# Predictability and Coupled Dynamics of MJO during DYNAMO:
*Role of diurnal SST in the initiation and intensity of the "MJO2"*


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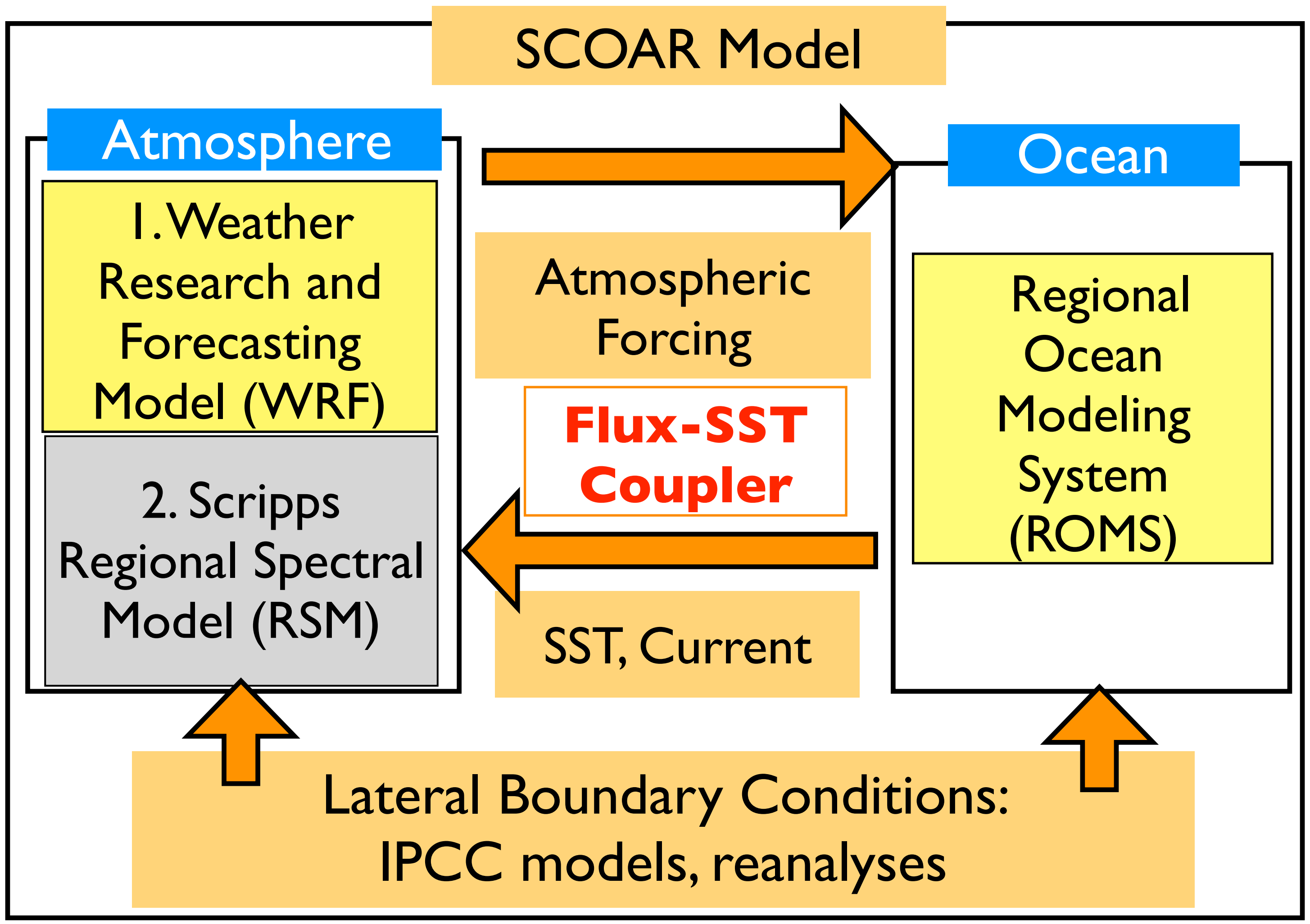
# Project's Overall Goal

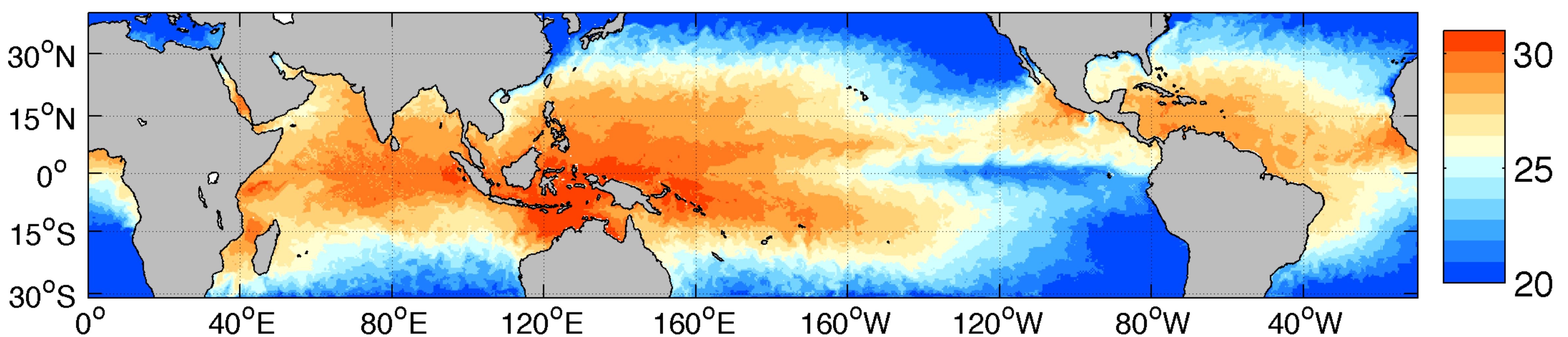
- To investigate the coupled boundary layer process and predictability of MJO
  - Global coupled modeling component (Miller, SIO)
    - NCAR CCSM4 featuring realistic MJOs (Dr. Aneesh Subramanian)
    - MJO diagnostics in the present and warming climate (Dr. Aneesh Subramanian)
    - Linear inverse modeling (Mr. Nick Cavanaugh)
  - **Regional coupled modeling component (Seo, WHOI)**
    - Construct a skillful regional O-A model for DYNAMO
    - Process-model to test the effect of coupled boundary layer process
      - <u>Diurnal cycle in SST</u> and barrier layer ↔ MJO convection

# Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model
## *VERSION II*




- Originally coupled RSM-ROMS in the tropical Pacific, Indian and Atlantic Oceans (Seo et al. 2007, J. Climate).
- Study mesoscale ocean-atmosphere interactions and large-scale climate.
- An input-output-based coupler
  - WRF-ROMS coupling
- WRF and ROMS are coupled in the tropical channel configuration.
- Matching horizontal grids at 40 km.

SST after 10 day initialization: 11/24/2013

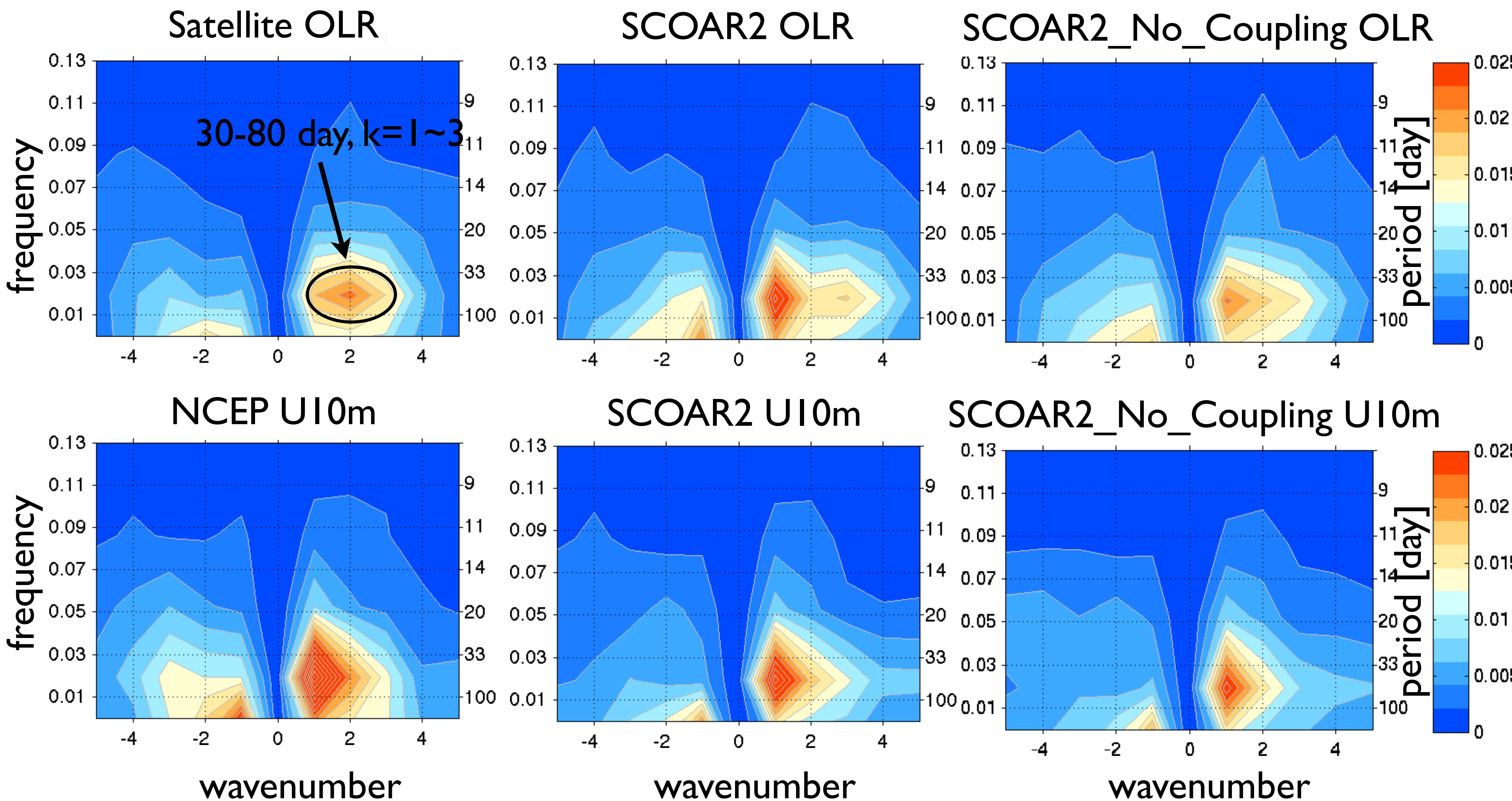


MJO diagnostics from multi-year SCOAR2 simulation

6-month integration (October to March) for 5 winters
2005-2006 to 2009-2010

Daily coupled (CF=24)
ROMS: HYCOM daily ocean analysis
WRF: ERA-Interim 6-hourly reanalysis

# Wavenumber-frequency spectra of symmetric component of OLR and U10m, 10S-10N



Effect of diurnal SST coupling in SCOAR for intensity of convection of MJO2 during DYNAMO

# Experiments for MJO2 during DYNAMO:

## Test the effect of diurnal SST on the MJO2 convection

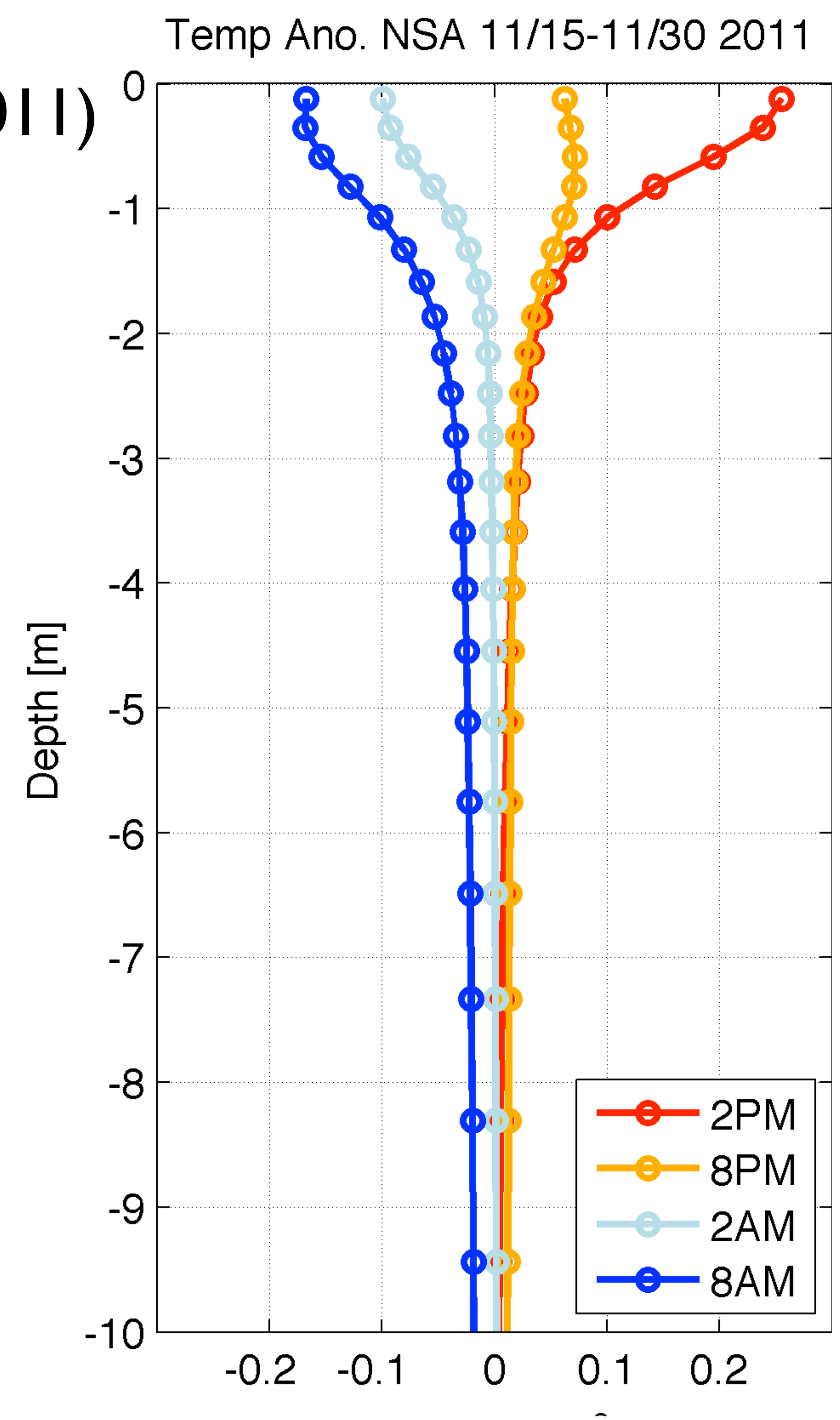
- Vertical levels: a large number of vertical levels in the upper ocean (e.g, Bernie et al. 2008, Klingaman et al. 2011)
  - Total # of levels: 55 layers
  - 5 layers in the upper 1 meter
  - 15 in the upper 15 meters

- Simulation Period: MJO2 period
  - One month, Nov. 14 - Dec. 14, 2012

- Initial and boundary conditions:
  - ROMS: HYCOM daily ocean analysis
  - WRF: ERA-Interim 6-hourly reanalysis

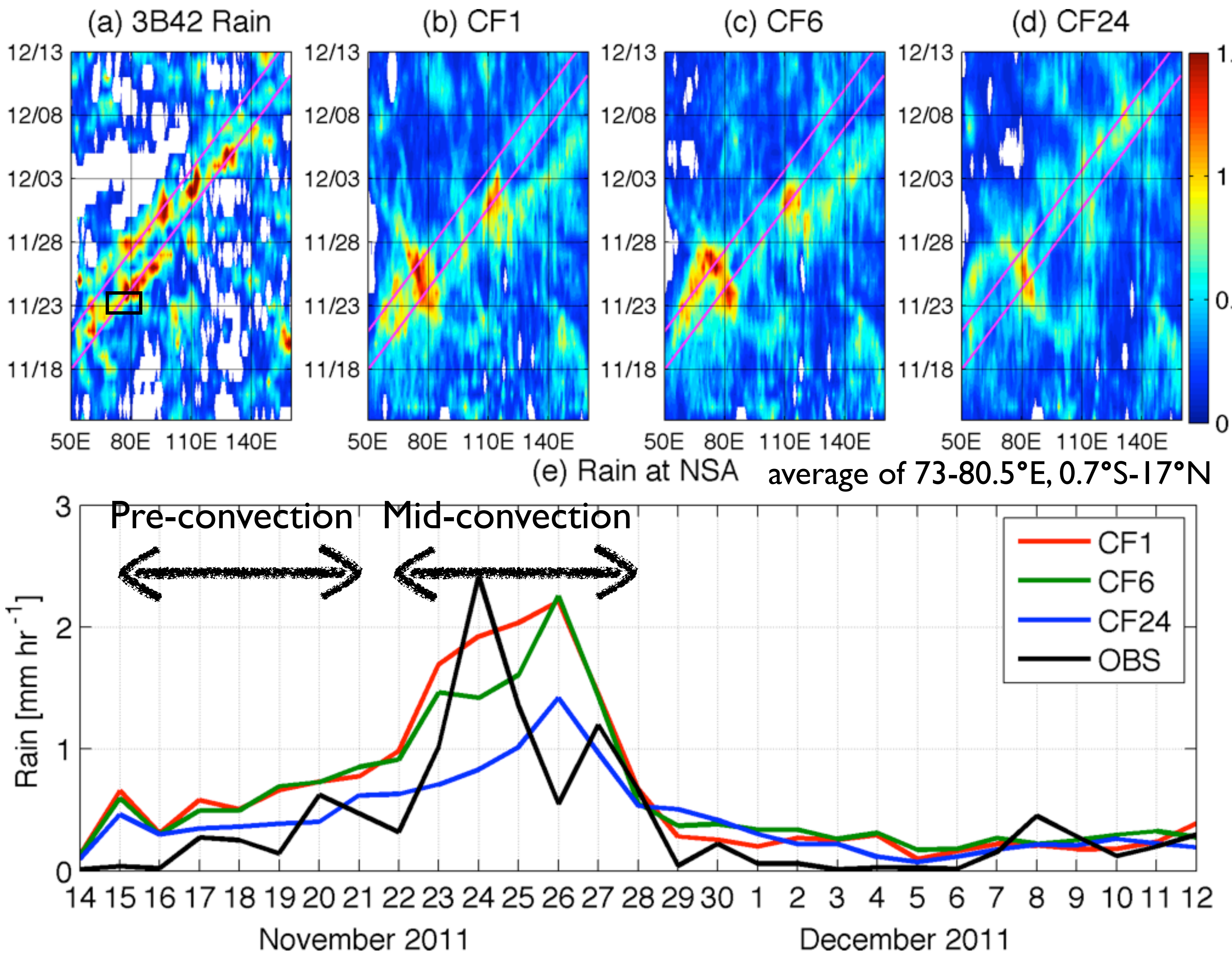
- Coupling frequency (CF): Different CFs applied to otherwise identical SCOAR2 runs.
  - CF=1, 3, 6, 24 hours

- Ensemble simulation: 5-member in each case



# Evolution of MJO2 precipitation with different coupling frequencies

10S-10N mean precipitation rates

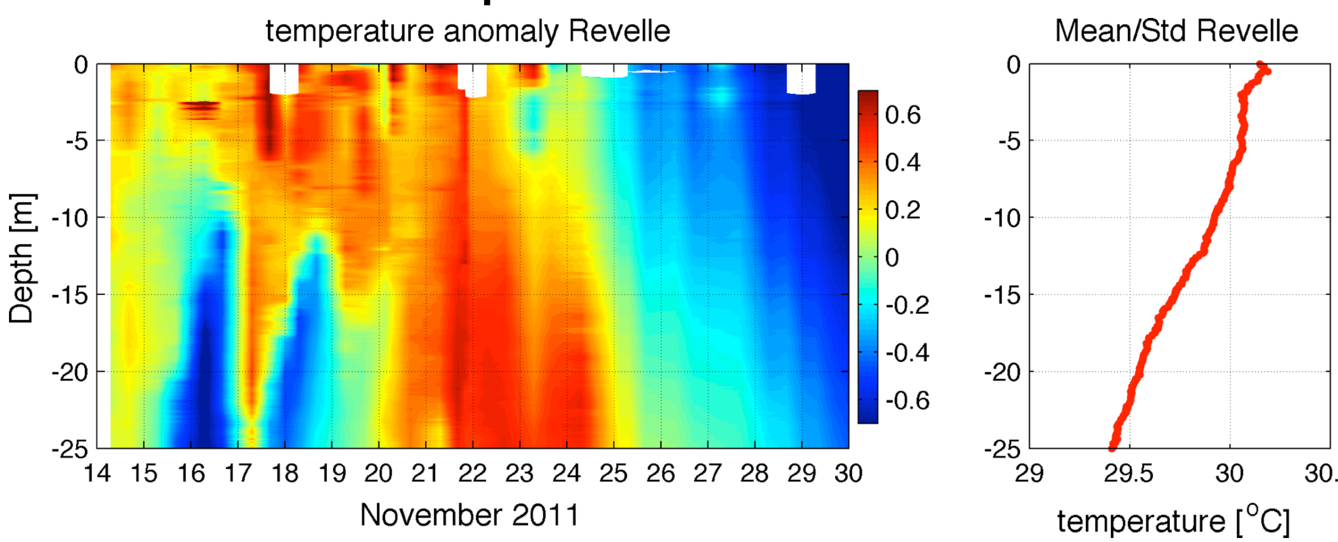



Why does it rain more with higher frequency coupling?

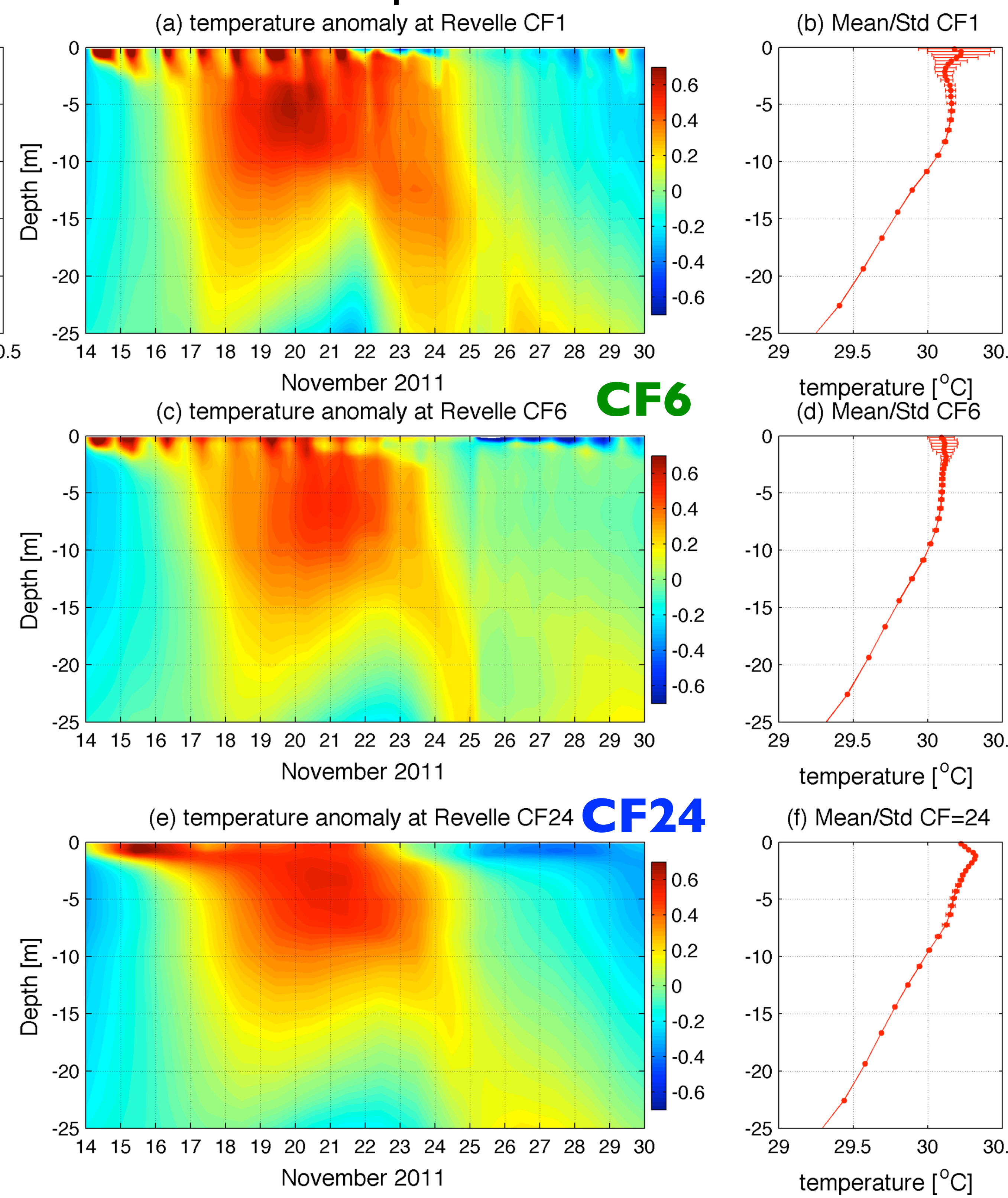
- **Observations**: MJO2 rainfall event on Nov. 24 with the eastward propagation at 5 $ms^{-1}$.
- **Models**: qualitatively consistent intraseasonal evolution of rainfall.
- With more frequent coupling, the higher amount of rainfall is achieved during the active phase of convection.

# Along-track evolution of the upper ocean temperature at the Revelle

## Revelle temp. anom. | Mean/STD



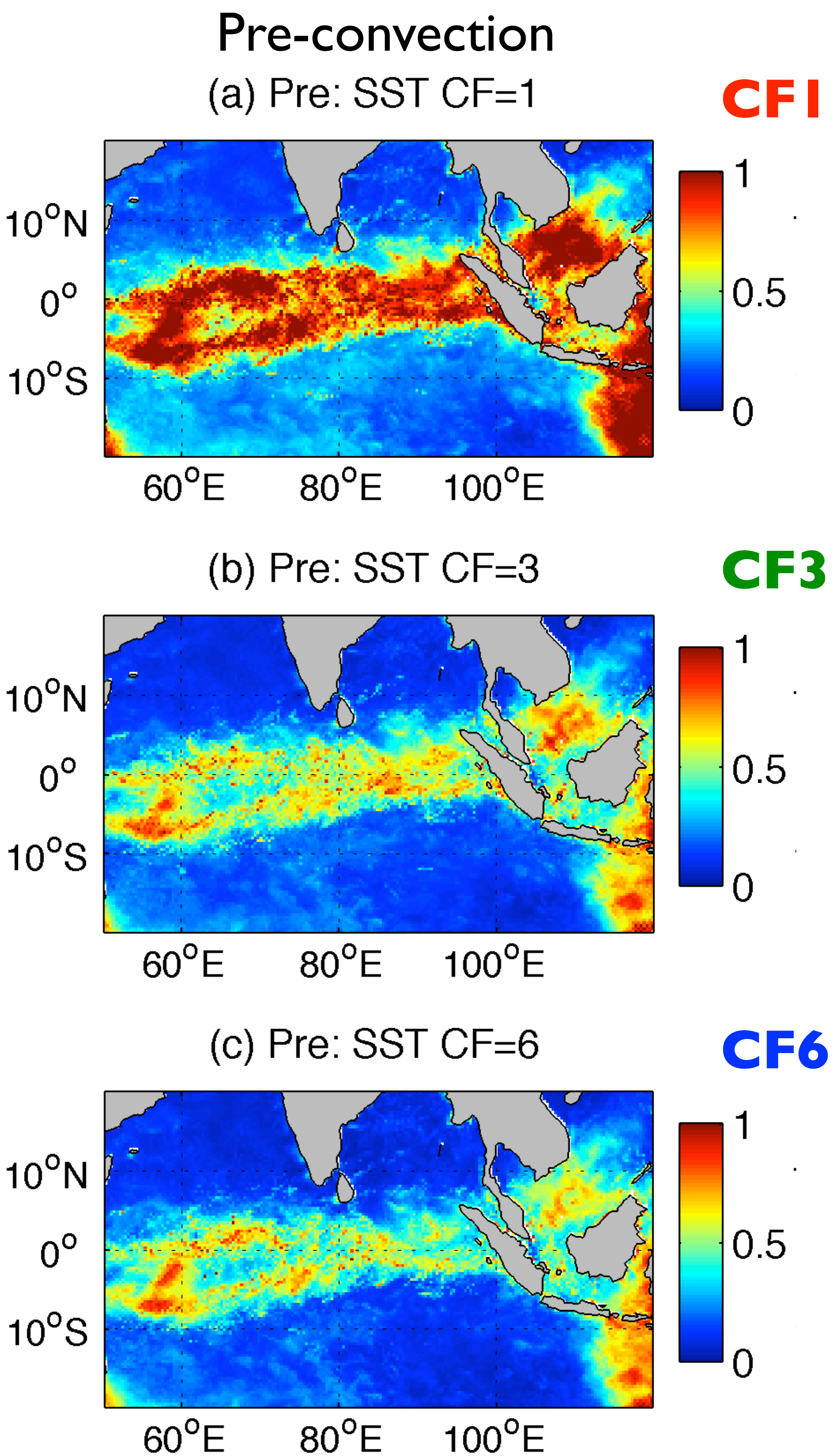

## Model temp. anom. CF1 | Mean/STD




- The upper ocean warms during the suppressed phase of MJO (recharge phase)
  - Pronounced diurnal variation in SST reaching >0.7C.
  - The peak warming is greater with stronger diurnal cycle.
  - Diurnal warm layer up to 3 meters.

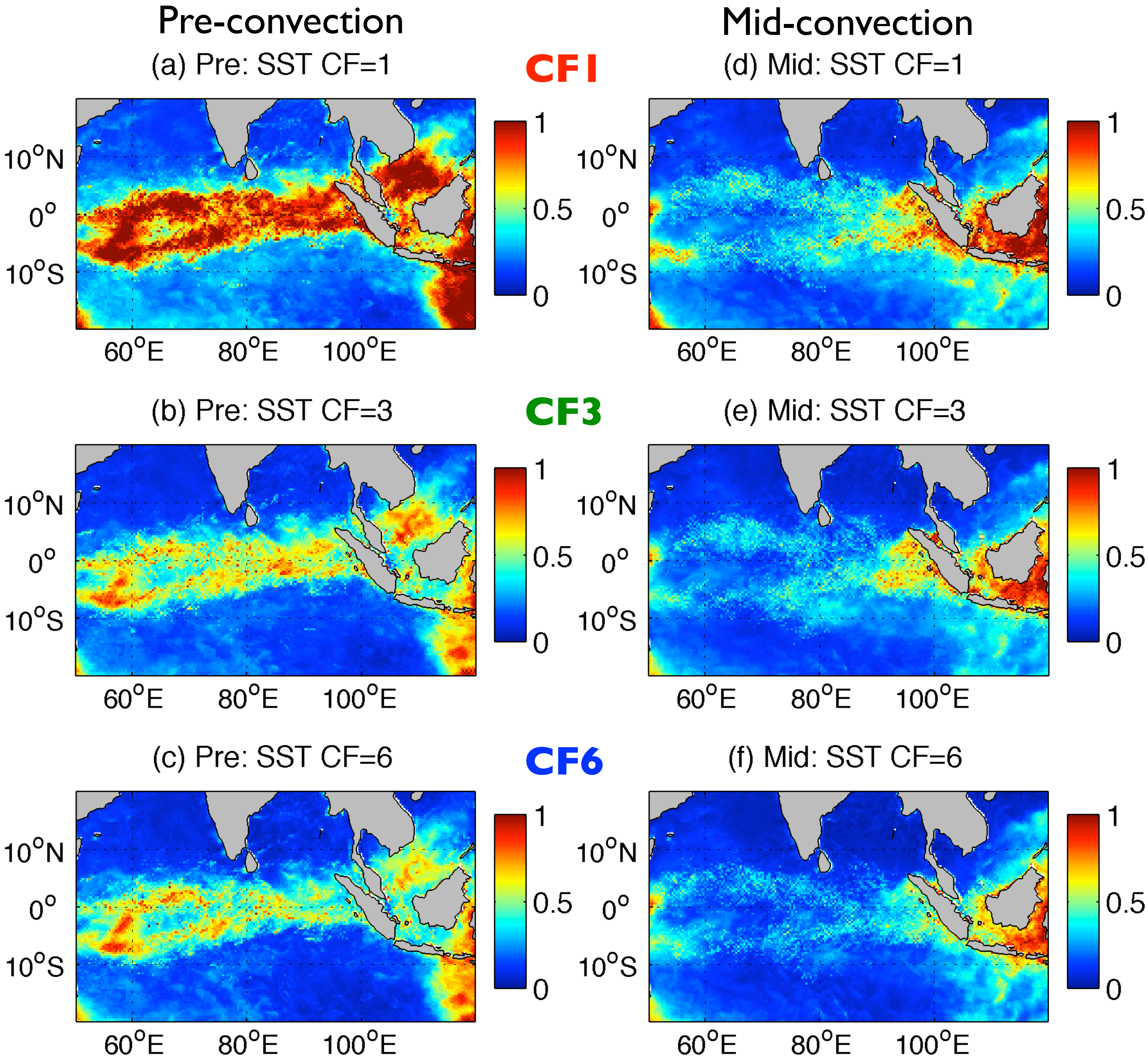
- Large diurnal variations help achieve higher SST values on diurnal time-scales during the suppressed phase.

# Spatial patterns in diurnal amplitude in SST




- Larger diurnal amplitude in SST during the pre-convection period.
- Higher coupling frequency allows greater amplitude of diurnal SST amplitude.
- Reduced diurnal cycle during the mid-convection period

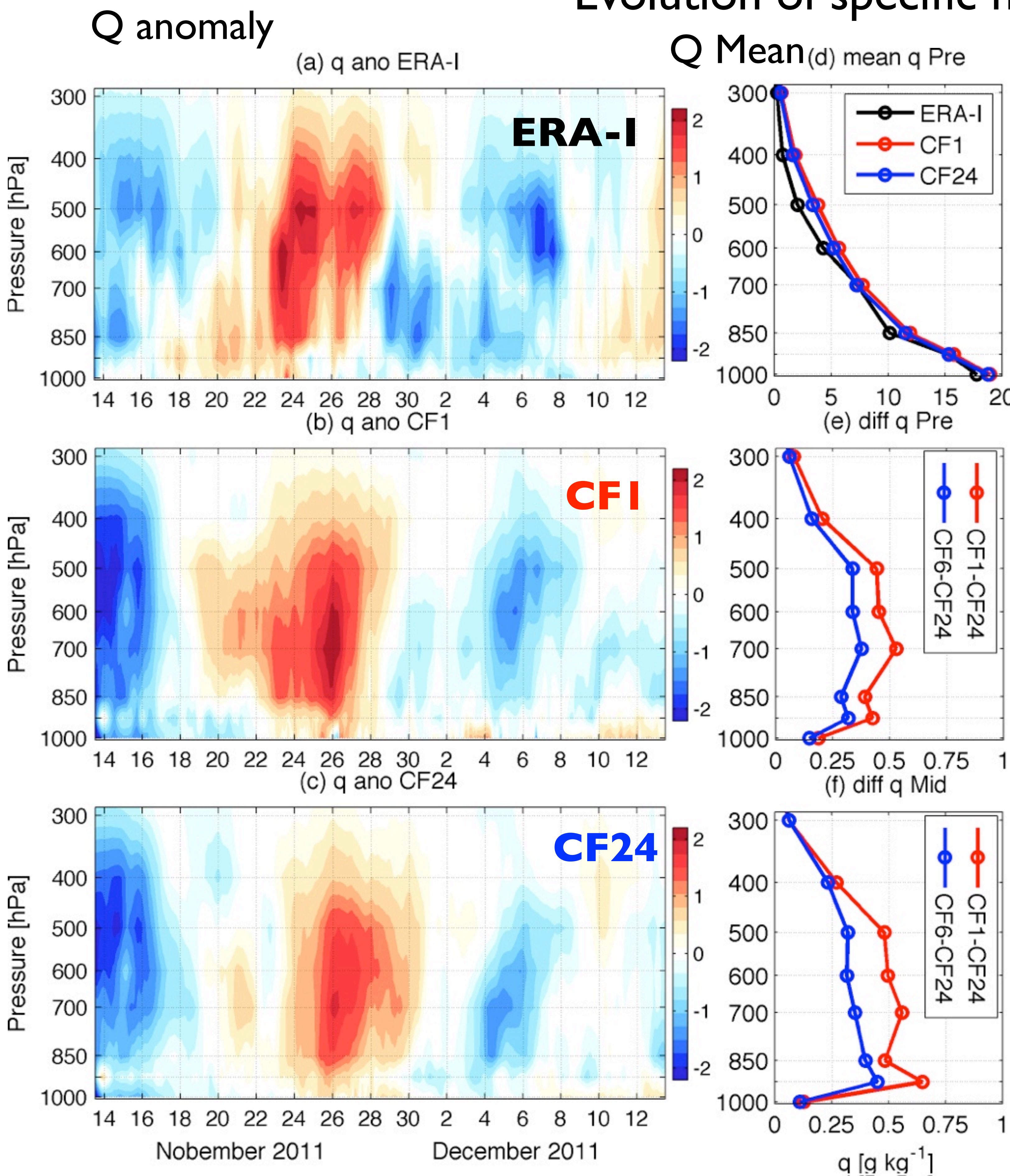
# Spatial patterns in diurnal amplitude in SST




- Larger diurnal amplitude in SST during the pre-convection period.
- Higher coupling frequency allows greater diurnal SST amplitude.
- Diurnal warm layer eroded by wind during the convection

What is the implication to the convection?

# Evolution of specific humidity




- The recharge period is characterized by drying of the atmosphere column.
- A gradual moistening of the atmosphere from Nov. 18 in ERA-Interim and models.
- The peak moistening on Nov. 24, coincident to the deep convection and the maximum rainfall.
- The extent to which the atmosphere is moistened is greater in CF1 than CF24.
- The mean specific humidity profiles suggests that the atmospheric column becomes moister with higher frequency coupling.

Why increased rainfall during the active phase of MJO with higher coupling frequency?

Column integrated Moist Static Energy (MSE) budget analysis

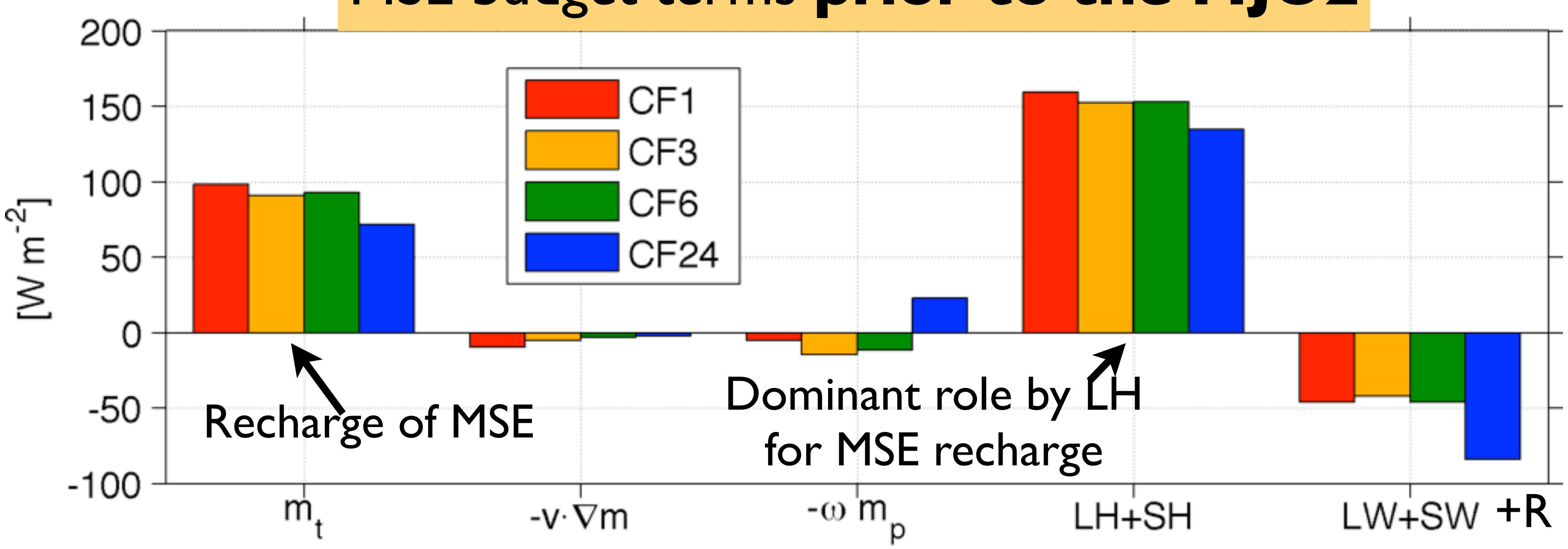
# MSE Budget over the Northern DYNAMO region

$$\underbrace{\langle m_t \rangle}_{tendency} = \underbrace{-\langle v_h \cdot \nabla m \rangle}_{\text{horizontal advection}} \underbrace{-\langle \omega m_p \rangle}_{\text{vertical advection}} \underbrace{+\left( LH + SH \right)}_{\text{latent+sensible flux}} \underbrace{+\langle LW + SW \rangle}_{\text{long+shortwave flux}}$$

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

Maloney 2009

MSE budget terms **prior to the MJO2**




- **MJO suppressed phase**
- Recharge of MSE by LH.
- A buildup of MSE is "faster" with higher coupling frequency, associated with stronger import by LH and export by LW.

(Maloney et al. 2010; Sobel et al. 2008)

# MSE Budget over the Northern DYNAMO region

$$\underbrace{\langle m_t \rangle}_{\text{tendency}} = \underbrace{-\langle v_h \cdot \nabla m \rangle}_{\text{horizontal advection}} \underbrace{-\langle \omega m_p \rangle}_{\text{vertical advection}} + \underbrace{(LH + SH)}_{\text{latent+sensible flux}} + \underbrace{\langle LW + SW \rangle}_{\text{long+shortwave flux}}$$

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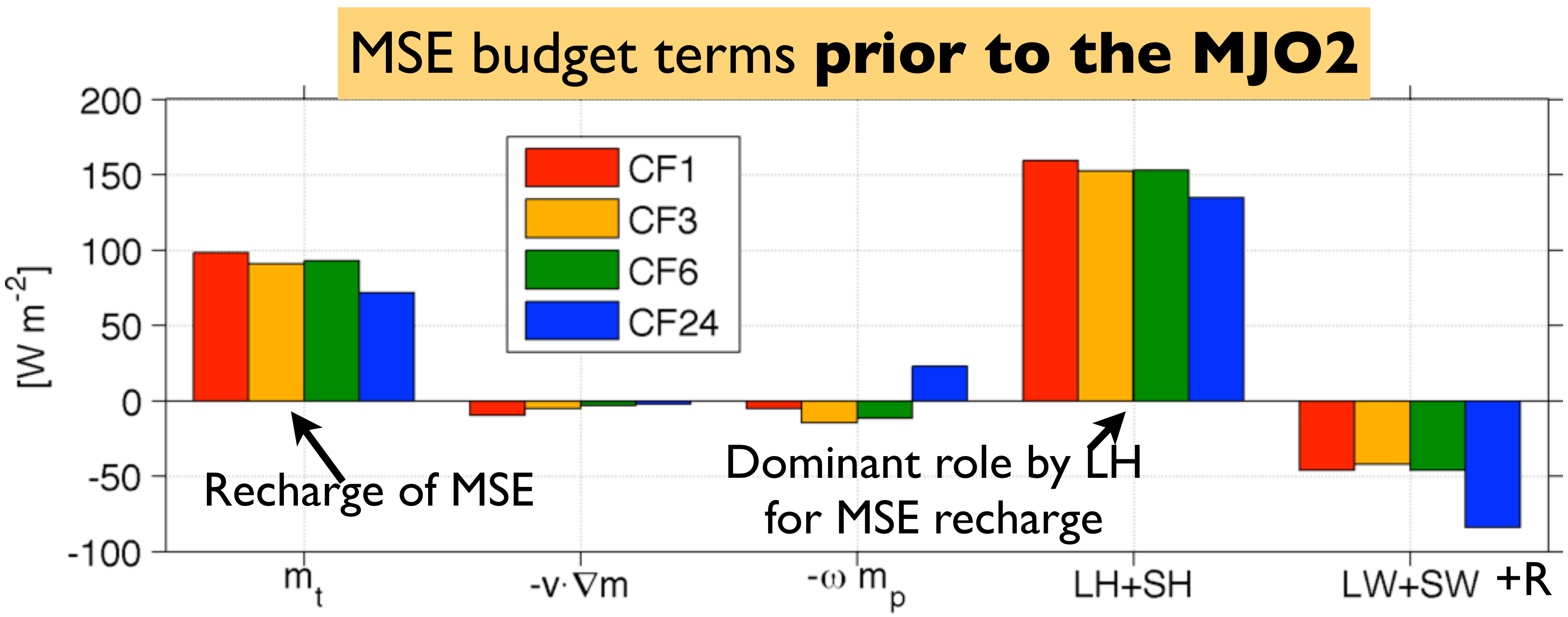


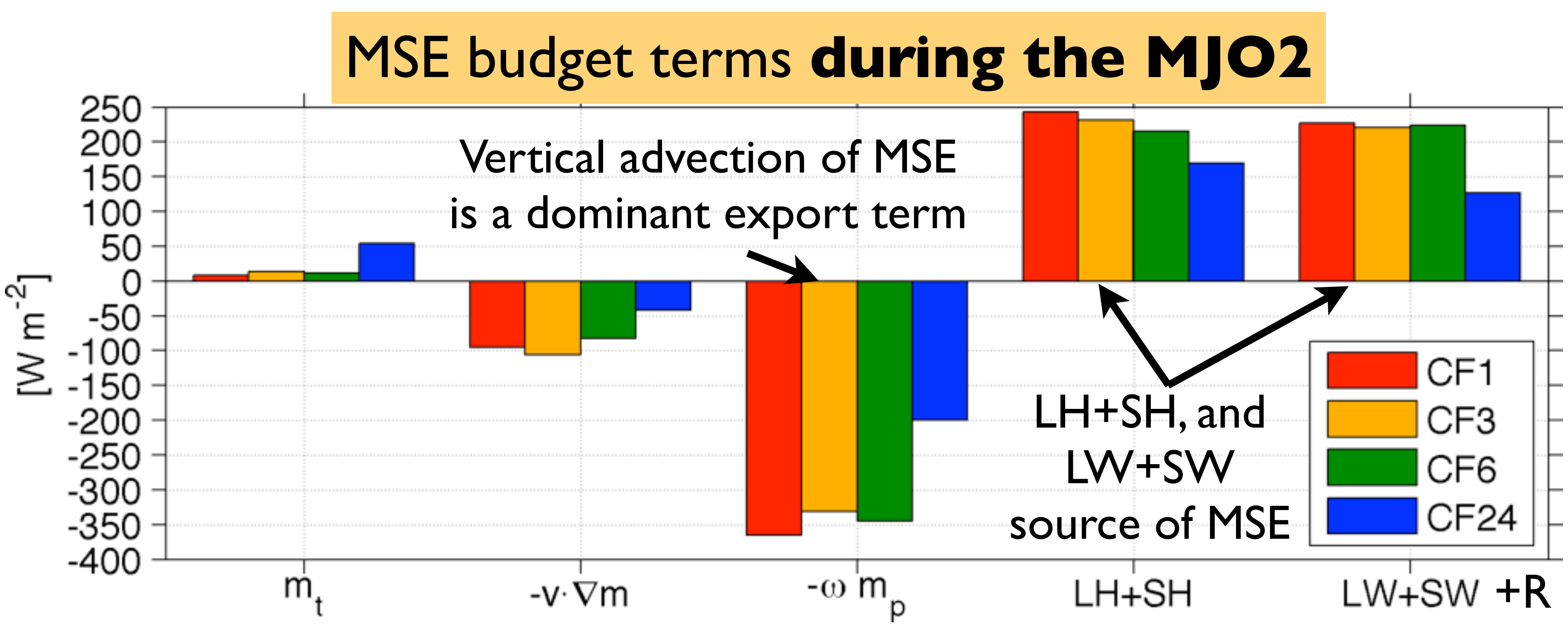


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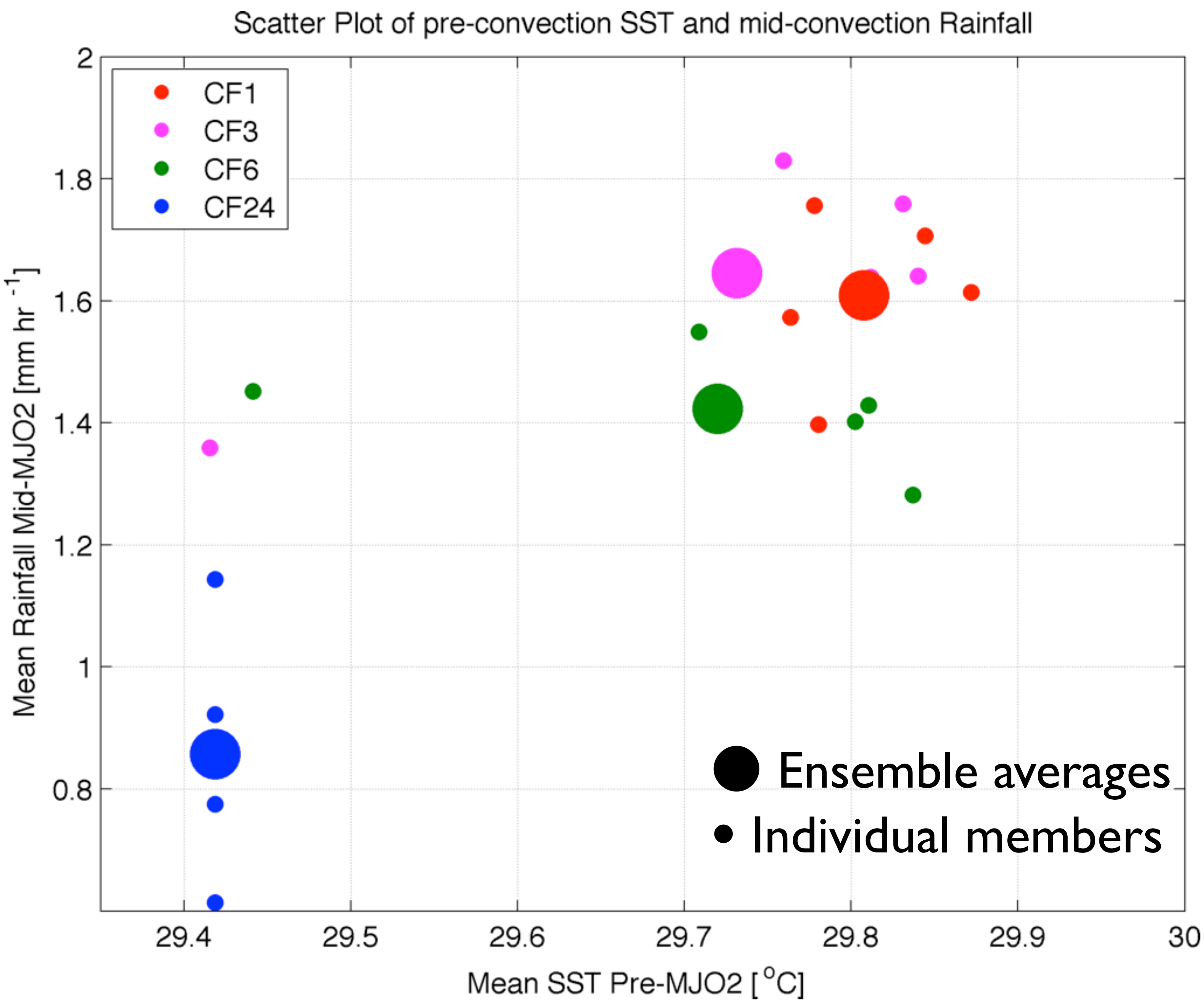
- **MJO active phase**
- LH+SH and LW+SW continue to be the major source terms of MSE.
- Vertical advection by deep convection is a dominant export process.
- Stronger vertical advection with more frequent coupling!

# Overall linear lead-lag relationship between SST and rainfall




- Higher CF leads to warmer SST during the suppressed phase.

- This leads to higher rainfall amount during the active phase.

- Heat and moisture flux feedback associated with warmer SST responsible for the intensity of convection (Arnold et al. 2013)

# Summary

• SCOAR2 supports significant eastward propagating convectively coupled disturbances in the MJO wavenumber-frequency band.

• Improved representation of diurnal cycle leads to higher SST during the suppressed phase of convection.

• LH plays an critical role in a rapid recharge of MSE.

• A buildup of MSE pre-conditions the deep convection, followed by intense precipitation during the active phase of MJO.

• Consistent with the recharge-discharge paradigm of Blade and Hartmann (1993).

• We found a quasi-linear relation in this recharge-discharge process to the frequency of coupling in a regional coupled model.

Thanks

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