VALIDATION OF ENVISAT SCIAMACHY ATMOSPHERIC TRACE GASES MEASUREMENTS WITH THE RUSSIAN GROUND-BASED MONITORING NETWORK

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ABSTRACT

Present report summarize the first results of comparisons between SCIAMACHY level 2 products and ground-based measurements at a number of stations in Russia and NIS, carried out for the period of commissioning phase validation. Basically, the study presents preliminary validation of SCIAMACHY ozone, NO_2, CO, CH_4 and H_2O vertical column data, coming from the measurements of SCIAMACHY in nadir mode.

1. INTRODUCTION

Russia and NIS (New Independent States) have a network of ground-based measurements of the total content and near-surface concentration of ozone and other trace gases. The network is equipped with a number UV/visible and IR spectrometers, providing regular data on O_3, NO_2, CO, CH_4 and H_2O vertical column amounts. Some of the instruments are involved in the international NDSC (Network for the Detection of Stratospheric Change) program as secondary stations. Besides, a special ground-based ozone monitoring network enumerates about 40 stations over the Russia and NIS with a regular measurements of total ozone content. The network is equipped with filter ozonometers M-124 calibrated against Dobson spectrophotometer, which is regularly compared with the WMO standard. Up to now, the data of Russian ground-based atmospheric trace gases measurements have been barely used for validation of satellite data. The recent validation of ERS-2 GOME operational products that involved comparisons with correlative Russian ground-based measurements of O_3 and NO_2 (ERS AO3-174), have demonstrated an importance of using that data in oder to extend the geographical region, duration and measurement conditions of the comparisons and, consequently, to enhance the quality of satellite data [1-8]. The present study is focused on the first validation results of SCIAMACHY nadir level 2 data by means of comparisons with correlative ground-based measurements (ENVISAT AO-427). Validation of SCIAMACHY nadir products will involve the data of ozone vertical columns observed over the network of about 20 stations (14-130°E/43-78°N), and also NO_2, CO, CH_4 and H_2O column measurements at several locations in Russia and NIS.

2. GROUND-BASED NETWORK OF ATMOSPHERIC REMOTE SENSING IN RUSSIA AND NIS

2.1 Ground-based measurements of ozone vertical column by ozonometer M-124

The Russian and NIS countries network of total ozone observations is equipped with filter ozonometers M-124 measuring the direct sun or scattered zenith radiation [9, 10]. Two spectral intervals with 302 and 326 nm maxima and half-width of about 20 nm are used for the observations. Total ozone is retrieved from direct sun measurements at zenith angles 20-70° and zenith scattered (both clear-sky and cloudy) radiation measurements at zenith angles 20-85°. The method provides measurements at high latitude stations and practically all-weather conditions. All the M-124

ozonometers are calibrated against the standard (for Russian network) measurement instrument - the Dobson spectrophotometer No.108, which is regularly compared with the WMO standard. Intercomparisons in Boulder (1988), Hradec Králové (1993), Kalavrita (1997) and Hohenpaissenberg (2001) showed that the measurement-scale drift of the Dobson No.108 did not exceed 1.0%. A permanent control of M-124 measurement scale is the obligatory part of instrument verification and provides total ozone measurements with errors less than 3-4%. The instruments are installed at a number of locations, both over Russia and NIS (Fig.1).

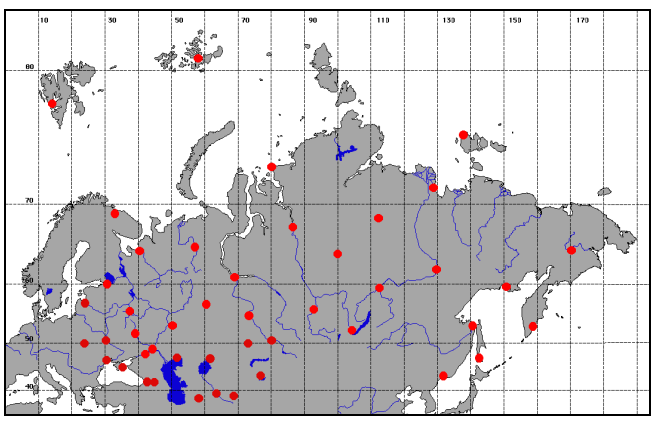

Fig. 1. Ground-based network of ozone vertical column measurements in Russia and NIS

2.2 Ground-based twilight measurements of NO_2 vertical column

NO_2 vertical columns are obtained from zenith-scattered solar radiation measured by the grating spectrometer MDR-23 operating in the 435-450 nm wavelength range with spectral resolution 0.7 nm. The measurements are taken at twilight in mornings and evenings at solar zenith angles 84°-96°, and during daytime, if necessary, to control NO_x pollution of the boundary layer. At the first stage of retrieval, the slant NO_2 columns as a function of solar zenith angle are derived by the nonlinear least-square fit of spectra including O_3 and NO_2 absorption, single molecular and aerosol scattering, and the Ring effect, to the reference spectrum. The reference spectra is obtained from high-sun measurements under stable conditions of clear-sky atmosphere with low NO_2 abundance. The measured slant NO_2 columns are then divided by air mass factors, computed using a spherical scattering model for solar radiation and a non-stationary one-dimensional photochemical model including the O_x and NO_x photochemistry. Finally, NO_2 vertical distribution in the 0-50 km altitude range is retrieved as an inversion with Chahine method applied [11]. Derived quantities are (1) NO_2 contents within 5 km thick layers in the stratosphere and the troposphere (0-50 km), (2) NO_2 content in the thin atmospheric surface layer, and (3) columnar NO_2 contents in the troposphere (0-10 km) and the stratosphere (10-50 km) as integrals over appropriate layers.

The instruments applying described technique are now installed at the following stations: Zvenigorod, Kislovodsk, Tomsk, Lovozero and Issyk-Kul (Fig.2).

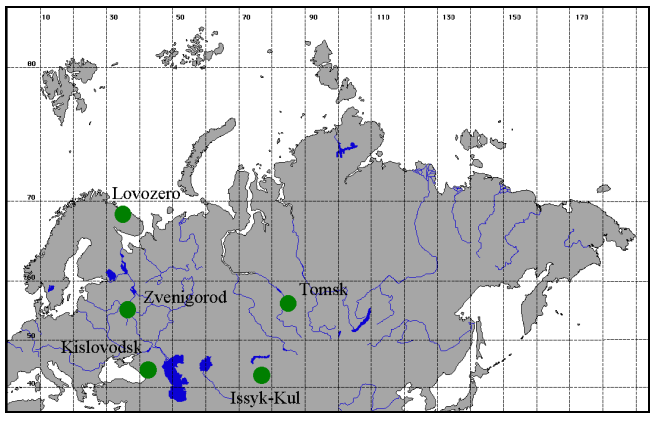

Fig. 2. The stations of spectroscopic atmospheric sounding in Russia and NIS (NO_2, CO, CH_4 and H_2O)

2.3 Ground-based spectroscopic measurements of CO, CH_4 and H_2O vertical columns

The column contents of carbon monoxide, methane and water vapor are retrieved from the direct sun IR measurements by grating spectrometer in the range of ~3-5 μm and ~0.3 cm^{-1} of spectral resolution. The retrieval algorithm applies then a nonlinear least squares fitting procedure of the observed spectra to the synthetic one. The corresponding random errors are ~7% for CO, ~5% for CH_4 and ~3% for H_2O [12, 13]. The instruments of that kind are installed at the following stations: Zvenigorod, Obninsk, St.Petersburg and Issuk-Kul (Fig.2).

3. COMPARISON OF SCIAMACHY LEVEL2 DATA WITH RUSSIAN GROUND-BASED MEASUREMENTS

The following comparisons of SCIAMACHY vertical column measurements in nadir mode with a data of ground-based network of Russia and NIS were performed as a contribution to ENVISAT Commissioning Phase Validation in the framework of ENVISAT AO-427. The study cover the period of July-October 2002 with correlative observations of ozone, carbon monoxide, methane and water vapor vertical columns over the number of locations in Russia and NIS. Most of the data was converted to the uniform HDF data format and uploaded to ENVISAT Calibration/Validation database at NADIR/NILU.

3.1 Validation of ozone vertical column data

In general, 17 stations of ground-based network in Russia and NIS equipped with M-124 instrument (Fig.3), provided regular measurements of daily mean ozone vertical column in the period of 01.07-31.10.2002. Overall, about 1600 measurements were available for validation, and finally 284 of them were found to correlate with with the data of SCIAMACHY. Nadir measurements collocated with the location of ground-based station within a range of 500 km were extracted from the data of SCIAMACHY (carried out at IASB, AO-158) and the nearest pixel was selected for the comparison. Only DOAS_0 data in the visible (325-335 nm) fitting window were studied here.

Since the processor of SCIAMACHY level 2 data was updating during the validation campaign, an analysis of general agreement of SCIAMACHY ozone vertical column data with correlative ground-based measurements in respect to different processor versions (3.51-3.53) was performed (Fig.4). As it is seen from the plot, the data of SCIAMACHY has a best agreement with ground-based measurements when processed with version 3.53. The following comparisons were therefore restricted to the data of SCIAMACHY V3.53 data, which was at that moment available starting from the middle of September. Consequently, the final dataset was now limited to 207 comparisons over 12 locations (30-130°E/43-68°N). The scatter plot of that comparison is presented on Fig.5. On the average, the data of SCIAMACHY is about 9% lower than ground-based measurements; the individual values of the underestimation found at different stations are presented in Table 1.

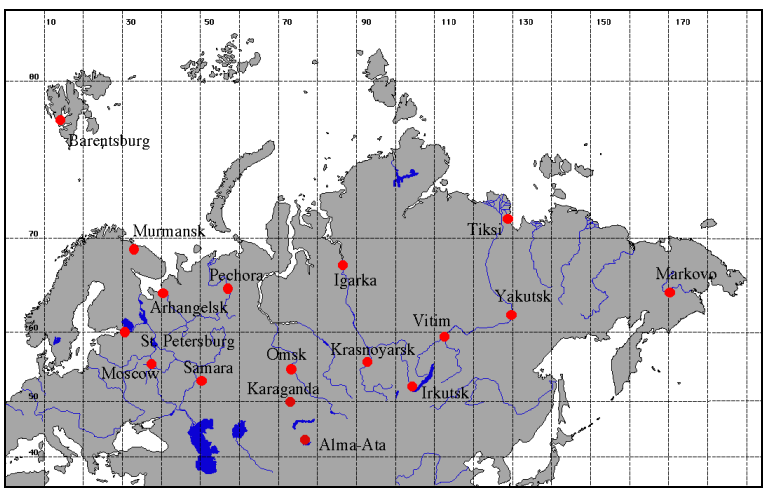

Fig. 3. The stations of ground-based ozone vertical column measurements in Russia and NIS, providing data for SCIAMACHY validation in July-October 2002

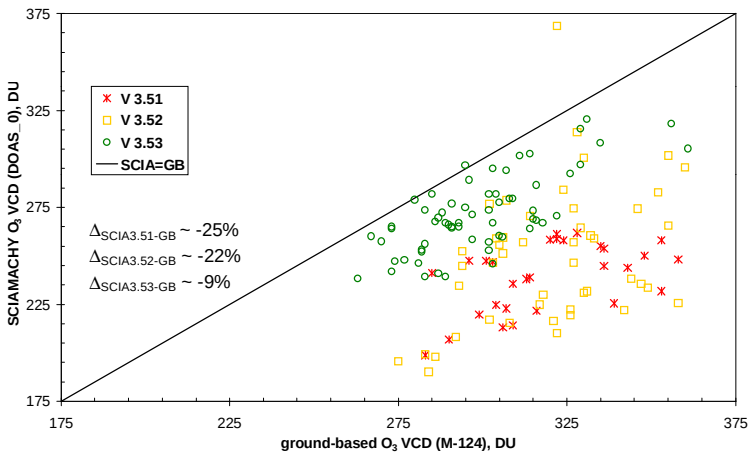

Fig. 4. Comparison of SCIAMACHY NRT (V3.51/3.52) and RV (V3.53) ozone vertical column data with correlative ground-based measurements in Russia and NIS (14-170°E/43-78°N, 18.07-28.09.2002)

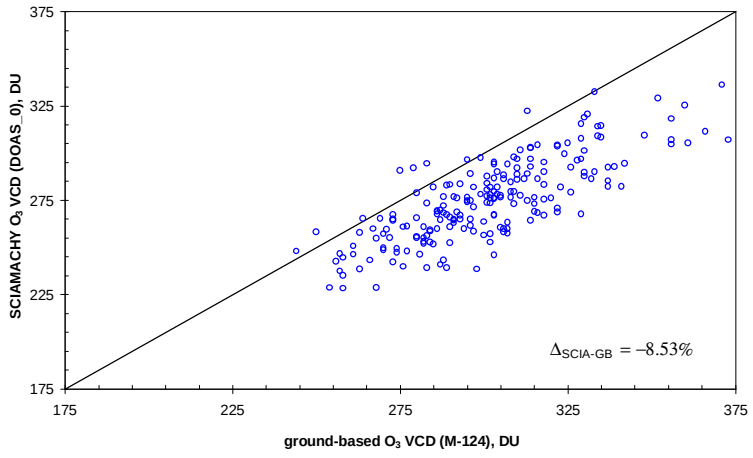

Fig. 5. Comparison of SCIAMACHY RV (V3.53) ozone vertical column data with correlative ground-based measurements in Russia and NIS (30-130°E/43-68°N, 17.09-31.10.2002)

Table 1. The number of comparisons found between SCIAMACHY RV (V3.53) data and ground-based ozone vertical column measurements, with a value of mean difference for each station (17.09-31.10.2002)

location:	**latitude:**	**longitude:**	**number of comparisons:**	**$\Delta_{SCIA-GB}$, %:**
ALMA-ATA	43.2	76.8	21	-8.7
KARAGANDA	49.8	73.1	25	-10.1
IRKUTSK	52.3	104.4	7	-11.2
SAMARA	53.2	50.4	26	-7.0
MOSCOW	55.8	37.6	7	-4.6
KRASNOYARSK	56.0	92.9	14	-9.6
VITIM	59.4	112.6	6	-8.6
ST.PETERSBURG	60.0	30.7	25	-7.7
YAKUTSK	62.1	129.8	4	-6.5
ARHANGELSK	64.6	40.5	20	-7.6
PECHORA	65.1	57.1	23	-4.7
MURMANSK	69.0	33.0	29	-13.0

3.1 Validation of NO_2 vertical column data

During the validation campaign, the twilight measurements of NO_2 vertical column were carried out at 2 sites: Zvenigorod and Issyk-Kul (see Fig.2). The overall number of successful daily measurements in the period of 01.07-30.11.2002 is ~70 at Zvenigorod and ~140 at Issyk-Kul. Only 11 of them were found to coincide with SCIAMACHY measurements provided in the NRT data files, 4 at Zvenigorod and 7 at Issyk-Kul. To find collocations, a special processing was carried out at IASB (Institut d'Aeronomie Spatiale Belgique) to extract SCIAMACHY pixels overlapping with an actual air mass probed by ground-based instrument during the dawn. The corresponding time series plot of ground-based measurements (dawn and dusk) and coincident SCIAMACHY data is shown in Fig.6. The data of SCIAMACHY is found to be high in comparison with ground-based measurements by the value of ~$3.6 \cdot 10^{15}$ mol/cm^2 at Zvenigorod and ~$0.7 \cdot 10^{15}$ mol/cm^2 at Issyk-Kul (SCIAMACHY-GROUNDBASED$_{AM}$).

3.3 Validation of CO, CH4 and H_2O vertical column data

The ground-based measurements of CO and CH_4 vertical columns were carried out at 3 sites: Zvenigorod, Obninsk and St.Petersburg, but only Zvenigorod and St.Petersburg provided their data for the moment of validation (see Fig.2). The total amount of daily averaged data obtained from these stations is 54 for CO and 51 for CH_4 measurements. For the comparison, the nearest pixel of SCIAMACHY nadir measurements to the station was selected in the range of 500 km (same as for O_3). Only BIAS_2 fitting window products were considered, due to the mostly unreasonable vertical column values found in the retrievals of CH_4 at BIAS_1. The time series plots of CO and CH_4 vertical column measurements at St.Petersburg and Zvenigorod with a values of collocated SCIAMACHY data, are presented in Fig.7 and 8, accordingly. In some cases, a permanent values of SCIAMACHY vertical column retrieval were found (2.38·10^{18} mol/cm^2 for CO, 3.54·10^{19} mol/cm^2 for CH_4), which were fixed along the part of the orbit with SZA>90º, although being close to ground-based measurements. On some dates of comparison, SCIAMACHY considerably exceed the value of the retrieved vertical columns in comparison to ground-based measurements (e.g., 3.56·10^{19} mol/cm^2 for CO, 4.05·10^{21} mol/cm^2 for CH_4).

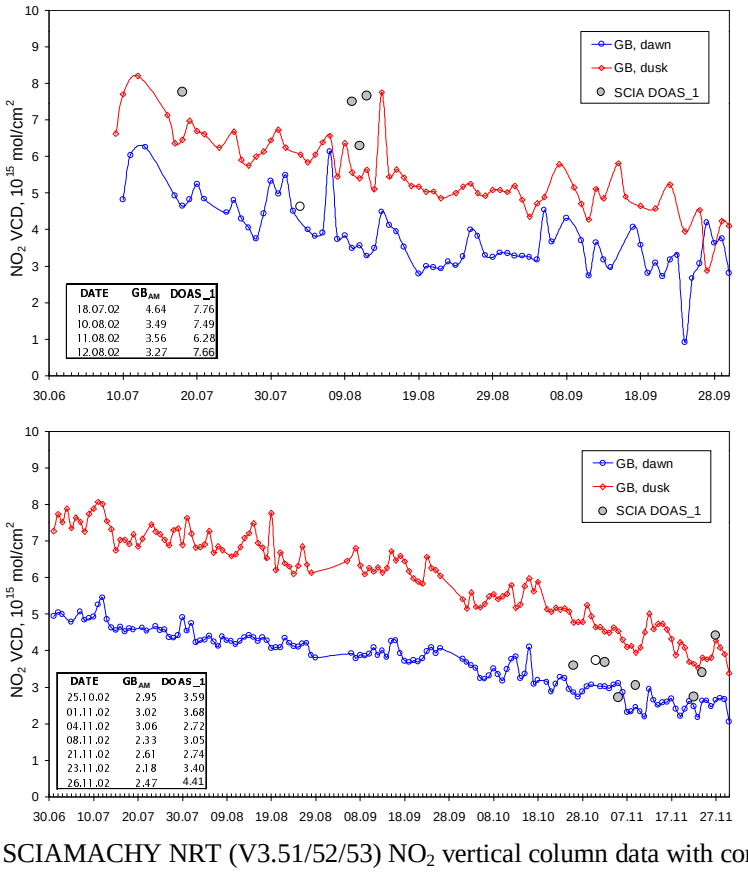

Fig. 6. Comparison of SCIAMACHY NRT (V3.51/52/53) NO_2 vertical column data with correlative ground-based measurements at Zvenigorod (37°E/56°N, upper) and Issyk-Kul (77°E/43°N, lower)

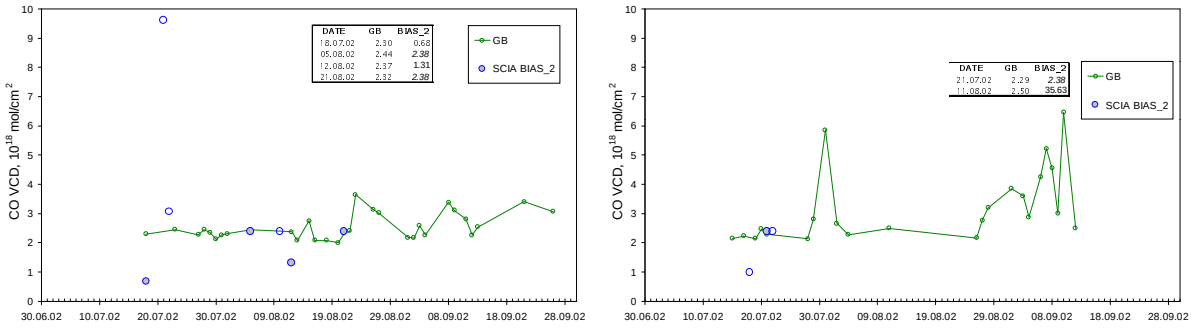

Fig. 7. Comparison of SCIAMACHY NRT (V3.51/52) CO vertical column data with correlative ground-based measurements at St.Petersburg (right) and Zvenigorod (left), 01.07-31.09.2002

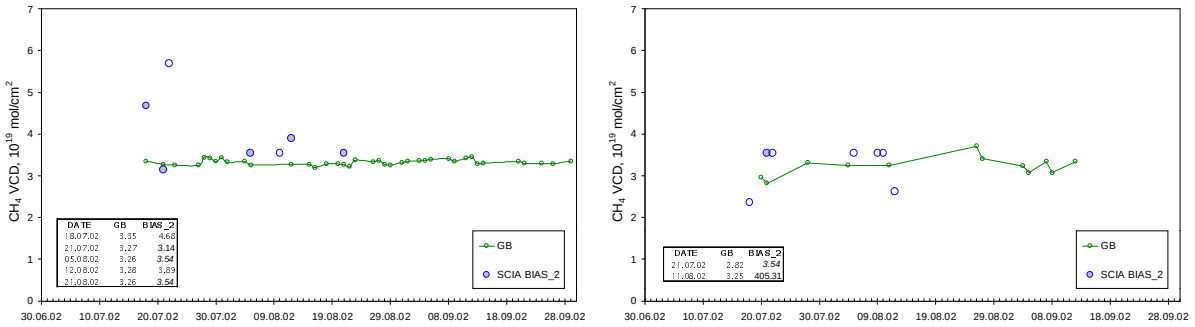

Fig. 8. Comparison of SCIAMACHY NRT (V3.51/52) CH_4 vertical column data with correlative ground-based measurements at St.Petersburg (right) and Zvenigorod (left), 01.07-31.09.2002

For the validation of SCIAMACHY H_2O vertical columns the measurements were performed at 3 sites: Zvenigorod, Obninsk and Issyk-Kul (see Fig.2). Unfortunately, no data have come from the Obninsk by the time of validation studies. The total number of H_2O vertical column, available for comparison, was 120 daily mean values in the period of 01.07-21.11.2002. To find correlative measurements, the same criteria was applied, as for CO and CH_4. Only those H_2O vertical columns retrieved in BIAS_0 fitting window were studied, as BIAS_1 values were found to be close to 0 or very high (10^{26}), and BIAS_2 were negative almost everywhere. Due to the limit of successful observations at Zvenigorod (14), only 4 collocated SCIAMACHY and ground-based measurements were found, which occurred over the Issyk-Kul station. The corresponding time series plot of H_2O vertical column measurements at Issyk-Kul with correlative SCIAMACHY data is shown in Fig.9. The data of SCIAMACHY is the same oder of ground-based measurements, although considerably deviate from it, both up and down (±100%).

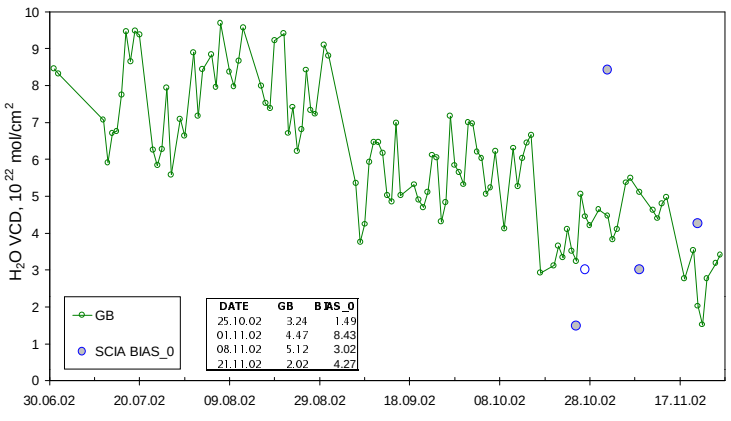

Fig. 9. Comparison of SCIAMACHY NRT (V3.53) H_2O vertical column data with correlative ground-based measurements at Issyk-Kul (77°E/43°N, of 01.07-21.11.2002)

5. SUMMARY

In general, the number of measurements available for the comparisons performed within this investigation was very limited, mostly due to the lack of correlative SCIAMACHY level 2 data for the main period of ground-based measurements – 01.07-31.09.2002. However, some preliminary conclusions on the quality of SCIAMACHY level 2 nadir products may be already given, as an outcome of this study. According to the comparisons of O_3 vertical column data with a measurements at 12 locations over Russia and NIS, the data of SCIAMACHY (RV, V3.53, DOAS_0) considerably underestimates total ozone value, by 9% on the average. The data of SCIAMACHY NO_2 vertical column was found to exceed ground-based measurements, compared to the results of dawn observations, by ~$4 \cdot 10^{15}$ mol/cm^2 at Zvenigorod (37°E/56°N) and ~$1 \cdot 10^{15}$ mol/cm^2 at Issyk-Kul (77°E/43°N). The data of SCIAMACHY retrievals in IR range of spectra (CO and CH_4, BIAS_2), demonstrate both unreasonably high vertical columns (10^{19} and 10^{21} mol/cm^2 for CO and CH_4, consequently) and the consistent ones (with some of them being constants at the low Sun part of the orbit: $2.38 \cdot 10^{18}$ mol/cm^2 for CO, $3.54 \cdot 10^{19}$ mol/cm^2 for CH_4). Among the H_2O vertical column products of SCIAMACHY only BIAS_0 were found to provide reasonable values, with both positive and negative deviations up to 100% from ground-based measurements at Issyk-Kul (77°E/43°N). Overall, this study may be enhanced considerably, provided with more SCIAMACHY level 2 data of better spatial and temporal coverage.

6. ACKNOWLEDGEMENTS

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