

# Resilience of an explicitly simulated MJO to extreme basic state variation challenges a moisture mode view

Mike Pritchard<sup>1</sup> and Da Yang<sup>2</sup>



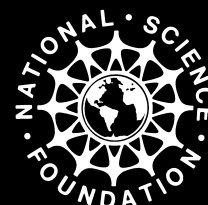
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<sup>2</sup> Dept. of Earth & Planetary Science, University of California, Berkeley



## Funding

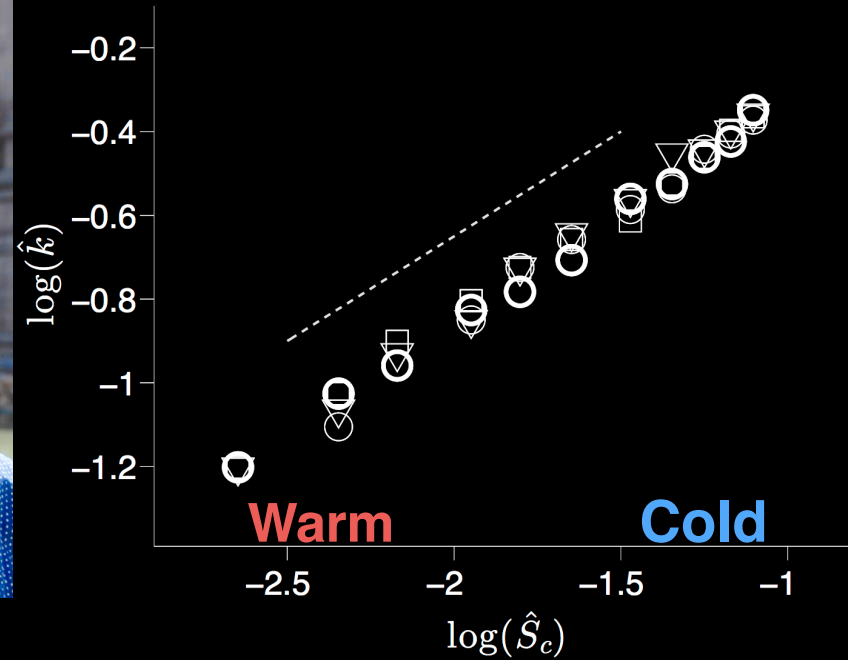
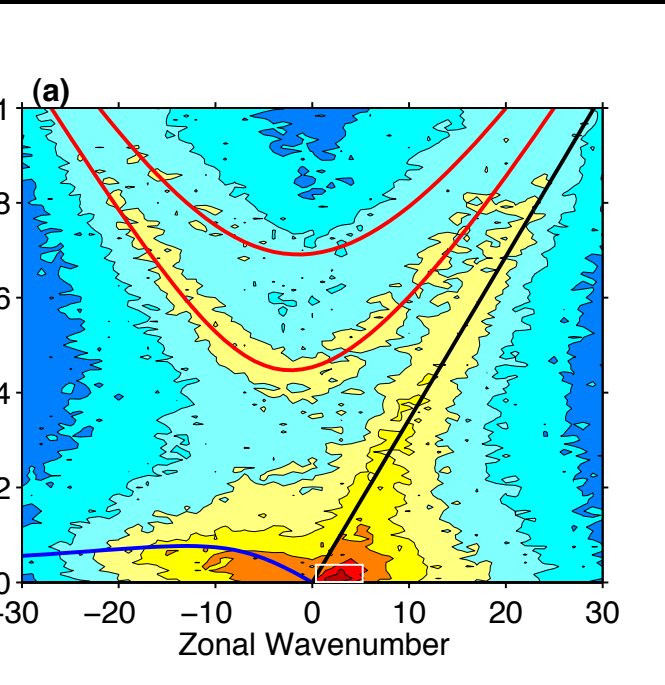


DOE Early Career & SciDac programs  
NSF Climate & Large Scale Dynamics  
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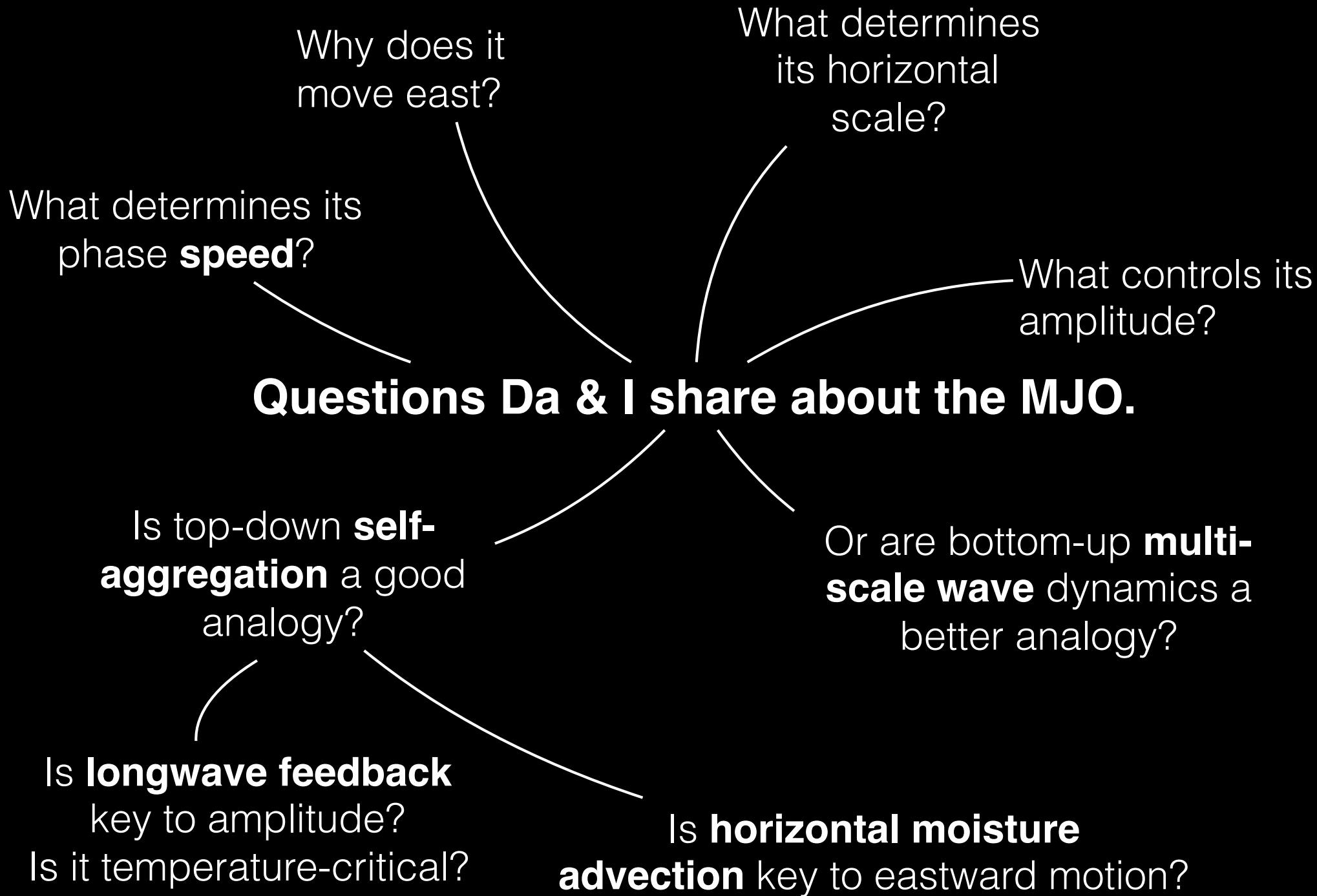
The Adolph C. and Mary Sprague  
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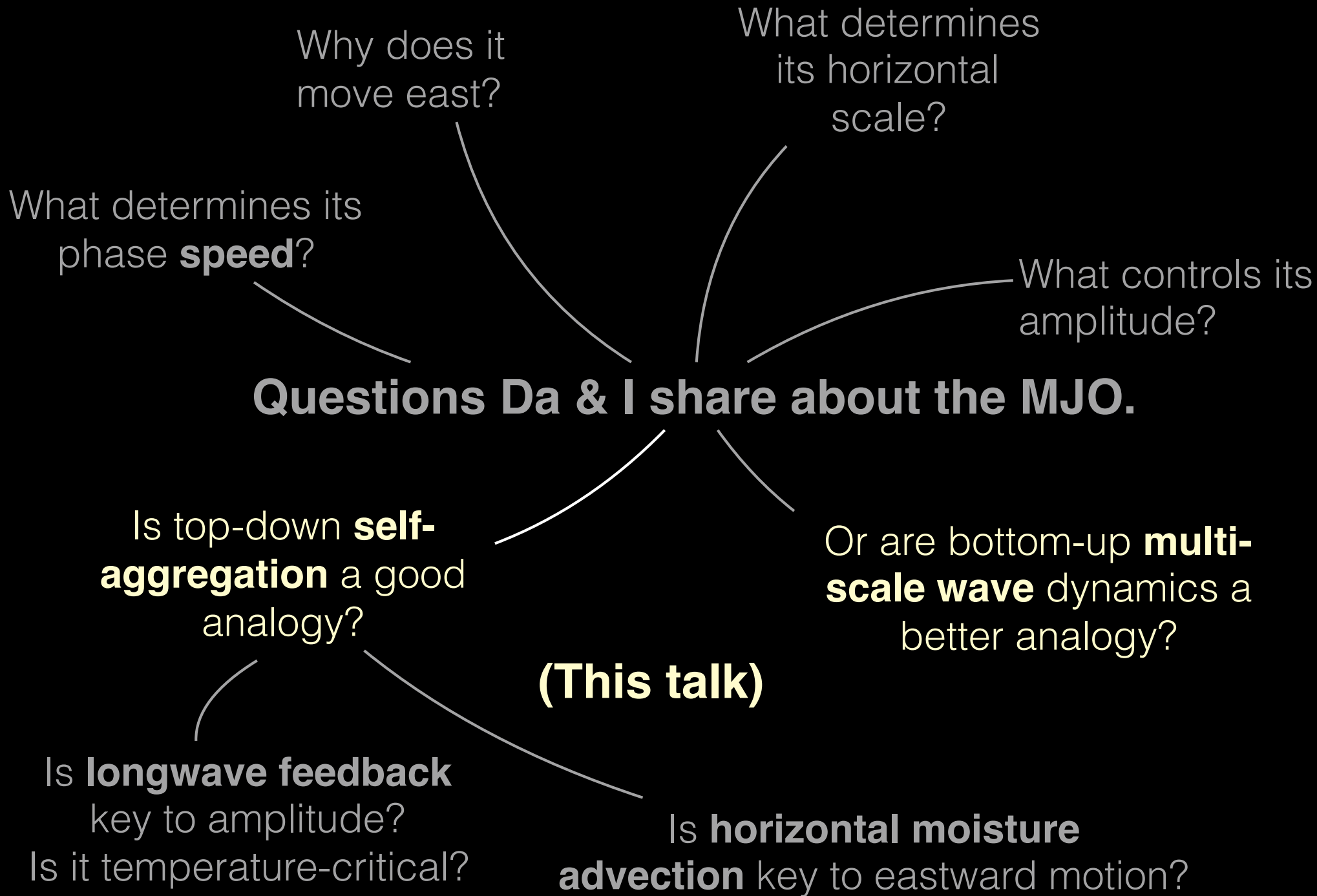
# Acknowledging Da Yang



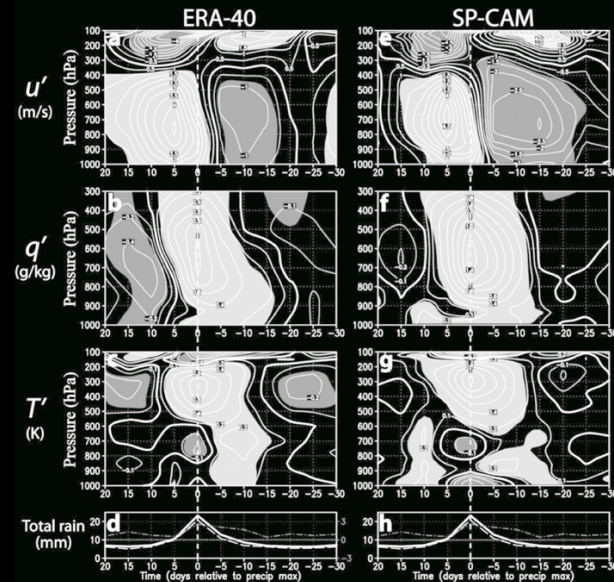
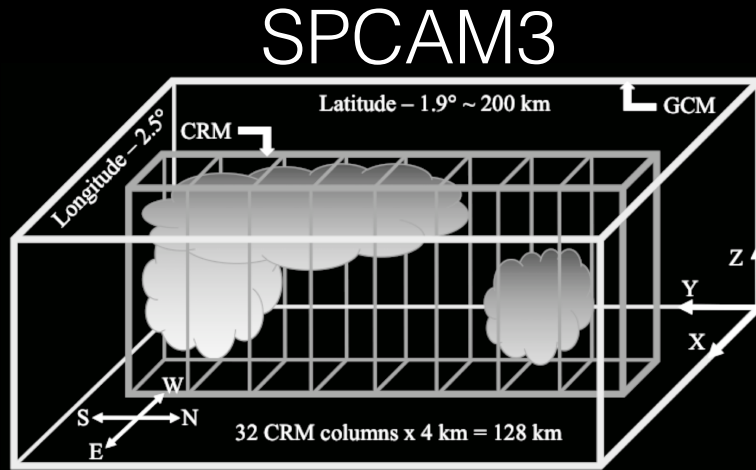
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Miller Research Fellow  
UC Berkeley

Yang and Ingersoll 2013, *JAS*  
Yang and Ingersoll 2014, *GRL*





# Strategy: Apply a model with a realistic MJO...



Benedict & Randall (2009)

... in an unusual basic state.

Aquaplanet

Nocturnal

Globally uniform SSTs

**Then vary climate extremely.**



*Yang and Pritchard, in review*  
*Pritchard and Yang, in review*

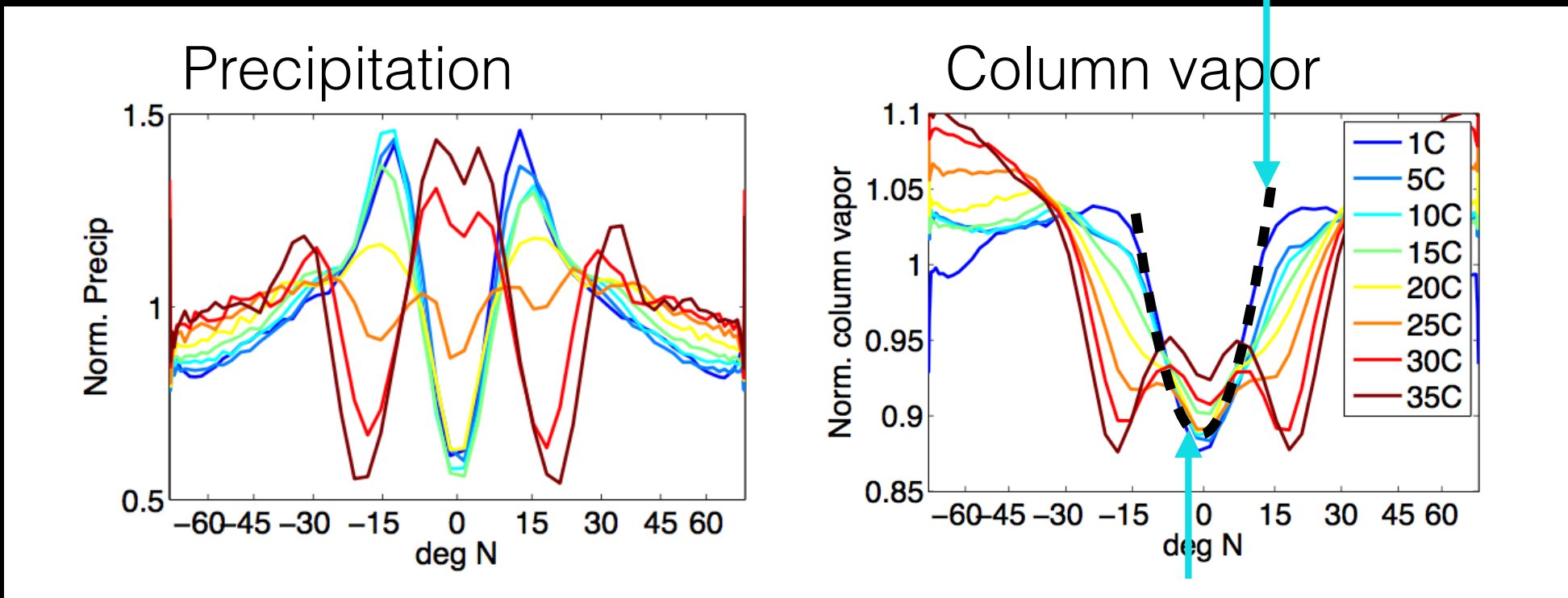
An exotic basic state.



# Zonal mean precipitation and column vapor



Meridional MSE gradients are reversed for SST < 25C



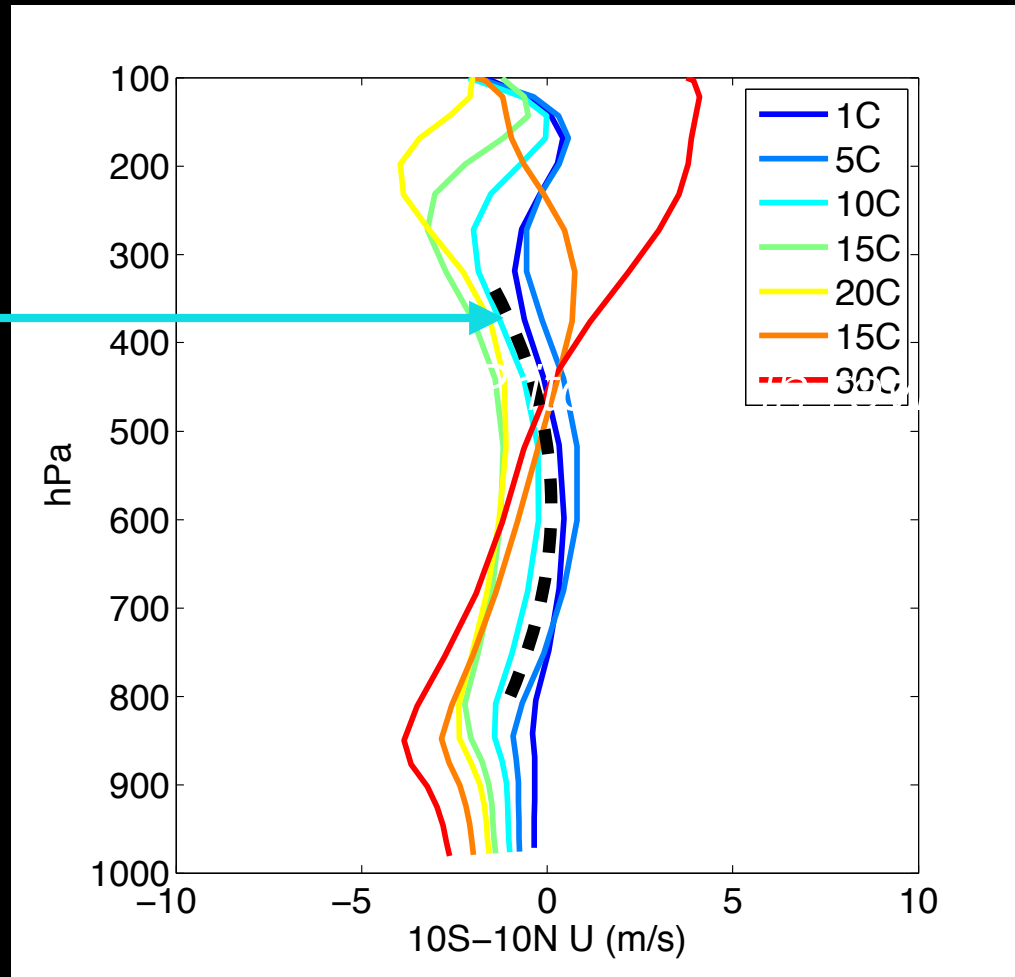
*Pritchard and Yang, in review*

.. equatorial vapor deficit



# 10S-10N zonal mean zonal wind profile

Vertical shear is very weak for SST < 25 C



*Pritchard and Yang, in review*



## Question

Should an MJO survive  
the effects of extreme cooling at constant SST?

*My expectation:*

**No.**

If the MJO is a form  
of planetary  
scale self-agg...

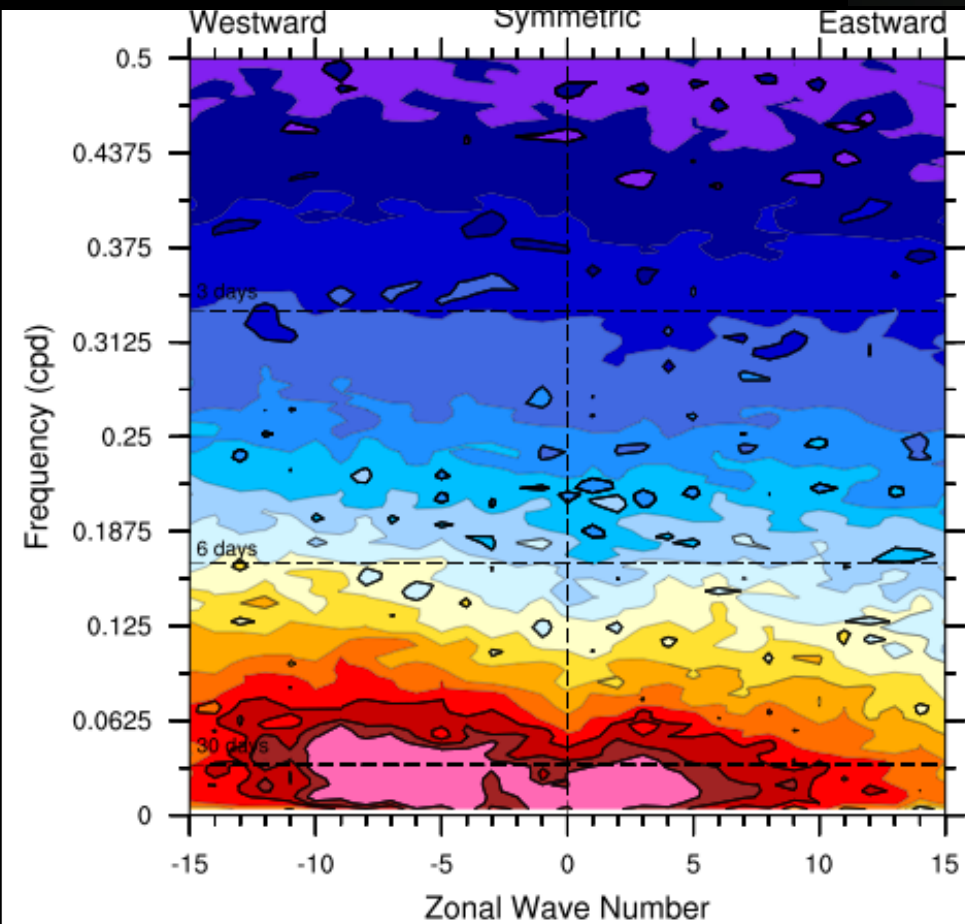
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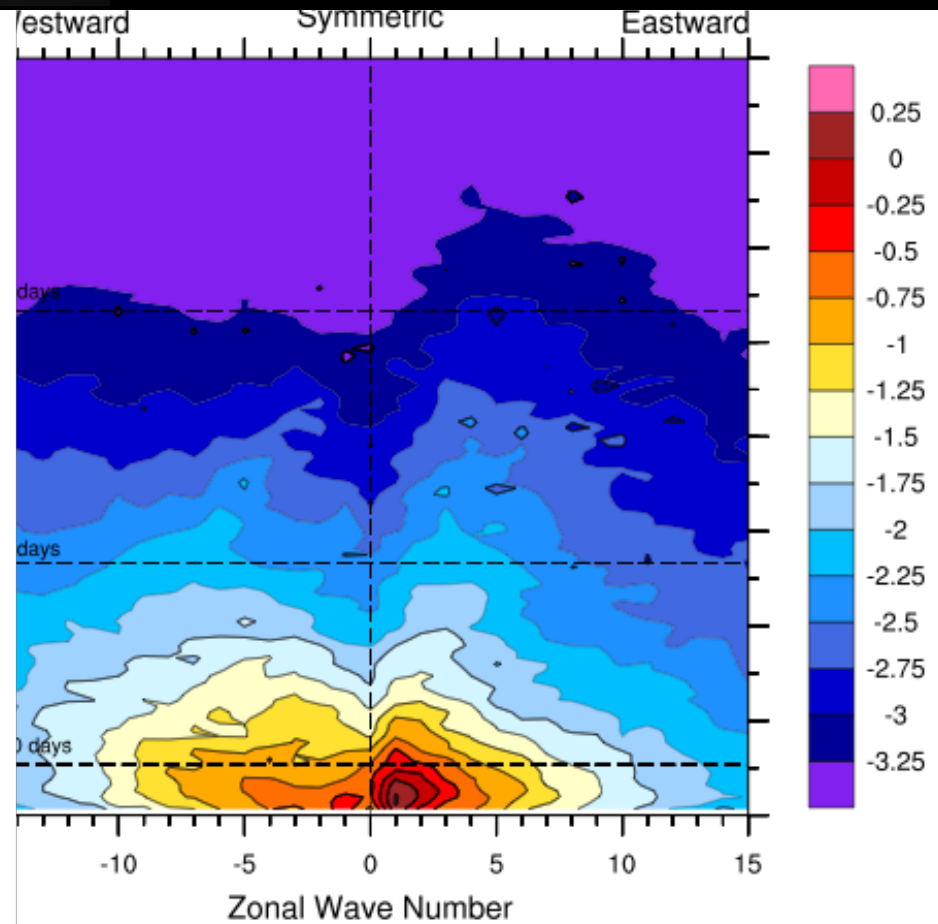
# Resilience of the MJO



*Pritchard and Yang, in review*

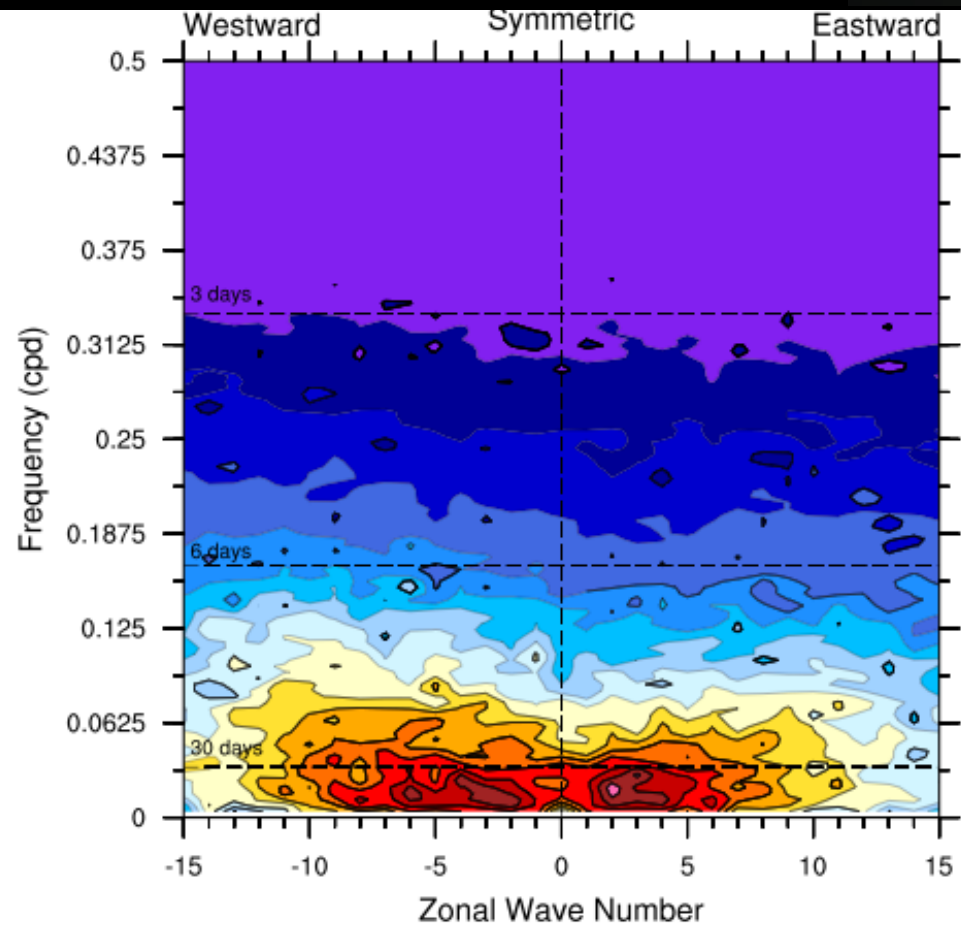


**Precipitation**

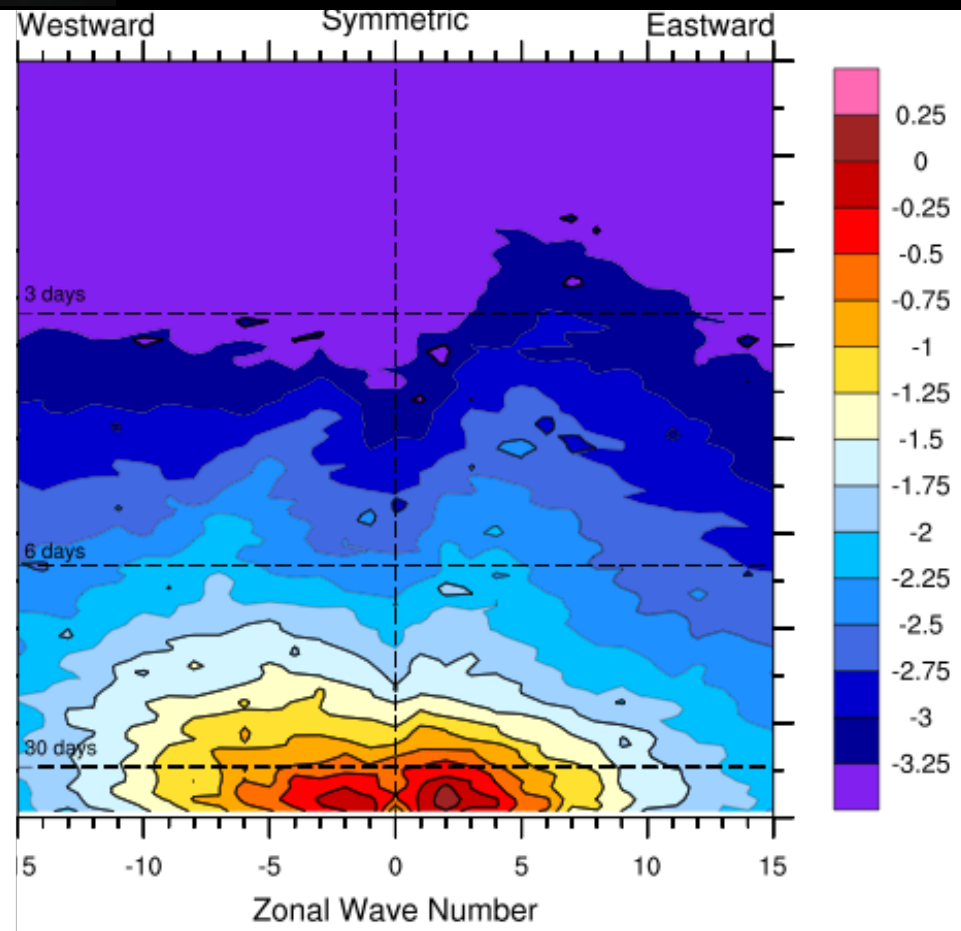


**850 hPa zonal wind**

10S-10N Wheeler-Kiladis equatorially symmetric wave spectra.

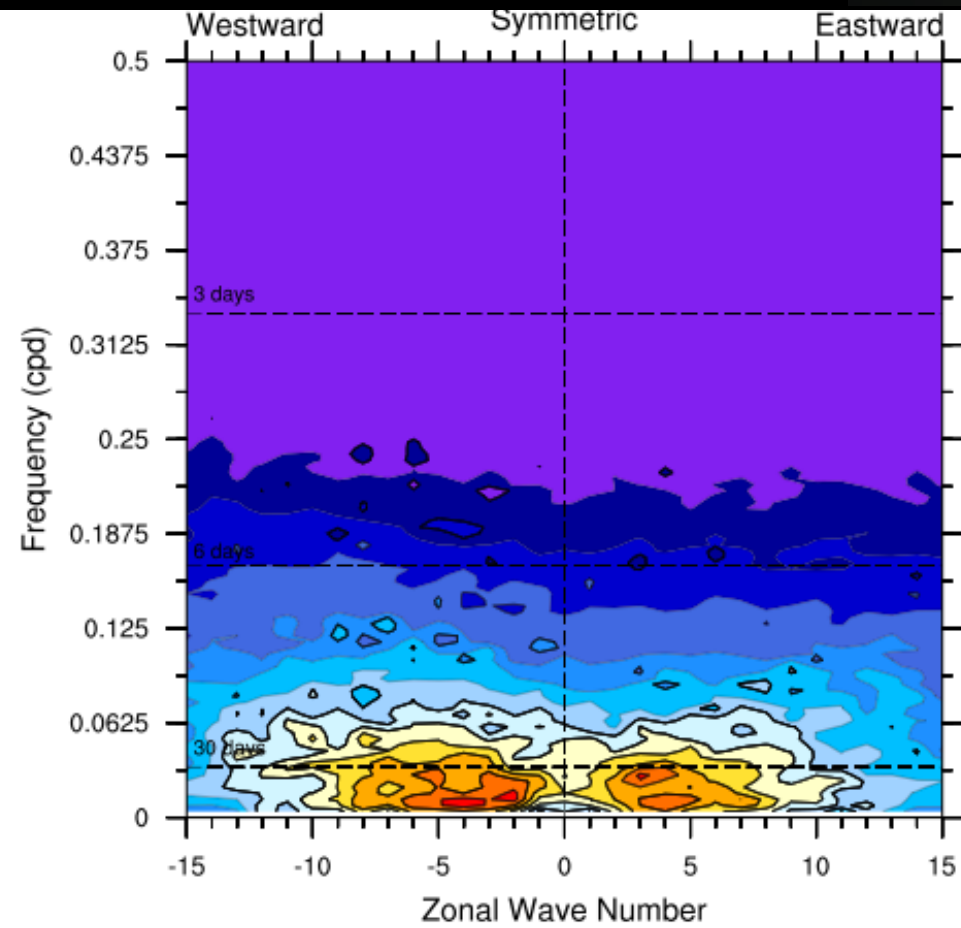


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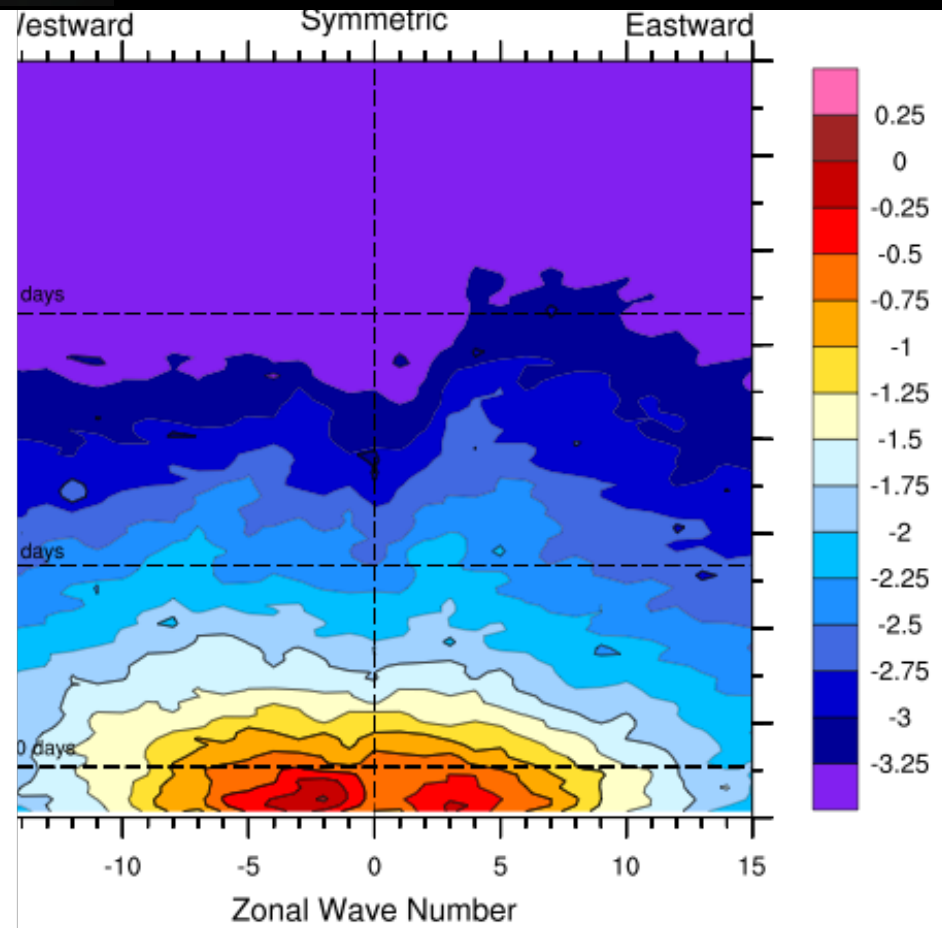


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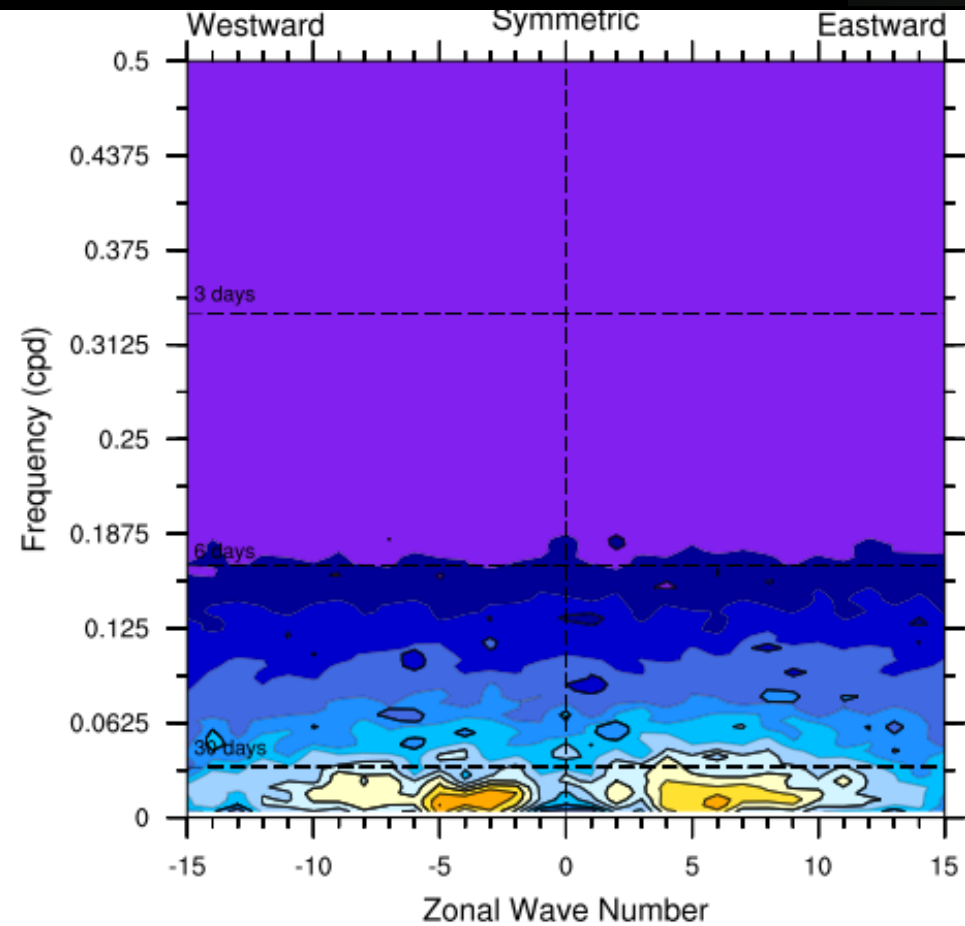


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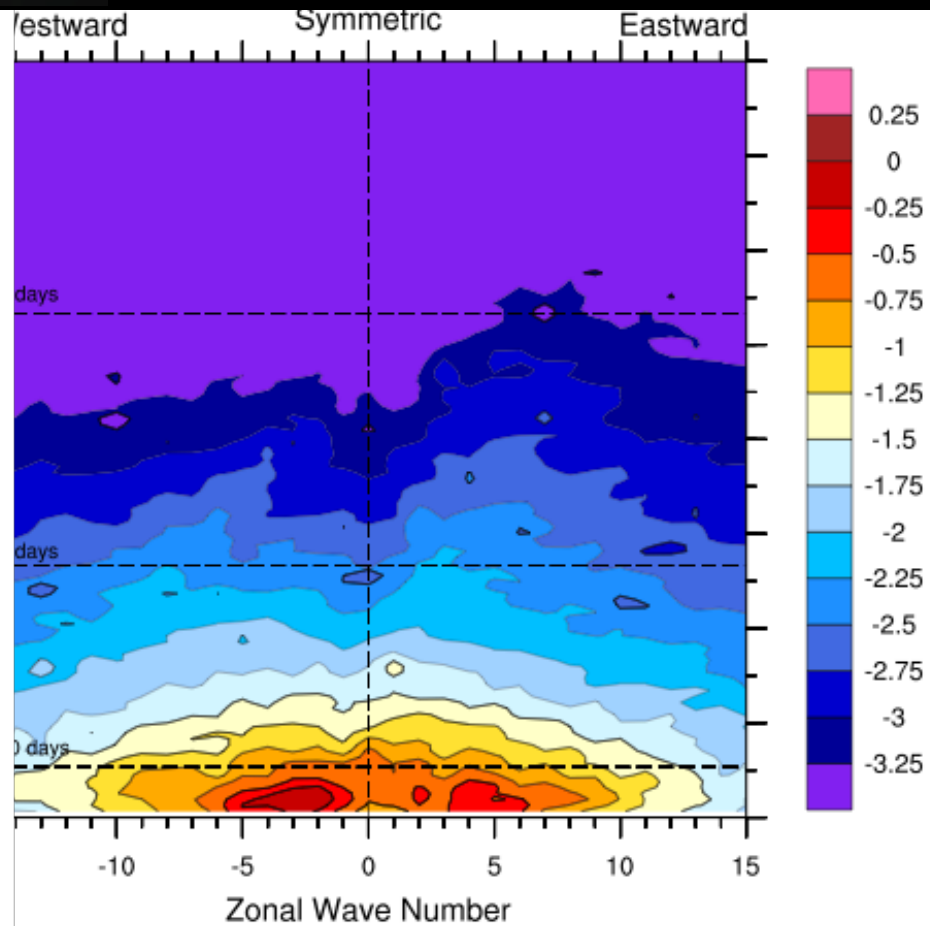


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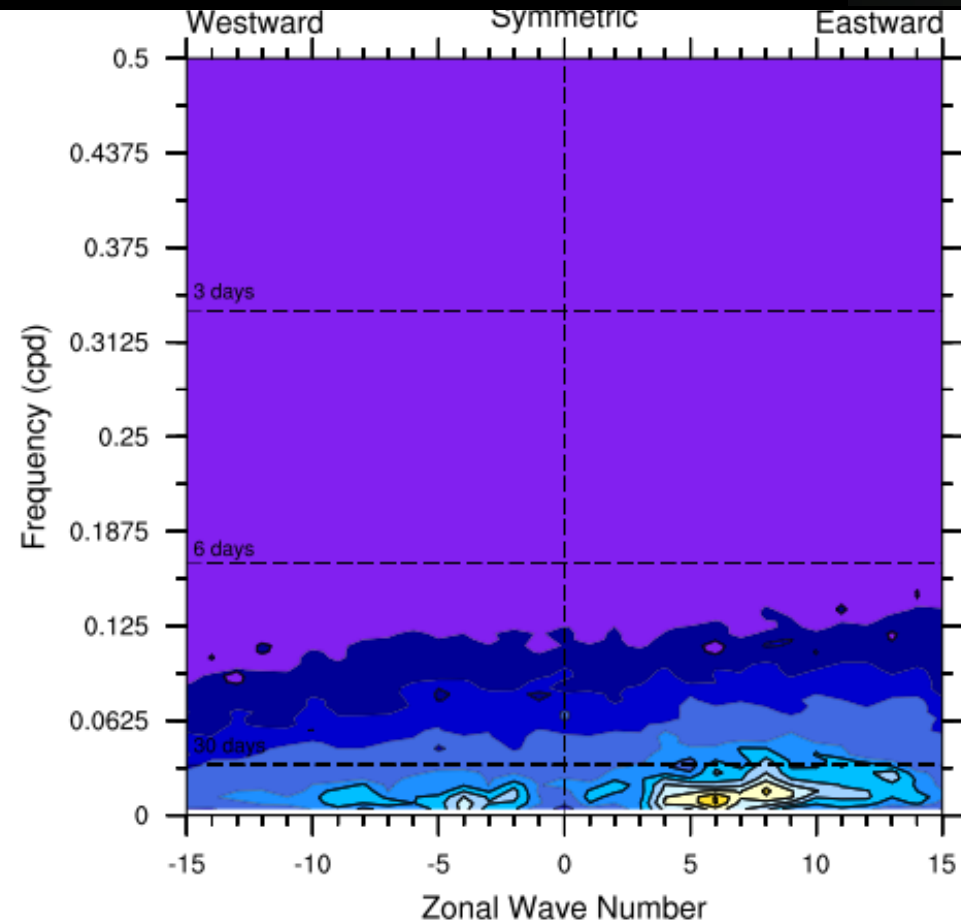
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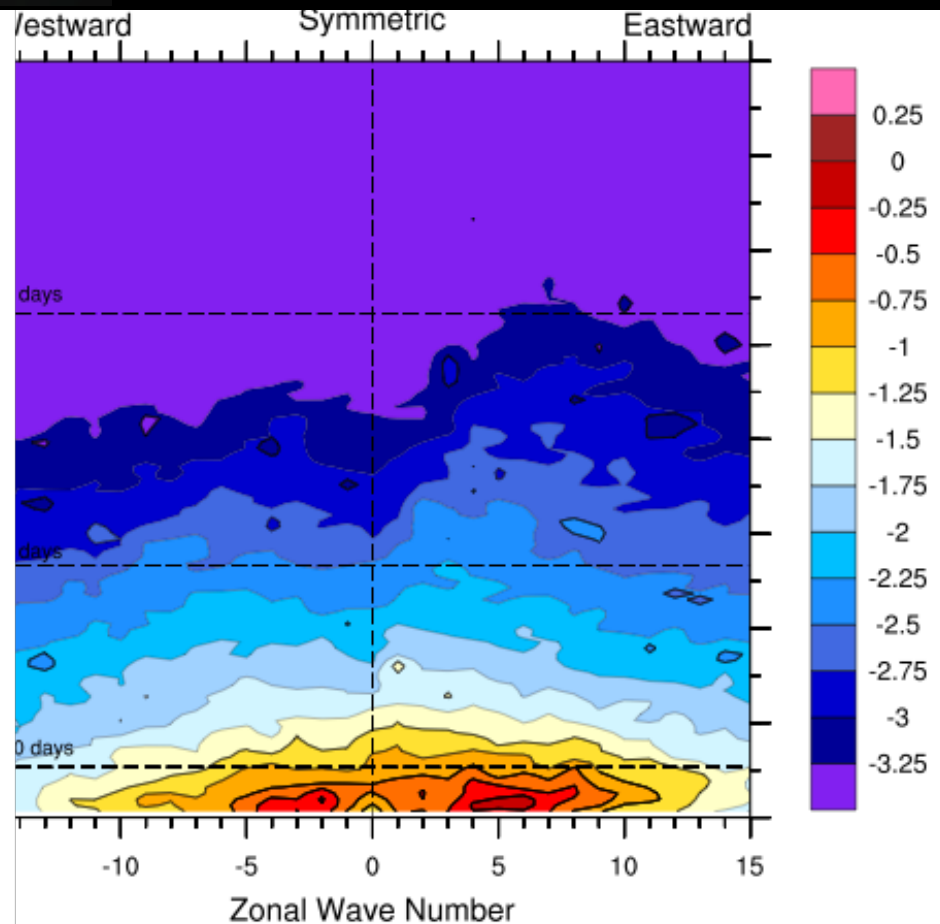
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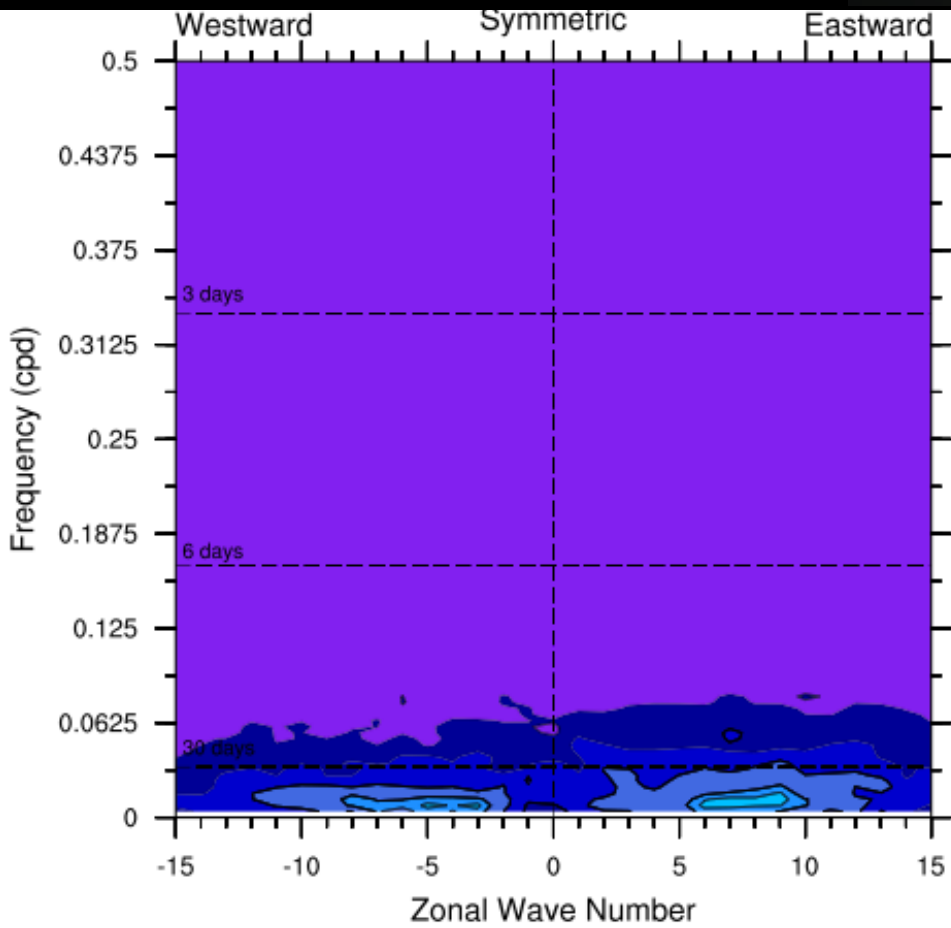


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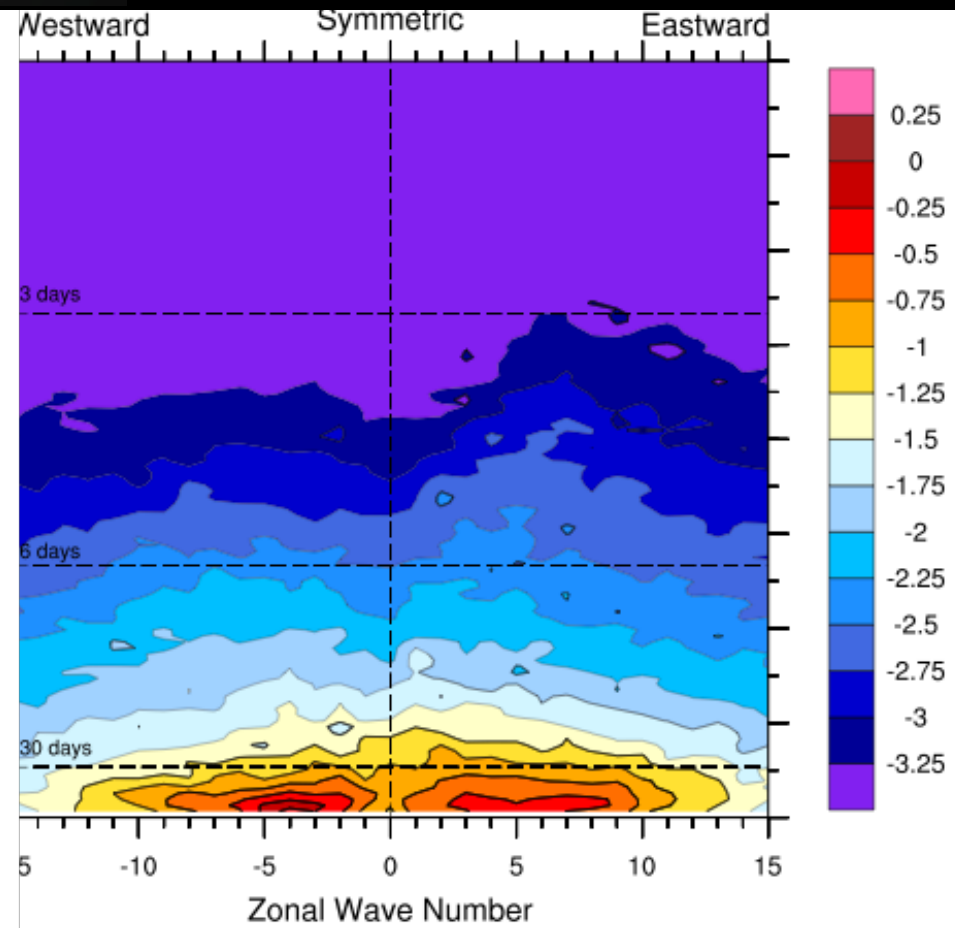


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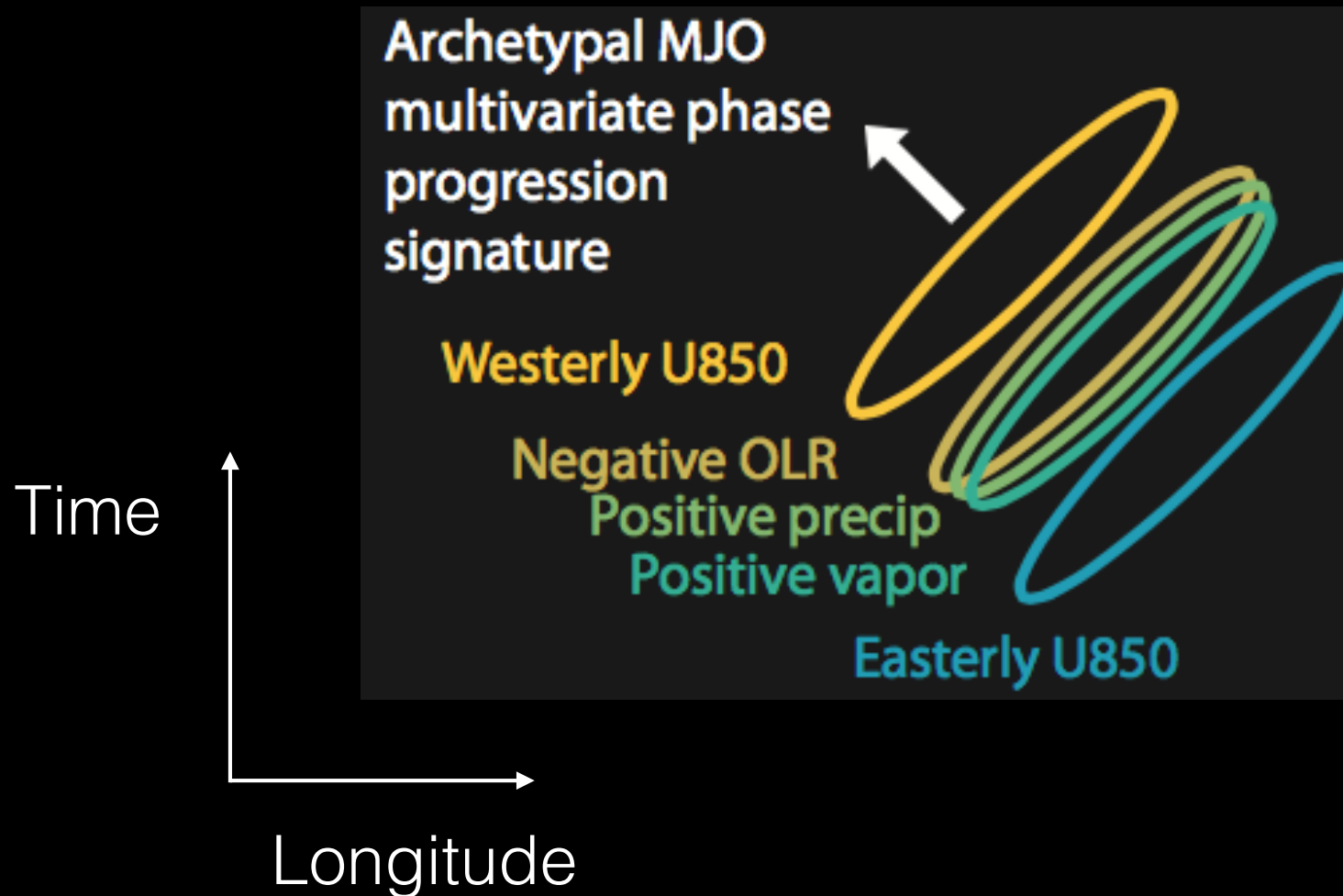


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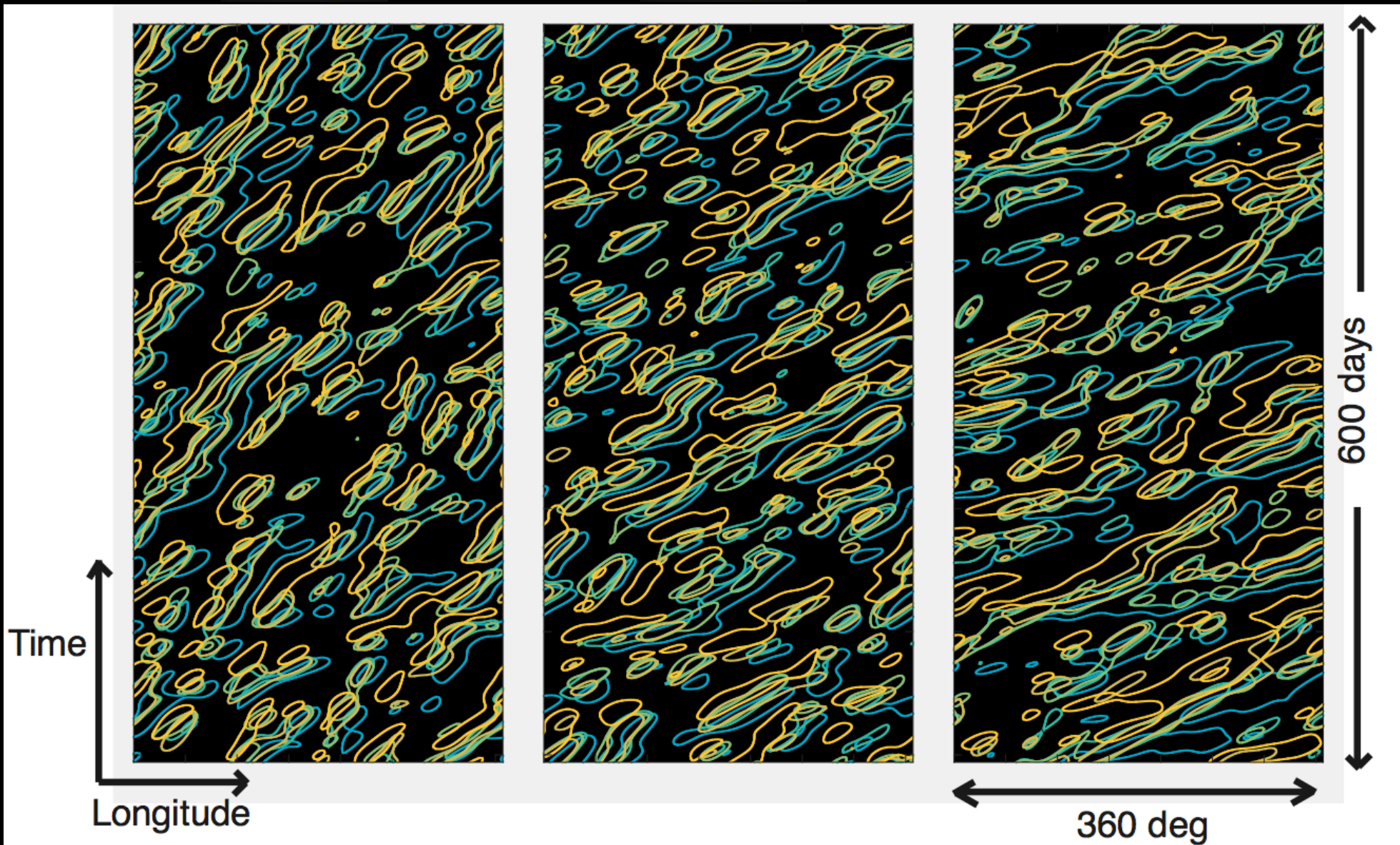
10S-10N Wheeler-Kiladis equatorially symmetric wave spectra.

Does the mode have an MJO-like dynamic structure?

# MJO-like multivariate phase relationships.



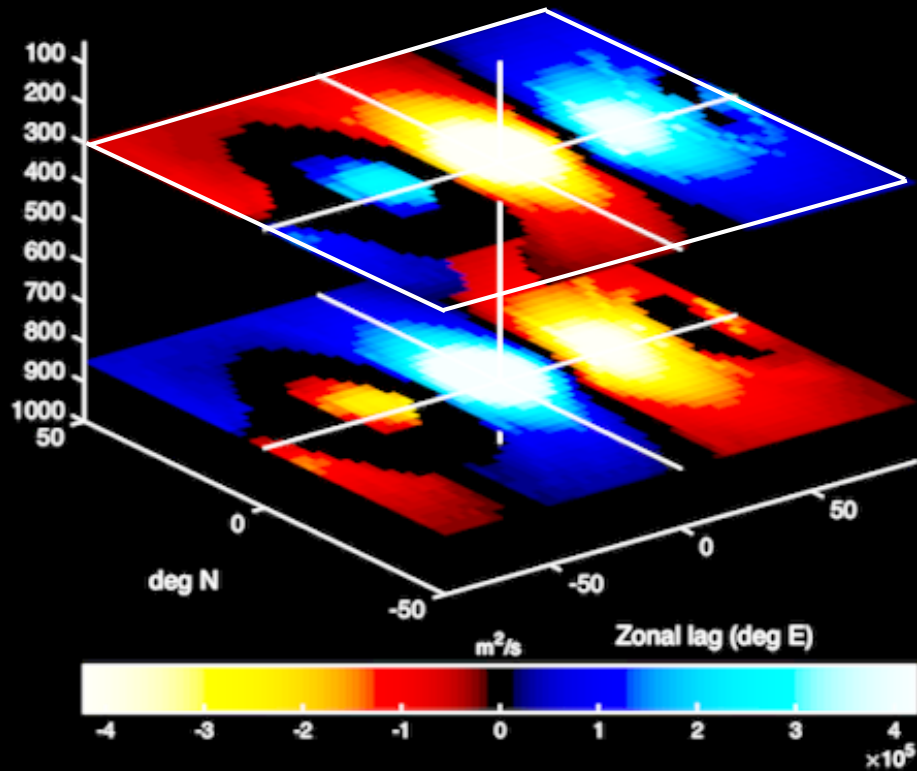
# MJO-like multivariate phase relationships.



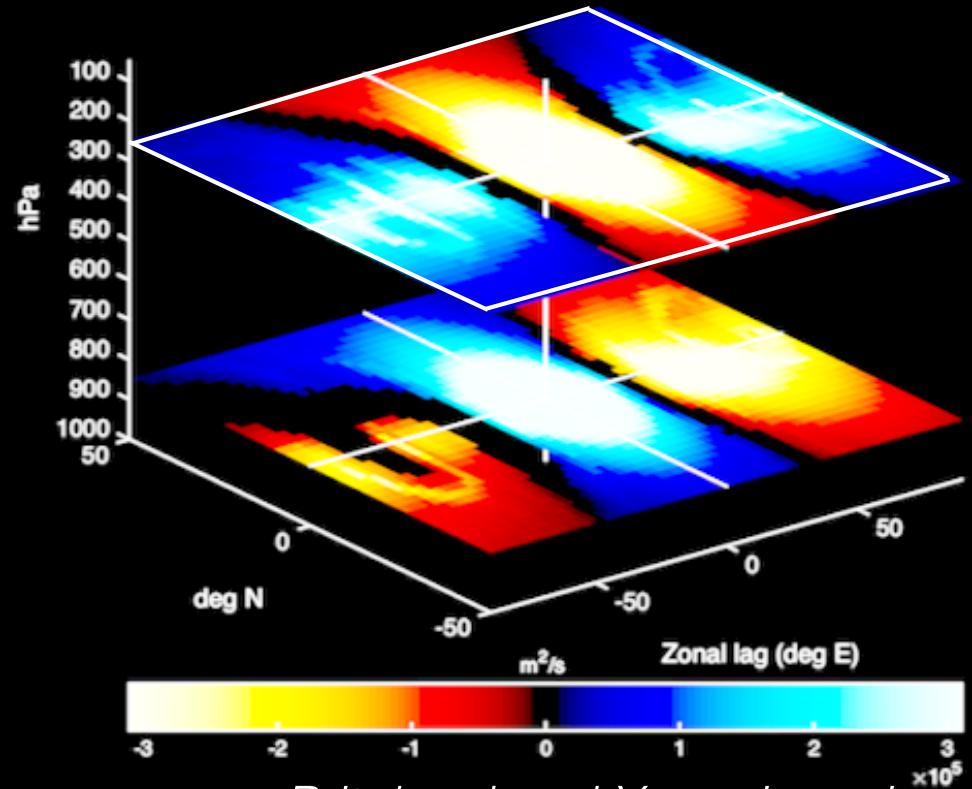


# MJO-like dynamical structure.

a) VP SST=1C



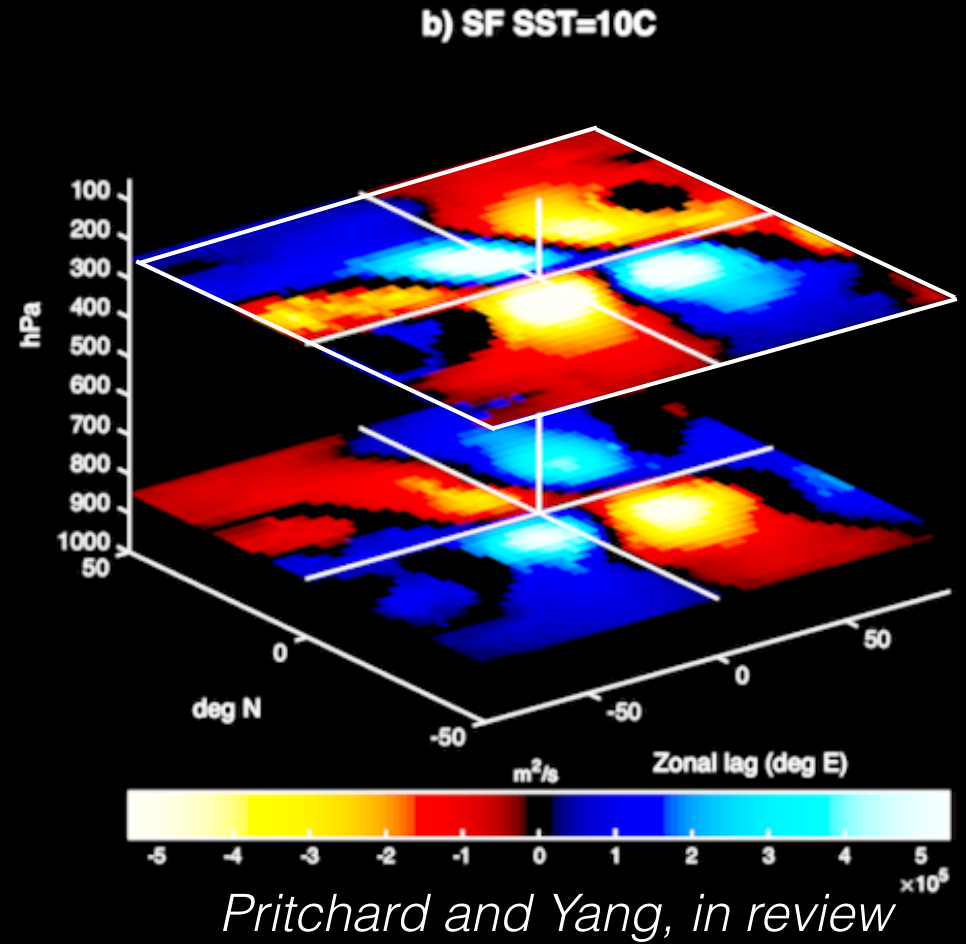
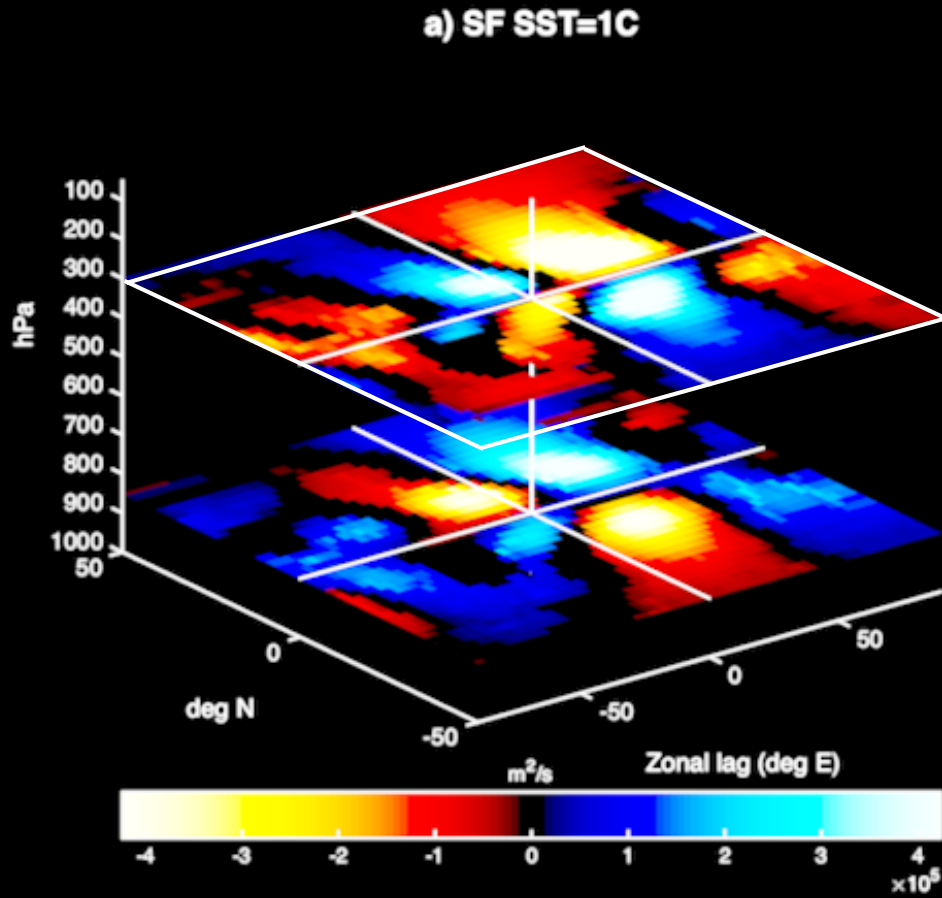
b) VP SST=10C



*Pritchard and Yang, in review*

Central vertically antiphase velocity potential dipoles.

# MJO-like dynamical structure.

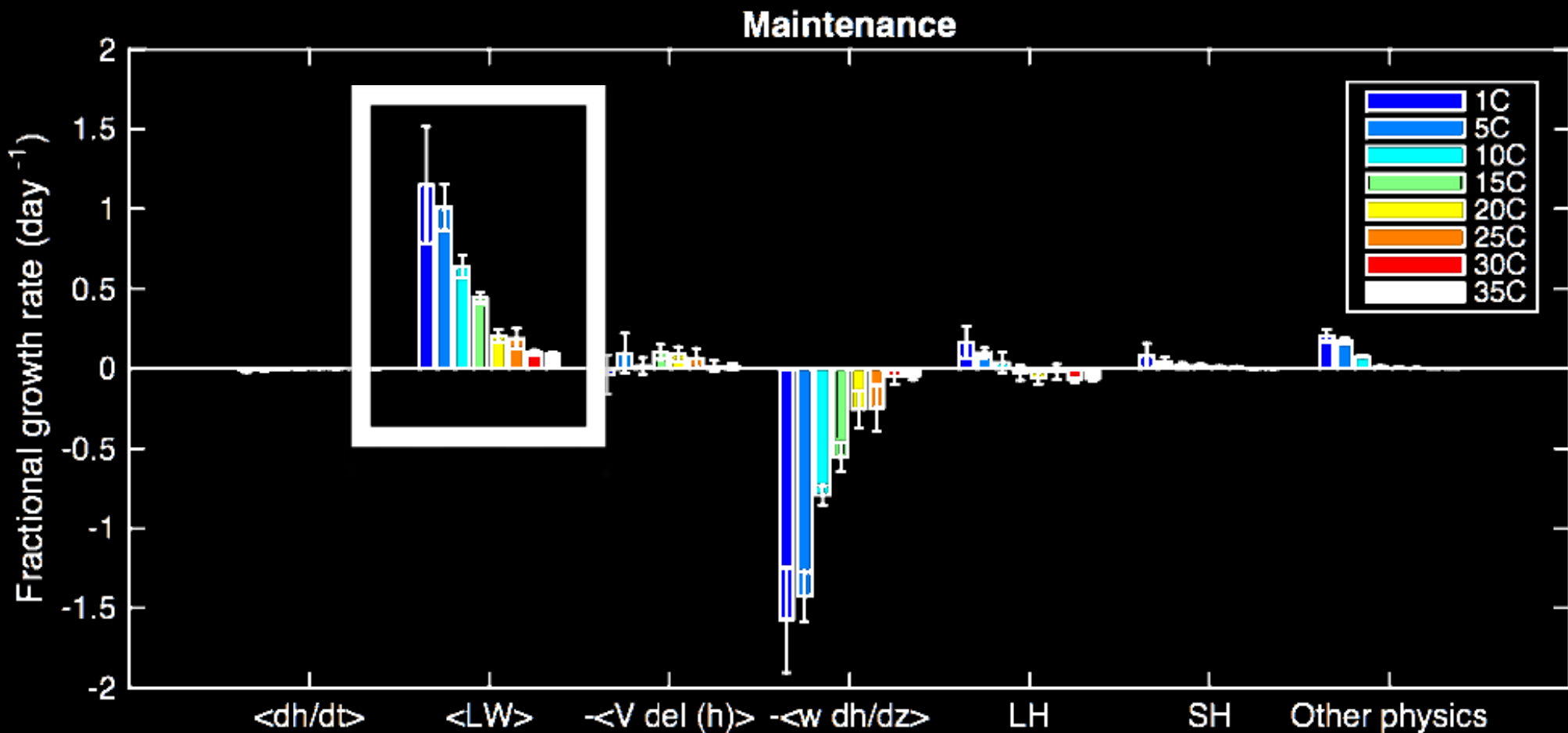


Vertically antiphase streamfunction quadrupoles



Column MSE analysis from a moisture mode view

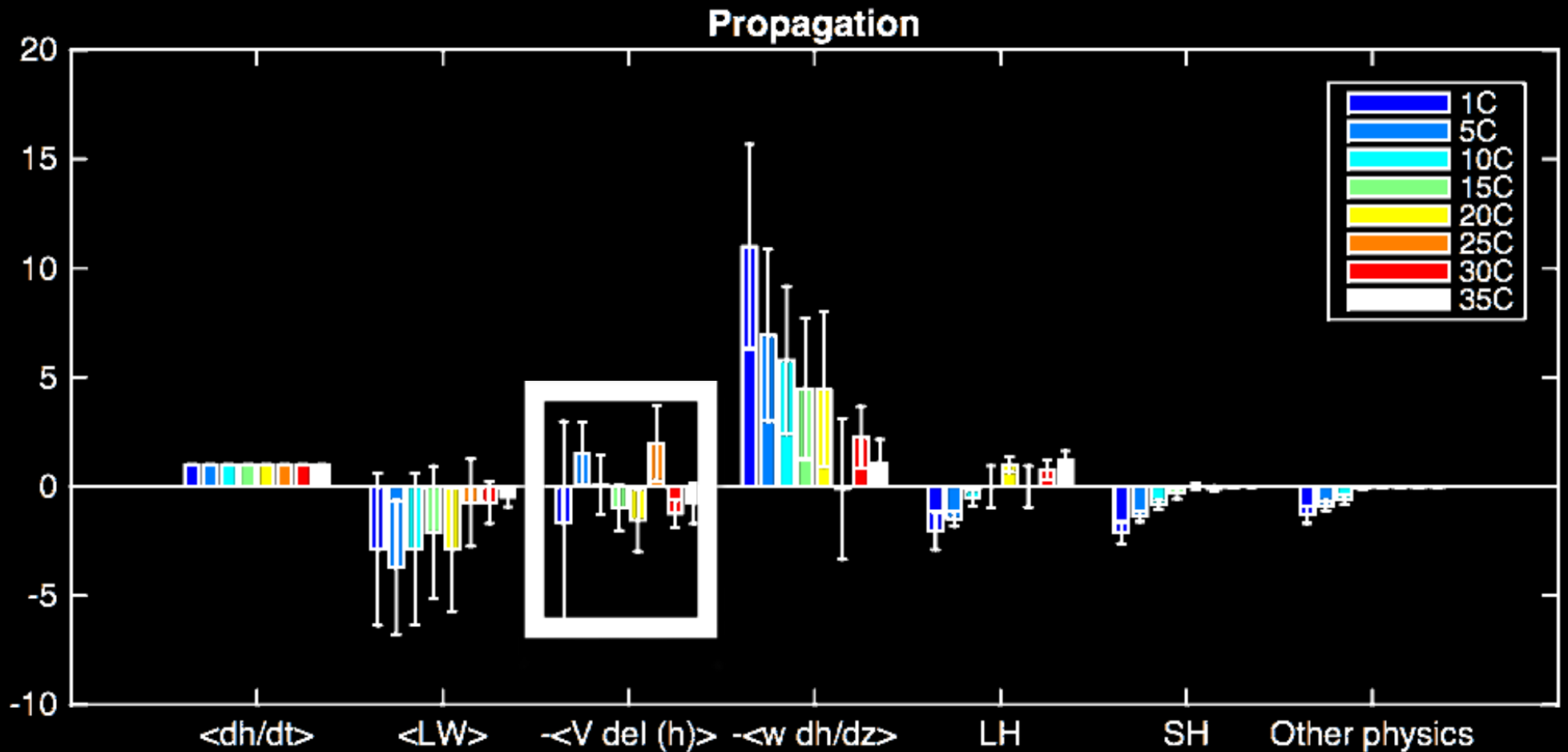
Column MSE budget shows longwave cooling in phase with MJO MSE anomalies even at very cold temperatures.



*Pritchard and Yang, in review*

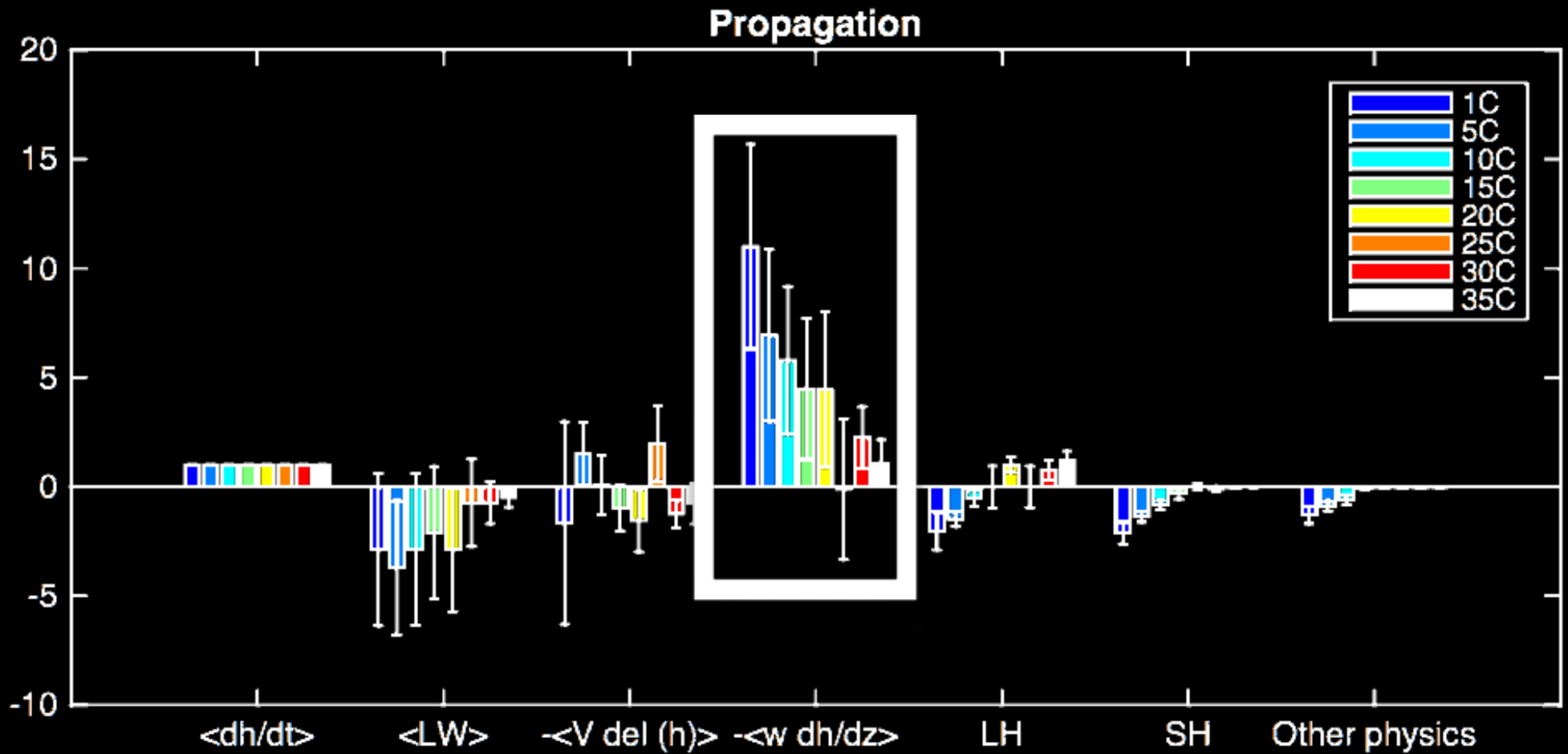
If SPCAM's MJO is energized by longwave self-aggregation, it is of a form that has no temperature criticality.

Horizontal MSE advection cannot explain the MJO eastward travel, in conflict with classic moisture mode views.



*Pritchard and Yang, in review*

Rather, the propagation is dominated by vertical advection.  
Reminiscent of higher frequency buoyancy-driven waves.



*Pritchard and Yang, in review*

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Besides, self-propulsion by  
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*Da's expectation:*

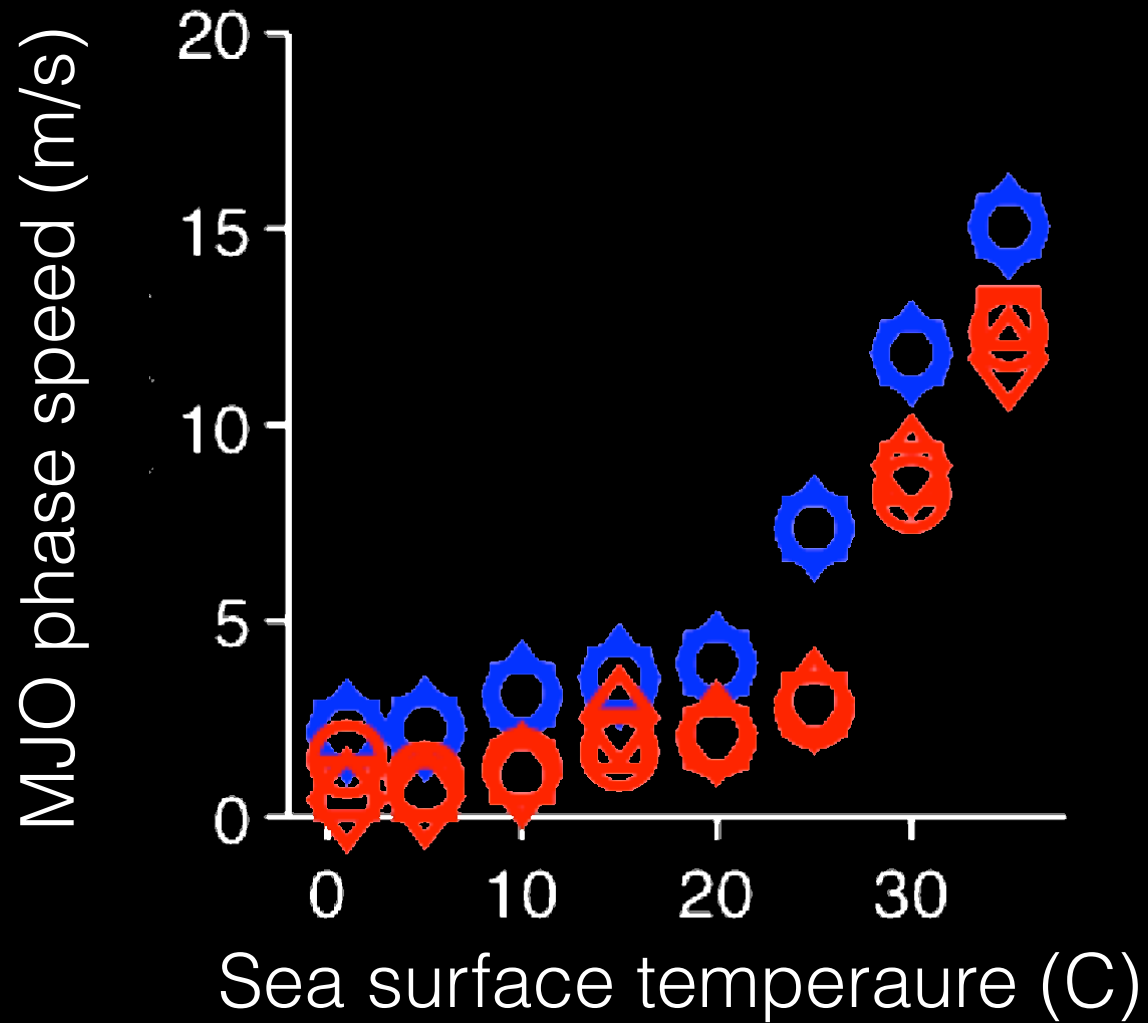
**Yes.**

If the MJO is an interference  
pattern of high-freq. waves  
linked to discrete rain events...

No reason why it couldn't  
exist even in this basic state.

Multiscale analysis from a Yang-Ingersoll view

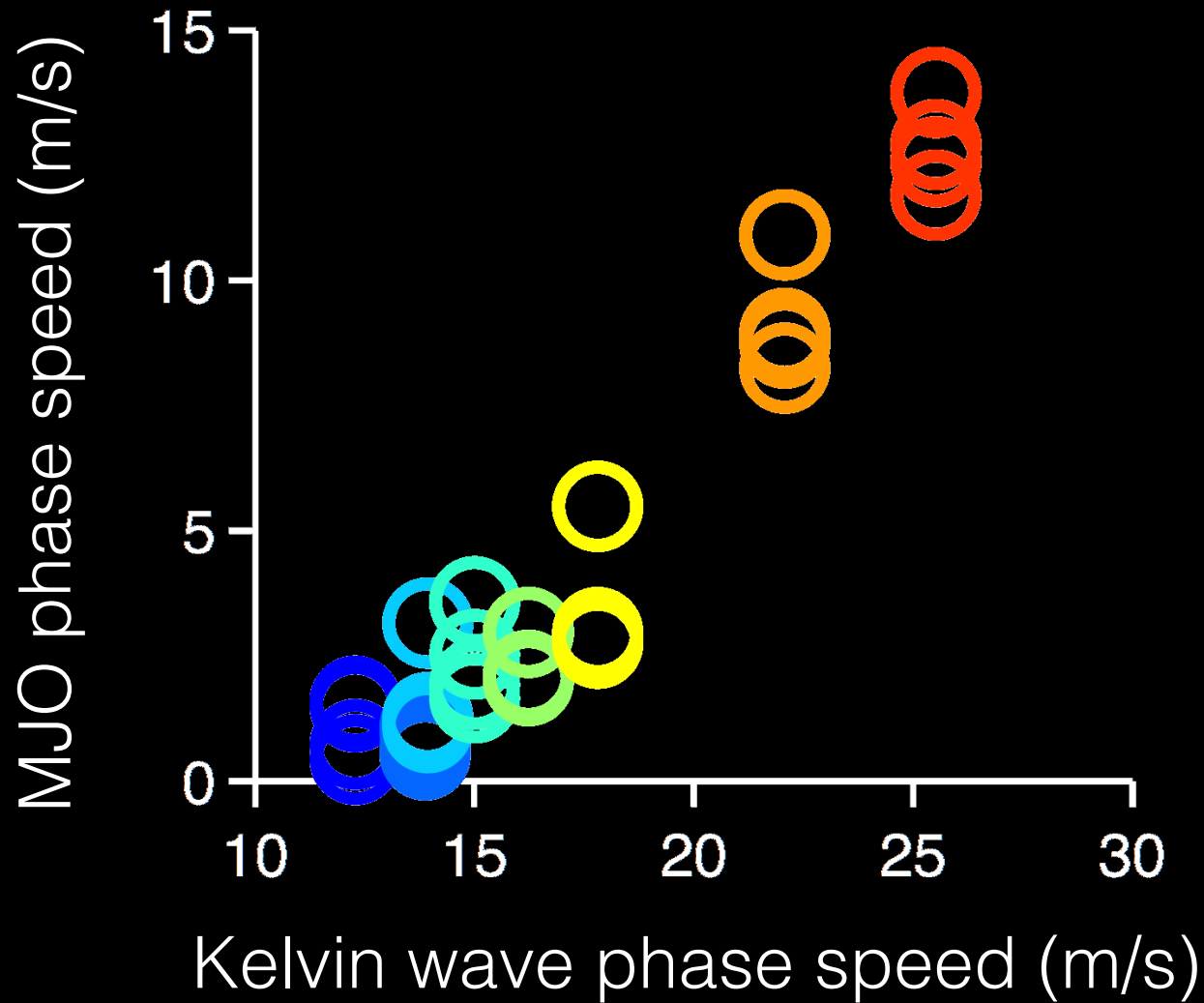
# MJO speeds up with SST



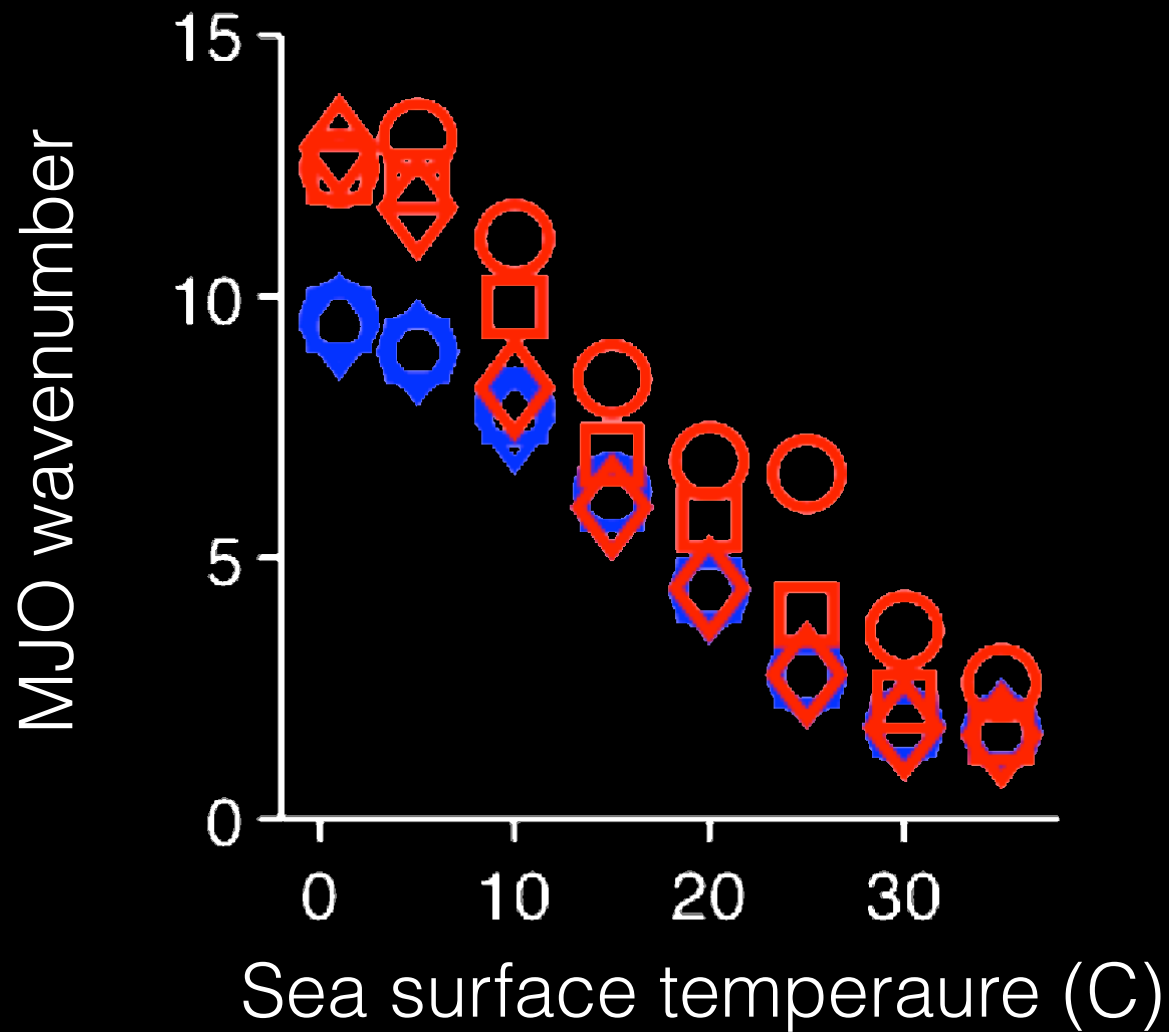
*Yang and Pritchard, in review.*



# High frequency tropical waves speed up too.



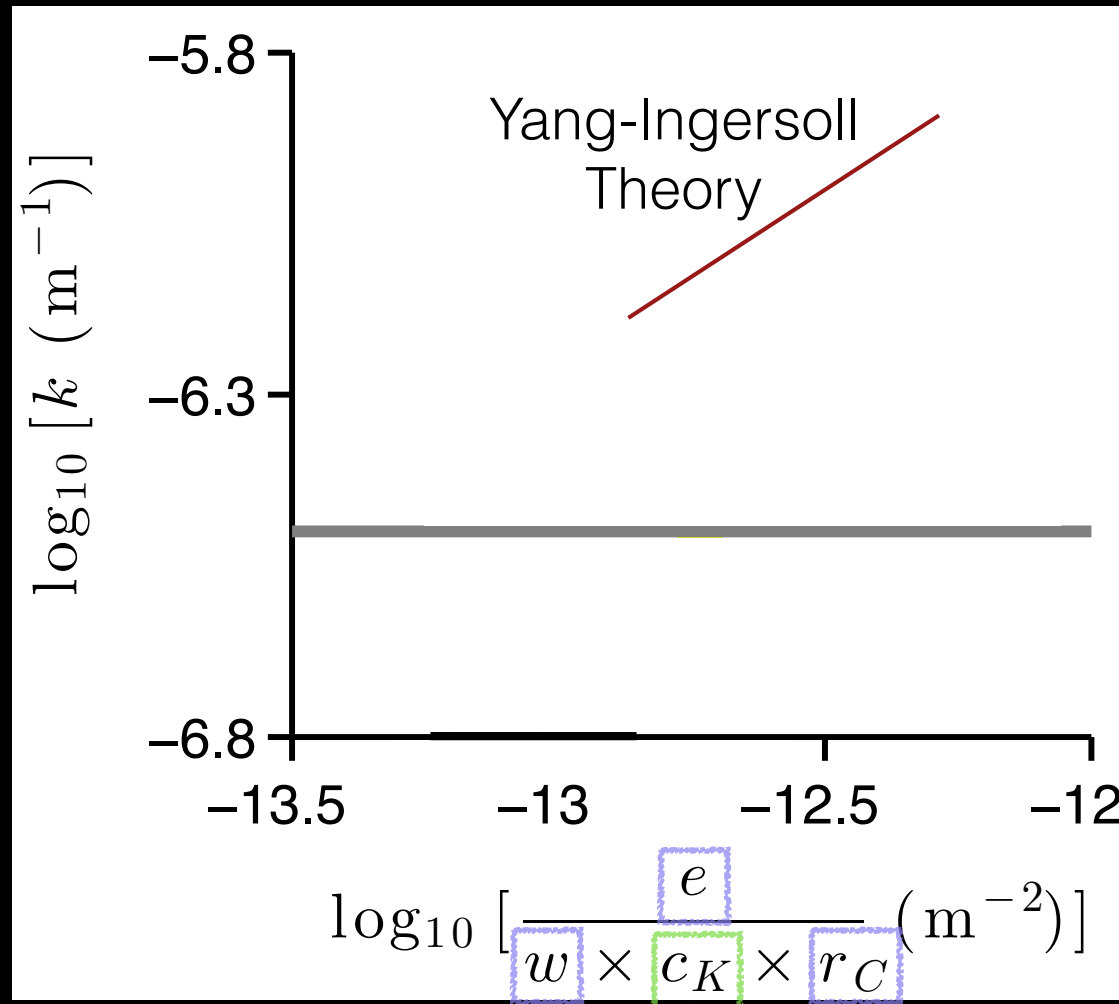
# MJO enlarges with SST



# A climate change scaling relationship from Y-I theory.

If MJO is built by high-frequency waves and discrete rain events...

...Its horizontal extent depends on...

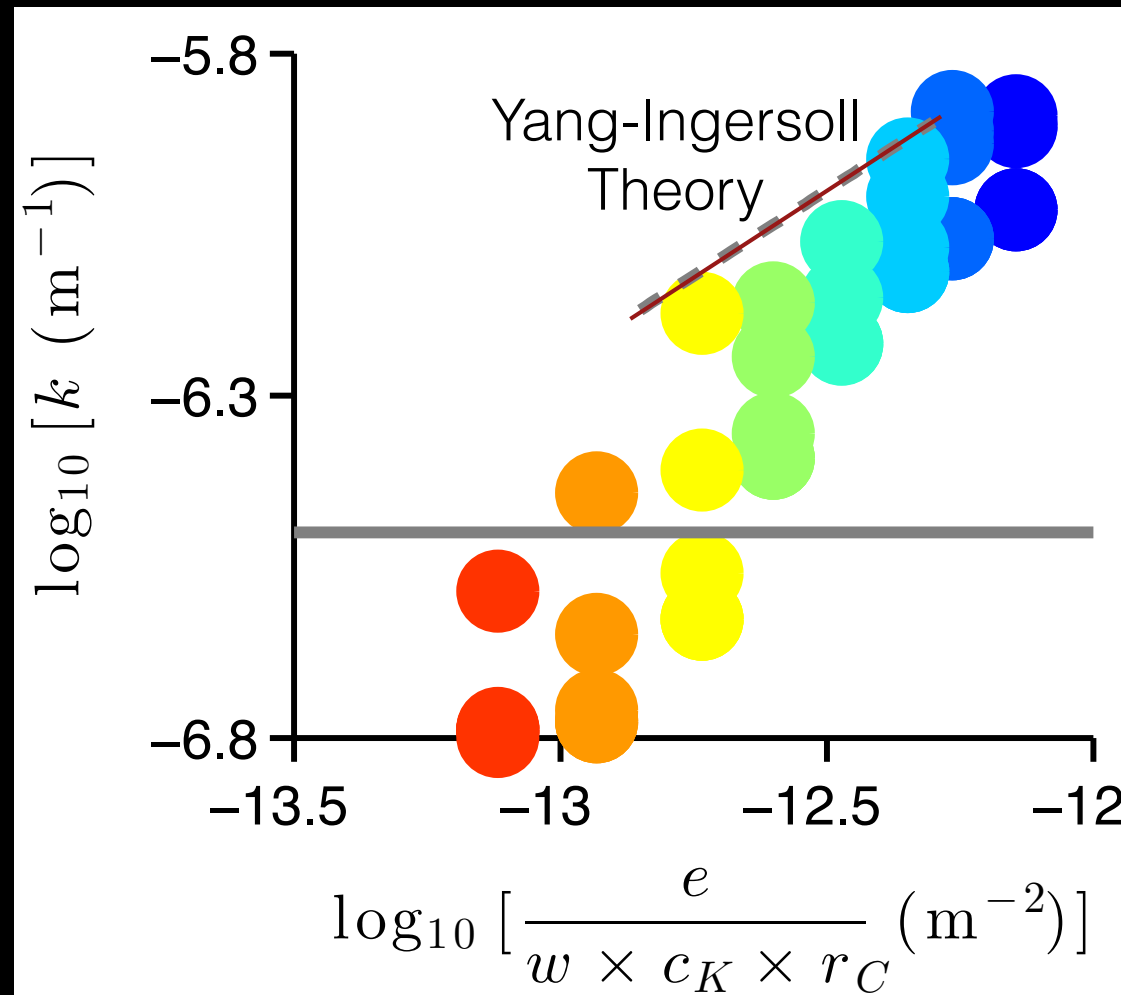


1) characteristic rain event strength

2) high-frequency tropical wave speed

A climate change scaling relationship from Y-I theory.

**... is a good fit to SPCAM simulation results.**



*Yang and Pritchard, in review*

Why do stronger, bigger and faster MJOs occur with climate warming? Viewed from the Yang-Ingersoll MJO paradigm:

As climate warms

Individual rain events  
get stronger / more  
intermittent

High frequency  
tropical waves speed up

The MJO packet  
gets stronger

The MJO packet  
enlarges

The MJO packet  
speeds up

# Summary

## Summary - 1/2

- Constant SST extreme climate variation is a useful experiment design for MJO theory stress testing.
- SPCAM's MJO survives extreme cooling, weak vertical shear and reversed meridional MSE gradients near the equator.
- Challenges some aspects of a moisture mode view:
  - Longwave maintenance need not be temperature-critical.
  - MJO propagation can occur without robust horizontal column moisture advection balance.



## Summary - 2/2

- SPCAM's MJO becomes smaller and travels slower as SSTs are cooled.
- In a proportion consistent with a key scaling relation from Yang-Ingersoll theory.
- May explain why MJOs get bigger, faster and stronger with warming.
- Worth considering this experiment and scaling relationship in more MJO-permitting GCMs.

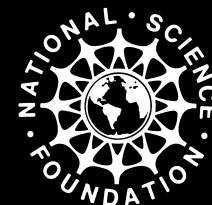
Thanks.

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