MJO simulation in UM

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1. Evaluation of MJO in UM

We use UK Met office Unified Model (UM) version 7.1 with pre-Hadgem3 configuration, in which convection scheme is based on mass flux scheme with CAPE closure.

The cross power spectrum of precipitation and U850 wind (Fig. 1) indicates that UM7.1 has no strong evidence of an intra seasonal spectral peak at MJO wave number and frequency.

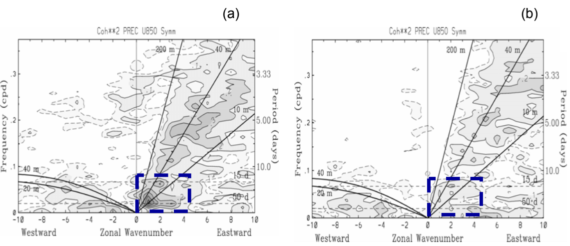


Figure 1: Cross power spectrum of precipitation and U850. (a) Observation; (b) UM7.1

Further investigation of the spatial distribution of rainfall variance (Fig. 2) reveals some additional deficiencies that may contribute to the lack of a MJO in the UM7.1 simulation: the peak rainfall variance in UM7.1 is about 30 degree west compared to observations in the tropical Indian Ocean, which is thought to be the incipient region for the MJO.

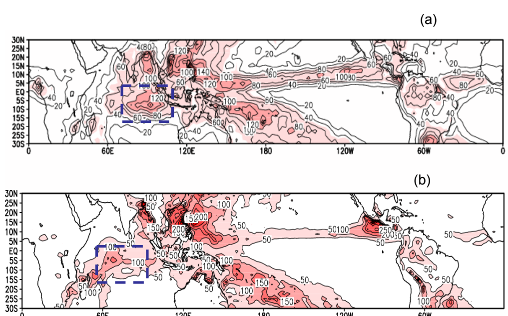
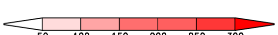


Fig. 2: Averaged precipitation variance for (a) observation, and (b) UM7.1 .



Problem: There is lack of active convection in the region of central Indian Ocean and West Pacific region.

2. Sensitivity Experiments

To improve convection in Indian Ocean and West Pacific region two sensitivity experiments are carried out:

Expt. 1: Trigger for shallow convection
Expt. 2: Excluding cumulus momentum transport

In UM model, W_test was added to shallow convection because shallow convection over the oceans tends to lead to too much low level cloud water. As a consequence, this constraint also prevents shallow convection to occur in most regions of Indian Ocean and West Pacific region, where air ascends. In Expt. 1, we remove the restriction of vertical velocity criteria for shallow convection.

Including momentum transport in the convection scheme could be a reason for the more barotropic nature of the zonal wind and easterly wind bias in the Indian Ocean and West Pacific region in UM simulation. In Expt. 2, cumulus momentum transport is excluded in the convection scheme.

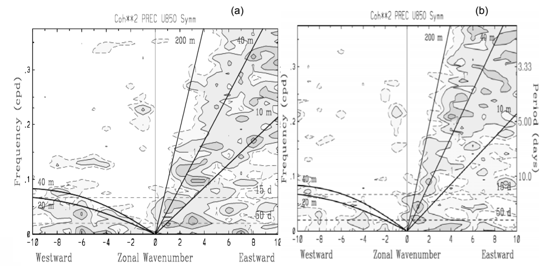


Fig. 3: Cross power spectrum of precipitation and U850 for Sens. Expt. 1 (a) and 2 (b).

Fig.3 shows that MJO simulations are improved in Sens. Expt. 1 and and Expt. 2 comparing to control experiment.

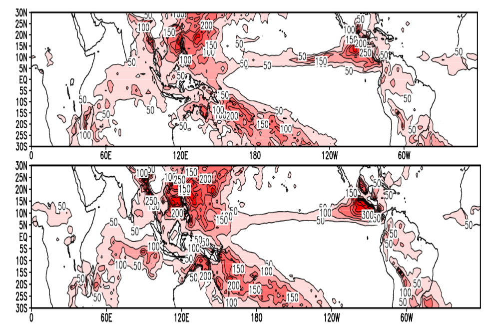


Fig.4 : Averaged precipitation variance for Expt. 1 (upper panel) and Expt. 2 (lower panel) .

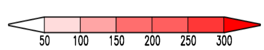


Fig. 4 shows that there is more variability of precipitation in the central Indian Ocean for both Expt. 1 and Expt. 2.

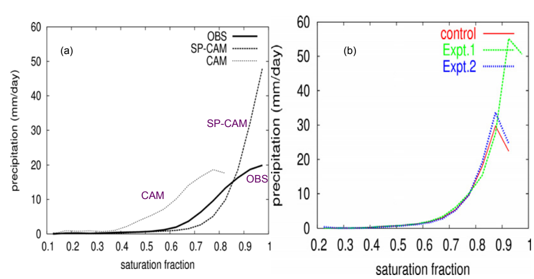


Fig.5: Daily mean moisture anomaly composited by the occurrence of daily mean precipitation rate anomaly greater than 9.6 mm / day for (a) Observation, Cam and SP-CAM. ; (b UM Expts.

Fig. 5 shows that in Sens. Expt. 1, the precipitation for the higher saturation fraction is almost double of the value in the control experiment. There is still a decrease of rainfall rate when the saturation fraction reaches 90%, which is perhaps due to the decreasing of latent heat flux (Fig.7a) . In Expt.2, the precipitation for the higher saturation fraction is slightly larger comparing to the control experiment.

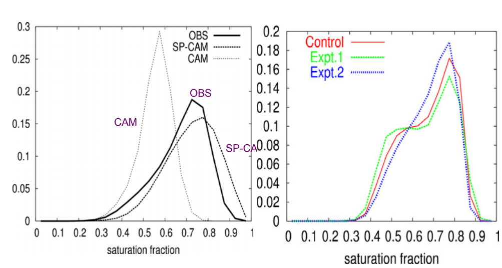


Fig. 6: Ratio of number of data points in each bin to the total number of data points. (a) for observation, CAM and SP-CAM; (b) for Expts in UM.

In Fig. 6, we also calculate the numbers of occurrences of precipitation in each bin of saturation fraction. The UM7.1 simulation exhibits two peaks, one near 0.45 and one near 0.8, indicating a tendency in UM7.1 to develop convection at too many grid points with moderate saturation. In Expt. 1, the rainfall events at the moderate saturation is increased slightly. This relationship is improved in Expt. 2 and the first peak near 0.45 disappears.

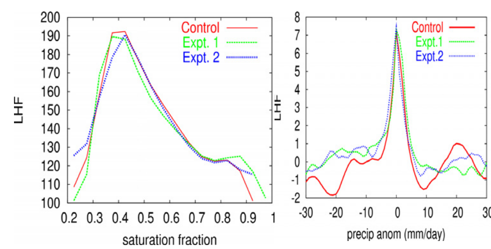


Fig.7: (a) Same as Fig. 5, but for latent heat flux. (b) Daily mean latent heat flux anomaly composited by the occurrence of daily mean precipitation rate anomaly greater than 9.6 mm /day.

In Fig. 7a, the latent heat flux for the higher saturation fraction (> 0.85 for Expt. 1 and > 0.9 for Expt. 2) are increased in the sensitivity experiments comparing to the control experiment. Latent heat fluxes in three experiments all have a decreasing tendency at higher saturation fraction.

In Fig. 7 (b) in the Sens. Expt.1 and 2, the latent heat fluxes increase gradually before -10 day, and quickly reduced to zero after 7 day. In the control Expt., there is less increase prior and a second peak of latent heat flux anomaly at +20 day.

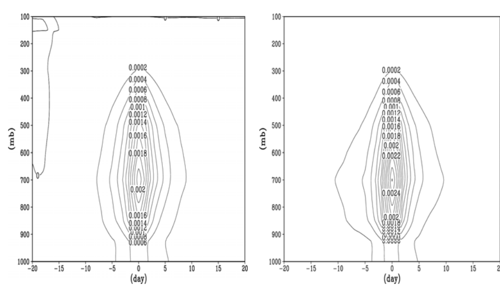


Figure 8: Daily mean moisture anomaly composited by the occurrence of daily mean precipitation rate anomaly greater than 9.6 mm / day for (a) Control Expt. ; (b) Sensitivity Expt 1.

In the Sens. Expt. 1, shallow convection pre-moistens the lower troposphere and increases the moisture anomalies at day 0.

Discussion: Shallow convection helps to build up a pre-condition for deep convection and also helps to stabilize atmosphere after the intense rainfall events.

Without Momentum transport, the rainfall events for the moderate saturation fraction reduces.

Both sensitivity experiments increases precipitation at the higher saturation fraction and increases the rainfall variability at the central Indian Ocean.