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The relationship between the Indian Ocean Dipole Mode and the interannual variation of Intraseasonal Oscillation over the south-eastern Indian Ocean

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1. Introduction

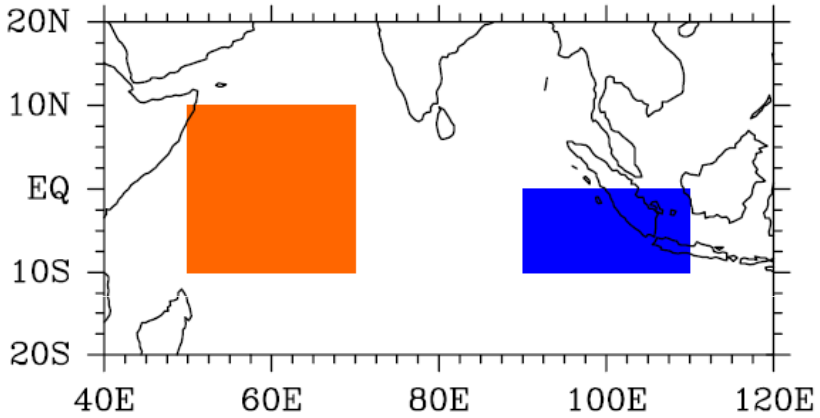
1-1. Indian Ocean Dipole Mode (IOD)

- Zonal dipole-like structure of SST anomaly.
- Pronounced season: boreal fall (Sep-Nov)

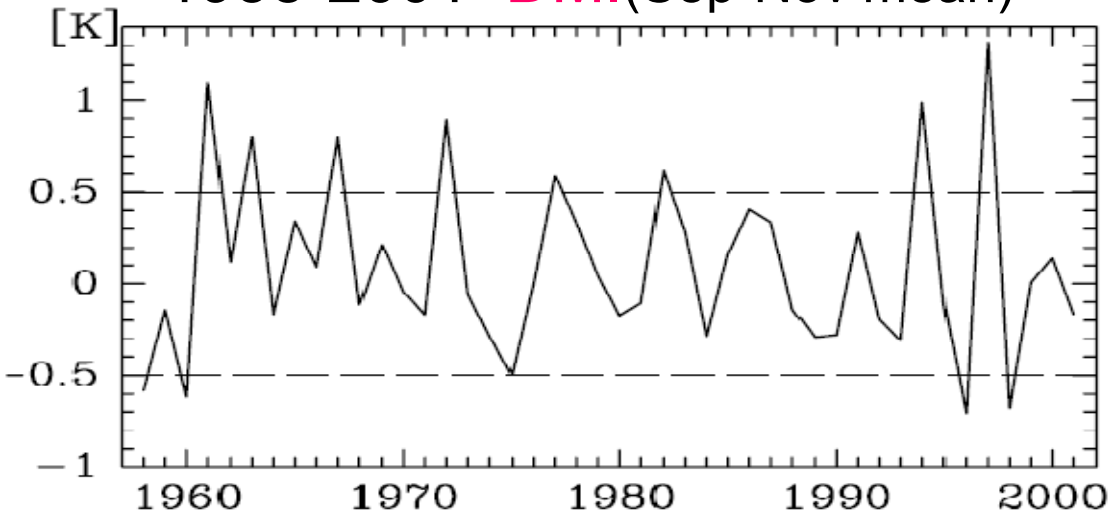
Dipole mode index (DMI)

$SST'_{WEST} - SST'_{EAST}$

(Saji et al. 1999)



1958-2001 DMI(Sep-Nov mean)



$SST'_{EAST} < 0$

Influence on atmosphere?

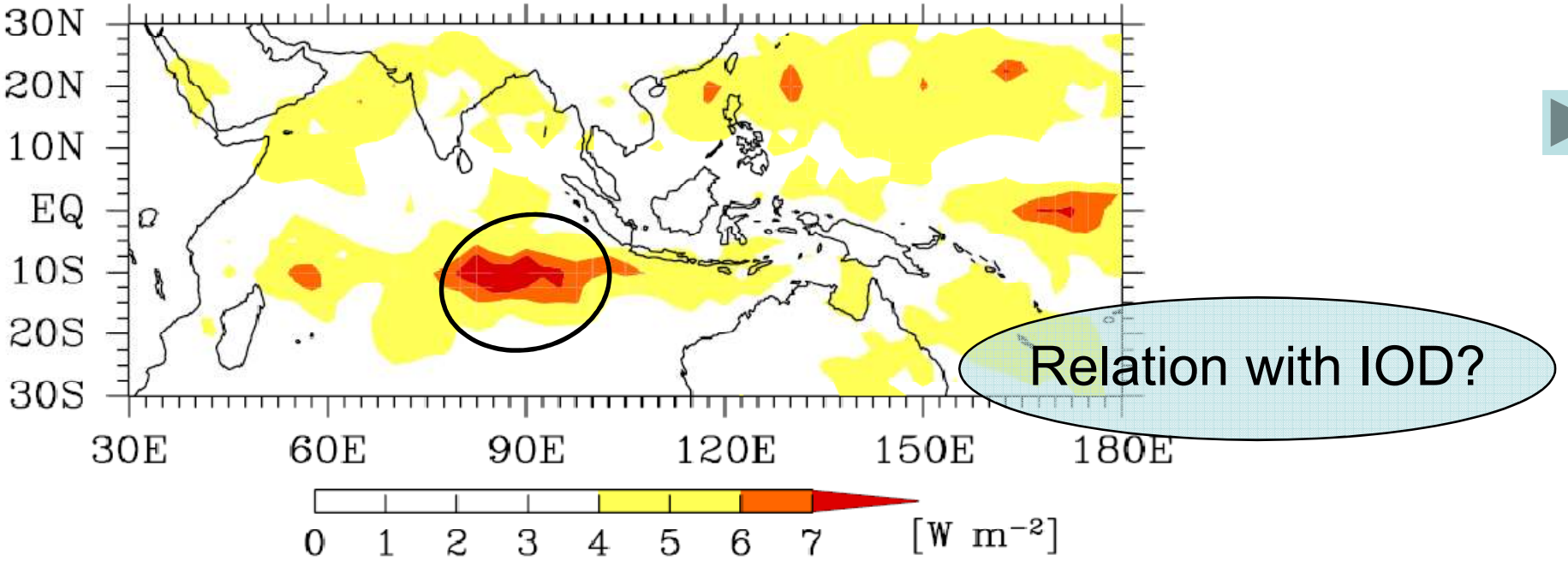
$SST'_{EAST} > 0$

1-2. Intraseasonal Oscillation (ISO)

- Divided into several types
  - ➢ 30-60-day Madden-Julian Oscillation（MJO）
  - ➢ 10-20-day variation of precipitation during the rainy season
- Large interannual variation of activity (e.g., Hendon et al. 1999)

OLR(6-30-day) interannual variation of activity

activity: standard deviation during boreal fall



1-3. Relation between ISO and IOD (Shinoda and Han 2005)

- ISO activity has negative correlation coefficient with DMI.
  In particular, 6-30-day ISO has larger correlation.
- Convectively coupled cyclonic circulations propagating southwestward are often generated during negative IOD years.

> • Structure of cyclonic circulations ?
> • These circulations are the only factor ?

Themes

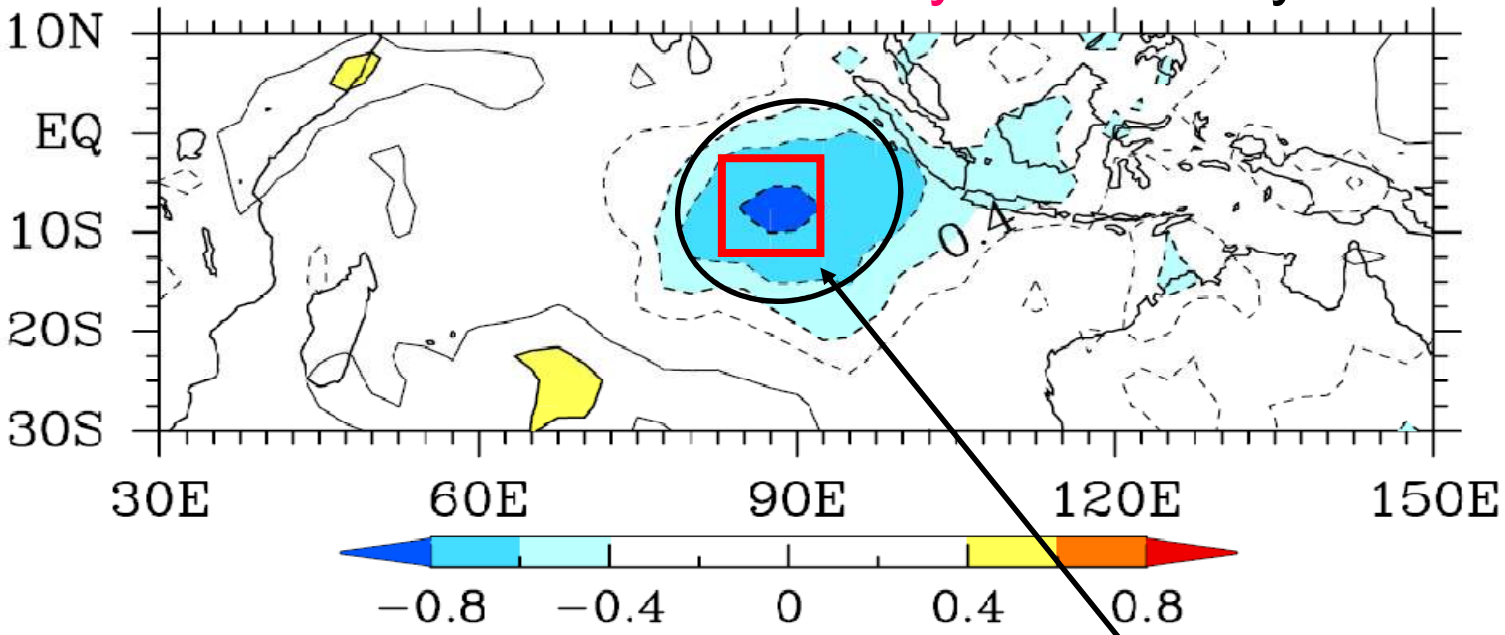
- Investigate the structure of cyclonic circulations.
- Clarify the cause of the interannual variation of ISO on 6-30-day time scales under the influence of IOD.

2. Data and Methods

- Data set
  - ERA-40 1958-2001 00UTC,12UTC
  - Monthly mean ERSST.v3(Extended Reconstructed SST) 1958-2001
  - Dairy mean NOAA OLR 1979-2001
- Analyzed period: 1958-2001 boreal fall [SON; Sep-Oct-Nov]
- Filtered into 6-30-day using Lanczos filter
  - Characters with a prime (') denote filterd data (e.g., v', u', φ')
- The index of IOD: DMI averaged over SON
- The index of ISO activity: standard deviation of 6-30-day bandpass-filtered meridional wind at 850 hPa(v'_{850}) during SON

3. Results

Correlation coefficient of 6-30-day ISO activity with DMI



High negative correlation over the southeastern Indian Ocean

ISES(**12.5S-2.5S,82.5E-92.5E**)

φ', OLR' are lag-regressed onto $\langle v'_{850} \rangle$ averaged over ISES

Day=0: the simultaneous relation when north wind is maximum in ISES

Regressed fields at 850 hPa

Contours : φ'

(dotted: negative value)

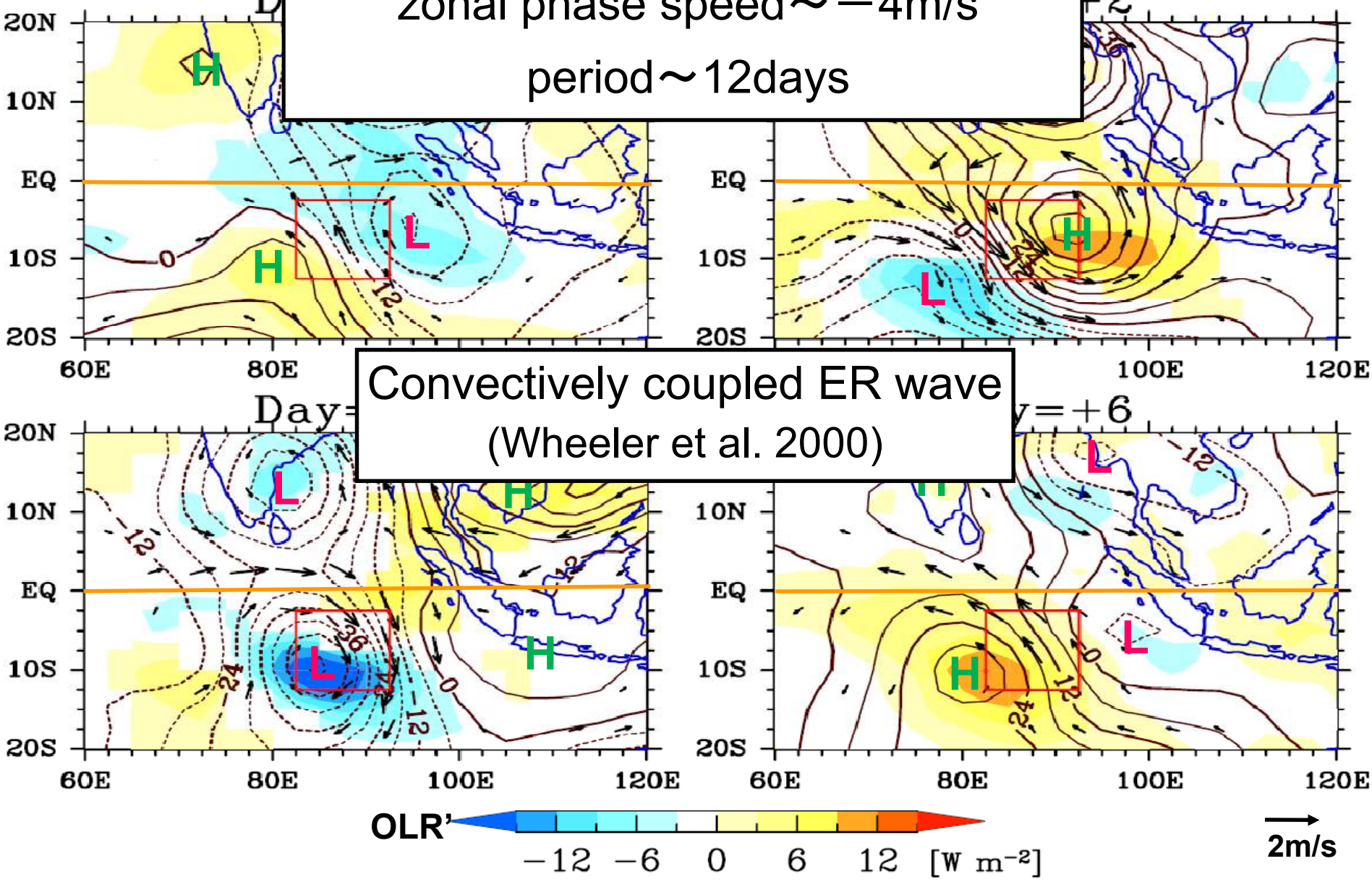
Confidence coefficient 99%

zonal phase speed～－4m/s

period～12days

Convectively coupled ER wave

(Wheeler et al. 2000)



Tracking all cyclonic disturbances generated over the southeastern Indian Ocean

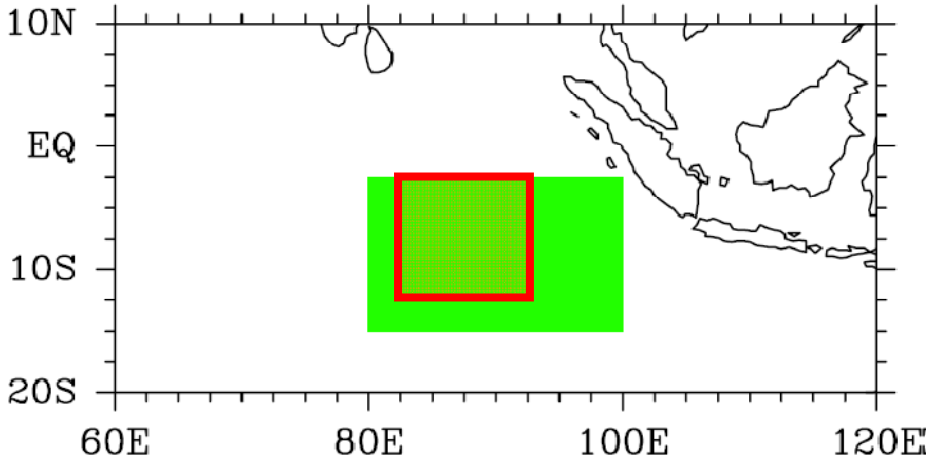
Using data:

relative vorticity at 850hPa ζ'_{850} [s^{-1}]

(spatially smoothed using low-pass filter (Sardeshmukh and Hoskins 1984))

Tracking region:

ISE（15S-2.5S, 80E-100E）



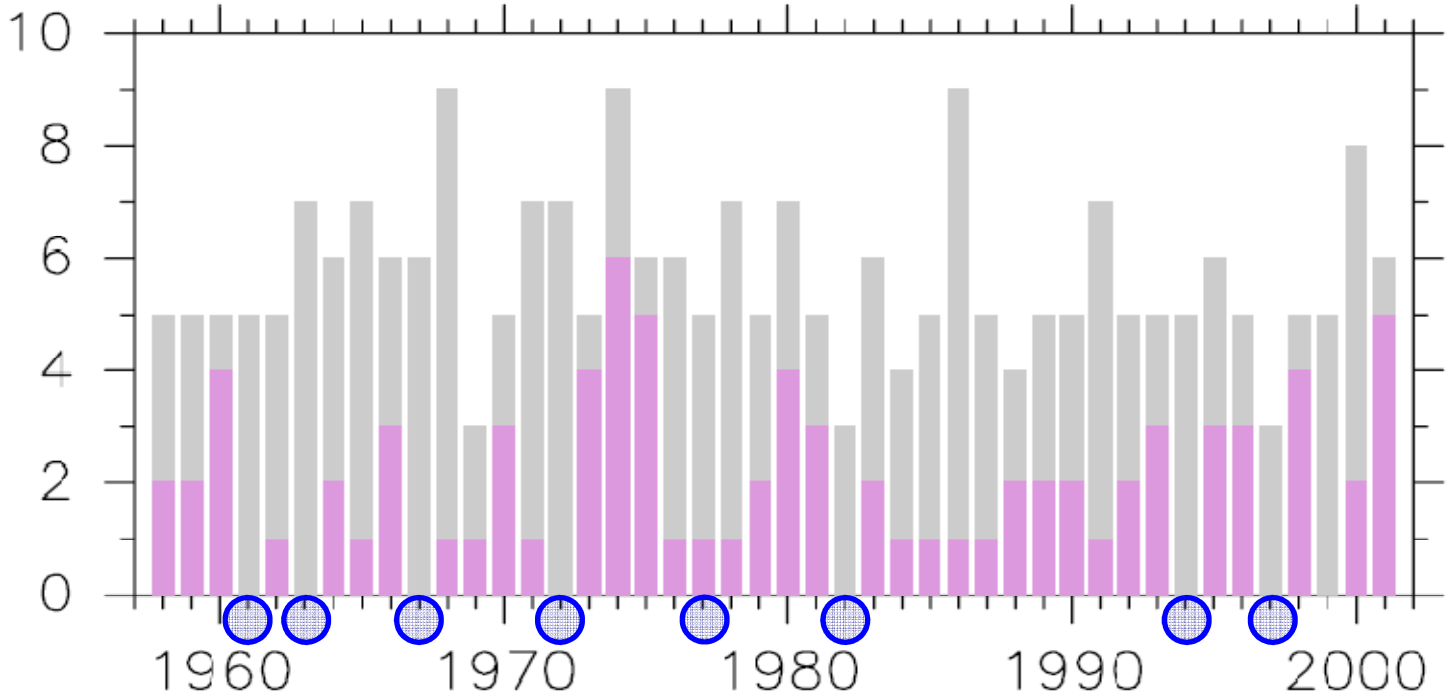
Red box shows ISES

Index of intensity of each cyclonic disturbance:

the maximum absolute negative anomaly (MNA) ≡

the minimum value of ζ'_{850} in ISE for each disturbance

Results of tracking



gray : the total number of cyclonic disturbances

purple : MNA ≧ 10^{-5} s^{-1}

○ Positive IOD years (DMI ≧ 0.5 K)

Relation with Tropical Cyclone

From 1980 to 2001,

26 out of 42 disturbances whose MNA $\geqq 10^{-5}$ s^{-1}

are recorded as TC

JTWC cyclone best-track

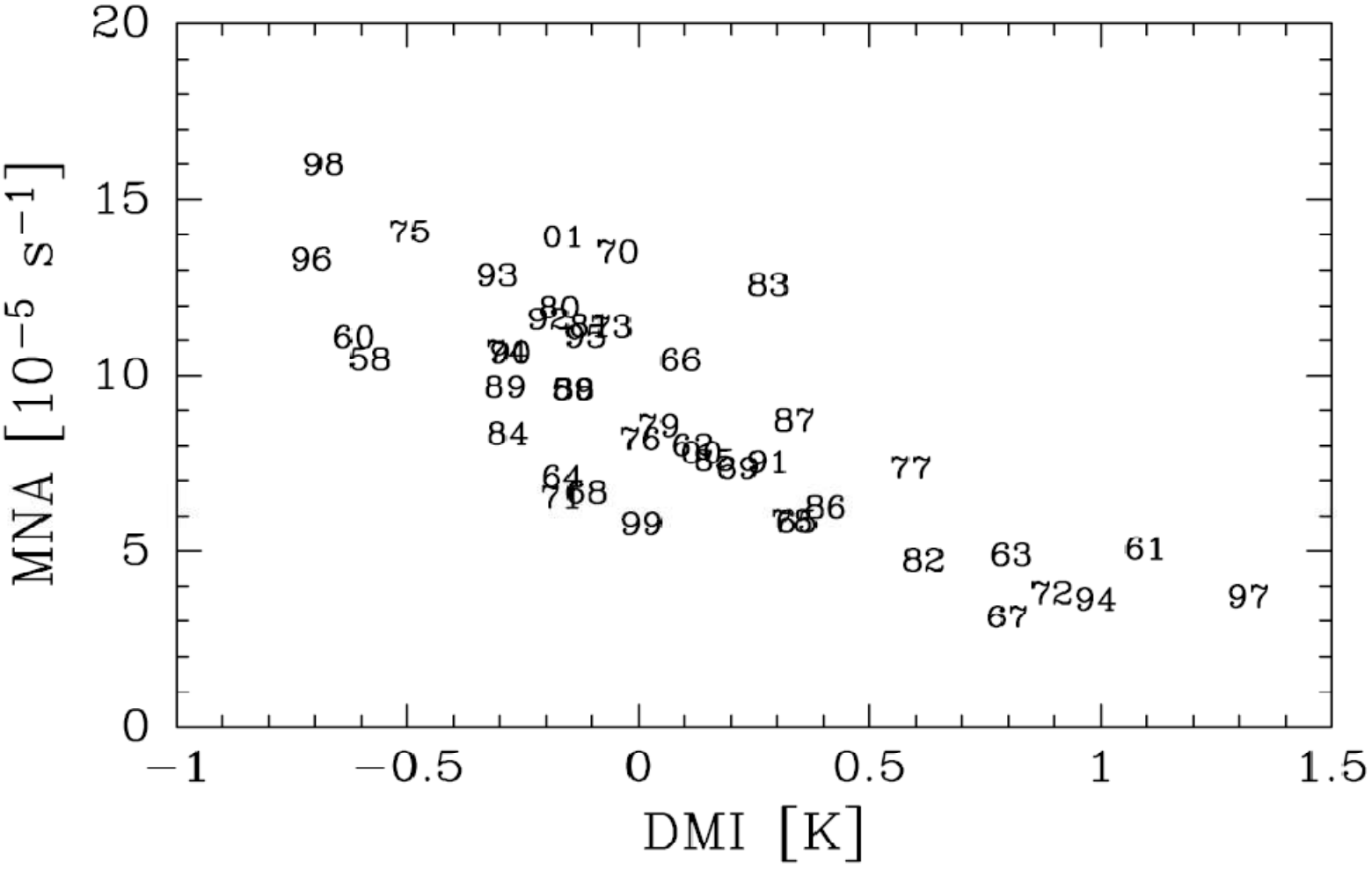
In TC genesis over the southern Indian Ocean,

- Vorticity anomaly in the lower troposphere
- OLR anomaly

produce by ER waves are important

Bessafi and Wheeler, 2006

MNA averaged for each year vs. DMI



Correlation coefficient -0.80

Change of background caused by IOD

- During positive IOD years,
  - negative SST anomalies in southeastern Indian Ocean
  - convective activity
  - humidity in the lower troposphere
  - easterly vertical shear

are suppressed over the southeastern Indian Ocean.

⇒ decay ER waves

(Xie and Wang 1996; Wang and Xie 1996)

⇒ produce TC

(Bessafi and Wheeler, 2006)

⇒ small **MNA** ⇒ small **ISO activity**

4. Summary and Discussion

- What is the cyclonic circulations?
  - ➢ Convectively coupled equatorial Rossby Waves
- The relation of interannual variation of ISO with IOD
  - ➢ The intensity of cyclonic disturbances (defined by the MNA averaged for each year) has negative correlation with DMI (correlation coefficient -0.80).
  - ➢ IOD changes the background (Convection, vertical shear, specific humidity)

↓

ISO activity has high negative correlaion with DMI

→ The large interannual variation of ISO over the southeastern Indian Ocean

Formation of IOD (Saji et al. 1999)

summer

Over the eastern Indian

- Easterly wind is enhanced
- Negative SST anomalies develop

Over the western Indian

- Positive SST anomalies develop

Fall

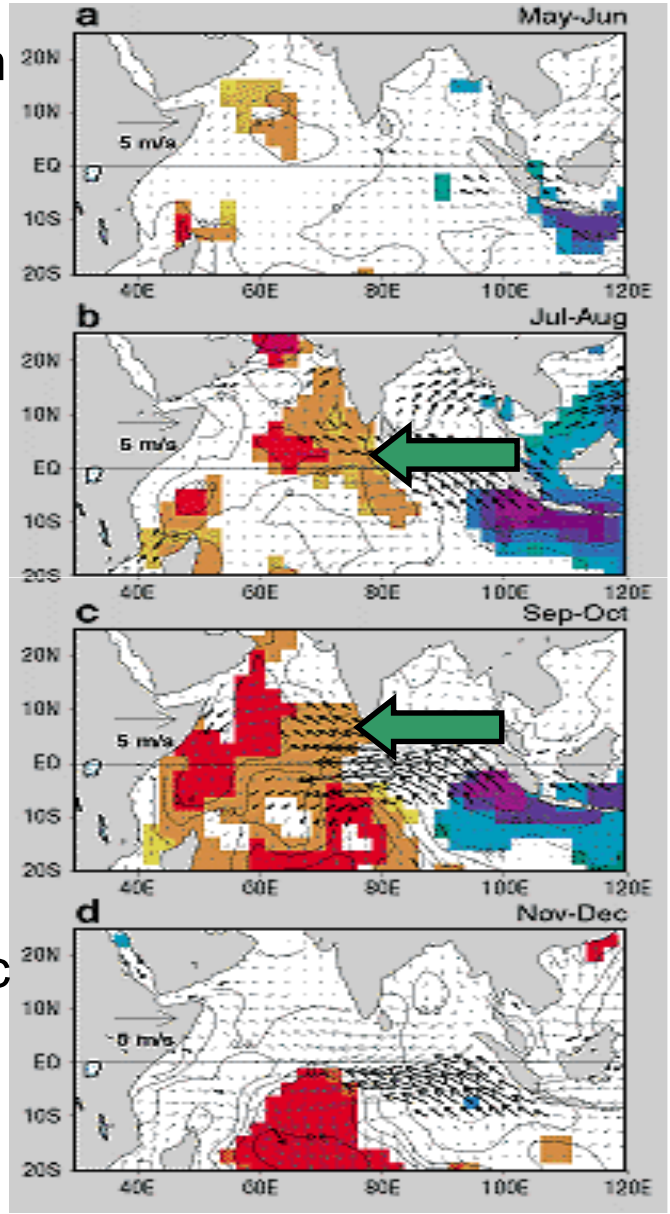
Zonal dipole-like structure become evident

May-Jun

Jul-Aug

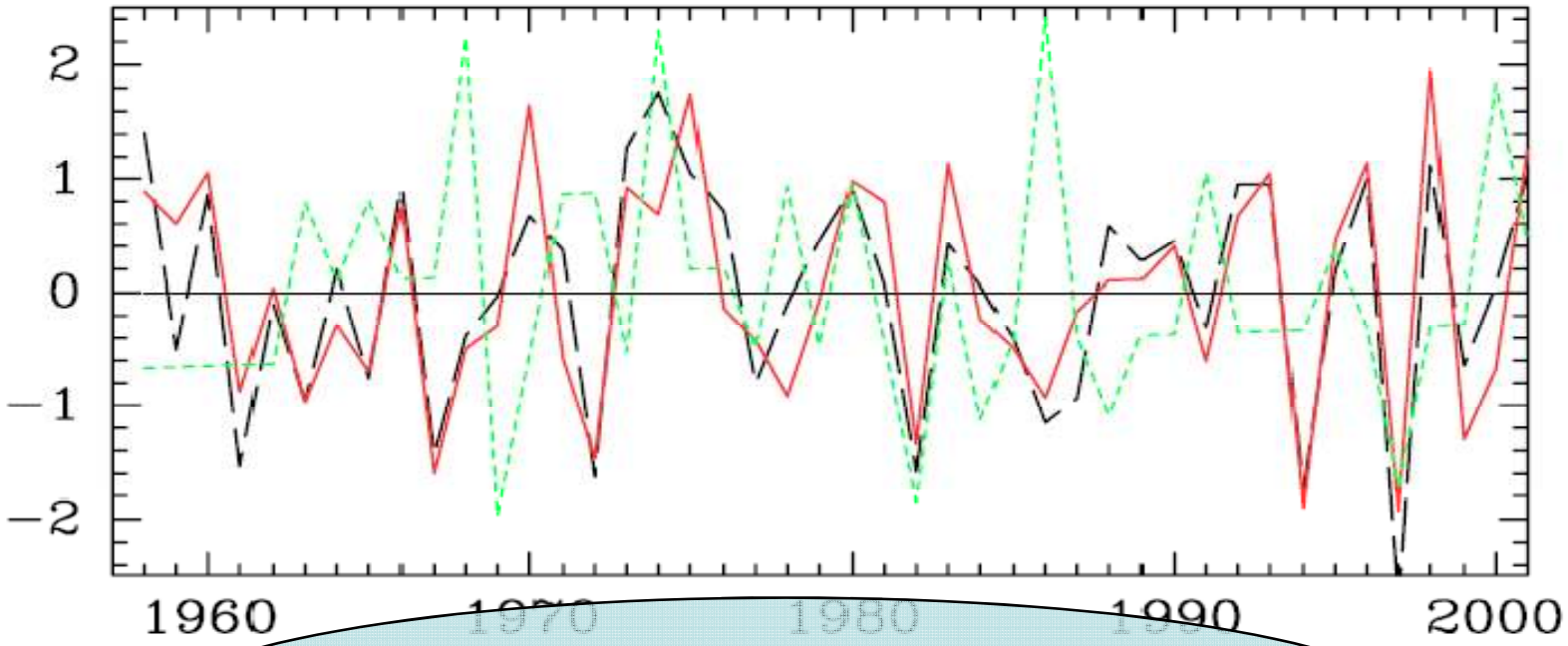
Sep-Oct

Nov-Dec



Saji et al.(1999)

Composite of SST and surface wind during positive IOD years



dashed-line : ISO activity averaged over 15E

dotted-line : the number of cyclonic disturbances

solid-line : MNA averaged for each year

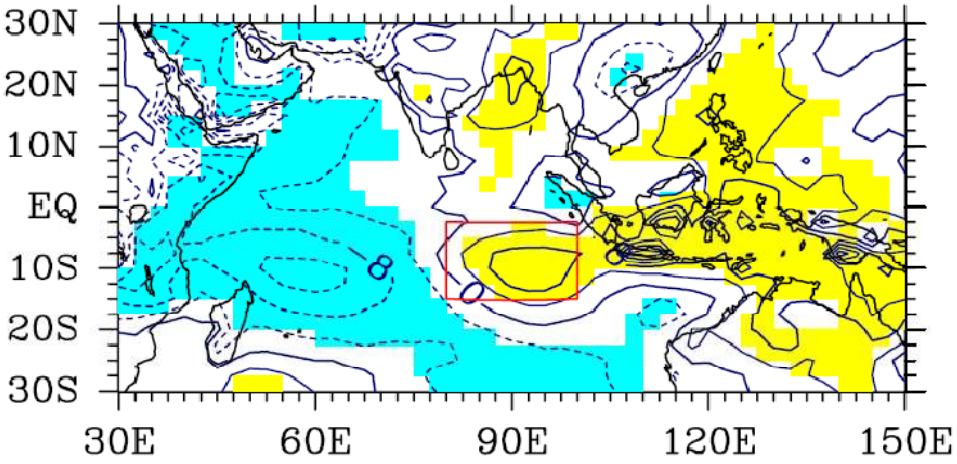
- ISO activity is affected by the intensity of cyclonic disturbances

ISO activity – number of cyclonic distuebances 0.119

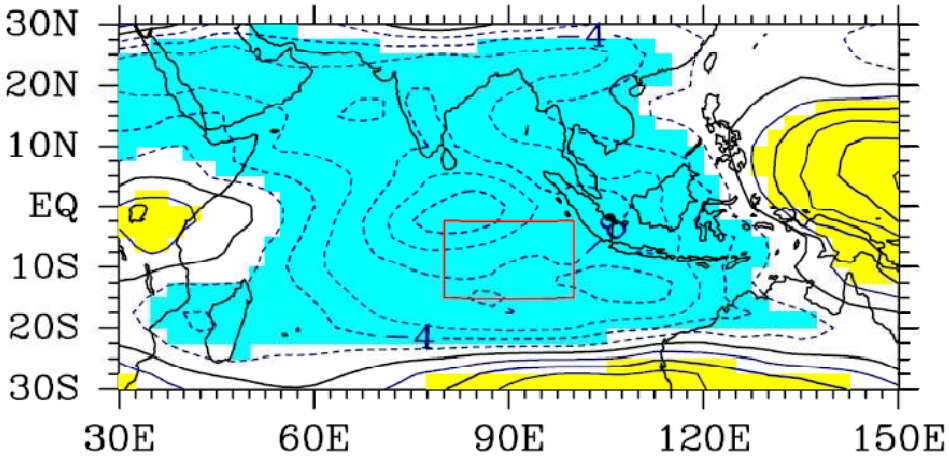
ISO activity – MNA averaged for each year 0.850

The cause of interannual variation of the intensity of disturbances?

Specific Humidity (1000 hPa)



Vertical shear of zonal wind

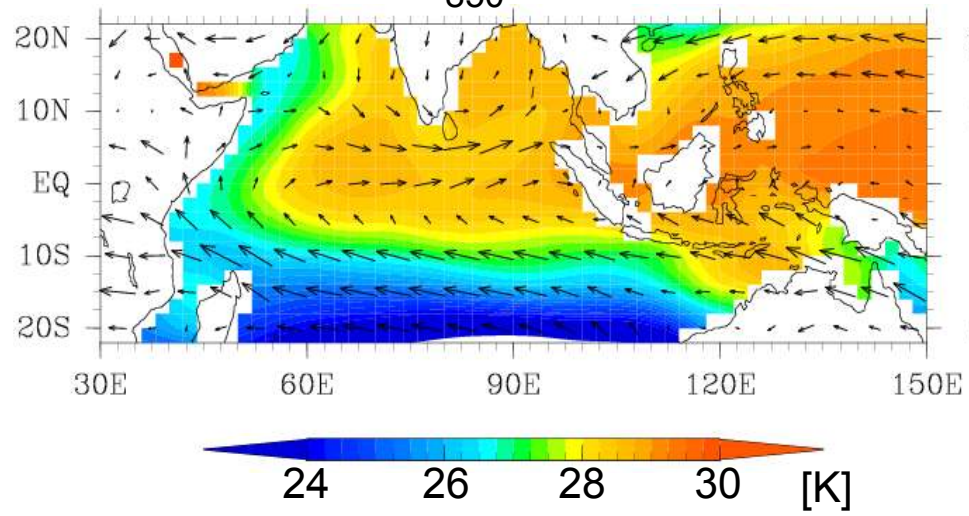


The difference between negative IOD years and positive IOD years

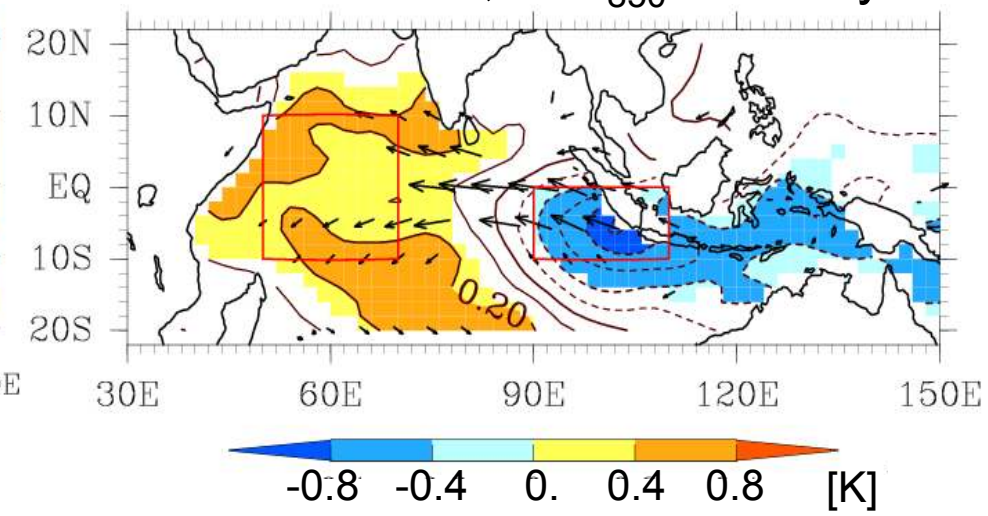
Yellow indicate positive value, and blue indicate negative value

Example of the influences of IOD on Atmosphere

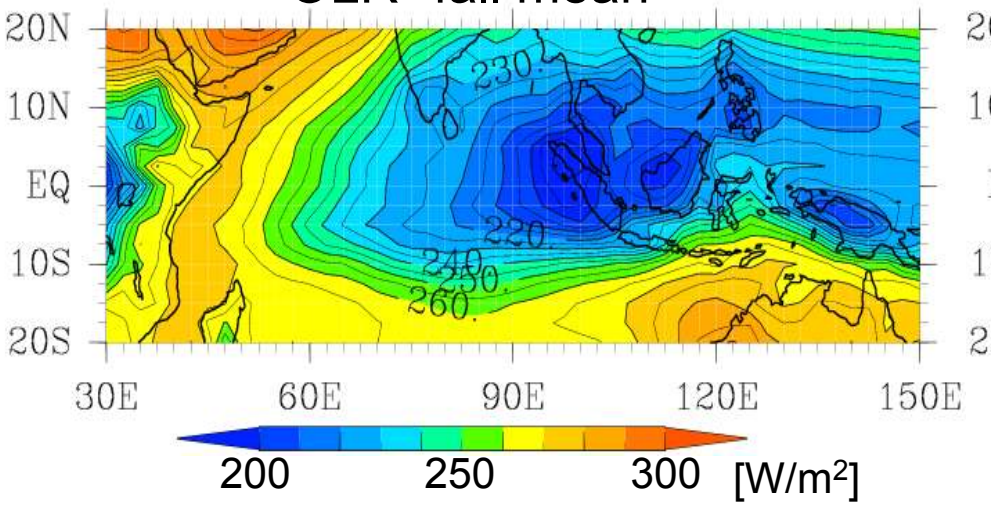
SST、$wind_{850}$ fall mean



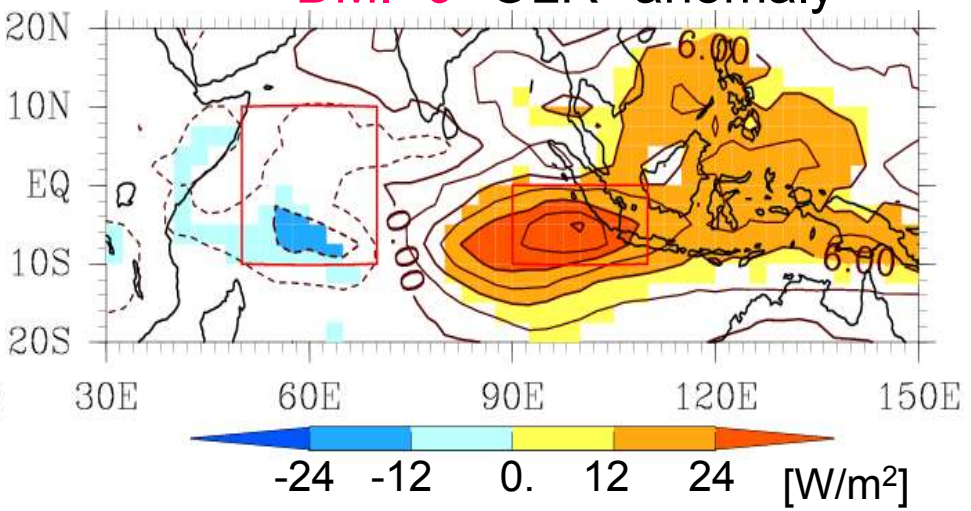
DMI>0 SST,$wind_{850}$ anomaly



OLR fall mean



DMI>0 OLR anomaly



data：NOAA-OLR、ERSST, ERA-40

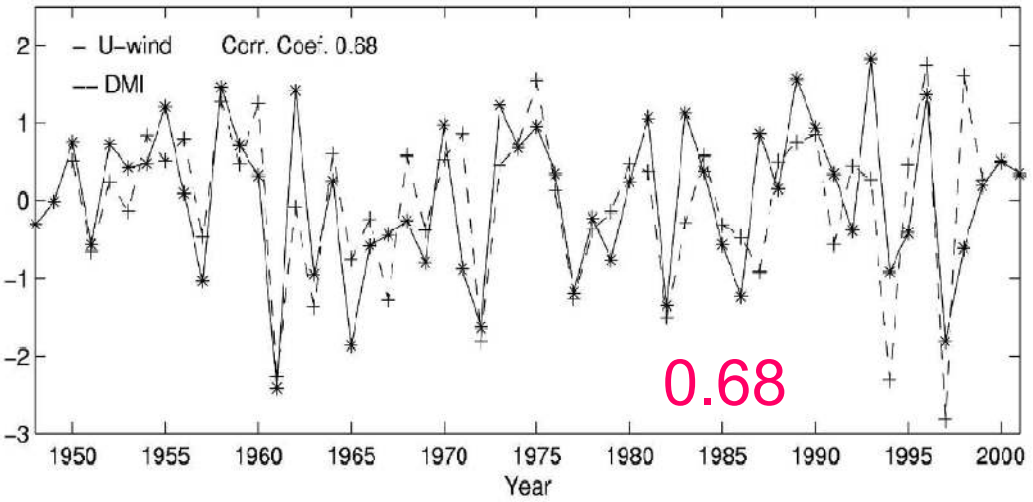
Shinoda and Han (2005)

Index of ISO activity

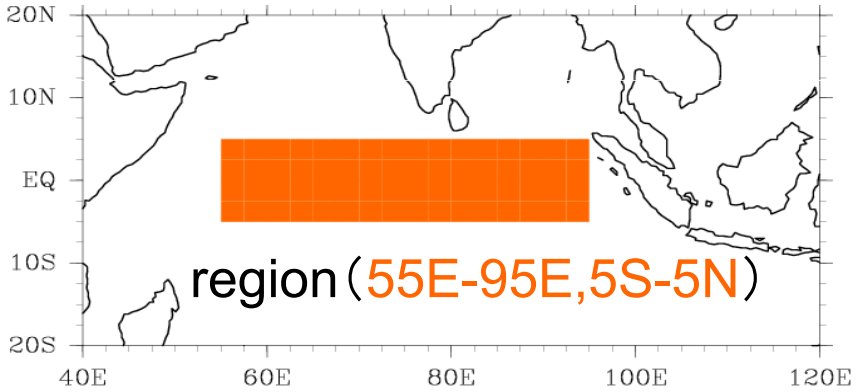
Standard deviation of band-pass filtered u_{1000} and OLR during boreal fall

- 30-90-day segment: MJO
- 6-30-day segment: 10-20-day variation, Tropical cyclone etc.

ISO(6-30-day) activity vs. −DMI



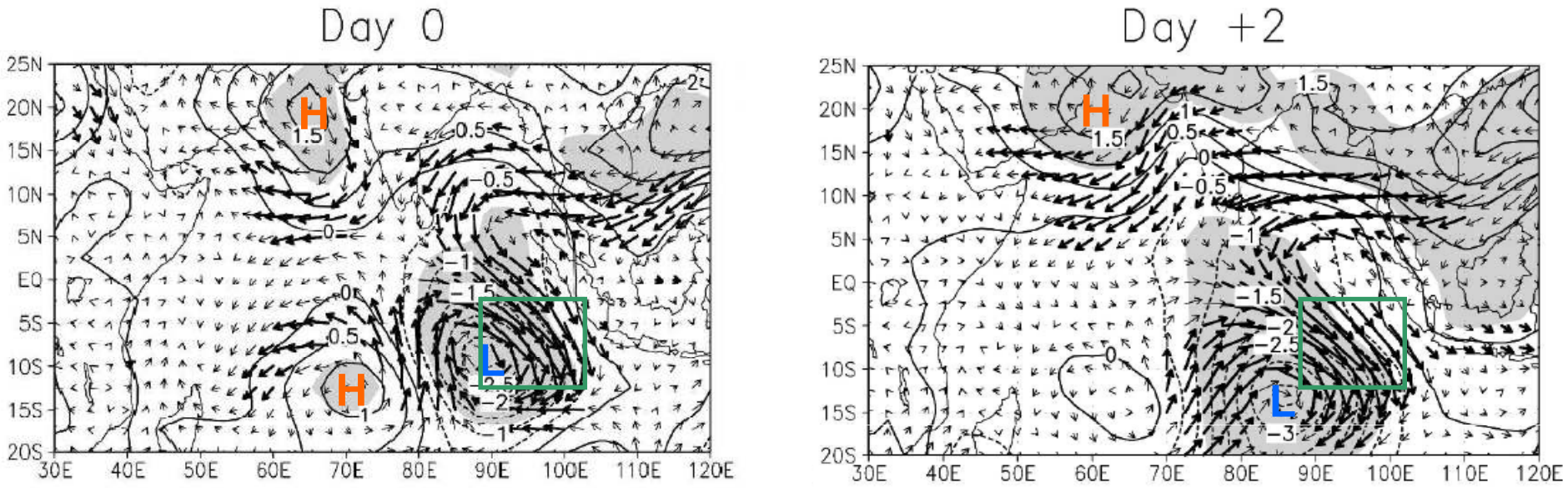
Dashed-line: −DMI
Solid-line: activity



- negative correlaton
- 6-30-day ISO has larger correlation

Lag-correlation analysis using

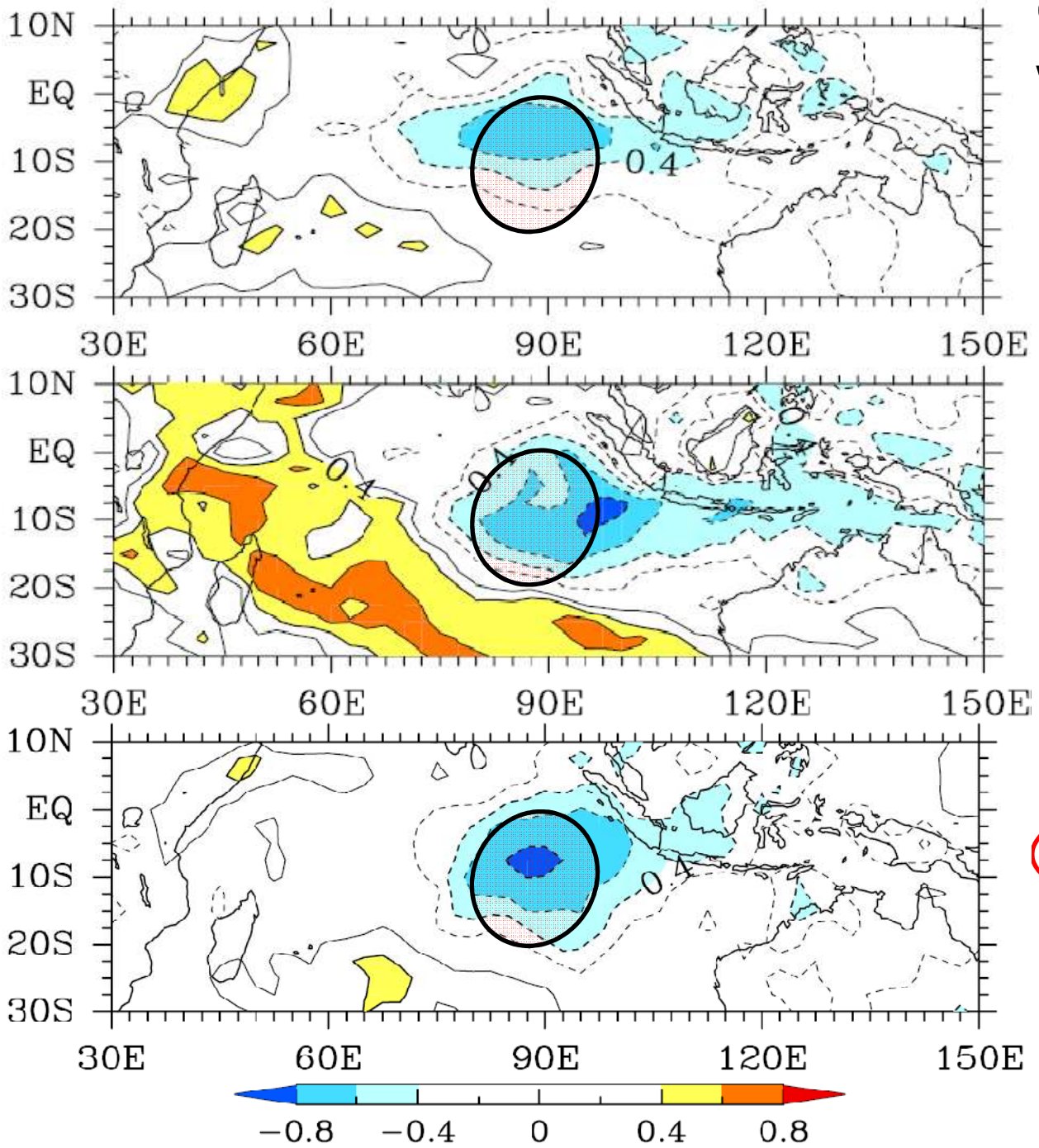
<OLR(6-30-day) averaged over the southeastern Indian Ocean>



The composite of negative DMI years

Northern component of circulations aren't evident.

Shinoda and Han (2005)



Correlation coefficient with DMI

6-30day u'_{1000}

Shinoda and Han (2005)

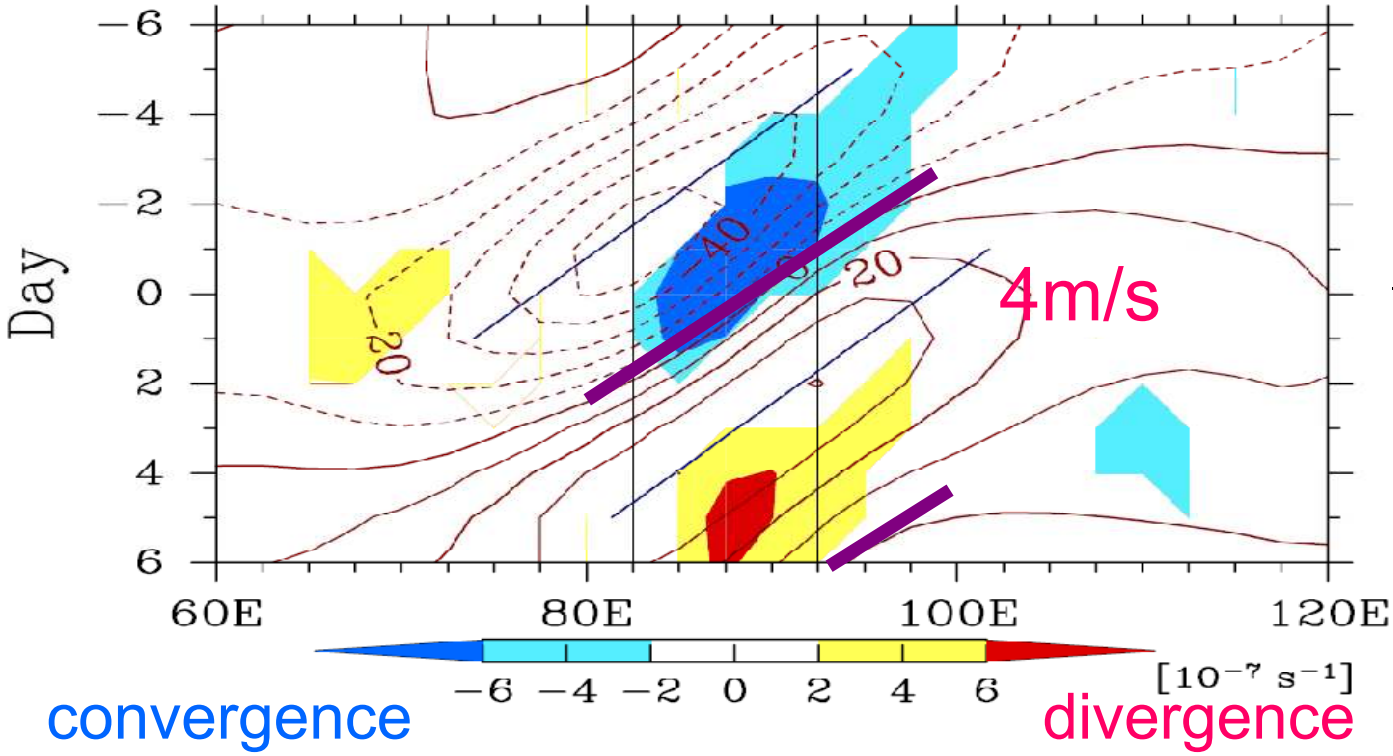
6-30day OLR'

Shinoda and Han (2005)

6-30day v'_{850}

Large interannual variation region

Time-Longitude cross section(850hPa)



contoursφ'_{850}

Dotted: negative

10S-7.5S mean

$$\omega = -\frac{\beta k}{k^2 + 3\beta/\sqrt{gH}}$$

$$L = \sqrt{\frac{\sqrt{gH}}{\beta}}$$

Matsuno (1966)

The lags between φ and DIV are small

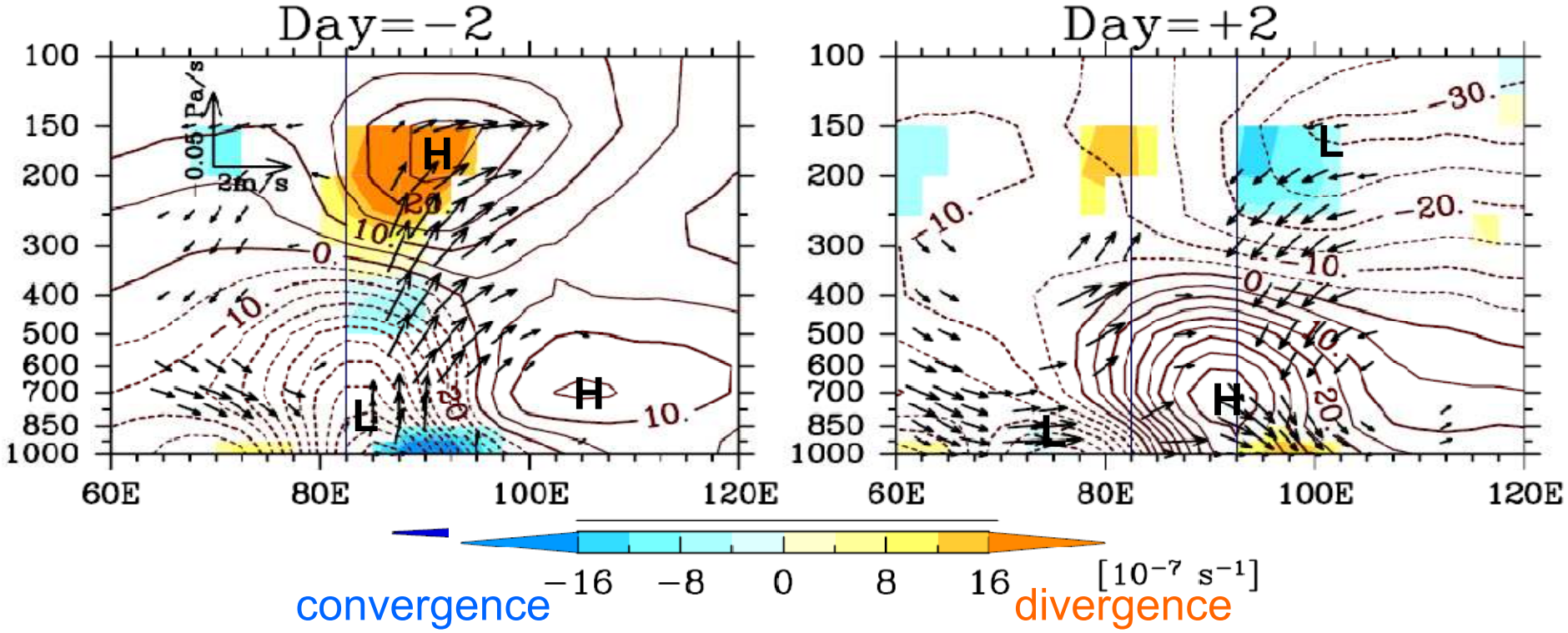
Phase speed C = −4 m/s

Period 12 days

Equivalent depth H=～40m

Rossby radius L=～8.4°

Longitude-Height cross section (10S-7.5S mean)



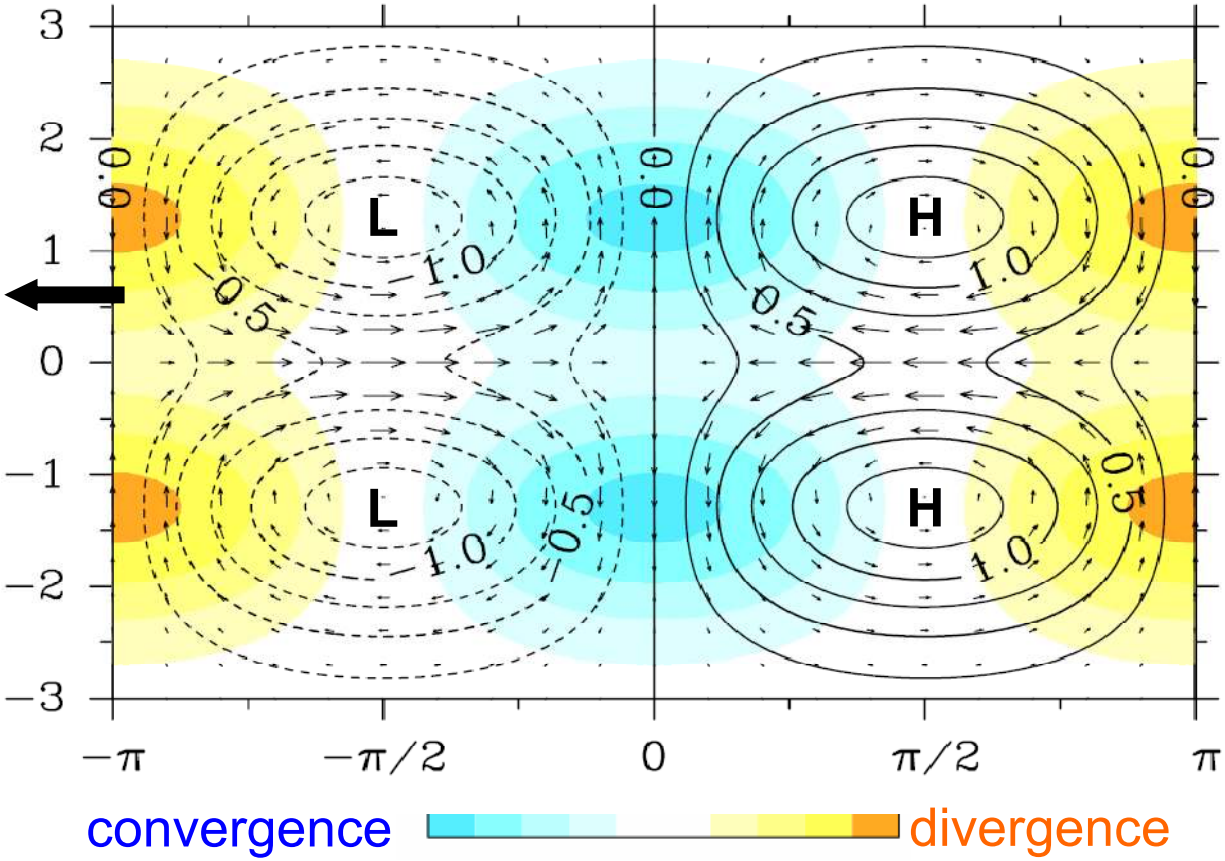
contours: φ' (dotted-line: negative values)

Arrows (u',ω')

- First vertical baloclinic structure with a node at 300-400 hPa
- Maximum upward (downward) motion slightly lags behind the low (high) pressure in the lower troposphere.
- Hydrostatic equilibrium

Theoretical n=1 ER wave

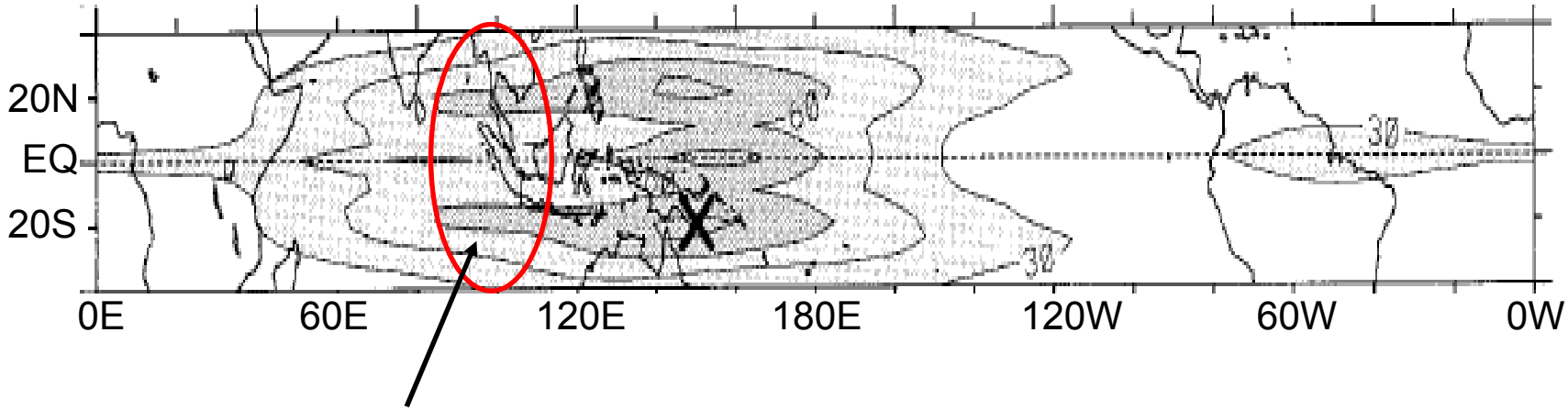
Matsuno (1966)



The phase of DIV lags behind that of height

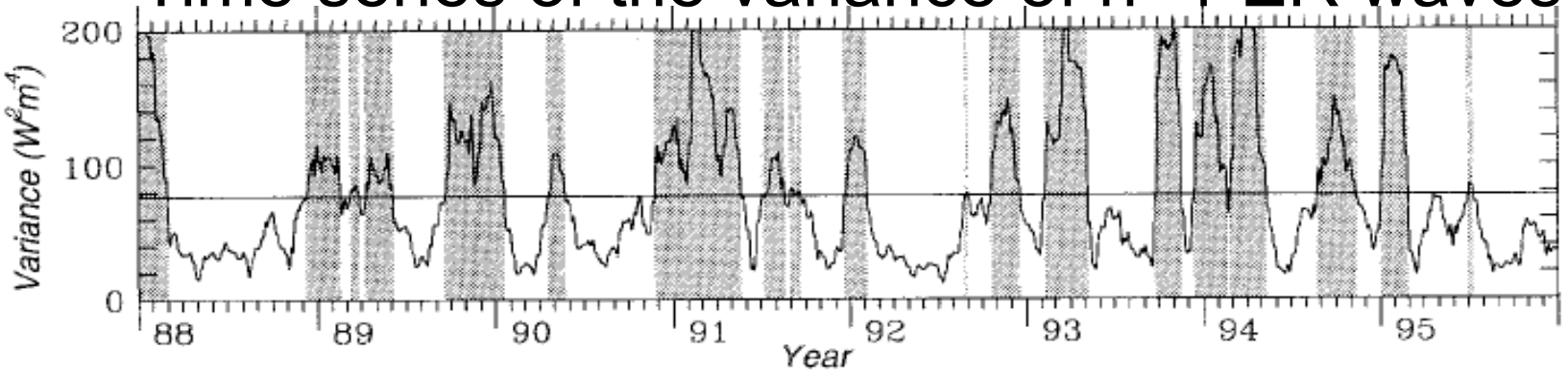
by 1/4 wavelength.

The activity of n=1 ER waves



The activity of n=1 ER waves is large

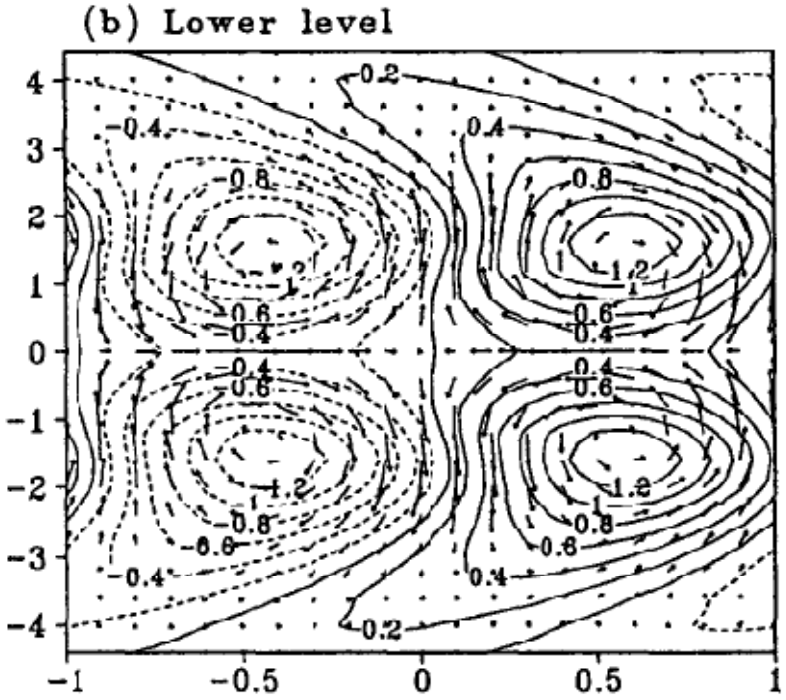
Time series of the variance of n=1 ER waves



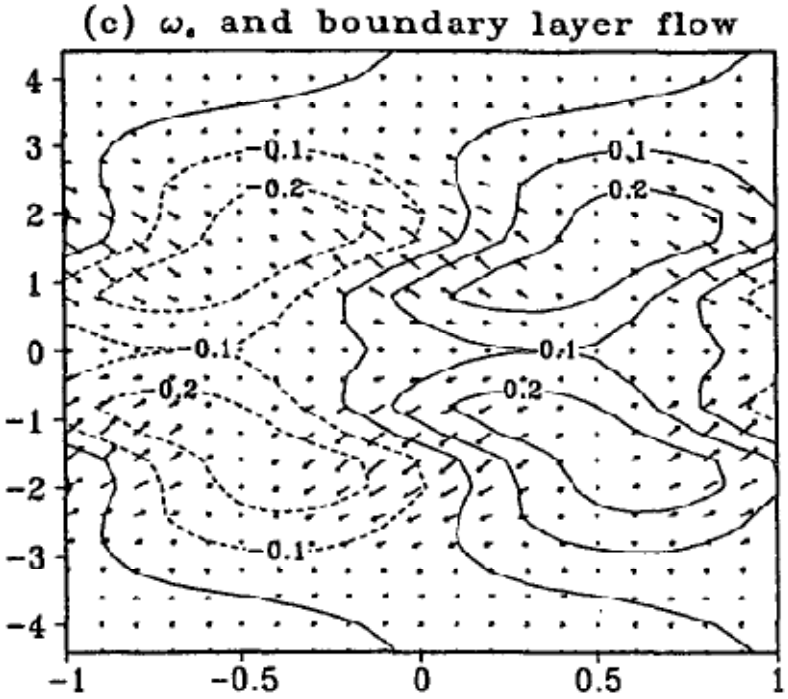
Wheeler et al.(2000)

The structure of unstable ER waves

under the presence of easterly shear and boundary layer



Φ in the lower layer



ω above the boundary layer

nearly in phase

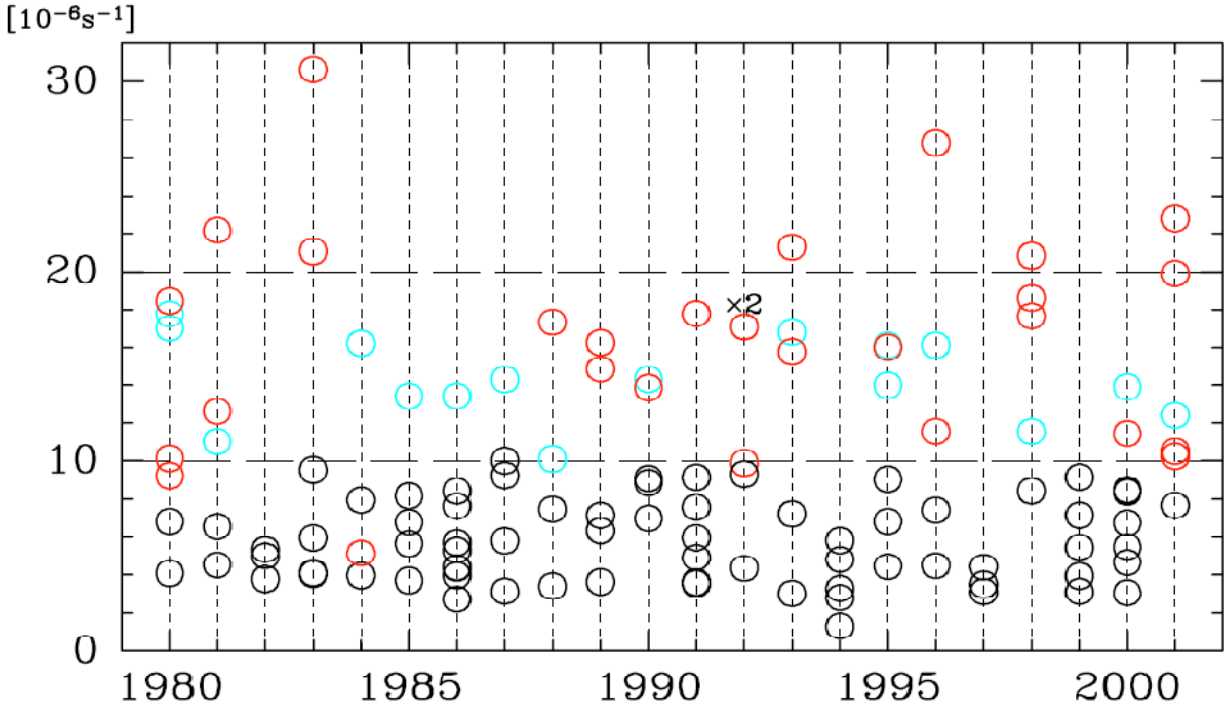
Relation with Tropical Cyclone

○: TC

○: non TC, and MNA≧10^{-5}

○: others

From 1980 to 2001,
<u>26 out of 42 cases are recorded as TC</u>



JTWC cyclone best-track

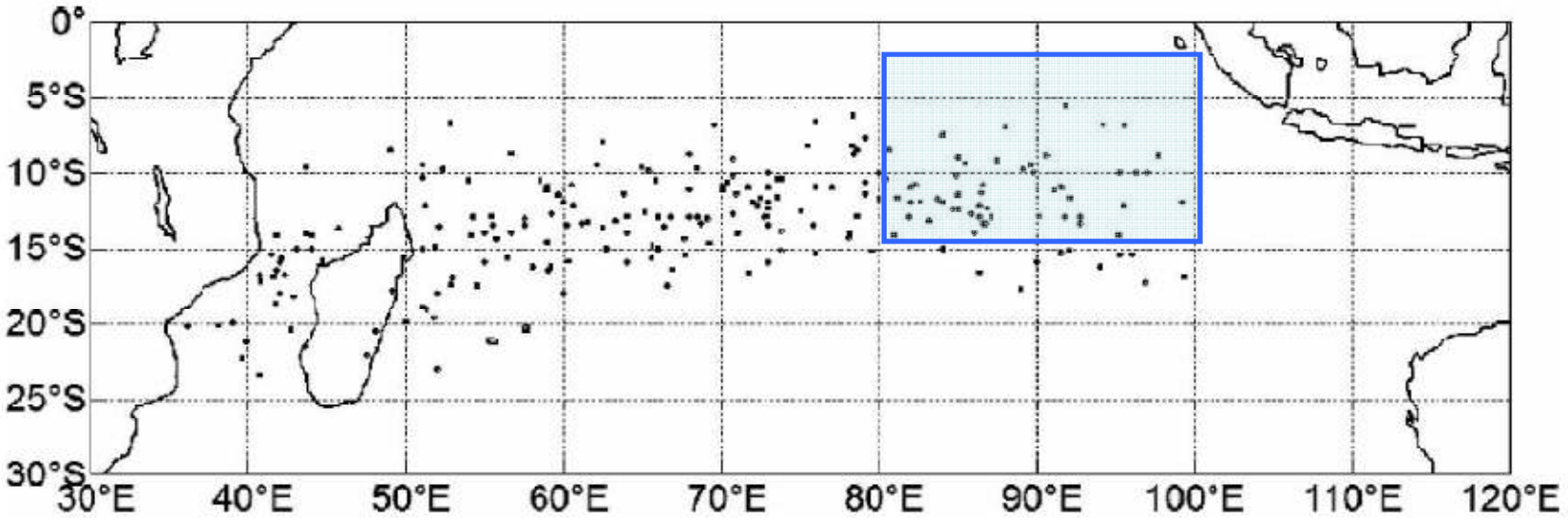
In TC genesis over the southern Indian Ocean,

- Vorticity anomaly in the lower troposphere
- OLR anomaly

produce by ER waves are important

Bessafi and Wheeler, 2006

TC-genesis region (1979-2004 Nov-Apr)

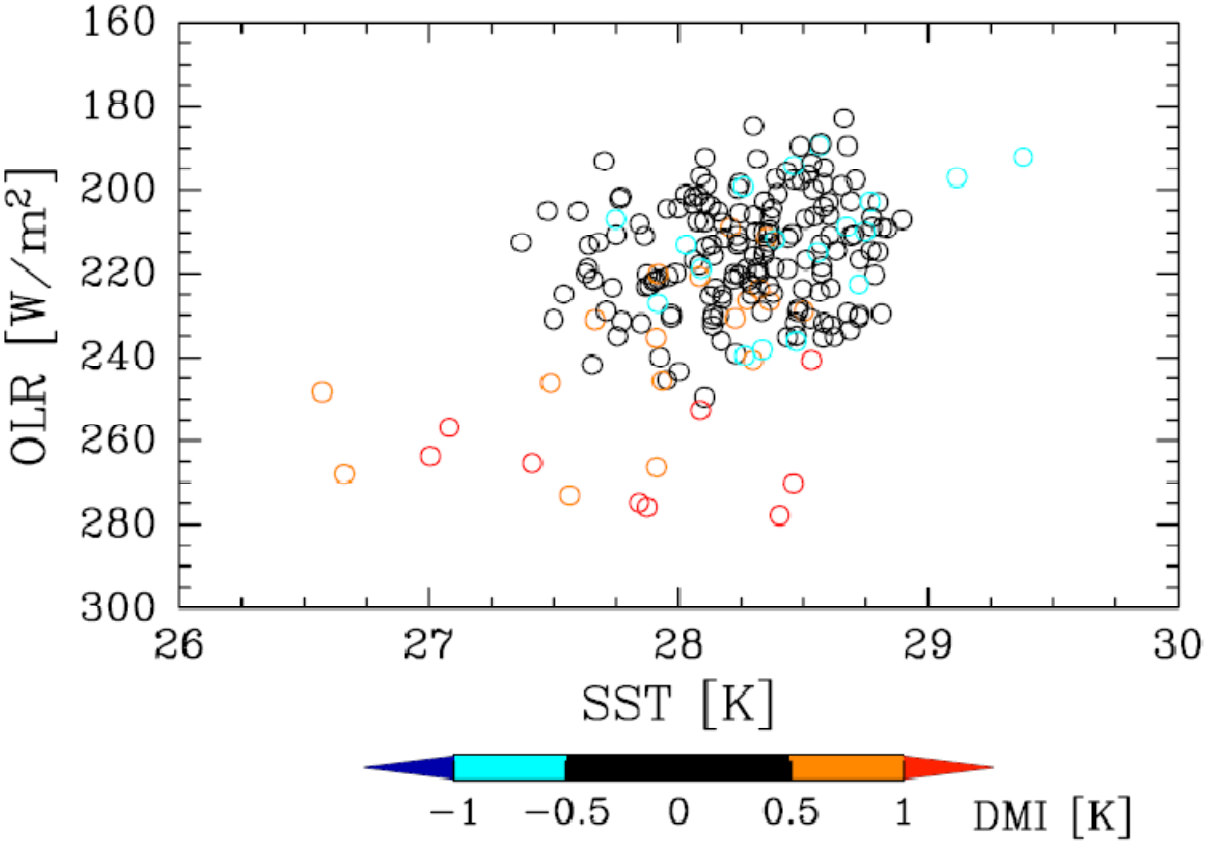


※ total 221 cases

Bessafi and Wheeler (2006)

SST-OLR

Southeastern Indian Ocean(80E, 90E,100E)



1979-2001 Sep-Nov

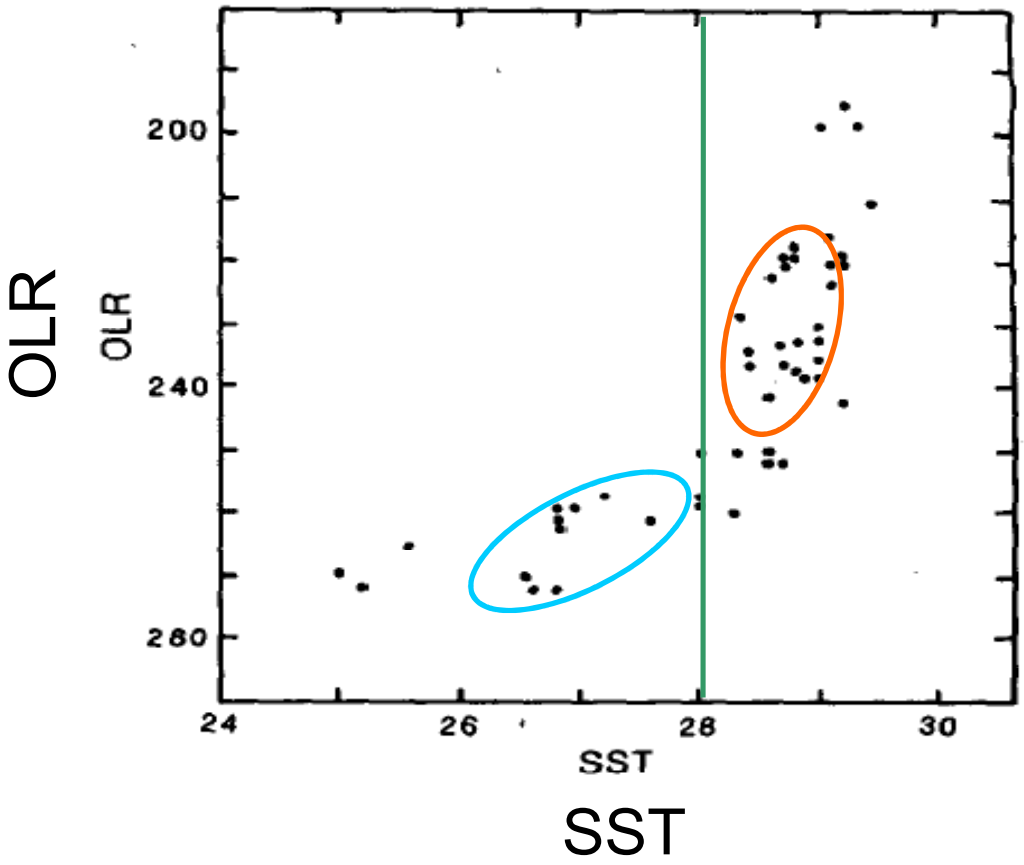
10S-0S mean

Monthly mean

OLR changes greatly between negative IOD years and positive IOD years

SST-OLR (Western Pacific)

Hirst 1986



The track of all cyclonic disturbances

MNA [s^{-1}]

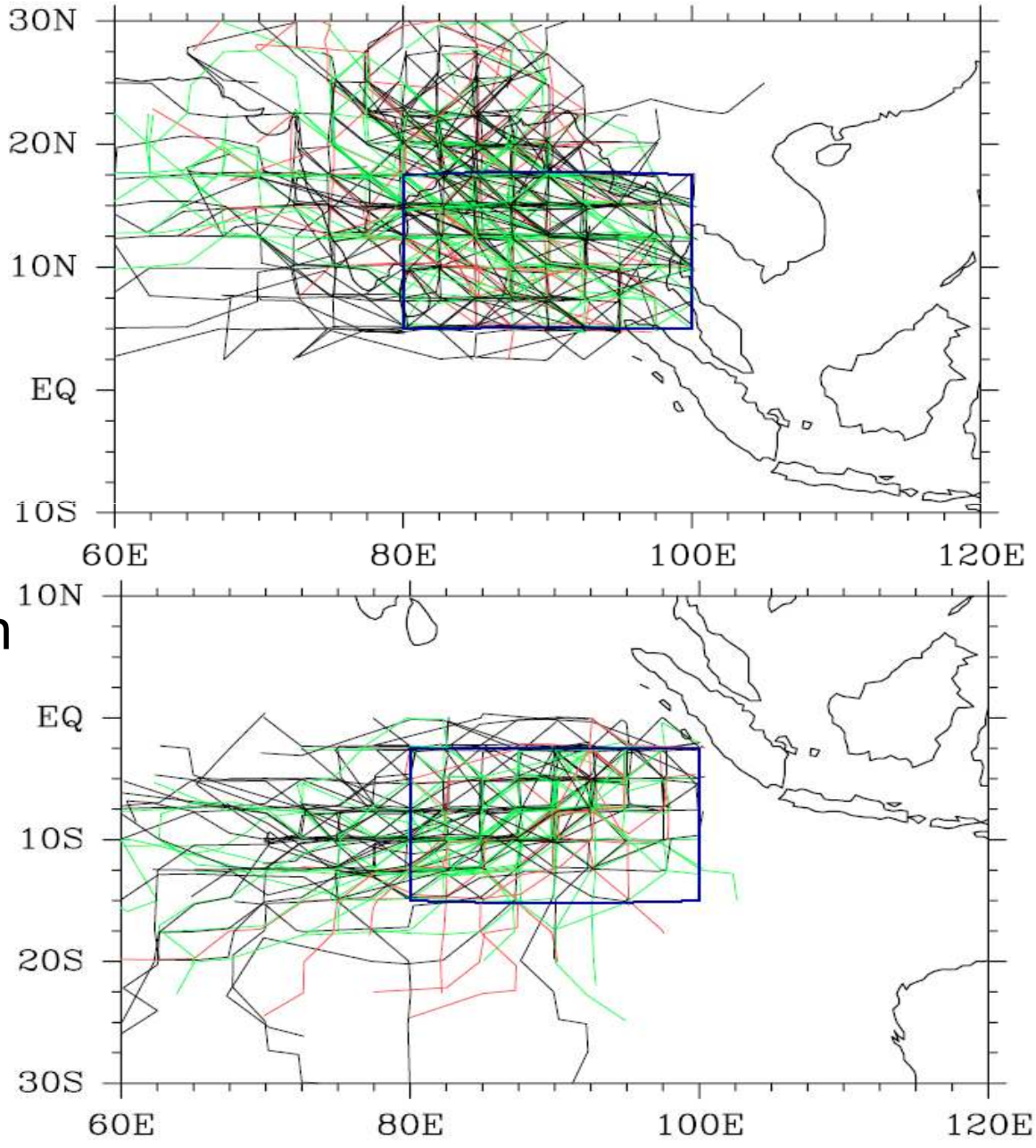
red: $\geqq 2.0 \times 10^{-5}$

green: $\geqq 1.5 \times 10^{-5}$

black: $\geqq 1.0 \times 10^{-5}$

North

South

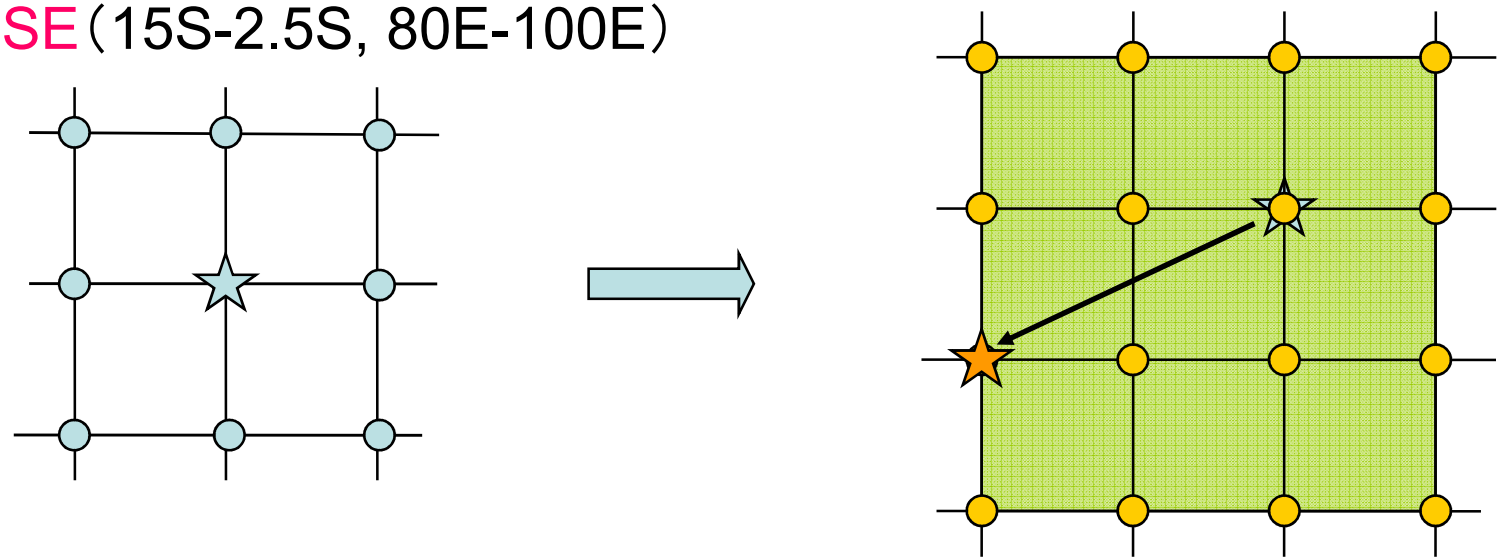


The method of tracking

Data ζ'_{850}

(spatially smoothed using low-pass filer with cutoff wavelength 7.5°)

Region ISE（15S-2.5S, 80E-100E）

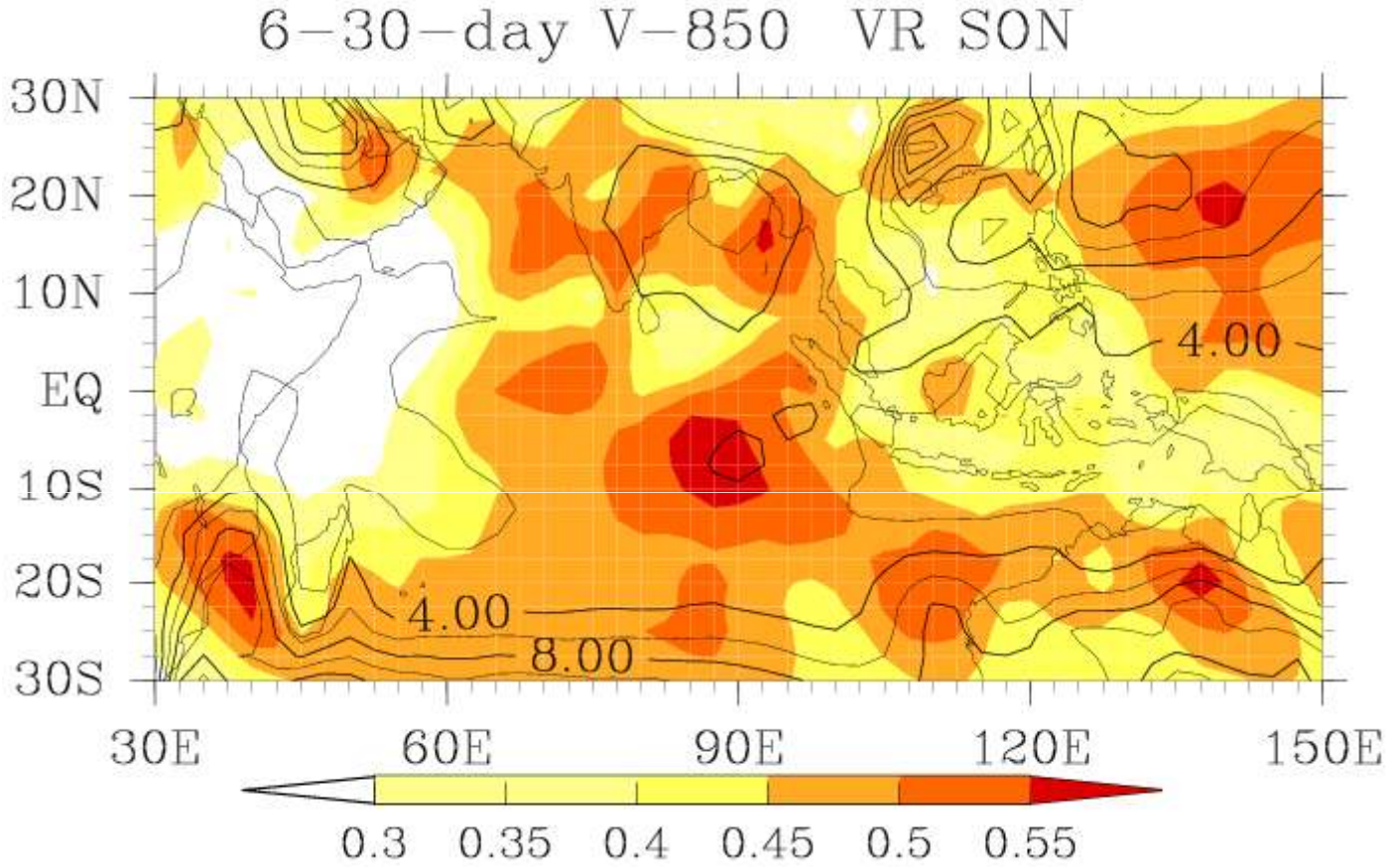


- The center of cyclone is defined as the minimum value of ζ_{850}'
- Only the disturbances that are traceable for 5 days or more are counted.

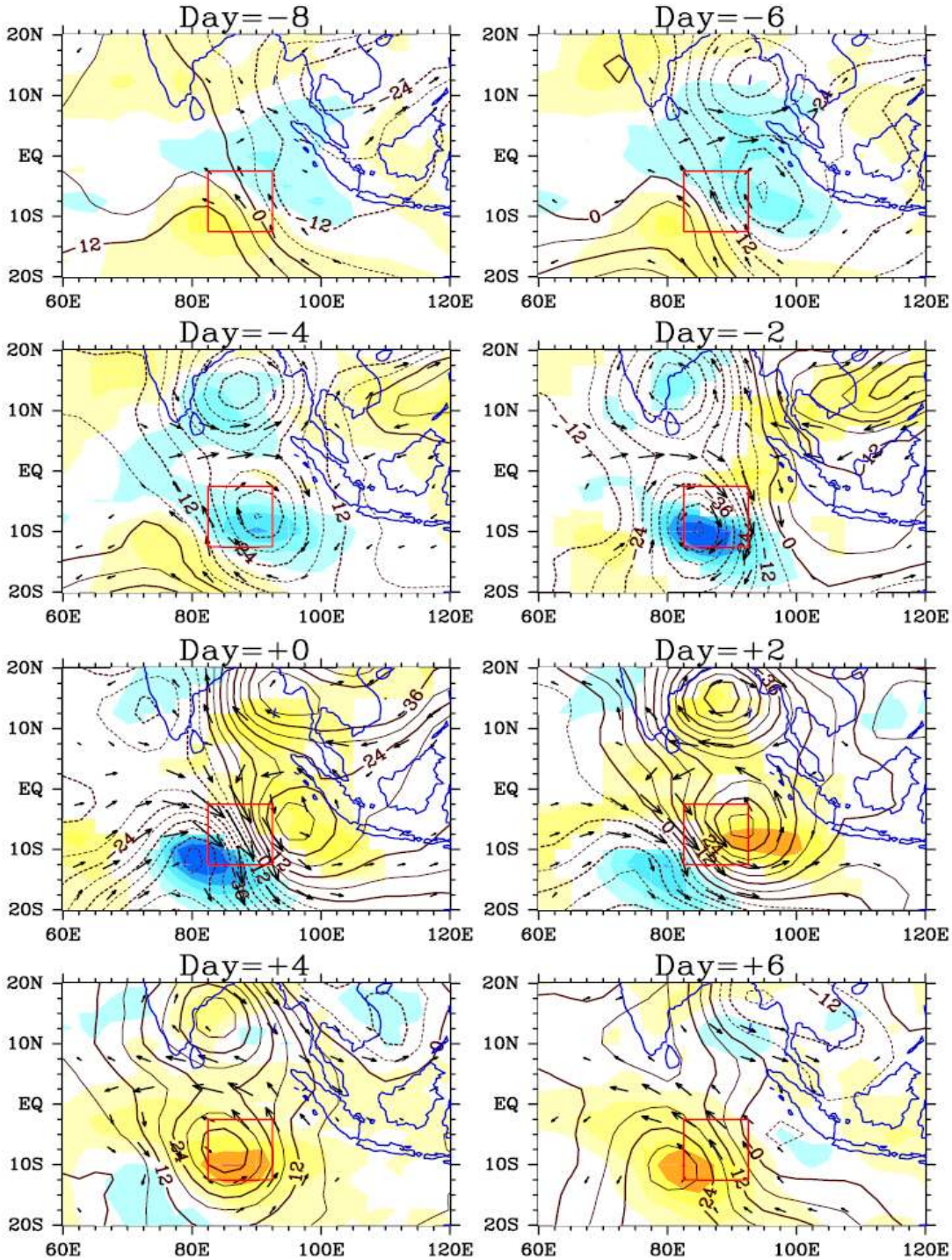
SST vs. interannual variation of ISO

- Fink et al. (1997)
  - MJO activity during boreal winter has positive correlation with SST anomalies over the eastern Pacific
- Hendon et al. (1999)
  - Large activity region of MJO shifts eastward during El Niño.
- Bergman et al. (2001)
  - MJO activity during boreal fall has positive correlation with SST anomalies during boreal fall over the western Pacific.

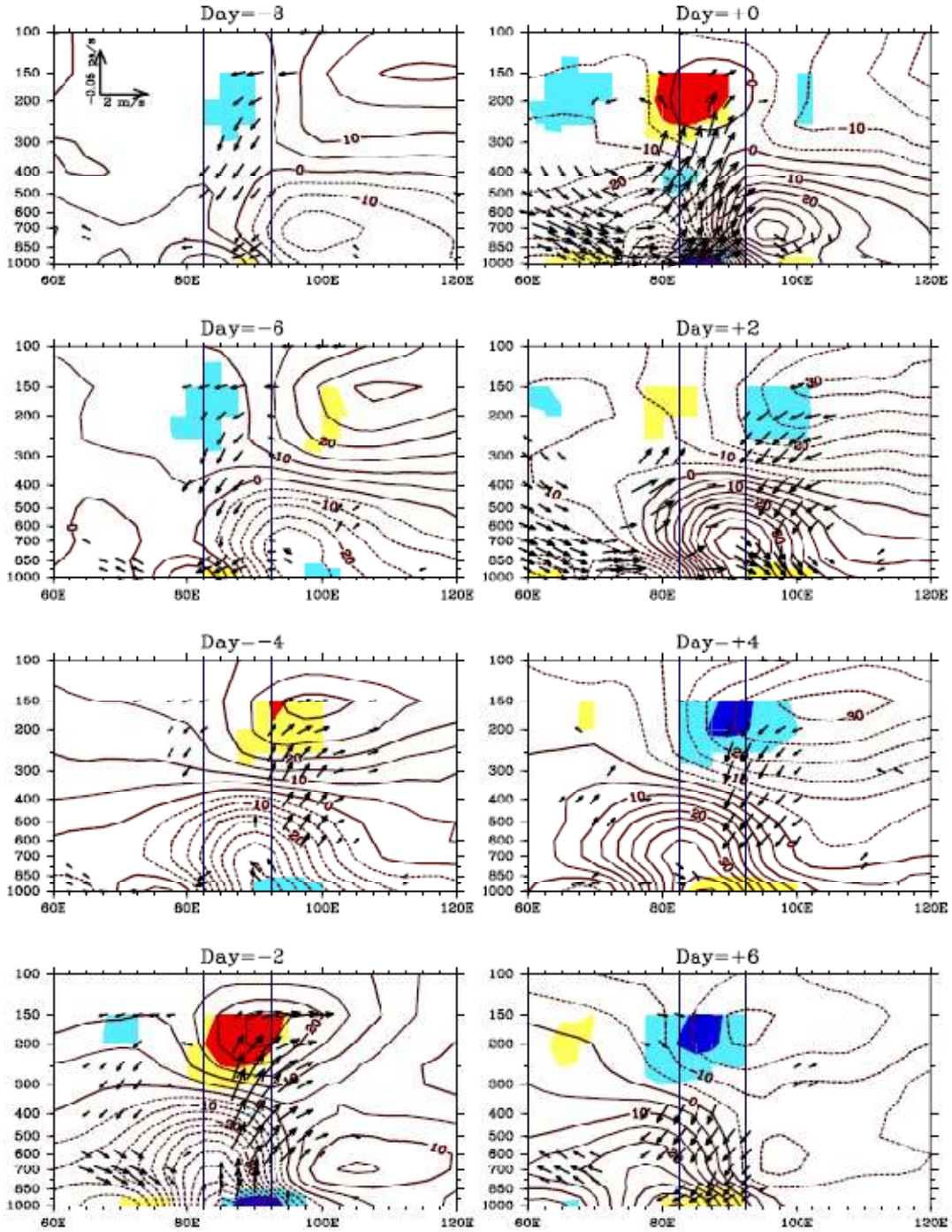
Variance rate of 6-30-day variation



Day=-8～+6
at 850hPa



Day=-8～+6



Example (relative vorticity at 850hPa)