German Contribution to the SCIAMACHY Validation

SCIAMACHY

Document prepared by the German national Co-ordinators

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Version 1

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1 Introduction

SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) is a new passive remote sounding instrument, and part of the payload of the ESA satellite ENVISAT. The life of ENVISAT is guaranteed for a minimum of 5 years.

SCIAMACHY measures the back scattered, reflected and transmitted light coming from the atmosphere and the extra-terrestrial solar irradiance. The division of these two measurements yields an angular dependent spectral reflectance up-welling from the atmosphere. The inversion of these measurements enables the atmospheric constituents and parameters to be retrieved. This process yields the so called SCIAMACHY data products such as trace gas profiles and total columns.

The primary scientific objective of SCIAMACHY is the study of the physical and chemical processes, which determine the behaviour of the stratosphere and troposphere. This is achieved by analysis of the observations of the spatial and temporal distributions of atmospheric trace constituents and parameters retrieved from the SCIAMACHY measurements. The need for an adequate validation of SCIAMACHY data products is a prerequisite for the successful completion of the SCIAMACHY mission. In this document a summary of the requirements and the German contribution to the validation of the SCIAMACHY data products (GC-VOS) is provided.

The experiments, measurements and analyses defined through a series of workshops to meet the validation requirements by the German research community are described. The resultant structure of GC-VOS is discussed. A milestone chart is provided as a guide to the project. This chart is sufficiently flexible to take into account changes in the ESA (European Space Agency) ENVISAT (ENVIronmental SATellite) planning.

From the above it is clear that the successful completion of the first phase of GC-VOS, which is the subject of this application, will lead to requirements for the GC-VOS dedicated to the long term validation of SCIAMACHY.

2. SCIAMACHY on ENVISAT

The SCIAMACHY Project was conceived in Germany in the middle of the 1980's [Burrows et al., 1988]. The objective of the SCIAMACHY project is to provide global information about important atmospheric parameters like trace gas concentrations or aerosol distribution by passive remote sensing of the troposphere and stratosphere. The SCIAMACHY project was proposed by an international group of scientists [for details see Burrows et al. 1995, Bovensmann et al. 1999 and references therein] following the ESA Announcement of Opportunity for the scientific Payload of the Polar Platform, now known as ENVISAT. The development of the SCIAMACHY instrument is a national contribution by the German, Dutch and Belgian governments to the atmospheric chemistry payload of ENVISAT.

SCIAMACHY data are of intrinsic scientific importance. However, it is also required to help to establish and monitor the functioning of international agreements, which aim to reduce the impact of anthropogenic activity on the atmosphere. Current examples being the Montreal Protocol and its amendments, which deal with the anthropogenic influence on the biologically important stratospheric ozone layer, and the Kyoto/Buenos Aires agreements, which address global warming. Similarly SCIAMACHY will provide important information for policy-makers working on and with European and national legislation related to air quality.

The SCIAMACHY project introduces a quantum leap in the amount and qality of information available about the physical and chemical processes, which determine thebehaviour of the atmosphere. Also new measurement principles and evaluation methods will be applied. In view of the many possible errors necessarily associated with new technology this information can only be useful and be used by the scientific community and the wider data user communities, if a thorough and well documented validation of the SCIAMACHY data products is performed.

2.1 SCIAMACHY instrument

The parameters targeted for retrieval from the SCIAMACHY measurements include trace gases, aerosol and cloud parameters, temperature, pressure density distributions and surface parameters such as the surface spectral reflectance. This information is required to understand the physical and chemical processes, which determine the behaviour and nature of the atmosphere. This enables both, biogeochemical processes, which determine the nature of the unperturbed atmosphere, and the role of man's activity through pollution, biomass burning, and land usage changes in global atmospheric change to be identified and studied.

The SCIAMACHY instrument observes backscattered, reflected, and transmitted radiation in the spectral range from the UV (240 nm) to the near IR (2380 nm) (see Fig. 2.1.1). The measurements will be performed in nadir, limb, and solar/lunar occultation geometry.

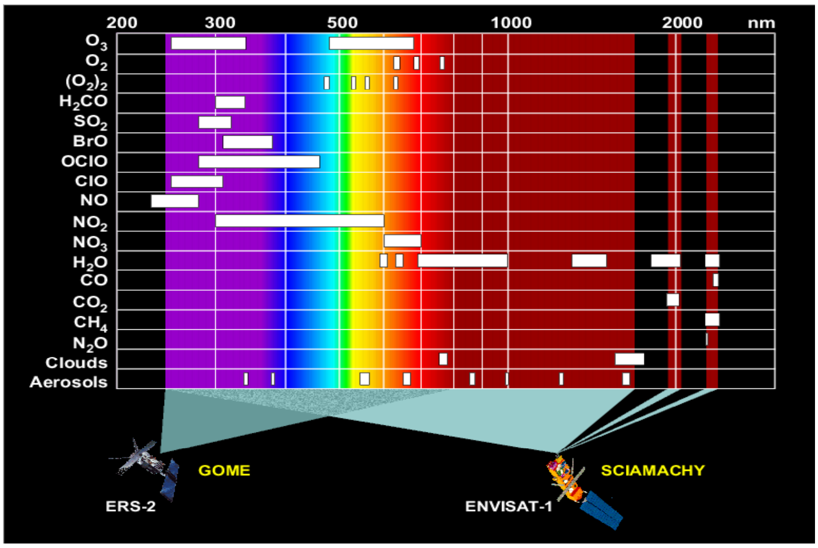

Figure 2.1.1: Spectral coverage and target species of the SCIAMACHY instrument.

From the nadir and limb measurements total column amounts and stratospheric profiles of a multitude of atmospheric constituents will be retrieved on a global scale. In addition, the de-dicated limb/nadir mode will enable the derivation of tropospheric trace gas column amounts.

The solar and lunar occultation measurements provide additional atmospheric profile information during sunrise and moonrise but have a restricted range of latitudes as a result of the sun synchronous orbit of ENVISAT (local equator crossing time of about 10.00 a.m. in descending node). An overview about the data products is given in Figure 2.1.2 and Table 2.1.1

Concerning the time of availability there are several types of SCIAMACHY data products:

1. Fast delivery (FD) data products, comprising the level 1 (earthshine and lunar radiances, and the solar irradiance) and level 2, selected total vertical column densities of selected traced gases from nadir observations, will be generated by the ESA ENVISAT data processing system.
2. Off-line (OL) data products will be generated by the German Processing and Archiving Facility (DFD-DLR) for the instrument providing agencies
3. In addition to these routine and operational data products, scientific teams will be developing advanced data products such as the tropospheric columns and/or profiles.

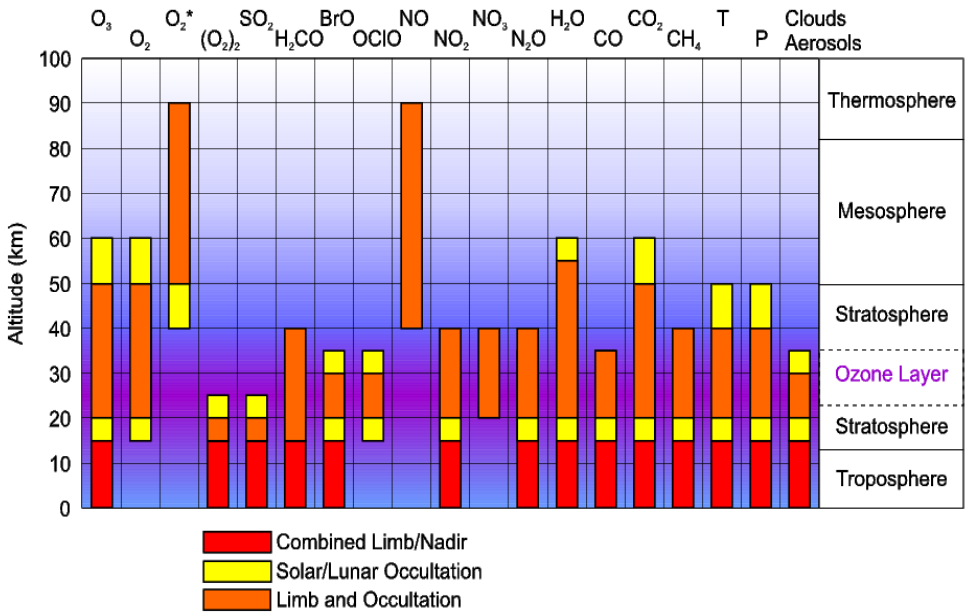

Figure 2.1.2: Altitude range of atmospheric constituents targeted by SCIAMACHY.

Table 2.1.1: Anticipated precision of the measurements to be made by SCIAMACHY. The operational products are indicated by 'FD' (fast delivery data products) or 'OL' (Off-line data products). Please note that all fast delivery data products will be also available as off line data products. ! = in the polluted troposphere; # = e.g. for biomass burning; § = column densities above 40 km; & = under ozone hole conditions; ## = feasibility shown with GOME data.

Molecule	**Nadir / Column**	**Vertical Profiles**			**Nadir / Limb**
		Occultation Solar	**Occultation** Lunar	**Limb**	**Tropospheric Column**
O_3	~1 % (FD)	~1 %	2 %	10 % (OL)	10 %
NO_2	2 %$^{\#\#}$ (FD)	~1 %	5 %	10 % (OL)	10 %
NO_3	5 %	50 % (day)	10 % (twilight)	?	—
BrO	5 %$^{\#\#}$ (FD)	5 %	?	50 % (OL)	?
OClO$^{\&}$	5 %$^{\#\#}$ (FD)	2 %	5 %	?	?
ClO$^{\&}$	20 %	50 %	?	50 %	—
HCHO$^{!\#}$	20 %$^{\#\#}$ (FD)	—	—	?	25 %
$SO_2$$^{!}$	10 %$^{\#\#}$ (FD)	—	—	?	10 %
H_2O	1 % (FD)	~1 %		10 % (OL)	~ 5 %
N_2O	5 % (FD)	~1 %		10 % (OL)	~10 %
CO	5 % (FD)	1.5 %		10 % (OL)	~10 %
CO_2	1 % (OL)	~1 %		10 % (OL)	~ 5 %
CH_4	1 % (FD)	~1 %		10 % (OL)	~ 5 %
NO§	20 %	~1 %		10 %	—
O_4	5 %	10 %		20 %	10 %
O_2	~1 %	~1 %		10 %	~10 %
O_2 ($^1\Delta_g$)	~1 %	~1 %		10 %	—

2.2 ENVISAT payload

Besides the SCIAMACHY instrument ENVISAT carries 9 on its payloads module (see Fig. 2.2.1). The ten instruments spanning the electromagnetic spectrum from microwave to ultraviolet frequencies.

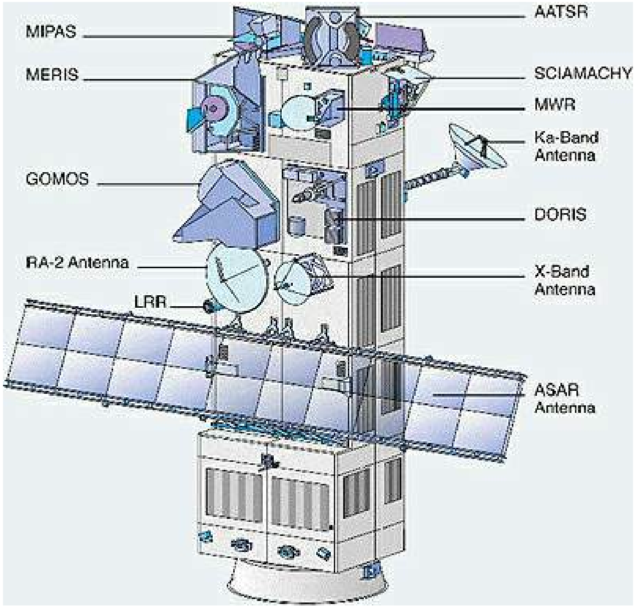

Figure 2.2.1: Payload of ENVISAT

1. Michelson Interferometer for Passive Atmospheric Sounding **(MIPAS)** is a Fourier Transform spectrometer for the measurement of high resolution gaseous emission spectra at the Earth's limb. It operates in the near to mid-infrared where many of the atmospheric trace gases playing a major role in atmospheric chemistry have important emission features. It also measures temperature profiles.
2. Global Ozone Monitoring by Occultation of Stars **(GOMOS)** provides altitude-resolved global ozone mapping between the tropo-pause and 100 km with a vertical resolution of 1.7 km. It also measures profiles of NO_2, NO_3, OClO, temperature and water vapour.
3. Medium Resolution Imaging Spectrometer **(MERIS)** is a push-broom instrument, measuring the solar reflected radiation from the Earth's surface and from clouds through the atmosphere in the visible and near infrared range during daytime. It measures ocean colour with high spectral resolution and, with ASAR, RA-2 and AATSR, it provides a synergistic mission for bio/geophysical characterisation of the oceans, land and coastal zones.
4. Advanced Along Track Scanning Radiometer **(AATSR)** continues the ATSR-1 and ATSR-2 (Along Track Scanning Radiometer) observations on ERS (European Remote sensing Satellite) of precise sea surface temperature (SST) providing a 10 year near-continuous data set at the levels of accuracy required (0.3K or better) for climate research. It also provides information about vegetation biomass, moisture, health and growth stage. Its visible channels will be used to measure cloud parameters, such as water/ice discrimination and particle size distribution.
5. Advanced Synthetic Aperture Radar **(ASAR)** is a high-resolution, wide-swath imaging radar instrument capable of taking images of the Earth's surface independent of weather conditions, cloud coverage and sun illumination. The ASAR can be used to monitor the Earth's environment to collect information on ocean wave characteristics, sea ice extent and motion, oil spills, snow and ice extent, glaciers, surface topography, land surface properties, soil moisture and wetland extent, deforestation, desertification and natural hazards.

6. Radar Altimeter 2 **(RA-2)** measures the two-way delay of the radar echo from the Earth's surface to a very high precision: less than a nanosecond. It also measures the power and the shape of the reflected radar pulses, which then allows the derivation of the parameters associated with ocean topography, bathymetry and the marine geoid. Furthermore, sea ice, polar ice sheets, and most land surfaces can be mapped. Measurement of the radar echo power and shape enables the determination of wind speed and significant wave height at sea.
7. Microwave Radiometer **(MWR)** measures the integrated atmospheric water vapour column and cloud liquid water content as correction terms for the Radar Altimeter signal. In addition, MWR measurement data are useful for the determination of surface emissivity and soil moisture over land, surface energy budget investigations and ice characterisation.
8. Doppler Orbitography and Radio-positioning Integrated by Satellite **(DORIS)** is a tracking system, which provides range-rate measurements of signals from a dense network of ground-based beacons. These make it possible to determine the satellite orbit with an accuracy of an order of centimetres. The data products are also used to help in understanding the dynamics of the solid Earth and to monitor glaciers, landslides and volcanoes. They also support the modelling of the Earth's gravity field and of the ionosphere.
9. The Laser Retro-Reflector **(LRR)** is a passive device used to reflect pulses from ground-based laser stations, to support satellite ranging and RA-2 altitude measurement calibration.

3. SCIAMACHY validation

The SCIAMACHY Validation encompasses the comparison of all data products with independent measurements and procedures. Obviously the enormous amount of data to be generated by SCIAMACHY can only be compared on a 'sample' basis, however care is being taken in this project that all relevant data products and observing conditions (e.g. geographical and seasonal dependence, column- and profile data) are adequately covered in the validation exercise.

The accuracy of the final data products depends on the ability of the algorithm development team to identify and remove systematic sources of error originating either from the instrument (e.g. pointing accuracy, accuracy of the radiometric and spectral calibrations) or within the algorithm (e.g. knowledge of reference spectra, interpolation routines, unidentified software errors, etc.).

3.1 Validation phases

The validation of SCIAMACHY will be divided in three phases: commissioning phase, main validation phase, and long term validation phase (Fig. 3.1.1). The commissioning phase covers the time period between ENVISAT launch (L) and six months thereafter (L + 6). Nominal operation is expected to start at L + 4.5 after outgassing and functional testing of the instruments.

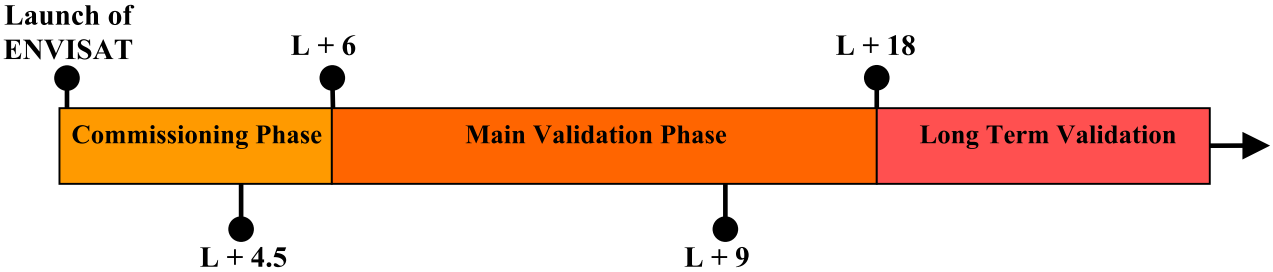

Figure 3.1.1: SCIAMACHY Validation Phases

The measurements during the commissioning phase will be used for a preliminary validation of level-1 and level-2 data. Particularly important are the irradiance, 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. 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. This is essential to establish a reliable data record. This necessitates a regular, optimised repetition of the essential elements of the main validation.

3.2. Organisation of the SCIAMACHY Validation

In order to assess and improve iteratively the quality of the SCIAMACHY data products and to establish a reliable long-term data record, which is required for the SCIAMACHY objectives to be achieved, a well-conceived and co-ordinated international validation is required. In this context, the German scientific community will make an essential contribution. This contribution will be complemented by the validation measurements planned in the framework of the Dutch and Belgian validation activities as well as those planned by ESA and co-ordinated within the ENVISAT Atmospheric Chemistry Validation Team (ACVT) (Fig. 3.2.1).

The Atmospheric Chemistry Validation Team has been created to address the validation of MIPAS, GOMOS and SCIAMACHY. The ACVT consists of four subgroups: balloon and aircraft campaigns, campaign database and ground based instruments, model assimilation and satellite intercomparison. This team will meet regularly to discuss the status of the validation and other related issues, like data distribution.

The requirements for the validation of SCIAMACHY have been developed by the SCIAMACHY Validation and Interpretation sub-Group (SCIAVALIG) of the SCIAMACHY Science Advisory Group (SSAG). One of the tasks of the SCIAMACHY Science Advisory Group is to give advice and assistance concerning the validation of SCIAMACHY. These activities are co-ordinated by the SCIAMACHY Validation and Interpretation Group. SCIAVALIG consists of an international scientific consortium of representatives of 12 institutes participating in the validation. Its activities are co-ordinated by the Royal Netherlands Meteorological Institute (KNMI).

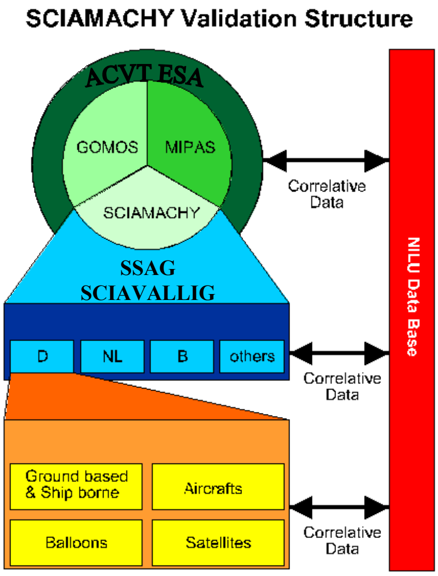

Figure 3.2.1: Integration of the German validation activities within those of other involved groups and agencies

Further on the product co-ordination was established. The SCIAMACHY validation product co-ordinators keep an overview of the validation results for the products. They signal inconsistencies between different validation results and initiate a discussion on this, if necessary. Their goal is to create a common view on the product quality among the validation scientists concerned. They take the necessary actions to achieve this goal. Their task is not to co-ordinate the individual validation activities as such, but to monitor the scientific process to create a common view from several different validation results.

The product co-ordinators report their findings to SCIAVALIG, ACVT and scientists. They give the input for the commissioning phase statement of SCIAVALIG and the yearly SCIAVALIG reports on data quality. During long-term validation the product co-ordinators are involved in the delta validation around processor upgrades.

The product co-ordinators collect their information mainly via the SCIAMACHY validation discussion pages on Internet, via validation meetings and via e-mail. In addition, interaction with algorithm developing teams and processor experts is necessary for an efficient translation from validation result towards algorithm change.

4. German validation activities

The overall concept for the German validation activities addresses the need to validate nearly all level-1 and level-2 data operational products, in an appropriate manner during all phases of the planned SCIAMACHY mission [Hoogen et al. 1999]. Details can also be found by [Platt and Burrows, 1998].

The German SCIAMACHY validation activities are to be co-ordinated by the Institute of Environmental Physics, Heidelberg and the Institute of Environmental Physics, Bremen. As defined in the SCIAMACHY Validation Requirements Document (SVRD) by SCIAVALIG, the validation will comprise two parts: the core validation and the Announcement of opportunity (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 German SCIAMACHY validation activities are part of the core validation and will be complemented by the so-called AO validation based on selected proposals submitted to ESA following the Announcement of Opportunity for ENVISAT validation issued in December 1997. Proposals were submitted in May 1998 and a peer review followed. Based on this review ESA made recommendations concerning the AOs on the 30th October 1998. German scientist were asked by the DLR to submit proposals to this ESA ENVISAT AO and a large number of proposals were successful.

Figure 4.1 provides a graphical representation of the structure of the German contribution to the SCIAMACHY validation. This structure has been optimised to facilitate the output of the study and reflects the variety of measurements, instruments and platforms required for a sufficient validation. Four working groups were established reflecting the different expertise needed for validation and available within the German research community: a) Validation by Ground based/ship borne Measurements: Speaker Klaus Bramsted, Univ. Bremen; b) Validation by Measurements from Aircraft Platforms: Speaker: Gerhard Ehret, DLR; c) Validation by Balloon Borne Measurements: Speaker Klaus Pfeilsticker, Univ. Heidelberg; d) Validation by independent Satellites Measurements: Speaker: M. Weber, Univ. Bremen.

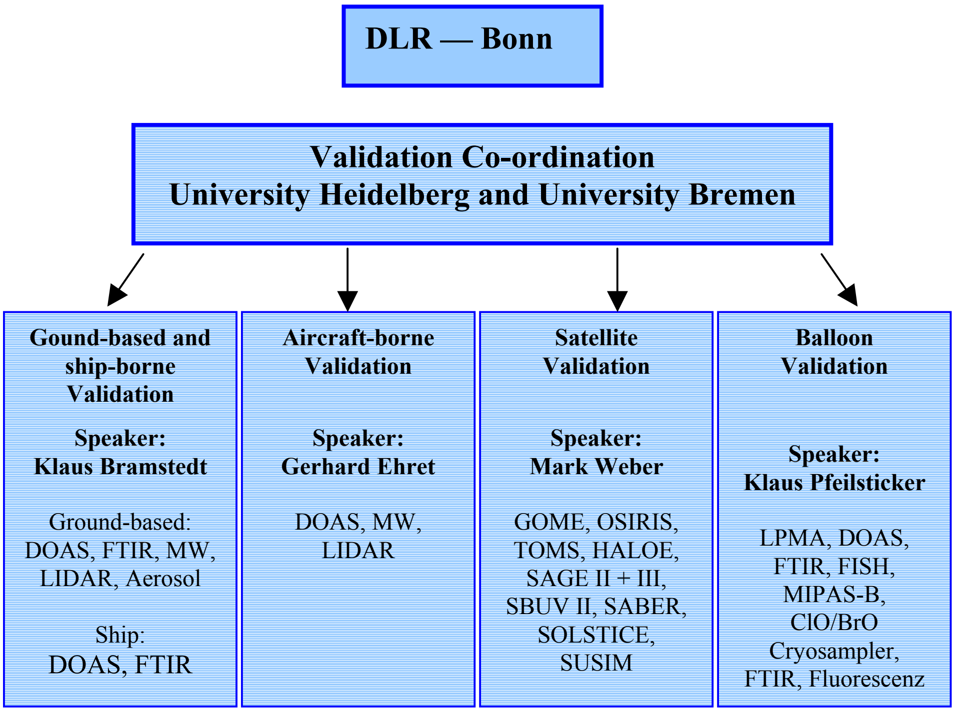

Figure 4.1: Structure of the German SCIAMACHY Validation

This structure will be used during the validation programme. Working groups will organise themselves by informal meeting. Regular and formal meetings will be held where the results of the measurements are presented and discussed. The objective of the final meeting is to present an assessment of the SCIAMACHY data products, which have been validated.

Clearly the Validation of SCIAMACHY data products relies on them being delivered. The responsibility for the operational data products lies with the responsible agency (i.e. ESA for NRT level 1 and 2 data and DLR for off-line data products). A database will be established within the German SCIAMACHY validation activities. For the scientific data products, produced by individual groups any validation of these products requires that an adequate amount of data for these products is provided to the data base. It is intended that the German SCIAMACHY validation activities data base be submitted to the ENVISAT data base which is being planned by ESA for the wider validation community.

4.1 Balloon borne Validation

Six different projects (for details see below) address coordinated balloon-borne observations at high, middle and equatorial latitudes that aim at the validation of SCIAMACHY level 1 and 2 products. Within that framework three different balloon gondolas (MIPAS, TRIPLE, LPMA/DOAS) measures solar irradiances, limb radiances and atmospheric parameters such as temperatures and pressures and profile of a suite of trace gases. While the validation of the atmospheric parameters by balloon-borne observation is a state of the art and proven concept, the validation of solar irradiances and limb radiances are new and were never attempted before.

For the validation of SCIAMACHY, the LPMA/DOAS (combing a Limb Profile Monitoring of the Atmosphere FT-IR and a Differential Optical Absorption Spectrometry instrument), TRIPLE (combing a resonance fluorescence ClO/BrO instrument, an in-situ Fluorescence Induced Stratospheric Hygrometer FISH, a total air sampler, a diode laser H_2O and CH_4 sensor) and the MIPAS-B (Michelson Interferometer for Passive Atmospheric Sounding – balloon version) balloon gondolas will be used. These balloon payloads are considered to be the backbone of the German effort of the validation of SCIAMACHY.

Together these three balloon payloads measure atmospheric profiles of O_3, O_4, NO, NO_2, NO_3, HNO_3, $ClNO_3$, N_2O_5, HNO_4, HCl, OClO, BrO, ClO, IO, HF, F_2CO, CH_4, N_2O, CFC's, C_2H_6, SF_6, H_2O, CO, CO_2, T and P which will allow to validate corresponding parameters (denoted by asterisks) monitored by ENVISAT's instruments during collocated overpasses of the satellite. According to experiences made in the past all these observations will allow a reliable validation of the ENVISAT level 1 and 2 products when corroborated with appropriate pre- and postflight meteorological analysis. Finally solar irradiance and limb radiance measured by SCIAMACHY will be also be validated by corresponding measurements from aboard the LPMA/DOAS gondola.

Table 4.1.1: Overview of scheduled balloon validation campaigns with the ESA/CNES/DLR agreement:

Location	Lat.	Long.	Period	Payload	Balloon Type
Aire sur l'Adour	43° N	0° E	Sept – Oct. 02	MIPAS-B2	100-400z
Aire sur l'Adour	43° N	0° E	Sept – Oct. 02	Triple	150z
Aire sur l'Adour (*)	43° N	0° E	Sept – Oct. 02	LPMA/DOAS	150z
Kiruna	68° N	22° E	Feb. – Mar. 03	MIPAS-B	150z
Kiruna	68° N	22° E	Feb. – Mar. 03	LPMA/DOAS	150z
Kiruna	68° N	22° E	Feb. – Mar. 03	Triple	150z
Kiruna (*)	68° N	22° E	April 2003	LPMA/DOAS	150z

(*) It is not yet decided (April 8, 2002) on the launch of either of the LPMA/DOAS balloon flights

All three balloon payload (LPMA/DOAS, TRIPLE and MIPAS-B) are chosen for SCIAMACHY validation not only because they provide complementary and redundant measurements, but they also apply independent methods that allows for internal consistency checks. All payloads have previously demonstrated to provide reliable and very accurate data. Though the proposed measurements are dedicated to SCIAMACHY several of the measured trace gases can be used to validate MIPAS and GOMOS instruments to be flown onboard ENVISAT as well.

4.1.1 Balloon validation of CO and CH_4 SCIAMACHY products and related studies

C. Camy-Peyret, K. Pfeilsticker, W. Gurlit
Related ESA-AO: #146

Executive Summary

We propose to perform a balloon flight of the LIMP Monitor of the Atmosphere (LPMA) instrument to record high resolution Fourier transform infrared (FTIR) atmospheric spectra from which vertical mixing ratio profiles (vmr) of CO and CH_4 will be retrieved and compared to the SCIAMACHY profiles. The LPMA instrument will be operate in its shortwave-infrared (SWIR) optical configuration.

Solar spectra in the 2 IR channels of SCIAMACHY (bands 7 and 8) exactly covered by LPMA will provide precise reference spectra documenting the photospheric solar features which appear in the vicinity of the telluric CO lines. The infrared LPMA measurements will complement the UV-visible measurements performed by the Differential Absorption Spectroscopy (DOAS) instrument of the University of Heidelberg accommodated on the same gondola and sharing the same sun-tracker, in the LPMA/DOAS configuration for an extensive balloon validation of SCIAMACHY products and for scientific studies.

Introduction

The present section describes key features of the validation activities related to ENVISAT SCIAMACHY's instrument by the LPMA operated on the LPMA/DOAS balloon payload.

Primarily the section summarizes the activities related to ENVISAT commissioning phase validation, which will take place in the period July 2002 through summer 2003. It is anticipated, however, that the LPMA/DOAS payload will also participated in a longer term validation that is about to be scheduled for the 2003 to 2005 time frame. More information on the LPMA measurements conducted from aboard the LPMA/DOAS payload can be obtained in corresponding in peer-reviewed articles published in international scientific journals (see the list references below). For example, a detailed description of the LPMA payload is provided in the publications of Camy-Peyret et al. [1993], Payan et al. [1998], and [1999] and references therein.

Accordingly, only some basic features and necessary information related to the LPMA balloon-borne observations are here provided which are necessary to understand our validation approach of SCIAMACHY.

Validation instrument

The Laboratoire de Physique Moléculaire et Applications (CNRS and Univ. P. & M. Curie, Paris) is operating, with support from CNES, a stratospheric gondola, which can accommodate a Fourier transform infrared (FTIR) instrument operating in the solar absorption mode. This interferometer, the Limb Profile Monitor of the Atmosphere or LPMA, operating at a spectral resolution of 0.02 cm^{-1} (maximum optical path difference of 50 cm), covers 4 bands of the atmospheric spectrum from 14 µm to 2.4 µm using the sun as a source of infrared radiation fed into the FTIR through a sun-tracker.

The Limb Profile Monitor of the Atmosphere (LPMA) has been developed over the recent years as a powerful balloon-borne remote sensing instrument for profile measurements of stratospheric species and for atmospheric radiative transfer studies in the mid-infrared as well as in the near-infrared.

The LPMA instrument (accommodated on a stratospheric gondola with azimuth control) is recording atmospheric absorption spectra (using the sun as a source) at an apodized spectral resolution of 0.020 cm^{-1} and at high signal to noise ratio. With a two detector output optics it can record simultaneously two interferograms providing information in different spectral regions. A mid-infrared configuration is used for vertical profile measurements of chlorine reservoirs ($ClONO_2$ with HgCdTe, HCl with InSb), nitrogen species (HNO_3, NO_2, NO), ozone and tracers (CH_4, N_2O, HF). A near-infrared configuration (Si photodiodes) has been used for testing radiative transfer algorithms and associated spectroscopic databases in the molecular oxygen. A-band region used by space instruments for the determination of temperature and pressure profiles. With support from CNES, the instrument is being upgraded as a spectro-radiometer (LPMA/IASI balloon) so that it can be operated from balloon in the nadir viewing geometry for recording calibrated radiance spectra of the Earth/atmosphere system in thermal emission at 0.1 cm^{-1} resolution.

Products to be validated (including a table with accuracy/precission of the own measurements)

The following table provides a compendium over the measured species, the expected accuracy and precision of the DOAS measurements on the LPMA/DOAS payload, and the covered height range.

Table 4.1.1.1: Validated SCIAMACHY key products by LPMA/DOAS

SCIAMACHY Products	Instrument	Precision/ Accuracy	Validation Height Range	SCIAMACHY Height Range
T		± 0.5 K	0 to 30/40 km	0 to 50 km
P		± 1 %	0 to 30/40 km	0 to50 km
O_3	DOAS	± 0.5 % 10^{10} molecule/cm^3	5 to 30/40 km	0 to 60 km
O_3	LPMA	± 4%	5 to 30/40 km	0 to 60 km
O_4	DOAS	± 4 %	5 to 30 km	0 to 25 km
NO_2	DOAS	± 2.0 % 10^9 mole/cm^3	5 to 30/40 km	0 to 40 km
NO_2	LPMA	± 11.0 %	15 to 30/40 km	0 to 40 km
NO_3	DOAS	± 10.0 %	5 to 30/40 km	20 to 40 km
BrO	DOAS	± 4.0 %	5 to 30/40 km	15 to 35 km
		± 12.0 %		
OClO	DOAS	± 3.0 %	5 to 30/40 km	15 to 35 km
		± 8.0 %		
CH_4	LPMA	± 7 %	10 to 30/40 km	0 to 40 km
CO	LPMA	± 7 %	5 to 30/40 km	0 to 35 km
N_2O	LPMA	± 10 %	5 to 30/40 km	0 to 40 km
CO_2	LPMA	± 5 %	10 to 30/40 km	0 to 60 km
$ClONO_2$	LPMA	± 15 %	10 to 30/40 km	—.

Validation method

Validation of SCIAMACHY's CO and CH_4 measurements will be provided by collocated NADIR and alternatively solar occultation measurements of the LPMA/DOAS payload. Accordingly to the present plannings the measurement will cover a range of latitudes and seasons. SCIAMACHY's measurements from as many as possible atmospheric parameters will be validated by direct comparison with the balloon measurements profiles. In order to meet as many different geophysical regimes as possible balloon flights will be performed at high, mid- and low latitudes temporally and spatially as close as possible with ENVISAT overpasses. Intensive calculations of the atmospheric transport will also be undertaken which may help to minimize effects due to mismatches in the probed air masses.

The balloon-borne LPMA-based validation of SCIAMACHY's trace gas measurements will be performed essentially applying two different methods:

- Profiles of photochemically stable atmospheric constituents (CO and CH_4) measured by SCIAMACHY will be directly validated against the LPMA readings after suitable corrections that account for profile changes caused by atmospheric dynamics. In the past this method has shown to be most suitable [Sugita et al., 2001; Lumpe et al., 2002; Randell et al., 2002]. In order to minimized atmospheric dynamic effects in our comparison studies, it will be attempted not to probe air masses with line of sights across known and predicable regimes of different atmospheric transport (i.e. across the vortex edge).
- Finally, the measured trace gas column amounts (from SCIAMACHY NADIR observations) or those inferred from measured profiles will also be compared. This will allow us a more independent check on the internal consistency of each instrument's readings since small deviations in the individual inferred profiles shape caused by different numerical inversion routines will cancel out.

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4.1.2 Validation of trace gas measurements of the ENVISAT instruments MIPAS, GOMOS, SCIAMACHY by using in-situ and remote sensing balloon borne techniques

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Related ESA-AO: #240

Sub-Project H. Oelhaf and H. Fischer

We propose to validate the ENVISAT SCIAMACHY level 2 data products H_2O, O_3, N_2O, CH_4, and NO_2 by means of vertical atmospheric profile measurements conducted with the proven balloon borne instrument technique MIPAS-B (Michelson Interferometer for Passive Atmospheric Sounding - Balloon version). MIPAS-B2 utilises the limb emission sounding technique being independent of the SCIAMACHY UV/Vis. spectroscopy technique and delivers accurate and vertically resolved measurements of several important atmospheric trace species from the middle/upper troposphere up to the balloon float level (32 to 40 km). While the employed technique relies as SCIAMACHY on remote sensing and provides therefore some path-integrated measure of trace constituents it utilises the infrared spectral domain and thus provides a totally independent validation of the respective SCIAMACHY data. Furthermore, as an emission sounder MIPAS-B can be operated day and night being not dependent on extraterrestrial light sources but providing a high degree of freedom in terms of measurement scenario (i.e. observation angles, integration times). CTM and trajectory modelling will be used to account for potential temporal/spatial mismatches between the SCIAMACHY and the MIPAS-B2 observations.

This proposal is embedded in the Working Group Proposal "Validation of SCIAMACHY Data Products by Balloon Measurements (VBB)" (Speaker: PD Dr. K Pfeilsticker, University of Heidelberg), henceforth called "Balloon Envelope Proposal".

Introduction

The absolute necessity of validation of satellite instrument products is obvious from experience with prior space instruments (e.g. Gille, 1996, Sasano et al., 1999). Increasing complexity of space instruments and enhanced diversity of products to be delivered by these instruments like SCIAMACHY even demands for increased efforts in validation. This challenge has been fully addressed in the 'SCIAMACHY Validation Document' and needs not to be repeated here. Apart from satellite measurements, balloon borne observations are the only tool to obtain a large number of molecules with sufficiently high vertical resolution over most of the stratospheric altitude region. They provide high precision and accuracy due to their quasi-Lagrangian measurement situation (providing e.g. long integration times) and since systematic errors can be kept small as the calibration/characterisation of the instruments is performed close to the time of the measurement. Therefore, balloon observations have to be regarded as a key component in any satellite validation exercise in spite of the limited number of profiles that can be obtained.

The present proposal is part of the efforts envisaged to validate some important scientific products of SCIAMACHY with balloon observations. It is embedded in the Working Group on 'Validation of SCIAMACHY data products by balloon measurements'. The general outline of the work to be conducted is described in the corresponding Envelope Proposal. Therefore, only information that is specific for this individual proposal is described in the following

Validation instrument

MIPAS-B is an advanced cryogenic Fourier Transform Infra Red (FTIR) spectrometer specially tailored to the operation on a stratospheric balloon gondola (Fischer and Oelhaf, 1996, Oelhaf et al., 1996, Friedl-Vallon et al., 1999). Equipped with suitable subsystems, MIPAS-B allows precise limb emission sounding of chemical constituents related to the stratospheric ozone problem and to the greenhouse effect. This method is appropriate to obtain vertical profiles of ozone and a considerable number of key radicals (NO, NO_2), reservoir species (HNO_3, N_2O_5, $ClONO_2$, and HO_2NO_2) as well as source gases (CH_4, N_2O, H_2O, CFC-11, CFC-12, CFC-22, CCl_4, CF_4, C_2H_6, and SF_6) simultaneously, with an altitude resolution of 2 to 3 km. Hence, MIPAS-B is able to measure the budget and partitioning of the complete NO_y family (i.e. NO + NO_2 + HNO_3 + $ClONO_2$ + 2*N_2O_5 + HO_2NO_2) together with its source gas N_2O and to assess denitrification, dehydration, budgets and tracer correlations (e.g. Oelhaf et al., 1996, Stowasser et al., 1999, Wetzel et al., 1997, Waibel et al., 1999). As an emission sounder MIPAS-B is independent of any extraterrestrial light source providing a high flexibility in terms of launching time of the day and observation geometry. Both azimuth and elevation angles can be commanded from ground. This flexibility allows long integration times and offers to adjust the Line of Sight direction according to geophysical constraints in an optimal way (e.g. in the case of strong gradients in the constituents' fields or during sunrise/sunset). An innovative pointing system ensures high precision and stability of acquired observation angles (Seefeldner et al., 1995, Maucher 1995). The capability of MIPAS-B to measure also at night is particularly useful for the validation of the SCIAMACHY moon occultation mode.

Products to be validated (including a table with accuracy/precission of the own measurements)

Table 4.1.2.1:Target Parameters (errors in % volume mixing ratio)

Parameter	Altitude Range (km)	Noise	Precision	Accuracy
Temperature	10 - CL	< 0.1 K	0.7 K	0.9 K
O3	10 - CL	< 1 %	5 %	10 %
N2O	15 - CL	2 %	5 %	8 %
	5 - 15	1 %	9 %	12 %
H2O	15 - CL	2 %	5 %	8 %
	5 - 15	1 %	7 %	12 %
CH4	15 - CL	2 %	5 %	8 %
	5 - 15	1 %	7 %	12 %
NO2	25 - CL	2 %	7 %	10 %
	20 - 25	3 %	10-25 %	15-30 %
	15 - 20	>10%	>50%	>50%
Aerosol/PSC extinction	case dependent	case dependent	case dependent	case dependent

Vertical resolution: 1.5 - 3 km; CL = Ceiling Level; precision: includes uncertainty due to noise, temperature errors, LOS errors, and onion peeling error propagation; accuracy: includes precision and systematic errors (including uncertainty of spectroscopic data)

Geophysical location / time period / frequency of measurements

The general outline is given in the Envelope Proposal of the Working Group on 'Validation of SCIAMACHY data products by balloon borne measurements (VBB)'. Within that consortium one MIPAS-B flight is foreseen as funded within this project. This plan is subject to the launch date of ENVISAT and needs to be coordinated with the other ENVISAT-related validation activities.

Validation method

MIPAS-B utilises the limb emission sounding technique being independent of the SCIAMACHY UV/Vis. spectroscopy technique and delivers accurate and vertically resolved measurements of several important atmospheric trace species from the middle/upper troposphere up to the balloon float level (32 to 40 km). MIPAS-B is a well established instrument and has proven to provide reliable data since several years (see e.g. Oelhaf et al., 1994, Fischer and Oelhaf, 1996, von Clarmann et al. 1995, Wetzel et al., 1997, Stowasser et al., 1999, Waibel et al., 1999). While the employed technique relies as SCIAMACHY on remote sensing and provides therefore some path-integrated measure of trace constituents it utilises the infrared spectral domain and thus provides a totally independent validation of the respective SCIAMACHY data. Furthermore, as an emission sounder MIPAS-B can be operated day and night being not dependent on extraterrestrial light sources but providing a high degree of freedom in terms of measurement scenario (i.e. observation angles, integration times). CTM and trajectory modelling will be used to account for potential temporal/spatial mismatches between the SCIAMACHY and the MIPAS-B2 observations, a method that has been successfully applied during the validation of ADEO/ILAS data (Oelhaf et al., 1998, Irie et al, 2002, Kanzawa et al., 2002, Koike et al, 2000).

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Sub-project C. Schiller and F. Stroh

Balloon-borne measurements of vertical profiles of H_2O, O_3, BrO, ClO, and the actinic flux will be made to validate the ENVISAT SCIAMACHY level 2 data products H_2O, O_3, BrO, and OClO. Proven, well characterised and highly accurate in-situ instruments, i.e. a Lyman-alpha hygrometer, a ClO/BrO resonance fluorescence monitor, an ozone photometer and filter radiometers, will be used on a joint payload with the cryogenic whole air sampler of University Frankfurt (Triple payload). Due to the employed techniques that rely on very different parameters from the DOAS technique the measurements proposed here provide a totally independent validation of the respective SCIAMACHY data products. Further, concentrations of chemically coupled species (hydrogen family, halogen radicals and source gases) will be determined simultaneously allowing for internal consistency checks.

Introduction

H_2O is one of the most prominent hydrogen species throughout the stratosphere that impacts the radiation budget, particle formation, and chemistry (source of OH) in the stratosphere. Further, it is an indicator of dynamics in the upper troposphere and lower stratosphere. It's atmospheric distribution has been determined in many experimental studies involving in-situ and remote sensing techniques [Kley et al., 2000, and references therein]. However, several uncertainties in its distribution and processes involving H_2O have been identified and need to be resolved, amongst others the distribution around the tropopause, the accurate determination of absolute H_2O abundances in the stratosphere, and the quantification of possible long term trends. The aforementioned questions can be addressed by future satellite experiments such as SCIAMACHY and MIPAS onboard ENVISAT. However, thorough validation and development of analysis tools down to the upper troposphere are requirements for high quality satellite data with sufficient accuracy and precision.

ClO and BrO are the direct products of stratospheric halogen catalyzed ozone destruction and their abundances are the most direct measure of the ozone depletion potential within a stratospheric air mass. Stratospheric ozone loss becomes apparent in two different phenomena: The gradual decline of ozone mixing ratios the mid-latitude lower stratosphere in late winter/spring especially over northern Europe and the drastic decrease observed in late winter and early spring in the Antarctic polar vortex. While the observed ozone loss within the Antarctic polar vortex can be well reproduced by current models including the most important known gas-phase and heterogeneous atmospheric chemical reactions the situation in the Arctic polar vortex is not quantitatively understood and generally underpredicted by models [e.g. Woyke et al., 1999, Becker at al., 1998].

SCIAMACHY measures OClO, which is a product of the reaction of ClO and BrO. OClO is often employed as a measure of the chlorine activation [e.g. Wahner and Schiller, 1992] in an air mass if no direct measurement of ClO is available. Through the direct measurement of BrO and ClO onboard Triple OClO can under certain conditions be derived employing a photochemical box model. This gives an indirect validation for the SCIAMACHY data product and in combination with other direct validation measurements of OClO a check of our understanding of the OClO formation can be enabled.

Validation instrument

The Triple payload will consist of the three core in-situ instruments:

1. The Lyman-alpha hygrometer (FISH) for the measurement of water vapor [Zöger et al., 1999].
2. The ClO/BrO instrument based on the chemical conversion/resonance fluorescence technique [Woyke et al., 1999].
3. A cryogenic whole air sampler (BONBON, University Frankfurt) to measure stable trace gases as N_2O, CH_4, CFCs, SF_6, and more.

Ad four smaller instruments

4. An ozone photometer
5. Filter radiometers to measure the actinic flux
6. A tunable diode laser spectrometer to measure H_2O and CH_4 (University Heidelberg)
7. An optical aerosol counter to measure aerosol size distribution will be mounted on the gondola (LMD Paris or Univ. Wyoming)

Products to be validated (including a table with accuracy/precission of the own measurements)

Table 4.1.2.2: Level 2 data products (vertical profiles):

product	accuracy	precision	atmospheric variability	expected reduction by correll	expected reduction by traj map	estimated total uncertainty
O_3	0.5%	0.5%	0.8 ppmv *	0.8 ppmv	0.2 ppmv	8%
H_2O	4%	0.15 ppmv	0.6 ppmv *	0.2 ppmv	0.1 ppmv	6%
BrO	35%	15%	> 30%	-	10% **	40%
ClO/OClO	20%	5%	> 100%	-	20% **	30%

Geophysical location / time period / frequency of measurements

Within different projects related to ENVISAT validation, Forschungszentrum Jülich will carry out four balloon flights in total that can be used for SCIAMACY validation:

Geophysical Location	Time period	comment
mid latitudes	late spring or summer 2002	dedicated SCIAMACHY validation
high latitudes	summer 2002	ENVISAT validation, funded by HGF
high latitudes	early 2003 (winter conditions)	to be funded by ESA
tropics	2003	dedicated SCIAMACHY validation

Validation method

Due to the employed techniques that rely on very different parameters from the DOAS technique the measurements proposed here provide a totally independent validation of the respective SCIAMACHY data products. In order to compensate for potential mis-matching with SCIAMACHY overpasses, the following strategies will be applied:

Flights will be carried out in regions where atmospheric variability is low. Optimal flight time and location will be decided on the basis of a trajectory mapping forecast, provided by the University of Berlin. Post-flight analysis will use trajectory mapping and RDF/CAS.

The target species of TRIPLE will also be measured from the M55 Geophysika aircraft (H_2O, ClO and BrO by FZ Jülich, long-lived tracers by University Frankfurt, and O_3 by other groups) for at least one of the ENVISAT correlative balloon measurement as part of a HGF-Vernetzungsfond project. These data will provide experimental support for the application of the aforementioned modelling tools. Other aircraft measurements at tropopause altitudes (e.g. Falcon, German Lear Jet) will be carried out in the same period.

If, for example, N_2O is used as an (altitude) parameter to which other trace gas measurements are correlated, much of atmospheric variability can be removed from mis-matching data sets. Since TRIPLE measures a large number of long-lived tracers and complete trace gas families (e.g. H_2O, CH_4, H_2) independent consistency checks are possible. Trace gas correlation are determined also from previous flights of this payload and have been applied e.g. for validation of ILAS.

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Sub-project A. Engel, U. Schmidt

Two dedicated flights of our cryogenic whole air samplers are planned for the validation of SCIAMACHY. These flights will – depending on the launch of ENVISAT – be carried out at mid latitudes in the first half of 2002 and in the tropics in 2003. Vertical profiles of many long lived trace gases, including the SCIAMACHY target species CH_4, N_2O and CO_2 will be provided with a vertical resolution of about 1 to 1.5 km.

Introduction

We will perform high precision balloon borne measurements of the Sciamachy target species CO_2, CH_4 and N_2O. We will also measure many CFCs (CFC-11, CFC-12, CFC-113 and HCFC-22), chlorine source gases (CH_3Cl, CH_3CCl_3 and CCl_4), SF_6 and H_2 , which will be used for consistency checks and to derive the total available chlorine, Cl_y, which is important in the interpretation of other measurements, like e.g. OClO. For the validation of ENVISAT SCIAMACHY level 2 data products (CH_4, CO_2 and N_2O) the method to be used is cryogenic whole air sampling with subsequent gaschromatographic analysis. The instrument is part of the multi-instrument balloon payload Triple (co-operation with Forschungszentrum Jülich). Very accurate measurements, using an independent method from the DOAS technique used for SCIAMACHY data, will provide reliable data for the validation of vertical profiles. A total of 15 samples collected during a flight yields a vertical resolution of about 1 to 1.5 km in the altitude region between 10 and 30 to 35 km which is covered routinely during balloon flights.

Validation instrument

Measurements of the vertical distribution of stratospheric trace gases are achieved by means of whole air samplers which collect stratospheric air, which is then analysed in the laboratory. Our cryogenic whole air samplers have been employed previously during a total of more than 35 flights. Each sampler has 15 individual containers, allowing to collect samples at an altitude resolution of about 1.5 km (assuming that a vertical profile will be measured between 10 and 30 to 35 km altitude). The altitude covered by each sample is – depending on altitude and vertical velocity of the balloon – between 100 and 1500 m. The samples are measured in the laboratory of the Institute for their content of CFCs, CH_3Cl, CH_3CCl_3, HCFC-22, CCl_4, N_2O, SF_6 and molecular hydrogen. The analysis is performed using different gas chromatographic systems, which all rely on the detection with an electron capture detector (ECD), with the exception of molecular hydrogen, where a reduction gas detector (RGD) is used. All measurements rely on internationally excepted long term standards, which allows for the detection of long term trends in the data. The analytical precision for the most important compounds is on the order of 1 % and better (see table 4.1.2.3). Methane and CO_2 are analysed by the University of Heidelberg, in the group of Ingeborg Levin. These measurements will be sub-contracted based on an agreement between the two institutes.

Products to be validated (including a table with accuracy/precission of the own measurements)

Table 4.1.2.3: Validated products

Compound	Unit	prec_abs	prec_rel	detect. limit	calibration source	accuracy of cal.
			%	ppx		%
N_2O	ppb	2.0	0.5	5	NOAA/CMDL	1.0
F11	ppt	1.5	0.5	0.1	NOAA/CMDL	1.0
F12	ppt	3.0	0.5	1	NOAA/CMDL	1.0
F113	ppt	2.0	1.0	0.5	NOAA/CMDL	1.0
CH_4 *	ppb	0.5	0.2	1.0	NOAA/CMDL	1.0
CCl_4	ppt	5.0	5.0	0.1	NOAA/CMDL	5.0
CH_3CCl_3	ppt	2.0	5.0	3	NOAA/CMDL	2.0
CH_3Cl	ppt	20.0	5.0	20	OGIST	5.0
F22	ppt	2.0	3.0	4	NOAA/CMDL	1.0
SF_6	ppt	0.05	2.0	0.1	Maiss/Levin,Univ. Hd	1.0
CO_2*	ppm	0.2	0.05		NOAA/CMDL	

* The measurements of CH_4 and CO_2 are performed by the University of Heidelberg

Abbreviations next page.

Abbreviations:

OGIST:	Oregon Institute for Science and Technology (Ray Rasmussen)
NOAA/CMDL:	Climate Monitoring and Diagnostics Laboratory, NOAA (Jim Elkins)
Maiss/Levin:	M. Maiss and I. Levin, University of Heidelberg

Geophysical location / time period / frequency of measurements

Alltogether 4 flights of the payload are planned for the validation of ENVISAT, 2 of these flights are dedicated to the validation of the SCIAMACHY instrument. the following table lists the planned validation measurements.

Geophysical Location	Time period	comment
mid latitudes	late spring or summer 2002	dedicated SCIAMACHY validation
high latitudes	summer 2002	ENVISAT validation, funded by HGF
high latitudes	early 2003 (winter conditions)	to be funded by ESA
tropics	2003	dedicated SCIAMACHY validation

Validation method

Due to the employed technique that relies on very different parameters from the DOAS technique the measurements proposed here provide a totally independent validation of the respective SCIAMACHY data products. In order to compensate for potential mis-matching with SCIAMACHY overpasses flights will be carried out in regions where atmospheric variability is low. Optimal flight time and location will be decided on the basis of a trajectory mapping forecast, provided by the University of Berlin. Post-flight analysis will use trajectory mapping and RDF/CAS.

If, for example, N_2O is used as an (altitude) parameter to which other trace gas measurements are correlated, much of atmospheric variability can be removed from mis-matching data sets. Since TRIPLE measures a large number of long-lived tracers and complete trace gas families (e.g. H_2O, CH_4, H_2) independent consistency checks are possible. Trace gas correlation are determined also from previous flights of this payload and have been applied e.g. for validation of ILAS.

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4.1.3 SCIAMACHY validation using radiometric calibration of the DOAS / FTIR instrument

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Related ESA-AO: #349

Solar occultation measurements of balloon-borne LPMA and DOAS spectrometers are used for SCIAMACHY validation. The SCIAMACHY level-1 product solar irradiance is validated by extrapolation of measured spectra at different solar zenith angles. To achieve this, a radiometric calibration is performed before and after each balloon flight. To correct for atmospheric effects, the Langley-plot method will be used to calculate the TOA (top of atmosphere) incoming solar irradiation. It is a standard procedure that has been applied for a number of satellite sensors like SeaWiFS [1], SBUV [2] (Nimbus 7) and many ground – based sensors [3-5]. As the campaign work will start in 2002, this paper concentrates on general theoretical and technical aspects of the solar irradiance validation.

SCIAMACHY on ENVISAT

The sensor to be validated by the procedures described here is SCIAMACHY on ENVISAT-1, a spaceborne atmospheric chemistry instrument. SCIAMACHY is a passive optical remote sensing instrument that measures the absorption, reflection and scattering characteristics of the atmosphere between 240 and 2380 nm wavelength. Measurements are made using scattered sunlight in nadir and limb geometry, transmitted solar and lunar radiation in occultation geometry, and solar and lunar irradiance. For each orbit solar occultation measurements, including measurements of the solar irradiance, will be performed during sunrise. All measurements will be converted to provide information about the amounts and distributions of selected atmospheric constituents (O_3, BrO, OCLO, SO_2, NO, NO_2, H_2O, CO, CO_2, CH_4, N_2O among others), as well as information about aerosol, pressure, temperature, radiation field, cloud cover, cloud top height and surface reflectance. Global coverage will be obtained each time after 3 days equaling 42 orbits.

Product: solar irradiance

The solar irradiance is a level 1 product of SCIAMACHY. It is an input quantity for retrieval algorithms like FURM (FULL Retrieval Method) which was already used for the retrieval of GOME O_3 profiles. Solar irradiance data also play a major role in the development of the data retrieval in limb-geometry and as an input parameter for chemical models (i.e. Ring). Solar irradiance measurements are useful for long-term instrument performance monitoring and their validation will help to maintain the calibration of SCIAMACHY during its lifetime. Instrument aging is known to be a large source of uncertainty. Experience with the GOME sensor [6] shows that the calibration may vary significantly after launch as a result of degradation in orbit. Further interest arises from the field of solar physics. The influence of the solar UV-light on the upper atmosphere and on earth´s climate has already been subject of dedicated satellite measurements. Spectrally resolved UV-irradiance with emphasis on the 27-day solar rotation and the 11-year solar cycle has been monitored by the satellite instruments SOLSTICE [7] (calibrated against stellar targets) and SUSIM [8]. Calibration concepts of these instruments had to take into account the strong degradation in orbit. In the case of SUSIM an independent backup instrument carried by Space-Shuttle was included, which could be repeatedly calibrated pre- and postflight. The solar irradiance validation of SCIAMACHY described here also relies on repeated calibrations of the balloon-borne spectrometers used.

General concept

The LPMA (Limb Profile Monitor of the Atmosphere, an IR Fourier-transform spectrometer) and DOAS [9] (Differential Optical Absorption Spectrometer, a UV / visible grating spectrometer) are used together as a combined balloon payload. During regular flights of the payload scheduled for the validation of SCIAMACHY level-2 products within the framwork of the ESABC (Envistat

Stratospheric Aircraft & Balloon Campaign), additional solar irradiance measurements will be made. Both the LPMA and the DOAS instrument use solar occultation for the determination of trace-gas profiles. The combined wavelength range of the instruments (320 – 2400 nm) covers most of the SCIAMACHY spectral range at a comparable resolution, and thus offers the unique opportunity for a validation of the level-1 product solar irradiance. SCIAMACHY channels 2 and 3 are covered by DOAS, while channels 5, 7, 8 and possibly 4 and 6 are accessible by the LPMA depending on its configuration.

Prerequisite for the validation is a radiometric calibration of the LPMA and DOAS instruments. The possibility to recalibrate the two instruments in the field prior and after each flight of the balloon is an advantage over satellite measurements that can increase overall accuracy. Radiation from a QTH (quarz tungsten halogen) calibration source will then be coupled into the optical inlet port of the LPMA / DOAS payload. The irradiance of the QTH lamp depends upon the distance between lamp and target, the orientation of the lamp, and the directional nature of the lamp´s output. A custom-designed field calibration unit containing the QTH source and an optomechanical arrangement to assure defined optical coupling will be used. As this will have to be done in the field prior to each balloon launch, evacuation of the calibration unit will be difficult to achive. Thus, atmospheric absorptions (mainly water vapor) on the path between QTH source and balloon instruments have to be considered as an error source. These lines will be visible in the recorded spectra and correction should be possible by a procedure described below. From the known spectral input to the instruments I_{cal}, and the instruments response I_2, the spectral response function I_{ins} of the balloon spectrometer can then be calculated as the ratio $I_{ins} = I_2/I_{cal}$. The desired solar spectrum I_{sun} for the given solar zenith angle (SZA) can be calculated by dividing the solar spectrum seen by the instrument I_{meas} by the instrument´s response function I_{ins} as $I_{sun} = I_{meas}/I_{ins}$. From these spectra, recorded as a function of SZA, the extraterrestrial solar irradiance is extrapolated.

Ballon lauches will be scheduled as to enable occultation measurements during sunrise or sunset from the float position at an altitude of 30-35 Km. Measurements can then be made at different solar zenith angles ranging from 83 to 95 degrees in a relatively short time interval. Airmass factor is a function of the SZA. As a result of the stratospheric observational position the airmass-factor is relatively small and the effects of the planetary boundary layer reported in [3] will be eliminated. Extrapolation of the spectra measured at different SZA to zero-airmass then yields the desired extraterrestrial solar irradiance using the Langley-plot method. It is important, that while the solar disk is monitored under different zenith angles, the atmosphere can be considered constant. The SZA should be the only variable parameter during the measurement. From the solar irradiance data acquired in stratospheric float and the instruments transmission function acquired using the calibration source, the solar spectrum can be calculated and plotted as a function of the airmass-factor. The zero-intercept (zero airmass) is the solar irradiation above the atmosphere.

The SCIAMACHY solar irradiance validation will be performed as an additional measurement using the two-instrument balloon-payload already included in the validation programme. There is no need for instrument modification or additional balloon launches.

Calibration Sources and Procedures

The balloon-instruments LPMA and DOAS used as transfer devices have to be radiometrically calibrated. This can be done using a light source of adequate and precisely known radiation. QTH sources similar to the lamps used in imaging systems like slide projectors can be used for this purpose. Selected lamps of high quality and temporal stability are individually calibrated by a (small) number of institutions like the NIST (National Institute of Standards and Technology) in the USA or the PTB (Physikalisch-Technische Bundesanstalt) in Germany. Both institutions realise the spectral radiation scale using a gold point blackbody and the Planck radiation law. Details of the procedure and the transfer standards involved can be found in [10]. As a spectral irradiance standard, NIST issues a 1000-watts QTH lamp which is used by a number of commercial vendors to produce secondary standards. All these lamps emit radiation in the spectral range between 240 and 2400 nm. Thus, a single source can be used to cover the entire range of interest in the calibration described here.

From a theoretical point of view, the spectral radiation for a given lamp could be calculated with formalism derived from the Planck blackbody radiation, if a number of lamp parameters were known precisely. The complete radiance then depends on one single parameter, the filament temperature as an analogy to the blackbody temperature. From that point of view, the spectral radiance for a given electrical power input could quite easily be calculated. However, the practical error budget of the QTH lamp´s radiation contains uncertainty from parameters like composition of filament, composition of glass envelope and difficulties to measure the precise color temperature. These data are hard to acquire by measurements, and are not available from the makers of the lamps. A mathematical model for QTH sources is under development, but for the work described here, a set of NIST (or NIST-traceable) QTH sources will be used. This is the most practical and safe way to transfer a certified calibration to the instruments.

For the radiometric calibration of a spectrometer aiming at solar irradiance measurements, one desires the calibration source (QTH lamp) to be as similar as possible to the source to be analysed (sun) in three aspects. These aspects are 1) similar irradiance, 2) similar spectral distribution (color temperature), and 3) similar imaging properties (geometry of rays, e.g. focused, divergent or collimated).

Irradiance

A similar irradiance (radiometric flux per unit area) of calibration source (QTH) and unknown source (sun) is preferable in order to stay well within the dynamic range of the optical sensors of the instrument to be radiometrically calibrated. If the intensites of the two sources to be compared differ by several orders of magnitude, dynamic limitations and nonlinearities of the sensors can introduce additional uncertainty. Total solar irradiance is in the order of 0.1 watts per cm^2 for small zenith angles and clear sky conditions. This power per area can be obtained from a 1000-watts lamp at an operating distance of approximately 28 cm (inverse square law), assuming uniform light distribution.

Spectrum (Color Temperature)

A similar color temperature (spectral distribution of the total irradiance) of the two sources is desired for very similar reasons: to assure sensor linearity by using similar intensities of calibration source and unknown source in each part of the spectrum. Unfortunately, this demand can only be fulfilled in part. As an approximation, the sun can be considered as a blackbody with a color temperature of 5800 K, with the UV radiation deviating somewhat from the Planck blackbody. An artifical calibration source of similar color temperature cannot be realised. The emission of a QTH lamp is also similar to a blackbody, but color temperature is typical around 3000 K, and in comparison to the sun significantly less UV-radiation is produced. As a result of the relatively low UV-power of the QTH lamp, uncertainty of the radiometric calibration below 350 nm is expected to be slightly larger than in the visible. Blackbody radiation at several color temperatures is shown in figure links [11]. The extraterrestrial solar irradiance compared to a blackbody at 5800 K can be seen in figure rechts [11].

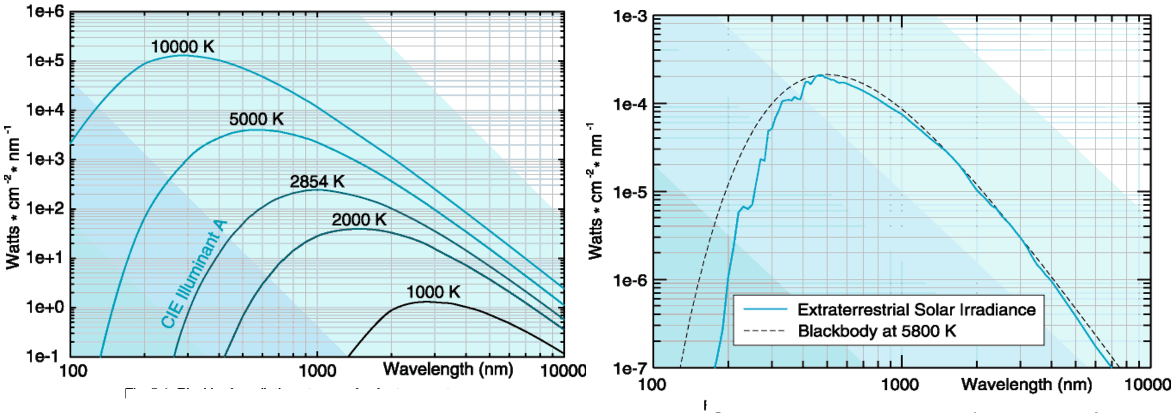

Figure 4.1.3.1 and 4.1.3.2: Blackbody Radiation [11] and Extraterrestrial Solar Irradiance [11]

Geometry

The sunlight reaching the instrument´s optical aperture can be considered a parallel, collimated beam as a result of the large distance between source and target. This is not true for a calibration source illuminating the entrance aperture of a spectrometer from a distance of typically 0.2 to 5 meters. Of the two instruments to be radiometrically calibrated in this work (LPMA and DOAS), especially the Fourier-transform meter LPMA relies on a collimated beam as a consequence of its interferometric working principle. From the imaging point of view, of course a collimating system, composed of a mirror or a lens, might be used. These components however will introduce spectral transmission (lens) or reflection (mirror) functions that will modulate the lamp´s spectral output. While one solution to the problem might be to have the lightsource (lamp and collimator) calibrated as a whole, in this work it is intended to use the bare lamp without any collimating system.

The experience gained during the radiometric calibration of SCIAMACHY in limb-mode using different geometries with the same light source is used here: In order to get an illumination independently of the distance between the source (1000 watts QTH) and the target (SCIAMACHY), a sperical mirror was used to produce a collimated beam. In practice the distance between source and target turned out to be an important parameter because filament imaging in the beam depended strongly on this distance [12]. Also, the reflectance properties of the spherical mirror may depend on the angle of incidence of the rays emitted by the lamp. This increases the risk that the spectral composition of the parallel beam may not be uniform throughout its cross-section. Finally, the beam may become partly polarised as a result of the reflection on the mirror´s surface.

If the bare lamp is used without any collimating system, a divergent beam will reach the entrance aperture of the LPMA / DOAS System. When the 60-mm aperture of the LPMA is illuminated by the bare lamp from a distance of one meter, the path difference between a ray on the optical axis reaching the center of the aperture, and a peripheral ray reaching the edge of the aperture is 450 micrometer. Instead of being planar like with a collimated beam, the divergent beam will produce a slightly sperical interferogram inside the FTIR spectrometer. Depending on instrumental parameters, this will cause some reduction of the spectral resolution. The DOAS uses an aperture of 10 mm spectro-diameter followed by light-fibres, and path difference will be around 130 micrometers for the same condition. Lab experiments to clarify the imaging aspects will be made with LPMA and DOAS in order to optimise the final design of the calibration source.

Error budget

The accuracy of the SCIAMACHY level-1 product solar irradiance is specified with 3-5 % [14], but the value is not given as a function of wavelength. For the 1990 NIST Scales of Spectral Radiance and Spectral Irradiance, Planck´s radiation law is used with a gold point blackbody as a reference standard. Calibration uncertainty of NIST lamps [10] (two standard deviation estimate) is specified with 1.8% at 240 nm, 0.9 % at 655 nm, 1.4% at 1600 nm and 4.4% at 2400 nm. The use of a secondary standard (NIST-traceable) adds another 1% of uncertainty. However, the use of more than a single lamp seems highly recommendable to improve the statistical significance. Sometimes even NIST-lamps fail to comply to their specification as found in a comparison study [4]. For the transfer of the radiometric calibration from the QTH source to the balloon instruments, as an estimation a total additional error of 2% can be expected [4] for the VIS and NIR part of the spectrum. These estimated 2% include uncertainties from optomechanical positioning (0.5 %), effects of lamp current uncertainty (0.1 %), atmospheric absorptions during calibration (0.8%) and spectrometer output uncertainty (0.5%).

As the pre- and postflight calibrations will be made in the field at ambient pressure, atmospheric absorbers (mainly water vapor) on the lightpath between calibration source and LPMA/DOAS optical inlet will increase uncertainty in some spectral regions. A calculated blackbody emission for these spectral regions can be used as a fit function to correct for the atmospheric absorbers. This approach is similar to the interpolation method recommended by NIST for wavelengths between the calibration points of the QTH-sources.

The precision limits (repeatability) of the balloon spectrometers used as transfer devices are another source of uncertainty, as some parameters of their optical detectors depend on temperature, which can only be kept constant with a limited accuracy during the balloon flight. For the LPMA, output has known to vary by several percents as a function of temperature fluctuations [private communication LPMA] depending on the configuration used. Error studies using the original balloon-instruments in the lab are currently under preparation and will be finalised well before the launch of ENVISAT.

Extrapolation of the stratospheric solar irradiance measured under various solar zenith angles to the top of atmosphere irradiance with the Langley-plot also the measurements under clean-air conditions at small airmass factors (high altitude) or small solar zenith angles (transmission uncertainty reduced). The high altitude of the balloon measurements provide small airmass, and stratospheric variability also can be considered small. In order to reach the overall target accuracy of 3%, the error produced by extrapolation of the solar irradiance measured under different SZAs should be no greater than 1%. In ground-based high-altitude applications of the method, total errors in the radiometric calibration using Langley-plot between 0.6 to 1.6% depending on spectral region [3] were reported. Measurement precision of the standard Dobson spectrophotometer is known to an uncertainty of 0.5% using Langley-plot method [13] over 25 years.

Laboratory back-up

The use of a single calibration source involves the risk of a change of the lamp´s radiation over time as a result of aging or degradation. Also, even the quite costly lamps issued by NIST have been found sometimes to contain outliers [4] and to not always comply with their specification. With a single lamp, there is a hardly any chance to detect these errors. For this reason, a set of three lamps will be purchased for intercomparison in the lab. This method of working with a "family" of calibration sources of the same type has proven to produce the best precisions (0.5%) over extended periods of time [13]. The sources can be compared to each other using a BRUKER 120 HR FTIR spectrometer available at the IUP lab as a transfer device.

Technical advances

QTH sources exhibit excellent stability in the laboratory. In order to maintain this stability in field campaigns where warm-up times and ambient temperature cannot always be kept constant, an active feedback and stabilisation scheme for the calibration unit has been developed. In addition to the constant-current drive normally used for QTH-lamps, a constant power drive using realtime power calculation for electronic feedback has been installed. Further, the lamp´s color temperature can be actively monitored using optical bandpass filters and feedback to correct the lamp´s operating parameters. This will compensate the negative effects of lamp degradation, ambient temperature fluctuations or necessary lamp changes and maintain a constant color temperature of the radiation.

Summary

The balloonborne spectrometers DOAS and LPMA already forming part of the ESABC will be additionally used to validate the SCIAMACHY level-1 pro-duct solar irradiance. To assure valid measurements, these spectrometers will be radiometrically calibrated before and after each flight using stabilised QTH calibration lamps. Solar occultation measurements can produce errors. In general it is preferable to make at the float altitude at different solar zenith angles can be extrapolated to calculate the extraterrestrial solar irradiance using the Langley-plot method. Almost the entire spectral range of SCIAMACHY will be covered.

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4.1.4 Validation of SCIAMACHY trace gas profiles by balloon-borne UV / visible/ near IR direct sun spectrometry

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Related ESA-AO:# 465

Executive Summary

We will perform LPMA/DOAS balloon flights of the Differential Optical Absorption Spectrometry (DOAS) (and Limb Profile Monitor of the Atmosphere (LPMA)) instrument to measure UV/visible (320-680nm) atmospheric absorption spectra. The measurements allow us to retrieve vertical profiles (and line of sight slant column amounts) of O_3, NO_2, BrO, OClO, IO, OIO and O_4 which are compared to the corresponding profiles measured by SCIAMACHY. The DOAS instrument will operate in similar resolution than the SCIAMACHY instrument. Line of sight column amounts of the radicals NO_2, BrO, OClO, OIO and IO will be intercompared with similar direct Sun measurements by SCIAMACHY and predictions of 3D-photochemical CTM models. For more details see also http://www.iup.uni-heidelberg.de/institut/forschung/.

The UV-visible DOAS measurements will complement the infrared CO and CH_4 measurements performed by the University Pierre et Marie Curie, Paris 6, Paris, accommodated on the same gondola and sharing the same sun-tracker, in the LPMA/DOAS configuration for an extensive balloon validation of SCIAMACHY products and for scientific studies.

Introduction

The present section describes key features of the validation activities related to ENVISAT SCIAMACHY's instrument by the DOAS instrument operated on the LPMA/DOAS balloon payload. Primarily the section summarizes the activities related to ENVISAT commissioning phase validation, which will take place in the period July 2002 through summer 2003. It is anticipated, however, that the LPMA/DOAS payload will also participated in a longer term validation that is about to be scheduled for the 2003 to 2005 time frame. More information on the DOAS measurements conducted from aboard the LPMA/DOAS payload can be obtained in corresponding in peer-reviewed articles published in international scientific journals (see the list references below).

For example, a detailed description of the DOAS instrument can be found in Ferlemann et al. [2000] and a detailed description of the LPMA payload is provided in papers by Camy-Peyret et al. [1993], Payan et al. [1998], and [1999] and references therein. The measurement of atmospheric BrO profiles by solar occultation observations using the DOAS instrument are discussed in Ferlemann et al. [1998], Harder et al. [1998] and [2000], Fitzenberger et al. [2000], and Pfeilsticker et al., 2000. Bösch et al. [2000] discusses the measurement of J(NO2) from aboard the balloon payload, and Pfeilsticker et al. [2001] the measurement of atmospheric profiles of O_4. The papers of Randell et al. [2002], Lumpe et al. [2002], and Sugita et al. [2002] discuss the validation of O_3 and NO_2 profiles measured by POAM II and III, SAGE II, and ILAS/ADEOS through corresponding balloon-borne DOAS observations. The articles of Harder et al. [1998] and Fitzenberger et al, [200] contain comparisons of total atmospheric column amounts of BrO measured by GOME instrument and simultaneously by DOAS from LPMA/DOAS. Finally, Hirsekorn et al. [2002] (Diploma thesis from the University of Heidelberg, Heidelberg, Germany) intercompares stratospheric aerosol extinction measurements by DOAS with observations by POAM II and SAGE II, and Bösch [2002] (PhD thesis from the University of Heidelberg, Heidelberg, Germany) reports on measurements of upper limits of stratospheric IO and OIO balloon-borne DOAS measurements. Scientific articles of the latter two studies are in preparation (April 2002), and copies of the drafts can be received upon request.

Accordingly, only some basic features and necessary information related to the DOAS-balloon techniques are provided here which are necessary to understand our validation approach of SCIAMACHY.

Validation instrument

The azimuth controlled French/German LPMA/DOAS gondola carries three spectrometers, that cover the wavelength range from 0.32 µm to roughly 2.4 µm, more or less the same wavelength range SCIAMACHY encompasses. The DOAS instruments are grating spectrometers (320 - 420 nm, FWHM = 0.45 nm and 416 - 670 nm, FWHM = 1.3 nm). Direct solar is collected by a sun tracker on balloon ascent/descent and solar occultation at balloon float altitude aboard the azimuth controlled LPMA/DOAS payload [Camy-Peyret et al., 1993, Payan et al., 1998, and 1999;

Ferlemann et al., 1998 and 2000; Harder et al., 1998 and 2000; Fitzenberger et al., 2000; Bösch et al., 2000; Pfeilsticker et al., 2000 and 2001; Sugita et al., 2002; Lumpe et al., 2002, Randell et al., 2000]. In recent years, the DOAS measurements were interpreted with respect to the atmospheric abundance of O_3, NO_2, BrO, OClO, IO, OIO and O_4, obtained during a suite of LPMA/DOAS balloon flights performed at high- and mid-latitude. Also the data obtained from two absolutely calibrated J(NO_2) radiometers aboard were interpreted [Bösch et al., 2000]. Both the DOAS and the J(NO_2) instruments separately allow us to determine accurately the total limb radiance in the near UV. All these studies have shown that the LPMA/DOAS balloon gondola is well suited to validate the below detailed SCIAMACHY products.

The solar irradiance and limb radiance will also be measured from aboard by absolutely calibrating all spectrometers prior and after the individual balloon flights. A calibration unit will be specifically built for this project [Oriel Handbook, 1999]. The method to infer the solar irradiance relies on the so called Langley-plot method [Bhartia et al., 1995; Solomon et al., 1987], where the measured irradiance is plotted as function of air mass and then extrapolated to zero air mass.

Validated Products

The following table provides a compendium over the measured species, the expected accuracy and precision of the DOAS measurements on the LPMA/DOAS payload, and the covered height range.

Table 4.1.4.1: Validated SCIAMACHY key products by LPMA/DOAS

SCIAMACHY Products	Instrument	Precision/ Accuracy	Validation Height Range	SCIAMACHY Height Range
T		± 0.5 K	0 to 30/40 km	0 to 50 km
P		± 1 %	0 to 30/40 km	0 to50 km
O_3	DOAS	± 0.5 % 10^{10} molecule/cm^3	5 to 30/40 km	0 to 60 km
O_3	LPMA	± 4%	5 to 30/40 km	0 to 60 km
O_4	DOAS	± 4 %	5 to 30 km	0 to 25 km
NO_2	DOAS	± 2.0 % 10^9 mole/cm^3	5 to 30/40 km	0 to 40 km
NO_2	LPMA	± 11.0 %	15 to 30/40 km	0 to 40 km
NO_3	DOAS	± 10.0 %	5 to 30/40 km	20 to 40 km
BrO	DOAS	± 4.0 %	5 to 30/40 km	15 to 35 km
		± 12.0 %		
OClO	DOAS	± 3.0 %	5 to 30/40 km	15 to 35 km
		± 8.0 %		
CH_4	LPMA	± 7 %	10 to 30/40 km	0 to 40 km
CO	LPMA	± 7 %	5 to 30/40 km	0 to 35 km
N_2O	LPMA	± 10 %	5 to 30/40 km	0 to 40 km
CO_2	LPMA	± 5 %	10 to 30/40 km	0 to 60 km
$ClONO_2$	LPMA	± 15 %	10 to 30/40 km	—.

Geophysical location, time period and frequency of measurements

Validation in ENVISAT's commissioning phase starting in July 2002 and ending by March 2003 by LPMA/DOAS flights will take from Kiruna in Feb. 2003, and again in April 2003, and from Air sur l'Adour by Sept. 2003. During long-term validation of ENVISAT, one more LPMA/DOAS flight already agreed will take place either from Kiruna or from Brazil, however, only after 2003.

Validation method

The LPMA/DOAS validation measurement will evidently cover a range of latitudes and seasons. SCIAMACHY's measurements from as many as possible atmospheric parameters will be validated by direct comparison with the balloon measurements profiles. In order to meet as many different geophysical regimes as possible balloon flights will be performed at high, mid- and low latitudes temporally and spatially as close as possible with ENVISAT overpasses. Intensive calculations of the atmospheric transport will also be undertaken which may help to minimize effects due to mismatches in the probed air masses.

The balloon-borne DOAS-based validation of SCIAMACHY's trace gas measurements will be performed essentially applying three different methods:

- Profiles of photochemically stable atmospheric constituents (O_3, H_2O, and O_4) measured by SCIAMACHY will be directly validated against the DOAS readings after suitable corrections that account for profile changes caused by atmospheric dynamics. In the past this method has shown to be most suitable [Sugita et al., 2001; Lumpe et al., 2002; Randell et al., 2002]. In order to minimized atmospheric dynamic effects in our comparison studies, it will be attempted not to probe air masses with line of sights across known and predicable regimes of different atmospheric transport (i.e. across the vortex edge).
- Since both SCIAMACHY and DOAS measure photochemically sensitive radicals (NO_2, BrO, OClO, IO and OIO) of which due to photochemistry the concentration may largely change over the course of a balloon flight, the measured slant column amounts (taken from the balloon payload to the Sun) are inter compared with modeled and satellite based predictions rather than instantaneous measured profiles. In the past this method has proven to be very reliable in validating CTM based predictions of photochemical fields (e.g., Harder et al., 2000, Fitzenberger et al., 2000).
- Finally, the directly measured vertical columns (from SCIAMACHY NADIR observations) or those inferred from measured profiles will also be compared after suitable photochemical corrections if necessary. This will allow a more independent check on the internal consistency of each instrument's readings since small deviations in the individual inferred profiles shape caused by different numerical inversion routines will cancel out.

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4.1.5 SCIAMACHY validation using water vapour and methan profiles obtained in-situ by balloon borne TDL measurements

W. Gurlit, J.P. Burrows, R. Zimmermann, V. Ebert

Related ESA-AO: no financial support until now

The instrument described here is planned to form part of the TRIPLE-balloon payload for the validation of the atmospheric chemistry instrument SCIAMACHY on ENVISAT within the framework of the ESABC (Envisat Stratospheric Aircraft and Balloon Campaign). The in-situ TDL spectrometer for the measurement of stratospheric CH_4 and H_2O profiles has low mass (<25 kg) and low power consumption (<50 W). The accuracy is 0.02 ppm (@ 20 km), 0.06 ppm (@ 30 km) for

H_2O and 0.05 ppm (@ 20 km), 0.1 ppm (@ 30 km) for CH_4. Both species H_2O and CH_4 are of utmost importance, justifying an extra effort to assure ultimate quality of the validation measurements. The compact design makes the instrument an ideal candidate for piggy-back operation on existing payloads. The TDL-spectrometer can – besides of providing its own SCIAMACHY-validation measurements – contribute to an improved statistics of the TRIPLE payload, providing high measurement frequency (3600 spectra per hour for each species) and altitude coverage. Measurement takes place in the free air using an open-path Herriott-cell, thus avoiding sampling and the associated inlet problems like deposition effects and pressure errors known from the more conventional TDL designs using a pressurised absorption cell. Fully automated measurements are possible over extended periods of time.

Long-term stability and accurate calibration are assured by a number of novel technical features. The instrument automatically detects contamination and drift of optical parts as well as ageing of the diode laser. Changes of light intensity caused by these effects are then compensated electronically in realtime. The most important sources of measurement artifacts are thus cancelled out. A self-calibration feature is incorporated using an automatic gain control in the signal processing chain, which keeps the measured intensity I_0 always at a defined absolute value. A novel strategy of signal processing combines balanced detection at baseband and harmonic modulation technique. This results in a low MDA (minimum detectable absorbance) and a high absolute accuracy at the same time. The instrument performed its first successful flight in fall of 2001 from Aire sour l´ Adour with the TRIPLE Gondola. Development and operation of the TDL spectrometer are performed within the framework of a joint project of the Universities of Bremen and Heidelberg.

4.1.6 Meteorology for validation (METVAL)

K. Labitzke, B. Naujokat, K. Grunow
Related ESA-AO: #694

This project offers meteorological support of validation campaigns with balloons, aircrafts, and from ground-based stations. The provision and interpretation of meteorological data during such measuring campaigns allow to schedule observations during the time of greatest interest and make it possible to carry out scientific interpretation of the data in the full meteorological context. Based on operational meteorological analyses and forecasts, this support will be provided on a near real-time basis to all experimenters. For- and backward (isentropic as well as quasi-isentropic) trajectories are calculated for particular requirements. The use of prognostic fields enables to plan aircraft flight tracks, to coordinate different validation instruments on different platforms, and to determine the best matches with the satellite flight tracks. The meteorological support includes one scientist at the campaign site and the distribution of meteorological documentations for the campaign periods to all experimenters.

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Experienced meteorological support of national and international campaigns, such as MAP/WINE, MAP/GLOBUS, STRAFAM, CHEOPS, EASOE, SESAME, UARS validation, ILAS validation, CRISTA validation, POLSTAR, APE/POLCAT, THESEO, SOLVE/THESEO2000

4.2 Ground based and ship borne Validation

Overall, seven German projects concentrate on the validation by ground-based and ship-borne activities (Annex A). In the framework of ACVT, the corresponding sub-group is the Ground-Based Measurements and Campaign Database (ACVT-GBMCD). Ground-based instruments are optimised for very precise measurements, other factors as limitations in weight, size or the need for remote control are usually less important. They are usually taken on a regular basis at a fixed location (see table 4.2.1). This leads to a rather small number of overpass measurements with SCIAMACHY in short time frames. Assuming daily ground-based measurements, we have one overpass measurement every six days at the equator and about every four days at 50 degree. In case of less frequent measurements, the situation is even worse and the measurements have to be carefully planned to match a SCIAMACHY overpass. The ground-based measurements during commissioning phase will be the starting point for long-term monitoring of the instrument, because there are many instruments involved, which are operating independent from SCIAMACHY validation activities. The commissioning phase plus the main validation phase will cover more than one year of ENVISAT measurements. Therefore, a large number of ground-based measurements will be available, covering all seasons and latitudes. Trace gas columns from ground-based instruments will be compared to columns and integrated profiles from ENVISAT. For ground-based profiles, the differences in altitude resolution have to be taken into account. A detailed analysis of the quality of SCIAMACHY products will be performed with this data sets. Seasonal variations can be identified already with measurements of single stations. However, small variations may need to be confirmed in the following years during long-term validation. Zonal dependencies needs merging of data from different stations.

Table 4.2.1: Location of the ground-based stations and the products to be validated

Project / ESA-AO	Station	Lat	Long	Intrument	Products
331 + 126	Bremen Ny-Ålesund Polarstern	53° N 79° N 50° S – 50°N	8° E 12° E	FTIR	**Columns:** CH_4, CO, CO_2, H_2O, N_2O, NO_2, O_3 **Profiles:** CH_4, CO, H_2O, N_2O, O_3
331	Polarstern	50° S – 50°N		DOAS	**Columns:** O_3, NO_2, BrO, IO, OClO, SO_2, H_2O, HCHO, O_4
?	Helgoland Bremen	54° N 53° N	8° E 8° E		Aerosole
331 + 126	Ny Ålesund Bremen Mérida	79° N 53° N 8° N	12° E 8° E 71° W	mm-wave radiometer	**Columns:** O_3, N_2O, H_2O, CLO **Profiles:** O_3, N_2O, H_2O, CLO
222	Esrange (near Kiruna)	68° N	21° E	LIDAR	**Profiles:** Temperature, particle size distribution, particle depolarization, aerosol and cloud backscatter
126	Kiruna Izaña (Tenerife)	68° N 28° N	22° E 17° W	FTIR	**Columns**: O_3, NO_2, N_2O, CO, CO_2, CH_4, H_2CO **Profiles:** O_3, N_2O, CH_4
331	Ny Ålesund Kiruna Bremen Merida Surinam Nairobi Neumayer Arrival Heights	79° N 68° N 53° N 8° N 6° N 1° S 70° S 78° S	12° E 22° E 8° E 71° W 55° W 36° E 8° W 167	DOAS	**Columns:** O_3, NO_2, BrO, OClO, H_2O, HCHO, SO_2, IO

4.2.1 Ground-based and Ship-borne Atmospheric FTIR Spectroscopy for the Sciamachy Validation

J.B. Burrows, J. Notholt, O. Schrems, A. Schulz
Related ESA-AO: 331, 126

Infrared absorption measurements by ground based spectrometers at three sites at different latitudes (Arctic, mid latitude and ship-based, traversing between 50°S and 50°N) are used for the validation of Sciamachy. The measurements allow the simultaneous validation of the total columns of seven trace gases detected by Sciamachy. Additionally, profiles in 2-4 atmospheric layers for five of these trace gases, will be compared.

Validation instruments, location and measurement times

Three commercial FTIR spectrometers will be used. These are passive instruments detecting the atmospheric absorption of the sun- or the moonlight. The measurements require a cloud free path between the light source and the instrument and are therefore restricted by weather conditions.

- A Bruker 120 HR spectrometer located in Ny-Ålesund, Spitsberg at 79°N and 12°E. The instrument is accepted within the NDSC, and is installed permanently at this site. Measurements at are performed all year round. During summer, when the sun is used as a light source, measurements can be performed typically once per week, in winter with the moonlight on up to six days around full moon.
- A Bruker 120 HR spectrometer located in Bremen, Germany at 53°N and 8°E. Here, measurements will be carried out on 2-3 days every second week.
- A Bruker 120 M interferometer that is mounted inside a container will be used on board the research vessel *Polarstern* during Atlantic transfer cruises. These cruises have a typical duration of 4 weeks during which a latitudinal range between 50°S and 50°N is traversed. The measurements on board the *Polarstern* are accepted within the NDSC. Under typical weather conditions measurements can be performed every second day. The first cruise is now planned for October/November 2002, the second for January/February 2003.

At all three sites, measurements will be intensified during satellite overpasses.

Products to be validated

The products to be validated include the total columns of CH_4, CO, CO_2, H_2O, N_2O, NO_2, and O_3. These data are obtained using the retrieval software GFIT (JPL, USA). Table 4.2.1.1 lists the uncertainties associated with the column data. Additionally, profiles in 2-4 layers will be provided for CH_4, CO, H_2O, N_2O, and O_3. These are derived using the optimal estimation method SFIT2 (NASA/Langley, USA, and NIWA/ Lauder, New Zealand). Both software packages are accepted within the NDSC.

Validation method

It will be aimed to adapt the timing of the measurements to satellite overpasses to achieve a high number of coincident measurements of total columns and profiles. These will be compared and treated statistically to detect any bias.

Table 4.2.1.1: Uncertainties of the FTIR column measurements. Column **A**: The precision represents the statistical 1 error for daily averages derived from signal/noise ratio. These are typical values for solar absorption measurements. Individual columns and lunar absorption measurements can have larger errors. Column **B**: Difference in total columns when shifting the initial vmr-profile 2 km upwards as a rough estimate of the sensitivity towards the initial vmr profile. Column **C**: Error intro-duced by the uncertainties of the line parameters as taken from the HITRAN database.

Trace gas	A: Precision [%]	B: 2 km shift [%]	C: Line parameters [%]
CH_2O	5	1.4	-
CH_4	0.5	1.1	1-10
CO	1-5	2.5	2-5
CO_2	1	0.12	1-5
H_2O	1	0.6	2-5 *
HDO	1	0.6	2-5 *
N_2O	0.5	2.5	2-5 *
NO	3-8	0.6	5-10
NO_2	5	8.0	10-20
O_3	1	10.0	5-10

* Does not refer exactly to the transitions used for the FTIR analysis, but to nearby lines of the same molecule.

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4.2.2 Validation of SCIAMACHY level 2 data products from Ship-borne DOAS observation

U. Platt, J.P. Burrows, A. Richter, T. Wagner

Related ESA-AO: 331

A DOAS instruments will be installed on the German research vessel Polarstern. During two ship cruises across the Atlantic latitudinal cross sections of different atmospheric trace gases will be measured and provided for the validation of the SCIAMACHY instrument aboard ENVISAT. The validation data set comprises the total columns of O_3, NO_2, OClO, BrO, H_2O, SO_2, and HCHO, which are all ‘near real time’ products of SCIAMACHY. Between the ship cruises the instrument will be operated in Heidelberg and will contribute to the SCIAMACHY validation by ground based DOAS observations.

Introduction

The SCIAMACHY instrument aboard the research satellite ENVISAT will for the first time provide stratospheric and tropospheric profiles of many atmospheric trace gases on a global scale. Corresponding to the new quality of the SCIAMACHY data set the requirements for the validation exceed those of previous instruments by far. For the validation of vertical trace gas profiles measured by SCIAMACHY several balloon flights are planned, which yield high quality data sets of vertically highly resolved trace gas concentrations. While for ozone and a few further trace gases (H_2O, ClO) vertical profiles are also provided by ozone sonde, Microwave and LIDAR-observations, for most of the target species of SCIAMACHY (like NO_2, BrO, OClO, SO_2) the DOAS instruments aboard these balloons are the most important means of validation. However, a crucial restriction of the validation with balloon soundings is their limited number and thus their limited spatial and temporal coverage.

To close the gap several other measurement platforms are used. To ensure the long-term stability of the satellite instrument e.g. data from long time ground based measurements are used. For the validation of spatially extended SCIAMACHY observations (e.g. longitudinal and latitudinal cross sections) air-borne, satellite and ship-borne measurements can be applied.

The intention of our observations is to create validation products from ship borne DOAS observations from the German research vessel ‘Polarstern’. The most important advantage of the proposed data sets is their large latitudinal extension: The measurements will be performed during supply cruises for the German Neumayer station in Antarctica from about 55°N to about 70°S. Such extended latitudinal cross sections are very important for the validation of SCIAMACHY measurements because of their strong dependence on the solar zenith angle (SZA), which varies systematically with latitude. The proposed measurements will in particular provide a significant contribution to the validation of SCIAMACHY products in tropical regions where validation data are extremely rare. Compared to validation data from air craft measurements ship borne observations cover larger periods of time and larger spatial extensions. In addition, they are very economic and thus reduce the amount of validation data from air crafts.

Validation Instrument

A state of the art DOAS instrument will be build within the proposed work. The spectral range will be from about 300 nm to about 590 nm. In this spectral range most of the target species of SCIAMACHY show characteristic absorption features and can be measured using the DOAS technique. The characteristics of the DOAS instrument are summarised in Table 4.2.2.1.

The light will be transmitted to the entrance slit of the instruments using a glass fibre bundles. The measurements will be performed and the spectra are stored automatically.

Table 4.2.2.1: Characteristics of the DOAS instruments

Instrument	UV	Visible
Wavelength range	330 – 445 nm	400 – 690 nm
spectral resolution	~0.5 nm	~1.2 nm
spectrometer	Acton SP 306	Ocean Optics
grating	600 grooves/mm	300 grooves/mm
dispersion	5.54 nm/mm	11.07 nm/mm
height of the entrance slit	6.5 mm	6.5 mm
detector	CCD array (1100 x 330 pixel)	CCD line detector
dimensions of the detector	26.4 x 7.92 mm	26.4 x 7.92 mm

Products to be validated

From the Multi-Axis-DOAS measurements the total atmospheric column but also some limited profile information can be retrieved. The precission and accuracy of the profile data has still to be quantified. This will take place after the first measurements have been analysed. In Table 4.2.2.2 the precision and accuracy for the total atmospheric columns are given.

Table 4.2.2.2: Accuracy of the ship borne DOAS measurements. For the uncertainty of the tropospheric column clear sky conditions were assumed.

Trace gas	Precission	Accuracy
O_3	**<2%**	**<3%**
NO_2	**<4%**	**<5%**
BrO	**<7%**	**<10%**
IO	**<25%**	**<30%**
OClO	**<12%**	**<15%**
SO_2	**<15%**	**<20%**
H_2O	**<4%**	**<15%**
O_4	**<4%**	**<15%**
HCHO	**<20%**	**<25%**

Validation method

The observations are analysed and the trace gas products are compared top the respective data products of SCIAMACHY. For that purpose the nearest (with respect to time and space) SCIAMACHY observations are selected.

Geophysical location, time period and frequency of measurements

The proposed latitudinal cross sections of validation data will be obtained during two ship cruises of the 'Polarstern' research vessel in 2001 and 2002. Similar ship borne DOAS measurements were successfully carried out by the Institute for environmental physics of the University of Heidelberg in 1990 [Kreher, 1991] and 1993 [Senne et al., 1996]. During the time periods between and after the ship cruises the instrument will be operated at a fixed location (e.g. at the Institute for Environmental Physics at the University of Heidelberg or at the Institute for Environmental Physics at the University of Bremen). Thus the measurements will also add a valuable contribution to the SCIAMACHY validation of the ground based DOAS network.

Figure 4.2.2.1: Route of the Polarstern in October/November 1993 when a DOAS instrument performed zenith sky observations of atmospheric trace gases [Senne et al., 1996]. Future cruises will follow routs of this type, thus allowing extended north-south cross-sections.

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4.2.3 Ground-based Sun- and Sky radiometer measurements for a Set-up and Validation of Look-up-Tables (LUT) for a Retrieval of Aerosol Optical Thickness from ENVISAT Radiometers SCIAMACHY and MERIS

W. von Hoyningen-Huene, J.P. Burrows
Related ESA-AO: # ?

Aerosol products from satellite retrievals as the AAI (Absorbing Aerosol Index) TOMS (planned for SCIAMACHY) presently do not give a quantitative aerosol information in terms of an aerosol optical thickness (AOT) or the retrieved AOT from satellite radiometers is only restricted to NIR channels and ocean surfaces (AVHRR, SeaWiFS, MODIS, MERIS (planned on ENVISAT). Only the dual-view-technique from ATSR-2, AATSR (planned on ENVISAT) and the angular scan of polarization information (POLDER) allows to retrieve also AOT over land surfaces. For the identification of aerosol sources, the main aerosol transports, the global and regional distribution of the atmospheric aerosol space-borne techniques for an aerosol retrieval also over land surfaces are required. Therefore tests are undertaken with a new method to retrieve the AOT for SW-VIS channels from nadir observations under consideration of the variable surface reflectance conditions (von Hoyningen-Huene et. al 2001, submitted to JGR). This technique is planned to be applied in off-line mode for SCIAMACHY cluster-read-outs and MERIS TOA radiance. Ground-based validation measurements should control the results from the ENVISAT aerosol retrievals.

Project summary

The entire project has the aim to validate nadir aerosol products of the ENVISAT radiometers SCIAMACHY and MERIS. However presently aerosol products are restricted only on the simple Absorbing Aerosol Index (AAI) over land and ocean for SCIAMACHY and only over ocean the aerosol optical thickness (AOT) at 870 nm from MERIS. Further aerosol products are scheduled by the IMF/DLR as third party OL-contributions. This scientific poor information on aerosol parameters requires the test and introduction of new approaches to retrieve the AOT also over land surfaces. Thus the development of a retrieval method for the AOT from nadir radiances is added to the main part, the validation task.

Task description

In more detail the scientific tasks are:

1. Development and improvement of the retrieval technique for the determination of the AOT over land surfaces from nadir TOA radiances, as described in von Hoyningen-Huene et. al 2001,

- for different land surface types (vegetation cover, arid regions, snow covered regions),
- for different aerosol types (Look-up-tables for different aerosol types, discrimination of different aerosol types).

These both partial tasks require RTM calculations of look-up-tables (LUT) for different aerosol types and different land surface conditions in selected channels for SCIAMACHY and MERIS free of gaseous absorbers. The retrieval over land can be made only for regions with known (low) surface reflectance. Therefore retrievals for channels in the region $\lambda < 0.55$ µm will be preferred. The characteristics of the variable land surface properties by the different vegetation cover (surface reflectance) is estimated from the NDVI by a linear mixing model of different surface types (as vegetation, bare soil, ...).

The existence of different aerosol types and different LUT for these types requires the discrimination of the aerosol type and the selection of the appropriate aerosol model (or type) for the retrieval. RTM calculations and satellite data analysis (L1B/C TOA-radiances) have to be performed, to derive discrimination criteria for the main different aerosol types from radiance ratios and surface parameters.

1. combination of the land-surface algorithm with the ocean retrieval algorithm.

The ocean algorithm is based until now on a clean water leaving reflectance considering a wavy surface reflection. In contrary to the land surfaces, the best retrieval results one obtains in NIR channels $\lambda > 670$ nm. The combination of the ocean and land part requires the combination of AOT results from NIR estimations (ocean) and short-wave estimations (land) by the estimation of the spectral behaviour of the AOT.

2. Validation of the regular aerosol products and the new aerosol retrieval method will be made by combined ground-based sun- and sky-radiometer measurements by the IFE/IUP of Univ. Bremen and by AERONET stations:

- spectral aerosol optical thickness from sun photometer measurements (validation parameters to compare ground-based, aerosol products and new retrieval approach),
- sky brightness functions from sky radiometer measurements,
- inversion of aerosol phase functions for the set-up of look-up-tables for the retrieval.
- comparison of AOT of 870 nm from ocean stations with the regular AOT-retrieval product by ENVISAT.
- comparison of the AOT of selected land positions with the retrieved AOT of the experimental OL aerosol product from land surfaces.

a) Preparatory Phase

- Ordering and preparation of one CIMEL CE-318 sun- and sky-radiometer, e.g. calibration and preparation for the operation within the AERONET network of NASA.
- Preparation of the data processing for the ground-based data

- Preparation of the data output of the CIMEL CE-318 for the use by the CIRATRA program for the retrieval of aerosol phase functions and other climate relevant aerosol parameters for the calculation of look-up-tables (LUT) and the absorbing aerosol index (AAI).
- preparation of the data output for the NILU data base for the validation.
- Set-up of the basic version of the AOT retrieval procedure for land surfaces.
- set-up and test of a model to calculate the AAI from ground-based AOT and sky-brightness measurements.

b) Commissioning Phase

Satellite data access will be achieved and the input procedures of the experimental OL-procedure for the AOT retrieval from SCIAMACHY and MERIS will be adapted to the L1B data structure and test retrievals will be performed.

c) Collection of data

Ground-based Validation Data: The data collection of ground-based data (spectral AOT (340 - 1020 nm) and sky brightness (same wavelength)) begins with the commissioning phase and is continued through the project. AOT will be measured, if cloud free conditions (and less cloudy conditions with direct solar radiation) exist, during the day with a focus on the over-flight times. Sky brightness only can be measured at solar elevations below 30° and only at cloud free conditions.

The measurements will be performed mainly at Bremen as a site, which is used as validation for land surface conditions. In cooperation with the GKSS data of the AERONET instrument at Helgoland are used for North Sea conditions. Selected other AERONET station will be used to validate special aerosol conditions (as biomass burning, desert dust, arctic haze, and other relevant aerosol types).

d) Analysis

The following data analysis will be performed:

- The measured ground based data of spectral AOT and skybrightness will be used to retrieve the aerosol phase function, and refractive index.
- The above parameters are used to estimate the AAI from ground based data by mean of RTM for the TOA.
- AOT retrievals with the experimental OL-procedure for the AOT retrieval from SCIAMACHY and MERIS for selected pathes (Europe).

e) Deliverables

Ground-based data for the NILU data base:

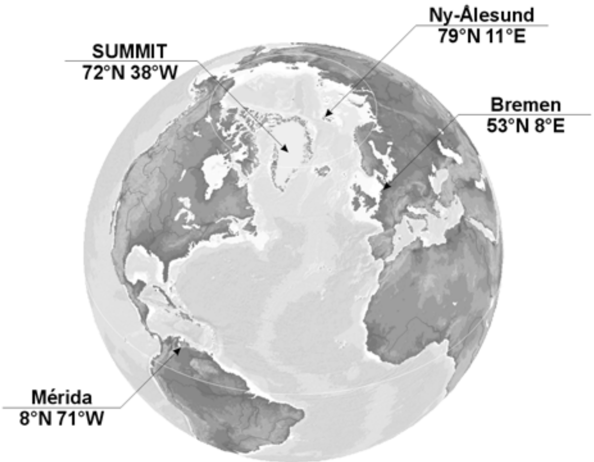
- spectral AOT (8 channels from 0.34 - 1.02 µm) main validation data
- for totally cloud free conditions retrieved aerosol phase function will be contributed to perform RTM calculations for LUT and AAI
- Estimated AAI from ground-based data.

4.2.4 The validation of SCIAMACHY products by ground-based millimetre-wave observation

M. Hoock, K. Lindner, I. Wohltmann, K. Künzi, H. Berg, G. Hochschild, G. Kopp
Related ESA-AO: # 331, 126

SCIAMACHY measurements of ozone (O_3), nitrous oxide (N_2O), water vapour (H_2O) and optional chlorine monoxide (ClO) shall be validated by profiles and columns derived from mm-wave radiometry at stations operating at high-, mid- and tropical latitudes (Fig. 4.2.4.1).

Figure 4.2.4.1: High-, mid- and tropical latitude observation sites with ground-based mm-wave radiometers, Ny-Ålesund and Bremen are operational stations, Mérida is planned to become operational in February 2002. For Summit development work is presently in progress, operationality is not expected before late 2002 or 2003.



The University of Bremen and the Forschungszentrum Karlsruhe will carry out the project jointly with support by the Universidad de los Andes in Mérida, Venezuela, for the tropical station. The University of Bremen is responsible for the maintenance and the operation of the high and mid-latitude stations. The high latitude station in Ny-Ålesund, Spitsbergen is equipped with three radiometers to measure ozone, water vapour and chlorine monoxide. At the mid-latitude station in Bremen, Germany, an ozone radiometer, also providing total columns of water vapour is operational since end of 2000 and presently in the validation phase. This latter instrument will be operated continuously during the time SCIAMACHY is in orbit. The Forschungszentrum Karlsruhe will install a well tested radiometer permitting to measure ozone, chlorine monoxide, nitrous oxide, nitric acid (HNO_3), and tropospheric water vapour columns at the high altitude equatorial site in Mérida, Venezuela. The University of Bremen will contribute a second frontend to observe stratospheric water vapour.

Introduction

The accuracy of satellite sensors depends on regular comparison to well calibrated and stable ground-based instruments. Such reference sensors are provided e.g. by the "Network for the Detection of Stratospheric Change" (NDSC). Millimetre-wave radiometers are very suitable for this purpose and have successfully been used in atmospheric research since the 1960s. Millimetre-wave radiometry enables nearly continiuous monitoring due to its independence from solar illumination and clear sky conditions. This results in a high number of matches between the ground-based observations and the satellite overpasses. Furthermore such sensors have excellent long term stability, and can be absolutely calibrated using black body radiators. Sensor technology has greatly improved over the past decade resulting in lower instrumental noise and better performance at higher frequencies.

Millimetre-wave radiometers detect the thermally induced rotational emission lines of atmospheric constituents. Relevant rotational level populations for these transitions are in thermodynamic equilibrium, and excitation energies are low relative to available thermal energy, and therefore the condition for local thermodynamic equilibrium (LTE) is well fulfilled up into the mesosphere. Heterodyne receivers are used to downconvert the observed atmospheric signal to a lower intermediate frequency while preserving all spectral information. The spectrally resolved line shapes contain altitude information through pressure broadening of the particular emission line. This can be used to retrieve altitude profiles of the volume mixing ratio of the respective atmospheric constituents.

The Institute of Environmental Physics at the University of Bremen has a long history in operating and developing ground-based and airborne mm-wave radiometers. The institute has participated in several intercomparison and validation campaigns of ground-based sensors, and satellite instruments. The data collected by the instruments in Ny-Ålesund are therefore well characterised, and have successfully been used for validating the space-borne sensors GOME onboard ERS-2 and ILAS onboard ADEOS. The instrument at Ny-Ålesund satisfies the very high accuracy standard required by the NDSC data protocol.

At the Institute of Meteorology and Climate Reasearch at the Forschungszentrum Karlsruhe ground-based mm-wave radiometry has been introduced in 1991 to complement IR observations.

Subsequently to a 142 GHz instrument for O_3, which started field operation in 1994, radiometers for ClO and other trace gases at 204 and 278 GHz have been developed [7]. Regular winter campaigns have been performed at IRF/Kiruna since 1996 [8], except for 1997 when an international ClO radiometer intercomparison campaign took place at Ny-Ålesund [9]. In the course of the construction and the operation of radiometers advanced calibration methods and retrieval procedures have been developed.

Objectives

The trace gases to be measured within this project (see Table 4.2.4.1 and 4.2.4.2) are part of the SCIAMACHY core validation campaign. All data products fulfil the precision criteria specified in the SCIAMACHY Validation Requirements Document. For cross validation purposes this project complements other SCIAMACHY validation projects that observe the same species at the same locations.

Note: ClO is not presently considered a routine SCIAMACHY data product, however ClO retrieval are part of so called scientific projects. Nevertheless since very few ClO validation sources are available world-wide, and because ClO data is provided at two of the sites at no additional costs, this parameter is included in the list of species to be validated. Since the 270 GHz radiometer that will be installed at Mérida is capable to perform HNO_3 soundings, this trace gas will be determined as an additional feature.

Table 4.2.4.1: List of products retrieved by mm-wave radiometry, their altitude range and accuracy

Product	Altitude range [km]	Accuracy
Ozone profiles	12 – 55	0.2 ppm or 10 %
Water vapour column	-	0.3 mm or 10 %
Water vapour profiles	25 – 55	0.3 ppm or 20 %
N_2O profiles	20 – 55	30 ppb or 15 %
ClO profiles, optional	16 – 35 (17 – 55 at Mérida)	0.4 ppb or 20 %
HNO_3 profiles, optional	17 – 55	1 ppb or 20 %

Besides SCIAMACHY validation the ozone measurements carried out within this project will be used to detect the chemical ozone loss inside the polar vortex, and to study horizontal transport phenomena, as described in [3] and [4]. The water vapour observations will be used as an indicator for the location of Ny-Ålesund with respect to the polar vortex. In Mérida the N_2O data will give information on vertical transport in the stratosphere. Chlorine monoxide measurements allow to determine the importance of anthropogenic ozone destruction and the presence of perturbed chemistry situations, as shown in [5] and [6]. All data will be submitted to the NDSC database.

Observation sites

Ny-Ålesund

The high latitude station Ny-Ålesund, Spitsbergen, (79° N, 12° E) is part of the Arctic primary station of NDSC. This station is equipped with mm-wave radiometers to observe ozone, chlorine monoxide and water vapour, all sensors are operational. The data collected by these instruments have been used successfully for validating the space borne sensors GOME onboard ERS-2 and ILAS onboard ADEOS.

Bremen

The instrument of the mid-latitude station Bremen, Germany, (53° N, 8° E) for the detection of stratospheric ozone profiles and total water vapour columns has been tested successfully. It is operational since end of 2000 and presently in the validation phase, which is expected to be finished before the launch of SCIAMACHY.

Mérida

At present two radiometers to observe ozone, nitrous oxide, HNO_3, ClO and water vapour in the stratosphere are being prepared for installation on the top of Pico Espejo near Mérida, Venezuela (8° N, 71° W), at an altitude of 4768 m. Such a high altitude is required in the tropics in order to avoid the high absorption by water vapour in the lower troposphere. The chosen site is well suited because of its excellent infrastructure and the local scientific support provided by the Universidad de los Andes. The Forschungszentrum Karlsruhe will install a radiometer, which operates near 270 GHz and includes an acousto optical spectrometer. The H_2O-radiometer will be provided by the University of Bremen.

Validation instruments

Ny-Ålesund

The Radiometer for Atmospheric Measurements (RAM) consists of three front-ends for the detection of the pressure broadened rotational emission lines of stratospheric water vapour at 22 GHz, ozone at 142 GHz and chlorine monoxide at 204 GHz. The three front-ends use alternately the same back-end, an acousto optical spectrometer, for spectral near real time detection. In winter the ClO measurements have the highest priority followed by ozone and water vapour. In summer only water vapour and ozone are observed. Since the stratospheric emission signal is affected by the tropospheric water vapour absorption, the integration time in order to achieve a sufficient signal to noise ratio depends on observing frequency, emission line strength and tropospheric opacity. In the case of ozone this time varies between 10 minutes in winter and 1 day for a very humid summer troposphere. The ozone profiles retrieved from the measurements in Spitsbergen have intensively been validated and show good agreement with other sensors at Ny-Ålesund, as shown in [1]. The integration time for a stratospheric water vapour measurement is between 6 h and 1 day in winter. During summer stratospheric water vapour observations are possible under favourable weather conditions. Water vapour columns are derived from the non resonant emission of tropospheric water vapour, producing an offset to stratospheric ozone emission. Chlorine monoxide measurements are performed during the winter month and need typically about 10 hours of integration time during day and night.

Bremen

The BREmen Radiometer for Atmospheric Measurements (BRERAM) operates at a frequency of 110 GHz. This frequency is more suitable to the rather humid tropospheric conditions in Bremen compared to Spitsbergen because tropospheric absorption is lower than at 142 GHz. Integration times will vary between 1 h under favourable weather conditions and 1 day for a humid, warm summer atmosphere. In case of rain, measurements will stop. The BRERAM ozone profiles are presently being validated using data from radiosondes launched at Hohenpeissenberg, Lindenberg, Germany and Uccle, Belgium, and if available profiles derived from GOME data. This process is expected to be finished before the launch of ENVISAT.

Mérida

Two radiometers, MIRA2 and WARAM, sharing a common acousto-optical spectrometer backend will be installed. The radiometer MIRA2 observes emission lines of O_3, ClO, HNO_3 and N_2O in the frequency range 268-280 GHz. This instrument, in operation since 1996, has been developed at the Forschungszentrum Karlsruhe and is well tested and validated during several arctic measurement campaigns. The radiometer WARAM observing the H_2O line at 22 GHz will be provided by the University of Bremen and is based on a similar instrument operating successfully at the NDSC station in Spitsbergen.

The installation of the microwave instruments will start in October 2001; full operation is planned for February 2002. This also is consistent with the present schedule for the validation of the atmospheric research instruments aboard ENVISAT, which is the major goal for the first phase of operation. Beyond this, long-term operation is envisaged to complement the present set of NDSC stations with a tropical location.

Table 4.2.4.2: List of trace gases to be measured and necessary integration time

Latitude/ Longitude	Ozone profiles	ClO profiles	Water vapour profiles	Water vapour columns	N_2O profiles	HNO_3 profiles
Ny-Ålesund 79° N/ 12° E	0.25 – 1 h	Feb. to April: typ. 10 h	6 – 24 h	0.25 – 1 h	n/a	n/a
Bremen 53° N/ 8° E	typ. 1 h	n/a	n/a	typ. 1 h	n/a	n/a
Mérida 8° N/71° W	0.3 – 1 h	typ. 3 h	6 – 24 h	0.3 h	1 –2 h	1 – 3 h

Validation method

Profiles of ozone and water vapour (and chlorine monoxide if desired) derived from SCIAMACHY observations and from ground-based mm-wave radiometry will be first processed to get comparable altitude resolution. In a next step the profiles will be compared, considering the very different spatial resolution of both sensors, and also taking into account the particular meteorological conditions. It should be noted that in a recently completed Ph. D. thesis the achievable accuracy for comparing profiles and total amounts of minor constituents, has been carefully analysed for the case of ozone [1] (see also [2]). This analysis included four ground-based instruments (Microwave Radiometer, FTIR, DOAS, and LIDAR), balloon soundings and three space-borne sensors, MLS on UARS, GOME on ERS-2 and TOMS on a NASA Earth Probe. Such an analysis is the basis for any meaningful intercomparison of data obtained from sensors with vastly different observing geometry.

Further radiometer development

Beside the above described mm-wave radiometers, part of the SCIAMACHY validation program, it should be mentioned that at present the new mm-wave Radiometer for Atmospheric Measurements at SUMMIT (RAMAS) is being developed for deployment at the SUMMIT research station (72° N, 38° W) in the interior of Greenland at an altitude of 3200 m. The project will be realised by the following partners: University of Bremen, Germany (Co-ordinator), University of Bordeaux, France, University of Leeds, U.K., and the Danish Meteorological Institute. It is supported by the European Commission (fifth frame work programme) and the US National Science Foundation.

Presently available stations in the Arctic are located between sea level and 600 m, where the observing conditions are still severely limited due to high tropospheric attenuation, whereas SUMMIT provides the only high altitude site available in the Arctic necessary for such a sensor. The principle aim will be to measure O_3, ClO, N_2O and HNO_3, over an altitude range and with a vertical resolution as shown in Table 4.2.4.3.

Table 4.2.4.3: List of products planed to be measured with RAMAS and the accuracy of the retrieved products

Product	Altitude range [km]	Accuracy
Ozone profile	12 – 55	0.2 ppm or 10 %
Water vapour column	-	0.3 mm or 10 %
N_2O profiles	15 – 45	10 to 30 ppb
ClO profiles	15 – 45	0.3 ppb
HNO_3	15 – 45	0.3 ppb

These observations will be analysed and compared with a three dimensional model. The observing band for the radiometer will cover the frequency range from 265 to 281 GHz, which is best suited for a site with extremely low water vapour, because it covers a large number of interesting species. It is planned to install RAMAS at SUMMIT in summer 2002. Routine operation can not expected to start before end 2002 or in 2003.

Co-operations

Our activities in these projects, in particular for the Ny-Ålesund and Mérida sites, will be conducted in close collaboration with the Alfred-Wegener Institute for Polar- and Marine Research, Potsdam, Germany in addition to the partners already listed above.

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4.2.5 Lidar measurements of temperature profiles, aerosol load and clouds from the Tropshere to the Mesosphere at the Artic circle from ESRANGE near KIRUNA

K.H. Fricke
Related ESA-AO: #222

For the validation of the instrument SCIAMACHY on the polar orbiting platform ENVISAT we plan to measure vertical profiles of the atmospheric temperature and aerosol load such as Ci, PSC, PMC, volcanic debris, and Sulfur bearing droplets covering the altitude range 5 to 95 km. Data are obtained with our backscatter Lidar on the Esrange (68N, 21E) near Kiruna (Sweden) just north of the Arctic circle. Our data is also useful for the validation of the instruments MIPAS and GOMOS on ENVISAT. The polar atmospheres are highly variable and can attain extreme states which allows to validate the ENVISAT atmosphere instruments over a wide range of the governing atmospheric parameters. The environmentally important polar stratospheric and mesospheric clouds occur only in the polar atmospheres. Our aerosol lidar provides altitude registration of clouds, altitude profiles of the backscatter ratio and the depolarization factor, transmission of cloud layers, integrated transmission from the ground to 30 km altitude, and altitude profiles of temperature above the aerosol layer and relative molecular density and pressure. We plan to conduct several field measurement campaigns of 4 to 6 weeks duration primarily during summer and winter, when the temperature in the polar atmosphere falls sufficiently for cloud formation in the mesosphere and the stratosphere, respectively. At the latitude of our Lidar site we expect at least one close (< 100 km) coincidence per day with the SCIAMACHY swath footprint. As our Lidar can measure in daylight we are able to schedule individual observations at the times of such close coincidences. Campaign periods will be coordinated with other validation measurements.

Introductions

SCIAMACHY is one of three instruments designed to investigate the state of the Earth atmosphere on the ESA environmental satellite ENVISAT to be launched in November 2001 in a polar orbit. Briefly, scia is a spectrometer which measures the spectral dependence of sunlight transmitted, reflected, and scattered by the Earth atmosphere or surface in one of three observation geometries: nadir, limb, and occultation. Expected scia data products presently make up a list of column densities and volume mixing ratios for 12 trace gas species in the troposphere and stratosphere as well as pressure, temperature, aerosol, cloud cover, cloud top height, and radiation.

We plan to undertake measurements with our backscatter Lidar located on the Esrange (68N, 21E) just north of the Arctic circle to validate (not to calibrate) scia aerosol and temperature data products. A Lidar transmits pulses of photons into the atmosphere, collects the backscattered photons, and after analysis according to wavelength and polarization the received intensity is registered as a function of round-trip time. This time is converted to a range, which for a zenith looking Lidar is altitude. The immediate data product of a Lidar measurement are altitude profiles of the relative molecular density and the aerosol load including clouds. In the aerosol-free part of the atmosphere the relative molecular profile can be converted to a relative pressure profile and to an absolute atmospheric temperature profile assuming hydrostatic equilibrium. Besides altitude profiles the Lidar measures directly column information: the absolute signal strength at a fixed altitude (usually 30 km) above the aerosol layer yields the transmission from the ground to this altitude and a signal-offset among the molecular signal profile below and above a cloud layer measures the vertical optical thickness of this cloud. Thus a Lidar is well suited to validate scia data products such as the nadir data cloud-top pressure, cloud optical depth, aerosol absorption index, and aerosol optical thickness, and the limb-and-occultation data aerosol scattering and extinction profiles and temperature-pressure profiles. A central part of limb data processing is the assignment of tangent altitudes. For thin cloud layers, which provide an unambiguous signature in scia data, the Lidar altitude gives direct validation of the scia altitude registration.

The polar atmosphere is highly variable and it often attains extreme states in particular in temperature, which e.g. generate clouds in the stratosphere and mesosphere - a unique phenomenon of the polar atmosphere. The clouds in the stratosphere modify the natural chemical balance, which leads to enhanced ozone destruction forming the ozone hole in polar spring and the clouds in the mesosphere might be early indicators of global warming, i.e. the polar atmosphere is very sensitive to anthropogenic modification of the Earth atmosphere. ENVISAT is in a polar orbit and thus designed to observe the polar atmosphere. From the standpoint of validation our Lidar-site north of the Arctic circle has the variability required by the CEOS WGCV for a preferred validation site and it is located in an environmentally important region.

Validation instrument

Table 4.2.5.1: Description of the U. Bonn Lidar on the Esrange

Goals:	vertical profiles of -aerosol and cloud backscatter -particle depolarization -particle size distribution -temperature (hydrostatic)
Location	Radarhill, Esrange, Sweden; 67.88° N; 21.06° E; z = 485 m
Transmitter:	Nd:YAG, 20 Hz, seeded, linearly polarized power @ 532nm: 600 mJ/pulse, 12 Watt beam widening 10 × to 50 μrad [∅ 5 m 100 km]
Telescope:	3 bore-sighted Newtonian telescopes (zenith looking) each 50-cm diameter, f = 2.5 m; FOV 300 μrad
Detectors:	bi-alkaline, GaAs, and S1 photomultipliers (counting mode) 3 intensity cascaded Rayleigh/Mie channels @ 532 nm 2 intensity cascaded cross-polarization channels @ 532 nm 1 N_2 vibrational Raman channel @ 608 nm 2 intensity cascaded Rayleigh/Mie channels @ 355 nm 1 Rayleigh/Mie channel @ 1064 nm spectral filtering: interference filters, fixed spacer etalons polarization cube @ 532 nm
System:	bi-axial (distance 0.5 m, overlap above 4 km) 532-nm power-aperture product 7 W m^2 maximum altitude range 5 -- 100 km (range gate 150 m) Operation one-colour (532 nm) mode
Modes:	upper stratosphere and mesosphere hydrostatic temperatures and NLC daylight operations three-colour (355/532/1064 nm) mode free troposphere and lower stratosphere aerosol, PSC, cirrus
Best Signal:	90 counts/km/laser-shot on 09Aug98 with Sun @-5° elev. reached 80 km altitude in 1.7 min integration time
Status:	early 2001
Plans:	improve sensitivity @ 355 nm; rotational Raman temperature

Objectives

We plan to measure aerosol and temperature profiles and the transmission of the lower atmosphere with a backscatter Lidar, convert these data to the geophysical quantities described as SCIAMACHY products, compare both data sets, and report the outcome to the SCIAVALIG and the ESA ACVT.

Products to be validated

1. SCIAMACHY nadir products

a) Absorbing Aerosol Index (AAI) (in some documents called Aerosol Absorption Indicator)

b) Aerosol optical thickness

c) Cloud top height

d) Cloud optical depth

2. SCIAMACHY limb-and-occultation products

a) altitude registration

b) pressure-temperature profiles

c) aerosol scattering and extinction profiles

Geophysical location, time-period and frequency of measurements

The Lidar is in a permanent location on the Radar Hill on the Esrange near Kiruna (Sweden) at 68N, 21E. Measurements will be done in several campaigns with expected durations of 4 to 6 weeks each. Campaigns will be conducted preferentially at times of expected extreme states in the polar atmosphere, i.e. winter and summer. Detailed campaign timing will be coordinated with other validation campaigns, in particular those utilizing the Esrange research balloon facility or the Kiruna airport. A provisional schedule is shown in Table 4.2.5.2.

Accuracy/Precision of measurements

There is no simple answer or single overall number for the accuracy or precision of lidar derived data. Both quantities depend in a complicated manner on altitude, spatial and temporal resolution, geophysical variability of the phenomenon studied, and boundary layer transmission.

1. Altitude: The lidar operates with range gates of 1 μs equivalent to 150 m length. This corresponds to a precision of ±75 m for the center of range gate altitudes. The accuracy depends on the synchronization of laser pulse and counters, which is measured to better than 10 ns or 1.5 m. The altitude above sea level of the lidar site is known to better than 1 m accuracy.

2. Signal counts: As the electronics is operated in counting mode the accuracy is inherently infinitely good as it is true for all counting operations. The precision is determined by Poisson statistics and is a strong function of altitude. By post-integration we can trade spatial and/or temporal resolution for improved precision.

3. Backscatter ratio: The backscatter ratio is derived by ratioing the Rayleigh/Mie channel to the vibrational Raman channel and normalizing to 1 in the aerosol-free part of the atmosphere. Counts and normalizing constant are accurately known and hence there is no accuracy bias in the backscatter ratio. The cross section for vibrational Raman scattering is about 3 orders of magnitude smaller than that for Rayleigh scattering, which decreases the precision by a factor of 30.

4. Temperature: Temperature is derived by integrating a ratio of lidar counts over altitude. It does not involve calibration and is theoretically completely accurate. The precision depends on the count statistics and the altitude interval used for integration.

Table 4.2.5.2: Proposed Schedule with Lidar Activities. We suggest a total of four lidar campaigns of 6 weeks duration each, two for winter and two for summer validation measurements. Detailed scheduling will involve coordinaton with other validation activities in northern Scandinavia.

Date	Activity
September 2000	Project start
during 2000 and 2001	Learning to deal with Envisat data and tools
November 2000	1st rehearsal campaign
June 2001	2nd rehearsal campaign
Jan. 2002	Envisat launch
Jan.02	lidar instrument check out
Apr.02	Envisat Functional Test Phase ends
July 2002	Envisat commissioning phase ends
from mid-July 02	lidar summer campaign ca 6 weeks (PMC)
	lidar data reduction and validation of Envisat data
Oct.02	1. Envisat Validation Workshop
Dec.02/Jan.03	lidar winter campaign ca 6 weeks (PSC)
Apr.03	lidar data reduction and validation of Envisat data
from June 03	2. Envisat Validation Workshop sf L+15
	lidar summer campaign ca 6 weeks (PMC)
July 2003	lidar data reduction and validation of Envisat data
	Envisat main validation phase
Aug.03	3. Envisat Validation Workshop sf L+20
Dec.03/Jan.04	lidar winter campaign ca 6 weeks (PSC)
	lidar data reduction and validation of Envisat data
Feb.04	4. Envisat Validation Workshop sf L+26

5. Transmission of an isolated cloud layer: The transmission offset in the Rayleigh profile above and below the cloud layer is determined by interpolation across the cloud layer. It does not involve calibration and is therefore theoretically accurate. The precision depends on that of the counts in the profile.

6. Integrated transmission of the atmosphere up to 30 km: The absolute Rayleigh scattered signal received from a fixed altitude (usually 30 km) above the aerosol layer depends primarily on the integrated transmission from the ground up to this altitude. Conversion to atmospheric transmission requires calibration, which is done by searching long time series of lidar data for the highest signal ever received from 30 km altitude and equating this signal to that expected for a purely Rayleigh scattering atmosphere. This procedure yields in principle an upper bound for the integrated transmission. At the time of writing we have not yet determined the bias (or accuracy) in this calibration procedure.

7. The lidar measurement is a point measurement, while the scia nadir footprint is typically 60 x 30 km large. The scia data will form an average over the footprint area. To convert the lidar point measurement to an area average the lidar data will be averaged in time commensurate with wind speed and footprint size. We expect that natural variability will introduce an accuracy bias in these two averages, which we cannot quantify.

Validation of other ENVISAT instruments

Several of the lidar data for validation of scia are well suited to validate other atmosphere instruments on ENVISAT, in particular MIPAS and GOMOS. For both instruments altitude registration as well as temperature profiles can be validated. Uncalibrated comparison of pressure and molecular density altitude profiles are also possible to validate the altitude variation (profile shape) of the two quantities. For GOMOS it is also possible to validate the aerosol vertical profiles. While the MERIS observed radiances depend on the atmospheric aerosol distribution, the long wavelengths used in MERIS will make separation of surface and atmospheric contributions difficult for our land-locked site and we do not consider MERIS a suitable candidate for validation.

4.2.6 Validation of SCIAMACHY products with ground-based FTIR observations from the NDSC Network 50E0008

R. Sussmann, T. Blumenstock
Related ESA-AO. #126

Within this project SCIAMACHY columns of O_3, NO_2, N_2O, CO, CO_2, CH_4, H_2CO, and profiles of O_3, N_2O, and CH_4 shall be validated with ground-based FTIR measurements. This project includes 2 sites: Kiruna (67.8N, 20.4E, 417 m asl) and Izaña (28.3N, 16.5W, 2367m asl), both are part of NDSC (Network of the Detection of Stratospheric Change). Correlative analyses (satellite versus ground) will be performed together with other NDSC sites (e.g. at Zugspitze by FhG-IFU, SCIAVALIG 50E0007) to assess accuracy and precision of SCIAMACHY products for different latitudes. The project includes case studies dealing with the analysis of trace gas profiles as well as with CTM model applications using KASIMA (KArlsruhe SImulation model of the Middle Atmosphere (KASIMA) in order to address differences in time and geo-location between ground-based and SCIAMACHY measurements.

Introduction

In order to validate data of SCIAMACHY ground-based FTIR measurements will be performed at 2 stations: Kiruna (67.8N, 20.4E, 417 m asl) in the Arctic and Izaña (28.3N, 16.5W, 2367m asl) in the sub-tropics. Data products of SCIAMACHY like columns of O_3, NO_2, N_2O, CO, CO_2, CH_4, H_2CO, and profiles of O_3, N_2O, and CH_4 shall be validated.

Validation instrument

Correlative ground-based measurements will be performed by the method of high resolution solar absorption FTIR-(Fourier Transform Infrared) spectrometry. FTIR observatories at two sites of significantly different geographical latitude are contributing to this project, both equipped with state-of-the-art high-resolution Bruker IFS 120 HR/M Fourier-Transform spectrometers for direct sun observations.

Products to be validated (including a table with accuracy / precision of the own measurements)

Total column amounts of O_3, NO_2, N_2O, CO, CO_2, CH_4, H_2CO as well as vertical profiles of O_3, N_2O, and CH_4 will be validated. The typical errors (1σ) are given in the following table. Please note that precision includes error sources except of spectroscopic errors.

Table 4.2.6.1: Typical errors (1σ) of total column amounts

Trace gas	Precision (%)	Accuracy (%)
O_3	4	7
N_2O	3	6
CH_4	4	7
NO_2	6	11
CO_2	6	8
CO	4	7

Geophysical location / time period / frequency of measurements

During commissioning and main validation phase measurements will be performed whenever weather conditions allows it. This is typically the case on 2 –3 days per week.

Table 4.2.6.2: Sites

Site	Latitude	Long.	Altitude [m]
Kiruna, S	67.8°N	20.4°E	419
Izaña, Tenerife I., E	28.3°N	16.5°W	2367

Validation method

Trace gas vertical column amounts and vertical profiles of species with pressure depending absorption features are derived from ground-based spectra using the retrieval code PROFFIT (PROFile FIT, IMK). In order to avoid systematic errors the instrumental line shape (ILS) is determined routinely by low pressure gas cell measurements analyzed with the LINEFIT software.

Of course, for the comparison with ground-based data the ENVISAT data will be taken which are nearest in time and space in respect to the ground-based observations. In order to check the influence of differences in time and space and of the observation geometry, the KArlsruhe SImulation model of the Middle Atmosphere (KASIMA) will be applied.

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4.2.7 Validation of SCIAMACHY level-2 data products from ground-based DOAS observations

J.P. Burrows, U. Platt, A. Richter, T. Wagner
Related ESA-AO: #331

A global network of high quality, largely automated ground-based DOAS instruments observing scattered sunlight and covering the geographical area from the Antarctic to the Arctic will provide a quality controlled set of validation data for a number of SCIAMACHY level-2 products (O_3, NO_2, BrO and OClO columns). In addition, some information on NO_2 profiles, PSC occurrence and H_2O, HCHO, IO and SO_2 columns will also be provided. The global network consists of already existing stations and several stations where DOAS instruments will be installed in the frame of this project. Validation data from all stations will be available for a period of about 24 months from the launch of ENVISAT to the end of the project.

Introduction

With the SCIAMACHY instrument on board of the ENVISAT satellite, the successful measurements of GOME on ERS2 will be continued and extended. SCIAMACHY will not only provide integrated columns of O_3, NO_2, BrO, OClO, SO_2, and HCHO from the UV/visible channels, but also H_2O, N_2O, CO and CH_4 from the IR. In addition, stratospheric profiles will be measured for most of these species in the Limb scanning mode. How valuable these measurements are for the scientific community depends strongly on the accuracy of the data products, and possibly even more on how well remaining inaccuracies are characterised. A thorough and continued validation therefore is of paramount importance for the success of the SCIAMACHY project.

In this project, a network of ground-based UV/visible spectrometers will be used for the validation of the near real time column measurements in SCIAMACHYs UV/visible channels. Validation of the column accuracy is of particular importance to ensure the continuity with the existing GOME data set and for the tropospheric products derived by combining the limb stratospheric profiles and the nadir columns.

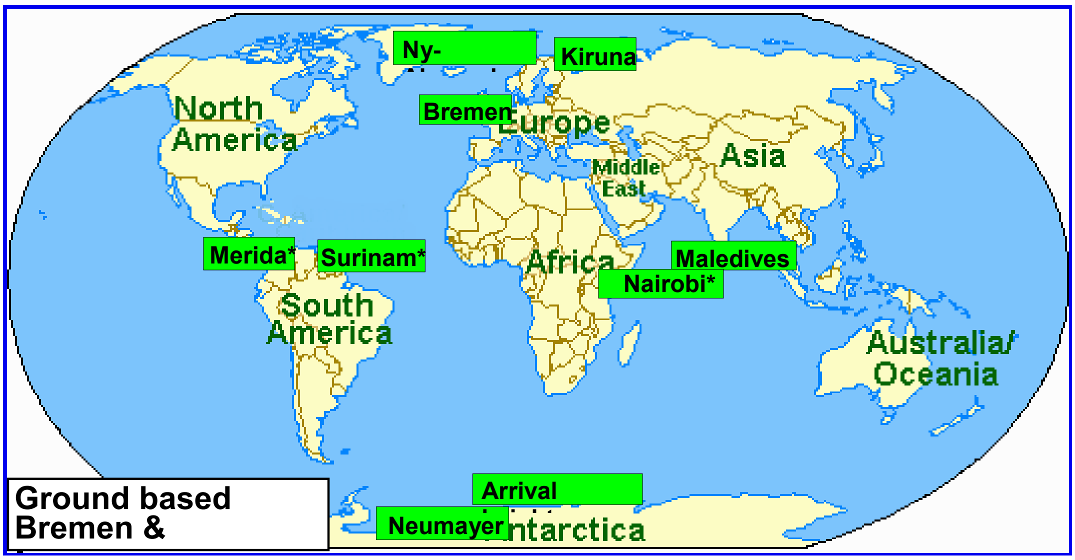

Figure 4.2.7.1: The German DOAS network

The validation method used, namely comparison with ground-based DOAS measurements has been successfully used for the validation of GOME data. Many problems in the operational GOME data processor have been identified using the ground-based measurements and solutions have been proposed by the validation teams. Examples are the solar zenith angle and column dependence of the O_3 columns, climatology problems for O_3 and NO_2, albedo problems for O_3, and water interference for NO_2. One major problem encountered in the GOME validation is the lack of reliable measurements in tropical latitudes, a region particular of importance for atmospheric dynamics and chemistry. To overcome this deficit, this project includes an extension of the existing DOAS network to tropical regions.

Validation instrument

The instruments used in this study are optimised for high stability and low noise, and therefore are also able to measure BrO and - if stratospheric chlorine is activated - OClO. If the range of solar zenith angles is sufficiently large, limited profile information can be derived for NO_2. In addition to the absorbers, the UV-visible spectrometers yield information on PSC occurrence in high latitudes.

The measurement technique used in this project is very similar to that of the SCIAMACHY instrument itself, both concerning the experimental set-up and the analysis procedure. Grating spectrometers covering the UV/visible spectral range are used to record sunlight scattered in the zenith-sky throughout the day. To achieve quasi simultaneous measurements at all wavelengths, diode arrays or spectroscopic CCD cameras are used as detectors. The detectors are cooled to reduce dark current and noise, and the spectrometers are temperature stabilised to achieve optimum stability. The instrument characteristics are monitored by daily measurements of white light and spectral line lamps to minimise the risk of drifts in the time series resulting from slow changes in the instrument.

Table 4.2.7.1: Instrument characteristics of the DOAS instruments, see Table 4.2.7.4 for details

Station	Wavelength range	Resolution FWHM	Detector
Ny-Ålesund	330 - 490 nm	0.9 nm	diode array
Kiruna / Vis	380 – 680 nm	1.5 – 3 nm	diode array
/ UV	300 – 400 nm	0.6 nm	diode array
Bremen / UV	320 - 400 nm	0.5 nm	CCD
/ Vis	400 - 700 nm	1.5 nm	diode array
*Merida (iii)	330 - 495 nm	0.9 nm	CCD
*Surinam (i)	330 – 495 nm	0.9 nm	CCD
*Nairobi (iv)	330 - 495 nm	0.9 nm	CCD
Neumayer (iii) Vis	415 – 670 nm	1.5 nm	diode array
UV	320 – 425 nm	0.6 nm	diode array
Arrival Heights	345 – 385 nm	0.6 nm	diode array

Zenith-sky spectroscopy using the **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (DOAS) technique is a standard technique for the measurements of O_3 and NO_2 columns from the ground. Atmospheric trace-gases are identified by their differential absorption structures in the UV and visible wavelength region. The primary result of the analysis are slant columns for the absorbers, which then have to be converted into vertical columns by the use of radiative transfer calculations (airmass factors). Due to the viewing geometry, the measured signal is strongly weighted towards the stratosphere, and only in heavily polluted regions or in situations with thick clouds contamination from tropospheric signals is observed.

Products to be validated

The products provided by the ground-based DOAS measurements are listed in Table 4.2.7.2.

Table 4.2.7.2: Data provided by the DOAS network and the SCIAMACHY target data product. NRT = Near real time, OL = off line, SC = scientific, * = to be confirmed

Product	Status	SCIAMACHY product	Comment
O_3 column	Routine	NRT	
NO_2 column	Routine	NRT	
BrO column	Routine	NRT*	
OClO column	Routine	NRT	chlorine activation only
H_2O column	Additional	NRT	
HCHO column	Additional	NRT	pollution events only
SO_2 column	Additional	NRT	pollution events only
IO column	Additional	SC	favourable conditions only
NO_2 profile	Tentative	OL	
PSC	Tentative	SC	

Measurements that are performed routinely at the existing stations are identified as "routine", "additional" products are measurements that have been demonstrated but are not routinely performed at all stations. NO_2 profiles and PSC identification have been derived from DOAS measurements, but further development is necessary prior to their use for validation purposes.

Accuracy/precision of the measurements

Two components contribute to the error of the zenith-sky DOAS measurements: The error in the slant column measurement itself and the error in the airmass factor used for the conversion to vertical columns. From several validation campaigns and intercomparison exercises, the following errors are estimated:

Table 4.2.7.3: Accuracy of DOAS data products

Trace gas column	error
O_3	<2%
NO_2	<5%
BrO	<10%
OClO	<12%
SO_2	<15%
H_2O	<4%
HCHO	<20%
NO_2 profile	To be determined
PSC	To be determined

An additional uncertainty arises from the difference in measurement volume and measurement time when compared to the SCIAMACHY measurements. This aspect will have to be studied in more detail during the project to reduce the uncertainties as much as possible by selecting the appropriate ground-based measurements for comparison.

Geophysical location, time period and frequency of measurements

The proposed network of DOAS instruments for the validation of SCIAMACHY data products is summarised in Table 4.2.7.4. In addition to the 5 existing stations, three new measurement locations will be operated in tropical regions.

Table 4.2.7.4: DOAS network for SCIAMACHY validation. Stations with a * are new stations. (i) in co-operation with KMNI/Netherlands; (ii) in co-operation with IRF/Kiruna; (iii) in co-operation with AWI Bremerhaven, (iv) in co-operation with UNEP

Station	Latitude	Longitude	Operator
Ny-Ålesund (iii)	79°N	12°E	(IUP Bremen)
Kiruna (ii)	68°N	20°E	(IUP Heidelberg)
Bremen	53°N	8°E	(IUP Bremen)
*Merida (iii)	8°N	71°W	(IUP Bremen)
*Surinam (i)	5,75 N	55.2 °W	(IUP Heidelberg)
*Nairobi (iv)	1°S	36°E	(IUP Bremen)
Neumayer (iii)	70°S	8°W	(IUP Heidelberg)
Arrival Heights	78°S	167°E	(NIWA)

All DOAS instruments are operated continuously with the exception of short maintenance breaks and the polar night. The sensitivity of the instruments is highest during twilight and therefore the standard product are two measurements per day (AM and PM value). To improve the temporal coincidence with the SCIAMACHY measurements, data can also be analysed for the time of the ENVISAT overpass, albeit with larger error bars. This proved to be useful for those absorbers with strong diurnal changes (OClO, BrO, possibly also NO_2) but for O_3 the more accurate measurements during twilight are to be preferred.

Validation method

This project concentrates on the provision of validation measurements from high quality ground-based sensors. Measurements will address both near real time and off-line lv2 data products of SCIAMACHY. The main objectives are

1) to provide continuous validation data sets for about 24 months from ground-based measurements on a number of stations that span from southern high latitudes (Antarctica), across the Tropics and mid-latitudes to the northern high latitudes (Arctic).
2) to provide these data in a suitable form for other validation activities of instruments (e.g. SCIAMACHY, MIPAS or GOMOS) integrated onboard the ENVISAT satellite
3) to validate SCIAMACHY near real time and off-line level-2 data products for the available stations with the established data-set
4) to study the influence of geophysical (SZA, latitude, meteorology, albedo, ...) and SCIAMACHY operational parameters on the accuracy of the data products,
5) to assess the accuracy of the data products
6) to give recommendations for possible improvements of the data products

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4.3 Aicraft-borne Validation

The validation by measurements from aircraft platforms (VAP) describes the validation of SCIAMACHY level 2 and off-line data products with measurements performed on board of the DLR's meteorological research aircraft Falcon 20. The measurements will be performed using three different types of remote sensing instruments: The Airborne SUbmillimeter wave Radiometer (ASUR), operated by IUP Bremen, the Ozone Lidar EXperiment (OLEX) operated by DLR and the Airborne MultiAxis Differential Optical Absorption Spectrometer AMAXDOAS developed and operated by both IUP Bremen and IUP Heidelberg. The target species addressed by both instruments are:

ASUR:	profiles of O_3, H_2O, N_2O, ClO, and BrO in the stratosphere
OLEX:	profiles of O_3, aerosol extinction, aerosol/molecular backscatter ratios and particle depolarisation in the stratosphere
AMAXDOAS:	stratospheric and tropospheric columns of O_3, NO_2, BrO, and OClO

The VAP activity is closely related to balloon-flights also proposed as part of the SCIAMACHY validation effort. The main objectives addressed are: to perform extensive validation measurements during a series of flights in the northern, mid- and tropical- latitudes, to use the aircraft data to extrapolate localised balloon measurements to the SCIAMACHY pixel, to perform an overall assessment of the SCIAMACHY data products accuracy, to give recommendations on possible improvements for the data products, and to make the data available for other ENVISAT related validation activities

Scheduled flights and validation strategy

For SCIAMACHY validation it is planned to perform two main campaigns. Both will consist of large-scale longitude cross sections from the polar regions to the tropics as well as latitudinal cross section at polar latitudes at about 70°N. The two campaigns are performed under different seasonal conditions. Each campaign consists of several flight missions for dedicated case studies in the mid-latitude/Arctic as well as mid-latitude/tropical region. In the northern part at high altitudes, additional case studies will be flown, e.g. in the east west direction, where more than one adjacent orbit of SCIAMACHY can be linked during a single flight. In particular, the northern route flies from Munich via Kiruna in northern Sweden to Spitzbergen and then across to Iceland and Greenland. This will enable both air pollution measurements over Europe and the stratosphere at the end of summer prior to the spin up of the polar vortex to be studied. The southern route flies from Munich to Yaounde on the west side of Africa and then across to Kenia and to the Seychelles. This route has as its major objective the validation of SCIAMACY data products of significance for air quality and the study of biomass burning and convective uplifting.

The campaigns are scheduled to take place in September 2002 and February 2003, respectively. For each of these campaigns a total of about 50 flight hours within a period of 3-4 weeks are considered.

4.3.1 Validation of SCIAMACHY level-2 data products using OLEX Lidar on board of the Falcon aircraft

A. Fix, C. Kiemle

Related ESA-AO: # 349

The aim of the project is to contribute to the SCIAMACHY validation activities using the airborne lidar OLEX. The measurements will be performed in conjunction with two other remote sensing instruments (ASUR and ADOAS) on board of the DLR research aircraft Falcon 20. The flight patterns will be co-ordinated with overpasses of the ENVISAT spacecraft and the flights of balloons, if applicable, which will be launched in the framework of the planned SCIAMACHY validation campaigns. Measurements performed by the airborne lidar are stratospheric O_3 profiles and stratospheric aerosol distribution with high spatial resolution, as well as the development and existence of polar stratospheric clouds (PSC). The planned missions will include the measurement of large-scale longitudinal and latitudinal cross-sections in polar, mid-latitude and tropical regions under different atmospheric conditions.

Introduction

In order to establish the reliability and accuracy of the measurements made by SCIAMACHY an adequate data set for the validation has to be derived from independent ground-based, airborne and satellite-borne measurements. A suitable measurement technique is atmospheric sounding with airborne lidar systems.

The operation of a lidar on board of an aircraft gives easy access to remote locations but also provides the flexibility to sound the atmosphere exactly where the satellite is measuring and, by moving along a predefined direction, to add the dimension which is missing in measurements from fixed positions and also balloon-borne experiments.

Validation Instrument

The main objective of this activity is the validation of SCIAMACHY data products by independent measurements performed by means of the airborne Ozone Lidar Experiment OLEX. These products will be derived from applying two different lidar techniques. The backscatter lidar technique performed at different wavelengths gives the optical properties of aerosols and PSCs while the differential absorption lidar technique (DIAL) applied in the ultraviolet spectral range allows to retrieve the ozone number density with a high spatial resolution. The DIAL technique does not need any calibration of the received signals and, being an active optical method, it is an independent measurement technique particularly well suited to validate passive satellite sensors such as SCIAMACHY.

The OLEX system on board of the research aircraft Falcon (see Figure 4.3.1.1) is a vertically upward pointing 4-wavelength lidar. It consists of two lidar transmitters. One is a Nd:YAG laser with second and third harmonic generation (i.e. 1064nm, 532nm, and 355nm). The other is a Xe:Cl excimer laser at 308nm. The two UV wavelengths (308nm and 355nm) are used to retrieve ozone profiles from about 2 km above the flight level to 26 km altitude by means of the differential absorption lidar (DIAL) technique. From the ratio of the backscatter signals at these two wavelengths – one of them is being absorbed by ozone while the second is not – profiles of ozone number density can be calculated.

Furthermore, the returns at the three Nd:YAG wavelengths are carrying information about size distribution of the scattering particles. The capability to measure the cross polarised return at 532 nm allows for phase discrimination (ice/water discrimination, PSC classification). In the proposed validation activities by airborne measurements OLEX will be one of three payload instruments installed on board of the DLR research aircraft Falcon 20.

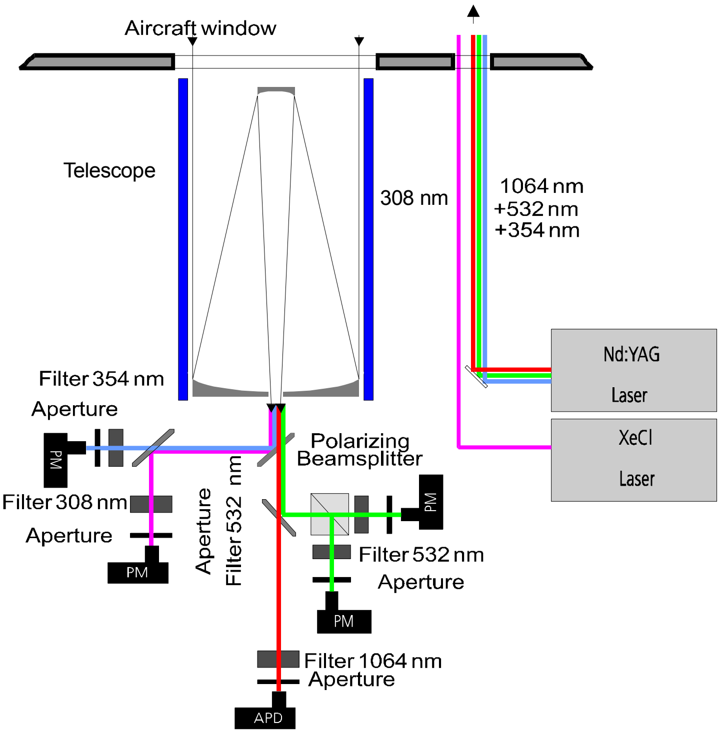

Figure 4.3.1.1: Schematic set-up of the OLEX system

Products to be validated

- Ozone profiles from 2 km above flight level to 26 km altitude
- Ozone columns (tropospheric contribution must be estimated)
- Aerosol optical properties: Vertical profiles of the atmospheric backscatter ratio at four wavelengths and colour ratio.
- Polar stratospheric clouds: Discrimination of type Ia, Ib and II, vertical distribution along the flight path, vertical profiles of backscatter ratio, colour ratio.

The accuracy, precision, and resolution for the parameters to be derived are listed in Table 4.3.1.1. These figures have been carefully assessed in past measurement campaigns.

Table 4.3.1.1: Derived parameters, their accuracy/precision and resolution

Species	Parameter	Accuracy/ Precision	Resolution Horizontal	Resolution Vertical
Aerosols	Backscatter ratio	5%	30 km	150 m
	Optical depth (OD)	10% for OD<3		
Polar Stratospheric Clouds	Geometric distribution		100 m	50 m
	Type classification			
Ozone	Number density	4%	30 km	700 m

It should be noted that the values for the resolution are typical but can be adapted depending on the required accuracy. The precision is generally enhanced when the signals are averaged over a larger vertical range or horizontal range, respectively, resulting in a reduced horizontal or vertical resolution.

Geophysical location, time period and frequency of measurements

Two main validation campaigns will be performed. Both comprise large-scale longitude cross sections from the polar regions to the tropics as well as latitudinal cross section at polar latitudes at about 70°N. The two main campaigns are scheduled to be performed under different seasonal conditions. For further details of the planned flight legs see the overview about the airborne validation activities.

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The airborne OLEX is a state-of-the-art, compact, and reliable lidar system which could demonstrate its excellent capability throughout a number of national and international campaigns such as EASOE, SESAME, THESEO. A selection of papers with respect to results gained by means of this system can be found below.

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4.3.2 Validation of SCIAMACHY level-2 data products from air-borne Multi-axis-DOAS observation

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Related ESA-AO: # 349

Two DOAS instruments one for the UV and one for the visible spectral range will be installed on the German research aircraft Falcon. During several campaigns different atmospheric trace gases will be measured and provided for the validation of the SCIAMACHY instrument aboard ENVISAT. The validation data set comprises the total columns of O_3, NO_2, OClO, BrO, H_2O, SO_2, and HCHO, which are all 'near real time' products of SCIAMACHY. In addition, the specific viewing geometry of the AMAX- (airborne multi axis-) DOAS instruments allows to separate the tropospheric part from the total columns. These data are well suited for the validation of the tropospheric column data derived from SCIAMACHY nadir- and limb observations (scientific data products).

Introduction

The intention of this project is to provide longitudinal and latitudinal cross sections of validation data for several atmospheric trace gases using DOAS instruments on board the Falcon aircraft. This extends the successful work carried out with airborne DOAS as used aboard the German Airforce Transall during EASOE (European Arctic stratospheric Ozone Experiment 1992). In order to fit into the Falcon restrictions the system is updated, adapted and optimised. In particular the novel viewing geometry (Multi-axis) now allows measurements in several directions above and below the aircraft.

In order to observe simultaneously the whole UV-vis spectral range with an appropriate spectral resolution two instruments, one for the UV (≈300 to 400 nm) and one for the visible (≈400 to 700 nm) are required. To derive information on the vertical profiles of the measured species a novel viewing geometry will be applied, measuring light from several different directions below and above the aircraft. This set of (up to 10) different atmospheric absorption paths enables the vertical column densities at least above and below the aircraft to be retrieved; i.e. at an flight altitude corresponding to the tropopause height the data allow the separation of the stratosphere and the troposphere. For some of the atmospheric trace gases (most probably for O_3 and NO_2) it will even be possible from the aircraft DOAS observations to resolve the atmospheric trace gas profiles at moderate vertical resolution.

Validation instrument

To observe the entire UV/Vis spectral range two separate DOAS instruments one for the UV (≈300 to 400 nm) and one for the visible (≈400 to 700 nm) are used (see Table 4.3.2.1).

Table 4.3.2.1: Characteristics of the DOAS instruments

Instrument	UV	Visible
Wavelength range	330 – 465 nm	400 – 690 nm
spectral resolution	~0.5 nm	~1 nm
spectrometer	Acton SP 306	Acton SP 306
grating	600 grooves/mm	300 grooves/mm
dispersion	5.54 nm/mm	11.07 nm/mm
height of the entrance slit	6.5 mm	6.5 mm
detector	CCD array (1100 x 330 pixel)	CCD array (1100 x 330 pixel)
dimensions of the detector	26.4 x 7.92 mm	26.4 x 7.92 mm

The light will be transmitted to the entrance slits of the instruments using glass fibre bundles (see Figure 4.3.2.1). The viewing geometry requires both viewing angles below and above the flight altitude. It is planned to use two fibre bundles, which transmit the light from the upper and lower window where the telescopes are mounted. At the instrument's end the fibre bundles are split to supply both instruments.

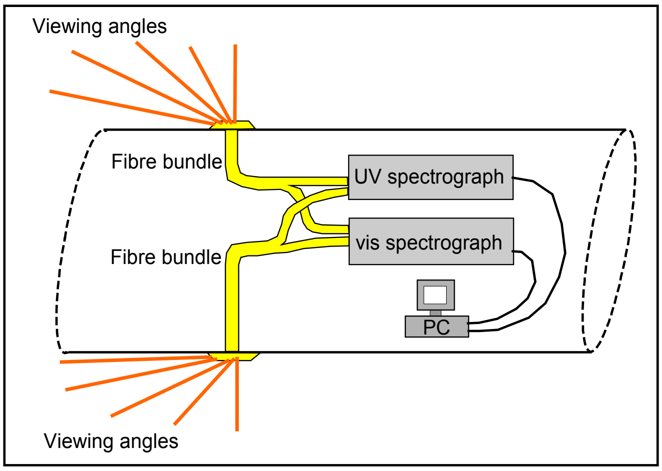

Figure 4.3.2.1: Scheme of the viewing angles above and below the aircraft's altitude and of the instrumental set-up inside the aircraft.

Accuracy/precision of measurements

The accuracy of the aircraft DOAS measurements depends on the uncertainties of the DOAS algorithm itself, the accuracy of the absorption cross section, and the uncertainties of the radiative transport modelling. While for species with strong atmospheric absorptions (like O_3, NO_2, H_2O and O_4) the uncertainty of the radiative transport modelling will constitute the dominant source of error, for species with weak atmospheric absorptions (like BrO, OClO, HCHO, IO) the uncertainty of the DOAS algorithm will dominate the total uncertainty.

Table 4.3.2.2 summarises the accuracy of the aircraft DOAS measurements. The errors of the tropospheric column density were estimated for clear sky conditions.

Table 4.3.2.2: Accuracy of the aircraft DOAS measurements. For the uncertainty of the tropospheric column clear sky conditions were assumed.

Trace gas	Accuracy of the DOAS algorithm	Accuracy of the tropospheric column	Accuracy of the stratospheric column
O_3	**<2%**	**<10%**	**<3%**
NO_2	**<4%**	**<10%**	**<5%**
BrO	**<7%**	**<20%**	**<10%**
IO	**<25%**	**<30%**	**<30%**
OClO	**<12%**	**<50%**	**<15%**
SO_2	**<15%**	**<20%**	**<20%**
H_2O	**<4%**	**<7%**	**<15%**
O_4	**<4%**	**<7%**	**<15%**
HCHO	**<20%**	**<25%**	**<25%**

Geophysical location, time period and frequency of measurements

Besides a short test flight before the validation campaign two major campaigns are planned. It is also possible to perform additional short flights for the investigation of specific atmospheric conditions (e.g. SO_2 smog episodes during the east Europe winter heating period). The larger campaigns will provide extended longitudinal and latitudinal cross sections of measurements. For each of the large campaigns about 50 flight hours are scheduled.

• First campaign: To take place approximately 3 to 5 months after the launch of ENVISAT.

-North-south-part: Flight track from Munich to Kiruna, then to Spitsbergen and back to Munich.

-East-west part: Flight track from Munich to the Seychelles and back. This part can be performed directly after the north-south part or with a temporal gap depending on atmospheric conditions and validation requirements.

• Second campaign: About 6 to 12 months after the launch of ENVISAT. It is planned that the atmospheric conditions should be significantly different from those during the first campaign to provide validation data for different atmospheric conditions. The flight tracks should be similar to those of the first campaign.

Validation method

For the evaluation of the measured spectra the DOAS method is applied. The trace gas absorptions in the measured spectra are analysed using the same wavelength ranges and fitting parameters as applied for the data analysis of SCIAMACHY. This will reduce systematic differences between both data sets. For a variety of trace gases (like O_3, NO_2, and BrO) commonly agreed parameters for the DOAS algorithms already exist (se e.g. Van Roozendael et al., [1999]). For much of the remaining species (e.g. IO, OClO, HCHO, SO_2) the sensitivity of the results to the variation of the analysis parameters will be investigated as part of this project. The information about the vertical profiles of the measured trace gases from the aircraft measurements is obtained from an inversion of the measured absorptions for different viewing angles. To convert this information into height profiles (in the simplest case the separation of the stratospheric and tropospheric column density) radiative transport modelling has to be applied. Appropriate models exist already both in Bremen and Heidelberg, which have to be adapted to the different light paths of the AMAX-DOAS measurements.

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4.3.3 Validation of SCIAMACHY level-2 data using the ASUR sensor on board the Falcon Aircraft

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Related ESA-AO:# 349

Since 1991 the Airborne SUbmillimeter Radiometer ASUR on board the German research aircraft FALCON contributed to all major European Arctic ozone campaigns [1-3], as well as to several satellite validation experiments [4-6]. Recently, during the international SOLVE / THESEO 2000 ozone campaign ASUR participated on board the NASA DC-8. During the SCIAMACHY (ENVISAT) validation campaign ASUR will be operated again on board the FALCON together with the OLEX lidar and the newly developed AMAXDOAS spectrometer. Validation instruments on board the FALCON aircraft are essential for the SCIAMACHY validation and specifically mentioned for the core campaign. ASUR is a component of the national core validation activity, and is a major part of the German SCIAMACHY validation contribution [7]. Two major campaigns during the main validation phase are planned. The missions will take place at different seasons over high, middle and tropical latitudes. Objectives of this project are the validation of operational level-2 near-real time, off-line, and experimental data products provided by SCIAMACHY and other sensors on ENVISAT.

The Sensor

The ASUR sensor is a passive submillimeter wave heterodyne radiometer. It is operated on board a highflying aircraft to avoid absorption by tropospheric water vapor [8]. During the last years the instrument has been improved considerably with respect to sensitivity and frequency range, thus enhancing the number of detectable molecules, as well as the reliability and applicability as a tool for atmospheric research and for satellite sensor validation. The key components of the radiometer consist of an appropriate aircraft window, a quasi-optics including a calibration unit and a single-side-band (SSB) filter, a tunable local oscillator, a liquid Helium cooled low noise superconducting (SIS) mixer, and an acousto-optical spectrometer.

The sensor is working in the frequency range 604 - 662 GHz where the Helium-cooled superconducting mixer permits low system noise temperatures of 500 - 1000 K (SSB). For the acousto-optical spectrometer a frequency resolution of 2 MHz within 1.5 GHz bandwidth is obtained.

Retrieval of vertical profiles

Using an up-looking geometry with a zenith angle of approximately 78 degree, thermal emission from rotational molecular lines is detected. The spectrally resolved pressure broadened line shape allows to retrieve vertical profiles of volume mixing ratios of the trace gases. The optimal estimation method has been used to analyse measured O_3, N_2O, ClO, HNO_3, and HCl spectra on an operational basis. Profile features are specified in the following table.

The vertical resolution, as well as the accuracy, both typically deteriorate from lower to higher altitudes (indicated by the interval). The horizontal resolution is limited by the integration time needed to obtain a sufficient signal-to-noise ratio. Besides the above mentioned species, the ASUR frequency range contains spectral signatures of CH_3Cl, HO_2, H_2O, and BrO, which need off-line analysis in order to obtain profile information. Some of the species will be measured simultaneously by ASUR (e.g. O_3/HCl, ClO/BrO, HNO_3/HO_2 or ClO/HO_2), others will be observed sequentially. Switching between molecules needs 2-3 minutes, integration time to obtain sufficient signal-to-noise ratio is usually 1-5 minutes depending on line strength.

Table 4.3.3.1: Specifications of ASUR operational data products

Molecule	**O_3**	**N_2O**	**ClO**	**HNO_3**	**HCl**
Altitude range	15 - 55 km	15 - 45 km	15 - 45 km	15 - 40 km	15 - 55 km
Vertical resolution	7 - 20 km	8 - 16 km	8 - 17 km	7 - 17 km	7 - 18 km
Horizontal resolution	12 km	25 km	30 km	30 km	12 km
Precision	0.12 ppm	0.01 ppm	0.05 ppb	0.5 ppb	0.1 ppb
Accuracy	0.4 - 1.1 ppm	0.03 - 0.05 ppm	0.08 - 0.13 ppb	0.8 – 1.4 ppb	0.2 - 0.5 ppb

Figure 4.3.3.1 shows typical vertical profiles for ClO, HCl, and O_3 as measured during SOLVE/ THESEO 2000. The retrieval algorithm here uses 2 km altitude steps. Error bars indicate measurement noise (dark red) and total error (light yellow) including a conservative systematic error estimation. Main error sources are statistical noise, instrumental uncertainties, inaccurate model parameters, uncertainties in spectroscopic data, and improperly selected a priori information. Smoothing caused by the limited vertical resolution has also to be considered in particular when compared to profiles obtained by other sensors with higher resolution. For a proper comparison the profiles have to be folded with the ASUR averaging kernel functions.

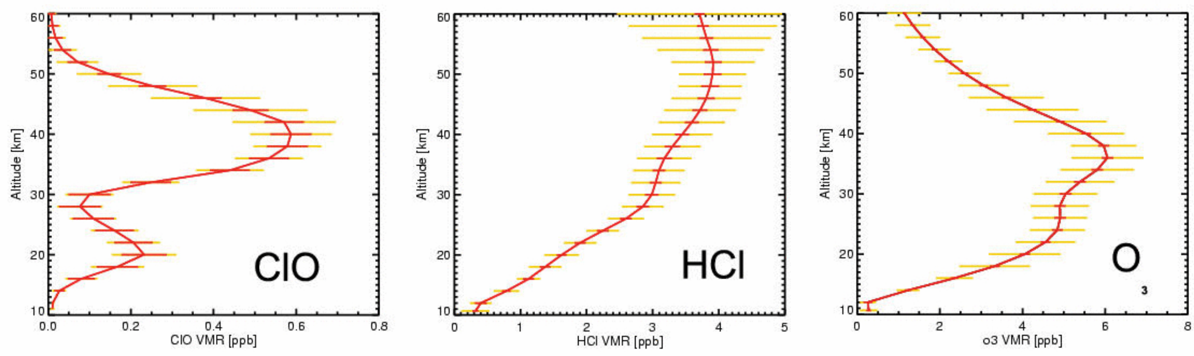

Figure 4.3.3.1: Vertical profiles of ClO, HCl, and O_3 obtained from ASUR measurements in winter 1999/2000.

Validation Method

Height information of stratospheric constituents such as ClO, HCl, N_2O, O_3, HNO_3, CH_3Cl, H_2O, HO_2, and BrO can be observed from microwave thermal emission lines. Using non-linear inversion techniques vertical profiles from 15 to over 50 km altitude are retrieved with a vertical resolution of typically 6 km in the lower and 12 km in the upper stratosphere. ASUR measures volume-mixing-ratio (VMR) profiles along the flight producing 2-dimensional cross sections of stratospheric composition, and also provides columns of the above mentioned species. The flexibility of the aircraft allows to investigate small and medium scale spatial variations in the stratosphere closing the gap between locally limited balloon measurements and synoptic satellite data. The high stability and reproducibility of the measurements performed with ASUR make this technique well suited for validation campaigns of space borne sensors as successfully done for UARS (MLS, HALOE), ATLAS (MAS), ERS-2 (GOME) and ADEOS (ILAS).

The main objective of the ASUR proposal is the validation of operational level-2 near-real time, and off-line data products provided by the SCIAMACHY instrument such as O_3, N_2O, H_2O, BrO and ClO. The measured vertical profiles and/or column densities will be compared with the SCIAMACHY data products, differences will be analysed with respect to parameters affecting the SCIAMACHY data retrieval such as location and solar zenith angle, and recommendations on possible improvements will be given. Also a contribution to MIPAS validation will be made by HNO_3 measurements.

Two main campaigns are planned, both consisting of cross sections from the Arctic (Kiruna / Greenland) to tropical regions (Seychelles). They are scheduled for September 2002 and for February 2003, respectively. For each of these campaigns a total of about 50 flight hours within a period of 3-4 weeks are considered adequate. The aircraft flights will be scheduled in order to give optimum temporal and spatial coincidence with the SCIAMACHY observations. Data will also be used to complement localised ground-based and balloon-borne validation efforts.

Conclusion

During the last decade ASUR took part in several important ozone campaigns and validation experiments for satellite sensors. The sensor will now contribute to the SCIAMACHY validation efforts on board the German FALCON aircraft together with the OLEX lidar and the new AMAXDOAS instrument. Two campaigns in 2002 and 2003 ranging from the arctic to the tropics are planned. ENVISAT data products to be validated are vertical profiles and/or columns of O_3, N_2O, H_2O, ClO, BrO, and HNO_3 (MIPAS).

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4.4 Satellite Validation

Several satellite instruments, some of them with a longterm operation record and others which will be launched close to the date of ENVISAT start, will be available for comparison with results from the ENVISAT atmospheric chemistry experiments. In most cases satellite measurements provide near global coverage and, therefore, are well suited for global validation in space and time. As part of ESA's ACVT, the Satellite Intercomparison subgroup (ACVT-SI) will be involved in both, validating level-1 data (calibration characterization) by comparing spectral data and validating level-2 trace gas data from coincident earth observations. Level-1 validation is particularly important for identifying possible error sources of secondary data products such as trace gas columns and profiles and will be crucial for preparing future data reprocessing.

The number of coincidences between SCIAMACHY and other space instruments will be sufficient high for obtaining a reasonable statistics on the validation within a short time period (several months) during the commissioning phase. Particular attention will be placed on validation with the GOME spectrometer which is following ENVISAT with a thirty minute delay in the same orbit. Since GOME spectral channels are identical to the short wave spectral channels of SCIAMACHY, there will be vast amount of data available for spectral comparisons as well as level-2 data validation, mainly trace gas columns and ozone profiles.

During commissioning phase validation satellite-to-satellite validation will be focusing on satellite instruments with a proven validation record. By the time of ENVISAT launch this will encompass among others: TOMS (first launch 1978), SBUV/2 (first launch 1978), SAGE II (launch 1984), HALOE (launch 1992), GOME (launch 1995), Mopitt (launch 1999), OSIRIS (launch 2000), SAGE III (launch 2001), and Saber (launch 2001). Individual groups involved in ACVT-SI include in many cases the PIs of the various satellite instruments used in validating SCIAMACHY. This will be valuable in interpreting and evaluating the validation results.

During the main validation phase seasonal cycle of the global trace gas data from SCIAMACHY can be investigated. More sophisticated methods to refine validation results are applicable. In addition, intercomparison between all three atmospheric chemistry experiments aboard ENVISAT can be performed for those trace gases at least measured by two of these instruments. It is expected that after data reprocessing following algorithm and calibration updates validation activities will be repeated to demonstrate improvement in the accuracy of the ENVISAT trace gas data.

During the main and longterm validation phase new satellite instruments will be launched complementing concurrently operating platforms. From the combination of data from several satellite missions a first attempt to homogenize the data sets for assessing global longterm trends shall be possible.

4.4.1 Validation of SCIAMACHY in-flight measured irradiances, radiances and selected tracegas products by comparison with measurements from independent satellite instruments

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Related ESA-AO: # 406, 651

In this study SCIAMACHY level 1 and level 2 data will be validated with the use of independent established satellite instruments. Later on the same SCIAMACHY data products will be intercompared to other new satellite instruments. The use of independent satellite measurements to validate SCIAMACHY products has the great advantage that the pole-to-pole coverage for all seasons is available and that the validation activities are not limited to a certain period and location. This paper gives an overview over the work plan and techniques used in the validation and intercomparison. All calibration activities will be performed on a case-study basis.

Workplan for level 1 data validation

There are several different types of SCIAMACHY Level 1 products: solar irradiances, earthshine radiances (in limb and nadir geometry), the fractional polarisation of the radiance, and solar/lunar occultation. Furthermore SCIAMACHY measurements cover a large spectral range, from the UV to the NIR (240 - 2400 nm), so several calibration sources have to be considered including satellite based measurements (Table 4.4.1.1) as well as theoretical calculations.

Table 4.4.1.1: Level 1 comparison with various satellite sensors, their expected accuracy, spectral range, and vertical resolution [1-5]

Instrument	Data Products	Accuracy	Range	Resolution
GOME	Solar Irradiance	3-5%	240-795 nm	0.2-0.4 nm
	Nadir Radiance			
OSIRIS	Solar Irradiance	≈ 5%	280-800 nm	1-2 nm
	Limb Radiance		15-60 km	>1 km
SBUV-2	Solar Irradiance	<3%	240-400 nm	1.1nm
SAGE III	Occultation Radiance		280-1030 nm	1-2 nm

Solar Irradiance

SCIAMACHY measurements are linked to the radiometric standard of GOME and SBUV type instruments. The probably most promising validation source is GOME as the solar irradiance and radiance measurements cover the same UV and visible wavelength region and have approximately the same spectral resolution as corresponding measurements by SCIAMACHY.

The large spectral wavelength range of SCIAMACHY is currently not covered by any other individual space-borne instrument. Therefore it is planned to use in addition to satellite sensors solar irradiance measurements obtained at the Kitt Peak National Solar Observatory [6,7].

Nadir Radiance

Because of its similarity both in design and observational geometry GOME measurements are planned to be used for the calibration of SCIAMACHY nadir radiances. In the infrared part of the spectrum which is not covered by GOME measurements, model calculations shall be performed using the spherical and pseudo-spherical radiative transfer codes CDI [8] and SCIATRAN, the latter an extension of the GOMETRAN model [2].

Limb Radiance

SCIAMACHY limb radiances shall be compared with limb measurements by the OSIRIS instrument. OSIRIS consists of an imaging spectrograph covering the spectral range between 280 nm and 800 nm and three near-infrared telescopes operating at 1.27 micrometers.

In order to gain information about spectral regions covered by SCIAMACHY but not by OSIRIS, radiative transfer model calculations with CDI and/or SCIATRAN shall be performed.

Solar and Lunar Occultation

Solar and lunar occultation spectra of SCIAMACHY can be directly compared with equivalent spectra provided by SAGE III. The spectral resolution is about a factor of five smaller than that of SCIAMACHY.

Polarisation

Because no internal light source of well-known polarisation is available, a direct in-flight monitoring of the polarisation properties of the instrument is not feasible. Therefore, only cross-checks using natural sources of polarised light can be performed. Several possibilities to verify the polarisation correction shall be investigated:

1. a theoretical study shall show if and how limb measurements may be used in this context. The main idea is to take limb measurements for tangent altitudes above about 30 km, i.e. altitudes where Rayleigh scattering dominates and the polarisation characteristics can be calculated.
2. using moon occultation spectra, which should show polarisation as a function of lunar phase. Since the relation between lunar phase and polarisation is currently not sufficiently known, a lunar polarisation database from the SCIAMACHY data themselves has to be build.
3. exploiting the fact that the sun is a non-polarised light source for polarisation cross checks.

Workplan for level 2 data validation

For the validation of level 2 data products satellite data from GOME/ERS-2, SAGEII/ERBS, TOMS/Earthprobe will be available; intercomparisons are planned to the new satellite instruments SABER/TIMED, QuikTOMS/ Taurus and SBUV2/NOAA-16 which have been recently launched or will be in the near future. Table 2 gives a summary of the data products to be validated by comparison with the various satellite sensors and the expected accuracy.

The level 2 trace gas validation with coincident independent satellite measurements will be carried out during all major validation phases as defined by ESA. Monthly means and seasonal dependencies will be determined and synoptic mapping will be used. Before launch of SCIAMACHY a database of satellite data used for validation is created and algorithms to find coincidences between SCIAMACHY and the other instruments are developed. The trajectory model to identify the collocation of air masses will be optimised. During the commissioning phase comparison to other satellite instruments will concentrate on those validation instruments which have after many years of operation and several algorithm upgrades achieved a high quality standard in their data products. The results of these validations will be concluded in recommendations for improving trace gas retrieval. During the main validation phase and long term validation phase (starting thereafter) the list of validation instruments will be extended to the new instruments, which have been or will be launched close to ENVISAT launch time. In the long term validation phase validation and intercomparison activities are continued in order to assess the data quality and to document improvements of updates of the retrieval algorithms. A data base for quick evaluation of algorithm development progress will be created which may be used after future regular updates of operational algorithms.

Table 4.4.1.2: Altitude, measurement type, accuracy, range and vertical resolution of validation and intercomparison measurements [1],[5],[9-12]; intercomparisons will be carried out only during main and long term validation phase

Instrument	Data Products	Altitude	Measurement type	Accuracy	Range	Resolution
GOME	O_3, NO_2 columns	800 km	nadir	5-15%	-	-
	O_3 profiles			10%	0-50 km	6-10 km
SAGE II	O_3, NO_2, H_2O profiles	610 km	occultation	5-15%	15-60 km	>2 km
TOMS	O_3 columns	500 km	nadir	5%	-	-
SBUV-2	O_3 profiles	870 km	nadir	10%	5-60 km	6-10 km
SABER	O_3, H_2O profiles	625 km	limb	10-15%	15-65 km	2 km
QuickTOMS	O_3 columns	800 km	nadir	5%		

Identifying collocated measurements

The simplest method for deriving collocations for comparisons between data of two different satellites is to look for *coincident measurements*. Two measurements are defined as coincident if they were taken within a certain time and within a certain distance to each other. For long lived substances, like ozone in the lower stratosphere, gradients in their horizontal distribution evolve from transport processes. Meridional transport is strongest in the winter hemisphere. At the edge of the polar vortex high ozone values arise which sharply decrease to both sides; thus the validation at the border of different air masses is rendered more difficult. A *trajectory model* enables to retrace the origin of air masses up to 10 days. By this method different air masses of two coincident measurements can be identified and collocated measurements within the same air mass can be found. An easier method for tracing the origin of air masses is the determination of potential vorticity (PV) distribution. In addition to the criteria given for potential and temporal coincidences an upper limit for the difference in PV can be defined. Instead of calculating zonal means, a presentation in the equivalent latitude system is advantageous. The later co-ordinate system is defined by the PV distribution.

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5. Non-German validation activities

5.1 Dutch validation activities

A. Pieters and H. Kelder

Coordination

The coordination of the international SCIAMACHY validation effort is performed by the SCIAMACHY Validation and Interpretation Group, a working group of the SCIAMACHY Science Advisory Group, and led by KNMI, the Netherlands. Chair: Hennie Kelder, general coordination: Ankie Piters and scientific secretary: Renske Timmermans

Support

The SCIAMACHY validation support office is located at KNMI. It maintains and updates the international SCIAMACHY validation web site http://www.sciamachy-validation.org/sv and gives support to individual scientists by e-mail (sciavalig@knmi.nl).

Product coordinators

The Netherlands deliver the product coordinators for ozone profile, water vapour column, T/p profile, UV index, clouds, radiance, irradiance, spectral surface reflectance, and polarisation.

Core validation

In the core validation programme defined by SCIAVALIG (see the SCIAMACHY Validation Handbook, August 1999, SDVS-02), the Netherlands are involved in the following activities:

validaion of radiance	with	GOME and AATSR
validation of polarisation	with	GOME and POLDER
validation of ozone columns	with	GOME, TOMS, Brewer/Dobson and data assimilation models
validation of ozone profiles	with	ozonesondes and data assimilation models
validation of water vapour columns	with	TOVS and radiosondes
validation of water vapour profiles	with	ECMWF data
validation of CO and CH4 columns	with	MOPITT
validation of T/p profiles	with	TOVS, radiosondes, and ECMWF data
validation of cloud cover and top height	with	MVIRI and AATSR
validation of aerosols	with	sun photometer
validation of UV index	with	models and groundbased measurements

AO validation

The complete international core validation programme is embedded in the ESA AO cal/val programme via AO 174. Apart from this a number of additional AO projects from the Netherlands have been submitted:

AO 174: Hennie Kelder, KNMI, "SCIAVAL, the SCIAMACHY validation programme, funded and agreed by the instrument providing agencies in Belgium, Germany and the Netherlands";

AO 241, Ilse Aben, SRON, "Validation of CO and METHane SCIAMACHY data products - COMETH";

AO 498, Erik Zoutman, TNO-TPD, "In-orbit validation/calibration of SCIAMACHY";

AO 548, Piet Stammes, KNMI, "SCIAMACHY validation and data usage: polarisation, radiance, cloud and aerosol";

AO 646, Albert Goede, KNMI, "Calibration of SCIAMACHY level 1 data";

AO 1111, Daan Swart, RIVM, "Envisat validation using RIVM tropospheric and stratospheric ozone lidars in Bilthoven (NL) and Lauder (NZ) (old id: 9003)";

Calibration

The Calibration working group of the SSAG is also led by the Netherlands. SRON is responsible for the in-flight calibration.

Algorithm verification

The Netherlands are involved in SCIAMACHY algorithm verification via the ACVT subgroup SCCVT (SCIAMACHY Calibration and Verification Team).

5.2 Belgium validation activities

J.-C. Lambert and P.C. Simon

The international SCIAMACHY validation effort [1,2] is coordinated by the SCIAMACHY Validation and Interpretation Group (SCIAVALIG). It contributes to the Envisat validation campaign through participation in the ESA's Atmospheric Chemistry Validation Team (ACVT). SCIAMACHY validation includes an intensive correlative programme involving measurements from a variety of ground-, balloon-, aircraft- and satellite-based instruments. An overview of the Belgian contribution to Phase E of Envisat SCIAMACHY is given in a dedicated document [2], including activities related to the validation of the expected data products. The present document reviews the August 2001 status of the Belgian contribution to the planned correlative programme and gives details of its implementation plan. An updated version of this preliminary plan will be issued after the launch of Envisat, currently scheduled for November 2001.

Contribution to the SCIAMACHY Correlative Programme

Three Belgian institutes are actively involved in the geophysical validation of SCIAMACHY data products, namely:

- Belgisch Instituut voor Ruimte-Aëronomie / Institut d'Aéronomie Spatiale de Belgique (BIRA-IASB)
- Institut Royal Météorologique / Koninklijk Meteorologisch Instituut (IRM-KMI)
- Institut d'Astrophysique, Université de Liège (ULg)

They will contribute through:

- Acquisition of correlative data;
- Coordination of validation activities relying on ground-based monitoring networks;
- Correlative analysis of SCIAMACHY level-1b and level-2 data;
- Further development and validation of level-1b-to-2 retrieval algorithms.

Further details of the specific contribution of Belgium are given hereafter.

SCIAMACHY Data Products

The SCIAMACHY spectrometers will measure the direct solar spectral irradiance and the Earth spectral radiance (level-1 data) in the ultraviolet (UV), visible (Vis) and near infrared (IR) wavelength range (from 220/240 nm to 2380 nm), at moderate spectral resolution (0.2 nm to 1.5 nm). The upwelling radiance will be observed in different viewing geometries: nadir, limb, and solar and lunar occultation. The vertical column and distribution of atmospheric species and parameters (level-2 data) will be inferred from the radiometric measurements. Geophysical data products that will be validated by Belgian scientists are highlighted in the list of SCIAMACHY data products displayed in Table 5.2.1..

Table 5.2.1: SCIAMACHY data products. Grey-shaded products will be validated by Belgian groups.

SCIAMACHY Data Products	Nadir Geometry			Limb / Occultation Geometry		
	UV / Vis	IR	UV / Vis / IR	UV / Vis	IR	UV / Vis / IR
Level-2	O_3 NO_2 BrO SO_2* OClO* H_2CO* UV index	H_2O CO CO_2 N_2O CH_4 P T	Clouds Aerosols absorbing index	O_3 NO_2 BrO	H_2O CO CO_2 N_2O CH_4 P T	Aerosols
Level-1b	**Solar spectral irradiance** Earth spectral radiance in nadir, limb and occultation mode Earth fractional polarisation (6 spectral bands) Polarisation Monitoring Device subpixel radiance (7 spectral bands)					

*These molecules can be detected only under special conditions.

Core Validation

The Validation Requirements Document [1] elaborated by the SCIAVALIG identifies the need for a 'core' validation programme. The core activities encompass a minimal but essential validation of SCIAMACHY. These activities are under the responsibility of the Instrument Providers (Germany, The Netherlands, and Belgium). The contribution of Belgium to the Core Validation Programme is outlined in Table 5.2.2. It is coordinated by BIRA-IASB and funded by the Federal Office for Science, Technical and Cultural Affairs (OSTC).

Announcement of Opportunity (AO) Validation

Core validation activities will be complemented by validation projects routed through the ESA AO for the use of Envisat data. The SCIAMACHY Validation Handbook [2] gives a global overview of both the core validation and the selected AO validation proposals. As listed in Table 5.2.3, four AO proposals submitted by Belgian Principal Investigators (PI) were reviewed and approved by the ESA Scientific Board and external experts. They will be funded by OSTC through the PRODEX programme. The four Belgian proposals were also selected as contributors to the ACVT Core Programme.

The first two AO projects aim at the pseudo-global, long-term validation of ozone- and climate-related species (O_3, NO_y compounds, BrO, OClO, CO, CH_4, H_2CO) of SCIAMACHY, MIPAS, and GOMOS. The sensitivity of Envisat measurements to relevant parameters (e.g., latitude and solar zenith angle), as well as the needed link with other spaceborne sensors, will be investigated by means of correlative ground-based network observations inventoried in the next section. A hierarchy of modelling tools (asynoptic mapping, chemical-transport and radiative transfer models etc.) will support the study. Emphasising global aspects, the two network-based projects will be achieved in collaboration with other AO projects focusing on local or regional aspects.

Table 5.2.2: Core validation activities coordinated by BIRA-IASB.

SCIAMACHY Data Product	Validation Data		
	Data Source	**Frequency / Time**	**Estimated Accuracy or Precision**
Solar Spectral Irradiance	***SOLSTICE***	Daily	Accuracy: 170-320 nm: 5.7%; 280-420 nm: 7.9%
	SOLSPEC	TBD	Accuracy: from 5.1% at 240 nm to 2.5% at 850 nm
O_3 Column	Brewer and Dobson	Weather permitting, daytime	Accuracy: 2% (summer) to 5-7% (low sun and T)
	UV-visible DOAS	Twice daily, twilight	Accuracy: 2.5% (summer) to 5% (polar winter)
	FTIR	Weather permitting, daytime	Precision: 2-3%
O_3 Profile	Lidar	Weather permitting, night-time	Precision: 1% (15-35 km) to 15% (>40 km)
NO_2 Column	UV-visible DOAS	Twice daily, twilight	Accuracy: 5-10%
	FTIR	Weather permitting, daytime	Precision: 2-3%
NO_2 Profile	SAOZ-Balloon	A few/year, twilight	Accuracy: 5% (from 8 to 35 km)
	UV-visible DOAS	Twice daily, twilight	Accuracy: 10% on integrated stratospheric columns
BrO Column	ERS-2 GOME	Daily, mid-morning	Error budget assessment in progress
	UV-visible DOAS	Twice daily, twilight	Error budget assessment in progress
OClO Column	UV-visible DOAS	Chlorine activation, twilight	Error budget assessment in progress
N_2O Column	FTIR	Weather permitting, daytime	Precision: 2-3%
CO_2 Column	FTIR	Weather permitting, daytime	Precision: 2-3%
CO Column	FTIR	Weather permitting, daytime	Precision: 2-3%
CH_4 Column	FTIR	Weather permitting, daytime	Precision: 2-3%

Table 5.2.3: AO validation projects coordinated by Belgian Principal Investigators.

AO ID	Proposal Title	PI	Institute(s)
126	FTIR-val: Validation of Envisat-1 level-2 products related to lower atmosphere O_3 and NO_y chemistry by an FTIR quasi-global network	M. De Mazière	BIRA-IASB (PI), ULg
158	CINAMON: Characterisation, INterpretation, Application, and Maturation of key Ozone-related Envisat-1 level-2 products, using correlative observations associated with the NDSC	J.-C. Lambert	BIRA-IASB
300	Validation of ozone, temperature and water vapour measurements from SCIAMACHY, MIPAS and GOMOS aboard the Envisat satellite	D. De Muer	IRM-KMI
330	UV studies using Envisat products: solar measurements validation and surface UV fields determination	P. Simon	BIRA-IASB

The objective of AO project ID-300 is to validate vertical column and profile of ozone, and profiles of temperature and water vapour, from SCIAMACHY, MIPAS, and GOMOS. Use will be made of UV spectrophotometer measurements and ozone soundings that are performed at Uccle. The results will be presented as a function of various variables such as (in the case of ozone) solar zenith angle, total ozone amount and cloud fraction.

In AO Project ID-330, SCIAMACHY irradiance data will be investigated using direct solar flux measurements from time-synchronous spacecraft: SOLSTICE/UARS (118-420 nm), SOLSTICE/SORCE (115-320 nm), SIM/SORCE (200-2000 nm), SOLSPEC/Alpha (180-3200 nm). MgII index will be generated and used to detect additional instrumental problems.

Most of correlative measurements generated by Belgian groups will be stored on the Envisat validation database at NILU. Regarding correlative measurements generated by other groups in the frame of AO ID-126 and ID-158, most of them will be delivered to NILU either by BIRA-IASB, or by his Co-Investigators when they are already committed to do so in the frame of other AO projects, namely AO ID-179, 191, 331, 360, 429, and 701. Practically, BIRA-IASB will generate a list of agreed data sets with his Co-Investigators and ESA. Subsequently BIRA-IASB will coordinate the delivery of the agreed data sets to the NILU facility.

Overall Planning

Planning of Belgian activities comply with the requirement to ensure the quality of SCIAMACHY data products through all phases of the instrument lifetime [1]:

- Commissioning phase (L+3 to L+6): Preliminary quality assessment of level-1 and level-2 data products.
- Main validation phase (L+6 to L+18): Detailed characterisation studies and quality assessments.
- Long-term validation phase (from L+18 onwards): To ensure data quality throughout Envisat lifetime, among others to allow the accurate detection of trends in geophysical parameters.

Correlative Data Acquisition Plan

Correlative studies planned by Belgium rely on measurements from ground-, balloon-, and satellite-based instruments. The contributing Belgian institutes will generate the correlative measurements listed in Table 5.2.4. The FTIR spectrometer installed at Reunion Island will operate first during a campaign scheduled within the commissioning phase. NDSC-type routine operation could be envisaged for the main validation phase. All other ground-based instruments perform on an operational basis. Starting from GDP level-1b data produced at the German Aerospace Centre (DFD/DLR) on behalf of ESA, BIRA-IASB will also generate GOME BrO level-2 data sets using the GWinDOAS software package [4].

Table 5.2.4: Correlative measurements generated by Belgian groups.

Station	Location	Instrument	Data Product	Institute
Harestua	Norway	UV-visible DOAS	O_3, NO_2, BrO, and OClO* total column; colour index	BIRA-IASB
Uccle	Belgium	Brewer	O_3 total column	IRM-KMI
		Dobson	O_3 total column	
		Ozonesonde	O_3, p, T, and humidity vertical distribution	
Jungfraujoch	Swiss Alps	UV-visible DOAS	O_3 and NO_2 column; colour index	BIRA-IASB
		FTIR	O_3, NO_2, NO, N_2O, HNO_3, H_2CO, CO, and CH_4 total column	ULg (PI) + BIRA-IASB
			O_3, N_2O, HNO_3, CO, and CH_4 vertical distribution	
O.H.P.	France	UV-visible DOAS	BrO, NO_2, O_3, and OClO* total column	BIRA-IASB
			BrO, NO_2, O_3, and H_2CO tropospheric column	
Saint Denis	Reunion Island	UV-visible DOAS	BrO, NO_2, and O_3 total column; colour index	BIRA-IASB
			BrO, NO_2, O_3, and H_2CO tropospheric column	
Reunion		FTIR	O_3, NO_2, NO, N_2O, HNO_3, H_2CO, CO, and CH_4 total column	
			O_3, N_2O, HNO_3, CO, and CH_4 vertical distribution	
Global (sunlit part)		ERS-2 GOME**	BrO total column	BIRA-IASB

* In case of chlorine activation.
** ESA satellite instrument, BIRA-IASB level-1b-to-2 processing.

Core, AO-126, and AO-158 activities rely also on the availability of ground-based measurements generated by many other groups. In general, those measurements are associated with the international Network for the Detection of Stratospheric Change (NDSC) [5], in which the three contributing institutes are active. NDSC Investigators 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 quick data delivery is crucial, such as satellite validation, arrangements may be organised on a case-by-case basis with individual NDSC Investigators to foster delivery of preliminary data. Network-based projects coordinated by Belgium are based on this principle. A fast delivery of correlative data for SCIAMACHY validation has been arranged through collaboration with about two dozen European and non-European institutes acknowledged in the Tables presented in the following subsections. For most of the stations and instruments involved in SCIAMACHY validation, a delivery within a few weeks is expected during the Commissioning Phase and within a few months during the Main Validation Phase. Several stations will continue fast delivery of preliminary data for routine verification in the long term.

Core validation will focus on measurements performed (a) by Belgian groups and (b) by other groups at so-called Primary Stations of the NDSC, covering the Arctic and the Antarctic, Northern and Southern middle latitudes, and the Tropics. This set of core validation stations encompass a broad range of representative atmospheric and measurement conditions. Based on a larger set of stations and techniques, AO studies will extend the core results to the pseudo-global domain and will yield access to further studies.

FTIR Spectrometer

The vertical column amount throughout the day of O_3, NO_2, NO, N_2O, HNO_3, H_2CO, CO, and CH_4 will be collected from a network of NDSC-certified Fourier Transform IR (FTIR) spectrometers [6] listed in Table 5.2.5. For most of the stations, the frequency of observation will vary from 2 weeks/month during commissioning phase, to 6x2 weeks/year during main and long-term validation phases. Limited information on the vertical distribution of O_3, N_2O, HNO_3, CO, and CH_4, can also be retrieved from FTIR measurements. Such height-resolved data products are under development at several sites, however, the final list of contributing sites will be determined later.

Table 5.2.5 Contributing FTIR spectrometers.

Station	Location	Lat.	Long.	Alt.	Species	Institute
Eureka	Canada	80.05N	86.42W	610m	All but H_2CO	MSC
Ny-Ålesund	Svalbard	78.91N	11.88E	20m	All	AWI
Kiruna	Sweden	67.84N	20.41E	419m	All but CO and H_2CO	IRF/IMK/STEL
Harestua	Norway	60.22N	10.75E	596m	O_3, N_2O, CH_4, and HNO_3	IVL
Zugspitze	German Alps	47.42N	11.98E	2964m	O_3, NO_2, N_2O, H_2CO, CH_4, CO	IFU/FHG
Jungfraujoch	Swiss Alps	46.47N	7.98E	3580m	All	ULg/BIRA-IASB
Kitt Peak	Arizona	31.9N	111.6W	2090m	CO and O_3	NASA/LaRC
Izaña	Tenerife	28.3N	16.5W	2367m	All but CO and H_2CO	IMK
Mauna Loa	Hawaii	19.54N	155.58W	3397m	TBC	UDE
Reunion*	Reunion Island	20.85S	55.47E		All	BIRA-IASB
Wollongong	Australia	34.4S	150.9E	30m	All but H_2CO	Uni. Wollongong
Lauder	New Zealand	45.05S	169.68E	370m	All but H_2CO	NIWA
Arrival Heights	Antarctica	77.82S	166.65E	190m	TBC	NIWA/UDE

*This instrument will operate during a campaign currently scheduled within the commissioning phase. NDSC-type routine operation could be envisaged for the main validation phase.

UV-visible Spectrometer

O_3, NO_2, BrO, and OClO column amount at twilight will be acquired/collected from a network of NDSC UV-visible Differential Optical Absorption Spectroscopy (DOAS) instruments (NIWA, SAOZ, and other DOAS systems) [7,8].

Table 5.2.6: Contributing UV-visible DOAS spectrometers.

Station	Location	Lat.	Long.	Alt.	Species	Institute
Ny-Ålesund	Svalbard	78.91N	11.88E	20m	O_3, NO_2, BrO, OClO*	IFE, NILU
Thule	Greenland	76.51N	68.76W	220m	O_3, NO_2	DMI
Scoresbysund	Greenland	70.48N	21.97W	10m	O_3, NO_2	CNRS/DMI
And¢ya	Norway	69.28N	16.028E	360m	O_3, NO_2, BrO, OClO*	NILU
Kiruna	Sweden	67.84N	21.06E	419m	NO_2	NIWA
Sodankylä	Finland	67.37N	26.67E	179m	O_3, NO_2	CNRS/FMI
Zhigansk	Eastern Siberia	66.72N	123.40E	50m	O_3, NO_2	CNRS/CAO
Salekhard	Western Siberia	66.53N	66.67E	419m	O_3, NO_2	CNRS/CAO
Harestua	Norway	60.22N	10.75E	596m	O_3, NO_2, BrO, OClO*	BIRA-IASB
Bremen	Germany	53.11N	8.86E		O_3, NO_2, BrO, OClO*	IFE
Aberystwyth	U.K.	52.42N	4.07W	20m	O_3, NO_2	U. Wales
Jungfraujoch	Swiss Alps	46.47N	7.98E	3580m	O_3, NO_2	BIRA-IASB
Station	**Location**	**Lat.**	**Long.**	**Alt.**	**Species**	**Institute**
O.H.P.	France	43.94N	5.71E	684m	O_3, NO_2, BrO, OClO*	BIRA-IASB, CNRS
Mauna Loa	Hawaii	19.54N	155.58W	3397m	NO_2	NIWA
Kaashidhoo	Maldives	4.97N	73.47E	0m	O_3, NO_2, BrO	IFE
Tarawa	Kiribati	1.37N	172.93E	0m	O_3, NO_2	CNRS
Nairobi	Kenya	1.25S	36.75E	1650m	O_3, NO_2, BrO	
Saint Denis	Reunion Island	20.85S	55.47E		O_3, NO_2, BrO	BIRA-IASB, U. Réunion
Bauru	Brazil	22.35S	49.03W	300m	O_3, NO_2	CNRS/UNESP
Lauder	New Zealand	45.05S	169.68E	370m	NO_2, BrO, OClO*	NIWA
Kerguelen	Kerguelen Islands	49.36S	70.26E	10m	O_3, NO_2	CNRS
Macquarie	New Zealand	54.50S	158.95E	6m	NO_2	NIWA
Dumont d'Urville	Antarctica	66.67S	140.01E	20m	O_3, NO_2	CNRS
Rothera	Antarctica	67.57S	68.13W	10m	O_3, NO_2	BAS
Arrival Heights	Antarctica	77.82S	166.65E	190m	O_3, NO_2, BrO, OClO*	NIWA

* In case of chlorine activation.

Dobson and Brewer Spectrophotometers - Global UV Radiometer

O_3 vertical column amount throughout the day will be acquired and collected from selected Dobson [9] and Brewer [10] UV spectrophotometers operating at NDSC stations, and from global UV radiometers [11].

Table 5.2.7: Contributing Dobson, Brewer, and GUV.

Station	Location	Lat.	Long.	Alt.	Instrument	Institute
Ny-Ålesund	Svalbard	78.91N	11.88E	20m	Dobson, GUV	NILU
Thule	Greenland	76.51N	68.76W	220m	Dobson	DMI
Tromsö	Norway	69.65N	18.95E	100m	Dobson, Brewer, NILU-UV	NILU
And¢ya	Norway	69.28N	16.028E	360m	GUV	
Sondre Str¢mfjord	Greenland	67.02N	50.62W	300m	Brewer	DMI
Sodankylä	Finland	67.37N	26.67E	179m	Brewer	FMI
Yakutsk	Eastern Siberia	62.02N	129.63E	98m	Brewer	CAO
Kjeller	Norway	60.0N	11.1E		NILU-UV	NILU
Oslo	Norway	59.91N	10.72E	90m	Dobson, Brewer, GUV	NILU
Uccle	Belgium	50.80N	4.35E	100m	Dobson, Brewer	KMI
Hohenpeißenberg	Germany	47.80N	11.02E	975m	Dobson, Brewer	DWD
Arosa	Swiss Alps	46.78N	9.68E	1840m	Dobson, Brewer	ETH
Bordeaux	France	45.83N	0.53W	73m	Dobson	U. Bordeaux
O.H.P.	France	43.94N	5.71E	684m	Dobson	U. Reims
Lauder	New Zealand	45.05S	169.68E	370m	Dobson	NIWA
TBD	Chile	TBD	TBD		3 GUV (optional)	NILU
Vernadsky/Faraday	Antarctica	65.22S	64.32W	10m	Dobson	BAS/KTSU
Halley	Antarctica	75.58S	26.77W	35m	Dobson	BAS

Ozone Lidar

Ozone profile measured at night in the stratosphere (typically 20-50 km) by differential absorption lidar will be collected from pole to pole at ground-based stations listed in Table 5.2.8.

Table 5.2.8: Contributing ozone lidars.

Station	Location	Lat.	Long.	Alt.	Institute
And¢ya	Norway	69.28N	16.028E	360m	CNRS/NILU
Sodankylä	Finland	67.37N	26.67E	179m	FMI
Hohenpeißenberg	Germany	47.80N	11.02E	975m	DWD
O.H.P.	France	43.94N	5.71E	684m	CNRS
Saint Denis (opt.)	Reunion Island	20.85S	55.47E	10m	CNRS
Lauder	New Zealand	45.05S	169.68E	370m	RIVM/NIWA
Dumont d'Urville	Antarctica	66.67S	140.01E	20m	CNRS

Ozone Microwave Radiometer

Ozone profile measured in the stratosphere (typically 20-60 km) by microwave radiometry will be collected from the five European NDSC stations listed in Table 5.2.9.

Table 5.2.9: Contributing ozone microwave radiometers.

Station	Location	Lat.	Long.	Alt.	Institute
Ny-Ålesund	Svalbard	78.91N	11.88E	20m	IFE
Kiruna	Sweden	67.84N	20.41E	419m	IMK/IRF
Bern	Swiss Alps	46.95N	7.45E	550m	U. Bern
Jungfraujoch	Swiss Alps	46.47N	7.98E	3580m	U. Bern/U. Bordeaux
Bordeaux	France	45.83N	0.53W	73m	U. Bordeaux

Ozonesonde

Ozone profile measured from ground up to burst point (about 30 km) by electrochemical ozonesonde will be acquired/collected from the list of stations displayed in Table 5.2.10.

Table 5.2.10: Contributing ozonesonde stations.

Station	Location	Lat.	Long.	Alt.	Institute
Thule	Greenland	76.51N	68.76W	220m	DMI
Bear Island (optional)	Norway	74.30N	19.01E		NILU
And¢ya	Norway	69.28N	16.028E	360m	NILU
Sodankylä	Finland	67.37N	26.67E	179m	FMI
Salekhard (optional)	Western Siberia	66.53N	66.67E	419m	CAO
Ørlandet	Norway	63.42N	9.24E		NILU
Yakutsk (optional)	Eastern Siberia	62.02N	129.63E	98m	CAO
Jokioinen	Finland	60.80N	23.48E		FMI
Gardermoen	Norway	60.12N	11.06E		NILU
Aberystwyth	U.K.	52.42N	4.07W	20m	U. Wales
Uccle	Belgium	50.80N	4.35E	100m	KMI
Hohenpeißenberg	Germany	47.80N	11.02E	975m	DWD
Payerne	Swiss Alps	46.49N	6.57E	500m	ETH/SMI
O.H.P.	France	43.94N	5.71E	684m	CNRS
Saint Denis	Reunion Island	20.85S	55.47E	10m	CNRS/U. Réunion
Lauder	New Zealand	45.05S	169.68E	370m	NIWA
Dumont d'Urville	Antarctica	66.67S	140.01E	20m	CNRS

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7. List of Acronyms

AAI: Absorbing Aerosol Index

AATSR: Advanced Along Track Scanning Radiometer

ACVT: Atmospheric Chemistry Validation Team

ACVT-GBMCD: ACVT-Ground-Based Measurements and Campaign Database

ACVT-SI: ACVT- Satellite Intercomparison

ADEOS: ADvanced Earth Observing Satellite

AMAX-DOAS: Air borne Multi-AXis DOAS

AO: Announcement of Opportunity

AOT: Aerosol Optical Thickness

ASAR: Advanced Synthetic Aperture Radar

ASUR: Air borne SUbmillimeter Radiometer

ATLAS: Atmosperic Laboratory for Applications and Science

ATSR-1,2: Along Track Scanning Radiometer

AVARR: Advanced Very High Resolution Radiometer

AWI: Alfred Wegener Institute for Polar and Marine Resaerch, Germany

BAS: British Antarctic Survey

BIRA-IASB: Belgisch Instituut voor Ruimte-Aëronomie - Institut d'Aeronomie spatiale de Belgique

BRERAM: BREmen Radiometer for Atmospheric Measurements

CAO: central Aerological Observatory

CAS: Contour Advection with Surgery

CDI: Combined Differebtial Integral approach (SCIATRAN)

CEOS: Committee for Earth Observation Satellites

CINAMON: Characterisation, INterpretation, Application, and Maturation of key-Ozone-related ENVISAT –1 level-2 products

CIRATRA: Coupled Inversion RAdiation TRAnsfer program

CL: Ceiling Level

CMDL: Climate Monitoring and Diagnostic Laboratory, NOAA, USA

CNES: Centre National d'Etude Spatiales, France

CNRS: Centre National pour la Recheche Scientifique, France

CTM: Chemical transport model

DFD: Deutsches Fernerkundungs-Datenzentrum (German Remote Sensing Data Centre)

DIAL: DIfferential Absorption Lidar

DLR: Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre)

DMI: Danmarks Meteorologiske Institut, Danmark

DOAS: Differential Optical Absorption Spectroscopy

DORIS: Doppler Orbitography and Radio-positioning Integrated by Satellite

DWD: Deutscher Wetterdienst

EASOE: European Arctic Stratospheric Ozone Experiment

ECD: Electron Capture Detector

ECMWF: European Centre for Medium-range Weather Prediction

ENVISAT: ENVIronmental SATellite
ESA: European Space Agency
ESABC: Envistat Stratospheric Aircraft & Balloon Campaign
ERBS: Earth Radiation Budget Satellite
ERS: European Remote sensing Satellite
ETH: Eidgenössische Technische Hochschule Zürich
FD-products: Fast Delivery products (sometimes also referred to as 'near real time products')
FhG-IFU: Fraunhofer Gesellschaft-Institut für Atmosphärische Umweltforschung
FISH: Fast in-situ Stratospheric Hygrometer
FMI: Finnish Meteorological Institute, Finnland
FTIR: Fourier Transform Infrared
FTS: Fourier Transform Spectroscopy
FURM: FUll Retrieval Method
FWHM: Full-Width Half-Maximum
GC-VOS: German Contribution to the Validation of the SCIAMACHY Data Products
GDP: GOME Data Processor
GOME: Global Ozone Monitoring Experiment
GOMETRAN:GOME radiative TRAsnfer Model
GOMOS: Global Ozone Measurement by the Occultation of Stars
GWinDOAS: GOME-Windows-DOAS
HALOE: HALogen Occultation Experiment
HGF: Hermann von Helmholtz-Gemeinschaft deutscher Forschungszentren, Germany
HITRAN: HIgh-resolution TRANsmission molecular absorption database
IFE: Institut für FErnerkundung, Bremen
ILAS: Improved Limb Atmospheric Spectrometer
IMF: Institut für Methodik der Fernerkundung, Germany
IMK: Institute for Meteorology and Climate Research, Germany
IUP: Institut für Umweltphysik, Bremen
IR: Infra-Red
IRF-Kiruna: Institutet för Rymdfysik (Swedish Institute of Space Physics), Sweden
IRM-KMI: Institut Royal Météorologique / Koninklijk Meteorologisch Instituut, Utrecht
IVL: Swedish Environmental Research Institute
KASIMA: KArlsruhe SImulation model of the Middle Atmosphere
KMI: Koninklijk Meteorologisch Instituut, Utrecht
KNMI: Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands meteorological institute), Utrecht
KTSU: Kyiv Taras Shevchenko University, Kyiv, Ukraine
LIDAR: Light Detection and Ranging
LINEFIT: Line fit, software pachage
LLR: Laser Retro—Reflector
LOS: Line of sight

LPMA: Laboratoire de Physique Moleculaire et Applications or Limb Profile Monitoring of the Atmosphere FT-IR

LTE: Local Thermodynamic Equilibrium

LUT: Look-Up Tables

MAS: Millimeter-wave Atmospheric Sounder

MDA: Minimum Detectable Absorbance

MERIS: MEdium Resolution Imaging Spectrometer

MIPAS: Michelson Interferometer for Passive Atmospheric Sounding

MIPAS-B: Michelson Interferometer for Passive Atmospheric Sounding – balloon version

MIRA: MIllimeterwave RAdiometer

MLS: Microwave Limb Sounder

MODIS: MODerate resolution Imaging Spectroradiometer

MOPPITT: Measurements of pollution in the troposphere

MSC: Meteorological Service of Canada

MVIRI: Meteosat Visible and Infra-Red Imager

MWR: MicroWave Radiometer

NASA: National Aeronautics and Space Agency, USA

NDSC: Network for the Detection of Stratospheric Change

NDVI: Normalized Difference Vegetation Index

NIR: Near Infra Red

NILU: Norsk Institutt for Luftforskning, Norway

NIST: National Institute of Standards and Technology, USA

NIWA: National Institute of Water and Atmospheric Research, New Zealand

NLC: Noctilucent Clouds

NOAA: National Oceanographcy and Atmospheric Administration, USA

NRT-products: Near real time products (sometimes also referred to as 'fast delivery products')

OLEX: Ozone Lidar EXperiment

OL-products: Off line products

OSIRIS: Odin spectrometer infrared imaging system

OSTC: Federal Office for Scientific, Technical and Cultural Affairs, Belgium

PI: Principle Investigator

PMC: Polar Mesopheric Clouds

POAM II: Polar Ozone and Aerosol Measurement II

POLDER: Polarisation and directionality of the earth's reflectance

PROFFIT: Profile fit

PRODEX: Scientific Experiment Development Programme (PRODEX), the acronym PRODEX comes from the French "PROgramme de Développement d'EXpériences Scientifiques

PSC: Polar Stratosheric Clouds

PTB Physikalisch-Technische Bundesanstalt, Germany

PV: Potential Vorticity

QTH: Quarz Tungsten Halogen

RA-2: Advanced Radar Altimeter

RAM: Radiometer for Atmospheric Measurements
RAMAS: mm-wave Radiometer for Atmospheric Measurements ar SUMMIT
RDF: Reverse Domain Filling trajectories
RGD: Reduction Gas Detector
RIVM: National Institute of Public Health and the Environment, Netherlands
RTM: radiative transfer model
SABER: Sounding of the atmosphere using broadband emission radiametry
SAGE-II: Stratospheric aerosol and gas experiment II
SBUV: Solar Backscatter Ultra Violet Instrument
SCCVT: SCIAMACHY Calibration and Verification Team
SCIAMACHY Scanning Imaging Absorption spectroMeter for Atmospheric ChartographY
SCIATRAN: radiative transfer model for geophysical applications in the 240-2400 nm pectral region
SCIAVALIG: SCIAMACHY validation and interpretation group
SeaWiFS: Sea-viewing Wide Field-of-view Sensor
SESAME: Second European Stratospheric Arctic and midlatitude Experiment
SFIT: Program package for FTIR data analysis
SIM / SORCE: Spectral Irradiance Monitor / SOlar Radiation and Climate Experiment
SIS: Superconductor Insulator Superconductor
SMI: Swiss Meteorological Institute, Switzerland
SOLVE: SAGE III Ozone Loss and Validation Experiment
SOLSTICE: Solar/Stellar irradiance comparison experiment
SOLSPEC: Solar spectrum instrument (from 180 to 3200 nm)
SOLSE/LORE: NASA Shuttle based experiment
SRON: Space Research organization Netherlands
SSAG: SCIAMACHY scientific advisory group
SSB: Single Side Band
SST: Sea Surface Temperature
STEL: Solar Terrestrial Environmental Laboratory, University of Nagoya, Japan
SUMMIT: Summit Greenland
SUSIM: Solar Ultraviolet Spectral Irradiance Monitor
SVRD: SCIAMACHY Validation Requirements Document
SW: spectroscopic workstation
SZA: Solar Zenith Angle
TDL: Tunable Diode Laser
THESEO: Third European Stratospheric Experiment on Ozone
TIROS: Television and InfraRed Observation Satellite
TOA: Top of Atmposphere
TOMS: Total ozone mapping spectrometer
TOVS: TIROS operational vertical sounder
Triple: Combing a resonance fluorescence ClO/BrO instrument, an in-situ Fluorescence Induced Stratospheric Hygrometer FISH, a total air sampler, a diode laser H_2O and CH_4 sensor

UARS: Upper Atmosphere Research Satellite
Ulg: Institut d’Astrophysique, Université de Liegè, Belgium
UNESP: UNiversidade EStadual Paulista, Bauru, São Paulo
UV: Ultra-Violet
VAP: Validation by Measurements from Aircraft Platforms
VMR: Vertical Mixing Ratio
VBB: Validation by Balloon Borne Measurements
VGS: Validation by Ground based/ship borne Measurements
VIS: Validation by independent Satellites Measurements
WARAM: Ground-Based Water Vapour Microwave Radiometry
WGCV: Working Group on Calibration and Validation

Annex A: Overview of the German validation projects

Balloon-Borne Validation

National Coordination: PD Dr. K. Pfeilsticker, IUP, Heidelberg

ESA-AO	PI	Titel
146	Prof. Dr. C. Camy-Peyret	Balloon validation of CO and CH_4 Sciamachy products and related studies
240	Prof. Dr. H. Fischer	Validation of trace gas measurements of the Envisat instruments MIPAS, GOMOS, SCIAMACHY by using in-situ and remote sensing balloon borne techniques
349	Prof. Dr. J.P. Burrows	Sciamachy validation using radiometric calibration of the DOAS/FTIR instrument
465	PD Dr. K. Pfeilsticker	Validation of Sciamachy trace gas profiles by balloon-borne UV/visible/near IR direct sun spectrometry
349	Prof. Dr. J.P. Burrows	Sciamachy validation using water vapour and methan profiles obtained in-situ by balloon-borne TDL measurements
694	Prof. Dr. Karin Labitzke	Meteorology for validation (METVAL)

Ground-based and ship-borne Validation

National Coordination: Dr. Klaus Bramstedt, IUP, Bremen

ESA-AO	PI	Titel
331 + 126	Prof. Dr. J.P. Burrows	Ground-based and Ship-borne Atmospheric FTIR Spectroscopy for the Sciamachy Validation
331	Prof. Dr. U. Platt	Validation of Sciamachy level 2 data products from ship-borne DOAS observations
—	Prof. Dr. J.P. Burrows	Ground-based sun- and sky radiometer measurements for a set-up and validation of look-up-tables (LUT) for a retrieval of aerosols optical thickness from Envisat radiometers Meris and Sciamachy
331 + 126	Michael Hoock	The validation of Sciamachy products by ground-based mm-wave observations
222	Dr. K.H. Fricke	Lidar Measurements of temperature profiles, aerosol load and clouds from the Troposhere to the Mesosphere at the Arctic circle from Esrange near Kiruna
126		Validation of Sciamachy products with ground-based FTIR observations from the NDSC Network
331	Prof. Dr. J.P. Burrows	Validation of Sciamachy level-2 data products from ground-based DOAS observations

Aircraft-borne Validation

National Coordination: Dr. G. Ehret, DLR, Oberpfaffenhofen

ESA-AO	PI	Titel
349	Prof. Dr. J.P. Burrows	Validation of Sciamachy level-2 data products using the OLEX Lidar on board of the Falcon aircraft
349	Prof. Dr. J.P. Burrows	Validation of Sciamachy level 2 data products from air-borne Multi-axis-DOAS observations
349	Prof. Dr. J.P. Burrows	Validation of Sciamachy level-2 data products using the ASUR sensor on board the Falcon aircraft

Satellite Validation

National Coordination: Dr. M. Weber, IUP, Bremen

ESA-AO	PI	Titel
406 + 651	Dr. M. Weber	Validation of Sciamachy in-flight measured irradiances, radiances, and selected tracegas products by comparison with measurements from independent satellite instruments

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