VALIDATION OF SCIAMACHY OZONE LIMB PROFILES BY ASUR


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ABSTRACT

The Airborne Submillimeter Radiometer (ASUR) is a microwave receiver, which has been used for observing stratospheric and mesospheric constituents. ASUR has also been deployed for validating many satellite sensors since 1996. The SCIAMACHY sensor is one of the atmospheric chemistry payloads onboard the ENVISAT satellite. SCIAVALUE is the aircraft campaign performed onboard the DLR Falcon in September 2002 and in February/March 2003 to validate the SCIAMACHY data products. The campaign covered a latitude band from the tropics to the Arctic in two different seasons to enable the validation activities under different atmospheric conditions. Ozone measurements gathered by the ASUR sensor during the campaign are compared with the SCIAMACHY ozone limb profiles. Two SCIAMACHY ozone datasets have been used for the validation, the ESA operational product version 2.1 and the in-house scientific product version 1.6. Both datasets give reasonable agreement at all latitude sections namely, tropics, midlatitudes and the Arctic. The difference between ASUR and SCIAMACHY is about 10-15% in an altitude range of 20-50 km. However, this is within the estimated accuracy of ASUR ozone retrievals. The comparisons indicate that the SCIAMACHY retrievals might have a pointing problem.

Key words: ASUR; SCIAMACHY; SCIAVALUE; ozone; validation.

1. INTRODUCTION

Satellites play a vital role in monitoring the earth’s environment. New satellite sensors are necessary for a continuous monitoring. The ENVISAT is such a novel experiment dedicated to monitor the earth’s environment from space. The SCIAMACHY sensor is one of ten instruments on the ENVISAT satellite, and is mainly aimed at measuring various atmospheric constituents. It is necessary to validate newly installed satellite sensors against well-tested and proven instruments to assess the quality of the data provided by the sensor, vertically resolved data products in particular. The Airborne Submillimeter Radiometer has been used for validating a number of satellite sensors. It includes MLS on UARS (1993), GOME onboard ERS-2 (1996), ILAS on ADEOS (1997) and SAGE-III on Meteor - 3M (1999-2000). Recently, the ASUR sensor was operated onboard the DLR Falcon research aircraft during the SCIAVALUE campaign. The data collected during the campaign are used in this study. The following sections describe the instrument, the campaign, the data analyses and validation results.

Figure 1. The averaging kernels of ASUR ozone retrievals. The resolution of measurements (derived from Full Width at Half Maximum of kernels - FWHM) is also shown.

2. THE AIRBORNE SUBMILLIMETER RADIOMETER

The ozone measurements were carried out by a passive microwave sensor, the Airborne Submillimeter Radiometer ASUR [Küllmann et al. (1999)]. The heterodyne receiver operates in a tunable frequency range of 604 GHz to 662 GHz. It is equipped with two spectrometers namely, an Acousto optical spectrometer (AOS) and a Chirp transform spectrometer (CTS). The AOS has a total bandwidth of 1.5 GHz, a resolution better than 1.5 MHz, whereas the CTS has a bandwidth of 178 MHz, and a resolution of 278 kHz. The broadband AOS is mainly used for stratospheric measurements, while the high resolution CTS is used for probing mesospheric constituents [see Kleinböhl et al. (2004)]. The sensor is operated onboard a research aircraft like the DLR Falcon, flying near the tropopause in order to avoid signal absorption due to tropospheric water vapour. The sensor looks upward at a zenith angle of 78 degree. The receiver detects thermal emissions from the rotational lines of various molecules. The altitude information comes from the pressure broadened lines. The Optimal Estimation Method described by Rodgers (1976) is used to retrieve the volume mixing ratio profiles. Apart from Ozone, ASUR measures a range of stratospheric molecules like CI0, HCl, HNO3, N2O. Ozone mixing ratios are retrieved usually for an altitude range 15 to 50 km. The vertical resolution of ASUR ozone measurements is 6-10 km in the lower stratosphere, and decreases towards higher altitudes. The horizontal resolution depends on integration time and ground speed of the aircraft and is about 18 km. The accuracy of
ASUR ozone measurement is 15% or 0.3 ppm whichever is higher. The averaging kernels of ASUR ozone retrievals are shown in figure 1. A detailed description of the ozone retrieval can be found in Bremer et al. (2002), Kleinböhl et al. (2004) and Kuttippurath et al. (2004).

3. THE SCIAMACHY SENSOR

SCIAMACHY is an atmospheric chemistry payload onboard ESA’s ENVISAT satellite. It measures a range of tropospheric, stratospheric and mesospheric constituents in nadir, limb and occultation modes. A detailed description of the sensor can be found in Bovensmann et al. (1999). In this work SCIAMACHY ozone limb profiles are compared with ASUR ozone profiles. ESA operational products and in-house scientific products have been used for this study.

4. THE VALIDATION CAMPAIGN

The airborne validation campaign SCIAVALUE was performed onboard the Falcon research aircraft operated by the German Aerospace Center (DLR), Oberpfaffenhofen. In order to validate the data in different atmospheric scenarios, the campaign was conducted during two seasons and at different latitudes. Apart from ASUR, the DLR’s OLEX lidar [Wirth and Renger (1995)], and the UV-VIS spectrometer AMAXDOAS [Bruns et al. (2004)], jointly operated by the University of Bremen and the University of Heidelberg were part of the Falcon payload. A total of 29 flights, 14 in the first deployment and 15 in the second deployment, were performed in two different seasons with more than 100 flight hours. The first deployment was conducted in fall 2002 and the second deployment in winter - spring 2003. The flight routes of the Falcon aircraft and the measurement pattern of ASUR are shown in figure 2. Only ozone measurements are indicated.

5. DATA ANALYSES

ASUR ozone measurements were selected for the validation within 2 degree latitude, 10 degree longitude and within 5 hours distance to the satellite measurements. Because of the numerous satellite underpasses, there are many measurements which are very close to the satellite footprints.

Two datasets have been analysed for the validation purpose. The official ESA operational product version 2.1 (hereafter ESA OP V2.1) and the current in-house (retrieval of Christian von Savigny) scientific product version 1.6 (hereafter UB V1.6). The ESA OP V2.1 data are available for few dates in September 2002. Data for 9 ASUR flights are analysed. Most of them belong to tropical latitudes. The criterion resulted in around 126 coincident measurements. Around 73 coincident measurements occurred.
in tropics (5S to 30 N), 28 in midlatitudes (30N to 60N) and 61 in the Arctic (60N to 90N). Because of ASUR’s limited vertical resolution the SCIAMACHY ozone profiles have been convolved with ASUR ozone averaging kernels for comparison.

The UB V1.6 ozone retrievals [von Savigny et al. (2004)] for September 2002 (5 flights), February 2003 (3 flights) and March 2003 (3 flights) are used for the comparison with ASUR flight days. As a result 57 tropical, 8 midlatitude and 19 high latitude coincidents are compared. The UB V1.6 ozone concentration profiles are converted into volume mixing ratio profiles using synoptic pressure and temperature profiles from the Data Assimilation Office (DAO), which were also used for retrieving the ASUR ozone profiles. The resulting mixing ratio profiles are then treated with smoothing by ASUR ozone averaging kernels. Since the UB V1.6 profiles have limited information above 40 km, the data are analysed up to 40 km only.

The SCIAMACHY limb data before December 2003 are affected by errors in the tangent height information. Tangent height errors of up to 3 km have been detected with various methods (e.g., Kaiser et al. [2004]). Tangent height errors are due to inaccurate knowledge of the spacecraft attitude and/or position. The limb pointing was found to be very accurate after the updates of the orbit propagator model on Envisat, that occur once a day. Between these updates, the pointing slowly deviates from nominal pointing. For the SCIAMACHY UB V1.6 ozone profile retrievals used here a pointing retrieval employing the TRUE (Tangent Height Retrieval by UV-B Exploitation) method [Kaiser et al. (2004)] was performed for every limb measurement.

Examples of comparison between ASUR and SCIAMACHY ozone profiles are shown in figures 3 and 4 for the datasets ESA OP V2.1 and UB V1.6 respectively. The statistics derived from the comparison is illustrated in figure 5.

6. RESULTS

Figure 5 (top panel) shows the statistics derived from the comparison between ASUR and ESA OP V2.1. The difference ASUR minus SCIAMACHY ESA OP V2.1 is in the order of 1-2 ppm at all latitude sections in absolute values.

Figure 5 (bottom panel) depicts the statistics derived from
the comparison between ASUR and UB V1.6. The difference ASUR minus SCIAMACHY UB V1.6 is also in the order of 1-2 ppm in absolute values. Though this version of retrieval has been corrected for pointing error, the altitude mismatch is evident in the figures. However, the mismatch is not present in all individual comparisons.

7. DISCUSSION

Both datasets show that the difference ASUR minus SCIAMACHY is about 1-2 ppm at all latitude sections. In tropics, the difference between ASUR and SCIAMACHY is larger in lower stratosphere. However, at mid and high latitudes, the altitude of maximum difference is found between 30 and 40 km. The difference of 1-2 ppm is within the estimated accuracy of ASUR ozone measurements and is consistent with earlier findings [Kleinbühl et al. (2004)].

The mismatch in altitude in the profiles is apparent in both datasets though the UB V1.6 has been corrected for pointing error. Tests show that ASUR retrievals are insensitive to the altitude shifts in a priori profiles used. The other possibility would be the uncertainties in pressure broadening coefficients used in the retrievals. Studies show that the changes in ozone mixing ratio due to the same can be up to 10 % [Kleinbühl et al. (2004)].

8. CONCLUSION

The validation of SCIAMACHY ozone profiles results in a reasonable agreement throughout the latitudes. The difference ASUR minus SCIAMACHY is about 1-2 ppm in absolute values and 10-15% in percentage scale. Since the ASUR ozone measurements are on high side by about 10-15%, the difference can also be resulted from this. The comparisons indicate that the SCIAMACHY retrievals might have a pointing problem.

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