

## **Reply to reviewers of the manuscript “The sensitivity of the Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM) mission to dust aerosols: a pseudo-observations analysis”, Sellitto et al.**

Dear Editor, dear anonymous Reviewers #1-2,

Many thanks for your very kind words, your constructive criticism and the useful comments. Based on your comments, we have produced a revised version of our manuscript. As a main change in the revised manuscript, among others, we have added a Supplementary file with additional information on the background atmospheric states and dust profiles used in our sensitivity analysis.

Please find more details and a point-by-point reply to the Reviewers' specific comments in the following (Reviewers' comments are in black and our replies in blue). We think that, thanks to your comments and suggestions, the present version of the manuscript is further improved with respect to the previous version.

Thank you very much,

Pasquale Sellitto on behalf of all co-authors

### **Reviewer #1**

In this article, the authors test the sensitivity to dust aerosols of the instrument planned to operate during the upcoming FORUM ESA EE9 mission. They extended an existing radiative transfer model to simulate satellite pseudo-observations in different atmosphere and dust layer configurations for FORUM and related measurements from IASI-NG. Their results show how FORUM measurements will complete IASI-NG in the far infrared in situations involving dust aerosols. The subject is appropriate to AMT and scientifically relevant, useful and novel. The article is well-written and easy to follow. The figures are clear and well described. The discussion draws clear conclusions.

From my point of view the article could be published as-is. I have a few small points below [...].

Thank you for the kind word about our work. We have modified our text according to the technical comments you proposed.

### **Reviewer #2**

This manuscript presents a sensitivity study of dust aerosols' mineralogy, loading, vertical distribution, and the background atmosphere to FIR (15-100  $\mu\text{m}$ ) observation from FORUM mission and compares the sensitivity to the MIR (2.5-15  $\mu\text{m}$ ) observation from IASI, using a pseudo-observation simulator. It demonstrates a significant FIR spectral signature of dust (up to 50% of the longwave spectrum), which can complement the MIS observation, especially for relatively thick dust in the free and upper troposphere. The manuscript is well-written with detailed demonstrations of the methodology. The science merits publication in AMT, I have some minor suggestions listed as follows.

1) Line 102: The PO is limited at nadir viewing angle, which should be recognized in the last section, as it is relatively important.

We added the specification that the pseudo-observations are with a pure zero-nadir-angle geometry.

2) Line 107: The two atmospheric profiles representing tropical and polar regions should be shown in either the manuscript or the supplementary documents, especially the water vapor profile, which is directly related to Section 3.3.

3) Line 115: What is the assumption of the two vertical distributions of dust (e.g., normal distribution with a central height)? The plot for dust vertical distributions is needed in either the manuscript or the supplementary documents.

We added a Supplementary file with these figures (Fig. S1: temperature and water vapour profiles for polar and tropical backgrounds; Fig. S2: the two dust aerosol profiles) and referenced these in the text.

4) Line 120: As this study is using a PO for the FORUM observations, why not use a more realistic particle size distribution (SD) (e.g., from in-situ measurements as presented in Formenti and Di Biagio (2024)) instead of using a monomodal lognormal size distribution?

While this is in principle possible, in our present implementation our RTM simulate the aerosol layer with a pure log-normal size distribution (SD). We plan to extend analyses of the SD sensitivity in future works.

5) Line 160: Using Mie calculation with spherical assumption for dust needs to be justified, for example, by providing the evidence (or direct references) that dust optical properties are insensitive to particle shape in MIR and FIR spectrum.

There is a sensitivity to particles shape, in the infrared region, but this is quite limited for these typical size/wavelengths combinations. To account for this, we added the following sentence: “The effect of dust particles asphericity on their optical properties calculations with a Mie code was estimated smaller than 10% in the MIR (e.g. Pierangelo et al., 2004) and is expected to be even smaller at longer wavelengths in the FIR spectral region (e.g. Bohren and Huffman, 1983).”

6) Line 173 and Table 1: At which wavelength is the AOD used as the input for the RTM in this study? It should be presented in text and in Table 1. It is also a bit confusing for “average value in the FORUM spectral range” in Table 1. Does it mean the spectral AODs in the entire FORUM spectral range are constant? If yes, it would not be appropriate, and it is suggested to follow the spectral extinction coefficients based on the CRI and SD. If not, the AOD at which specific wavelength is needed.

The AOD used in the input of KOPRA-FIR, and estimated with the embedded Mie code as mentioned in the text, is for the whole FIR and MIR spectral range of the FORUM and IASI-NG PO. Specifically for the two simulations listed in Tab.1 (see also e.g. Fig. 3), we optimised the aerosol concentration profiles so to have AODs values averaged in the FORUM range ( $100\text{-}1600\text{ cm}^{-1}$ ) of 0.2 and 0.5. While, of course the spectral AOD in the entire FORUM range is not constant, the variability is relatively small because of the relatively small particles when compared with the wavelengths, especially in the FIR.

7) In Section 3.2, the Jacobian calculated in this study is the radiance to the number concentration, which is optically to the AOD with the fixed particle size distribution assumption. Therefore, the sensitivity of dust in MIR and FIR is with respect to the aerosol burden, which is similar in terms of spectral behaviors in MIR and FIR. Therefore, using either MIR or FIR could have similar spectral radiance sensitivity to the AOD or number concentrations. The FIR does not provide additional information content in terms of retrieving AOD. Therefore, the contribution of FIR to the total sensitivity in infrared is not appropriate to be simply divided by the add-up sensitivity, as the information content between them is similar.

We are not completely sure to get this comment. The specific study in Sect. 3.2 is for the sensitivity to the vertical profile of the dust aerosols number density with the 4-dimensional variability of dust and atmospheric parameters. The sensitivity is different at different altitudes (see e.g. Fig. 5c and 6) and depends on the different scenarios, including the two AOD scenarios, producing different sensitivities in the MIR, FIR and their ratios (Fig. 6) in terms of both magnitude and vertical shape. Thus we think that it is appropriate and informative to use the sensitivity parameter defined in Eq. 2.

8) Based on Figures 3 and 4, the FIR sensitivity to dust CRI is more distinguishable from the CRI sensitivity in MIR. Thus, it is suggested to calculate Jacobians with respect to the different mineral fractions (e.g., Quartz and Feldspar) to further look at the sensitivity contribution of the FIR.

9) According to the size parameter differences in different wavelengths with the same particle SD, the sensitivity of spectral radiances to dust particle SD would also be different between FIR and MIR, which is also suggested for the authors to consider.

Both these two sensitivity analyses will be possible with future implementations of our RTM and are active matter of ongoing work (see also Comment 4).

Reference:

Formenti, P. and Di Biagio, C.: Large synthesis of in situ field measurements of the size distribution of mineral dust aerosols across their life cycles, *Earth Syst. Sci. Data*, 16, 4995-5007, 10.5194/essd-16-4995-2024, 2024.