YOTC dataset analysis, MJO sensitivity, and ECMWF forecast skill

Thank You Organizers

(Mitch, Duane, Jenny Lin)

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[1]ECMWF

[2]Reading University, UK

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YO TC = YO UNG = "YMCA" (see Posters)!

- **Linda Hirons, Reading University**: Investigation of the physical mechanisms responsible for the recent MJO forecast improvements in the ECMWF IFS.

- **King-Fai Li, CIT, USA**: The Madden-Julian oscillation of tropospheric Carbon Monoxide assimilated in ECMWF

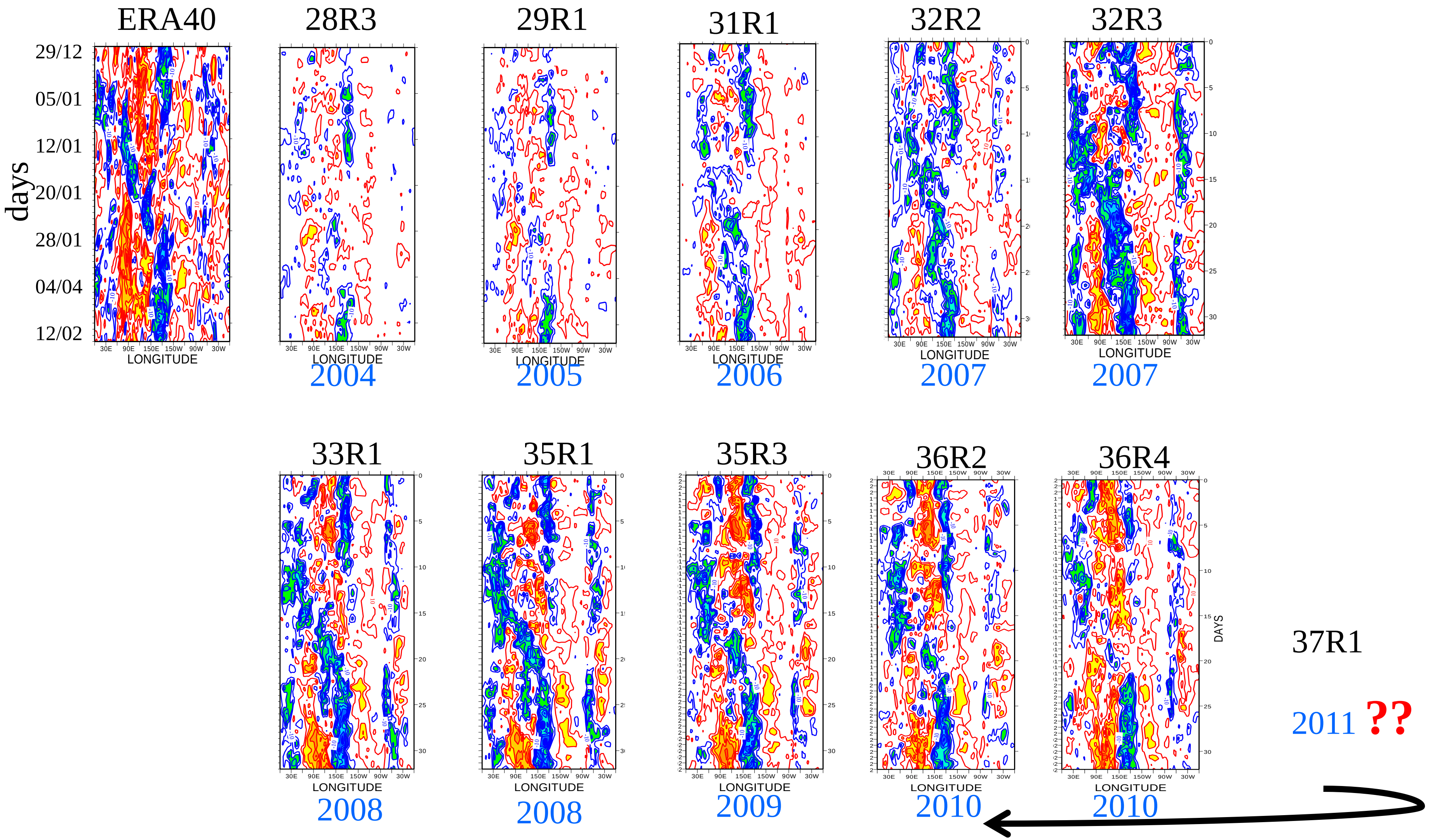
- **Tomoki,Myakawa, Tokyo University, Japan**: Convective momentum transport by rainbands within a Madden-Julian oscillation in a global nonhydrostatic model NICAM.

And friends from CMA: Qiying, Chengong, Jiandong, Xiaoding, Han-Wei

Outline

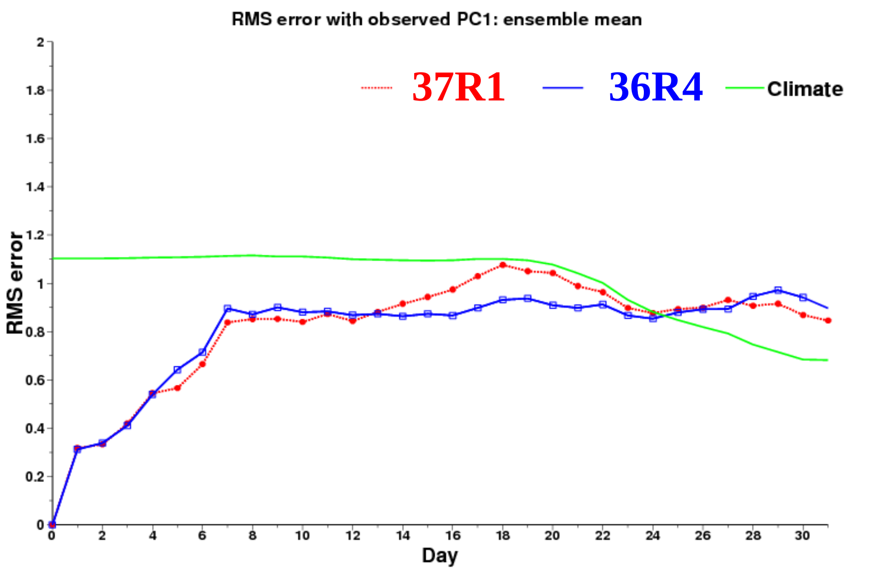
- T159 coupled ensemble prediction: Analysis and reruns of our winter 1992/1993 benchmark MJO case
- T799 high-resolution: MJO Analysis during YOTC and reruns of
- SCM studies on environmental relative humidity

MJO 1992/1993 OLR anomalies - Forecast range: day 15

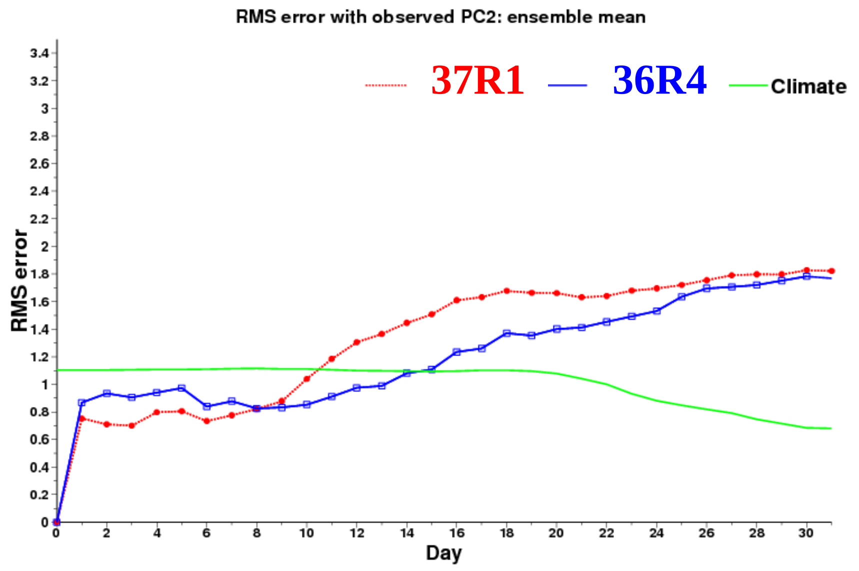


MJO rms errors for PC1 and PC2

PC1



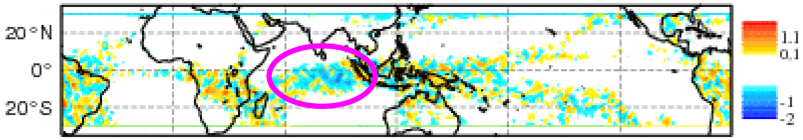
PC2



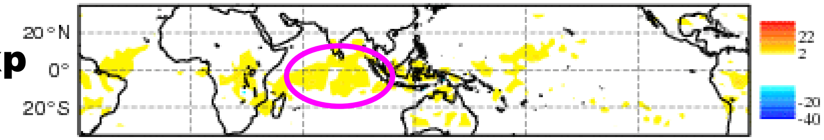
MJO Phase 2/3 and 6/7 composites and differences between 37R1 and 36R4

Precipitation | **OLR**

MJOcomp Phase 2/3 24 h TP diff 37r1-36r4 (mm/day)

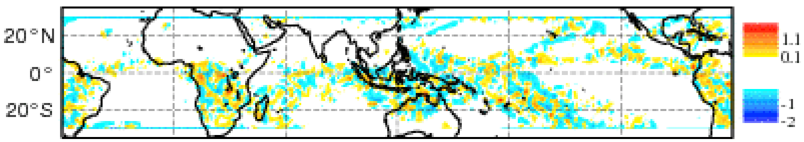


MJOcomp Phase 2/3 24 h TTR diff 37r1-36r4 (W/m2)

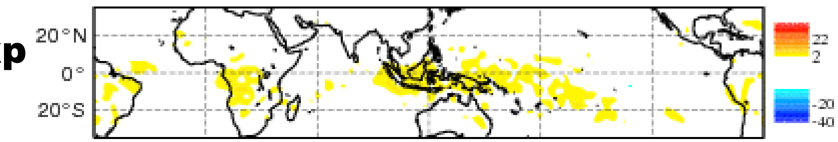


Diff exp 2/3

MJOcomp Phase 6/7 24 h TP diff 37r1-36r4 (mm/day)

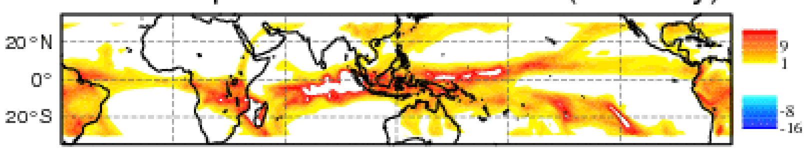


MJOcomp Phase 6/7 24 h TTR diff 37r1-36r4 (W/m2)

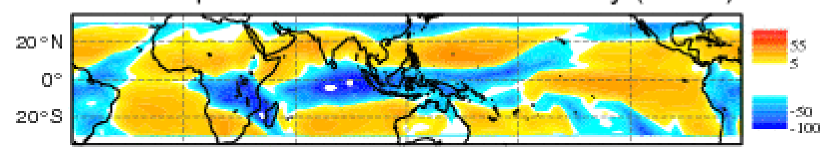


Diff exp 6/7

MJOcomp Phase 2/3 24 h TP (mm/day)

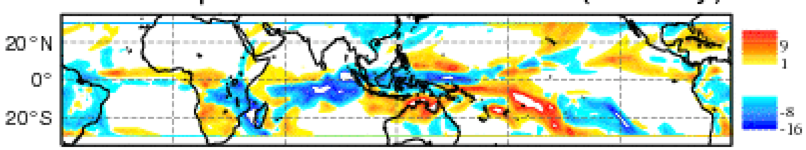


MJOcomp Phase 2/3 24 h TTR anomaly (W/m2)

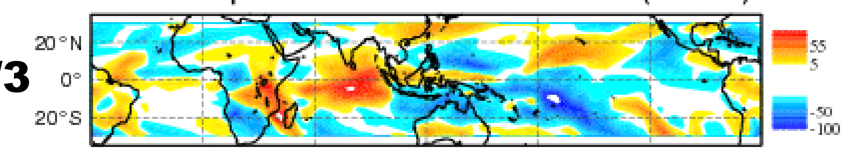


2/3

MJOcomp Phase 6/7-2/3 24 h TP (mm/day)

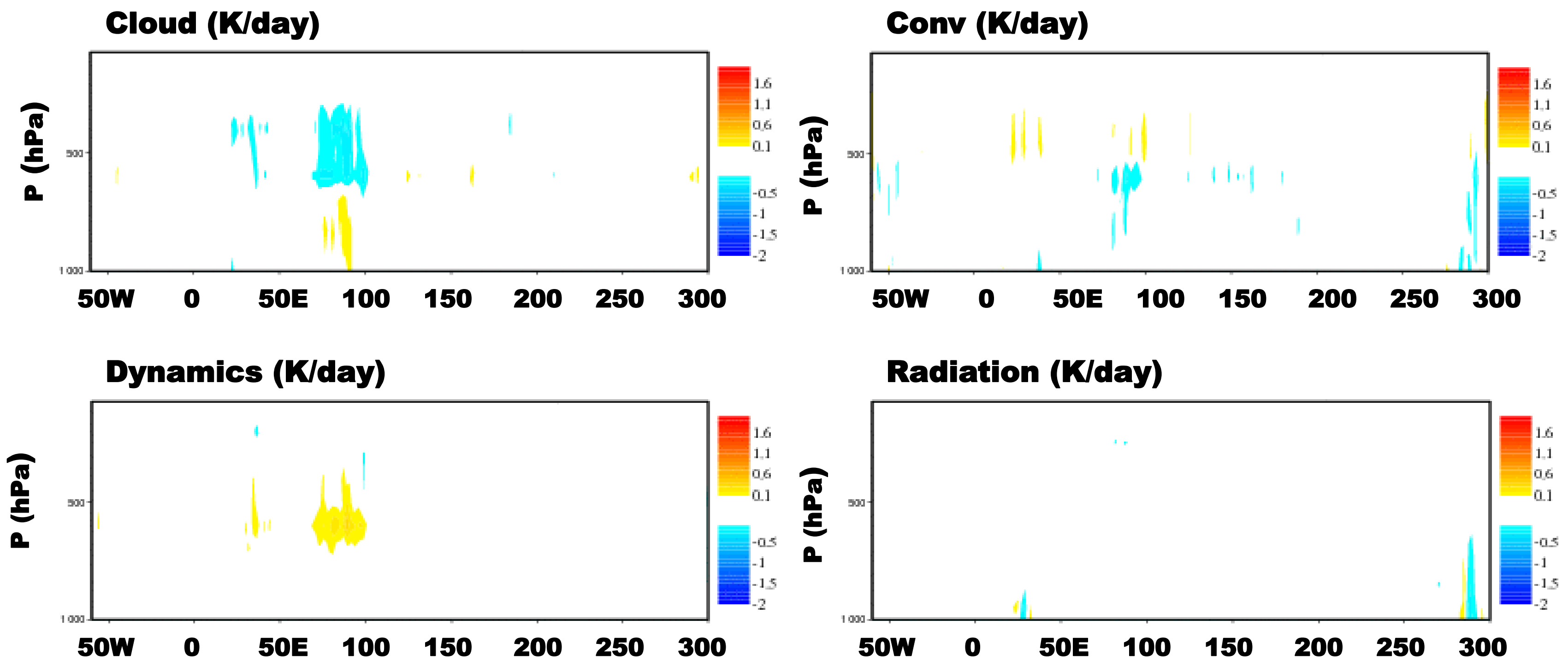


MJOcomp Phase 6/7-2/3 24 h TTR (W/m2)

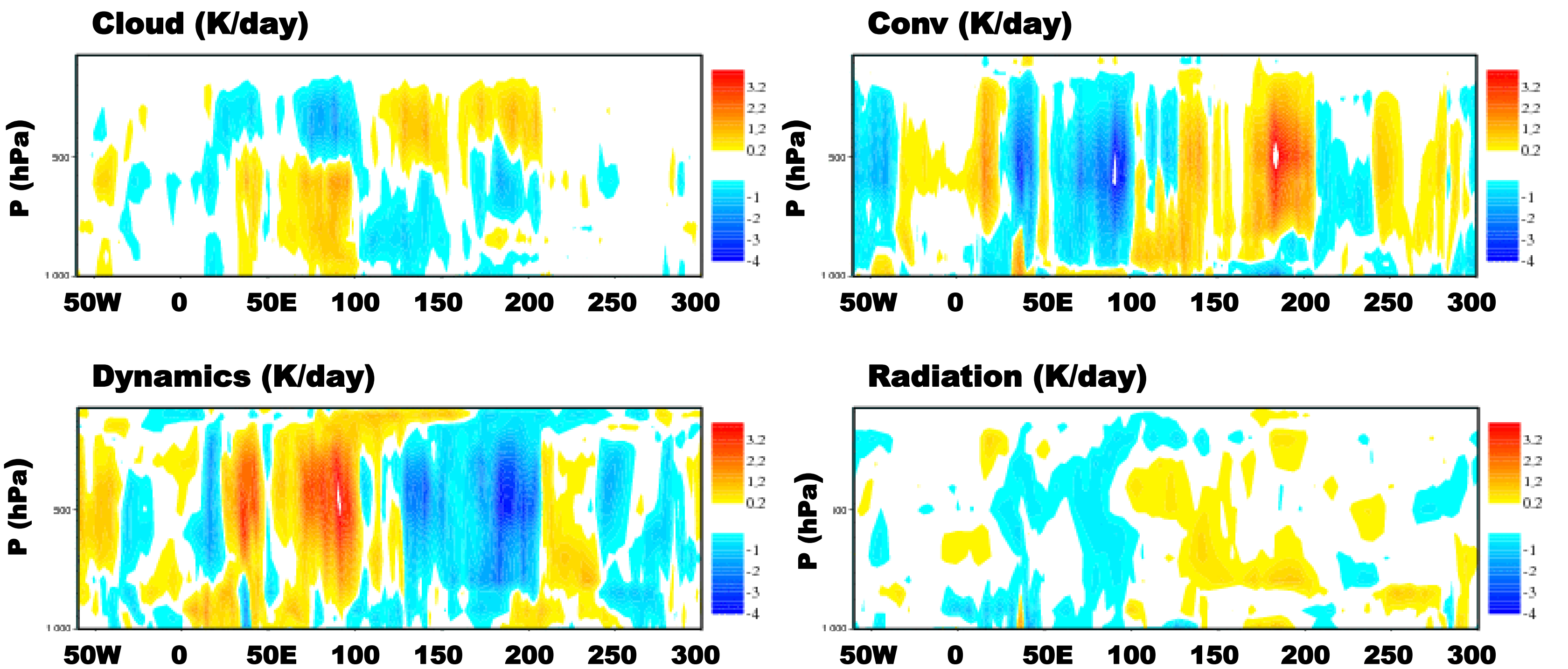


6/7-2/3

MJO Phase 2/3 24h T-tendency composites and differences between 37R1 and 36R4



Difference Phase 6/7-2/3 T-tendency composites for 37R1



T159 Experiments (in coupled ensemble mode) for 1992/1993 period based on next operational cycle 37R3

	Cycle (Exp Identifier)	Details
Cy 37r3	Cycle 37r3 (eifc)	Summer 2011 operational cycle 37r3
ENTR	(file)	Do NOT use RH dependent term in entrainment
RAD	(filf)	Call Radiation every 1h and at T159 grid (instead of 3h and T95 grid)
CA	(fild)	Couple convection with a cellular Automaton (prognostic+advection)

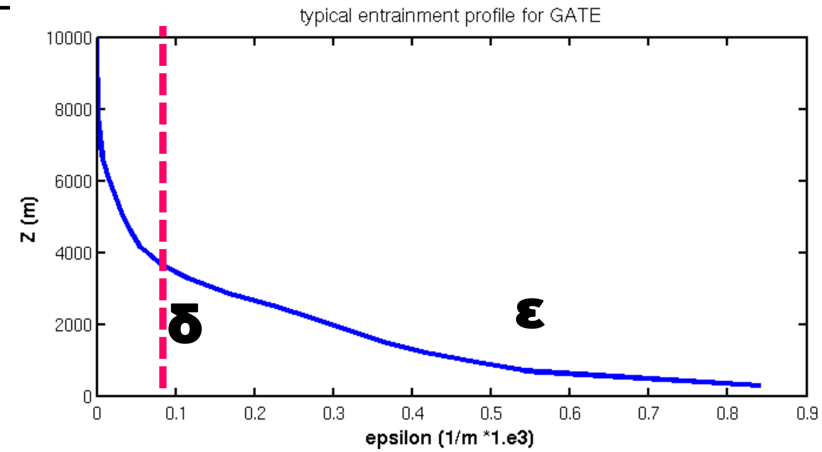
Table 1: Summary of IFS convection scheme sensitivity experiment

Entrainment/detrainment in IFS

$$\varepsilon = \alpha \; 1.3 - RH \left(\frac{q_{sat}}{q_{sat}^{base}} \right)^3; \quad \alpha = 1.8 \times 10^{-3} m^{-1}$$

Further simplified compared to Bechtold et al. (2008)

$$\delta_{turb} = 0.75 \times 10^{-4} m^{-1}; \quad \delta_{org} \approx \frac{\partial w_u^2}{\partial z}$$



alternative:

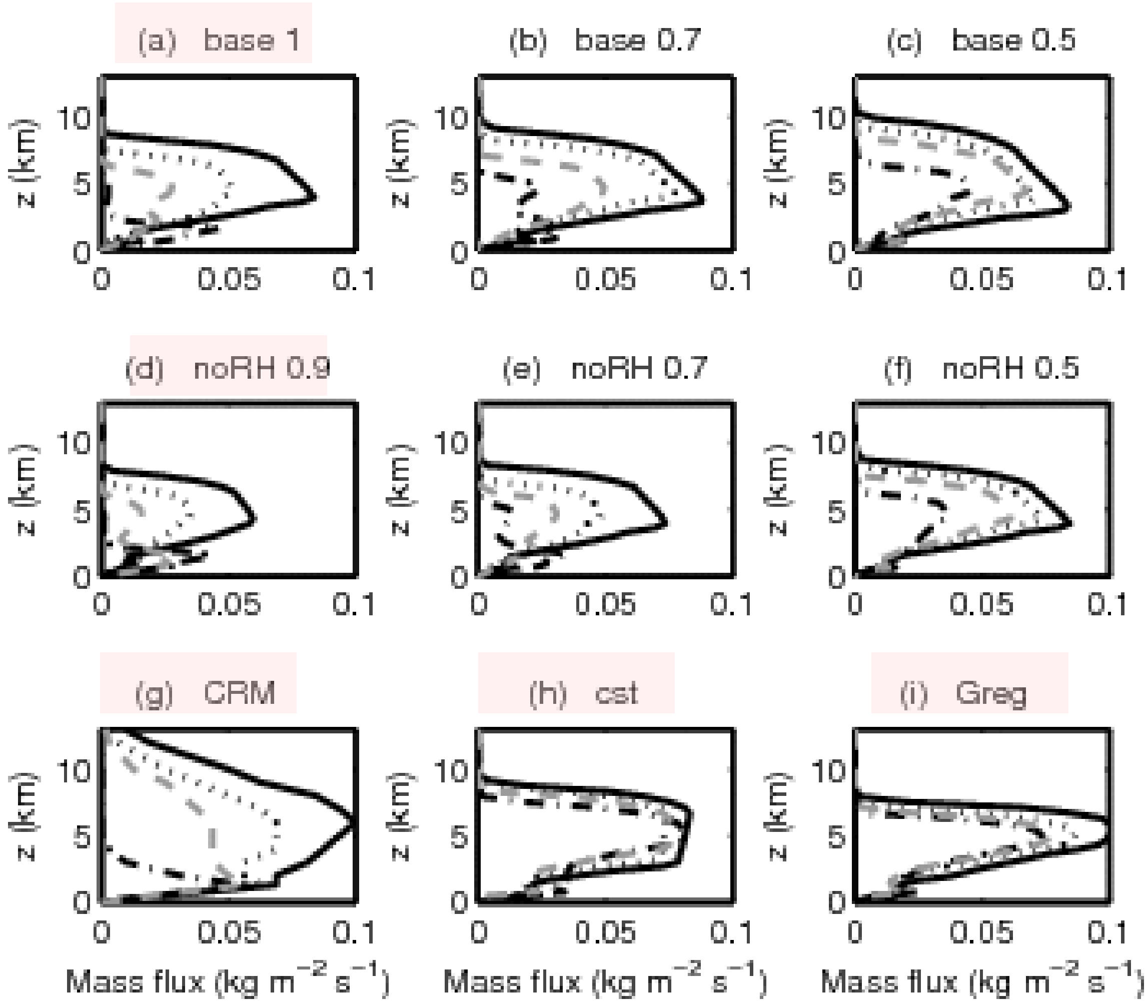
$$\varepsilon = \alpha \frac{B}{w_u^2};$$

Use buoyancy and updraught vertical velocity: D. Gregory (2001), D. Kim+I-S Kang (2011), Chikira (2010), Del Genio and Wu (2010)

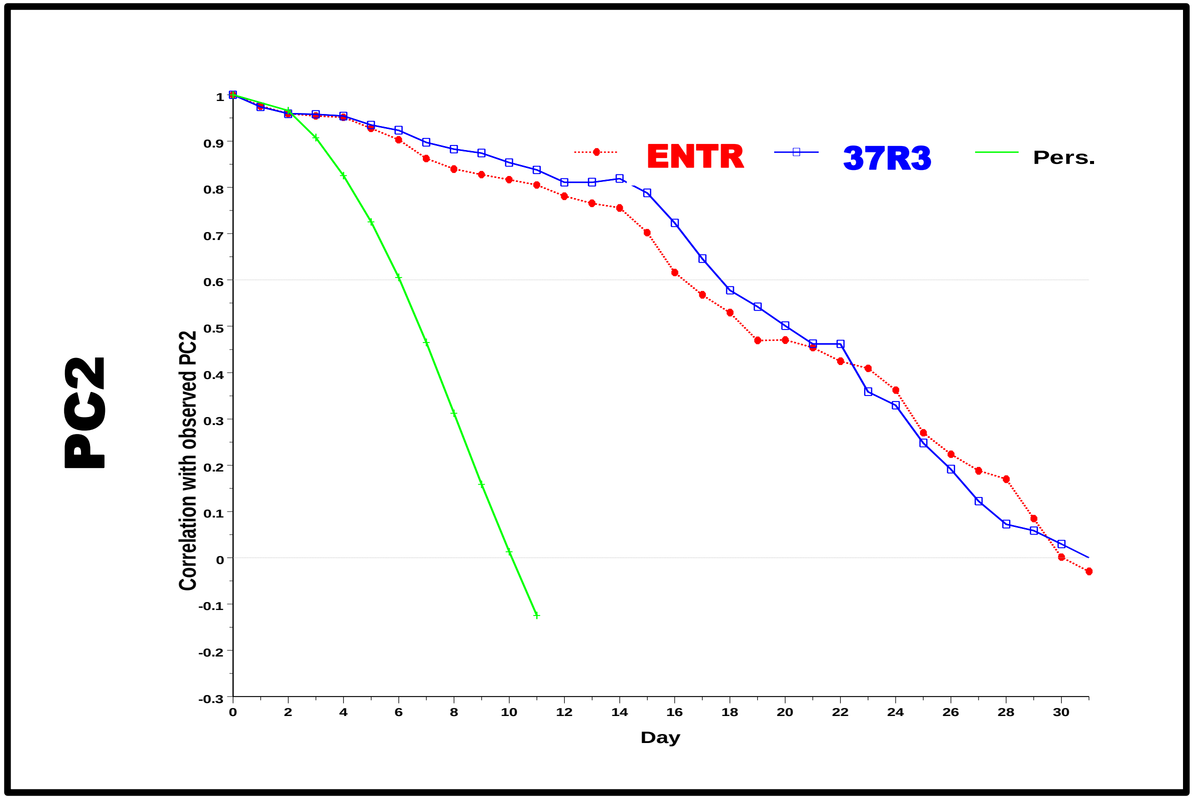
SCM model study with relaxed tropospheric RH

Following Derbyshire et al. 2004, QJRMS

RH=25, 50, 75, 90%

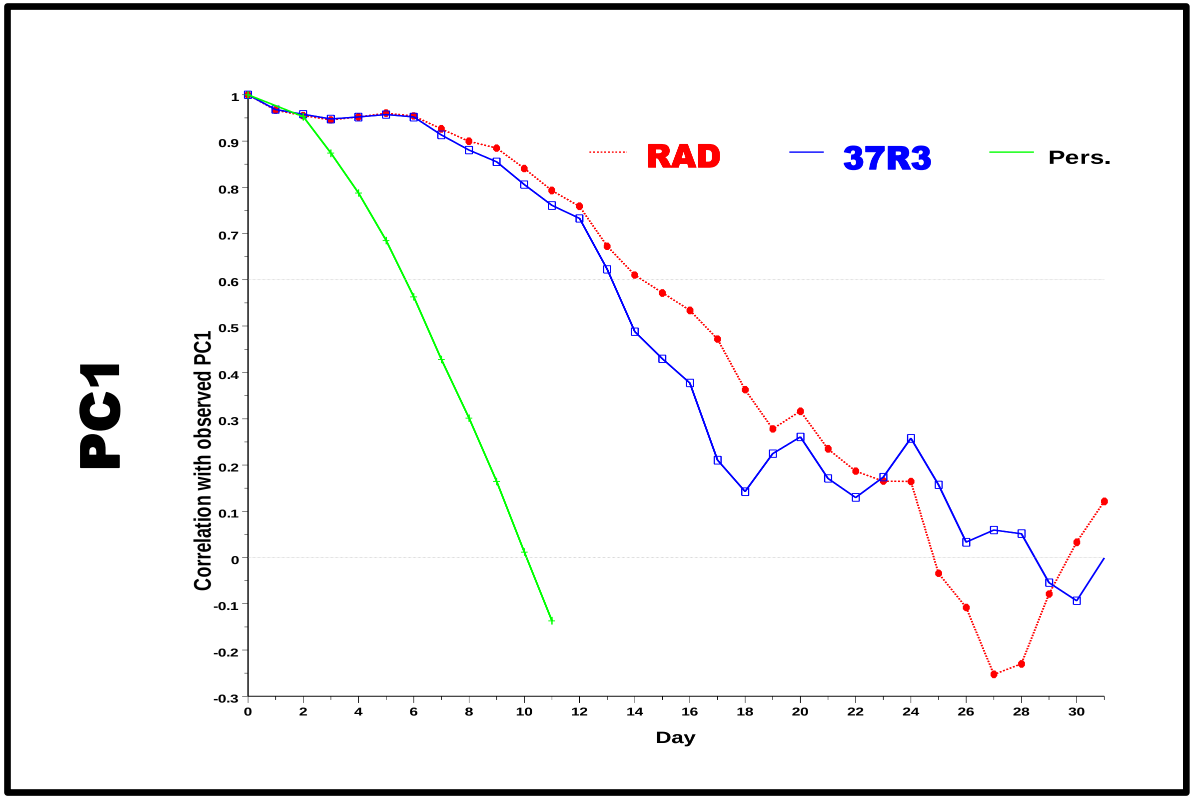


MJO skill - ENTRainment experiment



PC1 is neutral !!

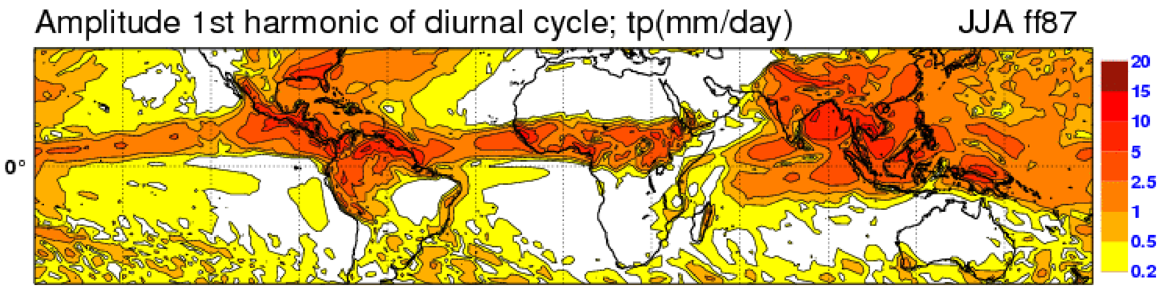
MJO skill - 1h radiation experiment



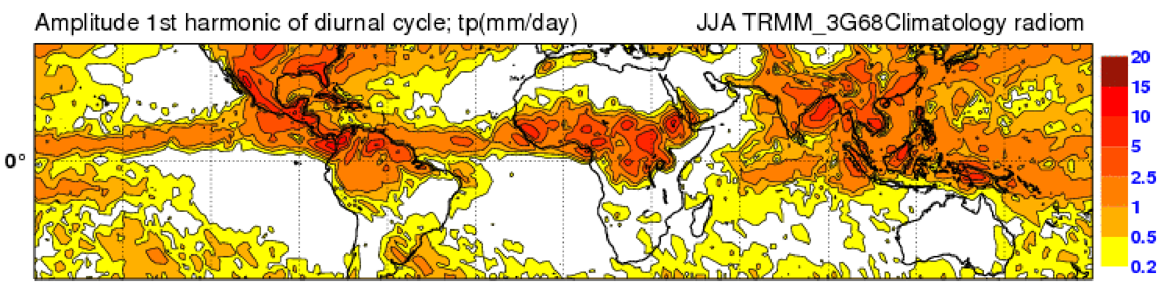
PC2 is neutral in correlation but also improved in rms !!

Diurnal Cycle JJA climate versus TRMM

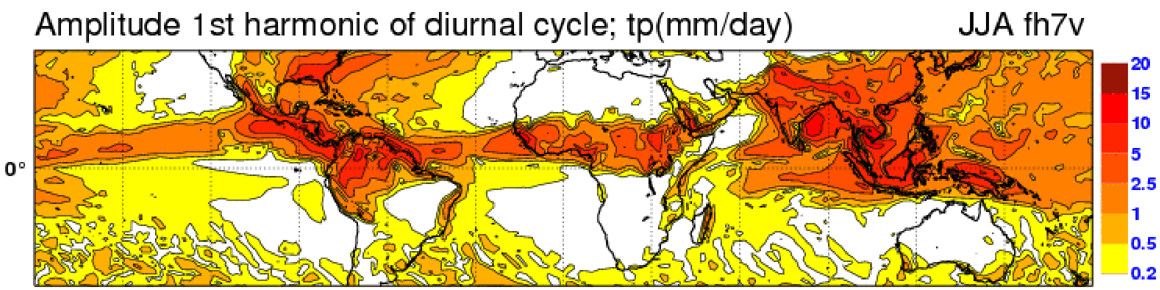
(Courtesy Drs Yukari Takayabu and Atsushi Hamada)



36R4 dt=900s rad=1h

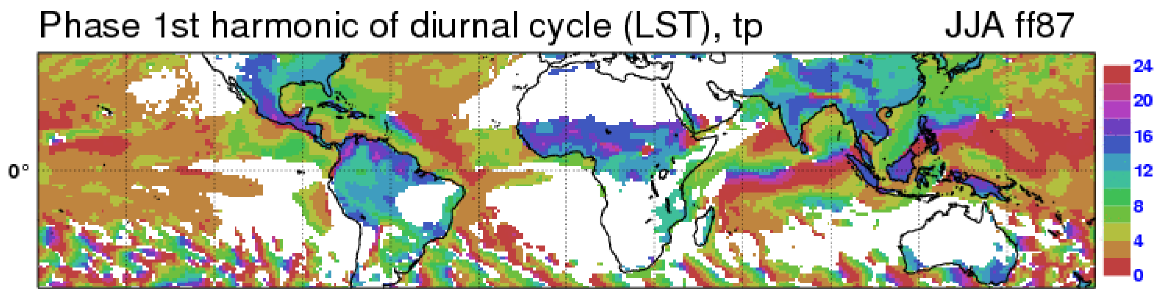


TRMM radiometer

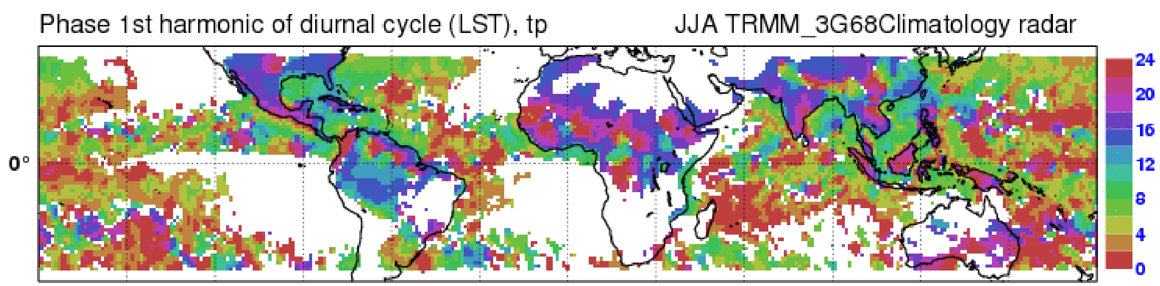


37R1 dt=1hrad=3h

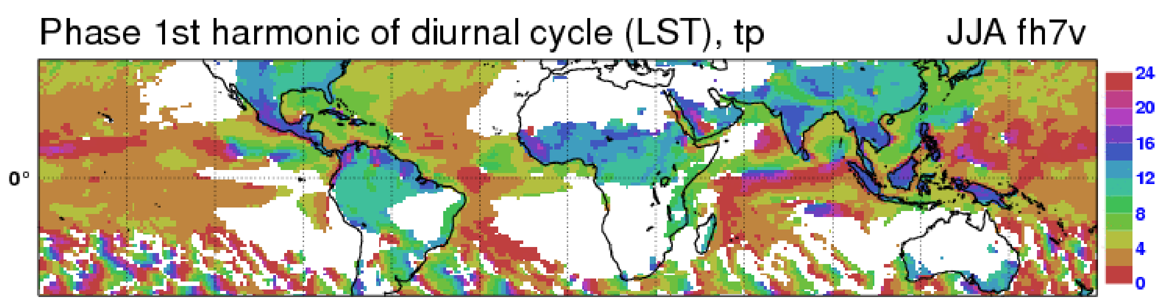
Diurnal Cycle JJA climate versus TRMM



36R4 dt=900s rad=1h



TRMM radar



37R1 dt=1h rad=3h

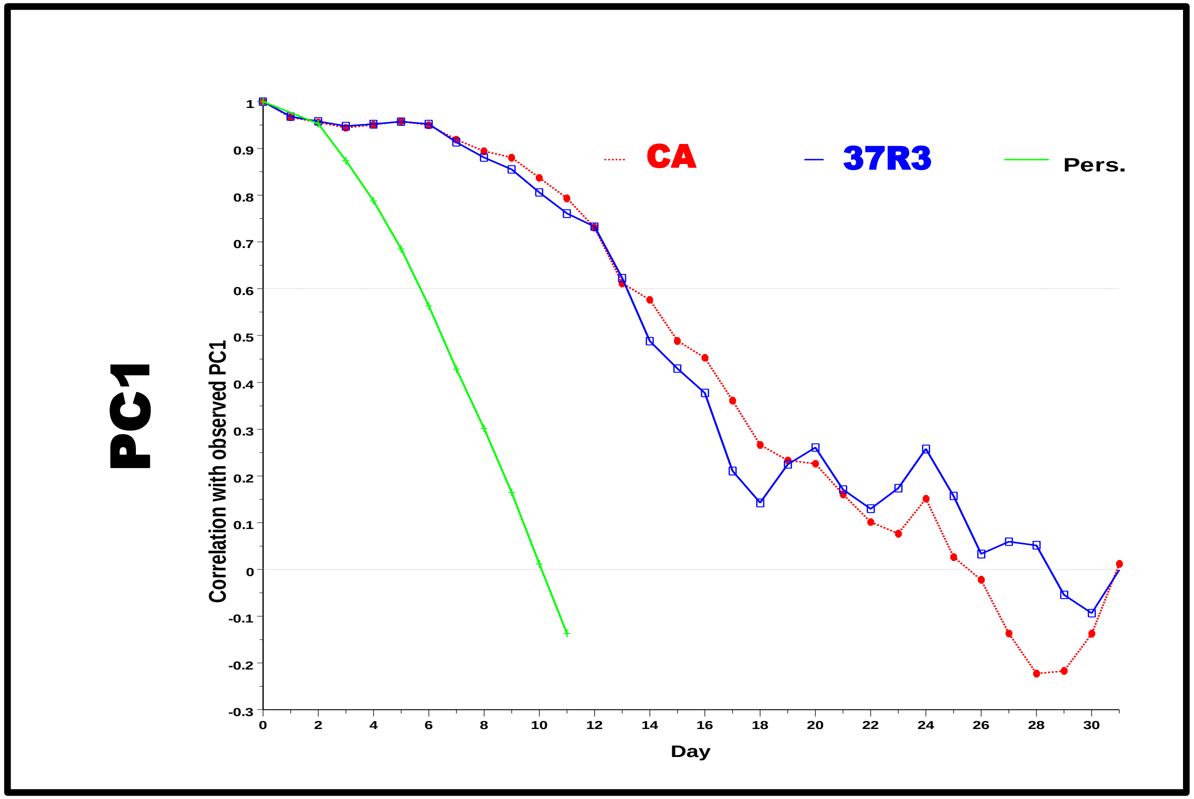
Cellular Automaton coupled to convection in the IFS, together with M. Steinheimer

- Stochastic representation of convective cell organization by coupling a Cellular Automaton to the convection parametrization, in order to improve advection and memory properties of convection

- CA consists of a number of gridded cells, whose discrete states are determined by rules based on the temporal history of each cell and its immediate neighbors

- Two way interaction of model and CA
  - Model -> CA: advect pattern with model wind, number of lives as function of CAPE, new cells initialized at grid points with deep convection
  - CA -> model: modification of T and/or q input profiles to convection scheme

MJO skill - Cellular Automaton experiment

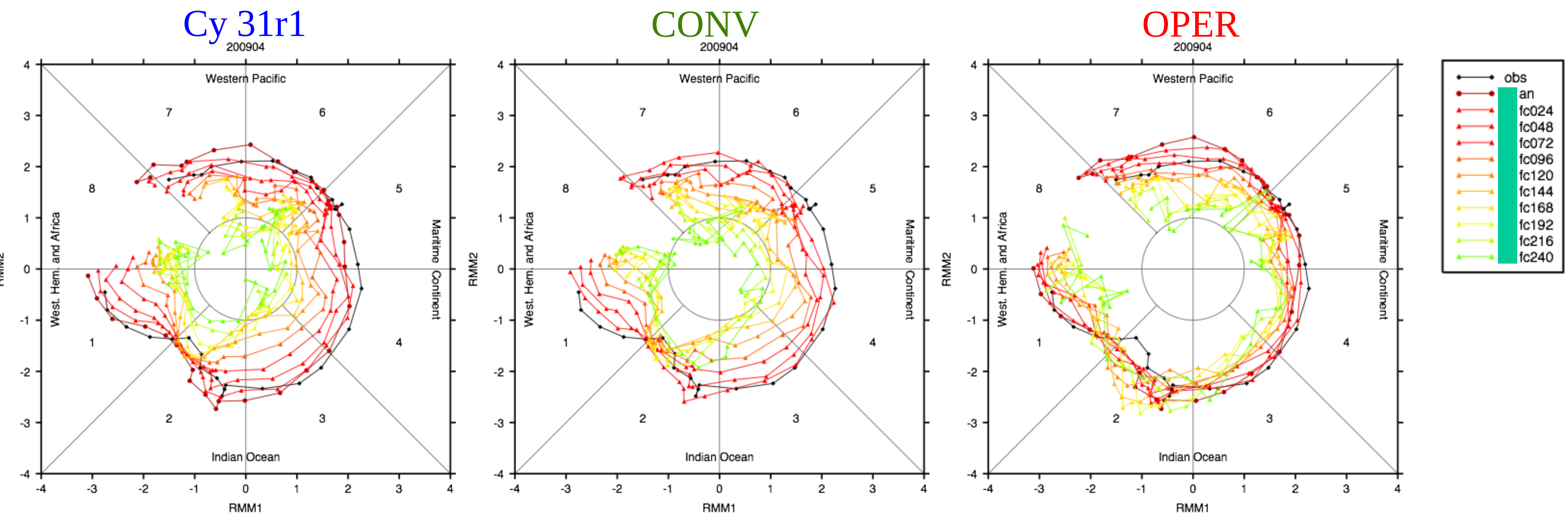


PC2 is neutral !!

YOTC data analysis and Forecasts only reruns – all T799 deterministic

	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	Tau~H/W 720-10800 s
ENTRN	Cycle 33r1 (fgk8)	YoTC period re-run using cycle 33r1, halving sensitivity to RH_e: 0.5*entrainment	'new' : (A), 0.5*(B)	'new'	TL 799	720-10800 s
CAPE	Cycle 33r1 (fgbl)	YoTC period re-run using cycle 33r1, with constant CAPE adjustment timescale τ	'new' : (B)	'new'	TL 799	720 s

Table : Summary of IFS convection scheme sensitivity experiments



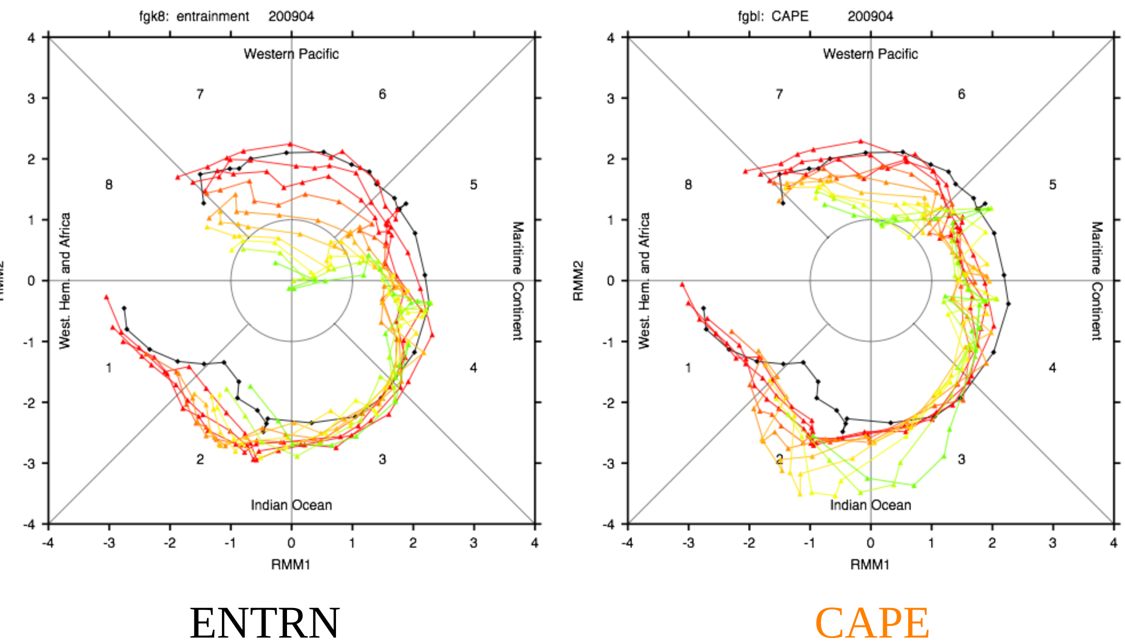


Figure 1: Multivariate MJO index for April 2009 casestudy at increasing forecast leadtime from t+24 h (red) to t+240 h (green).

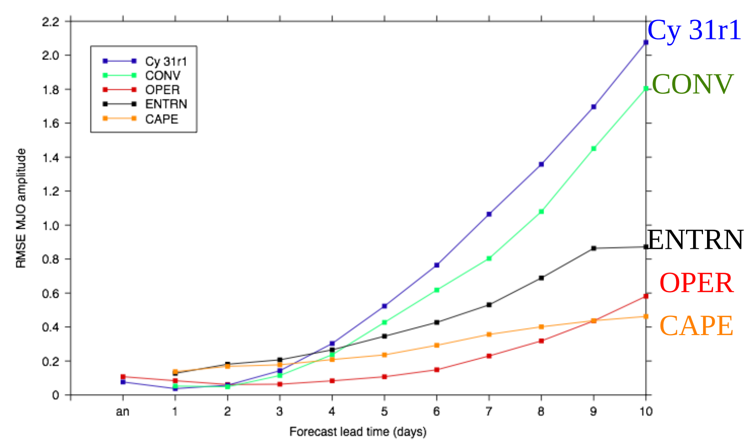


Figure 2: RMSE of MJO amplitude for April 2009 casestudy.

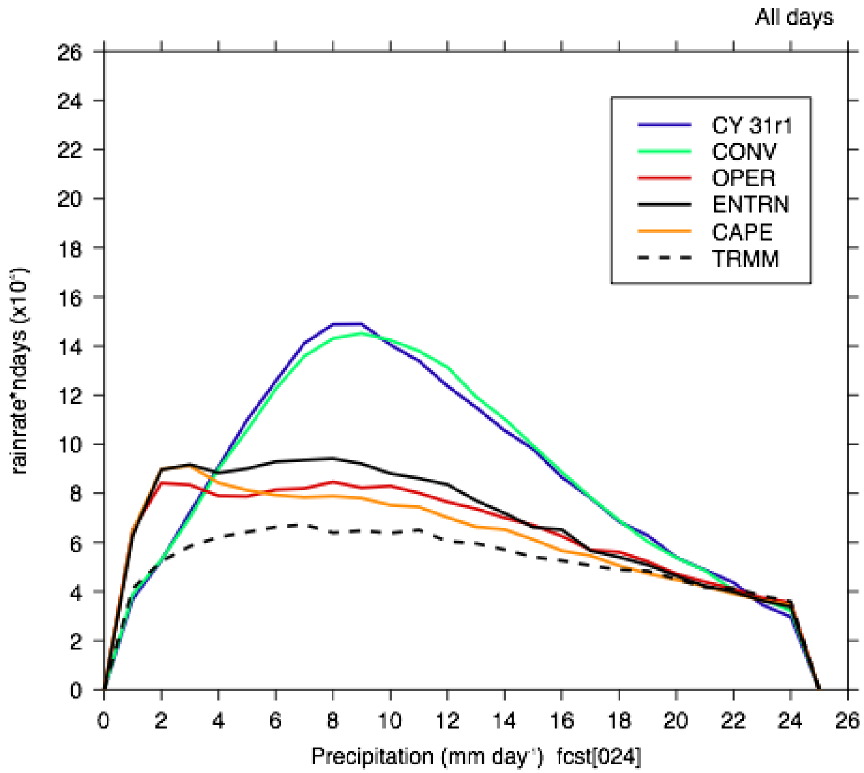


Figure 3: Precipitation distribution at t+24 h for all experiments and TRMM observations (dashed line).

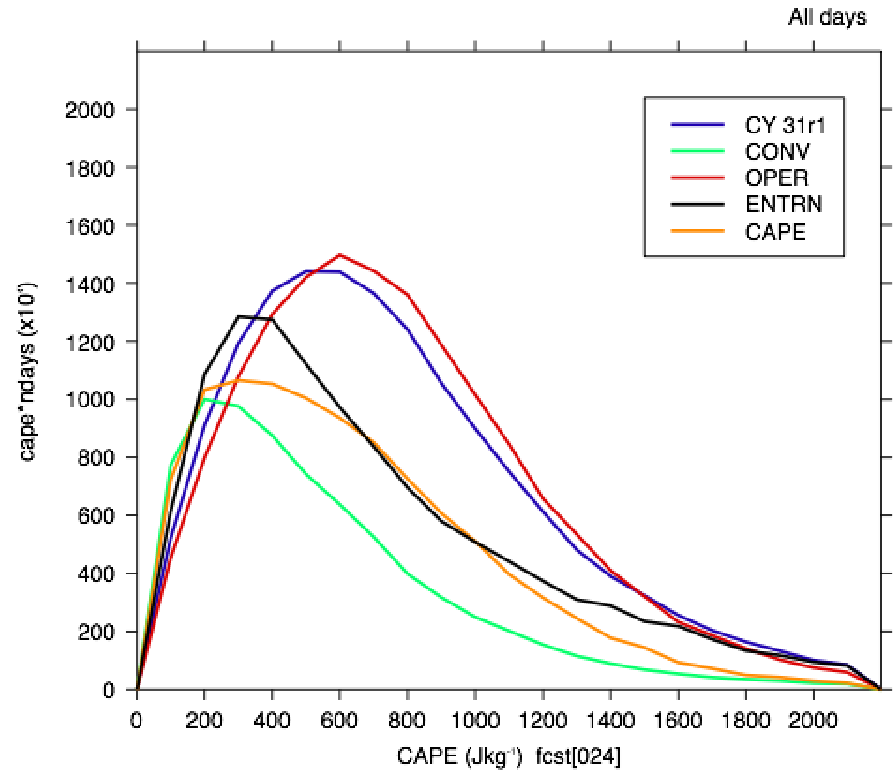


Figure 4: CAPE distribution at t+24 h for all experiments.

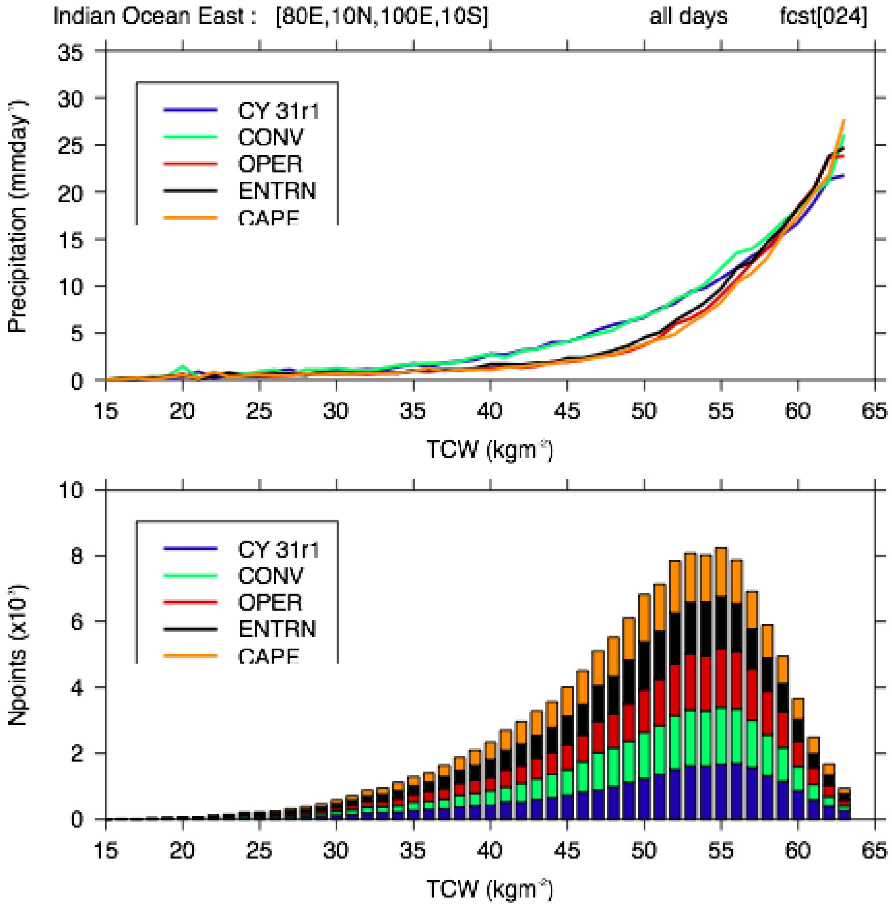


Figure 5: Daily averaged precipitation in 1 kg m^{-2} wide bins of Total Column Water (TCW) for t+24 h.

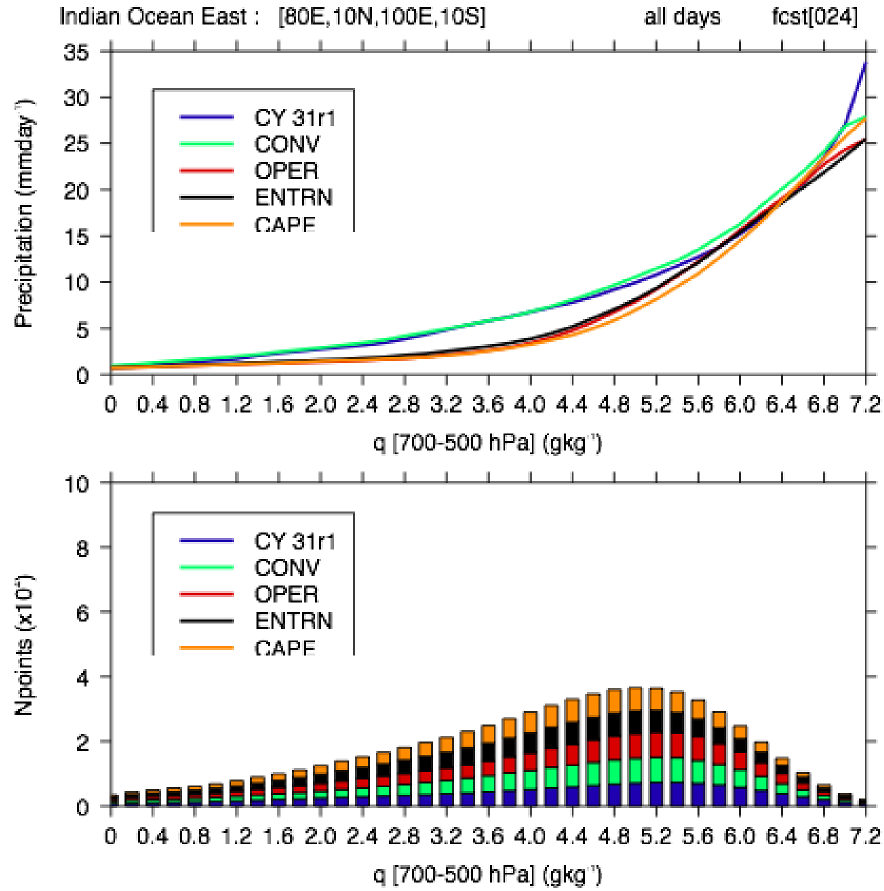
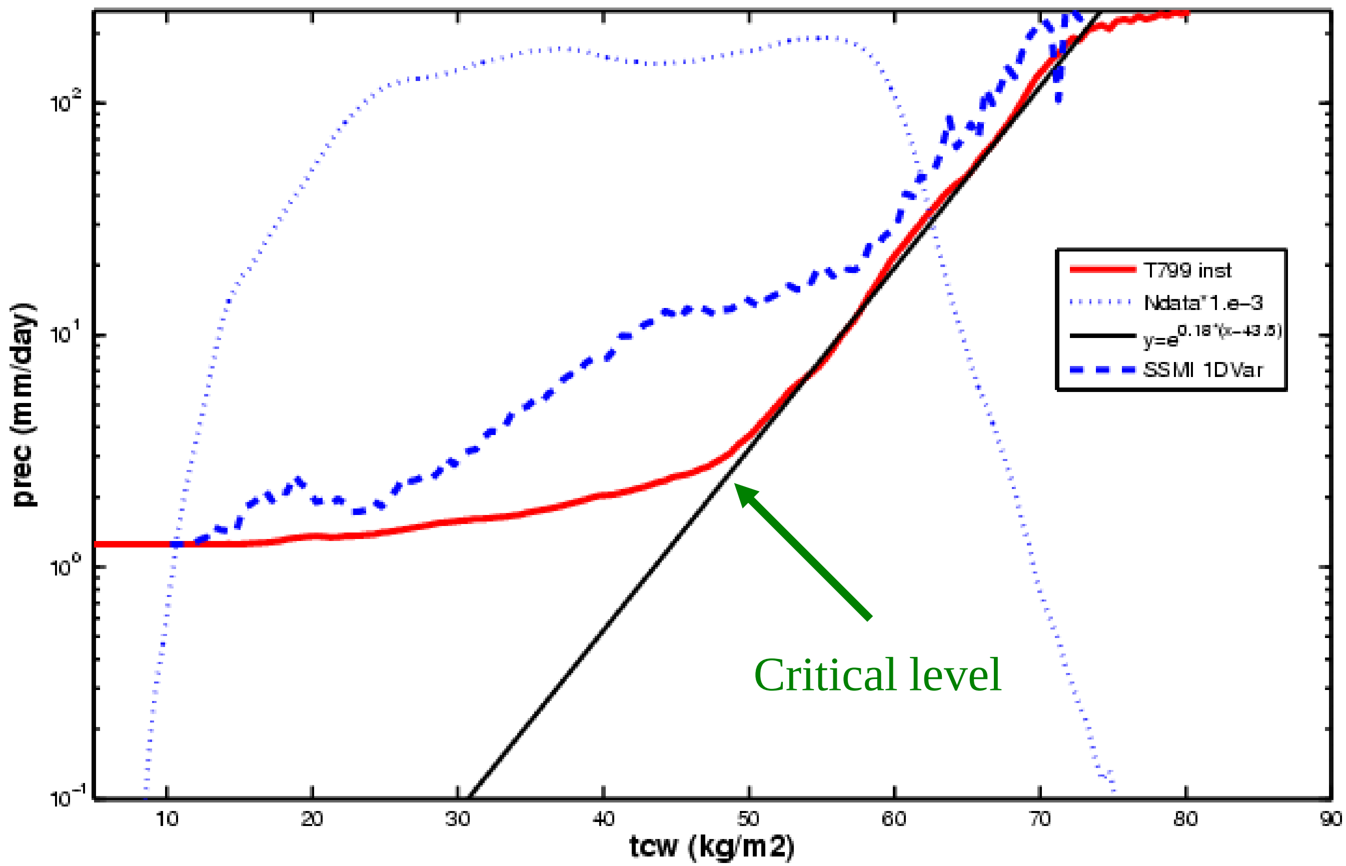


Figure 6: Daily averaged precipitation in 0.2 g kg^{-1} wide bins of 700 to 500 hPa averaged specific humidity (q) for t+24 h.

Mean Precip versus TCW from 2D Pdf

together with A. Geer

from T799 instantaneous precipitation rates with cycle 33r1 during first 24h



SSMI is from 1D-Var, but underestimates high rain rates (high TCW) as columns where more than 1/3 of precip is snow have been discarded

The global Lorenz Energy cycle

including subgrid generation/conversion rates of APE

Generation **-Conversion**

$$\frac{da}{dt} = NQ + \alpha\omega = N\bar{Q} + \bar{\alpha}\bar{\omega} + \overline{\alpha'\omega'}$$

Lorenz efficiency factor

Net heating

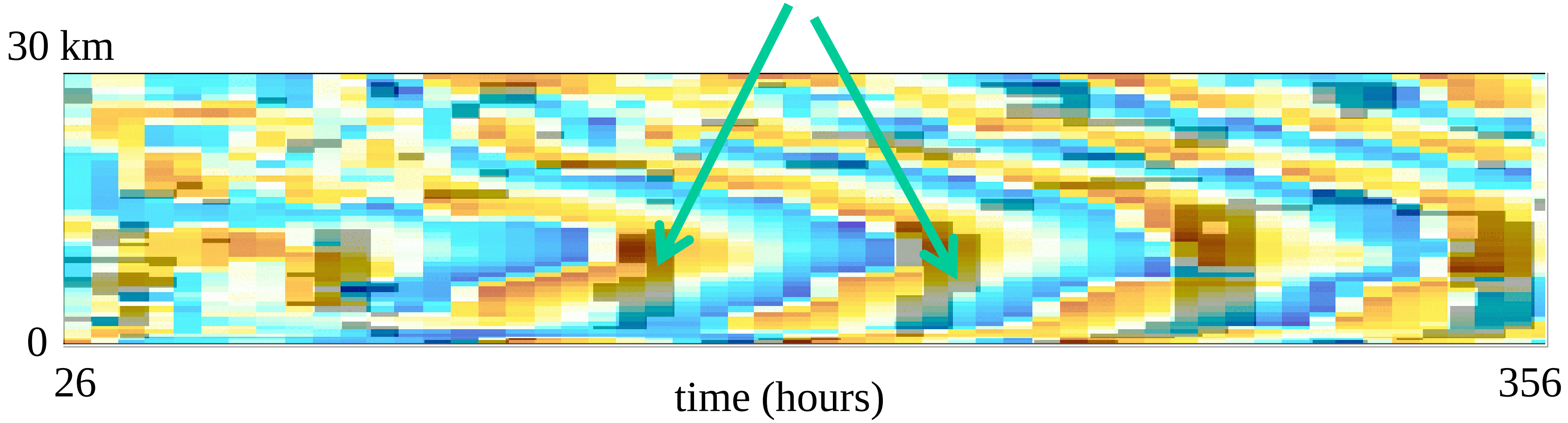
$$\overline{\alpha'\omega'} = \frac{R}{P}[1 + (\varepsilon^{-1} - 1)]\,\overline{T'\omega'} + (\varepsilon^{-1} - 1)\bar{\alpha}\,\overline{q'\omega'}$$

M Steinheimer, M Hantel, P Bechtold (Tellus, Oct 2008)

Motivation: CRM equatorial channel simulations by Glenn Shutts (presented at Martin Miller symposium, Jan 2011)

Composite of the time-height sections of **wavenumber** 10 phase for θ and Q.

At z~10 km, θ and convective heating are in phase



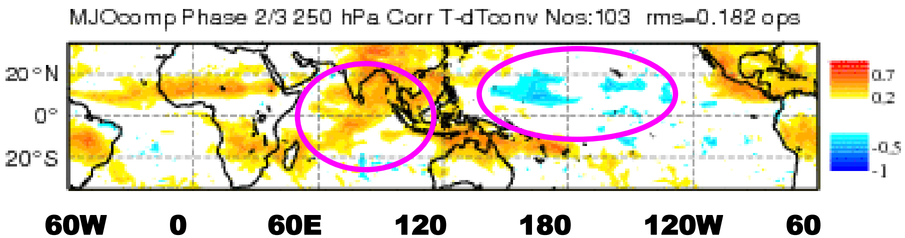
Think of red/orange as warm regions in m=10 wave

and dark shading represents convective warming

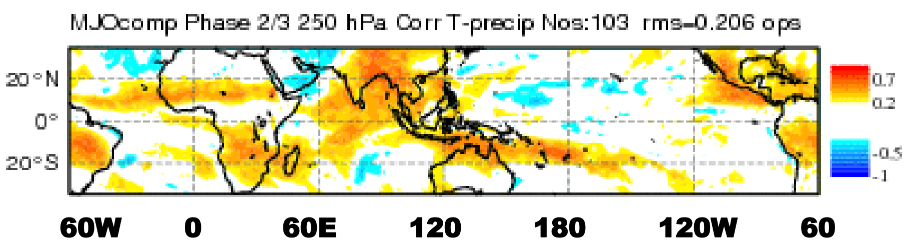
Correlations with T' at 250 hPa for **Phase 2/3** and forecast steps 12-36

Oper

dT/dt_conv

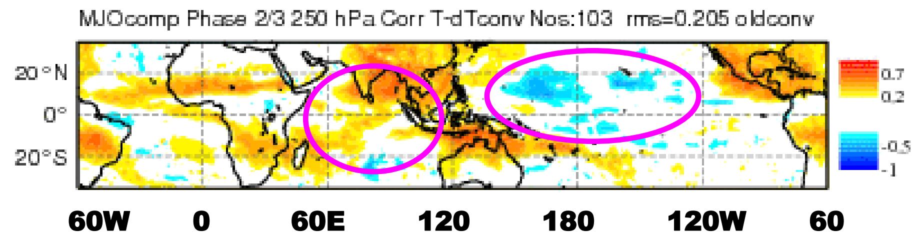


Precip

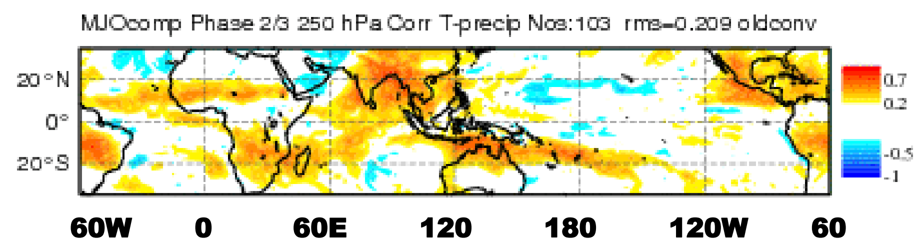


Old Conv

dT/dt_conv



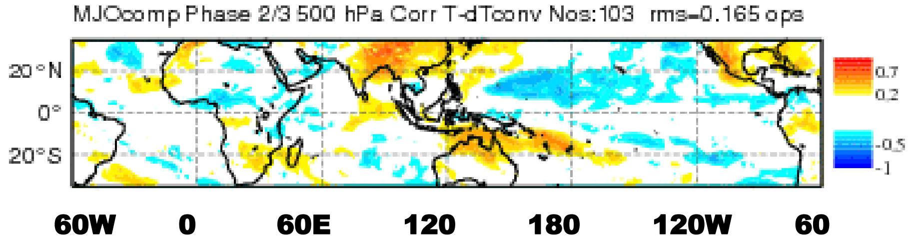
Precip



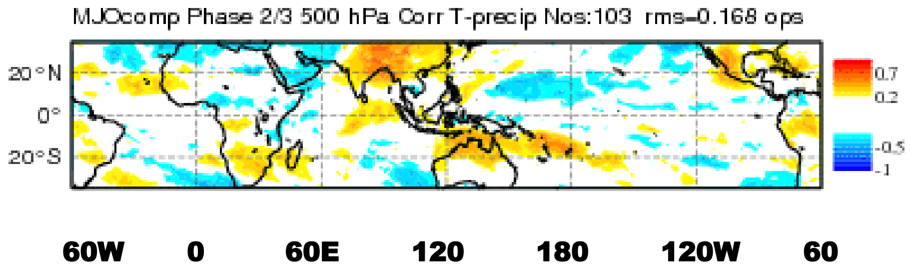
Correlations with T' at 500 hPa for **Phase 2/3** and forecast steps 12-36

Oper

dT/dt conv



Precip

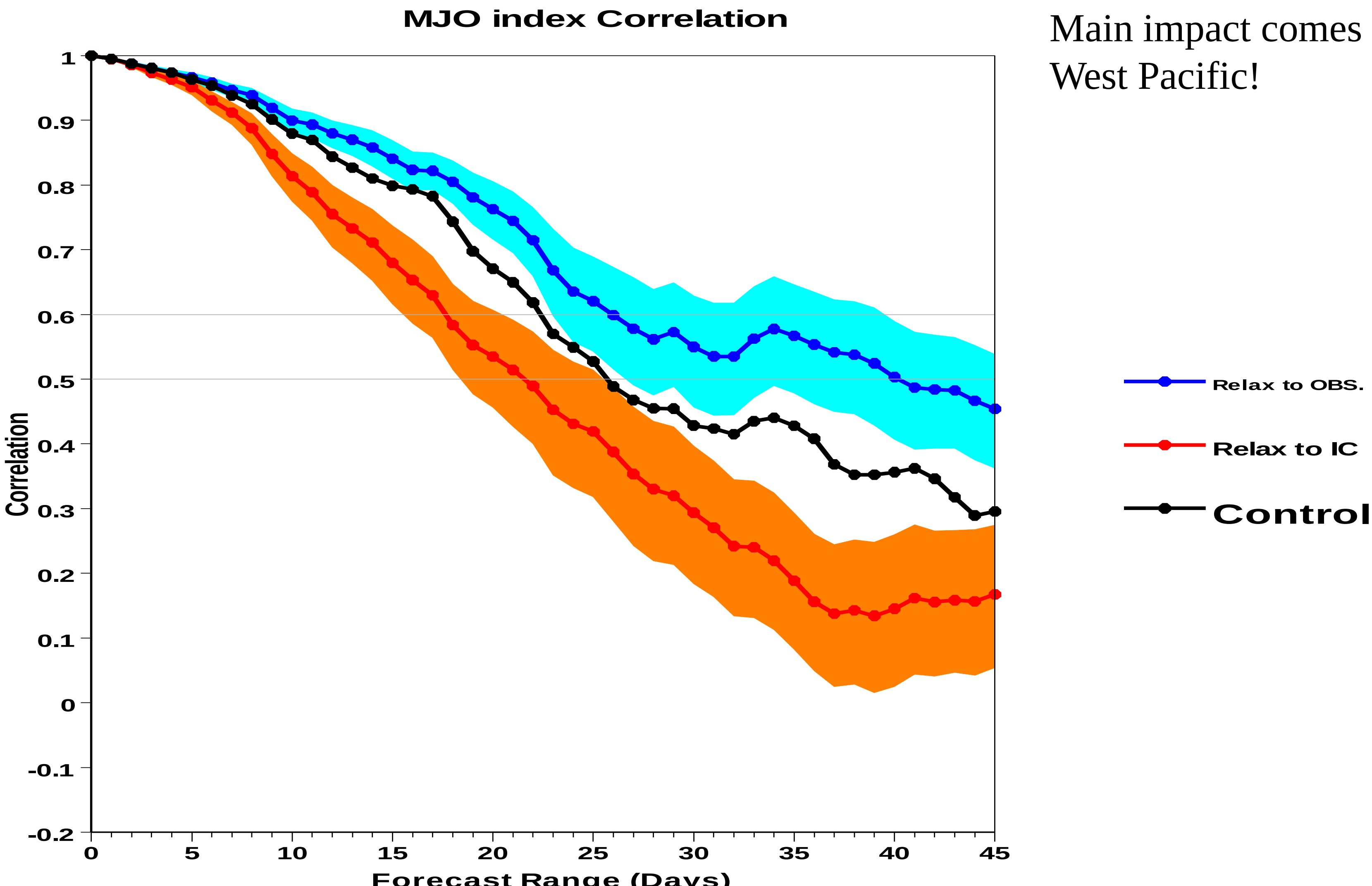


For energy transformations in MJO see also Yanai, Chen, Tung (2000), and Matthews et a. (1999)

Conclusions

- MJO very sensitive to model formulations for PC2 (Indian Ocean) where all processes are of similar importance……. And biggest gain might be achieved
- Mainly convection –dynamics equilibrium for Pacific. Radiation and diurnal cycle important over Maritime Continent -> PC1 (Tibetan plateau heating and aerosols?)
- Model convection/entrainment formulation very reasonable and produces "right" moisture and precipitation sensitivities
- Explain the MJO by energy cycle / correlations by energy generation in upper troposphere
- Further optimal model (parameter) tuning of all physical processes unavoidable (even so or even more for next CRMs) to further improve MJO……… gain expected up to few days…….. What is theoretical gain from perfect extra-Tropics?

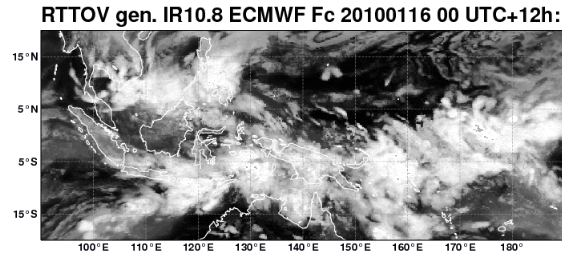
Impact of N. Extratropics on MJO forecast skill

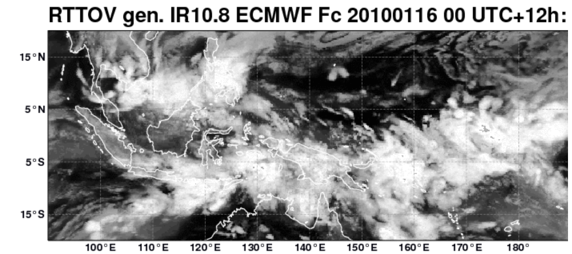


Main impact comes from West Pacific!

Vitart and Jung, GRL 2010

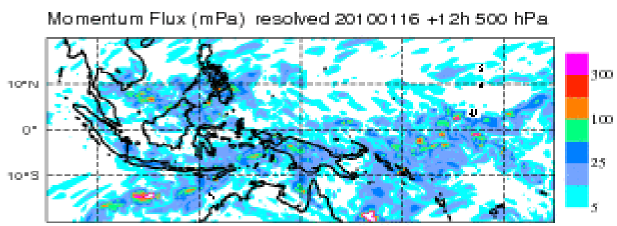
YOTC Momentum fluxes resolved & parametrised

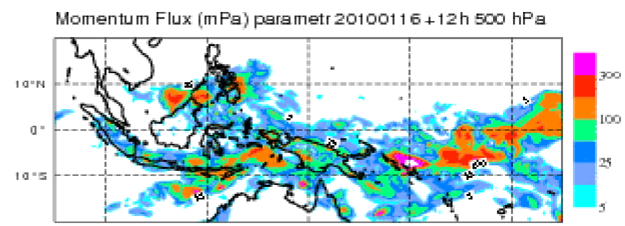




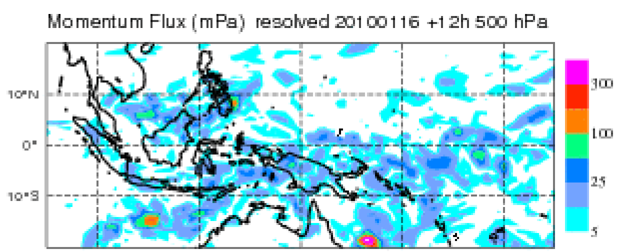
resolved **parametrised**

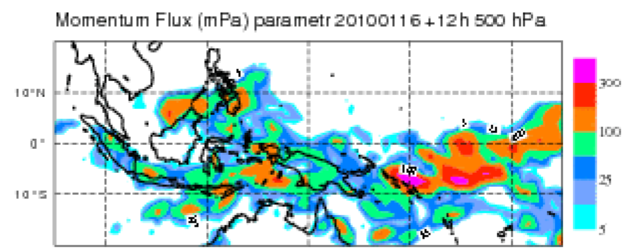
T799





T159





Method: minus time mean state