Why do air-sea interactions improve predictions of the MJO?

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Introduction and motivation

- Air-sea interactions improve the representation of the Madden-Julian Oscillation (MJO) in climate models and initialised forecasts.
- Intra-seasonal SST anomalies may feed back to the MJO through surface fluxes, either directly or indirectly via the atmospheric circulation.

Above: Forecast skill during two YOTC MJO events for coupled and uncoupled models (Shelley et al., 2014).

Right: OLR lag regressions for OBServations, ATMosphere-only and CouPLed climate simulations (Klingaman and Woolnough, 2014)
Introduction and motivation

• Despite many simulations, it is not clear why air-sea coupling and/or intraseasonal SSTs improve the MJO.
  • SST diurnal cycle enhances sub-seasonal variability
  • Coupling alters SST gradients and hence circulation
  • SST-driven surface convergence
  • Warm SSTs enhance surface fluxes

• Coupling affects the mean state, which may in turn affect the MJO. Even when coupled and uncoupled simulations have the same SST!

Above: OLR anomalies (from period mean) averaged 10S-10N. Data: NOAA CIRES satellite-derived OLR
## Initialized forecast experiments

- Process-oriented experiments to understand air-sea coupling mechanisms
- Initialized simulations to mitigate effects of model physics changes on the mean state.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Coupling?</th>
<th>Perturbation</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPL-CTL</td>
<td>Yes</td>
<td>None</td>
<td>Control experiment</td>
</tr>
<tr>
<td>ATM-DAY</td>
<td>No</td>
<td>Persist initial raw SST</td>
<td>Compare to CPL-CTL: Role of coupling</td>
</tr>
<tr>
<td>ATM-BGD</td>
<td>No</td>
<td>Persist initial 71-day mean SST</td>
<td>Compare to ATM-DAY: Role of initial intraseasonal SST anomalies</td>
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- 1hr coupling mixed-layer ocean with high vertical resolution, in which coupled SST can be easily controlled.
- 4-member ensemble of 20-day forecasts initialised every day for 1 October – 5 December 2011.
- All results for ensemble-mean.
- Each experiment is equivalent to 15 years of climate simulation!
Air-sea coupling and intraseasonal SST

- Coupling makes little difference at day 5.
- Intraseasonal SST variability improves amplitude and coherence.

Hovmollers of OLR anomalies (from period mean) averaged 10S-10N.
Forecasts at 5 day lead time.
Air-sea coupling and intraseasonal SST

- Coupling greatly improves longer-lead predictions of November event, but not October event.
- Intraseasonal SST variability has less effect at longer lead times (neither ATM run does well).

Hovmollers of OLR anomalies (from period mean) averaged 10S-10N.
Forecasts at 15 day lead time.
Air-sea coupling and intraseasonal SST

- Coupling improves prediction skill.
- Including initial intraseasonal SSTs improves skill more.
- Coupling improves skill for winds more than for OLR.
Initialized forecast experiments

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<tr>
<td>CPL-NDC-ALL</td>
<td>Yes</td>
<td>Daily coupling</td>
<td>Role of diurnal SST</td>
</tr>
<tr>
<td>CPL-NDC-SHF</td>
<td>Yes</td>
<td>SHF sees daily SST</td>
<td>Role of diurnal SST on SHF only</td>
</tr>
<tr>
<td>CPL-NDC-LHF</td>
<td>Yes</td>
<td>LHF sees daily SST</td>
<td>Role of diurnal SST on LHF only</td>
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Diurnal cycle of SST

- Diurnal cycle of SST makes little difference at day 5

Hovmollers of OLR anomalies (from period mean) averaged 10S-10N. Forecasts at 5 day lead time.
Diurnal cycle of SST

- Removing diurnal cycle of SST quickens propagation, particularly for November event, and increases amplitude (?!).
- Perturbing LHF has a greater effect than perturbing SHF.

Hovmollers of OLR anomalies (from period mean) averaged 10S-10N.
Forecasts at 15 day lead time.
Diurnal cycle of SST

- Removing diurnal cycle of SST degrades predictions of all RMM components.
- Effect of diurnal SST on LHF is responsible for all of this.
- Effect of diurnal SST is about half of the effect of coupling.
Initialized forecast experiments

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<td>CPL-NMG-ALL</td>
<td>Yes</td>
<td>Smooth SST anomalies 15S-15N</td>
<td>Role of intraseasonal meridional SST gradient</td>
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Meridional SST gradients

- Removing meridional gradient of intraseasonal SST has little effect at 5 day lead time.
- Slightly reduced OLR anomalies near Maritime Continent in first suppressed event.
Meridional SST gradients

- Removing meridional gradient of intraseasonal SST has more substantial effect at 15 day lead time.
- Disrupted propagation of November event through Maritime Continent.
Meridional SST gradients

- Removing meridional gradient of intraseasonal SSTs reduces skill by more than removing diurnal cycle.
- Due more to effect on SHF than to changes on LHF.
Summary and conclusions

- MetUM coupled mixed-layer model predicts DYNAMO MJO events well. November event is better predicted than October event.

- Coupling improves predictions, as does the initial intraseasonal SST variability. Atmospheric precursor signals alone are not sufficient for skilful predictions.

- The diurnal cycle of SST has relatively little effect, except on phase speed at long leads.

- Meridional gradient of intraseasonal SST anomalies is important, particularly for propagation through the Maritime Continent.

- Initialized forecasts allow targeting the effect of air-sea coupled mechanisms on the MJO, while minimising the complications from mean-state changes. But they’re expensive!