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

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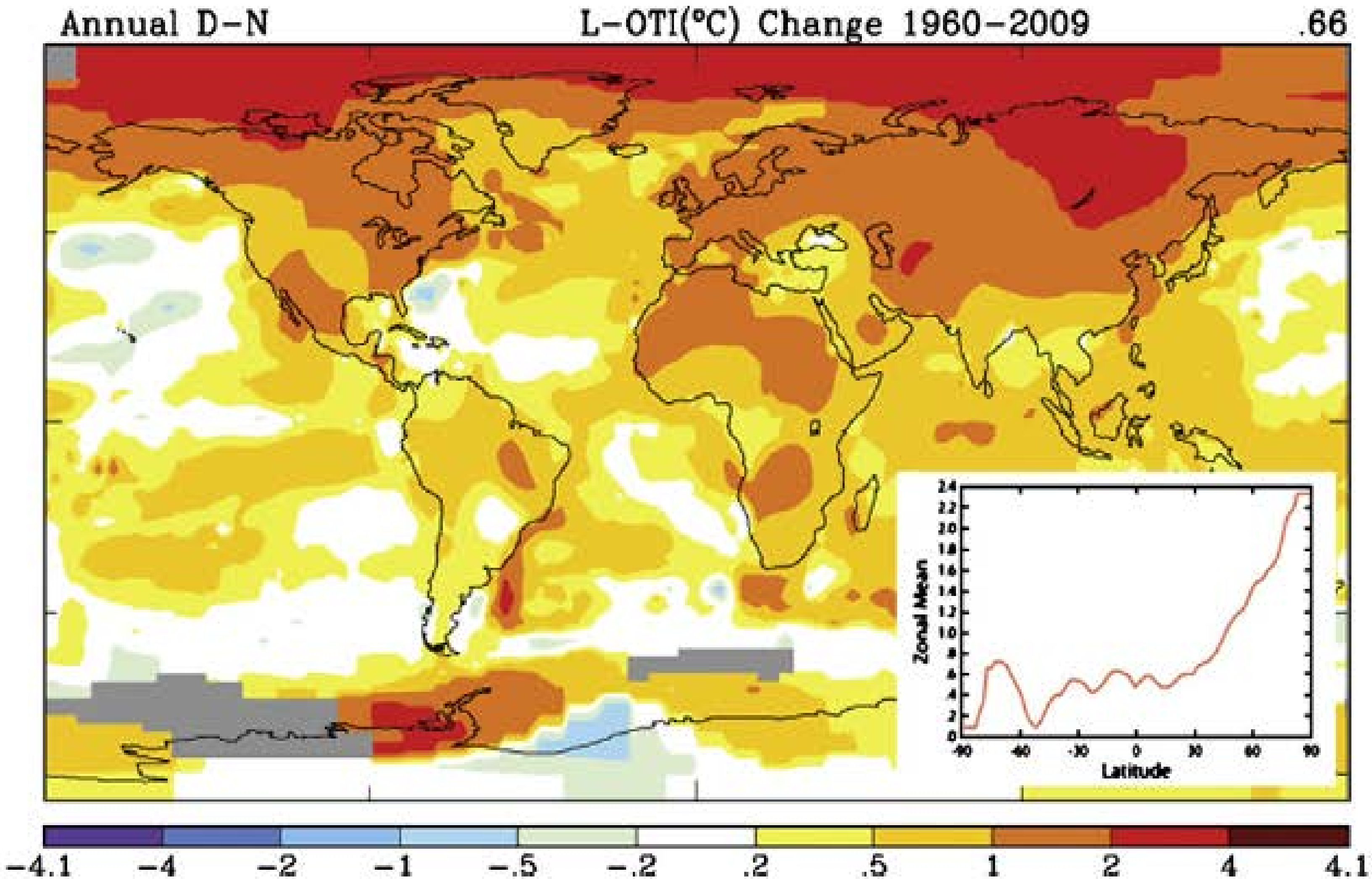
Monash University
APEC Climate Center

Photo: James Balog

The fastest warming rate in the Arctic and Antarctic Peninsula



Serreze and Barry 2011

Warming trend is sensitive to start/end of a time period

Surf-T poleward of 59N

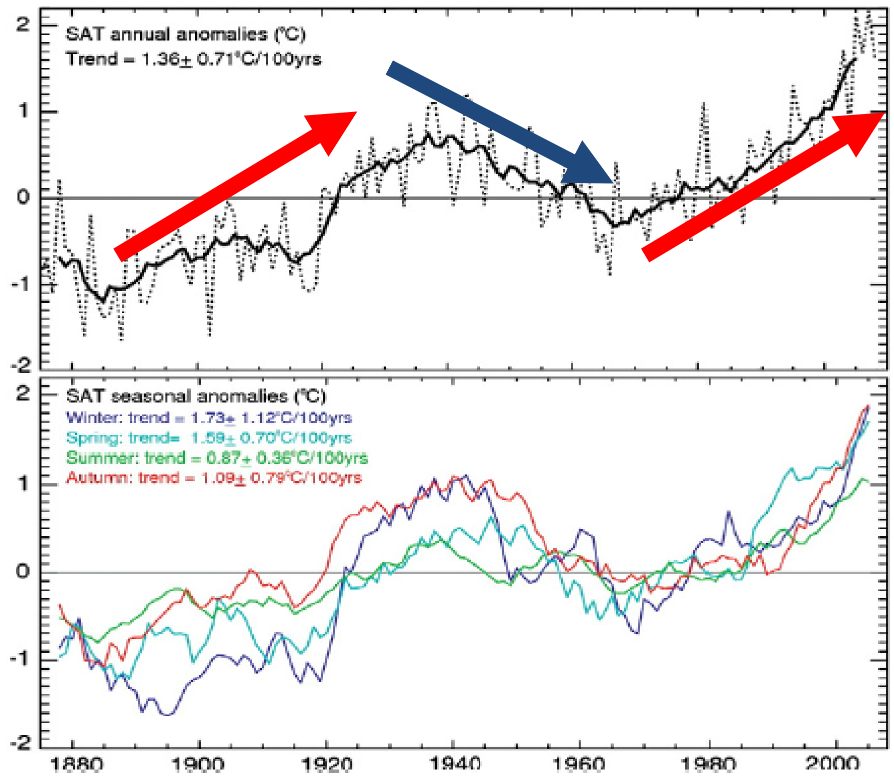


Fig. 3. Composite time series of the (top) annual and (bottom) seasonal surface air temperature anomalies (°C) for the region poleward of 59°N. The dotted lines show unsmoothed values, the solid lines are seven year running means. The liner trends listed in the legend are computed using data for the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

Arctic amplification

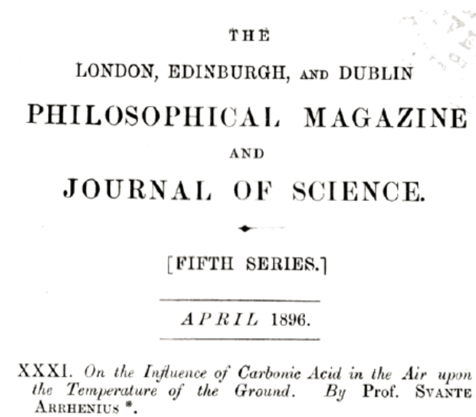
Local causes (anthropogenic)

- 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

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JOURNAL OF SCIENCE.

[FIFTH SERIES.]

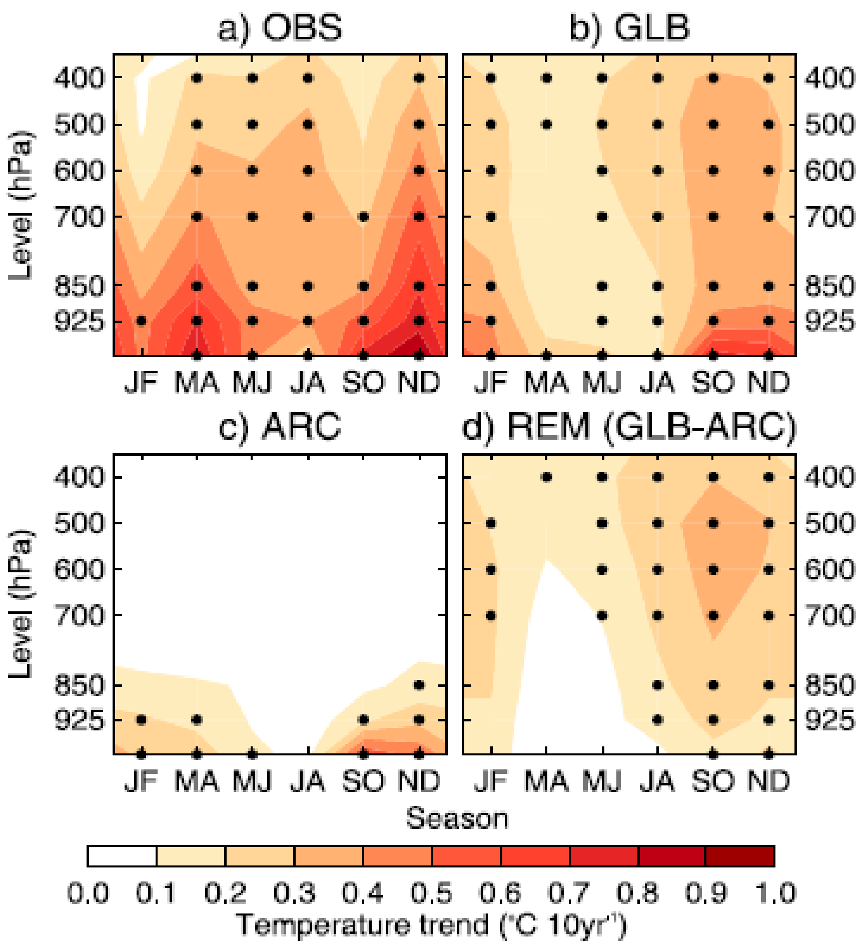
APRIL 1896.

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

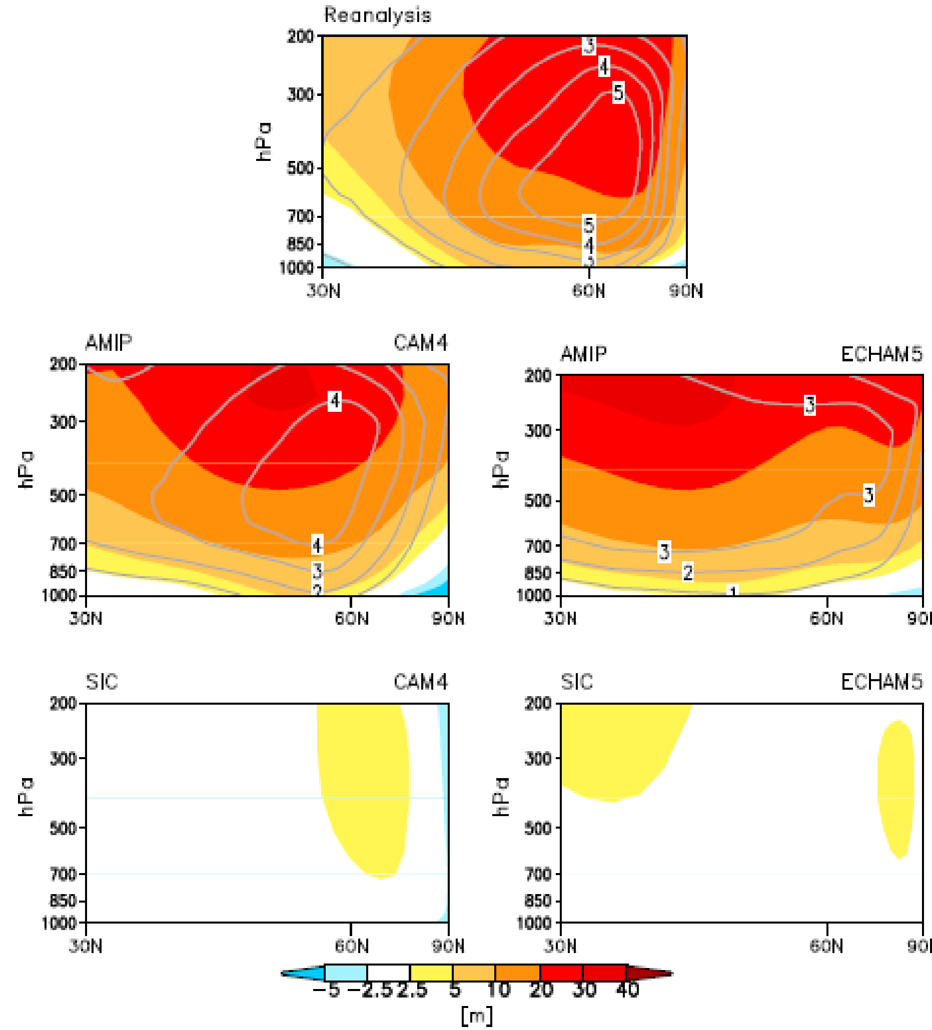
Min et al., 2008; Kay et al., 2011a; Schweiger et al., 2011; Notz and Marotzke, 2012,Serreze et al., 2009; Screen and Simmonds, 2010a,b,, Francis and Hunter, 2006; Kay et al., 2008; Choi et al., 2014, Alexeev et al., 2005; Graverson and Wang, 2009; Zhang et al., 2013, Bintanja et al., 2011, Hansen and Nazarenko, 2004, Shindell and Faluvegi, 2009, Graverson et al., 2008; Yang et al., 2010; Lee et al., 2012; Kapsch et al., 2013; Lee et al., 2014, Hurrell, 1996; Poliakov et al., 2002; Bengston et al., 2004; Woodgate et al., 2006; Shimada et al., 2006; Chylek et al., 2009

Impact of remote SST on Arctic warming

Temperature



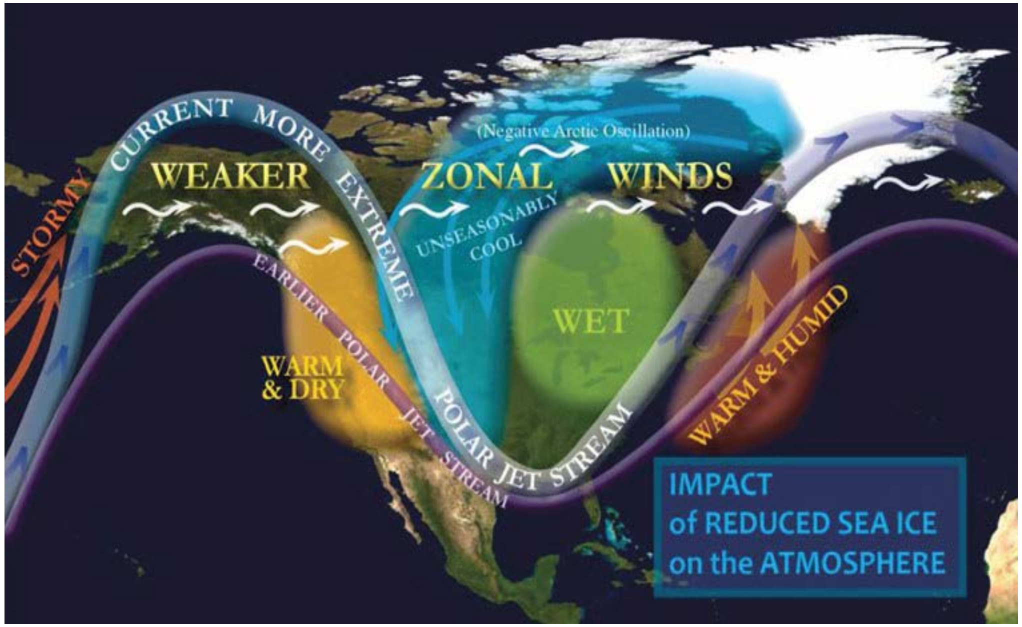
Geopotential heights



Screen et al 2014

Perlwitz et al. 2015

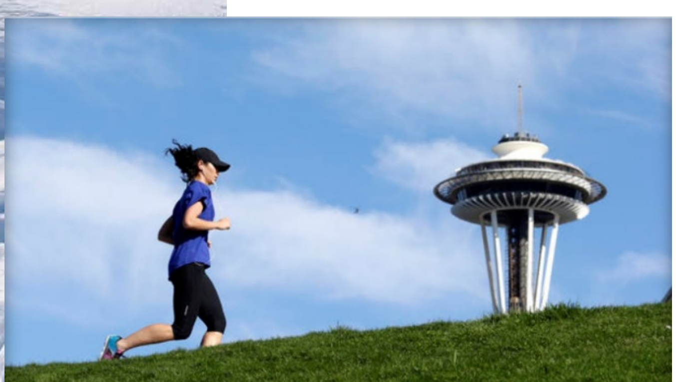
Arctic warming and extreme events



Barns and Screen 2015
Francis and Skific 2015
Overland and Wang 2015

Francis and Vavrus 2012

Seattle in Feb, 2015



2014/15 brutal Winter in New England

Cohen et al., 2009; Screen and Simmonds, 2010b; Overland and Wang, 2010; Overland et al., 2011; Liu et al., 2012; Francis and Vavrus, 2012; Wyatt and Curry, 2013; Kim et al., 2014

Key Questions

- What is the relative contributions of the external and internal forcing in the recent warming of the Arctic?
- How is the internal forcing causing 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 20th 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

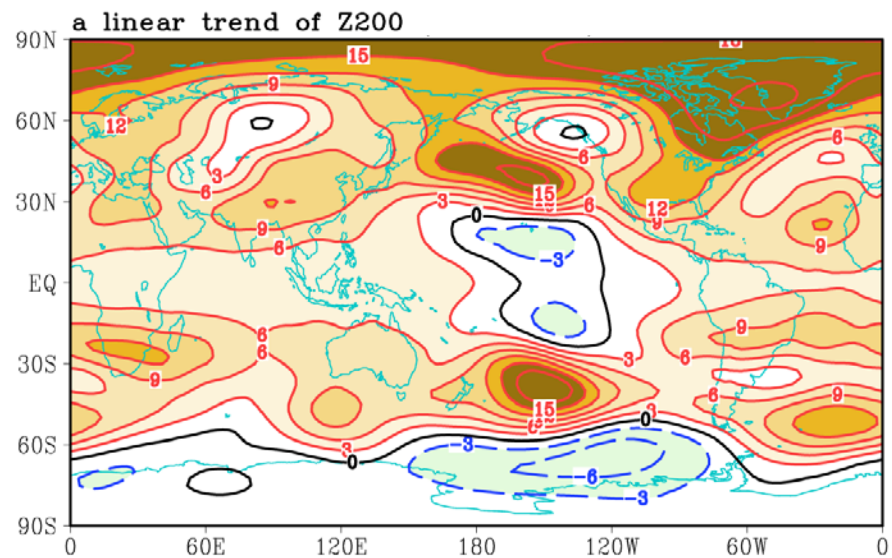
Method

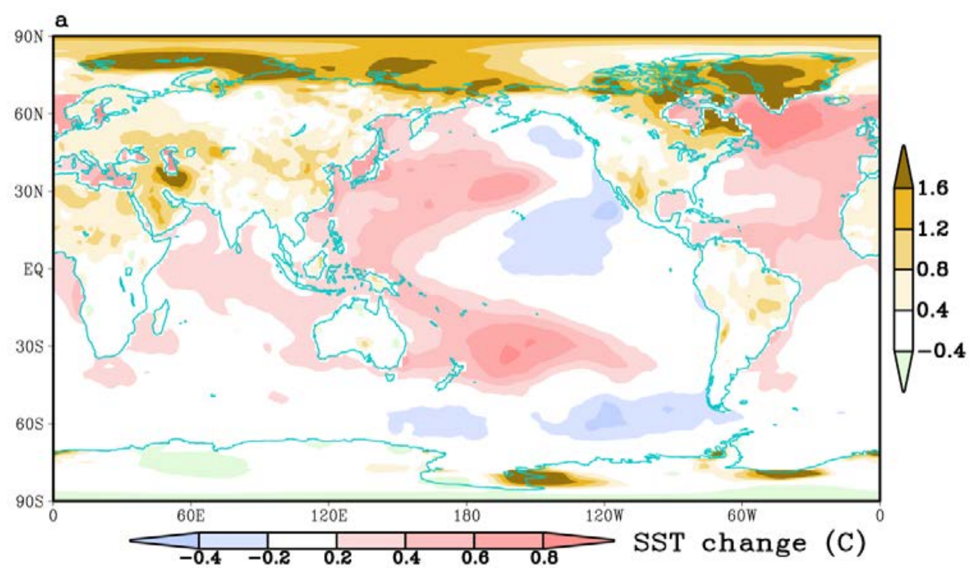
- Annual mean (June- May)
- Trend: epochal difference or linear trend
- Trend significance (signal to noise ratio, Mann-kendall test)
- Upper level circulation

Internal variability vs forced response

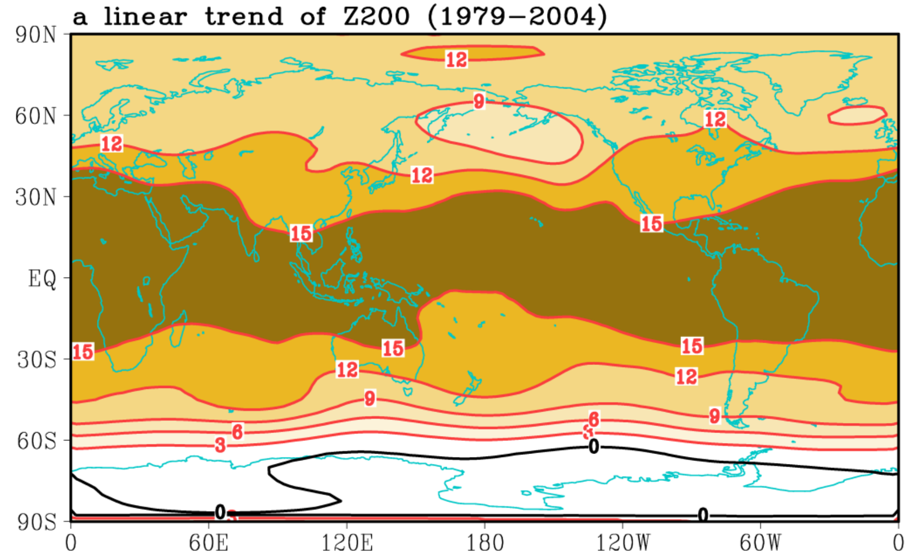
Annual mean
m/decade

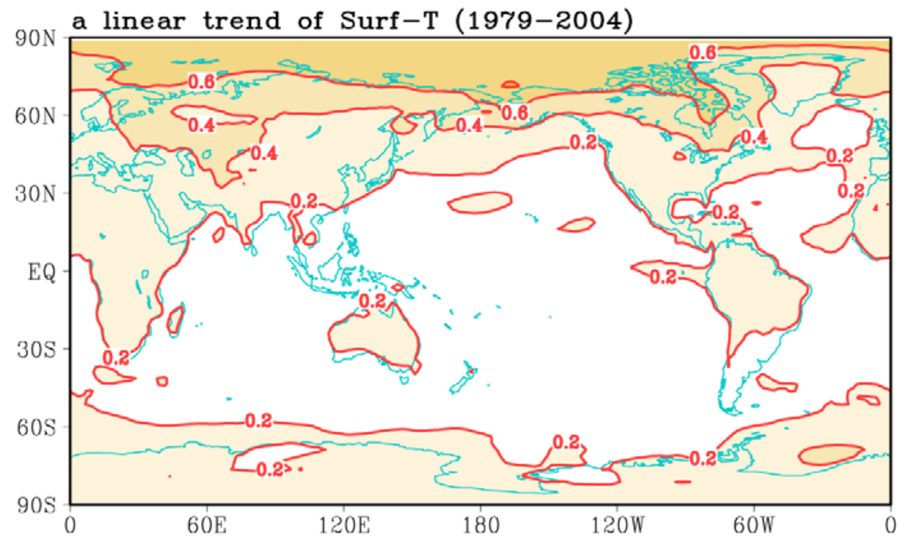
Reanalysis (1979-2013)





IPCC AR5 historical run
(ensemble mean of 40 model)

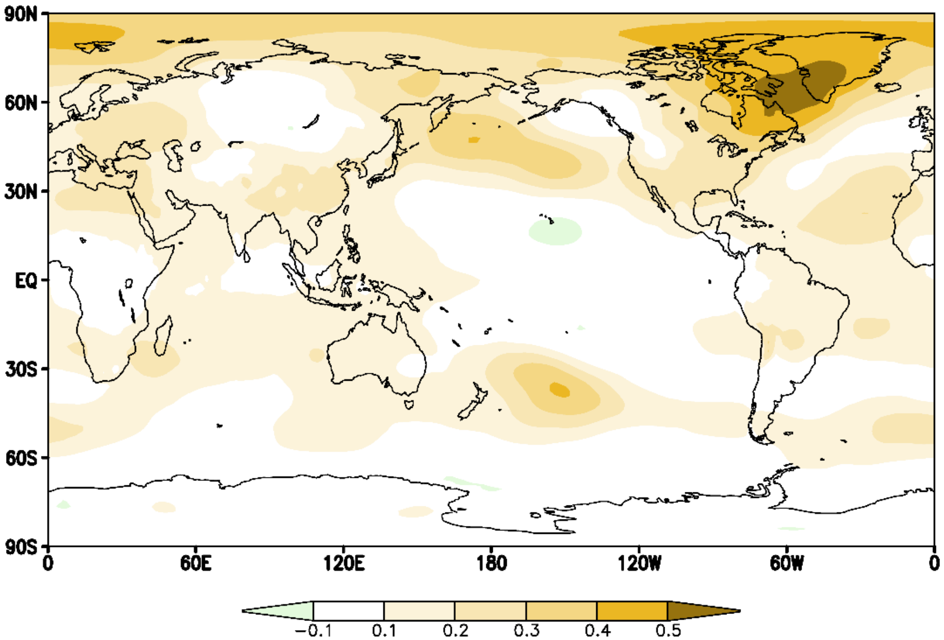




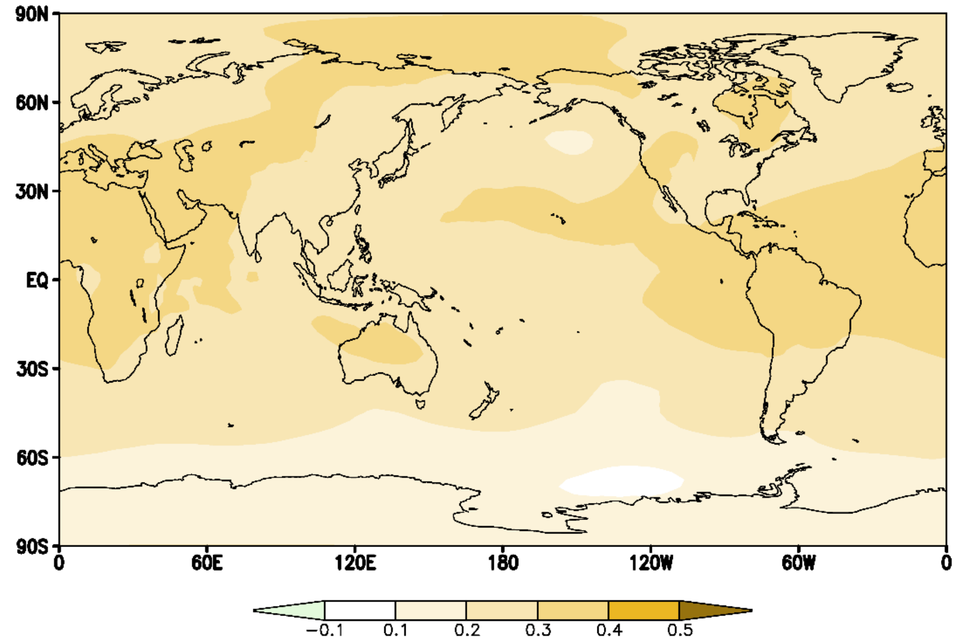
Internal variability vs forced response

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

Reanalysis

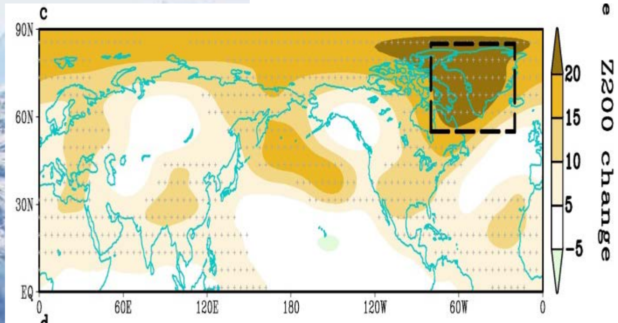


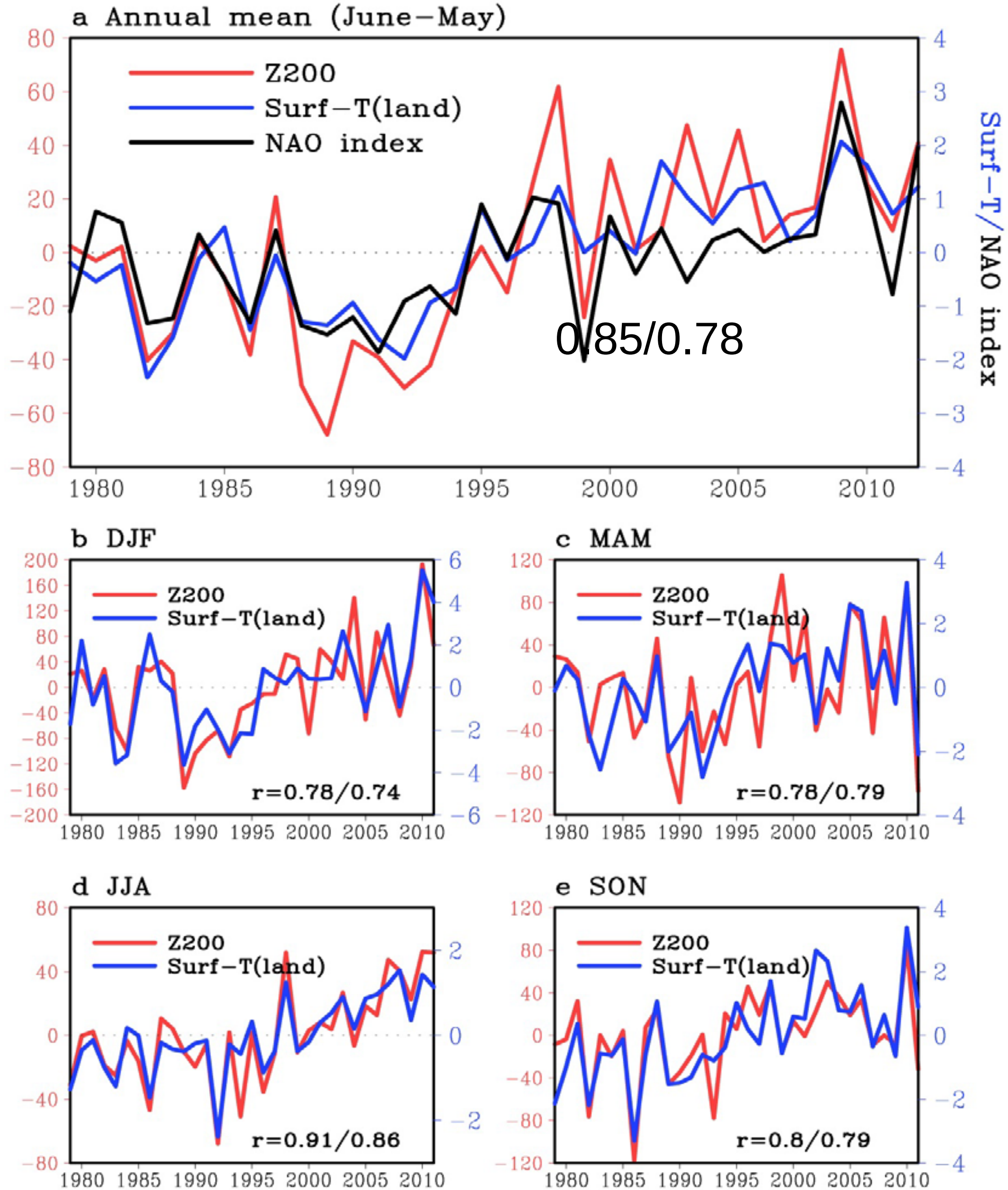
CMIP5



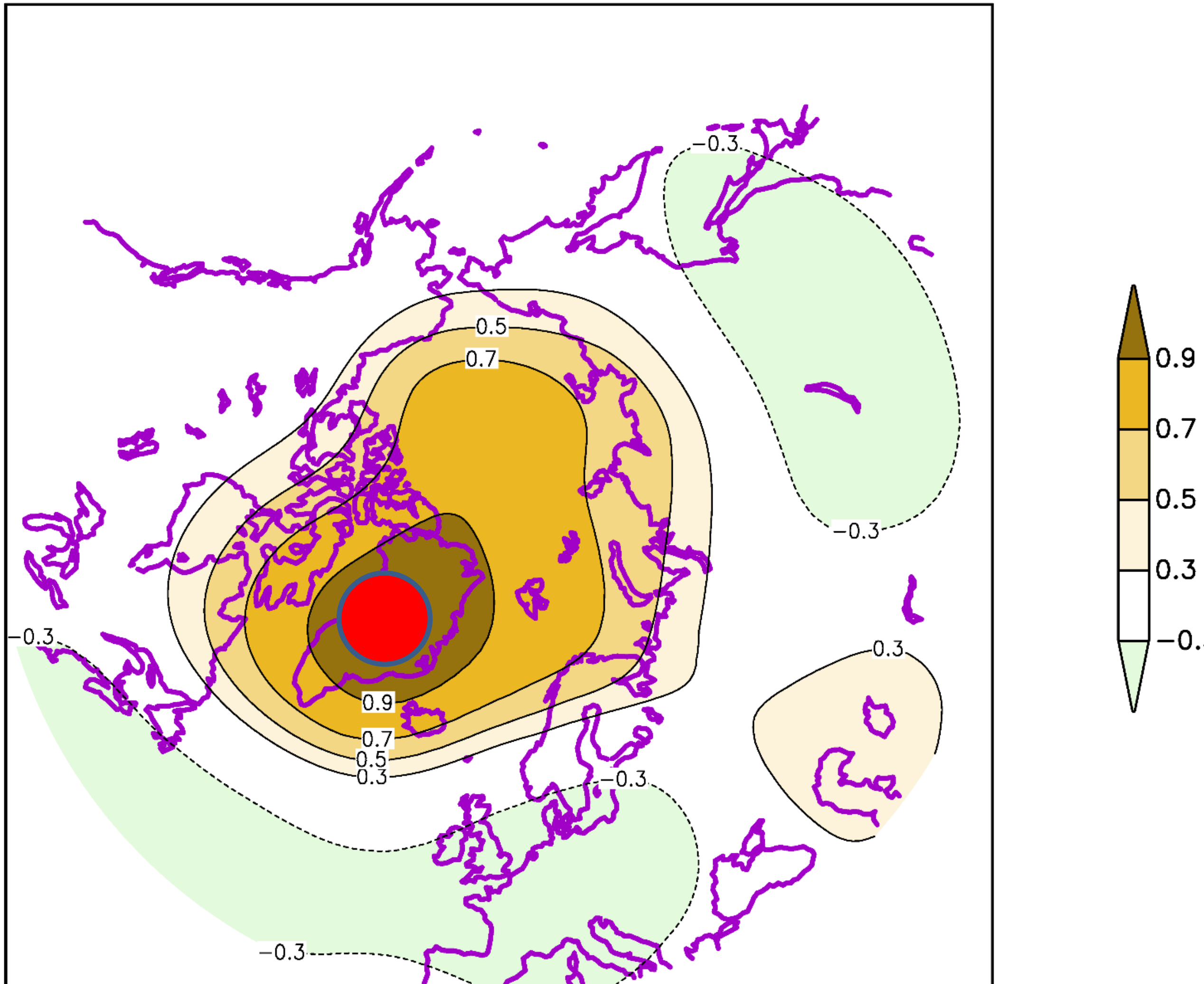
c/decade

Interdecadal-like change



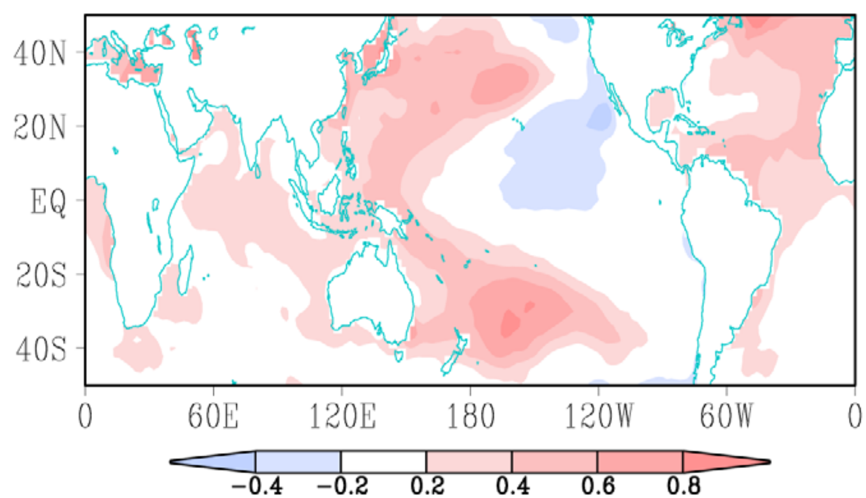


Correlation of NH Z200 with Z200 over Greenland (Detreneded)

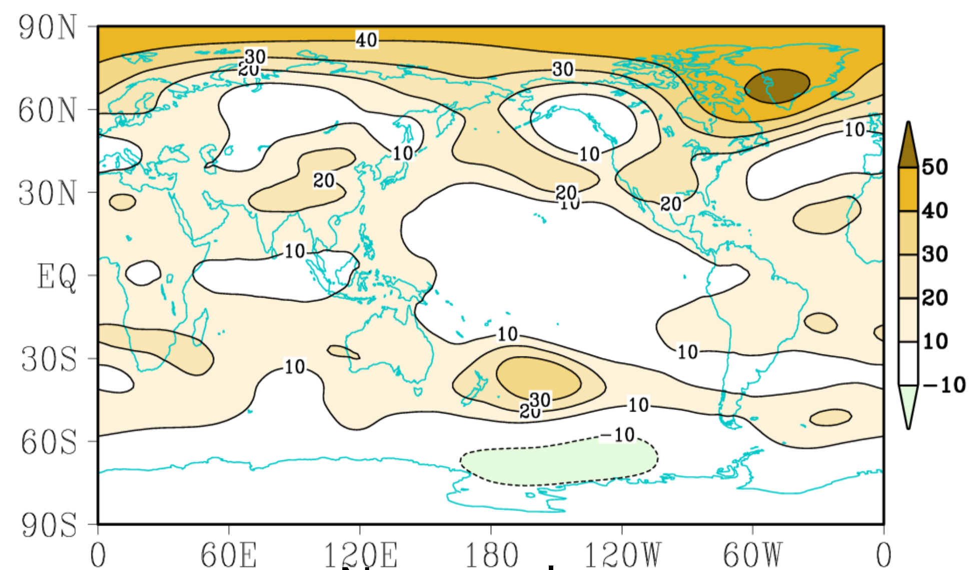


Annual mean SST and Z200 change (1996-2013 minus 1979-1995)

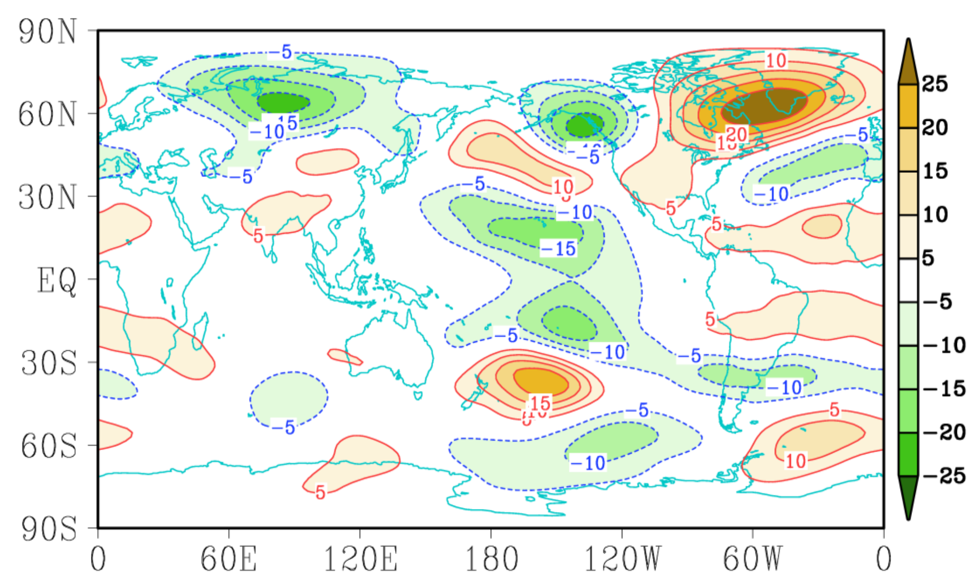
SST change



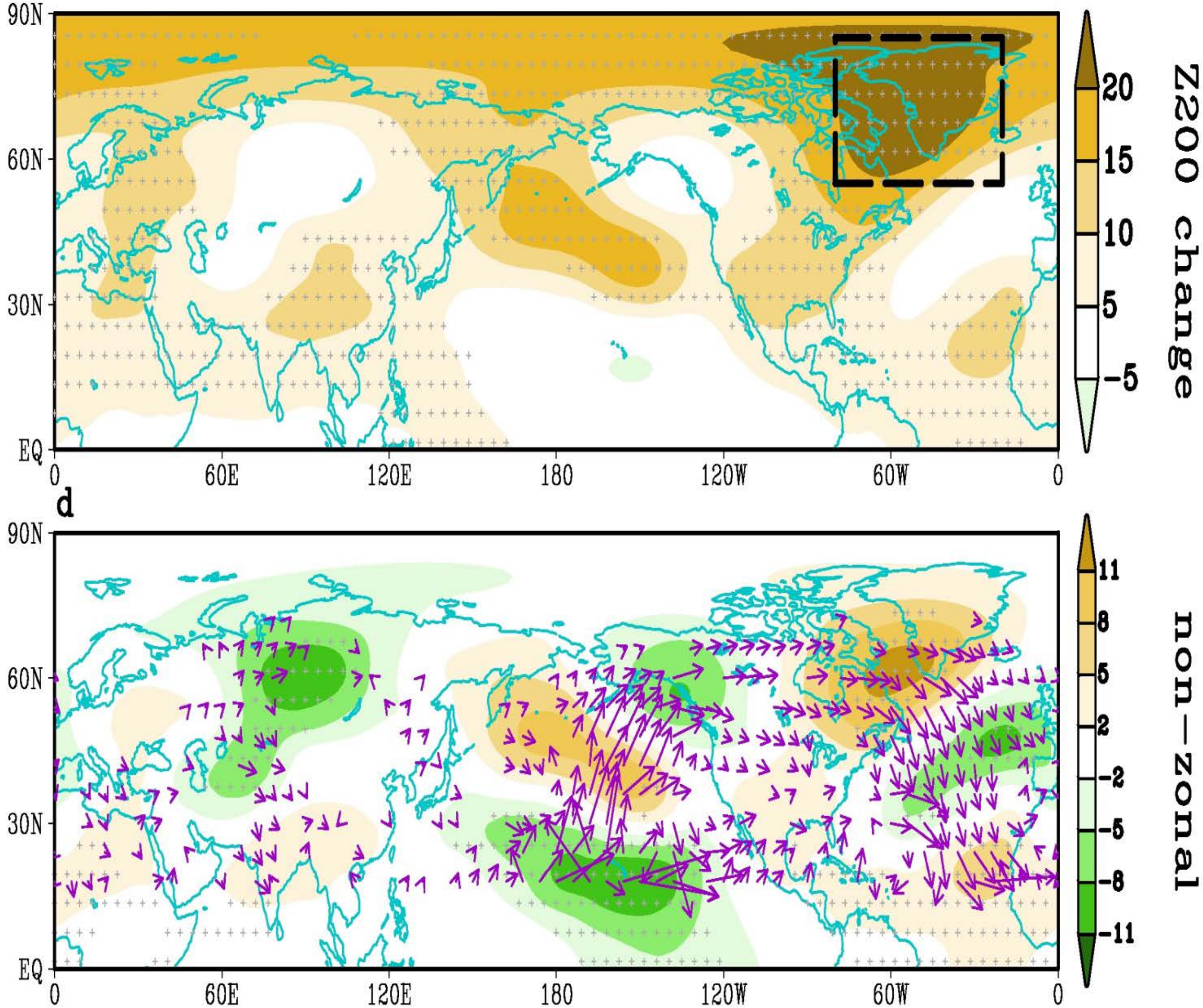
Z200 change



Non-zonal



Annual mean Z200 trend (1979-2013)

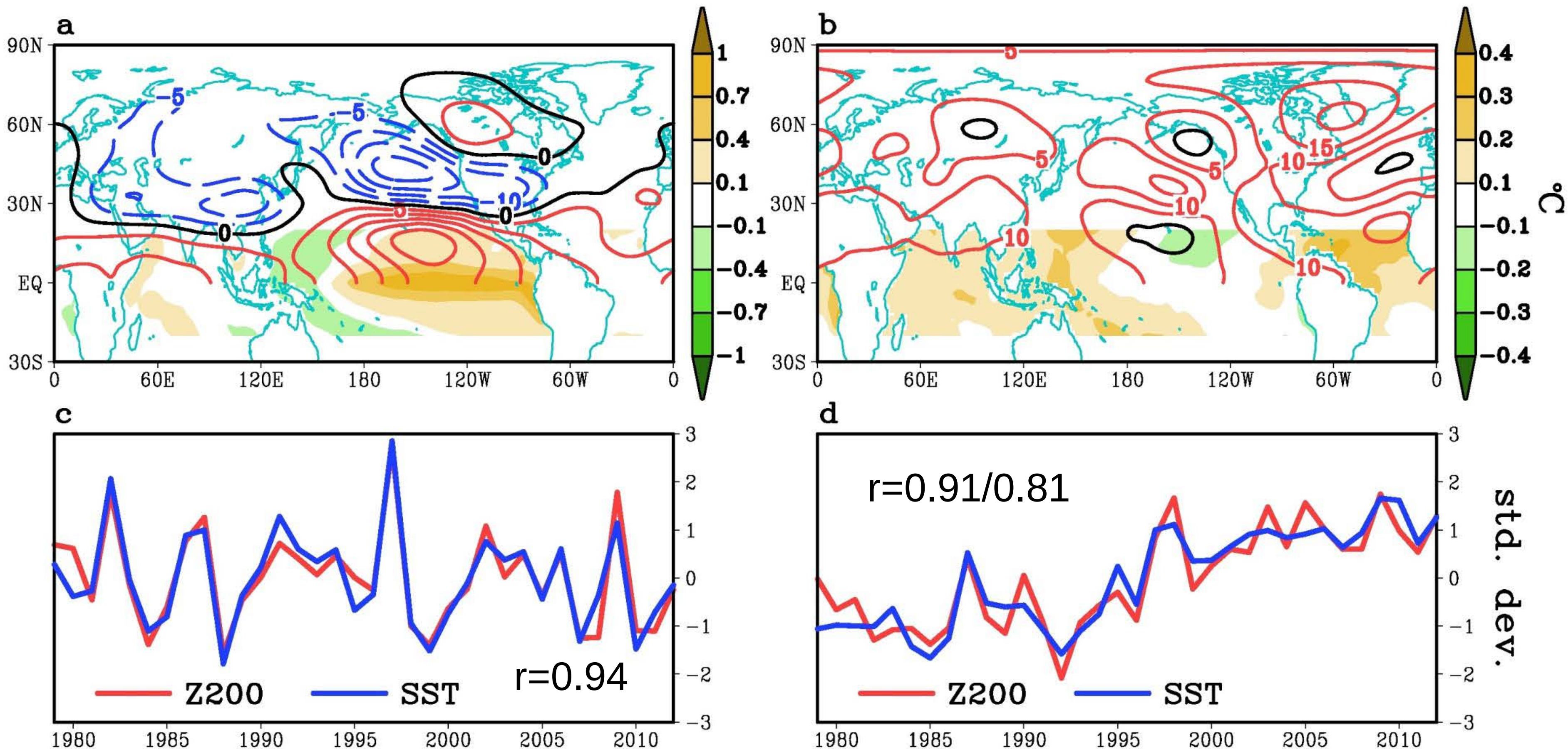


the Arctic is running a tropical fever

Plumb flux 1985

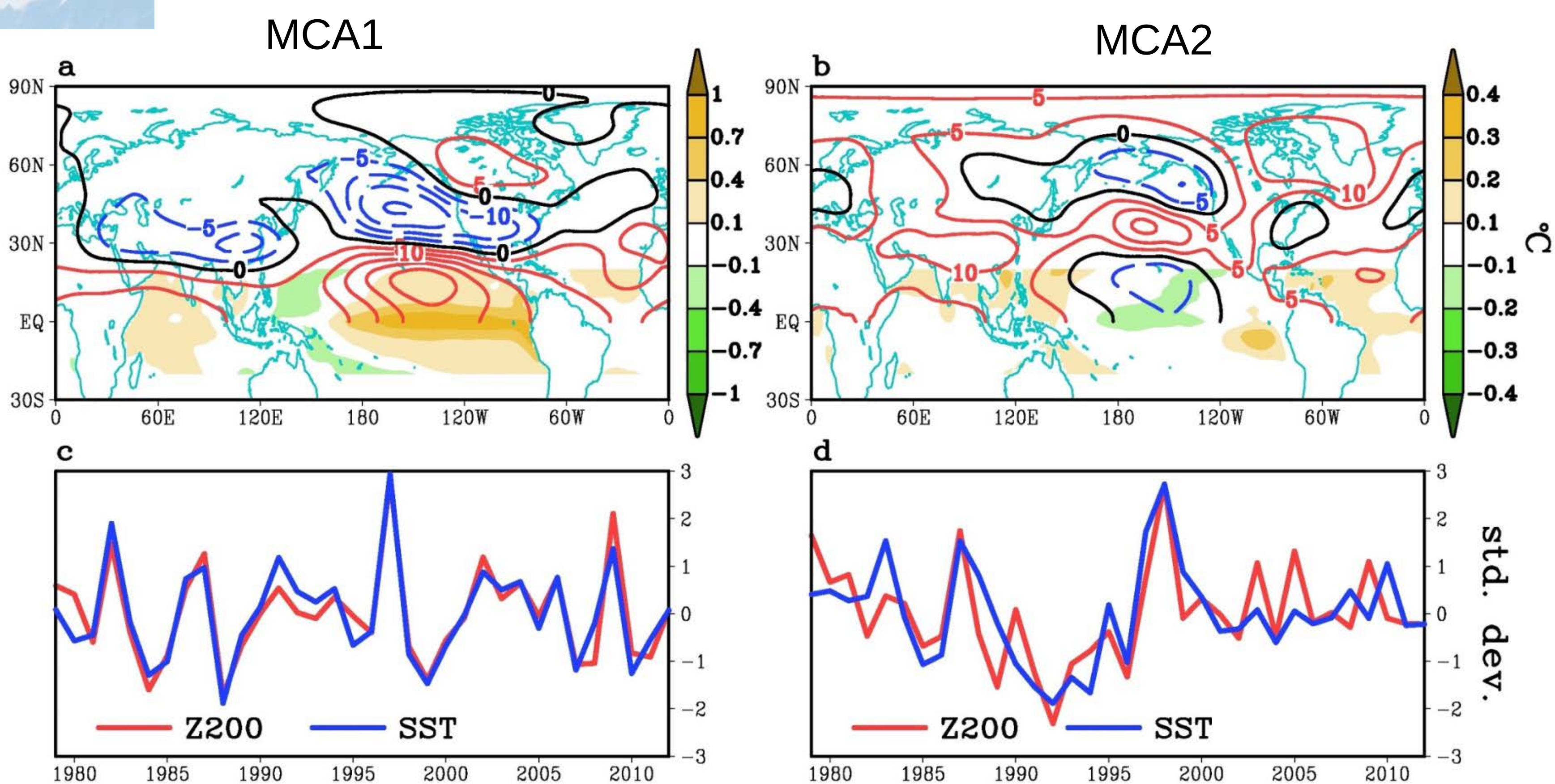
Covariability of annual mean tropical SST and NH Z200 (1979-2012)

SCF=70% SCF=26%



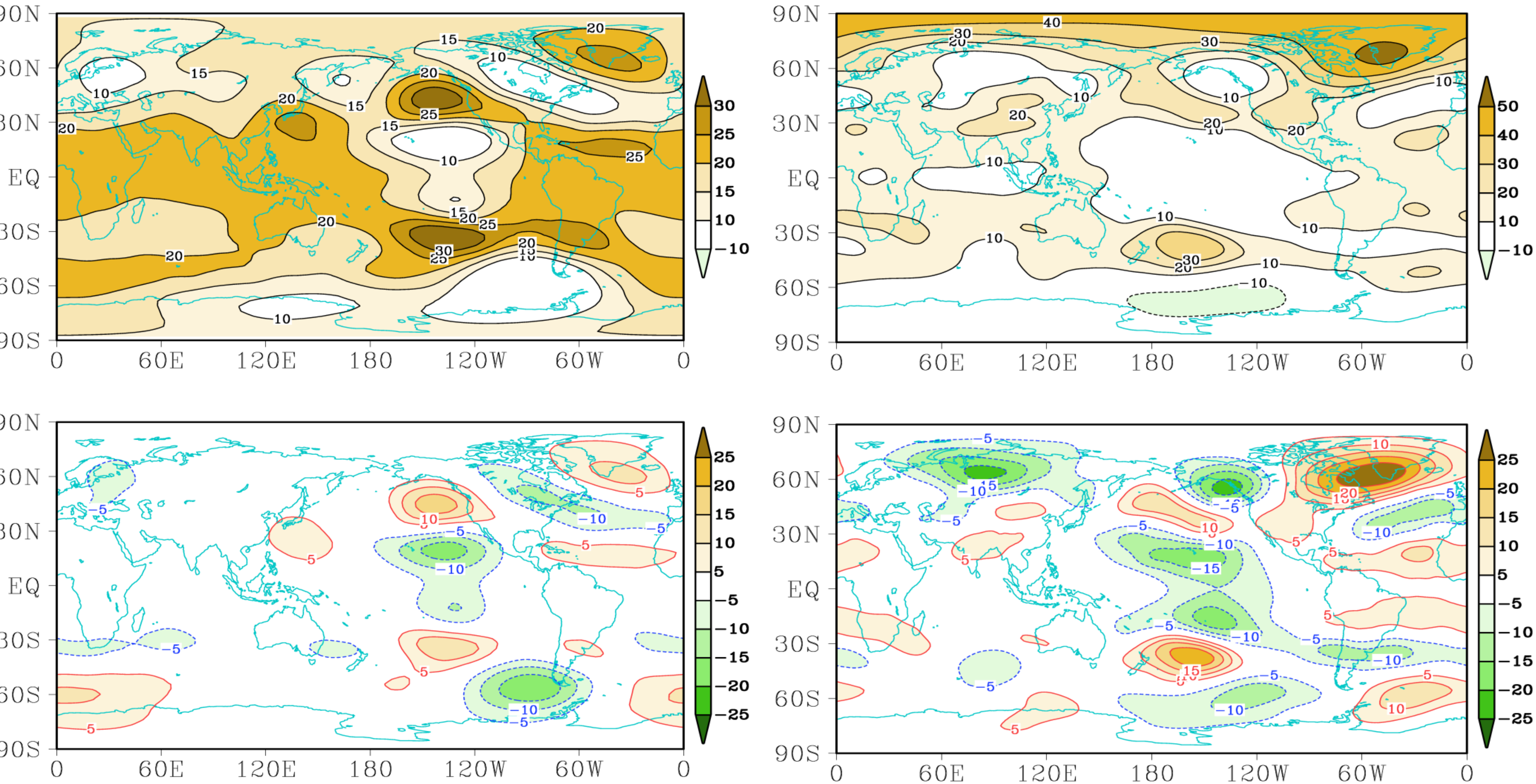
a low frequency tropical SST mode(shifted at 1997/1998)
not the typical ENSO

MCA modes for detrended Z200 and tropical SST



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

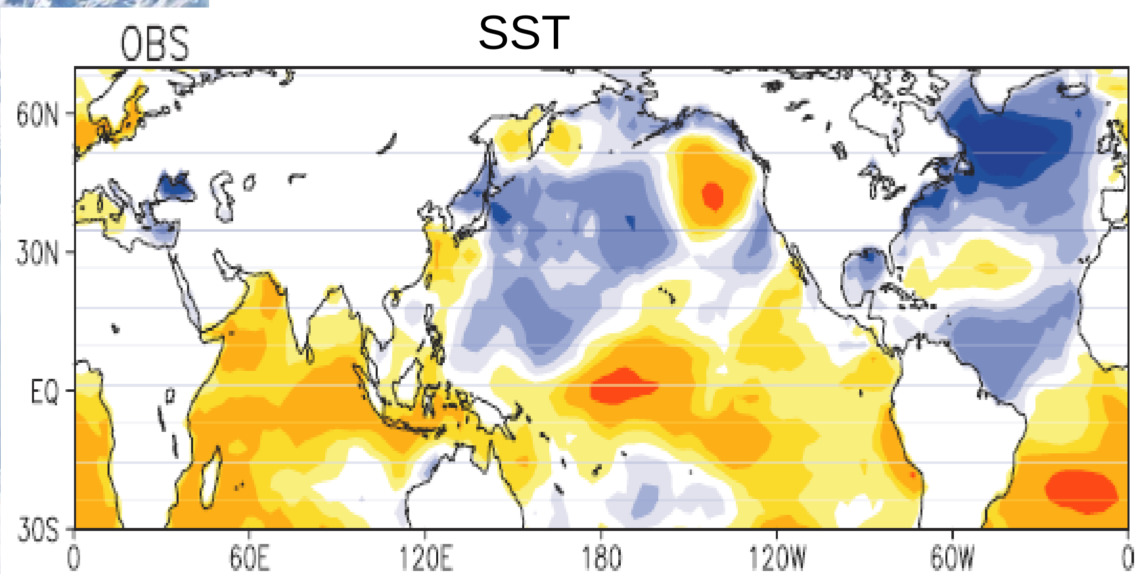
ECHAM4 Simulation | observation



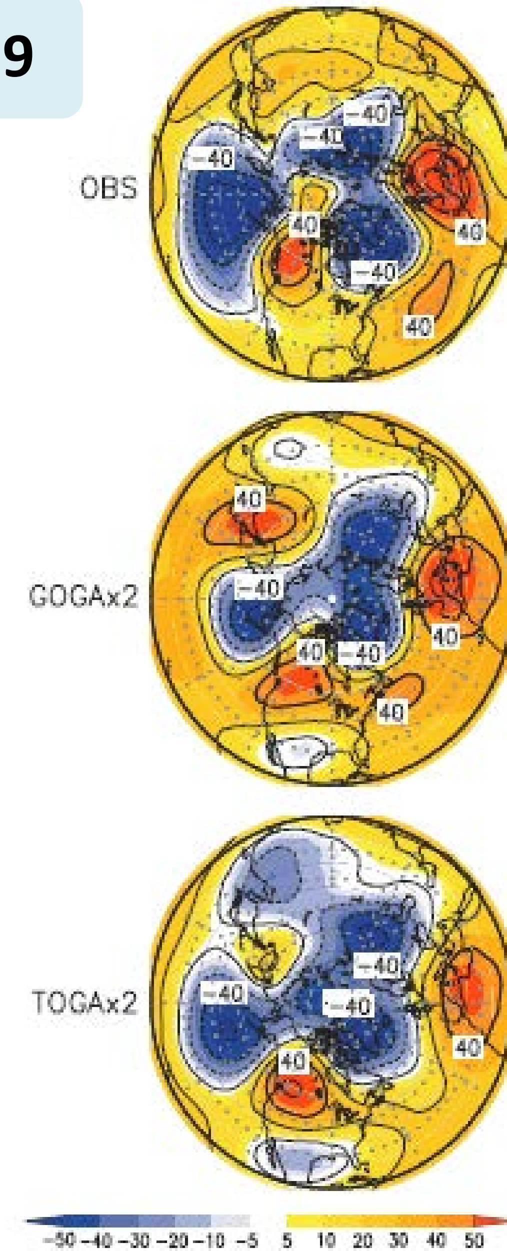
Tropical origin of the NAO over 1950-1999

1950-1999 DJF

SST

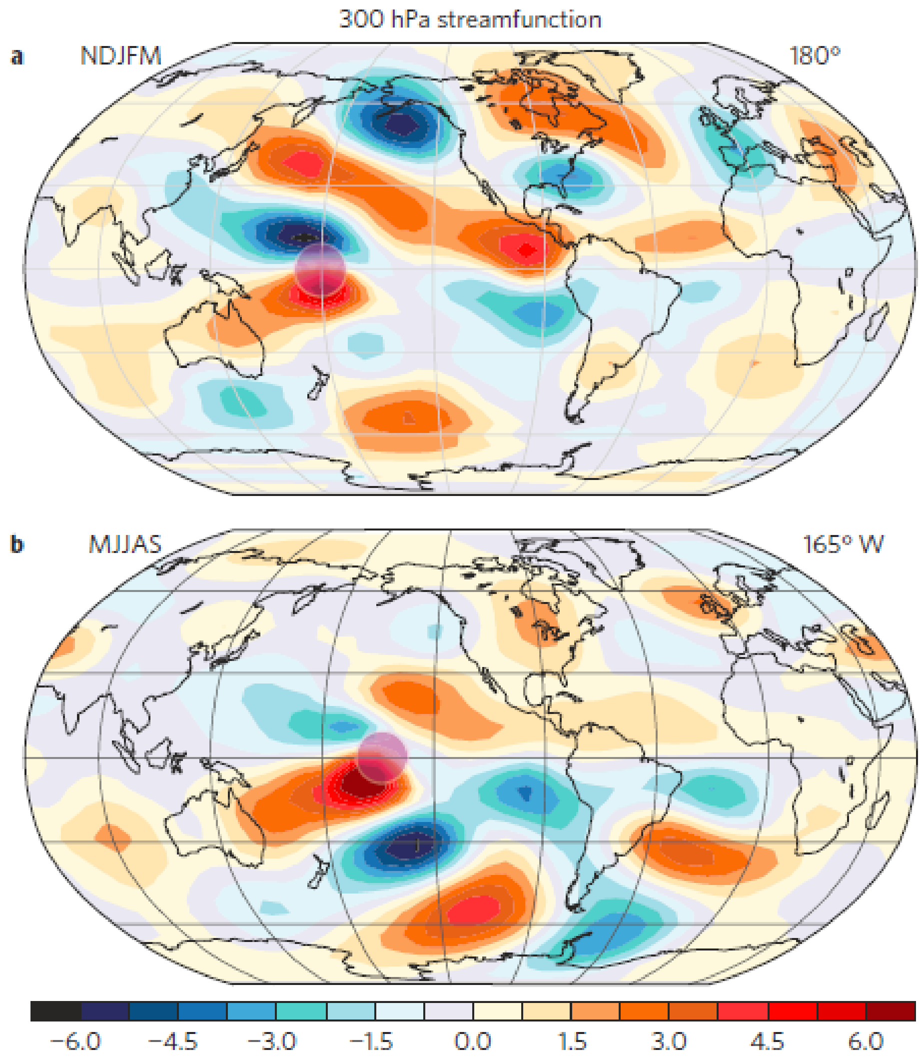


Z500



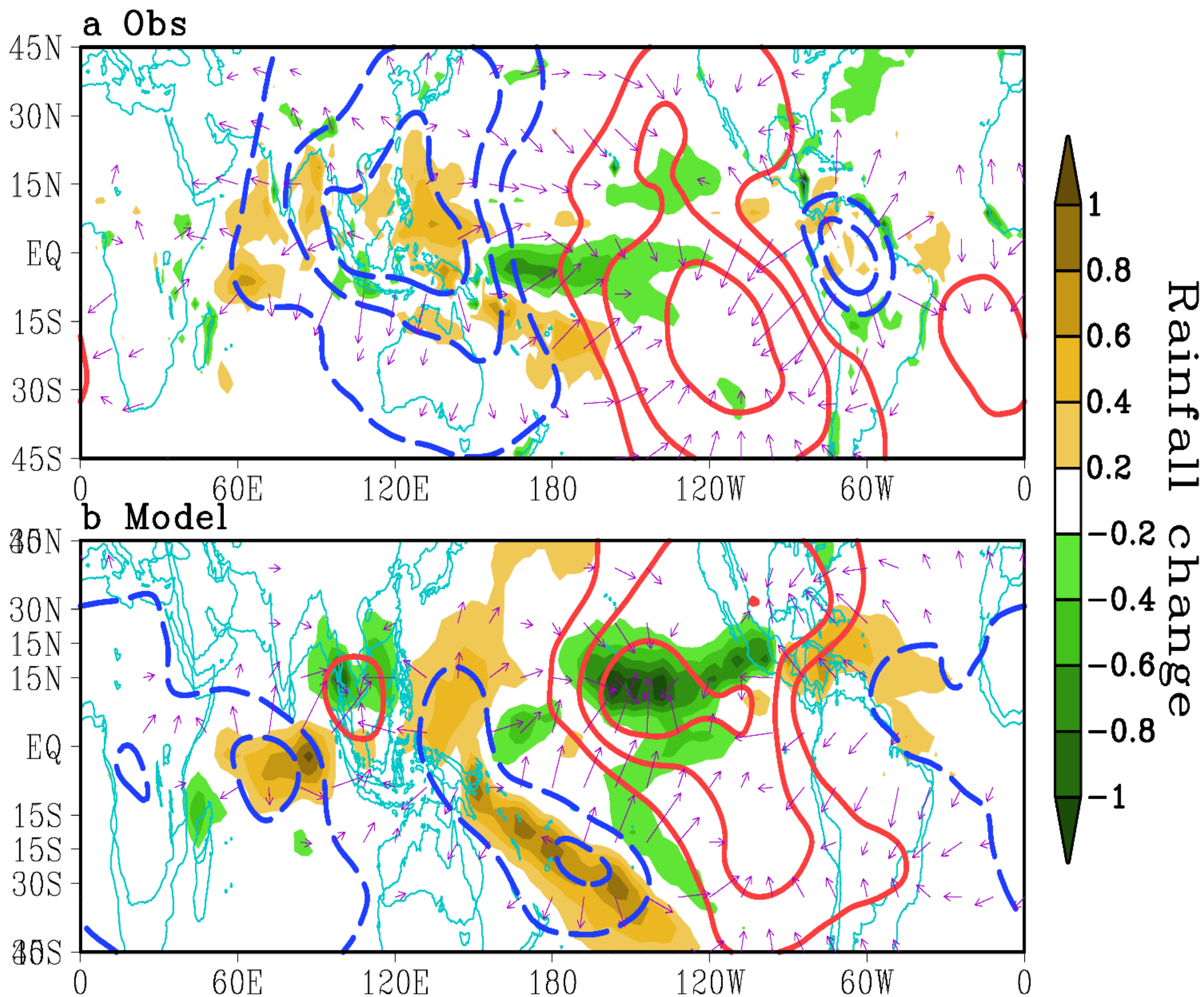
Hoerling et al 2001

CAM model response to tropical heating anomalies

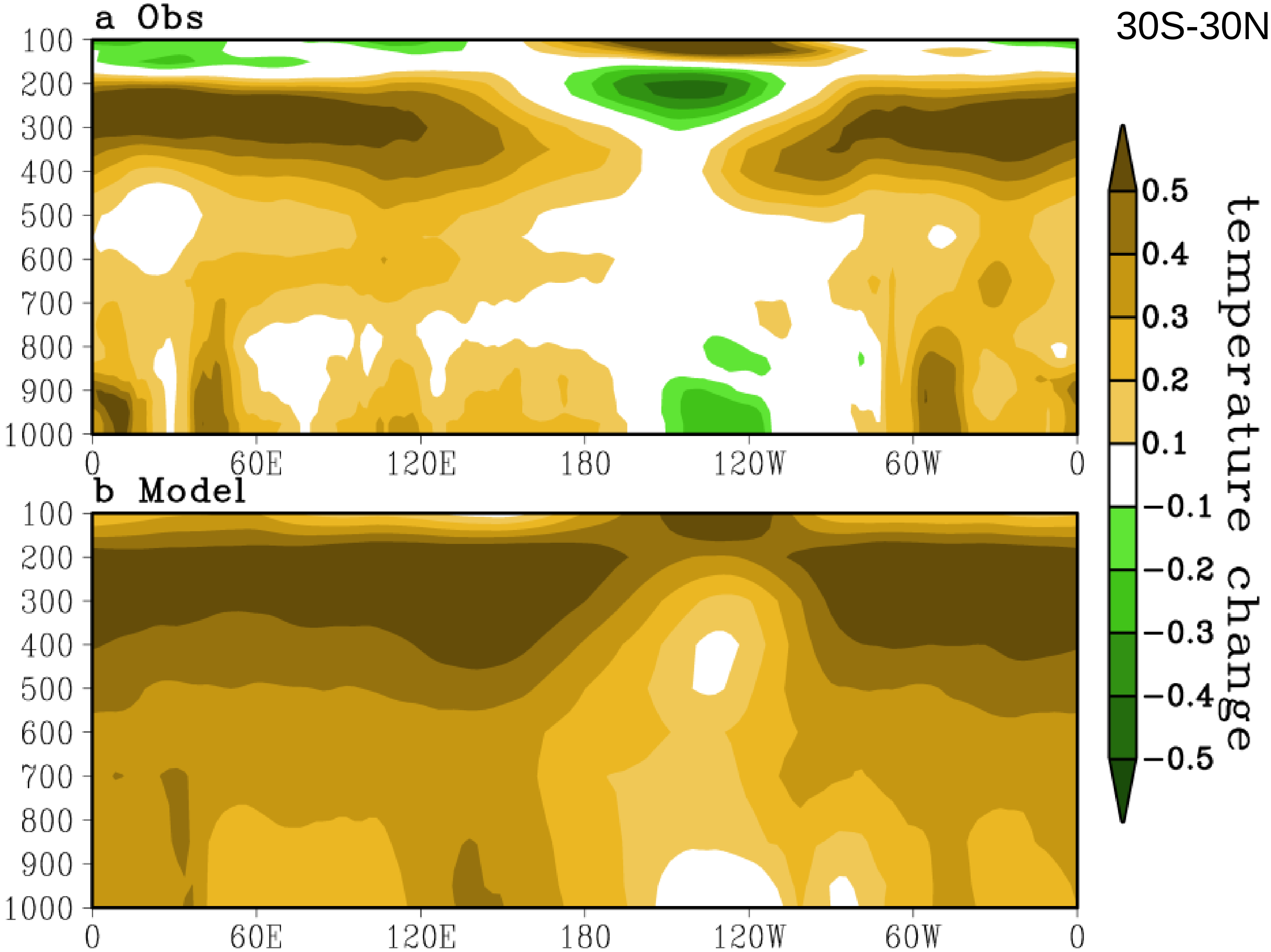


Trenberth et al. 2014

Annual mean rainfall trend in 1979-2013



Annual mean tropical temperature trend in 1979-2013

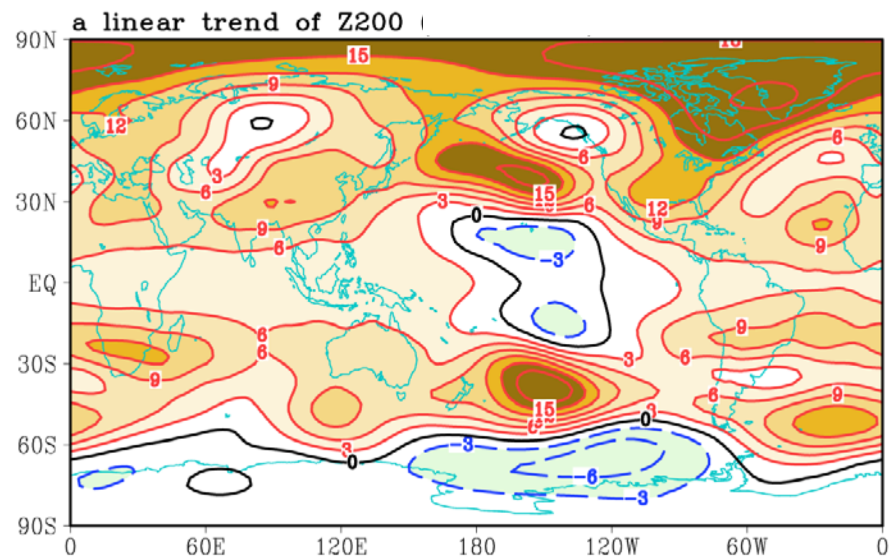


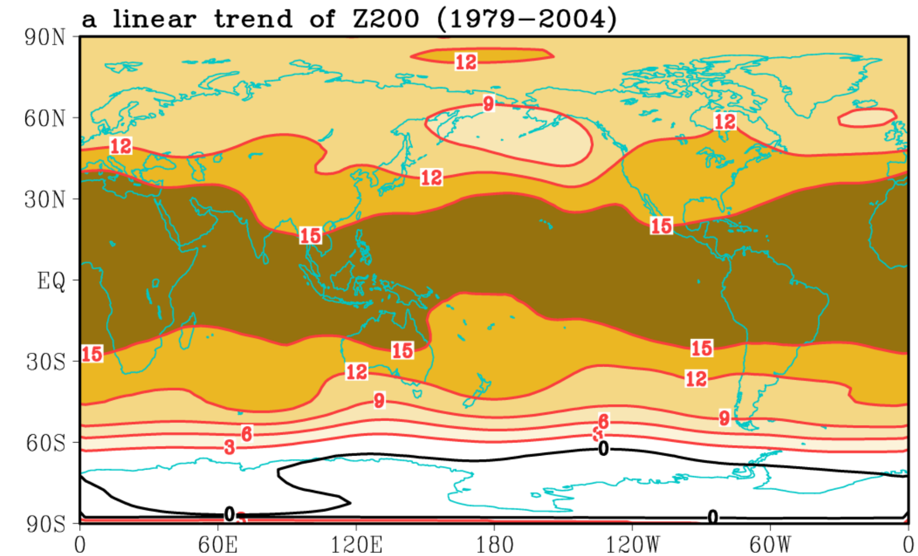
Internal variability vs forced response

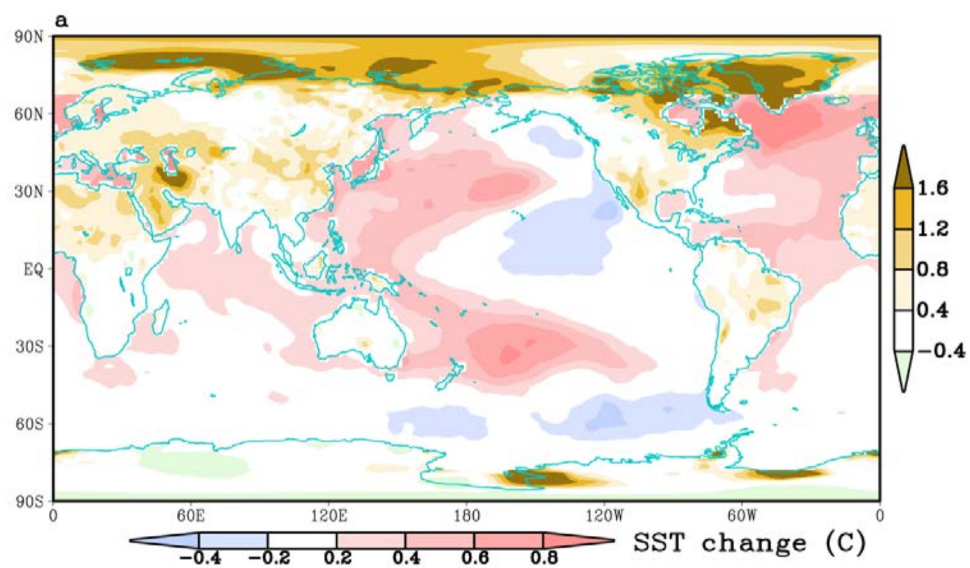
Annual mean
m/decade

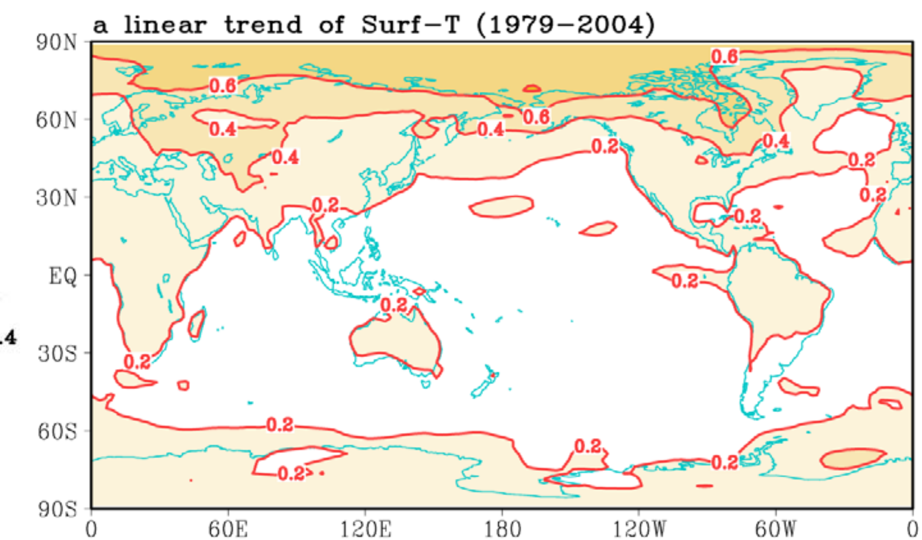
Reanalysis (1979-2013)

IPCC AR5 historical run
(ensemble mean of 40 model)

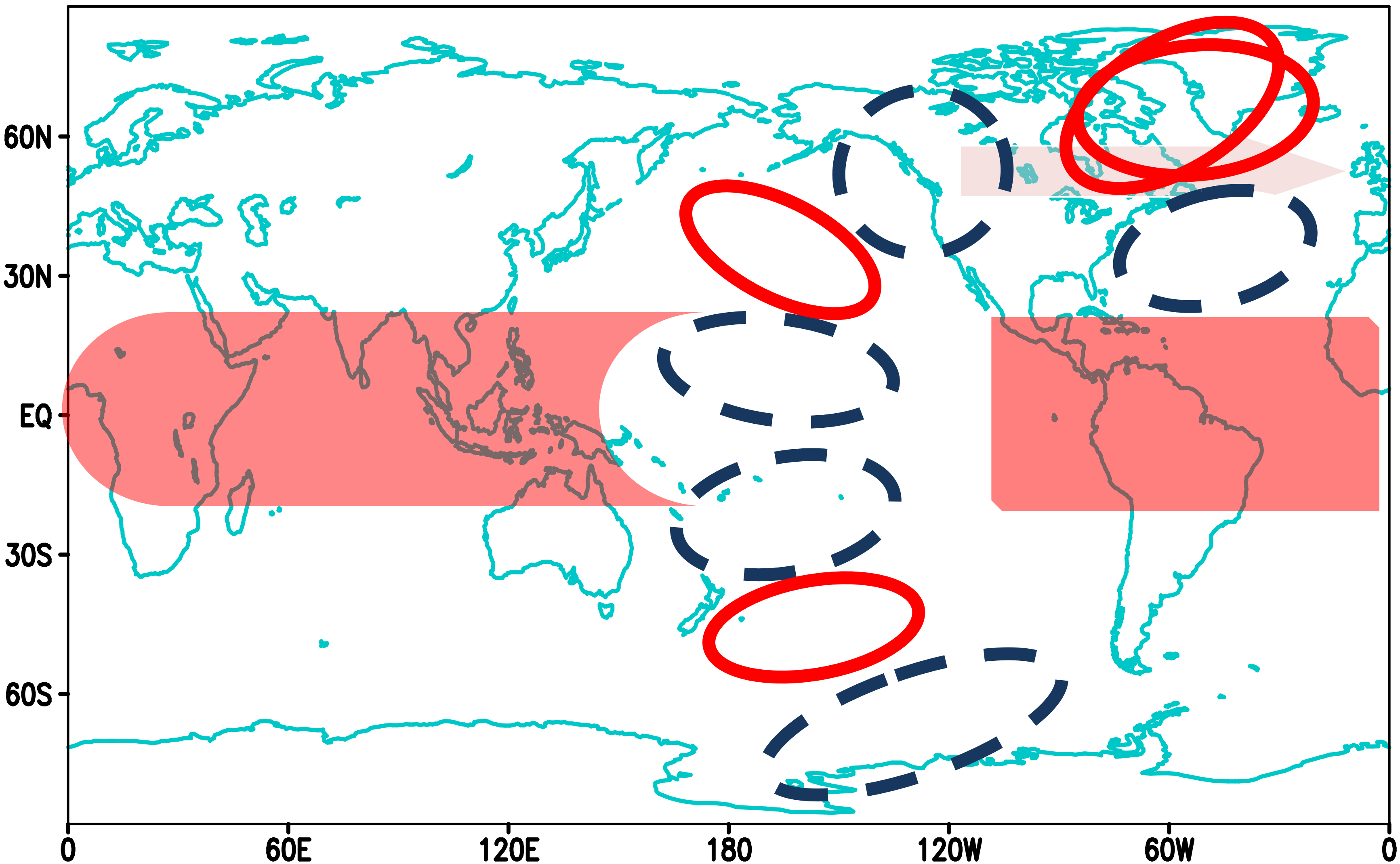




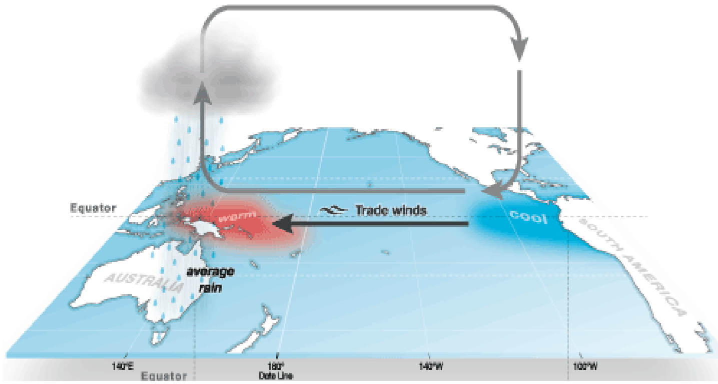




How is the tropical forcing causing polar warming?



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



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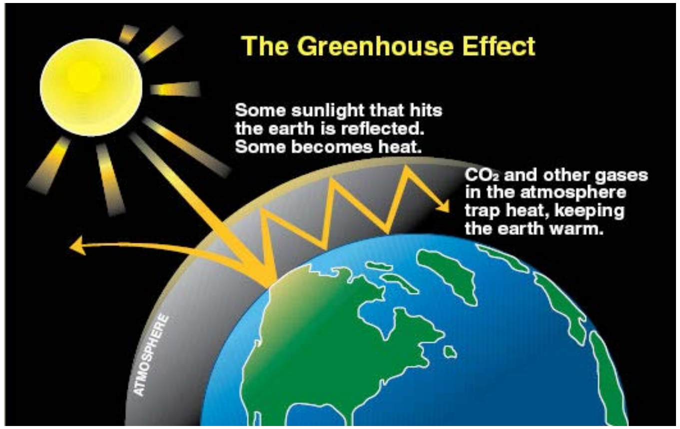
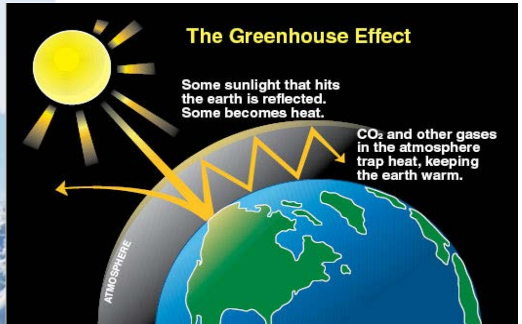


Arctic warming vs tropical forcing



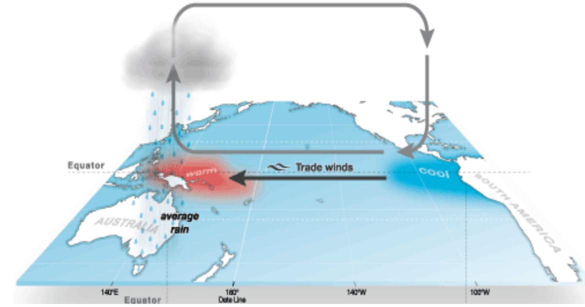
Global warming

Artic warming

Midlatitude wavy flow

Extreme events

Francis and Vavrus 2012



Tropical internal

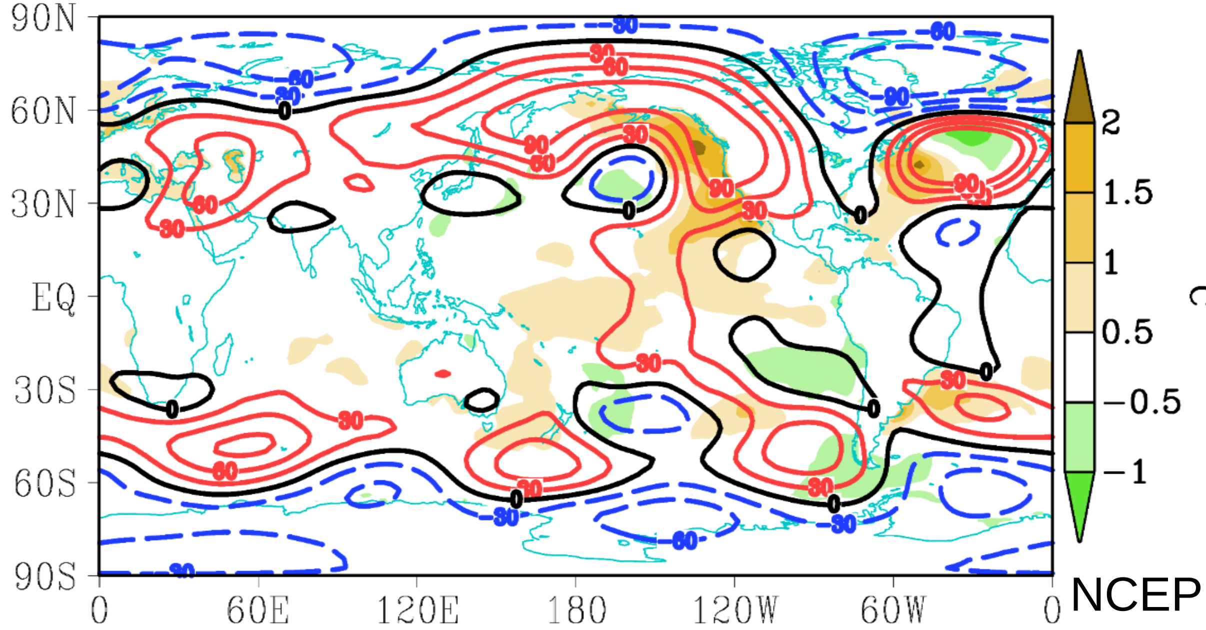
Midlatitude wavy flow

Extreme events

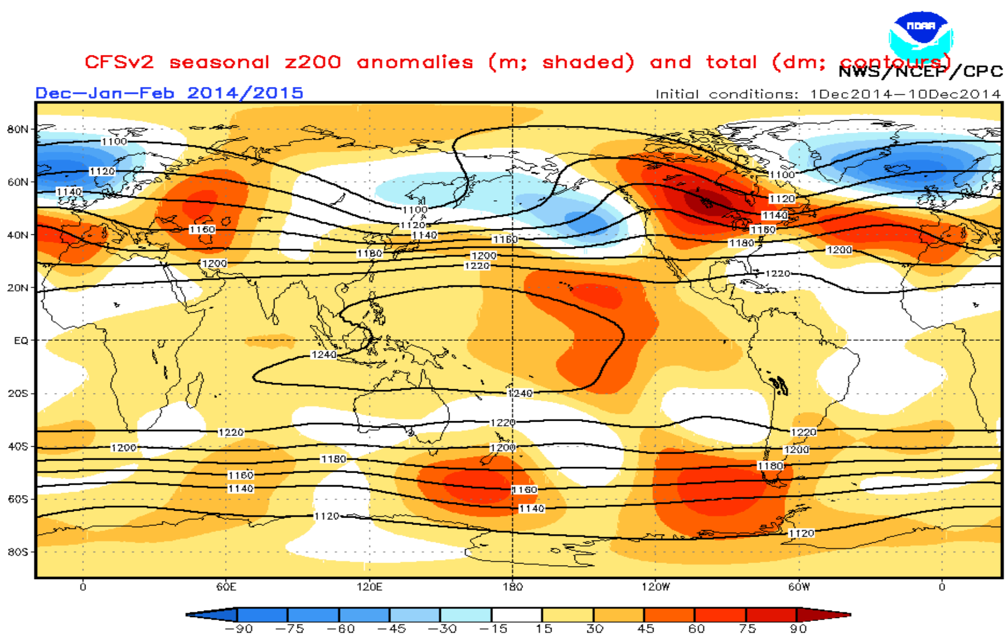
Artic change

Global warming

Z200 and SST in 2014/2015 DJF



NCEP1 and ERSST3
mean state:1979-2015



CFSv2
DJF Z200 anomalies
Initial Condition
2014 Dec,1-10

Take-home message

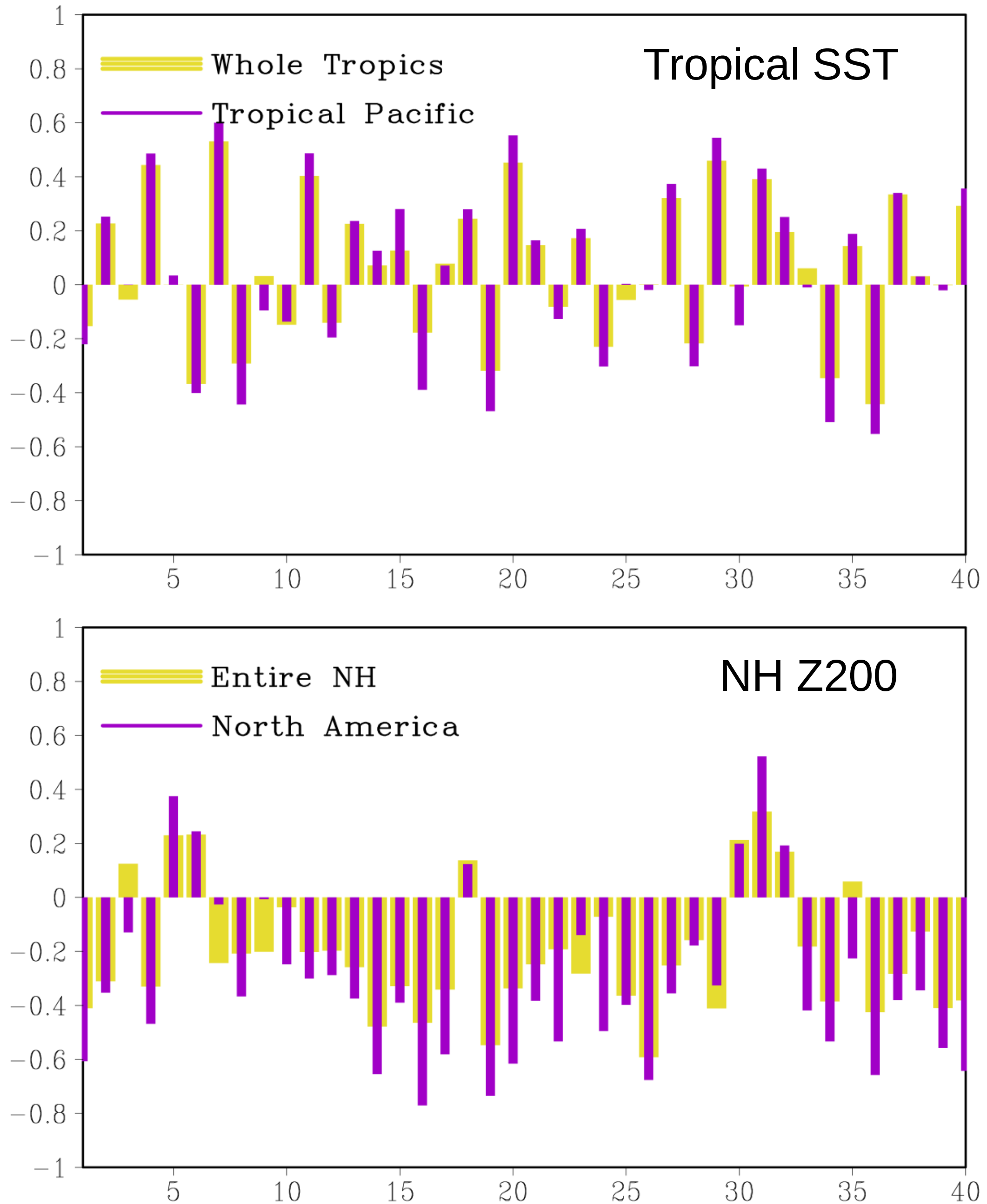
We still have time to save the Arctic, if we work fast!!!

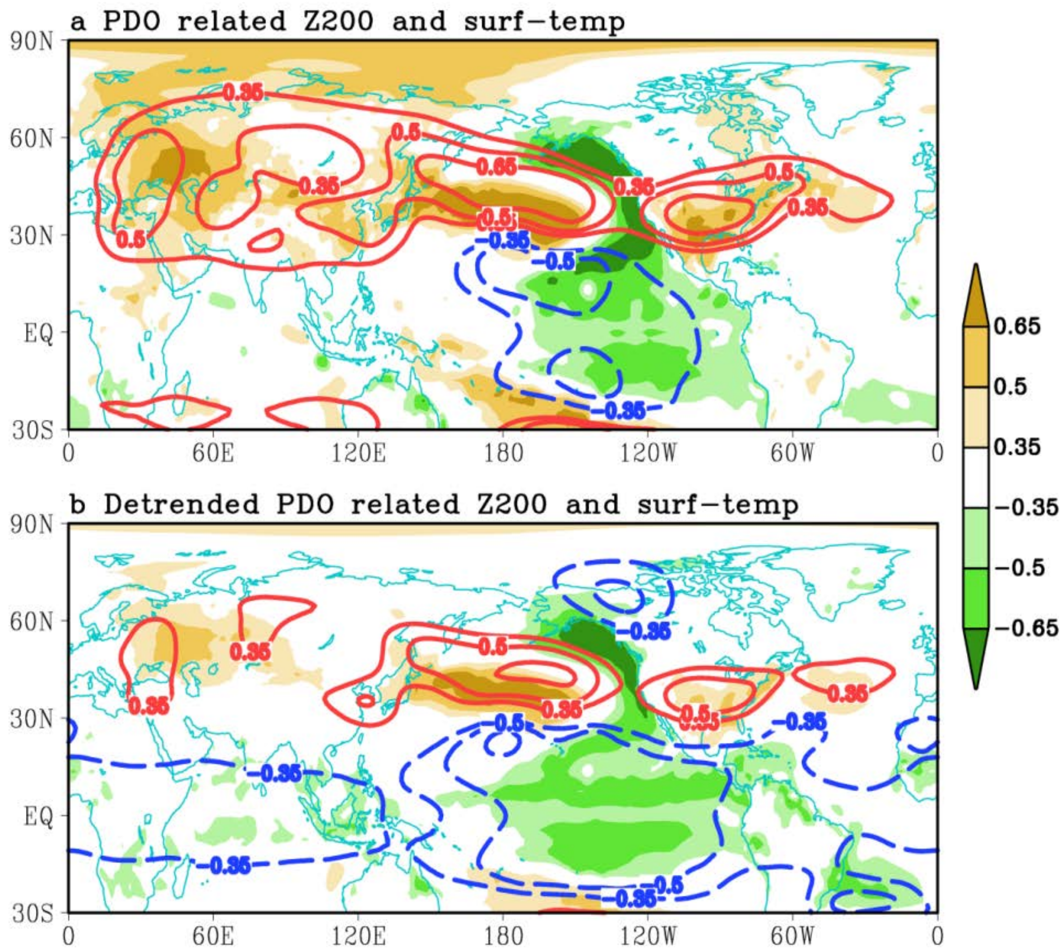
Recent climate change in the Arctic and Antarctic is related to a low-frequency SST variability in the tropical Pacific.

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.

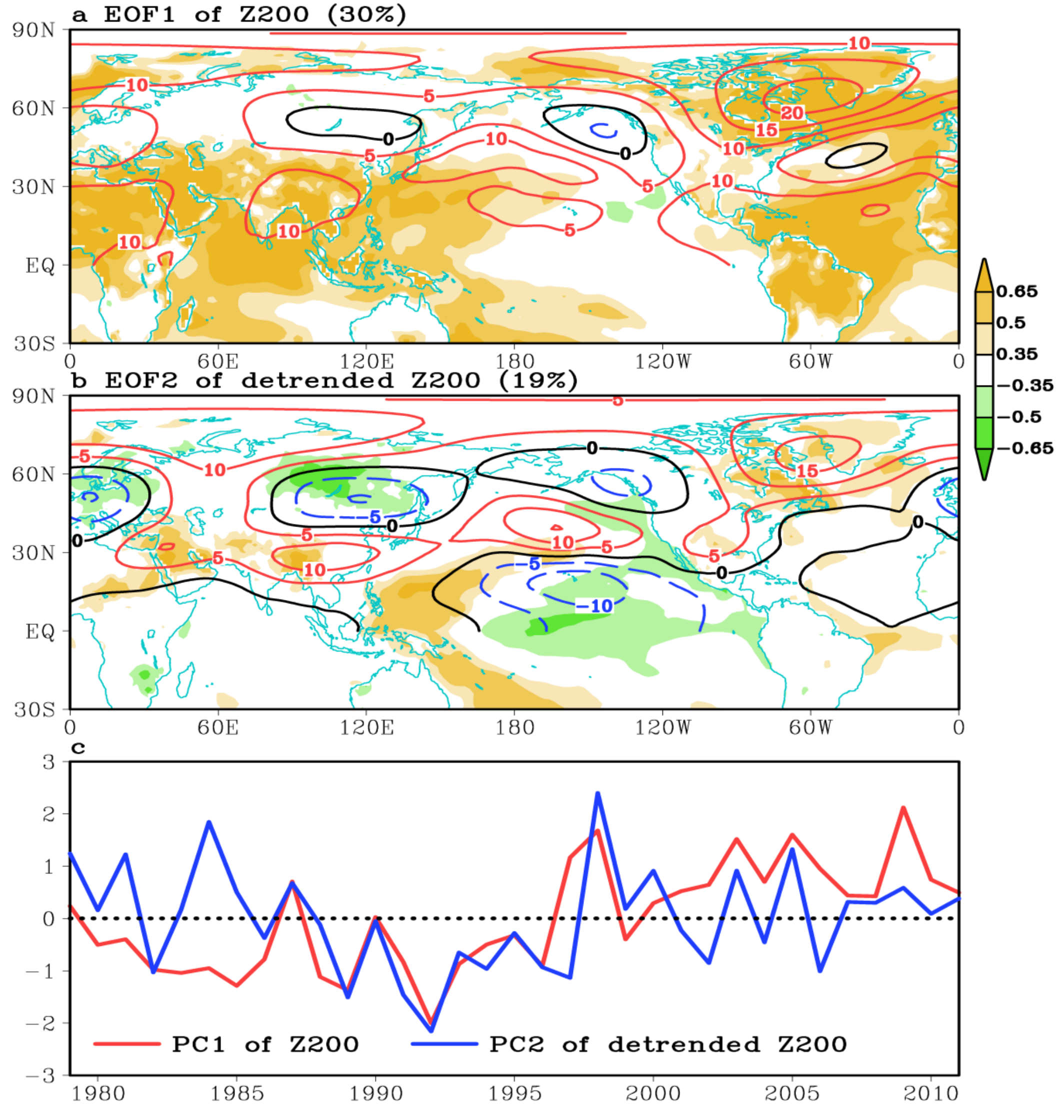
Future projections of how tropical Pacific low-frequency SST variability will change in response to both continued anthropogenic radiative forcing and natural interdecadal variability represents a significant source of uncertainty of projections of the polar climate.

Is there a best-fit model in CMIP5?

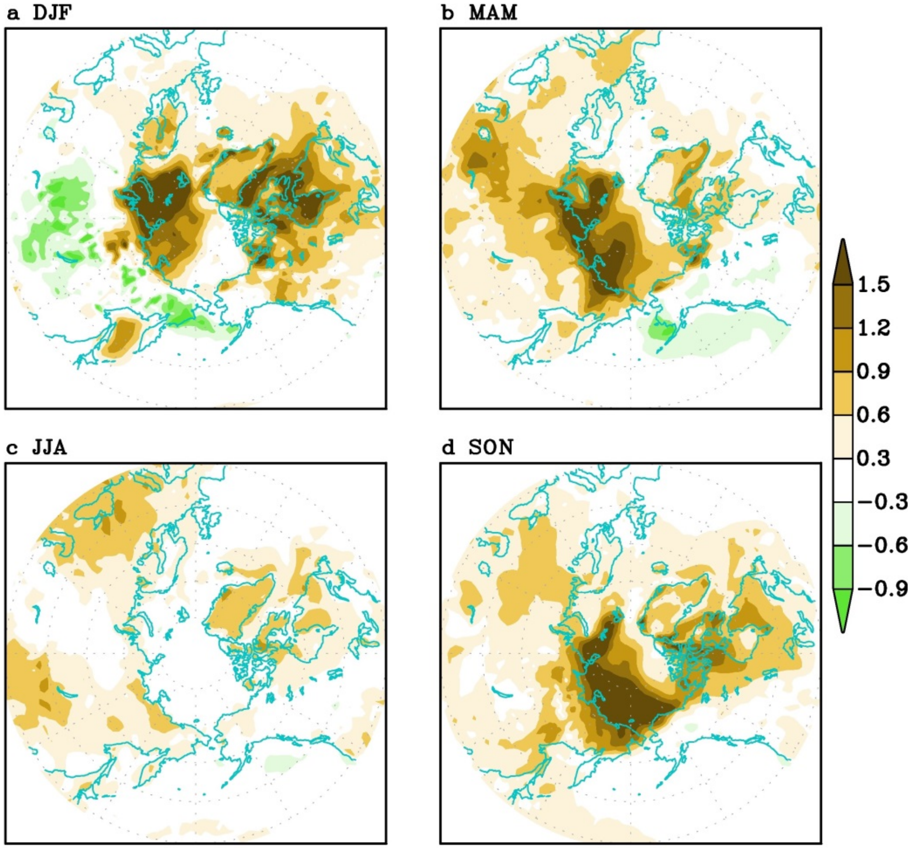




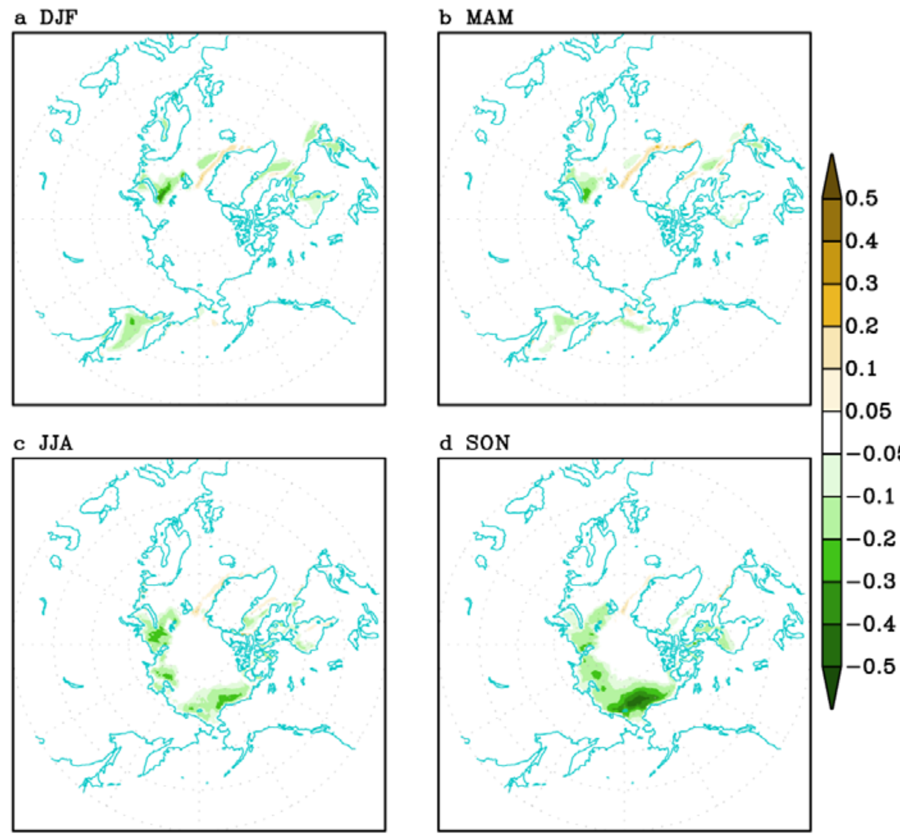
a PDO related Z200 and surf−temp
b Detrended PDO related Z200 and surf−temp
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
0.65
0.5
0.35
−0.35
−0.5
−0.65


a EOF1 of Z200 (30%)
90N
60N
30N
EQ
30S
0
60E
120E
180
120W
60W
0
b EOF2 of detrended Z200 (19%)
0.65
0.5
0.35
−0.35
−0.5
−0.65
c
3
2
1
0
−1
−2
−3
PC1 of Z200
PC2 of detrended Z200
1980
1985
1990
1995
2000
2005
2010

Surface temperature trend
(1979-2012)

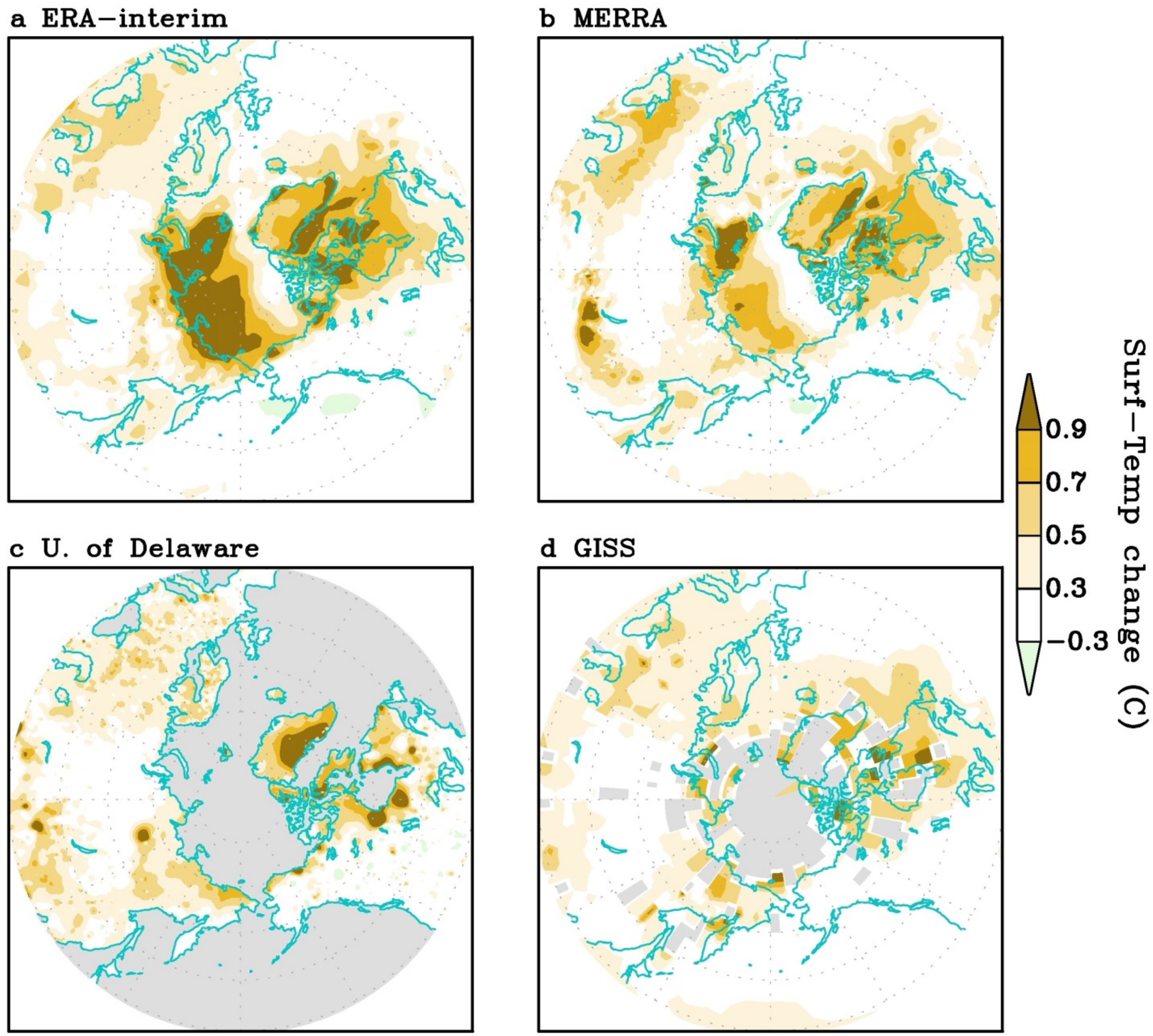


Sea ice trend
(1979-2012)



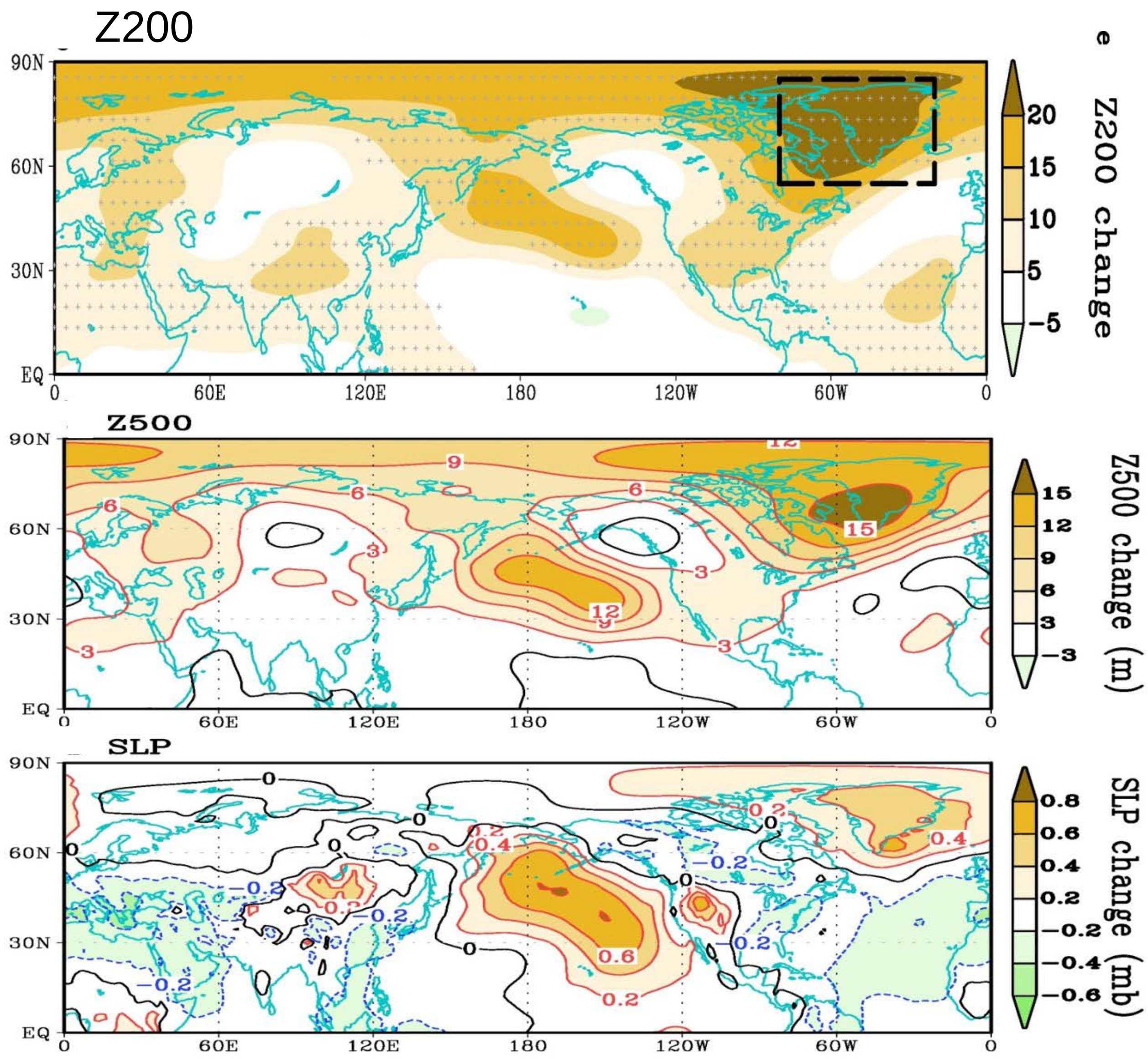
Maximum regional warming occurs in non-melting season

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