Recent variabilities of East Asian winter monsoon

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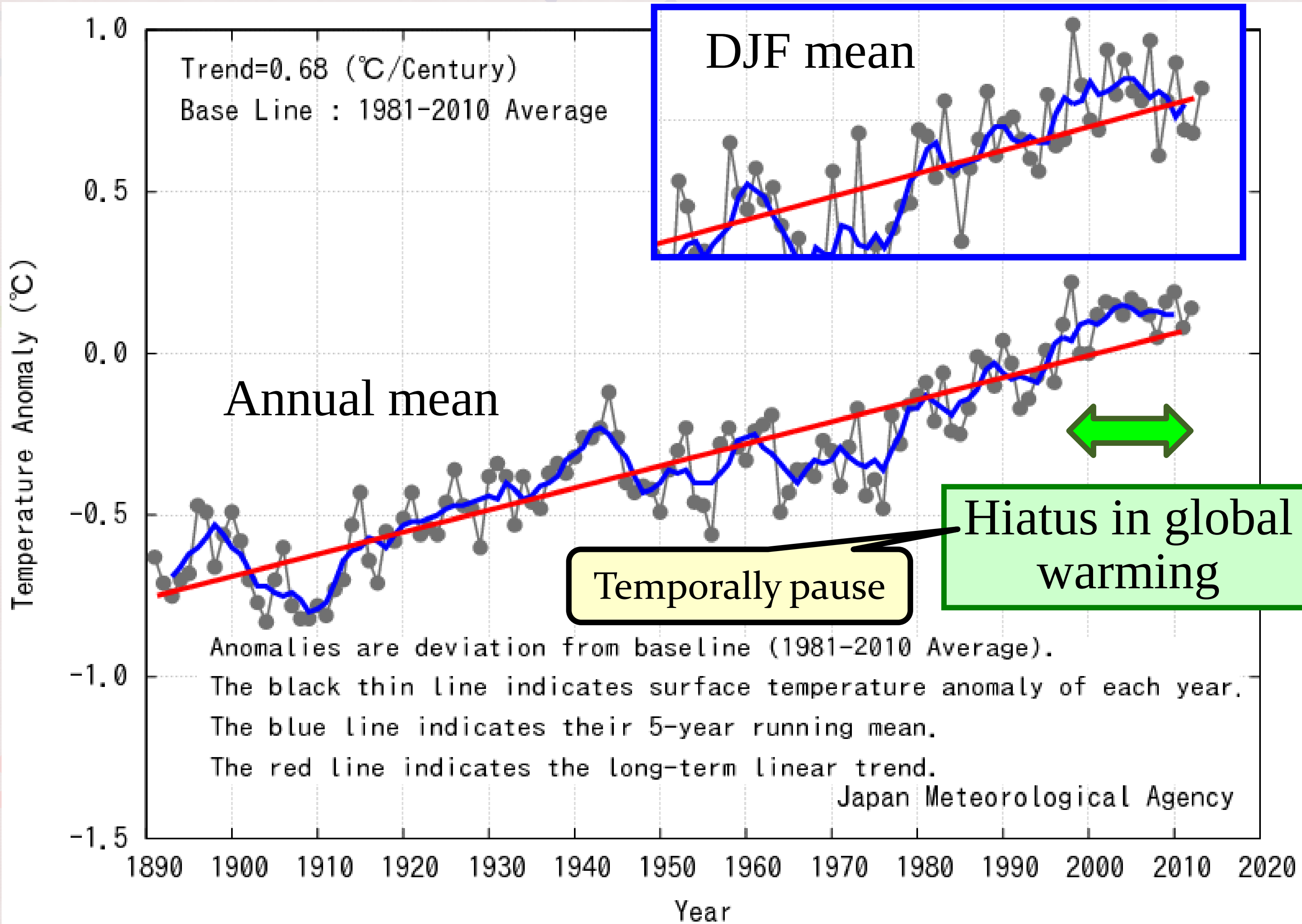
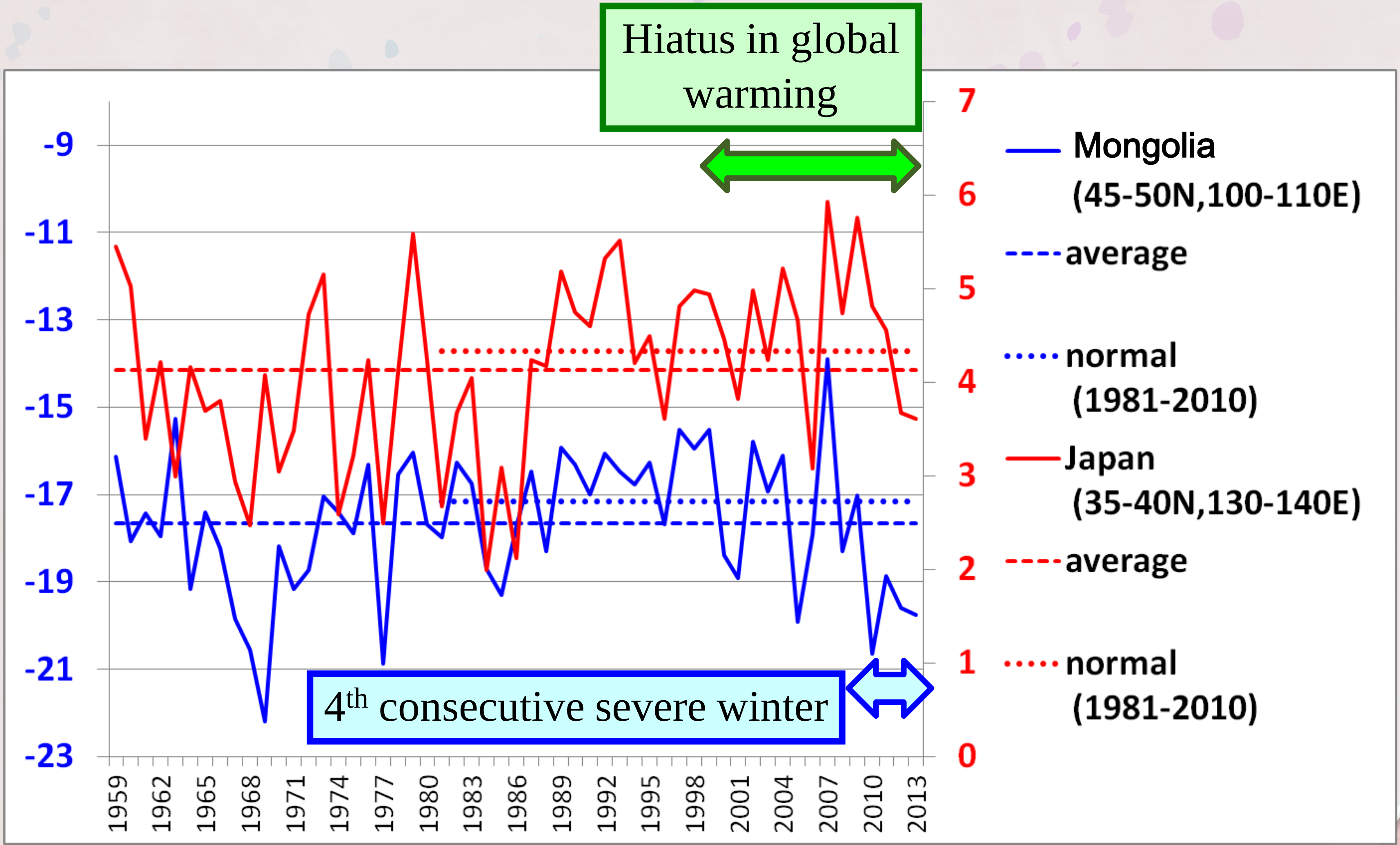
Structure of this presentation

- How has the winter been in East Asia recently?
- What atmospheric phenomena bring recent severe winter in East Asia?
- To where and how?
- What is the factor of interannual variability?
  - Tropical forcing?
  - Decadal variability?
  - Arctic sea ice?
  - Stratosphere?
- Summary and conclusion

Global mean temperature



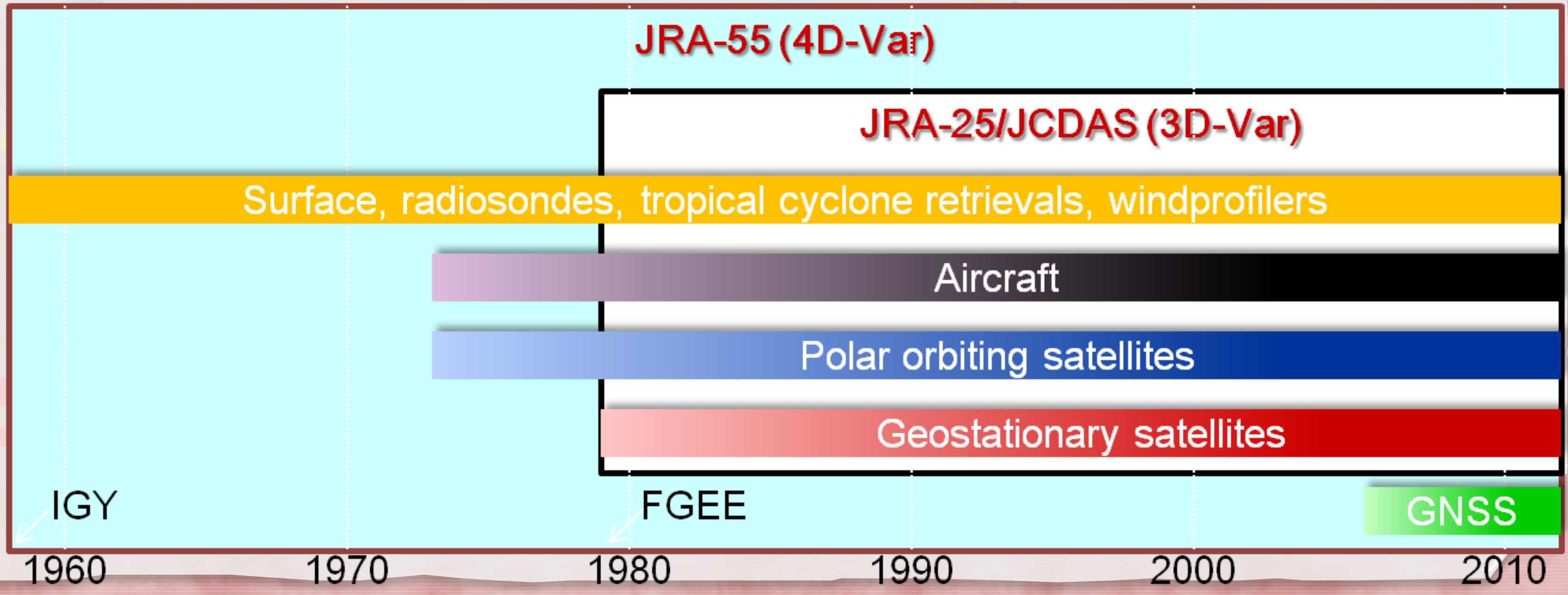
Interannual variability of winter temperature



Area averaged surface temperature by JRA-55

Outline of JRA-55

- The second Japanese global reanalysis conducted by JMA
- The first comprehensive global atmospheric reanalysis that applies 4D-Var to the last half century
- Aiming at providing a comprehensive atmospheric dataset that is suitable for studies of climate change and multi-decadal variability



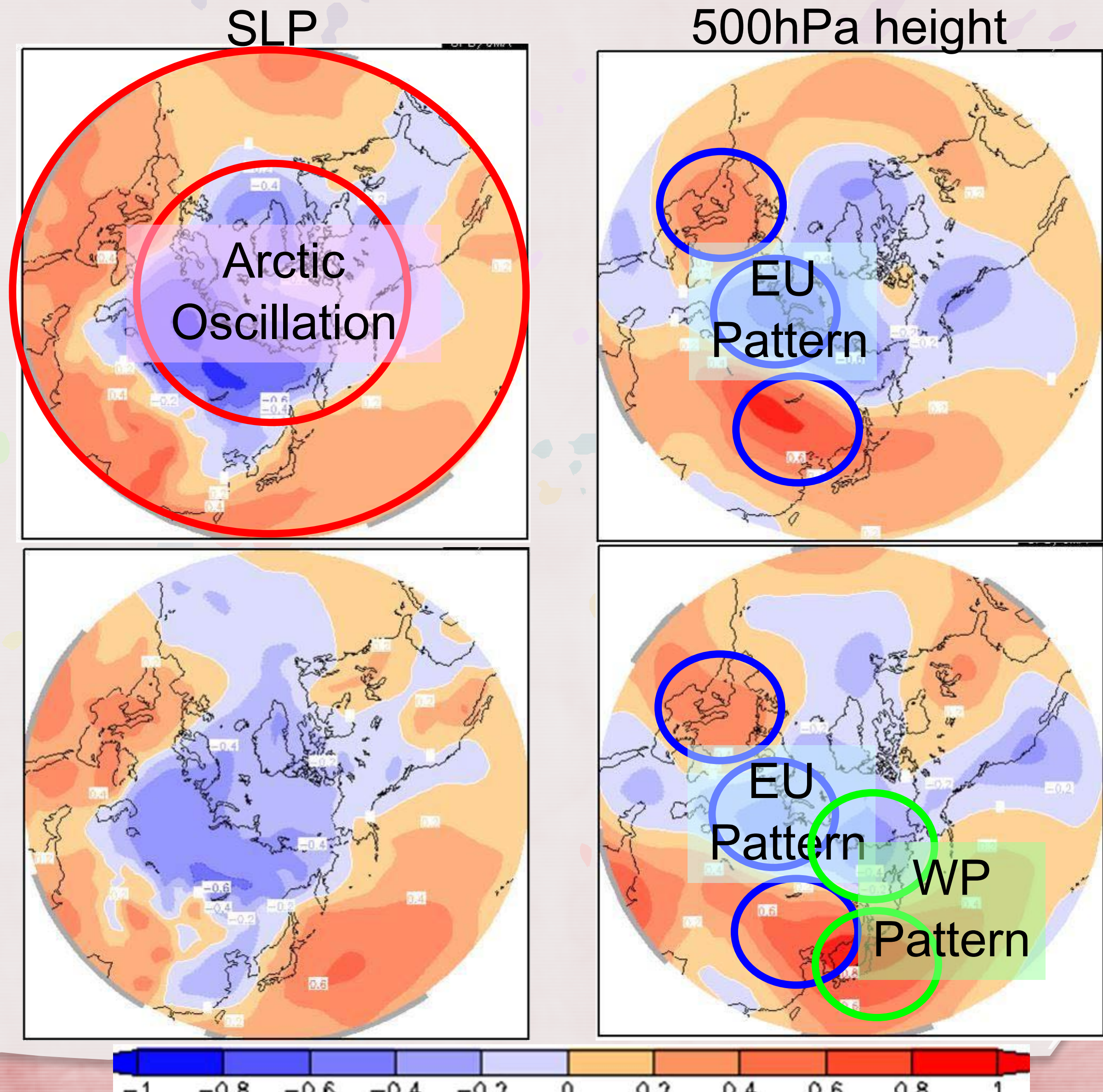
Data assimilation system

	JRA-25/JCDAS	JRA-55
Version	Operational as of Mar 2004	Operational as of Dec 2009
Resolution	T106L40 (~ 120 km) top layer at 0.4 hPa	TL319L60 (~ 60 km) top layer at 0.1 hPa
Assimilation scheme	3D-Var 6-hour time window T106 resolution	4D-Var 6-hour time window T106 inner model *Background error covariances are inflated by 1.8 before 1972*
Satellite radiance bias correction	Adaptive but not variational (Sakamoto and Christy 2009)	Variational Bias Correction (VarBC) (Dee 2005)
Long-wave radiation scheme	*Line absorption* Statistical band model *Water vapor continuum* e-type only	*Line absorption* Table lookup + K-distribution *Water vapor continuum* e-type + P-type
Green house gases	CO_2 only (constant at 375 ppmv)	CO_2, CH_4, N_2O, CFC-11, CFC-12, HCFC-22 (historical concentrations)

Relationship between temperature and SLP or Z500

Mongolia area
(45-50N, 100-110E)

Japan area
(35-40N, 130-140E)

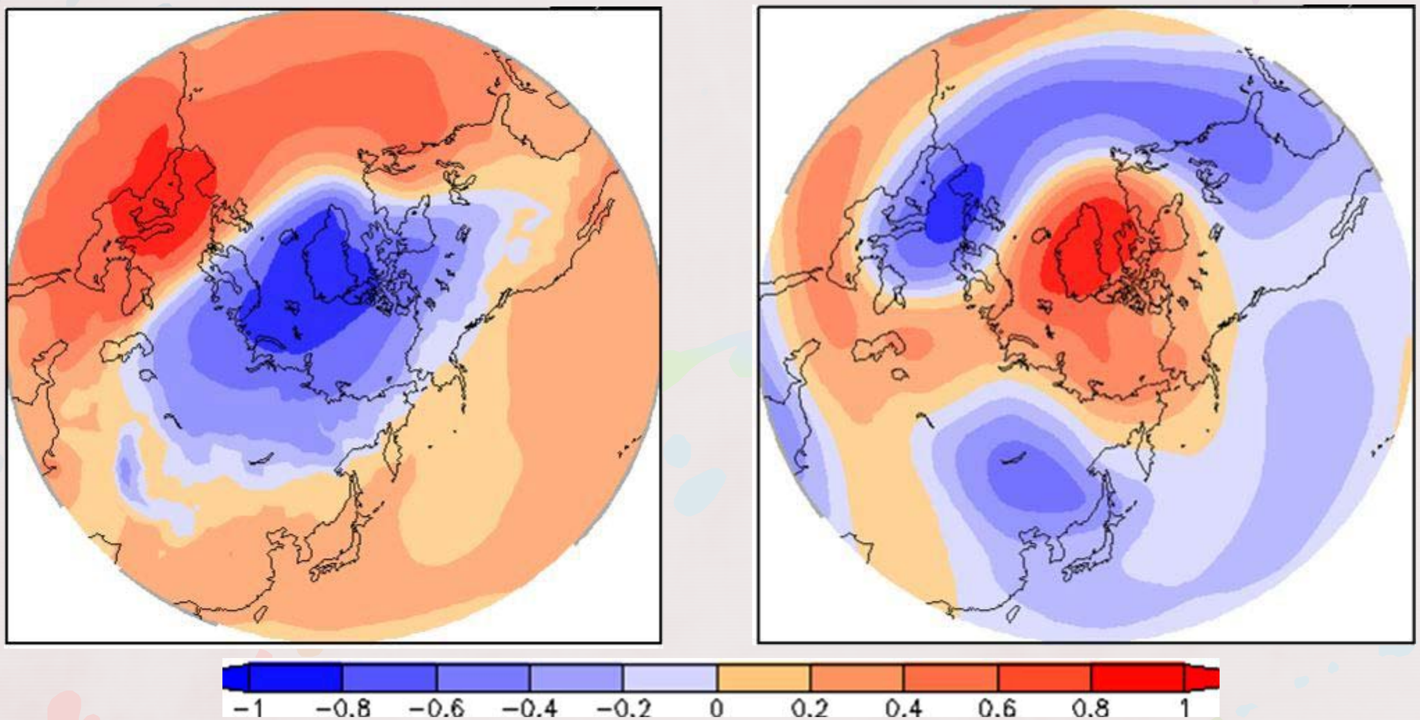


Correlation coefficient to area averaged temperature in 1958-2012 winter by JRA-55

Arctic Oscillation mode

(EOF 1st mode in N.H. winter)

SLP 500hPa height



Correlation coefficient to EOF-1 in 1958-2012 winter by JRA-55

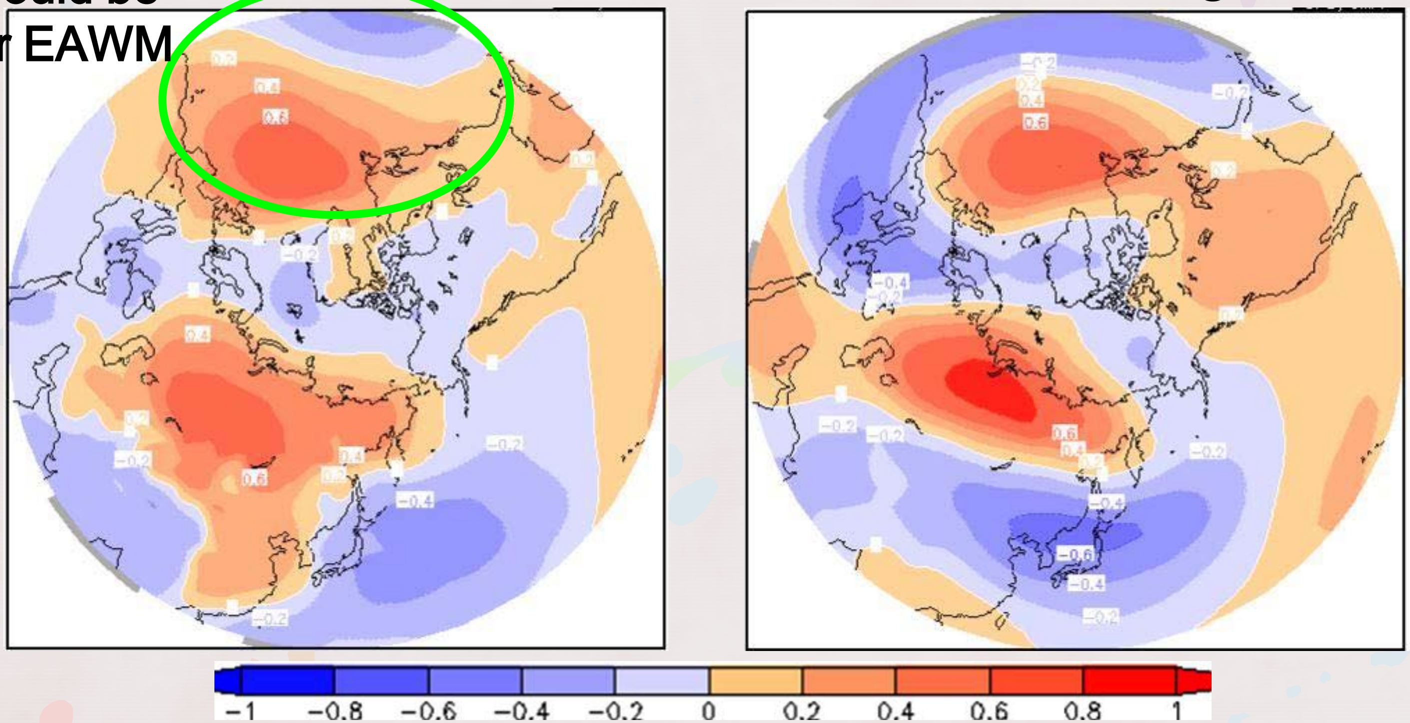
EU and WP pattern

(EOF 3rd mode in N.H. winter)

The pattern over the Atlantic should be ignored for EAWM

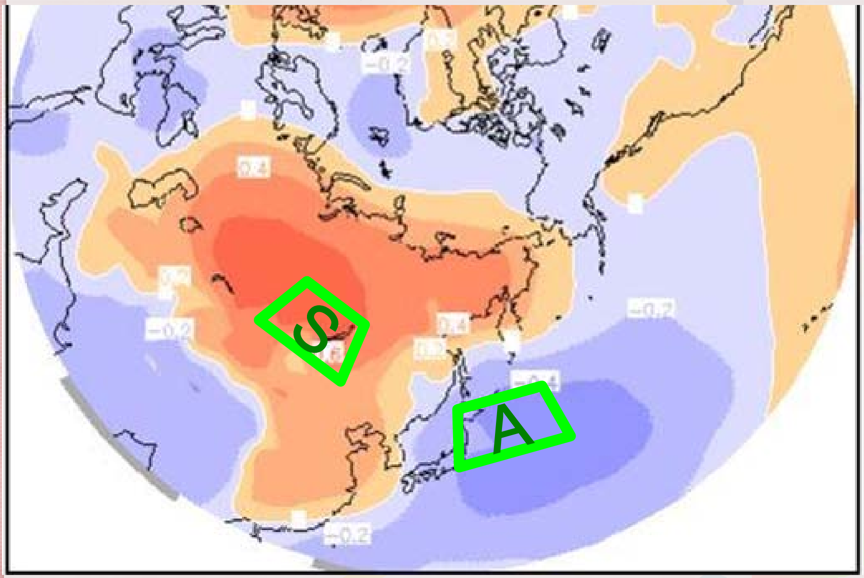
SLP

500hPa height



Correlation coefficient to EOF-3 1958-2012 winter by JRA-55

EAWM is composed of EU and WP

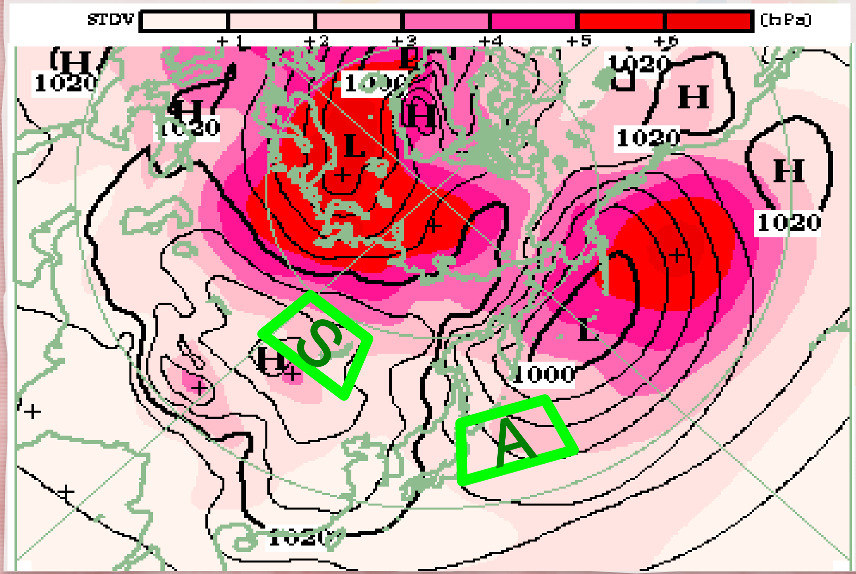


Correlation coefficient to EOF-3 for SLP 1958-2012 winter by JRA-55

Conveniently we define EAWM-Index as follows,

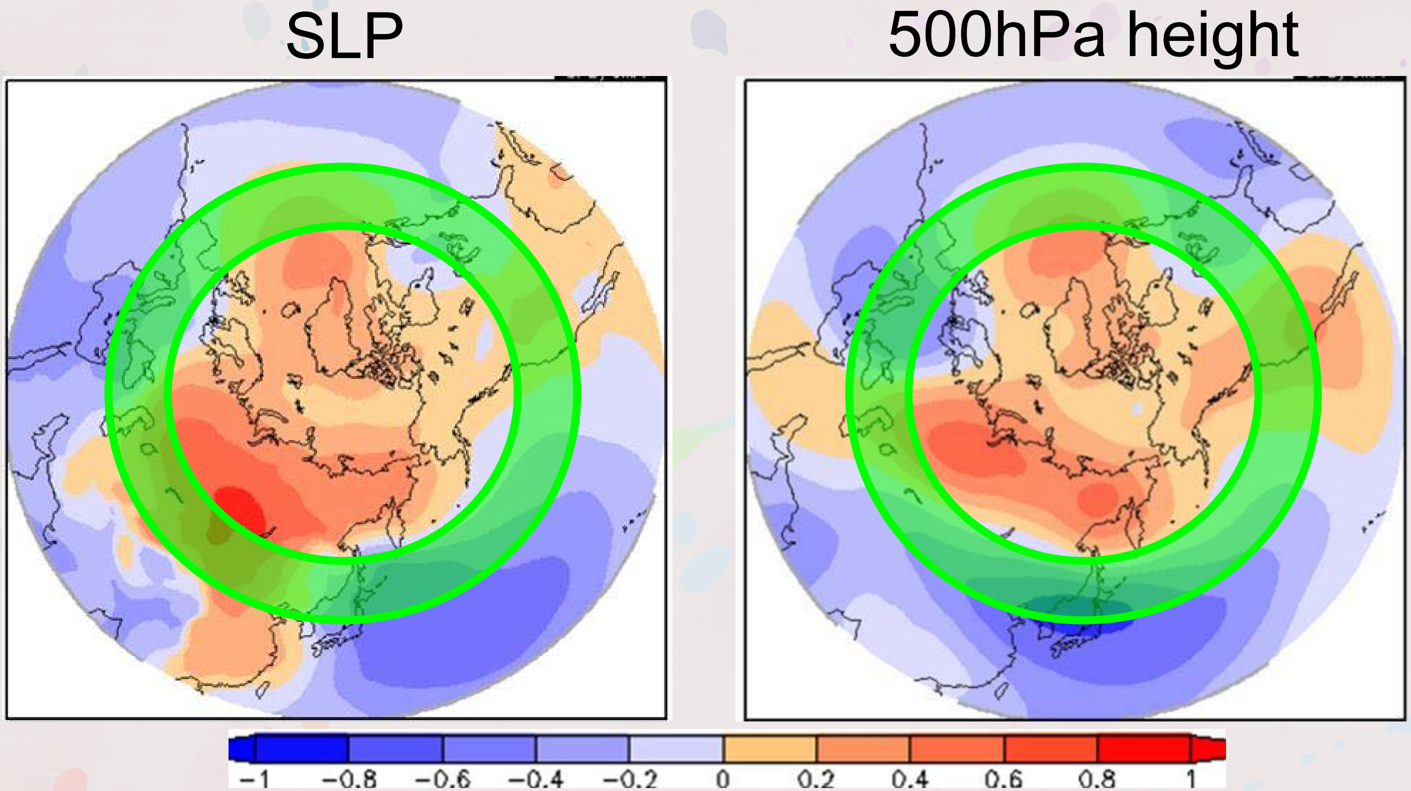
EAWM-Index =
SLP(S) – SLP(A)

where
area S : 50-60N, 90-110E
area A : 35-45N, 140-160E



Climatic normal for winter mean SLP and its standard deviation of interannual variability

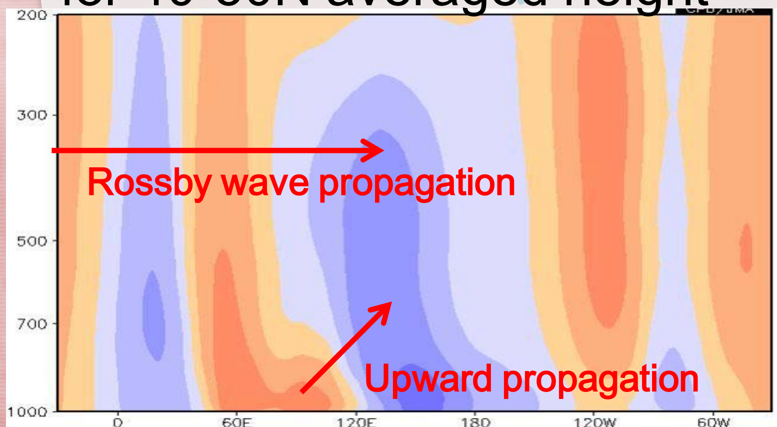
EAWM mode



Correlation coefficient to EAWM-index in 1958-2012 winter by JRA-55

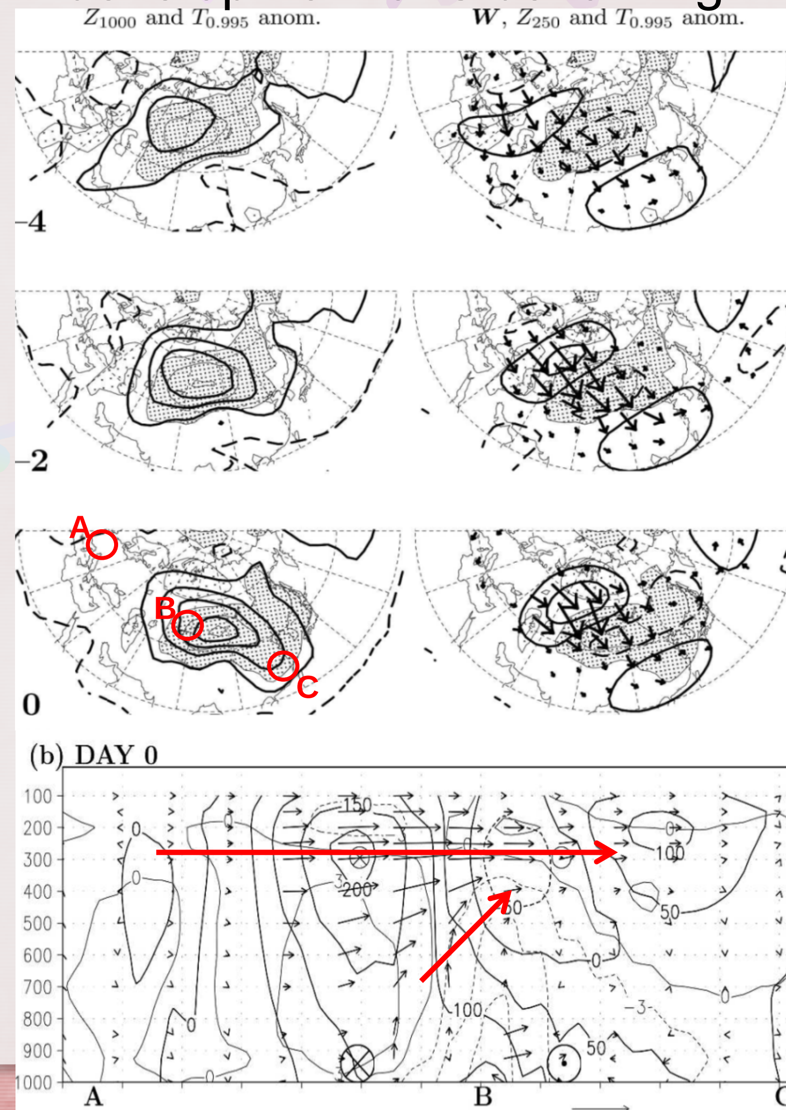
Development of Siberian high with EAWM mode

Height-longitude cross section of correlation coefficient to EAWM for 40-50N averaged height



Same structure

Lag composite for typical development of Siberian high



1. Strong radiative cooling over Siberia
2. Stationary Rossby wave propagation from the Atlantic
3. Development of barotropic anti-cyclonic circulation around 60E
4. Southward advection of lower cold air mass
5. Cold air mass strengthen Siberian high
6. Upward propagation of Rossby wave merge with one propagated from the Atlantic
7. Development of Far East trough and strong cold wave hit Eastern Asia

Takaya and Nakamura (2005)

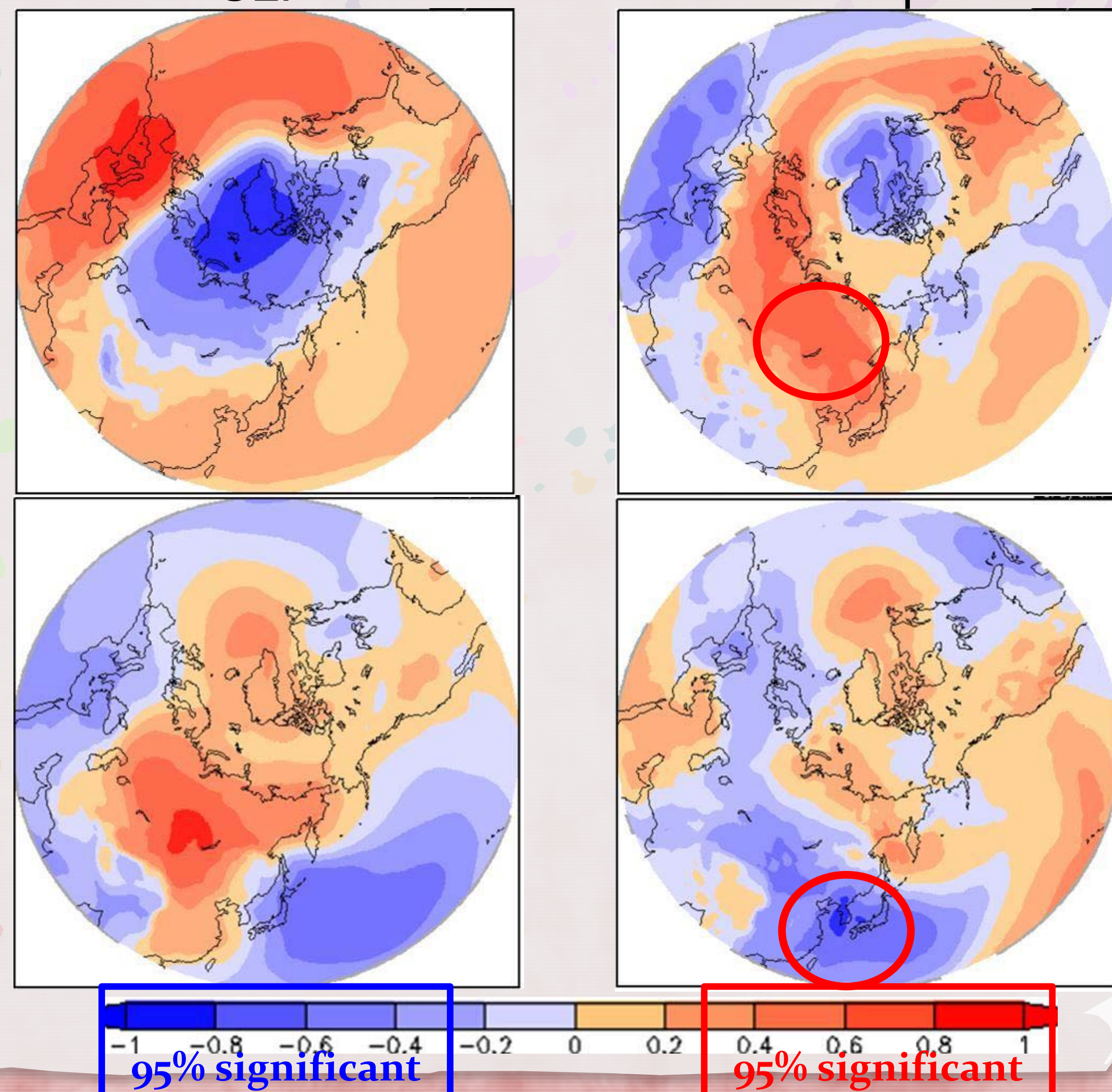
Where do AO and EAWM bring sever winter

AO mode
>>>
mainly affect
northern East Asia

EAWM mode
>>>
mainly affect
Eastern East Asia

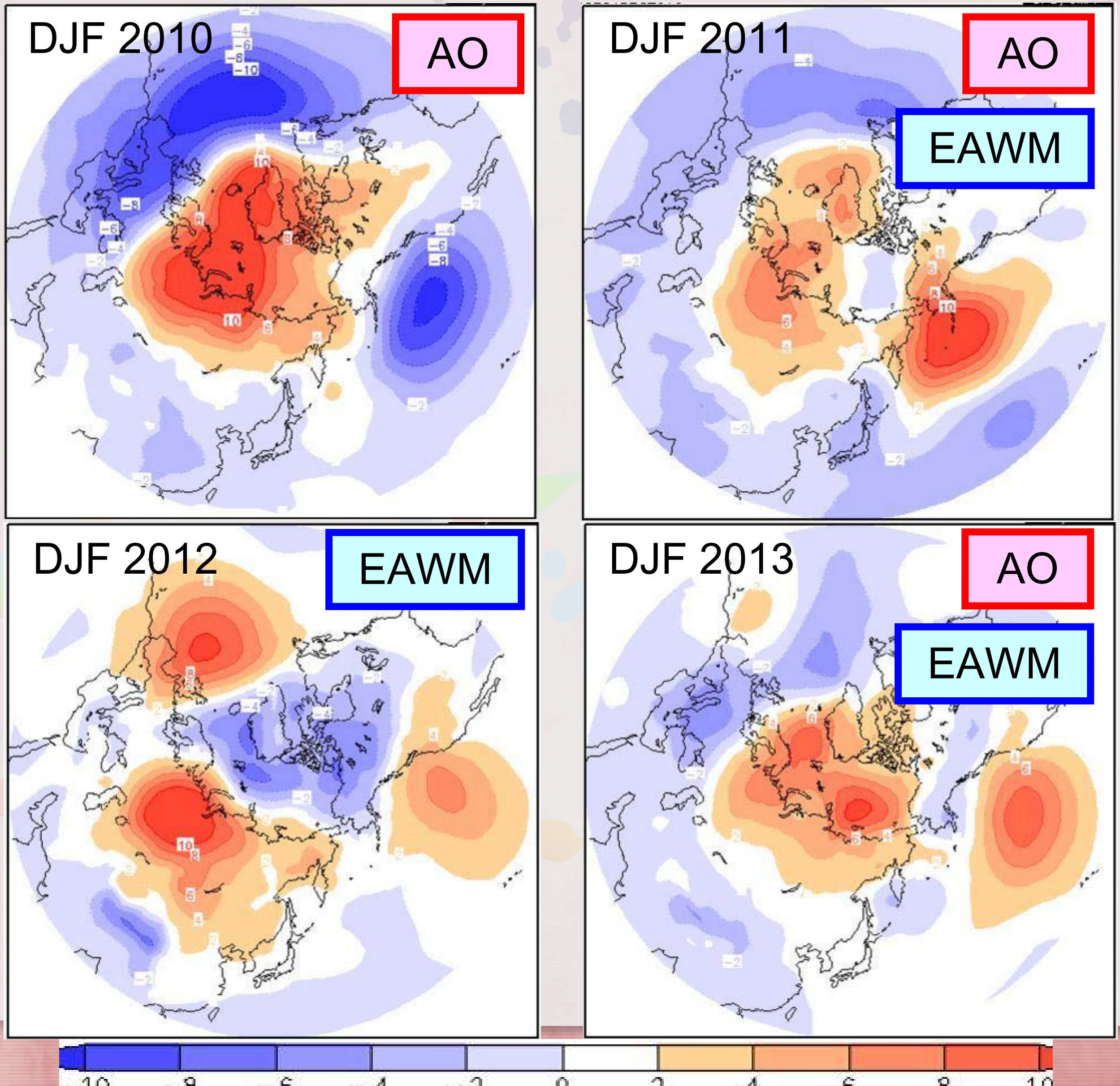
SLP

Surface temperature

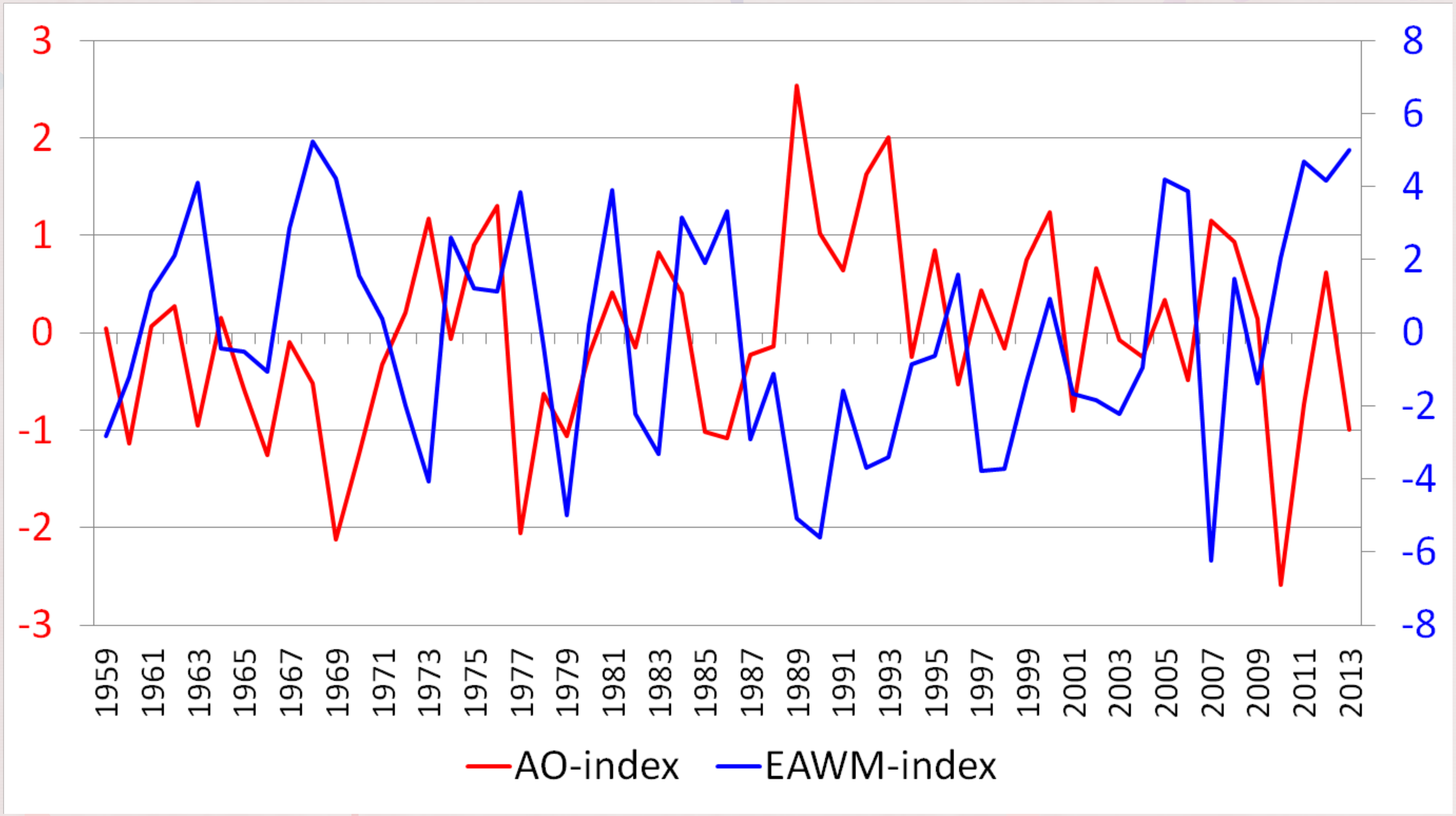


Correlation coefficient to each mode in 1958-2012 winter by JRA-55

Recent four winter SLP anomaly pattern

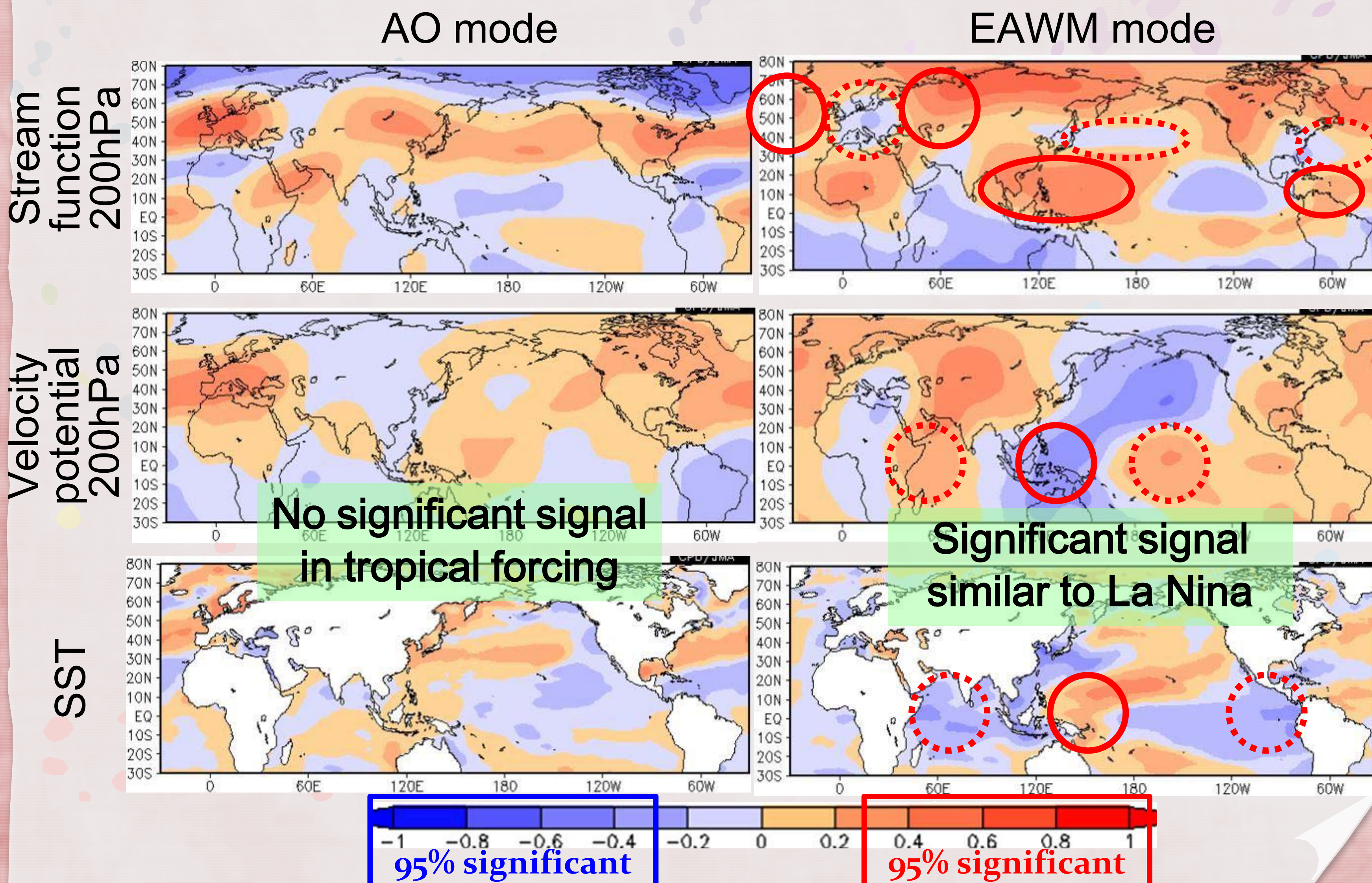


Interannual variability of AO and EAWM



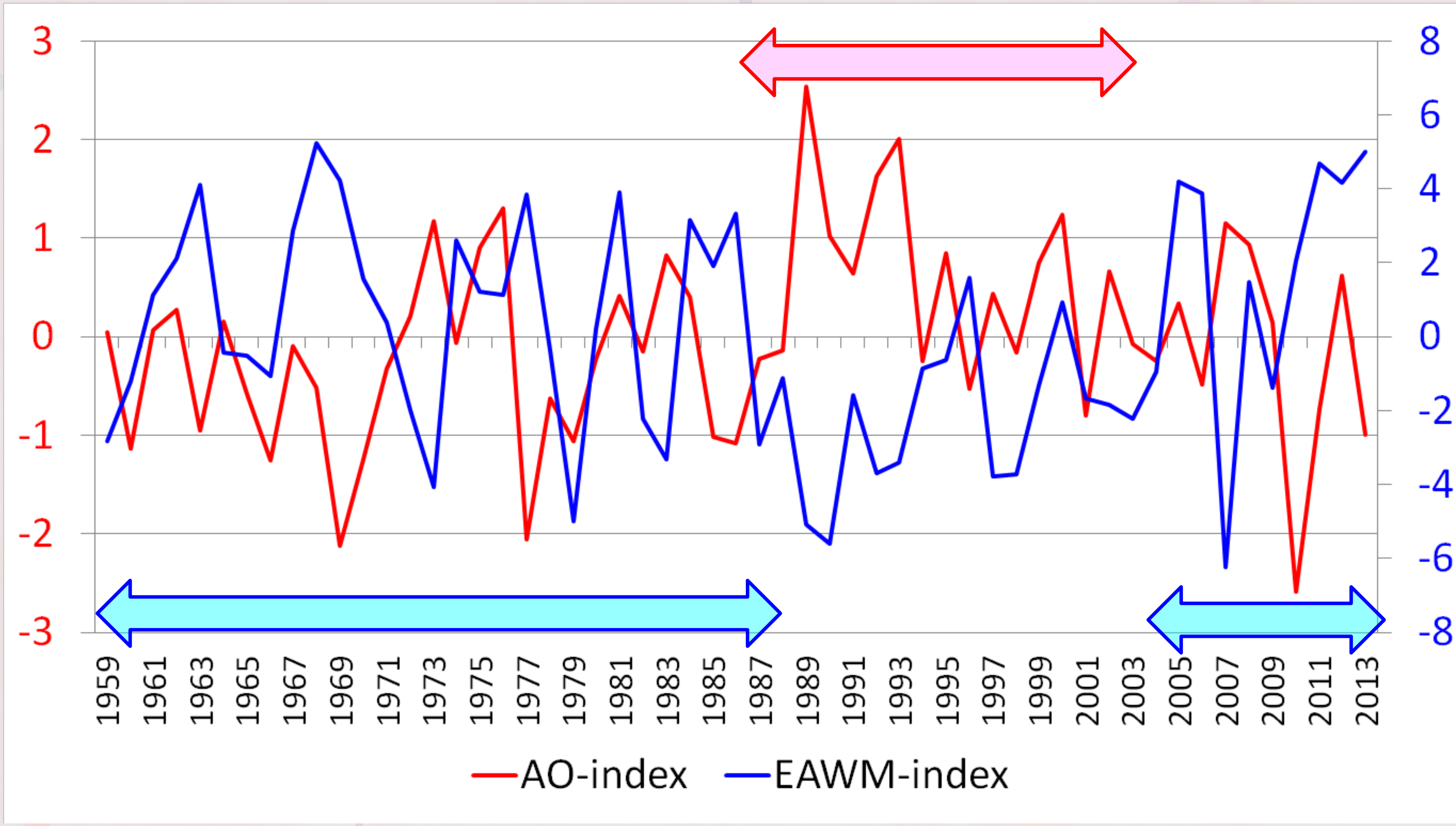
Correlation coefficient between AO and EAWM is -0.46

Tropical forcing to AO and EAWM (interannual)



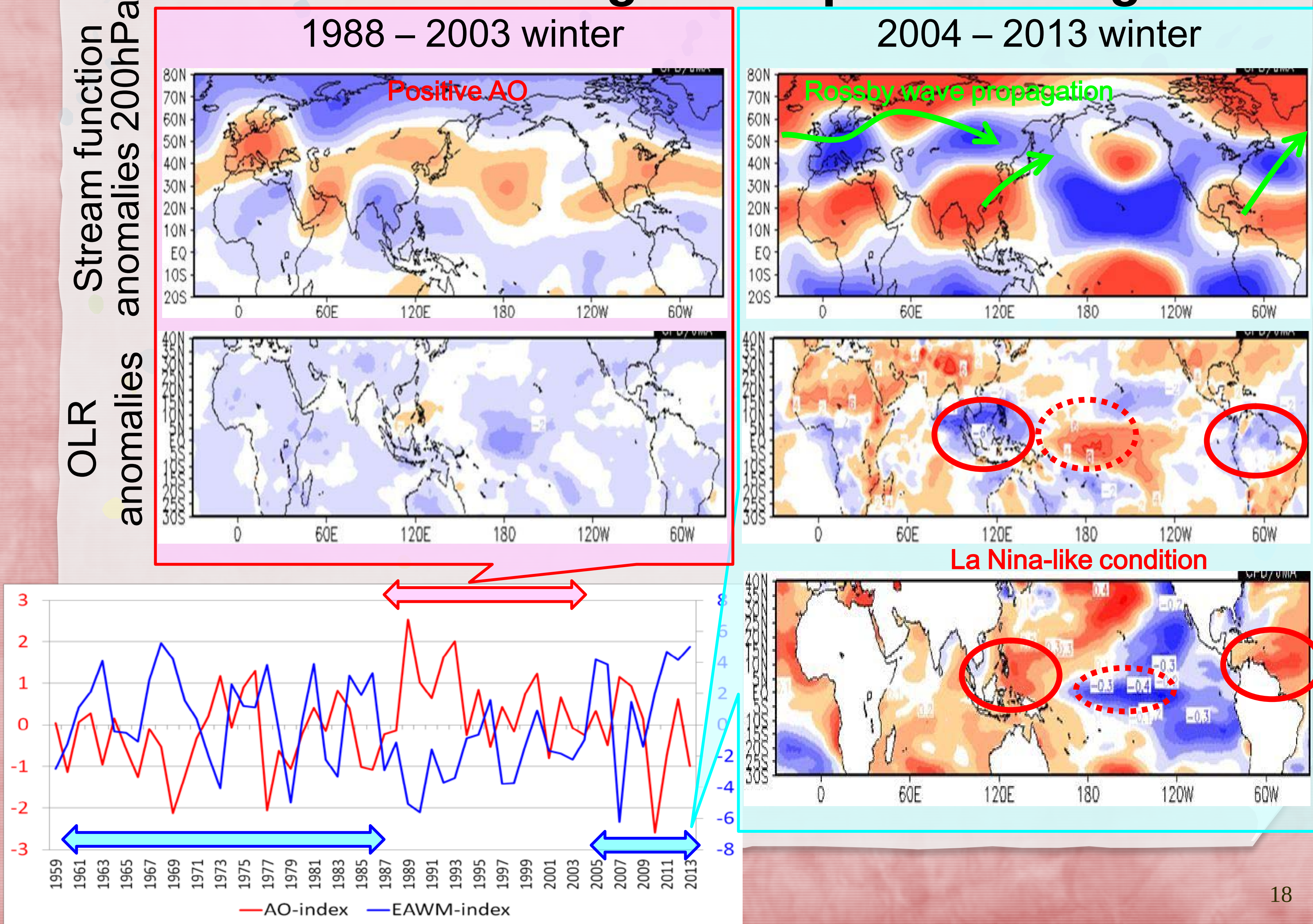
Correlation coefficient to each mode in 1958-2012 winter by JRA-55

Interannual variability of AO and EAWM

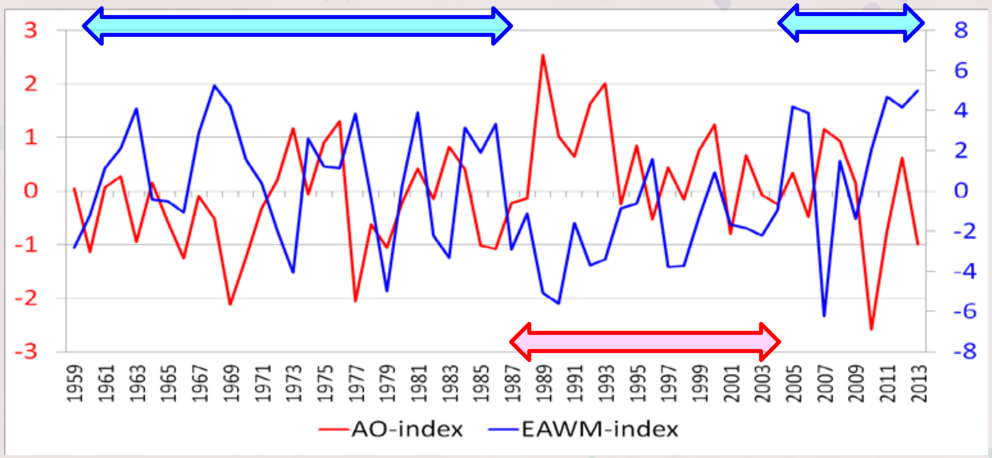


Correlation coefficient between AO and EAWM is -0.46

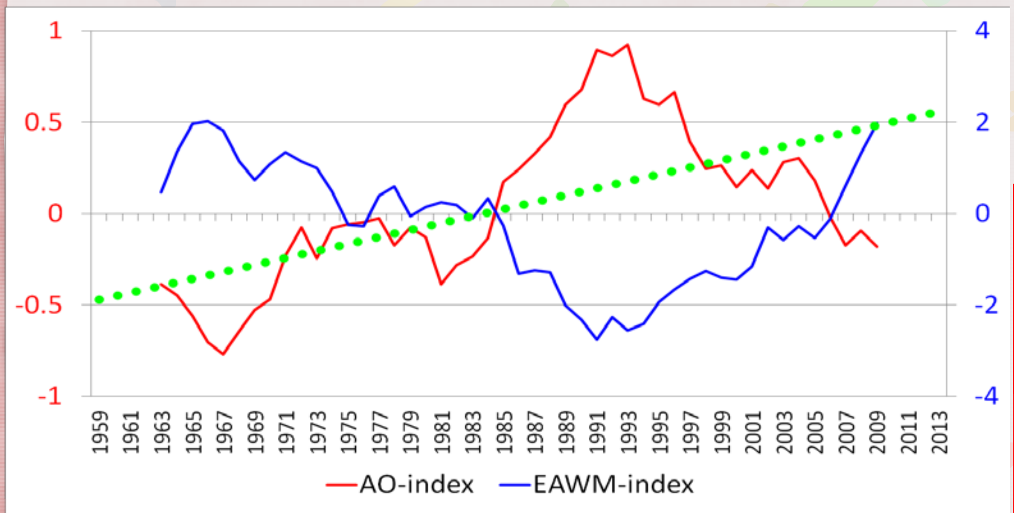
Decadal change of tropical forcing



Intra-inter decadal variability of AO & EAWM

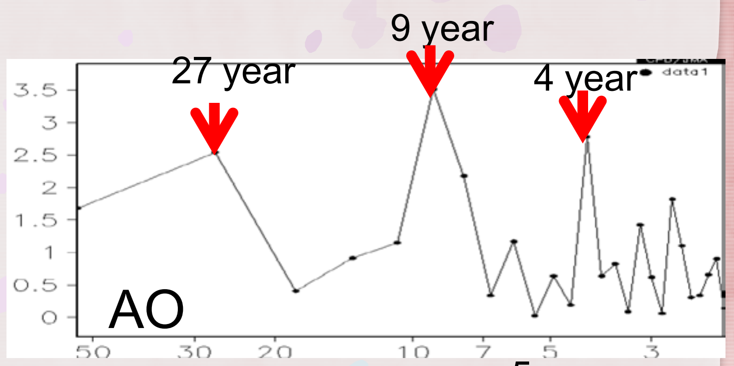


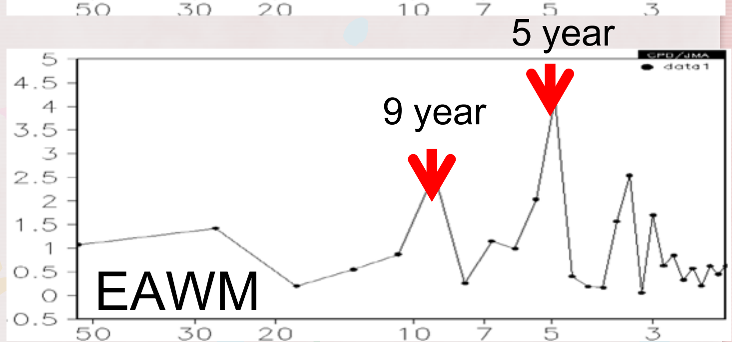
9-year running mean



Correlation coefficient between AO and EAWM is -0.92

Power spectra by FFT analysis





AO also has

- decadal variability
- multi-decadal variability

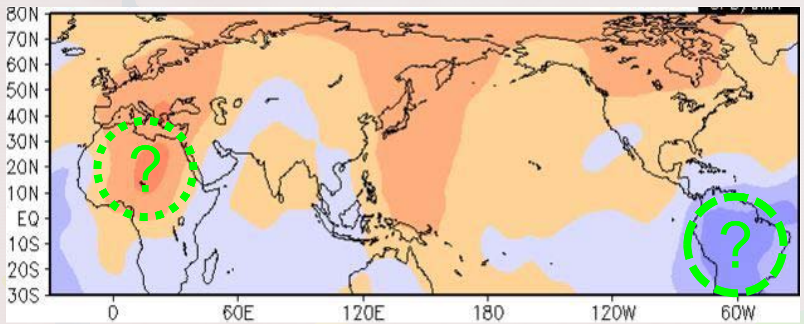
Meanwhile,

- long-term trend maybe apparent due to lack of data

Tropical forcing to AO (decadal)

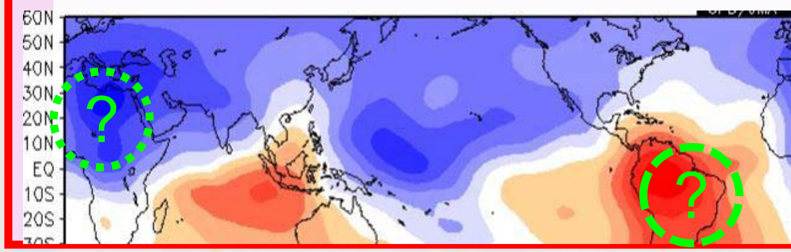
Correlation coefficient to 9-year running mean AO

Velocity potential 200hPa

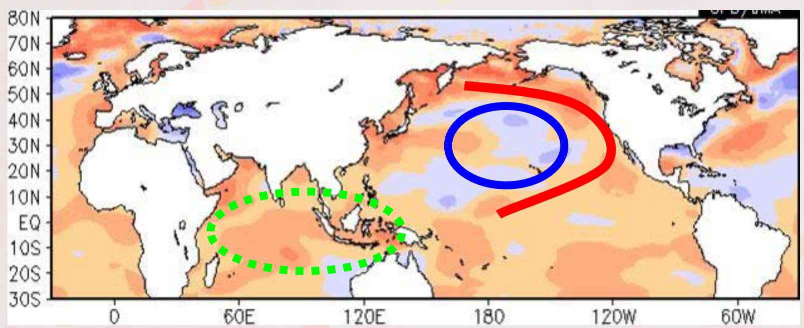


The discontinuity in the tropical convection due to the existence or non-existence of satellite data shows a trend of velocity potential in JRA-55. → ignored

EOF3 for V.P.200hPa (trend mode)

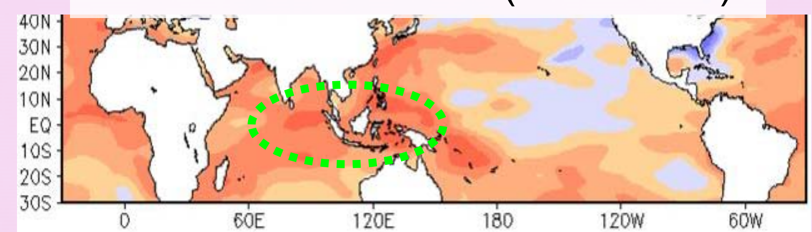


SST



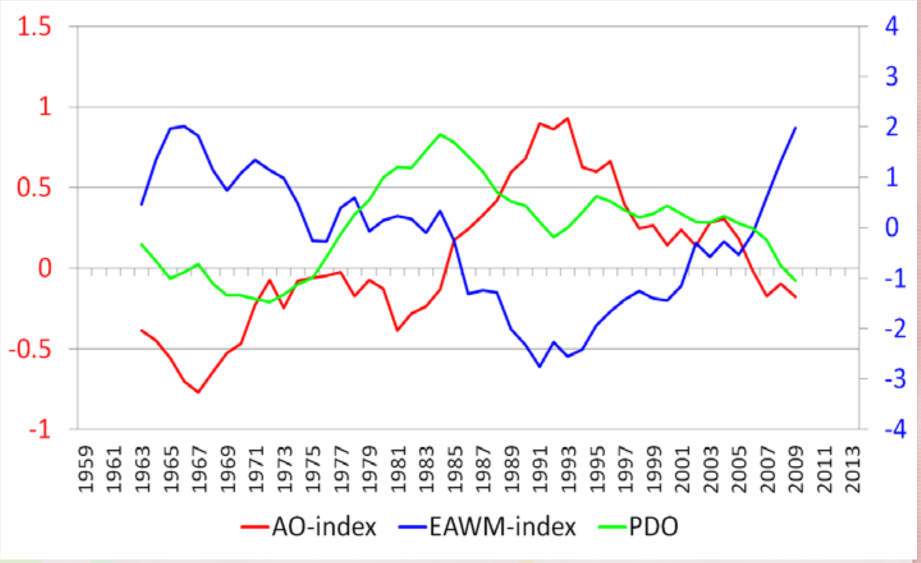
Apparent trend of AO and the positive SST trend in the Indian Ocean are well correlated. -> ignored

Trend of SST in DJF (1958-2012)

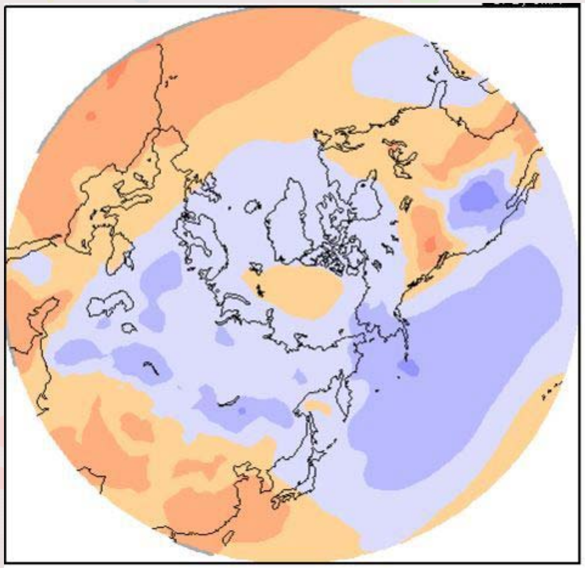


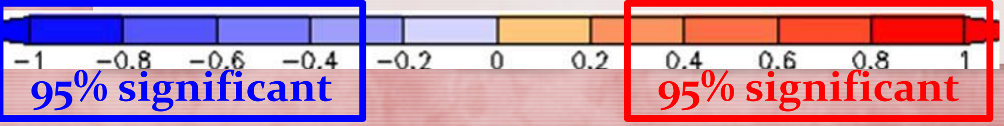
Does AO have any relationship with PDO?

Correlation coefficient between AO and PDO
for each year is +0.23
for 9-year running mean is +0.40



Statistical relationship in two indices shows significant signal, but,



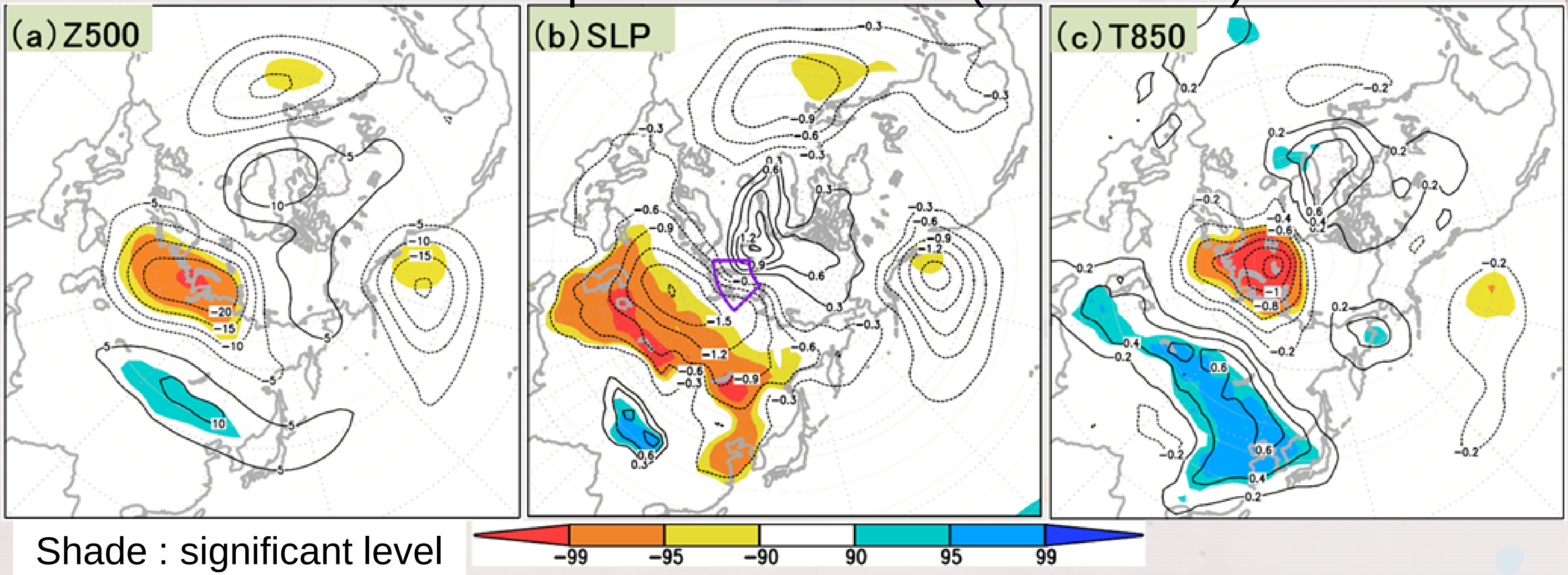


Distribution of Correlation coefficient between PDO and SLP does not show the typical AO pattern.

Relationship between AO and PDO is not so significant. In other words, there maybe a weak relationship.

Effect of Arctic sea ice to EAWM

Relationship between sea ice concentration in the Barents sea and atmospheric circulations (detrended)



Shade : significant level

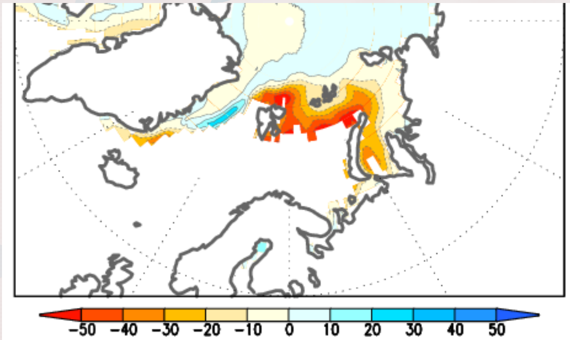
Contour: regression coefficients (1980-2013)

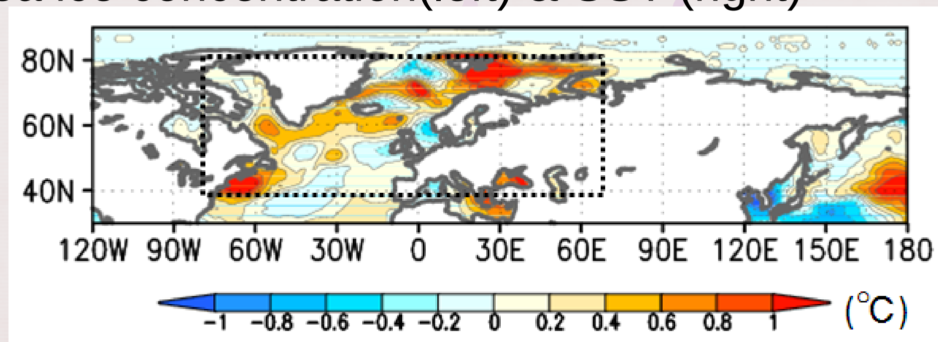
Is the dominant Siberian high in less sea ice years a cause or an effect or both (positive feedback)?

Impact experiment of sea ice and SST in the Atlantic area for 2012/2013 winter

11 ensemble run of AGCM (TL159L60 SST anomaly fix) from 1st Nov. 2012

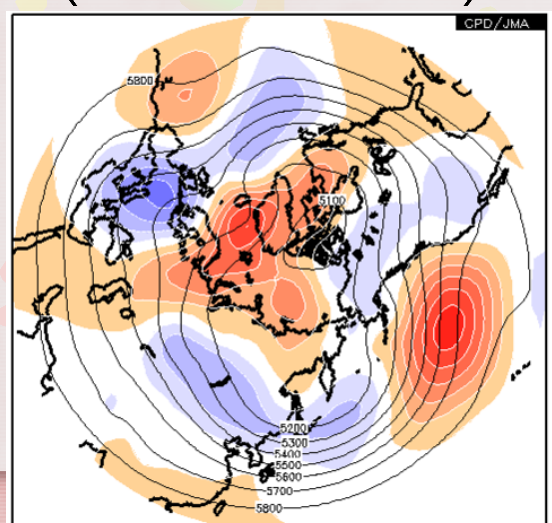
Given anomalies for sea ice concentration(left) & SST (right)



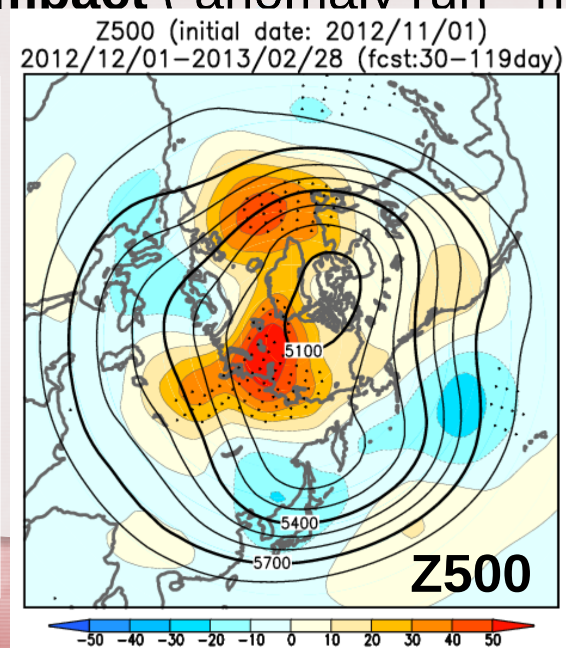


Analysis

(Z500 & anomalies)



Impact (anomaly run - normal sea ice & SST run)

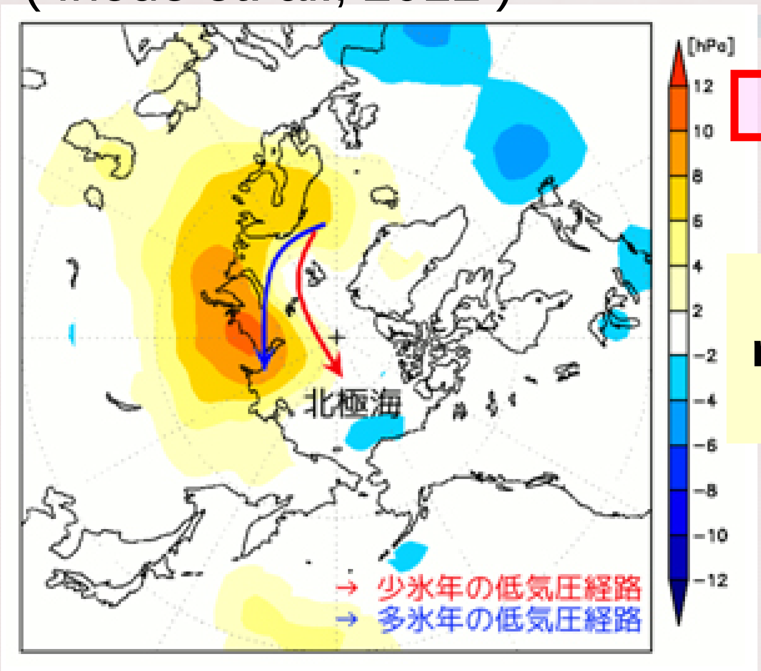


In case of winter 2012/13, it is possible that warmer Atlantic and less sea ice are one of the factors behind the dominant AO and EU.

How does Arctic sea ice affect EAWM

One hypothesis

SLP anomalies composite for less sea ice years in the Barents sea (Inoue et. al., 2012)



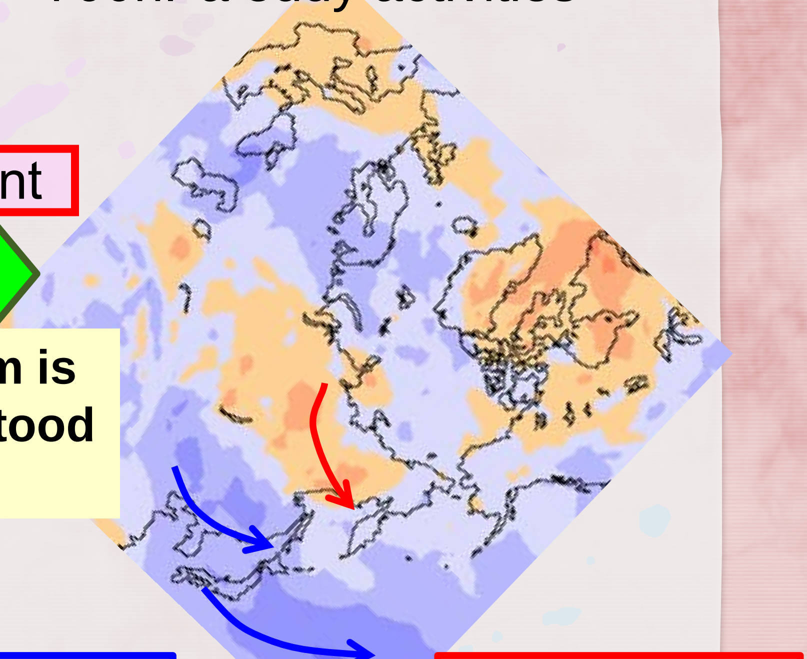
Typical cyclone track
in less sea ice years
in more sea ice years

inconsistent

Mechanism is not understood yet

Statistical relationship

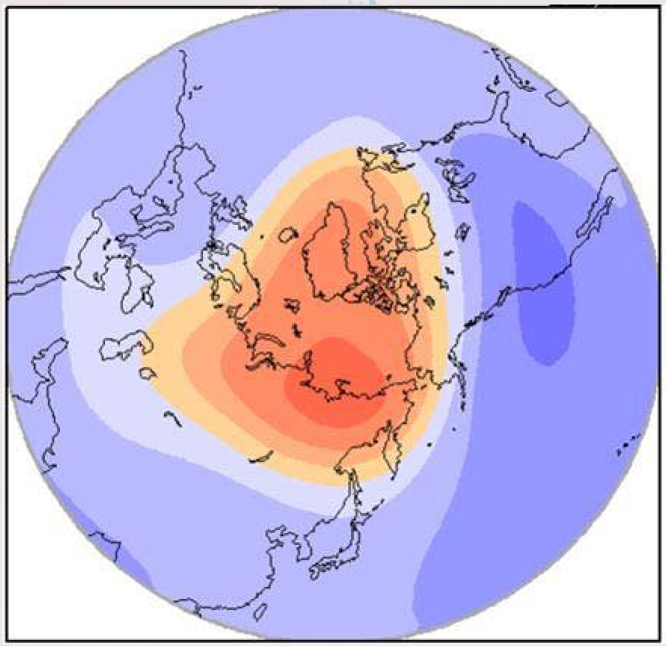
between EAWM and 700hPa eddy activities



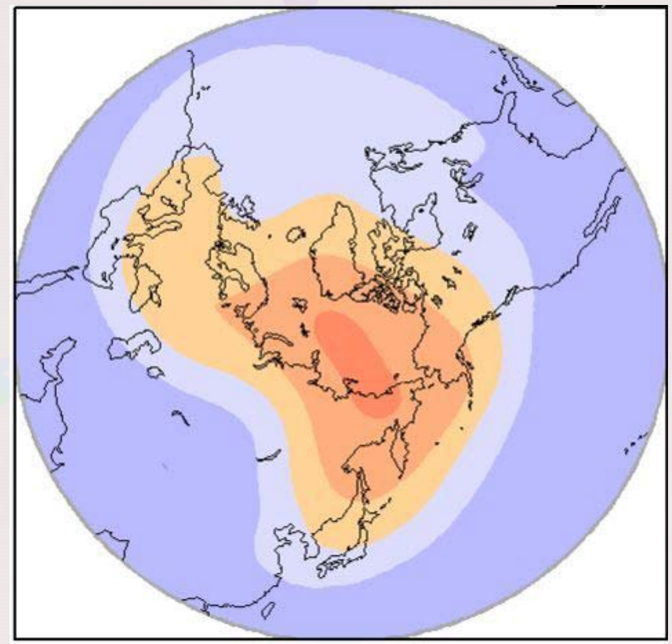
Correlation coefficient in 1958-2012 winter by JRA-55

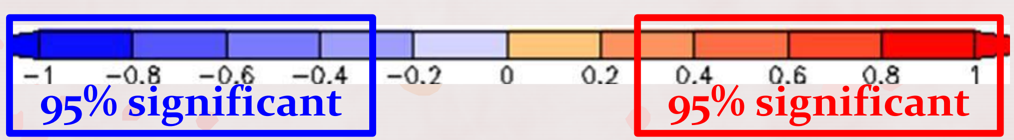
Effect of stratosphere to AO

Correlation coefficient between AO-index and 30hPa height (DJF)



Lag correlation coefficient between AO-index (**DJF**) and 30hPa height (**Nov.**)

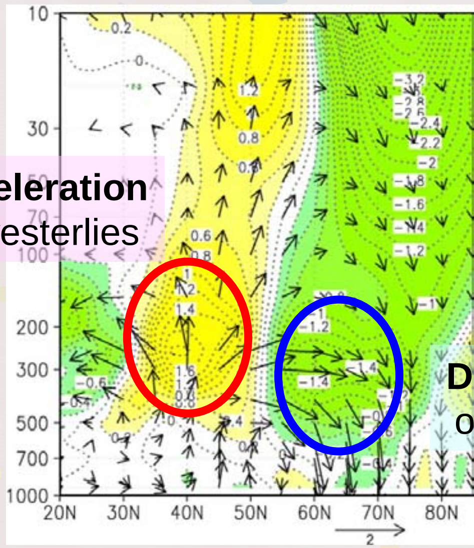




Correlation coefficient in 1958-2012 winter by JRA-55

Effect of stratosphere to AO

Typical vertical structure throughout troposphere and stratosphere in the negative AO (2012/13 winter)

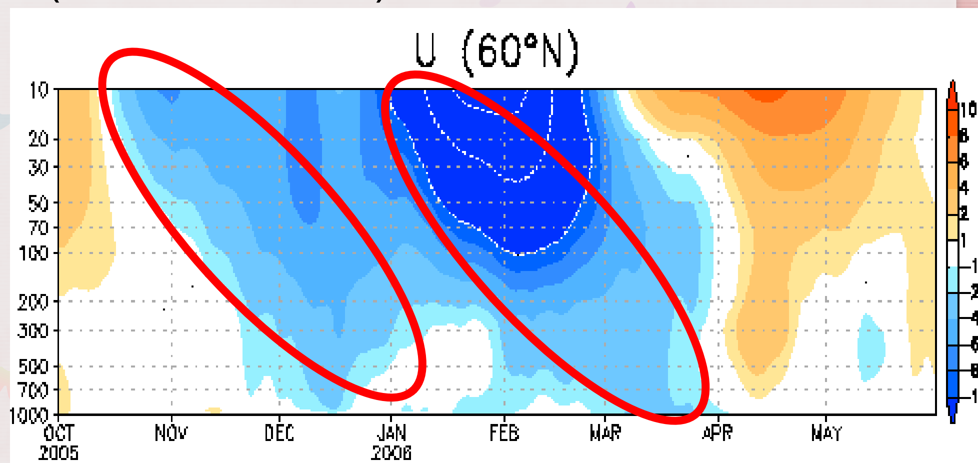


Acceleration of westerlies

Deceleration of westerlies

Arrow: EP-flux anomalies
Contour: divergence anomalies of EP-flux
Shade:
  yellow: divergence anomalies
  green: convergence anomalies

Typical downward evolution of deceleration of westerlies in the dominant AO(-) winter (2005/06 winter)



1. Strong upward propagation of Rossby wave
2. Convergence of EP-flux decelerate westerlies
3. Rossby wave is disable to propagate upward and refract to high latitude under the condition of weak westerlies
4. Deceleration of westerlies progress downward
5. The case that refraction of Rossby wave at lower stratosphere contribute to strengthen the EU pattern is also reported

Summary

- There seems to be a decadal variability in East Asian winter monsoon.
  - Recently, the phase of decadal variability shows a strong EAWM.
- The interannual variability of EAWM is mainly accompanied with the EU teleconnection pattern.
  - The EU pattern is basically considered an internal mode of atmosphere, but it is possible that the tropical convection is concerned with the exciting of Rossy wave source which build the EU pattern.
  - It is possible that the less sea ice in the Barents sea is one of the cause of dominant Siberian high, but the mechanism has not been understood yet.
- Interannual variability of AO is also considered an internal mode of atmosphere.
  - Decadal and multi-decadal variability of AO maybe concerned with those of ocean. The relationship is not so significant.
  - Stratospheric circulation in late Autumn seems to be a precursor of AO in winter.

Conclusion

Recent strong EAWM has been caused by the recent La Nina-like condition under the negative AO phase in multi-decadal time scale.

Thank you