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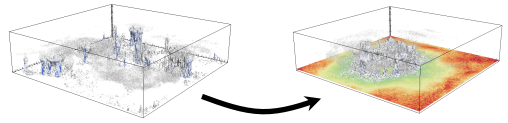
Radiative controls on the speed of growth of convective self-aggregation

Motivation

To connect self-aggregation in idealized models and observations, we investigate the role of radiative cooling on local features (moist margins) and transient properties (growth from unaggregated to aggregated convection) of convective organization, in SAM. Defining the moist margin from humidity tendencies, we find that aggregation is first initiated as a drying in the upper/mid-troposphere and then grows once the drying reaches the lower free troposphere.

- Can these 2 steps be related to radiative cooling contribution?

System for Atmospheric Modeling
Δx = 4km, L = 768km, square domain
Interactive CAM3 radiation



Framework

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Similarly to Craig & Mack (2013), we write a column humidity budget:

$$\frac{\partial PW}{\partial t} = \left(\frac{\partial PW}{\partial t}\right)_{rad} + \left(\frac{\partial PW}{\partial t}\right)_{conv} + \left(\frac{\partial PW}{\partial t}\right)_{adv} + F_s$$

- But diagnose it in moisture space
- And focus on the radiative term. First attempt:

$$\left(\frac{\partial PW}{\partial t}\right)_{rad} = \int_{950}^{200} w_{rad} \frac{\partial q_v}{\partial z} \frac{dp}{g} \quad \text{where} \quad w_{rad} = \frac{Q_{rad}}{\frac{T}{\theta}\frac{d\theta}{dz}}$$

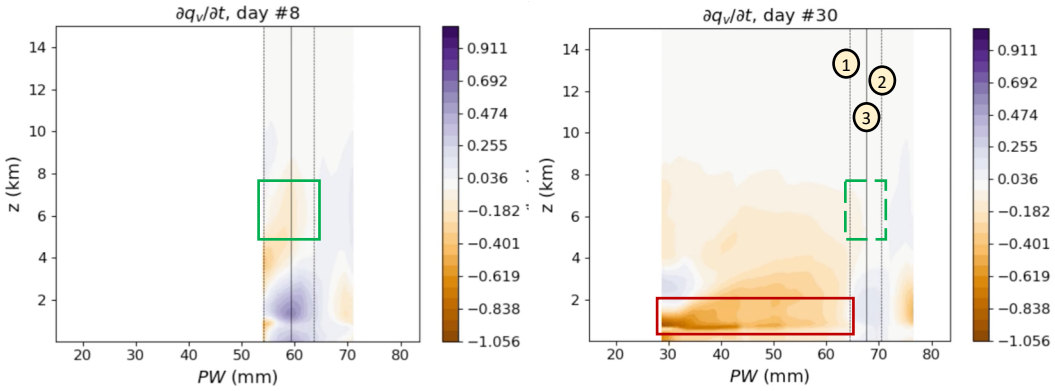
Following the drying in the zone between the moist and dry region during the transition from pop-corn to aggregated convection

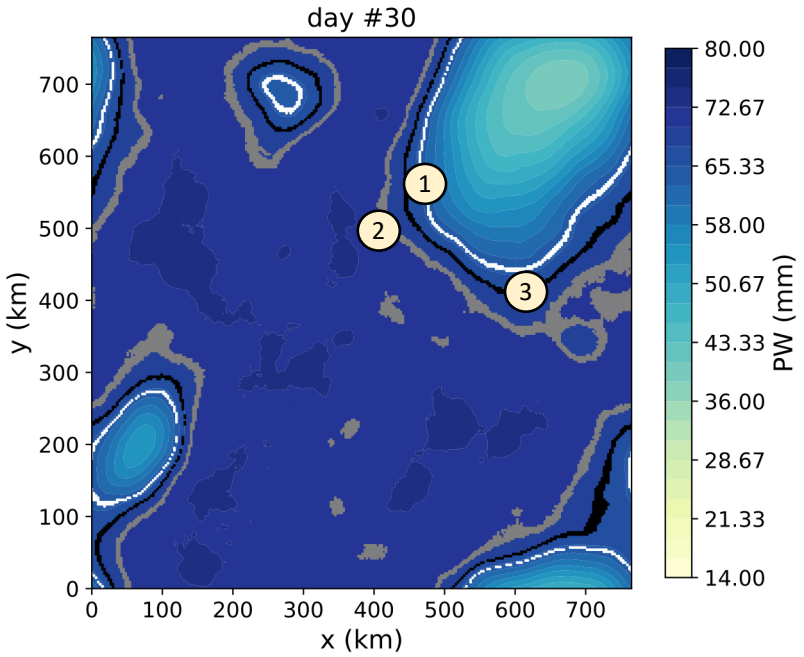
Initiation phase

Upper/mid-tropospheric drying

Growth phase

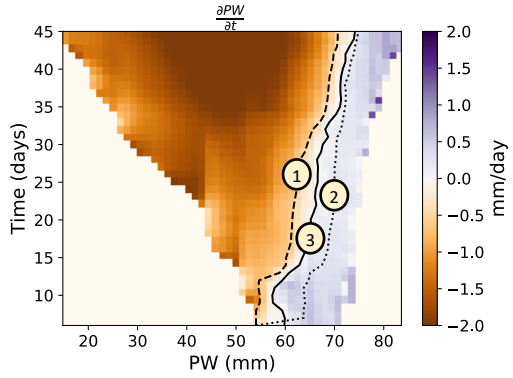
Lower-tropospheric drying

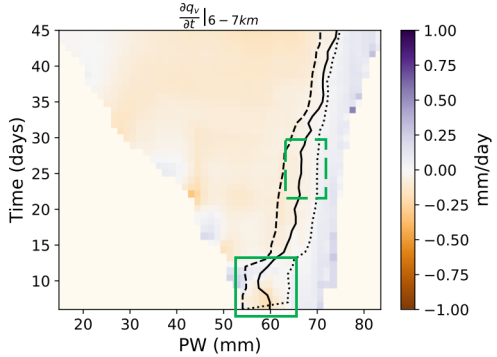


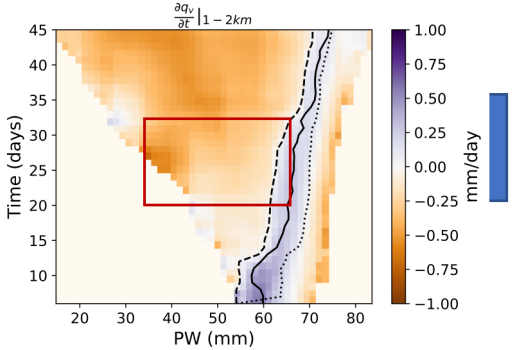


3 margins defined as:

1. PW where the low-tropospheric tendency is zero
2. PW where the mid-tropospheric tendency is zero
3. PW where the column PW tendency is zero







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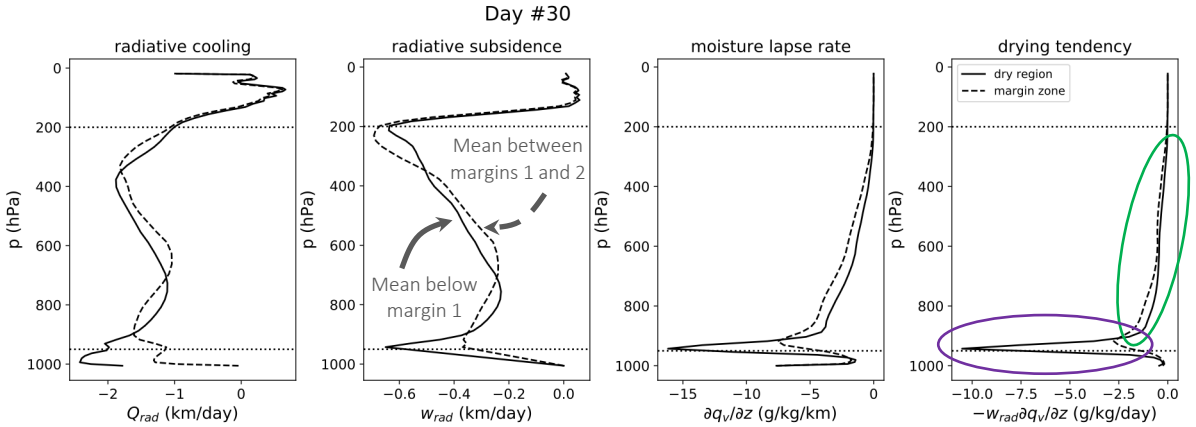
Qualitative consistency with a different kind of radiative drying in the two phases



Upper/mid-tropospheric radiative drying in the intermediate region

Low-tropospheric radiative drying in the dry region

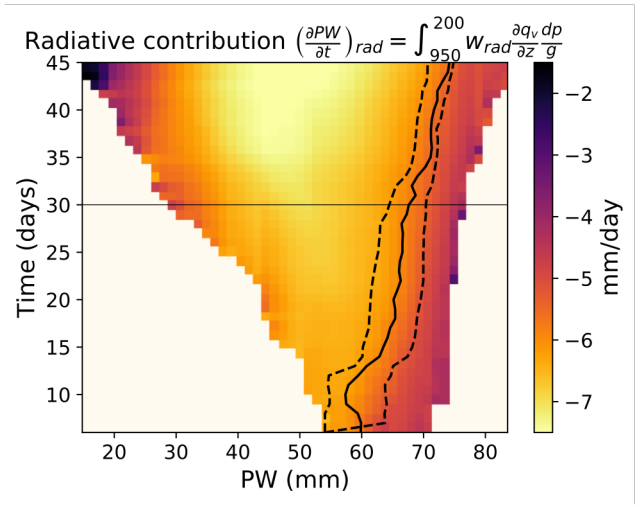
PW budget

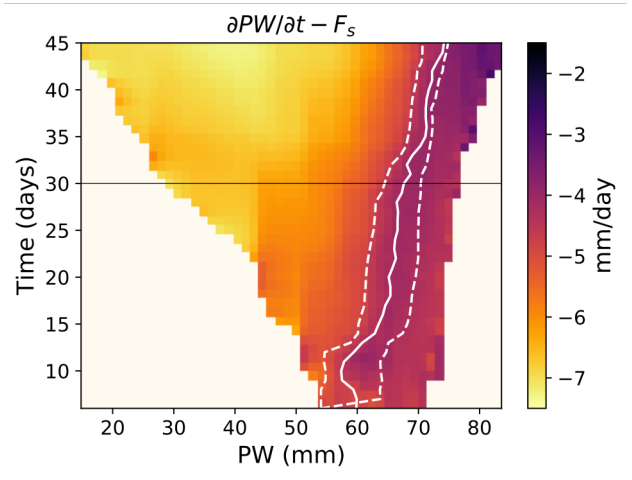
$$\frac{\partial PW}{\partial t} = \left(\frac{\partial PW}{\partial t}\right)_{rad} + \left(\frac{\partial PW}{\partial t}\right)_{conv} + \left(\frac{\partial PW}{\partial t}\right)_{adv} + F_s$$

Radiative contribution

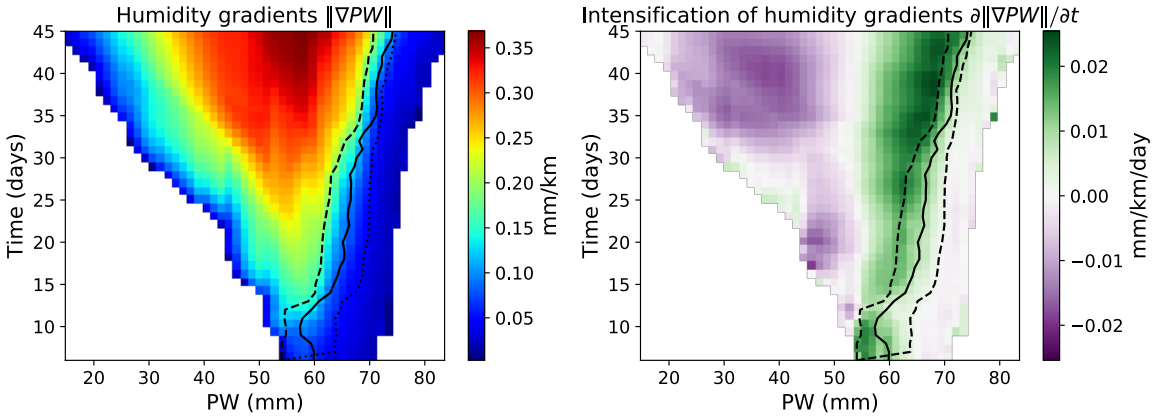
$$\left(\frac{\partial PW}{\partial t}\right)_{rad} = \int_{950}^{200} w_{rad} \frac{\partial q_v}{\partial z} \frac{dp}{g} \quad \text{where} \quad w_{rad} = \frac{Q_{rad}}{\frac{T}{\theta}\frac{d\theta}{dz}}$$

Quantitatively, radiative drying of the dry region balances the total drying minus moistening by surface fluxes





Further link to make with observations: connection to the strength of moist margins in the tropics



Conclusion and next steps

(1) Mid-tropospheric radiative subsidence seems to initiate aggregation and drive drying at the edge of the dry patch, and (2) low-tropospheric radiative cooling seems to dictate the expansion phase. Next, we will:

- quantify the other terms in the moisture budget
- compare simulations at different SSTs
- construct two timescales to diagnose these two phases in observations