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Diurnal cycle in SST and the MJO initiation during DYNAMO: A regional coupled modeling study

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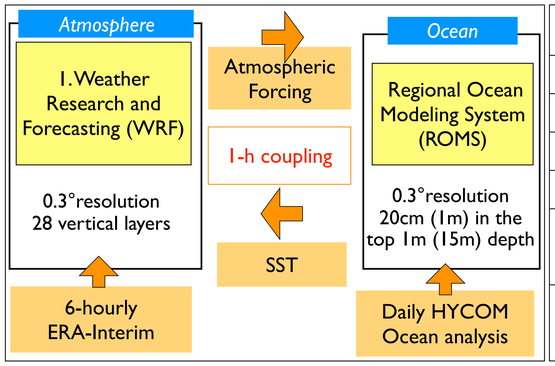
1. Summary

Goal #1: Quantify the effect of diurnal SST variability on the onset and intensity of the MJO convection during DYNAMO in the Indian Ocean.
Method: Use a systematic set of tropical-channel regional coupled model simulations (SCOAR model) with varied coupling intervals (1h to 24 h).
Result: Stronger diurnal SST amplitude (dSST) leads to higher time-mean SST and latent heat flux (LH) prior to MJO convection. LH diurnal peak is collocated with that of SST and specific humidity, maximizing a diurnal moistening of the troposphere. The intensity of MJO deep convection scales quasi-linearly with pre-convection dSST. A column integrated moist static energy (MSE) budget analysis confirms the critical role of the diurnal moistening in the MSE recharge and the strength of MJO convection.

Goal #2: Elucidate the role of diurnal SST fluctuation in the predictive skill of MJO during DYNAMO
Method: Based on two additional atmosphere-only simulations forced with persistent initial SST (CF1PS) and daily-mean SST (CF1DM) obtained from the 1-hourly coupled run (CF1).
Result: CF1PS, lacking enhanced pre-convection warming and moistening, produces a weaker and delayed convection compared to CF1. CF1DM with no diurnal fluctuation, while eliminating the delayed peak, continues to exhibit a weaker convection due to lack of moistening on a diurnal basis.

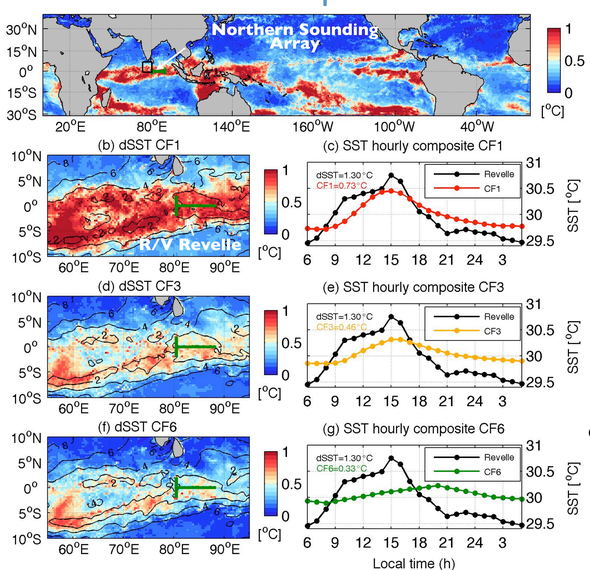
2. Scripps Coupled Ocean-Atmosphere Regional (SCOAR) Model



Experiment	Description
CF1	Coupled 1-h
CF3	Coupled 3-h
CF6	Coupled 6-h
CF24	Coupled 24-h
CF1DM	WRF forced with daily mean SST from CF1
CF1PS	WRF forced with time-invariant initial SST from CF1

Simulation period: 1 month (14 Nov - 13 Dec, 2011) covering the second MJO event during DYNAMO (aka MJO2).

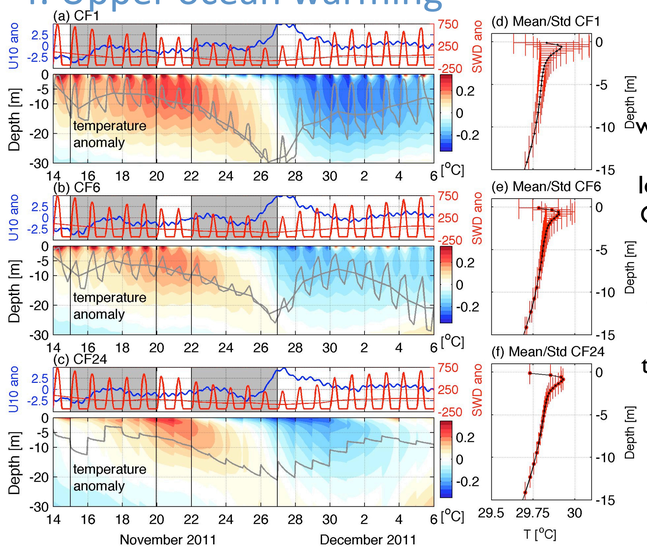
3. Diurnal SST amplitude in the model and obs



Maps of dSST on 15-19 November, 2011 prior to the MJO convection.

- High dSST (>1°C) in the DYNAMO region where surface wind speed is weak (<4 ms^{-1}).
- dSST in CF1 is 0.7°C, underestimating the observed value of 1.3°C.
- dSST is weaker with less frequent coupling.

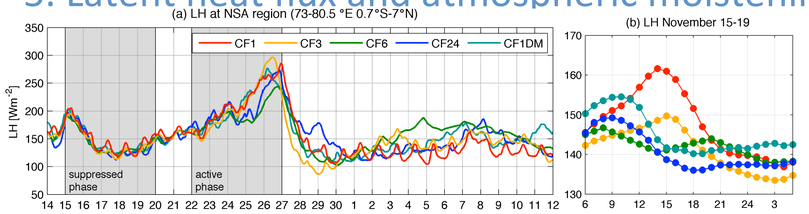
4. Upper ocean warming



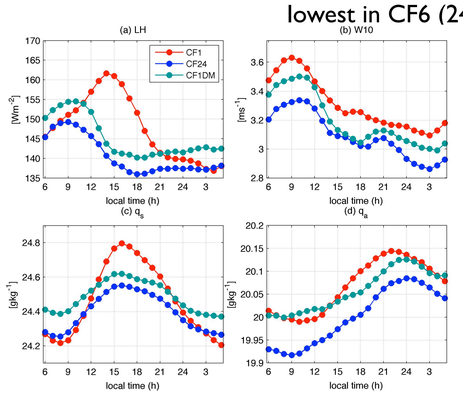
- Strong ML warming in CF1 and evidently less warming in CF6 and CF24.
- The diurnal fluctuation of the ML temperature is strongest in CF1.

The more frequent coupling leads to a stronger dSST and a higher time-mean SST. Mean SST in CF1 is significantly higher >0.1°C in CF1 than CF24.

5. Latent heat flux and atmospheric moistening



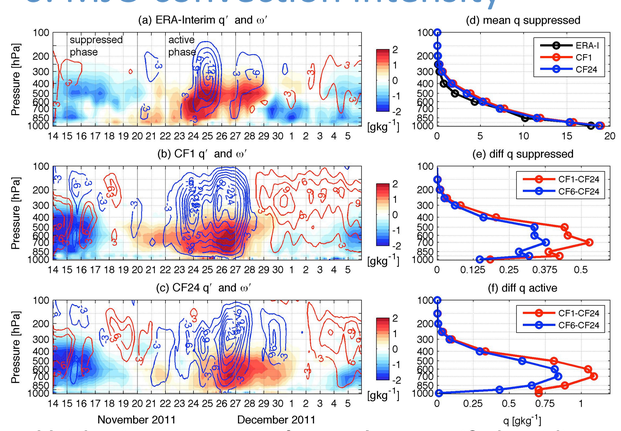
The time-mean LH to the atmosphere is higher by >10 Wm^{-2} in CF1, with diurnal difference up to >20 Wm^{-2}. dLH is highest in CF1 (30 Wm^{-2}) and lowest in CF6 (24 Wm^{-2}).



$$LH = \rho L C_H W10 (q_s - q_a)$$

- With no dSST, the LH diurnal peak occurs in the morning, following the peak of W10.
- In CF1, the diurnal peak of LH is determined by that of q_s, peaking in the afternoon following the SST.
- This co-location of diurnal peaks in LH and SST maximizes the moistening of the atmosphere.

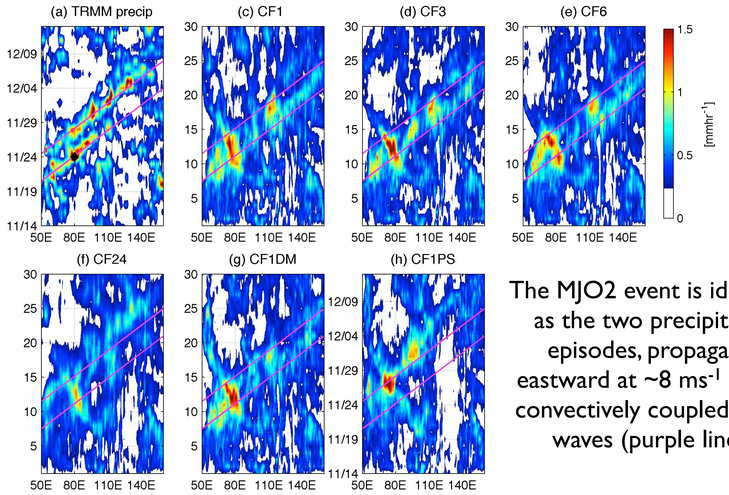
6. MJO convection intensity



- Low-level moistening in the initially dry troposphere implies the development of shallow convection.
- The mid-level moistening by deep convection is stronger in CF1.

Height-time structure of anomalous specific humidity and pressure vertical velocity over the NSA region

7. MJO precipitation intensity



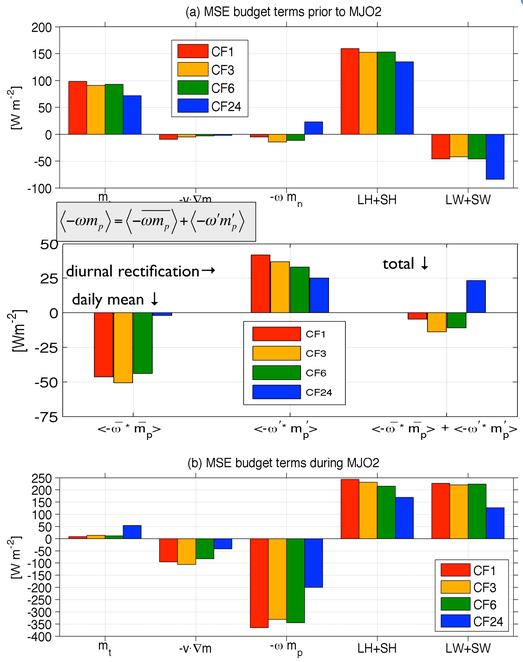
The MJO2 event is identified as the two precipitation episodes, propagating eastward at ~8 ms^{-1} as two convectively coupled Kelvin waves (purple lines).

	TRMM	CF1	CF3	CF6	CF24	CF1DM	CF1PS
Rainfall	1.14	1.72	1.63	1.51	0.93	1.62	1.02

Higher mean SST and dSST
⬇
Higher mean rainfall

- CF1PS has a delayed peak in precipitation on November 27, suggesting that the lack of pre-convection warming and moistening lowers the predictive skill of the onset (or timing) of convection.
- CF1DM eliminates the delayed peak but continues to exhibit a weaker convection due to lack of strong moistening on a diurnal basis.

8. Column moist static energy (MSE) budget



The MSE recharge during the suppressed phase is higher with more frequent coupling. LH is the dominant source term.

Decomposition of the vertical advection: The diurnal rectification effect moistens the atmosphere and accelerates the MSE recharge, which nearly cancels the MSE export by the convective downdrafts.

The intensity of deep convection via vertical advection is proportional to dSST.

9. Summary and Implications

- Higher dSST prior to MJO convection leads to enhanced time-mean LH and dLH. Diurnal peaks of LH and SST are coincident, providing an effective mechanism for low-level moistening and stronger MJO convection.
- Interactive SST with diurnal fluctuations strongly influences the onset and intensity of the MJO convection.

→ Consistent with previous studies that identified an improved representation of diurnal SST as a potential source of MJO predictability (e.g., Bernie et al. 2007; Woolnough et al. 2007).