

Supporting Information for ”Distinct Mixing Regimes in Shallow Cumulus Clouds”

Yael Arieli¹, Eshkol Eytan¹, Orit Altaratz¹, Alexander Khain², Ilan Koren¹

¹Department of Earth and Planetary Science, Weizmann Institute of Science, Rehovot, Israel

²Institute of Earth Science, Hebrew University, Jerusalem, Israel

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S1: the AF calculation method

Eytan et al. (2021) present several ways to calculate the LWC_{ad} , and the method found to be the most accurate follows the analytical derivation of Korolev and Mazin (2003) of the supersaturation in an adiabatic ascending parcel while changing the time domain to vertical coordinates (and changing $q_w = \frac{LWC}{\rho_d}$)

$$\frac{d \log(S + 1)}{dz} = A_1 - A_2 \frac{dLWC}{dz} \quad (1)$$

$$A_1 = \frac{g}{T} \left(\frac{L_w}{c_p R_v T} - \frac{1}{R_a} \right) \quad (2)$$

$$A_2 = \frac{1}{\rho_v} + \frac{L_w^2}{c_p R_v T^2 \rho_d} \quad (3)$$

where S is the supersaturation, g is the gravity acceleration, T is the temperature, L_w is the latent heat of water evaporation, c_p is the specific heat of air at constant pressure, R_v and R_a are the specific gas constants of water vapor and dry air, respectively, and ρ_v and ρ_d are the respective density of water vapor and dry air. Since these equations do not include mixing effects, we can consider that $LWC = LWC_{ad}$. Additionally, for $S \ll 1$, Eq.1 can be approximated to

$$LWC_{ad}(z) \approx \int_{z_0}^{z'} \frac{A_1(z')}{A_2(z')} dz' - \int_{z_0}^z \frac{1}{A_2(z')} \frac{dS}{dz'} dz' \quad (4)$$

where $z_0 = 0$ at the cloud base.

S2: distance between entry and exit levels

Figure S2 presents two histograms of the vertical distance between the height of the cloud top and the entry height of the tracer into the cloud. It presents only the tracers

that passed $0.3 < AF_{max} < 0.8$ during their travel in the cloud and ascend a vertical displacement of more than 150[m]. Hence, it depicts only tracers that are part of the periphery-associated mixing regime. In the blue histogram, the entries were restricted to between 27 and 32 min; the mean value is 440[m] with a standard deviation of 210[m]. There is a preferred entry height of 230 – 650[m] below the cloud top. Meaning that when the cloud-top is higher than 1400[m] (after 27 min of simulation), most of the entrance levels are above 700[m]. This agrees with the known features of the toroidal vortex [eytan2023]-] and can explain the sparse band observed in Figure 2. In the red histogram, the entry is restricted to 27 min; at that time, the cloud reaches a 1400[m] height. The preferred entry here is at 220 ± 120 [m] below the cloud top. Hence, even when the cloud top is approximately ~ 1000 [m], most of the entrainment takes place above 700[m].

References

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- Korolev, A. V., & Mazin, I. P. (2003). Supersaturation of water vapor in clouds. *Journal of the Atmospheric Sciences*, 60(24), 2957 - 2974. Retrieved from https://journals.ametsoc.org/view/journals/atsc/60/24/1520-0469_2003_060_2957_sowvic_2.0.co_2.xml doi: 10.1175/1520-0469(2003)060<2957:SOWVIC>2.0.CO;2

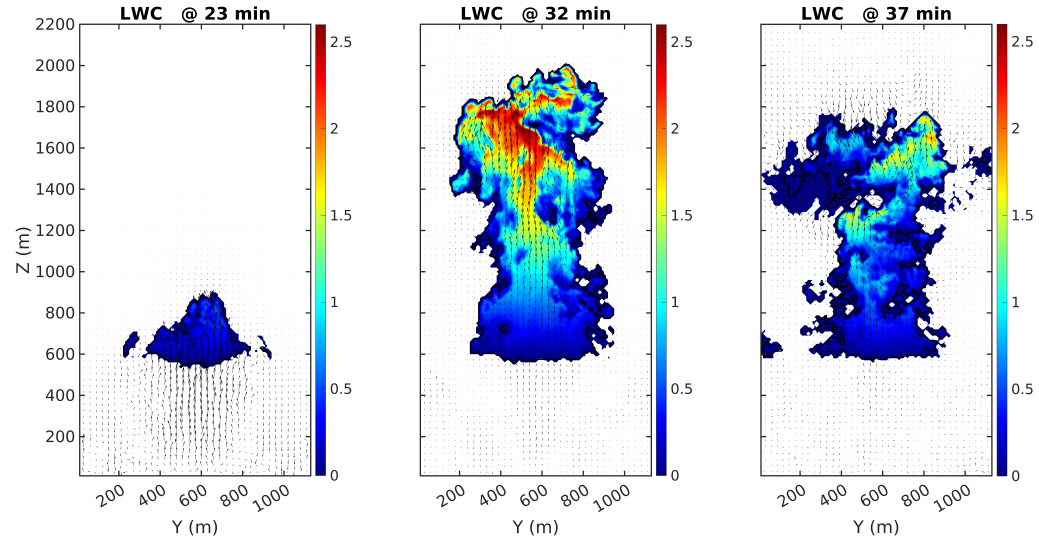


Figure S1. Cross section of the cloud at 23,32, and 37 min of simulation. The color scale represents the LWC [g/kg], and the arrows are the velocity field.

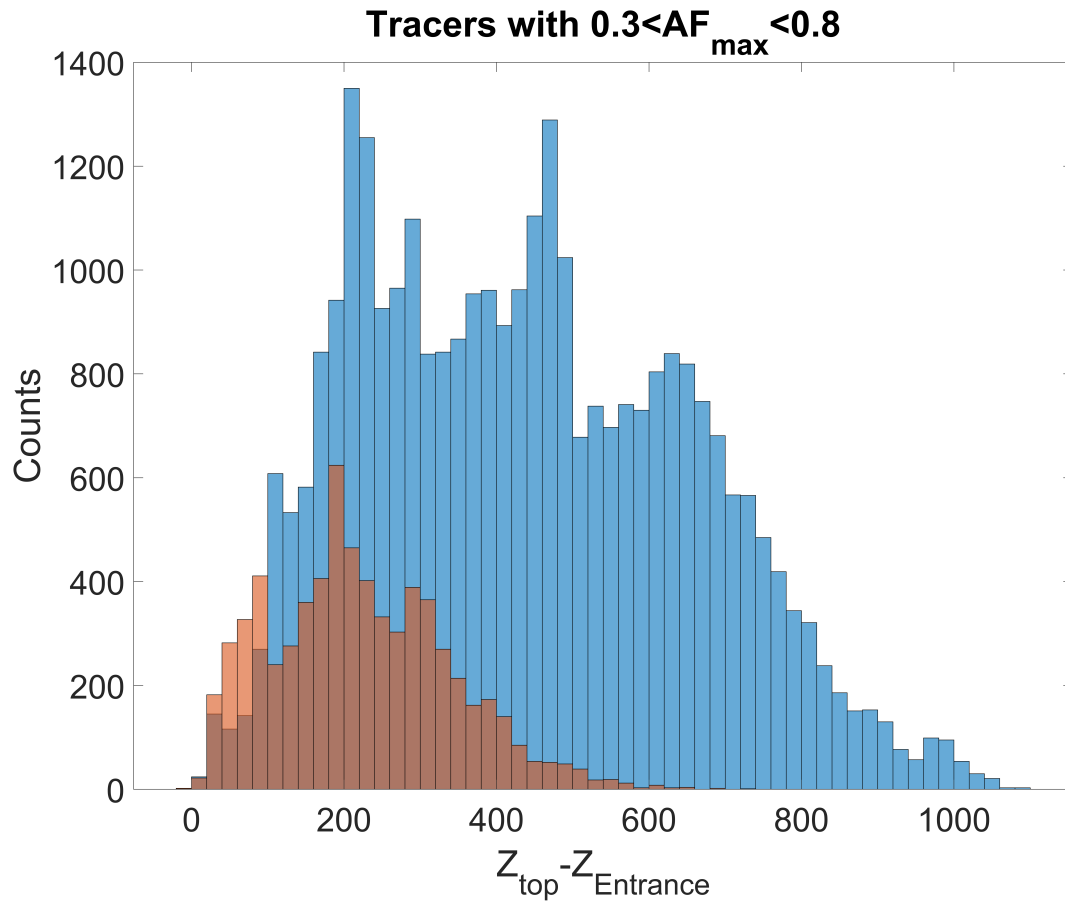


Figure S2. Histograms of the vertical distance between the height of the cloud top and the entry height of the tracer at that time, including only tracers that passed through $0.3 < AF_{\max} < 0.8$ inside the cloud. The blue (red) histogram includes only tracers that entered the cloud between 27 to 32 min (before 27 min).

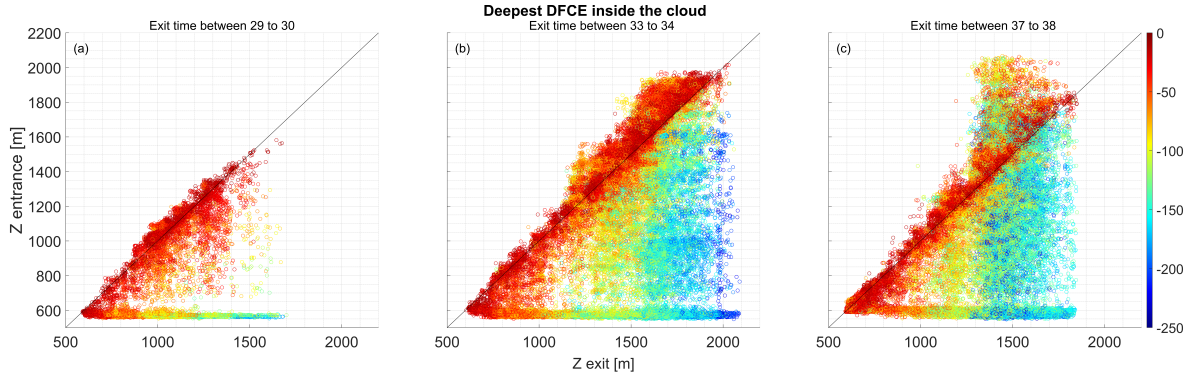


Figure S3. Time evolution. Entry height as a function of the exit height for each tracer that entered and exited the cloud. The colors represent the deepest distance the tracer reached inside the cloud. In panel **a**, the entry is before 30 min, and the exit is between 29 to 30 min. In panel **b**, the entry is before 34 min, and the exit is between 33 to 34 min. In panel **c**, the entry is before 38 min, and the exit is between 37 to 38 min.