Reply to the Interactive Comment Atmos. Meas. Tech. Discuss., 8, C5512–C5514, 2016

**Comments:**

**1) p. 13732 l.1-3: Plese revise this senstence, which does not seem to make any grammatical sense. I assume that either the word "be" or the word "show" have not been deleted from a Prior Version of the manuscript.**

**2) p. 13732 l.13: I do not agree that 12km is "excellent" horizontal Resolution, please replace by "good" or something else.**

**3) p. 13733 l.14: Please replace "measured", as the IASI measurements only provide radiation intensity. I would rather suggest something like "...retrieved operationally from IASI measurements..."**

**4) p. 13733 l.17: Please specify "infrared solar spectra".**

All the suggestions proposed by the referee in the comments 1-4 will be implemented in the revised manuscript.

**5) p. 13737 l.3-11: It might be worth to already here pointing out that Izana episodically observes outbreaks of desert dust from the Sahara.**

In order to improve the description of the Izaña Atmospheric Observatory's atmospheric conditions, we have extended the section 3 including the referee's suggestion as follows (the new text is highlighted in italic):

The Izaña Atmospheric Observatory (IZO), run by the Izaña Atmospheric Research Centre (IARC, http://izana.aemet.es) belonging to the Spanish Meteorological Agency (AEMET), is a subtropical high-mountain observatory on Tenerife (Canary Islands, 28.3ºN, 16.5ºW, and 2373 ma.s.l., Fig. 1), *and only 350 km away from the African continent*. It is usually well above the level of a strong subtropical temperature inversion layer, which acts as a natural barrier for local pollution. This fact, together with the quasi-permanent subsidence regime typical of the subtropical region, makes the air surrounding the observatory representative of the background free troposphere (particularly at night-time) (Gómez-Peláez et al., 2013; Cuevas et al., 2015, and references therein). *These conditions are only significantly modified by episodes of mineral desert dust events during summertime, when Saharan dust long-range transport into the Atlantic (which even can reach the Caribbean) is quite common (e.g., García et al., 2012, and references therein).*

**6) p. 13739 l. 8-16: I am missing an acknowledgement of the possibility of errors not included in the model, such as the ignorance of desert dust or thin cirrus clouds in the fields-of-view. Is that by any means represented in the Rodgers formalism? Otherwise the error Budget might be significantly underestimated.**

As the referee suggested, our error estimates could slightly be underestimated due to the disregard of error sources as well as the underestimation of the assumed uncertainty values. However, we consider that the leading error sources affecting the different FTS products, identified from our wide experience on the ground-based FTS technique and from the literature, are properly taken into account. In addition, as the paper stated in section 3, a continuous experimental documentation of the quality of the different FTS products is performed at IZO by comparing to other high-quality measurement techniques. The numerous studies carried out at IZO (see Table 3 of the paper for references) show a rather good agreement between our theoretical error estimations and the experimental errors obtained. This fact also provides confidence to our results. However, following the referee's suggestion we will add the following text to the FTS error estimation (new text is highlighted in italic):

"The theoretical error estimation strongly depends on the assumed uncertainties. In our case, we consider the error sources and values listed in Table A1 for the input parameters, which are *the leading error sources affecting the different FTS products, identified from our experience and the literature*…"

Regarding including external error sources such as clouds and atmospheric aerosols, they could be introduced as model parameter errors in the Rodgers formalism. Examples of such approaches are shown by Wiegele et al. [2014], where the authors analysed the effect of thick and thin clouds on space-based water vapour retrievals. Nonetheless, these error sources were not included in our error estimation since a minor impact on the ground-based FTS retrievals is expected.
On the one hand, the FTS solar absorption spectra are acquired under cloud-free conditions, since if the intensity of the incoming solar radiation varies during the acquisition of an interferogram, which occurs when there are clouds in the path between the FTS instrument and the Sun, the resulting spectrum will be distorted. This is due to the fact that the continuum level will have a different gain signal than the higher-resolution spectral structure. Although this distortion may be subtle, it can significantly alter the FTS retrievals. Therefore, observations can only be performed under homogeneous sky conditions (generally clear sky conditions). In addition, at IZO the FTS spectra and the subsequent FTS retrievals are cloud-screened to avoid possible cloud contamination (please refer to comment number 7 for the explanation of the cloud filter used).
On the other hand, the desert mineral dust has a very broadband signature on the mid-infrared solar absorption spectra compared with the atmospheric molecules' signatures [e.g., Vandenbussche et al., 2013, Chapelle et al., 2014 and references therein]. Therefore, the presence of this aerosol is expected to mainly affect the continuum level of measured solar absorption spectra, but not the very narrow spectral windows used here for retrieving the different FTS trace gas products (recall Table 3 and references therein). In addition, since our FTS retrieval strategy simultaneously fits the surrounding continuum with the trace gases concentrations, the possible impact of mineral dust on the FTS retrievals is expected to be minimised.

**7) p. 13739 l.17-23: I am missing a short outline of cloud Screening strategy (in both, the FTS and the IASI descriptions).**

The FTS spectra are only recorded when the line of sight between the instrument and the Sun is cloud-free. However, to avoid possible contamination of thin clouds, the FTS observations are, in a second step, filtered according to co-located global solar radiation observations taken at IZO in the framework of the Baseline Solar Radiation Network (BSRN, http://bsrn.awi.de). By using a cloud detection method on the coincident solar radiation measurements (based on Long and Ackerman (2000) and adapted for IZO by García et al., 2014), the cloud-free periods in the FTS records are easily identified. Once the FTS retrievals are computed, they are filtered in a third step according to (i) the number of iterations at which the convergence is reached and (ii) the residues of the simulated-measured spectrum comparison. This final step ensures that unstable or imprecise FTS retrievals can be considered (which could likely be introduced by remaining thin clouds).
The cloud detection in IASI L2 products relies on five different cloud detection tests, based on the combined information of the measured IASI L1C spectra and of other remote sensors flying with IASI (AVHRR, AMSU and ATOVS) as well as of comparison to synthetic radiances. An IASI pixel is flagged cloudy if at least one of the cloud tests detects the presence of clouds. For more details, refer to August et al. (2012) and the Products User Guide (EUM/OPSEPS/MAN/04/0033, EUMETSAT).
This information will be included in the sections 2 and 3 of the revised manuscript.

**8) p. 13744 l.20-27: As the observations from Metop-A and Metop-B have shown to be consistent, why do the authors not include Metop-B in this Analysis in order to increase the sample size?**

The IASI-FTS intercomparison was addressed using only the Metop-A/IASI observations to ensure the same sampling during the whole period analysed, 2010-2014. If Metop-B/IASI data are also added to the analysis, the period 2013-2014 will have more weight on the comparison statistics. However, as the paper documented, the observations from both IASI sensors have shown to be very consistent and, thus, they can be merged to obtain a unique IASI database. By using this merged IASI database, we have re-evaluated the IASI-FTS comparison obtaining the results summarized in Table 1, which are compared to the results only using the IASI-A database.

| | IASI-A | | | | IASI-A+IASI-B | | | |
|---|---|---|---|---|---|---|---|---|
| | Des+Det 1h | Des+Det Daily | Annual Cycle | Long-term Trend | Des+Det 1h | Des+Det Daily | Annual Cycle | Long-term Trend |
| | Correlation Coefficient | | | | Correlation Coefficient | | | |
| O3 | 0.85 | 0.83 | 0.96 | 0.99 | 0.88 | 0.85 | 0.97 | 0.94 |
| CO | 0.32 | 0.50 | 0.95 | 0.96 | 0.31 | 0.50 | 0.96 | 0.98 |
| N2O | -- | 0.17 | 0.87 | 0.96 | -- | 0.22 | 0.91 | 0.98 |
| CH4 | -- | 0.23 | 0.75 | 0.94 | -- | 0.27 | 0.72 | 0.87 |
| CO2 | -- | 0.07 | 0.07 | 0.69 | -- | 0.09 | 0.04 | 0.63 |
| | Standard Deviation | | | | Standard Deviation | | | |
| O3 | 2.38 | 2.71 | 1.47 | 0.93 | 2.40 | 2.51 | 1.60 | 1.26 |
| CO | 10.60 | 8.11 | 5.30 | 6.40 | 10.61 | 7.71 | 4.62 | 6.46 |
| N2O | -- | 1.20 | 0.26 | 0.15 | -- | 1.03 | 0.22 | 0.10 |
| CH4 | -- | 0.92 | 0.36 | ,0.19 | -- | 0.83 | 0.39 | 0.25 |
| CO2 | -- | 1.33 | 0.70 | 0.80 | -- | 1.15 | 0.61 | 0.62 |

Table 1. Correlation Coefficient between IASI and FTS observations, when considering only IASI-A data (left columns) or the merged IASI-A+IASI-B data (right columns) at different time scales: single measurements (de-trended+ de-seasonalised variability within ±1h, Des+Det 1h), daily (de-trended+ de-seasonalised variability within the same day, Des+Det Daily), annual, and long-term trend. Also, the standard deviation (in %) of the relative differences are shown in the bottom rows.

As expected, the results using both IASI database are very consistent. As a consequence of the higher number of coincidences, the IASI-FTS agreement has overall improved (higher correlation between IASI and FTS observations and smaller standard deviation of the relative differences). When considering both IASI sensors, the number of coincidence increases by 52% for O3 (from 2338 to 3550), by 41% for CO (from 2003 to 2830) and only by 5% for N2O, CH4 and CO2 (from 425to 446). For O3 and CO the significant increase of the coincidences is due to the fact that the IASI-FTS observations are co-located within ±1h, thereby the inclusion of IASI-B data is more noticeable, while for N2O, CH4 and CO daily medians are paired.
Therefore, we consider more appropriate to address the IASI-FTS comparison only focusing on IASI-A data, but a clarification will be included in the section 6 as follows (the new text is highlighted in italic):

“The consistency between both IASI sensors has been documented in the previous section. Thereby, here we only focus on IASI-A since it has the longest time series of measurements (September 2010-September 2014 for V5) *as well as to ensure a homogeneous sampling during the whole period analysed.* “

**9) p. 13745 l.9-11: Is the amount of tropospheric ozone found around Izana (thus in rather pristine conditions) significant?**

The averaged annual cycles of the ozone tropospheric and upper troposphere/lower stratosphere (ULTS) partial columns as observed by ground-based FTS at IZO are displayed in Figure 1 (left plot). These partial columns are calculated, according to García et al. (2012), from the IZO altitude (2.37 km) until 13 km for the troposphere (PCT) and from 12 km until 18 km for the ULTS region (PCULTS). As observed the maximum annual values in these layers are reached in spring and early summer, when the largest differences between the IASI and FTS ozone annual cycles are documented (recall Figure 6 of the paper). In order to quantify to what extent the missing sensitivity of IASI in the troposphere and ULTS could account for the differences observed in the ozone annual cycles, we have analysed the differences between the averaged annual cycles observed by both remote sensors as a function of the variability observed by FTS in the troposphere and ULTS with respect to the total ozone column amounts (right plot of Figure 1). The latter is computed as:

$$FTS\,Trop + ULTS\,Variability_i\,[\%] = \frac{[(PCT_i - MPCT) + (PCULTS_i - MPCULTS)]}{MTC} \cdot 100$$

where *i* means each month from January to December, PCT and MPCT are the tropospheric partial column for each month and the annual mean of the tropospheric partial column amounts, respectively; PCULTS and MPCULTS are the same, but for the ULTS region, and MTC is the annual mean of the total column amounts.

As observed in Figure 1 (right panel), the differences between the IASI and FTS annual cycles are consistently and positively correlated with the annual variability observed in the troposphere and ULTS by the ground-based FTS (correlation coefficient, R, of 0.79). This evidences that IASI is not able to capture well the amplitude/phase of the ozone annual cycle in the troposphere and in the tropopause region. Note that if we consider the troposphere variability or ULTS variability separately to carry out this analysis, the correlation significantly decreases (R of about 0.60 for both cases).

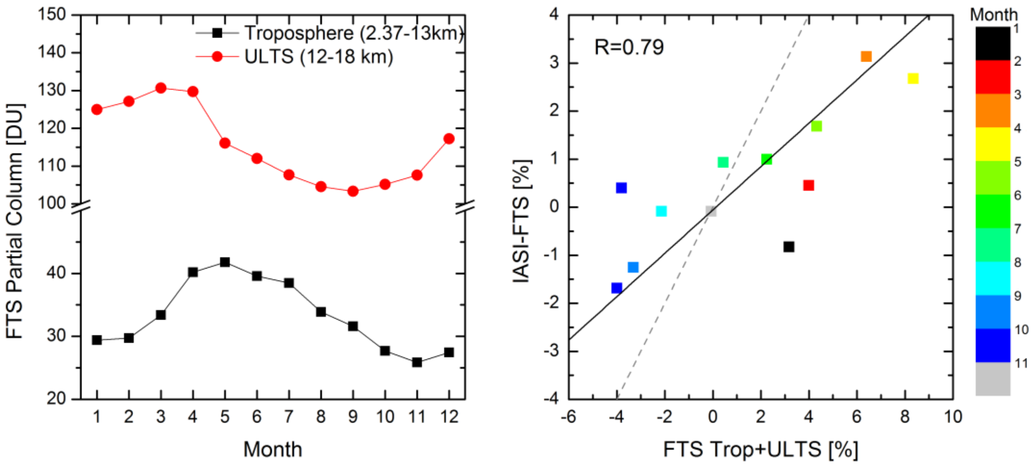


Figure 1. Left panel: averaged annual cycle of the ozone tropospheric and upper troposphere/lower stratosphere (ULTS) partial columns as observed by ground-based FTS at IZO for the period 2010-2014. Right panel: Differences between the averaged annual cycles of total ozone columns as observed by IASI and FTS in the period 2010-2014 as a function of the variability observed in the troposphere and ULTS by the FTS.

Therefore, only the missing sensitivity of IASI in the troposphere is not enough to explain the differences observed in the annual cycles, as we have stated in the original paper. This will be modified in the section 6 of the revised manuscript as follows (the new text is highlighted in italic):

"For O3 the largest differences are observed during spring-early summer, *due to the missing sensitivity of IASI in the troposphere and in part in the tropopause region* (recall Fig.2), while for CO we observe that IASI tends to overestimate the variability observed by the FTS. "

**10) p. 13746 l. 23-29: There is another AERONET Station, La_Laguna, Close to Izana. That one is operated at much lower altitude and consequently captures more of the episodical low level desert dust outbreaks and aerosol events. It is a better representation of the Aerosol loading over the ocean surrounding the islands than Izana. It might be worth to at least discuss this Topic.**

**11) p. 13741 l.1-4: With this box size I would say it is absolutely necessary to at least discuss expected the impact of desert dust on the IASI retrievals. Even if the Izana observatory may be situated above the dust, the IASI observations including the surrounding ocean will clearly be affected in the case of an outbreak from the Sahara. Many Researchers have shown significant Impacts on the radiative field in the spectral domain used here.**

Note that we will address the answer of the two comments together since both involve the impact of desert mineral dust on the IASI retrievals.

We totally agree with the referee in that the aerosol optical depth (AOD) measured at IZO could not be a good proxy for identifying and quantifying the mineral dust outbreaks that affect the IASI validation box used here. This is especially true for the Saharan dust events occurring in wintertime, which rarely reach the IZO altitude since they are confined below 1.5-2 km of altitude (Díaz et al., 2006; Alonso et al., 2011 and references therein). On the contrary, the mineral dust exports in summertime occur within the so-called Saharan Air Layer (SAL, Prospero et al., 2012), with a vertical extension between 2-6 km of altitude (Prospero et al., 2002, Rodríguez et al., 2011 and references therein). Therefore, following the referee suggestion, we have changed the AERONET station used to characterise the mineral dust aerosol load in the total column. But, instead of using La Laguna site as recommended by the referee, we have selected the Santa Cruz de Tenerife station (SCO), located about 50 m a.s.l. very close to the ocean. We think the AOD observations taken at this station can better quantify both the winter and summer mineral dust outbreaks over subtropical North Atlantic region. Therefore, considering AOD values recorded at SCO station, we have re-evaluated the impact of Saharan mineral dust events on the differences between IASI and FTS short-term variability. The results are summarized on Figure 2 (recall Figure 9 of the paper), where now winter and summer mineral dust events are distinguished. As observed, during summertime we reproduce the pattern already documented when considering the AOD measurements at IZO, i.e., the differences between IASI and FTS observations seem to be affected by the range of the aerosol load, increasing (absolute value) as the corresponding AOD values increase. This pattern was mainly attributed to the different type of observations, being the thermal emission spectra recorded by IASI more affected by mineral dust signatures than the FTS solar direct absorption spectra. In fact, numerous works in the literature have widely demonstrated that IASI is sensitive to the mineral dust signatures and its ability to provide reliable estimations of mineral dust AOD [e.g., Vandenbussche et al., 2013; Peyridieu et al., 2013; Chapelle et al., 2014 and references therein]. But, in winter, the IASI-FTS differences seem to be independent on AOD. This fact is likely due to the limited sensitivity of IASI to the boundary layer due to the decreasing thermal contrast between the surface and the atmosphere when approaching the surface.

This discussion will be incorporated to the revised manuscript in section 6 and the Figure 9 will be updated.

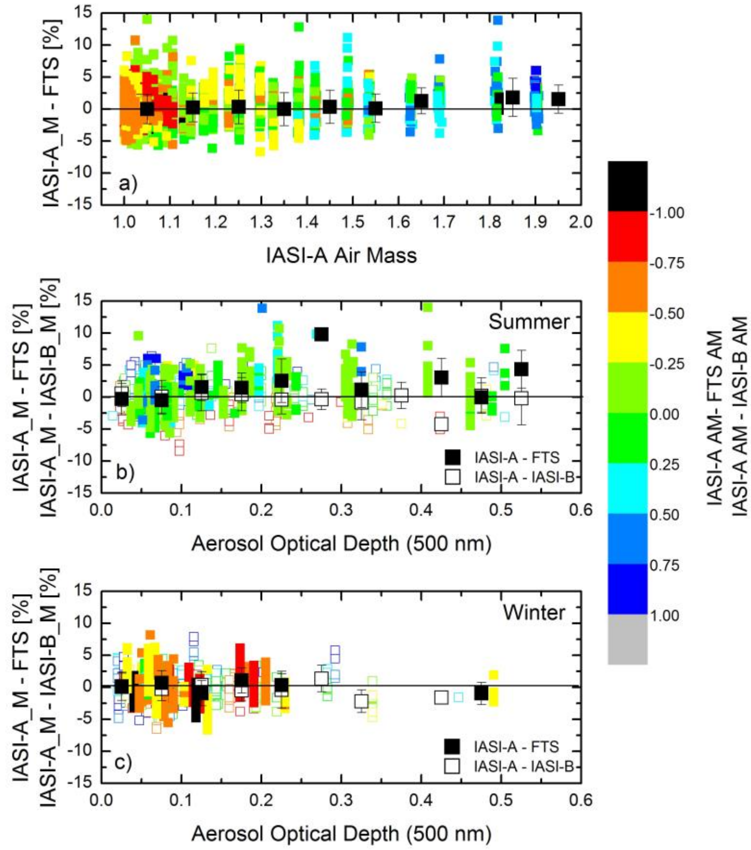


Figure 2: (a) Differences between the O3 de-trended and de-seasonalised variability time series from IASI-A and FTS [in %] as a function of the IASI-A air mass (AM) plotted as black squares with error bar (median and standard deviation per bins of 0.1 of AM), and simultaneous 2D plot showing the difference between the IASI-A and FTS AMs. (b) The same as (a), but versus the aerosol optical depth, AOD, at 500 nm recorded at AERONET SCO station during summer. Also, the differences between IASI-A and IASI-B are included. The black and white squares represent the median and the standard deviation per bins of 0.05 of AOD for the IASI-A – FTS and IASI-A – IASI-B differences, respectively. (c) The same as (b), but for winter.

<u>References</u>

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