MJO in idealized and comprehensive models (and observations)

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(Thanks Daehyun Kim, Eric Maloney, Shuguang Wang, and others as cited)
Motivation

• We seek to understand the basic physics of the MJO.
• Understanding should ultimately be captured in an idealized model.
• The history of attempts to do this is one of failure over many decades – many idealized models, no community agreement.
• What has changed now is that we have the capability to simulate (and predict!) the MJO in comprehensive models. We should use this.
Even some CMIP-class models are not too bad!

Klingaman et al. 2015
Moisture-convection feedback is critical to the MJO. The convection has to be sufficiently sensitive to moisture.

D. Kim et al. 2012

(and Wang and Schlesinger 1999; Maloney and Hartmann 2001; Lee et al. 2003; Lin et al. 2008; Benedict et al. 2013)
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This suggests that the moisture field carries the signal of the MJO.

D. Kim et al. 2012

(and Wang and Schlesinger 1999; Maloney and Hartmann 2001; Lee et al. 2003; Lin et al. 2008; Benedict et al. 2013)
Radiative-convective feedback maintains the MJO (and to some extent surface fluxes do too)

- MJO weakens over land (Sobel et al. 2008, 2010); model diagnostics (Andersen and Kuang 2011, Chikira 2014)
- budget studies (Inoue and Back 2014; Sobel et al. 2014, Wolding et al. 2015)
MJO as self-aggregation on the Equatorial beta plane or sphere (Arnold and Randall 2015)

Radiation is critical.
“Moisture mode”: the MJO is essentially a huge blob of moisture that maintains itself by longwave radiative feedback (and maybe surface fluxes) and moves by horizontal moisture advection.
A linear moisture mode model (Sobel and Maloney 2012, 2013, JAS)

\[
\frac{\partial W'}{\partial t} + U \frac{\partial W'}{\partial x} = -\tilde{M} P' + E' - (1 - \tilde{M}) R'
\]

$W'$ is perturbation column moist static energy; $U$ is constant background wind; $P' = P'(W')$ – if linear $P = W'/\tau_c$; (moisture-convection feedback) $E' = cu'$; zonal wind anomaly is computed diagnostically from $P'$ using projection (Green’s) function $R' = rP'$; Normalized gross moist stability $\tilde{M}$ is constant, $<1$.

Green’s function for wind derived from Gill (1980)
Extended by Adames and D. Kim (2015) to include meridional moisture advection and horizontal wavenumber-dependent radiation

Observed symmetric OLR spectrum & theoretical dispersion curves – westward group velocity for $k>1$

Moisture anomaly (contour)
Low-level flow (arrows)
Moisture tendency due to Kelvin (top) & Rossby (bottom) components
A variety of things can happen on aqua-planets. If they’re zonally symmetric, an MJO often doesn’t appear.

Bretherton and Khairoutdinov 2015
Pritchard and Yang (2016) – MJO (or something) survives even in very cold climates. Still lives by radiative feedback!

Doesn’t necessarily prefer eastward propagation.
Pritchard and Yang (2016) – MJO (or something) survives even in very cold climates. Still lives by radiative feedback!

These mean climates are very different – from each other, and from Earth’s.
Yet even small changes in basic state can have a large impact on MJO dynamics (Ma and Kuang 2016)
Multiscale models

• “Skeleton” – Majda and Stechmann (2009) and many subsequent papers
• High-frequency gravity wave coupling (Yang and Ingersoll)
• These neglect radiation & surface fluxes a priori
• The key *mechanisms* (not just the dispersion relation or other predicted MJO features) of these idealized models should be diagnosable in comprehensive models (and observations)
Final thoughts

• A mode in which moisture + convection anomalies live a long time, maintained by moisture-convection feedback and longwave radiative feedback, seems quite generic in models with enough moisture sensitivity.
• When it is near the equator, large in horizontal scale, and goes slowly eastward, as it tends to do in our present climate, we call it the MJO.
• Eastward propagation (and other MJO specifics) appear dependent on the mean climate.
• Simple models can do many things for many reasons. We now have the capability to use comprehensive models to test mechanisms.
Roundy (2012) shows that the MJO-Kelvin separation in spectral diagrams results from mixing of events with different properties in easterly & westerly base states. No separation in mean westerlies. Continuous MJO-Kelvin transition (2012b)?
In fact we can see the transition in pressure-wind relation in many individual events as they move east from Indian to Pacific Ocean (Sobel & Kim 2012).

Surface pressure (contours)
Zonal wind at 850 hPa (arrows)
OLR (colors)
In other models, radiative feedbacks are important while surface turbulent flux feedbacks are not – but both are moist static energy sources.

Andersen and Kuang 2011

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**Radiative Contribution to Maintenance of MSE Anomaly**

- Fractional Contribution to MSE anomaly maintenance (per day)

Radiative contribution to maintenance of MSE anomaly

Andersen and Kuang 2011