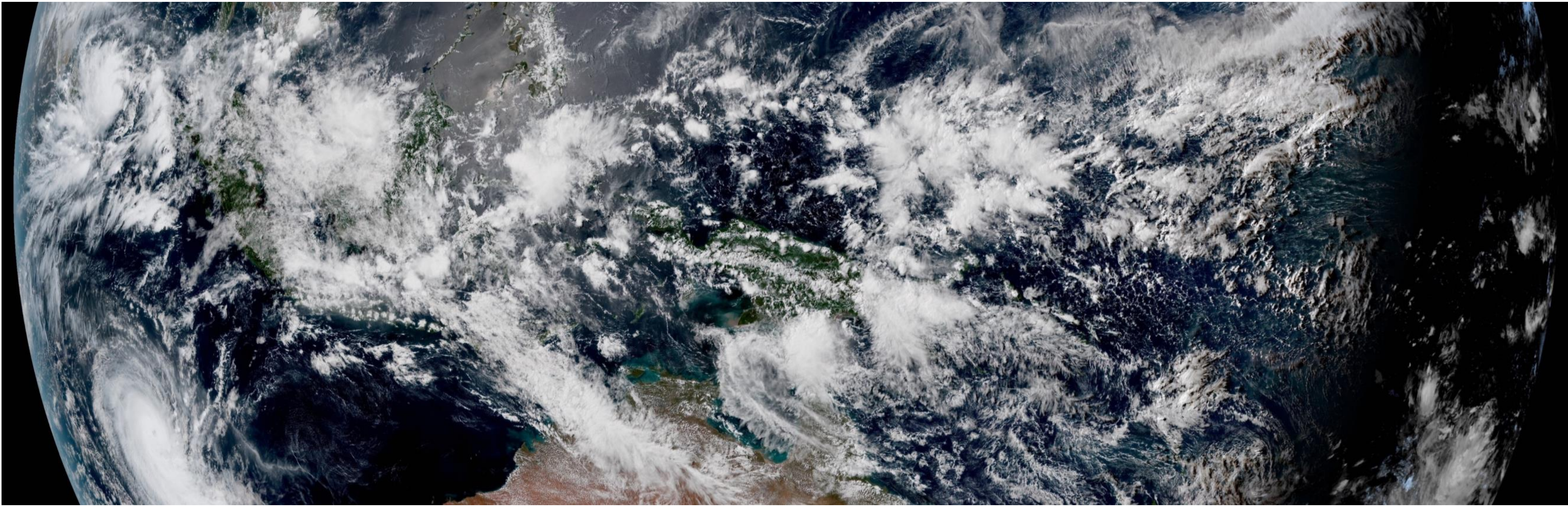
Why do air-sea interactions improve predictions of the MJO?



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NATURAL ENVIRONMENT RESEARCH COUNCIL

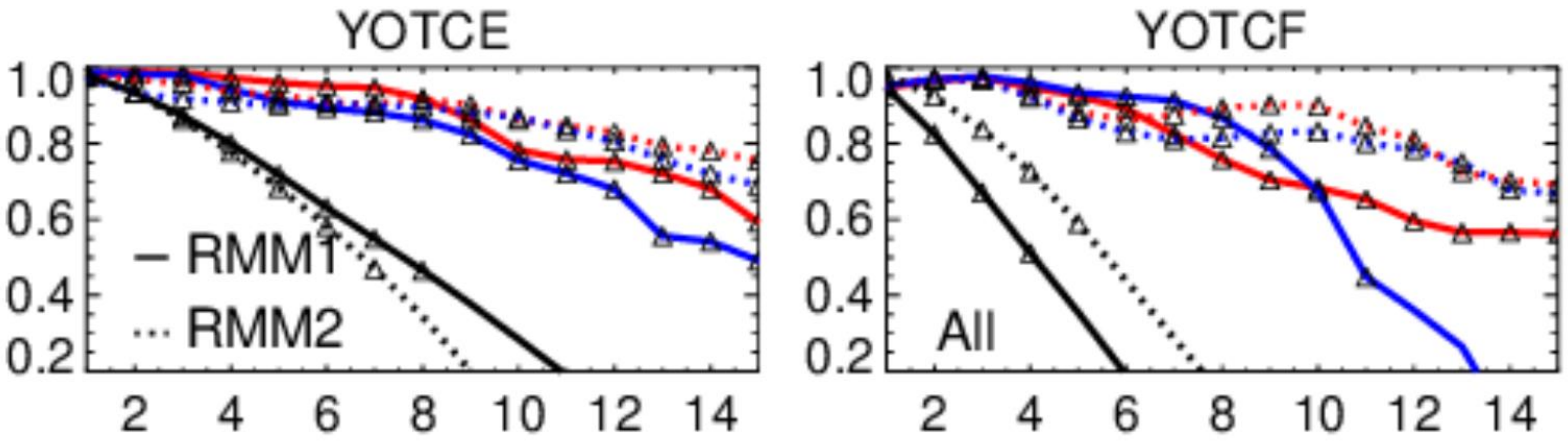
Colorado State University

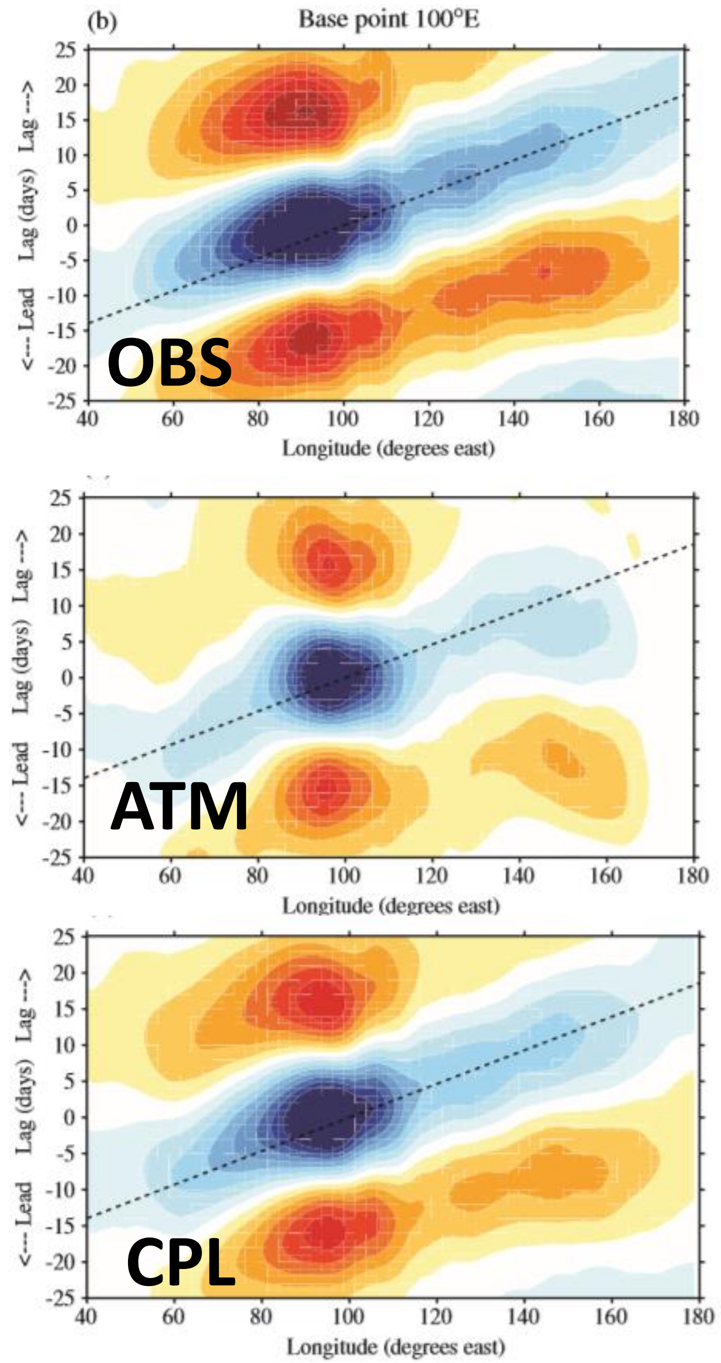
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Nicholas Klingaman and Charlotte DeMott
CLIVAR Tropical Convection and Air-Sea Interaction Workshop, Boulder – May 2019

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.



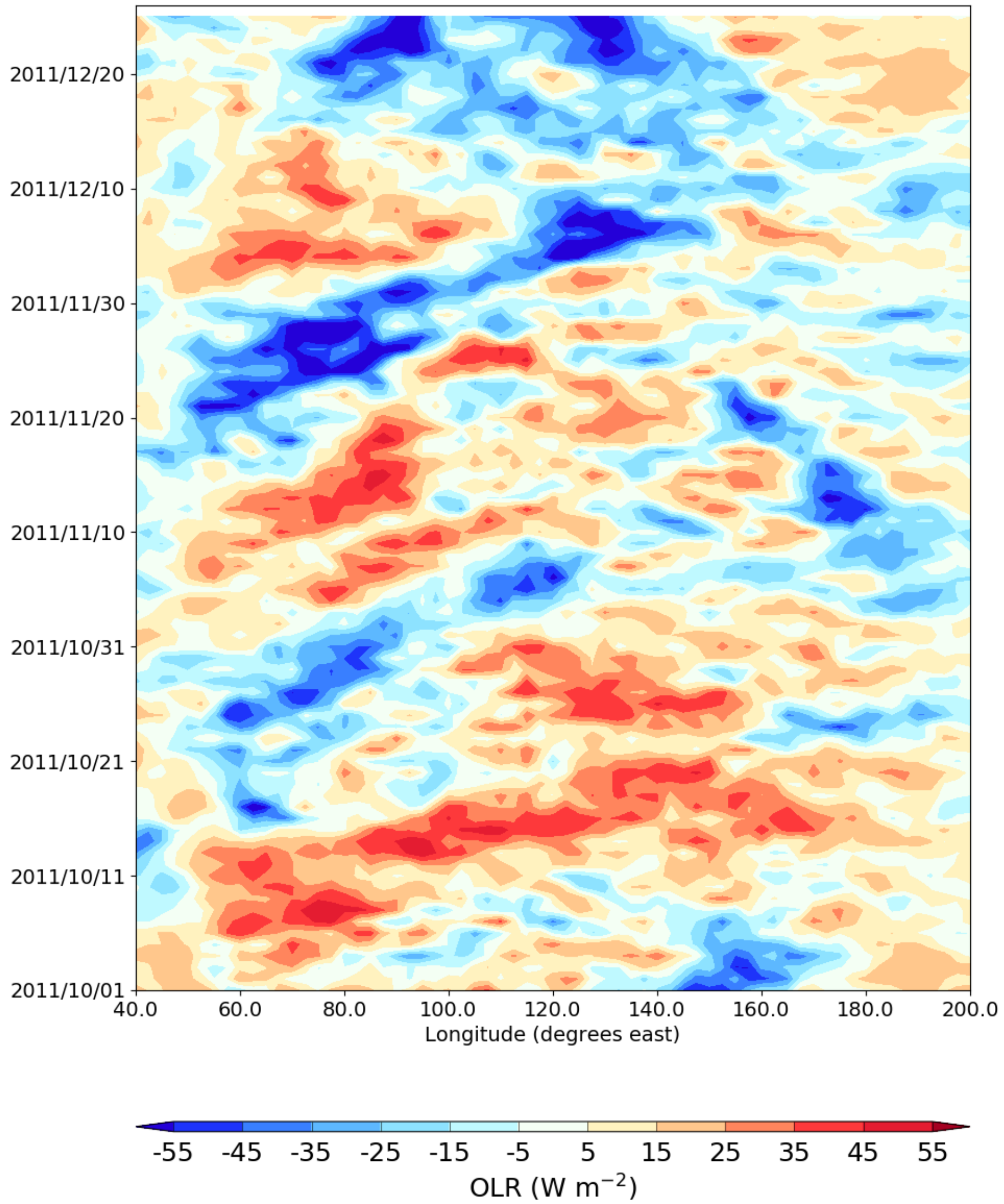


Above: Forecast skill during two YOTC MJO events for coupled and uncoupled models (Shelley et al., 2014).
Right: OLR lag regressions for OBServations, ATMosphere-only and CouPLed climate simulations (Klingaman and Woolnough, 2014)

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

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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.

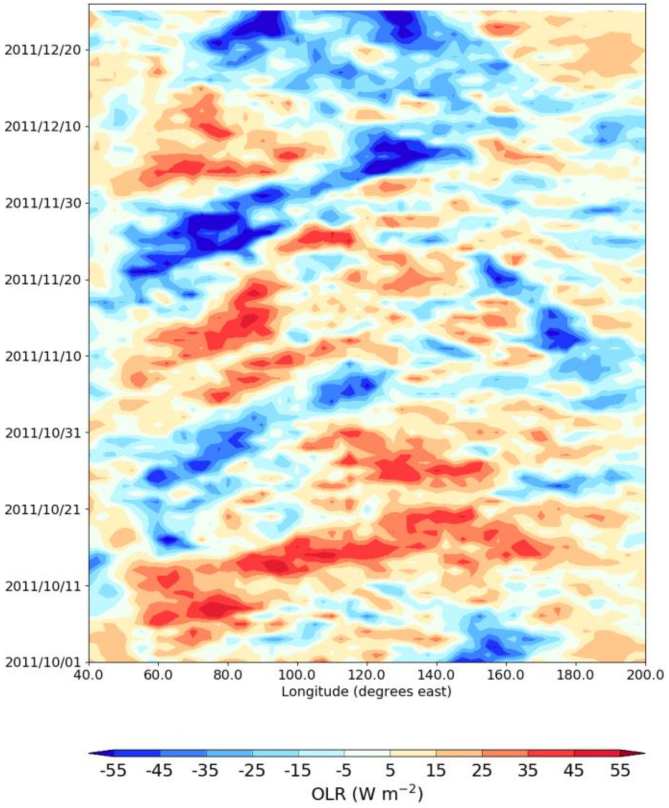
Experiment	Coupling?	Perturbation	Interpretation
CPL-CTL	Yes	None	Control experiment
ATM-DAY	No	Persist initial raw SST	Compare to CPL-CTL: Role of coupling
ATM-BGD	No	Persist initial 71-day mean SST	Compare to ATM-DAY: Role of initial intraseasonal SST anomalies

- 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!

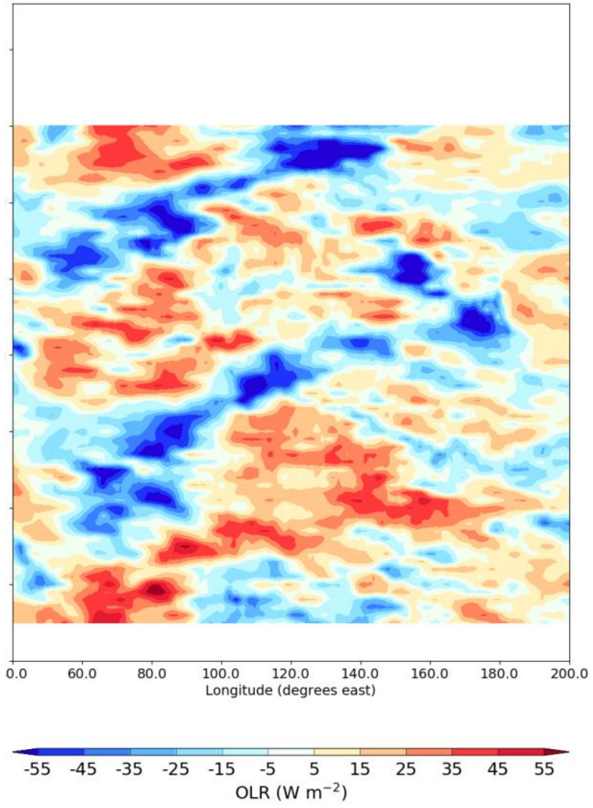
Air-sea coupling and intraseasonal SST

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

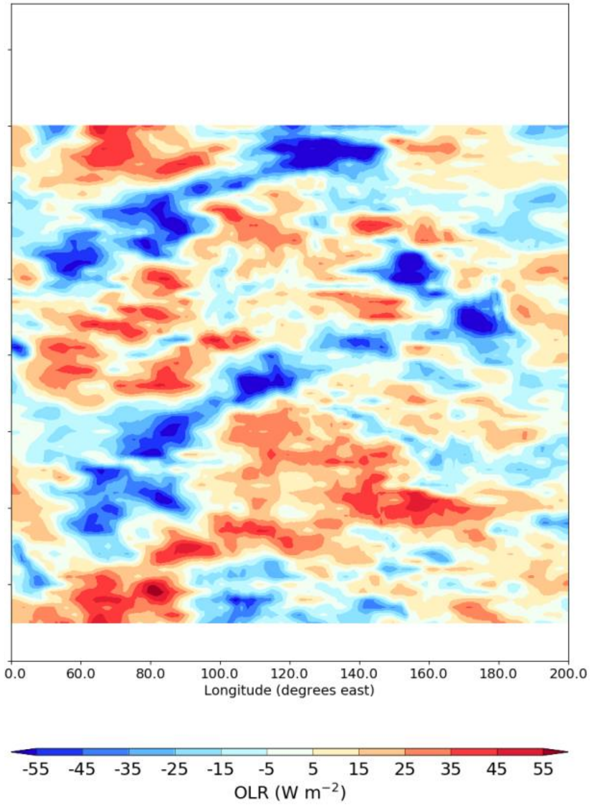
Observations



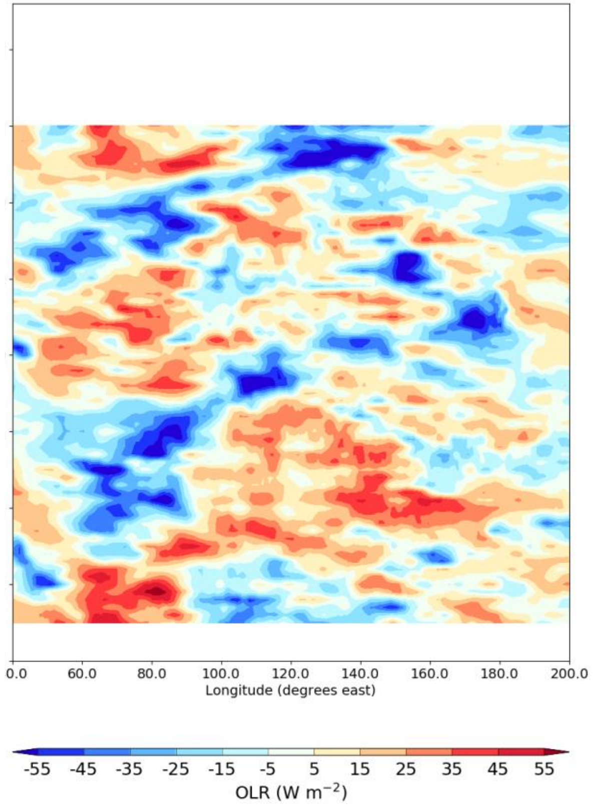
CPL-CTL



ATM-DAY



ATM-BGD



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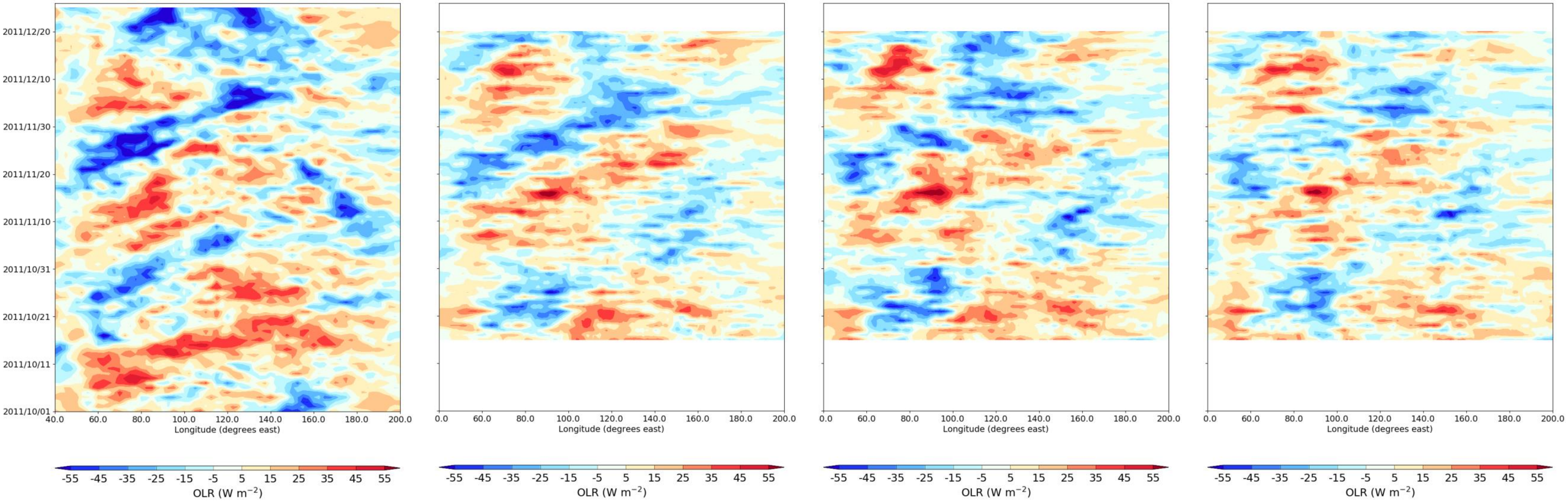
Hovmollers of OLR anomalies (from period mean) averaged 10S-10N.
Forecasts at **5 day** lead time.

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).

Observations | **CPL-CTL** | **ATM-DAY** | **ATM-BGD**



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

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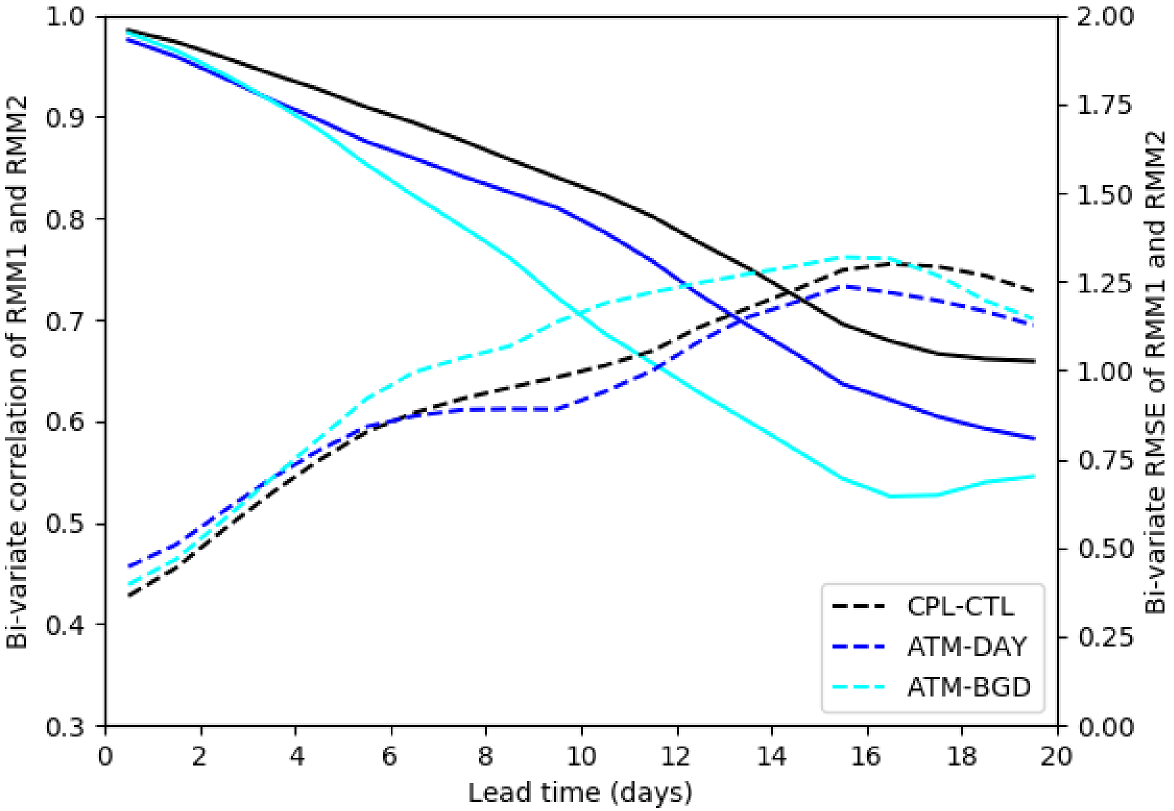
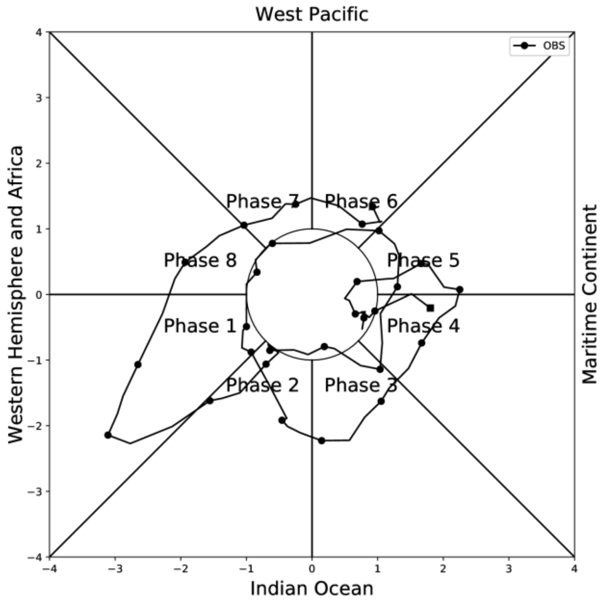
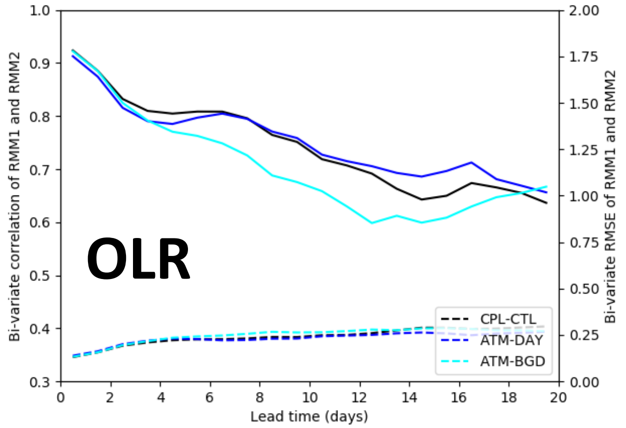
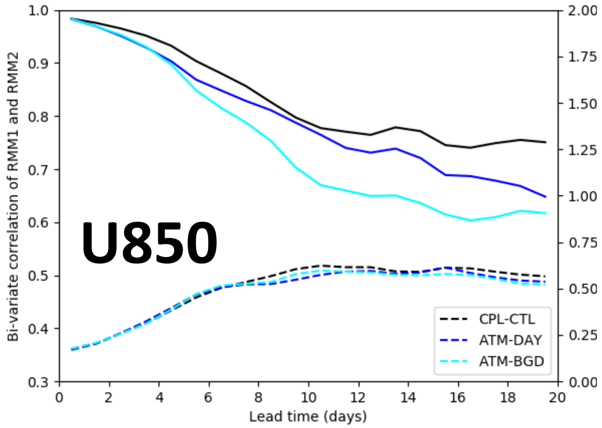
Air-sea coupling and intraseasonal SST

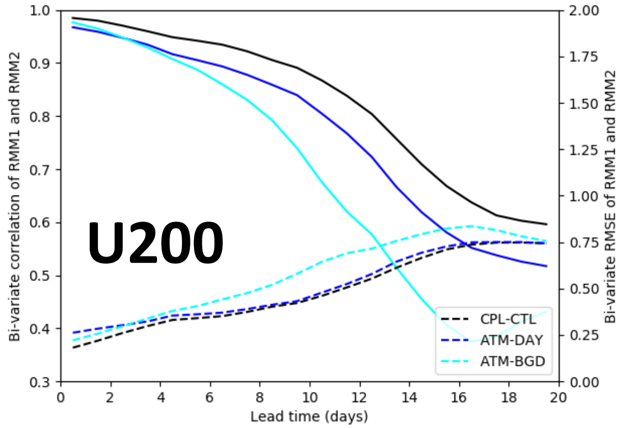
- Coupling improves prediction skill.
- Including initial intraseasonal SSTs improves skill more.
- Coupling improves skill for winds more than for OLR.











Initialized forecast experiments

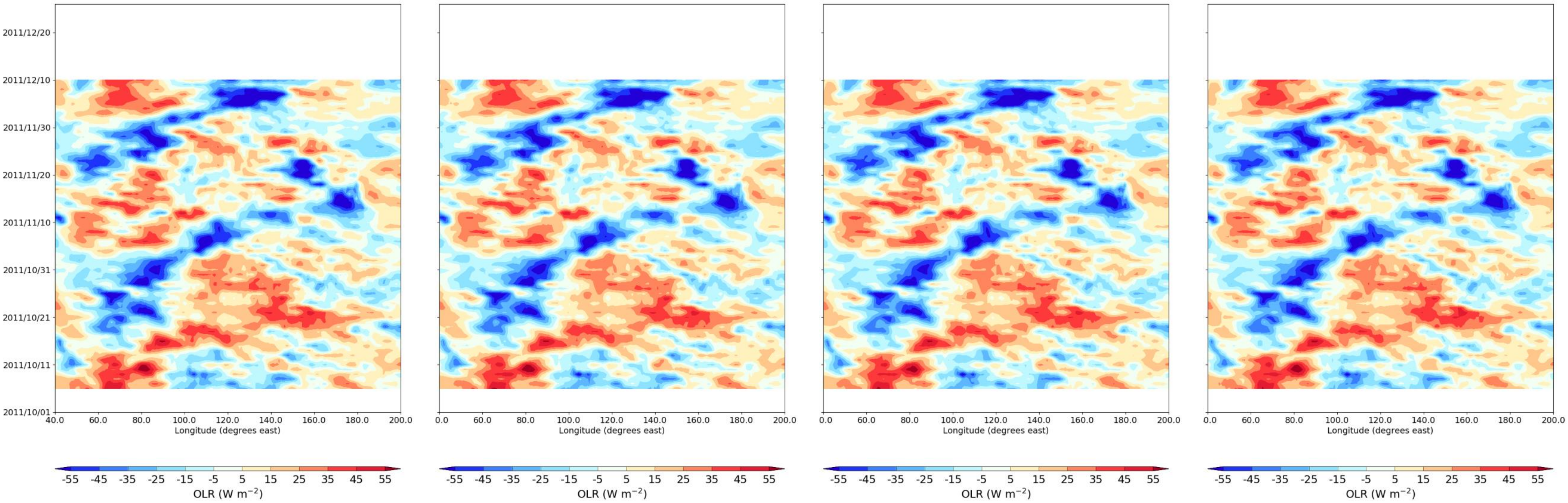
- Process-oriented experiments to understand air-sea coupling mechanisms
- Initialized simulations to mitigate effects of model physics changes on the mean state.

Experiment	Coupling?	Perturbation	Interpretation
CPL-CTL	Yes	None	Control experiment
ATM-DAY	No	Persist initial raw SST	Role of coupling
CPL-NDC-ALL	Yes	Daily coupling	Role of diurnal SST
CPL-NDC-SHF	Yes	SHF sees daily SST	Role of diurnal SST on SHF only
CPL-NDC-LHF	Yes	LHF sees daily SST	Role of diurnal SST on LHF only

Diurnal cycle of SST

- Diurnal cycle of SST makes little difference at day 5

CPL-CTL **CPL-NDC-SHF** **CPL-NDC-LHF** **CPL-NDC-ALL**



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

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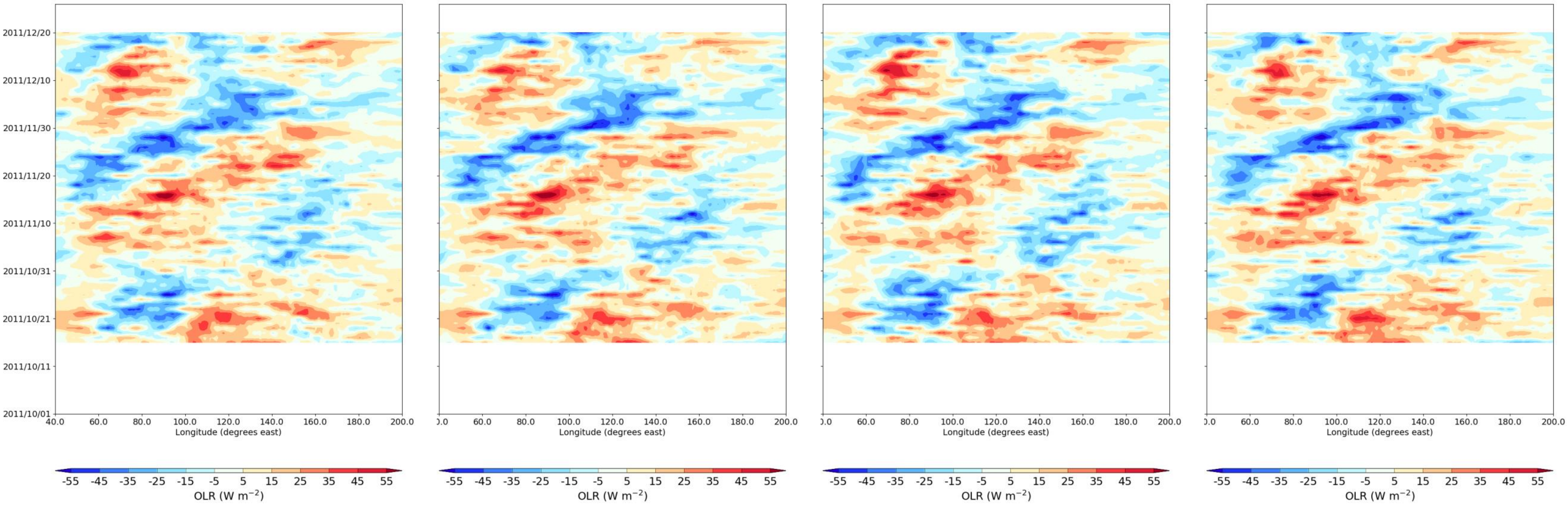
Diurnal cycle of SST

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

CPL-CTL **CPL-NDC-SHF** **CPL-NDC-LHF** **CPL-NDC-ALL**



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

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Diurnal cycle of SST

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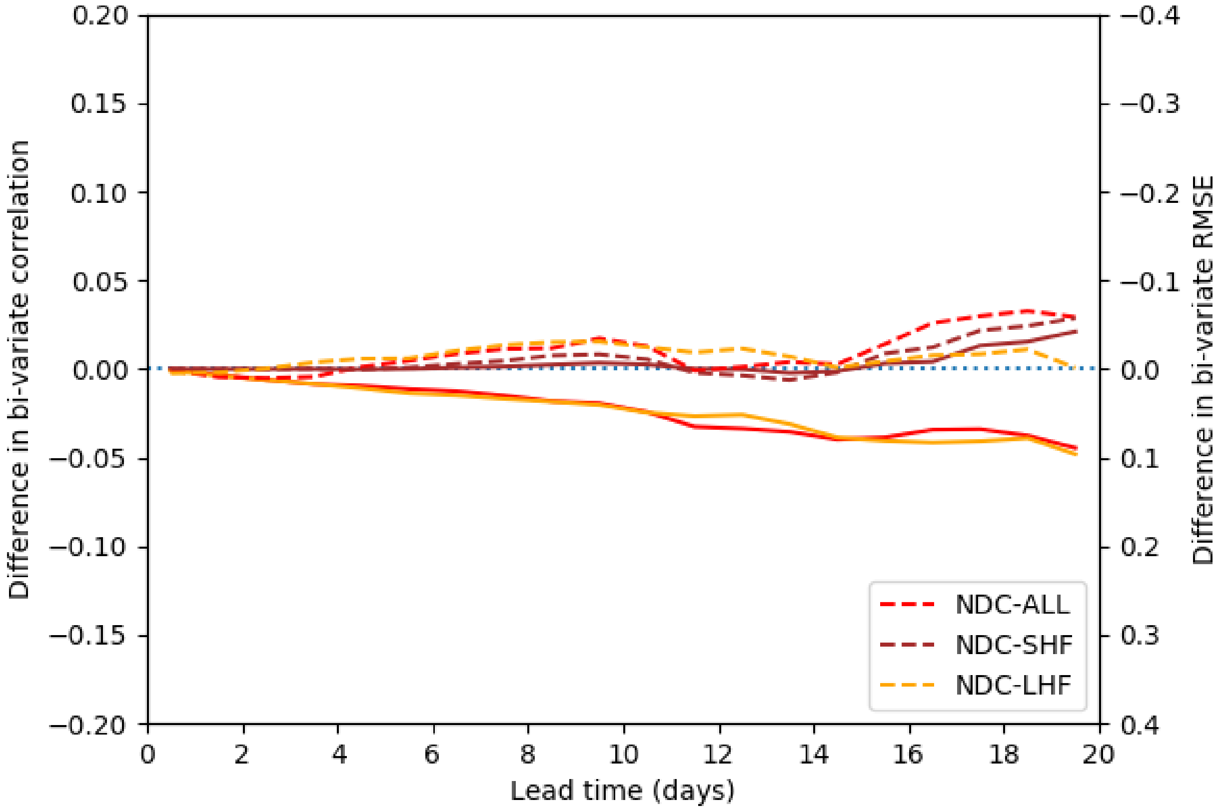
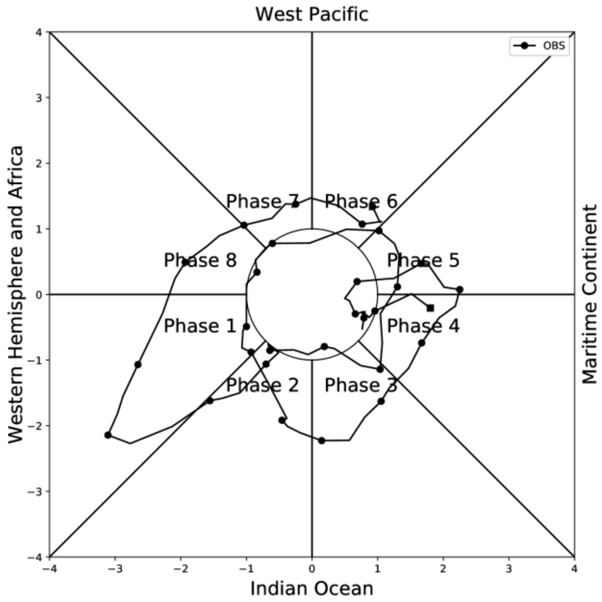
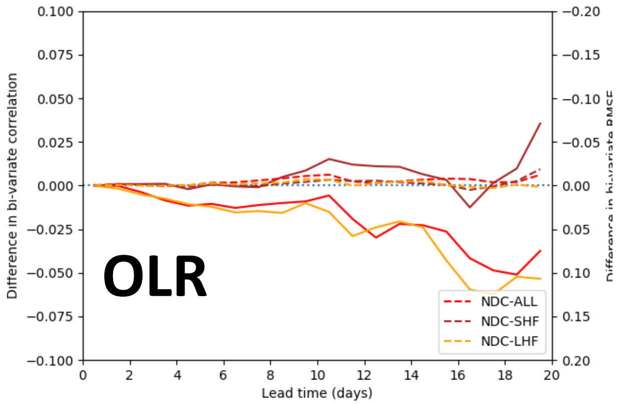
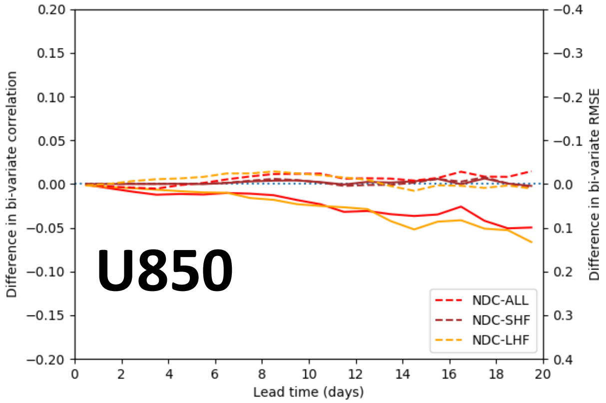
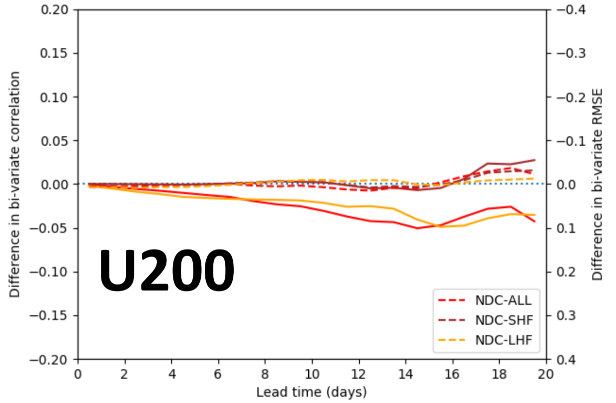
- Removing diurnal cycle of SST degrades predictions of all RMM components.
- Effect of diurnal SST on LHF is responsible for all of this.
- Effect of diurnal SST is about half of the effect of coupling.











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Initialized forecast experiments

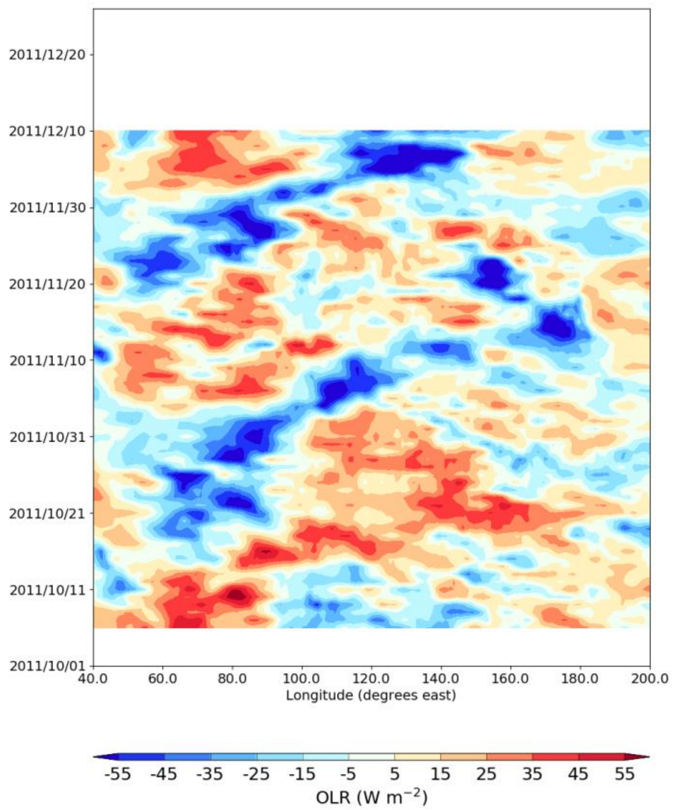
- Process-oriented experiments to understand air-sea coupling mechanisms
- Initialized simulations to mitigate effects of model physics changes on the mean state.

Experiment	Coupling?	Perturbation	Interpretation
CPL-CTL	Yes	None	Control experiment
ATM-DAY	No	Persist initial raw SST	Role of coupling
CPL-NMG-ALL	Yes	Smooth SST anomalies 15S-15N	Role of intraseasonal meridional SST gradient
CPL-NMG-SHF	Yes	SHF sees 15S-15N smoothed SSTs	Role of intraseasonal meridional SST gradient on SHF only
CPL-NMG-LHF	Yes	LHF sees 15S-15N smoothed SSTs	Role of intraseasonal meridional SST gradient on LHF only

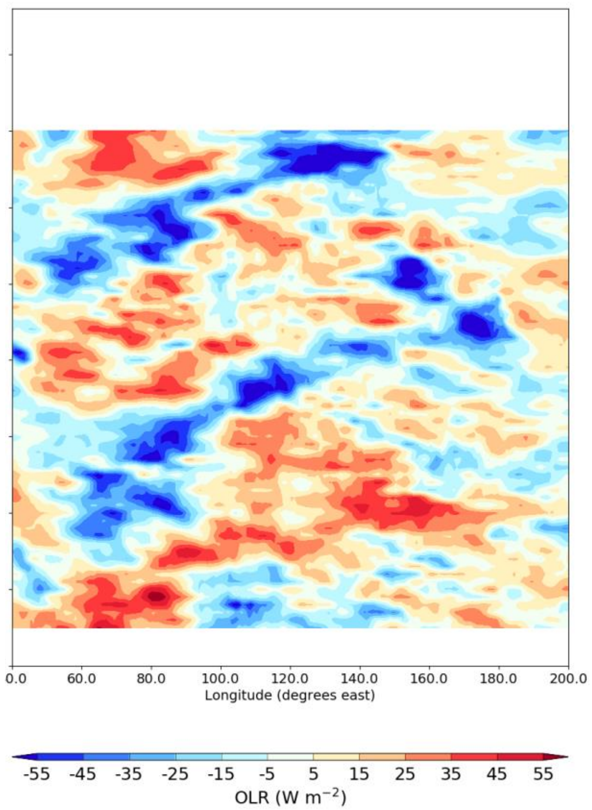
Meridional SST gradients

- 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.

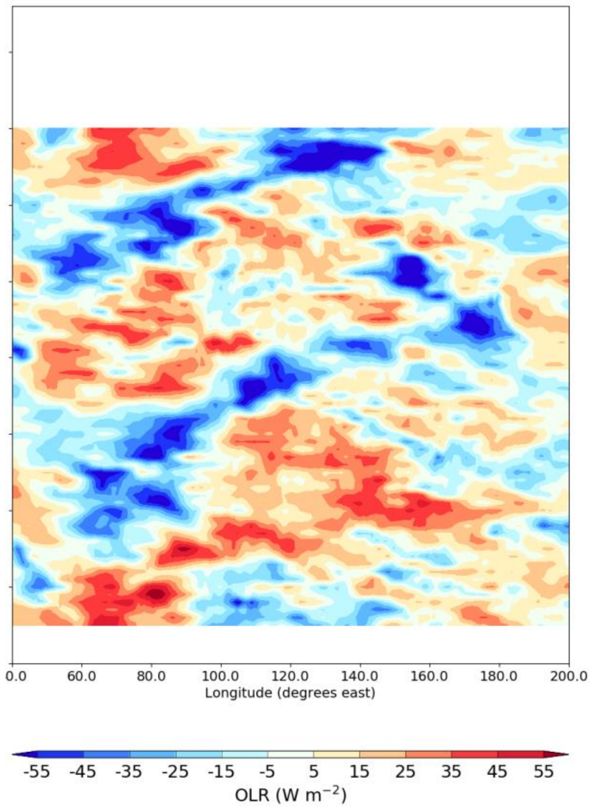
CPL-CTL



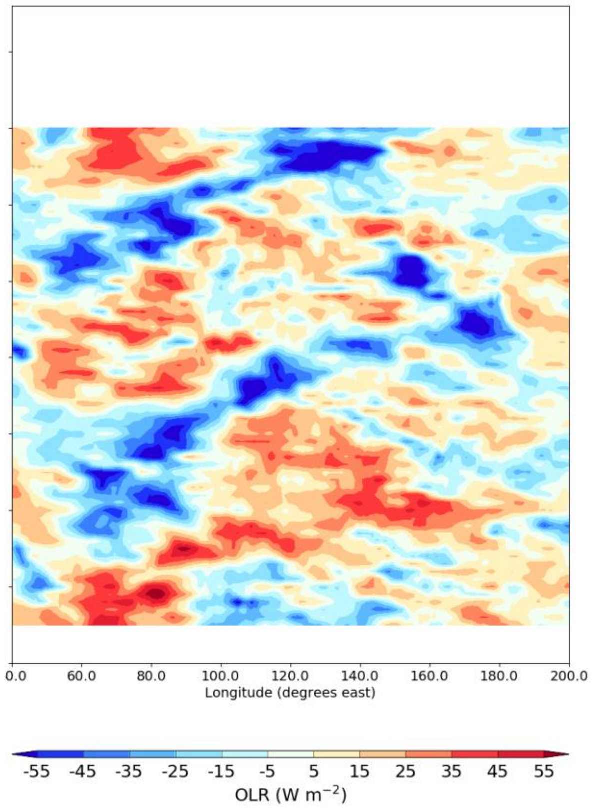
CPL-NMG-ALL



CPL-NMG-SHF



CPL-NMG-LHF



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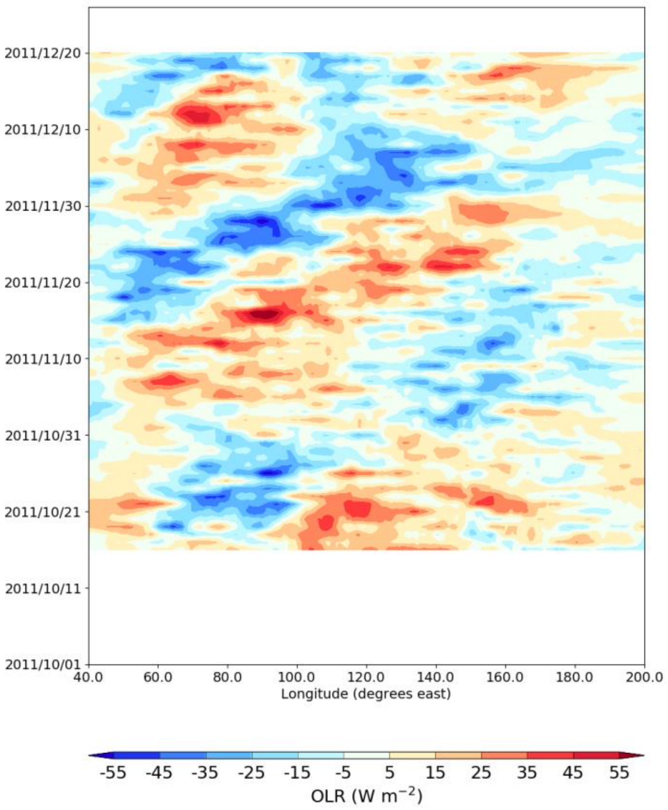
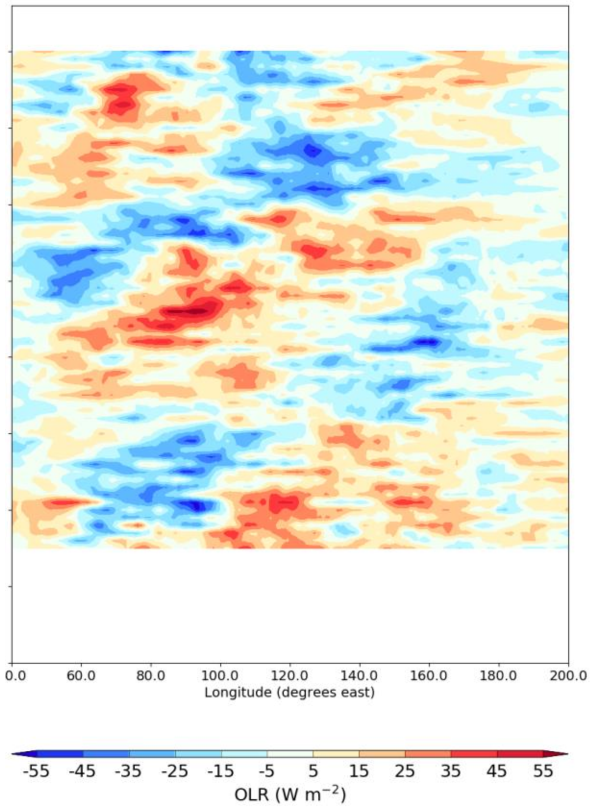
Meridional SST gradients

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

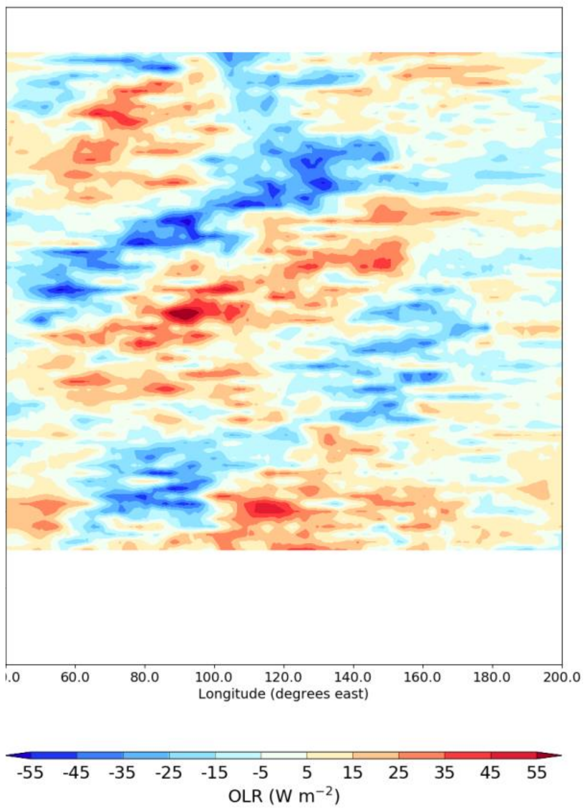
CPL-CTL



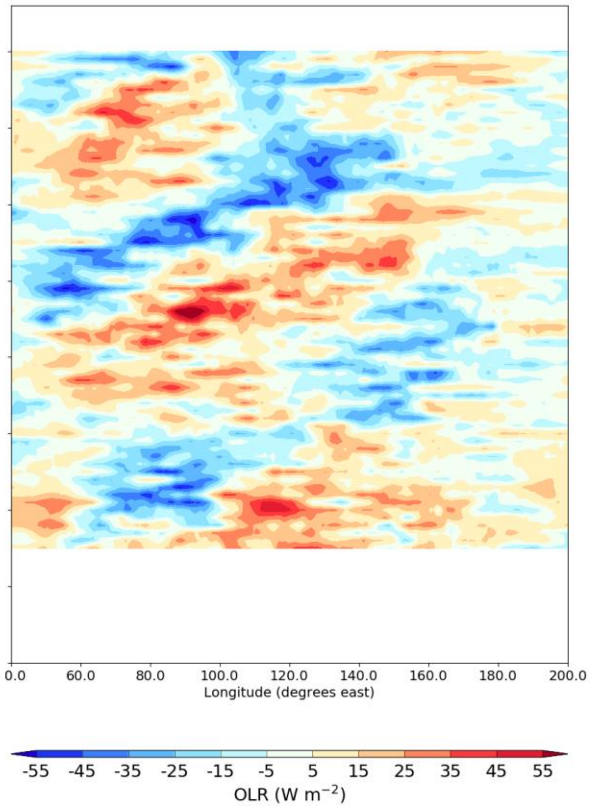
CPL-NMG-ALL



CPL-NMG-SHF



CPL-NMG-LHF



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Meridional SST gradients

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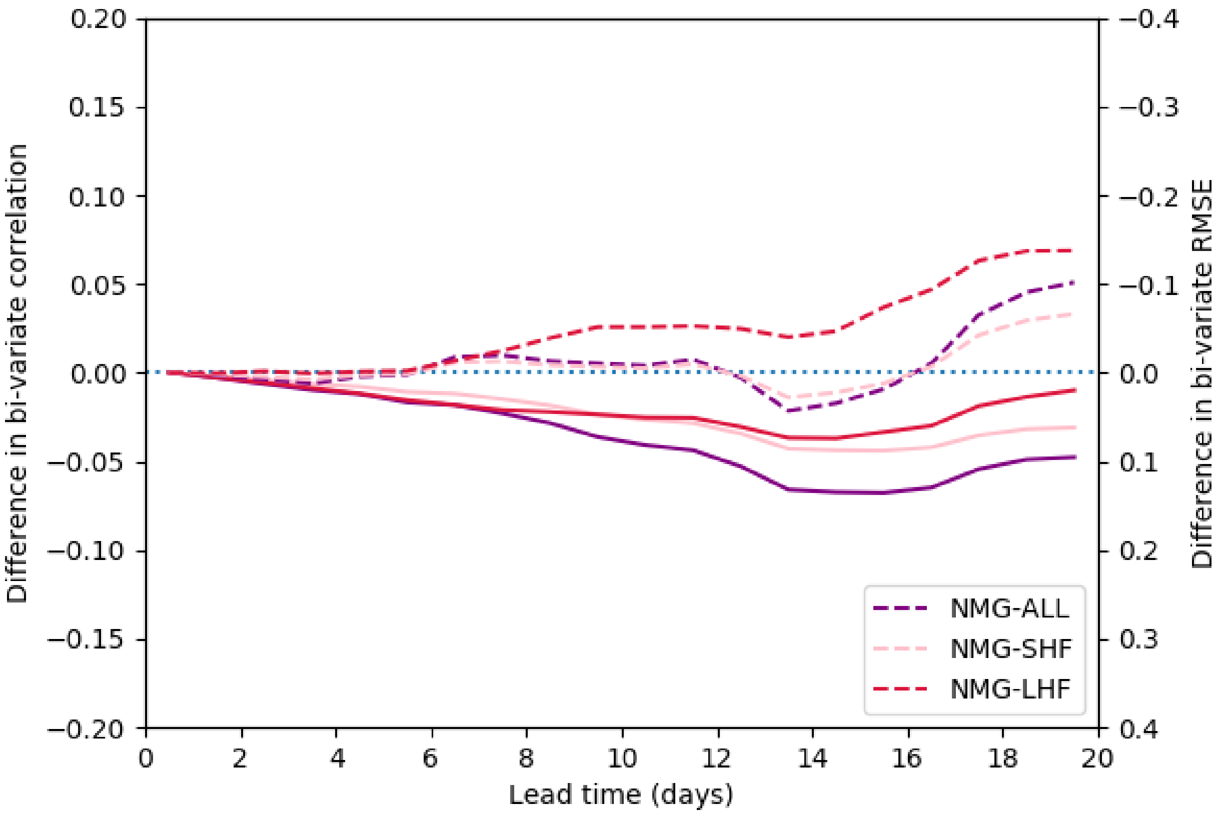
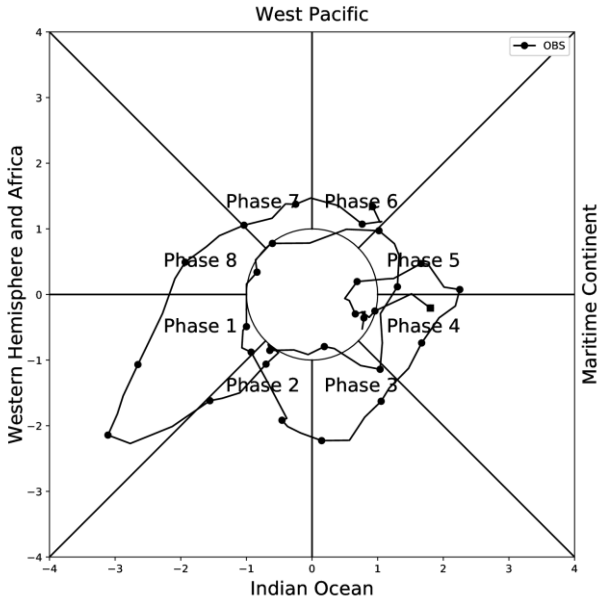
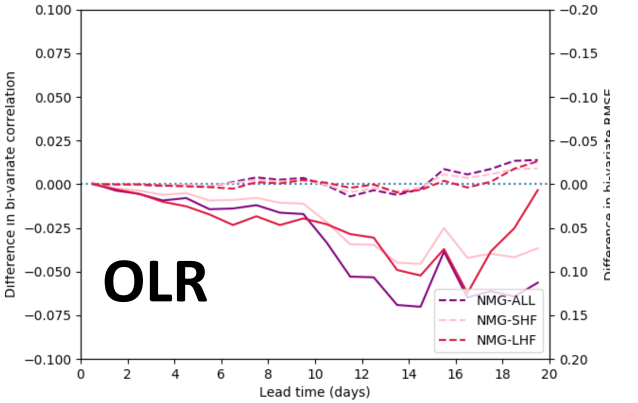
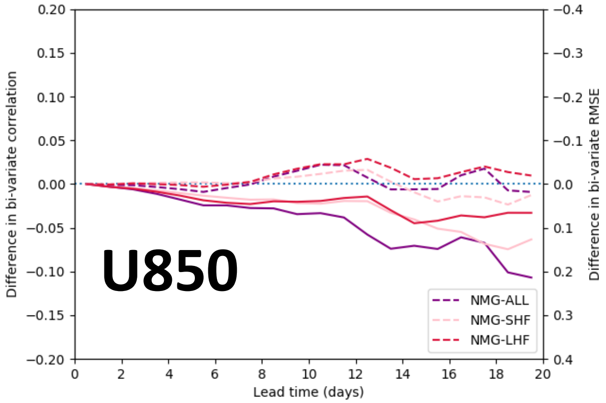
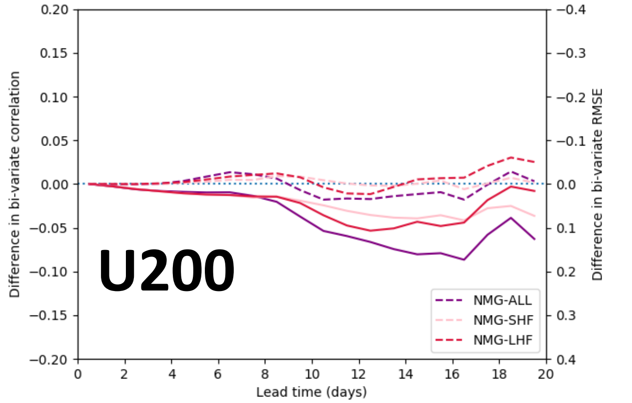
- Removing meridional gradient of intraseasonal SSTs reduces skill by more than removing diurnal cycle.
- Due more to effect on SHF than to changes on LHF.











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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!