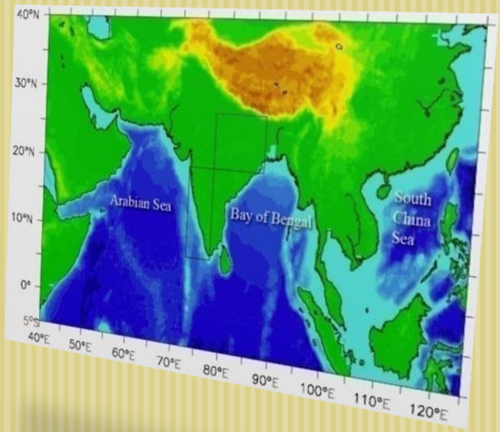
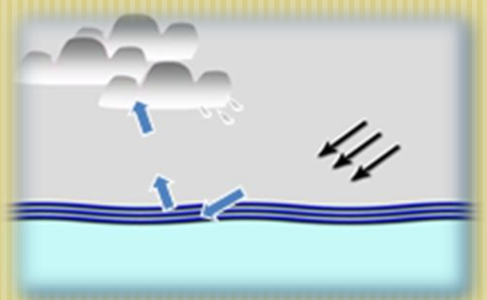
Intraseasonal SST-precipitation relationship and its "spatial variability" over the tropical summer monsoon region



– as in observations and the CFSv2



1. Evolution of SST and SST-Precip. relationship
2. Spatial variability of SST-Precip. relationship
3. Mean state, model bias and ISV

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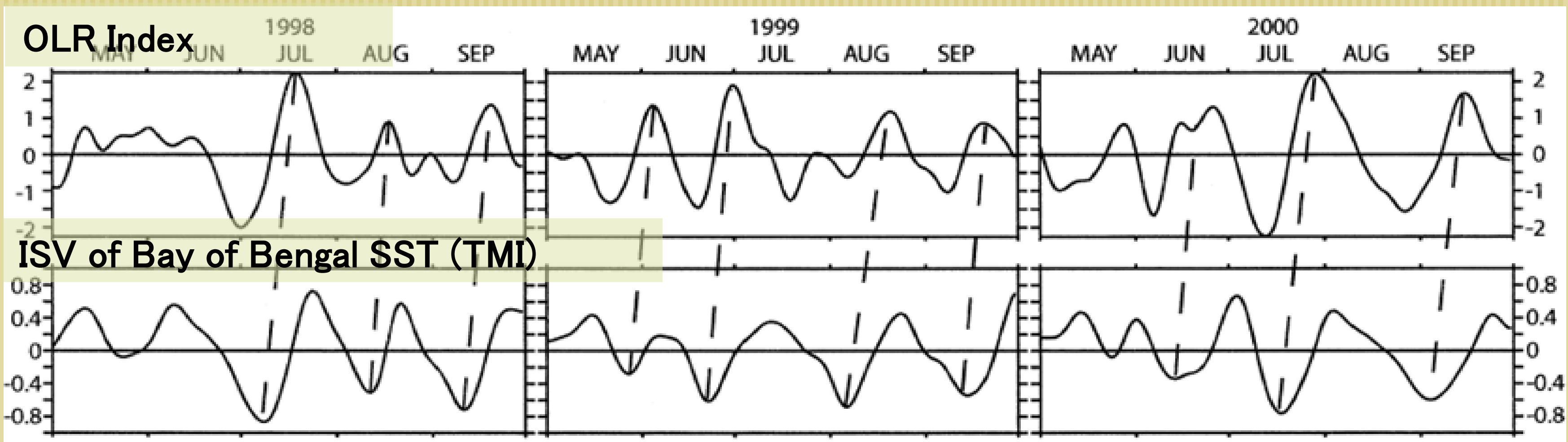
SST-precipitation relationship in the monsoon ISV; Earlier Studies

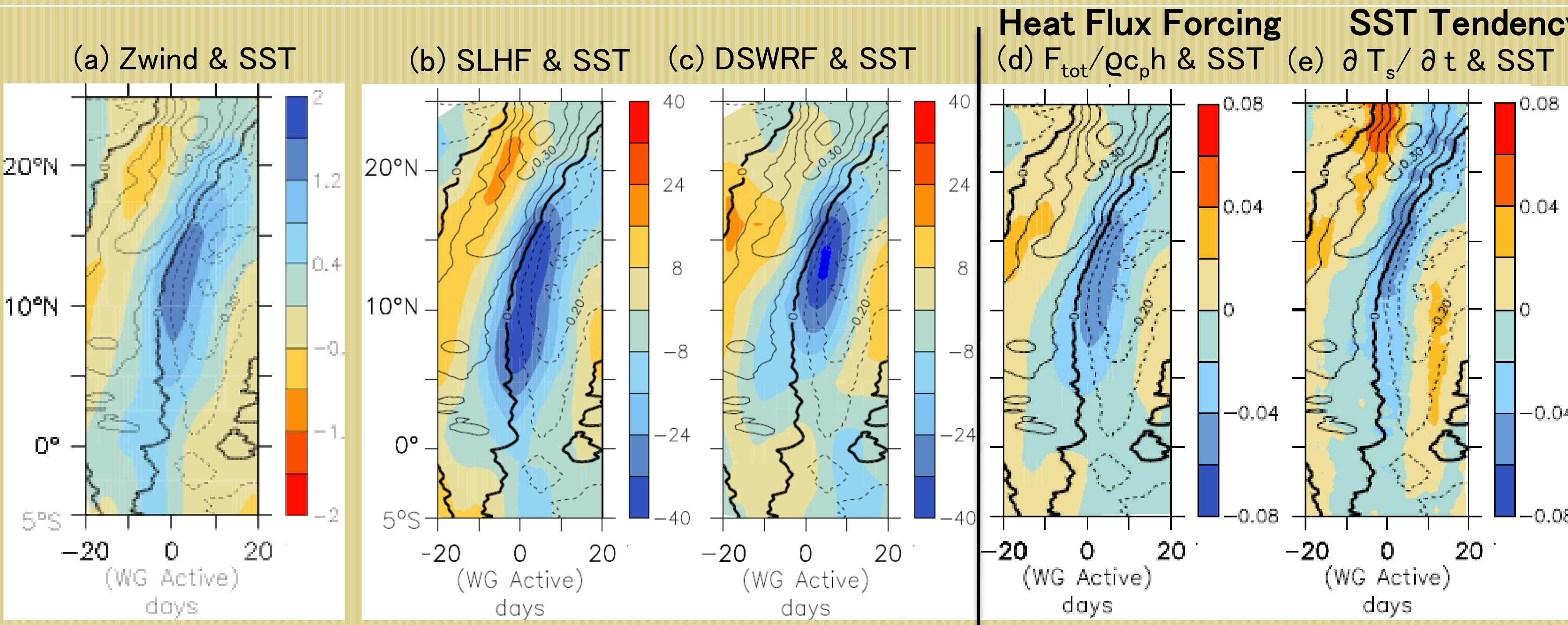
1. SST and heat flux anomalies associated with monsoon ISV are observed over a large domain, Arabian Sea -> s. China Sea -> w. North Pacific (Webster et al. 1998; Sengupta et al. 2001; Xie et al. 2007)
2. Intraseasonal SST driven by downward SW radiation flux (dominant) and LHF anomalies.(Hendon & Glick 1997). Over "central Indian Ocean"
3. Intraseasonal SST influence the atmospheric variability, eg: Precipitation (Vecchi and Harrison 2002, Fu et al. 2008). Over "Bay of Bengal"



VH 2002: Negative SST lead monsoon break by 10 days (r = 0.67).
Step by step process on the SST- precipitation relationship?

SST-precipitation relationship in the monsoon ISV; Earlier Studies: Evolution of SST

4. Intraseasonal SST over Arabian Sea and Bay of Bengal: driven by both LHF (dominant!) and SWF anomalies (Roxy and Tanimoto 2007, JMSJ).



SST tendency equation: $\partial T_s / \partial t = F_{tot}/\rho c_p h$ Arabian Sea (60–70E)

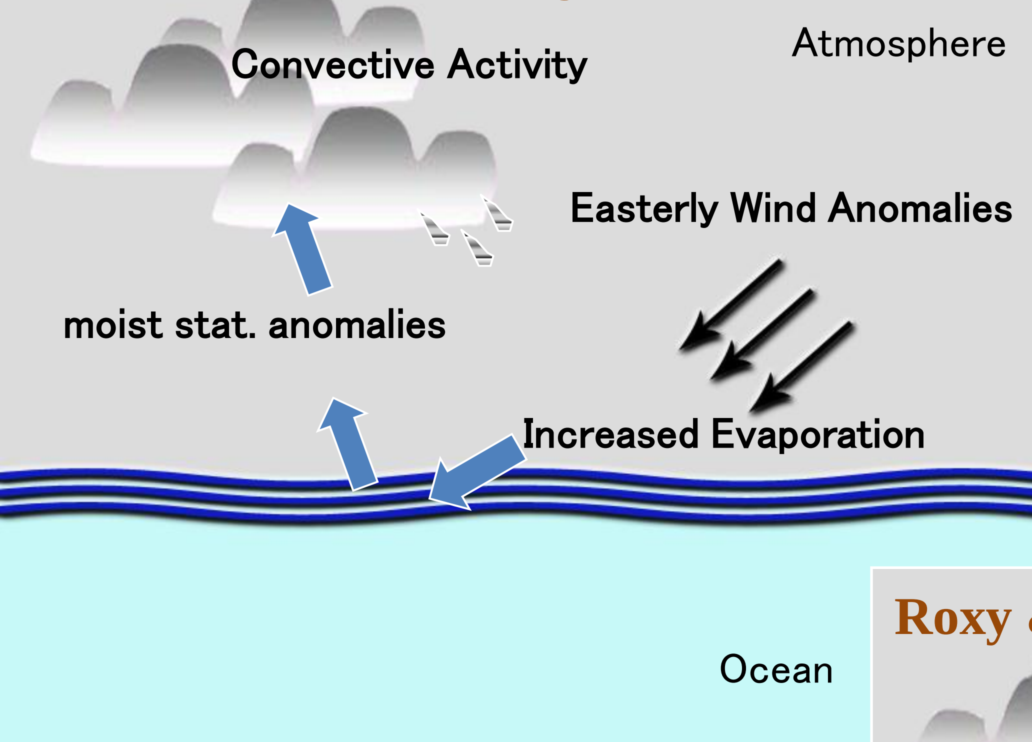
[where T_s is the SST, F_{tot} is the total heat flux, ρ is density of water, c_p is the specific heat of water at constant pressure, and h is the depth of the mixed layer: h = 40 m (Kara et. al 2003)].

Quantitatively:

F_{tot} of 50 Wm^{-2}, h of 40 m, standard ρ & c_p => $F_{tot}/\rho c_p h = 0.025^{\circ}C\ day^{-1}$

SST change of 0.8°C in 40 days => $\partial T_s/\partial t = 0.02^{\circ}C\ day^{-1}$

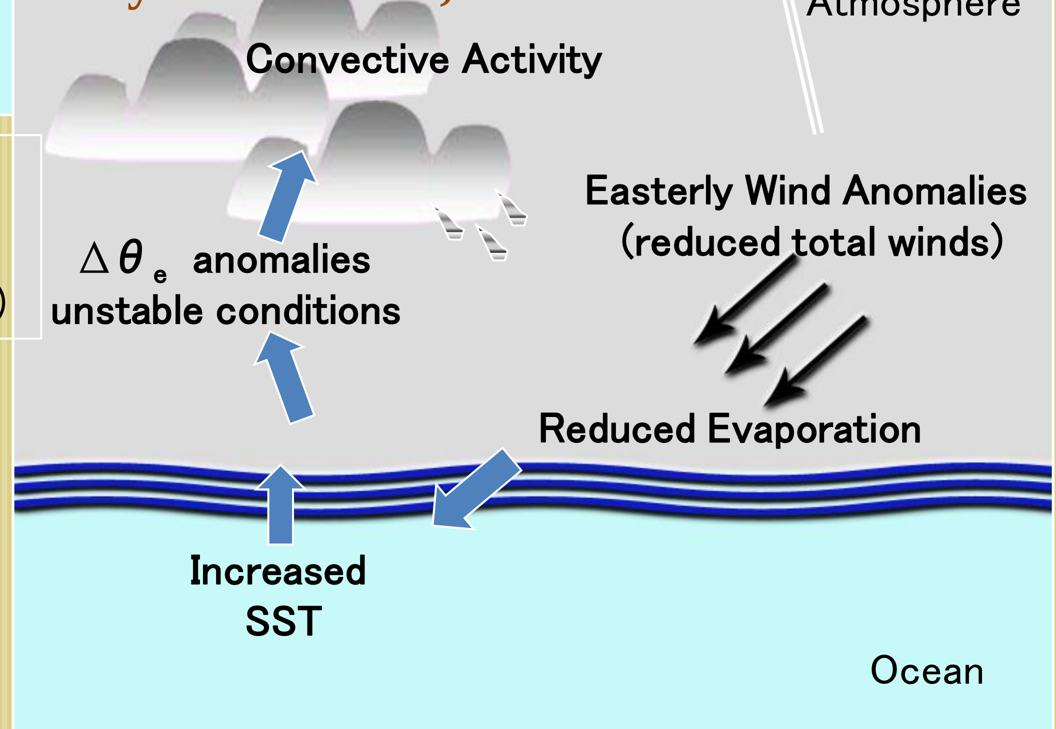
Kemball-Cook & Wang, 2001



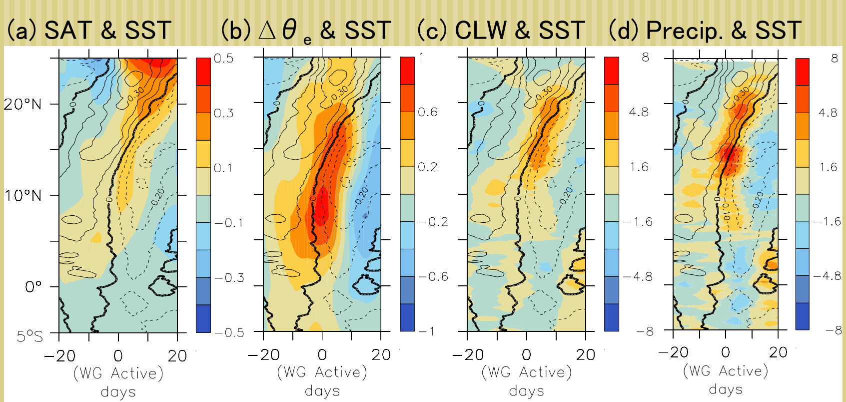
5. Intraseasonal latent heat flux (−ve upward) anomalies enhance precipitation by enhancing the moist static energy (Kemball−Cook and Wang 2001)

Mean zonal winds are westerly !

Roxy & Tanimoto, 2007



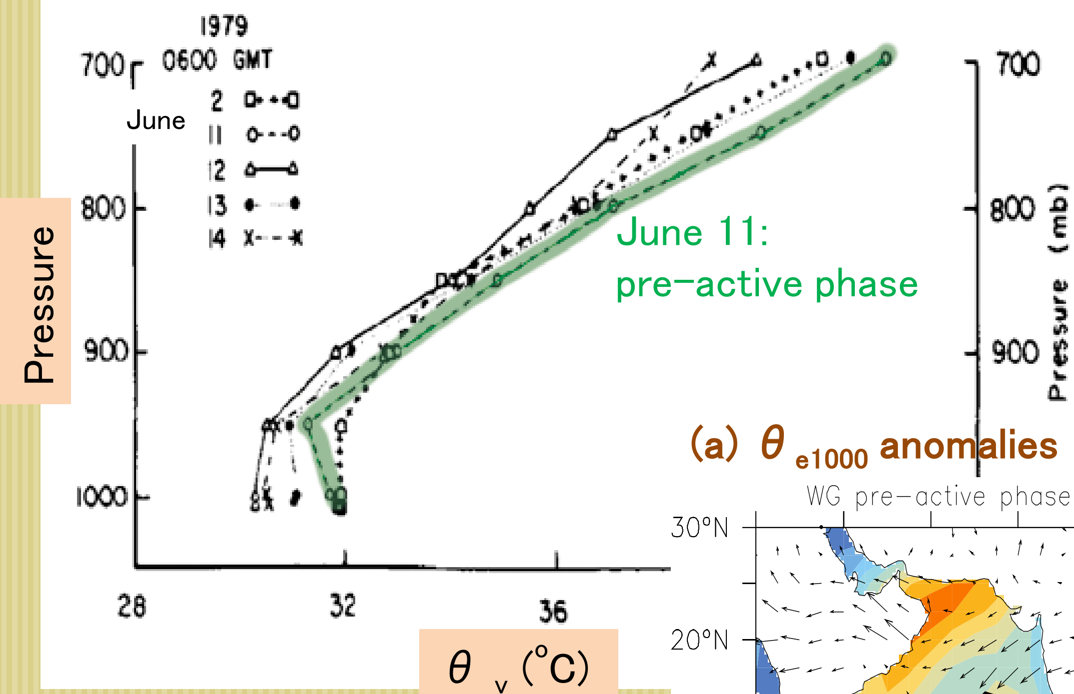
6. positive SST anomalies
=> destabilize lower atmos. column
=> convective activity (R & T 2007)



SST influence on the destabilization of lower atmospheric column:

Virtual potential temperature (θ_v) over Arabian Sea during pre-active phase

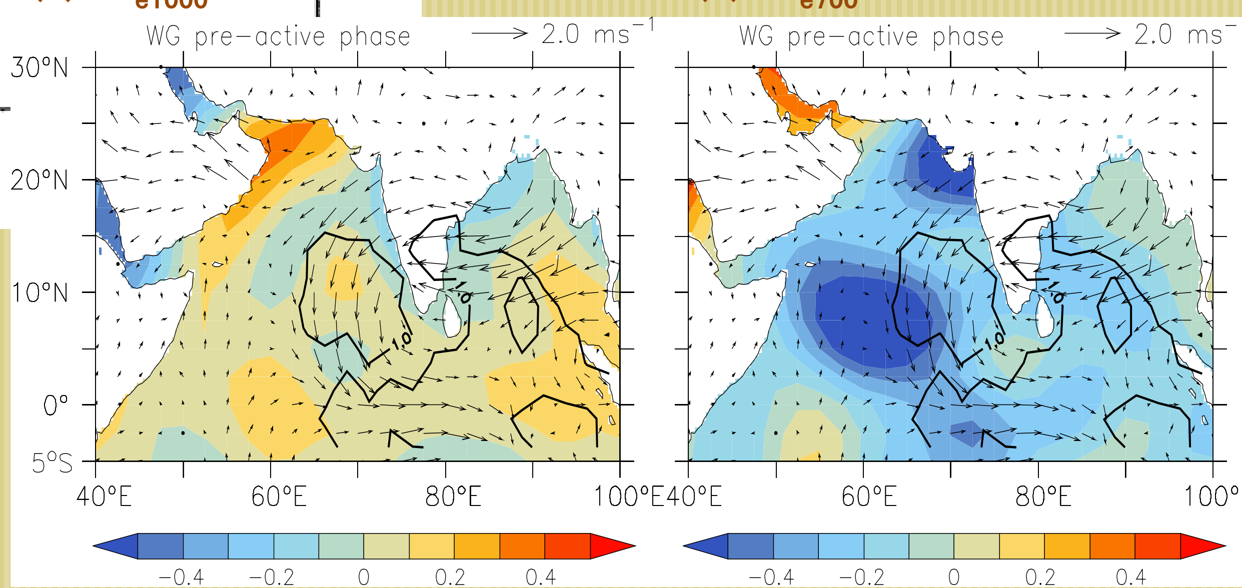
Atmospheric soundings between June 2-14



Mean profile of virtual potential temperature θ_v, for 0600 GMT on 2 June (pre-monsoon) and 11-14 June (onset) from **MONEX 79 ship data over Arabian Sea**. **Holt and Raman, 1987**.

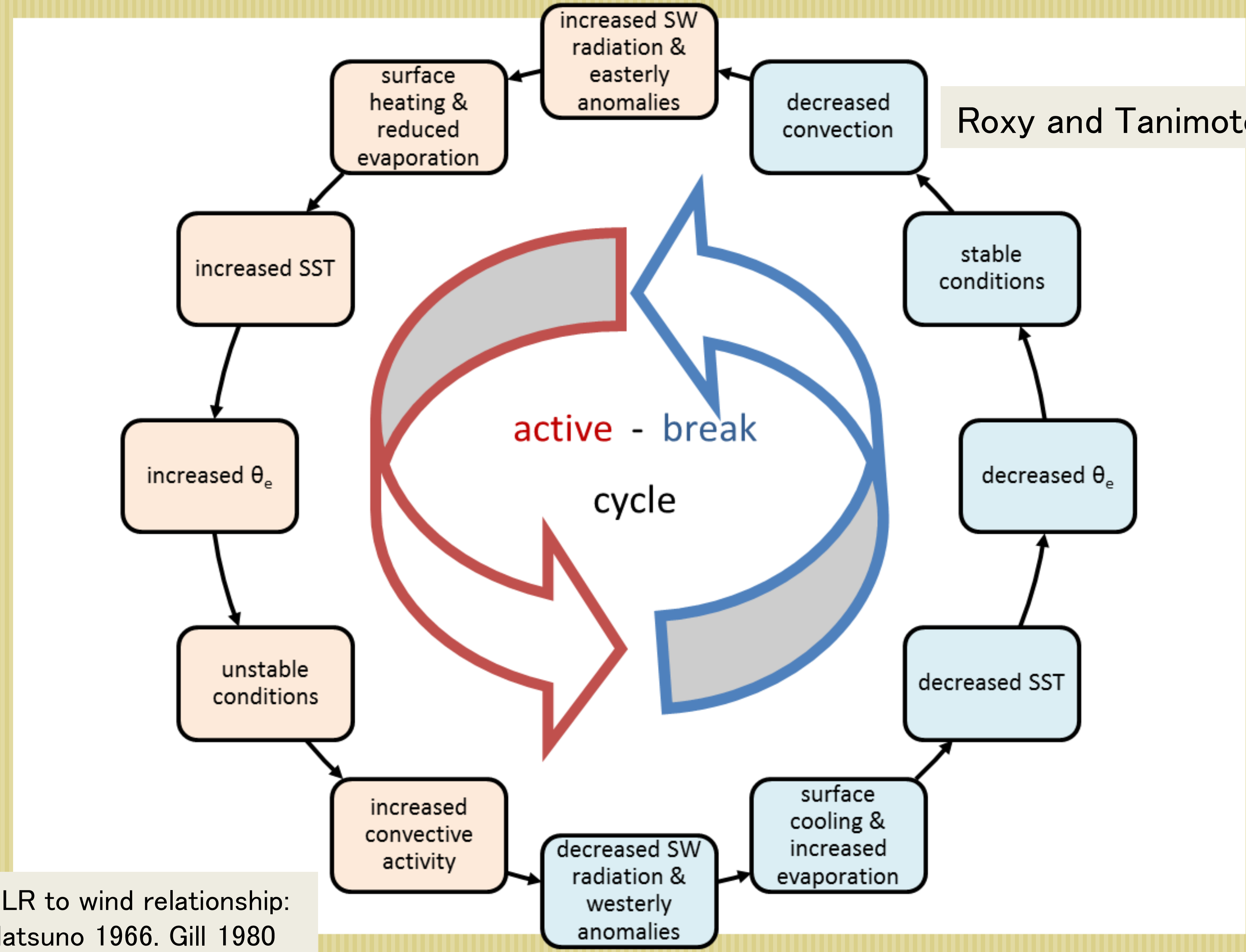
(a) θ_{e1000} anomalies

(b) θ_{e700} anomalies



Evolution of SST and its role in modulating the ISV of the Asian Summer Monsoon

Positive SST anomalies induce unstable conditions over the lower atmosphere, which results in enhanced precipitation over the Arabian Sea/Bay of Bengal/South China Sea



Roxy and Tanimoto, 2011

OLR to wind relationship: Matsuno 1966. Gill 1980

Data, Model and Methods

Observations

SST, Precipitation: **TMI**
Winds: **QuickSCAT**
Fluxes: **TropFlux**

1998–2009 (**12 years**)

NCEP CFSv2

Atmosphere: NCEP Global Forecast System (GFS)
horizontal: spectral T126, ~90 km
vertical: 64 sigma-pressure hybrid levels

Ocean: GFDL Modular Ocean Model v4 (MOM4p0)
40 levels in the vertical, 0.25–0.5° horizontal.

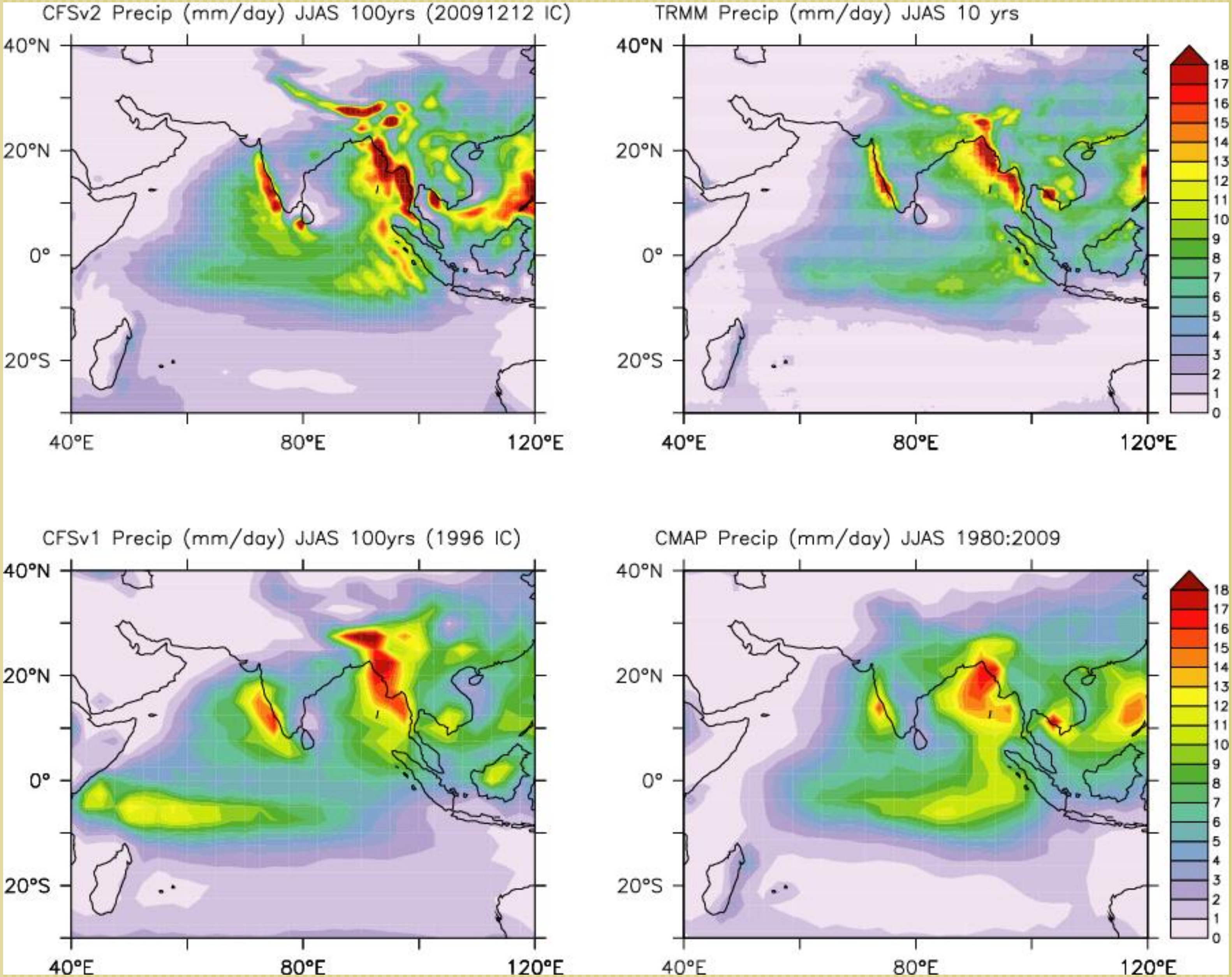
Sea Ice: GFDL Sea Ice Simulator (SIS)
an interactive, 2 layer sea-ice model

Land: NOAH, an interactive land surface model with 4 soil levels

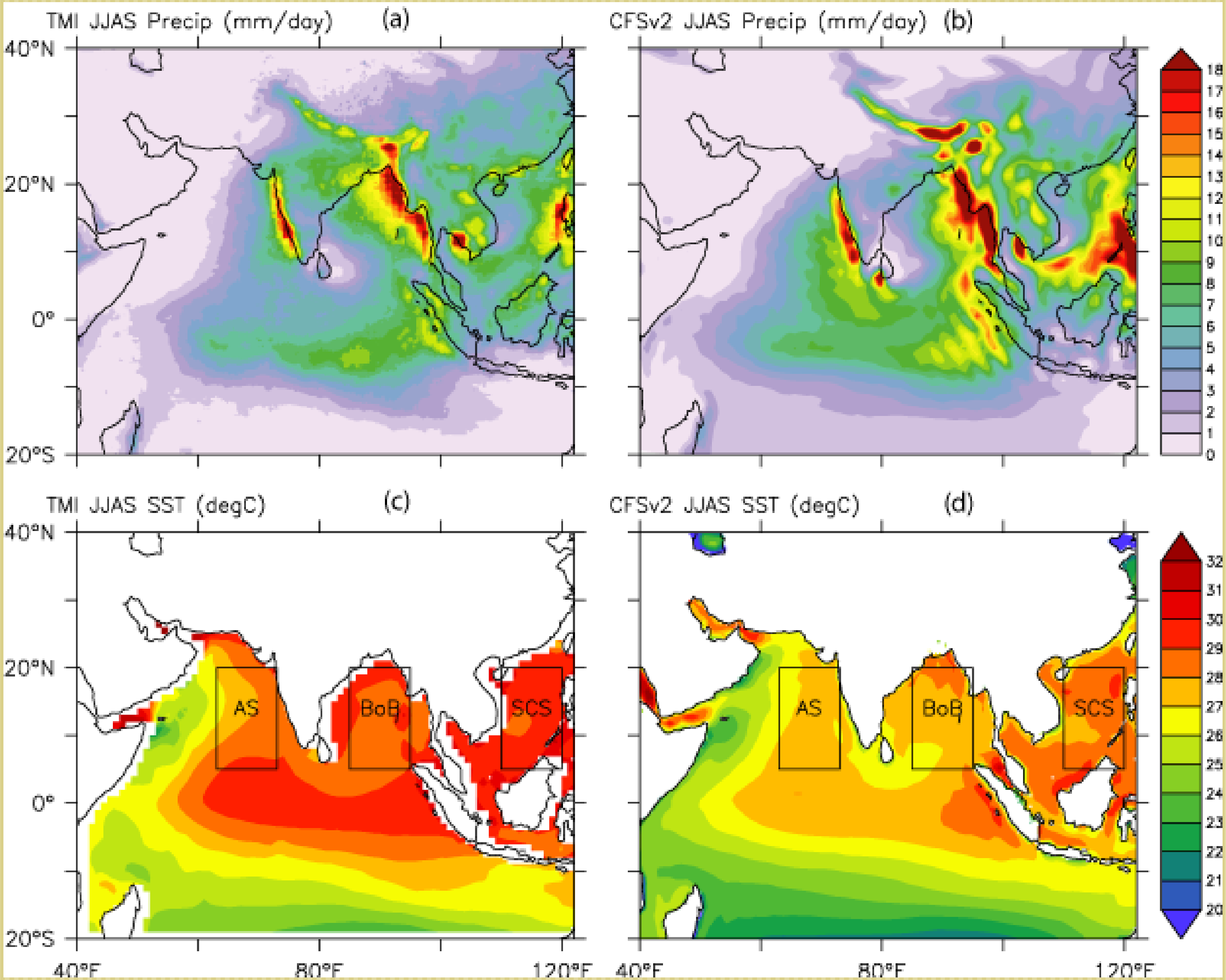
~ **100 years** simulation with mixing ratios of time varying forcing agents set for the current decade

Anomalies obtained for all variables by removing seasonal means and bandpass filtered for **10–90 days** to retain the ISV over the Asian monsoon region, for **June–September**.

Climatology of Precipitation (June-Sept)

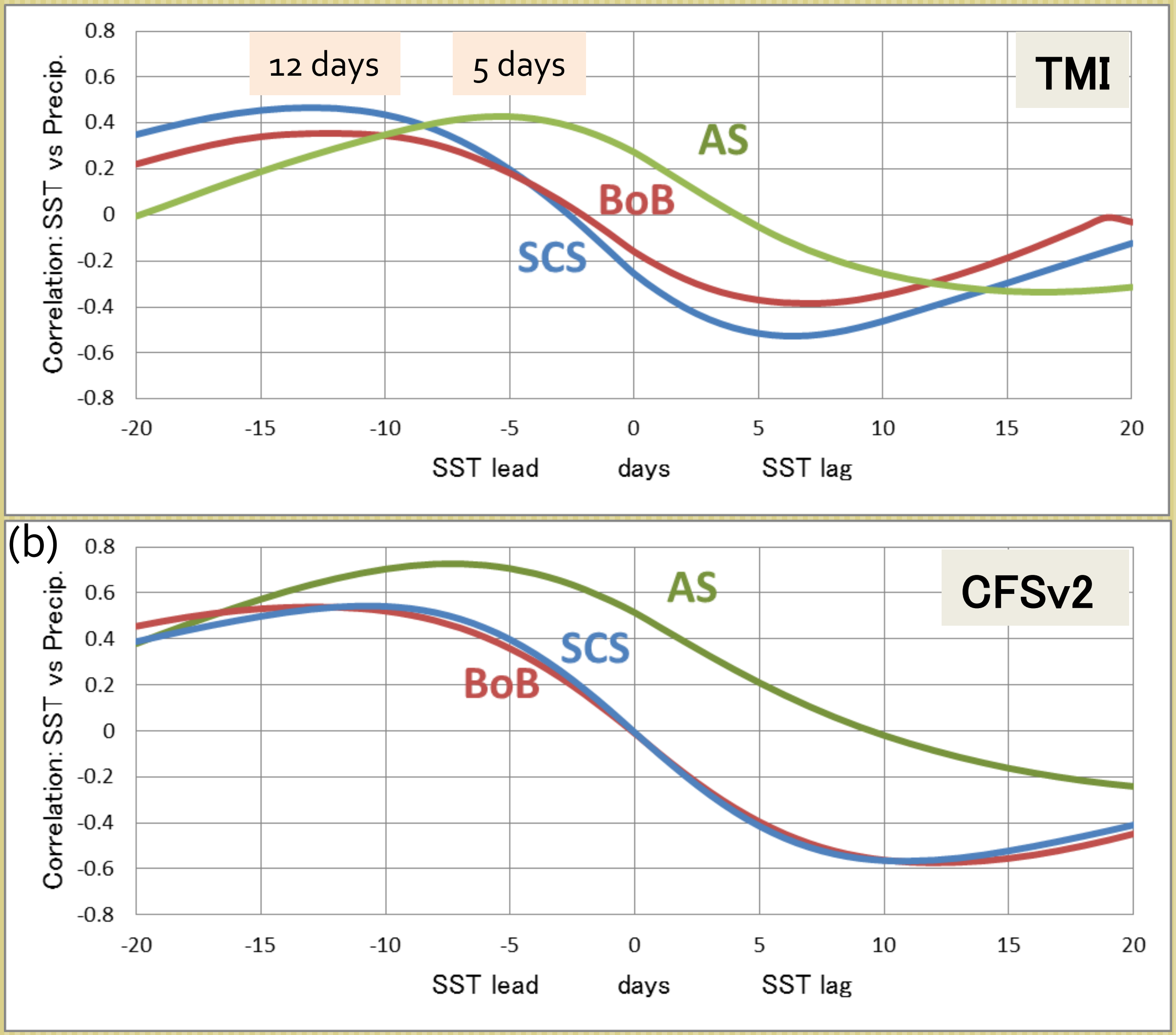


Climatology of Precipitation and SST (June-Sept)



Spatial variability of SST – Precipitation relationship

The SST–precipitation relationship have different lead–lags over the Arabian Sea and the Bay of Bengal/South China Sea

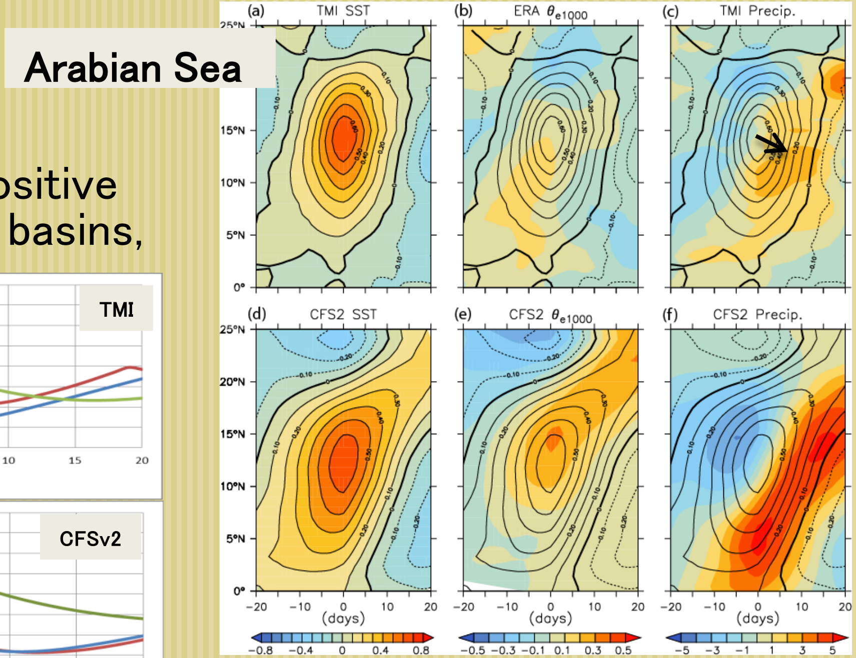


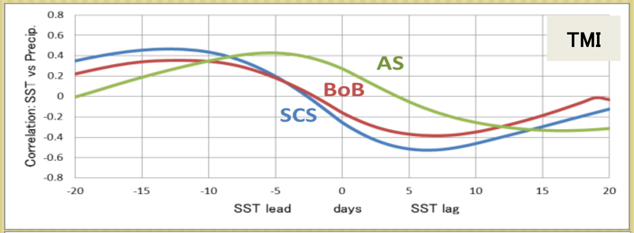
In CFSv2, correlation between SST & precip. is overestimated:

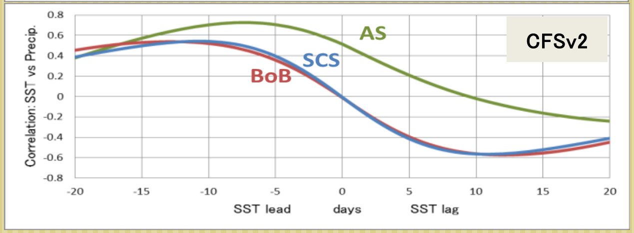
TMI r_{max}= 0.4
CFSv2 r_{max}= 0.7

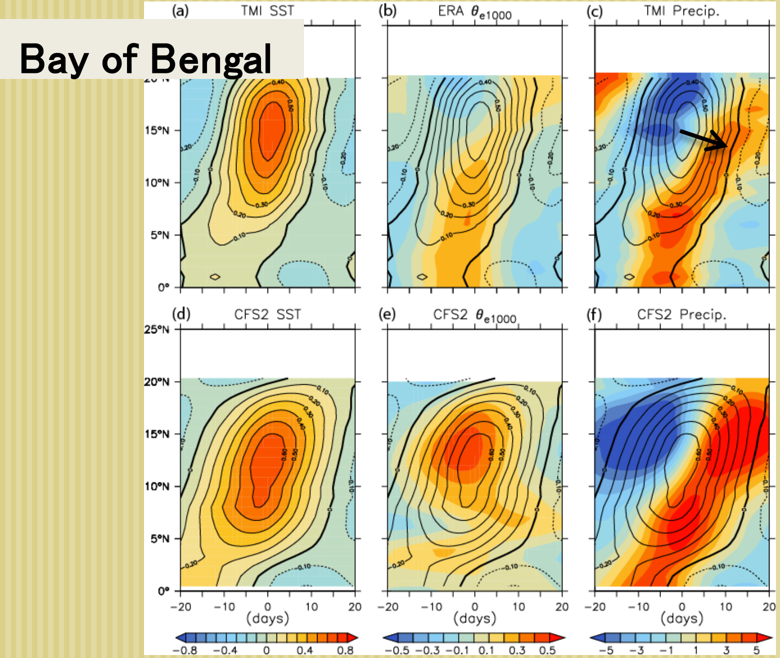
SST -> Precipitation

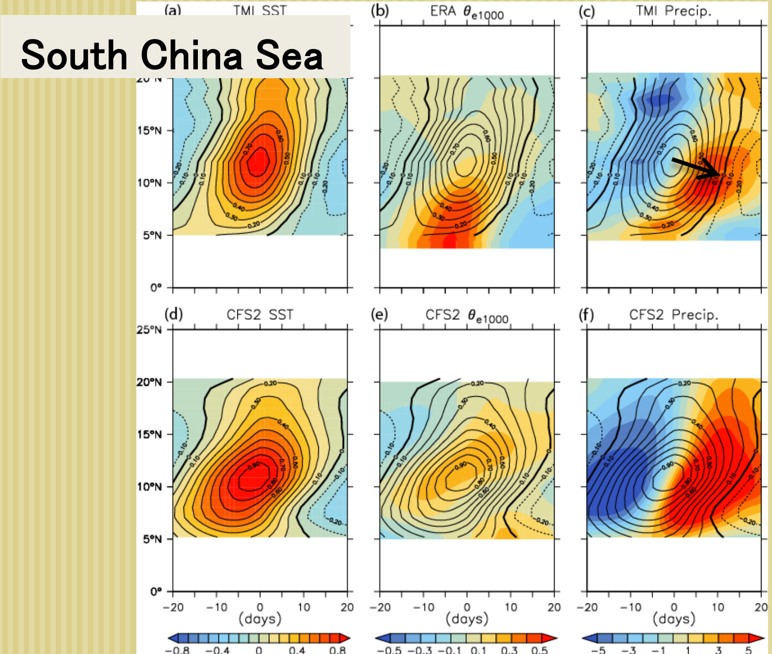
The positive SST anomalies translate to positive θ e anomalies instantaneously over all the basins, BUT the response in the precipitation anomalies is different.



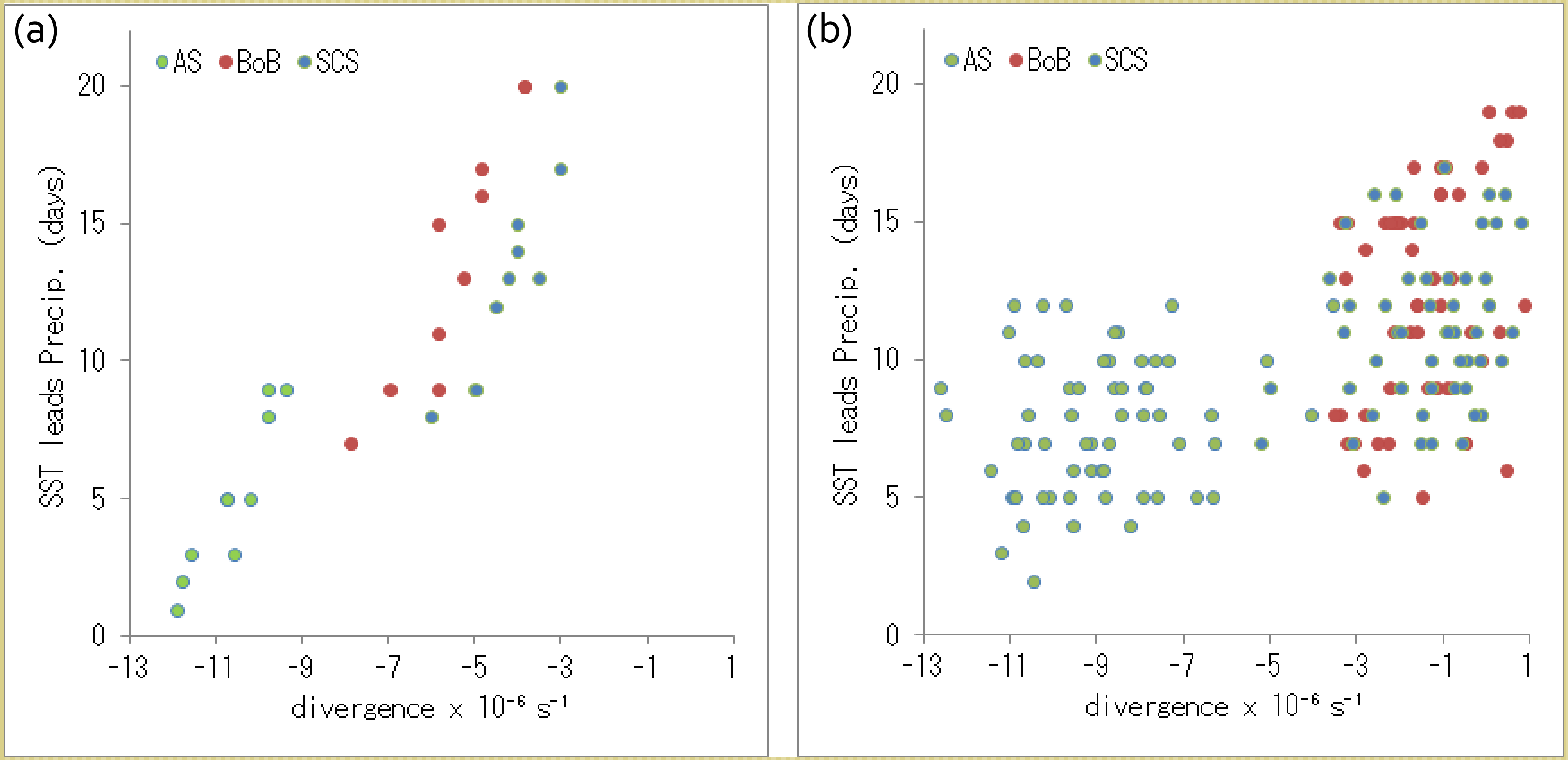








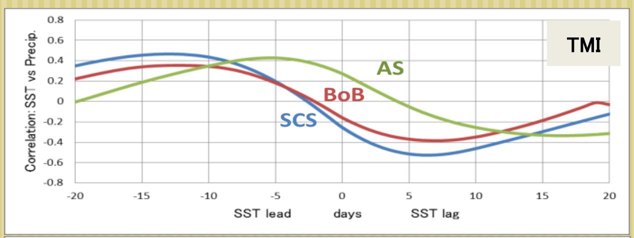
Spatial variability of SST – Precipitation relationship

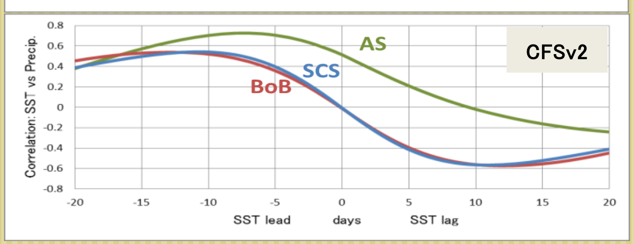


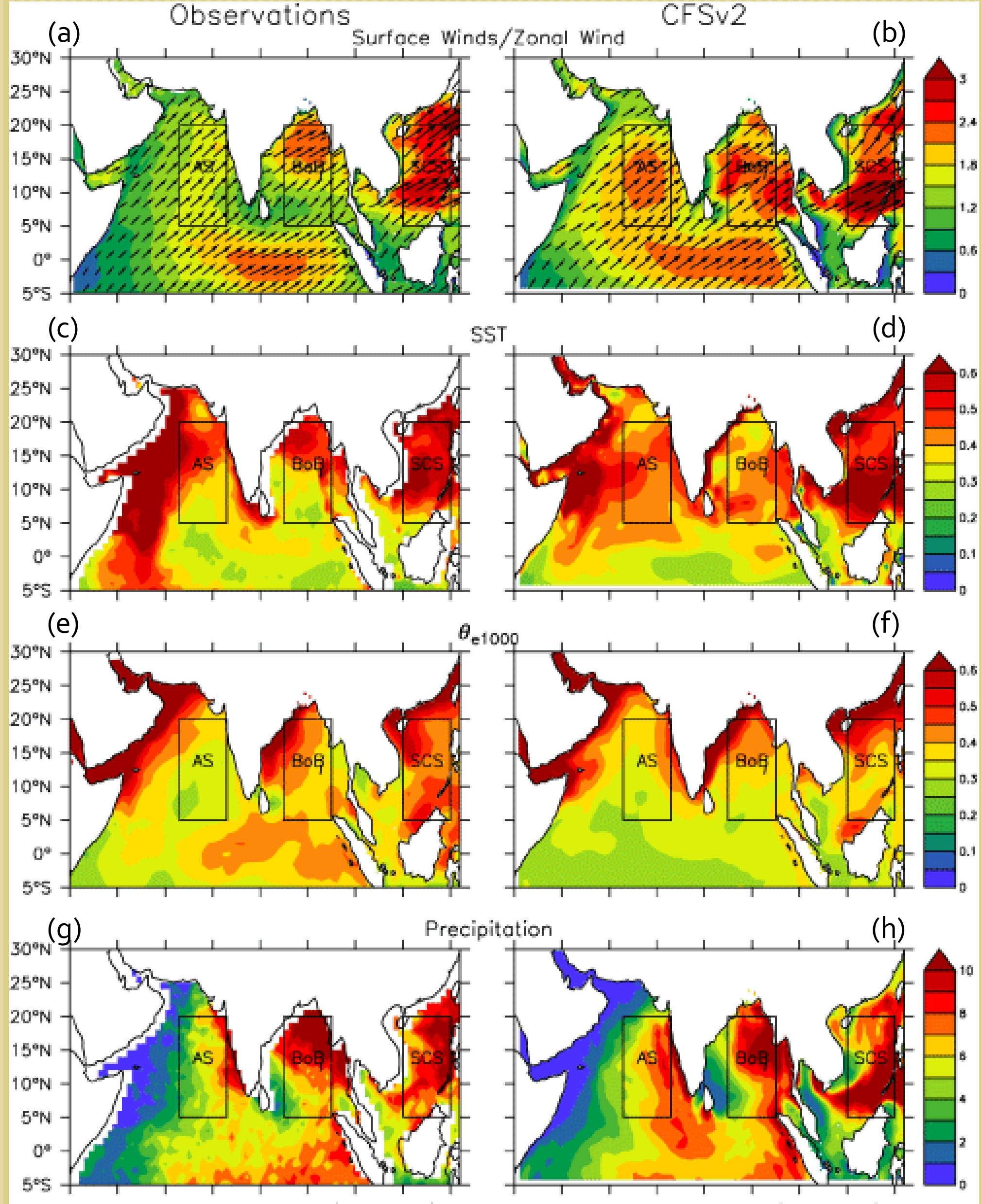
Relatively stronger surface convergence over the Arabian Sea
accelerates the uplift of the moist air,
resulting in a relatively faster response in the local precipitation anomalies

ISV of anomalies in Observations and CFSv2

ISV overestimated over the
n. Indian Ocean, esp. Arabian Sea







Overestimation of ISV in the CFSv2; model bias

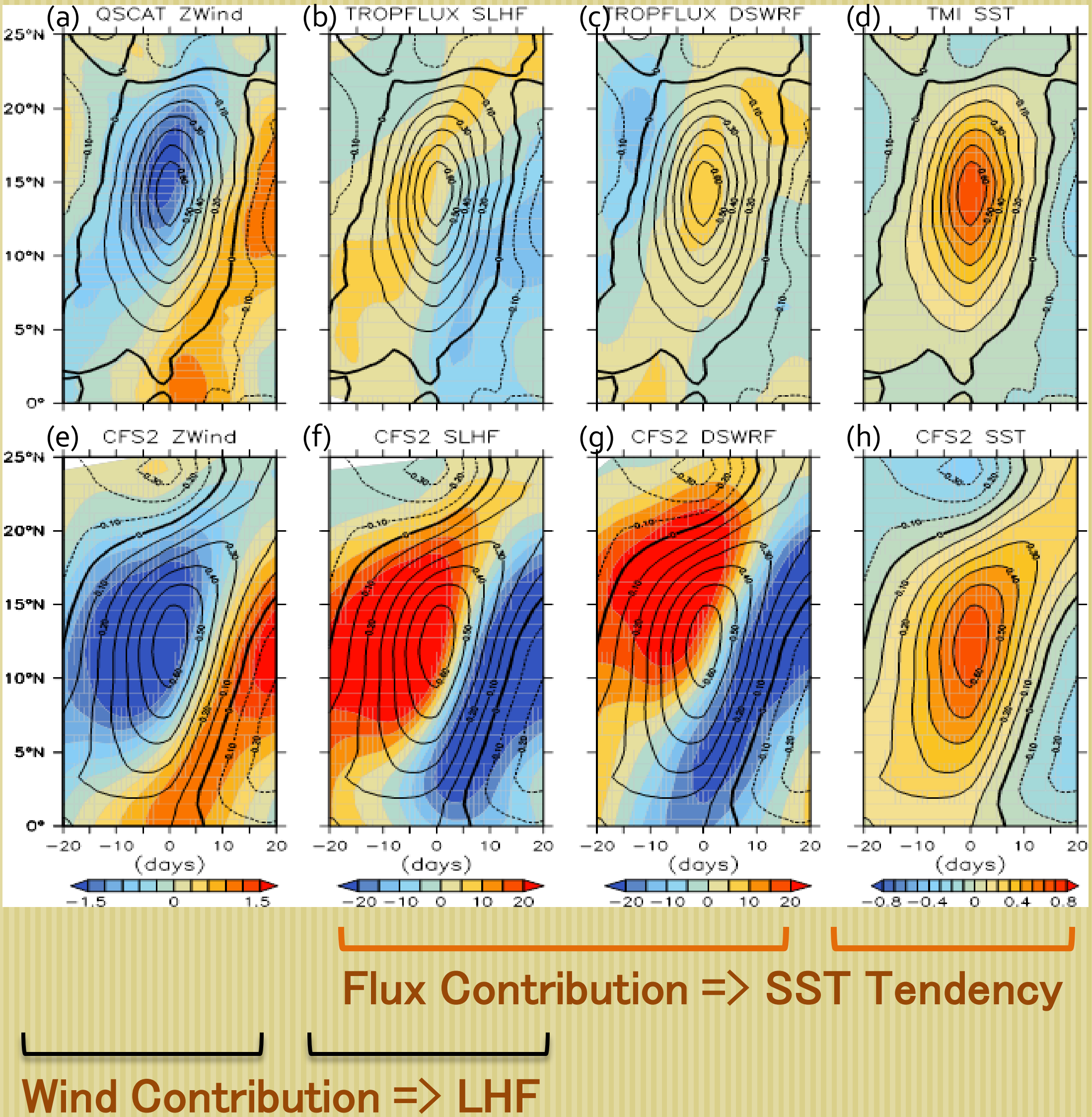
Is it due to coupling mismatch?

Flux Contribution => SST Tendency

The increased SST anomalies in the model are comparable to the simulated net surface flux anomalies, For 30 W m^{-2} (30m mld), dT = 0.025C day^{-1}.

Wind Contribution => LHF

Using the bulk aerodynamic equations, an overestimation of 1 m s^{-1} of wind speed is comparable to an increase of 14 W m^{-2} of latent heat flux anomalies, in the model.

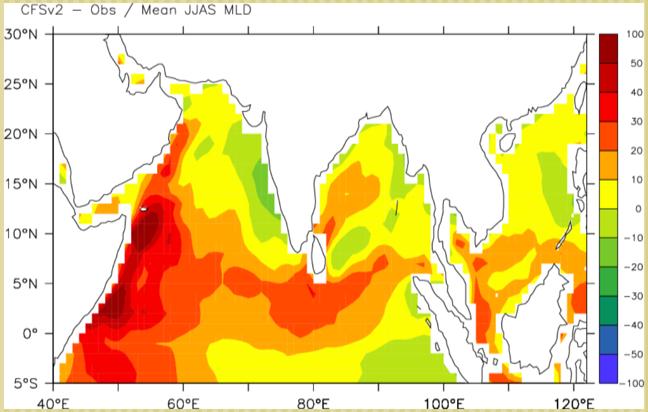


ISV of anomalies in Observations and CFSv2

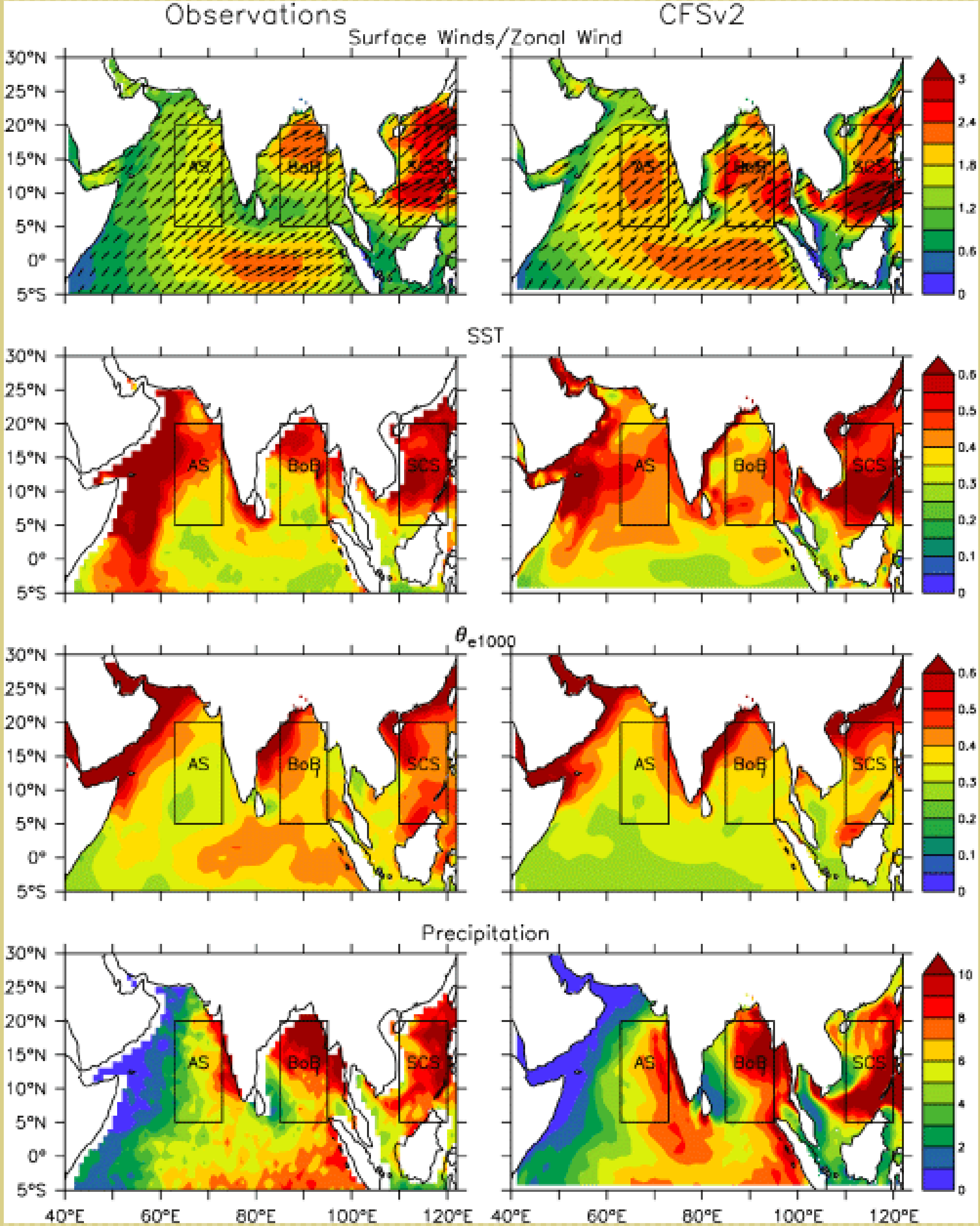
ISV overestimated over the n. Indian Ocean, esp. Arabian Sea

$$\frac{\partial T_s}{\partial t} = \frac{F_{tot}}{\rho c_p * \mathbf{MLD}}$$

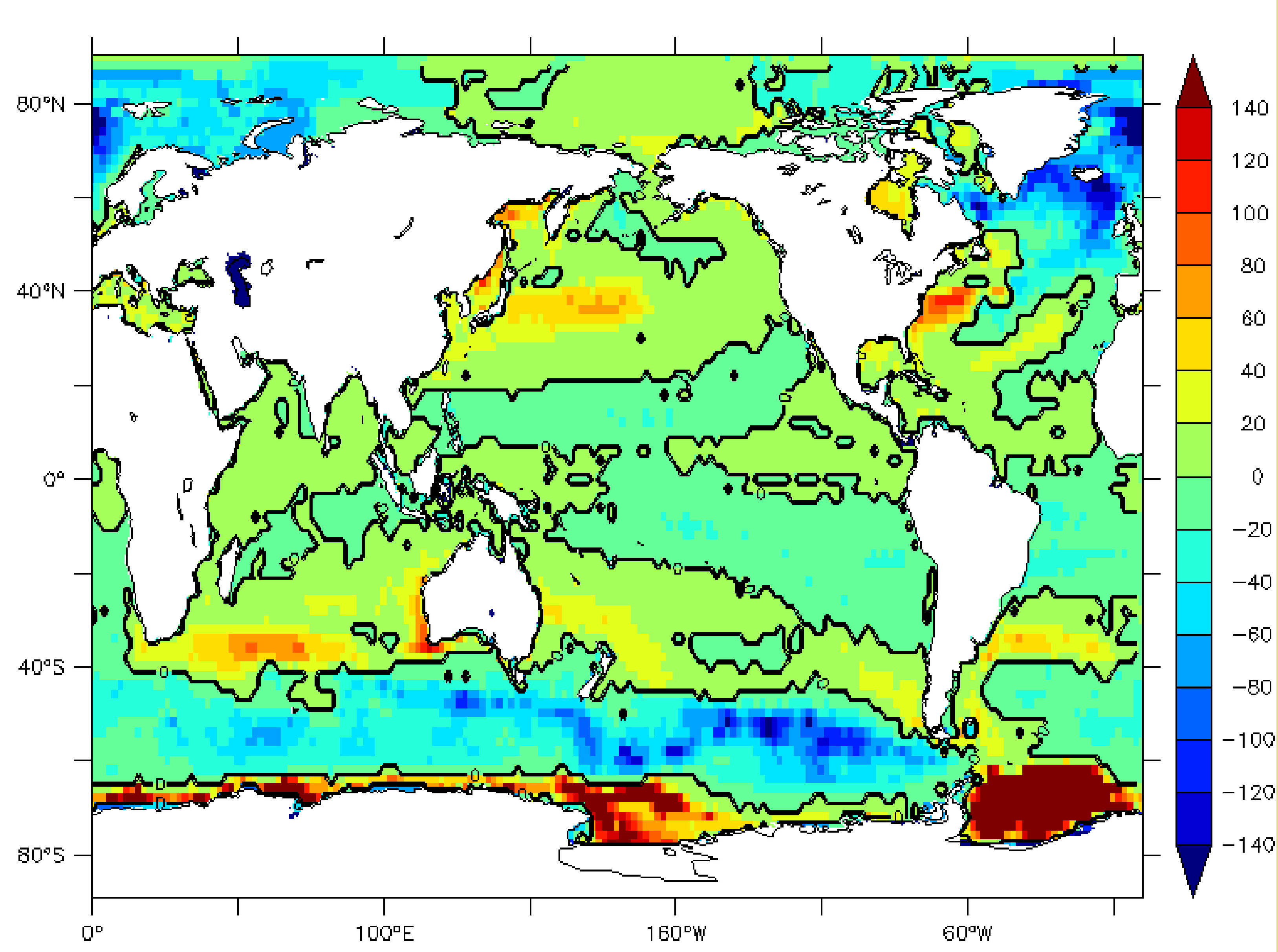
JJAS MLD Diff. [CFSv2 - Boyer]



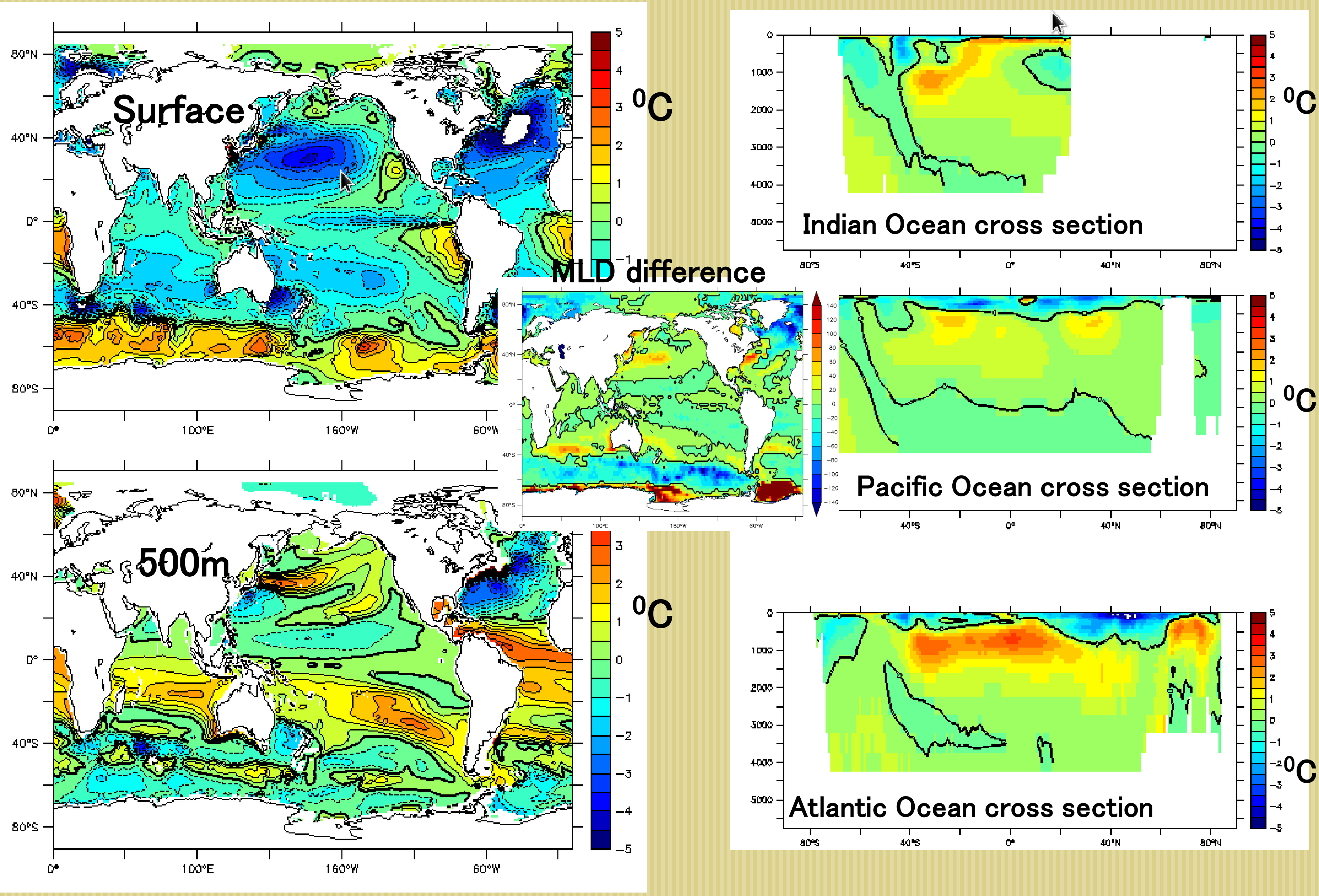
For the same magnitude of fluxes, change in SST is different:
Shallow MLD –> ISV amplified
Deep MLD –> ISV weakened
***r* = 0.5**, significant at 95% levels



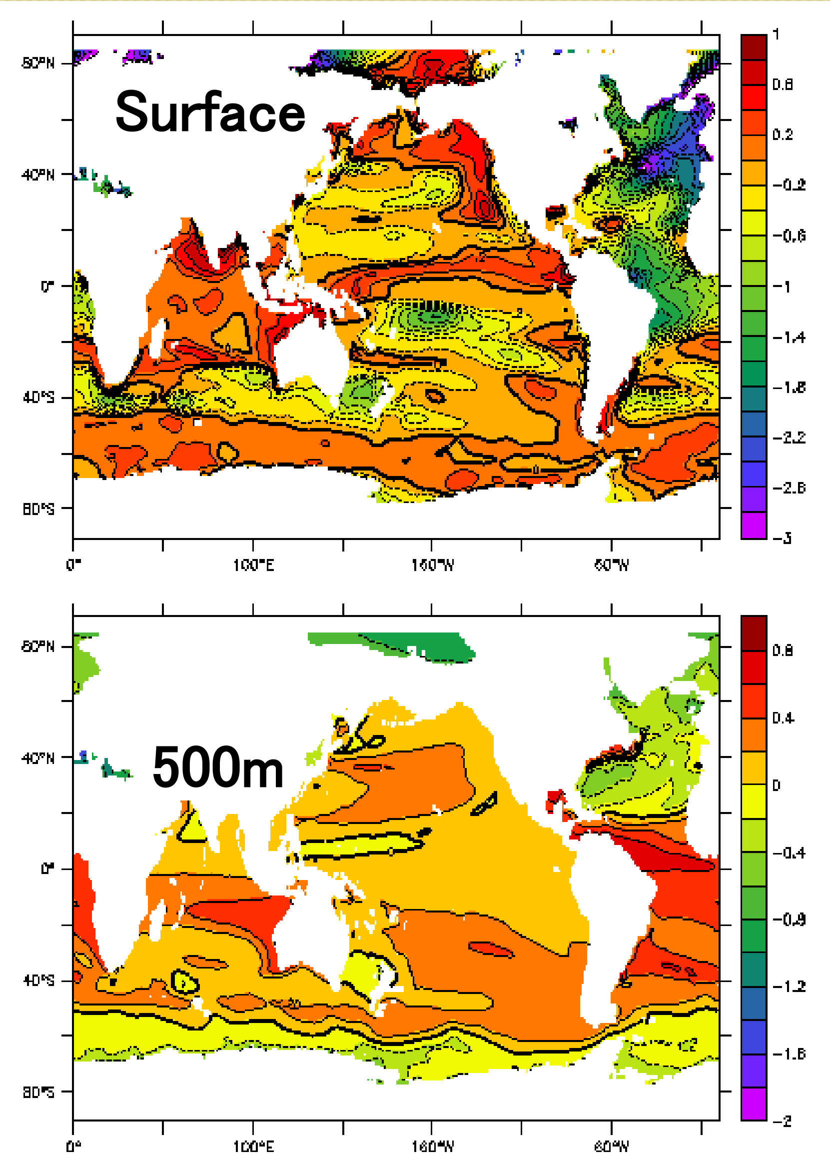
Annual mean MLD difference between model and observations.

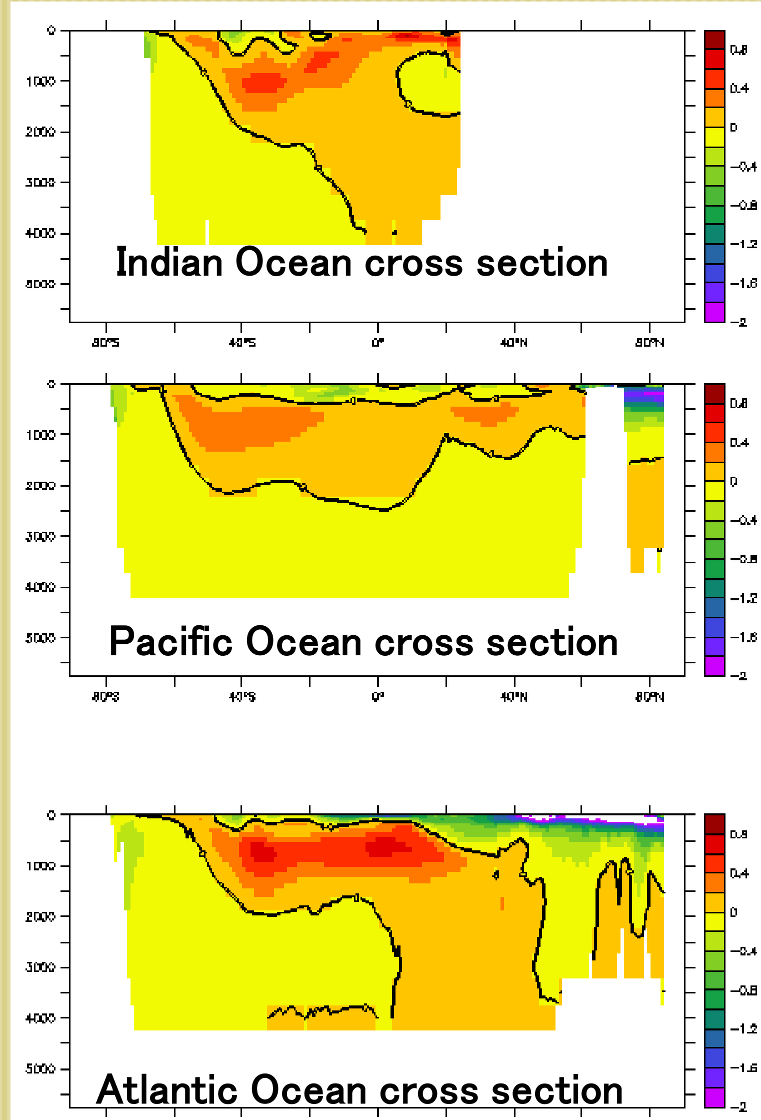


Annual mean **Temp difference** between model and observations (WOA02)



Annual mean Salinity difference between model and observations (WOA02)



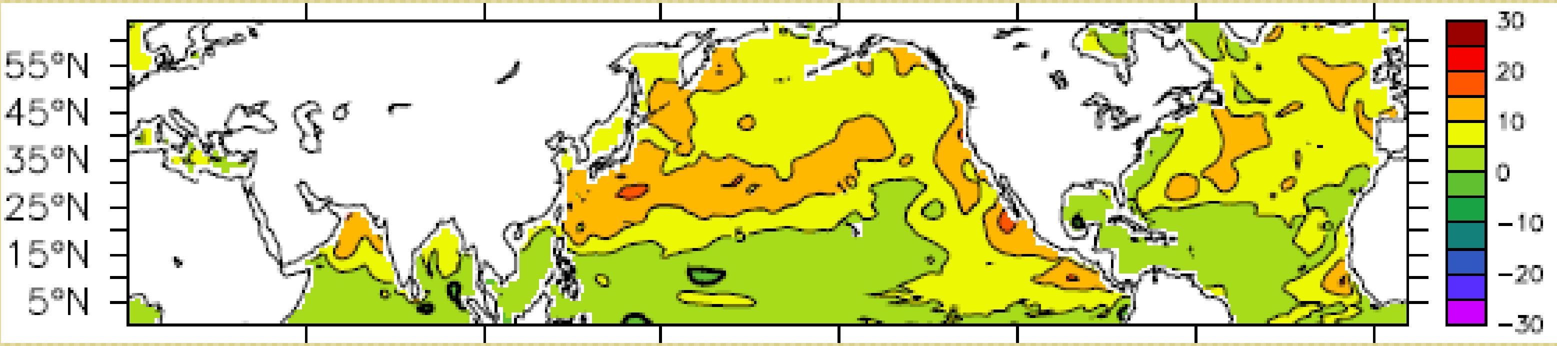


Surface waves could deliver mixing/turbulences to depth of the order of 100 m directly (Babanin et al. 2009).

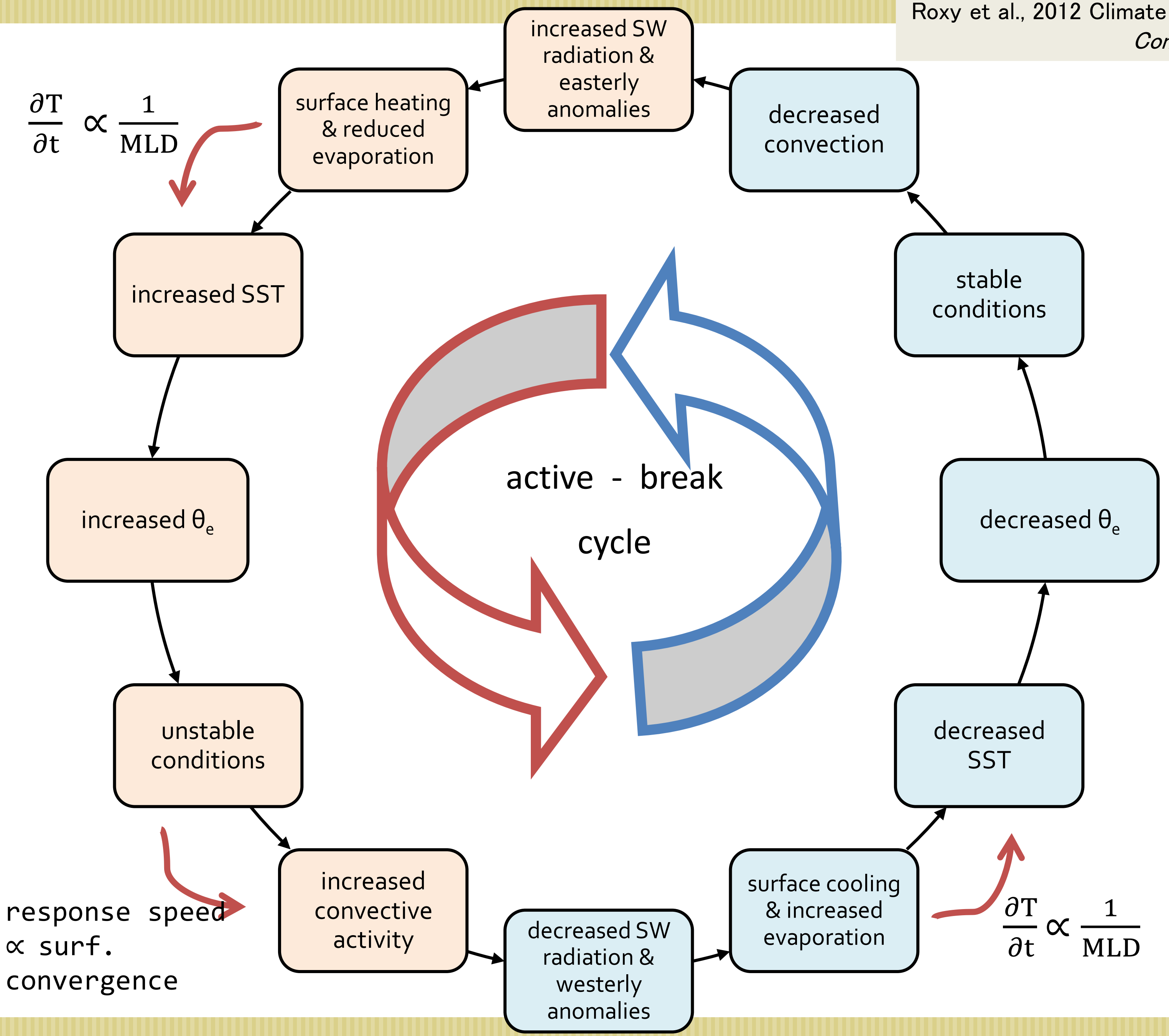
Some physical processes such as **Langmuir circulation and wave-induced vertical mixing** have not been properly included in the ocean component, which may be the main reasons for these biases. Langmuir circulation can induce vertical mixing and play an important role in deepening upper-ocean mixed layer (Li et al., 1995; McWilliams and Sullivan, 2000).

Besides Langmuir circulation and surface wave breaking, **nonbreaking surface waves** can also induce vertical mixing in the upper-ocean (Qiao et al., 2004; Dai et al., 2010).

Shu et al 2011, MLD diff. in July, with/without wave induced surface mixing



Roxy et al., 2012 Climate Dynamics
Communicated



Response to CO_2 in CFSv2