Moist Thermodynamics of Madden Julian Oscillation in a Cloud Resolving Regional Model

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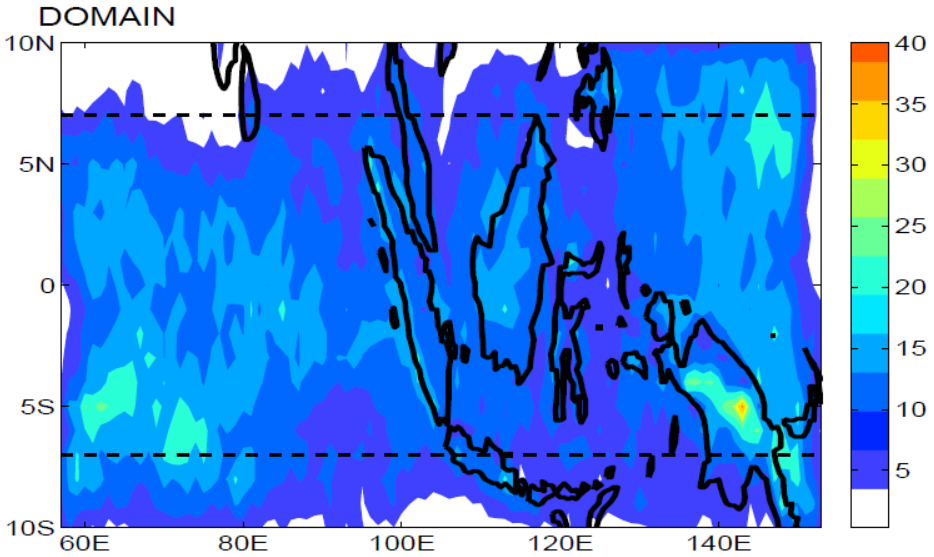
Objectives

Using a high resolution regional model simulation that captures the main features of the Oscillation, we aim to identify the moist-thermodynamic processes;

- responsible for its observed time-scales and,
- that supply the energy for its propagation.

Model and Experiment

- WRF V3.1 at 4km resolution. GFS forecast data is used for lateral, initial, and surface boundary conditions.
- The RRTM, YSU and WSM-3 schemes are used to parameterize radiation, PBL and microphysics respectively.
- No cumulus parameterization.



Mean precipitation ($mmday^{-1}$) for the period of the simulations. 01 Oct 2007 to 31 Jan 2008.

The subsequent figures depict averages over 7°S to 7°N.

Computer Time: 0.13 Million processor hours (not very cheap).

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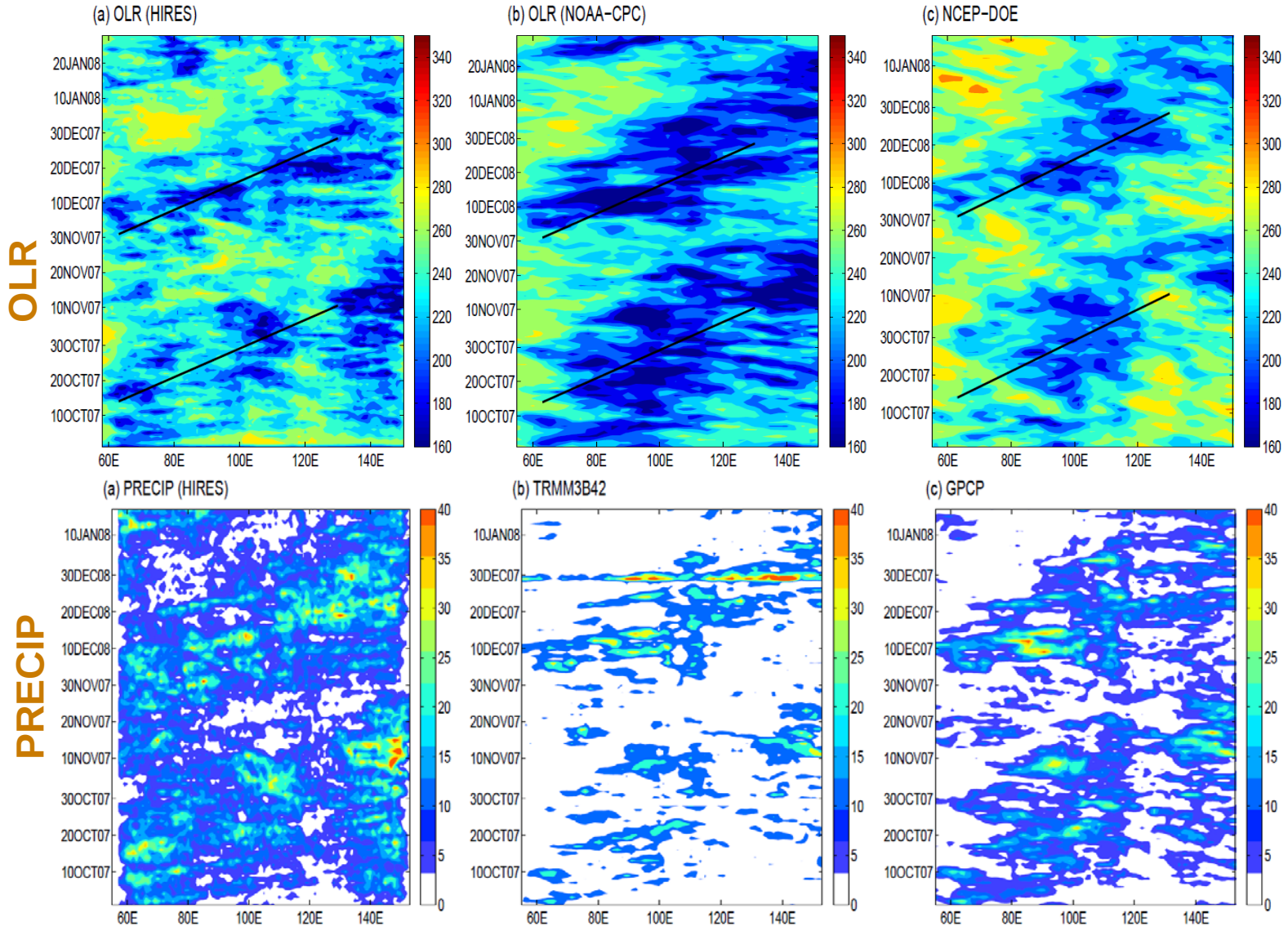

The OLR (Wm^{-2}) and precipitation ($mmday^{-1}$) signals . The lines mark propagation speed of 5 m/s.

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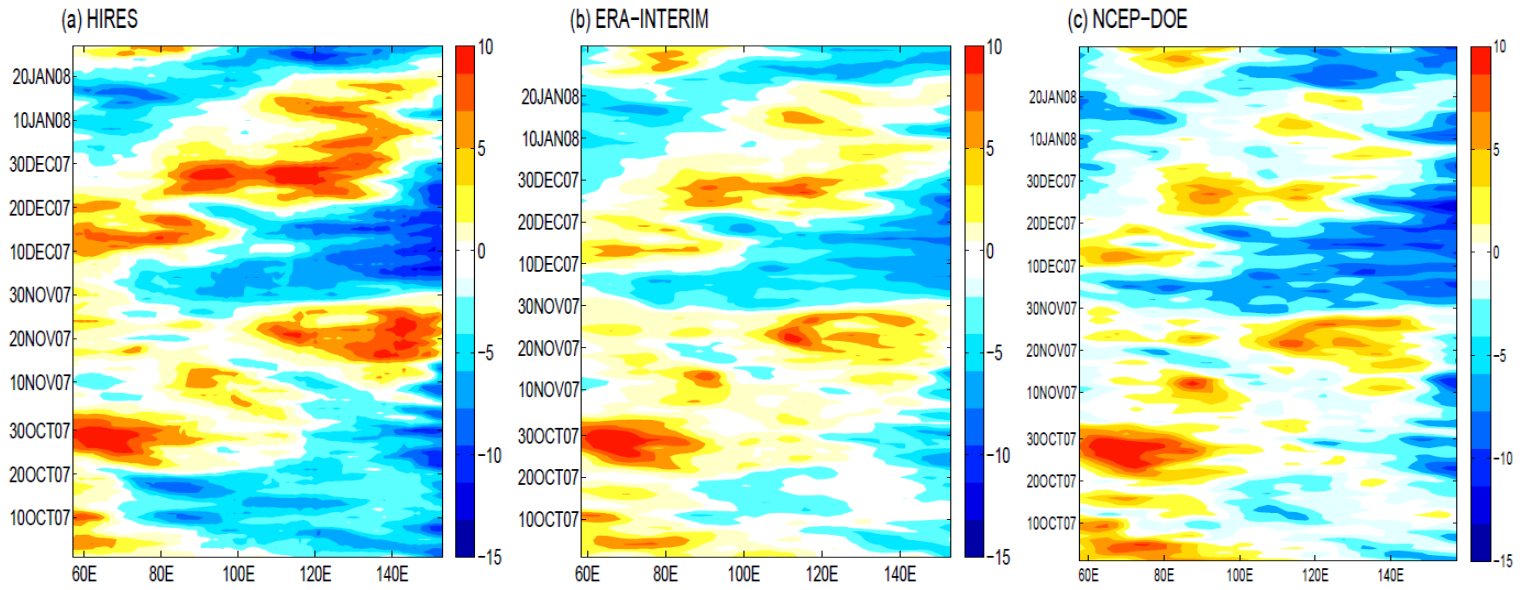
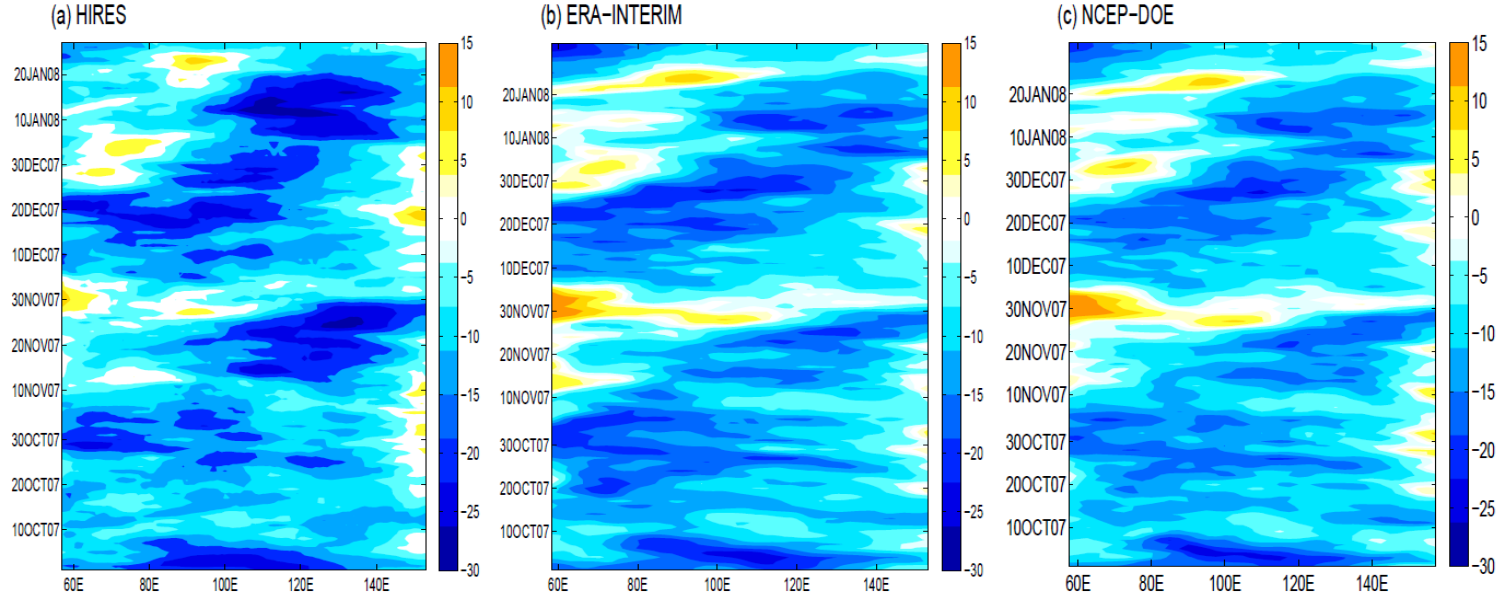
850 hPa



200 hPa



Zonal wind at 850 hPa and 200 hPa (ms^{-1}) from the high resolution experiment , ERA-Interim and NCEP-DOE reanalysis .

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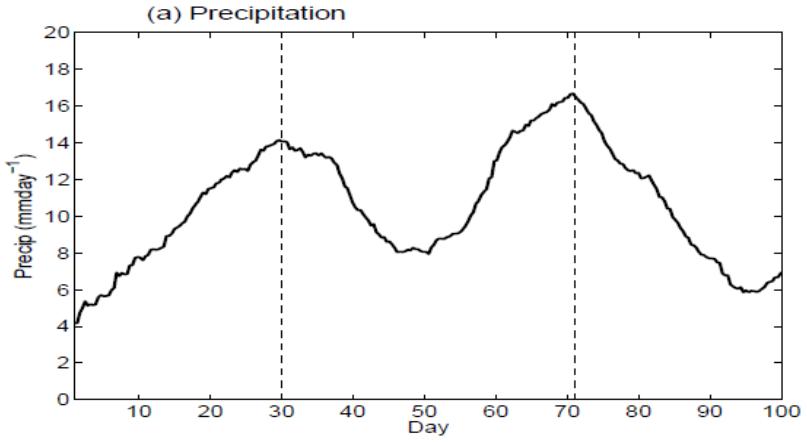

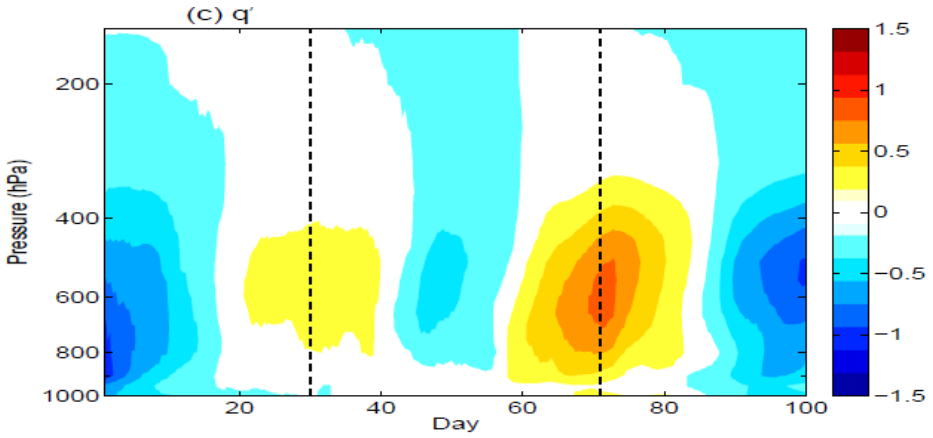

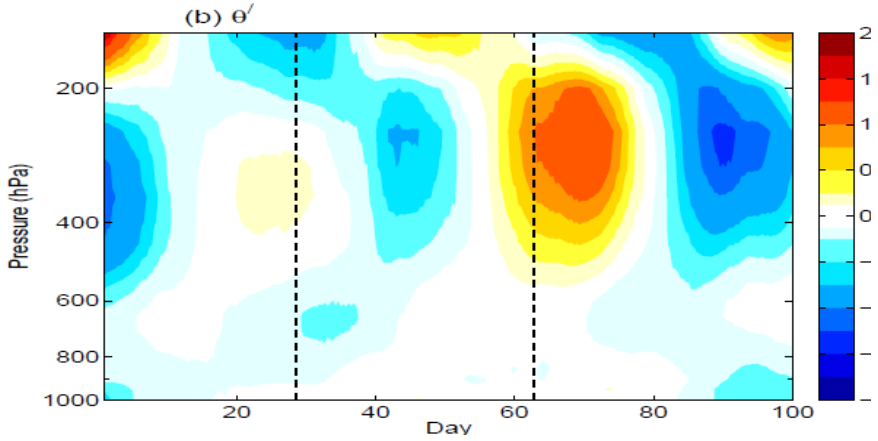

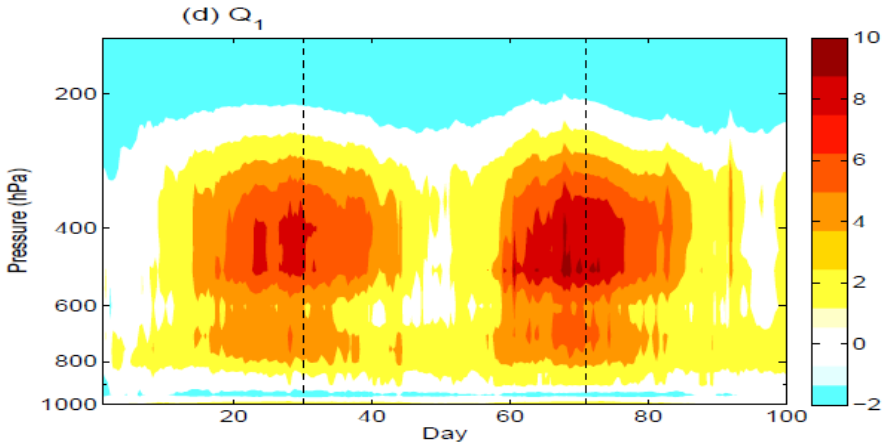

Composites of precipitation (mmday^{-1}) , potential temperature anomaly (K), moisture anomaly (gkg^{-1}) and total diabatic heating (Kday^{-1}) for the two MJO episodes about a point that propagates at 5ms^{-1} . The anomalies are with respect to the four month mean and are smoothed by 12 day running mean .

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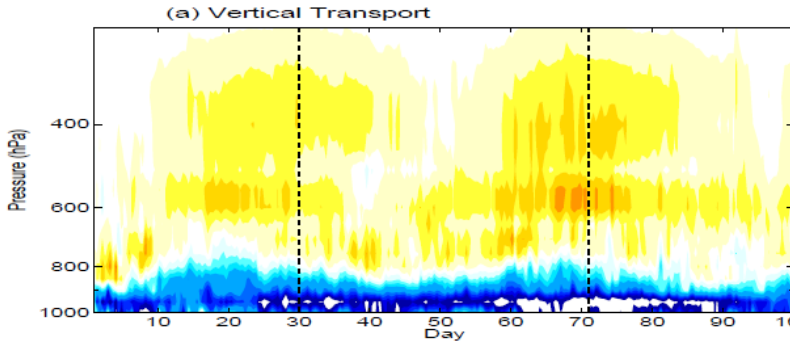
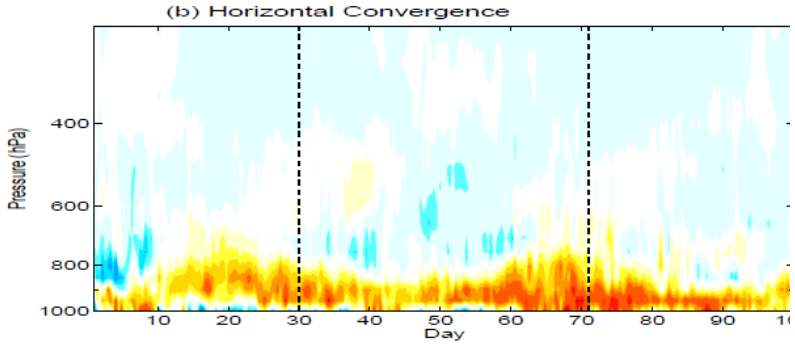
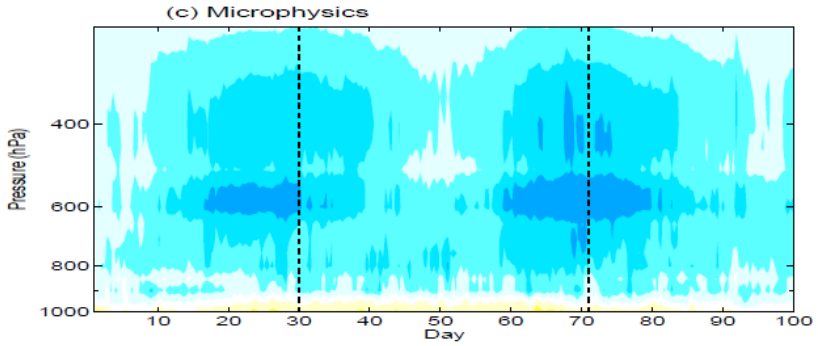
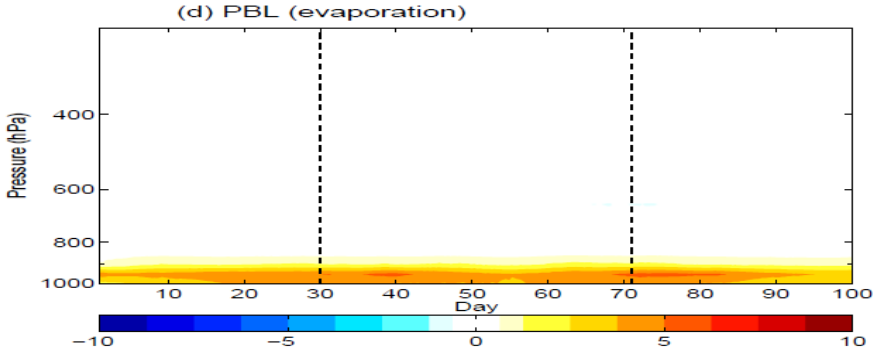
Sources and sinks of moisture

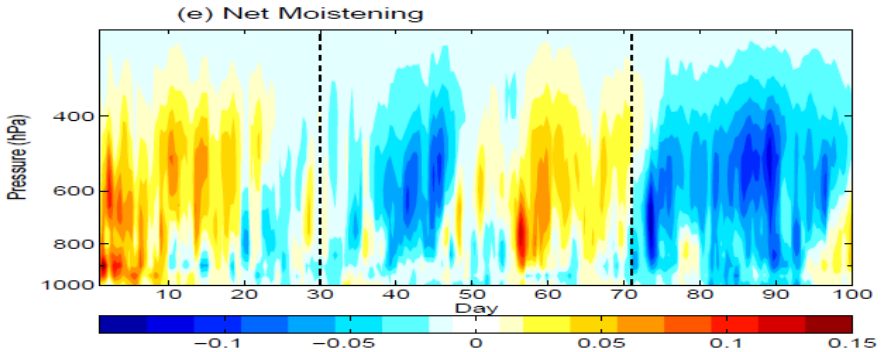
$$\frac{\partial q}{\partial t} = -\nabla\cdot(q\mathbf{v}_h) - \frac{\partial(q\omega)}{\partial p} + Q_{2(pbl)} + Q_{2(microphys)}$$







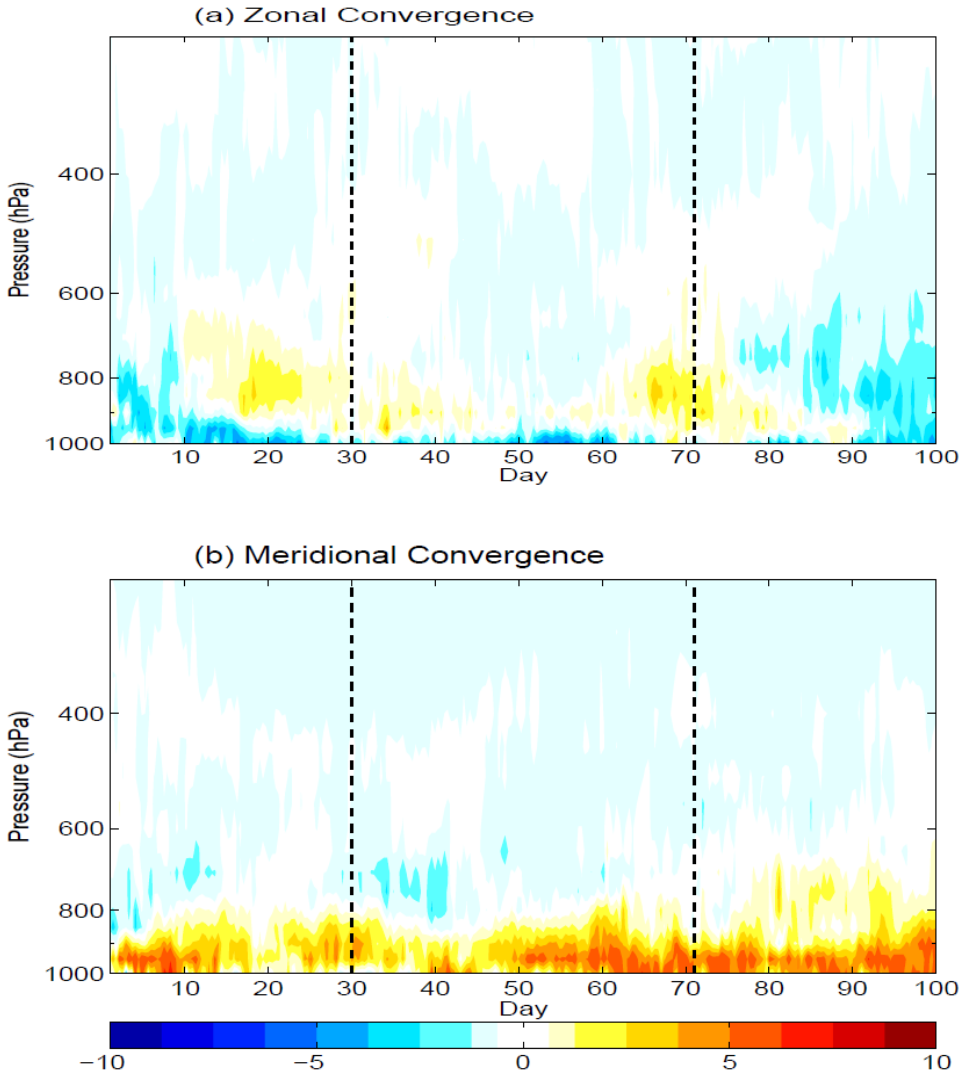




Sources and sinks of moisture (g (kgday)$^{-1}$) .

The source of moisture deepens as the lower troposphere is gradually moistened.

$$-\nabla\cdot(q\mathbf{v}_h) = -\frac{\partial(qu)}{\partial x} - \frac{\partial(qv)}{\partial y}$$



Convergence of zonal wind weaker and slightly elevated. Frictional convergence of easterlies cannot account for moistening.

Components of horizontal moisture convergence (g (kgday)$^{-1}$) .

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Moist processes and the time-scale of MJO

Contributions of the moist processes to the MJO timescale can be estimated as follows.

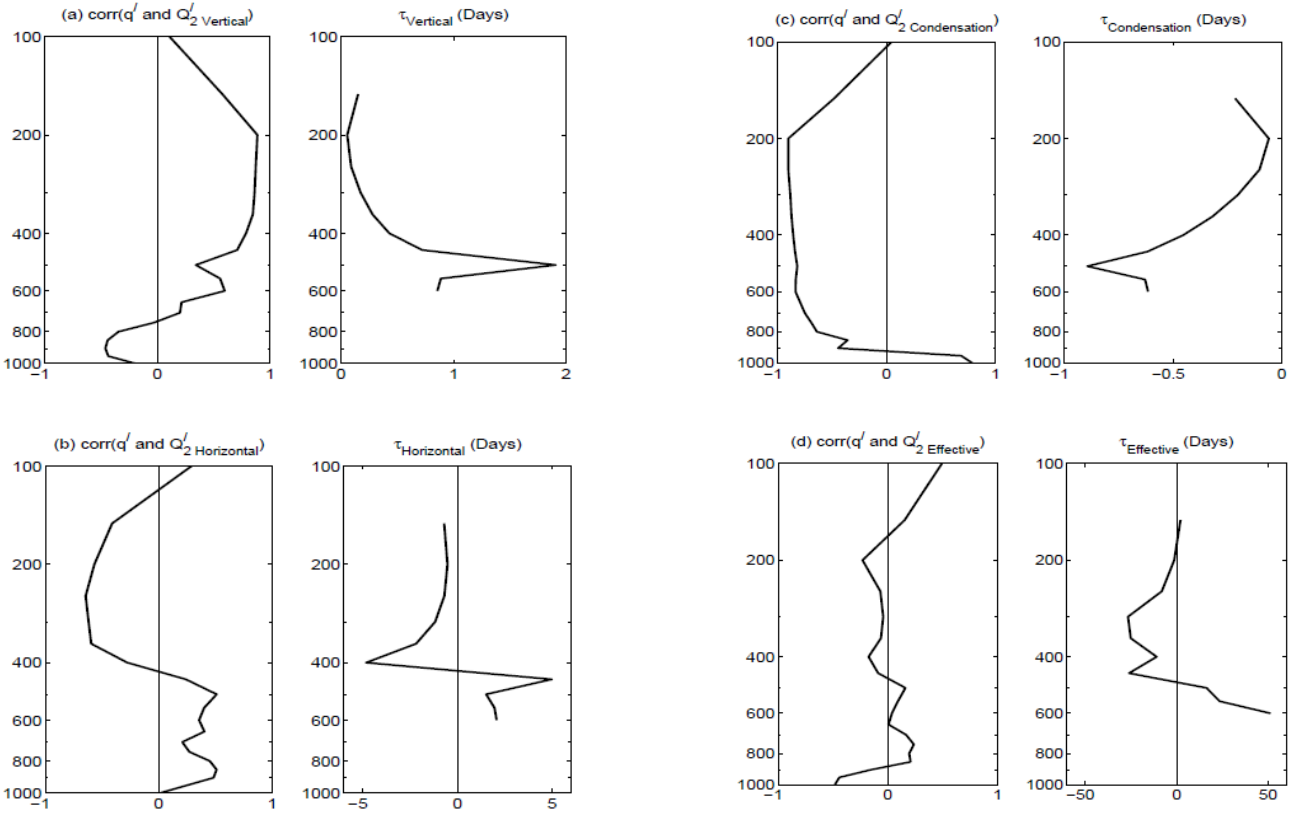
$$\frac{\partial q'}{\partial t} \approx Q'_{2(vertical)} + Q'_{2(horizontal)} + Q'_{2(condensation)}$$

$$\frac{\partial q'}{\partial t} \approx \frac{q'}{\tau_{vertical}} + \frac{q'}{\tau_{horizontal}} + \frac{q'}{\tau_{condensation}}$$

$$\tau_{effective} = \frac{\tau_{vertical}\tau_{horizontal}\tau_{condensation}}{\tau_{vertical}\tau_{horizontal} + \tau_{vertical}\tau_{condensation} + \tau_{horizontal}\tau_{condensation}}$$

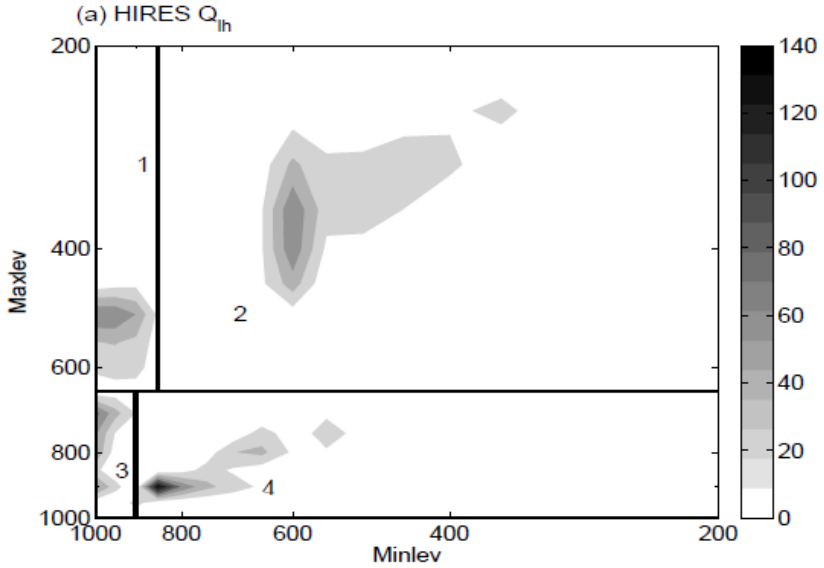
$$\frac{\partial q'}{\partial t} \approx \frac{q'}{\tau_{effective}}$$

Time-scales of moist processes



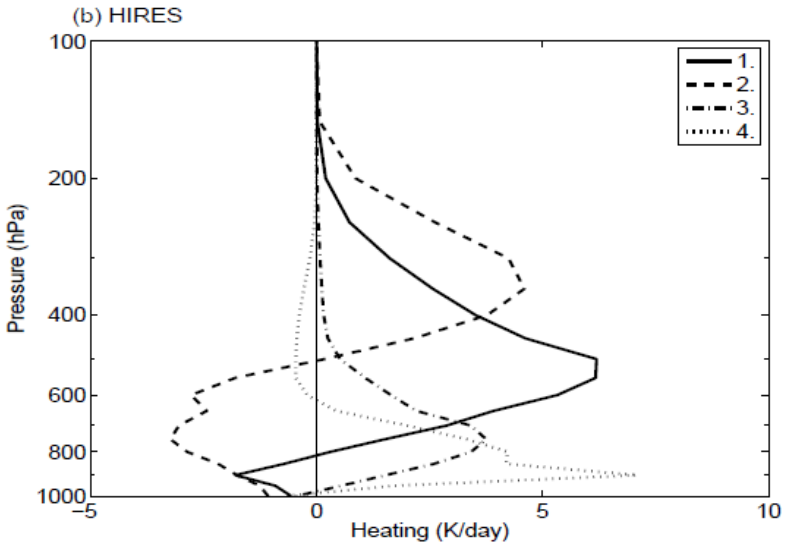
- The effective timescale is between 15-20 days which corresponds to 30-40 day period of the MJO.
- It arises from small differences among the timescales of convective updraft, horizontal mixing and condensation.

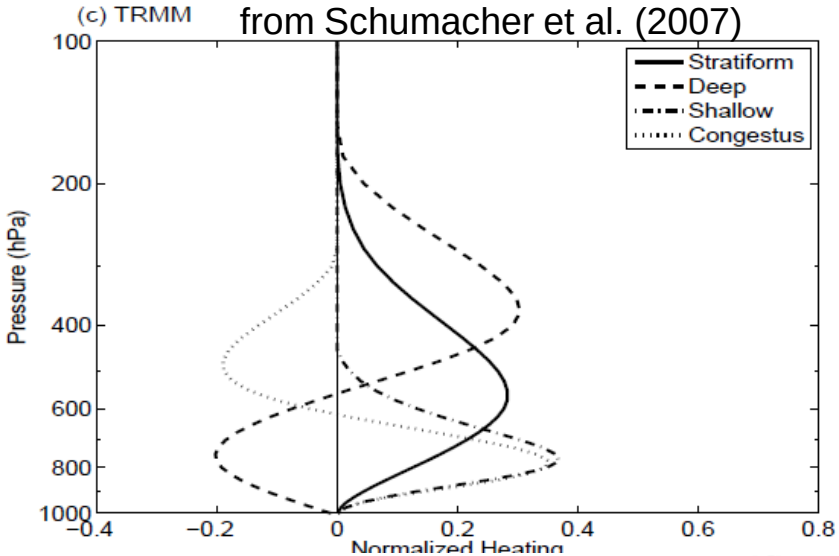
Clouds in the "cloud resolving" model.



Bi-variate PDF of latent heating with respect to the levels of maximum and minimum heating. (K day^{-1}) .

The clouds that significantly contribute to the latent heating can be approximately categorized into four types according to their heating profile.





from Schumacher et al. (2007)

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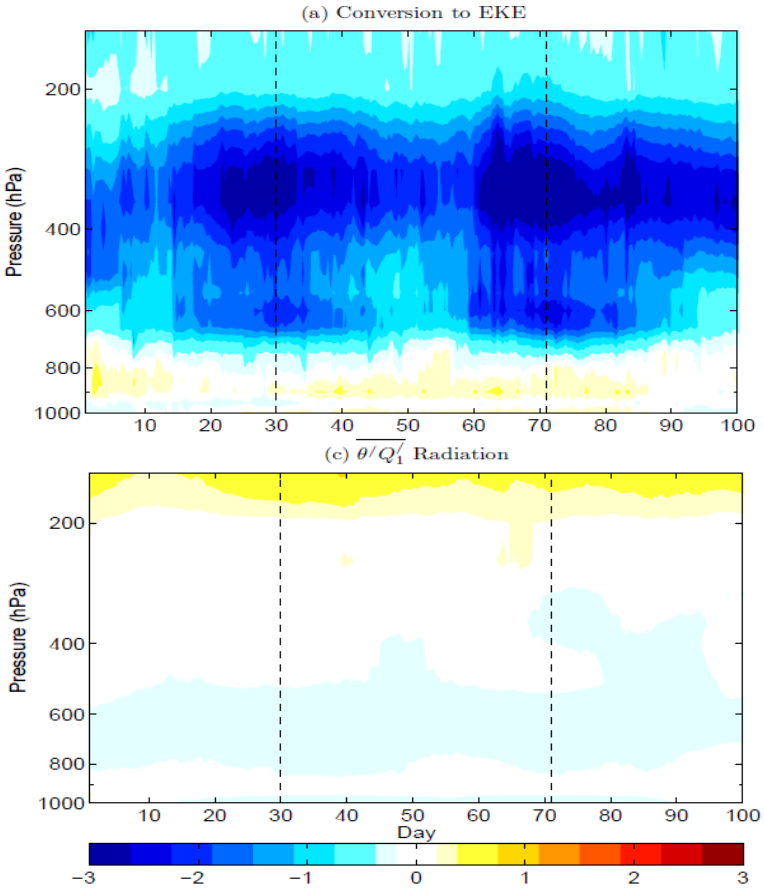
Thermodynamics

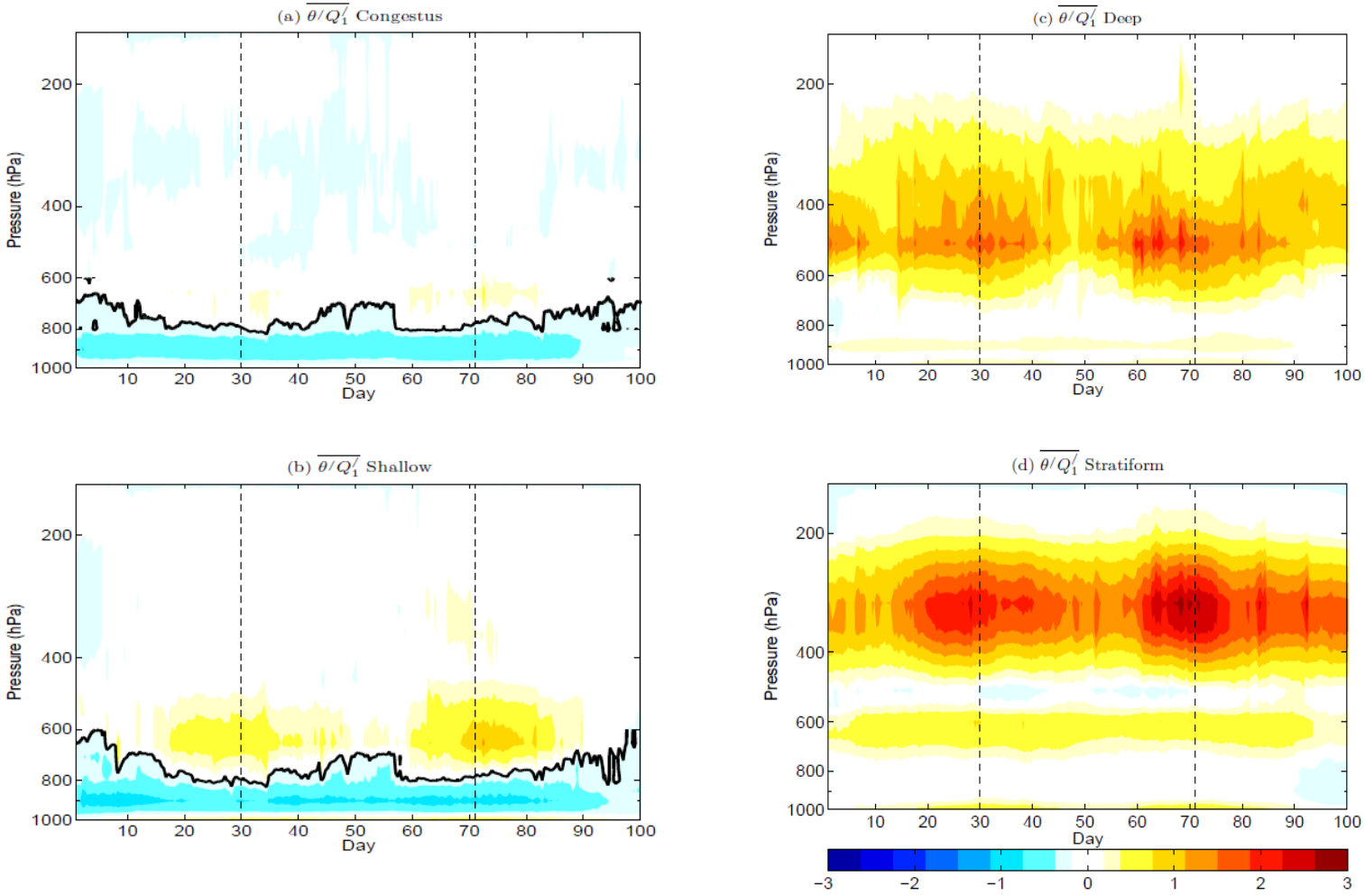
Eddy available potential energy budget

$$\frac{\overline{\partial \theta' \theta'}}{2\partial t} = \overline{-\theta'(\nabla \cdot (\boldsymbol{v}\theta))'} + \overline{\theta' Q'}_{1(latent)} + \overline{\theta' Q'}_{1(radiation)} + \overline{\theta' Q'}_{1(pbl)}$$



Sources and sinks of eddy available potential energy (K^2 day^{-1}) .

Contributions of clouds to the eddy available potential energy budget.



Contributions of the various cloud type to EAPE tendency by latent heating (K^2 day^{-1}) .

Summary

- **Hypothesis 1:** The long timescale of recharge and discharge in MJO is related to a small differences in the timescales of the vertical fluxes, mixing and condensation.
- **Hypothesis 2:** A simplified paradigm of MJO thermodynamics.