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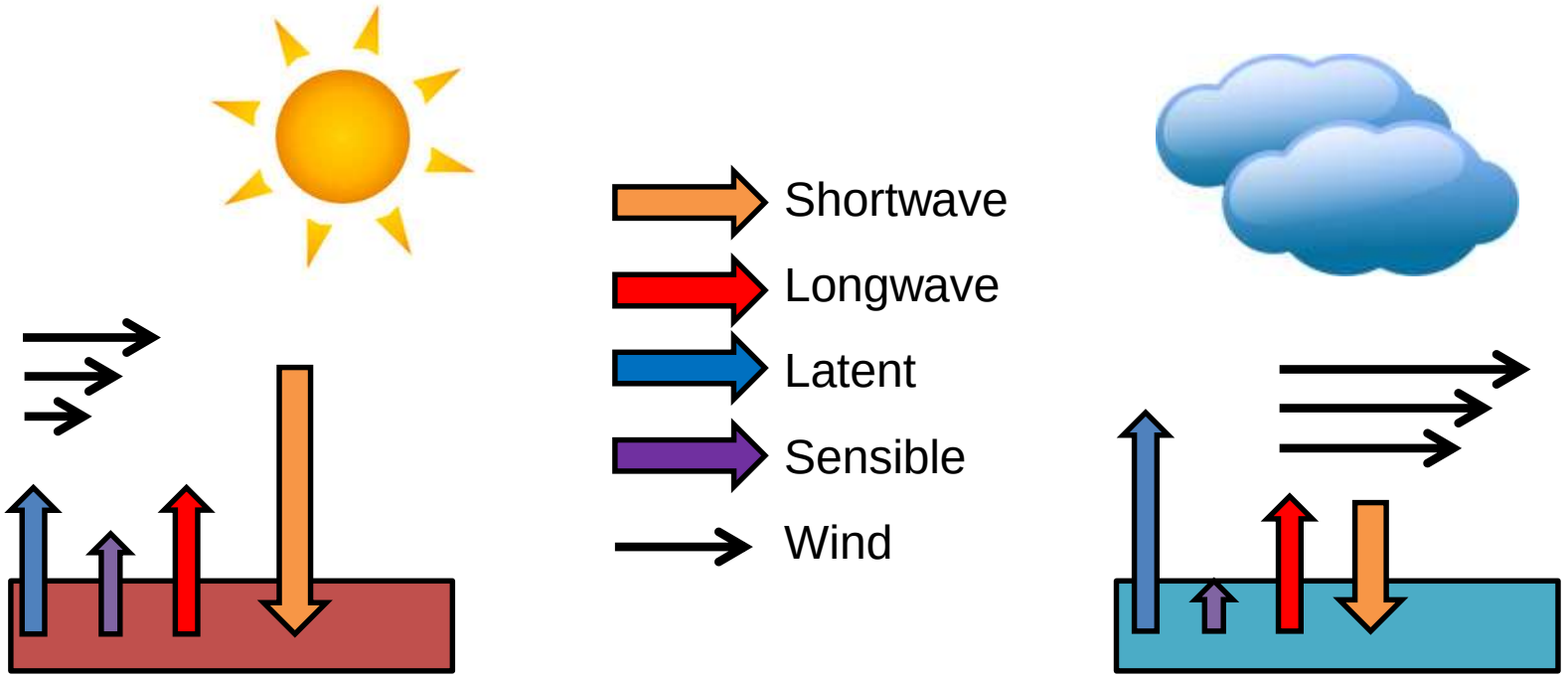
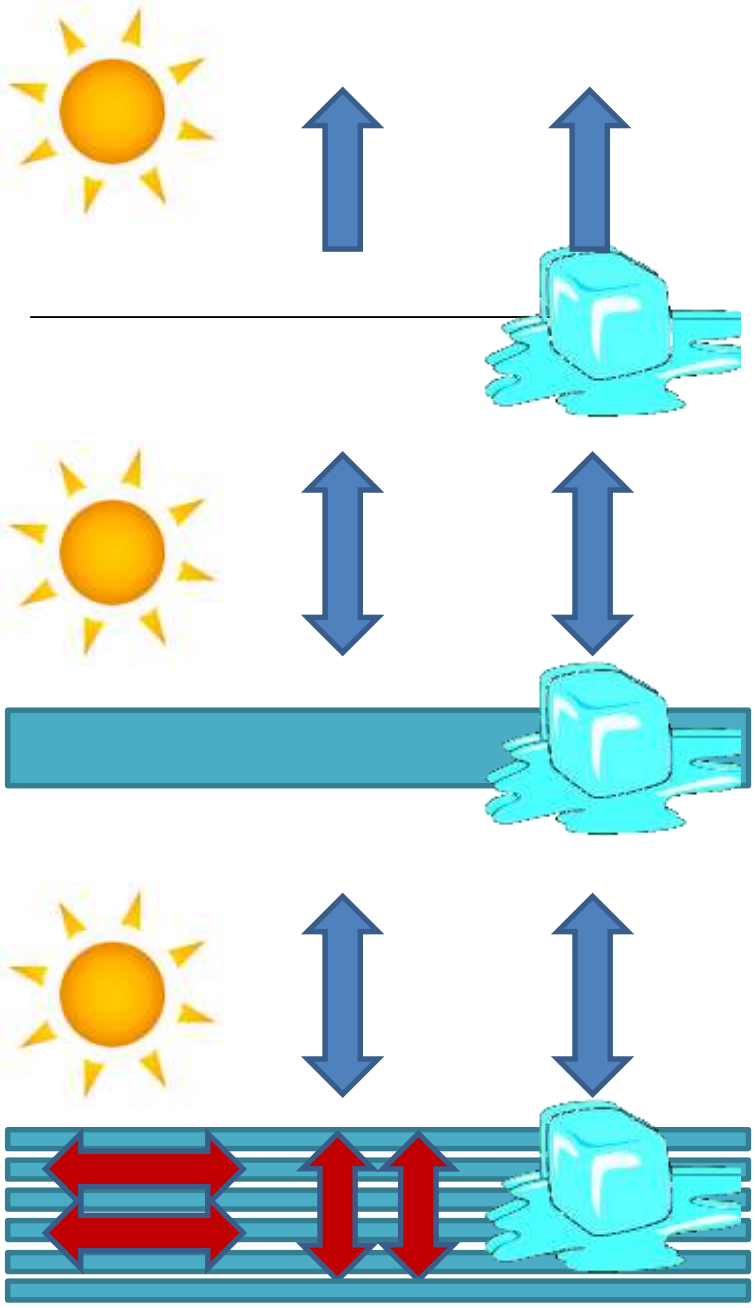
MC-KPP: Efficient, flexible and accurate air-sea coupling

Nick Klingaman
NCAS-Climate, University of Reading





Prescribe SSTs and sea ice

- **Pro:** Computationally inexpensive, requires only an atmospheric model, get the "right" mean SSTs and ice
- **Con:** No response of SST or ice to atmospheric variability

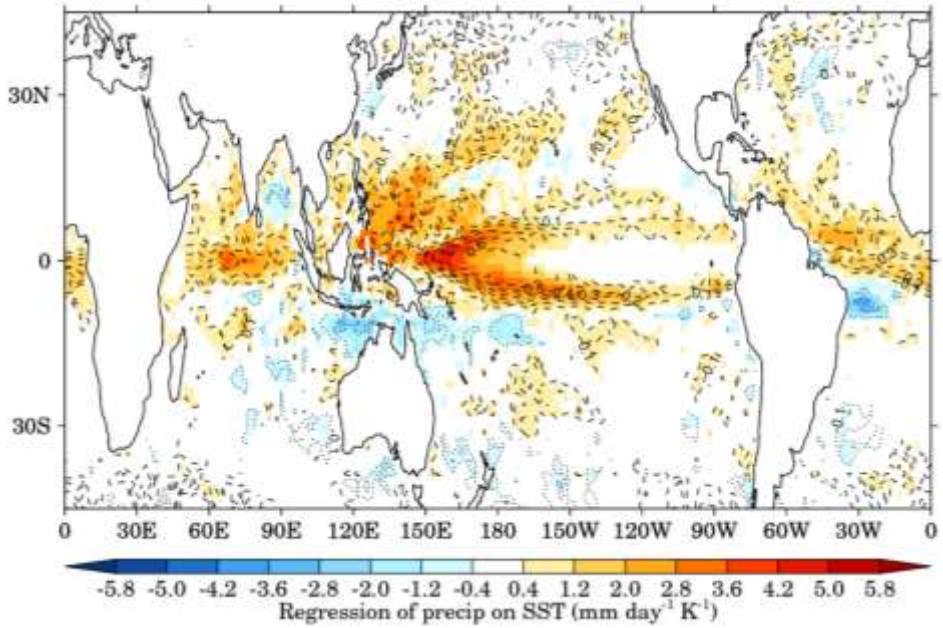
Couple to a slab ocean

- **Pro:** Computationally inexpensive, ocean responds thermodynamically to atmosphere, get the "right" mean SSTs
- **Con:** Muted SST response to atmosphere, no dynamical response, must impose heat transports, sketchy representation of ice

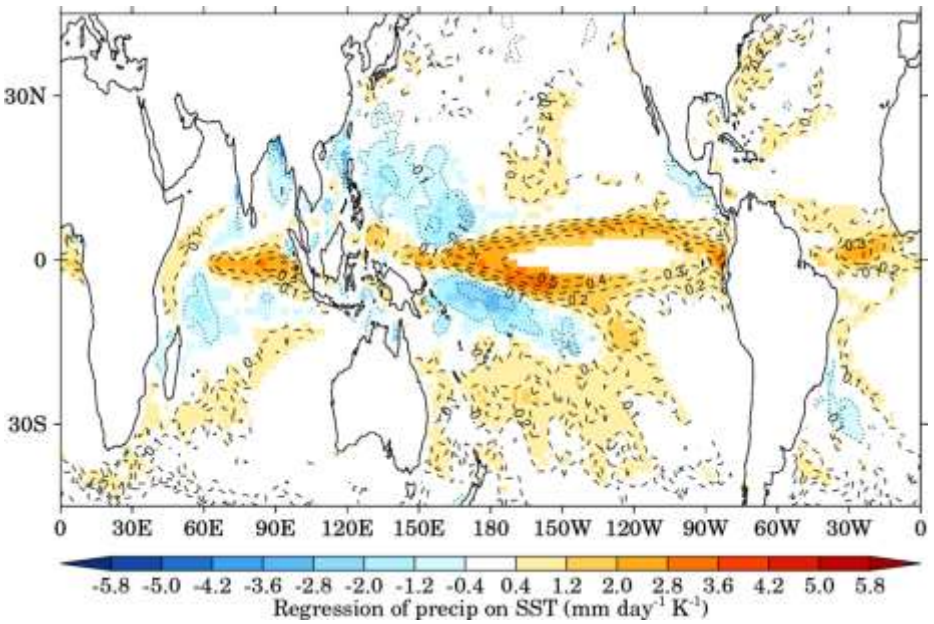
Couple to a dynamical ocean

- **Pro:** Thermodynamic and dynamic response of ocean to atmosphere, no need to prescribe heat transports
- **Con:** Computationally expensive, large mean-state errors in ocean and ice, muted SST response to atmosphere

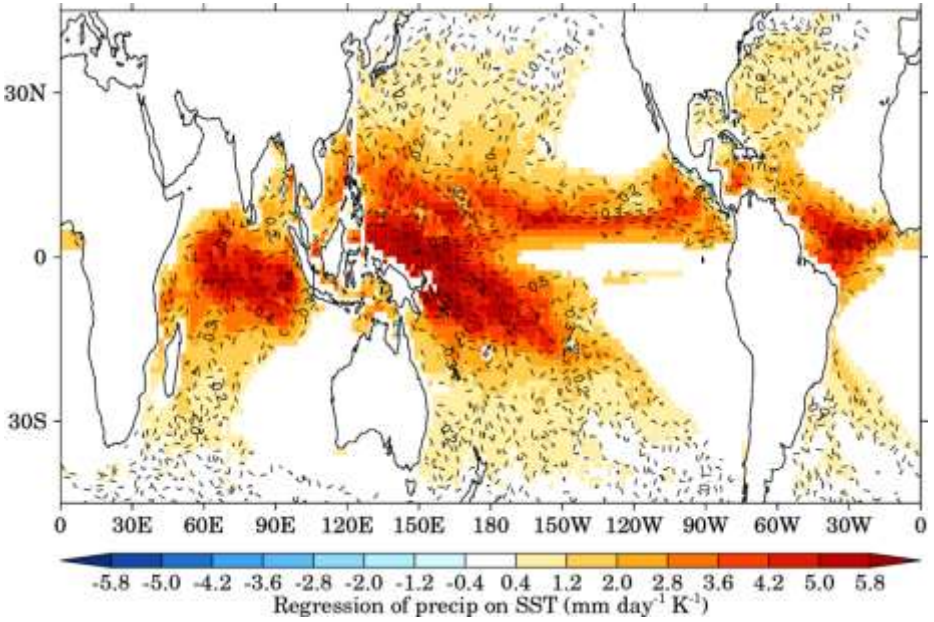
Observations



Met Office coupled model



Met Office atmosphere-only model



Instantaneous linear (shading) regressions and (contours) correlations between 31-day running means of gridpoint SST and precipitation, using anomalies from the seasonal cycle.

Coupling tries to stop the atmosphere from chucking it down over warm SSTs.

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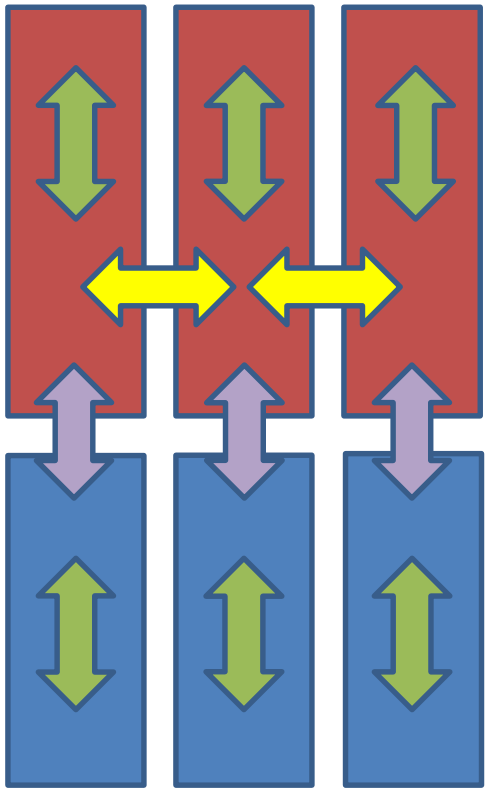
MetUM-GOML modelling framework



Hadley Centre atmospheric model

OASIS coupler
3 hourly exchanges

MC-KPP 1D ocean model (vertically resolved)

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, seasonally varying heat and salt tendencies are applied at every ocean point (x,y,z) to represent

- (a) the mean advection in the ocean
- (b) corrections for biases in atmospheric surface fluxes

Hirons et al. (2015, *Geosci. Model Dev.*)

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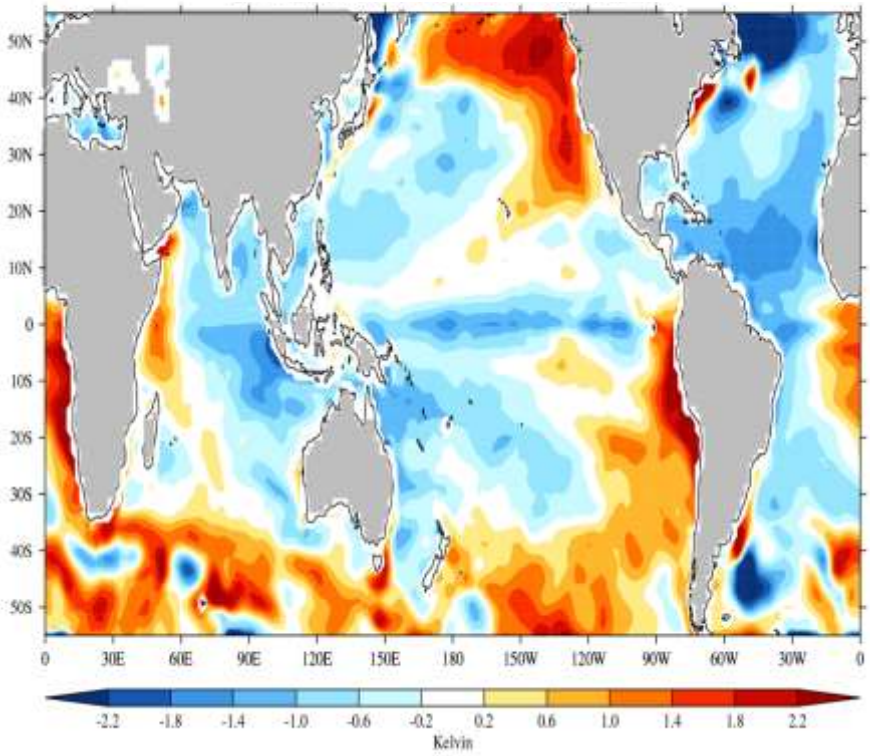
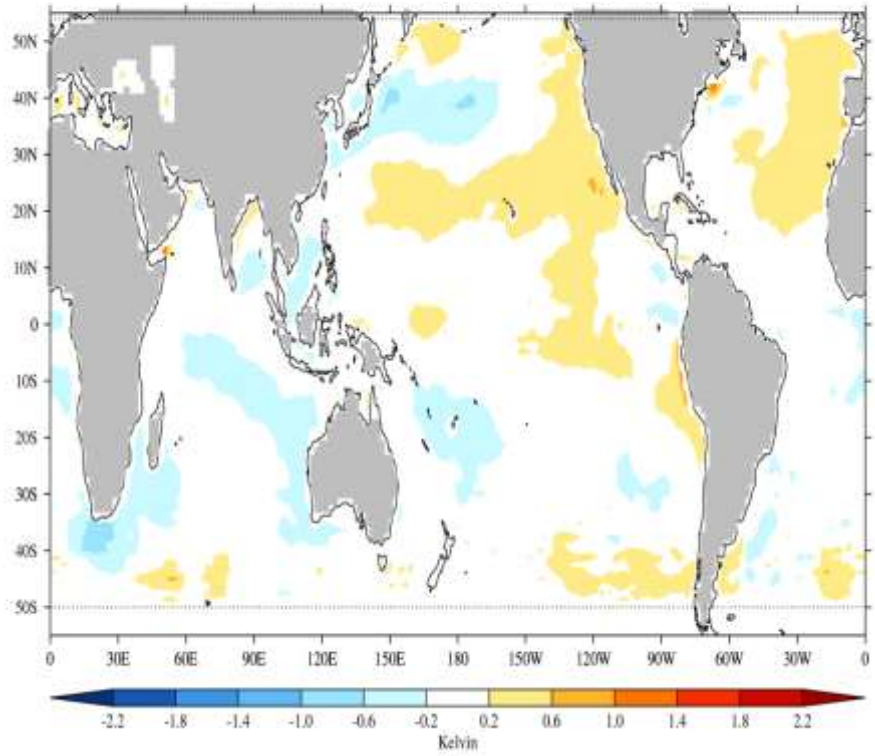
MetUM-GOML modelling framework

MetUM-GC1 (fully coupled)



MetUM-GOML1 (mixed-layer ocean)



By using climatological heat and salt corrections, MetUM-GOML1 produces much smaller mean SST biases than a fully coupled GCM.

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MetUM-GOML framework

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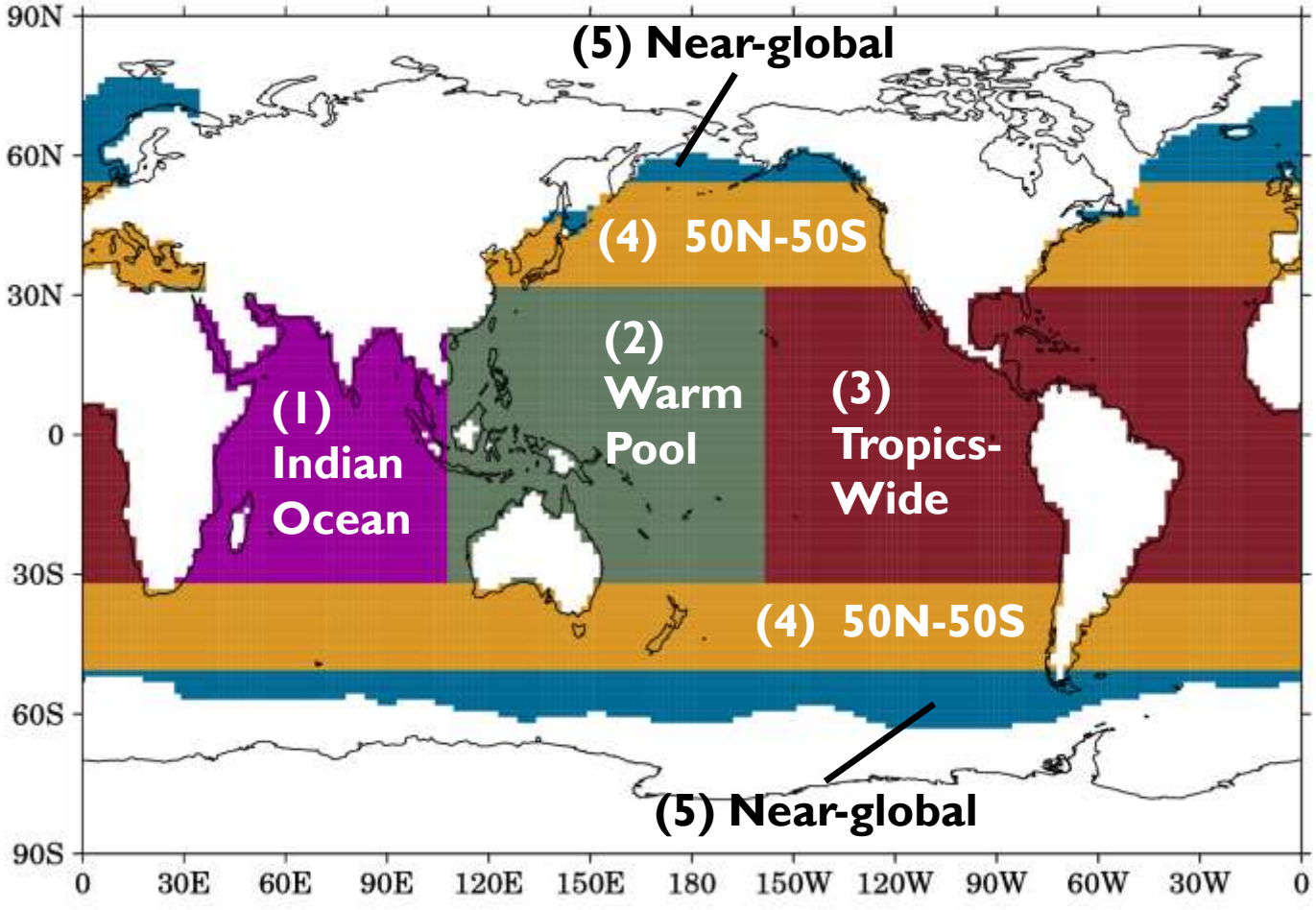

- Because the KPP columns do not communicate, there is complete flexibility in where the atmosphere and ocean are coupled (except over sea ice)
- SSTs and sea ice are prescribed outside the coupling region.

The Madden—Julian oscillation

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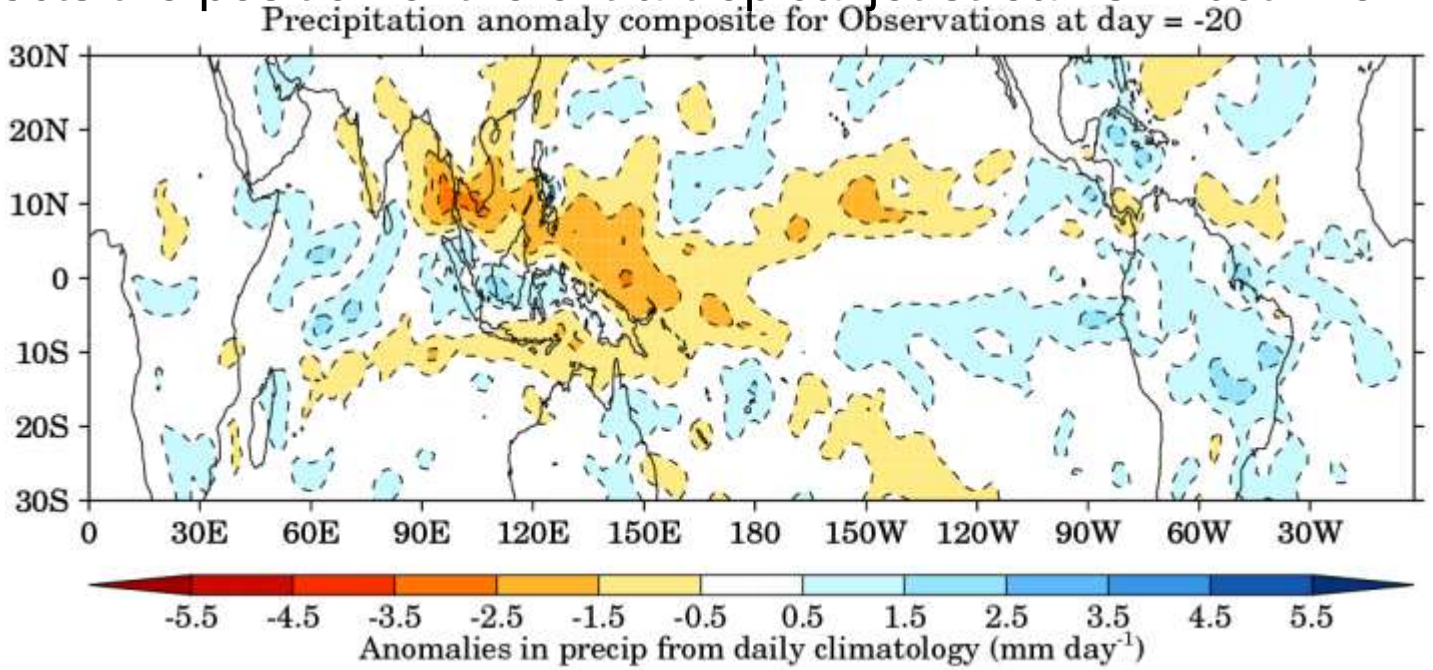
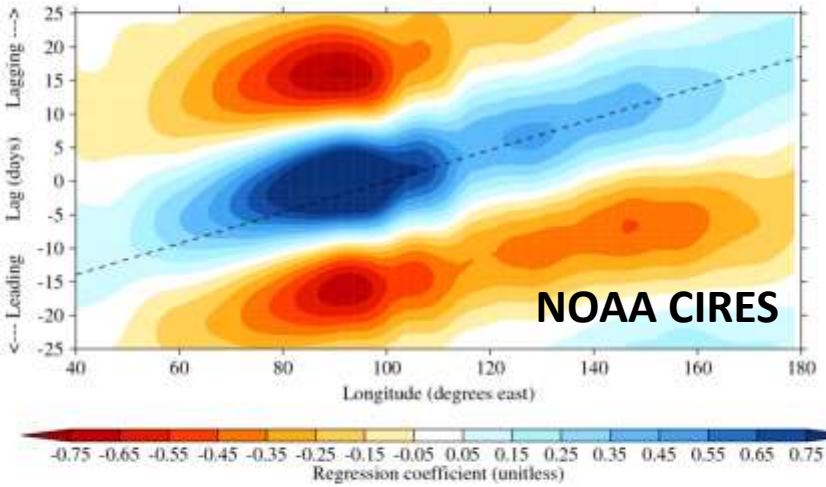
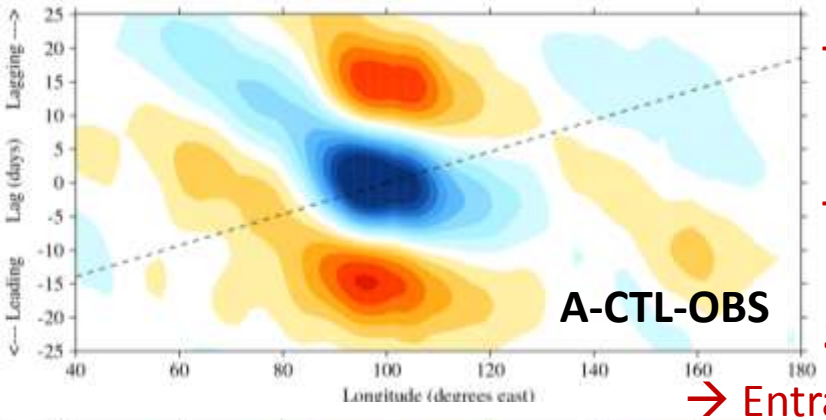
- The leading cause of weekly-monthly rainfall variations throughout the tropics.
- Controls “active” and “break” phases of the Indian, Australian, southeast Asian and African monsoons (more than two billion people).
- Triggers El Niño events via westerly wind bursts in the West Pacific.
- Controls tropical cyclogenesis in the Indian, Pacific and Atlantic Oceans.
- Affects the position of the extra-tropical jet streams in both hemispheres.



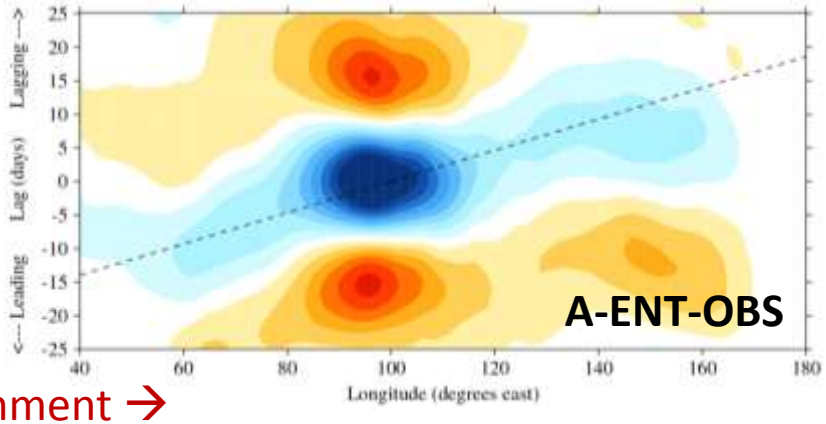


- At default entrainment and detrainment rates, coupling somewhat improves MJO propagation and amplitude.
- At higher entrainment and detrainment rates, coupling considerably improves MJO propagation.

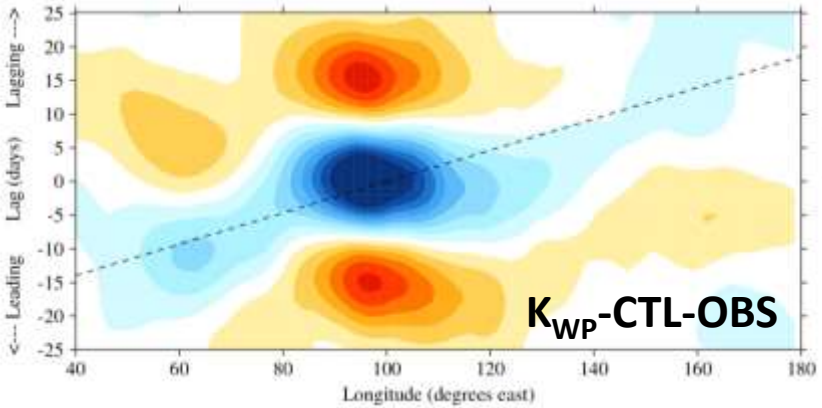
Klingaman and Woolnough (2014b, *QJRMS*)



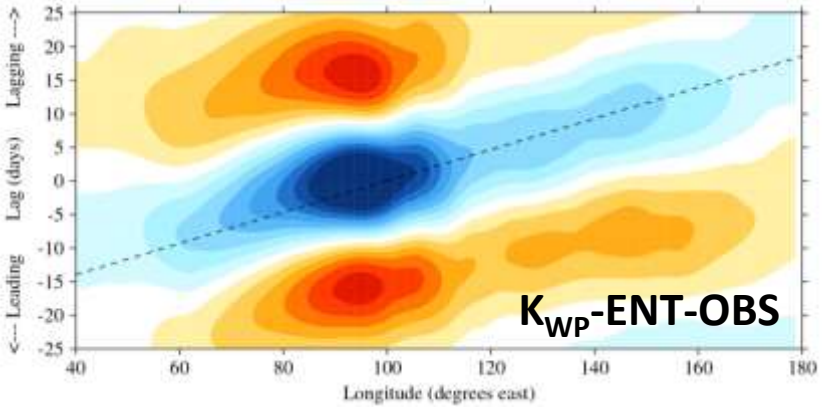
Atmosphere-only

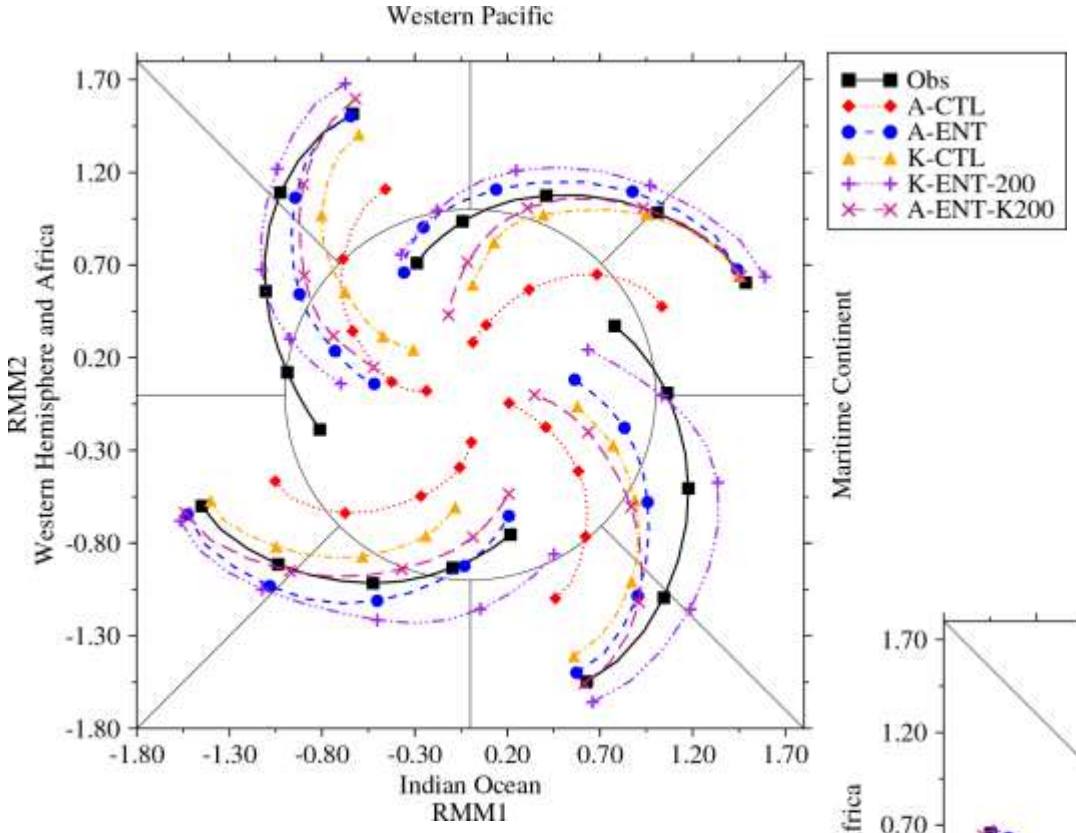


→ Entrainment →

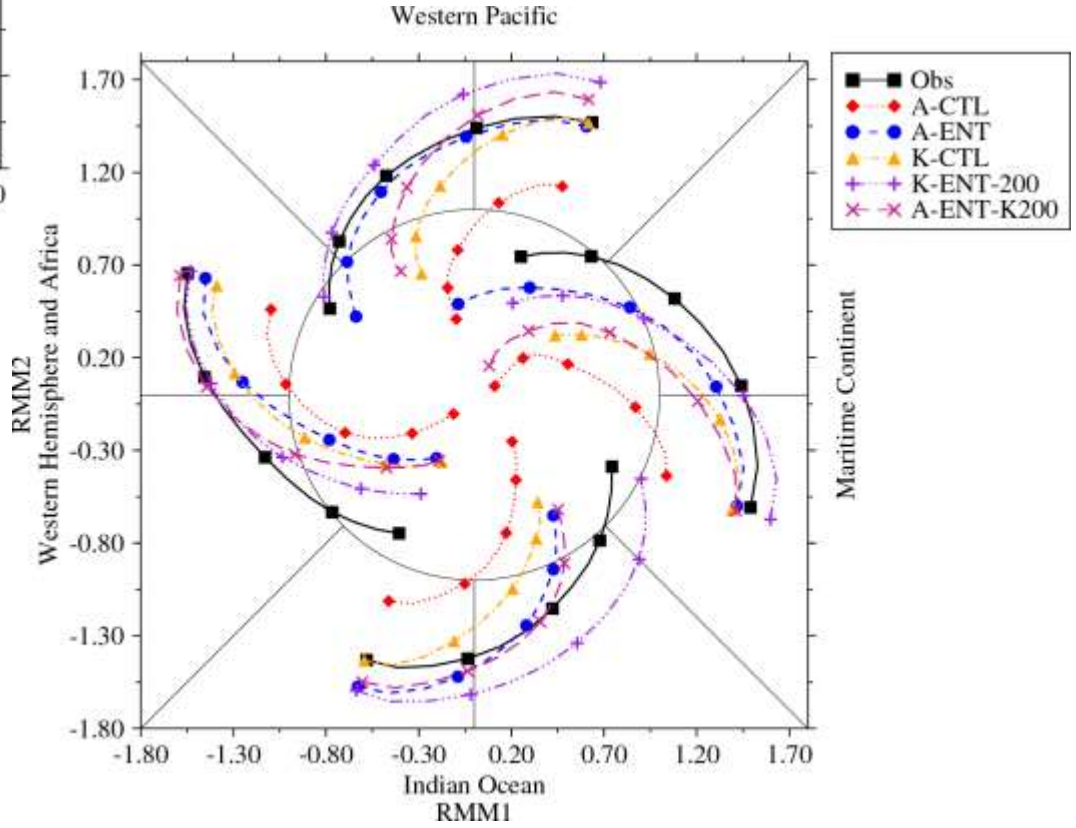


Coupled





Coupling at higher entrainment and detrainment rates improves propagation in most phases, particularly from the Indian Ocean to the Maritime Continent.



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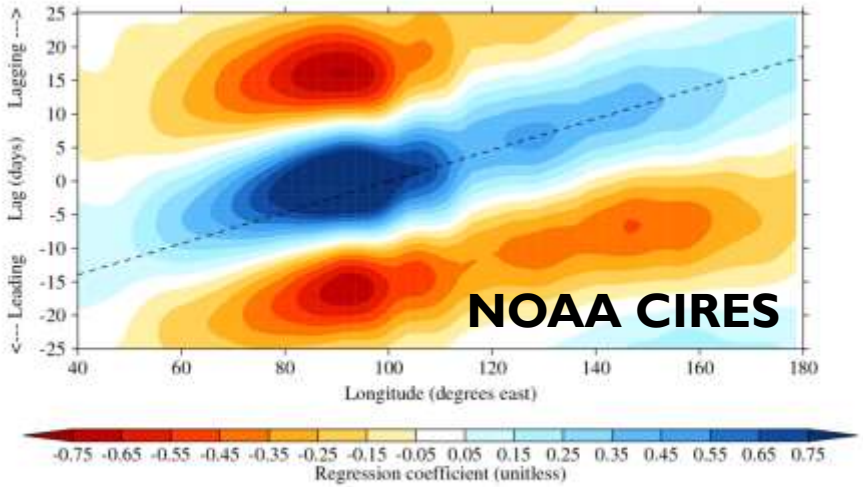
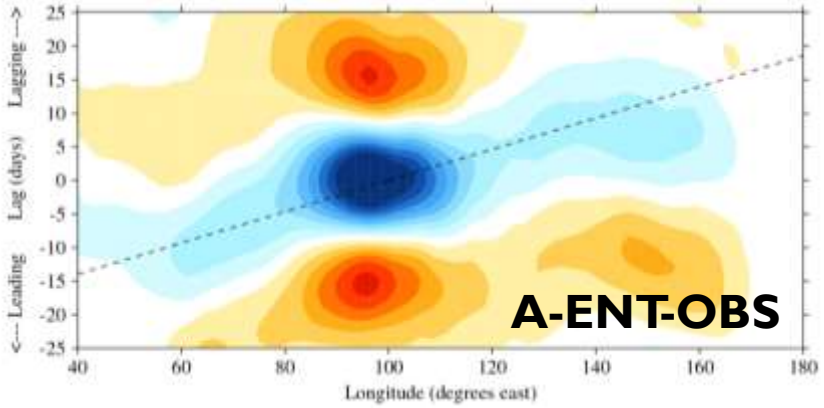
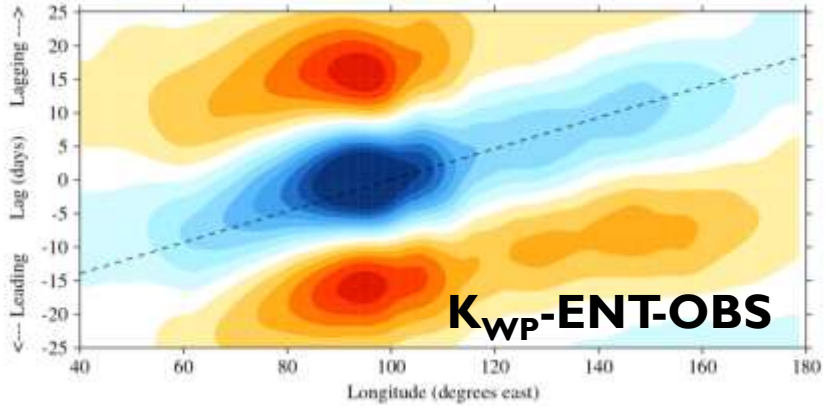
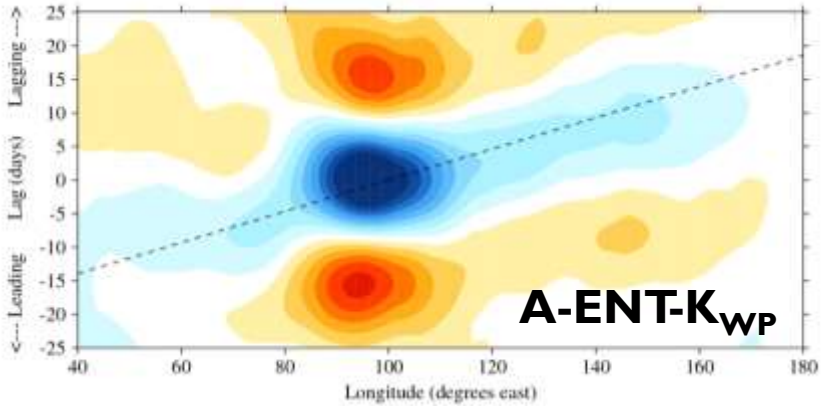
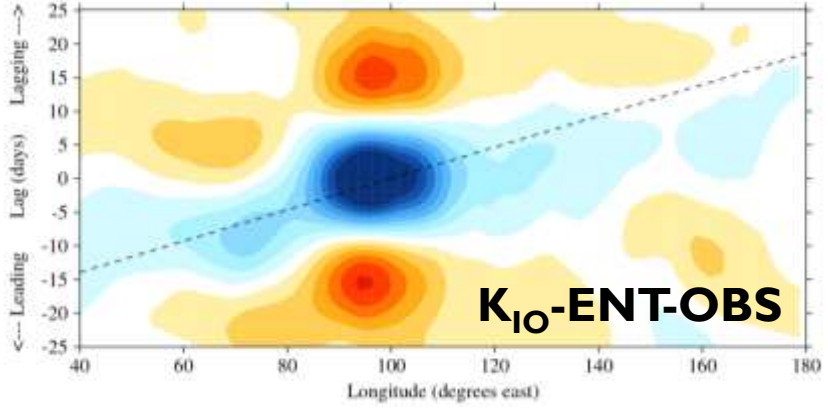


- Better propagation in K_{WP}-ENT-OBS is largely from coupling itself, **not** impact of coupling on the mean SST.
- Coupling in both the Indian Ocean and the West Pacific is crucial for MJO propagation in this model.

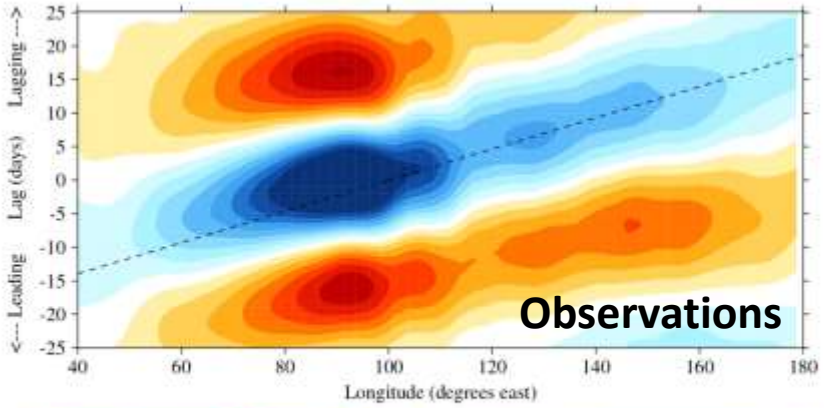


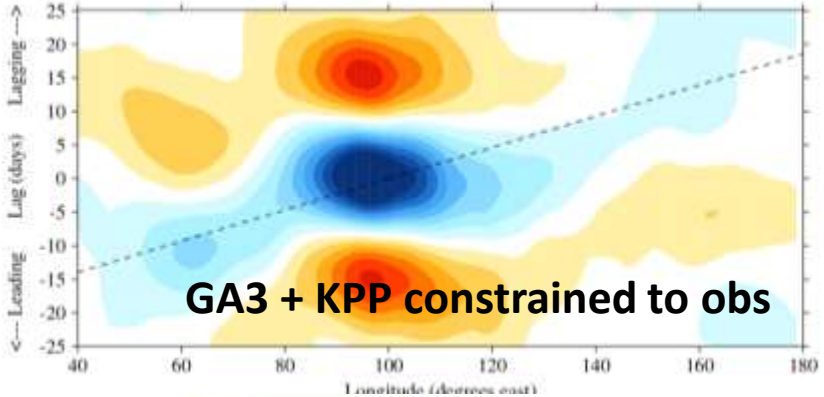


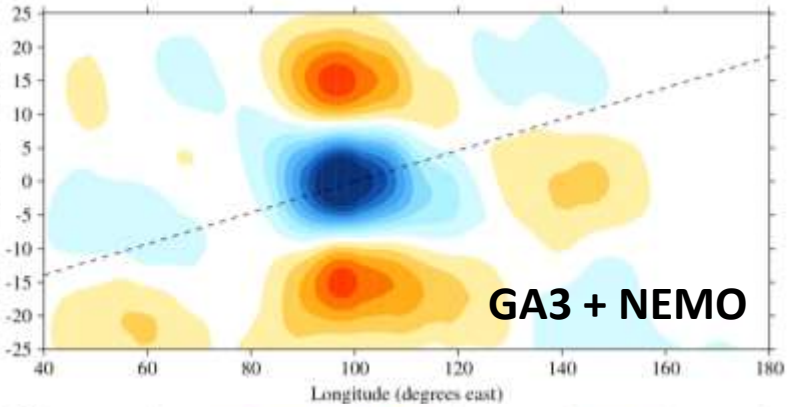


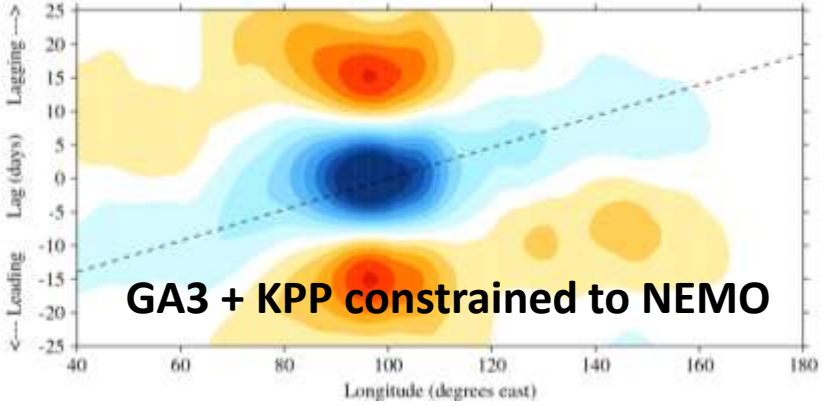


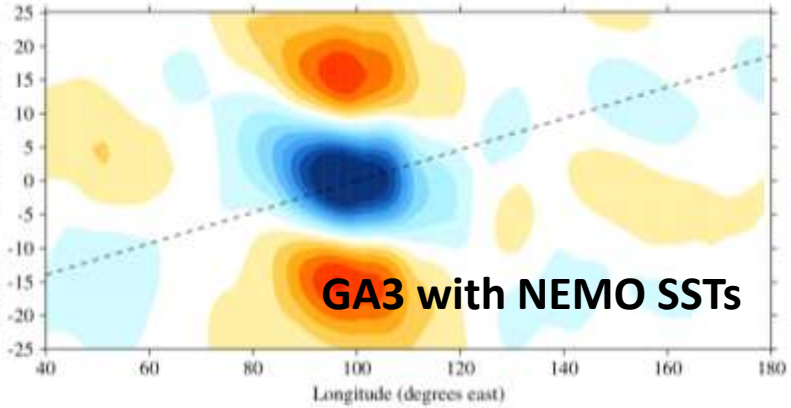
Evaluating the role of coupled-model systematic errors with a coupled framework.





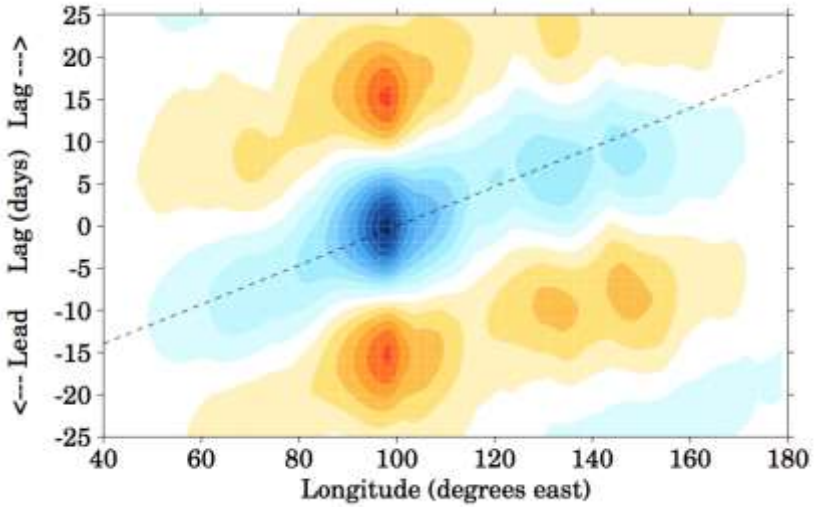




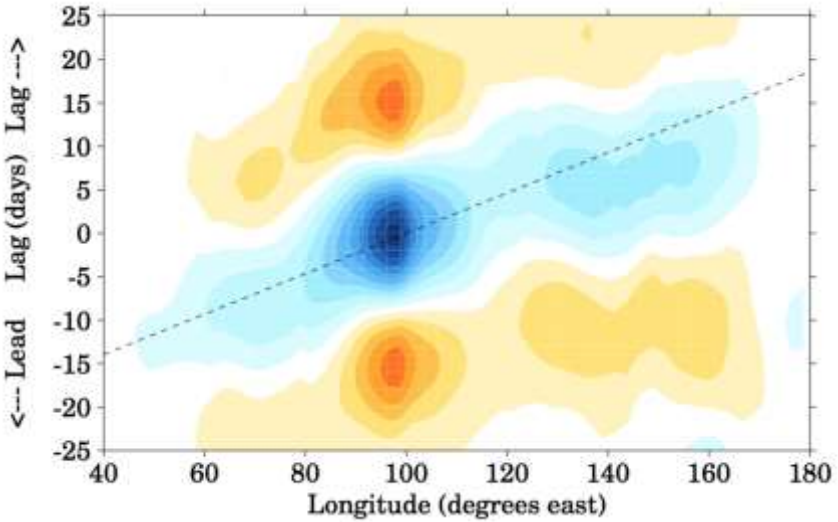


Applications to other models

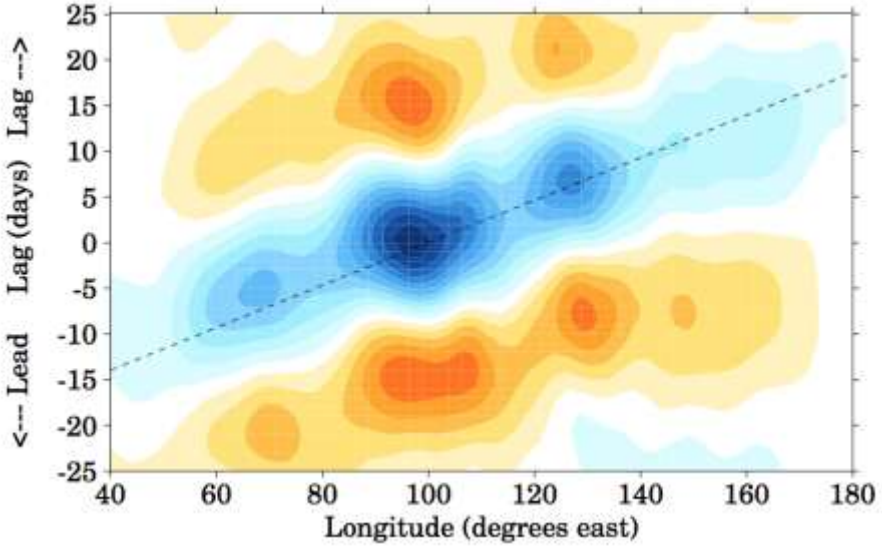
SPCAM-KPP



SPCAM with 31-day SPCAM-KPP SSTs



SPCCSM

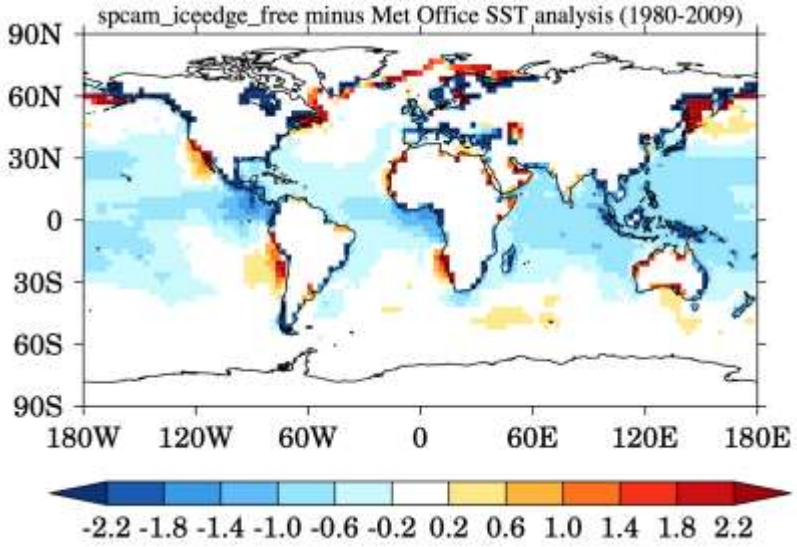


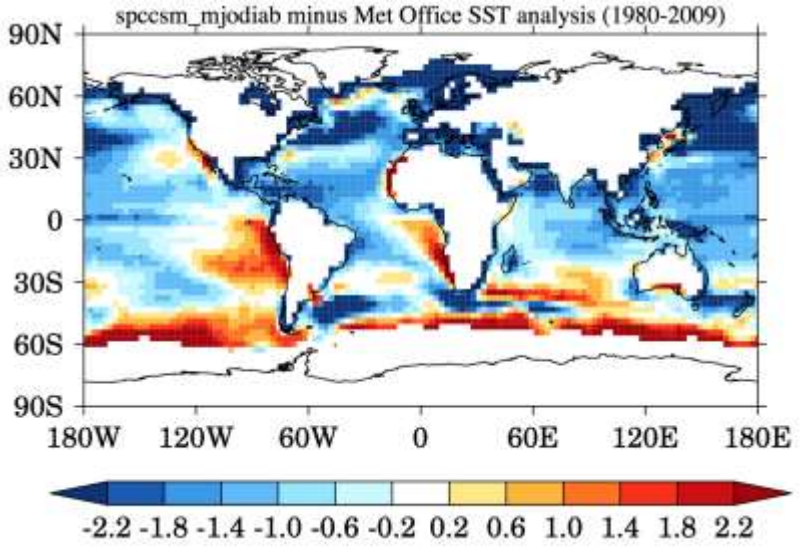
Applications to other models

SPCAM-KPP

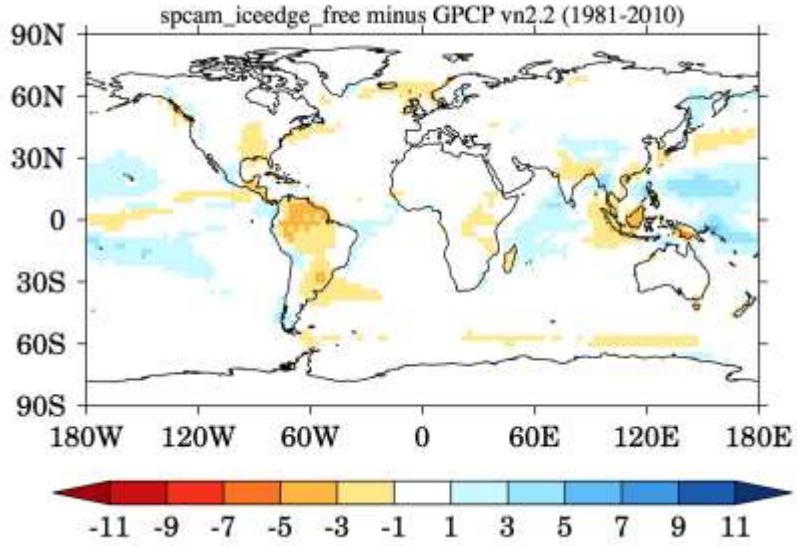
SPCCSM

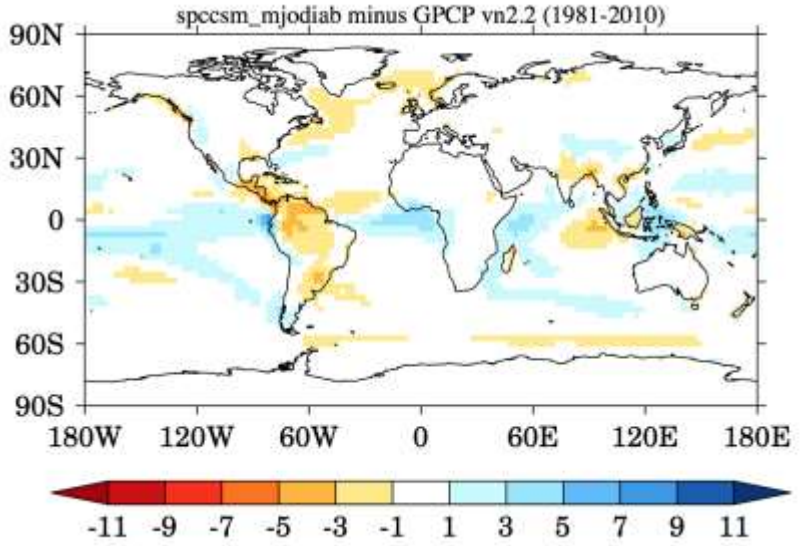
SST biases

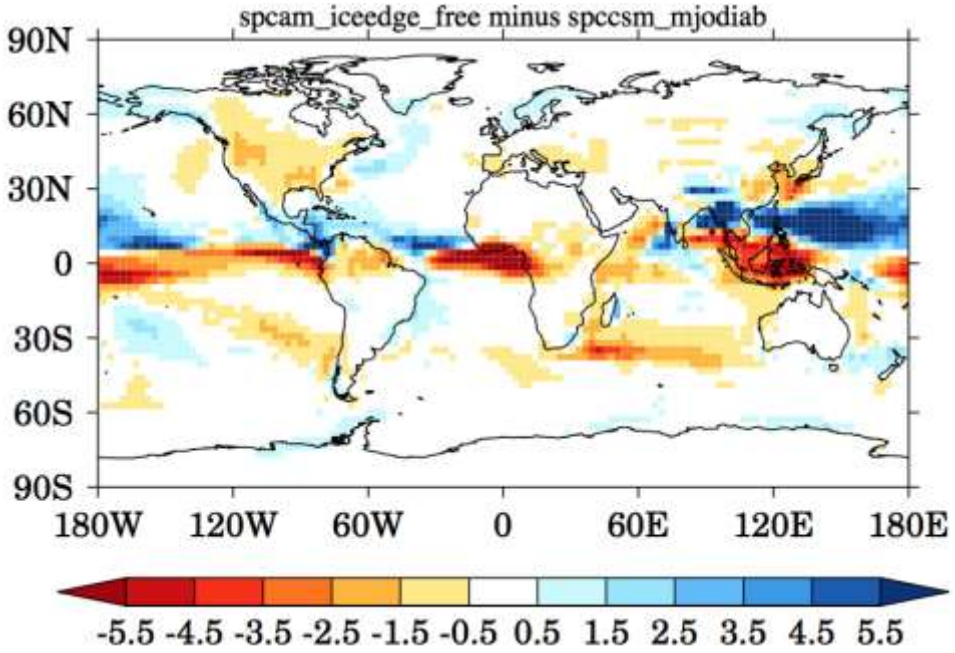




Precip biases

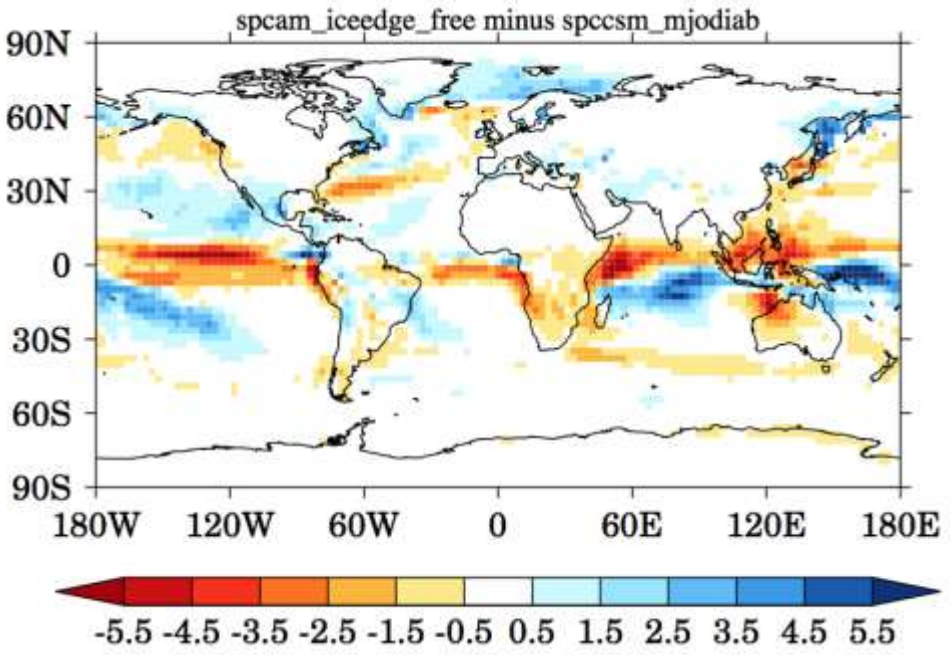






JJA precipitation difference
SPCAM-KPP minus SPCCSM

Preference for off-equatorial convection in SPCAM-KPP, due to changes in SST gradient?



DJF precipitation difference
SPCAM-KPP minus SPCCSM

Summary and Conclusions

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- Coupling to a one-dimensional ocean model allows …
  - The ocean mean state to be easily controlled, either to observations or to a fully coupled model.
  - Sensitivity tests of the effects of global or regional air-sea coupling, without changing the ocean mean state.
  - Multi-model comparisons of the effects of air-sea coupling, under similar ocean mean states.

- The MC-KPP ocean model will be implemented within the OpenIFS as part of my NERC Independent Research Fellowship on the role of air-sea coupling in sub-seasonal variability (2015-2020).
  - MJO, monsoon onsets, extra-tropical blocking
  - Comparisons of MetUM, OpenIFS and SPCAM