Response for egusphere-2026-4291 (minor revisions)

We thank Dr Rob Warren for his careful and detailed rereading of the manuscript. His thorough comments have helped improve the manuscript, and we greatly appreciate the time and attention he has given it.

The reviewer's comments are listed below in black and responded to individually in blue. Revised sentences are in red.

Response to individual comments:

"Downpours and deluges" in L16 and the manuscript title.

We agree with the reviewer and have removed the terms "downpours" and "deluges" from the manuscript.

L33: How did the large-scale environments of localised "showers" and widespread "rains" identified by Raymond et al. (2024) differ? You've clarified this for some of the other studies discussed in this paragraph but not this one.

We have clarified this as follows:

Combining observations and numerical simulations, Raymond et al. (2024) showed that the intense but localised "showers" tend to occur in drier but more unstable environments, whereas the weaker but widespread "rains" are associated with very moist environments with weak instability.

L113: "dry air–vapour mixture" needs an en dash. There are also a few places where hyphens need replacing with en dashes.

We have revised this following the reviewer's suggestion.

L130–131: Surely only Eq. 5 can be solved for h_e^* since this variable does not appear in Eq. 3.

Thanks for this point. What we meant is that one can use either (3) or (5) to calculate h_e^*. Using (3) requires an iteration to calculate the value of h_e^* given $h(z)$ under the condition that the cloud and environment have the same density. We have revised this as follows:

...either (3) or (5) may be used to infer the saturation moist static energy of the environment, …

L141–143: I suggest revising the second part of this sentence (after the colon) as follows: "$m_b(\epsilon') = M_0/\epsilon_0$, where M_0 is the cloud-base mass flux required under conditions of radiative–convective equilibrium and ϵ_0 is a characteristic entrainment rate."

We have revised this following the reviewer's suggestion.

L150: Please replace ϵ in this equation with $\epsilon(z)$. I kept reading $\epsilon(z - z_b)$ as the entrainment rate at height $z - z_b$, rather than the product of $\epsilon(z)$ and $z - z_b$.

We have revised this following the reviewer's suggestion.

L168–169: When you say "low levels" and "upper levels", do you mean "below 10 km" and "above 10 km", respectively? If so, consider revising to make this explicit. Also "upper levels" doesn't need a hyphen here as it is not acting as a compound modifier.

Yes, thanks. We have revised this to read:

In each case, $\epsilon(z)$ decreases with height, partially to counteract the growth of plumes through entrainment, and additionally, at heights above 10 km, due to the decrease in total mass flux following $\eta(z)$.

L181: Change "uniform" to "constant" and "$z = z_b$ " to just "z_b".

We have revised this following the reviewer's suggestion.

L186: Change "humidity" to "specific humidity".

We have revised this following the reviewer's suggestion.

L193: I assume that z_t represents the cloud top (LNB), but this has not been stated anywhere.

Yes, this is the height at which a given plume is neutrally buoyant. We have revised the passage to include this:

where T_{vp} and T_{ve} are the virtual temperatures of the plume and environment, respectively, and z_t is the height at which the plume becomes neutrally buoyant.

L211: This line shouldn't be indented.

We have applied a \noindent command in LaTeX to remove the indentation.

L222–223: There seems to be a stray ϵ at the end of this sentence. I suspect you meant for it to go after "effective entrainment rate".

We have revised this following the reviewer's suggestion.

L233: The dependence of w_{ext} on humidity is weak across much of the phase space but becomes more significant for high entrainment rates (ϵ > 0.25 km^{-1}). This makes physical sense, as strongly entraining plumes will only be able to maintain large vertical velocities if the entrained air is relatively moist (and therefore dilution of updraft buoyancy is limited).

We have integrated the reviewer's comment into the manuscript as follows:

On the other hand, the extreme updraft w_{ext} increases primarily with instability but also exhibits a weak dependence on humidity owing to entrainment, with larger values occurring in a *drier* atmosphere. This dependence is weak across much of the phase space but becomes more pronounced for high entrainment rates ($\bar{\epsilon}$ > 0.25 km^{-1}), where strongly entraining plumes can maintain large vertical velocities only if the entrained air is relatively moist, which limits the dilution of updraft buoyancy.

L240: Consider changing "Although we note that" to "We note, however, that".

We have revised this following the reviewer's suggestion.

L266: You can delete the acronym BoM as it isn't used again.

We have revised this following the reviewer's suggestion.

L287–288: Delete "based on the Steiner et al. (1995) convective–stratiform classification" (the classification algorithm has already been noted on L272).

We have revised this following the reviewer's suggestion.

L295: It might be worth noting that large convective systems (e.g., long squall lines) may still be truncated by the 150 km maximum range of the radar data.

We have noted this as follows:

To minimise edge effects, cells intersecting the 100 km radius boundary are retained in their entirety, rather than restricting the analysis to only the portion within the domain. Very large systems (e.g. long squall lines) may still be truncated at 150 km, but would still be identified as large systems.

L304: Here and in Eq. 15, you could denote the total domain area as simply D (dropping the subscript "a").

We have revised this following the reviewer's suggestion.

L323: In ERA5, CIN is calculated as minus the integrated negative buoyancy below the LFC, such that values are positive. Personally, I much prefer this convention as it means that higher (i.e., more positive) CIN corresponds to stronger inhibition; however, many studies (particularly in the US) define CIN without the minus sign in the equation, such that values are negative.

We have noted this as follows:

It is calculated as the integrated negative buoyancy below the LFC of the moist unstable parcel defined above (ECMWF, 2026). This gives CIN positive values, with larger values indicating stronger inhibition.

L334–335: It still isn't clear to me what data Palmer and Singh (2024) used for precipitation. You said in your reply to my previous comment that they didn't use radar data, but what did they use (satellite, reanalysis, rain gauges, etc.)?

We have clarified this as follows:

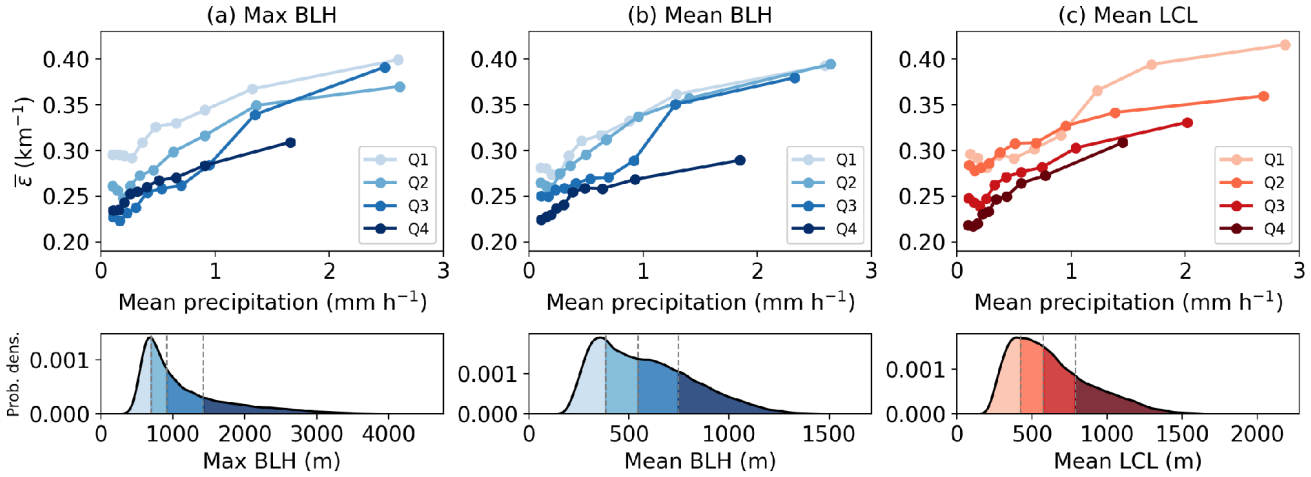
Given that all 175,610 radar scenes are drawn from identified rainfall events, this result is consistent with that of Palmer and Singh (2024). They analysed the large-scale environment from reanalysis and radiosonde observations associated with precipitation exceeding 5 mm day−1, defined from reanalysis precipitation and station precipitation, respectively.

L371–372: Replace "level of free convection" with "LFC" and "equilibrium level" with "LNB".

We have revised this following the reviewer's suggestion.

Figure 9: Similar to Fig. 7, it might be useful to add a second row of panels showing the distribution of each variable with shading showing the four quartiles. Alternatively, you could add this as an inset to each panel and then create a single legend for the figure (although this would mean using the same colours for panel c as for panels a and b).

We have added the distribution of each variable in Fig. 9 as shown below.



L432–433: I think you mean to say that ϵ generally decreases with increasing boundary-layer depth (i.e., with increasing mean and maximum BLH and mean LCL).

The reviewer is correct. We have corrected this in the revised manuscript.

L436: Rather than "(not shown)", you could say "(cf. Fig. 5c and Fig. 8a,c)".

We have revised this following the reviewer's suggestion.

L447–450: Here and in Fig. 8d, I recommend using σ_{SF} to represent the standard deviation of the saturation fraction.

We have revised this following the reviewer's suggestion.

L472–473: Since the 100 km radius only applies to the radar observations and not the reanalysis data (for which you have used a 3° x 3° area), I recommend replacing "within a 100 km radius of a radar site in Darwin, Australia" with simply "for Darwin, Australia".

We have revised this following the reviewer's suggestion.

L510–511: Statements about adiabatic ("reversible") CAPE.

We have revised this following the reviewer's suggestion.

References: Capitalisation needs fixing in the paper title for some reference (e.g., Allen et al. 2014) and in the journal name for others (e.g., Brooks et al. 2013).

We have checked and fixed the references following the reviewer's suggestion.