We thank Reviewer 2 for very useful comments, suggestions and corrections which have significantly improved our manuscript. Our detailed replies are mark in bold below. Changes in the revised manuscript are highlighted in yellow.

Review of "A novel infrared imager for studies of hydroxyl and oxygen nightglow emissions in the mesopause above northern Scandinavia - Peter Dalin et al. 2023"

The authors present a new imaging system that measures the OH and O2 airglow emission originating from two different altitude layers in the middle atmosphere. The imager is equipped with overall five filters, four interference filters and one dark filter. Two of the interference filters are for the observation of OH(3-1) P1(2) and P1(4) to derive the rotational temperature in about 87km altitude, one for to observation of the O2 emission layer in about 94km, and one for the background. An additional dark filter is for corrections of the dark current. One complete cycle through all filters is done every 2.75 minutes. The instrument is thoroughly calibrated with an absolute calibration considering the imager and all the optical components. A geometrical calibration is used for georeferencing the all-sky observations.

The OH rotational temperature is derived from the two observed OH(3-1) emission lines following a procedure based to the one from Pautet et al. (2014), but slightly modified with new Einstein A-coefficients. An error analysis for the temperature derivation is done and shown in detail. The derived temperatures are compared with the temperature observations of a nearby LIDAR instrument at Esrange in about 40km distance of the new imager's site for the imager's pixel location nearest to the LIDAR and the altitude of the OH layer in the LIDAR data. The author's find a good agreement of both measurements within about 3 K for a particular night and only -0.2K±1.6K on average. Additionally, they compare the temperatures derived from the imager with Aura/MLS satellite measurements and find an average temperature difference of 2.8K±7.8K. Considering the different field-of-views and spatial distances between ground-based instrument and satellite this seems reasonable.

In a case study the authors highlight the observation of a ripple structure visible in the OH temperature map with about 4-6 K temperature amplitude and with a horizontal wavelength of 4-8 km. This shows nicely the potential of the imager to resolve small-scale structures in the temperature maps. Also, they show a medium-scale gravity wave which is visible in the OH and O2 layer simultaneously. Analyzing daily mean OH rotational temperatures from January to April 2023 the authors see seasonal temperature variations typical for the site's location. They also see peaks in the data and speculate whether these could be due to the sudden stratospheric warming event starting in February 2023.

Overall the author's present a valuable new imager instrument for atmospheric observations in the middle atmosphere utilizing two airglow emissions. Especially the combination of OH temperature maps and observing the O2 layer quasi simultaneously offers great opportunities for future investigations of gravity waves and many other phenomena. The manuscript is well written and the analyses described concisely. I recommend it to be published in AMT after addressing the following few minor points.

General remarks:

1. I suggest a short paragraph about currently used imagers to emphasize the novel aspects of the presented imager instrument. E.g. many imagers operate in the VIS-NIR range (e..g Li et al. 2005), but also many in the SWIR range. When integrating over larger

parts of the SWIR range the integration time is often of the order of a second (Hannawald et al. (2016)). There are also other instruments utilizing a filter wheel to observe different airglow emissions simultaneously, but often integrating over larger parts of e.g. the OH bands (e.g. Mukherjee et al. 2010), so that no temperature derivation is possible. On the other hand, Pautet et al. (2014) uses the AMTM to derive temperatures (which was shortly mentioned in the manuscript). Other imager types focus on very small scales (e.g. Sedlak et al. (2016), Hecht et al. 2023 (https://doi.org/10.1029/2023JD038754)). However, none of these instruments - as far as I am aware of - derives temperature and uses multiple emission layers. It would be valuable to work out the differences of the new imager to current imagers.

More than fifty sites conducting spectroscopic and imaging airglow observations are presented at the Network for the Detection of Mesospheric Change (NDMC) which is a global program investigating climate change signals in the mesopause region (https://ndmc.dlr.de/). Li et al. (2018) have summarized a global distribution of all-sky airglow imager sites (see Table 1 in their paper and references therein). Some of OH spectrographs and imaging instruments have a narrow field of view of 30 degrees and less such as the Ground-based Infrared P-branch Spectrometer instrument (GRIPS 6) in Oberpfaffenhofen, Germany (Schmidt et al., 2013), the Aerospace Nightglow Imager 2 (ANI2) in the Andes, Chile (Hecht et al., 2023), and the Spectral Airglow Temperature Imager (SATI) in Resolute Bay, Canada (Wiens et al., 1997). A number of OH imaging instruments measure OH emissions in relative units without mesopause temperature derivations such as the ANI2, OH all-sky airglow imager in Kazan, Russia (Li et al., 2018), and the Fast Airglow IMager (FAIM) in Oberpfaffenhofen, Germany (Hannawald et al., 2016). Some of the OH imagers register OH emissions (including temperature derivations) without capturing infrared emissions coming from the O_2 layer such as the Advanced Mesospheric Temperature Mapper (AMTM) at South Pole (Pautet et al., 2014), and the Near InfraRed Aurora Camera (NIRAC) in Svalbard, Norway (Nishiyama et al., 2024). In the present paper, we describe a novel infrared wide-angle imaging instrument capable of registering emissions coming from two emitted layers (OH and O_2) and deriving the mesopause temperature. The OH imager is the first one of its kind installed in northern Scandinavia.

We have provided this information in the revised manuscript (lines 71-89).

2. The shown images and the temperature map look very nice and highlight the capabilities of the instrument. However, I imagine that one or a few video sequences of the shown night as supplement data might by quite more impressive and useful to show the potential of the instrument.

   We agree with it and have added a video sequence (OH_imager_video_160223.avi) of the shown night as supplement data which can be obtained from the Swedish National Data Center (https://snd.gu.se/en/catalogue/dataset/preview/d5776ec9-d346-4e6a-a8c3-1445e75201b6/1

Specific remarks:

L44-45: “hot topic of current atmospheric research.” It would be nice to have more up to date articles . Wüst et al. (2023, https://doi.org/10.5194/acp-23-1599-2023) might be a good fit.

We have updated “hot topics” up to date in the revised manuscript (line 44).

L136: The re-imaging lens was not described in the setup before while the primary lens and telecentric lens were. Could you also describe it shortly?

The reimaging optics consist of a doublet field lens, and a combination of a second doublet and a f/1 compound lens in front of the sensor. We have added this information in the revised manuscript (lines 152-154).

L146-147: "…implying that the instrument can readily resolve the highest frequency range in the gravity wave spectrum." Waves with frequencies near the Brunt-Väisälä-Frequency (2*pi/(5 * 60) = 0.021 assuming a BV-period of 5min at the mesopause) might be aliased as the Nyquist frequency of the instrument is f_ny = (0.5 * 2*pi / (2.75 * 60) = 0.019. Especially small-scale gravity waves tend to have periods near the BV-period (see e.g. Tang et al. 2014). I suggest to formulate the sentence a little more cautiously. In this context is it even nicer to see the ripple structure proposed later in the manuscript to show the potential of the instrument even for small-scale variations.

Reviewer 2 is right, a BV-period might be aliased with the Nyquist frequency of the instrument. But we do not intent to study such extremely high frequencies which are very close to the Brunt-Väisälä frequency. In general, the spectral analysis is applied to frequencies which are less than the Nyquist frequency. Besides, a BV-period is varied in the mesopause around 5 minutes. That is why our intension is to study gravity waves having observed periods around 10 minutes and more. We have added this information in the revised manuscript (lines 163-167).

L184-185: How was the flat-field correction done? Was a black-body source used or an average of measurements or something different? I can imagine it wasn't easy to perform a flat-field correction with a 120° field-of-view.

The flat-field is a complicated procedure but basically it consists of three steps:

1. **The cylindrically symmetric component of the lenses is characterized first. This is done on an optical bench (180° rotary table) and an integrating sphere, where the sphere is illuminated with a tunable laser at the emission wavelengths of each of the two OH channels. This is done with an uncoated glass blank in the optical path to have the exact same optical system, but without the filter contribution.**
2. **Then the imager is inserted into the integrating sphere. An additional diffuser is placed over the fisheye lens. Images are taken with the filters in place and with the uncoated glass blank in place. This is to find the attenuation of the filters relative to the uncoated glass blanks.**
3. **Zernike polynomials are then used for the fitting to produce the smooth flat fields.**
   We have provided a short description of this procedure in the revised manuscript (lines 206-213).

L193-197, L204: Can you give some additional information about the geometrical calibration? Unfortunately, in Dalin et al. (2015) I couldn't find more details on the geometrical calibration with reference stars (also not in the publication Dubietis et al. (2011) therein) which is directly related to the geometrical calibration done here. E.g. have you used an infrared star catalogue to find reference stars as you observe in the SWIR range rather then the VIS-NIR? What form has the 3rd order polynomial?

The PPM Star Catalogue (Positions and Proper Motions Star Catalogue) was used to identify positions of the reference stars. It contains positions and proper motions of 378,910 stars on the whole sky in the J2000 coordinate system. Since the majority of stars emit light in the VIS-NIR as well as in SWIR range, it was possible to identify 50 reference stars on images with the wide-band filter (1000-1600 nm).

The 3rd order polynomial has the following form:

$$P=a_1\cdot x^3 + a_2\cdot x^2y + a_3\cdot y^2x + a_4\cdot y^3 + a_5\cdot x^2 + a_6\cdot xy + a_7\cdot y^2 + a_8\cdot x + a_9\cdot y + a_{10}$$

where ten a_i are free coefficients determined under solving this equation in the least-squared sense, x and y are horizontal coordinates of the reference stars on the analyzed image. We have provided this information in the revised manuscript (lines 220-225).

L209-210: For me it is not clear where this formula is coming from, especially the meaning of k_1 to k_7. Is k_4 e.g. the standard deviation of the noise n_dc? Why is there a different parameter for n_dc in denominator and numerator? What is meaning of the scaling factors k_1 and k_5? I think that formula would be much clearer with a few lines about what the coefficients mean and how they are "determined in a laboratory".

Equation 2 (new Equation 3 in the revised manuscript) comes from Equation 1 in the following way. The *R* brightness ratio $B(P_1(2))/B(P_1(4))$ in Equation 1 is in the absolute units (Rayleigh). The instrument registers emission intensities (P1(2), P1(4) and atmospheric background) in relative digital units (counts). In order to relate relative to absolute units, the absolute calibration is performed. The main part of this procedure is to determine filter absolute sensitivities which are different for each filter. These are the coefficients *k2*, *k3* and *k6* in Eq.3. In addition, the dark noise is subtracted both from the P1(2) and P1(4) lines as well as from the atmospheric background line which, in turn, is finally subtracted from the P1(2) and P1(4) lines. Since the coefficients k_2, k_3 and k_6 are different this procedure results in different constants (0.22 and 0.60) for the subtracted dark noise in the numerator and denominator in Equation 3. These constants have positive signs since the dark noise is subtracted from the $P_1(2)$ and $P_1(4)$ lines as well as from the atmospheric background line having different coefficients. The coefficients k_4 and k_7 describe the flat field correction factors being different for each OH (3-1) emission line. Finally, the coefficients k_1 and k_5 convert photometric units to the Rayleigh, which includes several multiplies and the geometric etendue.
We have provided this information is the revised manuscript (lines 245-258).

L222: I may be wrong, but I would calculate the angular side length of a single pixel with 120° / 512 pixels = 0.23 °/pixel.

Here we present a single-pixel area (0.003 x 0.003°) as projected onto the Earth's surface. This is not the angular side length of a single pixel.

L333: "due to small-scale gravity waves (ripples)…". Following Li et al. (2017) and references therein, ripples are not gravity waves rather than instability structures and are often referred to as "wavelike structures" or simple "ripples". It might be difficult to distinguish between small-scale gravity waves and ripples. I suggest rephrasing to make clear that these are different phenomena.

In general, both small-scale gravity waves and ripples are atmospheric gravity waves since a restoring force is the buoyancy force acting on any disturbed air parcel in small-scale waves and ripples, at least at the beginning phase of their formation. But due to multiple definitions of ripples we have removed "ripples" from the revised manuscript, which is not important for this content.

L476: The doi of Dalin eta al 2015 seems to be wrong, I think it should be https://doi.org/10.1002/2014GL062776

Reviewer 2 is right, the doi number has been corrected.

Figure 6: I wonder about the same timestamp in the title of all 3 emission plots (6a-c). I would expect 30-32s gaps between P1(2), P1(4) and O2.

Reviewer 2 is right, there are 30 s gaps between P1(2), P1(4) and O2 maps in Fig.6. The presented timestamp corresponds to the time of the middle point of a current filter wheel cycle which takes 2.75 min. We consider it is better to present the same timestamp for all maps shown in Fig.6 for consistency purposes as well as it is very convenient for a successive time series analysis. We have added this information to the capture of Fig.6 (lines 769-771).

Additionally, I can't recognize the small wave structure of 4-8 km in P1(2) or P1(4) which could be an issue of contrast/color range (I can see it in the rotational temperature map). I suggest to add another figure with a small crop/zoom of the whole images focusing on the small-scale structure and adjusted color range.

We have added another figure (new Figure 7) with a zoom of the whole image focusing on small-scale structures of 4-6 km wavelength and have adjusted color ranges in Figs. 6 and 7.