The Diurnal Variability of Upper Ocean Structure during the Suppressed Phase of MJO

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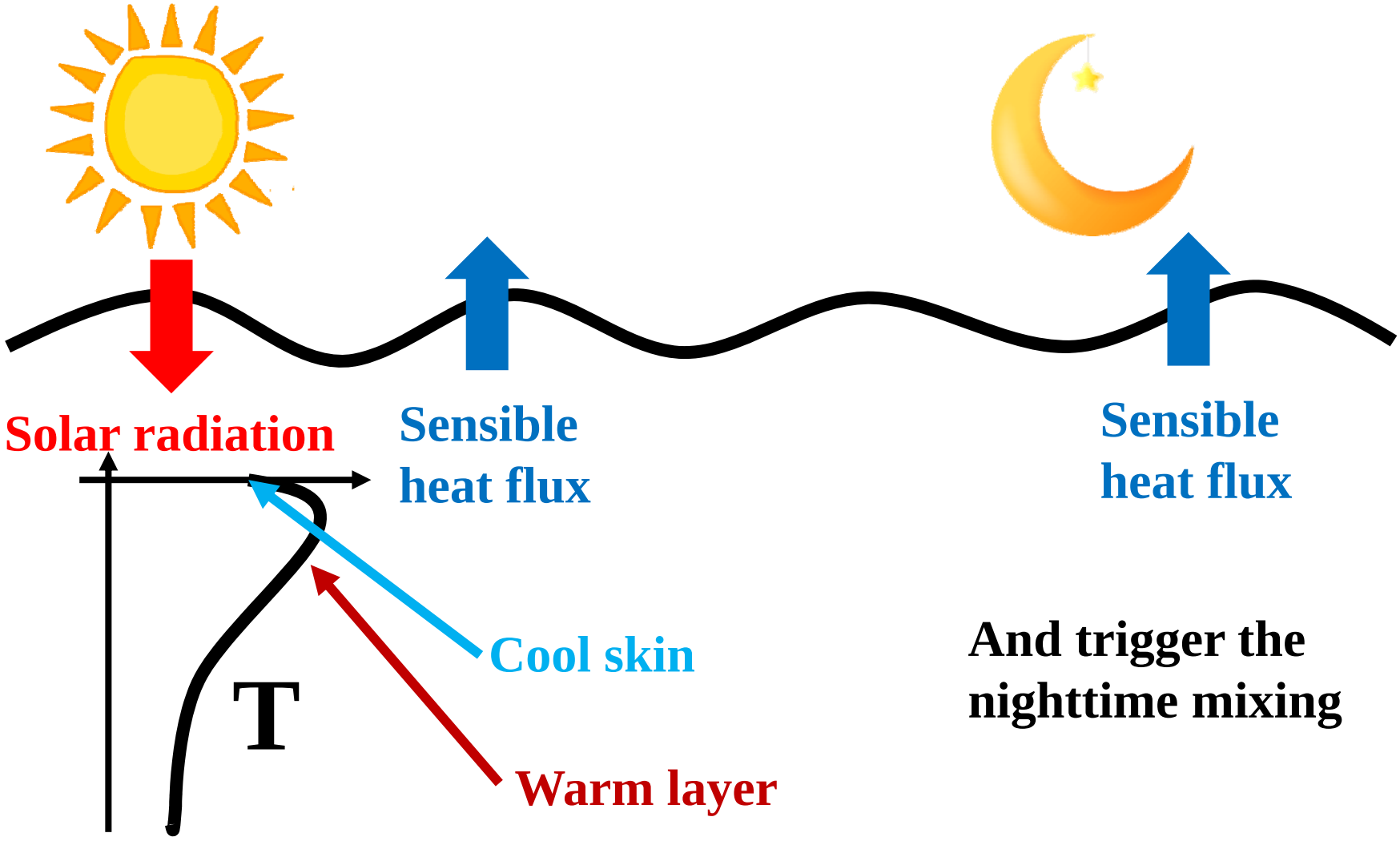
Outline

1. Introduction of diurnal variability (DV) of SST
2. The Suppressed Phase of Three MJO events
3. ACCESS-S1 Coupled model
4. MTSAT-1R satellite SST
5. Factors to the DV SST
6. Effects of DV SST
7. Conclusion

Introduction of Diurnal Variability (DV)



And trigger the nighttime mixing

Importance of DV SST

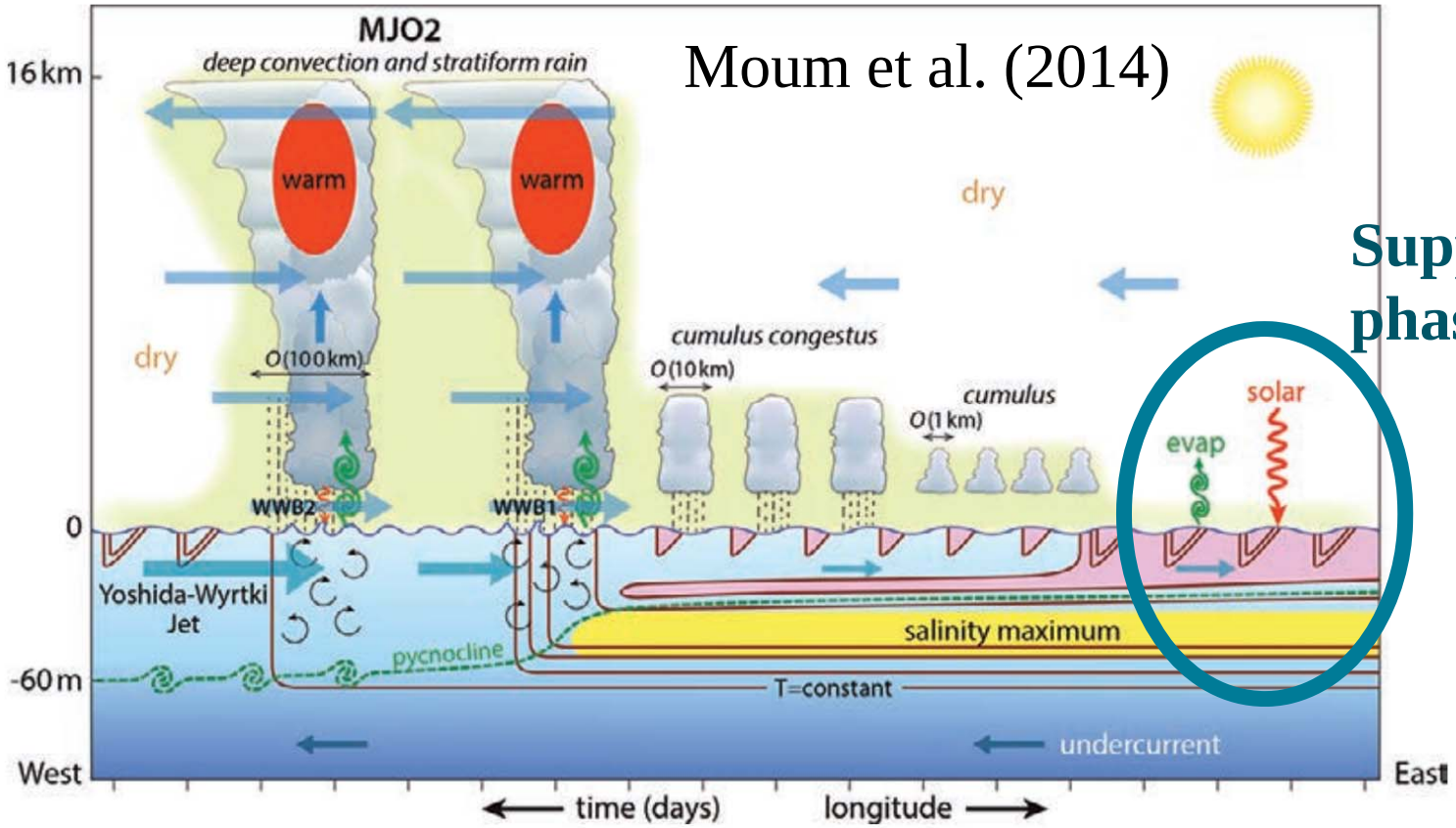
1. Stronger DV SST leads to higher daily-mean SST (Seo et al. 2014)

2. Stronger DV SST will have more precipitation during the MJO (Bernie et al. 2008).

3. Without the DV SST in the coupled models, surface air temperature, pressure and precipitation over the oceans weaker than the measurements (Dai and Trenberth 2004).

4. During the suppressed phase of MJO, strong DV SST may lead to the shallow cloud, unlike the deep convection during the active phase of MJO (e.g., Chen and Houze, 1997; Johnson et al.,1999).

Why interested in the Suppressed Phase



Moum et al. (2014)

Suppressed phase

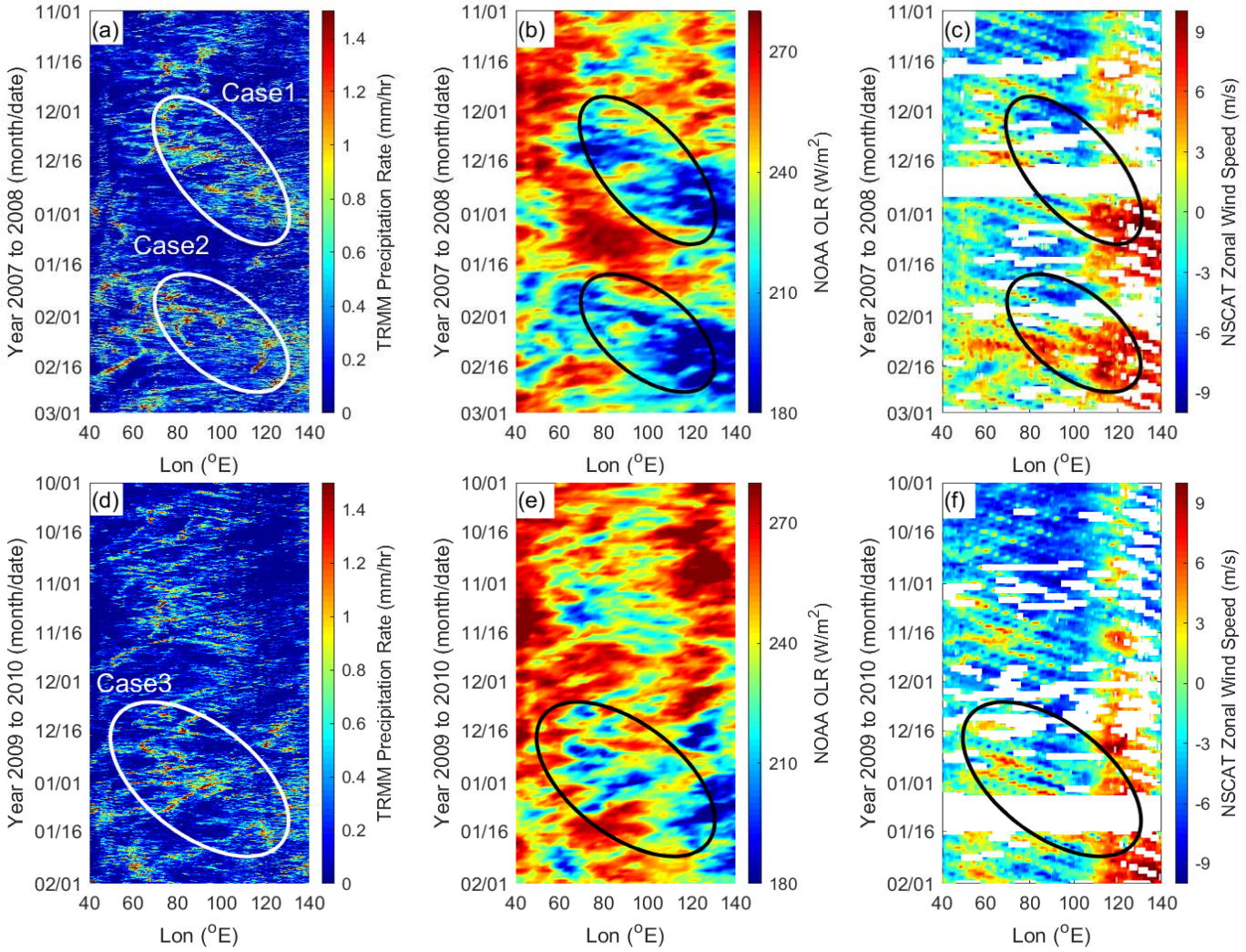
The accumulation of moisture or moist static energy (MSE) during the suppressed phase is crucial to the development of MJO.

Three MJO Events

Averaged from 20 °S to equator

Case1:
Dec 2007
Case2:
Jan 2008
Case3:
Dec 2009

Focus on the region of
Lon=105-125 °E;
Lat=20-10°S



ACCESS-S1 Coupled Model

1. Atmosphere-land-ocean-ice global coupled model, developed by UK Met Office

2. The NEMO model dz = 1 m at depth z < 5 m and dz ~ 2 m at z = 5-20 m.

3. The setting of coupling frequency in the model is 1 hr.

4. Initialisation:
   Atmosphere: ECMWF ERA-interim
   Ocean: NEMOVAR model and in-situ data

5. Six ensemble members

MTSAT-1R SSTs

1. An infrared satellite launched by Japan Aerospace Exploration Agency (JAXA).

2. Horizontal resolution: 5 km. Temporal resolution: 1 hr

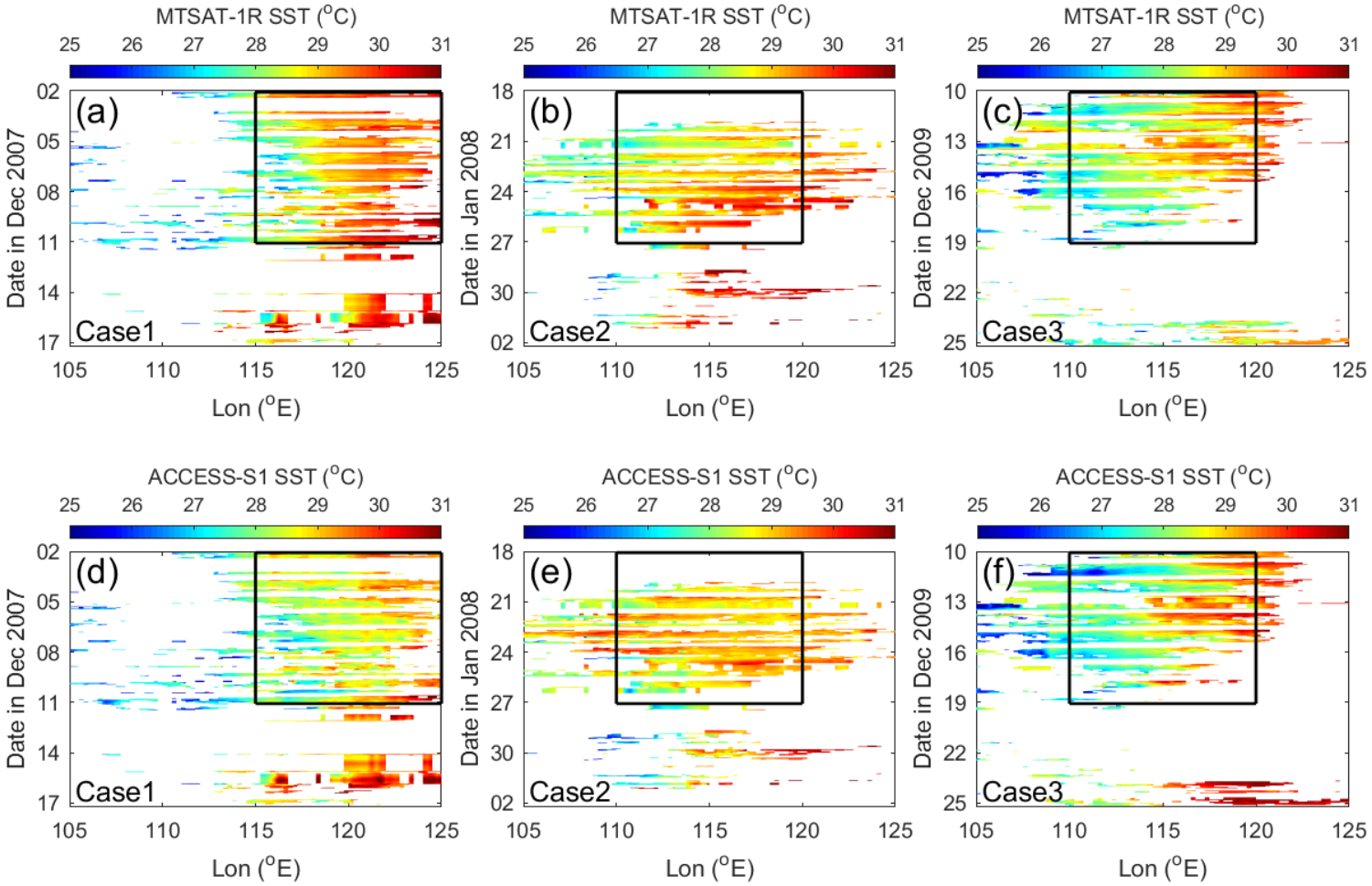
3. Several studies have used the MTSAT-1R SSTs to discuss the DV SST in the tropical warm pool (e.g., Zhang et al. 2016).

4. The iQuam data set is used to validate and correct the MTSAT-1R SSTs due to the uncertainty varying in time.

5. Six ensemble members for each case are simulated and averaged.

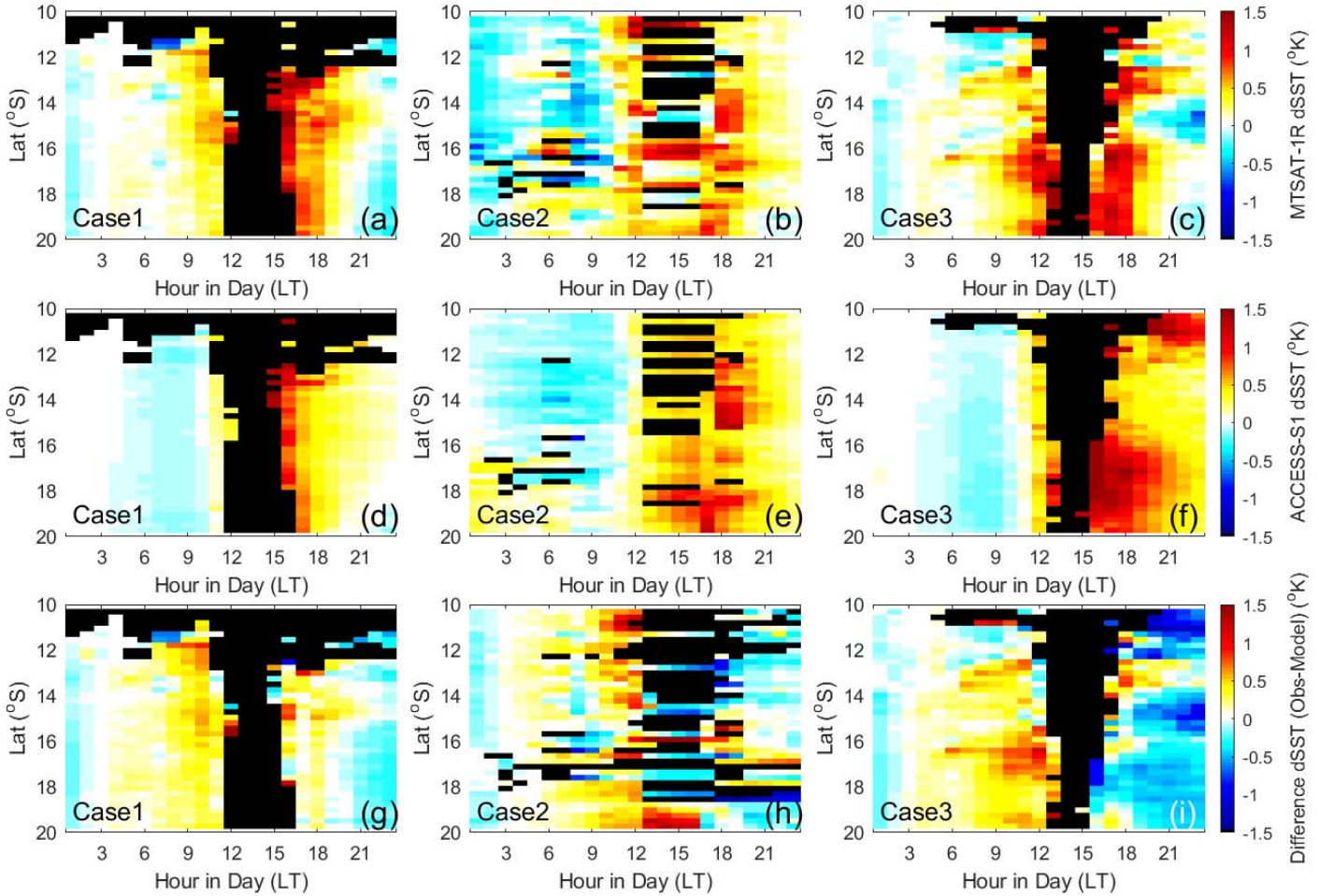
MTSAT-1R vs. ACCESS-S1 SSTs

Model results with no observations are excluded. The plot averaged along each longitude from 20 to 10 °S



Comparison of DV SST

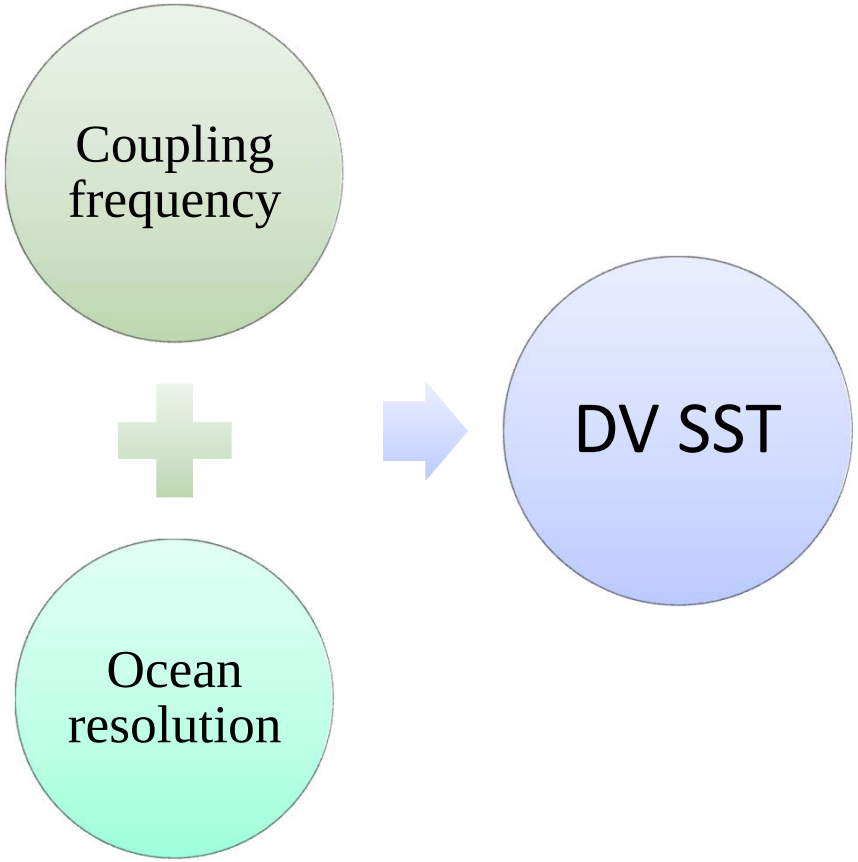
- dSST = SST(t) – SST_{fnd}, where SST_{fnd} is $\overline{SST(12-4\ am)}$
- The observed dSST > simulated dSST in the morning, but smaller after 4 pm.



Simulations of DV SST

Bernie et al. (2005): Simulation with coupling frequency (CF) < 3 h and upper ocean vertical resolution of 1 m can capture 90% DV SST

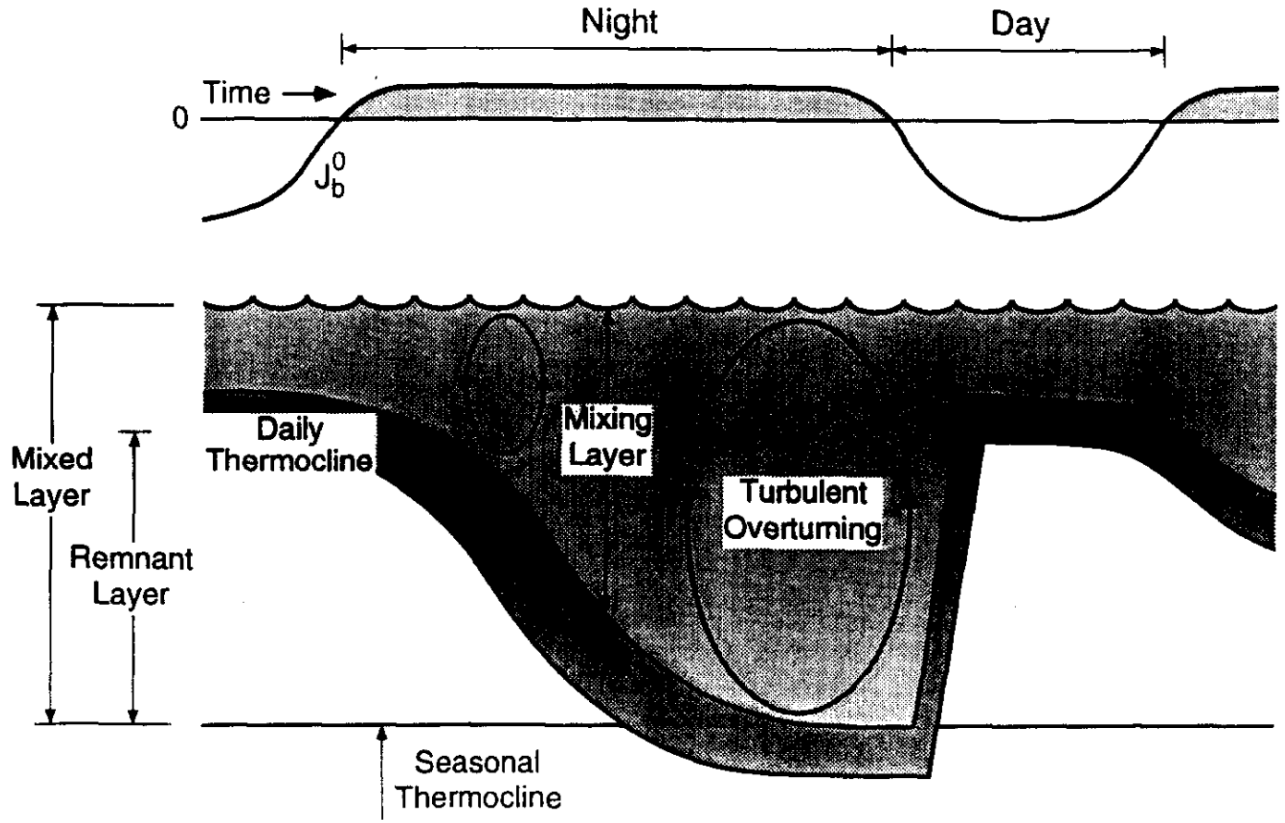
Associated with air-sea net heat fluxes



Associated with thermal stratification and vertical mixing

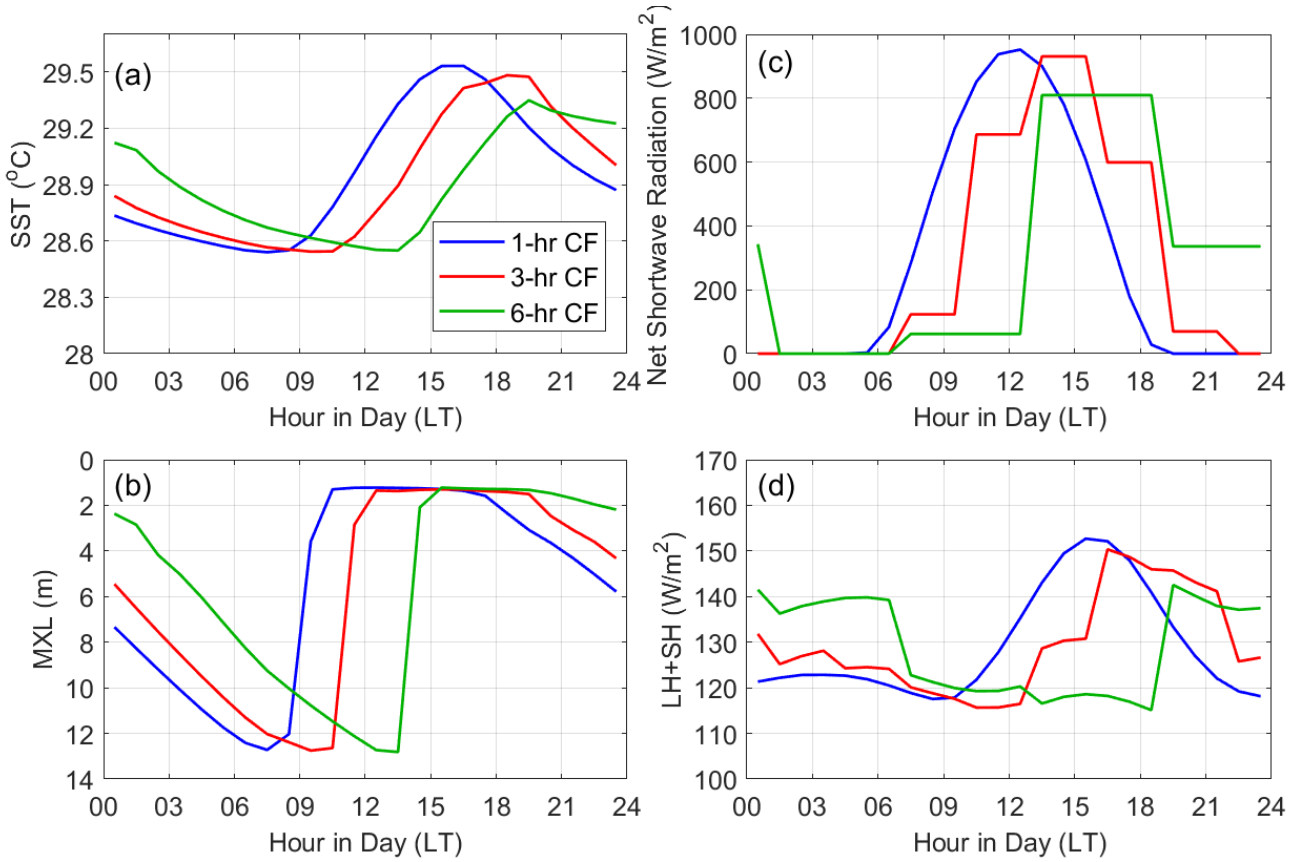
Ocean Mixing Layer (MXL)

Brainerd and Gregg (1995) define **mixing layer (MXL)** as the depth zone being actively mixed from the surface, which there is strong turbulence directly driven by surface forcing



Different coupling frequency (CF)

- 1-hr CF has similar magnitude of DV SST but different phase, presumably due to similar integrated net-heat flux
- The DV SST phase will then affect the phase of (LH+SH)
- The parameterization of shortwave radiation at CF < 3 h is reliable because of similar DV SST magnitude

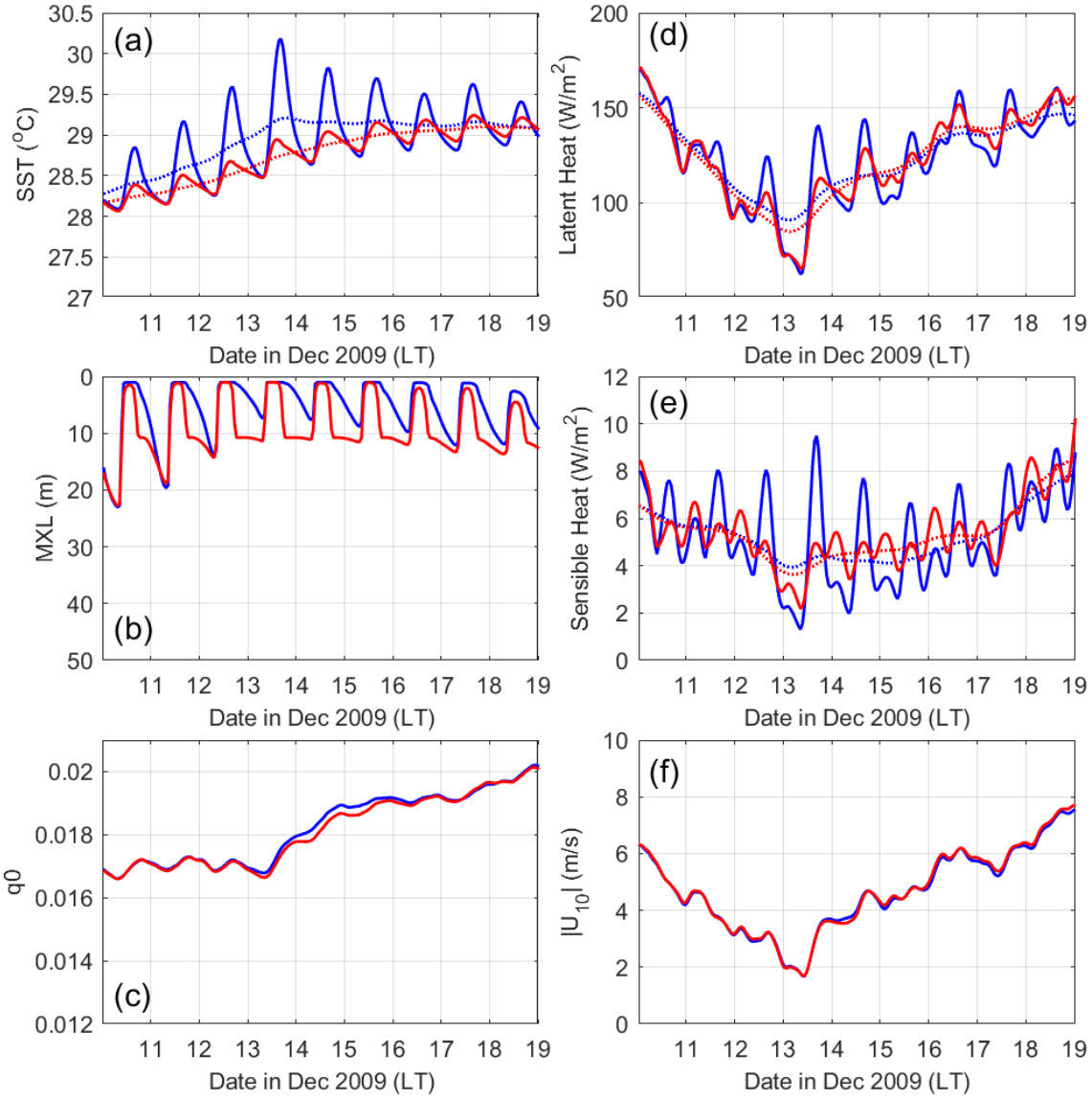


Upper 10-m Mixed Ocean Simulations

EXP: 1-hr CF

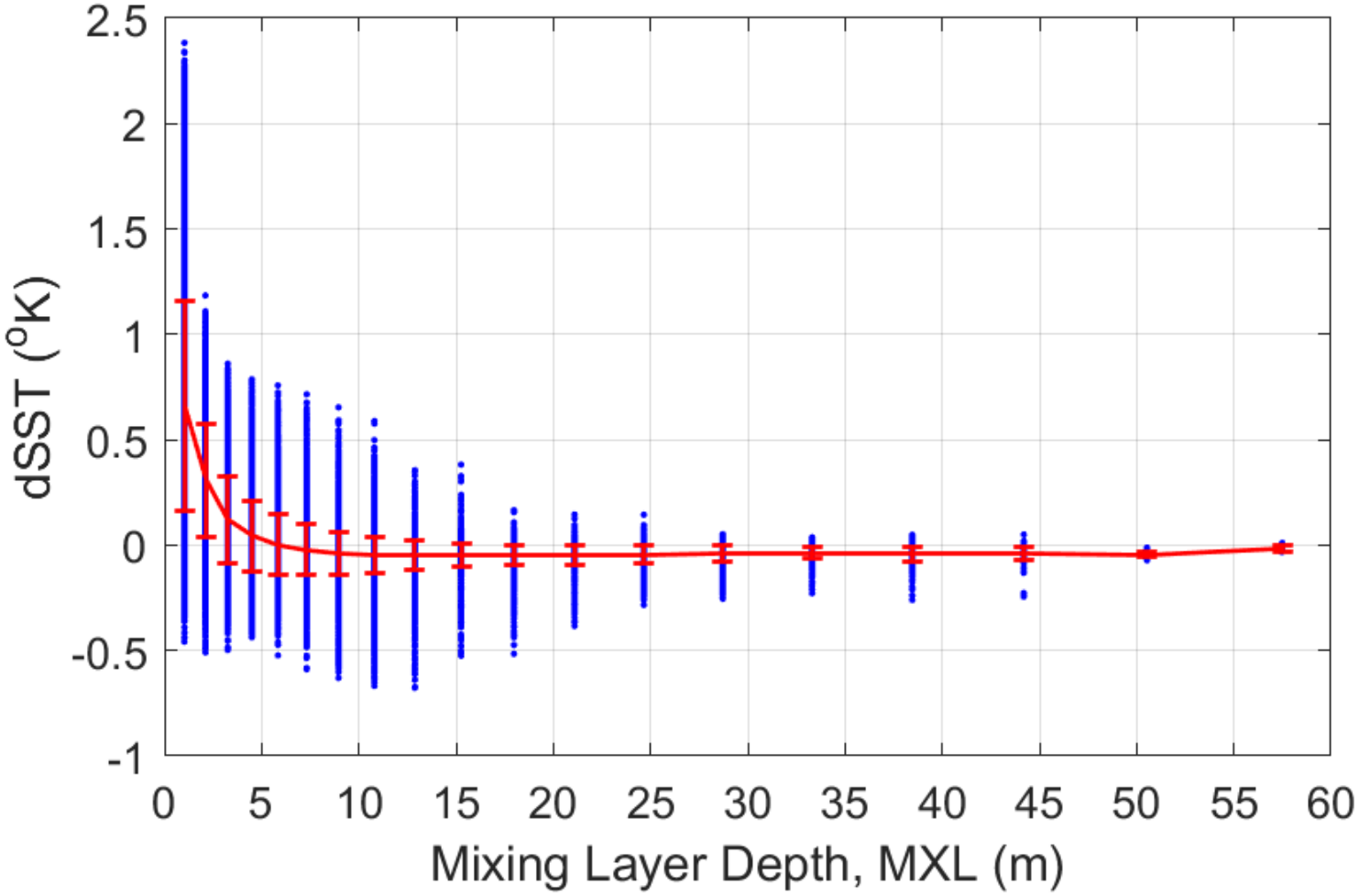
CTL: artificially mixed the upper 10 m ocean

- CTL has much smaller DV SST due to deeper MXL
- It greatly affects the LH and SH
- The moisture near ocean surface affected after strongest DV SST



Dependence of dSST on MXL

Using the model results of dSST and MXL in 1-hr CF



Short Summary

1. The ACCESS-S1 model predicts the magnitude of DV SST reliably, but the phase of DV SST is ~ 3h later than the observations

2. The CF < 3 h in the model can still simulate the reliable magnitude of DV SST

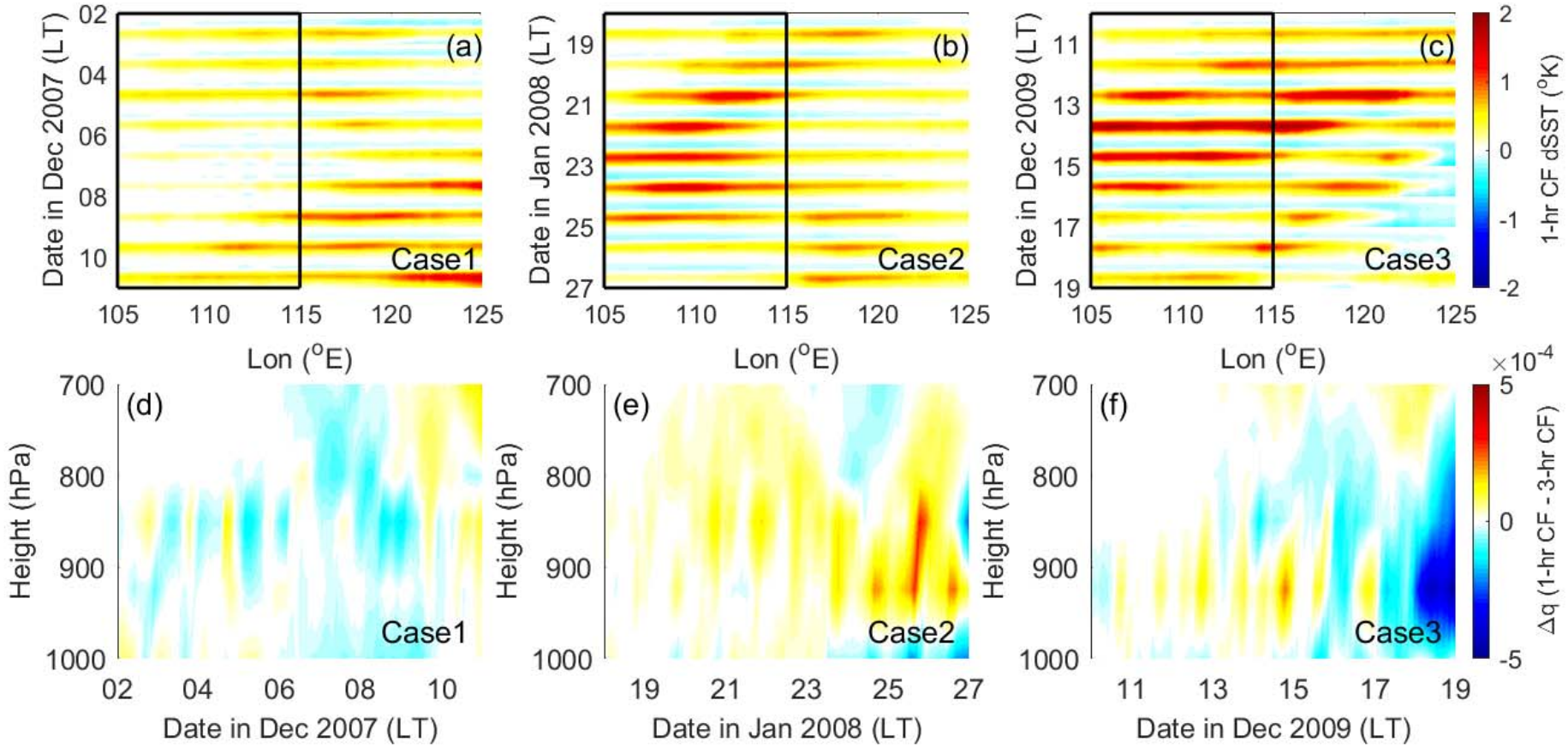
3. The vertical resolution or the mixing in the upper ocean affects the DV SST much more than the CF of several hours

4. The dSST > 1 °K happens only when MXL ~ 1 m.

5. The unsuccessful prediction on the DV SST phase may be due to the vertical mixing in the upper ocean.

Effects of DV SST Phase to Moisture

Compare the difference of specific humidity in the lower troposphere with the studied region, Δ=1-hr CF – 3-hr CF.



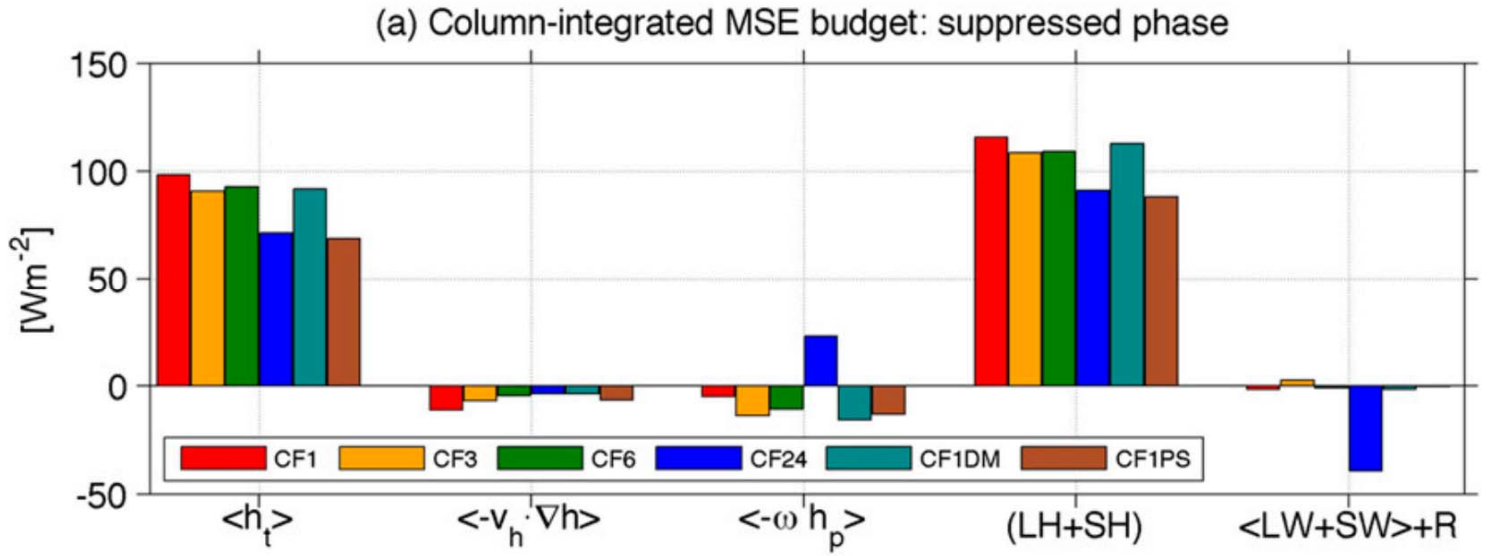
Moist Static Energy (MSE) Budget

$$\left\langle \frac{\partial h}{\partial t} \right\rangle = \langle -v_h \nabla h \rangle + \left\langle -\omega \frac{\partial h}{\partial p} \right\rangle + (LH + SH) + \langle LW + SW \rangle + R$$

h = $c_p T$ + gz +Lq: moist static energy. c_p the specific heat, LW long wave heating rate and SW shortwave heating rate

Seo et al. (2014):

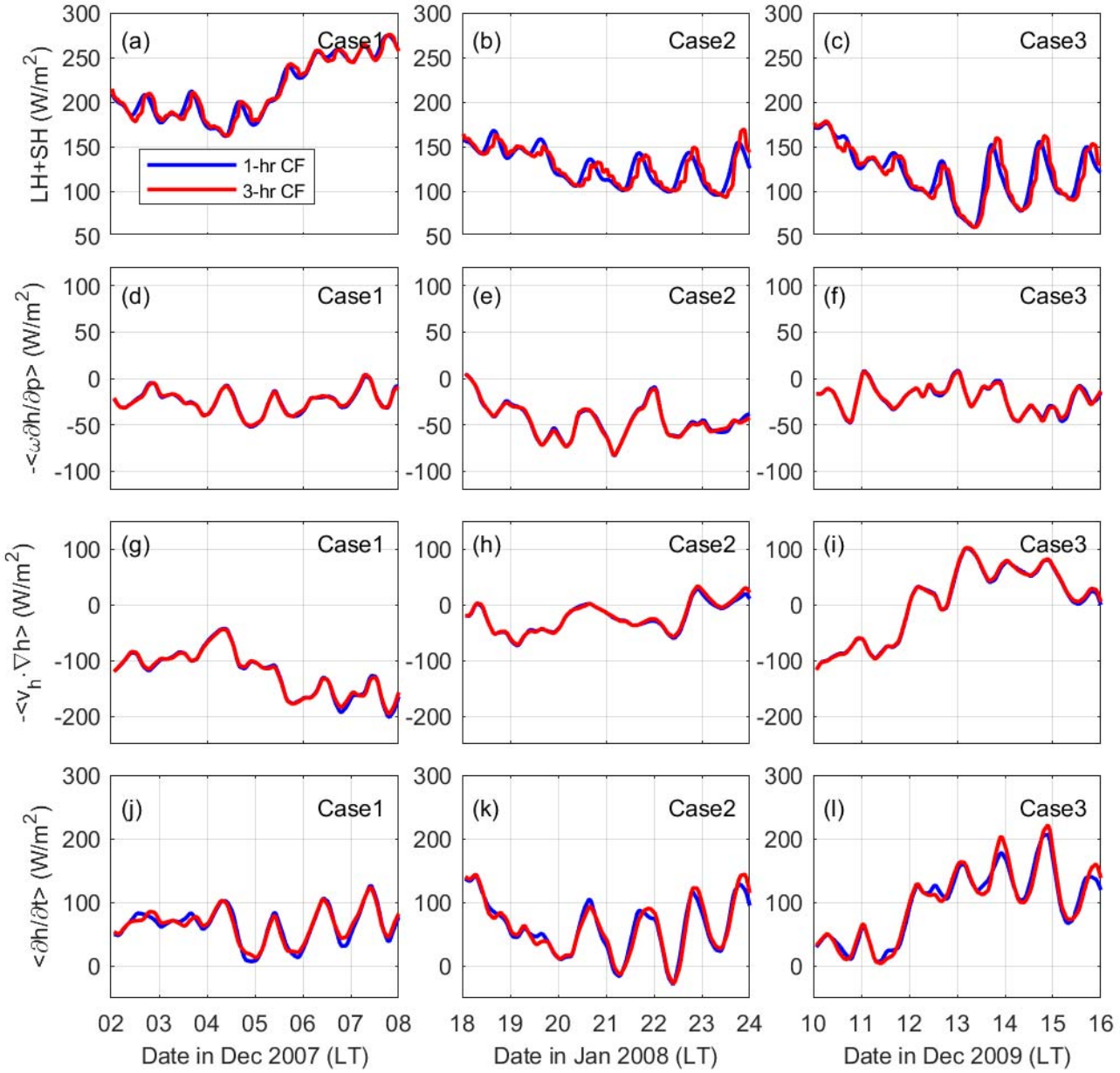
The integration of $\langle LW + SW \rangle + R$ from 1000 to 100 hPa is negligible compared to other terms in the DV studies



MSE Budget of 1-hr and 3-hr CF

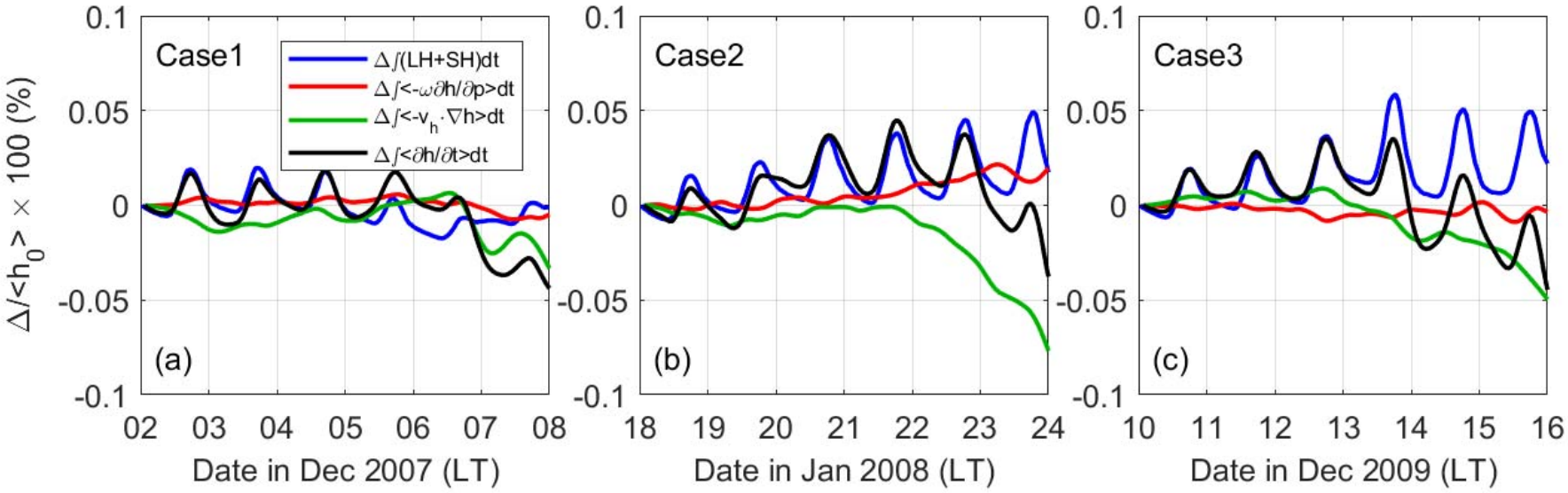
1-hr CF (blue)
3-hr CF (red)

- The (LH+SH) is the most dominant term in the MSE budget
- The DV SST mainly affects the (LH+SH) in the MSE budget



Time-integrated MSE

Integrate the terms in the MSE with the time, and compare the difference.



- $\Delta \int \langle h_t \rangle dt$ in Case2 and Case3 larger than the Case1 at the first few days.
- Positive Δq in the lower troposphere during the strong DV SST may be due to MSE, i.e., affected by the (LH+SH)

Short Summary on DV SST Phase

- The phase of DV SST will affect the moisture in the lower troposphere during the suppressed phase of MJO
- The moisture difference may be due to the change of (LH+SH) phase in the MSE budget

Thanks for your listening~~~!!!

Q&A time