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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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We thank the reviewer for the detailed remarks and the effort to improve our paper. We responded to all comments as best as we can. We attached Section 5.2 (comparisons of data sets) of the changed manuscript to the answers.

General comments:
This paper deals with new progress about the instrumental corrections of the SCIAMACHY data. The special interest is to improve the solar spectral data. The paper is well written and contains interesting and important results for users of SCIAMACHY

data. I would like to recommend the publication of this paper in AMT. I have the following minor comments and questions.

Specific comments:
1. p2, line 27: "Shortly after SCIAMACHY,. . .". Add "launch" after SCIAMACHY.

The sentence is changed according to the suggestion: "Shortly after SCIAMACHY was launched, ..."

2. p3, line15: Please add some comments about the contamination problem: Is SCIAMACHY's contamination problem worse or better when compared with similar instruments? If worse, what went wrong?
3. p3, line 15: Please, tell briefly about water and the other contaminants: Are they always on separated surfaces (mirrors, diffusers, detectors)?

Contamination, which depends on the outgassing from the platform, is different for each instrument and platform. Even for very similar instruments this may differ strongly as the outgassing from the satellite and its thermal history plays an important role. The degradation of the GOME-2 instruments on MetOp A B and C, which are in principle identical instruments on identical platforms, is similar but not identical.

Identification of the contaminant species and processes that lead to degradation are difficult or hardly possible by in-flight monitoring, as indicated e.g. in Krijger et al. 2014: "Studies like e.g. the one by Stiegman et al. (1993) on diffusers, show some organic effluent present, but did not allow for the identification of the contaminant. Also, Chommeloux et al. (1998) showed the on-ground degradation as a result of UV or photon radiation, as did Georgiev and Butler (2007) or Fuqua et al. (2004). [...] In summary, most of the early satellites suffered from degradation caused by outgassing. However, the exact identity of the contaminant causing the Ultraviolet to visible (UV–VIS) degradation remained unclear. McMullin et al. (2002) studied the degradation of SOHO/SEM, and found that they could explain the degradation with a thin layer of carbon forming on the forward aluminium filter. The exact source of the contaminant is unknown, but is suspected to be outgassing of the satellite itself. Schläppi et al. (2010) attempted in situ mass spectrometry with ROSETTA to measure the constituents of their contamination, and found the main contaminants to be water. In addition, organics from the spacecraft structure electronics and insulations were identified. Water was also found in SCIAMACHY, where it was deposited onto the cold detectors (Lichtenberg et al., 2006). In fact, Earth-observing satellites suffer from degradation, both in throughput and in the polarisation and/or scan-angle dependence, such as GOME (Krijger et al., 2005a; Slijkhuis et al., 2006), MODIS (Xiong et al., 2003; Xiong and Barnes, 2006; Meister and Franz, 2011), SeaWiFs (Eplee et al., 2007), VIIRS (Lei et al., 2012), MERIS (Delwart, 2010), SCIAMACHY (Bramstedt et al., 2009), and the two GOME-2 (Lang, 2012) instruments currently in orbit."

Lichtenberg et al., 2006, give some explanation about water/ice in SCIAMACHY: "Shortly after the very first cooling of the detectors, a significant loss of transmission in channel 7 and 8 was discovered. Investigations showed that an ice layer growing on top of the cylindrical lens covering the detectors was responsible. Only channel 7 and 8 are affected because these channels are cooled down to around 145 K while the other channels have temperatures of 200 K or higher. A likely source of the contamination is the carbon fibre supporting structure of ENVISAT itself, since it is known that carbon fibres can accumulate a substantial amount of water. The water contained in the fibres started to gas out once the satellite was in orbit. SCIAMACHY is covered by a double layer of multilayer insulation (MLI) blankets, one from ENVISAT and one from the instrument itself to prevent strong thermal gradients while in orbit. The MLI has a number of venting holes to allow the outgassing of the Instrument and prevent a contamination of surfaces, but apparently the venting volume allowed by the

holes is not large enough or the holes are obstructed. Thus, the contaminant is not (or too slowly) removed from the instrument volume. Other instruments on ENVISAT have also reported problems due to contamination (see e.g. Perron, 2004; Smith, 2002)."

In the manuscript, we clarified the impact of water for SCIAMACHY. We change:

"Another critical species of contaminant is water that can be deposited on the detectors as was the case with SCIAMACHY (Lichtenberg et al., 2006)."

to:

"Another critical species of contaminant is water that can be deposited on cooled surfaces in the instrument as it was the case for SCIAMACHY's NIR detectors (Lichtenberg et al., 2006). In addition, water vapour is photolysed in the hard UV to generate OH and H free radicals. In particular OH is a very strong oxidising agent and initiates the oxidation of volatile organic compounds which are also photolysed in the UV and result in additional low volatile organic compounds deposited on the optical surfaces of the instrument."

We added this statement to the end of the paragraph (p.3):

"Detailed discussions on contamination of optical surfaces in various space instruments are provided by BenMoussa et al. (2013); Krijger et al. (2014); Meftah et al (2017) among others. Despite the numerous studies available, the composition of contaminants as well as the exact processes for their build-up remain highly uncertain. For each instrument and platform, the individual construction (platform, instrument) and performance lead to different effects, and are difficult to quantify without having direct access in space. SCIAMACHY and its precursor GOME show moderate degradation in the UV and visible spectral range, whereas the successor GOME-2 series show more rapid degradation."

4. p3: Perhaps you could say something about occultation instruments, which are to some extent more resilient to contamination problems due to the self-calibrating property.

Occultation instruments are self-calibrating only in case of atmospheric measurements, because then the same type of measurements above and through the atmosphere are divided to derive the transmission spectra. An absolute radiometric calibration of irradiance measurements is therefore not required ("self-calibrating"). As far as we are aware of, occultation instruments usually do not provide absolute calibrated solar spectra. Even SCIAMACHY's solar occultation measurements do not provide calibrated irradiance. Therefore we think occultation measurements are not relevant for this paper.

5. p7, line 10: Another kind of. . . . Is this story part of the story on line 13 where you tell that "there are basically two types. . ."? I am confused.

The paragraph summarises the issues of the selected light paths (measurements) in the V9.01 degradation correction. For some light paths several issues arise:
- missing sub-solar measurements 2002
- changed temperature settings (all light paths)
- measurements including small extra mirror
- small aperture (sub-solar, limb, extra-mirror light paths)

The following paragraph (in Sec. 3.2.) was changed from

"The following issues arise in the current degradation correction. Firstly, the sub-solar

measurements were missing in 2002 and therefore the OBM m-factors before February 2003 were calculated assuming fixed settings for the contamination layers (as defined at the reference day in February 2003) and a constant Sun for the ESM diffuser light path. Additionally, temperature settings of the instrument were changed in February 2003. ***Another kind of solar measurements*** *uses an extra mirror such that the light path crosses the ESM mirror twice. The extra mirror ..."*

to

"The following issues arise in the current degradation correction. Firstly, for operational reasons, the sub-solar measurements were not made in 2002. As a result the OBM m-factors before February 2003 were calculated assuming fixed settings for the contamination layers (as defined at the reference day in February 2003) and a constant Sun for the ESM diffuser light path. Additionally, temperature settings of the instrument were changed in February 2003. An additional solar light path uses an extra mirror such that the light crosses the ESM mirror twice. The extra mirror..."

6. p7, line 25: You have detected spectral features by the ESM diffuser. On line 26 you say that's why the ASM diffuser was added but without pre-launch calibration. Are you sure that ASM does not have similar spectral features than ESM?

The pre-flight calibration identified spectral features in the ESM diffuser. As a result an ASM diffuser was added to the instrument. As mentioned in the text, an absolute radiometric calibration was not possible, because the ASM diffuser was added to the instrument after the (commercial) radiometric calibration campaign was completed. Pre-launch characterisation was undertaken and showed that the ASM diffuser has much less spectral features. The features in the ESM have two possible origins: i) the inability to make truly amorphous diffuser plates by the manufacturer and ii) the ring used to hold the ESM diffuser in place may have also introduced some optical effects. The ASM diffuser is significantly larger than the ESM diffuser and have much less residual parallel scattering, which induces etalon features.

7. p12, line 5: I get the impression that the ASM diffuser contamination increases along the mission, but the ESM contamination remains constant. Is this right and what is the reason?

The contamination layer thickness of the ESM Diffuser is kept constant in the modified degradation correction. This assumption is based on previous studies for SCIAMACHY V8/9. The ASM Diffuser was included in the model for the first time within this study, and therefore, no previous values exist. Overall our results indicate that the ASM Diffuser has a relatively small and constant contamination during the mission. We assume that the cause of contamination is the accumulated exposure to solar UV radiation. This is confirmed by previous investigations of the SCIAMACHY degradation. See also answer to Referee #1, item 6.

8. p14, line 5: Could you tell something more about the change of the thermal environment?

Gottwald et al, 2016, SCIAMACHY In-orbit Mission Report, p. 67, reported: "Shortly before the ENVISAT orbit manoeuvre in October 2010 an anomaly occurred in the Ka-band antenna subsystem (KBS). This required switching from KBS-2 to KBS-3 and to a change in its operating procedure. While KBS-2 had been intermittently turned 'on' and 'off', for safety reasons, KBS-3 remained 'on' the whole time. Therefore about 120 W more energy were dissipated thus changing the thermal environment of ENVISAT, including the payload instruments." Effects on SCIAMACHY were e.g.

increased detector temperatures (0.3 K to 0.5 K, channel dependent) and increased Electronic Assembly subsystem temperatures (1.1 to 2.7 °C, subsystem dependent).

In the text (Sec. 4), we changed:

"A possible explanation is a change in the use of electrical devices on Envisat by the end of October 2010 that resulted in a change in the thermal environment (Gottwald et al., 2016)."

to:

"A possible explanation is the additional permanent use of a backup system after an anomaly in the Ka-band antenna subsystem. About 120W more energy were dissipated resulting in a change of the thermal environment of Envisat. Increased temperatures (0.3 – 2.7 °C, subsytem dependent) were observed by SCIAMACHY's internal temperature sensors (Gottwald et al, 2016). This changes the outgassing and thus the photochemical processing."

9. p15, line 22: outlier ->outliers
Corrected.

10. p16, line 5: At 330nm in Fig. 10 the SIM curve seems to deviate clearly from the other curves, but your comment is more positive. Could you explain?

In this part of the paper the intention was not to explain differences but rather to describe them. Since our new SCIAMACHY SSI result also deviates from the other data sets, detailed comparisons are not applicable at this stage. We expanded and reordered the paragraph. Please see changed manuscript.

11. p18, Conclusions: Your conclusions are quite upbeat which is understandable after very tedious and extensive work. But if I consider the results shown in Fig.10 to be the most important outcome, the situation is not looking very promising. Is it possible that something important is still waiting to be found?

The intention of the paper was to present the method and the successful implementation of the WLS and ASM diffuser solar measurements in the model. We agree, Figure 10 shows indeed some weakness in the SCIAMACHY SSI with respect to other instrument or model data. Nevertheless, the improvement over the latest (unpublished) SCIAMACHY V9.01 is demonstrated. Comparisons with older SCIAMACHY version are not possible, since V9.01 is the first one that accounts for solar variability on solar cycle time scales. The method has the potential to produce improved results for SCIAMACHY after additional modifications. In addition the paper demonstrates the value of using WLS observations for degradation monitoring for other instruments, as mentioned in the conclusions.

Nevertheless, we change in the conclusion:

"there are still some limitations in the degradation corrections"

to

"there are still limitations in the degradation corrections" (omitting "some")

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-433/amt-2019-433-AC3-supplement.pdf

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