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Response to the reviewers

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Reviewer 1

This paper deals with exploring the capabilities in aerosol optical properties retrieval with the Flexible Combined Imager (FCI) onboard the Metosoat Third Generation satellite. The core of the study is to explore the improved retrievals in AOD using the VIS04 channel in FCI and compare the potential of these new retrievals with those in SEVIRI MSG. Authors also explore the capabilities of determining aerosol fine mode fraction using NIR22 channel. The topics are of interest to the scientific community and deserve publication in AMT. However, there are some concerns that need to be addressed before: First, I believe there is essentially nothing new in the retrieval algorithm and the title should be re-though. But most importantly, in my opinion the paper is too lengthy, and it is difficult to catch the main message. I believe that the manuscript can be shortened significantly but keeping the essence of the study. But I understand that the style of the authors must be respected.

We thank the reviewer for the valuable comments and the time spent reviewing our work. We have attentively addressed all the raised issues and have produced a shorter revised version of the manuscript as suggested. Please find below our replies to the comments and questions from the reviewer (shown in italics). The line numbers given in our answers correspond to the revised manuscript, with the "track changes" mode on.

While it is worth noting that the main purpose of our work is to assess the FCI potential for aerosol retrieval (and not to propose new inversion methods), the reviewer is right when saying that the AOD retrieval algorithm used in our manuscript is not new. Indeed, this corresponds to the method we satisfactorily used in previous works using real GEO data (Ceamanos et al., 2023; Georgeot et al., 2024). However, it must be noted that the AOD/FMF retrieval method contains a certain novelty, mainly in the use of the linear mixing model to account for fine and coarse modes. We agree that the initial title could be a bit misleading, as both AOD and FMF are variables that are commonly retrieved from satellite missions, mainly LEO-based. This is however not the case for geostationary missions, and Meteosat in particular, which makes AOD/FMF retrieval novel in this context. We have therefore modified the title accordingly as it follows: "Towards improved retrieval of aerosol properties **from the geostationary orbit** with the new Meteosat Third Generation-Imager geostationary satellite".

Regarding the length of the manuscript, we have produced a shorter version as suggested by the reviewer by removing some parts of the initial manuscript (e.g., Figure 1, Sect. 4.3.1, equations in Appendix B) and moving some others to the appendices (e.g., Sect. 2.3, Sect. 4.1 and Sect 4.2). With this, and after revising many parts of the manuscript to improve its clarity, we believe that the revised manuscript enables to catch the main messages more easily now, while keeping the essential information.

Apart of my previous concerns related to the shape and structure of the manuscript, I believe that there is not enough discussion of the sensitivity of the retrieval to errors in the input optical data – or at least it as not been clear for me -. For example, I see many diurnal patterns in TOL, AOD... that seems to follow the pattern in SZA and I wonder if there is an artifact in the retrievals that amplifies errors. I also believe that the assumptions in surface and aerosol models are too strong when going to the real world. This should be at least discussed, although it is true that the information content for

aerosols is low in the FCI when compared with more advanced imagers/polarimeters.

We acknowledge the existence of retrieval errors that depend on SZA (and therefore the time of the day in GEO observations) in some of our experiments based on synthetic data. According to our experience, this is something expected in AOD retrieval from real GEO satellite data due to the variation of the AOD information content during the day. This diurnal variation actually comes from the diurnal change in solar geometry, which results in a diurnally varying aerosol scattering (peaking when SZA is high, and therefore scattering angle is low; eg. at the beginning and end of the day over regions along the 0° meridian) and an also diurnally varying surface reflectance (peaking when SZA is low, and therefore scattering angle is high; eg. around local noon along the 0° meridian, see TOL reflectance curves in Fig. 3a). As a result, AOD retrieval becomes more difficult at noon over Western Europe, for example, due to the combination of a weak aerosol signal and a much stronger surface reflectance, which in turn amplifies any bias existing in the input data. This explanation was added in L321 of the revised manuscript. It must be noted that some of our experiments, other parameters such as surface reflectance do not introduce errors in the retrieval process because they are known in the retrieval (e.g. Sect. 3.2.1; in this case, the retrieval error comes from other sources, and can be amplified by the diurnally changing AOD information content). In experiments in Sect. 3.2.2, however, some parameters are intentionally biased before their use in the retrieval to mimic more realistic situations in satellite remote sensing, thus impacting the quality of AOD retrieval.

As for the assumptions on aerosol model and surface reflectance, experiments in Sect. 3.3.2 aim to get closer to real world conditions by assessing the impact of using some "wrong" parameters (ie. different from the input data used for simulation) for inversion. In particular, experiments A and B consider wrong aerosol properties, while experiment C considers a wrong surface reflectance. In this section, we observe less good results than in the "ideal" case (Sect. 3.2.1) mainly for FCI channel VIS06, while results are still good for channel VIS04 thanks to its increased information content. In our opinion, these experiments show that it should still be possible to obtain accurate information on aerosols with real FCI data even if surface and aerosol models are not perfectly known. According to the reviewer suggestion, we have added a new paragraph on this point in the conclusions: see L493 "It must be noted that the retrieval accuracies observed in this study may be degraded when processing real FCI data, mainly due to differences between the optical properties of the aerosol models used for inversion and those of the real world aerosols observed by FCI (e.g., showing a large variability of mixtures in the case of desert dust and biomass burning particles). In the near future, the inversion methods used in this work will be tested with actual FCI data and real world limitations will be determined. For example, the consistency of the hybrid model used for FMF/AOD inversion with respect to the natural variability of smoke and dust particles will be assessed. Furthermore, the use of daily averages of retrieved AOD and FMF to constraint the second inversion of the two-step method will have to be circumvented if we are to meet near real time constraints."

MINOR REVISIONS

- *Line 36: It is not true that you try to address particle size distribution. You are trying to estimate fine mode fraction. Please correct.* This was corrected.
- *Line 48: FCI is not constantly covering the entire Earth, just part of it. Please correct.* This was corrected.
- *Figure 1: It is not discussed in the text. What is the point of including Figure 1.* Figure 1 was removed.
- *Figure 2: Biomass-burning and dessert dust are illustrated as aerosol types. But in the real world, there are large variability and mixtures of biomass-burning and dessert dust. Assuming all aerosols within these types have the same properties is too simple, although it helps in satellite retrievals. I recommend being careful in the discussions.* We agree that our dust and smoke models are a simplification of real world conditions, which we made in our study for the sake of simplicity. The larger variability of real aerosols and the potential impact of not accounting for it is now mentioned in a new paragraph in the conclusions (see L493). It is worth noting, however, that this point was addressed when adding uncertainties in the retrieval process in Section 3.2.2. For example, we have seen in Exp. B that modifying the single scattering albedo (and therefore

considering that the observed smoke or dust do not correspond to the aerosol model used for inversion) does affect the quality of AOD retrieval, but much less in channel VIS04 than in channel VIS06. Similar results are obtained in Exp. A when a completely different aerosol model is used.

- *Line 139: I do not understand the expression 'satellite synoptic'.* The term "synoptic" was removed.

- *Section 2.3 Simulation of Synthetic Data: I strongly recommend using a box-chart to help the reader better understand the different steps.* A new figure has been added (see Fig. A1).

- *Line 147: What is TOL? Please define the acronyms at least the first time they appear. Similar happen to others (i.e. MSA, DFS, SZA, RAA). Please, be careful.* We have added a table of acronyms in Appendix E and made sure all of them are explained when they first appear in the text.

- *Section 3.1 Sensitivity Study: To me, a sensitivity study is to study the impact of random and systematic errors in the retrievals. Maybe it is necessary to rephrase this section.* This word usage was incorrect and has been corrected. Now, all occurrences of "sensitivity study" in the manuscript have been renamed "information Content Analysis".

- *Line 259: I do not see clearly how Table 2 confirms NIR22 potential to distinguish between fine and coarse mode. Can you specify ?* According to the reviewer comments, this was clarified by adding the following sentences L251: "as in this channel DFS is much higher for coarse aerosols (predominant in CS1) than for fine aerosols (predominant in CS2), respectively, 0.52 versus 0.03. The latter value confirms the almost inexistent information content on fine particles in NIR22, which means that an AOD signal retrieved in this channel will very likely mean that the observed aerosols consist of coarse particles"

- *Table 3: What is w.r.t VIS06?* This was corrected, and replaced by "diff. to VIS06", meaning the scores difference with respect to VIS06. This is now explained in the caption of the table.

- *Table 5: Can you explain better the first column? What is w?* This was corrected, and ω was replaced by the acronym of single scattering albedo (i.e. SSA).

- *Section 4.5.1: I wonder how you are going to apply your inversion approach to real FCI data. Can you explain something?* We have added some discussion about this subject in the "Conclusions" section (L495): "In the near future, the inversion methods used in this work will be tested with actual FCI data and real world limitations will be determined. For example, the consistency of the hybrid model used for inversion with respect to the natural variability of smoke and dust particles will be assessed. Furthermore, the use of daily averages of retrieved AOD and FMF to constraint the second inversion of the two-step method will have to be circumvented if we are to meet near real time constraints."