AGU PUBLICATIONS

Geophysical Research Letters

Supporting Information for

Physics or Knob-Tuning? Tropical Anvil Peak is Captured by GCMs

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Text S1: Analytical calculation of RH response to vertical velocity perturbation

Consider an unsaturated air parcel experiencing adiabatic ascent. By assuming no mixing and condensation, the specific humidity of the air parcel remains unchanged. So, the Lagrangian rate of change of RH is:

$$\frac{dRH}{dt} = -\frac{q_v}{q^{*2}}\frac{dq^*}{dt} = -RH\frac{dlnq^*}{dt}, \qquad (1)$$

in which the q_v and q^* are specific humidity and saturation specific humidity, respectively. The $\frac{dlnq^*}{dt}$ can be expressed as:

$$\frac{dlnq^*}{dt} = \frac{dlne_s}{dt} - \frac{dlnp}{dt}, \qquad (2)$$

in which the e_s is the saturation water vapor pressure. Applying the Clausius-Clapeyron relation, the Equation (2) becomes:

$$\frac{dlnq^*}{dt} = \frac{L_v}{R_v T^2}\frac{dT}{dt} - \frac{1}{p}\frac{dp}{dt}, \qquad (3)$$

in which the L_v is latent heat of vaporization and R_v is specific gas constant for water vapor. Using the chain rule ($\frac{d}{dt} = w\frac{d}{dz}$) and hydrostatic balance ($-\frac{1}{p}\frac{dp}{dz} = \frac{g}{R_a T}$), Equation (3) becomes:

$$\frac{dlnq^*}{dt} = \left(-\frac{L_v}{R_v T^2}\Gamma + \frac{g}{R_a T}\right)w, \qquad (4)$$

in which R_a is specific gas constant of dry air, w is the vertical velocity (m/s), and $\Gamma = -\frac{dT}{dz}$ is the temperature lapse rate. Combining Eq. (4) and Eq. (1) yields:

$$\frac{dRH}{dt} = -RH\left(\frac{L_v}{R_v T^2}\Gamma - \frac{g}{R_a T}\right)w, \qquad (5)$$

For a given w, the ratio of $\frac{dRH}{dt}$ between 200 and 800 hPa can be quantified using the simulated Γ and T only (the RH is similar between the two levels):

$$\frac{dRH_{200}}{dRH_{800}} = \frac{\frac{L_v}{R_v {T_{200}}^2}\Gamma_{200} - \frac{g}{R_a T_{200}}}{\frac{L_v}{R_v {T_{800}}^2}\Gamma_{800} - \frac{g}{R_a T_{800}}} = 1.7 \qquad (6)$$

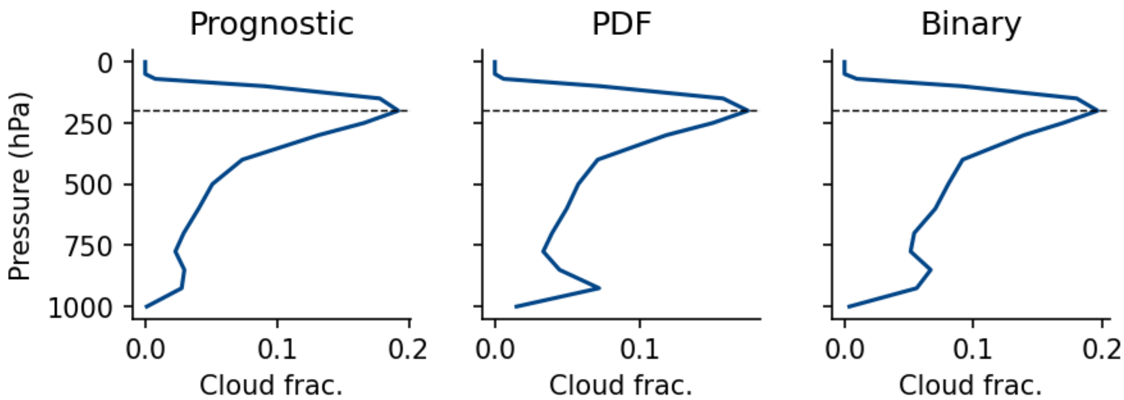

Figure S1: The same as upper panel of Figure 2 but for 30-year free runs.

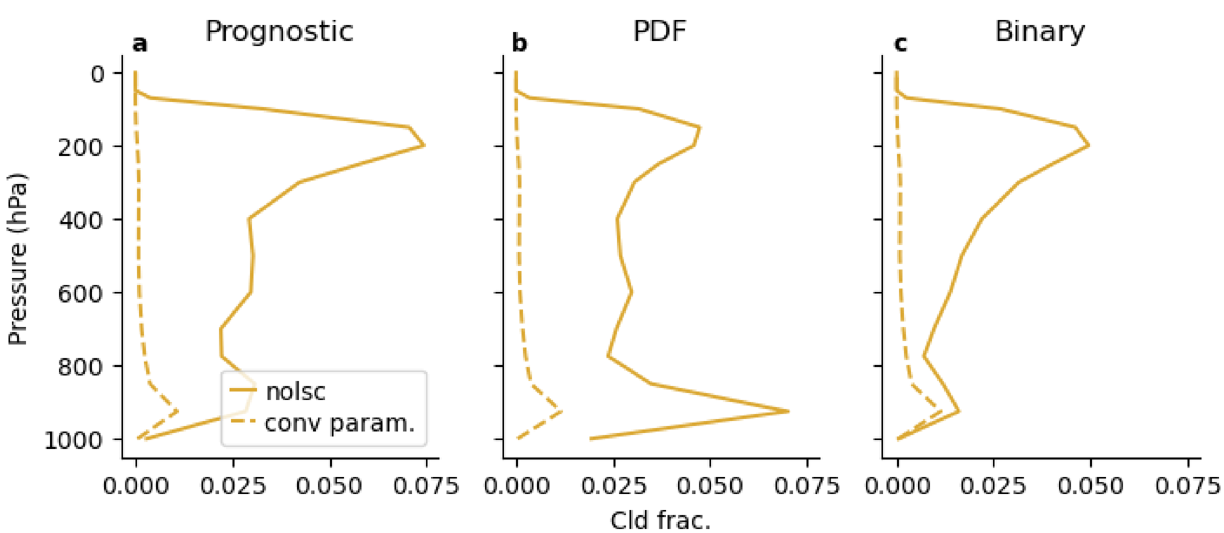

Figure S2: Comparisons of $\overline{CF_{nolsc}}$ and cloud fraction generated by cumulus parameterization.

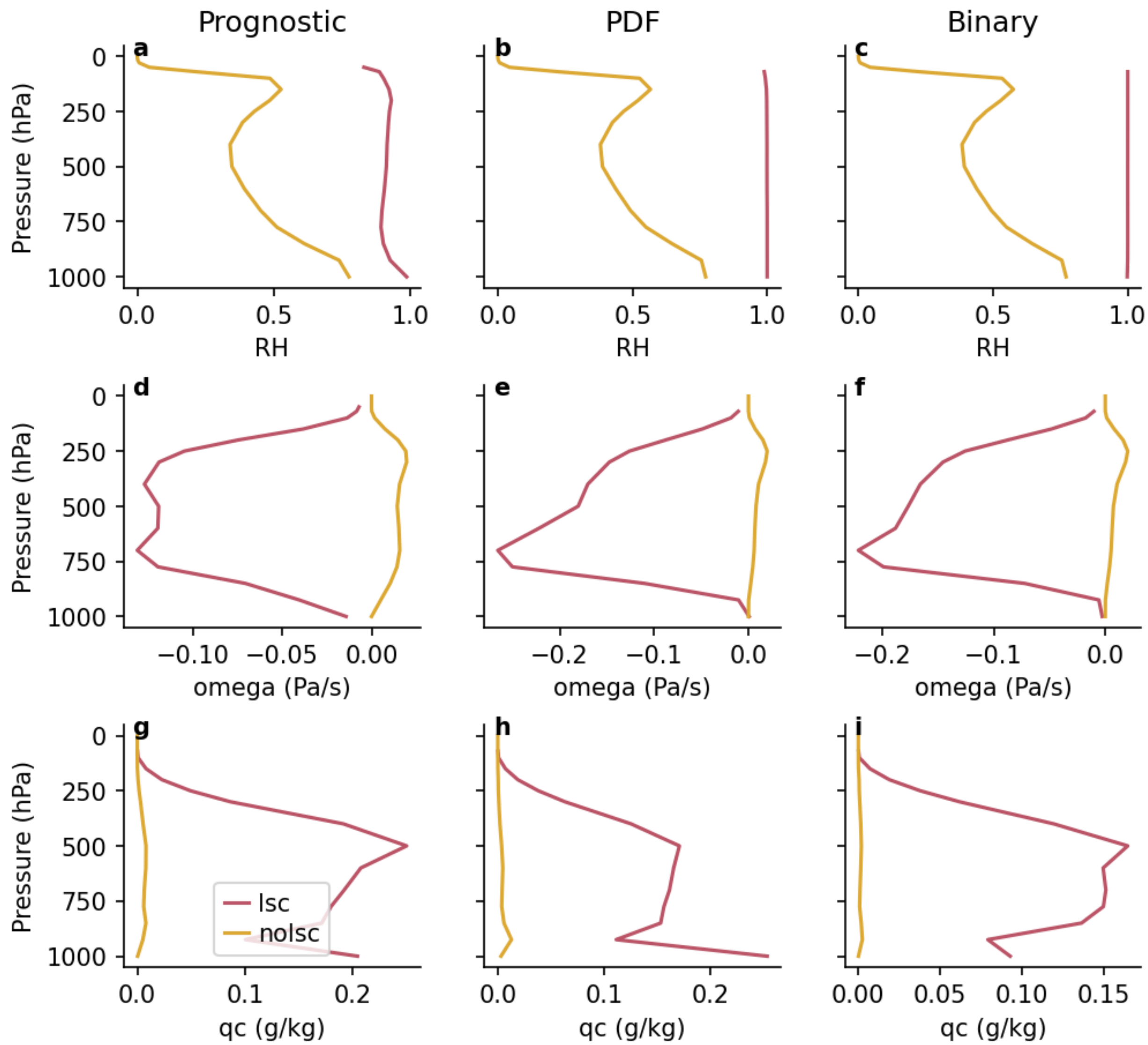

Figure S3: Comparisons of mean RH, omega, and cloud water content under conditions with and without large-scale condensation.

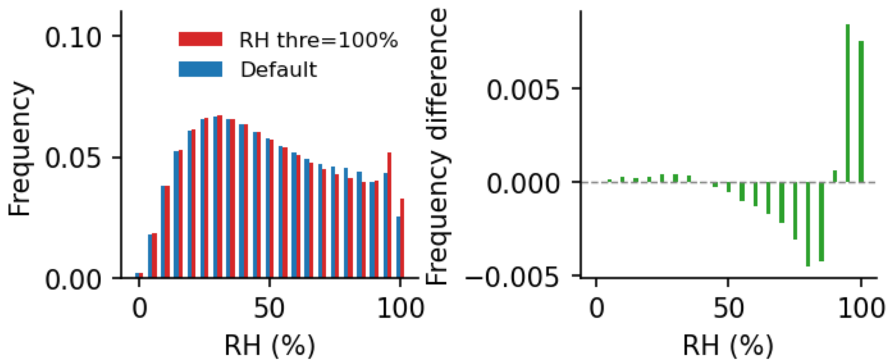

Figure S4: Histograms of 200 hPa RH for the default Tiedtke scheme (blue) and new experiment with RH threshold of 100% (red) (left) and their difference (right).

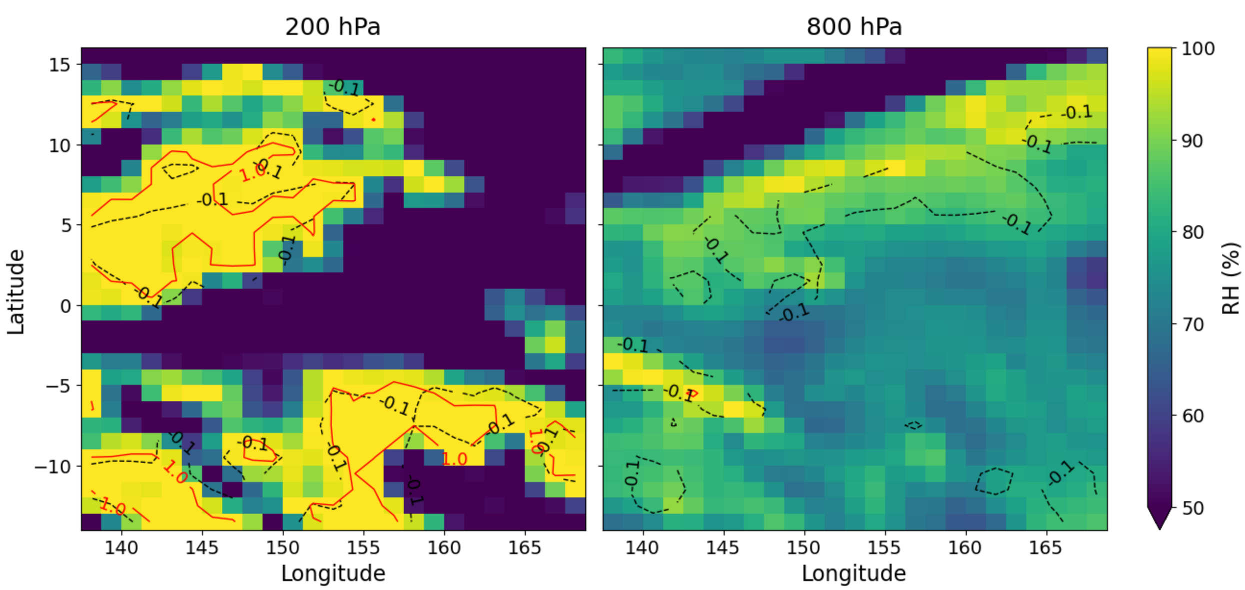

Figure S5: Snapshots of RH (color), omega (dashed black line, -0.1 Pa/sec), and cloud fraction (red solid line, 100%), and at 200 (left) and 800 (right) hPa levels.

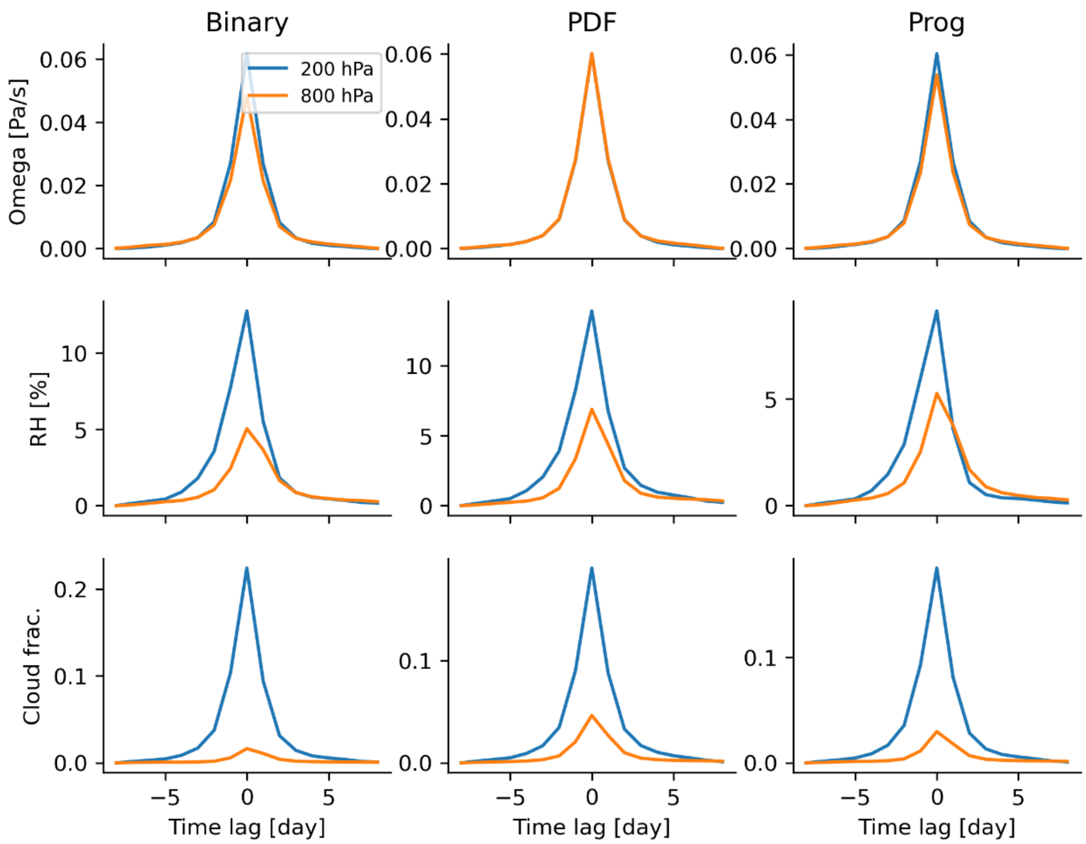

Figure S6: Time evolutions of composite changes in omega, RH, and cloud fraction from 7 days before to 7 days after updraft events.

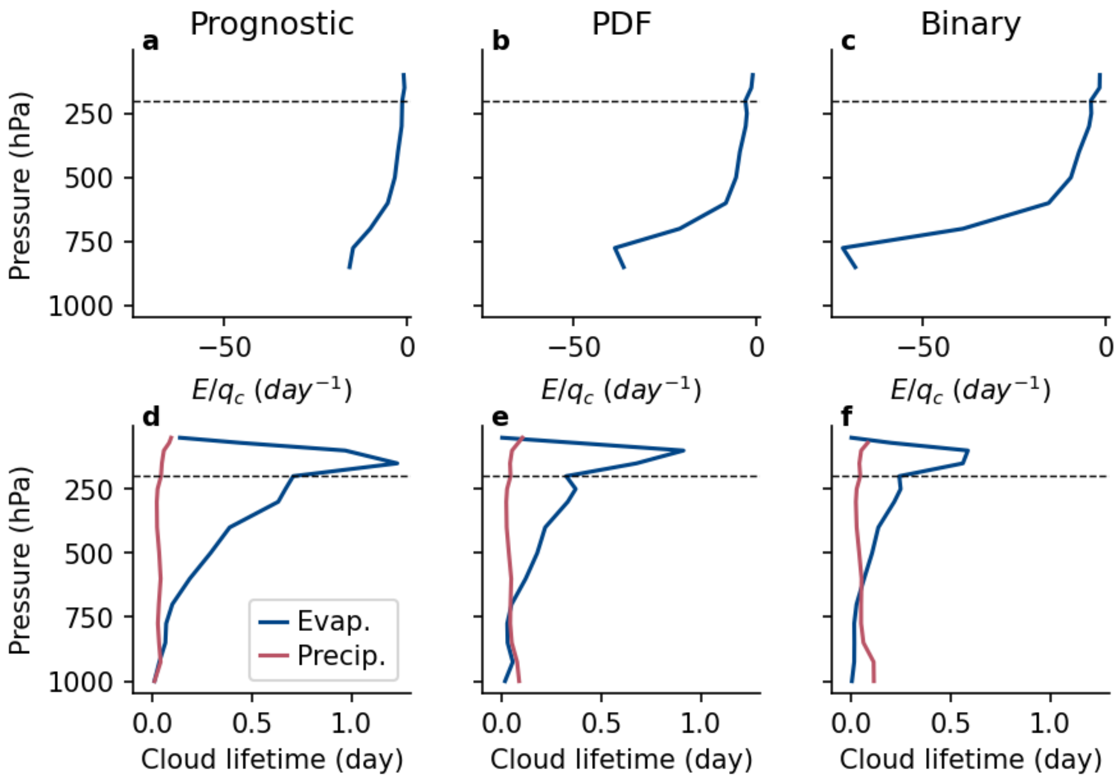

Figure S7: The same as Figure 3 but with the same x-axis limits for all the panels.