AOS 801: Advanced Tropical Meteorology

Lecture 21 Spring 2023

Instabilities under WTG balance

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Announcements

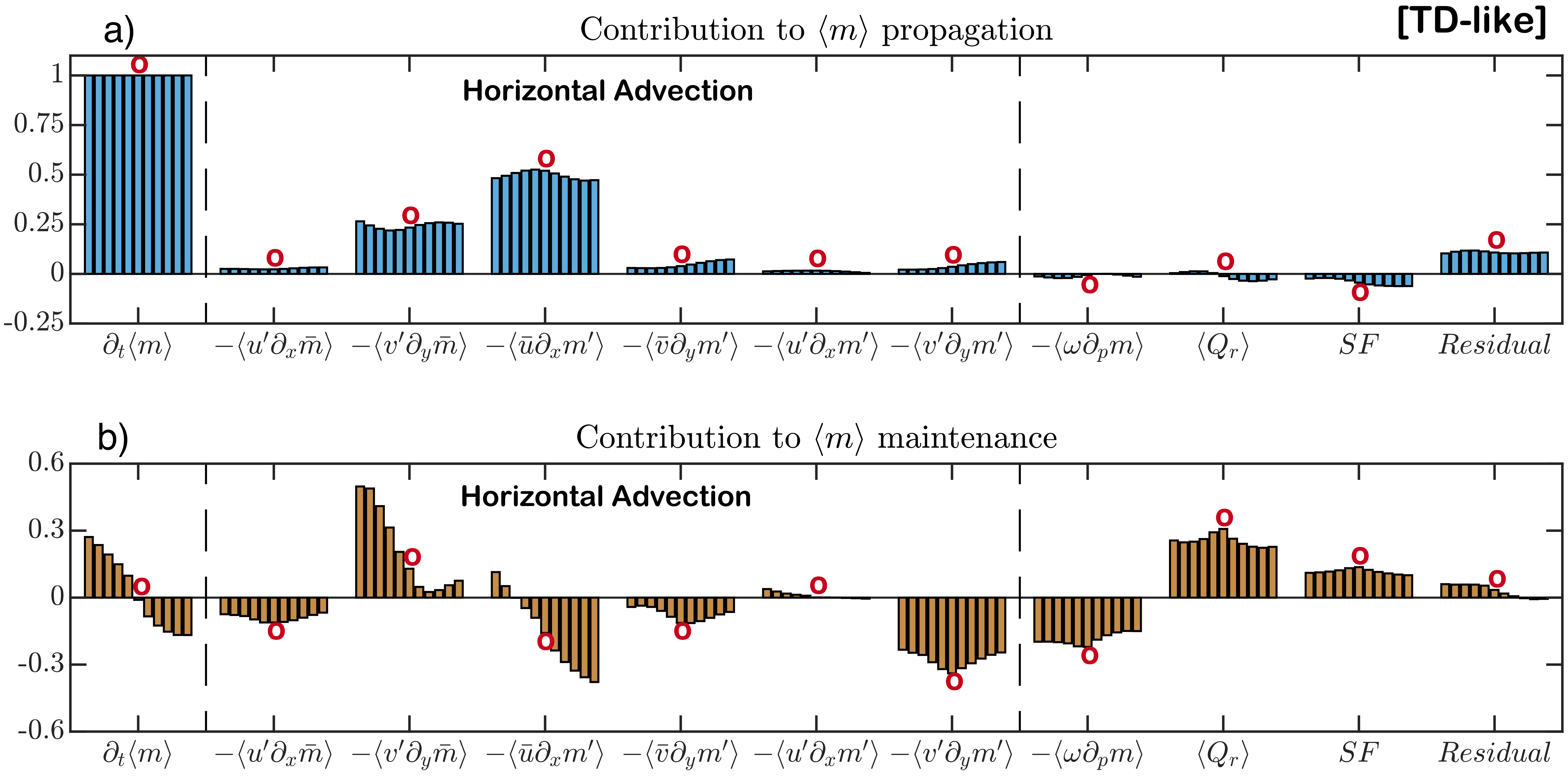
HW4/PA4 is due Tuesday. It already accounts for slight delay in previous HW.

Please choose your time and topic for the final presentation by the end of the week.

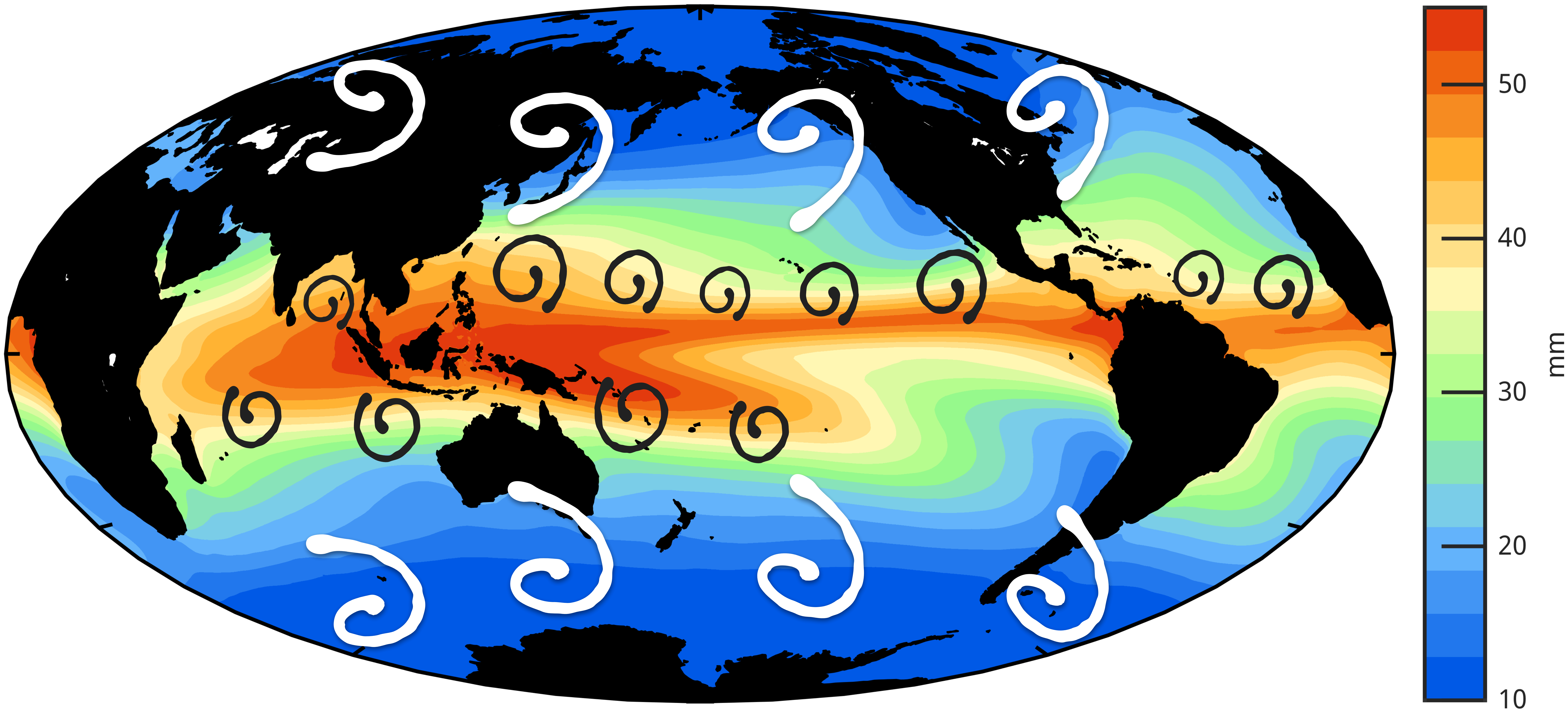
https://docs.google.com/spreadsheets/d/1qCP6THaTo-mq1jVIla6XUvFDtPnNHQUhCtG2zq1flVk/edit?usp=sharing

Paper discussion

What TD-like waves is this plot showing? Discuss the different terms in the budget.



Synthesize everything. Based on the results, what is this schematic telling us?

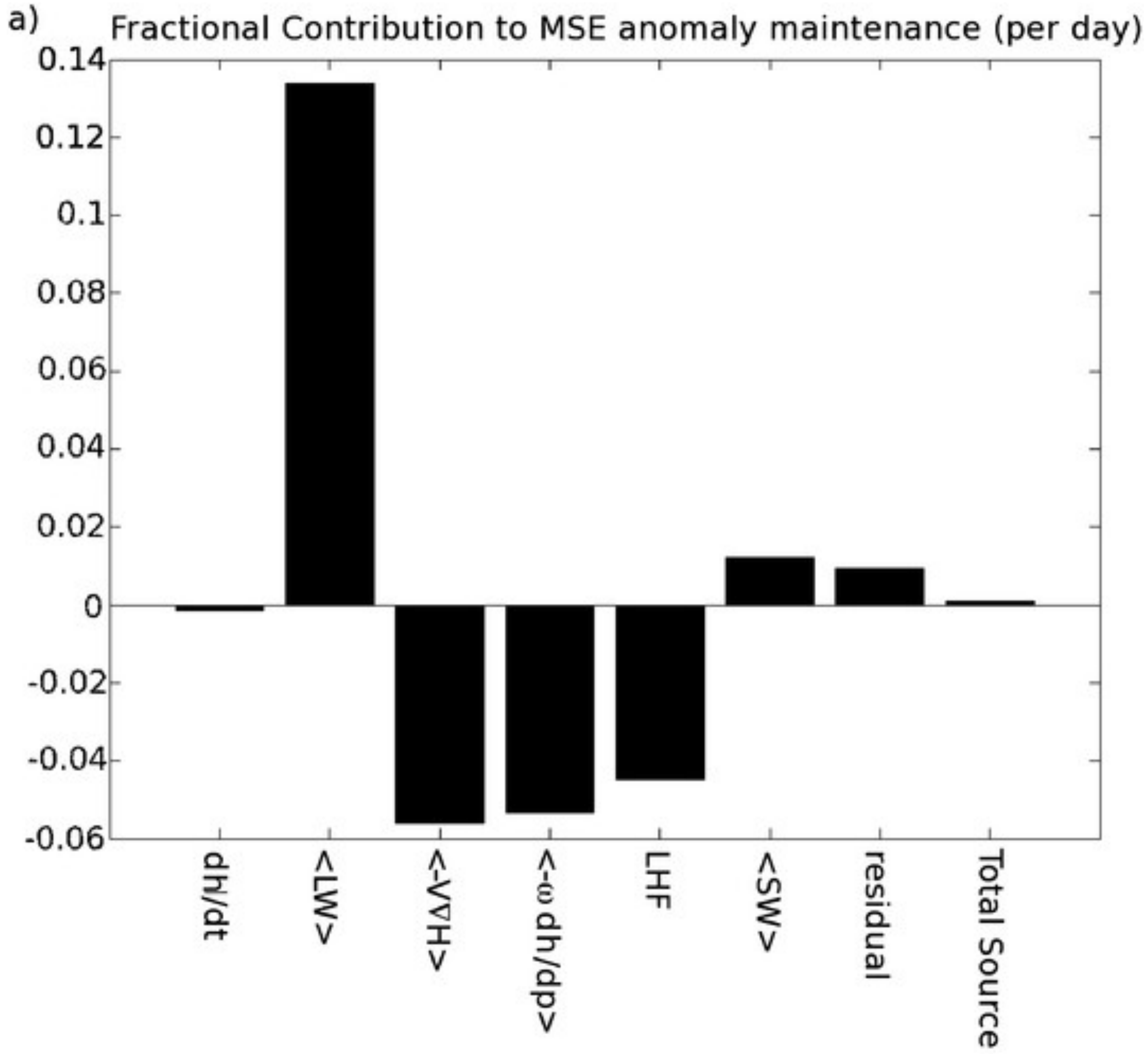


Let’s wrap up our discussion on moisture modes

The growth of moisture modes.

The mechanism of growth can be understood as a variance budget

$$\frac{\partial L_v \langle q' \rangle^2}{\partial t} = -\langle q' \rangle \left(\langle \mathbf{v} \cdot \nabla_h L_v q \rangle' - \left\langle \omega_w \frac{\partial \mathrm{MSE}}{\partial p} \right\rangle' + \langle Q_r' \rangle + L_v E' + \mathrm{SHF}' \right)$$



For a process to contribute to the growth of moisture anomalies, it must occur in phase with the moisture anomalies.

$$\frac{\partial L_v \langle q' \rangle^2}{\partial t} > 0 \textbf{ growth}$$

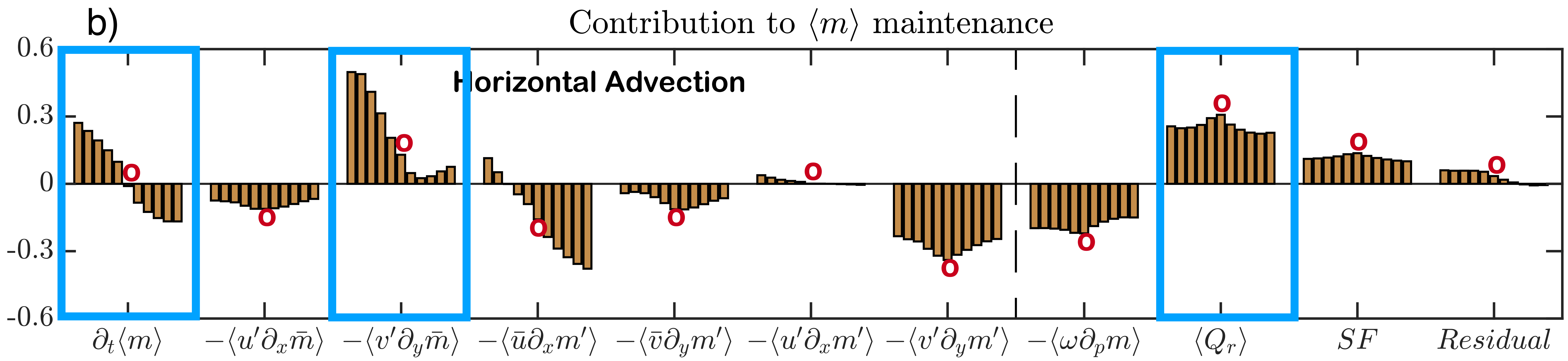
$$\frac{\partial L_v \langle q' \rangle^2}{\partial t} < 0 \textbf{ decay}$$

The growth of moisture modes.

The mechanism of growth can be understood as a variance budget

$$\frac{\partial L_v \langle q' \rangle^2}{\partial t} = -\langle q' \rangle \left(\langle \mathbf{v} \cdot \nabla_h L_v q \rangle' - \left\langle \omega_w \frac{\partial \mathrm{MSE}}{\partial p} \right\rangle' + \langle Q_r' \rangle + L_v E' + \mathrm{SHF}' \right)$$

In PA4 we see that there are two dominant processes that lead to growth.

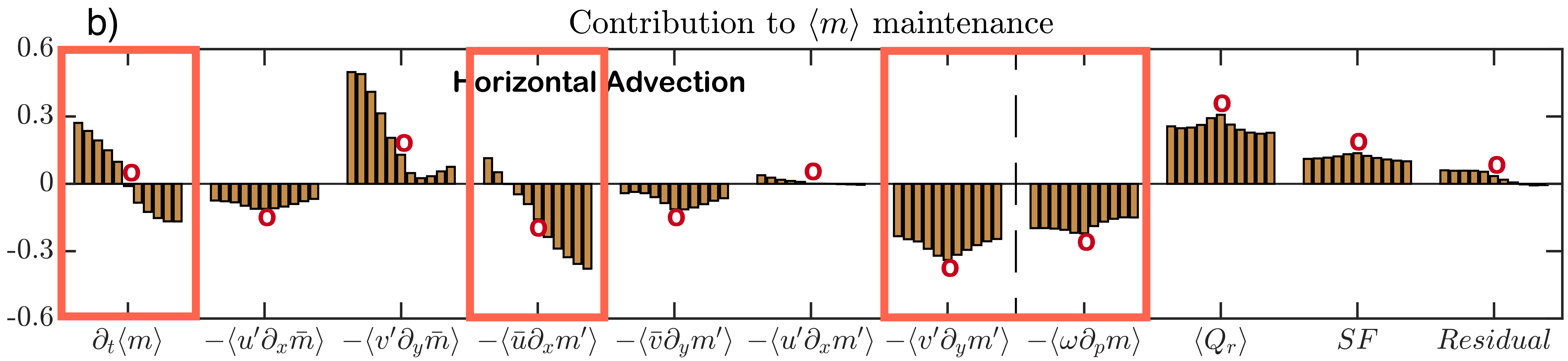


The growth of moisture modes.

The mechanism of growth can be understood as a variance budget

$$\frac{1}{2}\frac{\partial L_v \langle q' \rangle^2}{\partial t} = -\langle q' \rangle \left(\langle \mathbf{v} \cdot \nabla_h L_v q \rangle' - \left\langle \omega_w \frac{\partial \mathrm{MSE}}{\partial p} \right\rangle' + \langle Q_r' \rangle + L_v E' + \mathrm{SHF}' \right)$$

In PA4 we see that there are three processes that lead to mode decay

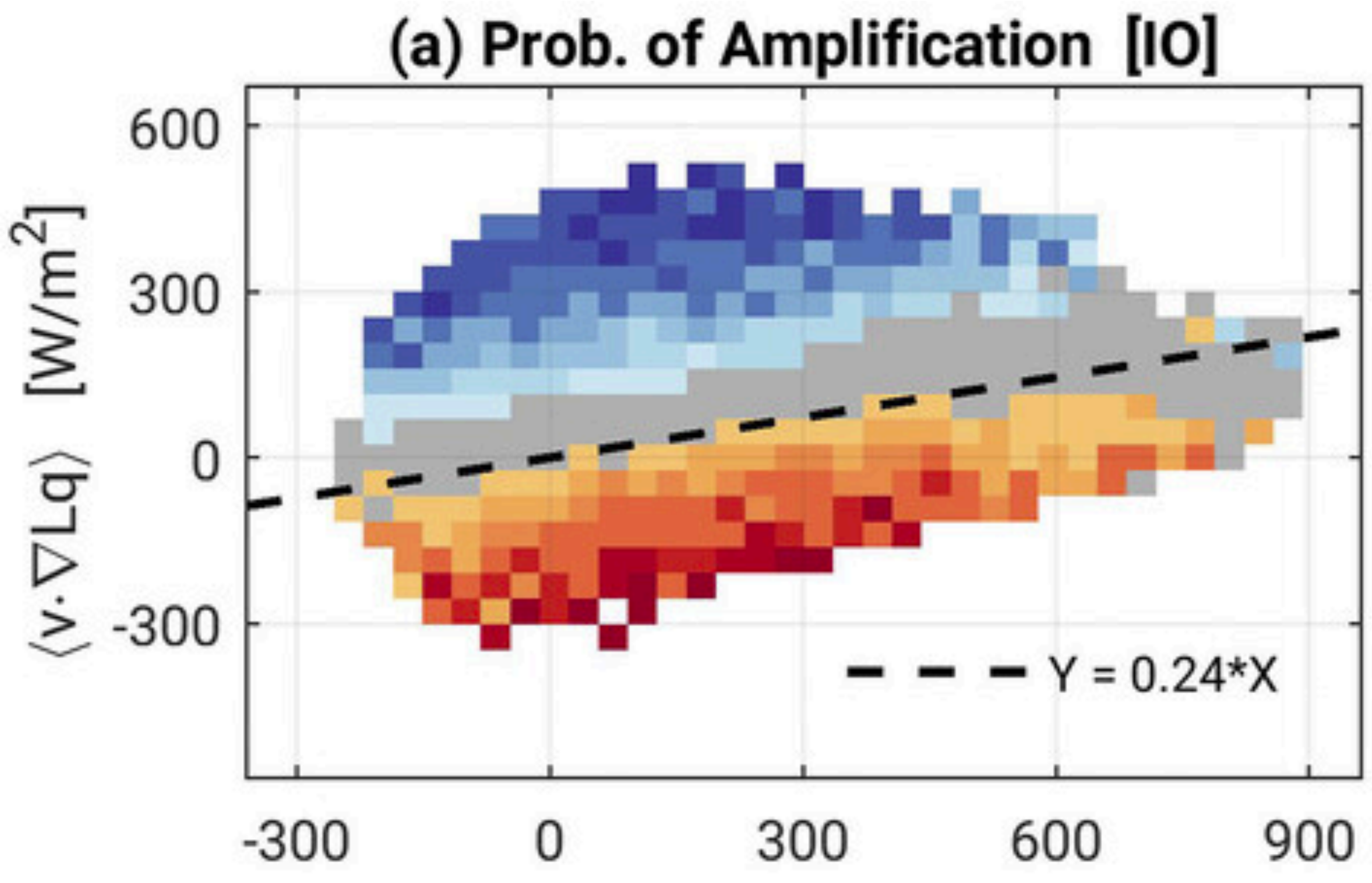


Importance of radiation

Let's return to Inoue and Back (2017), and Inoue et al. (2021) and assume no horizontal moisture gradient:

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

$\Gamma_e = \dfrac{\omega \partial_p \mathrm{MSE} - \mathrm{D}}{\nabla_h \cdot \langle \mathbf{v}\mathrm{DSE} \rangle}$ is the effective gross moist stability. Let's assume it's a constant



Inoue et al. (2021)

Importance of radiation

Where Let's assume it's a complex constant and that clear sky radiation cancels the surface fluxes (HW3/PA3), so that

$$\Gamma_e = \Gamma - r(1 - \Gamma).$$

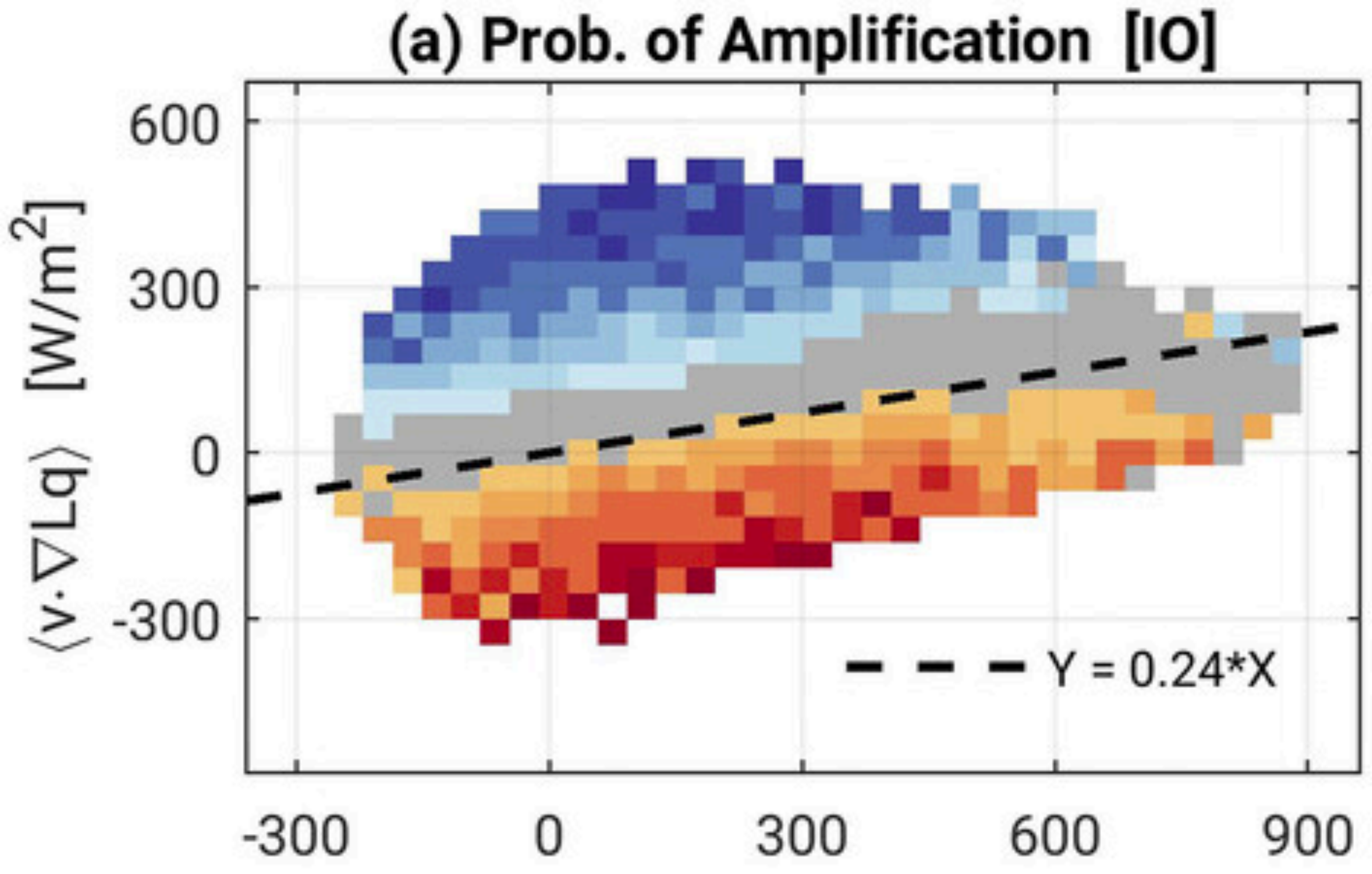
With several assumptions and approximations

$$\frac{\partial P'}{\partial t} \simeq -\frac{\Gamma_e P'}{\tau_c}$$

Which we can solve to obtain

$$P' = P_0 \exp\left(-\frac{\Gamma_e}{\tau_c} t\right)$$

The solution could be oscillating in time if Γ_e has an imaginary component, but can grow or decay if it has real component. Let's focus on the latter.



Inoue et al. (2021)

Importance of radiation

$$P' = P_0 \exp\left(-\frac{\Gamma_e}{\tau_c}\right) \qquad \Gamma_e = \Gamma - r(1 - \Gamma)$$

If $r(1-\Gamma) > \Gamma$ then Γ_e is negative and the solution grows. This mechanism has many names, from "moisture mode instability" to "radiative-convective instability". The important part is that is purely due to column processes that involve convection and its feedbacks alone.