We thank the editor and the reviewer for their thorough assessment, feedback and comments on our manuscript. Please find our answers to the comments below with the original comment in *italics with light grey shading*, followed by our reply.

COMMENTS BY THE REVIEWER

1.) Instrument uncertainties: The MWR is an essential instrument in your study. And you are using it to analyze the atmosphere around heavy precipitation events. Ground-based MWR are prone to errors due to a wet radome. Please provide information on how you quality control/assure your observational data in this sense. You may find some useful information here: https://zenodo.org/records/11422901
or here: https://egusphere.copernicus.org/preprints/2025/egusphere-2025-1727/

Thank you for providing the link to the preprint, we are aware of the methodology by the authors and have already adopted it for the next iteration of our quality control system. For the MWR data used in this study (Version 1.0), we use a rather conservative radome time-to-dry estimate of 30 minutes (see Kvas et al. 2024 for details) after the last recorded rainfall (as measured by the radiometer-mounted weather stations and neighboring rain gauges) at the radiometer site. In contrast, Böck et al. (2025) observe time-to-dry values of 20 minutes as a worst case (Fig. 12). This means that generally more observations than necessary are flagged, but ensures that a wet radome does not influence our conclusions. We amended the manuscript with:

> *L240: To avoid these biases influencing our analysis, we exclude all microwave radiometer observations between the first recorded rainfall and 30 min after the last recorded rainfall at the radiometer site.*

to clarify our approach.

Böck, T., Löffler, M., Marke, T., Pospichal, B., Knist, C., and Löhnert, U.: Instrument uncertainties of network-suitable ground-based microwave radiometers: overview, quantification, and mitigation strategies, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-1727, 2025.

Kvas, A., Fuchsberger, J., & Kirchengast, G. (2024). Algorithm Theoretical Basis Document for Version 1.0 of the WegenerNet 3D Observing System L1 and L2 Data Products (WegenerNet Technical Report No. 2/2024). Wegener Center for Climate and Global Change, University of Graz.
https://wegenernet.org/downloads/Kvas_et_al_2024_WEGN3D_v1_ATBD-WEGN-TR-2-2024.pdf

2.) In section 3.1 you now write: Most HPEs observed do not form within the comparatively small region of the WEGN. This means that before a HPE the sky is either clear or filled with some fair weather clouds which get displaced by cumulus clouds close to the actual event. This is represented by a decrease in the CBH anomaly of about 1000 m prior to the event onset.

You are implying a physical causality here that I cannot recognize. 1h before the HPE, you see an >1kg/m2 increase in IWV (Fig. 3). Don't you think this could lead to lowering of the CBH, e.g. through a lowering of the LCL or CCL? Did you check the near-surface spread (T-Td) for this?

After reading your comment, we checked the T-Td vertical structure and got very similar results to the vertical RH structure shown in Figure 4b. In our opinion, there are two possible conditions before an HPE in our study region:

1. The HPE forms outside the WEGN region and moves into the study region. This is the situation we described in the manuscript, where there are no clouds (or some fair-weather clouds) in the study region before the event, which then get displaced by cumulus clouds. Since the cumulus clouds have a lower CBH than the fair-weather clouds, this would explain the observed drop of CBH.

2. The HPE forms inside the WEGN region. In this case we agree, that the lowering of the CBH is probably connected to a lowering in LCL.

Considering that we know that most of the observed events do not form within the region of the WEGN, we cannot be sure which is the dominating mechanism that leads to the observed drop in CBH. We changed the corresponding sentences in the manuscript to clarify that our explanation might not be the only one:

> *L171: There are multiple mechanisms that can explain the decrease in CBH anomaly of about 1000 m detected close to the event onset. Connected to the increase in IWV anomaly described above, a lowering of the lifting condensation level could result in a lowering of the CBH. However, we also find that most HPEs observed do not form within the comparatively small region of the WEGN. This means that before a HPE the sky is either clear or filled with some fair-weather clouds which get displaced by cumulus clouds close to the actual event, which could also lead to the observed decrease in CBH.*

3.) It great that you have provided a figure with the LR time series. But why put it in the appendix? Your paper does not have too many figures and the LR figure is an additional analysis, so I suggest moving it to the main body of the paper. In any case, you need to discuss this figure more quantitively if you add it to the paper. Fig. B1 before the HPE makes sense (strong instability close to the surface and then conditional stability above). But I wonder what is going on after the HPE. Why do you see a persistent inversion up to 12h after the event peaking around 500m?

Thank you for that input. We consider the analysis of the LR as supporting information and therefore decided to leave it in the appendix. There are two possible reasons for the observed inversion up to 12 h after the event:

1. The difference between pre- and post-event temperature is higher at lower altitudes (Fig. 4a). This means that the lower layers are cooler after the event than the higher layers which leads to an inversion in the LR.

2. As shown in Figure 2, most of our events occur in the afternoon (around 15 h). The 12 h after the event are therefore mainly during the night time, when inversion layers often occur because the surface-near layers are cooling faster than the higher layers. After the 12 h, the next day already started and temperatures begin to rise again, and the inversion layer vanishes.

We agree that our description of the LR figure was a bit scarce. We therefore adjusted the following paragraph:

> *L191: In the hours after the event, we observe decreased LR values and a persistent inversion layer at roughly 500 m. Figure 4a shows that the temperature difference between pre and after event is higher at lower altitudes, which we attribute to the increased moisture at these levels. As a consequence, the lower layers are cooler after the event then higher layers, resulting in an inversion layer. At higher altitudes the decrease in LR values might be connected to the release of latent heat during the rainfall event. Further, due to the events' tendency to occur mainly in the afternoon, the hours after the event are often during the night time, where radiation effects often lead to LR inversions.*

4.) Cold pools, you now write: Another reason for the increase in temperature variability might come from convective cold pools (Kirsch et al., 2024) which are often detected at the location of HPEs before the event onsets. While we do find indications of such cold pools for a few of the investigated HPEs (not shown), most of the HPEs do not form directly in the region covered by the WEGN, which means that potential cold pools cannot be found in that area as well.

Could you include an argument why cold pools cannot be detected if the HPE doesn't form in the WEGN region? Cold pools are generally defined by rapid horizontal wind increase (gust front) and simultaneous temperature drop shortly before the event, both which you nicely see in Fig. 3.

You are correct, we do see an increase in wind speeds and a drop in temperatures shortly before the event onset in our data. However, since we know that most of our events do not form within our study region, cold pools connected to these events would likely also not be located in our comparatively small study area. We therefore do not want to argue that the rise in wind speeds and the drop in temperature we observe in our region is connected to the formation of cold pools. Such a claim would need further investigation, which we consider to be beyond the scope of this study.

COMMENTS BY THE EDITOR

L10: The sentence "Beginning with ..." seems to me grammatically wrong, please rephrase.

Thank you for pointing that out. We changed the corresponding sentence to:

> *L11: Beginning with the event formation stage (i.e., the 8 hours before the event), temperatures are usually already quite high and continue to rise, while the first clouds begin to form, followed by an increase in wind speeds and a darkening sky.*

L13: please specify "we find an increase ...": when? during the 8 h before the event? or do you mean that during events these parameters are increased compared to climatology? please clarify.

To clarify our statement, we added *"… in the 8 h prior to the event onset."* at the end of the sentence.

abstract: I would find it very interesting if you could mention in the abstract the timing of your 94 events (at what time of the day do they typically occur? and in what months of the year?).

To characterize our events more precisely, we adjusted the following sentence:

> *Here we follow the life cycle of 94 heavy rainfall events by investigating multiple atmospheric parameters in WEGN3D and global reanalysis data.*

[changed to]

> *L9: Here we follow the life cycle of 94 heavy rainfall events, which mainly occur in the afternoon hours in the warm season, by investigating multiple atmospheric parameters in WEGN3D and global reanalysis data.*

L36 but also in other places: please list references chronologically

Thank you for pointing this out to us, we changed ordered the references accordingly.

L68: "unprecedented holistic way" is maybe a bit exaggerated, maybe chose a more modest formulation.

We changed the corresponding sentence to:

> *L68: In this study, we leverage the different instruments available in the WEGN3D Open-Air Lab to holistically investigate local HPE precursors in high-resolution data.*

Eq. 1: this is not good notation, why is hourly precipitation called I_P and 5-min precipitation PA? I would just write that hourly precipitation rates are estimated from 5-min accumulated measurements by multiplying with a factor of 12.

Thank you for noticing. We removed the equation, since it is not used later on anyways and changed the corresponding sentence to:

L117: Note that due to the 5 min temporal resolution of the WEGN, hourly precipitation rates are derived by multiplying the 5 min precipitation amounts with a factor of 12.

Section 2.2.2: please re-consider your notation. I have never seen AH for absolute humidity (you mean specific humidity in g/kg? or mixing ratio in g/m3?); q or w would be the more common symbols. For all variables, please indicate their unit, and if you use symbols (like T for temperature, then T should be in italics). Abbreviations (RH, IWV, …) should remain in roman letters.

In our study we use the absolute humidity (i.e., the mass of water vapor per volume of air) and not the specific humidity. Analogue to RH for relative humidity, the abbreviation AH is not uncommon in climate studies. See also the corresponding Wikipedia article: https://en.wikipedia.org/wiki/Humidity#Absolute_humidity. We therefore decided to stick to AH for absolute humidity.

We changed all occurrences of T to italics. The units of all parameters can be found in Table 1.

Figure 6: it is unclear to me what you mean by "regional anomaly" - is this a deviation from the domain mean, or from climatology? And which event are you showing in Fig. 6 (indicate the date)? And what do you mean by "accumulated PA" (is this the total precipitation within 20 minutes)?

After reading your comment, we agree that the figure was not described sufficiently. We added a short description of how the regional anomaly is computed and some additional information about the event date and the meaning of the accumulated PA in the manuscript where the figure is introduced. We also added the event date in the figure caption.

L242: Figure 6 shows a snapshot of the regional T2M anomaly, along with accumulated precipitation amounts (from event start to 20 min into the event) derived from radar and gauge measurements, 20 min into the event on 2022-09-15. The T2M anomaly is calculated by subtracting the spatial mean over the whole region from the data.

Figure 7: for panel c, the caption says it is T2M, but it is likely a T2M anomaly (again, relative to what?)

Thank you for bringing that to our attention. We corrected the figure caption. A description of how the anomaly is calculated is given in Section 2.2.2. To emphasize that the anomaly shown in Figure 7 is calculated in the same way, we added a sentence referring to the corresponding section:

L249: The temperature anomaly is again calculated with the steps described in Section 2.2.2.

L317: again, it is important that the reader here understand what you mean by "anomaly" (deviation from climatology? from domain mean? From …?)

To clarify what we mean by “anomalies”, we added a sentence in Section 2.2.2 where the preprocessing of the data is explained:

L141: Anomalies shown in this study should therefore be considered as 'event anomalies'.

L326: it is good tradition when reporting about observations, to make the point that they are important for improving models (and predictions). But do you have a specific suggestion how your results could help with this? I very much like your observational analysis, but I don't see immediately how a model can be improved given your study, and therefore the final statement sounds a bit overly general. Maybe you would like to emphasise that one could do similar analyses with high-resolution weather prediction models and quantify whether they have the correct time evolution of T2M, CAPE etc. prior to HPEs?

Thank you for this suggestion. As we already cover this topic in the Discussion, we added the following sentences to the Discussion Section:

L310: Another potential application is the verification of high-resolution weather models by comparing the temporal evolution of the parameters examined in this study (cf. Table 1) with the corresponding model outputs. The models could also be tuned to more accurately reproduce the observed behavior of these parameters.