SCIAMACHY LIGHT PATH MONITORING RESULTS

Stefan Noël(1), Heinrich Bovensmann(1), Klaus Bramstedt(1), John P. Burrows(1), Manfred Gottwald(2), and Eckhart Krieg(2)

(1) Institute of Environmental Physics, University of Bremen, FB 1, P. O. Box 330440, D-28334 Bremen, Germany
(2) DLR–IMF, P. O. Box 1116 , D-82230 Weßling, Germany

ABSTRACT

The spectrometer SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) on-board ENVISAT is measuring solar irradiances and Earthshine radiances from the UV to the SWIR spectral region in nadir, limb and lunar/solar occultation geometry. From these measurements the amount and distribution of various atmospheric constituents are derived. To assure the quality of these data products at any time during the whole mission a detailed knowledge of the instrument status and behaviour is mandatory. To achieve this a comprehensive monitoring concept has been developed and implemented, involving various dedicated calibration and monitoring measurements. In this paper, selected results from the analysis of these monitoring data are shown. Special emphasis is placed on the performance monitoring for the various light paths.

1. INTRODUCTION

The SCIAMACHY (Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY) instrument is part of the atmospheric chemistry payload of the European environmental satellite ENVISAT. Since the ENVISAT launch in March 2002, SCIAMACHY is measuring both the Earthshine radiance and the solar irradiance in the spectral region from the UV (214 nm) to the short wave infrared (2380 nm) at a spectral resolution between about 0.2 and 1.5 nm. The SCIAMACHY measurements are performed in three different viewing geometries, namely nadir, limb and (both solar and lunar) occultation. From inversion of these spectral measurements the amount and global distribution of a large number of atmospheric constituents, such as O_3, BrO, SO_2, H_2CO, NO_2, CO, CO_2, CH_4, H_2O, clouds, and aerosols can be determined, see e.g. [1, 2] for details.

To assure the high quality of the SCIAMACHY data products over the mission, a continuous monitoring of the SCIAMACHY functionality and performance is essential. For this purpose dedicated calibration activities are performed on a regular basis, comprising measurements with the internal White Light Source (WLS) and observations of the un-obscured sun above the atmosphere; see e.g. [3, 4] for details and previous results.

The current paper focuses on the following aspects: (1) The actual performance status of all light paths is presented based on channel average data; this is an update of previously published light path monitoring results. (2) New spectrally resolved throughput monitoring data are presented. (3) First results from the monitoring of the PMD (Polarisation Measurement Device) light paths are shown.

2. LIGHT PATH MONITORING RESULTS

As mentioned before, SCIAMACHY is performing scientific measurements in nadir, limb, and occultation geometry. Additionally, solar irradiance reference measurements are performed via the so-called calibration light path. Depending on the viewing geometry, different optical components are involved in the light path which may degrade in a different way. Therefore, each of these light paths needs to be monitored separately (see Fig. 1). The relevant optical components in this context are especially the Azimuth Scanner Module (ASM) and the Elevation Scanner Module (ESM). Both modules consists of a mirror and a diffuser which is mounted on the backside of the mirror. Nadir measurements are performed via the ESM mirror, limb and occultation measurements via the combination of ASM mirror and ESM mirror; in this sense the limb and occultation light paths are identical. Absolutely calibrated solar irradiances are measured via the ASM mirror and the ESM diffuser. The are also solar irradiance measurements performed via the combination ASM diffuser and ESM mirror which are used as relative reference within certain retrievals. However, the ASM diffuser is not radiometrically calibrated and therefore currently excluded from operational monitoring (although this is foreseen to be added in the future).

The general idea for long-term performance monitoring is to repeat measurements for a certain light path using a known light source at different times. The ratio of a measurement at one time to the same measurement at a reference time then gives the end-to-end performance change for the specific light path over the time between the two measurements.

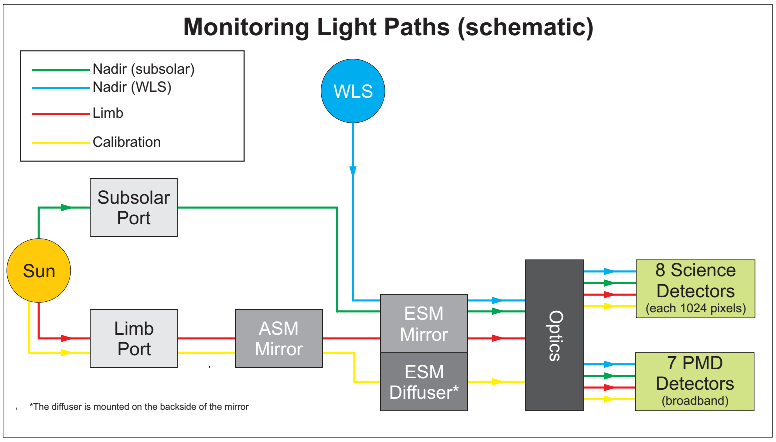

Figure 1. Simplified schematic view of the SCIAMACHY monitoring light paths relevant in this paper.

In the case of SCIAMACHY there are two known light sources available: The sun (measured above the atmosphere) and the internal White Light Source (WLS) which has proven to be rather stable over time (see e.g. [4]). Therefore SCIAMACHY long-term monitoring activities include regular solar and WLS measurements. In the case of solar measurements the sun is observed either via the limb port (for the limb/occultation and the calibration light paths) or via a dedicated so-called 'subsolar' port through which the sun can be viewed at a certain orbital position via the ESM mirror alone. Subsolar and WLS measurements are used to monitor the nadir light path.

These measurements are currently analysed in three different ways for which the actual results are presented in the following subsections. Note that all results shown in this paper are based on specially processed uncalibrated Level 0 data. Small variations (in the percentage range) of the monitoring data may therefore be related to an incomplete calibration. As reference time the 2 August 2002 (at about orbit 2200) has been chosen, except for subsolar data which have been referred to orbit 4519 (10 January 2003). This is because subsolar measurements before 30 November 2002 were affected by an angular misalignment resulting in strong variations of the measured subsolar signal. Data of times with reduced instrument performance (e.g. during decontamination periods) have been omitted. Note that regularly updated SCIAMACHY monitoring data are available via the IUP web site (http://www.iup.physik.uni.bremen.de). The monitoring results are also included in the ESA SCIAMACHY bi-monthly reports (see http://earth.esa.int/pcs/envisat/sciamachy/reports/).

2.1. Science Channel Averages

The first analysis method has already been described previously (see e.g. [4]). In this case a time series is produced based on spectrally averaged data resulting in one value per time for each of the science channels. The actual results for this type of monitoring are shown in Fig. 2. The main findings from these data are as follows:

There is an increasing degradation in the UV (especially channels 1 and 2) with a current rate of about 1% per month. Such a degradation has been expected, but it turned out to be less for SCIAMACHY than e.g. for its predecessor instrument GOME (Global Ozone Monitoring Experiment, see e.g. [5, 6]), which showed a relative intensity loss in the UV (based on solar irradiance measurements) of up to 40% after three years of operation.

From the smaller degradation of the calibration light path compared to the others it can be concluded that the ESM mirror is the optical component which degrades most (which is plausible as the ESM mirror is used most, i.e. it is exposed to light in all limb, nadir and occultation measurements).

Also in Channel 3 some first signs for a degradation are visible, but the average throughput loss is currently only about 2%. Except for some small seasonal variations the throughput in channels 4 to 6 remains quite stable, partly on a sub-percent level (see also [4]).

The throughput in the IR channels 7 and 8 is highly variable because of the effect of growing ice layers on the detectors. These ice layers can be removed by a decontamination (heating) procedure, by which the original throughput is restored (clearly visible in the channel 7 and 8 data shown in Fig. 2), but afterwards the ice usually starts to grow again, at least until a certain limit given probably mainly by the amount of available water. The last decontamination in January 2005 resulted in a stable throughput at almost 100% for channel 7 and (depending on light path) at about 80% for channel 8 which is sufficiently high such that currently no further decontamination is planned. Note that the apparently higher throughput for the subsolar light path in channel 8 is not real but caused by a systematic offset induced by the specific scan mode (fast sweep) used for the analysis. Future monitoring activities will be based on subsolar measurements in nominal scan mode (as for the PMDs, see below) which provide more reliable results but are currently performed only once per month.

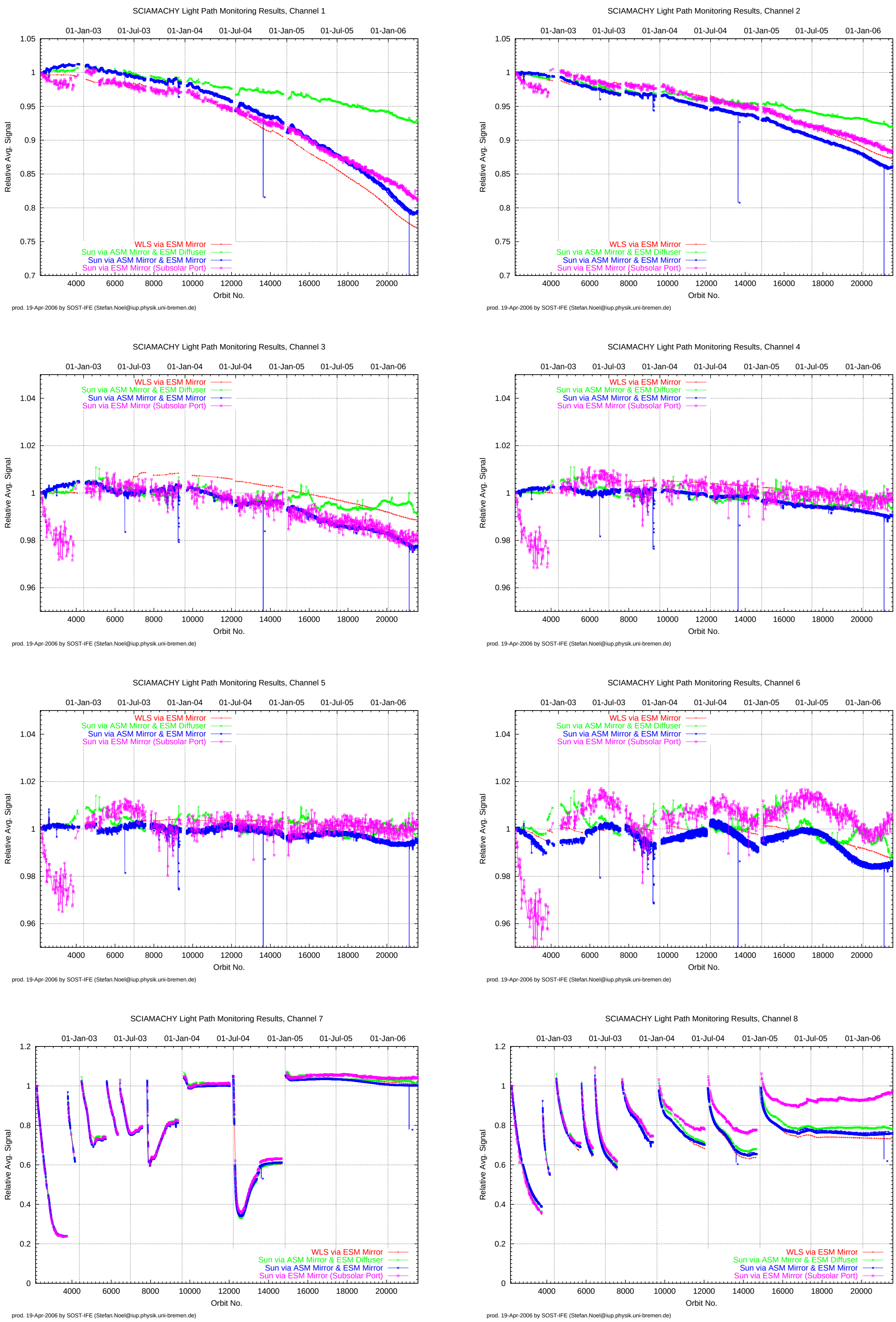

Figure 2. Average throughput change per channel as a function of time for the different SCIAMACHY light paths.

2.2. Science Channel Spectral Results

Recently, the SCIAMACHY monitoring activities have been extended to include also spectrally resolved science channel data. The underlying data analysis is essentially the same as for the channel average data (but of course without the averaging).

An example for the results of these monitoring activities is shown in Fig. 3 for the limb light path. Except for the general differences observed already in the channel average data the results for the other light paths are very similar. From the spectral results more information about the spectral behaviour of the degradation can be derived. As can be seen from Fig. 3, a large degradation typically occurs close to the channel edges, probably caused by changes of the dichroics used to separate the wavelength regions. As expected, the degradation increases towards the UV (note that the wavelength axis of channel 2 is inverted!) and reaches at the lower wavelength edge of channel 1 already a remaining throughput of about 60% only. An indication for a small degradation is also visible at the low wavelength edge of channel 3. However, there are also special regions like e.g. around 350 nm where the throughput loss is extremely high. Possible reasons for these degradations are currently under investigation. Interestingly, the low throughput regions are just where also the polarisation sensitivity of the instrument is high, but this may just be a coincidence.

Some high frequent spectral fluctuations are also visible in the spectral monitoring data for the limb light path, especially in channel 8. These structures can be attributed to the small aperture which is in the light path for all solar measurement not involving a diffuser. The WLS and calibration light path data are spectrally much smoother.

2.3. PMD Results

SCIAMACHY is a polarisation sensitive instrument, i.e. the measured signal depends on the polarisation of the incoming light. The operational data processing takes this into account by including a dedicated polarisation correction algorithm. This algorithm uses as input on the one hand the polarisation sensitivity of the instrument (which has been determined during the on-ground calibration). On the other hand, the algorithm requires the actual polarisation of the incoming light, which is measured by a Polarisation Measurement Device (PMD) which consists of seven broad-band detectors. In contrast to the science channel detectors which give an integrated signal over an exposure time, the PMD detectors are sampled at 40 Hz. PMD 1 to 6 (sometimes also called A to F) are measuring linear polarised light, whereas PMD 7 (or 45) measures the 45° polarised component at the same spectral window as PMD 4. Currently PMD 7 data are not used in the operational data processing because they seem to be significantly contaminated by stray light. They have therefore also been excluded from the monitoring results presented here.

The PMD monitoring is in general based on the same measurements as the science channel monitoring, with the following differences: (1) WLS data are not available for all PMD detectors because of saturation. (2) The nadir light path is monitored using a different subsolar scan mode (pointing instead of fast sweep) which is currently only performed once per month. This is necessary because the variation of the fast sweep signal on the (sampling) PMD is too high; pointing measurements provide data which are much more stable in time.

First preliminary PMD monitoring results are shown in Fig. 4. Considering the broad spectral regions covered by the PMD these results are quite comparable to the science channel data. However, there are some specific issues for the PMD which require further investigation. Most remarkable are the considerably large throughput loss for PMD 4 and the remaining seasonal variations in the PMD throughput which seem to increase in amplitude with higher wavelength. Furthermore, the large relative variation of the PMD 6 dark current is currently unexplained.

3. SUMMARY AND CONCLUSIONS

The SCIAMACHY performance monitoring has been extended from science channel averages to a spectrally resolved monitoring by which specific degradation features can be identified. Furthermore, first results from the monitoring of the PMD light paths are now available, which are in general consistent with the science channel data.

The long-term monitoring results show that after more than four years of operation the SCIAMACHY instrument is still in good shape. In the UV, an enhanced degradation of currently about 1% per month is visible which is still less than expected, Channels 3 to 6 remain very stable, although there is some indication for the onset of a degradation at the lower wavelength edge of channel 3. Even channels 7 and 8 now show a rather stable transmission, although at about 80% for channel 8. Nevertheless, the icing problem seems to be no issue for the current data.

From the performance point of view SCIAMACHY is therefore well prepared for an extended ENVISAT mission until 2010.

ACKNOWLEDGEMENTS

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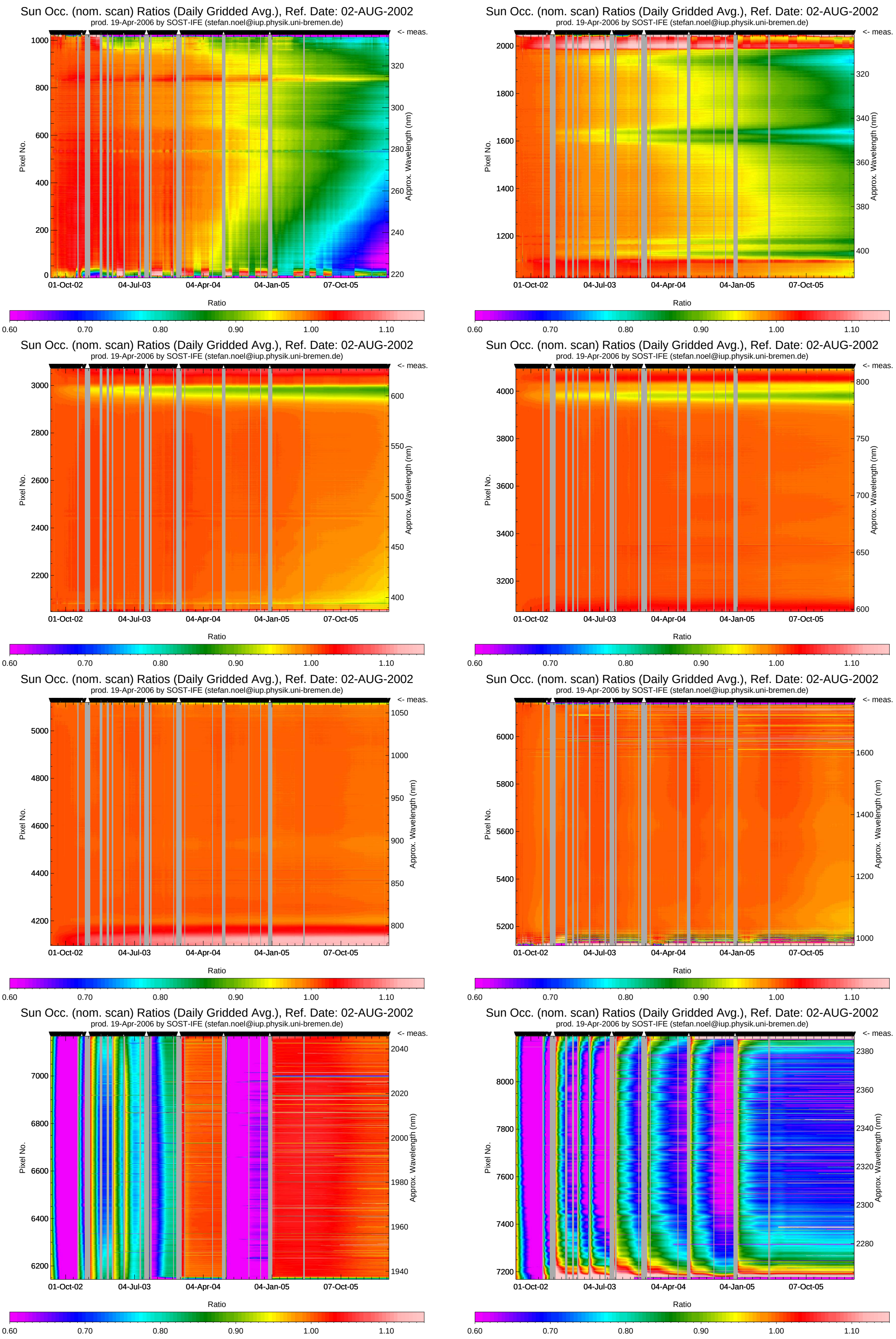

Figure 3. Spectrally resolved throughput change as a function of time for the SCIAMACHY limb light path.

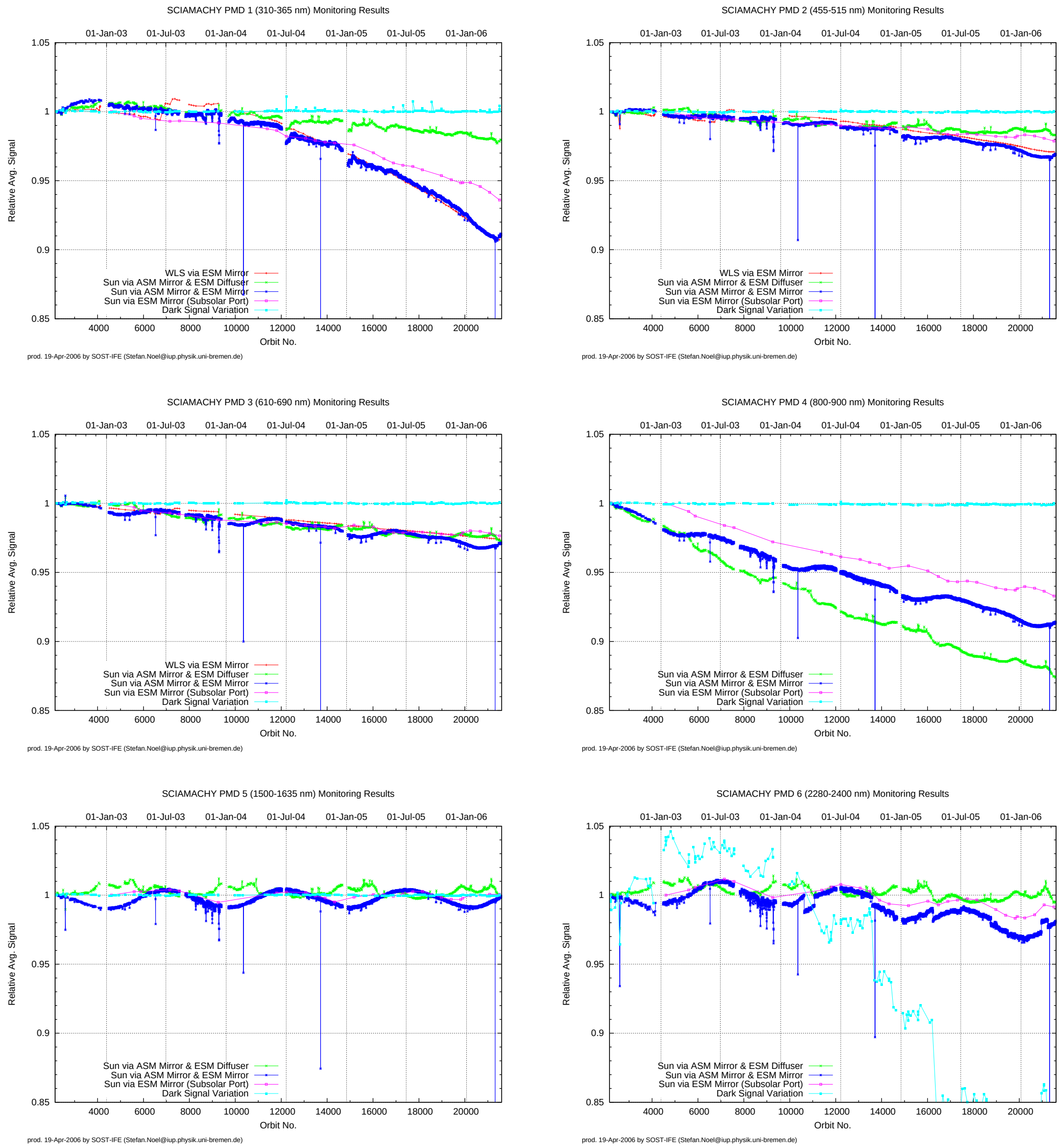

Figure 4. First PMD monitoring results.

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