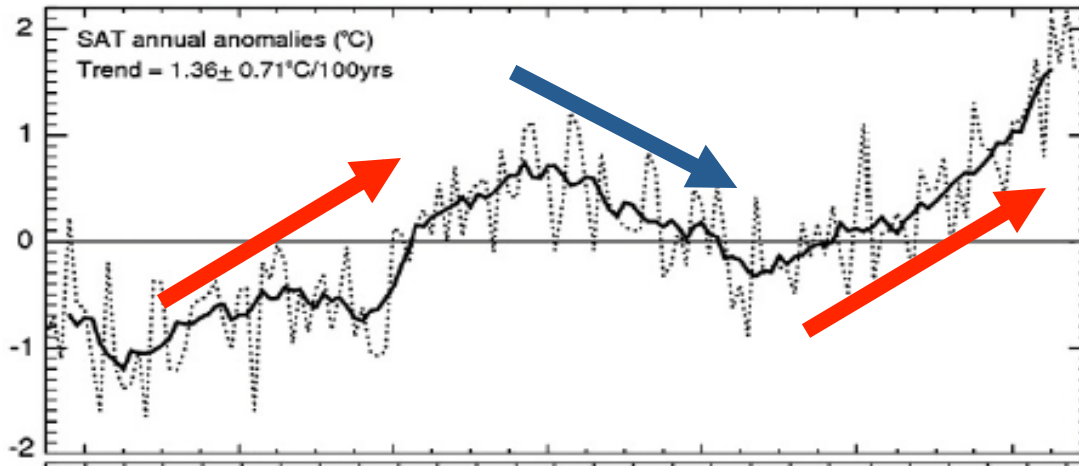
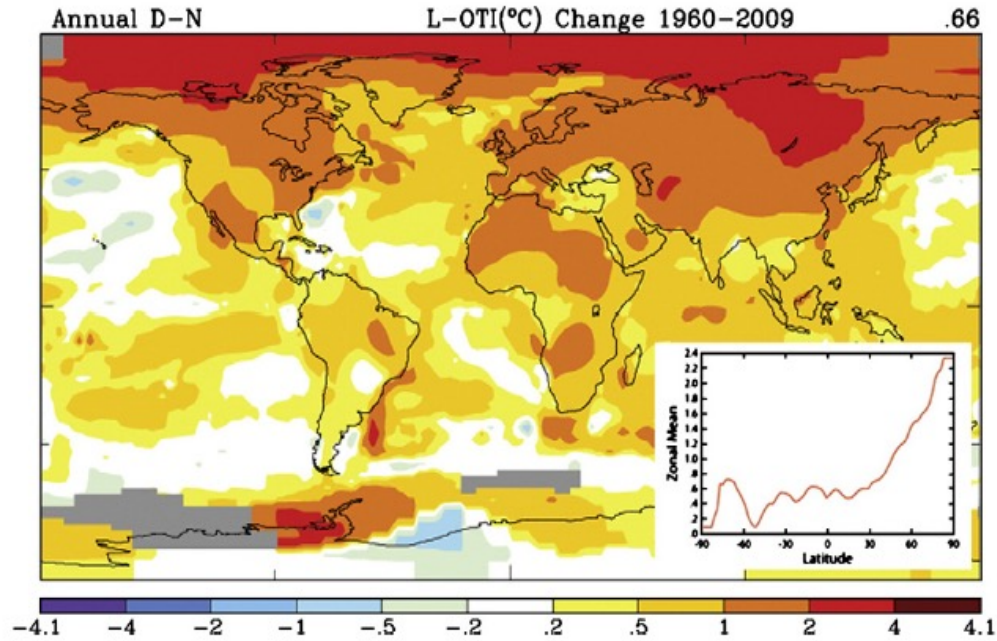


A mechanism linking the Arctic to the tropics

Qinghua Ding, David Battisti, Eric Steig and Axel Schweiger

University of Washington

The fastest warming rate in the Arctic and Antarctic Peninsula



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.]

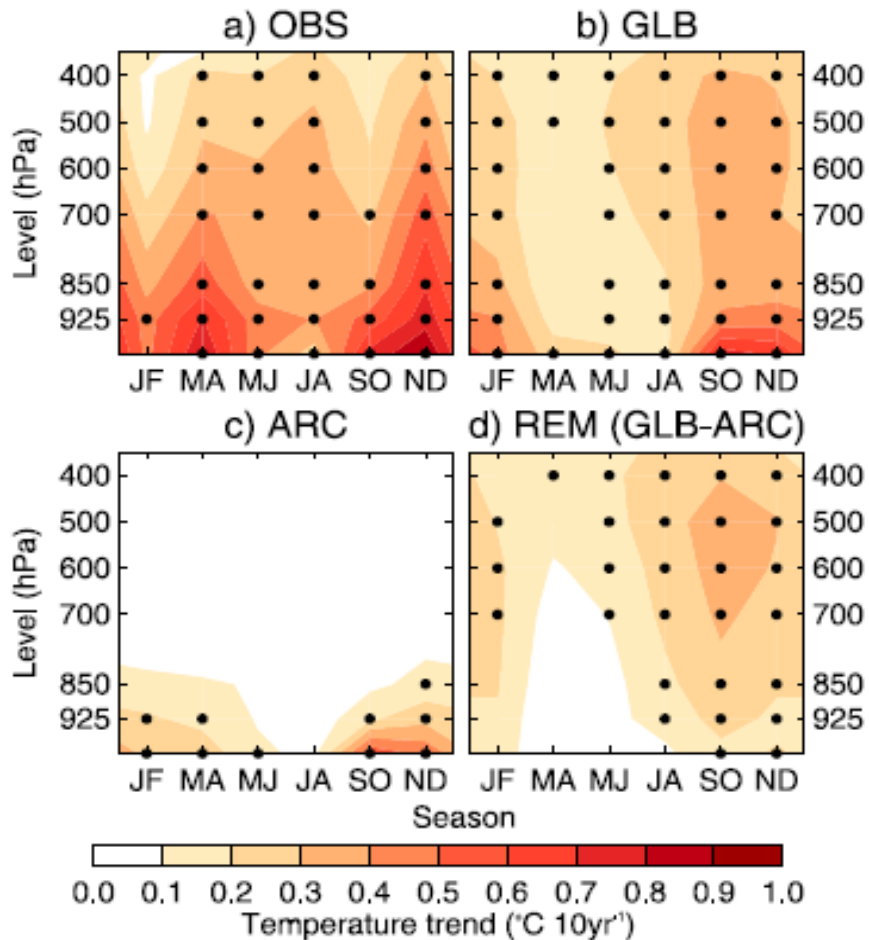
APRIL 1896.

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

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; Bengtson et al., 2004; Woodgate et al., 2006; Shimada et al., 2006; Chylek et al., 2009

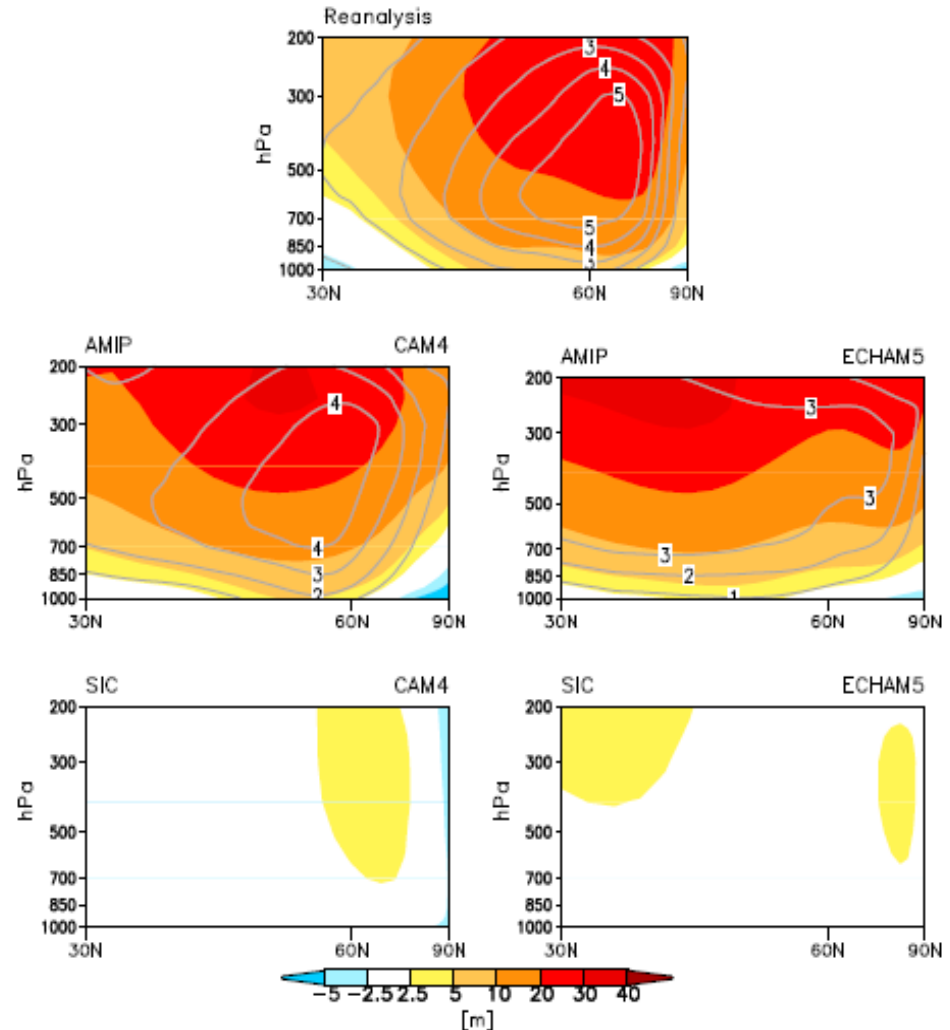
Impact of remote SST on Arctic warming

Temperature



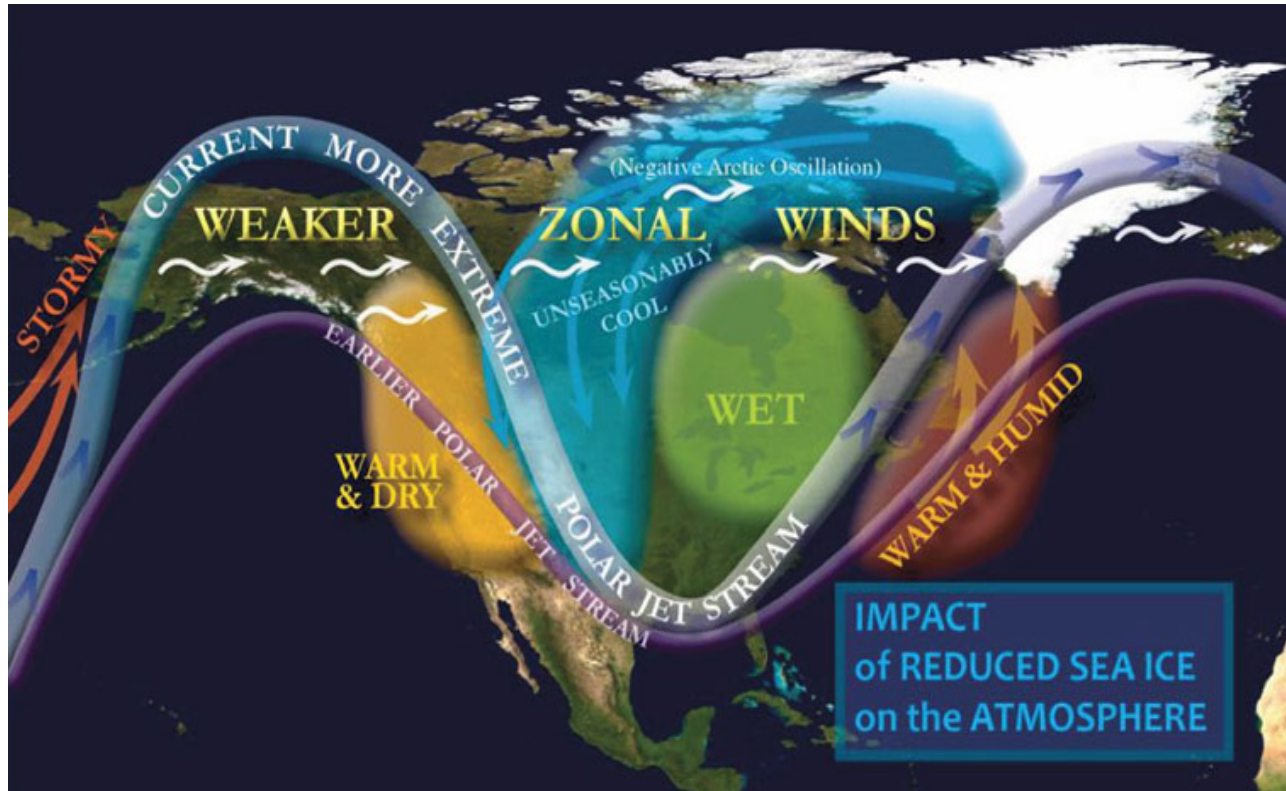
Screen et al 2014

Geopotential heights



Perlwitz et al. 2015

Arctic warming and extreme events



Francis and Vavrus 2012

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

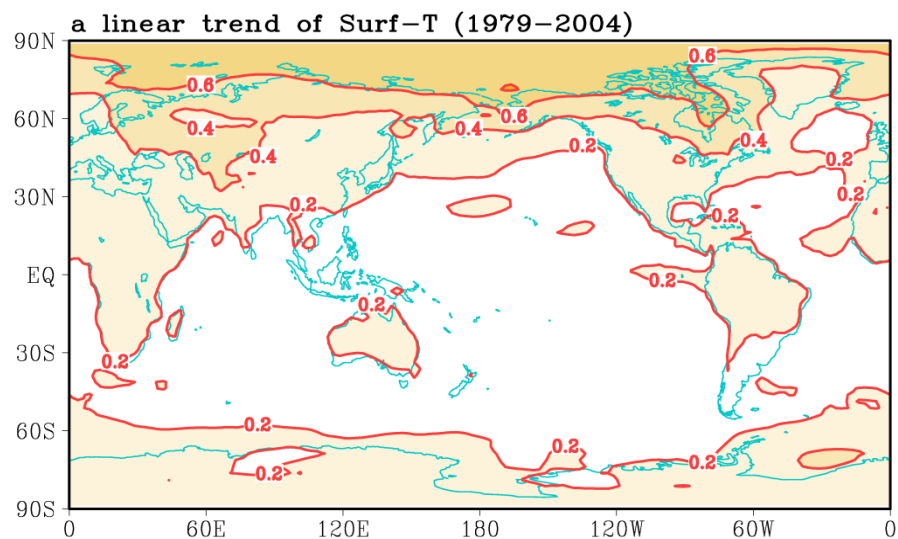
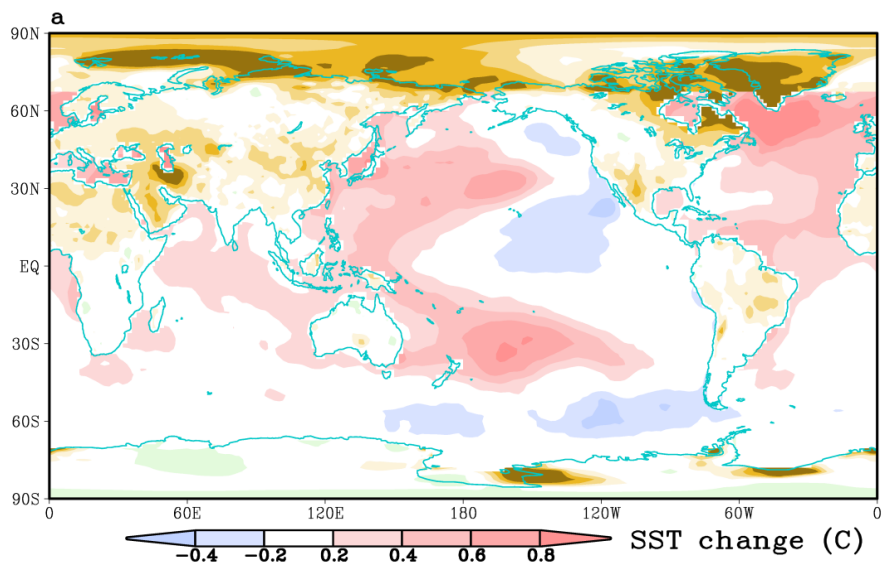
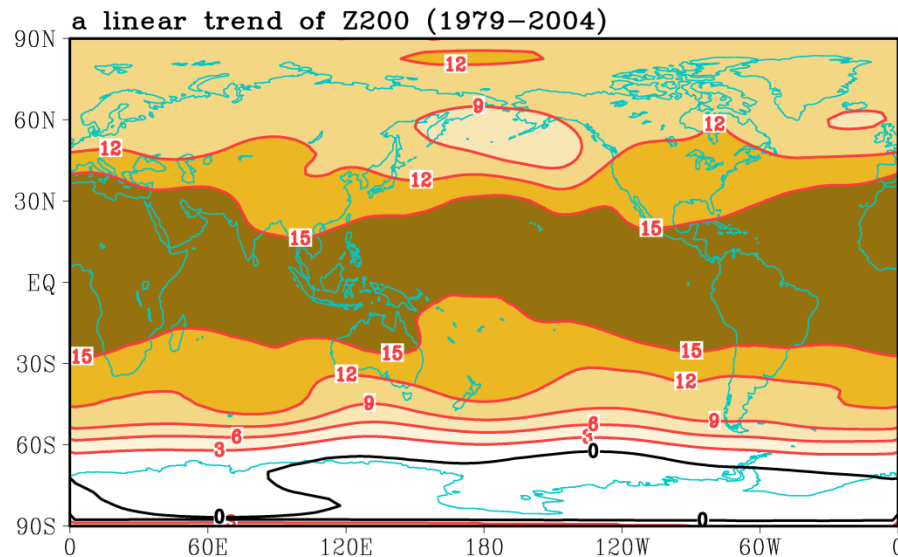
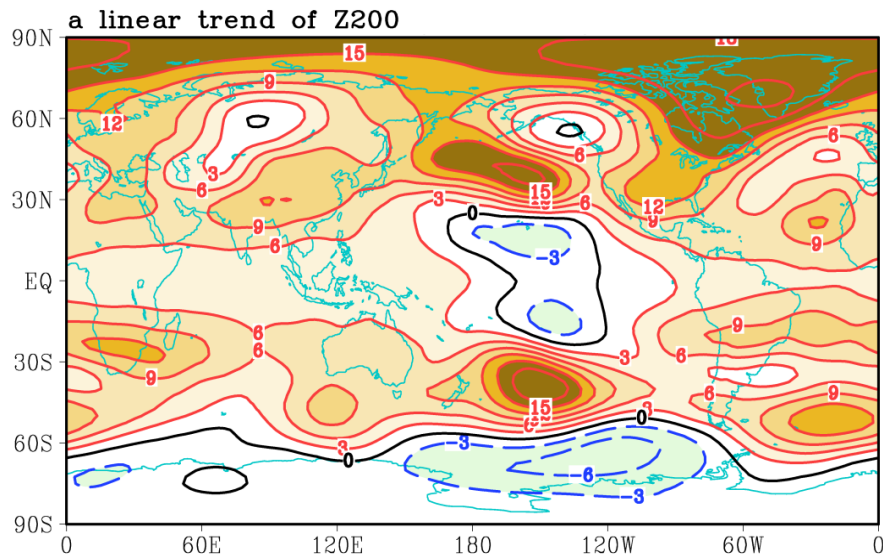
- DATA
- Reanalysis : **ERA-interim** (1979-2012) , ERA40 (1958-1978), NCEP II (1979-2012) , NCEP (1948-2012), MERRA(1979-2012), NOAA 20th reanalysis
 - SST & sea ice: **ERSST3**, HADISST, Kaplan, COBE
 - Surface temperature: GISS-TEMP, Delaware, CRU, ERA-interim, MERRA, AVHRR
 - IPCC AR5 historical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

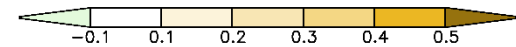
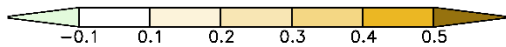
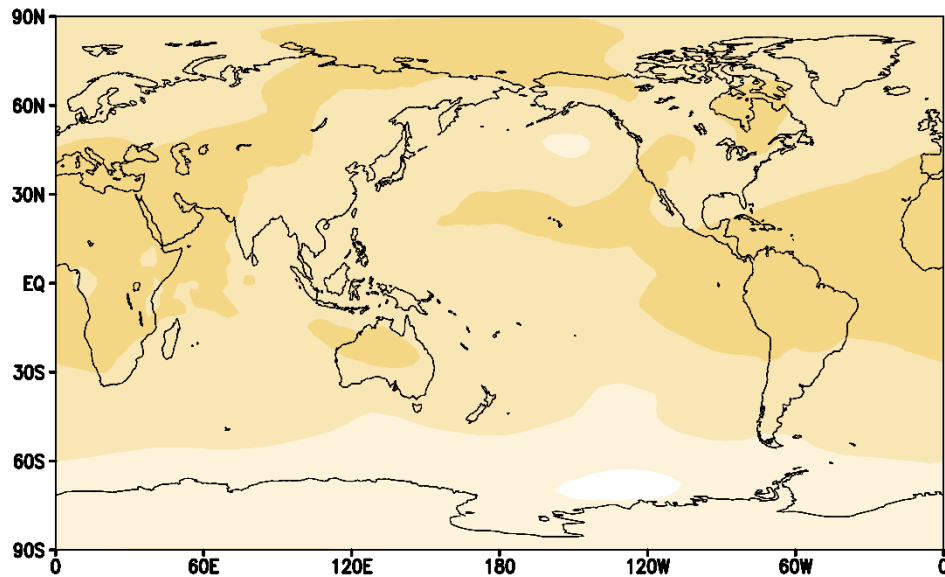
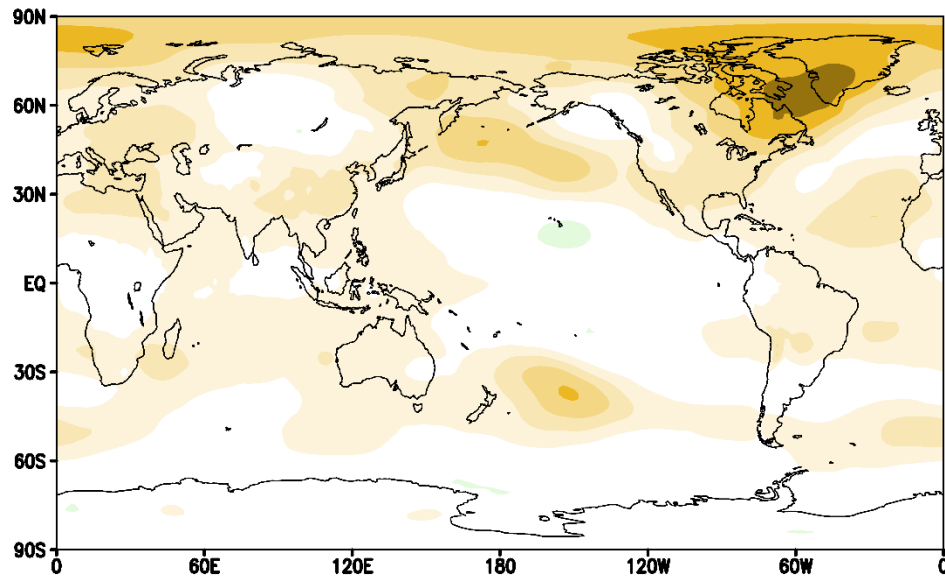


Internal variability vs forced response

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

Reanalysis

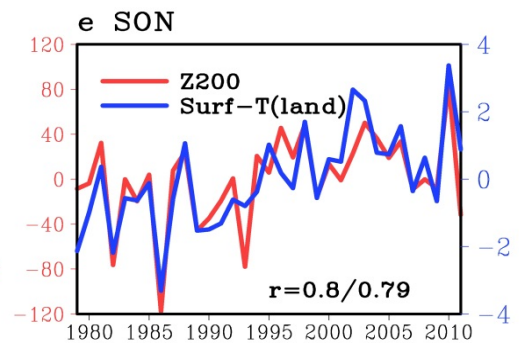
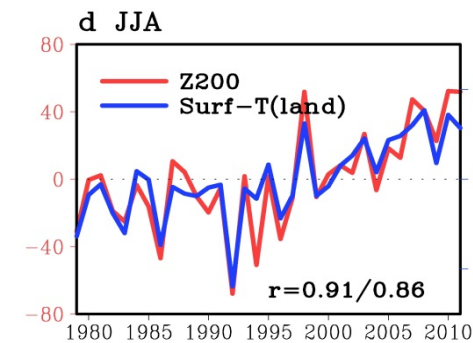
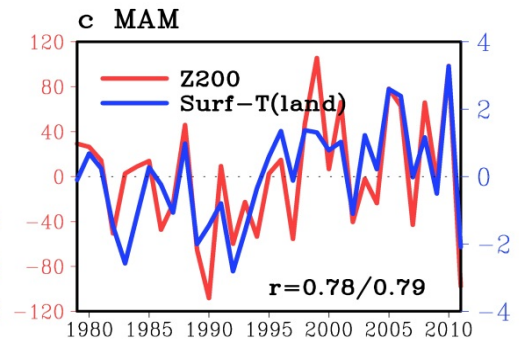
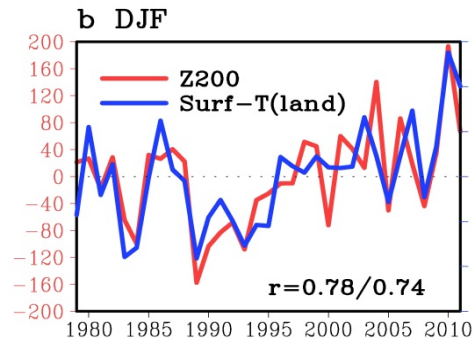
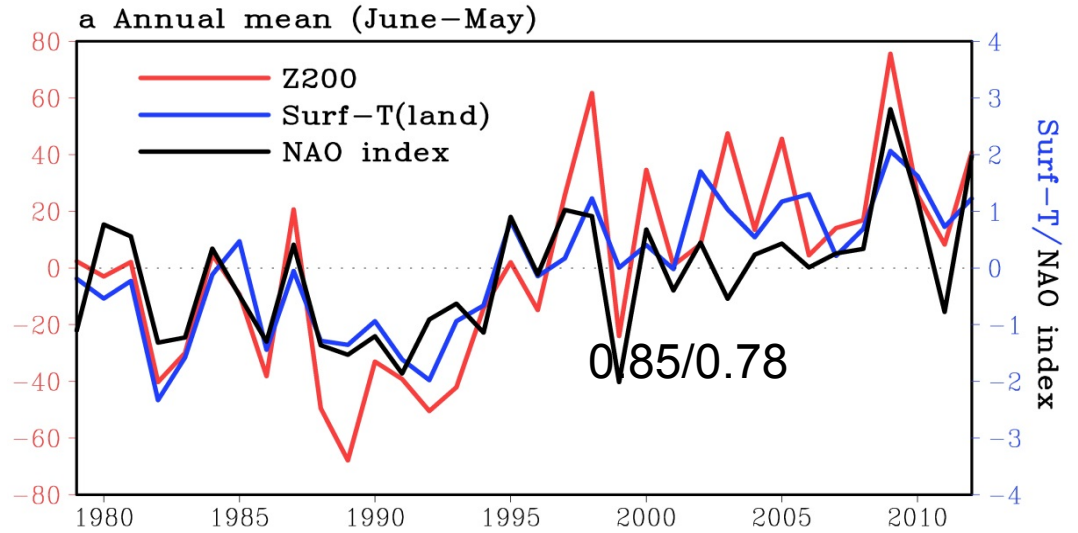
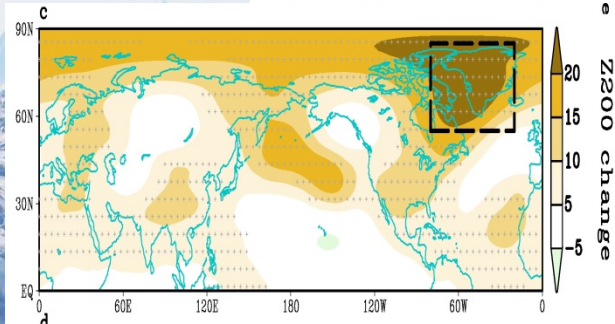
CMIP5



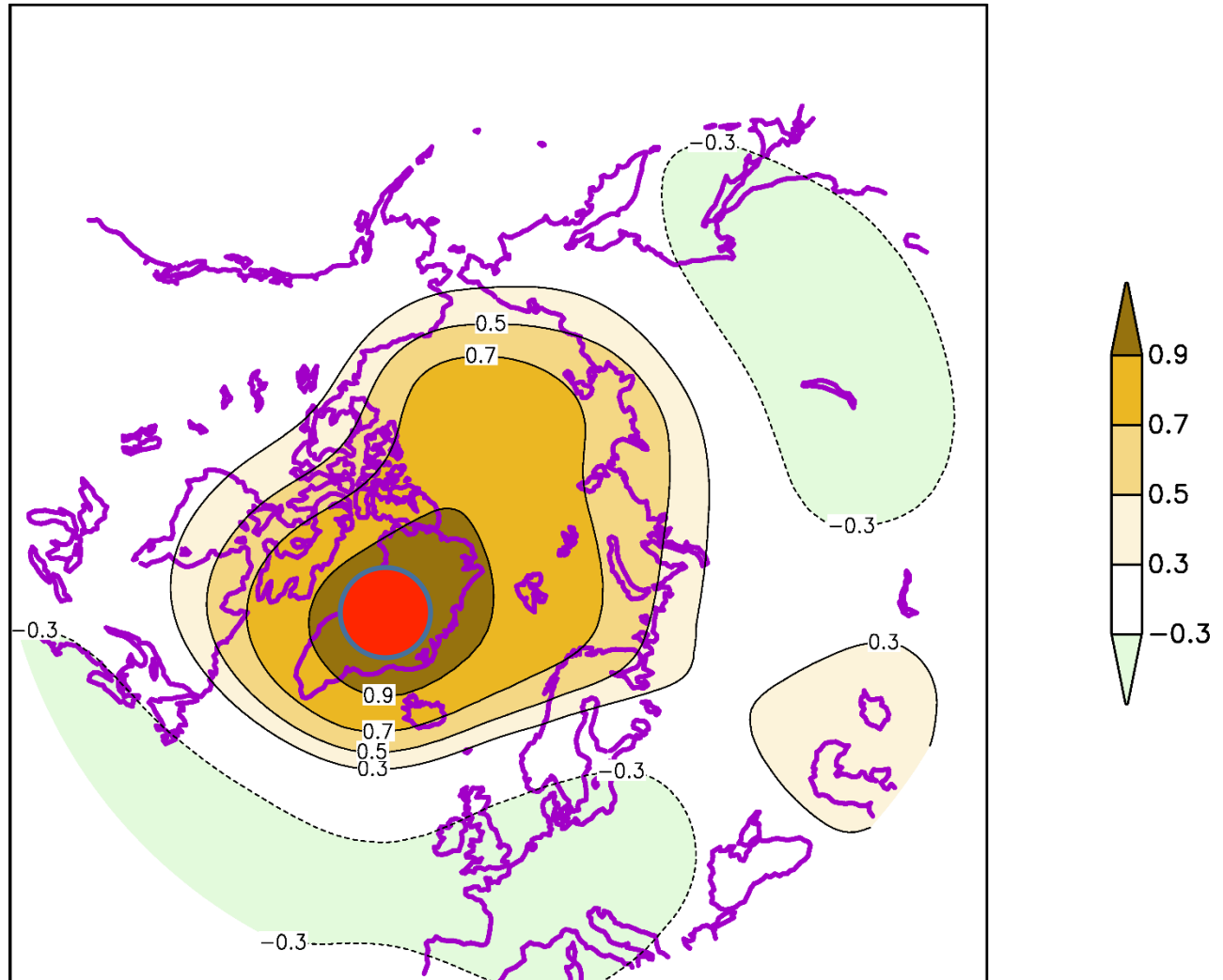
c/decade



Interdecadal-like change

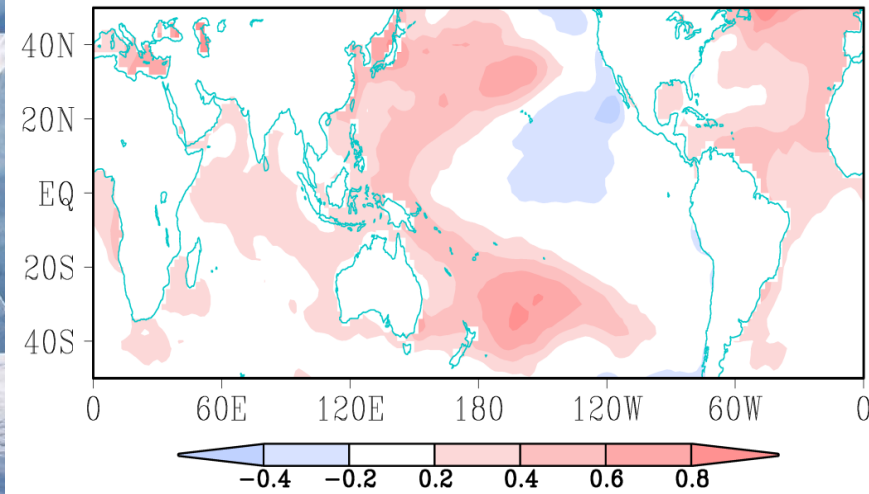


Correlation of NH Z200 with Z200 over Greenland (Detrended)

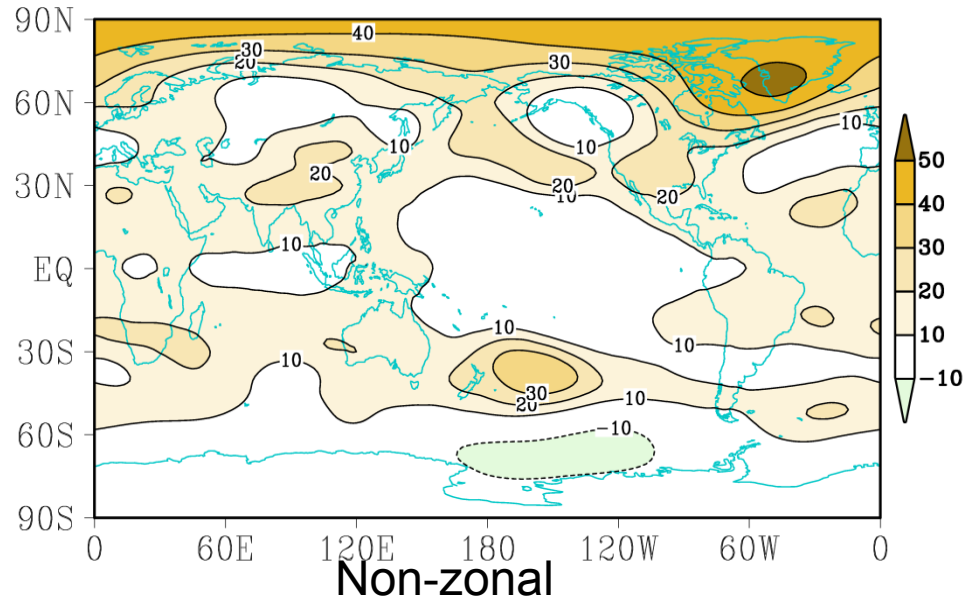


Annual mean SST and Z200 change (1996-2013 minus 1979-1995)

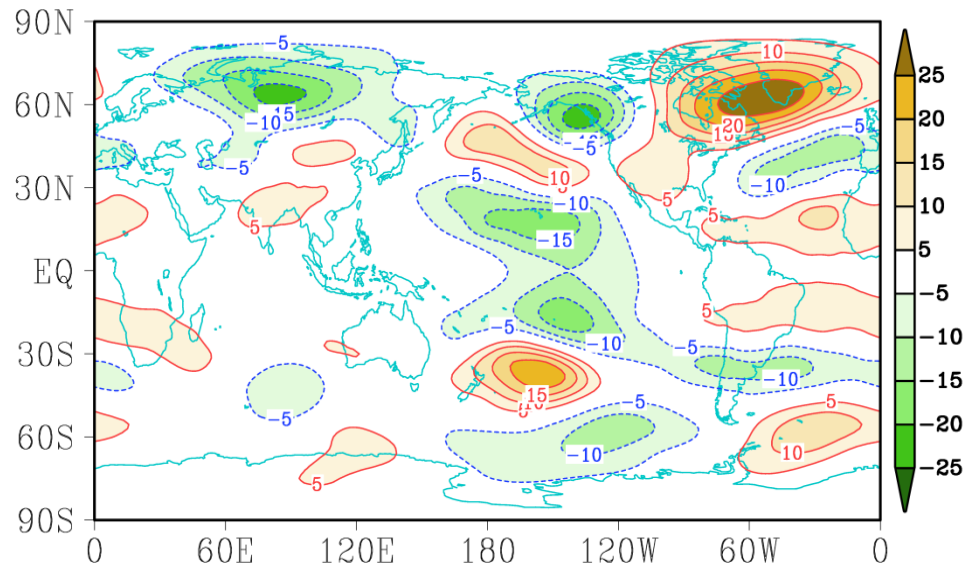
SST change



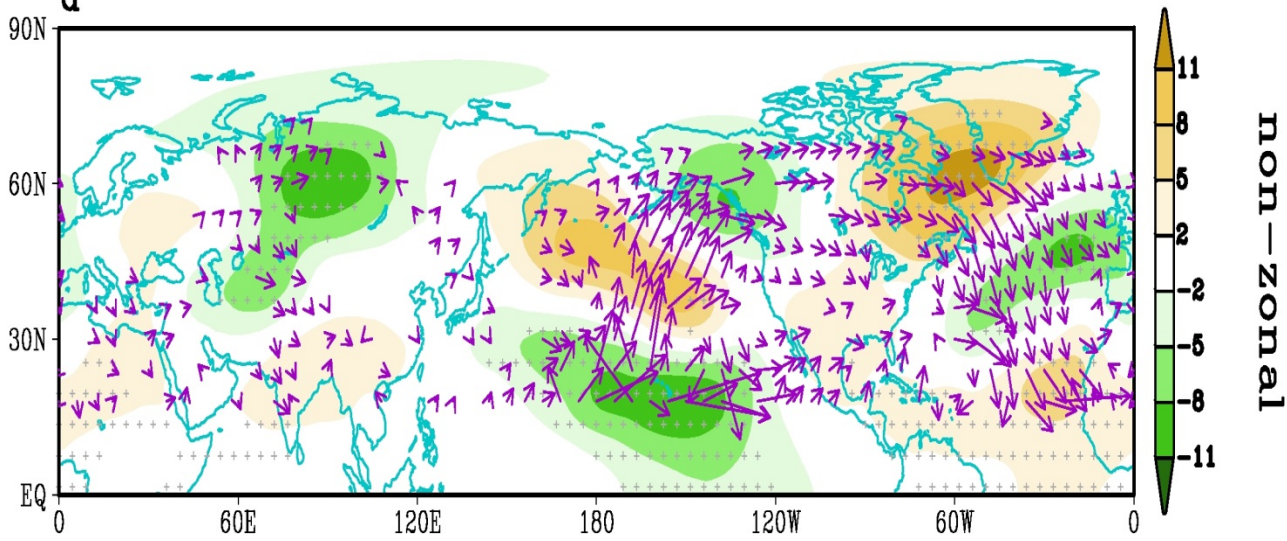
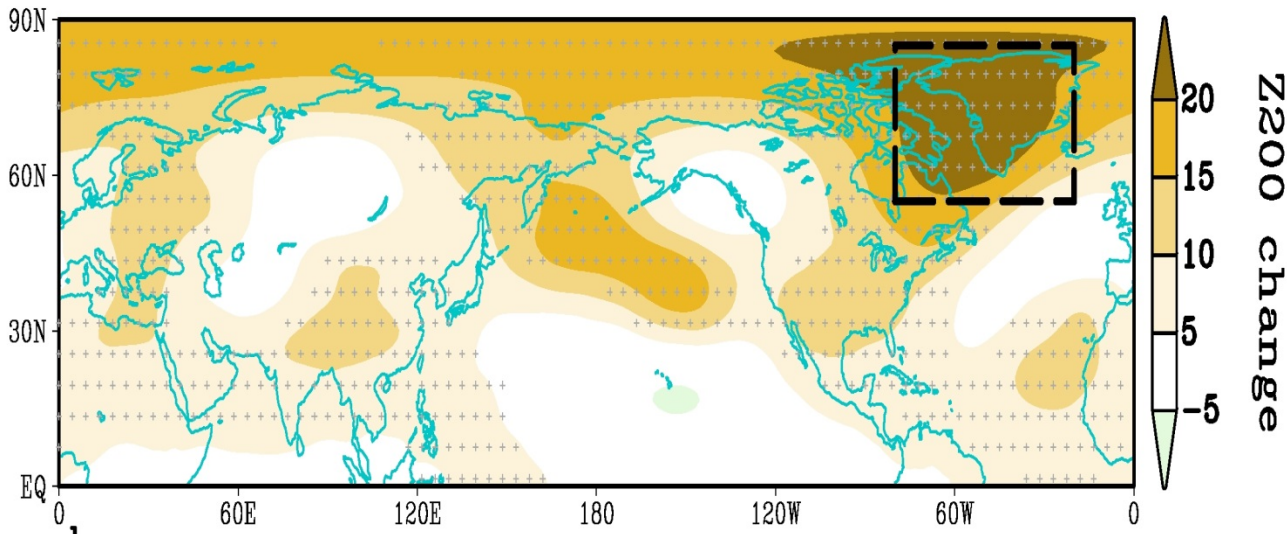
Z200 change



Non-zonal



Annual mean Z200 trend (1979-2013)



the Arctic is running a tropical fever

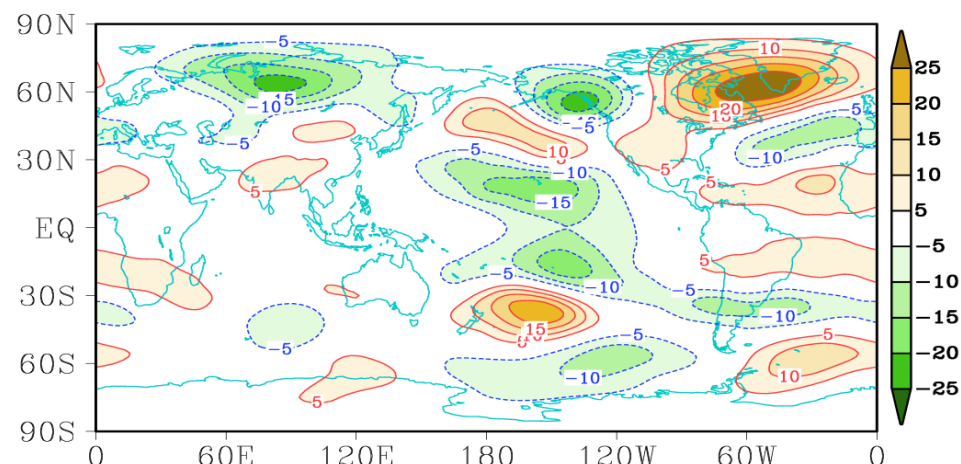
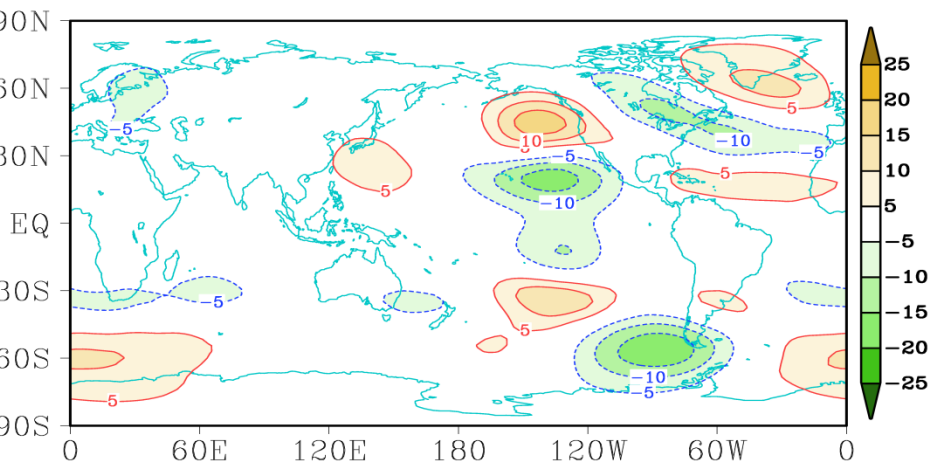
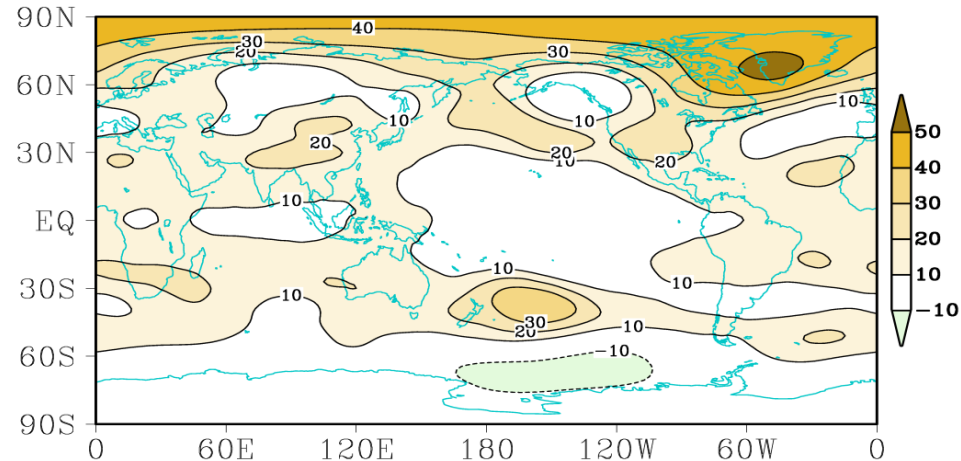
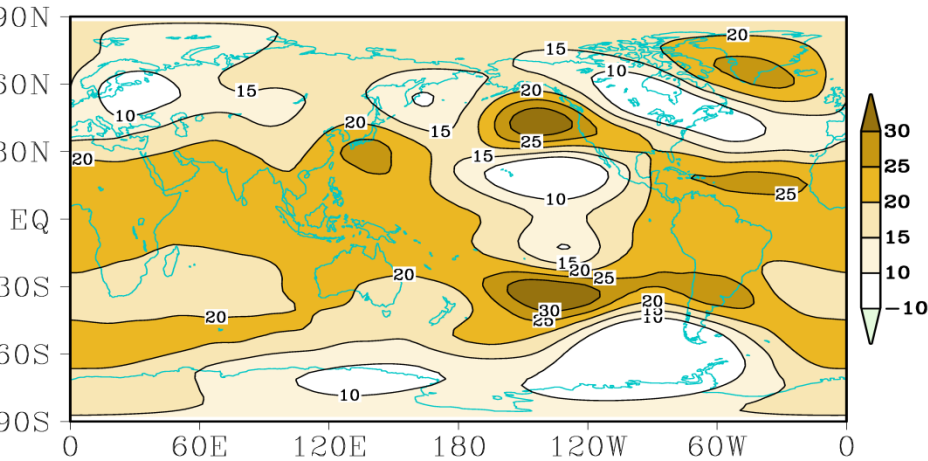
Plumb flux 1985



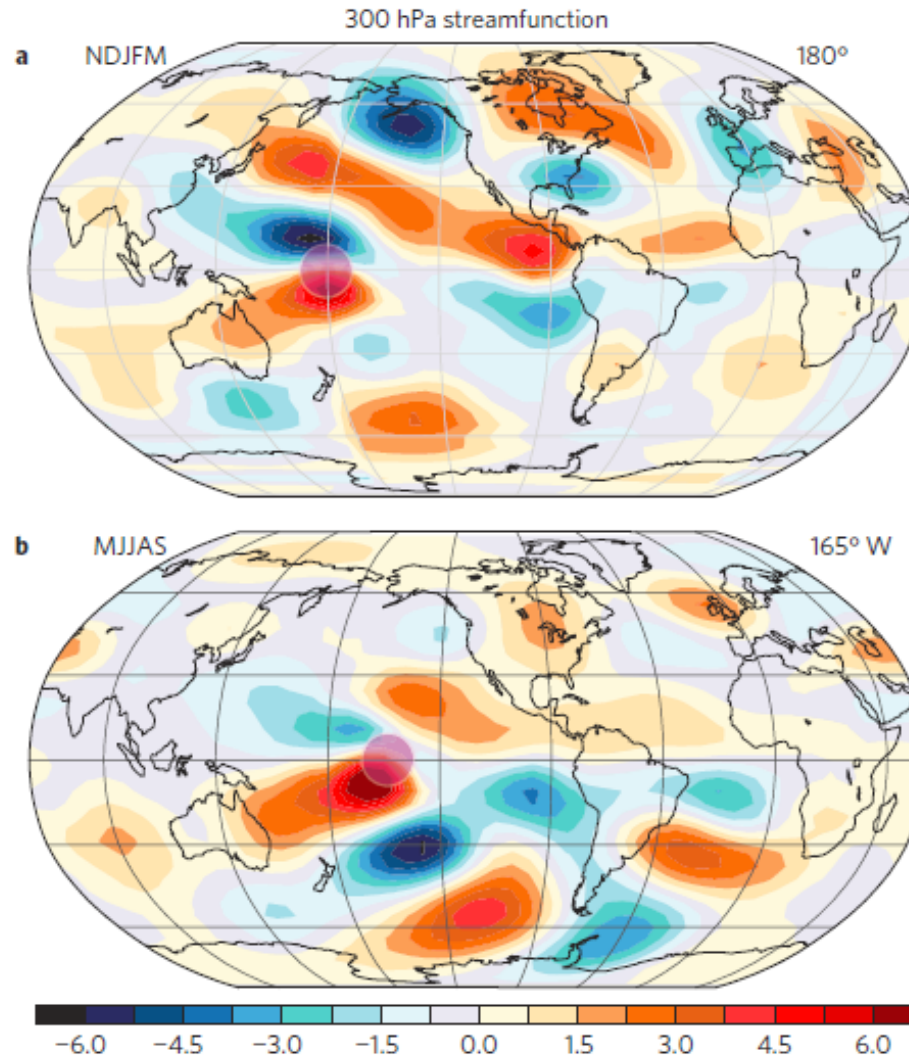
Annual mean Z200 change (1996-2013 minus 1979-1995)

ECHAM4 Simulation

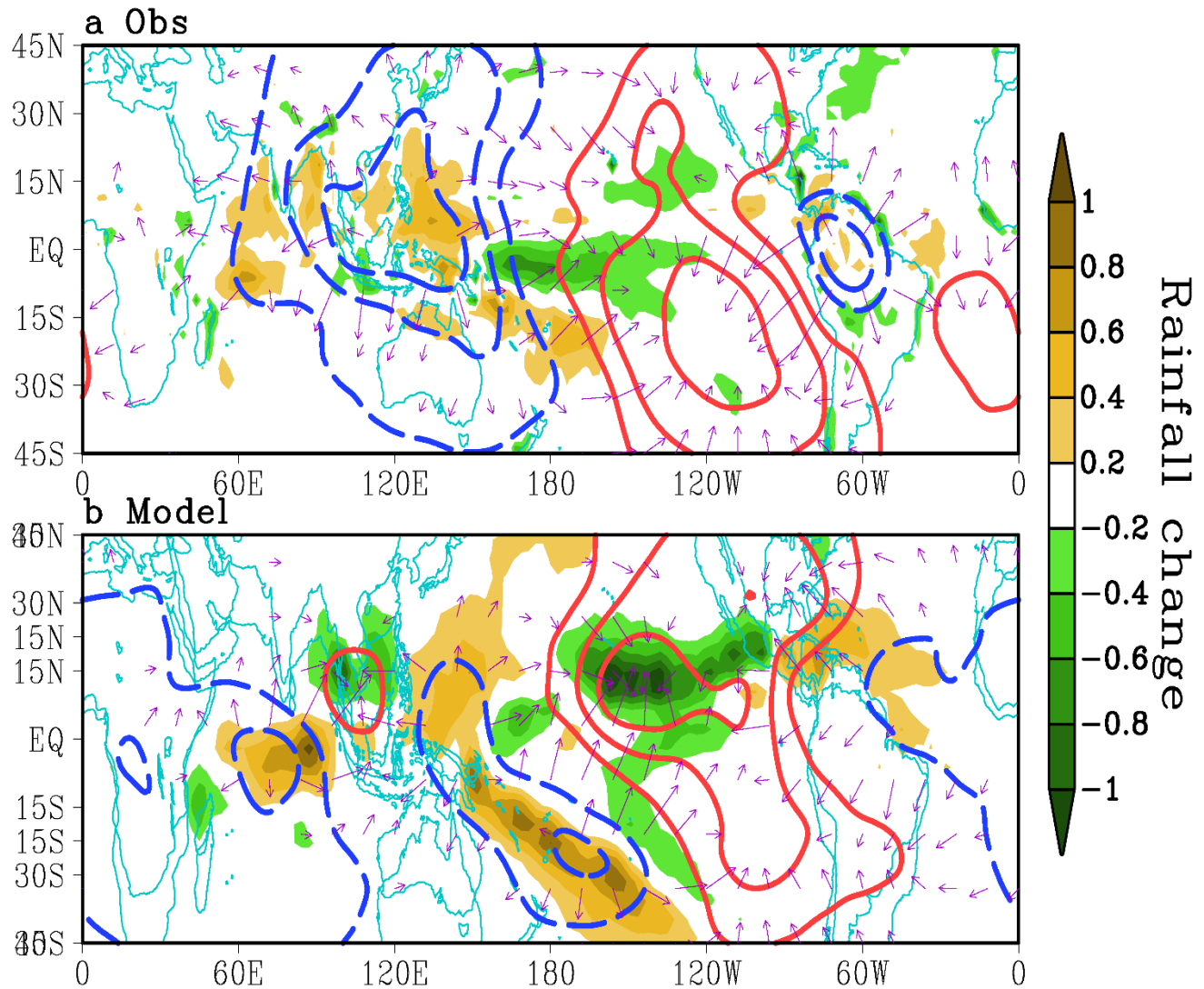
observation



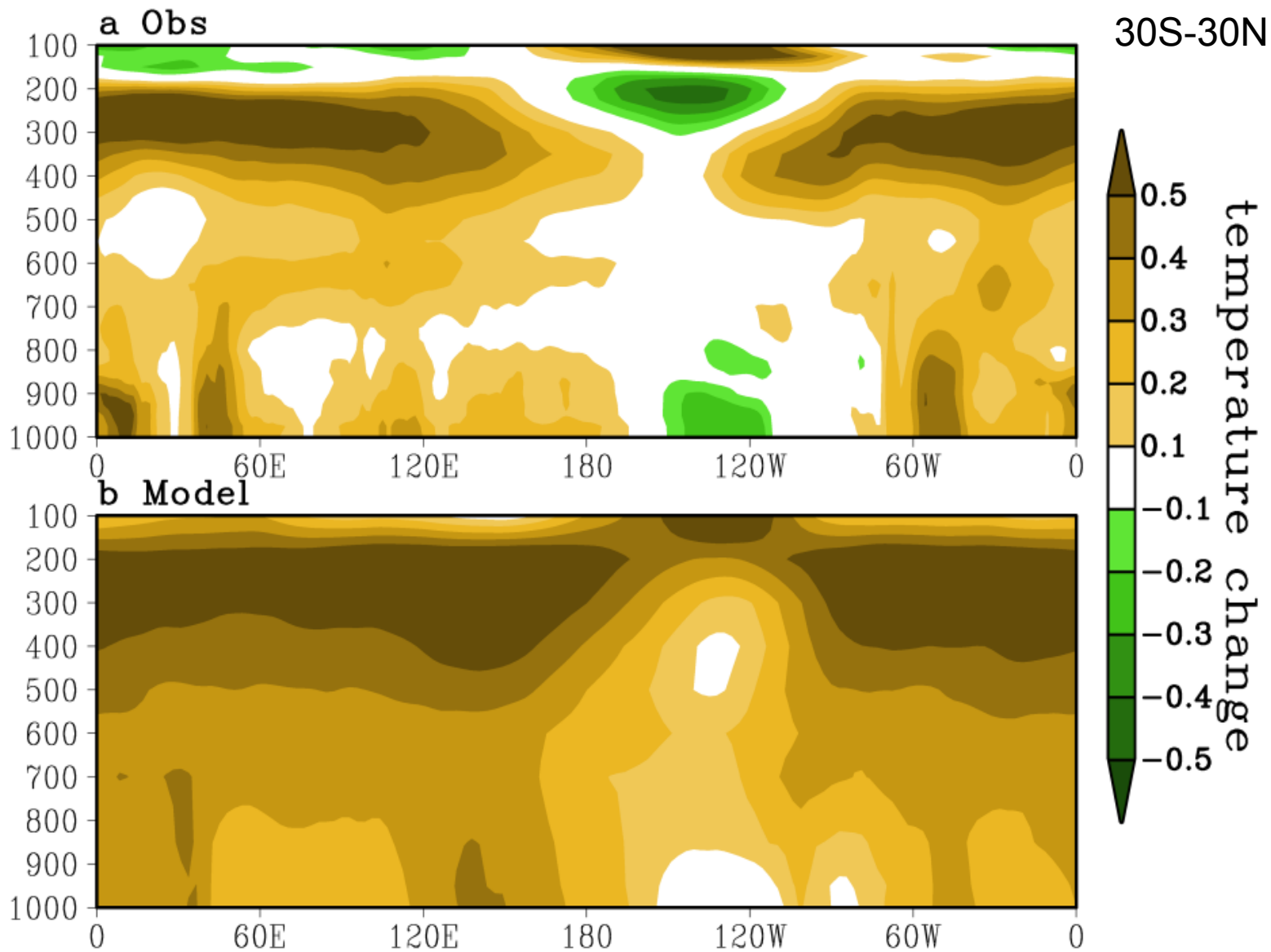
CAM model response to tropical heating anomalies



Annual mean rainfall trend in 1979-2013



Annual mean tropical temperature trend in 1979-2013

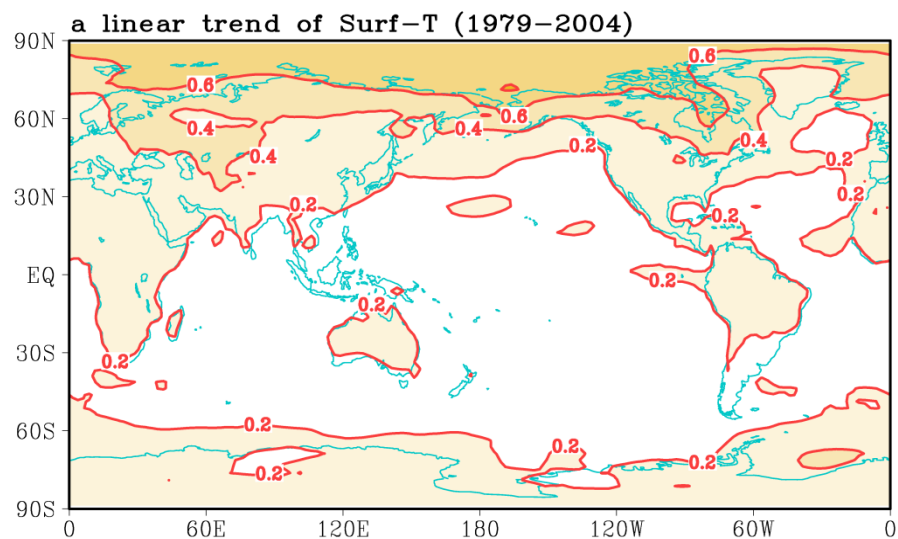
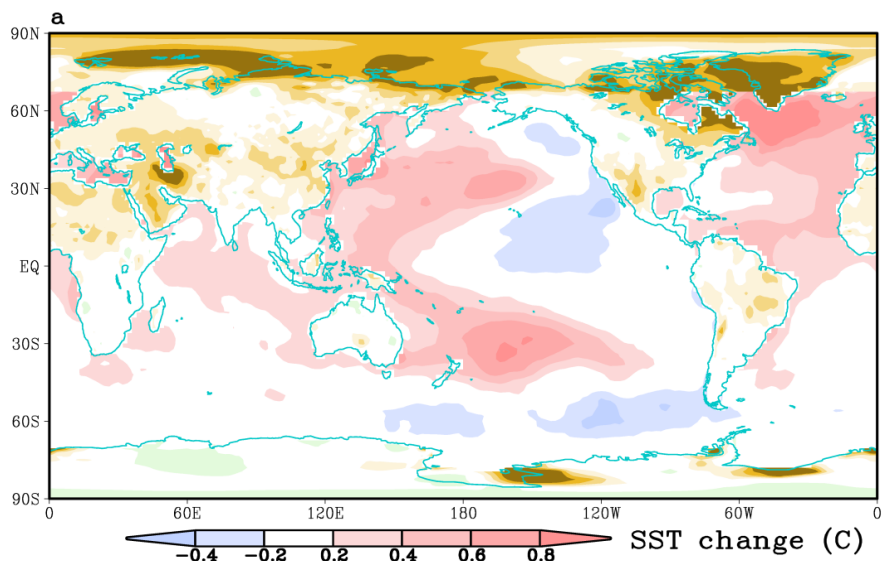
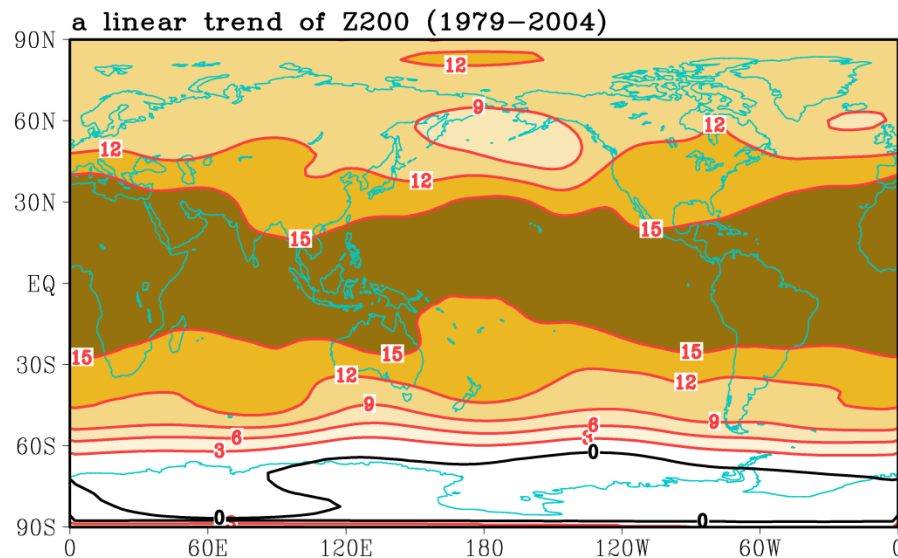
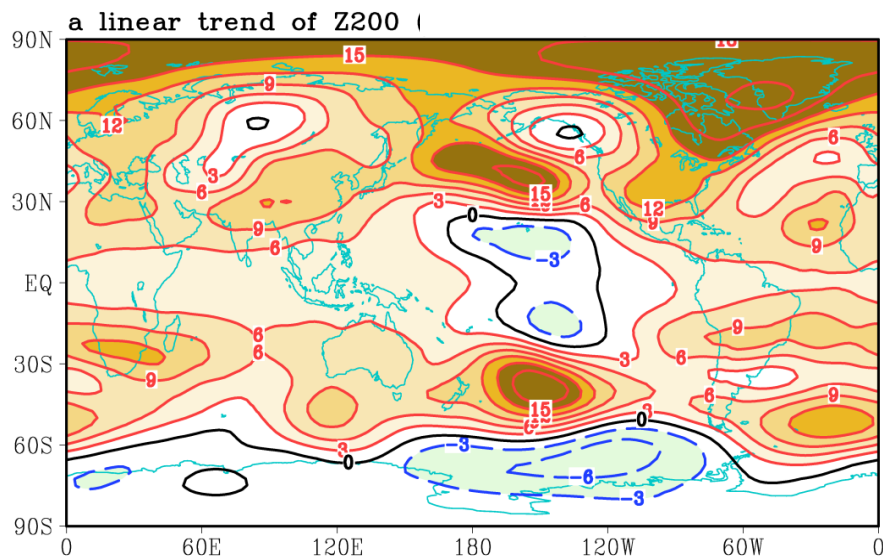


Internal variability vs forced response

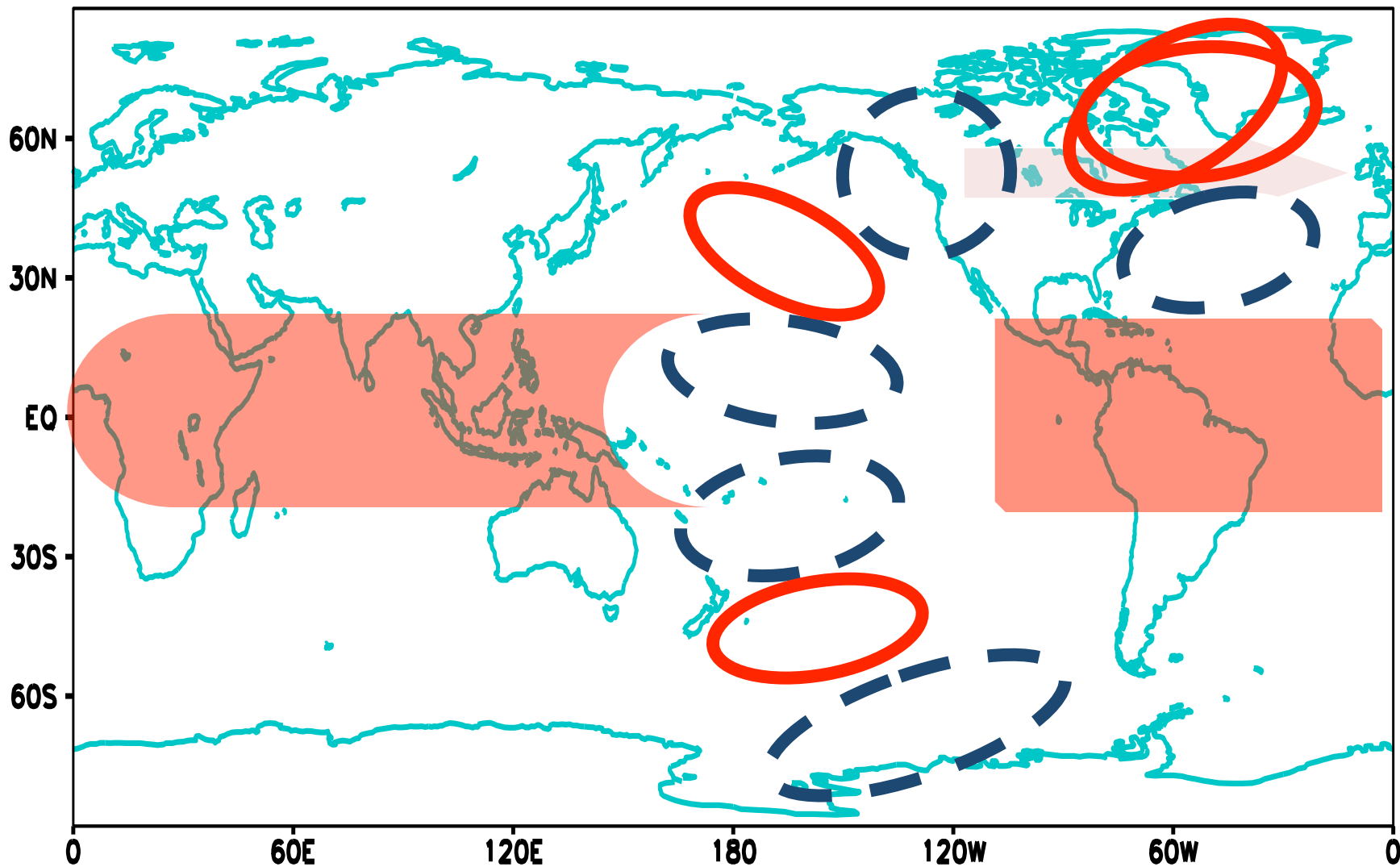
Annual mean
m/decade

Reanalysis (1979-2013)

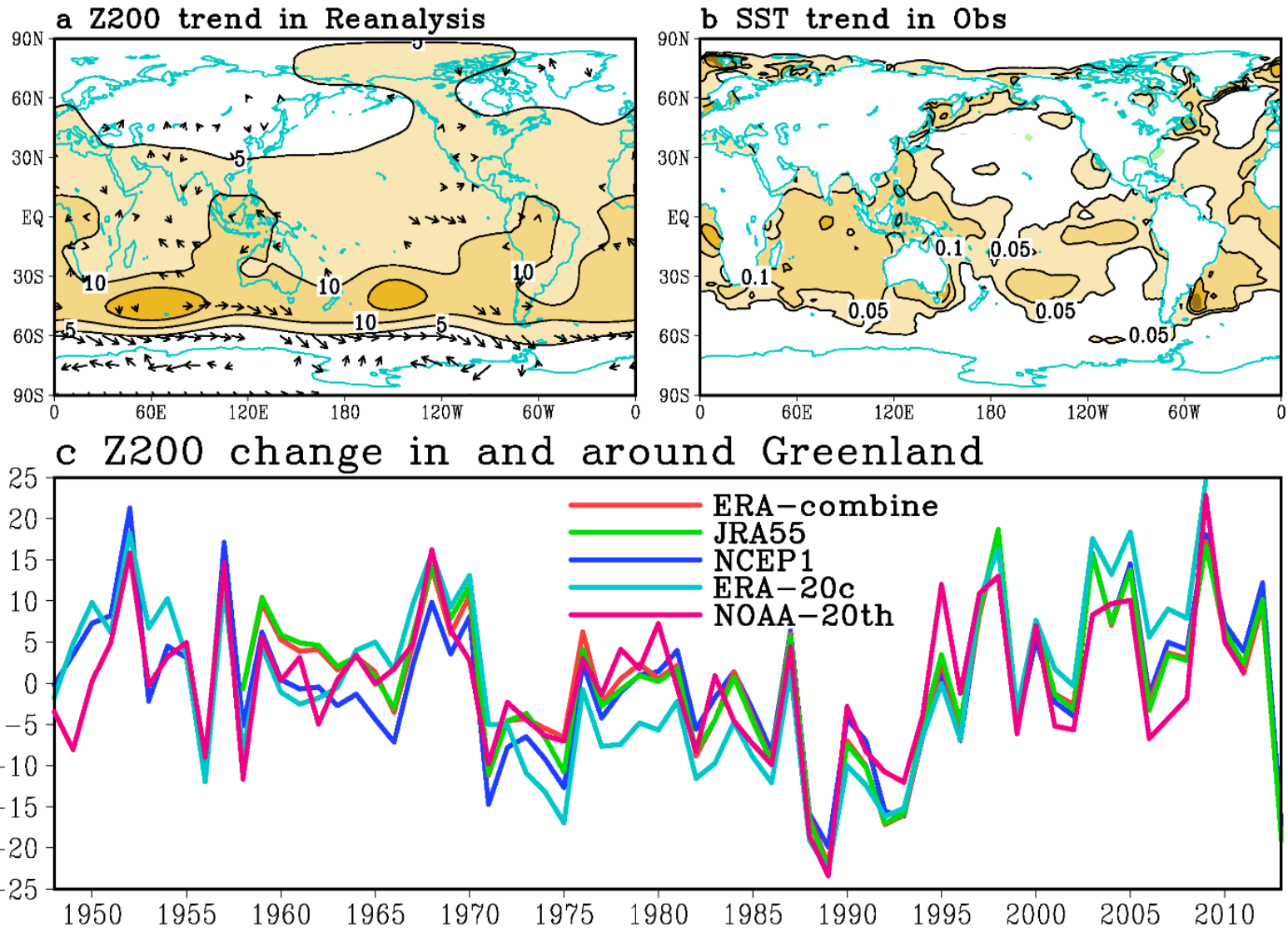
IPCC AR5 historical run (ensemble mean of 40 model)



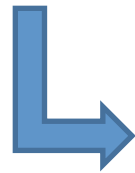
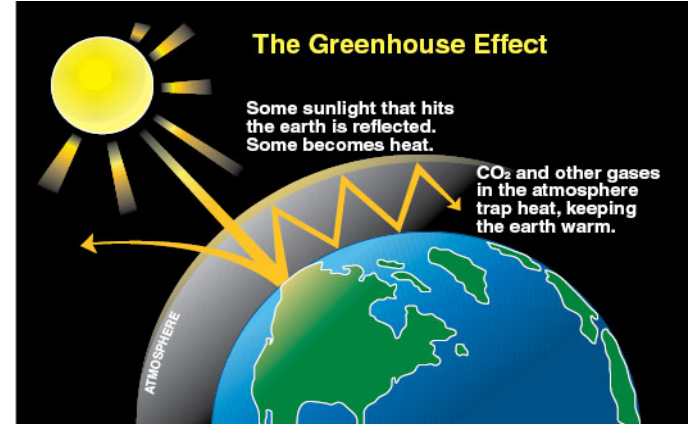
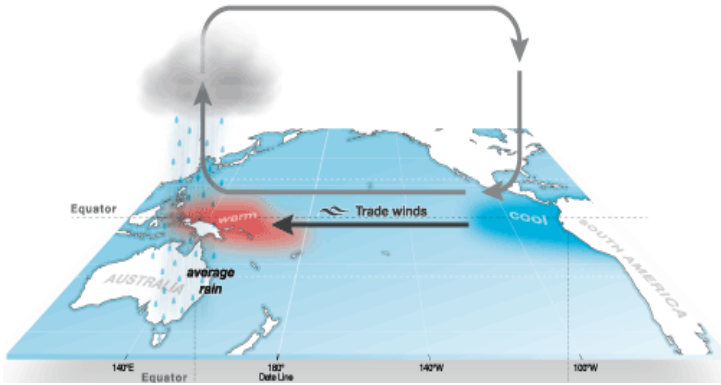
How is the tropical forcing causing polar warming?



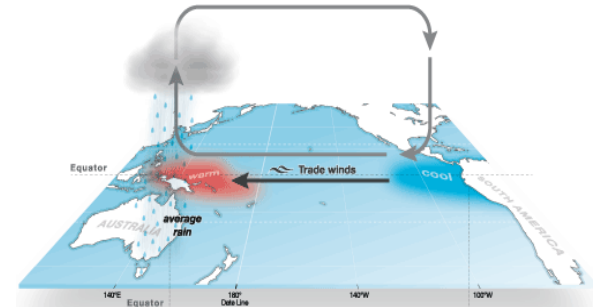
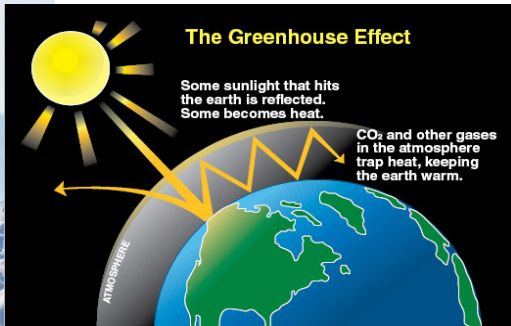
Long term trend of Z200 and SST over 1948-2013



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



Arctic warming vs tropical forcing



Global warming

Arctic warming

Midlatitude wavy flow

Extreme events

Tropical internal

Midlatitude wavy flow

Extreme events

Arctic change

Global warming

Take-home message

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

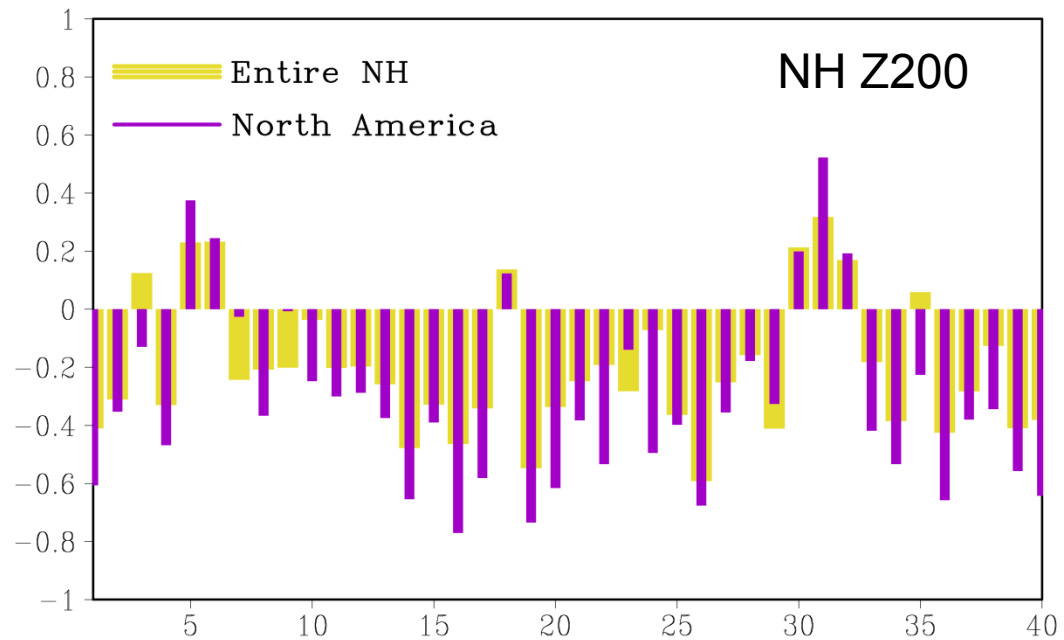
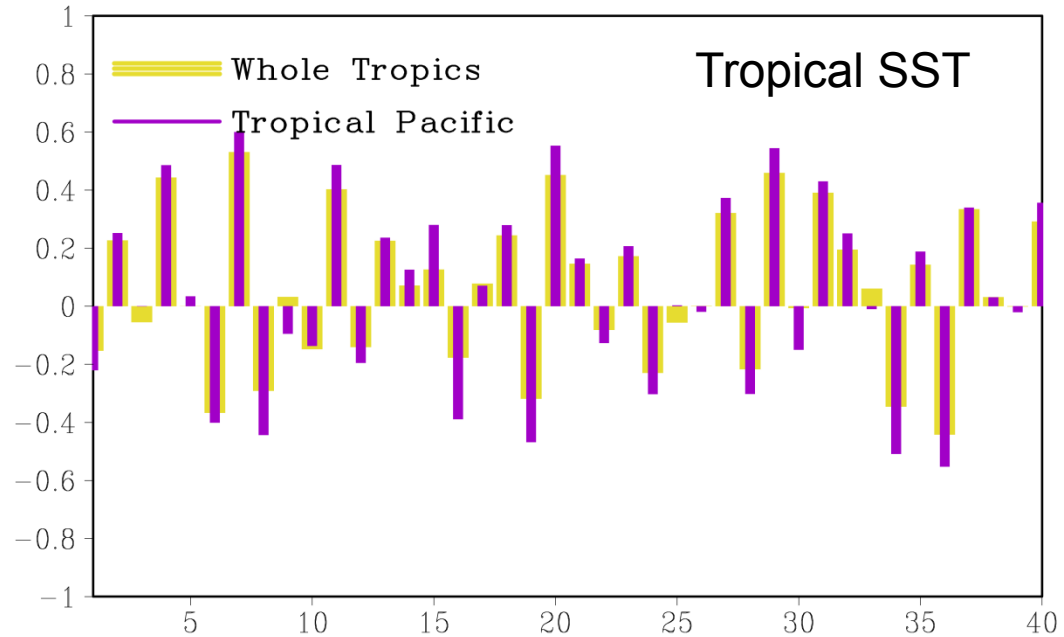
Recent climate change in the Arctic and Antarctic is related to a low-frequency SST variability in the tropical Pacific.

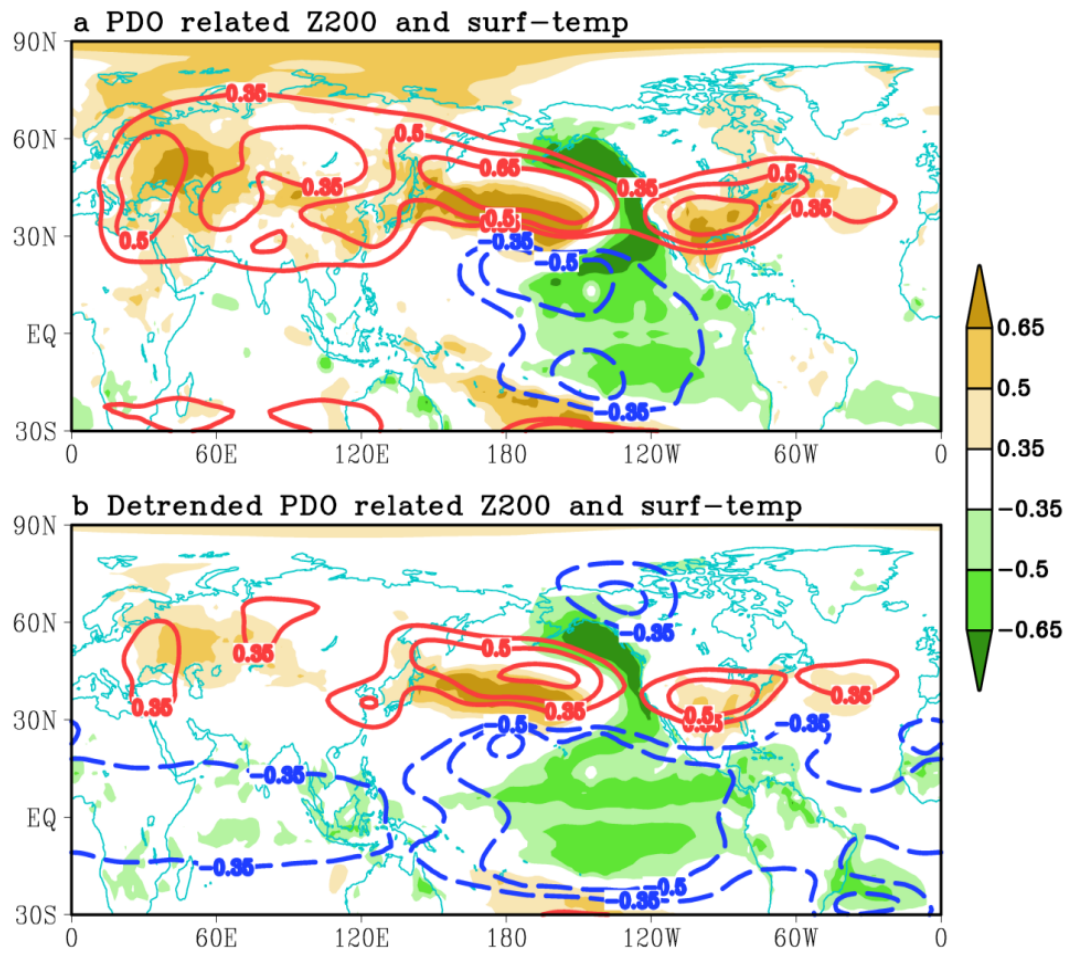
To predict the future change of SH+NH circulation and related change in the Arctic and Antarctic, we need to better understand and predict the low-frequency SST variability in the tropics and its polar impact.

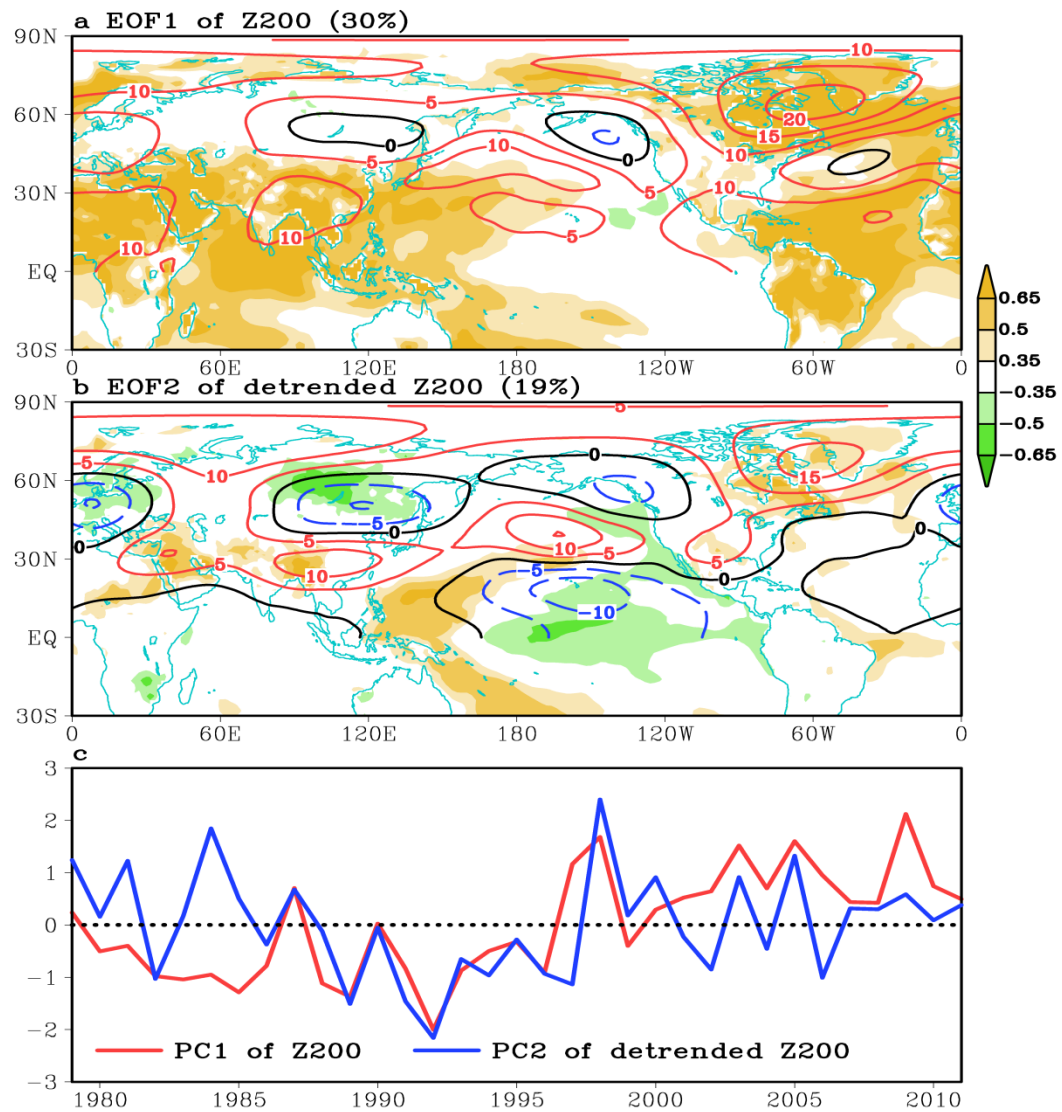
Future projections of how tropical Pacific low-frequency SST variability will change in response to both continued anthropogenic radiative forcing and natural interdecadal variability represents a significant source of uncertainty of projections of the polar climate.



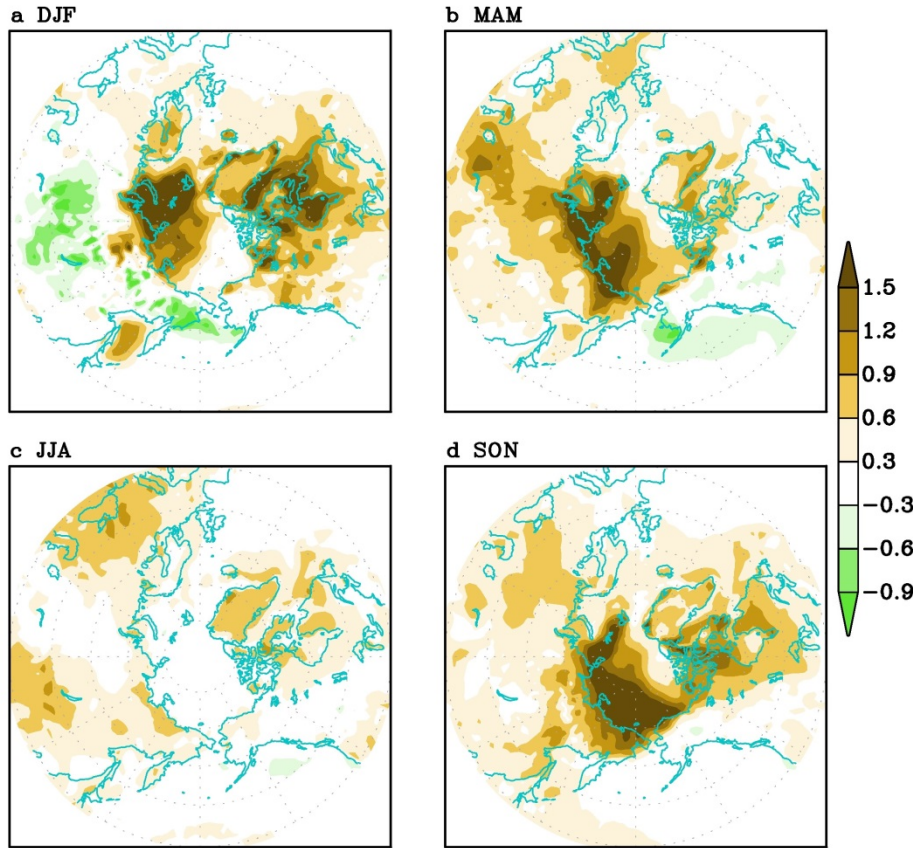
Is there a best-fit model in CMIP5?



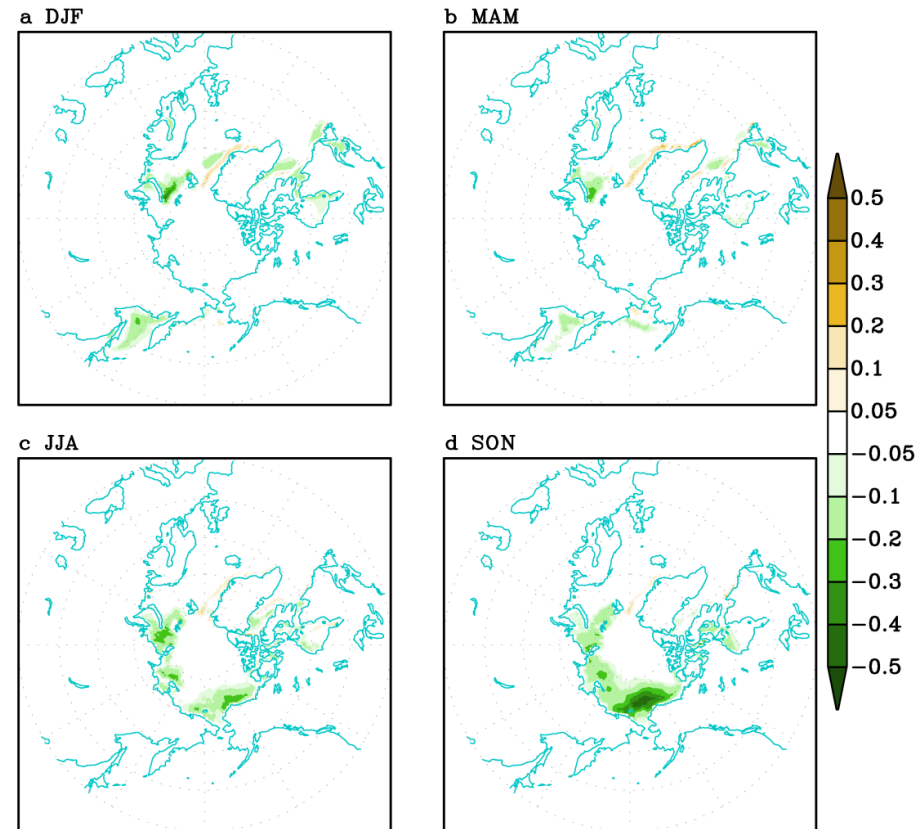




Surface temperature trend (1979-2012)



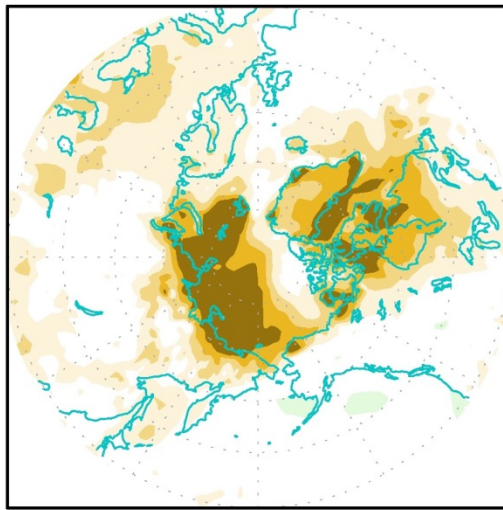
Sea ice trend (1979-2012)



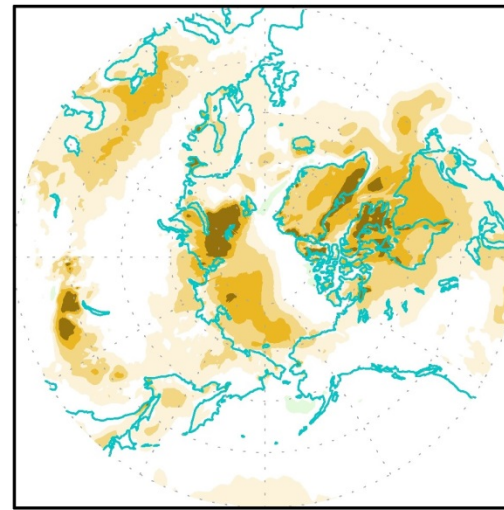
Maximum regional warming occurs in non-melting season

Annual mean surface temperature trend (1979-2012)

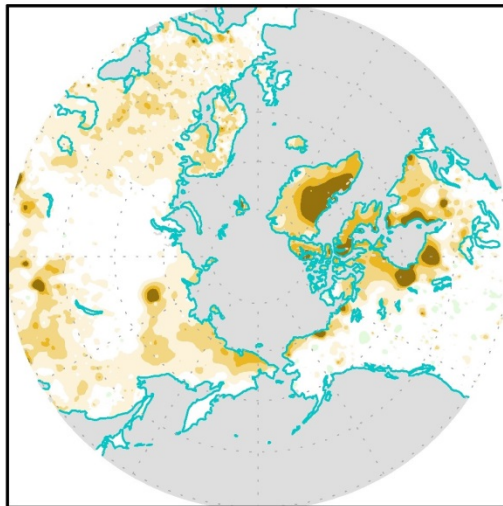
a ERA-interim



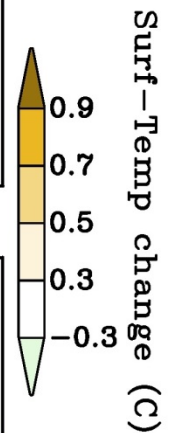
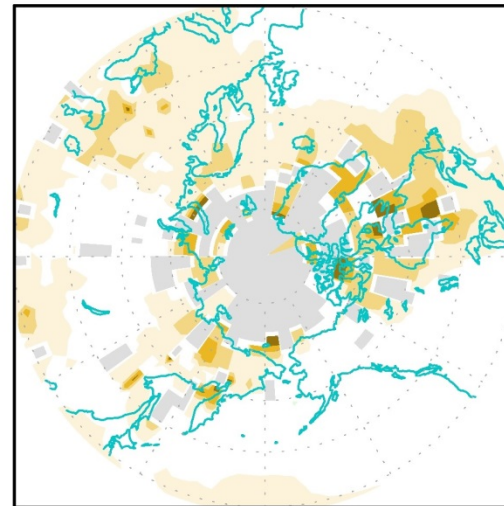
b MERRA



c U. of Delaware



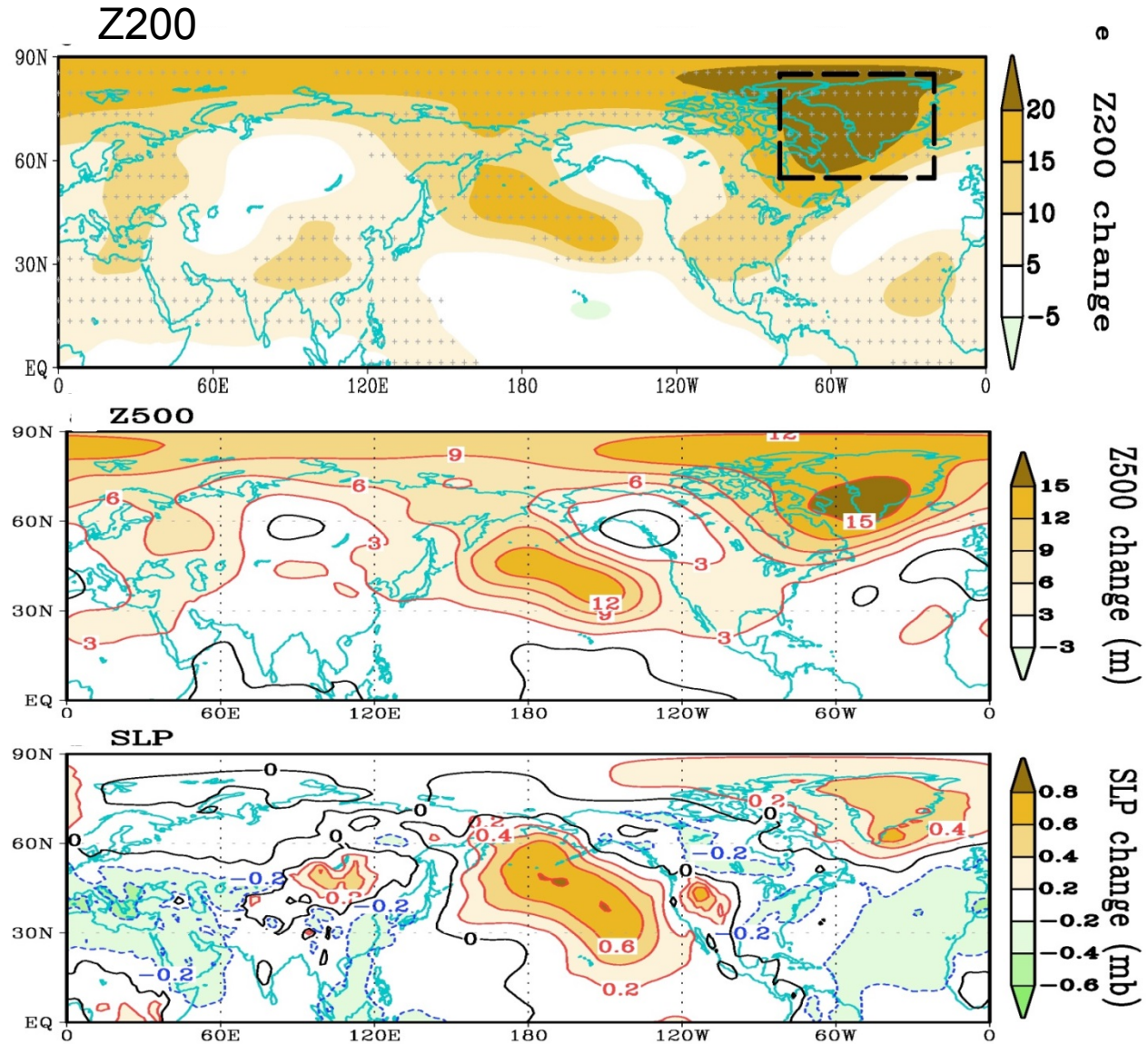
d GISS



All data agree



Annual mean geopotential height trend (1979-2012)

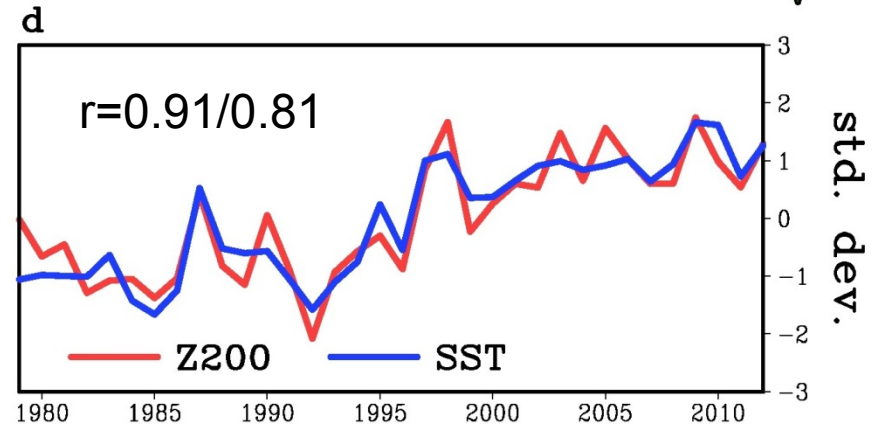
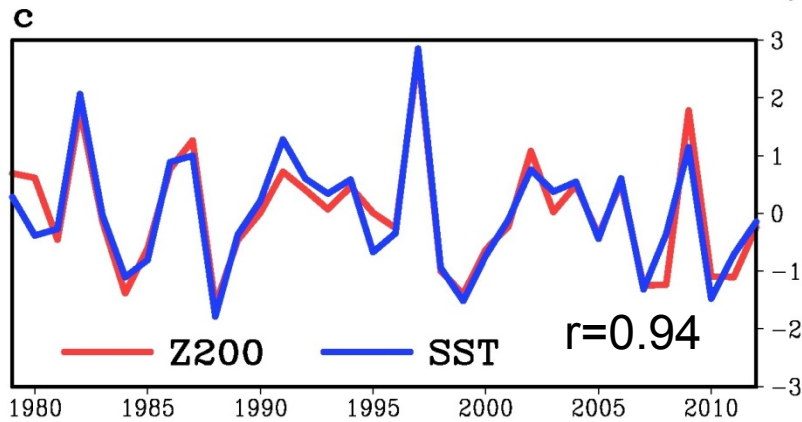
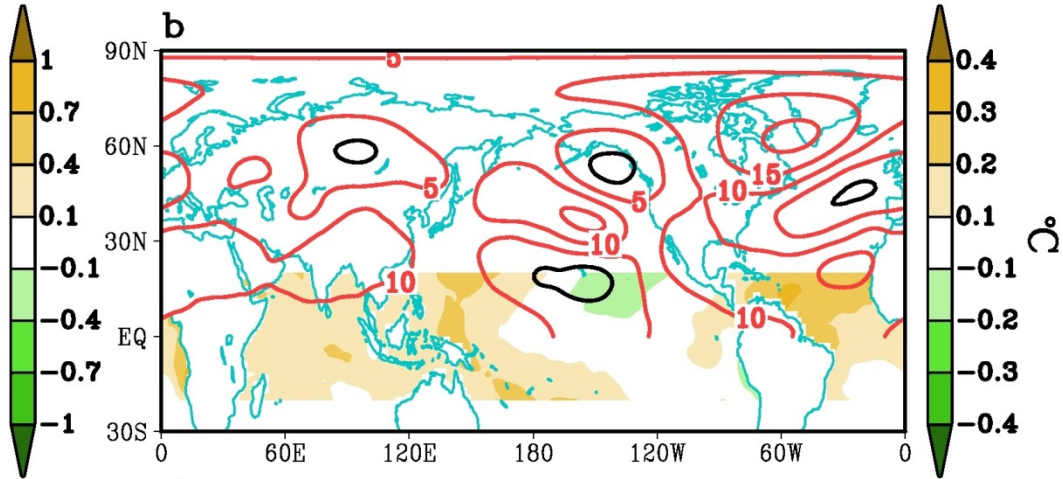
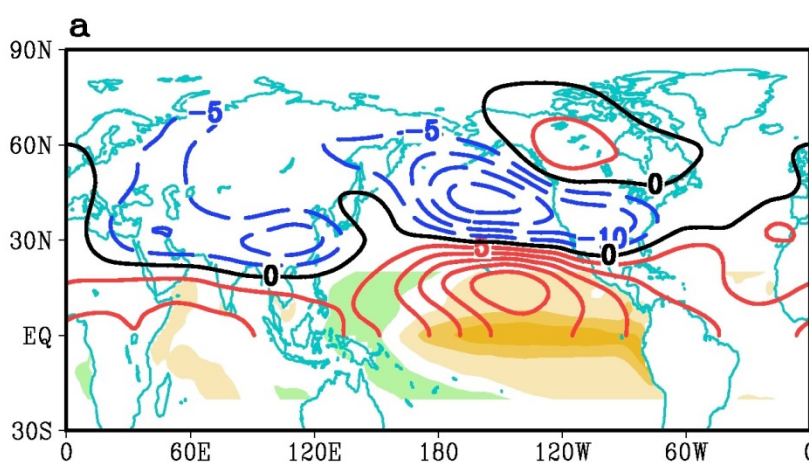


Circulation change may be a driver of the regional warming

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

SCF=70%

SCF=26%

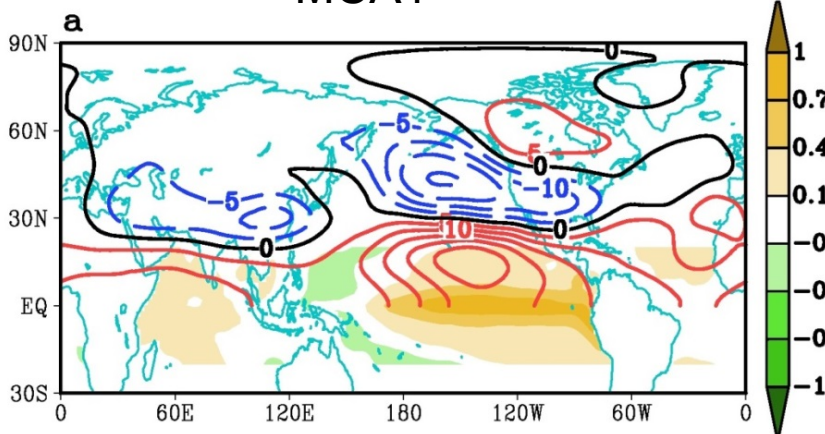


*a low frequency tropical SST mode (shifted at 1997/1998)
not the typical ENSO*

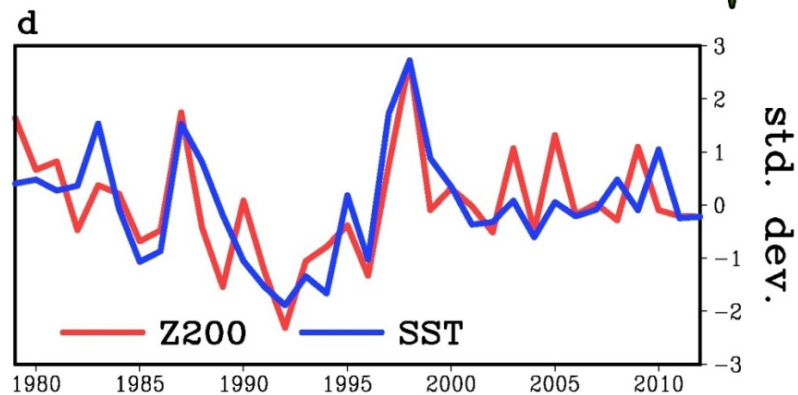
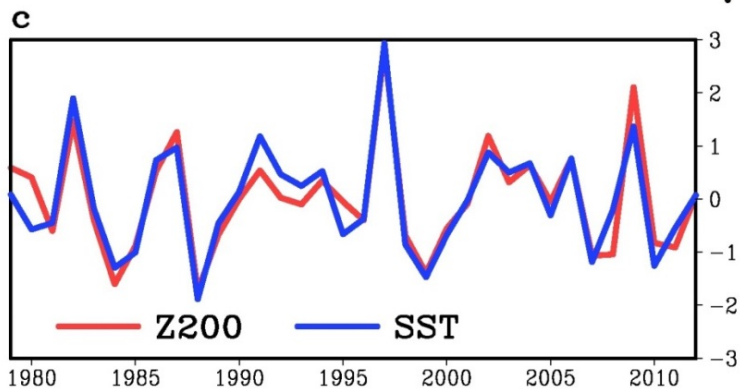
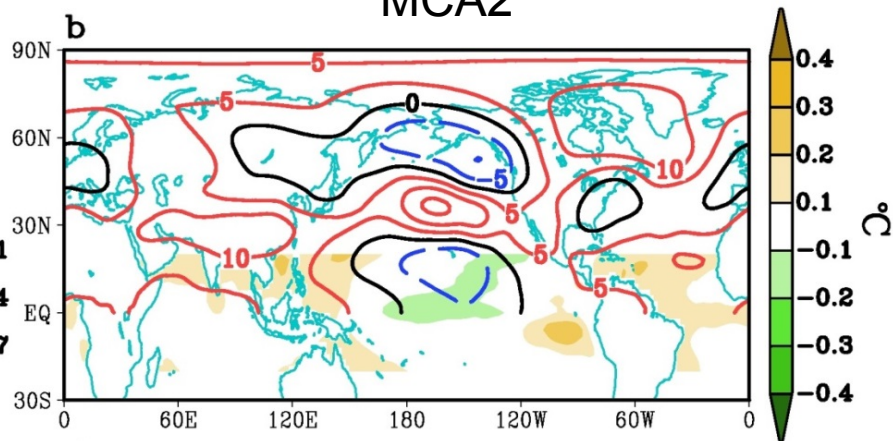


MCA modes for detrended Z200 and tropical SST

MCA1

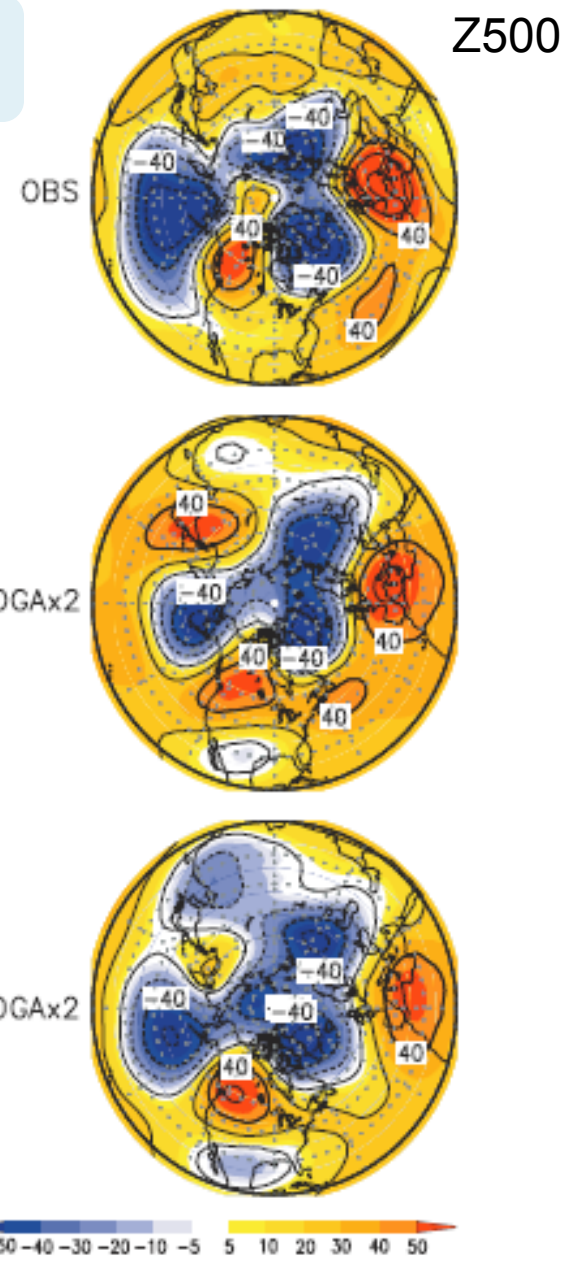
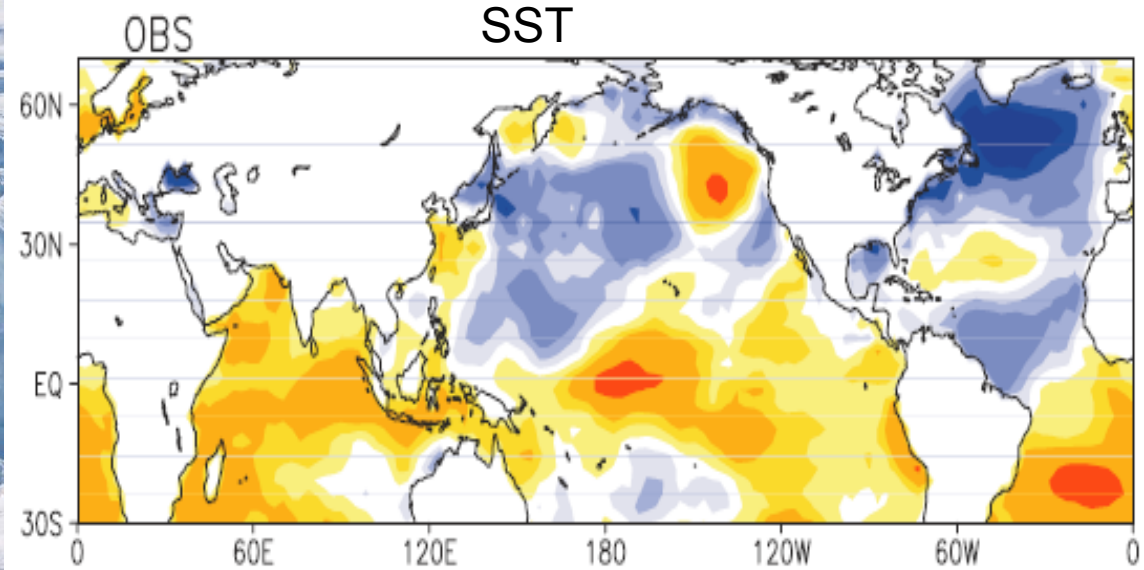


MCA2

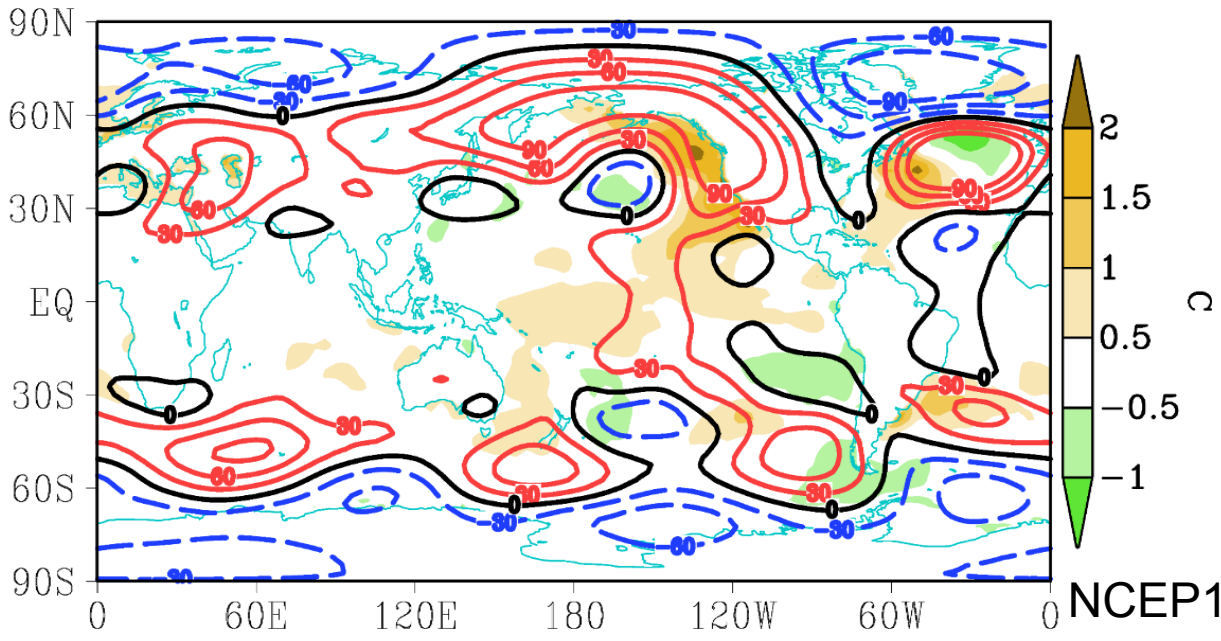


Tropical origin of the NAO over 1950-1999

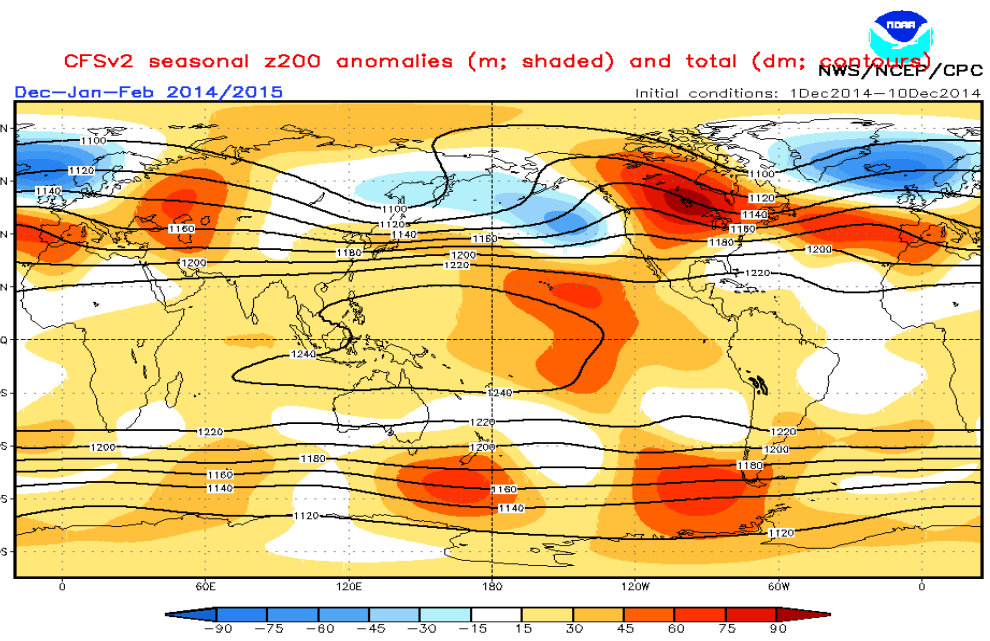
1950-1999 DJF



Z200 and SST in 2014/2015 DJF



NCEP1 and ERSST3
mean state: 1979-2015



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

