

Extremely Negative Arctic Oscillation in Winter 2009/2010

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Tokyo Climate Center
Japan Meteorological Agency

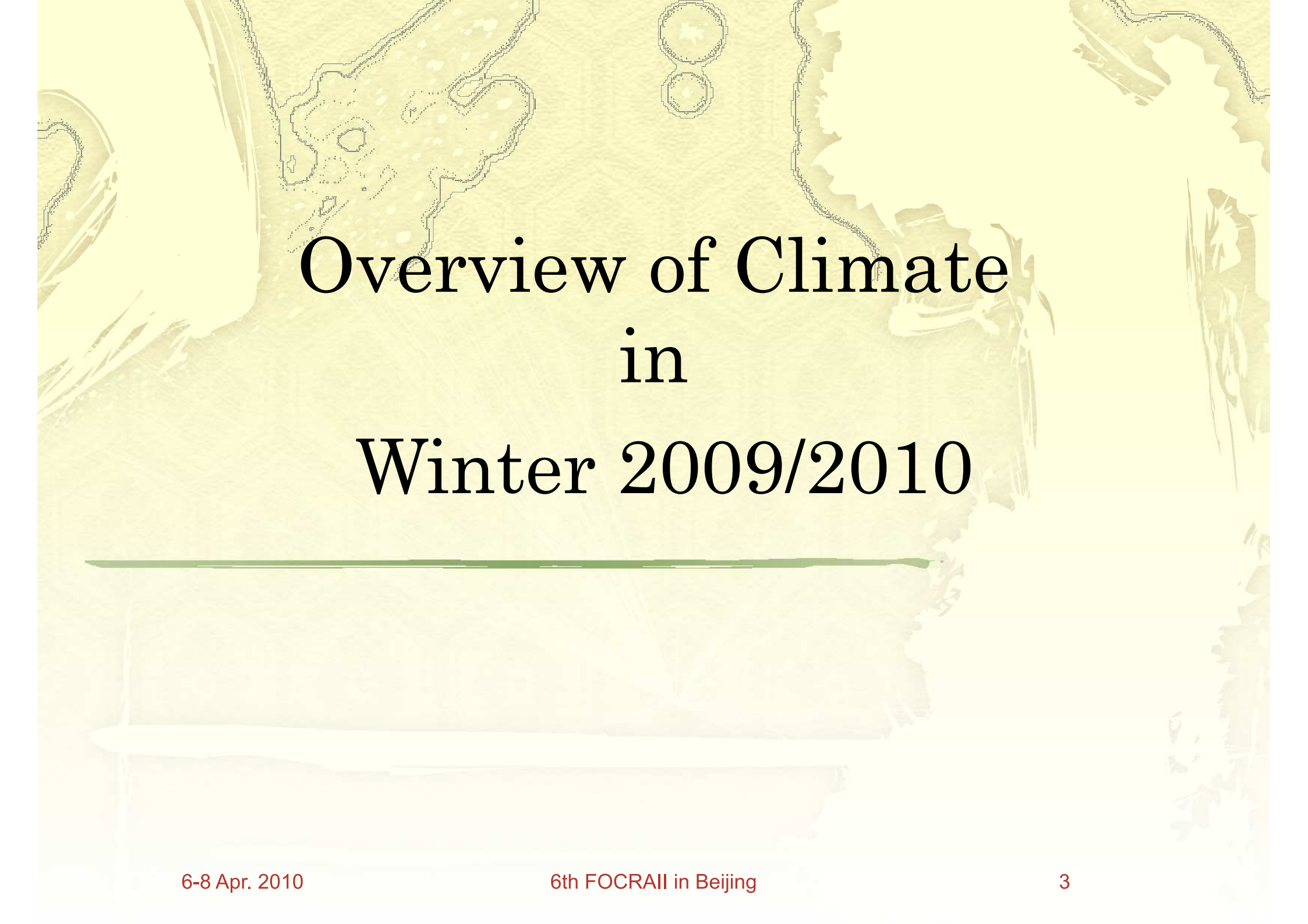
E-mail: tcc@climar.kishou.go.jp

URL: <http://ds.data.jma.go.jp/tcc/tcc/index.html>

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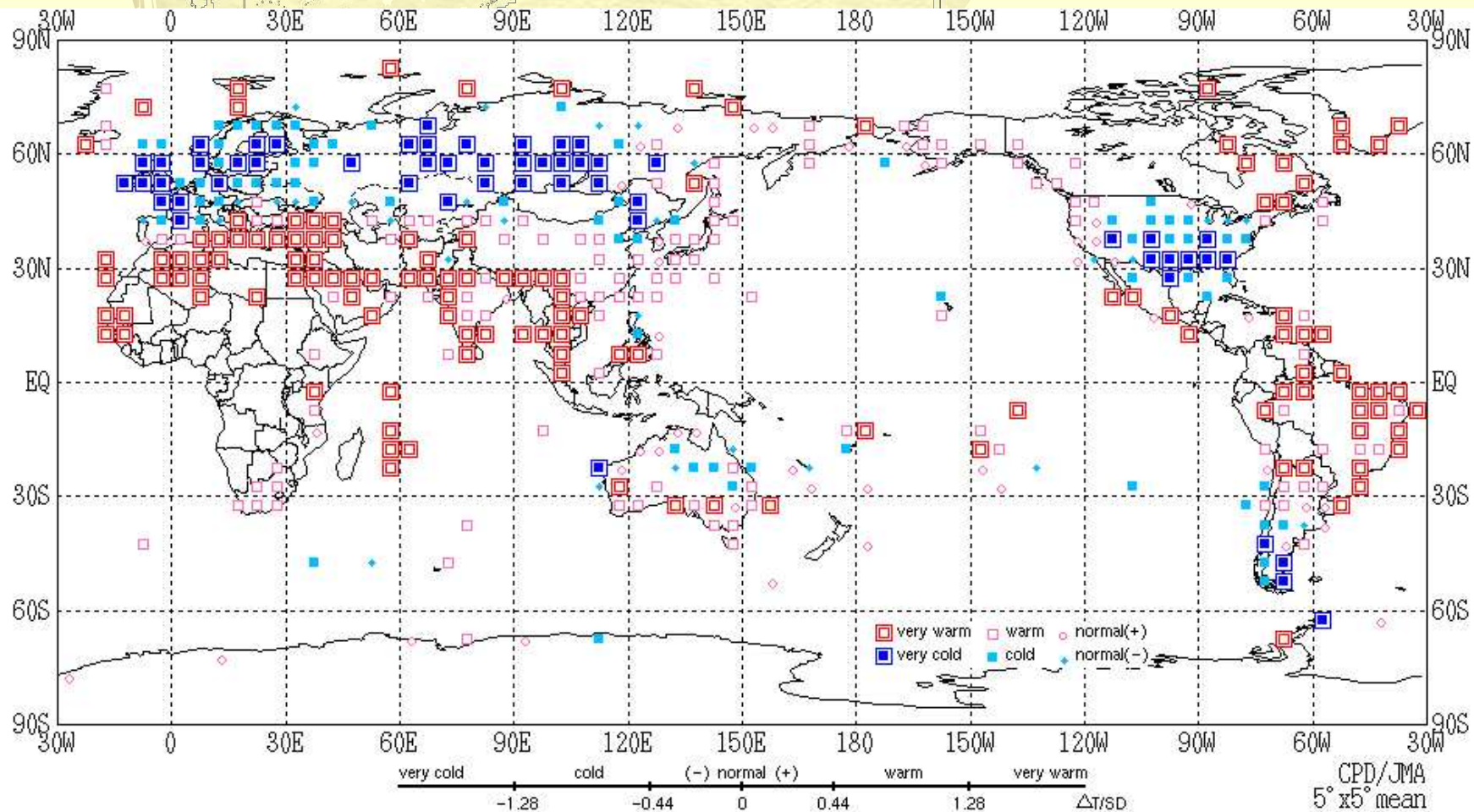
- **Overview of Climate in Winter 2009/2010**
- **Extremely Negative Arctic Oscillation in Winter 2009/2010**
 - **Significant Features**
 - **Maintenance Mechanism**

- **Impact on Climate in Japan**
- **Forecast Verification**
- **Advisory Panel on Extreme Climate Events**



Overview of Climate in Winter 2009/2010

Severe Winter in some area of the N.H. mid-latitude



Seasonal Mean Temperature Anomaly (Normalized) (Dec 2009 - Feb 2010)

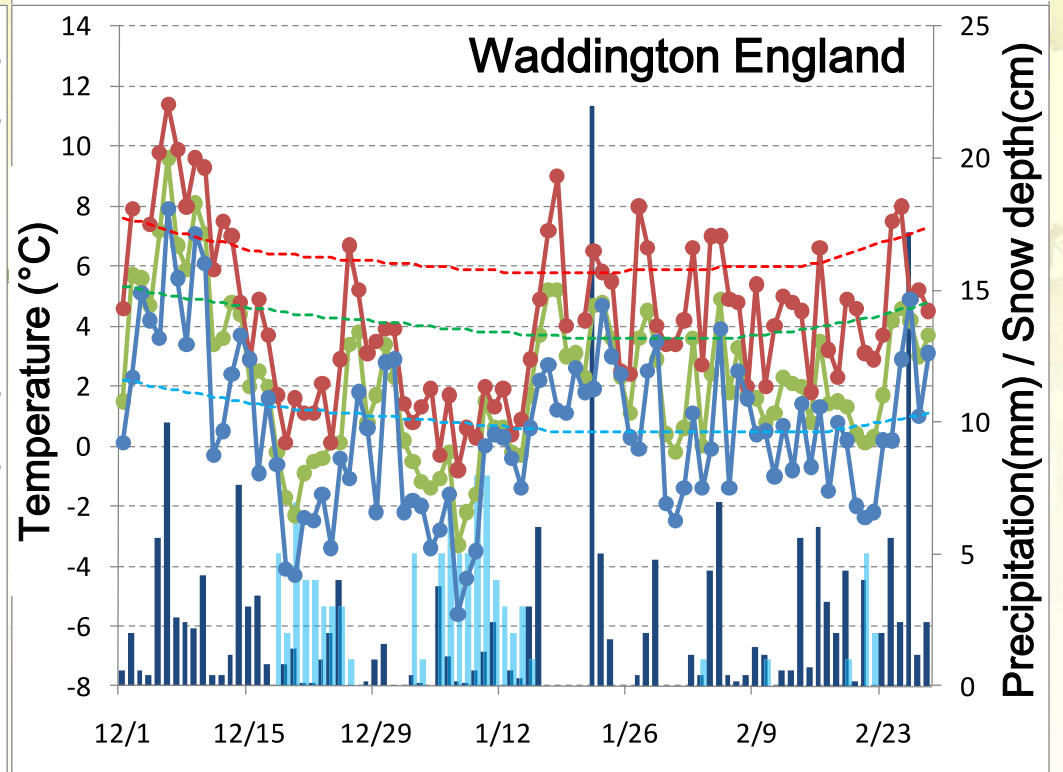
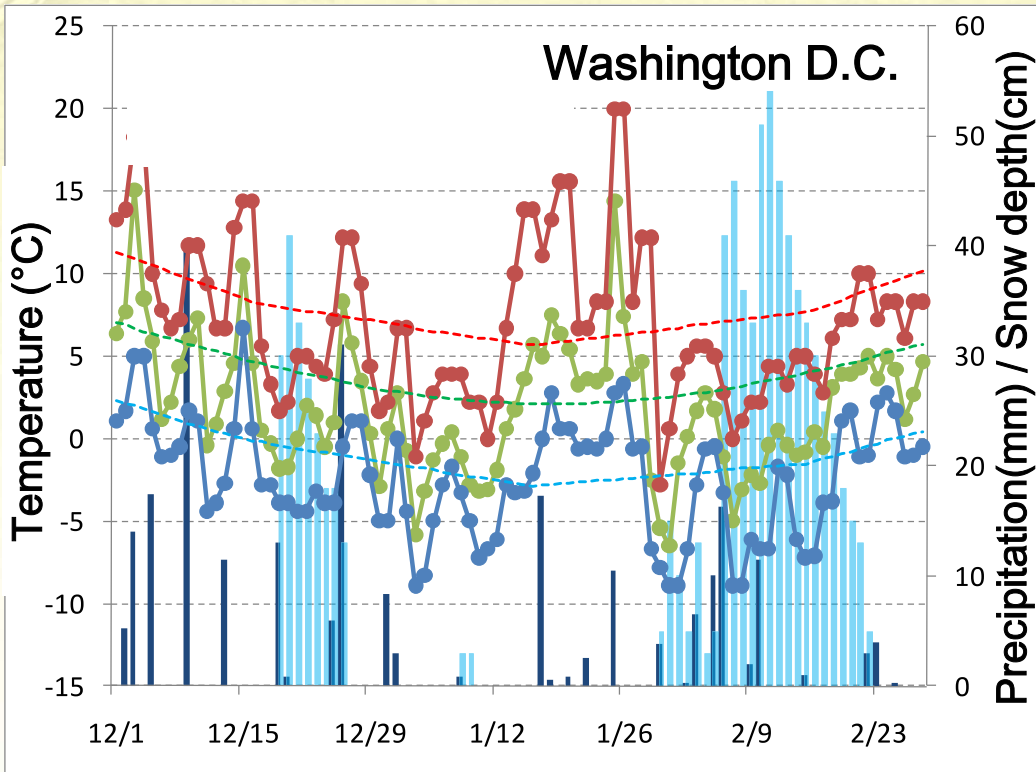
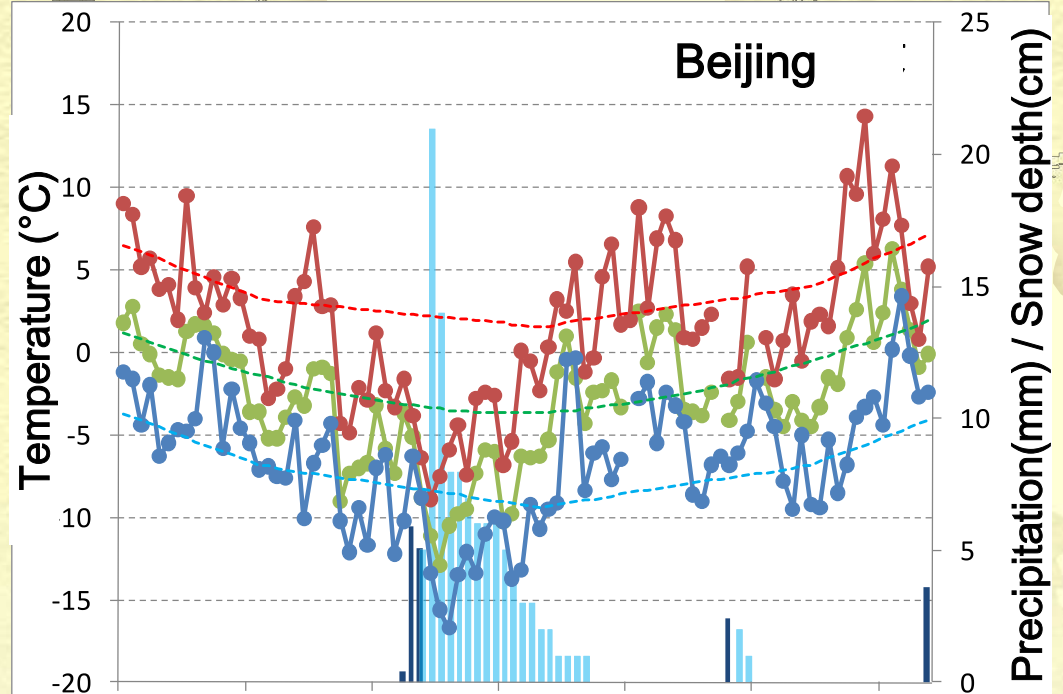
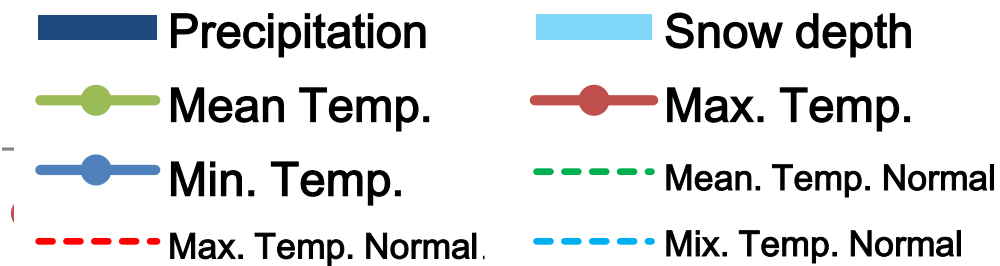
<http://ds.data.jma.go.jp/tcc/tcc/products/climate/seasonal.html>

6-8 Apr. 2010

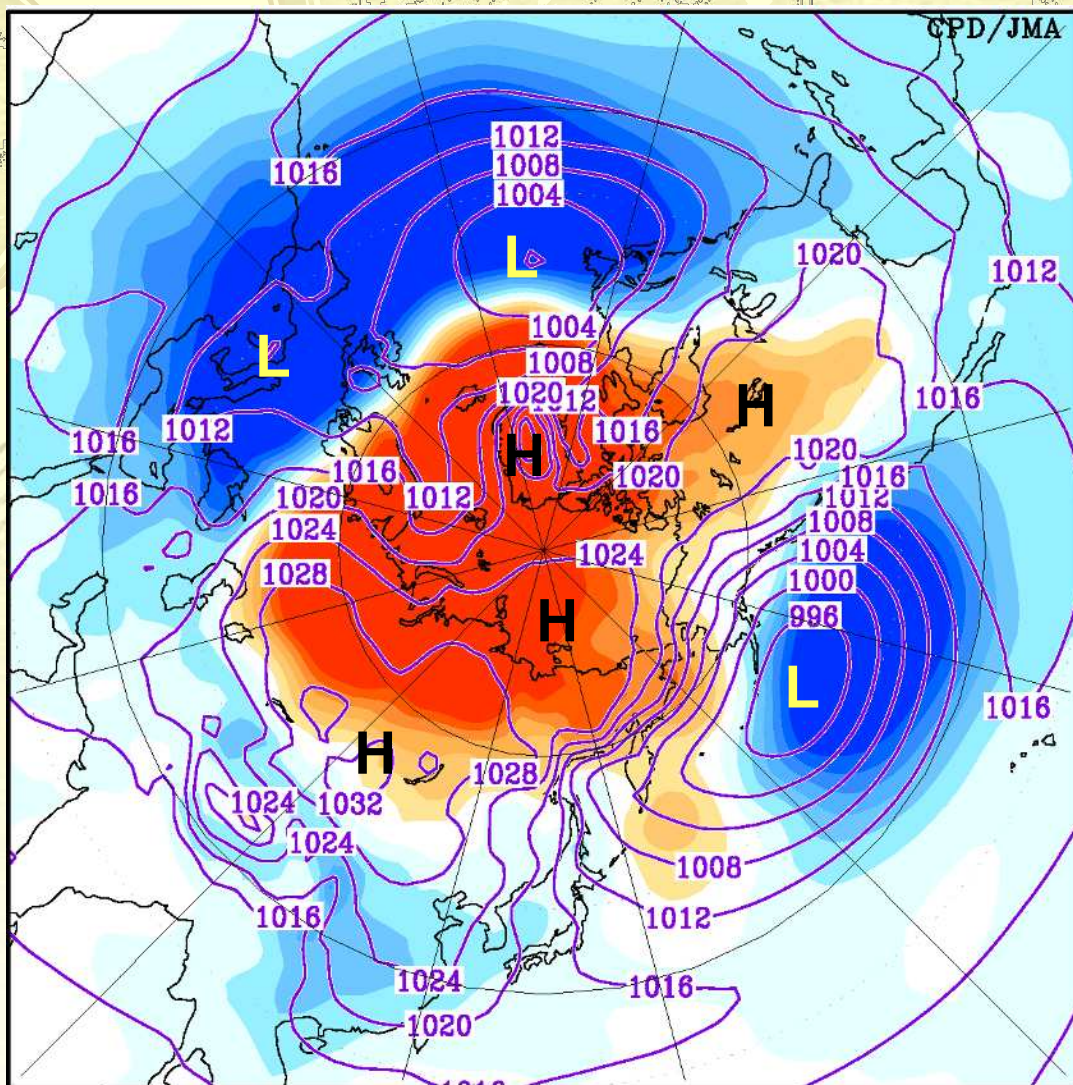
6th FOCRAII in Beijing

4

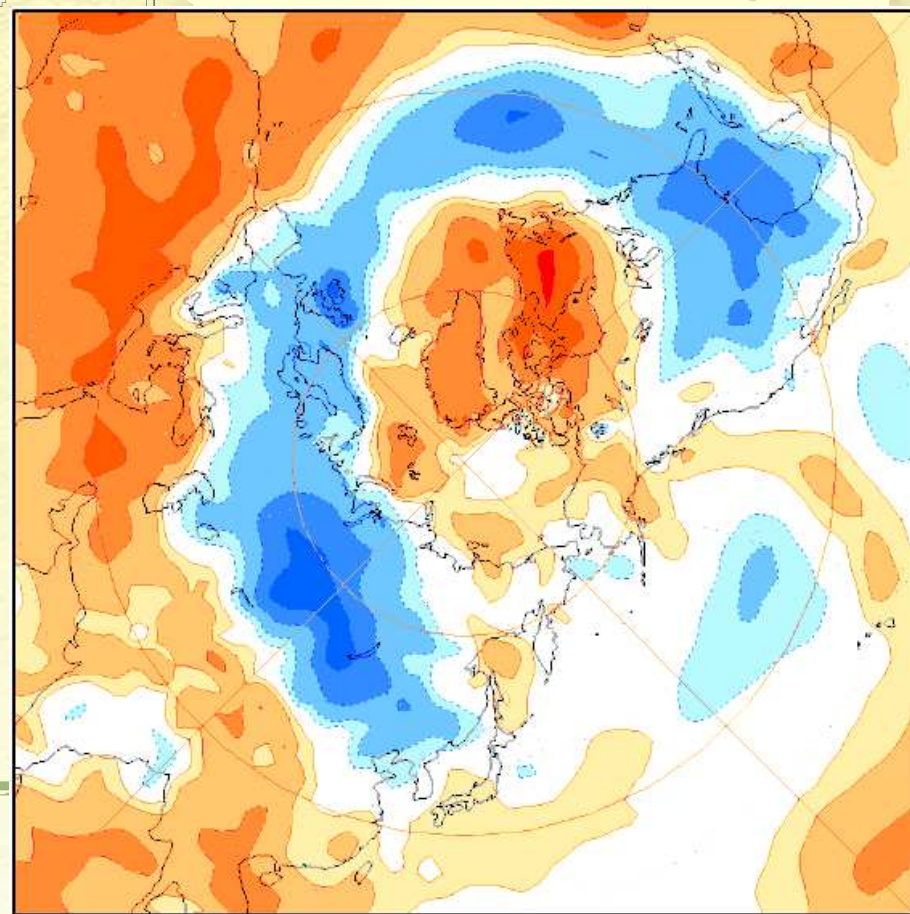
Cold Spells and Heavy Snow



Dominant Circulation Pattern in the N.H.

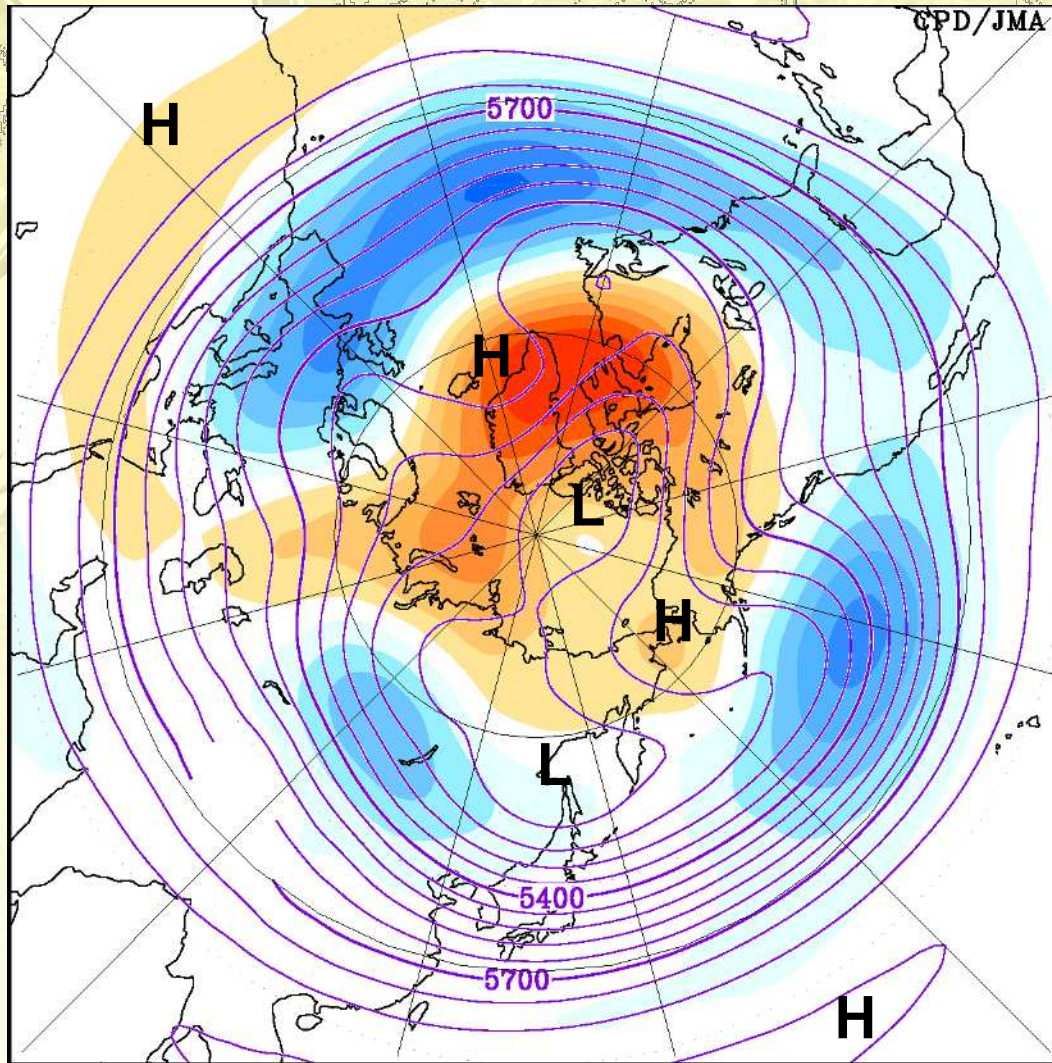


Seasonal Mean Sea Level Pressure and Anomaly (DJF 2009/2010)



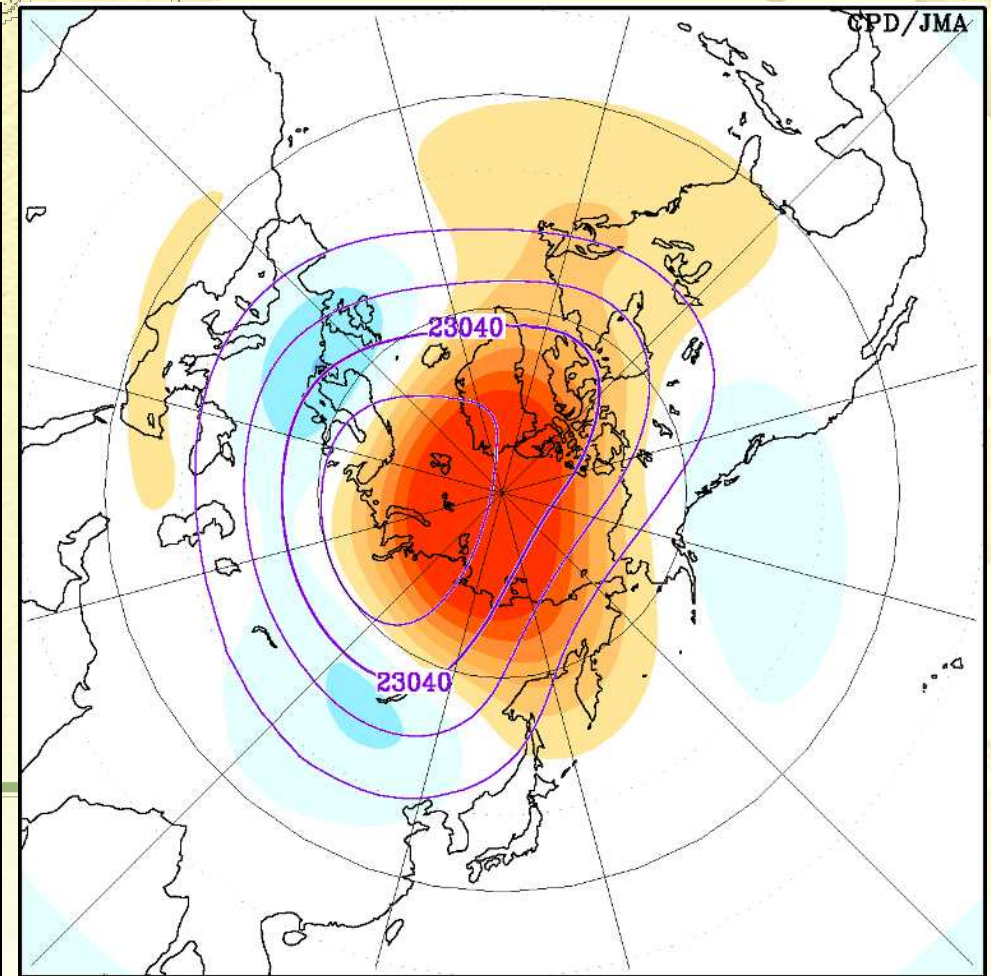
Seasonal Mean Surface Temperature Normalized Anomaly (DJF 2009/2010)

Dominant Circulation Pattern in the N.H.



Seasonal Mean 500-hPa Height and Anomaly (DJF 2009/2010)

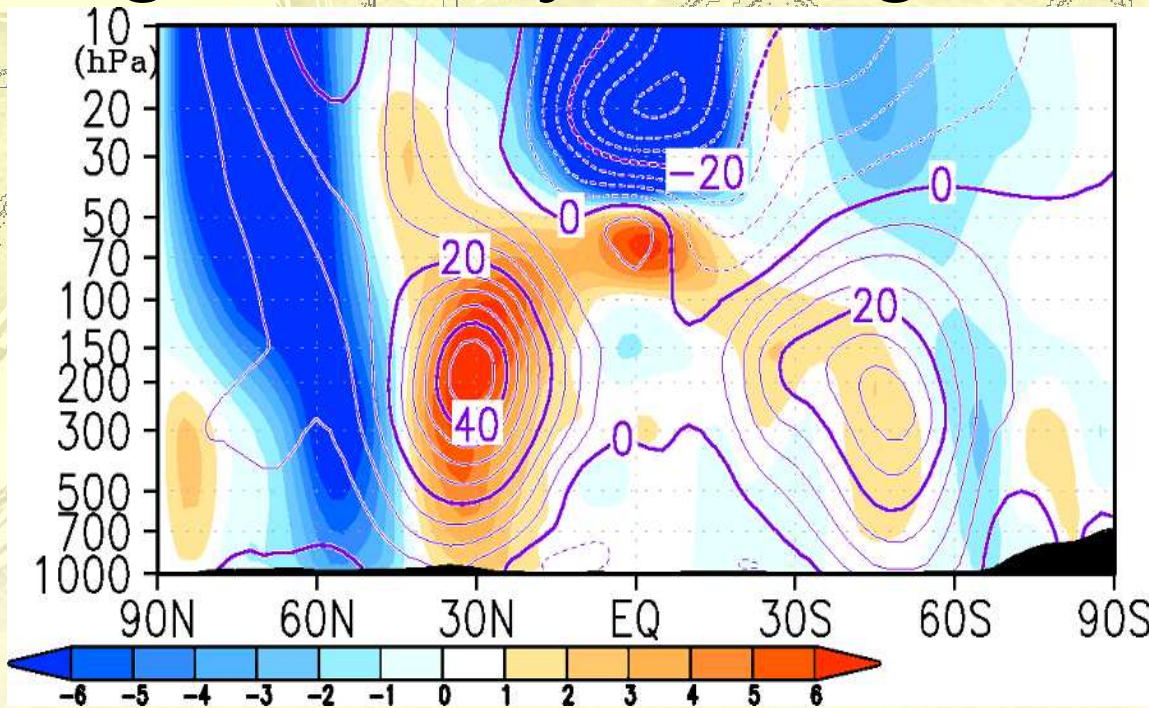
6-8 Apr. 2010



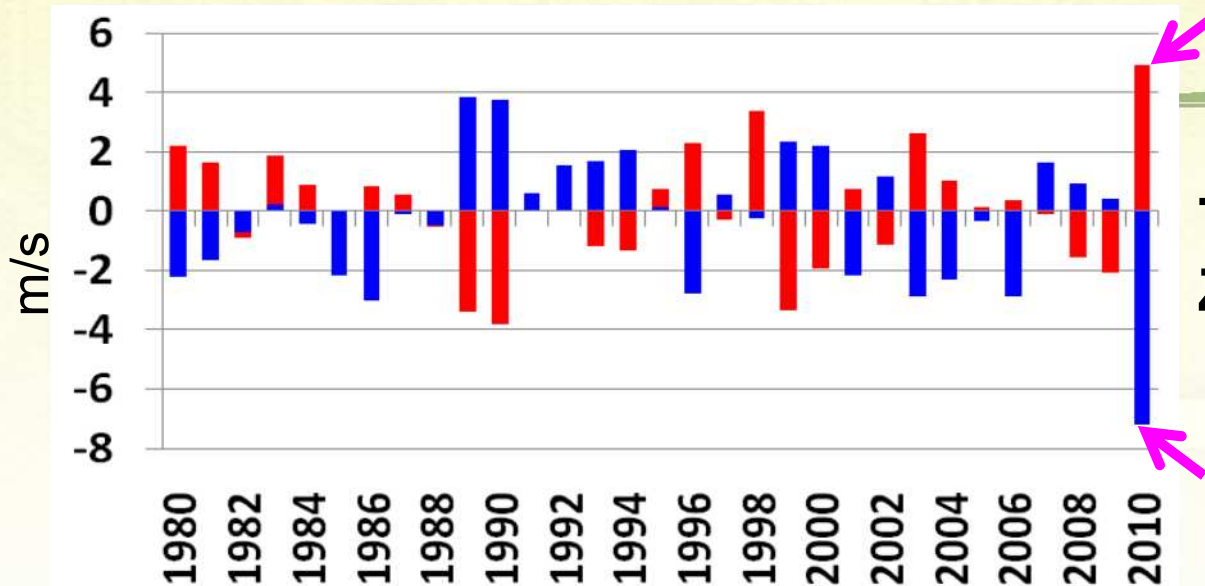
Seasonal Mean 30-hPa Height and Anomaly (DJF 2009/2010)

6th FOCRAII in Beijing

Significantly Strong Sub-tropical Jet Stream



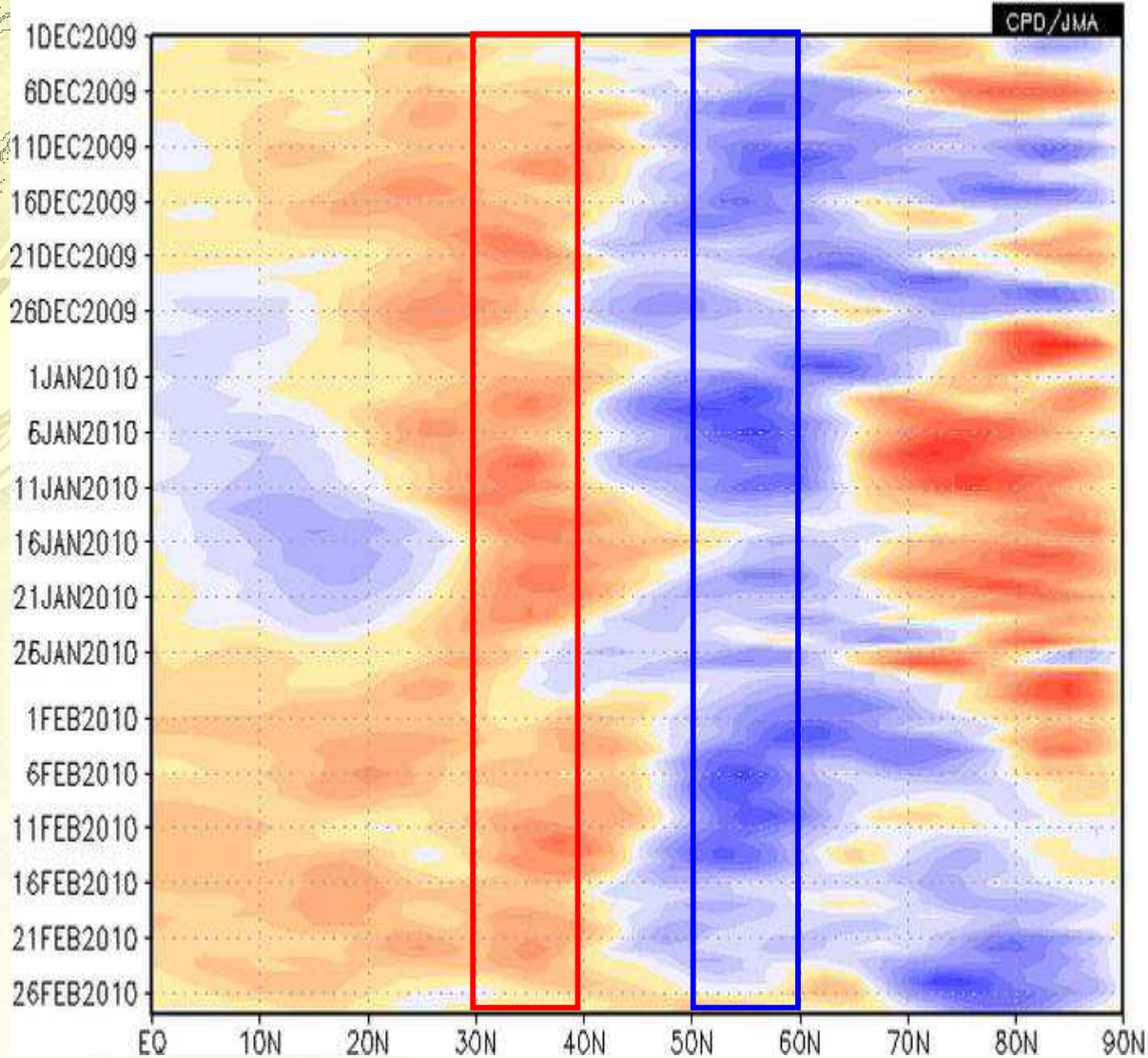
Seasonal Mean Zonal Averaged Zonal Wind and Anomaly (DJF 2009/2010)



Time Series of Zonal Averaged Zonal Wind Anomaly at 300hPa

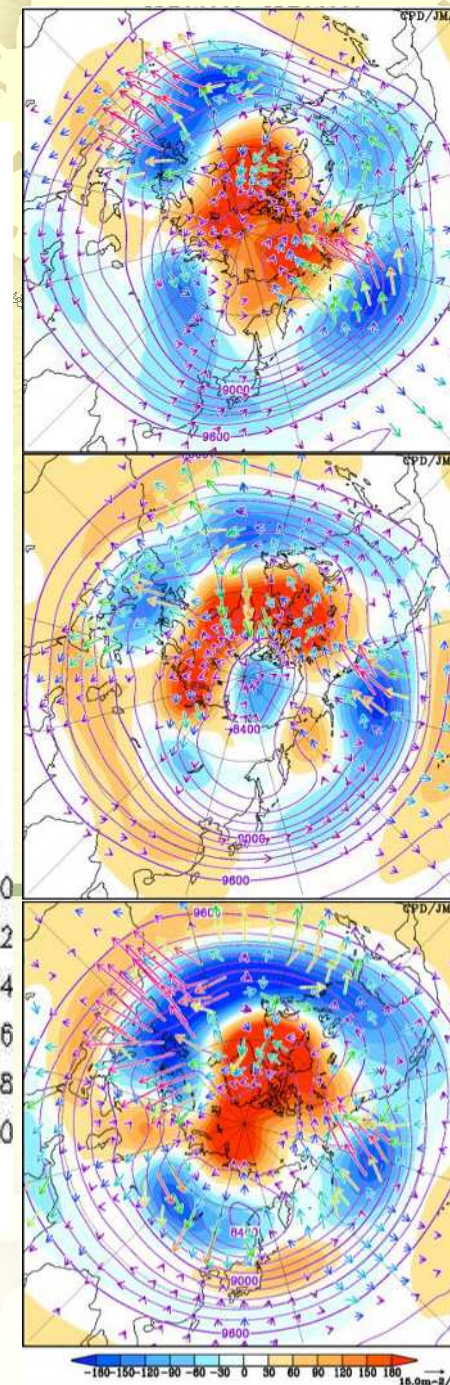
- Latitudinal band from 25N to 35N
- Latitudinal band from 40N to 50N

Persistent of Jet Structure



Time Longitude Cross Section of Zonal Averaged Zonal Wind Anomaly

**500-hPa
Height and
Anomaly**

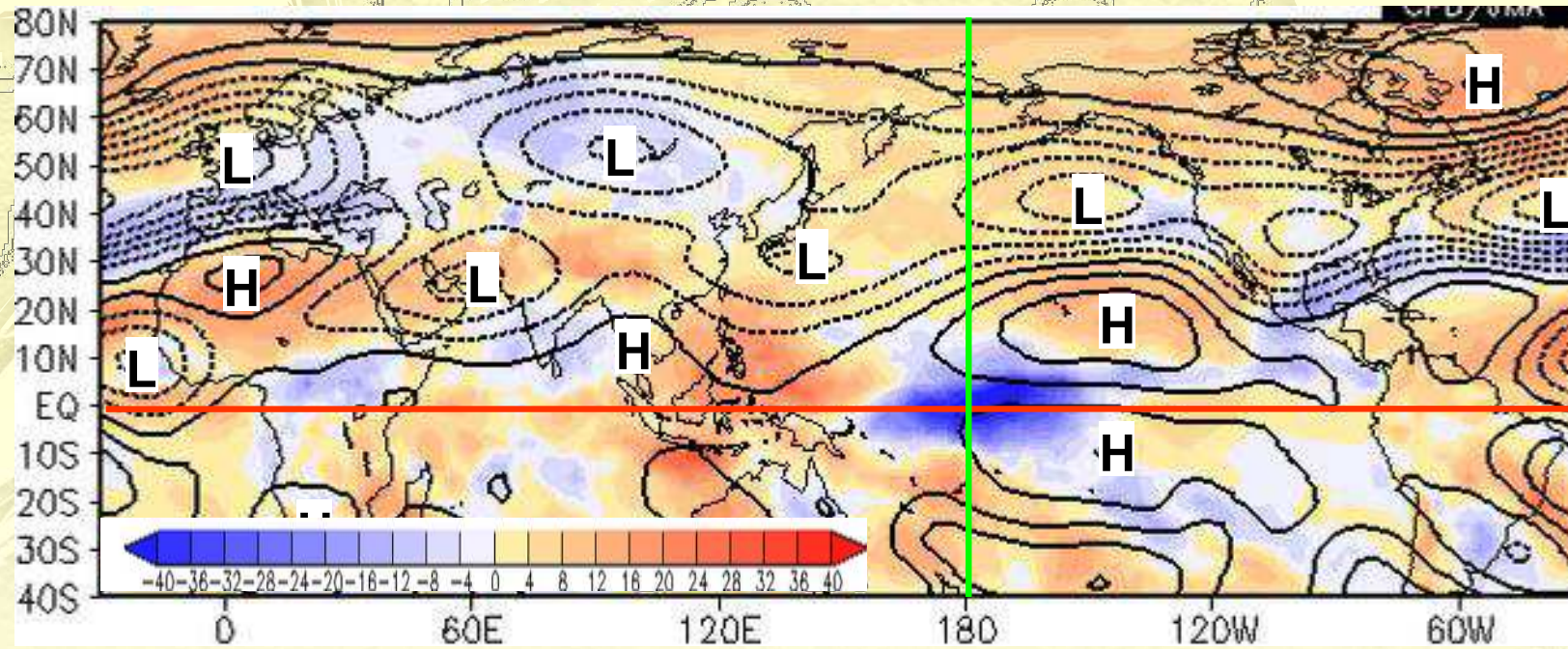


Dec.

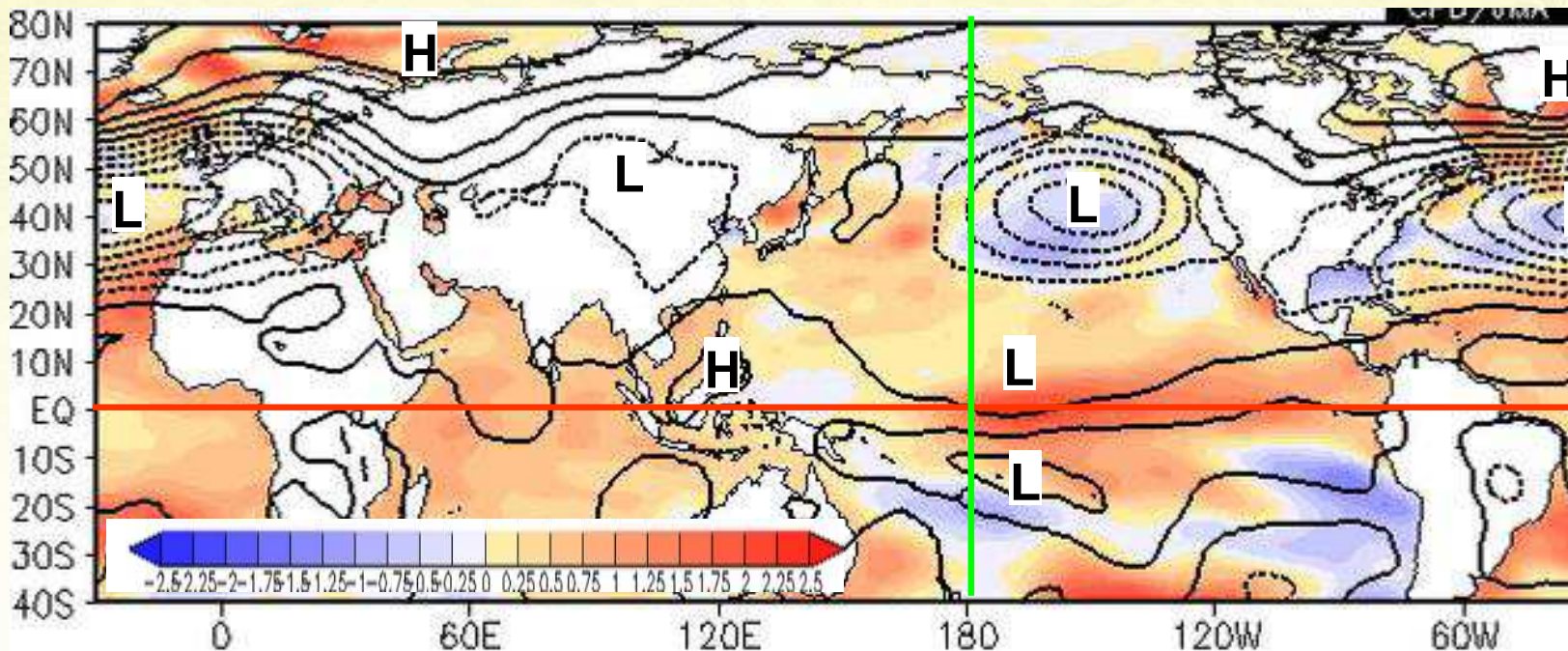
Jan.

Feb.

Tropical Convection and Circulations



OLR Anomaly (Shaded) and 200-hPa Stream Function Anomaly (Contour)



SST Anomaly (Shaded) and 850-hPa Stream Function Anomaly (Contour)

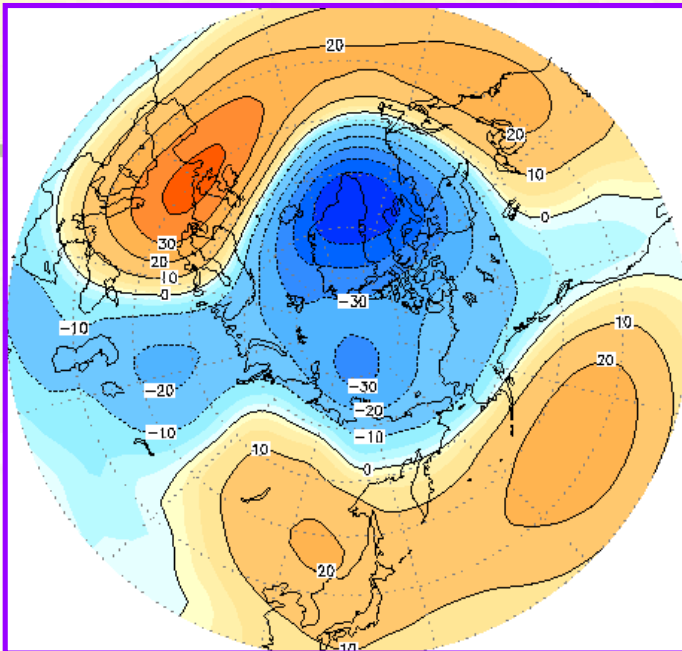
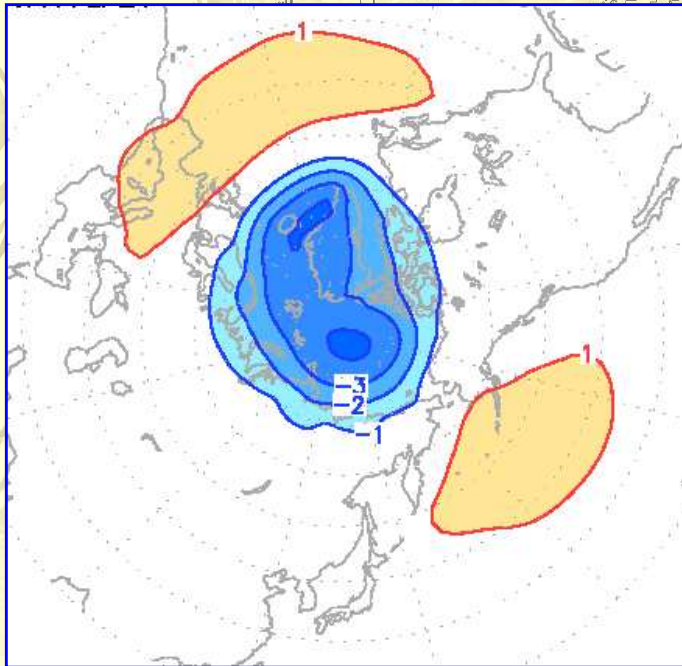


Negative Arctic Oscillation in Winter 2009/2010



Significant Features

Arctic Oscillation Index



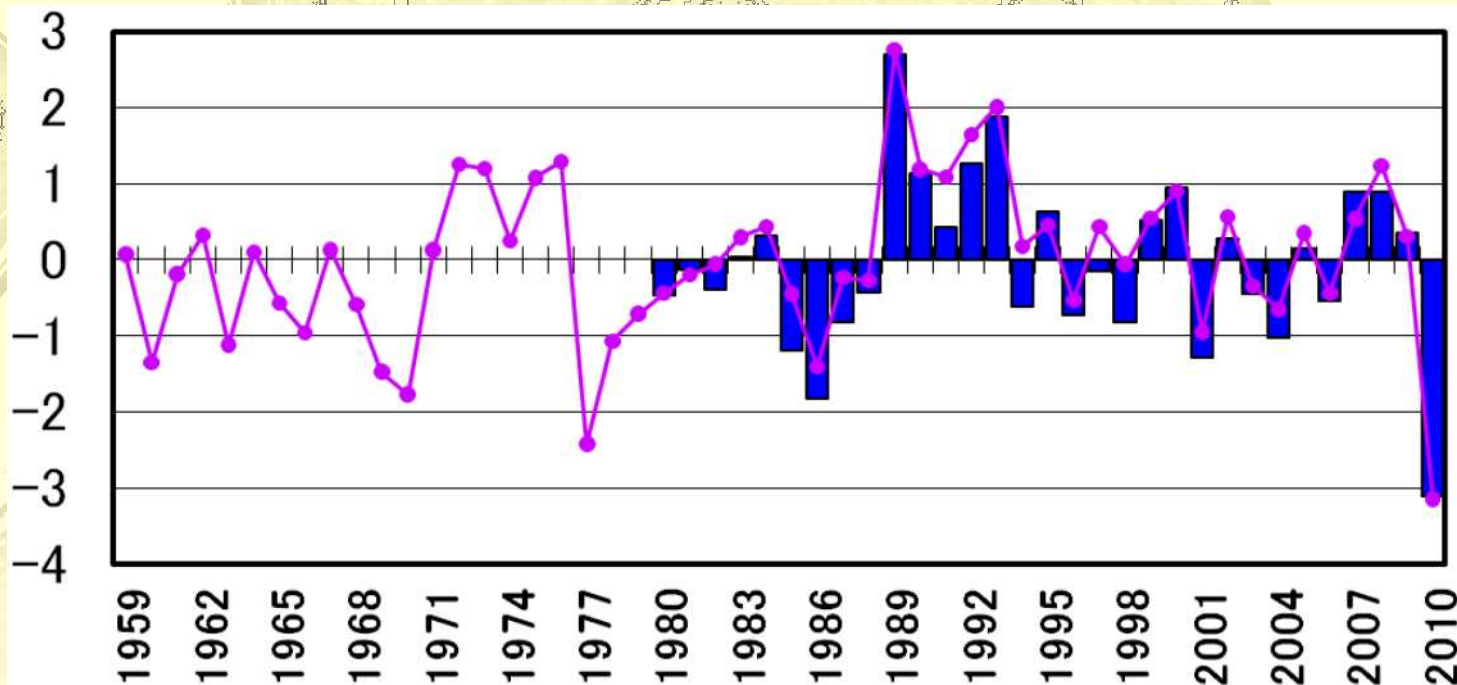
AO Index – based on JRA-25

1. Apply EOF to each monthly mean SLP north of 20N year-round.
2. Average annular modes of each EOF as an annual AO mode (Top Figure).
3. Project historical SLP fields to an AO mode and calculate scores.
4. Standardize scores by a standard deviation in the period of 1979-2004. -> AO index
5. This method is applied for year-round monthly and daily indices, which brings in monitoring the AO status smoothly.

Winter EOF1 Index based on ERA-40 and JRA-25

1. Apply EOF to seasonal mean 500h-Pa height north of 20N. The first mode is shown in the bottom figure.
2. Standardize scores by a standard deviation in the period of 1979-2004.
-> Winter EOF1 Index

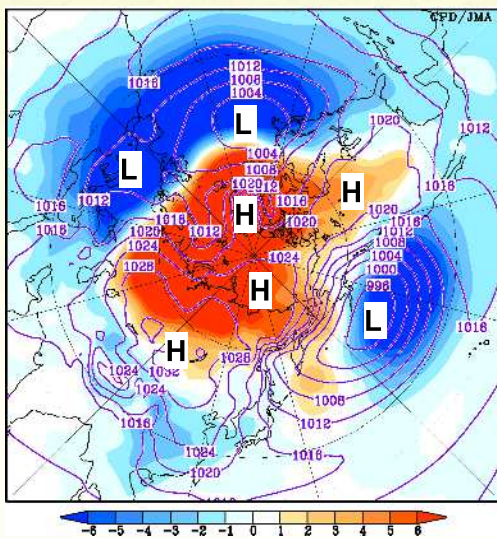
Extremely Negative Arctic Oscillation



AO index
Winter EOF1 index

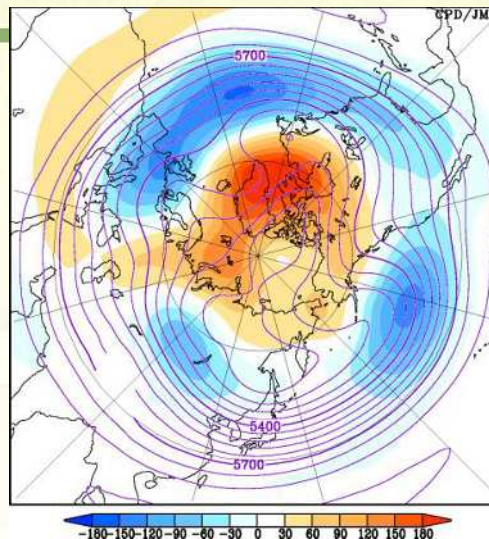
2009/2010 = -3.1
The lowest record!

Time Series of the AO and the Winter EOF1 indices



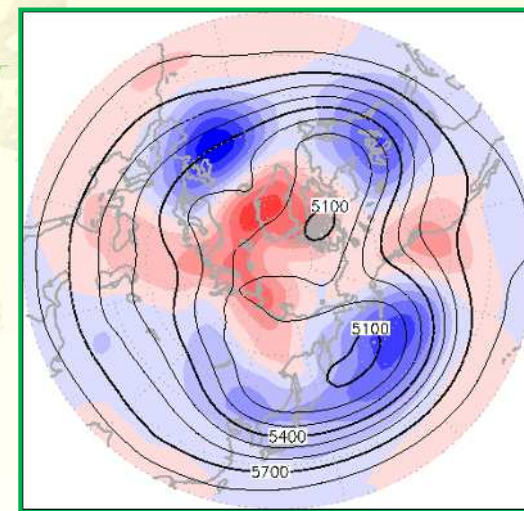
SLP (DJF 2009/2010)

6-8 Apr. 2010



Z500 (DJF 2009/2010)

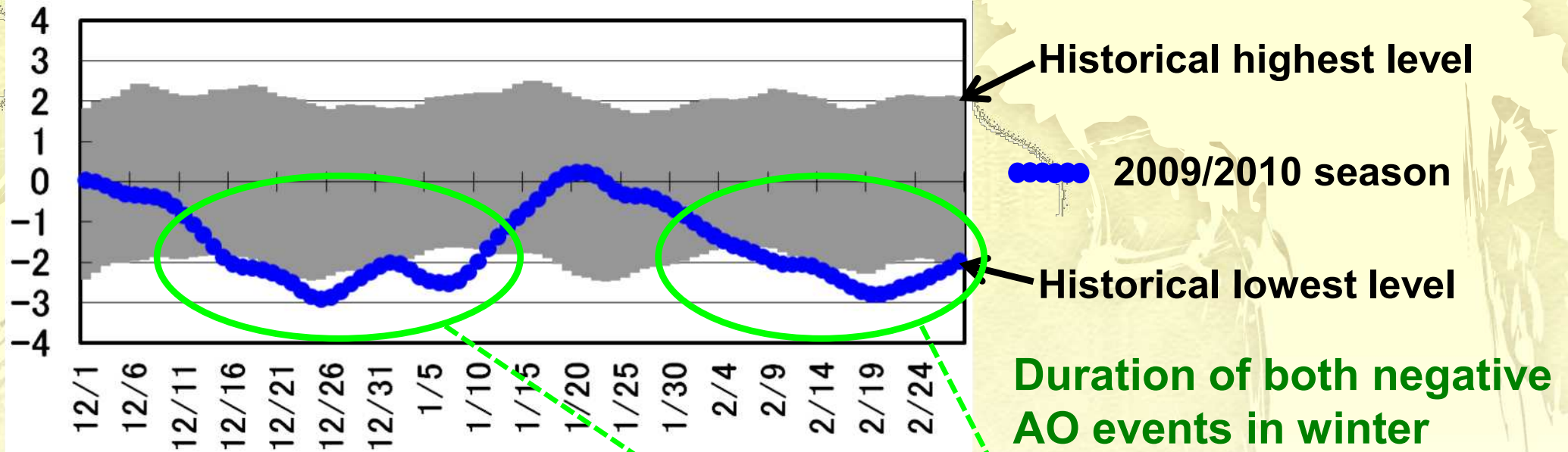
6th FOCRAII in Beijing



Z500 (DJF 1976/1977)

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Double Dip of Strong and Long-life Negative AO



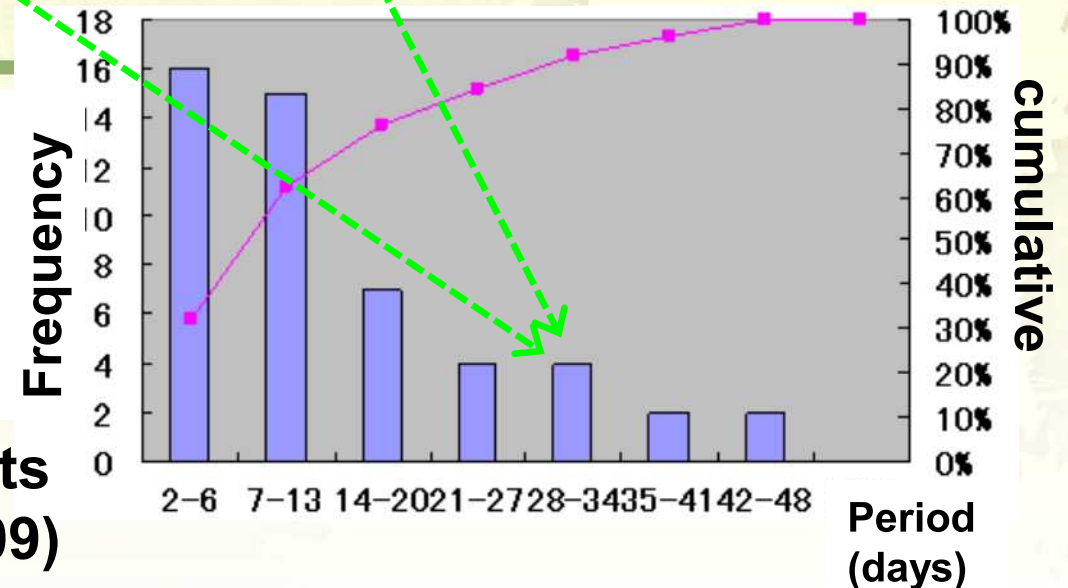
7-day running mean Daily AO index in winter

Duration of both negative AO events in winter 2009/2010 is 33 days

AO event is defined by the threshold ± 0.5 in 7-day running mean daily AO index

Frequency
cumulative

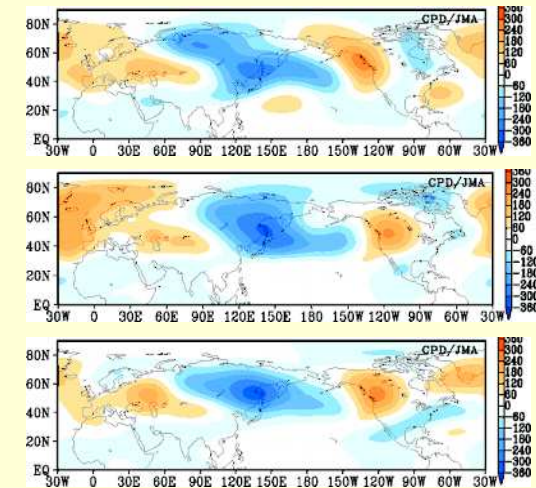
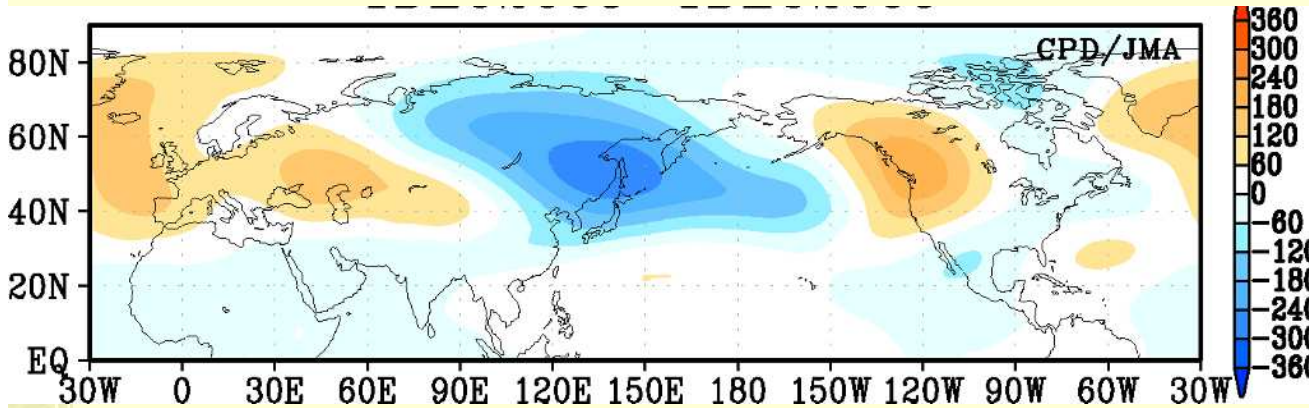
Histogram for Length of AO events (1979-2009)



The background of the slide is a light green map of China. A thick, solid green horizontal line is drawn across the middle of the map, passing behind the title text.

Maintenance Mechanism and External influences

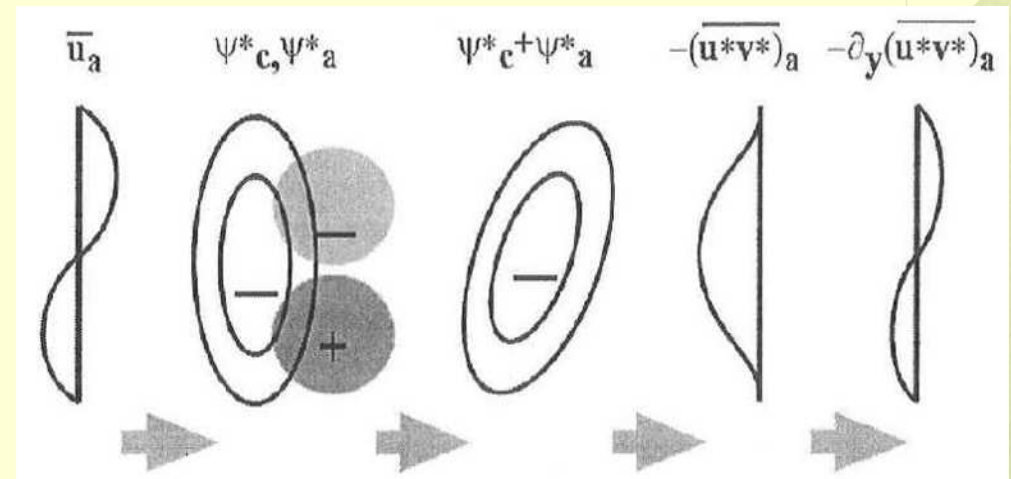
Positive Feedback between Jet and Eddies in maintenance of negative AO



Suppose first a dipolar zonal wind anomaly.

This gives a meridional tilt of the wave, which give rise to a southward zonal momentum flux centered at the nodal latitude.

Then, the divergence of this flux gives a zonal flow acceleration that projects positively to the original zonal flow anomaly.

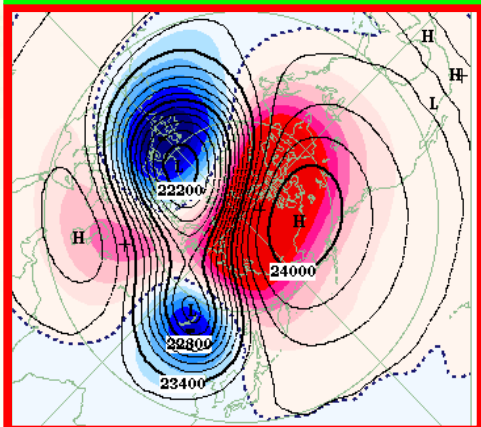
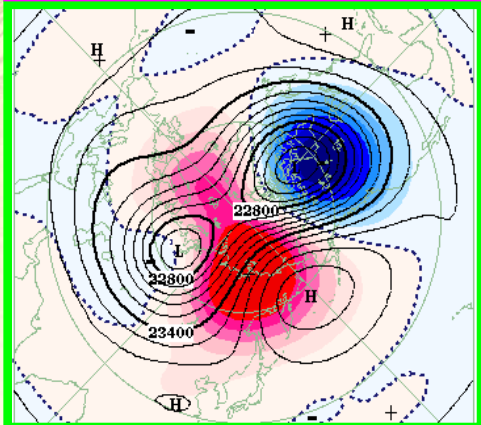
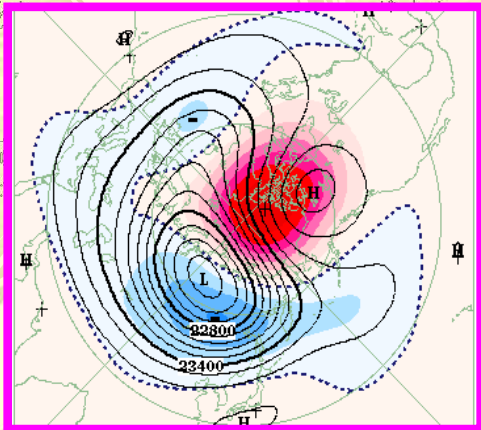


**Tilted Trough Mechanism
(Kimoto et. al, 2001)**

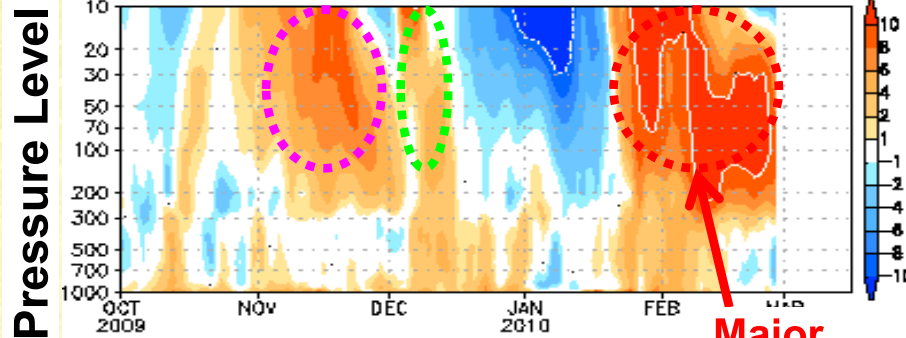
Stratospheric Sudden Warming and Negative Arctic Oscillation

Z30 & anomalies

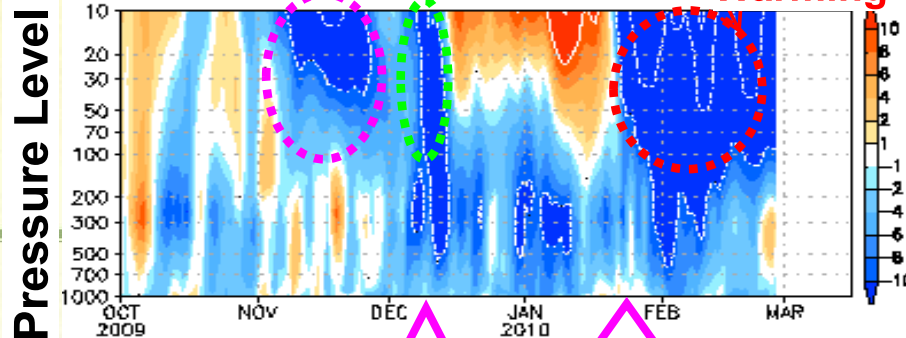
Canadian Warming
Minor Warming



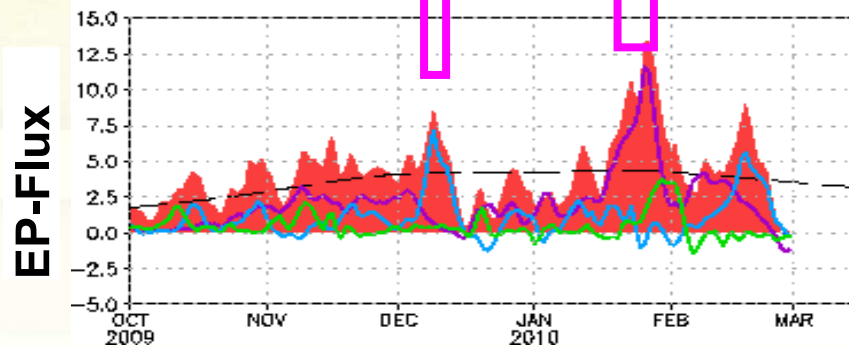
6-8 Apr. 2010



Temperature anomalies averaged 75-90°N



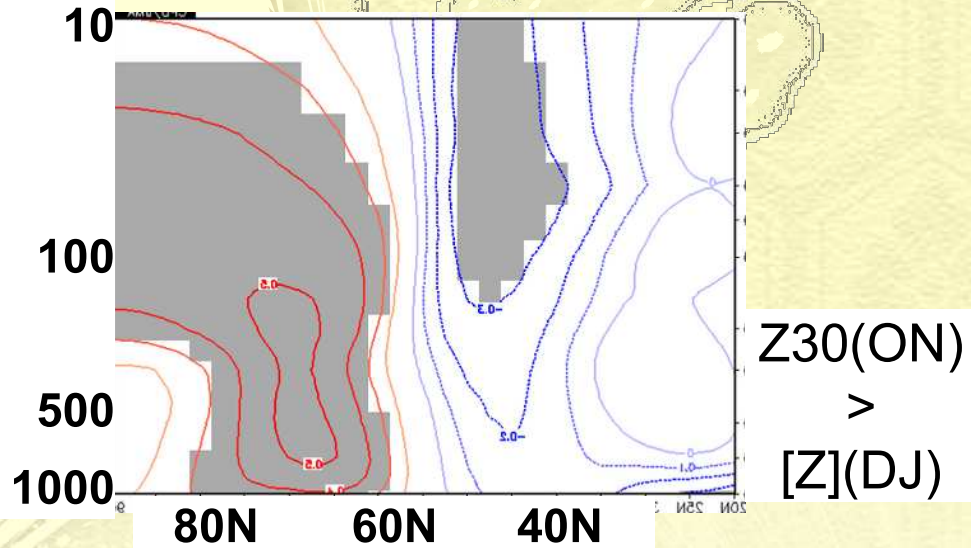
Zonal Wind anomalies at 60°N



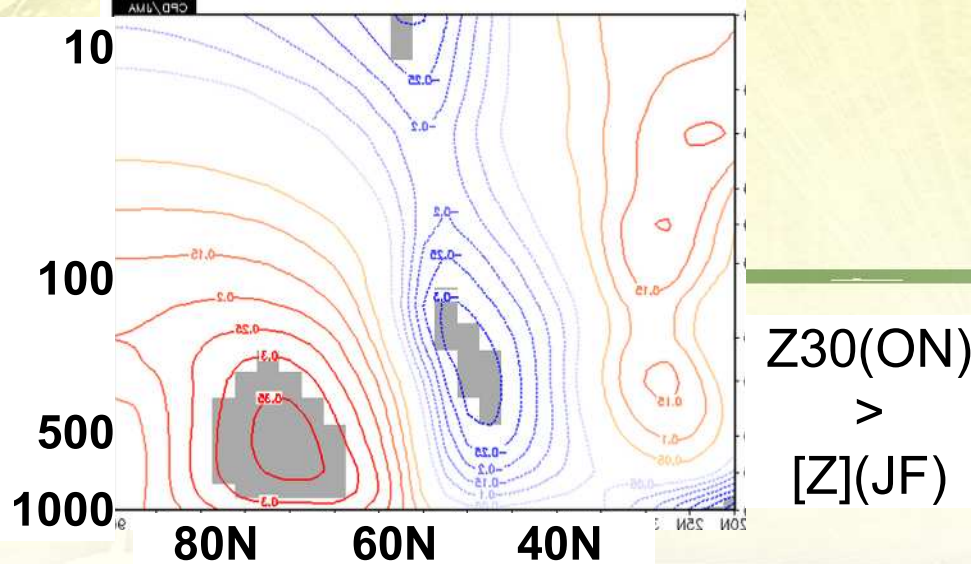
Upward EP-Flux averaged 30-90°N

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Lag Relationship of Negative AO to SSW

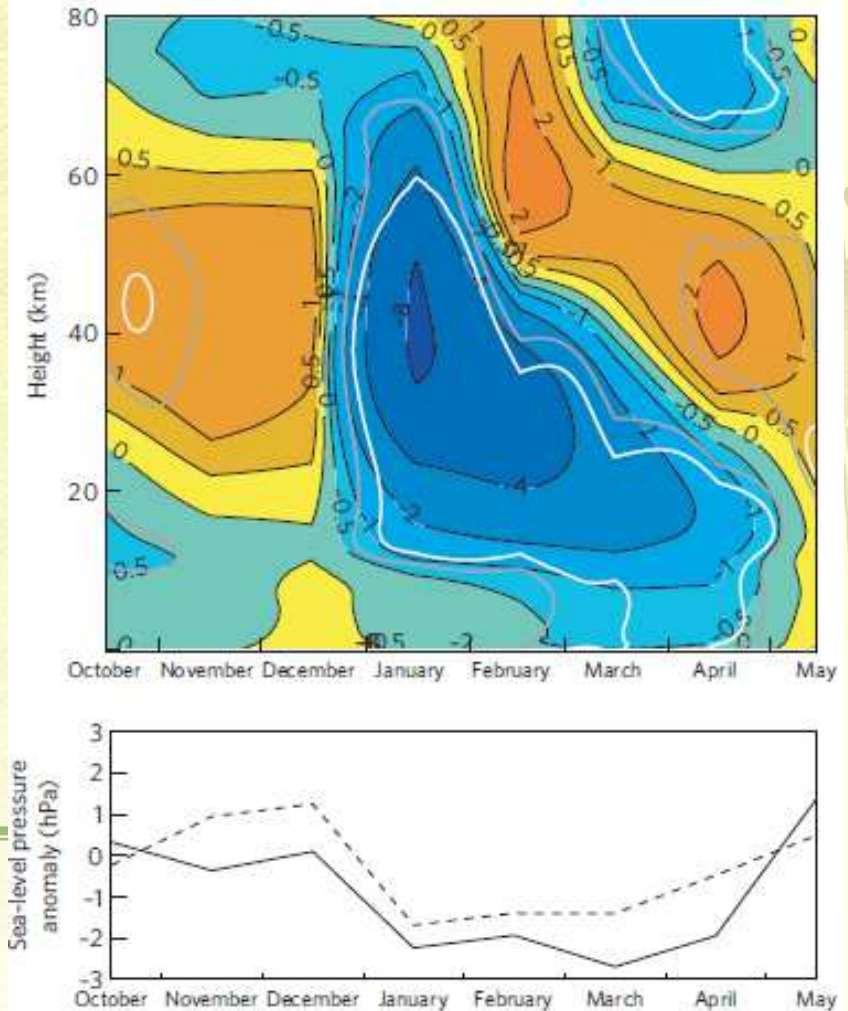


Z30(ON)
>
[Z](DJ)



Z30(ON)
>
[Z](JF)

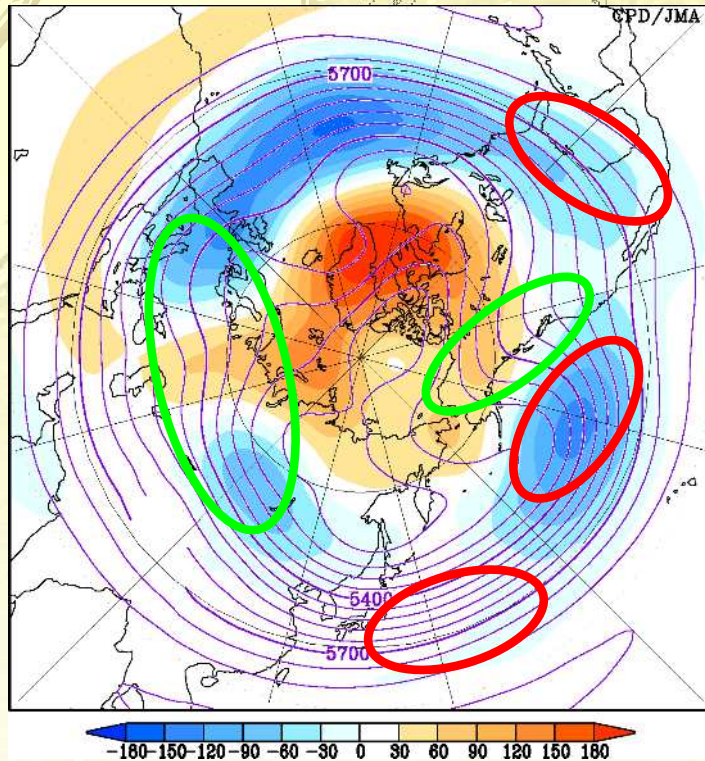
Lag correlation coefficients of zonal averaged height to 30-hPa height over the Arctic region



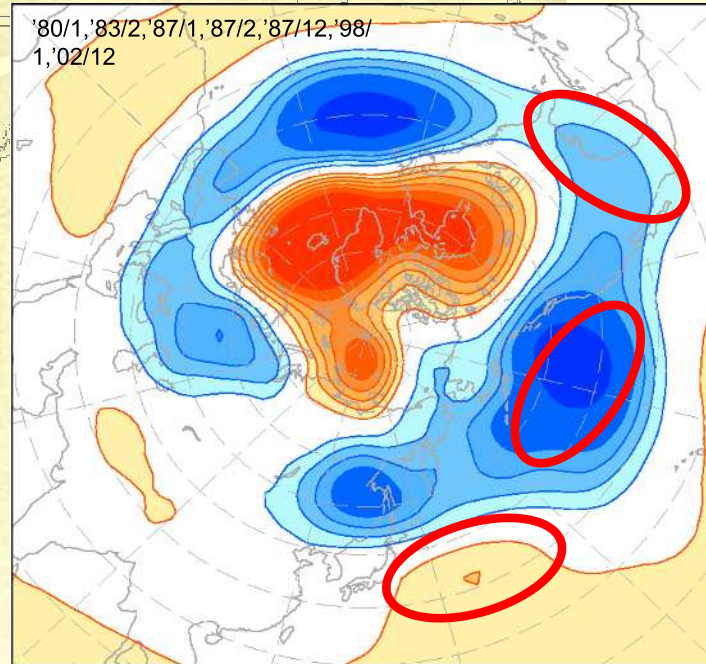
Downward progression of El Niño climate signal (Ineson and Scaife, 2008)

Upper: Model composite zonal wind anomaly at 60N
Bottom: SLP anomaly difference between the mid-latitude and the Arctic region

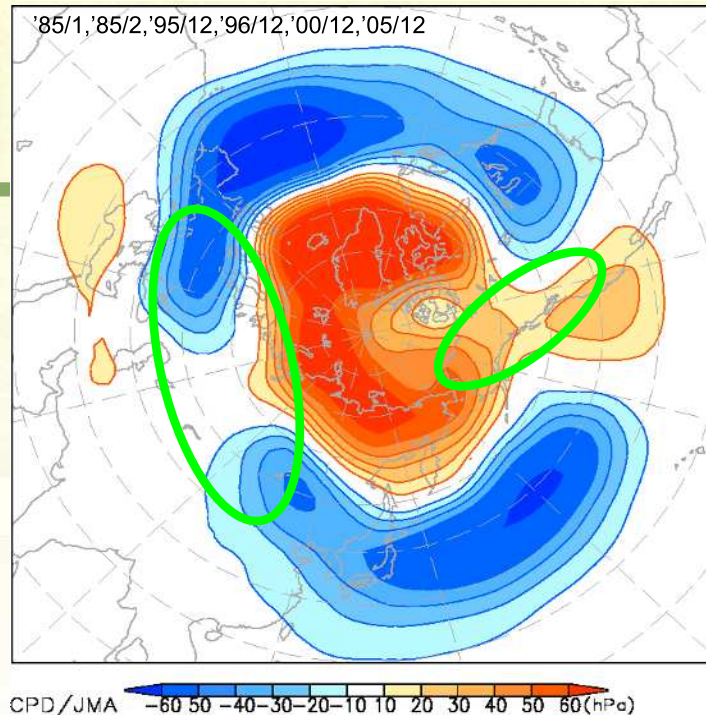
Negative AO and El Niño/La Niña



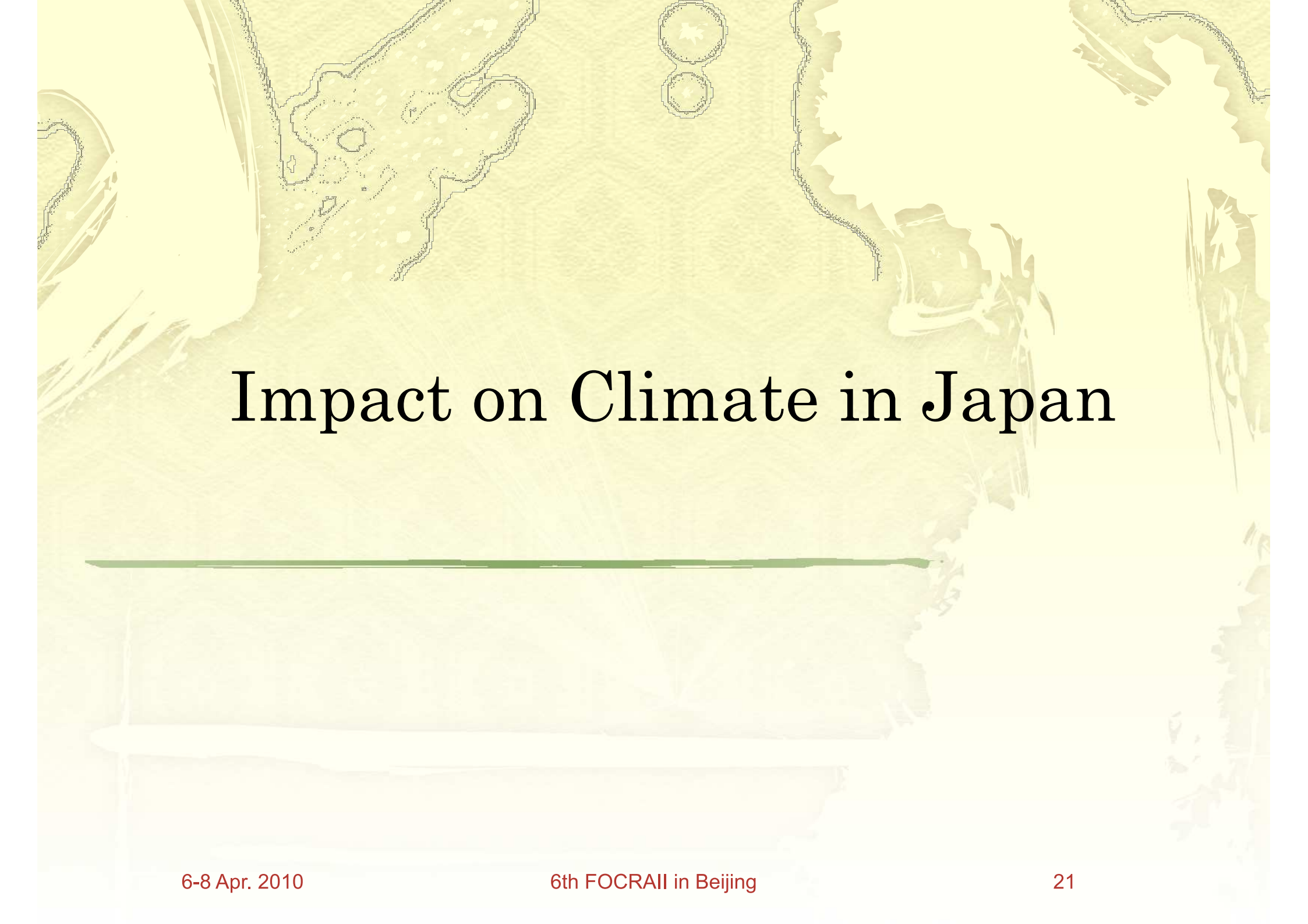
**Z500 & anomalies
(DJF 2009/2010)**



Composite map of Z500 anomalies in case of both AO- and El Niño



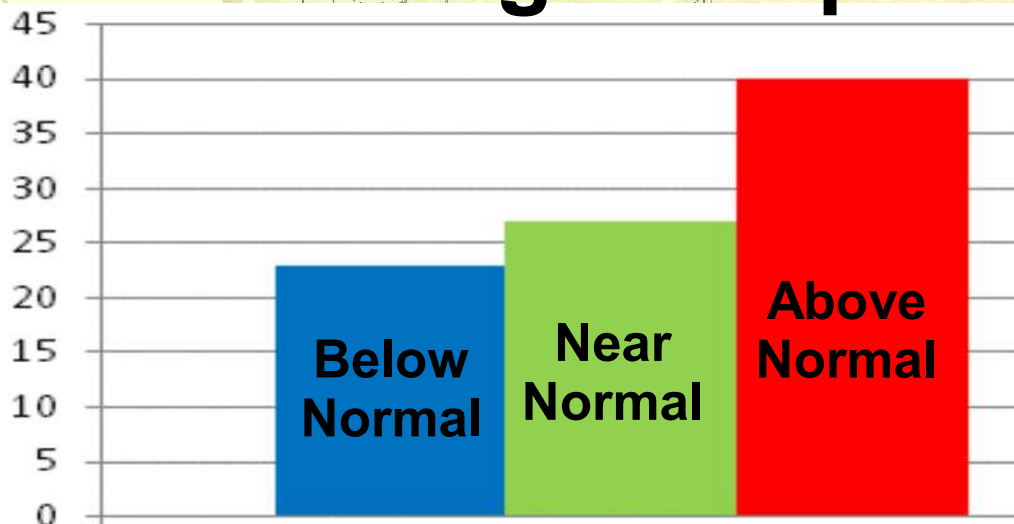
Composite map of Z500 anomalies in case of both AO- and La Niña

The background of the slide is a light yellow-green color with a faint, stylized map of Japan. A pair of glasses is superimposed on the map, with the lenses positioned over the main islands. The title "Impact on Climate in Japan" is centered in a black serif font.

Impact on Climate in Japan

Generally Warm Winter in Japan, but Large Temperature Fluctuation

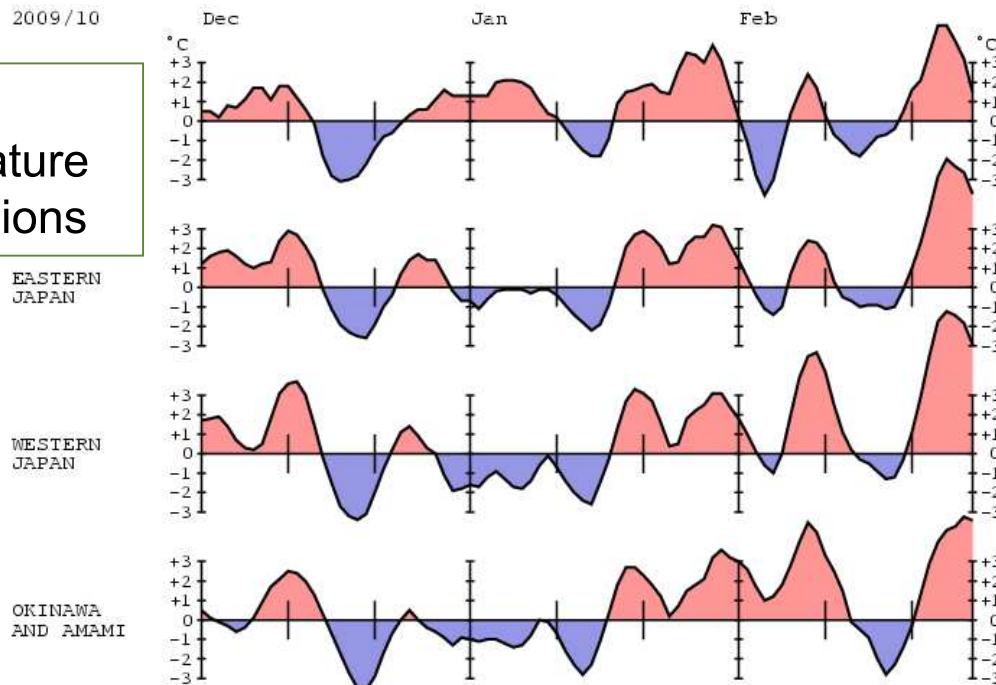
Occurrence Probability



Histogram for Categories of Daily Mean Temperature at Tokyo in Winter 2009/2010

Time series of 5-day running mean temperature anomalies for subdivisions

2009/10



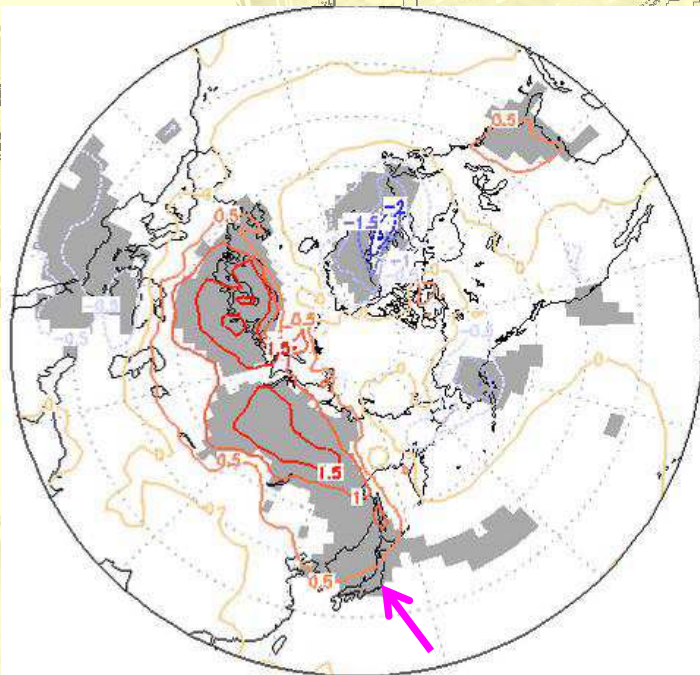
Northern Japan

Eastern Japan

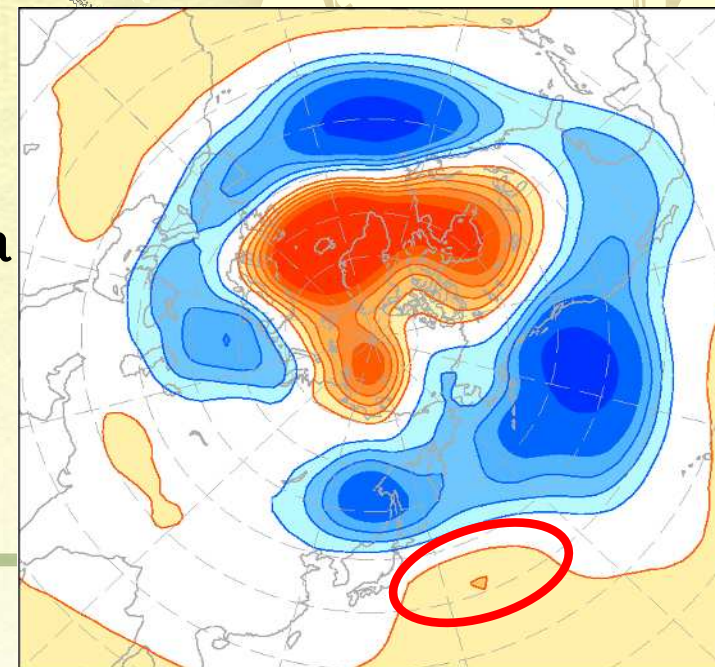
Western Japan

Okinawa/Amami

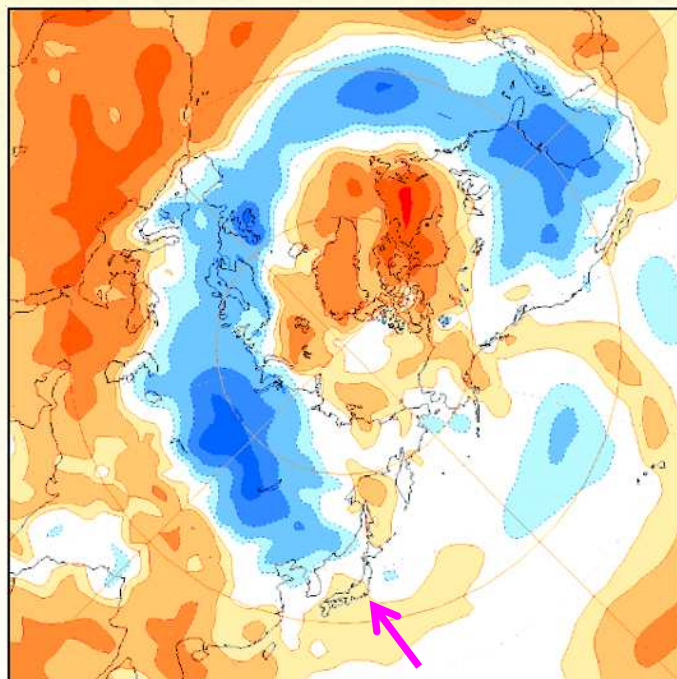
El Niño rescued Japan from Severe Winter by AO-



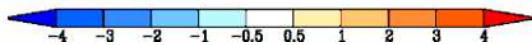
Regression map of surface temperature in case of AO- (95% Significant area is filled with gray shade)



Composite map of Z500 anomalies in case of both AO- and El Niño



Seasonal mean Standardized surface temperature in DJF 2009/2010

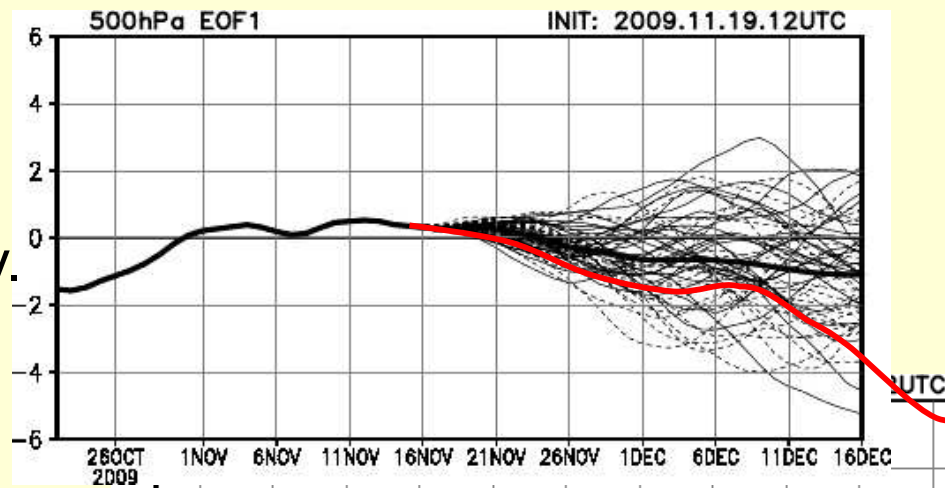


The background of the slide is a light green map of China. A thick, solid green horizontal line is drawn across the middle of the map, passing behind the title. The map shows the outline of the country and some internal regional boundaries.

Forecast Verification

One month forecast for a development of the first AO- event

Initial
19 Nov.



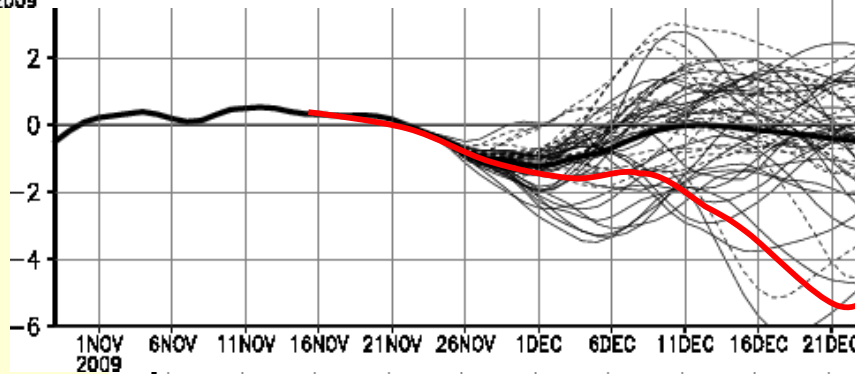
The score of EOF1

Red Line : Analysis

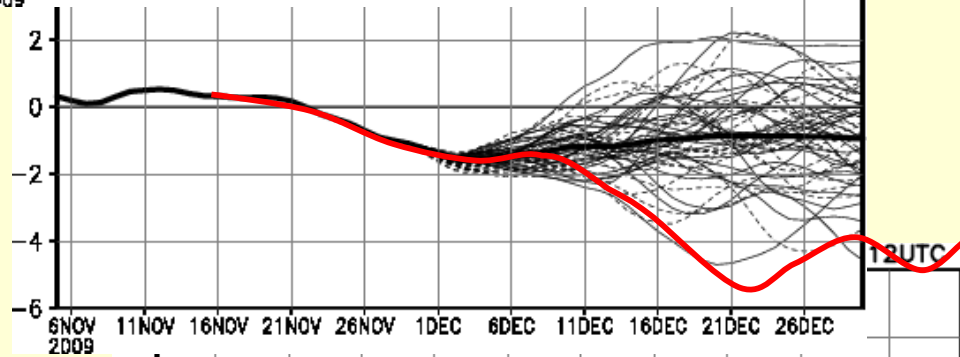
Thick Line : Ensemble mean

Thin Line : Each member

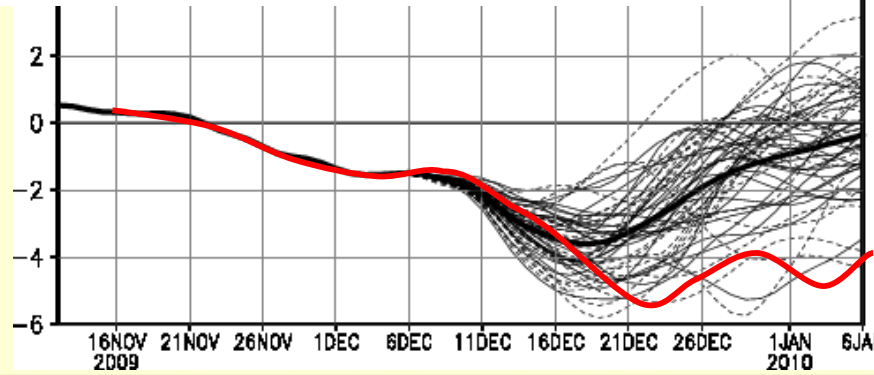
Initial
26 Nov.



Initial
3 Dec.

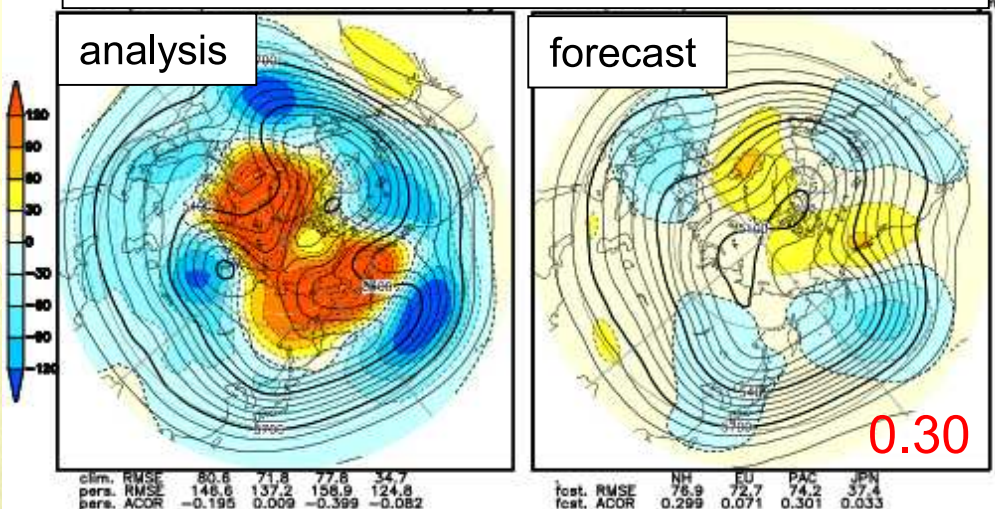


Initial
10 Dec.

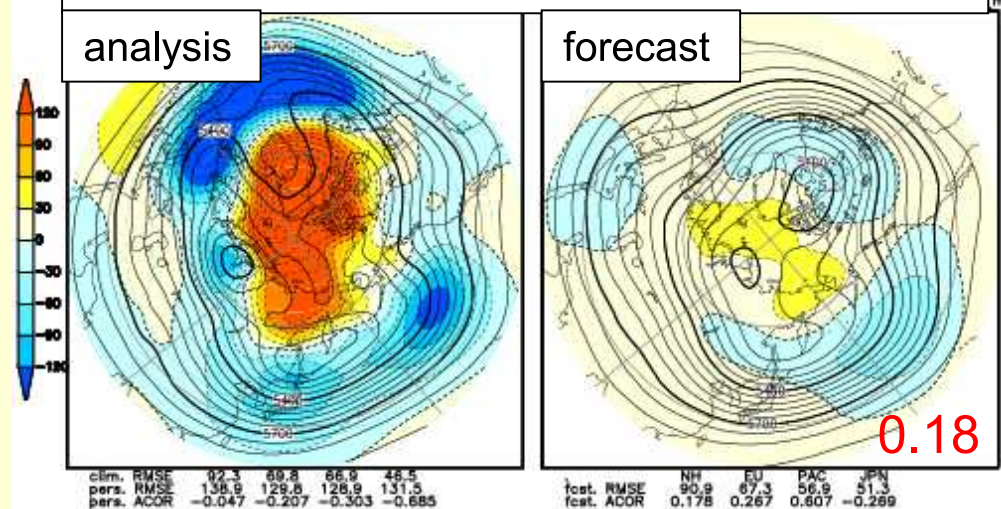


Two weeks lead forecast of the first AO- event

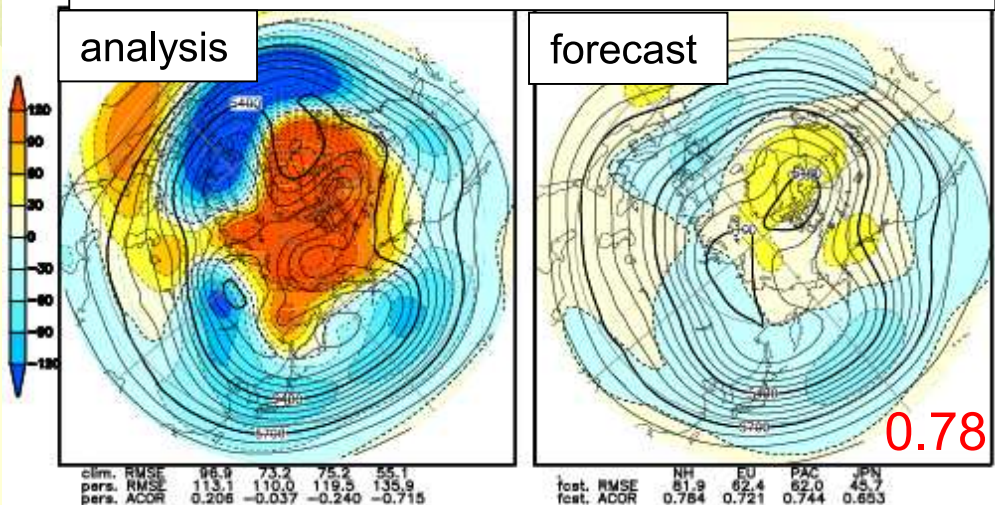
Initial 19 Nov. Valid 5 Dec. – 18 Dec.



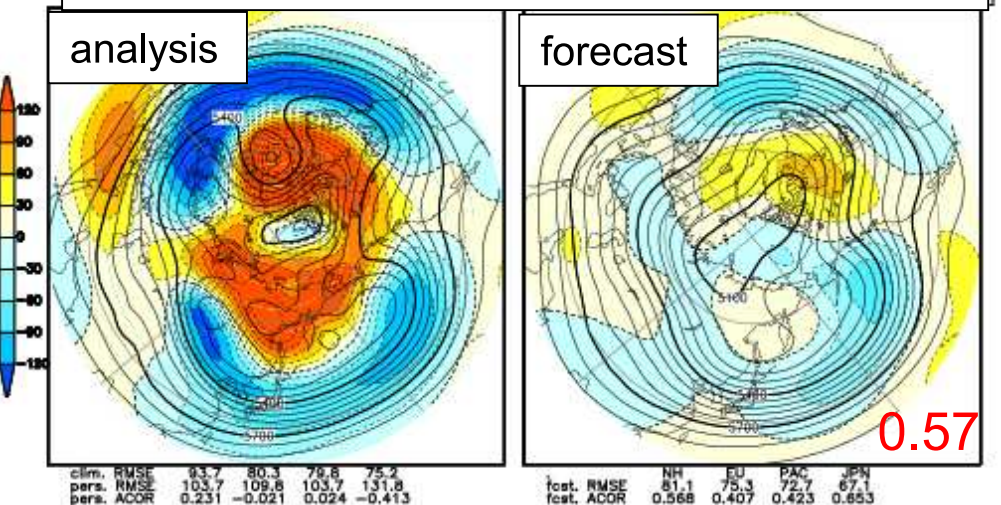
Initial 26 Nov. Valid 12 Dec. – 25 Dec.



Initial 3 Dec. Valid 17 Dec. – 1 Jan.



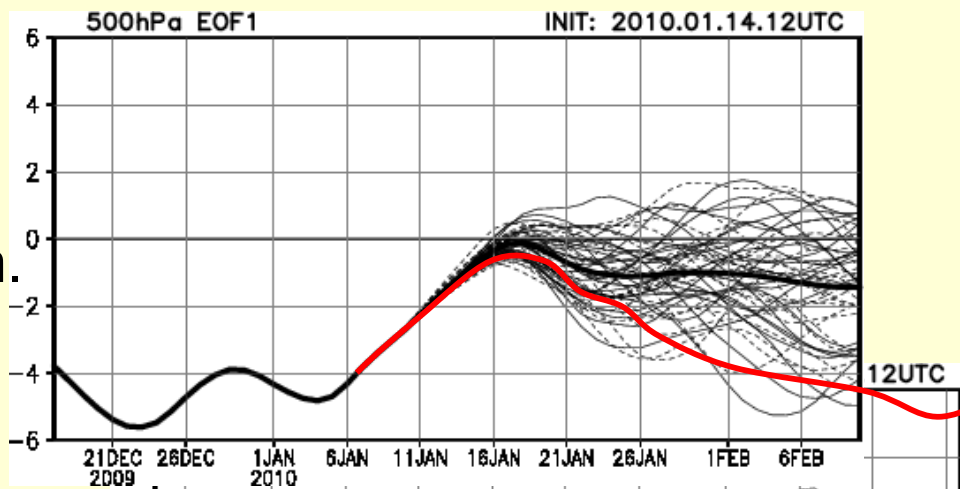
Initial 10 Dec. Valid 26 Dec. – 8 Jan.



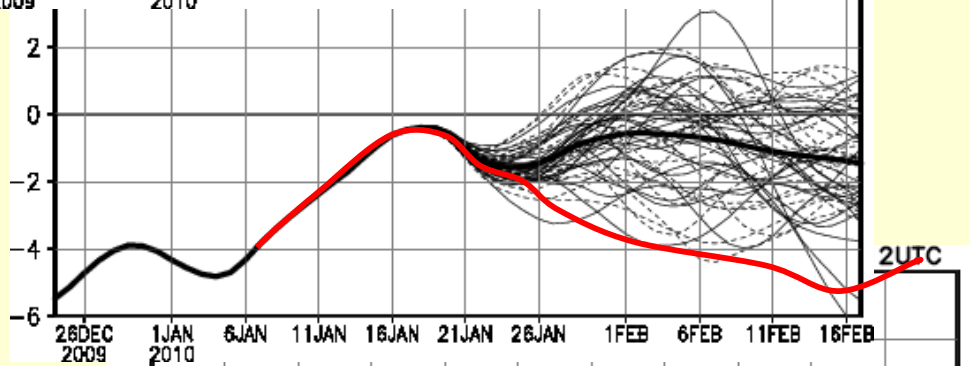
Red number is an anomaly correlation coefficient at 500 hPa geopotential height

Forecast for a development of the second AO- event

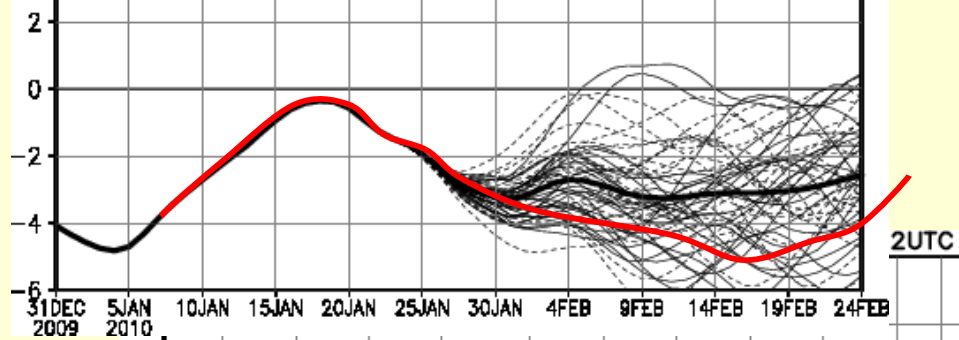
Initial
14 Jan.



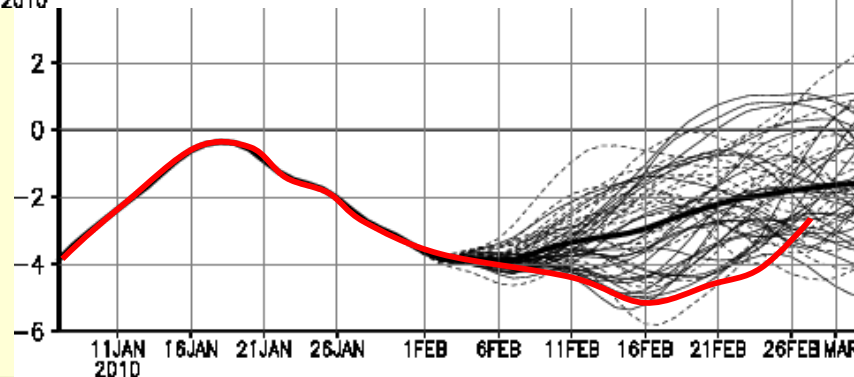
Initial
21 Jan.



Initial
28 Jan.



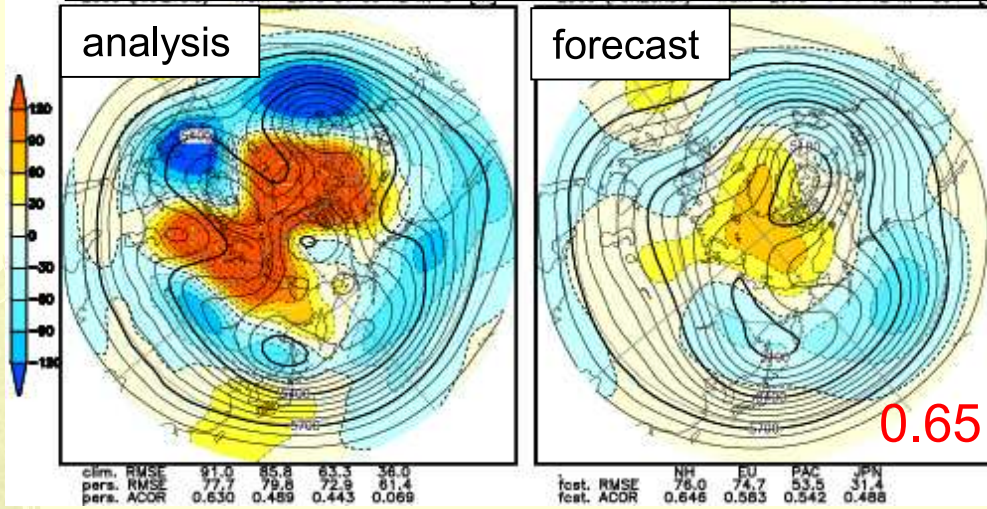
Initial
4 Feb.



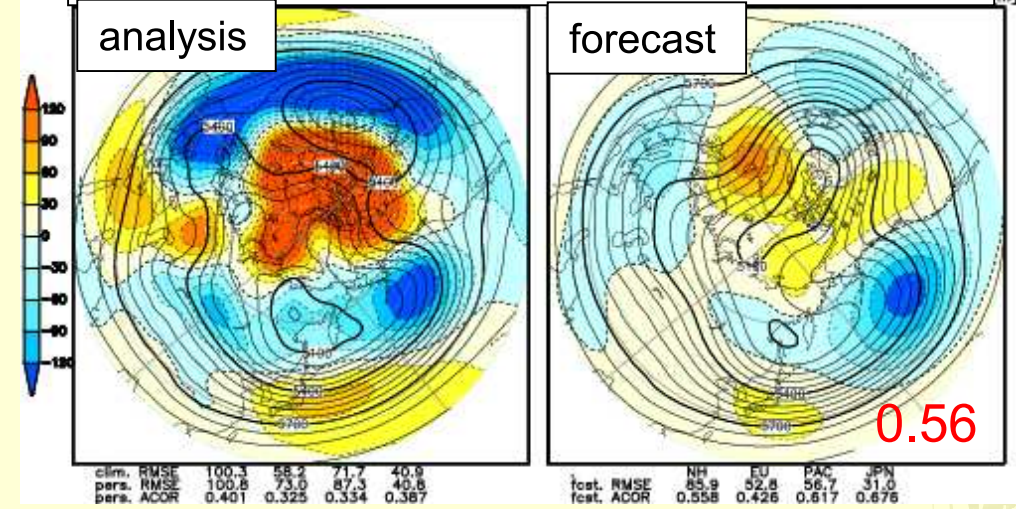
The score of EOF1
Red Line : Analysis
Thick Line : Ensemble mean
Thin Line : Each member

Two weeks lead forecast of the second AO- event

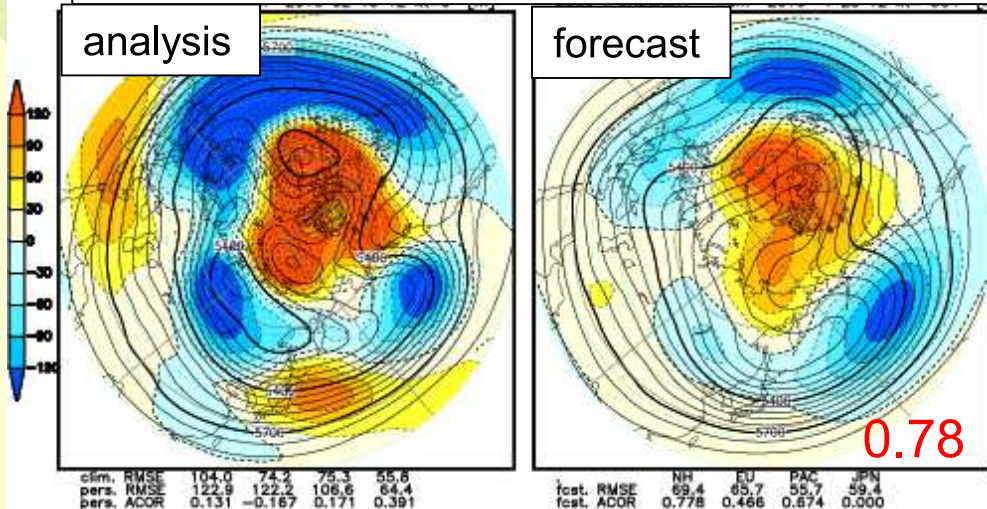
Initial 14 Jan. Valid 30 Jan. – 12 Feb.



Initial 21 Jan. Valid 6 Feb. – 19 Feb.



Initial 28 Jan. Valid 13 Feb. – 26 Feb.

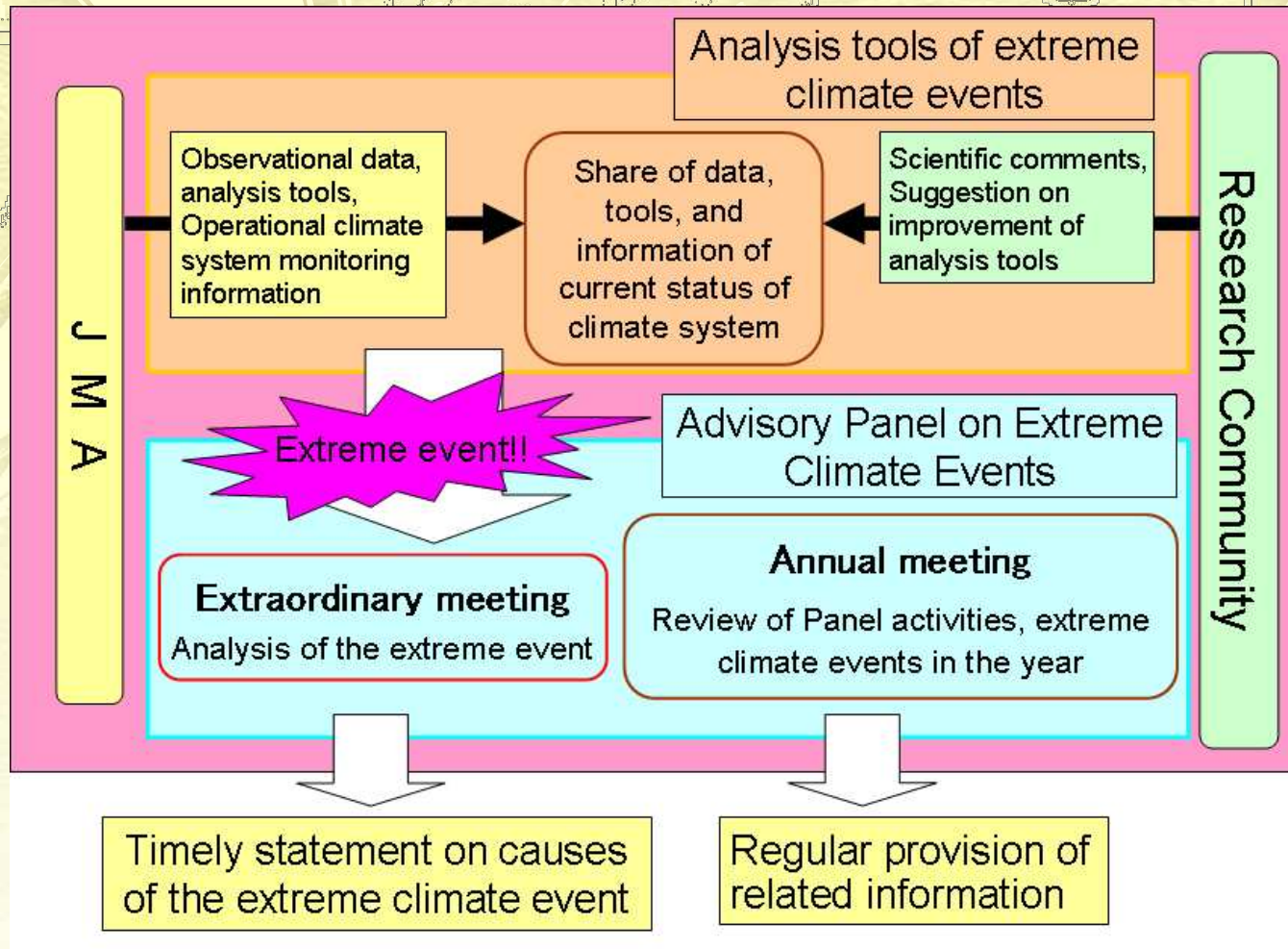


Red number is an anomaly correlation coefficient

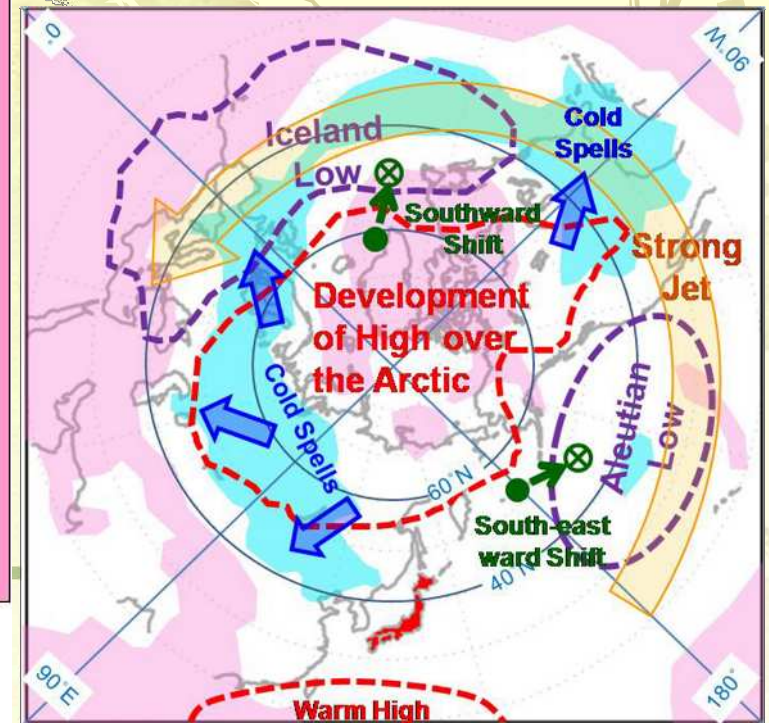
The background of the slide is a light green map of China. A thick, solid green horizontal line runs across the lower portion of the map, positioned below the main title. The map shows the outline of China and some internal regional boundaries.

Advisory Panel on Extreme Climate Events

Advisory Panel on Extreme Climate Events



Flow of analysis in Advisory Panel on Extreme Climate Events



Schematic Chart describing for the causes of winter 2009/2010 issued by the Panel

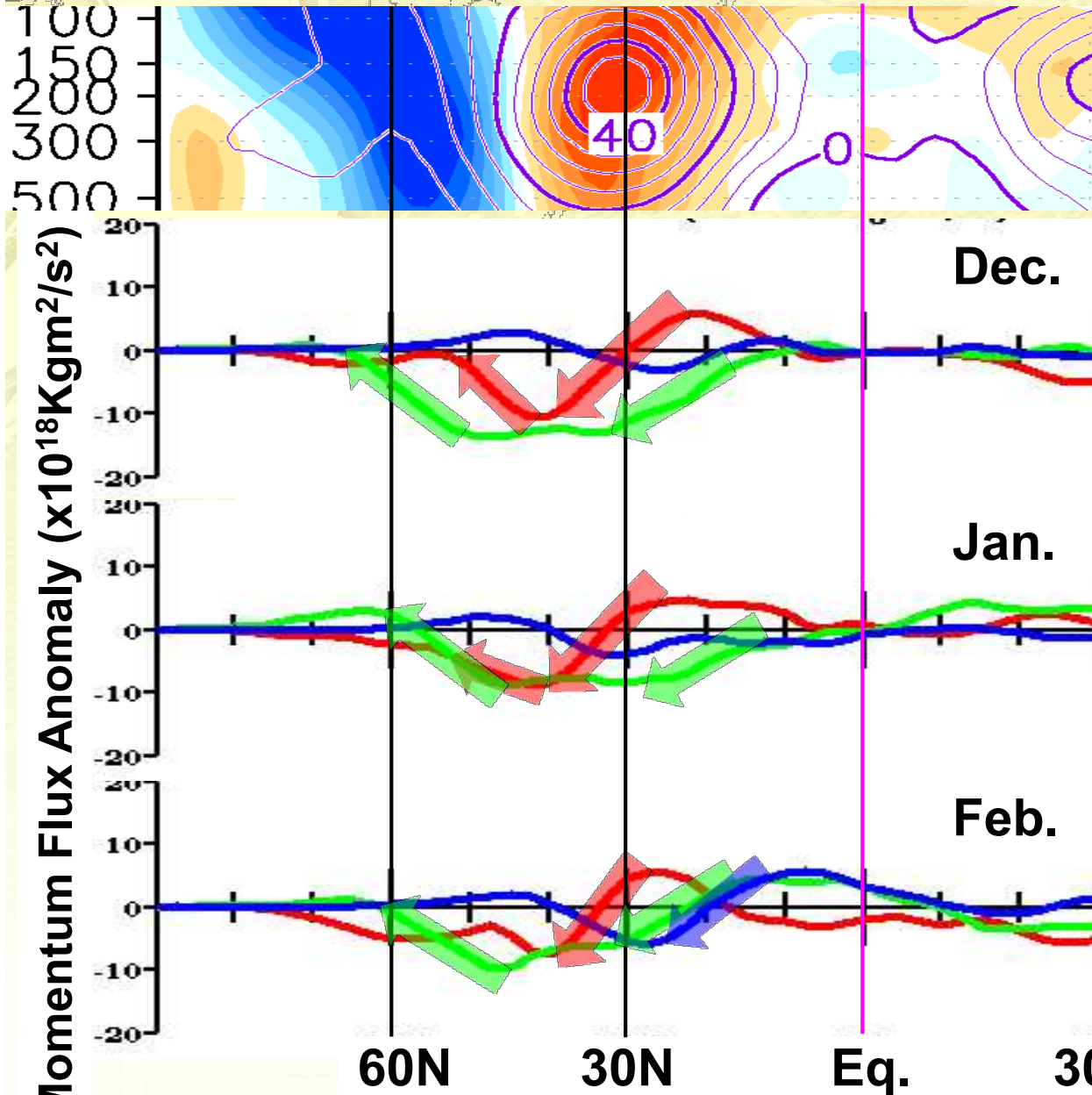


NHK (TV news) 2010/3/3

The background of the slide is a light yellow-green color with a faint, stylized map of China. A pair of glasses is superimposed on the map, with the lenses positioned over the central part of the country. The text "Thank You" is centered on the slide in a large, black, serif font.

Thank You

Contribution of Eddies to Sharp and Strong Jet

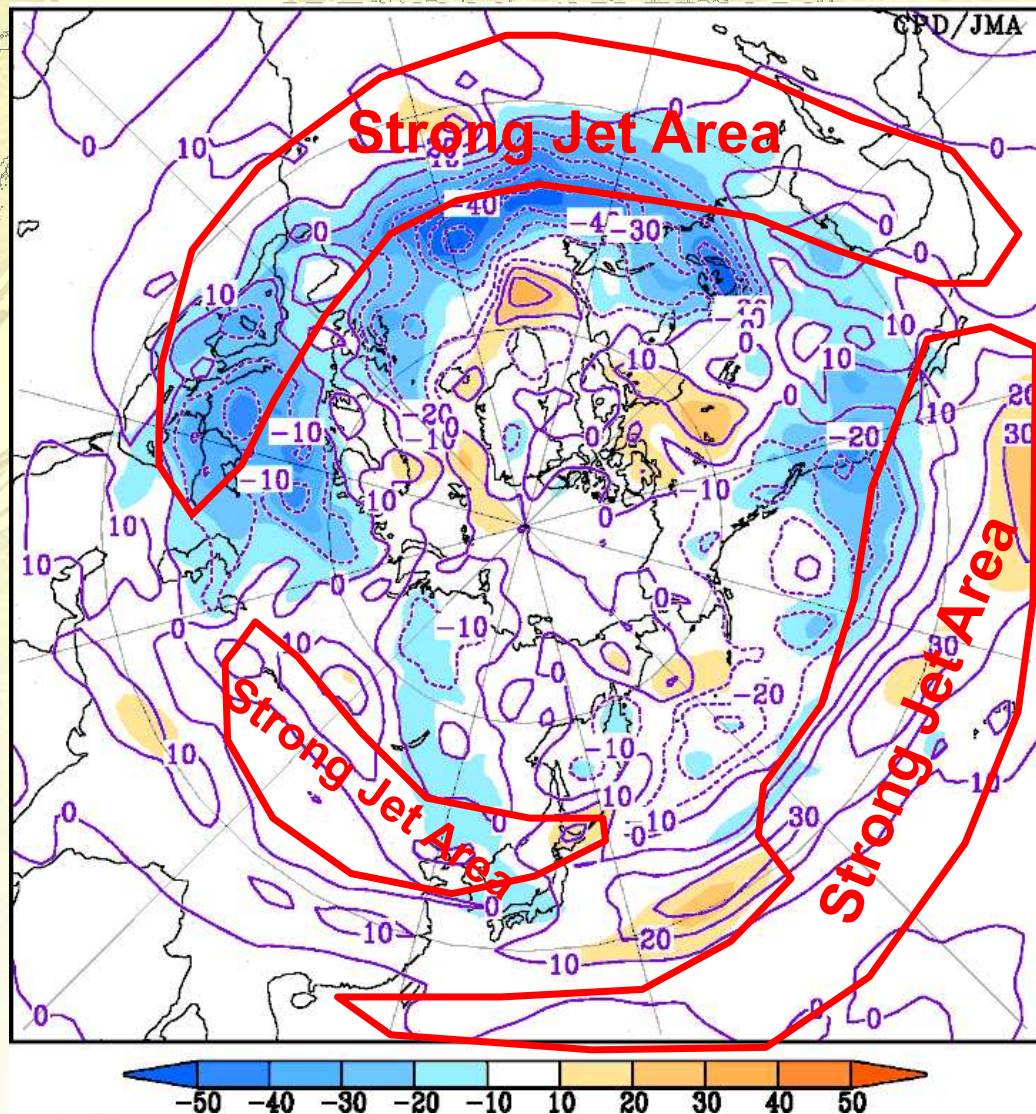


Seasonal Mean Zonal
Averaged Zonal Wind and
Anomaly (DJF 2009/2010)

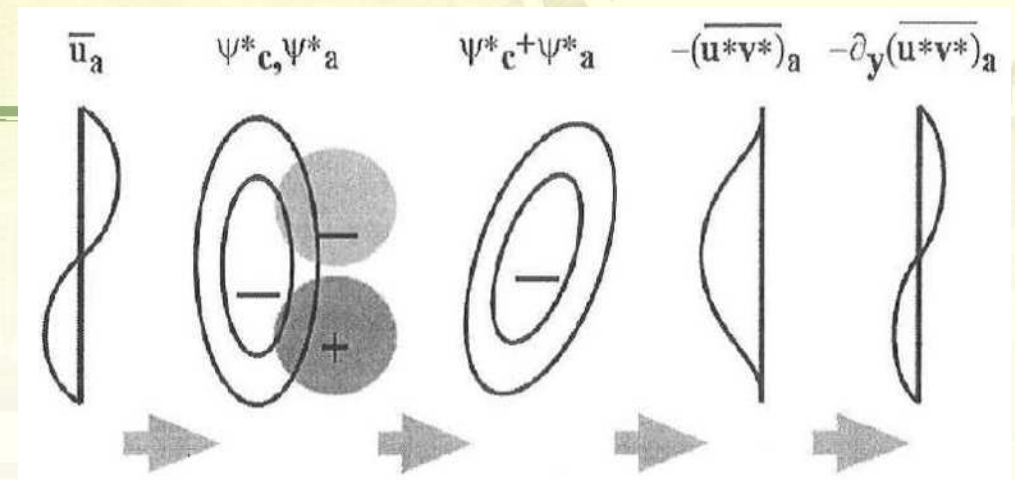
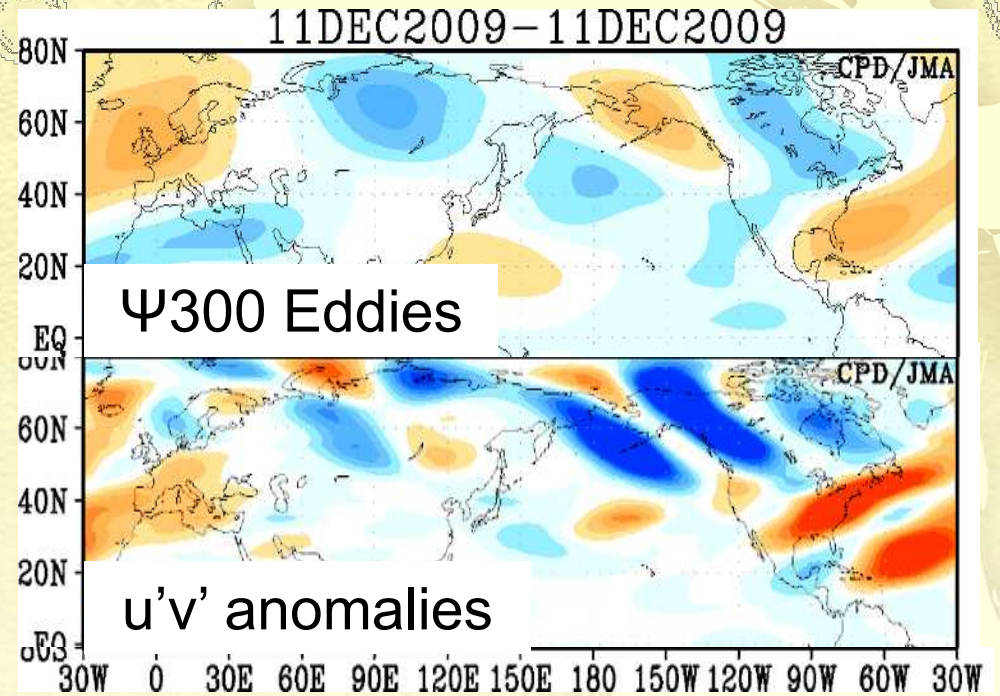
Northward Flux anomaly
of Horizontal Momentum
in the upper troposphere

- Momentum flux by Transient eddies
- Momentum flux by Stationary eddies
- Momentum flux by Mean meridional circulation
- ↙ ↙ ↙ Acceleration of Westerlies
- ↘ ↘ ↘ deceleration of Westerlies

Positive Feedback between Jet and Eddies



Momentum Flux by High-frequency Variation ($u'v'$) and anomaly at 300hPa

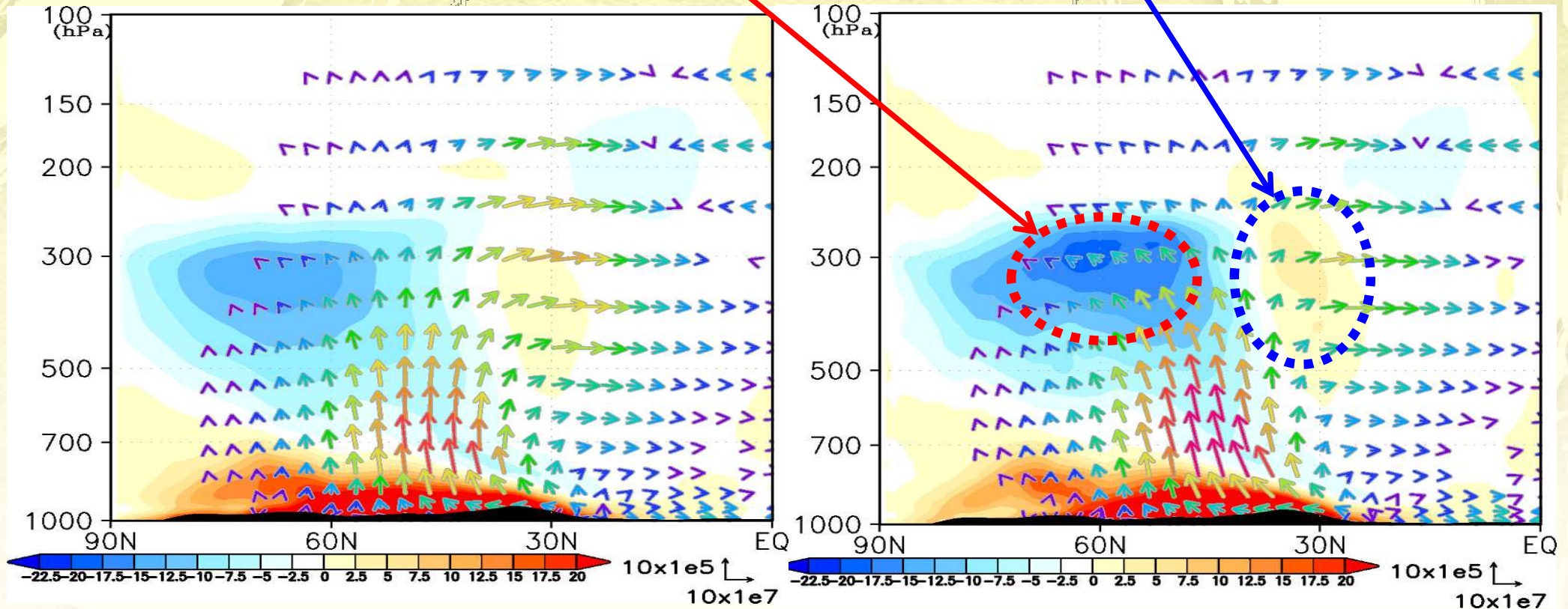


Tilted Trough Mechanism (Kimoto et. al, 2001)

Activities of Eddies in a view of EP-Flux

Strong EP-Flux convergence
means deceleration of westerlies

Strong EP-Flux divergence
means acceleration of westerlies

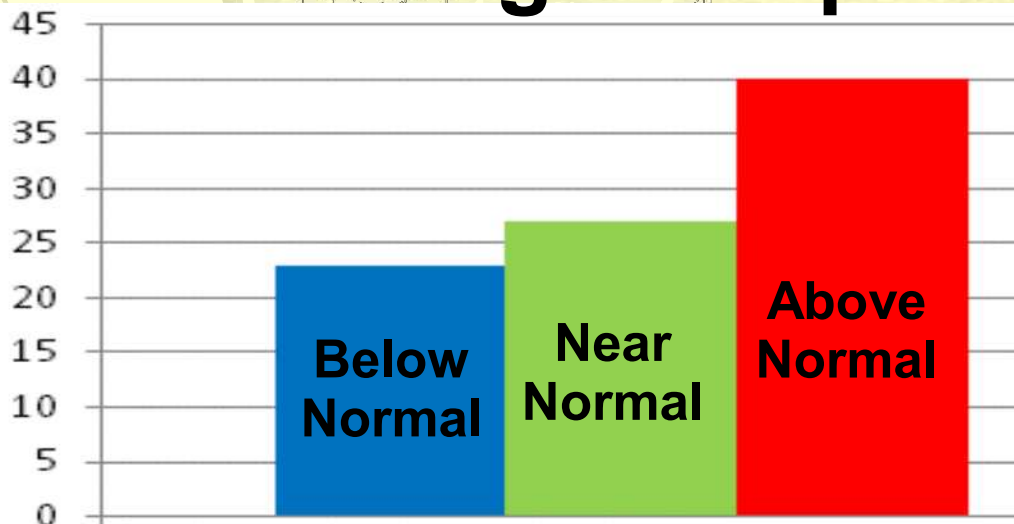


**EP-Flux and divergence
(DJF Normal : 1979-2004)**

**EP-Flux and divergence
(DJF 2009/2010)**

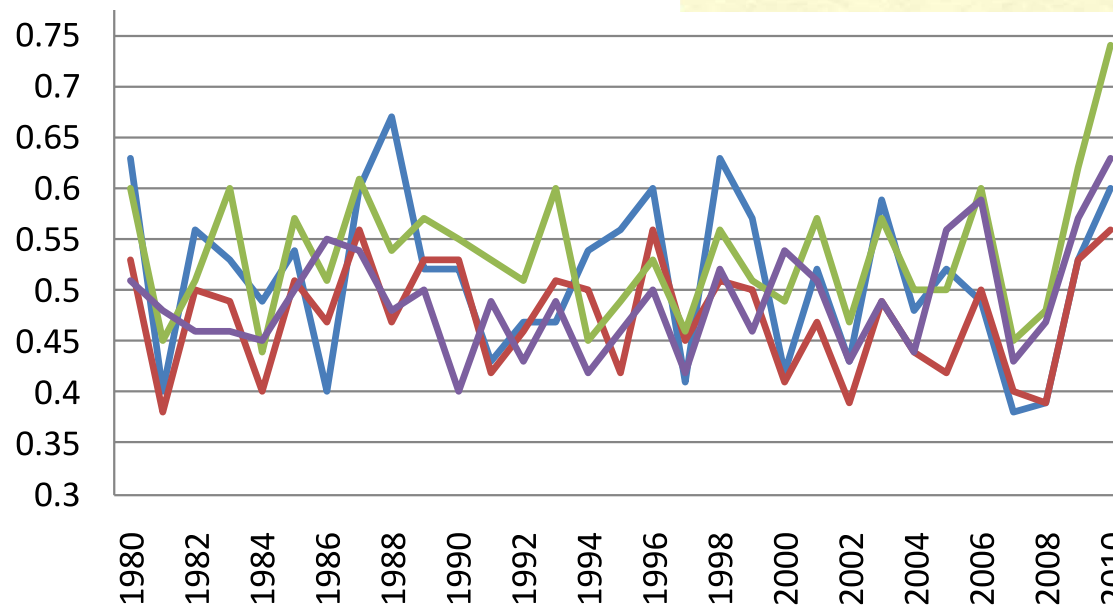
Generally Warm Winter in Japan, but Large Temperature Fluctuation

Occurrence Probability



Histogram for Categories of Daily Mean Temperature at Tokyo in Winter 2009/2010

Seasonal Mean Temperature Difference from before day using 5-day running mean



Seasonal Temperature Fluctuation Index