Calculation of new absolute radiometric keydata for SCIAMACHY based on NASA sphere measurements

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Introduction

The **SC**anning **I**maging **A**bsorption spectro**M**eter for **A**tmospheric **CH**artograph**Y** (SCIAMACHY) has been launched in March 2002 on board the European environmental satellite ENVISAT.

First comparisons of radiances and irradiances measured by SCIAMACHY with independent sources indicated an error in the absolute radiometric calibration, which has a strong impact on the quality of most level-1 data products.

To overcome this problem, an extensive re-analysis of the radiometric on-ground calibration measurements of SCIAMACHY has been performed, and a new procedure has been developed to recalculate some of the radiometric key data from existing end-to-end measurements.

These calculations were primarily based on a subset of NASA sphere measurements, performed for SCIAMACHY's radiance and irradiance validation during the OPTEC-5 on-ground calibration period in 1999/2000. This integrating sphere is a 20" diameter internally illuminated sphere coated with $BaSO_4$. It has a long history of providing accurate absolute radiances for NASA's SBUV2 and TOMS programs and has also been used for the validation of the GOME absolute radiance calibration.

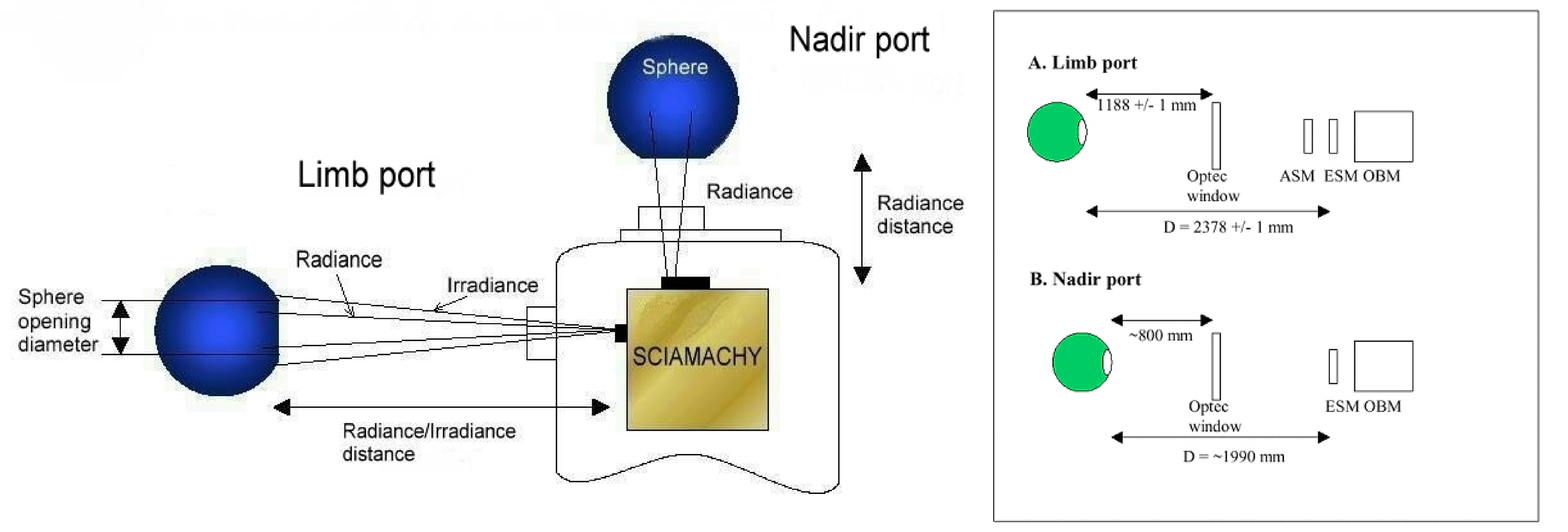
Measurements

During the OPTEC-5 campaign, four different types of measurements were used to calculate the radiance of the sphere in absolute values and determine SCIAMACHY's radiance/irradiance response. These measurements are in particular:

1. Limb measurement of the irradiance of a bare FEL lamp over the ASM- mirror & ESM-diffuser.
2. Measurement of the spheres irradiance response in limb geometry over the ASM-mirror & ESM-diffuser.
3. Measurement of the spheres radiance response in limb geometry over the ASM- & ESM-mirror.
4. Measurement of the spheres radiance response in nadir geometry over the ESM-mirror.

From these measurements only the instrument response in [BU/s] from measurements 2+3, the ESM/ASM-mirror reflectivity (EL_AZ_0) and the geometry of the illumination set-up are needed to calculate the absolute value of SCIAMACHY's ESM diffuser BRDF for a fixed angle.

Measurement Setup



Various NASA sphere measurement setups have been used for the validation of SCIAMACHY's radiance and irradiance calibration during the OPTEC-5 calibration campaign.
The limb radiance was measured over SCIAMACHY's ASM and ESM mirrors. The limb irradiance was measured over SCIAMACHY's ESM diffuser and the ASM mirror. The nadir radiance was measured over the ESM mirror.
For limb irradiance measurements, SCIAMACHY was switched from radiance to irradiance mode by rotating the ESM mirror, which is installed back to back with the ESM diffuser plate. For that reason, radiance and irradiance measurements can be performed shortly one after each other.

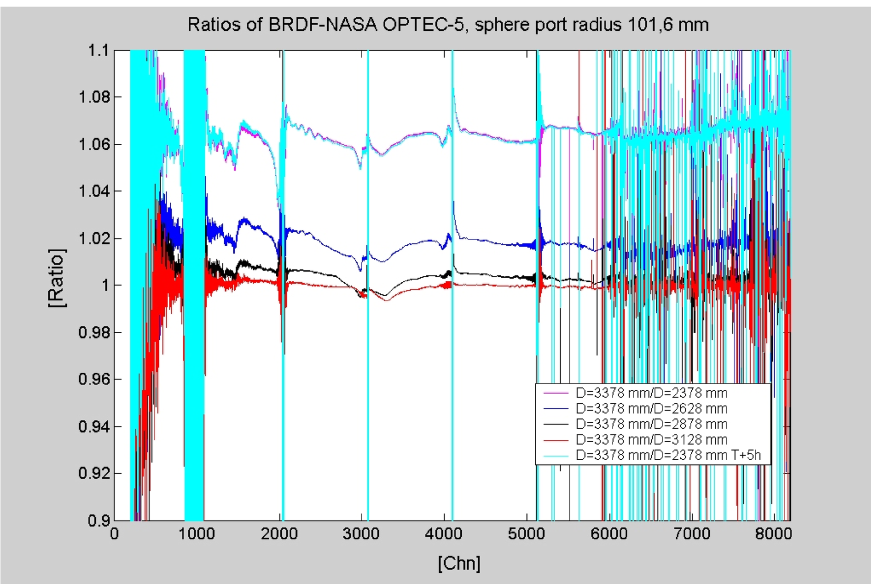
Calculation of the ESM-BRDF

In particular, the absolute value of SCIAMACHY's ESM diffuser BRDF for a fixed angle can be derived from:

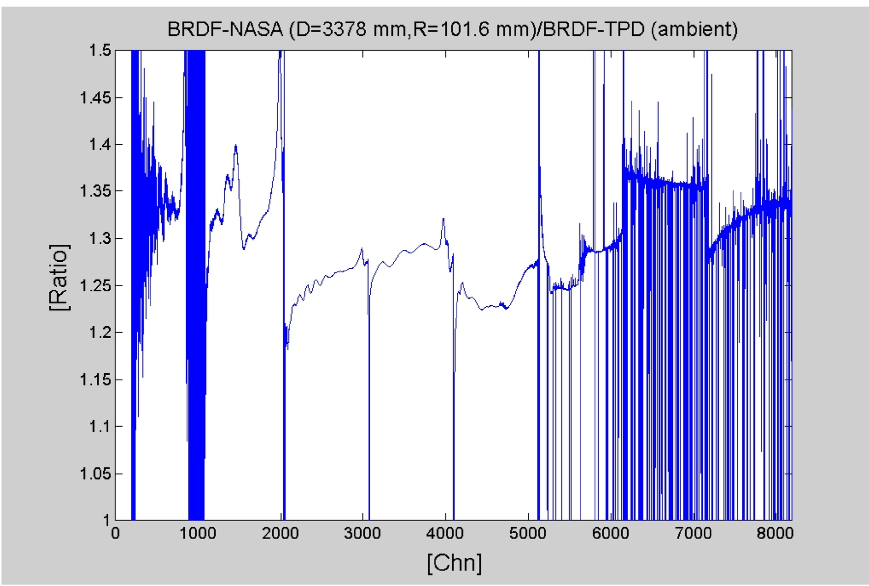
$$BRDF_{ESM} = [Sig\_Sp\_Irrad/ Sig\_Sp\_Rad]*[EL\_AZ_0/ \ _{Sphere}]$$

with: $_{sphere} = (\ *r_1^{\,2})/[r_1^{\,2} + r_2^{\,2} + D^2]$ (Walker factor, (*Walker, 1987*))
Sig_Sp_Irrad : SCIAMACHY's irradiance response [BU/s]
Sig_Sp_Rad : SCIAMACHY's radiance response [BU/s]
EL_AZ_0 : ESM and ASM mirror reflectivity

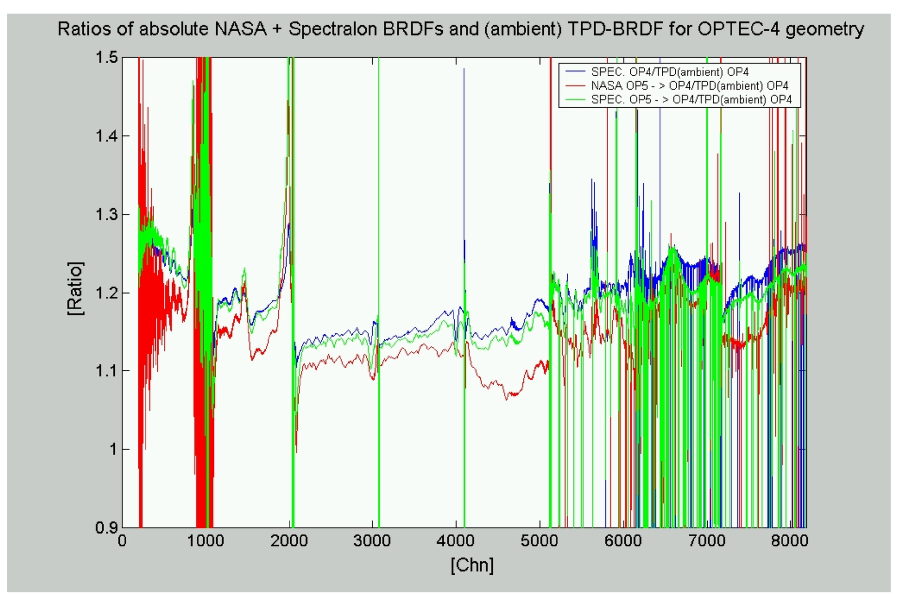
Results



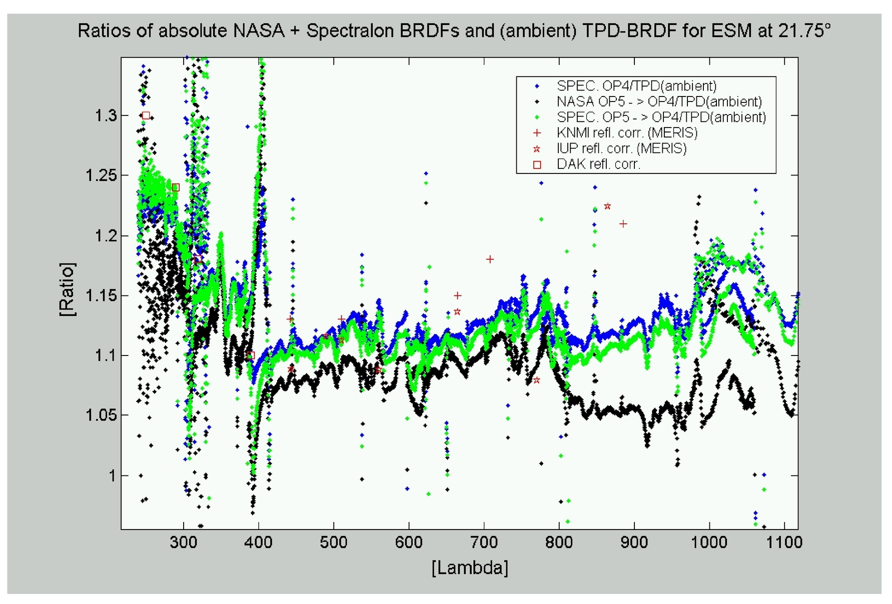
[Fig. 1] Dependency of the NASA-BRDF from the distance between the sphere and the ESM reference plane.



[Fig. 2] Deviation of the NASA-BRDF from SCIAMACHY's ambient-measured BRDF for OPTEC-5 geometry.

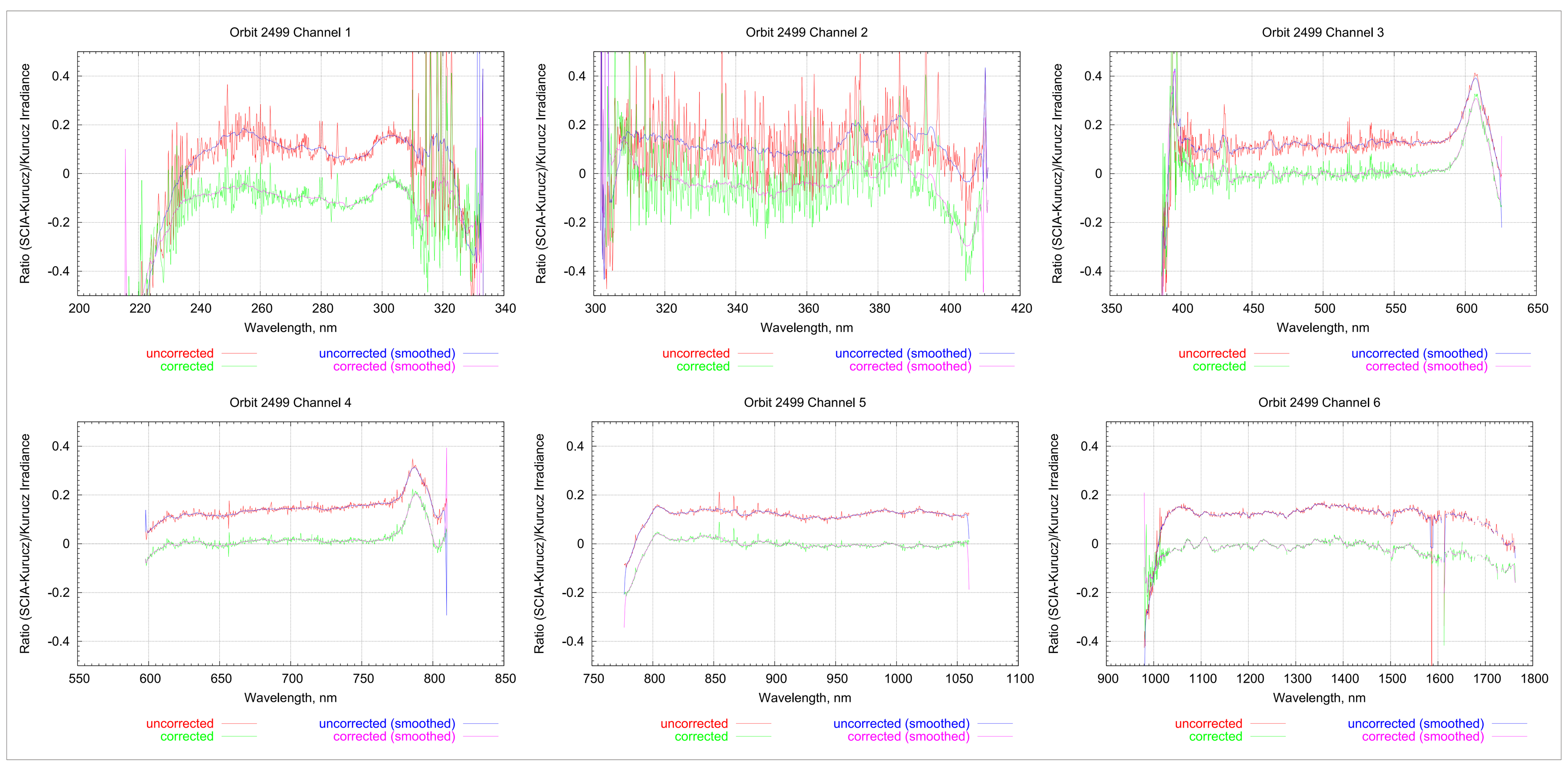


[Fig. 3] Deviation of the NASA-BRDF transferred to OPTEC-4 geometry from SCIAMACHY's ambient measured BRDF. For comparison, BRDFs calculated for FEL-lamp irradiance and FEL-lamp and Spectralon diffuser radiance measurements are also shown.



[Fig. 4] Comparison of SCIAMACHY reflectance correction obtained from NASA-BRDF calculations with reflectance corrections obtained from (1) end-to-end FEL/Spectralon diffuser measurements (2) MERIS reflectances, and (3) theoretical model (DAK).

- The amount of straylight and vignetting for measurements made at distances longer than 2878 mm between the NASA sphere and SCIAMACHY's ESM diffuser is smaller than 1% [Fig. 1].
- The difference between the BRDF as calculated from NASA sphere measurements for such distances and the ambient-measured SCIAMACHY ESM diffuser BRDF is on the order of 25-35% for OPTEC-5 geometry (i.e. ASM mirror at -45°, ESM diffuser at -25.4°) [Fig. 2].
- After transfer to OPTEC-4 geometry (ASM mirror at -30°, ESM diffuser at -22.5°; equivalent to SCIAMACHY's in-flight configuration at the start of the sun irradiance measurement) the difference between the new NASA-BRDF and SCIAMACHY's ambient measured BRDF is on the order of 10-20% [Fig. 3]. This indicates also an error of the relative values of SCIAMACHY's ambient measured ESM diffuser BRDF.
- For the verification of these issues, OPTEC-5 and OPTEC-4 BRDF's from end-to-end FEL lamp & Spectralon diffuser radiance and irradiance measurements were calculated. Here, a good agreement in the 400-800nm spectral range was found. The reason for the somewhat larger deviation of the FEL/Spectralon BRDF's from the NASA BRDF in the 800-2400 nm spectral range [Fig. 3,4] is currently under investigation.
- A comparison of SCIAMACHY reflectance corrections obtained from end-to-end NASA and FEL lamp & Spectralon diffuser radiance and irradiance measurements with corrections obtained from MERIS reflectances by IUP-BREMEN and KNMI shows a good agreement in the 400-800 nm spectral range, but unreasonably high deviations at the wavelength 880 nm. SCIAMACHY reflectance corrections in the 240 - 400 nm spectral range as obtained by KNMI using a radiative transfer model (DAK) show a somewhat better agreement with reflectance corrections obtained from FEL/Spectralon BRDF calculations than reflectance corrections obtained from NASA BRDF calculations. The reason for that behavior is possibly the weak UV output of the sphere during SCIAMACHY irradiance measurements.



[Fig. 5] Comparison between uncorrected and NASA corrected SCIAMACHY channel 1-6 solar irradiance spectra with the 'new Kurucz' solar irradiance spectrum from MODTRAN 3.7 convolved to SCIAMACHY's spectral resolution. The deviations observed at the channel boundaries are caused by changes of the instrument response after launch. An algorithm using ratios of on-ground and in-flight internal white light source measurements to overcome this problem is currently under development.

- By using NASA sphere's BRDF and radiance corrections, a good aggreement between the 'new Kurucz' spectrum and SCIAMACHY solar irradiance spectra can be obtained [Fig. 5].

Selected References

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Conclusions

New radiometric keydata for SCIAMACHY have been derived from NASA sphere measurements. Especially the new Bidirectional Reflectance Distribution Function (BRDF) for the ESM Diffuser shows a significant difference to the on-ground ambient measured data.
First applications to in/flight measurements indicate that the radiometric calibration of SCIAMACHY can be significantly improved by using these newly calculated keydata.
An improvement of the quality of level-2 data products is also expected.

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