MJO propagation and SST biases in the Met Office coupled and uncoupled NWP systems

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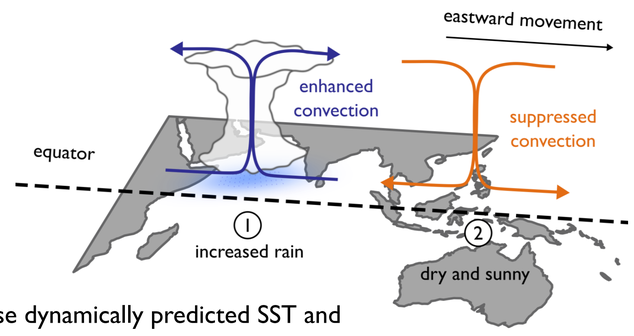
Background

- **Madden-Julian Oscillation (MJO)** is an eastward propagating intraseasonal convection pattern in the tropics.
- Sea surface temperatures (SST) influence MJO convection.



Coupled ocean-atmosphere models use dynamically predicted SST and usually perform better than atmosphere-only models with constant SST.

- The Met Office has been running daily a **coupled NWP system** since May 2016, alongside the **atmosphere-only** version of the model.
- Both models show skillful MJO prediction with Real-time Multivariate MJO index (RMM)[1,2] (Fig. 1a).
- The **coupled** model predicts **faster MJO** propagation than atmosphere-only model and observations (Fig. 1b).
- Here we examine potential sources of this erroneous propagation.

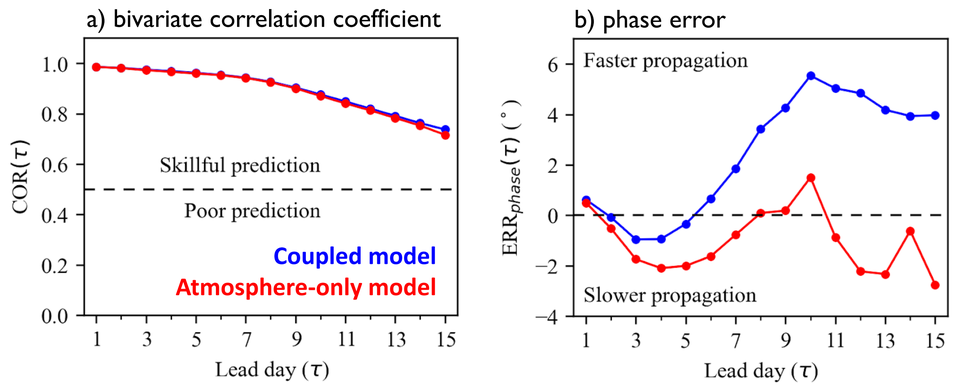


Figure 1
RMM skill statistics as a function of lead day calculated with ECMWF Reanalysis indices[3,4]. Only active MJO data with RMM amplitude above 1.0 was used. Data was generated with lower resolution (N240 and N320) hindcasts of the real-time model runs. Data period: 2016-11-01 to 2021-03-01 (Nov-April). Real-time model runs show qualitatively the same results for 7 and 10 forecast lead days for atmosphere-only and coupled versions, respectively.

MJO phases 1 and 4

MJO phase 1:

- Coupled model has **increased SST** to the east of convection in the **central Maritime Continent** within the first 24 hours of the forecast.
- By lead day 7 (forecast day cut-off for operational atmosphere-only NWP system), **the coupled model produces too much convection** in the central Maritime Continent.

MJO phase 4:

- **Colder SST** are observed in the coupled model to the west of convection, in **the equatorial Indian Ocean** region.
- By lead day 7, **the coupled model is too sunny** in the equatorial Indian Ocean region.

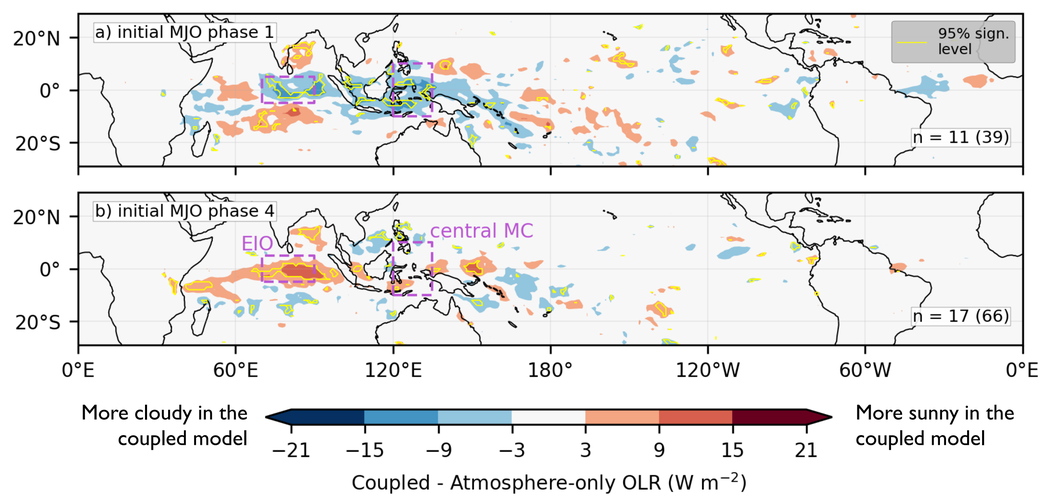


Figure 2
Difference between coupled and atmosphere-only models at lead day 7 for 20-200 day boreal winter anomaly of outgoing longwave radiation (OLR) at the top of the atmosphere for forecasts initialised in MJO phases (a) 1 and (b) 4. Data period: 2016-11-01 to 2021-01-07 (Nov-Apr, active MJO days only). Number n denotes the amount of independent events used in the composite (total number of days used displayed in the bracket). EIO – equatorial Indian Ocean MC – Maritime continent.

Real-time NWP system specifications:
- Horizontal resolution - first year N768, then N1280 (15 km latitude and 10 km longitude horizontal resolution at the equator)
- Vertical levels in the atmosphere - atmosphere-only NWP model has 70 vertical levels across the whole study period, coupled model had 85 for first two years (15 extra in the stratosphe), then 70 levels matching atmosphere-only version
- Ocean model in the coupled NWP system - NEMO model with 75 vertical levels, for first two years using ORCA025, then eORCA025 (1/4 degree horizontal resolution) grid

Proposed feedback for MJO phase 1 in the coupled model

Too much shortwave (SW) radiation into the ocean → Rapid increase in MJO SST anomaly in the first 24 hours of the forecast → Increased latent heat flux (LH) into the atmosphere in the coupled model → More MJO convection ahead of the convective envelope → Faster MJO propagation

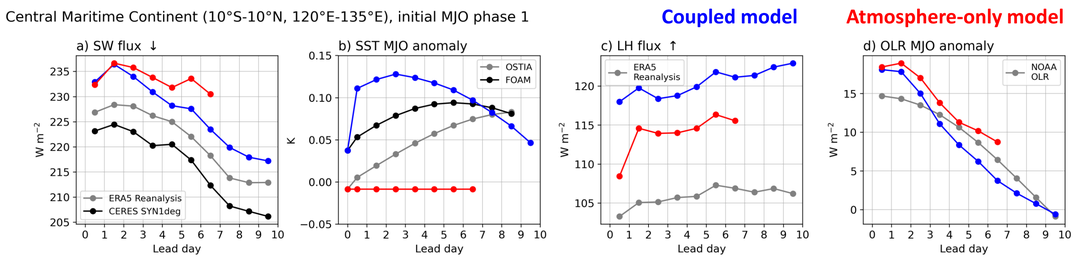


Figure 3
Daily composite averages within central MC region for forecasts starting in phase 1 for coupled (blue) and atmosphere-only (red) models. Data period: 2016-11-01 till 2021-01-22 (2021-01-07 for OLR) (Nov-Apr, active MJO days only). MJO anomalies denote anomalies filtered with 20-200 day bandpass Lanczos filter.

- Regardless of the MJO phase, central MC region shows overall too high SW flux into the ocean compared to observations by ~5-10 W/m^2 (Fig. 4)

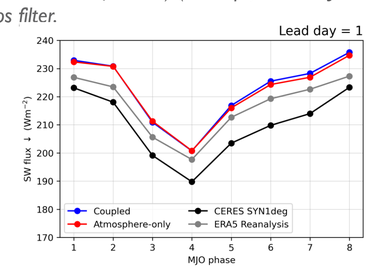


Figure 4
SW flux average within central MC region at lead day 1 across different MJO phases. Data period: 2016-11-01 to 2021-01-22 (Nov-Apr, active MJO days only).

Proposed feedback for MJO phase 4 in the coupled model

Too high 10 m windspeed MJO anomaly compared to ERA5 Reanalysis → Too high LH flux into the atmosphere in the coupled model → Rapid decrease in MJO SST anomaly in the first 24 hours of the forecast → Less MJO convection behind the convective envelope → Faster MJO propagation

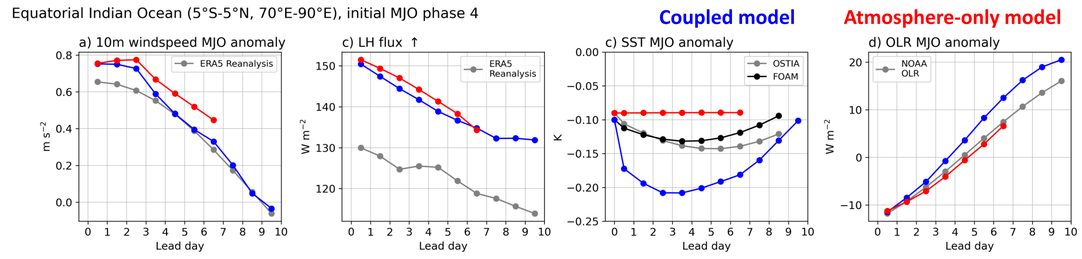


Figure 5
Daily composite averages within EIO region for forecasts starting in phase 4 for coupled (blue) and atmosphere-only (red) models. Data period: 2016-11-01 till 2021-01-22 (2021-01-07 for OLR) (Nov-Apr, active MJO days only). MJO anomalies denote anomalies filtered with 20-200 day bandpass Lanczos filter.

- Mixed layer depth in EIO region is deeper by ~2 m in the coupled model compared to observations, however, it is not enough to cause the SST change within the first 24 hours of the forecast
- SW flux bias is similar across other phases here, yet no sharp jumps in SST are recorded on lead day 1, suggesting that too strong winds are more likely the cause for SST decrease

Case studies testing SST-OLR response

MJO phase 1:

- Decreased persisted SST in the atmosphere-only model by 1 K in EIO region
- Colder SST cause decreased convective activity from lead day 1 in that region

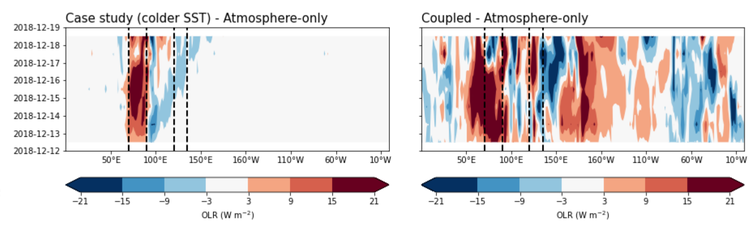


Figure 6
Hovmoller diagram for 5S-5N band for OLR difference between case study and atmosphere-only model and coupled model and atmosphere-only model. Vertical lines denote EIO and central MC region.

MJO phase 4:

- Increased persisted SST in the atmosphere-only model by 1 K in central MC region
- Warmer SST in central MC region cause increased convection there from lead day 1

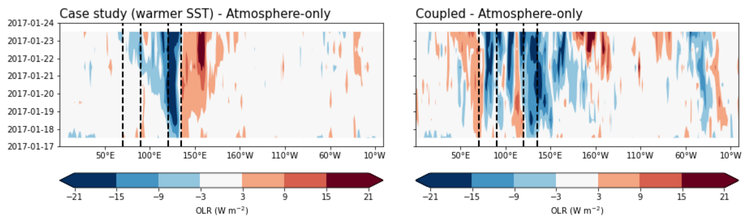


Figure 7
Hovmoller diagram for 10S-10N band for OLR difference between case study and atmosphere-only model and coupled model and atmosphere-only model. Vertical lines denote EIO and central MC region.

References:
[1] Wheeler, B. And H. Hendon (2004), *Mon. Weather Rev.*
[2] Gottschalck et *al.* (2010), *Bull. Amer. Meteor..*
[3] Hersback et *al.* (2020), *Q. J. R. Meteorol. Soc.*
[4] Bureau of Meterology. *RMM indices.*

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