AMT-2022-12: Response to reviewers

03 May 2022

The co-authors would like to thank all reviewers for their feedback and thoughtful suggestions. We have responded to each comment below. All line numbers refer to lines in the revised document unless otherwise stated.

In addition to edits made in response to reviewer comments, we have made the following additional minor corrections which have no further implications on the results:

1) We have corrected a typo on line 201, the number of verified clear sky hours between June and September 2019 is 179 not 236.
2) We have corrected an error in Fig. 4 panel (d): The original plot showed the temperature standard deviation ratio on the x-axis rather than the water vapor standard deviation ratio.

Original reviewer comments are included in *italics* below. Co-author responses are in simple text, and quotations from the revised manuscript are enclosed in square brackets [“..”].

Response to RC3:

Overview:

This paper investigates the capability of two passive instruments, the AERI and HATPRO MWR to detect shallow surface-based temperature inversions and to provide good retrievals of LWP under thin radiative fog events. I think the paper is very well written and of a very good scientific quality. It is also very interesting and important for the scientific community as this is the first time the benefit of the AERI instrument for fog forecast is evaluated. However, there are a few points that I think are important to clarify before the publication of this manuscript.

I would recommend a more moderated conclusion through the manuscript instead of trying to prove that AERI is better than the MWR for fog forecast improvements.

This is a point made by multiple reviewers and we have tried to re-word the manuscript to address this. Notable additions include the follow:

To the discussion (lines 449 to 469):

[“This study focuses on cases of thin radiative fog (LWP < 40 g m-2), which is the most common type of fog at Summit, and draws attention to the benefits of the AERI, which is particularly sensitive to the small changes in LWP and strong shallow temperature inversions that are characteristic of these events. For other types of fog, onset might not be initiated by a small increase in LWP, for example in stratus lowering events, the reduction in cloud base height from the ceilometer might be a better indicator of fog onset. At other locations (in the mid-latitudes for example) thicker fogs with LWP > 50 g m-2 are more common and can be

100's of meters deep (Toledo et al., 2021). Although the AERI might still be a useful instrument for the early detection of such events, once the fog becomes optically thick in the infrared, the AERI can no longer provide information about the thermodynamic profile above the fog or the trend in LWP, both of which are useful parameters for understanding the development of deep well-mixed fog (Toledo et al.,2021). In such cases, thermodynamic profile and LWP retrievals from the MWR are valuable. The TROPoe algorithm can combine both AERI and MWR measurements in the same retrieval. Below cloud thermodynamic profiles from the combined MWR+AERI are essentially the same as retrievals based on AERI measurements alone (Turner and Lohnert, 2021) but the uncertainty in the LWP retrieval when both instruments are combined is < 20% across the entire range in LWP from 1 to over 500 g m-2 (Turner 2007b).

Although this study focuses on the passive remote sensing instruments that are essential for fog detection (since the active remote-sensing instruments have a blind spot immediately above the surface). Complementary information from active remote-sensing instruments are also necessary for accurate results. We demonstrate in section 3.1 that accurate cloud base height detection (from the ceilometer) is an important input for the AERIoe retrievals, and the radar is also required to filter out precipitation events than can invalidate retrievals from both the MWR and the AERI. Overall, this study highlights the importance of instrument synergy to provide optimal thermodynamic profile and LWP retrievals, supporting the findings of previous studies (Turner et al., 2007a; Löhnert et al., 2009; Turner and Lohnert, 2021; Smith et al., 2021; Djalalova et al.,2021), and expanding on this conclusion to include the specific conditions pertaining to the development of radiation fog.”]

And to the conclusion (lines 517 to 521):

[“This highlights the importance of a multi-instrument approach to improve fog forecasting under all sky conditions: ceilometer cloud base heights are necessary to generate accurate thermodynamic profile retrievals from the AERI, MWRs are needed to retrieve LWP and thermodynamic profiles above optically thick fog / clouds, and radar data is required to determine the presence of precipitation, which can invalidate retrievals from both passive instruments.”]

In fact, I think the major issue of the lack of visibility data should really limit the conclusions that AERI can really detect fog onset before the MWR. To be more objective, with the current dataset used in the paper, what is demonstrated is an increase signal in LWP detected earlier with AERI compared to the MWR but without « real » proof that this is related to fog presence.

This somewhat comes down to the chosen definition of fog. For many practical purposes, fog is defined by a visibility threshold (normally < 1,000 m horizontal visibility). Using this definition, we agree that it is not possible to determine the ability of either instrument to detect fog onset in the absence of continuous horizontal visibility data. However, neither instrument is suitable for the direct measurement of horizontal visibility (which is a function of fog depth and particle size distribution in addition to LWP), and this is not what we are trying to demonstrate in this analysis.

Rather than focusing on horizontal visibility, we focus on the detection of the presence of near surface liquid water, which is a requirement for fog, and is additionally important from a radiative perspective, and for moisture/aerosol cycling in the boundary layer. Limiting the definition of fogs to only those which reduce visibility to less than 1,000 m, although practical for safety concerns, encourages thinner fogs to be dismissed or incorrectly classified as clear sky events. Being able to accurately measure these thinner fog events is extremely important because (a) they form the precursor to thicker fog and hence can potentially provide an early warning, (b) even if they do not develop into thicker fog, they modify the surface moisture, aerosol, temperature and radiative structure which might impact fog development later down the line, and (c) they can have important radiative and climatological influences even without developing into a thick fog, but are not captured well in numerical models, so accurate measurements are essential for improving model performance in this area.

We have tried to make this point clearer by adding the following paragraph at the beginning of section 2.2:

Lines 184 to 192:
["For forecasting and nowcasting purposes, fog is usually defined by a threshold in horizontal visibility (typically < 1,000 m) which has important implications from a safety perspective (Gultepe et al., 2007). However, limiting the definition of fogs to those that reduce visibility to < 1,000 m encourages thinner fogs (or mists) to be ignored or incorrectly classified as clear sky events. Being able to accurately measure thinner fogs is extremely important because (a) they form the precursor to thick fog, (b) they modify the surface moisture, aerosol, temperature and radiative structure which might impact fog development further down the line (Haeffelin at al., 2013) and (c) they can have important radiative and climatological impacts even without developing into a thick fog (Cox et al., 2019, Hachfeld et al., 2000). Because both the MWR and AERI are inherently sensitive to the radiative impact of fog (as opposed to visibility), for the purpose of this study, we define fog as the presence of near surface liquid water that has a detectable radiative impact."]

Nonetheless, the fact that our independent 'truth' dataset is limited is still a good point, and we have tried to address this by including more data from the ceilometer (which is sensitive to the presence of liquid water drops above 15 m but not very sensitive to ice crystals, Van Trich et al., 2014). We provide more details of these changes in our response to your specific recommendations below.

Secondly, I think the discussion on the temperature lapse rate should also be more widely discussed in the paper because in-situ temperature surface from the MWR should be integrated in the 0-10m lapse rate comparisons.

We have integrated appendix B into the main text and included the lapse rate comparison of the MWRoe-sfc (with the surface temperature constraint) onto Fig. 6. However, it is important to note that when the MWRoe is constrained by the surface temperature measurements, the retrieval results are no longer independent from the tower measurements and the correlation reflects this.

We have pointed this out in the text:
Lines 357 to 361: ["When the in-situ surface temperatures are used to constrain the MWR retrieval (in the MWRoe-sfc), the ability of the retrieval to capture the shallow temperature inversions is considerably improved (Fig. 6a). Note that the correlation between the MWRoe-sfc near surface temperature inversion and the in-situ measurements in Fig. 6a is not a fair assessment of performance since the retrieval results are not independent from the in-situ

measurements. Nonetheless, it highlights the importance of using accurate surface temperature measurements to constrain MWR temperature retrievals."]

I also believe that the temperature inversion over a thicker layer might already be a good proxy for radiative fog and the comparison considering only a 10m thick layer is clearly penalizing the MWR.

The comparison of the 100 m – 10 m lapse rate between the retrievals and radiosonde profiles for the 14 coincident radiosonde launches has been added to Fig. 6. We disagree that showing the 10 m – 0 m comparison is "penalising" the MWR, rather it is demonstrating the true limitations of the instrument.

Finally, I think a discussion about the use of LWP retrievals for fog nowcasting dissipation (Toledo et al 2021, ACP) would be beneficial to the article. In fact, even if AERI might detect fog formation a bit earlier due to very low LWP values, what about potential limitations for fog dissipation when the fog is thicker and might reach the saturation signal of the AERI ? Would the AERI be a good candidate to apply the conceptual model described in Toledo et al 2021 or the MWR would be a better candidate this time ? This question might probably lead to a more balanced conclusion not trying to put the AERI against the MWR but to open the perspective of the instrumental synergy highlighting the benefit of each instrument depending on the fog stages.

Toledo et al., (2021) focus on the dissipation of well mixed adiabatic fog (with LWP > 30-40 g m^{-2} and with fog top heights > 85 m) through a reduction in LWP and/or fog base lifting. They develop a parameterisation to determine the critical LWP required to sustain visibility < 1,000 m at the surface for a given fog/cloud top height. According to this parameterization, when fog top heights are greater than 250-300 m, the critical LWP required to sustain fog is greater than 50 g m^{-3}. In such cases, when the fog is opaque in the infrared, the AERI would not be sensitive to the changes in LWP that would indicate fog dissipation and the MWR LWP would be required. For fogs with cloud tops lower than 200 m, the critical LWP is < 40 g m^{-2}, and on these such occasions, a more accurate retrieval of LWP from an instrument such as the AERI could potentially be useful. When AERI and MWR measurements are combined in the TROPoe algorithm (Turner 2007b, Turner and Lohnert, 2021), the uncertainty in the LWP retrievals is < 20% across the entire range of LWP (1 to < 500 g m-2), which is potentially the optimal solution (with the disadvantage that it requires two instruments).

None of the cases we consider in this study are suitable candidates for this algorithm, since the LWP is almost always < 40 g m^{-2} and the fogs rarely become well mixed – this is a feature of the very dry and shallow boundary layers at Summit. We realise that by not including thicker fogs we are neglecting to discuss a whole category of fogs that might be particularly relevant (and more impactful) at mid-latitudes.

In the introduction and abstract we have drawn attention to the fact that we are only focusing on radiatively thin fogs, and to the discussion we have added the following paragraph:

To the discussion (lines 449 to 469):

["This study focuses on cases of thin radiative fog (LWP < 40 g m-2), which is the most common type of fog at Summit, and draws attention to the benefits of the AERI, which is particularly sensitive to the small changes in LWP and strong shallow temperature inversions that are characteristic of these events. For other types of fog, onset might not be initiated by a small increase in LWP, for example in stratus lowering events, the reduction in cloud base height from the ceilometer might be a better indicator of fog onset. At other locations (in the mid-latitudes for example) thicker fogs with LWP > 50 g m-2 are more common and can be 100's of meters deep (Toledo et al., 2021). Although the AERI might still be a useful instrument for the early detection of such events, once the fog becomes optically thick in the infrared, the AERI can no longer provide information about the thermodynamic profile above the fog or the trend in LWP, both of which are useful parameters for understanding the development of deep well-mixed fog (Toledo et al.,2021). In such cases, thermodynamic profile and LWP retrievals from the MWR are valuable. The TROPoe algorithm can combine both AERI and MWR measurements in the same retrieval. Below cloud thermodynamic profiles from the combined MWR+AERI are essentially the same as retrievals based on AERI measurements alone (Turner and Lohnert, 2021) but the uncertainty in the LWP retrieval when both instruments are combined is < 20% across the entire range in LWP from 1 to over 500 g m-2 (Turner 2007b).

Although this study focuses on the passive remote sensing instruments that are essential for fog detection (since the active remote-sensing instruments have a blind spot immediately above the surface). Complementary information from active remote-sensing instruments are also necessary for accurate results. We demonstrate in section 3.1 that accurate cloud base height detection (from the ceilometer) is an important input for the AERIoe retrievals, and the radar is also required to filter out precipitation events than can invalidate retrievals from both the MWR and the AERI. Overall, this study highlights the importance of instrument synergy to provide optimal thermodynamic profile and LWP retrievals, supporting the findings of previous studies (Turner et al., 2007a; Löhnert et al., 2009; Turner and Lohnert, 2021; Smith et al., 2021; Djalalova et al.,2021), and expanding on this conclusion to include the specific conditions pertaining to the development of radiation fog."]

Major points :

Lack of visibility data :

One of the major issues for me is the lack of visibility measurements which is the « reference » instrument to detect fog events. This is for me especially problematic for figures 10 and 11. I think, lacking this important reference measurements, the authors are going a bit too fast concluding that AERI is able to detect fog onset 4 hours before the MWR. What is true is that we detect a signal of LWP increase in the AERI earlier than observed in the MWR. However, as there is no reference instrument to give the exact time of fog formation, we cannot rely on the fact that an increase of 0.1 g/m² in the AERI LWP determines the true time of fog formation. I think it is particularly important as, if I understood well, the AERI LWP increase could also be due to the presence of ice crystals in the atmosphere that can't be detected by the MWR for example.

As mentioned above, determining the 'exact time' of fog formation is definition dependent, and in this study our focus is on the presence versus absence of near surface liquid water as an indicator of fog rather than a horizontal visibility criterion. This is partly because of lack of visibility data, but also because the ability to detect even small amounts of liquid water is important (mentioned above).

We have added an independent definition of 'fog onset' from the ceilometer. We used the same subset of verified clear days that we used to identify the fog signal form the AERI initially to determine the distribution of 'clear sky' total backscatter from the ceilometer and identified fog onset from the ceilometer as the time when the total backscatter increases greater than 3 standard deviations above the mean clear sky total backscatter. The ceilometer backscatter is insensitive to low concentrations of ice crystals (Van Tricht et al., 2014), and the ceilometer also detects fog in 11/12 of the events, suggesting that these fogs were indeed present but not well detected by the MWR.

We have described this addition in lines 404 to 408:

["For independent verification, we also determine fog onset from the ceilometer range-corrected attenuated backscatter. We define the ceilometer fog onset as where the 5-minute mean total backscatter increases greater than three standard deviations from the mean clear sky backscatter at Summit between 01 June and 30 September 2019 (the mean clear sky backscatter is determined using the same subset of verified clear sky hours used to identify fog events from the AERI radiance, section 2.2)"]

We have added the ceilometer derived 'fog onset' to figure 11 for comparison to the other two instruments and described the results in lines: 410 to 416 (below). I also realised in inspecting this closely that some of the MWRoe fog onset times occurred after the end of the 'fog event' defined in Table 3 and were actually a result of low-level cloud moving in after the end of the fog event (this was the case for the 5th Sept and 8th June case). We have now restricted the fog onset determination to the actual fog time window listed in the updated Table 3 (rather than the extended time for which we ran the TROPoe). This has resulted in a slight change in the values depicted in figure 11 and we have updated the text accordingly (see below).

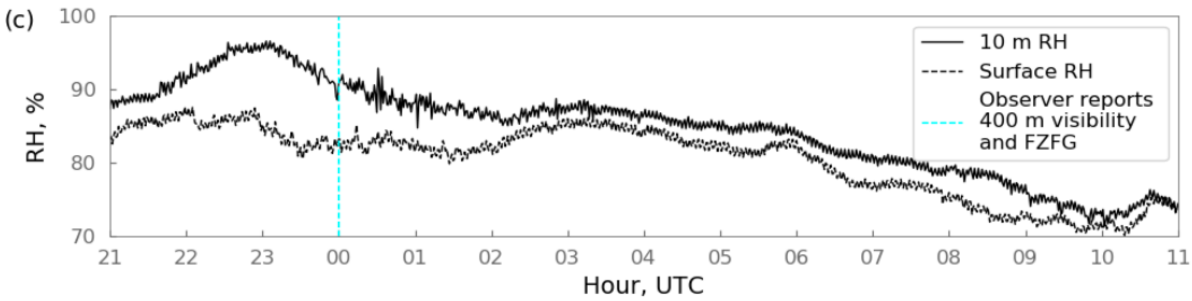
Lines 412 to 418:

["The ceilometer detects fog for all cases with the exception of case 7 (04 August). During this case the fog was extremely thin (maximum LWP from the AERI only 2 g m−2), but the onsite observer logged the presence of a fog bow between 07:15 and 08:30, demonstrating that liquid water droplets were indeed present. This was a very marginal case that demonstrates the ability of the AERI to detect very small amounts of liquid water when even the ceilometer cannot. The MWRoe retrieval only detects fog for 6/12 cases (Fig. 11), and for those 6 cases, the AERIoe retrieval consistently detects the onset of fog (via the increase in LWP) before the MWRoe retrieval by 25 to 185 minutes (Fig. 11). For the 6 cases where the MWRoe does not detect the fog, the mean LWP detected by the AERIoe is very low (1.4 to 3.1 g m−2)"]

To help clarifying this point, can the authors provide with figure 10, the time series of ceilometer CBH / vertical visibility for that specific day and the time serie of relative humidity observed at the ground and 10m on the tower ? In fact, I would expect even thin radiative fogs to be detected by the ceilometer which should provide a CBH lower than 50m within these conditions or a vertical visibility and could be a first good validation of when the fog really forms. You could also look at the time series of relative humidity (RH) from the tower measurements : though a RH > 95 % is not always a good proxy of the presence of fog, a RH < 95 % would easily show that there is little chance of fog.

We have added the time series of ceilometer total backscatter and vertical visibility (note that no CBH were reported by the ceilometer) this event to figure 10.

As for the relative humidity measurements, the near surface RH profile measured at Summit is quite interesting in that we rarely measure 100% RH even when we know there is fog present (i.e. surface visibility is reduced to < 1,000 m). Possibly this is a calibration issue with the sensors, or perhaps it is a unique property of the environment at Summit where the fog droplets form in a saturated layer 10's of m above the surface and settle/ evaporate in the very near surface layer. There is some evidence for the latter in the work of Cox et al., (2019) and Berkelhammer et al., (2016). It is outside the scope of this study to investigate this conundrum further, so we choose not to show the relative humidity measurements in this study as we believe they will add a layer of confusion and take away from the main message without adding additional value. However, we do include a plot of the RH measurements for the 15 July case study below for your reference. The maximum 10 m RH occurs at the same time as fog onset is detected by the AERIoe, and the RH is higher at 10 m than at the surface, providing support to the idea that the fog droplets form in a saturated layer above this height. In any case the vertical visibility at 00h was only 400 m, indicating that fog was present despite the apparently unsaturated surface layer.



I think this lack of visibility data might also be problematic for the definition of the 13 fog cases provided in table 3. I understand that only two criteria have been used : an increase in the downwelling infrared radiances representative of a cloud presence and no cloud detected above 200m by the MMCR. However, as mentioned later in the manuscrit, the ceilometer CBH should be used to detect clouds with CBH below 50m or ceilometer data providing a vertical visibility in general informing of fog presence to at least avoid wrongly classifying low clouds (with a CBH < 200 m) in fog if they do not reach the ground.
It would be interesting to specify for each of the 13 fog events identified the maximal CBH or vertical visibility height within each fog event detected by the CT25K to be sure that no potentially « low louds » have been wrongly classified as fog.

We have added the minimum ceilometer vertical visibility field to Table 3 to give a further independent indication of the visibility reduction at the surface during each event. Except for event ID 12, the ceilometer does not detect a cloud base height during any of these events, so rather than add an additional column to the table, we added this the following statement:

Lines 207 to 210 :
["Note that for 11 of these cases, there is no cloud base height detected by the ceilometer during the event indicating that the events were indeed fog as opposed to low cloud. The only exception is for case ID 11, during which the ceilometer detected a cloud base between 52 and 105 m intermittently between periods of obscured vertical visibility."]

We choose to retain event 11 even though the fog appears to intermittently lift from the surface since during most of the event the ceilometer does report restricted vertical visibility and on-site observers logged FZFG on that day.

The current methodology used in the paper is particularly questioning when looking at figure 3 which shows the ceilometer CBH for an identified radiative fog starting at 2 UTC and ending at 12 UTC. Here the ceilometer CBH is around 1300 m until 3h30 while table 3 specifies a starting fog time at 2 UTC : could you explain how fog could form even in the presence of this low cloud and why the MMCR does not detect any cloud at that altitude ?

This point arises from the fact that after the identification of events, we expanded the time either side of the events during which we would run the TROPoe retrievals so that we could include the conditions before fog onset and after the fog dissipation. We realise that it was misleading to include the times for which we ran the TROPoe in Table 3 rather than the start and end times of the fog as per our initial case identification criteria. We have updated the times in Table 3 to correct this and we have updated Figure 2 to reflect the corrected times. We added Line 251 to clarify that the TROPoe runs encapsulated the times prior to fog onset and after dissipation.

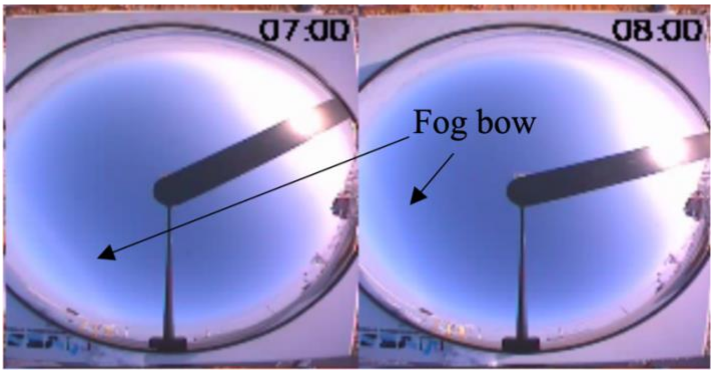
The definition of the fog events used in this study is also questionable when it is mentioned line 223 that, for some fog events, no CBH or vertical visibility is provided by the ceilometer : in that case how can we be sure that the increase in downwelling infrared radiances is not due to ice particles instead of fog presence that would not be detected by the ceilometer ?

Part of this is due to the fact mentioned above, that we expanded the TROPoe runs either side of the fog event to capture the onset and dissipation, so there are times included in the retrievals where the ceilometer does not see any fog.

Aside from that, there were also three cases where the ceilometer does not report obscured vertical visibility during the detected 'fog'. One of these cases (the 9th August case), is an extremely tenuous case and (although the observer reported a horizontal visibility reduction to 1,600 m) I agree that it is not possible to determine whether or not the signal is due to liquid droplets or ice crystals. We have therefore removed this case from the study (and updated all plots accordingly). The other two cases you can see in the updated Table 3 are cases IDs 7 and 12.

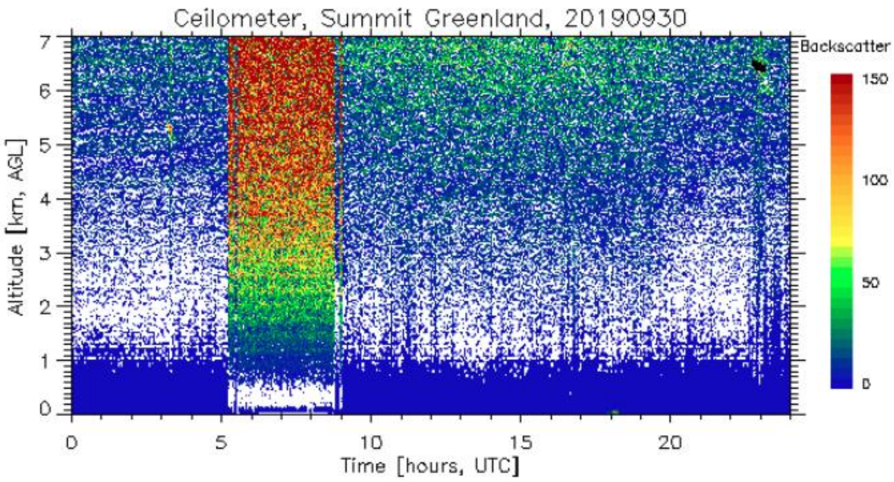
For case 7, the total ceilometer backscatter is never high enough to indicate the presence of liquid water. However, the onsite observer logged the presence of a fog bow between 07:15 and 08:30 that is indicative of liquid water droplets (ice particles do not form fog bows). The fog bow was also visible in TSI images from the 04 Aug 2019 (see below). Clearly this was a very marginal case that demonstrates the ability of the AERI to detect very small amounts of liquid water when even the ceilometer cannot.

TSI images from 07:00 and 08:00 UTC on 04 August 2019:



For case 13, although the ceilometer does not report obstructed vertical visibility, the signal is clearly attenuated (see the backscatter plot below), and the ceilometer still detects a ‘fog onset’ based on the criteria described in lines 402 to 405. The signal in the AERI in this case is equivalent to a maximum liquid water path of 4.8 g m^{-2}. If the equivalent optical depth resulted from ice crystals, these would likely have been observed in the POSS. The onsite observer log verifies FZFG.

Ceilometer backscatter for 30th September 2019:



Temperature lapse rate :

It is well known that MWRs cannot provide two independent informations of temperature at surface and 10m a.g.l as their vertical resolution is approximately higher than 50m. This is a common approach to combine the MWR with an in-situ surface station (either the one provided with the HATPRO or an external station as MWRs are often deployed in instrumented sites). This combination is used for atmospheric boundary layer height detection and the detection of stable boundary layer conditions from MWR measurements often based on the temperature difference between a higher altitude level and 50m (and not the MWR retrievals at 0m). In that sense, I think figure 6 is not entirely objective in the way the MWR lapse rate is evaluated and compared against the AERI. However, this figure demonstrates the capability of the AERI to retrieve this lapse rate while the MWR can’t without integrating the surface station. For a more balanced conclusion, I would first recommend to include in figure 6, the comparison with the

MWR lapse rate calculated with the in-situ surface temperature station integrated with the MWR (as it is shown in Appendix B).

We have included the lapse rate comparison of the MWRoe-sfc (with the surface temperature constraint) onto Fig. 6. However, we think it is important to note that when the MWRoe is constrained by the surface temperature measurements, the retrieval results are no longer independent from the tower measurements and the correlation reflects this.

We have pointed this out in the text:
Lines 357 to 361: ["When the in-situ surface temperatures are used to constrain the MWR retrieval (in the MWRoe-sfc), the ability of the retrieval to capture the shallow temperature inversions is considerably improved (Fig. 6a). Note that the correlation between the MWRoe-sfc near surface temperature inversion and the in-situ measurements in Fig. 6a is not a fair assessment of performance since the retrieval results are not independent from the in-situ measurements. Nonetheless, it highlights the importance of using accurate surface temperature measurements to constrain MWR temperature retrievals."]

Additionally, I think the authors should also compare the AERI lapse rate and MWR lapse rates together with higher altitude levels (like T100m-T50m). This is important because even if the figure demonstrates the capability of the AERI to better capture the 0-10m temperature inversion, I am not entirely convinced that the 0-10m lapse rate is the « key » proxy of fog formation. I expect temperature inversions during radiative fog to spread over a larger atmospheric layer, where there is a high chance that the MWR can detect the inversion as well as the AERI and could already be an information sufficient to improve fog nowcasting. As for data assimilation, an improved lapse rate between 0 and 10m seems too resolved compared to the capability of current data assimilation systems (and knowing that surface stations are already assimilated in NWP models, I think it is really pertinent to investigate the MWR capability versus AERI on a larger layer than only 10 m…).

We have also added a comparison of the 100 m – 10 m lapse rate between the retrievals and radiosonde profiles for the 14 coincident radiosonde launches to Fig. 6.
The additional discussion of this figure we have included in the following lines:

Lines 362 to 366: ["The radiosonde profiles provide an alternative independent measure of surface inversion strength, allowing the comparison of the ability of each retrieval configuration to capture surface temperature inversions over a deeper layer. Fig 6b compares the 100 m - 10 m retrieved inversion strength with that measured by the 14 coincident radiosonde profiles. Over this depth the RMSE of the AERIoe and the MWRoe-sfc are comparable to the values for the 10 m - 0 m comparison (1.65 and 1.83 C m^{-1} respectively), but the MWRoe RMSE remains much larger (2.22 C m^{-1}), demonstrating that the MWRoe alone is not capable of accurate retrievals of surface temperature inversions even in this deeper layer. Only the AERIoe retrievals in this case are significantly correlated (r=0.46) with the radiosonde measurements, although the small number of radiosondes available for comparison makes it difficult to draw robust conclusions from this result. Klein et al. (2015) compared AERI derived lapse rate 100 m -10 m against more than 200 radiosondes in Oklahome (southern US) , and found very good agreement with r2 values > 0.93 "]

Minor points :

line 84 : large error during thin fogs → large **relative** errors during thin fogs

I added relative here – thanks!

line 154 : plus the current and temperature of Stirling cooler : I don't entirely understand the sentence as if one word is missing after « current ».

I see that this is confusing! I have added the word 'electric' so it's clear that we're monitoring the electric current and temperature of the Stirling cooler.

line 388 : It looks like « Results of Appendix B » should appear within parenthesis and the « ... » before and after should be removed.

This was indeed a mistype but has now been removed since Appendix B has been integrated into the main text.