The Role of Ocean-Atmosphere Coupling in the MJO

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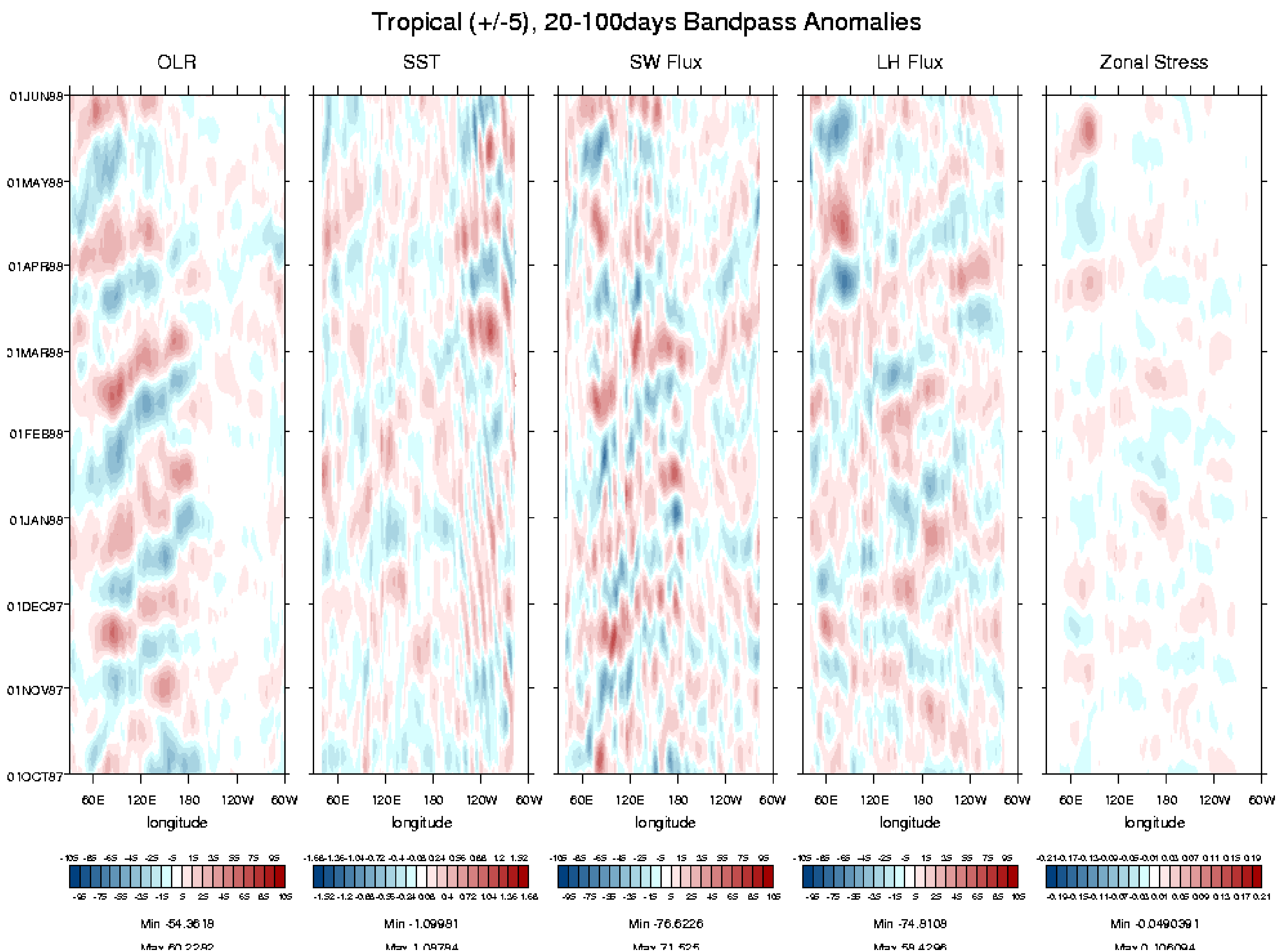
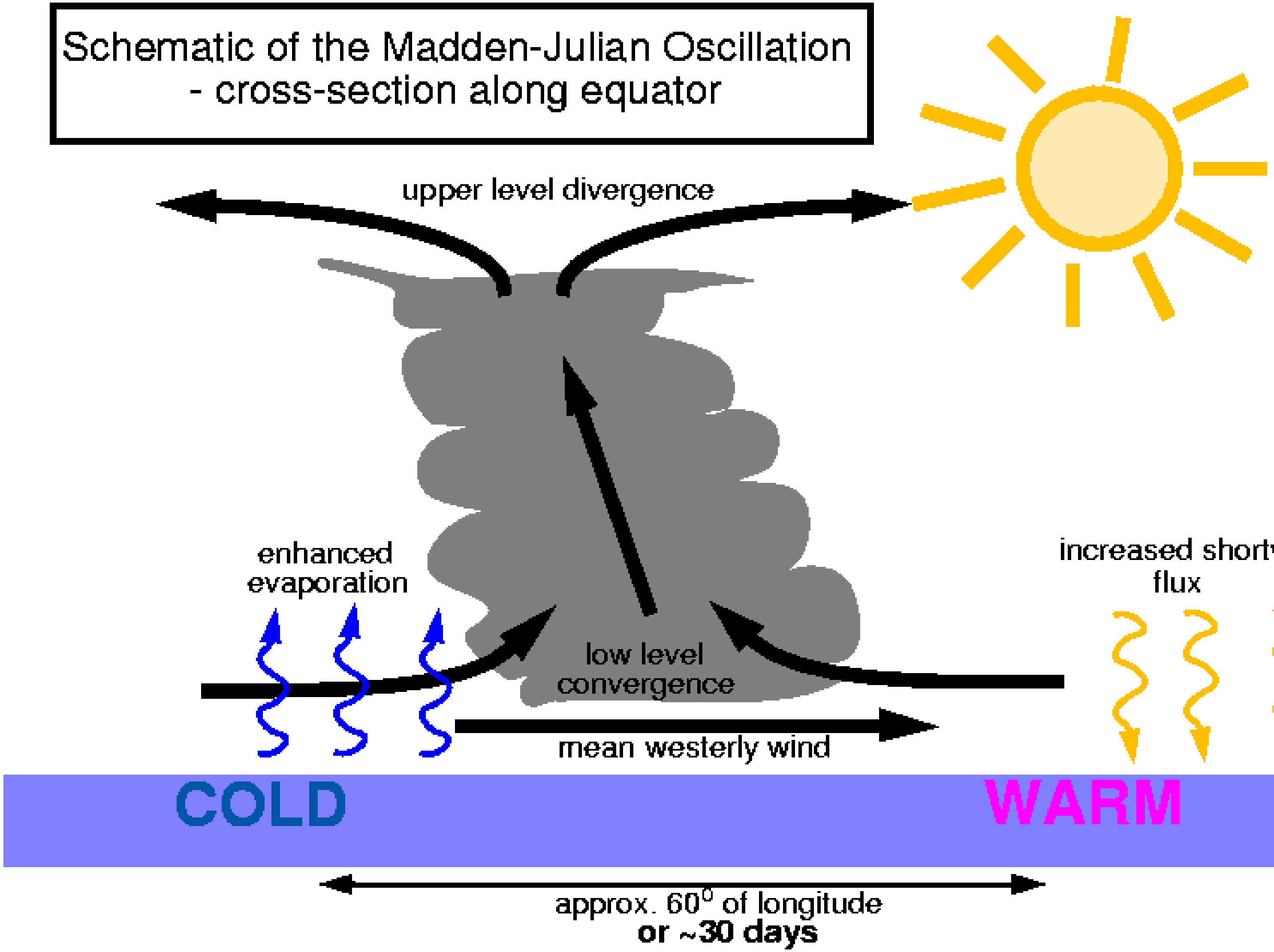

Tropical (+/-5), 20-100days Bandpass Anomalies
OLR
SST
SW Flux
LH Flux
Zonal Stress
01JUN98
01MAY98
01APR98
01MAR98
01FEB98
01JAN98
01DEC97
01NOV97
01OCT97
60E
120E
180
120W
60W
longitude
Min -54.3618
Min -1.09981
Min -76.6226
Min -74.8109
Min -0.0490391

Outline

- The influence of the atmosphere on the ocean
  - The large scale signal from observations
  - The mixed layer response
- The organization of convection by intraseasonal SST anomalies
- A coupled mechanism?

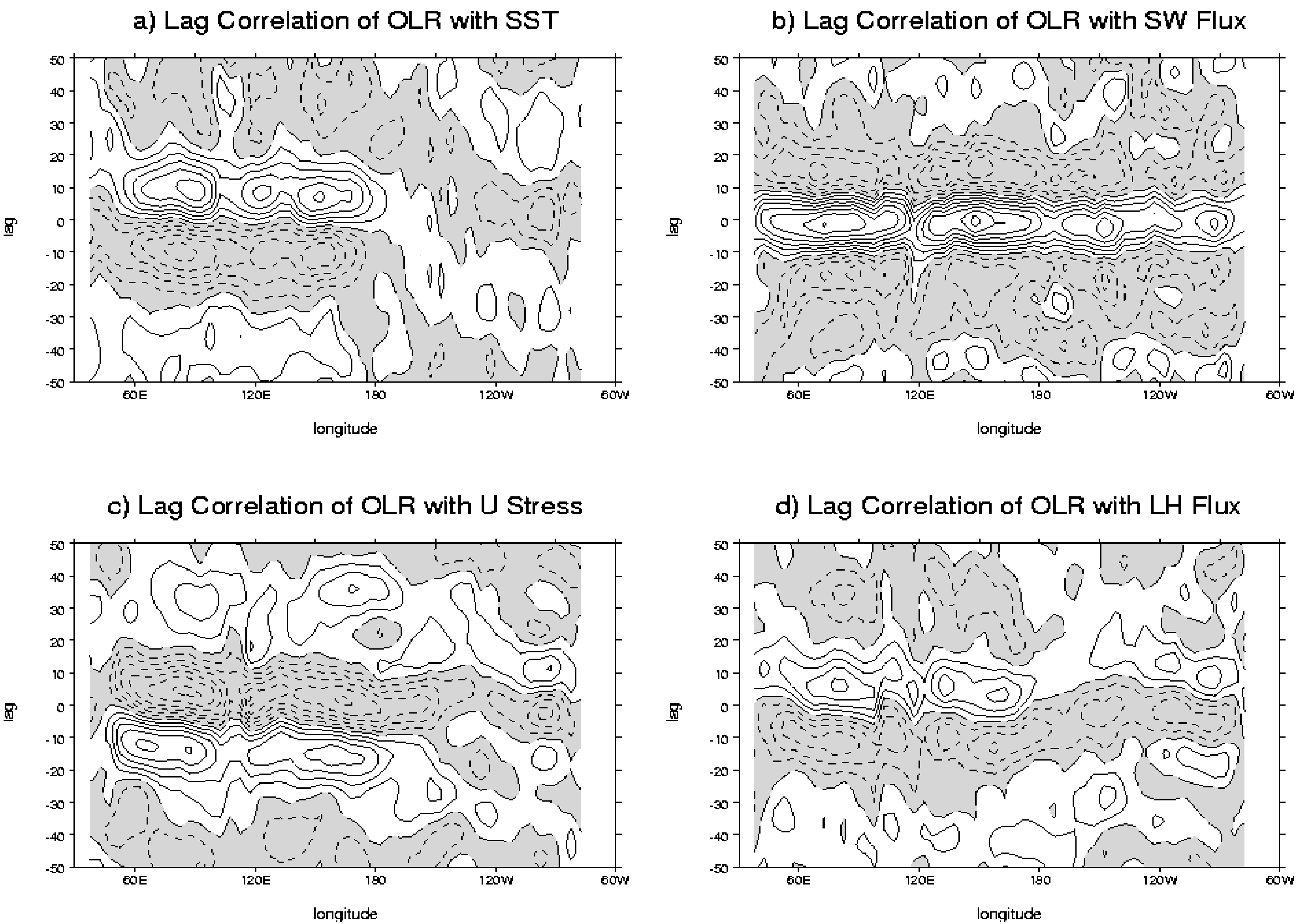


After Flatau et al. (*J. Atmos. Sci.*, 1997)

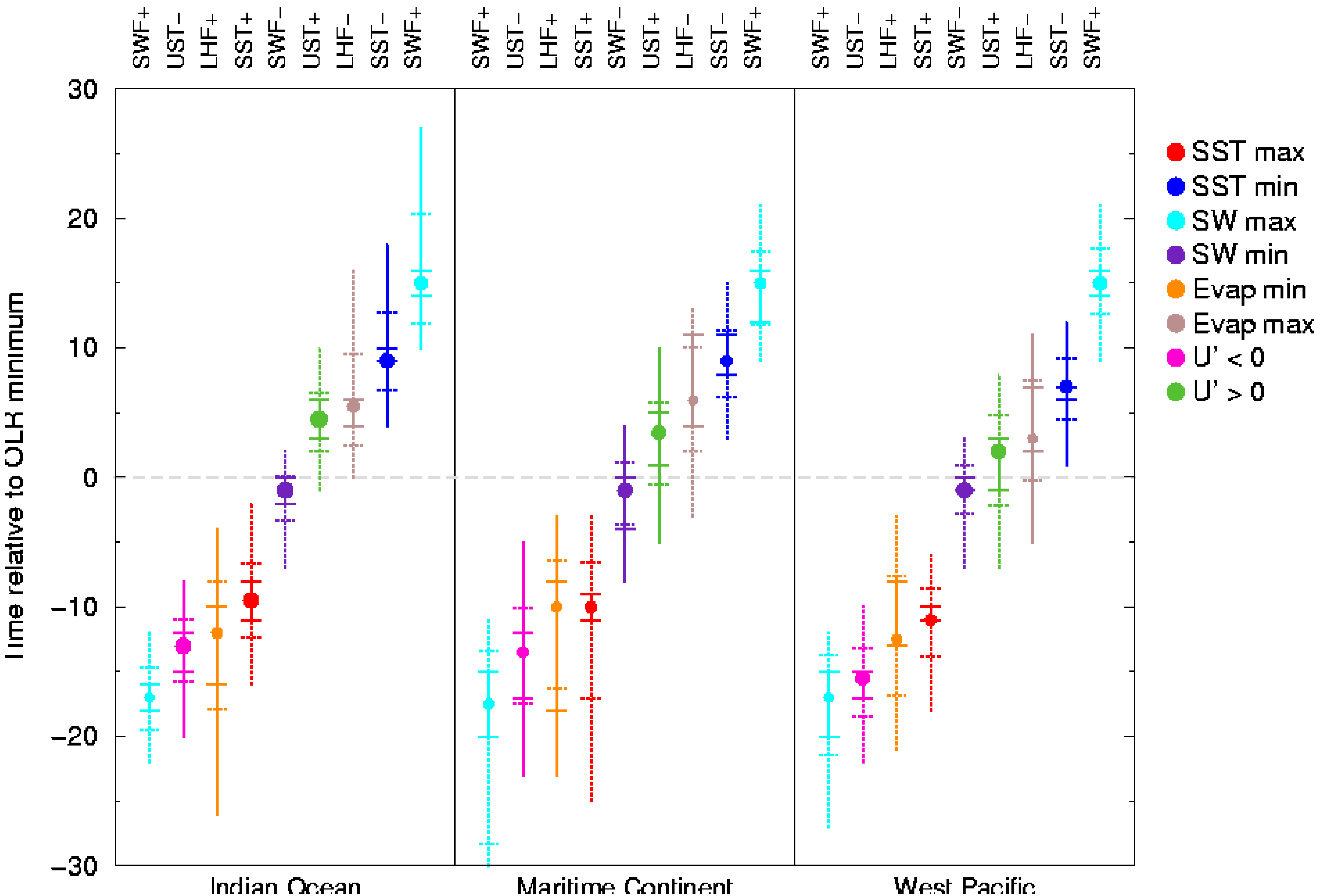
The Large Scale Signal

Woolnough et al. (J. Clim 2000)

- 15 years of
  - ERA and ECMWF surface data
  - Reynolds SST
  - NOAA OLR
- Correlations for individual seasons and whole timeseries
- Composites for eastward propagating MJO-like events

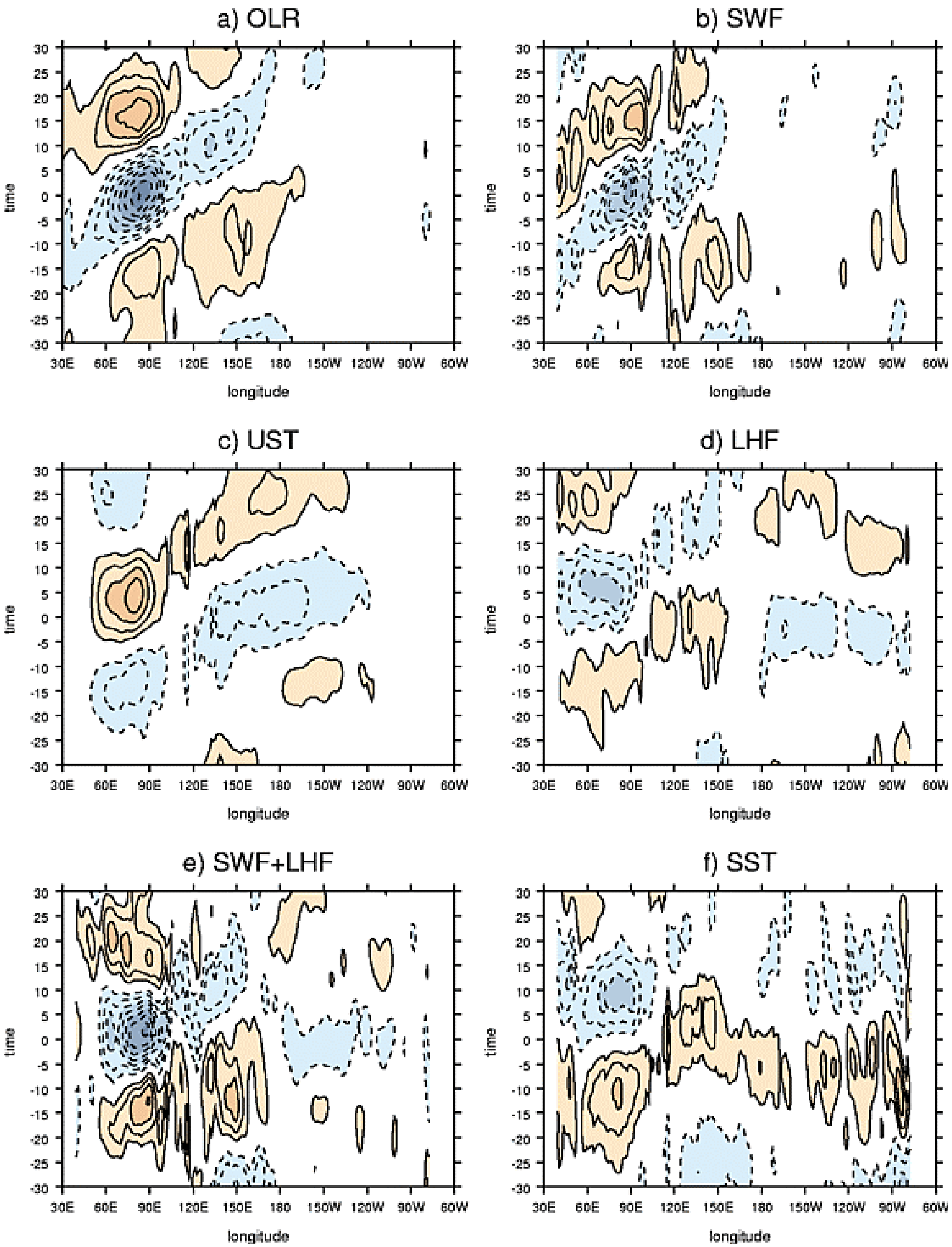


a) Lag Correlation of OLR with SST
b) Lag Correlation of OLR with SW Flux
c) Lag Correlation of OLR with U Stress
d) Lag Correlation of OLR with LH Flux
lag
longitude
50
40
30
20
10
0
-10
-20
-30
-40
-50
60E
120E
180
120W
60W



SWF+
UST−
LHF+
SST+
SWF−
UST+
LHF−
SST−
SWF+
30
20
10
0
−10
−20
−30
Time relative to OLR minimum
Indian Ocean
Maritime Continent
West Pacific
SST max
SST min
SW max
SW min
Evap min
Evap max
U' < 0
U' > 0

Composite Anomalies

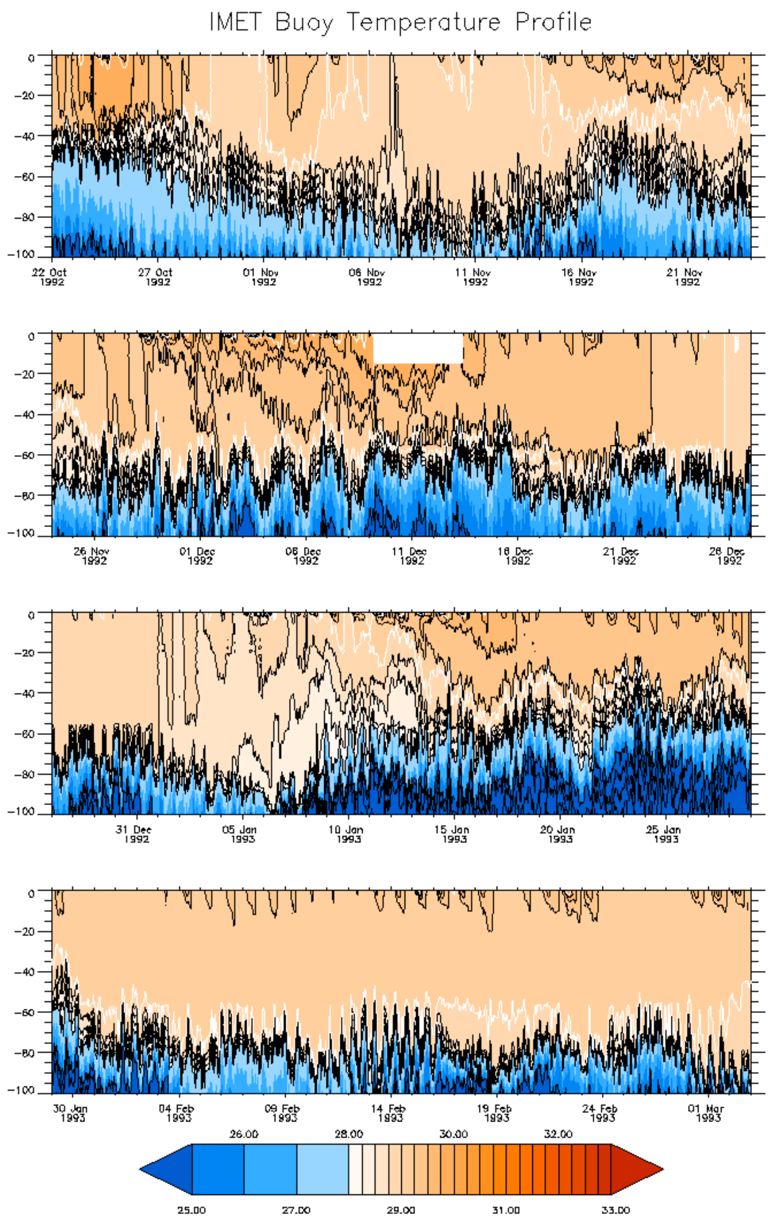


- Composite based on 36 MJO events passing through 82.5°E
- Composite flux anomalies about 15-20Wm^{-2}
- Composite SST anomalies about 0.15-0.2°C

Mixed Layer Response

- Observations from the IOP of TOGA-COARE
  - IMET Mooring at 156°E 1°45´S
  - October 1992 – March 2003
- Mixed Layer Modelling
  - 1D model with KPP mixing scheme
  - Forced by fluxes from IMET buoy

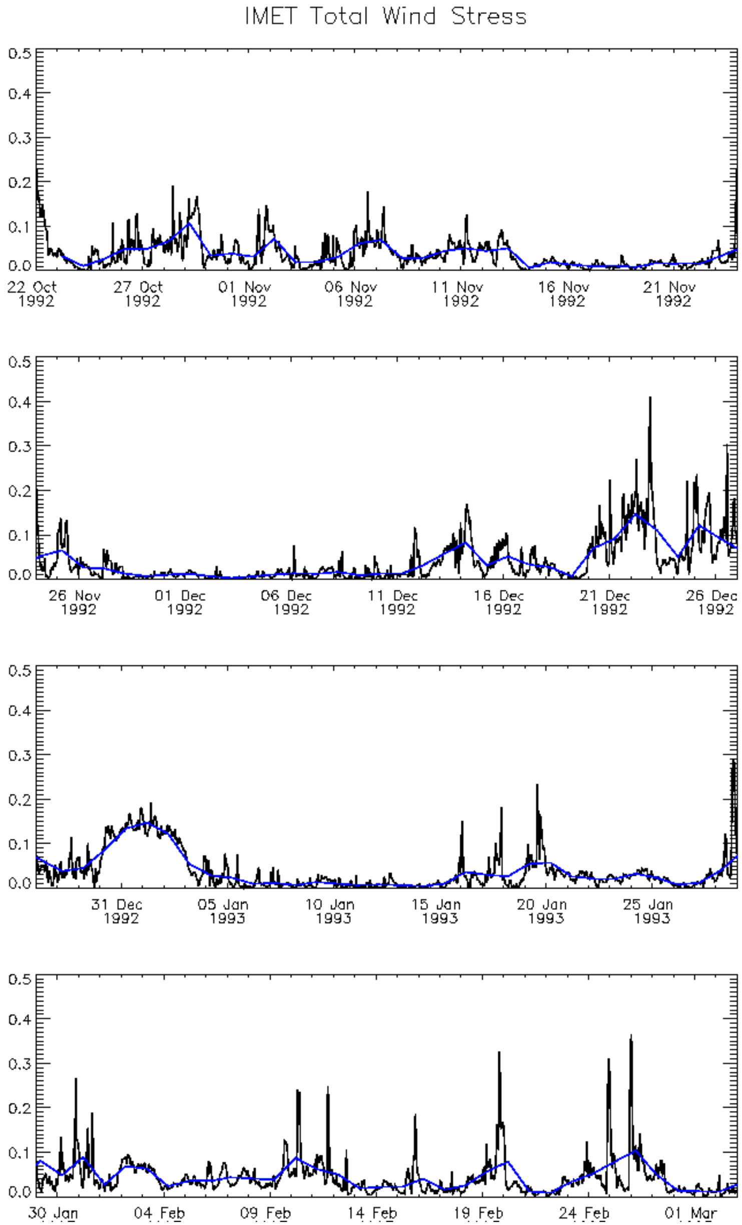
Mixed Layer Response



- Mean thermocline depth around 60-80m with strong intraseasonal variability
- Warm events
  - 16-23 Nov
  - 28 Nov – 14 Dec
  - 10-20 Jan

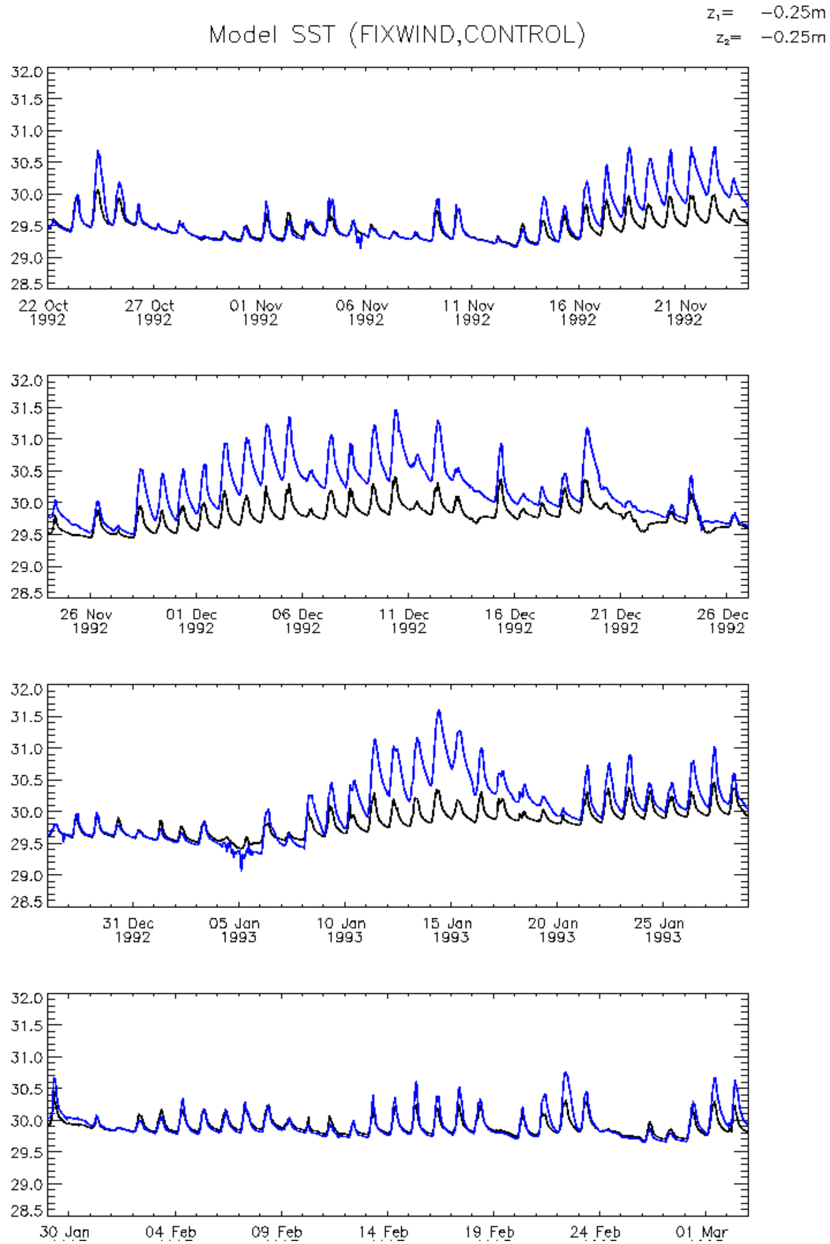
are confined to the top 20-30m and deepen slowly

IMET Total Wind Stress



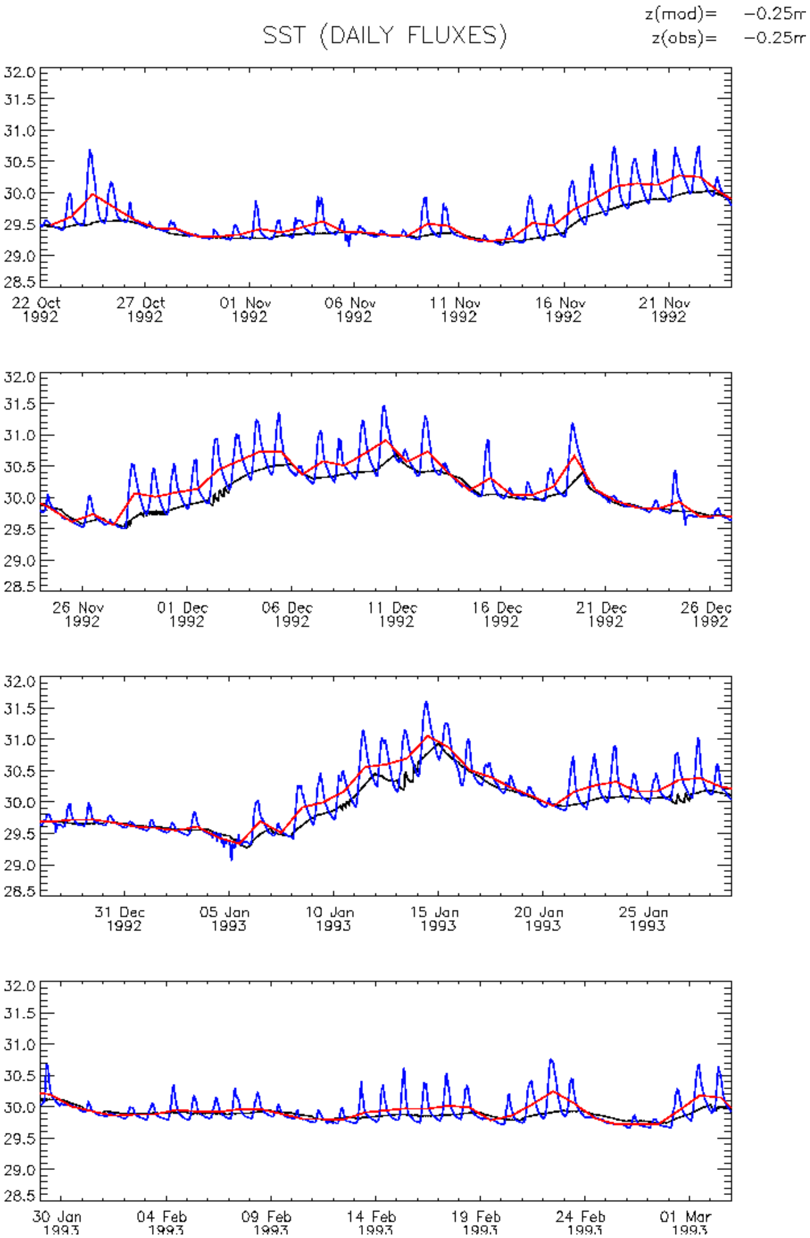
- Strong wind stress events
  - Westerly Wind Burst (20 Dec – 4 Jan)
  - Squall Lines (30 Jan – 1 Mar)
- Low wind events
  - 13 Nov – 20 Nov
  - 1 Dec – 6 Dec
  - 6 Jan – 15 Jan

The role of the light wind periods



- Fixed the wind stress to the time mean value (0.039Nm^{-2})
- Intraseasonal warming is underestimated by 0.5-0.75°C compared to the control integration
- Amplitude of the diurnal variability is underestimated

The role of the diurnal cycle



- Force the model with daily mean surface fluxes
- Daily mean SST during the periods of with a strong diurnal cycle is underestimated by about 0.25-0.5°C

Ocean response to atmosphere

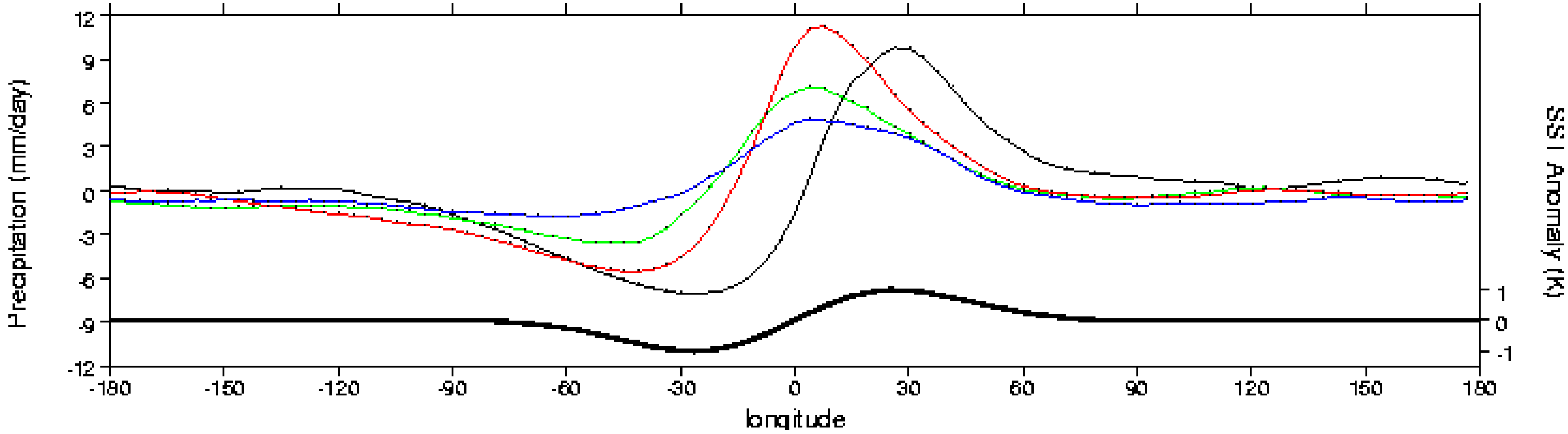
- Intraseasonal SST anomalies of 0.5-1°C associated with passage of MJO
- Driven by intraseasonal variability in surface fluxes and surface winds
- Light wind conditions crucial for warming period
  - Allows shoaling of mixed layer and gives larger SST response to the flux anomalies
- Rectification of the diurnal cycle of SST increases magnitude of intraseasonal warming by about 30%

Response to SST anomalies

Woolnough et al. (2001)

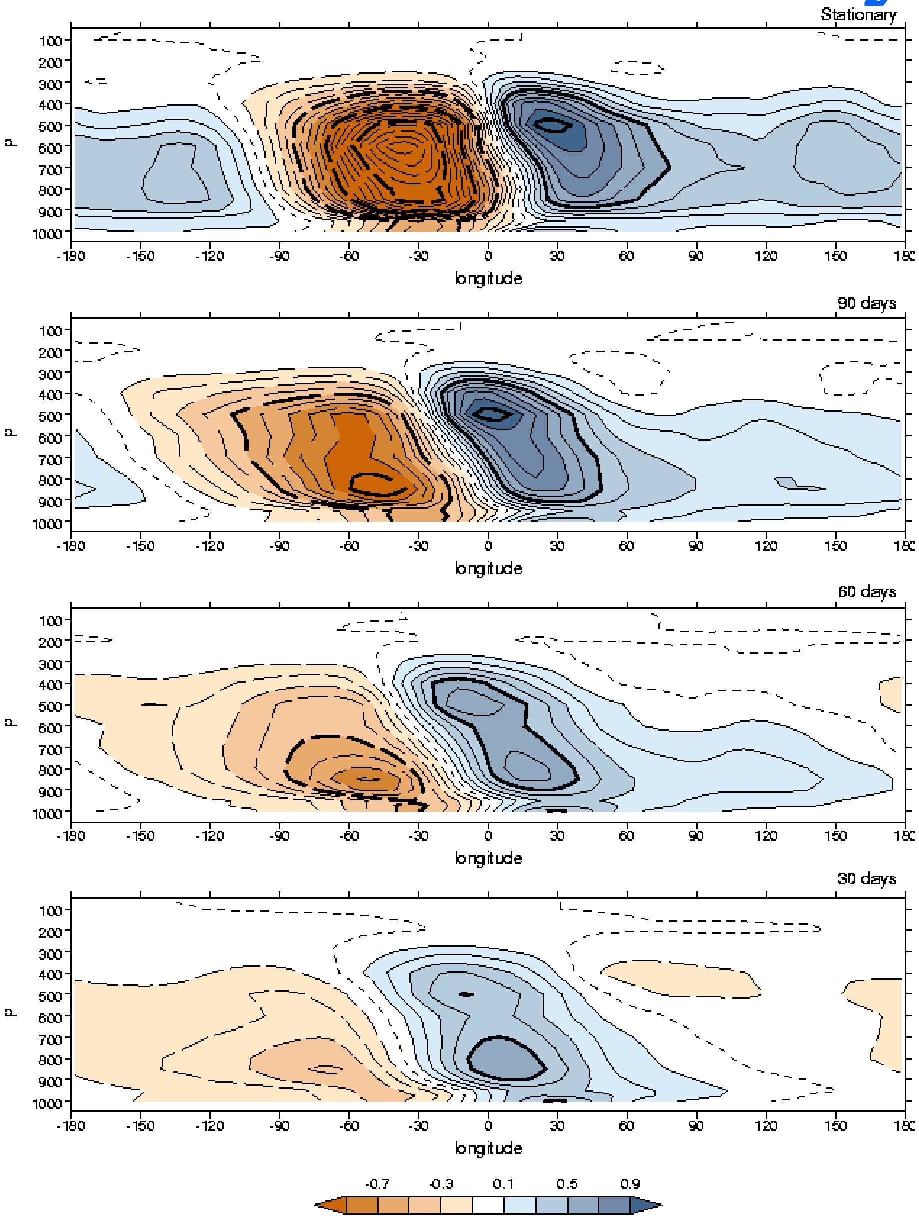
- Aquaplanet version of UM forced by SST anomalies
  - Confined dipole similar to observed SST anomalies
  - Vary propagation speed
  - Composite results relative to the moving SST anomaly

Precipitation response



- Precip. Anomaly larger for slower SST anomaly
- For moving SST anomalies precip max colocated with centre of dipole

Humidity response



- Boundary layer q_{max} colocated with SST max
- Delayed response lower troposphere
- Further delay above the freezing level
- Precipitation responds to mid-level q anomalies for timing and magnitude

Role of the diurnal cycle?

- Johnson et al (*J. Clim*, 1999) report the importance of the shallow and mid-level clouds for moistening the atmosphere during undisturbed period
- Diurnal cycle of these clouds more more typical of land convection (afternoon peak) (Sui et al., *J. Atmos. Sci*., 1997)
- Diurnal cycle of SST during undisturbed period may be important for promoting mid-level convection

Response to SST anomalies

- Intraseasonal SST anomalies can force intraseasonal variability in convection
- Convection maximum occurs between the positive and negative SST anomalies
- Magnitude of precipitation anomaly increases with period of anomaly
- Humidity anomalies appear to be important for location and magnitude of precipitation response

Coupling and Propagation Speed

- Slow moving SST anomalies generate large precipitation anomalies and hence large surface flux anomalies – inconsistent with slow moving SST anomalies
- Fast moving SST anomalies generate weak precipitation anomalies and hence weak surface flux anomalies – inconsistent with fast moving SST anomalies

$\Rightarrow$ Coupled mode will have a preferred timescale

Propagation Speed – a simple model

$$SST = \Delta T \sin(m\lambda - \omega t)$$

$$PPT = \frac{\alpha \Delta T}{\omega} \cos(m\lambda - \omega t)$$

$$FLUX = -\beta \bullet PPT$$

$$\frac{d}{dt} SST = -\gamma \bullet FLUX$$

$$\Rightarrow \omega = \sqrt{\alpha\beta\gamma}$$

- $\alpha \sim 0.6$ mm K^{-1} day^{-2} (from aquaplanet experiments)
- $\beta \sim 8$ W m^{-2}/(mm day^{-1}) (from observations)
- $\gamma \sim 1.2 \times 10^{-8}$ K m^2 J^{-1} (H~20m)

$\Rightarrow$ Period ~ 90 days

Summary

- SST anomalies forced by surface fluxes and winds associated with the MJO
  - Light wind conditions important
    - Allows shoaling of mixed layer to increase SST response to fluxes
    - Permits large diurnal cycle in SST which elevates daily mean SST
- Convective response to SST anomalies consistent with observations
  - Humidity response seems important for location and magnitude of SST anomalies
  - Magnitude of precipitation anomaly increases with period of anomaly
- Coupled mechanism has preferred frequency on intraseasonal timescales