気象庁
Japan Meteorological Agency

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ENSO and its influence over East Asia

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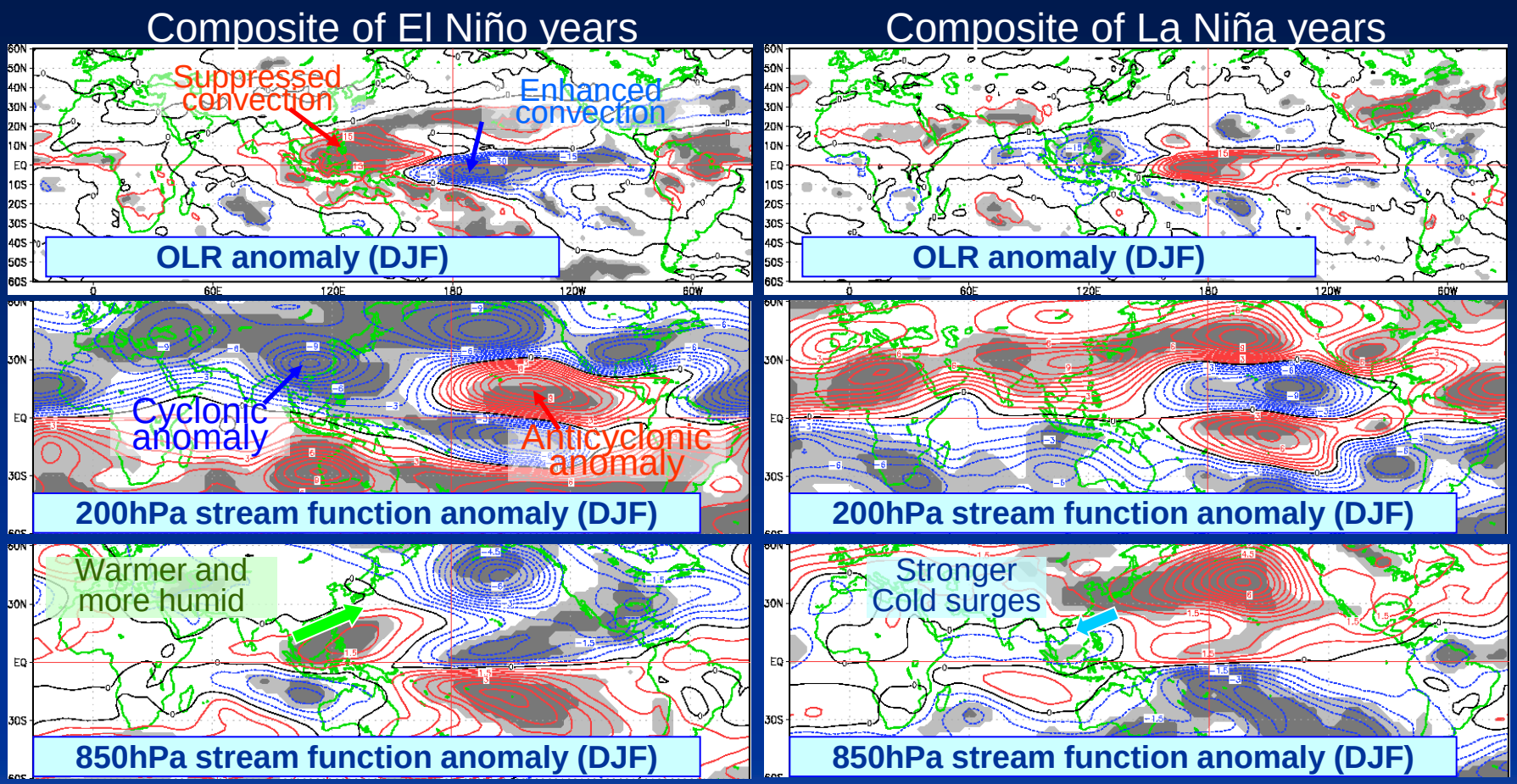
Statistical features of ENSO impact on Asian winter monsoon



El Niño year 82,86,87,91,97,02

La Niña year 84,88,95,98,99,00,05,07

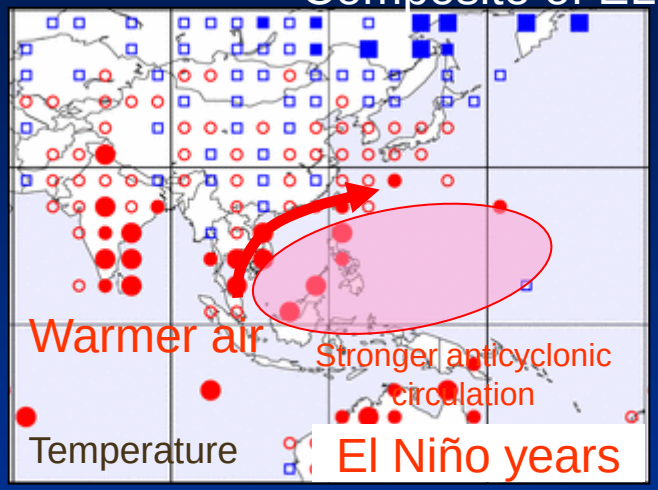
Dark and light shadings show 95% and 90% confidence level based on t-test, respectively.

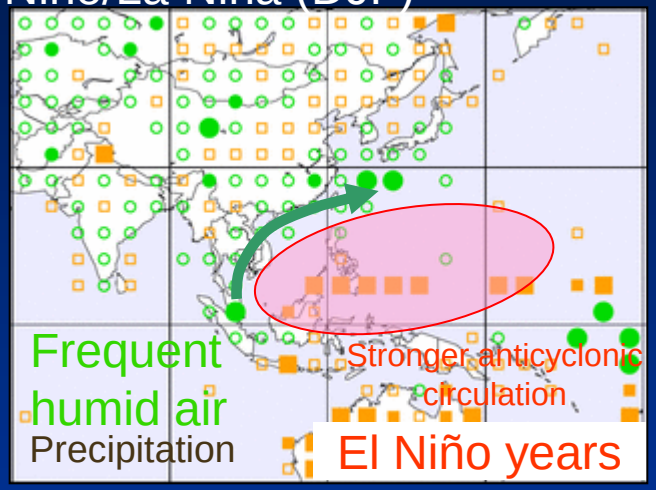
- In the upper troposphere, cyclonic (anticyclonic) anomaly over southern China during El Niño (La Niña).

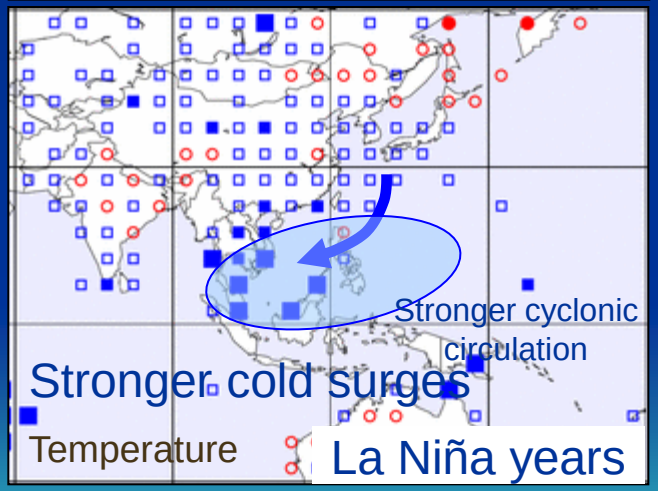
- In the lower troposphere, anticyclonic (cyclonic) anomaly over Southeast Asia during El Niño (La Niña).

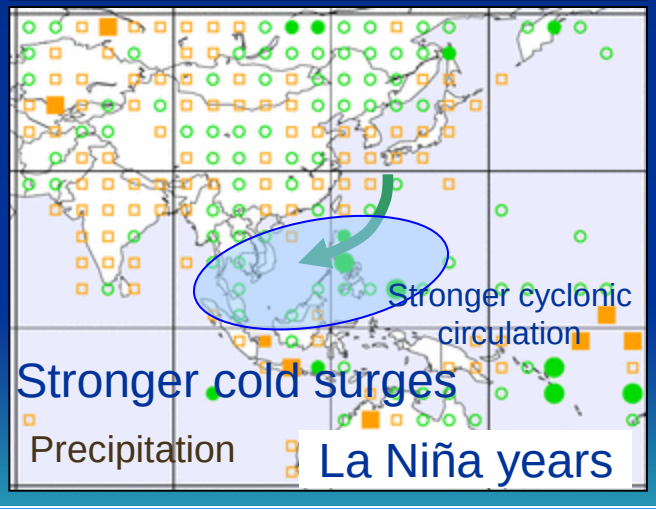
Statistical features of ENSO impact on Asian winter monsoon

Composite of EL Niño/La Niña (DJF)









In El Niño Years:
- Warm in South Asia to southern Japan.
- Dry around Indonesia, wet in eastern China to southern Japan.

El Niño Years: 51, 57, 63, 65, 68, 69, 72, 76, 82, 86, 87, 91, 97, 02

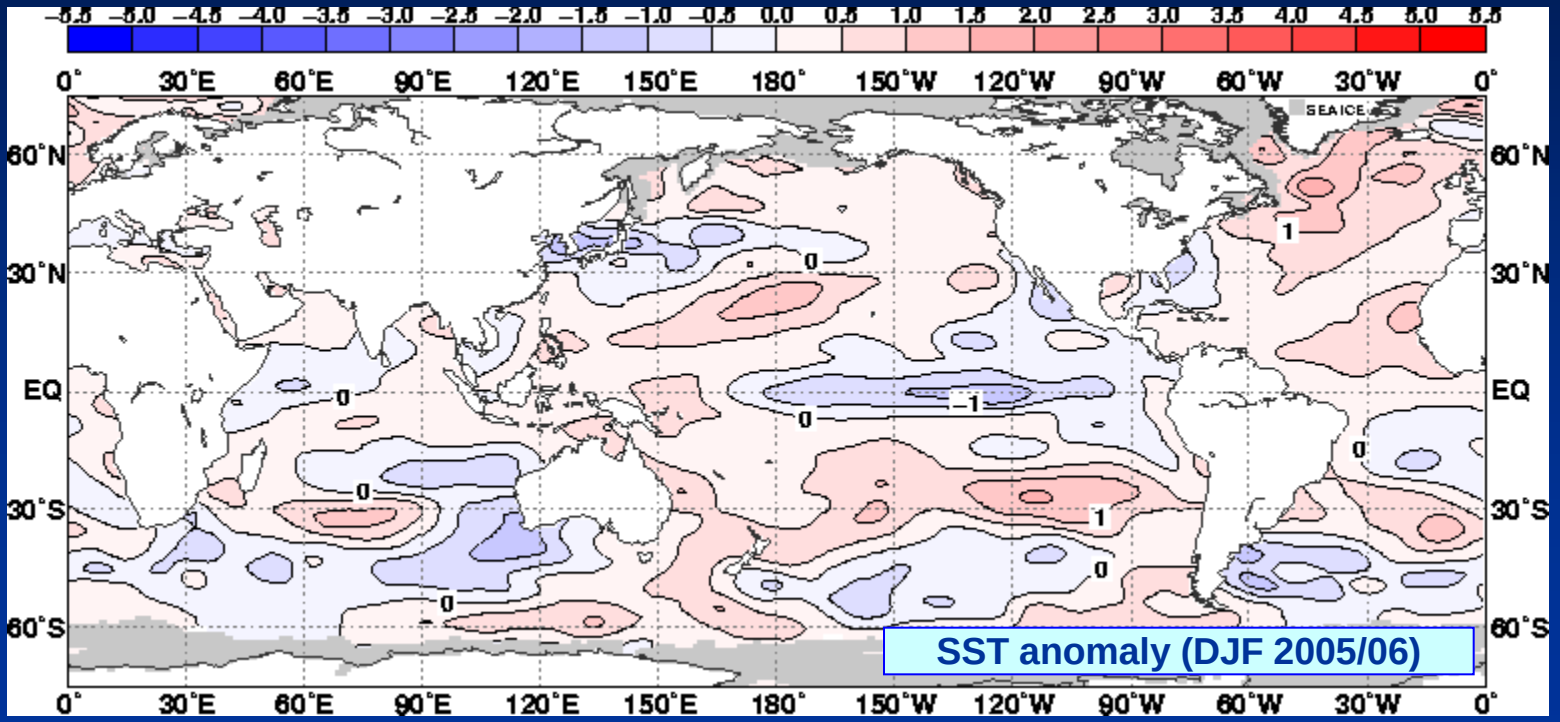
In La Niña Years:
- Cold in Asia, especially Southeast Asia.
- Wet around Southeast Asia.

La Niña Years: 49, 54, 55, 64, 67, 70, 73, 75, 84, 88, 95, 98, 99

( ) : normalized temperature anomaly compared with neutral phase >= 0 (< 0)
( ) : precipitation ratio compared with neutral phase >= 100% (< 100%)
: significant at 95% or more of confidence level based on t-test
: significant at 90% or more and less than 95% of confidence level based on t-test

Brought by frequent cold surges formed by anomalous circ.

SST anomaly in 2005/2006 winter

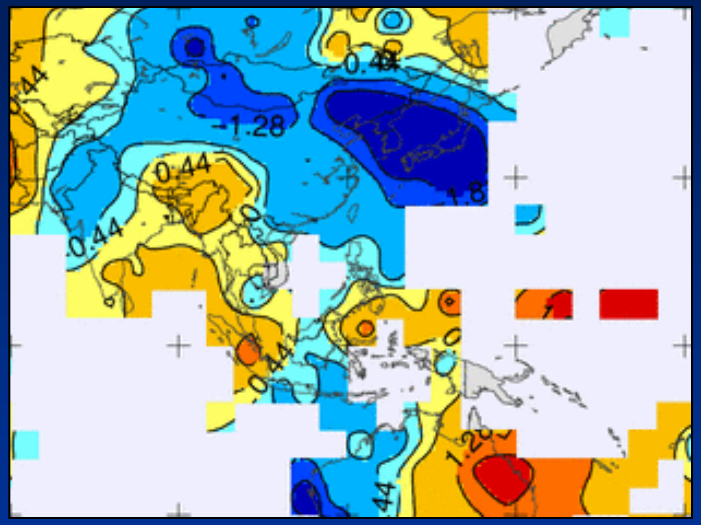


- La Niña event had continued since autumn 2005.

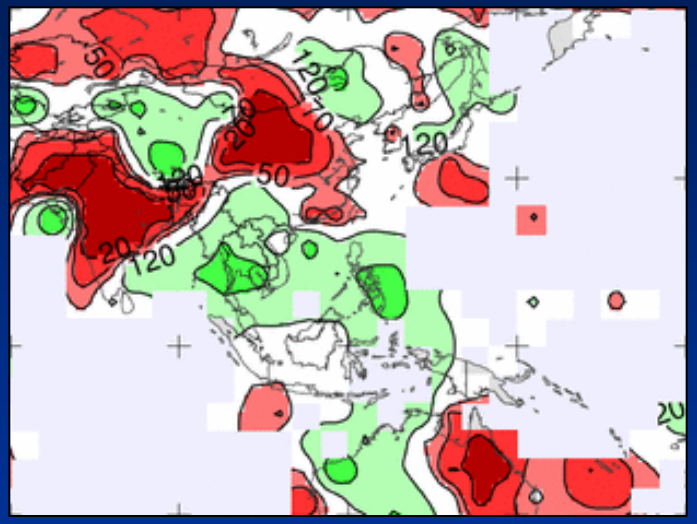
Features of recent El & La event, discuss some mechanism of ENSO impact

La Nina in 05/06 win.

Climate in December 2005



Normalized temperature anomaly
(Dec. 2005)



Precipitation ratio
(Dec. 2005)

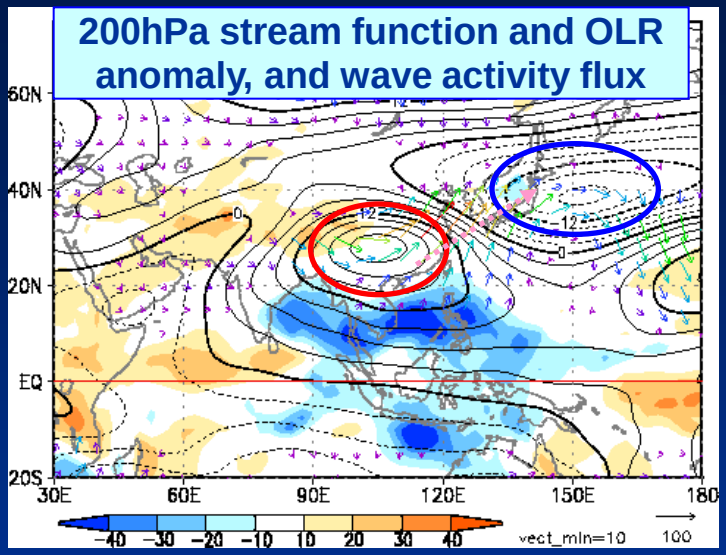
- Extremely cold temperature was observed over northeastern Asia.
- Monthly mean temperature of Japan was the lowest since 1948.
- Extremely wet condition was observed in the Philippines.

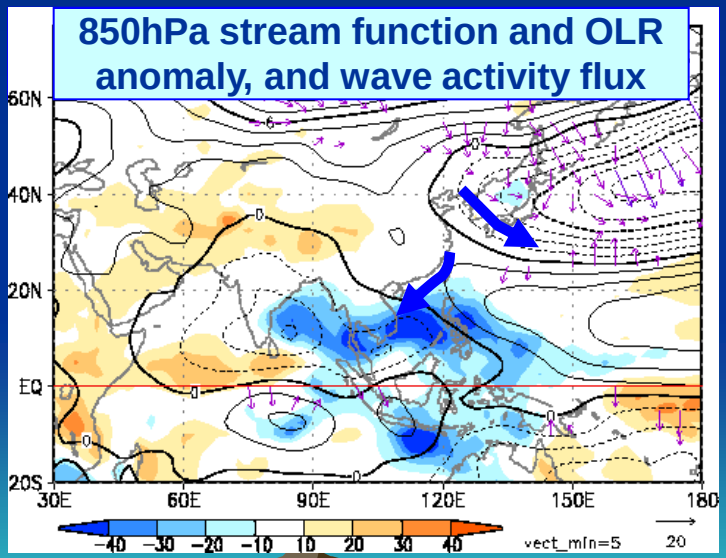
Features of early winter because quite anomalous pattern appeared

What atmospheric condition brought such a cold weather

Atmospheric feature in December 2005

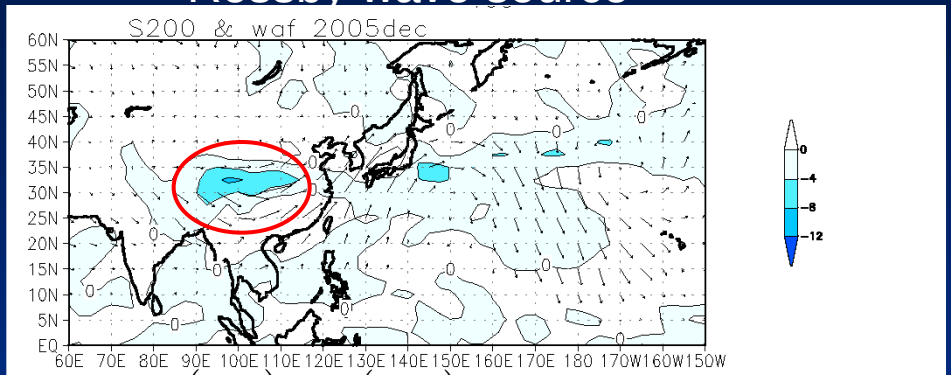
Negative Rossby w. s. means anticyclonic anom. generated by div. flow.





- Wave activity flux: Takaya and Nakamura (2001)
- It indicates propagation of Rossby waves

Rossby wave source



$$S' = -\nabla\cdot\left(v'_\chi\bar{\zeta}\right) - \nabla\cdot\left(\bar{v}_\chi\zeta'\right)$$

Sardeshmukh and Hoskins (1988)

v_χ : divergent wind

ζ : absolute vorticity

$'$: anomaly from climatology

$\bar{}$: climatology

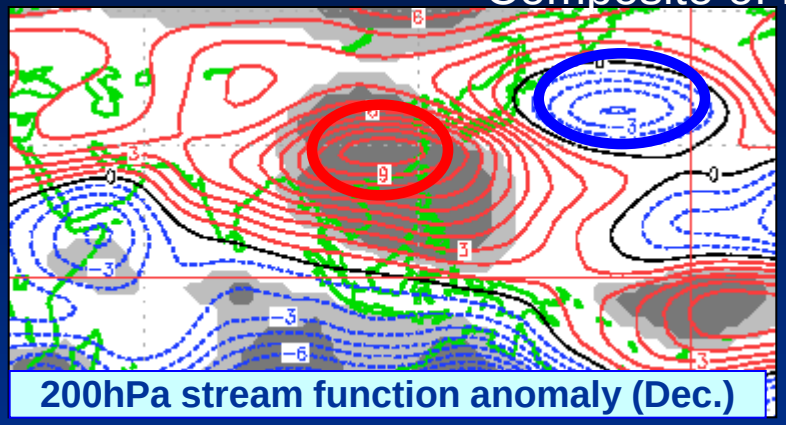
- Rossby wave source is derived from vorticity equation
- It indicates the advection of absolute vorticity by divergent flow

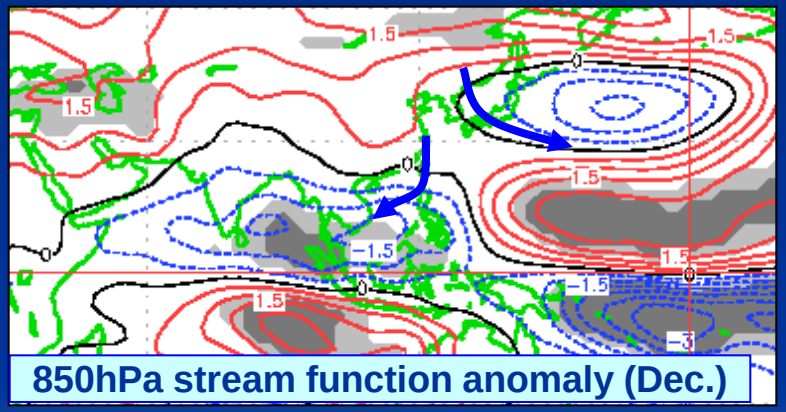
- Anticyclonic anomaly in southern China was generated by divergent wind anomaly in association with active convection over the South China Sea.
- Rossby wave packets propagated eastward from southern China.
- The jet stream meandered around East Asia and brought extreme cold air outbreaks around Japan.

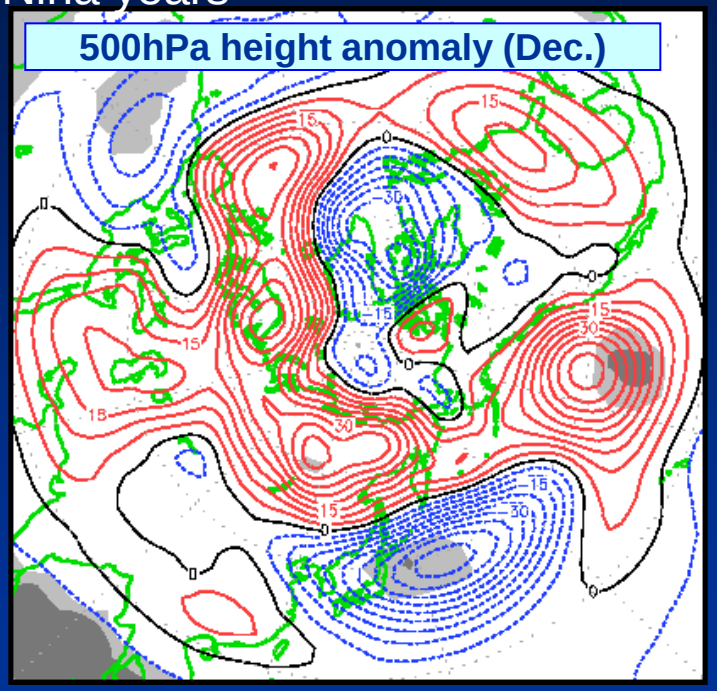
Features are clearly seen statistically in early winter

Statistical features of La Niña impact in early winter

Composite of La Niña years







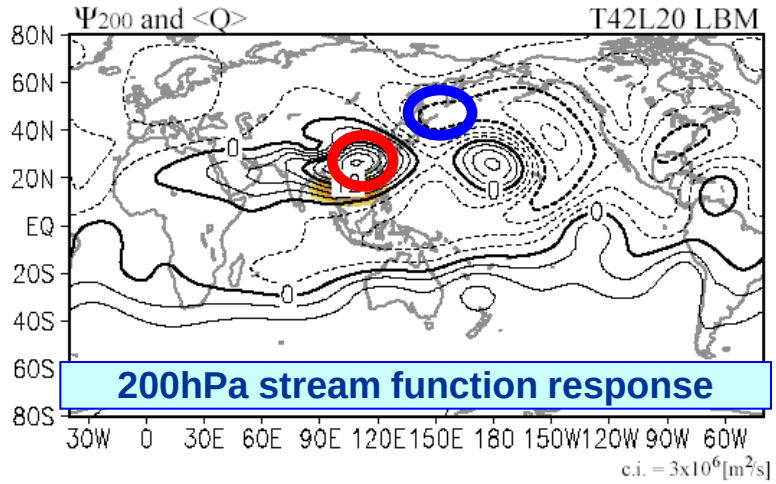
La Niña years 84, 88, 95, 98, 99, 00, 05, 07

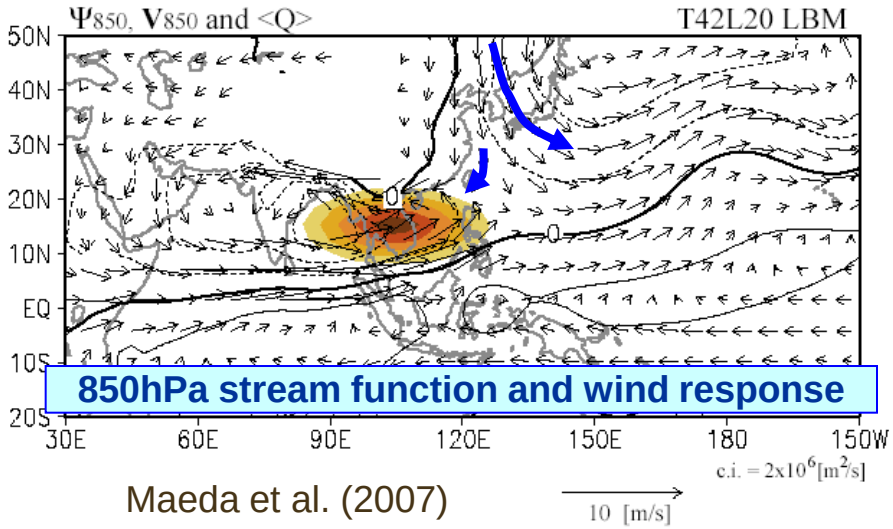
- In the upper troposphere, anticyclonic and cyclonic anomalies in southern China and the Pacific Ocean east of Japan were dominant in early winter.

- In the lower troposphere, stronger Asian winter monsoon is suggested.

Atmospheric response to the heating by the LBM

Reinforce impact of conv. on mid-lat. atoms. circ. by LBM





Maeda et al. (2007)

Color: Vertical-integrated diabatic heating anomalies (maximum 8 K/day) around 400 hPa

- The atmospheric response to the diabatic heating from the Bay of Bengal to the South China Sea is…

- Anticyclonic and cyclonic anomalies are found in the upper troposphere.

- Stronger cold surges are also found in the lower troposphere.

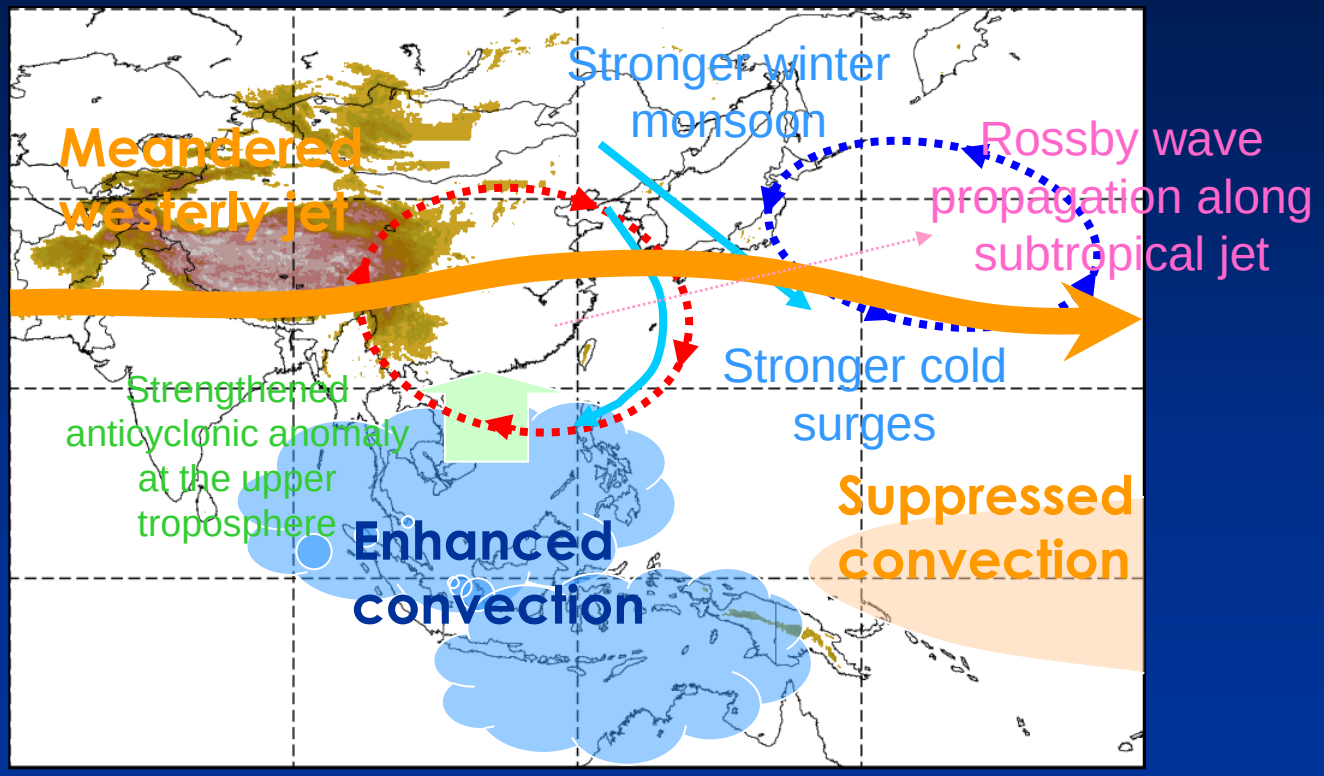
- These suggest the active convection there is important for the formation of the observed atmospheric anomalies over East Asia.

LBM: Linear baroclinic model
Watanabe and Kimoto (2000)

Response is quite similar to the observed anomalies

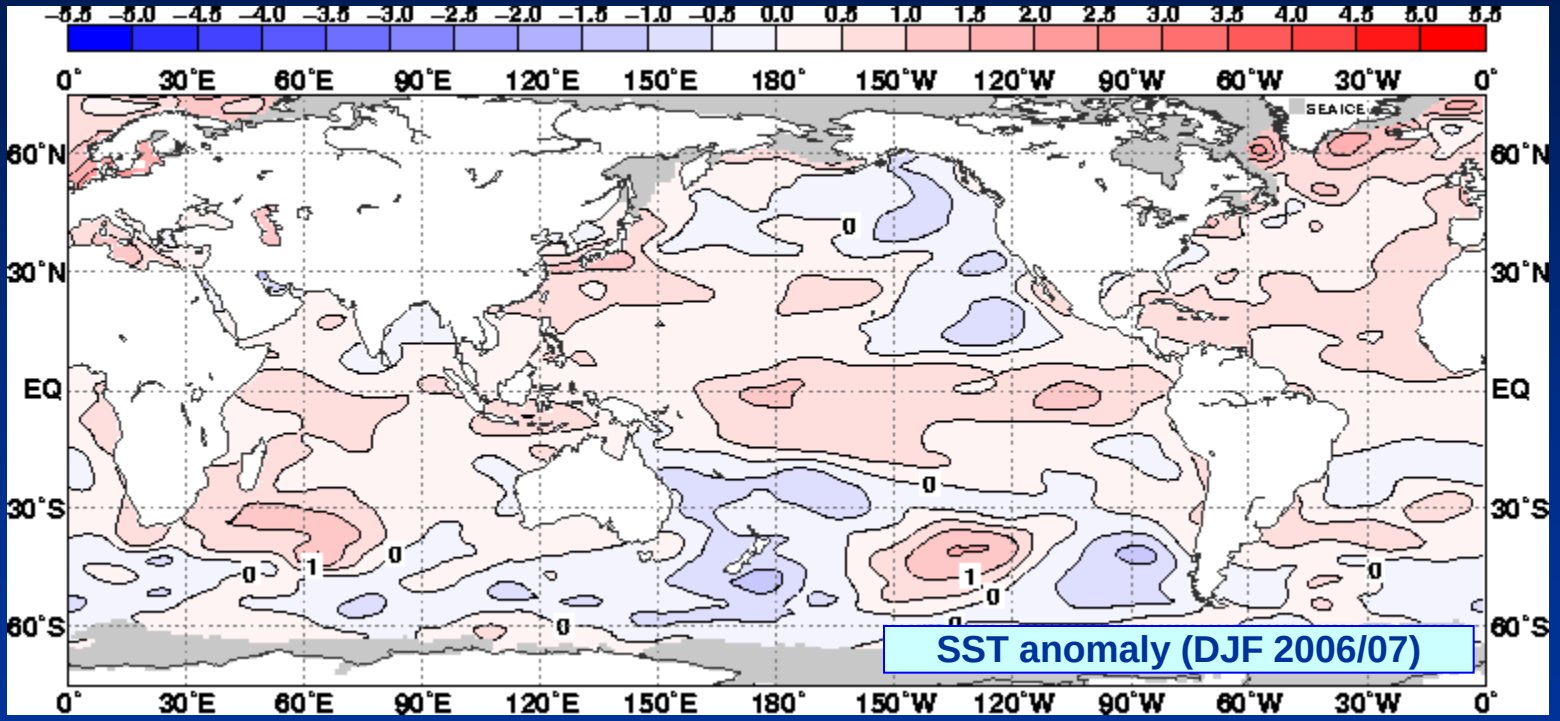
Global, time-dependent, primitive equation model linearized about the observed climatology

Possible mechanism during the La Niña event



- Anticyclonic anomaly in southern China in the upper troposphere is generated by divergent wind anomaly associated with active convection over the South China Sea.
- Rossby wave packets propagate eastward from southern China to east of Japan.
- The jet stream meanders around East Asia.
- It brings cold air outbreaks around Japan and Southeast Asia.

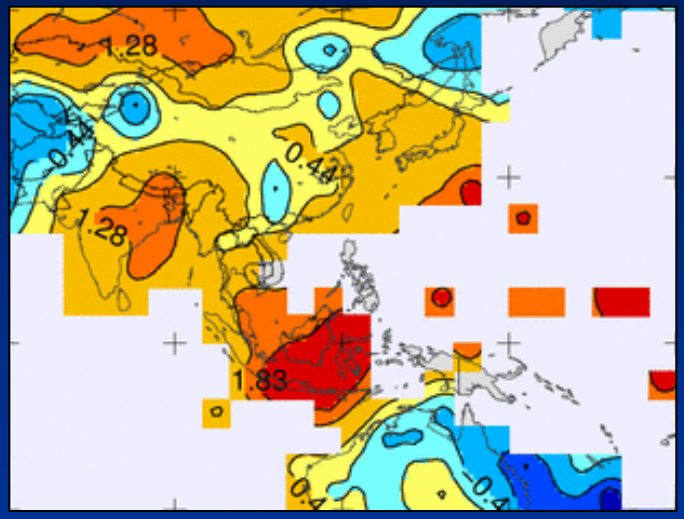
SST anomaly in 2006/2007 winter



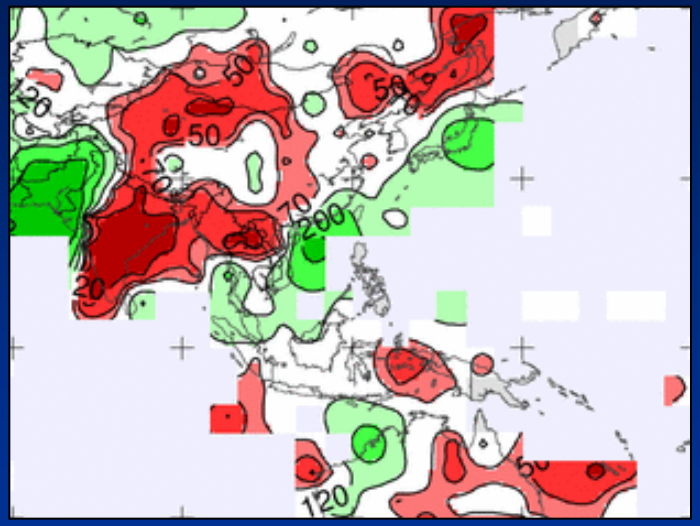
- El Niño condition had continued since summer 2006 although JMA's definition of El Niño event did not satisfy.
- SST anomaly over the Indian Ocean was above normal.

JMA defines that the El Niño (La Niña) is such that the 5-month running mean SST deviation for Niño.3 continues +0.5ºC (-0.5ºC) or higher (lower) for six consecutive months or longer.

Climate in December 2006



Normalized temperature anomaly
(Dec. 2006)



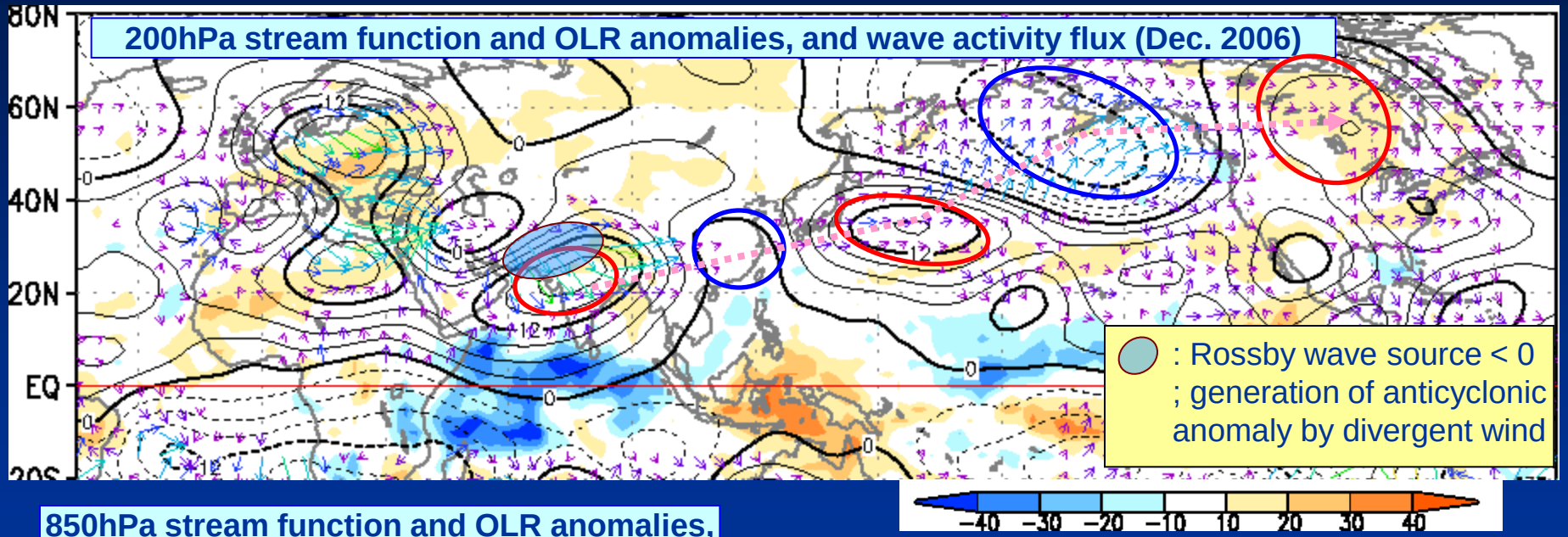
Precipitation ratio
(Dec. 2006)

- Above normal temperature was observed in most of East and South Asia.
- In Japan, warm and extremely wet condition was observed.

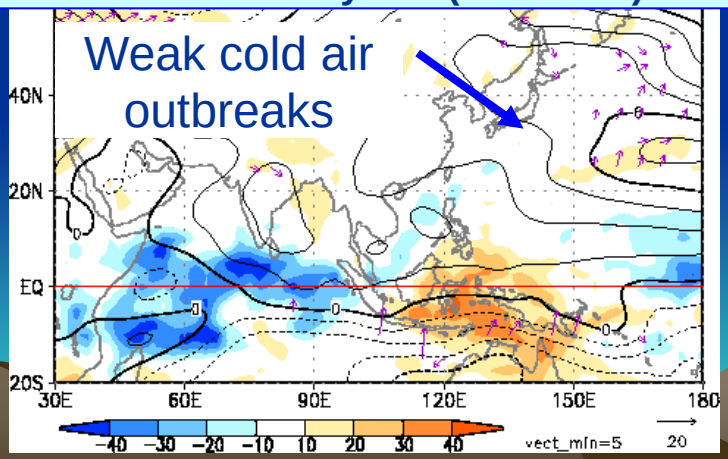
Features of early winter because quite anomalous pattern appeared

What atmospheric condition brought such a warm weather

Atmospheric feature in December 2006



850hPa stream function and OLR anomalies, and wave activity flux (Dec. 2006)



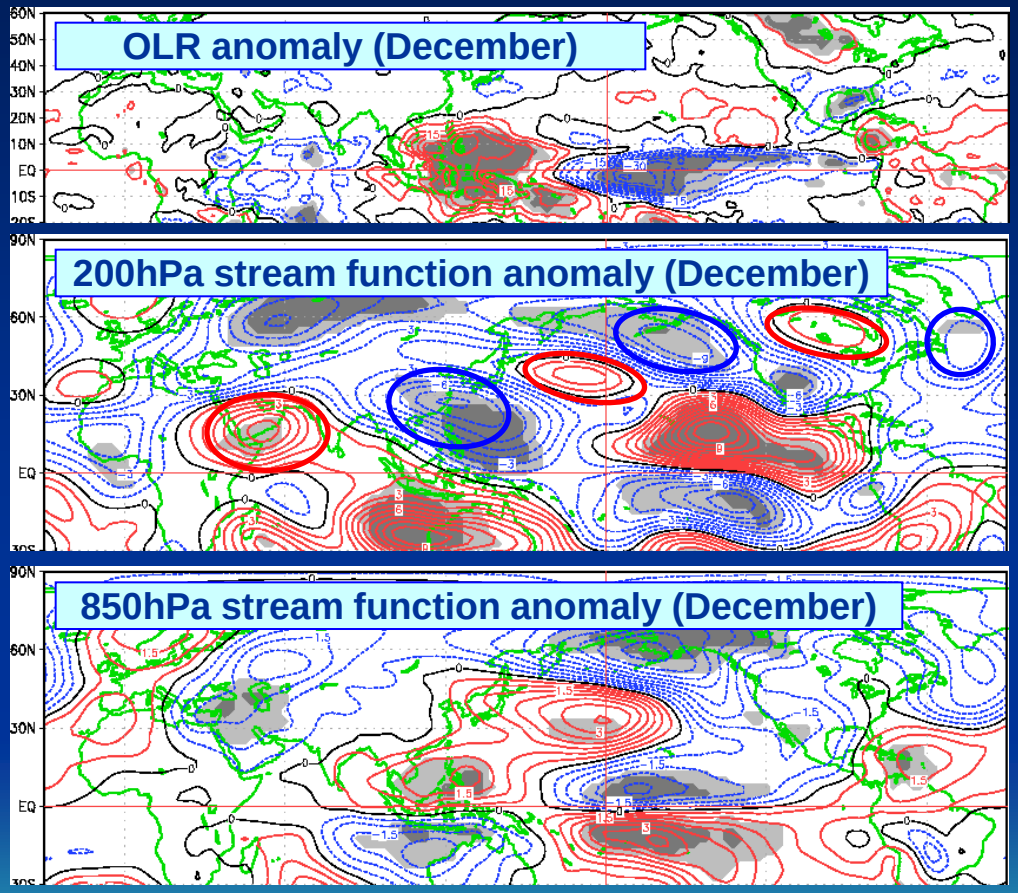
- Anticyclonic anomaly over India was enhanced by divergent wind anomaly associated with active convection over the Indian Ocean.

- Rossby wave propagation strengthened cyclonic and anticyclonic anomalies over southern China / Aleutian and east of Japan.

Features are clearly seen statistically in early winter

Statistical features of El Niño impact in early winter

Composite of El Niño years



El Niño years 82,86,87,91,97,02

In early winter during El Niño,

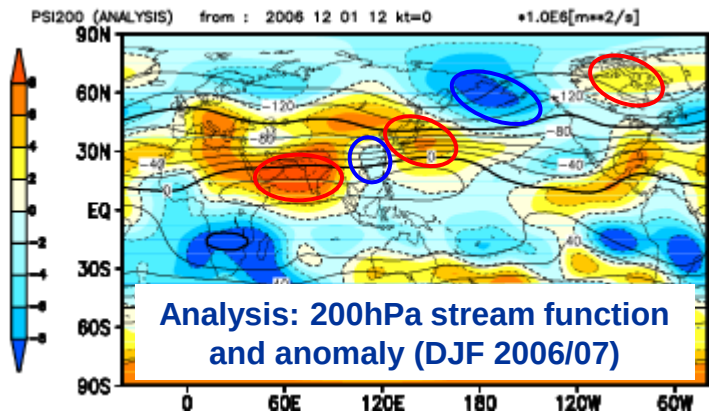
- Convective activities were enhanced not only over the central Pacific but the Indian Ocean,

- At the upper troposphere anticyclonic anomalies found over the Arabian Sea.

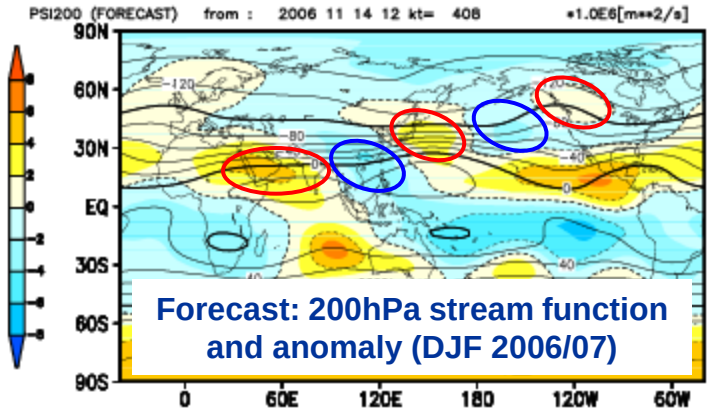
- A wave train appears from the Indian Ocean to North America.

The JMA's seasonal forecast model in winter 2006/2007

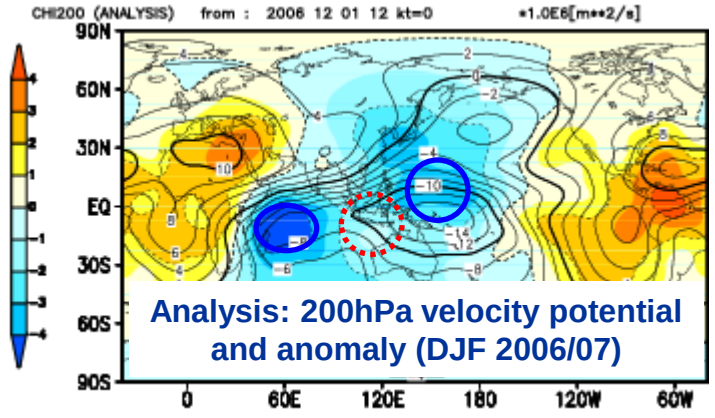
How did the JMA model predicted the anom.



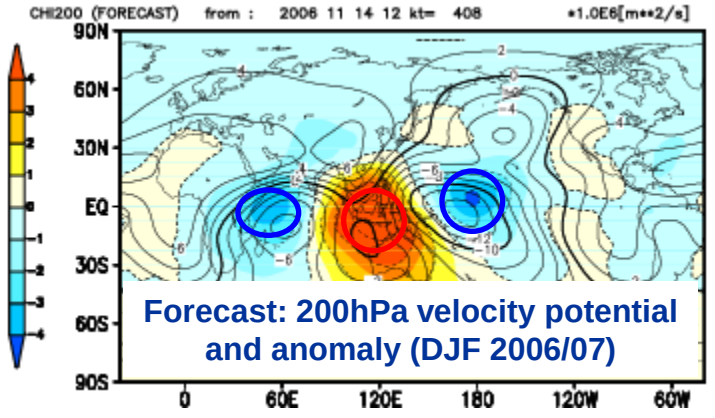
Analysis: 200hPa stream function and anomaly (DJF 2006/07)



Forecast: 200hPa stream function and anomaly (DJF 2006/07)



Analysis: 200hPa velocity potential and anomaly (DJF 2006/07)

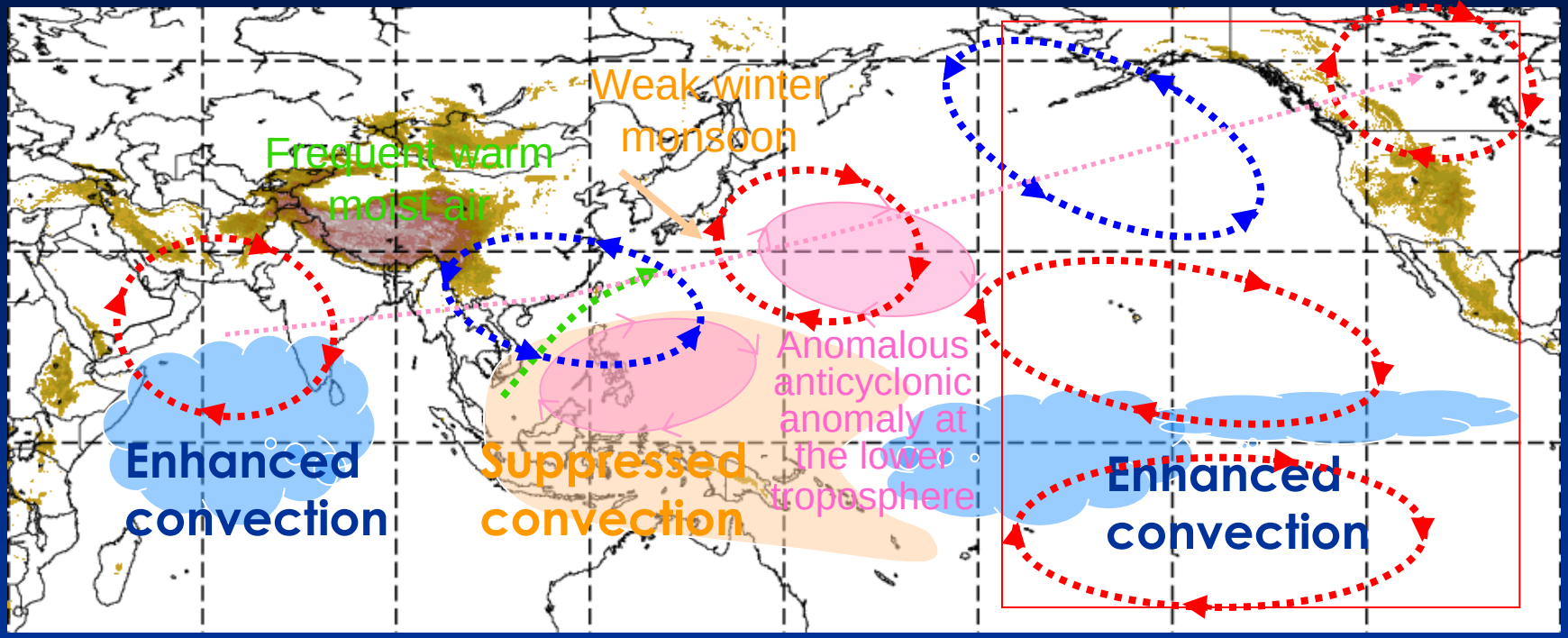


Forecast: 200hPa velocity potential and anomaly (DJF 2006/07)

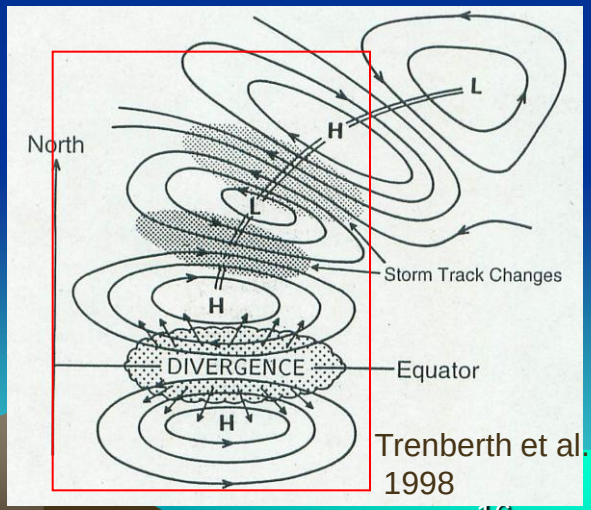
- Ensemble forecast model predicted similar tropical divergence and wave train as in the analysis.

- It suggests this wave train was strengthened by the tropical convective activities including over the Indian Ocean.

Possible mechanisms during the El Niño event



- Anticyclonic anomalies over the Arabian Sea associated with enhanced convection are strengthened.
- Rossby wave packets propagating along Asian jet form a wave train from the Indian Ocean to North America.
- This mechanism is different from Trenberth et al..
- At the lower troposphere anticyclonic anomalies are observed over the Philippines and east of Japan.
- It results in warm and humid weather over East Asia.



Trenberth et al. 1998

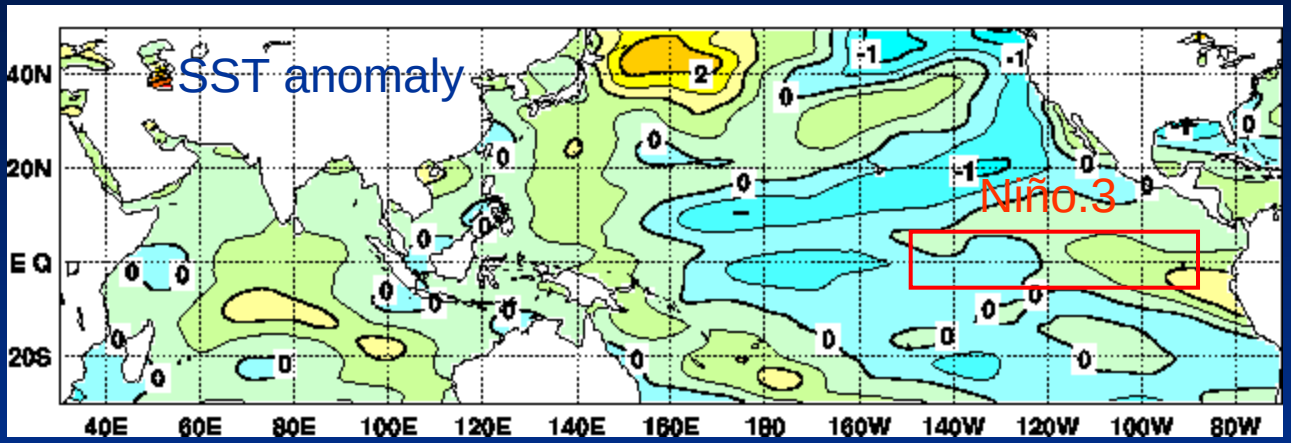
- Trenberth et al. suggests active convection over the eastern Pacific relates to the generation of a wave train.

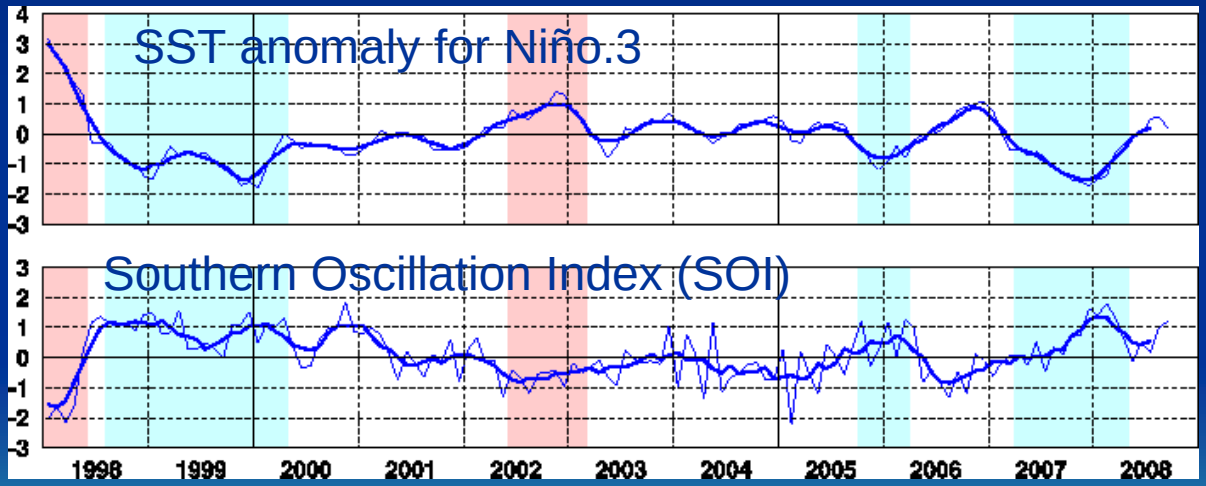
Current oceanic and atmospheric condition

and

El Niño outlook in winter 2008/2009

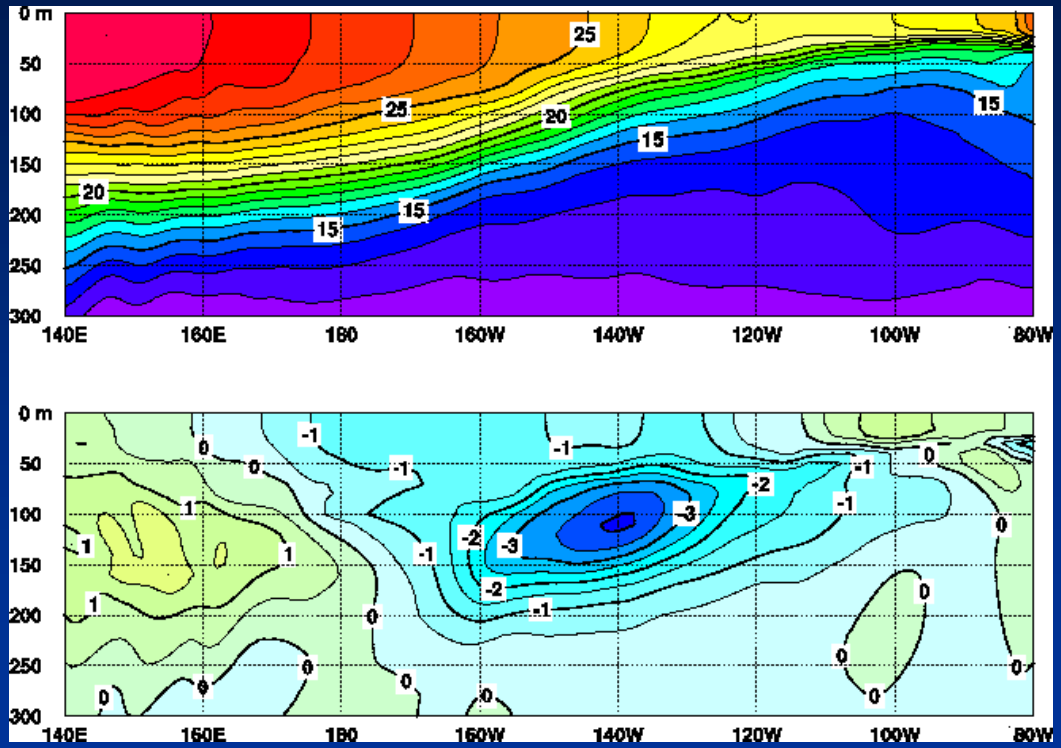
Oceanic condition in September 2008



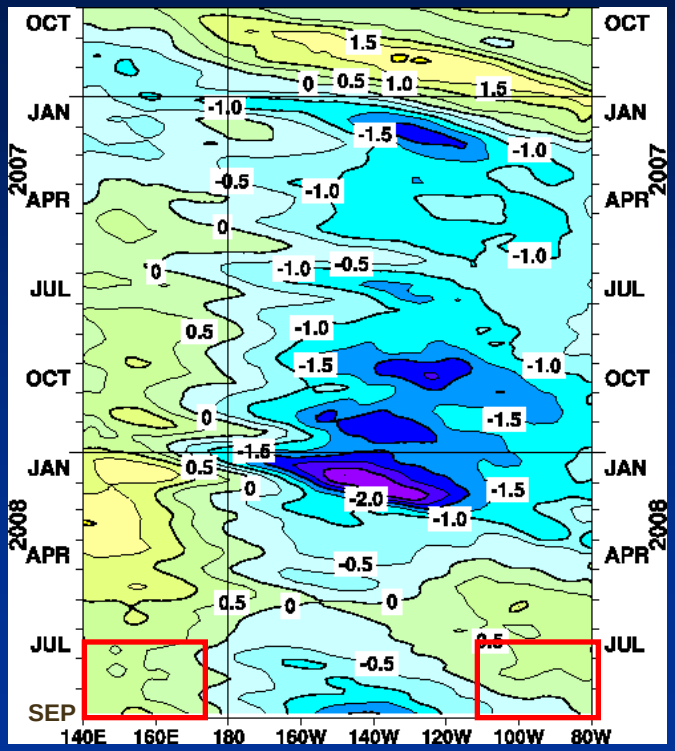


- In September 2008, the SST over the Niño.3 was near normal.
- Positive SST anomalies in the western and eastern equatorial Pacific, and negative SST in the central part were observed.

Oceanic condition in September 2008



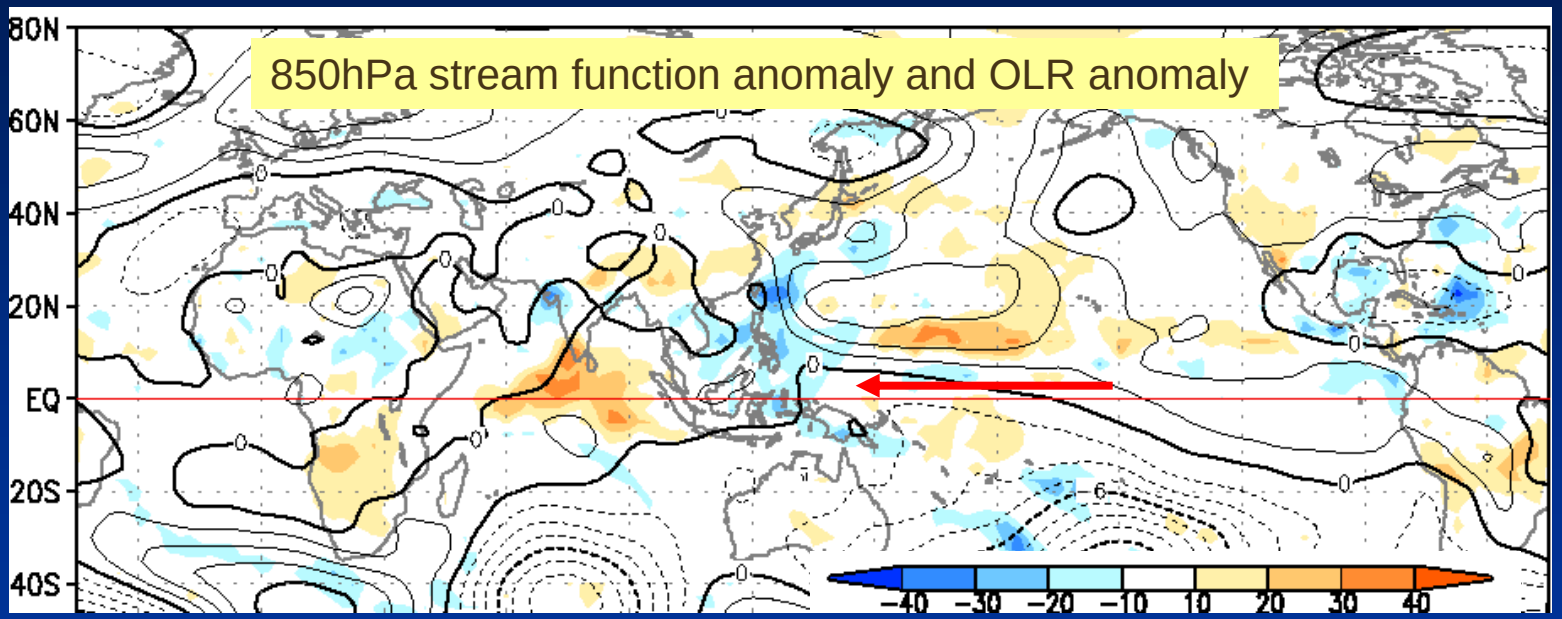
Depth-longitude cross sections of temperature (upper) and anomalies (lower) along the equator in the Pacific Ocean.



Time-longitude cross section of OHC (vertically averaged temperature in the top 300 m) anomalies along the equator in the Pacific Ocean.

- Subsurface negative temperature anomalies in the central part strengthened.
- Positive anomalies in the eastern part weakened.
- Positive anomalies in the western part persisted.

Atmospheric condition in September 2008

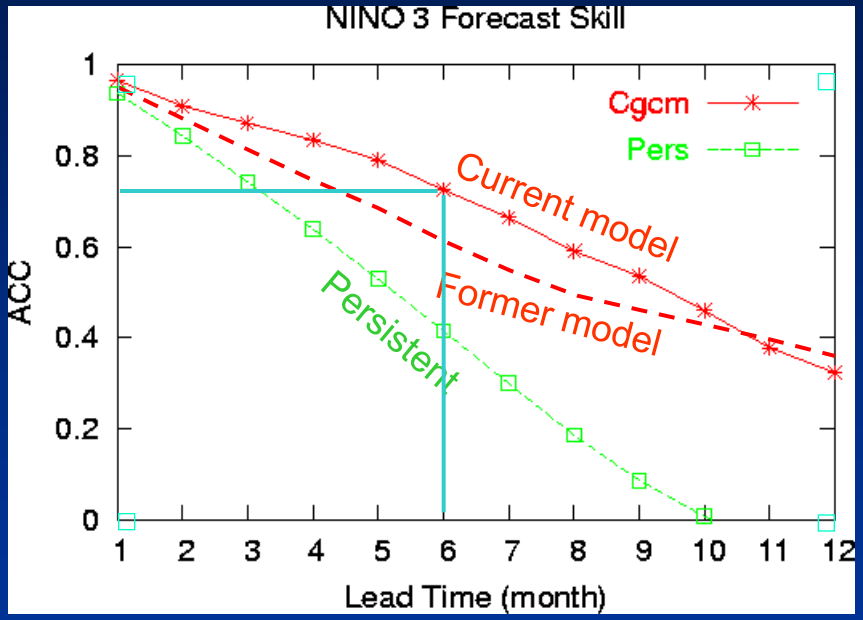


- Convective activities were enhanced near the Philippines and over eastern Indonesia, and suppressed over the equatorial Indian Ocean.

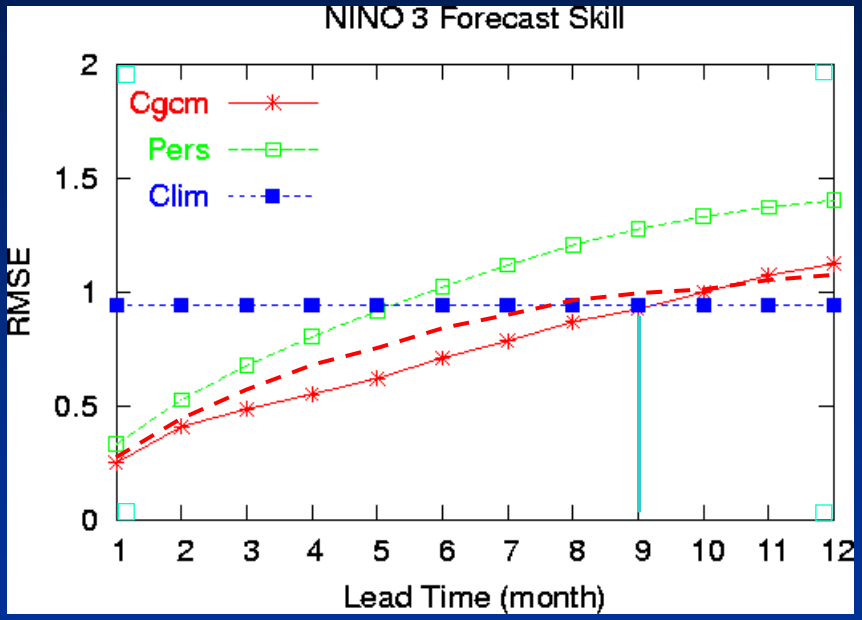
- In the central Pacific, easterly wind anomalies were observed at the lower troposphere during September.

Performance of El Niño forecast model

Anomaly Correlation



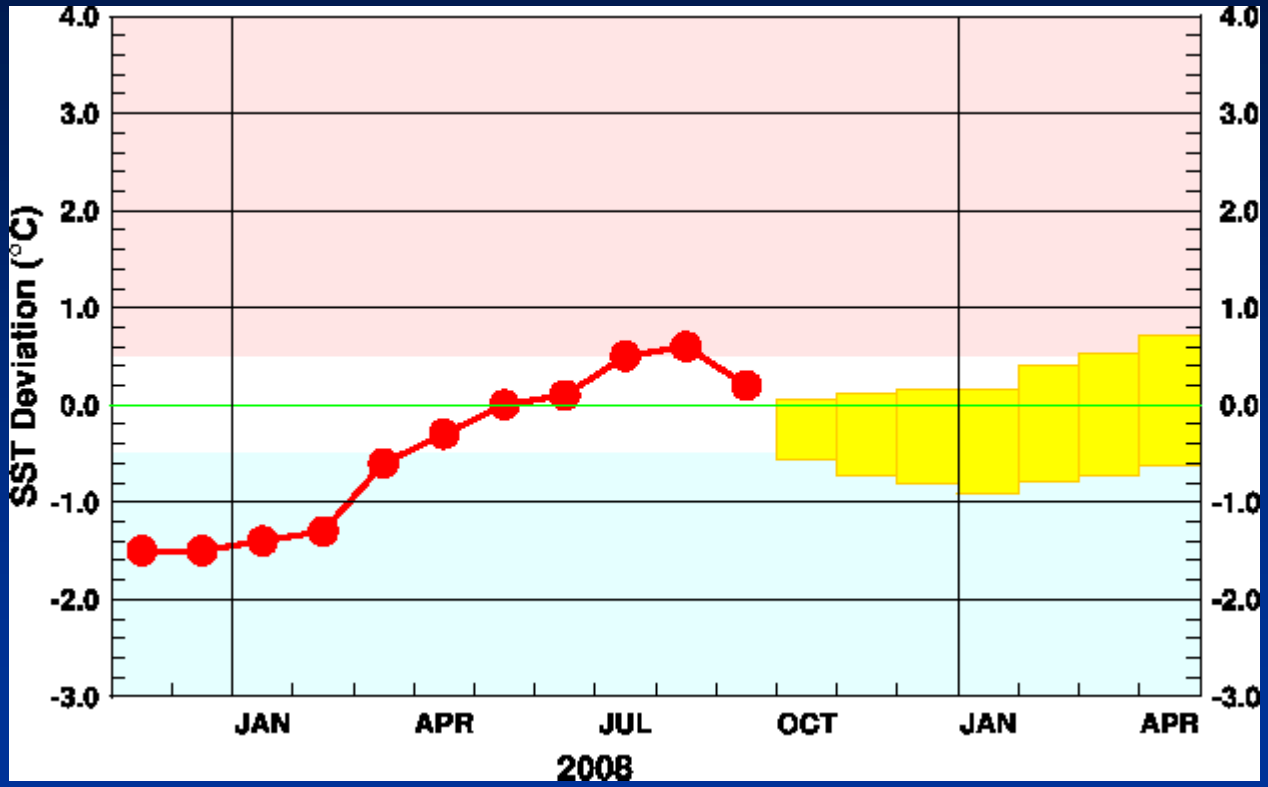
RMS Error



- The CGCM as the El Niño forecast model was replaced with new one having higher oceanic and atmospheric resolutions in March 2008.
- According to 300 hindcast experiments from 1979 to 2003, the forecast skill was much improved.
- The anomaly correlation for 6-month lead time is over 0.7.
- The RMSE of the current model is less than climatology by 9 months lead-time.

CGCM: Coupled ocean-atmosphere General Circulation Model

Model Forecast for Niño.3



Thick line shows the observed SST deviation for Niño.3 and boxes show the predicted one by the El Niño forecast model. Each box denotes the range with the probability of 70%.

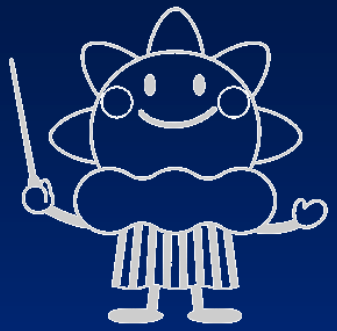
- The Niño.3 SST will be near normal during the prediction period.

Conclusion for the El Niño outlook

- The Niño.3 SST is likely to be near normal in the months ahead.

- During autumn and winter, El Niño and La Niña event, which are the dominant predictable inter-annual variation of the climate system, are unlikely to develop.

- Without El Niño or La Niña event, it is difficult to make a winter season prediction from the viewpoint of inter-annual variation.



Thank you for your attention

(References)

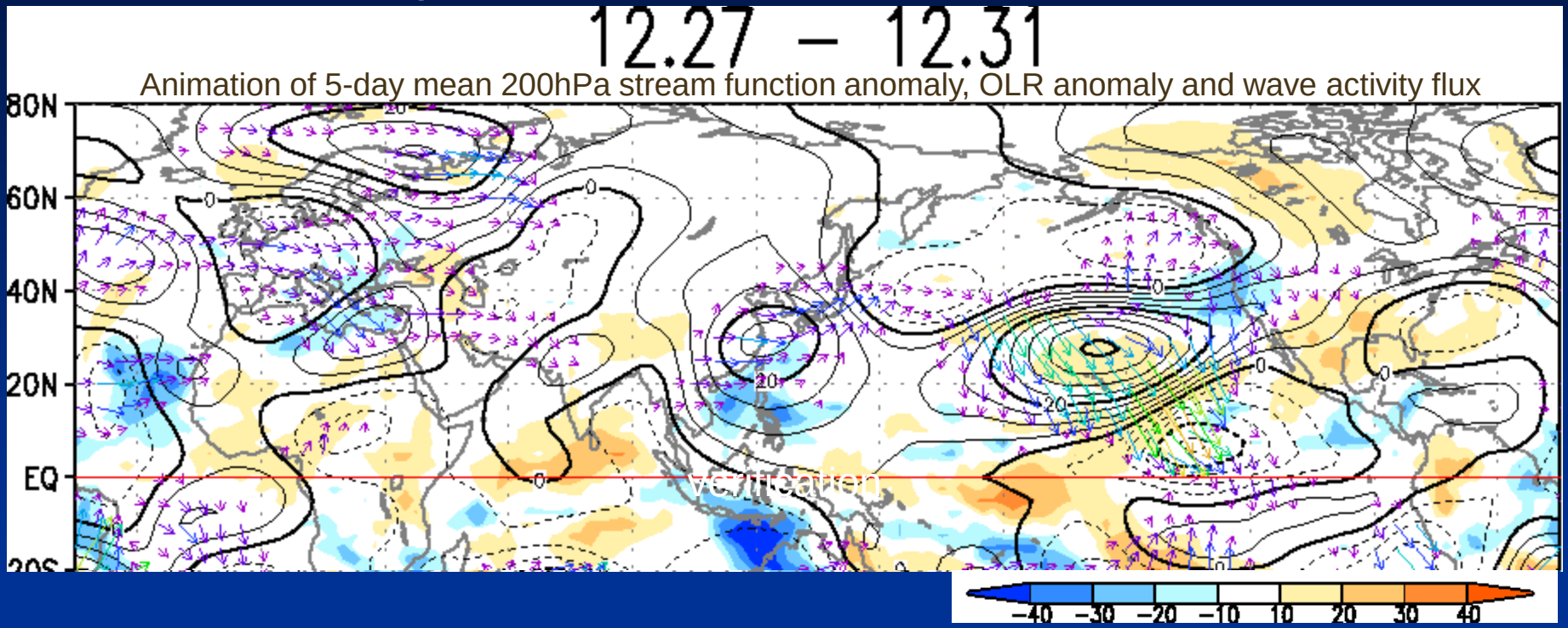
Maeda, S., H. Sato, M. Watanabe 2007: Tropical convective activities and extreme cold climate around Japan in December 2005, Meteorological Study Note, 216, 89-94 (in Japanese).

Takaya, K., and H. Nakamura, 2001: A Formulation of a Phase-Independent Wave-Activity Flux for Stationary and Migratory Quasigeostrophic Eddies on a Zonally Varying Basic Flow. J. Atmos. Sci., 58, 608-627.

Trenberth, K. E., Branstator, G. W., Karoly, D., Lau, N. -C., and Ropelewski, C. F., 1998. 'Progress during TOGA in understanding and modeling global teleconnections associated with tropical sea surface temperatures', J. Geophys. Res., 103, 14291–14324.

Watanabe M., and M. Kimoto, 2000: Atmosphere-ocean thermal coupling in the north atlantic: A positive feedback. Quart. J. R. Met. Soc., 126, 3343-2369.

Atmospheric feature in December 2005



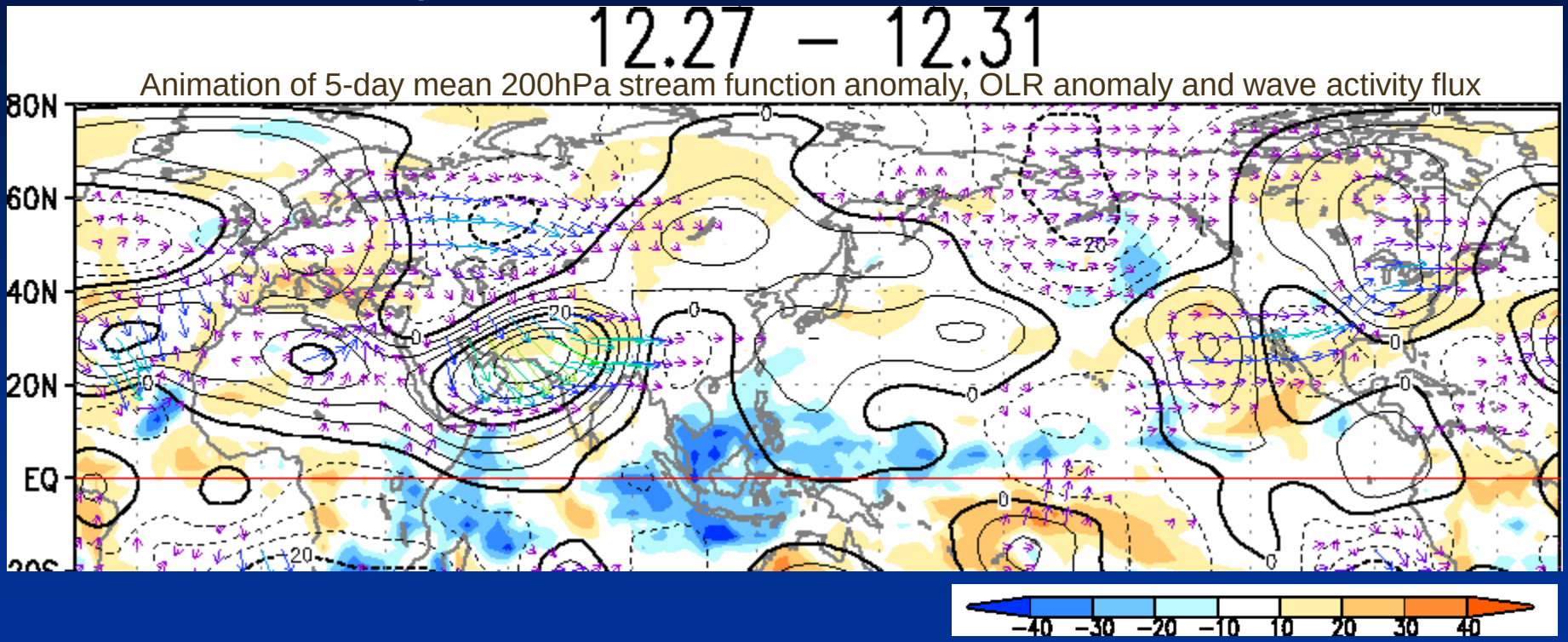
-Convective activities were enhanced over Bay of Bengal and South China Sea associated with the La Niña event

- Strong anticyclone was formed over southern China

- The quasi stationary Rossby wave packets propagated along the Asian Jet

- Cyclonic anomaly was dominated over the Pacific Ocean east of Japan

Atmospheric feature in December 2006



- Convective activities were enhanced over the Indian Ocean
- Anitcyclone was observed over India to the Arabian Sea
- Quasi stationary Rossby wave sometimes propagated eastward along Asian Jet
- Cyclonic and Anticyclonic anomalies were enhanced over southern China and the Pacific Ocean east of Japan
- Alutian Low shifted eastward from normal position