AOS 801: Advanced Tropical Meteorology

Lecture 19   Spring 2023

Moisture Mode Generality

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Announcements

People that got extension: Please upload HW3/PA3 by the end of the day.

HW4 and PA4 are online. They are due on Monday, April 18.

PA4 will be discussed next Monday. Come prepared.

HW5 and PA5 will be assigned then.

Last two classes will be final presentations. Instructions are in this slide.

Final Presentation

The presentations will be the last 2 classes. It is 10% of your final grade

You will choose the topic of your presentation. It can be a paper review. It can be how aspects of your research are related to class (it cannot be directly the project you are working on).

Presentations will be 15 mins. 10 mins for presentation and 5 minutes for questions. Only 4 students can present per day.

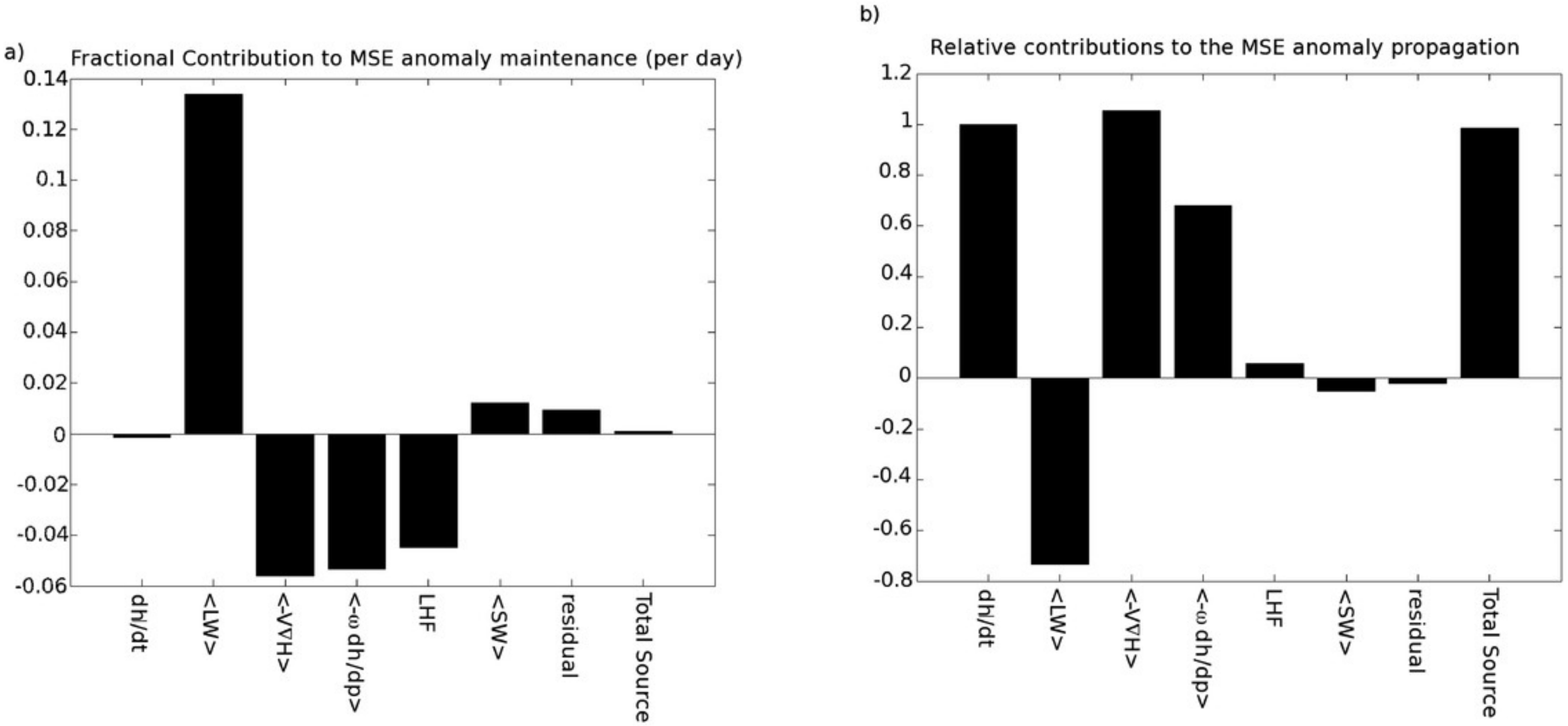
You will be evaluated based on a rubric. It will be uploaded to Canvas

Choose preferred date on a Spreadsheet.
https://docs.google.com/spreadsheets/d/1qCP6THaTo-mq1jVIla6XUvFDtPnNHQUhCtG2zq1flVk/edit?usp=sharing

Last Class: The MJO

The MSE budget under WTG can be interpreted as:

$$\frac{\partial L_v \langle q \rangle}{\partial t} = -\langle \mathbf{v} \cdot \nabla_h L_v q \rangle - \left\langle \omega_w \frac{\partial \text{MSE}}{\partial p} \right\rangle + \langle Q_r \rangle + L_v E + \text{SHF}$$



Moisture mode candidates

The first disturbance to be thought to be a moisture mode is the Madden-Julian Oscillation. ✔

More recent research has shown that moisture modes are commonplace.

Recent candidates include:

1. Equatorial Rossby Waves
2. Oceanic Tropical depression-like waves
    a. *Easterly waves*
    b. *Monsoon low-pressure systems*

Today

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Recent candidates include:

1. Equatorial Rossby Waves
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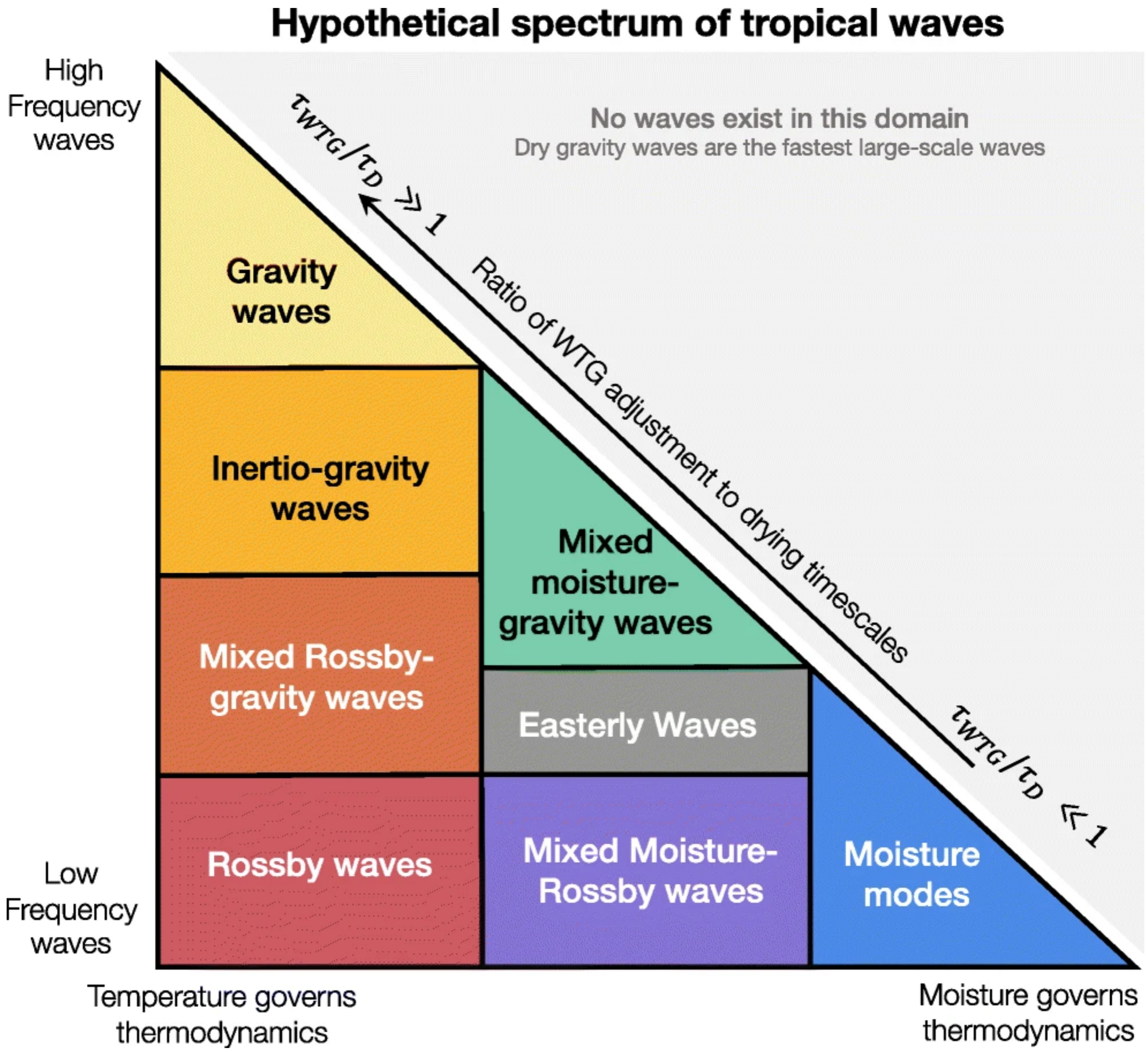
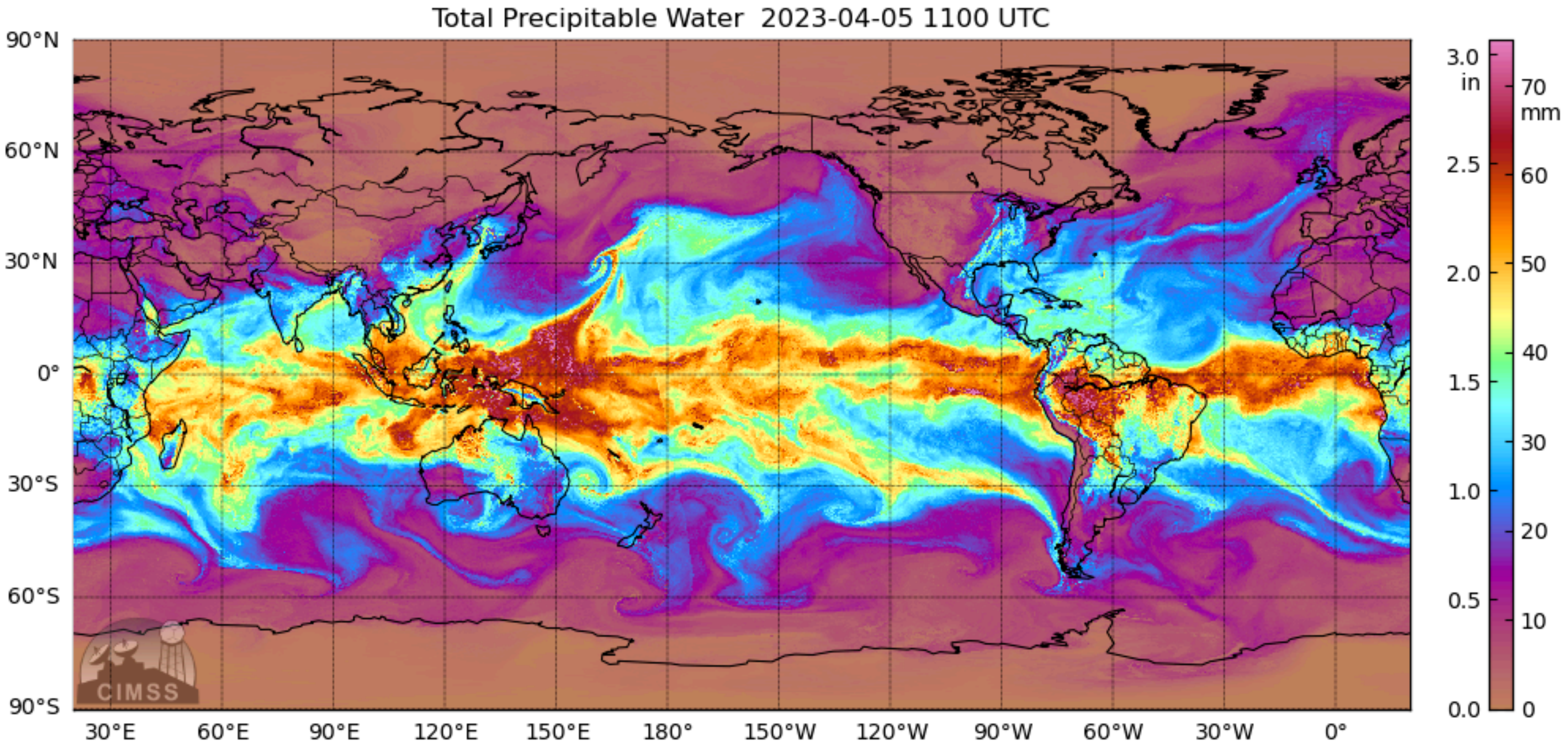
    a. *Easterly waves*
    b. *Monsoon low-pressure systems*

Next Monday's discussion will go into detail the latter point.

Moisture Modes





Alternate form of WTG balance

Under WTG balance, the following approximation is fairly accurate

$$\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle \simeq \langle \omega \partial_p \mathrm{DSE} \rangle$$

So that the thermodynamic equation can be written as:

$$\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle \simeq L_v P + \langle Q_r \rangle$$

Let us write the WTG MSE (moisture) budget as:

$$\frac{\partial L_v \langle q \rangle}{\partial t} \simeq -\nabla_h \cdot \langle \mathbf{v}\mathrm{MSE} \rangle + \mathrm{D}$$

Where $\mathrm{D} = \langle Q_r \rangle + L_v E + \mathrm{SHF}$ is the diabatic source of MSE.

Normalized MSE Budget

We can obtain a normalized version of the MSE budget if we divide by $\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle$:

$$\frac{1}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle} \frac{\partial L_v \langle q \rangle}{\partial t} \simeq -\left(\Gamma - \gamma\right)$$

Where

$\Gamma = \dfrac{\nabla_h \cdot \langle \mathbf{v}\mathrm{MSE} \rangle}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle}$ is known as the "gross moist stability (GMS)"

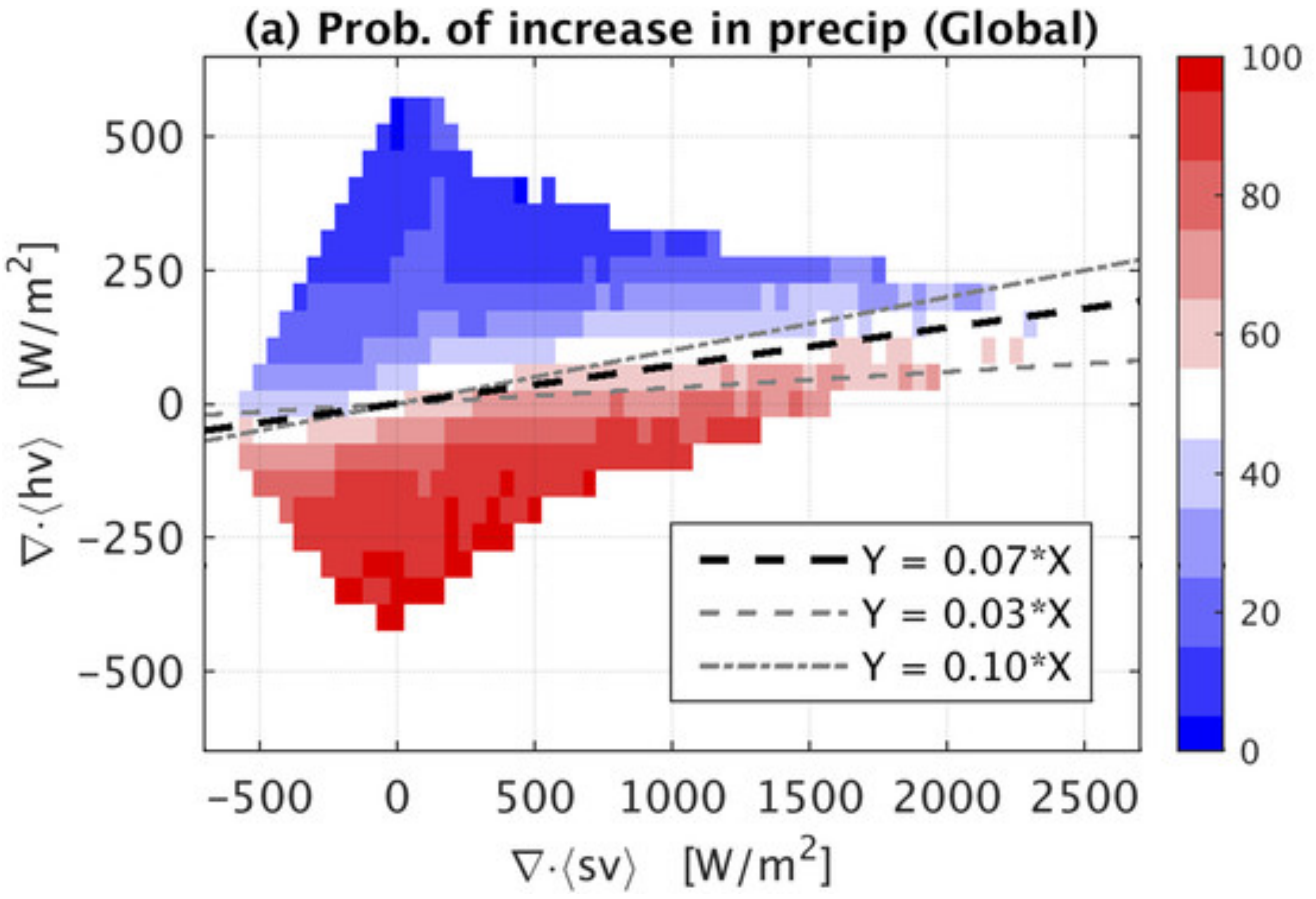
$\gamma = \dfrac{\mathrm{D}}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle}$ = constant , is referred to as the "critical GMS". It's value ranges from 0.06 to 0.08

Energy fluxes determine precipitation growth/decay

Since $\gamma \sim 0.07$ it is always a source of moisture, and will amplify precipitation in the column. It follows that fluctuations in Γ determine the evolution of the system.

$$\frac{1}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle} \frac{\partial L_v \langle q \rangle}{\partial t} \simeq -\left(\Gamma - \gamma\right)$$

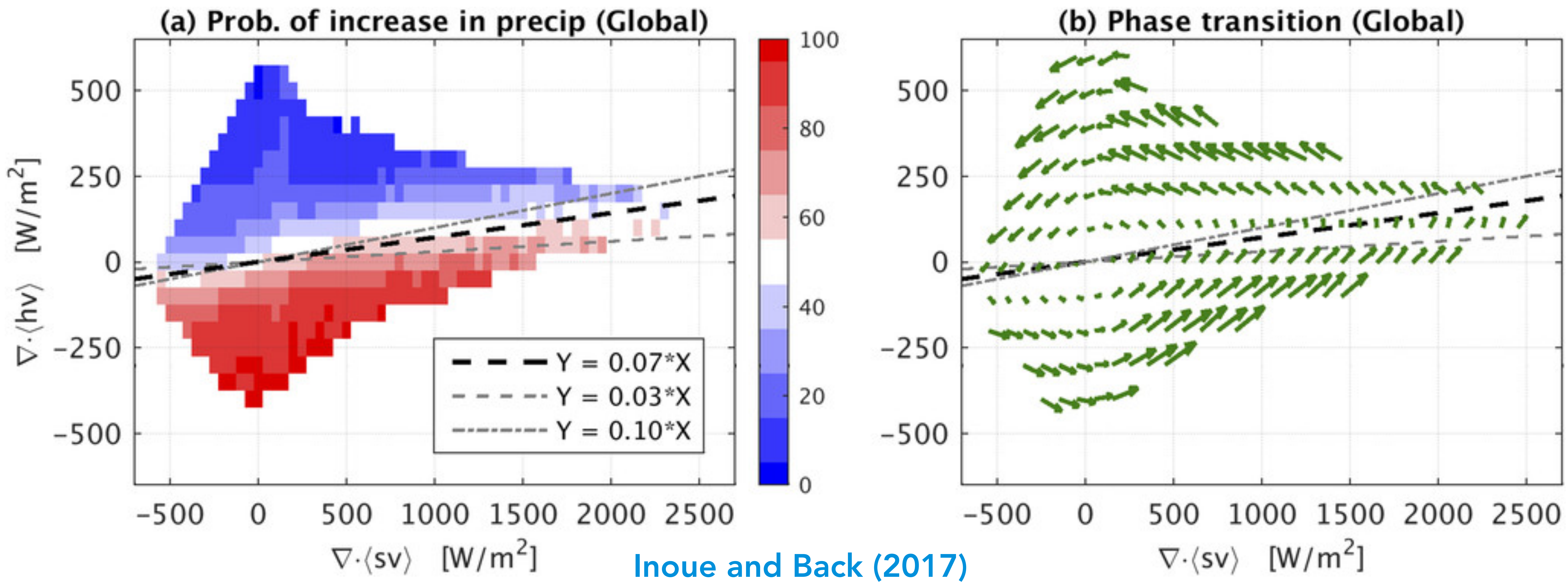
Thus precipitation exhibits a cycle that is driven by the divergence of the column MSE flux. Influx of energy increases rainfall.



Inoue and Back (2017)

MSE discharge-recharge cycles

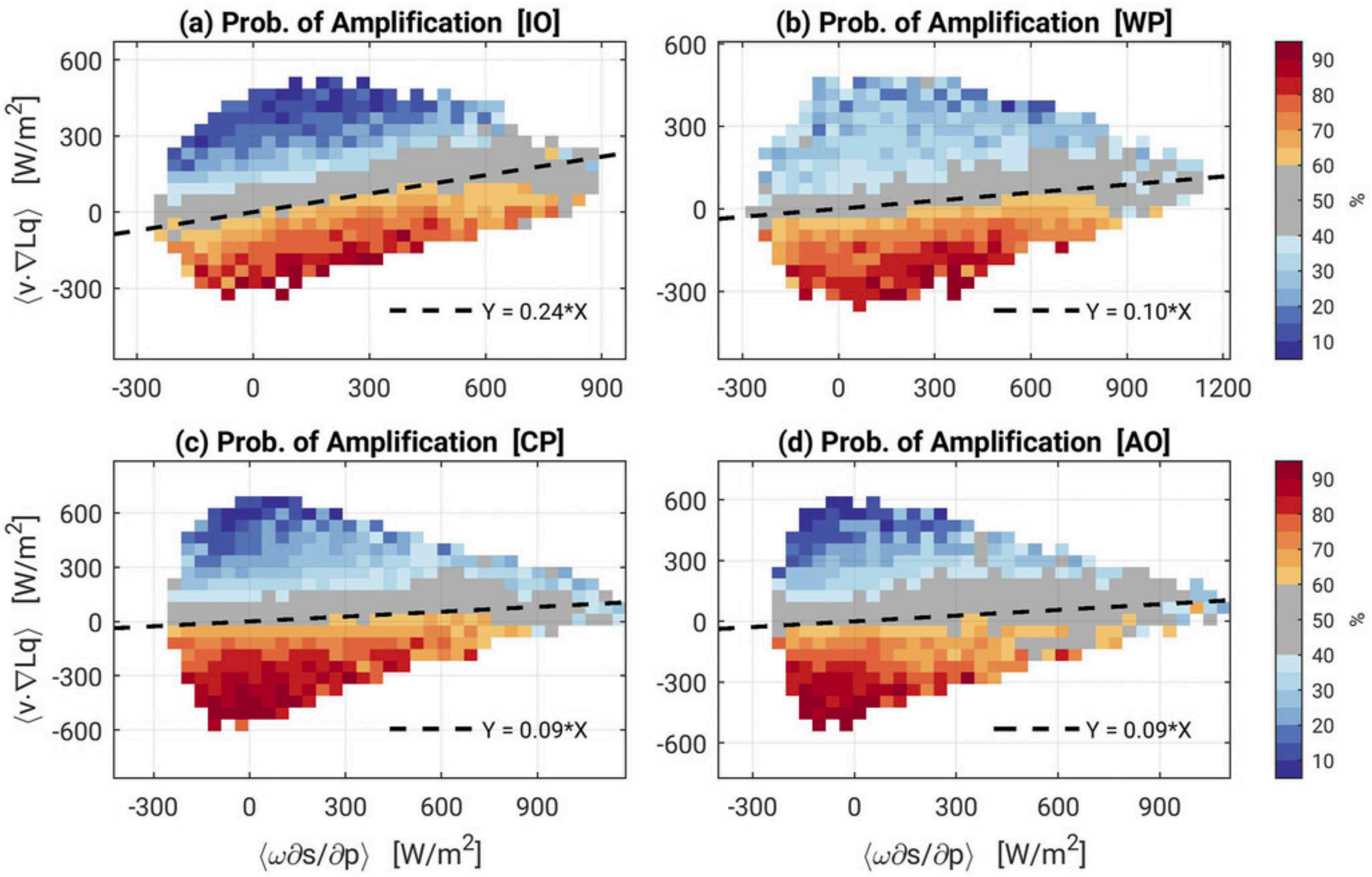
$$\frac{1}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE}\rangle}\frac{\partial L_v\langle q\rangle}{\partial t} \simeq -\left(\Gamma - \gamma\right)$$



Inoue and Back (2017)

Generality

But the column divergence of the MSE flux is composed of horizontal and vertical MSE advection. Are they equally important?



Inoue et al. (2021)

Generality

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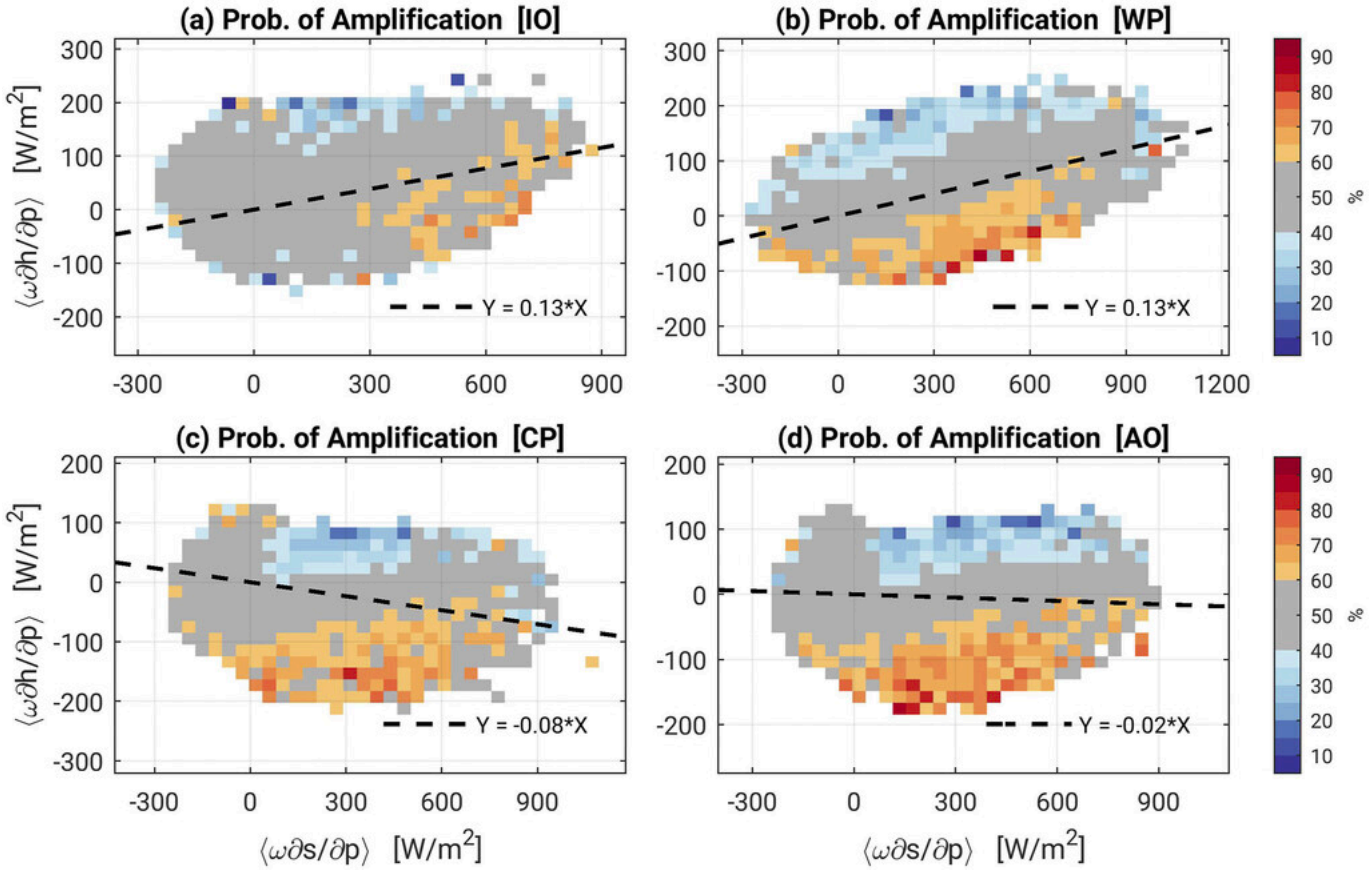


Inoue et al. (2021)

Generality

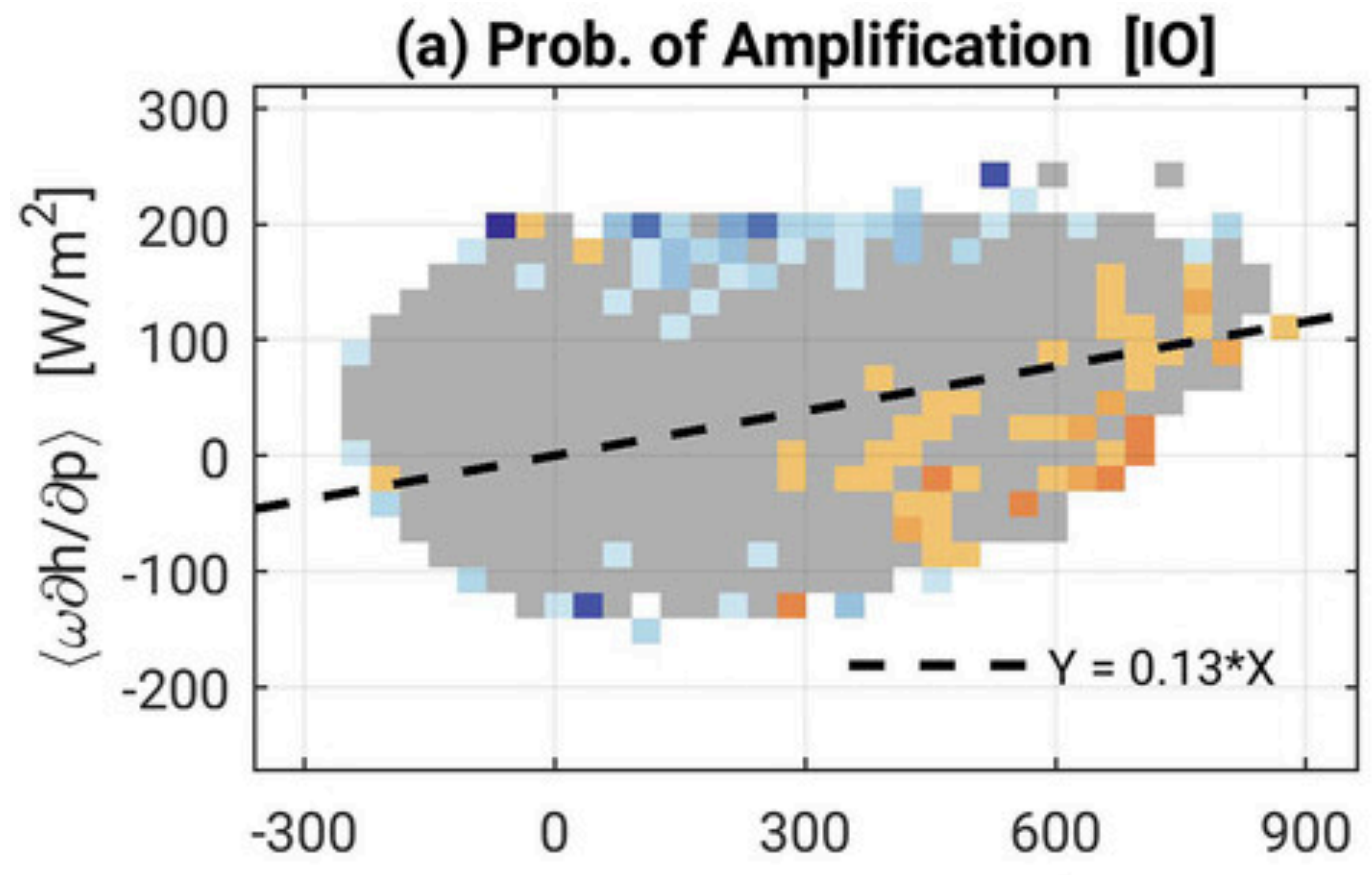
Horizontal moisture advection is a stronger predictor for the evolution of rainfall than vertical MSE advection.

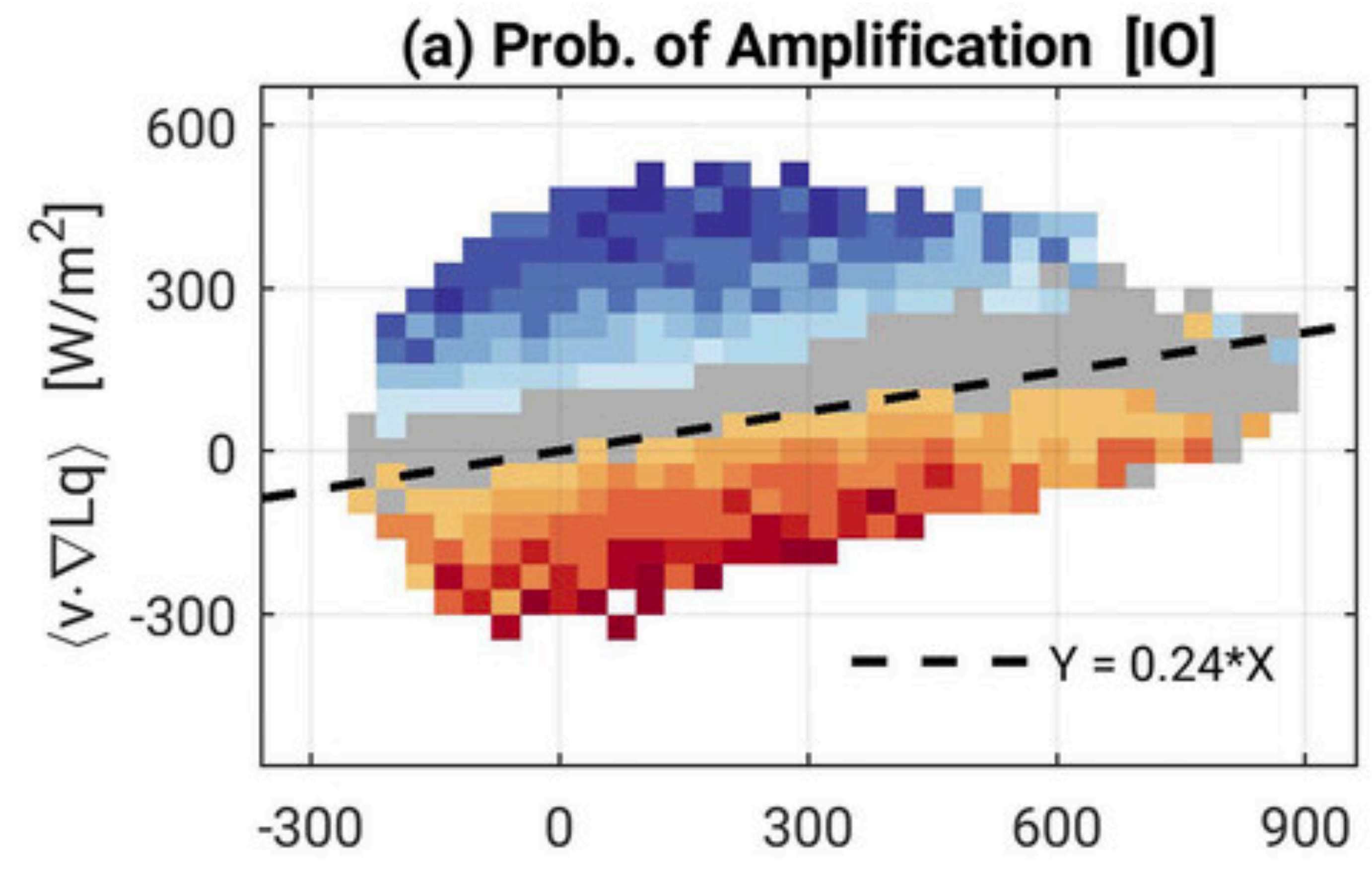
Horizontal advection is a strong control on precipitation occurrence.

Inoue et al. (2021) found that the column moisture budget can be written as:

$$\frac{\partial L_v \langle q \rangle}{\partial t} \simeq -\langle \mathbf{v} \cdot \nabla_h L_v q \rangle - \Gamma_e \nabla_h \cdot \langle \mathbf{v}\text{DSE} \rangle$$

$\Gamma_e = \dfrac{\omega \partial_p \text{MSE} - \text{D}}{\nabla_h \cdot \langle \mathbf{v}\text{DSE} \rangle}$ is the effective gross moist stability.

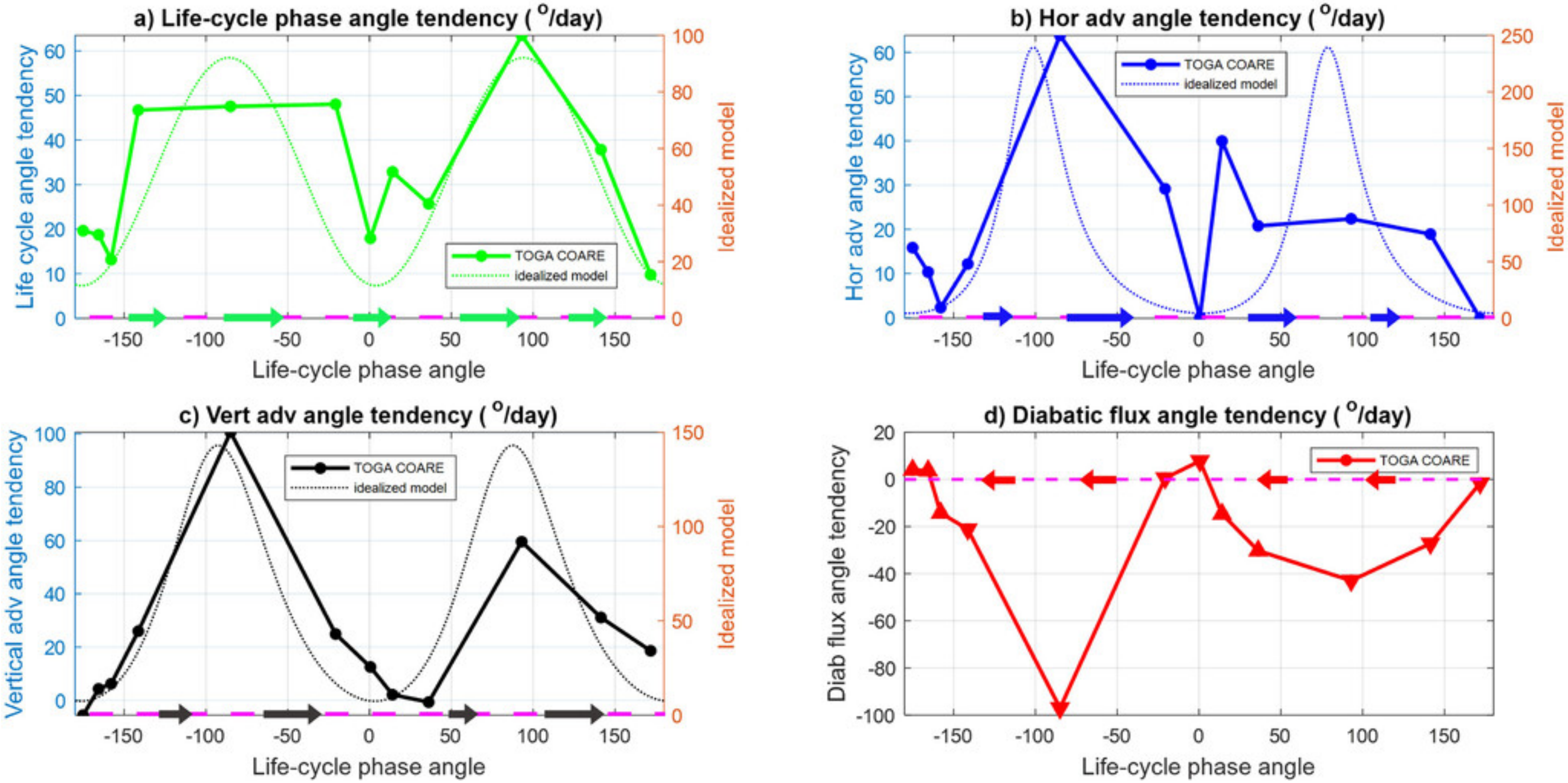




Inoue et al. (2021)

Generality

Discharge-recharge cycles in MSE in the tropics qualitatively match moisture mode behavior, hinting at the commonality of moisture modes.



Maithel and Back (2022)

Generality

All these figures show that moisture modes may be a common feature of the tropics.

On average, horizontal moisture advection appears to be the common cause of precipitation variance.

What is the meaning of all this?