

Atmos. Meas. Tech. Discuss., author comment AC1
<https://doi.org/10.5194/amt-2022-82-AC1>, 2022
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Reply on RC1

Marco Ridolfi et al.

Author comment on "Synergistic retrieval and complete data fusion methods applied to simulated FORUM and IASI-NG measurements" by Marco Ridolfi et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2022-82-AC1>, 2022

Please find below, Author Replies to referee #2 comments. For convenience, original referee's comments are included in *italic*.

Review of "Synergistic retrieval and Complete Data Fusion methods applied to FORUM and IASI-NG simulated measurements" by Ridolfi et al.

General comments

In this new study, Ridolfi et al. explore and compare the synergistic retrieval (SR) and complete data fusion (CDF) techniques for the upcoming European FORUM and IASI-NG infrared sounders. The authors discuss retrieval experiments for temperature, humidity, and surface temperature and emissivity for a clear-sky Antarctic atmosphere. Retrieval experiments are conducted for the cases of i) perfectly matching nadir observations of FORUM and IASI-NG and ii) potential mismatch or co-location errors of both instruments. It is demonstrated that the retrieval results of both, the SR and CDF techniques, provide good performance and agree well within the measurement noise errors of the FORUM and IASI instruments for both test cases.

Overall, this is a very carefully designed study with convincing results. The manuscript is well written, clear, and concise. It will be of interest to the retrieval community and I would like to recommend considering it for publication in AMT, subject to a few specific comments and corrections as listed below.

We thank the anonymous reviewer for the constructive comments. According to the reviewer's main comment, we have now run two additional test experiments: one based at Mid-Latitudes and one based at the Tropics. In the revised manuscript, we will summarize also the results of these two additional experiments, which, actually, do not change the conclusions of the paper, though, as expected, we find surface emissivity errors much larger than in the dry Antarctic conditions. We plan to supply as "supplemental material" (or to upload to Zenodo) the plots relating to the new experiments. We believe that, with this integration, the results presented are more robust and consolidated than before.

Specific comments

134-38: A number of references on the CDF technique is given below, but it seems this paragraph is lacking references on the SR technique.

We agree, in the revised manuscript we will cite a few papers on the SR technique also at this instance. Namely, we plan to cite Cuesta et al. 2013, 2018; Fu et al. 2013, 2016; Kuai et al. 2013; Landgraf, J. and Hasekamp, 2007 and Natraj et al. 2011.

152-59: I remember seeing a few new papers on FORUM being submitted or published during the last 1-2 years. As FORUM is a new instrument, perhaps it might be good to add a few more references to this paper to provide a bit more background information for the reader? Same for IASI-NG.

In the revised version of the manuscript, for FORUM we will cite also Carnicero et al. 2020, Pachot et al. 2020, Di Natale et al. 2020, Ben Yami et al. 2022, Di Natale and Palchetti, 2022, Sgheri et al. 2022. For IASI-NG, we plan to cite Bermudo et al. 2014, Clerbaux and Crevoisier 2013 and Andrès et al. 2018. We are open to include further references that the reviewers may wish to suggest.

164-66: The retrieval test cases presented here refer to a perfect situation due to the transparency and sensitivity to surface emissions of the Antarctic winter clear-sky atmosphere. The reader might ask, though, how large are the degradations for non-optimal atmospheric conditions at mid-latitudes or in the tropics?

This is correct. At latitudes different from Polar, when the atmosphere is not so dry, surface parameters can be hardly retrieved. Particularly, the sensitivity of the FIR spectral radiance to FIR surface spectral emissivity vanishes as soon as the atmosphere becomes opaque in this region, due to the water vapour absorption. A detailed study of the FIR emissivity retrieval performance for varying latitude and season is still missing, though it may be part of our future activities. So far, some results on this issue are presented in Oetjen et al. 2019, in Ridolfi et al. 2000 and in Ben Yami et al. 2022. Roughly, the outcome of these investigations is that FIR emissivity can be retrieved from FORUM with useful accuracy (absolute error in the range 0.01 – 0.02) only in dry Polar atmospheres. On the other hand, Polar Regions are the most interesting for the study of FIR surface emissivity, as the latter has an impact on the Outgoing Longwave Radiation, thus it influences the capability of our planet to lose heat to space.

Regarding temperature and water vapour profiles, as shown in Ridolfi et al. 2000, their retrieval error depends less critically on latitude / atmospheric conditions, as the retrieval extracts information on these parameters from the whole spectral interval measured.

In the revised paper, we will further extend the explanations in lines 64 – 66, and will include a summary of the results of the two additional experiments we have run for Mid- and Tropical latitudes (see also the general answer given above).

How often are perfect conditions in the atmosphere being found so that the SR and CDF techniques can be applied ?

The SR and CDF techniques can always be applied, as the retrieval is based on optimal estimation, thus the inversion is always possible, even in the unlucky scenarios in which the measurements are not sensitive to the target parameters. Of course, in the latter case

the retrieval and the CDF return the a priori state, thus the solution does not provide (or provides only little) extra information as compared to the a priori. In this case, the solution has an error equal (or similar) to the a priori error and its number of degrees of freedom approaches zero.

To which extent do the findings on the good agreement between SR and CDF still hold for non-optimal conditions?

This is an important point, thus in the mean time we carried out two additional test experiments at Mid- and Tropical- latitudes. In the revised version of the paper, we will report also the outcome of these new tests. The agreement between SR and CDF is linked to the degree of linearity of the forward model for variations of the state \mathbf{x} in the range of the solutions \mathbf{x}_1 and \mathbf{x}_2 of the individual retrievals. Since the individual retrievals are constrained with the same a priori estimate, with a reasonably "small" error, we do not observe an important degradation of the agreement between SR and CDF for different atmospheric conditions.

176: I would like to suggest to introduce a new subsection directly at the beginning of Sect. 2. For example, "2.1 SR and CDF retrieval theory", or similar.

OK, this can be done.

1309-313: This might be another place in the paper suitable to discuss and motivate why only a single (perfect) scenario was selected for the retrieval experiments.

Yes, in the revised version of the manuscript, here we will include a paragraph to further explain the rationale of this choice and we will complement the discussion with the results of the new test experiments mentioned above.

1320 and 1374: Introduce a new subsection 5.1 ("Results for perfectly matching measurements") at the beginning of Sect. 5?

OK, this can be done.

1377-380: I may have missed it earlier in the paper, but when considering the horizontal mismatch of up to 26 km, did you also consider horizontal smoothing effects related to the IFOV of the FORUM and IASI-NG instruments?

No, the smoothing effect of the finite aperture of the IFOV (15 and 12 km for FORUM and IASI-NG, respectively) is not considered, neither in the forward, nor in the inverse simulations. This choice is motivated by the fact that: a) we do not have a very high resolution (~ 1 km) atmosphere / surface model to simulate realistic IFOV inhomogeneities and b) so far a detailed instrument model with the capability to predict the effect of IFOV inhomogeneities onto the measured spectral radiance is not available. In the revised paper, we will mention explicitly this assumption.

l381-383 and l391-392: Why are different surface emissivity models for snow applied for FORUM and IASI-NG?

This is to emulate the mismatch between the measurements, i.e., the two instruments may not sample exactly the same surface area, thus the sounded snow may be different.

l416: Maybe clarify "For a specific test scenario _with perfect/most suitable atmospheric conditions_ ..."?

Yes, in the revised manuscript, this sentence will be modified, also considering the outcome of the new test experiments we carried out in the meantime.

Technical corrections

l331: fix sentence ("...is the reference a coarse snow...")

l399-400: merge dangling sentence with previous or next paragraph

l402: "this latter" -> "the latter"

All the technical corrections will be implemented in the revised manuscript.

Thanks again for your kind support.