

A moist static energy budget analysis of the MJO in the Superparameterized Community Atmosphere Model

Mike Pritchard
University of Washington

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ECHAM

Tiedke + Nordeng

In two of these models, aspects of the MJO may be consistent with a “**moisture mode**” paradigm.

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Column MSE budget is key:

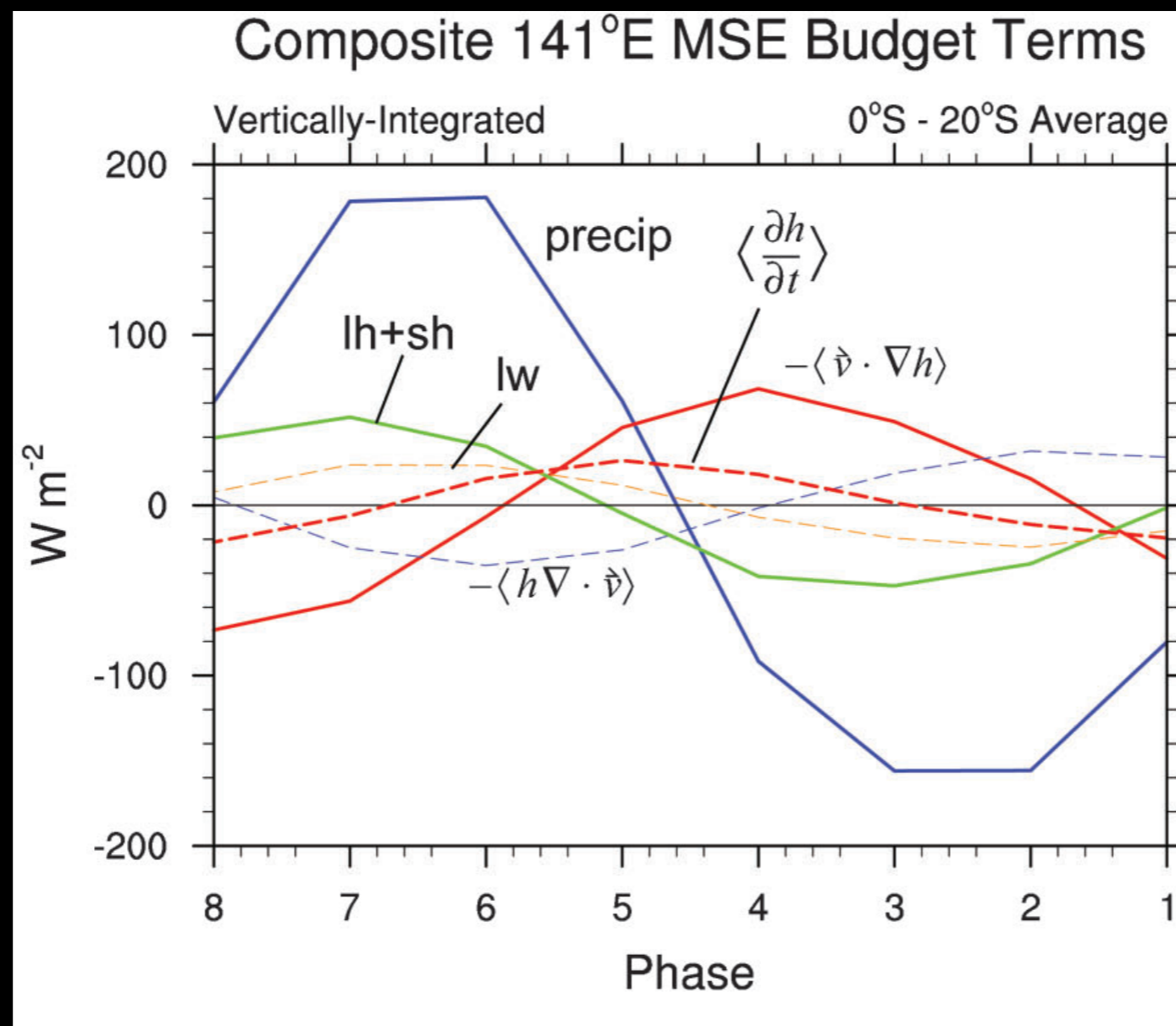
$$\frac{d}{dt} \langle \text{MSE} \rangle (x,y,t) = \mathbf{why?}$$

(column MSE budget
tendency variables)

Example:

Maloney's CAM3 w. tighter q-precip coupling

- Comparing MJO-related variations in the column moist static energy budget.



Maloney et al.,
JAMES, 2010

← Time (or x →)

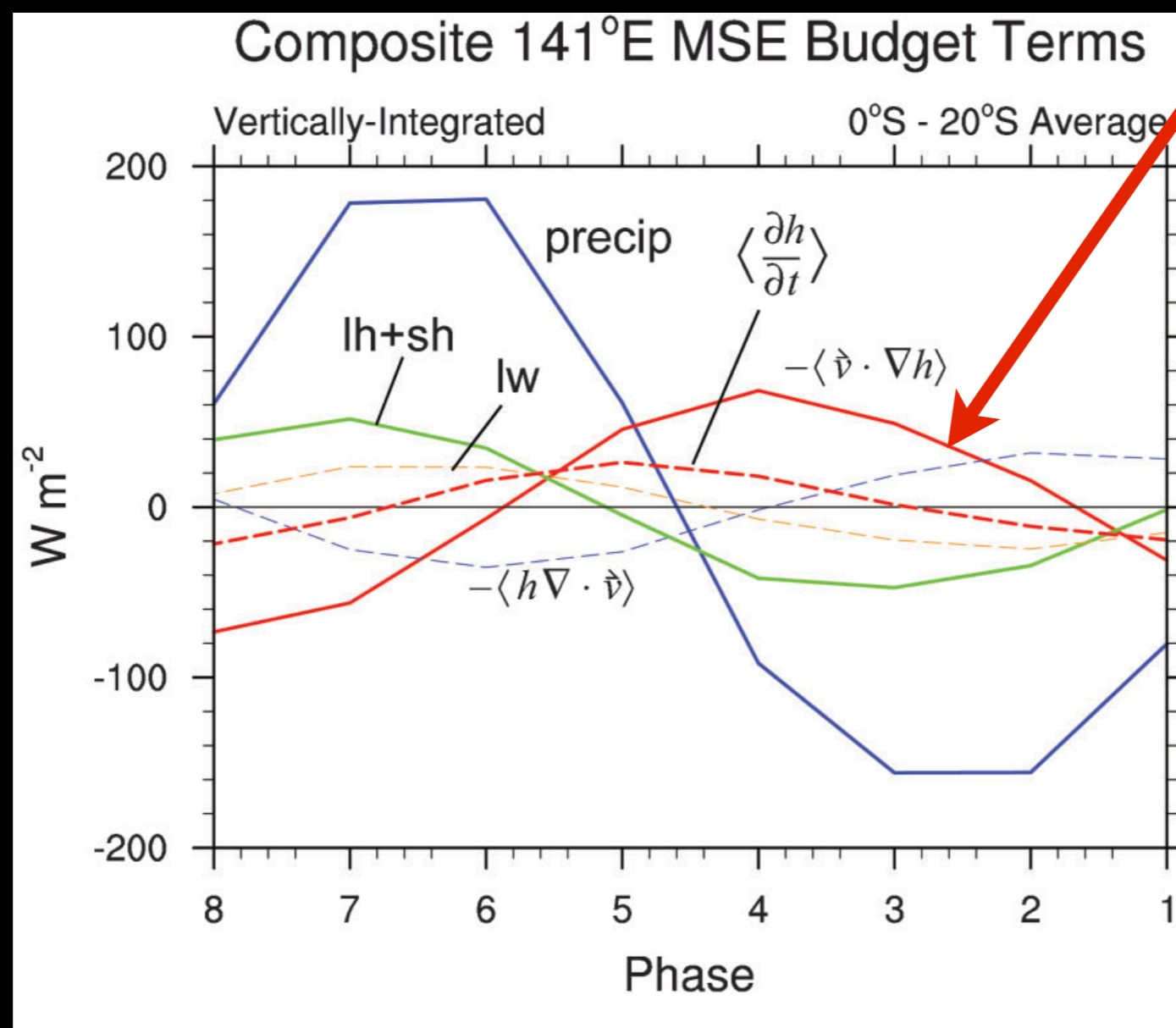
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A moisture mode signature:

Horizontal MSE advection mediating propagation



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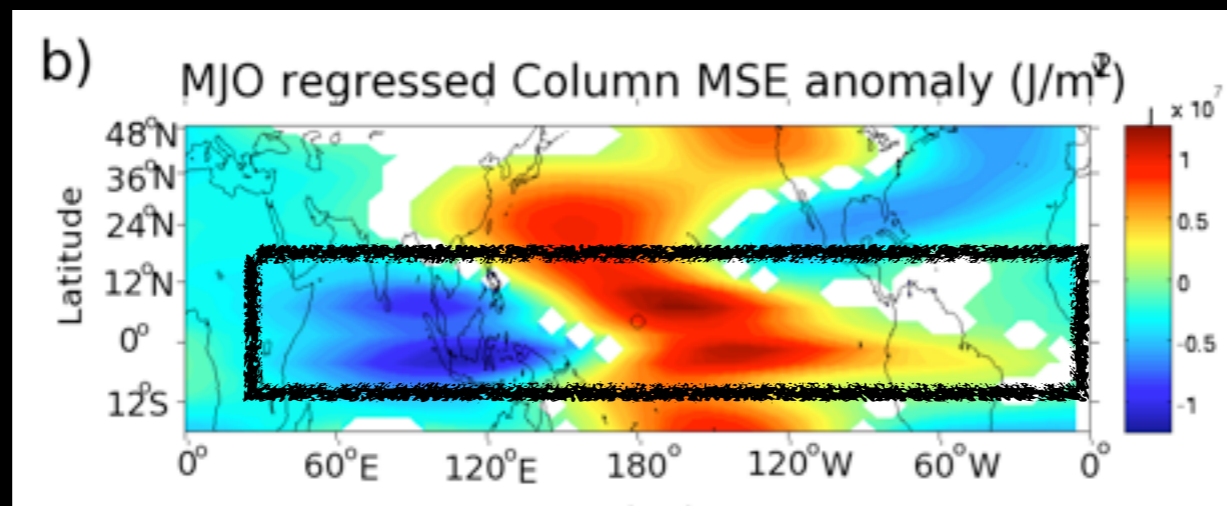
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Example:

Aquaplanet SPCAM w. zonally symmetric SSTs.

(Andersen & Kuang, *J. Clim.*, in press.)

(x,y) structure of MJO-related column MSE

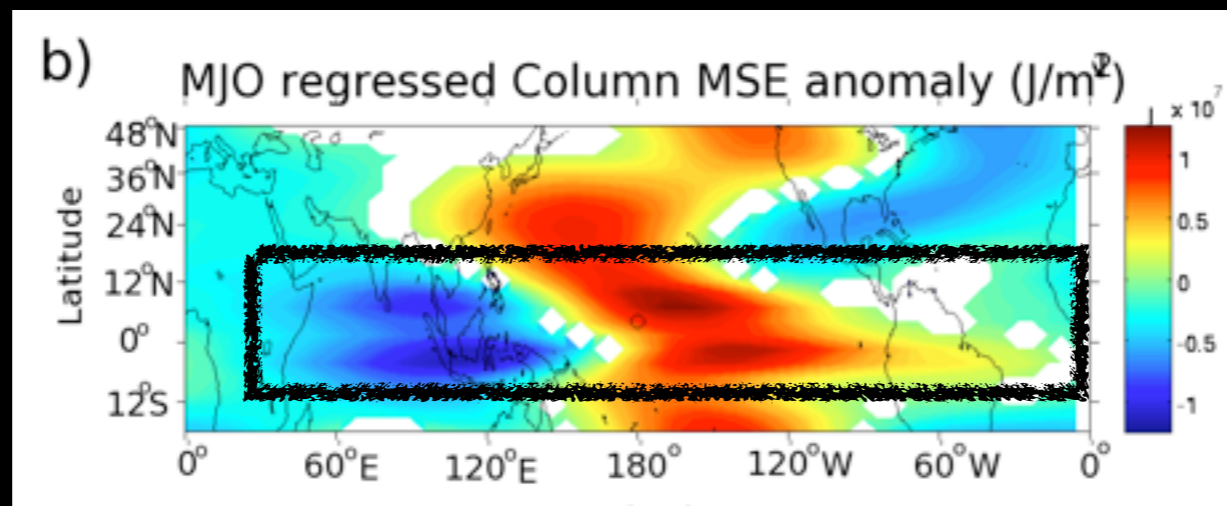


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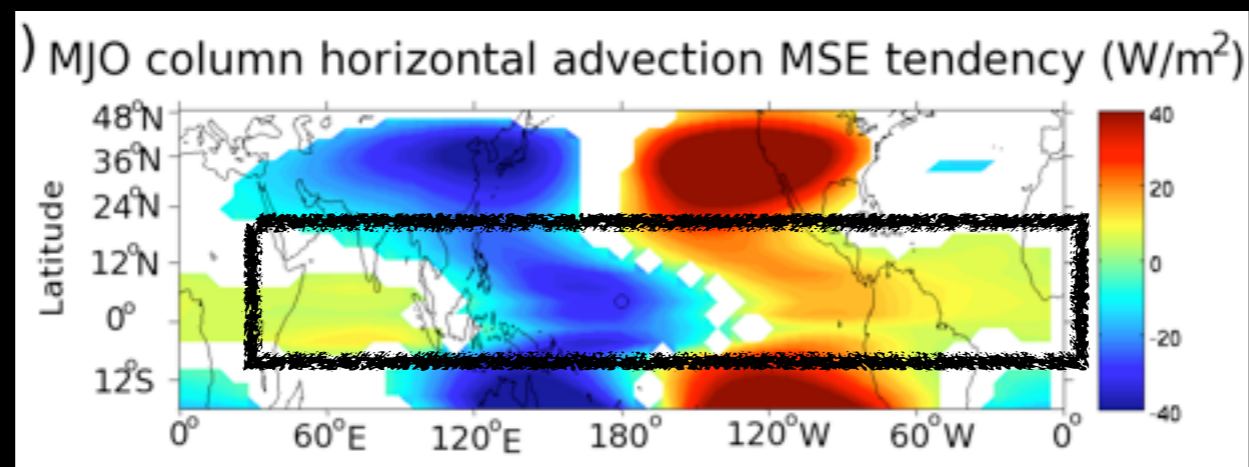
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(x,y) structure of MJO-related column MSE



vs.



(x,y) structure of column MSE horizontal advection

This has raised basic questions.

1. How are the intraseasonal moisture modes destabilized?
2. How do the intraseasonal column moist static energy anomalies travel through space?

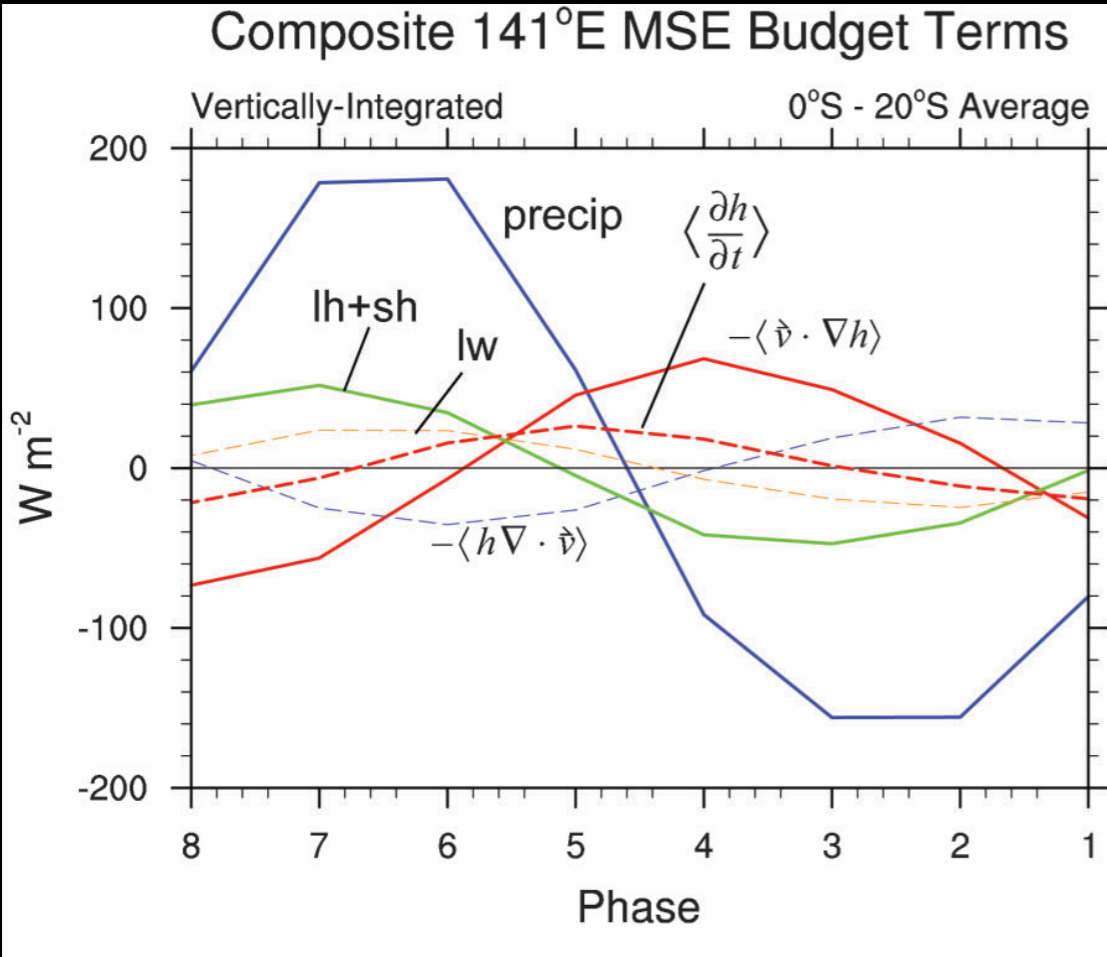
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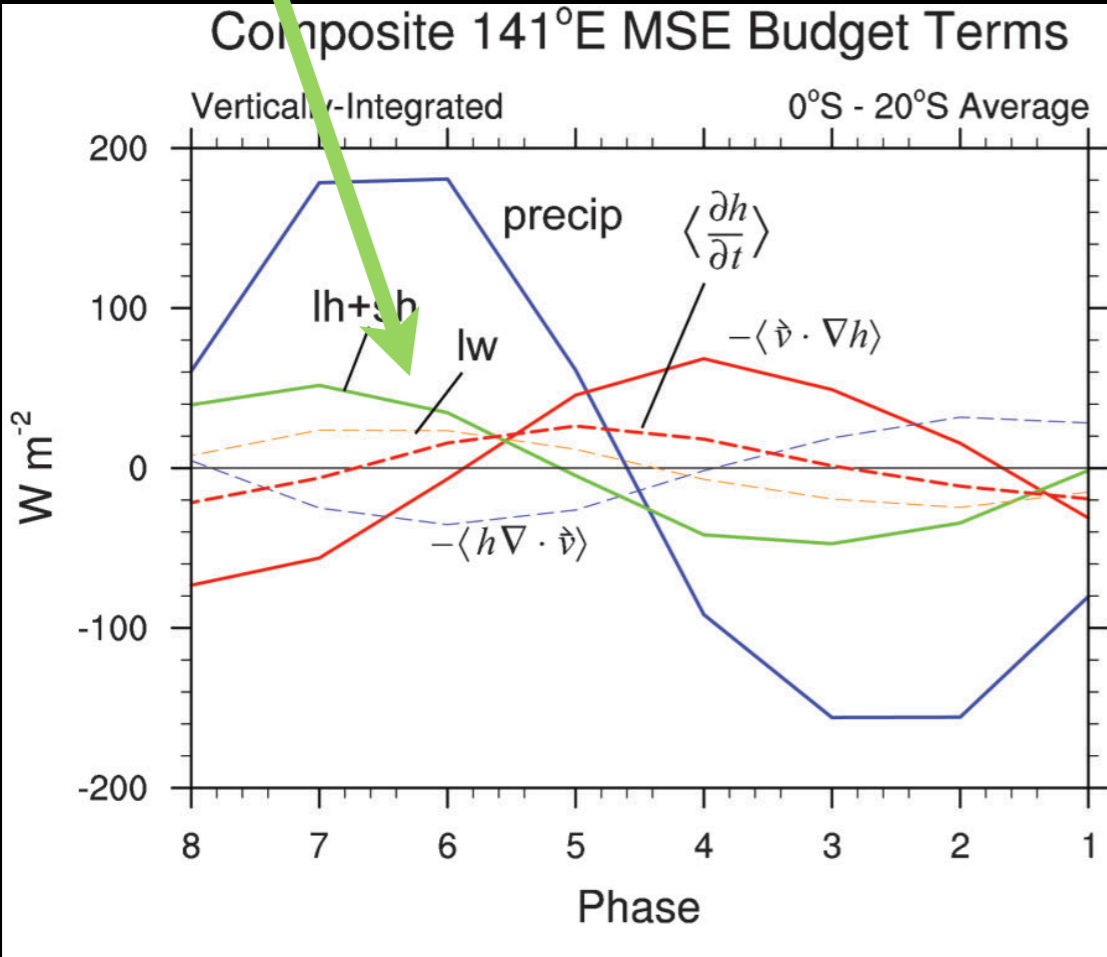
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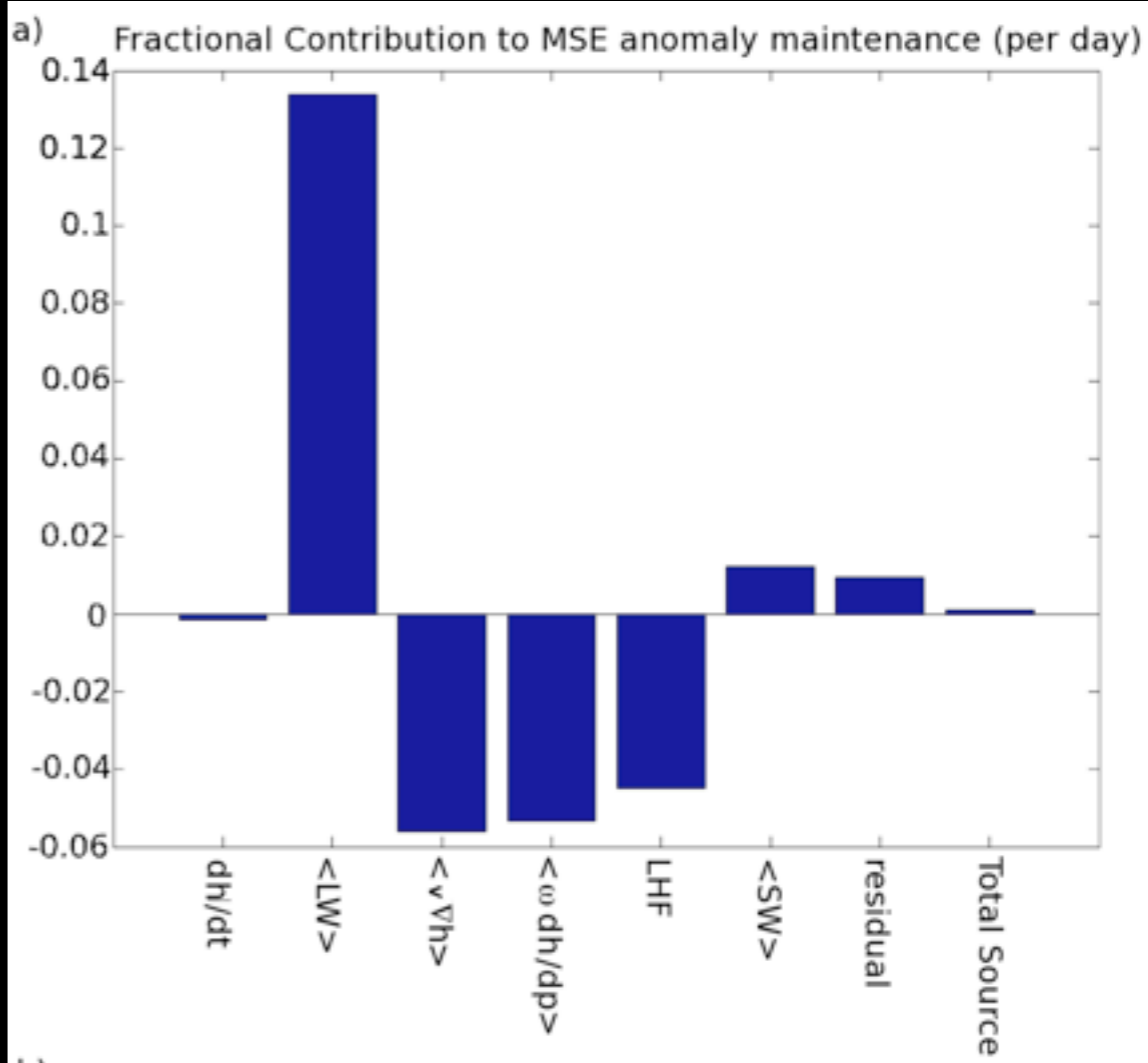
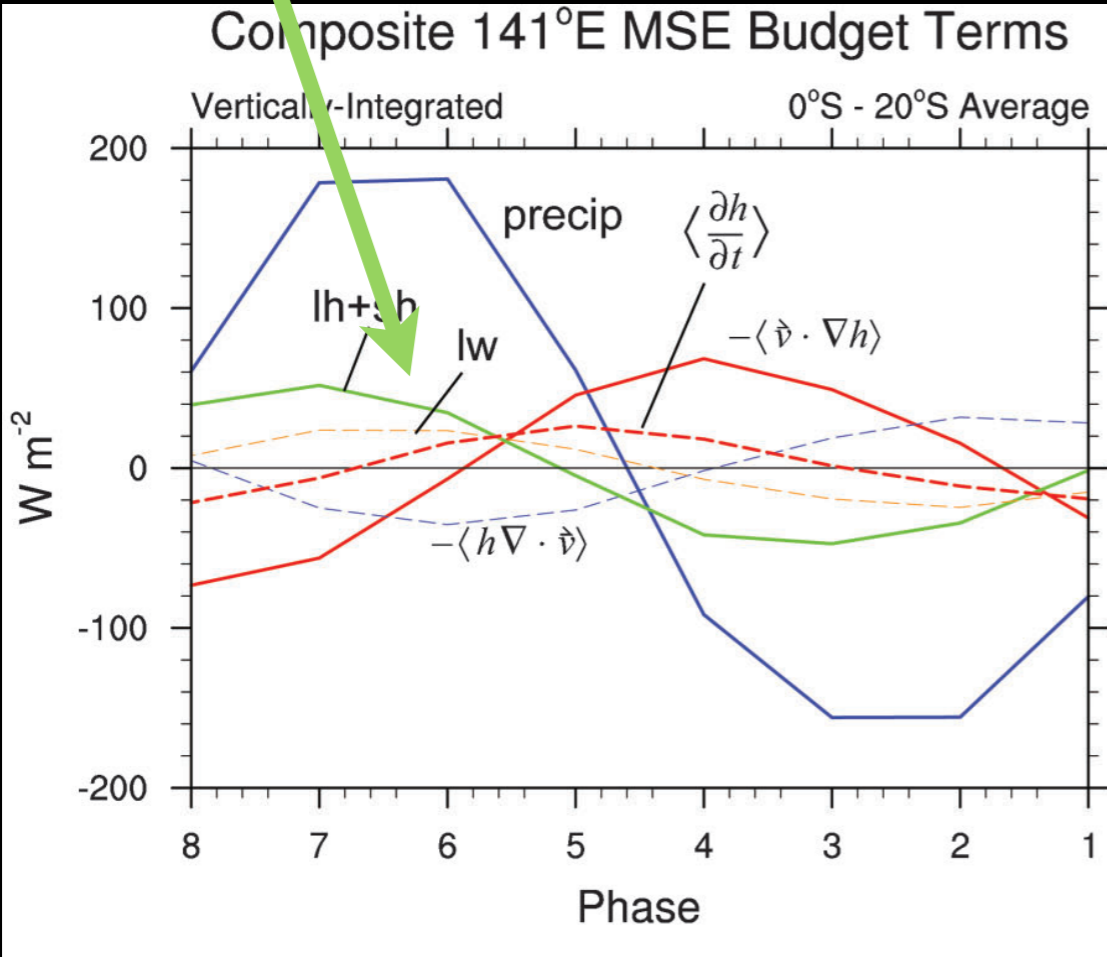
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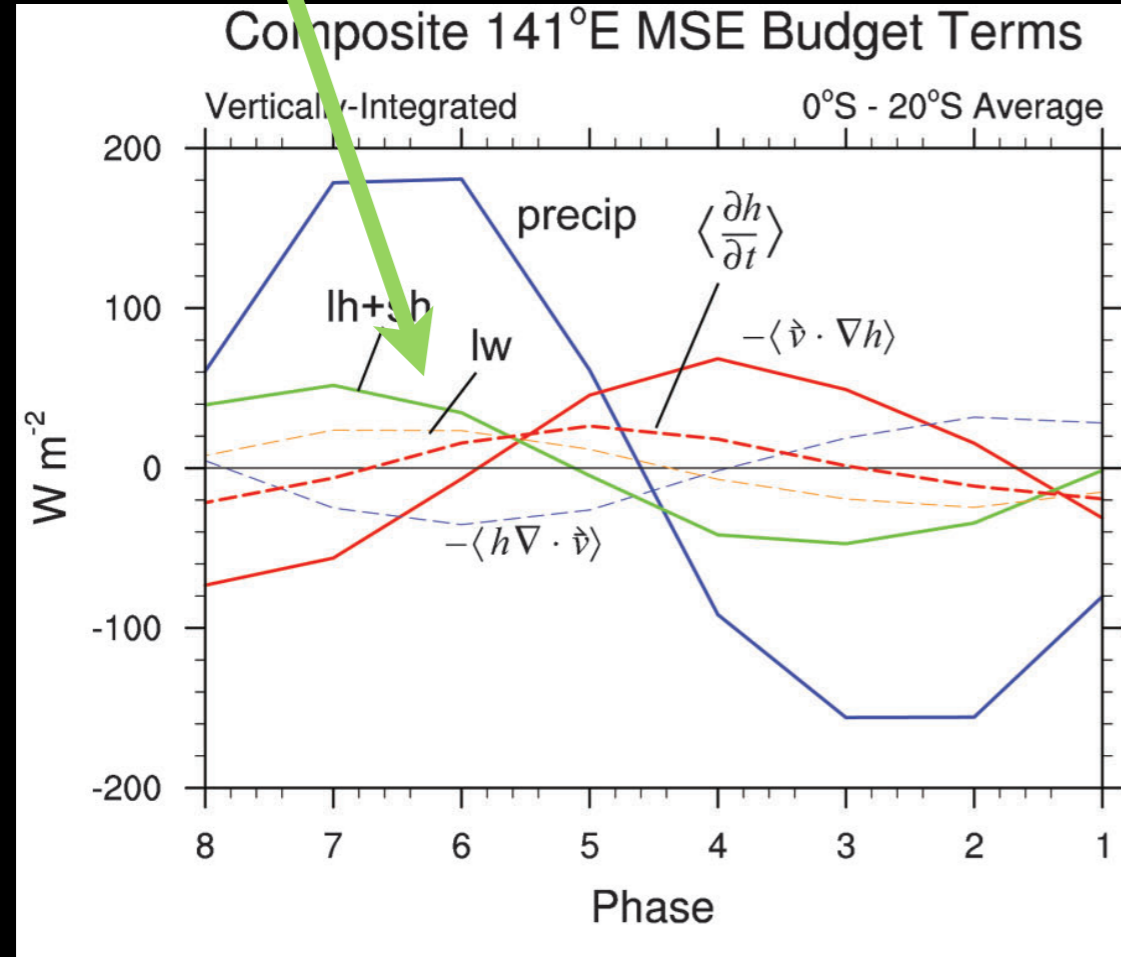
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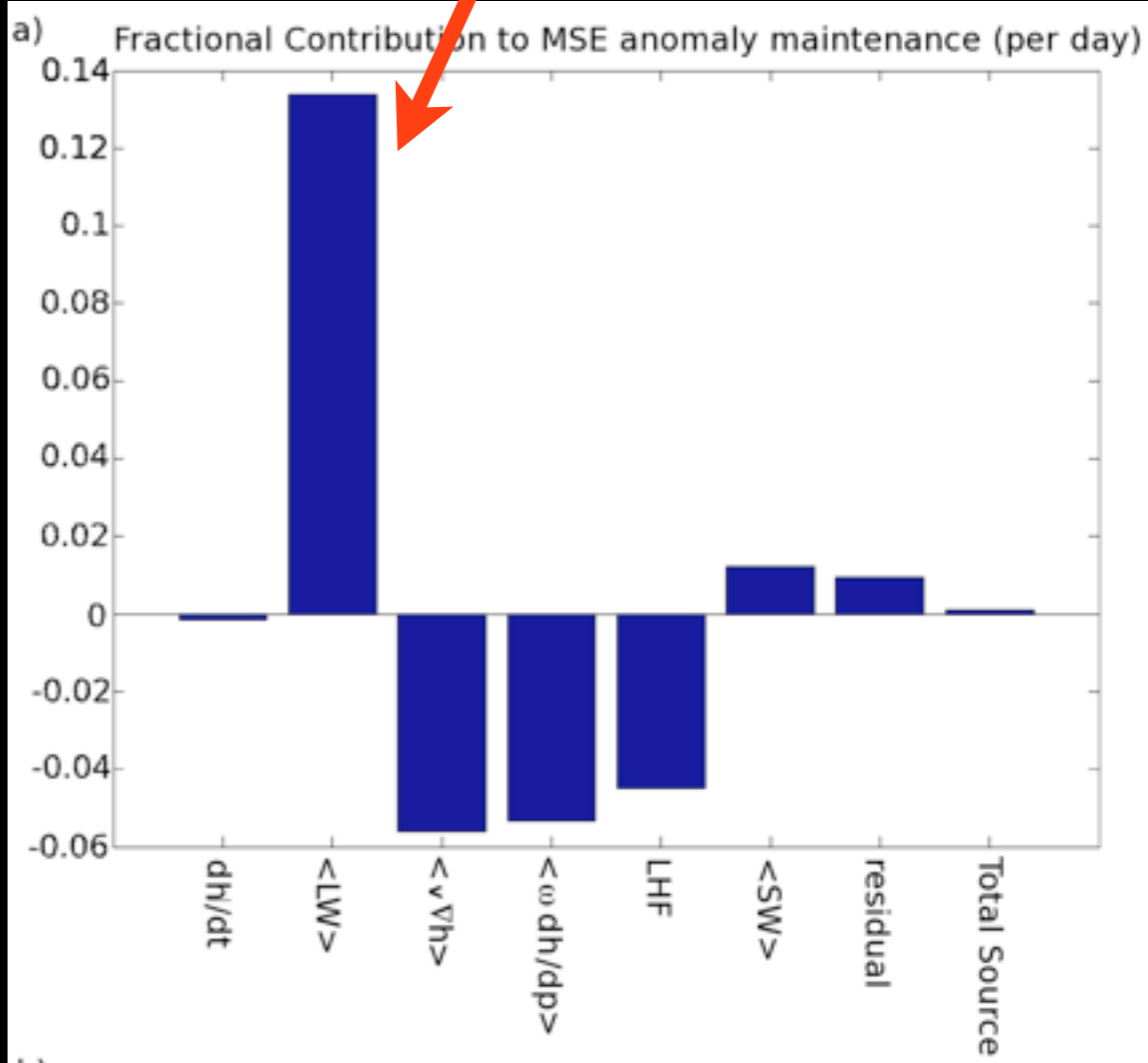
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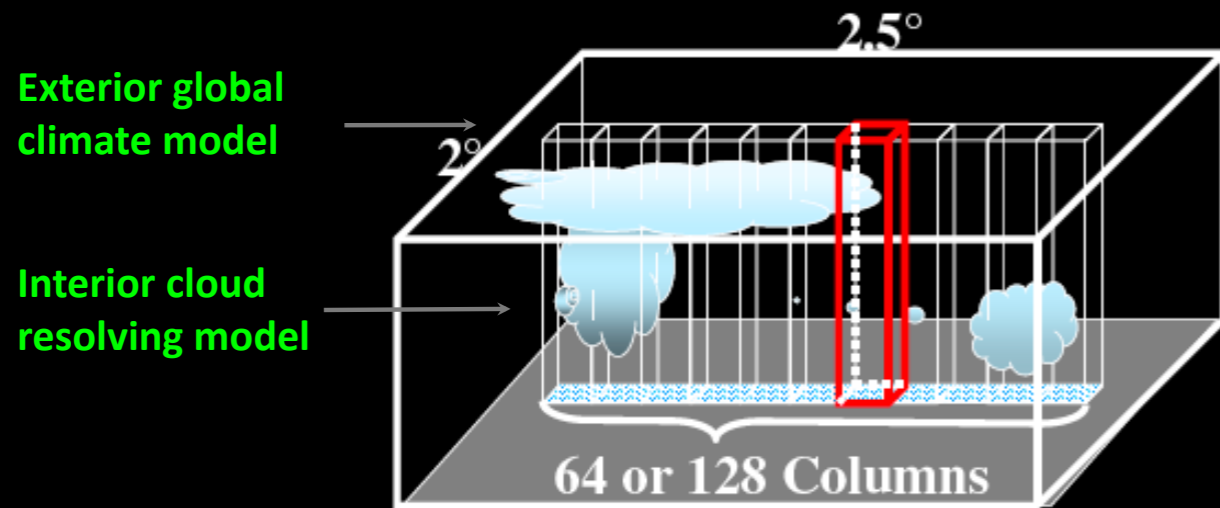
How does the column MSE move through (x,y,t) ?

Adding another model to the debate: Real-world SPCAM

CMMAP's prescribed SST SPCAM3.0 run.

(Thanks to Marat Khairoutdinov!)

The Multi-scale Modeling Framework (MMF) approach
(a.k.a. "super-parameterization")



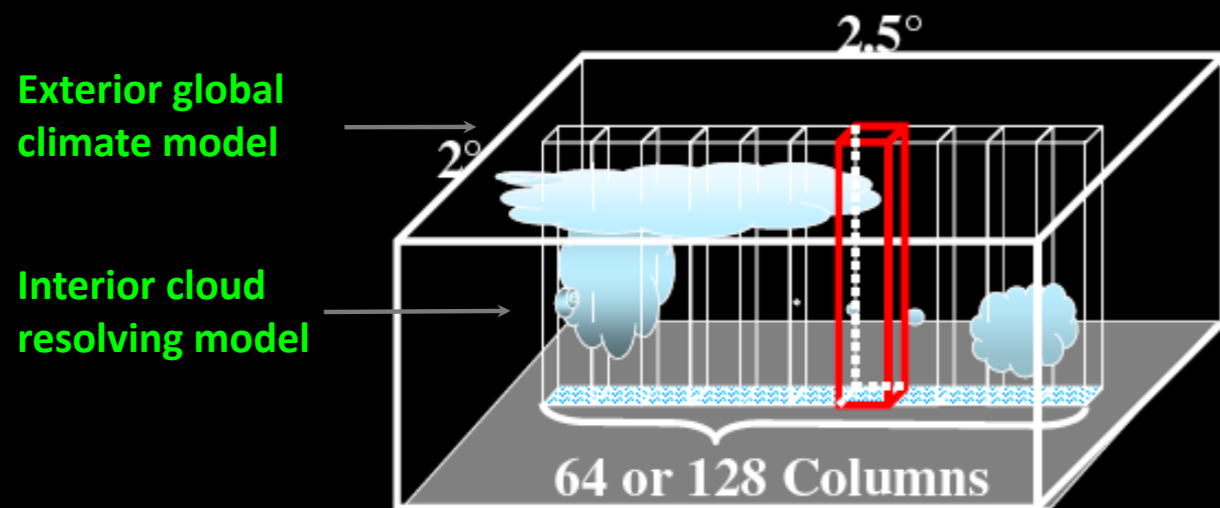
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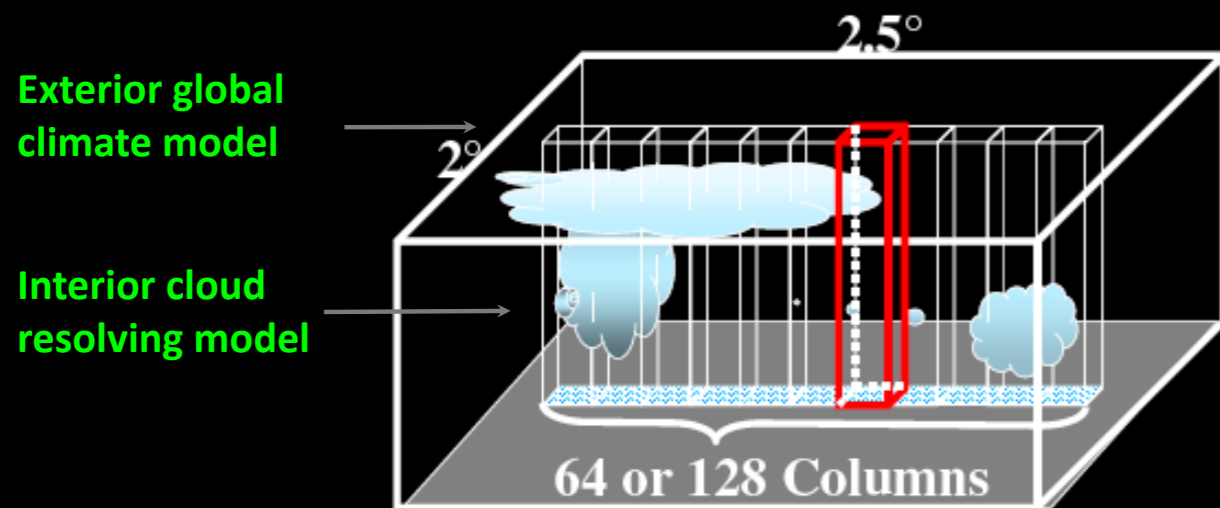
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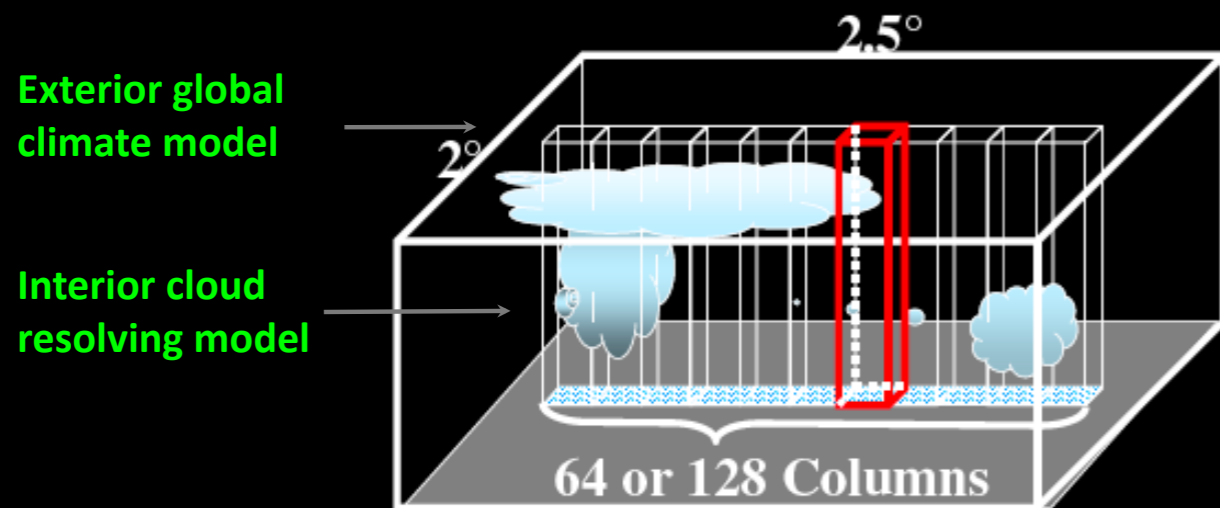
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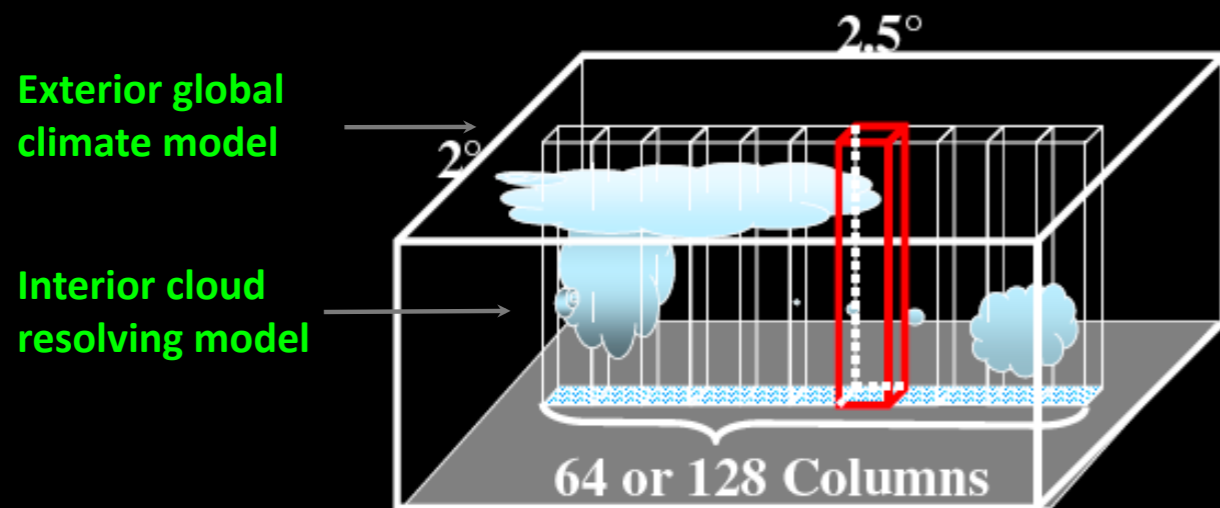
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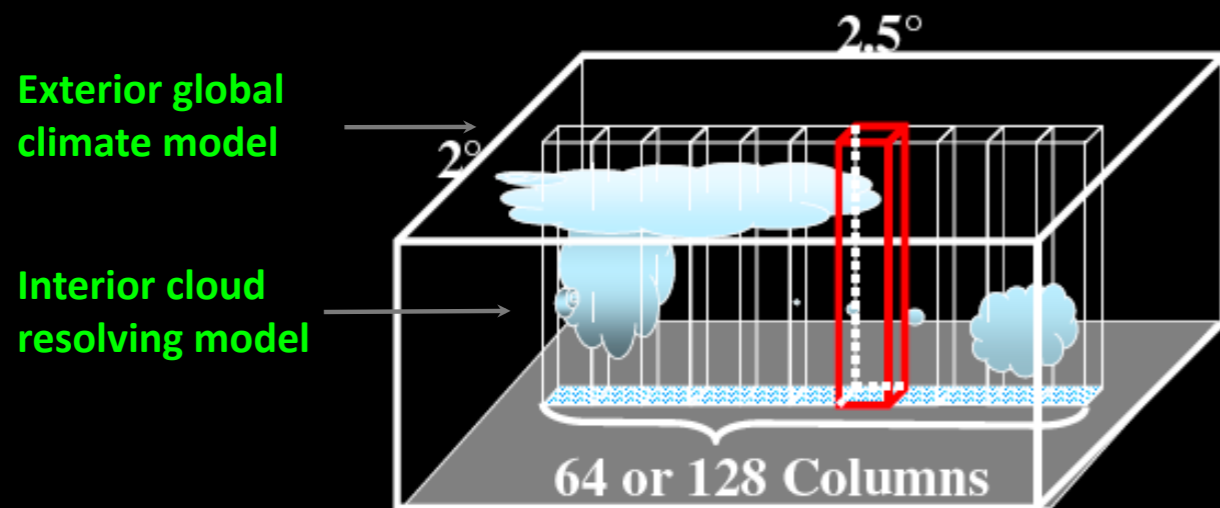
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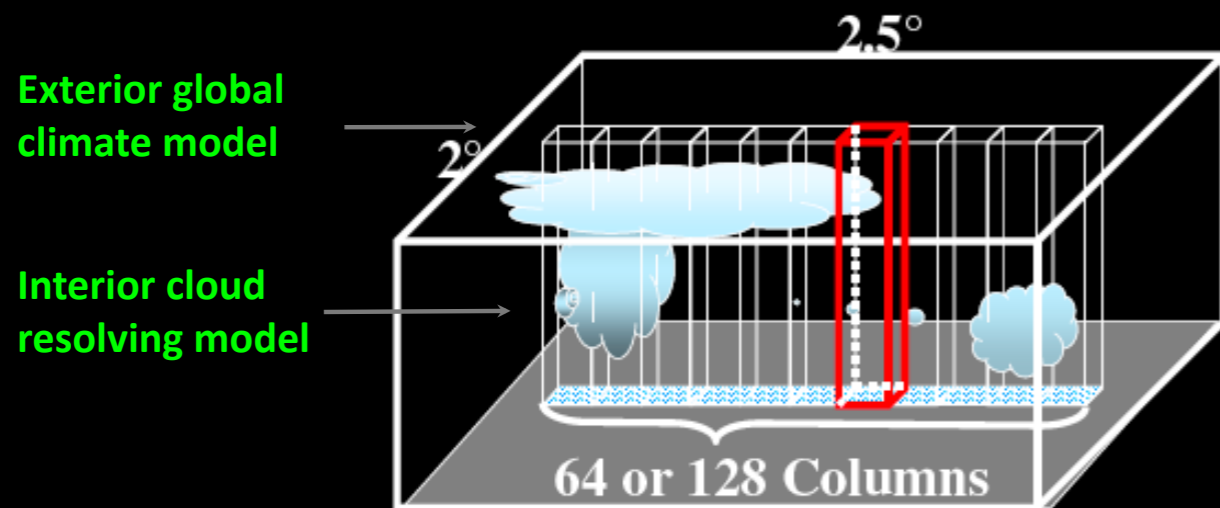
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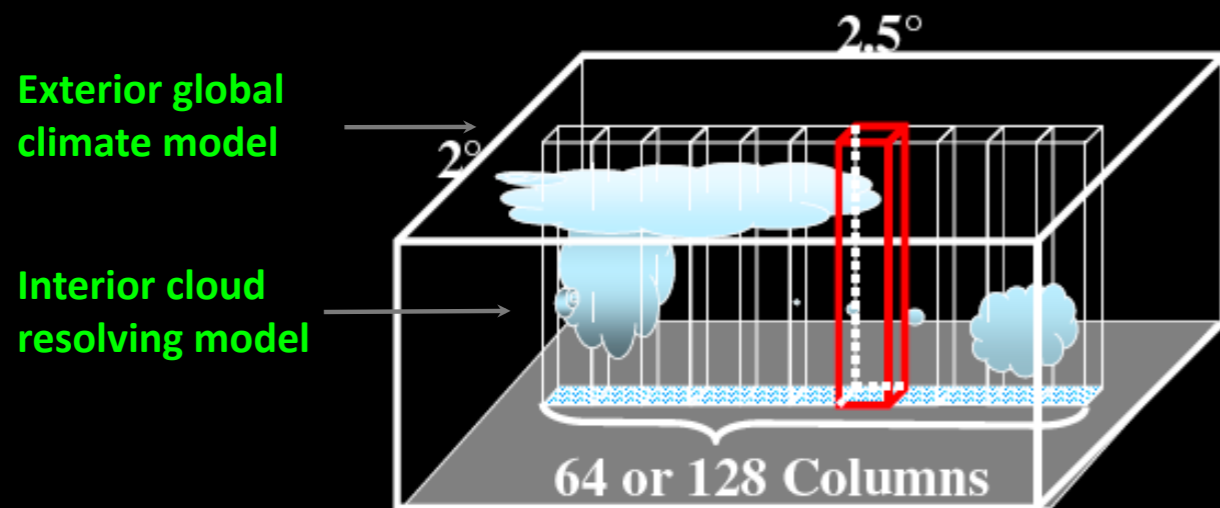
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Insufficient output to
completely close the
column MSE budget

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$$\frac{d}{dt} \langle \text{MSE} \rangle (x,y,t) =$$

horizontal advection

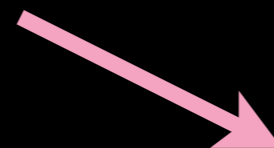
surface fluxes

Well constrained in the run



longwave heating

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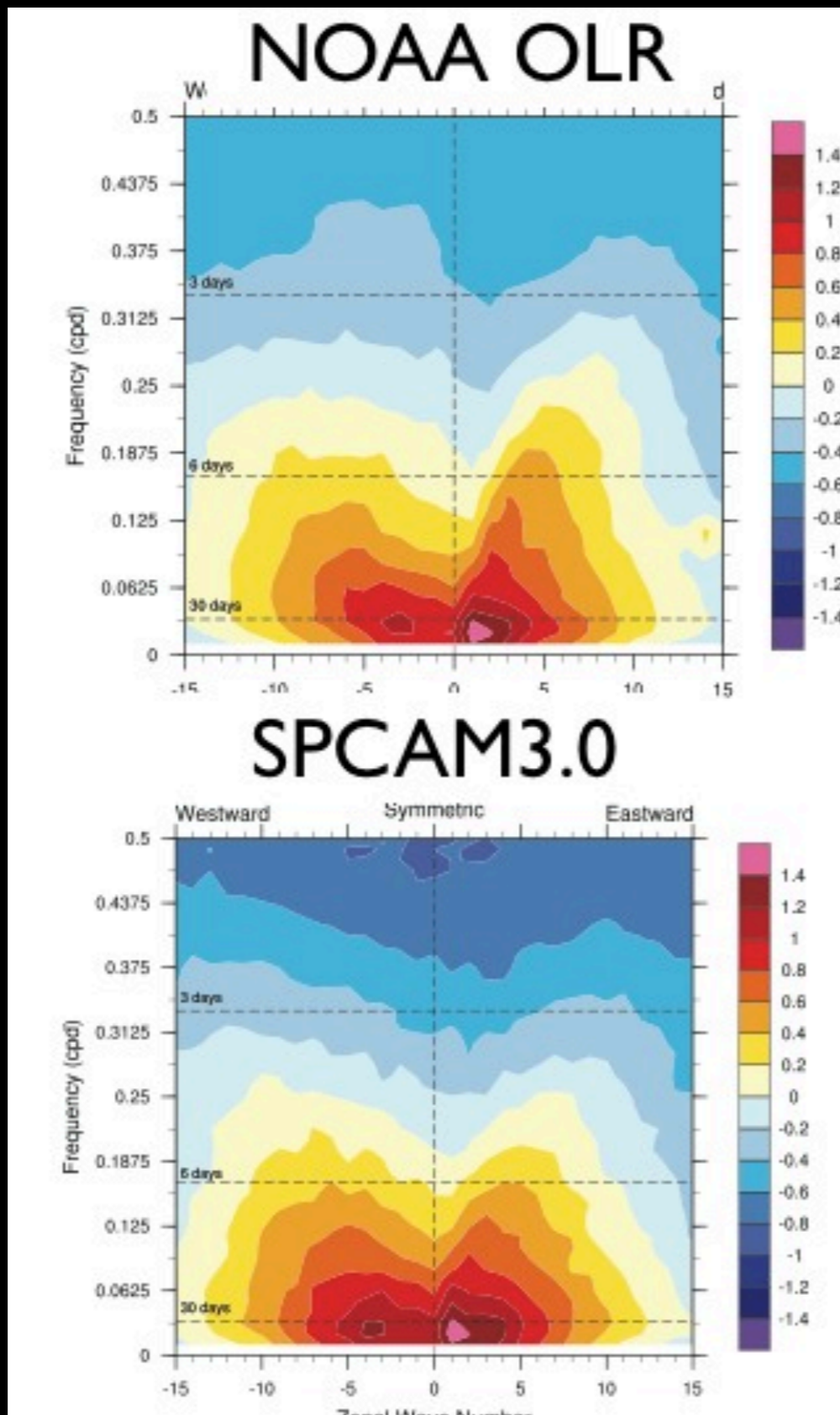
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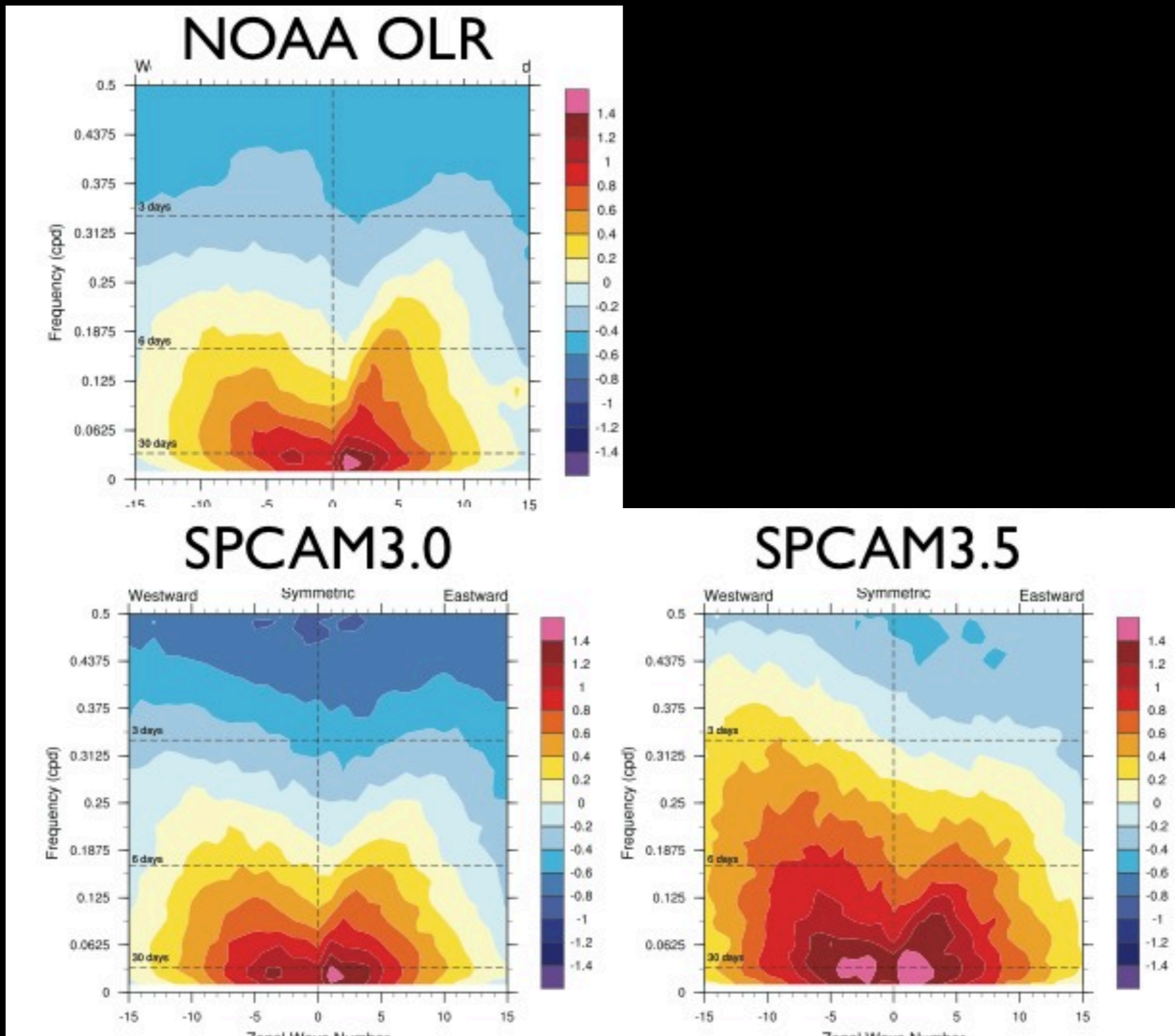
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Why not analyze one of the newer prototype MMFs?
The original SPCAM3.0 has a better uncoupled MJO.

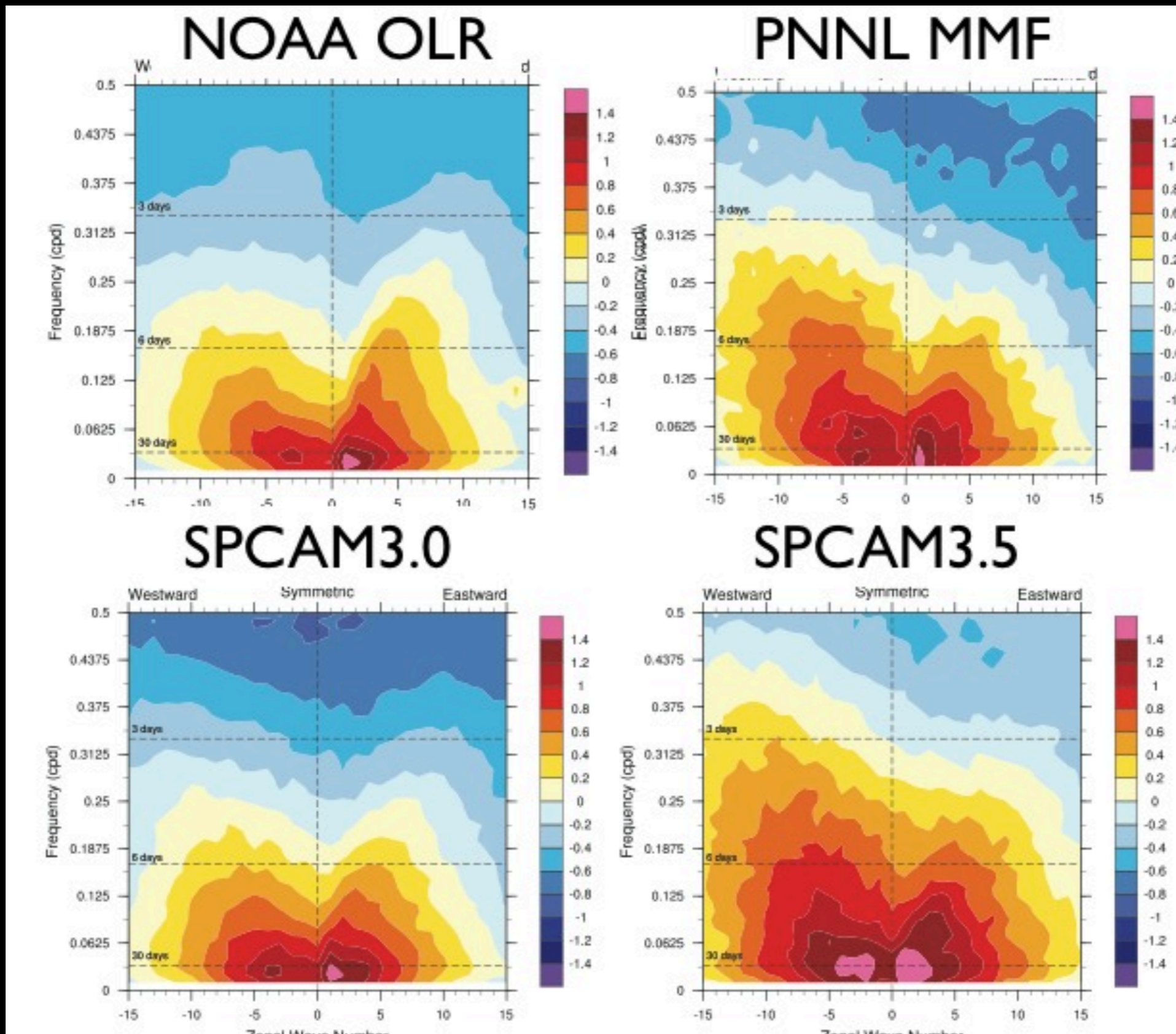


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What destabilizes the mature
Pacific moisture mode in real-world SPCAM?

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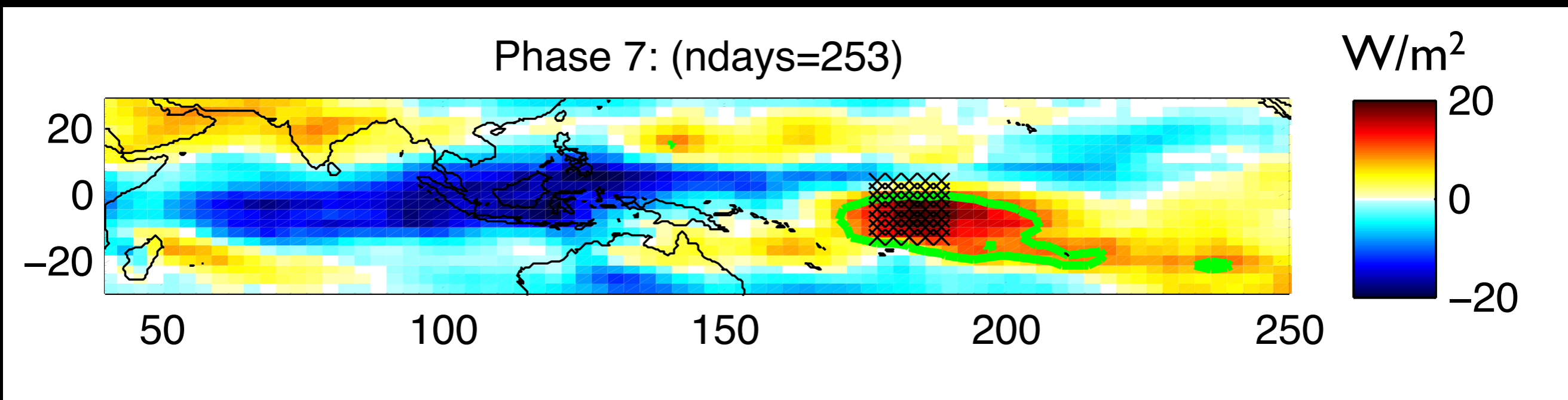
- Pick a baseline regression time series: 20-100 day filtered OLR averaged in a zonally phase-aligned 10-deg wide box, 10S-5N.

- Lag-regress in (x,y) unfiltered column MSE budget terms, visualize statistically significant regression slopes.

(as in Andersen & Kuang 2011)

For consistency with other models, focus on (x,y) budget during a mature Pacific MJO phase.

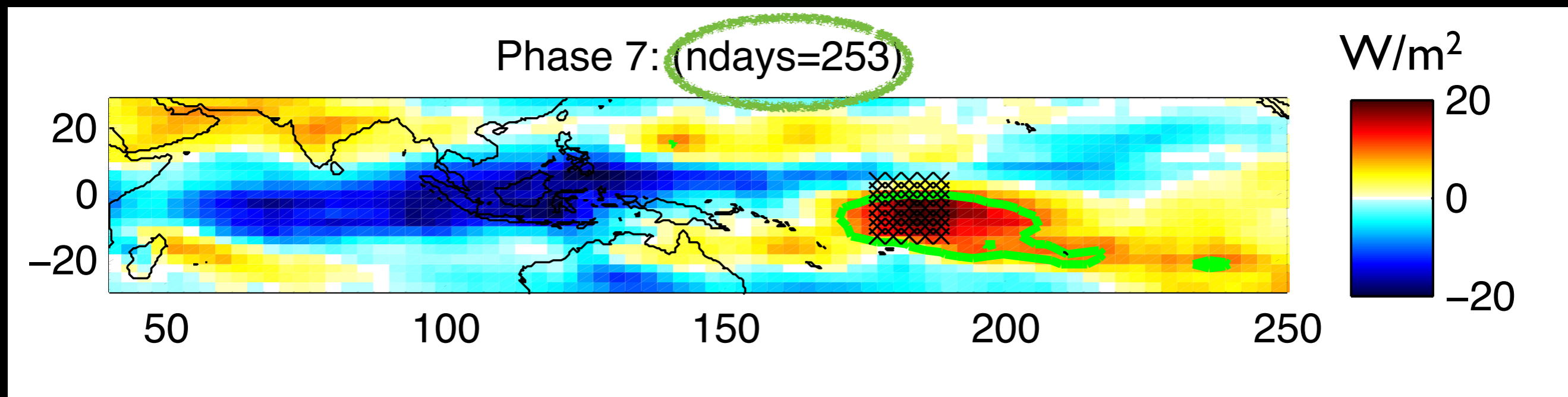
Phase 7: The MJO convection index (negative filtered OLR) composite



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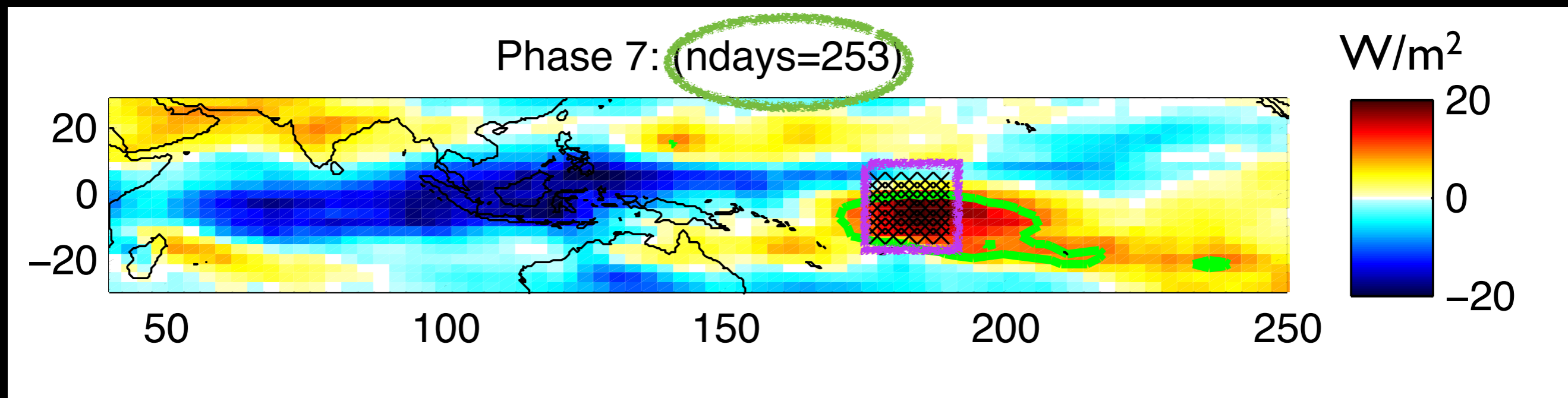
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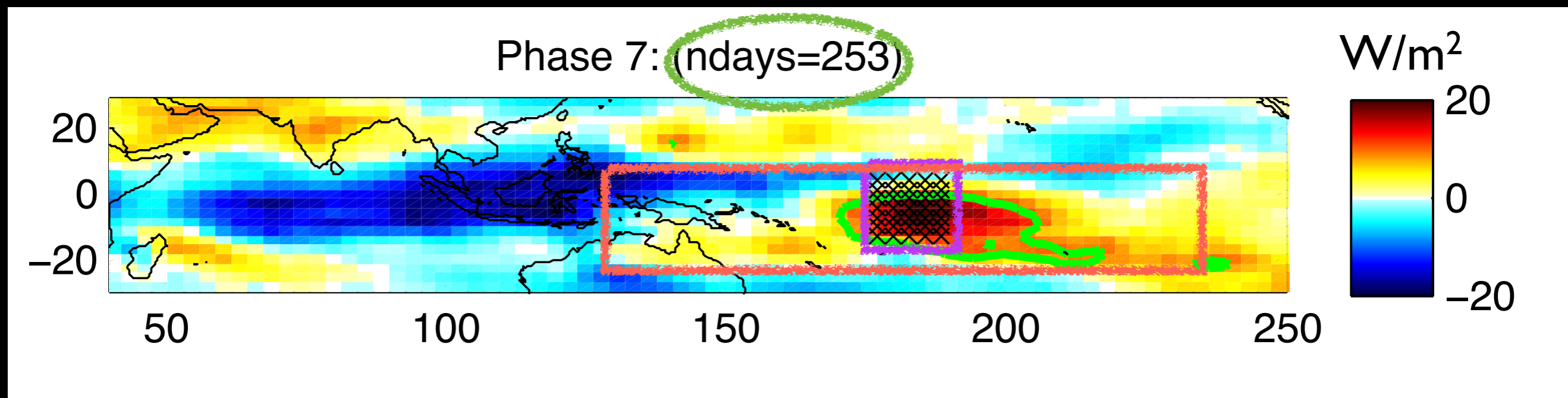


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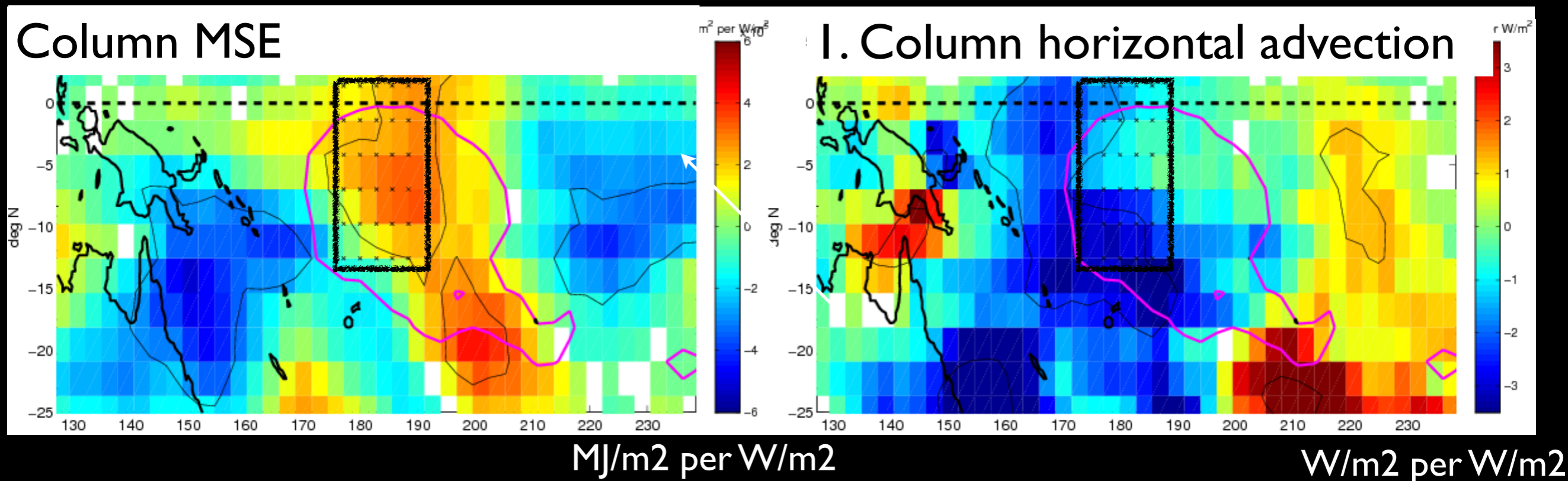


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Focus on column MSE budget at **latitudes** of maximum MJO convection

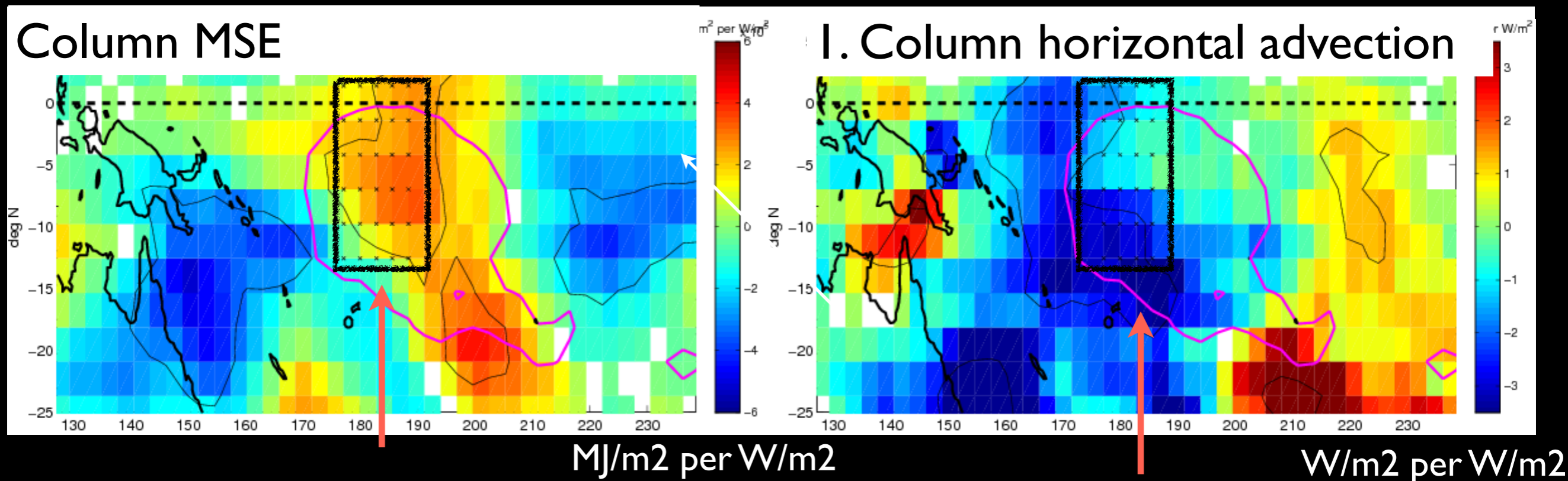
Real-world SPCAM's phasing of horizontal column MSE advection is consistent with a moisture mode.

Lag (x,y) regression slope magnitude of (left) unfiltered column MSE & (right) the horizontal advection tendency term in its budget.



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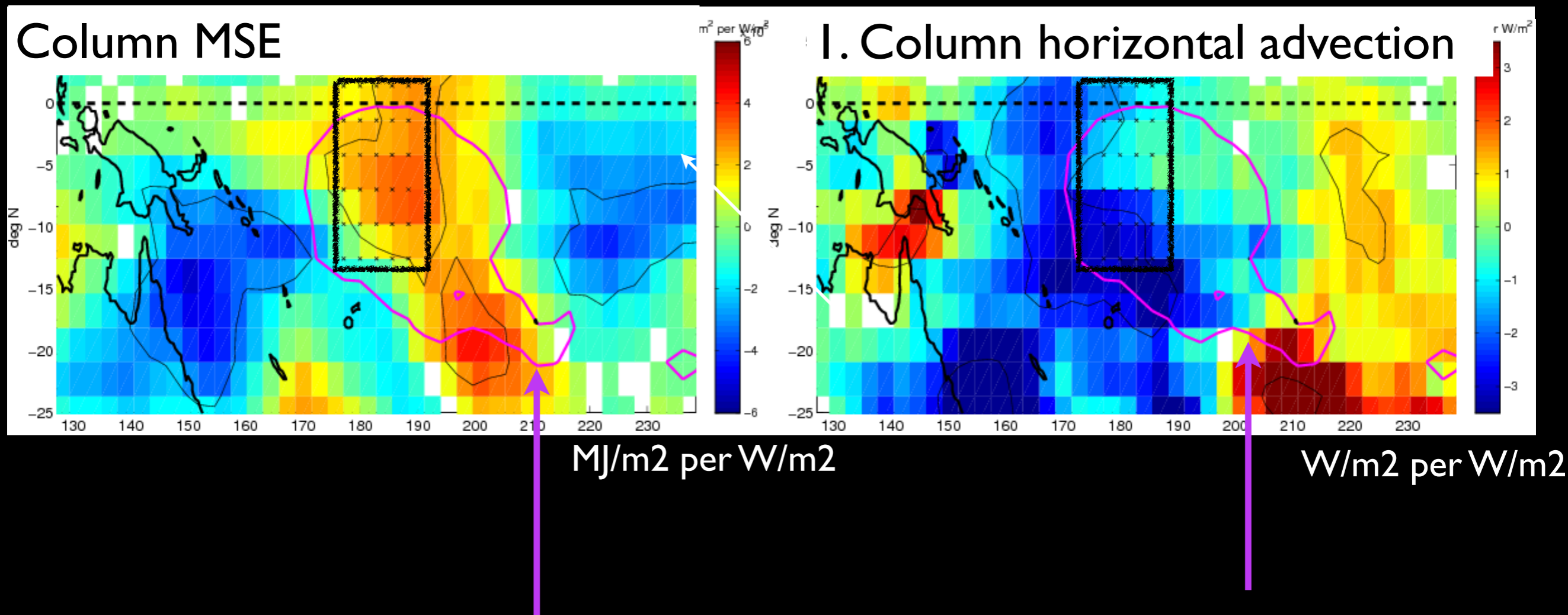
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(Regressed against MJO convection index in these boxes)

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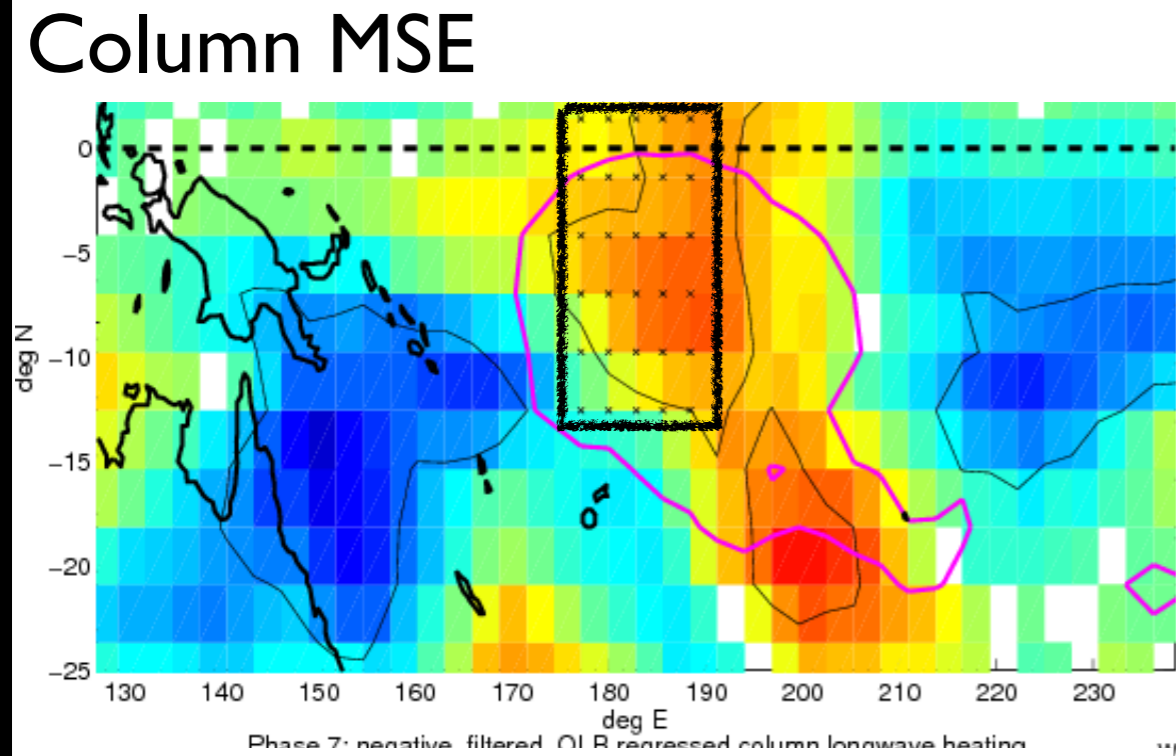


This OLR contour outlines the convective center

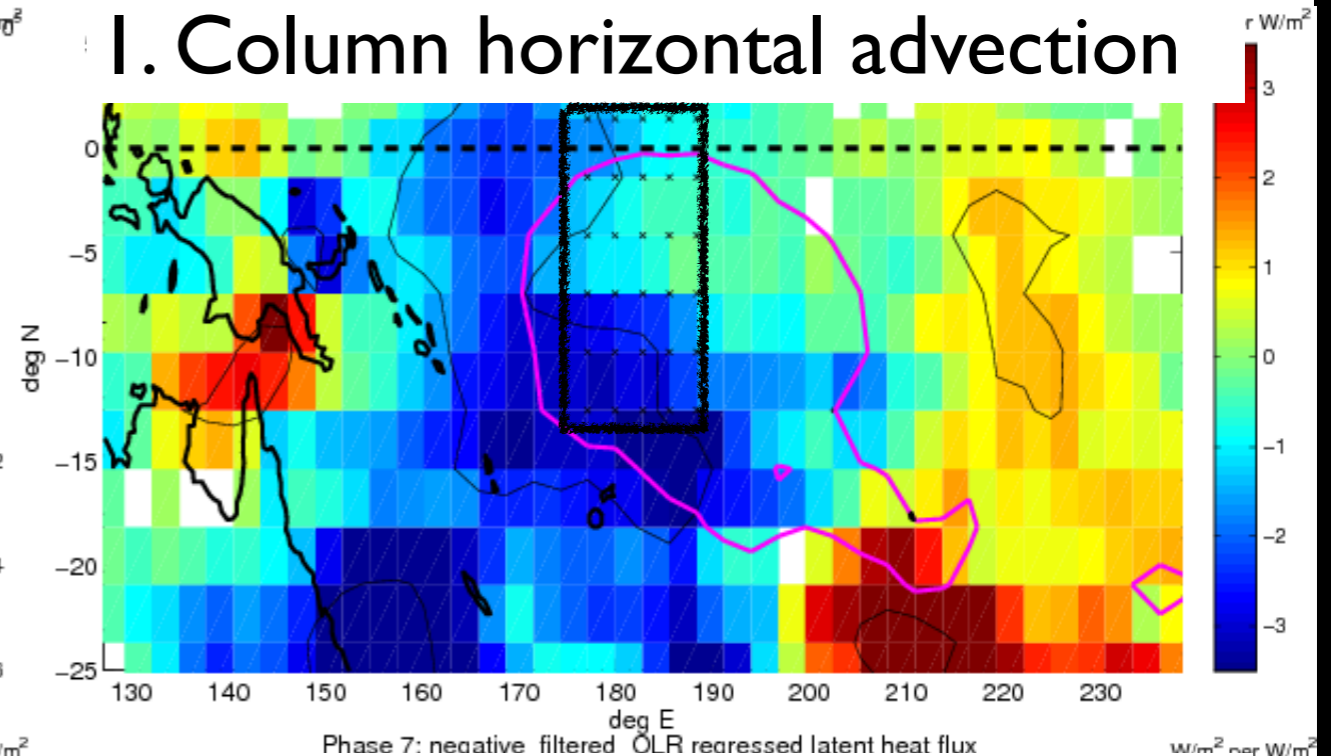
Surface fluxes play a major role in maintaining real-world SPCAM's intraseasonal column MSE.

The 3 budget tendencies are shown on the same color scale (W/m^2 per W/m^2)

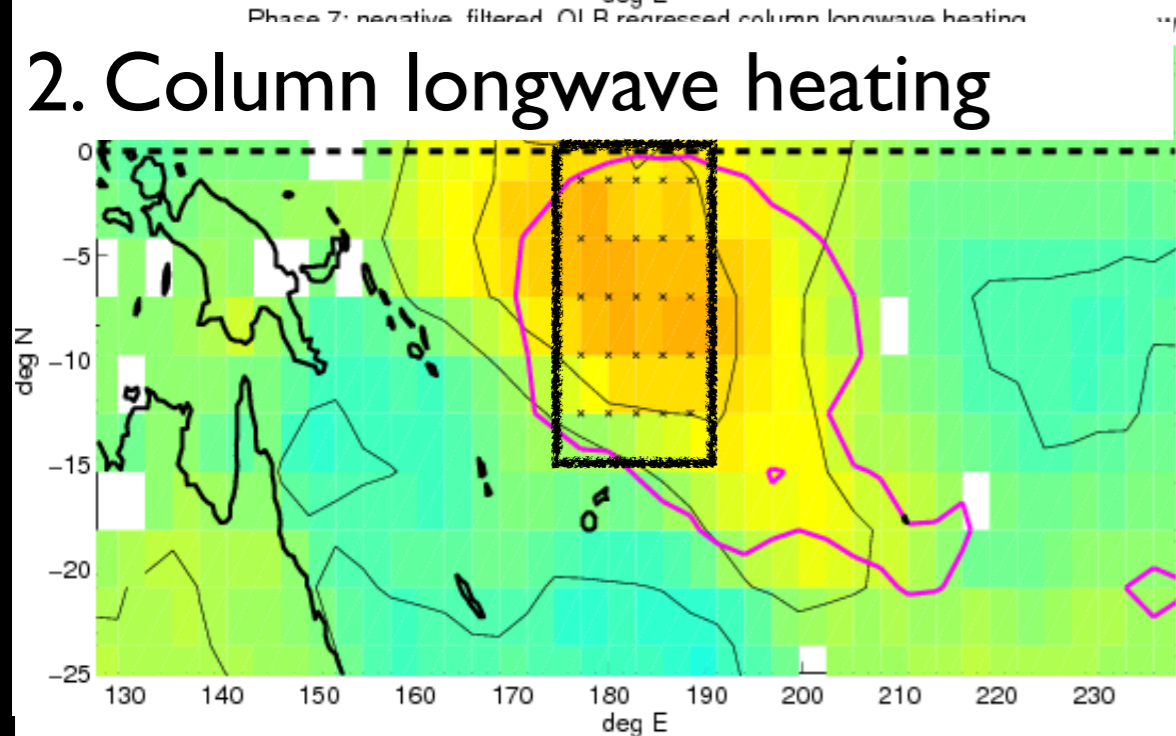
Column MSE



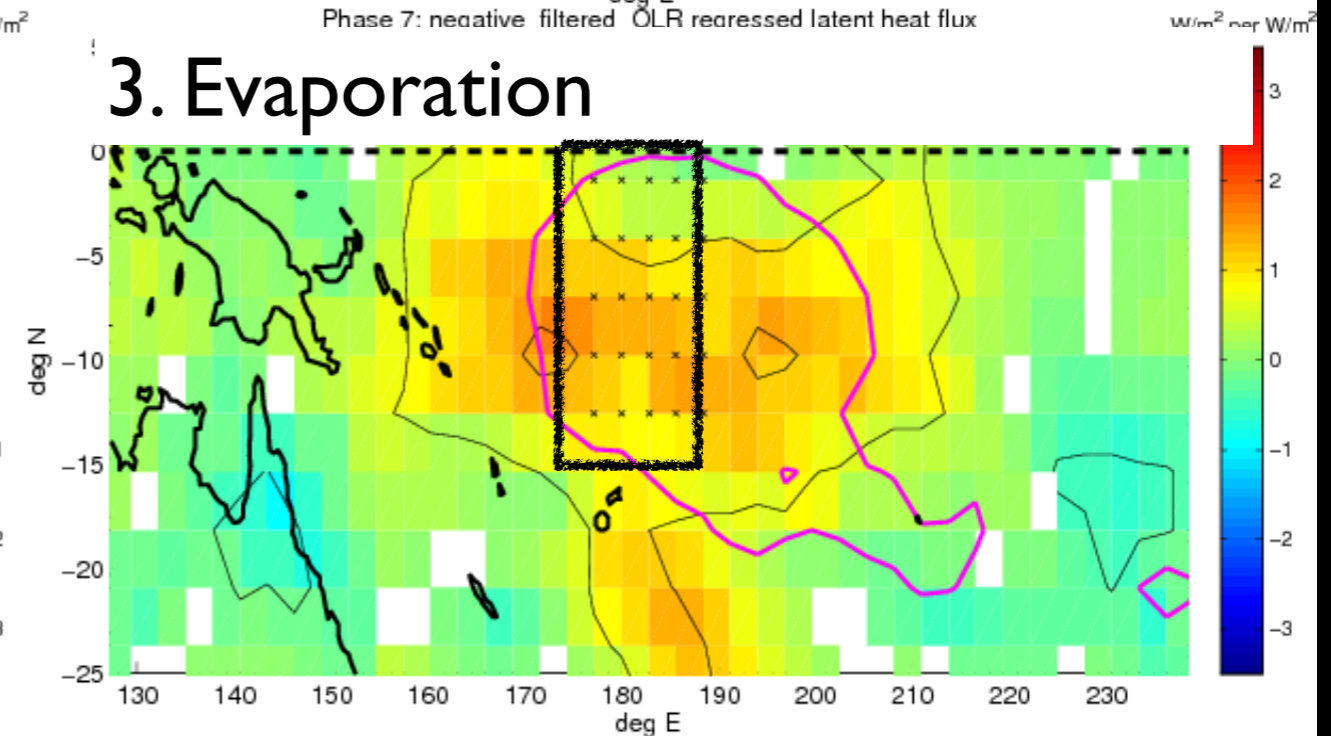
1. Column horizontal advection



2. Column longwave heating



3. Evaporation



How does real-world SPCAM's mature phase oceanic intraseasonal moisture mode compare to other models?

Modified CAM3

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Role of longwave heating anomalies?	Hard to say	Strongly destabilizing	Moderately destabilizing
Role of surface flux anomalies?			

How does real-world SPCAM's mature phase oceanic intraseasonal moisture mode compare to other models?

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Questions

What destabilizes the mature
Pacific moisture mode in real-world SPCAM?

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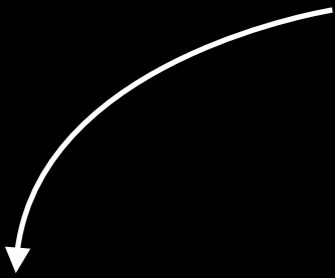
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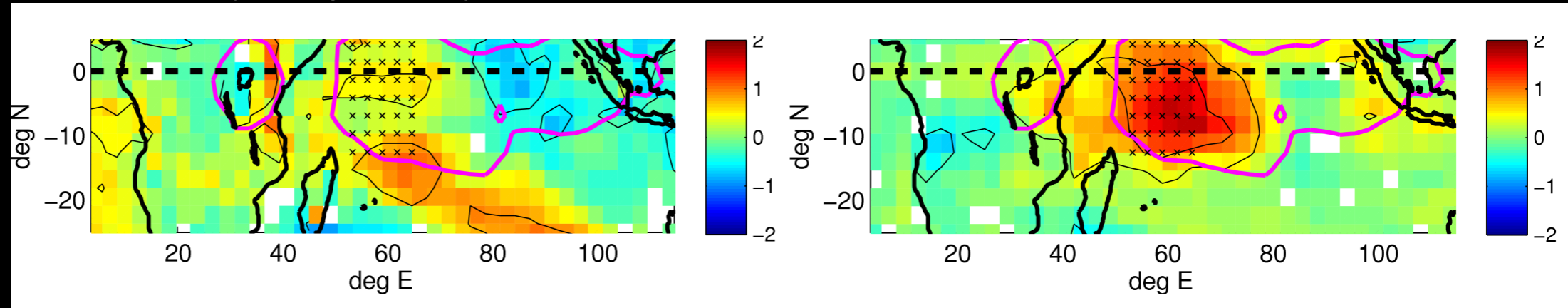
Does destabilization occur differently over the Indian Ocean and Maritime Continent?

Radiative destabilization seems to play a larger role in the column MSE budget over the Indian Ocean and Maritime Continent sectors.

Evaporation
(W/m^2 per W/m^2)

vs. Column longwave heating
(W/m^2 per W/m^2)

Phase 2
(initiation)



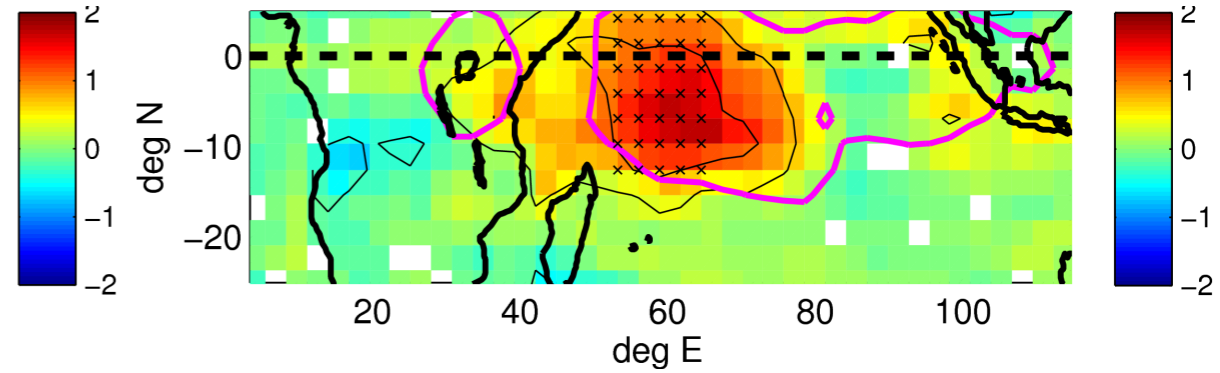
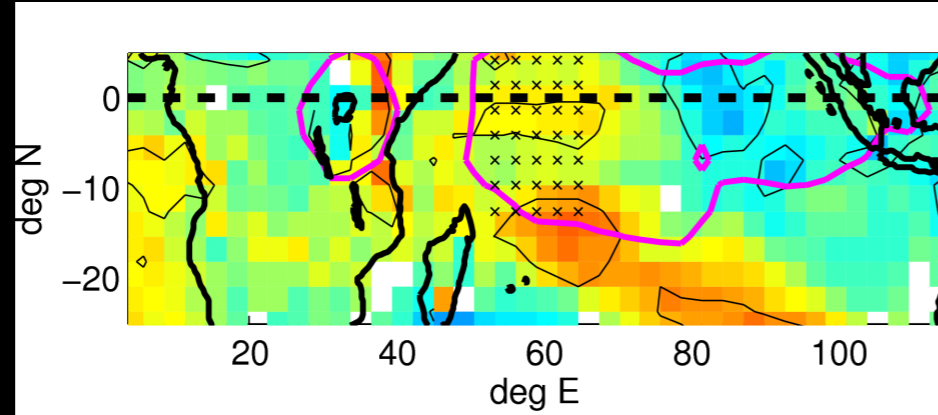
(As before, colors show regression slope magnitude of unfiltered budget tendencies relative to MJO convection index in central region)

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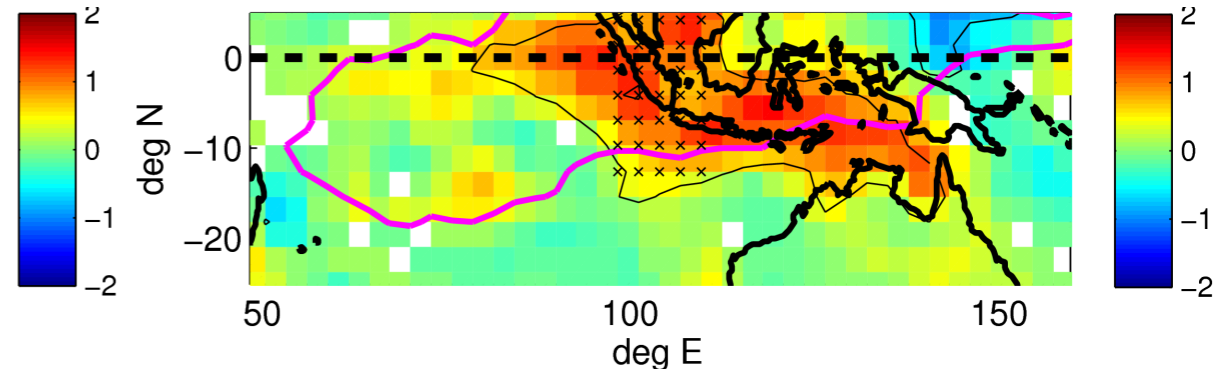
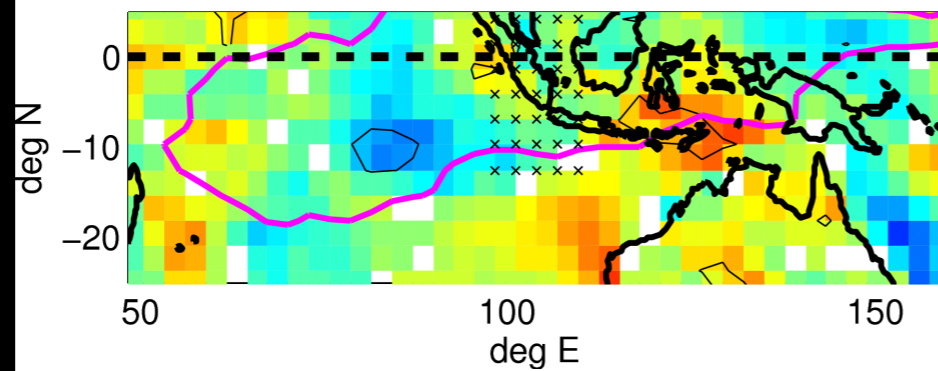
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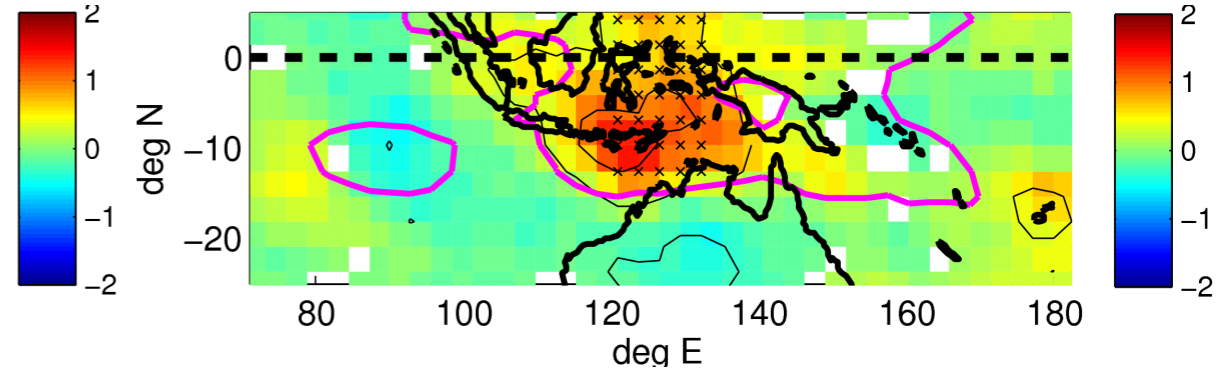
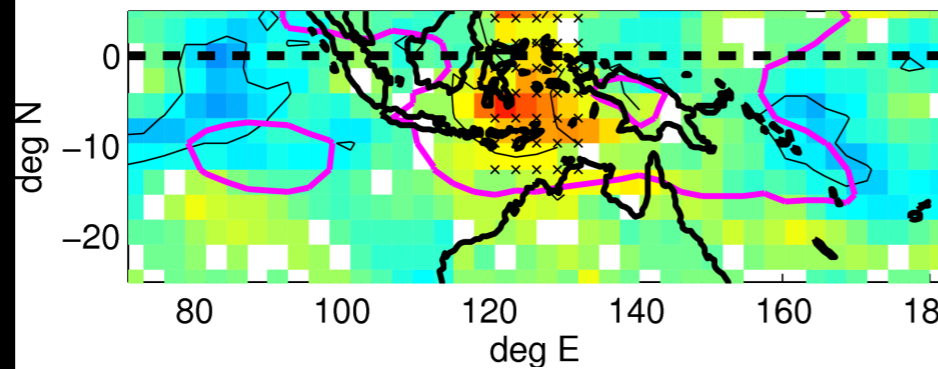
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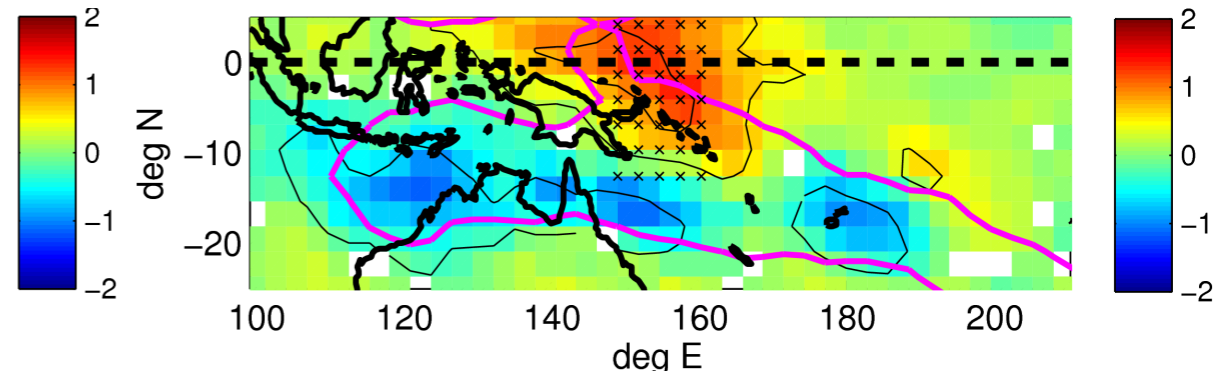
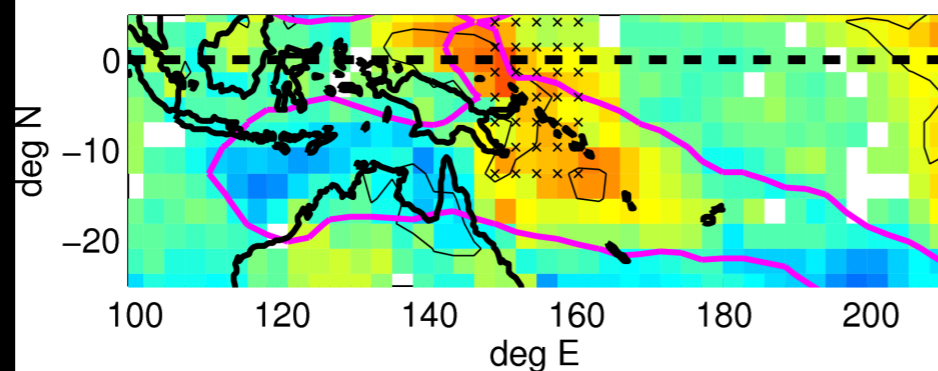
Phase 3



Phase 4



Phase 5

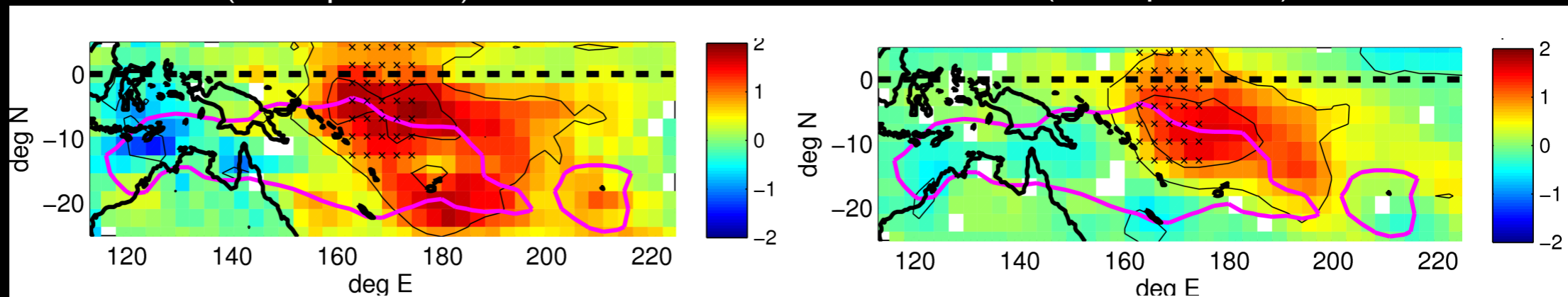


Evaporative destabilization is dominant over all Warm Pool phases.

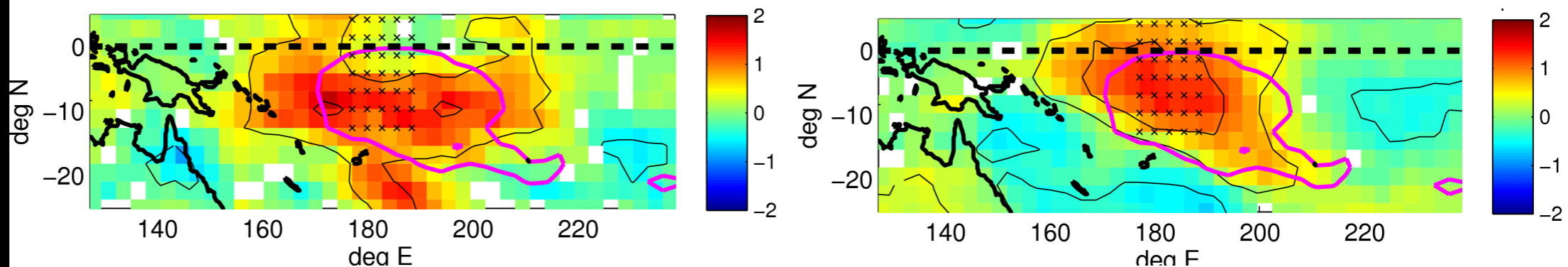
Evaporation
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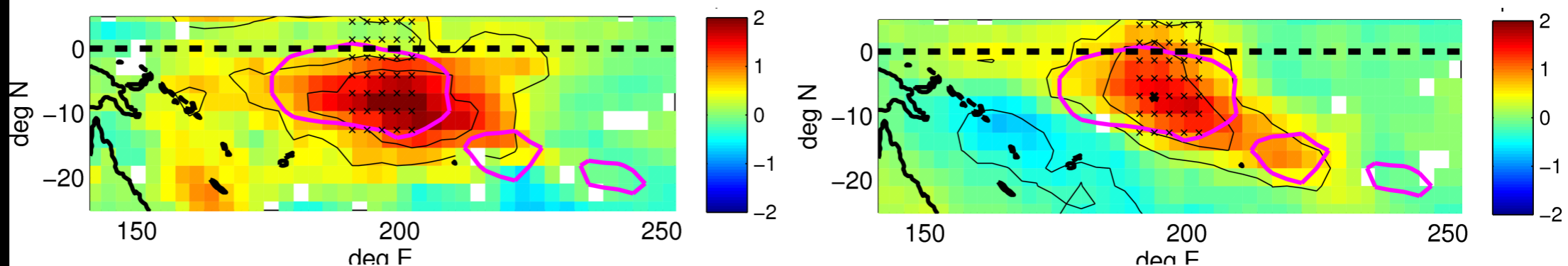
Phase 6



Phase 7



Phase 8



Regression slope of unfiltered latent heat flux and column radiative heating against 20-100 day MJO convection index across the reference region.

Questions

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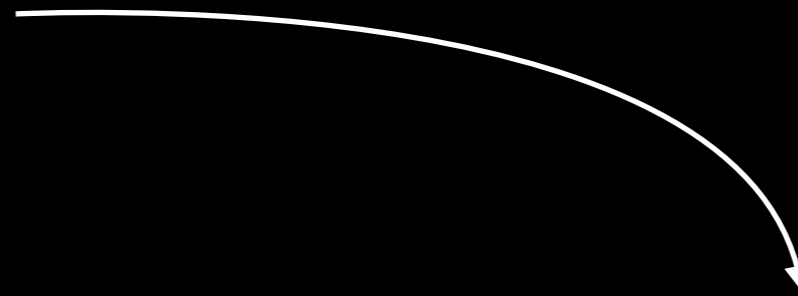
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What does the unsteady evolution of column MSE look like in SPCAM?

Exploring the idea of moisture mode dynamics means examining column moist static energy evolution.

$$\frac{d}{dt} \langle \text{MSE} \rangle (x,y,t) = \mathbf{why?}$$

(budget tendency variables)

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So far we have used a traditional **time mean** (\mathbf{x}, \mathbf{y}) composite view of intraseasonal anomalies to this balance.

What does an **unsteady** ($\mathbf{x}, \mathbf{y}, t$) view say about how SPCAM's column MSE is evolving via **self-aggregation** physics?

Extending the lag regression of column MSE to (x,y,t)

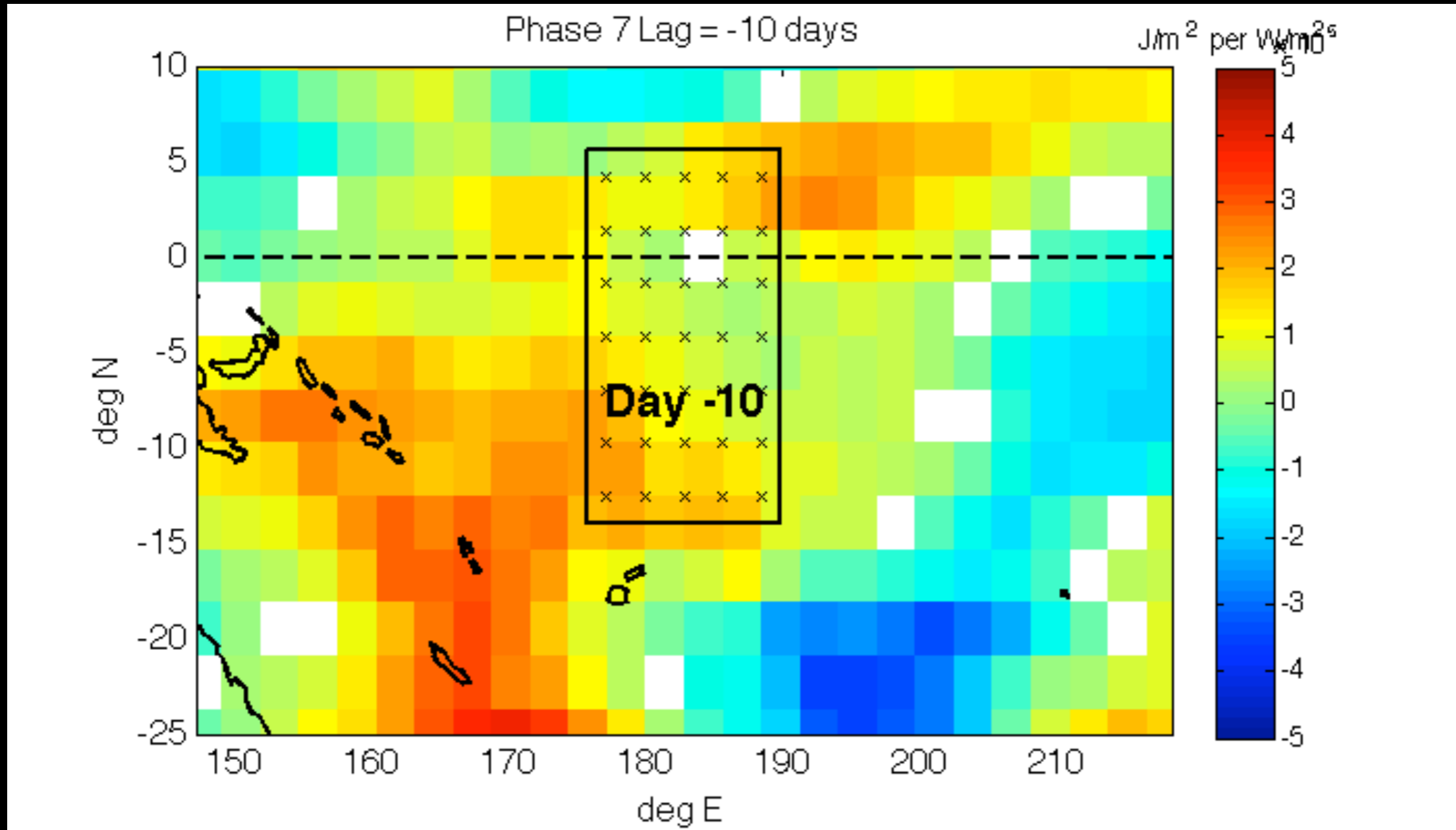
The unsteady evolution of column MSE in SPCAM's composite MJO is richly structured in (x,y,t).

Phase 7: (Mature, Pacific)

Colors show the regression slope of unfiltered column MSE lag-regressed against 20-100 day filtered column MSE across the reference region.

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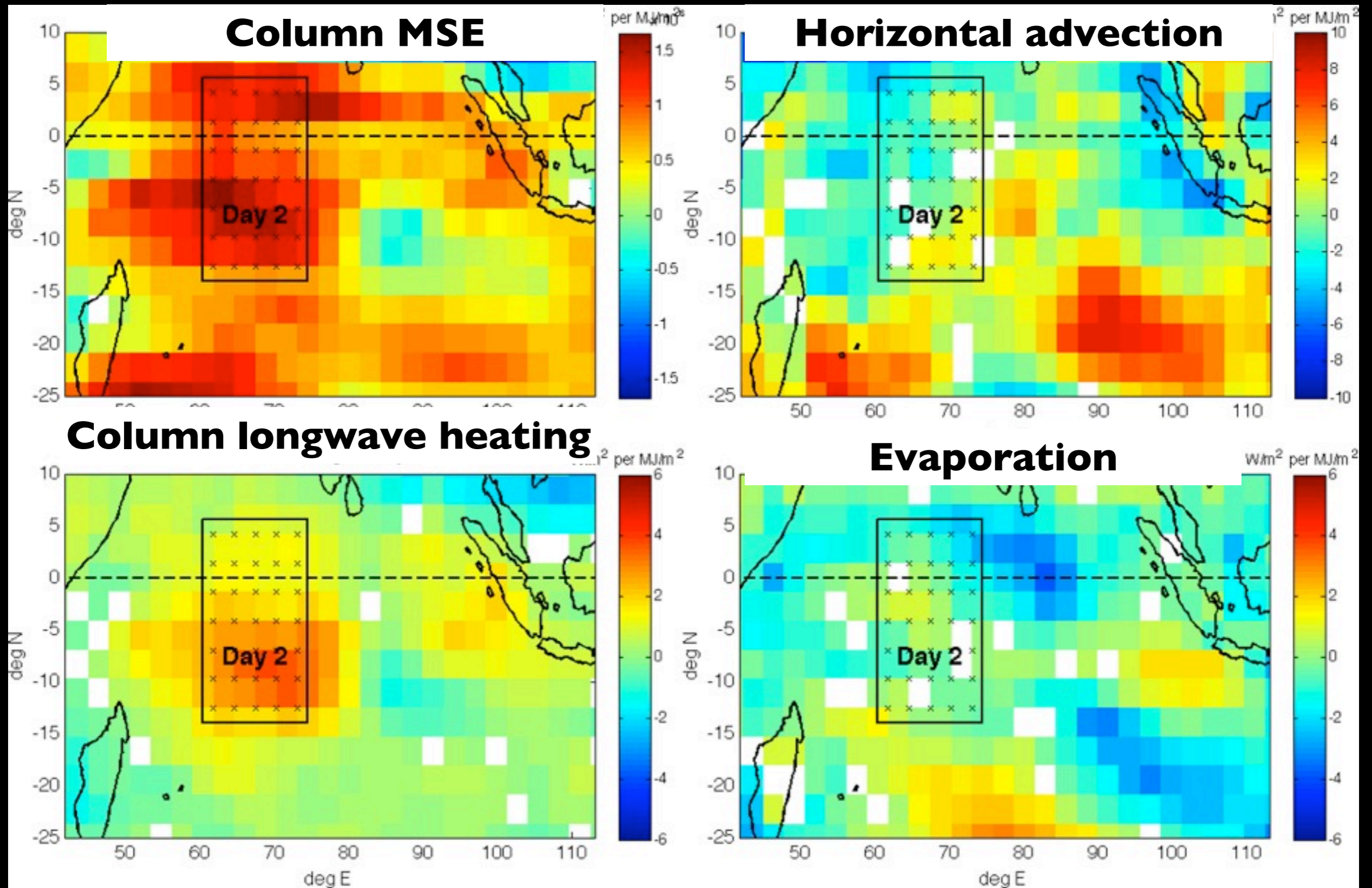
Phase 7: (Mature, Pacific)



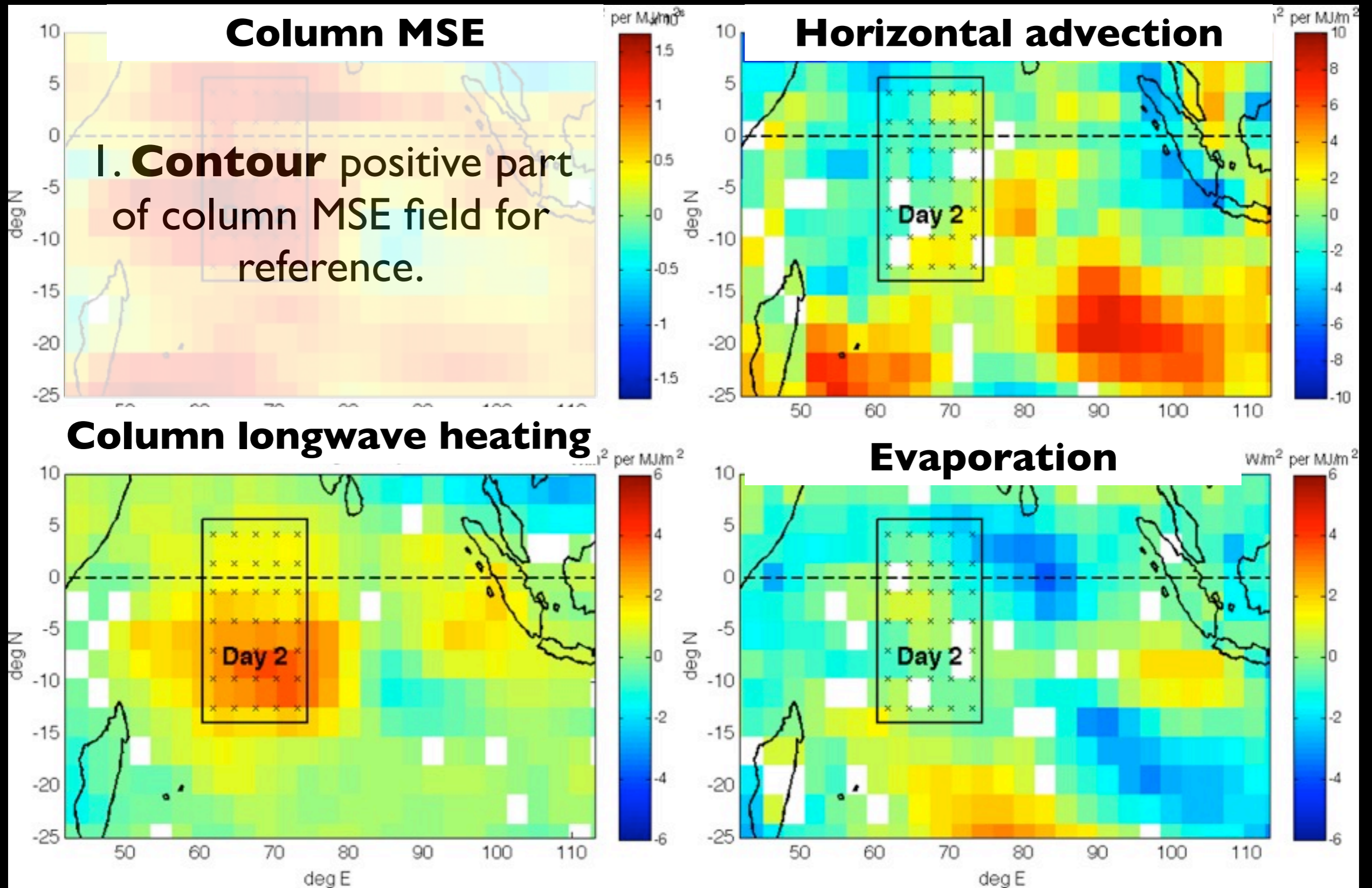
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Understanding the (x,y,t) structure of balances in the column MSE budget visually can be challenging.

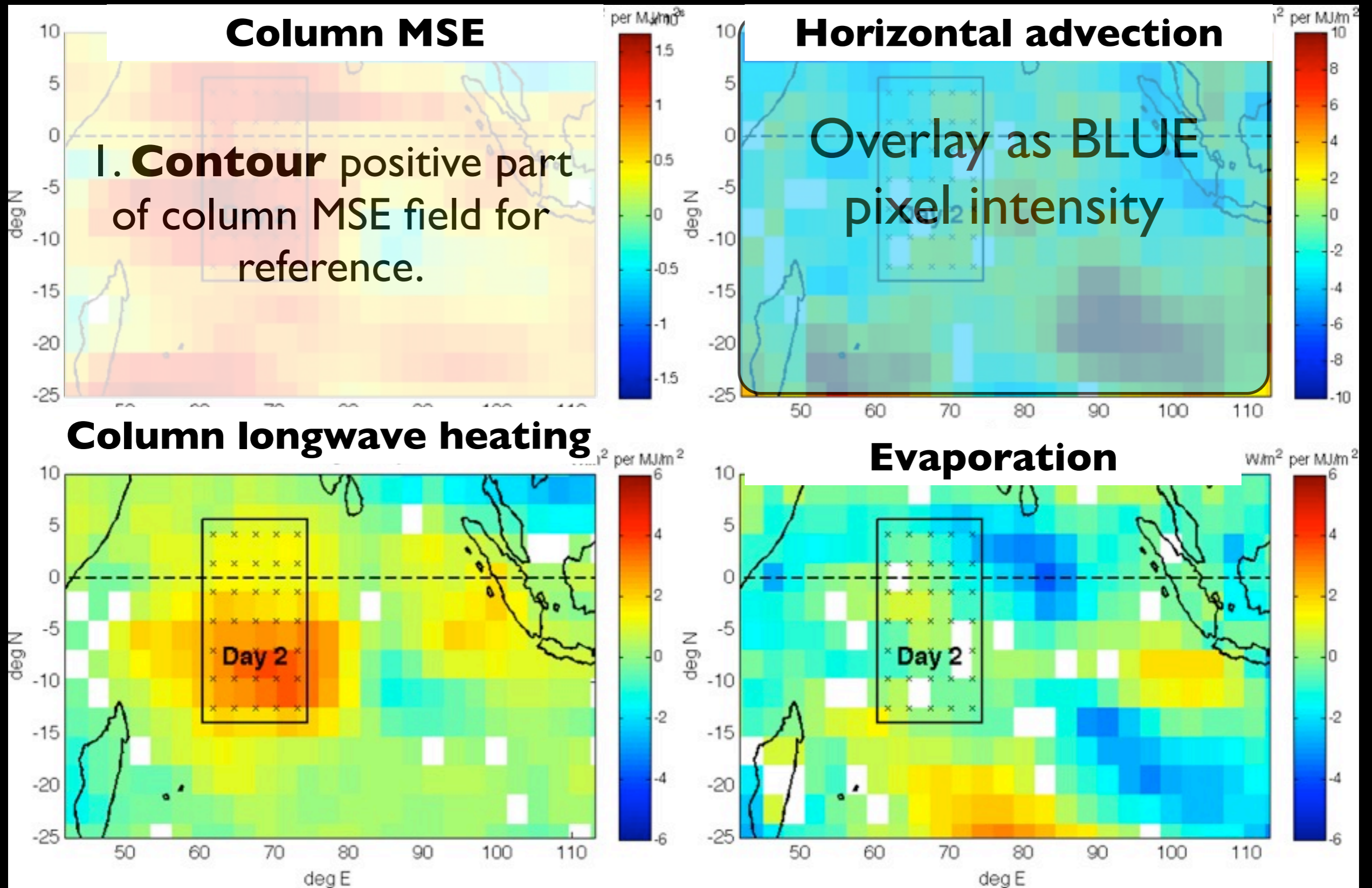
A visualization strategy to clarify SPCAM's moisture mode dynamics.



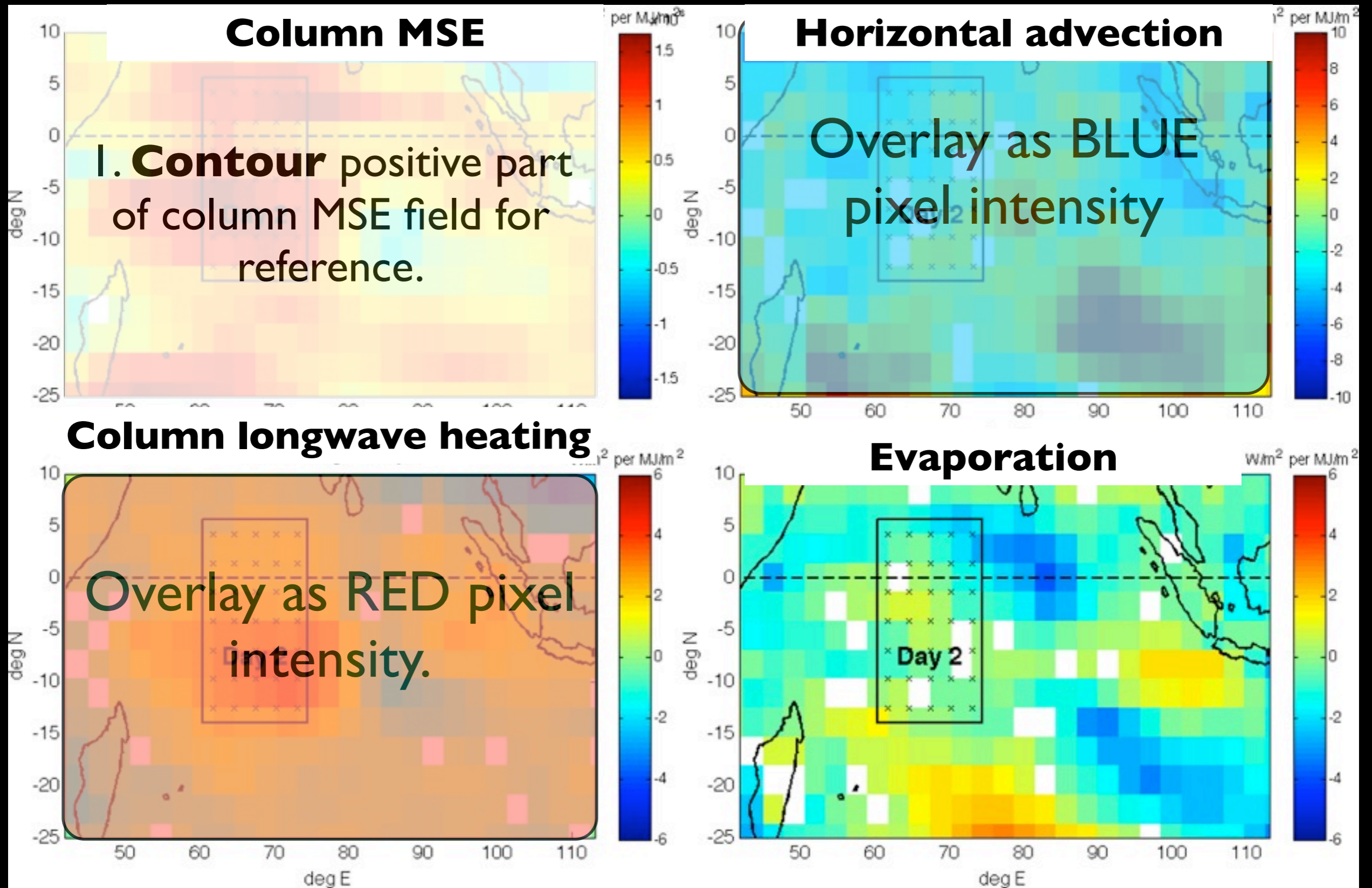
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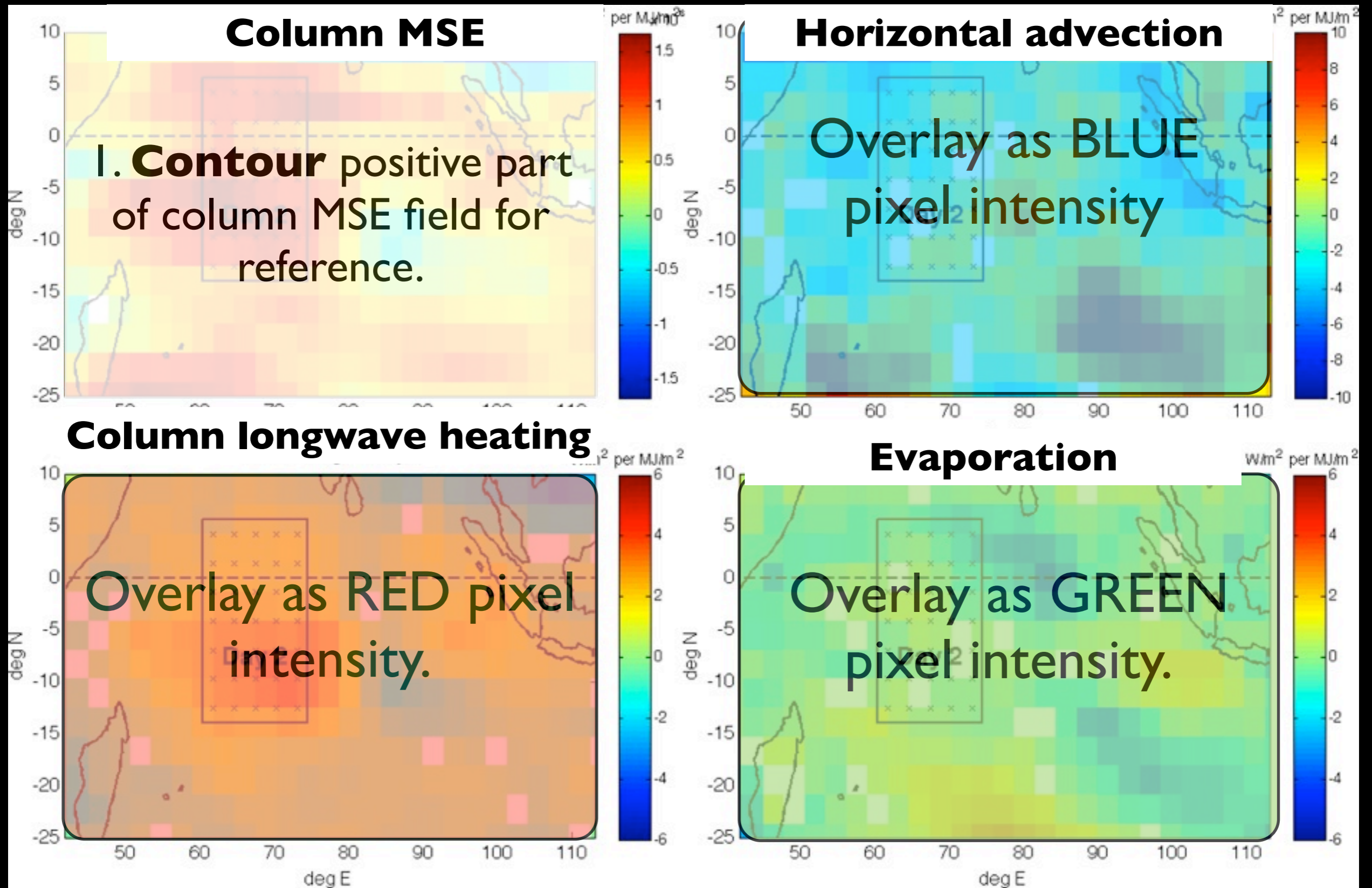
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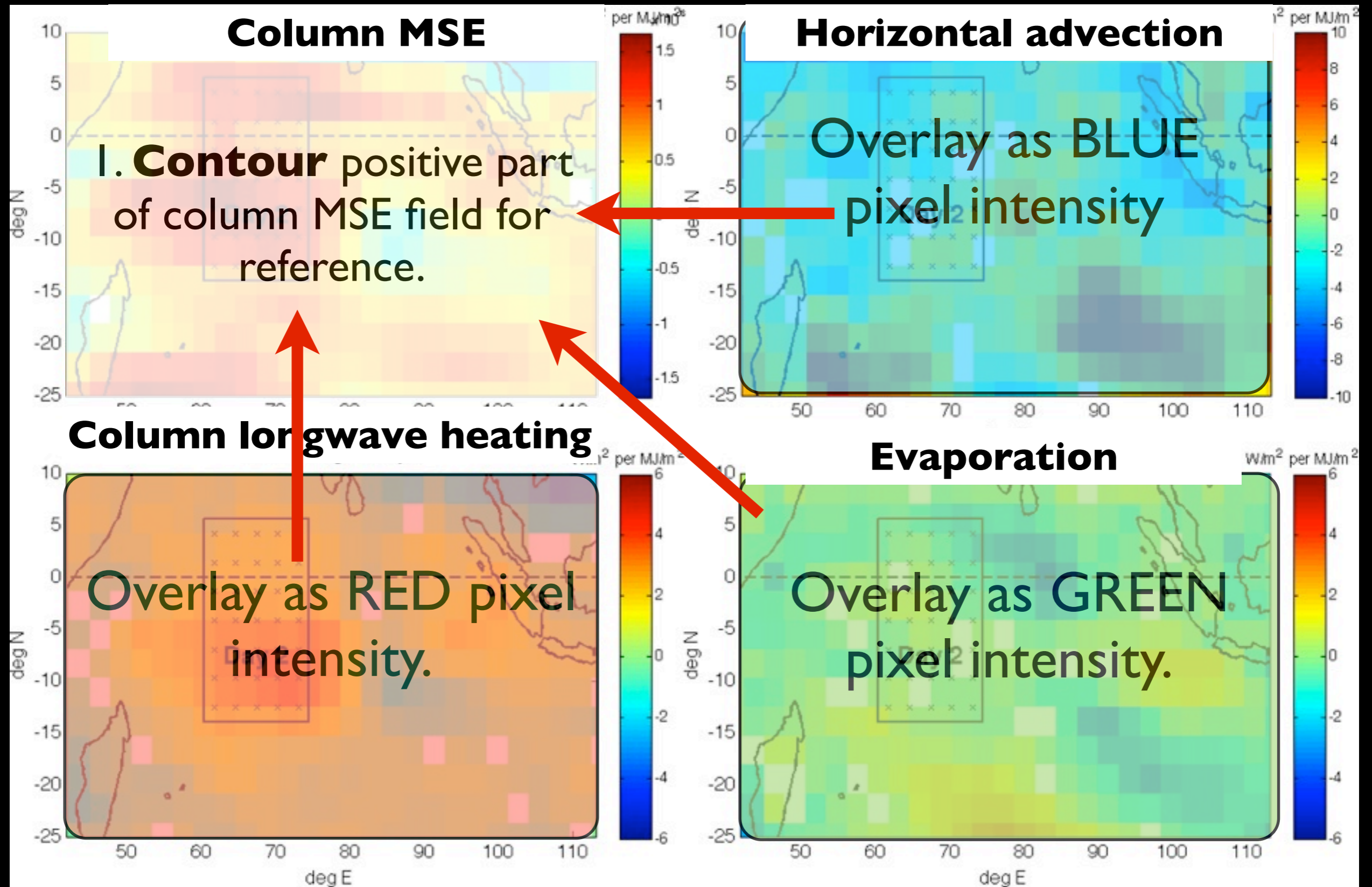
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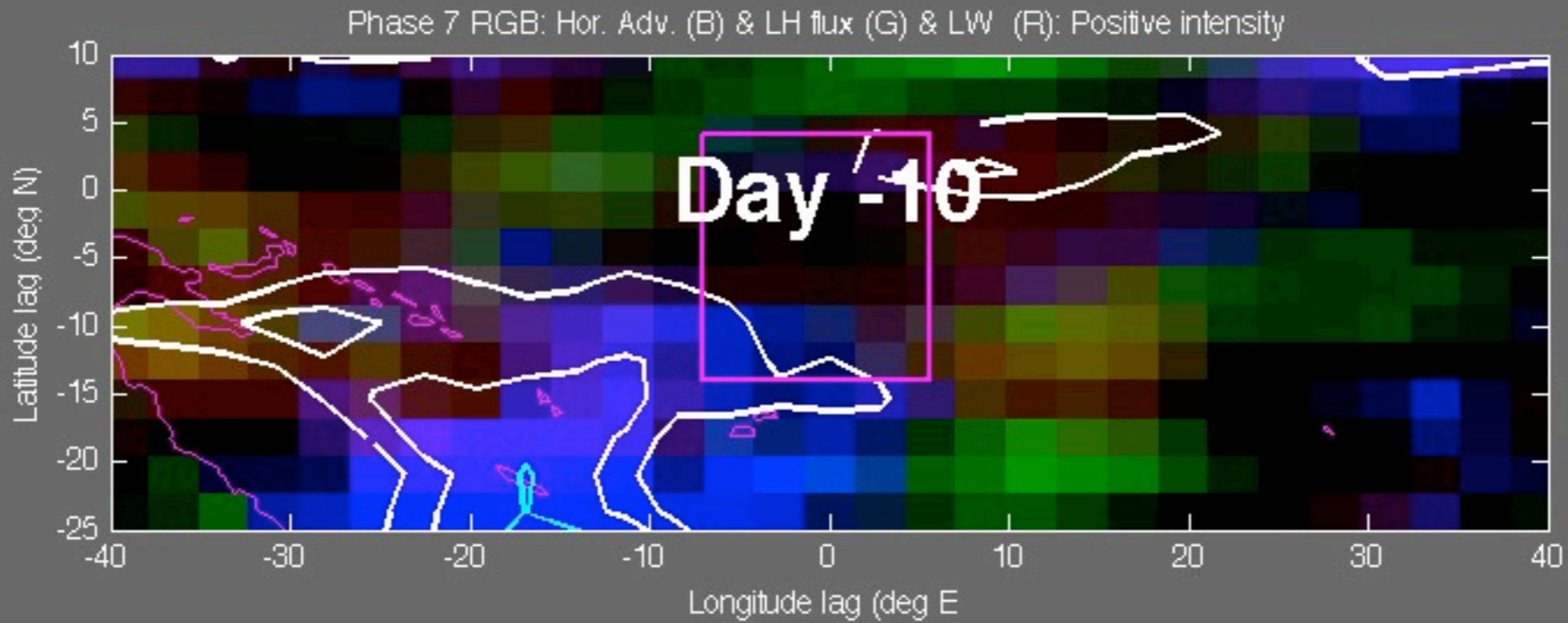


An unsteady view of SPCAM's mature Pacific moisture mode.

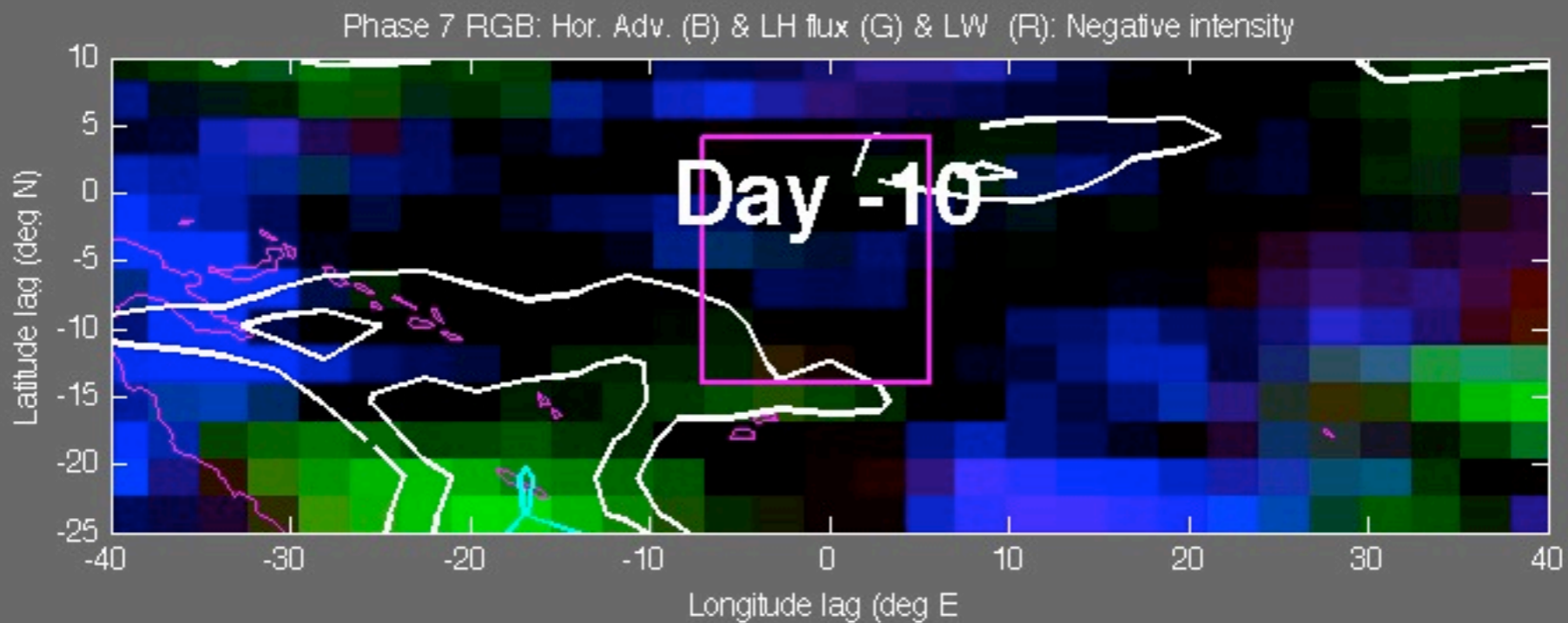
The contours show where the column MSE is.

Colors show horizontal advection + latent heat flux + longwave heating

Sources



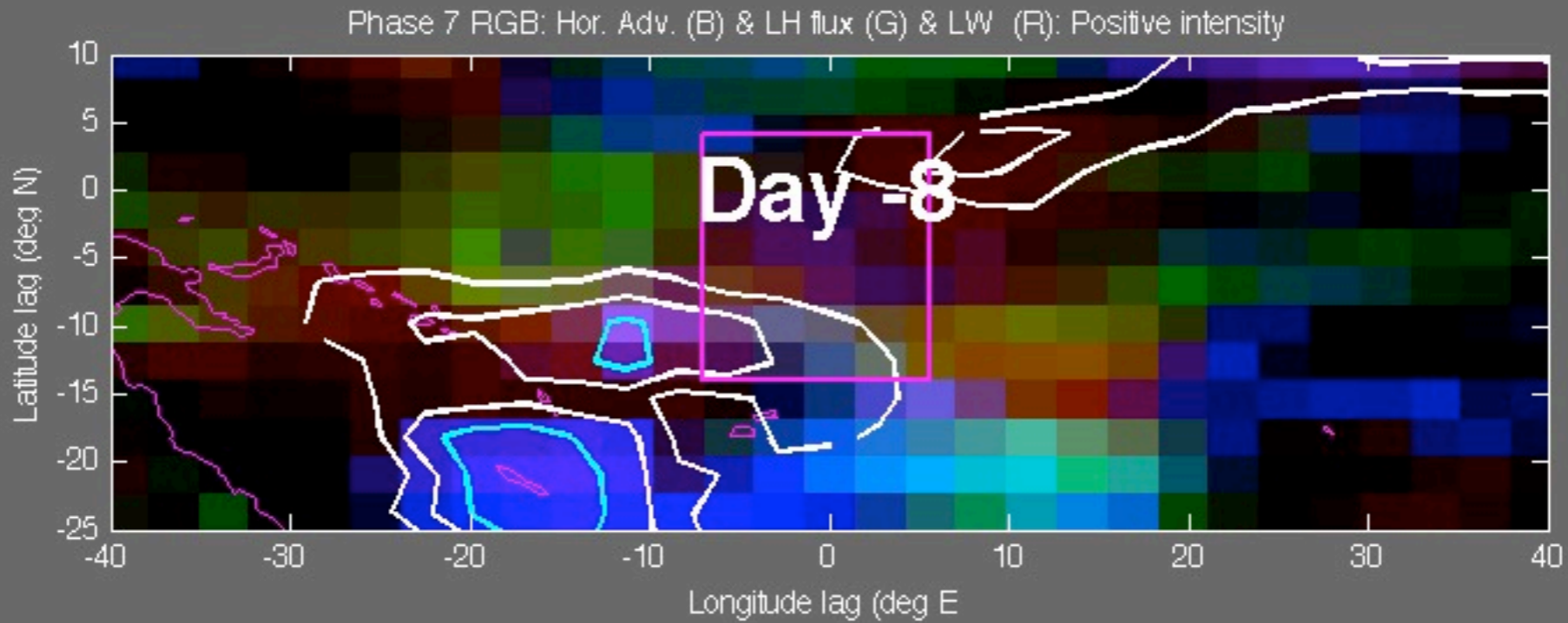
Sinks



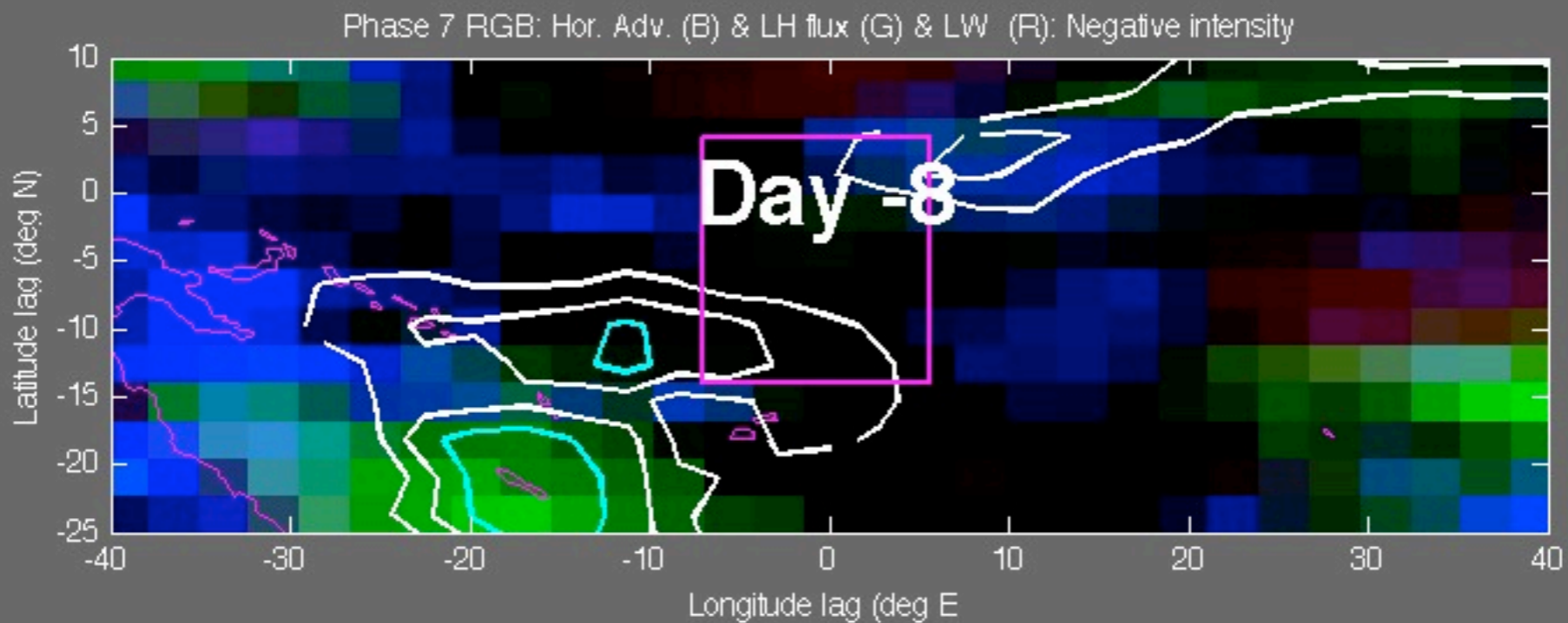
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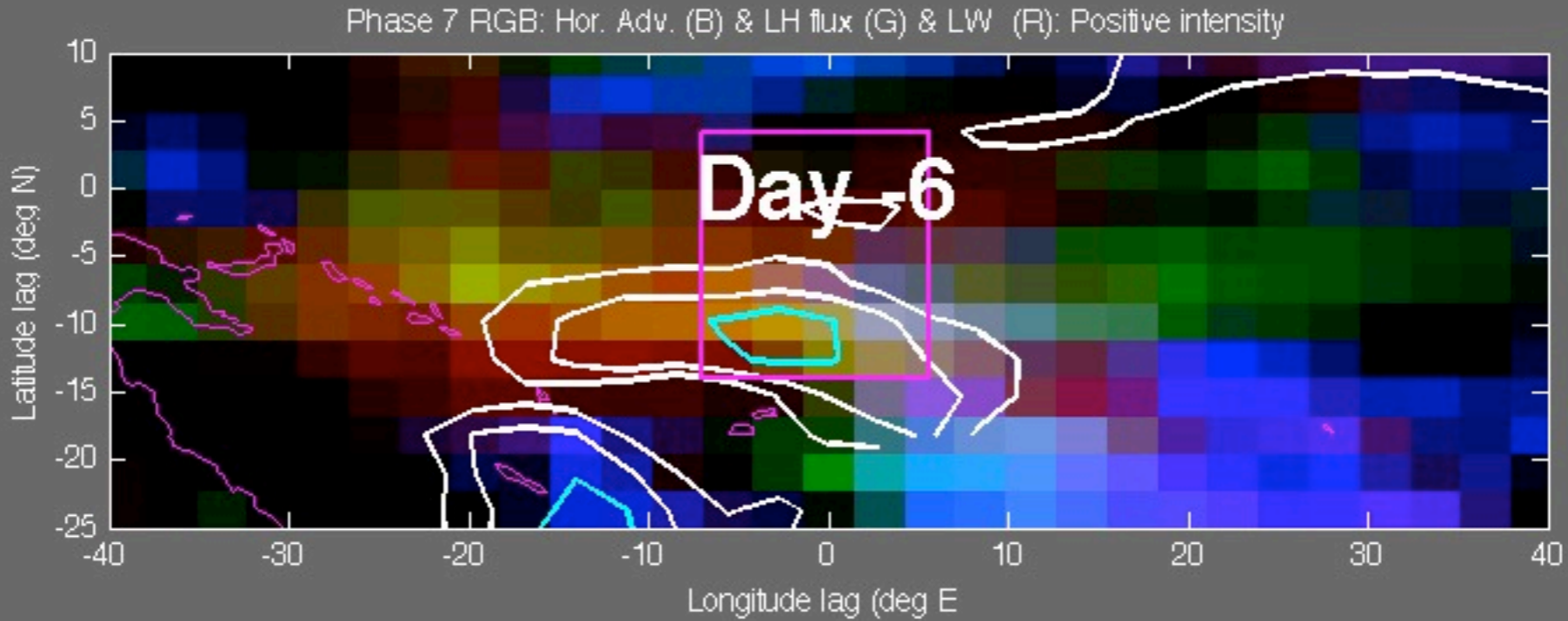
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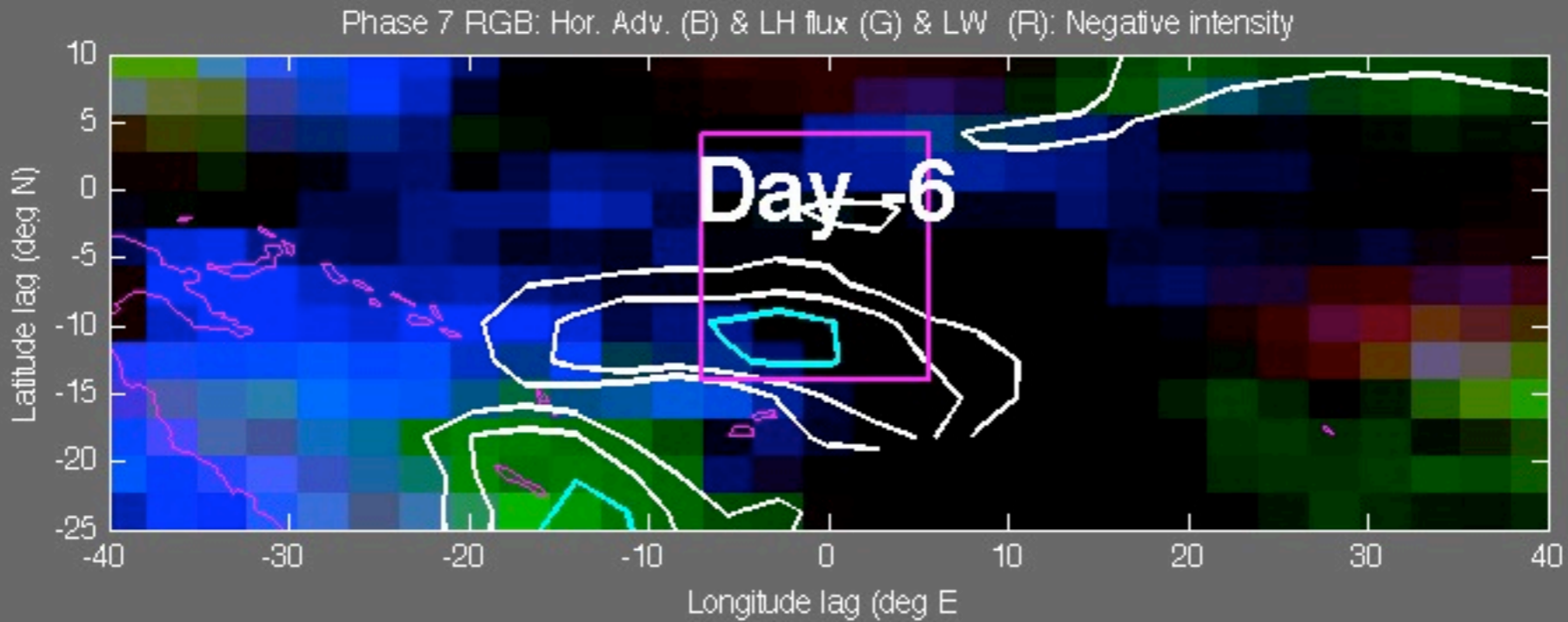
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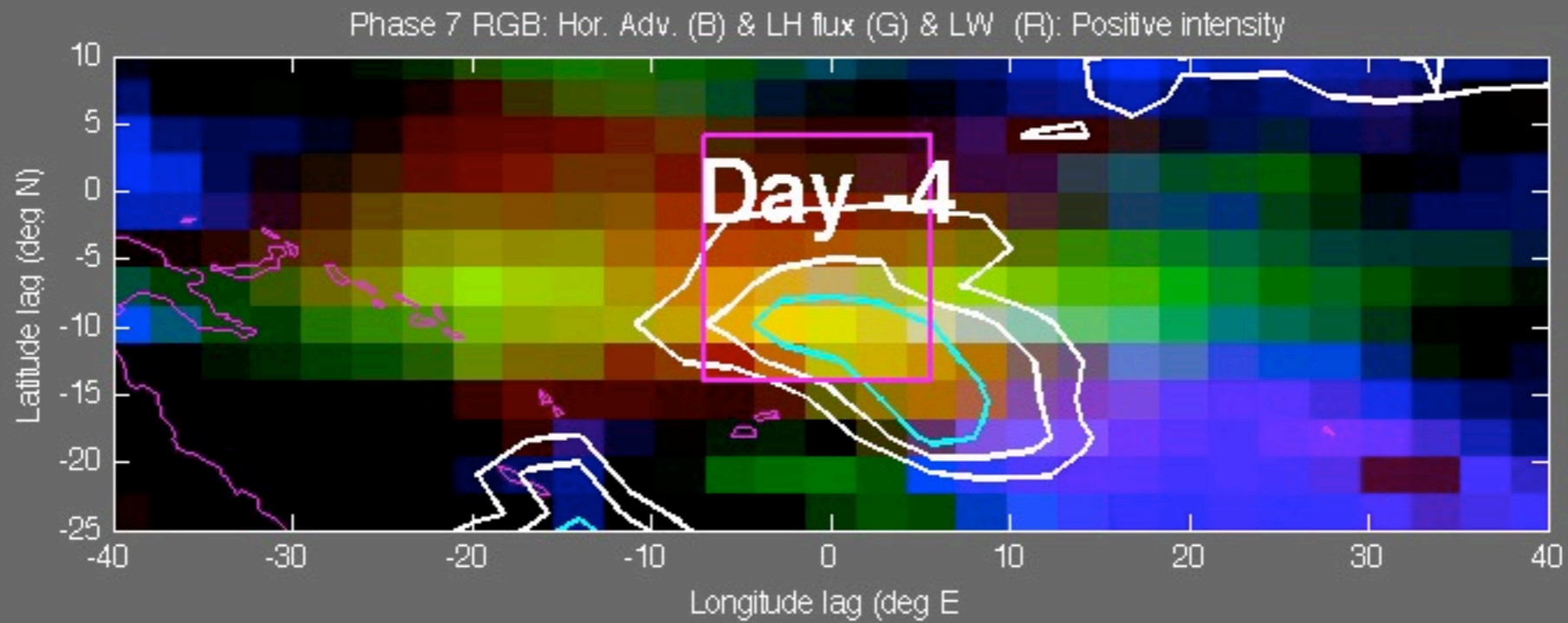
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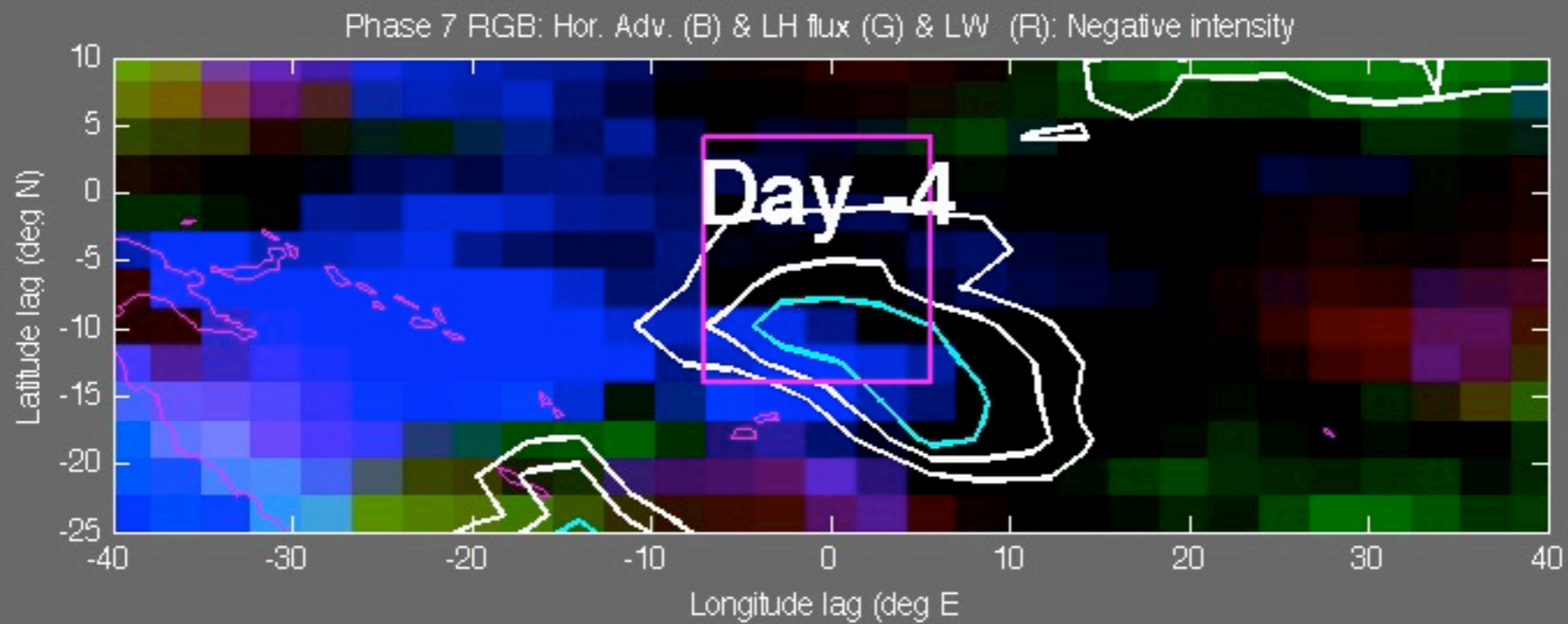
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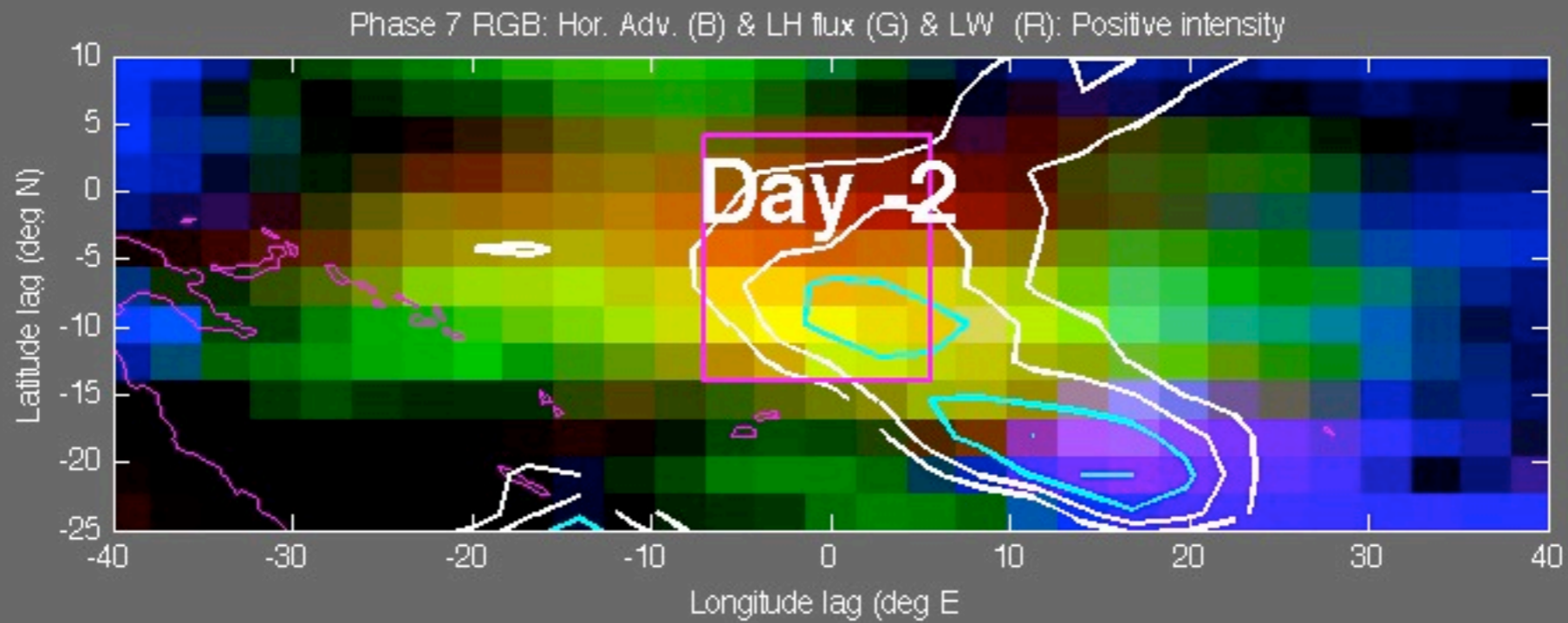
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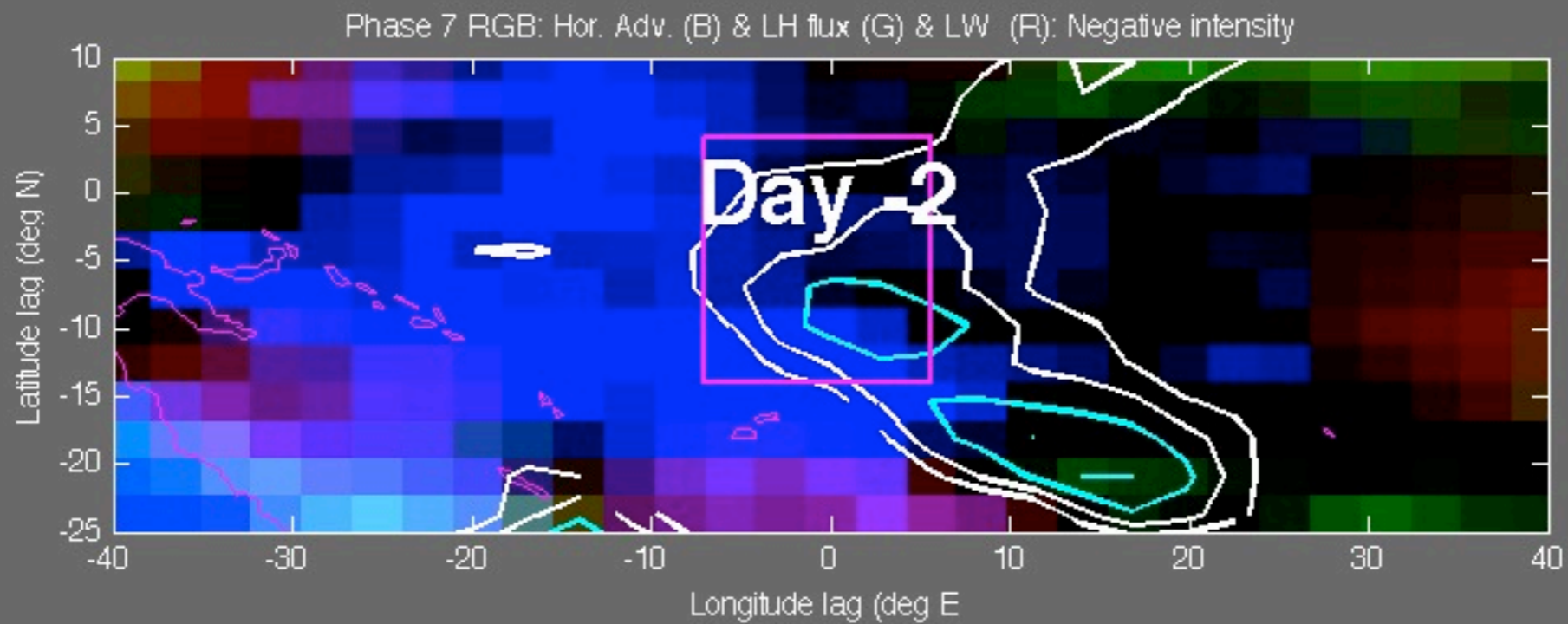
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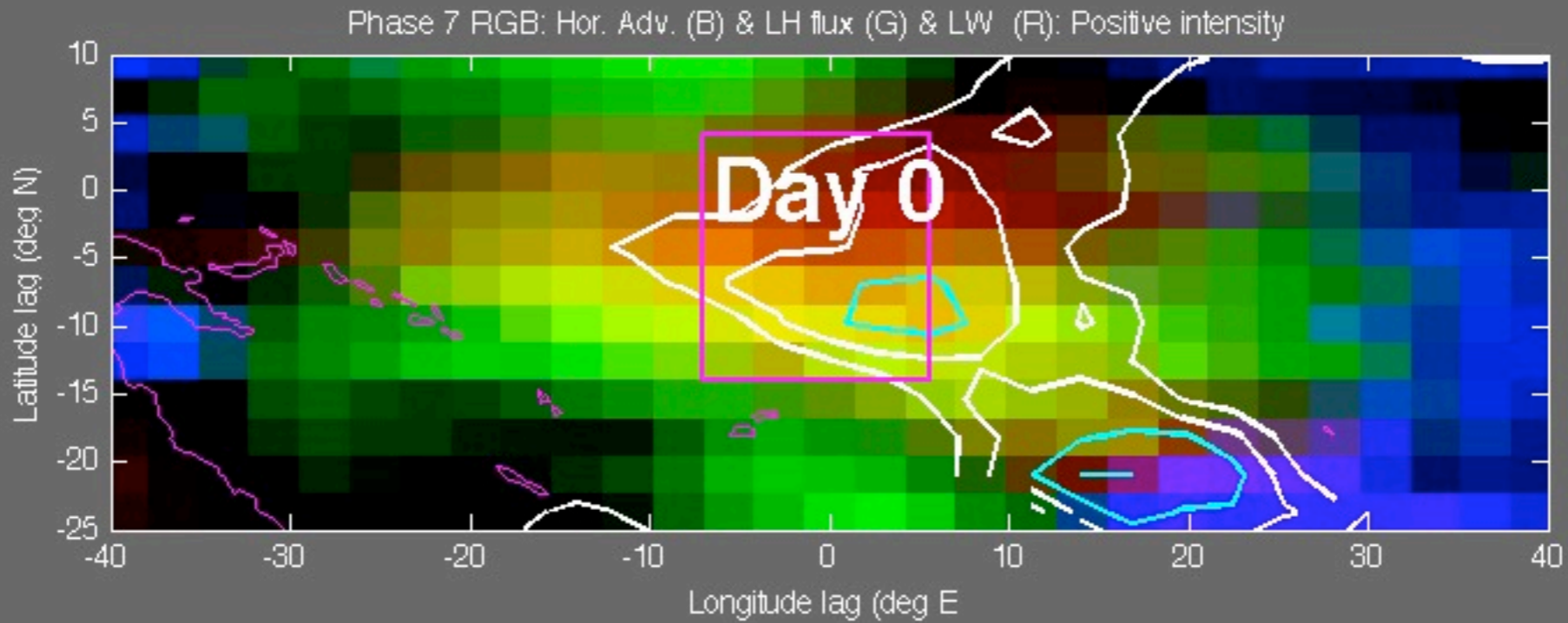
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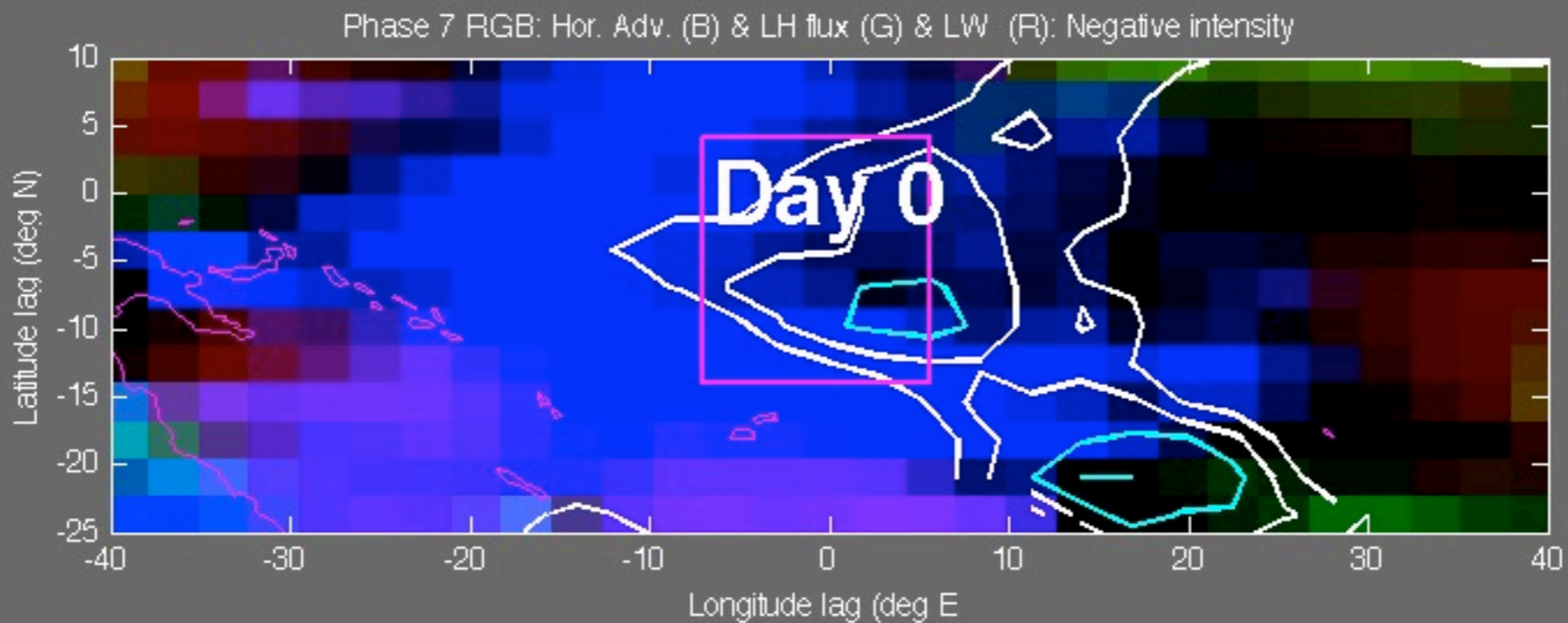
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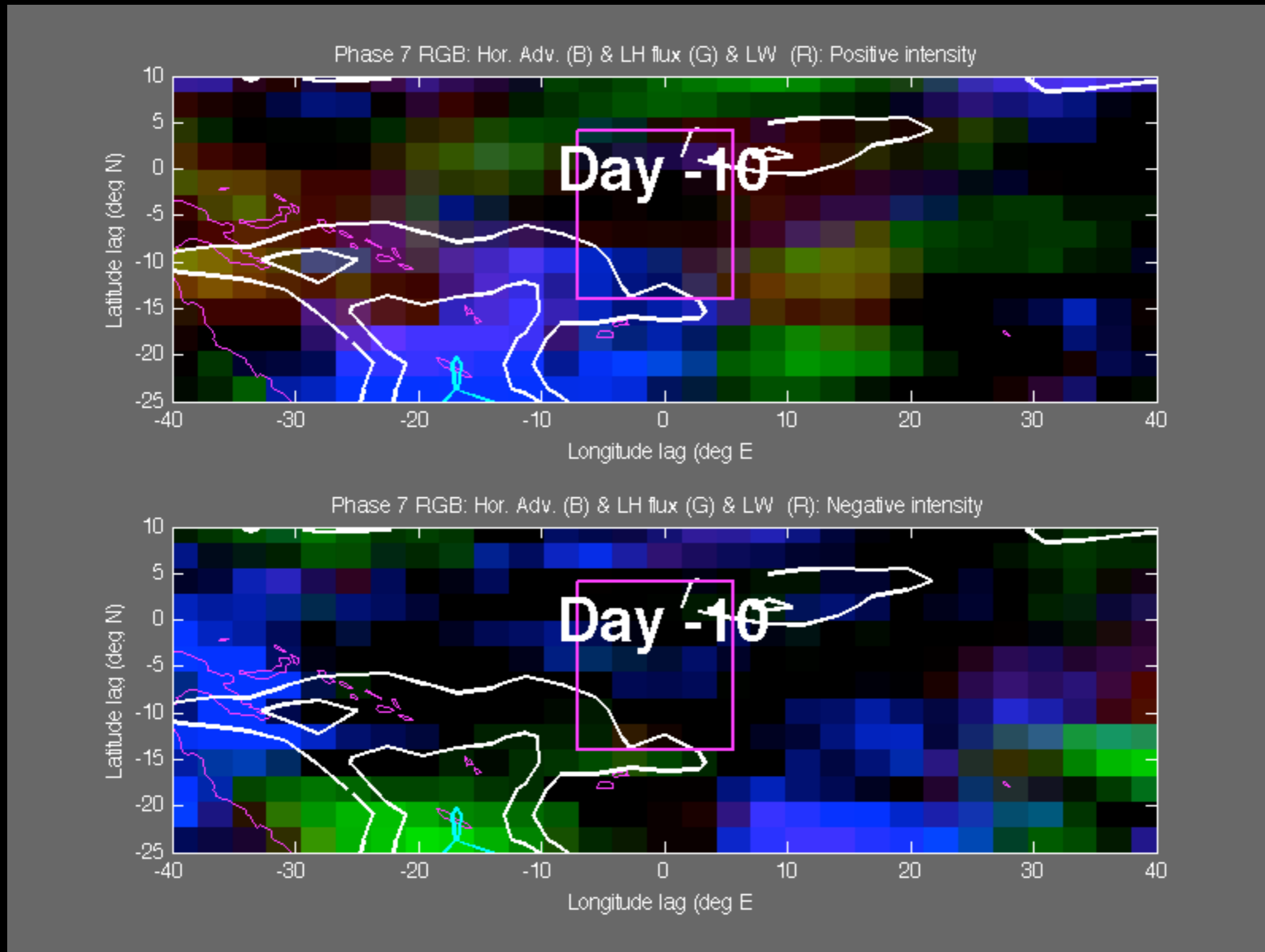
Sinks



The mature Pacific moisture mode in real-world SPCAM.

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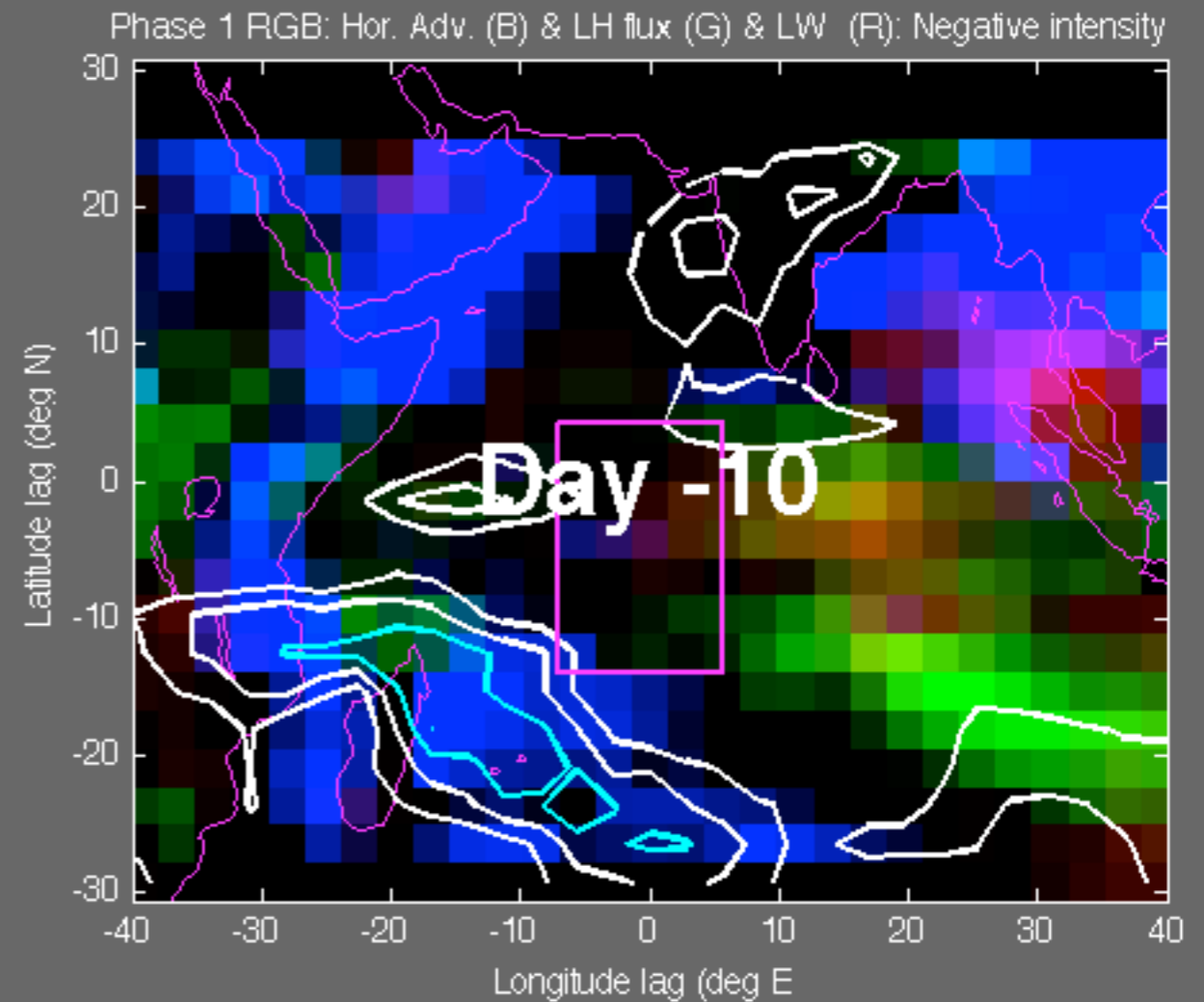
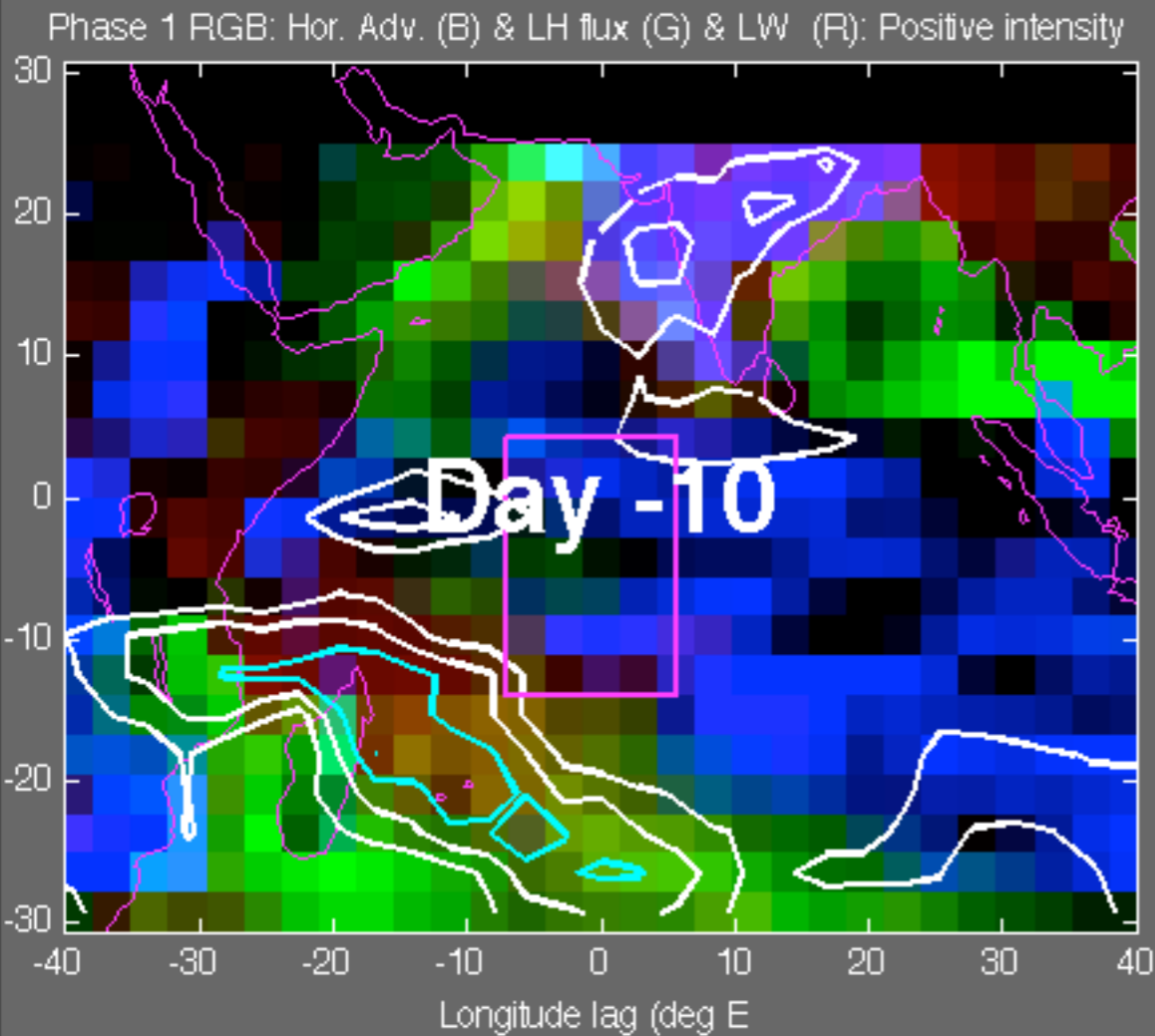
Initiation of SPCAM's MJO in the Indian Ocean.

The contours show where the column MSE is.

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MSE sources

MSE sinks

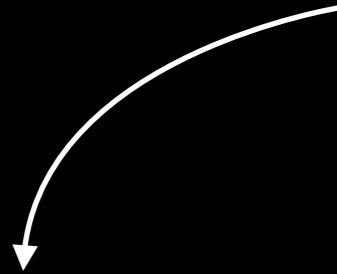


Regression time series: 20-100 day column MSE in reference region.

Questions

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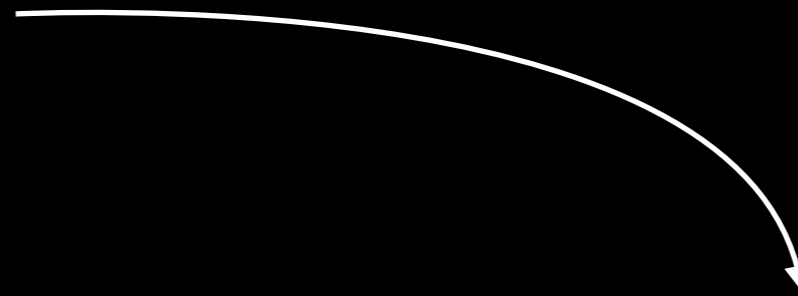
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Visualizing the (x,y,t) structure emphasizes multiple action centers, and shifts in SPCAM's MJO energetics with time.