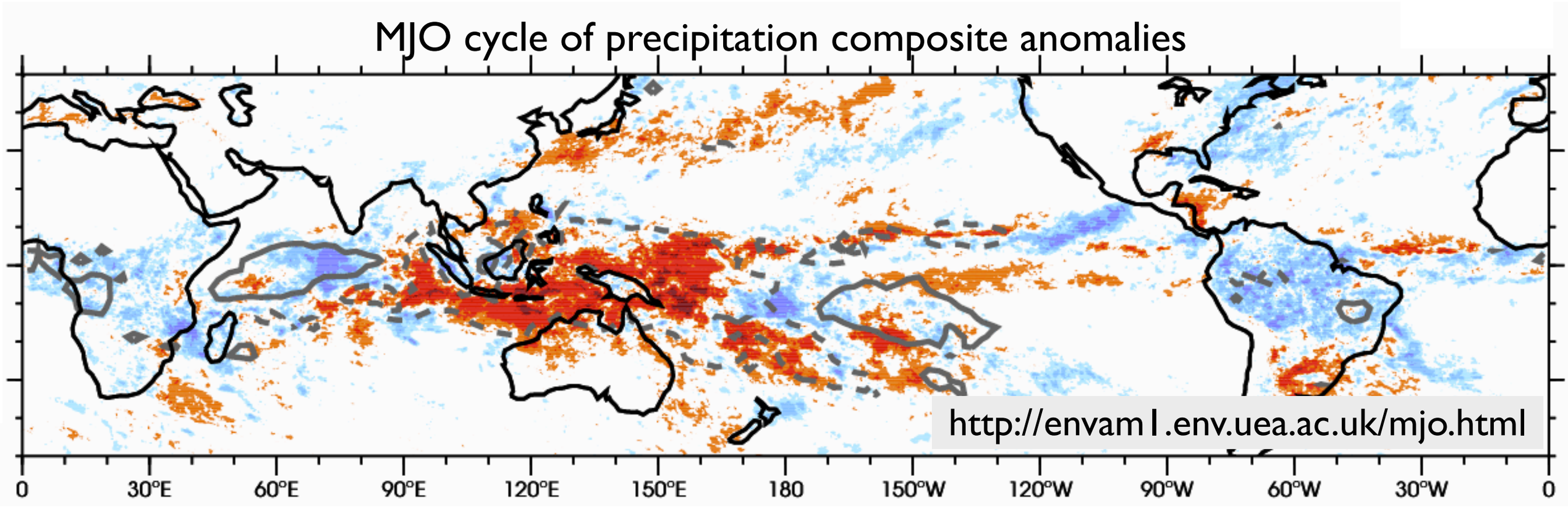
Coupled impacts of the diurnal cycle of sea surface temperature on the Madden-Julian Oscillation



- Planetary-scale, eastward propagating, equatorially-trapped, baroclinic oscillations
- 30-90 day variability & 10-30 day predictability time-scale.
- Global importance in weather and climate
- A coupled ocean-atmosphere process

Hyodae Seo
Woods Hole
Oceanographic Institution

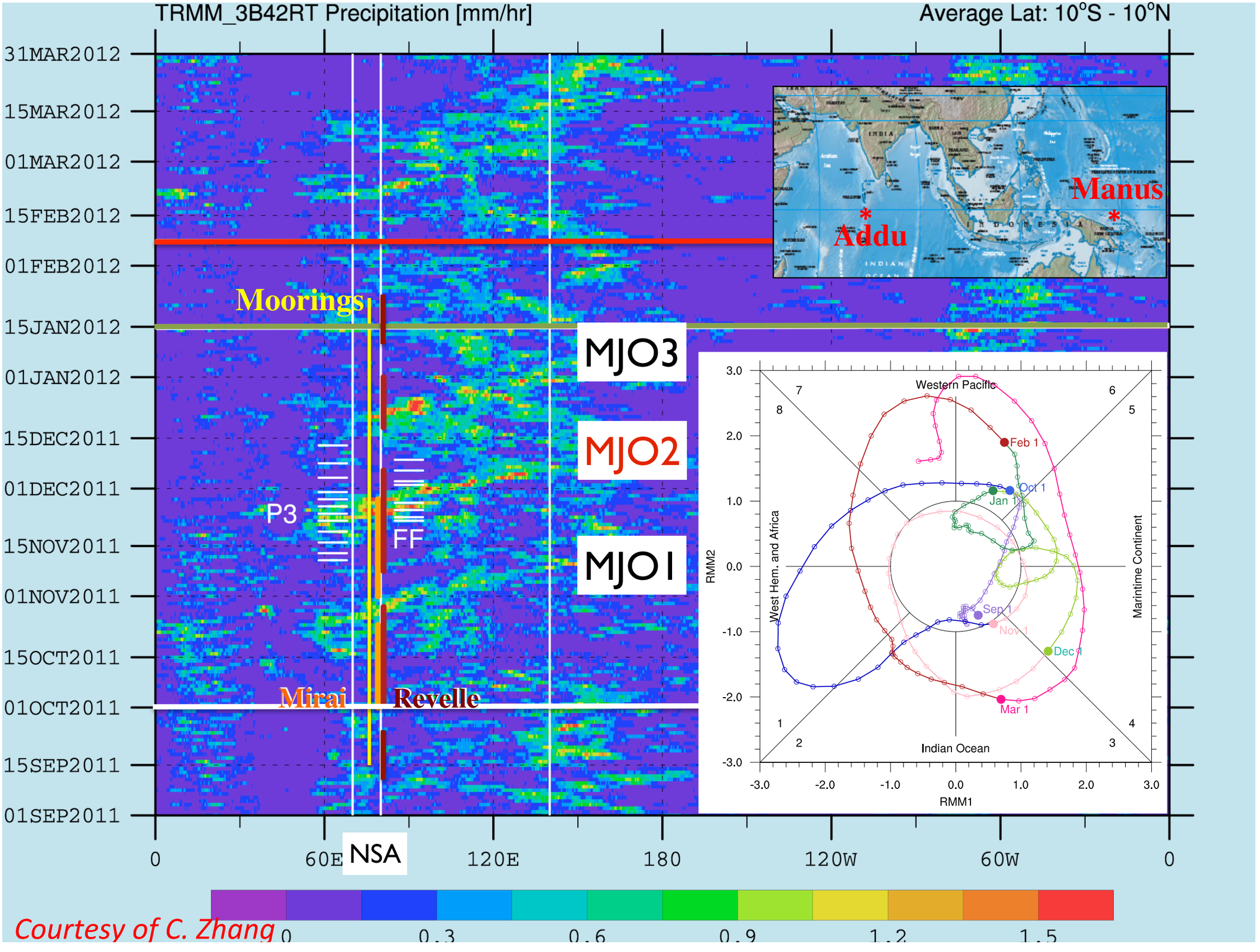
RSM Workshop
Yokohama, Japan
Nov. 27 2014

DYNAMO experiment (Dynamics of MJO):

Initiation/Intensity of MJO convection ↔ Upper-ocean variability and air-sea flux

Chidong Zhang

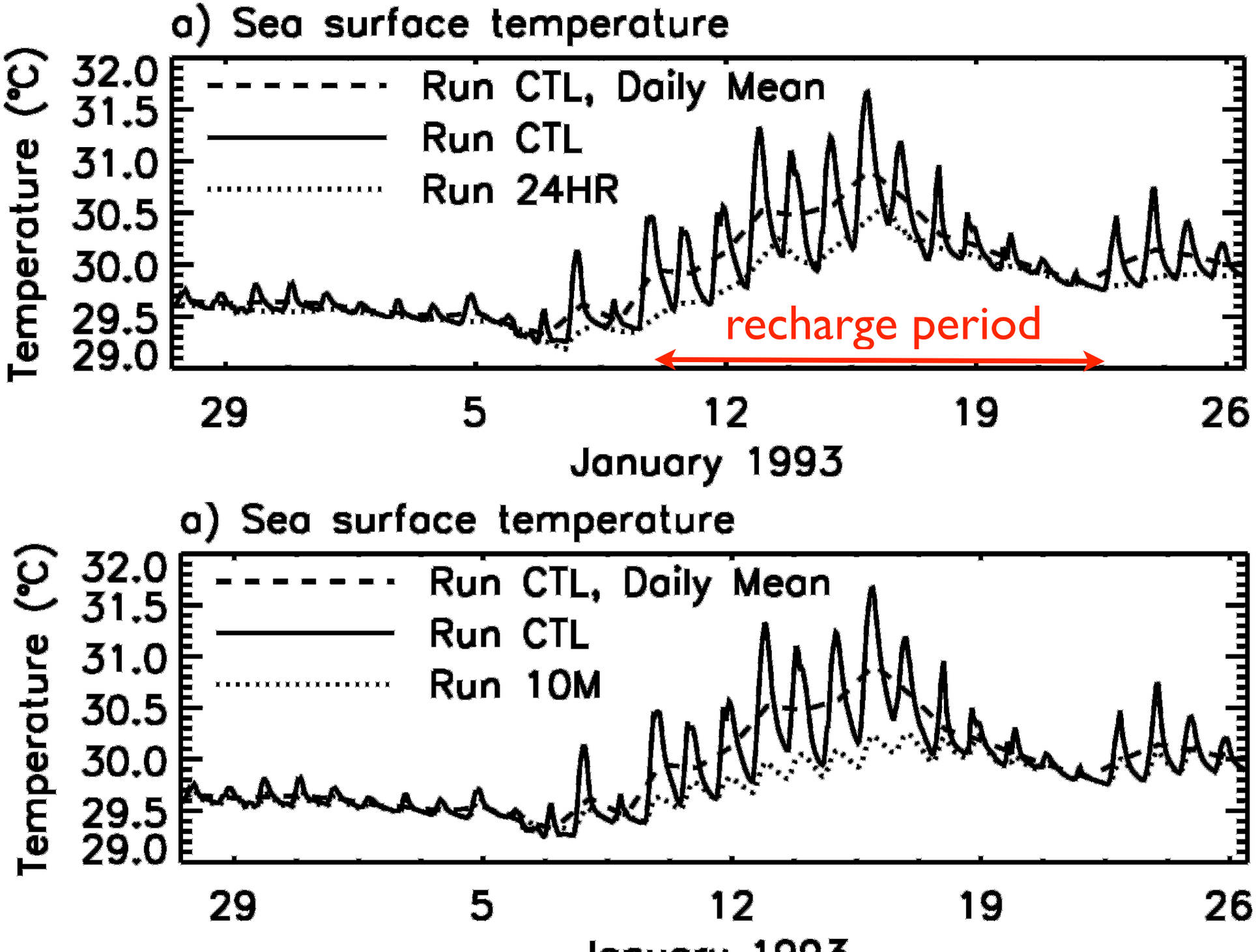
Three MJOs during DYNAMO



Courtesy of C. Zhang

Key factors for the diurnal SST: Frequency of Flux & Vertical Resolution

1-D KPP modeling study (Bernie et al. 2005)



Forcing frequency
3h vs 24h

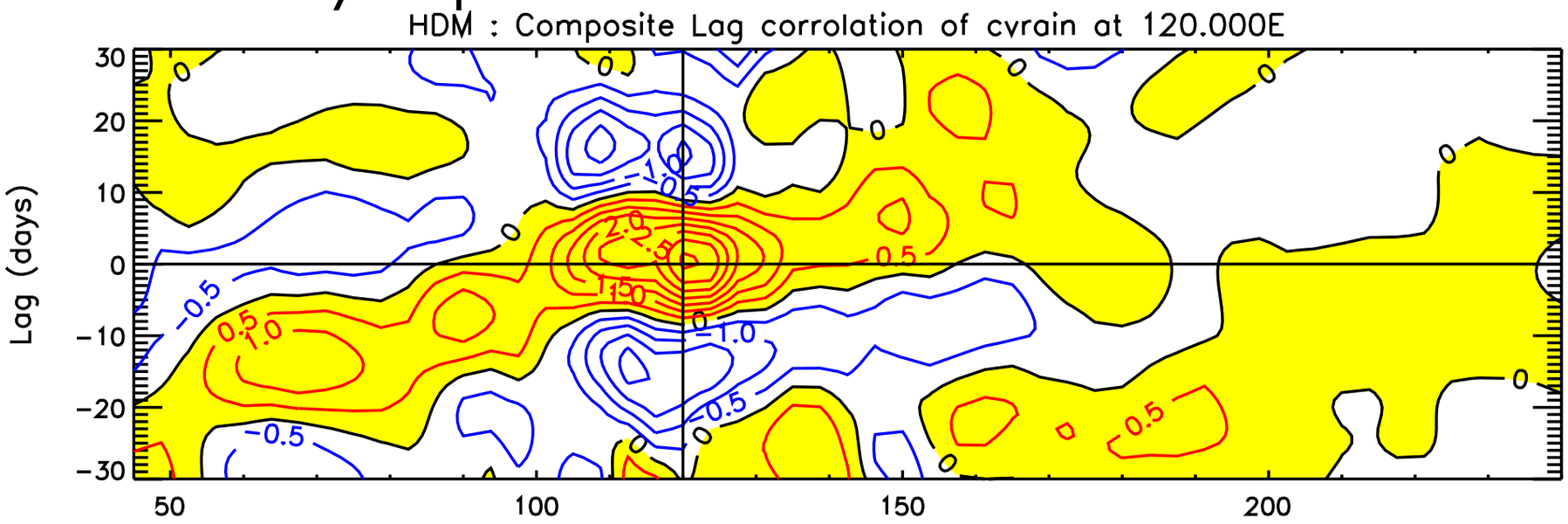
Vertical resolution
1m vs 10m

How does it impact the MJO convection?

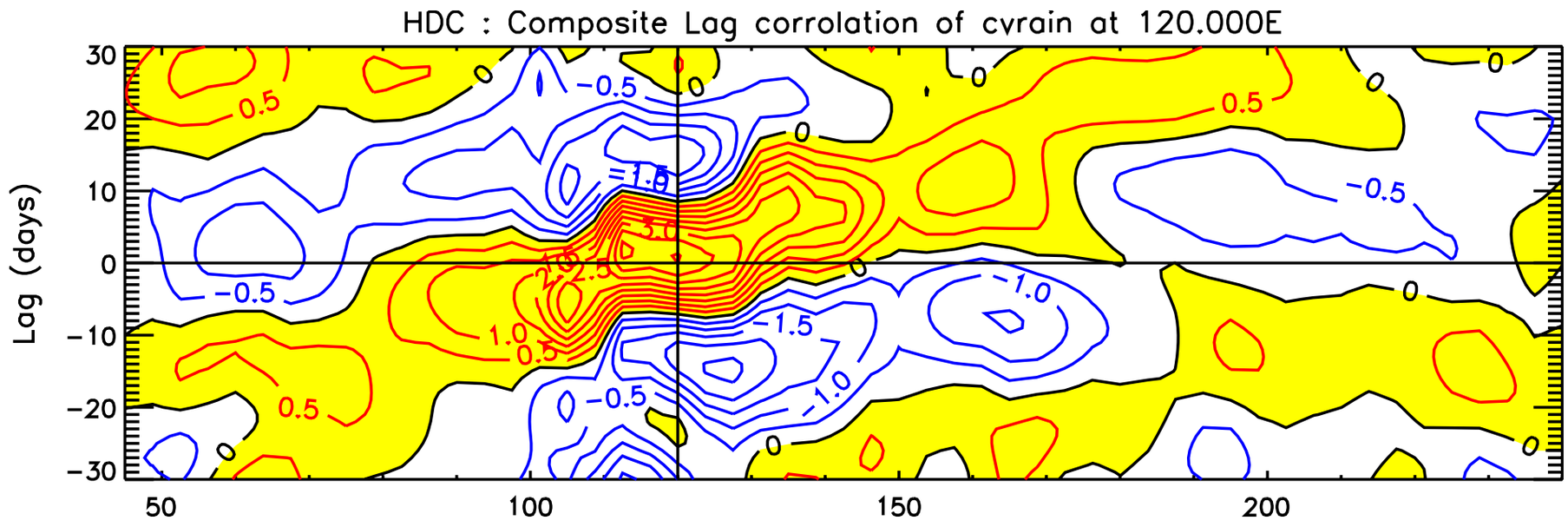
Stronger and more coherent MJO

A coupled GCM study (Bernie et al. 2008)

Daily coupled

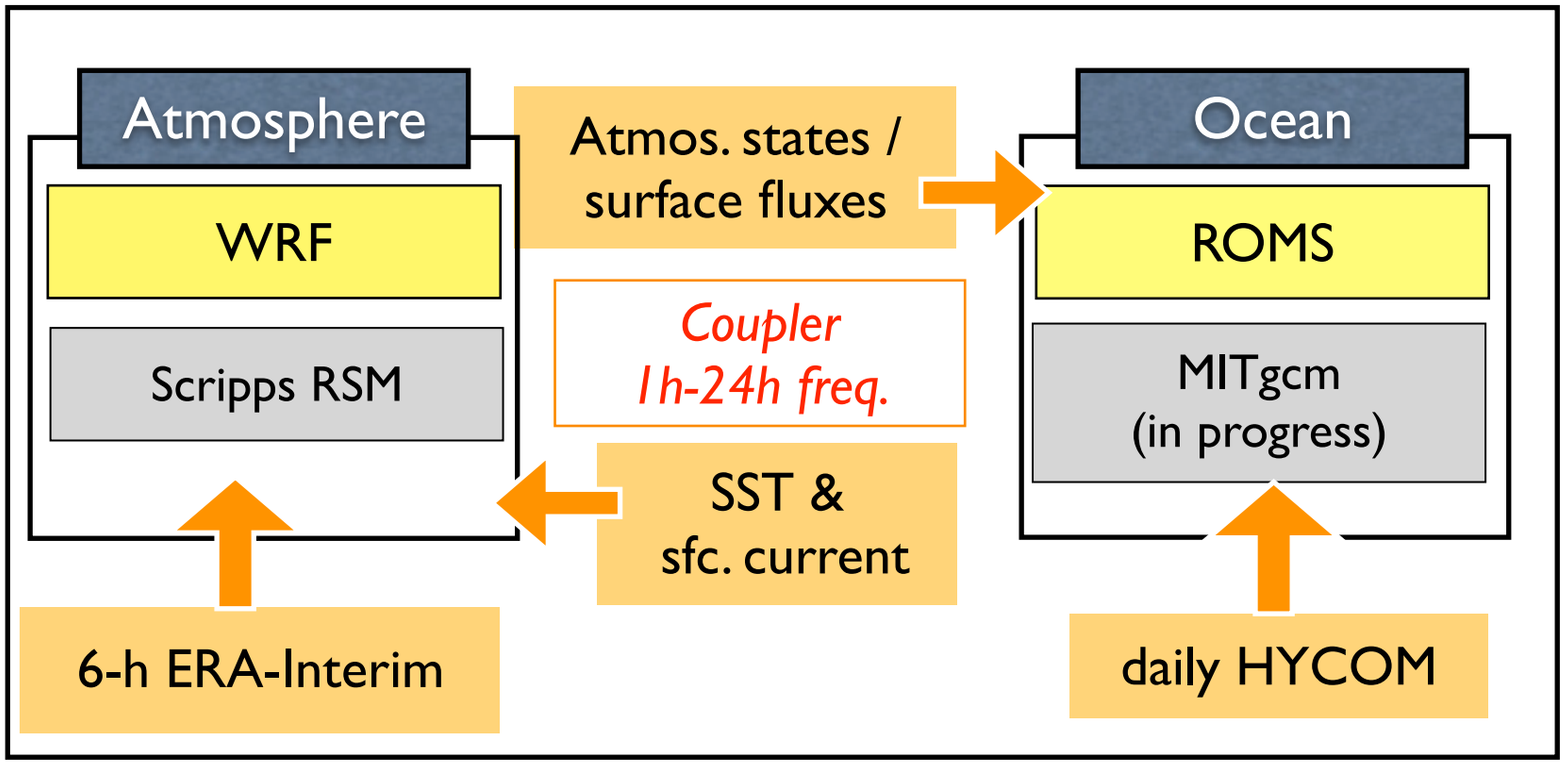


3-h coupled

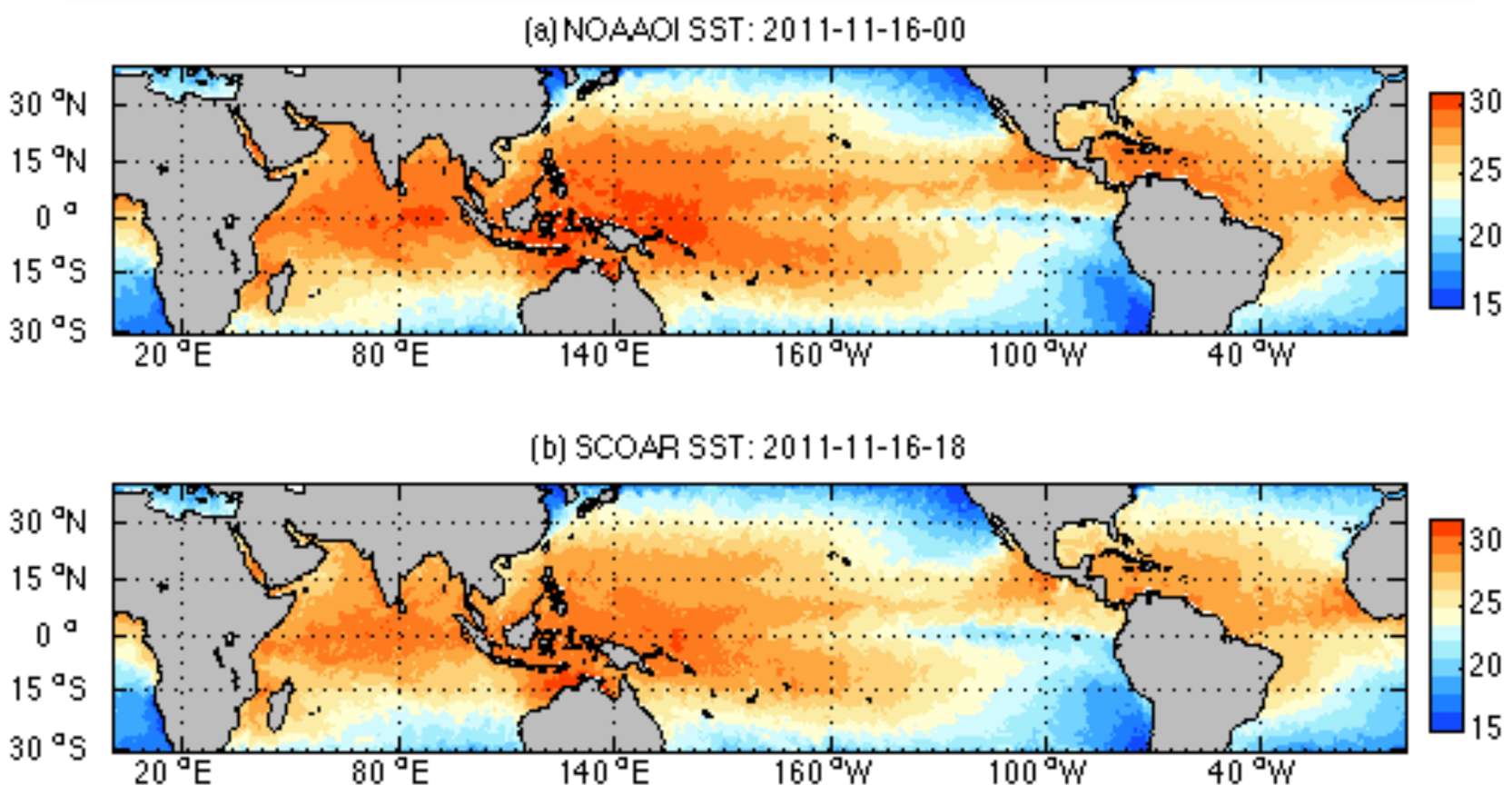


Lagged composites of convective precipitation

Regional coupled modeling study: SCOAR model



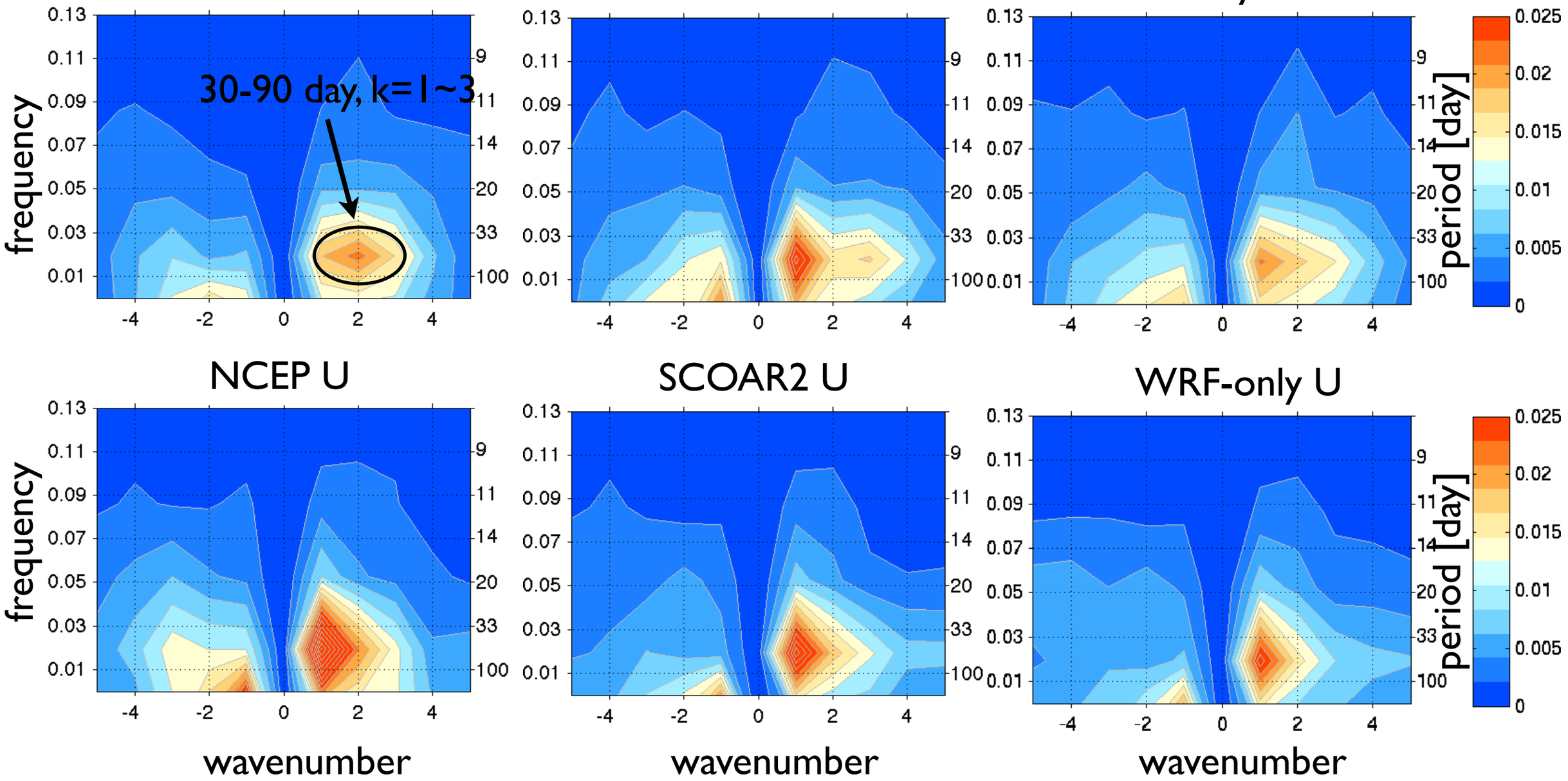
- SCOAR1: RSM-ROMS
  - *Seo et al. 2007*
- SCOAR2: WRF-ROMS
  - *Seo et al. 2014*
- *An input-output based coupler;*
  - *portable, flexible, expandable*



- Circum-equatorial tropical disturbances are allowed to interact with high-resolution oceanic process
- 40 km O-A resolutions & matching mask
- Deep & shallow convection and PBL schemes for MJO simulation

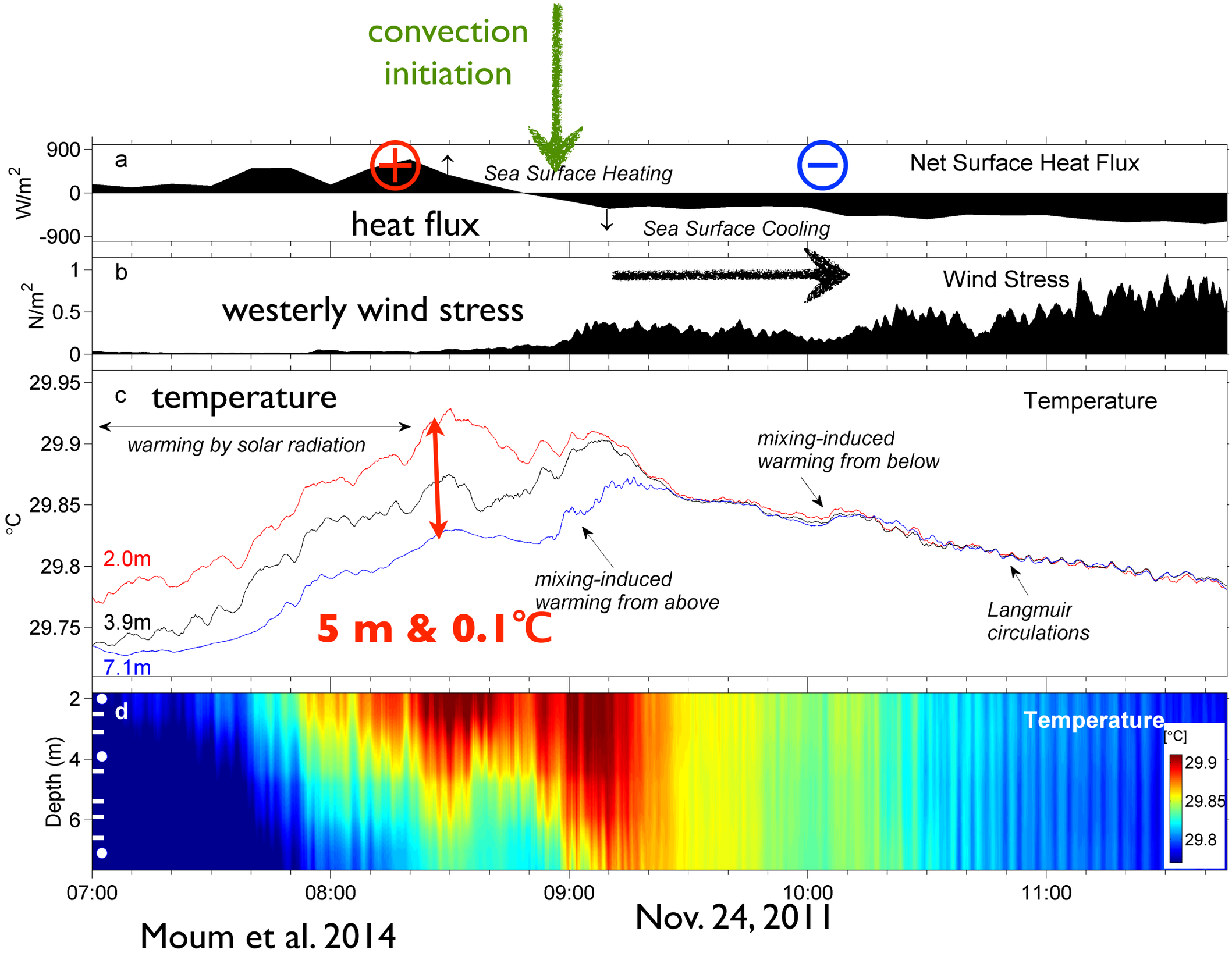
MJO diagnostics from the 5-yr baseline SCOAR simulation

Wavenumber-frequency spectra of symmetric component of OLR and U10m



- SCOAR reproduces reasonably the observed level of power at MJO κ-ω band.
- Interactive SST acts to straighten the MJO.
- Have some trust in model and its credibility for MJO simulation!

Observed diurnal warm layer during DYNAMO

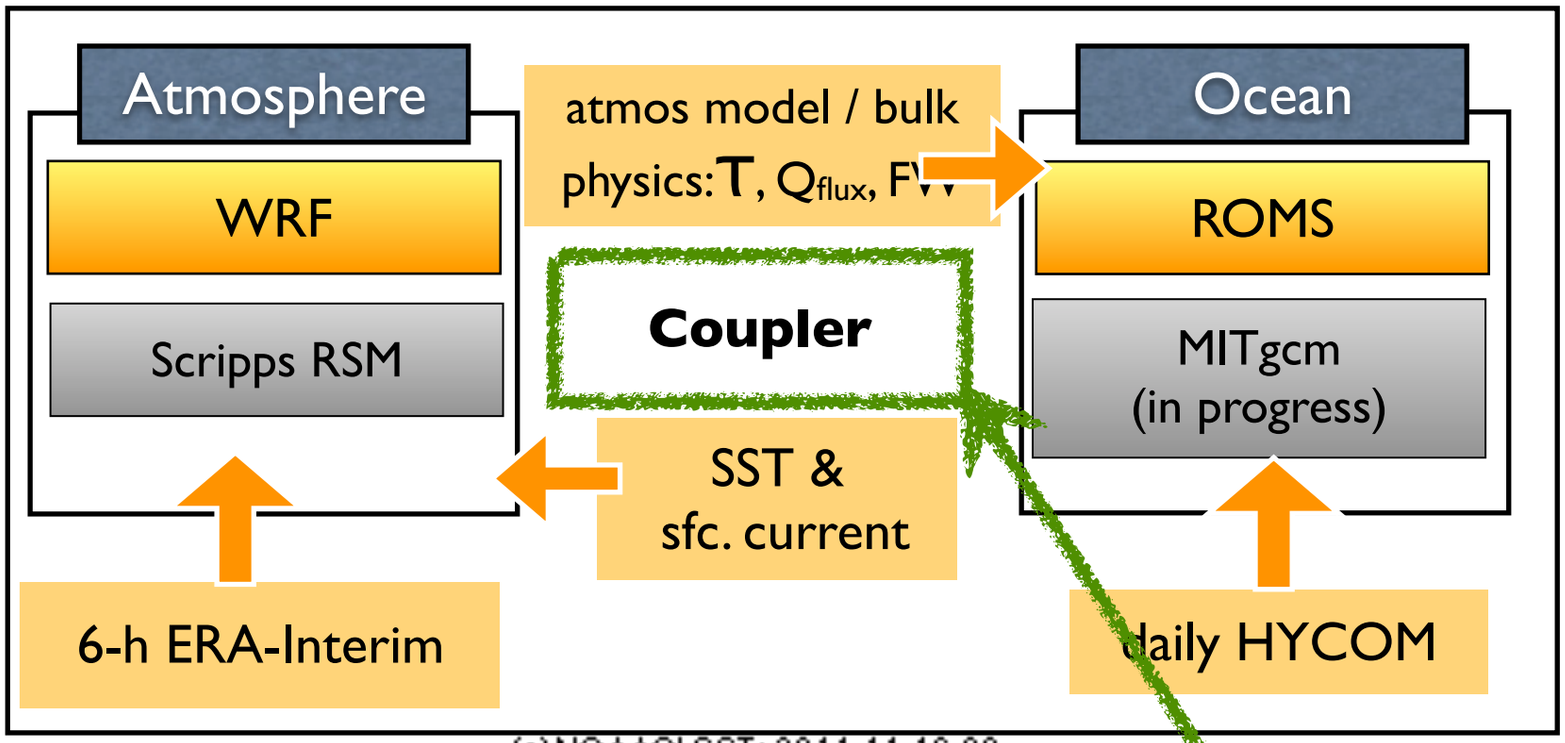


Moum et al. 2014

Modeling of diurnal cycle of SST and the MJO

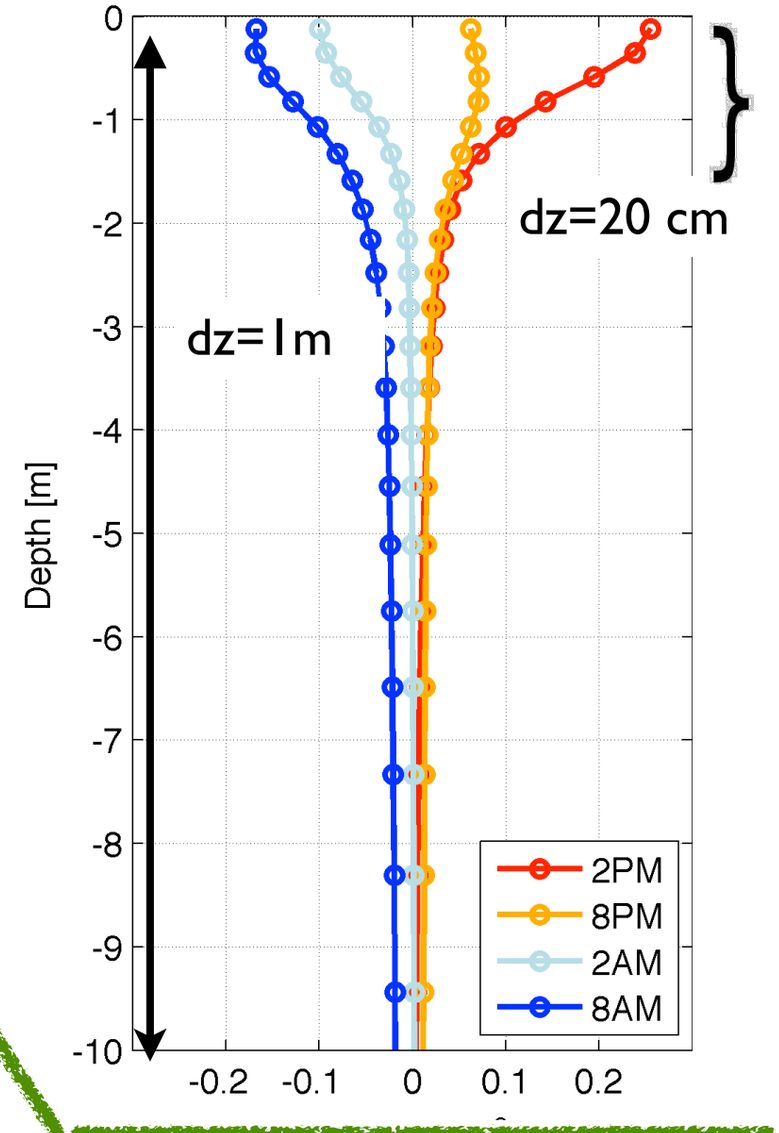
Scripps Coupled Ocean-Atmosphere Regional (SCOAR) model

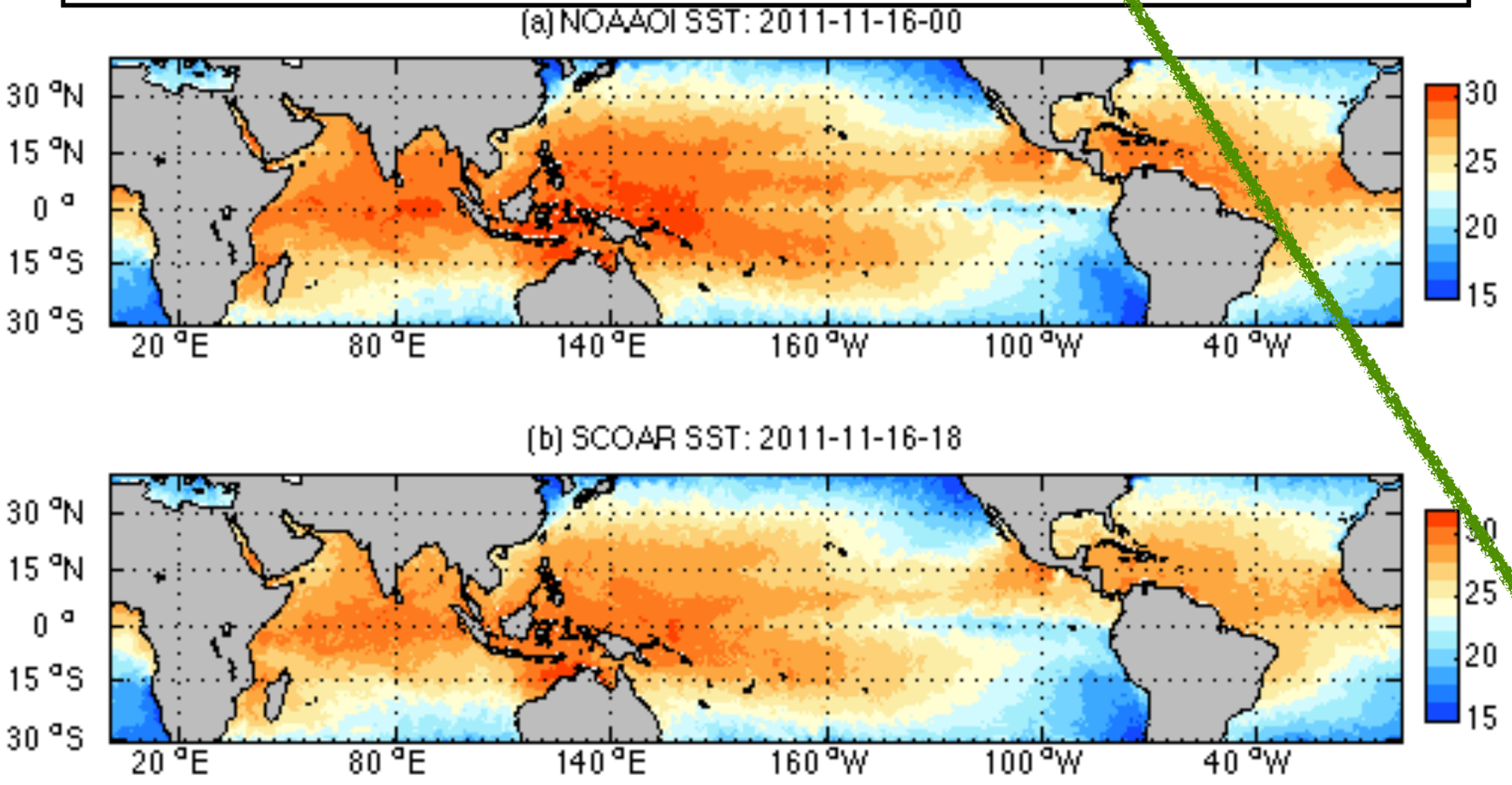
Seo, Miller, Roads, 2007



40km matching resolution in a tropical channel configuration

High vertical resolution

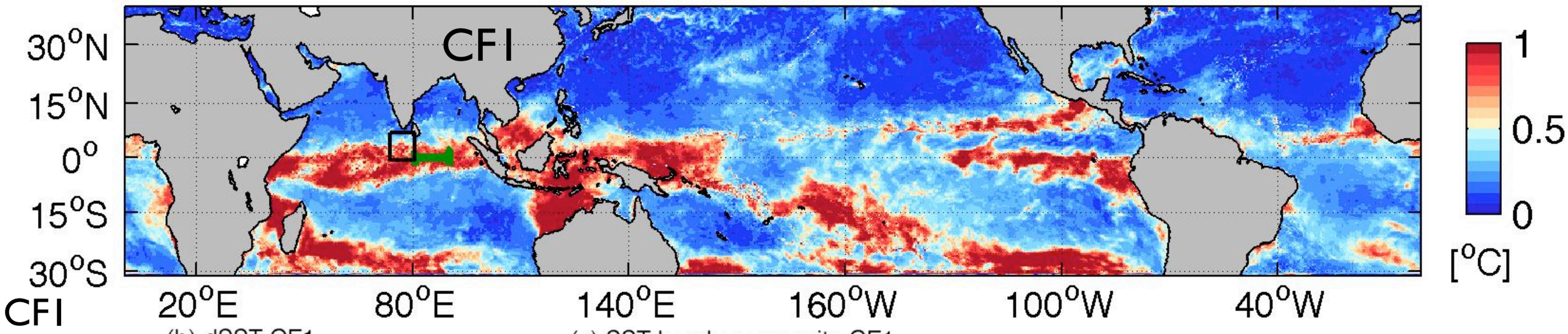




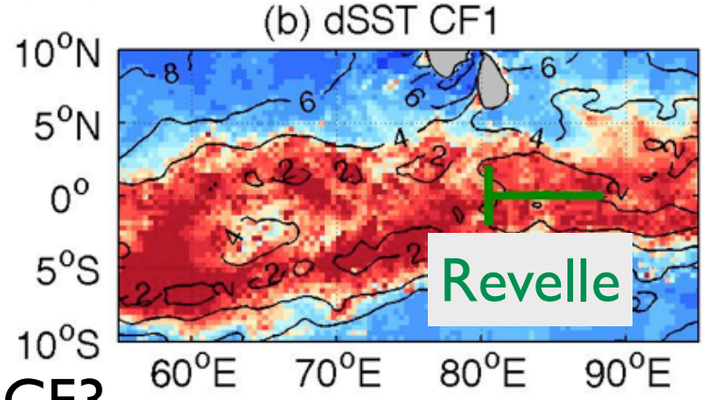
Coupling frequency
CF1, CF3, CF6, CF24

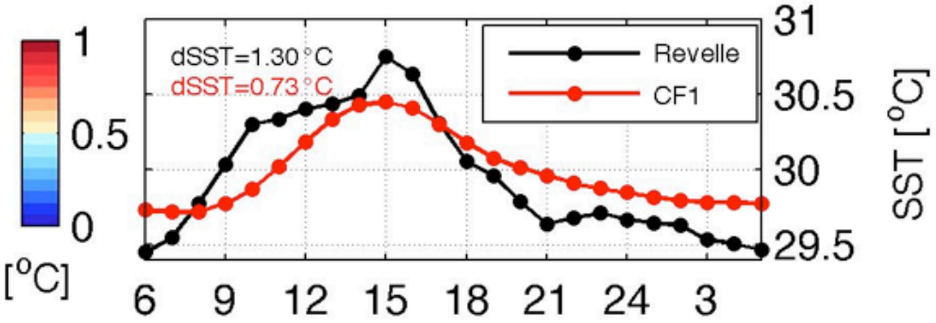
Seo et al. 2014

Diurnal SST amplitude prior to the deep convection

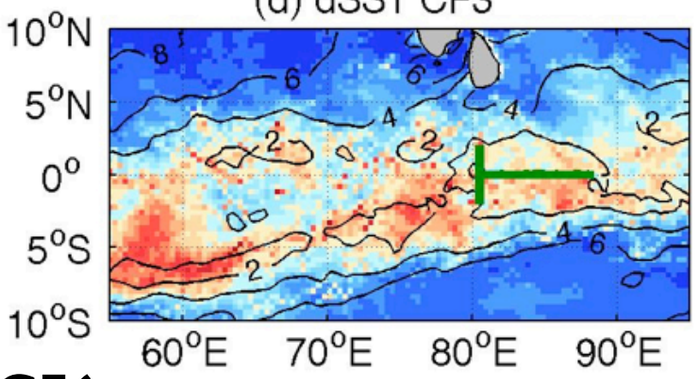


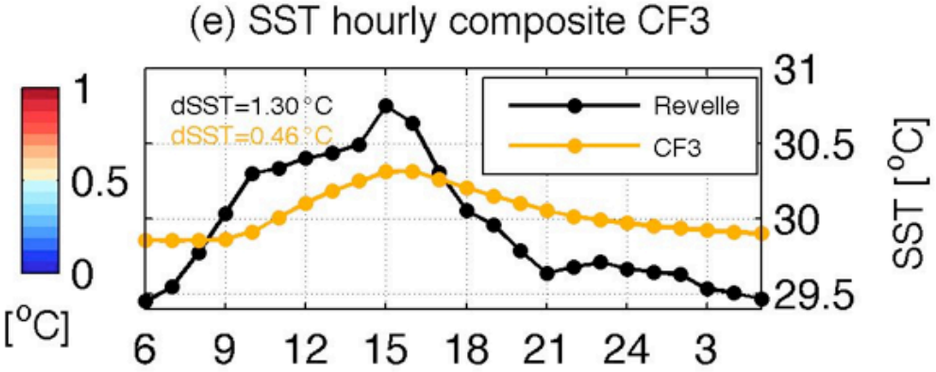
CF1



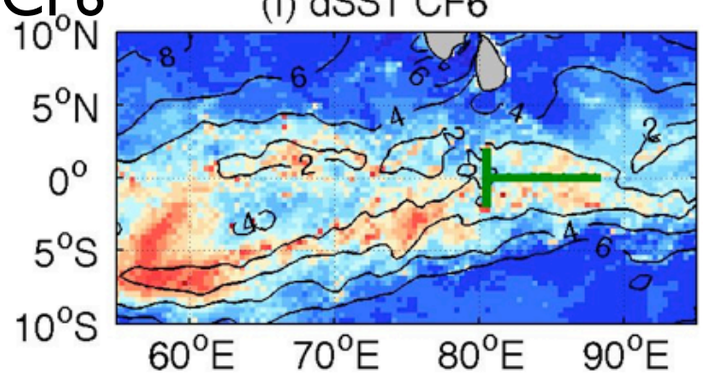


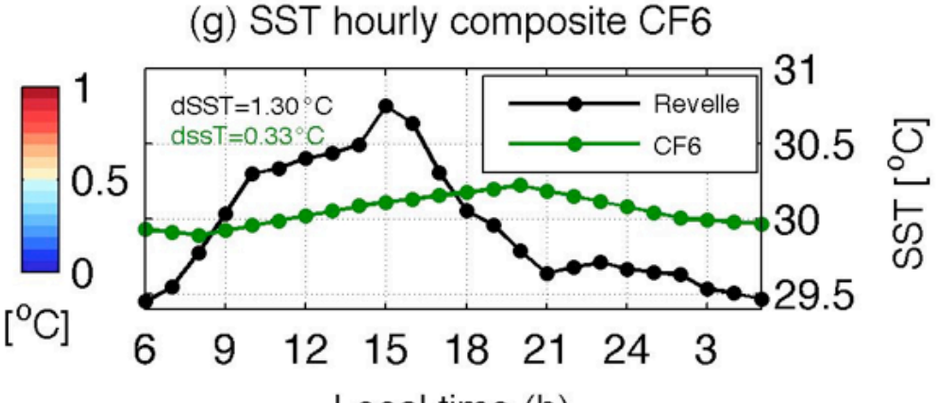
CF3

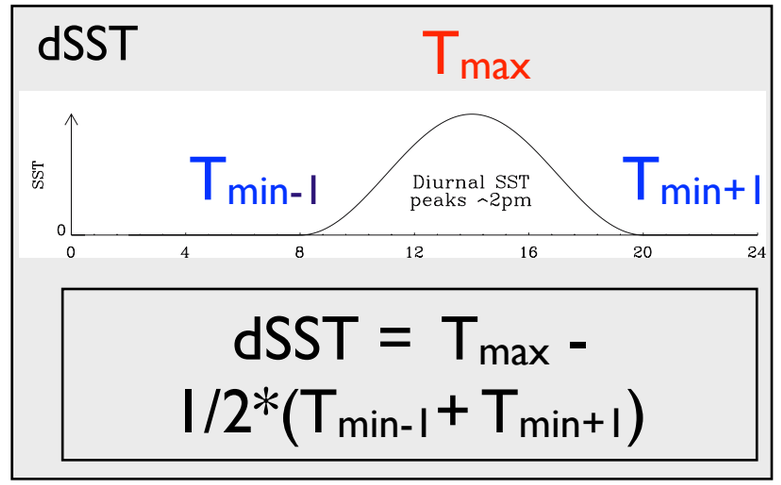




CF6

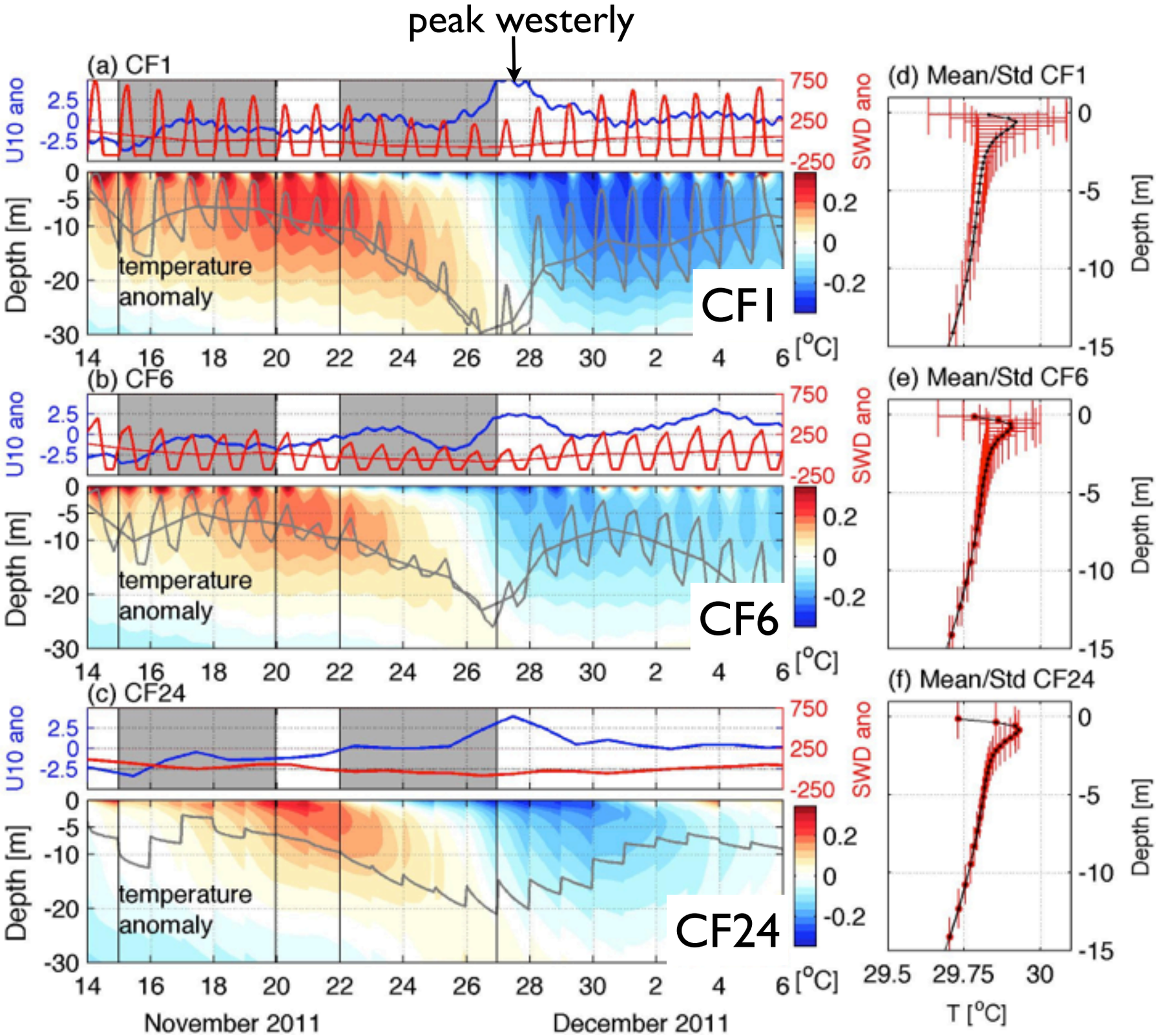






- CF1 represents ~56% of the observed dSST.
- Higher mean SST and dSST in CF1.

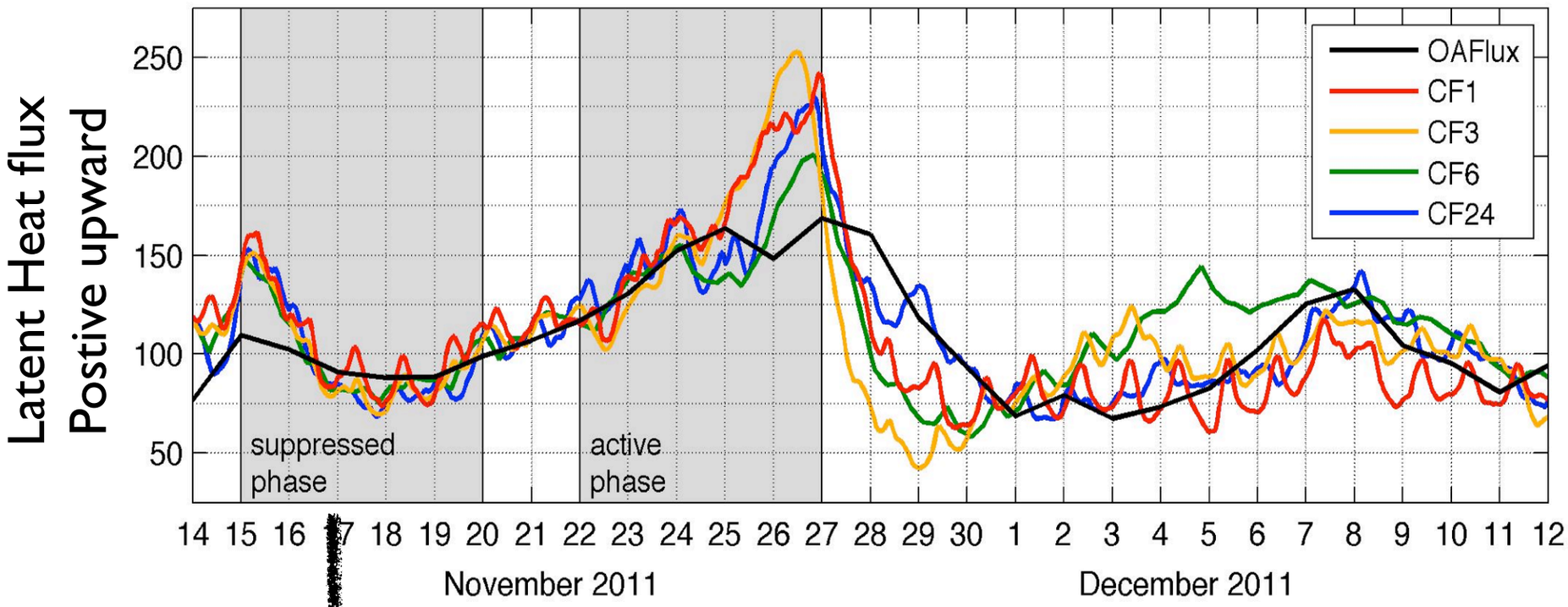
Warmer upper ocean temperature before convection



	Suppressed phase	
	Mean T	dSST
CF1	29.8	0.6
CF3	29.7	0.4
CF6	29.7	0.3
CF24	29.7	0.0

- Stronger diurnal variation helps achieve higher (>0.1℃) SST on a diurnal basis.

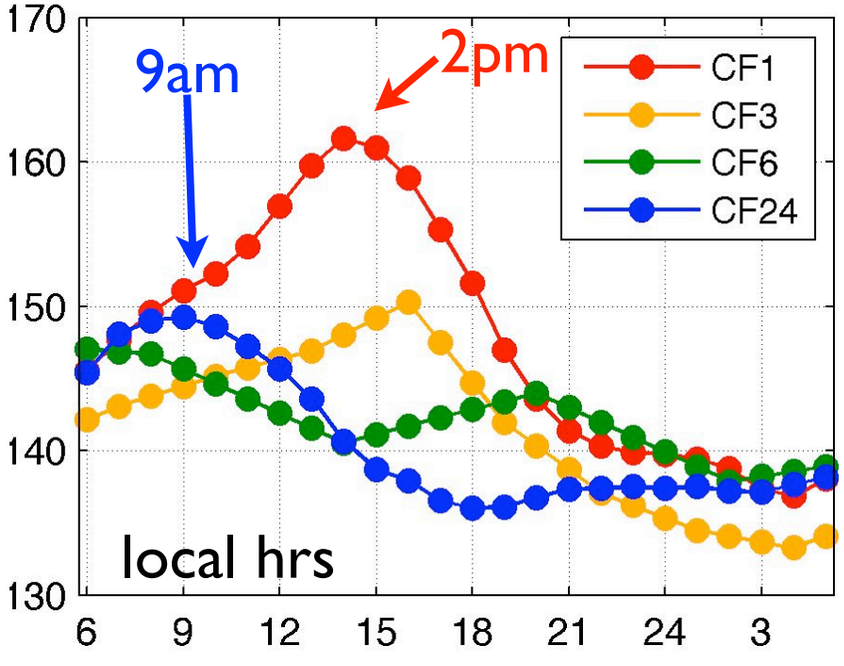
Stronger moistening of the lower troposphere



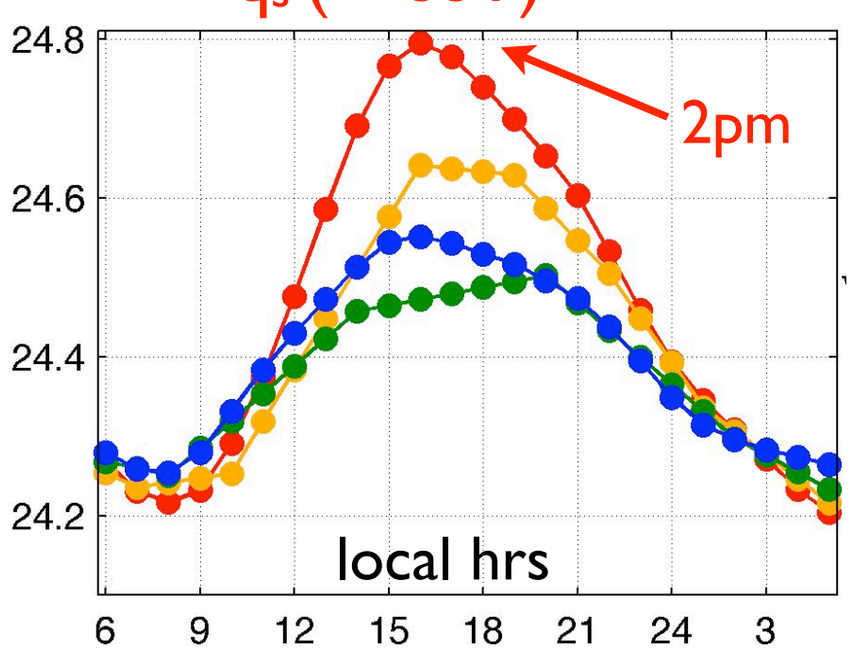
	Mean LH	dLH
OAFlux	96	N/A
CF1	104	30.2
CF3	99	24.6
CF6	98	21.1
CF24	97	30.2

Hourly composites of **LH**=$\rho L C_H (q_s - q_a) W_{10}$

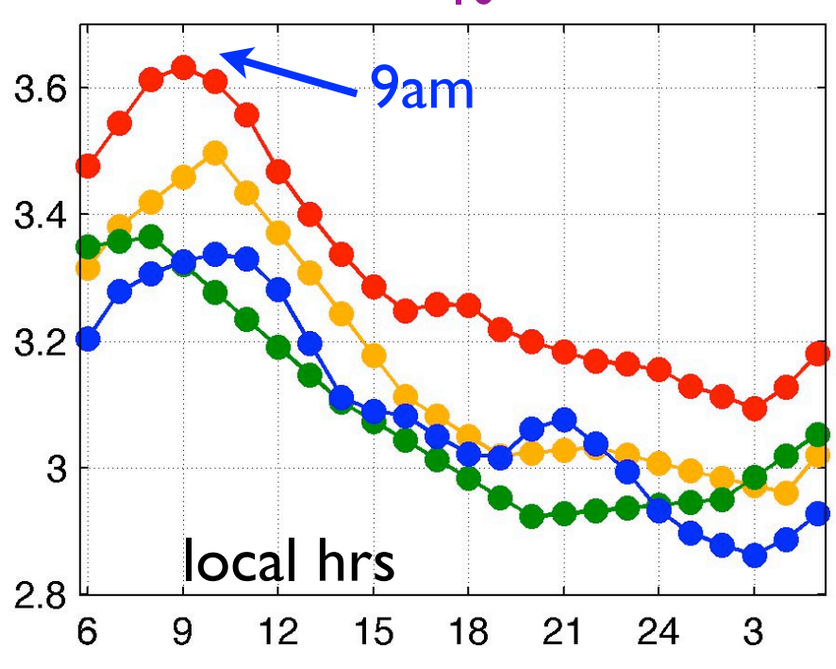
LH



q_s (←SST)

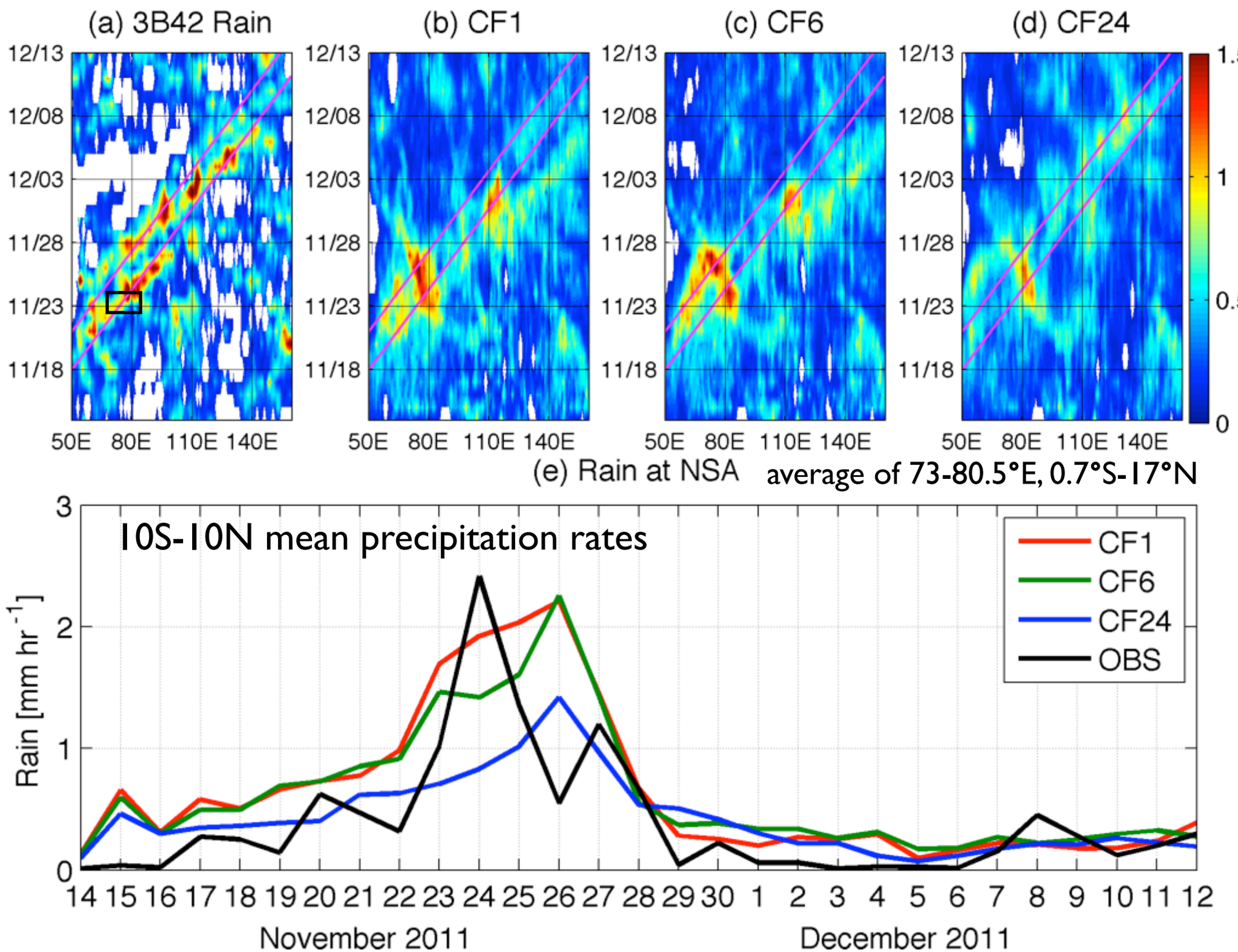


W_{10}



q_s (SST) plays a leading role in maximizing the moistening effect of the troposphere on a diurnal basis.

Impact on the MJO deep convection



- MJO2 rainfall event on Nov. 24 with the eastward propagation at 5 ms^{-1}.
- Models: qualitatively consistent intraseasonal evolution of rainfall.

•: Precipitation intensity

•proportional to pre-convection diurnal SST

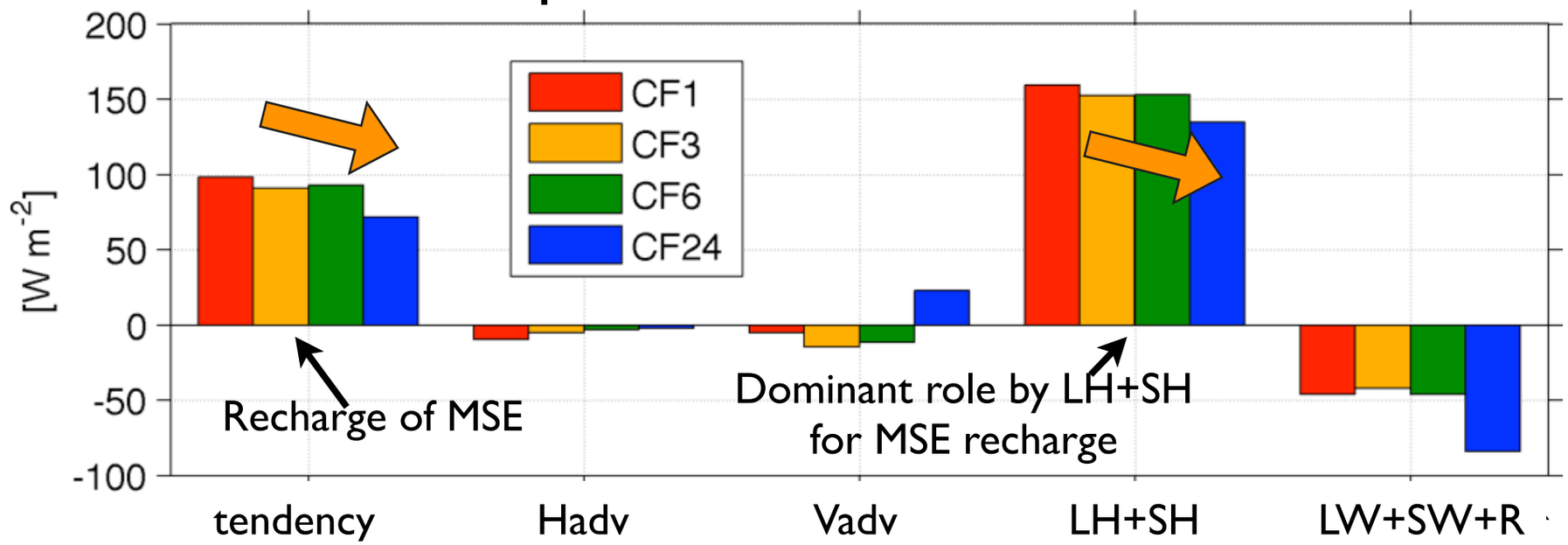
Column-integrated moist static energy (MSE) budget

$$\underbrace{\langle m_t \rangle}_{\text{tendency}} = \underbrace{-\langle v_h \cdot \nabla m \rangle}_{\text{Hadv}} \underbrace{-\langle \omega m_p \rangle}_{\text{Vadv}} \underbrace{+(LH + SH)}_{\text{LH+SH}} \underbrace{+\langle LW + SW \rangle}_{\text{LW+SW}}$$

$$m = c_p T + gz + Lq$$

Maloney 2009

prior to the convection



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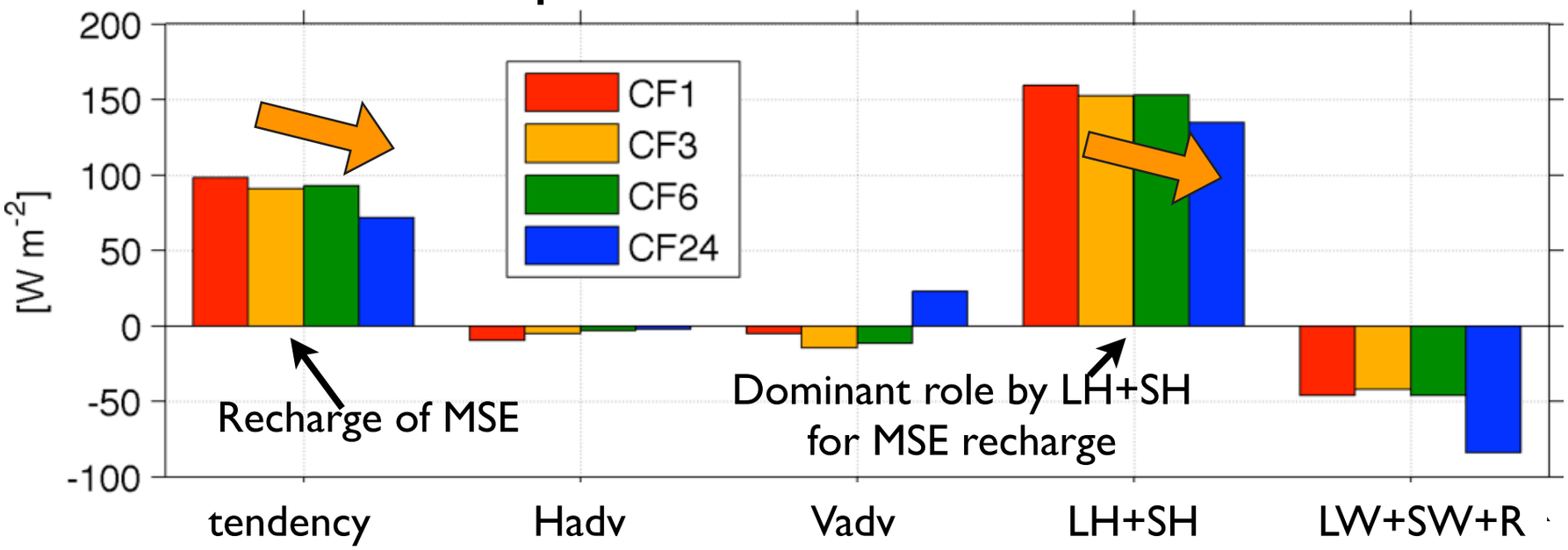
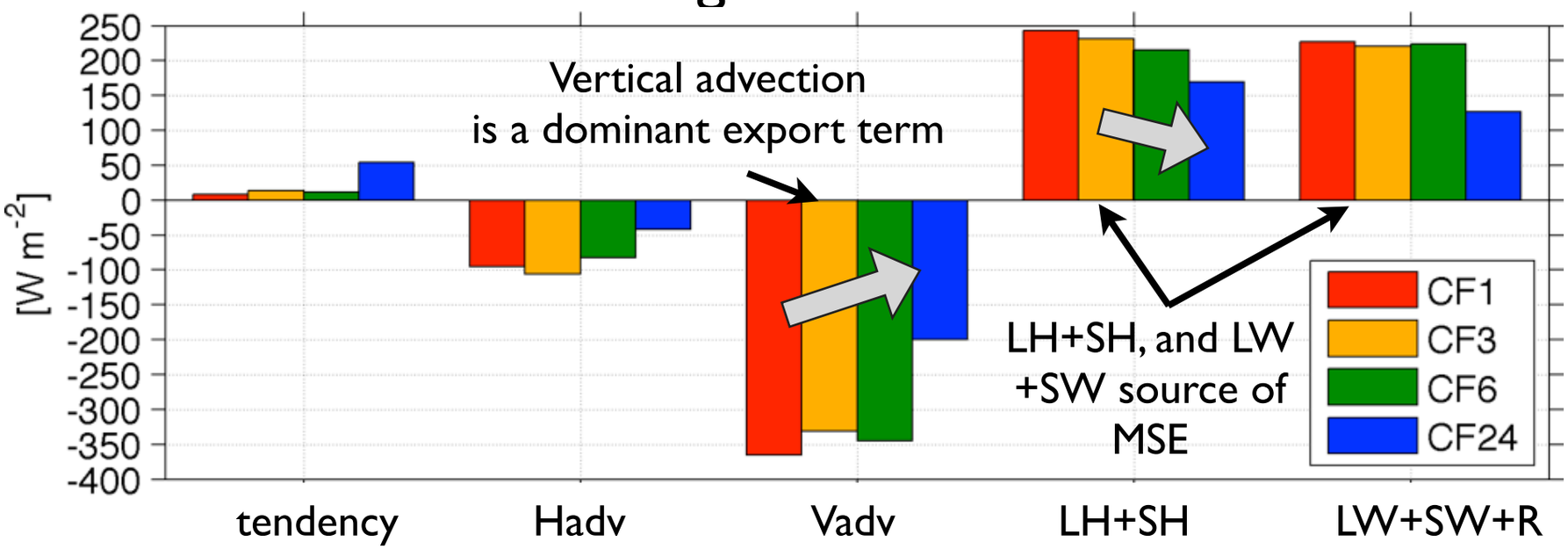
Maloney 2009

prior to the convection



during the convection



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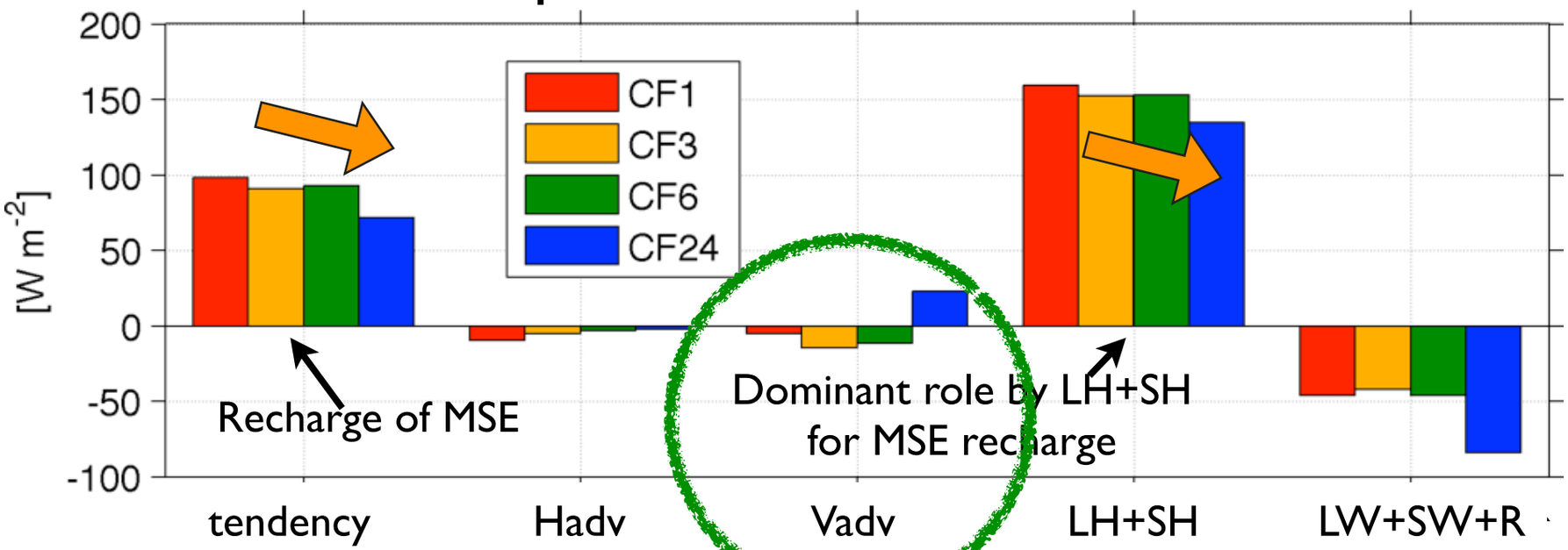
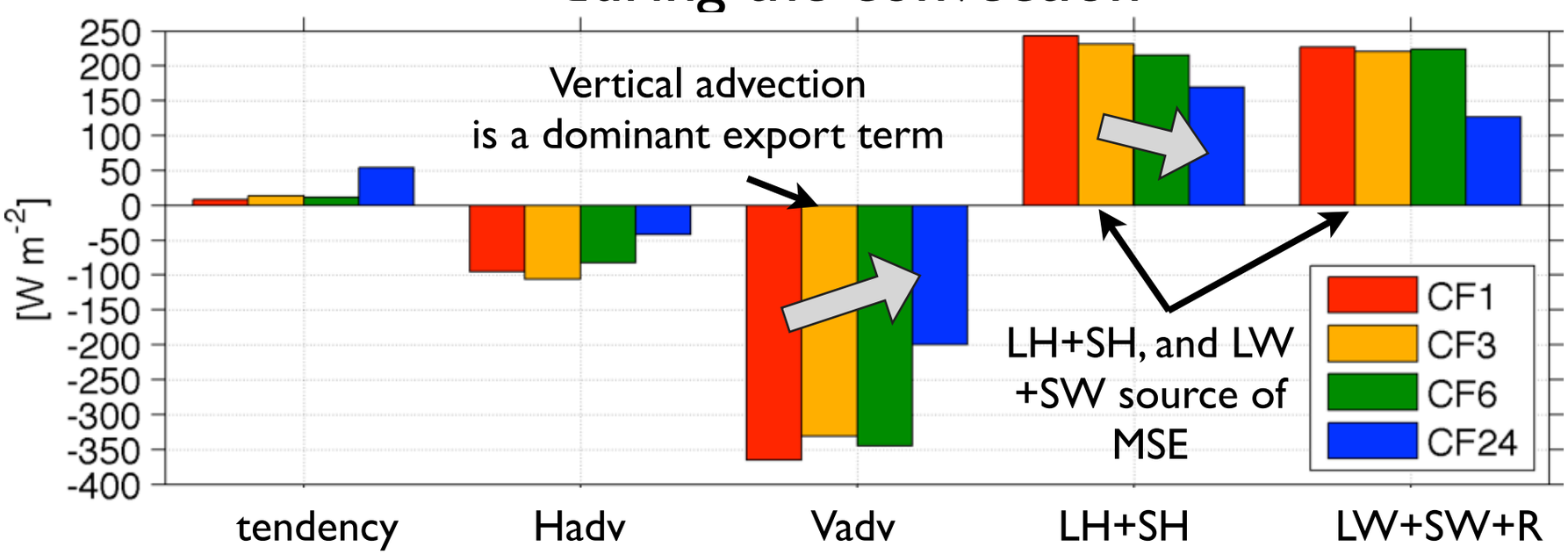
Maloney 2009

prior to the convection



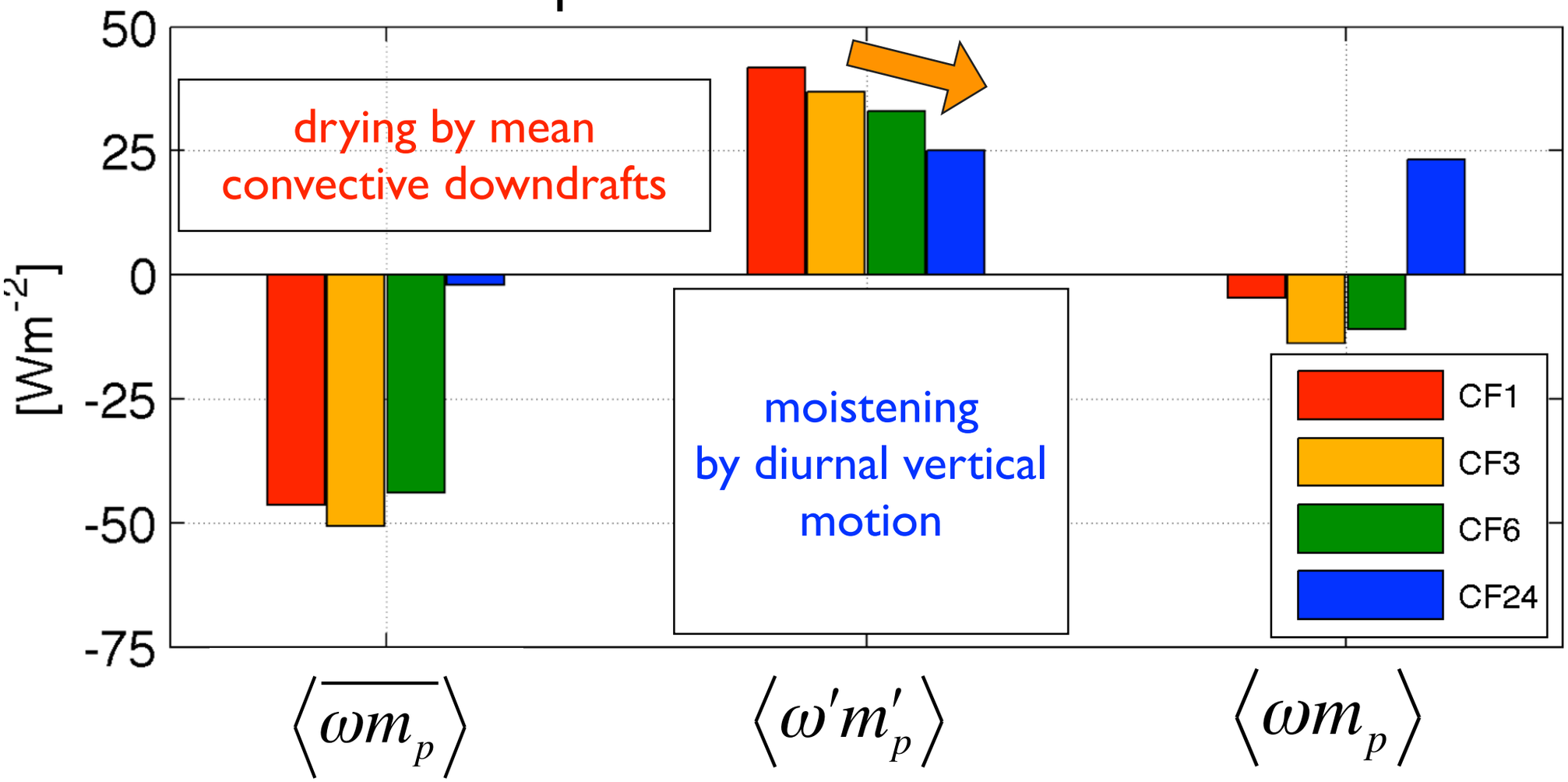
during the convection



Diurnal moistening of the lower troposphere

$$\left\langle \omega m_p \right\rangle = \left\langle \overline{\omega m_p} \right\rangle + \left\langle \overline{\omega' m'_p} \right\rangle$$

prior to the convection

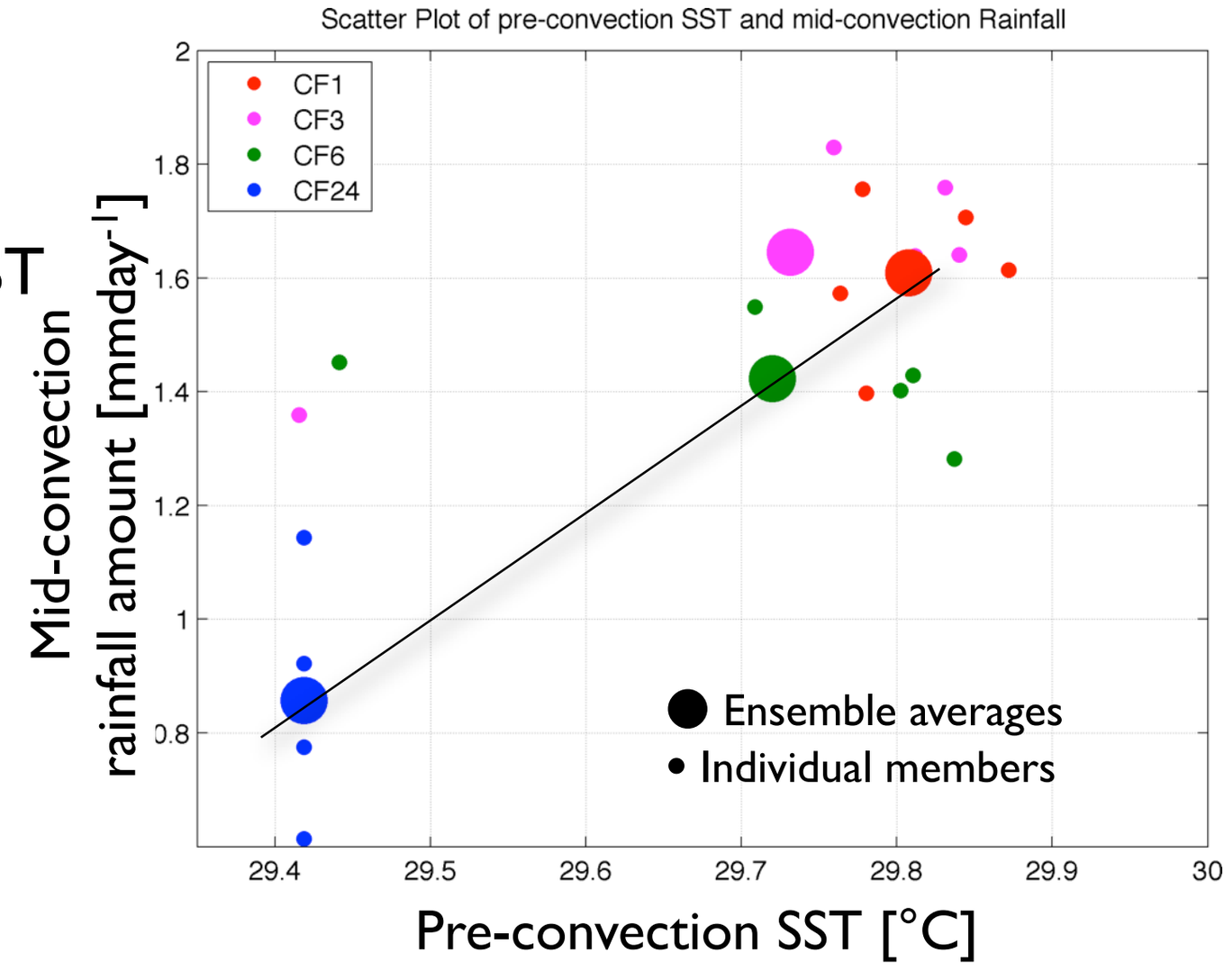


- The daily mean advection dries the air column (~ by mean convective downdrafts?)
- Not related to pre-convection dSST

- Diurnal moistening is a source of MSE and proportional to pre-convection dSST

Summary

1. SCOAR regional coupled modeling for the MJO and diurnal SST
   - Tropical channel, high vertical resolution, coupling, shallow/deep convection
2. Diurnal SST variability prior to the deep convection
   - raises time-mean SST and LH: via diurnal rectified effect
   - enhances diurnal moistening: via coincident diurnal peaks of LH & SST
3. Precipitation amount scales quasi-linearly with pre-convection diurnal SST



- LH feedback over higher SST instrumental in stronger convection intensity (Arnold et al. 2013).
- An improved representation of diurnally evolving SST is a potential source of MJO predictability.

Thanks!

Seo, Subramanian, Miller and Cavanaugh, 2014,
Coupled impacts of the diurnal cycle of sea surface temperature on the Madden-Julian Oscillation. J. Climate