Second review of “**Toward a versatile spaceborne architecture for immediate monitoring of the global methane pledge**”

The authors have updated their manuscript with suggestions from two reviewers and a reader, and the manuscript is somewhat improved. I believe it could make a useful contribution to the field of monitoring CH4 from space. But there are still sections that are unclear and many awkward wordings. Below I have listed locations that need some clarification, along with multiple minor corrections.

Questions:

Lines 176-178: what does “subtracting the current signal from the data” mean? Which “recent enhancement estimates”?

Line 190 : Is ΔXCH4 multiplied by ***f?***

Line 224: Why are the polygons around the plumes masked out? Please clarify.

Line 261: Please summarize the main results of the uncertainty analysis presented in supplement and refer to values shown in Table S1 whenever citing your emission estimates. I assume these uncertainties are used in Figures 3 and 4; please state this clearly.

Lines 301 and 348: Are the Yanquan emissions 30000 kg/h or 7000 kg/h?

Line 311: In line 281 the detection limit for PRISMA is estimated at 800 kg/h. Yet in line 311 the detection threshold is 300 kg/h. Please clarify.

Line 315: The authors state “the overpass timing of TROPOMI can be nearly concordant with that of PRISMA.” Ten days does not sound like good co-location. Please justify why ten days is a good enough co-location criteria.

Line 337: The authors state: “To this end, we apply a multi-spectral retrieval algorithm to eliminate this effect to a large extent. The detailed illustrations are shown in Supplementary Information (Fig. S5).” Please provide a sentence or two on the algorithm used.

Line 401: Please explain what is meant by “spatial proxies”.

Line 405: A compromise between what? Maybe the authors mean a combination of inventory data and downwind measurements?

Line 409: Are the authors stating that the Rumaila and Hassi Messaud EDGAR emissions are biased low with respect to he results in this paper? Please make this clearer. Please explain why the factors in this paragraph would apply only to these two locations.

Line 485: Does the shading in the violin plots represent the uncertainty In each plume estimate? Or something else? Please clarify.

Minor editing suggestions:

Replace **multi-tiered** with **two-tiered** wherever the current work is discussed.

Line 34: within “the” narrow window…

Line 35: We focused on several regions (United States, China, the Middle East,
36 and North Africa,) and …

Line 36: and uncovered …

Line 40: and thus is sufficiently versatile for ….

Line 46: within the narrow window …

Line 49: it has been rising since 2007, with a surge in 2014 and a record high in 2021 (insert references I omitted)

Line 53: policymakers

Line 54: on the eve of the Paris target, large uncertainties in emissions remain, and thus hinder …

Line 60: for example, field campaigns report nearly double official claims of methane emissions in the United States by detecting missing leaks

Line 65: defined as emission sources that …

Line 68: with dimensions varying from …

Line 72: In contrast to area sources (e.g., cities), super-emitters are typically coal mines, wells, gathering stations, storage tanks, pipelines, and flares, with diameters on the order of dozens of metres or less, but generating plums of highly concentrated methane.

Line 80: spatially limited

Line 81: and miss many super emitters

Line 87: wide swaths and high-resolution sampling have not been simultaneously available

Line 88: Recently global methane monitoring has become possible..

Line 90: It provides daily global methane columns,

Line 91: and a high signal-to-noise ratio

Line 92: Next-generation satellite missions, pioneered by the GHGSat constellation (three satellites at the moment), have emerged

Line 96: great potential

Line 98: Note that the regions these satellites usually observe are already know to contain many super-emitters

Line 101: existing studies still struggle to survey global methane super-emitters due to the fact that individual satellite missions, such as TROPOMI or PRISMA, do not both have a wide swath and high resolution sampling.

Line 103: TROPOMI

Line 106: Using this framework, we focused on China, the United States, Iraq, Kuwait, and Algeria

Line 107: We also monitored a single source to map multiple plumes and to look for possible methane leaks.

Line 109: is not in place, the two-tiered satellite constellation presented in this study has great potential for measuring progress towards global methane pledges

Line 114: due to its large swath (~2600 km)

Line 115: revisit time, moderate footprint …, and excellent sounding precision and accuracy.

Line 116: TROPOMI observes approximately

Line 117: the first consisting of near infrared

Line 127: super-emitters due to their unprecedented resolution

Line 138: Two-tiered methane retrievals

Line 139: we employ the operational TROPOMI methane products.

Line 140: which is retrieved

Line 160: especially for observations from instruments deployed on satellite and aircraft

Line 163: can implicitly account for

Line 168: the physically based method requires background concentrations that are …

Line 173: The calculation process of methane enhancements (ΔXCH4, ppb) is as follows.

Line 179: in PRISMA, enhancements are calculated …

Line 186: with decreasing surface albedo

Line 197: Two-tiered attribution

Line 203: in a versatile spaceborne …

Line 218: progressively decreasing downwind

Line 222: and originate from …

Line 233: in high source regions, such as megacities, there are likely super-emitters that are undetectable following our method.

Line 235: Two-tiered quantification

Line 257: these processes have been described in previous studies

Line 259: the $\boldsymbol{U10}$ term., which typically has a random error on the order of 50%

Line 263: that can monitor global methane pledges

Line 265: originates. We need to account for

Line 278: As the robust relationship between the “minimum source” and the related methane enhancement developed by Jacob et al. (2016) and Guanter et al. (2021) shows, the detection threshold for the TROPOMI instrument is

Line 280: for the PRISMA instrument …

Line 287: shown potential for monitoring natural methane hotspots

Line 307: plumes originate

Line 338: the only explanation

Line 339: This has previously only been seen in …. Therefore, our multi-tiered outcomes indicate there are more widespread methane leaks than have been previously detected. Note that the multi-spectral retrieval algorithm cannot completely remove the albedo effects on our results. However, our methods could lead to targeted on-site re-inspection on O&G fields worldwide.

Line 343: Our framework detects

Line 346: current satellite constellations alone

Line 347: More satellites could capture changes during even shorter time windows.

Line 349: Figure 2 illustrates the extent to which the second-tier of our two-tiered satellite constellation explains the regional budget detected by the first tier.

Line 350:Delete this sentence: The overpass times (in Fig. 1) are usually different between the first and second tier observations.

Line 351. The share of the regional budget due to the plumes ranges from 8.2% (Hassi Messaud) to 53.8 ~ 65.9% (Rumaila, Burgan, and Wattenberg).

Line 354: different overpass time.

Line 361: this reinforces our hypothesis that

Line 363: different spatial scales

Line 366: different overpass times between the two-tiered results

Line 369: A regional survey in a California field provides some useful data for evaluating our results, owing to

Lines 371: The survey was conducted

Line 373: and included five campaigns

Line 375: The survey reports 1181 methane plumes, more than 500 times the number of plumes reported by previous aerial studies.

Line 377: Even though some regions of interest in our study are far less well known than the California fields, Line 378: the plumes detected by

Line 380: were conducted

Line 380: Satellite observations taken over the Permian basin ((one of the top O&G bases worldwide) from 2019 to 2020 (need reference here) provide additional comparison data.

Line 381: took advantage of

Line 383: survey acquired

Line 387: basin reported a much higher number of strong methane super-emitters, whose median emission rates (1850 kg/h) are much closer to

Line 388: although such comparisons are not quantitative due to many differences in measurement characteristics (e.g., spatial resolution and detection limit),

Line 389: they provide context for the emission magnitudes of the methane super-emitters we have identified and indicate that our results are within the range of values obtained from field campaigns.

Line 391: More importantly, these results highlight

Line 392: possibly emit as much methane as the California fields and Permian basin.

Line 393: Comparing emissions from our two-tiered approach with a state of the art methane emission inventory (EDGARv6.0) for 2018, (Fig. 4), we find that our emission estimates using TROPOMI data over methane hotspots are roughly consistent with the inventory, with biases ranging from -49.9% to +91.8% with an average bias of 63.2%. The exception is the Hassi Messaoud field in Algeria where the O&G sector is in rapid development: here our estimate is 498.2% of the EDGARv6.0 inventory.

Line 398: On the other hand, our estimates using PRISMA data over plumes are orders of magnitude greater than the EDGARv6.0 emissions. This suggests that traditional emission inventories may have acceptable performance for methane abundant regions but may grossly underestimate emission from methane super-emitters.

Line 401: There are a number of possible explanations for the low estimates from EDGARv6.0

Line 421: We have presented a two-tiered …

Line 422: We have demonstrated this framework with examples from around the world, with synergistic …

Line 423: We have located new methane super-emitters, tracked potential methane leakages from storage tanks, and resolved multiple methane plumes from a single source.

Line 426: our results suggest inventories miss unknown super-emitters and underestimate emission magnitudes, partly due to a surge in the number of oil and gas (O&G) facilities and widespread abnormalities in O&G operations.

Line 428: Our data prove that existing satellite missions can already lead to immediate …

Line 429: While window for achieving the Paris target is rapidly closing, our approach can provide improved methane emission estimates before the deployment of more advanced instruments, which can also be integrated into our system.

Line 432: Delete sentence starting with "In addition .."

Line 435: It should be noted that the multi-tiered framework is extremely flexible.

Line 441: based on multiple satellites, aircrafts, and UAVs will provide greater spatial coverages and more frequent revisits

Line 442: This flexibility will provide effective, efficient, and economic monitoring of global methane pledges, though this will require careful balancing of coverage and resolution between instruments.

Line 444: of our next study.

Line 445: LIDAR instruments (e.g., MERLIN (need reference) can retrieve methane fluxes day and night at all latitudes, in all-seasons, and in all-weather.

Line 447: Fourth, better characterizing methane vertical profiles would help to optimize our analysis, by minimizing the uncertainties in tropospheric air mass factors and subsequent methane enhancements.

Line 448: Finally, rapid advances in artificial intelligence (AI) techniques can significantly speed up the detection of faint signals from methane enhancements, and to …

Line 456: Still, large gaps remain in coverage and implementation (?). This is especially true for low- and middle-income countries, where tight budgets dim the hopes for filling these gaps by 2030, while methane emissions are likely to rise as countries continue to develop. In this context, the present framework can serve as a cost-effective component of the global methane monitoring network and thus support fair climate negotiations between countries.

This framework harmonizes global scale and high-resolution methane retrievals, with a dual focus on mapping region-scale and plant-level drivers. In this work the framework reconciles the wide swath of TROPOMI (i.e., ~ 2600 km) with the high resolution of PRISMA (i.e., 30x30 m2), in contrast to conventional satellite-based surveys, which suffer from either low resolution or narrow swaths.. Looking forward, developments of Earth's monitoring platforms (e.g., satellites, aircrafts, and unmanned drones) and artificial intelligence will continue to strengthen the performance of methane plume retrievals and emission estimates. On eve of the Paris target, at least while a methane product obtained from a instrument with a wide swath, high resolution, and agile analysis is not in place, our multi-tiered satellite constellation has important implications for measuring global methane pledges.

Line 464: Methane-abundant regions and associated super-emitters as captured by TROPOMI and PRISMA locations are marked by black rectangles and dots. Placenames were obtained from GoogleMaps, and are usually the names of the nearest O&G fields and coal mines. (b ~ g) Each row presents a methane-abundant region and the super-emitters detected within it (b1 ~ b4, c1 ~ c4, d1 ~ d4, e1 ~ e4, f1 ~ f2, and g1 ~ g2). For each super emitter (five-pointed stars), the overpass times of the multi-tiered satellite constellation and the consequent emissions estimate are presented. The base maps were obtained from GoogleMaps. The second color bar for PRISMA images is suitable for the super-emitters in China, while the first applies for other countries. Plume sources in the PRISMA results are marked by red circles.

Line 483: shown in Fig. 1. The 1:1 line is shown by grey dashes.

Line 486: The images of TROPOMI, MethaneSAT, PRISMA, and EnMAP are obtained from http://www.tropomi.eu/, https://www.methanesat.org, https://www.asi.it/en/earth-science/prisma/, and https://www.enmap.org/, respectively. The methane maps from TROPOMI and PRISMA refer to the results in Figs. 1e and 1b1. The grey marks indicate upcoming platforms (i.e., MethaneSAT and EnMAP) and techniques (e.g., AI techniques that can optimize the identification and quantification ofmethane super-emitters).