LDEO,June,2-3,2014

Tropical forcing of the recent rapid Arctic warming in northeastern Canada and Greenland

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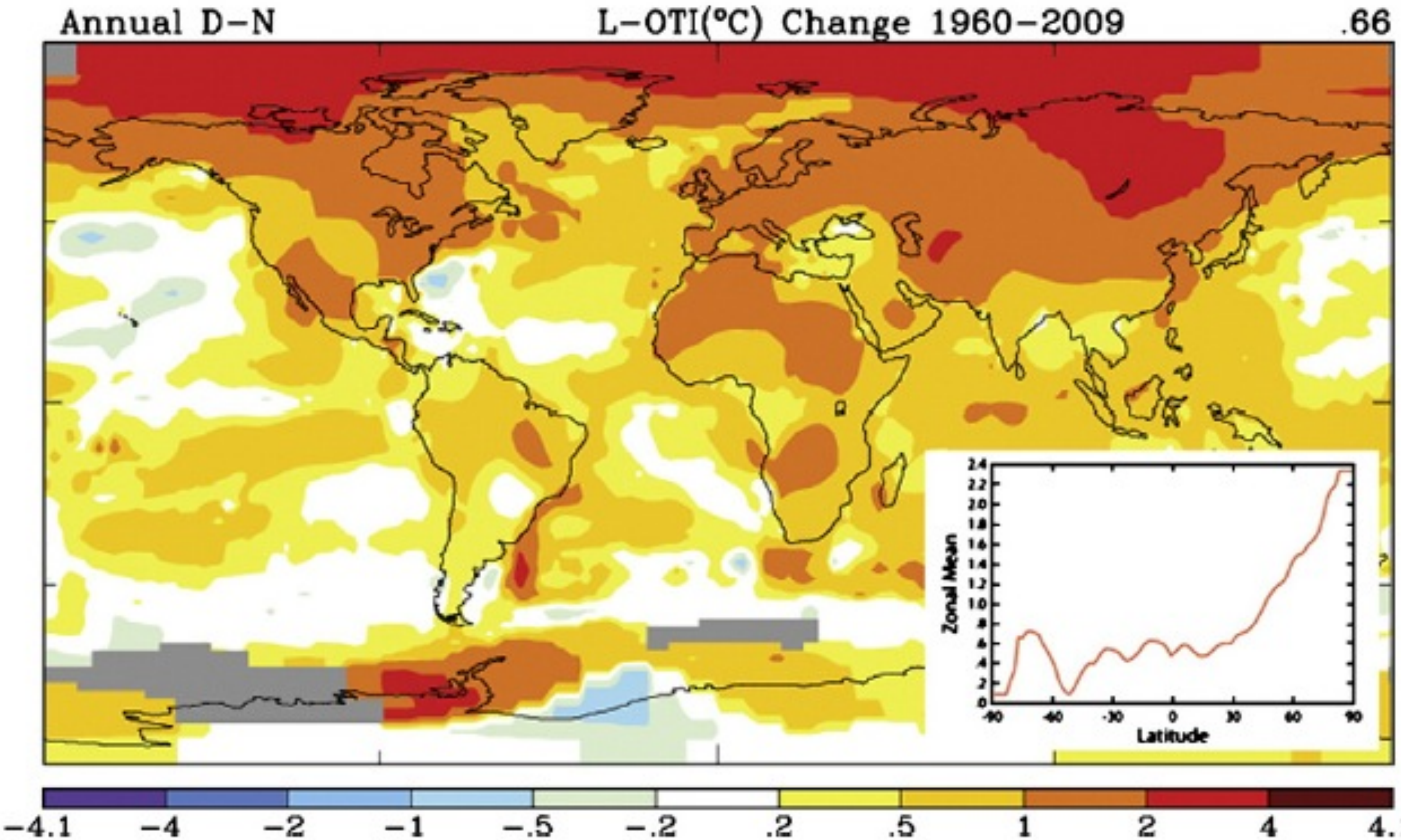
Ailie Gallant, HyungJin Kim, Lei Geng

University of Washington
Monash University
APEC Climate Center

Photo: James Balog

The fastest warming rate in the Arctic and Antarctic Peninsula



Serreze and Barry 2011

The 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 +natural)

- Poleward heat and moisture transport by atmosphere and ocean
- Remote SST impact
- Internal variability

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 *.

Warming trend is sensitive to start/end of a period

Surf-T poleward of 59N

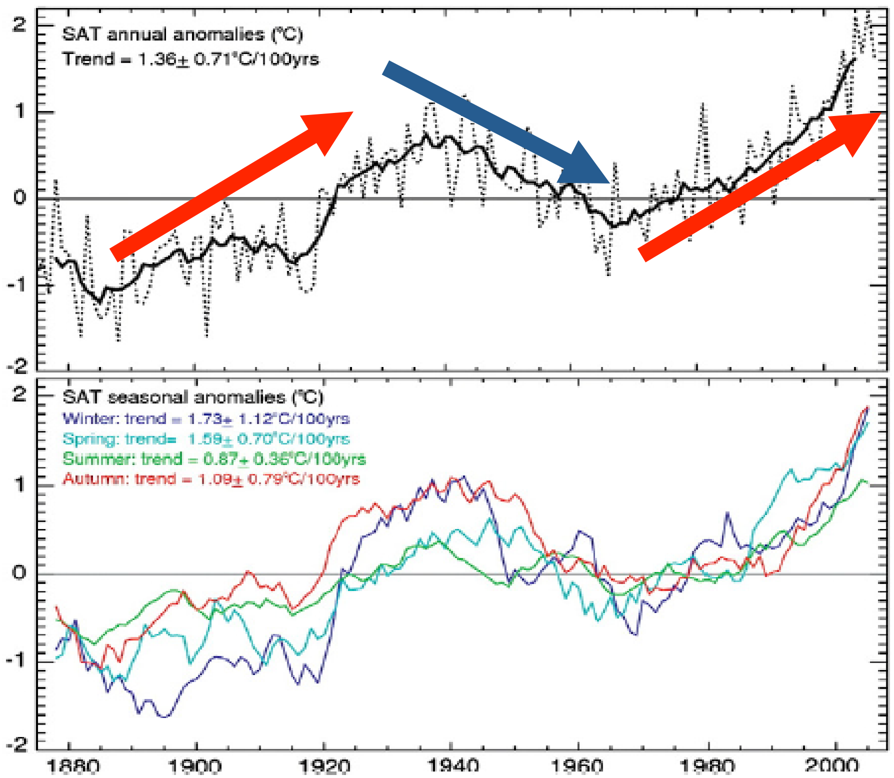


Fig. 3. Composite time series of the (top) annual and (bottom) seasonal surface air temperature anomalies (°C) for the region poleward of 59°N. The dotted lines show unsmoothed values, the solid lines are seven year running means. The liner trends listed in the legend are computed using data for the 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

Key Questions

- What is the relative contribution of the external and internal forcing in the recent warming of the Arctic?

- How is the internal forcing causing the Arctic warming?

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

Contents

Observational result | **ECHAM4 Exp** | **IPCC AR5 model**

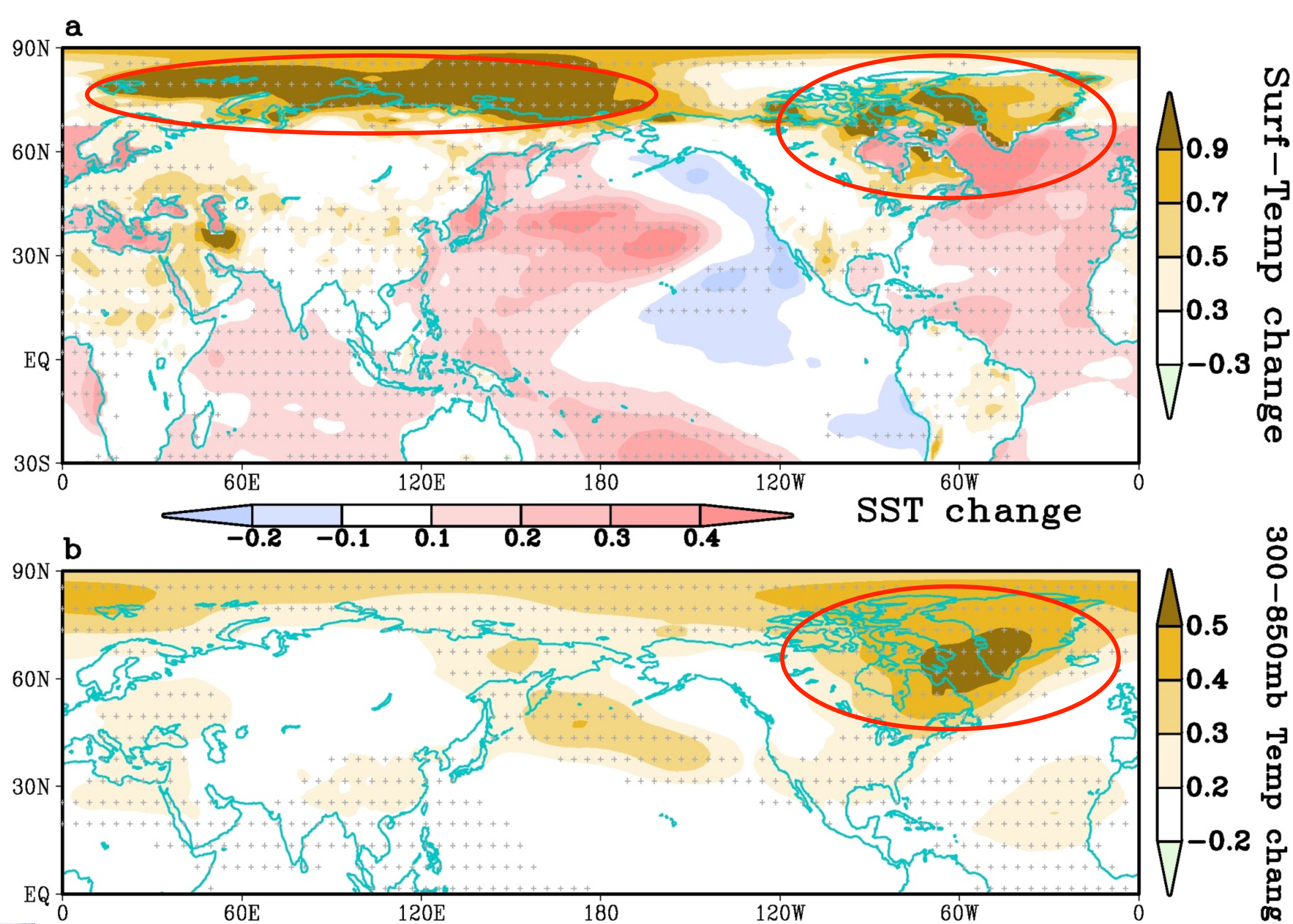
Focus of this study: 1979-2013 period

DATA
- Reanalysis : ERA-interim (1979-2012) , ERA40 (1958-1978), NCEPII (1979-2012) ,NCEP (1948-2012), MERRA(1979-2012), NOAA 20^{th} reanalysis
- SST & sea ice: ERSST3, HADISST, Kaplan, COBE
- Surface temperature: GISS-TEMP, Delaware, CRU, ERA-interim, MERRA, AVHRR
- IPCC AR5 historical run (1979-2004)

Model
- ECHAM4.6 model (T42L19)+ slab ocean/sea ice

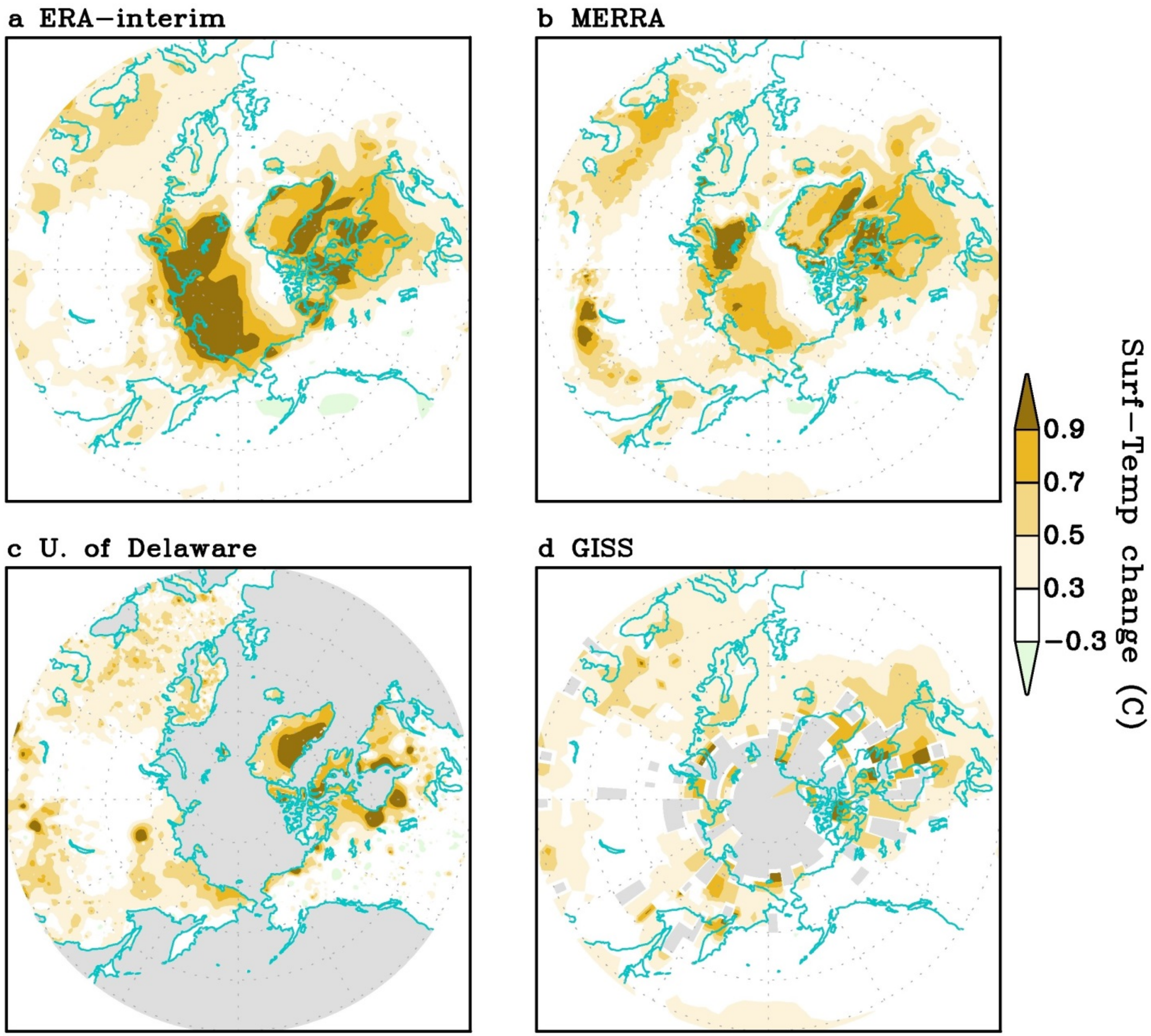
Method
- Annual mean (June- May)
- Trend: epochal difference or linear trend
- Trend significance (signal to noise ratio, Mann-kendall test)
- Upper level circulation

Annual mean surface/tropospheric temperature trend (1979-2012)



Strong regional warming in northeastern Canada and Greenland

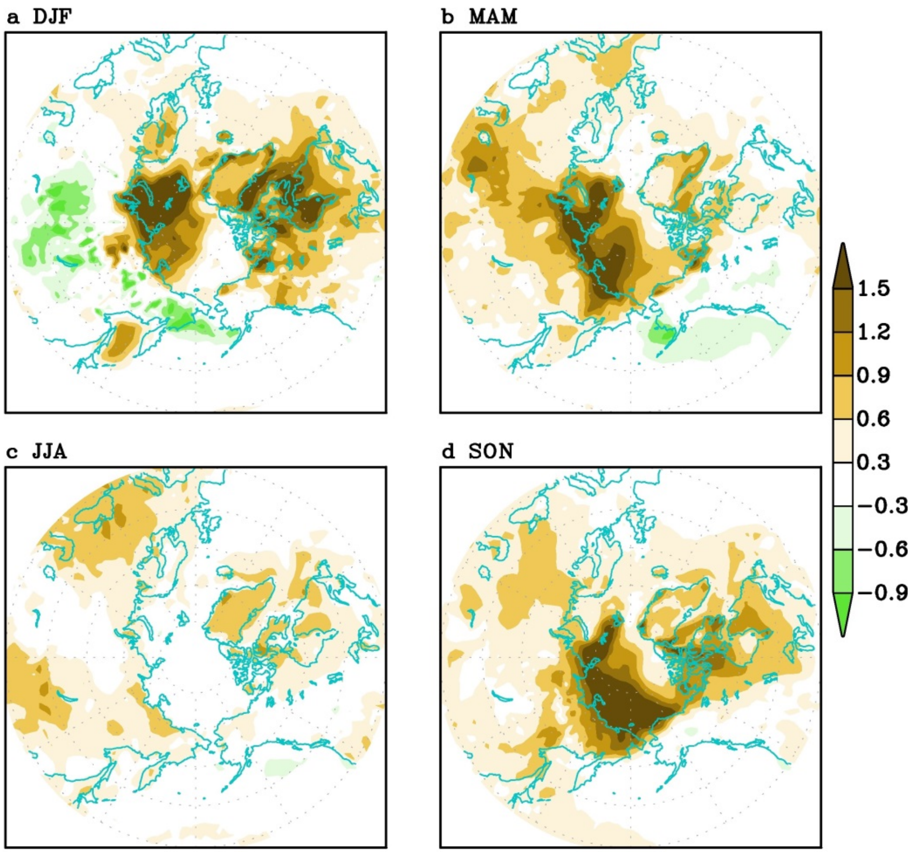
Annual mean surface temperature trend (1979-2012)

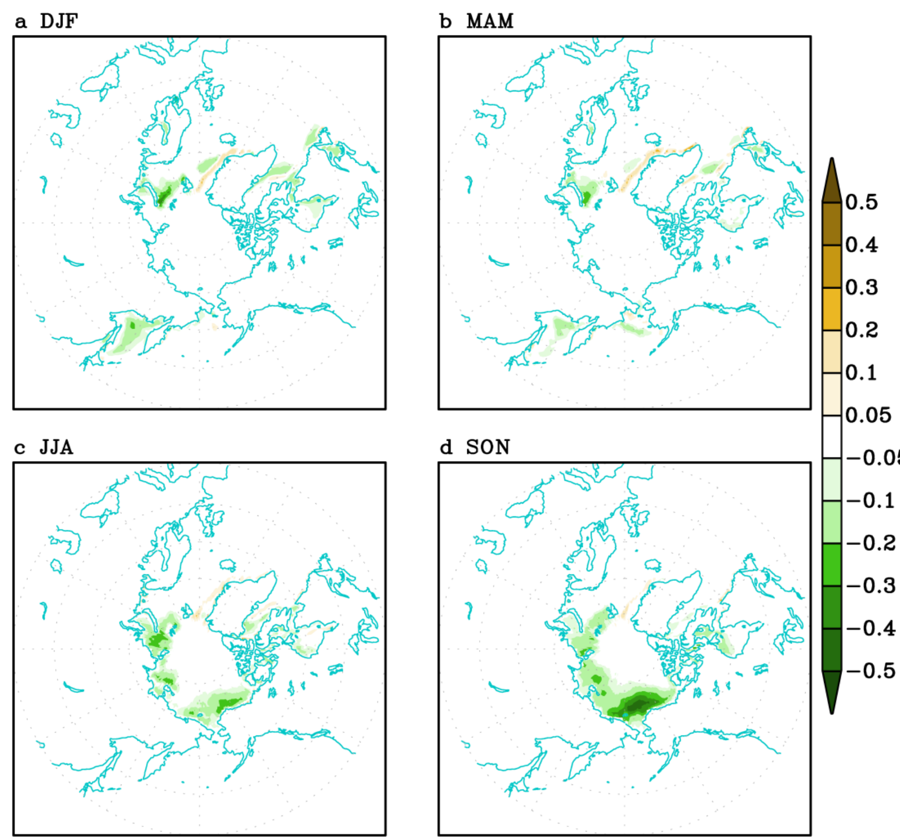


All data agree

Surface temperature trend
(1979-2012)

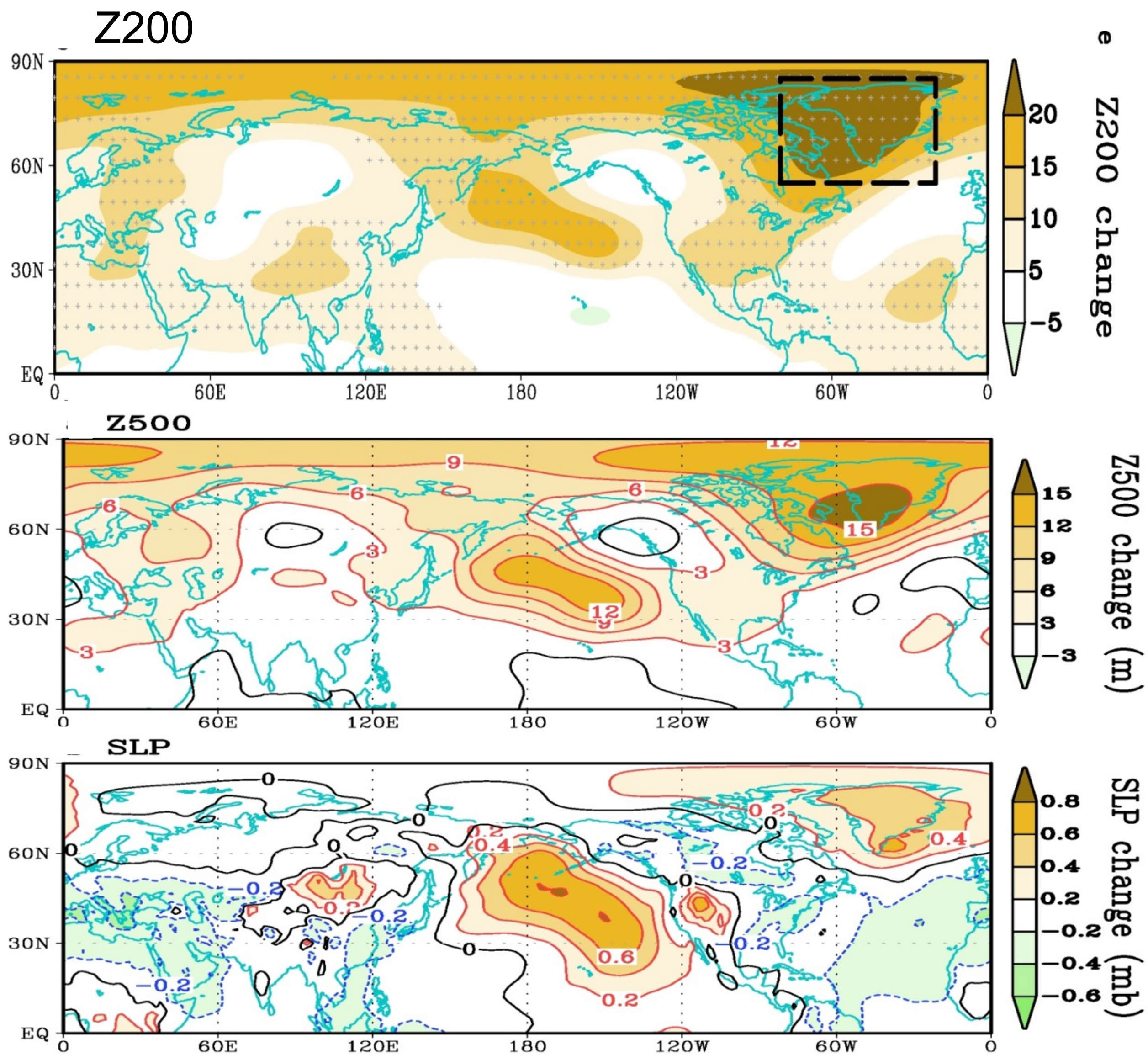
Sea ice trend
(1979-2012)





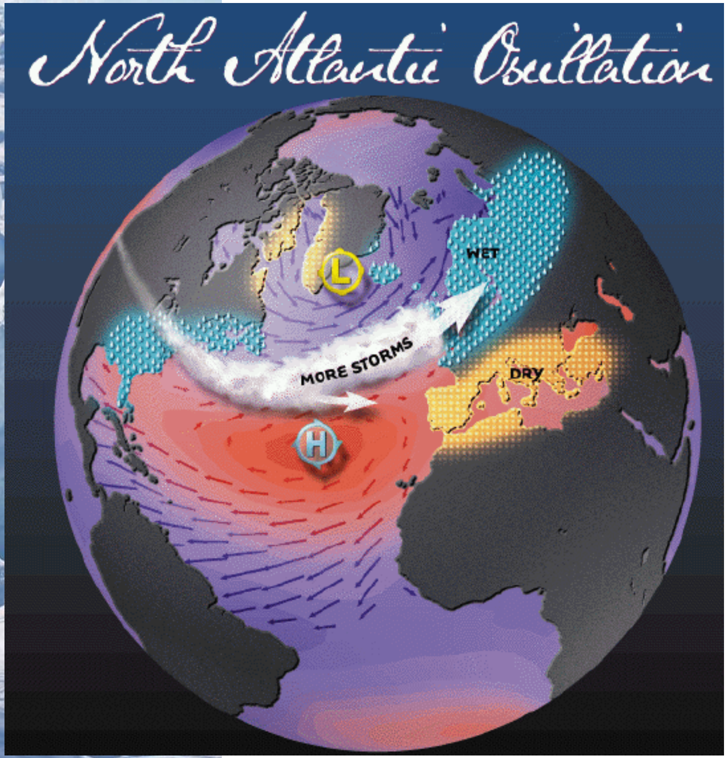
Maximum regional warming occurs in non-melting season

Annual mean geopotential height trend (1979-2012)

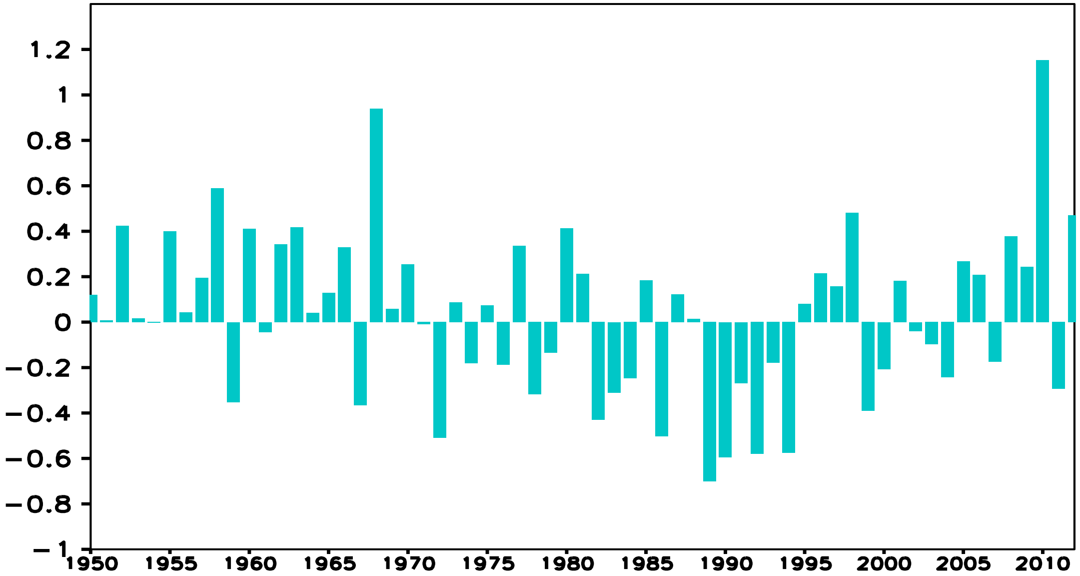


Circulation change may be a driver of the regional warming

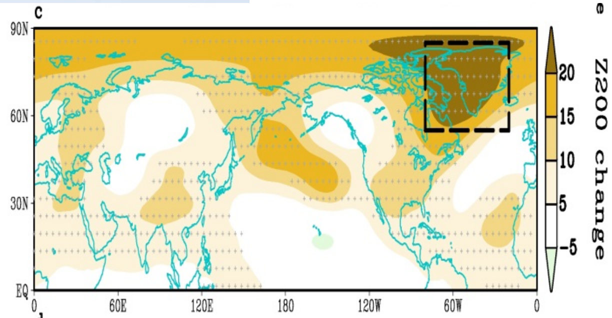
Leading mode of NH circulation: North Atlantic Oscillation

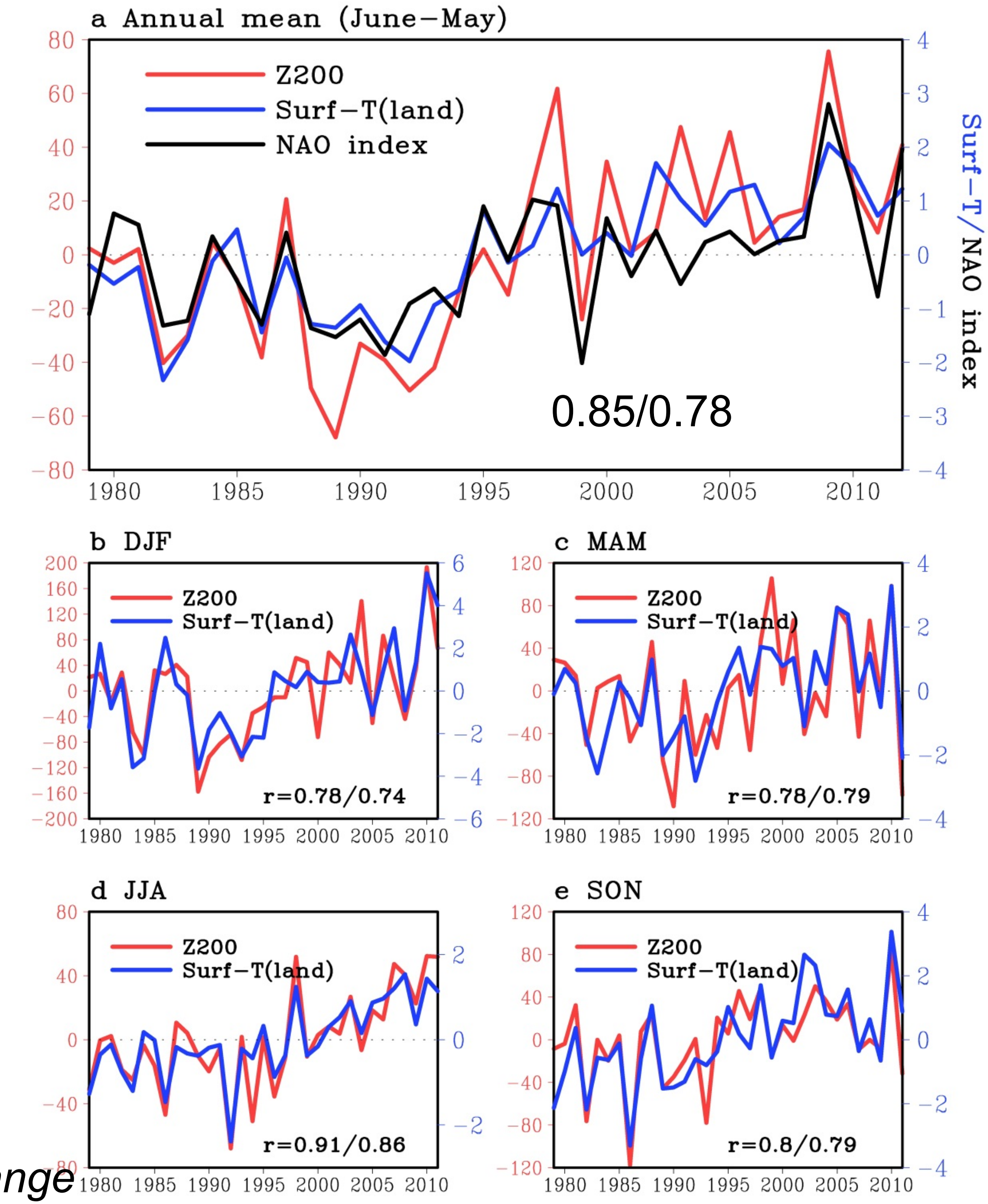


NOAA NAO index (annual mean, reversed)



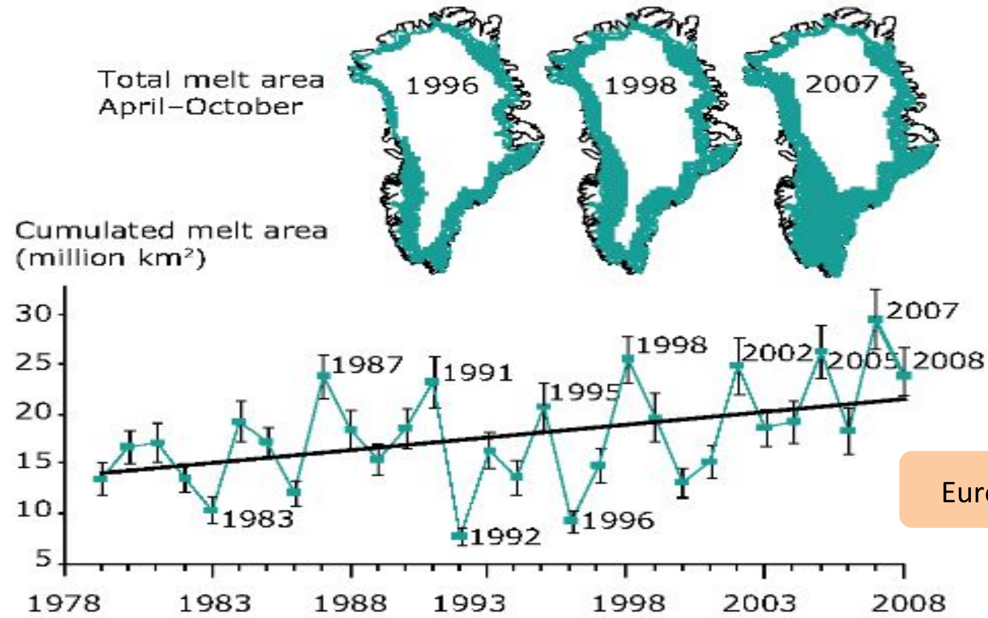
http://www.ldeo.columbia.edu/res/pi/NAO/



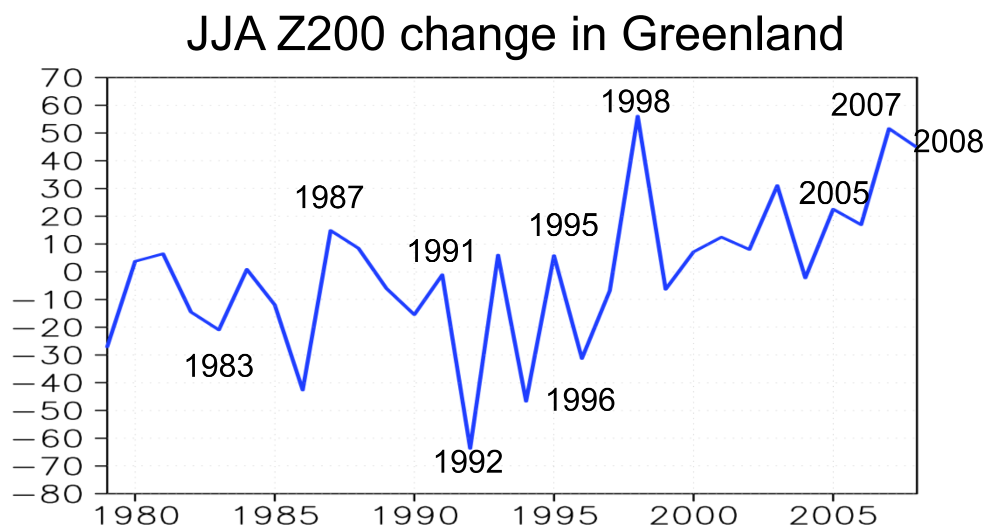


Interdecadal-like change

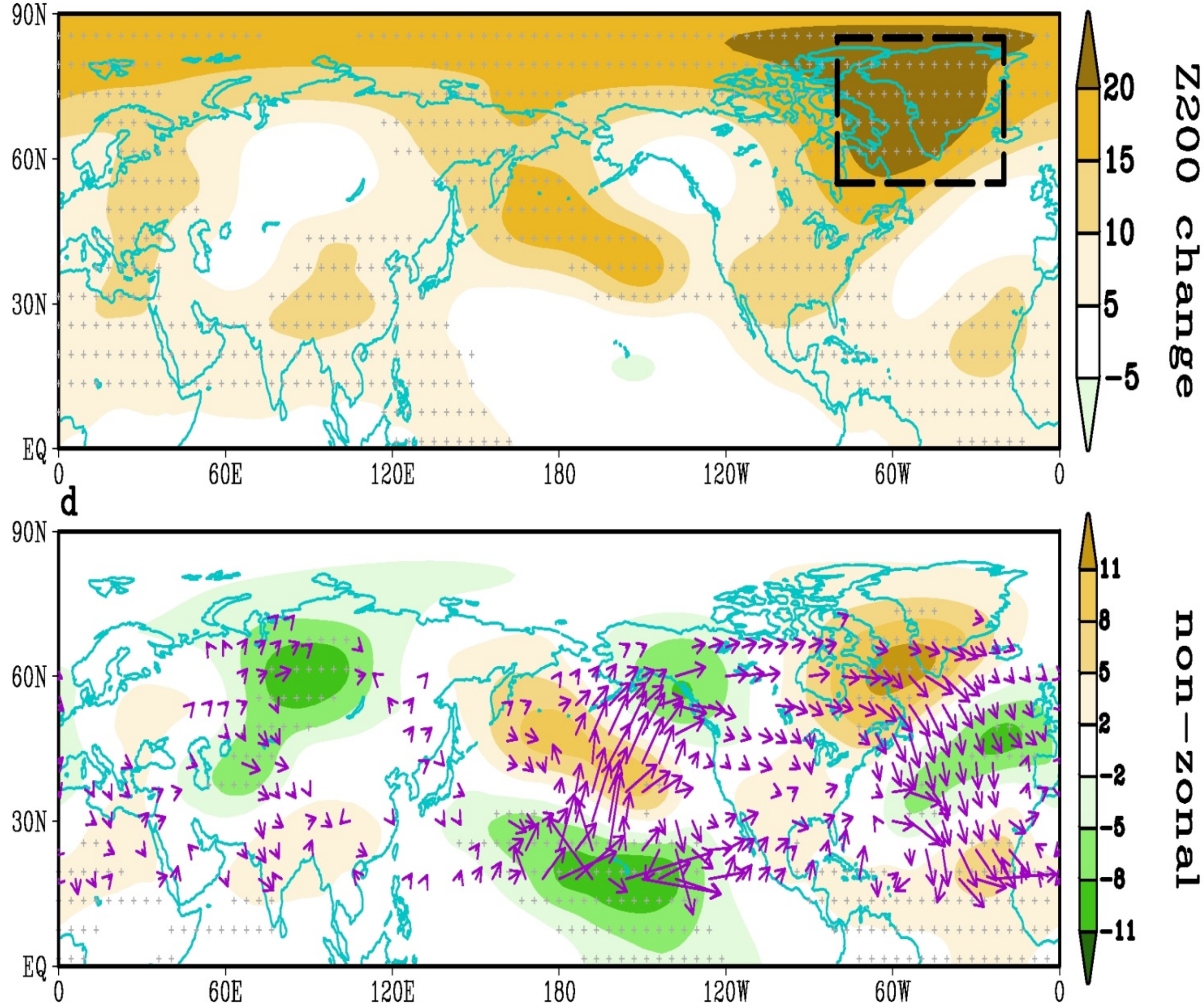
Greenland ice sheet melt extent



European Environment Agency



Annual mean Z200 trend (1979-2012)

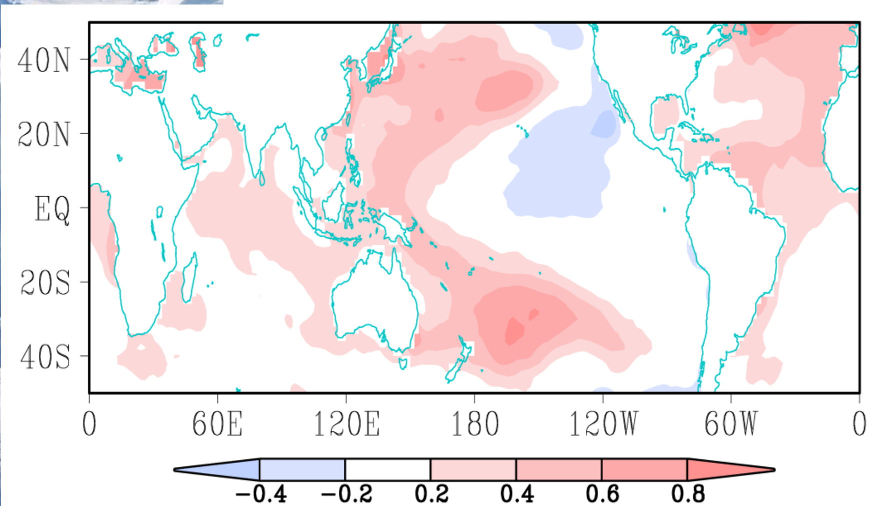


the Arctic is running a tropical fever

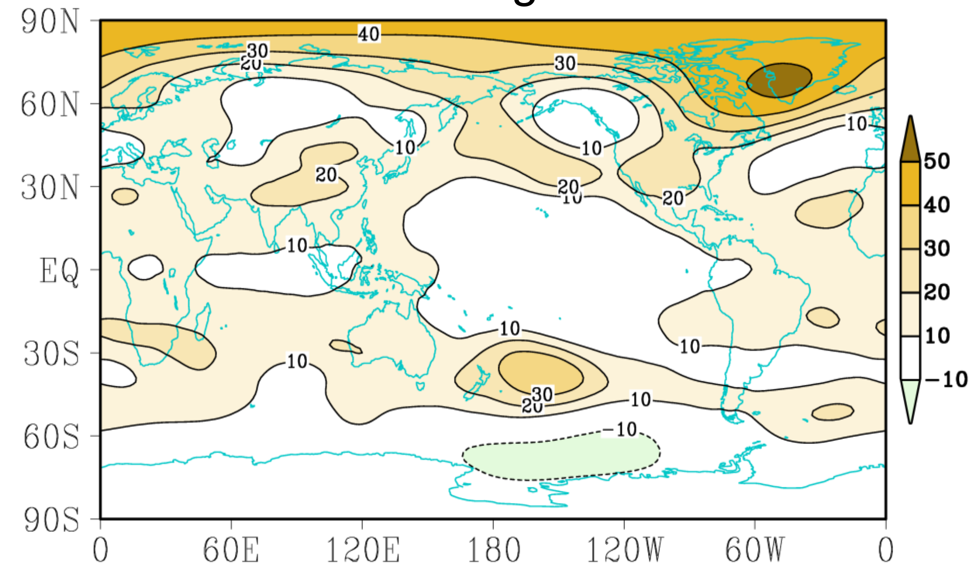
Plumb flux 1985

Annual mean SST and Z200 change (1996-2012 minus 1979-1995)

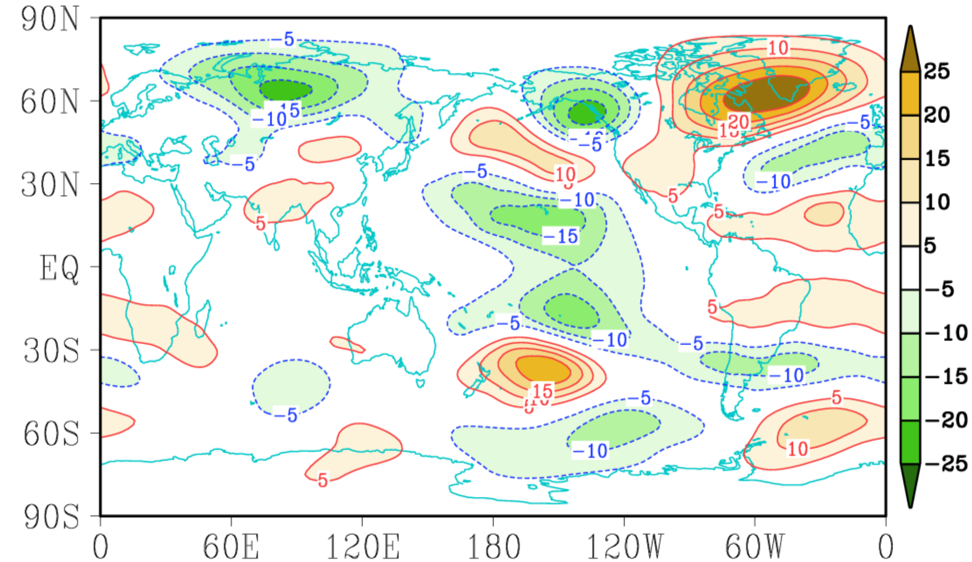
SST change



Z200 change

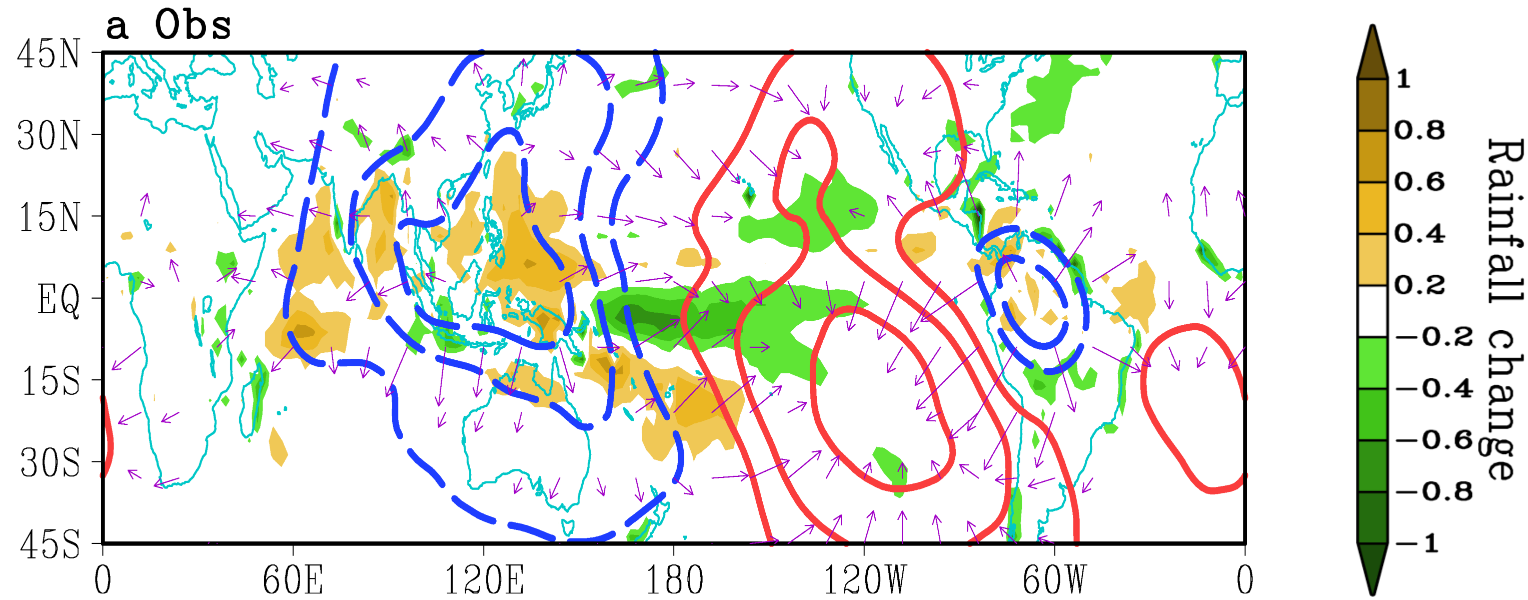


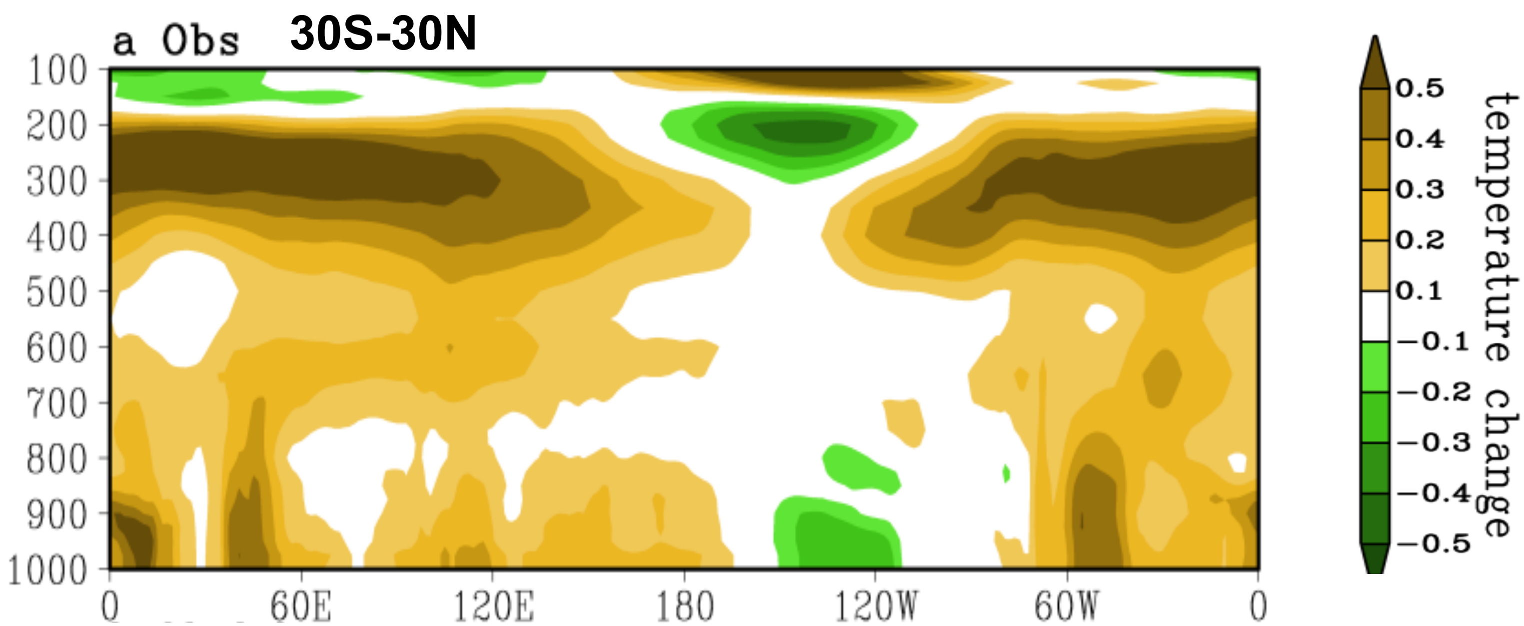
Non-zonal



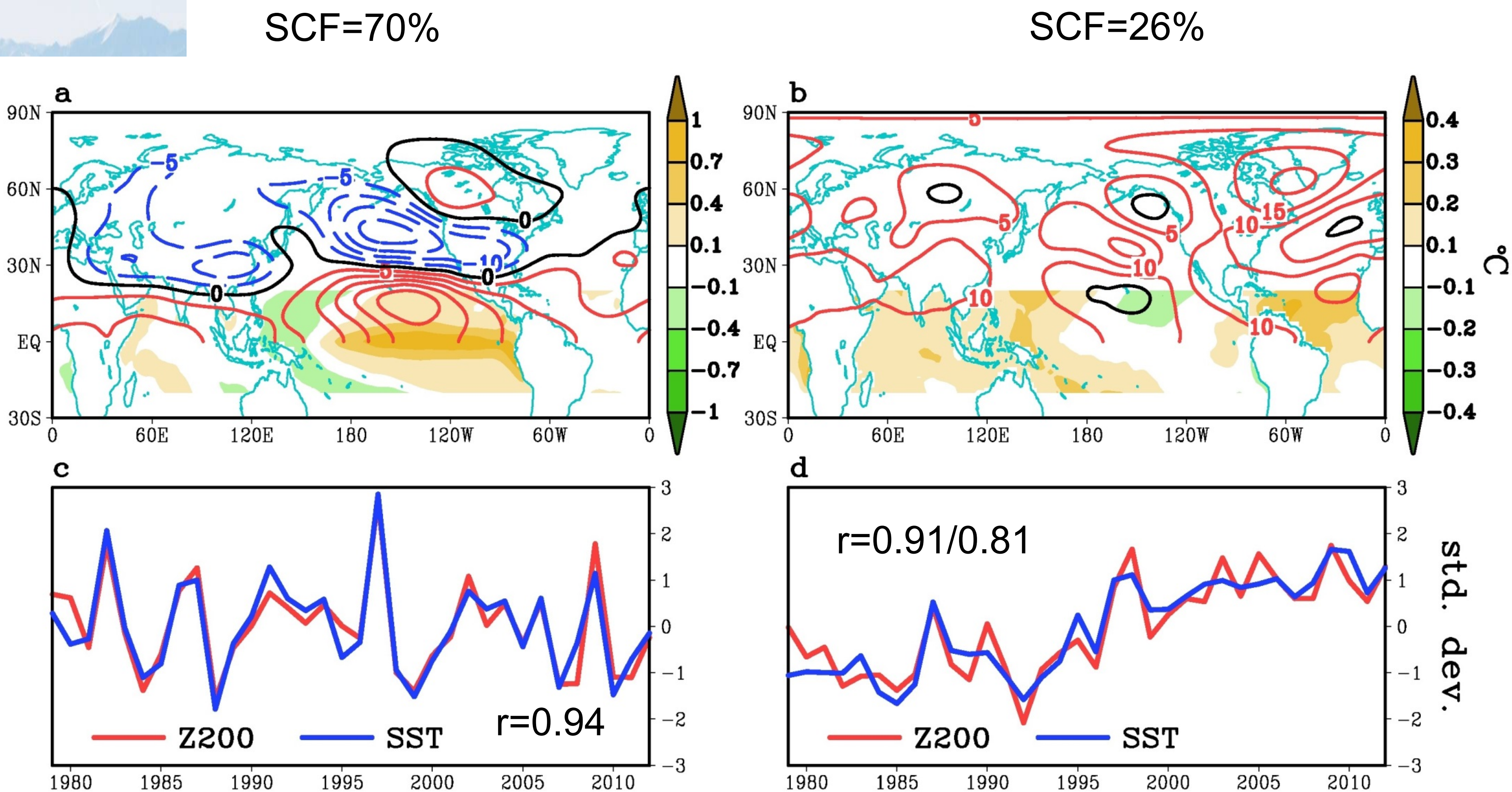
the Antarctic Peninsula too

What is happening in the tropics?



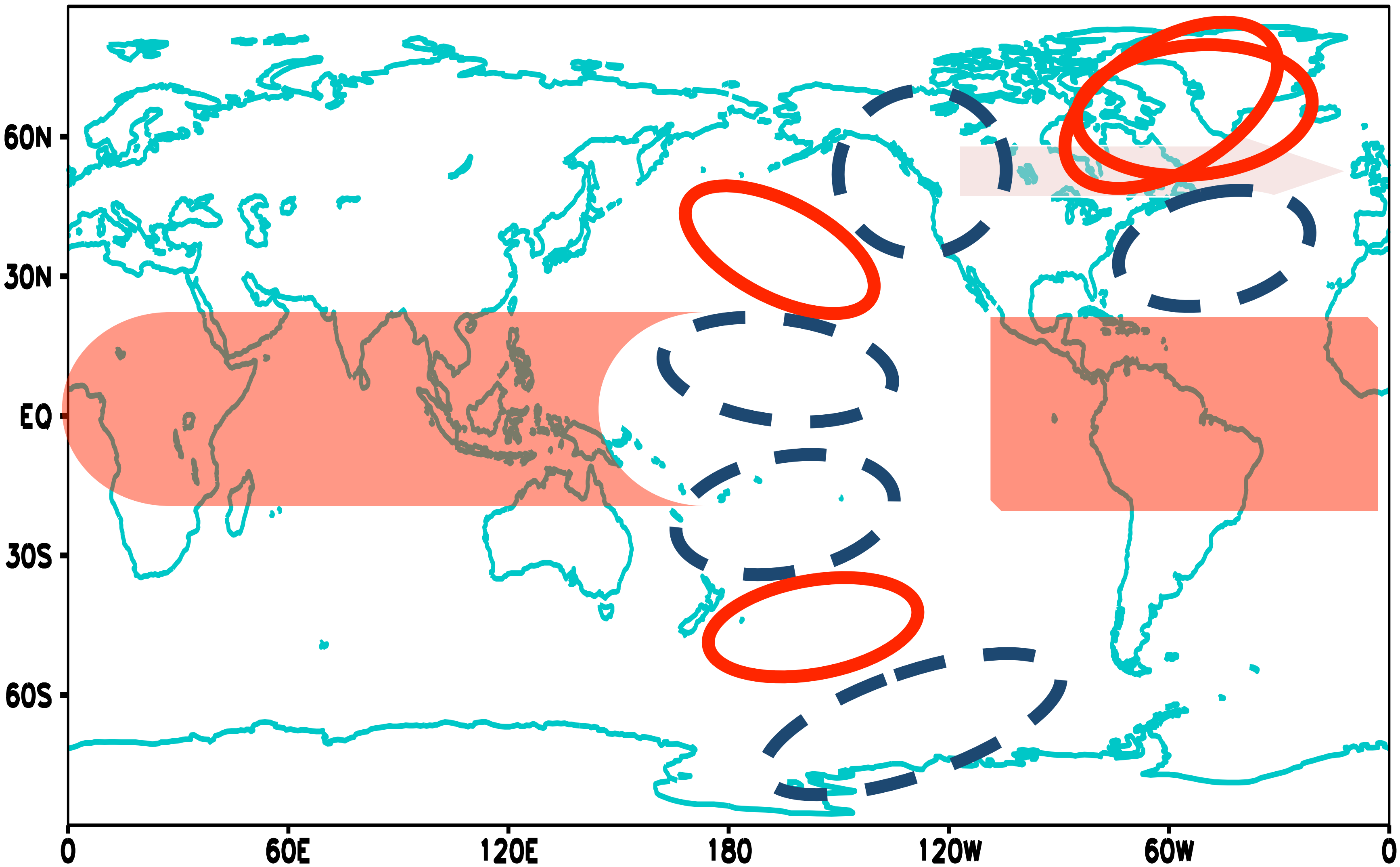


Covariability of annual mean tropical SST and NH Z200 (1979-2012)



a low frequency tropical SST mode(shifted at 1997/1998)
not the typical ENSO

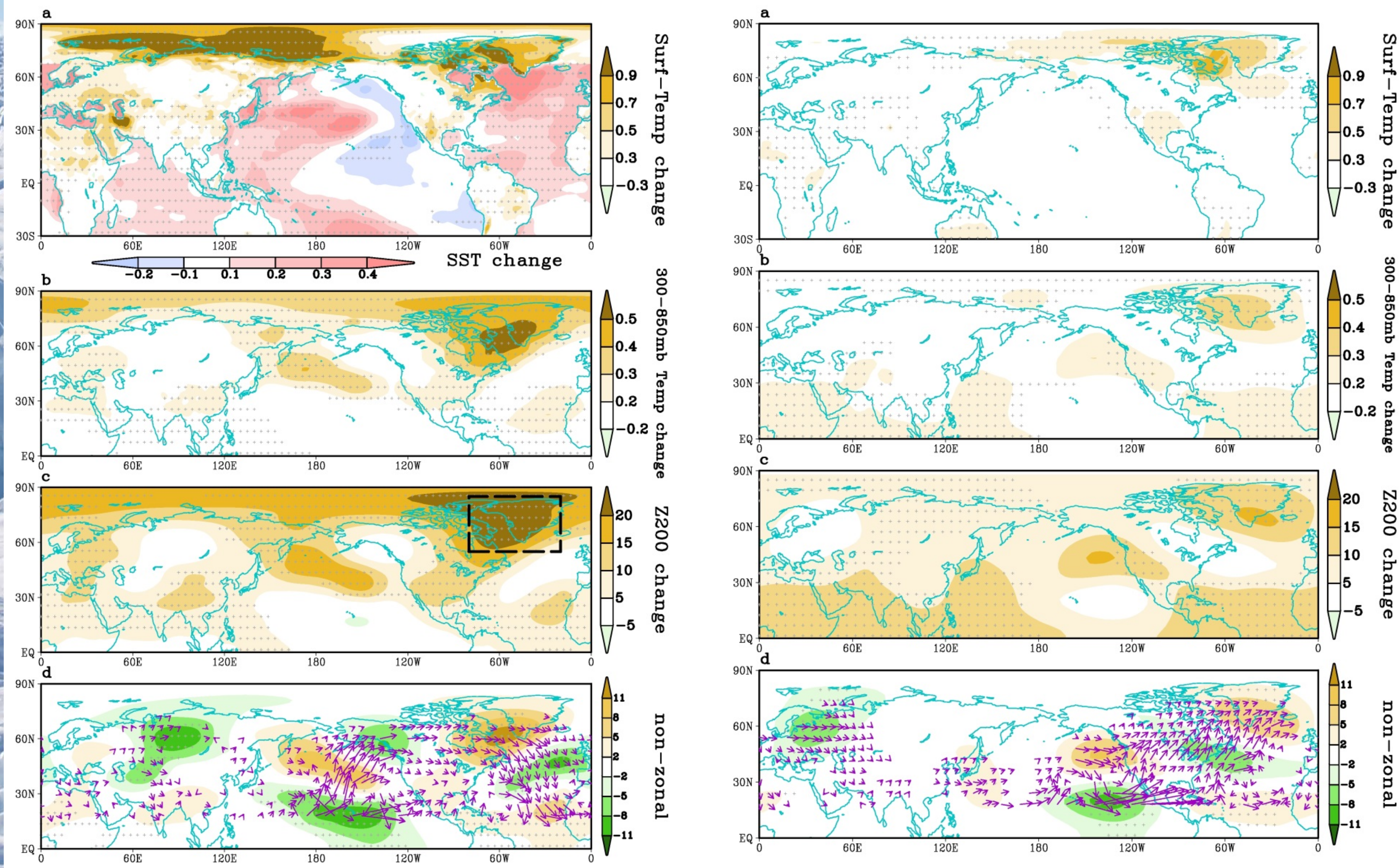
How is the tropical forcing causing the Arctic warming?



ECHAM4.6 model response to observed tropical SST (1979-2012)

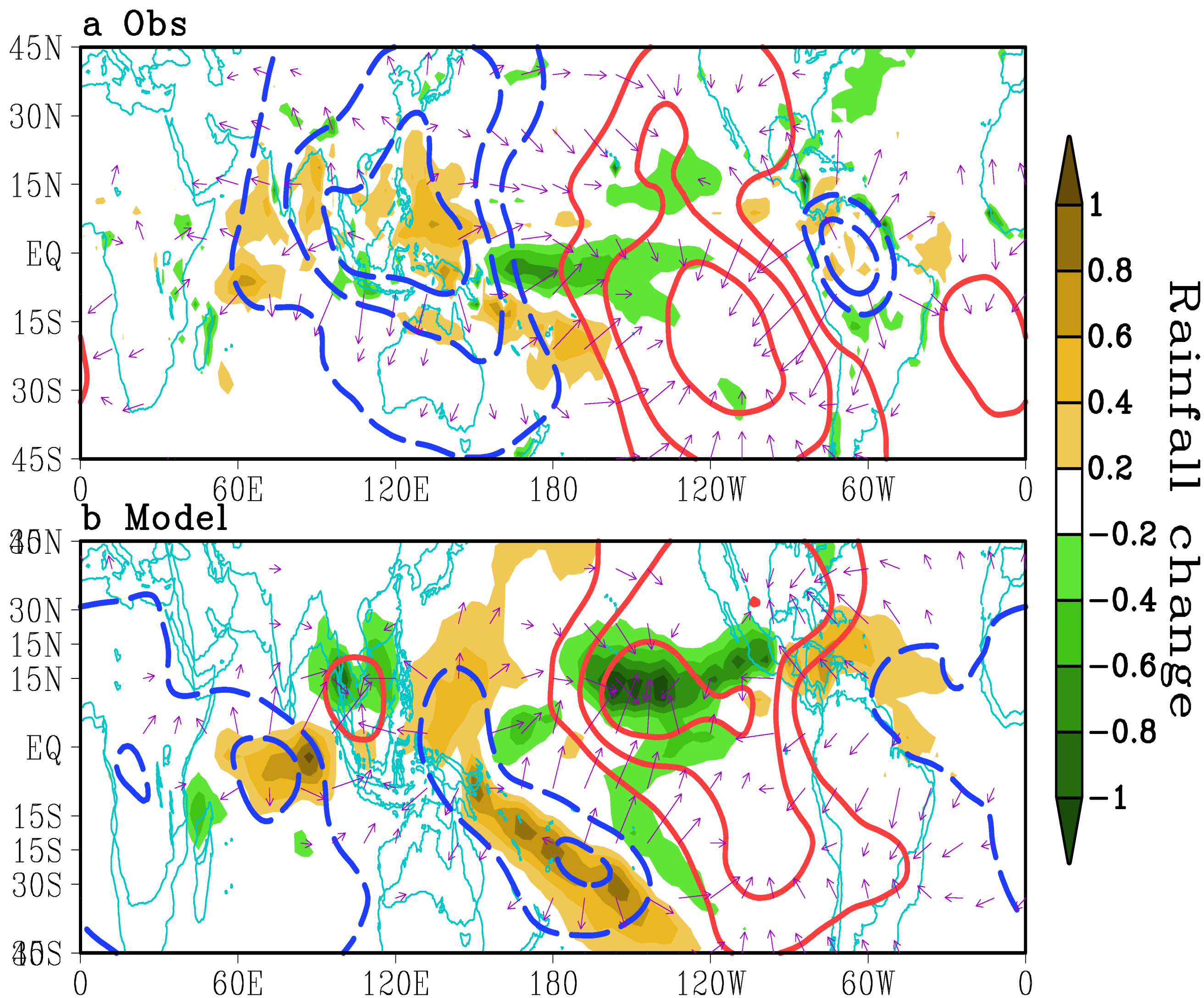
Tropics: observed SST   Extratropics: slab ocean/sea ice   10 members run

Observation   Simulation

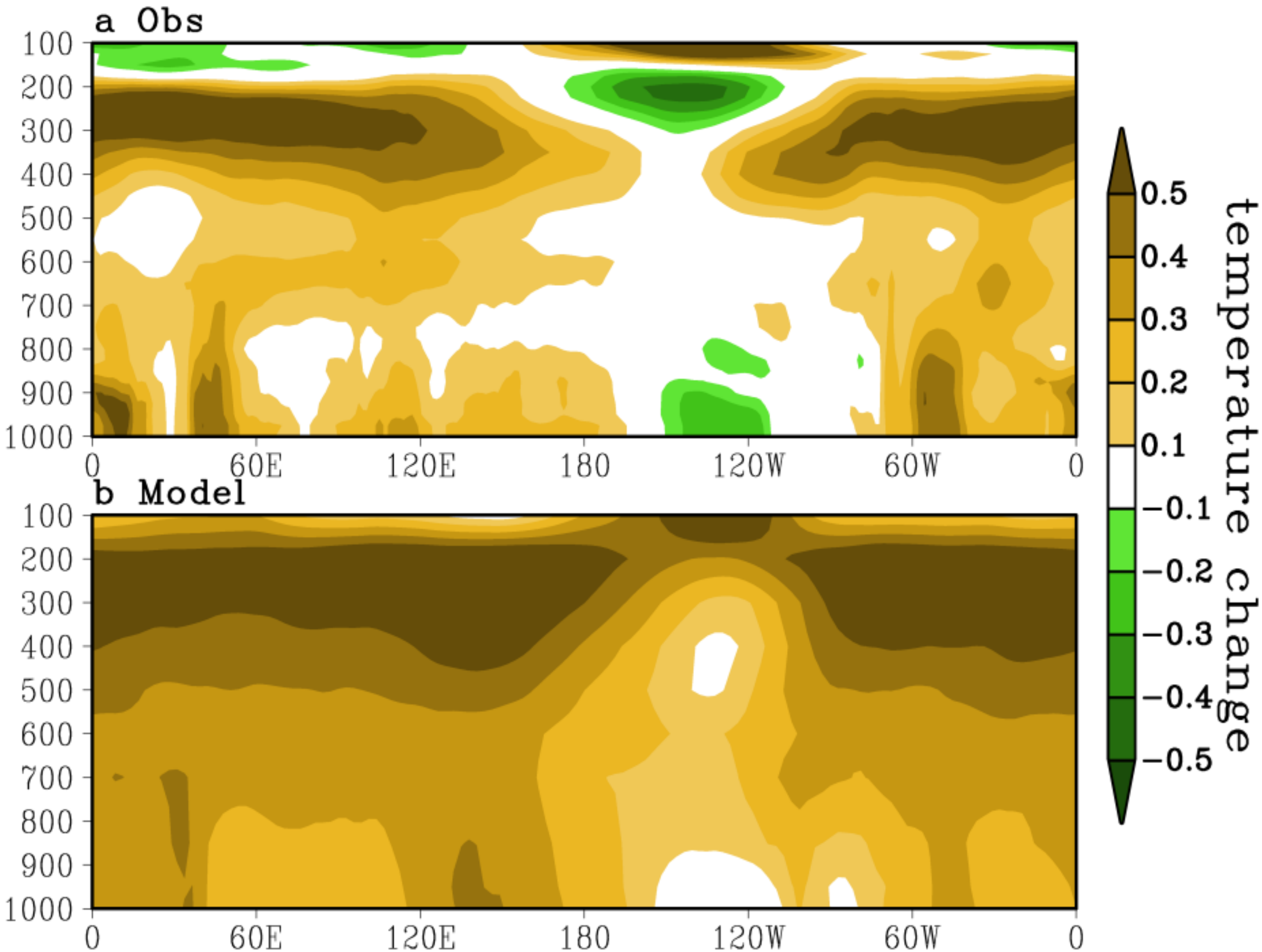


Tropical SST can explain 50% of warming over the Arctic

Annual mean rainfall trend in 1979-2012



Annual mean tropical temperature trend in 1979-2012



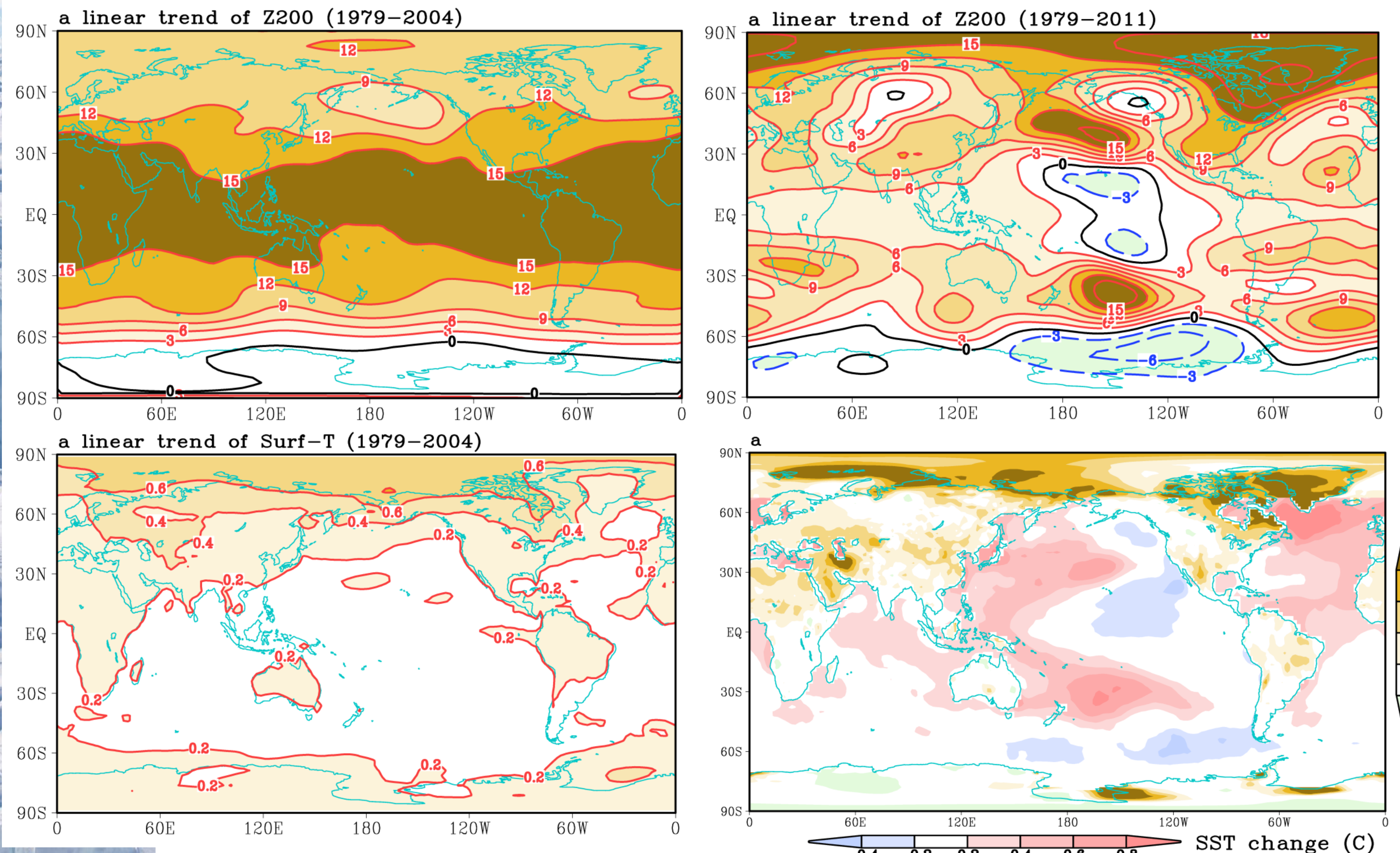
Forced response vs internal variability

Annual mean

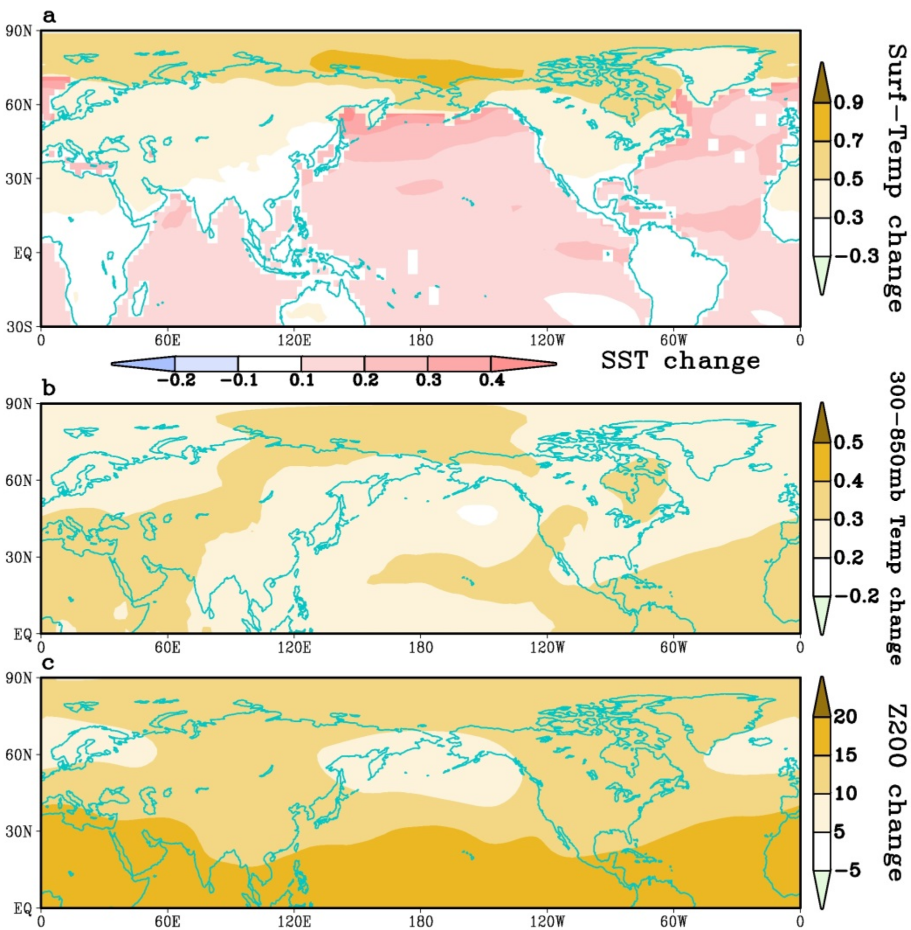
IPCC AR5 historical run
(ensemble mean of 40 model)

m/decade

Observation

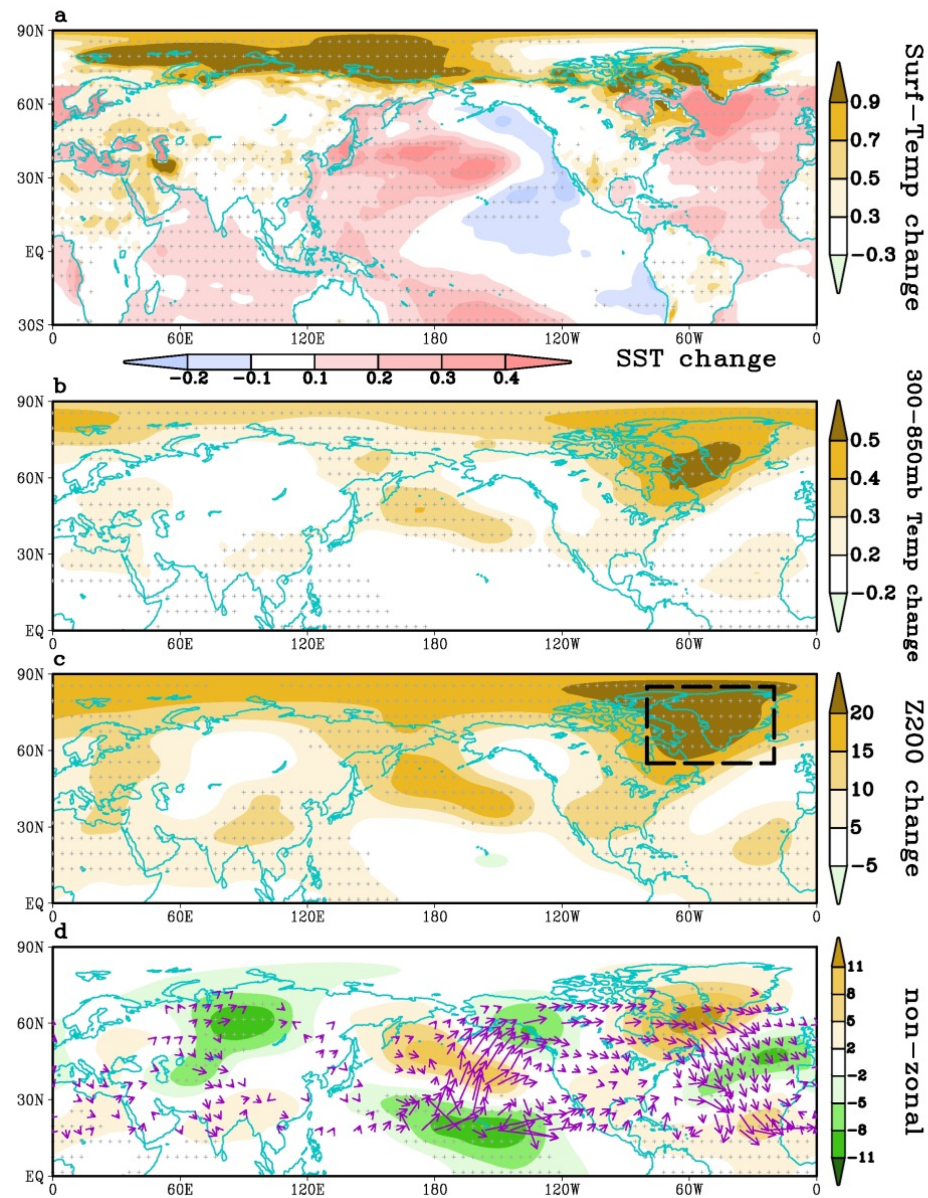


IPCC AR5 historical run (ensemble mean of 40 model)

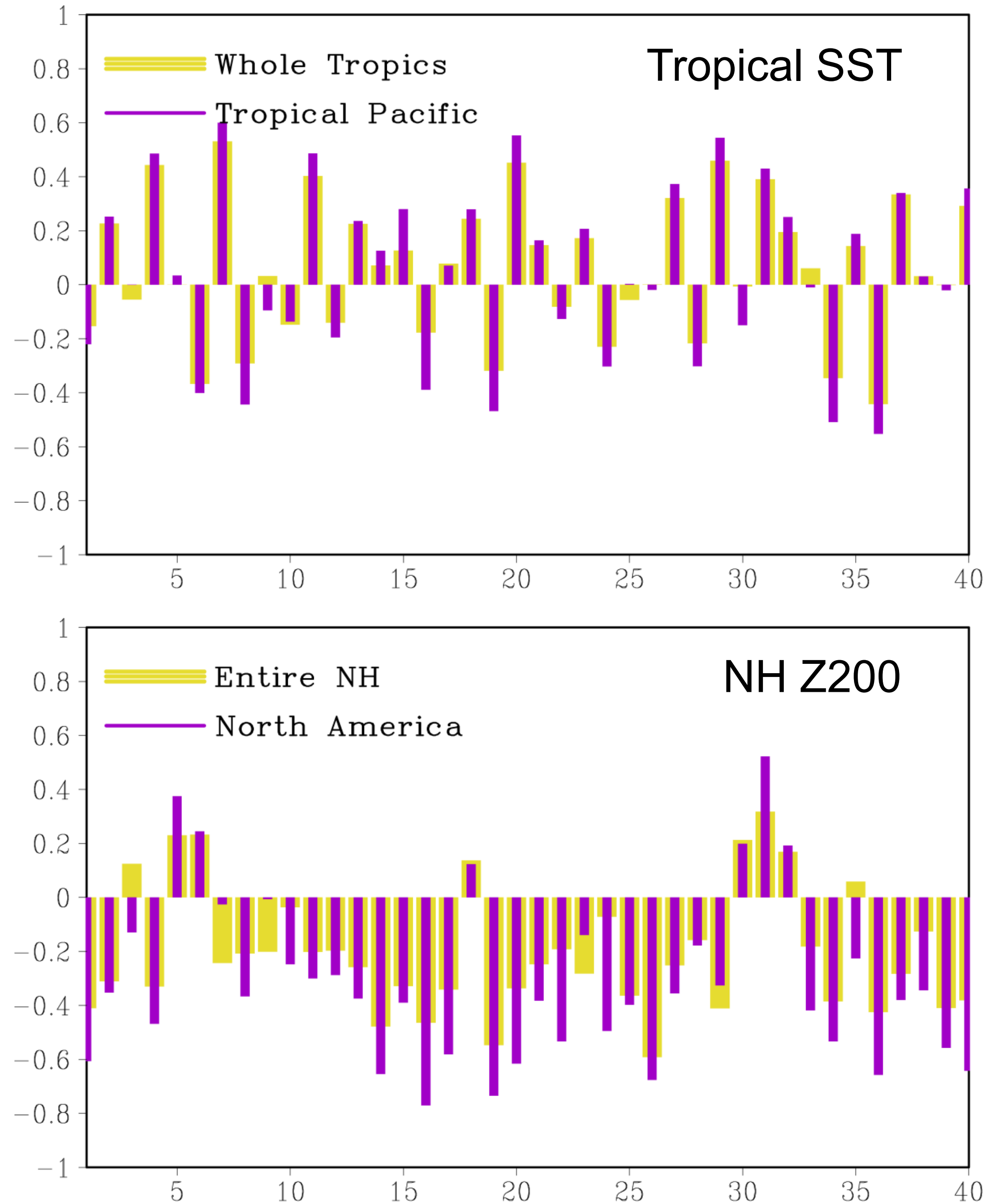


Anthropogenic forcing can explain another 50% of the Arctic warming

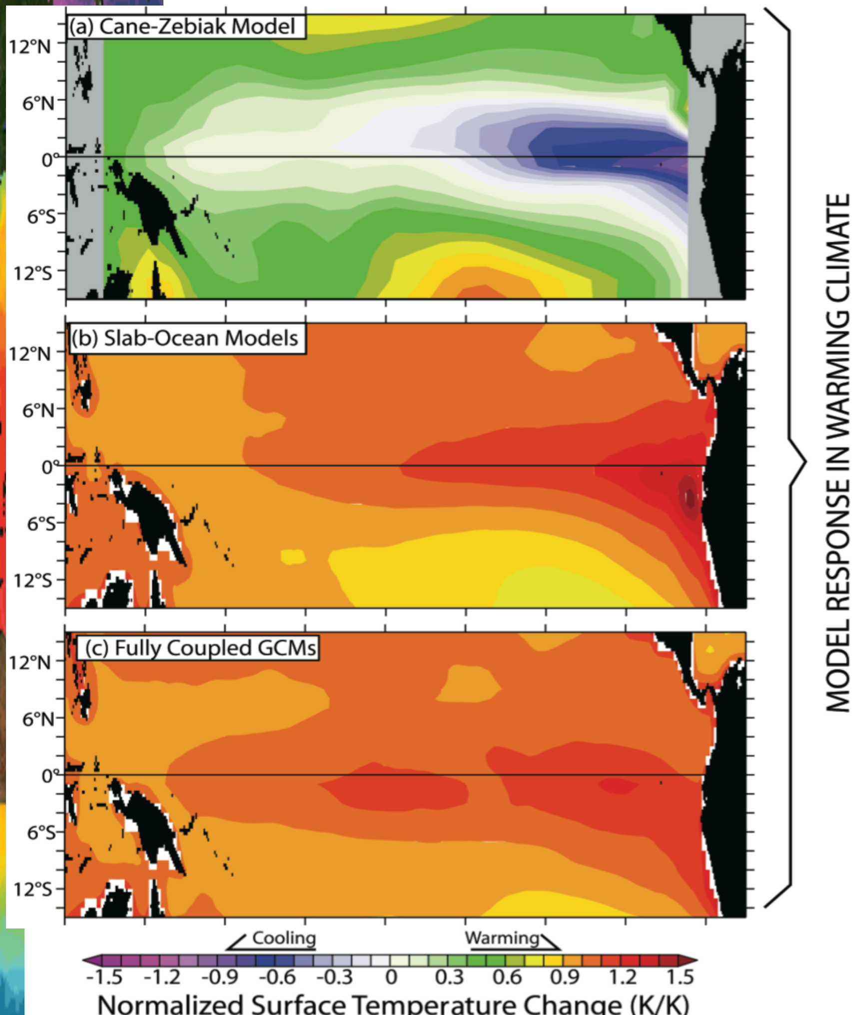
Observation

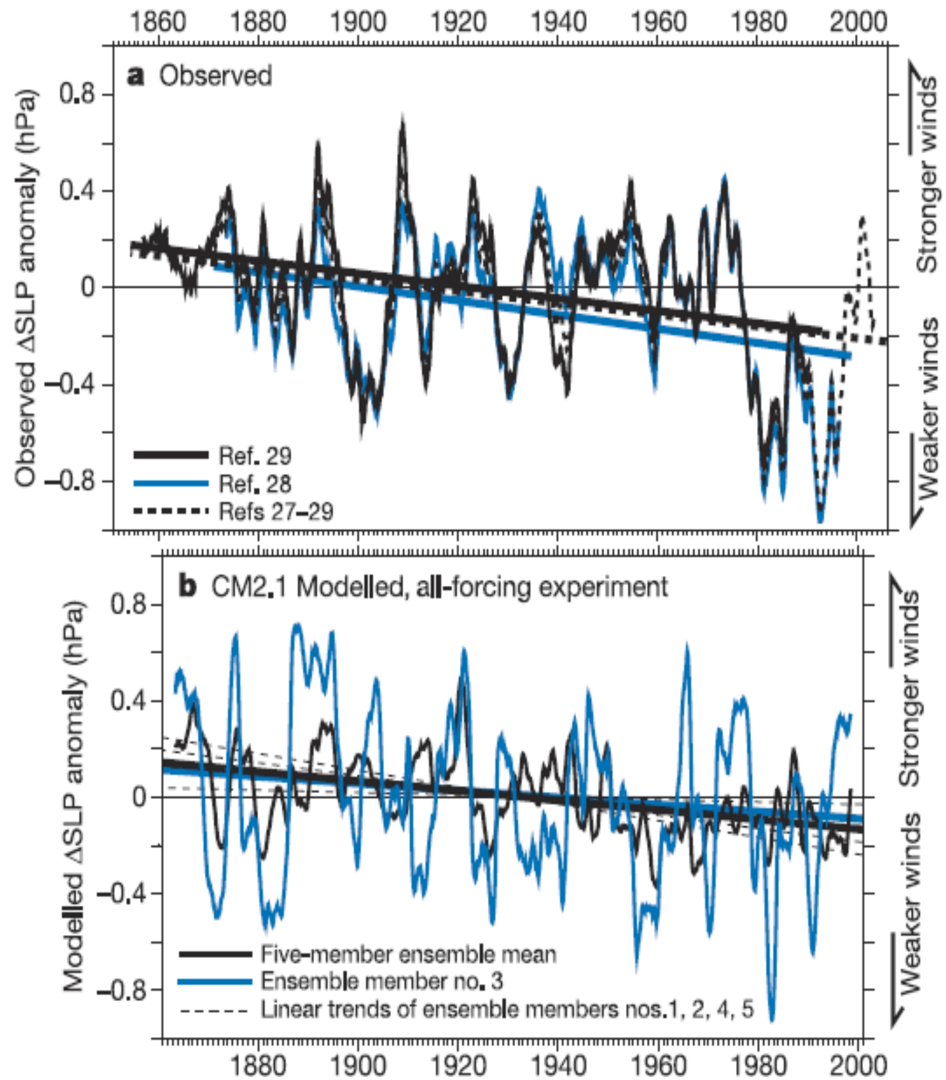


Is there a best-fit model in CMIP5?



The tropical response to warming climate

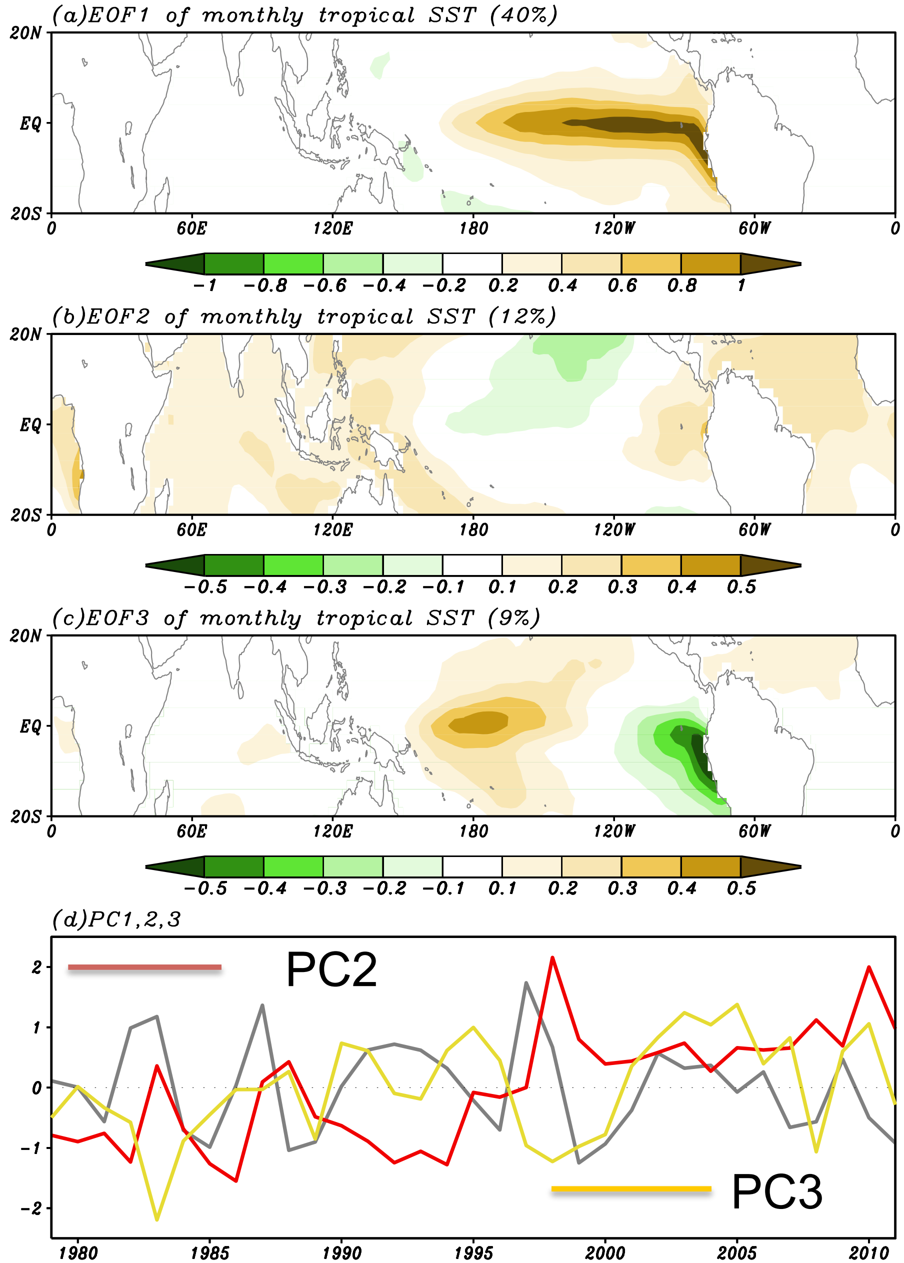




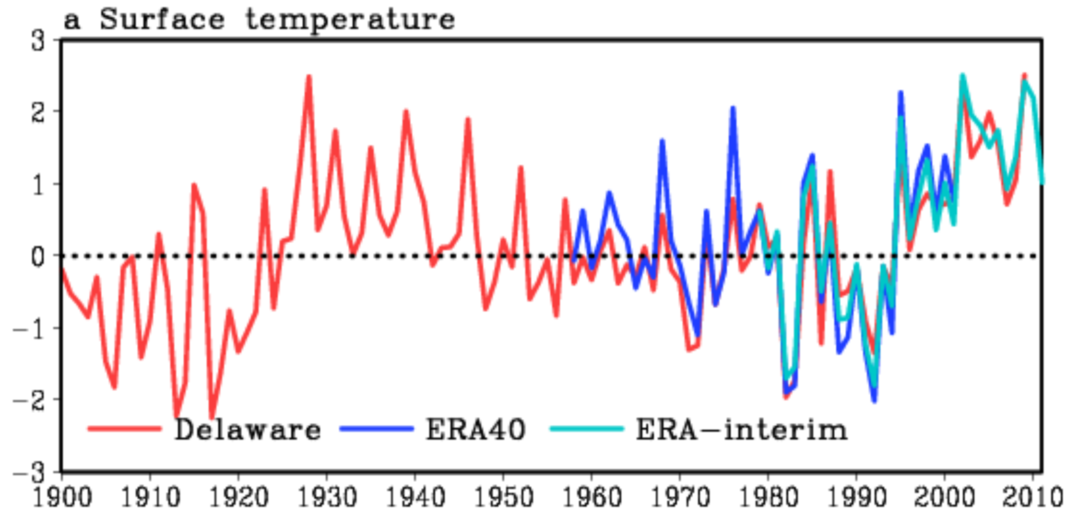
Vecchi et al. 2008

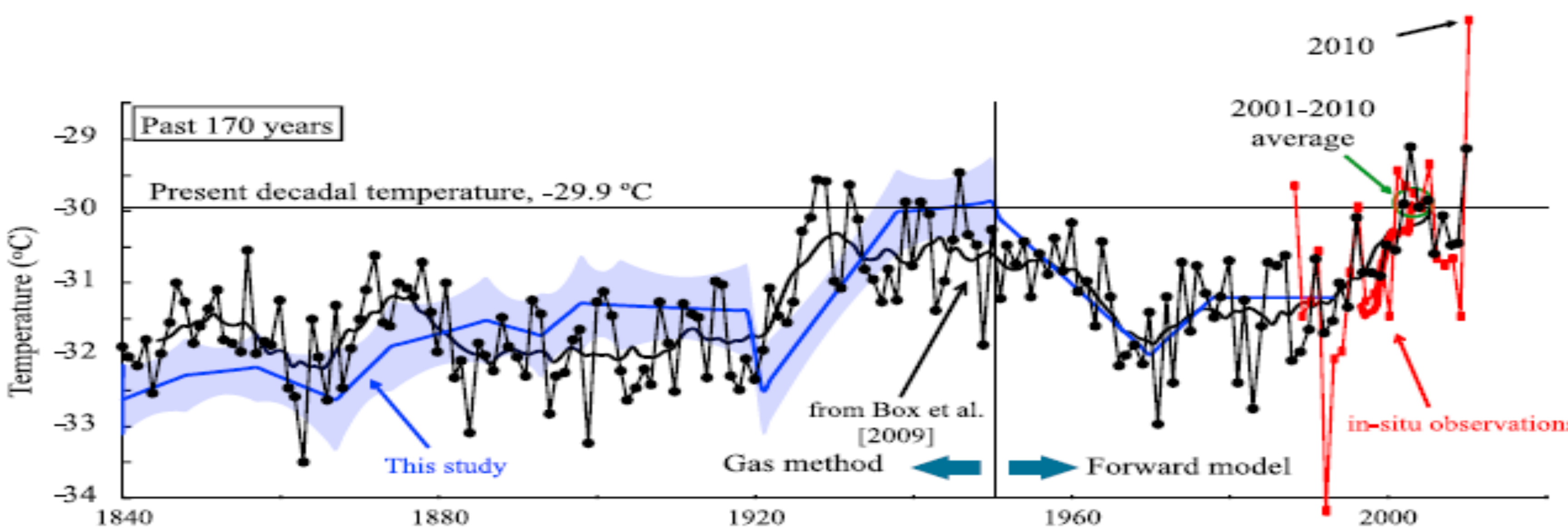
Vecchi et al 2006

EOFs of Monthly SST in the tropics 1979-2011



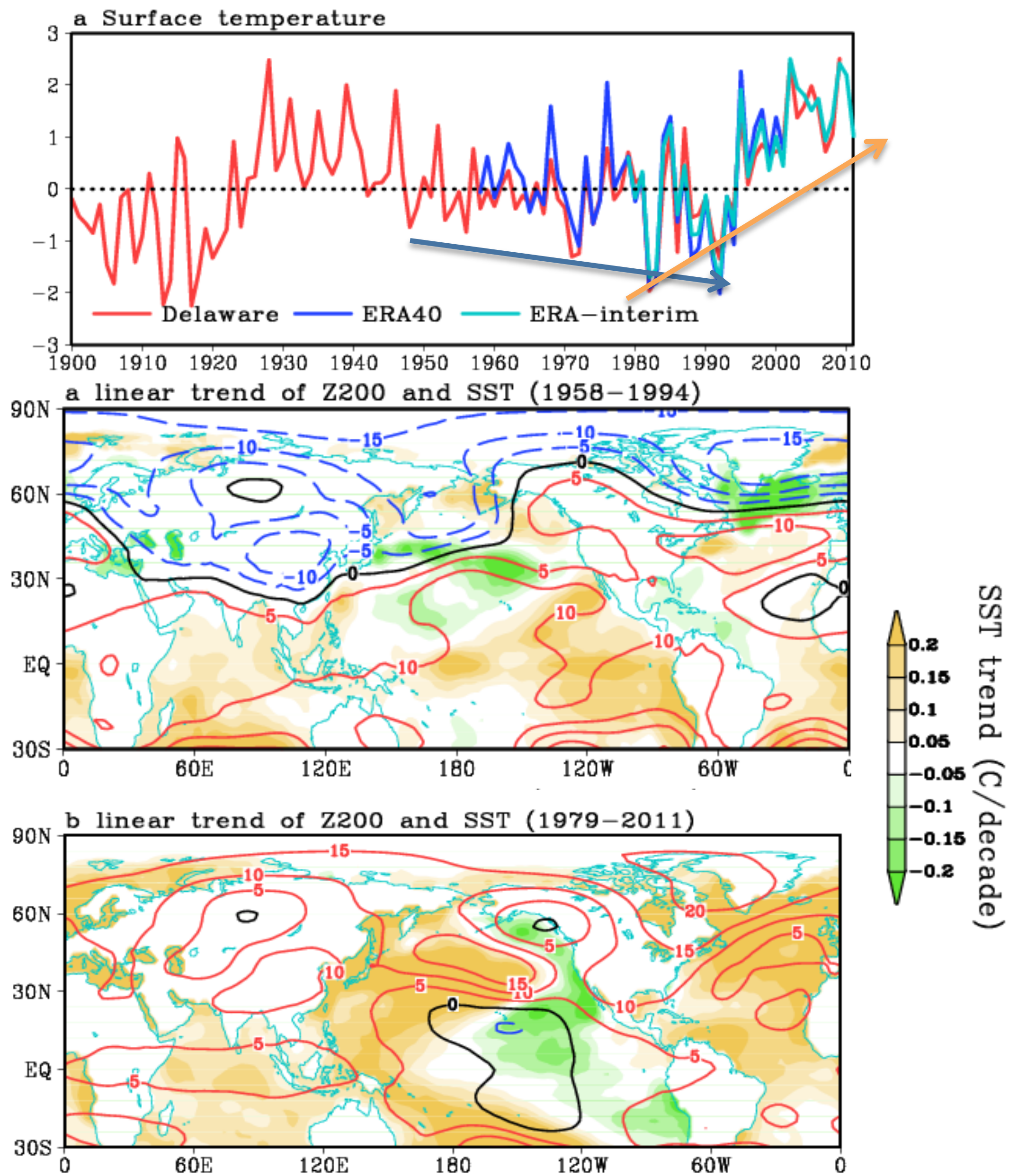
Multi-decadal variability of surface temperature in Greenland





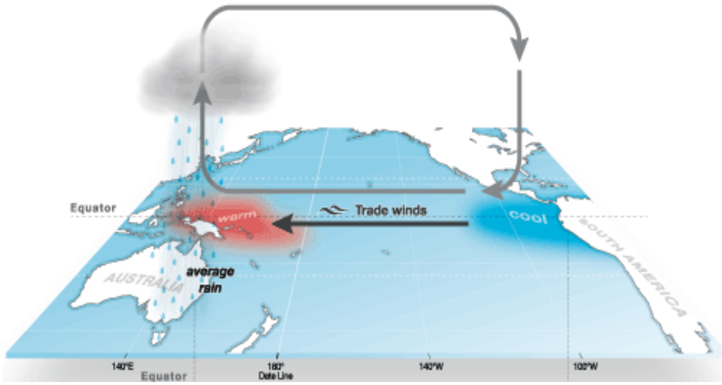
Kobashi et al 2011

Interdecadal SST variability in the tropical Pacific
A main driver of global climate

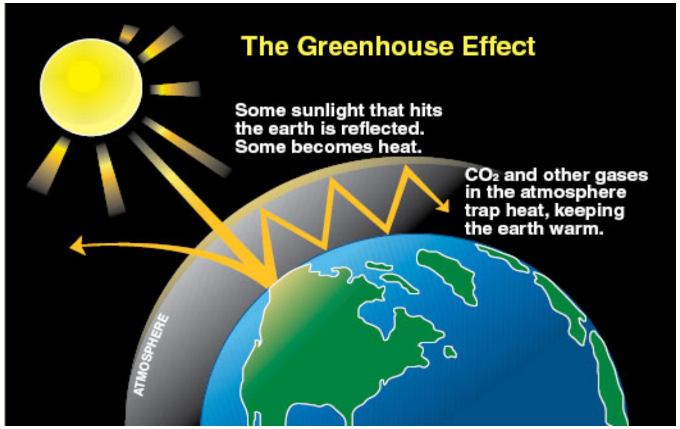


Annual mean

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



?



Take-home message

We still have time to save the Arctic, if we work fast!!!

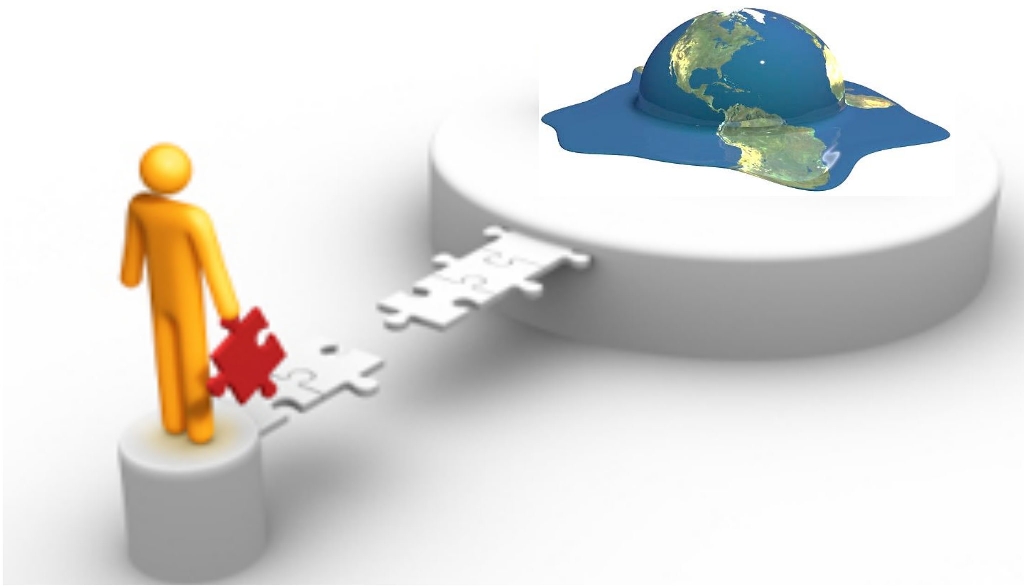
Recent climate change in the Arctic and Antarctic is related to a low-frequency SST variability in the tropical Pacific.

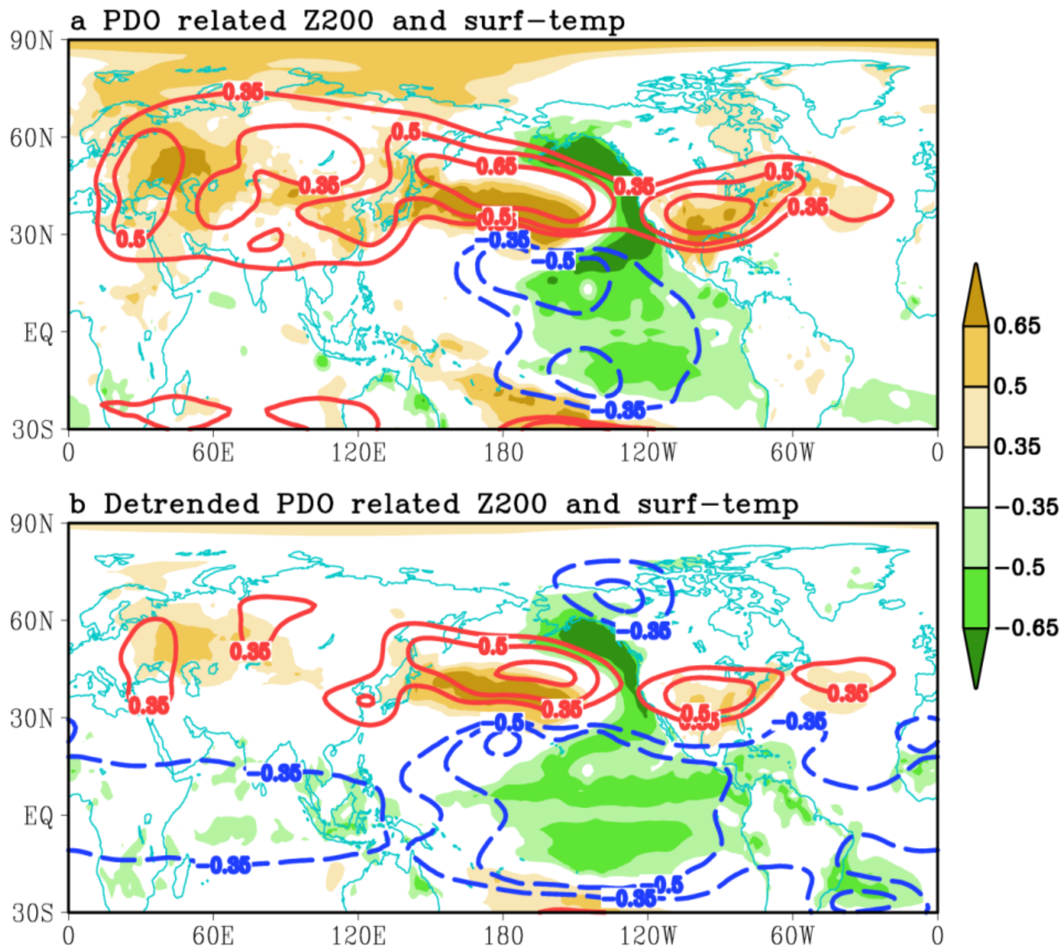
To predict the future change of SH+NH circulation and related change in the Arctic and Antarctic, we need to better understand and predict the low-frequency SST variability in the tropics and its polar impact.

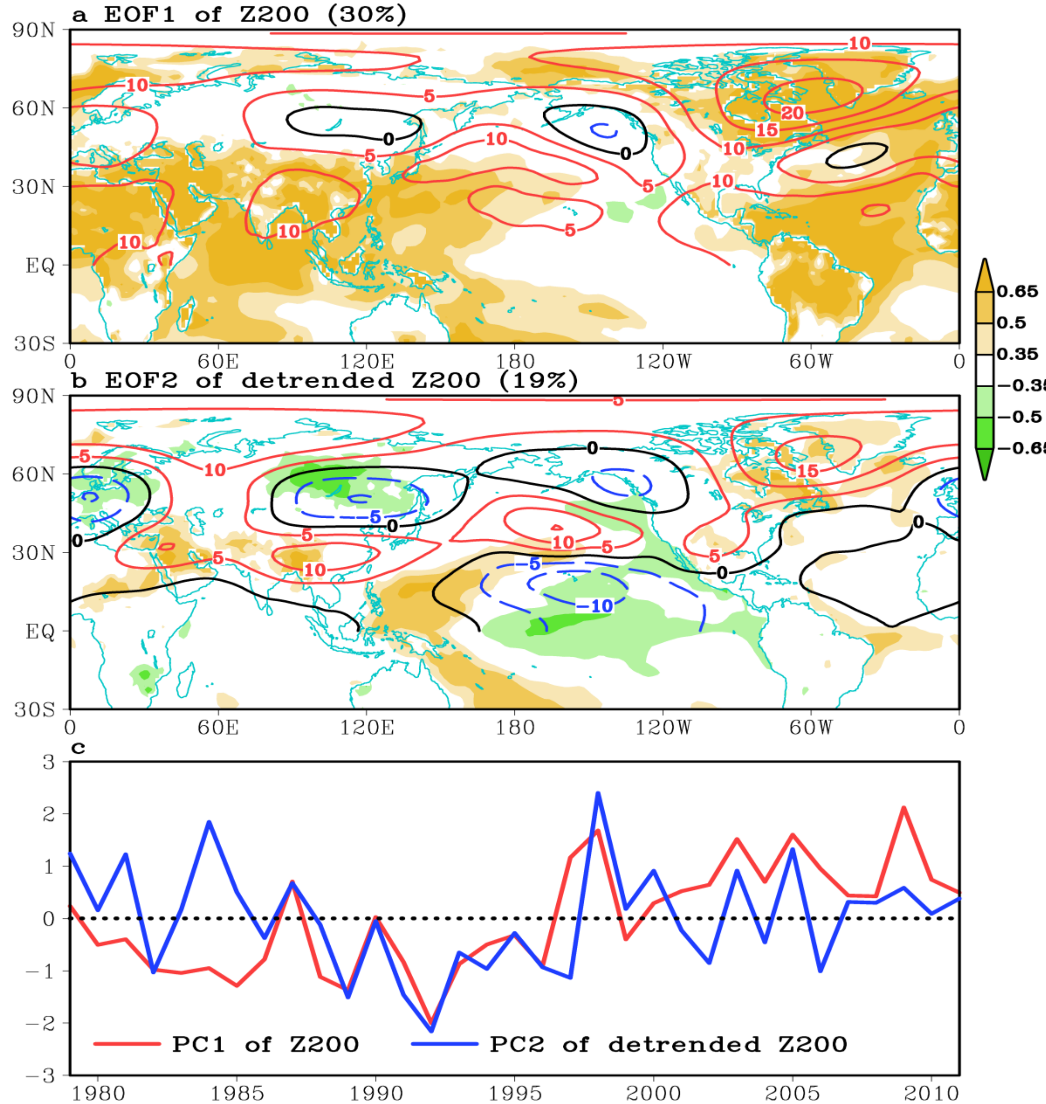
Future projections of how tropical Pacific low-frequency SST variability will change in response to both continued anthropogenic radiative forcing and natural interdecadal variability represents a significant source of uncertainty of projections of the polar climate.

Thank you very much!

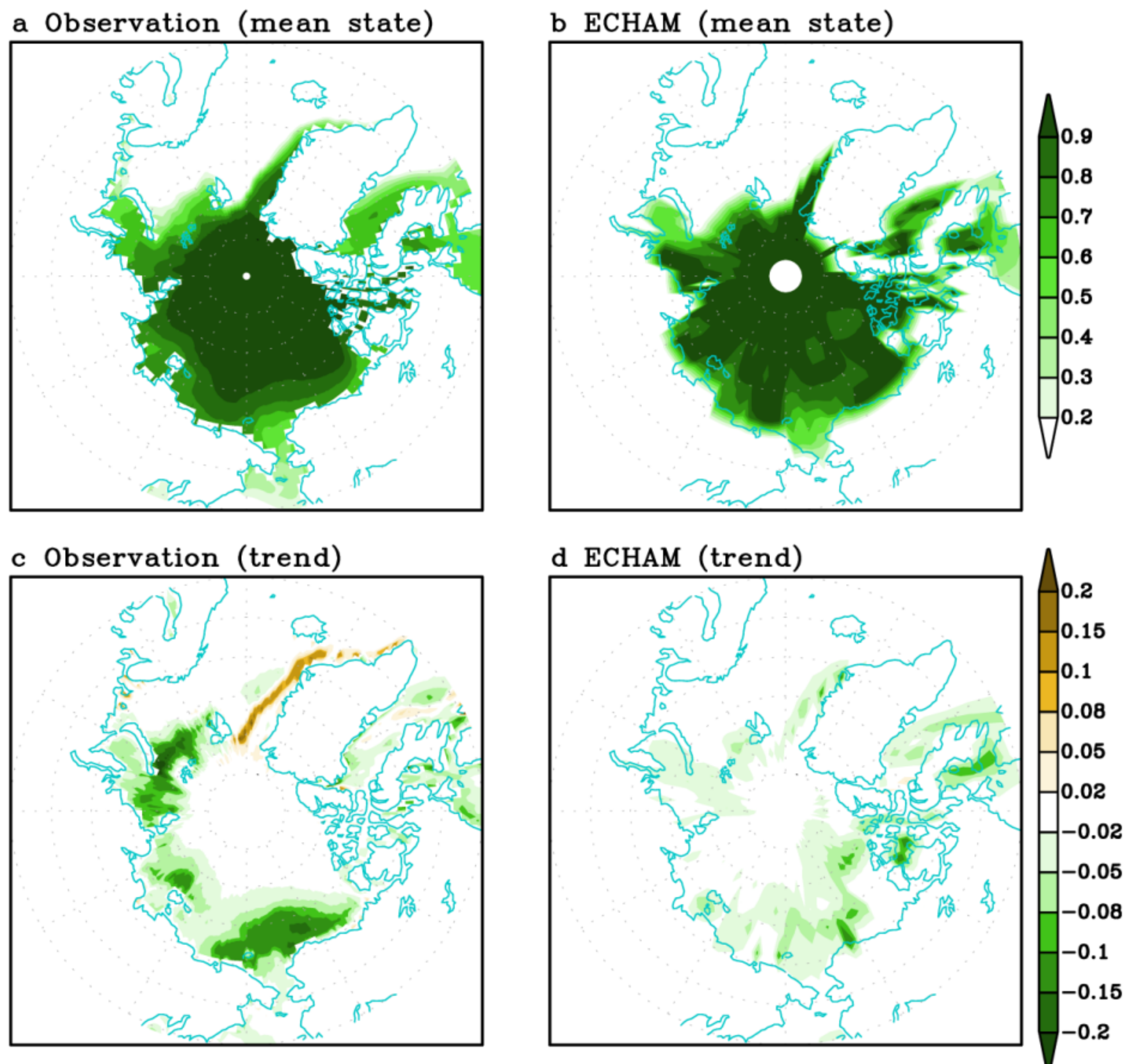
Goal: How will the polar circulation change in the next two-three decades and how will it impact the Arctic and Antarctic ocean-air-ice-biosphere climate system.




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

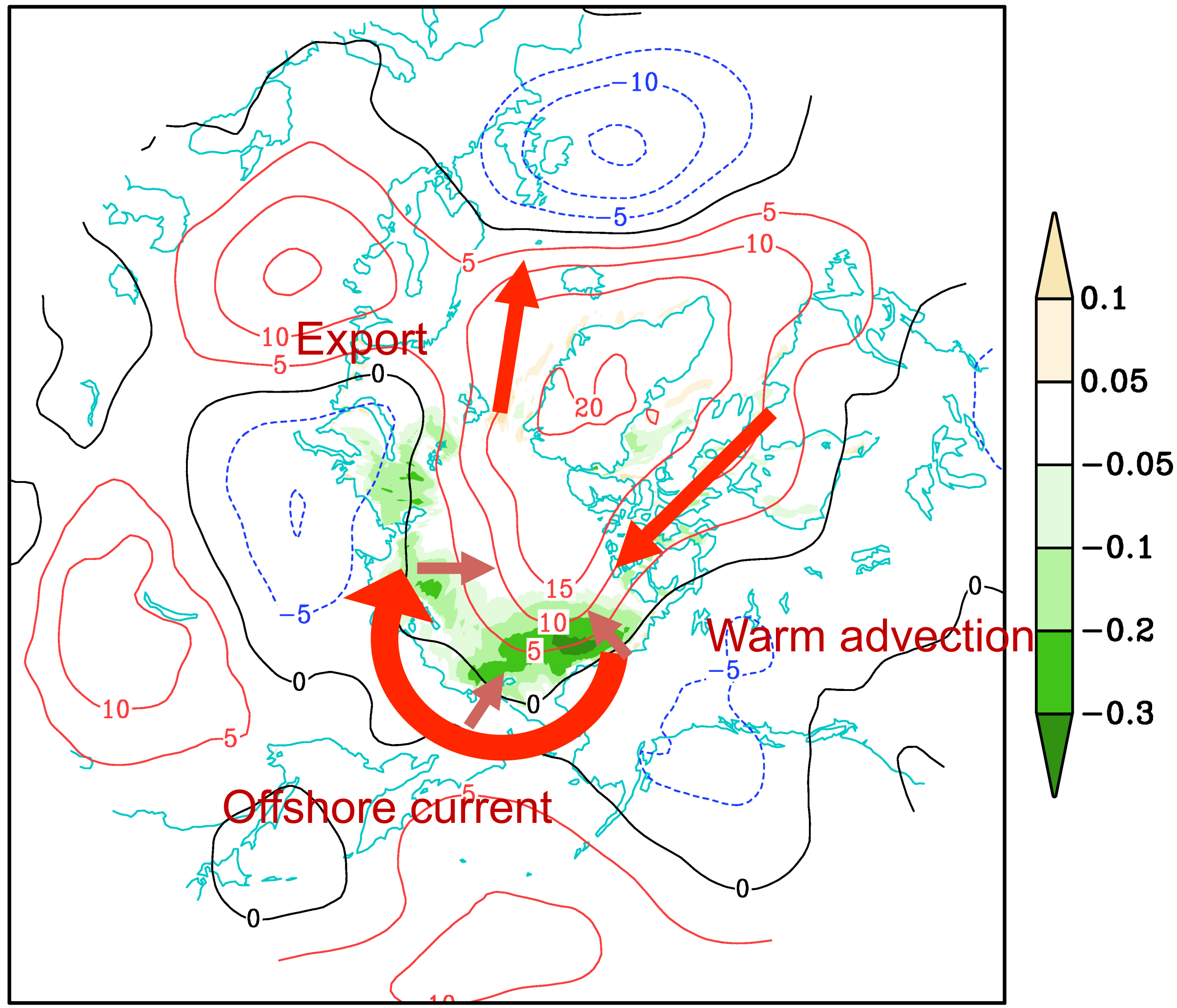

a EOF1 of Z200 (30%)
b EOF2 of detrended Z200 (19%)
c
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0.65
0.5
0.35
−0.35
−0.5
−0.65
PC1 of Z200
PC2 of detrended Z200
1980
1985
1990
1995
2000
2005
2010

Sea ice response in the model

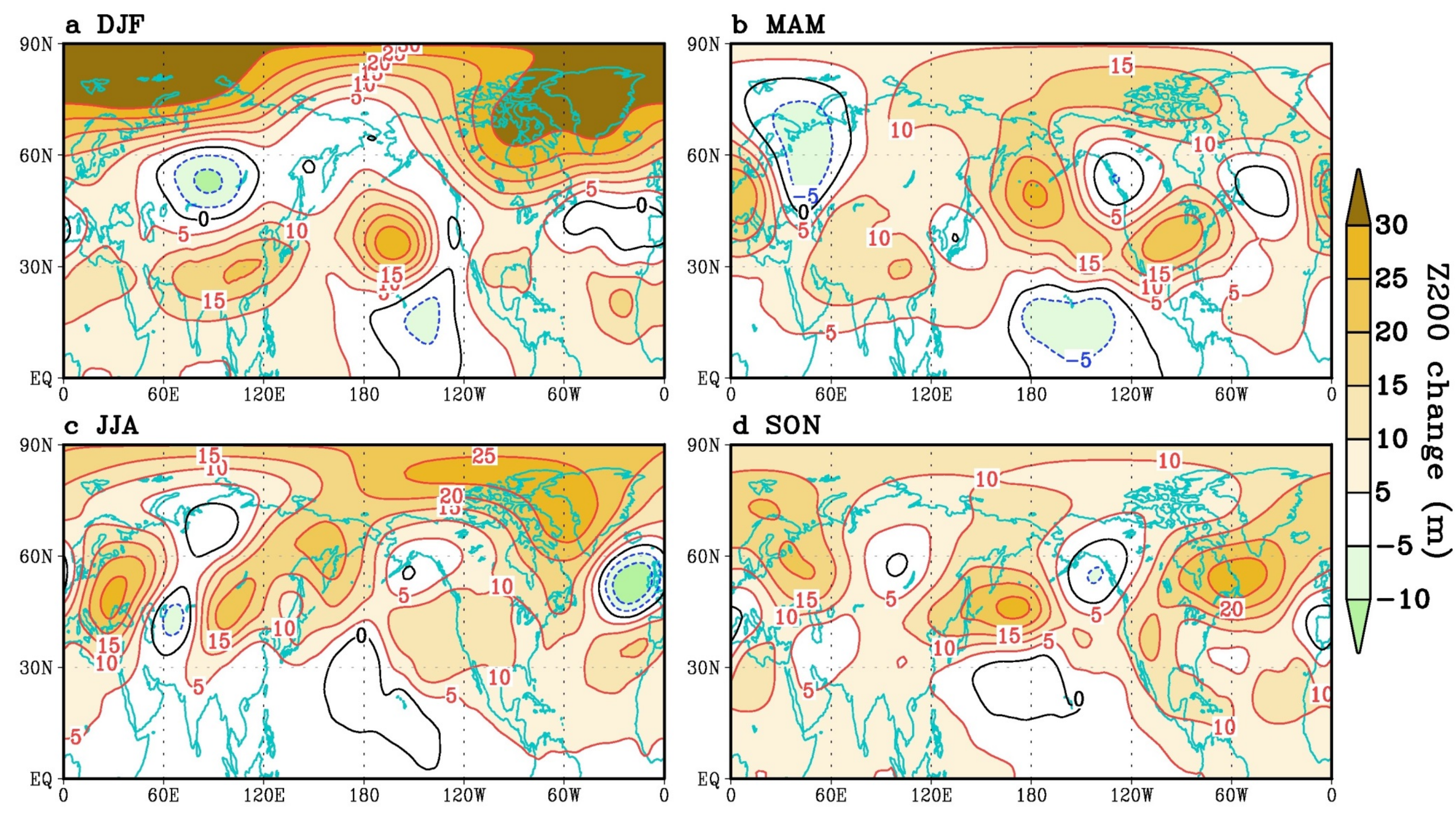


Circulation change may reduce the Arctic sea ice

JJA Z850 and JJAS sea ice trend



Annual mean Z200 trend (1979-2012)



Impact of remote SST on the Arctic warming

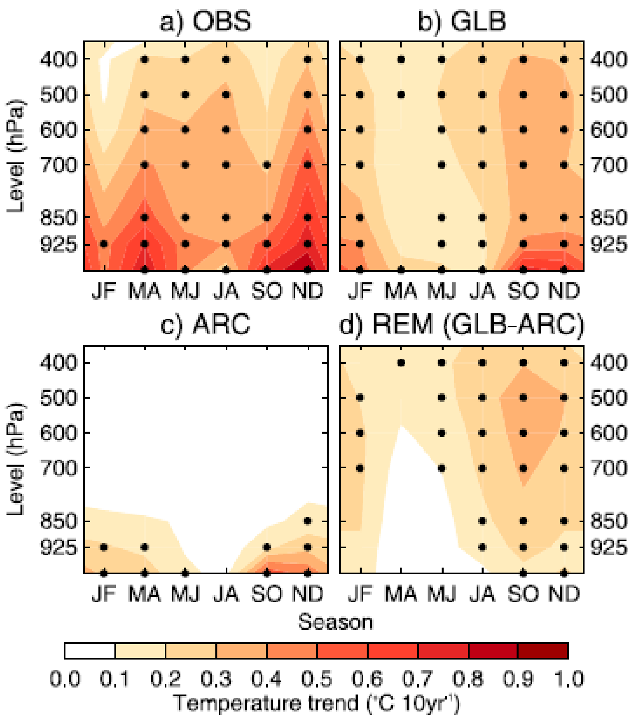


Figure 3. (a) Vertical and seasonal structure of the reanalysis ensemble-mean (OBS) Arctic-mean temperature trends (1979–2008). (b–d) As in Figure 3a, but for the model ensemble-mean trends in the GLB and ARC experiments, and their difference (REM), respectively. Black dots show trends that are statistically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

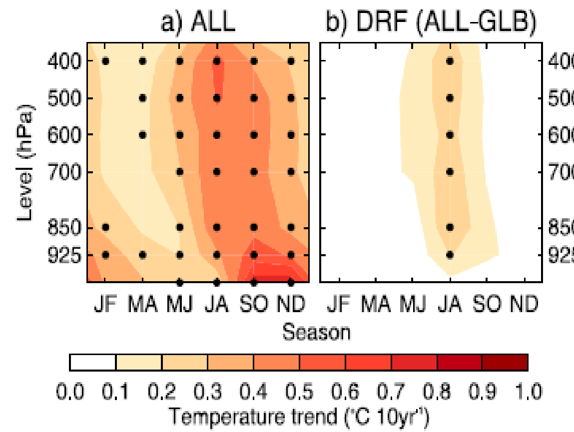
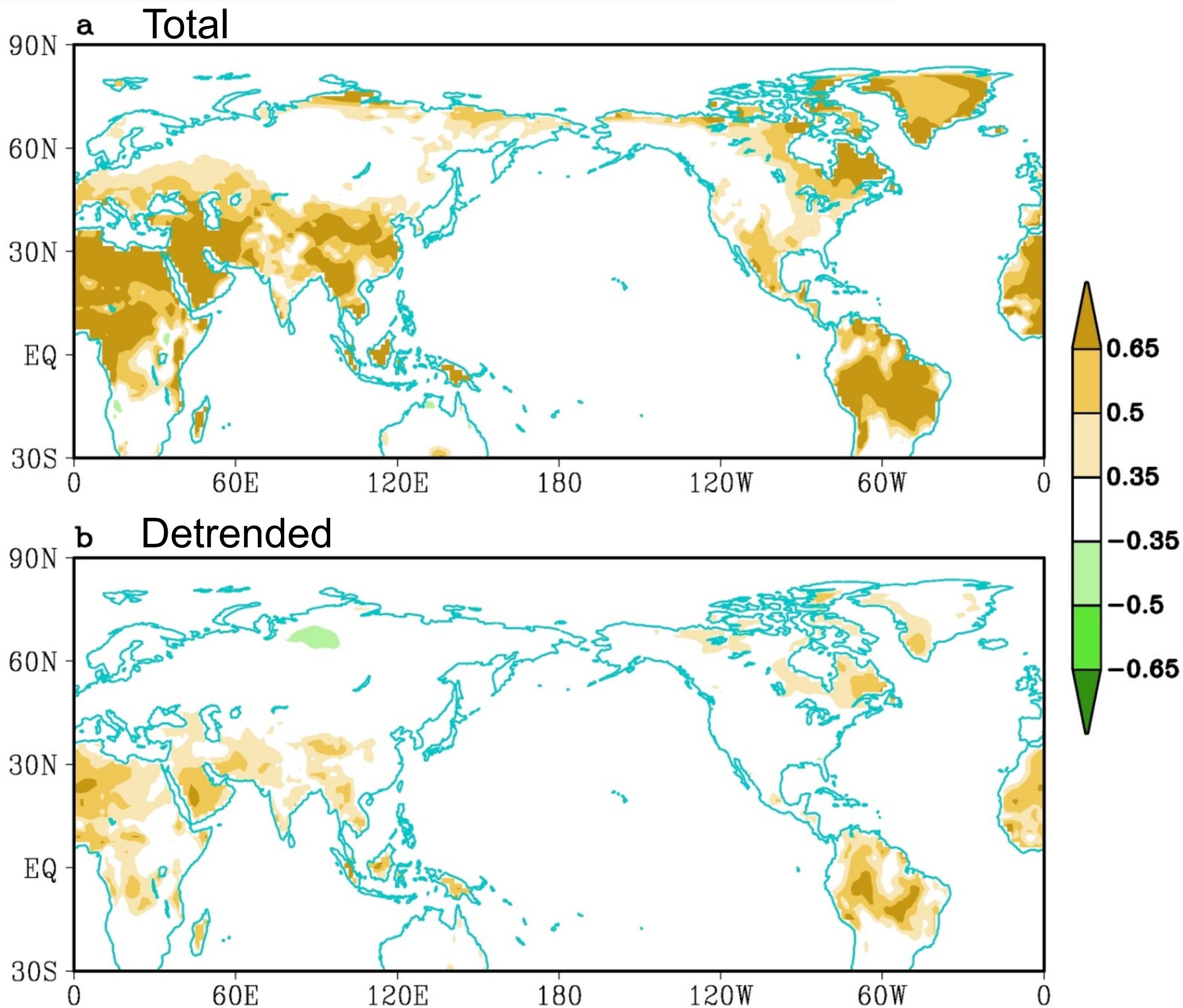


Figure 4. (a) Vertical and seasonal structure of the ensemble-mean Arctic-mean temperature trends (1979–2008) in the ALL experiment. (b) As in Figure 4a, but for difference between the ALL and GLB experiments. Black dots show trends that are statistically significant at the 95% level ($p < 0.05$).

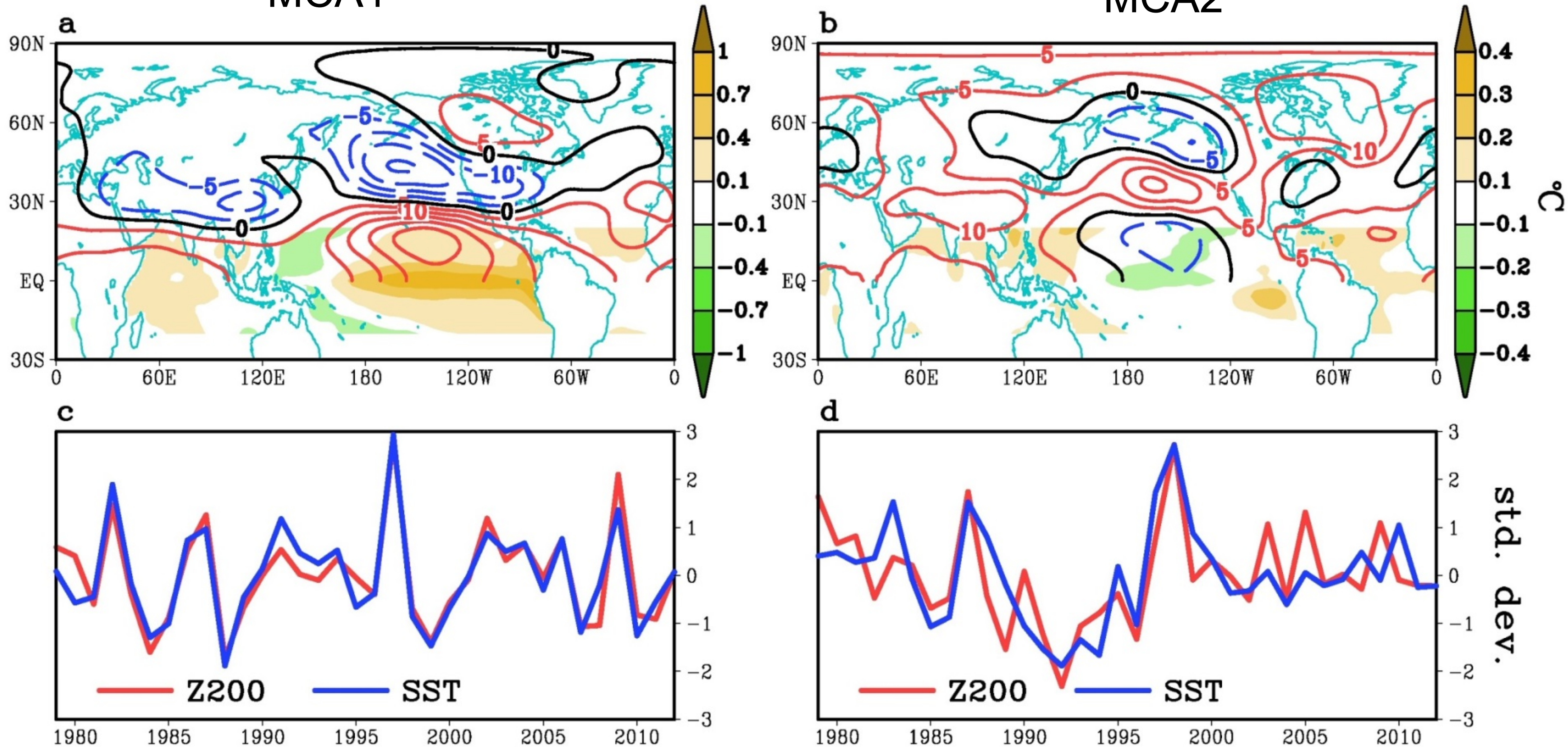
Screen et al 2012

MCA2 SST mode related surface temperature



MCA modes for detrended Z200 and tropical SST

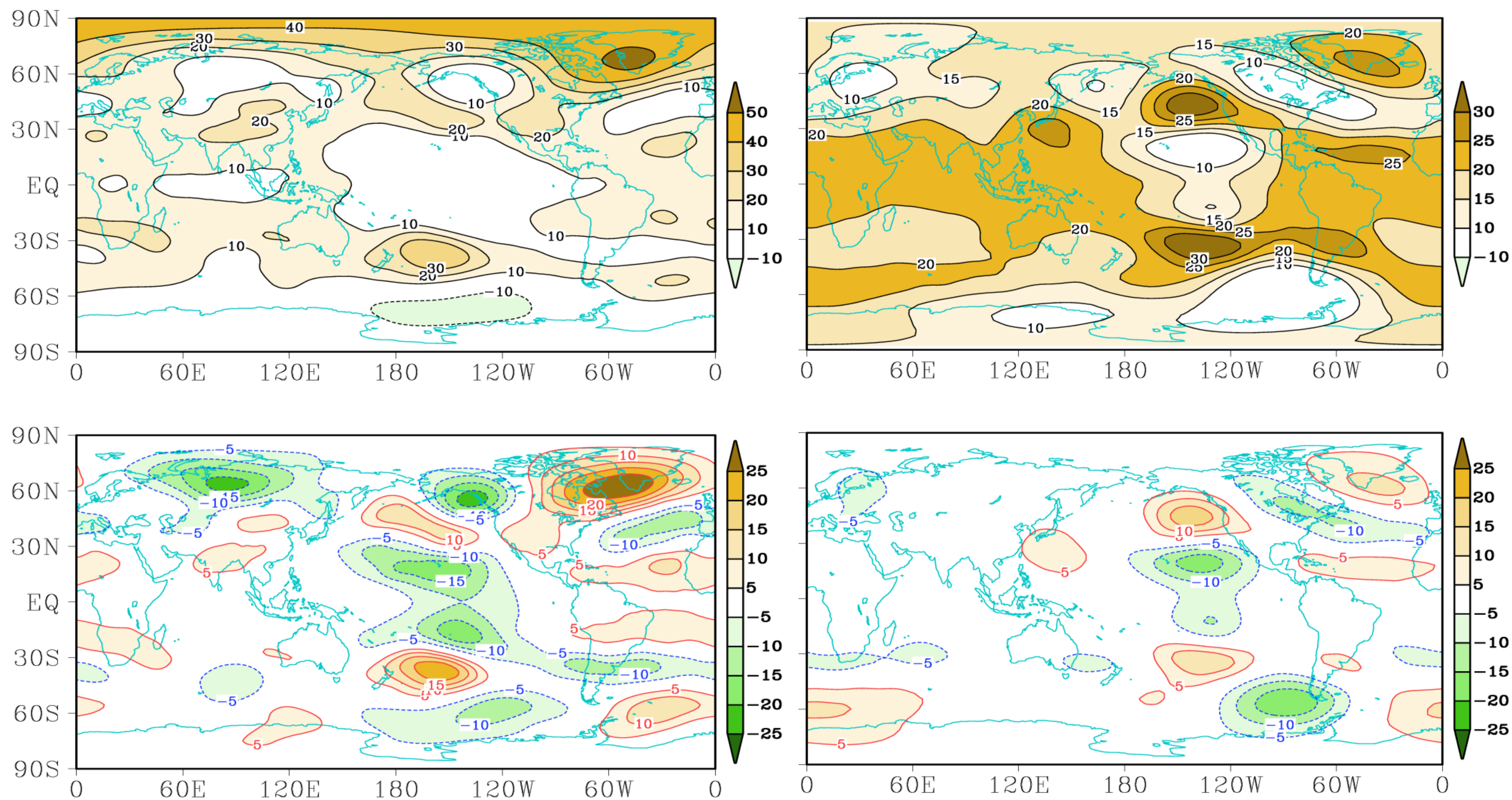
MCA1 MCA2



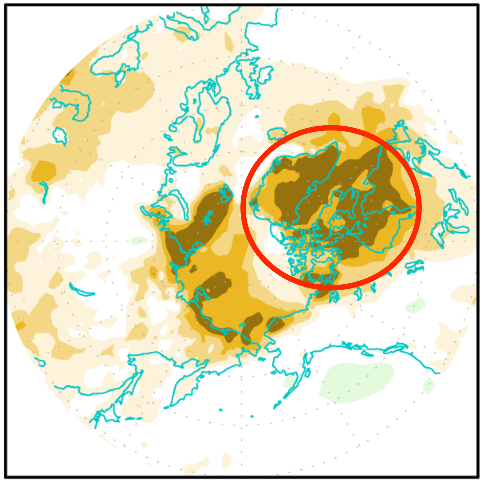
Annual mean Z200 change (1996-2012 minus 1979-1995)

Observation

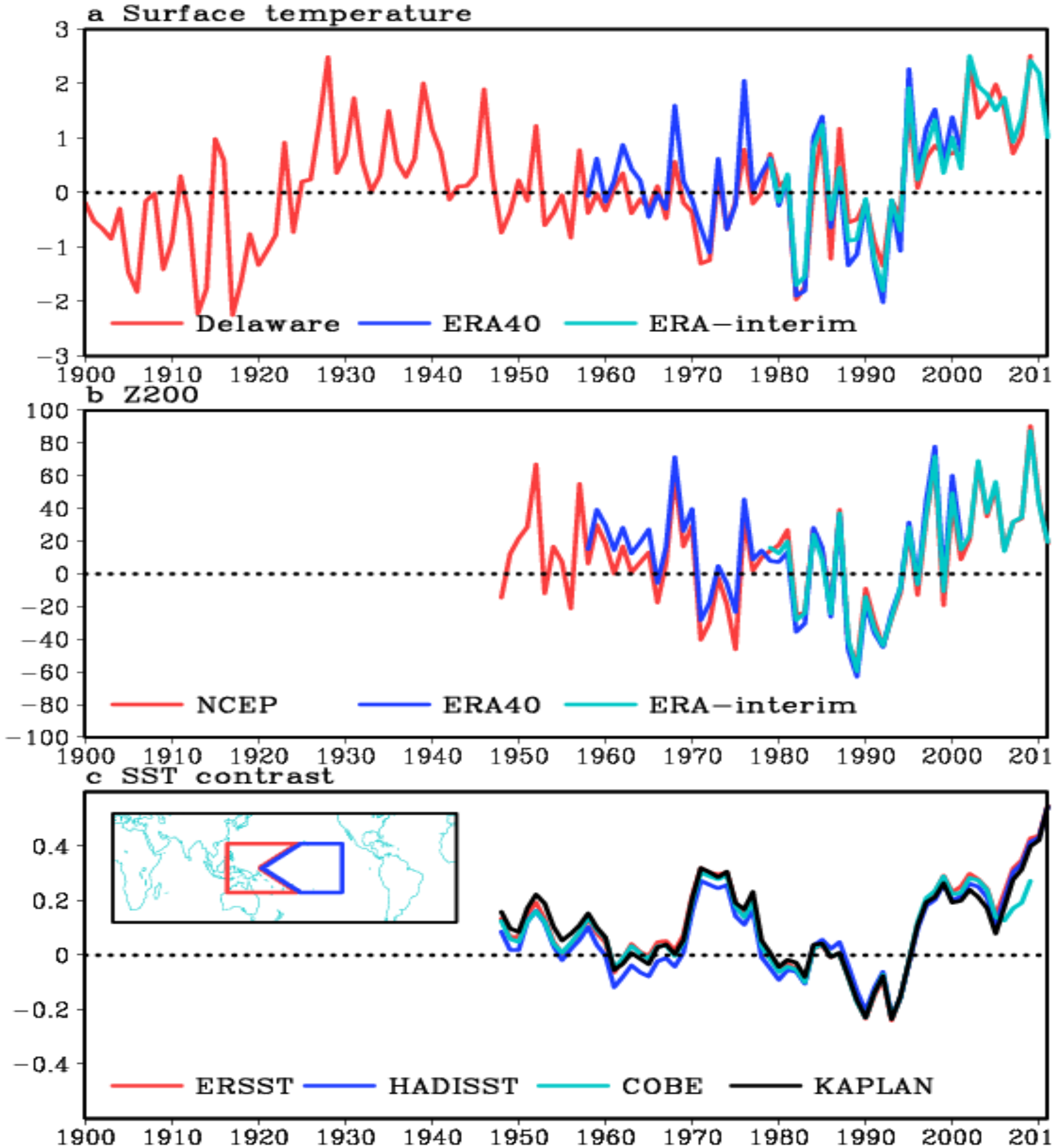
Simulation

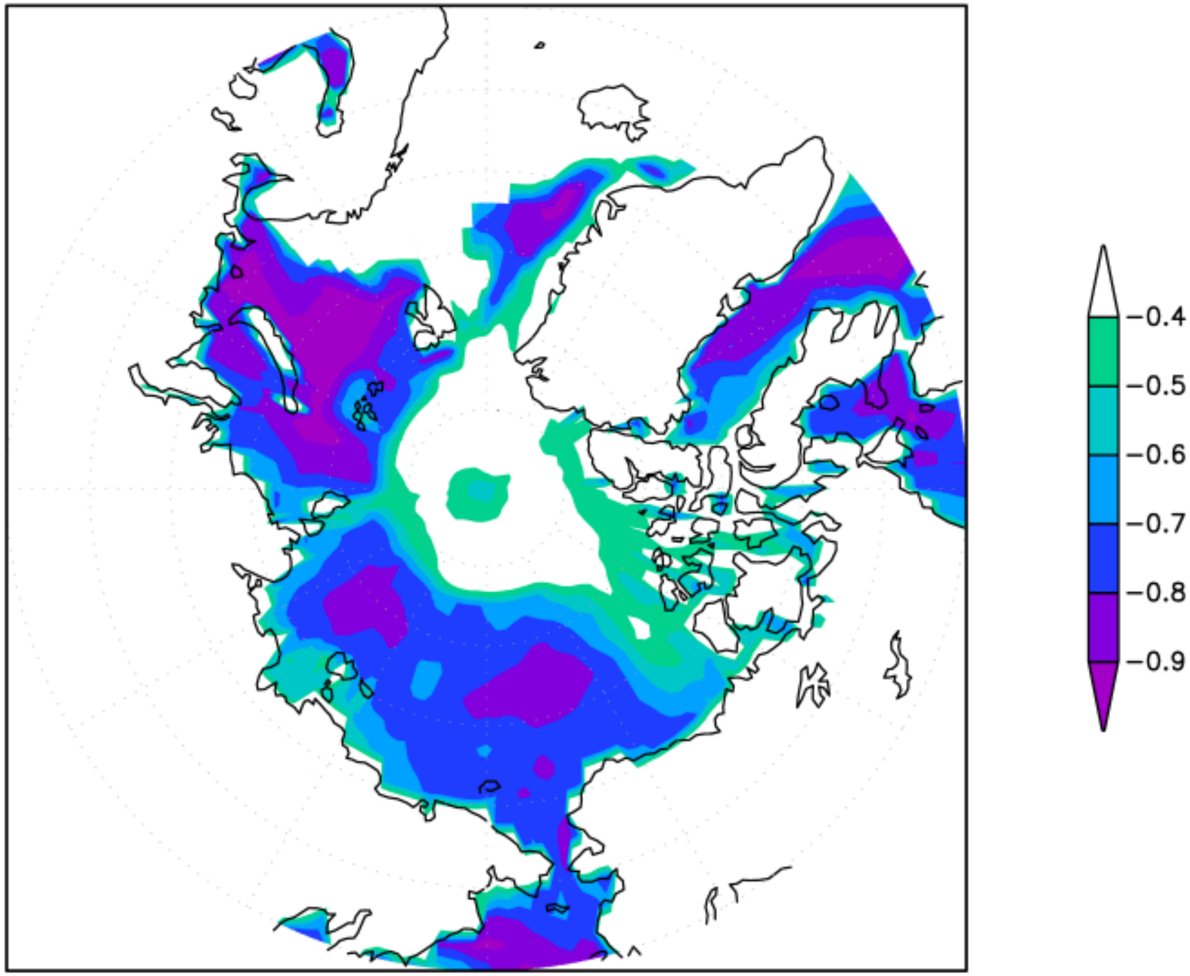


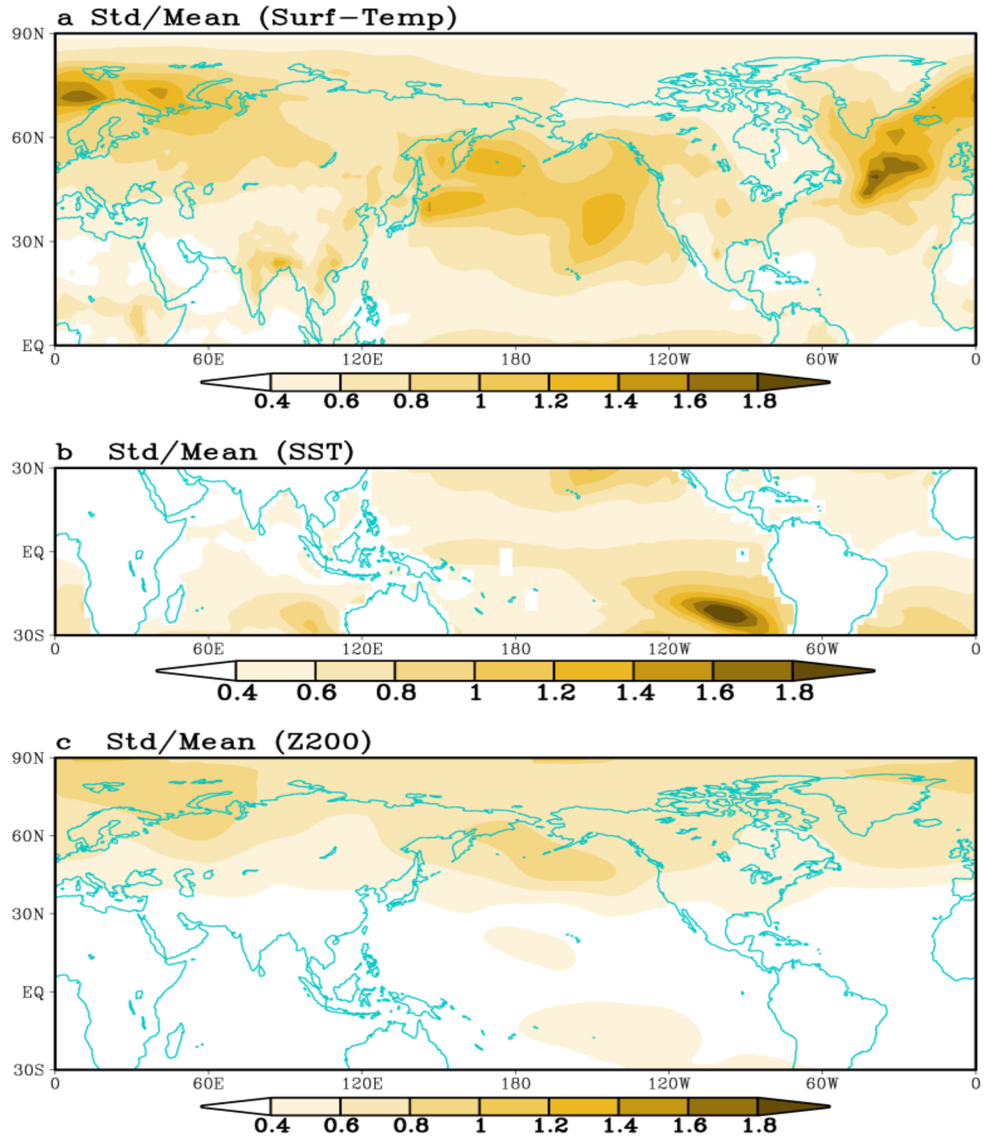
a ERA−interim

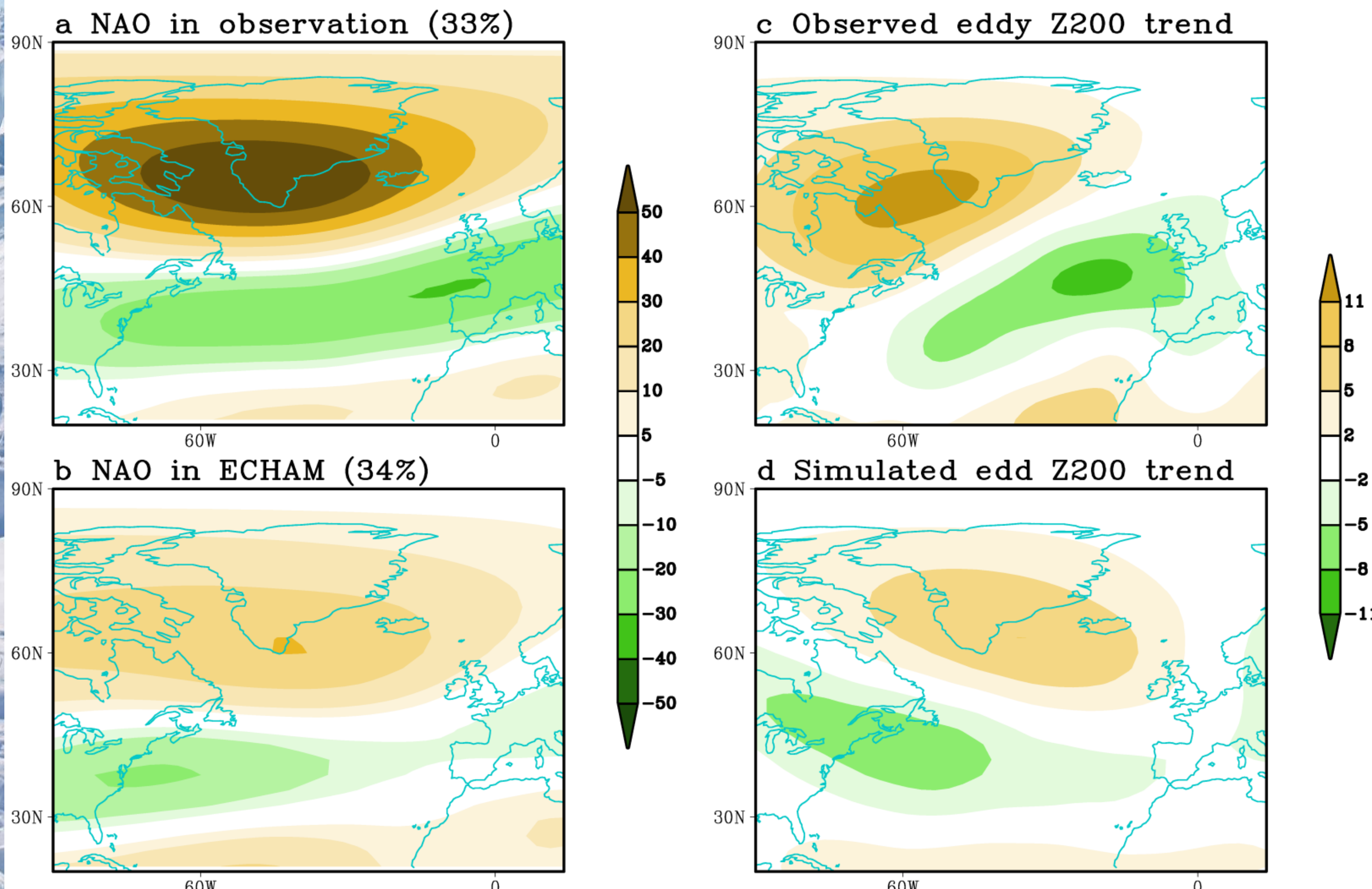


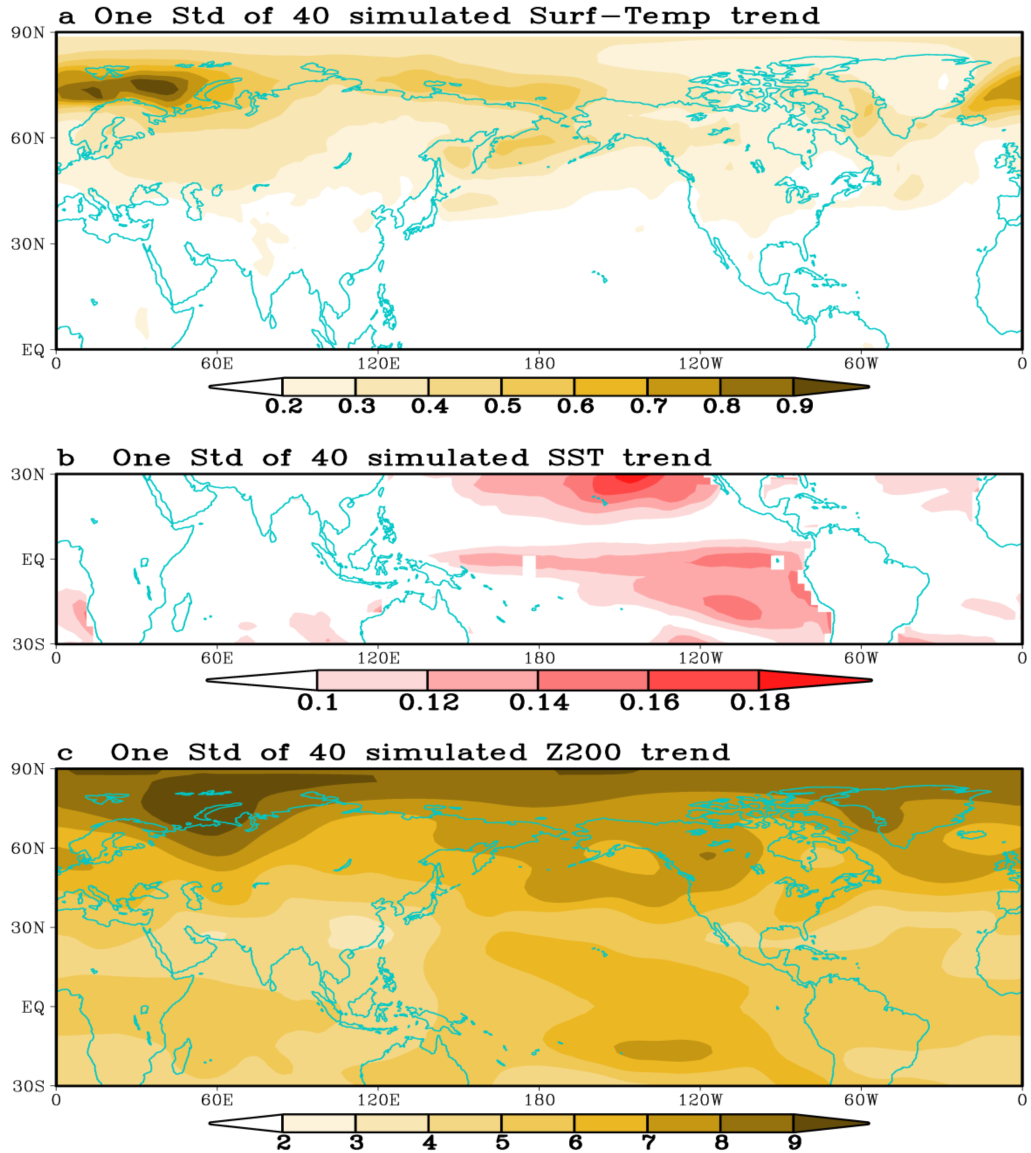
Annual mean

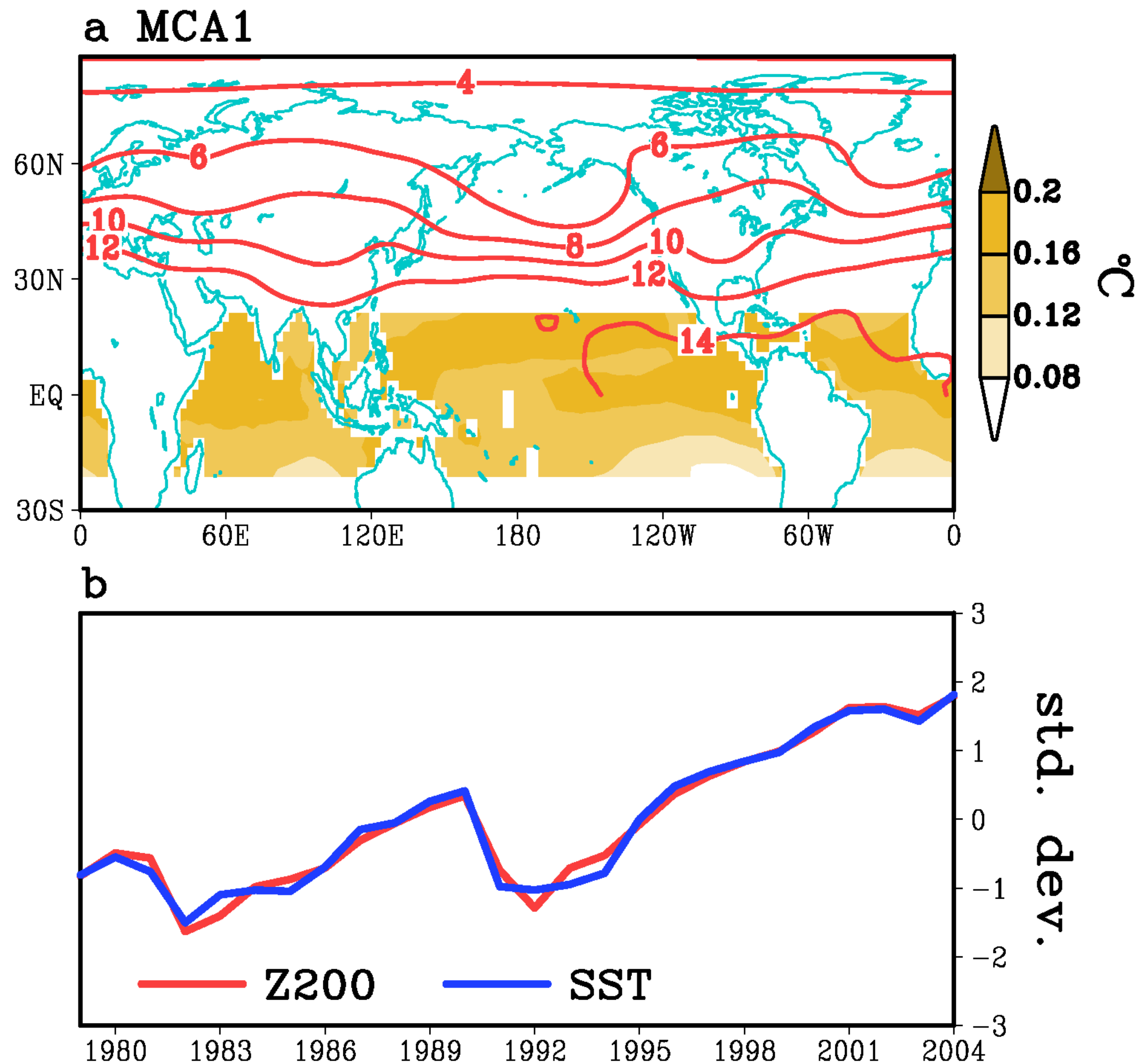


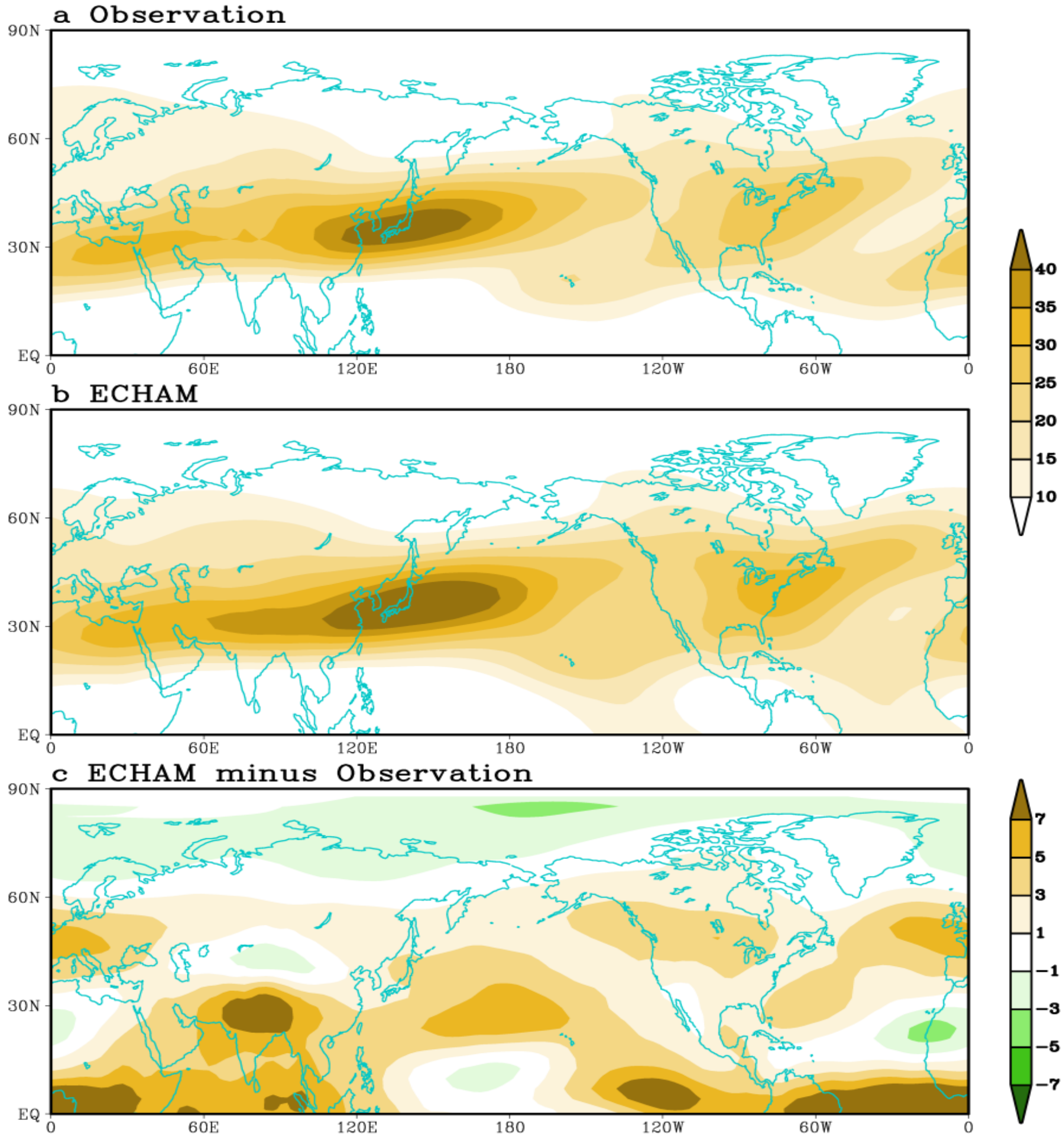

-0.4
-0.5
-0.6
-0.7
-0.8
-0.9


a Std/Mean (Surf−Temp)
90N
60N
30N
EQ
0
60E
120E
180
120W
60W
0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
b Std/Mean (SST)
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
c Std/Mean (Z200)
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8


a NAO in observation (33%)
b NAO in ECHAM (34%)
c Observed eddy Z200 trend
d Simulated edd Z200 trend
90N
60N
30N
60W
0
50
40
30
20
10
5
-5
-10
-20
-30
-40
-50
11
8
5
2
-2
-5
-8
-11


a One Std of 40 simulated Surf−Temp trend
90N
60N
30N
EQ
0
60E
120E
180
120W
60W
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
b One Std of 40 simulated SST trend
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.1
0.12
0.14
0.16
0.18
c One Std of 40 simulated Z200 trend
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
2
3
4
5
6
7
8
9

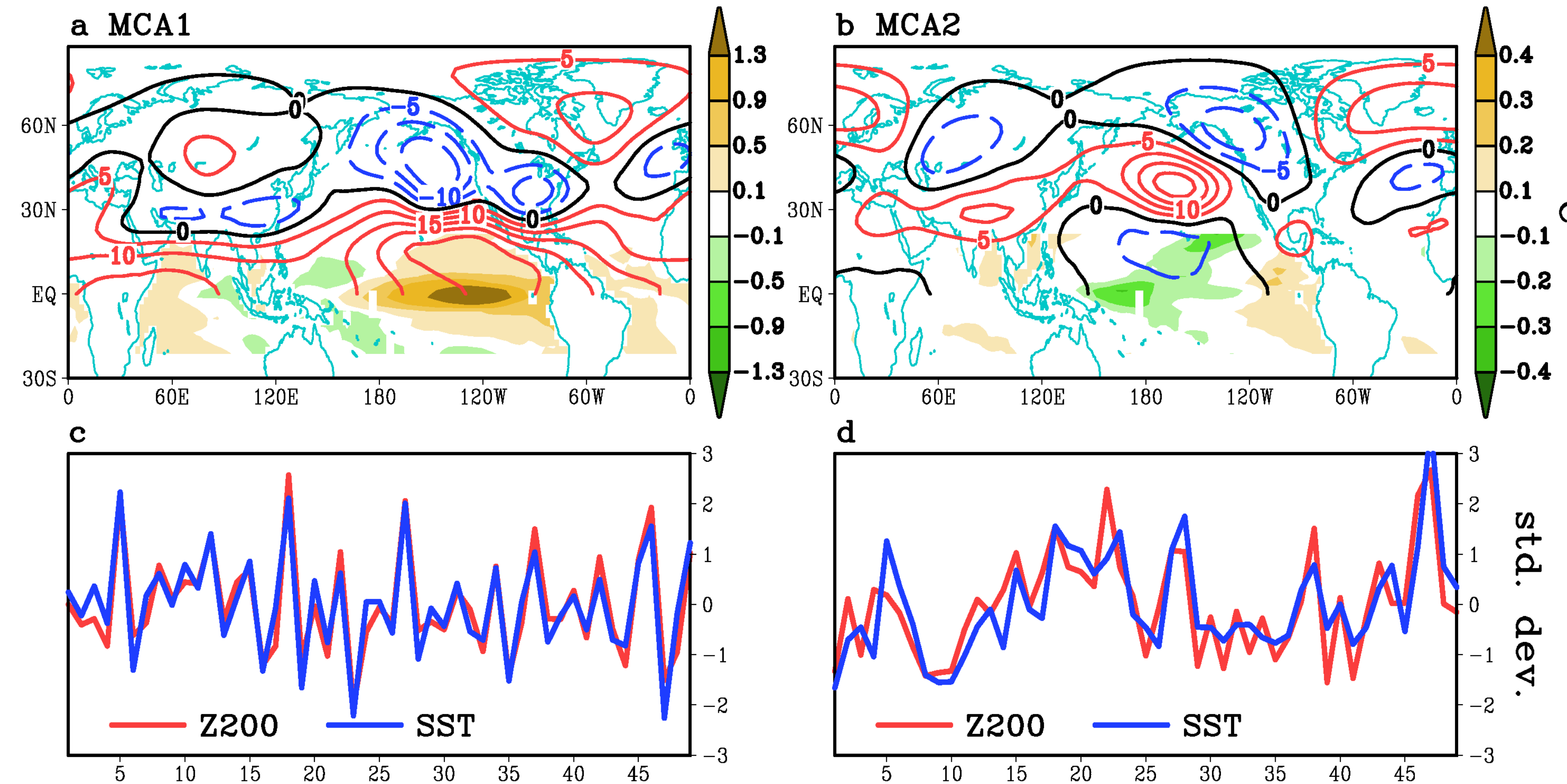

a MCA1
4
6
6
8
10
10
12
12
14
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.2
0.16
0.12
0.08
°C
b
Z200
SST
3
2
1
0
−1
−2
−3
std. dev.
1980
1983
1986
1989
1992
1995
1998
2001
2004


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

Future research: task 2

Evaluate IPCC model performance on the past 100 year climate variability in the tropics and the NH+SH extratropical region

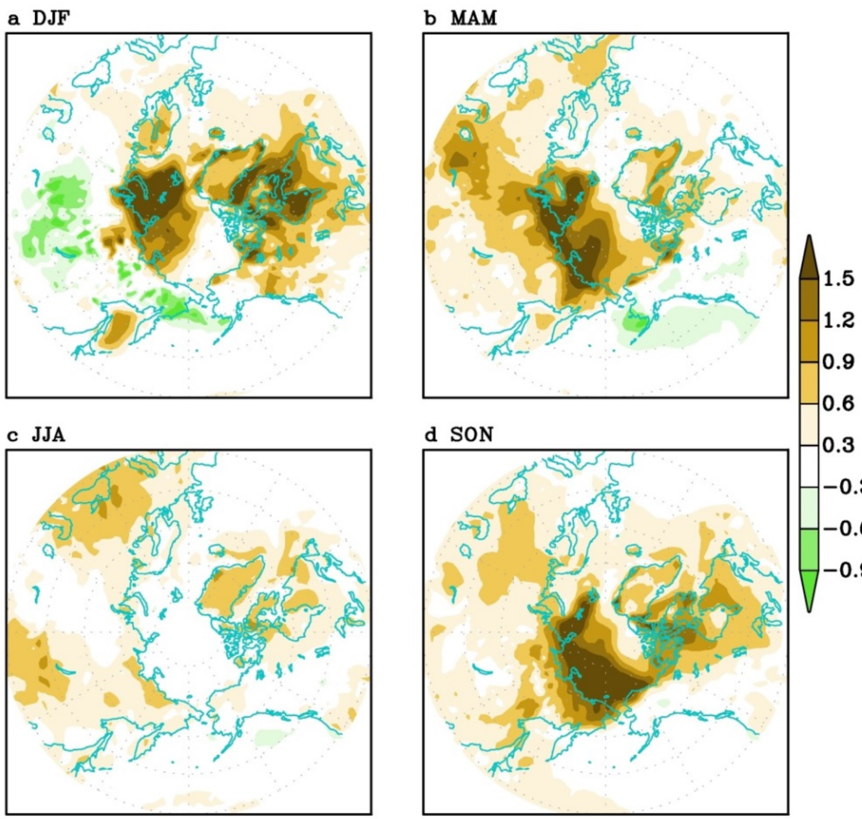
50 years Pre-Industrial control run in CMIP5

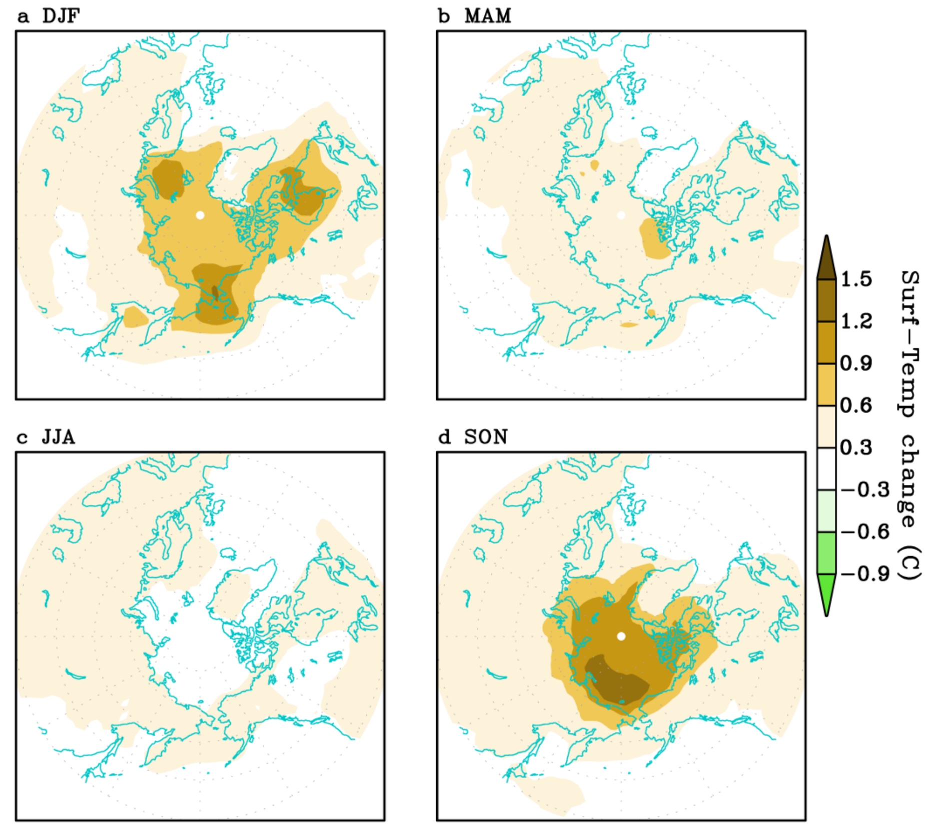


Surface temperature trend (1979-2012)

Obs

IPCC AR5





Anthropogenic forcing can explain another 50% of the Arctic warming
Related to the Sea ice reduction