Response to reviewer #1

Item-by-item responses to the specific comments are provided below, in which the reviews' comments are in **blue**, our responses are in **black**, and modifications of the original manuscript are highlighted in **yellow** in the revised manuscript.

This study introduces the first multi-year dataset of geostationary ammonia observations from the FengYun-4B satellite. A comprehensive evaluation of the dataset is presented through comparison with polar orbiting satellites, as well as ground-based FTIR observations. The peak months of ammonia over East Asia are also examined, revealing an interesting pattern related to agricultural emissions. The uniqueness of the data is highlighted by investigating diurnal ammonia variations from early morning to afternoon. Large discrepancies between observations and modelling, as revealed by the data, show that modelling still needs to improve its ability to capture diurnal ammonia variations. Overall, the paper is well structured and clearly written. The retrieval data are unique, and the findings are novel. Given that the IRS, which overlooks Europe and Africa, has recently been launched, and that more geostationary hyperspectral sounders may be in the planning stage, this study is timely. The paper fits the scope of ACP and can be published once the following minor issues have been addressed.

Thank you for your positive comments and constructive suggestions. We have made major and careful modifications to the original manuscript according to all the comments and suggestions from the reviewers. The major modifications are summarized as follows:

(1) GIIRS NH_3 retrieval algorithm and data comparison. A detailed description of the retrieval algorithm has been added in the appendix, including the interpretation and calculation of column averaging kernel (AVK). We also clarified the data coverage in Fig. 1 and added Fig. S2 to illustrate the impact of the thermal contrast (TC) filtering on data availability.

(2) Text revisions and additional references. Some paragraphs and sentences have been rewritten for improved clarity and completeness. Additional references have been included to strengthen the discussion, including those related to geostationary satellite observations, the reliability of the MIX emission inventory, and NH_3 emission studies over the Sichuan Basin.

(3) Figure revisions and optimization. Several figures have been refined and simplified to reduce redundancy, particularly Fig. 1 and Figs. 12–14. The definition of the study regions has been made clearer. Figure 1 now highlights the three key regions discussed in the manuscript, while Fig. S4 shows locally enhanced areas. Figure S16 presents the selection of eight major agricultural areas, and Figs. 11–14 display the spatial and temporal distributions of daytime NH_3 variations.

For details, please see our point-by-point responses to your specific comments below.

(1) In the introduction section, atmospheric chemistry modelling, such as GEOSchem, has been widely used to study ammonia at global and regional scales. Several studies related to improving NH_3 modelling are suggested for addition.

Response: Thanks for your suggestion. In the revised manuscript, we have added statements and references to highlight improvements in NH_3 modelling. The revised text is as follows:

"Given its short atmospheric lifetime of a few hours to several days, NH_3 exhibits large intra-day variability in concentration from both agricultural and non-agricultural sources. Several studies have employed surface measurements to investigate the diurnal variability of NH_3 and its controlling mechanisms, revealing that diurnal patterns in urban and rural areas differ markedly across seasons (Gu et al., 2022; He et al., 2020; Chang et al., 2019; Huy et al., 2017; Meng Z. et al., 2011). These analyses are limited by the sparse spatial coverage and short temporal duration of ground-based monitoring networks. To complement observations, atmospheric chemistry models have been applied to simulate NH_3 at regional and global scales, and refinements in surface exchange schemes have improved NH_3 modeling (Jongenelen et al., 2025; Cao et al., 2022). However, the mechanisms underlying the diurnal variability of atmospheric NH_3 in different emission regions still remain poorly understood."

Jongenelen, T., van Zanten, M., Dammers, E., Wichink Kruit, R., Hensen, A., Geers, L., and Erisman, J. W.: Validation and uncertainty quantification of three state-of-the-art ammonia surface exchange schemes using NH_3 flux measurements in a dune ecosystem, Atmos. Chem. Phys., 25, 4943–4963, https://doi.org/10.5194/acp-25-4943-2025, 2025.

Cao, H., Henze, D. K., Zhu, L., Shephard, M. W., Cady-Pereira, K., Dammers, E., and Capps, S. L.: 4D-Var inversion of European NH_3 emissions using CrIS NH_3 measurements and GEOS-Chem adjoint with bi-directional and uni-directional flux schemes, J. Geophys. Res.-Atmos., 127, e2021JD035687, https://doi.org/10.1029/2021JD035687, 2022.

(2) Figure 1. Why do the observation domains have curved edges? Perhaps the domain has been filtered by viewing zenith angle. Please clarify.

Response: Thanks for your helpful question and suggestion. The curved edges of the observation domains arise from the filtering applied to the viewing zenith angle (VZA) in the NH_3 retrievals. Specifically, observations with viewing zenith angles greater than 70° are excluded.

To clarify this point, we have revised the description of Figure 1 in the manuscript to explicitly clarify the spatial extents of GIIRS observations and NH_3 retrievals. The added text and revised figure are as follows:

"In the NH_3 retrievals, regions with viewing zenith angles greater than 70° are excluded from the retrieval algorithm, as large zenith angles increase the atmospheric path length and scattering effects while reducing the signal-to-noise ratio and retrieval reliability."

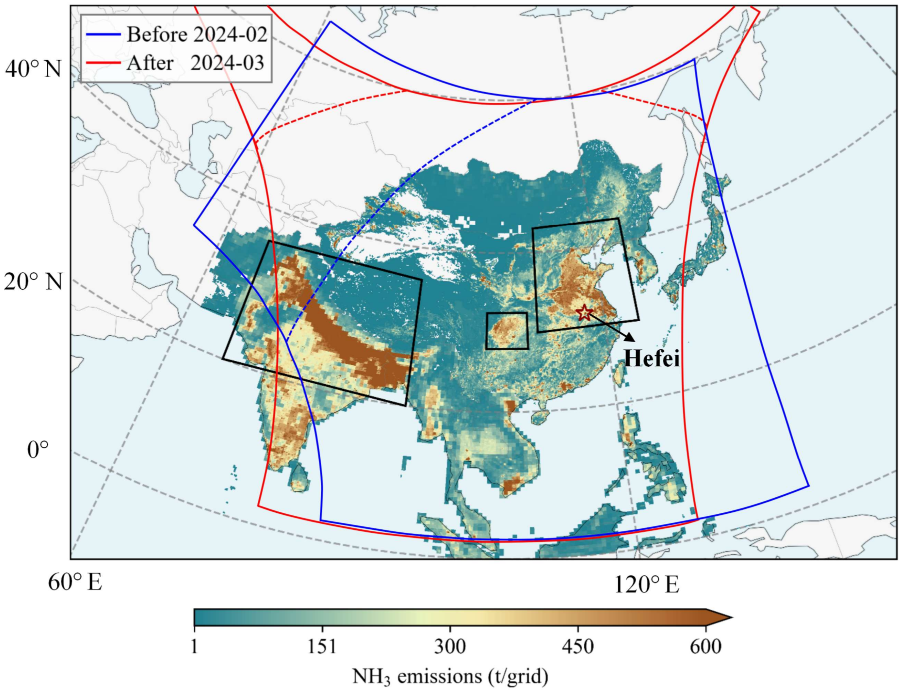

Figure 1. Spatial domain of FY-4B/GIIRS observations and NH_3 retrievals over East Asia. Blue and red solid lines outline GIIRS observational coverage before and after the FY-4B orbital relocation, respectively. Blue and red dashed lines denote the corresponding NH_3 retrieval domains, with viewing zenith angles greater than 70° excluded. The background map shows total anthropogenic NH_3 emissions in 2017 from the MIXv2 emission inventory at a 0.1° grid resolution (Li et al., 2024). The red pentagram marks the location of the Hefei station, which is further described in Sect. 3.2. Black boxes outline major agricultural areas, including the North-Northeast China Plain, the Sichuan Basin, and the Indo-Gangetic Plain.

(3) L166. Using the TC threshold may affect the results. Here, 5K is used. Please describe how much data can be retained after this filtering. Perhaps a histogram of the data numbers for different TCs could be made.

Response: Thank you for your constructive suggestion. In the original manuscript, the fraction of retained observations after applying the TC > 5K filtering criterion was described in Sect. 3.3 for the three major source regions: "Compared to the dataset used in Sect. 3.1, the fractions of valid observations remaining in the three study regions were about 83 %, 88 %, and 73 %, respectively.”

To improve clarity for readers, the description has been moved to Sect. 2.1.1 and slightly revised in the manuscript. In addition, Figure S2 has been added to the Supplementary Material to provide a more detailed illustration of the effect of different TC thresholds on GIIRS NH_3 retrievals.

The updated text reads: **“Figure S2 shows the number of data points before and after applying the TC > 5 K filtering criterion. The fractions of valid observations remaining in the North-Northeast China Plains, the Sichuan Basin, and the Indo-Gangetic Plain (as shown in Fig. 1) are about 83 %, 88 %, and 73 %, respectively. ”**

Figure S2 presents spatial comparisons of the number of valid observations, as well as histograms of TC values and NH_3 columns under different TC thresholds for three representative emission regions. These additions help clarify how the TC filtering affects data availability and the resulting NH_3 observations.

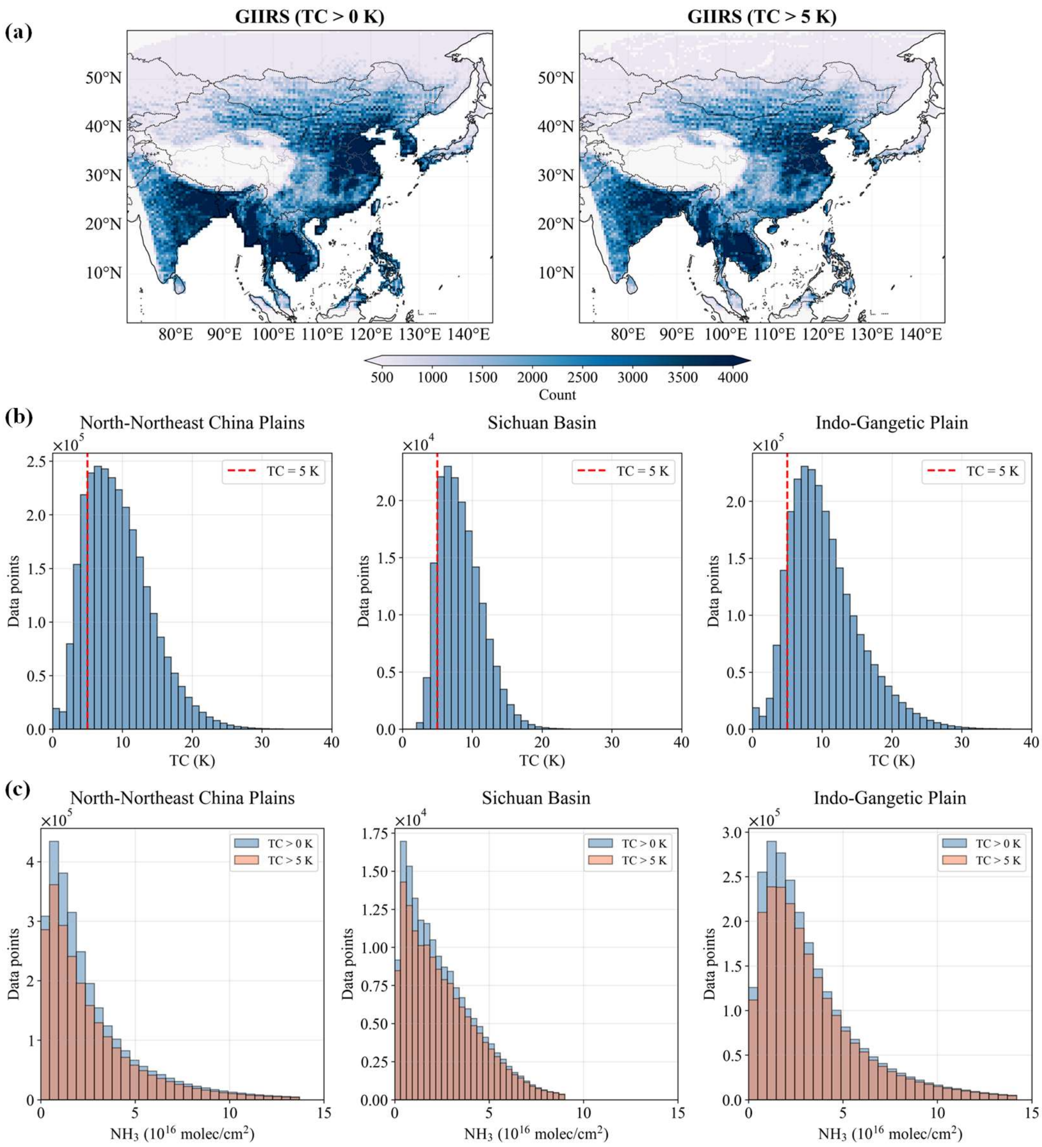

Figure S1. Valid data points of FY-4B/GIIRS NH_3 retrievals from July 2022 to June 2025. (a) Spatial distribution of data numbers under different TC thresholds at a 0.5° × 0.5° grid resolution. (b) Histogram of data points with TC > 0 K for three major emission regions. (c) Histogram of NH_3 column concentrations using different TC thresholds for three major emission regions.

(4) Figure 2: The spatial maps for 7–9 h and 17–19 h show some unrealistic edges that look odd. Are these due to the different observation hours? Please explain and see if this can be mitigated.

Response: Thank you for noticing this issue. The apparent edges in the spatial maps are related to the step-stare scanning mode and temporal sampling of the FY-4B/GIIRS instrument. GIIRS observations cover the study region approximately every two hours in UTC. If the data are aggregated using these UTC-based two-hour intervals, the spatial coverage remains continuous and the edges disappear.

In this study, however, the analysis is conducted using local solar time (LST) to better represent the diurnal variation of NH_3. Because the study domain spans multiple time zones, observations aggregated within the same LST interval originate from different UTC observation times across longitudes. In addition, the data availability in the early morning (7–9 h) and evening (17–19 h) periods is more strongly affected by retrieval constraints such as thermal contrast (TC), resulting in uneven spatial sampling across longitude bands and the visible edges in the maps.

In the original manuscript, the figure caption indicates that the time refers to local solar time (LST). To further clarify this point, an additional explanation has been added in Sect. 3.1 of the revised manuscript. The added text reads as follows:

"Figure 2 illustrates the three-year averaged seasonal NH_3 column concentrations retrieved from FY-4B/GIIRS observations over East Asia from July 2022 to June 2025, presented on a 0.5° × 0.5° grid at two-hour intervals. The observations are aggregated according to local solar time (LST) to facilitate the analysis of NH_3 diurnal variations and consistent comparisons. The study region spans multiple time zones and data availability during the 7–9 h and 17–19 h periods is substantially reduced due to retrieval filtering, resulting in noticeable boundaries across longitudes."

(5) The agreement in Figure 5 looks very good. In Southeast Asia, there are strong biomass burning emissions every spring. How might this affect the peak? Currently, I see that the majority of the region peaks in March and April.

Response: Thank you for your insightful question. In the original manuscript, the potential influence of biomass burning in Southeast Asia was briefly discussed as follows: "The consistent spatial distribution of NH_3 observed by GIIRS and IASI over Southeast Asia also reflects the influence of biomass burning associated with fires on its seasonal variations."

In the revised manuscript, we have further clarified the relationship between the peak months of NH_3 observations and the timing of biomass burning in this region. A more detailed description has been added to discuss how springtime biomass burning in Southeast Asia may contribute to the observed NH_3 peak in March-April.

The revised text reads as follows: "**Spring is a period of intense fire activity in the Indochina Peninsula, which is largely driven by agricultural residue burning, land-clearing, and naturally flammable vegetation during the dry season (Chang et al., 2021; Vadrevu et al., 2019). The NH_3 maxima mainly occur in March-April, and the consistent spatial distribution of these NH_3 peaks observed by GIIRS and IASI over Southeast Asia suggests the influence of biomass burning associated with fires on its seasonal variations.**"

Chang, Y., Zhang, Y.-L., Kawichai, S., Wang, Q., Van Damme, M., Clarisse, L., Prapamontol, T., and Lehmann, M. F.: Convergent evidence for the pervasive but limited contribution of biomass burning to atmospheric ammonia in peninsular Southeast Asia, Atmos. Chem. Phys., 21, 7187–7198, https://doi.org/10.5194/acp-21-7187-2021, 2021.

Vadrevu, K. P., Lasko, K., Giglio, L., Schroeder, W., Biswas, S., and Justice, C.: Trends in Vegetation fires in South and Southeast Asian Countries, Sci. Rep., 9, 7422, https://doi.org/10.1038/s41598-019-43940-x, 2019.

(6) The MIX inventory data in L315-316 can differ greatly from the observations. Could you provide one or two more references that use the MIX inventory? How reliable is this inventory?

Response: Thanks for your suggestion. The reliability of the MIX inventory is based on its integration of multiple established emission inventories. For China, it primarily relies on a process-based NH_3 emission inventory developed by Peking University (PKU-NH_3) for China; for other Asian countries and regions, it incorporates other high-resolution inventories to improve coverage and ensure applicability across the study domain. In the revised manuscript, the paragraph describing the MIX inventory has been rewritten, and relevant studies have been cited.

The revised text reads as follows: **"The MIXv2 Asian emission inventory was developed under the framework of the Model Inter-Comparison Study for Asia Phase IV (MICS-Asia IV) project by assembling a mosaic of up-to-date regional and national emission inventories (Li et al., 2024). It provides monthly estimates of NH_3 emissions for 2010–2017 at a spatial resolution of 0.1°× 0.1° grid across seven sectors. The inventory incorporated nine regional and two global emission inventories, covering 23 countries and regions in East, Southeast and South Asia. Anthropogenic NH_3 emissions were based on the best available emission inventories, including a process-based NH_3 emission inventory developed by Peking University (PKU-NH_3) for China, the official Japan emission inventory (JPN), and the Clean Air Policy Support System (CAPSS) emissions for the Republic of Korea, and were gap-filled with REAS version 3 for Asia (REASv3). Studies have suggested that the spatial distribution of NH_3 emissions in the inventory is generally reliable, with differences compared to other emission inventories and satellite-constrained NH_3 emissions typically within 20–50% (Luo et al., 2022; Zhang et al., 2019; Kang et al., 2016)."**

Kang, Y., Liu, M., Song, Y., Huang, X., Yao, H., Cai, X., Zhang, H., Kang, L., Liu, X., Yan, X., He, H., Zhang, Q., Shao, M., and Zhu, T.: High-resolution ammonia emissions inventories in China from 1980 to 2012, Atmos. Chem. Phys., 16, 2043–2058, https://doi.org/10.5194/acp-16-2043-2016, 2016.

Luo, Z., Zhang, Y., Chen, W., Van Damme, M., Coheur, P.-F., and Clarisse, L.: Estimating global

ammonia (NH3) emissions based on IASI observations from 2008 to 2018, Atmos. Chem. Phys., 22, 10375–10388, https://doi.org/10.5194/acp-22-10375-2022, 2022.

Zhang, Q., Pan, Y., He, Y., Zhao, Y., Zhu, L., Zhang, X., Xu, X., Ji, D., Gao, J., Tian, S., Gao, W., and Wang, Y.: Bias in ammonia emission inventory and implications on emission control of nitrogen oxides over North China Plain, Atmospheric Environment, 214, 116869, https://doi.org/10.1016/j.atmosenv.2019.116869, 2019.

(7) The number of data points in Figure 8 varies considerably between satellites, especially for CrIS, which has many fewer data points. Please explain.

Response: Thanks for pointing this out. The differences in the number of data points among the satellites are primarily due to the different data filtering criteria applied to each dataset and the temporal overlap periods used for matching with FTIR observations.

As described in Sect. 2.1.3, our analysis focuses on NH_3 retrievals over land, characterized by land fraction > 0, quality flag ≥ 4, cloud flag ≠ 1, and DOFS ≥ 0.1. After applying these filters, the number of valid CrIS observations over Hefei becomes relatively small (Fig. S3), which further contributes to the reduced number of collocated data points.

The geostationary GIIRS instrument provides observations throughout the daytime, resulting in a relatively large number of matching data points. In contrast, polar-orbiting satellites only overlap with FTIR observations for approximately 3–5 hours per day. To maximize the number of matched data points for validation, we used IASI observations from both Metop-B and Metop-C during the FTIR observation period (2017–2024), providing longer temporal coverage than CrIS, which is only available from March 2019. This difference leads to fewer matching points for CrIS. The explanation has been added in the caption of Figure 8.

We also performed a comparison using data from the same temporal period, which yielded similar results. This confirms that the differences in cross-validation are primarily attributable to the satellite observations themselves, rather than to differences in the overlap periods.

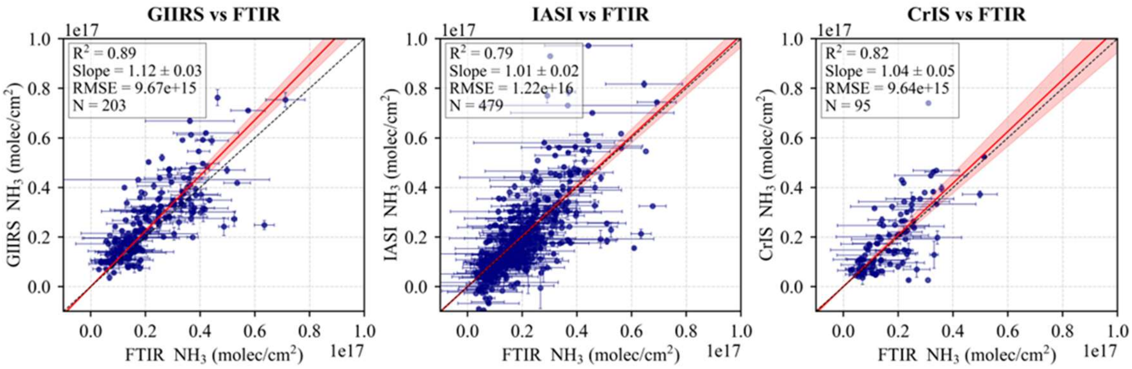

Figure 2. Cross-validation of hourly NH_3 columns from GIIRS, IASI, and CrIS with FTIR measurements at the Hefei station. The overlapping periods span January 2017 (IASI), March 2019 (CrIS), and July 2022 (GIIRS) to December 2024. GIIRS data encompass all daytime hours, while IASI and CrIS data correspond specifically to their respective overpass times.

(8) In Section 3.3, the Sichuan Basin is an interesting case, as the topographic effect can be significant. L454-458 does not provide much background information on this region. I suggest adding some references to studies of NH_3 in this region. What is the current understanding of ammonia emissions over this region from polar orbiting satellites?

Response: Thanks for your suggestion. In the revised manuscript, we have added background information on NH_3 emissions over the Sichuan Basin and included relevant references based on ammonia emission inventories and previous satellite observations.

The added text is as follows: **"The Sichuan Basin, located in southwestern China, is an important agricultural region encompassing the Chengdu-Chongqing urban agglomeration. Ammonia emissions exhibit a clear east-west gradient, reflecting regional differences in agricultural practices and livestock management (Li et al., 2021; Zhang, L., et al., 2018; Kang et al., 2016). Studies based on IASI observations indicate that NH_3 hotspots in the Sichuan Basin are primarily concentrated in the Chengdu Plain, and the southern urban clusters, and northwestern Sichuan(Yang et al., 2024; Van Dammers et al., 2019; Damme et al., 2018), where agricultural sources dominate ammonia emissions."**

Yang, X., He, J., and Wang, S.: Interannual variability of atmospheric ammonia over the Sichuan Basin, southwestern China: Trend, sources, and implications on particle matter control, Atmos. Chem. Phys., 299, 107170, https://doi.org/10.1016/j.atmosres.2023.107170, 2024.

Dammers, E., McLinden, C. A., Griffin, D., Shephard, M. W., Van Der Graaf, S., Lutsch, E., Schaap, M., Gainairu-Matz, Y., Fioletov, V., Van Damme, M., Whitburn, S., Clarisse, L., Cady-Pereira, K., Clerbaux, C., Coheur, P. F., and Erisman, J. W.: NH3 emissions from large point sources derived from CrIS and IASI satellite observations, Atmos. Chem. Phys., 19, 12261–12293, https://doi.org/10.5194/acp-19-12261-2019, 2019.

Van Damme, M., Clarisse, L., Whitburn, S., Hadji-Lazaro, J., Hurtmans, D., Clerbaux, C., and Coheur, P.-F.: Industrial and agricultural ammonia point sources exposed, Nature, 564, 99–103, https://doi.org/10.1038/s41586-018-0747-1, 2018.

(9) L530: FY-4C/GIIRS was launched in late 2025. This can be reflected in the rephrases. Could you also provide more details on FY-4C/GIIRS and explain what improvements it offers over 4A and 4B GIIRS?

Response: Thank you very much for your valuable suggestion. Following the review period, the FY-4C satellite was successfully launched in late 2025 as planned. We have updated the manuscript to reflect this new status. Additionally, following your advice, we have added more details regarding the FY-4C/GIIRS and its improvements over its predecessor FY-4B/GIIRS. The specific modifications are as follows:

"The upgraded FY-4C/GIIRS was launched in December 2025, further enhancing the FY-4 geostationary observational capabilities. Compared to its predecessor FY-4B/GIIRS, which provides a spatial resolution of 12 km and a temporal resolution of 2 hours, FY-4C/GIIRS achieves a significant improvement to 8 km and 1 hour, respectively."

(10) Please also provide a description of the IRS onboard the MTG, which was launched in 2025.

Response: Thanks for your suggestion. A description of the Infrared Sounder (IRS) onboards the Meteosat Third Generation sounding satellite (MTG-S1), launched in July 2025, has been added to the Introduction.

The added text reads: **"Similarly, the Meteosat Third Generation sounding satellite (MTG-S1), launched in July 2025, carries the Infrared Sounder (IRS), another geostationary hyperspectral infrared instrument designed to provide higher spatio-temporal resolution observations (every 30 minutes) over Europe (Holmlund et al., 2021)."**

Holmlund, K., Grandell, J., Schmetz, J., Stuhlmann, R., Bojkov, B., Munro, R., Lekouara, M., Coppens, D., Viticchie, B., August, T., Theodore, B., Watts, P., Dobber, M., Fowler, G., Bojinski, S., Schmid, A., Salonen, K., Tjemkes, S., Aminou, D., and Blythe, P.: Meteosat Third Generation (MTG): Continuation and innovation of observations from geostationary orbit, Bull. Amer. Meteor. Soc., 102, E990–E1015, https://doi.org/10.1175/BAMS-D-19-0304.1, 2021.