Influence of Process Interactions on MJO-Like Convective Structures in the IFS model

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Conclusions

One month ago…

Original Talk Plan

- Show strengths & inadequacies of MJO in IFS
- Conduct sensitivities tests to obtain perfect MJO
- Go home happy and have a cup of tea
Outline

ECMWF products:
- 10 day forecasts at T511 L60 resolution
- 6 month seasonal forecasts at T95 L60 resolution (coupled)
- 1 month coupled forecasts

1. MJO in default model
2. Possible Thermodynamic Feedbacks
3. Aqua Planet Sensitivity Tests
Obvious Westward and Eastward propagating modes

Signs of slow eastward propagation of large wave numbers

T511 Operations Year 2003
10 day forecasts “pasted” together
Approach

Problem with T511:
- “Short” forecasts
- Expensive to conduct sensitivity Experiments
- Influenced by initial conditions

Thus this study will use T95 (L60) resolution
- As used by seasonal forecast

A series of 6 month forecasts conducted
- 1962-2000 April and October starts
  - Can examine interannual variability
  - ERA40 period
Convective rainfall Shows similar organisation to T511 operational model
200hPa Velocity Potential
Spectral Power of 200hPa VP as a function of wavenumber

Small Loss of power at wavenumber 1

Solid: ERA40 analysis
Dashed: T95 forecasts
Broken: T511
Dashed: T159
EOF Analysis of T95 and ERA40

High frequencies well reproduced
Low Frequency in main MJO-"band" under represented – Less coherent propagation of signal

Solid:ERA
Dashed: T95

Summer

Winter

MJO Workshop 2003    A.Tompkins and T. Jung
Convective Organisation

Thermodynamic mechanisms have been suggested:

- Cloud-radiation feedback
- Role of SST perturbations (coupling)
- Convective-water vapour feedback
Water Vapour Feedback

- Precipitating convection dries the atmosphere:
- In a Eulerian view, drying is associated with subsidence, while local environment is moistened through convective detrainment
- This local moistening can “precondition” the atmosphere, making it favourable for future convection
How does water vapour favour preconditioning?

Entrainment into Updraughts

Boundary Layer Theta_e

Complication of downdraughts and organisation!
This cloud resolving model integration showed a strong “water vapour” mode. Packets of convection were modulated by the phasing of boundary layer theta_e and free tropospheric moisture structure.
Reminder: The IFS Tiedtke scheme is a bulk mass flux model

Bulk model:
Dry air uniformly mixed into updraught

Episodic model
Emanuel 1991
Raymond and Blyth 92
Some unmixed air always survives

Subcloud layer

Which is closest to a CRM with a 2km horizontal resolution?
Two Examples of Targeted Sensitivity Tests

Boundary Layer
Theta_e

Entrainment into
Updraughts

ENHANCE/INHIBIT
RAINFALL
EVAPORATION

Enhance:
Coverage from 5% to 30%
Double evaporation rate
Increase RH limit from 80% to 100%

ENHANCE
ENTRAINMENT
FACTOR

Enhance:
Entrainment increase by factor of 5
Considerable interannual variability

T95 and ERA40

Interannual variability considerable in standard setup
Use Aqua Planet investigation to allow phase space investigation
Aqua Planet Investigation

To reduce variability: Test in aqua planet mode
Zonally symmetric SSTs, peaking on the equator
Wave-number frequency Spectra – Control Run

Aqua

Land

Projection on EOFs VPOT 1987 5 efrm

Squared Coherency

Phase

Power

95% confidence level

PC1 and 2
Enhanced Rainfall Evaporation

Enhanced Rainfall Evaporation Ratio

Projection on EOFs VPOT 1987 5 efv6

Enhanced
Slow moving mode grows at “MJO” expense

Projection on EOFs VPOT 1987 5 efrm

Control
Convective systems do not appear altered
5 x Entrainment

Ratio

Projection on EOFs VPOT 1987 5 efw

More power in k=1, 17m/s mode

Ratio

Projection on EOFs VPOT 1987 5 efm

Control
Effect on LSP/CP balance

Control

5 x Entrainment

Convective precipitation (mm d⁻¹)
Region: -7.5/7.5°
enr: 19870501

Time (days)
0 90 180 270 360
Longitude (degrees)

Time (days)
0 90 180 270 360
Longitude (degrees)
19870501 1200 step 3000 [10.0,-180.0,-10.0,180.0] saturation over water, expver efrm

Expected effect in “Cloud Resolving Model” world

5 x entrainment

In fact remarkably little effect
So is the change in “MJO-“MJO-like” peak power associated with the gridscale/convective-scale latent heating balance?
Increasing Large-scale activity increases MJO-like peak power ($K=1,2,3\ 15\text{days}<p<120\text{days}$)

Aqua Planet Runs

Increasing gridscale activity

Increasing "MJO-like" mode

Normalized Peak MJO Power (200hPa VP)

Grid/Convective Scale Rain Ratio
This is not to say water vapour does not have an influence.
Large-Scale Latent Heating, and the ENB Paradigm

- Unlike ENB model, gross moist stability for large scales not always positive in IFS
- A significant proportion of the large-scale rainfall is *not* associated with the stratiform mode
- Rather it is expressed in gridscale convective motions
- Moreover the cloud scheme permits negative effective moist stability to occur before the gridpoint attains saturation
Latent heating (from cloud scheme) directly in phase with upward motion by construction. Changes in cloud scheme have large influence on incidence of grid-scale convection.
The convection parameterization is not so constrained, and responds to \textit{PBL theta}_e, CAPE, (humidity). Can provide heating out of phase, possibly damping the wave.
T95 Default
Strong positive positive precipitation anomaly coinciding with with upward motion

Perturbation for convective precipitation much smaller
T159 Default
Large-scale precipitation anomaly coinciding with with upward motion

No convective signal
However, strongest precipitation appears to be associated with advection of low level humidity anomalies.
Conclusions I

- The MJO-like eastward propagating signal in the ECMWF appears to be independent of resolution and coupling:
  - T95, T159, T255, T95-coupled, T511
  - T159 and higher resolutions show weaker signal

- The phase speed is approx. 20 m/s, peak at wavenumber 1

- In these faster phase speeds (>20 m/s) models produce interannual variability well
Conclusions II

- Sensitivity tests showed little evidence of “water vapour-convection” feedback mode in the model.
- Is there a fundamental physical process missing from the model?
- The 20 m/s mode appears to be a consequence of coupling between large-scale dynamics and GRIDSCALE latent heating.
  - The convective parameterization scheme damps this mode.
  - But does not affect the propagation velocity.
- What should the LSP/CP balance be?

Stolen from Kenneth Sperber.
Previous “old” (25r1) model cycle produced slow water vapour mode: Role of shallow convection?
EOF Analysis of T95 and ERA40

First two (independent) EOFs in quadrature signifying propagating signal at wavenumber 1.