# SCIAMACHY SOLAR IRRADIANCE VALIDATION USING RADIOMETRIC CALIBRATION OF BALLOONBORNE, AIRBORNE AND GROUND-BASED SPECTROMETERS

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## ABSTRACT

Solar occultation measurements of balloonborne LPMA and DOAS spectrometers are used for SCIAMACHY validation. The SCIAMACHY level-1 product solar irradiance is validated by extrapolation of measured spectra at different solar zenith angles. To achieve this, a radiometric calibration is performed before and after each balloon flight. To correct for atmospheric effects, the Langley-plot method can be used to calculate the TOA (top of atmosphere) incoming solar irradiation. In order to further broaden the database for level-1 validation of SCIAMACHY, the range of sensors has been extended to airborne and ground-based DOAS-spectrometers. These can be useful for the validation of level-1 radiance measurements of SCIAMACHY.

## 1. SCIAMACHY ON ENVISAT

The sensor validated by the procedures described here is SCIAMACHY on ENVISAT, a spaceborne atmospheric chemistry instrument. SCIAMACHY is a passive optical remote sensing instrument that measures the absorption, reflection and scattering characteristics of the atmosphere between 240 and 2380 nm wavelength. Measurements are made using scattered sunlight in nadir and limb geometry, transmitted solar and lunar radiation in occultation geometry, and solar and lunar irradiance. For each orbit solar occultation measurements, including measurements of the solar irradiance, are made during sunrise. All measurements will be converted to provide information about the amounts and distributions of selected atmospheric constituents ($O_3$, BrO, OCLO, $SO_2$, NO, $NO_2$, $H_2O$, CO, $CO_2$, $CH_4$, $N_2O$ among others), as well as information about aerosol, pressure, temperature, radiation field, cloud cover, cloud top height and surface reflectance. ENVISAT was launched on 28 february 2002 from Kurou using an Ariane-5 launcher.

## 2. PRODUCT: SOLAR IRRADIANCE

The solar irradiance is a level 1 product of SCIAMACHY. It is an input quantity for retrieval algorithms like FURM (FULL Retrieval Method) which was already used for the retrieval of GOME $O_3$ profiles. Solar irradiance data also play a major role in the development of the data retrieval in limb-geometry and as an input parameter for chemical models (i.e. Ring). Solar irradiance measurements are useful for long-term instrument performance monitoring and their validation will help to maintain the calibration of SCIAMACHY during its lifetime. Instrument aging is known to be a large source of uncertainty. Experience with the GOME sensor [1] shows that the calibration may vary significantly after launch as a result of degradation in orbit. Further interest arises from the field of solar physics. The influence of the solar UV-light on the upper atmosphere and on earth´s climate has already been subject of dedicated satellite measurements. Spectrally resolved UV-irradiance with emphasis on the 27-day solar rotation and the 11-year solar cycle has been monitored by the satellite instruments SOLSTICE [2] (calibrated against stellar targets) and SUSIM [3]. Calibration concepts of these instruments had to take into account the strong degradation in orbit. In the case of SUSIM an independent backup instrument carried by Space-Shuttle was included, which could be repeatedly calibrated pre- and postflight. The solar irradiance validation of SCIAMACHY described here also relies on repeated calibrations of the balloonborne spectrometers used.

## 3. GENERAL CONCEPT

The LPMA (Limb Profile Monitor of the Atmosphere, an IR Fourier-transform spectrometer) and DOAS [4] (Differential Optical Absorption Spectrometer, a UV / visible grating spectrometer) are used together as a combined balloon payload. During regular flights of the payload scheduled for the validation of ENVISAT level-2 products

*Proc. of Envisat Validation Workshop, Frascati, Italy, 9 – 13 December 2002 (ESA SP-531, August 2003)*

within the framwork of the ESABC (Envisat Stratospheric Aircraft & Balloon Campaigns), additional solar irradiance measurements are made. Both the LPMA and the DOAS instrument use solar occultation for the determination of trace-gas profiles. The combined wavelength range of the instruments (320 – 2400 nm) covers most of the SCIAMACHY spectral range at a comparable resolution, and thus offers the unique opportunity for a validation of the level-1 product solar irradiance. SCIAMACHY channels 2 and 3 are covered by DOAS, while channels 5, 7, 8 and possibly 4 and 6 are accessible by the LPMA depending on its configuration.

**4. CALIBRATION SOURCE**

Prerequisite for the validation is a radiometric calibration of the LPMA and DOAS spectrometers. The possibility to recalibrate the two instruments in the field prior and after each flight of the balloon is an advantage over satellite measurements that can increase overall accuracy. Radiation from a specially desiged and completely characterized irradiance stimulator (fig. 1)  is then brought onto the optical entrance (the sun-tracker mirror) of the LPMA / DOAS payload. The irradiance stimulator newly developed at the University of Bremen uses a special beam geometry, which was optimized for the LPMA and DOAS spectrometers during a series of laborarory campaigns. In contrast to conventional optical calibration set-up´s, whose irradiance depend on the distance between the source and the device to be calibrated, our calibration source produces a uniform irradiance (radiometric flux per unit area) at distances between 1 and 15 meters, as long as atmospheric absorptions along the light-path are not taken into account.  This is the result of a novel optical geometry to be reported elsewhere. In addition, a complete optical calibration laboratory was installed at the University of Bremen. Several calibration lamps, detectors and integration spheres fully characterized and certified by the leading institutes NIST [5], PTB and NLP are available. This makes possible the routinely  recalibration of our irradiance stimulator and other campaign calibration sources in order to keep uncertainty of the spectral radiation as low as possible.

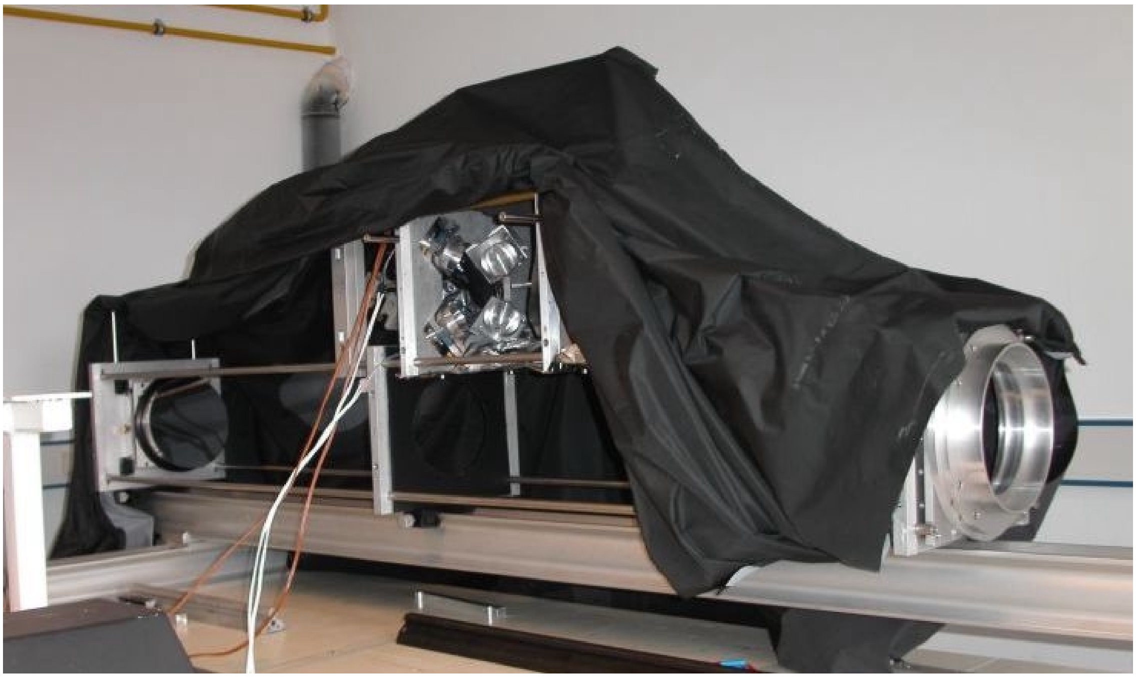
Fig. 1: Irradiance Stimulator for ballonborne LPMA-DOAS

**5. CAMPAIGNS**

Ballon lauches are scheduled as to enable occultation measurements during sunrise or sunset from the float position at an altitude of 30-35 Km. Measurements can then be made at different solar zenith angles ranging from 83 to 95 degrees in a relatively short time interval. The first LPMA-DOAS flight which uses the calibration source was scheduled by the ESABC community and CNES for march 2003 from Kiruna. The SCIAMACHY solar irradiance validation will then be performed as an additional measurement using the two-instrument balloon-payload already included in the validation programme. There is no need for instrument modification or additional balloon launches.

## 6. ADDITIONAL SENSORS

In order to get a broader data base for level-1 validation, airborne and ground-based DOAS spectrometers using nadir and zenith-sky geometry were also radiometrically calibrated using NIST (original and NIST-traceable) and PTB-traceable, fully certified and characterized calibration sources (fig. 2). The airborne multiaxis-DOAS (AMAXDOAS) onboard the DLR Falcon twinjet [6] and two ground based instruments in Bremen and in Nairobi, Kenia, are delivering absolute radiance measurements. Radiometric calibration was very successful and showed good agreement within 3% before and after the north leg (to Kiruna and back) of the SCIA-VALUE campaign (fig. 3). However, stability of the AMAXDOAS can be further improved relatively easy. Data from the AMAXDOAS is available from approximately 50 flight-hours during the SCIA-VALUE campaign (fall 2002), while the two ground-based units are delivering a constant flow of data. The unit operated now in Bremen is later to be shipped to Merida (Venezuela). The SCIAMACHY level-1 validation by using absolutely calibrated radiance measurements involves the use of the radiance transfer model SCIATRAN to compare the different viewing geometries. Tracer and aerosol measurements additionally performed during SCIAMACHY overpasses enable a very realistic modelling and keep the error budget small enough to make a meaningful radiance comparison and validation.

Fig. 2: Radiometric calibration of the AMAXDOAS optical telescopes

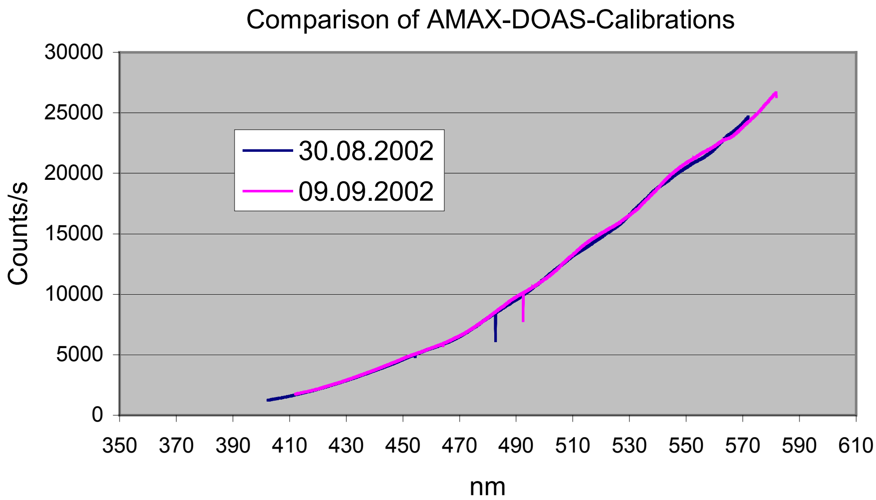


Fig. 3: Comparison of two AMAXDOAS calibrations made before and after the flight of the FALCON to Kiruna and back during the SCIAVALUE campaign

## 7. OUTLOOK

Best accuracy is expected from the occultation measurements using LPMA and DOAS, resulting from the clear definition of the optical path. The series of flights was scheduled to begin in march 2003 from Kiruna. However, validation of level-1 radiance values from SCIAMACHY can already now be made using the radiometrically calibrated airborne and ground-based DOAS measurements. For performance and possibly degradation monitoring of

SCIAMACHY, we expect our level-1 validation measurements to be very relevant and of even increasing importance during the mission lifetime.

## 8. ACKNOWLEDGEMENT

The Authors wish to acknowledge the support from Andreas Richter and the AMAXDOAS team.
This work was funded by DLR (Deutsches Luft- und Raumfahrtzentrum) and BMBF (Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie) under contract number 50 EE 0019.

## 9. REFERENCES

1. Eisinger M., Burrows J. P., Richter A., *Studies on the precision of GOME irradiance and radiance products and GOME measurements of OCLO and BrO over Antarctica,* GOME calibration and valiadation handbook

2. SOLSTICE homepage: http://lasp.colorado.edu/solstice

3. SUSIM homepage: http://wwwsolar.nrl..navy.mil/susim.html

4. Ferlemann F., Bauer N., Fitzenberger R., Harder H., Osterkamp H., Perner D., Platt U., Schneider M., Vradelis P., Pfeilsticker K., *Differential optical absorption spectroscopy instrument for stratospheric trace-gas studies*, Appl. Opt.Vol 39, No 15, 2377-2386, 2000.

5. NIST website: http://www.physics.nist.gov/Divisions/Div844/facilities/fascal/fascal.htm

6. Wagner T., Bruns M., Burrows J. P., Heue K.-P., Platt U., Pundt I., Richter A., v. Friedeburg C., Wang P., *Validation of tropospheric species measured by SCIAMACHY using the AMAXDOAS instrument onboard the DLR FALCON*, this issue