We thank the reviewer for their thoughtful and helpful comments. Our responses to each of the specific comments are provided after the general comments are restated. The text in bold font is the reviewers' comments. The text in normal font is our direct response to the reviewers and the text in italic font is the added or modified text included in the revised manuscript.

Specific comments

1. **Line 90 – Is the factor of 1.6 mentioned here an issue with the current approach? My understanding form later sections is that it is not. If this is the case, I believe it would be worth explicitly stating that here.**

   The factor of 1.6 is not an issue with the current approach. This is only true because we have recently started using the vibrational population rates provided in Ajello et al. (2020) that were determined from GOLD data instead of the theoretical Franck Condon factors as stated in line 96. However, there are uncertainties around the vibrational population rates in Ajello et al. (2020) which adds another error source that will be discussed in the response to Comment 2. Section 2.1 will be updated such that the discussion on the excitation and extinction source will be removed and the focus will be on the band model as follows:

   Section 2.1: *The forward model used to produce synthetic LBH emissions is built with the Global Airglow Model (GLOW) and a radiative transfer model (Solomon, 2017). GLOW computes LBH volume emission rates as a function of altitude that are input into the radiative transfer model to produce line-of-sight emissions of the LBH band system. The most important component of the forward model for the purposes of deriving thermospheric temperatures is the LBH vibrational-rotational band model (Budzien et al., 2001). The band model is a look-up table of laboratory spectra that specifies, for a given temperature, a unique spectrum for the upper vibrational states v′=0–9 of N_2. In the current implementation of the forward model, the v′=0–9 vibrational population rates are those provided in Ajello et al. (2020) Figure 8 based on GOLD observations and are held constant. The population rate distribution can vary with the energy distribution of the electron flux in addition to variation in excitation sources other than direct excitation such as radiative cascade and collision-induced electronic transition (Ajello et al., 2020, Eastes et al., 2000a,b; Ajello et al., 1985). Ajello et al. 1985 states that excitation thresholding should be included in airglow models to accurately reproduce LBH band intensity. However, as discussed in the following section, absolute band intensity is not needed to extract the N_2 rotational temperature.*

2. **Line 177 – Is this statement true, if the model for LBH with temperature is imperfect?**

Thank you for pointing this out. No, this statement would not be true if the model for LBH with temperature is imperfect. The model for LBH with temperature is the rotational-vibrational band model. The greatest source of imperfection to this model is the specification of the v′=0-9 population rates. The manuscript in various sections is updated and a new figure is added to Section 3.2 to quantify this error as follows:

Abstract – line 12: *The benefits of the two-channel ratio approach include a reduction in representativeness error as radiometrically calibrated LBH intensities are not required in the derivation procedure and a reduction in systematic measurement error caused by variations in the instrument performance across the LBH band system as a fully resolved system is also not required.*

Section 3.2 – line 177: deleted

Section 3.2 – added text: *Sources of representativeness error are those that cause relative differences in the channel intensity other than temperature that are not captured in the rotational vibrational band model. Photoabsorption by* O_2 *is one source to consider. There is only a 1.5% difference in the mean absorption cross section between the two channels that corresponds to a negligible difference in transmittance due to* O_2 *along the line of sight considering the* O_2 *absorption cross section variation with temperature. Another source of representativeness error associated with the (2,0) band is due to the overlap of the bright (2,0) transition and the weak (5,2) transition. Inaccurate specification of the v′=2 and v′=5 vibrational population rates would cause a slight change in shape of the band with respect to the observations that would be interpreted as a change in temperature. Figure 8 in Ajello et al. (2020) provides the v′=0-6 population rates and their uncertainties. These uncertainties are used to determine the associated error in the derived temperatures using the (2,0) band due to inaccurate specification of the v′=2 and v′=5 population rates. It is important to note that this representativeness error does not exist if the (1,1) or (2,3) bands are used in the derivation instead of the (2,0) band, however, these bands are much weaker and suffer from significantly larger random error due to shot noise. Figure *** shows the total random measurement error and representativeness error in the derived temperature using the (2,0) band. The representativeness error is a function of temperature while the random measurement error is a function of the (2,0) band intensity.*

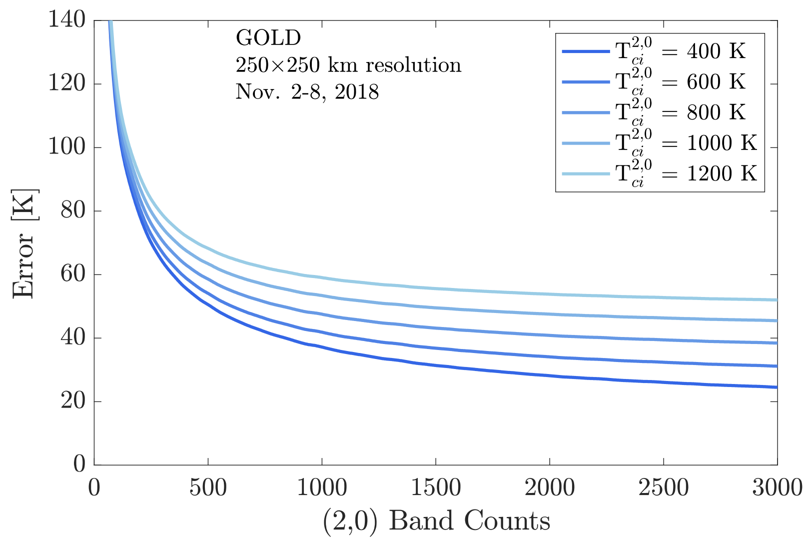

*Figure ***: Total random measurement error (not including particle noise) and representativeness error for T_{ci} using the (2,0) band. The range of (2,0) band counts for GOLD data (250 ×250 km resolution at nadir) used in the case study in Section 4 is highlighted by the grey box.*

Section 5 – line 318: *In this two-channel ratio approach, representativeness errors originating from forward modeling are reduced because radiometrically calibrated LBH band intensities are not required in the derivation procedure, and negative impact of systematic measurement errors, stemming from variations across the band system in the instrument's wavelength registration and resolution, are reduced because a fully resolved LBH band system is not required.*

3. **Line 180 – I believe that the O_2 absorption cross-section also varies (albeit not strongly) as a function of temperature. This will further complicate this factor, although it is likely still minor.**

   The O_2 absorption cross section does vary with temperature, however, this temperature dependence does not change the relative absorption between the two channels. The main text is updated as follows:

   There is only a 1.5% difference in the mean absorption cross section between the two channels that corresponds to a negligible difference in transmittance due to O_2 along the line of sight considering the O_2 absorption cross section variation with temperature.

4. **Line 182 – It is certainly true that the shot noise, which is proportional to the square root of the emission signal, is a major part of the instrumental**

noise. However, particle noise is, at least at some times, an additional random noise source. Importantly, it's behavior is not the same as the shot noise as it is unrelated to the brightness of the signal being observed. See for example the description of the particle background and its associated flag in GOLD Release Notes Revision 4 - https://gold.cs.ucf.edu/wp-content/documentation/GOLD_Release_Notes_Rev4.1.pdf. This may, potentially, be an important consideration in the case study presented in this manuscript.

We agree with the reviewer. The need to consider particle noise as another random noise source is a strong point. We have reviewed the particle background counts and its associated flag for observations used in the case study and found relatively low counts (~0-0.3) with the high background flag set to false. Therefore, we do not think the particle background counts affect the results of this manuscript, but it will be important moving forward to (1) quantify the statistics of background counts as a function of wavelength and (2) quantify the associated temperature errors. The following text is included in Section 3.2:

Particle background counts is at times an additional random noise source. For the case study with GOLD data, the particle backgrounds were low as indicated by the High_Background flag in the Level 1C data and therefore this error source is not considered. The statistics of background counts and the associated temperature errors should be quantified for the general application of this technique to any time period.

Line 267 – The east-west gradient that is described here is not clear to me in Figure 5. I would recommend that this be demonstrated more clearly, perhaps in a line-figure such as Figure 6, as I believe it is an important point that current, at least I struggle to see from the image.

To address the reviewer's concern, Figure 6 (shown below) has been updated such that the RMSD plot has been removed and replaced with the MBD as a function of longitude. Note that the comparison between T_G_ci and T_MSIS changed because the MSIS temperatures are updated based on new sampling with respect to both OZA and SZA (see AC3 to Reviewer 1). Also, note that since the comparison has been updated with T_DISK version 3, the interpretation of Figure 5 and Figure 6 has changed but the major conclusions from the manuscript remain unchanged. The east-west gradient is more pronounced now in the TDISK product similar to that in T_G_ci, although the T_G_ci is still more pronounced as seen in the updated Figure 6 below. These interpretations will be updated in the manuscript.

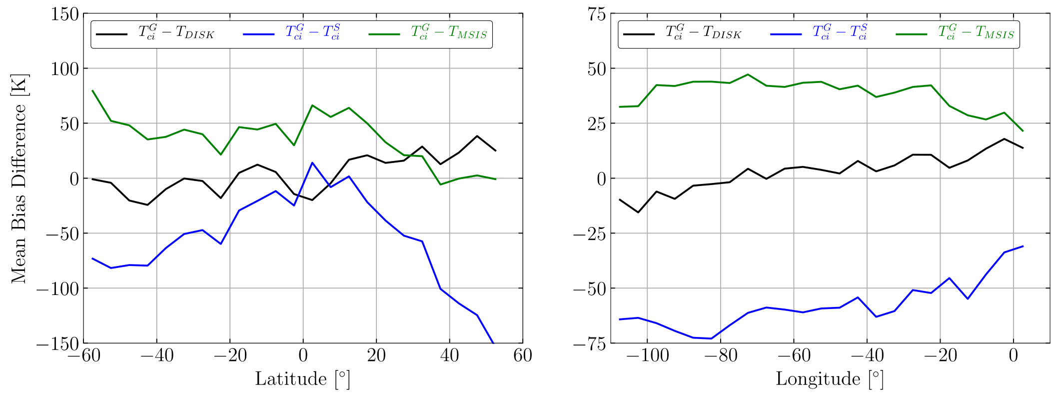

Figure 6: Mean bias difference of T_{ci}^{G} from T_{DISK}, T_{MSIS}, and T_{ci}^{s} as a function of latitude (left) and longitude (right) for November 2-8, 2018 at 15 UT.

5. **Figure 5 – The range over the disk where T_ci_G appear is smaller than that of Tdisk. Is the origin of this a differences in the solar zenith angle ranges, or some other criteria used in the approach described here that differs from the publicly available Tdisk?**

   There was an error in the plotting routine that masked more T_ci_G compared to TDISK as a function of solar and observing zenith angle. This error has been corrected and each of the temperature products is plotted over the same range of observing zenith angle and solar zenith angle as shown in the updated Figure 5.