



**The Abdus Salam
International Centre for Theoretical Physics**



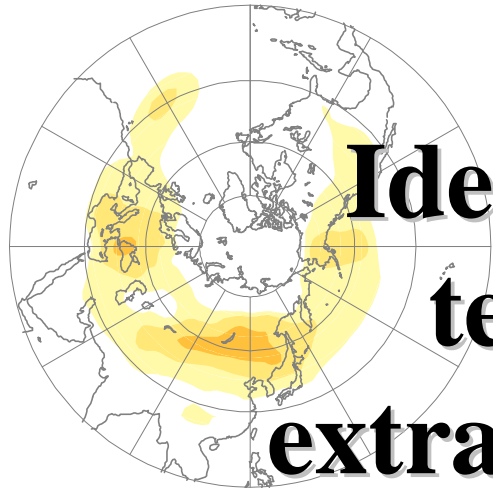
1968-51

Conference on Teleconnections in the Atmosphere and Oceans

17 - 20 November 2008

Identification of a multi-decadal teleconnection pattern in the extratropical northern hemisphere

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10617 Taipei
TAIWAN - CHINA*



Identification of an **interdecadal** teleconnection pattern in the extratropical Northern Hemisphere

Huang-Hsiung Hsu and Ming-Ying Lee

Department of Atmospheric Sciences

National Taiwan University

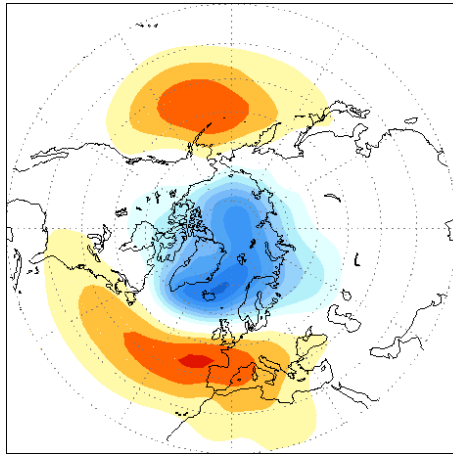
Taipei, Taiwan

Conference on Teleconnections in the Atmosphere and Oceans

21 Oct 2008



Leading EOF (19%) shown as regression map of 1000mb height (m)



Teleconnection Families

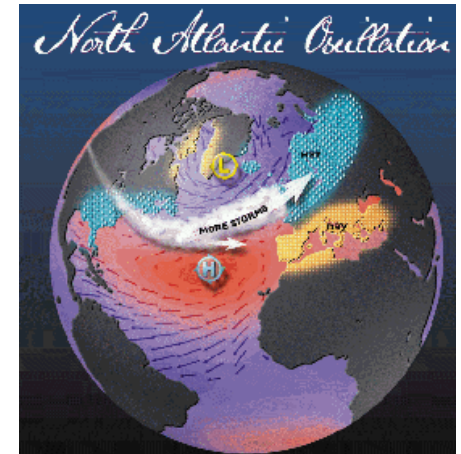
Family of “P”: EA, WP, PNA, EU, TNH, ...

Family of “O”: NAO, ENSO, PDO, AO, AMO...

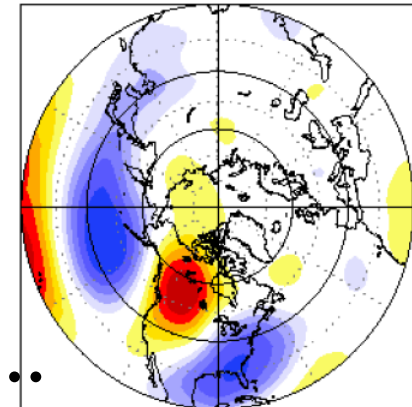
Family of “M”: IOZM(IOD), NAM, SAM, AMM, ...

A new baby in the family?

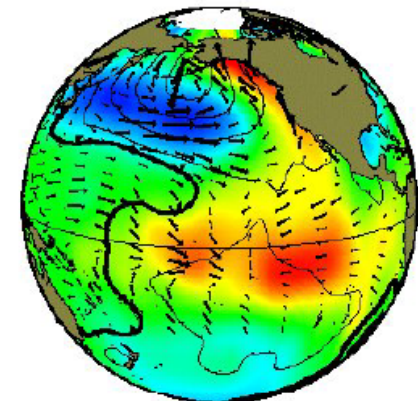
- **Location – Eurasia/North Pacific, upper tropospher**
- **Time scale: Interdecadal**



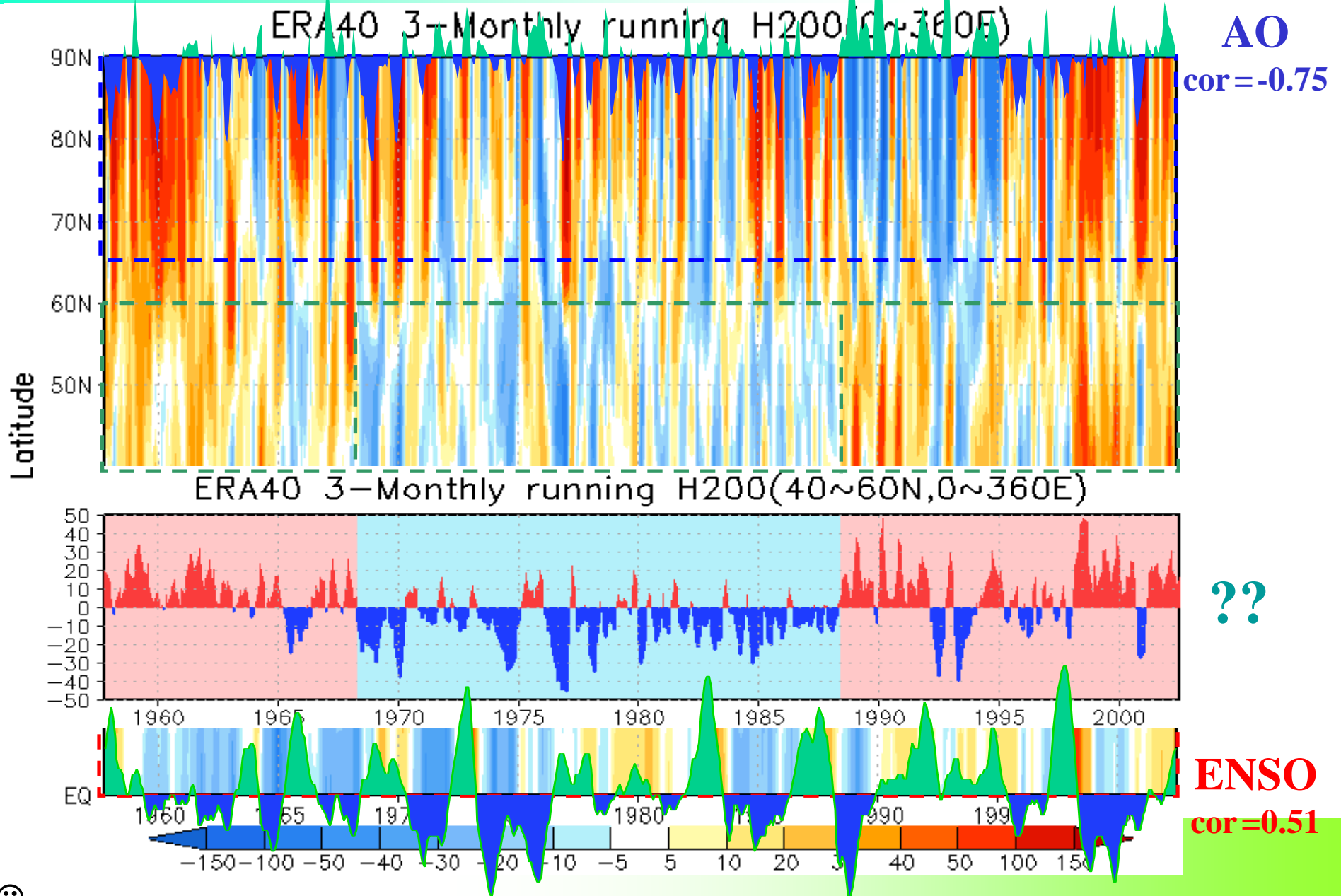
PNA 500z +



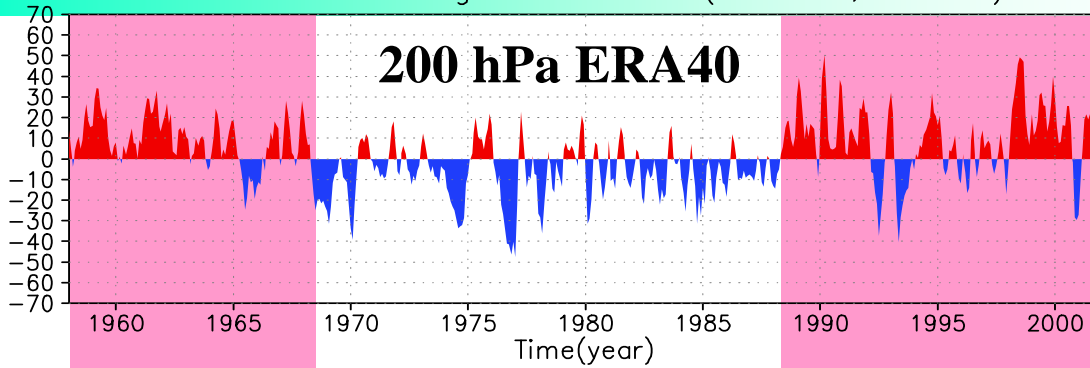
Pacific Decadal Oscillation



Zonally-averaged 200 hPa height anomaly

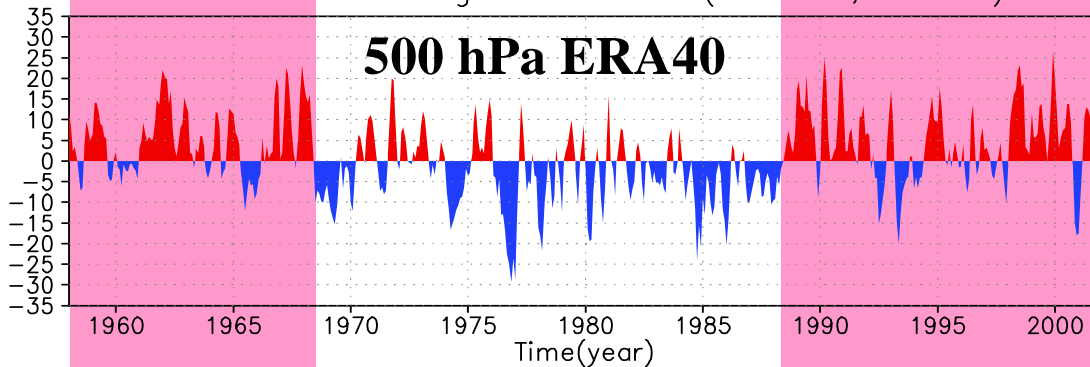


3-Months running ERA40 H200(40~60N,0~360E)

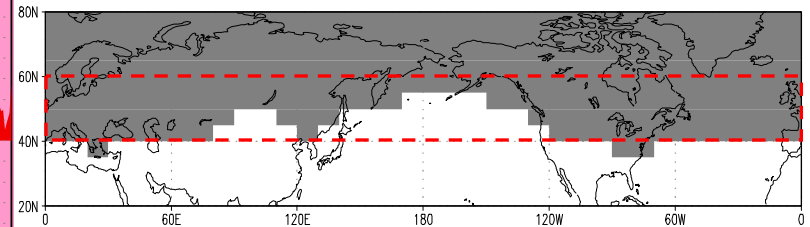
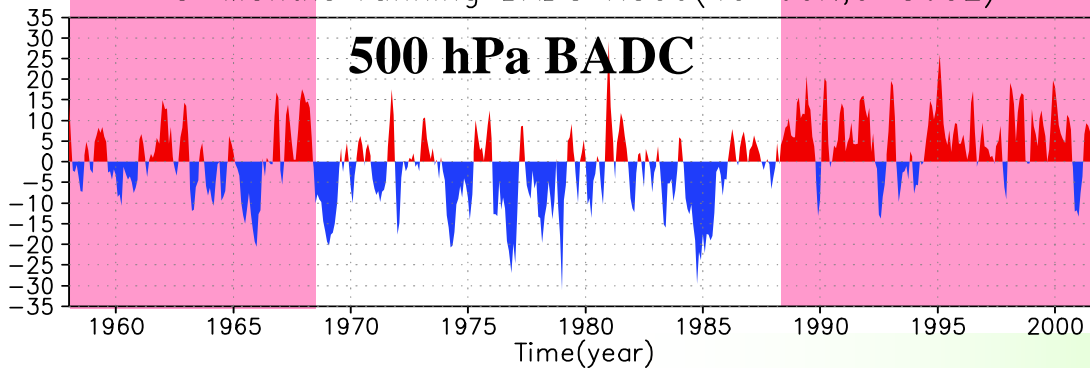


Also seen at other levels
and in BADC 500hPa height
(sounding) data

3-Months running ERA40 H500(40~60N,0~360E)

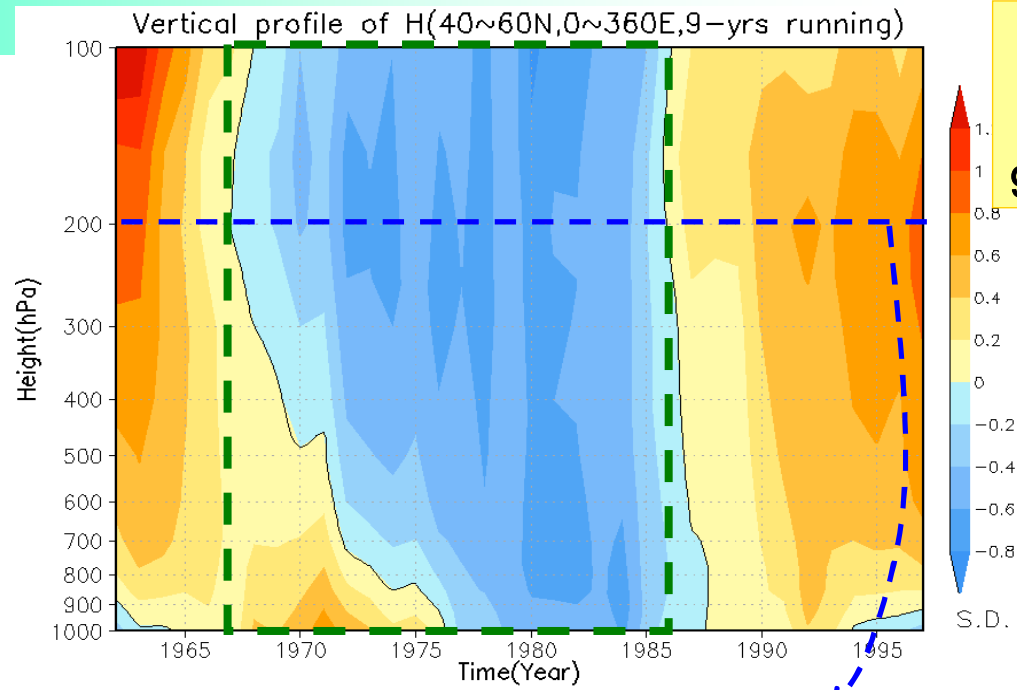


3-Months running BADC H500(40~60N,0~360E)

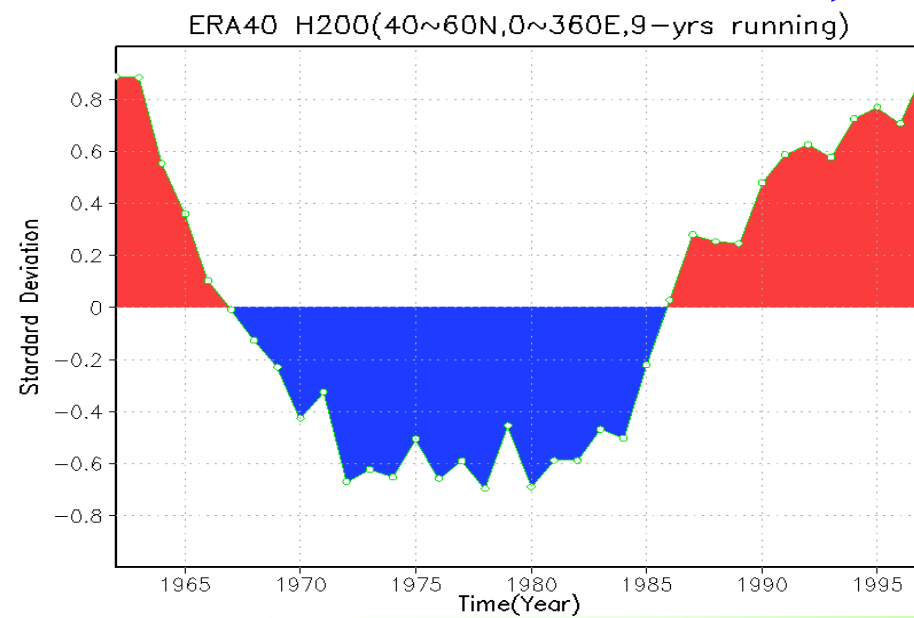


BADC (British Atmospheric Data Centre)





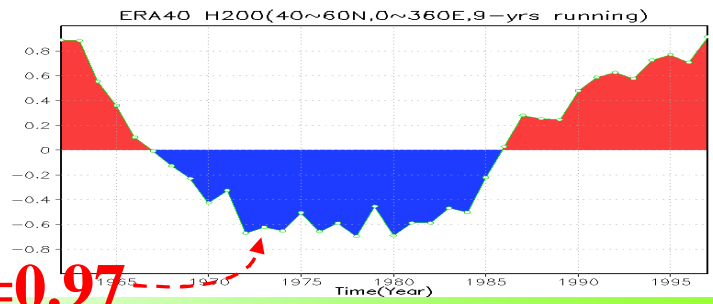
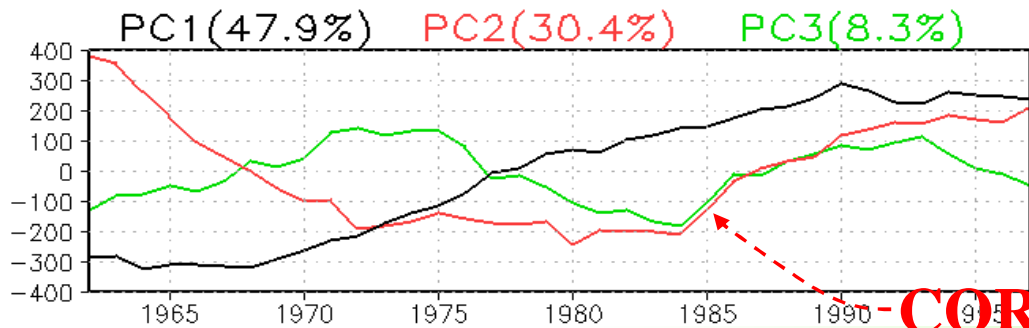
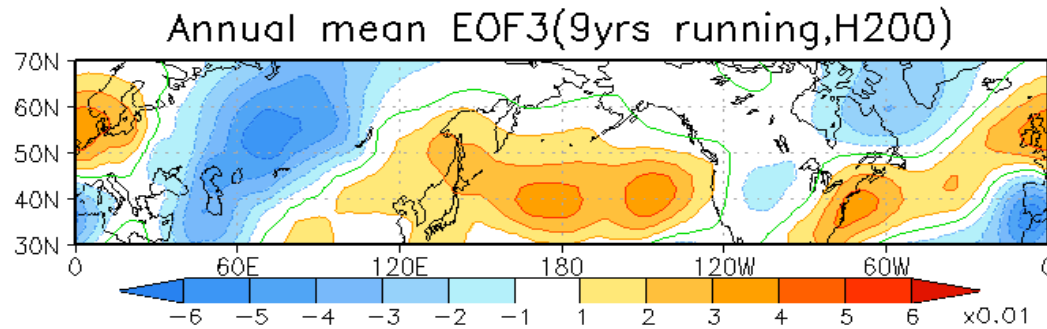
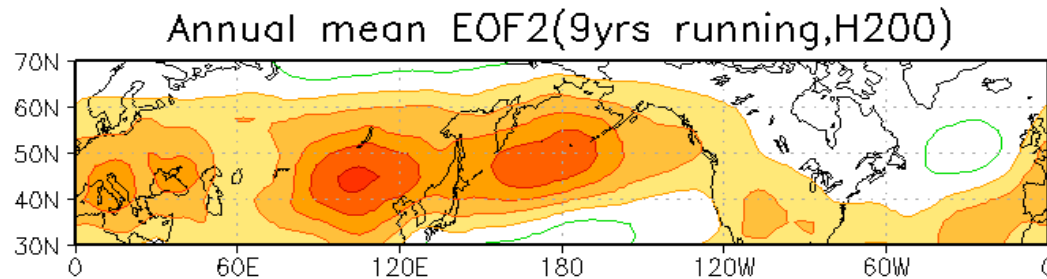
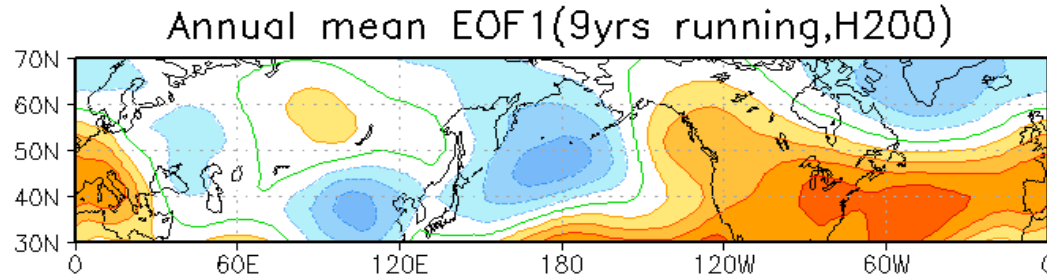
40N-60N
Zonal mean
9 Year running mean



EOF analysis

Northern Hemisphere

What is EOF1?



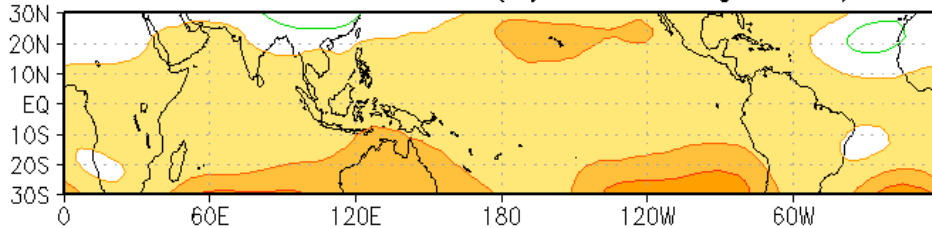
COR=0.97



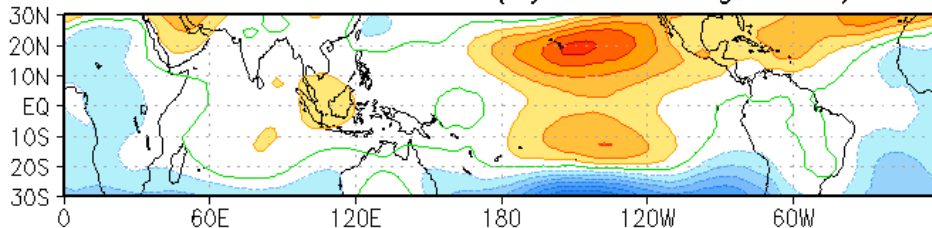
EOF analysis

Tropical

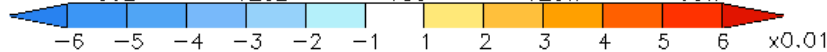
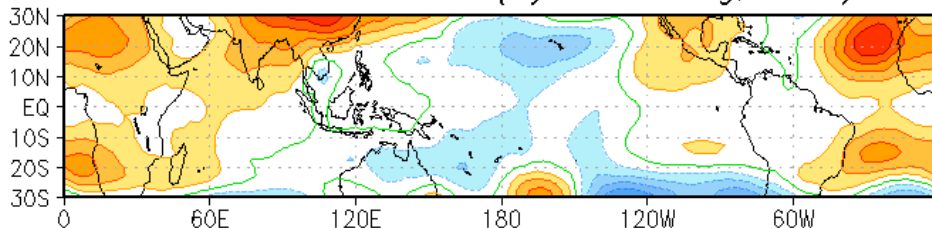
Annual mean EOF1(9yrs running,H200)



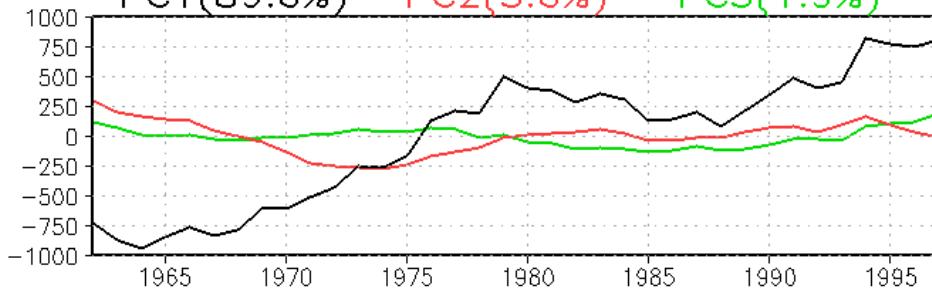
Annual mean EOF2(9yrs running,H200)



Annual mean EOF3(9yrs running,H200)

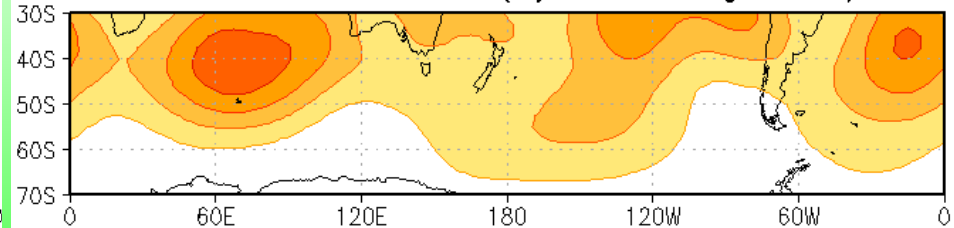


PC1(89.6%) PC2(5.6%) PC3(1.9%)

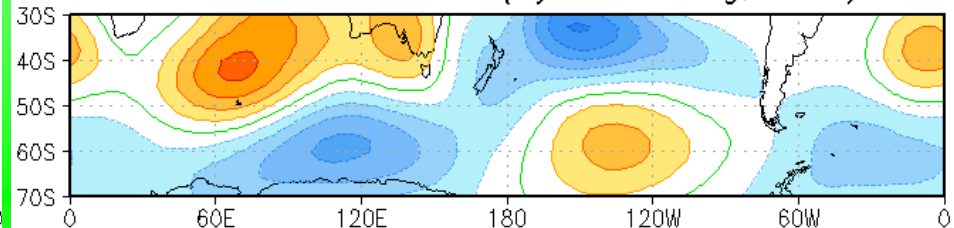


Southern Hemisphere

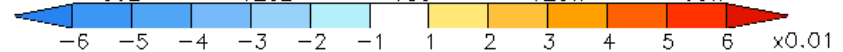
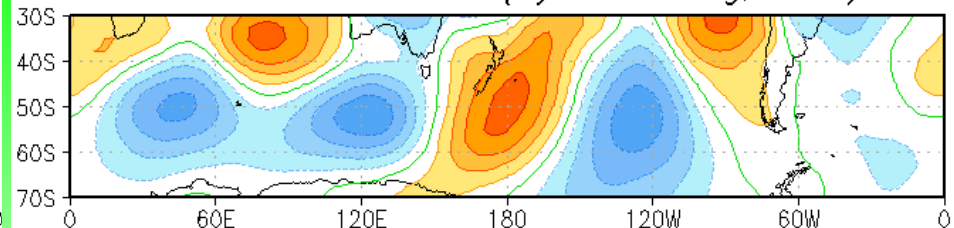
Annual mean EOF1(9yrs running,H200)



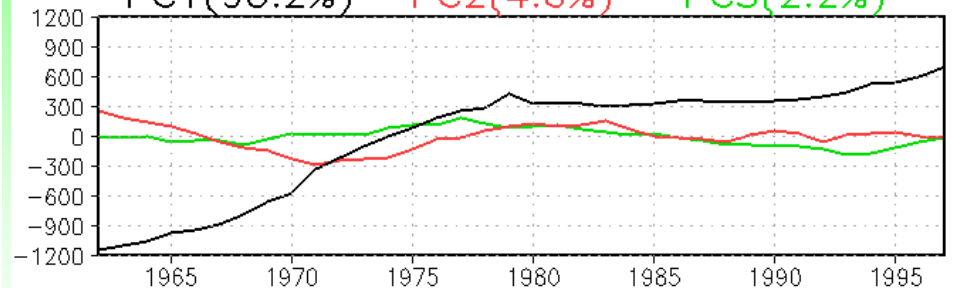
Annual mean EOF2(9yrs running,H200)



Annual mean EOF3(9yrs running,H200)

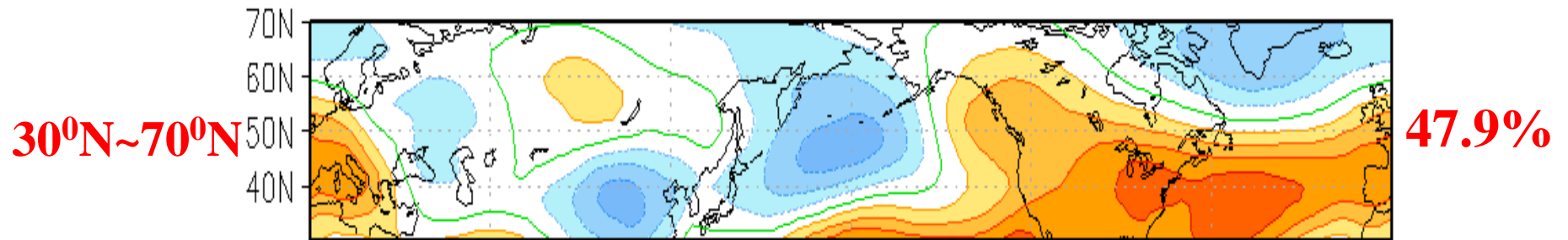


PC1(90.2%) PC2(4.6%) PC3(2.2%)

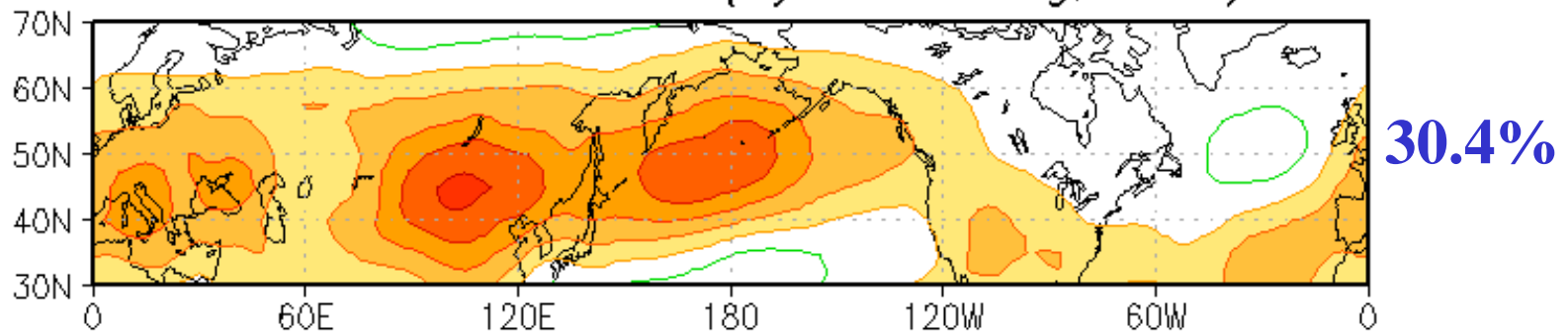


EOF analysis

EOF 1



Annual mean EOF2(9yrs running,H200)

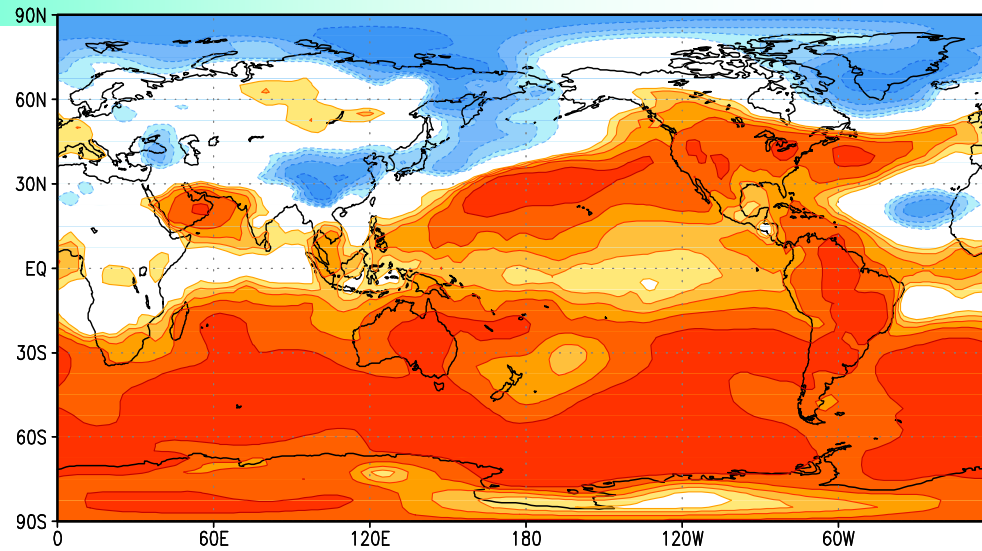


Correlation

Correlation EOF PC1 & ERA40 t700200

T700~200

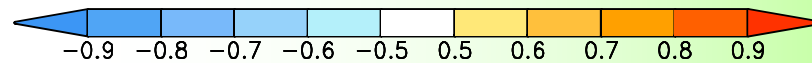
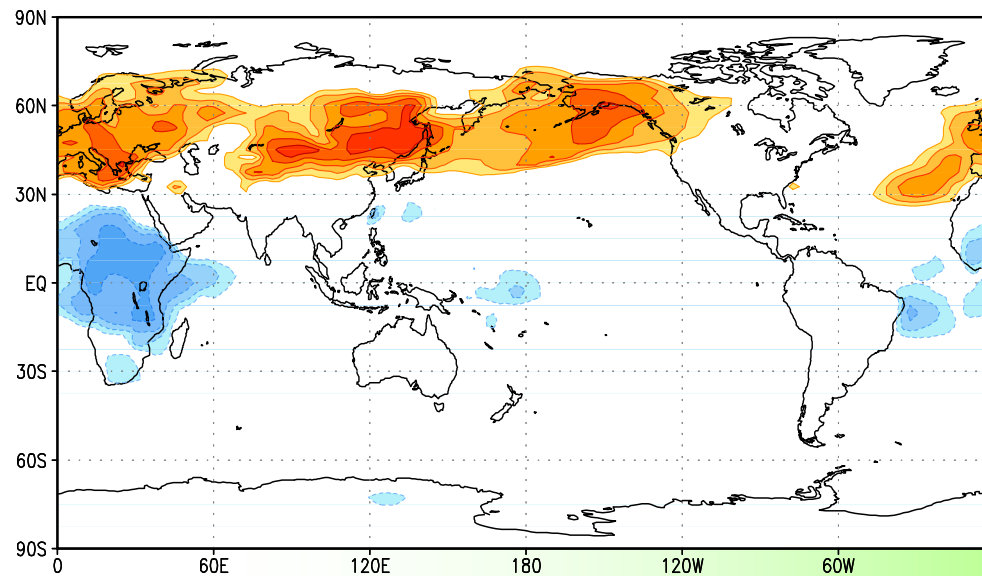
.vs. PC1



Correlation EOF PC2 & ERA40 t700200

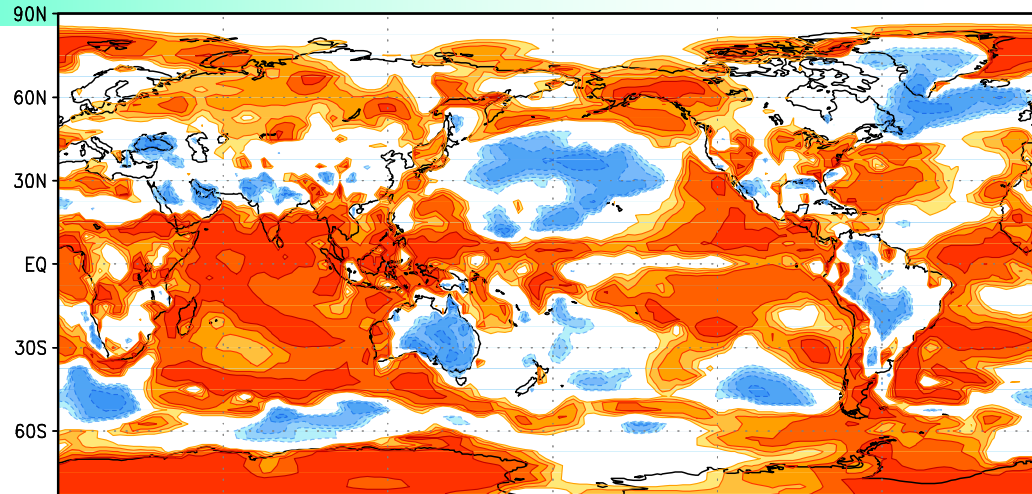
T700~200

.vs. PC2



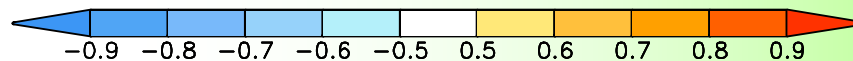
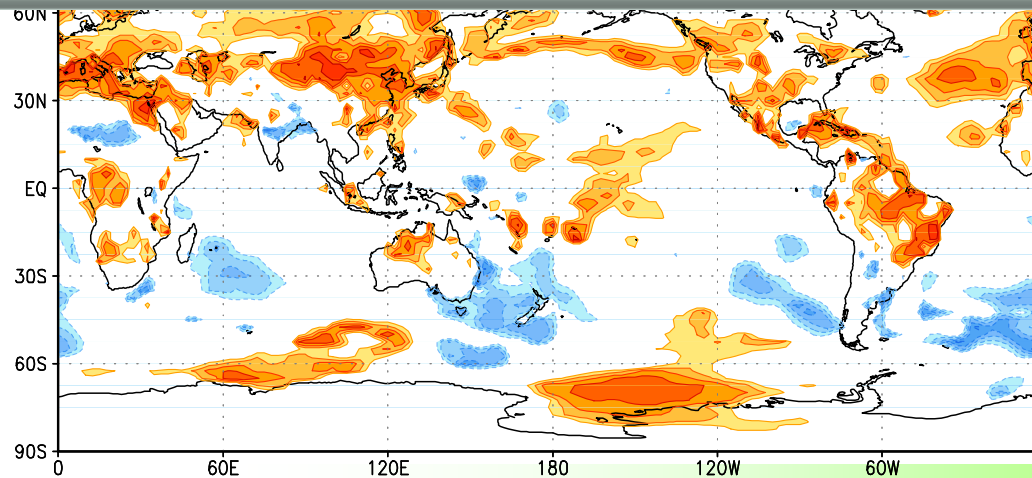
Correlation

Correlation EOF PC1 & ERA40 2mT *T2m* .vs. *PC1*

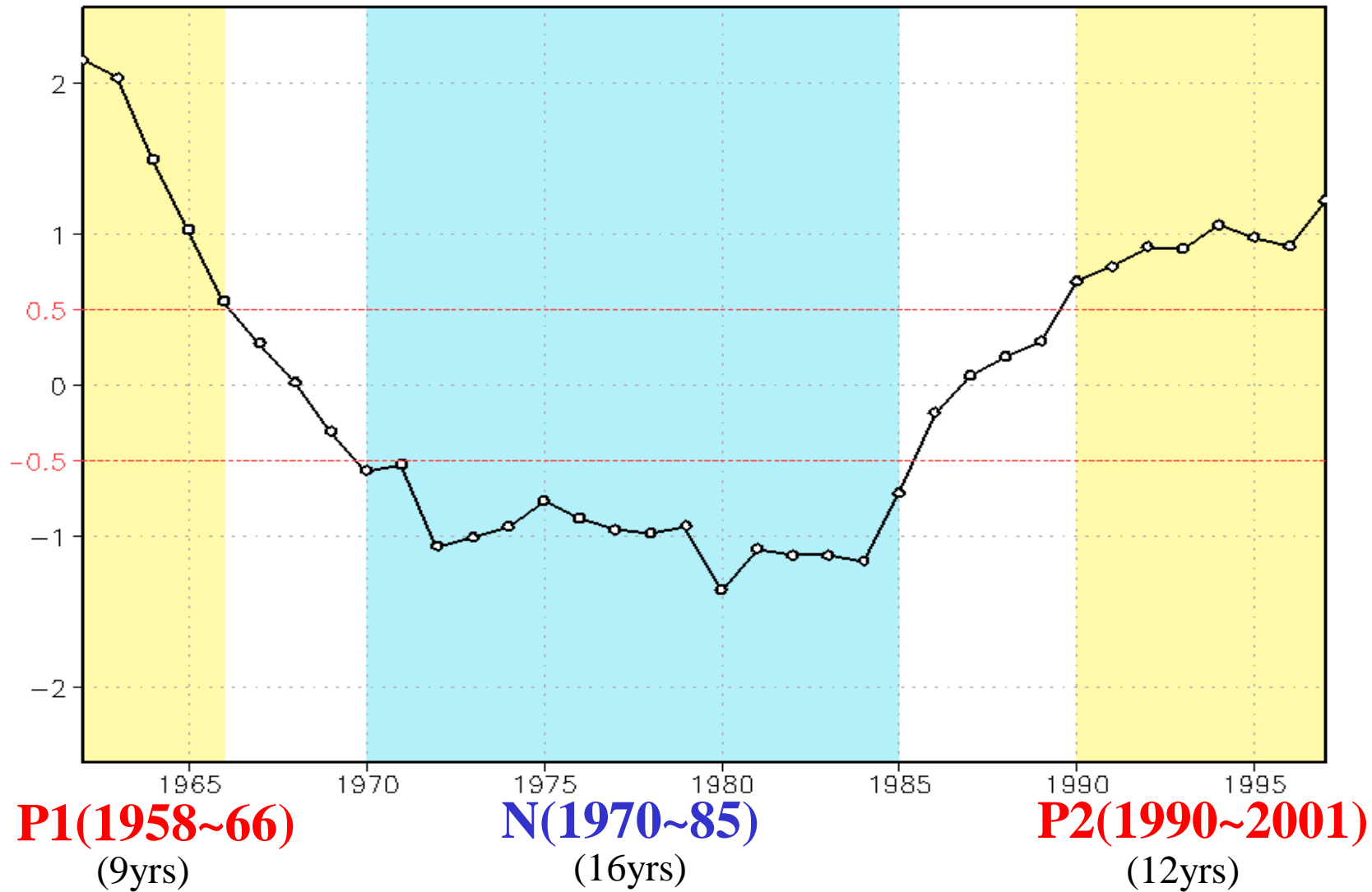


It takes two modes to form the “global” warming pattern.

T2m .vs. *PC2*



Normalized PC2



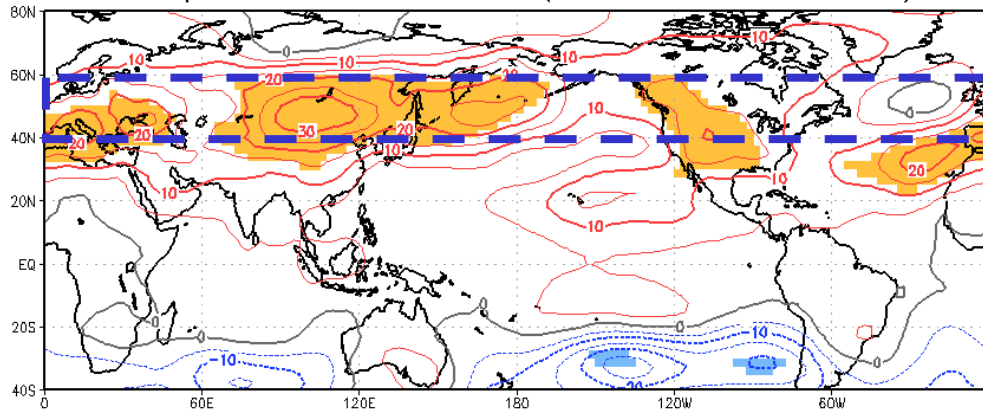
→ Composite: **P1&P2** minus **N**



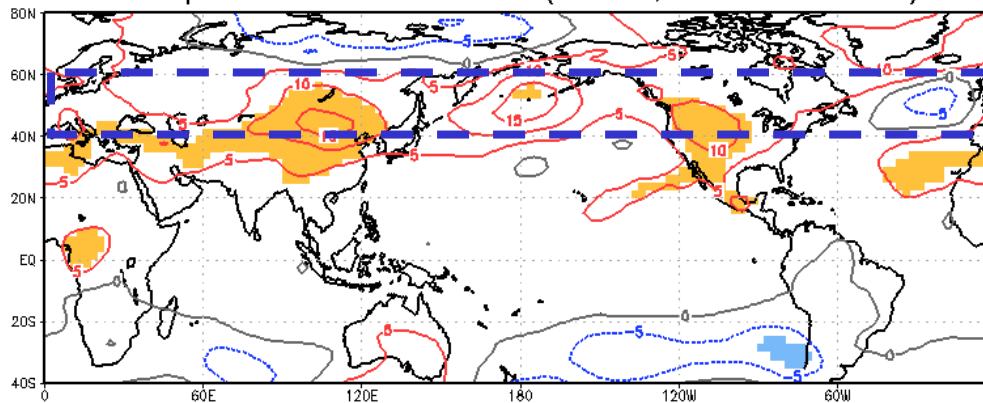
Composite

Annual mean of H200 and H500

Composite of ERA40 H200 (Annual,P1&P2 minus N)

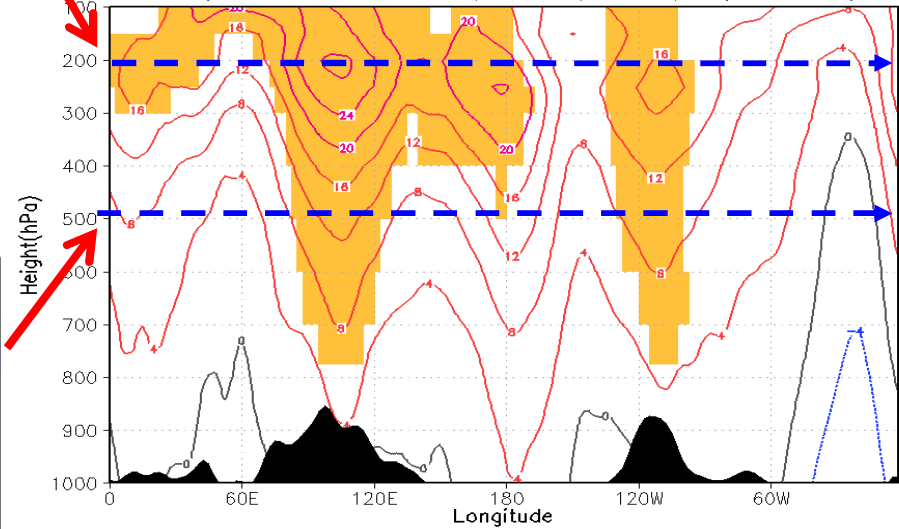


Composite of ERA40 H500 (Annual,P1&P2 minus N)



Vertical profile (40° ~ 60°N) Geopotential

Composite of ERA40 H (Annual,(P1+P2)-N), 40~60N



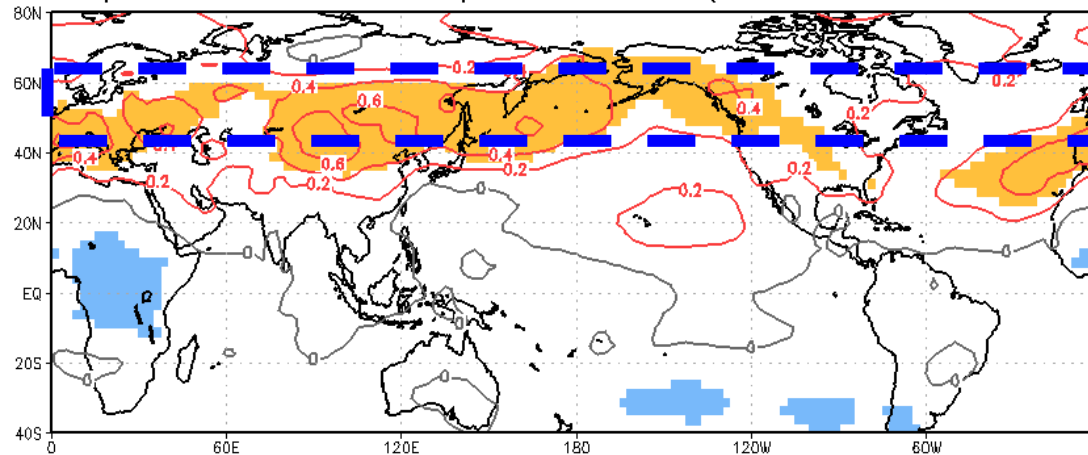
Significant at the 5% level are shaded



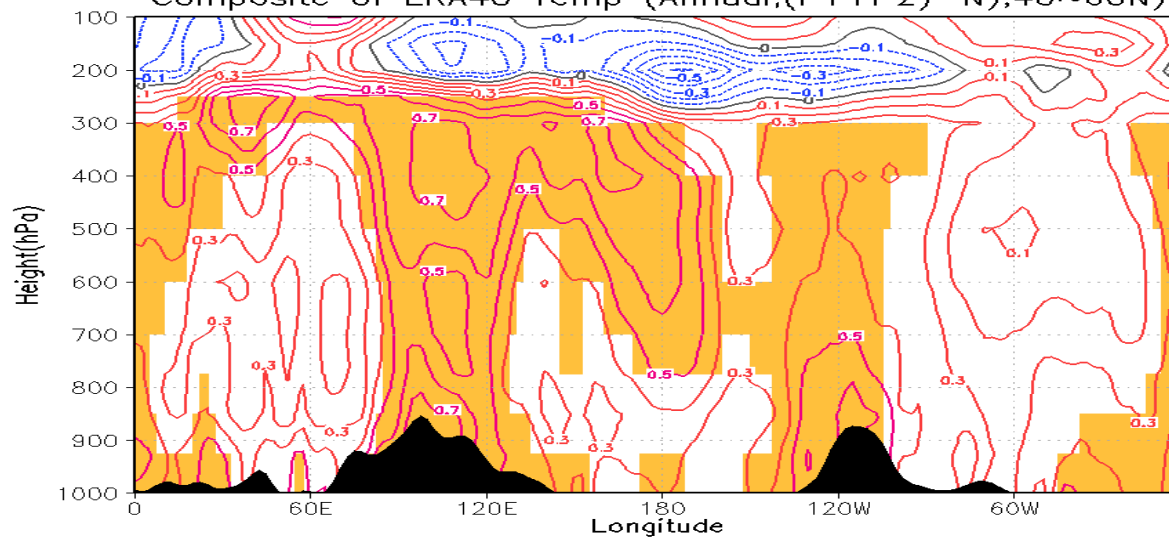
Composite

Annual mean of 700-200hPa Temperature

Composite of ERA40 Temp.700~200hPa(Annual,P1&P2 minus N)



Composite of ERA40 Temp (Annual,(P1+P2)-N),40~60N



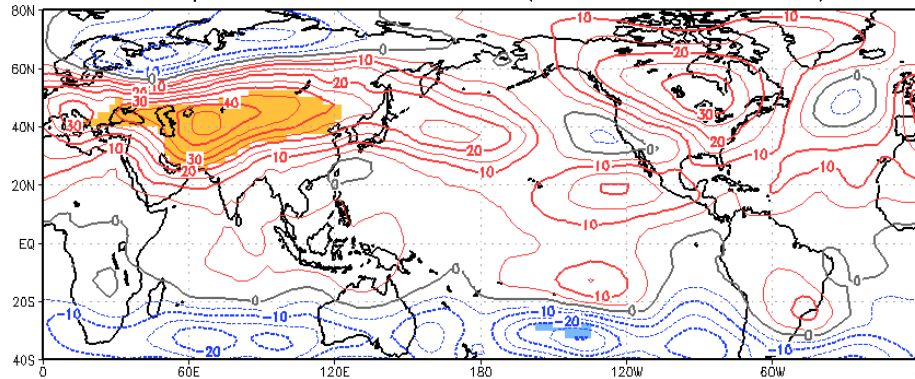
Significant at the 5% level are shaded



Composite for four seasons

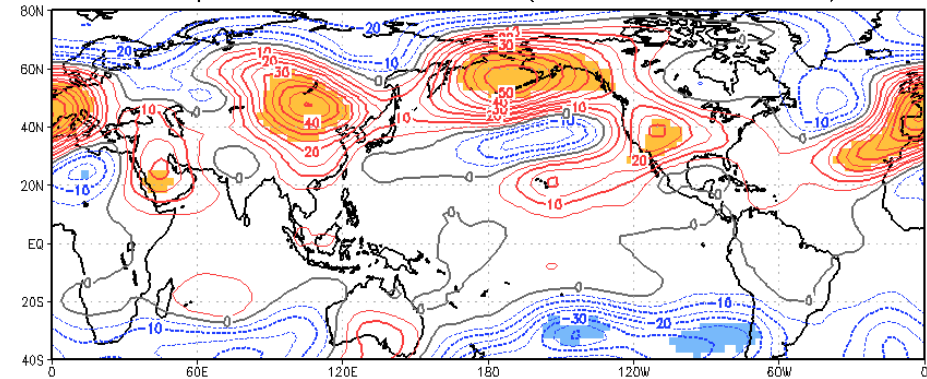
H200(DJF)

Composite of ERA40 H200 (DJF,P1&P2 minus N)



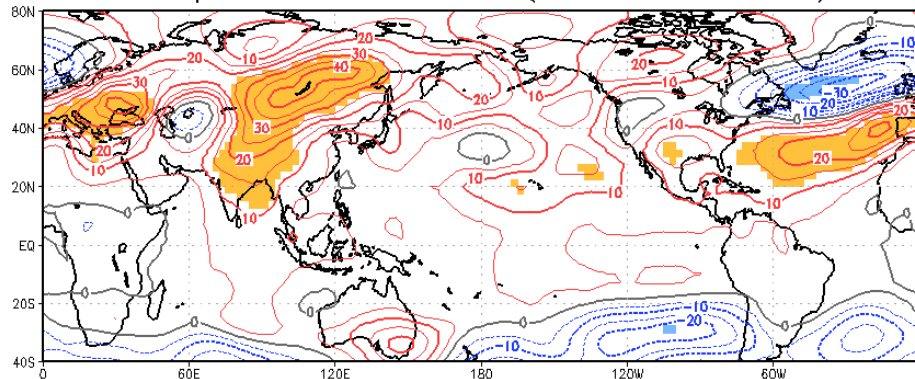
H200(MAM)

Composite of ERA40 H200 (MAM,P1&P2 minus N)



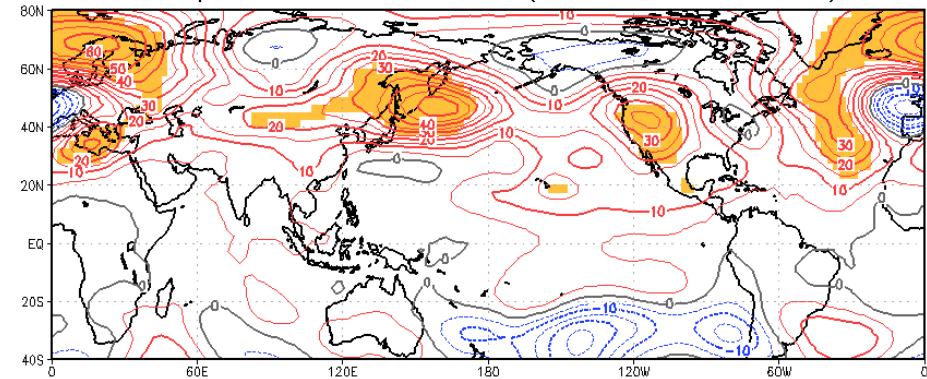
H200(JJA)

Composite of ERA40 H200 (JJA,P1&P2 minus N)



H200(SON)

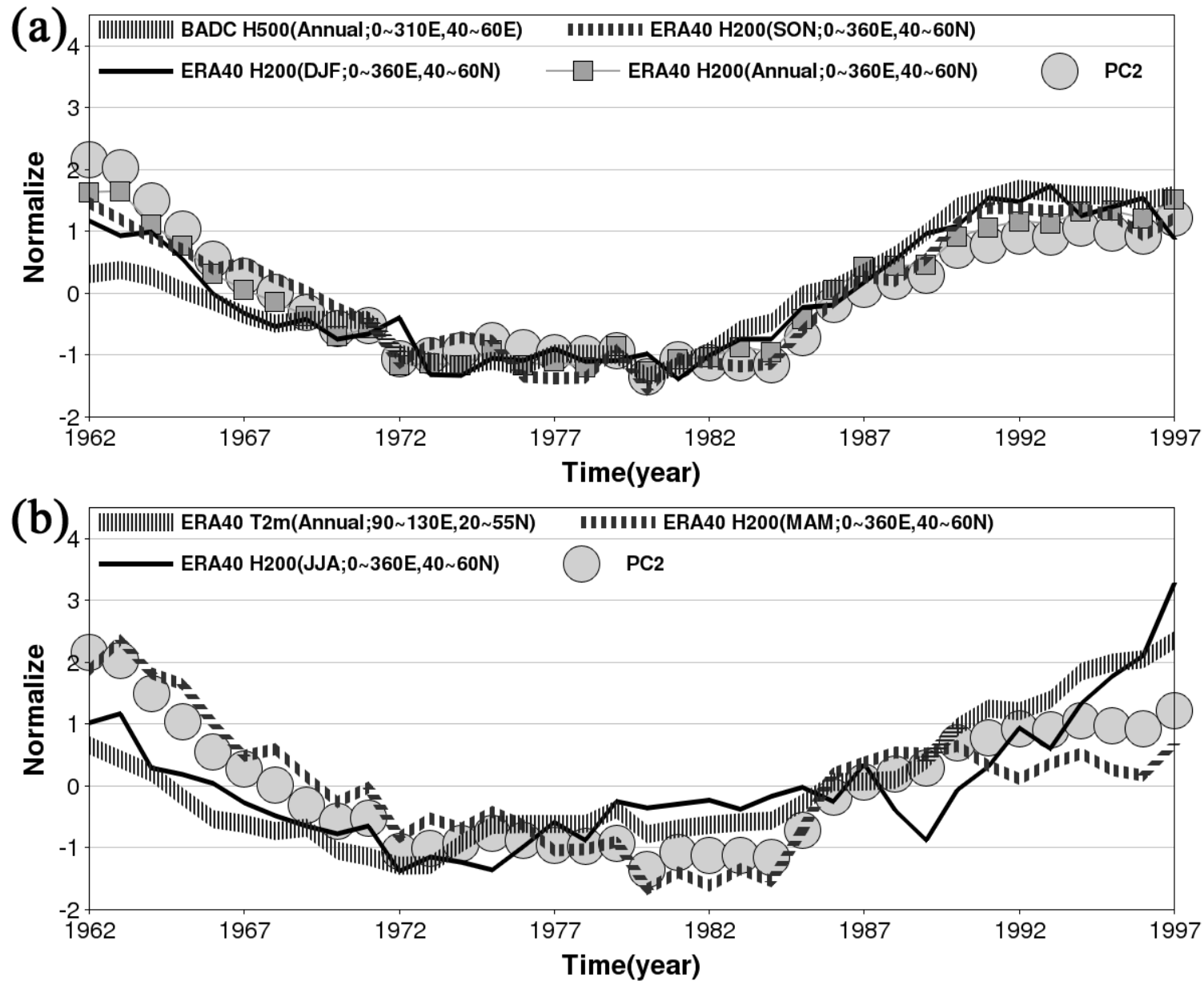
Composite of ERA40 H200 (SON,P1&P2 minus N)



Significant at the 5% level are shaded

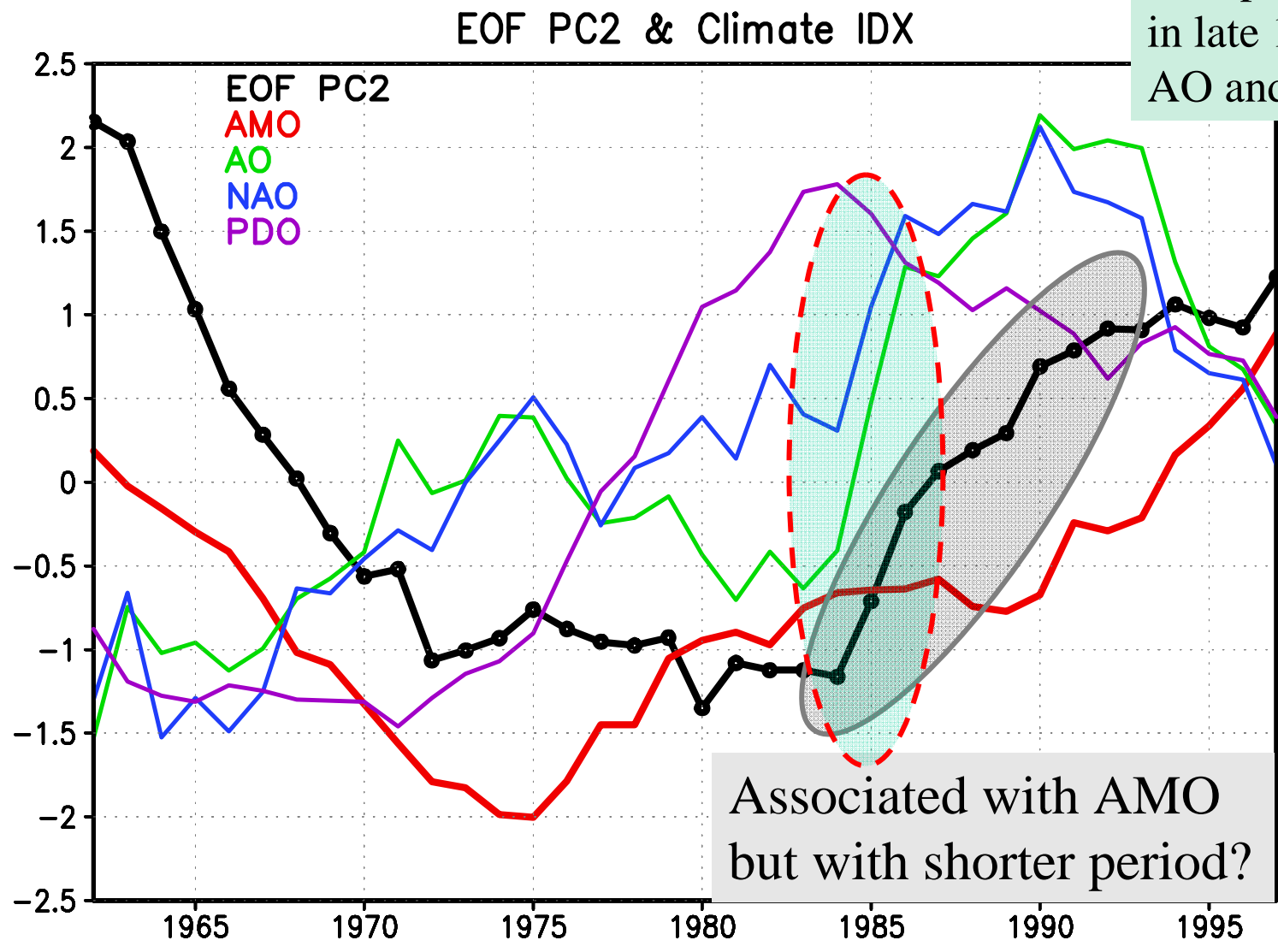


Zonally-averaged H200 of annual and seasonal means



BADC: British Atmospheric Data Centre)

Relationship with Climate Indices?



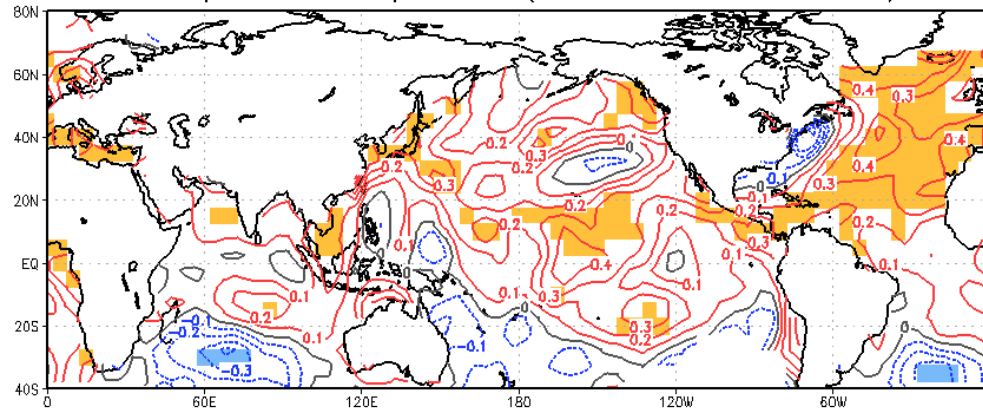
Abrupt change in late 1980s, AO and NAO, too!



Composite

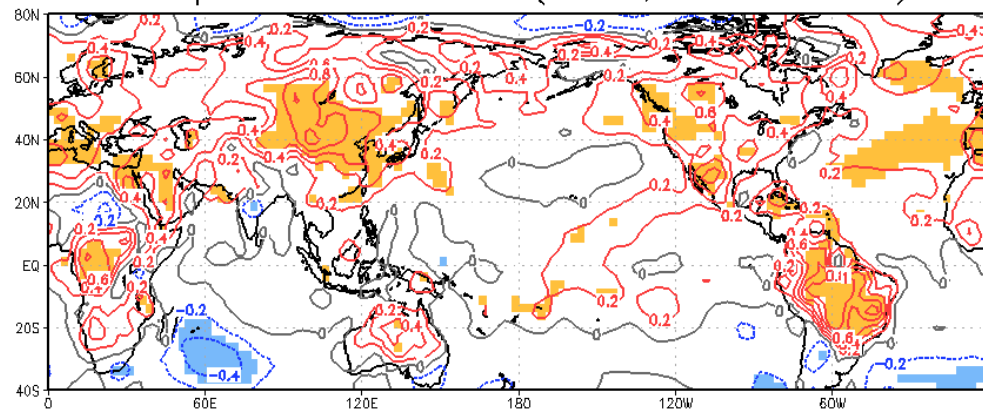
Annual mean Kaplan SST

Composite of KaplanSST (Annual,P1&P2 minus N)

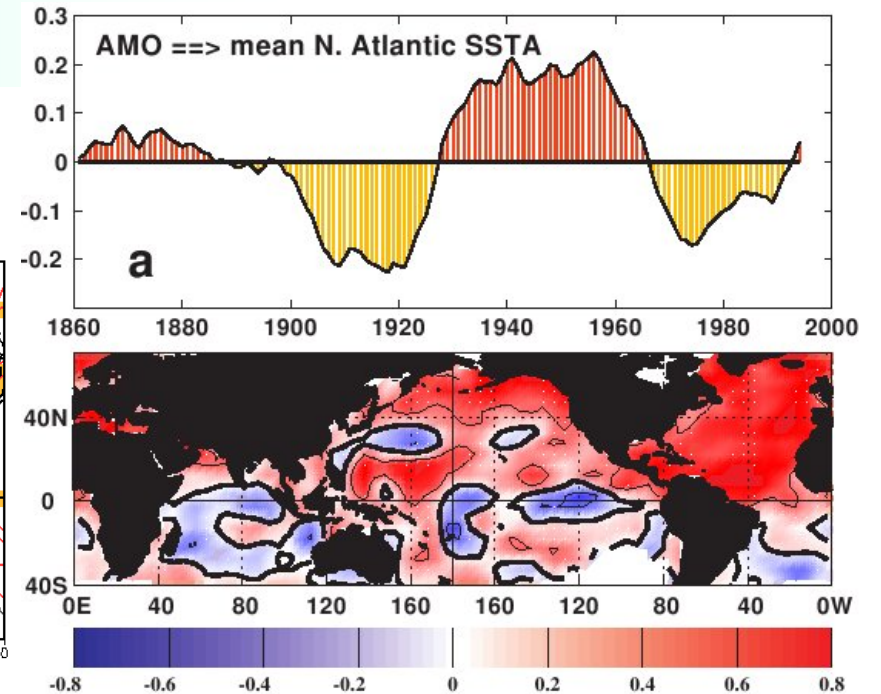


ERA40 T2m

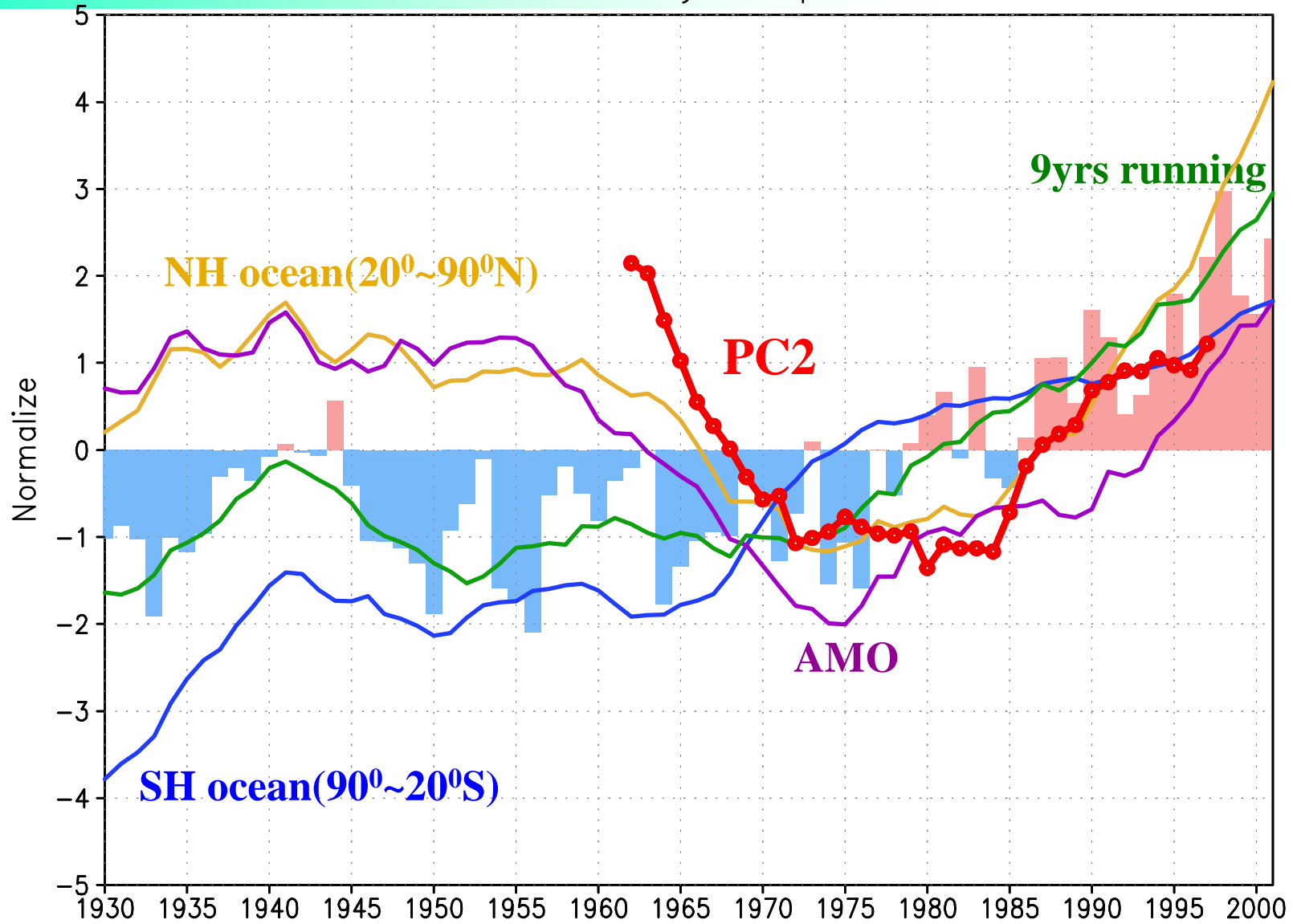
Composite of ERA40 T2m (Annual,P1&P2 minus N)



Significant at the 5% level are shaded



Global Anomaly Temperature



Data from: NCDC (<ftp://ftp.ncdc.noaa.gov>)



Summary

- **An interdecadal pattern over Eurasia/North Pacific is identified.**
- **Most apparent in the upper troposphere**
- **Associated with AMO, but period seems to be shorter**
- **Independent of “global warming” mode**
- **EOF1+EOF2 to account for recent change**
- **Why the long period? Mechanism? (AMO? ...)**
- **Is it truly an oscillation?**
- **Natural or anthropogenic induced mode? (IPCC/CMIP3)**

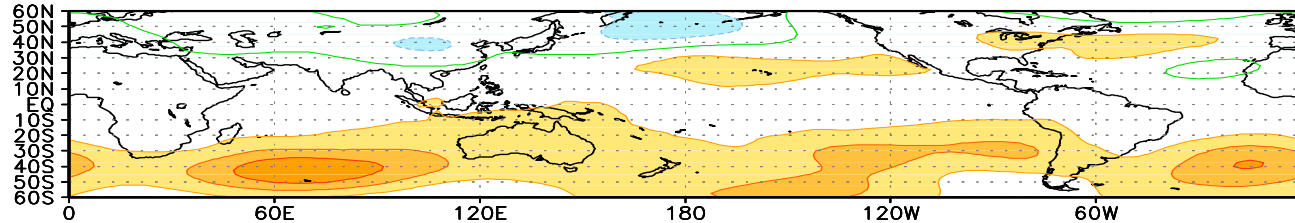


Thank You

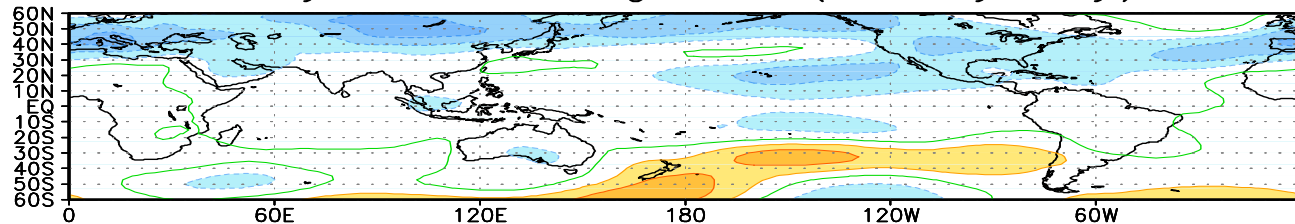


EOF analysis

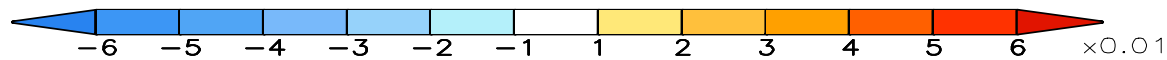
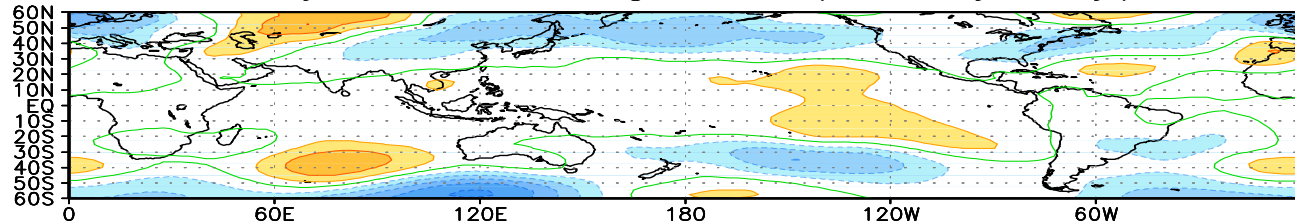
9-years running EOF1(H200,yearly)



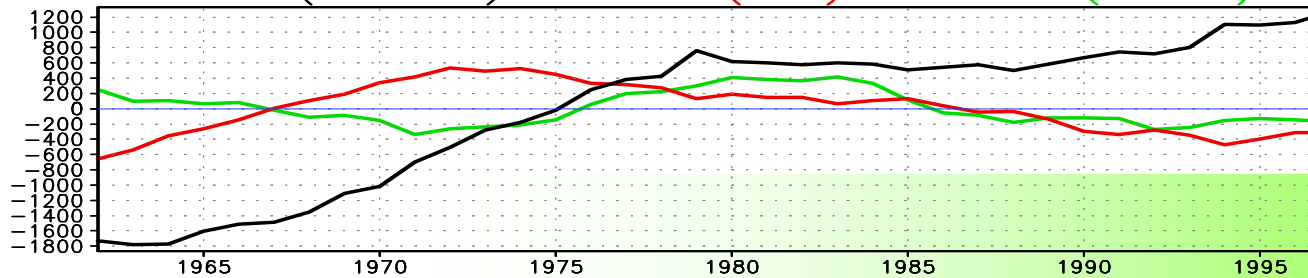
9-years running EOF2(H200,yearly)

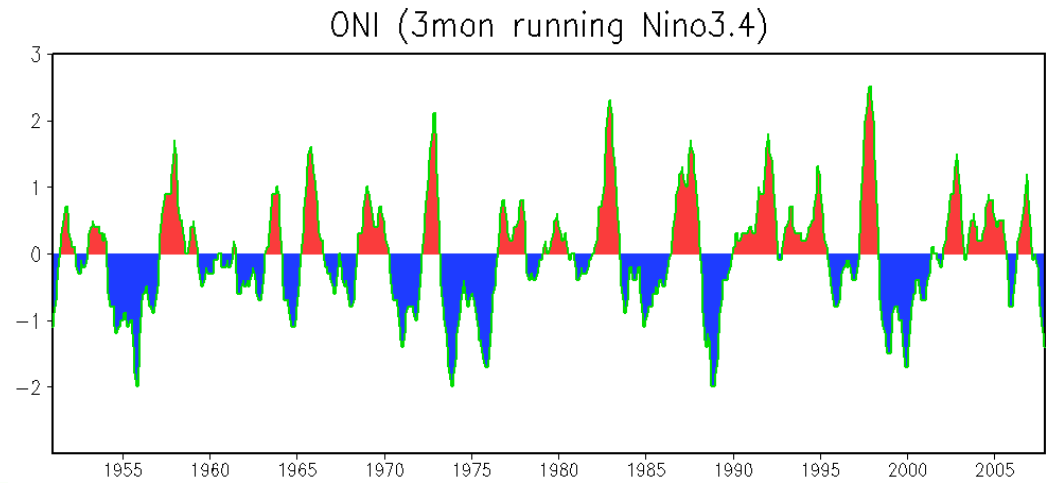
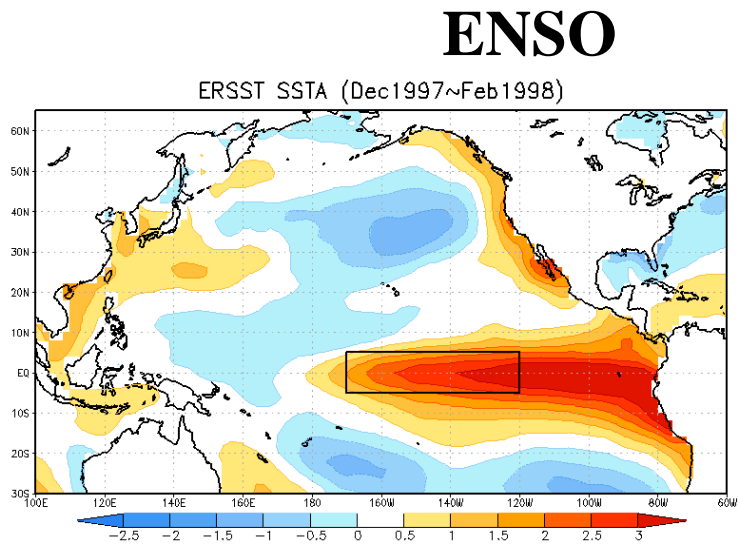
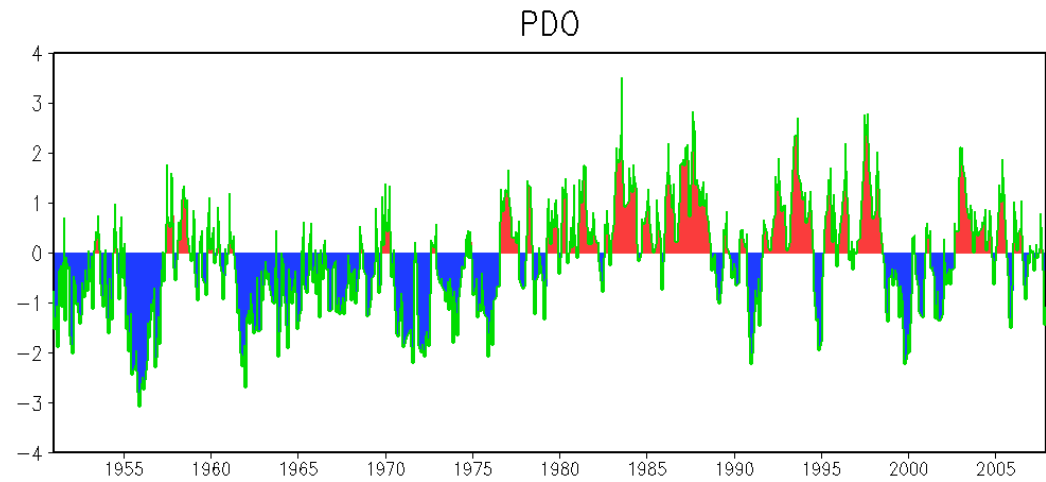
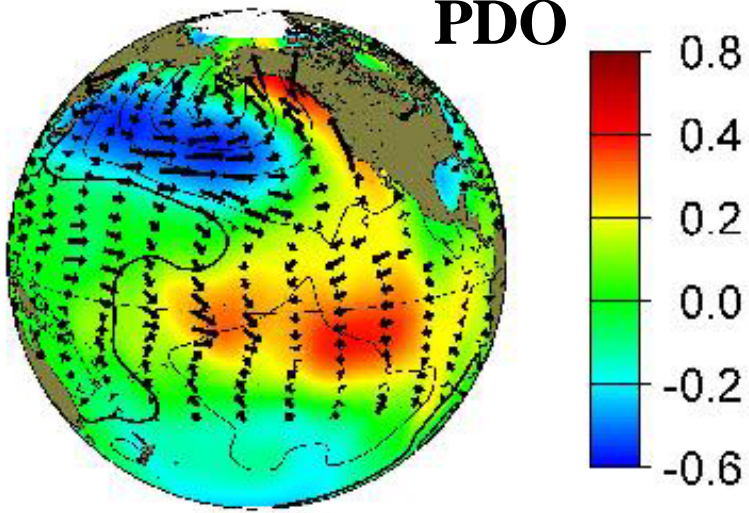


9-years running EOF3(H200,yearly)



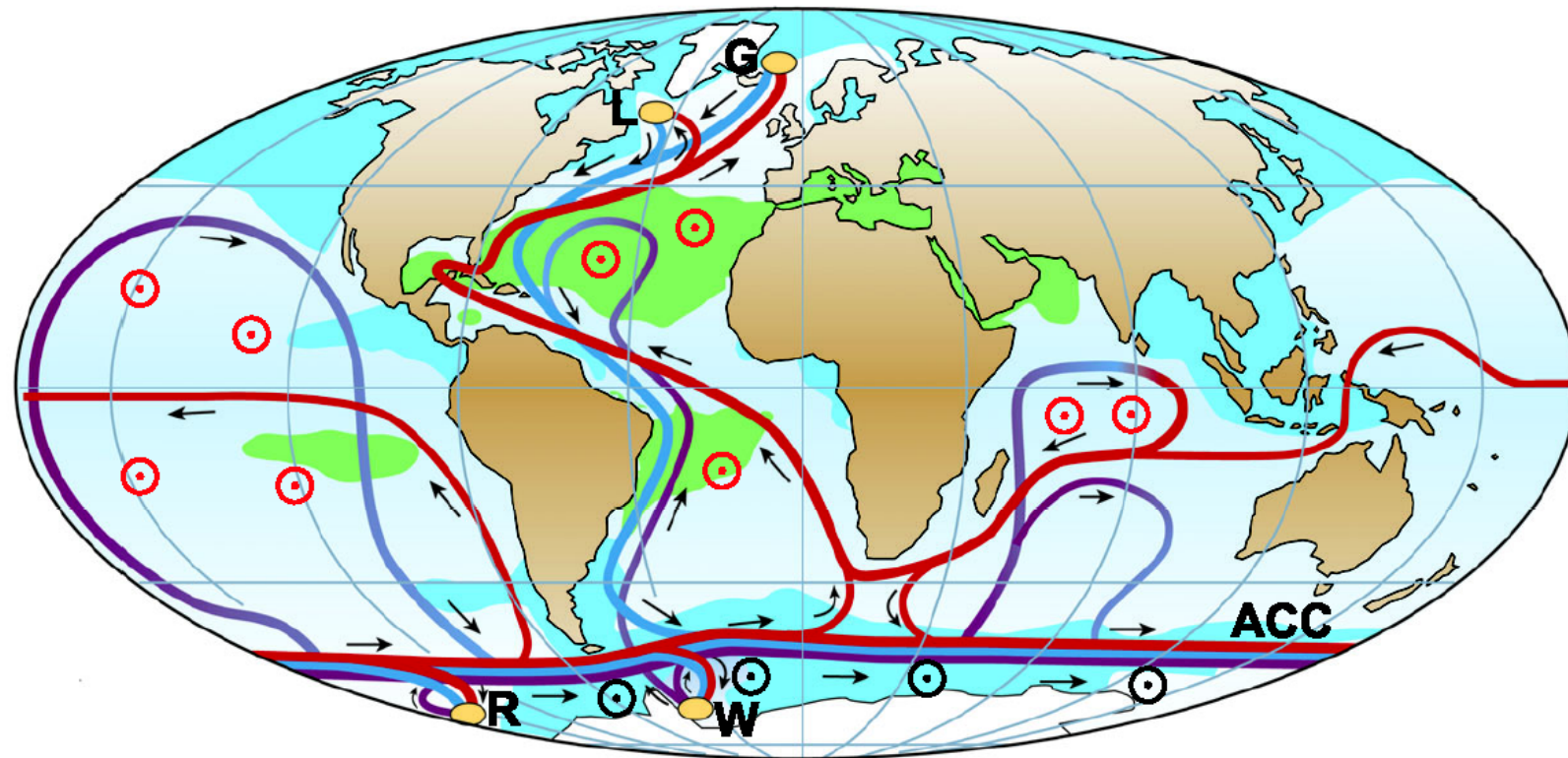
PC-1 (80.6%) PC-2 (9%) PC-3 (4.1%)





What is **Thermohaline** circulation ?

(Meridional Overturning Circulation, MOC)

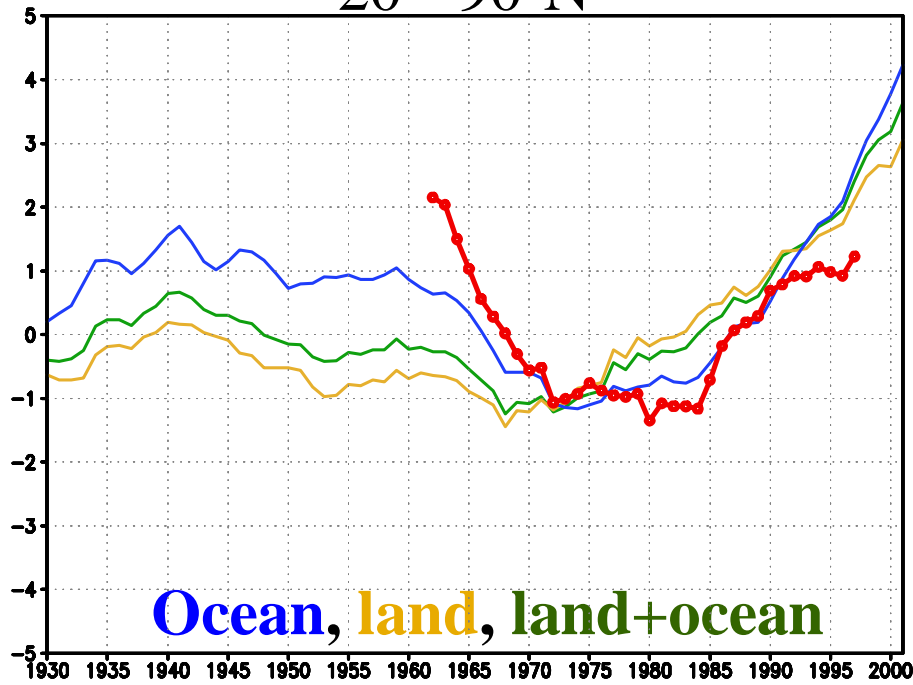


- | | | |
|------------------------|---------------------------|-----------------|
| — Surface flow | ⊙ Wind-driven upwelling | L Labrador Sea |
| — Deep flow | ⊙ Mixing-driven upwelling | G Greenland Sea |
| — Bottom flow | ■ Salinity > 36 ‰ | W Weddell Sea |
| ● Deep Water Formation | ■ Salinity < 34 ‰ | R Ross Sea |

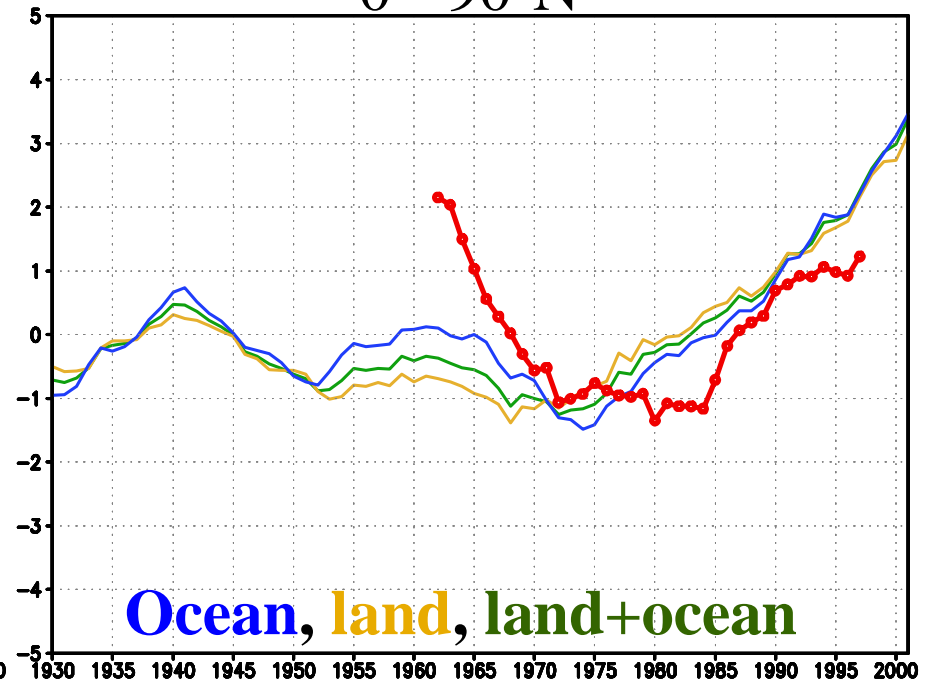


(Rahmatorf, 2006)

20°~90°N



0°~90°N



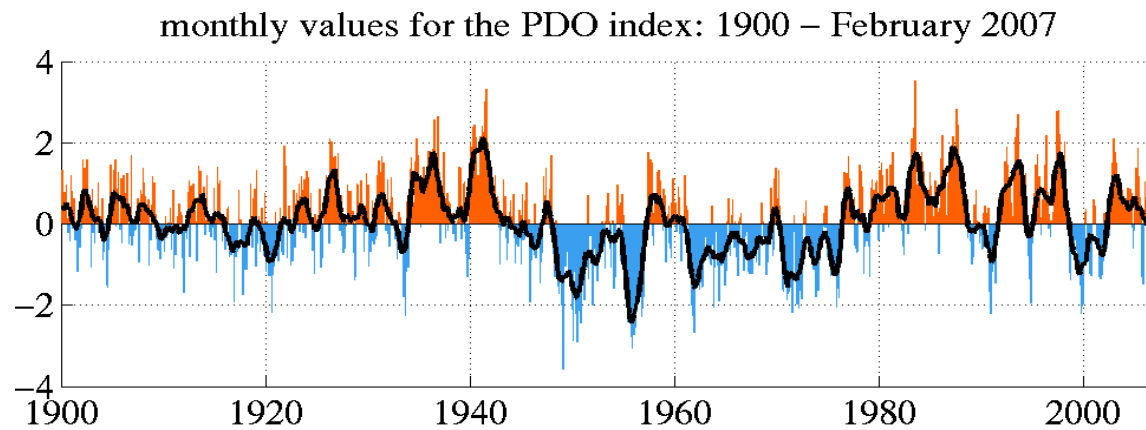
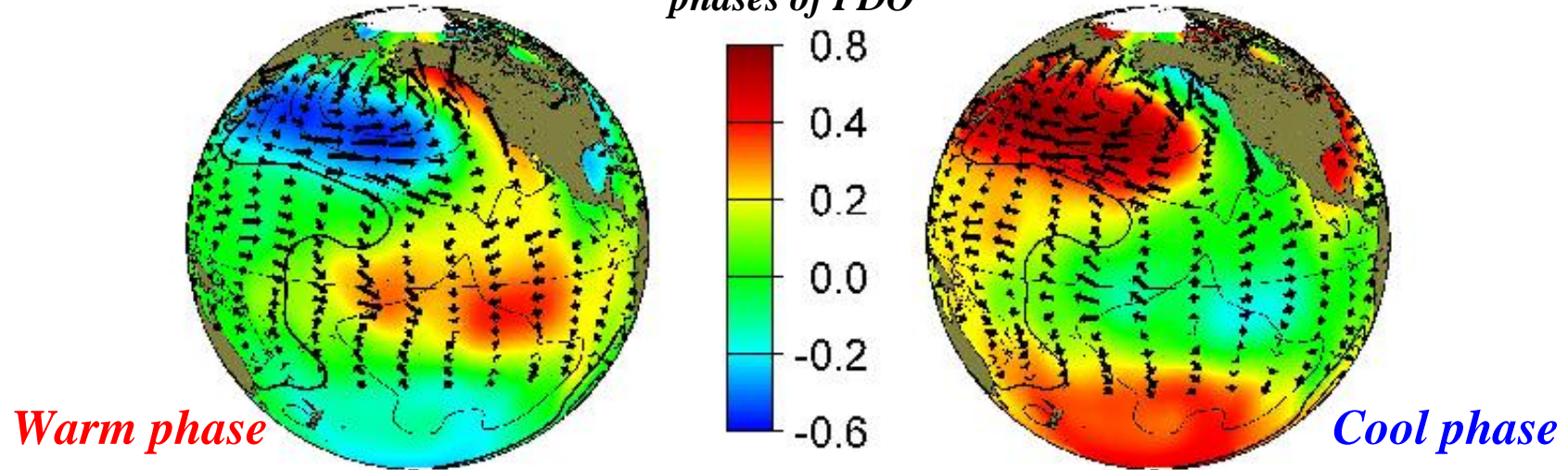


**How many Decadal to Multidecadal
fluctuations in the Northern Hemisphere ?**



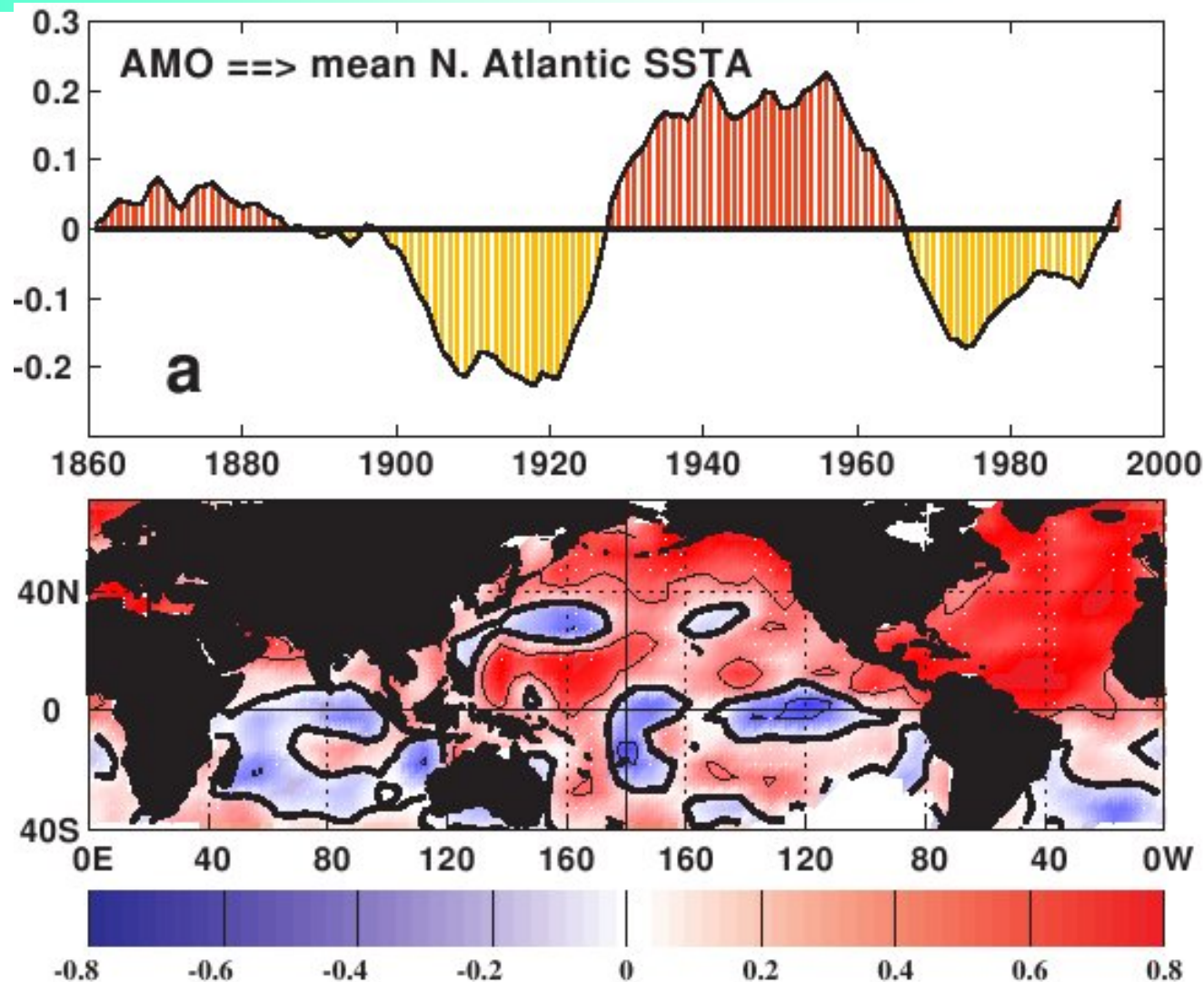
Pacific Decadal Oscillation (PDO)

*Typical wintertime Sea Surface Temperature (colors),
Sea Level Pressure (contours) and surface windstress (arrows) anomaly patterns during warm and cool
phases of PDO*



From: <http://jisao.washington.edu/pdo/>

Atlantic Multidecadal Oscillation (AMO)

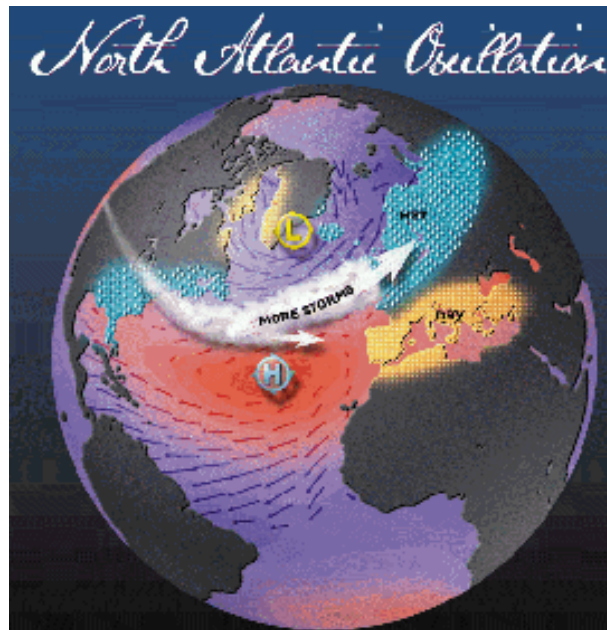


Upper panel: AMO index: the ten-year running mean of detrended Atlantic sea surface temperature anomaly (SSTA, °C) north of the equator. Lower panel: Correlation of the AMO index with gridded SSTA over the world ocean (all seasons). The thick contour is zero and thin contours denote the 95% significance level.

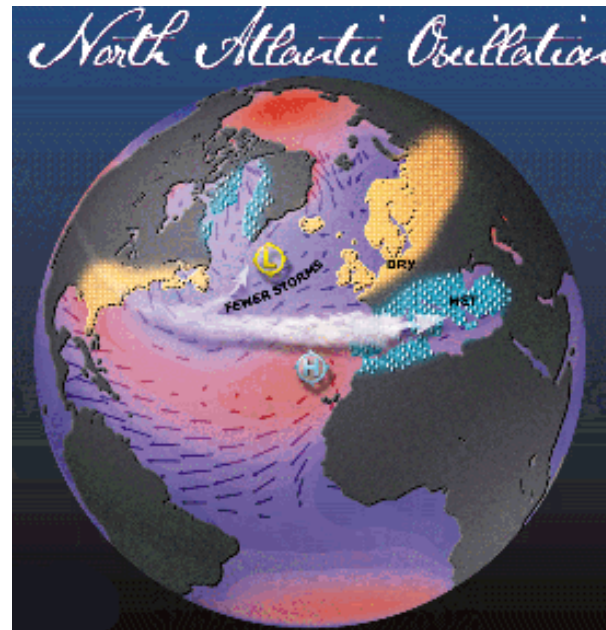


Form:http://www.aoml.noaa.gov/phod/amo_fig.php

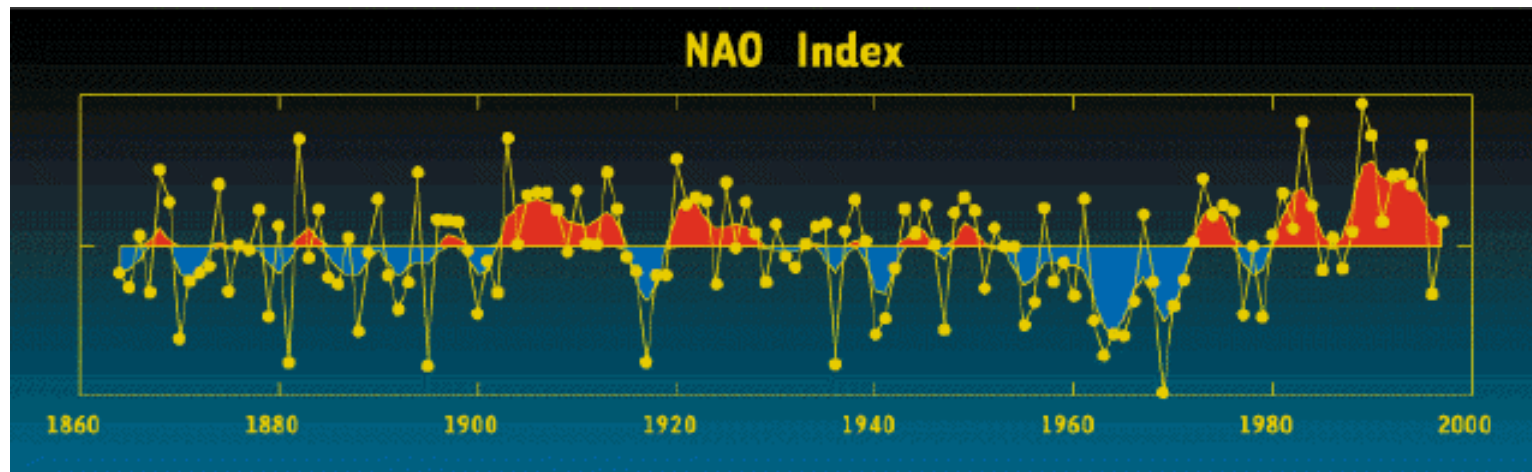
North Atlantic Oscillation(NAO)



Positive NAO



Negative NAO

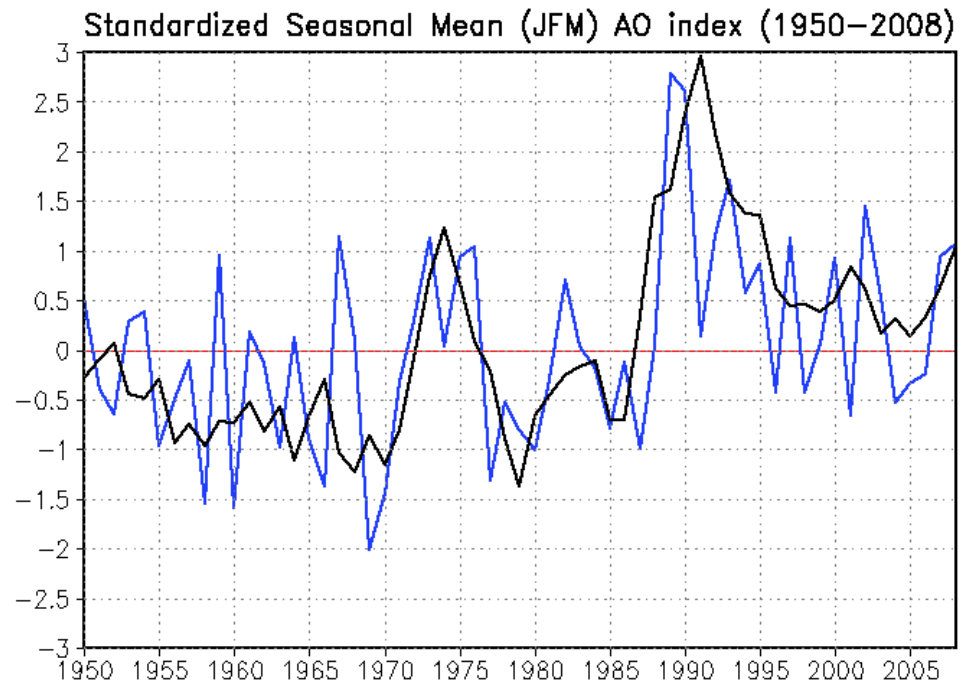
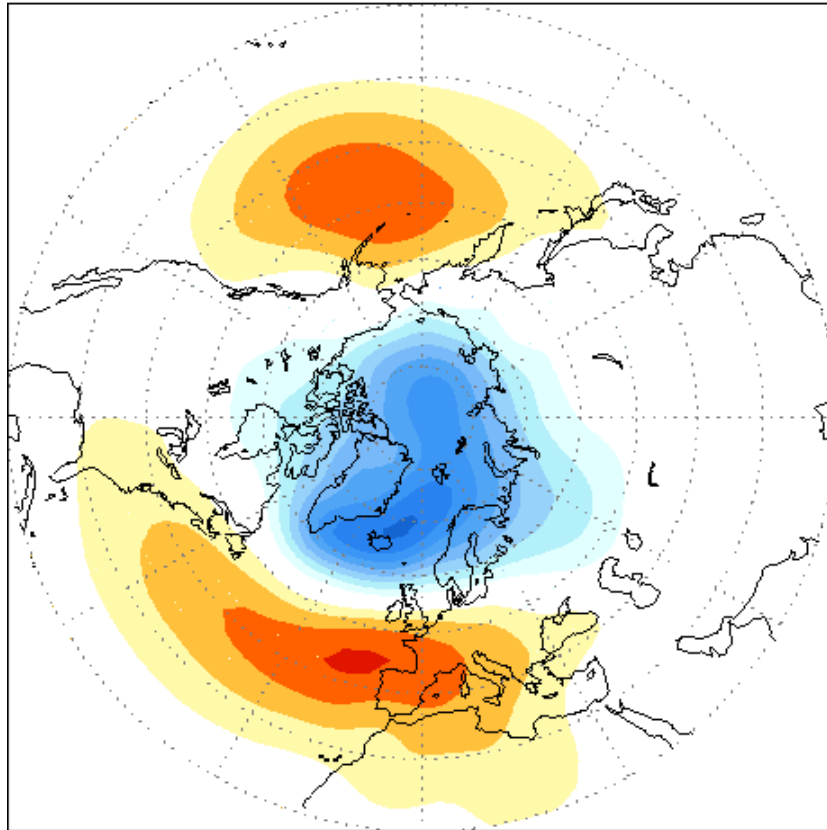


From : <http://www.ldeo.columbia.edu/res/pi/NAO/>



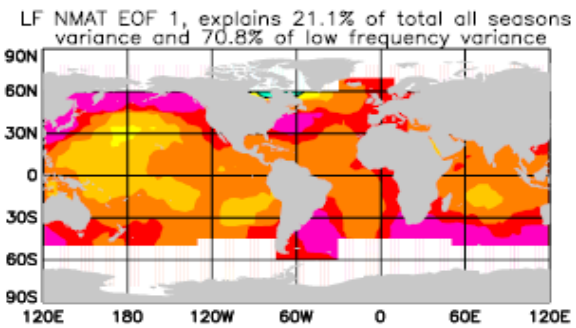
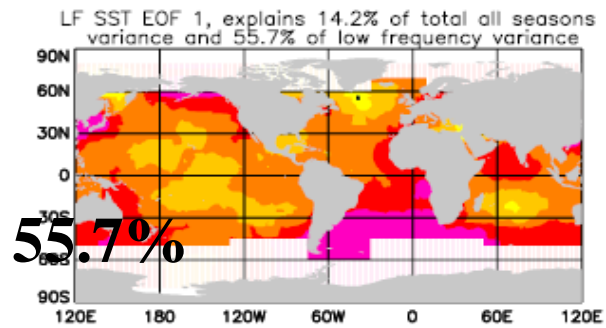
Arctic Oscillation (AO)

Leading EOF (19%) shown as regression map of 1000mb height (m)

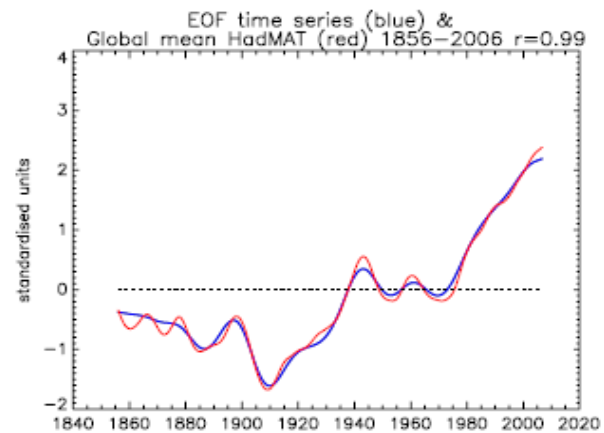
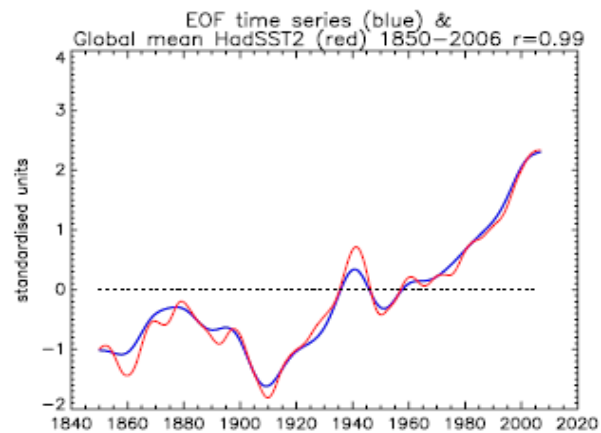


From: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml





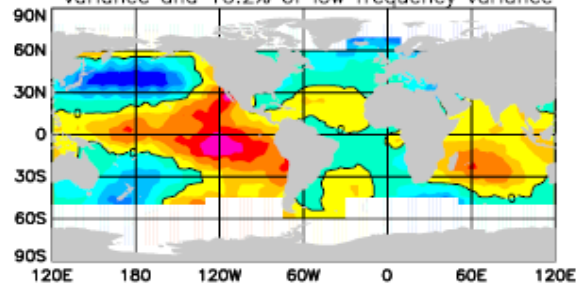
**EOF1 \equiv
Global Warming**



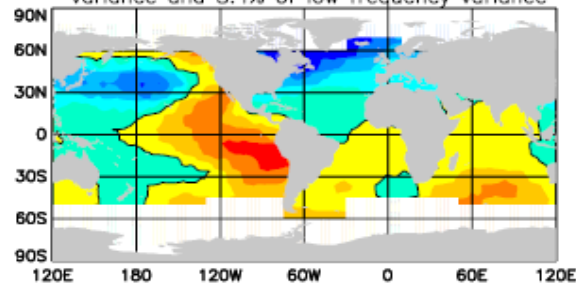
Parker et al.(2007)



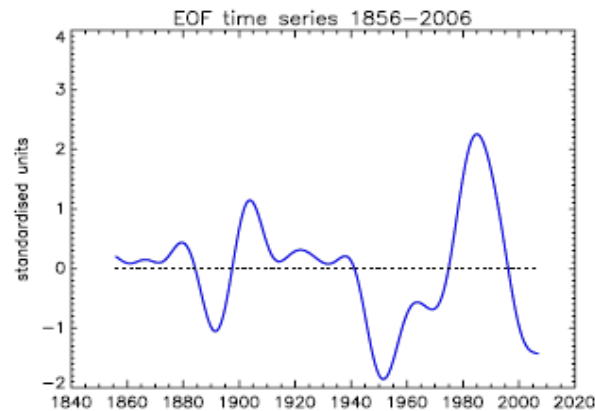
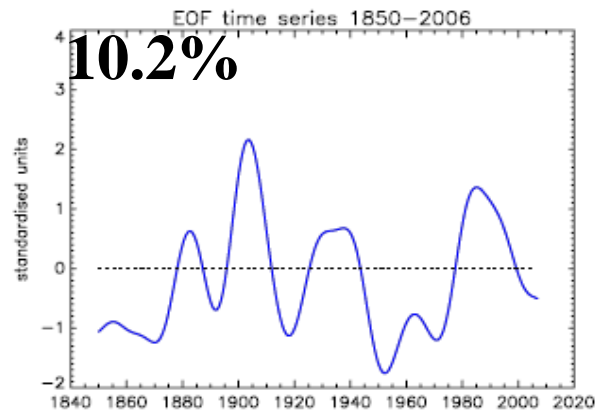
LF SST EOF 2, explains 2.6% of total all seasons variance and 10.2% of low frequency variance



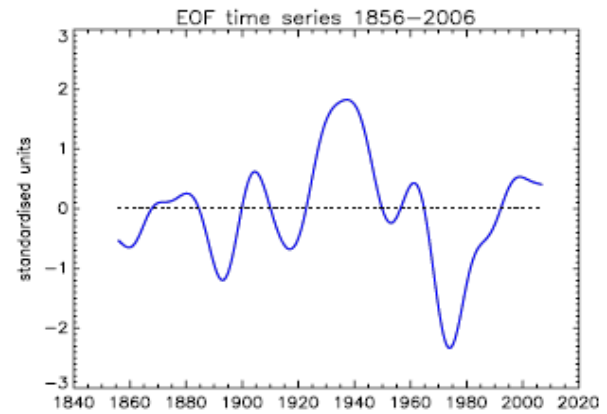
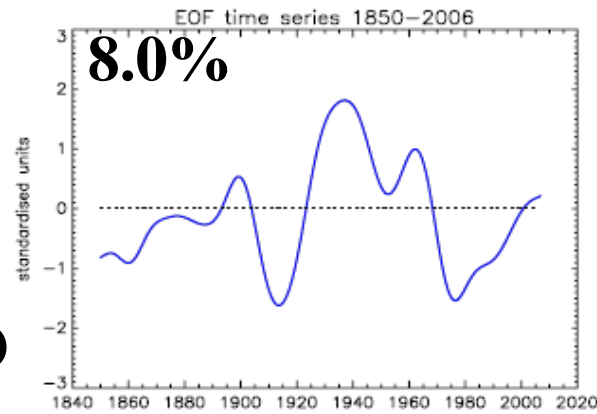
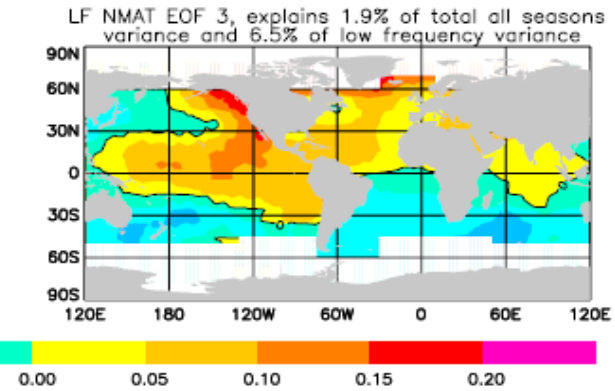
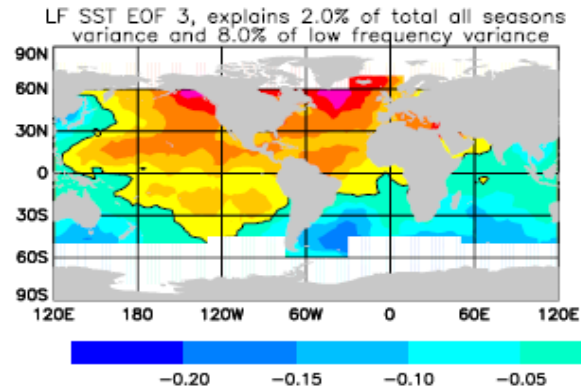
LF NMAT EOF 2, explains 2.5% of total all seasons variance and 8.4% of low frequency variance



EOF2 \equiv PDO



Parker et al.(2007)

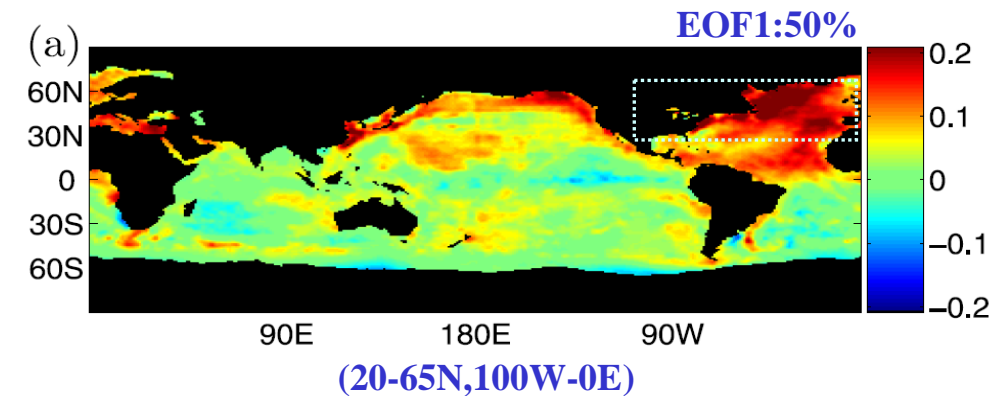
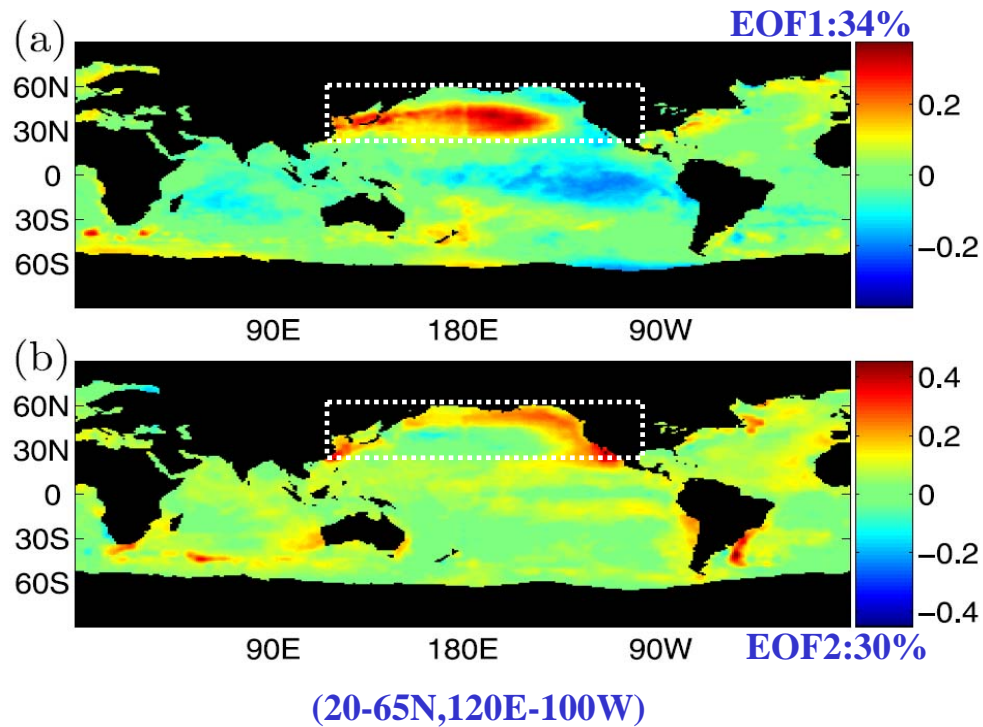


EOF3 ≡ AMO

Parker et al.(2007)



(d'Orgeville and Peltier, 2007)



Hadley Center SST

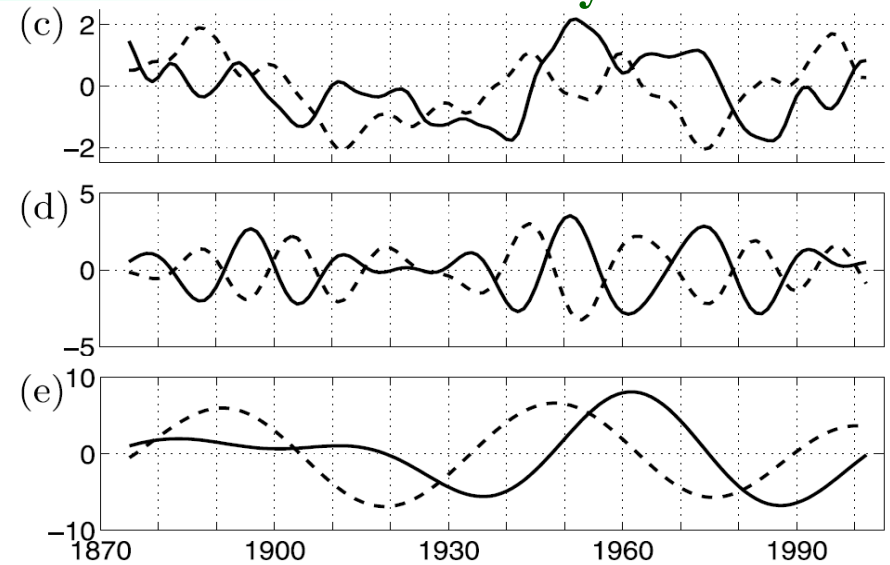


Figure 1. (a and b) First two EOFs (EOF_1^{NP} and EOF_2^{NP}) of SST anomalies for 1870 to present. (c) Corresponding principal components (PC_1^{NP} , solid; PC_2^{NP} , dashed) and their respective continuous wavelet transform coefficients for a (d) 20 year and (e) 60 year Morlet wavelet.

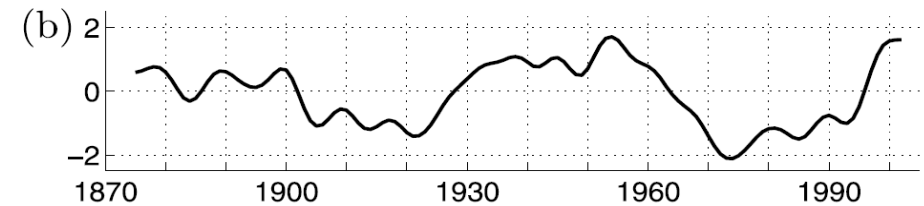
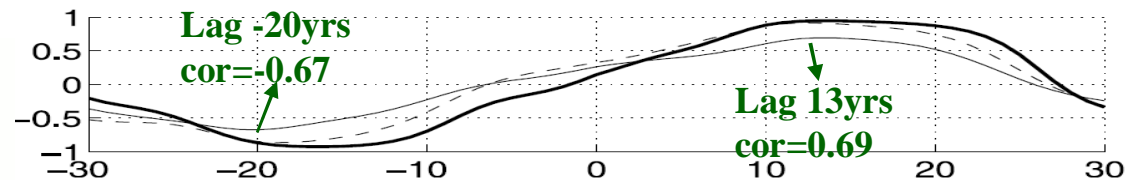


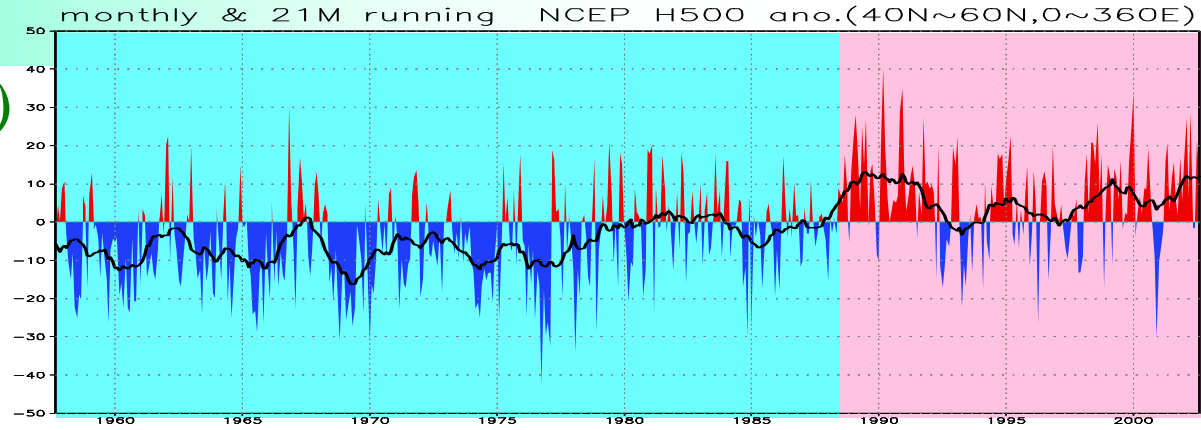
Figure 3. (a) AMO structure as the first EOFs of SST anomalies in the North Atlantic (EOF^{NA}) for 1870 to present (maximum of 0.4°C in the NA region). (b) AMO index defined as the corresponding principal component (PC^{NA}).



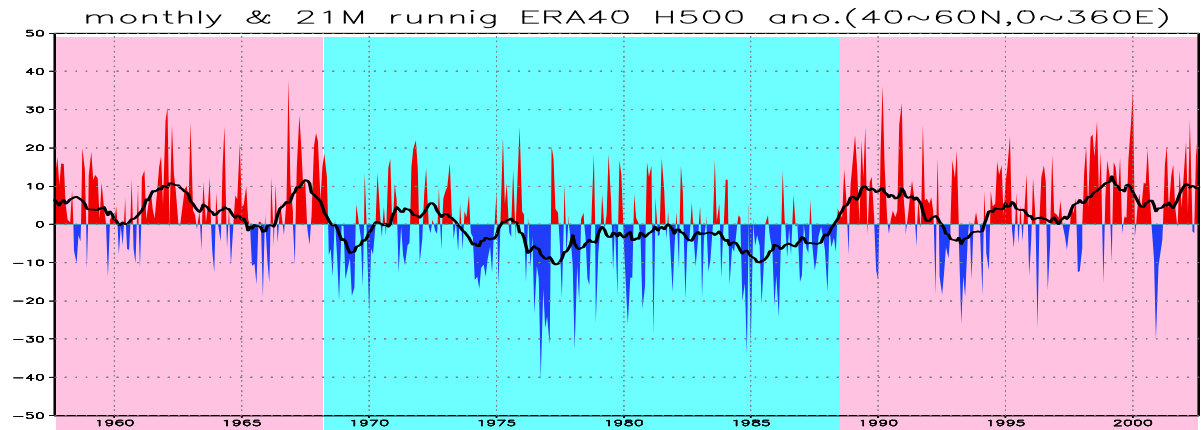
Monthly H500 Ano.

(40°~60°N, 0°~360°E)

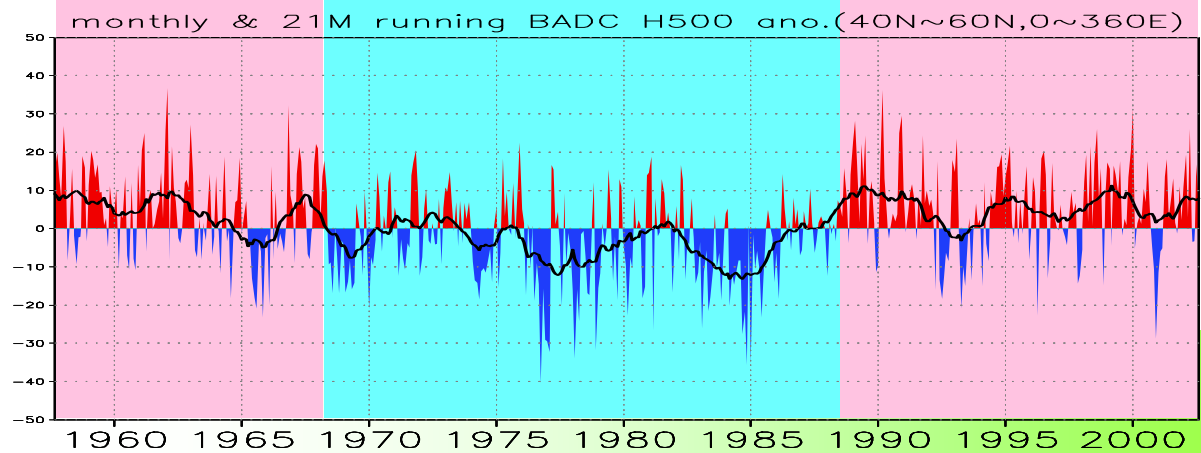
NCEP



ERA40

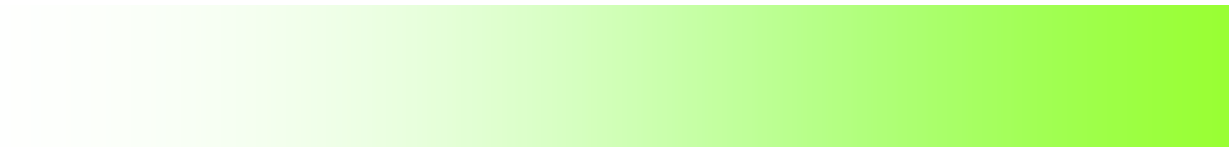


BADC

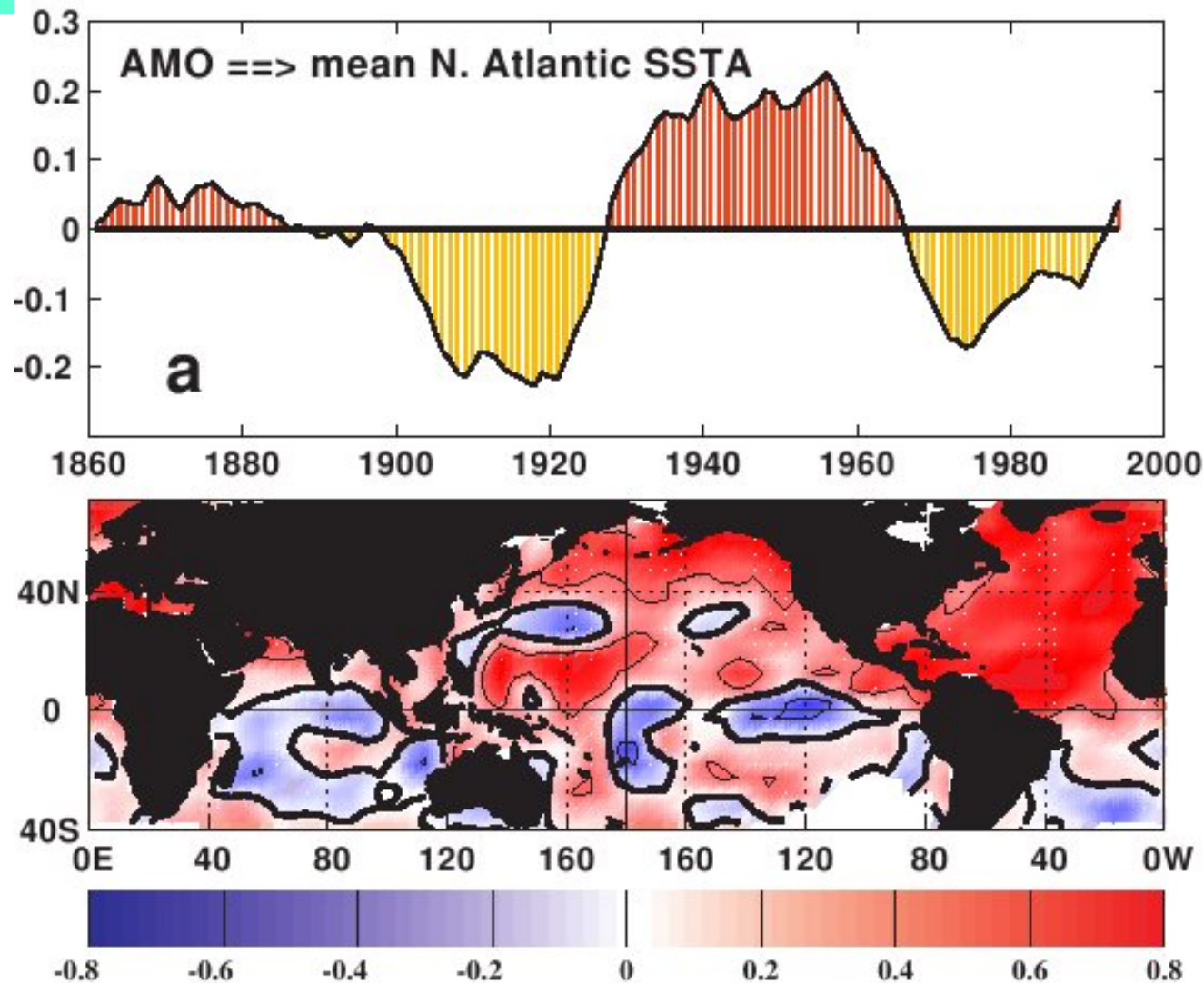




What effects the Atlantic Multidecadal Oscillation have ?



Atlantic Multidecadal Oscillation (AMO)

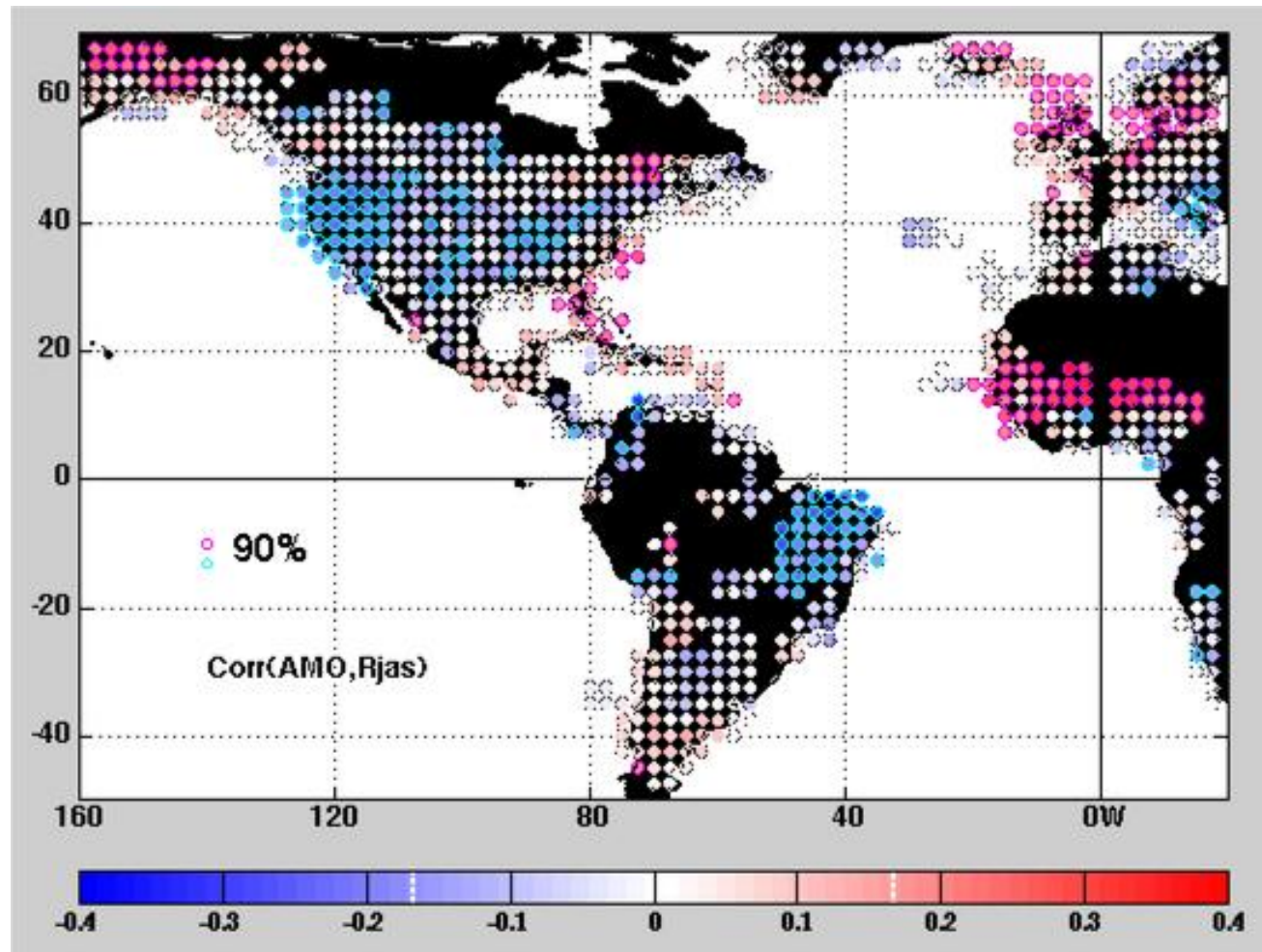


Upper panel: AMO index: the ten-year running mean of detrended Atlantic sea surface temperature anomaly (SSTA, °C) north of the equator. Lower panel: Correlation of the AMO index with gridded SSTA over the world ocean (all seasons). The thick contour is zero and thin contours denote the 95% significance level.



Form:http://www.aoml.noaa.gov/phod/amo_fig.php

What are the impacts of the AMO?

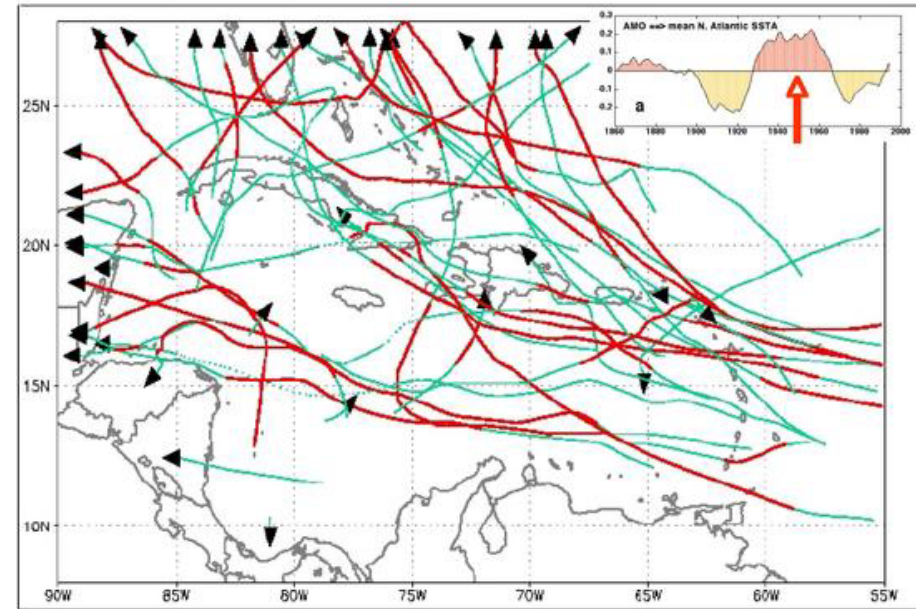
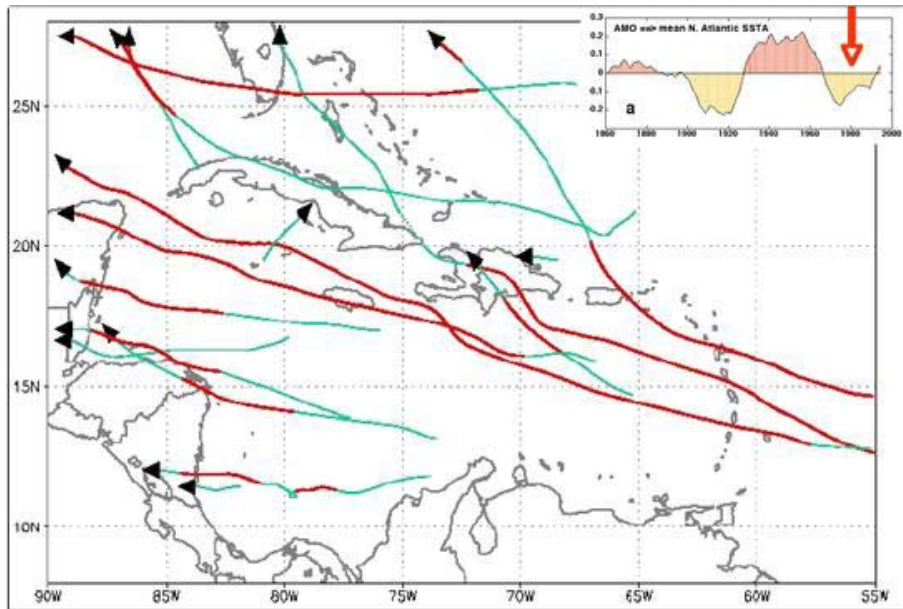


Red and blue colored dots represent positive and negative correlations of **Northern Hemisphere summer rainfall** with the AMO index. When the AMO is positive (warm Atlantic) there is less rainfall over most of the United States and northeastern South America, and more rainfall in southern Alaska, northern Europe, west Africa and Florida.



Form:http://www.aoml.noaa.gov/phod/amo_fig.php

AMO & hurricanes



During warm phases of the AMO, the numbers of tropical storms that mature into severe hurricanes is much greater than during cool phases, at least twice as many. Since the AMO switched to its warm phase around 1995, severe hurricanes have become much more frequent and this has led to a crisis in the insurance industry.



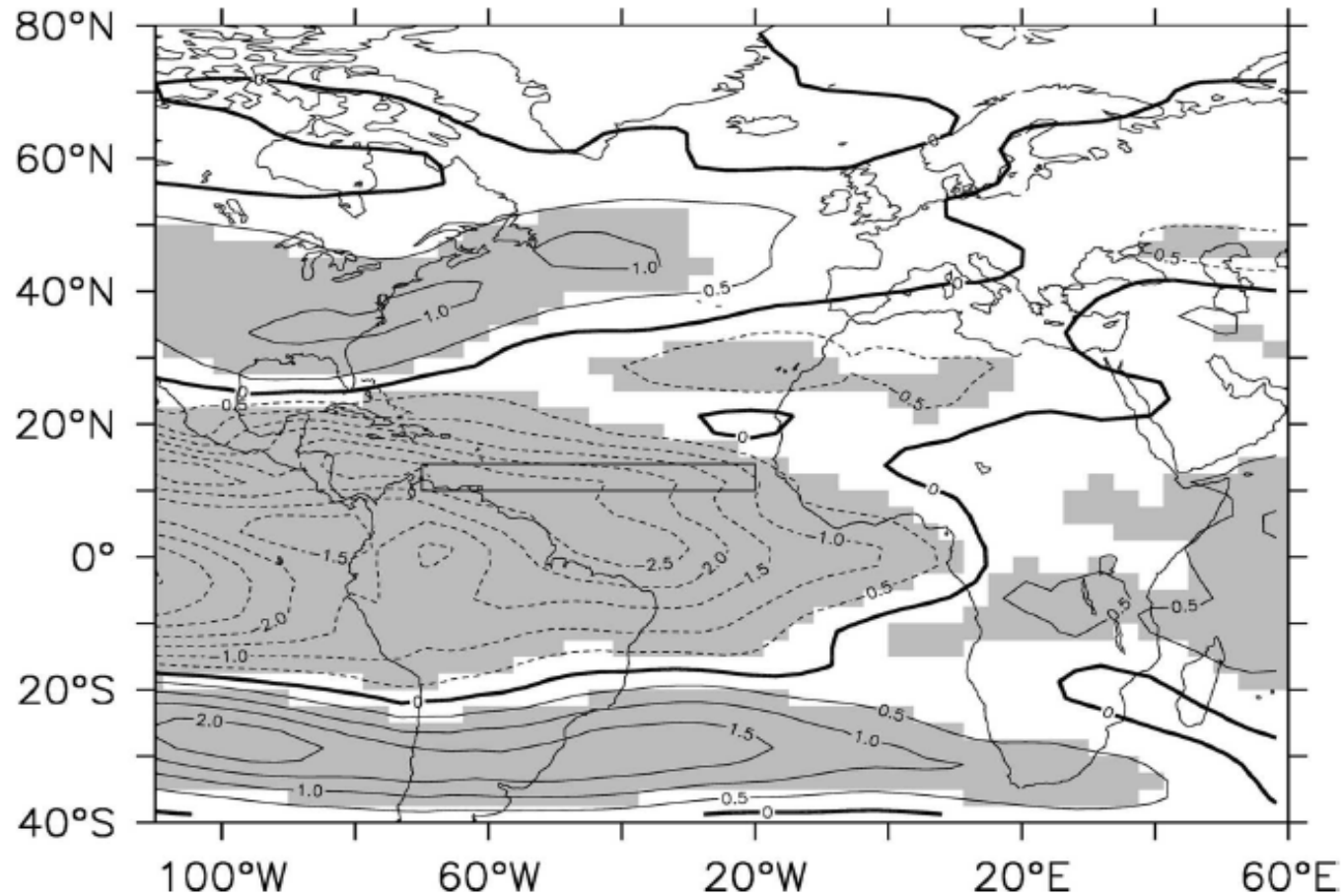


FIG. 9. Response of vertical shear of the zonal wind to warming of the North Atlantic ($NA^+ - NA^-$) in ASO. Shown are anomalies in the vertical shear of the zonal wind between 200 and 850 mb. Units are $m s^{-1}$. The box shows the MDR for Atlantic hurricanes. ASO is the primary season for hurricanes.

Weaker Vertical wind shear

Warmer Atlantic

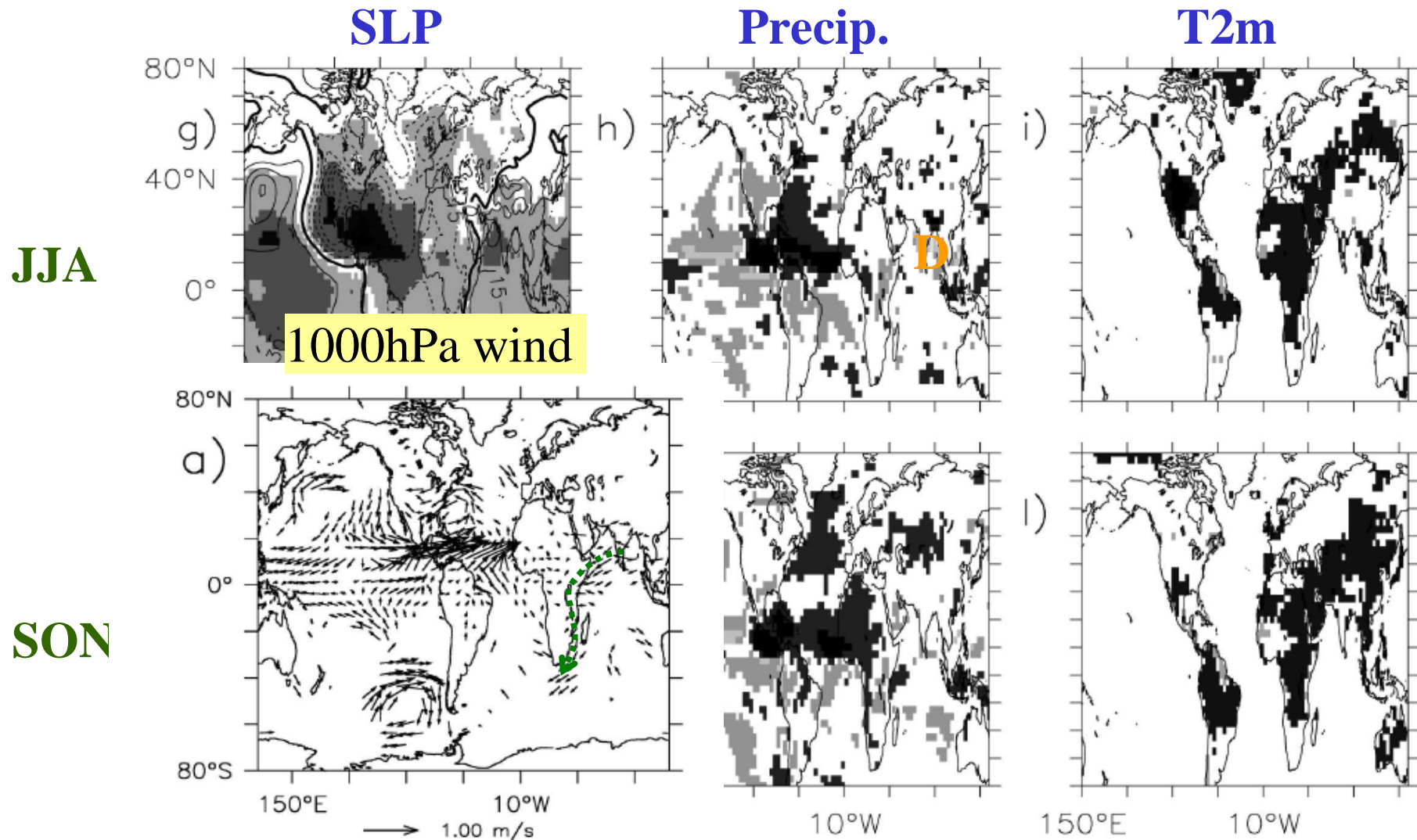
More hurricanes

(Sutton and Hodson, 2007)



HadAM3

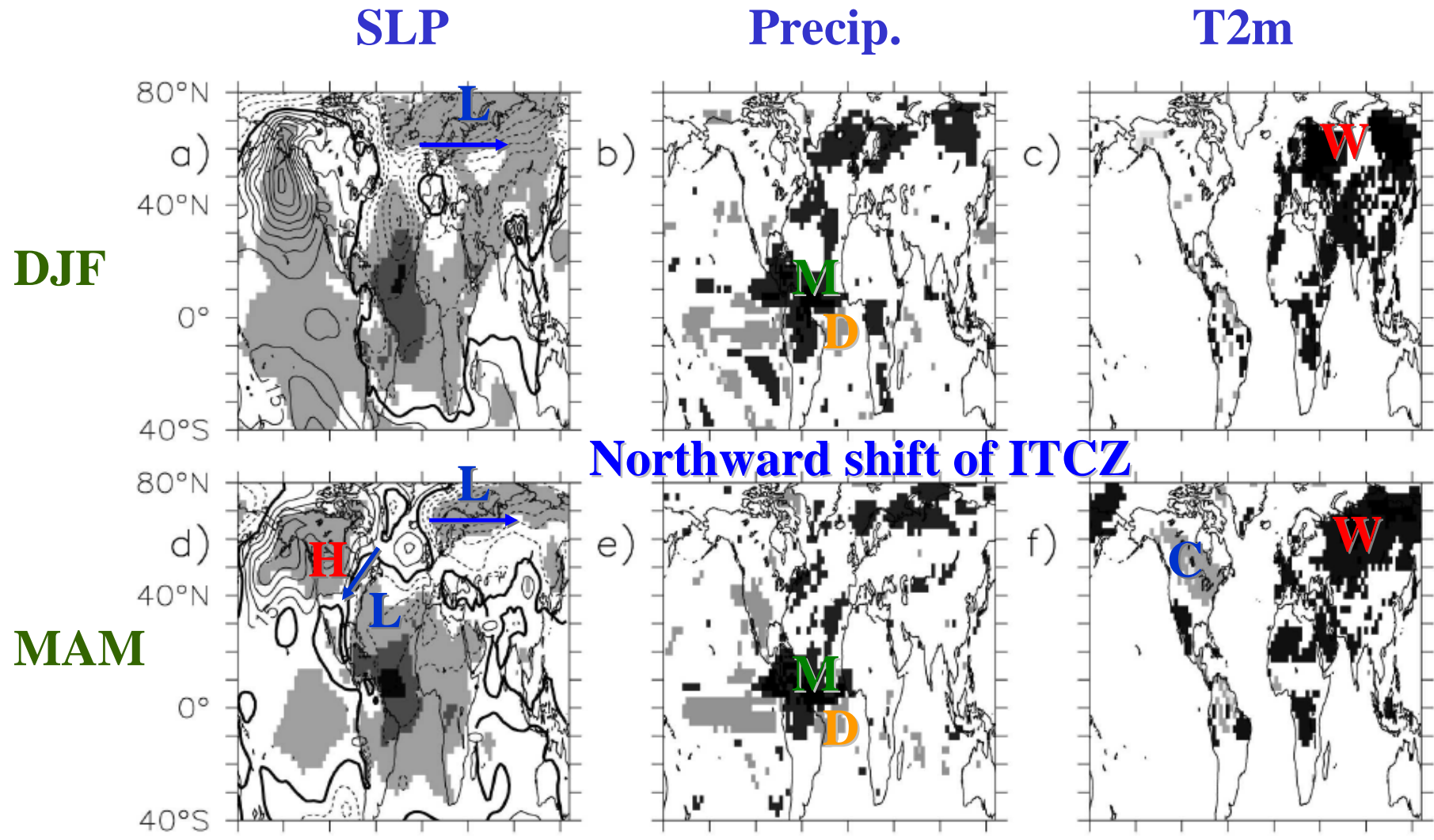
Atmospheric response to **warming** of the North Atlantic.



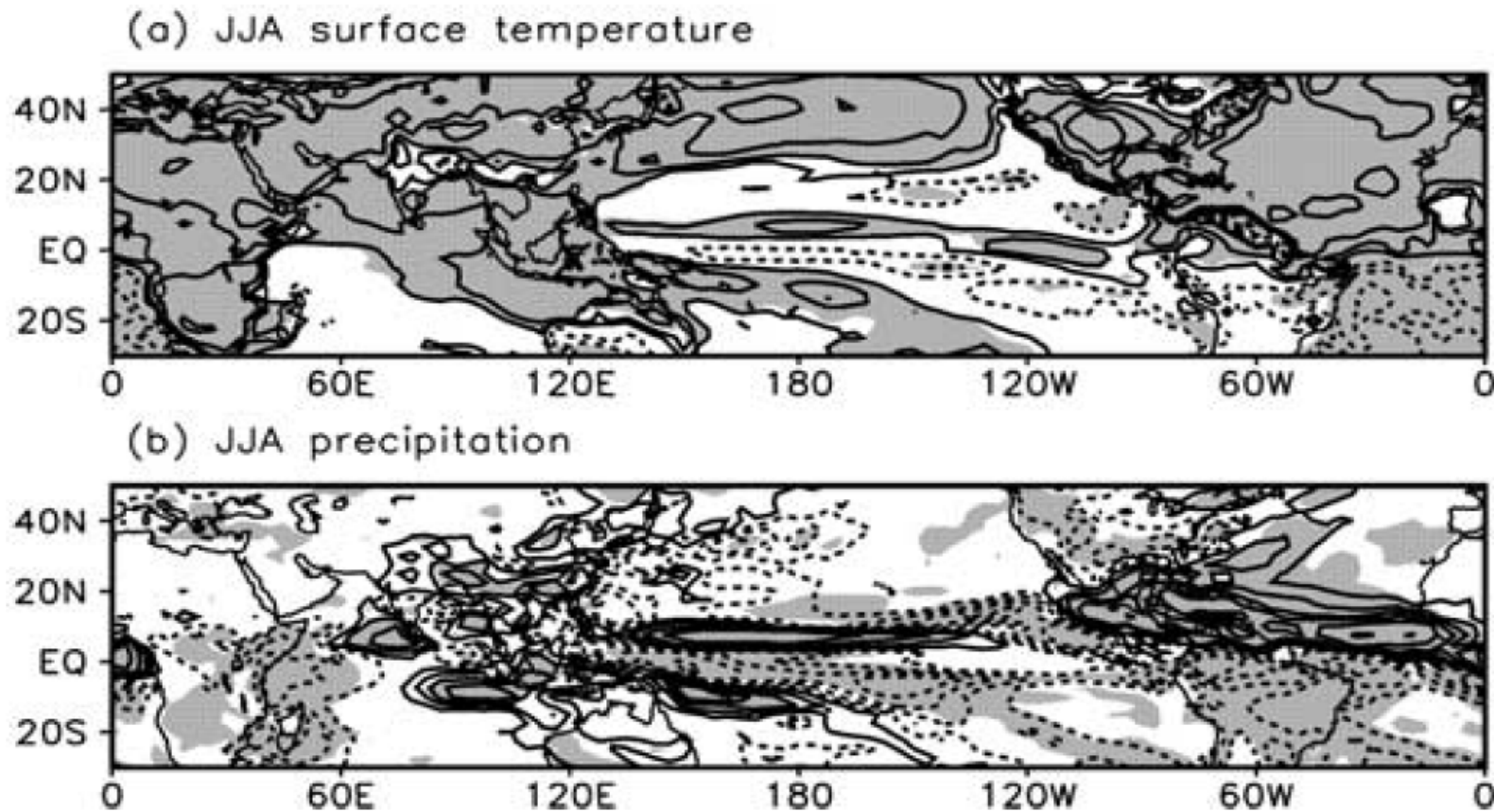
(Sutton and Hodson, 2007)

HadAM3

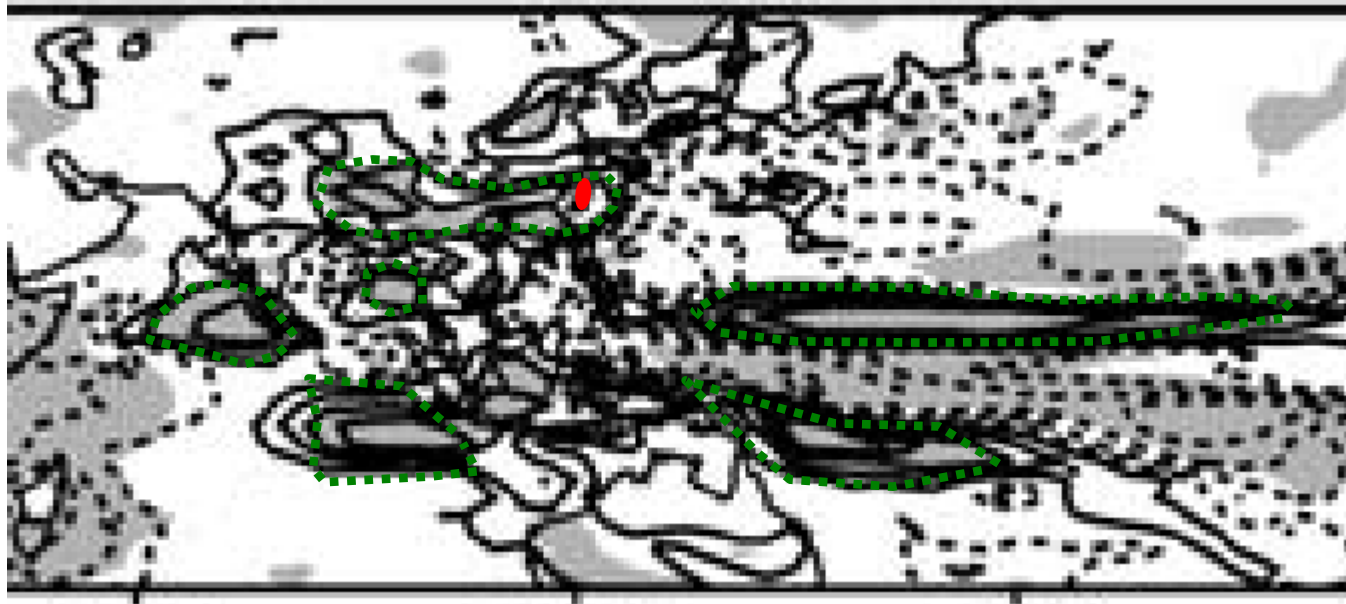
Atmospheric response to **warming** of the North Atlantic.



HadCM3 $AMO_+ - AMO_-$



the positive SST anomalies in the eastern Indian Ocean and maritime continent, which are a response to the AMO through atmosphere-ocean interactions, may play a crucial role in extending the AMO's influences to the Asian monsoon

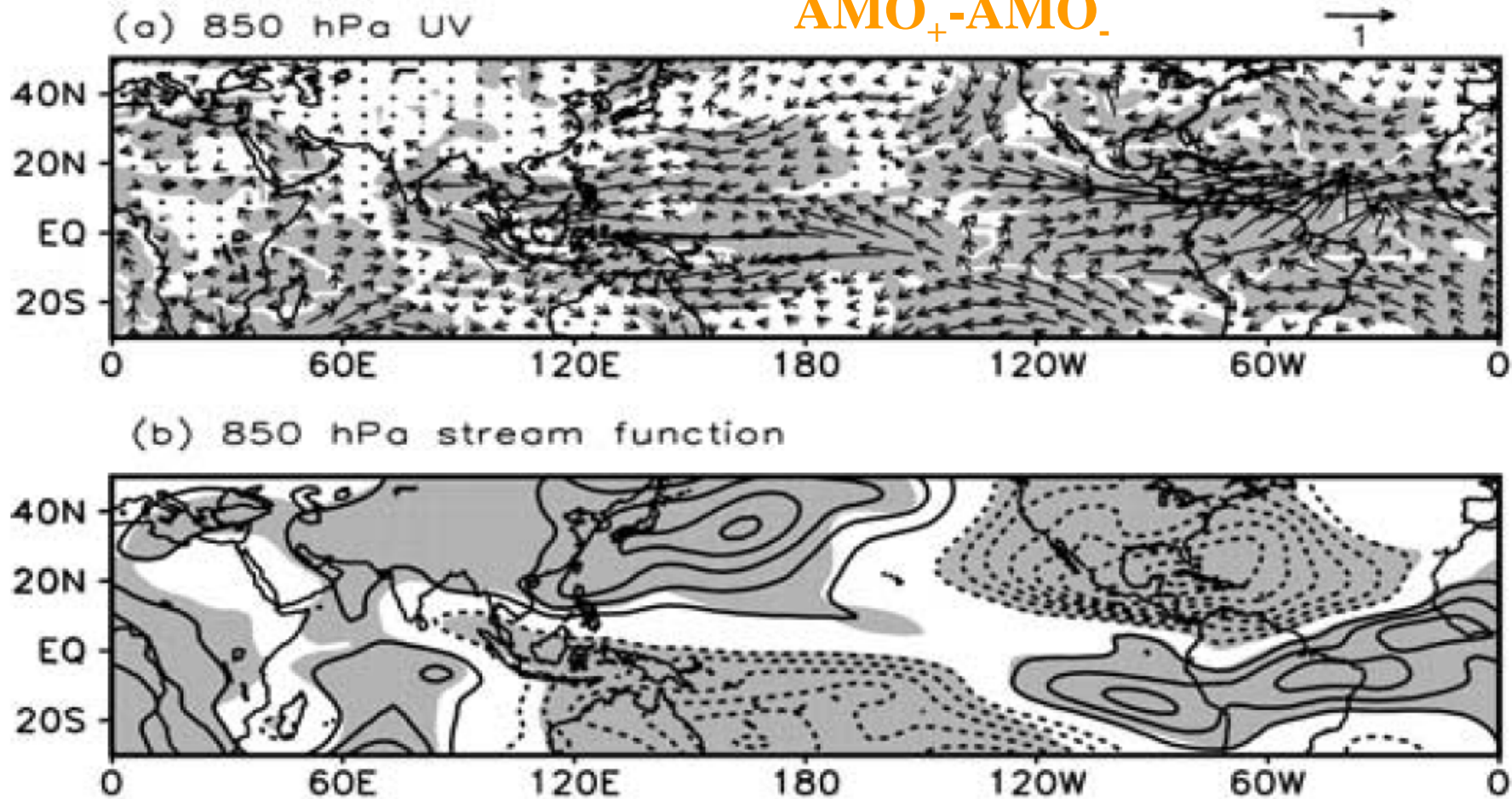


the positive SST anomalies in the eastern Indian Ocean and maritime continent, which are a response to the AMO through atmosphere-ocean interactions, may play a crucial role in extending the AMO's influences to the Asian monsoon



(Lu et al, 2007)

AMO₊-AMO₋



The anticyclonic anomaly in the western North Pacific results in westward extension of the climatological subtropical anticyclone, enhances the east Asian monsoon circulation and leads to more precipitations in east Asia. These circulation anomalies tend to exhibit a baroclinic vertical structure, but with weaker signals at upper troposphere.

(Lu et al, 2007)

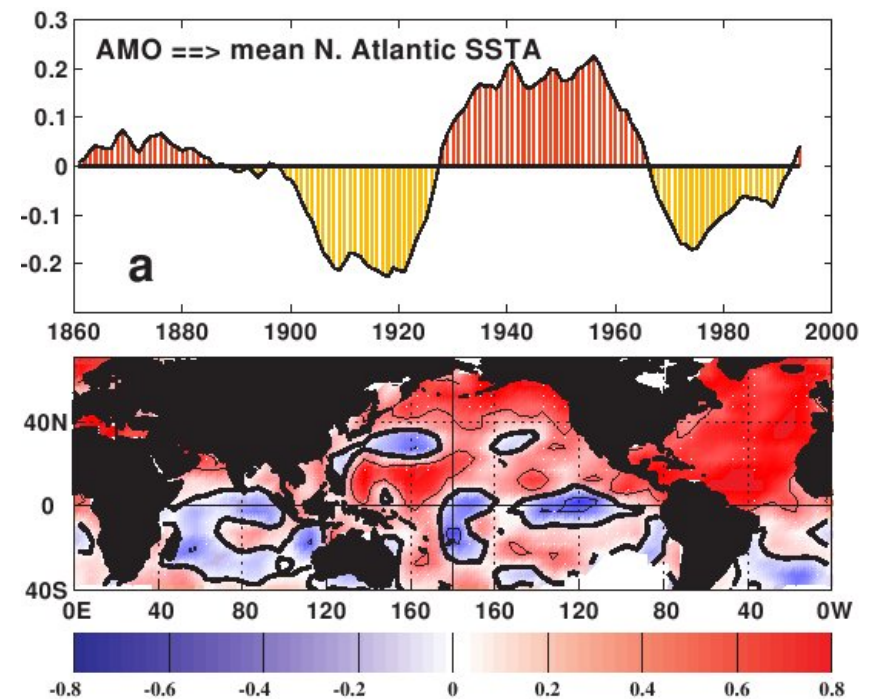
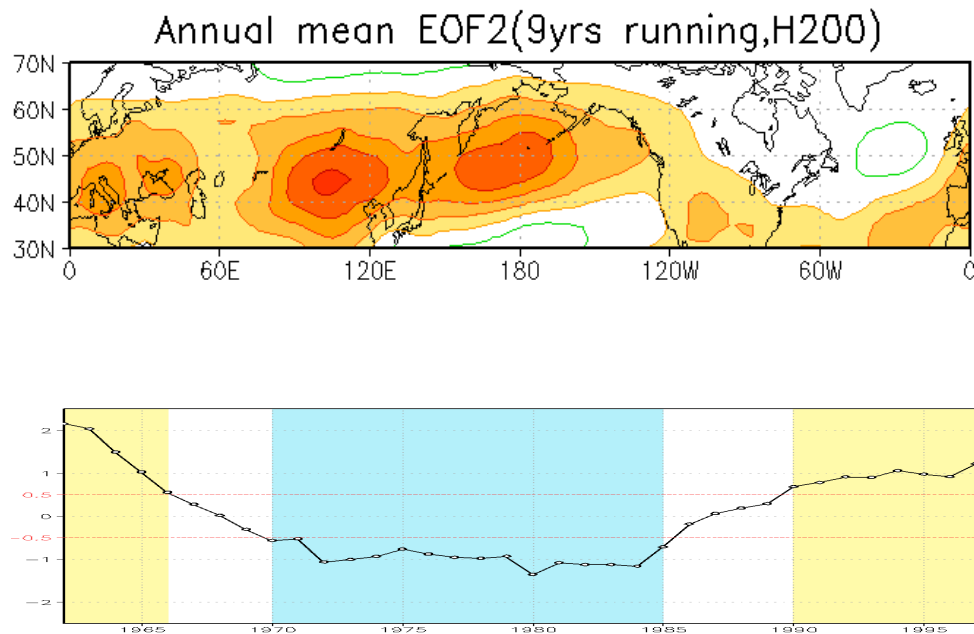




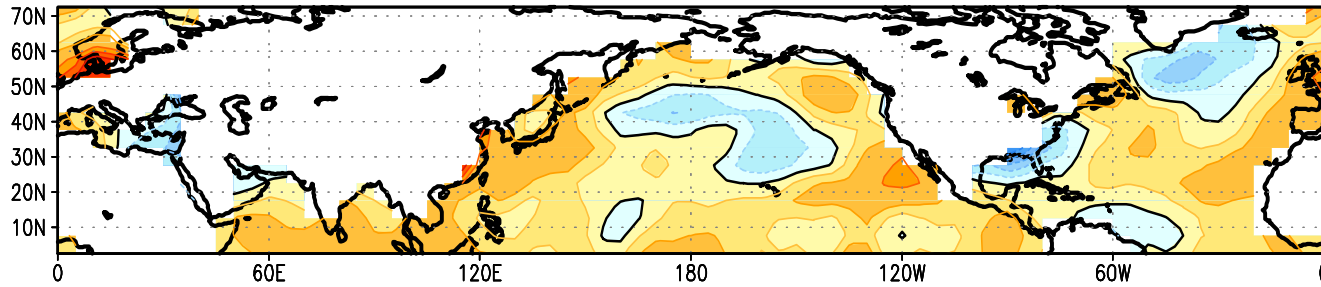
Is it a Global fluctuation??



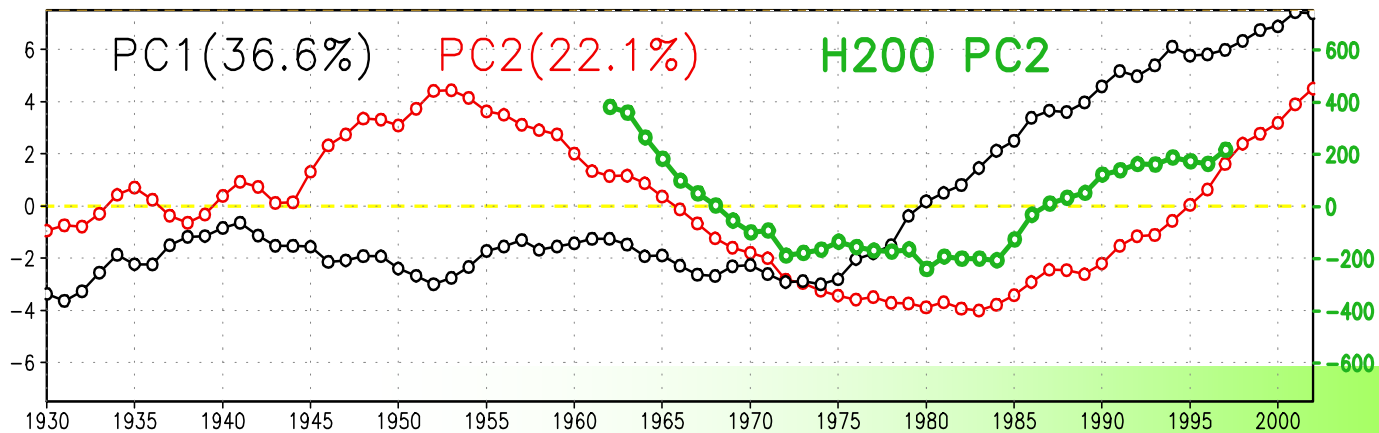
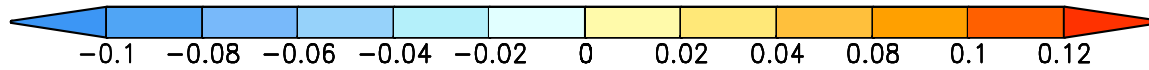
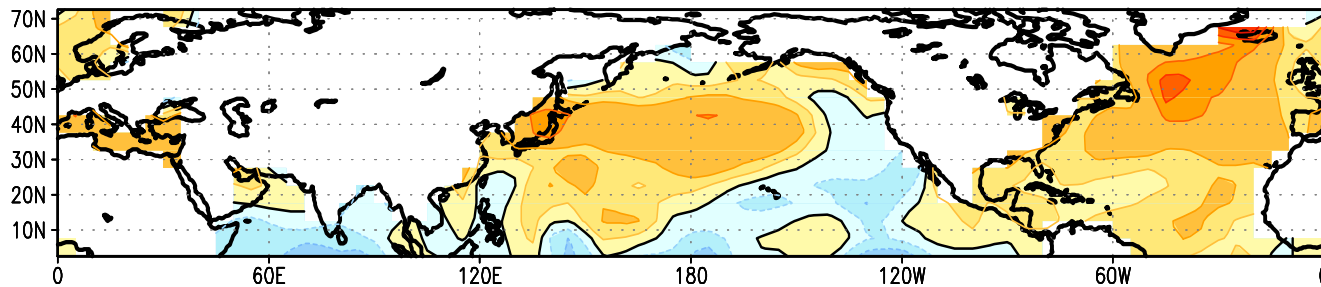
Little is known about the relationship between the AMO and the pattern (Eurasian Pacific (multi)Decadal pattern).



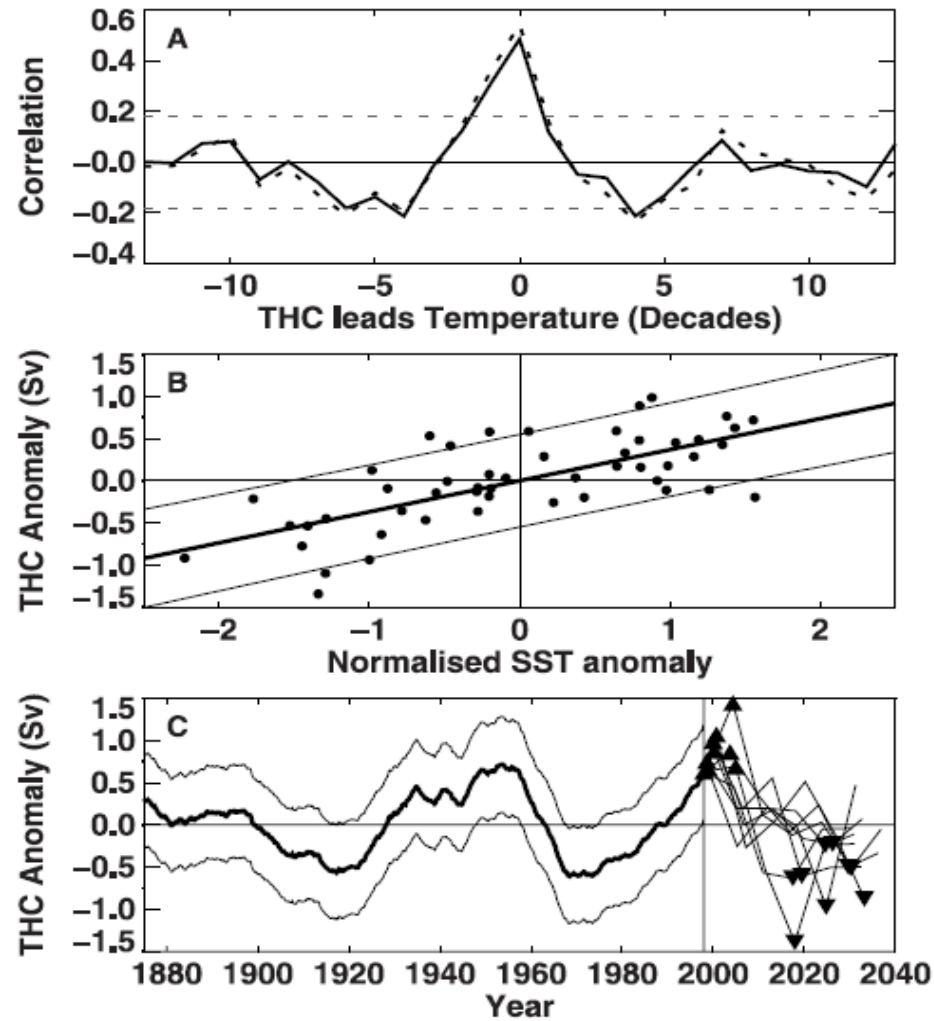
Annual KaplanSST EOF1 (9-yrs running)



Annual KaplanSST EOF2 (9-yrs running)



AMO and Thermohaline Circulation



(Knight et al. 2005)



Future work :

- **Analysis the IPCC AR4 or other data.**
 - **More certain for this fluctuations.**
 - **Compare past ,current and future condition.**
- **Climate Models.(If possible)**