TCC Training Seminar on One-month Forecast Products
7 – 9 November 2011
Tokyo, Japan

Atmospheric circulation analysis for seasonal forecasting

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Outline

1. Introduction
2. Climatological normal
3. MJO (tropical intraseasonal oscillation)
4. ENSO
5. Current conditions (October 2011)
6. Summary

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Objectives of atmospheric circulation analysis

- Understand and assess the background of climate, especially extreme climate events, which significantly influences socio-economic sectors.
- Accumulation of findings on atmospheric circulation through operational analysis can contribute to understanding the mechanism of climate system and furthermore to the improvement of seasonal prediction.

Important phenomena in one-month forecasting

- Tropical intraseasonal oscillations (e.g. MJO)
- El Niño/La Niña phenomena (ENSO)

It is crucial:

- to understand these phenomena and their possible impacts on climate;
- to monitor their current condition;
- to predict evolution of these phenomena.

(understand prediction model performance and appropriate interpretation of model products)

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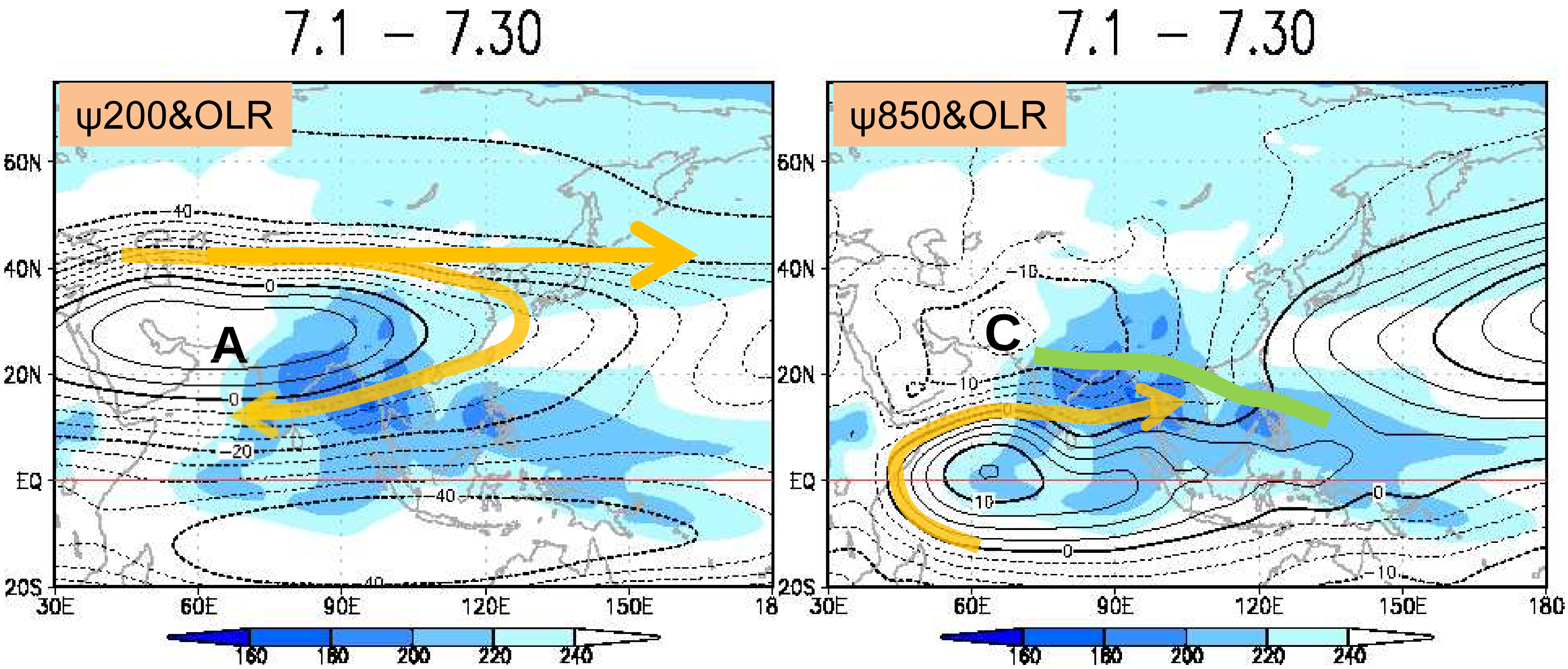
Climatological normal

- In climate system monitoring and prediction, we assess the system including atmospheric circulation compared to climatological normal. (“anomaly”, deviation from long-term average, is analyzed and predicted.)
- Therefore, it is important to understand climatological normal of atmospheric circulation and its boundary conditions.

Climatological normals in Asian summer monsoon (1)



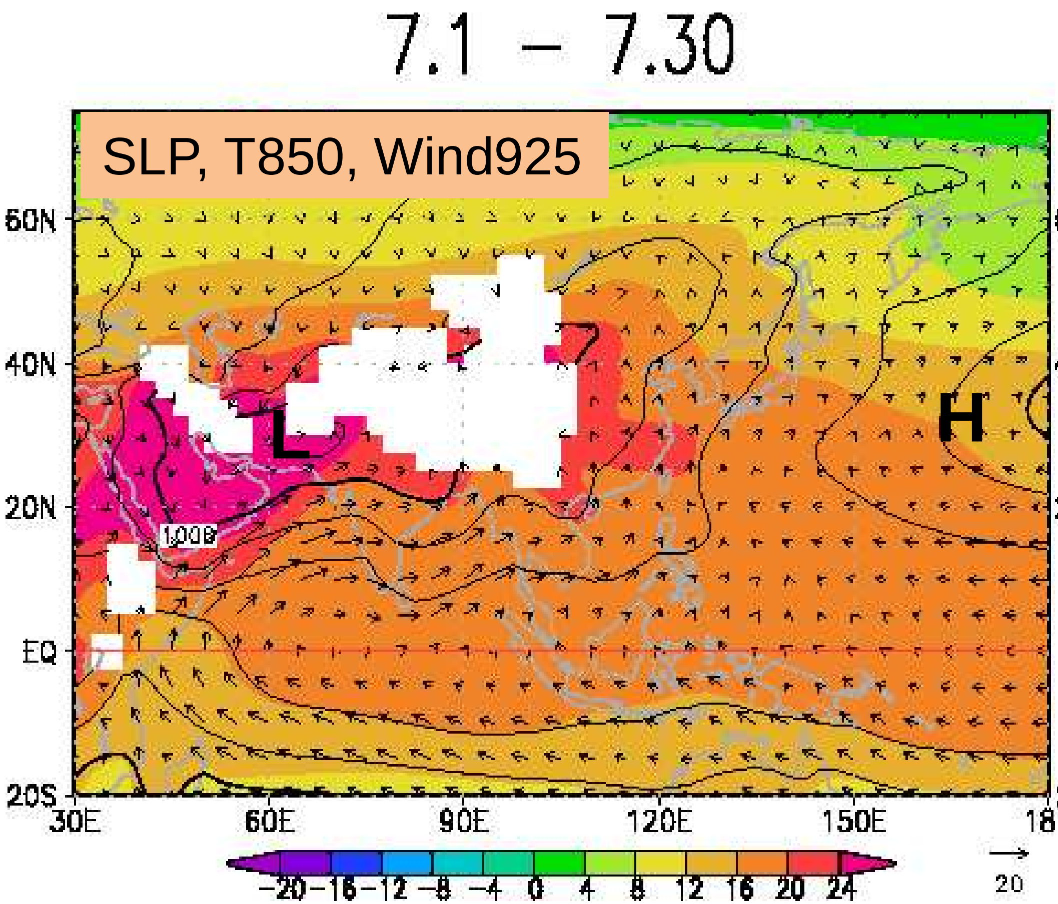
Climatological normals of atmospheric circulation and convection (July)

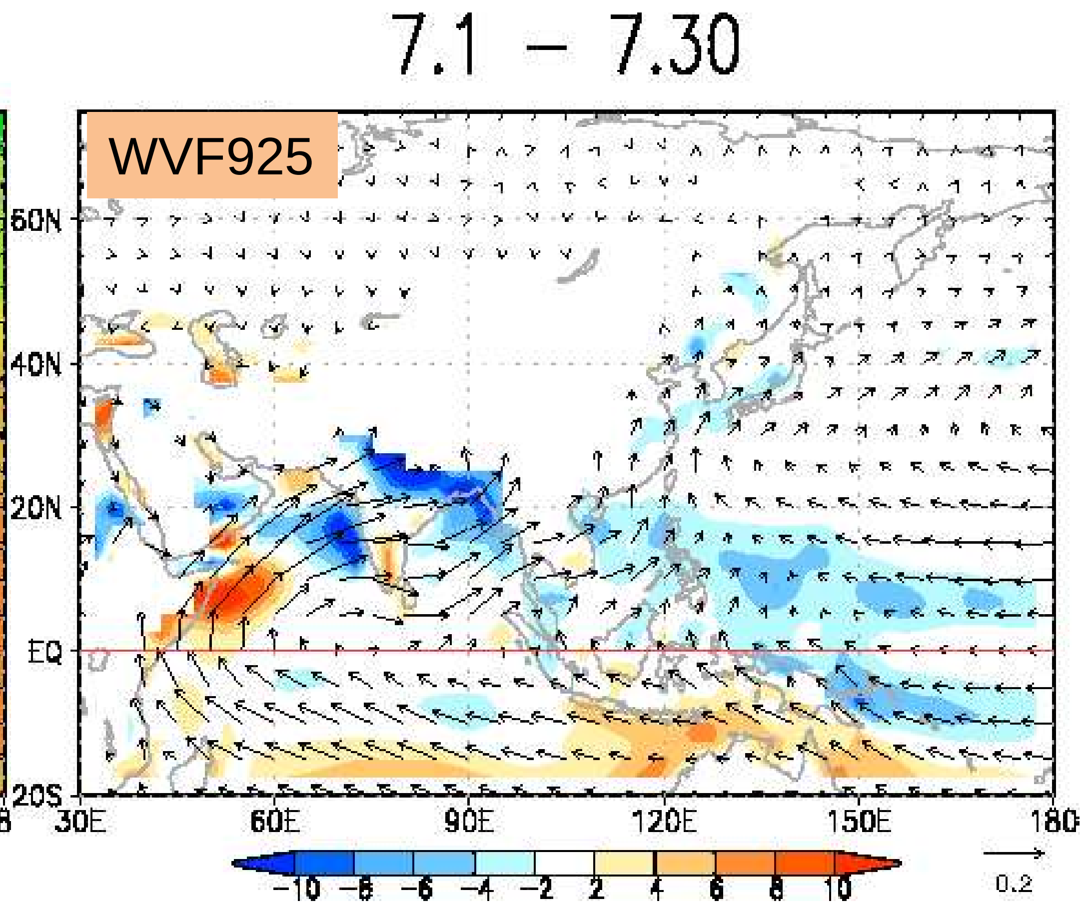
Contours: 200-hPa (left) and 850-hPa (right) stream function (JRA/JCDAS)

Shading: outgoing longwave radiation (OLR), observed by NOAA satellites

Base period for normal: 1981 – 2010

Climatological normals in Asian summer monsoon (2)





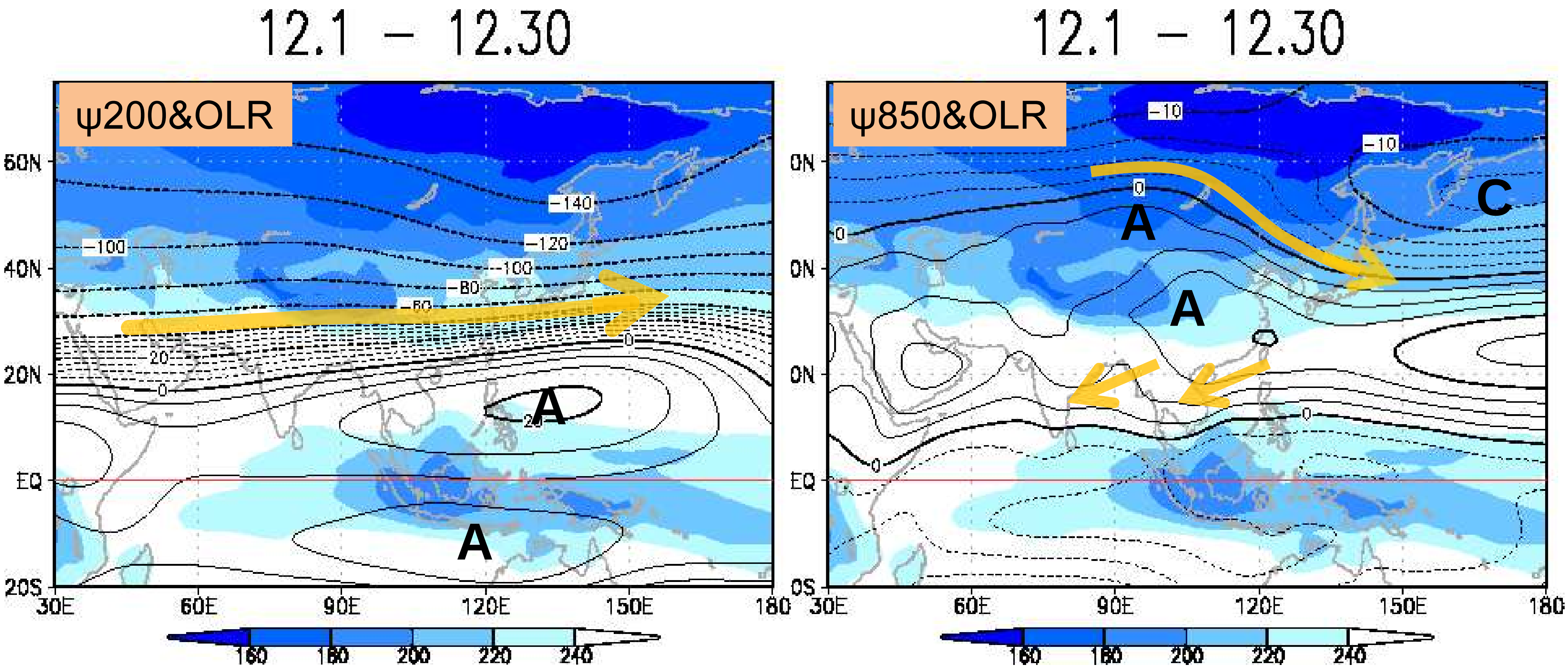
<u>Climatological normals of atmospheric circulation and convection (July)</u>

Left: Sea level pressure (contour), 850-hPa temperature (shading) and 925-hPa wind vectors

Right: 925-hPa water vapor flux (vector) and its divergence/convergence (shading)

Base period for normal: 1981 – 2010

Climatological normals in Asian winter monsoon (1)



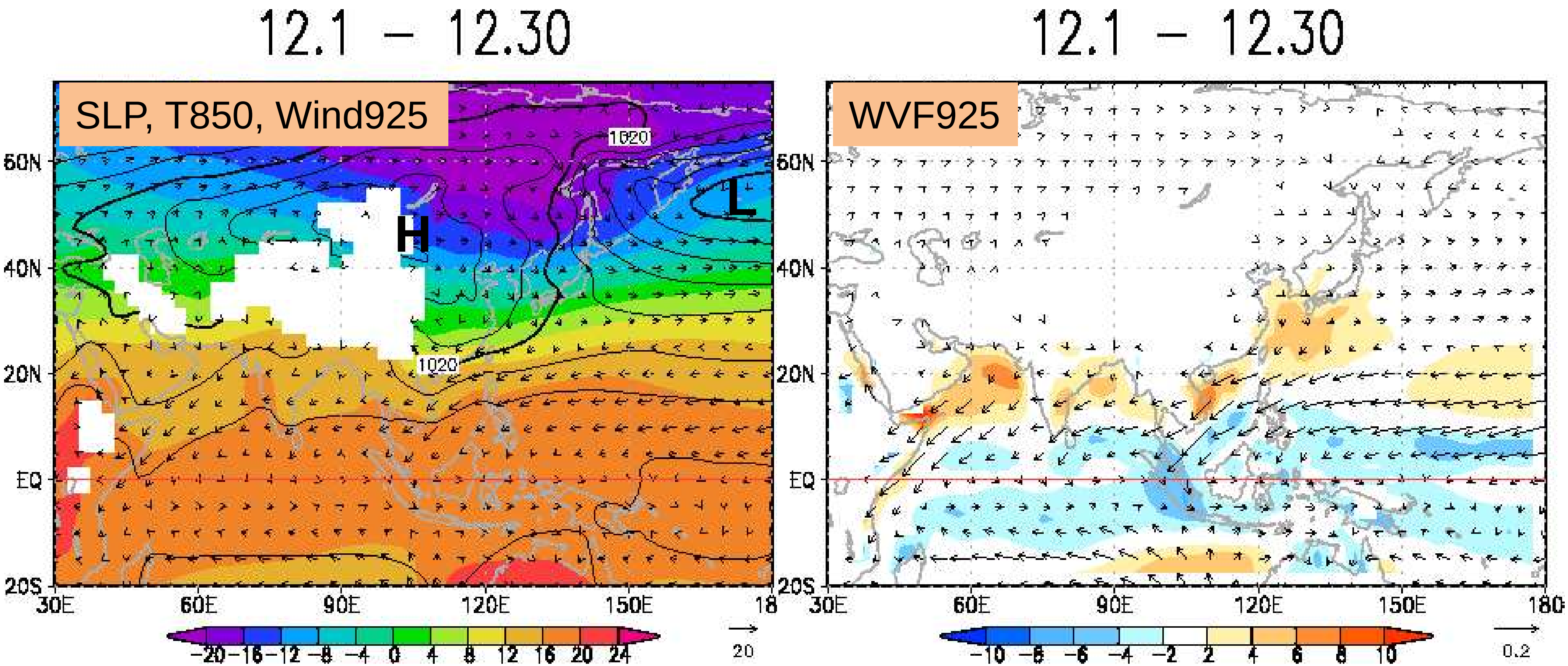
<u>Climatological normals of atmospheric circulation and convection (December)</u>

Contours: 200-hPa (left) and 850-hPa (right) stream function (JRA/JCDAS)

Shading: OLR (observed by NOAA satellites)

Base period for normal: 1981 – 2010

Climatological normals in Asian winter monsoon (2)



<u>Climatological normals of atmospheric circulation and convection (December)</u>

Left: Sea level pressure (contour), 850-hPa temperature (shading) and 925-hPa wind vectors

Right: 925-hPa water vapor flux (vector) and its divergence/convergence (shading)

Base period for normal: 1981 – 2010

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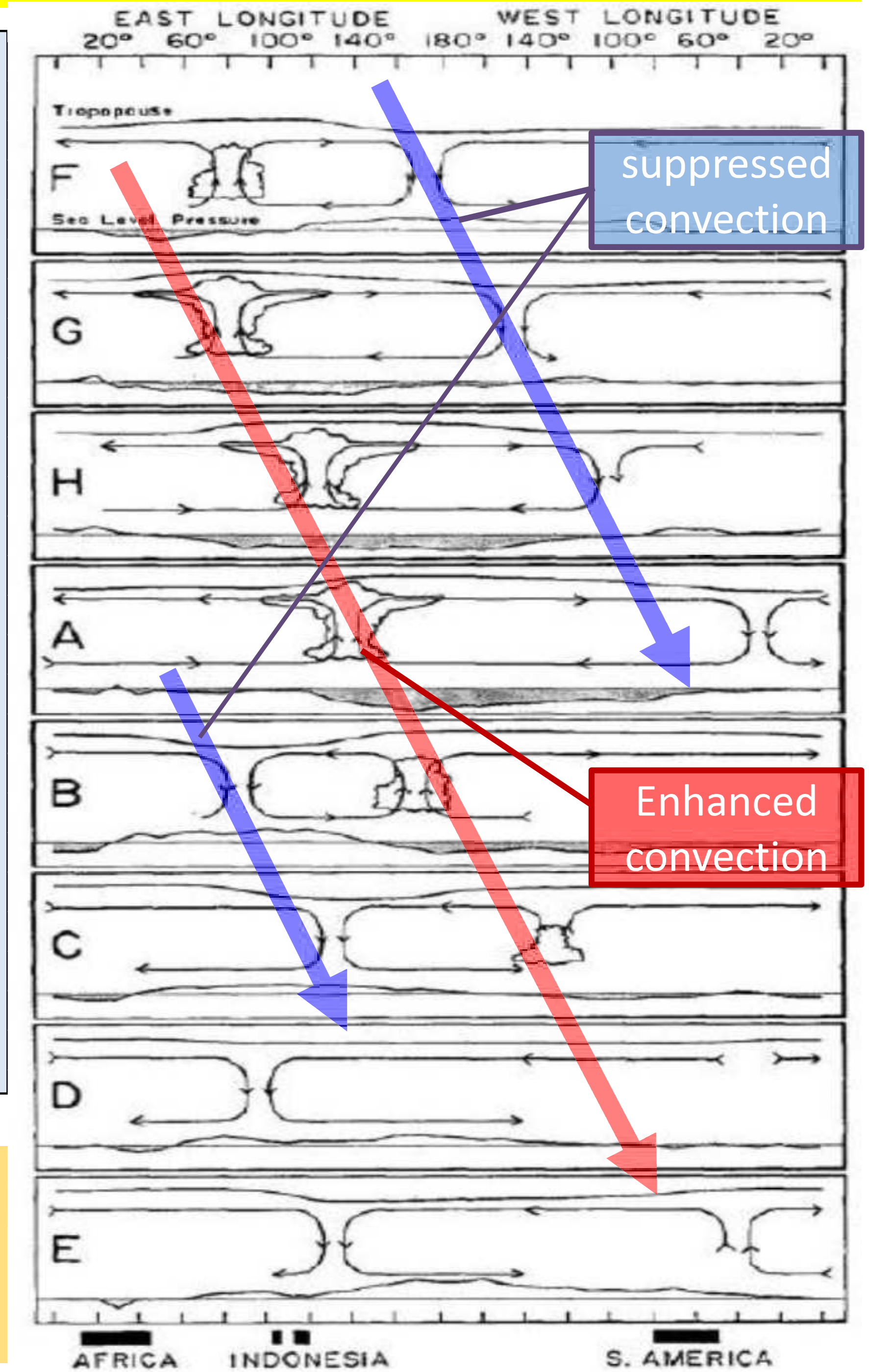
Madden-Julian Oscillation (MJO)

- In 1971, Madden and Julian first documented an equatorial intrasoasonal oscillation propagating eastward, using modern observations. Therefore, this is called Madden-Julian Oscillation (MJO).
- MJO is one of major phenomena in the tropical atmosphere, influencing on not only tropical but also extratropical weather and climate.
- MJO is a very important phenomenon in medium and extended range forecasting.
- However, it is difficult to simulate and predict MJO accurately, because we don't know completely understand the mechanism of MJO, especially its generation and persistence.

Characteristics of MJO

MJO

- propagates eastward along the equator with periods of 30 – 60 days,
- is a large-scale coupled pattern between deep convection and atmospheric circulation,
- is more active in boreal winter than in boreal summer,
- has a clearer signal in convection over the Indian Ocean and the western Pacific than other regions.

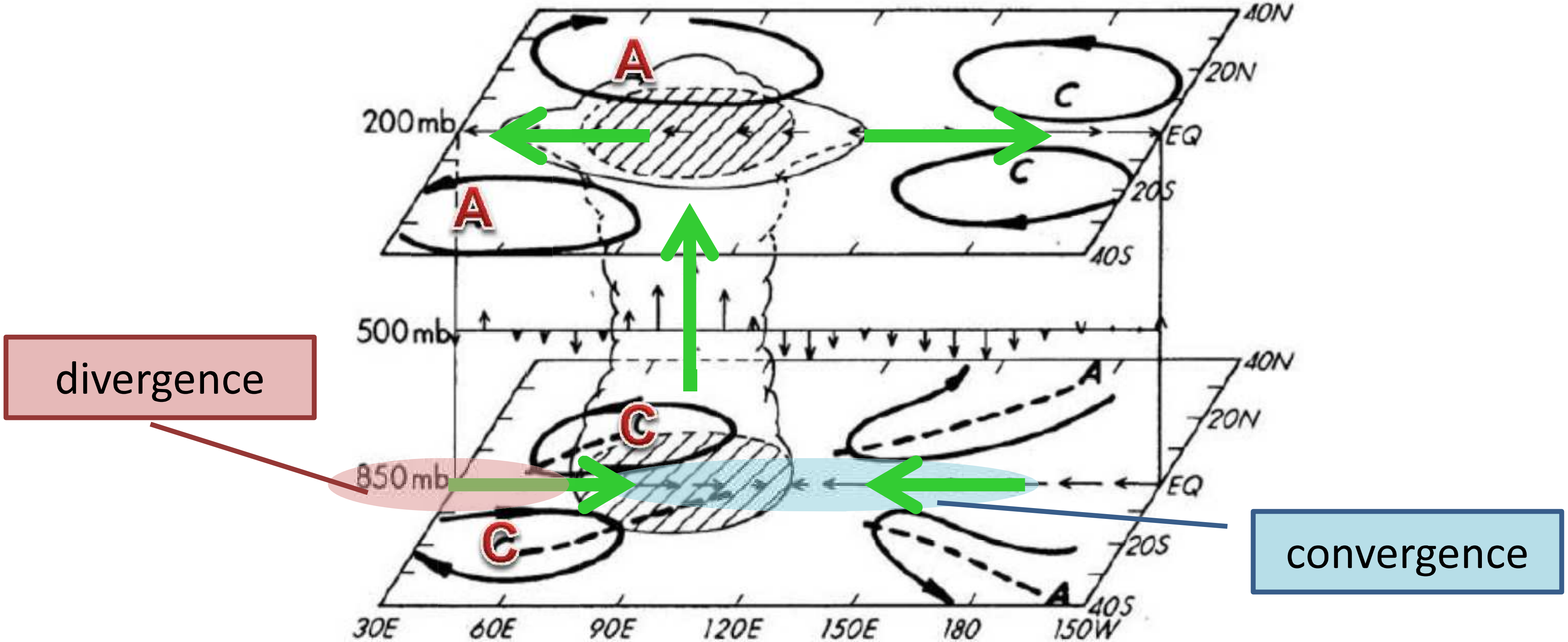


Schematic of MJO
time increasing downward
(Madden and Julian 1972)

Dynamical structure of MJO

• MJO has characteristics of both the equatorial Kelvin wave and the equatorial Rossby wave.

• The 3D-structure of MJO resembles atmospheric circulation anomalies responding to convective heating (Matsuno-Gill model)



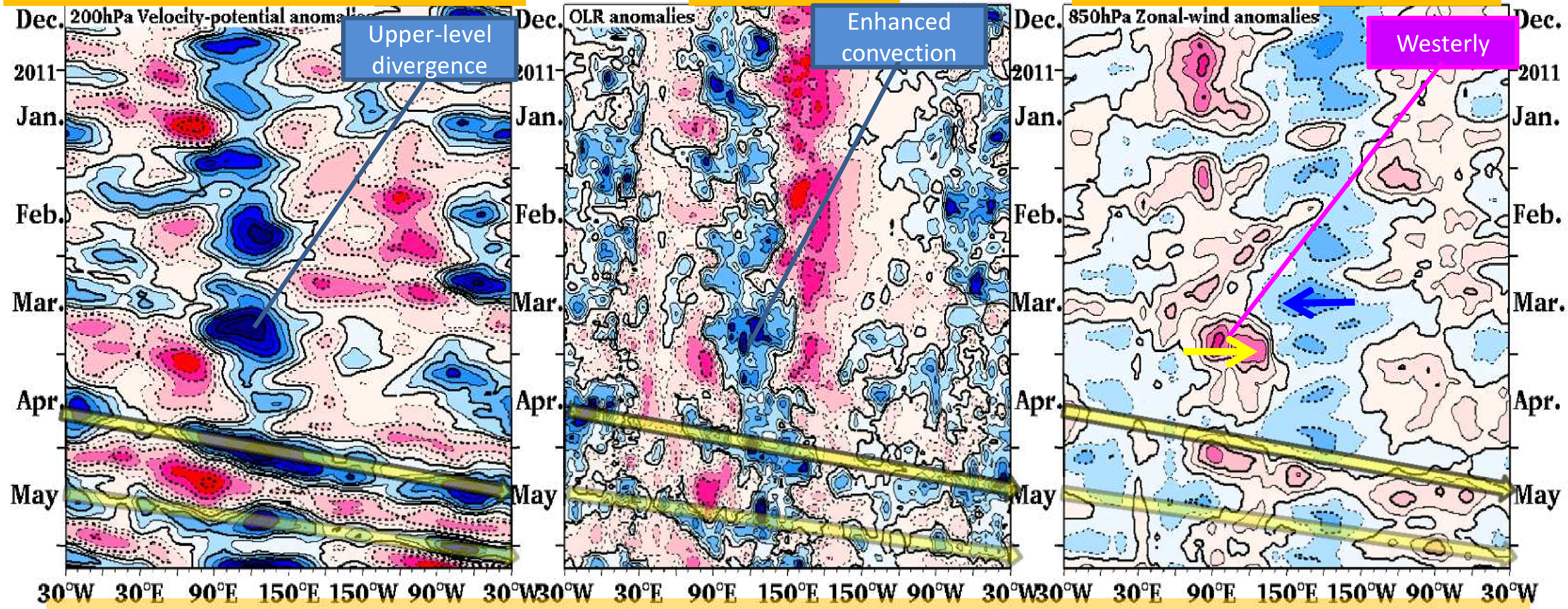
Schematic depiction of large-scale wind structure of MJO (Indian Ocean)

The cloud symbol indicates the convective center. Arrows represent anomalous winds at 850 and 200 hPa and the vertical motions at 500 hPa. “A” and “C” mark the anticyclonic and cyclonic circulation centers, respectively. (Rui and Wang 1990)

Analysis of MJO

It is easy to discern MJO using observations, without any advanced techniques, when MJO is active.

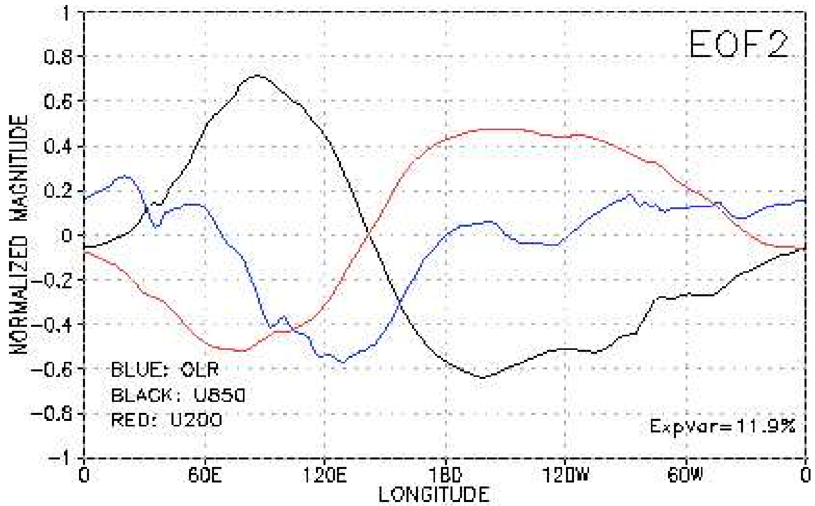
200-hPa velocity potential anomaly | **OLR anomaly** | **850-hPa zonal wind anomaly**

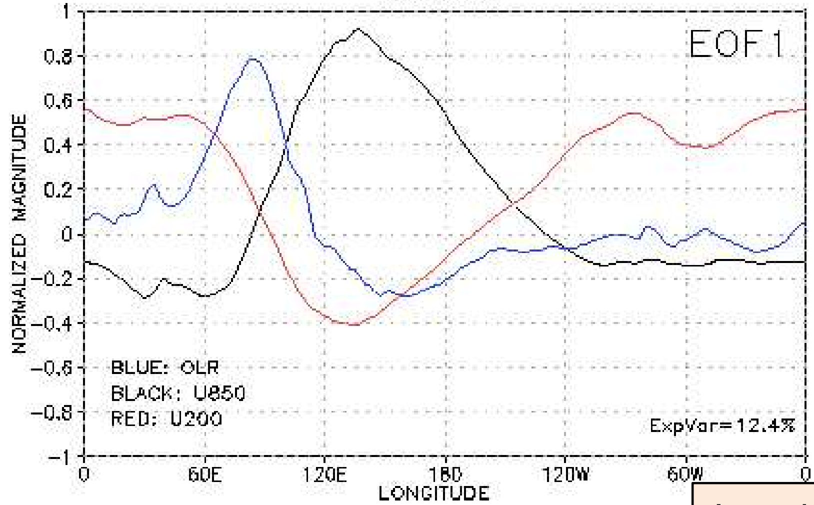


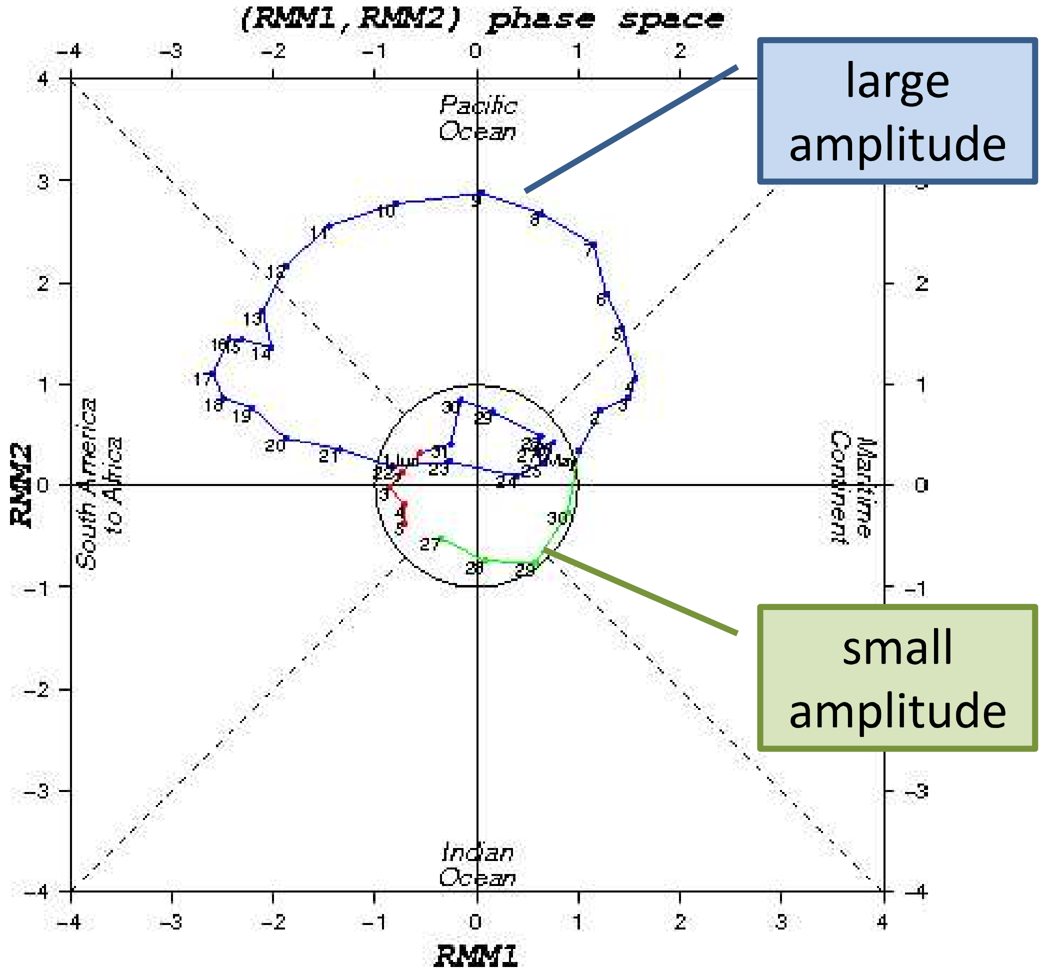
Longitude-time cross sections of 200-hPa velocity potential anomaly (left), outgoing longwave radiation (OLR) anomaly (center) and 850-hPa zonal wind anomaly (right), which are 7-day running mean values and averaged around the equator (5S-5N), from December 2010 to May 2011.

MJO Index

Wheeler and Hendon（2004）defined MJO indices based on the EOF of OLR, U200 and U850 in which seasonal, interannual and ENSO variations are subtracted in advance.





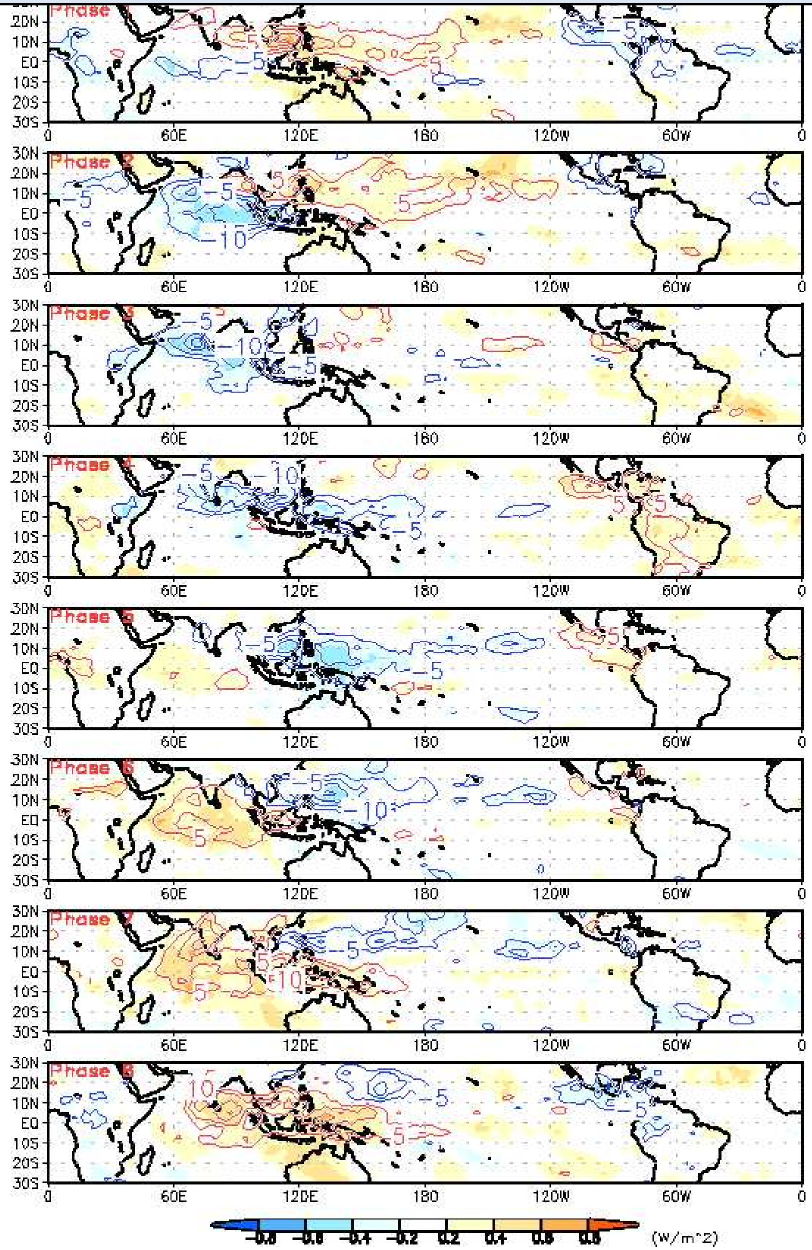


http://ds.data.jma.go.jp/tcc/tcc/products/clisys/mjo/monitor.html

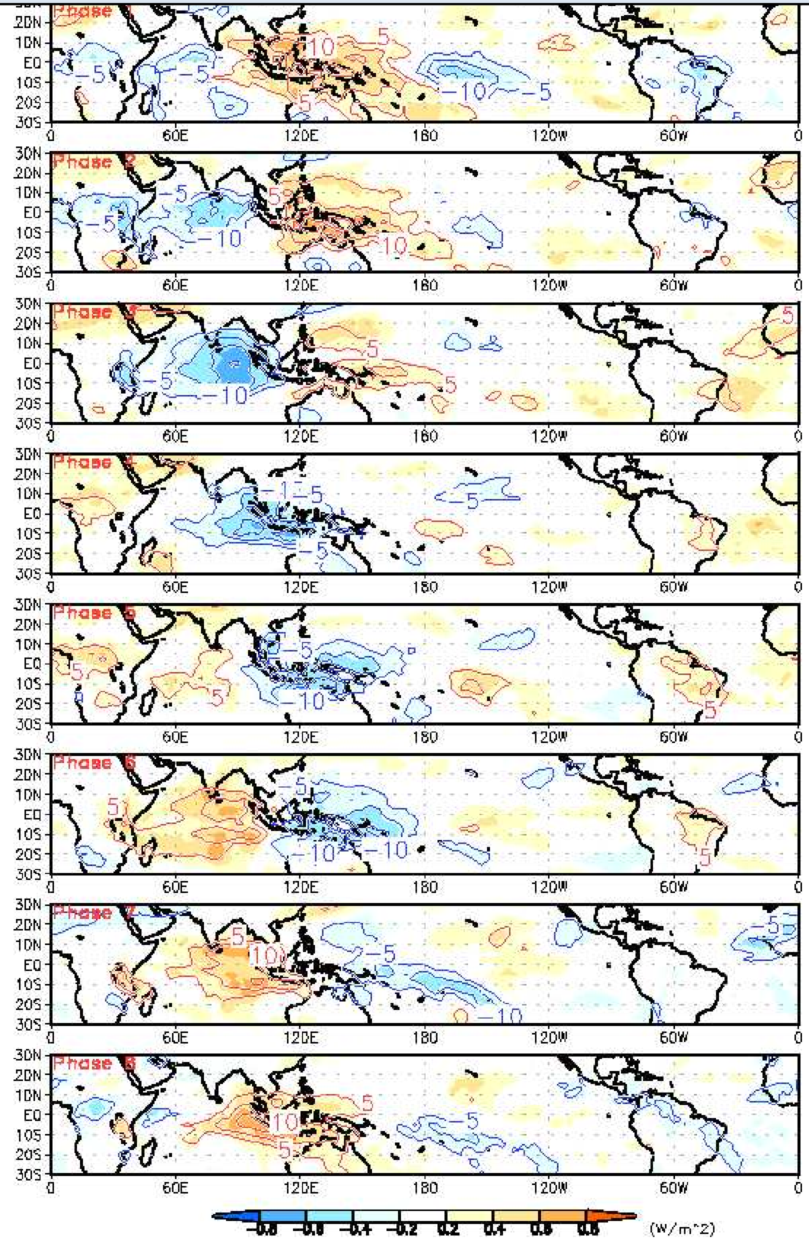
MJO in boreal summer and austral summer

In boreal summer, northward propagation is seen over the Indian Ocean and western Pacific. In austral summer, eastward propagation is dominant.

JJA

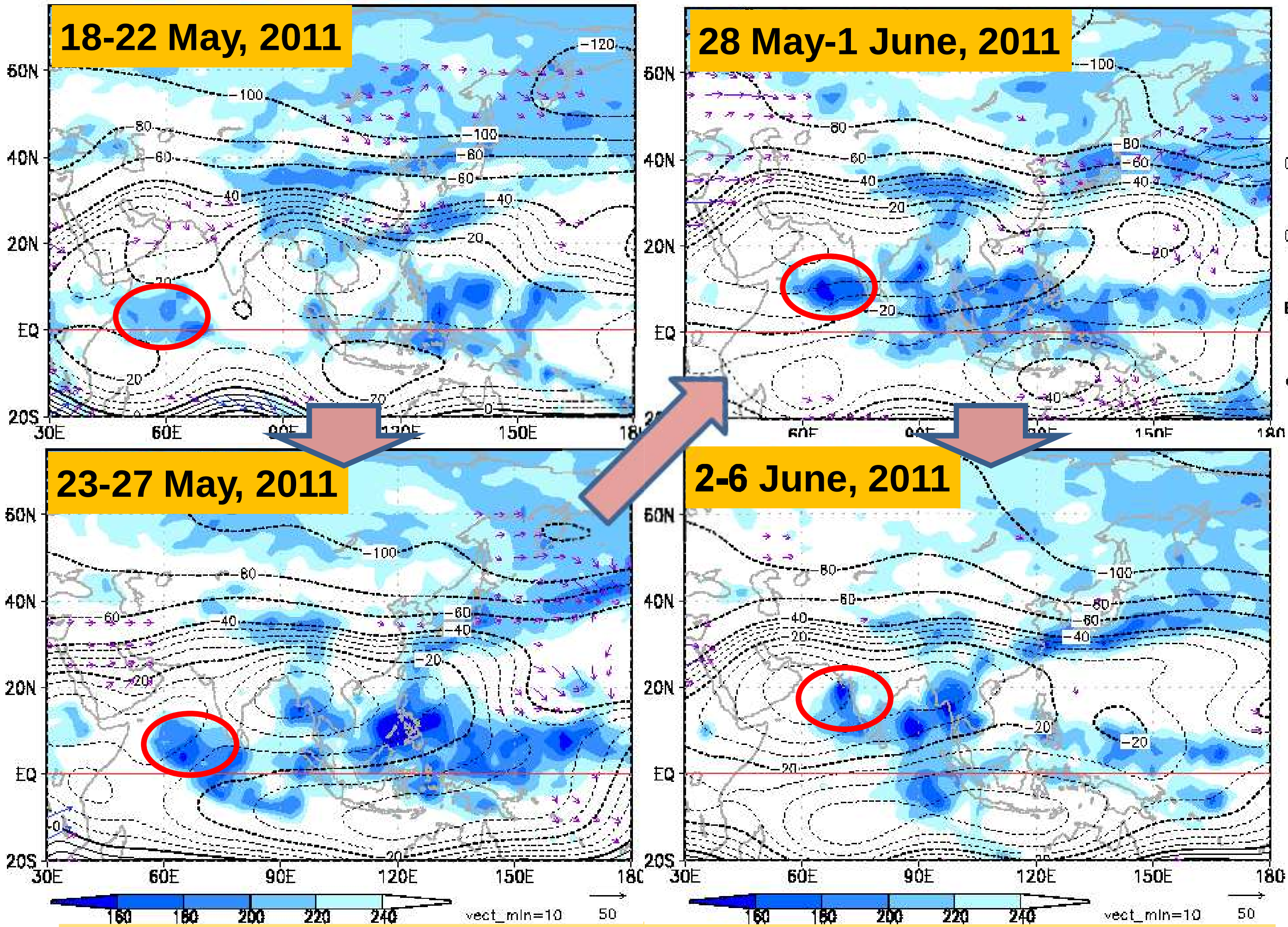


DJF

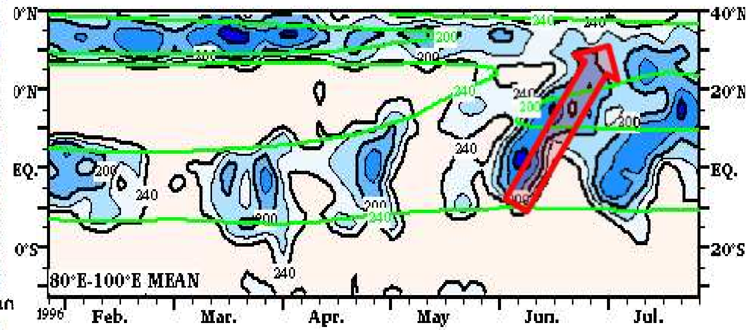


Boreal summer intraseasonal oscillation (BSISO)

- Approximately, half of the northward propagations are associated with the equatorial eastward propagation (MJO), and the other are independent.
- Monsoon onset and break are closely related to MJO.



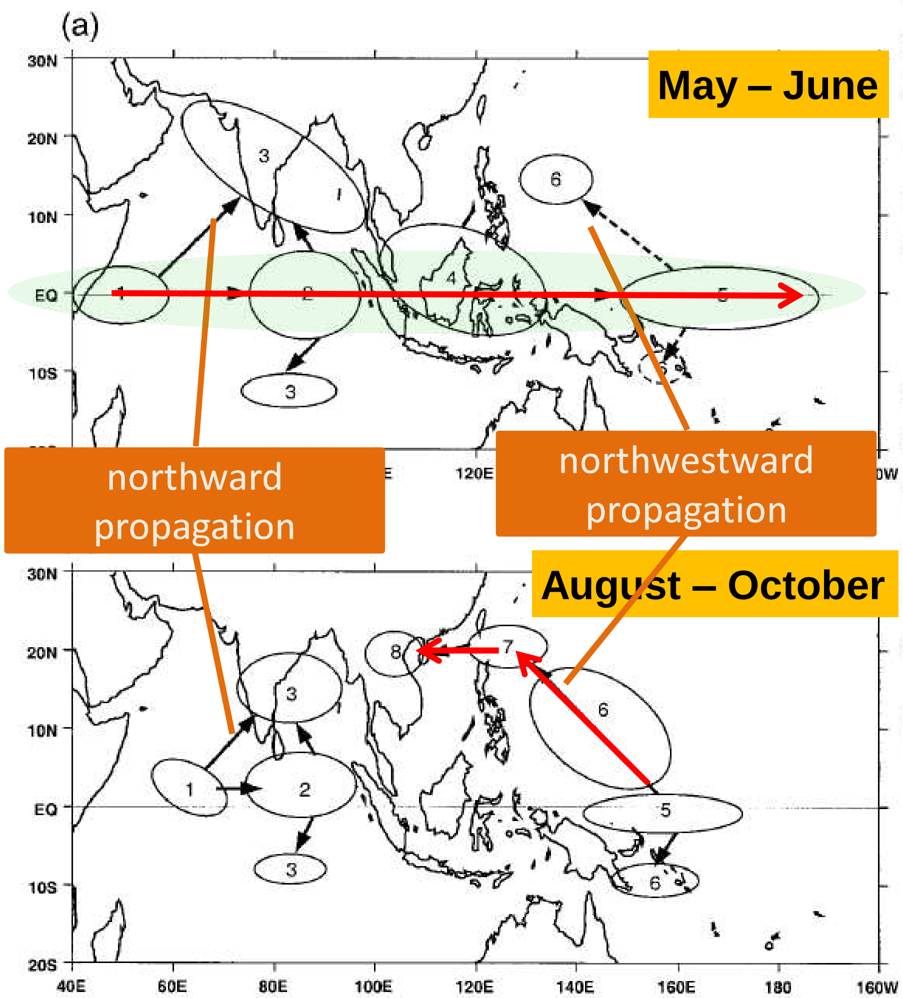
Five-day mean 200-hPa stream function and OLR



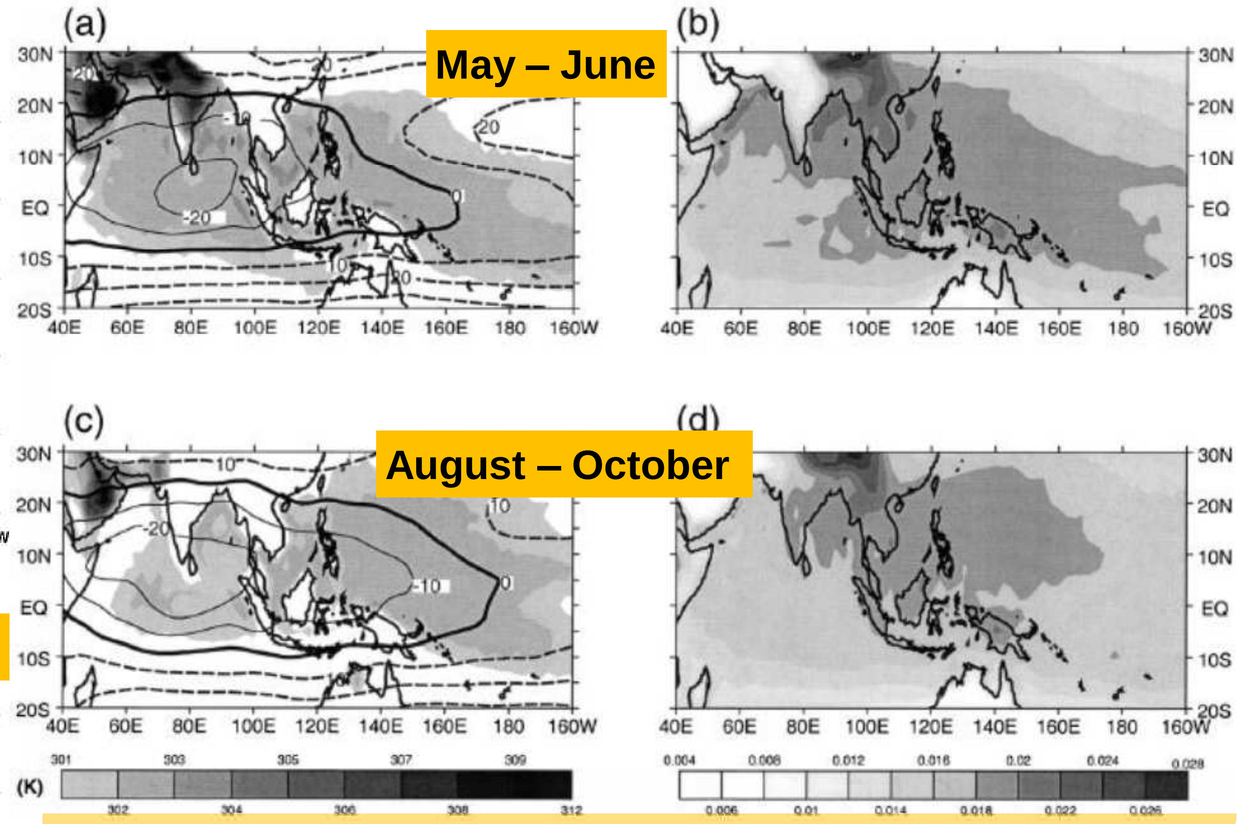
Latitude-time cross section of seven-day running mean OLR averaged 80-100 degree E (around Indian sub-continent)

Life cycle of BSISO

There are differences in the characteristics of BSISO between early and late boreal summer, due to the differences in climatological conditions.

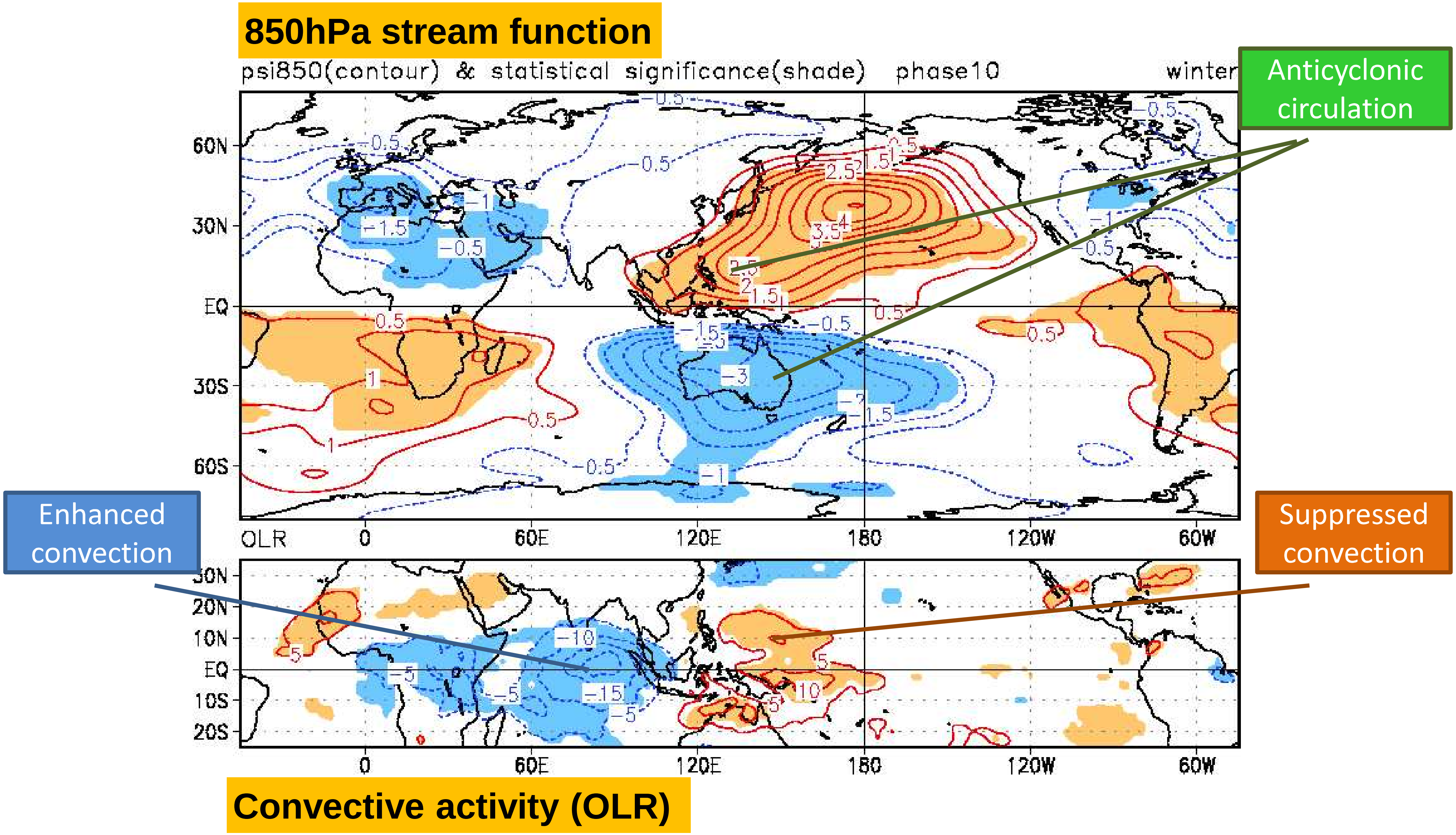


BSISO convection life cycle
(Kemball-Cook and Wang 2001)



Climatological condition in May – June (top) and August – October (bottom)
In left panels, contours indicate vertical shear of zonal wind (U200 – U850), and shading shows surface temperature. In right panels, shading shows specific humidity at 1000 hPa (Kemball-Cook and Wang 2001)

Impacts of MJO



http://juice.cpd.naps.kishou.go.jp/gmd/cpd/data/fruit_wwwroot/MATERIALS/mjo2/index.html
(This is experimental products and available only on a JMA internal website)

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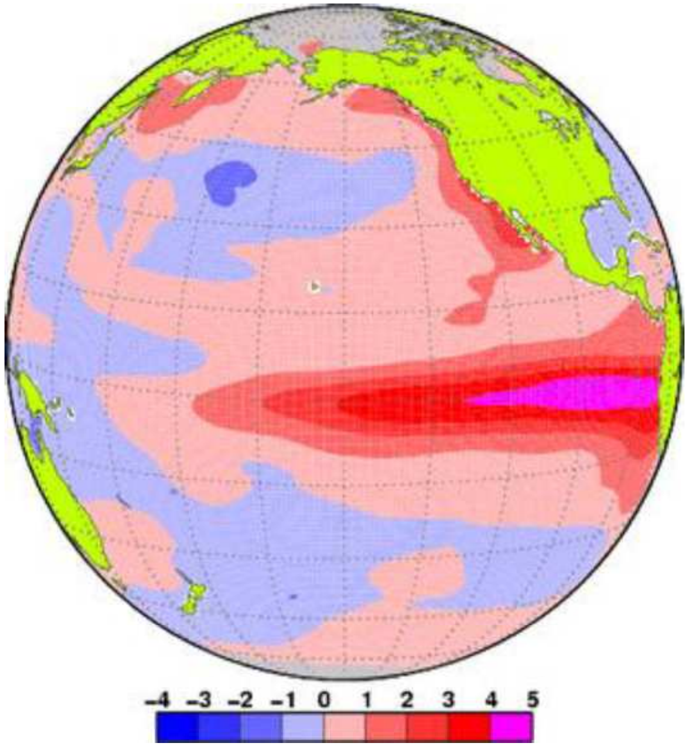
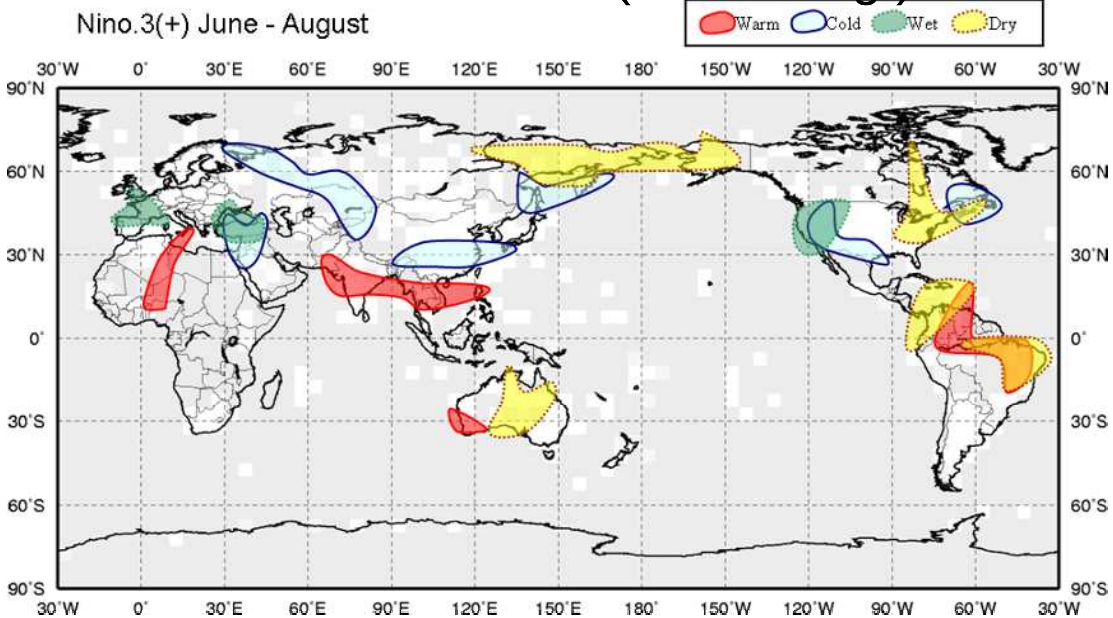
El Niño/La Niña-Southern Oscillation (ENSO)

- ENSO, quasi-periodical and ocean-atmosphere interactive phenomenon, occurs with approximately five-year intervals.
- It has broad, significant impacts on world climate.



SST anomaly (Nov. 1997)

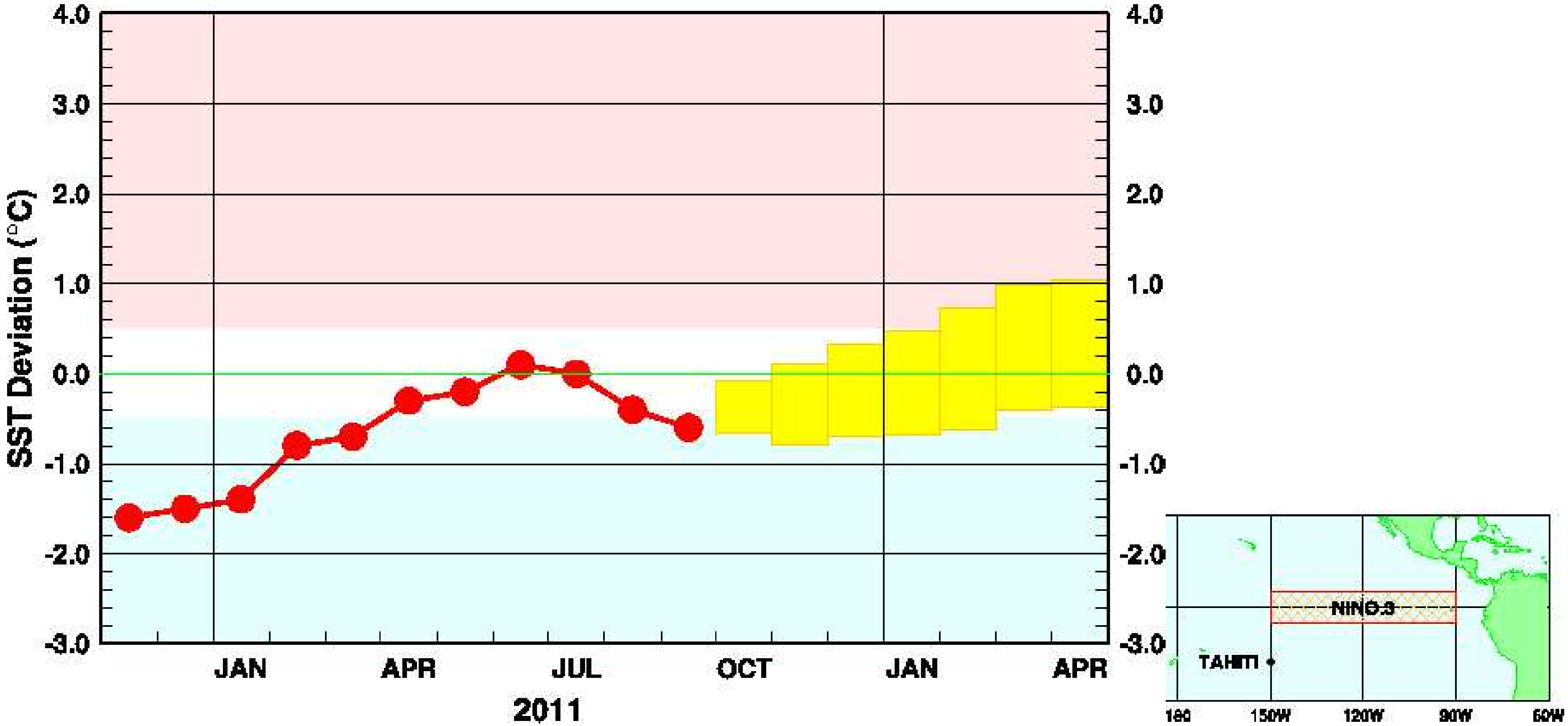
Climate in El Niño (Jun. – Aug.)



http://ds.data.jma.go.jp/tcc/tcc/products/climate/ENSO/index.htm

JMA's *El Niño Outlook* (updated 12 October 2011)

It is more likely than not that La Niña conditions will develop during boreal autumn and winter.

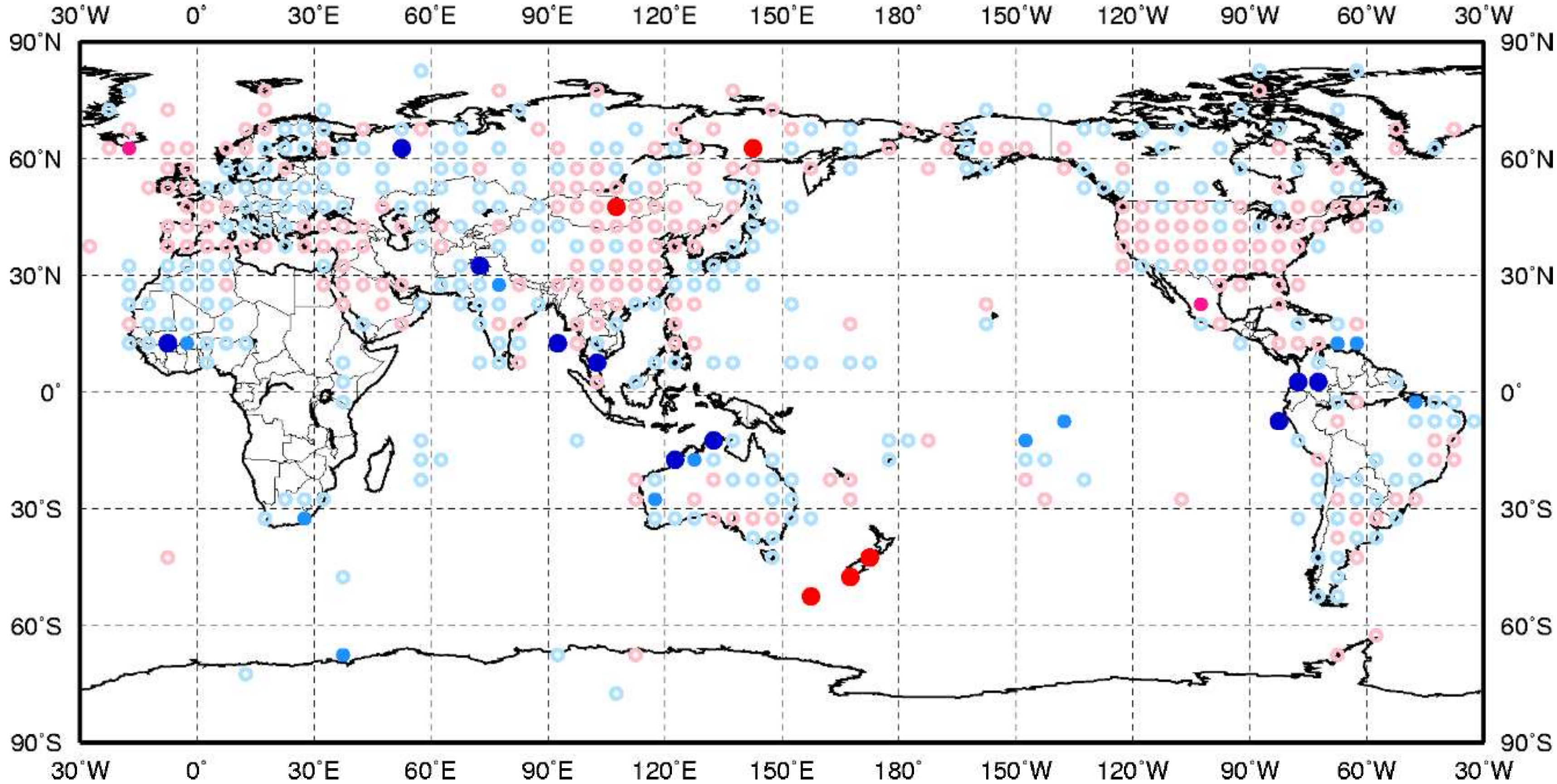


Outlook of the SST deviation for **NINO.3** by the JMA's El Niño prediction model.

Red line with closed circle: observed SST deviation.

Yellow boxes: range of predicted SST deviation with 70% probability.

Impacts of La Niña on world climate
Temperature (December)



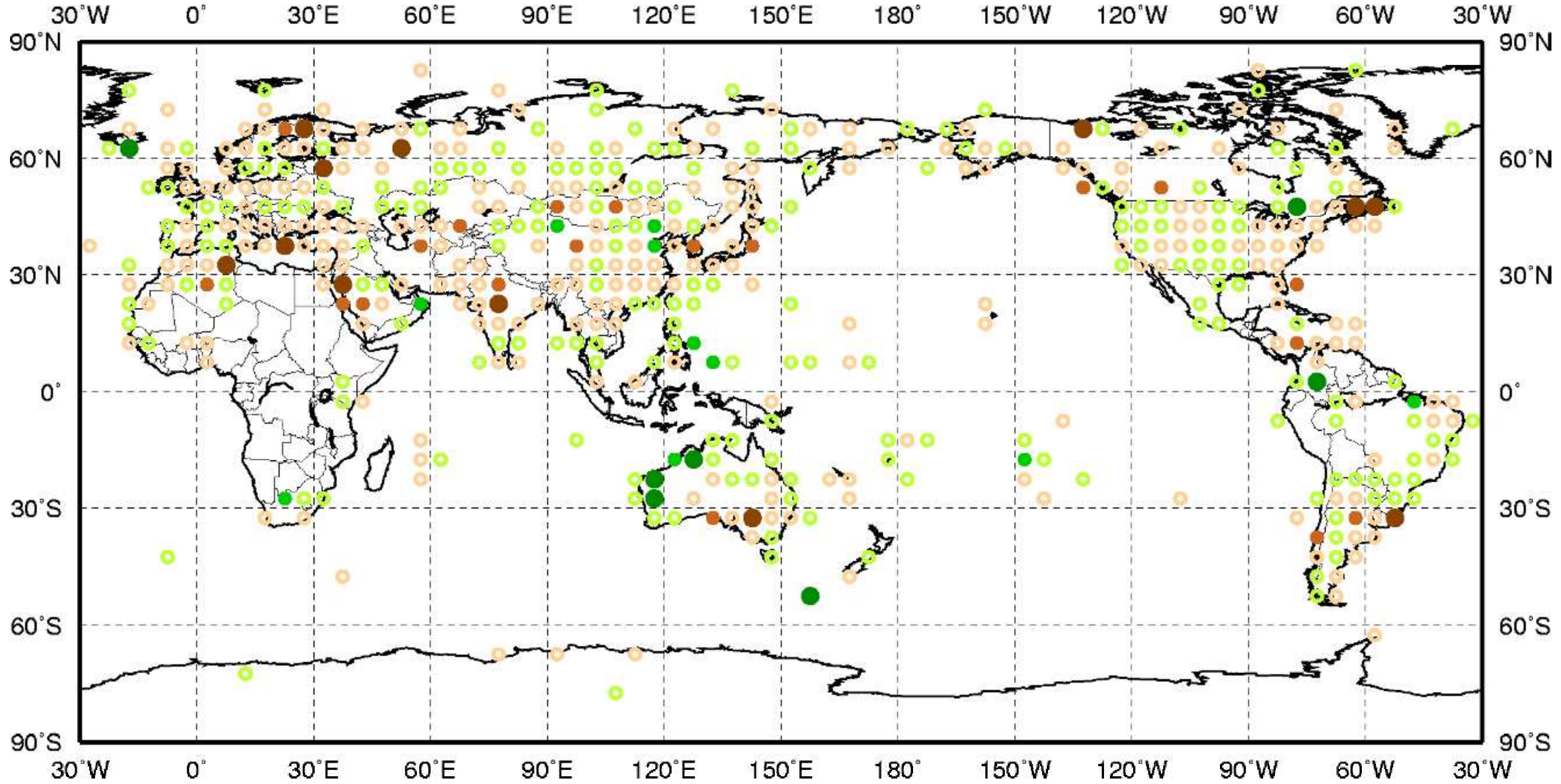
Red: above normal Blue: below normal

Large filled circle: statistical confidence level is 95 % or above.

Small filled circle: statistical confidence level is above 90 % and below 95 %.

Non filled circle: statistical confidence level is below 90 %.

Impacts of La Niña on world climate
Precipitation (December)



Green: above normal   Brown: below normal

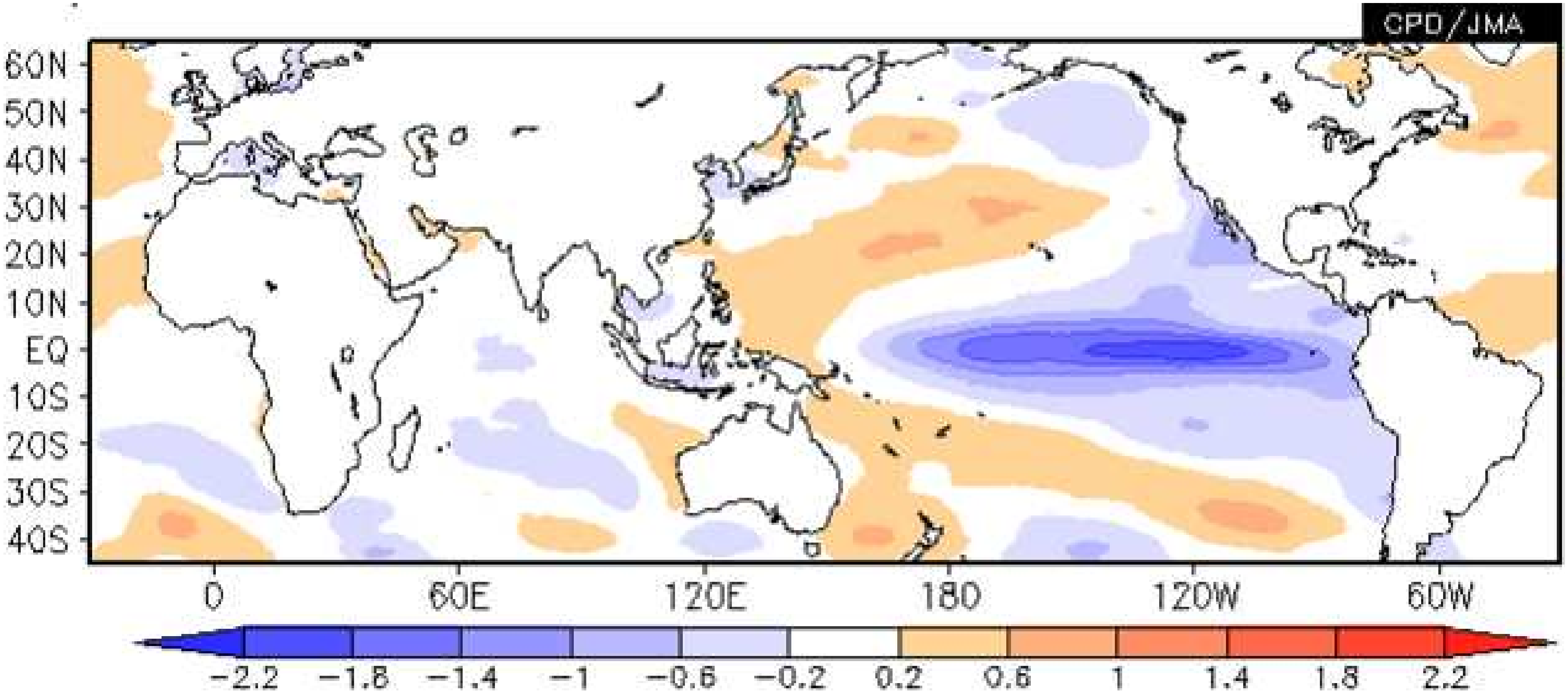
Large filled circle: statistical confidence level is 95 % or above.

Small filled circle: statistical confidence level is above 90 % and below 95 %.

Non filled circle: statistical confidence level is below 90 %.

La Niña composite (December)

Sea surface temperature



below normal **above normal**

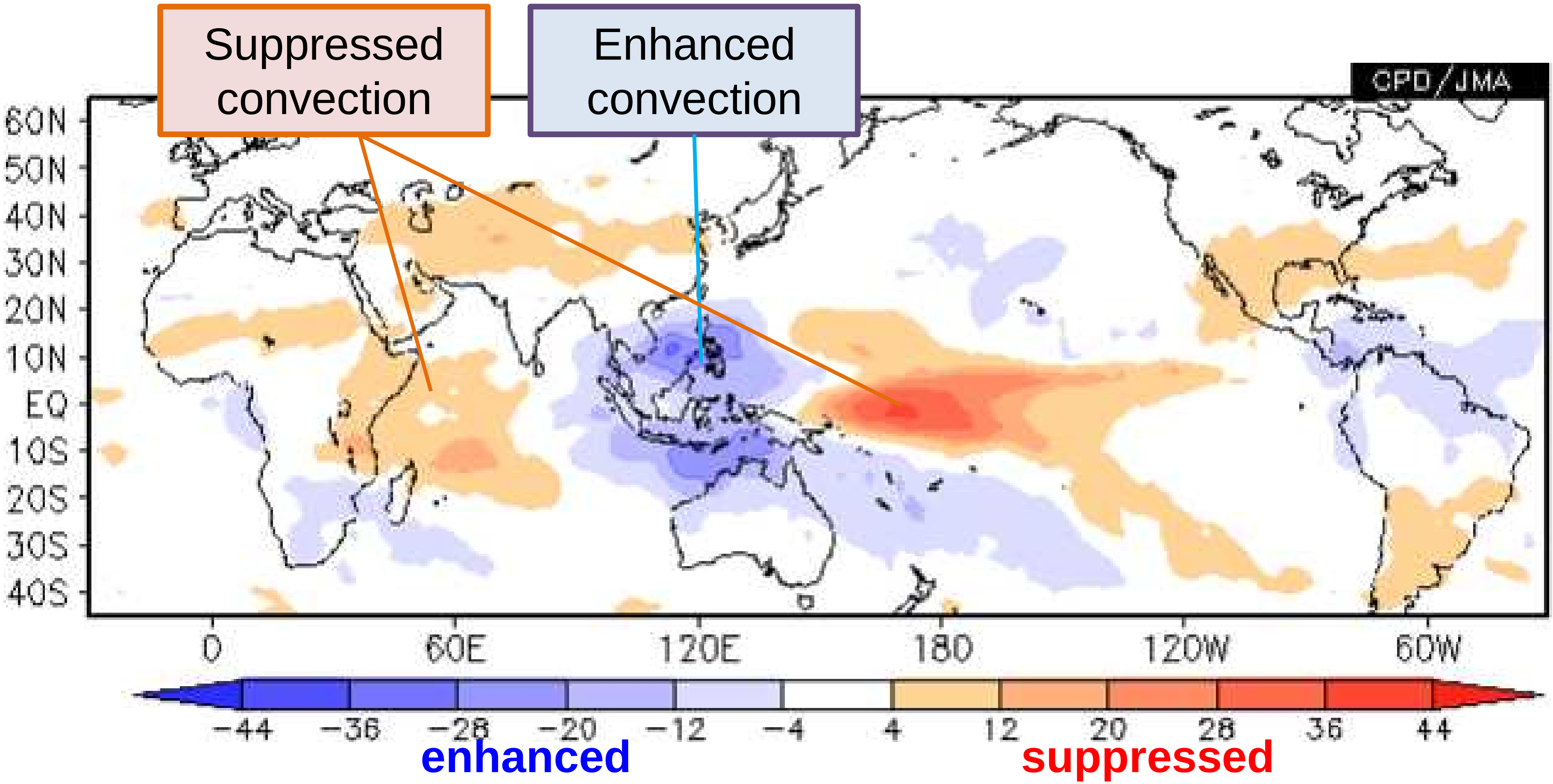
<u>Sea surface temperature (SST) anomaly (degree C)</u>

La Niña years (Dec.) : 1988, 1995, 1998, 1999, 2005, 2007, 2010

Climatological normal: 1981 – 2010 average

La Niña composite (December)

Convective activity



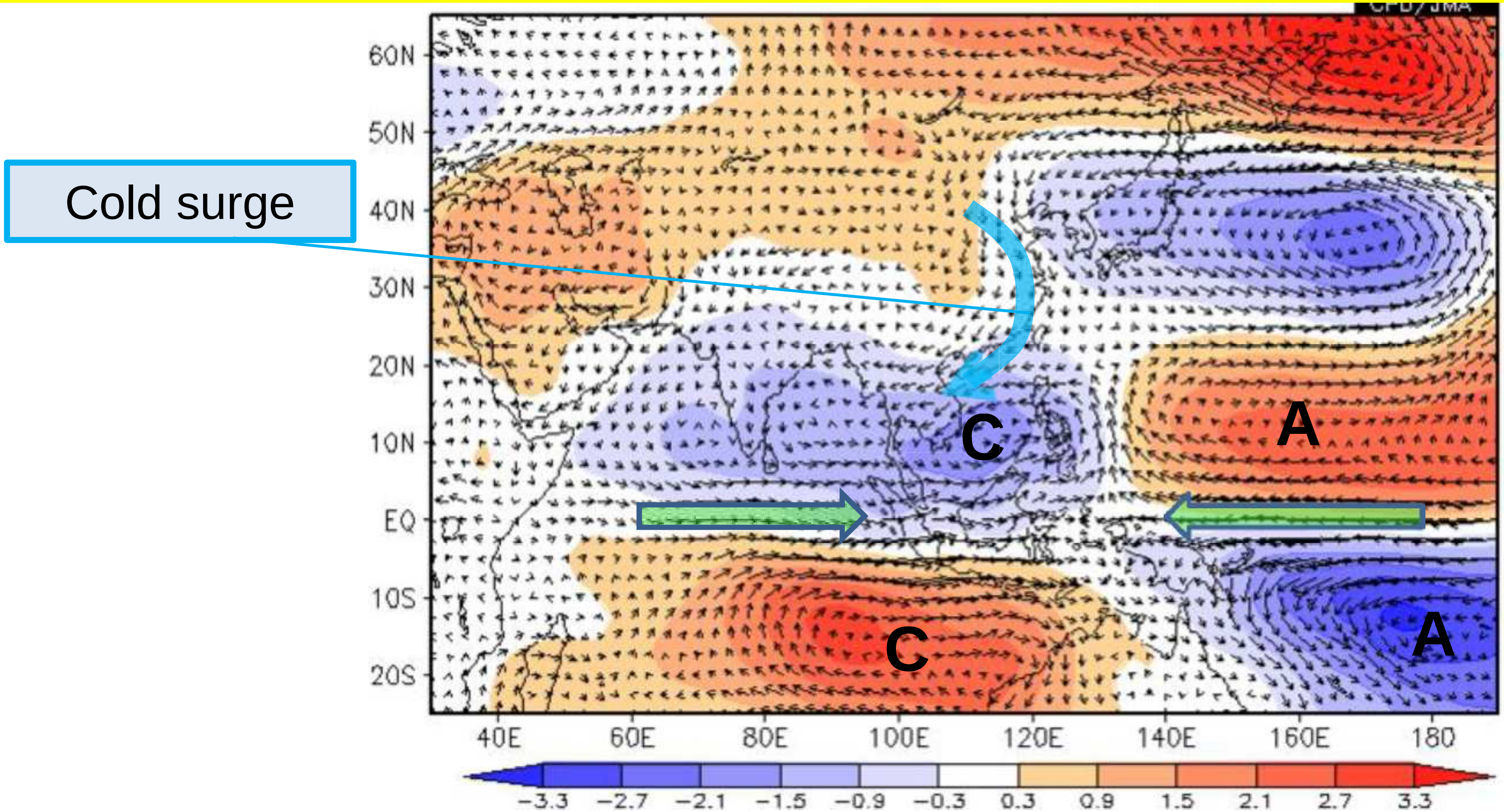
Outgoing longwave radiation (OLR) anomaly (W/m^2)

La Niña years (Dec.) : 1988, 1995, 1998, 1999, 2005, 2007, 2010

Climatological normal: 1981 – 2010 average

La Niña composite (December)

Atmospheric circulation anomaly in the lower troposphere



N.H. (S.H.): cyclonic (anti-cyclonic) anti-cyclonic (cyclonic)

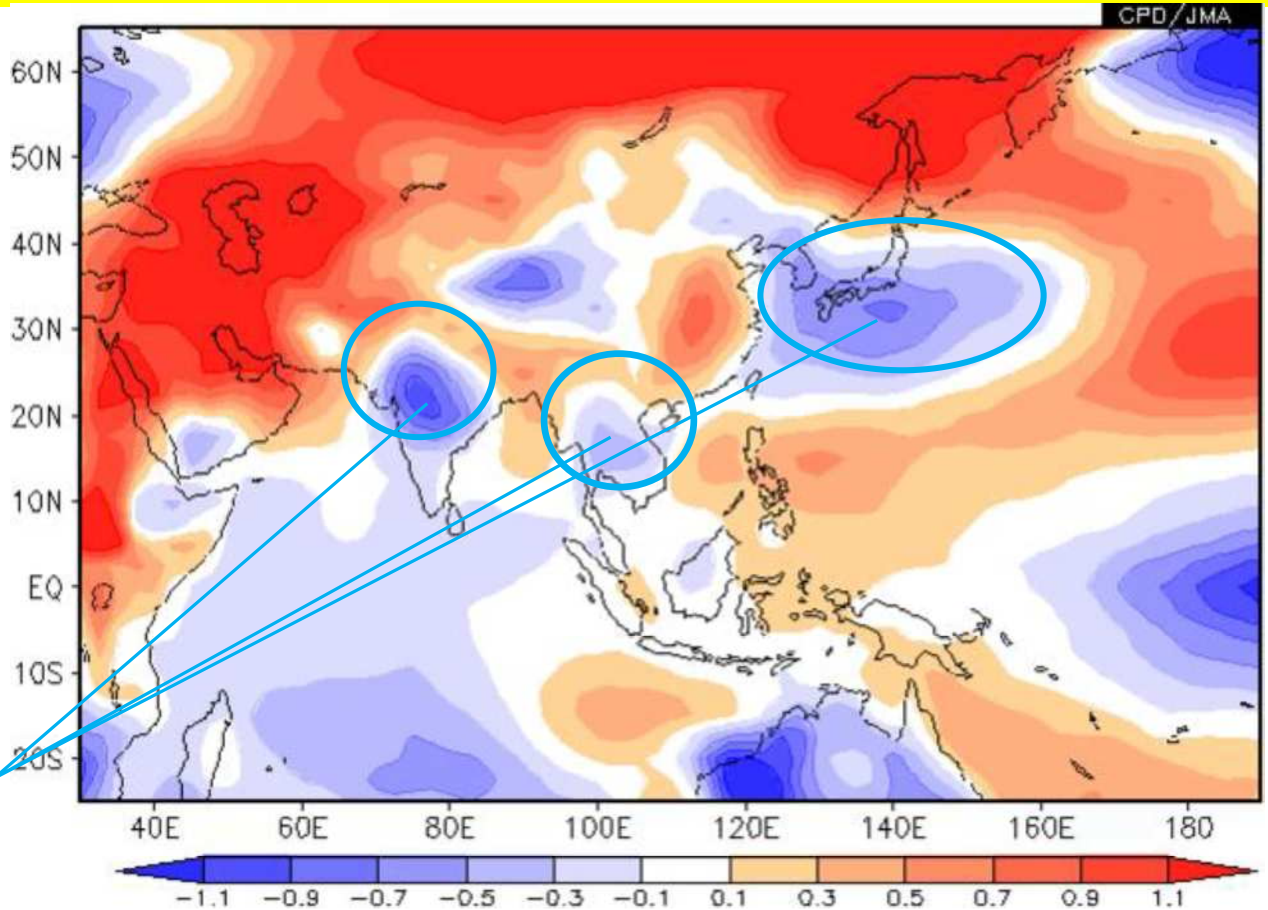
850-hPa wind anomaly (vector) and stream function (contour) and anomaly (shading) (unit: $\times 10^6 m^2/s$)

La Niña years (Dec.) : 1988, 1995, 1998, 1999, 2005, 2007, 2010

Climatological normal: 1981 – 2010 average

La Niña composite (December)

Air temperature anomaly in the lower troposphere



Below-normal temperature

below normal **above normal**

<u>925-hPa air temperature anomaly (unit: degree C)</u>

La Niña years (Dec.) : 1988, 1995, 1998, 1999, 2005, 2007, 2010

Climatological normal: 1981 – 2010 average

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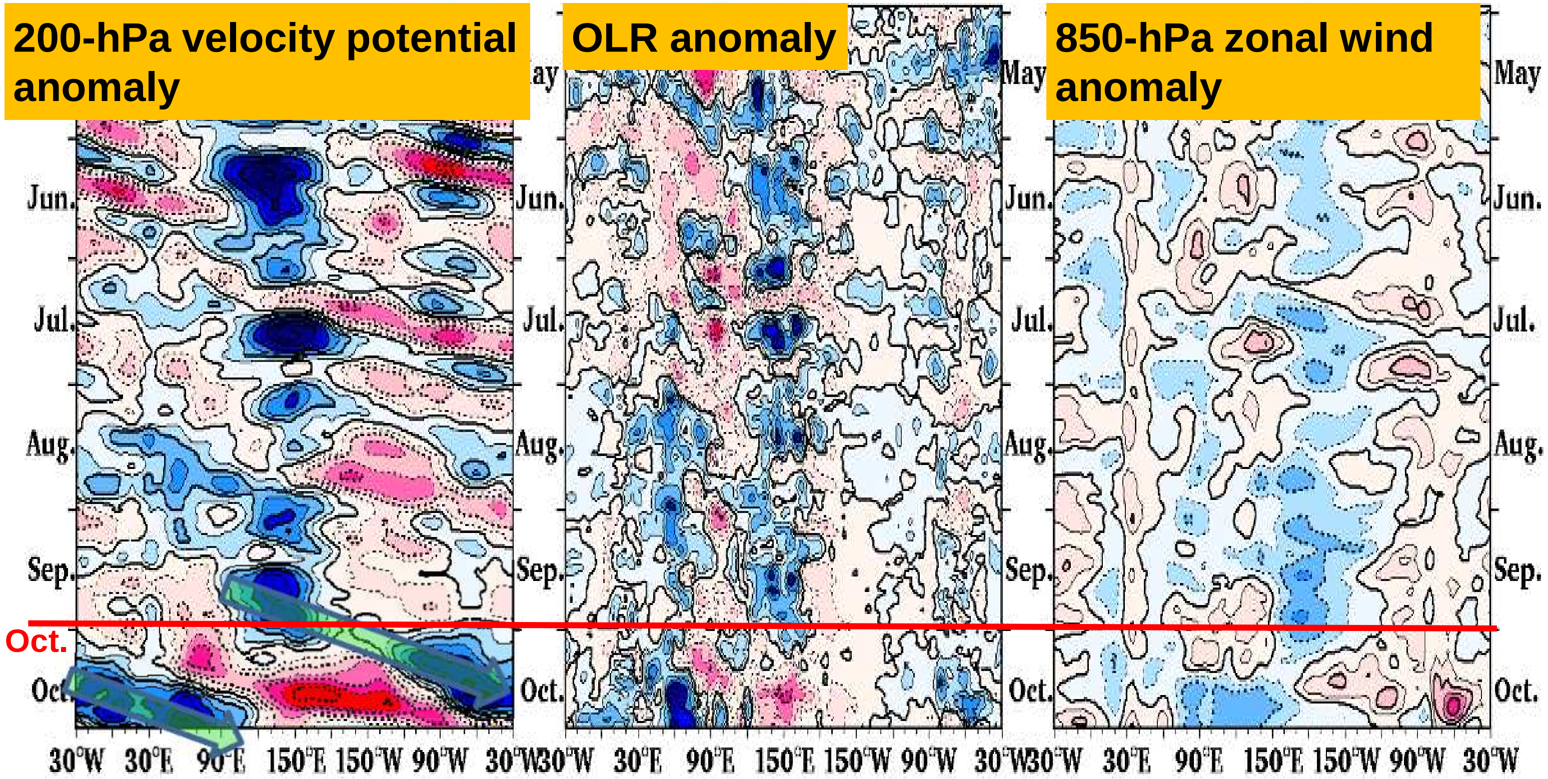
MJO

In October, a large-amplitude MJO propagated from northern South America to the Indian Ocean, and was stuck in phase over the Indian Ocean late the month.

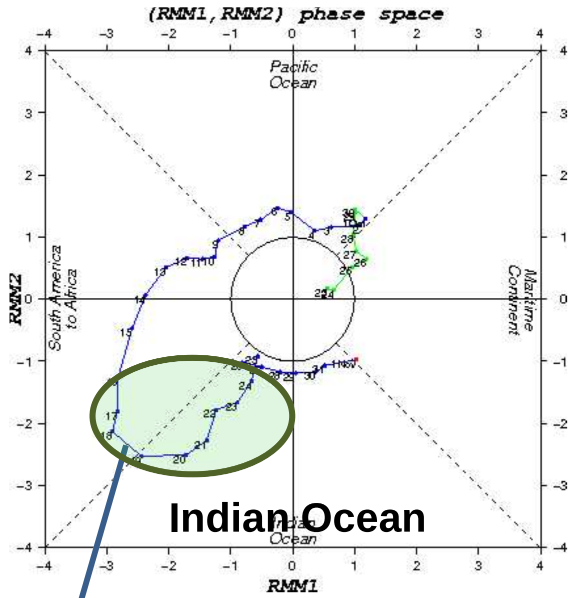
200-hPa velocity potential anomaly

OLR anomaly

850-hPa zonal wind anomaly



MJO Index (phase & space)

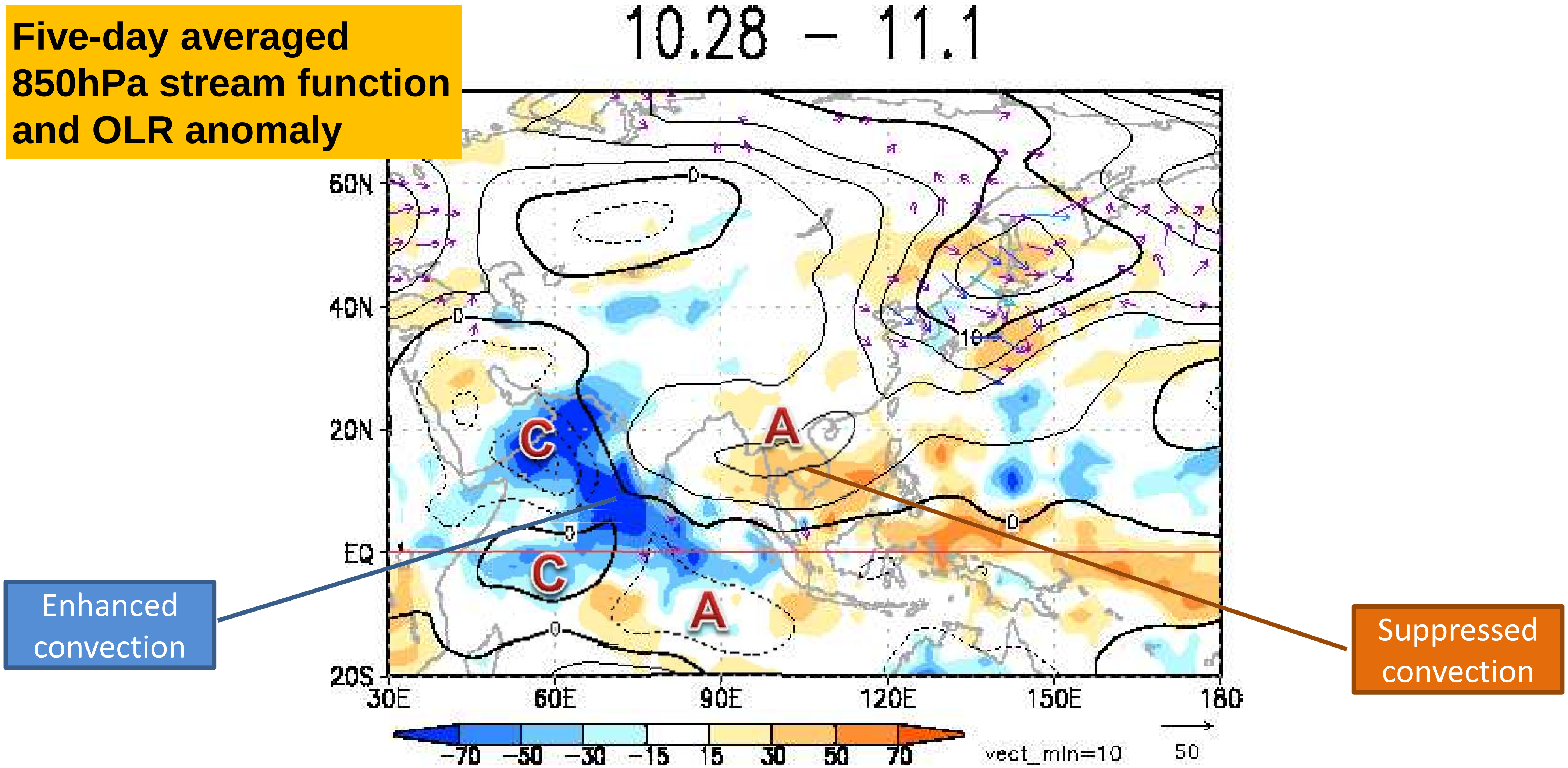


Longitude-time cross sections of 200-hPa velocity potential anomaly (left), outgoing longwave radiation (OLR) anomaly (center) and 850-hPa zonal wind anomaly (right), which are 7-day running mean values and averaged around the equator (5S-5N).
(from May to October 2011)

In late October, the MJO is stuck in phase.

Convective activity and atmospheric circulation

Five-day averaged 850hPa stream function and OLR anomaly

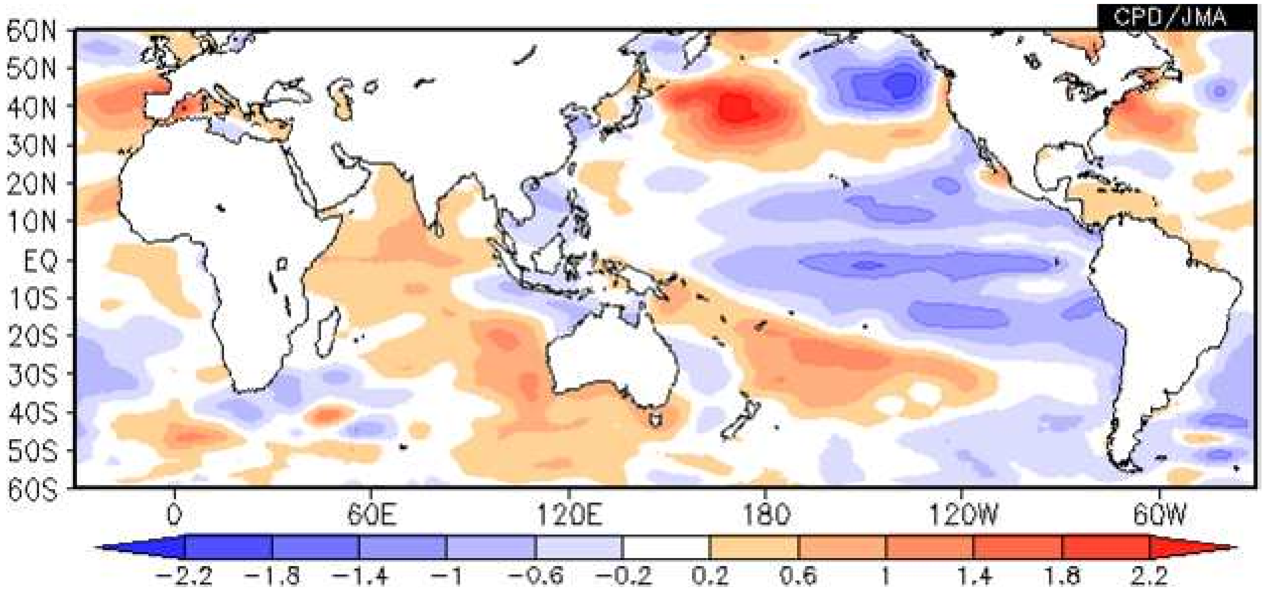


http://juice.cpd.naps.kishou.go.jp/gmd/cpd/data/fruit_wwwroot/anim/anim_asia.html
(This is experimental products and available only on a JMA internal website)

Tropical conditions (October 2011)

La Niña-like conditions and above-normal over the Indian Ocean.

SST anomaly

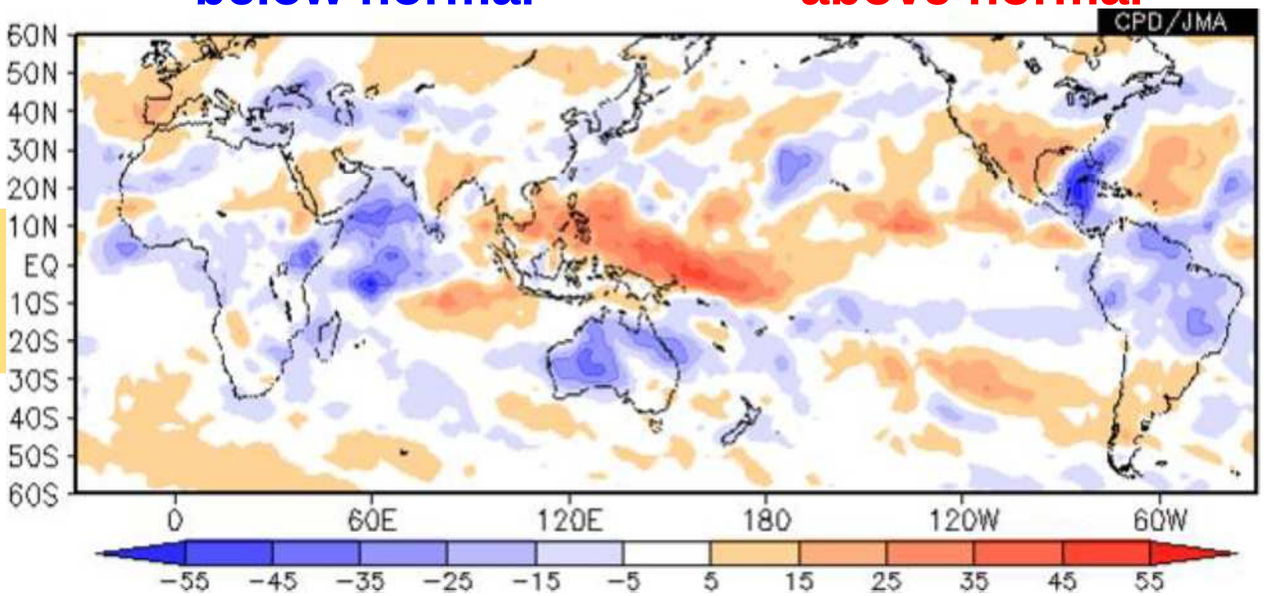


degree C

below normal

above normal

OLR anomaly
(convective activity)



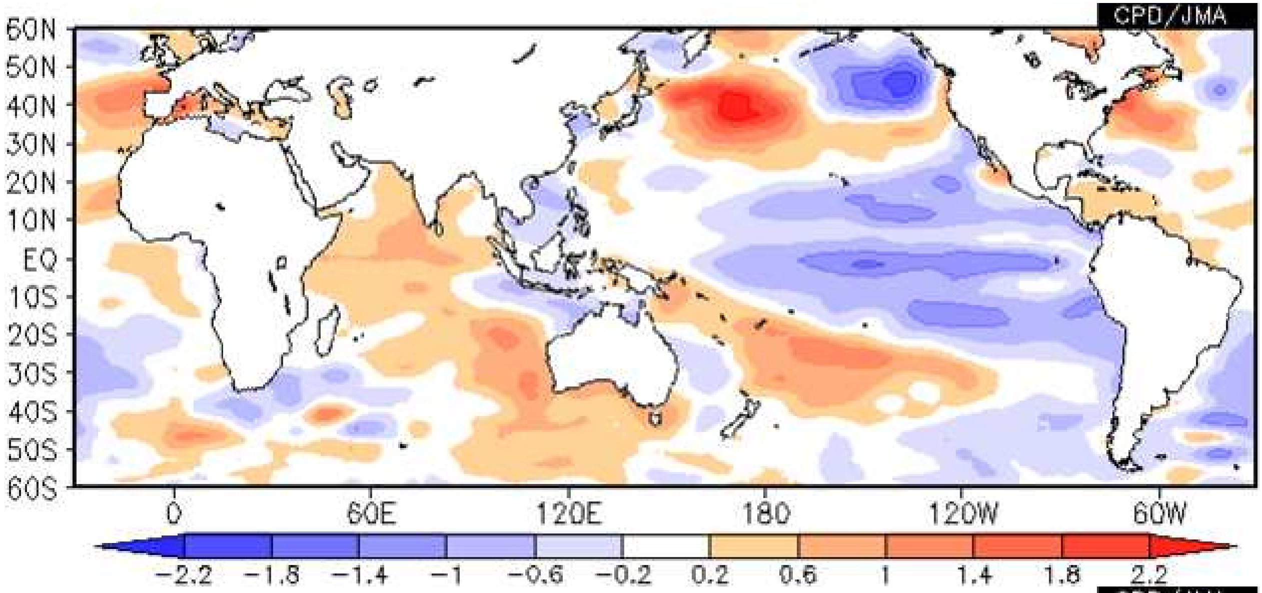
W/m^2

enhanced

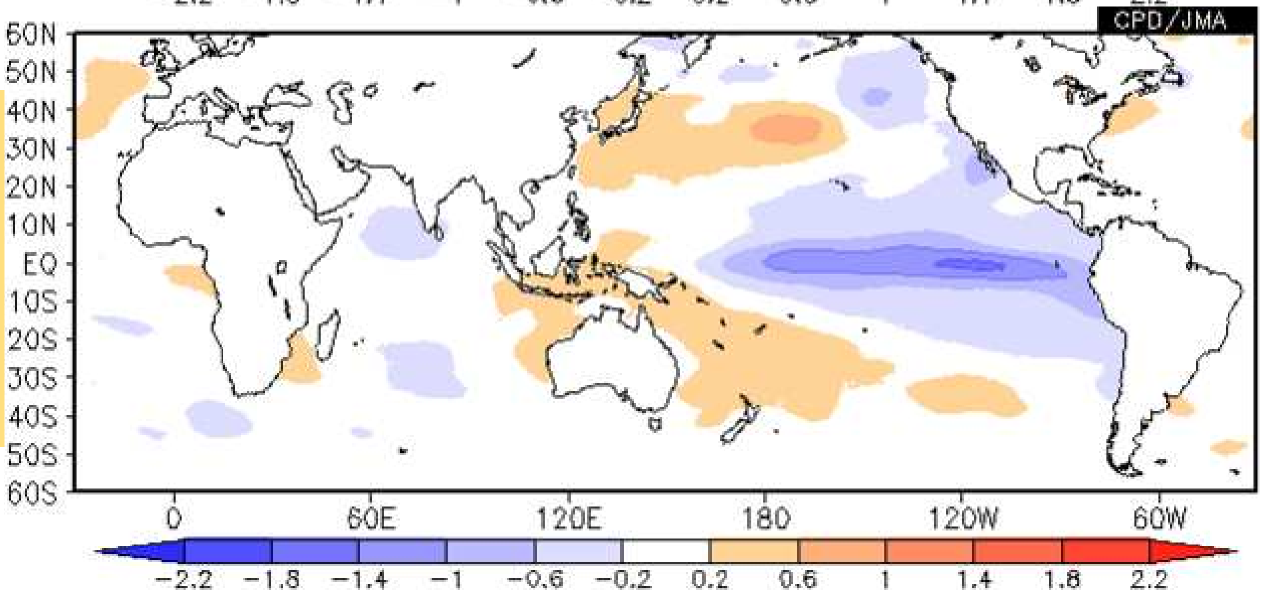
suppressed

Comparison to past La Niña
Sea surface temperature anomaly (SST)

SST anomaly
(October 2011)



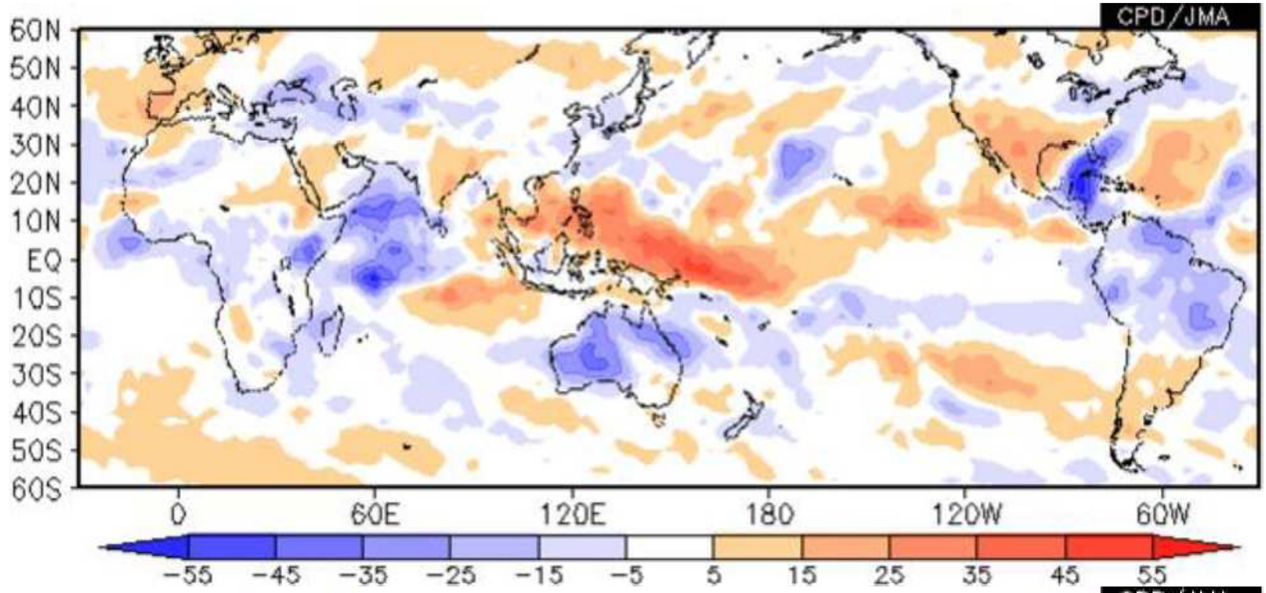
La Niña composite
(October)
1984, 1985, 1988, 1995, 1998, 1999, 2005, 2007, 2010



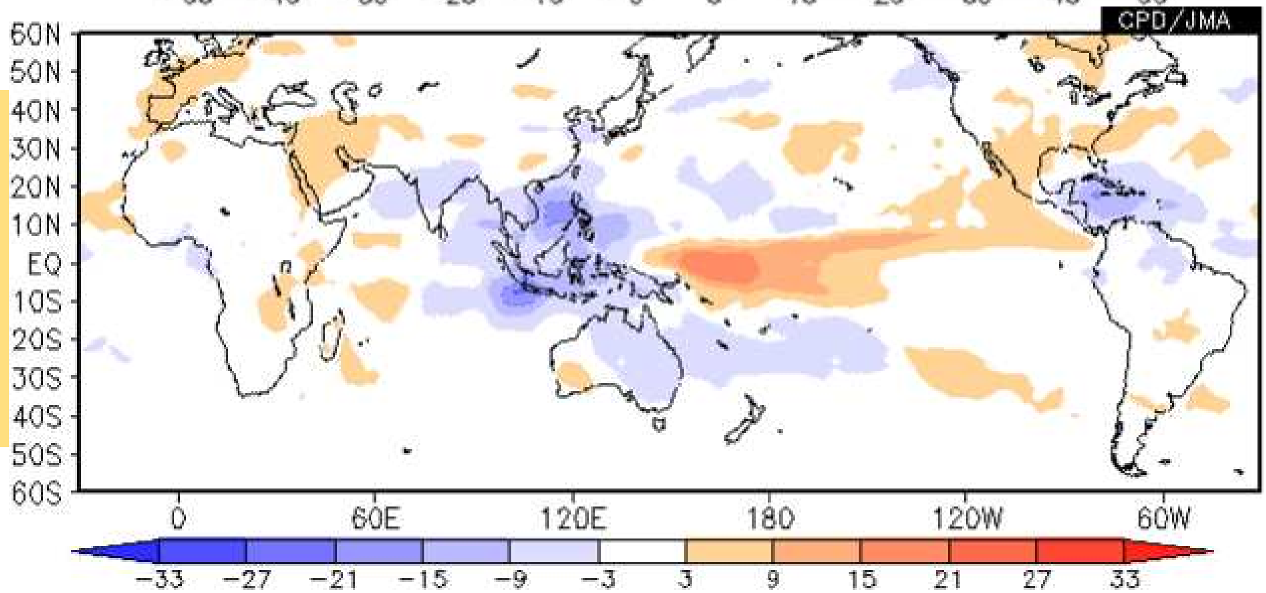
below normal **above normal**

Comparison to past La Niña
OLR anomaly (Convective Activity)

OLR anomaly
(October 2011)



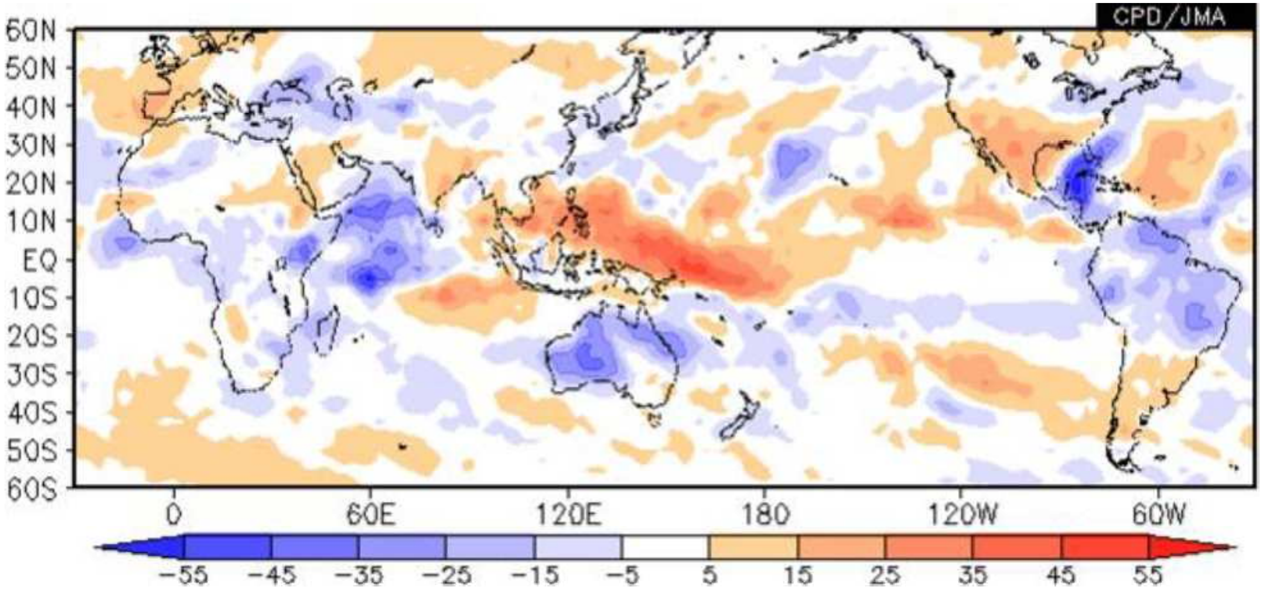
La Niña composite
(October)
1984, 1985, 1988, 1995, 1998, 1999, 2005, 2007, 2010



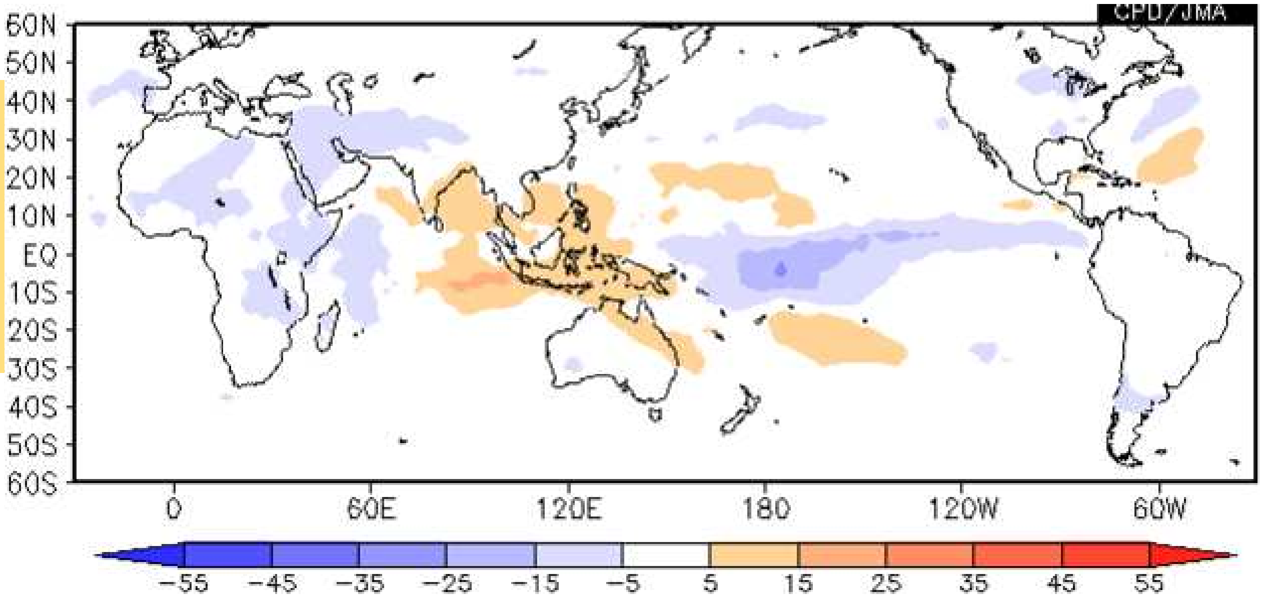
enhanced **suppressed**

Comparison to past high IOBW SST Index
OLR anomaly (Convective Activity)

OLR anomaly (October 2011)



IOBW+ composite (October)
1982, 1987, 1988, 1997, 2001, 2002, 2009



enhanced **suppressed**

Diagnosis of the current condition

In October, a large-amplitude MJO propagated from northern South America to the Indian Ocean.

Associated with the MJO and above-normal SST over the Indian Ocean, convective activity was enhanced over the western Indian Ocean and suppressed over the Maritime Continent and the western Pacific, which is similar to the characteristics in past above-normal IOBW SST years.

In upcoming season, it is likely that the IOBW SST will be near normal and is more likely than not that La Nina conditions will develop.

Considering this outlook, the current anomaly pattern in convective activity temporarily shows that in IOBW+ years and possibly will return to that in La Nina years.

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Summary

In the climate monitoring and one-month forecasting, it is important to focus on MJO and ENSO, with knowledge of their characteristics including possible impacts (and model performance and interpretation of model products).

Appendices

JMA's climate system monitoring products

- TCC routinely updates various kinds of monitoring products on world climate and climate system.
- Please see the following slides for more information on monitoring products.

Monthly Highlights on Climate System

- This monthly report contains climate in Japan and the world, atmospheric and oceanographic conditions for the previous month,
- issued around 15th every month,
- provided through the TCC website.

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

16 November, 2010 *Japan Meteorological Agency*

Monthly Highlights on Climate System (October 2010)

Highlights in October 2010
- Monthly mean temperatures were above normal in the whole Japan.
- Monthly precipitation amounts were extremely heavy around the South China Sea and Indonesia.
- In the 500-hPa height field, a wavy pattern of anomalies was found from the Pacific to North America.
- Convective activities were enhanced from the eastern Indian Ocean to Indonesia and around the South China Sea.
- Remarkably negative SST anomalies were dominant in the equatorial Pacific.

Climate in Japan (Fig. 1):

Due to the large influence of fronts and cyclones, cloudy and rainy weather was dominant compared to the normal. Monthly sunshine durations were below normal in most of Japan. In the latter period of the middle 10 days, Amami region experienced record-breaking heavy rains.

Temperatures were above normal in the first and middle 10 days in the whole Japan, while in the last 10 days they were below normal in Northern and Eastern Japan due to severe cold-air outbreaks.

World Climate (Figs. 2 and 3):

The monthly anomaly of the global average surface temperature in October 2010 (i.e. the average of the near-surface air temperature over land and the SST) was +0.26 °C (10th warmest since 1891) (Fig.2). On a longer time scale, global average surface temperatures have been rising at a rate of about 0.60°C per century. Extreme climate events are

the lower troposphere were below normal in eastern and southern China. Zonally-averaged tropospheric air temperature in the middle and high latitudes of the Northern Hemisphere decreased but remained remarkably higher than normal from summer 2010, which was the fifth highest on record for October since 1979.

Tropics (Figs. 6, 7 and 8):

Convective activities were enhanced from the eastern Indian Ocean to Indonesia, from India to the Philippines, around the Caribbean Sea, and in the intertropical convergence zone of Africa, while they were suppressed across the equatorial Pacific (Fig. 6). The active phase of the Madden-Julian Oscillation (MJO) moved eastward around Indonesia early this month (Fig. 7). In the lower troposphere, easterly wind anomalies were dominant from July 2010 (Fig. 7). Corresponding with this, the Southern Oscillation Index (SOI) was +1.8. In the upper troposphere,

16 November, 2010 *Japan Meteorological Agency*

Fig. 4 Monthly mean 500-hPa height and anomaly in the Northern Hemisphere (October 2010)
Contours show heights at an interval of 60 m. Shaded patterns show height anomalies. Base period for the normal is 1979-2004.

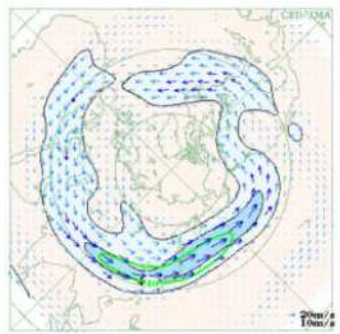


Fig. 5 Monthly mean 200-hPa wind speed and vectors in the Northern Hemisphere (October 2010)
Black lines show wind speeds at an interval of 20 m/s. Blue shading shows values greater than 40 m/s. Green lines show normal wind speeds at an interval of 40 m/s. Base period for the normal is 1979-2004.

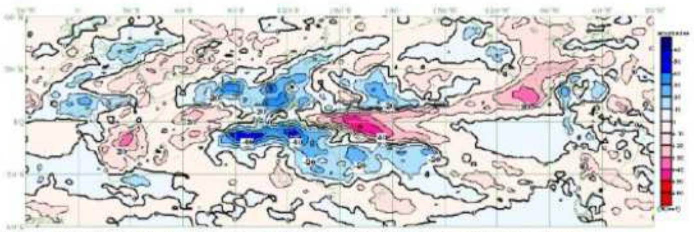


Fig. 6 Monthly mean Outgoing Longwave Radiation (OLR) anomaly (October 2010)
Contour interval is 10 W/m². Base period for the normal is 1979-2004. Original data are provided by courtesy of NOAA.

Annual Report on Climate System

- This annual report contains reports on major climate events (e.g. summary on El Nino/La Nina events, Asian summer monsoon) as well as overviews on climate in Japan and the world, atmospheric and oceanographic conditions,

- issued in March every year,

- provided through the TCC website.

  http://ds.data.jma.go.jp/tcc/tcc/products/clisys/arcs.html

2.7 Summary of the Asian Summer Monsoon in 2009

The figures referred to in this section can be found on pp. 66 – 68.

Observing Asian summer monsoon activity is very important, since fluctuations in convective activities and atmospheric circulation associated with it can influence the summer climate in Asia, including that of Japan. In this section, the characteristics of the Asian summer monsoon from June to September 2009 are described.

2.7.1 Asian summer monsoon activities and atmospheric circulation in summer 2009

Asian summer monsoon activities inferred from the seasonal mean (i.e., from June to September) of Outgoing Longwave Radiation (OLR) were enhanced from the east of the Philippines to the western Pacific (Fig. 2.7.1), and were suppressed over western Indonesia and from India to the area around Taiwan.

Asian summer monsoon activities were generally suppressed throughout the season except in the West North Pacific Monsoon (WNPM) region (Table 2.7.1). In the lower troposphere, monsoon circulation was stronger than normal over the eastern Indian Ocean, though its northward penetration was weaker than normal (Fig. 2.7.2a). Cyclonic circulation anomalies were observed around the Philippines, indicating that the monsoon trough was deeper than normal and

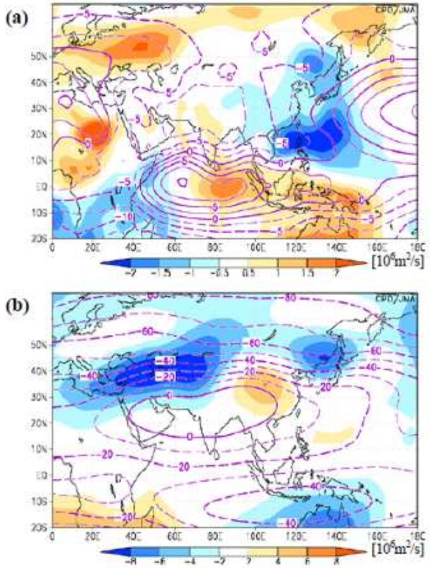


Fig. 2.7.2 Four-month mean stream function and its anomaly for June – September 2009
(a) The contours indicate the 850-hPa stream function (m^2/s) at intervals of 2.5×10^6 m^2/s, and the color shading indicates 850-hPa stream function anomalies. (b) The contours indicate the 200-hPa stream function (m^2/s) at intervals of 10×10^6 m^2/s, and the color shading indicates 200-hPa stream function anomalies.

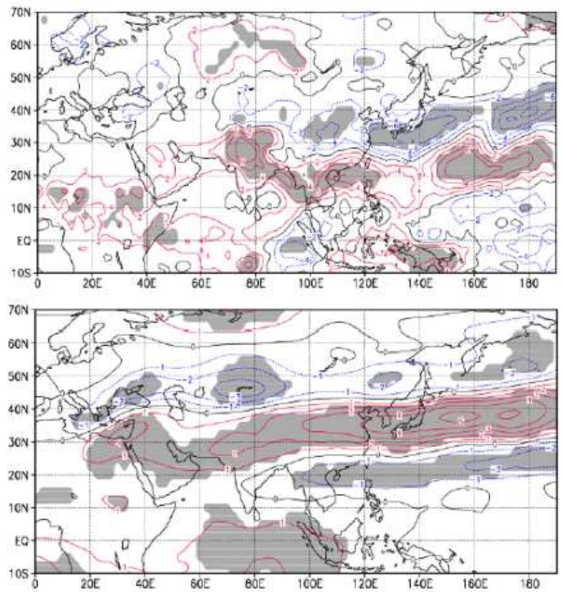


Fig. 4.3.8 Monthly mean linear regression coefficient of OLR (top) and 200 hPa zonal wind (bottom) with part of southward mode score not predicted by NINO.3.
The contour interval is 2 W/m^2 on the left and 1 m/s on the right. The shading shows a 95% confidence level based on F-testing.

El Niño Outlook

- This report contains current condition of and outlook for ENSO,
- issued around 10th every month,
- provided through the TCC website.

http://ds.data.jma.go.jp/tcc/tcc/products/elnino/outlook.html

El Niño Outlook

(January 2011 - July 2011)

Last Updated: **11 January 2011**

- **La Niña conditions are likely to persist during boreal winter and decay in boreal spring.**

[Pacific Ocean]

In December 2010, the SST deviation from a sliding 30-year mean SST averaged over the NINO.3 region was -1.5°C. The five-month running-mean value of the NINO.3 SST deviations was -1.4°C for October. The Southern Oscillation Index for December was +3.0 (Table and Fig.1). In December, negative SST anomalies prevailed over most of the equatorial Pacific, except near Indonesia (Fig.2 and Fig.4). Subsurface temperature anomalies were remarkably positive in the western equatorial Pacific, and were remarkably negative in the central and the eastern parts (Fig.3 and Fig.5). In the equatorial Pacific, convective activities in the western part and near the date line were below normal. Easterly wind anomalies in the lower troposphere prevailed in the western and the central equatorial Pacific (Fig.6, Fig.7 and Fig.8). The oceanic and atmospheric features mentioned above reflect La Niña conditions.

In the equatorial Pacific, persistent easterly anomalies in the lower troposphere maintained the negative subsurface temperature anomalies in the central and the eastern parts. The negative subsurface temperature anomalies will, in turn, keep SSTs below normal.

The JMA's El Niño prediction model predicts that the NINO.3 SST will be below normal during boreal winter, and will gradually become near normal during boreal spring, and will be near or above normal during boreal summer (Fig.9).

Considering all the above, La Niña conditions are likely to persist during boreal winter and decay in boreal spring.

It is likely that the SST in the NINO.WEST will be above normal during boreal winter, and will gradually become near normal during boreal spring and summer (Fig.10).

[Indian Ocean]

The SST averaged over the tropical Indian Ocean (IOBW) region became below normal in December (Fig.1). It is likely that the SST in the IOBW region will be below normal during boreal winter, and near or below normal during boreal spring and summer (Fig.11).

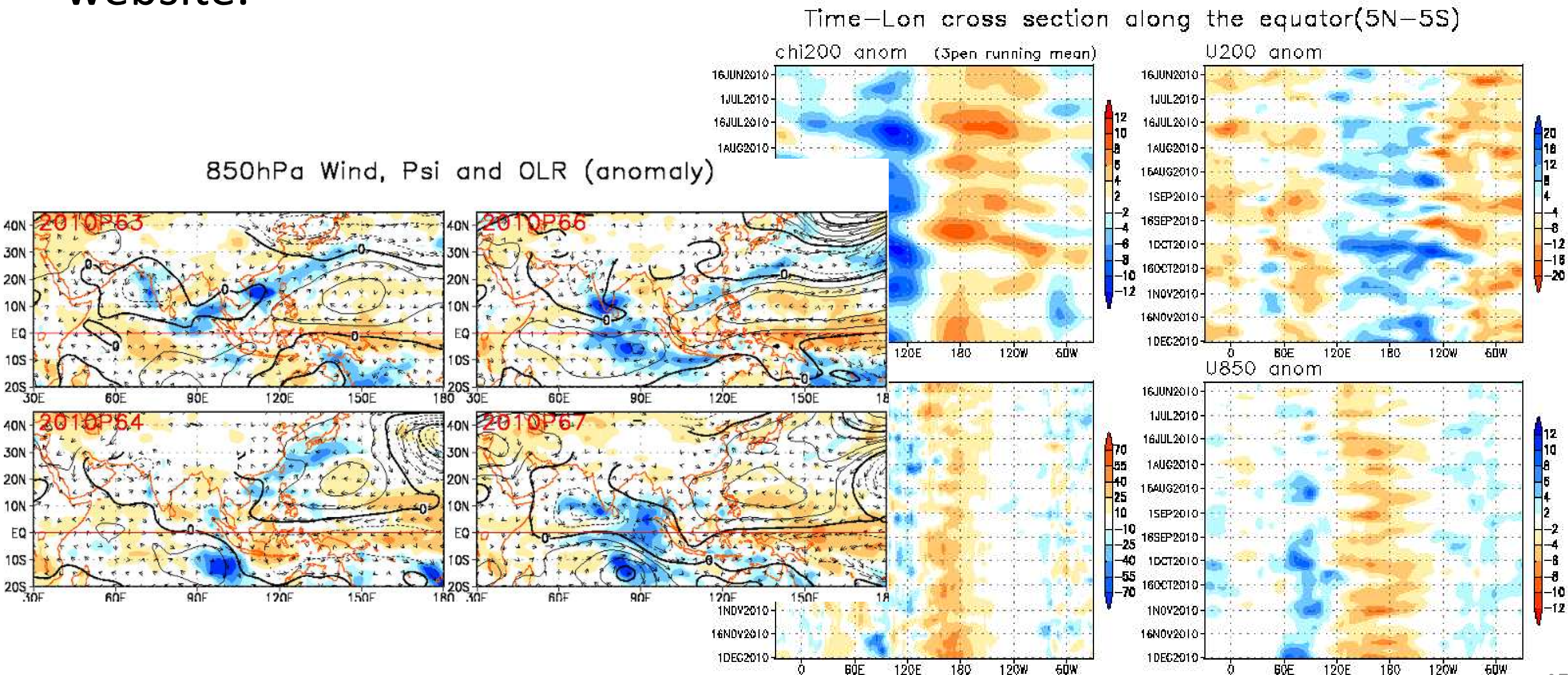
Asian Monsoon Monitoring

- This product contains a variety of analysis products (figures) to assess the current condition of climate system related to Asian,

- provided through the TCC website.

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

- In addition to this, ***MJO Monitoring*** is provided through the website.



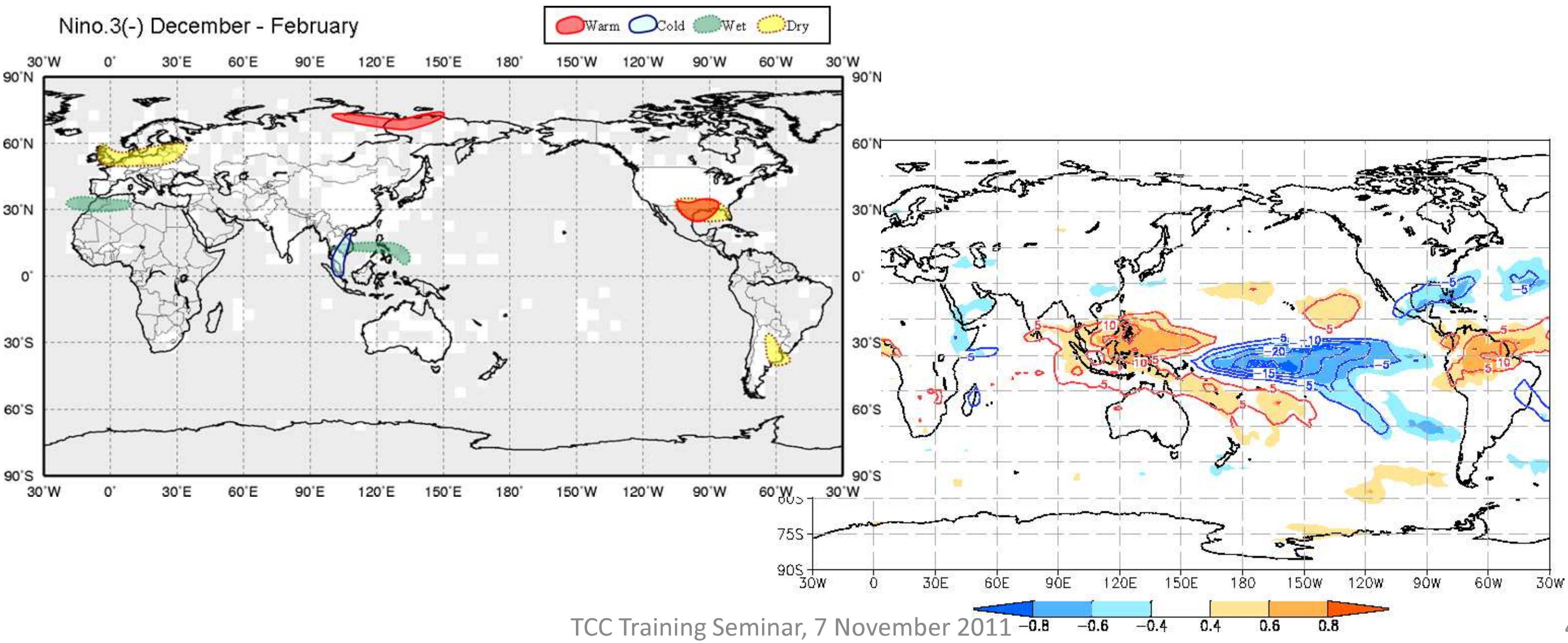
Statistical Research

- Regression and correlation analysis between atmospheric circulation and major monitoring indices related to ENSO:

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

- Composite maps of temperature and precipitation in El Nino/La Nina events:

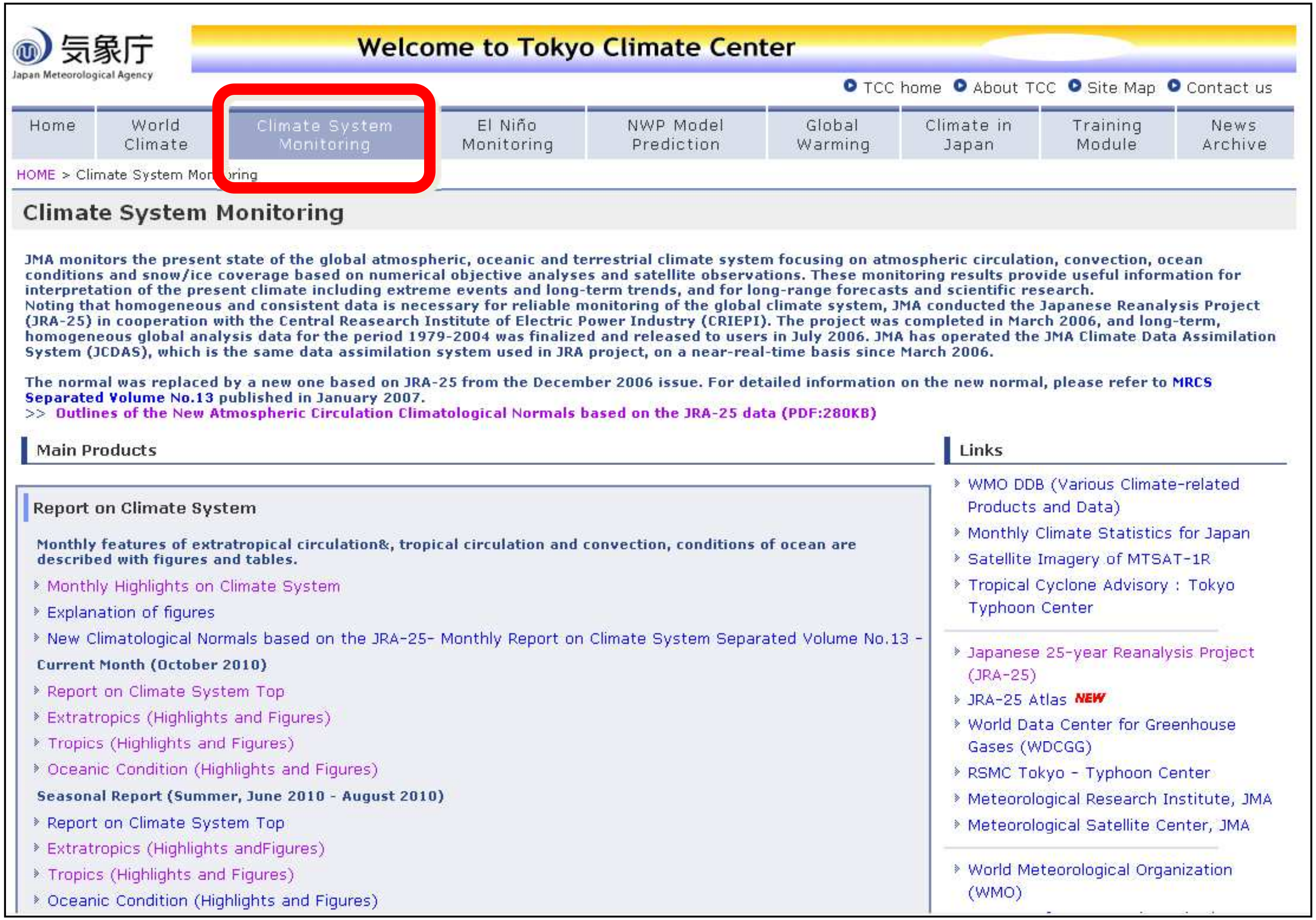
  http://ds.data.jma.go.jp/tcc/tcc/products/climate/ENSO/index.htm



Climate System Monitoring page of the TCC website

- The JMA's climate system monitoring products are provided through the TCC website:

  http://ds.data.jma.go.jp/tcc/tcc/products/clisys/index.html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Climate System Monitoring

JMA monitors the present state of the global atmospheric, oceanic and terrestrial climate system focusing on atmospheric circulation, convection, ocean conditions and snow/ice coverage based on numerical objective analyses and satellite observations. These monitoring results provide useful information for interpretation of the present climate including extreme events and long-term trends, and for long-range forecasts and scientific research.
Noting that homogeneous and consistent data is necessary for reliable monitoring of the global climate system, JMA conducted the Japanese Reanalysis Project (JRA-25) in cooperation with the Central Reasearch Institute of Electric Power Industry (CRIEPI). The project was completed in March 2006, and long-term, homogeneous global analysis data for the period 1979-2004 was finalized and released to users in July 2006. JMA has operated the JMA Climate Data Assimilation System (JCDAS), which is the same data assimilation system used in JRA project, on a near-real-time basis since March 2006.

The normal was replaced by a new one based on JRA-25 from the December 2006 issue. For detailed information on the new normal, please refer to MRCS Separated Volume No.13 published in January 2007.
>> Outlines of the New Atmospheric Circulation Climatological Normals based on the JRA-25 data (PDF:280KB)

Main Products

Report on Climate System

Monthly features of extratropical circulation&, tropical circulation and convection, conditions of ocean are described with figures and tables.

- Monthly Highlights on Climate System
- Explanation of figures
- New Climatological Normals based on the JRA-25- Monthly Report on Climate System Separated Volume No.13 -

Current Month (October 2010)

- Report on Climate System Top
- Extratropics (Highlights and Figures)
- Tropics (Highlights and Figures)
- Oceanic Condition (Highlights and Figures)

Seasonal Report (Summer, June 2010 - August 2010)

- Report on Climate System Top
- Extratropics (Highlights andFigures)
- Tropics (Highlights and Figures)
- Oceanic Condition (Highlights and Figures)

Links

- WMO DDB (Various Climate-related Products and Data)
- Monthly Climate Statistics for Japan
- Satellite Imagery of MTSAT-1R
- Tropical Cyclone Advisory : Tokyo Typhoon Center
- Japanese 25-year Reanalysis Project (JRA-25)
- JRA-25 Atlas NEW
- World Data Center for Greenhouse Gases (WDCGG)
- RSMC Tokyo - Typhoon Center
- Meteorological Research Institute, JMA
- Meteorological Satellite Center, JMA
- World Meteorological Organization (WMO)

Global Surface Climate Monitoring

- Weekly, monthly and seasonal monitoring reports on extreme climate events with brief descriptions on disastrous events are available on the TCC website.

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

El Niño Monitoring

- Monthly diagnosis reports, ENSO monitoring products, ENSO indices and El Niño outlooks are available on the TCC website.

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