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Atmospheric Measurement Techniques Discussions

Interactive comment on "Retrieval of MetOp-A/IASI CO profiles and validation with MOZAIC data" *by* E. De Wachter et al.

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We would like to thank the referees for their time and useful comments to help improve this paper. Hereby our replies to the different points which were addressed.

Anonymous referee #2

Major issues

1) *Given that it appears this is the first time this algorithm is introduced, and that its products will be widely distributed, I would expect a more detailed description of the algorithm (and future data users deserve to have one). But there is no reference to any detail algorithm description or something like an Algorithm Theoretical Baseline Document (ATBD), so I assume none exists (at least not publicly).*

The heart of SOFRID is the RTTOV radiative transfer code developed within the NWP-SAF by the European meteorological community (ECMWF , Met-Office, Météo-France, KNMI...). RTTOV which is used for a wide range of applications by a wide community possesses a number of documents that describe it. The general documents describing RTTOV are available on the website of the NWP-SAF (http://research.metoffice.gov.uk/research/interproj/nwpsaf/rtm/rtm_rttov9.html). The website is constantly updated for the RTTOV large user's community. The most important documents describing RTTOV are the user guide and the Science and Validation report.
Furthermore, specific developments concerning IASI in RTTOV are published as Technical Memos on the ECMWF website (www.ecmwf.int/publications/). For instance, the fundamentals of the IASI radiative transfer module in RTTOV are described in details in many ECMWF memos since 2000 (tm324 in 2000, tm345 in 2001, tm425 in 2003). The latest generation of RTTOV regression coefficients for IASI is also described in http://www.ecmwf.int/publications/library/ecpublications/_pdf/tm/501-600/tm564.pdf.
Finally, RTTOV is described in details in scientific papers that synthesize the information given in the above-mentioned technical documents. In our paper we cite the most important RTTOV publications where the reader will find more details and references to the technical documents.

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We can therefore state that SOFRID is based on RTTOV because RTTOV is used by a large community, updated regularly and is fully documented as it has been shown above. This was maybe not clear to the reader from the previous text, so we changed page 3275, L24-25 as follows:
"The radiative transfer calculations are performed with the RTTOV-9.3 fast radiative transfer model developed for the meteorological community within the NWP-SAF. The RTTOV algorithm is described in detail in Saunders et al. (1999) and Matricardi et al. (2004). The overall accuracy of RTTOV has been addressed using IASI data in Matricardi et al. (2009). The RTTOV software is available free of charge on request from NWP-SAF at http://research.metoffice.gov.uk/research/interproj/nwpsaf/rtm/rtm_rttov9.html.
General documentation about RTTOV is provided at this website and detailed information about the IASI radiative transfer in RTTOV is provided in Technical Memoranda (cited in the above mentioned publications) at the ECMWF website (http://www.ecmwf.int/publications/library/do/references/list/14)."

SOFRID also uses the 1D-Var retrieval scheme developed at UKMO within the NWP-SAF. The UKMO 1D-Var reference publication is cited in the paper together with the Rodger (2000) paper describing the fundamentals of the optimal estimation method (or 1D-Var). As 1D-Var is a widespread retrieval method, we find it unnecessary to describe it in detail.

Referee #2 also stated that *If that is the case, then the algorithm description in this paper is insufficient. For example what is missing are sensitivity and error analyses. How sensitive is the retrieval to errors in the spectroscopy, meteorological input like temperature, humidity, wind speed, surface pressure and skin temperature, the surface emissivity database, instrument errors and calibration, the simultaneous N2O retrieval and the cloud filtering. Such detailed information was provided for FORLI*

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in the study by Hurtmans et al. (2012), so I think this is also required for SOFRID.

Here we disagree with reviewer #2 for 2 main reasons:
First, SOFRID and FORLI beneficiate from equally detailed descriptions.
The paper by Hurtmans et al. (2012) describes the FORLI retrieval algorithm. Section 3 of Hurtmans et al. (2012) describes the forward model which is done among others in Matricardi et al (2004) for RTTOV (and therefore SOFRID). Section 4 describes the inverse model. Paragraph 4.1 is dedicated to the calculations of derivatives which are described in Saunders et al. (1999) for RTTOV. Paragraph 4.2 describes the optimal estimation method used for the retrieval in FORLI. SOFRID uses the same retrieval method which is described in details in Rodgers (2000) (cited in the paper). Paragraph 4.3 gives the parameters used for the retrieval of the 3 gases (O_3, CO and HNO_3) by FORLI. These parameters are given with all the necessary information for SOFRID CO retrievals in the present paper. Finally, Hurtmans et al. (2012) gives some technical details about the performances of FORLI and shows some global results and characterization of the products.

Secondly, both SOFRID and FORLI lack of detailed description of a number of error sources:
Indeed, Hurtmans et al. does not give "detailed information" about "How sensitive is the retrieval to errors in the spectroscopy, meteorological input like temperature, humidity, wind speed, surface pressure and skin temperature, the surface emissivity database, instrument errors and calibration, the simultaneous N_2O retrieval and the cloud filtering". Instead, it is stated in Hurtmans et al. (2012) that: "the error sources from fixed parameters are currently not explicitly taken into account in FORLI".
Such a detailed information concerning IASI CO retrievals is also not provided in George et al. (2009) or Turquety et al. (2009) which were the first publications concerning IASI CO retrievals. Nevertheless, a detailed error analysis concerning CO retrievals from a spaceborne FTIR spectrometer very similar to IASI (IMG on

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the ADEOS plateform) was done in Barret et al. (2005). In this study, it was shown that: "...the dominant error at all altitudes is the smoothing error. The three other contributing errors are the measurement error and the errors uncertainties on the air temperature and on the Instrumental Line Shape (ILS). The two latter terms contribute mainly below and above 10 km, respectively. Errors caused by the simultaneous retrievals of the surface temperature, H_2O and N_2O are not shown as they do not provide a significant contribution to the total error."
A detailed study of errors for TES (also a nadir FTIR spectrometer) retrievals is also available in Worden et al. (2004). Concerning CO, they come to the same conclusions as Barret et al. (2005). They show that the dominant source of error is smoothing and that the measurement error is larger than the systematic error which takes into account uncertainties on atmospheric and surface temperature and on water vapour.
Following Barret et al. (2005) and Worden et al. (2004) we therefore assume that the dominant source of error for IASI CO retrievals is the smoothing error followed by the measurement error.

Concerning the other error sources cited by reviewer #2:

- wind speed: retrieval tests with this parameter used to compute the sea emissivity or with a constant sea emissivity has shown a negligible impact on the retrieval. Furthermore, FORLI is not using a wind speed dependent sea emissivity and no particular discrepancies are found between SOFRID and FORLI over seas.
- surface pressure: we use ECMWF surface pressure which accuracy is estimated to be 2-3 hPa (O'Dell et al., AMT, 2012) which represents 0.2-0.3% at sea level. Even increased by interpolation to the IASI pixel, surface pressure errors are therefore causing negligible errors compared to the smoothing error.
- skin temperature: it is strongly correlated to the surface temperature which retrieval (simultaneous with the CO profile such as in FORLI) is not responsible for

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important errors according to Barret et al. (2005).

- instrument error and calibration: their impact upon the retrieval is included in the "measurement error" which is part of the retrieval error computed by SOFRID and given in the paper.
- surface emissivity: within the narrow retrieval window (4.58-4.66 mm) the surface emissivity is almost constant constant (variations lower than 0.01). Therefore, as both parameters are strongly correlated, retrieving the surface temperature (which is done in FORLI and SOFRID) is similar to retrieving the surface emissivity and biases in surface emissivity are corrected. Furthermore differences between FORLI and SOFRID emissivities at both sites are within 0.01. This small difference between 2 databases is a proxy for the uncertainty on the emissivity and shows that this uncertainty could not impact CO retrievals more than 1%. We can therefore assume that emissivity errors will have only a negligible impact upon CO retrievals.
- spectroscopy: the study dedicated to evaluate errors for TES retrievals (Worden et al., JGR, 2004) have shown that CO line parameters uncertainties in the 4.7 mm domain were "small enough to ignore".

2) Clarity comparison *all* MOZAIC profiles + extension different airports:

Indeed, in Section 4.3 the results for all coincident profiles are discussed. From this set 438 coincidences for Frankfurt and 229 coincidences for Windhoek were found. For the other airports represented in this set usually $<$5 coincidences up to a max. of $\sim$60 coincidences (for only 4 airports) were found. This is a quite poor representation of the other locations compared to Frankfurt and Windhoek. It was our

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choice to discuss the temporal variation of the CO partial columns, which I believe gives a great deal of insight into the quality of the data. Only the two locations Frankfurt and Windhoek give a sufficient number of datapoints to discuss the temporal variation. Including here a statistical analysis on 4 additional airports gives little extra value to the paper, I believe, and would only draw the attention away from the more detailed analysis later on.

To clarify that coincidences with *all* MOZAIC profiles are discussed in Section 4.3, we adjusted the last paragraph of Section 3, at the same time clarifying the minor point on page 3279, L11-13 (*Do you mean that there are many measurements (many take-offs and landings) so that it properly samples the seasonal cycle?*):
"For the validation of IASI CO, all MOZAIC observations taken at take-off and landing in 2008–2009 were taken into account. The results of the statistical analysis are given in Sect. 4.3. For most of the 30 airports sampled by MOZAIC in 2008–2009 the number of coincidences with IASI data comprised between 5 and 60 and was insufficient to sample seasonal variations. The two airports, Frankfurt, Germany (50.1 N, 8.7 E) and Windhoek, Namibia (22.6 S, 17.1 E) are sampled with a high frequency during the 2008-2009 period, and give us the opportunity to study the seasonal cycle at these geographical locations. Therefore a comparative study of the temporal behavior of the IASI data and the MOZAIC data recorded during take-off and landing at these two airports is investigated in Sect. 4.4."

In addition, the first line of Section 4.3. was changed to:
"Table 1 presents the results of a linear regression analysis between the two IASI retrieval products and MOZAIC partial columns for 980 coincident observations taken at 30 airports in 2008 and 2009."

In the conclusion, after the second sentence:
"A quality assessment of the retrieved IASI CO products was given by a detailed

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comparison with airborne observations recorded observations recorded at 30 airports in 2008–2009 within the MOZAIC program."

and at L20 (Page 3286):
"During 2008–2009 these two airports are the only ones to have enough MOZAIC CO observations for a correct seasonal cycle sampling."

3) The missing information in MOZAIC for altitudes where IASI is still sensitive:

The MOZAIC aircraft profiles are complemented by Aura/MLS profiles at altitudes higher than the aircraft altitude. The upper limit of 225 hPa was still chosen to be within the boundary limit of the aircraft profiles, so that if there would be any bias at the highest altitudes we would not have to question whether this would be due to the Aura/MLS data. This was indeed not clearly mentioned in the paper. Thank you for pointing that out. We added the following sentence at page 3281, after L26:
"The MOZAIC profiles were completed by coincident profiles from Aura/MLS at altitudes above the cruise altitude of the aircraft, to account for the missing altitudes where IASI is still sensitive."

Minor issues

Page 3273, L3: was changed accordingly.

Page 3273, L6: this reference was added.

Page 3273, L12: was changed to: "Thermal infrared (TIR) nadir sounders can provide information about the vertical distribution of tropospheric trace gases with a high spatial resolution."

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Page 3274, L14-17: this was changed accordingly.

Page 3274, L18-19: this was changed accordingly.

Page 3275, first paragraph: the spatial resolution was given in the last sentence of the first paragraph "..(12 km at nadir).", but we expanded this to:
"It provides global Earth coverage twice a day, with an overpass time at ∼09:30 and ∼21:30 LT (local time) and a nadir spatial resolution of 50 km x 50 km, composed of 2x2 circular pixels, each corresponding to a 12 km diameter footprint on the ground at nadir (Clerbaux et al., 2009)."

Page 3276, L5-6: this was changed accordingly.

Page 3278, L11: this was changed accordingly.

Page 3279, L11-13: yes, indeed. See reply on major point 2.

Page 3280, L5: : this was changed accordingly.

Page 3280, section 4.2: The goal of the paper is to give a quantitative comparison of the two IASI products, SOFRID and FORLI, with a reference set (the MOZAIC data) and not compare the two IASI products. We therefore only wanted to give a brief qualitative comparison of the global IASI data, to see how they perform on a global scale, whether the same features are observed by the 2 products etc. Including the statistics here would ask for a more detailed description on how the calculation was done and a continuation of the quantitative comparison between SOFRID and FORLI later on, which is beyond the scope of this study.

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Page 3281, L1: this was changed accordingly.

Page 3282, L15-16: this was changed accordingly.

Page 3283, L2-3: this was changed accordingly.

Page 3283, L7-8 and L9-10: this was changed to:
"This is linked to the insensitivity of IASI to boundary layer (BL) pollution in winter-spring when the BL height and the thermal contrasts are low (see the discussion below on Figs. 7 and 8)."
I would still like to reference to the later discussion on this matter.

Page 3283, L25: this sentence was omitted (following the changes made including now the rmsd).

Page 3286, L22: this was changed accordingly.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 3271, 2012.