SCIAMACHY MISSION OBJECTIVES AND VALIDATION CONCEPT: THE GERMAN CONTRIBUTION

R. Hoogen, J. P. Burrows, and S. Noël

Institut für Umweltphysik, Universität Bremen (FB 1),
Postfach 33 04 40, D-28334 Bremen, Germany
email: Ricarda.Hoogen@iup.physik.uni-bremen.de

U. Platt, T. Wagner

Institut für Umweltphysik, Ruprecht-Karls-Universität Heidelberg,
Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany

ABSTRACT

SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) is a spectrometer designed to measure sunlight transmitted, reflected, and scattered by the Earth's atmosphere or surface. It is part of the payload of ESA's Envisat-1 satellite scheduled for launch in late 2000. SCIAMACHY measurements will provide information about the atmospheric constituents O_3, BrO, OClO, SO_2, H_2CO, NO, NO_2, NO_3, CO, CO_2, CH_4, H_2O, N_2O, and possibly ClO, as well as information about aerosol, pressure, temperature, radiation field, cloud cover, cloud top height, and surface reflectance.

A dedicated validation is essential to assess the quality of the SCIAMACHY data. Given the large variety of data products from SCIAMACHY, the validation requirements far exceed those of any previous space instrument. To establish the validity and accuracy of the SCIAMACHY measurements and of the derived geophysical data products, comparisons will be performed with ground based, aircraft borne, shipboard, balloon, and satellite borne instruments for all relevant atmospheric scenarios.

1. INTRODUCTION

To improve our knowledge about the physical and chemical processes controlling the composition and behaviour of the atmosphere and to monitor atmospheric changes, global measurements of atmospheric constituents are indispensable. Over the past two decades pioneering efforts have been made by the scientific community to establish both ground-based networks and satellite projects having the aim to provide an adequate global observing system. The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) is part of this effort. It was proposed by an international team of scientists following the call for Earth observation instrumentation in the Announcement of Opportunity (AO) for the European Space Agency's Polar Platform (Ref. 1). After peer review SCIAMACHY was selected for flight on the Polar Platform now known as Envisat-1, which is scheduled for launch in late 2000. As an AO instrument SCIAMACHY is a national contribution to Envisat-1 funded by the German (DLR, formerly DARA) and Dutch (NIVR) space agencies, including a Belgian (IASB) contribution.

This paper gives an overview of the capabilities of SCIAMACHY and of the validation set-up and coordination with emphasis on the German contribution. A detailed description of the instrument and the mission can be found elsewhere (Refs. 2, 3).

2. INSTRUMENT

SCIAMACHY is a UV-vis-NIR imaging spectrometer combining and extending the measurement principles and observational modes of the nadir scattered sunlight measuring instruments SBUV, TOMS, and GOME (Refs. 4, 5), the solar occultation instrument SAGE (Ref. 6), and the limb scattered sunlight measuring instrument Solar Mesospheric Explorer (SME) (Ref. 7). It comprises a mirror system, a sun diffusor, a telescope, a spectrometer, a calibration unit, and thermal and electronic subsystems. Except for the scan mirrors, all spectrometer parts are fixed. The spectra are recorded simultaneously from 240 to 1750 nm and in two smaller windows, 1940-2040 nm and 2265-2380 nm, using eight passively cooled diode array detectors. The spectral resolution varies from 0.2 to 1.5 nm depending on channel. To cope with the large dynamic range of the input signals (six to eight orders of magnitude), the integration times of the single channels can be selected independently between 0.03125 s and 80 s (Ref. 3).

3. MEASUREMENT MODES

Envisat-1 will fly in a polar, sun-synchronous orbit with equator crossing time 1000 LT. SCIAMACHY

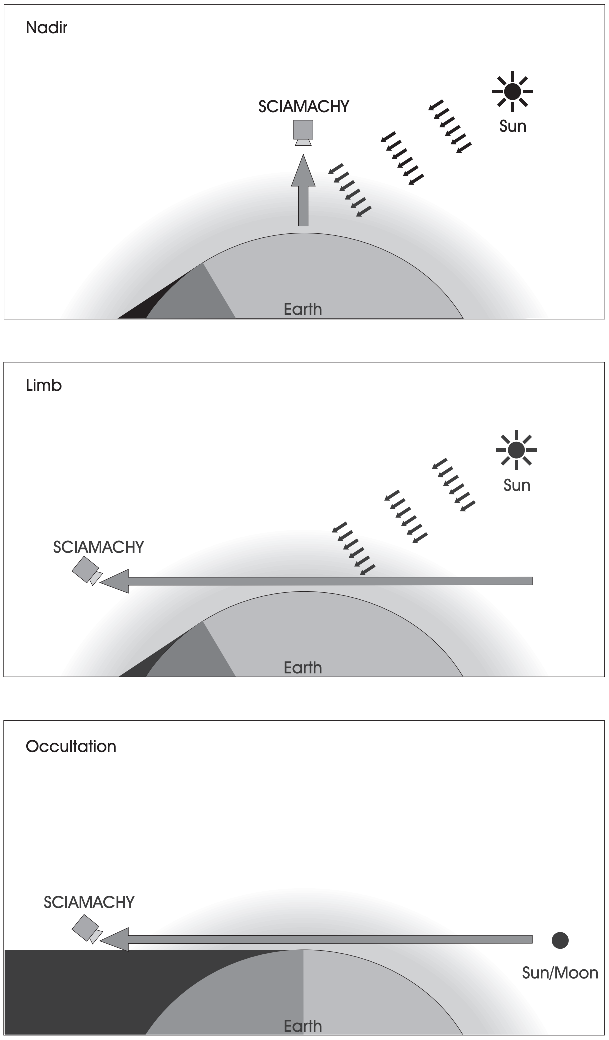

Figure 1: SCIAMACHY observation geometries.

measurements will be performed in nadir, limb, and solar/lunar occultation geometry as illustrated in Figure 1. The measurement sequence for a typical orbit is displayed in Figure 2. On the night side of the orbit calibration measurements will be performed; this includes dark current measurements and measurements with the on-board spectral and white light calibration lamps. For each orbit solar occultation measurements, including measurements of the solar irradiance, will be performed during sunrise. Over the year latitudes between 90° N and 65° N will be covered. For periods of five to eight days per month lunar occultation measurements will be performed in every second orbit, yielding latitudinal coverage from 30° S to 90° S. During most of the sunlit part of the orbit alternating limb and nadir measurements will be performed. For the nominal scan pattern global coverage will be achieved within six days. The effective spatial resolution of the nadir measurements will vary along the orbit because of

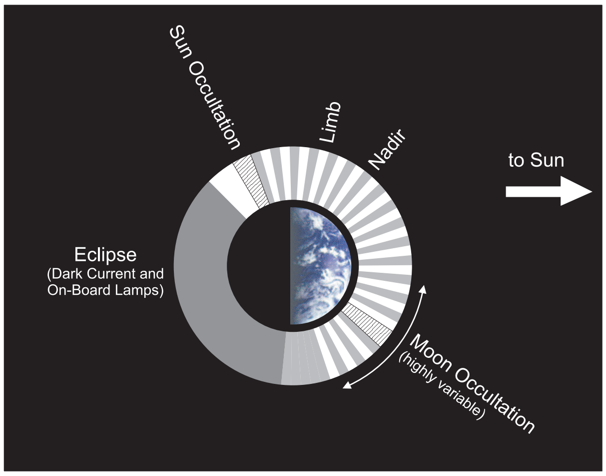

Figure 2: Sequence of measurements during a typical orbit.

signal-to-noise requirements and data rate limitations. Between 60° N and 60° S the maximum allowed data rate will require on-board co-adding of data. The typical ground pixel size will be 240 km across track by 30 km along track. For selected spectral windows data will be down-linked with reduced co-adding leading to a ground pixel size of 60 km across track by 30 km along track. In limb mode the total swath of 960 km in azimuth direction and a typical 240 km spatial resolution in horizontal direction will explicitly match the spatial resolution of the nadir measurements. This optimized limb-nadir mode will allow to observe the same atmospheric volume both in limb and in nadir viewing geometry within a few minutes.

A detailed description of the observational modes as well as spatial coverage and resolution can be found elsewhere (Ref. 3).

4. MISSION OBJECTIVES

SCIAMACHY will provide height-resolved information about a multitude of atmospheric constituents on a global scale. This will allow to address important issues in atmospheric sciences such as

- stratospheric chemistry, in particular in polar regions (i.e., under ozone hole conditions) and at midlatitudes
- tropospheric pollution arising from industrial activity and biomass burning
- increasing greenhouse gas concentrations
- stratosphere-troposphere exchange processes
- modulations of atmospheric composition resulting from natural phenomena (e.g., volcanic eruptions, solar cycle)

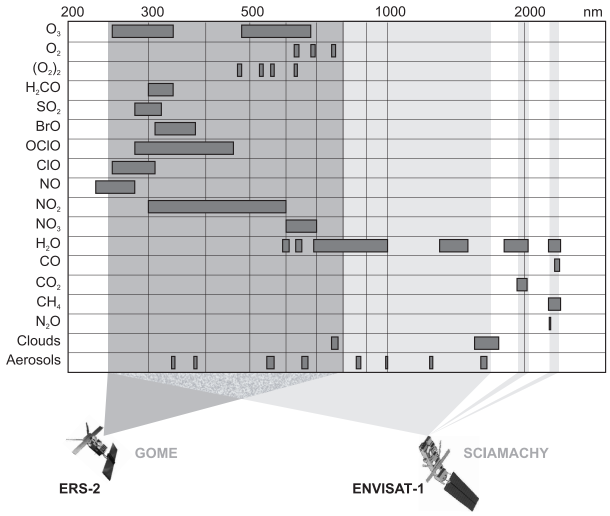

Figure 3: Wavelength ranges covered by SCIAMACHY and GOME and spectral windows suitable for the retrieval of target constituents.

Figure 3 shows the wavelength ranges of SCIAMACHY and GOME and the spectral windows where atmospheric constituents are to be retrieved. The GOME instrument launched aboard the European Remote Sensing satellite ERS-2 in April 1995 is a descoped version of SCIAMACHY measuring in nadir mode only and covering a smaller wavelength range. With GOME the feasibility of the instrument and retrieval concepts has been successfully demonstrated for nadir observations. Column amounts of O_3 and NO_2 are retrieved operationally from GOME measurements and column amounts of BrO, OClO, SO_2, H_2CO, and H_2O as well as O_3 profiles have also been readily derived (Refs. 5, 8, and references therein). Studies of ClO, NO_3, aerosol, and cloud retrieval are proceeding. In addition to these constituents the extended wavelength range covered by SCIAMACHY will enable the retrieval of CO, CO_2, CH_4, and N_2O amounts. Limb and occultation measurements will provide height-resolved information about all above-mentioned constituents and about NO and $O_2(^1\Delta_g)$, which unlike the other molecules will not be detected in absorption but in emission. In addition to trace gas amounts, pressure and temperature profiles as well as information about aerosols, clouds, and the surface reflectance will be derived.

5. RETRIEVAL METHODS

5.1. Trace gas total columns

Total column amounts of trace gases will be retrieved from nadir measurements using the well-known DOAS (Differential Optical Absorption Spectroscopy) approach, which has been originally developed for ground-based measurements (Refs. 9, 10, 11). The applicability of DOAS for the retrieval of trace gas amounts from space-based spectral measurements has been successfully demonstrated for the first time in the frame of the GOME mission (Ref. 5, and references therein).

For the DOAS method small fit windows of typically 10 nm width are used. In these small fit windows broad band spectral features (e.g., scattering by air molecules and aerosol and cloud particles, broad band absorption features, surface reflection) can be approximated by a low order polynomial. This polynomial is subtracted from the measured sun-normalized spectrum. To the resulting differential signal a linear combination of differential reference absorption cross sections is fitted in a least-squares fit, the fit coefficients being the trace gas slant column amounts. The slant columns are then converted to the corresponding vertical columns by means of so-called air mass factors, which are determined from radiative transfer calculations.

Because of its easy implementation and high computational speed, in particular when using look-up tables instead of radiative transfer calculations, the DOAS method is very well suited for operational processing of large amounts of data as demonstrated with GOME.

5.2. Trace gas profiles

From UV nadir measurements O_3 profiles with a vertical resolution of 6-10 km can be derived. The method is essentially based on the fact that due to ozone absorption the penetration depth of solar UV radiation into the atmosphere strongly depends on wavelength. Thus UV nadir spectra contain altitude information about ozone. For the retrieval of O_3 profiles from GOME measurements the Full Retrieval Method FURM has been developed, which can be readily applied to SCIAMACHY measurements as well. It is based on an optimal estimation inversion scheme which iteratively matches a sun-normalized spectrum simulated with a radiative transfer model to the actually measured spectrum. Details of the method are given elsewhere (Ref. 12).

Trace gas profiles with a vertical resolution of approximately 3-5 km can be derived from limb and occultation measurements. Dedicated retrieval algorithms are currently being developed (Ref. 13). The most accurate method is the “global fitting” approach where simulated spectra are iteratively matched to measured values simultaneously for all atmospheric layers. In this sense, the “global fitting” approach is similar to FURM, with the difference that limb or occultation measurements are used instead of nadir data. An alternative approach is the "onion peeling" scheme, which computes the vertical column for each individual layer starting at the top of the atmosphere. This can be done by scaling appropriate reference spectra obtained from radiative transfer calculations. The columns of the lower layers are derived by subtracting the upper columns. The disadvantage of the "onion peeling" method is that contributions to the measured spectrum from altitudes below the tangent height are not taken into account. Thus it is not adequate for limb measurements and its applicability to occultation measurements has to be investigated.

5.3. Tropospheric columns

A unique feature of SCIAMACHY is the optimized limb/nadir mode enabling the determination of tropospheric column amounts of O_3, NO_2, BrO, CO, CO_2, CH_4, H_2O, N_2O, SO_2, and H_2CO down to the Earth surface or to cloud top, respectively. For this purpose the stratospheric profiles derived from the limb measurements will be integrated to yield stratospheric column amounts, which will then be subtracted from the total column amounts retrieved from the subsequent nadir measurements of the same atmospheric volume. A similar residual technique has already been applied for the determination of tropospheric O_3 columns from a combination of TOMS total O_3 columns and integrated SBUV or SAGE-II stratospheric O_3 profiles (Refs. 14, 15). The great advantage of SCIAMACHY over this approach is that the stratospheric profiles and the total column amounts are derived from measurements performed by a single instrument within a few minutes. This leads to a much better temporal and spatial coincidence of the measurements than if different instruments on different platforms were used.

6. OPERATIONAL TRACE GAS PRODUCTS

An operational SCIAMACHY product is defined as a regularly generated, quality controlled, and archived product. Currently, it is planned that all nadir and limb measurements will be operationally processed. Scientific products derived from solar and lunar occultation measurements as well as tropospheric products derived from limb/nadir measurements will be generated by specific scientific groups.

The operational data products are organized in three levels. Raw data (i.e., detector count rates as a function of pixel number) are called level-0 data. Geolocated and spectrally and radiometrically calibrated radiance and irradiance spectra form the level-1 data product. Application of appropriate retrieval algorithms to the level-1 data yields trace gas column amounts and profiles as well as aerosol and cloud information (level-2 data).

	Nadir Total Column Amount			Limb Stratospheric Profile		
	UV/Vis	IR	UV to IR	UV/Vis	IR	UV to IR
Near Real-Time	O_3 NO_2 OClO * SO_2 * H_2CO * BrO **	H_2O N_2O CO CH_4 #	Clouds Aerosol			
Off-Line	O_3 NO_2 BrO OClO * SO_2 * H_2CO * UV Index**	H_2O N_2O CO CO_2 CH_4 Pressure Temp.	Clouds Aerosol	O_3 NO_2 BrO**	H_2O CO_2 CH_4 Pressure Temp. N_2O** CO**	Aerosol

*observed under special condition (volcanic eruption, ozone hole, heavy tropospheric pollution)

#reduced quality at CO fitting window

**recommended by Science Advisory Group, implementation under negotiation with agencies

Figure 4: SCIAMACHY operational level-2 products.

There are two categories of operational SCIAMACHY level-2 data products: Fast delivery or near real-time (FD/NRT) products and off-line (OL) products. The NRT products are to be generated directly after downlink at the ESA ground stations, a few hours after spectrum acquisition. The OL products are consolidated products processed off-line at the German Processing and Archiving Center installed at DLR-DFD. In Figure 4 the operational level-2 products are listed.

Several sensitivity studies have been performed to estimate the precision of the data products. The precision of the O_3, H_2O, CO_2, and CH_4 nadir columns is expected to be 1 %. The precisions for the other trace gases vary between 2 and 20 %. The precision of the limb profiles is expected to be of the order of 10 %. More details can be found elsewhere (Ref. 3).

7. VALIDATION

7.1. Objectives

The objective of the SCIAMACHY validation is to determine the accuracy of both operational and scientific data products for all relevant atmospheric conditions. This will be achieved by comparison of the SCIAMACHY data products with temporally and spatially coincident measurements performed by independent instrumentation from various platforms (ground-based, aircraft, ship, balloon, satellite). In this context it is important to achieve adequate spatial coverage to account for the various geophysical conditions (e.g., surface characteristics, solar zenith angle) encountered around the globe. Another essential requirement is adequate temporal coverage and resolution to investigate the effects of seasonal variations (e.g., temperature, snow cover).

7.2. Coordination and set-up

Given the broad range of data products that can be derived from SCIAMACHY measurements, the validation of these products is a challenge requiring coordinated action both on an international and on a national basis.

The Atmospheric Chemistry Validation Team (ACVT) chaired by ESA is responsible for the overall validation planning, data acquisition, data processing, data analysis, and reporting for the atmospheric chemistry instruments SCIAMACHY, MIPAS, and GOMOS on Envisat-1. The German contributions to the SCIAMACHY validation are coordinated by the Institute of Environmental Physics, Heidelberg, with support from the Institute of Environmental Physics, Bremen.

As proposed by the SCIAMACHY Validation and Interpretation Group (SCIAVALIG), a subgroup of the SCIAMACHY Science Advisory Group (SSAG), the validation will comprise two parts (Ref. 16): core validation and AO validation. The core validation aims at providing a minimal but essential validation of SCIAMACHY products. It will be performed primarily by relevant groups from those countries which have funded SCIAMACHY. For each data product it is intended to have at least one "global" (i.e., satellite-borne) and one "local" (e.g., ground-based, aircraft, balloon) validation source. The core validation will be complemented by the so-called AO validation based on selected proposals submitted to ESA following the Announcement of Opportunity for SCIAMACHY validation. The AO validation is open to all scientists.

7.3. Validation phases

The validation of SCIAMACHY will be divided in three phases: commissioning phase, main validation phase, and long-term validation phase.

The commissioning phase will last from launch (L) until six months after launch (L+6). Nominal operation is expected to start at L+3 after outgassing and functional testing of the instrument. The measurements acquired during the commissioning phase will be used for a preliminary validation of level-1 and level-2 data. Particularly important are the irradiance and limb and nadir radiance products since all higher level products depend on the accuracy of these products. The release of preliminary data is foreseen for L+9.

During the main validation phase, which will last from L+6 to L+18, intensive validation activities will be performed. Each level-1 and level-2 product has to be rigorously validated during this period to establish its accuracy. The results of this validation phase will be presented in a dedicated validation workshop around L+20. Official data release is foreseen for L+20.

Since the instrument performance is likely to degrade in time and since several updates of data inversion algorithms are expected, a long-term validation beginning at L+18 and extending over the entire lifetime of SCIAMACHY is essential to establish a reliable data record. This necessitates a regular, optimized repetition of the essential elements of the main validation.

8. GERMAN CONTRIBUTION TO SCIAMACHY VALIDATION

In this section a brief overview of the validation activities planned by German groups is given. Most activities will be financed by the German Education and Science Ministry (BMBF) and by the German Aerospace Agency (DLR). However, for those activities that will be directly used by other validation participants (e.g., meteorological support) ESA funding will be applied for. Since the validation planning is still at an early stage the lists of instruments and measurement sites are preliminary and may be updated in the future. Only those data products that are relevant for the SCIAMACHY validation are explicitly mentioned, although some instruments may measure additional species not covered by SCIAMACHY.

8.1. Ground-based measurements

UV-visible zenith-sky spectroscopy using the DOAS technique provides column amounts of O_3 (relative error $\approx 2\,\%$), NO_2 (5 %), BrO (30 %), and OClO (10 %) on a daily basis. The German DOAS community operates instruments at the following stations: Ny-Ålesund (79° N, 12° E), Kiruna (68° N, 20° E), Bremen (53°N, 8°E), Neumayer (70° S, 8° W), and Arrival Heights (78° S, 167° E). The high latitude sites provide data in the very important regions of springtime stratospheric ozone depletion, whereas Bremen is representative of polluted continental regions. It is proposed to install additional DOAS instruments in the subtropics and tropics, for example in Izana (28° N, 16° W), Merida (8° N, 71° W), Surinam (6° N, 55° W), and possibly on the Maldives (3° N, 73° E).

From ground-based Fourier Transform Spectroscopy (FTS) measurements in the UV, visible, and IR spectral regions performed in solar (and possibly lunar) occultation total columns and number density profiles of O_3, NO_2, H_2O, CO, N_2O, CO_2, H_2CO, and CH_4 as well as other molecules not covered by SCIAMACHY can be derived. Furthermore, from extrapolation of measurements at different solar zenith angles the zero-airmass solar spectrum can be obtained. The relative uncertainties of the column amounts vary between 1 and 10 % depending on species. The German scientific community operates FTS instruments in Ny-Ålesund, Kiruna, Bremen, Oberpfaffenhofen (48°N, 11° E), Zugspitze (48° N, 11° E), Izana, and Merida.

In addition to the ground-based measurements, FTS and DOAS instruments are planned to be operated on the German research vessel Polarstern during its Atlantic transfer cruises. This facilitates the validation of SCIAMACHY measurements in remote marine regions.

Ground-based microwave (MW) radiometers measure the thermally induced rotational emission of selected species. From the pressure broadening of the spectral lines stratospheric trace gas profiles with a vertical resolution of approximately 8 to 10 km can be derived. This is a well-established approach for O_3 and H_2O and has recently been successfully applied to ClO as well. Continuous MW measurements of O_3, H_2O, and ClO are performed by German scientists in Ny-Ålesund. The operation of O_3 and H_2O radiometers in Kiruna, Bremen, and Merida is planned.

The Differential Absorption Lidar (DIAL) technique provides ozone profiles between 15 and 50 km altitude with a vertical resolution varying from 0.5 to 8 km with increasing altitude. DIAL measurements are operationally performed during cloud-free nights in Hohenpeißenberg (48° N, 11° E) and Ny-Ålesund. Backscatter lidars provide vertical distributions of aerosol and cloud properties (e.g., backscatter ratio, depolarization ratio). In addition, from the Rayleigh backscattered signal temperature profiles in the stratosphere and mesosphere can be derived. A backscatter lidar is operated on a campaign basis in Esrange (68° N, 21° E). Other lidar instruments will also be taken into account.

Meteorological sondes provide vertical profiles of pressure, temperature, water vapour, and, in case an ozone sonde is attached, ozone from the ground to maximum altitudes between 30 and 40 km with a vertical resolution of approximately 100 m. Sondes are launched by several German research groups at a variety of locations in Germany as well as in Ny-Ålesund and Neumayer. For the Arctic and Antarctic stations as well as for at least one German station two to three launches per week closely correlated with Envisat-1 overpasses are desirable.

In addition to the above-mentioned DOAS, FTIR, microwave, Lidar, and ozone sonde measurements data from the Brewer, Dobson, and NDSC networks will be available for SCIAMACHY validation.

8.2. Balloon campaigns

For the validation of SCIAMACHY trace gas vertical profiles derived from limb and occultation measurements three payloads are proposed to fly on large stratospheric balloons.

The first payload contains a DOAS instrument measuring in solar occultation geometry and covering the spectral range 300-700 nm. From the DOAS measurements stratospheric profiles of O_3, NO_2, BrO, and OClO can be derived. The DOAS instrument will be flown together with the Limb Profile Monitor of the Atmosphere (LPMA) operated by Laboratoire de Physique Moléculaire et Applications/CNRS (France). The LPMA is an FTIR instrument measuring in solar occultation in the 1-2.5 μm region. It provides stratospheric profiles of CO, CH_4, N_2O, O_3, NO_2, H_2O, and CO_2. The vertical resolution of the LPMA/DOAS profiles is approximately 2-3 km, the accuracy varies from 1 to 15 % depending on species. The LPMA/DOAS payload has been successfully applied to the validation of ILAS/ADEOS in 1997. As a novelty it is planned to provide the LPMA and DOAS instruments with an absolute radiometric calibration before and after each flight. This will allow to extrapolate the zero-airmass solar irradiance from measurements performed at different solar zenith angles using the Langley-plot method. In addition, a tunable diode laser absorption spectrometer providing in-situ measurements of H_2O and CH_4 shall fly piggy-back on the LPMA/DOAS gondola.

The second balloon payload is the MIPAS-B instrument, an advanced cryogenic limb emission FTIR spectrometer providing stratospheric profiles of O_3, H_2O, CH_4, N_2O, NO_2, ClO, temperature, and pressure.

The third payload is the TRIPLE package comprising the following in-situ instruments: cryogenic whole air sampler, Lyman-alpha fluorescence hygrometer, and ClO/BrO resonance fluorescence sensor.

So far, no precise schedule defining the number of flights, the launch sites, and the launch dates has been fixed. It is planned to perform flights at high- and mid-latitudes, and possibly in the tropics in different seasons. For economical reasons it is planned to develop a common schedule for all balloon activities.

8.3. Aircraft-borne measurements

Aircraft can fly almost everywhere on the globe under most weather conditions and in all seasons. Furthermore, aircraft campaigns can be planned to achieve close temporal and spatial coincidence with satellite overpasses. These advantages make aircraft excellent platforms for the validation of satellite instruments.

The German aircraft validation activities will concentrate on missions with the Falcon aircraft operated by the German Aerospace Center (DLR). The payload will comprise the ASUR sensor, the OLEX system, and a DOAS instrument. ASUR is a sub-millimeter wave radiometer providing profiles of O_3, H_2O, N_2O, BrO, and ClO between approximately 15 and 55 km altitude. OLEX is a 4-wavelength lidar providing O_3 profiles in the lower stratosphere and information about aerosol, clouds, and PSCs in the upper troposphere and lower/middle stratosphere. Both ASUR and OLEX have been successfully operated aboard the Falcon during the EASOE and SESAME campaigns. The DOAS instrument will be able to look both upwards and downwards, which will enable the validation of stratospheric and tropospheric columns of O_3, NO_2, BrO, and OClO. Several flight campaigns are planned for northern high- and mid-latitudes and tropical regions.

Furthermore, the high-altitude aircraft Geophysika was proposed as a platform for SCIAMACHY validation by ESA. The payload operated by German groups will comprise several remote sensing and in-situ instruments providing information about O_3, NO_2, H_2O, N_2O, CH_4, CO_2, BrO, CO, ClO, and OClO.

8.4. Satellite measurements

Measurements by independent satellite instruments will facilitate a pole-to-pole validation of most SCIAMACHY products for all seasons. The focus will be on the validation of SCIAMACHY trace gas products with collocated measurements of GOME on ERS-2, TOMS on Earthprobe, HALOE on UARS, and SAGE-II on ERBS. The validation is planned in close cooperation with the principal investigators of the respective instruments. The data products from these instruments have been carefully validated and improved through several version upgrades. GOME data will be used to validate SCIAMACHY nadir profiles of O_3 and columns of O_3, and NO_2. TOMS data will be used to validate O_3 total columns. HALOE provides profiles of O_3, NO_2, CH_4, and H_2O, and SAGE-II of O_3, NO_2, and H_2O. Although HALOE and SAGE-II have already exceeded their expected lifetimes, it is likely that these instruments will be operational at least during the first year of SCIAMACHY measurements.

By the time of the launch of Envisat-1 several new satellite sensors will have been launched, among them SAGE-III on Meteor-3 (providing profiles of O_3, NO_2, H_2O, and OClO), SABER on TIMED (O_3 and H_2O profiles), and SBUV-2 on the NOAA platforms (O_3 profiles). Cross-comparison studies of trace gas measurements performed by these instruments and by SCIAMACHY are planned.

In addition to the trace gas products, level-1 products will be validated with independent satellite measurements as well. SCIAMACHY solar irradiances will be compared with irradiances measured by GOME and, if available, by SUSIM and SOLSTICE on UARS. Together these three instruments cover the UV-visible spectral range of SCIAMACHY with a comparable spectral resolution. For the validation of the infrared part of the SCIAMACHY irradiances ground-based measurements obtained at the Kitt Peak National Solar Observatory will be used. UV-vis nadir radiances will be compared with GOME radiances for comparable atmospheric scenarios and viewing geometries. In the IR spectral region comparisons with radiative transfer calculations are planned. The SCIAMACHY limb radiances will be compared with measurements of the OSIRIS instrument on the ODIN satellite and with radiative transfer calculations.

8.5. Chemistry models and meteorological support

Several German groups are developing chemistry transport models. These are valuable tools, which can be used to account for temporal and spatial deviations between correlative measurements and to help in the interpretation of measurement results.

For the coordination and planning of measurement campaigns (in particular of balloon and aircraft campaigns) and for the interpretation of intercomparison results meteorological data (temperature and pressure profiles, wind fields etc.) are indispensable. The German contribution to the meteorological support will be provided by the Free University Berlin.

8.6. Current status

The coordinator of the German SCIAMACHY validation activities has invited relevant groups to submit project outlines specifying their respective contributions. These will be bundled to a limited number of proposals for national funding. It is expected that decisive statements about the funding situation will be available by the end of 1999 so that the first pre-launch activities necessary for the validation can start in early 2000.

9. SUMMARY

SCIAMACHY is a space-based spectrometer measuring almost continuously from the UV to the near IR spectral region. It is part of the atmospheric chemistry payload on the Envisat-1 satellite, which will be launched in late 2000. SCIAMACHY will perform measurements in nadir, limb, and solar/lunar occultation geometry. From these measurements total column amounts and stratospheric profiles of a multitude of atmospheric constituents will be retrieved on a global scale. In addition, the dedicated limb/nadir mode will enable the derivation of tropospheric trace gas column amounts.

In order to assess and iteratively improve the quality of the SCIAMACHY data products and to establish a reliable long-term data record, a well-conceived and coordinated validation is required. Here, the German scientific community will make an essential contribution. Correlative measurements will be performed by a variety of ground-based and ship, balloon, and aircraft borne instruments for a wide range of locations and atmospheric conditions. Furthermore, measurements by independent satellite sensors will be taken into account. Support to campaign planning and interpretation of measurements will be provided in the form of meteorological analyses and chemistry transport models. The German validation activities will cover almost all level-1 and level-2 data products during all phases of the operational life of SCIAMACHY. Accuracy and precision will be established for all validated products. Recommendations for algorithm improvements will lead to iterative reprocessing and validation converging finally to high quality data products.

REFERENCES

1. Burrows J P & al 1988, SCIAMACHY - A European proposal for atmospheric remote sensing from the ESA Polar Platform, 95 pp., Max-Planck-Institut für Chemie, Mainz, Germany.

2. Burrows J P & al 1995, SCIAMACHY - Scanning Imaging Absorption Spectrometer for Atmospheric Chartography, *Acta Astr.*, 35, 445–451.

3. Bovensmann H & al 1999, SCIAMACHY: Mission objectives and measurement modes, *J. Atmos. Sci.*, 56, 127–150.

4. Heath D F & al 1975, The solar backscatter ultraviolet and total ozone mapping spectrometer (SBUV/TOMS) for Nimbus G, *Opt. Eng.*, 14, 323–331.

5. Burrows J P & al 1999, The Global Ozone Monitoring Experiment (GOME): Mission concept and first scientific results, *J. Atmos. Sci.*, 56, 151–175.

6. Mauldin L E & al 1985, Stratospheric aerosol and gas experiment II instrument: A functional description, *Opt. Eng.*, 24, 307–321.

7. Barth C A & al 1983, Solar Mesosphere Explorer: Scientific objectives and results, *Geophys. Res. Lett.*, 10, 237–240.

8. Noël S & al 1999, Atmospheric water vapor amounts retrieved from GOME satellite data, *Geophys. Res. Lett.*, (in press).

9. Brewer A W & al 1973, Nitrogen dioxide concentrations in the atmosphere, *Nature*, 246, 129–133.

10. Platt U & Perner D 1980, Direct measurements of atmosperic CH_2O, HNO_2, O_3, NO_2, and SO_2 by differential optical absorption in the near UV, *J. Geophys. Res.*, 85, 7453–7458.

11. Solomon S & al 1987, On the interpretation of zenith sky absorption measurements, *J. Geophys. Res.*, 92, 8311–8319.

12. Hoogen R & al 1999, Ozone profiles from GOME satellite data: Algorithm description and first validation, *J. Geophys. Res.*, 104, 8263–8280.

13. Kaiser J W & al 1999, Steps towards limb profile retrieval using a spherical radiative transfer model based on the single scattering approximation, *Proc. Eur. Symp. on Atmospheric Measurements from Space*, ESA/ESTEC, Noordwijk, The Netherlands, 20-22 January, 1999.

14. Fishman J & al 1990, Distribution of tropospheric ozone determined from satellite data, *J. Geophys. Res.*, 95, 3599–3617.

15. Fishman J & al 1996, Tropospheric ozone derived from TOMS/SBUV measurements during TRACE A, *J. Geophys. Res.*, 101, 24,069–24,082.

16. SCIAMACHY Validation and Interpretation Group 1998, SCIAMACHY Validation Requirements Document, SCIAMACHY Validation Documents Series (SVDS) 01, published by KNMI and NIVR, available on internet: http://www.knmi.nl/onderzk/atmosam/sciavalig.