Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-433-AC1, 2020


Atmospheric Measurement Techniques Discussions

# *Interactive comment on* "Optimised degradation correction for SCIAMACHY satellite solar measurements from 330 to 1600 nm by using its internal white light source" *by* Tina Hilbig et al.

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Received and published: 24 April 2020

We thank the reviewer for the detailed remarks and the efforts to improve our paper. We responded to all comments as best as we can. We added Section 5.2 of the manuscript as supplement.

**GENERAL SUMMARY AND COMMENTS**

This paper presents a revised analysis of the long-term degradation of the SCIAMACHY instrument flown on the Envisat satellite, focusing on corrections for solar spectral irradiance (SSI) measurements. Since SCIAMACHY did not make end-to-end



calibration measurements on-orbit, data from an internal white light source (WLS) are used in combination with a physical model of optical surface contamination to characterize instrument changes. This paper is well-written, with good discussion of the procedures that were developed and the key results. Some suggestions and comments related to specific items are provided below.

**SPECIFIC COMMENTS**

**1. p. 4, line 3:** As a point of terminology, I would call the results presented in Hilbig et al. (2018) the "absolute radiometric calibration", whereas the work presented here improves the relative (or time-dependent) instrument calibration.

To clarify this point we suggest the following change:

*"The goal of our investigations is to improve the absolute radiometric calibration of the solar extraterrestrial spectrum measured by SCIAMACHY. This is achieved by adaption of the degradation correction for the SCIAMACHY instrument by..."*

is changed to:

*"The goal of our investigations is to improve the absolute radiometric calibration of the time series of the solar extraterrestrial spectra measured by SCIAMACHY. The degradation is derived relative to a reference measurement with published absolute calibration (Hilbig et al. 2018). ..."*

**2. p. 9, lines 2-3:** I'm not sure about this assumption. Many instruments experience the most rapid degradation early in their lifetime, when contaminants are fresh. It is true that cumulative degradation in early 2003 will be small compared to the end of the SCIAMACHY mission.

SCIAMACHY does not show a rapid degradation immediately after launch. Degradation occurs in the early phase of the mission, but the degradation rate increases over time until about 2006. The degradation rate is then stable until 2011. Thereafter a rapid recovery of the throughput started. We attribute the recovery to a changed thermal environment of the platform and thus of the atmosphere around the platform (see also issue 6 below). A change of outgassing rates from the platform leads to time-varying growth of an absorbing layer on the mirror.

To clarify this point we suggest the following change:

*"Assuming that in the early phase of the mission the degradation of the instrument is small, Sun-Earth distance normalised in-flight measurements from February to March 2003 are used to generate a wavelength dependent look-up-table (LUT) for the diffuser sensitivity."*

is changed to:

*"The degradation itself as well as the degradation rate is lowest in the early phase of the mission. Therefore, Sun-Earth distance normalised in-flight measurements from February to March 2003 are used to generate a wavelength dependent look-up-table (LUT) for the diffuser sensitivity."*

**3. p. 10, lines 11-13:** What is the typical amount of burning time per year for the WLS? Figure 5 suggests 40-50 minutes per year during 2003-2012, although apparently there was more usage during 2002 (180 minutes?) that is not used for the degradation correction. Does the statement on p. 11, lines 18-20 mean that the WLS was used weekly? If so, this would imply only 1 minute of operation during each sequence, which represents a fairly short duration for an on-orbit lamp to reach stable operating conditions. Please comment.



WLS measurements before 2nd August 2002 (start of regular operations) are special measurements during the calibration activities on-ground and during the commissioning phase just after launch and before nominal operation. Figure 5, top panel, shows all regular WLS measurements, meaning WLS over ESM mirror as shown in Fig. 1. More precisely, each WLS measurement has a duration of 12s. The first 8s (4 detector readouts) are omitted, the last 4 s (2 detector readouts) have a stable signal and are used.

These regular WLS measurements are performed weekly. In between, further WLS monitoring measurements using different optical elements in the light path are performed. Consequently the latter are not used for deriving the WLS ageing correction (and are not shown in Fig.5). The burning time is accounted for in the accumulated burning time. The WLS is a life-limited item of the instrument with a total budget of 25 hours. About one-third of this budget was used during the mission.

We added more details in the text, Sec.3.4 (bold).

*"SCIAMACHY's internal White Light Source (WLS) is a 5 W UV-optimised Tungsten Halogen lamp. Its primary role is to determine the pixel-to-pixel gain, check the overall throughput of the instrument, and correct wavelength dependent effects (e.g. etalon effect, quantum efficiency).* ***The WLS has been used already during the calibration activities on-ground and during the commissioning phase after launch. In nominal operation, the regular WLS measurements are performed weekly. In between, further WLS monitoring measurements using different optical elements in the light path are performed. Each nominal WLS measurement has a burning time of 12s with the last 4s used as measurement signal.***
*In the new degradation model, the WLS is used as an independent second light source. . .."*

**4. p. 11, lines 4-6:** How does the uncertainty in the degradation fit change with wavelength? The relative uncertainty at 630 nm shown in Figure 5 [bottom] is clearly small. Was there a specific threshold that caused you to set 330 nm as a lower limit? I ask in part because corrected SCIAMACHY SSI data covering 212-330 nm would be a valuable addition to the SSI database during 2003-2012.

For smaller wavelengths the uncorrected instrument degradation (not WLS itself) becomes more prominent already after the first years/earlier in the mission. Therefore, it is more problematic to define an adequate fitting range to derive the WLS ageing. The fit residuals of the WLS ageing correction increase with decreasing wavelengths.

On the one hand the instrument degradation is strongest at smallest wavelengths, therefore these wavelengths would be beneficial in the degradation modelling. On the other hand the WLS ageing correction for wavelengths below 400 nm cannot be derived at the same quality as for the visible (as shown in Fig. 5). Due to the Wood anomaly feature around 350 nm (Liebing et al., 2018), we avoided the spectral range 340 – 360 nm. We therefore decided to only include two wavelengths for SCIAMACHY's spectral channel 2 (300 – 400 nm) in the fit.

In the paper, we added the following (Sec. 3.5, p. 13): *"Due to the Wood anomaly feature around 350 nm (Liebing et al., 2018), the spectral range 340 – 360 nm was omitted in the fit and only two wavelengths, 330 nm and 370 nm, for SCIAMACHY's spectral channel 2 (300 – 400 nm) were included."*

We fully agree, that an extension to lower wavelengths would be highly beneficial. With further improvements of the approach it might be possible to include wavelengths down to about 300 nm, but the correction of SCIAMACHY's spectral channel 1 (212 – 300 nm) remains challenging.



**5. p. 11, line 18:** Figure 6 is very useful.

**6. p. 12, lines 12-14:** I don't understand why the ESM mirror appears to have a steady buildup of contaminant throughout the mission (Figure 7), while the ESM diffuser has a constant layer of contaminant (p. 12, lines 4-5). Is there a large difference in exposure to contaminating material between these two elements?

We assume, as supported by earlier studies of SCIAMACHY optical degradation, that the accumulated exposure to solar UV radiation is closely related to the degradation of the optical elements of SCIAMACHY. The observed behaviour is consistent with the hard UV photolysing outgassed molecules (e.g. organic compounds from the printed circuit boards and water vapour carried on surface of the platform) in a thin atmosphere around the ENVISAT. The photochemical processing initiated by the UV creates low volatility species, which deposit. They absorb much more strongly in the UV than in the visible.

There is a large difference in exposure time to UV radiation for the ESM mirror and diffuser. The ESM diffuser was regularly used once a day for solar measurements (and a few monitoring measurements), the ESM mirror is part of all other measurement light paths including regular scientific Earth observations. Thus, the ESM mirror was longer exposed to the harsh UV radiation. For this reason, there was only a very slow build up of the contamination layer on the ESM diffuser. Consequently, the change of the ESM diffuser with time can be neglected.

Due to our approach of not using solar measurements involving the small aperture in the light path, the number of measurements (light paths) in the degradation modelling is limited. Adding the layer thickness on the ESM diffuser as an additional fit parameter does not provide unique/distinct results.

**7. p. 13, lines 3-5:** The magnitude of the SCIAMACHY solar cycle decrease at 330 nm (0.8%) is still somewhat larger than would be expected from TSI change (~0.1-0.2%). Meanwhile, the 430 nm time series shows an increase of 0.3-0.4% that is out of phase with the TSI variation. This result is discussed more extensively in Section 5.2, but it might be helpful to mention it here.

The focus of this section lies in the comparison of the two versions of SCIAMACHY data. We added the following (bold) here. See also further changes in Sec. 5.2 due to comments of other Referees.

*"With respect to ESA V9.01, a general improvement can be seen in the time series, especially for measurements after 2008. The new results show a more stable signal in the NIR with less small-scale structure. Reasonable results are also obtained in the UV near 330 nm. Here ESA V9.01 shows variations that can not be attributed to natural solar variability, while our results show more clearly the continuous decrease as expected from the descending phase of solar cycle 23 with a clear minimum at 2008/2009 as evident from other SSI measurements (e.g. Mauceri et al., 2018).* ***However, values are higher than expected from TSI variability (~0.1% solar cycle; Kopp, 2016). Furthermore, an unexpected anti-cyclic increase during solar minimum, similar to the behaviour of V9.01, becomes evident in the NUV and above; see further discussion and comparisons with other SSI data sets in Section 5."***

**8. p. 17, lines 1-2:** I feel that the authors have done a lot of excellent work to reach this level of accuracy.

**9. p. 17, lines 12-14:** The SCIAMACHY SSI data are valuable for studies of short-term



solar variations because they have sufficient spectral resolution in the visible and near-IR to provide unique information about the behavior of solar absorption features in those spectral regions.

**10. p. 18, lines 24-25:** Are there any plans to release these revised SSI data? Is there a timetable for the creation of an ESA Version 10 data product?

ESA projects to study further SSI from SCIAMACHY have been initiated. At the moment it is not possible to give a schedule for possible data release. It is also still unclear, if the work will be used in the next version, as the priorities of ESA are the impact on level 2 (atmospheric parameters) products.

The data set derived in this study and shown in the paper will be made available at http://www.iup.uni-bremen.de/UVSAT/datasets

**TYPOGRAPHICAL ERRORS**
p. 1, line 22: "simultaneous" should be "simultaneously".
p. 6, line 9: "begin" should be "beginning".
p. 6, line 31: "reasonable" should be "reasonably".
p. 12, line 12: "now clearly the" could be changed to "now clearly follow the".

All typographical errors are corrected.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-433/amt-2019-433-AC1-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-433, 2019.