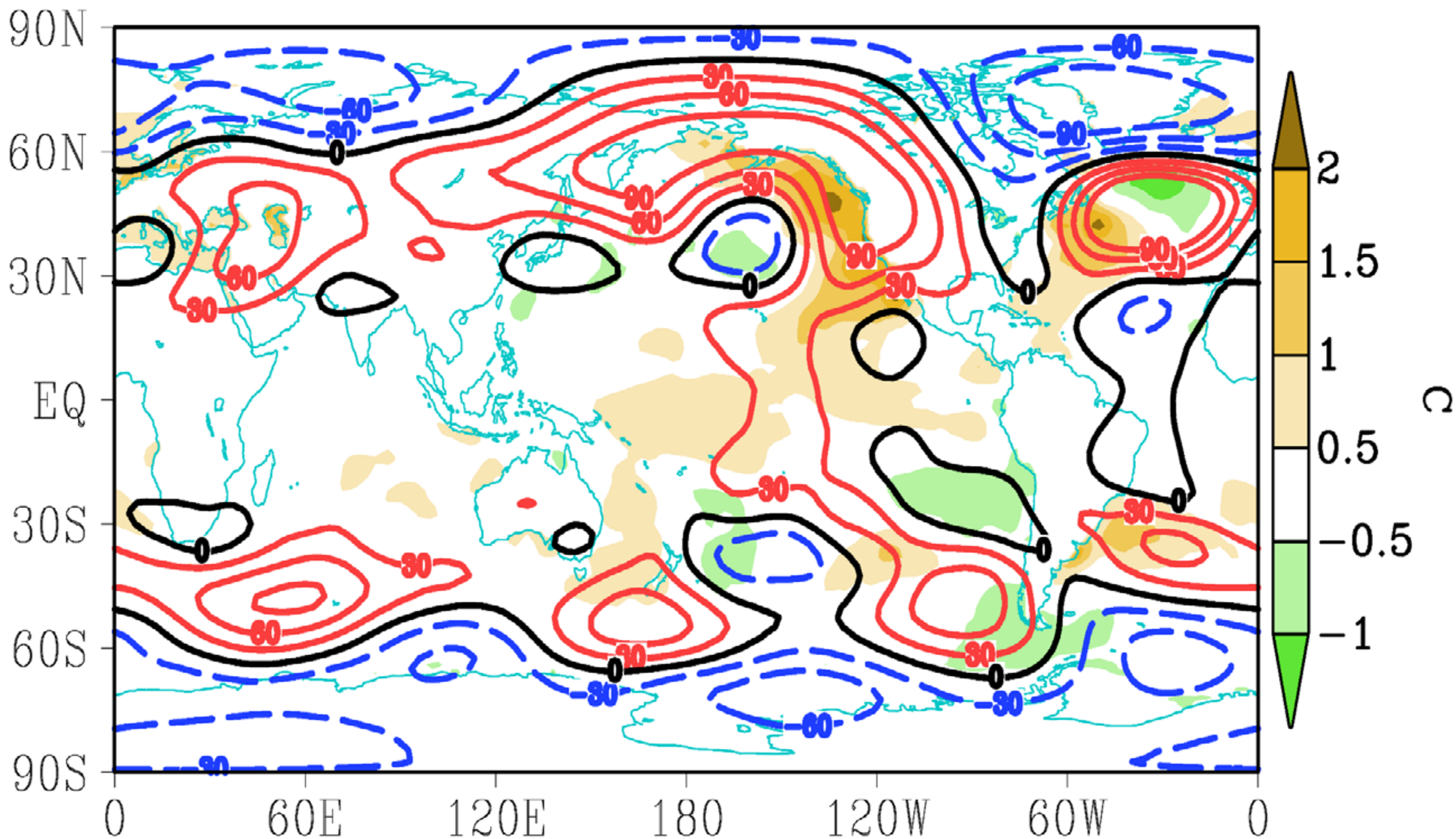


SST anomalies August, 2015



mean state:1995-2009

Z200 and SST in 2014/2015 DJF



NCEP1 and ERSST3, mean state:1979-2015

Take-home message

Recent climate change in the Arctic and Antarctic is related to a low-frequency SST variability in the tropical Pacific.

To predict the future change of SH+NH circulation and related change in the Arctic and Antarctic, we need to better understand and predict the low-frequency SST variability in the tropics and its polar impacts.

Future projections of how tropical Pacific low-frequency SST variability will change in response to both continued anthropogenic radiative forcing and natural interdecadal variability represents a significant source of uncertainty of projections of the polar climate.

Impact of remote SST on the Arctic warming

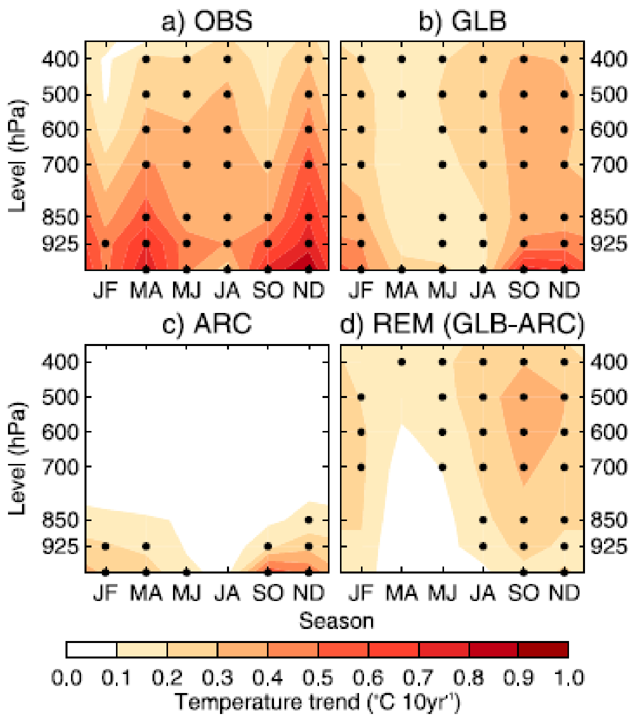


Figure 3. (a) Vertical and seasonal structure of the reanalysis ensemble-mean (OBS) Arctic-mean temperature trends (1979–2008). (b–d) As in Figure 3a, but for the model ensemble-mean trends in the GLB and ARC experiments, and their difference (REM), respectively. Black dots show trends that are statistically significant at the 95% level ($p < 0.05$).

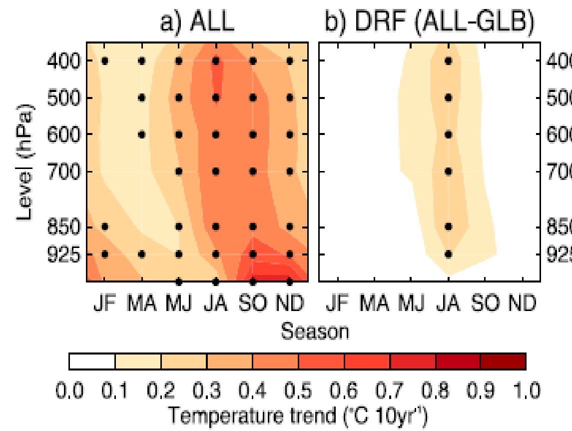
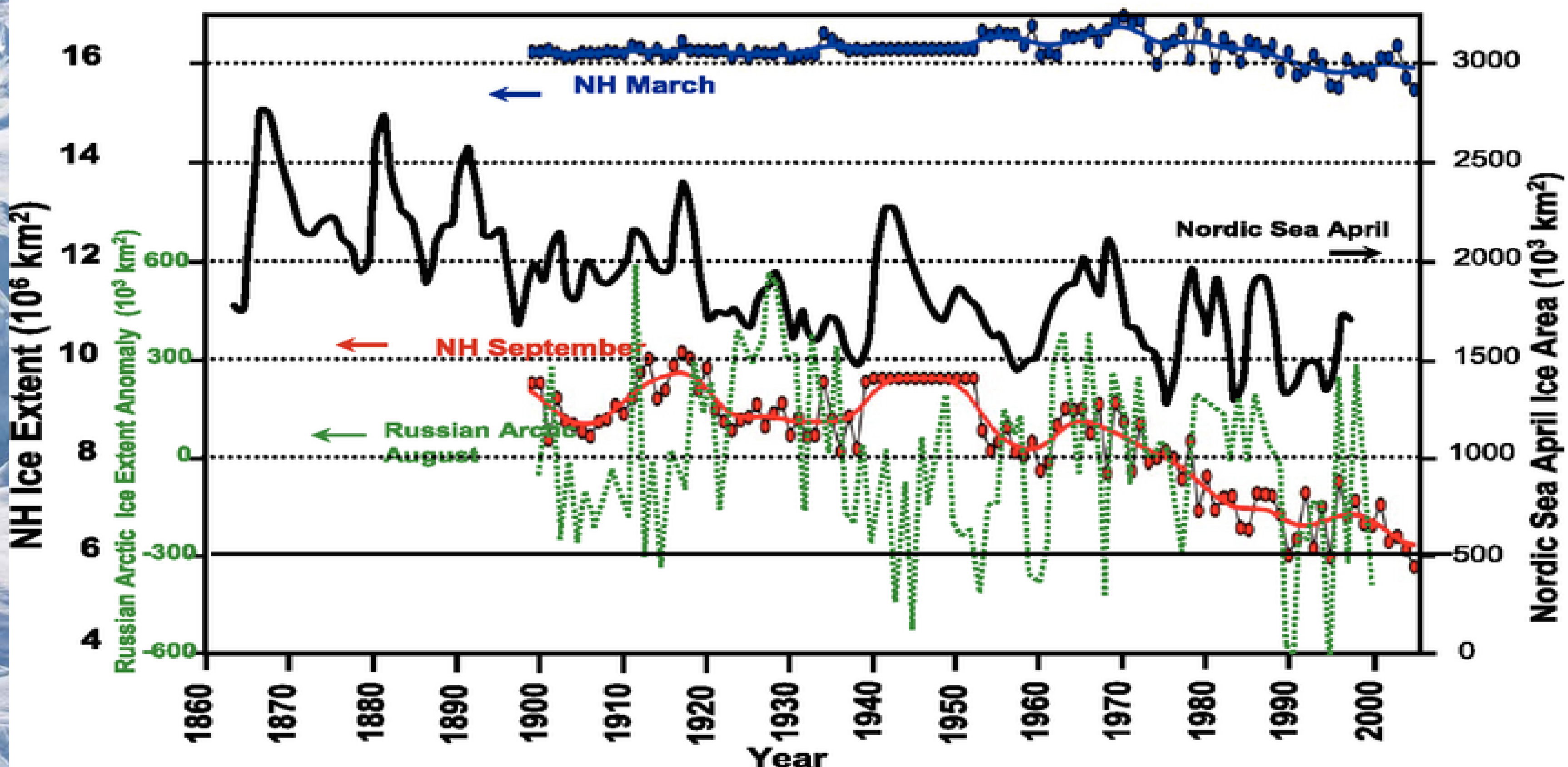


Figure 4. (a) Vertical and seasonal structure of the ensemble-mean Arctic-mean temperature trends (1979–2008) in the ALL experiment. (b) As in Figure 4a, but for difference between the ALL and GLB experiments. Black dots show trends that are statistically significant at the 95% level ($p < 0.05$).

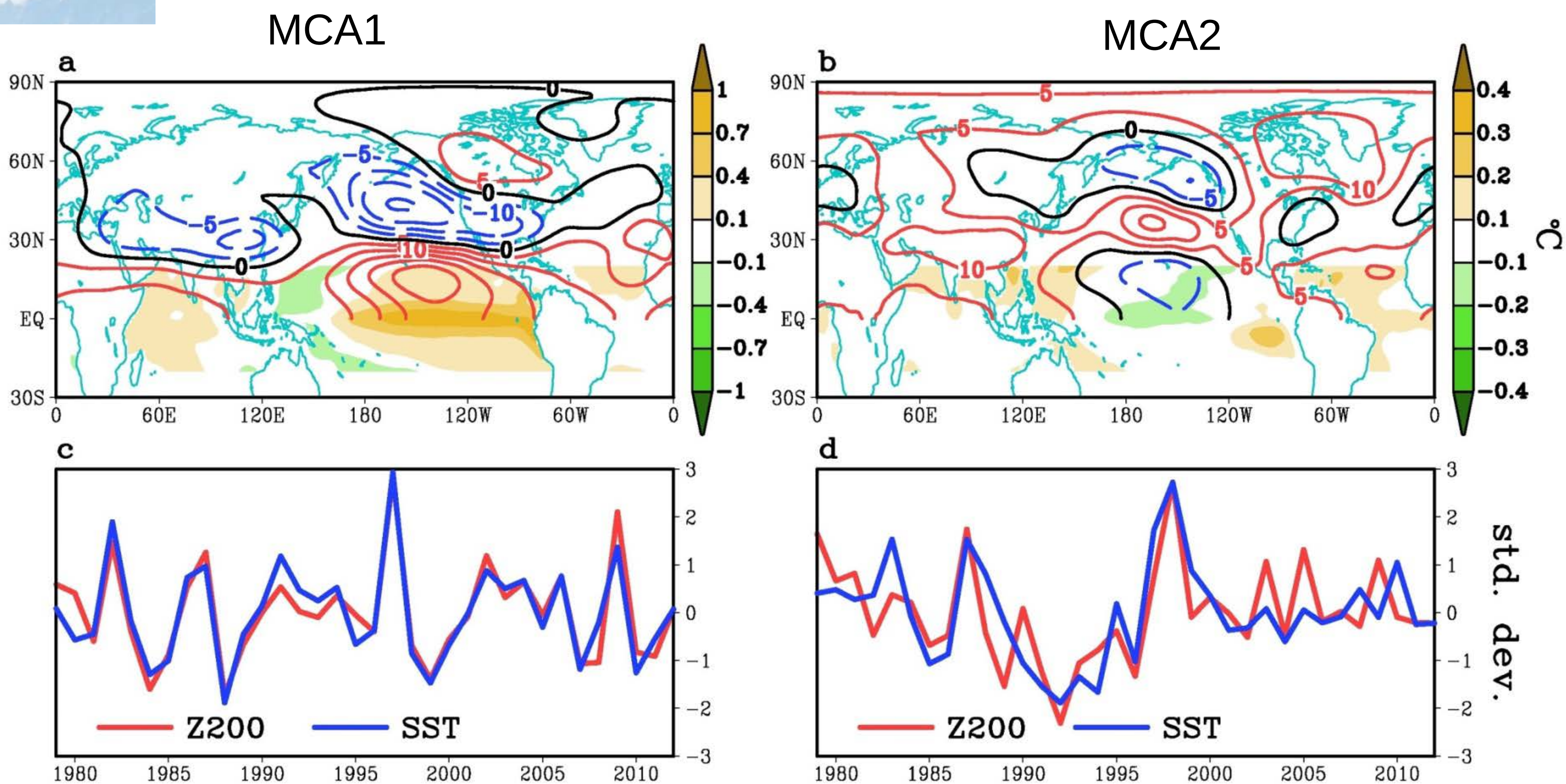
Screen et al 2012

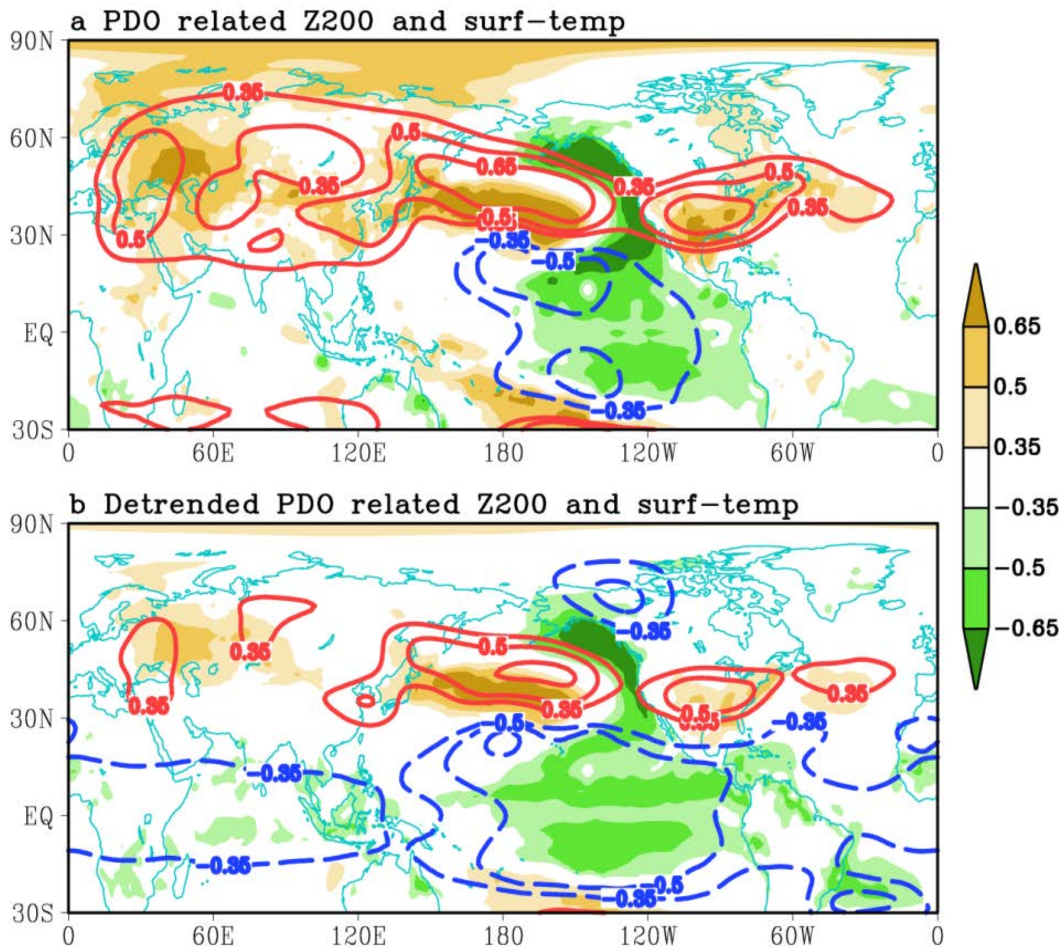
Sea ice record back to 1860

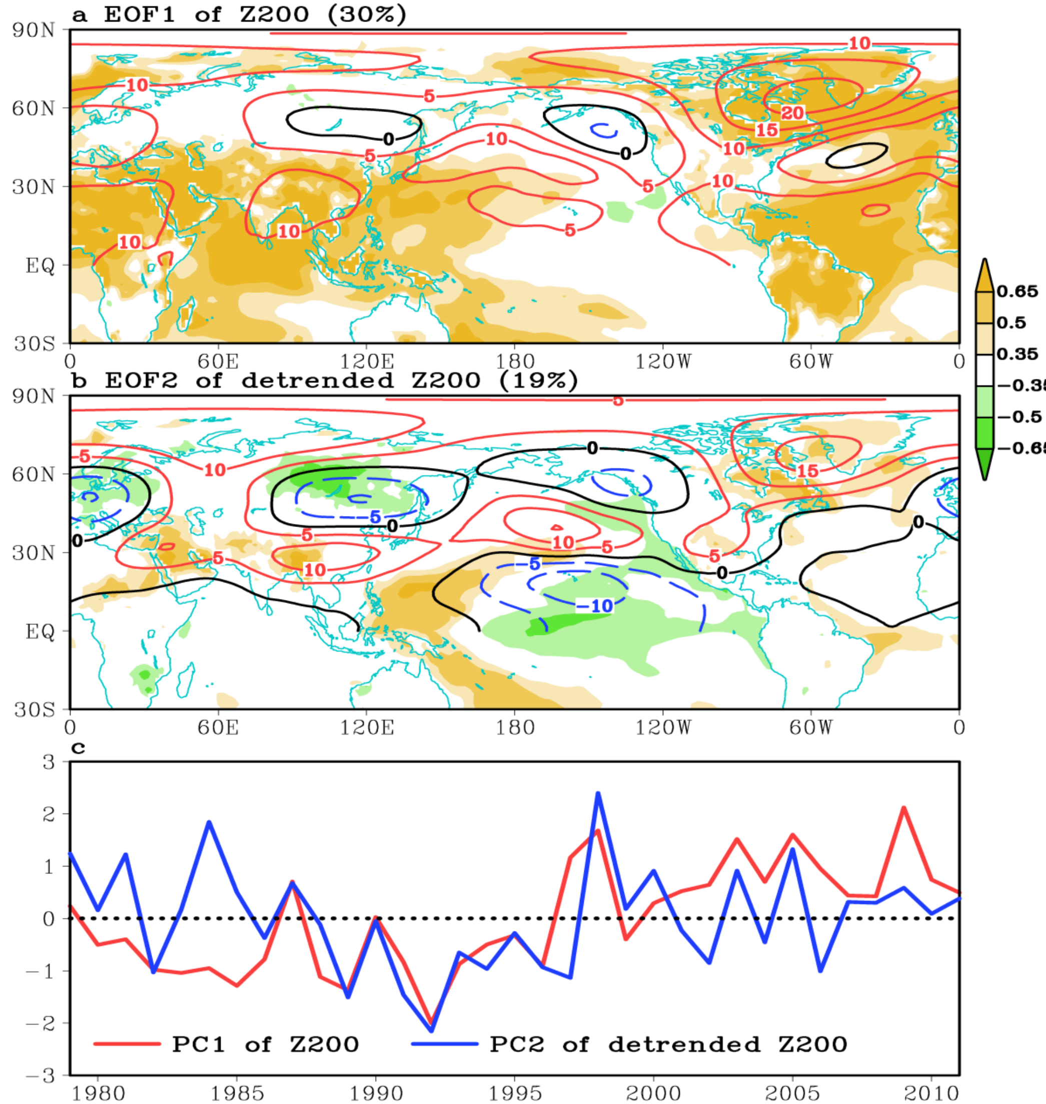


IPCC 2007

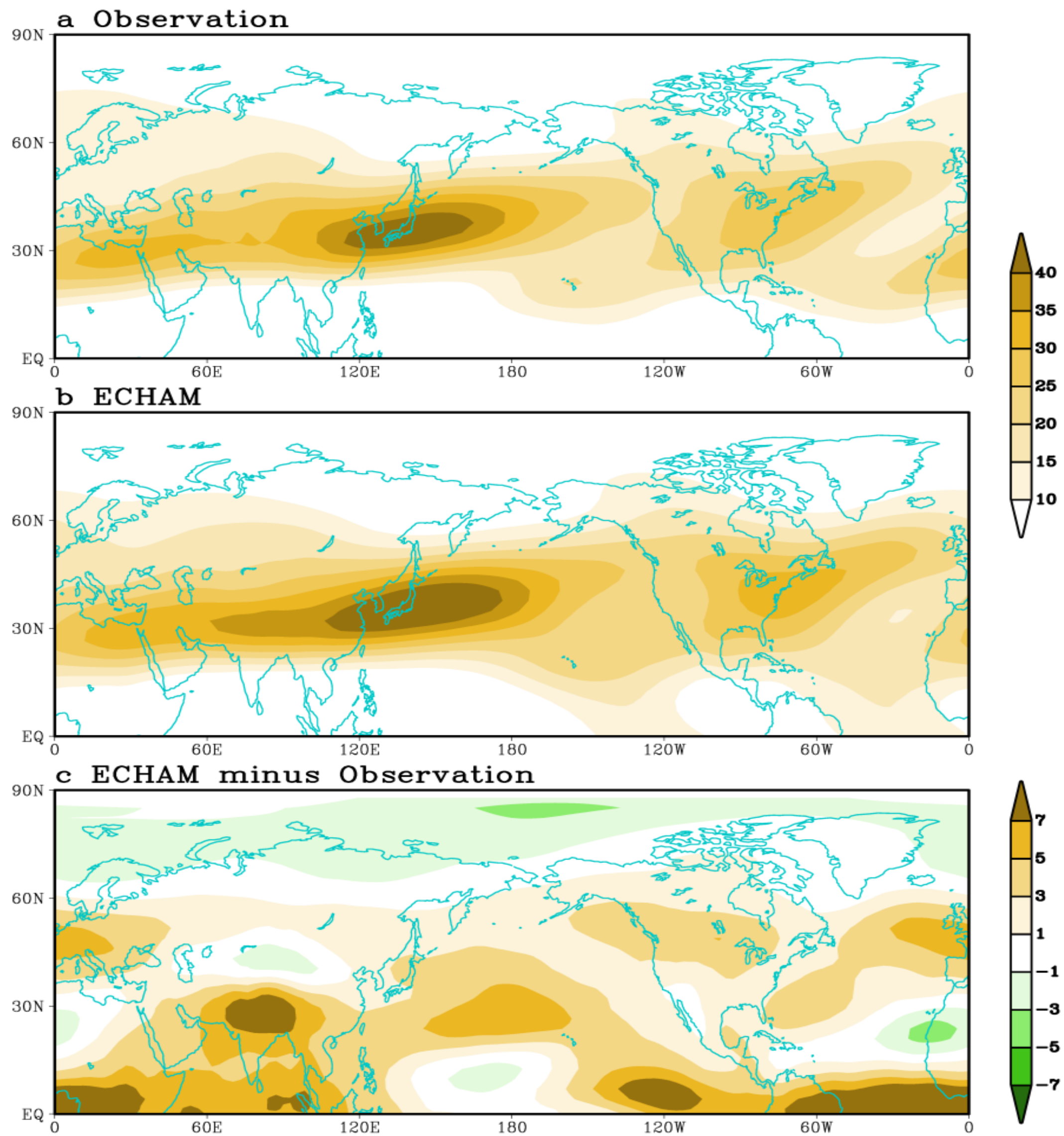
MCA modes for detrended Z200 and tropical SST




a PDO related Z200 and surf−temp
b Detrended PDO related Z200 and surf−temp
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.65
0.5
0.35
−0.35
−0.5
−0.65

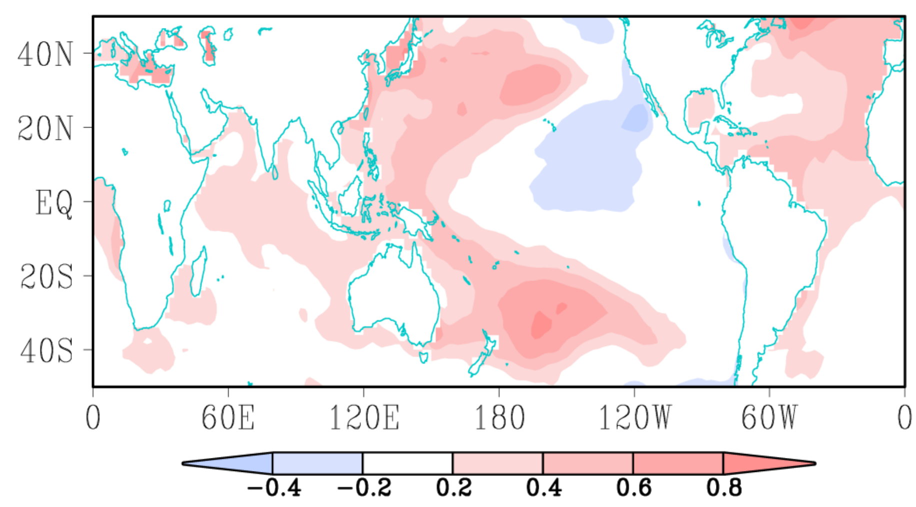


a EOF1 of Z200 (30%)
b EOF2 of detrended Z200 (19%)
c
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0.65
0.5
0.35
−0.35
−0.5
−0.65
PC1 of Z200
PC2 of detrended Z200
1980
1985
1990
1995
2000
2005
2010

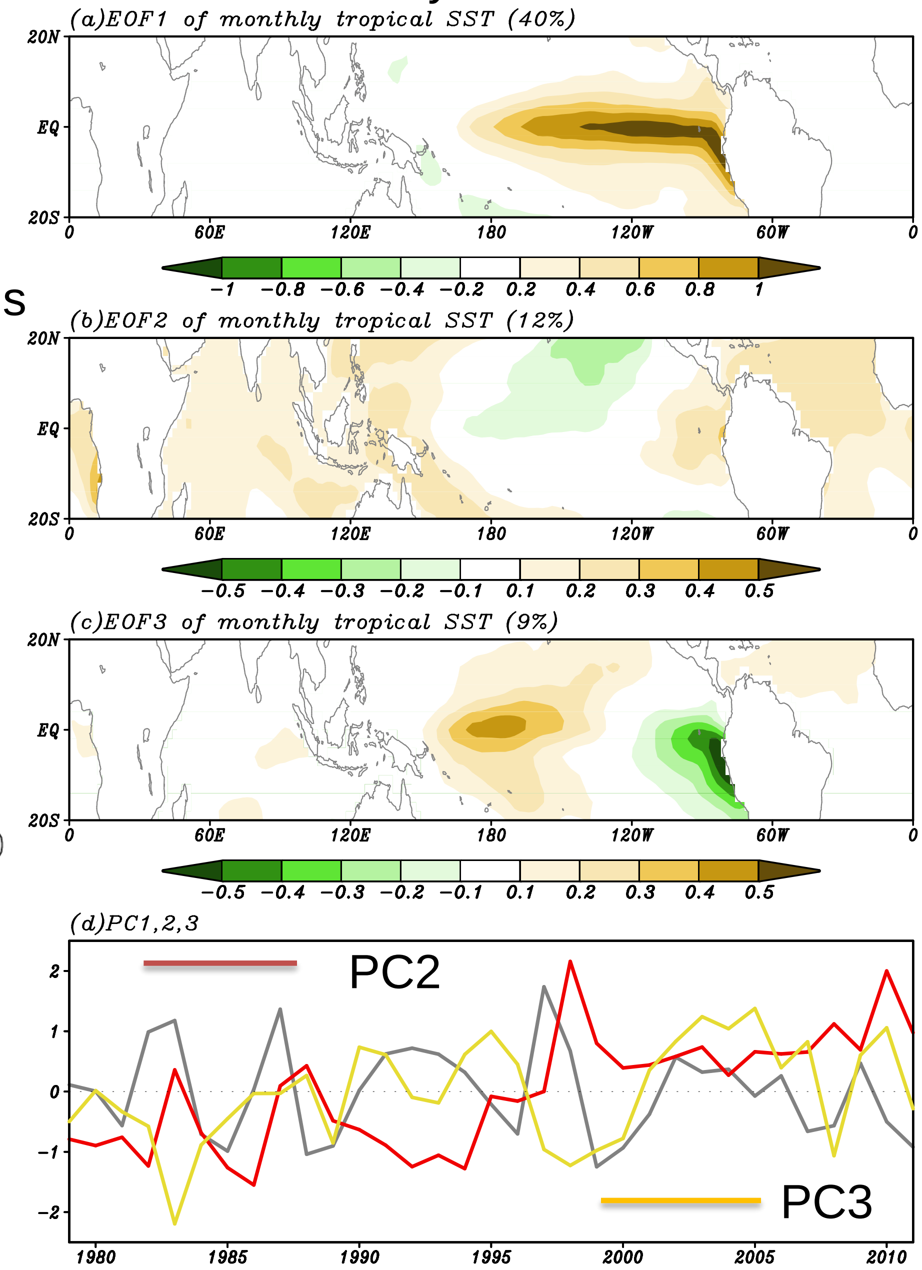

a Observation
b ECHAM
c ECHAM minus Observation
90N
60N
30N
EQ
0
60E
120E
180
120W
60W
0
40
35
30
25
20
15
10
7
5
3
1
−1
−3
−5
−7

Recent change in the tropics

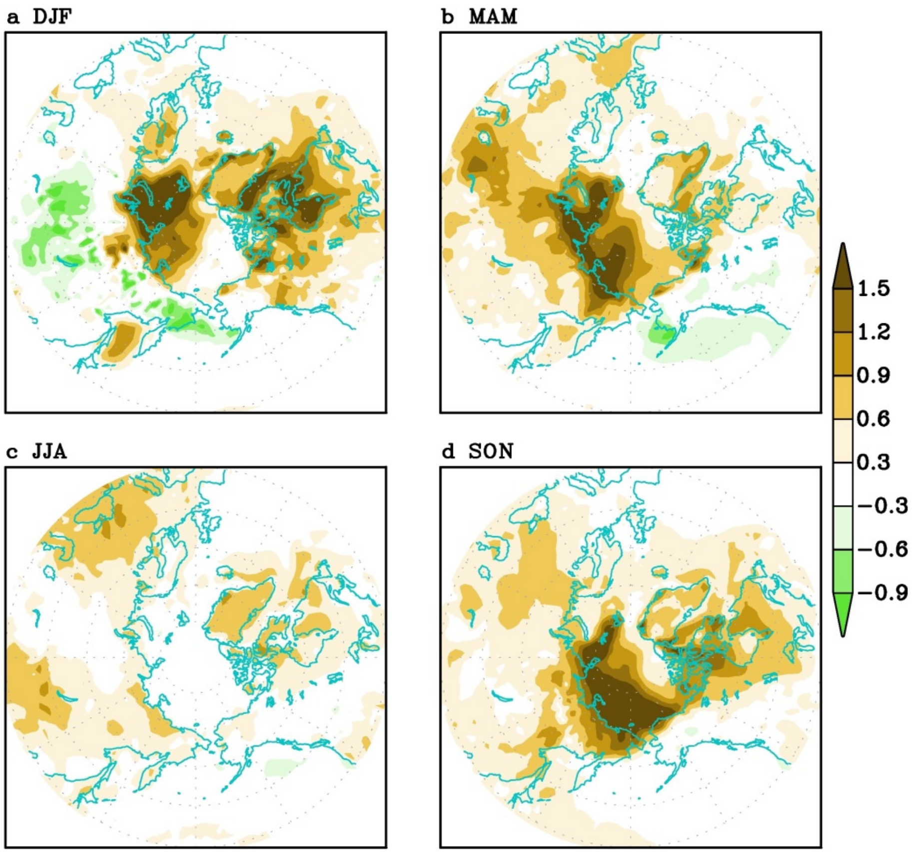
Annual mean SST change (1996-2012 minus 1979-1995)



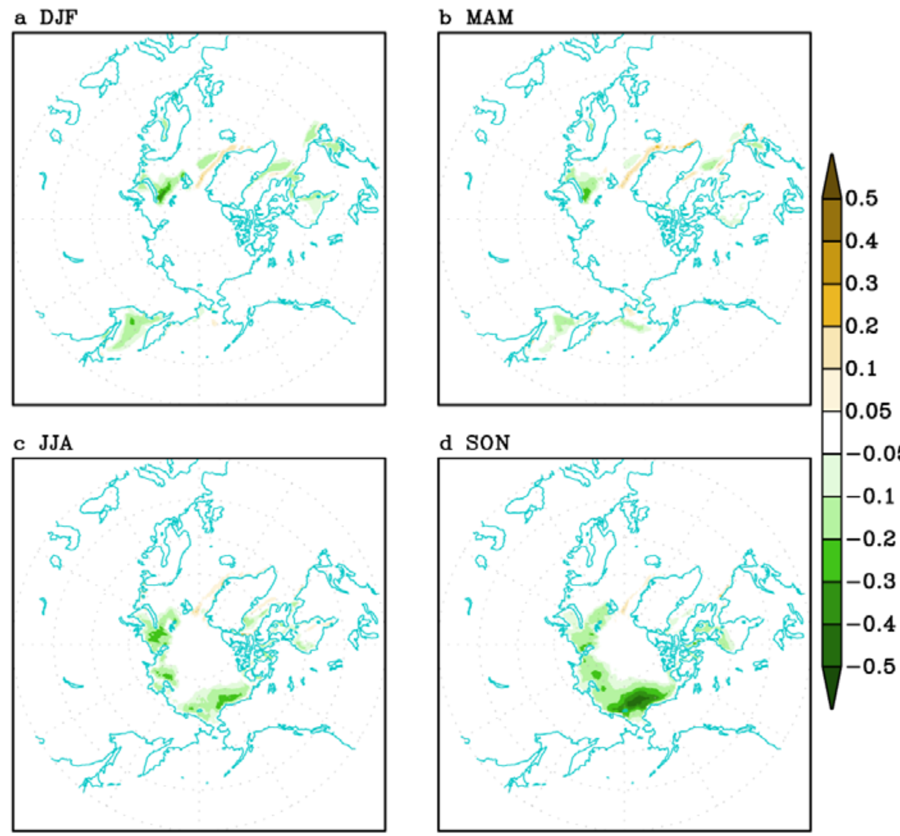
Monthly data 1979-2012



Surface temperature trend
(1979-2012)

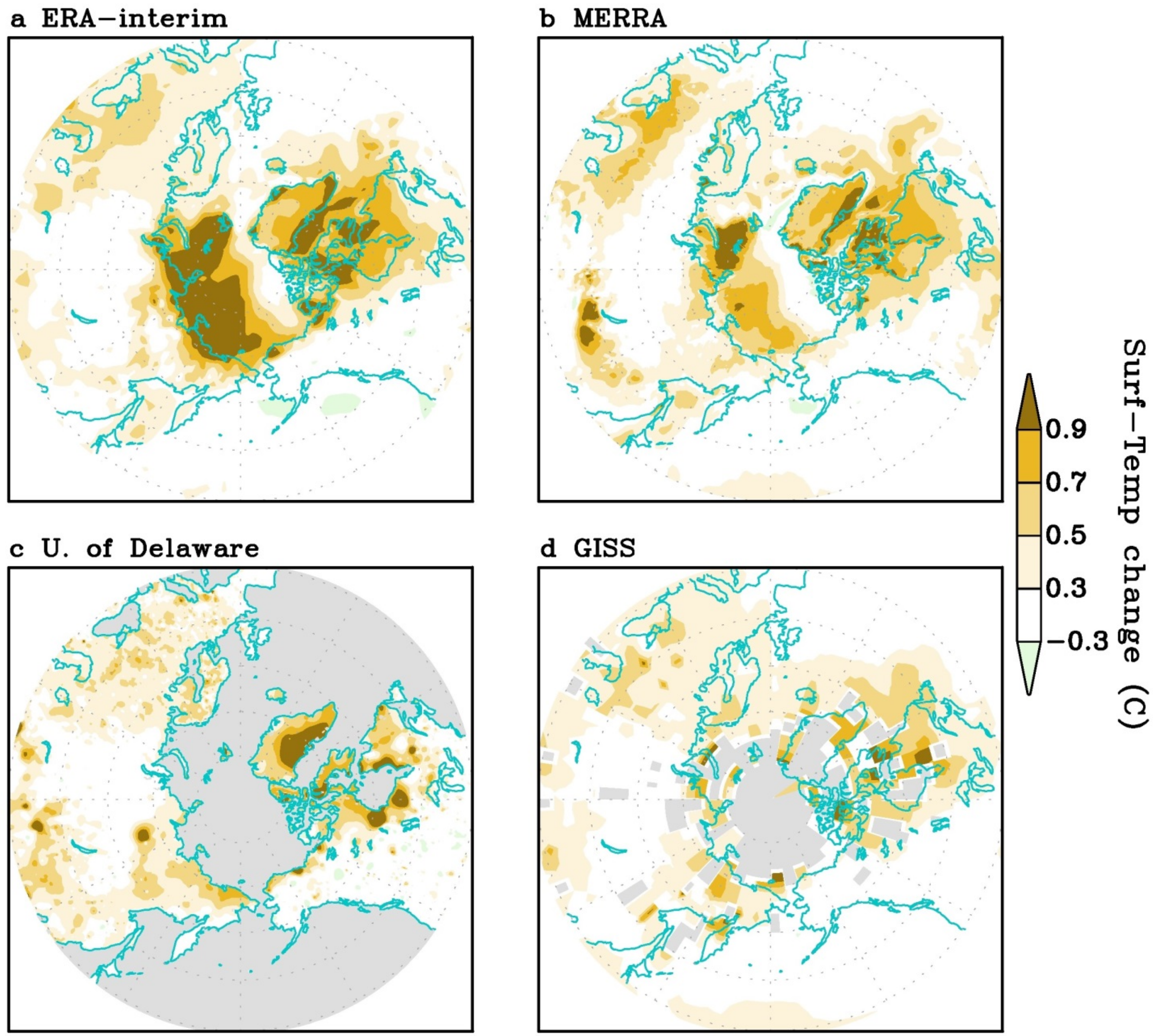


Sea ice trend
(1979-2012)



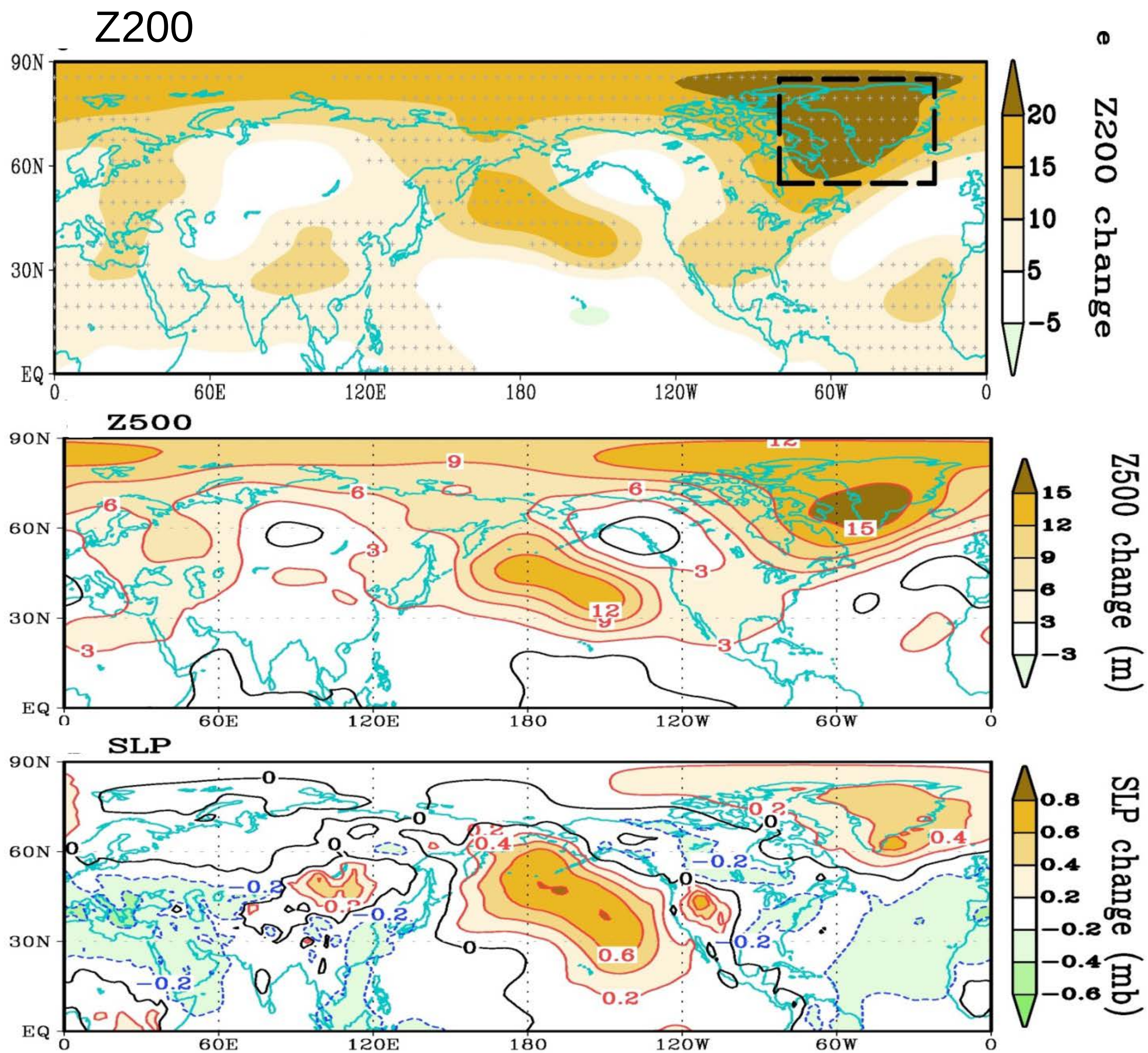
Maximum regional warming occurs in non-melting season

Annual mean surface temperature trend (1979-2012)



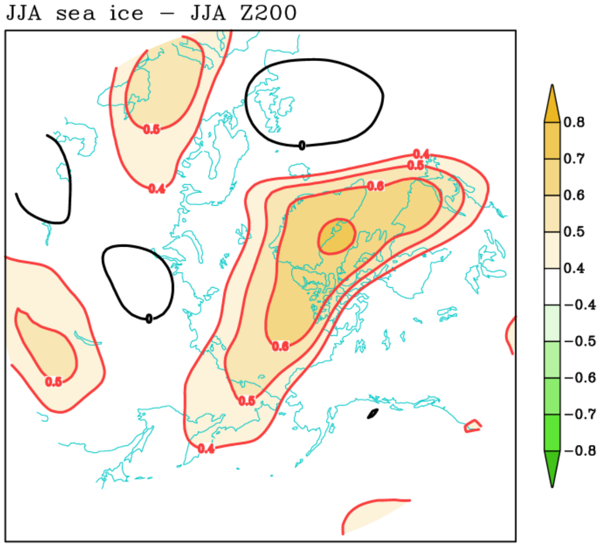
All data agree

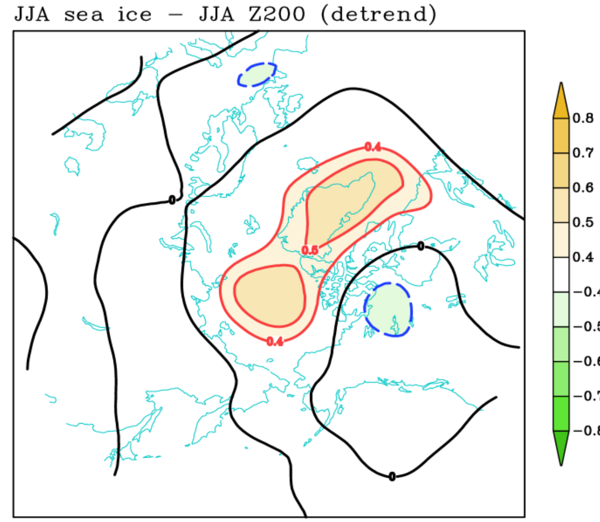
Annual mean geopotential height trend (1979-2012)



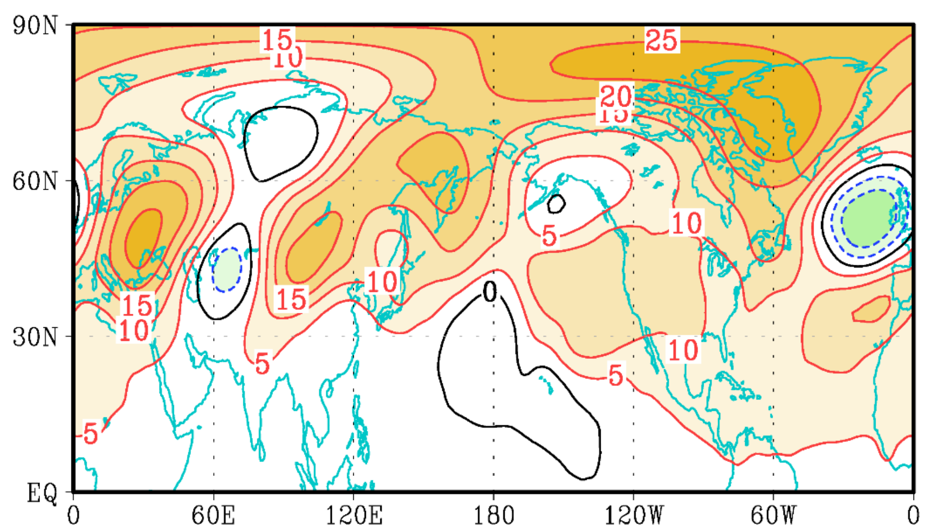
Circulation change may be a driver of the regional warming

JJA sea ice change is only related to JJA Z200 variability





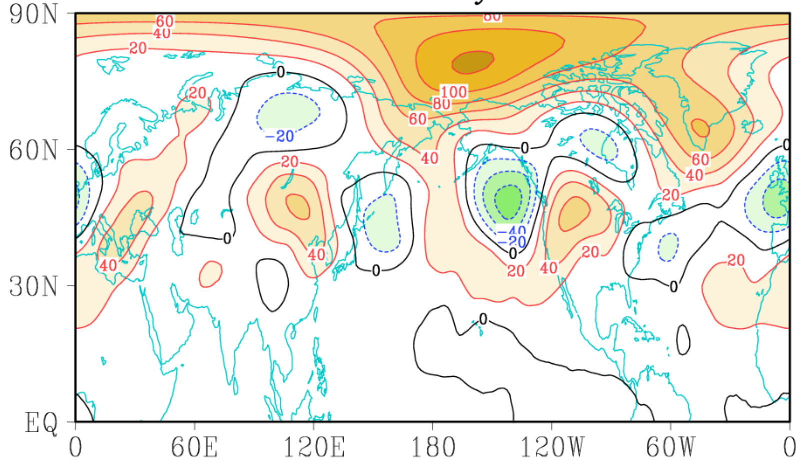
JJA Z200 trend (1979-2013)



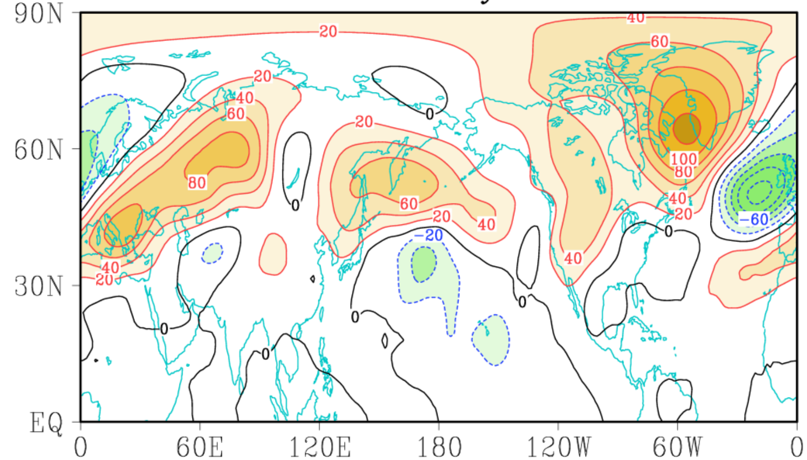
Two extreme years: 2007 and 2012

Mean:1979-2012

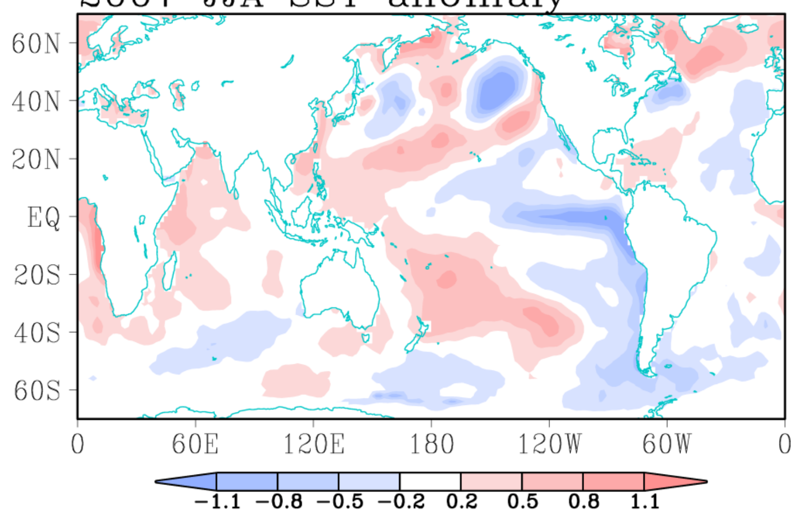
2007 JJA Z200 anomaly



2012 JJA Z200 anomaly



2007 JJA SST anomaly



2012 JJA SST anomaly