Author response to Referee #3:

Dear Referee,

We sincerely thank you for your thoughtful and constructive comments, which have greatly helped us improve the manuscript. Below, we provide our point-by-point responses to each comment. All changes made to the manuscript according to the comments of the three reviewers have been carefully highlighted in the revised version.

General comments:

This paper is to use synergistic satellite data from active instruments; it also applies artificial neural network regressions on InfraRed Sounder data, and meteorological reanalyses to investigate the relationship between latent heating (LH) and radiative heating (RH) for mesoscale convective systems (MCS).

The main results show (1) the zonal averages of vertically integrated LH (LP) at 1:30AM and PM LT align well with those from the diurnal sampling of TRMM–SLH LH over ocean; (2) the surface temperature has a larger impact on the **atmospheric cloud radiative effect (ACRE)** in dry than in humid environments for **Upper Tropospheric (UT)** clouds; (3) humidity plays a large role in enhanced ACRE for lower clouds, producing relatively small latent heat; (4) the mean ACRE per MCS increases with LP; and (5) LH profiles of mature MCSs have a larger contribution of stratiform rain than the smaller MCSs,

This paper is interesting because it applies artificial neural network to investigate the relationship between LH and RH.

I have comments that the authors need to address to have paper to be published.

Specific comments

- Line 17: Suggest deleting “the precipitating parts of”.
- Line 25: Suggest deleting “closer”.

  All taken into account

- Line 32, tropical: May identify the area of “tropical: (i.e., 30o or 20o south to north).

  Thank you for your suggestion. We agree that specifying the exact latitudinal range of the tropical region improve clarity from the beginning on. In the revised manuscript, we have added the following sentence at the end of this paragraph:

  "... The data expansion and the following analyses cover the latitudinal band 30°N-30°S."

- Line 83; Hagos et al.: Not sure if this reference needed.

  Thank you for pointing this out. Since Hagos et al. (2010) does not directly compare the latest versions of the SLH and CSH retrievals, we have removed this part from the text.

- Line 85, continuous: Not sure what it means.

  "Continuous" refers to how the SLH algorithm generates vertical profiles of latent heating that smoothly vary with PR echo-top height, rather than relying on a limited set of discrete profiles stored in LUTs, as described in Hagos et al. (2010). However, since Hagos et al. (2010) does not reflect the latest versions of either SLH or CSH, we have removed this sentence. In the revised text,

we have rewritten this paragraph to clarify the methodologies used in the latest versions of SLH and CSH, and provided a clearer comparison between the two algorithms.

- Line 87: Please check the year of Shige et al. (2004 or 2003).

  We apologize for the error. The correct year should be Shige et al. (2004), and we have now corrected it in the manuscript. Thank you for catching this mistake.

- Line 94-95: Tao et al. (2022) did not state (or show) the comparison between SLH derived heating and re-analyzed heating profile. The CSH and SLH derived LH shown in Hagos et al. (2010) are from old version of CSH and SLH retrieved LH. The new version for both SLH and CSH is V6 (shown in Tao et al. 2022).
  In addition, the reanalyzed is a combination of model and observation. That is why different re-analyzed LH (shown in Hagos el. 2010) are different.

  Thank you for your valuable comment. In the revised manuscript, we have removed the comparison between CSH and SLH from Hagos et al. (2010), as it is based on older versions of both algorithms. Instead, we have carefully reviewed and incorporated the comparison between the latest versions of CSH and SLH (V6) presented in Tao et al. (2022). The related text has been revised accordingly.

- Line 95: It is Shige et al. (2007) that paper described the SLH algorithm.

  Thanks for your comment. You are right, Shige et al. (2007) provides a more detailed description of the SLH algorithm. We have updated the citation in the revised manuscript to better reflect this.

- Line 99-128 (section 2.2): What is the horizontal and vertical resolution (0.5 × 0.5 degree and 50 layers) of these three-satellite derived cloud information (AIRS, IASI and CIRS)?

  First of all, AIRS and IASI are IR sounder instruments. CIRS is the cloud retrieval algorithm which is applied to both of them. Since sounders are passive instruments, the cloud retrieval only provides information on the uppermost cloud in the case of multi-layer clouds. Therefore, there is only a horizontal resolution, because the results are 2D, with latitude and longitude as coordinates. The initial spatial resolution of these instruments is 13.5 km and 12 km at nadir, respectively (lines 100-110, previous version). Then these data have been merged to 0.5°, but with keeping sub-grid information (coming from the footprints), like fraction of different cloud types and rain fractions shown in Table 1. The vertical resolution of the CIRS-ML radiative heating rates, which were initially derived from CloudSat-CALIPSO data (Stubenrauch et al. 2021), has been reduced to 21 layers, because the input information is only 2D.

- ERA interim's horizontal resolution is 0.75 × 0.75 degree. Could you please describe what are spatial resolution of these three-satellite derived cloud information? Does cubic spline function also apply to the satellite cloud information (0.5 × 0.5 or 075 × 0.75degree)?

  The cubic spline interpolation was only used for time interpolation. ERA-Interim data were used as ancillary data (for T, humidity profiles and surface T and pressure as well as snow / ice presence) in the CIRS retrieval (Stubenrauch et al. 2017). The collocation in space was such that one array of footprints (3 × 3 for AIRS and 2 × 2 for IASI) was assigned to the closest ERA-Interim grid cell.

  To improve clarity, we have added the corresponding description in the revised manuscript.

- Line 135: What is sub-grid structure? Is it for making all data to 0.5 × 0.5 degree and 10 vertical layers?

The subgrid structure comes from the footprints which have a size of about 13.5 km and 12 km at nadir for AIRS and IASI, respectively, and therefore is only the horizontal subgrid structure. We added this in the text to make it clearer.

The vertical structure of the ERA-Interim T and water vapour profiles used for the ANN regressions was reduced to 10 layers (section 2.3, line 163-165).

- Line 144-145: Would it be nice to also use TRMM/GPM derived rainfall intensity?

  If we wanted to use information on the rain intensity or rain fraction in the training, we needed to use data which are available over the whole production period (2004-2018) for each of the AIRS and IASI footprints. Since we have used CloudSat-CALIPSO data earlier to expand the radiative heating rates (Stubenrauch et al. 2021), we used CloudSat precipitation rate data (2C-PRECIP-COLUMN, Haynes et al. 2009) to expand information on precipitation (Stubenrauch et al. 2023). Since the distribution of precipitation rate is highly skewed, we were not able to do an ANN regression of this precipitation rate, but we succeeded to build an ANN classification, separating no-rain, light-rain and heavy-rain scenes (Stubenrauch et al. 2023). In that article, we have also shown that this scene identification was more powerful to separate TRMM SLH latent heating rates than cold brightness temperature.

  We could not use TRMM data, because as we have shown before, these are only available for less than 5% of the AIRS and IASI footprints. There may be a possibility to use GPCP data, but again the L2 data would have been needed to collocate with the complete AIRS and IASI datasets in time and space, and we are not sure if there is a 100% overlap. Since we have had already this CIRS-ML rain intensity classification, we pursued this path.

  During this review, we have analysed the complete collocated dataset further, and we found indeed some noise linked to the difference between fraction of certain rain from CloudSat (using CIRS-ML) and from TRMM, but the CIRS-ML dataset seems to be coherent with the certain rain fraction, though it was not used as input for the ANN (see replies to referee #1).

  In this article we have shown one method to expand the latent heat with CIRS data; there may be better ways, but since the whole procedure took quite an effort, it was not possible to pursue two paths in parallel. It would be nice if this work inspires other researchers to improve the methods to get a complete 3D dataset of UT cloud systems.

- Figure 1: What do dark, and light blue color represent?

  We apologize for the lack of clarity in the original figure caption.

  Dark and light blue color represent the time difference between TRMM and AIRS. We have added the colorbar and one sentence in caption of Figure 1 to:

  "The narrow swaths represent TRMM–PR orbits, while the broader swaths represent Aqua–AIRS orbits. Shades of blue indicate variations in sampling time difference."

- Line 160: What do you mean the "maximum" 0.0 mm h-1?

  Indeed, this was not clear. We meant a large peak at 0.0 mm h^{-1}. To clarify, we have revised this in the text to "with a peak at..."

- Line 162-166: The "%" is for frequency (or area coverage). The non-precipitation means no surface rain. Correct?

Yes, it's correct, the "%" is for frequency. And the non-precipitation means no surface rain.

- Figure 2: The LH profiles are from SLH algorithm. Correct? In addition, please just refer one specific SLH paper that describes the algorithm design. The figure uses two different scale for LH (from -10 to 40) and RH (-10 to 30). Suggest using the same scale for both LH and RH.

  Yes, the LH profiles are derived from TRMM-SLH data collocated with CIRS-AIRS and CIRS-IASI (see section 2.4).

  We have also revised the caption to reference only Shige et al. (2007) to describe the algorithm design, as you suggested.

  In addition, we have adjusted the scales in Figure 2 to ensure consistency between LH over ocean and LH over land.

  We sincerely thank the reviewer for these valuable suggestions, which have helped us improve the clarity and consistency of the figure and the manuscript.

- Line 160-211; section 2.5.1: It may be a good idea to have a schematic diagram that shows the design of ANN for predicting LH/RH. Maybe a good idea to show the key parameters for predicting LH in diagram.

  We appreciate the reviewer's helpful suggestion. A schematic diagram illustrating the structure of the ANN used in this has been added as Figure S2 in the supplementary material.

  Unfortunately, we could not find out the key parameters. We tried this already for the expansion of the radiative heating rates, but we only found that once the basic 20 variables were used, the improvement with any additional variable was small (Stubenrauch et al. 2021). We have shown all variables used for the training in Table 1.

- Would ANN-LH predict certainty or uncertainty?

  The ANN-LH model currently provides deterministic predictions, meaning it outputs a single value for latent heat without explicitly quantifying uncertainty. However, we acknowledge the importance of uncertainty estimation in predictive modeling. In order to get an idea of the uncertainties and in particular of the biases, we have done the analyses described in section 3.2 and 3.3, unfortunately most are only qualitative, but they give an idea. Since Figure 3 shows that the range of the predicted LH is reduced compared to the original data, the slopes in Figure 6 show that in general extreme values are not predicted. Furthermore, for small LP the predicted LH is larger when there is a mismatch between TRMM rain fraction and CIRS-ML rain fraction (originally from CloudSat), which may come from different sampling sizes (5km against 1.25 km × 2.5 km).

- Line 185: What is impact on "randomly divided" on the retrieved product? Line 186: What is the validation data? (Is it SLH derived LH?)

  The random division of the collocated dataset into training, validation, and test sets ensures that the data distribution is statistically similar across all subsets.

  Yes, the validation data is SLH-derived LH from 20% of the total input data. It is used for iterative optimization during model development, helping to tune hyperparameters and prevent overfitting.

- Line 215: How are the convective and stratiform rain classified (from TRMM or else)?

In the beginning, we looked at the stratiform and convective parts in the TRMM SLH data, but we did not keep this information for further study, because we found that at a spatial resolution of 0.5°, if the convective LH is very strong, the shape is dominated by this. However, since the pure stratiform and convective shapes of the profiles are very different (see for example Chang and L'Ecuyer 2019, Figure 3), the variability mostly comes from the partition of these (and additional shallow convection).

- Line 223: What is the "true data"?

  We sincerely apologize for the confusion caused by the inconsistent terminology used in the manuscript.

  In this case, the true data is the same as the test data, and it comes from the original TRMM-SLH data. It is a completely independent dataset that is never seen during model training and validation. It is only used at the end to evaluate the model's final performance.

  To avoid further misunderstanding, we have revised the text to:

  "We have evaluated the LH prediction results by comparing them with those of the target TRMM-SLH, using the 20% test data of the collocated data.

- Figure 3: RH is for longwave (not total radiative heating/cooling). Why is only LW shown? Line 230: How do the meting processes affect longwave cooling?

  In Figure 3, the choice of LW was made it provides a clear and representative illustration of the radiative processes we aim to analyze. While we acknowledge that total radiative heating (including both LW and shortwave components) could also be considered, we believe that the LW component alone is sufficient to demonstrate the key features and validate the model's performance. We were here interested in the variability of the profiles. There exists a whole other article which shows the performance of the CIRS-ML expansion of the radiative heating, which includes the SW part (Stubenrauch et al. 2021).

  The cooling observed at approximately 550 hPa due to melting is a result of latent heat absorption. When solid precipitation (such as snow or ice) melts, it requires energy to transition from a solid to a liquid state. This energy is drawn from the surrounding atmosphere in the form of latent heat, which leads to a cooling effect in the local environment (Yasunaga et al., 2008). In the radiative LW heating profile, this cooling appears because the absorbed energy lowers the local temperature, reducing the thermal emission in the longwave spectrum.

- Figs. 2, 3 and 4: Please also plot/show total and UT LH in Figure 3 (for comparison with LH showing in Figure 4). In addition, please plot/show the LH over ocean vs land as those shown in Figure 4.

  Thank you very much for the suggestion. Indeed, we show Figure 3 separately over ocean and over land in the supplement (Figure S7). We had initially also Figure 4 separately over ocean and land for TRMM-SLH in the supplement, but then we tried to reduce the number of figures. So, we have put this figure back (now Figure S1), and we have also done Figure 3 for all and UT clouds, over ocean and land, as you suggested (Figure S5). In the text we have added the comparison between these.

- Line 267: Change minor to small (also in other places).

  Taken into account

- Figure 5: What is LP from TRMM? Is it SLH derived LH? Is GPM data used?

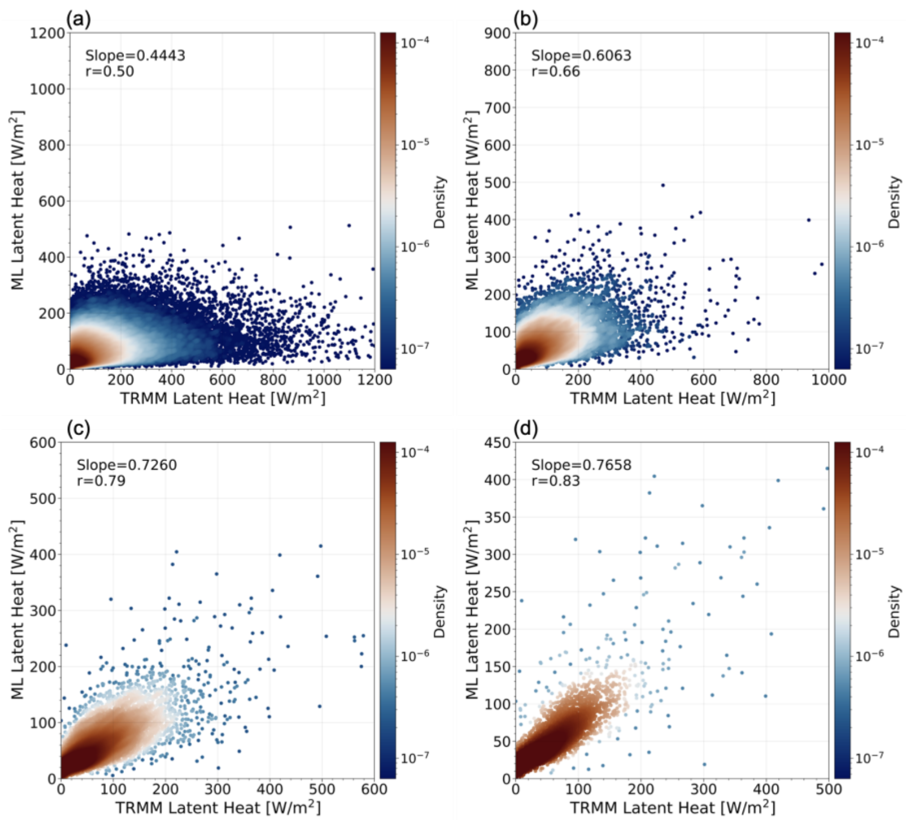
  Yes, LP from TRMM is the vertically integral of the SLH profiles. Only TRMM data are used.

- Please use the term TRMM-LSH (not TRMM). Please also change TRMM to TRMM-LSH in the text and figure caption.

  Yes, it is SLH derived LP, we have changed TRMM to TRMM-SLH in the text and figure caption. Thank you for your thoughtful suggestion.

- Fig.6: Please elaborate why LH/RH is only from 10 S to 10 N). Why does not show, 30S – 30, as shown in other figures?

  Thank you for your comment. The intention here was to illustrate the non-uniform diurnal sampling issue of TRMM. To simplify the manuscript and avoid adding too many figures, we chose to show only the results for 10°S–10°N, as this region has a shorter TRMM repeat cycle, leading to more reliable results: the slopes between monthly mean LP of TRMM-SLH and CIRS–ML are 0.54 to 0.82 in the band close to the equator (10°N-10°S), they vary from 0.44 to 0.77(see figure below) at the higher latitudes (20°-30° N/S) with a TRMM repeat cycle which is only half as large, we put here the figures correspond to Fig.6 for 20°-30°N/S, which are not shown in the manuscript:



  We have added an explanation in the revised manuscript to clarify why only the 10°N–10°S region is shown:

  "As the TRMM revisit cycle depends strongly on latitude (Negri et al. 2002), with 23 days at the equator and up to 46 days at the highest latitudes (the latter should have different observation times sampled in different months), we limited the latitudinal band to 10°N–10°S for this comparison…"

- Line 292-293: Please elaborate more details (why ANN does not capture extreme event; also, what is "well" extreme events). Also need to use TRMM-SLH (not TRMM) in the statement

  It is known that ANN regression captures well the average, as was shown here. While for the radiative heating rates, the spread is also well predicted, for the LH the spread is reduced; there are several reasons for this: (1) the input information is not enough to predict the relationship precisely enough and most (2) the distributions are skewed, with most of the events have no rain and only very few have heavy rain; we could already reduce the underestimation by separately training for different rain intensity scenes. We have shown in (Stubenrauch et al. 2021), that by training over all high-level clouds, the average of the heating rates was smaller than when separately training for Cbs, which are rare.

  To make it clear, we have added one sentence in the revised manuscript:

  "… the ANN regression does not capture well extreme events, mainly because of insufficient input information and the skewed distribution of input data, as mentioned in section 2.5…"

  And we have corrected all occurrences to consistently use TRMM-SLH instead of TRMM where appropriate. Thank you for helping us improve the clarity and precision of the text.

- Line 298: Change Figure 7a-d to Figure**s** 7a-d (or change show to shows).

  Taken into account

- Line 312-313: Why is there "less convective activity, there is more low-level cloud formation"? Figure 7: What is 1h 30 AM/PM? (at the end of caption).

  When convection is weak, vertical air movement is limited, making the atmosphere more stable. This causes moisture to build up in the lower atmosphere, which helps form low-level clouds.

  1:30 AM/PM is the sampling time of AIRS. This is to show that the LP data we use for this figure comes from ML regression trained on TRMM-AIRS collocated data. To avoid confusion, we changed the end of the Figure 7 caption to: "…at 1:30 AM/PM (AIRS)"

- Figs. 7 and 8: Suggest quantifying the similarity and difference with statistical analyses.

  We sincerely thank the reviewer for this valuable suggestion. These figures were primarily intended for illustration purposes, to provide context for the overall conditions during the selected La Niña and El Niño periods. The main focus of our analysis is presented in Section 5. There have been many publications on ENSO, and considering that ENSO itself is not the primary focus of this study, we believe that a more detailed statistical analysis on these particular figures would not significantly enhance the scientific contribution of the paper, as it would not add substantial new knowledge regarding ENSO.

  However, we have now provided the ratios (CIRS–ML LP / TRMM LP or GPCP LP) corresponding to Figure 8 and have added a discussion on these ratios in the revised manuscript.

- Line 343: What is "less" 26,000 MCSs? Please also show the global – geographic distribution of these MCSs. Are only convective cores in these MCSs considered? Usually, there are stratiform cloud (generally with large area coverage than that of convective core). Is it possible to estimate stratiform % in these MCSs??

  We rewrote the definition of oceanic systems and explained why we used only 25N-25S as:

"Furthermore, we concentrate only on oceanic systems, defined as systems with less than 10% of their size overlapping land, and we limit the latitude band to 25N-25S, because most of these systems are located there according to Figure 5 of (Protopapadaki et al. 2017). These criteria leave us with about 26358 convective systems (CSs) for the period of 2004–2018."

The MCSs include both, convective cores and anvils. Our concept of UT cloud system reconstruction is not new, we have first presented it in (Protopapadaki et al. 2017), which also show geographical distributions (Figure 5). Then we have refined it and shown results of core and anvil properties in (for ex. Figure 7 and 8 of Stubenrauch et al. 2023). We have added a few lines into section 4 about this. Instead of determining the % of stratiform anvil, we have determined the % of the core within these systems (core fraction), which we used as a proxy for the life stage (close to one in the developing phase and decreasing with life time). This concept has been shown in the earlier publications, and it has also been used for the evaluation of a new ice scheme in the LMDZ climate model (Stubenrauch et al. 2019).

To help improve clarity, we have updated Section 4 in the revised manuscript by improving the explanation and adding relevant references:

"We define a convective system as an UT cloud system with at least one convective core and the presence of precipitation. Earlier studies (Protopapadaki et al. 2017, Stubenrauch et al. 2019, Stubenrauch et al. 2023) have shown that the convective core fraction, given by the ratio of convective core size over MCS size, can be used as a proxy of the maturity stage (e. g. Stubenrauch et al. 2023)."

- Figure 9: Why is there large/small cooling within the Figure 9a?

  Section 4 was brought in to describe the construction of the mesoscale convective systems. We then thought to illustrate the effect of different proxies for precipitation intensity. Some of these proxies are very indirect, like the size of the systems or the minimum cooling above the precipitating part of the convective system (the LW cooling above the cloud stands for the opacity). For the latter, we select the grid cell within the precipitating part of the convective system with the minimum value of the cooling above the cloud. We compare the latent heating rate profiles with the one for heavy rain MCSs, which is the most direct proxy. Figure 9 was meant to test the coherence of the data. The LW cooling above the core comes from the CIRS-ML data and the core identification from CIRS and using CIRS-ML rain classification. And we can show that the CIRS-ML latent heating profiles change in coherence with the different proxies.

  Furthermore, we show that on average the minimum LW cooling above the heavily raining MCS's is the largest. This shows again that the minimum cooling above the participating part of the convective system seems to be an interesting proxy for rain intensity.

- Line 352, -7.5 K Day^{-1}; Line 356, 40 K Day^{-1}: It is supposed to heating (release heating from condensation/deposition) in the convective core.

  The -7.5 K/day is the threshold of the minimum cooling above the cloud, whereas the 40 K/day is the LH. Indeed, this paragraph was not well written, we have modified it (in particular taking out the description of the thresholds which cut the flow and moving this to the legend) and hope that it is now easier to read.

- Line 357: Change "produce" to "show".

  Taken into account

- Line 363-364: It is not clear, what is ***intensity*** is directly related to heavy precipitation? What is heavy precipitation (do you mean precipitation event)?

One proxy for precipitation intensity may be given by the presence of heavy precipitation. The presence of heavy precipitation means a convective system which includes at least one grid cell with a large precipitation rate (more than approximately 2.5mm/h). We have added a more detailed on the determination of light and heavy precipitation in section 2.3, and we have slightly rewritten the two paragraphs following Figure 9.

- Line 398: Change "produce" to "release". Line 405: Change "greater" to higher.

  All taken into account

- Line 404-409: There are other dynamic factors "i.e., low-level wind share, CAPE" that can play important role on cloud development.

  The impact of lower tropospheric moisture on buoyancy through entrainment appears to be particularly important compared to other mechanisms. However, you are absolutely right that additional processes may also play a role, such as CAPE and low-level wind shear, as you mentioned. Therefore, we have added a discussion of these factors in the revised manuscript.

- Line 412: Does humidity have impact on atmospheric radiative effect? (Heat atmosphere could reduce relative humidity).

  Here we investigated how the ACRE and LP are distributed in environments of different SST and CWV. We are not able to study feedbacks like you suggest. For this we would need a Lagrangian study, which is foreseen for future studies.

- Line 418, 420: What is mid-heavy, bottom-heavy, and top-heavy convective regime? Line 419: Where is "on top of lower convection"?

  Mid-heavy, bottom-heavy, and top-heavy convective regimes have been defined by Masunaga and Takahashi (2024) based on the net moisture and moist static energy (MSE) transport associated with vertical motion. Figure 5 of their article shows a very nice summary illustration. In Figure 6 of their article, they associated the different parts of the ACRE–LP space to these convective regimes, again according to import and export of net moisture and MSE.

  For clarity, we have revised lines 415–417(previous version) to:

  "The occurrences in the LP–ACRE plane and their associated average environments can be compared to the results of Masunaga and Takahashi (2024): They have characterized three convective regimes (bottom-heavy, mid-heavy, and top-heavy) based on the net moisture and moist static energy (MSE) transport associated with vertical motion (their Figure 5) and then associated different parts of the ACRE–LP space to these convective regimes, again according to import and export of net moisture and MSE (their Figure 6)."

  'UT clouds on top of lower convection' means 'UT clouds above lower convection'. Changed in the text.

- Line 423, two LP intervals: Need to mention that "the two regimes are with LP > and < 500 W m^2.]".

  Taken into account

- Line 424-425: Please elaborate in detail on the statement: the LH profiles seem to be dominated by stratiform rain, with a relatively narrow LH peak around 410 hPa. This maybe the 1st time that the authors mention the stratiform rain.

We have added the following sentences in section 2.1 after the description of what the TRMM radar measures:

"In general, convective LH profiles show heating throughout the vertical layers, except near the surface due to evaporation at lower levels. LH profiles of the stratiform rain within the anvils show cooling at low levels below a melting level and heating at levels above (e. g. Figure 3, Chang and L'Ecuyer 2019). The peak in LH of isolated convection is also lower in altitude than the one of complex convective systems including stratiform rain in the anvils (e. g. Hartmann et al. 1984)."

- Figure 12: The scales used in Figure 12a (-2 to 6) and Fig.12b (-5 to 25) are quite different. Please mention this in the text.

  Thank you for pointing this out. We have added the following sentence on line 429:

  "Note that the scales of LH in Figure 12a (-2 to 6 K day−1) and Figure 12b (-5 to 25 K day−1) are different, reflecting the large difference in the LH peak values between the two LP intervals."

- Line 436-438, life cycle: Can you justify the discussions on "can ANN produce the life cycle information"?

  Sorry, we forgot to add a reference to this finding:

  "The smaller height may be interpreted as anvils of convective systems having descended at a later stage of their life cycle (Figure 5.15 of Strandgren, 2018) …"

  It was a tracking study using geostationary passive data (SEVIRI) combined with active data (CALIPSO) and ANN.

- Figs. 13 and 14 caption: Is 1:30 AM or PM local time? Also, why not consider 30 S to 30 N (as some of other figures) in the discussion?

  Yes, it is 1:30 AM/PM local time. To make this clearer, we have revised the captions for Figure 13 to Figure 15 to say "1:30 AM/PM local time."

  Indeed, we did not explain the reason. We expect MCSs in the deeper tropics (see geographical distribution of convective systems in Figure 5 of Protopapadaki et al. 2017), so we limited the latitude band to 25N-25S for the MCS analysis. We have added a sentence on this in the revised text :

  "Furthermore… and limit the latitude band to 25° N-25° S, because most of these systems are located there according to Figure 5 of (Protopapadaki et al. 2017)."

- The definition of developing, mature and dissipating stage of MCS need to be elaborated in detail (or refer to observation or show the structure – both vertical and horizontal for these)

  As mentioned before, the concept of core fraction within convective system as proxy for life stage was already presented and tested in Protopapadaki et al. 2017 and Stubenrauch et al. 2023. We added some more explaining text, pointing to figures in these publications.

- Line 449: What is the "minimum" temperature within the convective core?

We compare the cloud top temperature of all grid cells being part of the convective core and choose the minimum value. This variable was already used in (Protopapadaki et al. 2017) as a proxy for convective depth.

To clarify this point, we have revised the text as follows:

"These behaviors are in line with those of the fraction of precipitation area within the MCS and the minimum cloud top temperature within the convective core, respectively…"

- Line 456, 0.35 compared to 0.60; Both are classified as mature stage. Why do you need to compare these two mature stages?

  Figure 14b includes all MCSs, while Figure 14c only shows the result for the mature state. We wanted to show that if we compare MCSs during the same life stage, the effect becomes even clearer.

  To avoid unnecessary confusion, we have removed Fig 14b in the revised manuscript and now focus only on the analysis during the mature stage (Figure 14c).

- Line 461, 20 km^2: I thought 0.5 degree is horizontal resolution. Where is 20 km^2 for small rainfall intensity from?

  Sorry, it was a mistake. I used the wrong unit when preparing the LaTeX manuscript. It should be 20 W/m^2, not 20 km^2. This error has been corrected in the revised version. Thanks for your question.

- Figure 15: What is the LP 212, LP 648, LP 1513, LP 255, LP 682 and LP 1357 (within the figure)? No discussion

  The LP intervals for which the profiles are shown in Figure 15 correspond to the first, third and fifth interval used in Figure 14. While the average LP intervals for small and large MCSs within the same interval show slight differences (LP 212 & 255 W/m^2, LP 648 & 682 W/m^2, LP 1513 & 1357 W/m^2, respectively for small and large MCSs), they generally correspond to approximately 220, 660, and 1400 W/m^2, respectively. Additionally, in response to Referee 1's concern that the results for small MCSs may be biased, we have revised both Figure 14 and Figure 15. Specifically, we have excluded MCSs smaller than 1° and, instead of applying a fixed size threshold, we now classify MCSs based on the 40% largest and smallest MCSs.

  We agree that this was not clearly explained in the original manuscript. To make this clearer, we have added the following explanation in the figure capture:

  "The LP intervals shown in the legend of Figure 15 correspond to the first, third, and fifth of Figure 14."

  Thank you for pointing out this omission, and we hope the added explanation clarifies the figure.

- Line 471-473 and Figure 15(a): Please elaborate the followings
  "Larger, more organized MCSs have a larger contribution of stratiform rain than the smaller MCSs, except for the most precipitating ones which show a large heating through the whole atmosphere". It is not clear where this information from Figure 15(a)

  If comparing with LH profiles of pure convection and stratiform anvil rain (for example shown in Figure 3 of Chang and L'Ecuyer 2019), with the stratiform having a peak which is slightly higher in altitude and a negative part below the melting point (about 5.5 km in the tropics), the LH profiles averaged over the mature MCSs with larger size show a larger decrease in the profile between peak *value and surface than the smaller MCSs, which can be interpreted as a larger contribution of stratiform rain. We have adapted the text in order to make it clearer.*

References:

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