Training Seminar on Climate Information and Forecasting
4th November 2008

Techniques for Climate System Monitoring

4th November, 2008

Yayoi Harada
Climate Prediction Division/JMA

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2. Report on the tropical convection and large scale circulation in September
3. Report on the extra-tropical atmospheric circulation in September 2008 (briefly)

1. Monthly Highlights on Climate System

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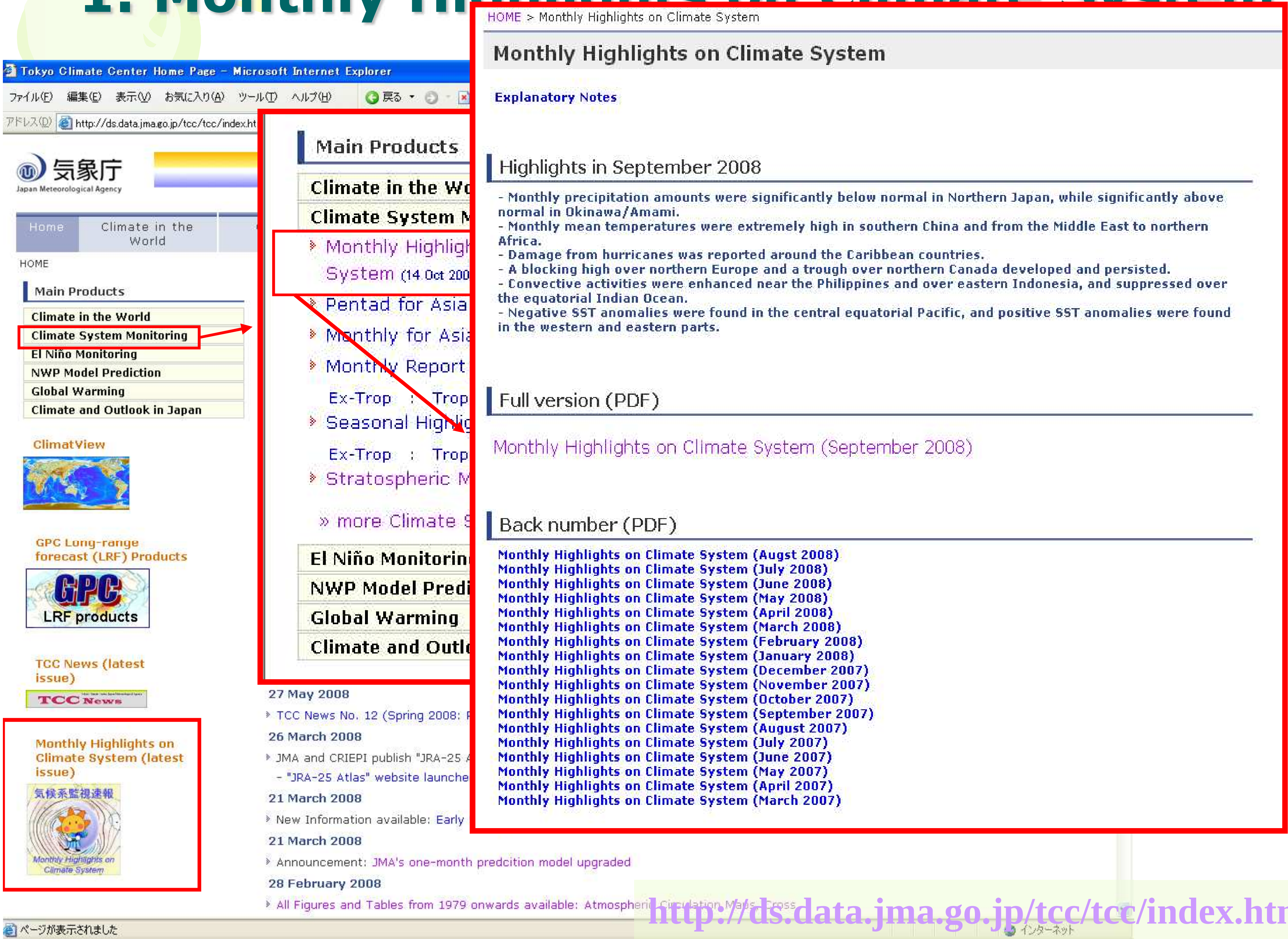

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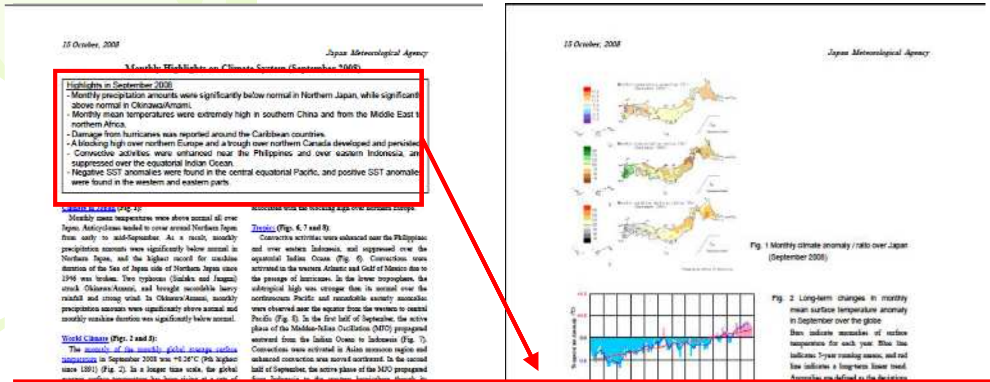

Monthly Highlights on Climate System (September 2008)

Highlights in September 2008

- Monthly precipitation amounts were significantly below normal in Northern Japan, while significantly above normal in Okinawa/Amami.
- Monthly mean temperatures were extremely high in southern China and from the Middle East to northern Africa.
- Damage from hurricanes was reported around the Caribbean countri…
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Climate in Japan

World Climate

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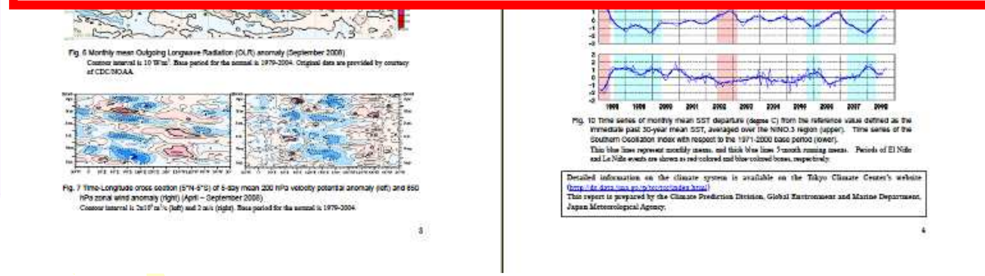
Tropics

Oceanograhpic conditions



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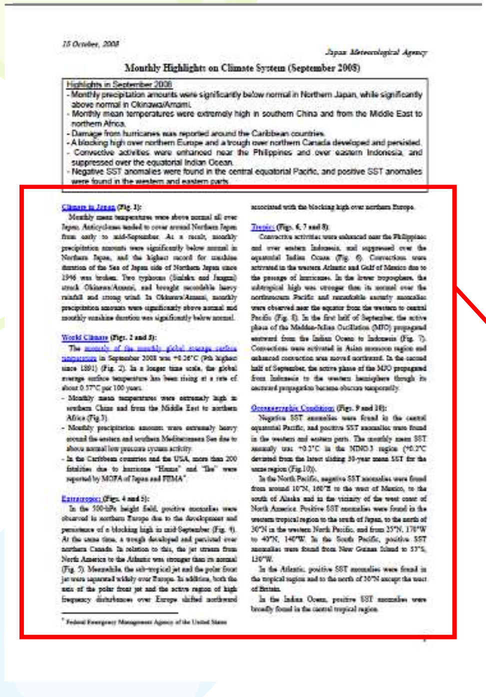

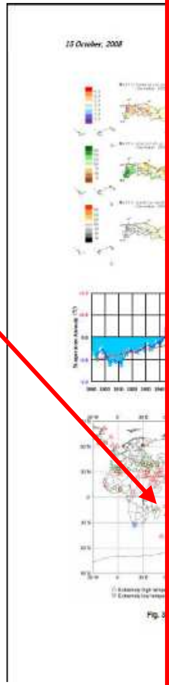

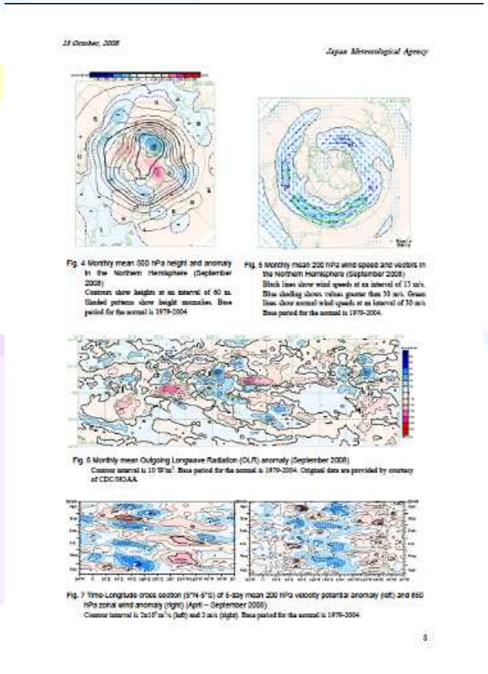

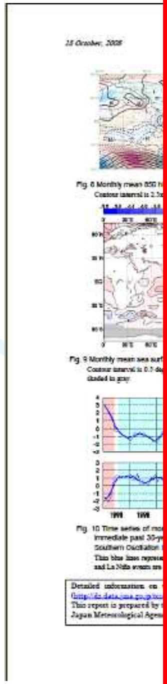

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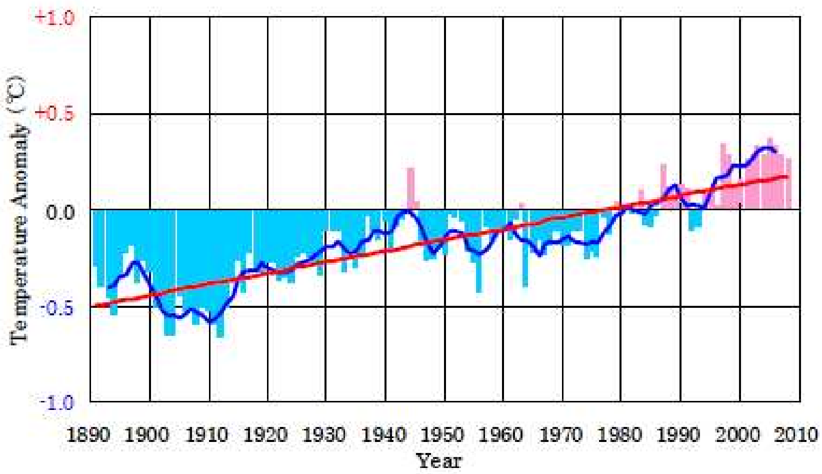

Fig. 2 Long-term changes in monthly mean surface temperature anomaly in September over the globe
Bars indicate anomalies of surface temperature for each year. Blue line indicates 5-year running means, and red line indicates a long-term linear trend. Anomalies are defined as the deviations from the normal (1971-2000 average).

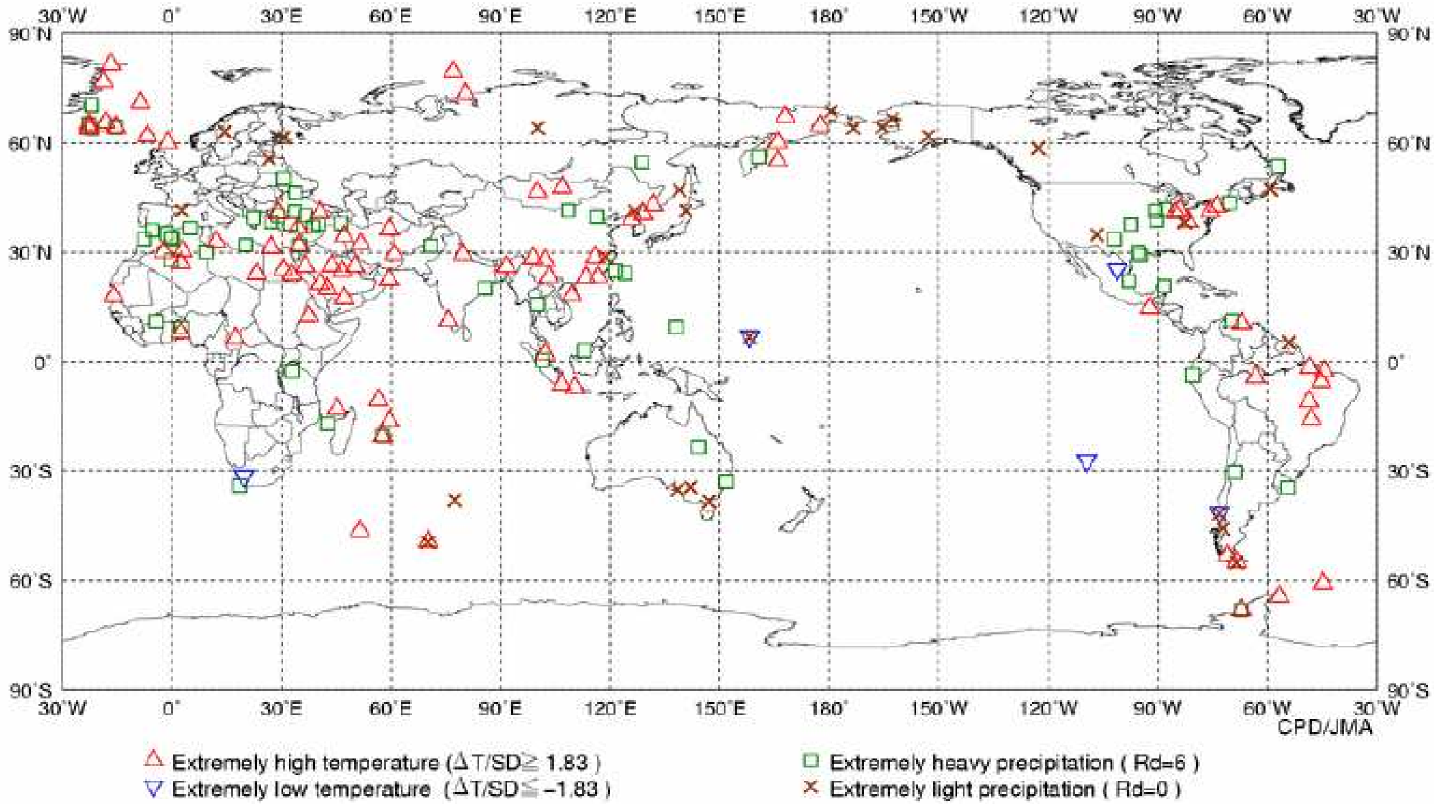

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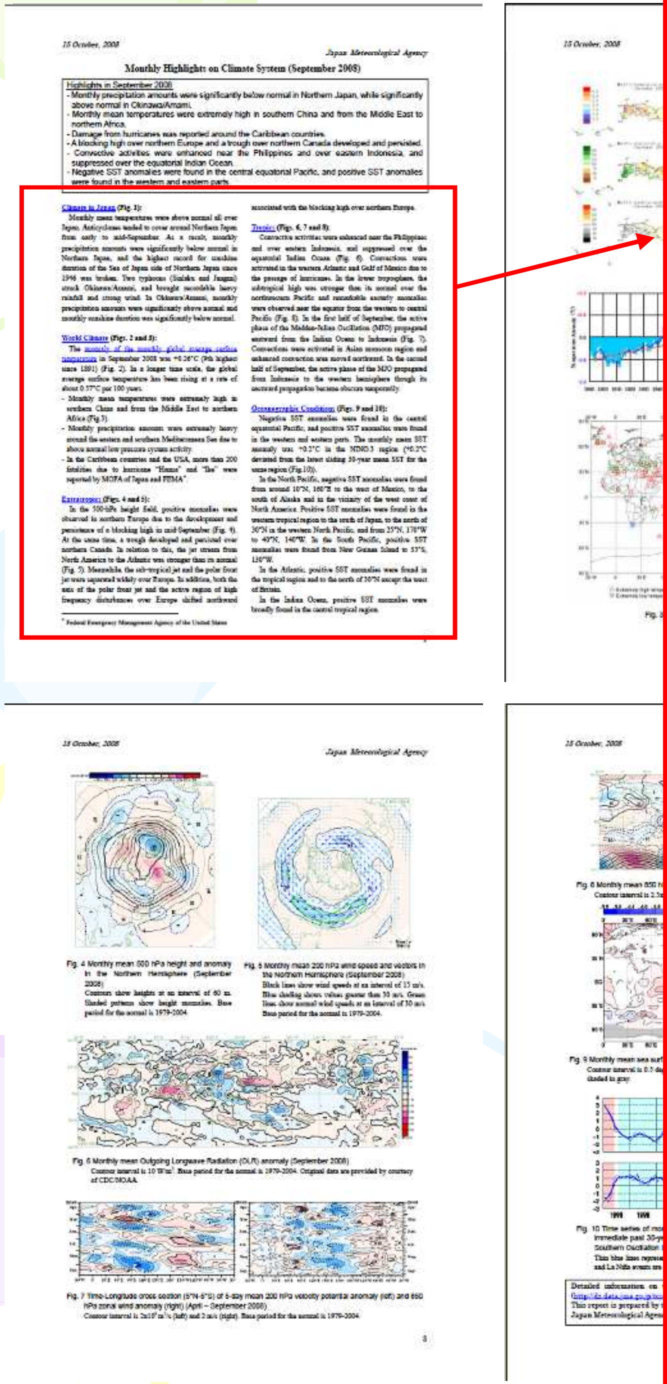
Fig. 3 Distribution of extreme climate events (September 2008)

1. Monthly Highlights on Climate System



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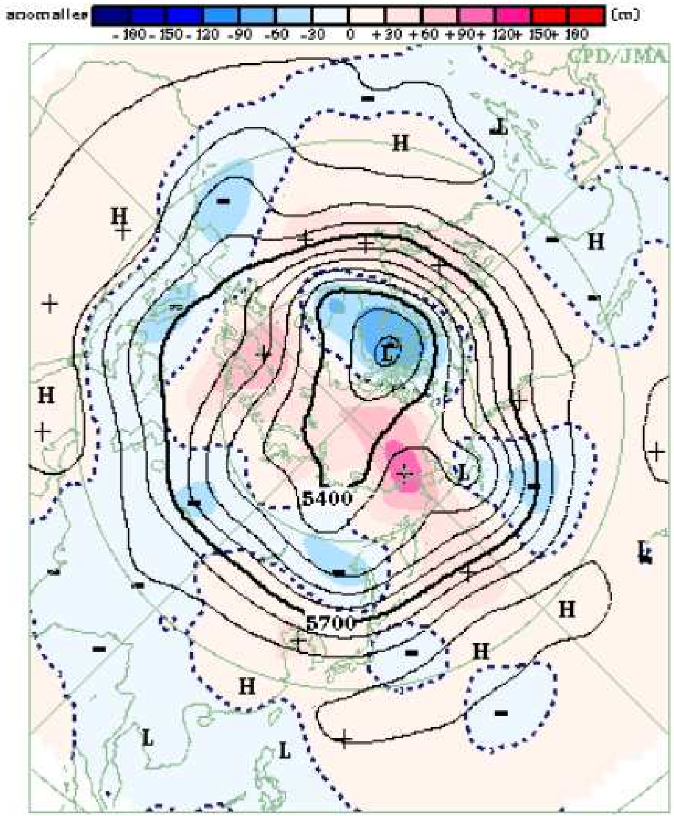

Fig. 4 Monthly mean 500 hPa height and anomaly in the Northern Hemisphere (September 2008)
Contours show heights at an interval of 60 m. Shaded patterns show height anomalies. Base period for the normal is 1979-2004.

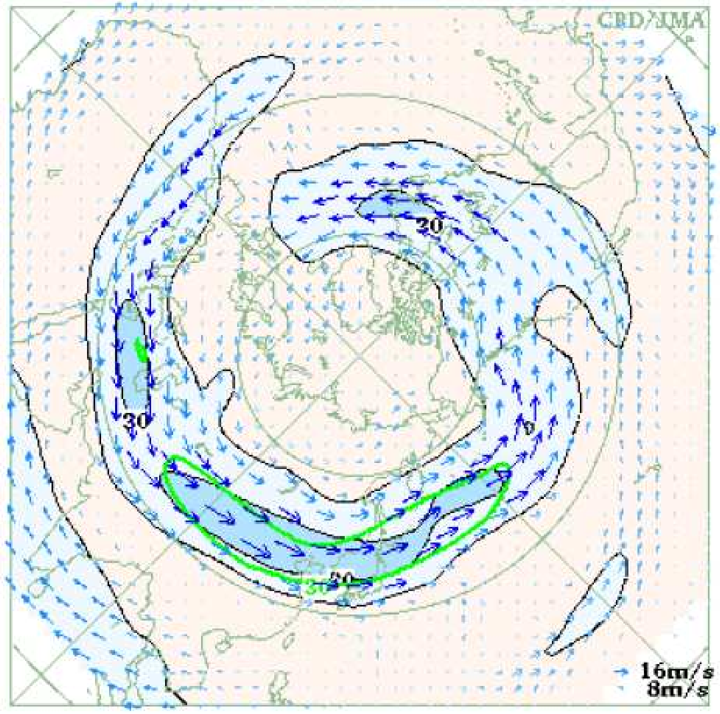

Fig. 5 Monthly mean 200 hPa wind speed and vectors in the Northern Hemisphere (September 2008)
Black lines show wind speeds at an interval of 15 m/s. Blue shading shows values greater than 30 m/s. Green lines show normal wind speeds at an interval of 30 m/s Base period for the normal is 1979-2004.

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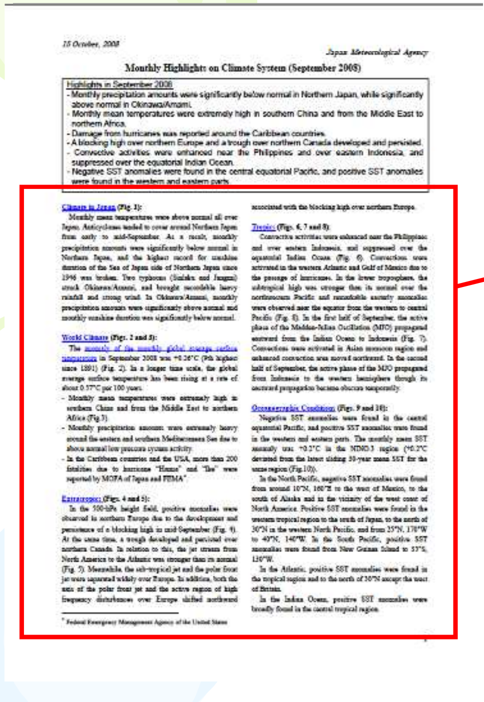

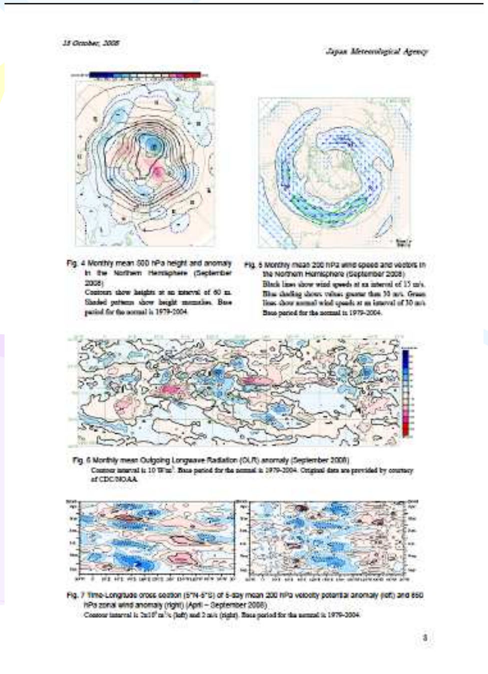

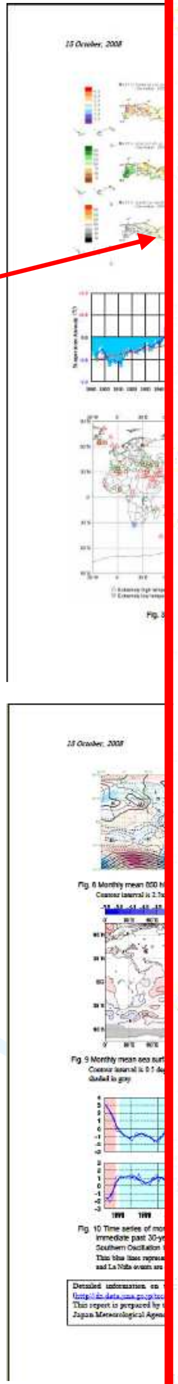

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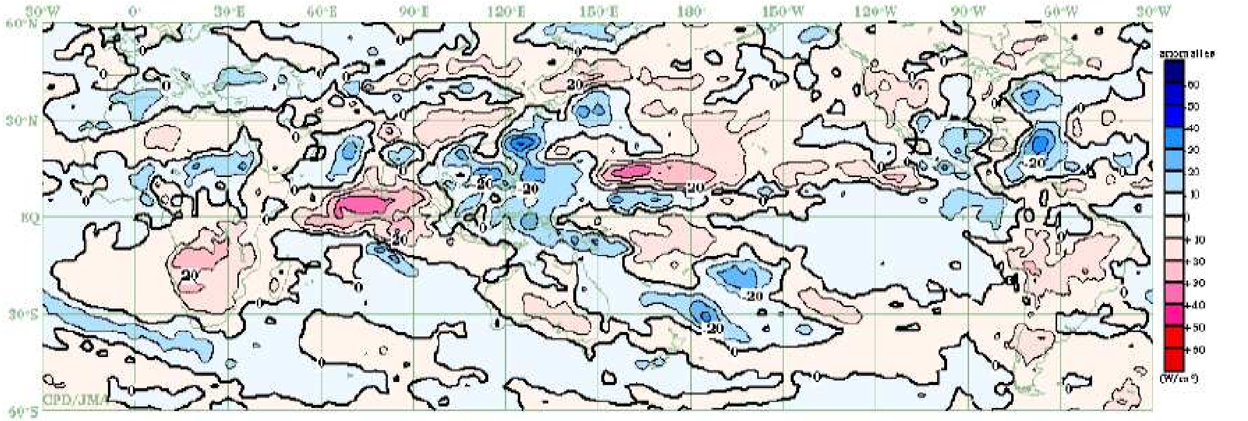

Fig. 6 Monthly mean Outgoing Longwave Radiation (OLR) anomaly (September 2008)
Contour interval is 10 W/m^2. Base period for the normal is 1979-2004. Original data are provided by courtesy of CDC/NOAA.

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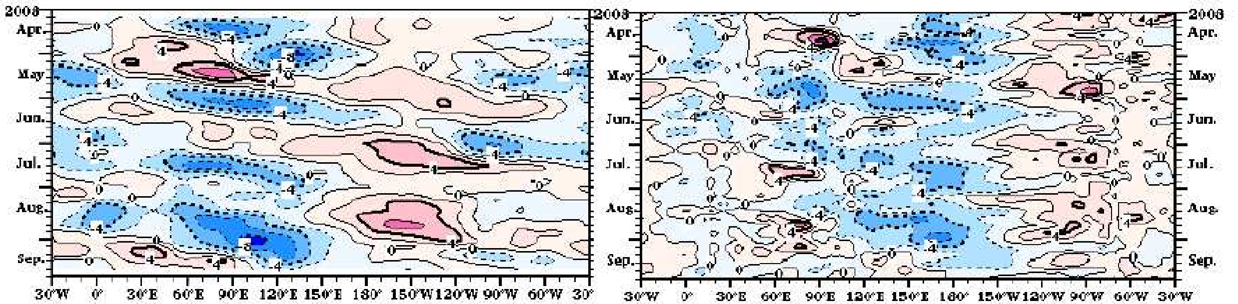

Fig. 7 Time-Longitude cross section (5°N-5°S) of 5-day mean 200 hPa velocity potential anomaly (left) and 850 hPa zonal wind anomaly (right) (April – September 2008)
Contour interval is 2x10^6 m^2/s (left) and 2 m/s (right). Base period for the normal is 1979-2004.

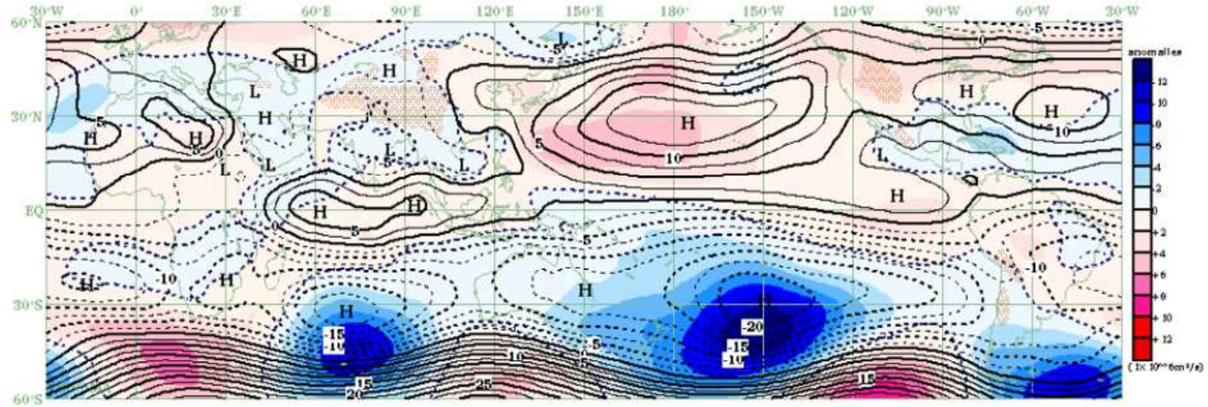

Fig. 8 Monthly mean 850 hPa stream function and anomaly (September 2008)
Contour interval is 2.5x10^{6}m^2/s. Base period for the normal is 1979-2004.

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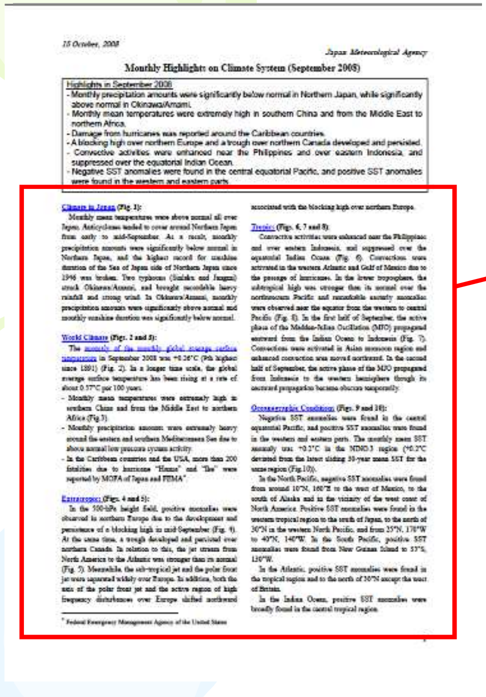

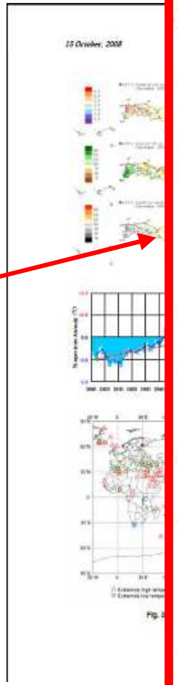

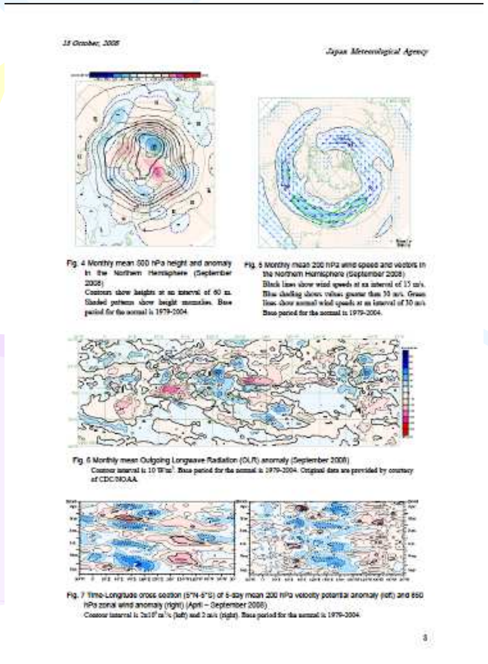

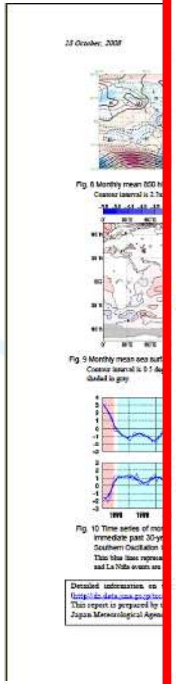

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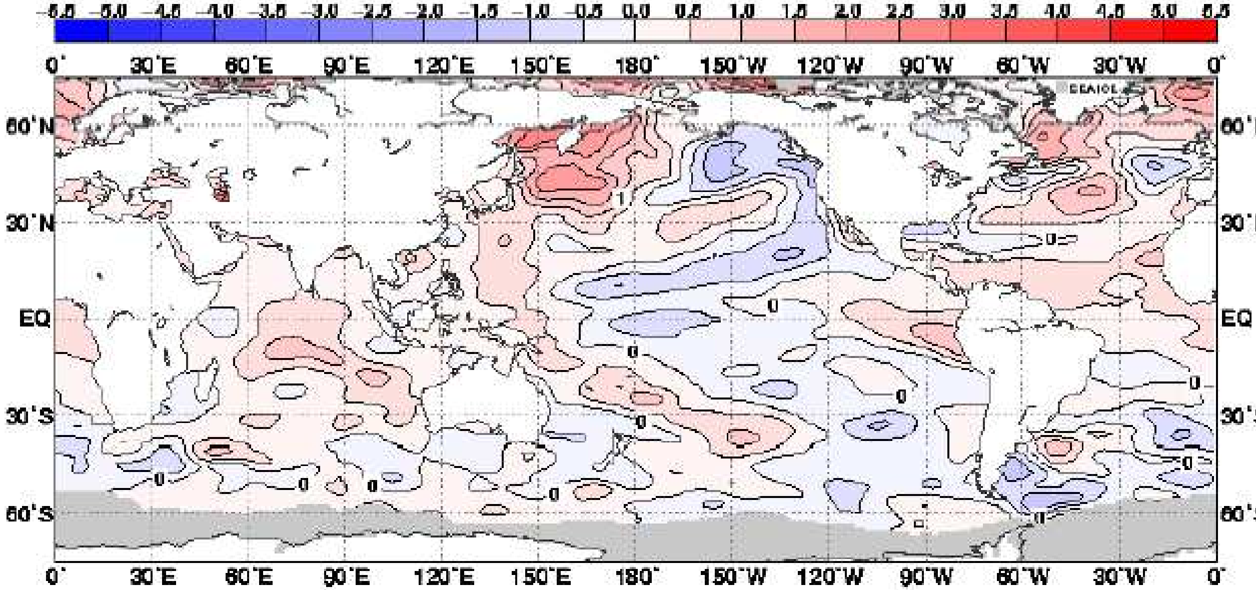

Fig. 9 Monthly mean sea surface temperature anomaly (September 2008)
Contour interval is 0.5 degree C. Base period for the normal is 1971-2000. Maximum coverage with sea ice is shaded in gray.

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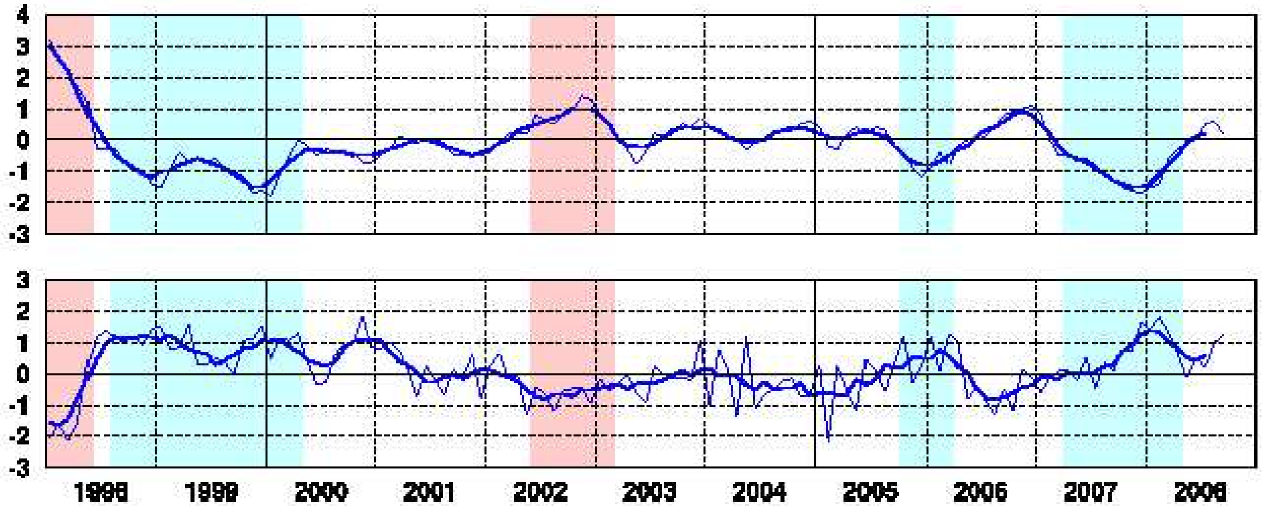

Fig. 10 Time series of monthly mean SST departure (degree C) from the reference value defined as the immediate past 30-year mean SST, averaged over the NINO.3 region (upper). Time series of the Southern Oscillation Index with respect to the 1971-2000 base period (lower).
Thin blue lines represent monthly means, and thick blue lines 5-month running means. Periods of El Niño and La Niña events are shown as red-colored and blue-colored boxes, respectively.

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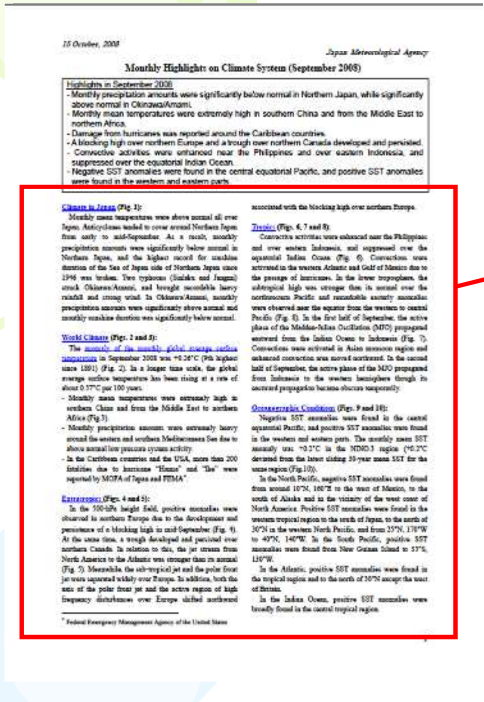

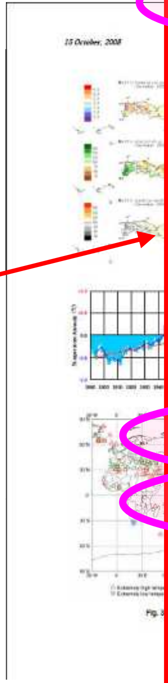

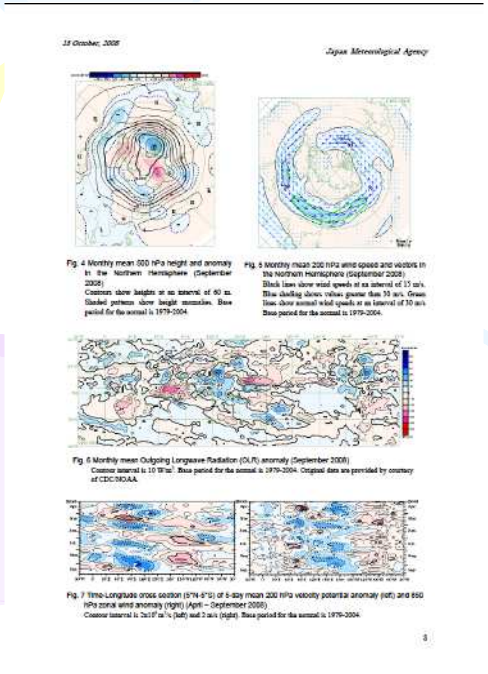

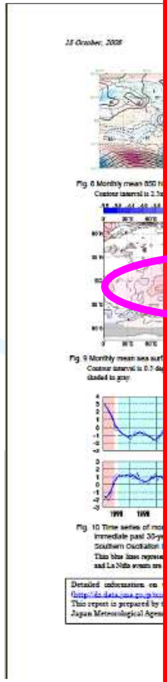

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Monthly mean temperatures were above normal all over Japan. Anticyclones tended to cover around Northern Japan from early to mid-September. As a result, monthly precipitation amounts were significantly below normal in Northern Japan, and the highest record for sunshine duration of the Sea of Japan side of Northern Japan since 1946 was broken. Two typhoons (Sinlaku and Jangmi) struck Okinawa/Amami, and brought recordable heavy rainfall and strong wind. In Okinawa/Amami, monthly precipitation amounts were significantly above normal and monthly sunshine duration was significantly below normal.

World Climate (Figs. 2 and 3):

The anomaly of the monthly global average surface temperature in September 2008 was +0.26°C (9th highest since 1891) (Fig. 2). In a longer time scale, the global average surface temperature has been rising at a rate of about 0.57°C per 100 years.

- Monthly mean temperatures were extremely high in southern China and from the Middle East to northern Africa (Fig.3).
- Monthly precipitation amounts were extremely heavy around the eastern and southern Mediterranean Sea due to above normal low pressure system activity.
- In the Caribbean countries and the USA, more than 200 fatalities due to hurricane "Hanna" and "Ike" were reported by MOFA of Japan and FEMA*.

Extratropics (Figs. 4 and 5):

In the 500-hPa height field, positive anomalies were observed in northern Europe due to the development and persistence of a blocking high in mid-September (Fig. 4). At the same time, a trough developed and persisted over northern Canada. In relation to this, the jet stream from North America to the Atlantic was stronger than its normal (Fig. 5). Meanwhile, the sub-tropical jet and the polar front jet were separated widely over Europe. In addition, both the axis of the polar front jet and the active region of high frequency disturbances over Europe shifted northward associated with the blocking high over northern Europe.

Tropics (Figs. 6, 7 and 8):

Convective activities were enhanced near the Philippines and over eastern Indonesia, and suppressed over the equatorial Indian Ocean (Fig. 6). Convections were activated in the western Atlantic and Gulf of Mexico due to the passage of hurricanes. In the lower troposphere, the subtropical high was stronger than its normal over the northwestern Pacific and remarkable easterly anomalies were observed near the equator from the western to central Pacific (Fig. 8). In the first half of September, the active phase of the Madden-Julian Oscillation (MJO) propagated eastward from the Indian Ocean to Indonesia (Fig. 7). Convections were activated in Asian monsoon region and enhanced convection area moved northward. In the second half of September, the active phase of the MJO propagated from Indonesia to the western hemisphere though its eastward propagation became obscure temporarily.

Oceanographic Conditions (Figs. 9 and 10):

Negative SST anomalies were found in the central equatorial Pacific, and positive SST anomalies were found in the western and eastern parts. The monthly mean SST anomaly was +0.2°C in the NINO.3 region (+0.2°C deviated from the latest sliding 30-year mean SST for the same region (Fig.10)).

In the North Pacific, negative SST anomalies were found from around 10°N, 160°E to the west of Mexico, to the south of Alaska and in the vicinity of the west coast of North America. Positive SST anomalies were found in the western tropical region to the south of Japan, to the north of 30°N in the western North Pacific, and from 25°N, 170°W to 40°N, 140°W. In the South Pacific, positive SST anomalies were found from New Guinea Island to 35°S, 130°W.

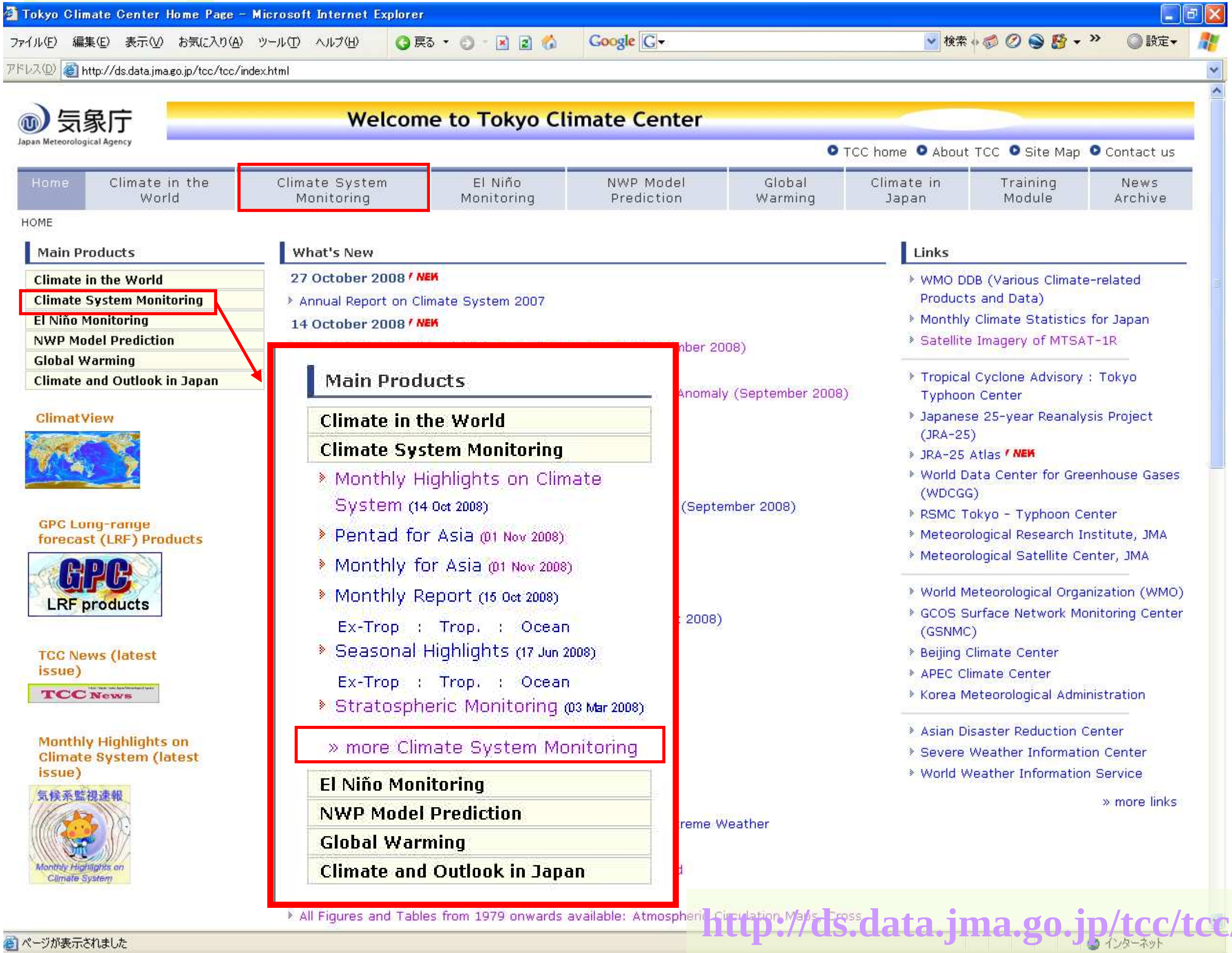
In the Atlantic, positive SST anomalies were found in the tropical region and to the north of 30°N except the west of Britain.

In the Indian Ocean, positive SST anomalies were broadly found in the central tropical region.

* Federal Emergency Management Agency of the United States

2. Report on Climate System

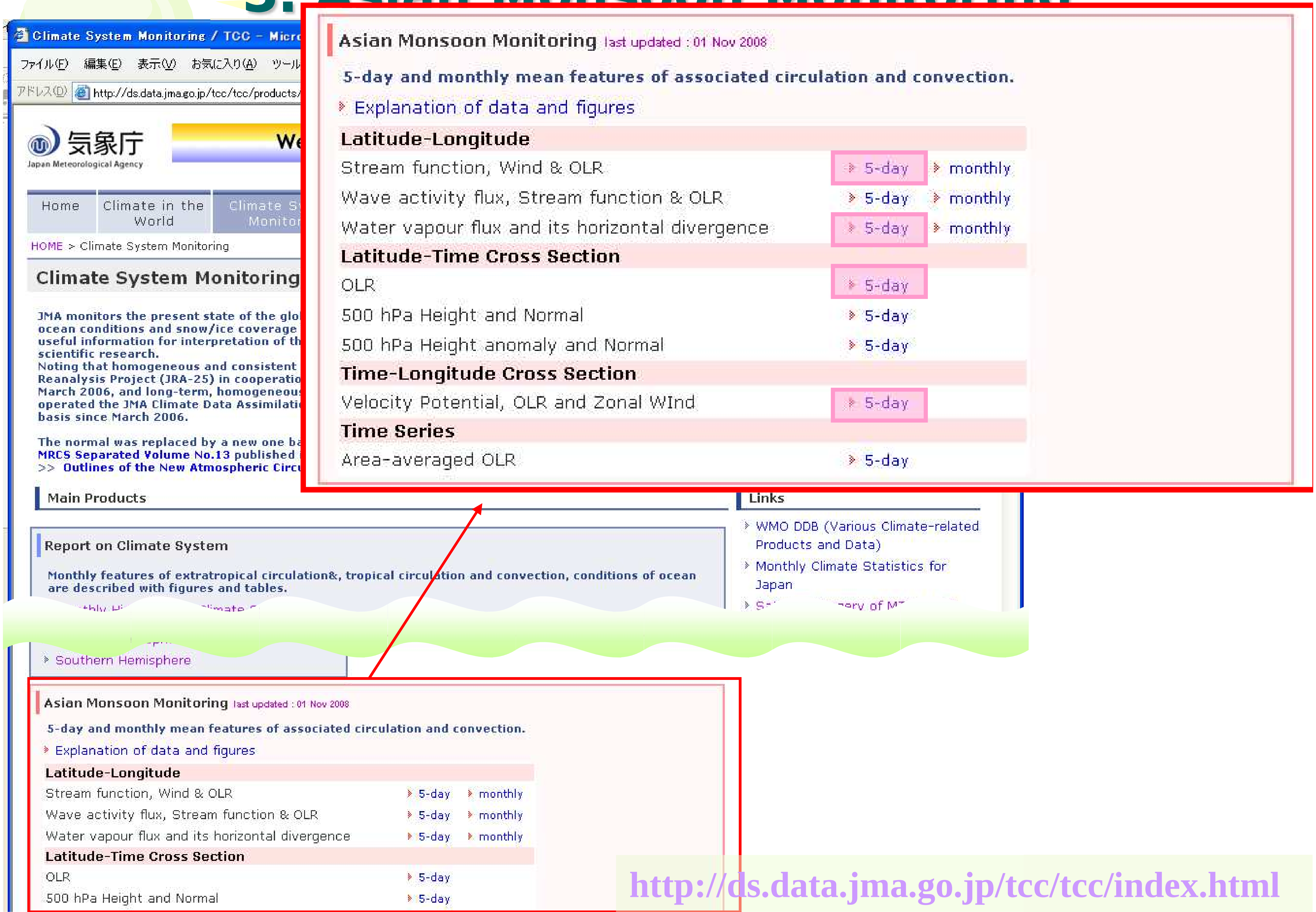
2. Report on Climate System



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

3. Asian monsoon monitoring

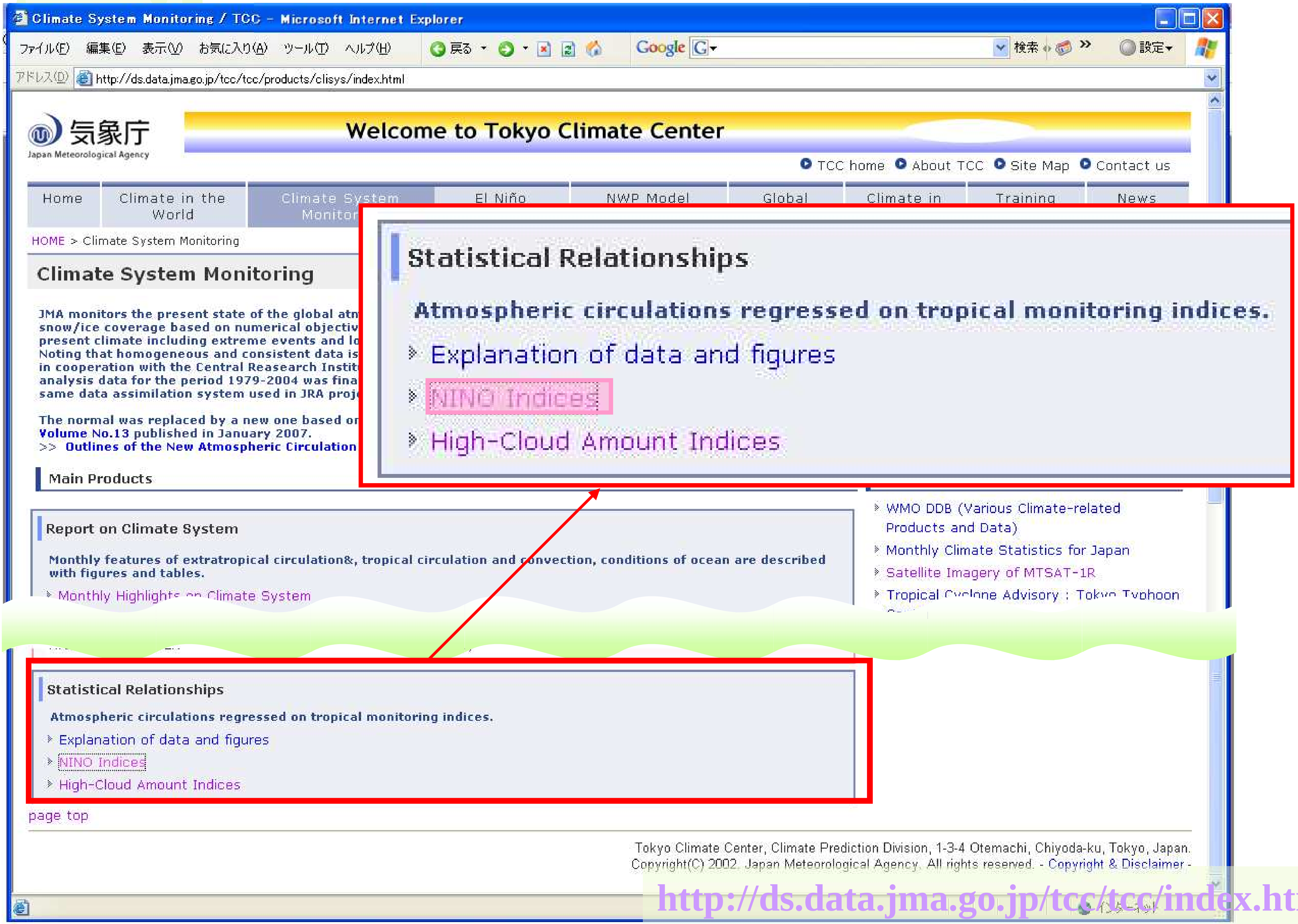
3. Asian Monsoon Monitoring



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

4. Statistical Relationships

4. Statistical Relationships



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

Introduction of
CPD's Climate Diagnostics Meeting

1. Outline of CPD's Climate Diagnostics Meeting

When? Around 8th every month

Who? Members of CPD/JMA

Members of Extreme Climate Events Diagnostics Group

Report and discuss about

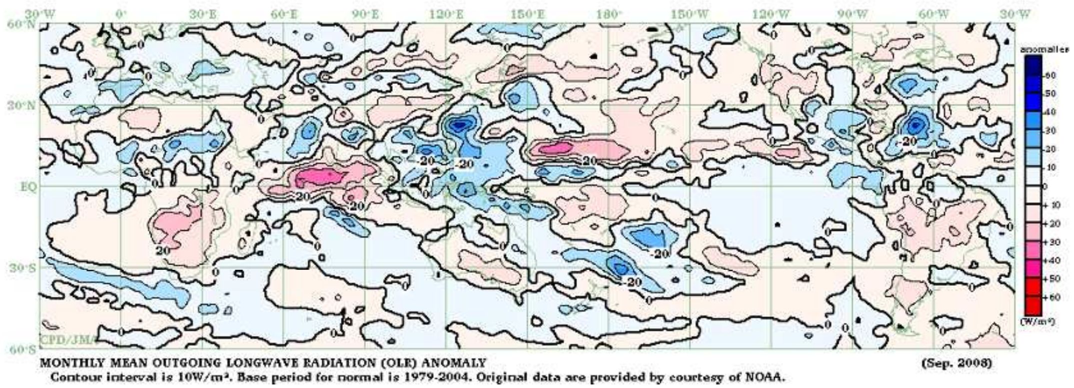
- **Climate in Japan**
- **World Climate**
- **Oceanographic conditions**
- **Tropics**
- **Extra-tropics**

Update Monthly highlights on Climate System on TCC Web Site at around the middle of every month !

2. Report on the tropical convection and large scale circulation in September

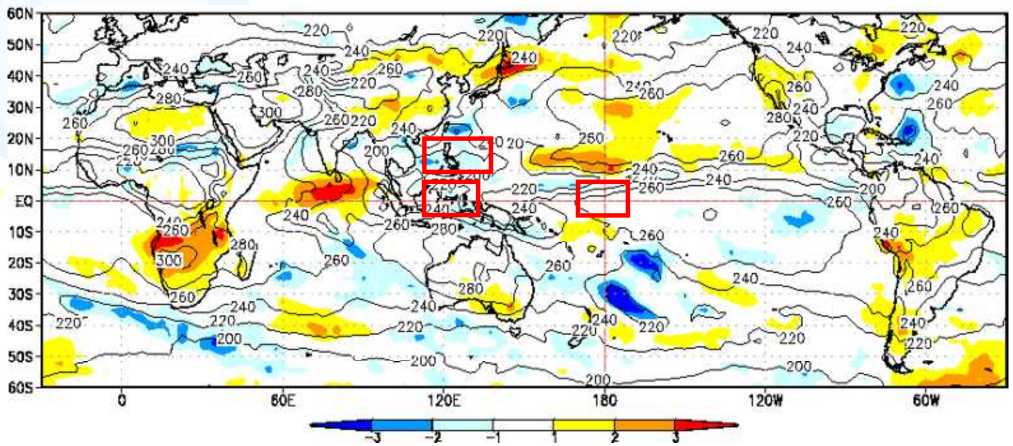
Climate Prediction Division, JMA

Outgoing Longwave Radiation



OLR anomaly

Convective activities were enhanced around Philippines and over eastern Maritime Continent, and suppressed over Indian Ocean. Enhanced convections were also observed over western Atlantic, Gulf of Mexico and eastern Pacific. Suppressed ones were observed over 10ºN-20ºN zone in Pacific.

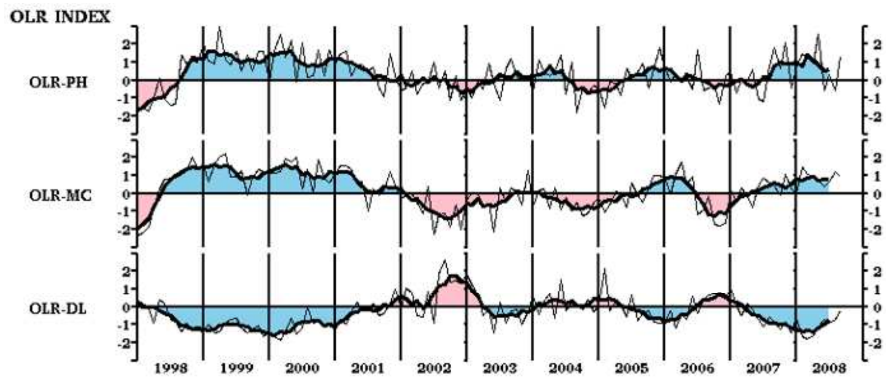


OLR (contours) and normalized OLR anomaly (shadings)

Tropical disturbances

Western Pacific: Typhoon 13, 14, 15th

Atlantic: Hurricane "IKE", "KYLE"

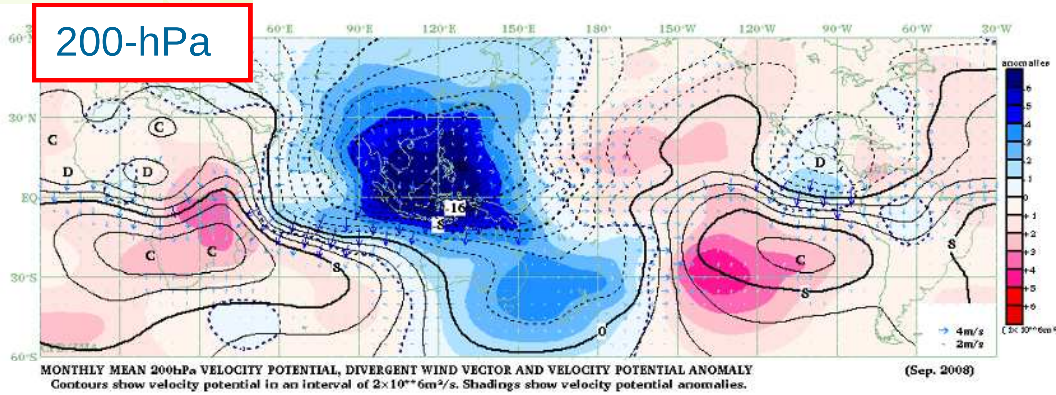


Time series of OLR index (1998-)

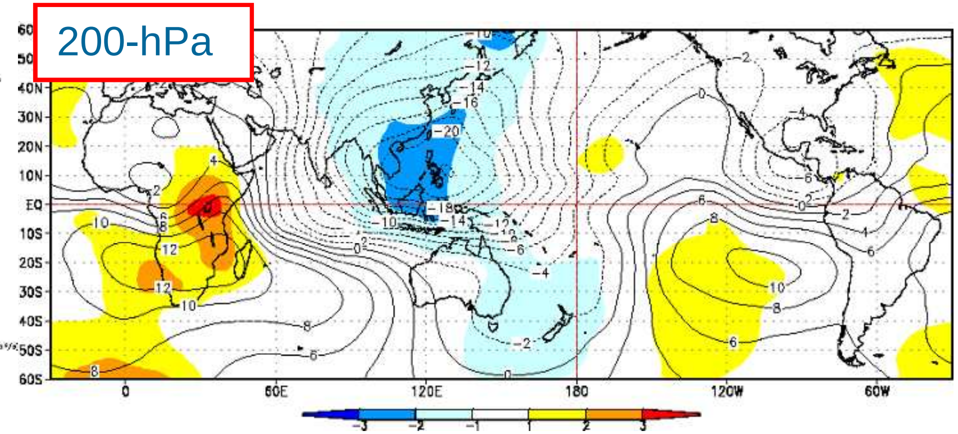
OLR-PH: +1.2 (-0.6)
OLR-MC: +0.8 (+1.2)
OLR-DL: -0.3 (-0.7)

SAMOI_A: +0.7 (-1.0)
SAMOI_N: +0.8 (+0.5)
SAMOI_W: -1.7 (+0.2)

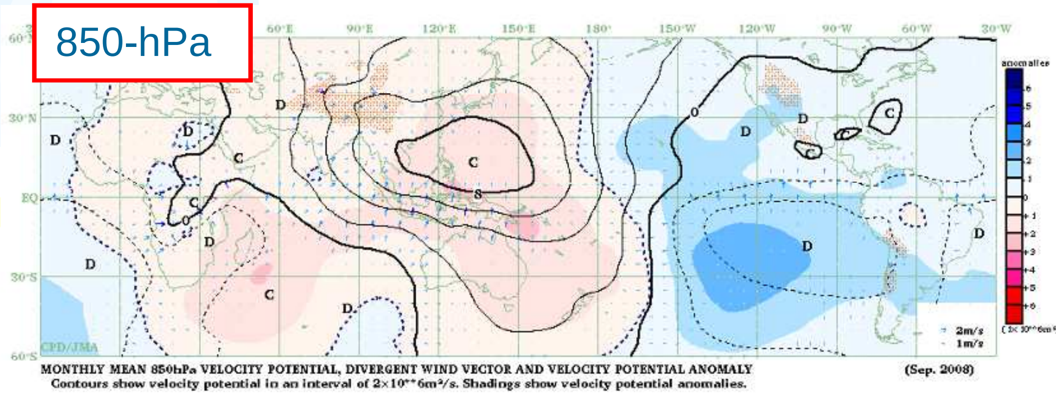
Velocity Potential



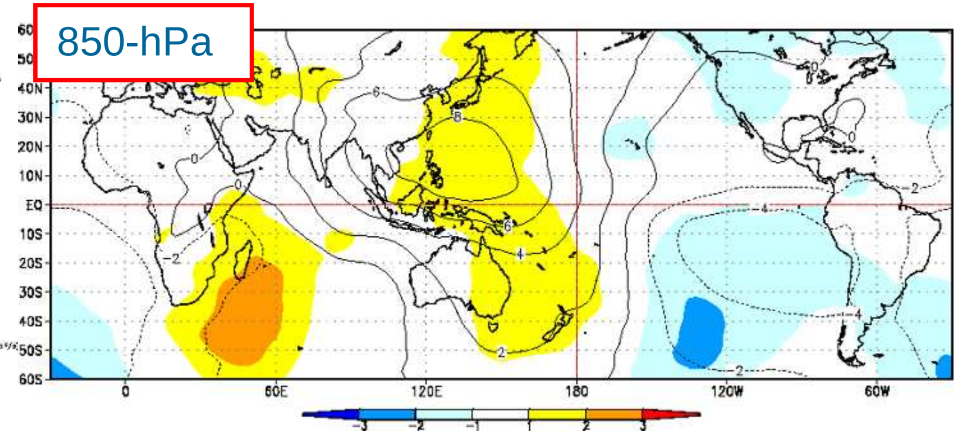
200-hPa velocity potential (contours) and velocity potential anomaly (shadings)



200-hPa velocity potential (contours) and normalized velocity potential anomaly (shadings)



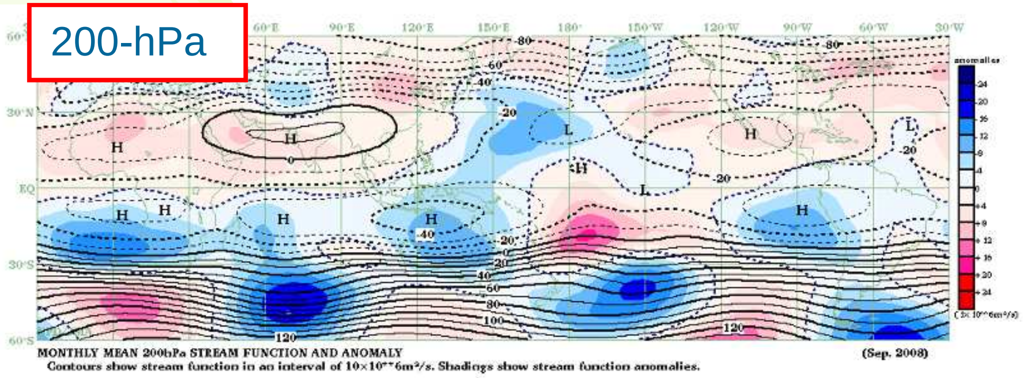
850-hPa velocity potential (contours) and velocity potential anomaly (shadings)



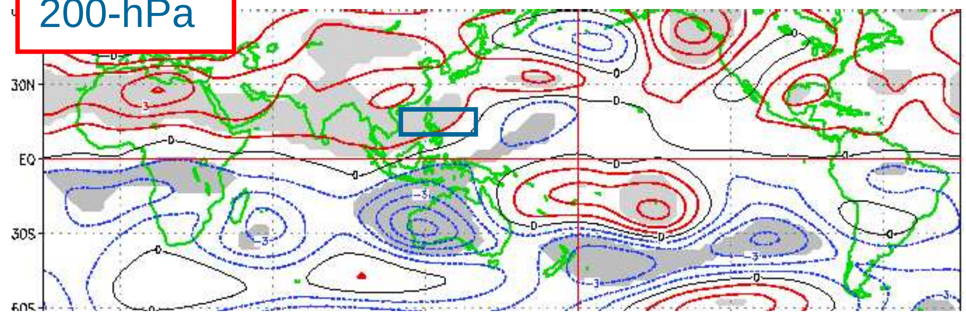
850-hPa velocity potential (contours) and normalized velocity potential anomaly (shadings)

In the upper troposphere, center of large scale divergent region was located over Philippines and shifted westward from its normal position. Divergent region was also observed over eastern Pacific.

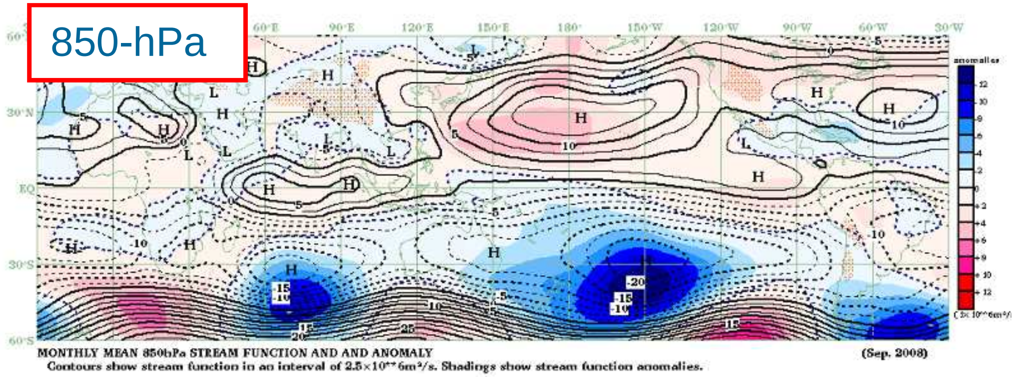
Stream Function



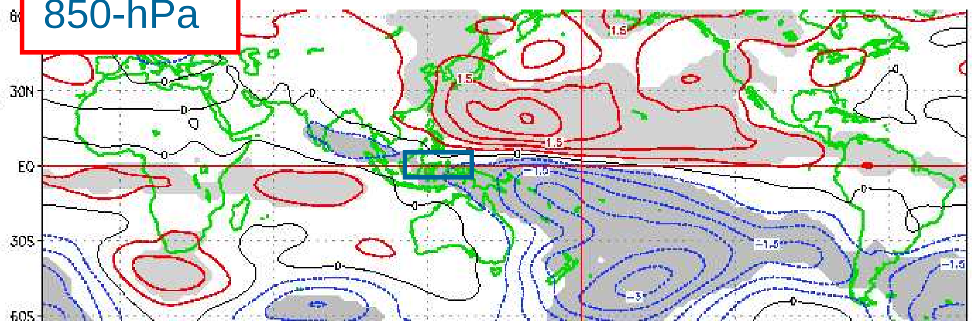
200-hPa stream function (contours) and stream function anomaly (shadings)



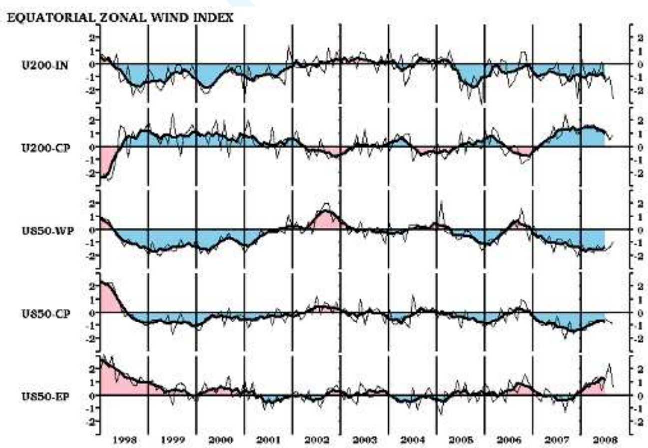
Regression coefficients between OLR-PH and Psi200 (Sep.)



850-hPa stream function (contours) and stream function anomaly (shadings)



Regression coefficients between OLR-MC and Psi850 (Sep.)



Time series of zonal wind index (1998-)

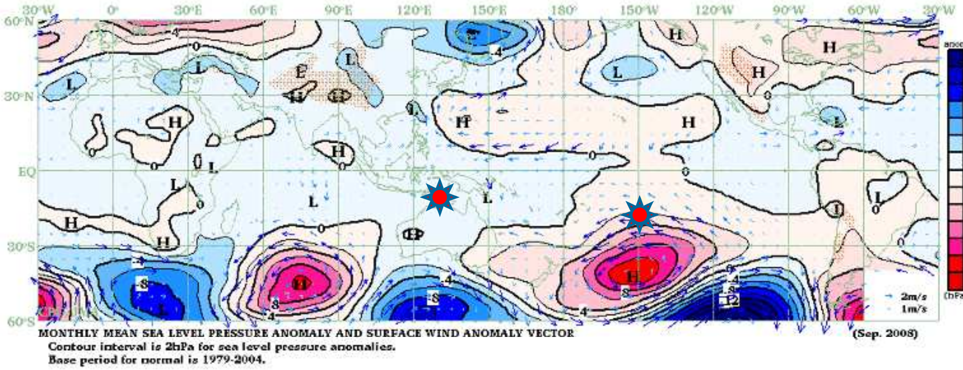
U200-IN: -2.7 (-1.0)
U200-CP: +0.9 (+0.5)

U850-WP: -0.9 (-1.4)
U850-CP: -0.9 (-0.7)
U850-EP: +0.6 (+2.4)

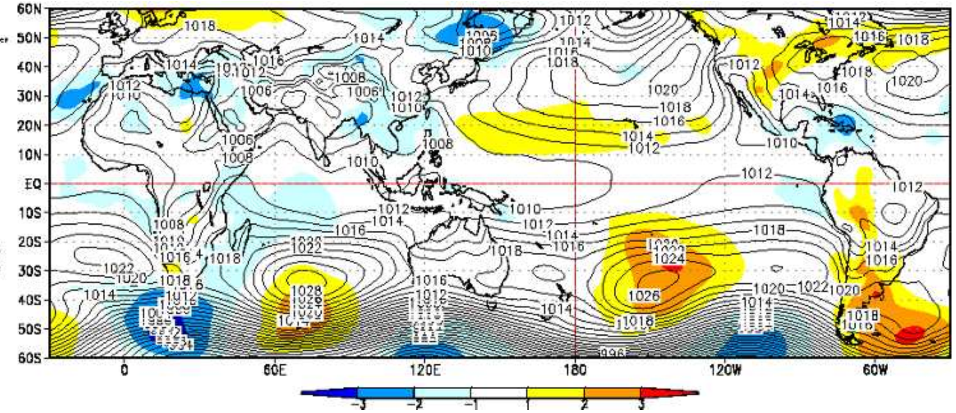
In the upper troposphere, remarkable anti-cyclonic circulation anomalies were observed in northern hemisphere side over Indian Ocean.

In the lower troposphere, Pacific subtropical high was stronger than its normal, especially remarkable over from the south from Japan to 150ºW.

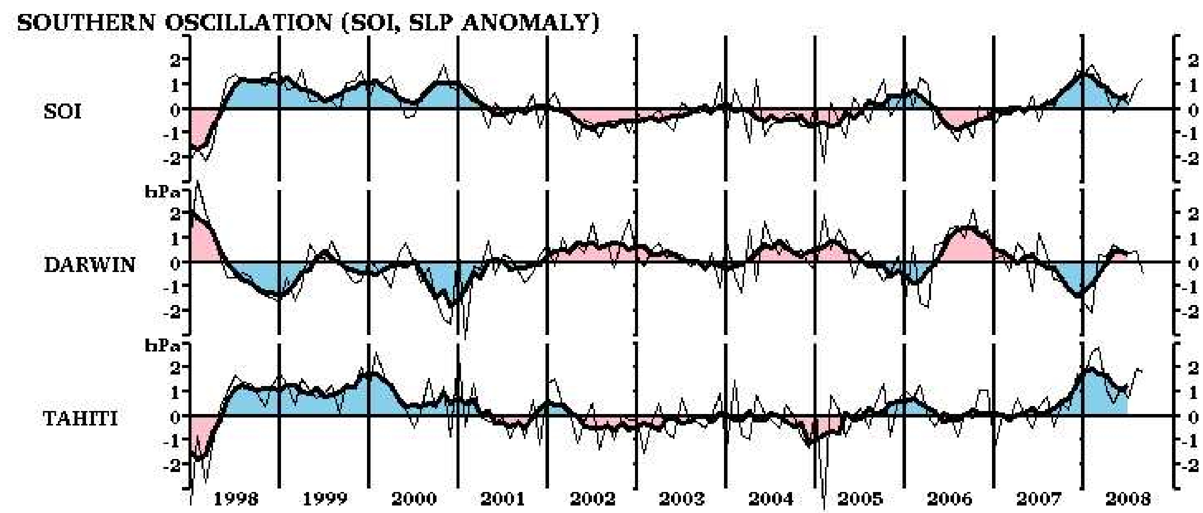
Sea Level Pressure and Southern Oscillation Index (SOI)



Sea level pressure anomalies (contours) and 10-m surface wind anomalies (vector)



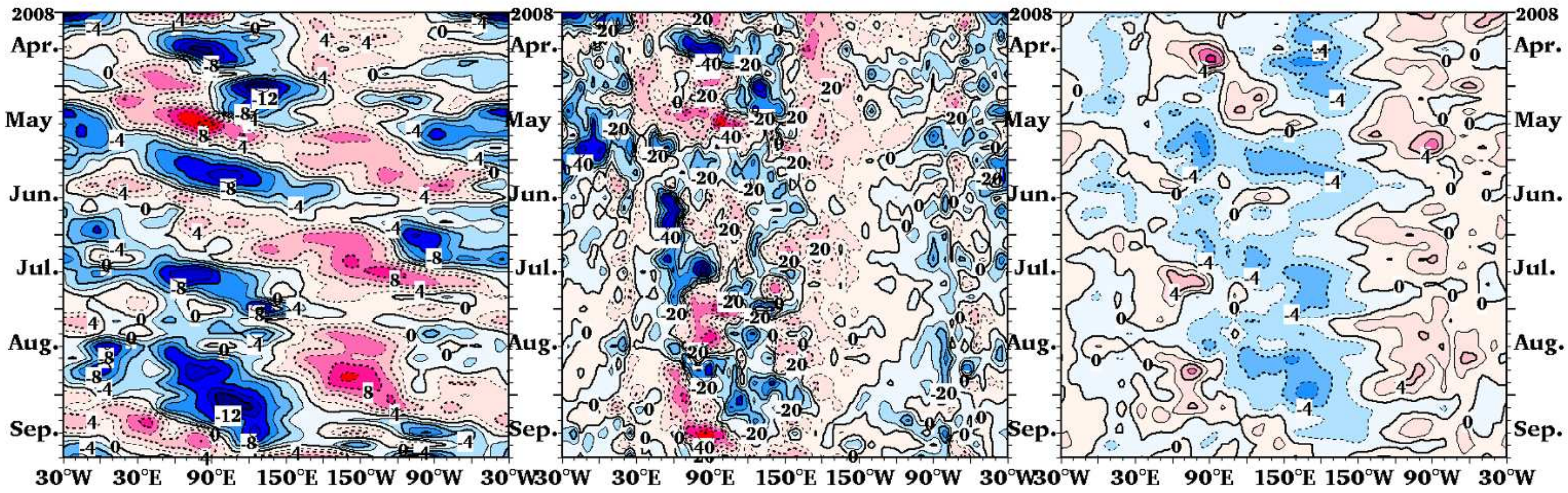
Sea level pressure (contours) and normalized sea level pressure anomalies (shadings)



Time series of SOI, SLP anomaly (1998-)

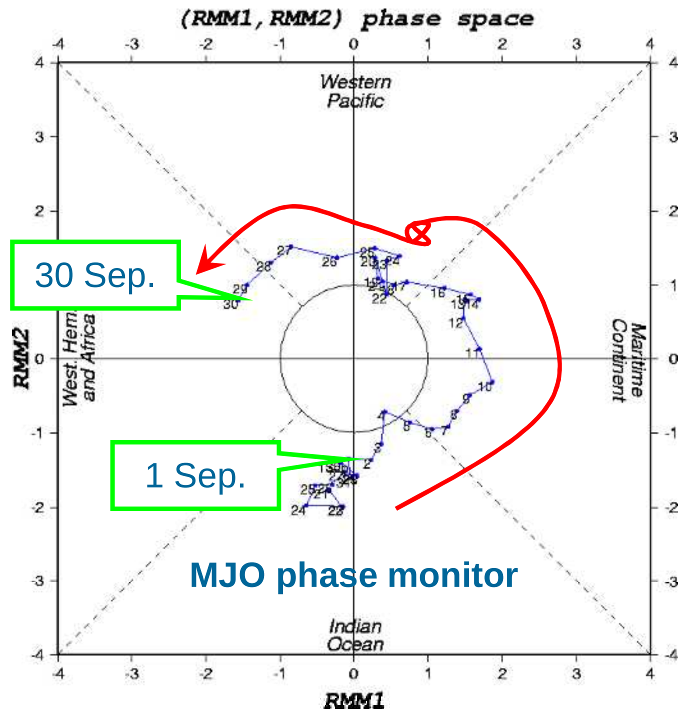
SOI: +1.2 (+1.1)
Darwin: -0.4 (+0.3) hPa
Tahiti: +1.8 (+2.0) hPa

Madden-Julian Oscillation (MJO)

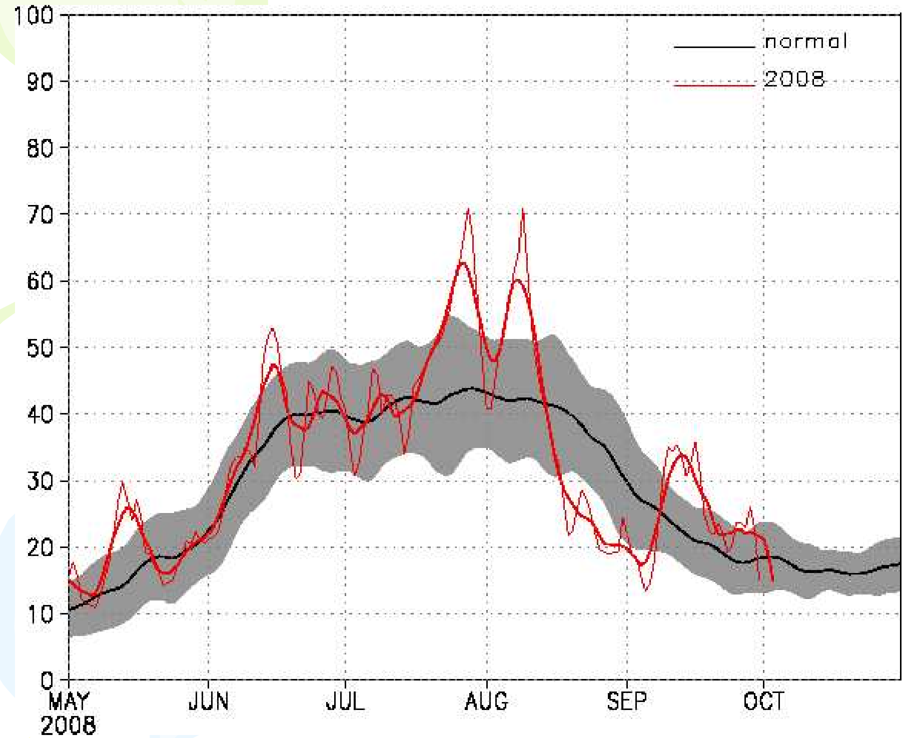


Hovmöller diagram of 200-hPa velocity potential anomalies (left), OLR anomalies (center) and 850-hPa zonal wind anomalies (right) (5ºS-5ºN averaged)

In early and mid-September, active phase of MJO clearly propagated eastward from Indian Ocean to Maritime Continent and 200-hPa velocity potential anomalies indicated zonal wave number 1 pattern. The eastward propagation temporarily became obscure over western Pacific.



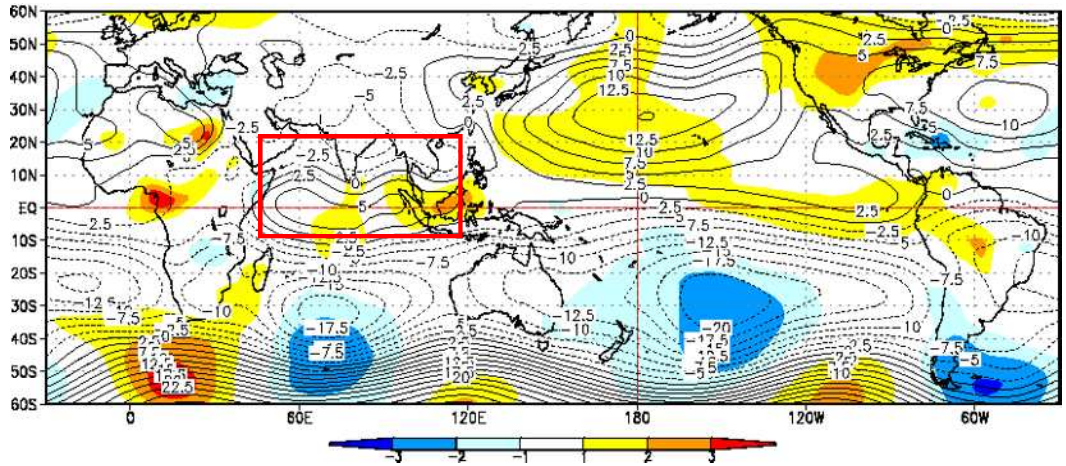
Asian Summer Monsoon



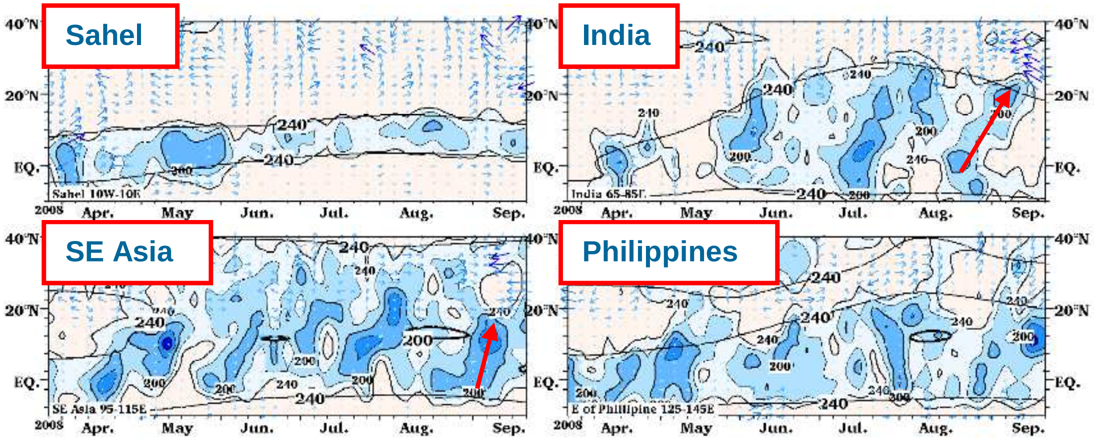
Kinetic energy calculated by 850-hPa rotational wind (unit: m^2/s^2)

The region for calculation is 10ºS-20ºN, 50ºE-120ºE. Thin red lines show daily value and thick red line shows 7-day running mean value. Shading indicates the standard deviation ±1.0.

Original by Masashi Ujiie (2006)



The region for calculation of Kinetic energy (red line rectangular area)

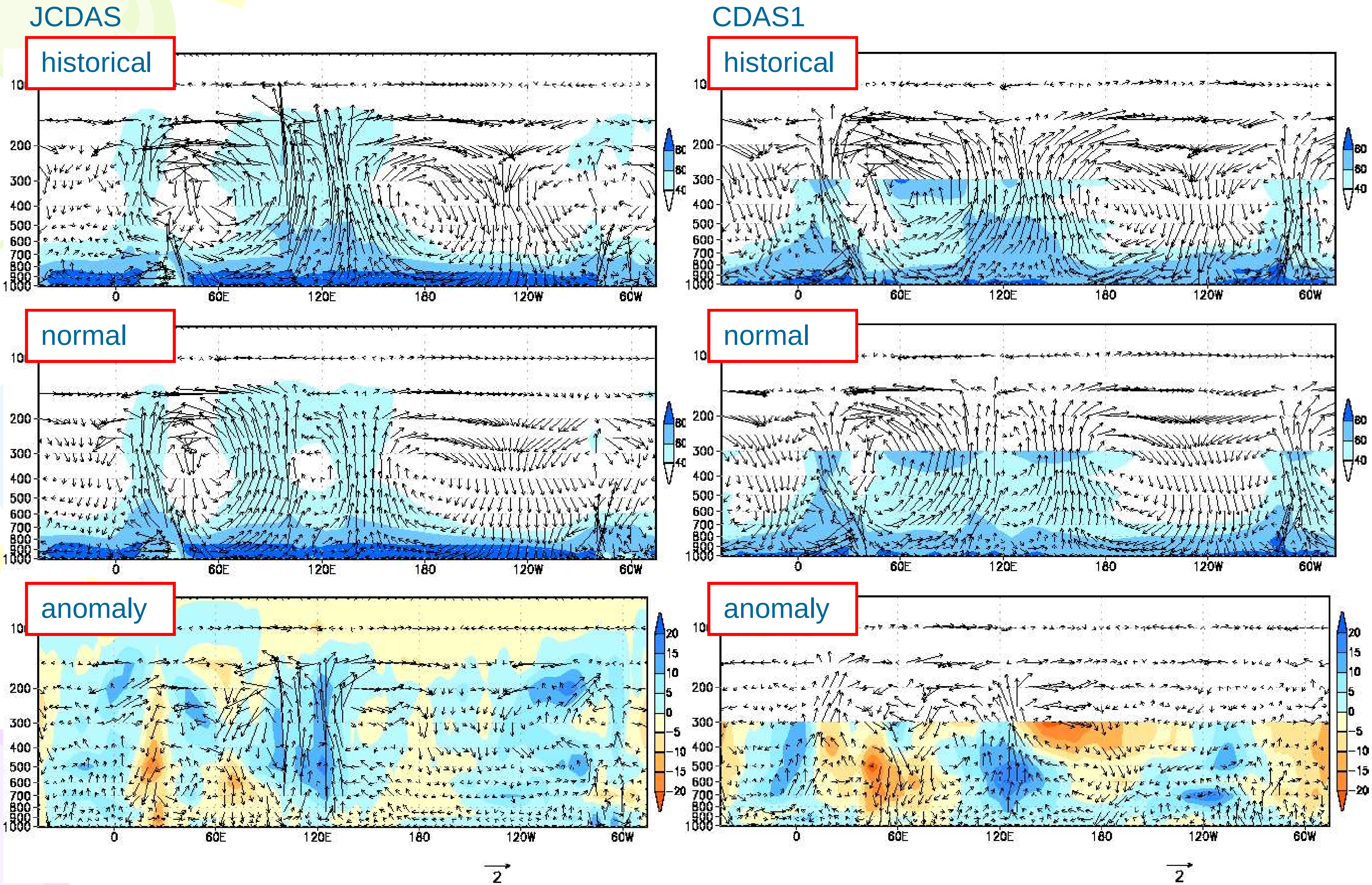


Latitude-time cross sections of OLR (shadings) and normal OLR (contours)

From the second half of August to early September, Asian monsoon circulation in the lower troposphere was weaker than normal, and supply of water vapor to the Asian monsoon region was less than normal. Convective activities were suppressed from Bay of Bengal to South China Sea and east of Philippines.

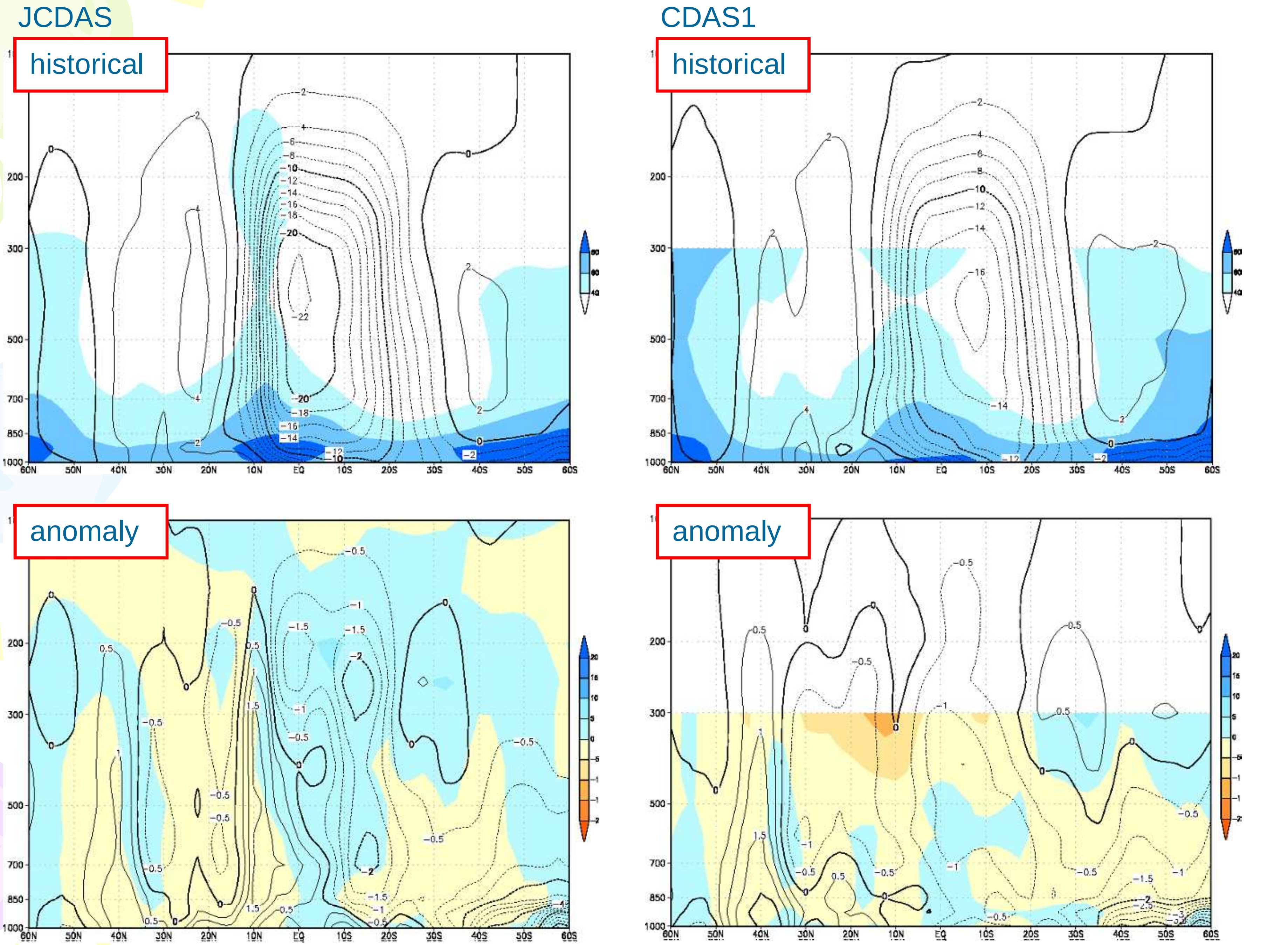
In mid-September, the monsoon circulation was strengthened associated with the passage of active phase of the MJO. Enhanced convective area moved northward in the Asian monsoon region, and convective activities were suppressed over Indian Ocean.

Walker Circulation (5ºS-5ºN mean)



Relative humidity (shadings), divergent zonal wind (m/s) and vertical velocity (×50*Pa/s) (vectors)

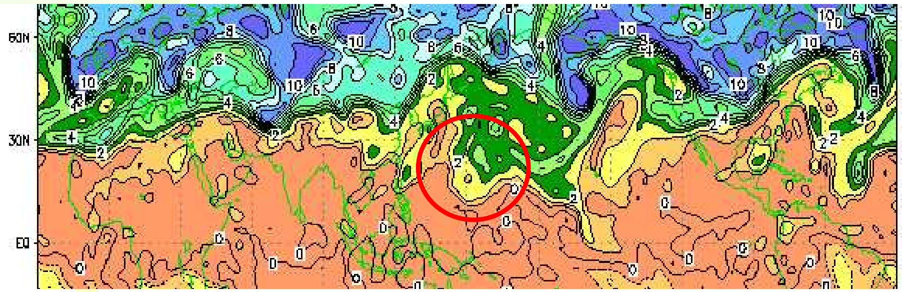
Hadley Circulation



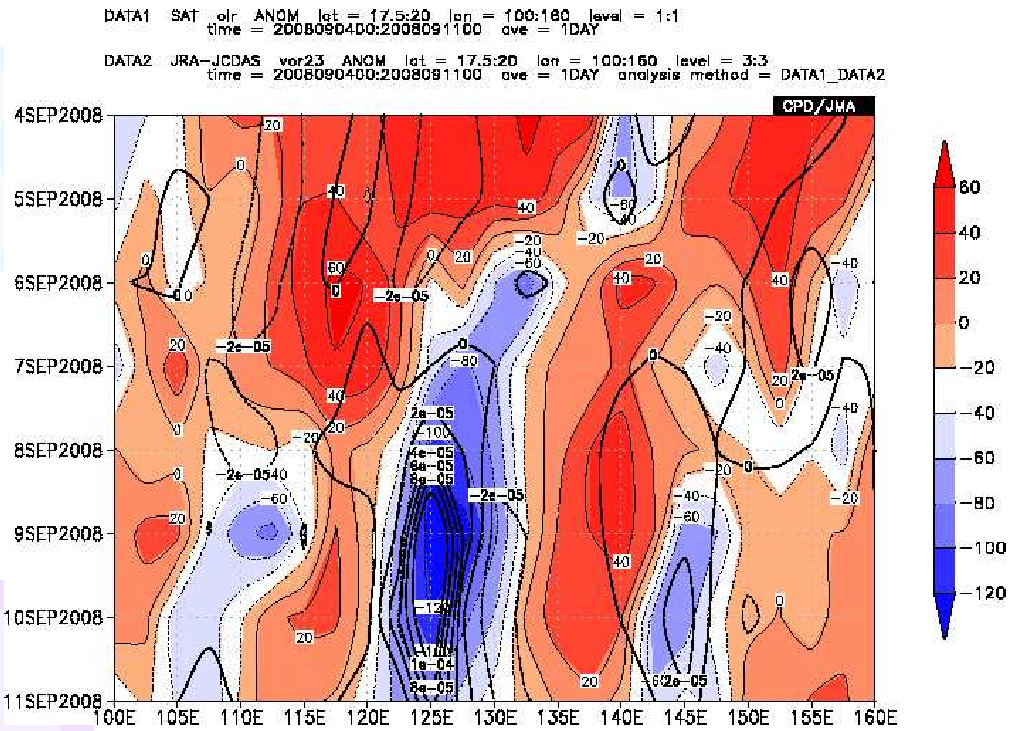
TEM stream function (× 10^{10} kg/s, contours) and relative humidity (shadings)

Tropical Disturbances

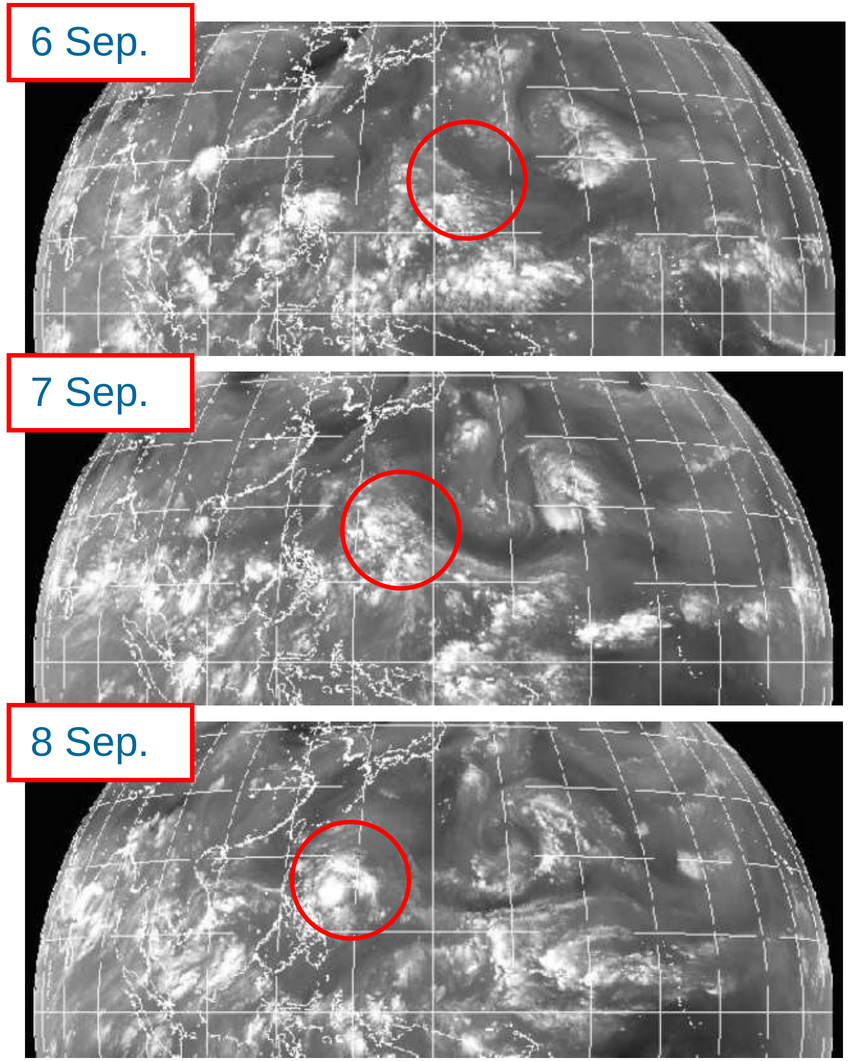
Typhoon 13th "SINLAKU" (8-20 Sep.)



Q-map at 350 K (00 UTC 6 Sep.)



Time-longitude cross section of 850-hPa relative vorticity anomaly (contours) and OLR anomaly (shadings) (17.5ºN-20ºN mean)

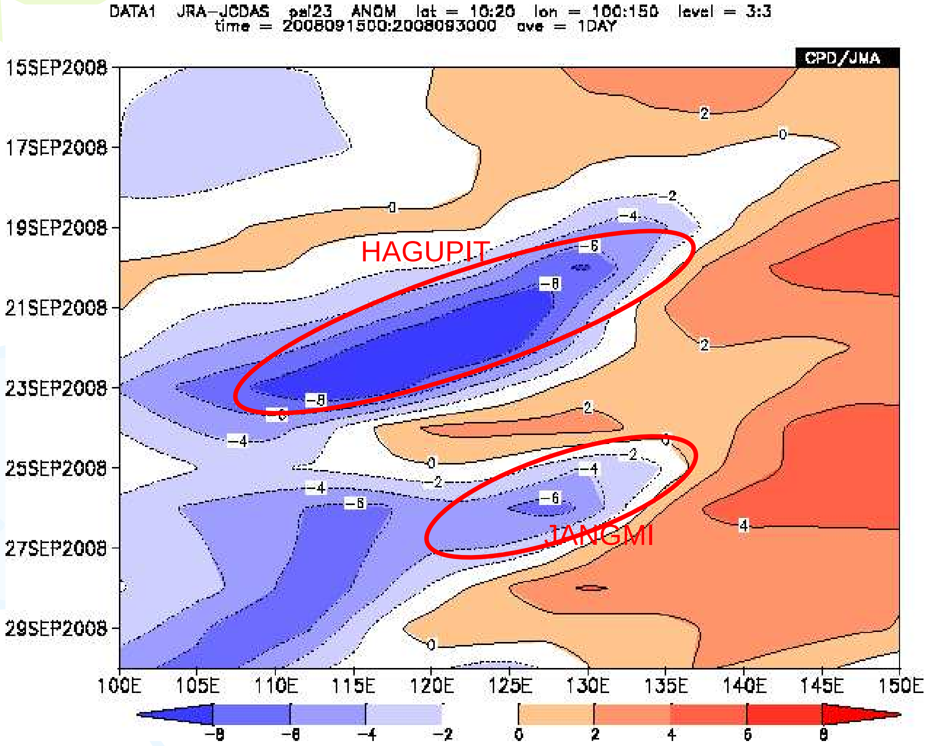


Satellite image of water vapor at 00 UTC

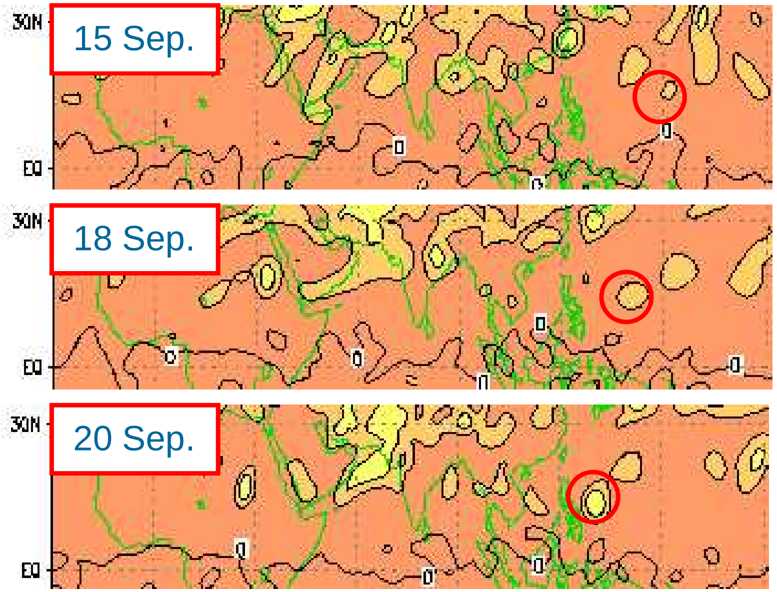
On 6 September, high potential vorticity moved southward from mid-latitude zone in the upper troposphere and activated convective activity there. The active convection propagated westward and developed into Typhoon 13th "SINLAKU".

Tropical Disturbances

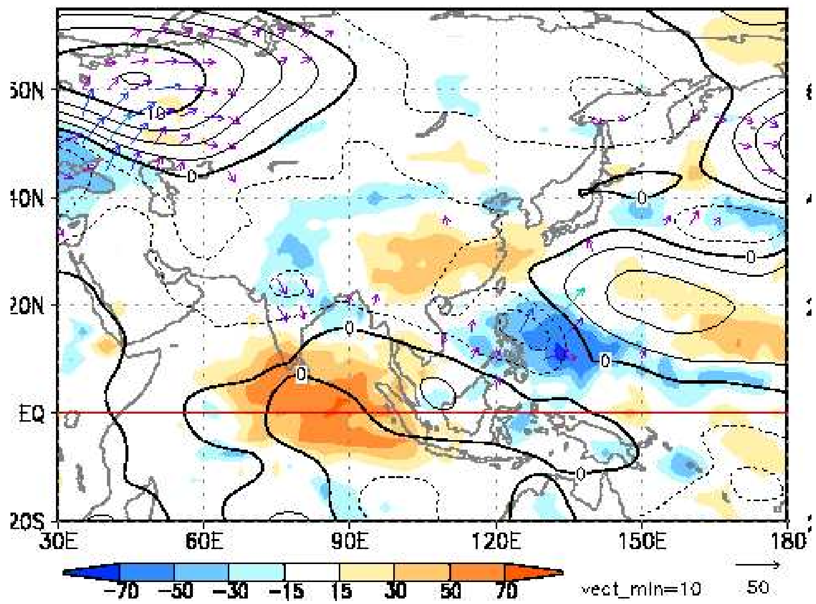
Typhoon 14th “HAGUPIT” (18-24 Sep.)



Time-longitude cross section of 850-hPa stream function anomaly (10ºN-20ºN mean)



Q-map at 330 K (00UTC)



850-hPa stream function anomaly (contours), OLR anomaly (shadings) and wave activity flux (vectors) (18-22 Sep.)

Vorticity, which moved westward in 15ºN-20ºN zone, developed into typhoon 14th “HAGPIT”. Cyclonic circulation anomaly associated with the typhoon emanated quasi-stationary Rossby wave packets to the northeast and strengthened anti-cyclonic anomaly over the south of Japan.

Summary

In the first half of September, active phase of MJO propagated from Indian Ocean to Maritime Continent. Asian monsoon activity was activated by the passage of active phase of MJO. Active convection area moved northward over Asian monsoon region and convective activities were suppressed over equatorial Indian Ocean.

In the equatorial lower troposphere, remarkable eastern wind anomalies were observed from western to central Pacific.

In the second half of September, the Active phase of MJO propagated from Maritime Continent to western Pacific, though its eastward propagation became obscure temporarily.

3. Report on the extra-tropical atmospheric circulation in September 2008

Climate Prediction Division, JMA

(PSI300 & WAF300)

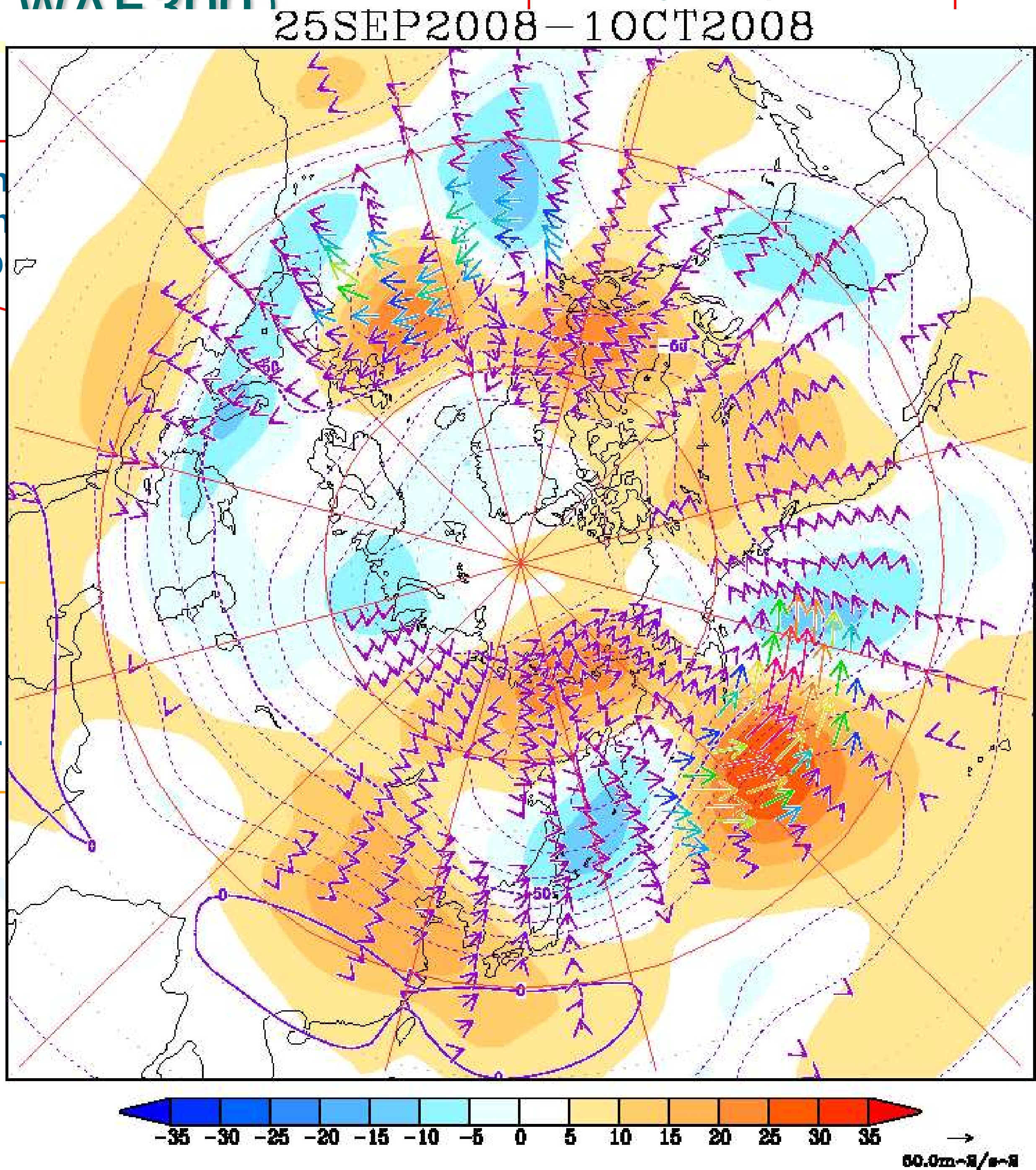
Trough deepened in

Blocking h
developed in
Septemb

developed in late
September

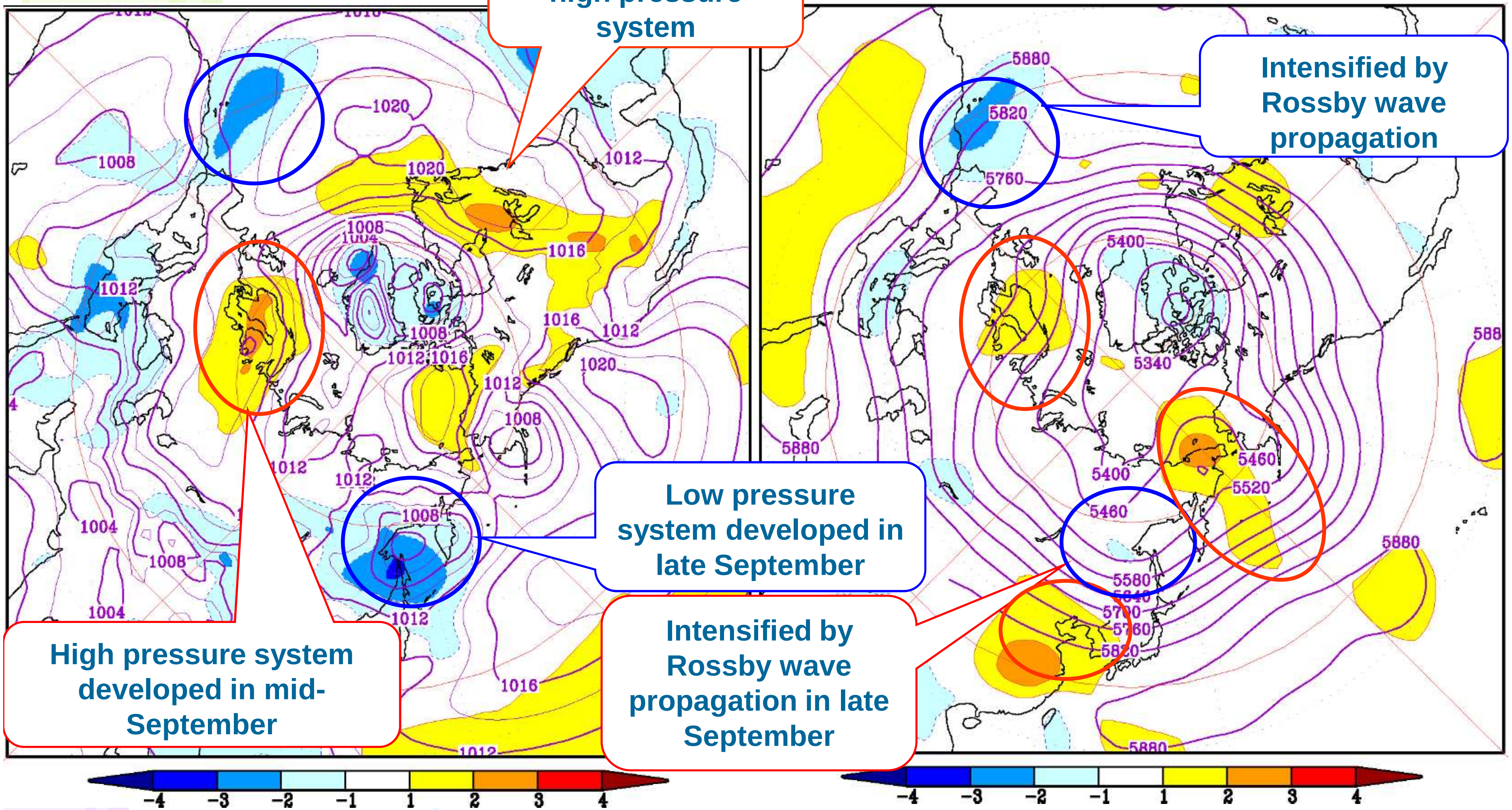
Rossby wave
pagation from early
o mid-September

Rossby wave
propagation
intensified Ridge
in late September



Monthly mean 300-hPa stream function, its anomalies and wave activity flux in Sep. 2008.
Shadings show 300-hPa stream function anomalies. Contours show 300-hPa stream function at an interval of 10x10e6(m^2/s^2).

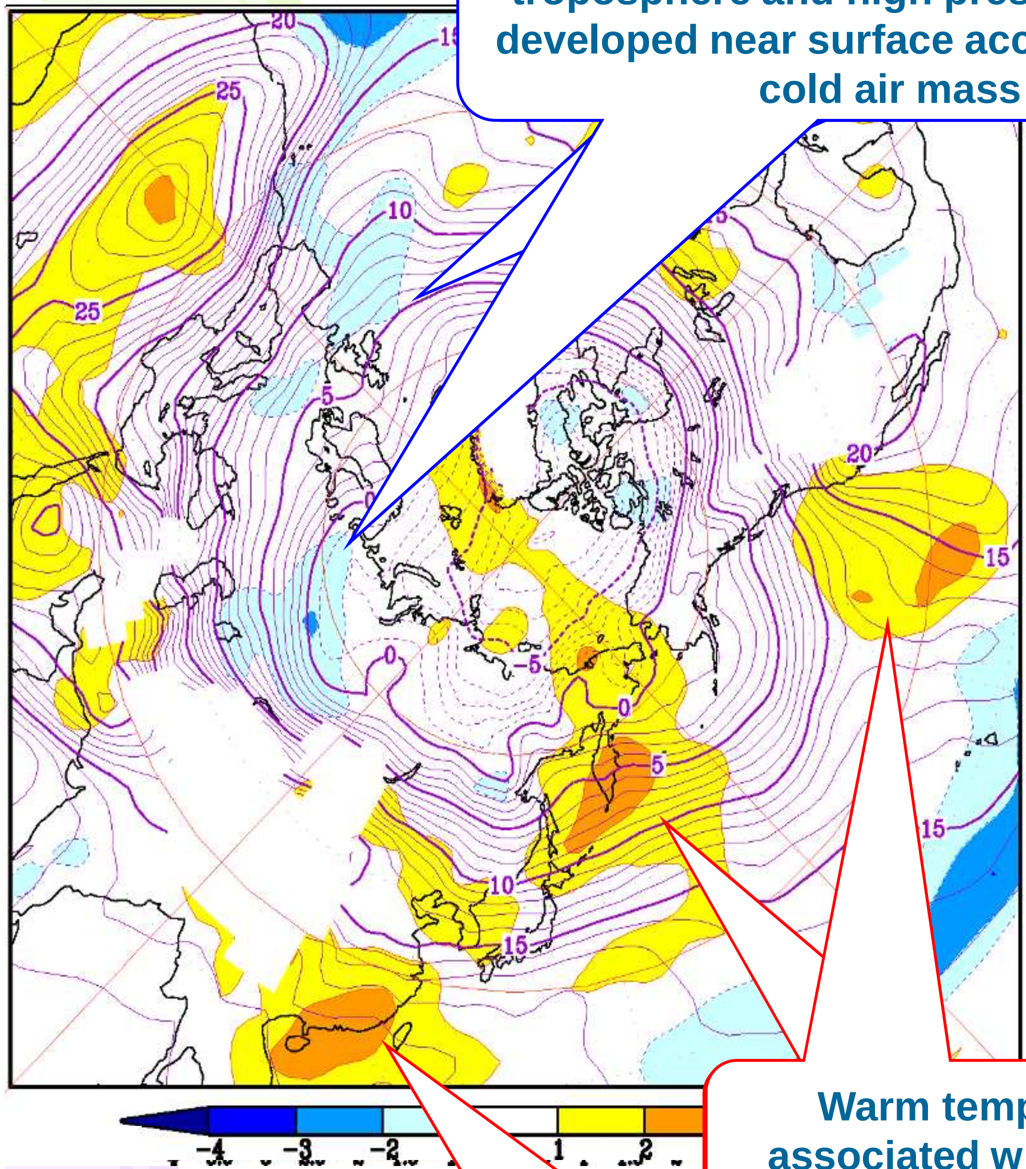
SLP、Z500



Monthly mean sea level pressure and its anomalies in Sep. 2008.
Shadings show sea level pressure anomalies. Contours show sea level pressure at an interval of 4-hPa.

Monthly mean 500-hPa height and its anomalies in Sep. 2008.
Shadings show 500-hPa height anomalies. Contours show 500hPa height at an interval of 60-m.

T850、SLP

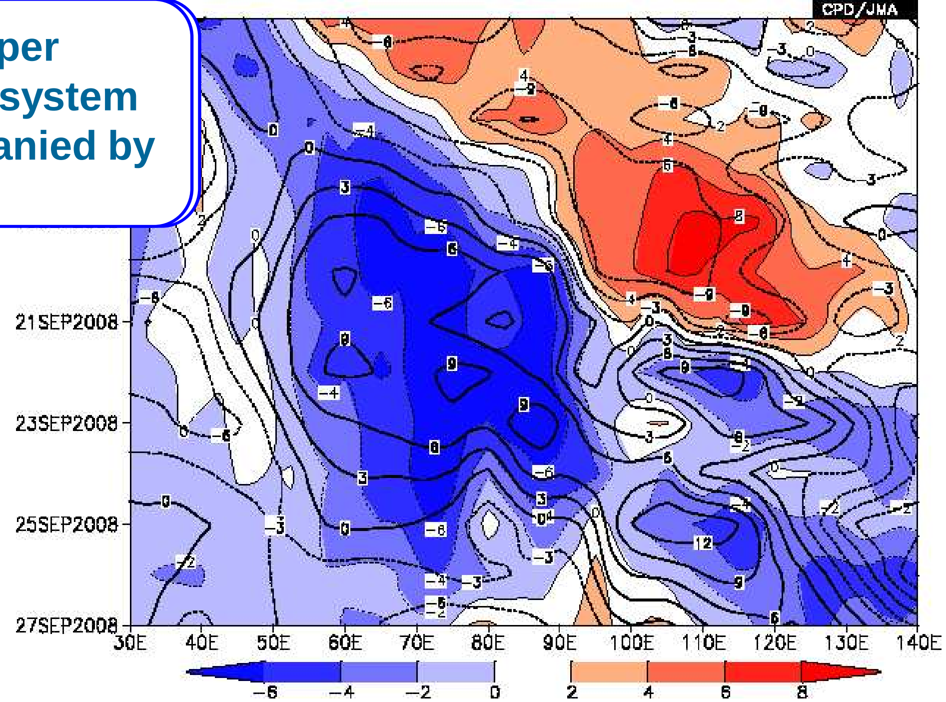


Trough developed in the upper troposphere and high pressure system developed near surface accompanied by cold air mass

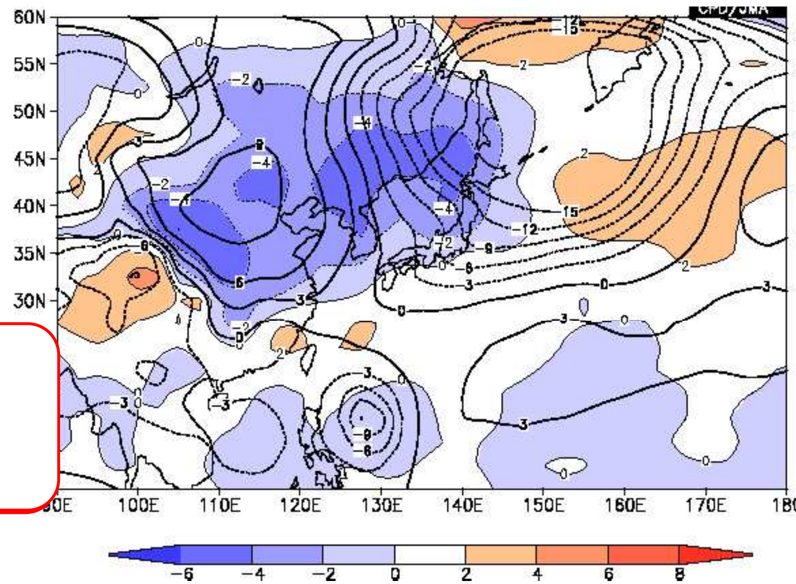
Warm temperature associated with Rossby wave propagations

Warm temperature associated with Rossby wave propagation in late September

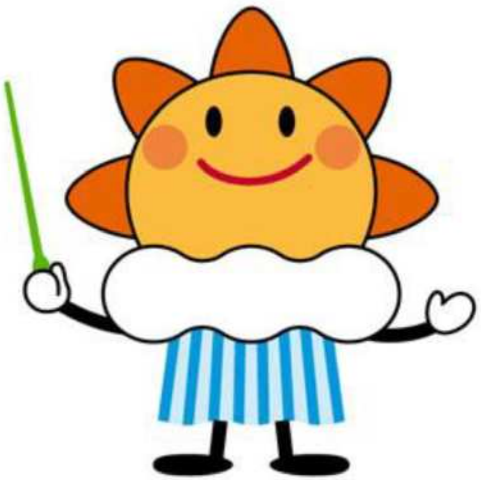
Monthly mean 850-hPa t... ture anomalies in Sep. 2008
Shadings show 850-hPa ...
850-hPa temperature at ...



Time-longitude cross section of sea level pressure anomaly (contours) and 2-m temperature anomaly (shadings) (along 45ºN). Contour interval is 3-hPa.



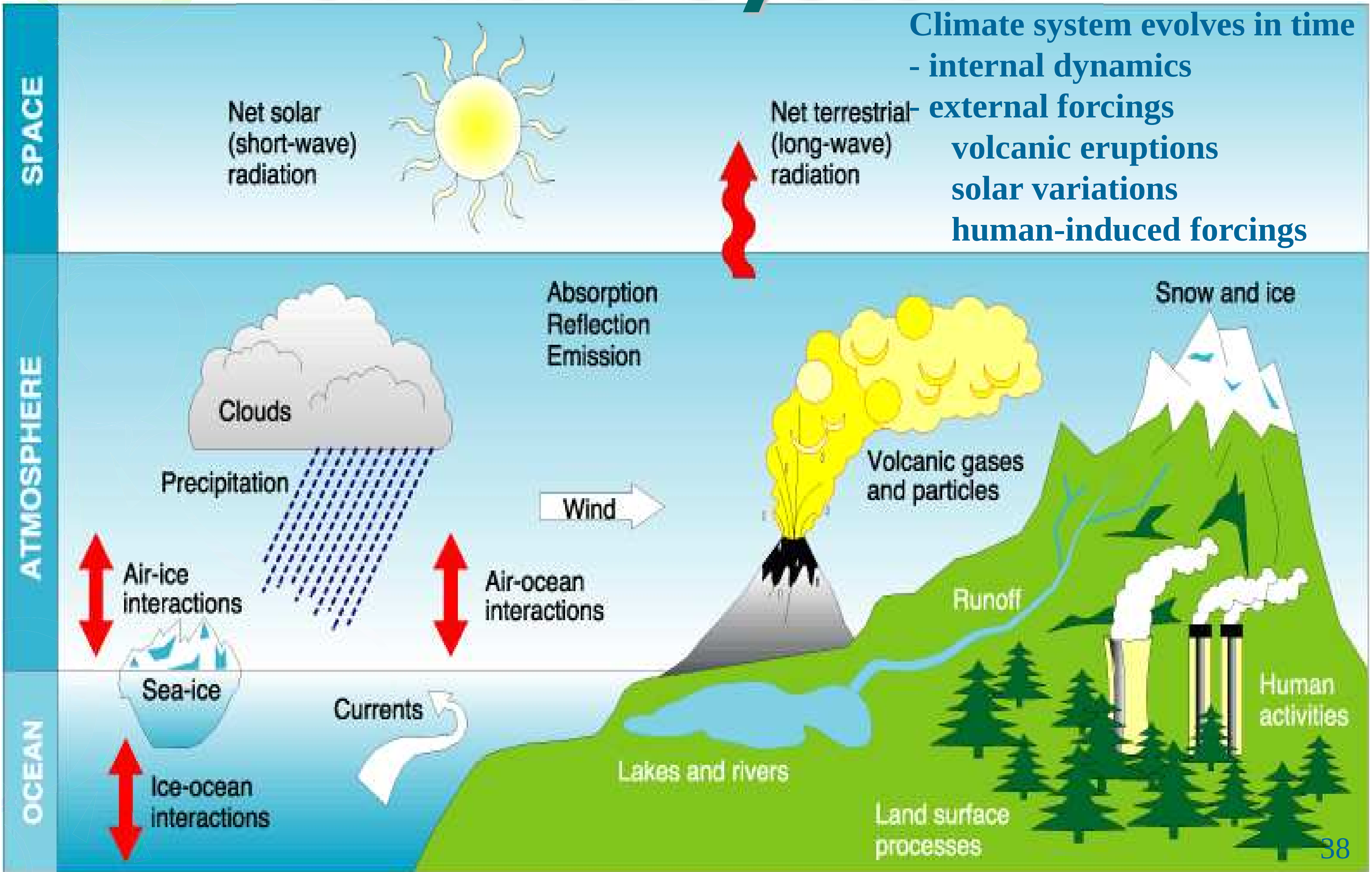
Sea level pressure anomaly (contours) and 2-m temperature anomaly (shadings) on 26 Sep. 2008. Contour interval is 3-hPa.



Thank you for your attention!

Climate System

Climate system evolves in time
- internal dynamics
- external forcings
  - volcanic eruptions
  - solar variations
  - human-induced forcings



$$\vec{v} = \vec{v}_\psi + \vec{v}_\chi$$

(solenodal + irroatational component)
(divergence-free) (curl-free) .
Helmholtz's theorem

(Rotational wind)

$$u_\psi = -\frac{\partial \psi}{\partial y}, v_\psi = \frac{\partial \psi}{\partial x}$$

ψ : stream function

Rotation

$$rot\vec{v}_\psi = \frac{\partial v_\psi}{\partial x} - \frac{\partial u_\psi}{\partial y} = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = \nabla^2 \psi$$

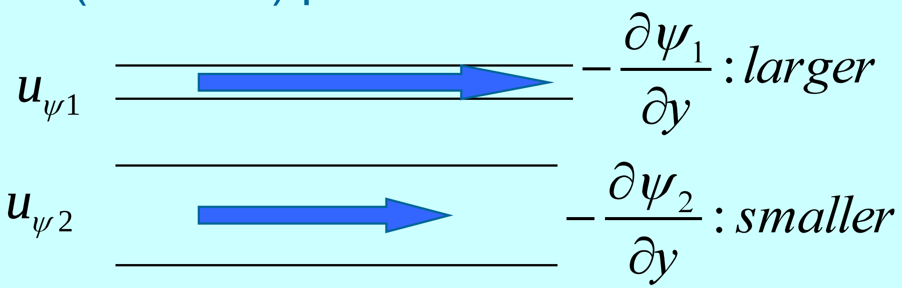
Divergence

$$div\vec{v}_\psi = \frac{\partial u_\psi}{\partial x} + \frac{\partial v_\psi}{\partial y} = -\frac{\partial^2 \psi}{\partial x \partial y} + \frac{\partial^2 \psi}{\partial y \partial x} = 0$$

- The larger gradient ψis, the stronger rotational wind is.
- Rotational wind blows parallel to ψ

- The wind blows with seeing smaller ψ on the left side

(left side)ψ: smaller



(right side)ψ: larger

Divergence Wind

(Divergence wind)

$$u_\chi = \frac{\partial \chi}{\partial x}, v_\chi = \frac{\partial \chi}{\partial y}$$

χ: Velocity potential

Rotation

$$rot\vec{v}_\chi = -\frac{\partial v_\chi}{\partial x} + \frac{\partial u_\chi}{\partial y} = -\frac{\partial^2 \chi}{\partial xy} + \frac{\partial^2 \chi}{\partial yx} = 0$$

Divergence

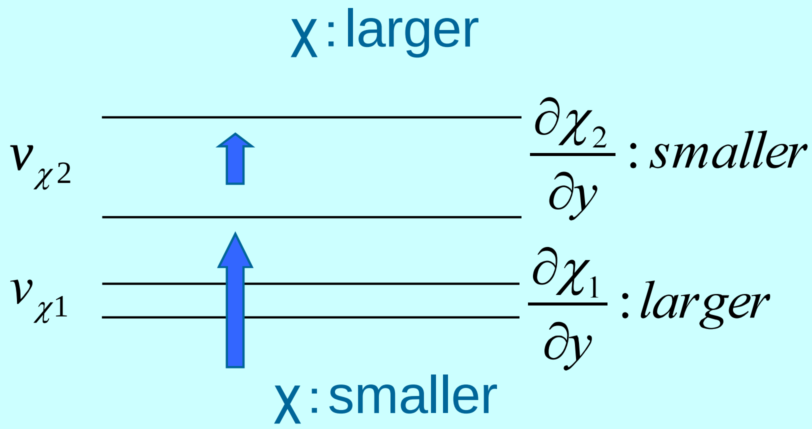
$$div\vec{v}_\chi = \frac{\partial u_\chi}{\partial x} + \frac{\partial v_\chi}{\partial y} = \frac{\partial^2 \chi}{\partial x^2} + \frac{\partial^2 \chi}{\partial y^2} = \nabla^2 \chi$$

$$div\vec{v} = div(\vec{v}_\chi + \vec{v}_\psi) = div\vec{v}_\chi = \nabla^2 \chi$$

$$rot\vec{v} = rot(\vec{v}_\psi + \vec{v}_\chi) = rot\vec{v}_\psi = \nabla^2 \psi$$

- Divergence wind blows at right angle to χ.

- The larger gradientχis, the stronger divergence wind is.



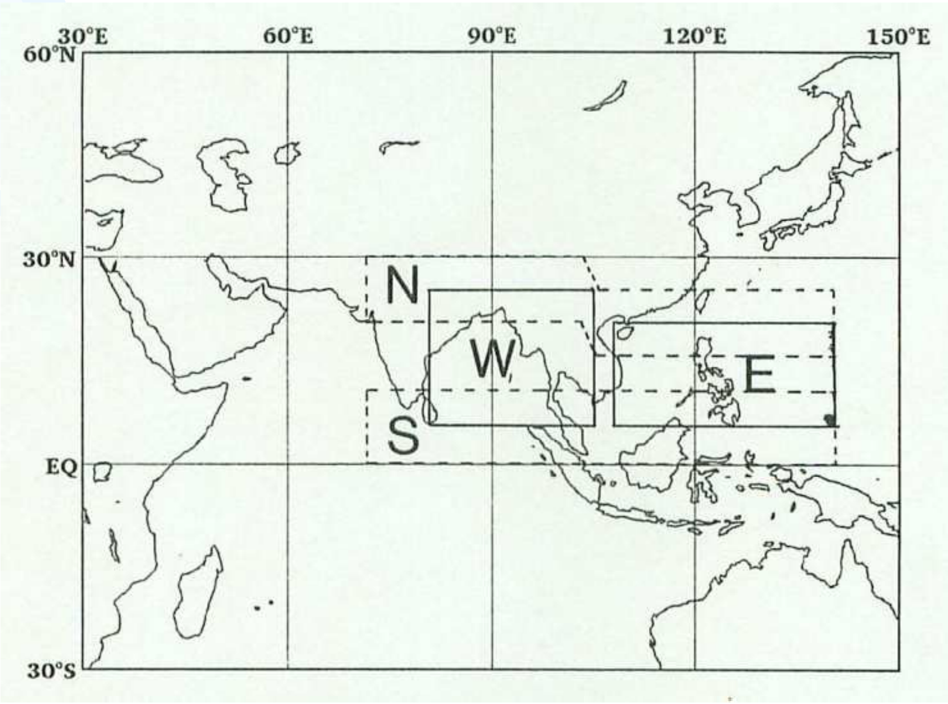
SAMOI : Summer Asian Monsoon OLR Indices

Indicator of convective activities with Asian Monsoon

SAMOI_A = normalized ((-1) × OLR(W+E)) → Activity

SAMOI_N = normalized (normalized OLR(S) - normalized OLR(N)) → Northward shift

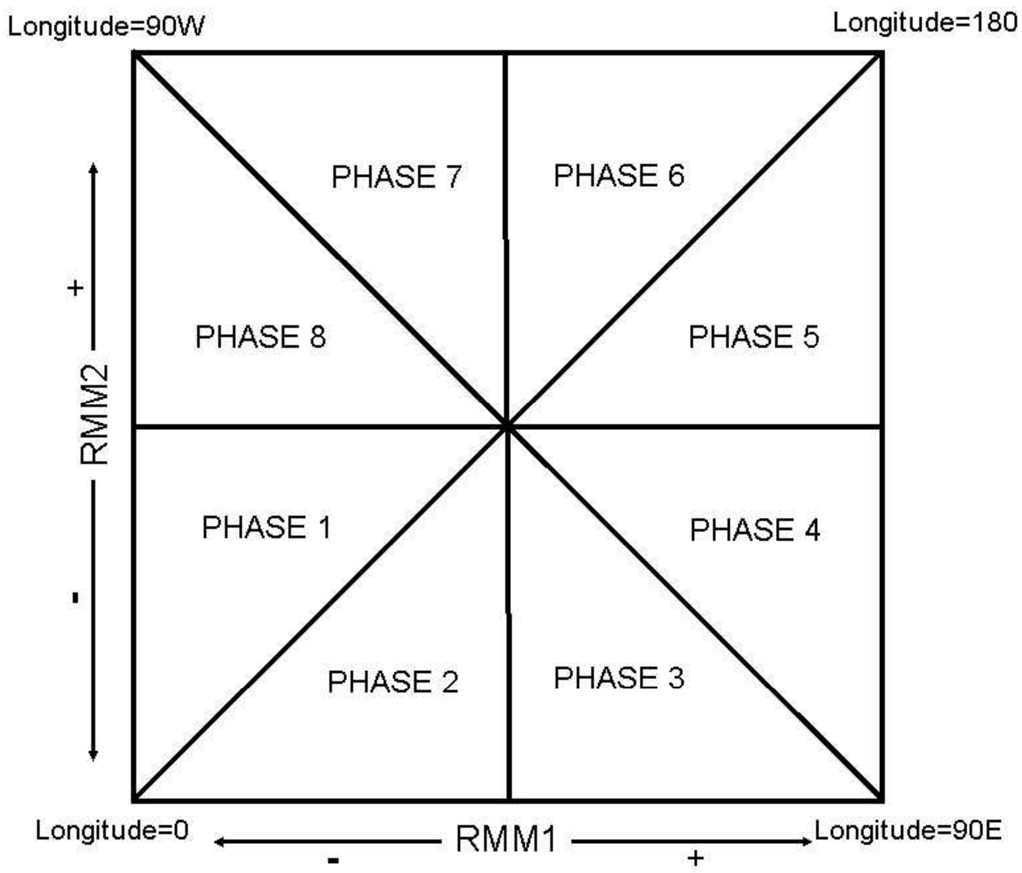
SAMOI_W = normalized (normalized OLR(E) - normalized OLR(W)) → Westward shift



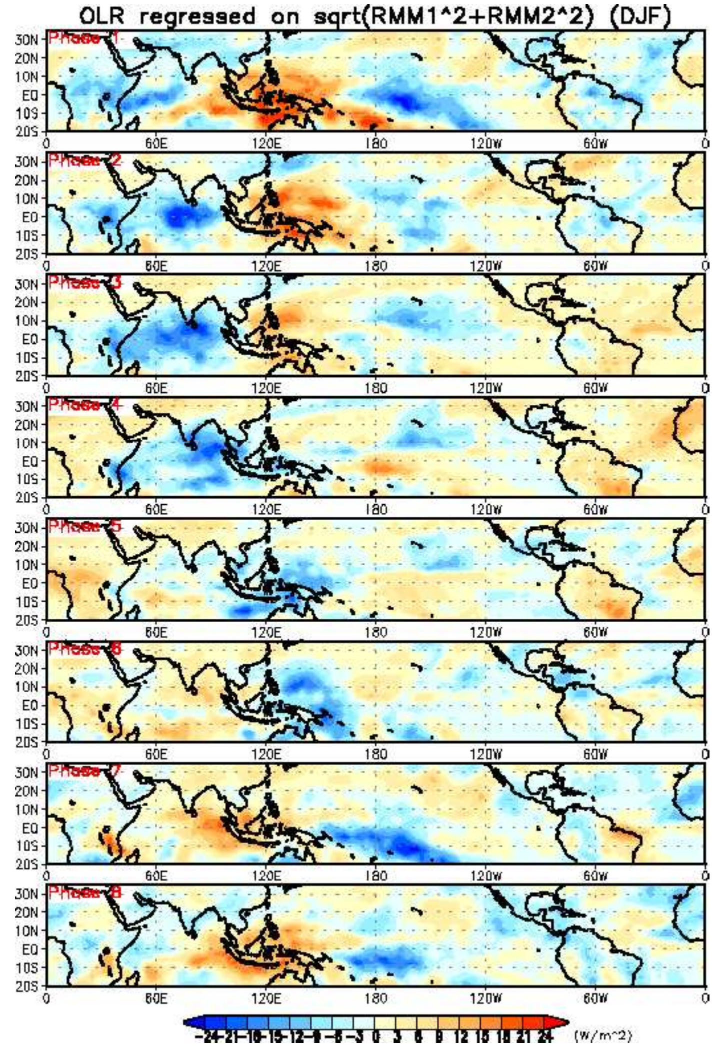
Region for calculation

SAMOI_A has a high correlation with summer northern Japan temperature.

About MJO…



OLR anomalies associated with MJO (winter time)



PHASE 1

PHASE 2

PHASE 3

PHASE 4

PHASE 5

PHASE 6

PHASE 7

PHASE 8

Index of MJO is based on a pair of empirical
orthogonal functions (EOFs) of the combined fields of near-equatorially-averaged
850 hPa zonal wind, 200 hPa zonal wind, and 200 hPa velocity potential data.
The pair of PC time series that form the index the Real-time Multivariate MJO series 1 (RMM1), and 2 (RMM2).
Removed the impact of ENSO with **Nino.3 index**.

(mainly based on Wheeler and Hendon (2004))

About wave activity flux…

- Formulization

$$W = \frac{p}{2|U|}\begin{pmatrix} U\left(\psi'^2_x - \psi'\psi'_{xx}\right) + V\left(\psi'_x\psi'_y - \psi'\psi'_{xy}\right) \\ U\left(\psi'_x\psi'_y - \psi'\psi'_{xy}\right) + V\left(\psi'^2 y - \psi'_{yy}\right) \\ \frac{f_0^2}{N^2}\left[U\left(\psi'_x\psi'_z - \psi'\psi'_{xz}\right) + V\left(\psi'_y\psi'_z - \psi'\psi'_{yz}\right)\right] \end{pmatrix} + C_U M$$

where, $p = (\text{pressure})/1000\text{hPa}$, $|U|$ is wind speed, ψ' means the anomaly of stream function.

C_U is phase propagation in the direction of wind.

M pseudomomentum.

- Interpretation
  - Wave activity flux *W* is parallel to the group velocity of quasi-stationary Rossby wave.
  - The divergence of *W* leads to realistic estimation of a wave source region.

For more detail, please refer to Takaya and Nakamura (2001, JAS)