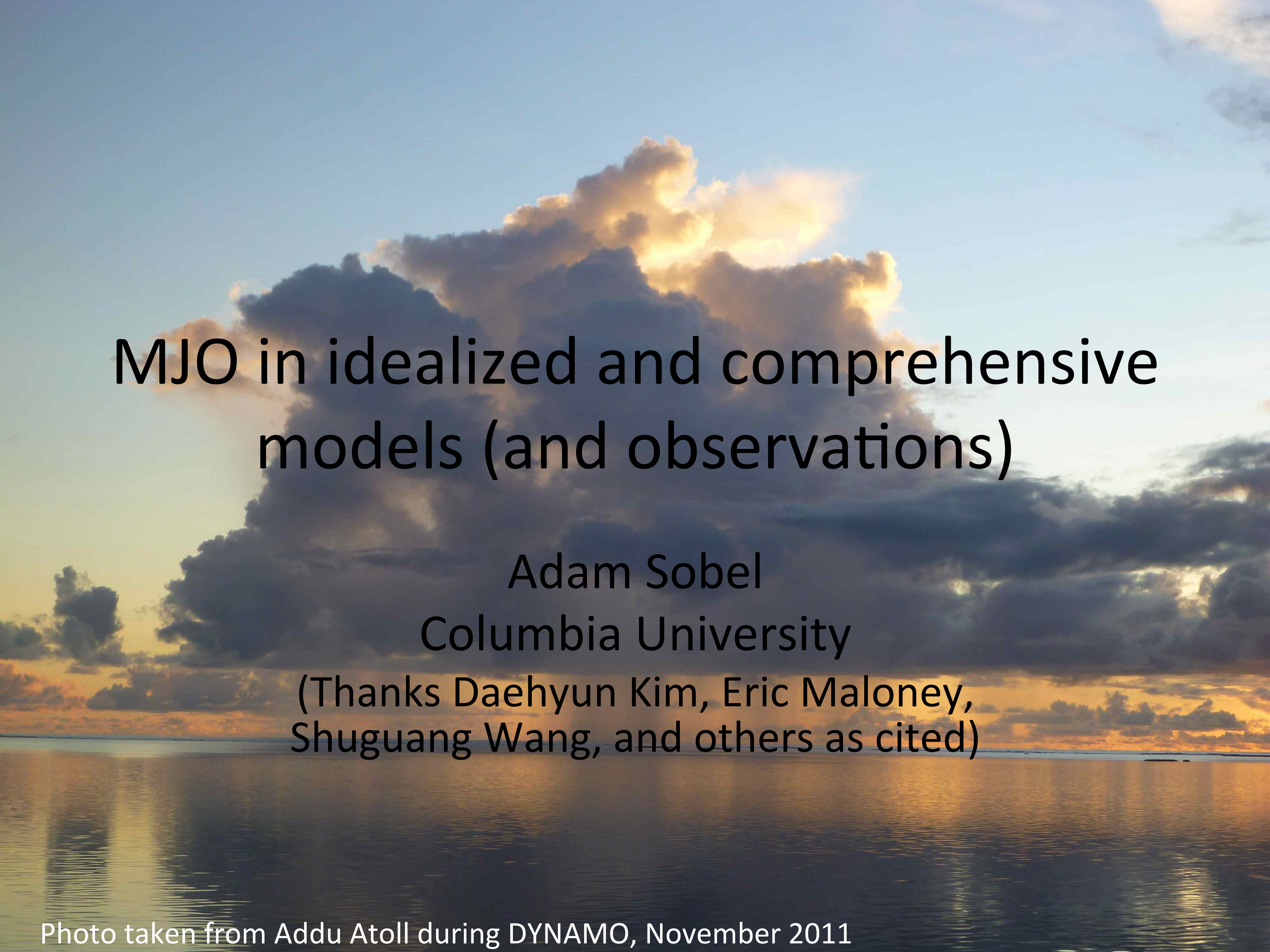

MJO in idealized and comprehensive models (and observations)

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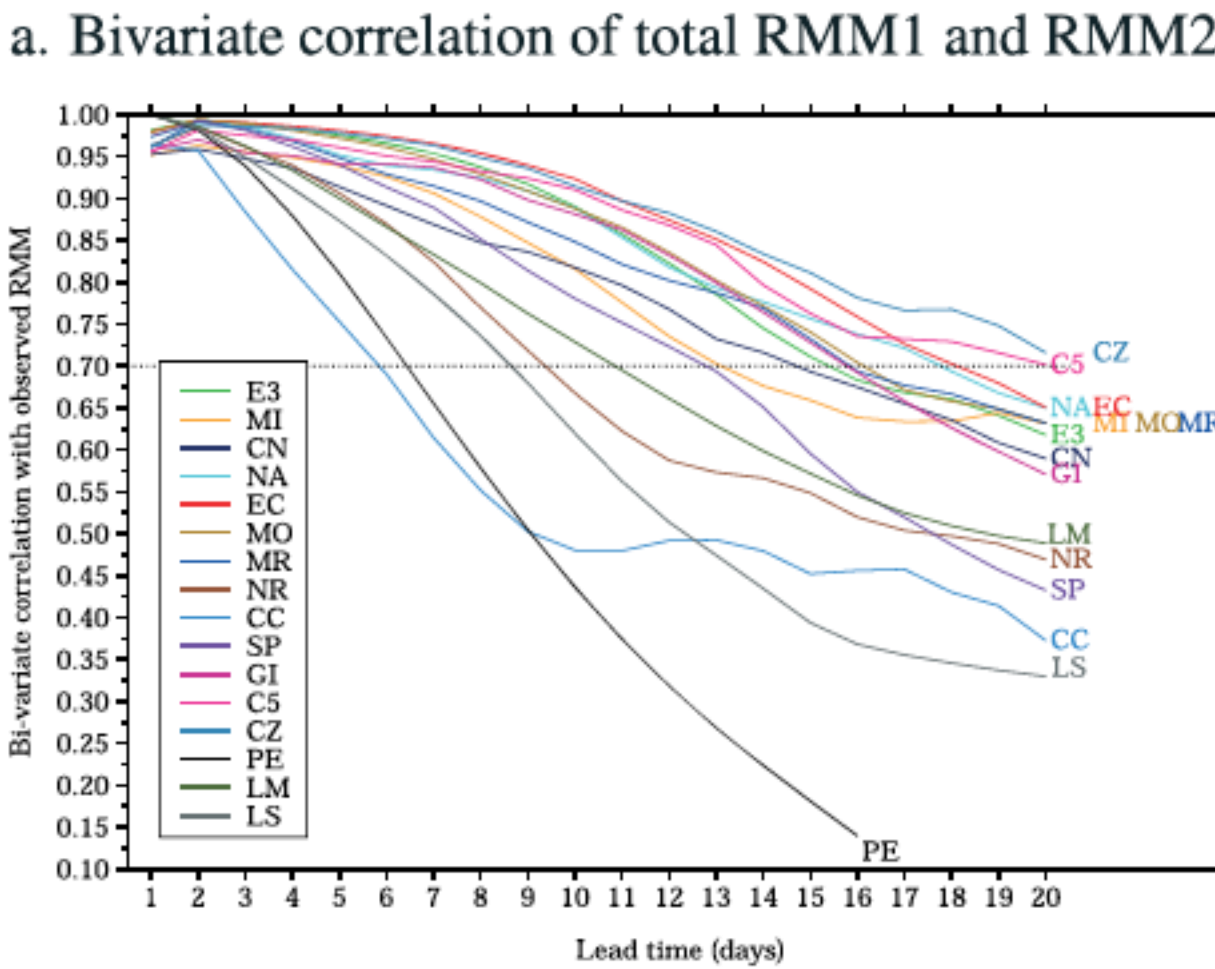
(Thanks Daehyun Kim, Eric Maloney, Shuguang Wang, and others as cited)

Photo taken from Addu Atoll during DYNAMO, November 2011

Motivation

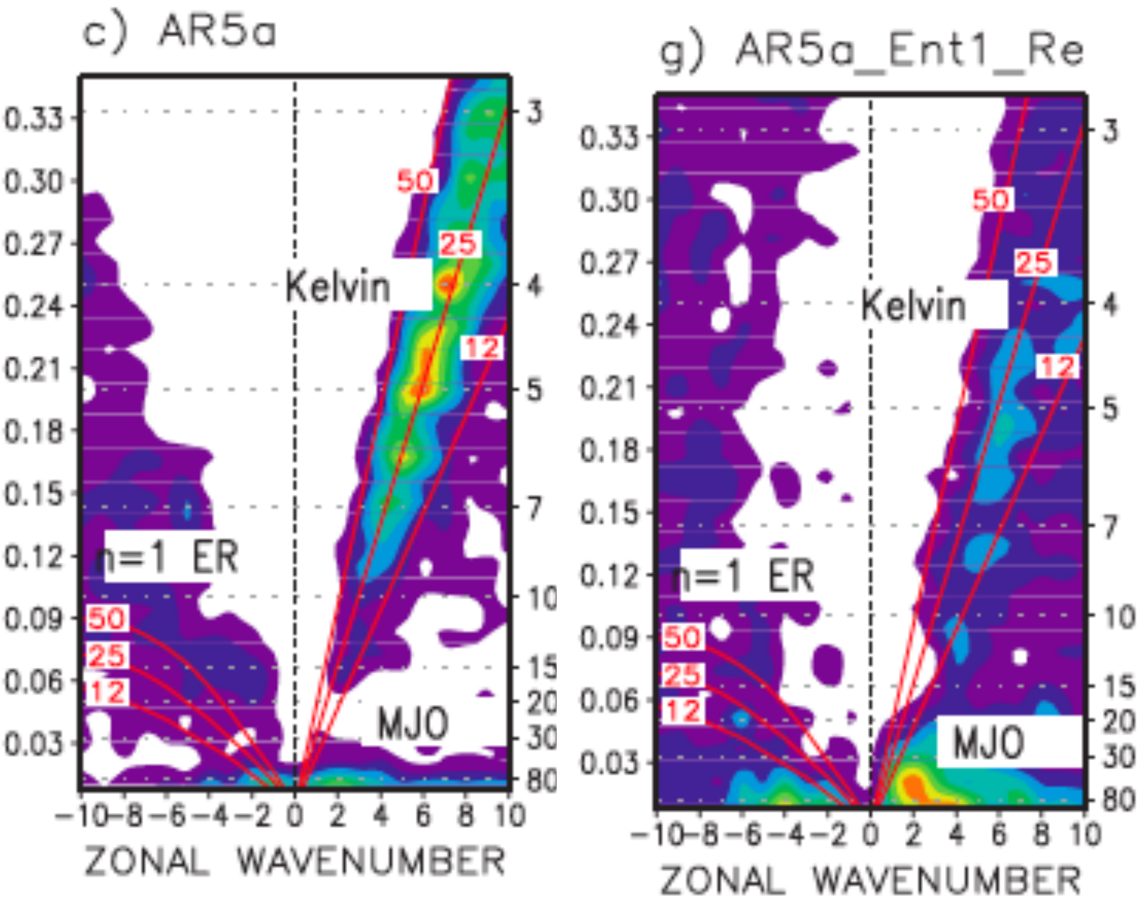
- We seek to understand the basic physics of the MJO.
- Understanding should ultimately be captured in an idealized model.
- The history of attempts to do this is one of failure over many decades – many idealized models, no community agreement.
- What has changed now is that we have the capability to 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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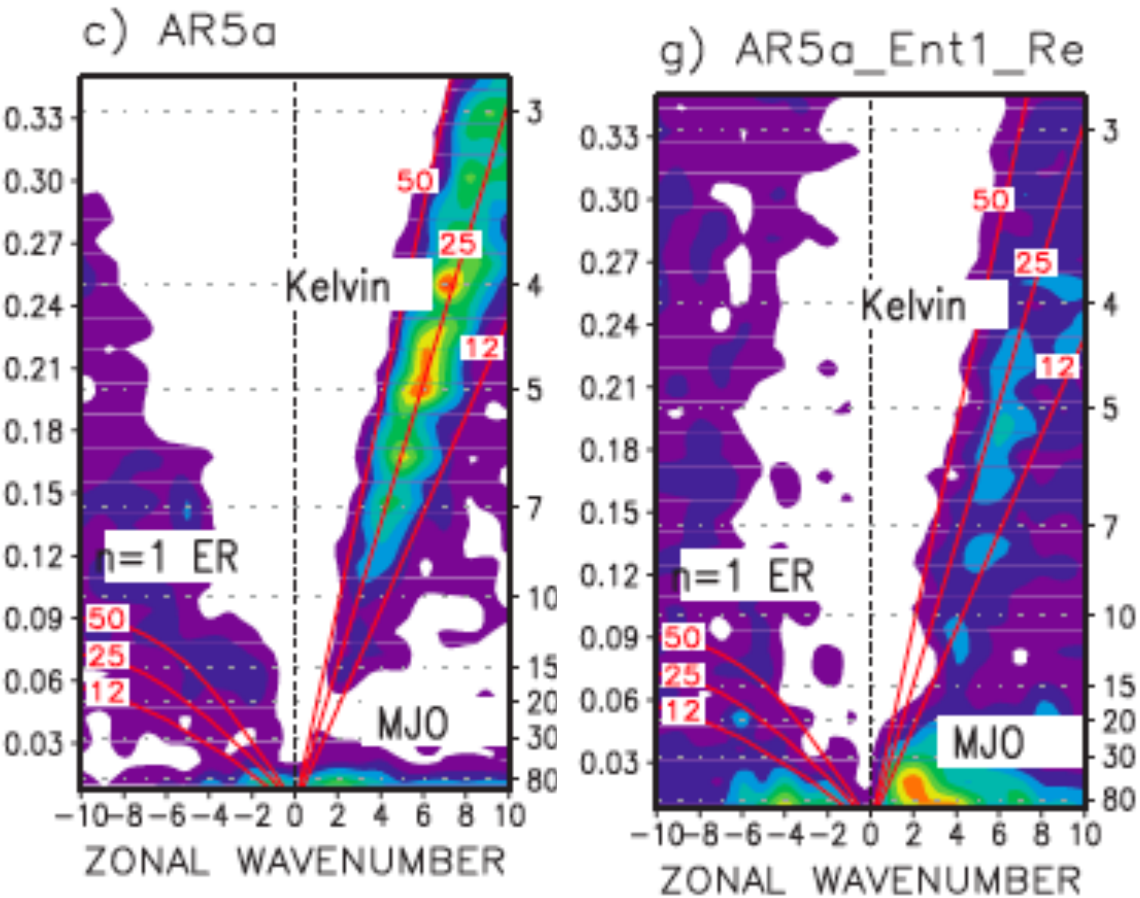


This suggests that the moisture field carries the signal of the MJO.

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)

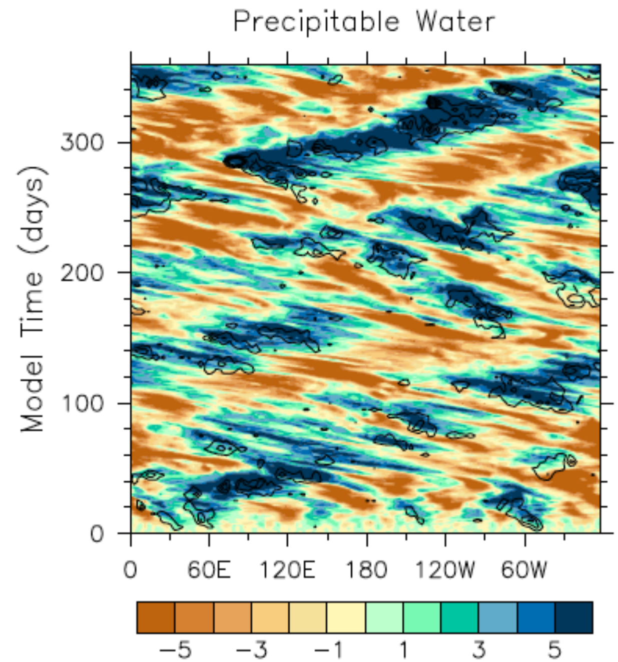
Radiative-convective feedback maintains the MJO
(and to some extent surface fluxes do too)

- MJO weakens over land (Sobel et al. 2008, 2010); model diagnostics (Andersen and Kuang 2011, Chikira 2014)
- mechanism denial (Landu and Maloney 2011, Kim et al. 2011, Arnold and Randall 2015, Wang et al. 2013, 2016, Ma and Kuang 2016)
- 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)

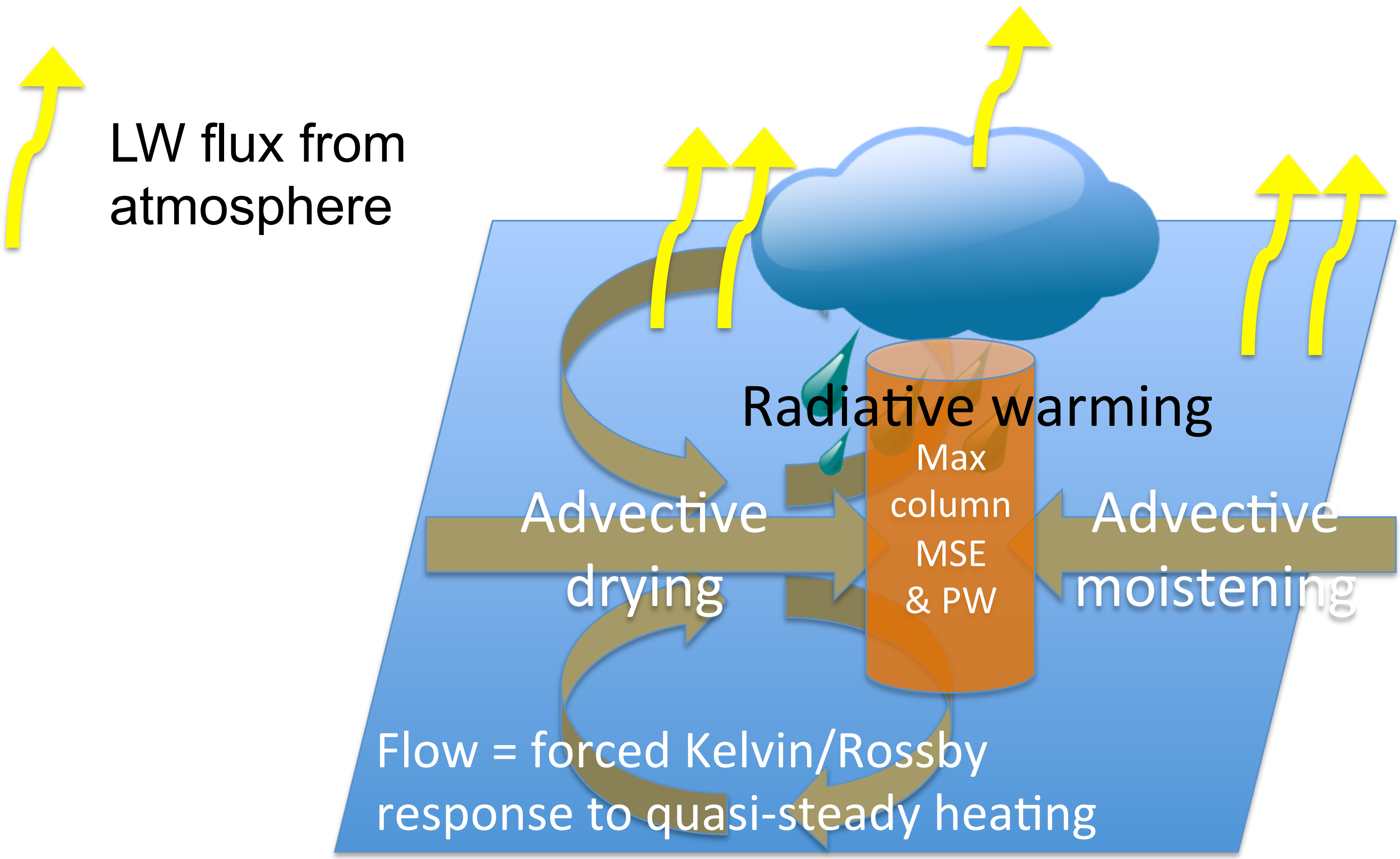
Radiation is critical.

Rotating, uniform SST



Nonrotating, uniform SST

“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

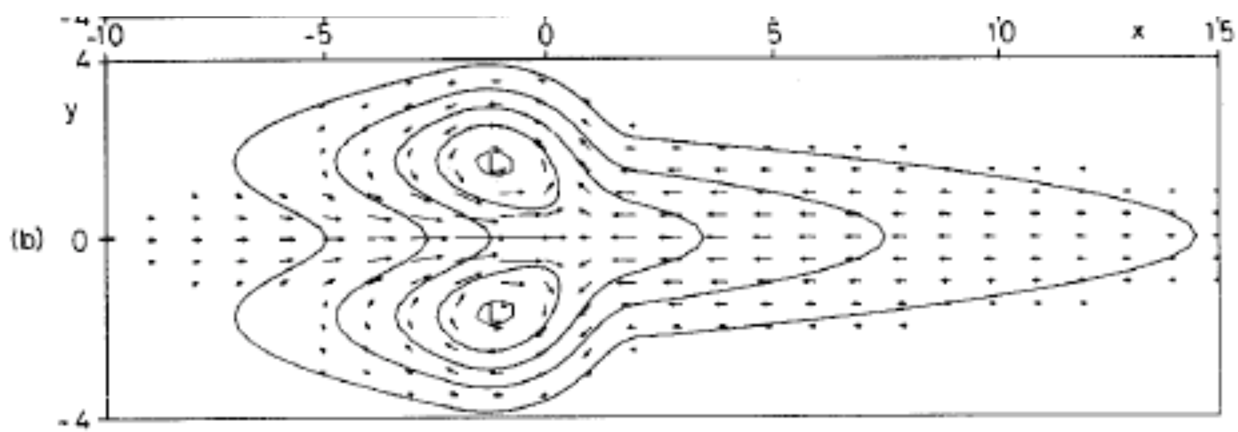


A linear moisture mode model (Sobel and Maloney 2012, 2013, *JAS*)

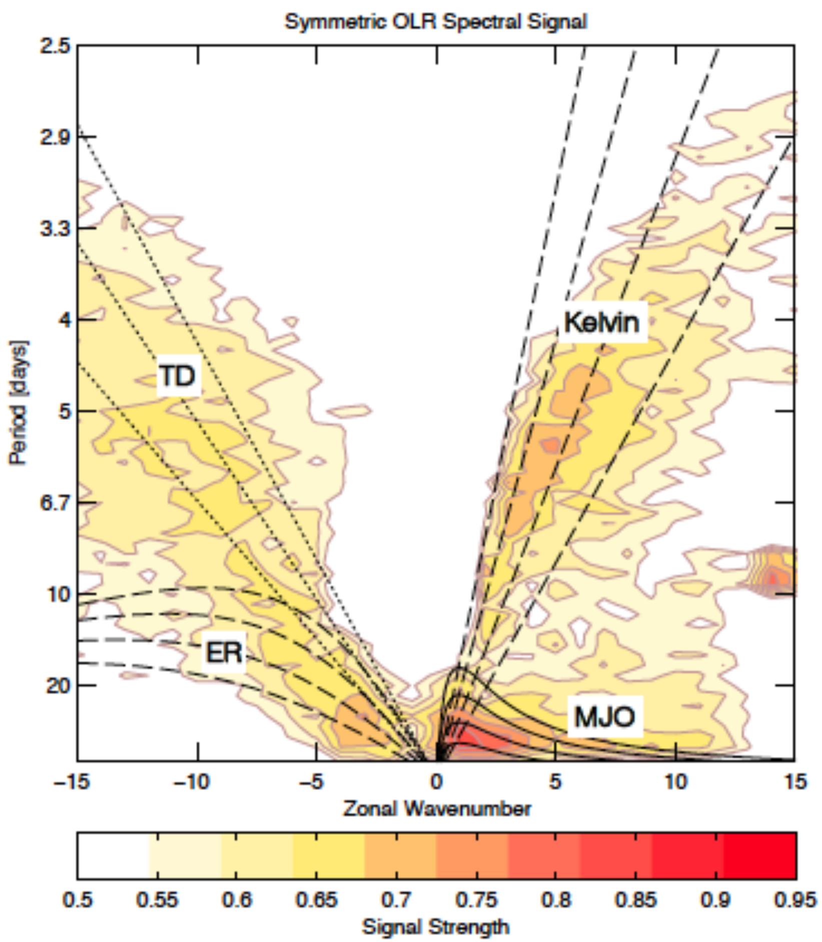
$$\frac{\partial W'}{\partial t} + U\frac{\partial W'}{\partial x} = -\tilde{M}P' + E' - (1-\tilde{M})R'$$

W' is perturbation column moist static energy;
U is constant background wind;
P' = P'(W') – if linear P=W'/τ_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.

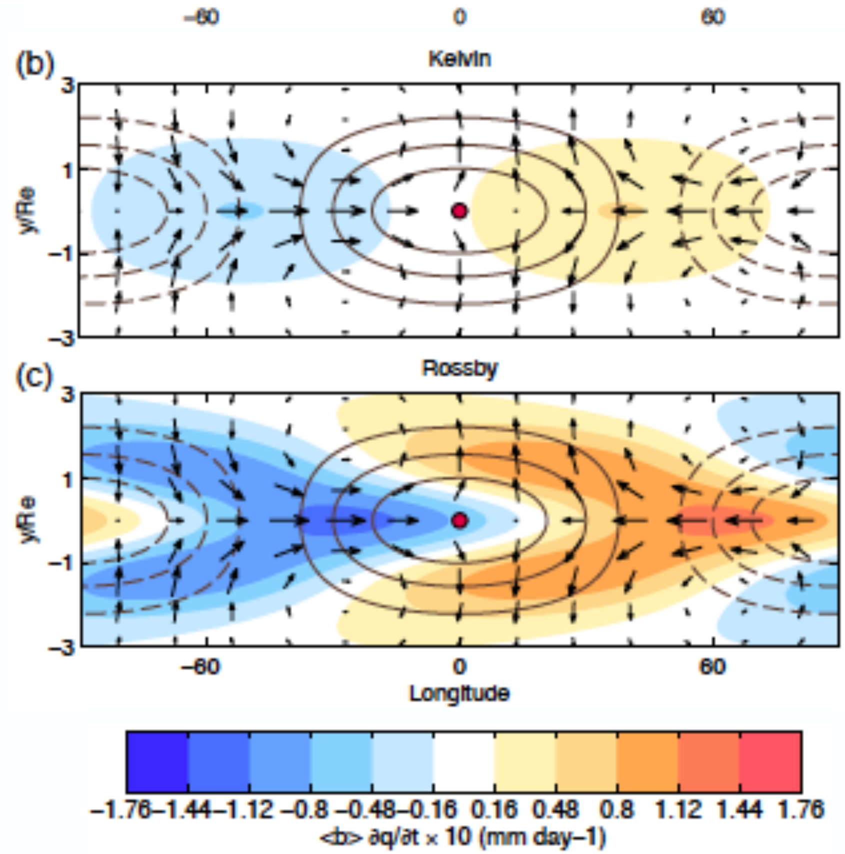
Green's function for wind derived from Gill (1980)



Extended by Adames and D. Kim (2015) to include meridional moisture advection and horizontal wavenumber-dependent radiation

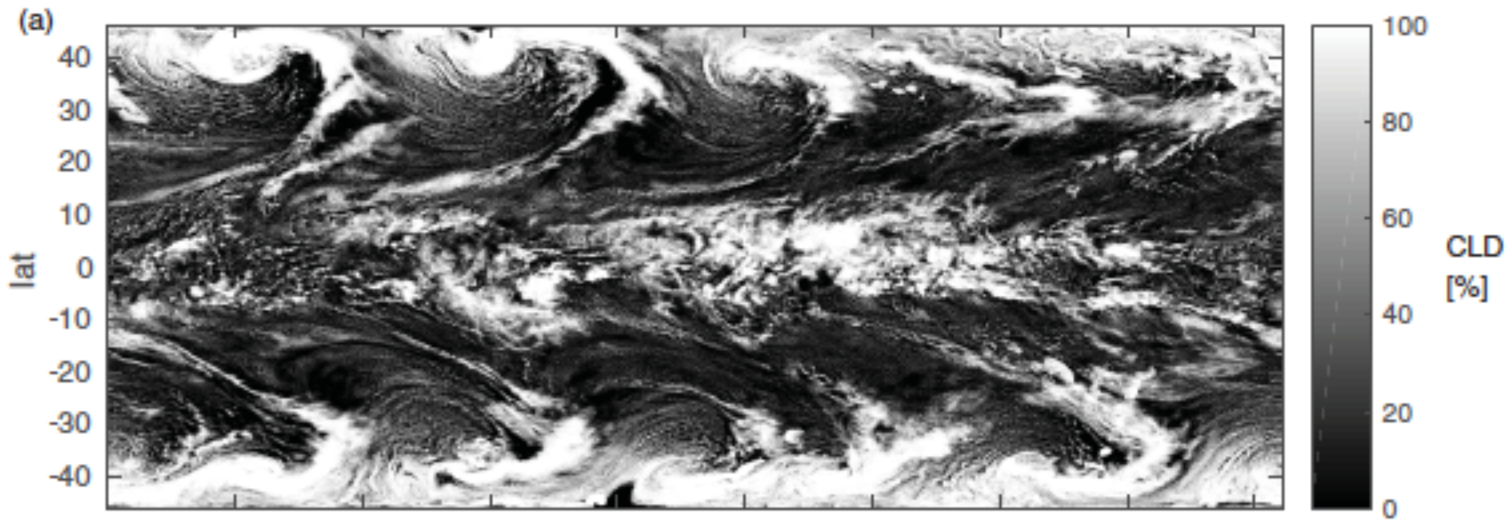


Observed symmetric OLR spectum & theoretical dispersion curves – westward group velocity for k>1



Moisture anomaly (contour)
Low-level flow (arrows)
Moisture tendency due to Kelvin (top) & Rossby (bottom) components

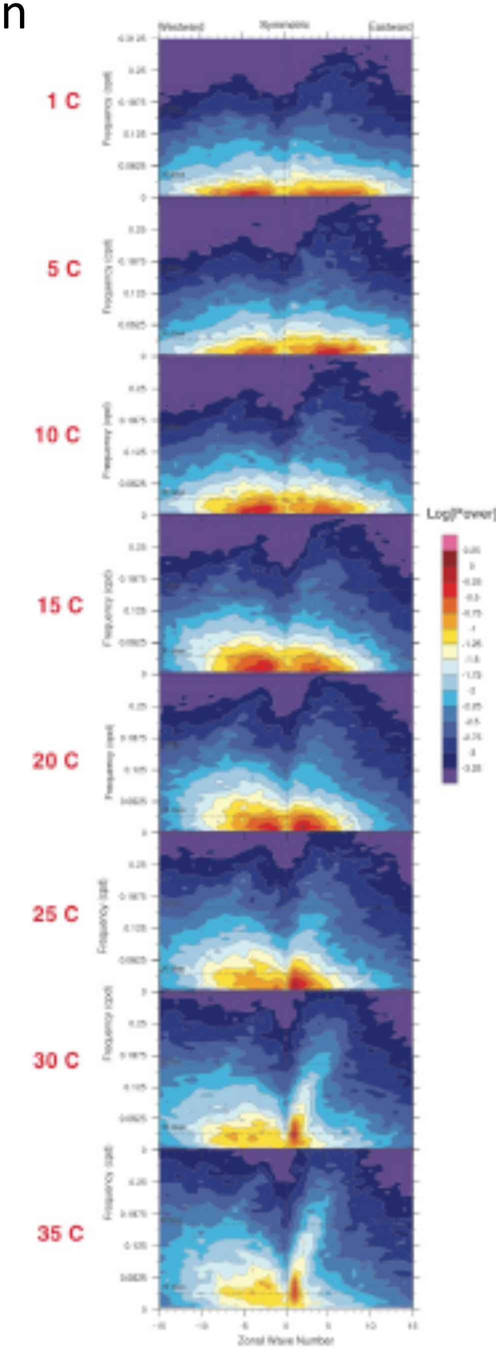
A variety of things can happen on aqua-planets. If they're zonally symmetric, an MJO often doesn't appear.



Bretherton and Khairoutdinov 2015

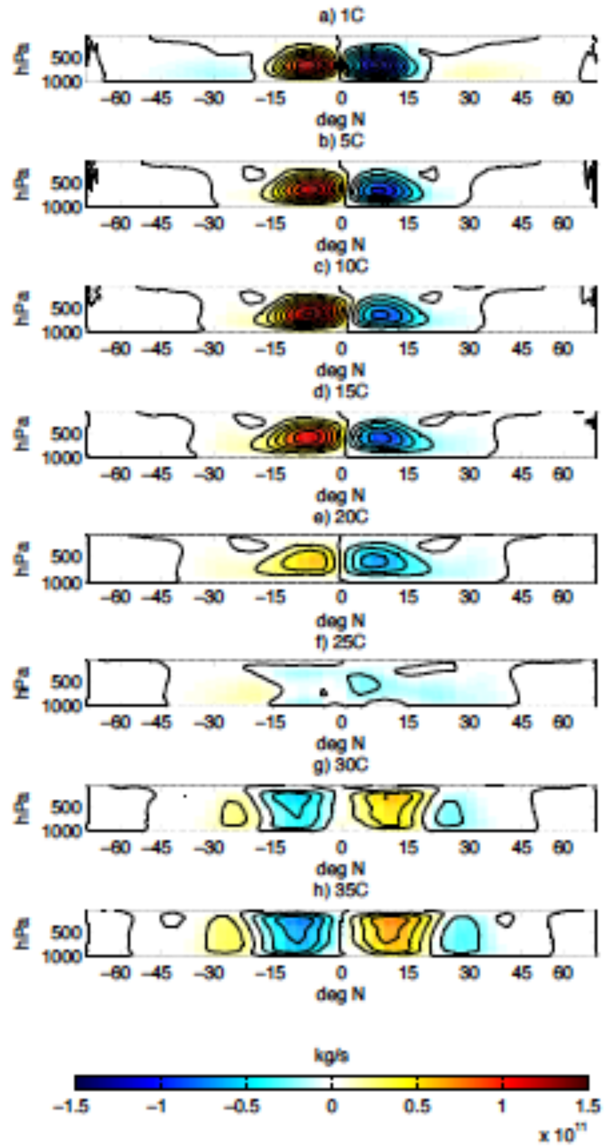
Pritchard and Yang (2016) – MJO (or something) survives even in very cold climates. Still lives by radiative feedback!

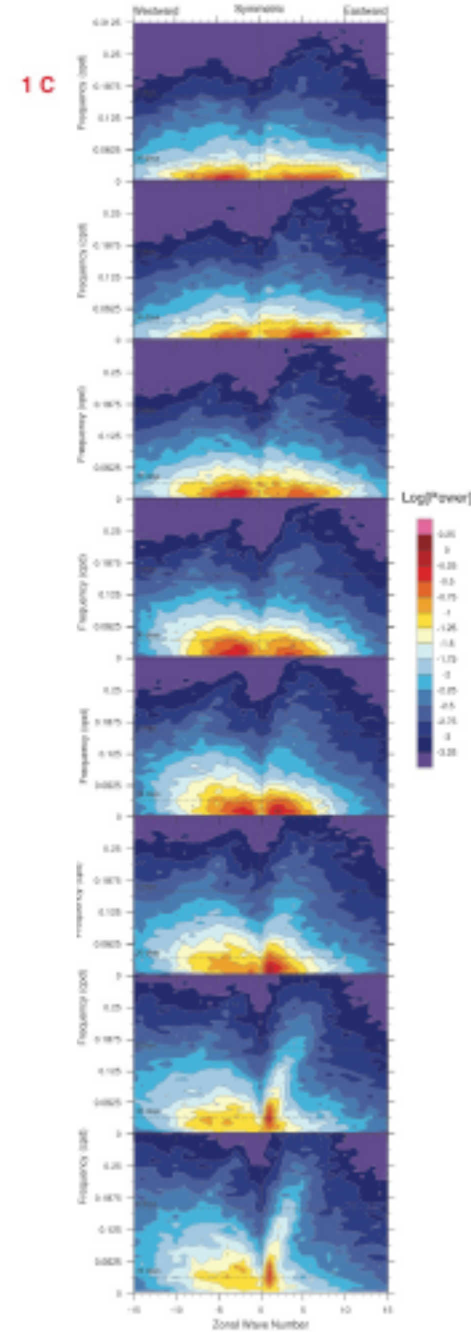
Doesn't necessarily prefer eastward propagation.



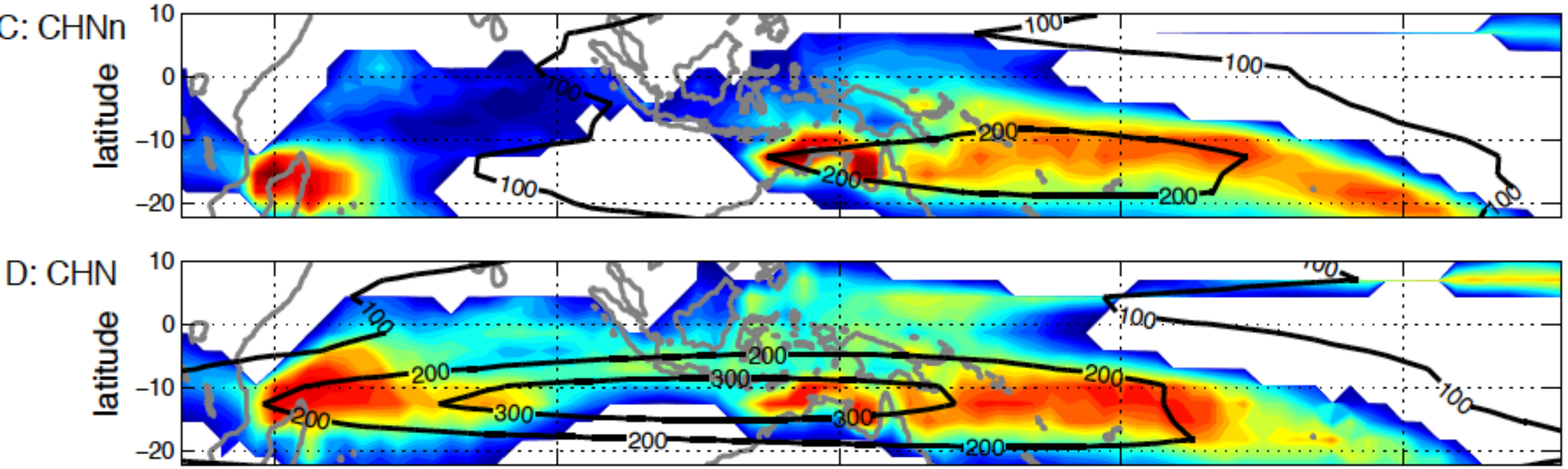
Pritchard and Yang (2016) – MJO (or something) survives even in very cold climates. Still lives by radiative feedback!

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)



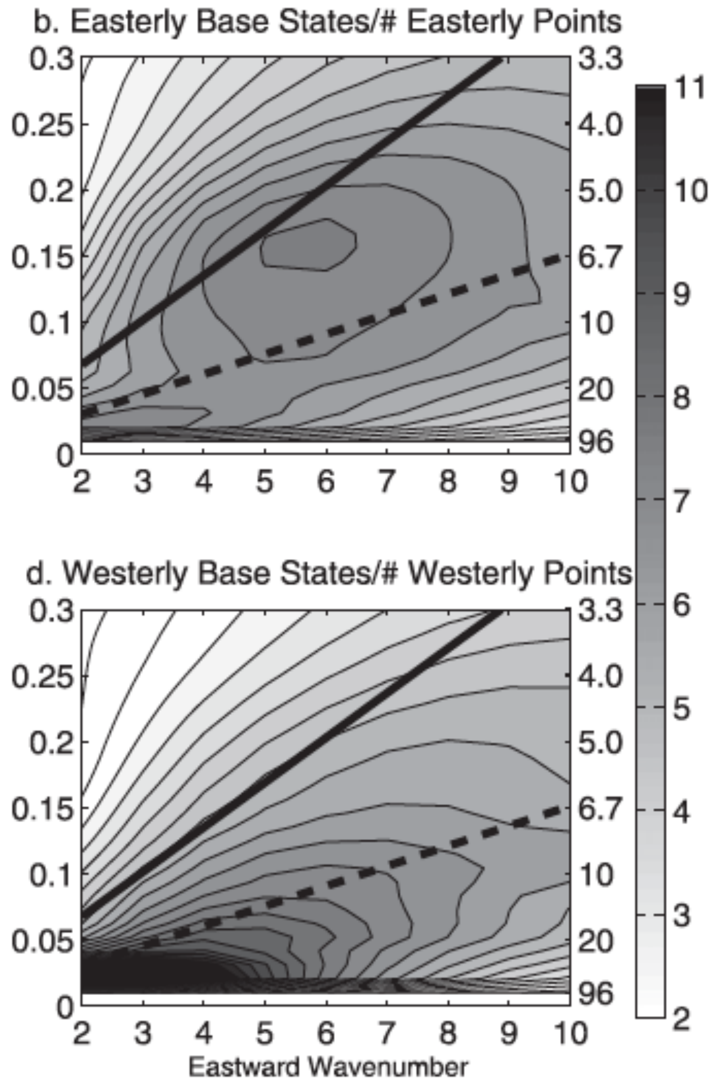
Multiscale models

- "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)

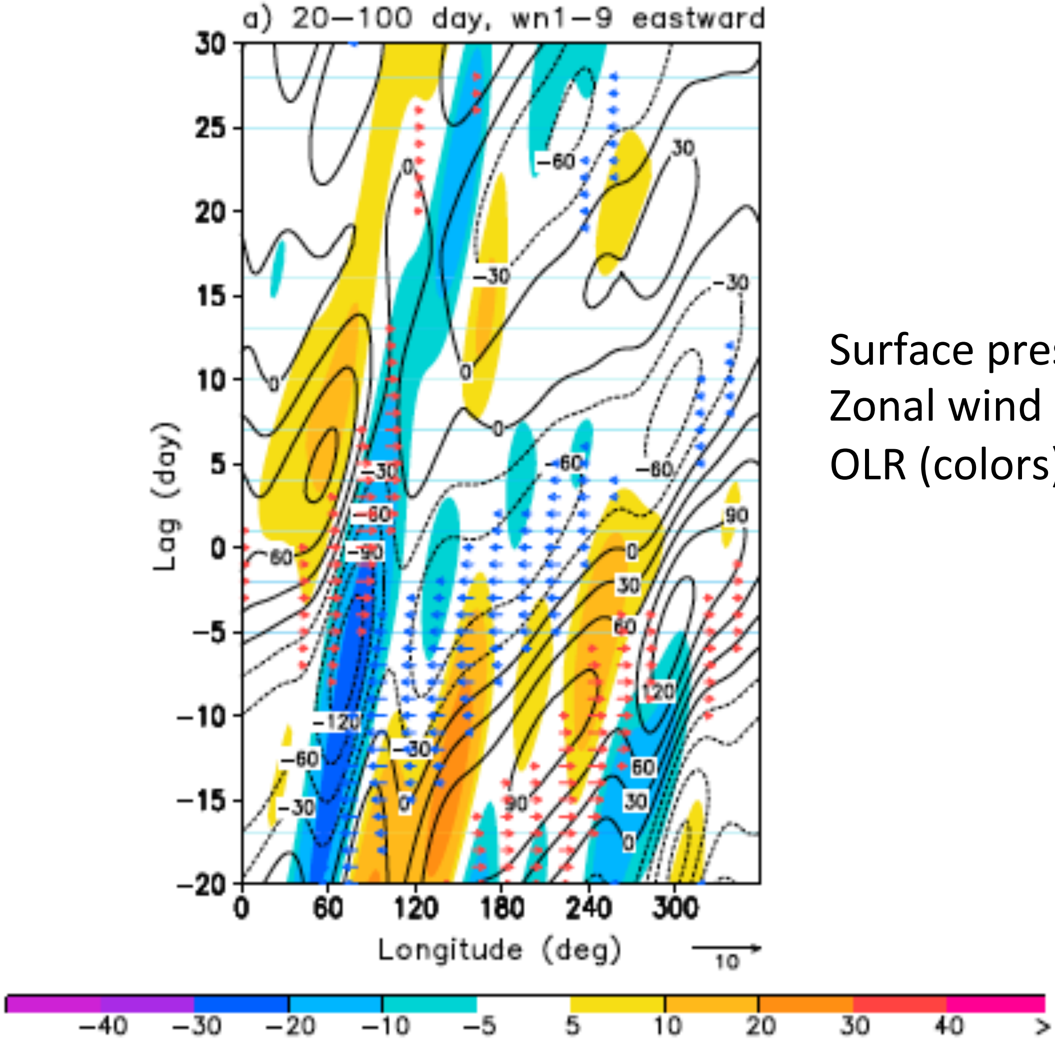
Final thoughts

- 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)?

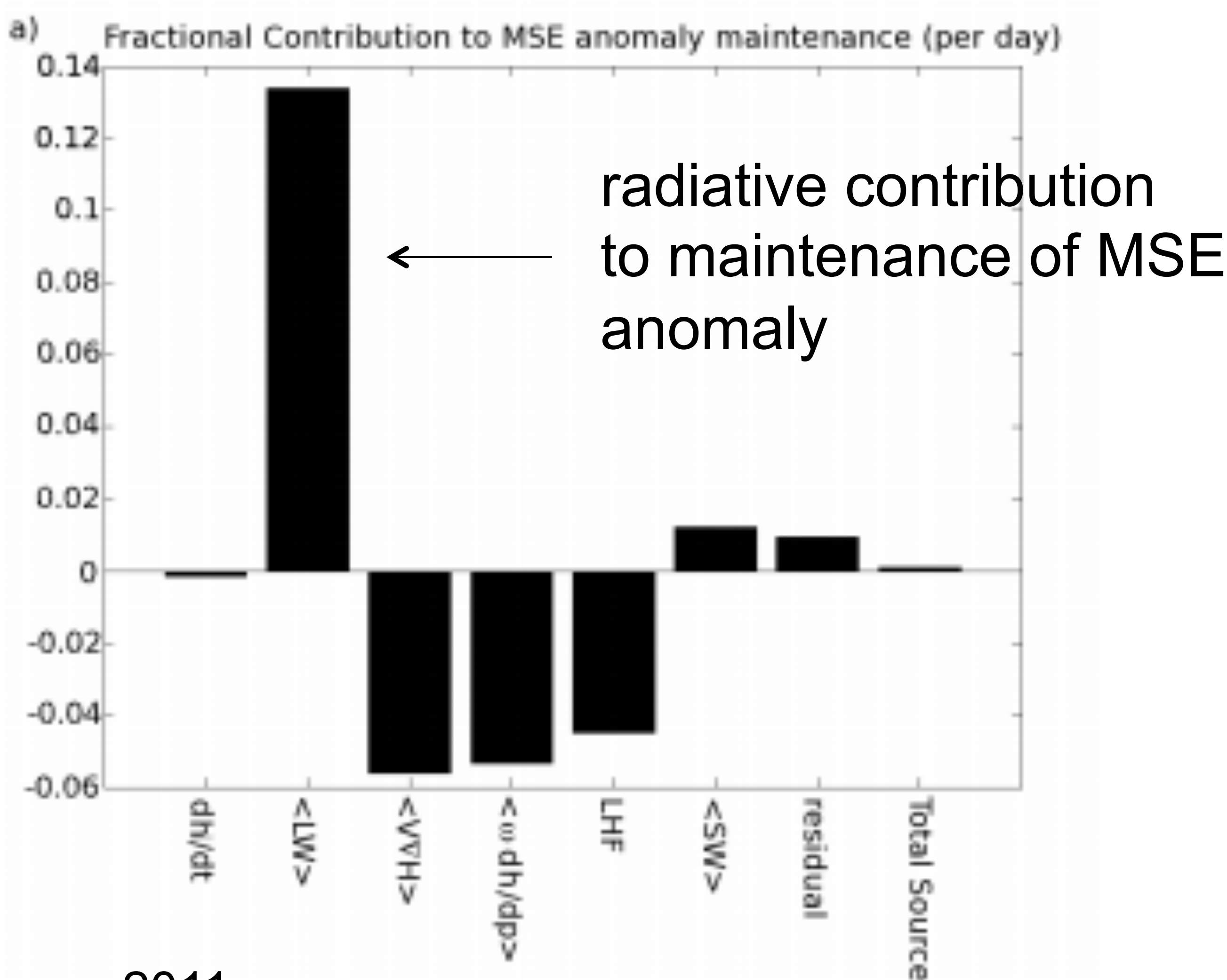


In fact we can see the transition in pressure-wind relation in many individual events as they move east from Indian to Pacific Ocean (Sobel & Kim 2012).



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