TCC Training Seminar on Climate Analysis Information
26 – 30 November 2012
Tokyo, Japan

Climate System Monitoring

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Outline

1. Introduction
2. Climate analysis information
3. Basic knowledge and technique
4. Asian monsoon
5. MJO
6. ENSO

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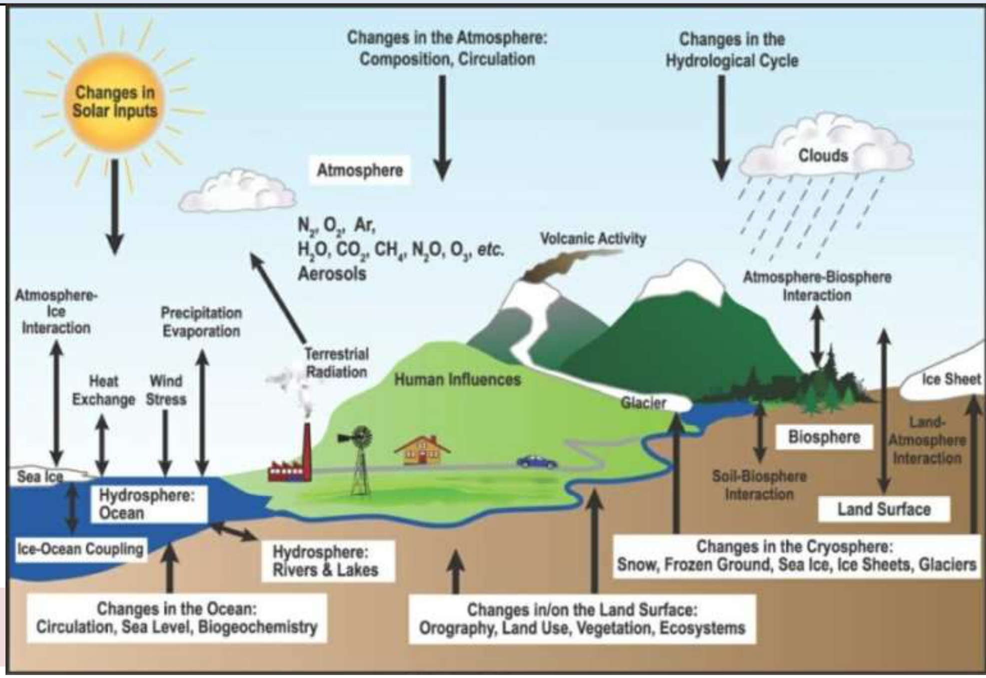
Climate system

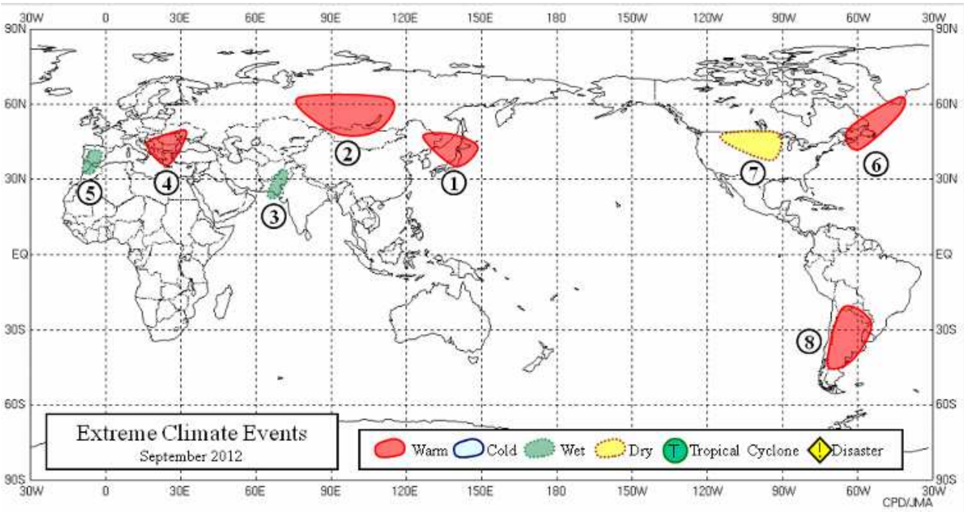
- Climate: The average weather over a period of time.
  - The statistics of meteorological elements such as temperature, rainfall, wind, atmospheric pressure…
- Climate system: Atmosphere, ocean, land, snow-ice, biosphere …
- Each component of the climate system varies due to its internal process and interactions with other components. The climate system is very complicated.



Components of climate system IPCC (2007)

Background

- The climate system has strong impact on socio-economic activities in the world through extreme climate events (e.g., heat/cold waves, droughts and heavy rainfall).
- It is important for society and people to appropriately deal with climate variability and extreme climate events for maximizing climate benefits and minimizing climate risks.
- To this end, it is necessary for them to understand present and possible future climate conditions, backgrounds and factors.



Objectives and mission

- National Meteorological and Hydrological Services (NMHSs) are responsible for contributing to realize a climate-resilient society, providing climate services.
- NMHSs should implement climate system monitoring services (in addition to climate prediction services):
  - Diagnose and assess conditions of the climate system through carefully and precisely monitoring and analyzing the climate system on a scientific approach.
  - Provide outcomes to the public timely and in appropriate formats.

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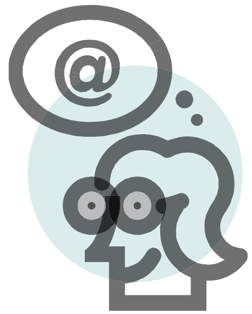
Climate analysis information

- NMHSs have a responsibility to provide scientifically accurate climate information and products.
- It is hard for people without meteorological and climatological knowledge to use scientific information with a lot of jargon.

- It is important to provide information depending on needs and users (user-oriented information).



Users

1. Non-experts (without meteorology)

- General public
- Decision-makers in socio-economic sectors (e.g., agriculture, water resource management, tourism, retail business)

2. Experts (with meteorology and advanced science)

- Weather forecasters (NMHS, private weather companies)
- Experts with meteorology and advanced science in socio-economic sectors
- Scientific journalists
- Science teachers

Types of information

1. Information for non-experts

- Tailored information based on users' needs,
- Easy-to-understand information that is summarized and interpreted without jargon for decision making.

2. Information for experts

- Specialistic information,
- Detailed information that includes climate system conditions associated with climate events and factor analysis.

Cold Wave over the Eurasian Continent

6 February 2012
Tokyo Climate Center, Japan Meteorological Agency

1. Overview

Since mid-January 2012, the Eurasian continent, especially in the mid-latitudes, has experienced significantly lower-than-normal temperatures due to strong cold-air inflow (Figure 1). As a result, temperatures have been extremely low from the northern part of East Asia to Central Asia (in and around Mongolia and Kazakhstan) since mid-January, and in Eastern Europe (in and around Ukraine) since the end of January. The influence of cold air has extended to Central to Western Europe as well as to all over Central Asia, such as Uzbekistan and Tajikistan, since the beginning of February.

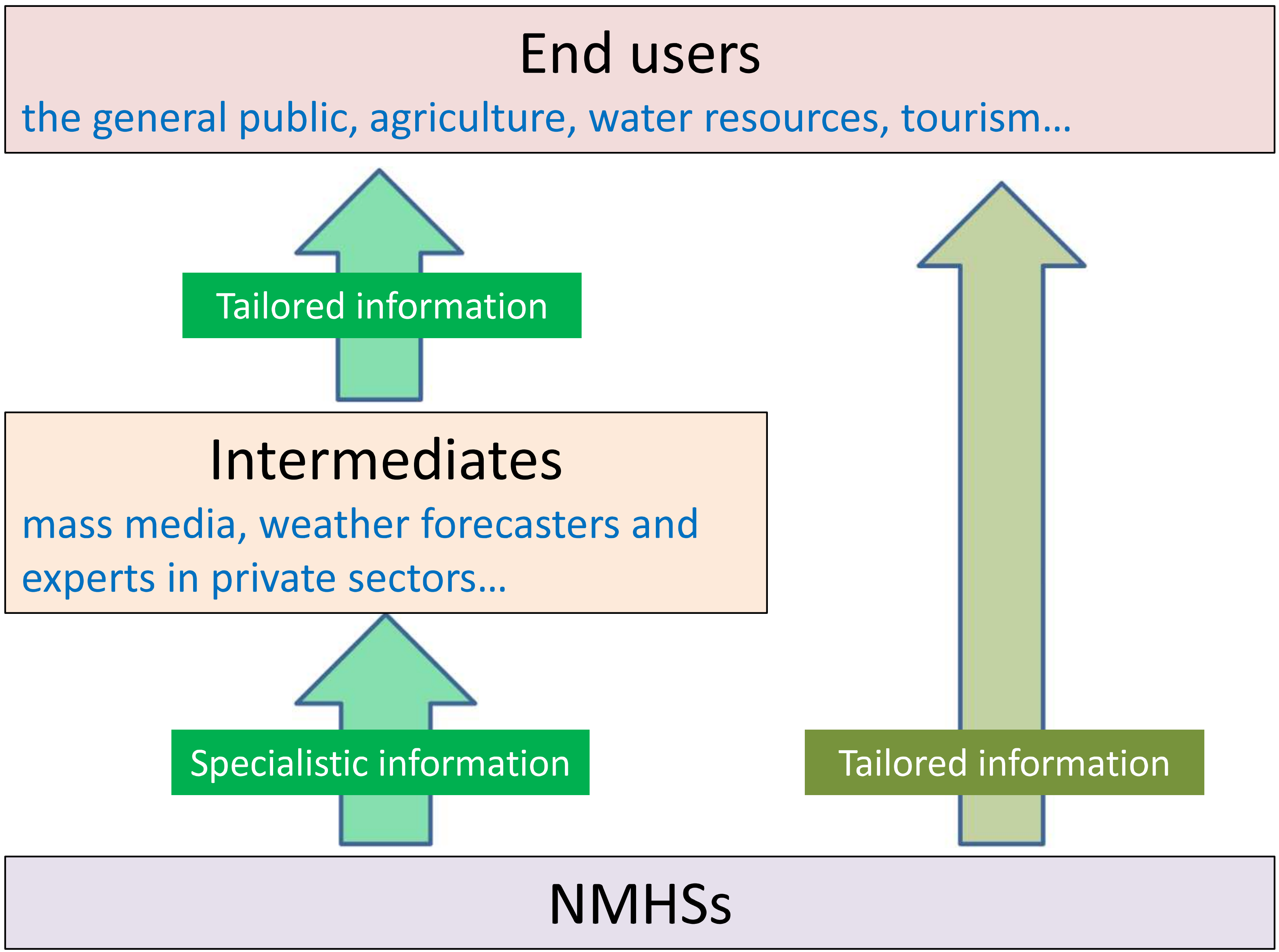
2. Climatic conditions

Table 1 summarizes weekly extreme climate events from mid-January. Figure 1 shows weekly temperature anomalies from mid-January in the Northern Hemisphere. Figure 2 shows daily temperatures at some meteorological stations in affected countries.

Table 1 Weekly extreme climate events and impacts

Period	Areas	Extreme Climatic Events and impacts
15 – 21 January	In and around Eastern Kazakhstan	Extremely low temperatures

Users and information flow



Basic structure of the information

1. Surface climate conditions and impacts

2. Characteristics of atmospheric circulation directly contributing to the surface climate conditions

3. (if possible) Primary factors associated with the characteristic atmospheric circulation

Procedure

- **Analyzing**

Step 1: Assess surface climate conditions and impacts.

Step 2: Identify atmospheric circulation directly contributing to the targeted surface climate conditions.

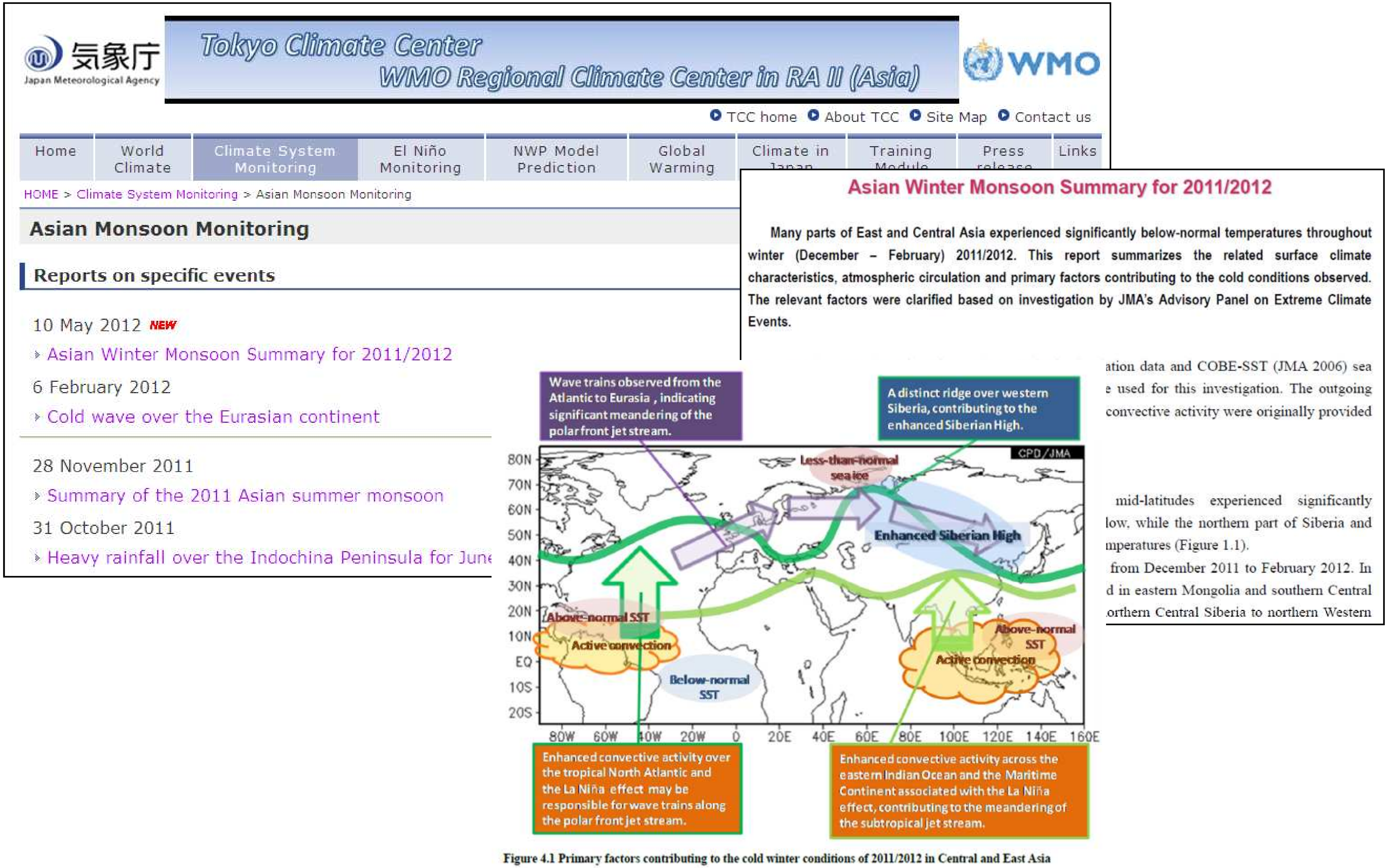
Step 3: Investigate the possible factors associated with the identified atmospheric circulation directly contributing to the targeted surface climate conditions.

- **Producing information**

- Information for non-experts: Step 1 and summary of Steps 2 and 3.
- Information for experts: Step 1, Step 2 and Step 3.

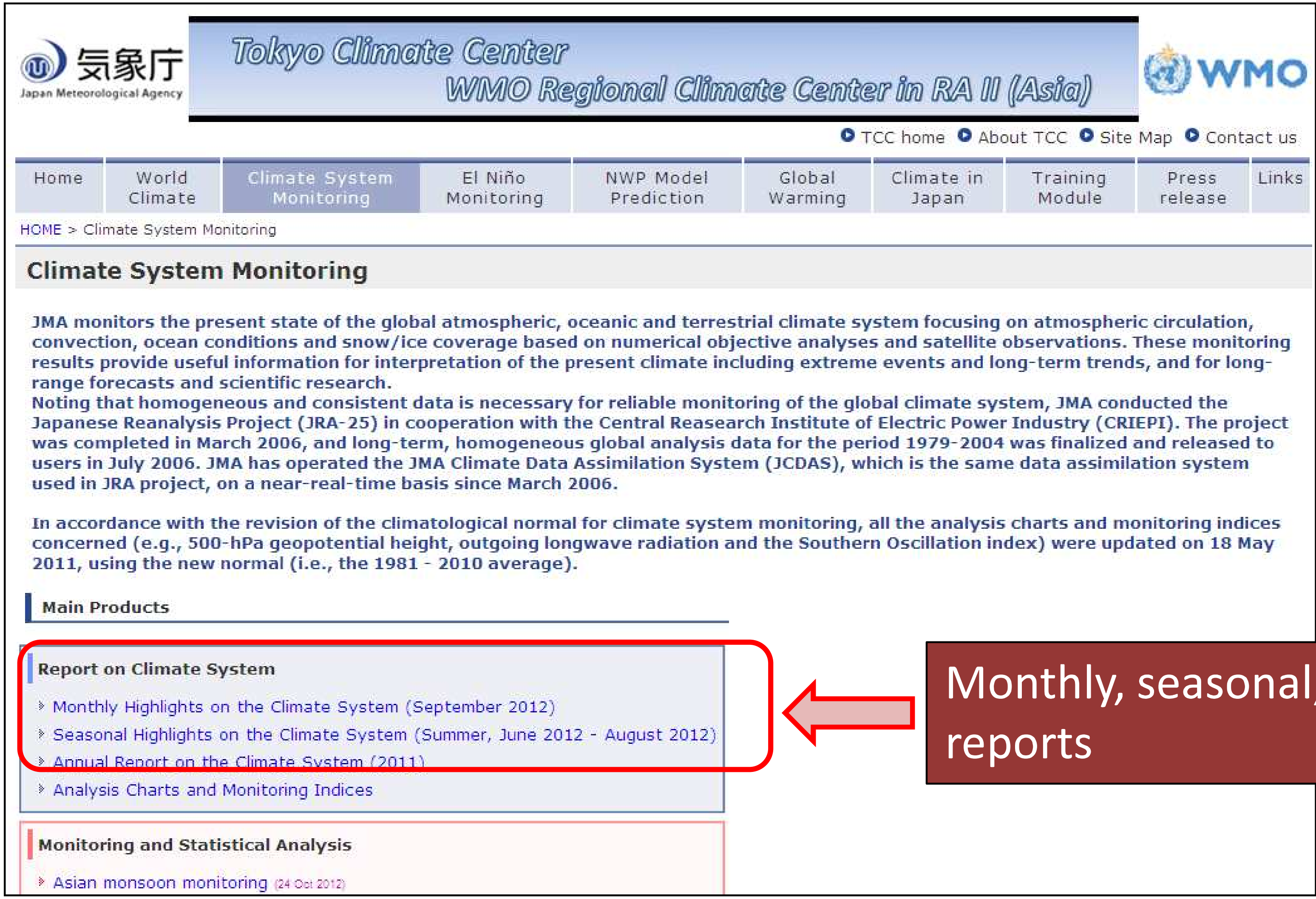
Information on specific climate events (TCC website)

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



Monthly, seasonal and annual reports on climate system conditions (TCC website)

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



Monthly, seasonal, and annual reports

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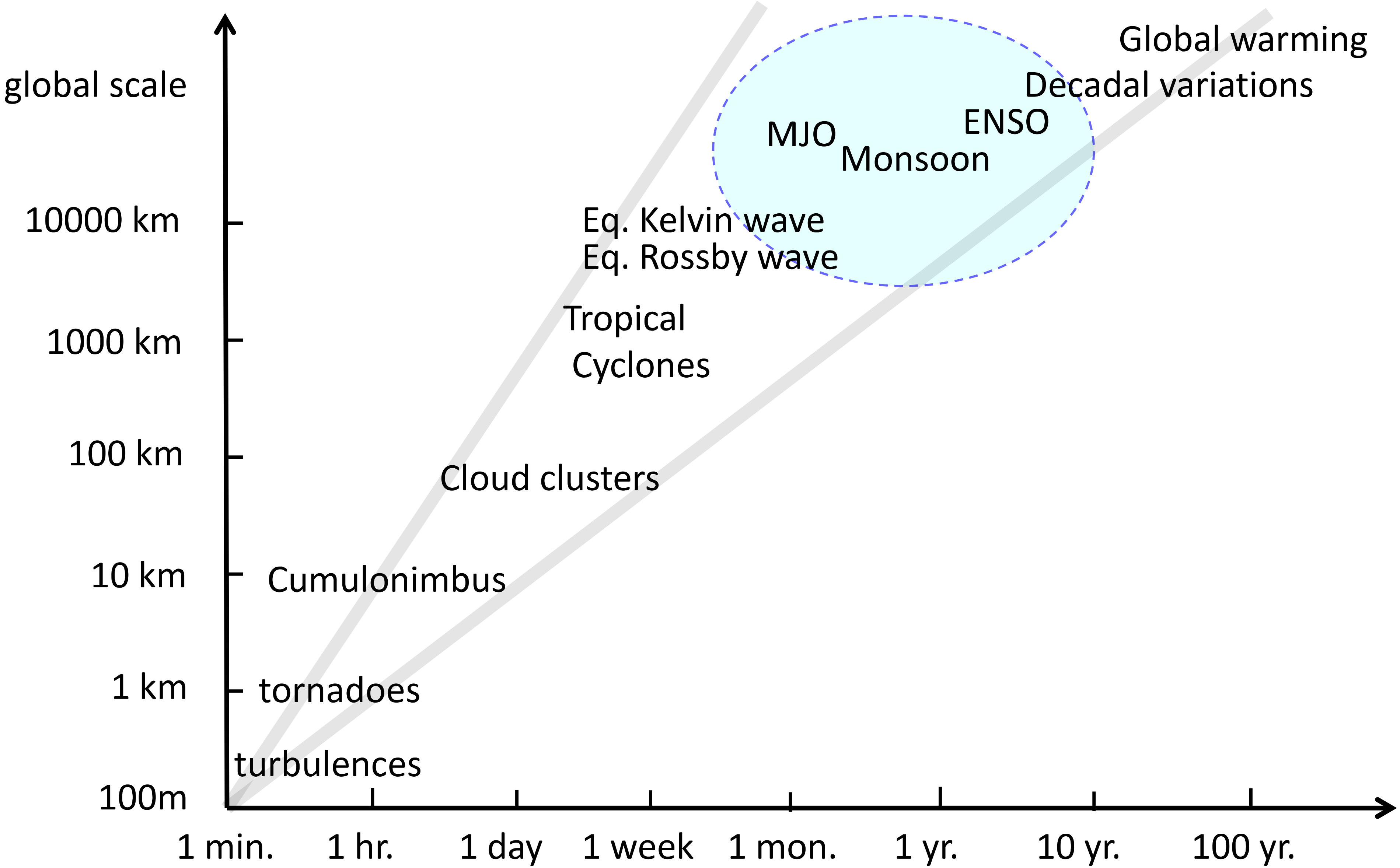
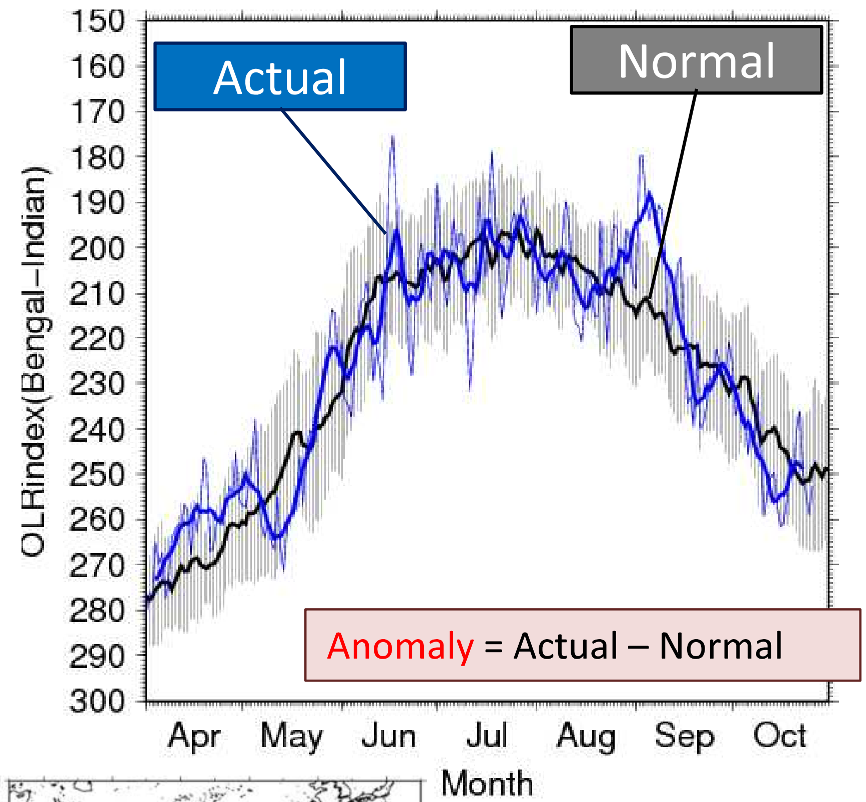
Variations in the tropics

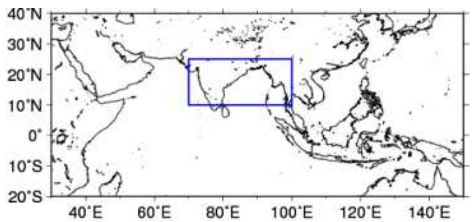
• There are a wide range of spatial- and time-scale variations in the tropics, interacting each other.



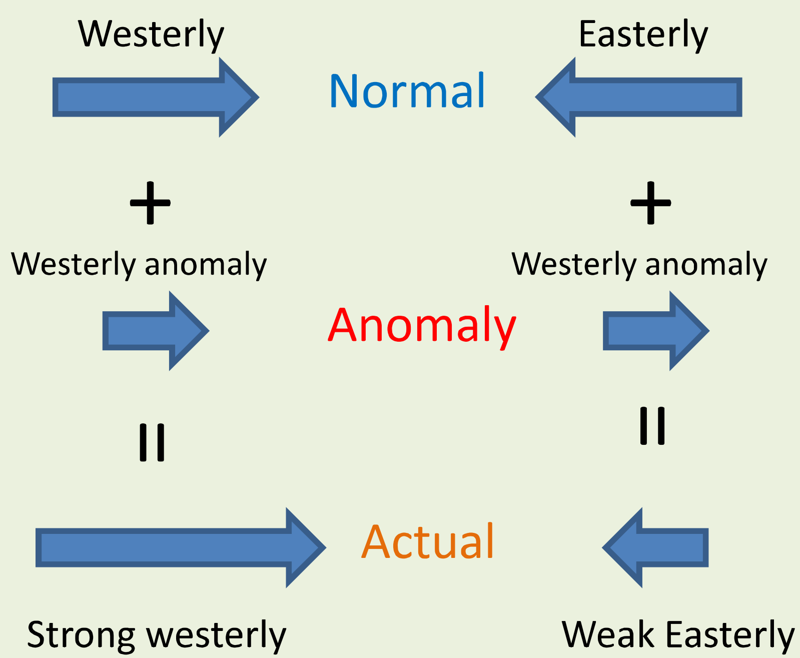
Normal and anomaly

- Anomalies (i.e., deviations from long-term average) are focused on in climate system analysis.
- It is essential to understand the climatological normal conditions (e.g., the 1981 – 2010 average) of the climate system.





Same anomalies, but different meanings



Stream function and velocity potential

- Decomposing wind into a rotational part and a divergent part (stream function and velocity potential) is useful to analyze atmospheric circulation.

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

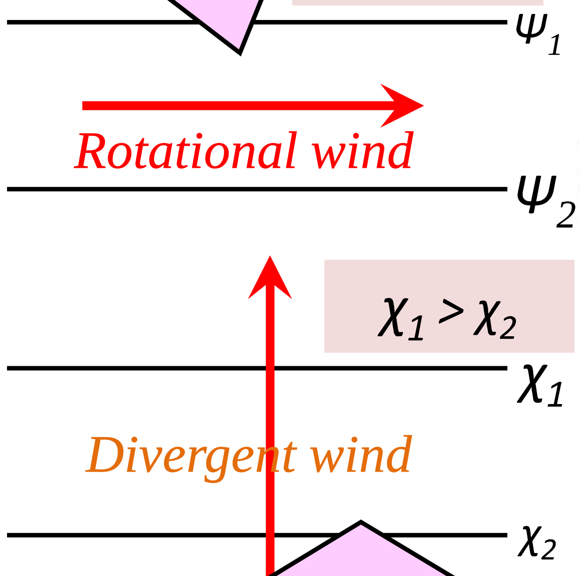
Rotational wind blows parallel to contours of stream function, with low values of stream function to the left, regardless of the hemisphere.

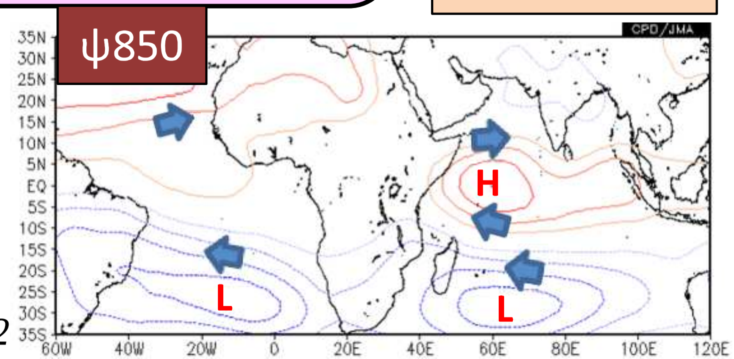
H: high value
L: Low value

< Rotational wind >

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

***Ψ*: Stream function**

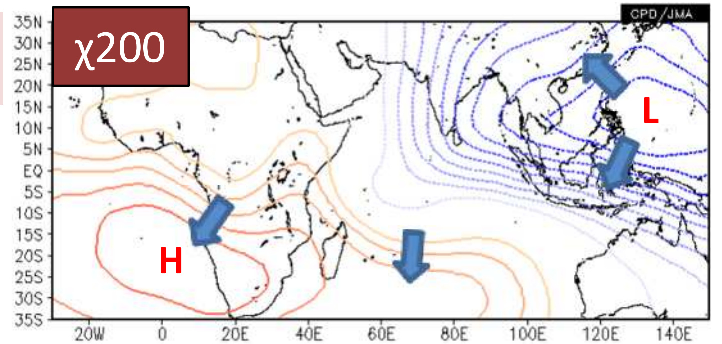




< Divergent wind >

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

***χ*: Velocity potential**



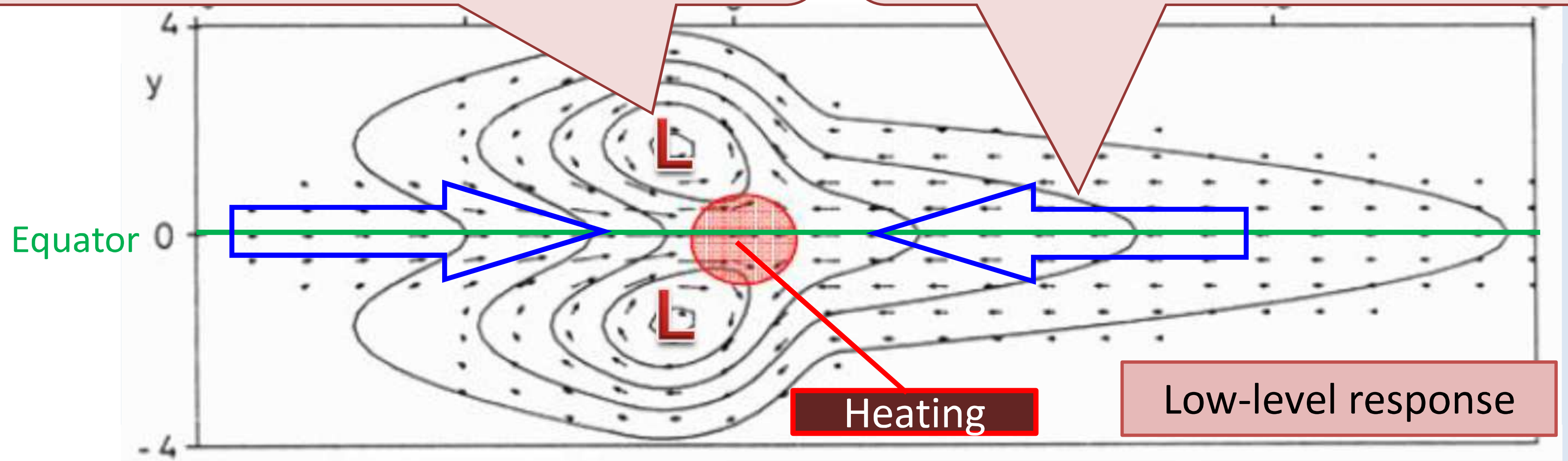
Divergent wind blows across contours of velocity potential, from areas of low to high velocity potential, regardless of the hemisphere.

Matsuno-Gill pattern

- Gill (1980) elucidated some basic features of the response of the tropical atmosphere to diabatic heating (related to convective activity).

A pair of cyclonic circulation straddling the equator on the western side of the heating (equatorial Rossby wave).

Low pressure and easterly winds along the equator east of the heating (equatorial Kelvin wave).



Atmospheric response in the lower troposphere to the heating symmetric about the equator

Contours indicate perturbation pressure, and vectors denote velocity field.

Red circle indicates the position of the heating. (Source: Gill 1980)

Upper-level response shows the reverse of the low-level response.

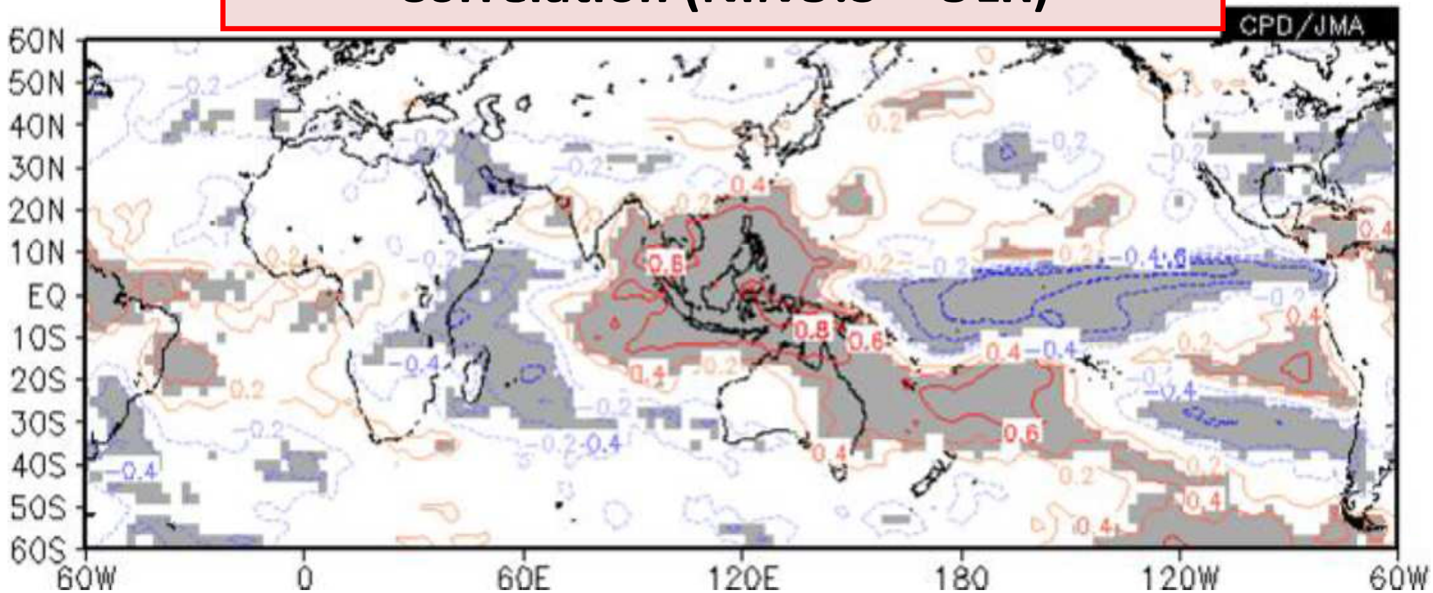
Correlation analysis

• This technique is used to investigate the linear relationship between two variations.

• Correlation coefficients range between -1 and 1. High (low) absolute values indicate strong (little) linear relationship.

r < 0 : Negative correlation
r = 0 : No correlation
r > 0 : Positive correlation

Correlation (NINO.3 – OLR)



Correlation coefficients between NINO.3 SST indices and OLR (Sep. – Nov.)
The base period for the analysis is 1979 – 2011. This is drawn by the ITACS.

Regression analysis

- Single regression analysis is used to investigate quantitatively to what extent a response variable is explained by a explanatory variable.
- Regression coefficient shows the anomaly of a response variable in one standard deviation of a explanatory variable.

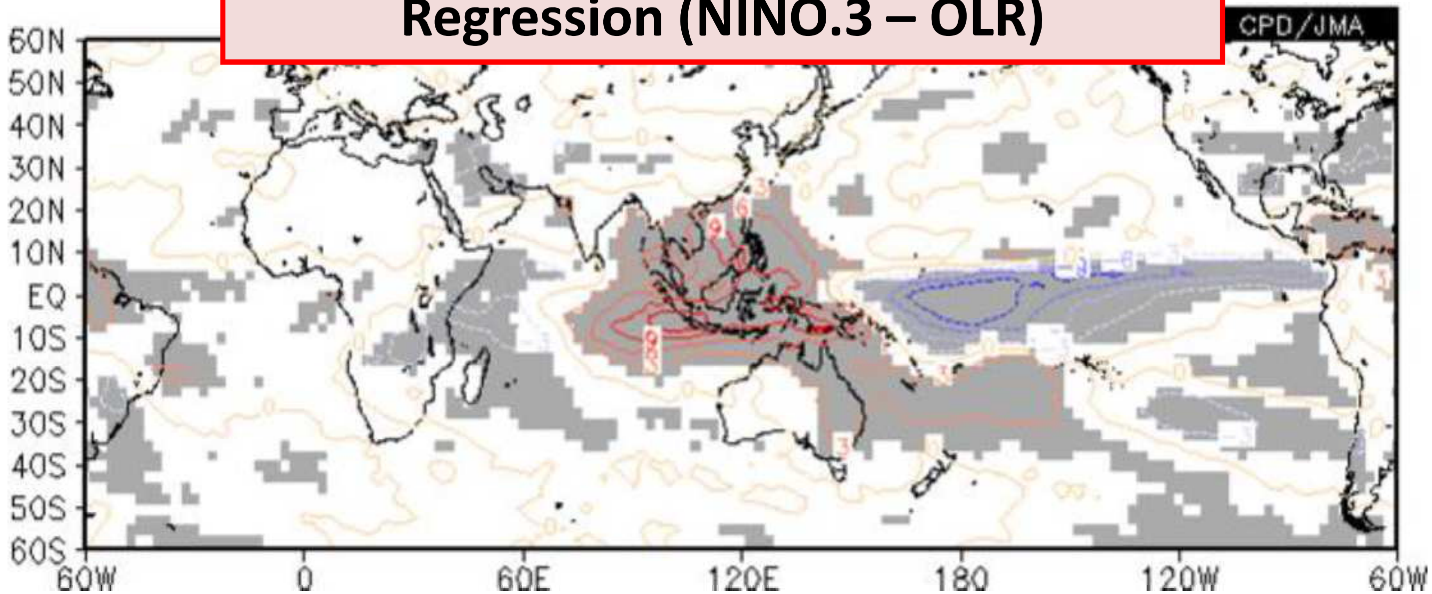
$$y = a\,x + b$$

Regression coefficient (a)

Intercept (b)

y: Response variable (e.g., stream function)
x: Explanatory variable (e.g., NINO.3 SST index)

Regression (NINO.3 – OLR)



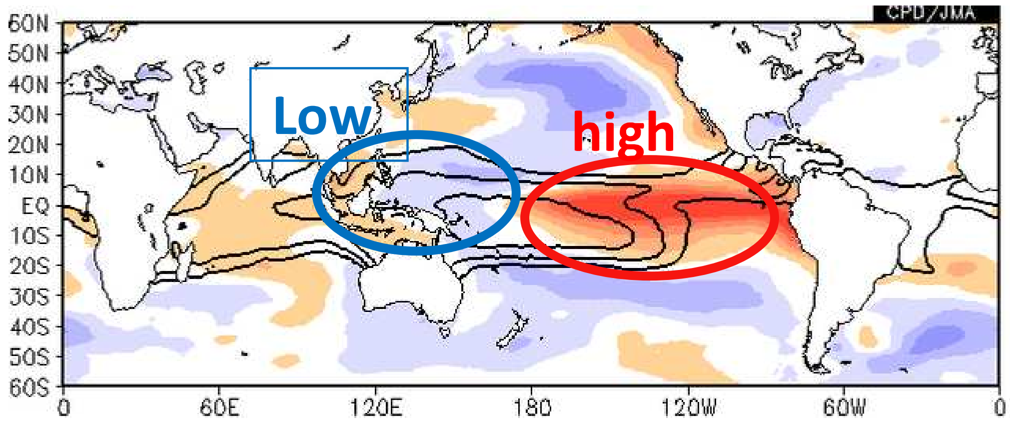
Regression coefficients of OLR (W/m^2) onto NINO.3 SST indices (Sep. – Nov.)
The base period for the analysis is 1979 – 2011. This is drawn by the ITACS.

Composite analysis

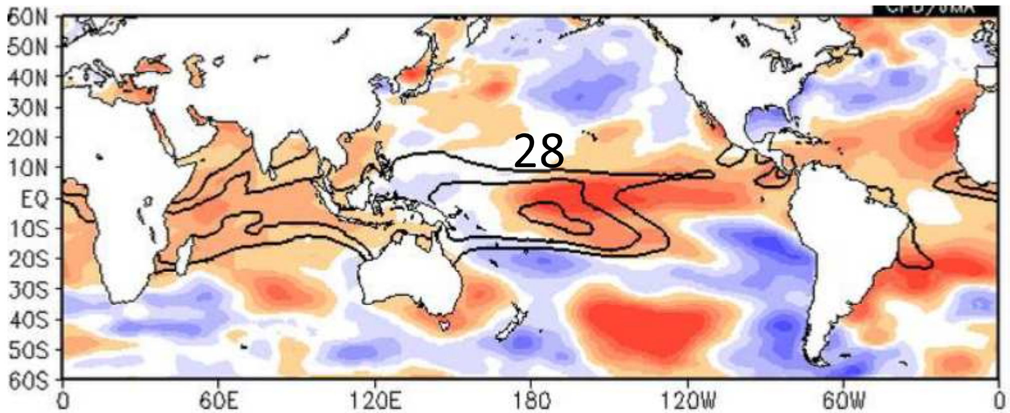
- Composite analysis is a statistical technique to extract the common characteristics in past events of a targeted phenomenon (e.g., El Niño and La Niña events) from the other phenomena.

SST Composite Map
In El Nino Phase (DJF)

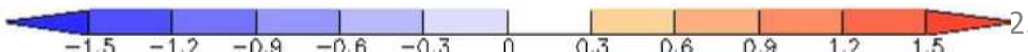
Contours: anomaly, Shadings: anomaly,
Statistical period: 1979 – 2009
(Composite year :
82/83,86/87,87/88,91/92,97/98,02/03)



SST for DJF 2009/10



3-month mean SST and anomalies (˚C)



Statistical analysis (brief comments)

- If a certain climate variation does not have a linear relationship with other variation (e.g., El Nino events), composite analysis is useful.
- If a certain climate variation has a linear relationship with other variation (e.g., El Nino events) and there are not enough samples to implement statistically reliable composite analysis, regression and correlation analyses are useful.

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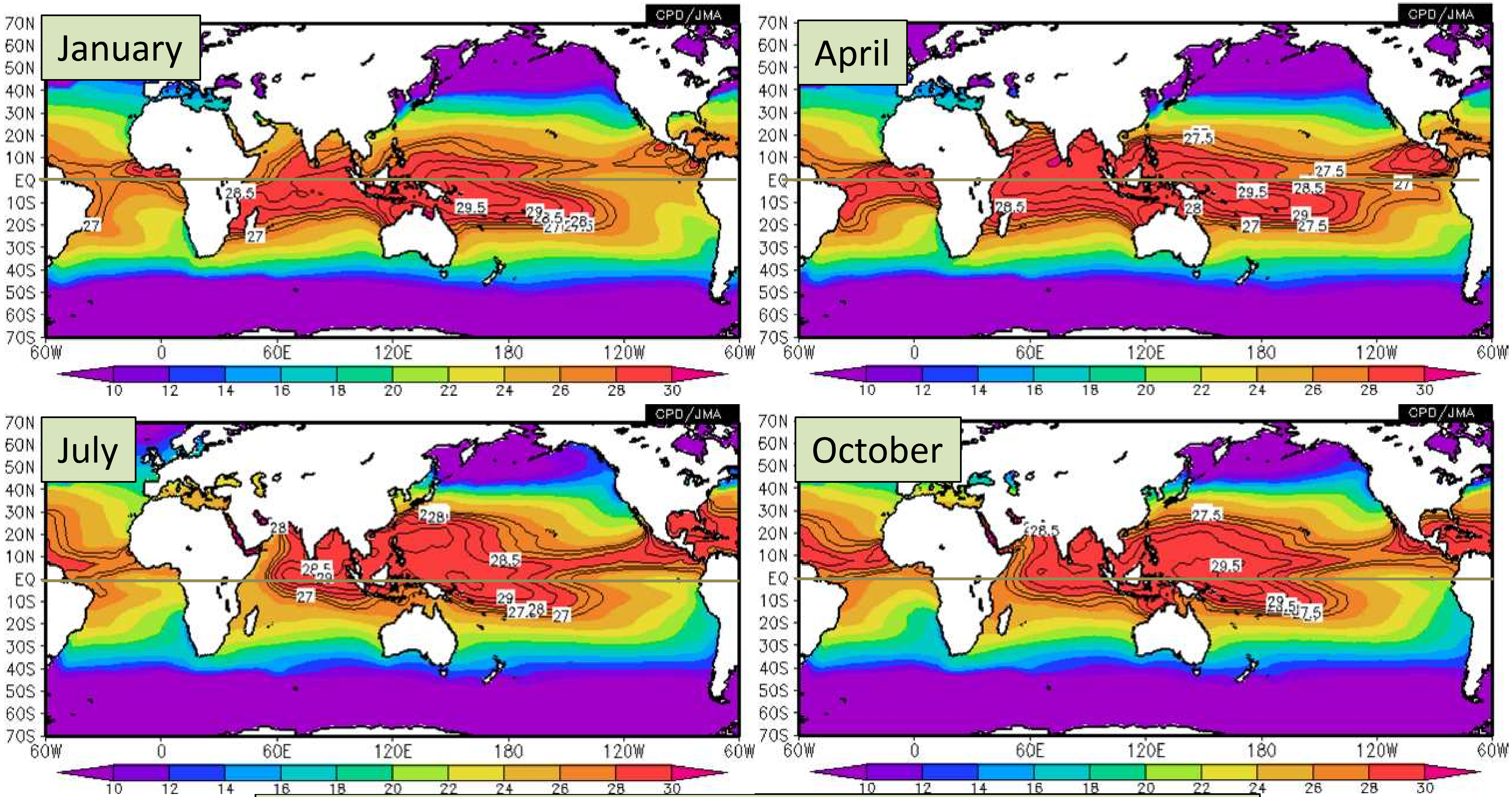
Sea surface temperature (SST)

• High SST areas (tropics) march meridionally (northwest – southeast), lagging solar elevation by a month or more.

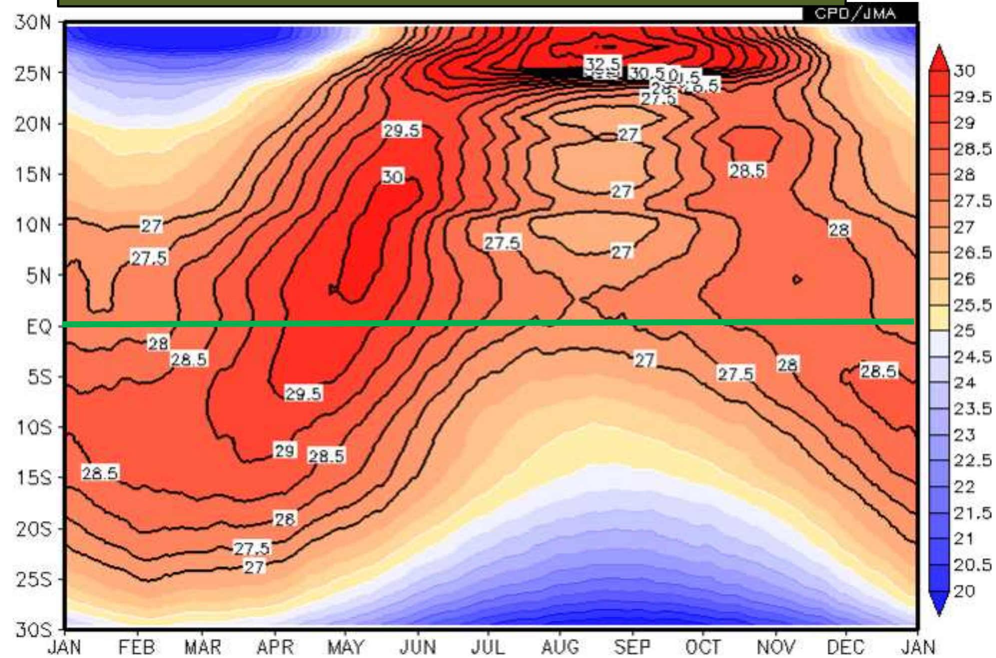


Monthly mean SST (the 1981 – 2010 average)

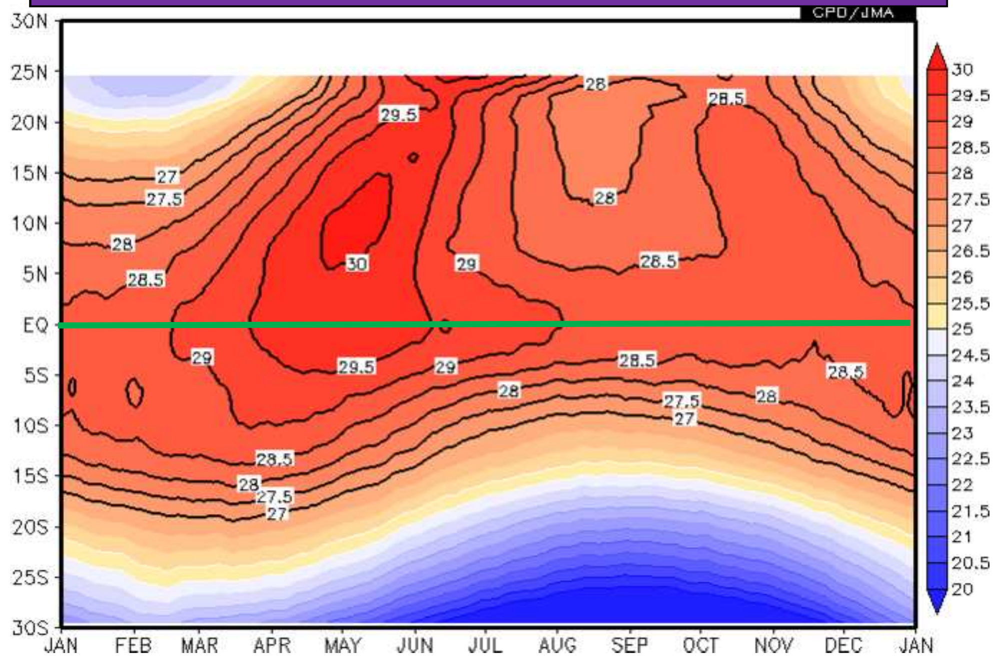
The contour interval is 0.5 ˚C (shown for 27˚C and above).

Annual cycle of SST (Indian Ocean)

Western Indian Ocean (40 – 70˚E)

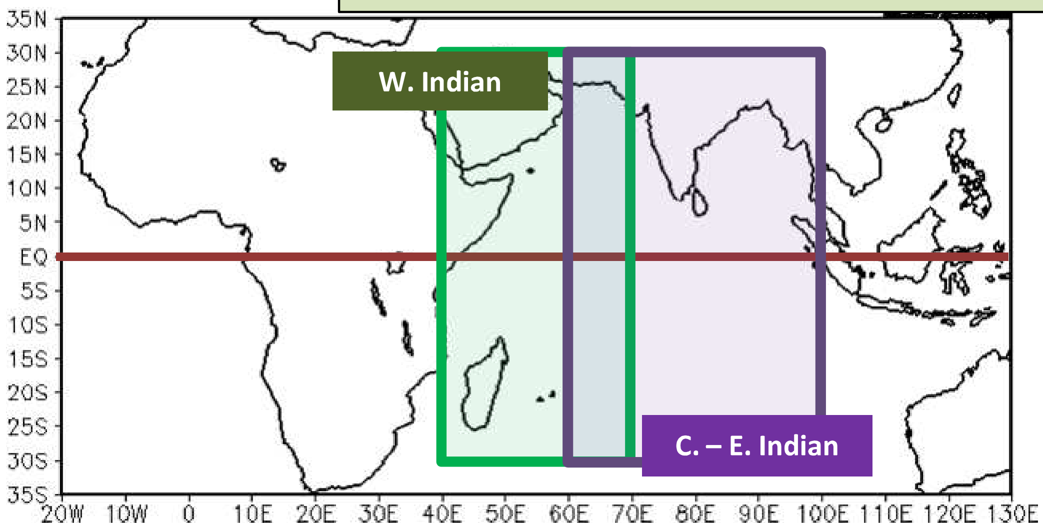


Central – eastern Indian Ocean (60 – 100˚E)



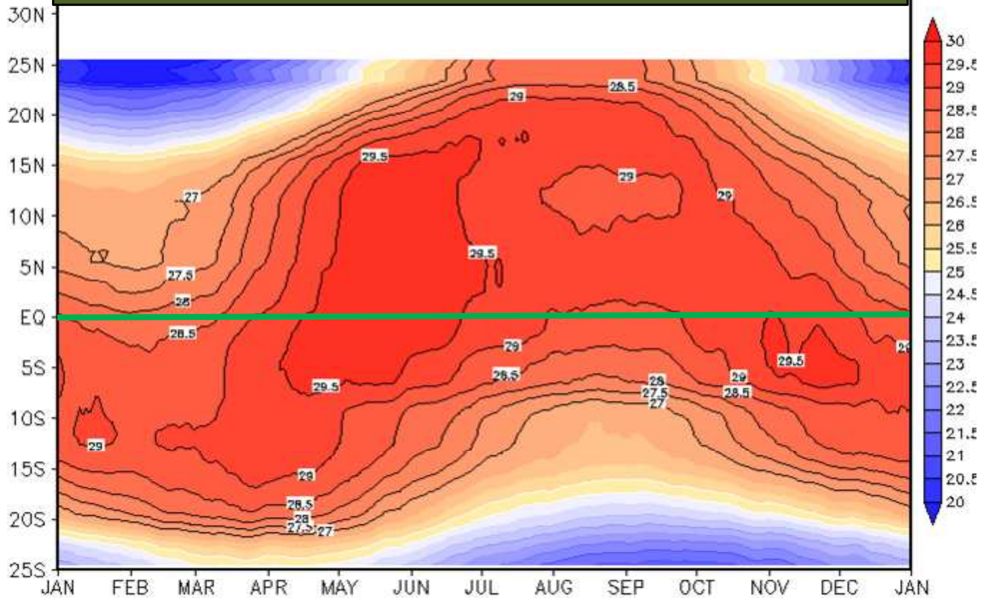
Zonal-average SST (the 1981 – 2010 average)

The contour interval is 0.5 ˚C (shown for 27˚C and above).

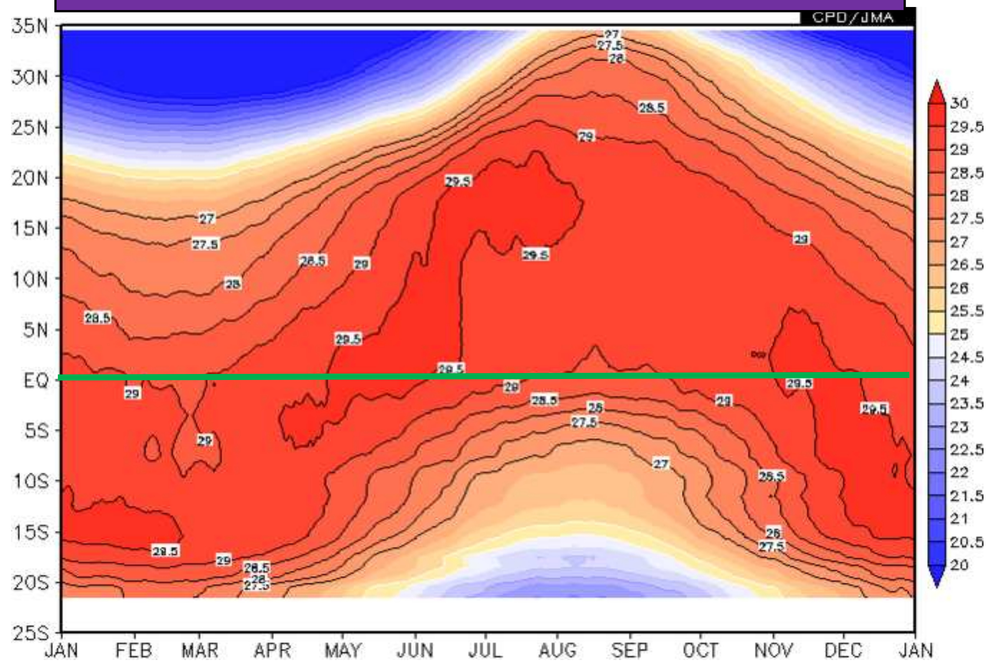


Annual cycle of SST (western Pacific)

South of Java and South China Sea
(105 – 120˚E)

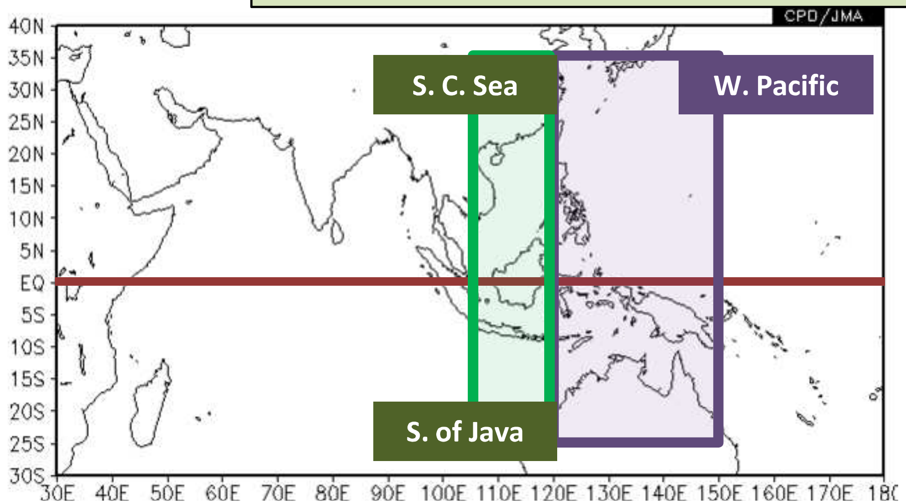


Western Pacific (120 – 150˚E)



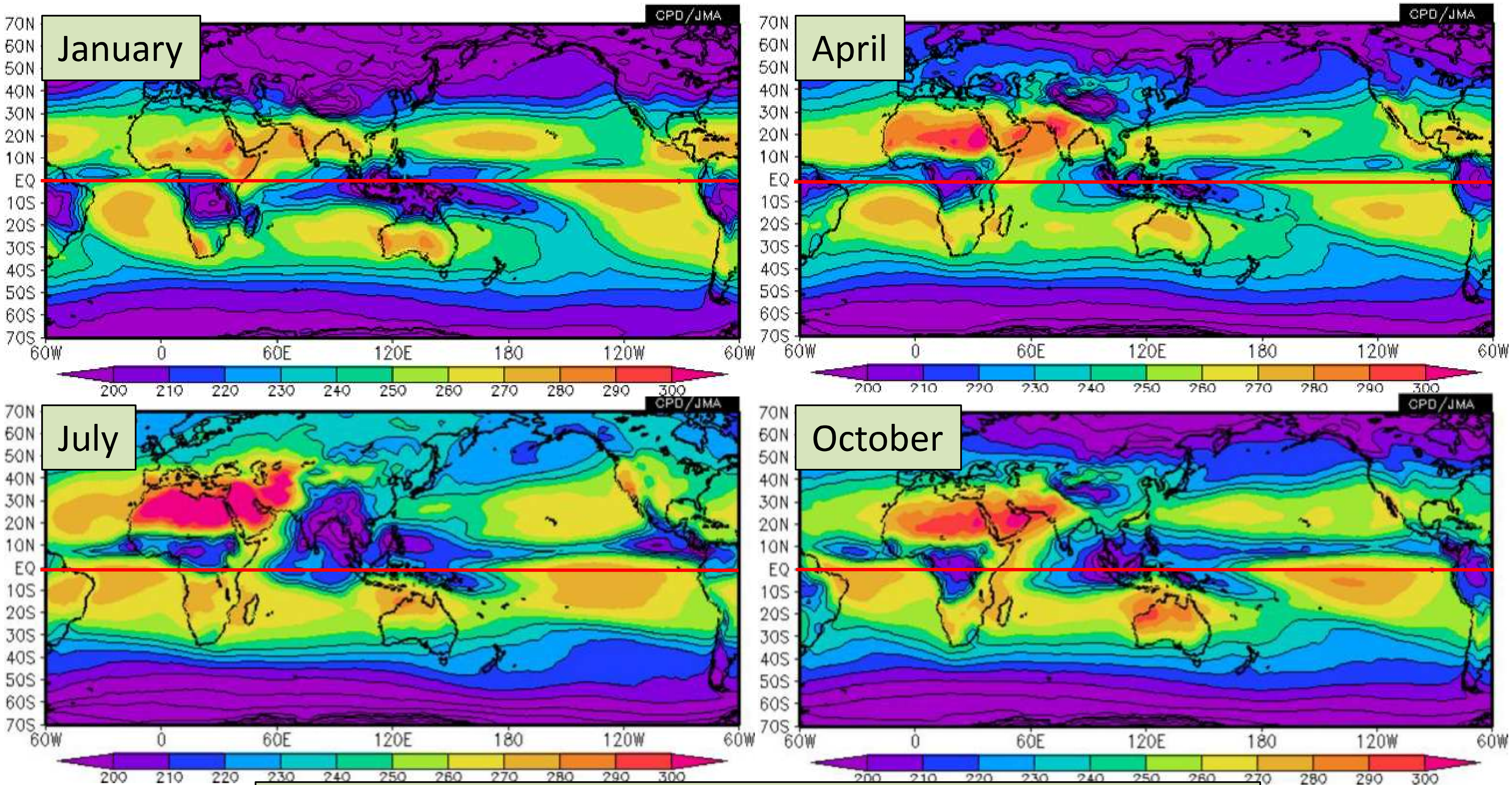
Zonal-average SST (the 1981 – 2010 average)

The contour interval is 0.5 ˚C (shown for 27˚C and above).



Outgoing Longwave Radiation (OLR)

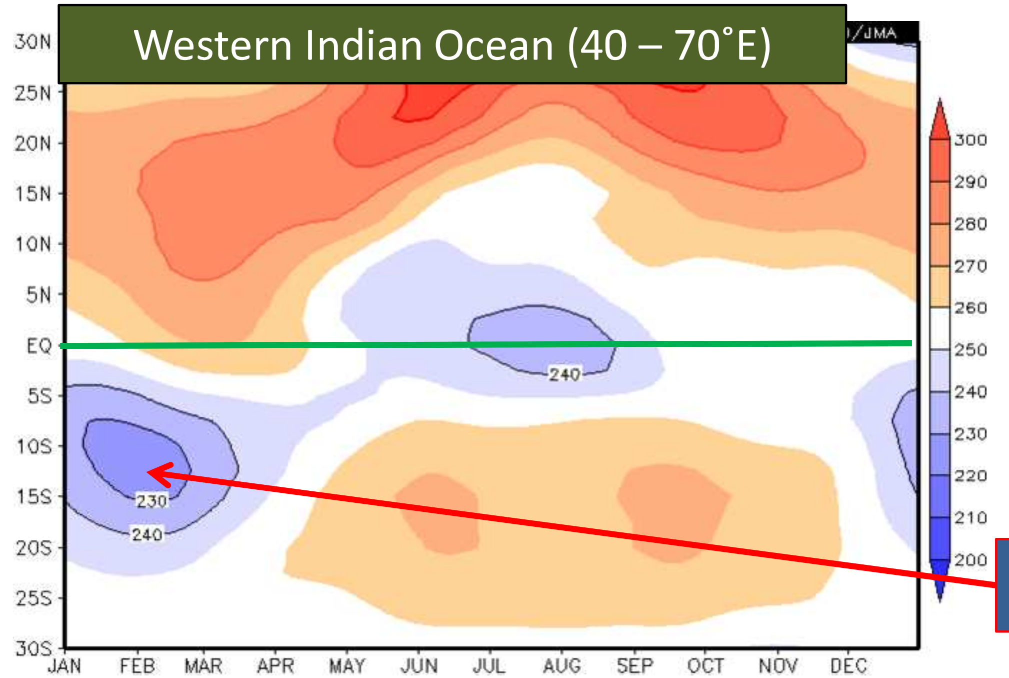
• Low OLR areas (active convection) march meridionally (northwest – southeast), generally in line with annual cycle of high SST areas.

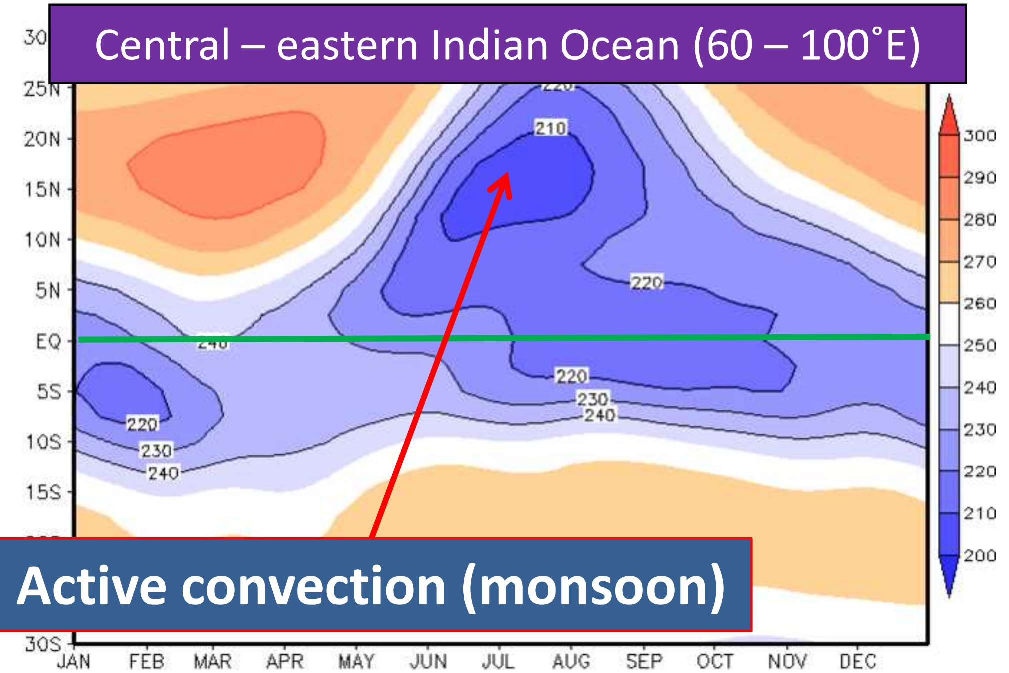


Monthly mean OLR (the 1981 – 2010 average)

The contour interval is 10 W/m^2 (shown for 240 W/m^2 and below).

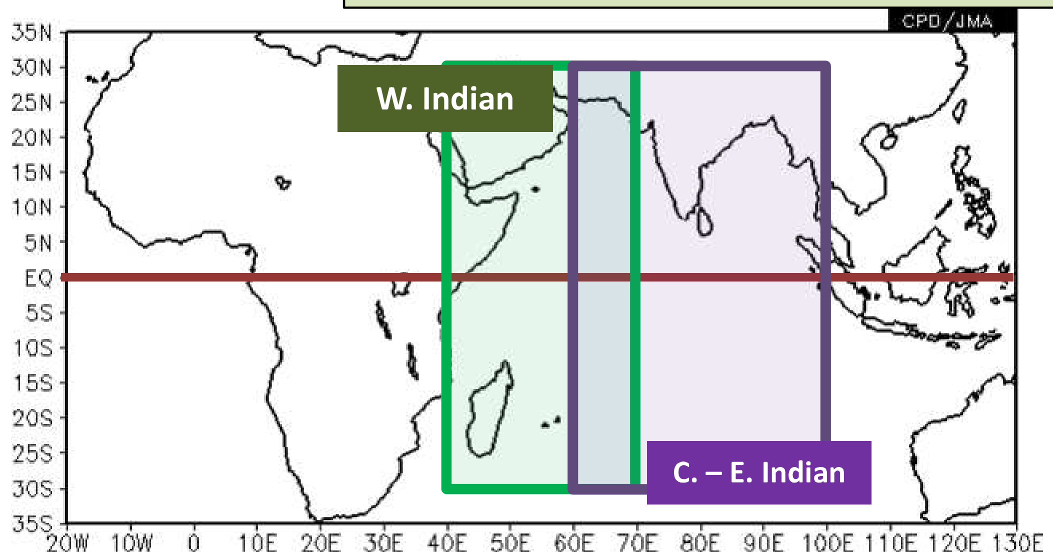
Annual cycle of OLR (Indian Ocean)





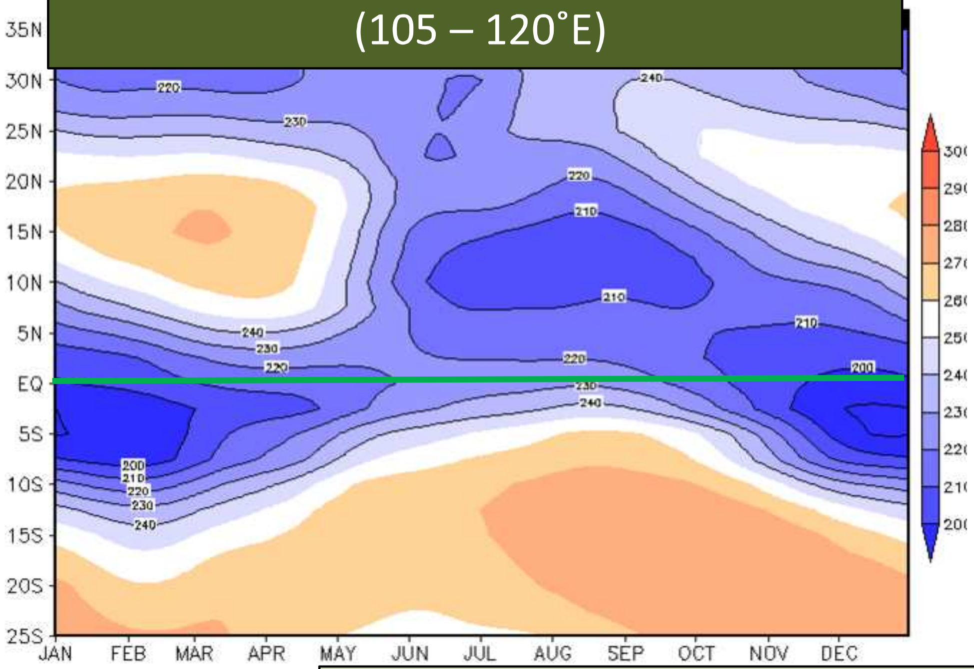
<u>Zonal-average OLR (the 1981 – 2010 average)</u>

The contour interval is 10 W/m^2 (shown for 240 W/m^2 and below).

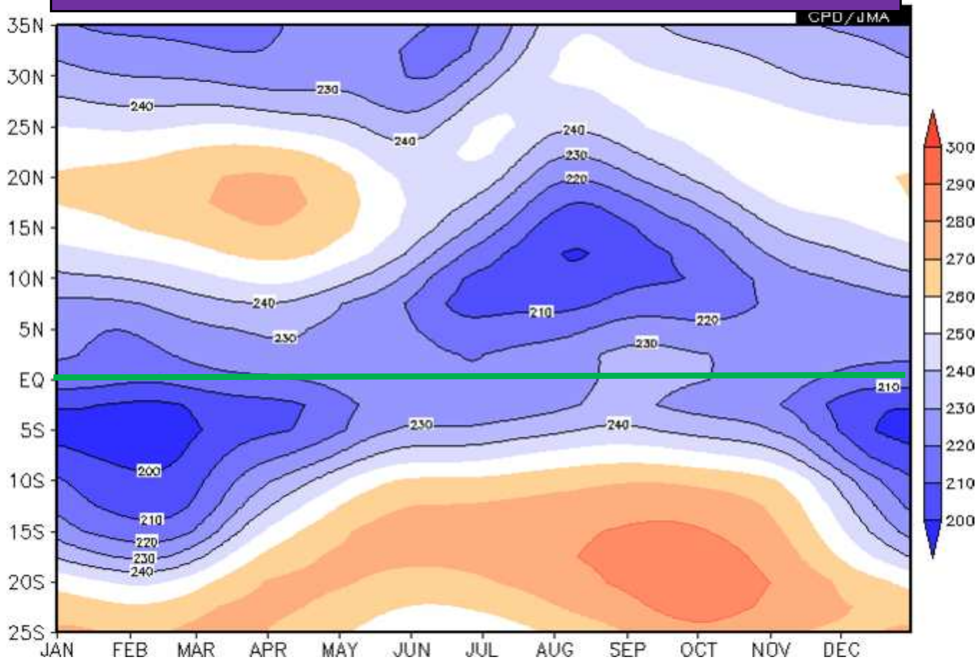


Annual cycle of OLR (western Pacific)

South of Java and South China Sea (105 – 120˚E)

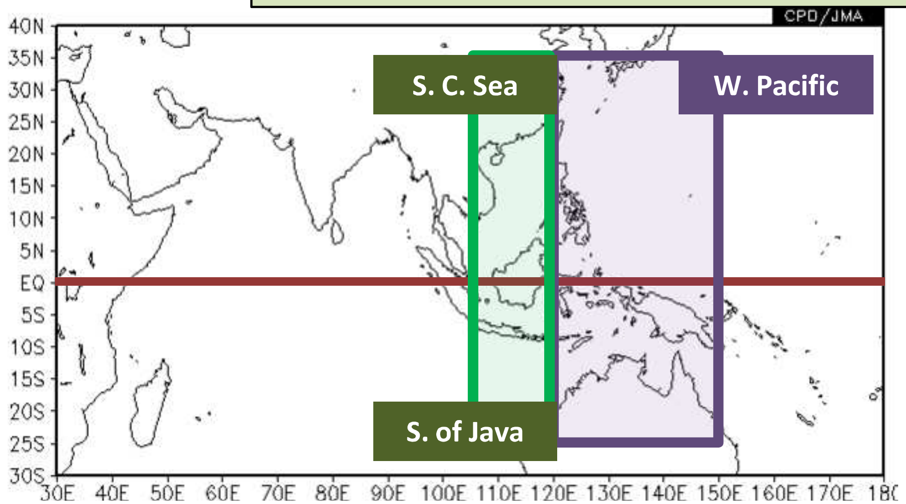


Western Pacific (120 – 150˚E)

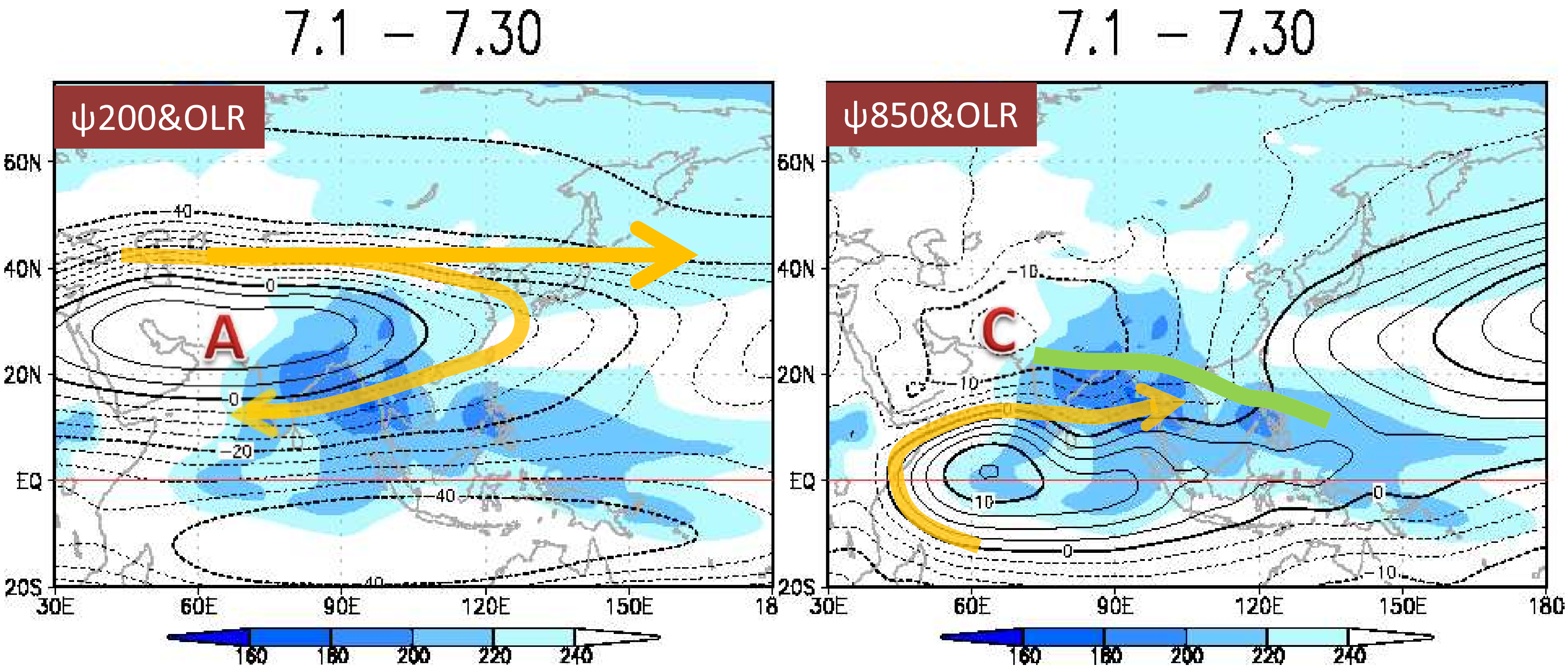


<u>Zonal-average OLR (the 1981 – 2010 average)</u>

The contour interval is 10 W/m^2 (shown for 240 W/m^2 and below).



Summer monsoon circulation (1)



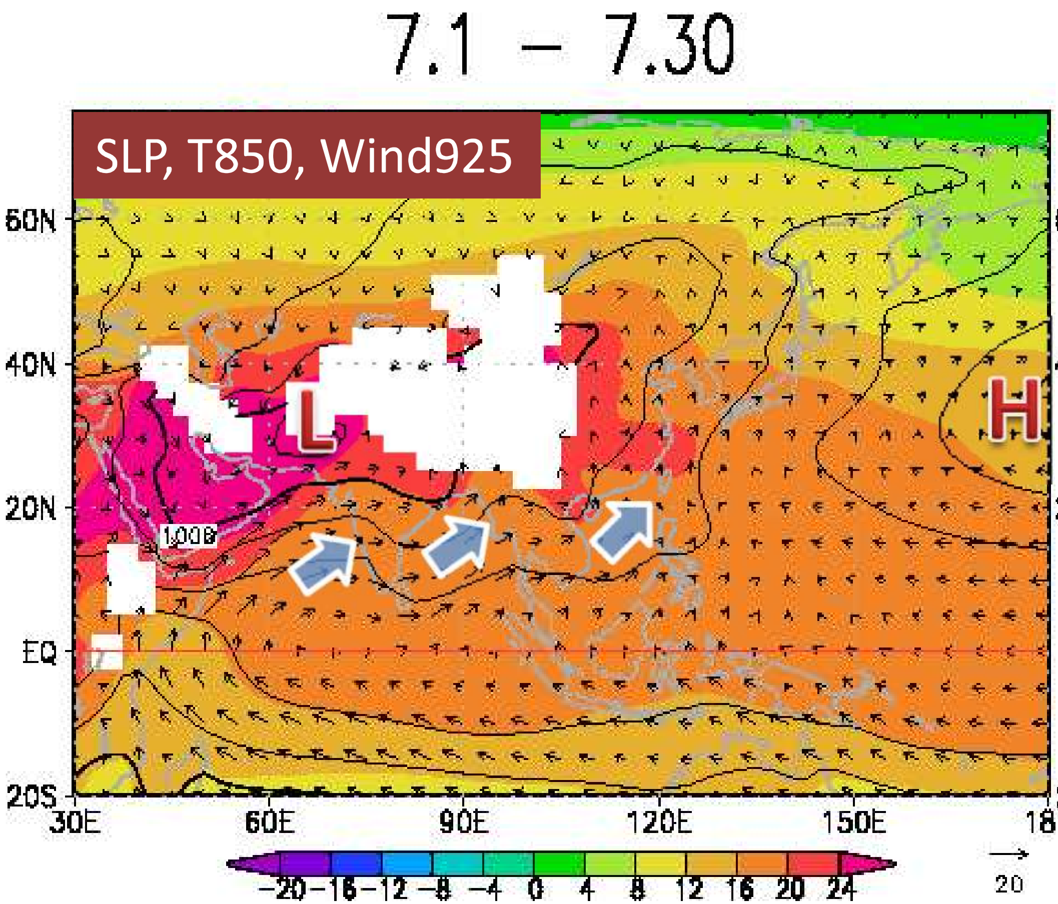
<u>Climatological normals of atmospheric circulation and convection (July)</u>

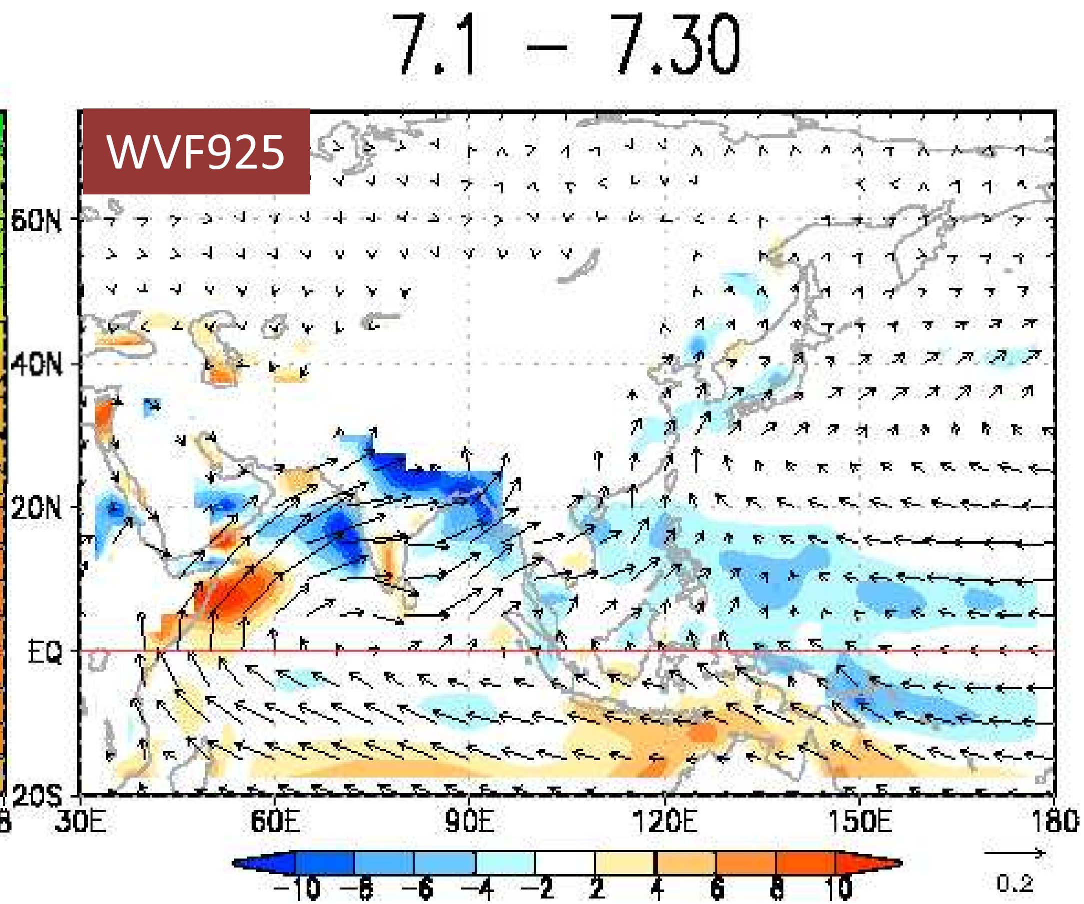
Contours: 200-hPa (left) and 850-hPa (right) stream function (JRA/JCDAS).

Shading: OLR (observed by NOAA satellites).

Base period for normal: 1981 – 2010.

Summer monsoon circulation (2)





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

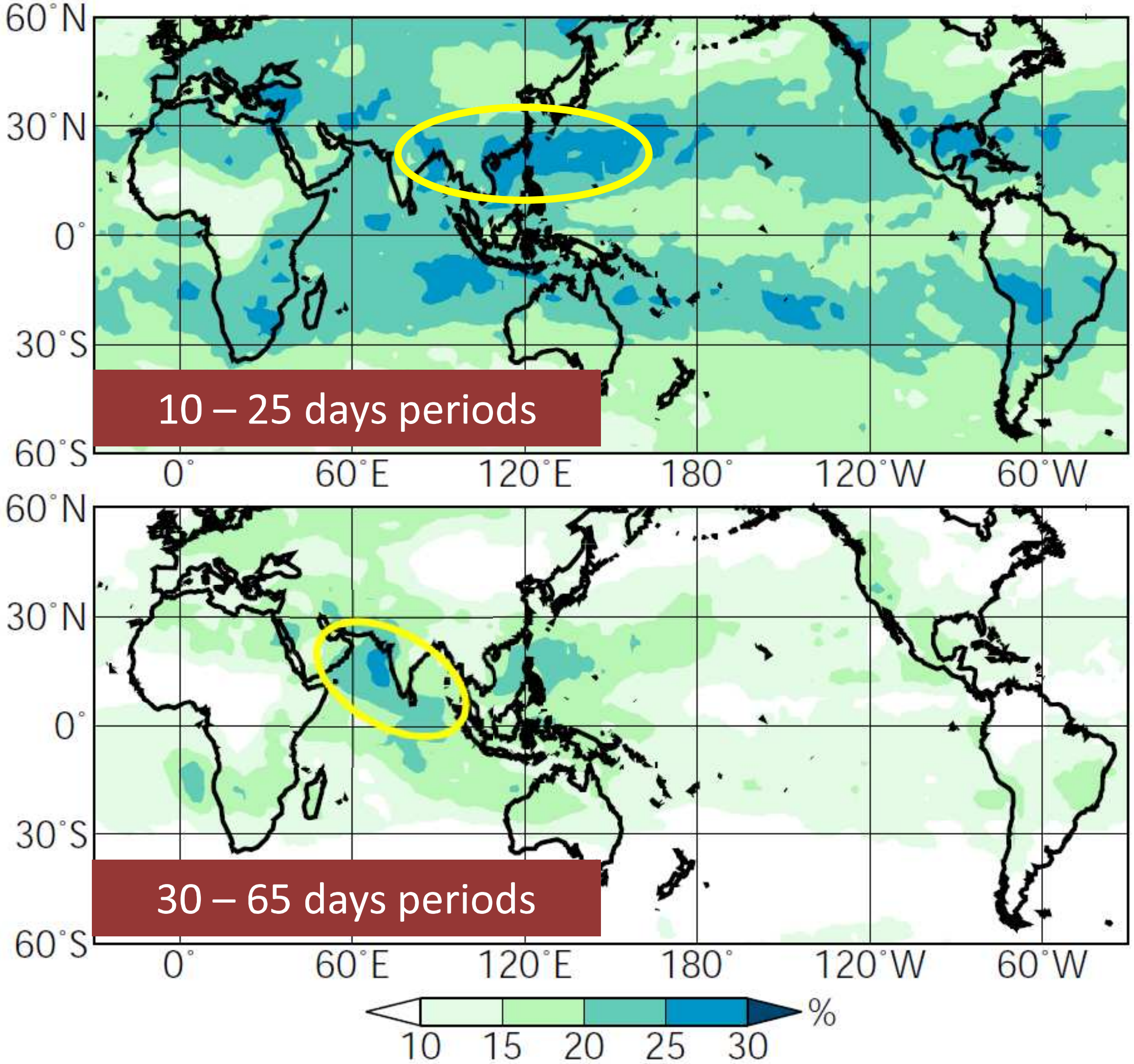
Left: Sea level pressure (contour), 850-hPa temperature (shading) and 925-hPa wind vectors.

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

Base period for normal: 1981 – 2010.

Intraseasonal oscillation (JJAS)

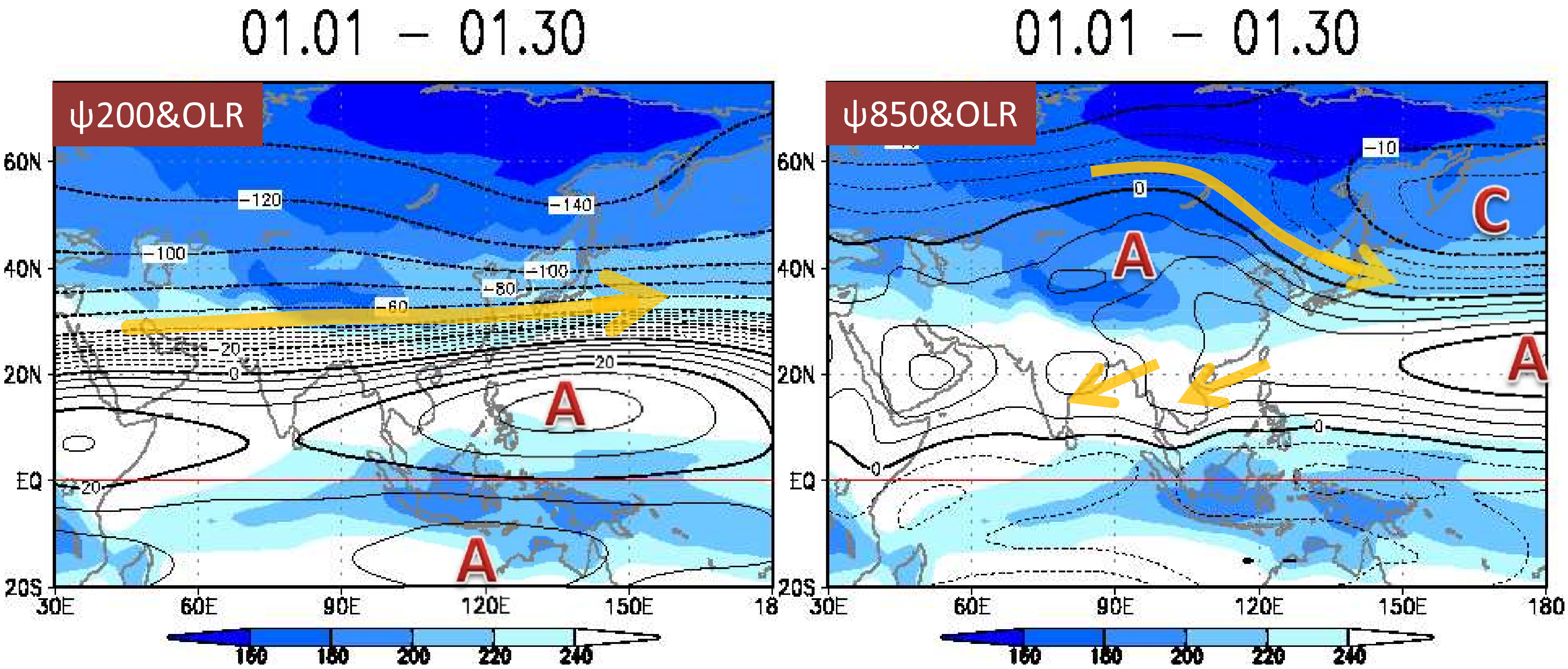
• Quasi-biweekly oscillations are dominant around the South China Sea and the Bay of Bengal.
• Monthly-scale oscillations are dominant around the Arabian Sea and the eastern Indian Ocean.



Distributions of ratios of intraseasonal OLR variance (top: 10 – 25 days, bottom: 30 – 65 days) to the total variance (unit: %) for June – September

The base period for the statistics is 1981 – 2010.

Winter monsoon circulation (1)



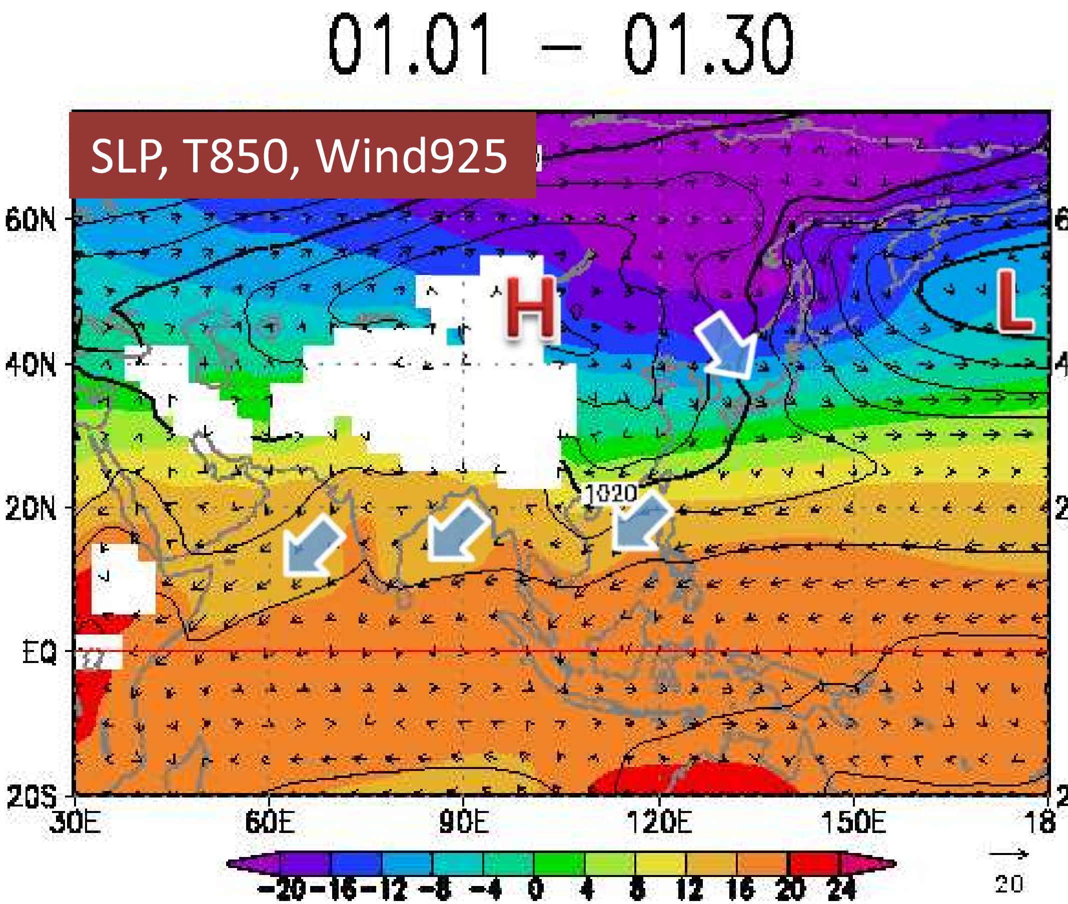
Climatological normals of atmospheric circulation and convection (January)

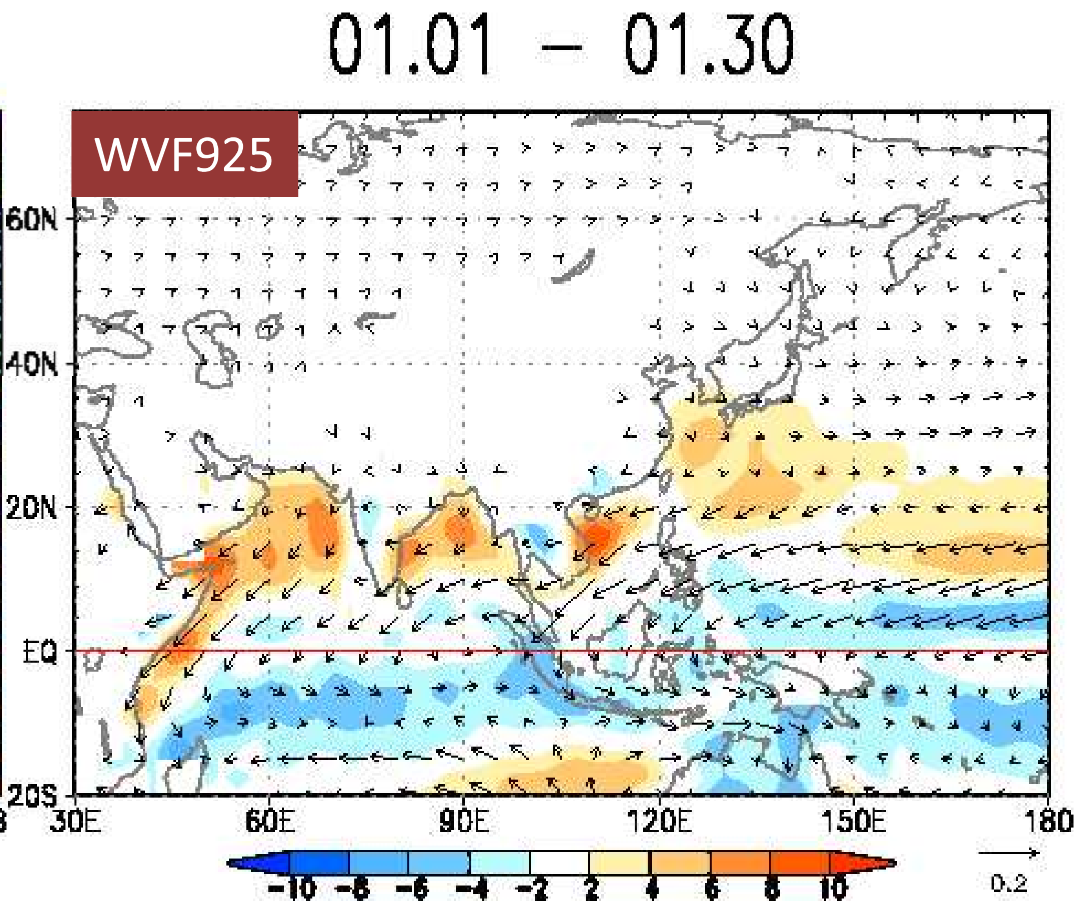
Contours: 200-hPa (left) and 850-hPa (right) stream function (JRA/JCDAS).

Shading: OLR (observed by NOAA satellites).

Base period for normal: 1981 – 2010.

Winter monsoon circulation (2)





Climatological normals of atmospheric circulation (January)

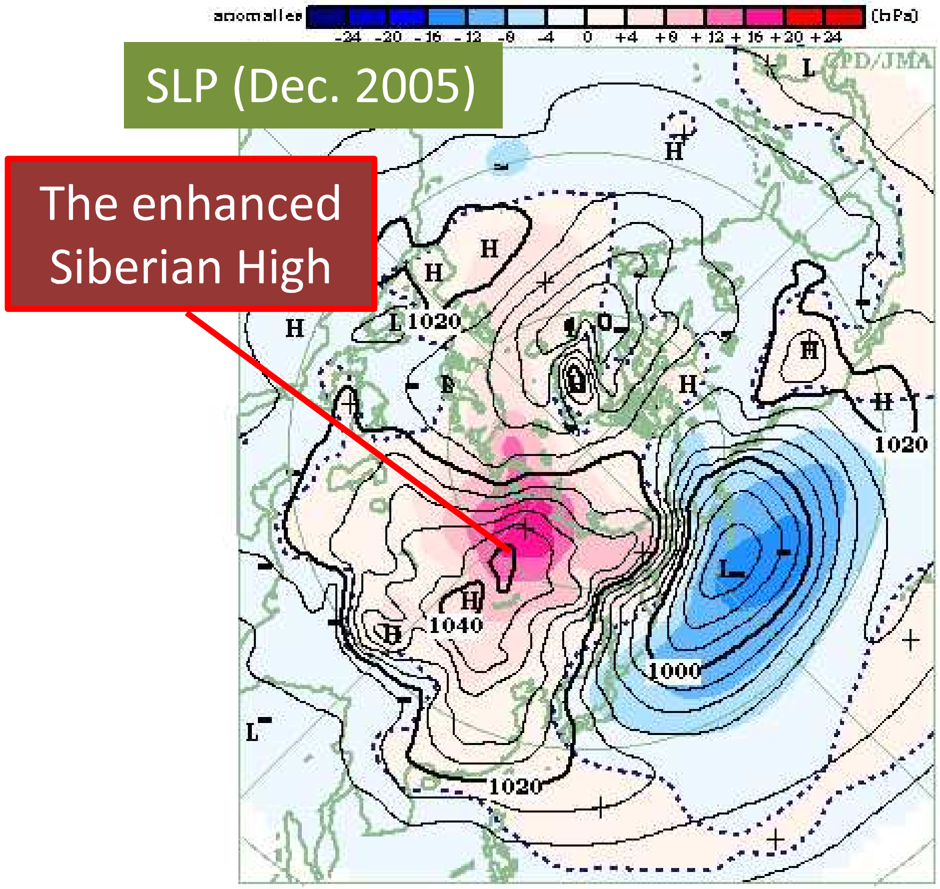
Left: Sea level pressure (contour), 850-hPa temperature (shading) and 925-hPa wind vectors.

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

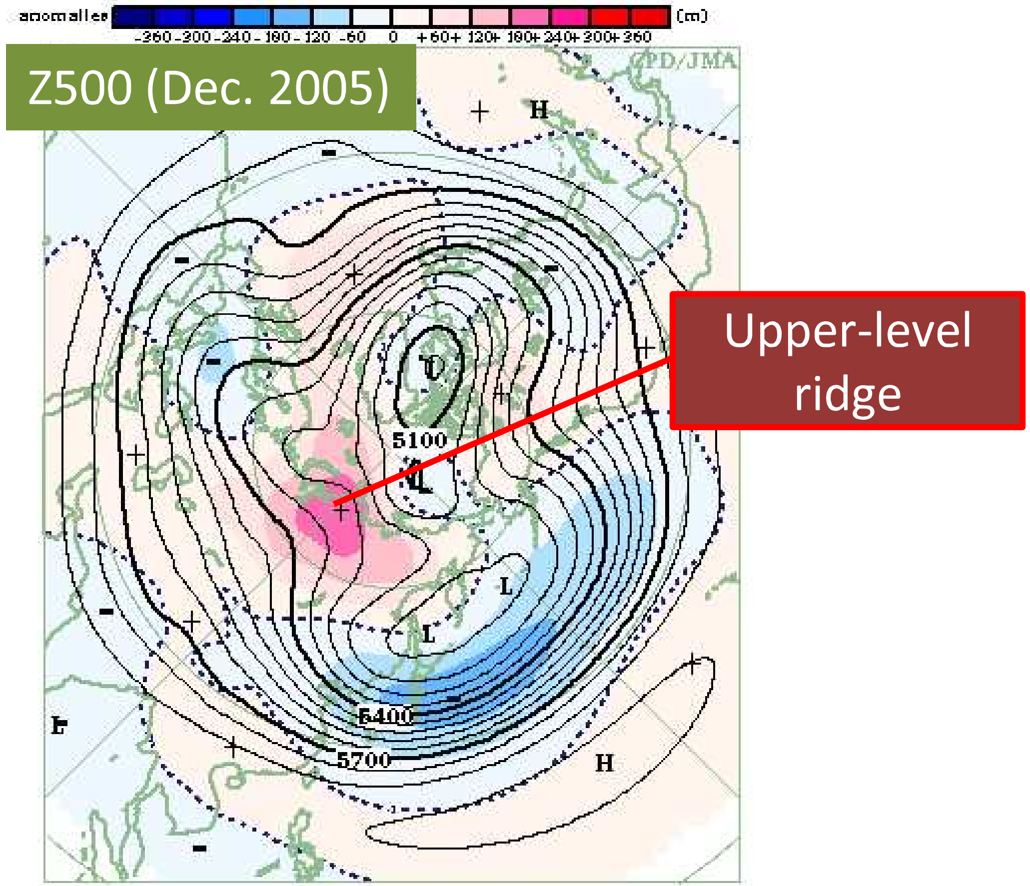
Base period for normal: 1981 – 2010.

Siberian High

- The Siberian High governs the winter monsoon in eastern Asia.
- The amplification of the surface high is associated with formation of a blocking ridge in the upper troposphere (Takaya and Nakamura 2005a; 2005b).



MONTHLY MEAN SEA LEVEL PRESSURE AND ANOMALY
IN THE NORTHERN HEMISPHERE (Dec. 2005)
The contours show sea level pressure at intervals of 4 hPa.
The shading indicates sea level pressure anomalies.
The base period for the normal is 1981-2010.



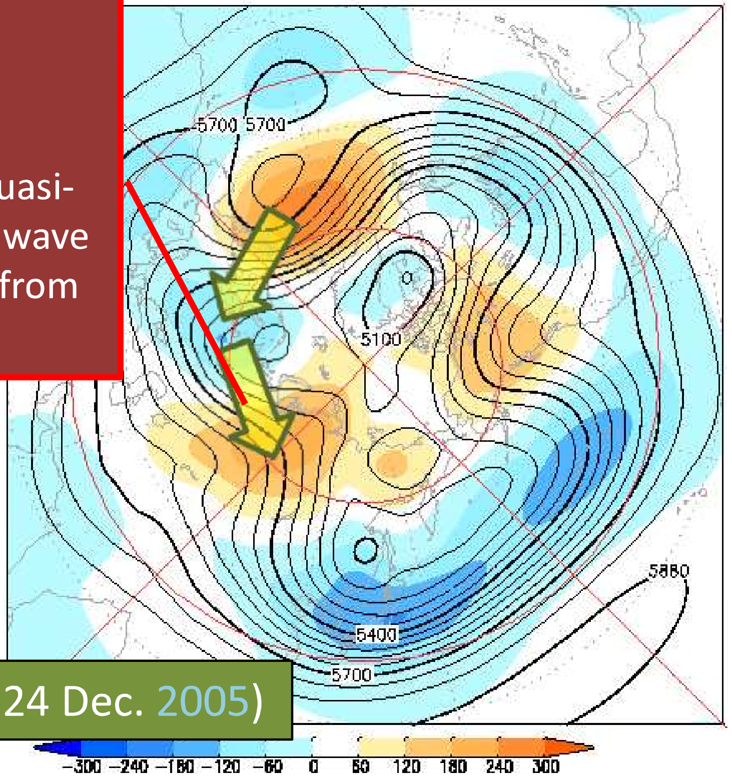
MONTHLY MEAN 500hPa HEIGHT AND ANOMALY
IN THE NORTHERN HEMISPHERE (Dec. 2005)
The contours show height at intervals of 60 m.
The shading indicates height anomalies.
The base period for the normal is 1981-2010.

Upper-level blocking associated with the Siberian High

• Takaya and Nakamura (2005a; 2005b) categorized the upper-level blocking formation associated with the amplification of the Siberian High into two types: “wave-train (Atlantic-origin)” type and “Pacific-origin” type.

“Wave-train (Atlantic-origin)” type

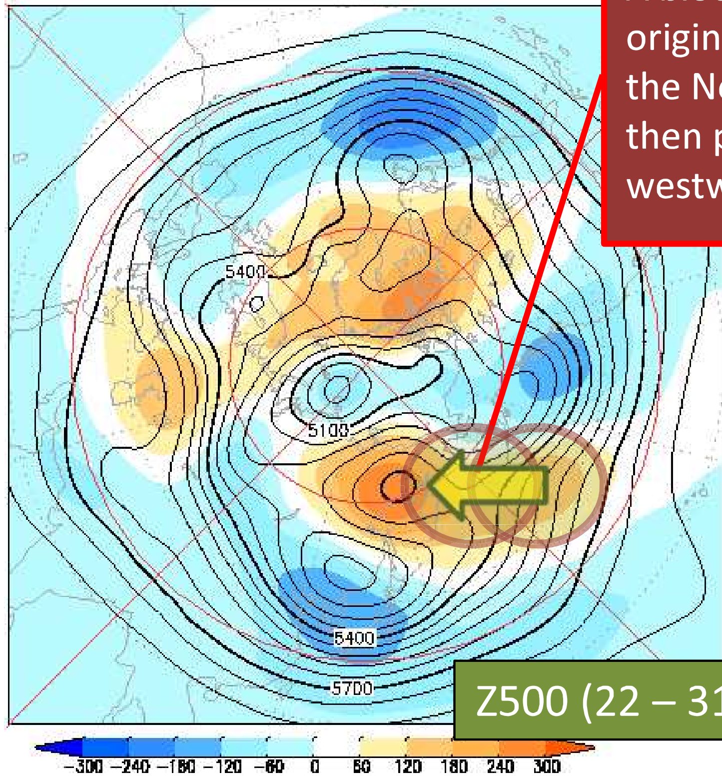
A blocking ridge developed from anomalies as a component of a quasi-stationary Rossby wave train propagating from the Atlantic.



Z500 (18 – 24 Dec. 2005)

“Pacific-origin” type

A blocking ridge originally formed over the North Pacific, and then propagated westward.

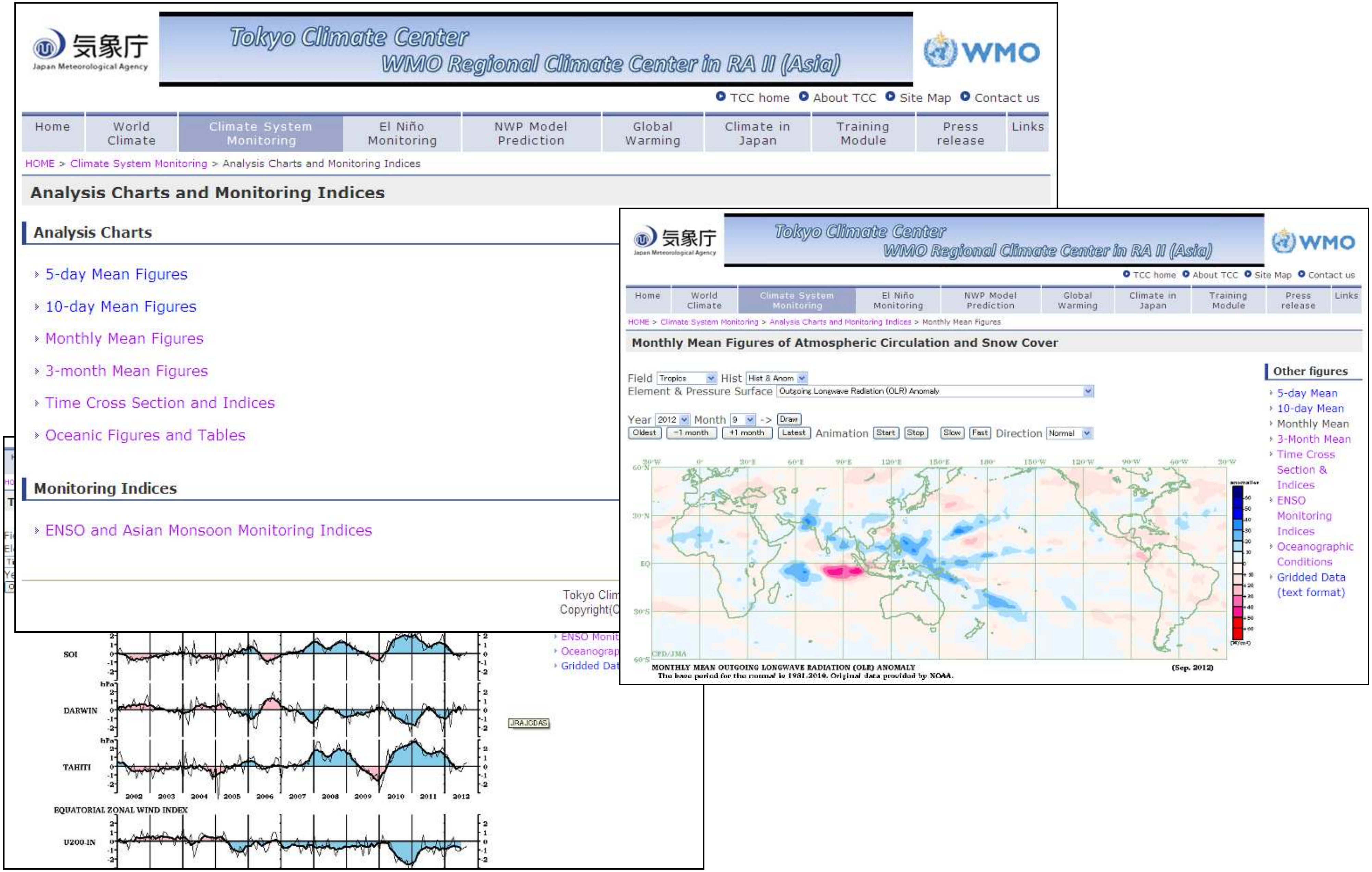


Z500 (22 – 31 Dec. 2010)

500-hPa height (contours) and anomalies (shading)

Analysis charts and monitoring indices (TCC website)

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



Asian monsoon monitoring (TCC website)

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

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WMO Regional Clim

Home | World Climate | Climate System Monitoring | El Niño Monitoring | NWP Model Prediction

HOME > Climate System Monitoring > Asian Monsoon Monitoring

Asian Monsoon Monitoring

Reports on specific events

10 May 2012 NEW !

- Asian Winter Monsoon Summary for 2011/2012

6 February 2012

- Cold wave over the Eurasian continent

28 November 2011

- Summary of the 2011 Asian summer monsoon

31 October 2011

- Heavy rainfall over the Indochina Peninsula for June - Sep

Analysis charts and monitoring indices

- Explanation of Data and Figures

Animation maps

- Asia, Global, Northern Hemisphere, Southern Hemisphere

Monitoring Indices

Asian Winter Monsoon Summary for 2011/2012

Many parts of East and Central Asia experienced significantly below-normal temperatures throughout winter (December – February) 2011/2012. This report summarizes the related surface climate characteristics, atmospheric circulation and primary factors contributing to the cold conditions observed. The relevant factors were clarified based on investigation by JMA's Advisory Panel on Extreme Climate Events.

Note: JRA/JCDAS (Onogi et al. 2007) atmospheric circulation data and COBE-SST (JMA 2006) sea surface temperature (SST)/sea ice concentration data were used for this investigation. The outgoing longwave radiation (OLR) data referenced to infer tropical convective activity were originally provided by NOAA. The base period for the normal is 1981 – 2010.

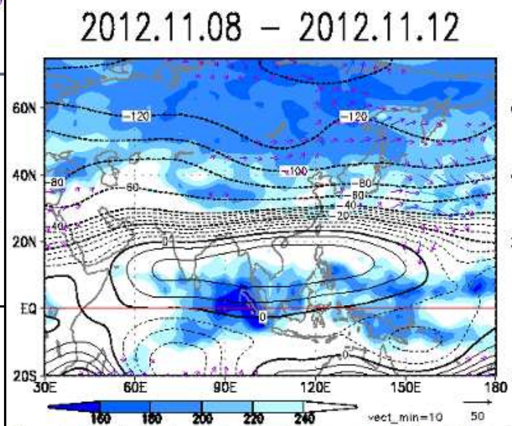
1. Surface climate conditions

Animation Maps (Asia Area)

5-day mean Year 2012 Month 11 Day 12 -> Draw

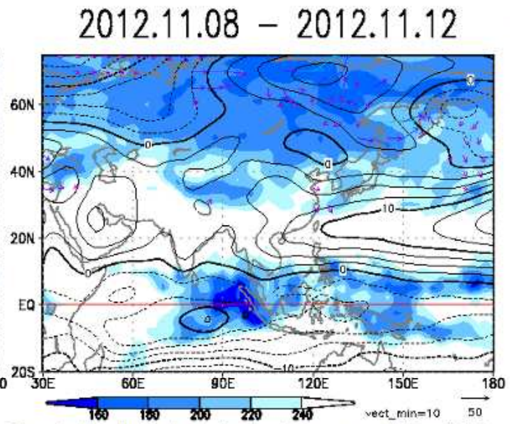
Oldest -1-day +1-day Latest Animation Start Stop Slow Fast Direction Normal

OLR & 200-hPa Stream Function & Wave Activity Flux



The shading indicates outgoing longwave radiation (OLR; W/m²). The contours show 200-hPa stream function at intervals of 5x10⁶ m²/s. The vectors denote 200-hPa wave activity fluxes (m²/s²), shown for the value of 'vect_min' and above.

OLR & 850-hPa Stream Function & Wave Activity Flux



The shading indicates outgoing longwave radiation (OLR; W/m²). The contours show 850-hPa stream function at intervals of 2.5x10⁶ m²/s. The vectors denote 850-hPa wave activity fluxes (m²/s²), shown for the value of 'vect_min' and above.

Other figures

- Northern Hemisphere Maps
- Southern Hemisphere Maps
- Global Area Maps

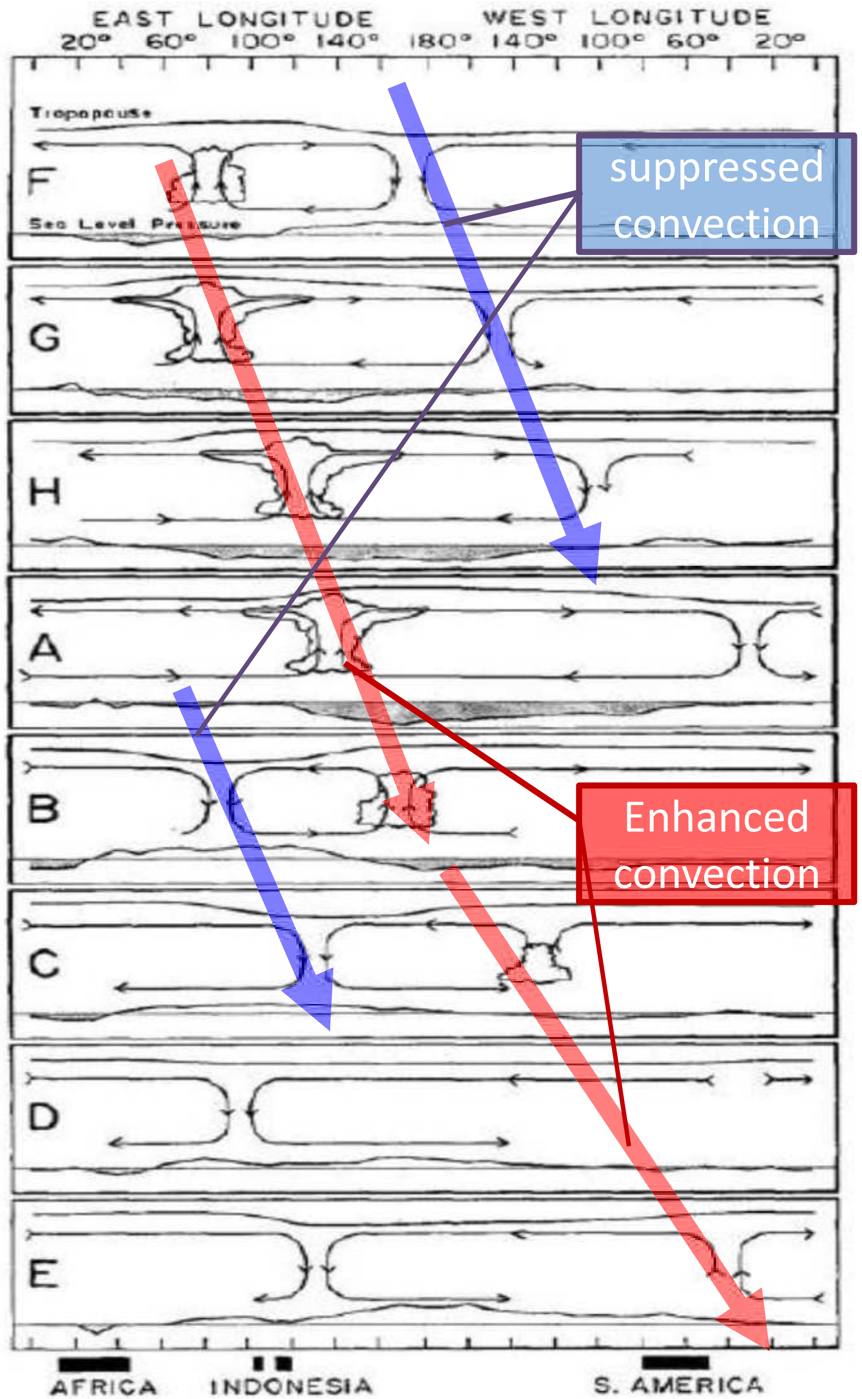
Outline

1. Introduction
2. Climate analysis information
3. Basic knowledge and technique
4. Asian monsoon
5. MJO (Madden-Julian Oscillation)
6. ENSO

General features of MJO

MJO:

- Is a major intraseasonal oscillation in the tropics,
- Propagates eastward along the equator with periods of 30 – 60 days,
- Is a large-scale coupled pattern between deep convection and atmospheric circulation,
- Has a clearer signal in convection over the Indian Ocean and the western Pacific than the other tropical regions.



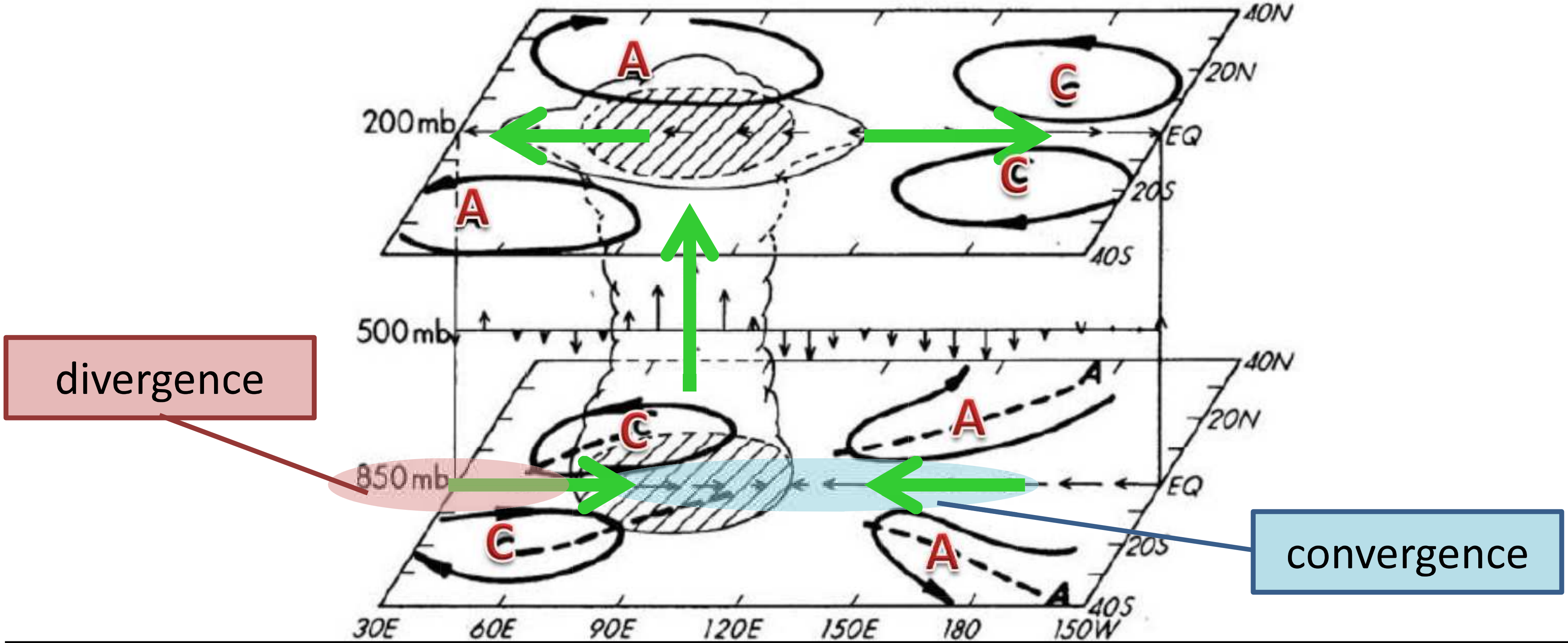
<u>Schematic of MJO</u>

Time increasing downward

(Madden and Julian 1972)

Dynamical structure of MJO

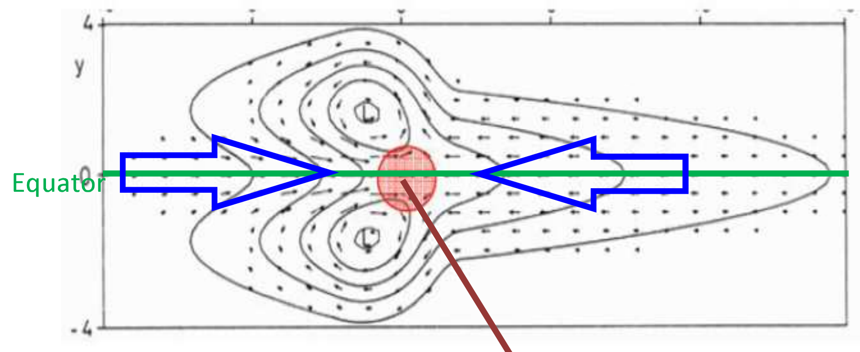
- MJO has characteristics of both the equatorial Kelvin wave and the equatorial Rossby wave.
- The 3D-structure of MJO resembles atmospheric circulation anomalies responding to convective heating (Matsuno-Gill pattern)



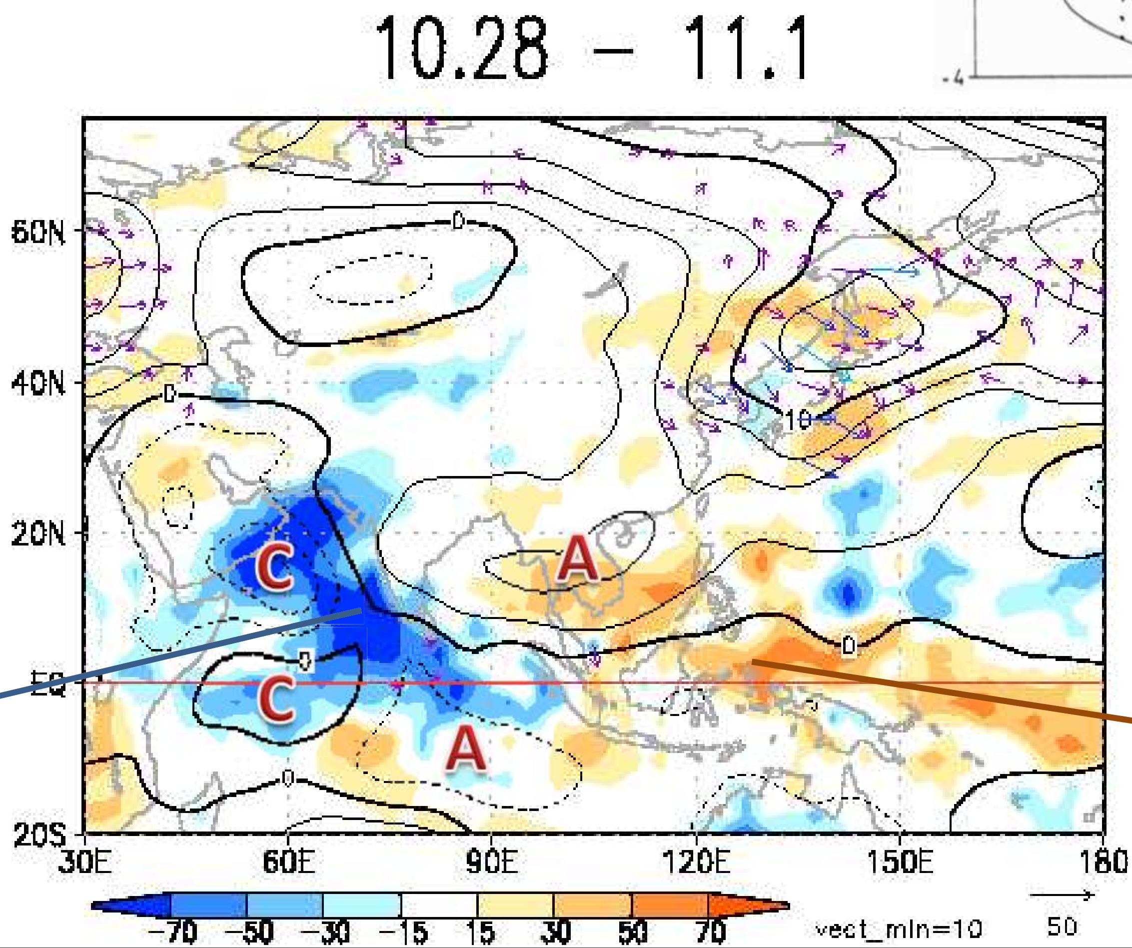
Schematic depiction of large-scale wind structure of MJO (Indian Ocean)

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)

MJO in the Indian Ocean



Matsuno-Gill pattern (low level response)



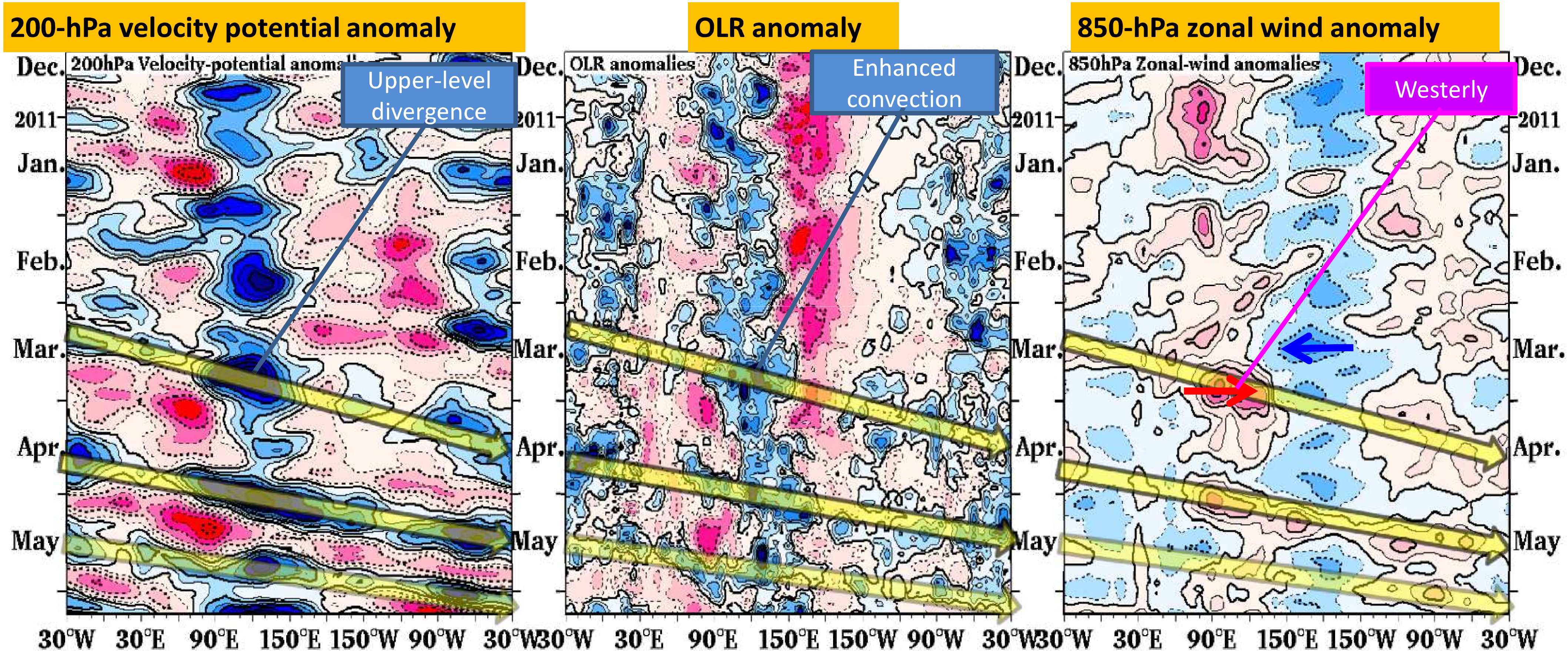
Enhanced convection

Suppressed convection

Five-day average 850-hPa stream function anomalies (contours) and OLR anomalies (shading) for 28 October – 1 November 2011

Analysis of MJO

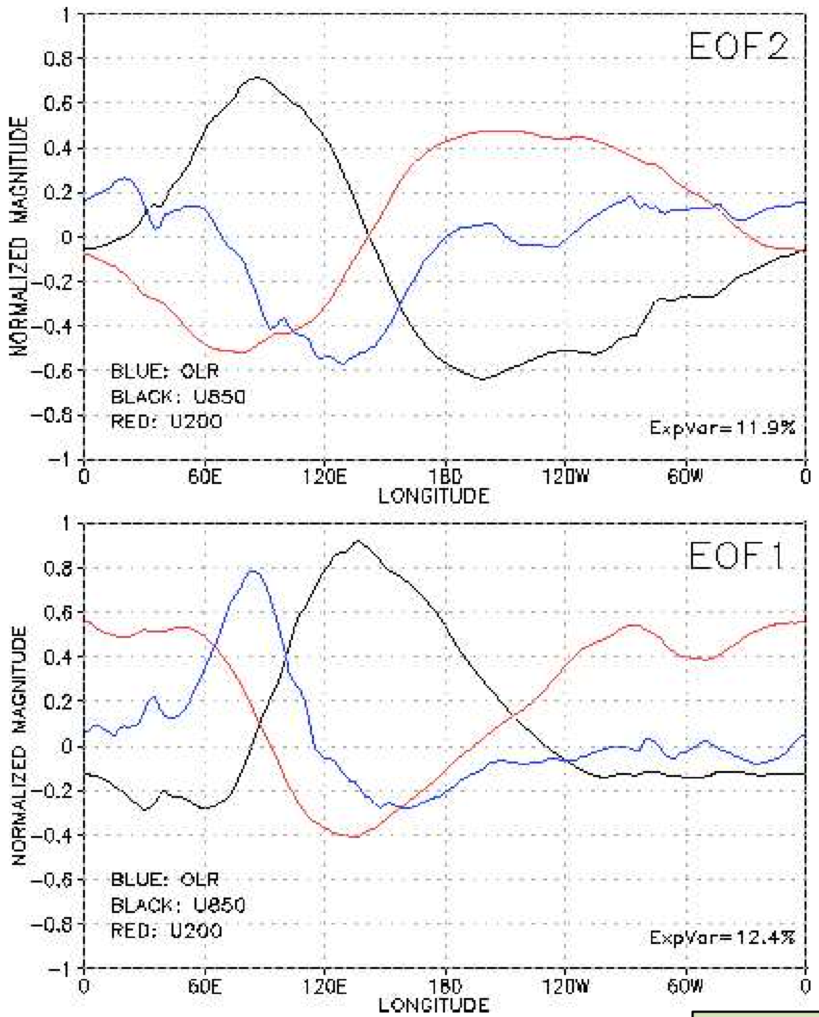
• It is able to identify MJO using Hovmoller diagrams of upper-level velocity potential and OLR.

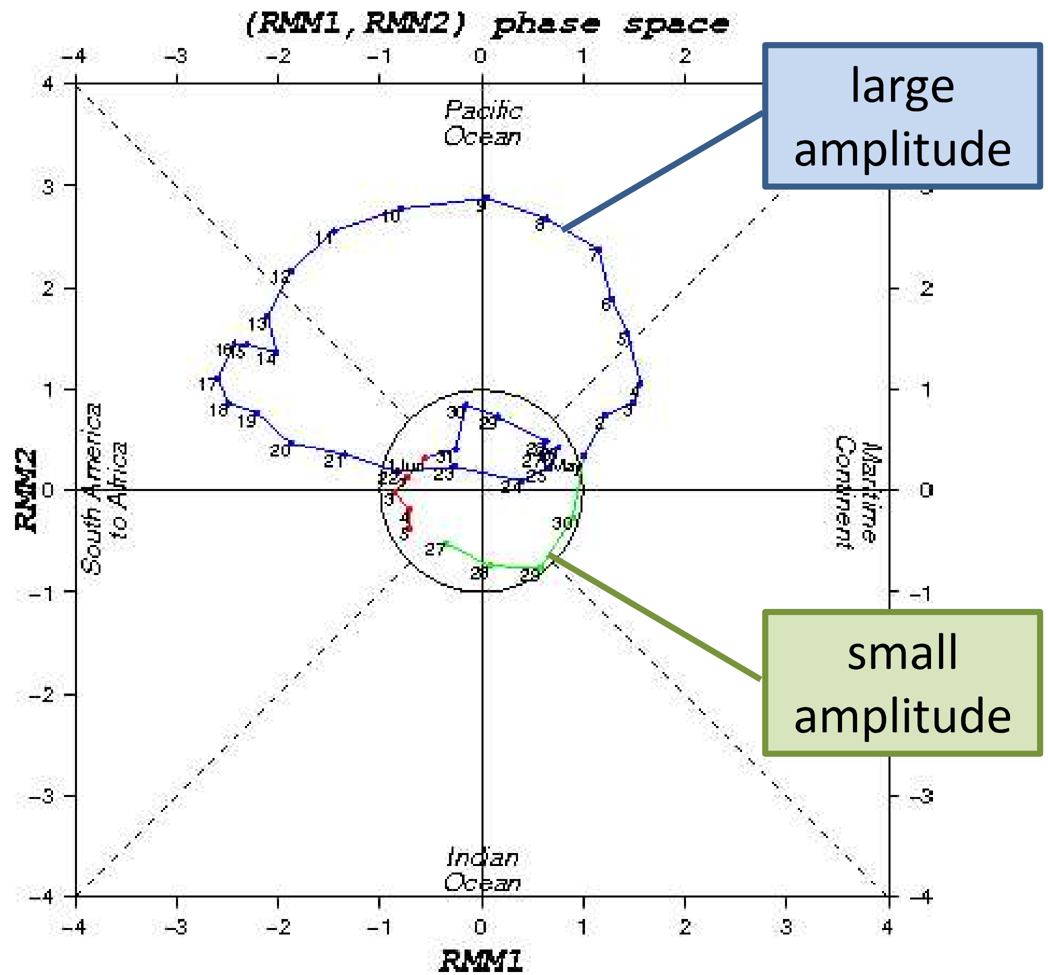


Longitude-time sections of seven-day running mean values of 200-hPa velocity potential anomaly (left), OLR anomaly (center) and 850-hPa zonal wind anomaly (right) around the equator (5S-5N), from December 2010 to May 2011.

MJO Index

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

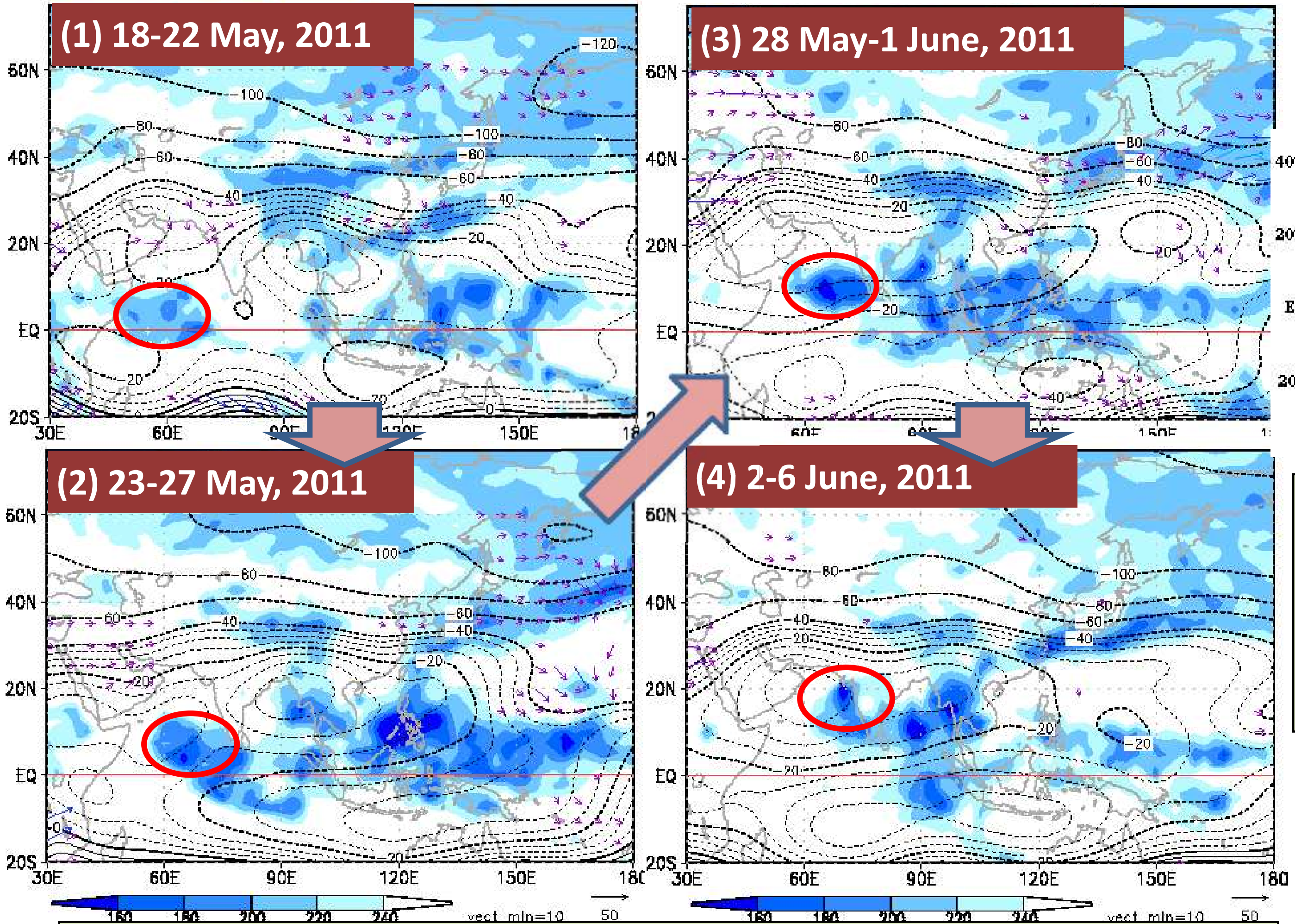




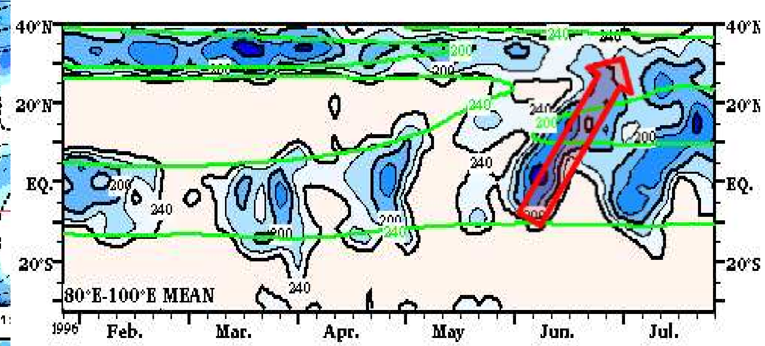
http://ds.data.jma.go.jp/tcc/tcc/products/clisys/mjo/monitor.html

Boreal summer intraseasonal oscillation (BSISO)

- Northward propagation of active/inactive convection areas are seen over the North Indian Ocean and the northwest Pacific, associated with MJO.
- This affects the monsoon onset and active/break (intraseasonal oscillation).



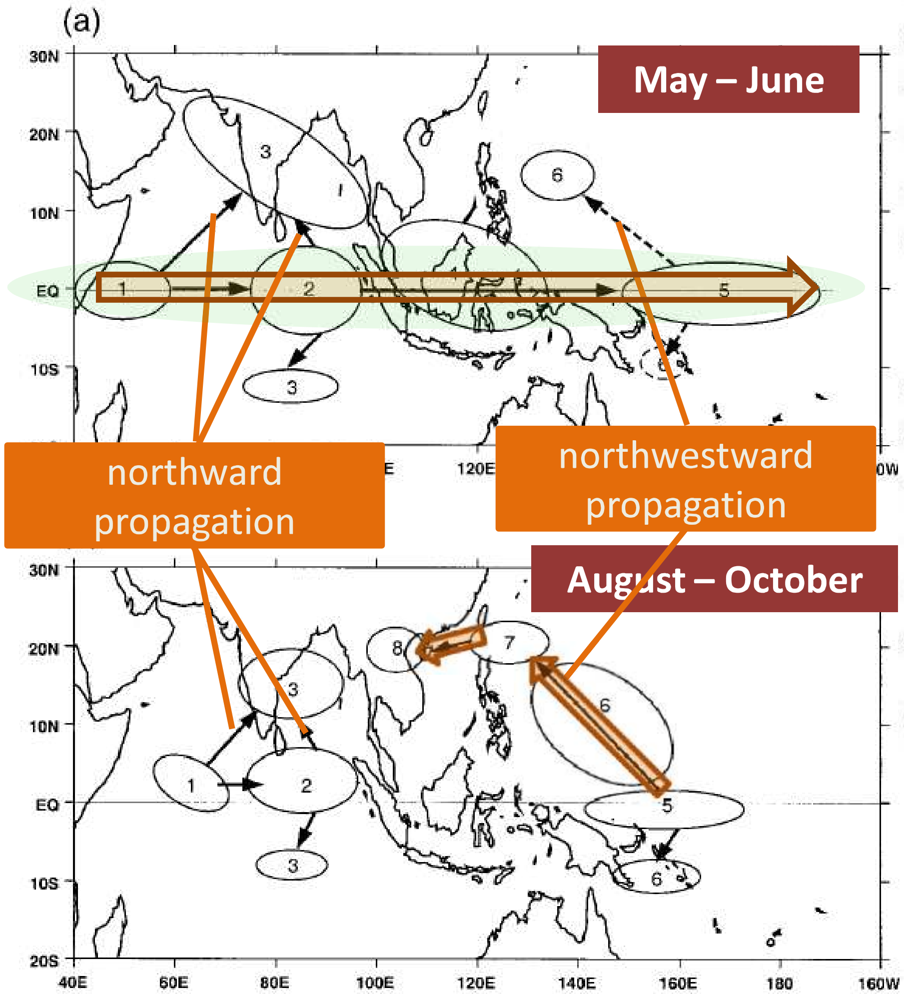
Five-day mean 200-hPa stream function and OLR



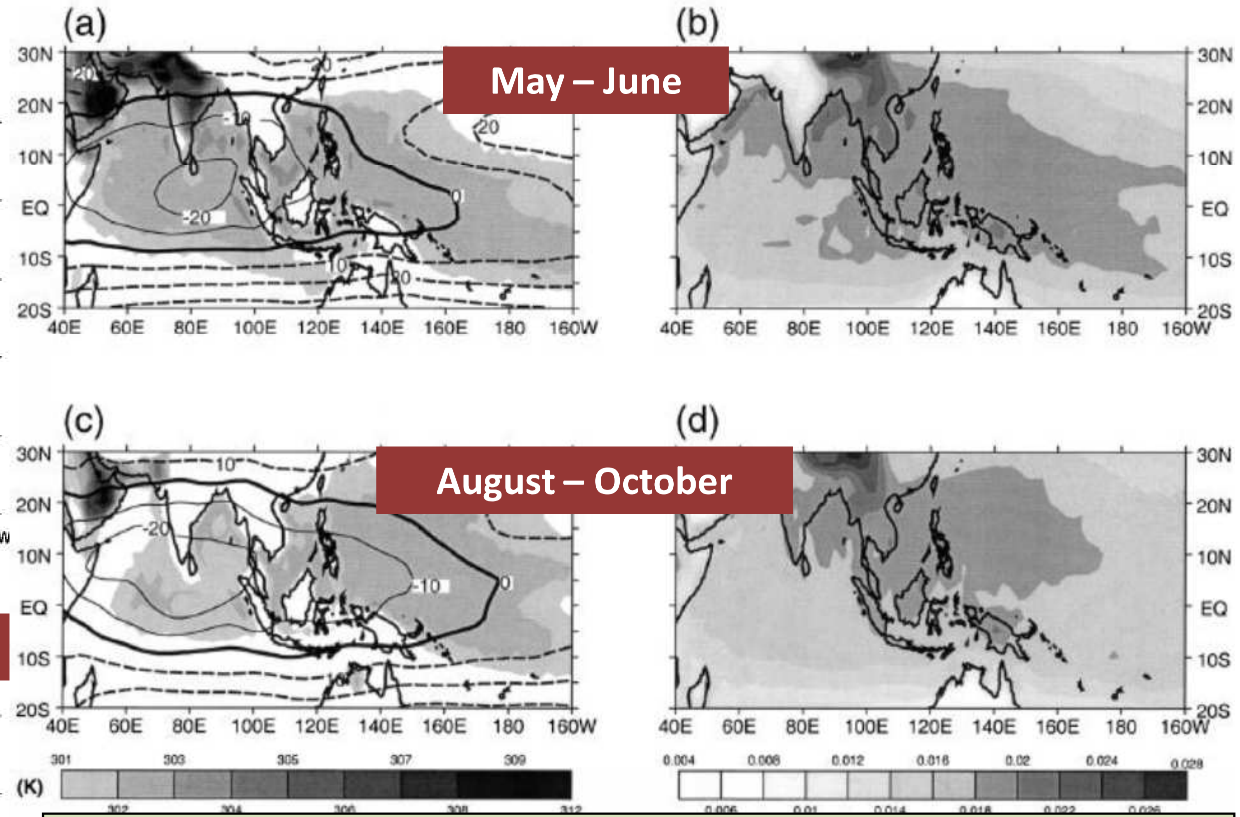
Latitude-time cross section of seven-day running mean OLR averaged 80˚E – 100˚E (around Indian sub-continent)

Life cycle of BSISO

• The characteristics of BSISO are different in early and late boreal summer, due to 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)

MJO products (TCC website)

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

気象庁 Japan Meteorological Agency

Tokyo Climate Center
WMO Regional Climate Center in RA II (Asia)

WMO

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HOME > Climate System Monitoring > Madden-Julian Oscillation (MJO)

Madden-Julian Oscillation (MJO)

Explanatory Notes

MJO Monitoring

- Phase and Amplitude monitor (last 40-day)
- Time-longitude cross section of phase and amplitude
- Time series of RMM1 and RMM2

Principal components of EOF (1980-2003)

- 1st (RMM1), 2nd (RMM2)

Composite, Regression and Correlation map of anomali

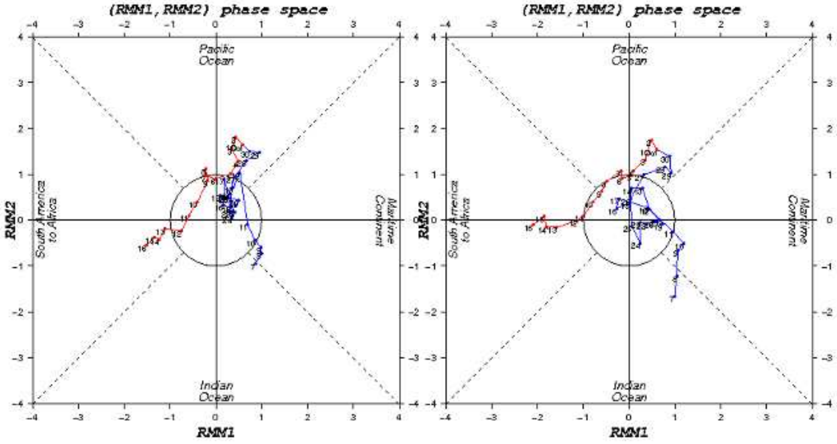
- 8-phase (1980-2003)

CSV file (1980-)

- RMM1, RMM2, phase and amplitude (OLR+u850+u200)
- RMM1, RMM2, phase and amplitude (chi200+u850+u200)

Phase and amplitude monitor (last 40-day)

Year 2012 Month 10 -1 Month +1 Month



MJO phase monitor based on multivariate EOF analysis (Left: OLR+U200+U850, Right: CHI200+U200+U850)
Data period for normal is from 1979 to 2004. Seasonal, interannual and ENSO variations were subtracted from the tropical variations (Wheeler and Hendon, 2004). JRA-25 and JCDAS are used for the atmospheric data. OLR data are provided by NOAA. COBE-SST data were used for calculating ENSO variation. Each figures show the last 40 days trajectory from the final day of each month.

Outline

1. Introduction
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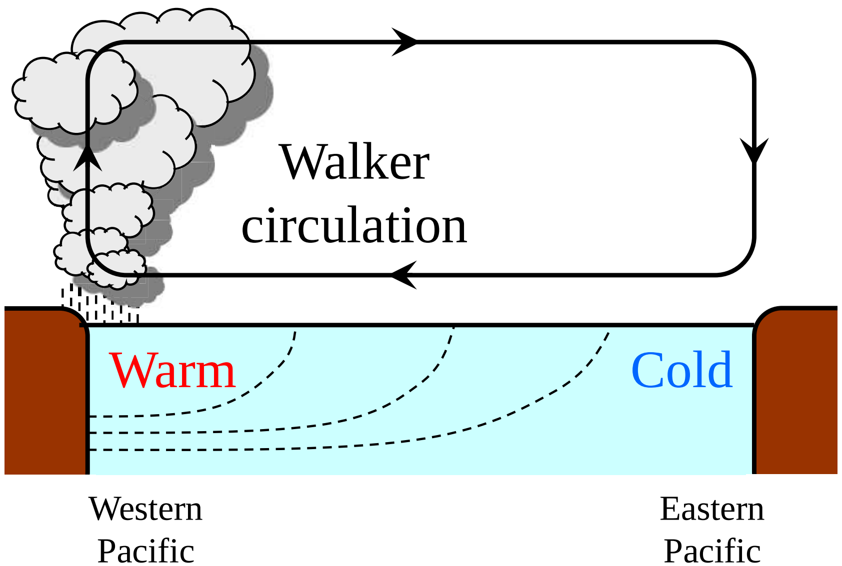
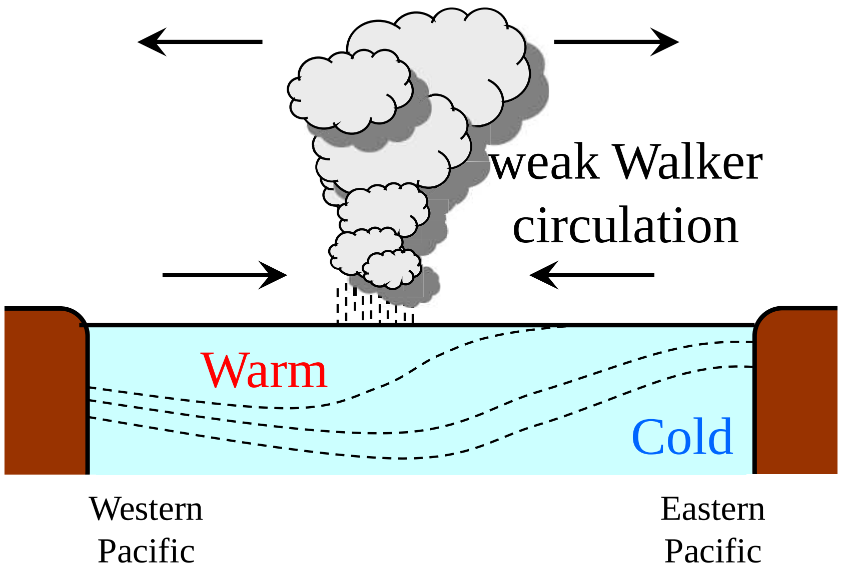
4. Asian monsoon
5. MJO
6. ENSO (El Niño-Southern Oscillation)

General features of ENSO

- El Niño (La Niña): A significant increase (decrease) in SST over the eastern and central equatorial Pacific that occurs at irregular intervals, generally ranging between two and seven years.
- Southern Oscillation (SO): Planetary-scale "seesaw" in sea level pressure, with one pole in the eastern Pacific and the other in the western Pacific–Indian Ocean region.
- The SO is recognized to be primarily a response to basin-scale SST variations in the equatorial Pacific arising from coupled ocean–atmosphere interactions, the opposite extremes of which are the El Niño and La Niña.



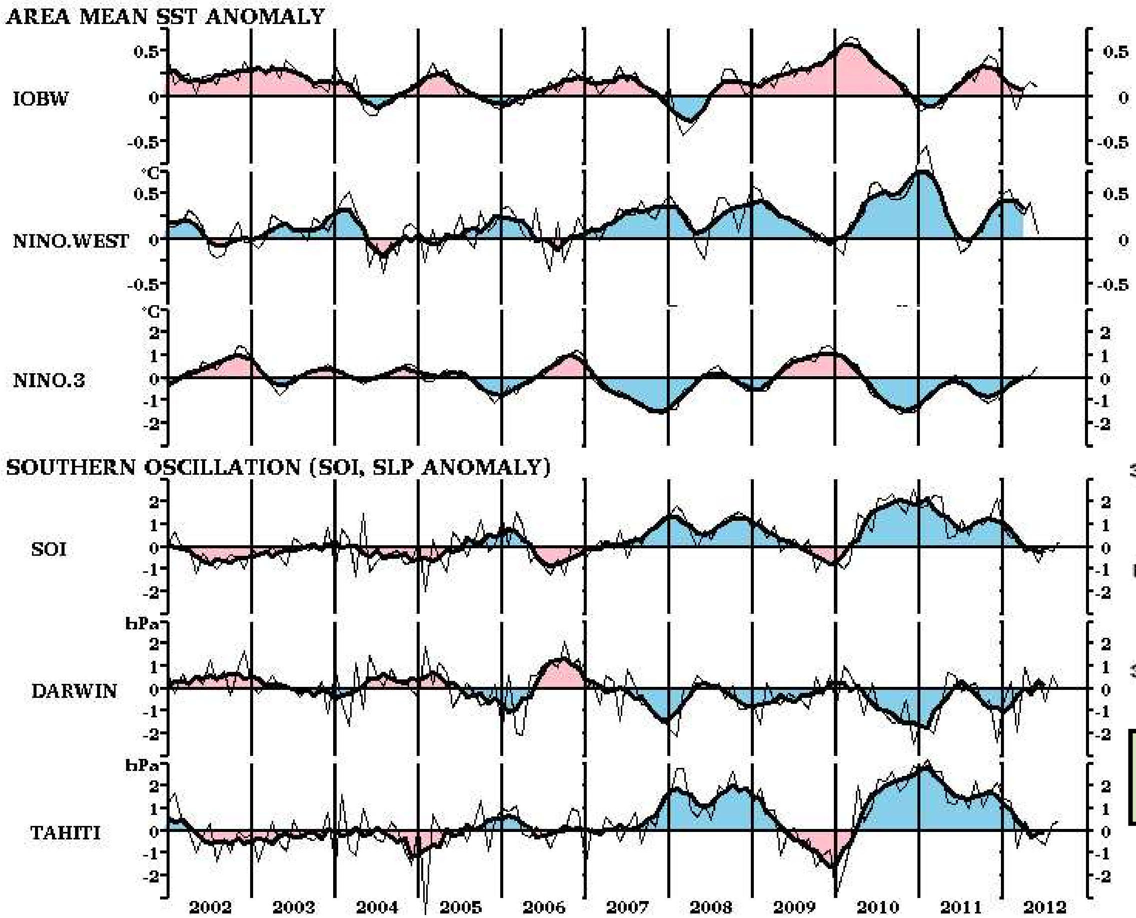
Normal (or La Niña)



El Niño

ENSO monitoring indices

- JMA defines El Niño/La Niña events as a phenomenon in which the five-month running-mean values of monthly SST deviations from the sliding 30-year mean for the El Niño monitoring region (NINO.3: 5˚S – 5˚N, 150˚W – 90˚W) stay at +0.5˚C or above/-0.5˚C or below for six consecutive months or longer.

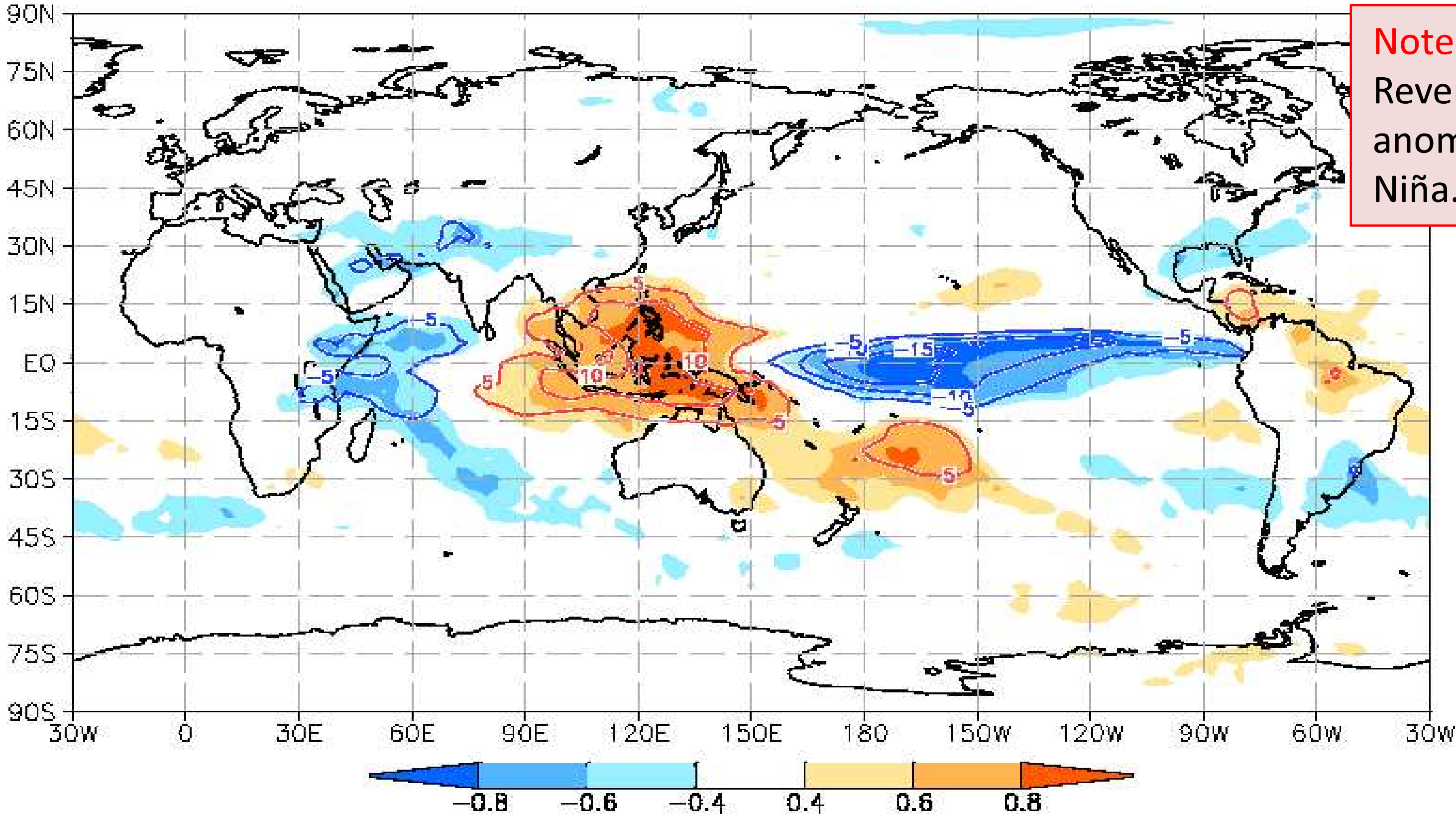


ENSO-related monitoring indices

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

ENSO and convective activity (OND)

• When El Niño (La Niña) events appear in OND, convective activity tends to be suppressed (enhanced) over the eastern Indian Ocean and the western Pacific.



Note:
Reverse signs of these anomalies are seen in La Niña.

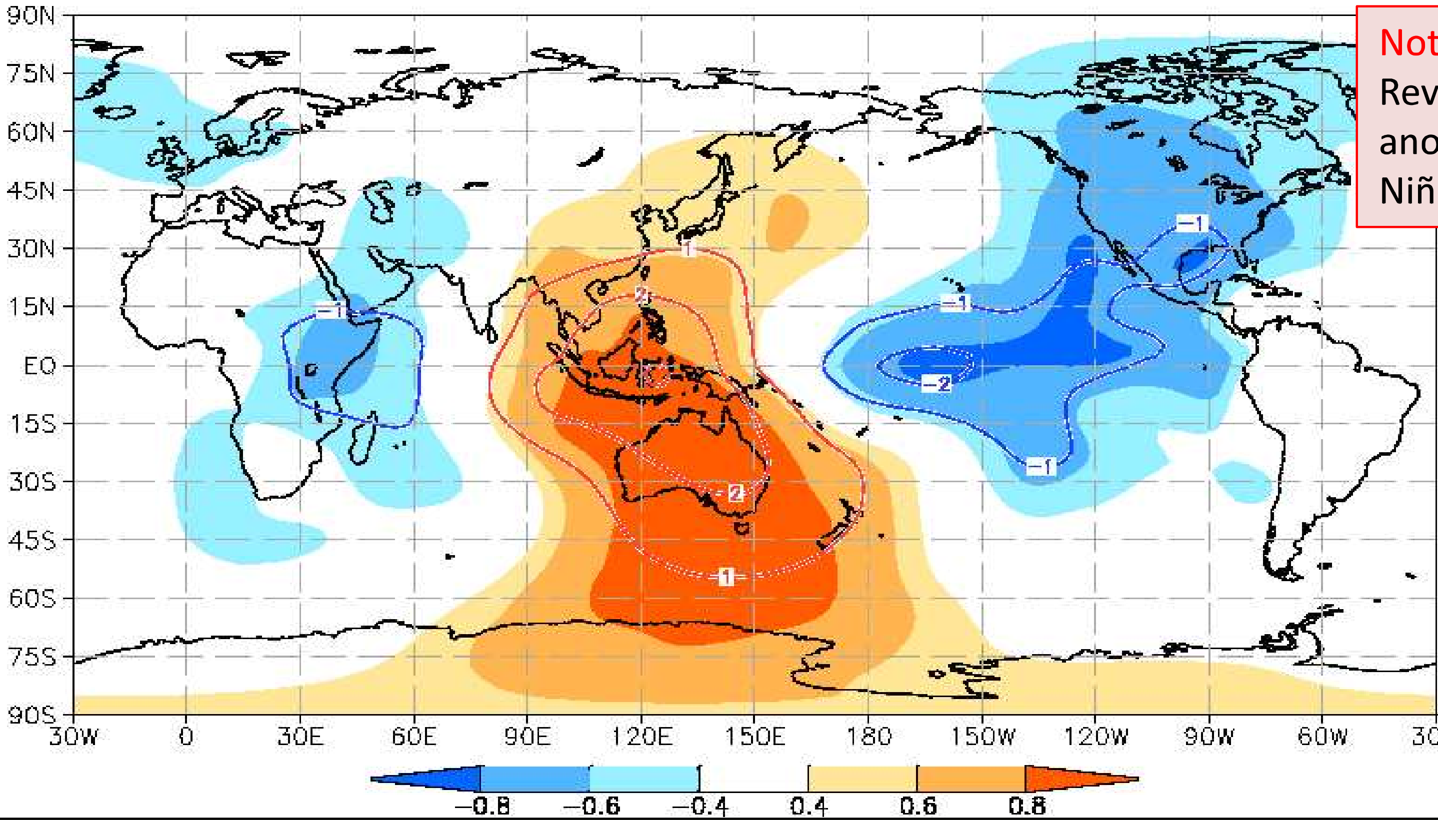
Regression and correlation between OLR and NINO.3 index (Oct. – Dec.)

The contours show OLR regressed on a time series of NINO.3 index.
The shading denotes correlation coefficients between OLR and NINO.3 index.
The base period for these analyses is 1979 – 2008.

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

ENSO and upper-level divergence/convergence (OND)

• When El Niño (La Niña) events appear in OND, upper-level large-scale convergence (divergence) anomalies tend to be seen over the Maritime Continent, in line with large-scale convective activity.



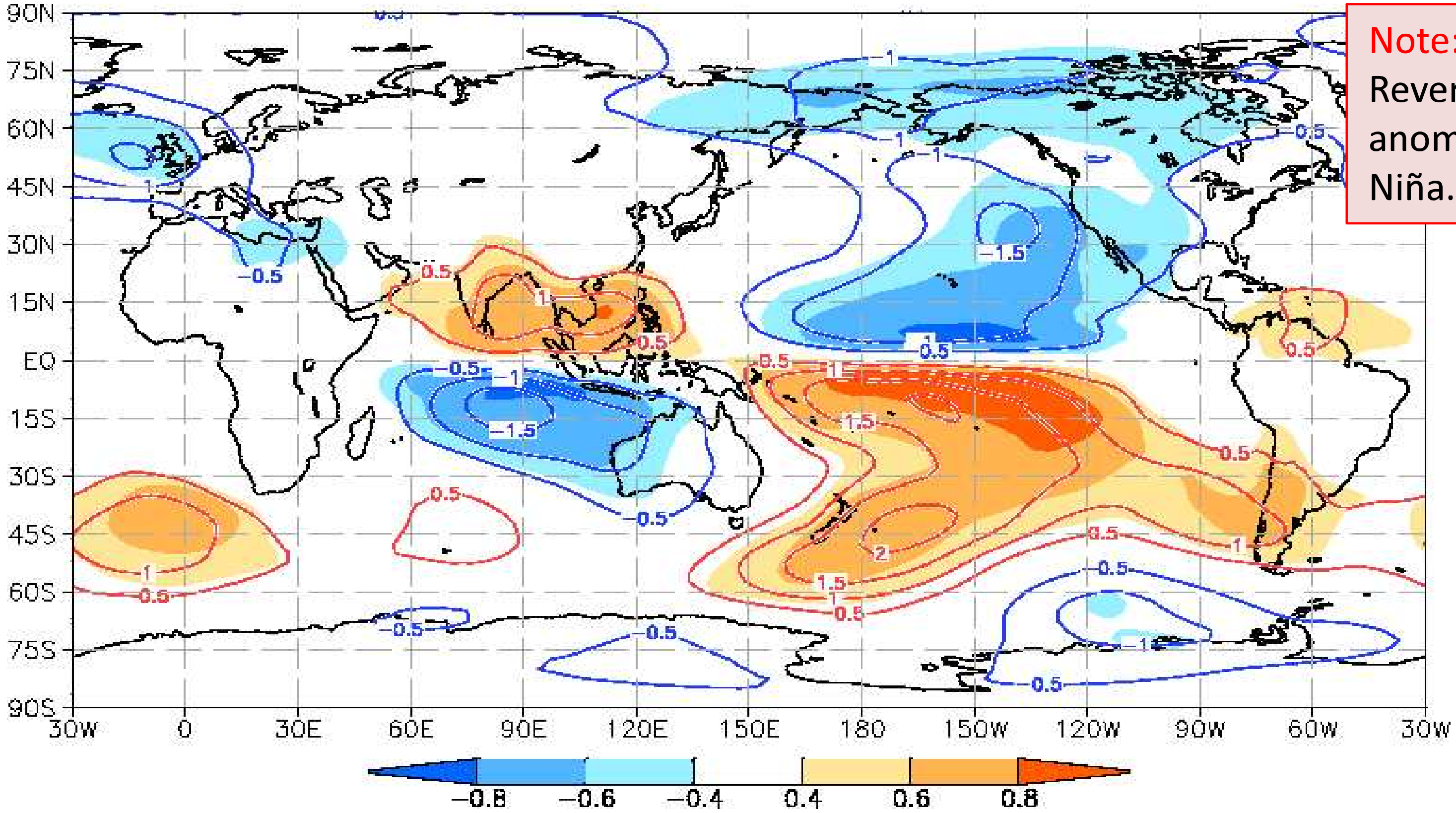
Note:
Reverse signs of these anomalies are seen in La Niña.

Regression and correlation between 200-hPa velocity potential and NINO.3 index (Oct. – Dec.)

The contours show velocity potential regressed on a time series of NINO.3 index. The shading denotes correlation coefficients between velocity potential and NINO.3 index. The base period for these analyses is 1979 – 2008. http://ds.data.jma.go.jp/tcc/tcc/products/clisys/newoceanindex/index.html

ENSO and low-level circulation (OND)

• When El Niño (La Niña) events appear in OND, a pair of anticyclonic (cyclonic) circulation anomalies tends to be seen over the Indian Ocean.



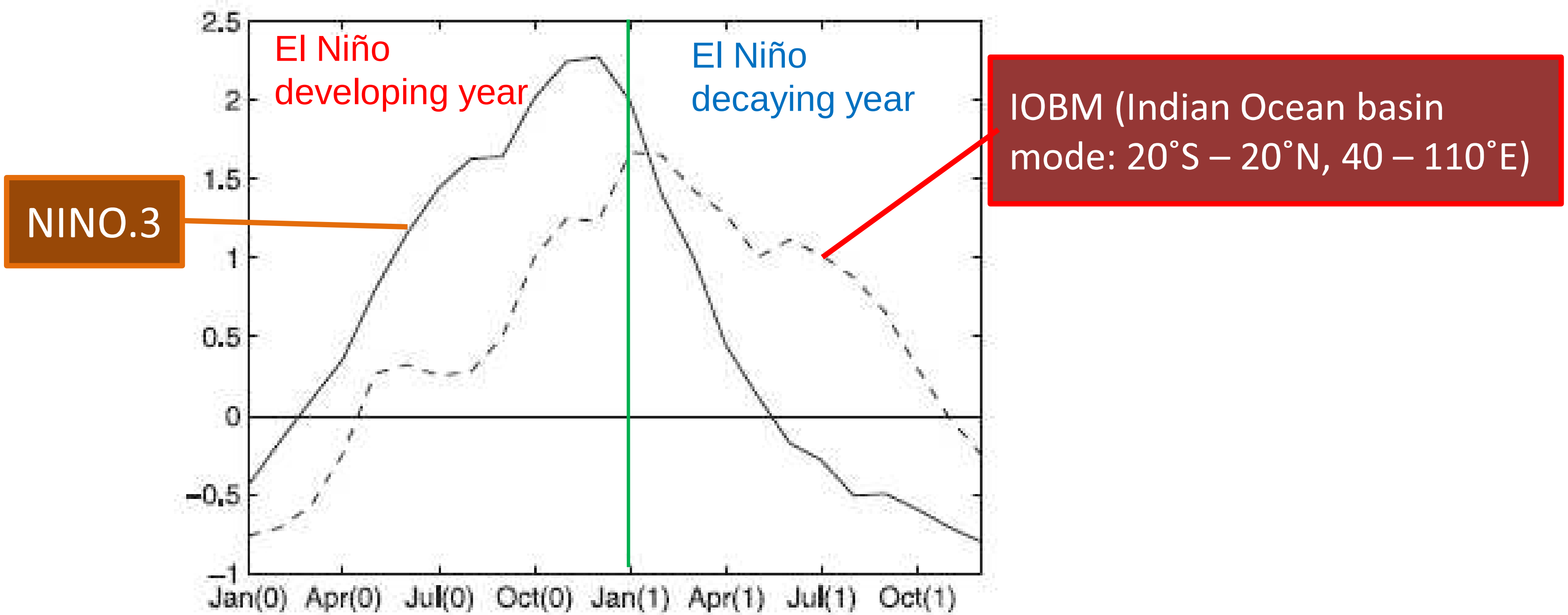
Note:
Reverse signs of these anomalies are seen in La Niña.

Regression and correlation between 850-hPa Stream function and NINO.3 index (Oct. – Dec.)

The contours show stream function regressed on a time series of NINO.3 index. The shading denotes correlation coefficients between stream function and NINO.3 index. The base period for these analyses is 1979 – 2008. http://ds.data.jma.go.jp/tcc/tcc/products/clisys/newoceanindex/index.html

Indian Ocean SSTs and ENSO

• Following an El Niño event, a basin-wide warming takes place over the tropical Indian Ocean, peaks in late boreal winter and early spring, and persists through boreal summer (e.g., Yang et al., 2007).

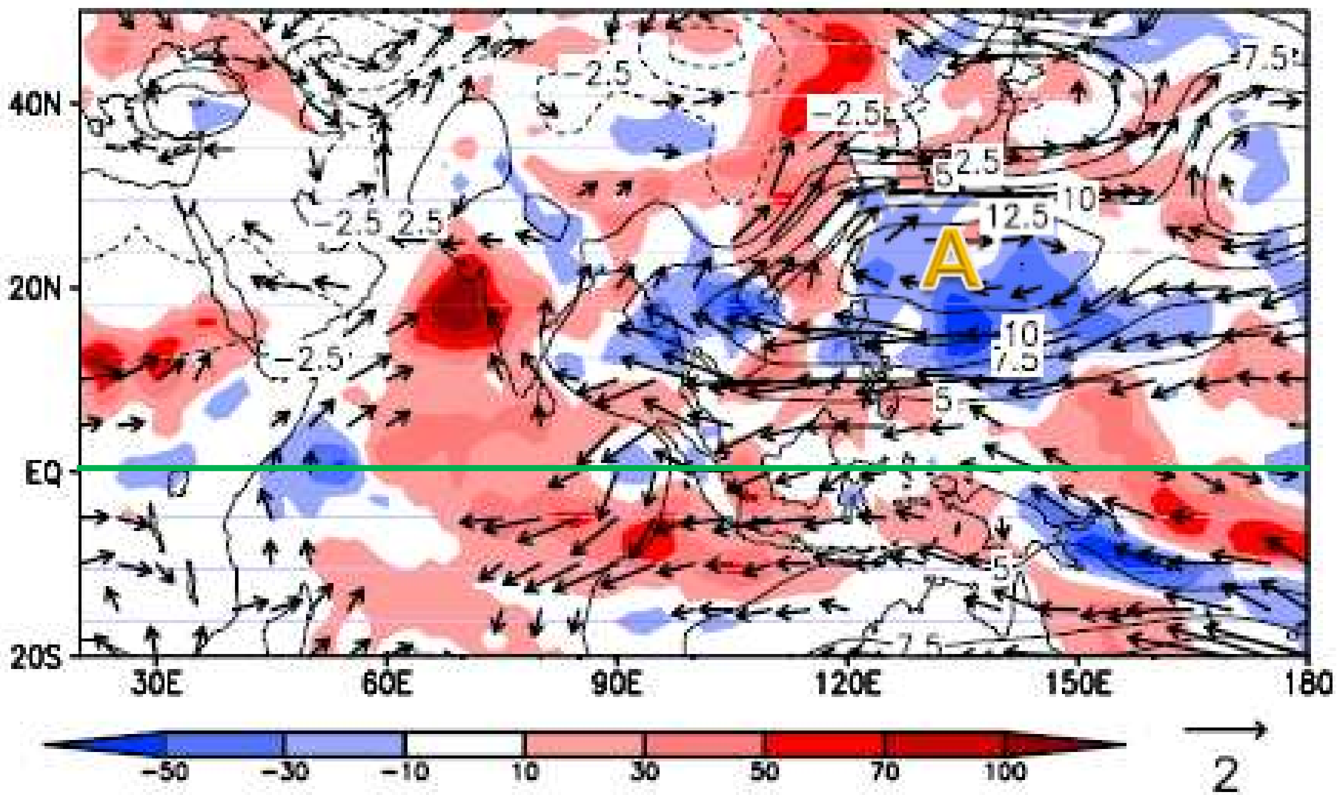


<u>Evolution of a composite El Niño event</u>

The NINO.3 (solid) and IOBM (dashed) indices normalized by their respective annual-mean standard deviations. Numerals “0” and “1” denote years during which El Niño develops and decays, respectively. (Yang et al. 2007)

Indian Ocean SSTs and Asian summer monsoon

• In response to the Indian Ocean warming, precipitation increases over most of the basin; the southwest monsoon intensifies over the Arabian Sea; anomalous anticyclone and reduced precipitation over the subtropical northwestern Pacific.



Composite differences for Jul/Aug between IOBM warm and cold events

Precipitation (color in mm/month), geopotential height (contours in m), and wind velocity (vectors in m/s) at 850 hPa. (Yang et al. 2007)

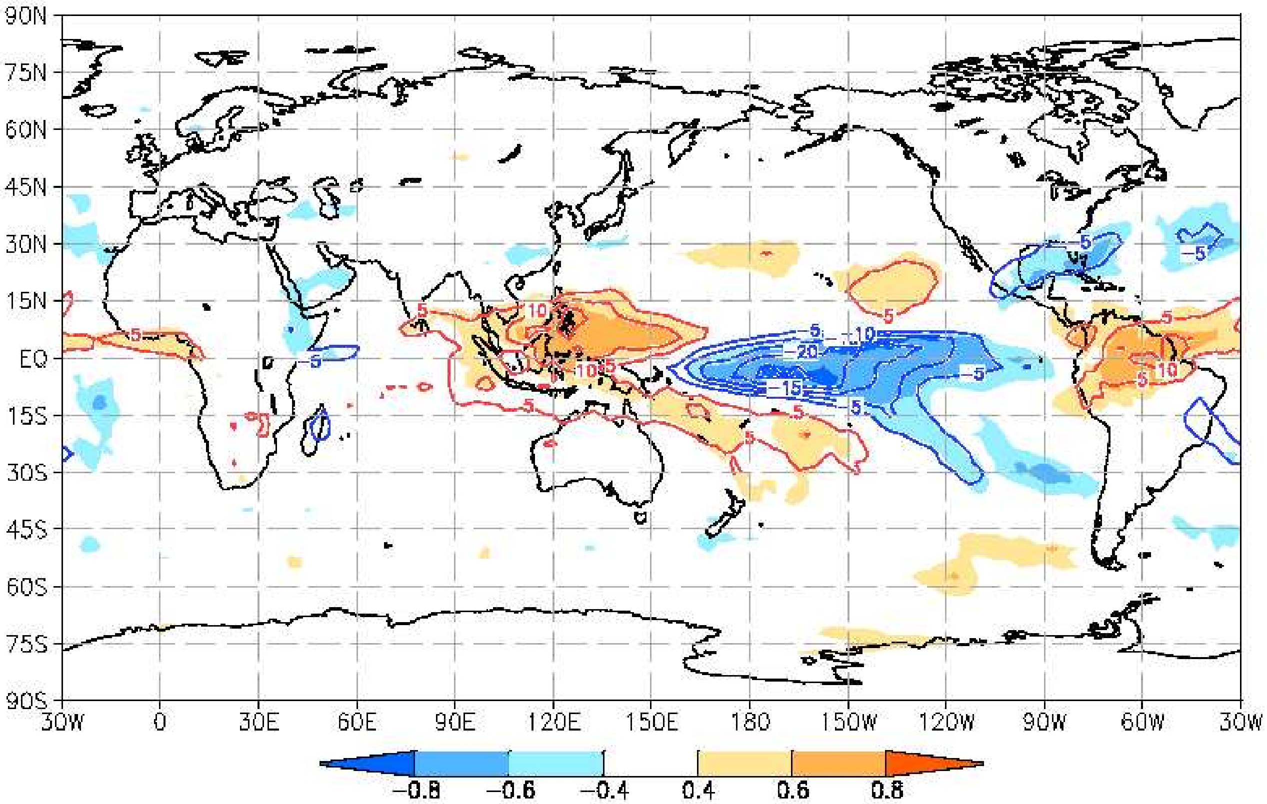
Statistical analysis related to ENSO (TCC website)

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

Atmosphere Circulation Regression and Correlation map

Explanatory Notes

Index NINO.3 Elements OLR monthly 1 -1 Month +1 Month Lag 0 month



Regression and correlation coefficients between each indices and atmospheric circulation fields.
Contours show atmospheric circulation anomalies when normalized indices are +1.0.
Red (blue) contours show positive (negative) anomalies.
0 lines are not shown.

Appendices

Data for climate system monitoring

- Atmospheric Circulation:
  - Objective analysis data produced by JMA and CRIEPI (JRA-25/JCDAS (Onogi, et. al., 2007))
- Tropical Convection:
  - Outgoing Longwave Radiation (OLR) from NOAA
- Sea Surface Temperature (SST):
  - Analysis data produced in JMA (COBE-SST (Ishii, et. al., 2005))
- Snow Cover and Sea Ice:
  - Observations with SSM/I onboard the DMSP polar orbiting satellites from NOAA

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