Coupled impacts of the diurnal cycle of sea surface temperature on the Madden-Julian Oscillation
— Diurnal SST and MJO convection

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Dynamics of MJO (DYNAMO)
Initiation/Intensity of MJO convection ↔ Upper-ocean variability and air-sea flux
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R/V Mirai
R/V B. Jaya-III
Sounding Network
R/V S. Kanya
DYNAMO Field Experiment (October 2011 – March 2012)
R/V R. Revelle
Falcon
S-PolKa
SMART-R
P-3
ISS
Addu Atoll
R/V B. Jaya-III
R/V R. Revelle
R/V S. Kanya
Male
Addu
Revelle
Mirai
Moorings
MJO3
MJO2
MJO1
TRMM_3B42RT Precipitation [mm/hr]
Average Lat: 10°S - 10°N
0 60W 120W 180W 60W 120W 180
0 60E 120E 180E 60E 120E 180
0 60S 120S 180S 60S 120S 180S
0 60N 120N 180N 60N 120N 180N
0 60W 120W 180W 60W 120W 180
0 60E 120E 180E 60E 120E 180E

Courtesy of C. Zhang

Chidong Zhang
Dynamics of MJO (DYNAMO)
Initiation/Intensity of MJO convection ↔ Upper-ocean variability and air-sea flux

Moum et al. 2014

- Diurnal warm layer thickness of ~1 to 5 m
- >0.1°C temperature difference across the diurnal warm layer
What is the effect of SST diurnal cycle on MJO?

Numerical model experiments: forcing frequency & vertical resolution (e.g. Bernie et al. 2005)

- SCOAR coupled model
  - Atmosphere: WRF
  - Ocean: ROMS
  - Coupler: surface fluxes
  - SST & sfc. current

- 6-h ERA-Interim
- Daily HYCOM

- Seo et al., 2007, JCLI

40km resolution tropical channel regional coupled model

High vertical resolution
- 8 layers
- 20 layers

Coupling frequency: CF1, CF3, CF6, CF24

Seo et al. 2014 JCLI
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SCOAR coupled model

Atmosphere

WRF

6-h ERA-Interim

Ocean

ROMS

SST & sfc. current

Coupling frequency CF1, CF3, CF6, CF24

High vertical resolution

Upper 10 meter of the ocean

Seo et al., 2007, JCLI

Seo et al. 2014 JCLI

40km resolution tropical channel regional coupled model

20 layers

8 layers

[a] NOAAOI SST: 2011-11-16-00

[b] SCOAR SST: 2011-11-16-18
Diurnal SST raises the *time-mean SST* prior to the deep convection.

Upper ocean temperature evolution

- **dSST**
  - **Revelle 1.30°C**
  - **CF1 0.73°C**
  - **CF6 0.33°C**

- **CF1**
- **CF6**
- **CF24**
Diurnal SST strengthens the *diurnal moistening* of the atmosphere during the suppressed phase. The equation for latent heat (LH) is given as:

\[ \text{LH} = \rho L C_H (q_s - q_a) W_{10} \]

Diurnal \( q_s \) plays a leading role in maximizing the moistening in the troposphere.
Impact on MJO rainfall:
Rainfall intensity proportional to pre-convection diurnal SST

- MJO 2 on Nov. 24 with the eastward propagation $\sim 5 \text{ ms}^{-1}$.
- Models: qualitatively consistent intraseasonal evolution of rainfall
  - Higher mean rainfall amount with stronger dSST.
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Column-integrated moist static energy (MSE) budget

\[
\left\langle m_t \right\rangle = -\left\langle v_h \cdot \nabla m \right\rangle - \left\langle \omega m_p \right\rangle + (LH + SH) + (LW + SW)
\]

\[m = c_p T + gz + Lq\]

Maloney 2009

prior to the convection

Recharge of MSE

Dominant role by LH+SH for MSE recharge

<table>
<thead>
<tr>
<th>CF1</th>
<th>CF3</th>
<th>CF6</th>
<th>CF24</th>
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</thead>
<tbody>
<tr>
<td>100</td>
<td>50</td>
<td>0</td>
<td>-50</td>
</tr>
<tr>
<td>150</td>
<td>100</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>200</td>
<td>150</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

\[\text{tendency} \quad \text{Hadv} \quad \text{Vadv} \quad \text{LH+SH} \quad \text{LW+SW} \]
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Maloney 2009

Prior to the convection

Recharge of MSE

Dominant role by LH+SH for MSE recharge

Sources of MSE during the convection

Dominant export term
Column-integrated moist static energy (MSE) budget

\[
\langle m_t \rangle = -\langle v_h \cdot \nabla m \rangle - \langle \omega m_p \rangle + (LH + SH) + \langle LW + SW \rangle
\]

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\]

Maloney 2009

prior to the convection

Domestic role by LH+SH for MSE recharge

during the convection

Domestic export term
Diurnal moistening of the lower troposphere

\[ \langle \omega m_p \rangle = \langle \omega m_p \rangle + \langle \omega' m'_p \rangle \]

- The daily mean advection dries the air column; not related to dSST
- Diurnal moistening is a source of MSE; proportional to dSST
Summary and discussion

1. SCOAR regional coupled modeling for the MJO and diurnal SST
   - Tropical channel, high vertical resolution, air-sea coupling
2. Diurnal SST variability prior to the deep convection
   - raises time-mean SST (and LH): via diurnal rectified effect
   - enhances diurnal moistening: via coincident peaks of LH & SST
3. Precipitation amount scales quasi-linearly with pre-convection diurnal SST amplitude
4. An improved representation of diurnal SST as a potential source of MJO predictability.
Thanks!

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Seo et al. 2014, Coupled impacts of the diurnal cycle of sea surface temperature on the Madden-Julian Oscillation. J. Climate