MJO-LIKE SYSTEMS AND MOISTURE-CONVECTION FEEDBACK IN IDEALIZED AQUAPLANET SIMULATIONS

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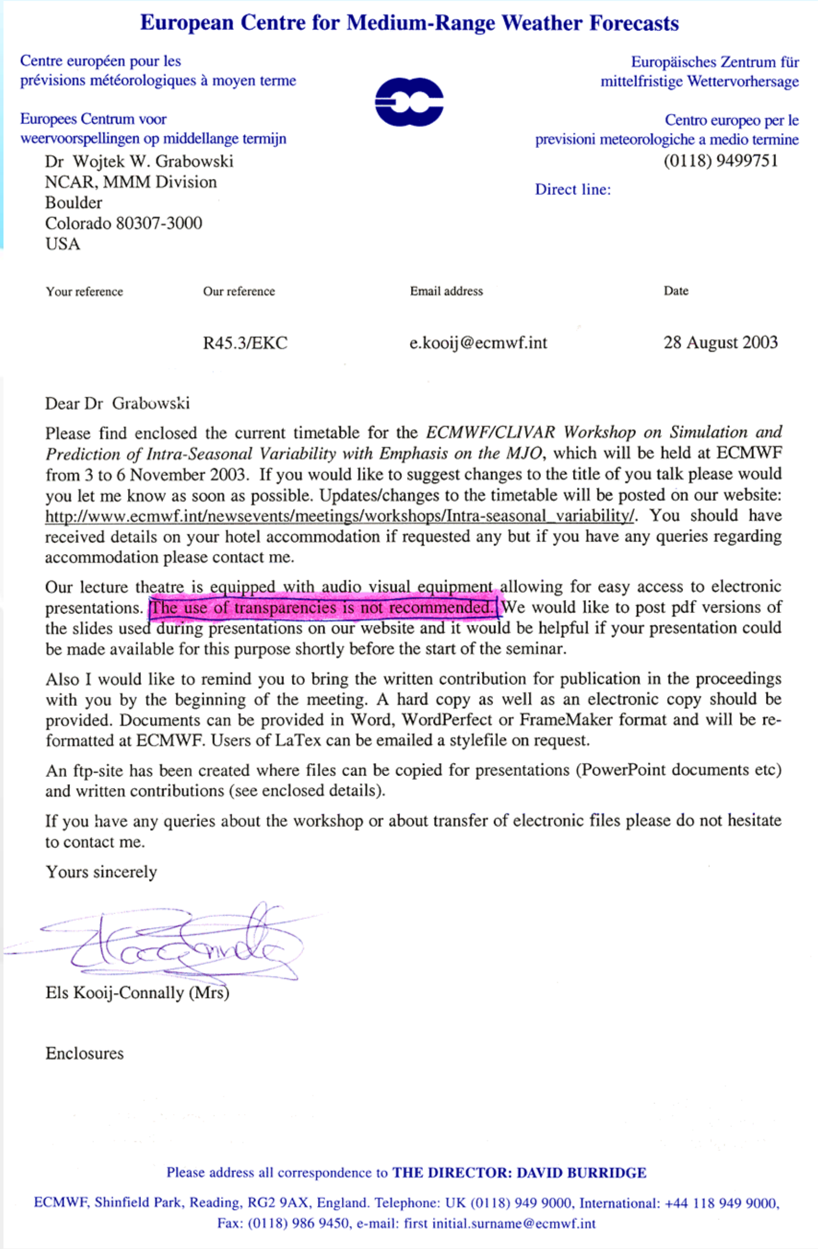

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Your reference	Our reference	Email address	Date
	R45.3/EKC	e.kooij@ecmwf.int	28 August 2003

Dear Dr Grabowski

Please find enclosed the current timetable for the *ECMWF/CLIVAR Workshop on Simulation and Prediction of Intra-Seasonal Variability with Emphasis on the MJO*, which will be held at ECMWF from 3 to 6 November 2003. If you would like to suggest changes to the title of you talk please would you let me know as soon as possible. Updates/changes to the timetable will be posted on our website: http://www.ecmwf.int/newsevents/meetings/workshops/Intra-seasonal_variability/. You should have received details on your hotel accommodation if requested any but if you have any queries regarding accommodation please contact me.

Our lecture theatre is equipped with audio visual equipment allowing for easy access to electronic presentations. The use of transparencies is not recommended. We would like to post pdf versions of the slides used during presentations on our website and it would be helpful if your presentation could be made available for this purpose shortly before the start of the seminar.

Also I would like to remind you to bring the written contribution for publication in the proceedings with you by the beginning of the meeting. A hard copy as well as an electronic copy should be provided. Documents can be provided in Word, WordPerfect or FrameMaker format and will be re-formatted at ECMWF. Users of LaTex can be emailed a stylefile on request.

An ftp-site has been created where files can be copied for presentations (PowerPoint documents etc) and written contributions (see enclosed details).

If you have any queries about the workshop or about transfer of electronic files please do not hesitate to contact me.

Yours sincerely

Els Kooij-Connally (Mrs)

Enclosures

Please address all correspondence to **THE DIRECTOR: DAVID BURRIDGE**

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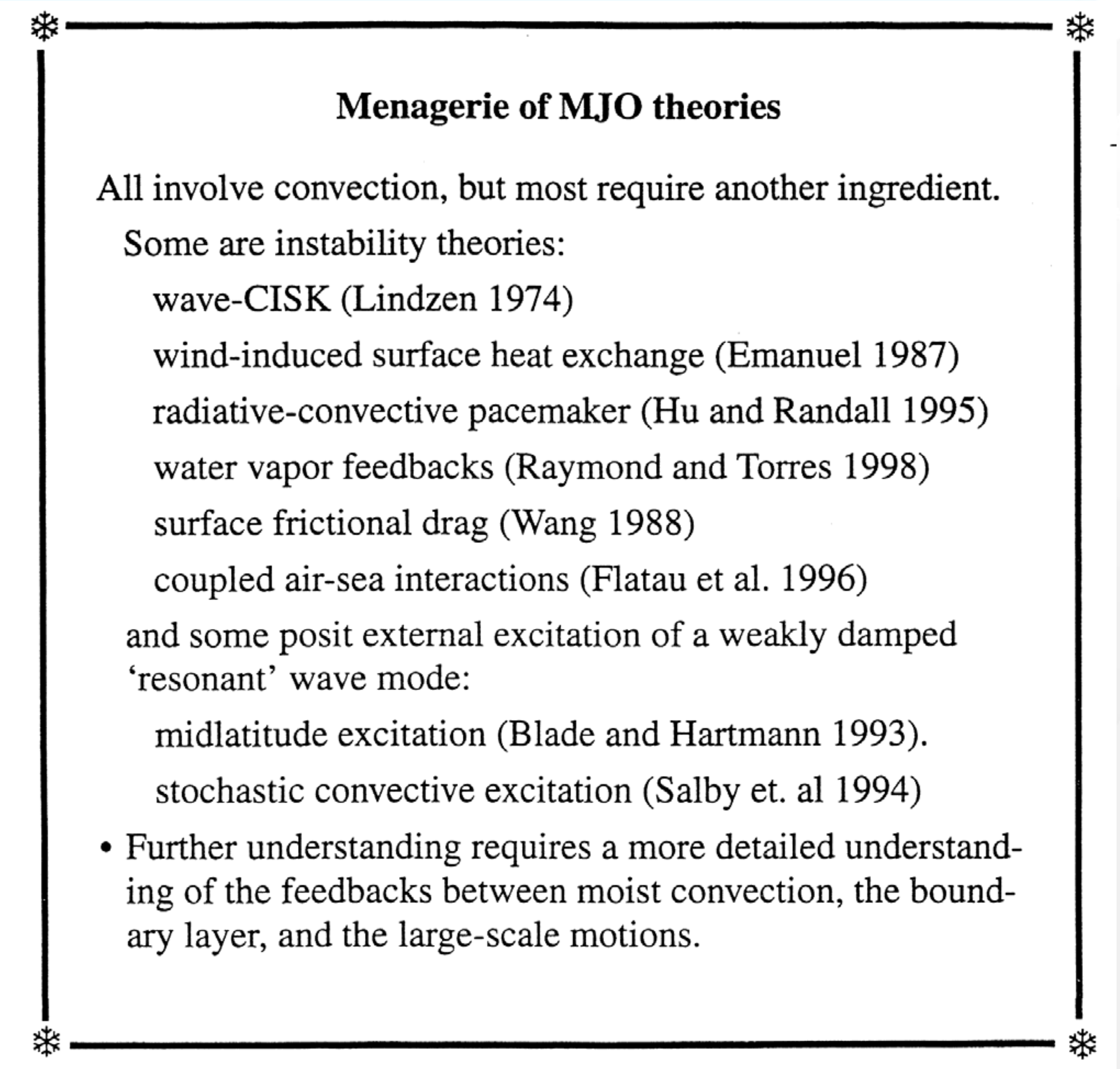


Menagerie of MJO theories

All involve convection, but most require another ingredient.

Some are instability theories:

- wave-CISK (Lindzen 1974)
- wind-induced surface heat exchange (Emanuel 1987)
- radiative-convective pacemaker (Hu and Randall 1995)
- water vapor feedbacks (Raymond and Torres 1998)
- surface frictional drag (Wang 1988)
- coupled air-sea interactions (Flatau et al. 1996)

and some posit external excitation of a weakly damped 'resonant' wave mode:

- midlatitude excitation (Blade and Hartmann 1993).
- stochastic convective excitation (Salby et. al 1994)

- Further understanding requires a more detailed understanding of the feedbacks between moist convection, the boundary layer, and the large-scale motions.

Cloud-Resolving Convection Parameterization (CRCP) “super-parameterization” multi-scale modeling framework

Grabowski and Smolarkiewicz, *Physica D* 1999
Grabowski, *J. Atmos. Sci*. 2001
Khairoutdinov and Randall, *Geophys. Res. Lett.* 2001
Grabowski, *Int. J. Numer. Methods in Fluids* 2002
Grabowski, *J. Atmos. Sci*. 2003
Grabowski, *J. Climate* 2003
Randall et al. *BAMS* 2003

The idea is to represent subgrid scales of the 3D large-scale model (with horizontal resolution of 100s km) *by embedding 2D periodic-domain cloud-resolving model* (with horizontal resolution of ~1 km) *in each column of the large-scale model*

Convective-radiative equilibrium on a rotating constant-SST aquaplanet

(Sumi 1992)

EULAS: Eulerian/semi-Lagrangian anelastic
nonhydrostatic fluid flow model in spherical geometry
(Smolarkiewicz et al. 2001)

EULAS SETUP:

- size and rotation: same as Earth's
- SST=303 K everywhere
- atmosphere at rest at $t = 0$
- radiative cooling: 1.5 K/day below 15 km *OR*
- radiation transfer model (inside CRCP domains)
- $(NX_E \times NY_E \times NZ_E) \equiv (32 \times 16 \times 51)$
- $(NX_E \times NY_E \times NZ_E) \equiv (48 \times 32 \times 51)$
- time step of 12 minutes

CRCP SETUP:

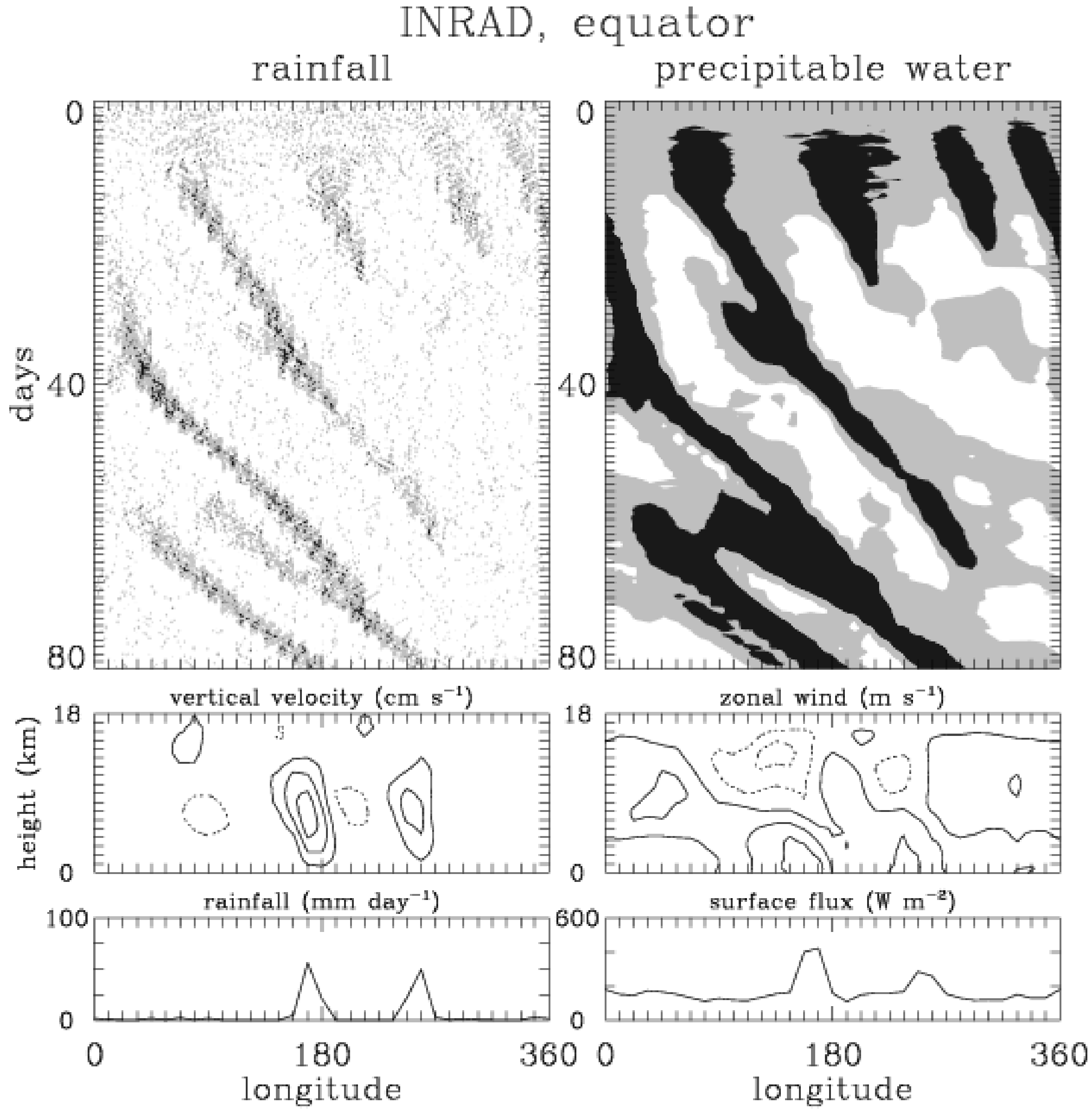
- all CRCP 2D models aligned zonally (E-W)
- role of convective momentum transport: all CRCP 2D models aligned meridionally (N-S)
- role of surface drag: all CRCP 2D models aligned along *local* low-level wind (changes among EULAS columns and in time)
- each CRCP model: $(NX_C \times NZ_C) \equiv (101 \times 51)$
- $\Delta x = 2$ km, time step of 0.5 min

MODEL START-UP:

1. Run a single 2D CRM into convective-radiative equilibrium with prescribed radiative cooling and no mean flow (takes about 2 months).

2. Apply convective-radiative equilibrium solution to each CRM of the CRCP and the mean profiles to each column of EULAS.

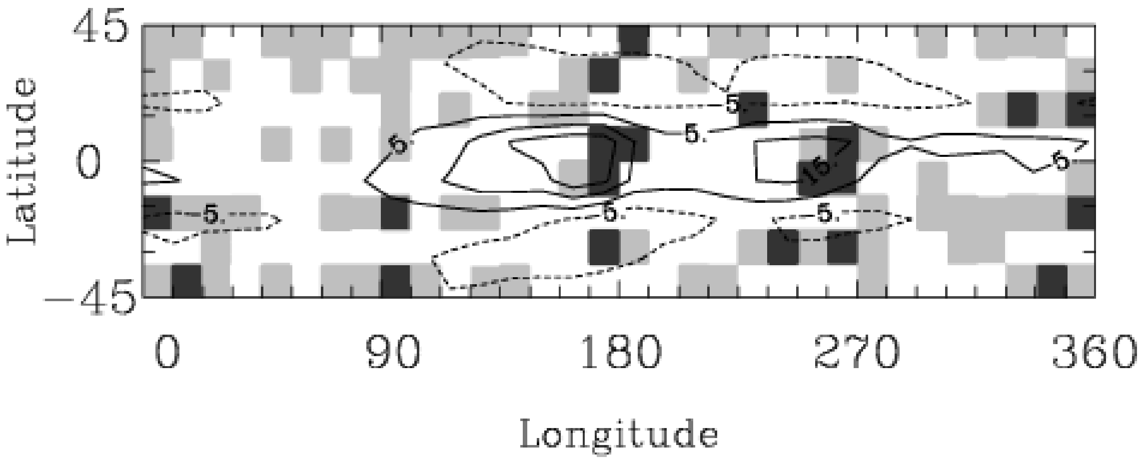
3. Let the model run and observe development of the large-scale flow.

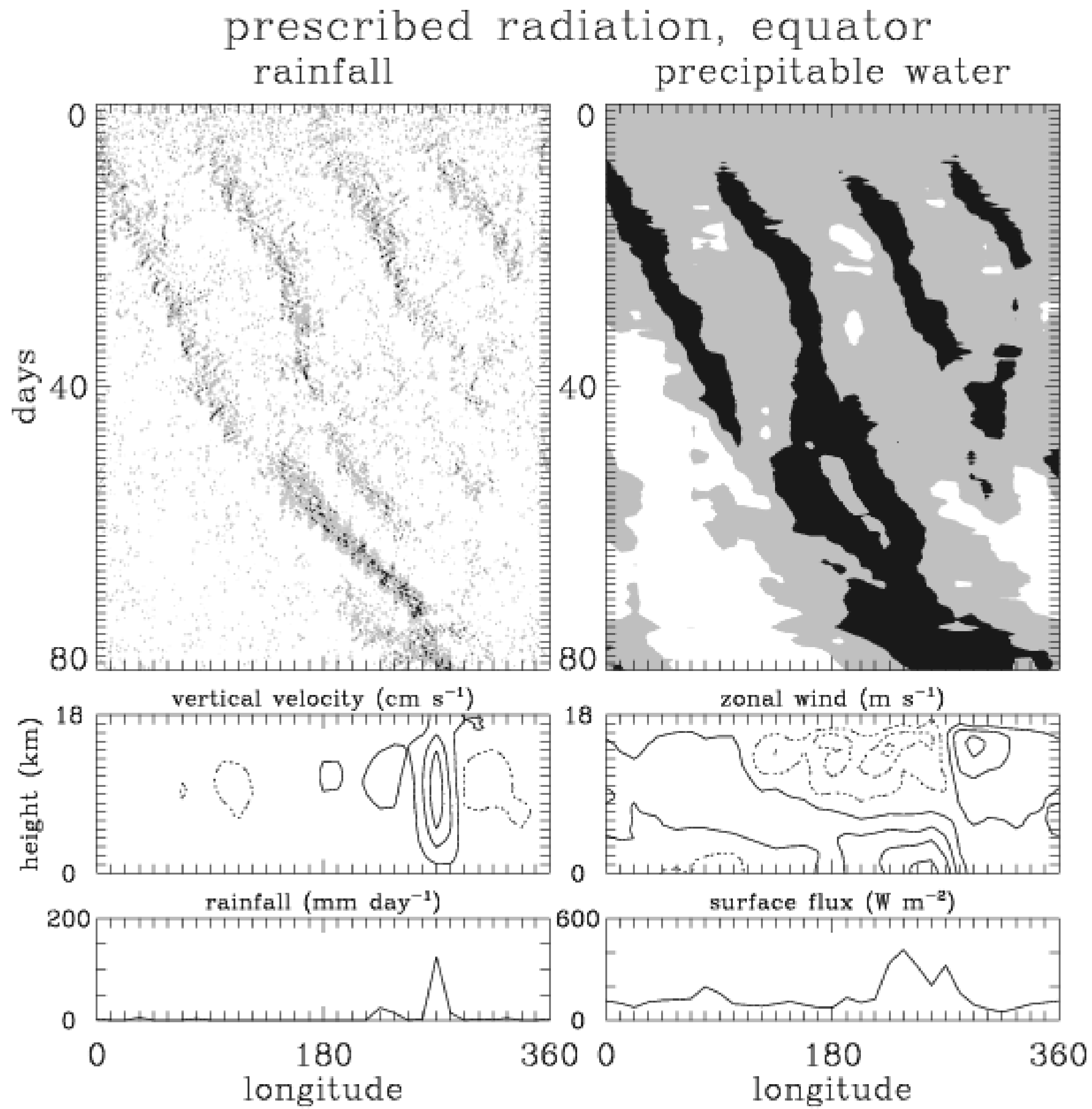

INRAD, equator
rainfall
precipitable water
days
0
40
80
vertical velocity (cm s⁻¹)
zonal wind (m s⁻¹)
height (km)
18
0
rainfall (mm day⁻¹)
surface flux (W m⁻²)
100
600
0
180
360
longitude

day 80.00

Surface zonal flow

Surface precipitation (1.5, 15 mm day^{-1})





prescribed radiation, equator

rainfall

precipitable water

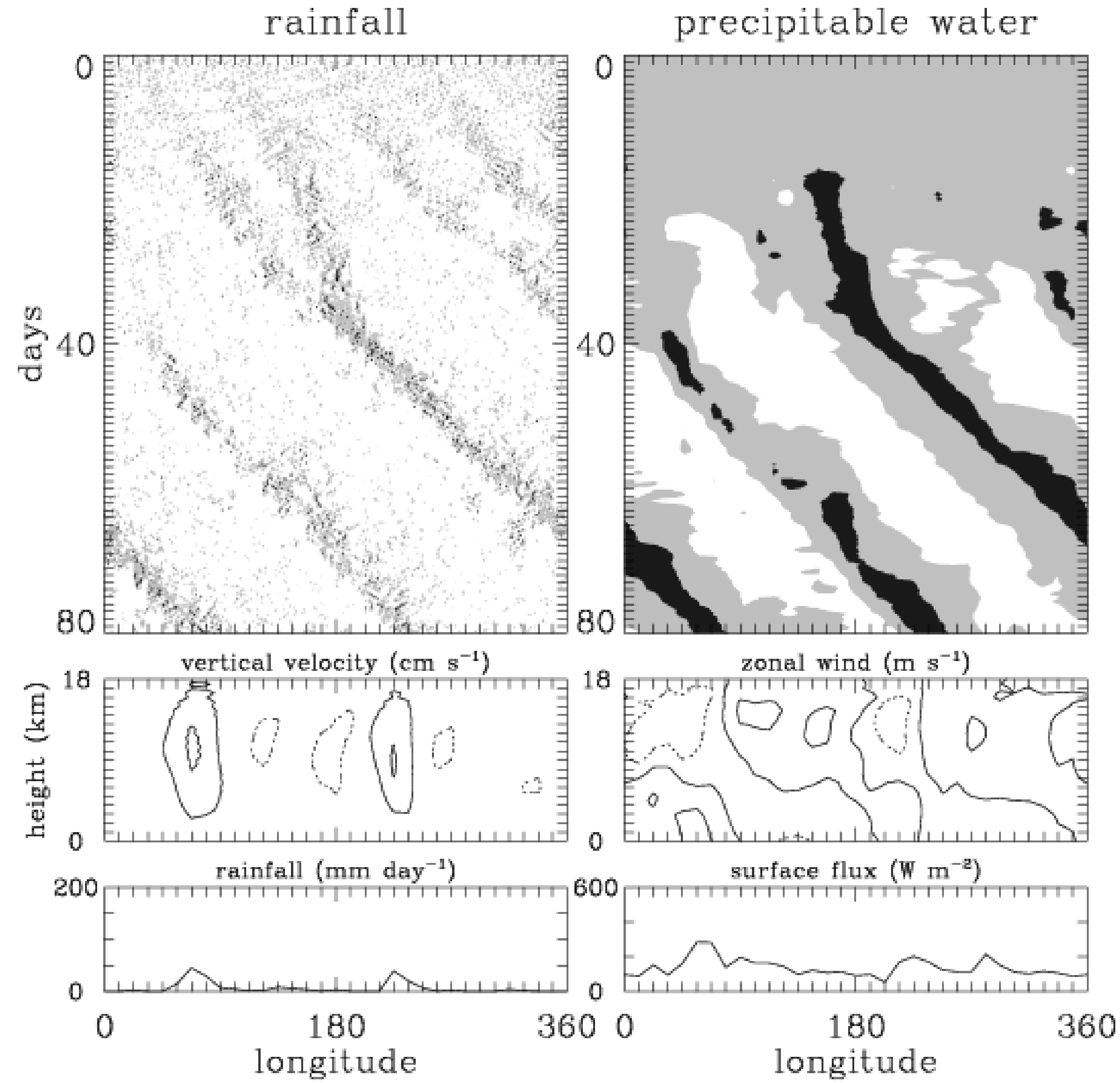
vertical velocity (cm s^{-1})

zonal wind (m s^{-1})

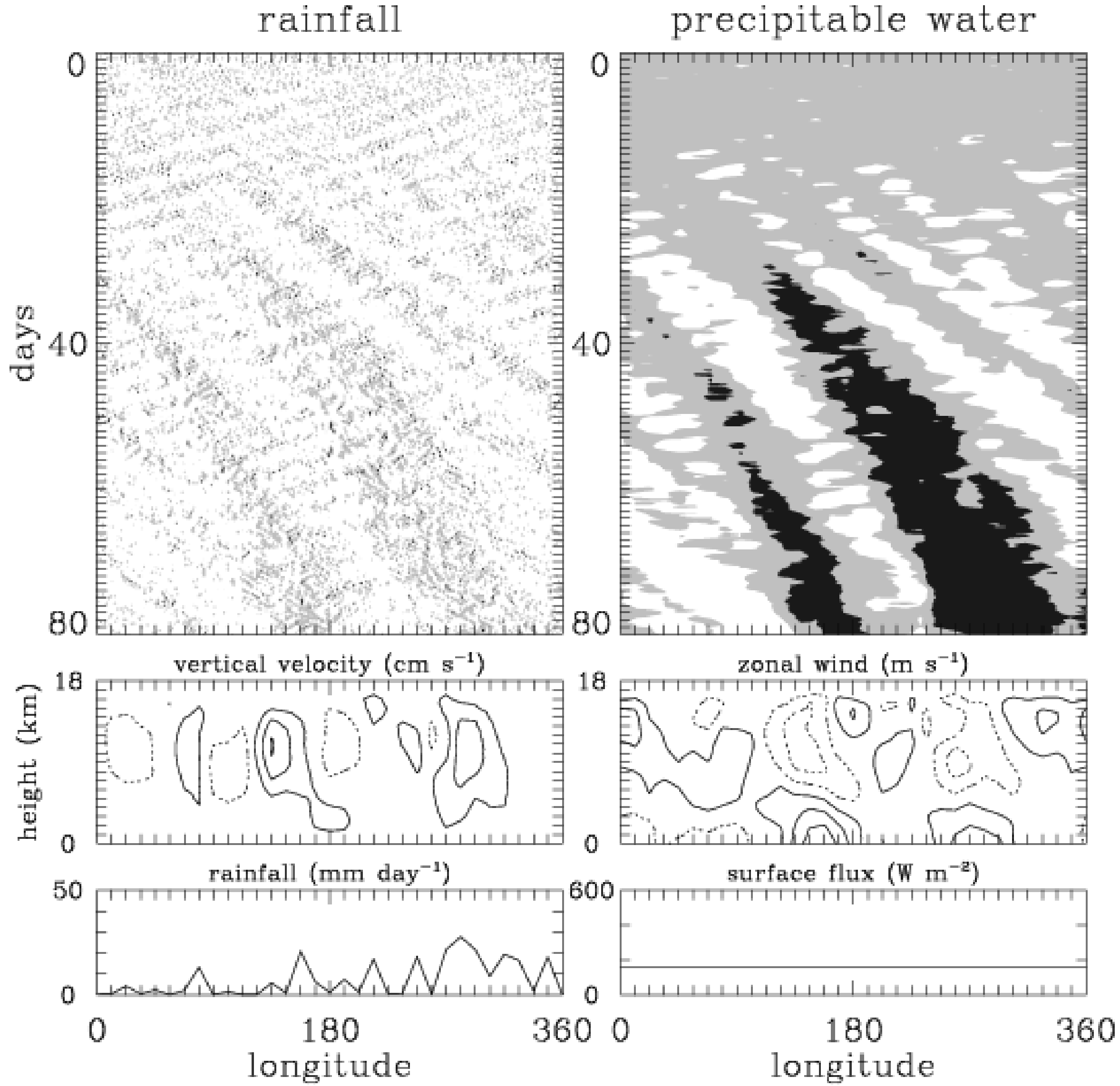
rainfall (mm day^{-1})

surface flux (W m^{-2})

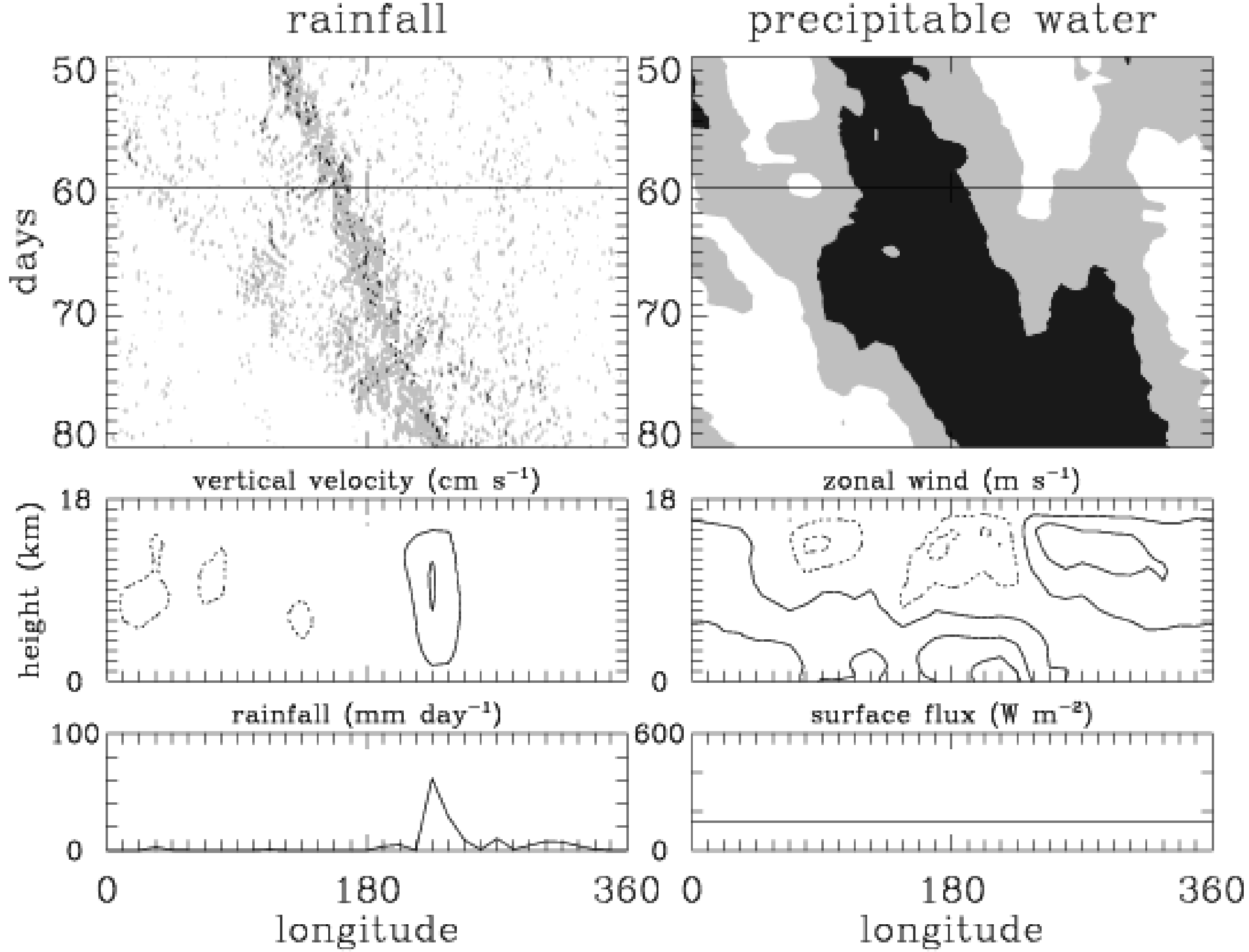
NS alignment, equator

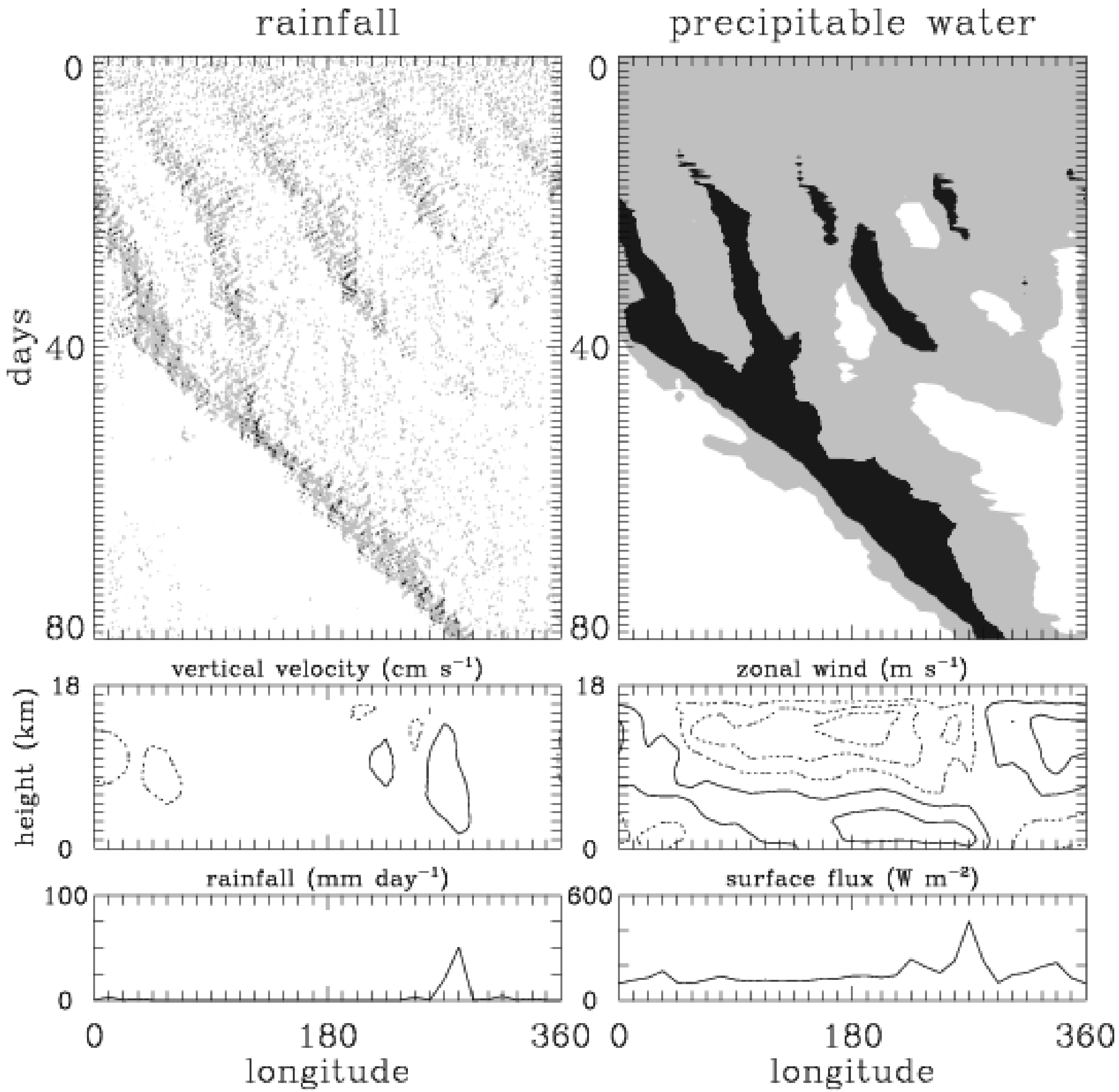


CONFL, equator



R–CONFL, equator





with surface friction, equator

rainfall

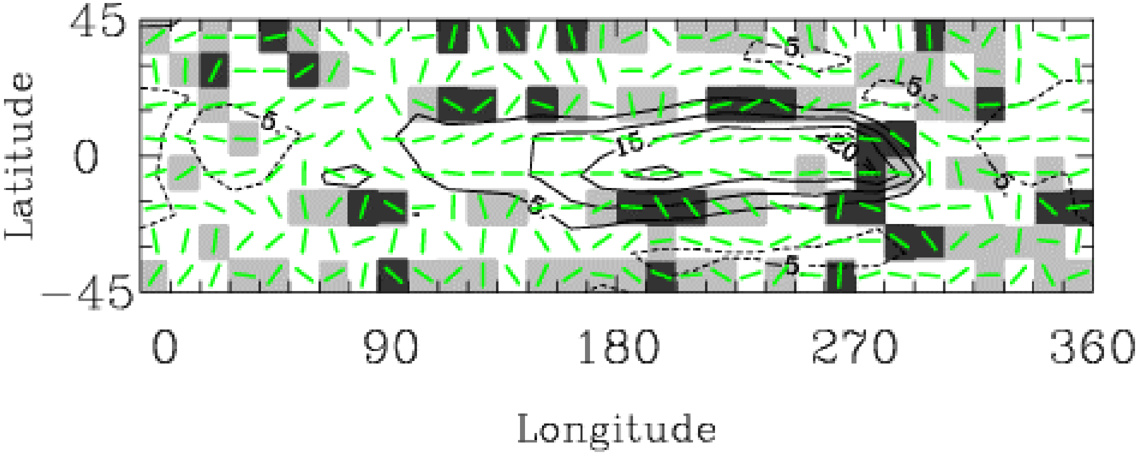
precipitable water

vertical velocity (cm s^{-1})

zonal wind (m s^{-1})

rainfall (mm day^{-1})

surface flux (W m^{-2})



day 80.00

Zonal flow at 2 km

Surface precipitation (1.5, 15 mm day^{-1})

Simulations with suppressed convection-moisture feedback

$$\left(\frac{\partial q_v}{\partial t}\right)_{rlx} = \frac{q_v - \langle q_v \rangle}{\tau}$$

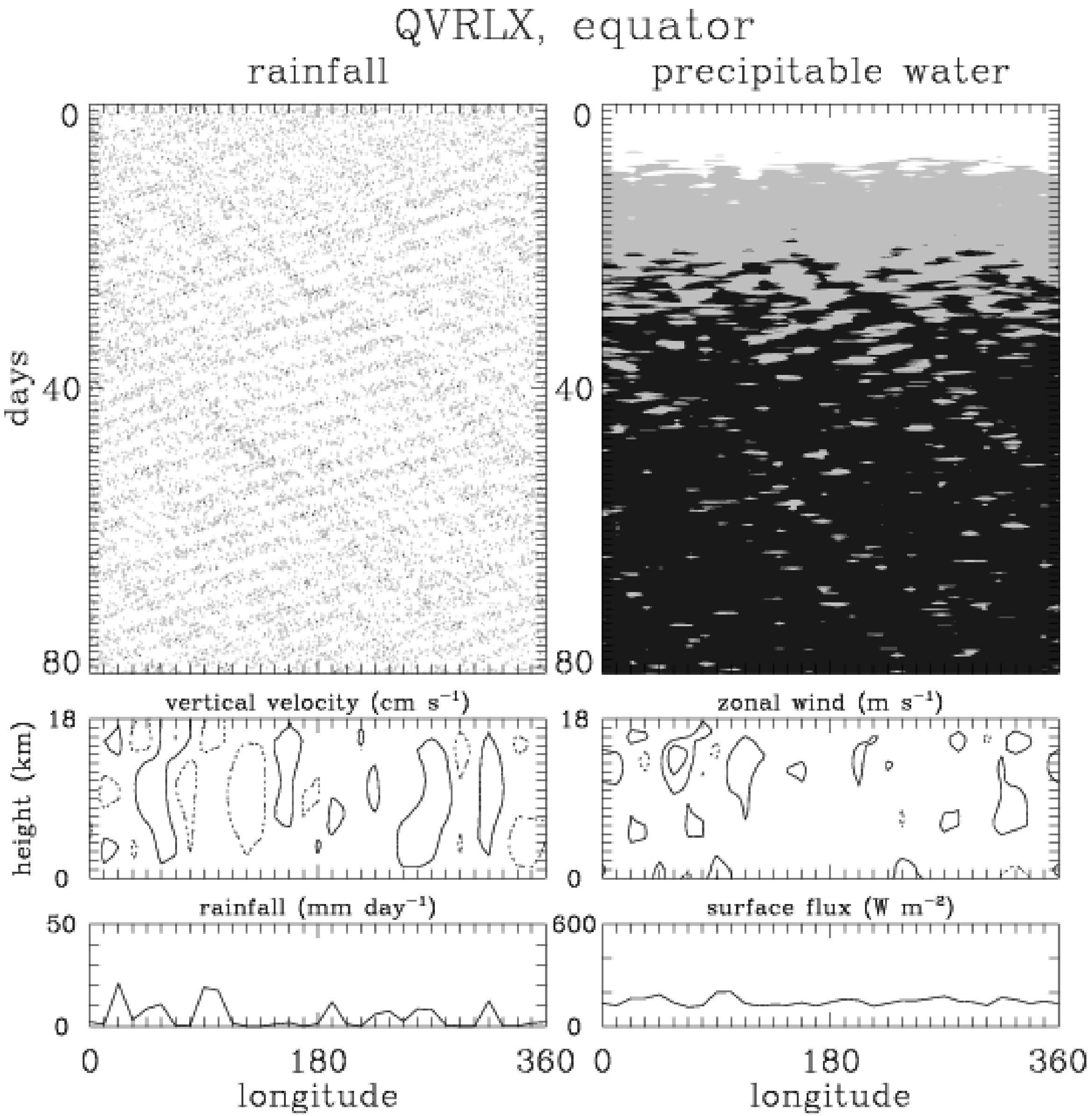
applied in the global model above 2 km

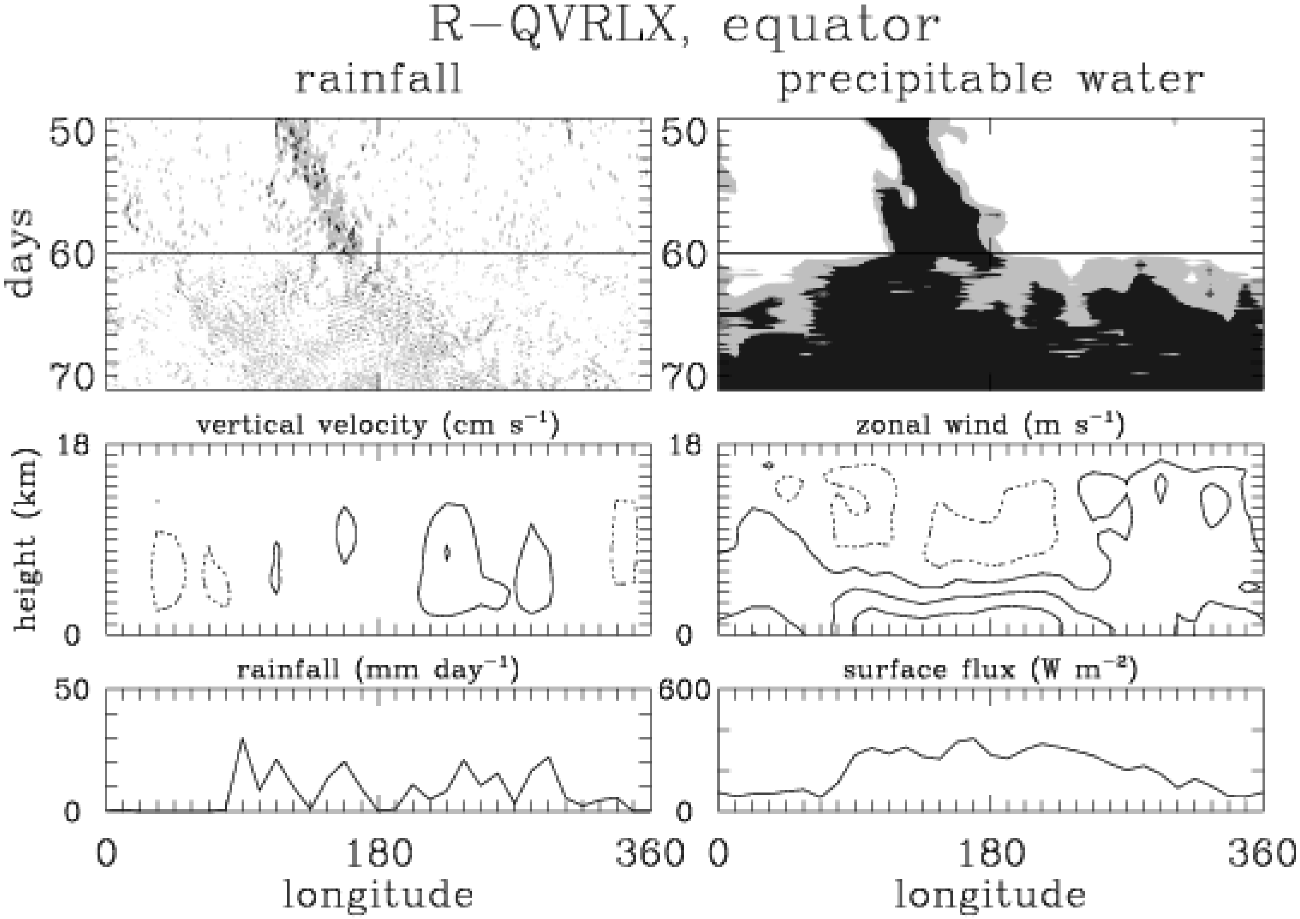
♏ ♐ - global average at a given level

τ - relaxation time scale (1-3 hrs)

Two simulations:

- QVRLX - start from t=0, run for 80 days
- R-QVRLX - start from day 60 of a simulation with a strong MJO-like structure


QVRLX, equator
rainfall
precipitable water
days
0
40
80
0
40
80
vertical velocity (cm s⁻¹)
zonal wind (m s⁻¹)
height (km)
18
0
18
0
rainfall (mm day⁻¹)
surface flux (W m⁻²)
50
0
600
0
0
180
360
longitude
0
180
360
longitude


R–QVRLX, equator
rainfall
precipitable water
days
50
60
70
vertical velocity (cm s⁻¹)
zonal wind (m s⁻¹)
height (km)
18
0
rainfall (mm day⁻¹)
surface flux (W m⁻²)
50
600
0
180
360
longitude

temporal (T_{mcf}) and spatial (L_{mcf}) scales at which *moisture-convection feedback* can operate efficiently:

$$\frac{1}{T_{mcf}} \sim \frac{1}{RH}\frac{d\,RH}{dt} \sim \frac{1}{q_v} w \frac{\partial q_v}{\partial z}$$

in convective-radiative quasi-equilibrium:

$$w \approx \frac{Q_R}{\Gamma}; \quad \Gamma = \frac{\partial \theta}{\partial z}; \qquad Q_R$$ - radiative cooling

$$q_v \sim q_{vs} \sim exp\left(-\frac{L}{R_v T}\right)$$

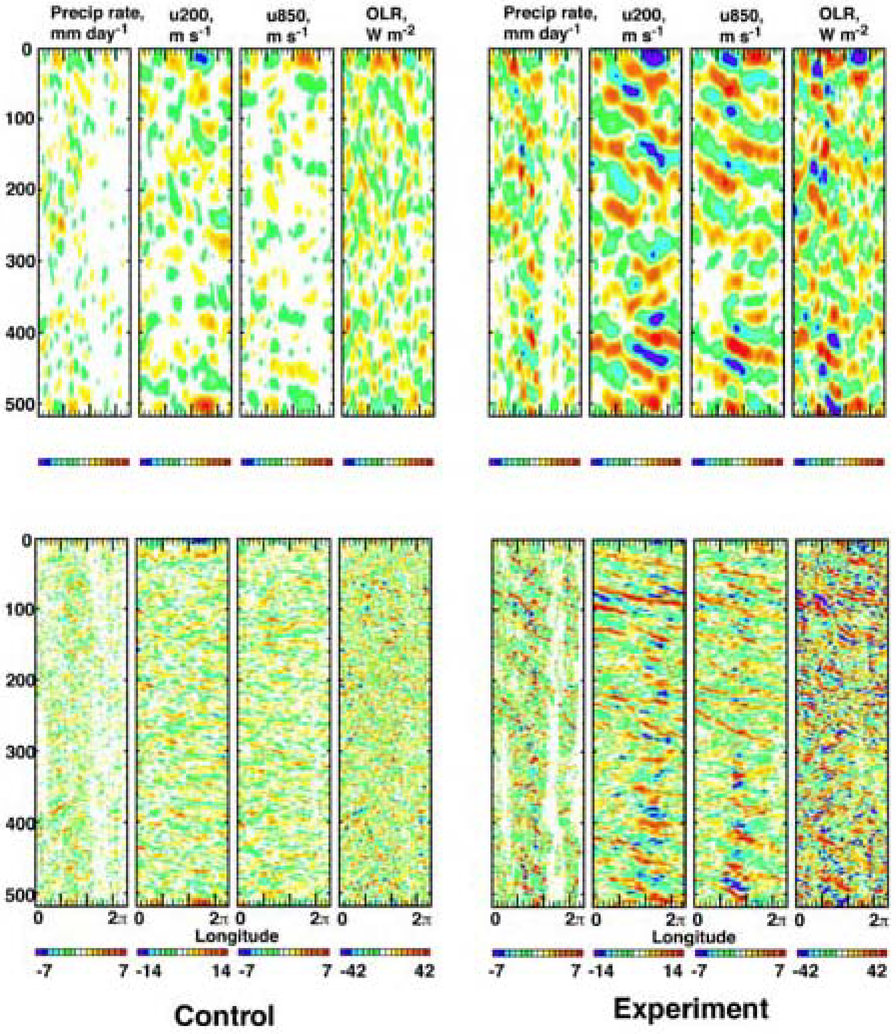
$$\frac{1}{q_v}\frac{\partial q_v}{\partial z} = \frac{L}{R_v T^2}\frac{\partial T}{\partial z}$$

for $Q_R = 1 \text{ K/day}, \ \frac{\partial T}{\partial z} = 6 \text{ K/km}, \ T = 250 \text{ K}$:

$$T_{mcf} \sim 10 \text{ days}$$

for $U = 5 \text{ m/s}$:

$$L_{mcf} \sim UT_{mcf} \sim 5{,}000 \text{ km}$$



20 - 100

Days

2 – 20

Days

Figure 13: Hovmuller diagrams for the precipitation rate, 200 mb zonal wind, 850 mb zonal wind, and outgoing longwave radiation (OLR) in a control run with the T21 CAM, and in an experiment with the same model modified to use the super-parameterization. In the top two panels, the results are filtered to show variability with periods in the range 20 to 100 days. The bottom two panels show variability in the range 2 to 20 days.

Randall et al.
BAMS 2003

Conclusions

- All physical processes/mechanisms considered in this study (radiative transfer, interactive surface temperature and moisture fluxes, convective momentum transport, surface friction) have some impact on MJO-like coherent structures simulated on the constant-SST aquaplanet using the super-parameterization, but neither seem essential for their development and maintenance.

- Interactions between large-scale free-troposheric humidity and deep convection, the moisture-convection feedback, is essential for both the development and the maintenance of MJO-like coherent structures.

Conclusions cont.

- The moisture-convection feedback operates efficiently on intraseasonal time scales and it involves cloud dynamics (i.e., convective clouds loosing their buoyancy more rapidly when environmental humidity is low), evaporation of precipitation before reaching the ground (i.e., less convective heating in dry environment), and radiative transfer (i.e., dry cloud-free areas experiencing stronger radiative cooling).
- Traditional convective parameterizations are typically weakly sensitive to free-tropospheric humidity. Does this explain why traditional models struggle with MJO? Results from NCAR's CAM with super-parameterization (cf. Randall et al. BAMS 2003, Khairoutdinov et al. submitted to JAS) support such a conjecture.