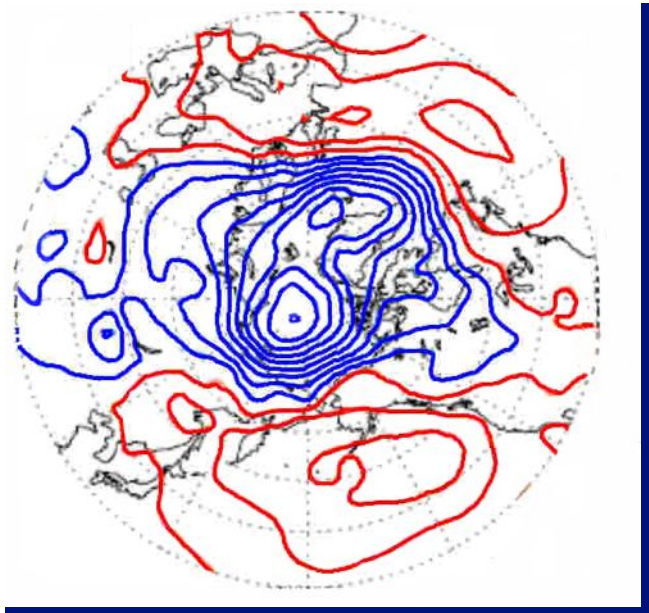
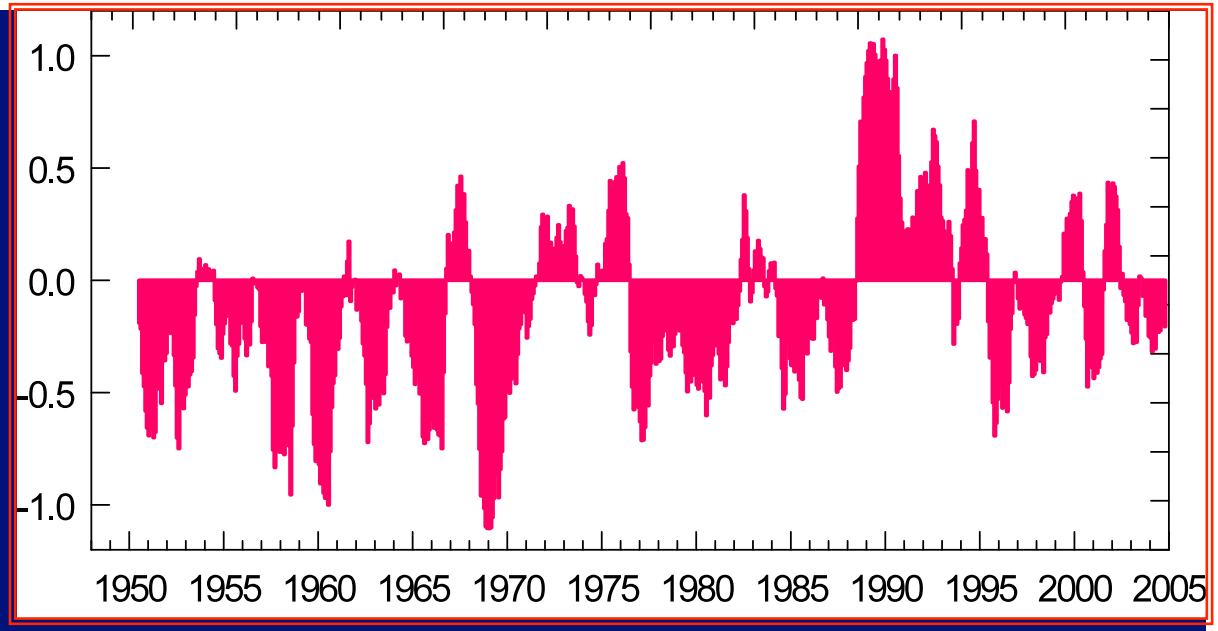
Spatial variation of the Arctic Oscillation and its long-term change

Jinping ZHAO, Yong Cao, and Jiuxin Shi
Ocean University of China

Why we study AO/NAO?

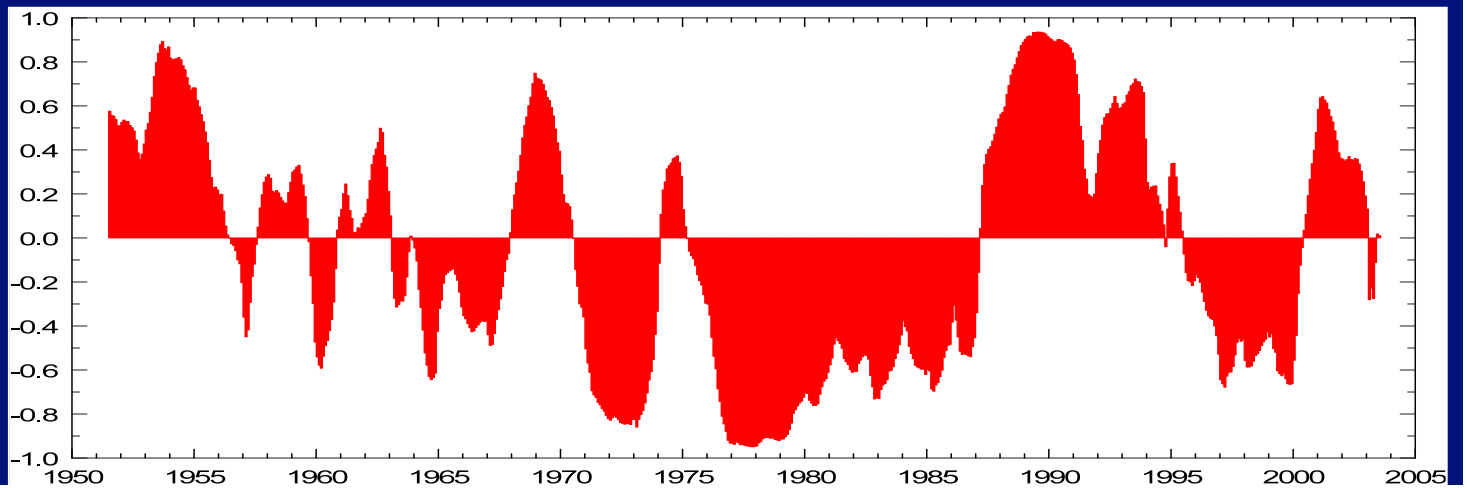
(1) AO/NAO is important for Arctic
(2) AO/NAO is important to China's climate variation
(3) I believe AO is dominated by ocean process





Arctic Oscillation is defined as the first mode of EOF of Sea Level Pressure (SLP) north of 20°N

- Correlation of air temperature between Canada (60N, 90W) and Russia (60N, 90E).



Spatial variation of AO

- AO is spatially varied, but we have little knowledge about
  - What is the spatial variation of AO?
  - How to describe the spatial variation?

Definition of the spatial variation of AO

The spatial variation of AO is defined here as **the temporal variation of the ensemble of the grids with SLP varying consistent with the AO index in a certain time span**

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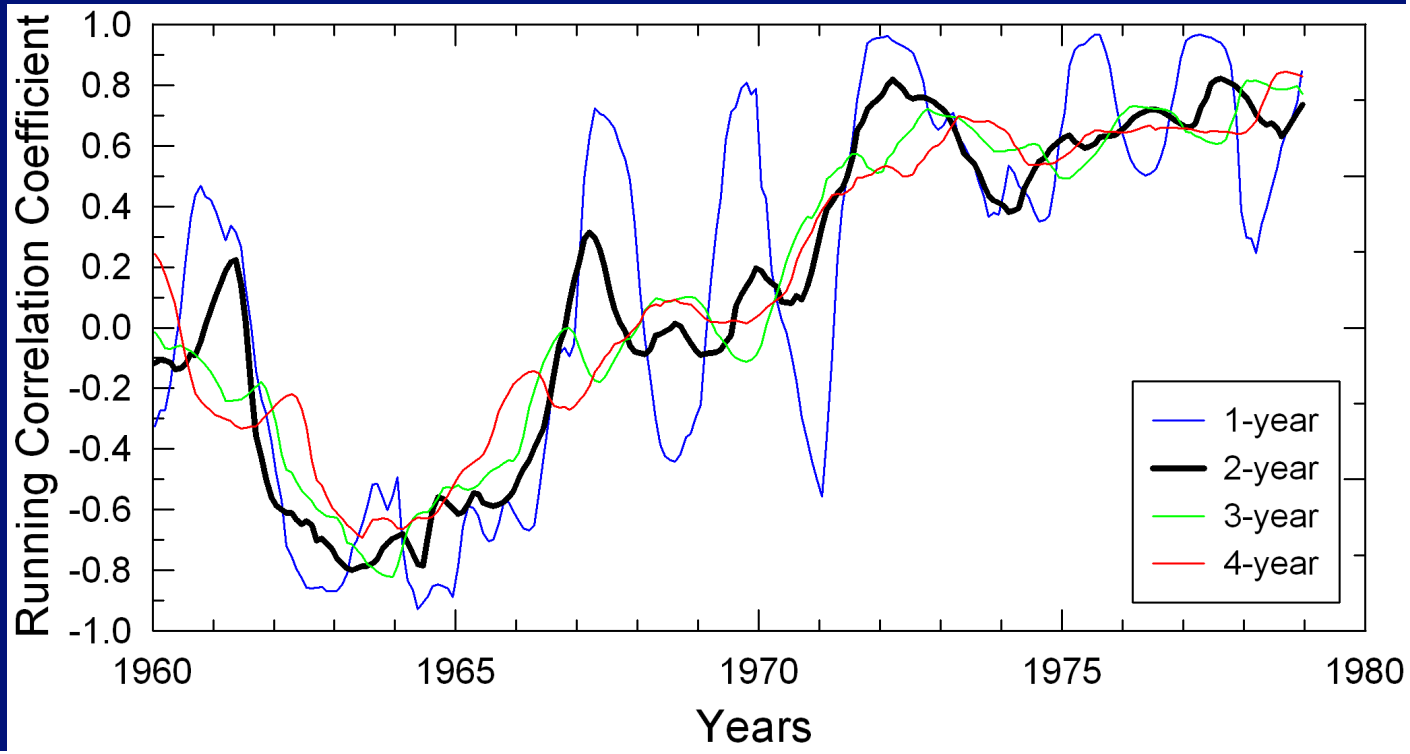
"ensemble of the grid" needs to express by the area of region consistent to AOI.

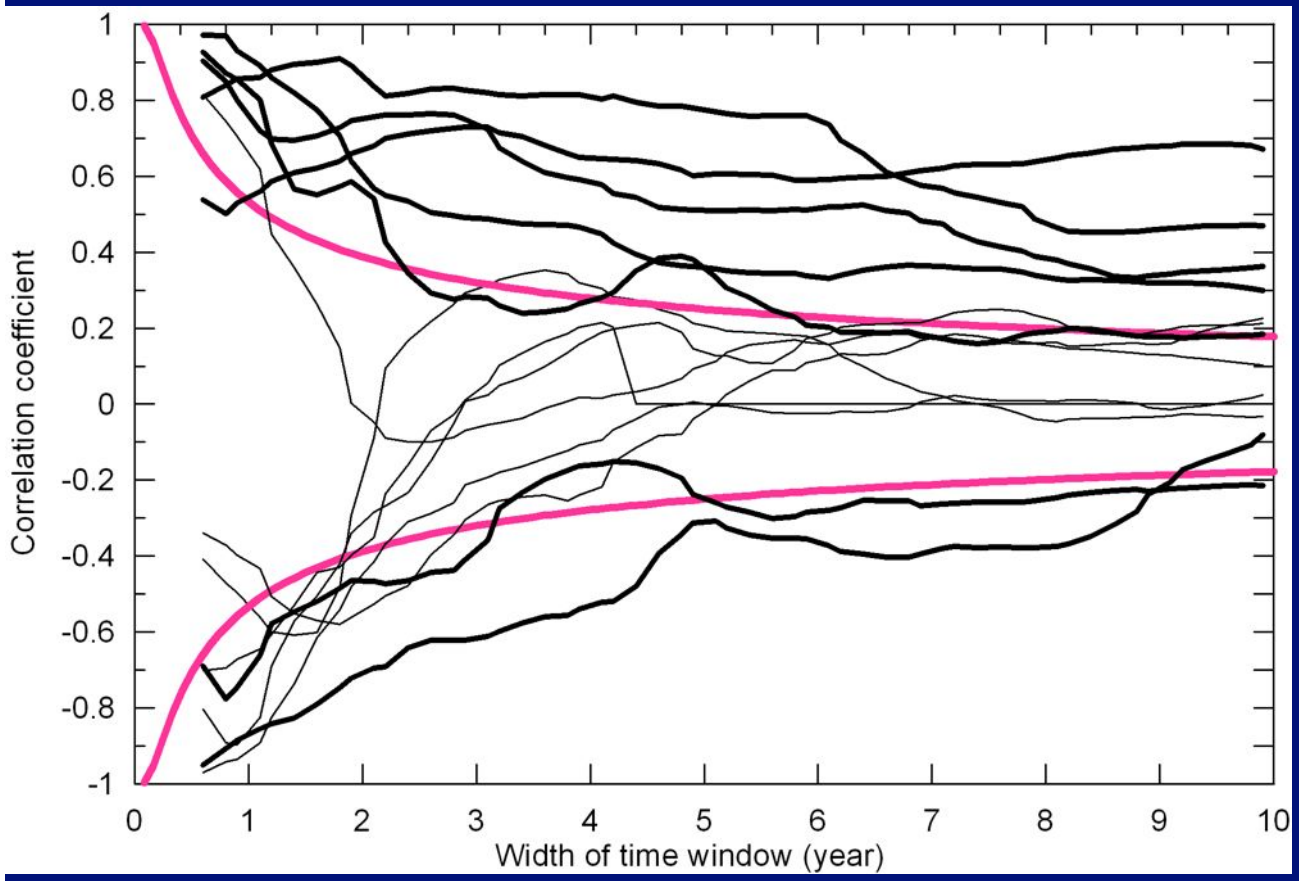
Running correlation coefficient (RCC) and the window width

$$R_i = \frac{\sum_{k=i-n}^{i+n} (X_k - \bar{X})(Y_k - \bar{Y})}{\sqrt{\sum_{k=i-n}^{i+n} (X_k - \bar{X})^2}\sqrt{\sum_{k=i-n}^{i+n} (Y_k - \bar{Y})}}$$

Window length n=24
two-year data is used



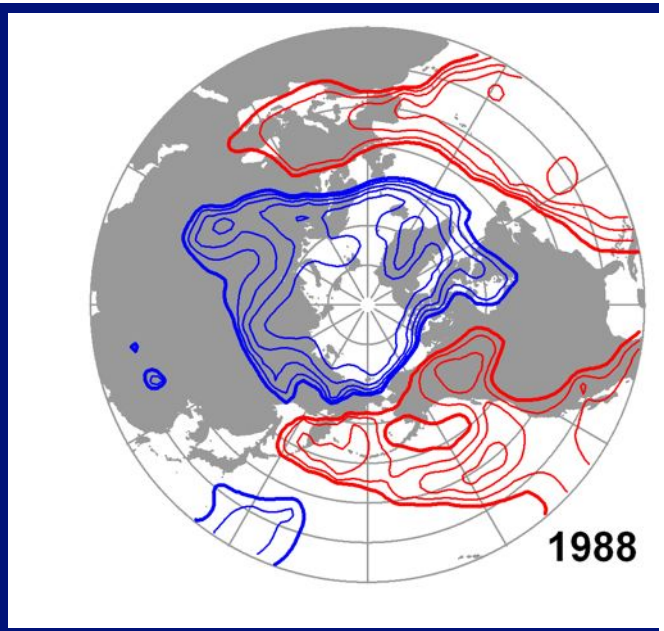
The window width of running correlation



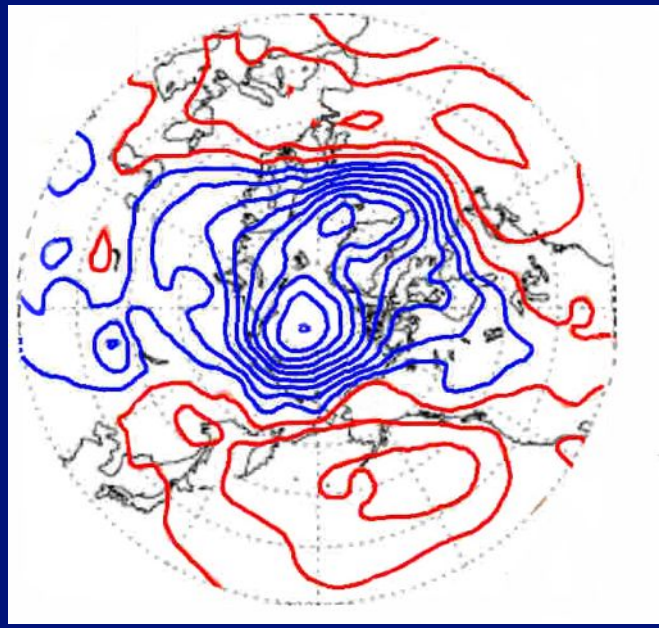
Pink lines are the confidence level for different data length

RCC patterns

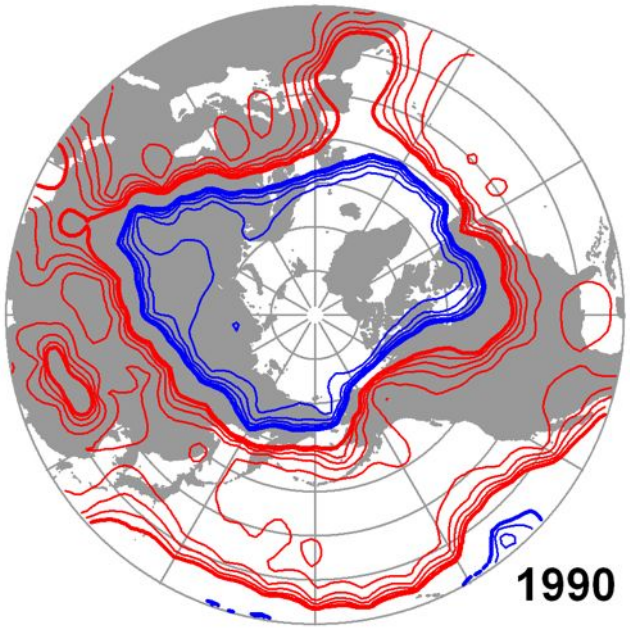
- Distribution of Running correlation coefficient (RCC) is a varying pattern and reveals the AO-dominant regions.
- RCC patterns for all years are obtained to embody the regions consistent to AO index.

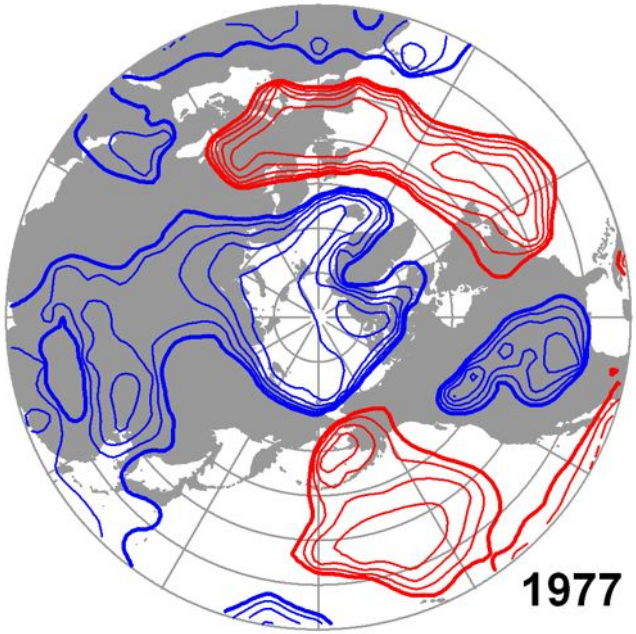


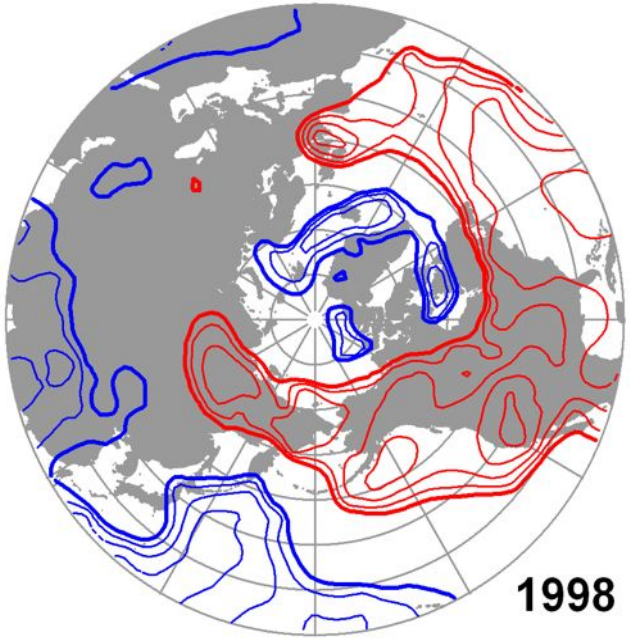
RCC pattern



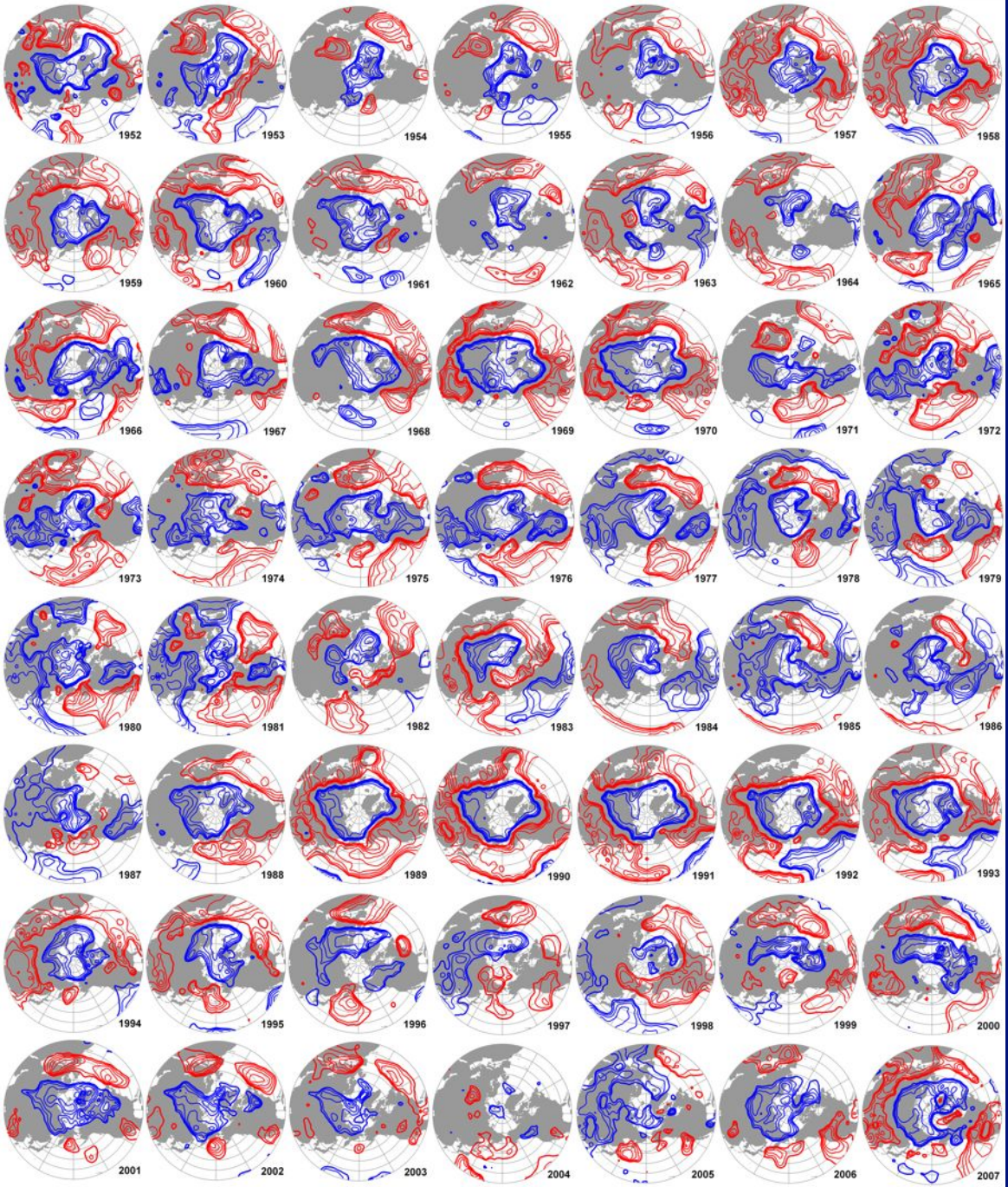
AO pattern





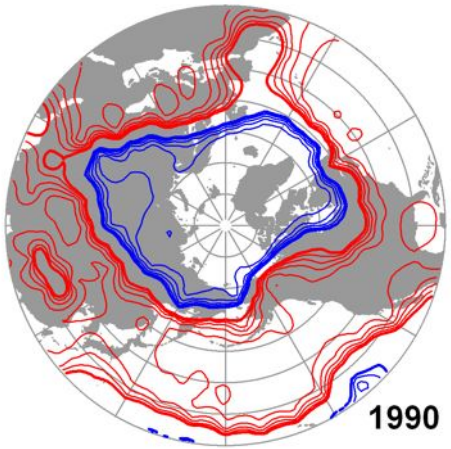


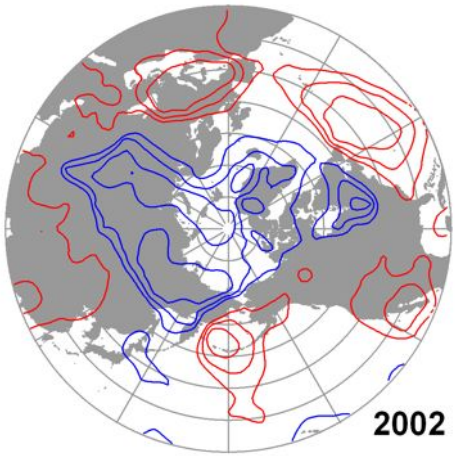
AO has spatial variation. It oscillated not only between polar and mid-latitude, but also between land and ocean. Sometimes its spatial distribution is complex.

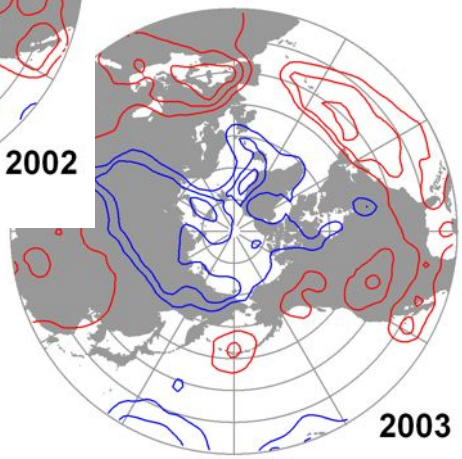


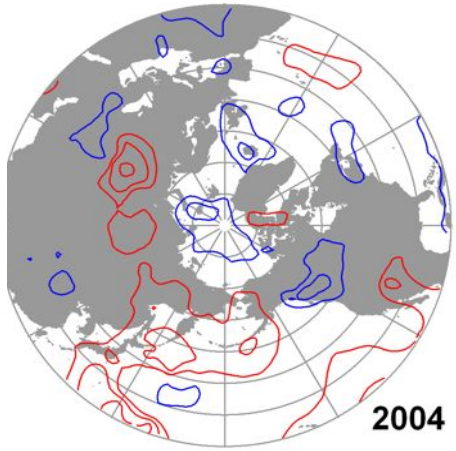
RCC patterns In past 56 years

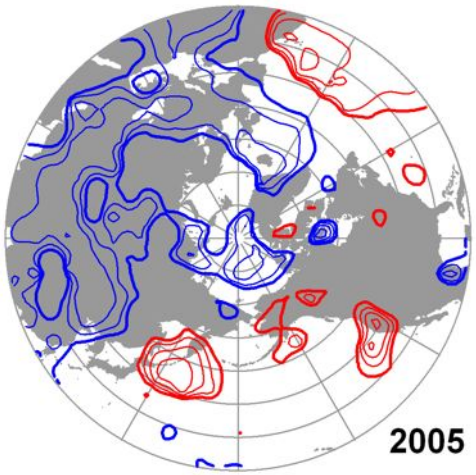
During the Arctic warming, the AO spatial distribution looks weak and unclear.

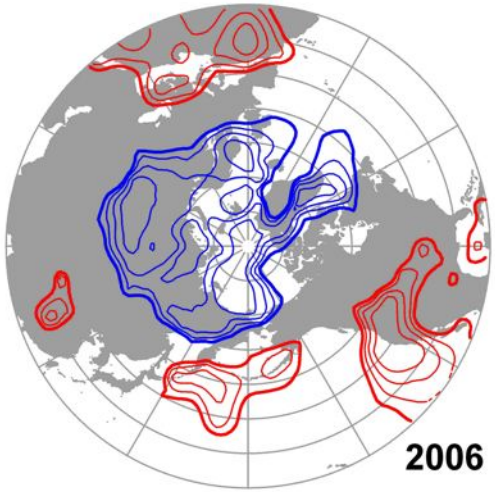


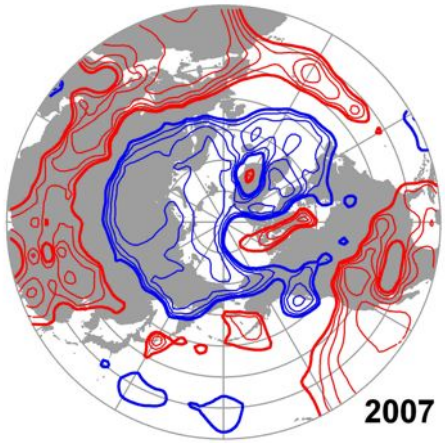


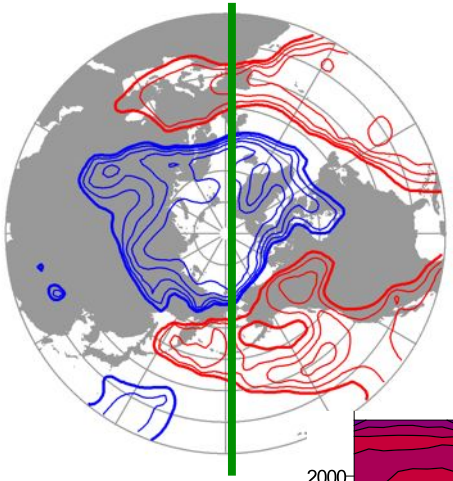






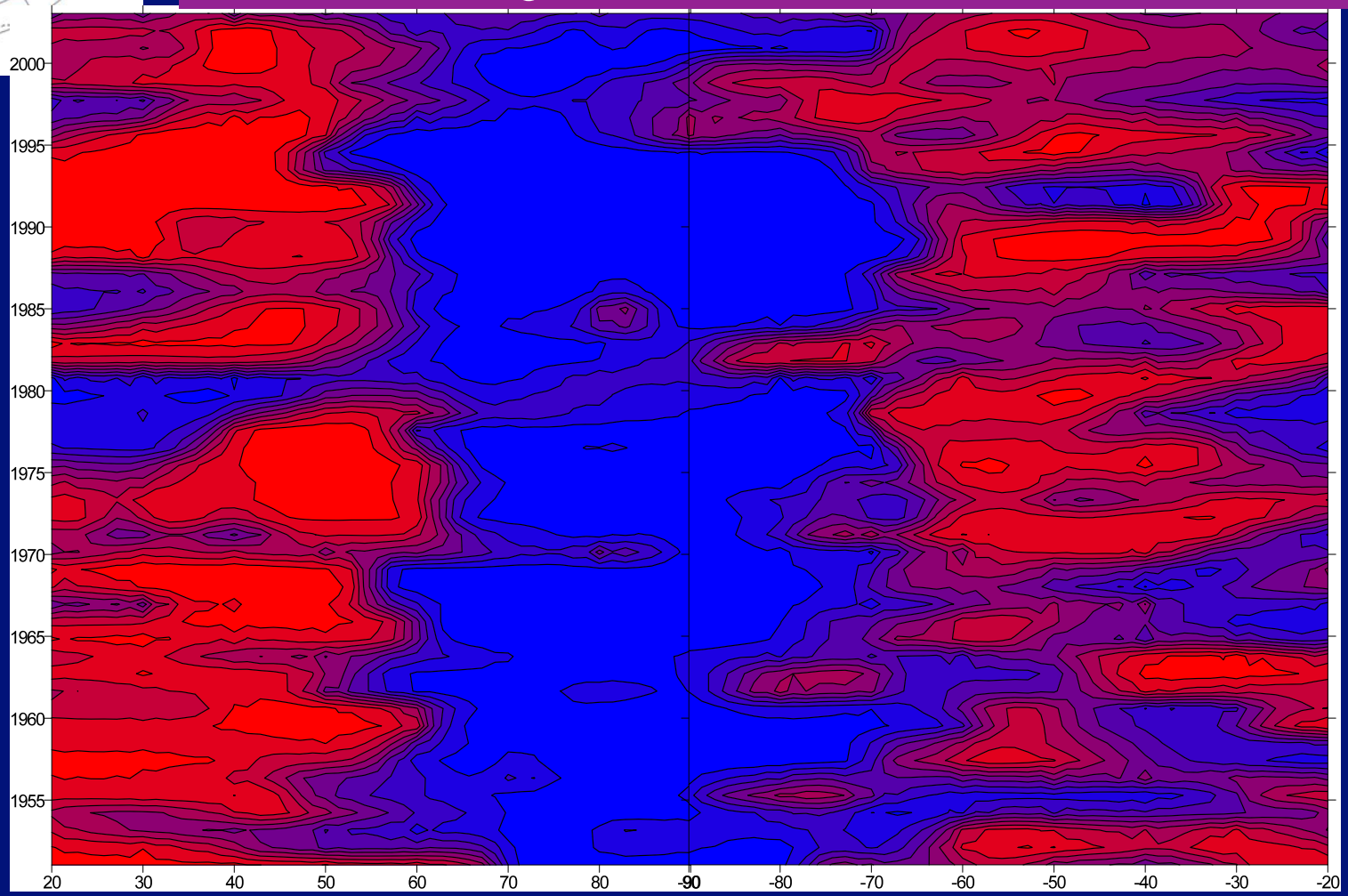


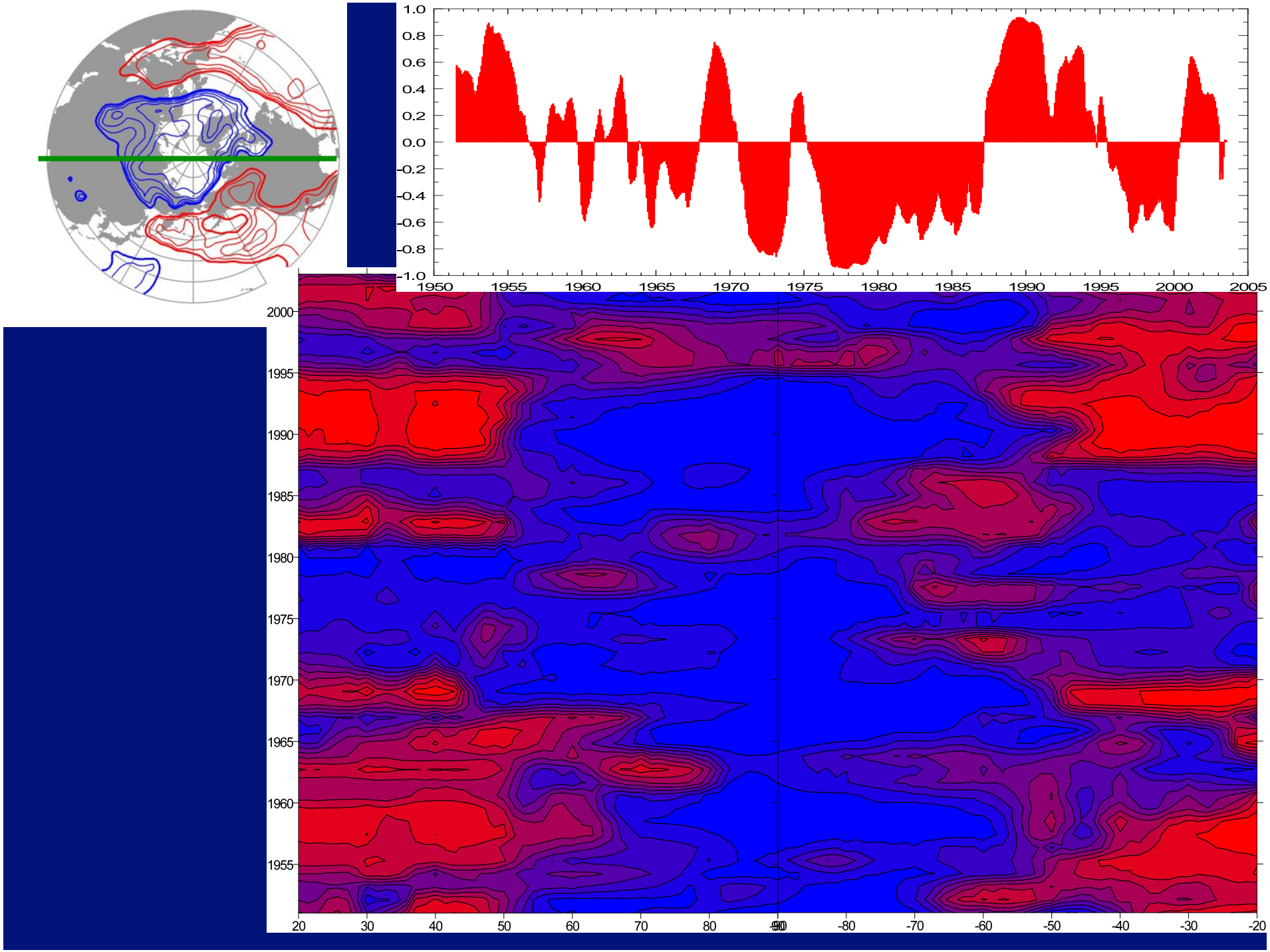




North Atlantic Oscillation is indeed a seesaw-like oscillation, as it stably exist and has a stable boundary with polar region.

In Pacific side, the oscillation exists, but is much weaker than in Atlantic. And the boundary swings north and south in large extent.




1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
20
30
40
50
60
70
80
90
-80
-70
-60
-50
-40
-30
-20

what we learnt from the result?

- What is the spatial variation of AO?

Answer: it is temporal variation of the AO-dominant region

- How to describe the spatial variation?

Answer: by calculate the running correlation coefficient of gridded SLP with AO index

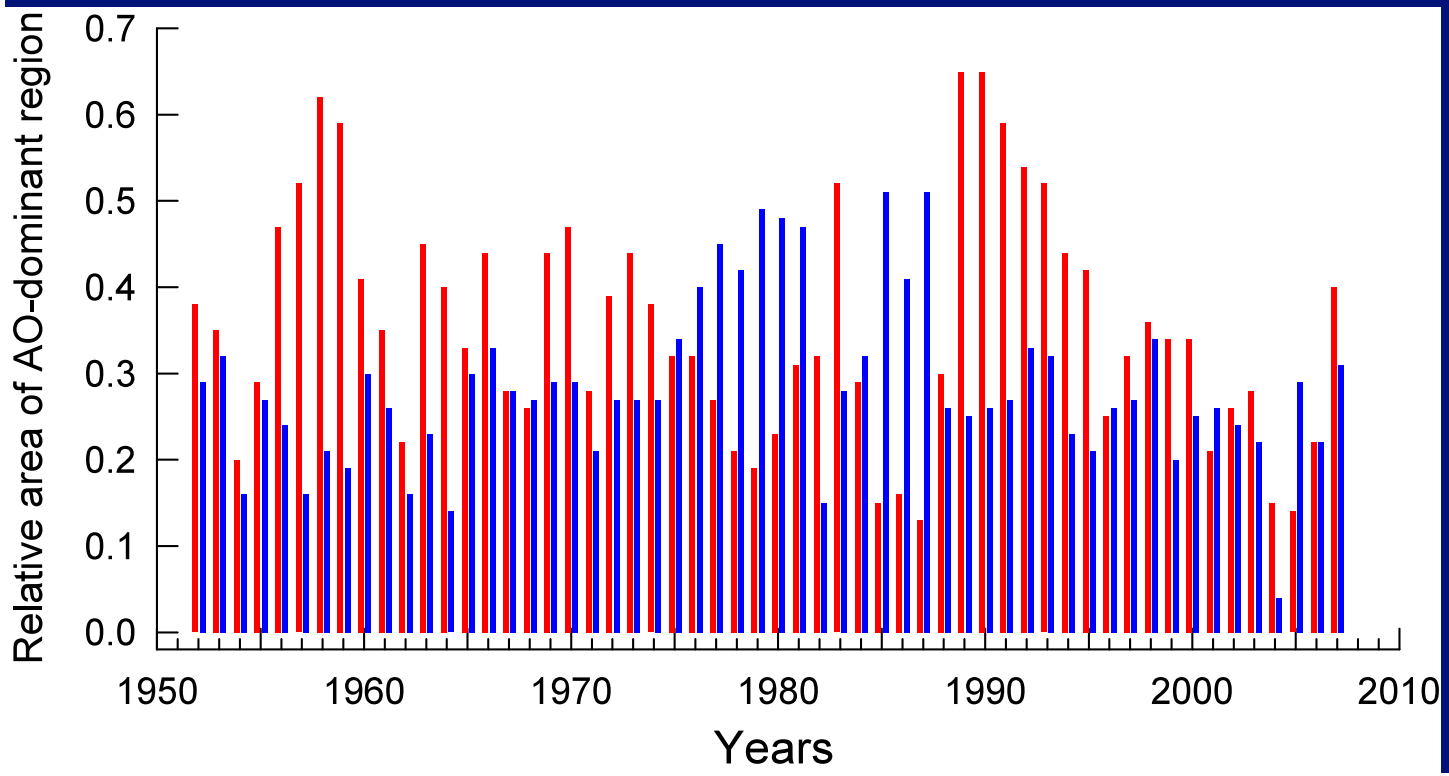
- What the spatial variation of AO tells us?

Answer: AO-dominant region variation: shape changing, area shrinking and extending, and boundary swinging

The relative area of the AO-dominant region

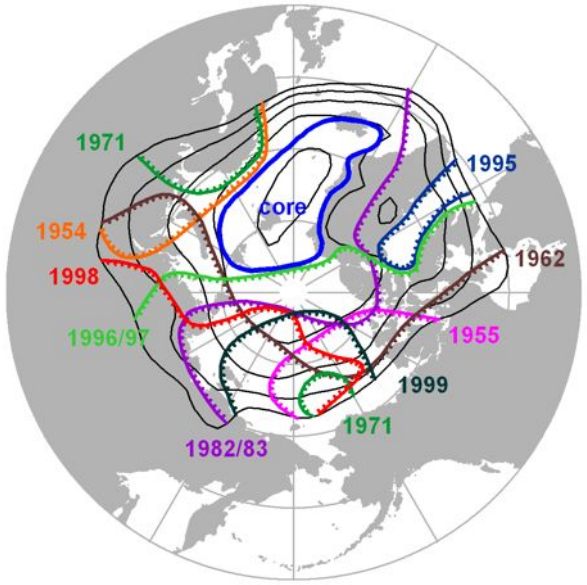
Relative area $\dfrac{\text{the area with coefficient} > 0.4}{\text{total area north of 20ºN}}$

Relative area of positive (red) and negative (blue) AO-dominant regions



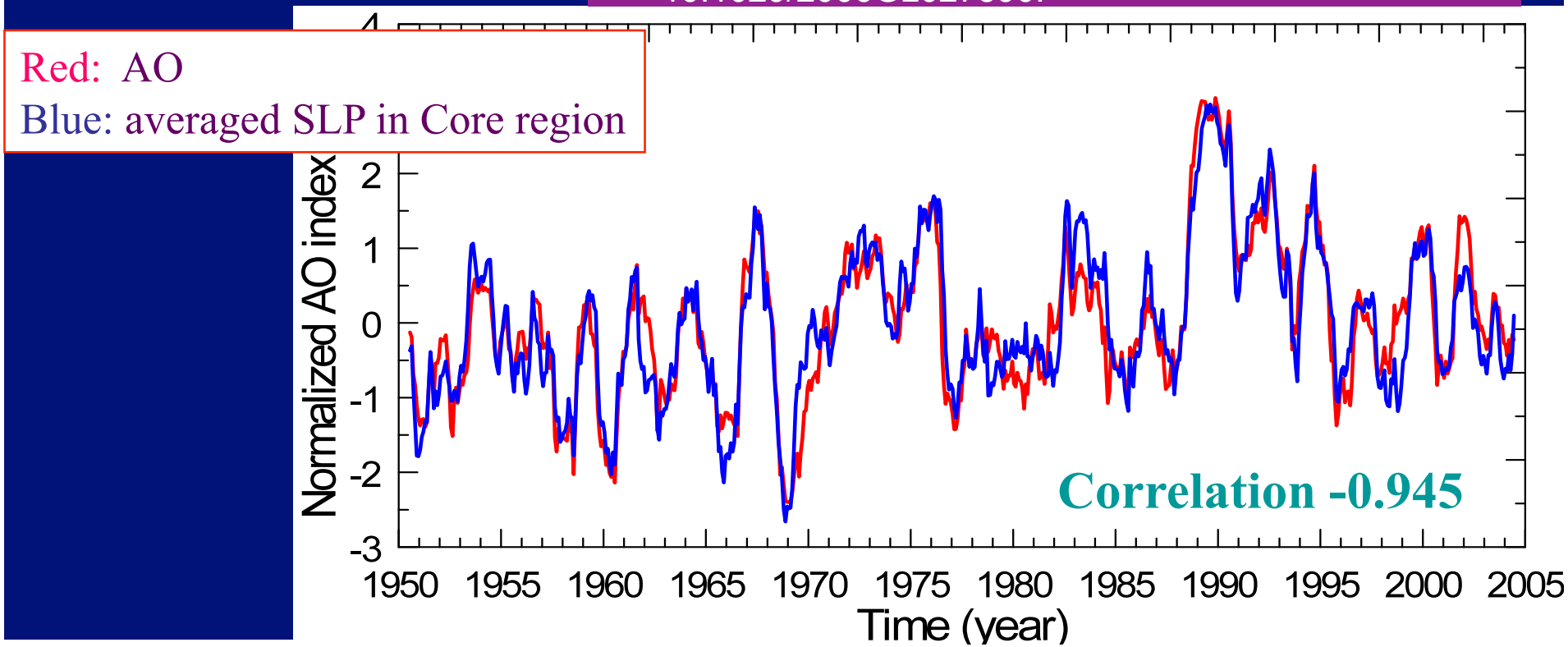
From
SLP to AOI

To
SLP to SLP anomaly

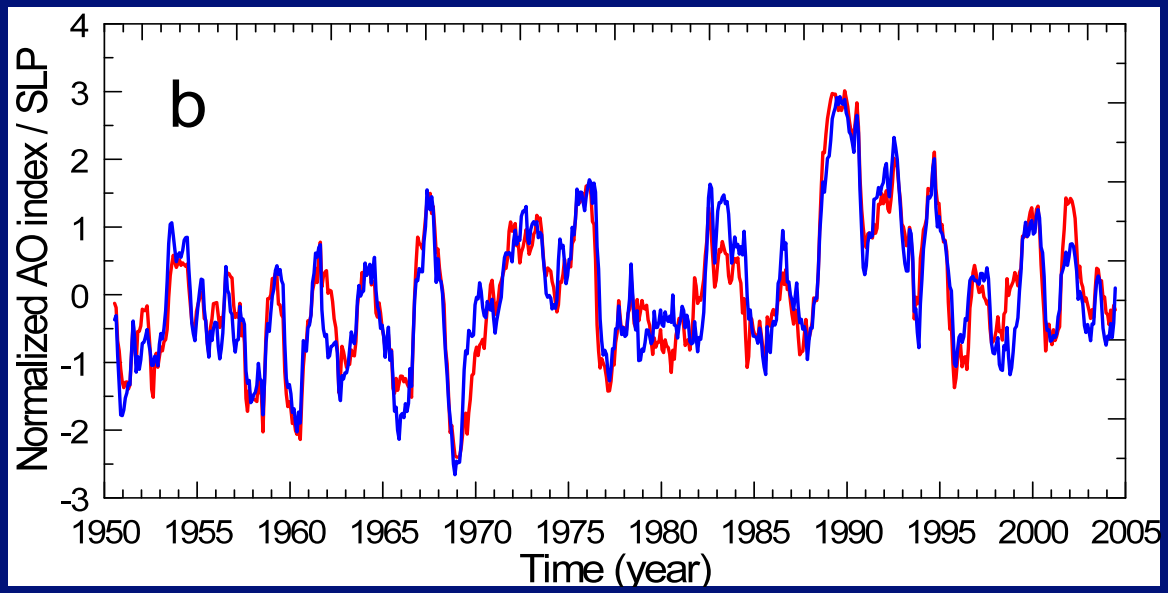


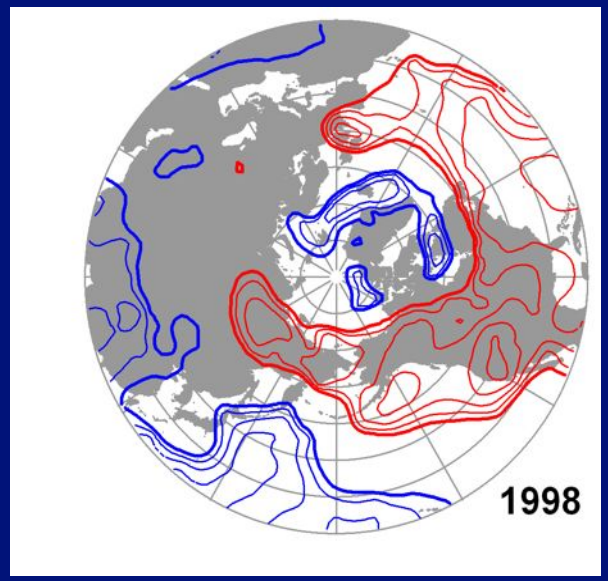
In Arctic Oscillation Core Region (AOCR), the averaged SLP is quite consistent with AO index, exchangeable with each other

Zhao, J., Y. Cao, and J. Shi (2006): Core region of Arctic Oscillation and the main atmospheric events impact on the Arctic. Geophys. Res. Lett., 33: L22708, doi: 10.1029/2006GL027590.



Relative area of ± SLP anomaly





AOI= — SLP of AOCR

When AO is in positive phase,

SLP anomaly in positive correlation region is negative

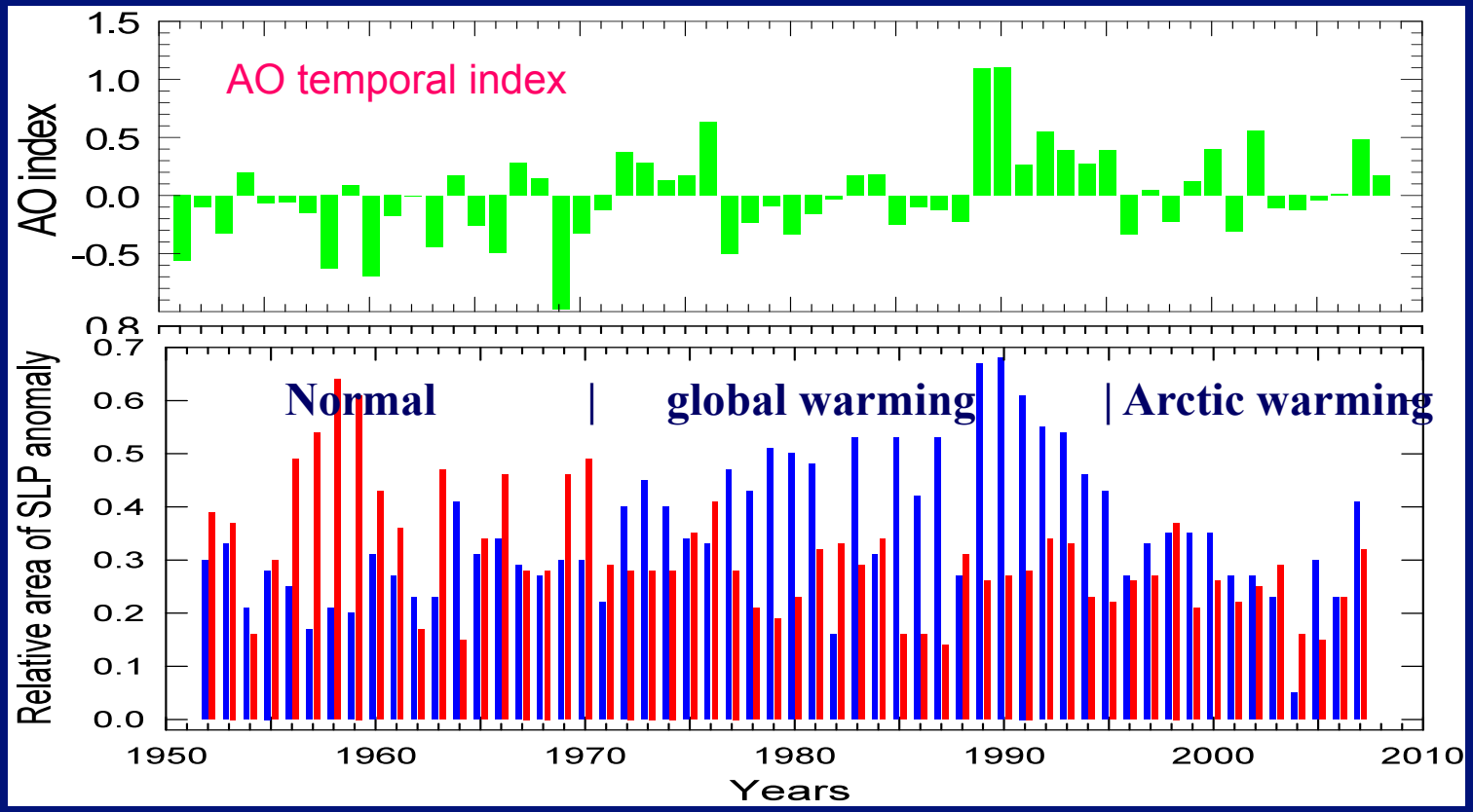
SLP anomaly in negative correlation region is positive

When AO is in negative phase

SLP anomaly in positive correlation region is positive

SLP anomaly in negative correlation region is negative

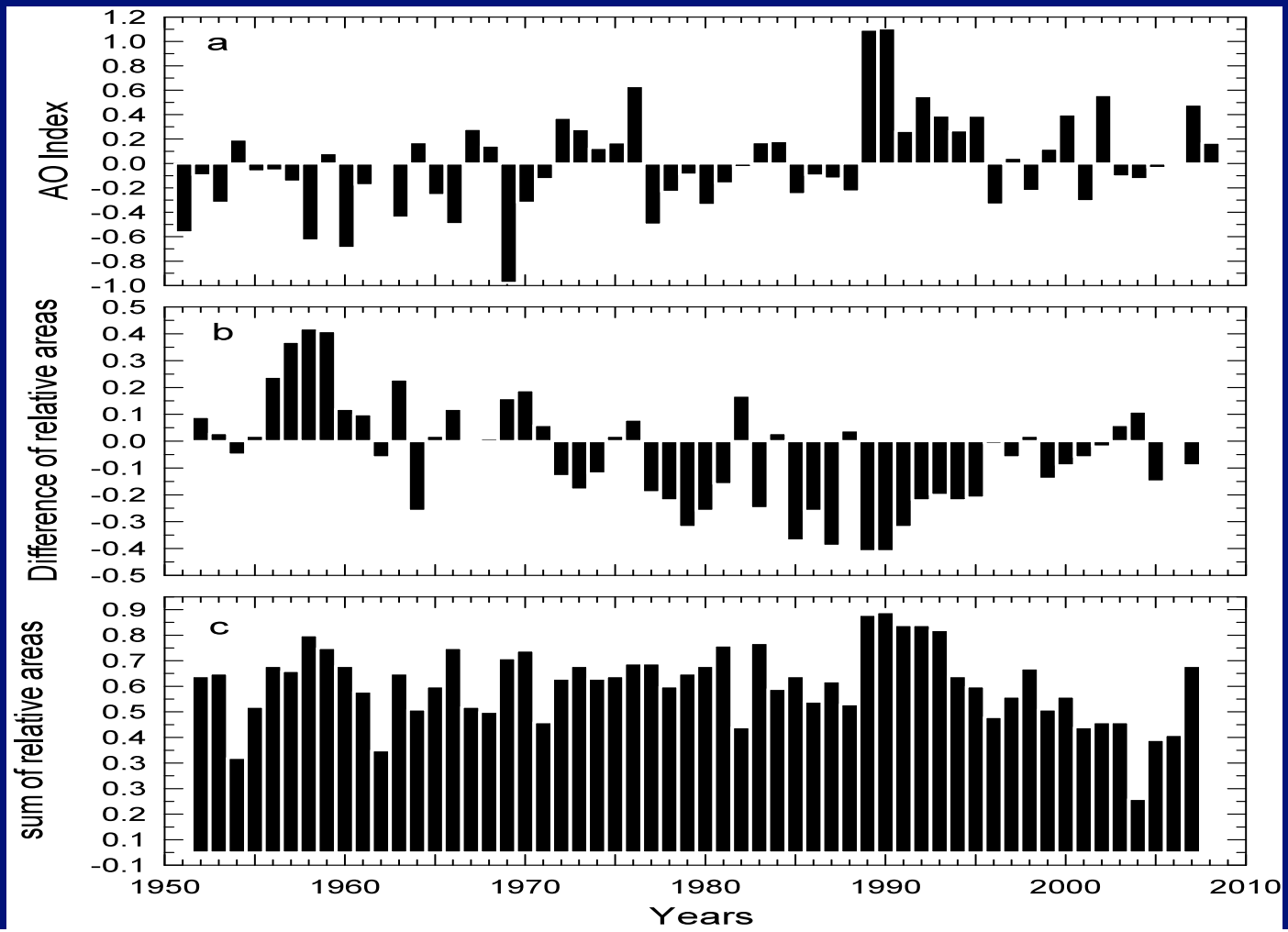
Relative area of ± SLP anomaly



Before 1970, the positive SLP anomaly region is dominant.
During 1971-1995, negative SLP anomaly region is dominant.
From 1996 to 2007, the areas of two regions are similar.

Difference of the relative area of positive and negative AO-dominant regions (DRA)

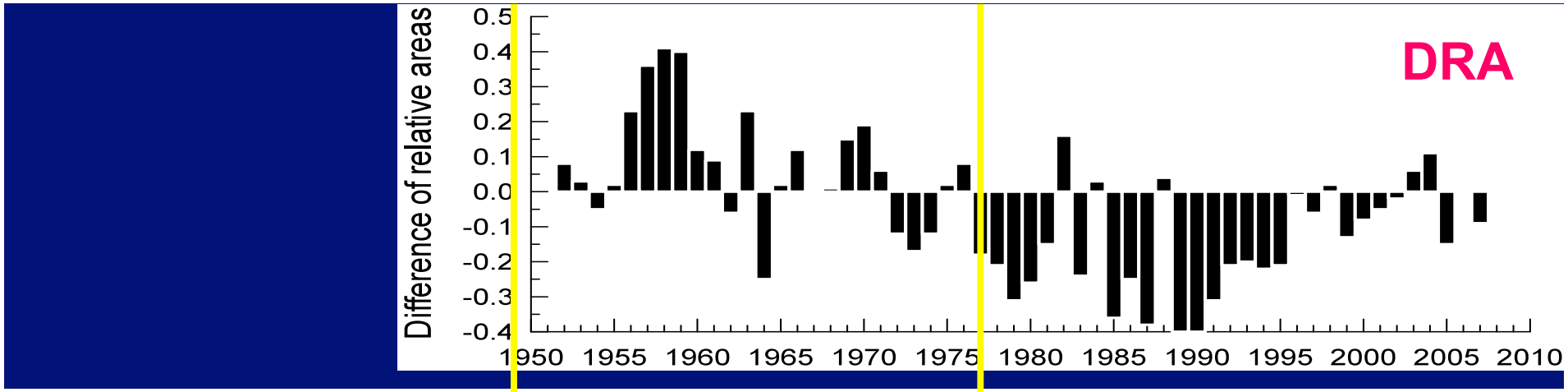
Sum of the relative area of positive and negative AO-dominant regions (SRA)

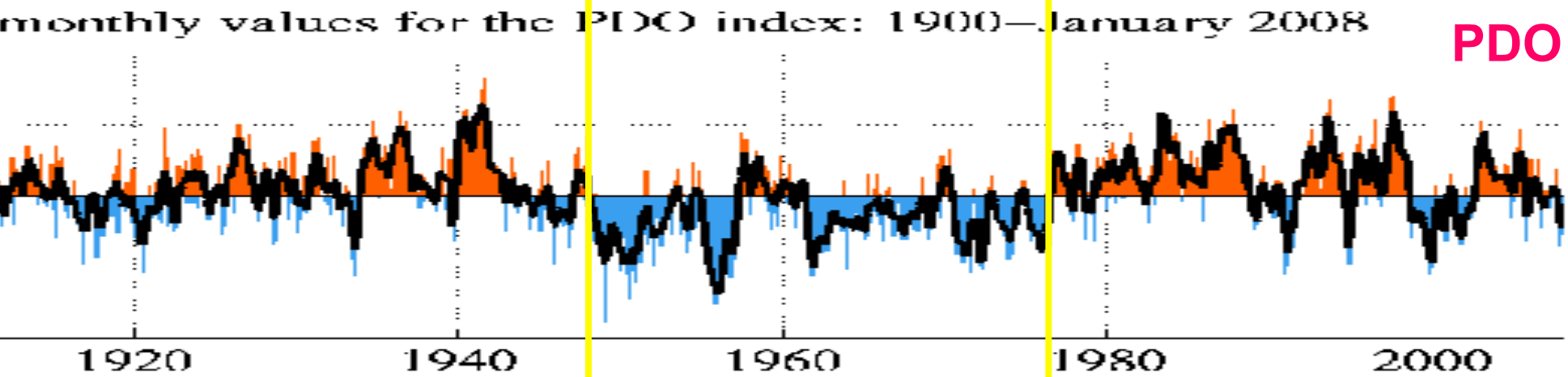


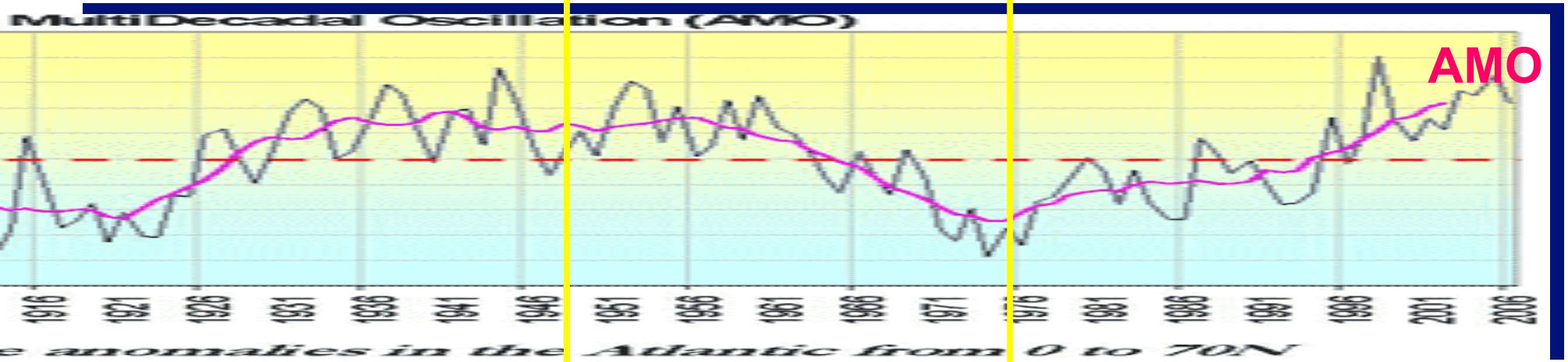
AO index

DRA

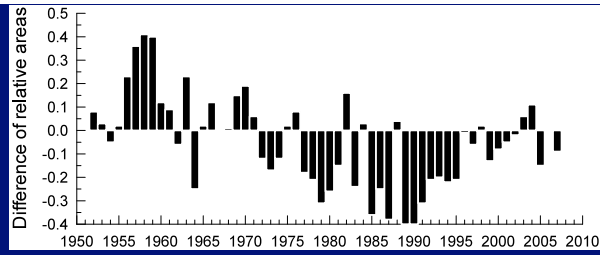
SRA


DRA
Difference of relative areas
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010


monthly values for the PDO index: 1900—January 2008
PDO
1920
1940
1960
1980
2000


MultiDecadal Oscillation (AMO)
AMO
anomalies in the Atlantic from 0 to 70N

Conclusion for the Spatial variation of AO



AO Core Region

AO index = - average SLP in AOCR

AO dominant Region

Spatial distribution of regions correlated positively and negatively with AO Index

Relative area of SLP anomaly

Relative area of regions correlated positively and negatively with SLP in AOCR

Difference of the Relative area

Index for long-term spatial variation of AO (DRA and SRA)

3 stages: Before global warming
Global warming
Global warming and Arctic warming

Possible linkage with multi-decadal oscillations