ANALYSIS OF 5 YEARS SCIAMACHY ABSORBING AEROSOL INDEX DATA

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ABSTRACT

We study the quality of the SCIAMACHY Absorbing Aerosol Index (AAI) product developed at our institutes. The AAI in general is determined from the reflectance at two wavelengths in the UV, and is highly sensitive to errors in the absolute radiometric calibration. We apply a degradation correction to the level-1 reflectance and test the temporal behaviour of the resulting AAI data. This we do by studying time series of AAI data for a selection of areas on the globe. We conclude that the AAI data we provide is of good quality and is stable over the entire time range of SCIAMACHY data currently available.

Key words: SCIAMACHY; Absorbing Aerosol Index; calibration; degradation.

1. INTRODUCTION OF RESIDUE AND AAI

The Absorbing Aerosol Index (AAI) was introduced to obtain from TOMS measurements in the UV information about the presence of UV-absorbing aerosols in the Earth's atmosphere. The AAI is derived directly from another quantity, the residue, which was defined by [1]

$$r = -100 \cdot \left\{ {}^{10}\log\Big(\frac{R_\lambda}{R_{\lambda_0}}\Big)^{\rm obs} - {}^{10}\log\Big(\frac{R_\lambda}{R_{\lambda_0}}\Big)^{\rm Ray} \right\} . \quad (1)$$

In this equation, R_λ denotes the Earth's reflectance at wavelength λ. The superscript $^{\rm obs}$ refers to reflectances which are measured by, in this case, SCIAMACHY [2], while the superscript $^{\rm Ray}$ refers to modelled reflectances. These modelled reflectances are calculated for a cloud-free and aerosol-free atmosphere in which only Rayleigh scattering, absorption by molecules, Lambertian surface reflection as well as surface absorption can take place.

The reflectance, in this paper, is defined as

$$R = \frac{\pi I}{\mu_0 E} , \quad (2)$$

where I is the radiance reflected by the Earth atmosphere (in $\rm Wm^{-2}nm^{-1}sr^{-1}$), E is the incident solar irradiance at the top of the atmosphere perpendicular to the solar beam (in $\rm Wm^{-2}nm^{-1}$), and μ_0 is the cosine of the solar zenith angle θ_0. As for the wavelengths involved, the wavelengths λ and λ_0 must lie in the UV, and were set to 340 and 380 nm, respectively, for SCIAMACHY.

The Rayleigh atmosphere in the simulations is bounded below by a Lambertian surface having a wavelength independent surface albedo $A_{\rm s}$, which is not meant to represent the actual ground albedo. It is obtained from requiring that the simulated reflectance equals the measured reflectance at λ_0 = 380 nm:

$$R^{\rm obs}_{\lambda_0} = R^{\rm Ray}_{\lambda_0}(A_{\rm s}) . \quad (3)$$

The surface albedo found in this way is used to calculate $R^{\rm Ray}_\lambda$, so one assumes that the surface albedo is constant in the wavelength interval $[\lambda, \lambda_0]$, which is true for most cases. Note that Eq. 1 can now be reduced to

$$r = -100 \cdot {}^{10}\log\Big(\frac{R^{\rm obs}_\lambda}{R^{\rm Ray}_\lambda}\Big) . \quad (4)$$

The importance of the residue, as defined above, lies in its ability to effectively detect the presence of absorbing aerosols even in the presence of clouds. When a positive residue ($r > 0$) is found, absorbing aerosols were detected. Negative or zero residues on the other hand ($r \leq 0$), suggest an absence of absorbing aerosols. For that reason, the AAI is defined as equal to the residue r where the residue is positive, and it is not defined where the residue has a negative value.

2. SCIAMACHY AAI DATA

The AAI we present in this paper is not the operational level-2 product (L2-AAI), but the "scientific" product (SC-AAI) developed at our institutes. The SC-AAI is based on operational level-1 data, and is calculated using our own algorithm. This algorithm uses lookup tables for the simulated reflectance which also include polarisation, identifies sunglint situations, and corrects the reflectance for the known calibration problems of the SCIAMACHY

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instrument in the UV wavelength range. These calibration problems include the well-known reflectance error at launch [3], and the degradation of the optics since that moment in time [4]. The latter problem, which is most important in the UV, has only recently been addressed.

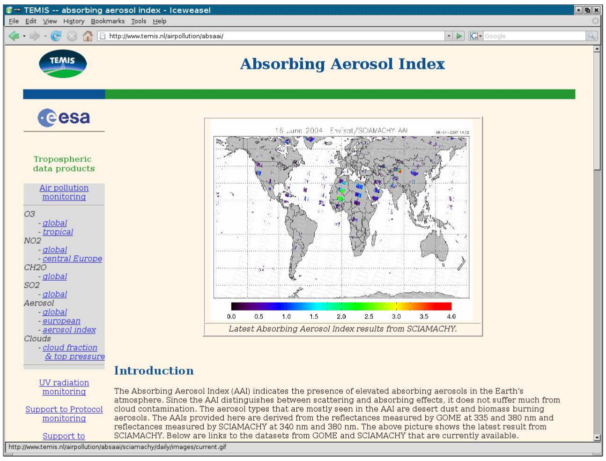

Figure 1. Absorbing Aerosol Index data from SCIAMACHY is available for download on the TEMIS website via the URL http://www.temis.nl/.

The SCIAMACHY AAI data can be downloaded from the TEMIS website via the URL http://www.temis.nl/ [5]. The daily AAI data is available in two flavours. Level-2 data (in ASCII) are available for users that are specifically interested in SCIAMACHY AAI data. For all other users, and in particular the ones that are familiar with the TOMS data format, 'gridded' (level-3) data are available in the well-known TOMS data format. Monthly averaged data are also available, in the same 'gridded' data format.

3. RADIOMETRIC CALIBRATION

3.1. Calibration correction

A correct absolute calibration of the reflectance is an essential ingredient for obtaining reliable AAI data. SCIAMACHY was after launch found to be underestimating the reflectance by 10–20% of its value in the UV. In our retrieval algorithm, the reflectances at 340 and 380 nm are therefore first multiplied by correction factors c_{340} and c_{380}, respectively. For data with software versions up to 5.04, the correction factors are $c_{340} = 1.20$ and $c_{380} = 1.13$. As of software version 6.02, which is equipped with a new (recalculated) set of key data intended for the absolute radiometric calibration, the correction factors were found to be $c_{380} = 1.014$ and $c_{380} = 1.004$.

These correction factors were determined from a study in which the SCIAMACHY UV reflectance was compared with the reflectance calculated by a radiative transfer code [3]. To have an idea about the impact of these correction factors, we recall [6] that the effect of these two correction factors may be approximated by the formula

$$\Delta r \approx -100 \cdot {}^{10}\log\left(\frac{c_{340}}{c_{380}}\right) . \qquad (5)$$

Filling in the appropriate corrections factors, we find that the operational level-2 product (L2-AAI), which is not being corrected for this calibration problem, is on average 2.6 index points higher than the SC-AAI for data versions up to 5.04, and roughly 0.5 index points higher than the SC-AAI for data version 6.02 and later versions.

3.2. Degradation correction

In a previous paper [6] it was shown that the SCIAMACHY AAI is suffering severely from degradation of the optics. The residue had increased by, on average, more than 2.5 index points over the last years, and an analysis indicated that the increase could be completely explained by the instrument degradation which was recorded by instrument Light Path Monitoring (LPM) measurements (which are taken on a regular basis).

To correct for the degradation, we make use of the so-called "White Light Source via ESM mirror" (WLS) monitoring data, which should be an indication for the degradation of the nadir radiance. Alternatively, we can also make use of so-called "Sun through subsolar port via ESM mirror, fast sweep" (FS) data. Both should ideally record the same nadir radiance degradation, but there are differences. At this point in time, it is not yet clear which of the two records is the preferred one.

Finally, the daily solar measurements deliver a record of the irradiance degradation. Combining this with the WLS or FS monitoring data, we can calculate the degradation in the reflectance signal. In our retrieval code, we correct the reflectances at 340 and 380 nm with multiplicative corrections factors d_{340} and d_{380}, respectively.

This removes most of the effects of degradation. In Fig. 2, we have plotted in green the globally averaged daily residue, not corrected for degradation, as a function of time. The vertical, dotted red lines indicate the time at which major decontaminations took place. These lines coincide with a few days of outliers. The blue curve is the effect of the reflectance degradation on the residue, recorded by the WLS LPM data and the irradiance LPM data, calculated using Eq. 5, and shifted vertically. The red curve is the same but then based on the FS data.

As can be seen, the WLS monitoring data (blue curve) appears to be better suited for explaining the degradation in the residue data quantitatively. Bear in mind, though, that formula 5 is an approximation, and that the real effect of the WLS and FS corrections may deviate. Also note that the outliers mentioned before, which are related to periodic (scheduled) decontaminations of the instrument, are not present in the WLS and FS data. Apart from this, the WLS correction, which is used in our retrieval code, leaves the globally averaged daily residue more or less stable, yet some deviation from the mean value remain.

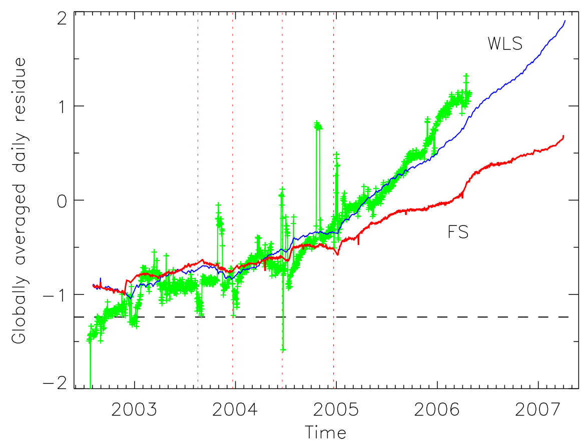

Figure 2. Globally averaged daily residue as a function of time, according to old versions of the SC-AAI data (in green), to which no degradation correction was applied. Also shown is the effect on the residue, calculated using Eq. 5, and based on WLS/irradiance monitoring data (blue curve) and FS/irradiance monitoring data (red curve). Both curves were shifted vertically for easy comparison with the global residue data.

As a next step in the retrieval process, we remove this deviation, which we believe to be unphysical, by assuming that the global average is constant in time and equal to the values reached at the start of the mission. For this we follow the approach taken in [7], which is based on the assumption that the globally averaged residue should be constant in time. We change d_{340} to achieve this, and use Eq. 5. In summary, in the retrieval code, we first apply reflectance correction factors d_{340} and d_{380} based on the WLS monitoring data, after which we apply a second correction on d_{340} to remove small remaining deviations.

4. TEMPORAL VARIATION OF THE RESIDUE

In order to verify the quality of our AAI/residue data, we monitored the temporal variation of the daily residue for a selection of 15 areas spread over the globe. These areas are shown graphically in Fig. 3.

In Fig. 4 we present time series of the daily residue for five of the areas shown in Fig. 3, namely, for 'Northwest Africa' (area 1), the 'North Atlantic Ocean' (area 2), 'Southwest Africa' (area 3), the 'South Atlantic Ocean' (area 4), and the 'Sahel' (area 5). For the analysis we used the so-called 'gridded' data that are available on the TEMIS website. The horizontal dotted line indicates the globally averaged daily residue, which has a value of roughly –1.2 under the conditions stated in Sect. 3.

An analysis, as the one presented in this section, was performed already earlier for GOME [8] data over the time period 1995–2000 [9]. The results we present, which are based on SCIAMACHY data, agree very well (that is, quantitatively) with these earlier GOME results.

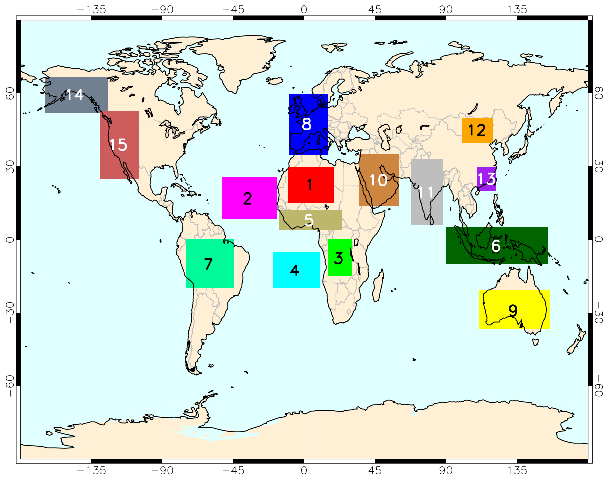

Figure 3. Shown are 15 regions for which the temporal behaviour of the average residue was monitored. Fig. 4 shows a selection of the resulting time series.

Taking a first look at the time series we can already conclude that trends in the residue, which would point to an improper degradation correction, are not found. The time series found for older versions of the residue data (that is, data without degradation correction), showed strong trends for each of the 15 regions. We consider the fact that no trend is found in the new residue data [for each of the monitored areas] a strong proof of the correctness of the degradation handling described in Sect. 3.

We further conclude that there is a clear seasonal dependence in the residue. For 'Northwest Africa' (area 1) and the 'North Atlantic Ocean' (area 2), we find high residue values throughout virtually the entire year. As mentioned in other papers [7, 10], the absorbing aerosols detected over the Atlantic Ocean (area 2) originate from Northwest Africa (area 1). This explains why the two time series are very similar in shape. A time lag between the two time series, as reported in, for instance, [10], is not found in the SCIAMACHY data.

The high residues found in 'Southwest Africa' (area 3) are mainly the result of biomass burning and the associated absorbing aerosols are being transported over the South Atlantic Ocean (towards area 4). This explains the similarity in shape of the time series of areas (3) and (4). Again, nothing in the data points to the existence of remaining degradation problems, or any other calibration problems.

We conclude, therefore, that (i) the temporal dependence of the residue data is as expected, that (ii) the degradation handling has successfully removed degradation effects, and that (iii) – as a result of this – the current residue and SC-AAI data (July 2002–March 2007) can be used for temporal analyses.

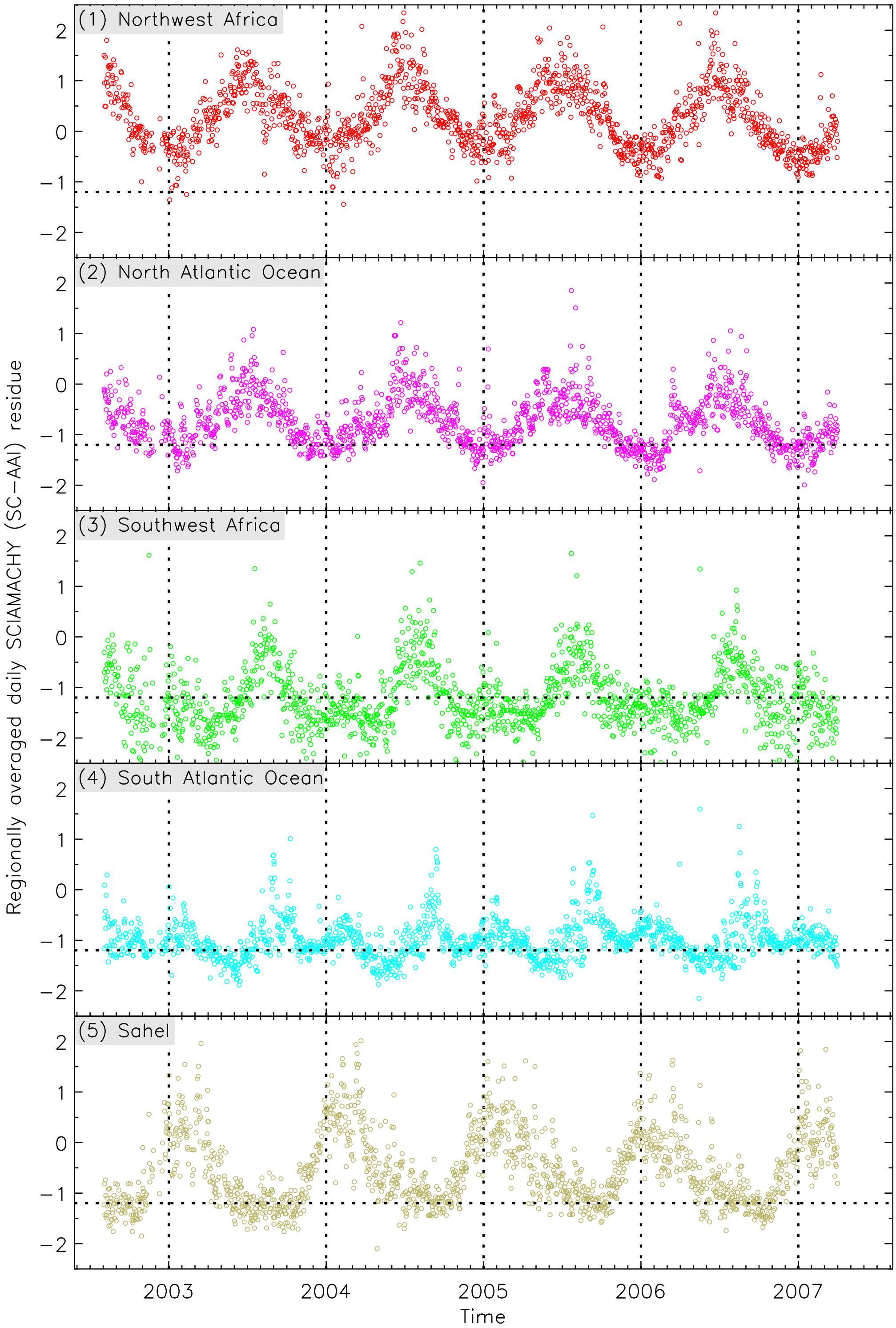

Figure 4. Time series of the daily residue averaged over the areas numbered 1 to 5 in Fig. 3. A clear seasonal variation is found in the data. For comparison, the horizontal dotted line shows the globally averaged residue.

5. CONCLUSIONS

We studied the quality of the SCIAMACHY AAI data, and in particular the quality of the degradation correction we apply. This was done by monitoring the temporal behaviour of the residue. We do not find any trend in the time series of the residue (which could be related to remnants of instrument degradation), and the seasonal variations we find are fully in accordance with earlier results for GOME data. In summary, the AAI data we provide on the TEMIS website are suited for use over the entire time range of SCIAMACHY data that is currently available.

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