We thank the reviewers for their excellent comments and suggestions. They significantly improved the clarity and usefulness of the paper. Our responses are summarized in the blue text that follows. We have copied reviewer 1's annotations on the .pdf file into this document by page number and comment number on the page.

Responses to Reviewer 1:

Page 1, Comment #1: Please provide the altitude range of lower-middle thermosphere.
Added

Page 1, Comment #2: This is not clear and may cause confusion. Solar radiation is the main source of energy for the upper atmosphere most of the times, except during major geomagnetic storms when Joule heating from the magnetosphere may exceed the solar heating. Solar activity, such as that induced by flare, eclipse, solar rotation or even solar cycle, just introduces variability to the solar heating.

Reworded to "solar forcing".

Page 1, Comment #3:
Changed "entire the" to "the entire"

Page 2, Comment #1: Change to another? there are other important variables such as winds, not sure which are most important, I would say they are equally important to understand thermospheric dynamics and energetics.
Current wording ("a second") does not limit the number to only two. While winds become a more prominent source of variability as altitude decreases to the mesosphere, at the altitudes being observed by GOLD, ~150 km, the effects of tides on the composition appears to be ~5-10% (Gan et al., in review).

Page 2, Comment #2: state and its variability
Added

Page 2, Comment #3: and dynamics
Added

Page 2, Comment #4: from space
Added "space-based" in the previous sentence to address this.

Page 3, Comment #1: suggest deleting "N2"
Deleted

Page 3, Comment #2: delete "molecular nitrogen"
Deleted

Page 3, Comment # 3 & 4: delete commas after “et al.”
Deleted

Page 3, Comment #5: delete “atmospheric”
Deleted

Page 3, Comment #6: Although it may be already shown in other publications, it is still valuable and for completeness to include a figure of the FUV bands GOLD observing, and the part of the band used for temperature retrieval.
Added as Figure 1

Page 4, Comment #1: The Tdisk temperature near Jan 2021 is significantly higher than in other years before 2023, especially at 15LT, any reason for that? The temperature enhancement appears larger than the annual anomaly considering Jan 2021 is still at solar minimum with weak geomagnetic activity.
Yes, and that’s a good question. We haven’t looked closely at that period and don’t currently know of any reason for the higher temperatures near Jan 2021.

Page 5, Comment #1: Please add a plot of LBH band brightness and SNR changes with time from 2018 to 2024.
Panels showing the brightness and SNR have been added.

Page 5, Comment #2: If it depends primarily on SZA, why there are sharp changes in Figs. 2b and 2c, before Jan. or near Oct., say before Jan 2022?? I would expect much smoother and slow variation with SZA?
We think the changes in 2b and 2c are attributable to increases in the SNR that at that time. There is a local peak (above the trend) in the disk temperature that appears in 2a (e.g., the 15 UT curve) near that time, and that increase in temperature suggests there was an increase in the geomagnetic and solar forcing.

Page 7, Comment #1: Please explain in more detail why do you believe there is a cold bias in the early versions, compared to any other datasets or models? and then why the 90K higher temperature is good or makes sense?
Analysis of the temperatures from individual images binned at a range of spatial and spectral resolutions show that the retrieved temperatures are consistent when SNR > 20 and that there is a cold bias that increases with decreasing SNR.

Page 7, Comment #2: Confused here, do you mean by limiting the wavelength scale contribution to 5K increases the uncertainties?
We have edited the sentence to clarify that an error of 0.01Angstroms in the wavelength scale adds 5K to the temperature uncertainty when retrieving the temperatures using the technique studied by Cantrall and Matsuo.

Page 8, Comment #1: Are you suggesting that the local time variation seen in Tdisk is mostly related to the GOLD observation geometry or SZA dependence, instead of the true local time variation of thermospheric temperature? or could the authors estimate how much is its contribution as compared to the true temperature variations as we know thermospheric temperature does increase with local time till about 3-4 pm.
Added: Modeling indicates a 50–100 K temperature increase for SZA values ranging from 0 to 70 deg (Evans et al., 2024). This SZA effect is not removed from the current Tdisk data.

Page 8, Comment #2: I thought GOLD was not in operation till Sep. 2018.
We have edited the sentence to clarify the intended distinction between 2018 and 2022 data coverage in local time.

Page 9, Comment #1: Auroral particle is heating is not a major source of energy, but Joule heating is.
We agree that Joule heating is responsible for most (~90%) of the auroral energy inputs to the thermosphere. The point we were attempting to make is that at high latitudes, even outside the aurora during quiet conditions, the temperatures are likely to be higher than at a lower latitude with a similar SZA.

We have reworded that sentence to more clearly express the possible reasons for the higher temperatures seen in a region within Figure 4.

Page 9, Comment #2-5: see response to previous comment.

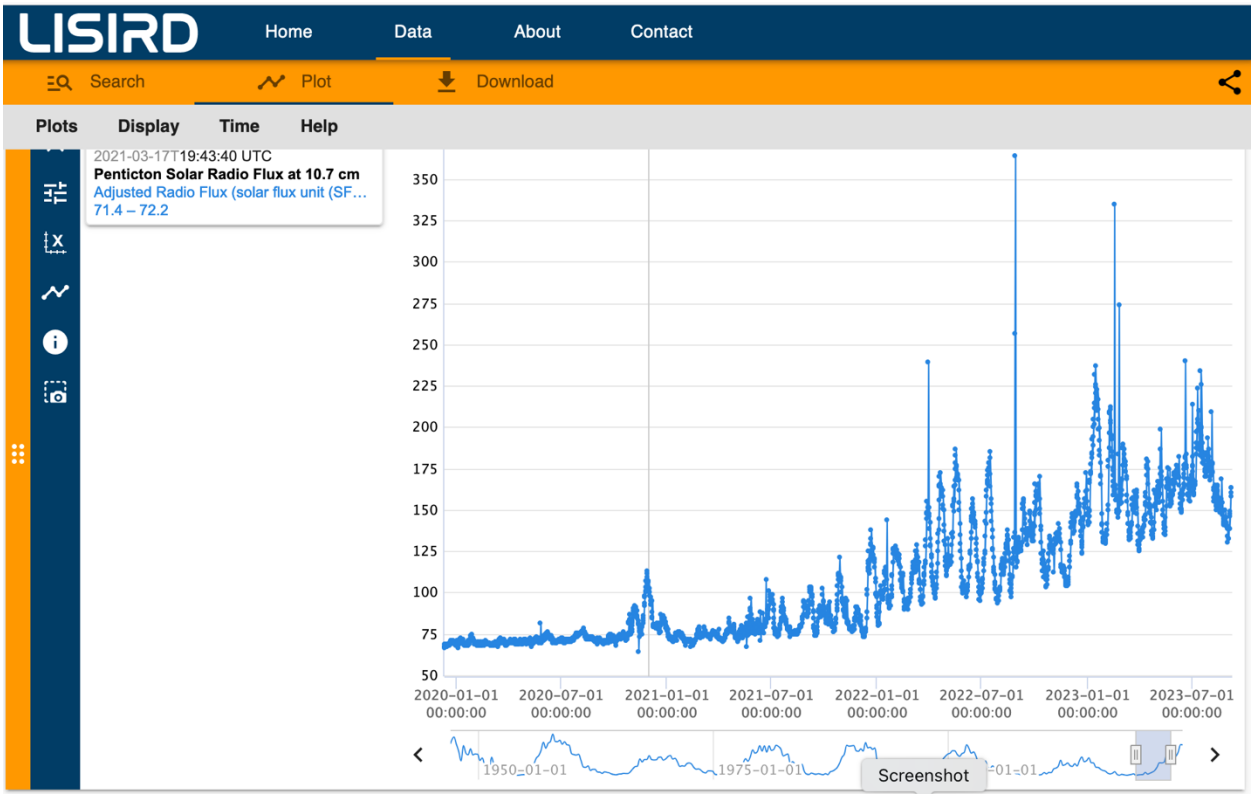
Page 9, Comment #6: Fig. 5
added.

Page 9, Comment # 7: Comparing with Fig. 2, I see a low Tdisk in Jan. in the daily averaged temperature, whereas at subsatellite location (Fig. 2), a large Tdisk is observed, why is this difference? Also how do you get the daily averaged Tdisk in Figure 5? please add more information.

The higher TDISK values near Jan 2021 are due to increased solar activity around that time. See plot of F107 below.

We revised the Figure 5 caption for clarity.
“Figure 5. Daily averaged Tdisk and Qeuv (a solar proxy derived from GOLD’s dayside disk observations from the beginning of operations (and Kp data from 1 Jan 2018) to 1 Jan 2023. Daily averaged Tdisk is calculated across all observed locations and local times.”

As now stated in figure captions, the daily averaged Tdisk in Figure 5 is derived by using all observations over all locations and local times from each day. The text and figure caption have been edited to include that information.


LISIRD
Home
Data
About
Contact
Search
Plot
Download
Plots
Display
Time
Help
2021-03-17T19:43:40 UTC
Penticton Solar Radio Flux at 10.7 cm
Adjusted Radio Flux (solar flux unit (SF…
71.4 – 72.2
350
325
300
275
250
225
200
175
150
125
100
75
50
2020-01-01 00:00:00
2020-07-01 00:00:00
2021-01-01 00:00:00
2021-07-01 00:00:00
2022-01-01 00:00:00
2022-07-01 00:00:00
2023-01-01 00:00:00
2023-07-01 00:00:00
1950-01-01
1975-01-01
Screenshot

Responses to reviewer 2:

Review of AMT-2024-52 “Remote sensing of lower-middle thermosphere temperatures using the N2 Lyman-Birge-Hopfield (LBH) bands”

by Eastes, Evans, Gan, McClintock, and Lumpe

Summary Comments
This paper summarizes the GOLD multi-band LBH temperature retrieval approach described in a recent paper, briefly discusses recent version 5 improvements of the TDISK product, and compares results to two other approaches for retrieving thermospheric from FUV observations. The paper argues that the absence of artifacts in new GOLD temperatures, the physical behavior of retrieved temperatures, and the low uncertainties from high signal-to-noise from multi-band retrievals make the GOLD thermospheric temperatures reliable. The paper provides an overview of retrieved GOLD temperatures and uncertainties during the mission. Moreover, examples of challenges in an alternate single-band rotational temperature retrieval method and a vibrational band ratio temperature retrieval method indicate that these methods are not yet mature and require further analysis to resolve issues regarding biases and uncertainties compared to GOLD temperature retrievals.

The paper is well-organized and supports the major conclusions with examples, particularly as the intent appears to be to more widely disseminate GOLD temperature products to the community and provide a basic understanding of GOLD temperature behavior and limitations. This paper is not an exhaustive modeling or statistical study of the GOLD temperature product versus other approaches. The wording is not as economical as possible and the figures would benefit from minor tweaks. An attachment details minor suggestions.

Line 9: “advance our understanding” Reword?
Reworded to, “better understand”. Also deleted “lower-middle”

Line 9: Suggest joining these two sentences: “in the lower-middle thermosphere, particularly in light of the rapid increase…”
Text was reworded

Line 11: “almost equivalently”. Remove.
Just deleting “almost equivalently” seems to result in redundancy because most of the changes in neutral density are related to temperature changes (composition changes also have an effect on density but that’s smaller), and satellite drag depends on neutral density. Therefore the sentences was edited to, “Geomagnetic activity can dramatically increase

thermospheric temperatures which increases the thermospheric densities and that increases satellite drag."

Line 12: "However, specification…satellites is large". Not clear why number of satellites affects the importance of quiet-time temperature specification.
Edited the sentence to be clearer

Line 16. Missing period after "gap"
Added

Line 17, "neutral temperature, which is a key…". Change to "neutral temperature, a key…"
Changed

Line 19. Instead of putting emphasis on researchers who are unfamiliar with GOLD, consider
"…launch of GOLD, its current observational capability relevant to data interpretation may not be widely known."
The sentence was edited to change the emphasis

Line 28. A reference for forcings as a significant source of variability in the T-I system might be useful versus the assertion here.
Added a reference

Line 35. Change to "Temperature is a fundamental state variable and key to understanding…" Line 38. "some informative analyses" seems ambiguous. Be more specific about what is relevant to this paper.
Done

Line 42. Delete "some" "that is": "…summarize additional information relevant to…"
Done

Line 59: Consider "Consequently, observed FUV emissions must…"
Modified wording but slightly differently than suggested

Line 64: Consider citing a reference for the peak of LBH emission trending higher as SZA increases.
The appropriate references are cited in the next (following) sentence

Line 67: The McClintock et al (2020) paper still exists. Use present tense to refer to Figure 4.

Changed

Line 77: Join the sentences that refer to the limb scale heigh temperature technique.
Done

Line 79: Change to “This paper focuses on…”
Edited

Line 86: Consider “…LBH excitation occurs by cascade…”
Edited

Line 94: Importantly, the peaks of the atomic 1356 and 1493 multiples do not shift with temperature as molecular bands might. GOLD also has the resolution to resolve components of the multiplets, at least in the case of 1356.
Sentence edited to note that the atomic line wavelengths do not change with temperature

Line 97: Remove comma: “small-scale wavelength errrors”
Removed

Line 129: This approach is related to the vibrational, not rotational, temperature. “…to deduce temperature from relative vibrational populations.”
Edited as suggested

Line 131: Add comma for independent clauses:”… technique is uncertain, because…”
We think that the phrasing “The reliability is uncertain because” makes better sense without a comma

Line 131: “because the vibrational populations are affected by…”
Edited as suggested

Line 136: Differences in rotational emission is more accurately specified as the distribution about the peak, not just the amount of long wavelength emission.
Agreed. The wording has been modified. Cantrall and Matsuo’s technique depends on the relative changes in short versus long wavelength at a wavelength longward of the peak

Line 140: Comment: Also, to determine the total amount of emission in two different upper state progression bands depends upon spectrally resolving the bands to measure them.
Yes. Some text (from individual bands (i.e., v’, v”)) was inserted to emphasize that

Figure 4: Please clearly label the differing dates for the two observations.
The dates have been added

Figure 4: The color scale is non-intuitive: cooler values are plotted as yellow, while hotter temperatures are plotted in progressively more intense values of blue, which is a "cool" color. Consider using a different color scale where higher temperatures are plotted as a "warmer" color. We have attempted to duplicate the color scale used in previous paper by Cantrall and Matsuo on the temperatures in the GOLD data. Consequently, we'd prefer to use the existing color scale to facilitate readers comparisons of the results

Line 196: "Results and analyses" is a very non-specific term. Much better to summarize in this sentence the particular results (SNR? Uncertainties? Viewing-geometry related behavior? Comparisons with model? Reduction of bias? Elimination of artifacts?) that demonstrate the robustness of the GOLD approach, or perhaps some rewording of this concluding paragraph.
Text was reworded to be more specific