ECMWF [2]

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Investigation of the physical mechanisms responsible for the recent MJO forecast improvements in the ECMWF IFS

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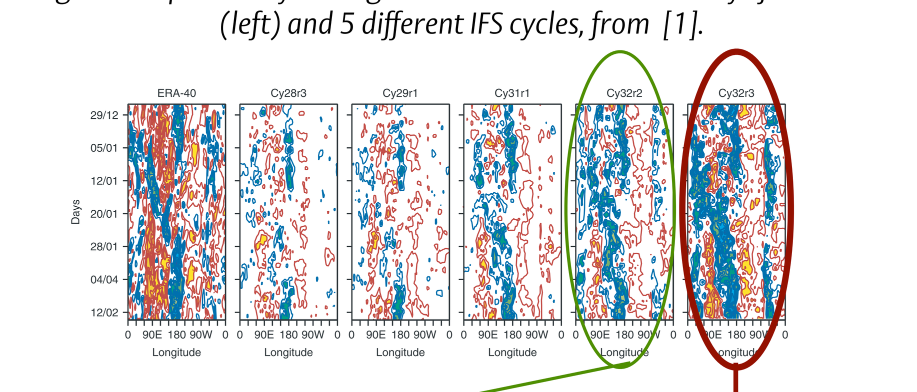
1. Introduction

Recent modifications to the ECMWF Integrated Forecasting System (IFS) have improved MJO simulation.

Figure 1: Equatorially averaged OLR anomalies at t+15 days for ERA-40 (left) and 5 different IFS cycles, from [1].



Cy 32r2:

- New **radiation** package McRad [2].
- → Reduction of systematic errors associated with the location of tropical convection.

Cy 32r3:

- Change to **convection and vertical diffusion** schemes [1].
- → Realistic representation of convectively coupled equatorial waves.
- → Sustained MJO amplitude.

2. Sensitivity Experiments

The modifications to the convection scheme in Cy 32r3 included:

(A) a variable convective adjustment timescale (τ).

(B) deep convective entrainment ∝ environmental relative humidity (RH_e).

Experiments (Table 1) have been designed to test the sensitivity of MJO simulation to:

- just the new convection scheme, excluding other IFS modifications: CONV : no (A) or (B).
- halving the sensitivity to RH_e : ENTRN : (A), 0.5*(B).
- allowing the convective adjustment timescale to vary: CAPE : only (B).

During the YoTC period comparisons have been made with an old IFS version Cy 31r1 : no (A) or (B) and the operational cycle OPER : (A) and (B).

Table1: Summary of IFS convection scheme sensitivity experiments.

	Cycle (Identifier)	Details	Convection	Radiation	Resolution	Adjustment timescale (τ)
Cy 31r1	Cycle 31r1 (eifc)	The cycle used for ERA Interim.	'old'	'old'	TL 255	3600 s
CONV	Cycle 33r1 (fbgq)	YoTC period re-run using cycle 33r1, replacing the 'new' convection with the 'old' version.	'old'	'new'	TL 799	720 s
OPER	Cycle 32r3 to Cycle 35r3 (odfc)	The operational cycle during the YoTC period.	'new' : (A),(B)	'new'	TL 799	600 s -3 h
ENTRN	Cycle 33r1 (fgk8)	YoTC period re-run using cycle 33r1, halving sensitivity to RH_e: 0.5*deep convective entrainment.	'new' : (A), 0.5* (B)	'new'	TL 799	600 s - 3 h
CAPE	Cycle 33r1 (fgbl)	YoTC period re-run using cycle 33r1, with constant CAPE adjustment timescale τ.	'new' : (B)	'new'	TL 799	720 s

3. Representation of the MJO

Multivariate MJO index [3], applied to the experiments for April 2009 casestudy (Figure 2).

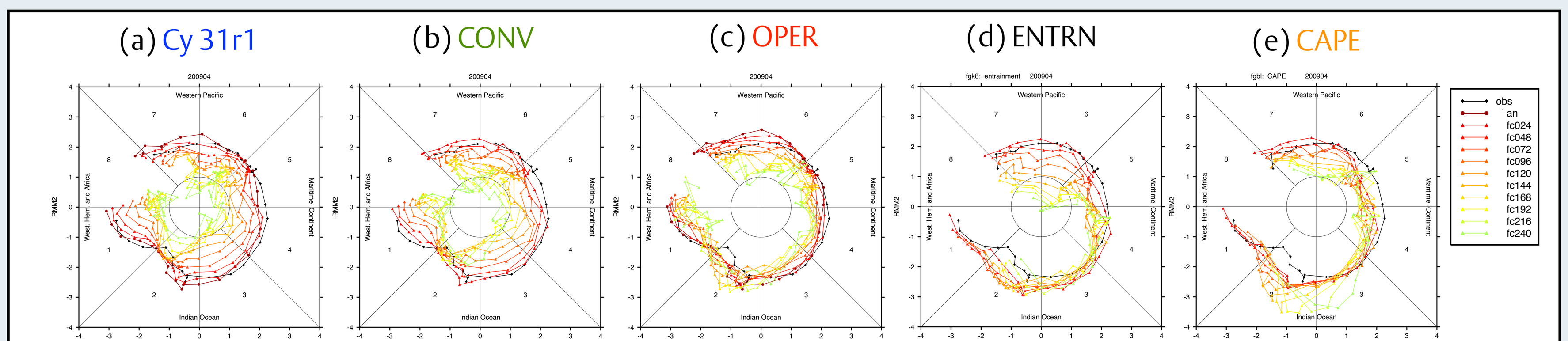


Figure 2: A multivariate MJO index [3] for the April 2009 MJO casestudy. The index uses combined EOFs of OLR, 850hPa zonal wind and 200hPa velocity potential. Red to green indicates increasing forecast lead time.

Effects of the new convection scheme:

- MJO amplitude maintained at longer forecast leadtimes, especially in the Indian Ocean. Although, in the CAPE experiment the amplitude is too strong in that region.
- considerable reduction in RMSE of MJO amplitude. By considering the contribution from the CONV experiment, 80% of the RMSE reduction between Cy 31r1 and OPER can be directly attributed to the new configuration of convection.

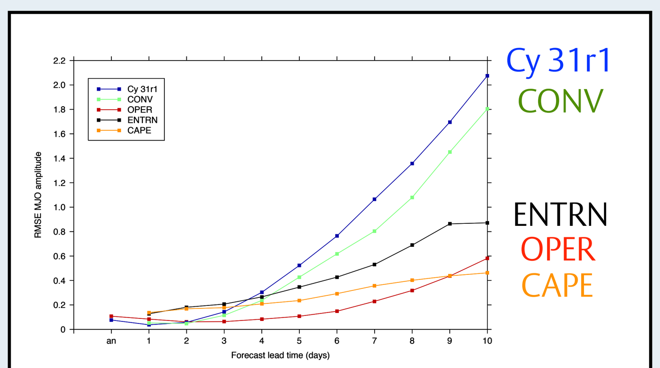


Figure 3: Root mean square error of forecast vs observed MJO amplitude for April 2009

4. Precipitation and CAPE

- All variations of the new convection scheme [OPER, ENTRN and CAPE] produce a precipitation distribution similar to TRMM observations. Cy 31r1 and CONV both produce too much rain, (Figure 4 (a)).
- CONV, ENTRN and CAPE all produce less CAPE than OPER, (Figure 4 (b)), and rain more at low values of CAPE, (Figure 5).
- Both the CAPE and ENTRN experiments weaken the constraints of OPER towards the CONV experiment which is reflected in their precipitation-CAPE relationship, (Figure 5).

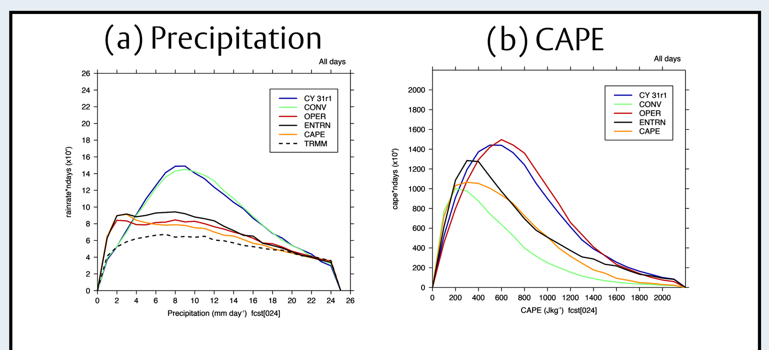


Figure 4: Precipitation (left) and CAPE (right) distribution at t+24 h for all experiments. TRMM observations of precipitation are shown by the dashed line.

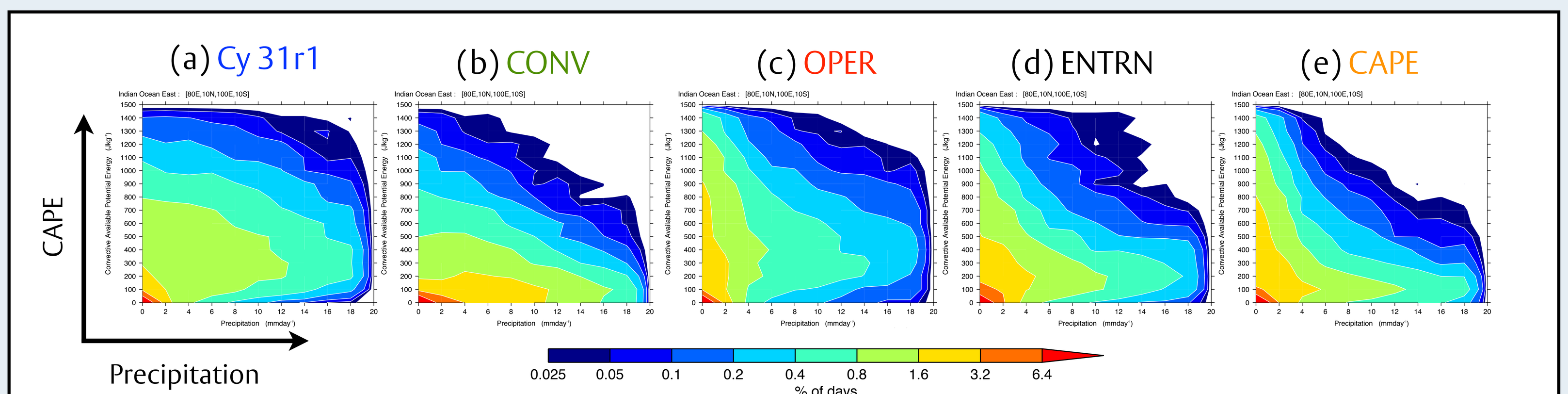


Figure 5: Precipitation-CAPE relationship for an equatorially averaged region in the eastern Indian Ocean.

5. The role of moisture

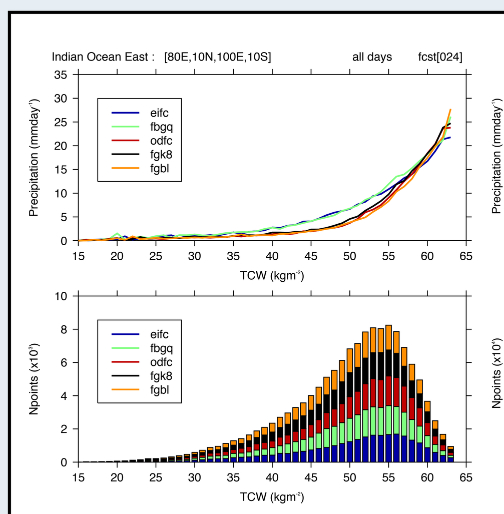


Figure 6: Daily averaged precipitation in 1- kg m^{-2} - wide bins of Total Column Water (TCW).

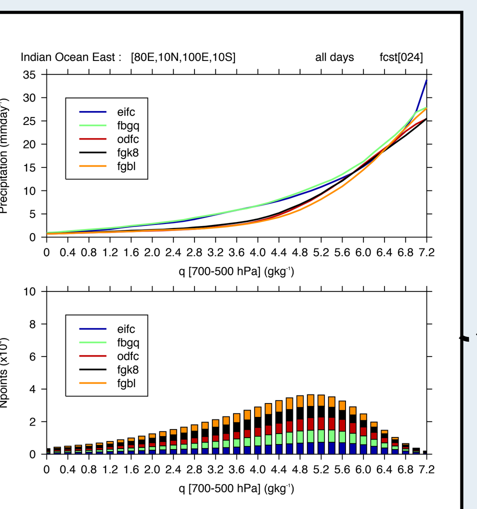


Figure 7: Daily averaged precipitation in 0.2- g kg^{-1} - wide bins of 700 to 500 hPa averaged specific humidity.

All variations of the new convection scheme [OPER, ENTRN and CAPE]:

- exhibit a similar relationship, that is distinct from Cy 31r1 and CONV, between precipitation, TCW (Figure 6) and mid-level humidity (Figure 7).
- tend to produce less precipitation for a given value of TCW or mid-level humidity.
- show rapidly increasing precipitation values at high TCW values (Figure 6).

By day 10:

- Cy 31r1, and to a lesser extent CONV, exhibit a distinct mid-tropospheric drying compared with ERA Interim. OPER exhibits a mid-tropospheric moistening, (Figure 8).
- none of the models have maintained the vertical structure of a dry phase leading a moist phase which is clear in ERA Interim.

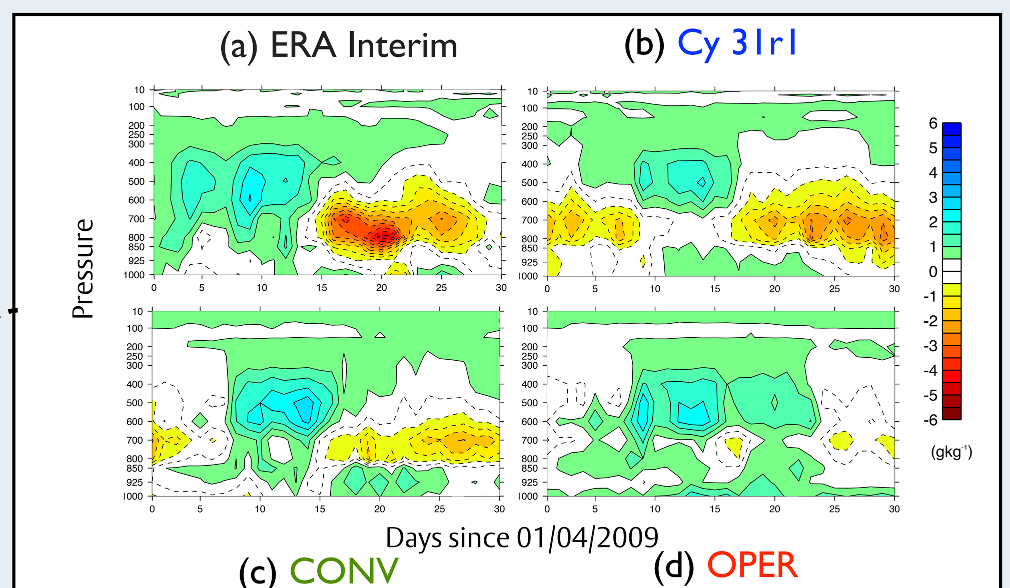


Figure 8 : Vertical structure of humidity for ERA Interim reanalysis and experiments at t+240h. Change from initial ERA Interim state on 1st April 2009.

6. Diabatic heating profiles

During the April 2009 casestudy:

- at t+24 h OPER exhibits strong diabatic heating followed by diabatic cooling.
- at t+24 h CONV exhibits a weaker amplitude of both the heating and cooling.
- by t+240 h CONV has lost the signal of diabatic cooling almost completely and the amplitude of the heating has further reduced.
- in CONV, as forecast leadtime increases, the main envelope of heating shifts east suggesting the model prolongs its time in that phase.

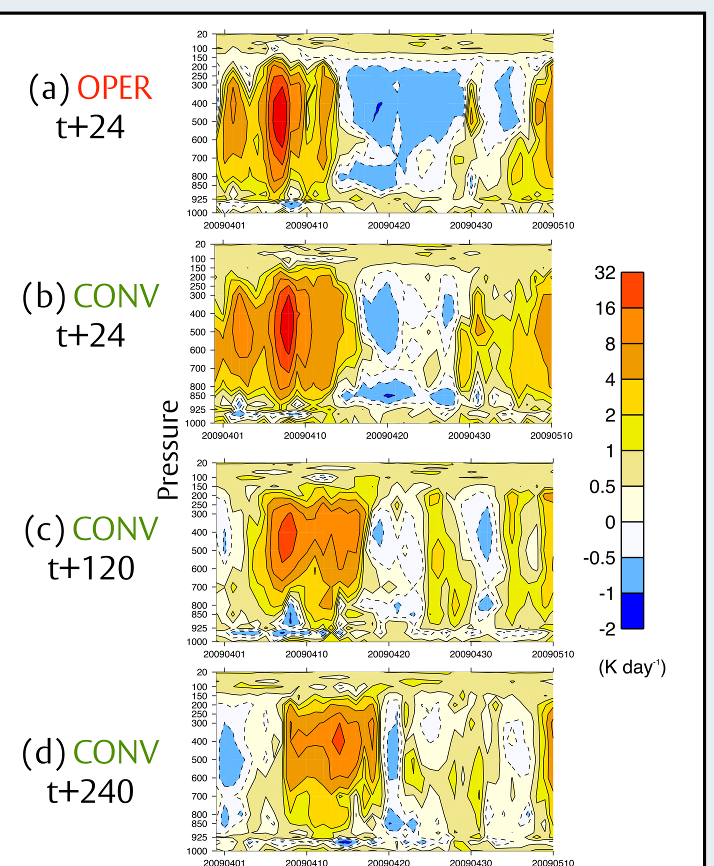


Figure 9: Vertical stucture of the dlabatic heating profiles from the physics tendencies in the equatorial Indian Ocean in April 2009.

7. Conclusions

- All variations of the new convection scheme [OPER, ENTRN and CAPE],
  - maintain the observed MJO amplitude at longer forecast leadtimes.
  - exhibit more realistic distributions of precipitation compared with observations.
  - have a similar relationship between precipitation and moisture.
- At short forecast leadtimes, experiments with shorter CAPE adjustment timescales [CONV and CAPE] produce more precipitation at low CAPE values.
- As forecast leadtime increases,
  - both Cy 31r1 and CONV exhibit a mid-tropospheric drying, while OPER exhibits a distinct mid-tropospheric moistening.
  - the amplitude of diabatic heating and cooling in CONV decreases.

References

[1] Bechtold et al,. 2008. Advances in Simulating Atmospheric Variability with the ECMWF model: From Synoptic to Decadal time-scales. *Q. J. R. Meteorol. Soc.* **134:** 1337-1351.

[2] Morcrette et al., 2007. A new Radiation Package McRAD. ECMWF Newsletter, 112:22-32.

[3] Wheeler MC and Hendon HH. 2004. An All-Seasonal Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction. Mon. Wea. Rev., 132:1917-1932.

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