Variability of the oceanic upper layers associated with the MJO

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Sato *et al.* (2008; submitted to *JGR*)

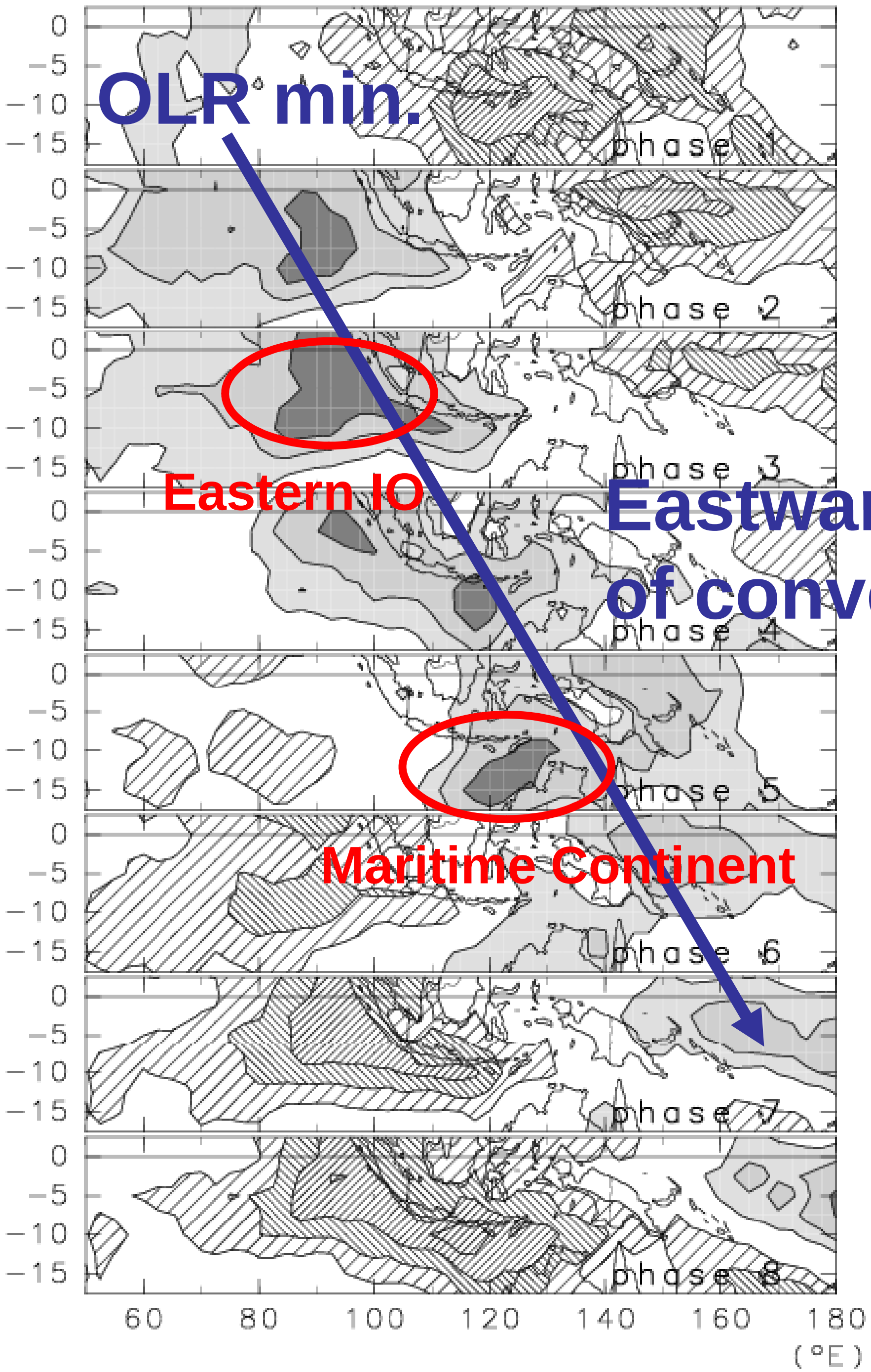
Introduction

- The SST changes associated with the MJO (e.g., Shinoda and Hendon 1998).
- However, the variability in the upper ocean associated with the MJO has not been well examined.

- Following Wheeler and Hendon (2004), we identifies the phase of the MJO.
- The composites of the meteorological and oceanological fields (DJF seasons only) are analyzed.

OLR anomaly

(Composed OLR anomaly for each phase)

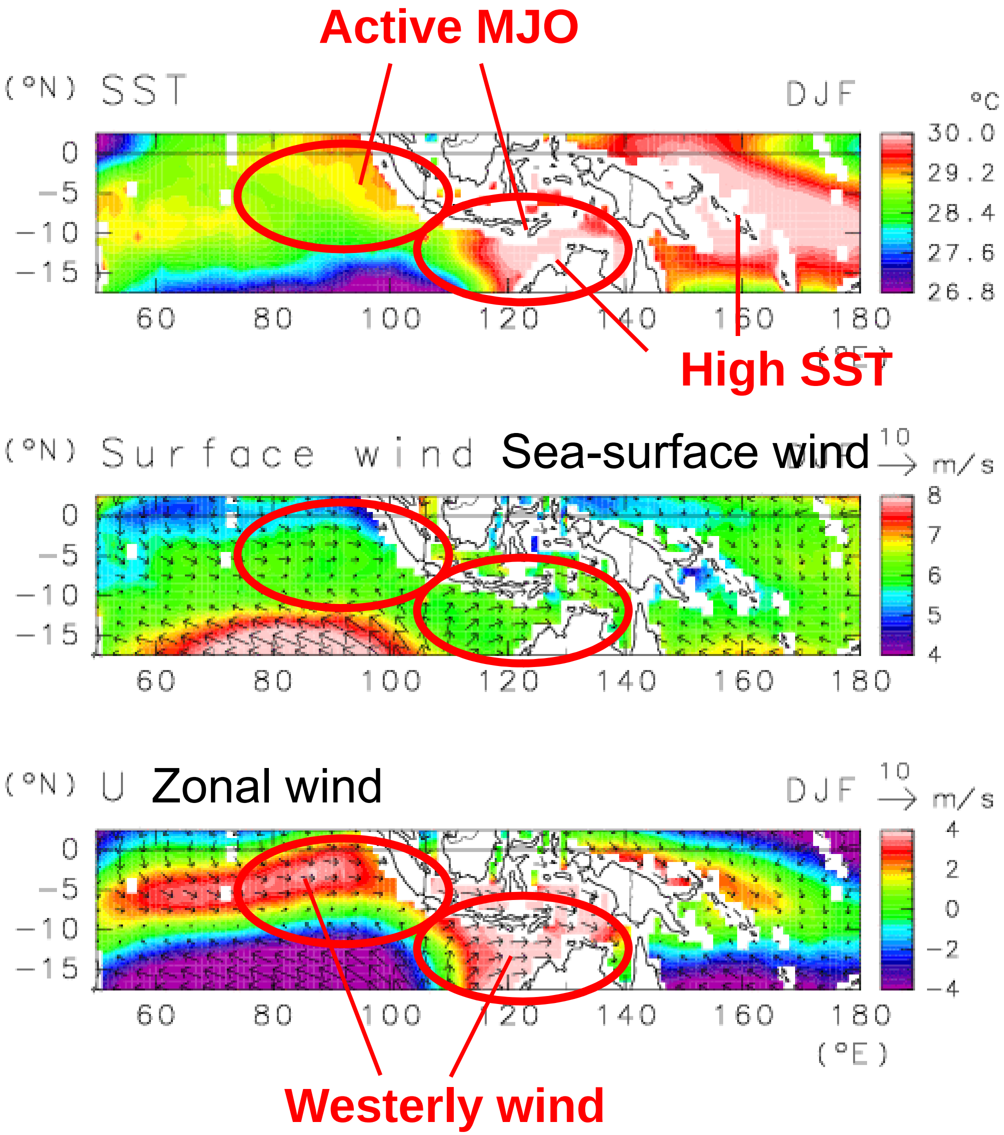


MJO

Eastward propagation of the active convection is clearly identified.

Variability of the convective activity is especially large over the eastern Indian Ocean and the maritime continent.

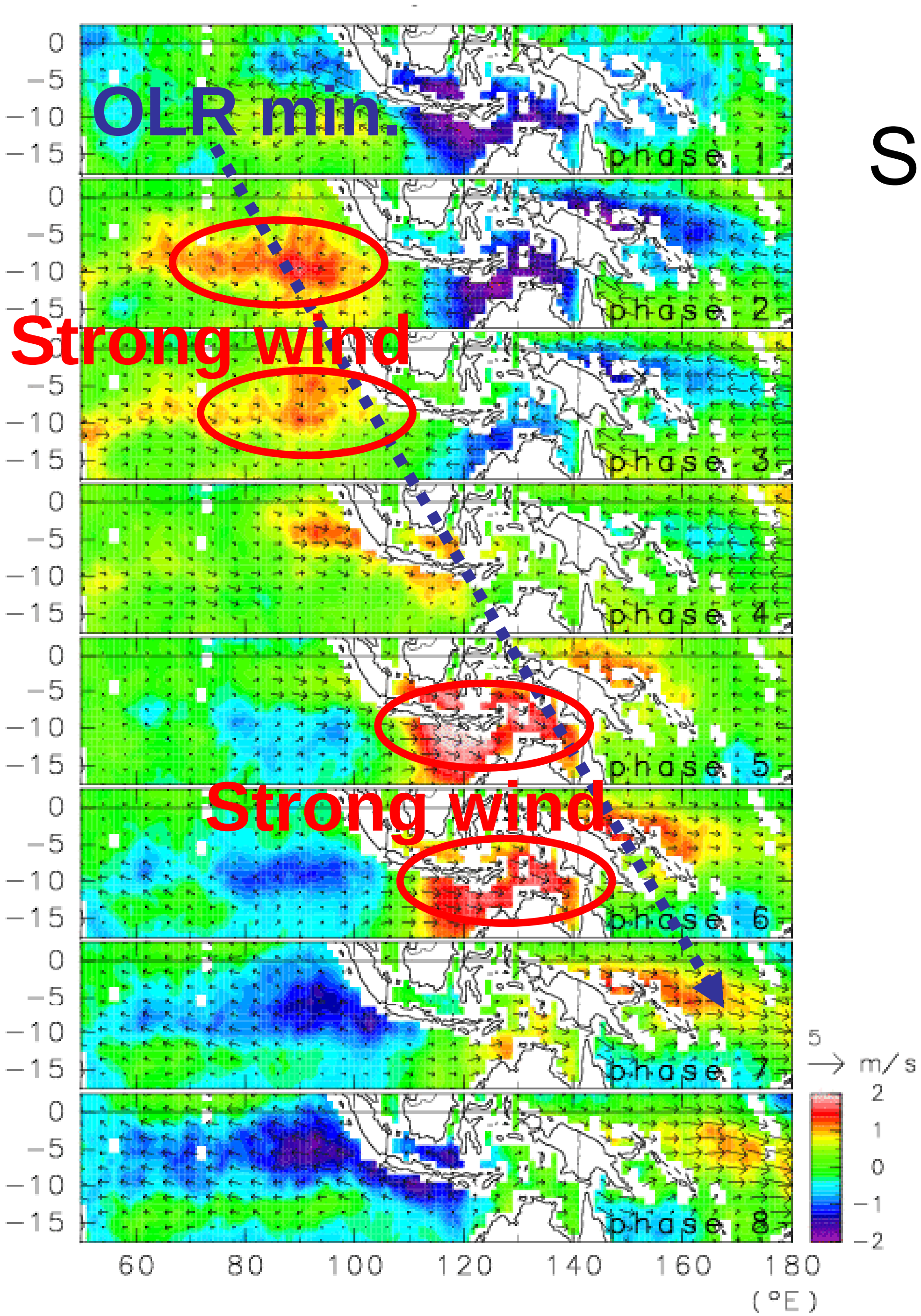
Climatology



The region where the MJO is active does not well correspond to the high-SST region.

It corresponds to the westerly-wind region.

Surface wind anom.



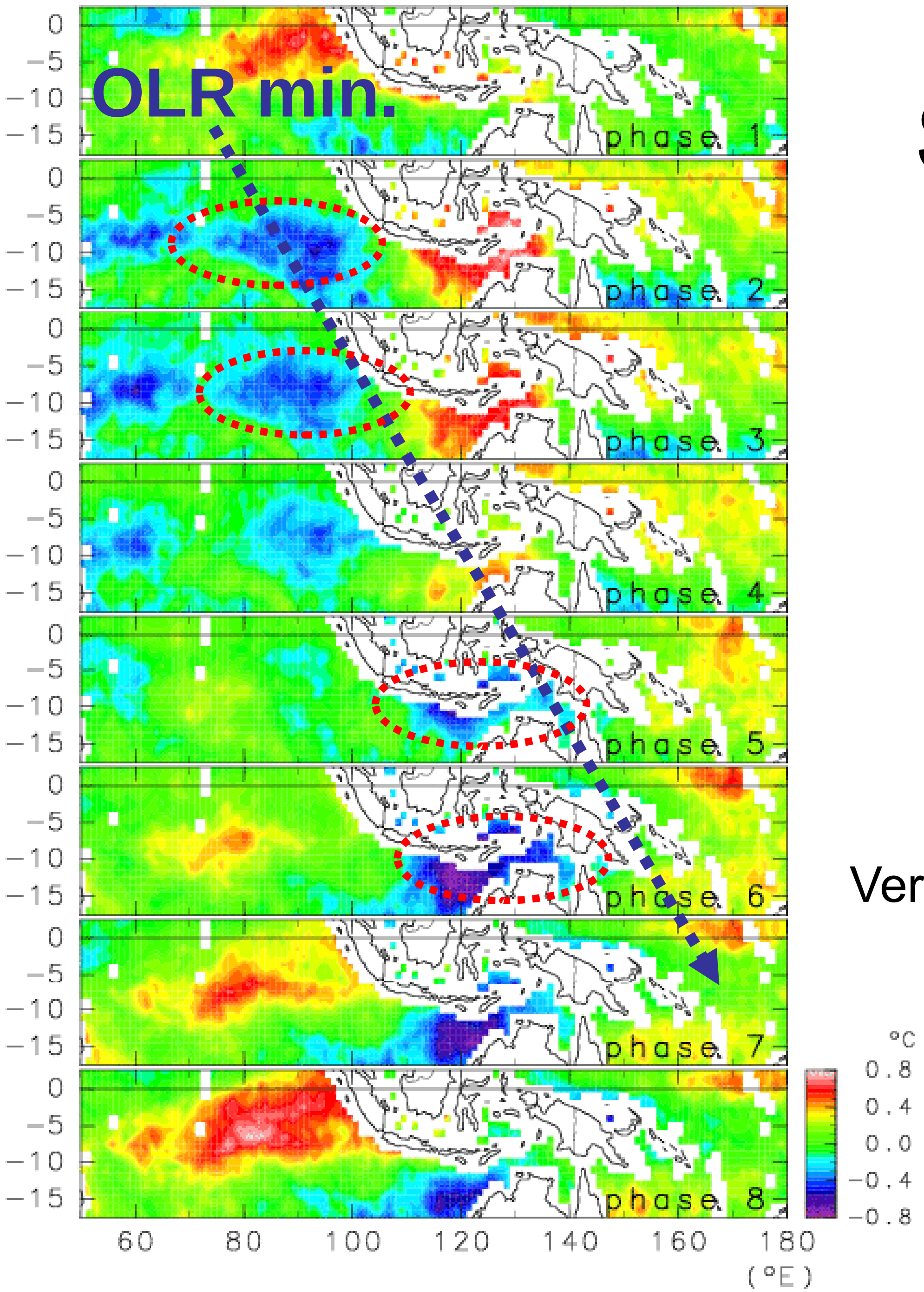
Disturbance

↓

Anomalous westerly

↓

Strong surface wind



SST anomaly

Disturbance

↓

Anomalous westerly

↓

Strong surface wind

Vertical mixing? ⋮ Surface heat flux?

↓

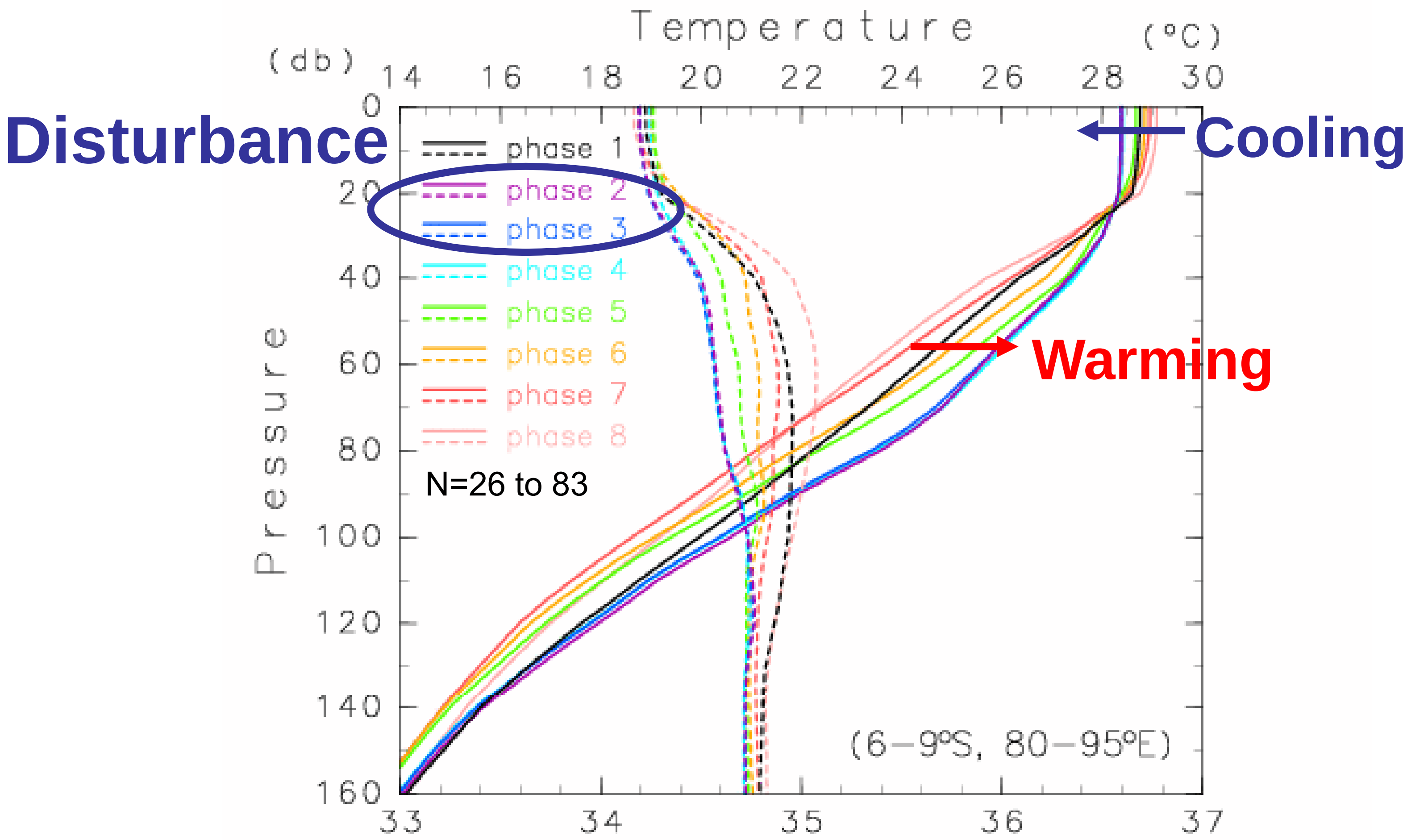
SST decrease

SST variance is large where the basic wind is westerly.

Analysis of Argo float data

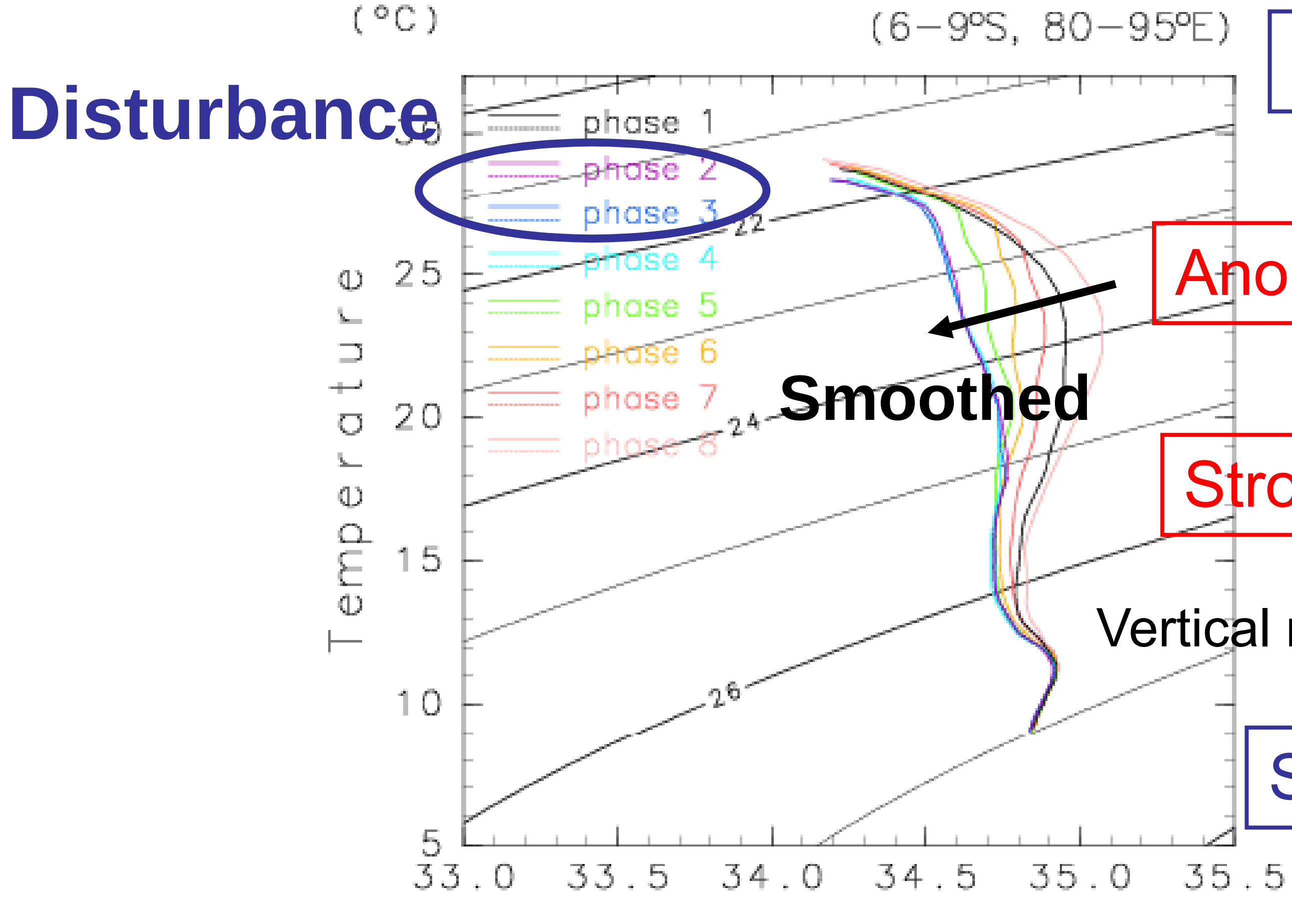
- Region: The eastern Indian Ocean (6-9S、80-95E) and the maritime continent (10-13S、110-125E).
- Profiles observed on days belonging to each phase are averaged in each region.

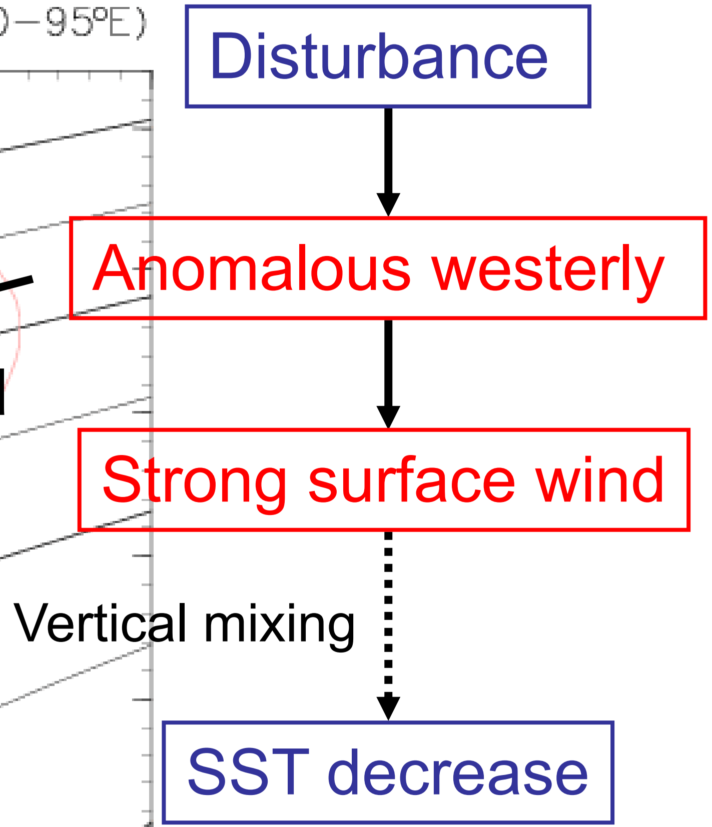
Temp & Salinity (Indian Ocean)



Cooling near the surface, and warming in the subsurface.
→Vertical mixing?

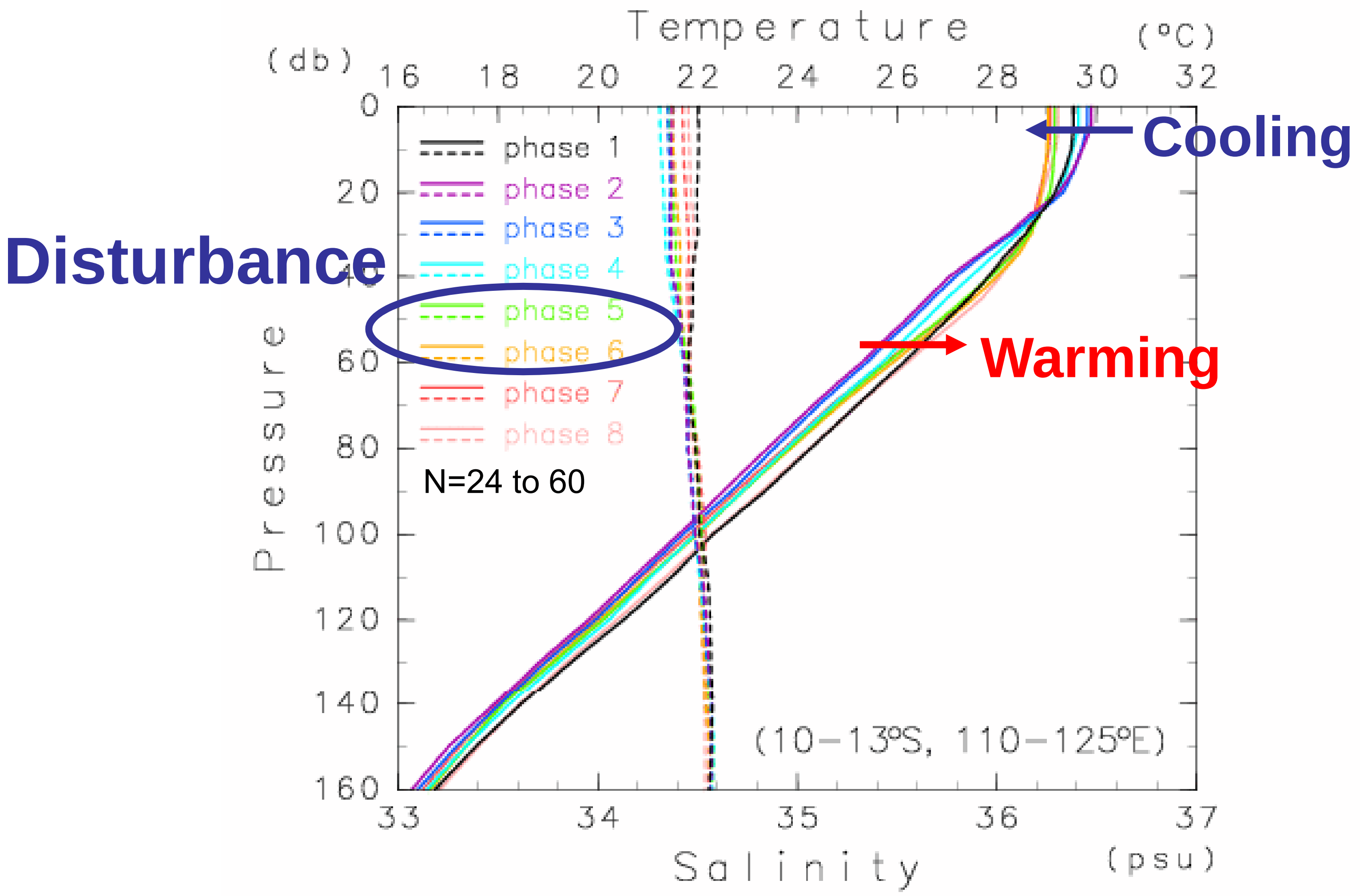
T-S diagram (Indian Ocean)





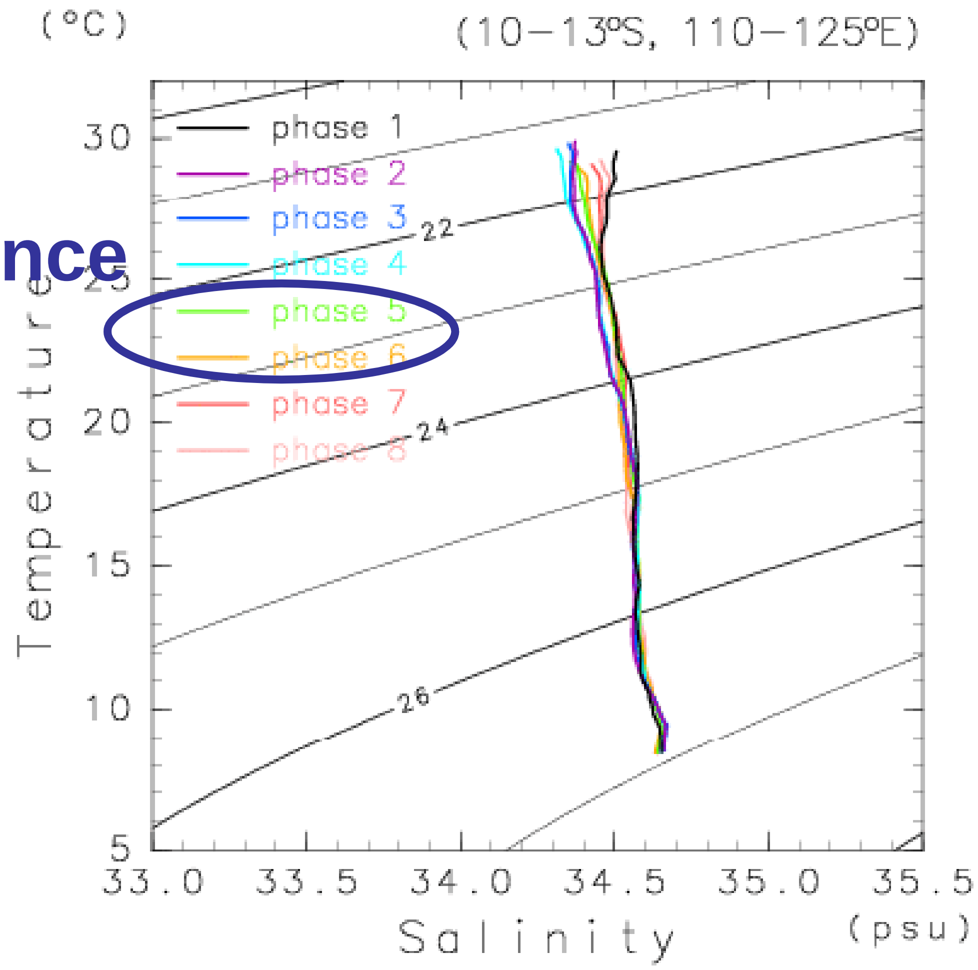
Smoothed during the passage of disturbance.
→Vertical mixing by surface wind.

Temp & Salinity (MC)

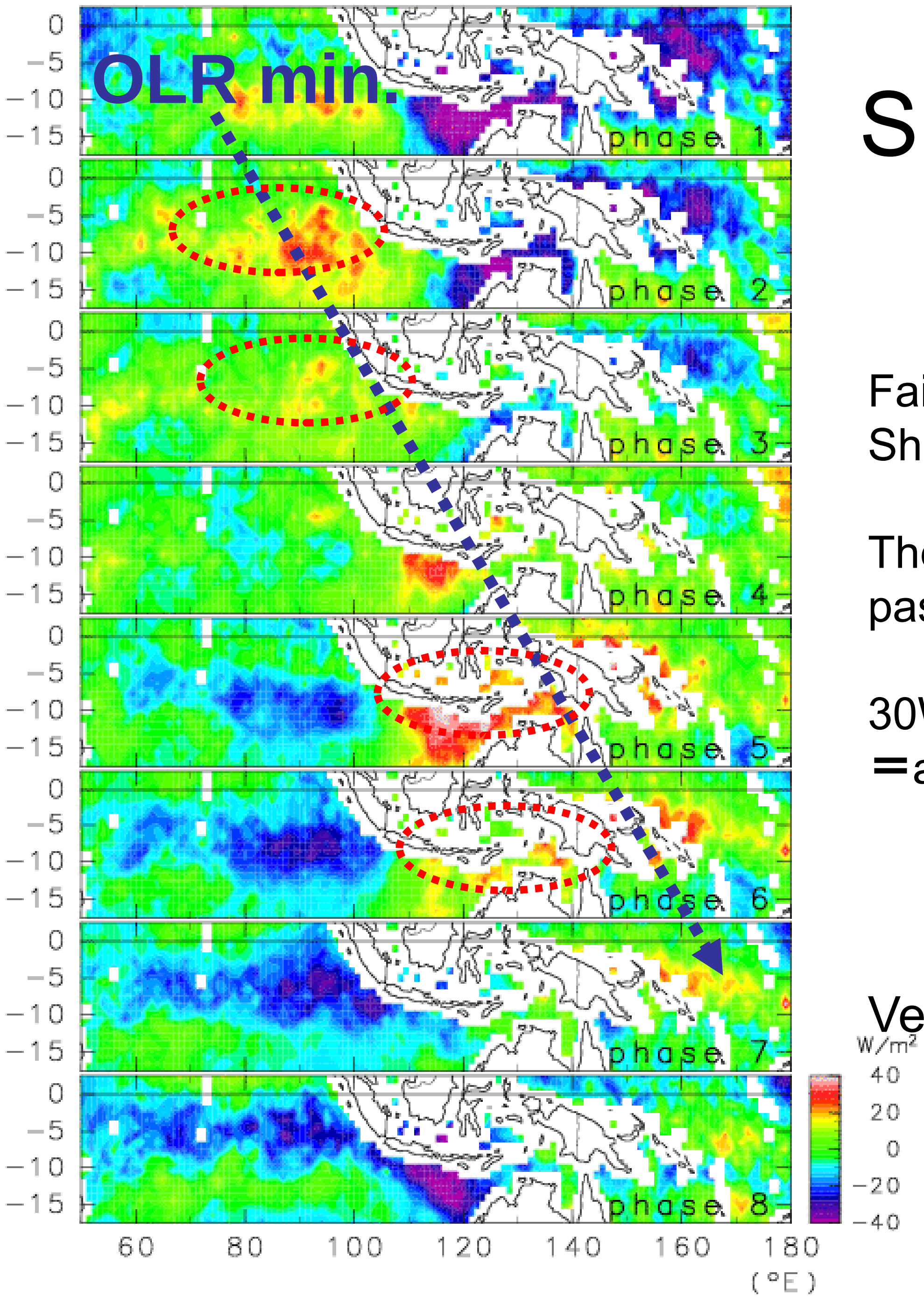


T-S diagram (MC)

Disturbance



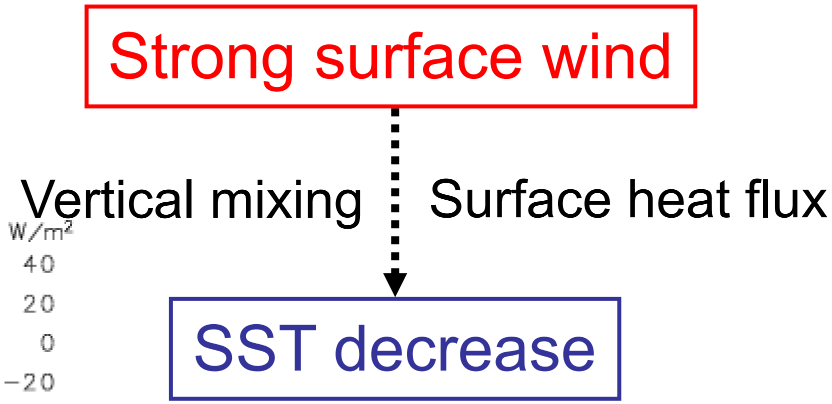
Surface Heat Flux

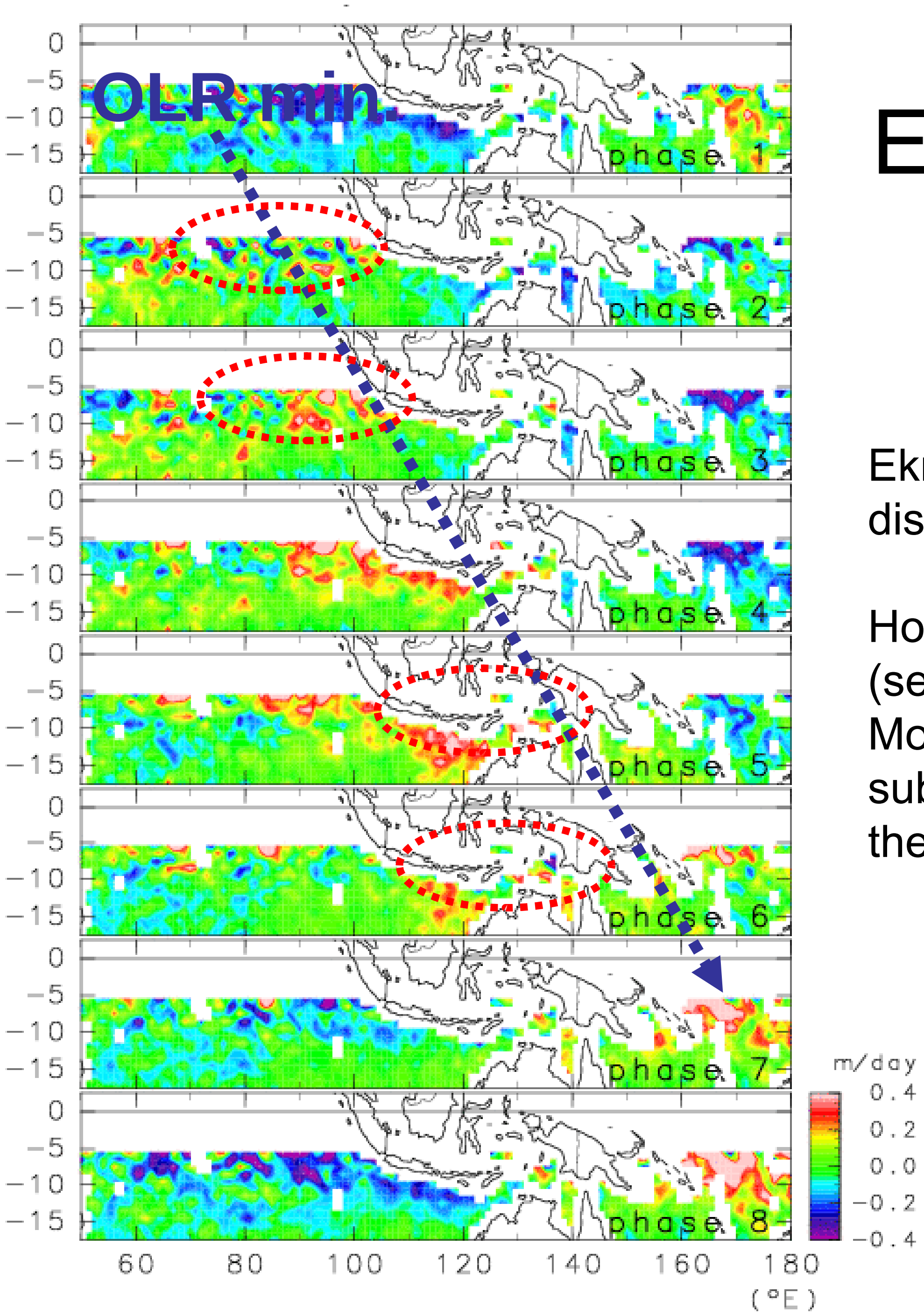


Fairall et al. (1996)
ShInoda and Hendon (1998)

The surface flux increases during the passage of disturbance.

30W/m^2
＝about 0.3K/10day for 25m depth.



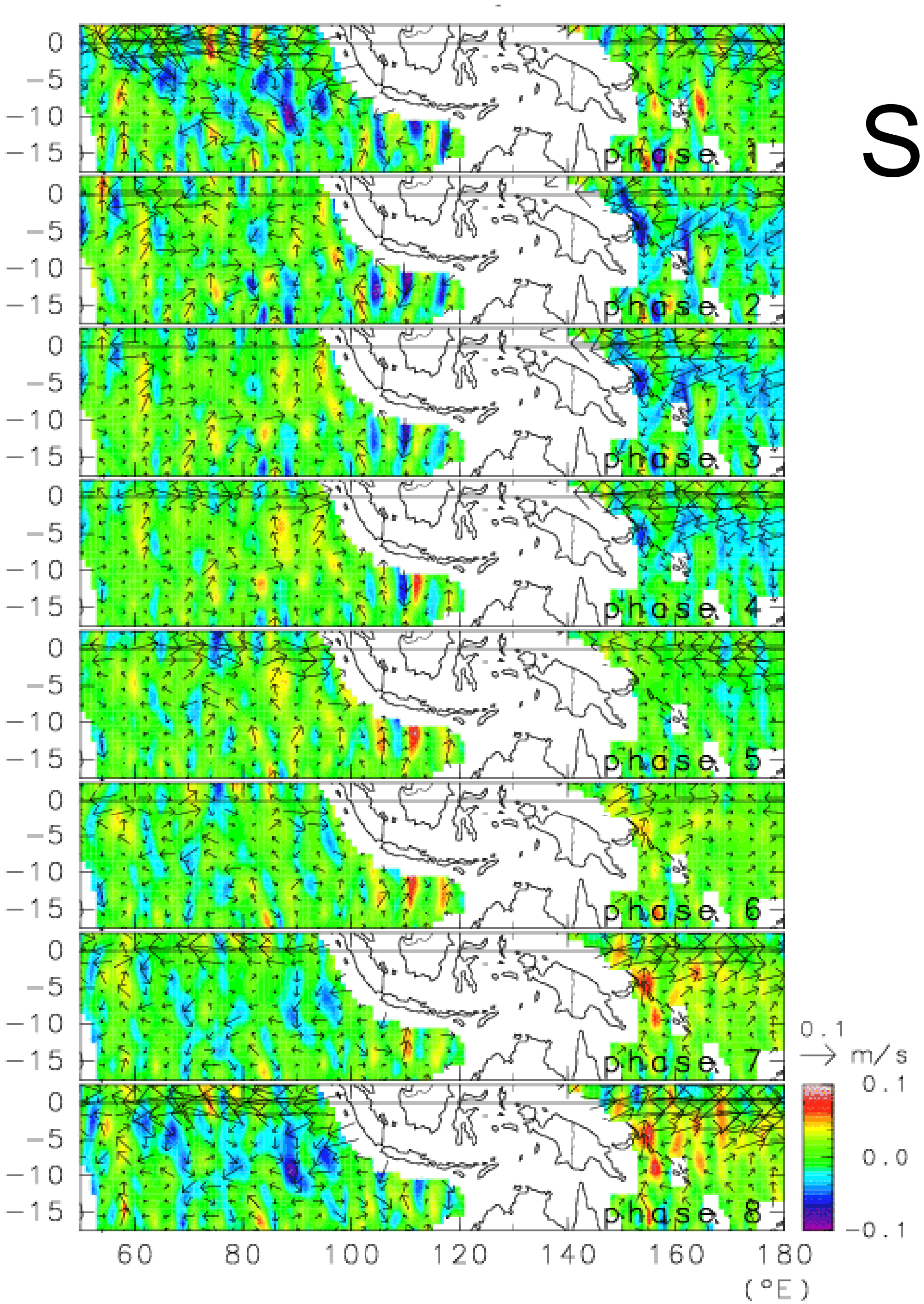


Ekman Upwelling

Ekman upwelling during the passage of disturbance.

However, the variance is not so large (several meters per 10 days). Moreover, it is not consistent with the subsurface warming associated with the disturbance.

Surface Current



Formation mechanism of SST anomaly associated with the MJO

- East of the MJO convection:
  - Anomalous easterly→weak surface wind→SST increase
- West of the MJO convection:
  - Anomalous westerly→strong surface wind→SST decrease

Vertical mixing & Heat flux

⇒Zonal SST gradient associated with the MJO

Conclusions

- The SST variability associated with the MJO is especially large in the eastern Indian Ocean and the maritime continent (～1.5K).
- The SST is high (low) before (after) the passage of the active convection.
- The SST decreases mainly due to <u>enhanced vertical mixing</u> and <u>increased sea-surface heat flux</u> associated the increase of surface wind speed.
- It is suggested that the westerly wind in the basic field is essentially important to the air-sea coupling associated with the MJO.

Formation mechanism of SST anomaly associated with the MJO

- East of the MJO convection:
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- We can mathematically express this relationship as

$$\frac{\partial}{\partial t'} T' = -c_2' u'$$

SST anom. (T')   Zonal wind anom. (u')

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Shallow-water eqs. in the β-plain

Traditional shallow-water equations:

$$\frac{\partial}{\partial t'}u' - \beta y' v' = -g\frac{\partial}{\partial x'}h' \tag{1}$$

$$\frac{\partial}{\partial t'}v' + \beta y' u' = -g\frac{\partial}{\partial y'}h' \tag{2}$$

$$\frac{\partial}{\partial t'}h' = -h_0\frac{\partial}{\partial x'}u' - h_0\frac{\partial}{\partial y'}v' \tag{3}$$

Shallow-water eqs. in the β-plain

Shallow-water equation with a forcing term:

$$\frac{\partial}{\partial t'}u' - \beta y' v' = -g\frac{\partial}{\partial x'}h' \quad (4)$$

$$\frac{\partial}{\partial t'}v' + \beta y' u' = -g\frac{\partial}{\partial y'}h' \quad (5)$$

Air temp.

$$\frac{\partial}{\partial t'}h' = -h_0\frac{\partial}{\partial x'}u' - h_0\frac{\partial}{\partial y'}v' - \underline{c_1' T'} \quad (6)$$

SST

$$\underline{\frac{\partial}{\partial t'}T' = -c_2' u'} \quad (7)$$

Thermal forcing related to SST

SST cooling ← Anomalous westerly

Shallow-water eqs. in the β-plain

By normalizing them,

$$\frac{\partial}{\partial t}u - yv = -\frac{\partial}{\partial x}h \tag{8}$$

$$\frac{\partial}{\partial t}v + yu = -\frac{\partial}{\partial y}h \tag{9}$$

$$\frac{\partial}{\partial t}h = -\frac{\partial}{\partial x}u - \frac{\partial}{\partial y}v - \underline{\kappa T} \tag{10}$$

$$\underline{\frac{\partial}{\partial t}T = -u} \tag{11}$$

Shallow-water eqs. in the β-plain

Assuming v =0,

$$\frac{\partial}{\partial t}u - yv = -\frac{\partial}{\partial x}h \tag{8}$$

$$\frac{\partial}{\partial t}v + yu = -\frac{\partial}{\partial y}h \tag{9}$$

$$\frac{\partial}{\partial t}h = -\frac{\partial}{\partial x}u - \frac{\partial}{\partial y}v - \kappa T \tag{10}$$

$$\frac{\partial}{\partial t}T = -u \tag{11}$$

Kelvin wave-like mode

Assuming *v* =0,

$$\frac{\partial}{\partial t}u = -\frac{\partial}{\partial x}h \tag{13}$$

$$yu = -\frac{\partial}{\partial y}h \tag{14}$$

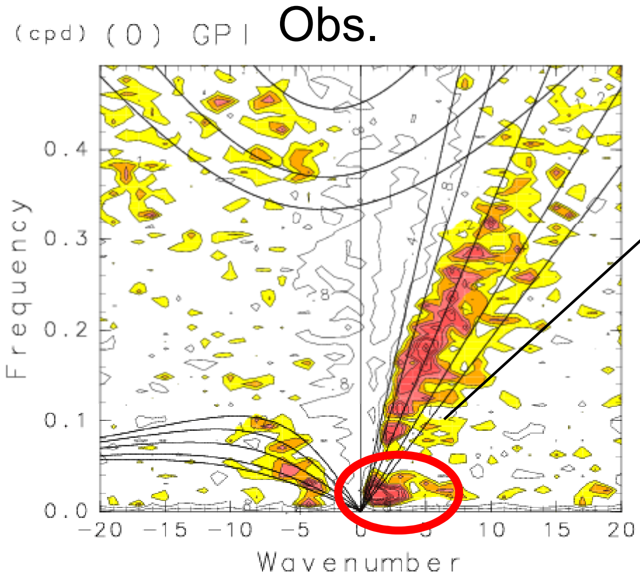
$$\frac{\partial}{\partial t}h = -\frac{\partial}{\partial x}u - \underline{\kappa T} \tag{15}$$

$$\underline{\frac{\partial}{\partial t}T = -u} \tag{16}$$

Dispersion relationship

$$\omega^3 - k^2\omega + \underline{\kappa k} = 0$$

Kelvin wave-like mode



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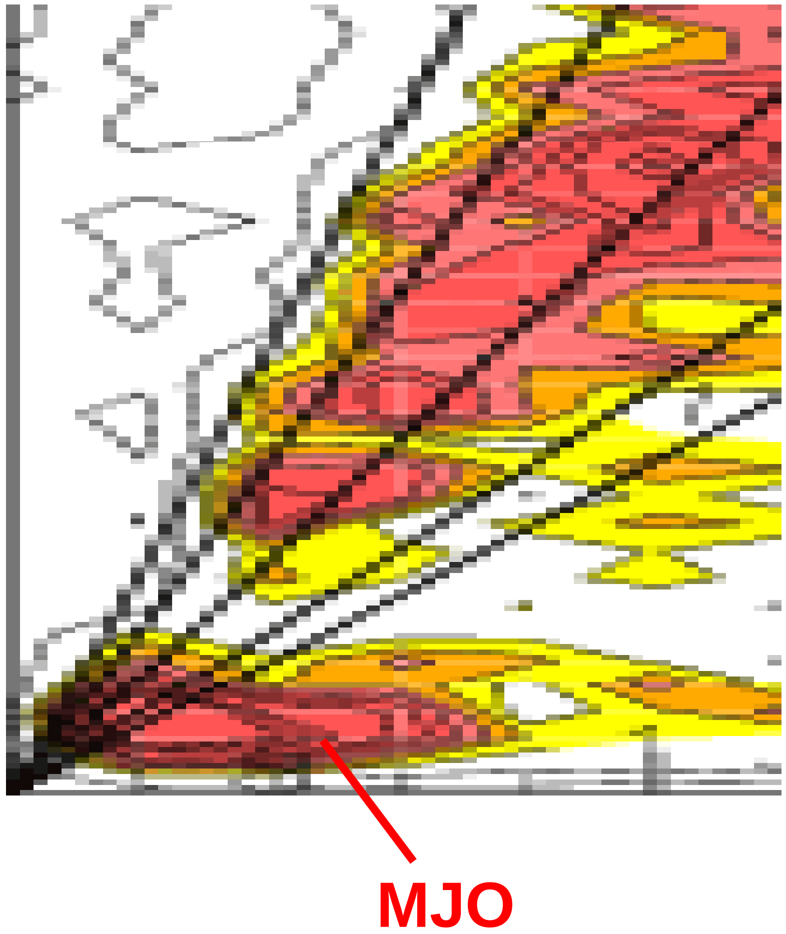

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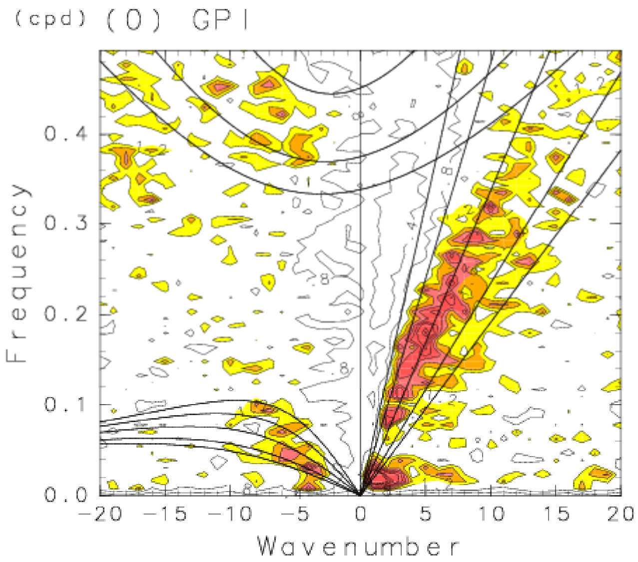

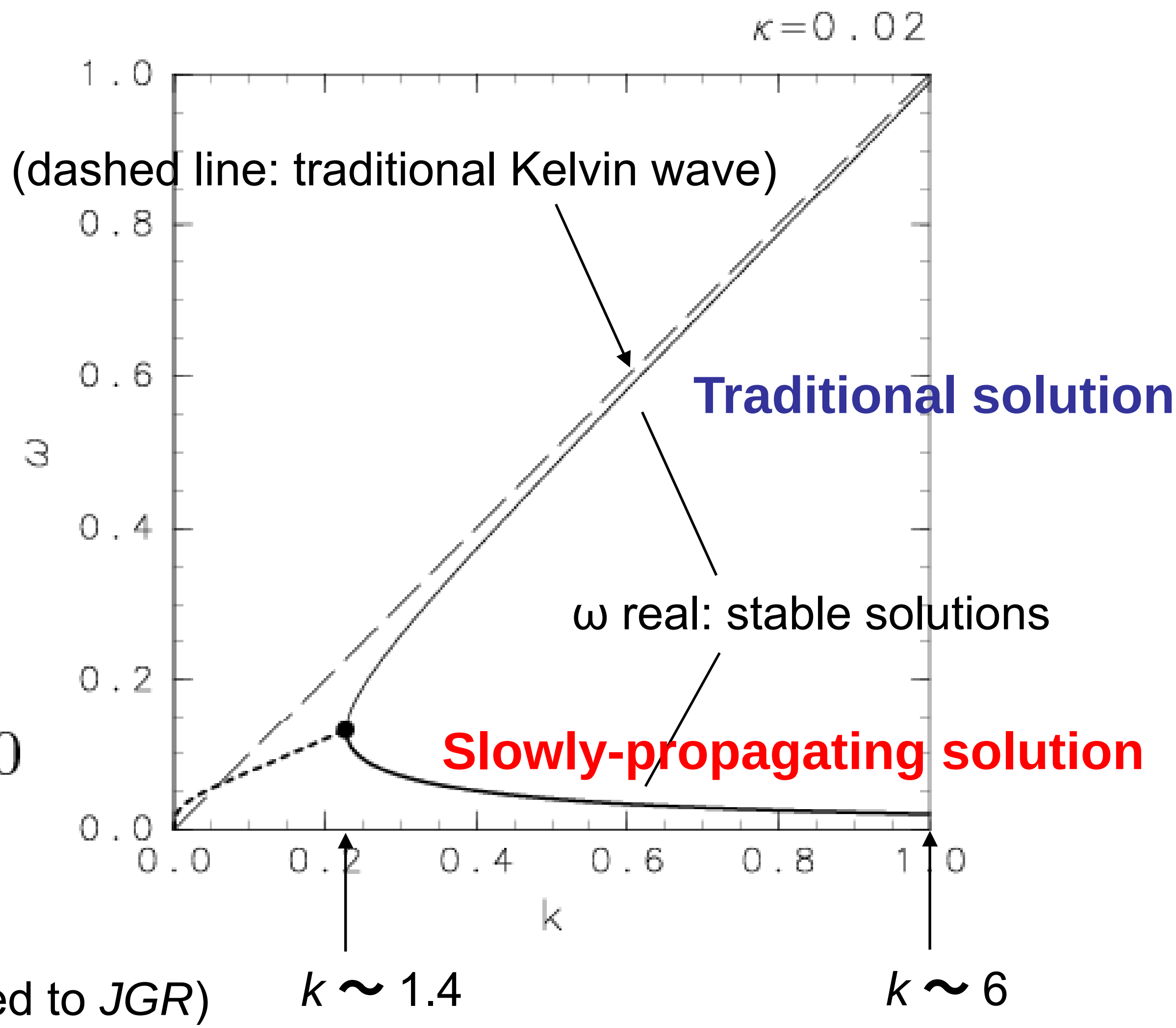

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