The role of air-sea coupling in MJO propagation in the Hadley Centre model

Nicholas Klingaman and Steve Woolnough
NCAS-Climate, University of Reading
Is SST variability just a “crutch” for bad models?

SST variability improved amplitude and propagation of sub-seasonal convection in atmosphere-only (K. et al., 2008) and coupled (K. et al., 2011) models.

Lag correlations of 70-100E 30-70 day rainfall against 12.5N (Lin et al., 2008).
Coupling produces the correct phase relationship between sub-seasonal precipitation and SST anomalies: warm SST leads heavy rainfall by ~6-8 days.

Atmosphere-only NWP models (which persist SSTs or SST anomalies) lose this relationship within a few days.
In its default configuration, the MetUM GA3.0 atmosphere-only model has approximately 60% of the observed level of MJO activity.

The GA3.0 MJO is as likely to die as it is to propagate to the next phase.
Increasing $F$ (entrainment and mixing detrainment) improves MJO activity in GA3.0, reducing “decay” and increasing “next”. Klingaman and Woolnough (2014a, QJRMS, accepted)
Climate experiments

<table>
<thead>
<tr>
<th>Integration</th>
<th>Entrainment</th>
<th>SSTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-CTL-OBS</td>
<td>Default</td>
<td>Repeating mean annual cycle of observed SSTs from 1980-2009, updated daily.</td>
</tr>
<tr>
<td>A-ENT-OBS</td>
<td>150%</td>
<td>As in A-CTL-OBS</td>
</tr>
<tr>
<td>K\textsubscript{WP}-CTL-OBS</td>
<td>Default</td>
<td>Within 40-200E, 30S-30N: Coupled to high-res (1m vertical) KPP boundary-layer ocean every 3 hours Elsewhere: Climatological SSTs as in A-CTL</td>
</tr>
<tr>
<td>K\textsubscript{WP}-ENT-OBS</td>
<td>150%</td>
<td>As in K\textsubscript{WP}-CTL-OBS</td>
</tr>
<tr>
<td>K\textsubscript{IO}-ENT-OBS</td>
<td>150%</td>
<td>Coupled to KPP within 40-100E, 30S-30N.</td>
</tr>
<tr>
<td>A-ENT-K\textsubscript{WP}</td>
<td>150%</td>
<td>Repeating mean annual cycle of K\textsubscript{WP}-ENT-OBS</td>
</tr>
</tbody>
</table>

- All integrations are at 1.875° lon x 1.25° lat with 85 vertical points.
- All integrations are 20 years long.
**Key advantages:**

- **Cheap:** < 5% of the cost of the atmosphere, allowing high (1 metre) ocean vertical resolution.
- **Controllable:** Easily constrainable to any desired ocean state (small SST biases).
- **Flexible:** Air-sea coupling can be applied selectively in space and time to explore the role of coupling in a range of phenomena.
- **Adaptable:** Works easily with any GCM grid.

Climatological three-dimensional heat and salt tendencies are applied to represent

- (a) the mean horizontal advection in the ocean
- (b) corrections for biases in atmospheric surface fluxes
• Because the KPP columns do not communicate, there is complete flexibility in where the atmosphere and ocean are coupled.
• The only limitation is that (for now) we cannot couple over sea ice.
• SSTs and sea ice are prescribed outside the coupling region.
At default $F$ ("bad model"), well-resolved coupling improves the amplitude of the MJO.
At higher $F$ ("good model"), well-resolved coupling does not change the amplitude of the MJO.
- At default $F$, coupling somewhat improves MJO propagation.
- At 1.5 $F$, coupling substantially improves MJO propagation.

Klingaman and Woolnough (2014b), *QJRMS*, accepted.
• Better propagation in $K_{WP}$-ENT-OBS is largely from coupling itself, not impact of coupling on the mean SST.
• Coupling in both the Indian Ocean and the West Pacific is crucial for MJO propagation in this model.
Even when using heat and salt corrections, coupling still produces slightly different mean SST and rainfall, particularly around the Maritime Continent.

Is improved MJO propagation related to these mean-state changes?
At the Met Office, coupling to the NEMO ocean model does not improve the MJO at default $F$. 
Imposing the GA3.0+NEMO SSTs in the atmosphere-only GA3.0 model makes the MJO worse.
Summary and conclusions

• The mixed-layer coupling framework provides an improved test bed for the role of air-sea coupling, because the mean state can be constrained without influencing variability.

• At default/“low” entrainment (poor atmospheric MJO), air-sea coupling improved MJO amplitude and propagation.

• At higher entrainment (better atmospheric MJO), air-sea coupling improved MJO propagation without affecting MJO amplitude.

• In atmospheric models with a poor MJO, coupling may be a crutch that amplifies weak sub-seasonal variability for the wrong reasons.

• The effect of coupling (even good coupling) may be strongly masked by biases in the mean state, limiting its perceived impacts.