Coordinated ground-based validation of ENVISAT atmospheric chemistry with NDSC network data : Commissioning phase report

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COORDINATED GROUND -BASED VALIDATION OF ENVISAT ATMOSPHERIC CHEMISTRY WITH NDSC NETWORK DATA: COMMISSIONING PHASE REPORT

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ABSTRACT

In the framework of the coordinated project called CINAMON, a list of ground-based stations associated with the Network for the Detection of Stratospheric Change (NDSC) contribute to the quasi-global validation of ENVISAT atmospheric chemistry data. This paper reports on such activities performed during the Commissioning Phase (CP) of the satellite. After a description of the correlative database generated during this period, preliminary ground-based studies relying on this database give a first picture of the quality of SCIAMACHY ozone and nitrogen dioxide columns, and GOMOS and MIPAS ozone profiles. Illustration of the global mapping of MIPAS ozone profile data is also presented. The paper concludes with perspectives for the Main Validation Phase of ENVISAT.

1. INTRODUCTION

On March 1, 2002, the third Earth observation satellite platform of ESA, ENVISAT-1, was launched onto a heliosynchronous polar orbit with 10:00 mean solar local time at descending node. The payload of ENVISAT includes three instruments dedicated to the chemistry and physics of the atmosphere: Global Ozone Monitoring by Occultation of Stars (GOMOS), Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), and SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY). Formalised through the ENVISAT Announcement of Opportunity (AO) issued in 1998, an intensive validation campaign of those sensors has been organised by the ESA Atmospheric Chemistry Validation Team (ACVT) and by the SCIAMACHY Validation and

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Interpretation Group (SCIAVALIG). Proposed in response to this AO, the CINAMON project (CHaracterisation, INterpretation, Application and Maturation of Ozone-related ENVISAT products using correlative observations from the NDSC) aims at (1) the geophysical validation of key ozone-related level-2 products (O_3, NO_2, BrO, OClO, and ClO) from GOMOS, MIPAS and SCIAMACHY, and (2) the maturation of related level-1-to-2 retrieval algorithms. The geophysical usability of the ENVISAT data products and their sensitivity to instrumental and atmospheric effects, are to be investigated from the Arctic to the Antarctic, over a variety of geophysical conditions. The aimed investigations rely on correlative studies of ENVISAT data with high-quality ground-based and balloon observations associated with the Network for the Detection of Stratospheric Change (NDSC). This network has proven capabilities for investigating the performance of spaceborne sensors from pole to pole and on the long term [1,2], among others with the GOME, POAM, SAGE, TOMS, and UARS sensors. The main objective of the CINAMON project is to extend this heritage to the three ENVISAT atmospheric chemistry sensors.

The present report gives an overview of CINAMON-related activities performed during the Commissioning Phase (CP) of ENVISAT. Reported activities span from the switch-on of the instruments to the ENVISAT Validation Workshop held at ESRIN on December 9-13, 2002. Pre-launch activities have already been reported in the Commissioning Phase Readiness Report of the project issued in June 2002. Section 2 presents the status of the correlative database generated during this period. In Section 3, after a brief description of level-2 verification activities, preliminary ground-based comparisons of SCIAMACHY ozone (O_3) and nitrogen dioxide (NO_2) columns conclude to a first quality assessment of those products. Section 4 and Section 5 show comparison results obtained with GOMOS and MIPAS ozone profiles, respectively. Application data processing is also foreseen in the frame of the project, as a support to validation and scientific end-users. Such an application is described in Section 5 with the global mapping of MIPAS ozone profile data. The paper concludes with perspectives for the Main Validation Phase, extending from September 2002 through September 2003. Results obtained by the CINAMON team have also contributed to the coordinated papers on SCIAMACHY ozone and nitrogen dioxide columns [3], and on GOMOS [4] and MIPAS [5] ozone profiles, published elsewhere in this issue.

2. CORRELATIVE MEASUREMENTS

2.1 General Organisation

A major task of the CINAMON project is to organise the collection of high quality, well-controlled correlative measurements acquired from pole to pole by several independent sensors associated with the NDSC. The list of contributing instruments is detailed in [6,7]. Fig. 1 gives an idea of the meridian coverage offered by participating total ozone and nitrogen dioxide sensors. Instrument Investigators affiliated with the NDSC are committed to submit validated data to the NDSC database for official endorsement and public release within two years after data acquisition. For special cases when faster data delivery is crucial, arrangements may be organised on a case-by-case basis with individual instrument investigators to foster timely delivery of preliminary data. The CINAMON project is based on this principle. A fast delivery of correlative data for ENVISAT validation has been arranged through collaboration with about two dozen European and non-European institutes, all acknowledged in the present report as Co-authors. For most of the involved instruments, a delivery within a few hours to a few weeks has been achieved during the Commissioning Phase. A fast delivery within a month is expected during the Main Validation Phase. Several stations are anticipated to continue fast delivery of preliminary data in the long term. Although the quality of preliminary data cannot be fully guaranteed, it should not differ significantly from the quality of validated data officially endorsed by the NDSC. Almost all contributing sensors have been certified for the NDSC after fruitful participation to major intercomparison campaigns and algorithm verification exercises organised through the NDSC and/or the EC Environment Programme. Contributing Dobson and Brewer spectrophotometers have been calibrated according to the WMO standards. Moreover, the homogeneity of collected data is checked at IASB before submitting them to the ENVISAT Cal/Val database established at NILU.

2.2 Vertical column of Ozone and Nitrogen Dioxide

Observations of total ozone and nitrogen dioxide at sunrise and sunset have been collected from a network of about 20 UV-visible DOAS spectrometers measuring zenith-scattered sunlight [8,9]. Due to this measurement geometry, they are mostly sensitive to the stratospheric contribution to the vertical column. Contributing sensors consist in: (a) scanning instruments developed by NIWA since the late 1970s [10]; (b) SAOZ grating instruments (Système d'Analyse par Observation Zénithale) developed by CNRS and performing automated network operation since the late 1980s [11]; and spectrometers of a similar design developed at (c) IASB [12], (d) IFE [13], and (e) NILU [14], respectively. Total ozone data at selected stations have also been provided Dobson [15] and Brewer [16] spectrophotometers. Calibrated onto the Dobson but extending its capabilities towards low solar elevation, multi-channel filter radiometers (GUV [17]) operated by NILU have provided total ozone data at a few stations in Norway. During NDSC-endorsed intercomparison campaigns [8,9], the agreement between the various instruments generally falls within the 3% range for total O_3 and the 5% to 10% range for total NO_2.

2.3 Vertical Distribution of Ozone

Differential absorption lidar, millimetre wave radiometer (MWR) and electrochemical ozonesonde constitute the backbone of the NDSC for the observation of the ozone vertical distribution. Useful references regarding those instruments can be found on the NDSC web site [2]. Ozonesondes have been launched at a variety of ground stations from the Arctic to the Antarctic, either as part of their regular activities or sometimes specially dedicated to ENVISAT validation. Ozonesonde data consist in the vertical distribution of ozone partial pressure, converted into ozone number density, and total pressure and temperature, from the ground up to burst point, typically 30 km, with a vertical resolution of about 100 m. Lidar soundings have been performed in the Arctic, in the Alps, and at Reunion Island, several times per week under clear skies. They yield ozone number density from 8-15 to 45-50 km with a vertical resolution of 300 m to 3 km depending on the altitude. Millimetre wave radiometers have acquired data in the Arctic, in the Alps, and in Venezuela. They can operate night and day, providing ozone volume mixing ratios integrated over typically 2 hours from 20-25 to 60 km, with a vertical resolution of 8 to 12 km. Combining those three independent techniques, comparisons with satellite ozone profiles can be carried out over the entire vertical range from the ground up to 70 km. The various measurement times permit the comparison of ground-based and space-based studies of features such as the diurnal variability of mesospheric ozone. If smoothed to the vertical resolution of the satellite instrument, e.g. using its averaging kernels, profile observations at high vertical resolution (ozonesonde and lidar) can also be valuable in testing the satellite retrieval algorithms.

2.4 Additional UV-visible Data Products

A list of UV-visible DOAS spectrometers operating in the zenith-sky geometry have also acquired column measurements of bromine dioxide (BrO) and, in case of chlorine activation, chlorine dioxide (OClO), an indicator of the BrO-ClO coupling. Similar spectrometers operating in the off-axis geometry have also acquired information on tropospheric BrO, NO_2, O_3, formaldehyde (CH_2O), and sulphur dioxide (SO_2). The retrieval of those additional UV-visible products is ongoing. They are expected to contribute to the validation of SCIAMACHY UV-visible data products still in the development loop or not delivered yet at present time.

3. SCIAMACHY OZONE AND NITROGEN DIOXIDE COLUMNS

3.1 Verification of Level-1-to-2 Retrieval Algorithms

Before starting quantitative comparisons between SCIAMACHY and correlative data, the CINAMON team at IASB has contributed to the level-2 verification effort coordinated jointly by ESA and the SCIAMACHY Operations Support Team (SOST). Using correlative data as a reference, the soundness of consecutive versions of the retrieved products has been checked. Further tests have been performed on intermediate parameters such as slant columns and air mass factors. An important study has addressed the equivalence between Meteo (SCI_RV) and NRT (SCI_NL) products. Since only a few orbits have been processed with both processors, a complete study was not feasible. The main outcome is that, unexpectedly, small differences exist between the two products. Fortunately, since those differences seem to occur only in the geolocation parameters and have a reduced amplitude – a maximum latitude difference of 0.15°, that is, 16 km – comparisons carried out with the Meteo and with the NRT products should not lead to significantly different conclusions. More generally, minor problems and bugs have been reported on the SOST [18] and SCIAVALIG [19] web sites and summarised elsewhere in this issue [20]. The project has also contributed to the preparation of upcoming verification studies for the off-line processor (SCI_OL).

3.2 Data Sets and Comparison Methods

Several partners of the CINAMON consortium have carried out a quasi-global evaluation of early SCIAMACHY total ozone and nitrogen dioxide data products using preliminary ground-based data collected within the project. The delivery of the Meteo product (SCI_RV) version 3.53 started on September 17, 2002, allowing studies over nearly 2.5

months of those operational data. The limited amount of information contained in this product – i.e. the ozone column value and its geolocation – limits the field of comparisons to time-series and column dependence. Further studies require additional parameters (solar zenith angle, line-of-sight etc.) reported in the near real-time (NRT) product (SCI_NL), which also includes the nitrogen dioxide data product. During the ENVISAT commissioning phase, four SCI_NL data sets were distributed. Unfortunately, each of those data sets covers a different time period in 2002 and has been processed with a different version of the near real-time SCI_NL level-1-to-2 processor: v3.51 in August, v3.52 in early September, v3.53 starting from October, and one orbit on August 23 processed with v4.0. Despite the lack of simultaneous collocation between two different versions of SCI_NL products and ground-based data, preliminary comparisons (not shown here but illustrated in [3]) indicate that v3.53 might yield the best agreement with ground-based data: e.g., typical results at Northern mid-latitude stations conclude to a mean total ozone underestimation of the order of 30% with v3.51, 25% with 3.52, and 6% with 3.53. The available v4.0 data set is too sparse to make any statement. Therefore, only results obtained with v3.53 are shown hereafter. Moreover, the equivalence established between Meteo and NRT products allows concentrating the ozone study on the Meteo product (SCI_RV v3.53), which offers the longest time-series available at present time.

SCIAMACHY data have been selected for comparison following different criteria, taking into account the effective air mass probed by the different instruments [1]. The advantage offered by such physically based methods is illustrated in Fig. 2-a for the zenith-sky geometry during Antarctic springtime, when atmospheric variability is significant. For several versions of the SCI_NL product, the amount of available collocations with ground-based data was sometimes so small that cruder selection criteria had to be used. For nitrogen dioxide, a major difficulty arises from the diurnal cycle of this molecule. Driven by the diurnal variation of solar illumination, this cycle consists in (i) a sharp decrease of NO_2 at sunrise resulting from its fast photolysis when daylight appears, followed by (ii) its daytime photochemical equilibrium with NO and the photolysis of their night-time reservoir N_2O_5, (iii) a sharp increase when NO_2 photolysis vanishes as sun sets, and finally (iv) a slow decrease during night due to the conversion of NO_x ($NO+NO_2$) species into the N_2O_5 reservoir. Varying with the solar illumination regime and with the vertical distribution of NO_x species and of temperature, this photochemical cycle exhibits marked seasonal and meridian features. Modelling studies carried out at IASB in collaboration with U. Leeds indicate that sunrise values acquired by twilight instruments (SAOZ/DOAS) might be reasonably close to the mid-morning values acquired by SCIAMACHY, within a few 10^{14} molecule.cm^{-2}. There are two main exceptions: (i) polar springtime, where strong changes of temperature and of NO_y partitioning make the amplitude of the diurnal cycle somewhat large and unpredictable; and (ii) polar day, where the strong NO_2 diurnal cycle of about 0.5-1.5 10^{15} molecule.cm^{-2}, driven only by the photochemical equilibrium between NO and NO_2, makes NO_2 alternate between a minimum around noon and a maximum under midnight sun conditions. For polar day conditions, an adjustment factor has been drawn as a function of the SCIAMACHY solar zenith angle, enabling quantitative comparisons.

3.3 Total Ozone Comparisons - Antarctic Ozone Hole 2002

From pole to pole, time-series of total ozone values reported by SCIAMACHY and by ground-based instruments have been looked at qualitatively and quantitatively. Qualitatively, short-term fluctuations reported by ground-based sensors are reproduced similarly by SCIAMACHY, data sets permitting. Other variations such as the seasonal cycle cannot be studied with the current data sets. Quantitatively, most of the stations from one polar circle to the other conclude to a 4%-10% general underestimation of the ground-based values by SCIAMACHY. Beyond the polar circles, the mean agreement improves to within 5%. Fig. 1-a displays the meridian variation of the mean difference between SCI_RV v3.53 total ozone and ground-based values.

Owing to the particular Southern Hemisphere polar vortex separation of this year, the project has investigated in details to what extent SCIAMACHY was able to reproduce this unexpected behaviour. The investigation is based on total ozone comparisons at five ground-based stations spread around Antarctica and surroundings and in the September-November 2002 time frame. The CNRS SAOZ at Kerguelen Island (49°S), a station usually located in the circumpolar belt characterised by high ozone values, reported in late September 2002 somewhat lower ozone values (around 300 DU instead of 400 DU), the station being close to the vortex edge. Simultaneously, in the Antarctic Peninsula, the Dobson operated by KTSU/BAS at Vernadsky (65°S), and the BAS SAOZ operated at Rothera (68°S), provided independent observations of the air mass that separated from the vortex. The CNRS SAOZ at Dumont d'Urville (67°S) in Terre Adélie, a station usually alternating between in-vortex and out-of-vortex conditions during spring, was found this time in the circumpolar belt where it recorded total ozone values over 400 DU. The high-latitude site of Halley (76°S), located permanently in the polar vortex and where the BAS Dobson reports very low ozone values every spring since the 80s, was now on the vortex edge, in the heart of its rupture. Despite the very unusual conditions observed this year in

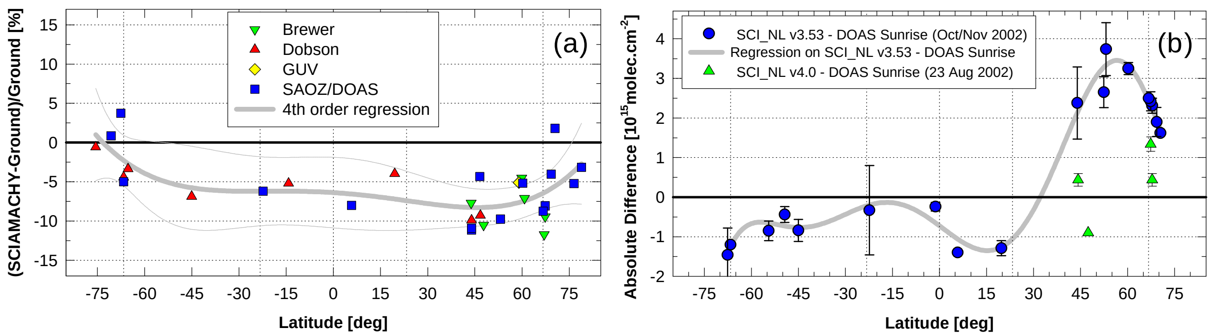

Fig. 1. Mean difference between early SCIAMACHY and ground-based column measurements as a function of the latitude. (a) Percent relative difference between Meteo v3.53 and ground-based total ozone: A general underestimation of ground-based values by SCIAMACHY vanishes near the poles. (b) Absolute difference between NRT v3.53 and ground-based total nitrogen dioxide: A strong meridian structure appears, that might be related to the use of an improper atmospheric profile database for the calculation of the SCIAMACHY AMF. Preliminary v4.0 results suggest some possible improvement.

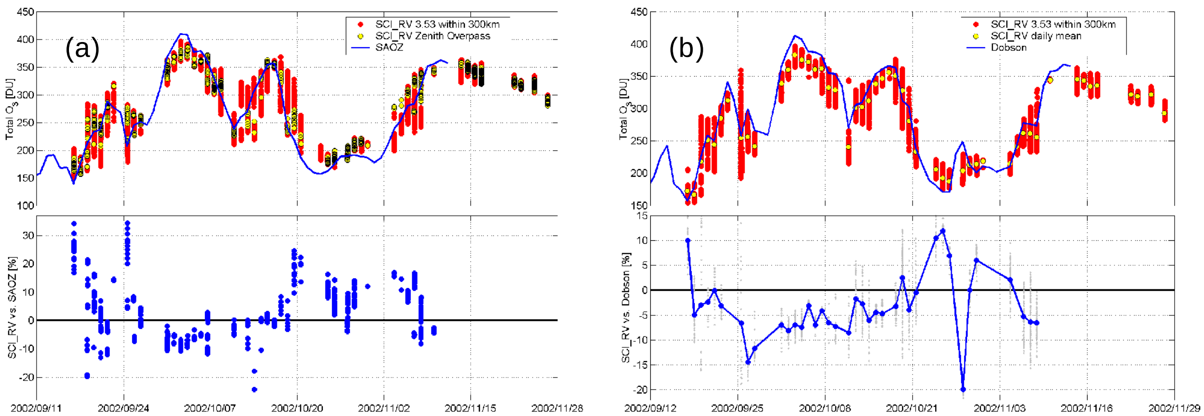

Fig. 2. Comparison of SCIAMACHY v3.53 with ground-based total ozone at two neighbouring NDSC/Antarctic stations: (a) with BAS SAOZ data at Rothera (68°S), and (b) with the KTSU/BAS Dobson data at Vernadsky (65°S). Upper panels: time-series of total ozone observed by SCIAMACHY (two methods of selection) and the ground-based instrument; lower panels: time-series of relative differences. Although the average agreement is excellent, systematic differences of ±15% are frequent. Those differences correlate with the ozone column value. The reduction of the scatter gained by a physically based selection method is well illustrated by the SCIAMACHY/SAOZ comparisons in (a).

Antarctica, the qualitative agreement of SCIAMACHY with ground-based data records looks excellent. Short- and mid-term variability is very well reproduced at all stations. In particular, SCIAMACHY and ground-based sensors give a view of dynamical features consistent with those described in the WMO Antarctic Bulletins [21].

Fig. 1-a and Fig. 2 show that the average relative difference does not exceed 5% at Antarctic stations, which might be considered as excellent for Antarctic springtime. A closer look at the data suggests that, as expected from the current state of the SCI_RV retrieval algorithms, the quantitative agreement is more questionable. A major issue consists in the strong overestimation of the lowest ozone column values appearing in Antarctica when the stations are located in the heart of the ozone hole. This is well illustrated in Fig. 2 where the difference between SCIAMACHY and ground-based sensors is found to correlate clearly with the ozone column. The known column dependence between BAS SAOZ and Dobson data can certainly not account for this strong correlation: its effect is significant on the lowest values but is limited to a few percent at 200 DU. A solar zenith angle dependence is also discernible at low sun elevation, but the available data sets are too sparse to give an accurate description of this dependence. More generally, individual differences of about 20-30% are frequent and the standard deviation of the differences is twice as large as that expected from natural variability. Although computing statistics with such a short and variable data record is hazardous, it is interesting to note that differences are less scattered elsewhere, e.g., at northern middle latitudes where SCIAMACHY underestimates ground-based values by 6% on the average. This suggests that the large scatter of the difference might

be linked – at least partly – to the high variability of stratospheric ozone in the studied conditions. Current data sets are too scarce to determine to what extent this apparent link can be attributed to differences in air masses, nevertheless contributions from the current SCIAMACHY algorithms have already been identified. It also happens that SCIAMACHY reports out-of-range values (negative or beyond 600 DU), and too high values at the end of orbits. Such effects might be caused by errors associated with high solar zenith angle and with the viewing angle, or simply by bugs, as already pointed out in [20]. Forward and backward scans of SCIAMACHY rarely differ by more than 1% in total ozone, which is acceptable compared to the level of agreement with ground-based data. The very limited information contained in the Meteo data files does not allow further studies of possible errors nor of additional molecules.

In summary, there is evidence that reliable ozone information is present in the SCIAMACHY Meteo product. It may be used for studies of the SH polar vortex separation of September 2002, provided that end-of-orbit and aberrant data are properly filtered out and that studies concentrate on qualitative aspects of the phenomenon. More quantitative studies of the phenomenon should take into account dependences on the ozone column and the solar zenith angle. The excellent average agreement during Antarctic springtime should not hide the systematic bias observed outside of polar areas.

3.4 Total Nitrogen Dioxide Comparisons

The absolute difference between SCIAMACHY and ground-based total NO_2 exhibits a striking meridian structure, as illustrated in Fig. 1-b. From an average 3-13 10^{14} molecule.cm^{-2} underestimation of ground-based values through the Southern Hemisphere and till the Northern Tropic, the difference rises rapidly towards the Northern middle latitudes to reach a maximum of 37 10^{14} molecule.cm^{-2} around 50°N. Such large differences, as well as the pronounced meridian structure, were not observed with GOME GDP 2.4 data, the version which SCI_NL is supposed to rely on. In the Southern Hemisphere, where stations often are characterised by an unpolluted troposphere, the agreement between the GOME and ground-based data records is within a few $\pm 10^{14}$ molecule.cm^{-2}. At several Northern Hemisphere stations, where clean and polluted conditions alternate, a bimodal behaviour appears due to the sensitivity of GOME to tropospheric NO_2: absolute differences of ± 5 10^{14} molecule.cm^{-2} are typical of clean conditions, while tropospheric pollution events produce an average overestimation of ground-based values ranging from 5 10^{14} in summertime to 25 10^{14} molecule.cm^{-2} during wintertime. The study concludes that differences observed between SCIAMACHY and ground-based total NO_2 exceed by far the differences observed with GOME and do not reproduce the same behaviour.

It has been pointed out that part of the difference observed between GOME and SCIAMACHY validation results might be associated to differences in absorption cross-sections. The meridian structure highlighted by our study indicates that other significant effects must be taken into account. The shape of this structure is symptomatic of nadir air mass factors (AMF) calculated with an improper atmospheric profile database relying on 2D modelling results. Such models propagate unrealistically high tropospheric NO_2 values in zones featuring NO_x emission sources. This propagation produces underestimated AMFs, leading to overestimated vertical columns. The meridian structure of SCIAMACHY/ground differences correlates well with the systematic error introduced by the database used with GOME GDP 2.0. If this matter of fact is verified, it is recommended to replace the GDP 2.0 database by that used in later versions of GOME GDP (2.3 and following). No statement can be made on SCI_NL version 4.0 since preliminary comparisons, also depicted on Fig. 1-b, cover only one orbit in a different time period.

4. GOMOS OZONE PROFILES

The correlative data sets collected through CINAMON have been used to test preliminary GOMOS ozone profiles processed and delivered by ACRI (France) on behalf of ESA, using the GOMOS level-1-to-2 prototype. A first reference data set (v5.0) was provided in September 2002 and, throughout the Commissioning Phase, several upgrades of the prototype generated different versions of GOMOS L2 data. Unfortunately, all data after v5.0 are systematically referenced as v5.3, what prevents from identifying the effective algorithm version. The comparisons made in this study are based on the inhomogeneous v5.3 data set without any further distinction.

A total of 164 GOMOS ozone profiles have been compared with NDSC ground-based millimetre wave radiometers, lidars and ozonesondes. Space-time coincidence criteria between the GOMOS and NDSC soundings are: (1) at least one tangent point of the GOMOS profile within 1000 km from the ground station, and (2) a maximum of 12 hours around the GOMOS start of measurement. In case of multiple coincidences, the closest in time is selected for comparison.

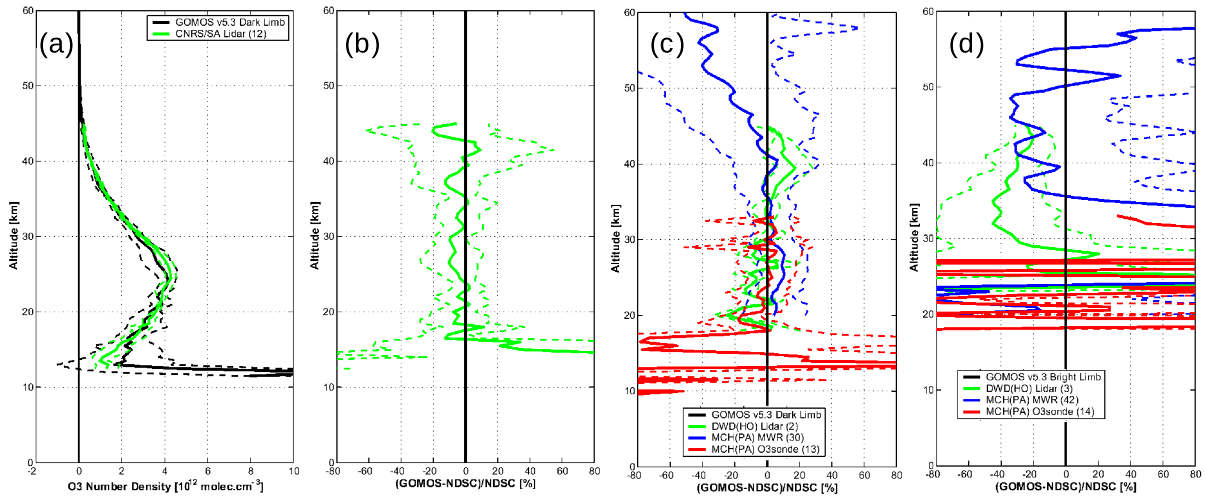

Fig. 3. Comparison between GOMOS and NDSC ozone profiles in the Alps. (a) Mean (continuous line) and standard deviation (dashed line) of 12 number density profiles measured at OHP by GOMOS in dark limb and by the CNRS lidar. (b) Percent relative difference and its standard deviation between the same GOMOS and lidar profiles as in (a). (c) Same GOMOS/NDSC differences as in (b), but at Hohenpeißenberg with DWD lidar and at Payerne with MCH ozonesonde and MWR. (d) Same GOMOS/NDSC differences as in (c), but using GOMOS bright limb data.

Practically, such criteria yield time coincidences with GOMOS night-time data of a few hours for lidar and MWR data and 4 to 12 hours for ozonesonde data. Due to the limited amount of available GOMOS profiles, more refined criteria based on the analysis of the properties of the stratospheric field and a closer time window would have reduced the significance of the comparisons. GOMOS ozone data have been compared to ground-based soundings in number density units (10^{12} molec.cm^{-2}), as a function of the altitude on a grid of 0.5 km, without any further vertical smoothing. Vertical smoothing effects are illustrated elsewhere in this issue [5].

GOMOS profiles have been sorted according to the limb brightness within the line-of-sight (LOS), that is, bright and dark limb. Fig. 3(a,b) shows the comparison of 12 night-time ozone profiles measured at the NDSC/Alpine station of O.H.P. (44°N) by GOMOS in dark limb mode and by the CNRS stratospheric lidar. Except below 15 km where lidar measurements exhibit increasing error bars but no known bias, the mean agreement falls within the 10% level, that is, the level reported in the literature for well-proven ozone sounders. Fig. 3(c,d) also illustrates the comparison with the three types of NDSC profilers over the NDSC/Alpine stations at Hohenpeißenberg (48°N) and Payerne (46°N), for both bright limb and dark limb conditions. The quality of GOMOS ozone profiles acquired in bright limb is obviously poor. On the other hand, GOMOS measurements in dark limb mode agree with the three types of NDSC sounders within 10% through the entire 20-40 km altitude range. At altitudes below 20 km, the discrepancy between GOMOS and ozonesonde data often exceeds 60%. Above 40 km, the difference between GOMOS and MWR data at Payerne increases systematically with the altitude. Part of this difference could be attributed to the increasing MWR null-space error and a-priori information content above 40 km, which combined to the systematic and random error contributions make up to a total MWR retrieval error of about 25 % at 50 km. Besides, GOMOS-related problems cannot be ruled out, especially if we consider the better agreement obtained with MIPAS at such altitudes, as shown in the next section.

5. MIPAS OZONE PROFILES

At the end of 2002, ESA level-1-to-2 processor v4.53 started operational generation of MIPAS near real-time (NL) level-2 data. The correlative database acquired through CINAMON has been used to conduct first correlative studies of MIPAS ozone profiles. Using the same coincidence criteria as used for GOMOS, the available data sets offer a total of 257 MIPAS/NDSC co-located profiles. Ozone profiles from MIPAS have been compared to correlative soundings in volume mixing ratio (VMR) unit and on a log-pressure grid, without any further vertical smoothing. Vertical smoothing effects are illustrated in [5]. Fig. 4 shows typical comparison results obtained at the NDSC/Alpine station of Payerne (46°N) with the MCH ozonesonde and MCH/U. Bern MWR. Between 50 hPa (˜ 20 km) and 0.4 hPa (˜ 50 km), the mean relative difference between MIPAS and two ground-based instruments falls within ±10%, with a standard deviation

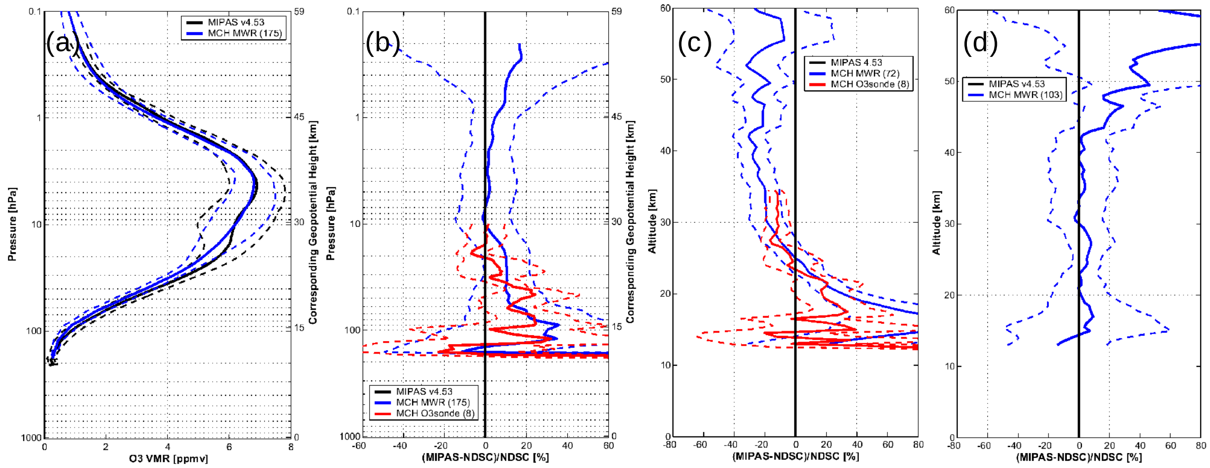

Fig. 4. Comparison between MIPAS and correlative ozone profiles at the NDSC/Alpine station of Payerne. (a) Mean (continuous line) and standard deviation (dashed line) of 175 VMR profiles in log-pressure scale, measured by MIPAS and by the millimetre wave radiometer (MWR). (b) Percentage relative difference between MIPAS and ground-based (MWR and ozonesonde) ozone VMR. (c) Same as (b), but on an altitude grid and with 72 MIPAS profiles acquired before November 13, 2002 12 h UT. (d) Same as (c), but with 103 MIPAS profiles after November 13, 2002 12 h UT.

of about 15%. Around the maximum of ozone VMR, between the 10 hPa (˜ 30km) to 2 hPa (40km) levels, the mean agreement is even better. Above and below the 50-0.4 hPa (˜ 20-50 km) range, MIPAS reports higher VMR values than those reported by MWR. MIPAS and ozonesonde data around the tropopause (200-100hPa, or ˜ 11-15km) differ systematically by 20-30% with a standard deviation of about 30%. Those preliminary comparisons conclude to a good agreement between MIPAS and NDSC ozone profile data through nearly the entire stratosphere. As with GOMOS, it remains to be verified whether MIPAS and NDSC sounders report similar geophysical features as well.

A pointing correction of the MIPAS LOS was implemented on November 13, 2002, 12:00 UTC. As a result, the effective tangent point height was shifted towards lower levels by approximately 1-2 km. This correction impacts dramatically the comparisons carried out in altitude scale. Fig. 4(c,d) compares the relative difference, in ozone number density and as a function of the altitude, between MIPAS and the ground-based ozone profiles at Payerne before and after implementation of the pointing correction. The correction leads to an obvious improvement of the agreement. It is worth noting that pressure and temperature profiles are retrieved directly from the MIPAS radiometric data by the level-2 processor. This explains why the comparisons in VMR and log-pressure space do not seem to be affected by LOS pointing errors.

6. GLOBAL MAPPING OF MIPAS OZONE DATA

The CINAMON project also includes application studies of ENVISAT data. NILU-Kjeller has carried out global mapping of ozone, from pole to pole, for the period October - November 2002. Along-track, level-2 MIPAS ozone data (Meteo Product MIP_RV) have been interpolated onto potential temperature levels, using MIPAS pressure and temperature measurements. For mapping purpose, several days of data have been grouped together, and binned in longitude and latitude. This simple binning algorithm has been used, as the large amount of missing data and orbits prohibited the use of the Salby synoptic-mapping method. Profiles have also been extracted for comparison with lidar and ozonesonde measurements.

A sequence of maps during the final disappearance of the southern hemisphere polar vortex is shown on Fig. 5. A low-ozone pool of air at high southern latitudes is seen on October 24-27 west of the Greenwich Meridian. The height is 650K or approximately 25 km. At this altitude, the high-latitude wintertime subsidence makes the vortex air poor in ozone compared to extra-vortex air. The ozone chemical destruction on polar stratospheric clouds is usually more pronounced lower down in the atmosphere. Over the following two weeks, the pool of low-ozone air is drifting eastwards and equator wards, before disappearing in mid-November. The temporal continuity in the feature displacement, and the consistency with other data, e.g. such as the GOME fast-delivery products (www.knmi.nl/gome_fd), insure that the MIPAS-based maps represent the actual disappearance of the large-scale remnant of the ozone-poor polar vortex.

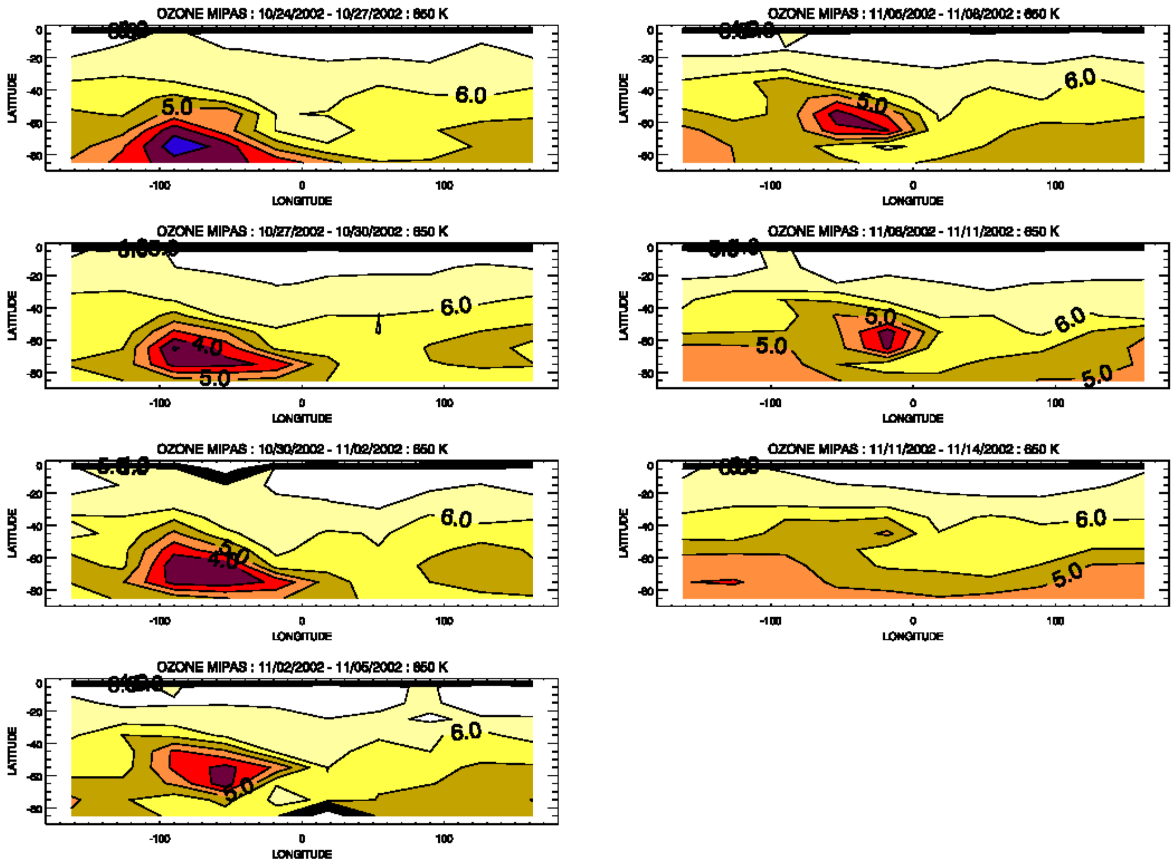

Fig. 5. Ozone mixing ratio at 650K over the southern hemisphere (in ppmv) from MIPAS L-2 observations, spanning from October 24 to November 15, 2002. Contours by 0.5 ppmv.

7. CONCLUSION AND PERSPECTIVES

In support to the ENVISAT validation campaign, the collection of correlative observations of ozone-related constituents acquired at a variety of NDSC stations, has been organised. A large set of data acquired during the Commissioning Phase has been verified, converted and uploaded to the ENVISAT Cal/Val database located at NILU. Actual data acquisition complies quite well with the planned data acquisition as proposed in the original project in April 1998. While a few instruments have been removed from the list, other instruments have been added in such a way that the scientific output of the validation studies should not be affected. The delivery rate to the ENVISAT Cal/Val database varies from one station to another, depending on local resources, on logistic issues, and on technical issues linked to the fast delivery. Data acquisition after CP will continue as part of regular NDSC monitoring activities. Data collection will continue during the main validation phase. It is anticipated that data collection will be organised at typical stations for long-term validation studies, according to the needs revealed by future validation results.

Preliminary comparisons of early ENVISAT data (SCIAMACHY O_3 and NO_2 columns; GOMOS and MIPAS O_3 profiles) with correlative data acquired by NDSC sounders have demonstrated the potential of the studied data products but they also highlighted some problems. The late delivery of ENVISAT data products, limited to the second half of the Northern fall season, has hampered the output of the planned effort. Provided that the operational delivery of ENVISAT gets on, it is anticipated that first geophysical validation results, that is, conclusions on the geophysical usability of ENVISAT data, could be drawn in the second part of 2003. Finally, the global mapping of MIPAS ozone data has demonstrated the qualitative potential of this ozone profile sensor for Antarctic ozone studies. Extended data sets in time and space are awaited for further studies and the application of the Salby synoptic-mapping method.

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