COMMENT 2:

Summary:
The paper discusses the topic of ground-based scanning radiometers and associated uncertainty related to the measurements and temperature retrievals. Uncertainties discussed include horizontal inhomogeneity, radiometer tilt, obstacles in the scanning path, and RFI. The paper addresses these aspects with simulations and data from a field campaign.

General comments:
In my opinion the manuscript is a little bit confused in several aspects and would benefit from rethinking of some sections. I offer here some detailed comments on the parts that could use improvement and clarifications.

The main shortcoming of the paper as it stands is the assumption explicitly stated in line 315 that "K-band channels do not play a role" in temperature retrieval. This assumption leads to several inaccuracies in the approach and great confusion for the reader in the understanding of how clouds and vapor are treated in the retrievals. The main problem is due to the fact that channels 8 (51.26), 9 (52.28), and in less amount 10 (53.86) are indeed sensitive to both vapor and liquid water for which the K-band channels are needed. The authors should therefore address in better detail how they are accounting for vapor and clouds effects in channels 8-10 even if they only use the zenith measurements.

- Thank you for that comment. We are aware that the channels 8-10 (situated in the V-band) are also sensitive to water vapor and liquid water, and not only oxygen. However, the retrievals include all these contributions. No observations in the K-band (channels 1-7) are needed to create retrievals for T-profiles.
- We are accounting for water vapor [via Turner et al. (2009) Liljegren et al. (2005)] and also clouds (via Liebe et al., 1993) in the statistical retrieval (multivariate regressions). The forward RT model does not need to take clouds into account, as our analyses in this paper which use the RT model are for cloud-free scenarios. We addressed that in Section 3.1. and 3.2. and added more details. You can see these added details in the following comment of yours.
- For a better general understanding: it is stated in Section 3.2. that the retrieval for T-profiles only uses the V-band channels and that for all T-profile retrievals in this paper, which make use of elevation scans, only channels 11-14 are utilized with elevation scans, whereas channels 8-10 are always only utilized in zenith.

Section 3.2 Retrieval method: It is not clear how the forward model simulations are conducted and how the coefficients are derived. Are clouds included in the forward model simulations? If yes, how are they included? Same questions for the retrieval coefficients.

- Section 3.1. tries to explain how the forward model simulations work (we tweaked the description to reduce confusion of what is included):
    - "…non-scattering radiative transfer simulations are carried out based on Simmer (1994). Gaseous absorption is calculated according to Rosenkranz (1998), whereby the water vapor continuum is modified according to Turner et al. (2009) and the 22 GHz water vapor line width is modified according to Liljegren et al. (2005). This model depicts the energy transfer in form of electromagnetic radiation through the atmosphere via absorption and emission by gas molecules and it is modified here to simulate physical obstacles at different distances and elevation angles and to assess pointing errors in a cloud-free atmosphere."
- And Section 3.2. explains in detail how the coefficient of the retrievals are derived. There, clouds are taken into account (via Liebe et al., 1993), so that we can use the retrievals also for cloudy conditions. We added that statement to the text:

- "The applied coefficients of this retrieval model incorporate absorption and emission from liquid water (Liebe et al., 1993), in addition to water vapor and oxygen."

Figure 1: If I well understand Fig. 1 shows the TBs simulated and then inverted to derive temperature profiles. Are all channels (8-14) used in the scanning configuration? Of course, these simulations predict an improvement of the scanning configuration over the zenith because in the simulations all the shortcomings of real-world scanning are absent. Although it is true that in a perfect clear sky scenario of a perfectly homogeneous atmosphere in a perfectly flat and free horizon, scanning would improve the sensitivity of the temperature retrieval, the interpretation of measurements from scanning instruments is not always simple. Additionally, it is my impression that the excessive standard deviation of the zenith view retrievals in the first 200 m is due to the fact that the retrieval doesn't include surface temperature, pressure, and humidity. These quantities (available from the hatpro) are essential in the zenith configuration to constrain the first retrieval level where the channels have no sensitivity. It would be important to include those measurements when developing the retrieval coefficients.

- As stated in the retrieval section, only channels 11-14 are used with all elevations angles. Channels 8-10 are always only used in zenith. This is true for the whole study.
- Indeed, the retrieval does not use the surface temperature, but are in-situ surface temperatures representative for surroundings? Oftentimes not, e.g. heating from the roof can falsify these measurements. But in most cases, when there are no obstacles or RFI, T-retrievals which make use of elevation scans will always be more precise (especially in the lowest 1000m of the troposphere), and this is the most important fact, regardless if surface temperatures are included or not. This was also already shown in Crewell & Löhnert (2007).

Figure 1: Is the standard deviation of the differences a measure of accuracy? I don't think this is true. It is rather a measure of precision. Perhaps the RMS error between radiosondes and retrievals can give us a better understanding of the two retrievals? In any case I think the label "accuracy" shouldn't apply here.

- As there is no bias to speak of, we can use standard deviation instead of RMS, they tell the same thing.
- The label "accuracy" has been changed in all sections with "precision".

Section 4.1: it is stated in line 196 that only clear sky cases are used to analyze the impact of horizontal inhomogeneity. However, in lines 220-230 and following the discussion of cloudy scenes is mentioned therefore it is not clear to the reader what is really being discussed here. Same in section 4.1.2. Are the profiles of section 4.1.2 clear sky or all cases? If cloudy scenes are included in the retrievals but PWV and LWP are not retrieved there will be a mismatch between what channels 8-10 detect and what the other channels detect, potentially leading to incorrect results even using channels 8-10 in zenith mode. This because the signal from vapor and clouds is interpreted in the retrieval as a signal from temperature.

- Line added that will hopefully make it clearer that clear and cloudy sky cases are analyzed:
    - "To exclude the influence of clouds when needed during analysis, …"
- In Section 4.1.2 both clear and cloudy cases are included and discussed and labeled as such. We wanted to include cloudy cases, because this gives a more realistic/complete view on the impact of horizontal inhomogeneities.
- There is no mismatch. The signal that stems from water vapor and liquid clouds does not affect the quality of the temperature profile as these contributions are also already accounted for in the retrieval development. PWV and LWP do not need to be retrieved separately.

Section 4.1.2. I think this section requires more discussion because the intended meaning is not clear. If I scan the instrument both sides, I am going to retrieve temperature using both scans. In this case, even if the instrument is tilted, the average of the two brightness temperatures at the corresponding angles should take care of the bias introduced by the tilt. Therefore, the effect of the radiometer tilt will be introduced only if the radiometer is scanned on one side. For this and many other reasons scanning on one side is never recommended. This section should perhaps clarify this concept.

- In Section 4.1.2. the MWR scanned on both sides, but for the retrieval first only one side was taken into account, which was then compared to the other side. There is no averaging taking place between north- and south-facing scans.
- The same is true for the simulation in Section 4.2.1. The simulations only ever assume scanning on one side of the radiometer. But a paragraph has been added here to clarify what it would mean if we would average scans on both sides:
    - "In real-world scenarios, scanning on both sides of the radiometer – if possible – can mitigate pointing uncertainties to a certain degree, when T-profiles are retrieved from the average of such scans. However, this approach comes with problems, such as longer measurement times, the assumption of horizontal homogeneity of the atmosphere, and the assumption that elevation scans on both sides even out linearly."
- Please consider that oftentimes, it is not possible to scan down to 5° on both sides of the MWR.

Section 4.1.2. Why not show the actual retrievals from the scanning configuration and the zenith configuration compared to the radiosondes during the JOYCE campaign? I think it will provide good information on how much improvement we can gain from scanning the radiometer from real world measurements rather than simulations.

- We guess you are referring to Section 4.2.2. and the FESSTVaL campaign here? For the observations at JOYCE we did not have co-located radiosonde observations.
- It is long since known that elevation scans do improve the T-profiles (Crewell & Löhnert, 2007). We used this as a motivation why we primarily analyze elevation scans. Fig. 1 shows that improvement..
- The blue line from Fig.1 represents the right plot from Fig. 5. Retrievals are made from calculated TBs derived from radiosondes from RAO. We added a statement in Section 4.2.2., to make the connection between Fig. 1 and Fig. 5 more clear:
    - "... (compare the standard deviations from Figure 5 with Figure 1; the blue line in Figure 1 corresponds to the content displayed in the right plot of Figure 5 when there is no tilt)."

Section 4.2 Again the importance of scanning both sides should be stated.

- Has been added (see two comments above).

Figure 5: Do retrievals in this figure use scanning data at all channels or only channels 11-14?

- Only channels 11-14, as it is always the case in this study (stated in Section 3.2.)

Figure 5: x-axis label should be RS-RET (K) – without "elevation"

- Has been fixed.

Line 343: "Nevertheless … pointing errors of up to ±1°". Again if I well understand, these results in Figure 5 are simulations. If these simulations are conducted scanning all channels (8-14) they are very difficult to implement in the real world because of the highly varying vapor and cloud fields that will require scanning the K-band channels as well.

- The TBs have been simulated or calculated from real-world radiosondes. And then the T-profiles have been retrieved from those TBs. As stated in previous comments, retrievals use only channels 11-14 with all elevations and channels 8-10 only in zenith (see Section 3.2.). K-band is not used at all, and retrievals also never use K-bands with elevations, as this would not make much sense. K-band channels are optically much too thin to make use of elevation scans. Only optically thick channels, like in the V-band (oxygen absorption) are suitable for elevation scans, as we reach different layers/heights of the atmosphere by doing such scans in these channels.

Section 4.3: If this section is meant to be a guide for users on field installation in my opinion is not very practical. When in the field, it is hard to know the temperature of an obstacle located 1km away and in table 2 there is not a direct connection with the height of the object. For example, an object located 3.5 km away needs to be at least 600 m tall to be detected at an elevation of 10.2 degrees (1st row, 3rd column in Table 2). Therefore, anything short of a small mountain or a very tall skyscraper won't be detected by the instrument at that elevation angle. In my opinion, the most direct question people face in the field is: How far (minimum distance) from a XX m tall obstacle do I need to install the radiometer if I want to scan down to YY degrees elevation? The answer could be given as a table of which I draw a simplified example below. The paper could also come up with an approximate way to calculate that distance in the field for each channel without the need to run a radiative transfer code.

- Table 2 already gives an overview of how far an obstacle needs to be away where it has no more influence on the observation. It does indeed not state how tall this obstacle would need to be, but this would be easy to find out via trigonometry. The end of section 4.3.2. also gives rough examples of the connection of obstacle distances and heights.
  But you're right that users wouldn't really know the temperature of an obstacle, which makes it harder to estimate minimum distances. Another factor is that the beam radius gets larger and larger the further away it is from the instrument, meaning that obstacles far away will probably not fill out the entire beam.
  That is why a full azimuth scan at different elevations at a new location is always advisable in order to detect such obstacles and if they may pose problems. Such a statement has been added in Section 5:
    - "In practical scenarios, accurately estimating the temperature and appropriate distance of an obstacle can pose challenging for the operator, particularly when the obstacle occupies only a small portion of the instrument's beam. This scanning method proves invaluable in such cases."

- The inclusion of such a table, where minimum distances of obstacles and their corresponding minimum height are written down, is an interesting idea but we are not sure if it would really benefit the reader. For example: channel 13 has a maximum penetration depth of ~600m at 5° elevation, meaning that an obstacle which is 600m or more away from the radiometer does not get noticed anymore. At 600m distance, the obstacle would need to stand at least ~57m tall, to be in the line of sight. But it could also be much taller than that (or smaller), it doesn't matter, because it is already too far way. If the obstacle is, let's say, only 40m tall and only 200m away, it would have an impact in channel 13. So including a table which only states minimum distances and their corresponding height would only paint an incomplete picture. We would have to include a lot of examples at various distances, which would render such a table rather confusing and not really helpful.
  Only knowing the maximum penetration depth of a channel should be enough for the operator. If there is a tall obstacle somewhere in the line of sight, the operator, knowing the maximum penetration depth of a channel at a certain elevation, can then calculate if the obstacle is too tall/big or not.