# Convective Self-Aggregation in SP-CAM: Implications for the MJO

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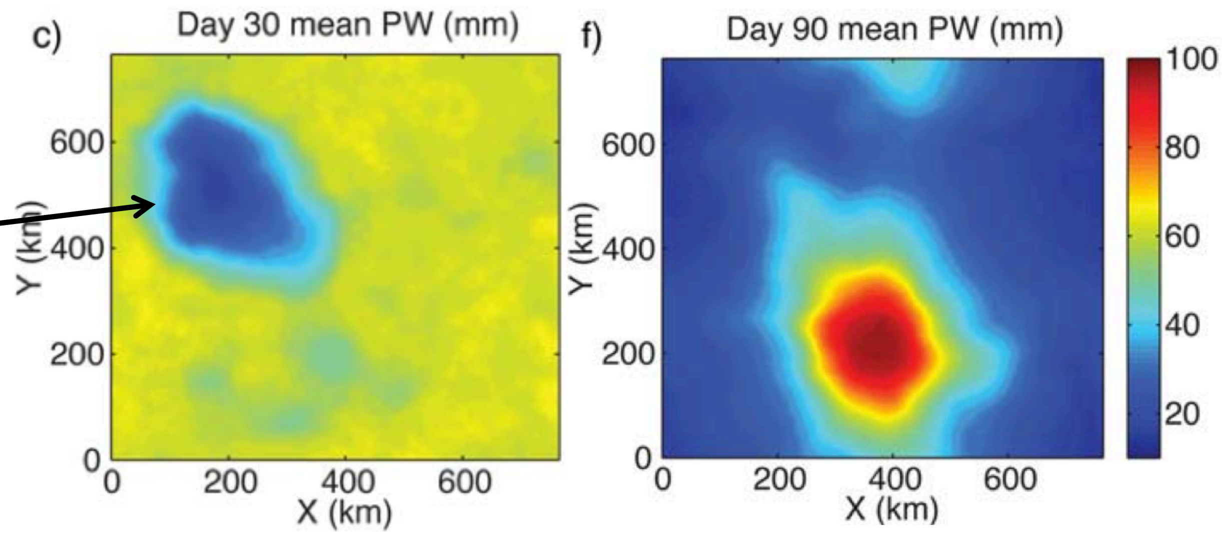
# Aggregation in non-rotating CRMs

- Domains ~200-1000km
- Aggregation typically begins with dry patch.

  Patch expands, feedbacks drive convection into isolated moist region.

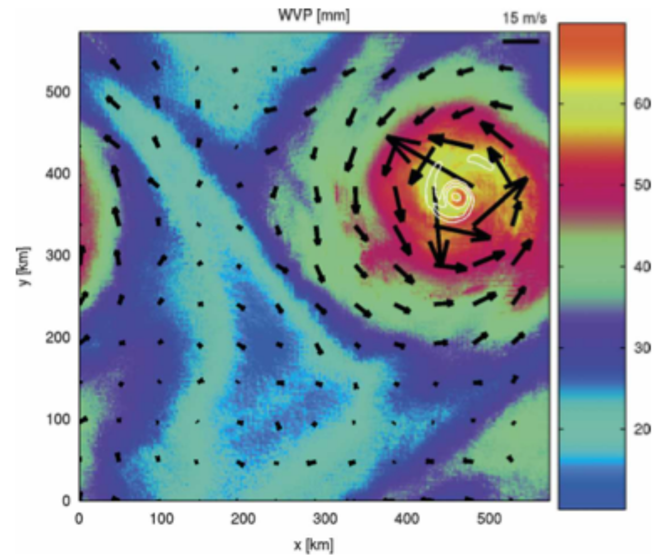



*Wing and Emanuel 2014*

- Processes important to aggregation:
  - Radiation interacting with clouds and moisture
  - Surface fluxes
  - Shallow circulation advecting MSE up-gradient

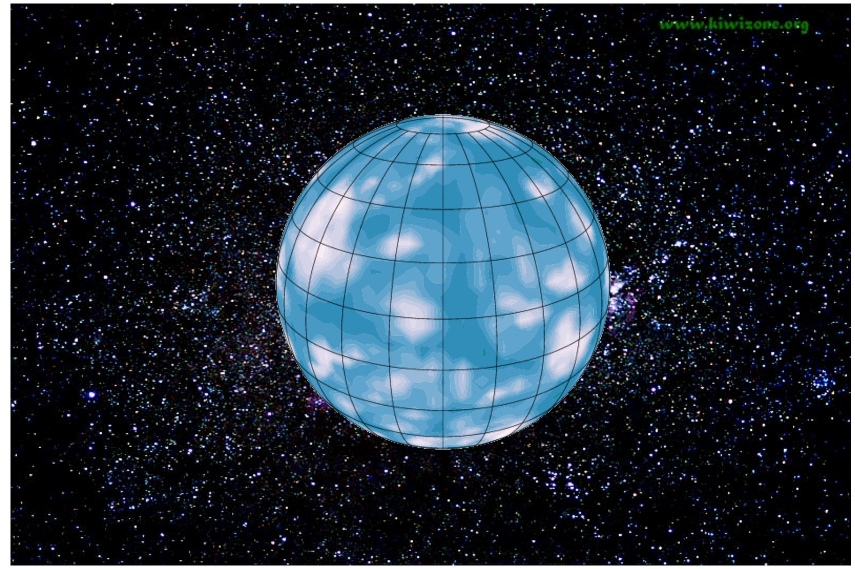
- Running on f-plane produces cyclones
  (Bretherton et al 2005; Khairoutdinov and Emanuel 2013)

  Is MJO aggregation on a beta-plane?




*Bretherton et al., 2005*

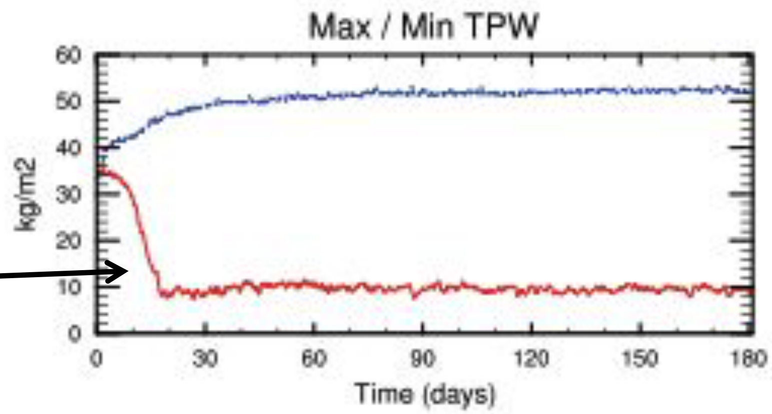
## Very idealized setup:
### A non-rotating sphere powered by starlight

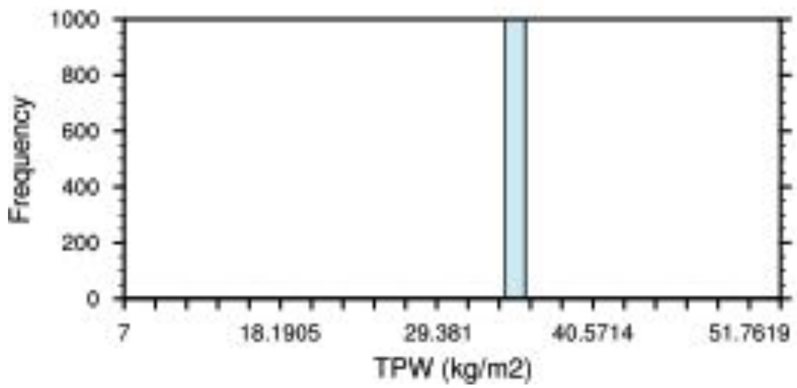


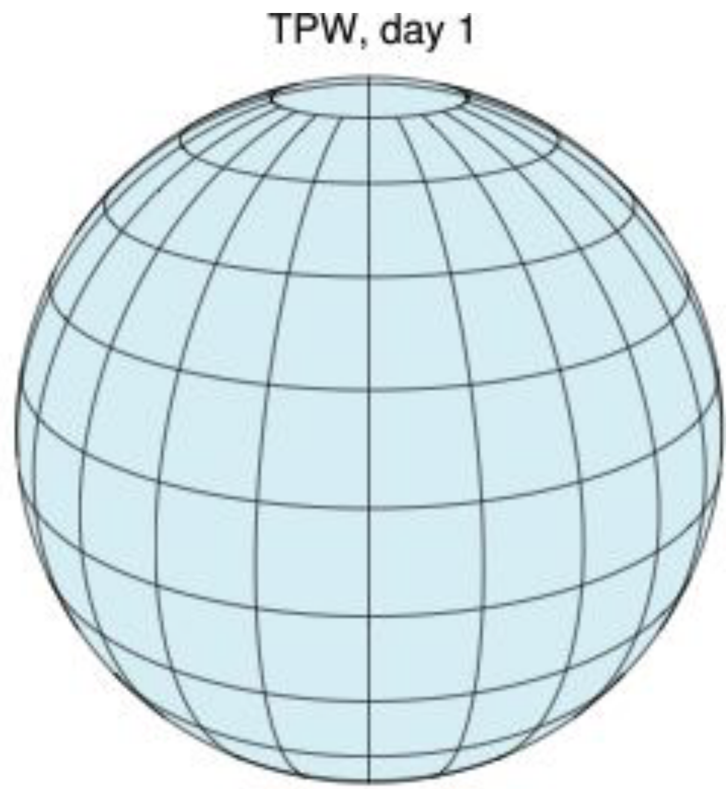

- Running SP-CAM3.0
    - SLD dycore, T42
    - CRM: 32x4km columns
- Make shortwave uniform:
  zenith angle = $50.5^{\circ}$, solar constant = $650.83 W/m^2$
  (following Bretherton et al 2005)
- SST uniform, fixed at $27^{\circ}$C
- No seasonal cycle or diurnal cycle.
- Initialized from uniform state (with random T perturbations)

# Aggregation from a uniform state of rest

Hints that dry regions form first?



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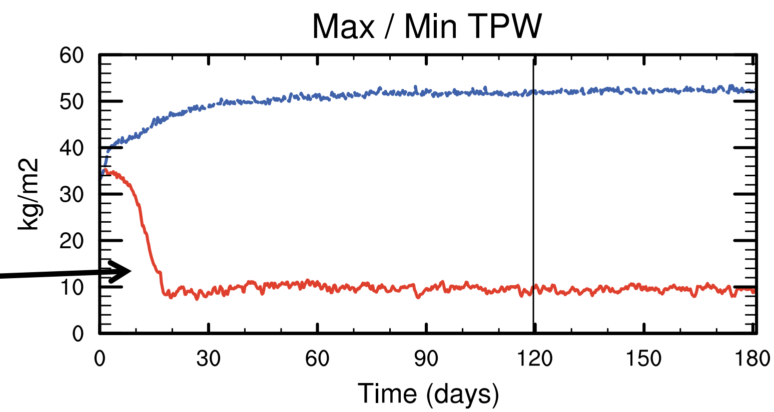
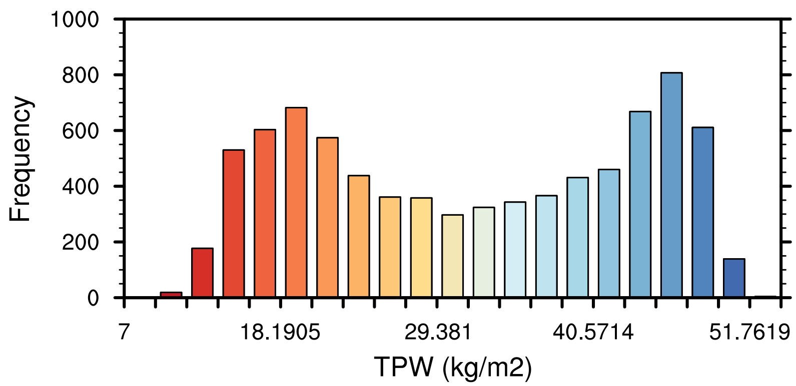
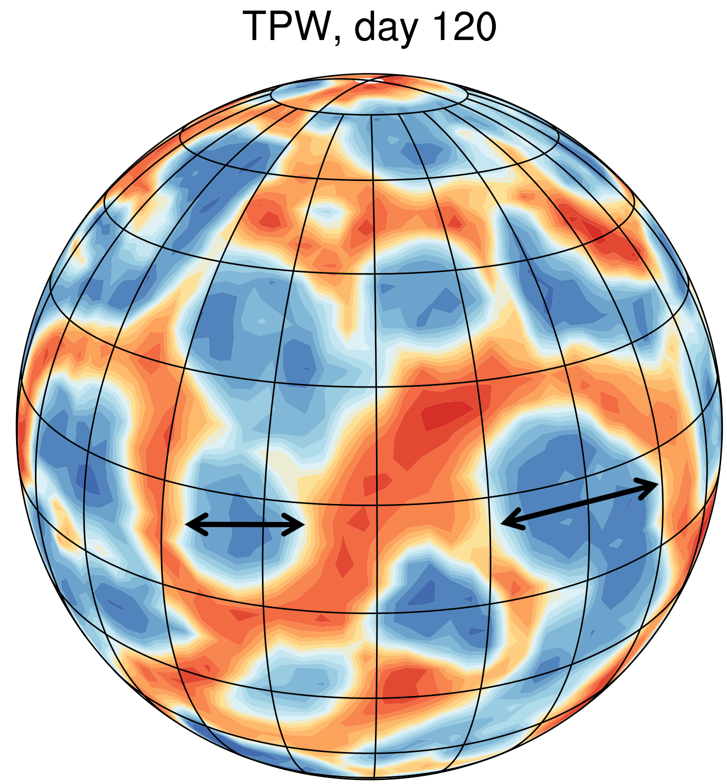


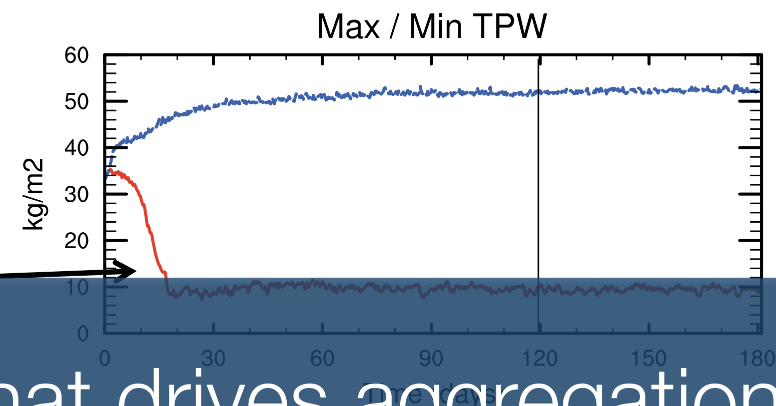




Distribution is strongly bi-modal.

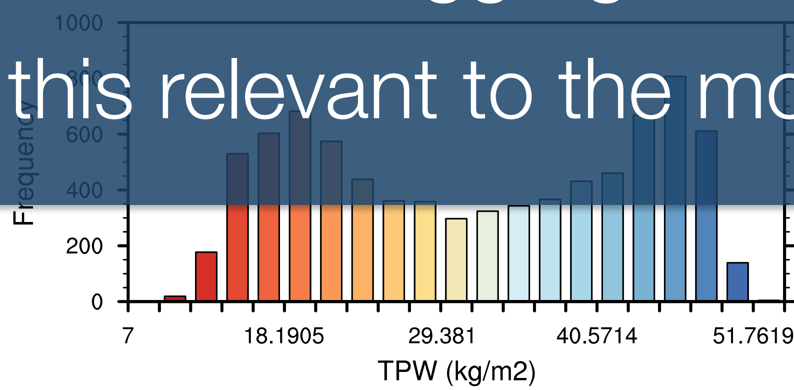



Moist regions are 2000-4000km across.

# Aggregation from a uniform state of rest




Hints that dry regions form first?





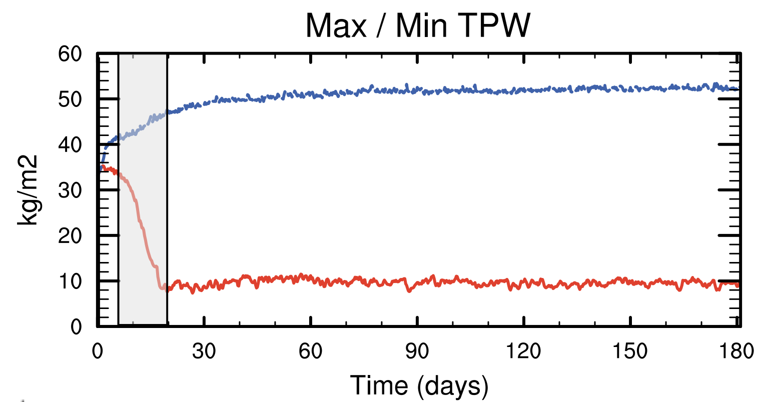
1) What drives aggregation? Same as in CRMs?

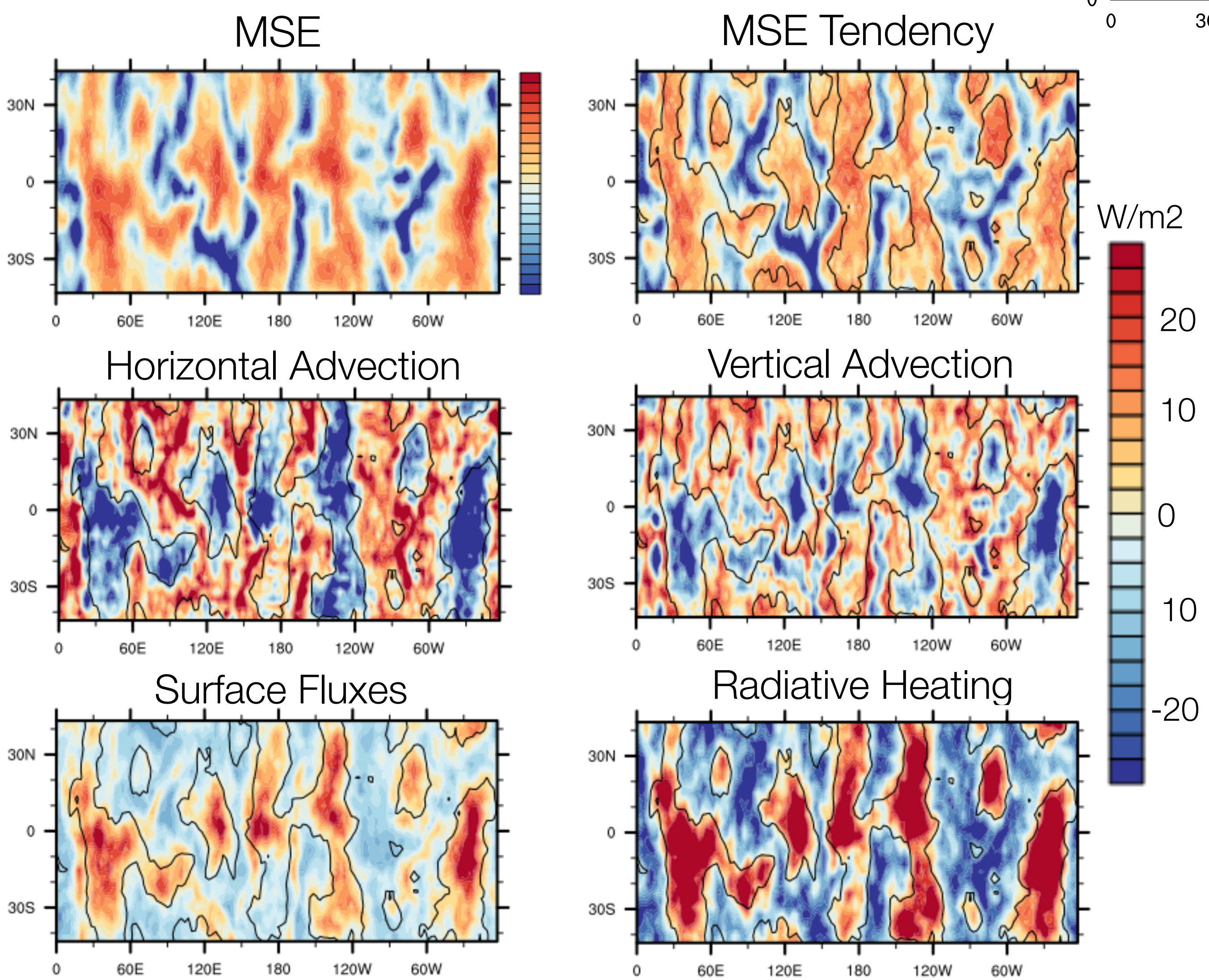
2) Is this relevant to the model's MJO?

Distribution is strongly bi-modal.

Moist regions are 2000-4000km across.

# Aggregation MSE Budget (days 5-20)



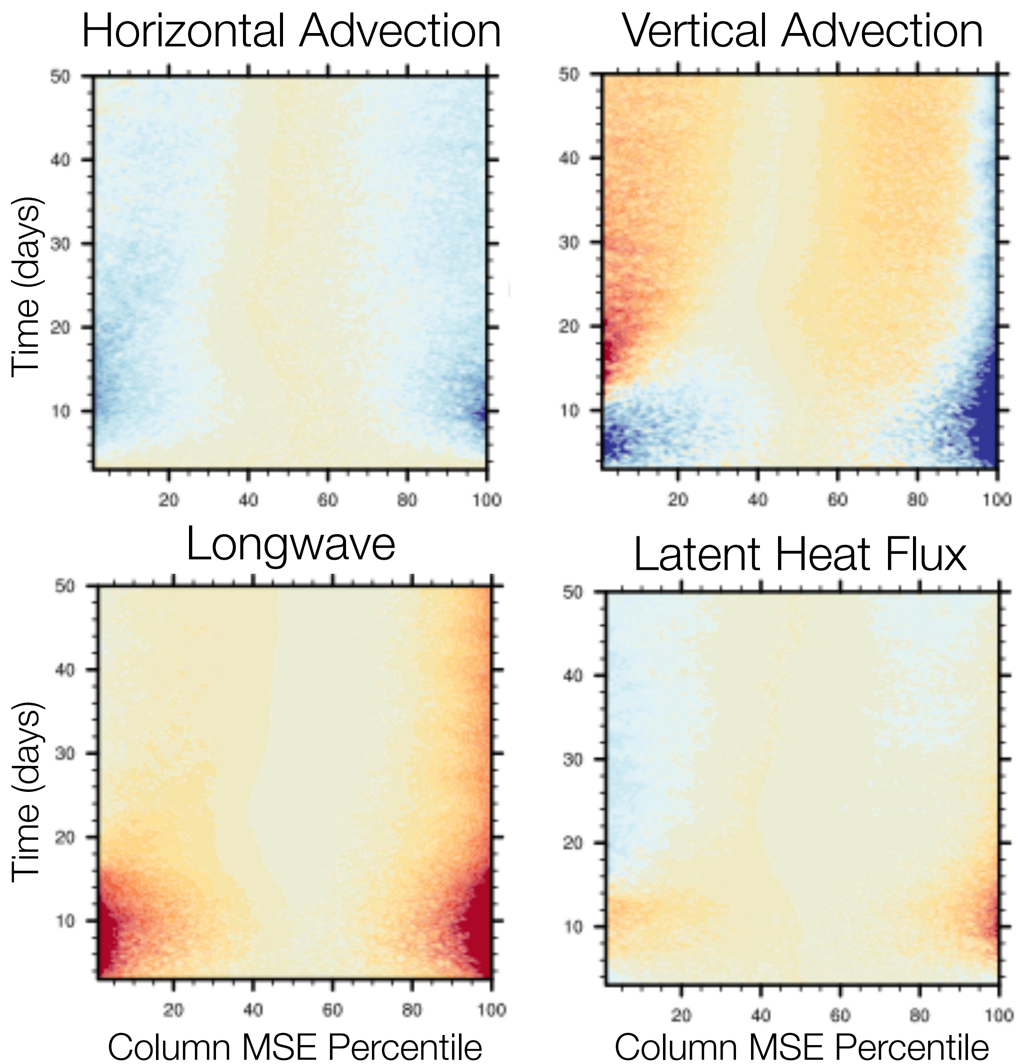

Initial aggregation driven by diabatic terms, opposed by advection.

# MSE Variance Budget, binned by column MSE

$$\frac{1}{2}\frac{\partial}{\partial t}h'^2 = LW'h' + ...$$

- Product of budget term and MSE anomalies = measure of anomaly growth rate due to term.
- At each timestep, sort into 100 bins, ranked by column MSE.
- Yields growth rates in time-moisture space.

Red = amplifies anomaly
Blue = weakens anomaly

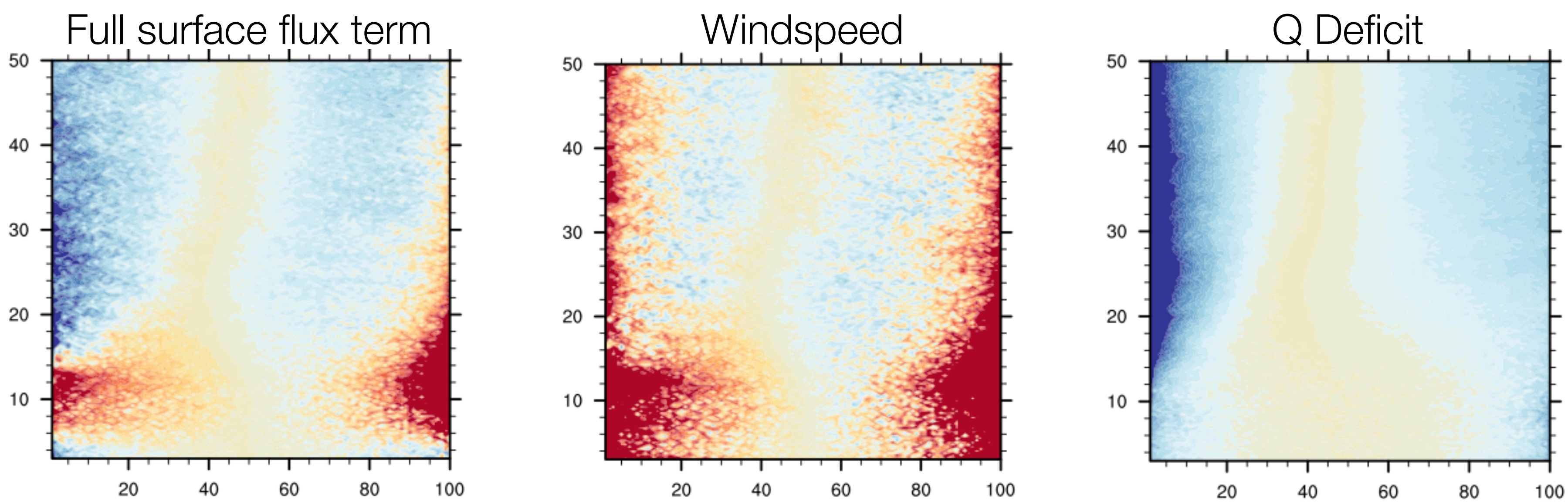



*Following Wing and Emanuel (2014)*

# Why does surface flux contribution reverse sign?

Decompose surface fluxes:

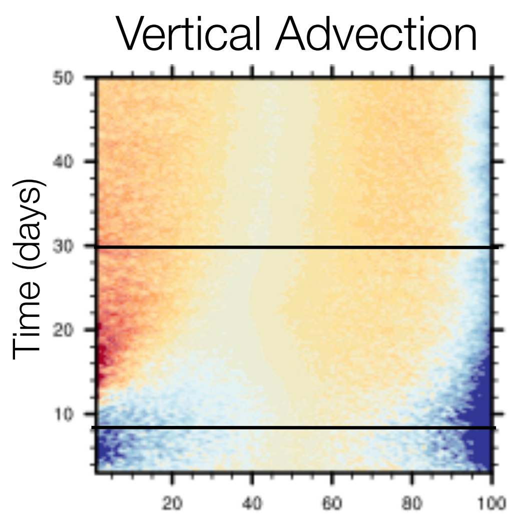
$$LHF = \rho_a C_E |\vec{v}|' \Delta q + \rho_a C_E |\vec{v}| \Delta q' + \rho_a C_E |\vec{v}|' \Delta q'$$




Two effects:

- Windspeed initially correlated with MSE, then anti-correlated after day 20.
- Surface air imbalance becomes smaller in moist region, larger in dry.

# Why does vertical advection contribution reverse?

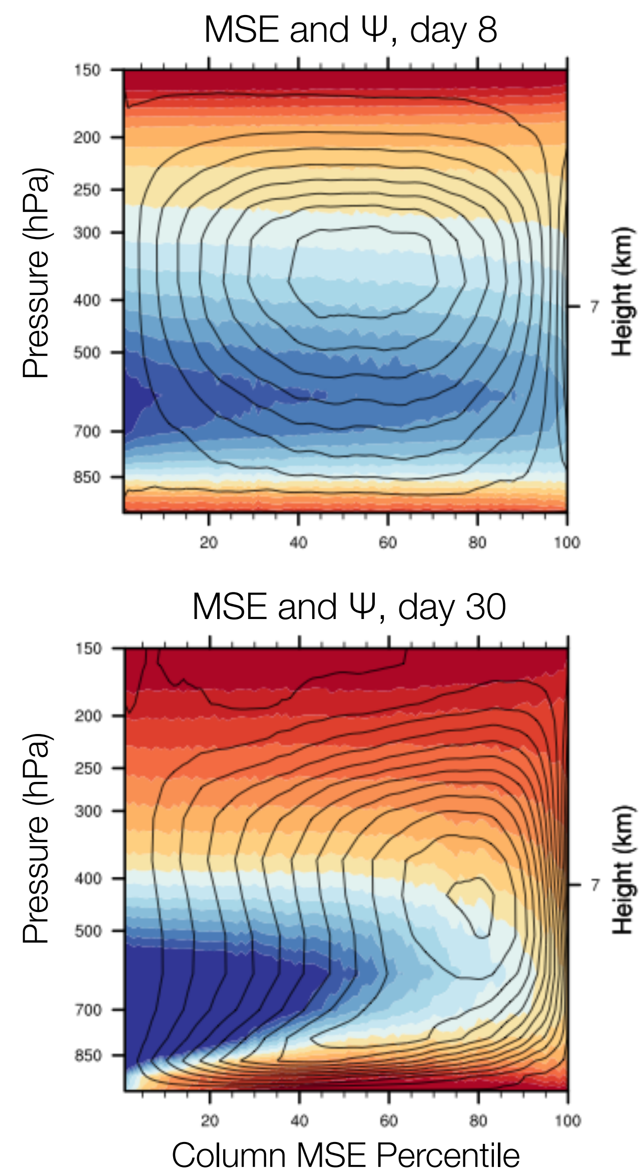



**Day 8:**
Top-heavy circulation, reduces MSE anomalies.

**Day 30:**
Dry-region subsidence more bottom heavy.

Shallow circulation provides up-gradient transport?

Similar to the mature-stage shallow circulation reported by Bretherton et al (2005) and others.



# Does inducing a zonal asymmetry cause moist regions to propagate?

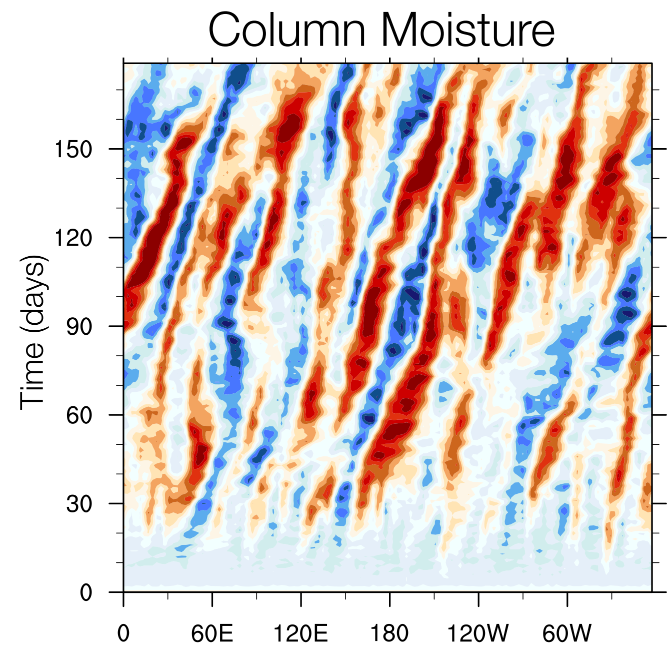
Artificial WISHE:

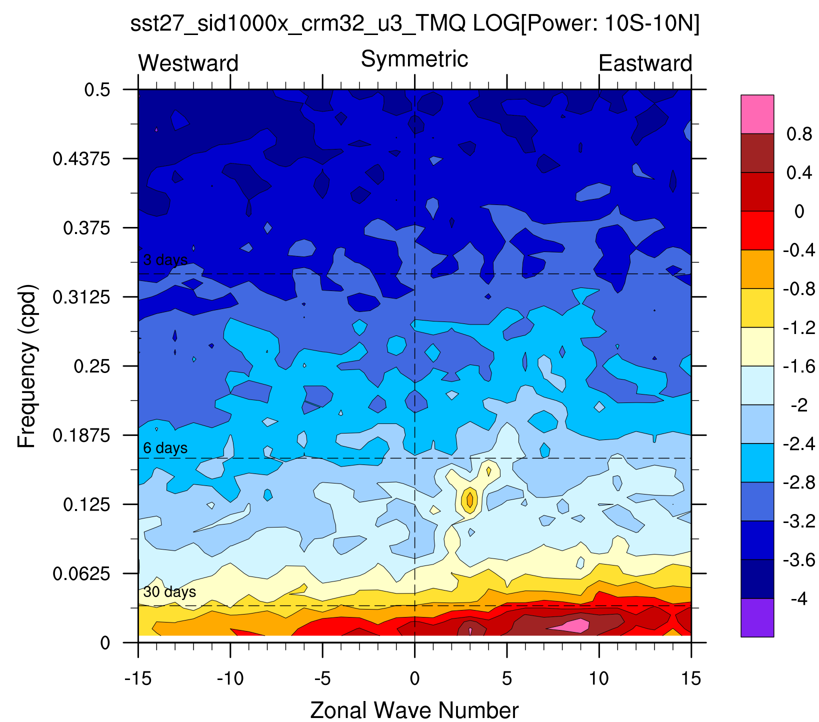
$$LHF = \rho_a C_E |\vec{v}| \Delta q$$

$$|v| = \sqrt{(u-3)^2 + v^2}$$

Add a phantom wind seen only by surface flux

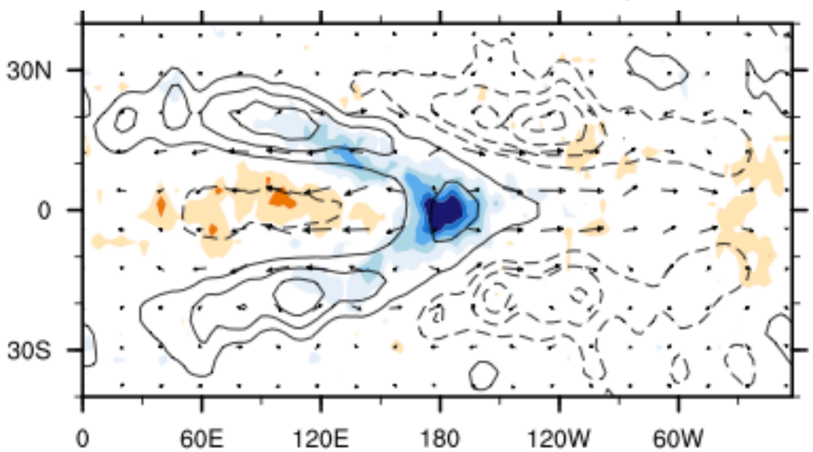
- Results in nice eastward movement (only 1m/s), broad spectral peak.
- Other processes required to capture correct zonal scale, faster propagation!



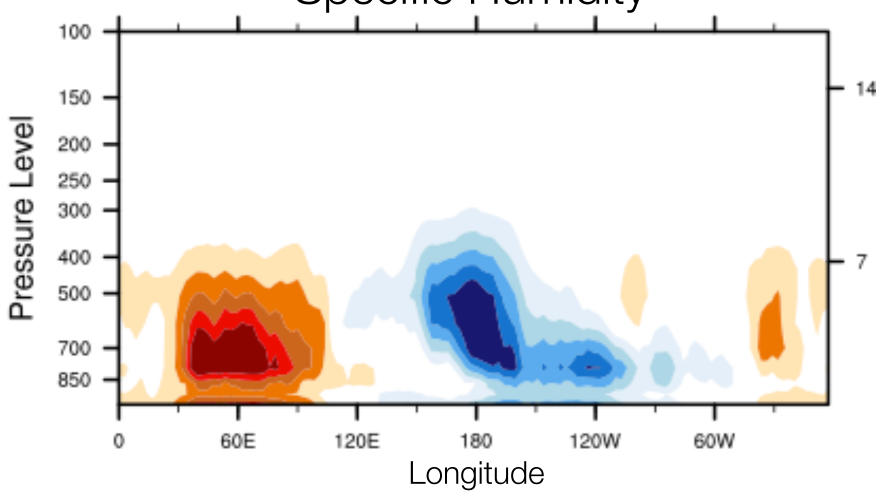



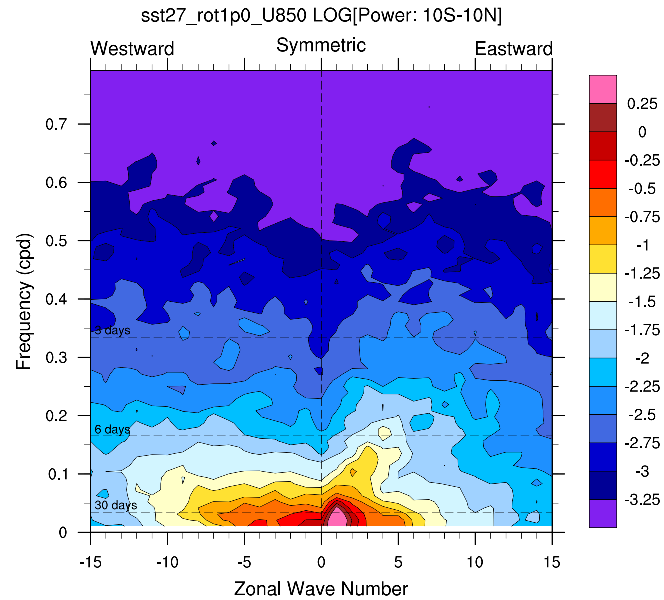
# Restoring rotation:
# Model produces a full "MJO"

200hPa Z and Precip

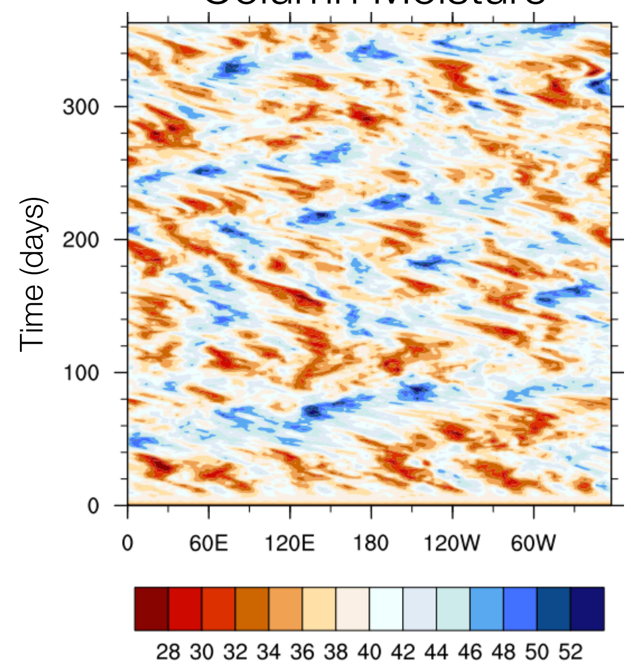



Specific Humidity

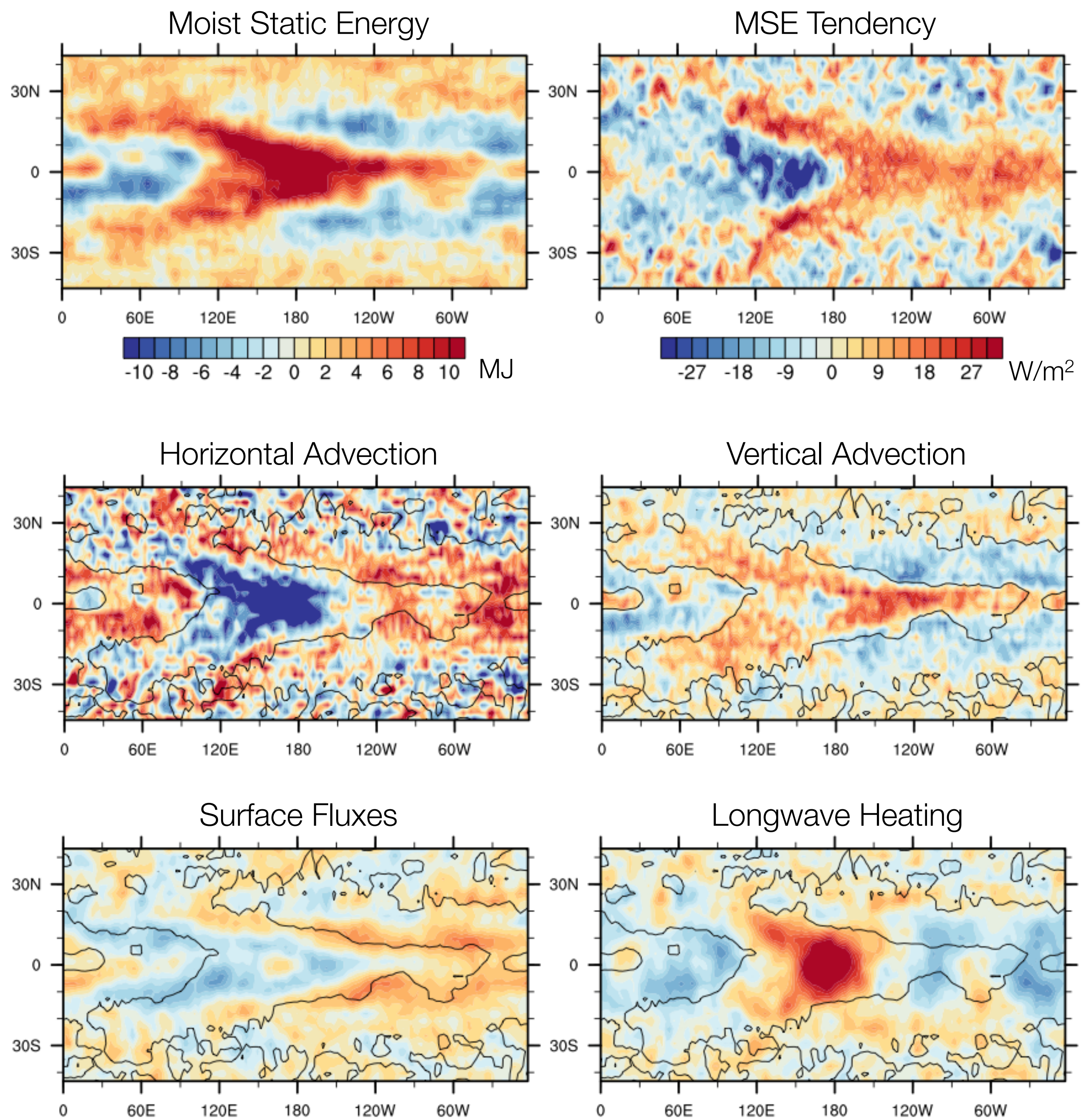



Column Moisture



# MJO’s MSE budget similar to other studies




- Supported by longwave.
- Damped by horizontal advection.
- Propagation by surface fluxes and advection.
- Surface fluxes unrealistic:
  Lack of gustiness
  Mean easterly winds

# Conclusions

- Convection spontaneously aggregates in globally uniform simulations with SP-CAM3.0, reminiscent of aggregation in CRMs.
- MSE budget suggests the SP-CAM aggregation is driven by similar processes:
    - Initially diabatically-driven by radiation (LW) and surface fluxes.
    - Shallow circulation develops and supports aggregated state.
- Adding artificial WISHE produces a zonal asymmetry which causes the moist anomalies to propagate eastward.
- When rotation is added the model produces an MJO, with an MSE budget similar to the aggregated state.
- More work is needed to solidify the connection, but this is consistent with the MJO being a form of aggregation on a β-plane.