Atmospheric Composition Research

Introduction • The division investigates the atmospheric composition and the coupling between changes in atmospheric composition and the climate system. The objective of this research is to contribute to the understanding of the natural variability in the atmospheric composition and the anthropogenically induced changes.
The research strategy is to study the atmospheric composition along three lines:
- Observations
- Global three-dimensional modelling
- Process studies

The different research activities are described in more detail below. The main activities of the division are focussed on research. However, considerable effort is put in advising and informing governmental services and the general public on results of our research, e.g. concerning effects of aircraft emissions. Contributions to the Intergovernmental Panel for Climate Change (IPCC) Special Report on ‘ Aviation and the global atmosphere’ and the participation in the chemical model intercomparisons of IPCC 2001 should also be mentioned.

One of the large programmes of the division is the scientific lead of the Dutch-Finnish Ozone Monitoring Instrument OMI that will fly on the NASA EOS AURA Mission. The Principal Investigator and the Dutch part of the science team has been staffed and embedded in the division.

An important development on observation side was the installation of an ozone observation station in Surinam in close co-operation with the Surinam Meteorological Service. Processes in the tropical regions are important for the global climate and the global atmospheric composition. The participation in Indoex (Indian Ocean Experiment) and this Surinam station emphasize our involvement in this promising field. An overview of the Surinam station is given in the section Recent Highlights.

The preparation of the validation of SCIAMACHY observations (the Scanning and Imaging Absorption Spectrometer for Atmospheric Cartography on board of the European Space Agency Envisat Satellite) under KNMI responsibility is a huge challenge. The funding, infrastructure and formation of teams in the different participating countries is now well organised.

Near real time availability of ozone data from the Global Ozone Monitoring Experiment (GOME) instrument on board of the European Space

Agency's (ESA) European Remote Sensing Satellite-2 (ERS-2) has been set up for the scientific community and broad public. Due to the near real time access KNMI was one of the first to detect the mini-ozone hole above Europe end of November 1999.

The work in the division is structured in three working groups:
- modelling of the atmospheric composition
- observations of the atmospheric composition
- the OMI programme

Co-operation between the three working groups is significant in the domains of chemical data assimilation, development and validation of retrieval algorithms and validation of models and reflects the synergy between the work programmes of the groups.

Modelling the atmospheric composition

Introduction

The objective of this working group is to study natural and anthropogenic changes in the atmospheric composition and their influence on climate. To simulate atmospheric chemistry and transport the group uses the Chemistry-Transport Model Version 3, TM3, and the Chemistry Climate Model of the Max Planck Institute, ECHAM. TM3 is mainly used for long-term simulations, whereas ECHAM is used for process and case studies, as it is computationally more expensive. Both models are developed further in co-operation with IMAU (Institute for Marine and Atmospheric Research Utrecht) and the German Max Planck Institutes for Chemistry and Meteorology in the framework of the Netherlands Centre for Climate Research (CKO) and the international research school COACh.

Meteorological (re-)analyses made with the weather forecast model of the European Centre for Medium Range Weather Forecast (ECMWF) are used to drive TM3 and to study trends in atmospheric transport. For process studies and model evaluation extensive use is made of instrumented aircraft measurements and satellite measurements. A promising technique to combine observations and models is chemical data assimilation, which is being developed in co-operation with the Observations working group. The TM3 model is also used for simulations for climate (e.g. IPCC) and ozone assessments (WMO and United Nations Environmental Programme, UNEP).

Understanding the tropospheric cycles of greenhouse gases and their pre-cursors

Brunner, Meijer, Olivié, Van Velthoven, Verver, Van Weele

Nitrogen oxides in the troposphere act as a catalyst that promotes the formation of ozone. The concentration of nitrogen oxides has strongly increased in recent decades due to increased fossil fuel burning by traffic and industry at the surface and by aircraft emissions in the free troposphere. Nitrogen oxides are also produced during lightning discharges. Both aircraft emissions and production by lightning occur in the upper troposphere where the produced ozone is especially effective as a greenhouse gas. Since global air traffic grows with a rate of 5-6 % per year the possible effect of aviation on climate has been the topic of many recent studies and a special IPCC report 'Aviation and the Global Atmosphere' (1999), to which we have contributed. While the magnitude of air traffic and surface emissions is rather well known, the production by lightning is only known to within an order of magnitude and its geographical distribution is also very uncertain. The bulk of the production by lightning is generally assumed to take place in the tropics. This means that nitrogen oxides emitted by aircraft are found mostly in northern mid-latitudes and nitrogen oxides produced by lightning mostly remain in other regions of the troposphere. If the production of nitrogen oxides by lightning at mid-latitudes is significant, a reconsideration of the estimated impact of aircraft emissions on ozone may be necessary. Using observations made during the European Lightning Nitrogen Oxides Experiment (EULINOX) the TM3 model simulations of nitrogen oxides have been evaluated and improved. The simulated distribution of lightning strikes has been compared to both ground-based and satellite lightning observations. It was found that the amount of lightning at mid-latitudes was underestimated, and the model description has been updated according to these findings. It has hitherto not been possible to calibrate the total global production by lightning with observations. With regard to aircraft emissions an important remaining question is how large the induced changes are in cloud cover and what their impact is on climate.

The surface and boundary-layer are important for the composition of the troposphere as a whole since they include the primary sources and sinks of many trace gases. It has been shown previously that for specific, simple cases the conventional approach to estimate turbulent transport and chemical transformations in terms of only mean concentrations can be significantly wrong due to the interaction of turbulent mixing and chemistry. These interactions were now studied for a comprehensive state-of-the-art chemistry scheme as used in current global and regional chemistry/transport models. In the more realistic cases considered, we found no significant effect on the mean concentrations of stable species. However, it was demonstrated that the turbulent flux itself as well as the concentrations of fast reacting radical species may be significantly wrong in the traditional approach.

The effect of stratospheric ozone depletion on the net ozone production in the troposphere was studied with a one-dimensional model. It was found that the tropospheric response is different in different chemical regimes, but that the global effect would be a decrease of tropospheric ozone production.

Finally, it should be mentioned that in preparation for IPCC 2001 we participated in an atmospheric transport and chemistry model intercomparison (OxComp). With the TM3 model simulations were performed for 2000 and 2001 based upon the IPCC emission scenarios. The results are documented in chapter 4 and 5 of the Third Assessment Report.

Aerosols: the Indian Ocean Experiment

Scheele, Siegmund, Verver, Zachariasse, Van Velthoven

The effect of atmospheric aerosols on climate is large but its exact magnitude is still highly uncertain. Therefore in recent years a number of experiments has been organised focussing on the climate forcing of aerosols (e.g. the second Aerosol Characterisation Experiment, ACE-2). One of the most extensive measurement campaigns, the Indian Ocean Experiment (INDOEX), took place in February and March 1999. It was a joint project organised by Indian, American, and several European research institutes. The primary goal of the experiment was to study the effect on climate of natural and anthropogenic aerosols over the Indian Ocean. The area and season of the experiment were chosen because emissions from India are large and steadily growing and because during to the north-east winter monsoon there is persistent outflow of pollutants from India over the Indian Ocean. Polluted Northern and clean Southern hemispheric air converge near the equator causing sharp gradients in aerosol concentrations and aerosol radiative forcing, making this an excellent environment for a measurement campaign.

The contribution of KNMI focussed on transport processes. Apart from meteorological support during the experiment, we performed post-campaign meteorological analyses in order to interpret the observations. Secondly, studies were made of the vertical distribution of ozone as observed by ozone soundings. The general picture that emerges from these studies is that the mid-latitude stratosphere feeds ozone into the tropical middle and upper troposphere from both the Northern and Southern Hemispheric sides. This process affects the ozone distribution in almost the entire north-south cross section of the Indian Ocean sampled during the 1999 measurements. Another finding was that upper-tropospheric interhemispheric transport occurs in certain preferred channels. Pollution from the Indian continent that has been transported in such a channel was sampled by the Netherlands research aircraft during INDOEX. The chemical consequences of these interhemispheric transport channels need to be further investigated.

Atmospheric tracer transport and dynamics

Cuijpers, Ollers, Meloen, Scheele, Siegmund, Sigmond, Van Velthoven, Zachariasse

The distribution of greenhouse gases in the atmosphere is to a large extent determined by transport by the general circulation. For instance, the seasonal variation of ozone in the troposphere is strongly affected by transport of ozone from the stratosphere to the troposphere. Due to the large internal variability of the atmosphere it is difficult to detect atmospheric circulation changes that may be due to enhanced concentrations of greenhouse gases. Therefore it is important to have consistent long-term (re-)analyses of the meteorological state of the atmosphere, like the 15-year re-analysis performed recently by ECMWF. A diagnostic study found no statistically significant trend in the strength of the stratospheric circulation during this 15-year period (1979-1993). Since 15 years is still a short time scale from the point of view of climate change analysis, we will perform a similar study using the forthcoming 40-year re-analysis by ECMWF. The 15-year re-analysis has further been used to study the relation between vertical wind and temperature variations in the tropical lower stratosphere.

The tropopause and the polar vortex edge with their strong gradients in potential vorticity are barriers for the transport of atmospheric constituents from one atmospheric compartment to another. This is the reason that the ozone hole is so well-isolated. New tools for the evaluation of transport across such atmospheric transport barriers were developed. A new Lagrangian technique to calculate the air mass flux across the dynamical tropopause was developed. It is applied in a case study of tropopause folding along the Southern Hemisphere subtropical jet. This folding was observed during the EU TRACAS experiment (TRAnsport of Chemical species Across the Subtropical tropopause). A trajectory model inter-comparison gave further confidence in the algorithm applied in this KNMI trajectory model. Three independently developed trajectory codes showed relative differences of only about 3-5 % for 2-day forward calculations. A study was performed to the use ECMWF ensemble forecasts to estimate the uncertainty in predicted trajectories due to errors in the meteorological input data.

A study using water vapour observations made in the lower stratosphere has shown that the transport of tropospheric air into the mid-latitude lowermost stratosphere is important up to about 5 km above the tropopause. This has implications for the assessment of the effects of human-made pollutants.

Observations of the atmospheric composition

Introduction

The task of the working group observations is to make, validate, improve, and interpret observations of the atmospheric composition using remote sensing techniques from satellites in combination with surface-based measurements. The present and future satellite instruments involved are GOME (launched in 1995), Sciamachy (to be launched in 2001), OMI (to be launched in 2003) and GOME-2 and successors (GOME-2 to be launched in 2005). In order to fulfil this task the activities can be grouped as follows:

- development of satellite retrieval algorithms,
- validation of satellite data,
- assimilation of satellite data,
- interpretation of ground-based and satellite observations,
- preparation of atmospheric chemistry missions, and
- monitoring of the atmospheric composition.

A special project is the OMI mission, of which KNMI has the scientific lead. A separate OMI working group was formed in the last two years. Therefore, the OMI project is described in a separate section.

Development of satellite retrieval algorithms

Van der A, Van Geffen, Van Gent, Van Oss, Piters, Valks

The main difference between satellite remote sensing observations of atmospheric composition and in-situ measurements is the additional need for complex, but accurate and validated retrieval algorithms that convert the radiation measurements of the satellite instrument into atmospheric and geophysical parameters. The development and validation of such algorithms is a non-trivial task and requires extensive scientific study.

Within the GOFAP project (GOME Fast delivery and value-Added Products) an operational system has been developed and put into use for near-real time (NRT) delivery (i.e. within 3 hours after observation) of GOME total ozone columns and stratospheric ozone profiles (http://www.knmi.nl/gome_fd/). The NRT ozone columns and profiles are distributed via the Netherlands Sciamachy Data Centre (Neonet, http://www.neonet.knmi.nl). The products have been validated through an extended pole-to-pole comparison with ground-based ozone data from NDSC stations. In order to deliver high-quality products several corrections of the reflectivity data have been implemented. Among these are an improved wavelength calibration algorithm based on a high-resolution solar spectrum, an instrument polarisation correction algorithm, and a correction for interference signals of the Peltier cooler. Furthermore, improved correction algorithms have been developed for the radiometric calibration mismatch and for the degradation of the measured reflectivity's of GOME.

Even better profiles can be expected from a newly developed algorithm (within the BCRS project DORAS (Development of an Ozone profile Retrieval Algorithm for ozone profiles from atmospheric Spectra)) to obtain height-resolved ozone distributions from GOME UV-VIS spectra. A tailor-made radiation transport model has been especially developed for the algorithm. It uses a fast 'four-stream' analytic method that includes the simultaneous calculation of the Jacobian derivatives needed for the retrieval.

In preparation for the Sciamachy mission, the project Sciamachy Radiative Transfer model development for Limb viewing (SCIARALI) aims at the development of an accurate radiative transfer model for limb observations that is fast enough to perform on an operational basis. During the first few months of the SCIARALI project, promising existing radiative transfer schemes have been selected that could be adopted in the development of a fast and accurate radiative transfer model for limb view.

Ozone profiles from GOME overpasses have been validated with observations at De Bilt (Netherlands) and Paramaribo (Surinam), representative for urban-mid-latitude and rural-tropical situations. Validation is performed by comparison with ozone sonde measurements (figure 1) and collocated satellite measurements from the Halogen Occultation Experiment (HALOE).

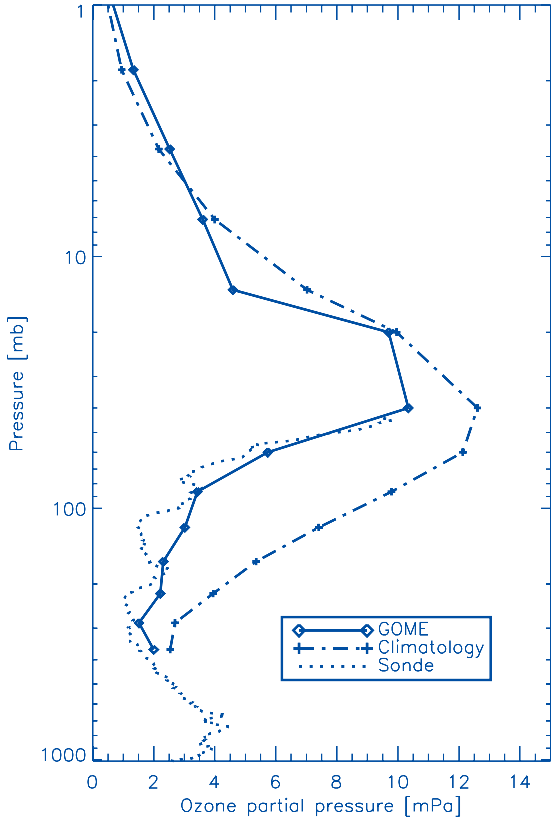

Figure 1. Ozone profiles above De Bilt on December 1, 1999. The solid line/diamonds: profile retrieved from GOME data. Dotted line: ozone sonde at De Bilt. Dashed line/plusses: climatology of Fortuin and Kelder (1998).

Validation of satellite data

Eskes, Kelder, Meijer, Piters, Timmermans, Valks

KNMI chairs the international validation of the German/Dutch/Belgium Sciamachy instrument on board of Envisat. The Sciamachy validation group (SCIAVALIG) is a sub-group of the Sciamachy Science Advisory Group (SSAG). The main objective of Sciamachy is to measure profiles and vertical columns of atmospheric trace gases. Envisat will be launched in summer 2001.

The validation group has issued two documents that describe the validation activities: The Sciamachy Validation Requirements Document and the Validation Handbook. A living validation website (http://www.knmi.nl/sciamachy-validation) was set-up where up to date information can be exchanged and discussed, and which will play a central role in the validation. Apart from co-ordination, Sciamachy validation activities at KNMI include (participation in) the validation of the following Sciamachy products: ozone columns and profiles, surface UV radiation, H_2O, temperature and pressure.

The ozone validation efforts within SCIAVALIG will be supported by data assimilation. The preparations in 1999 and 2000 consisted of the development of operational assimilation software and a friendly internet interface to the data produced, to be used by the validation teams.

Assimilation of satellite data

Eskes, ElSerafy, Kelder, Van Velthoven

In chemical data assimilation, observations of the atmospheric gases made by satellite instruments are combined with chemistry-transport models. Data assimilation is used to generate synoptic maps from the incomplete sequential data sets provided by the satellites. It provides information on the quality of the data and the performance of the model.

The EU project Studies of Ozone Distributions based on Assimilated satellite measurements, SODA, has been successfully completed in 1999. The aim of the project was the development of ozone data assimilation for numerical weather prediction models and chemistry-transport models. One important focus of SODA was the inclusion of ozone in the ECMWF model.

A database of assimilated GOME ozone fields has been created from November 1999 to the present, using the TM3-DAM (TM3 Data Assimilation Model) model. The new 60-layer ECMWF analyses and forecasts drive this model, which has a fast parameterised description of the stratospheric chemistry. The assimilation work was done in the BCRS project Sciamachy and the EU project Gome Data Interpretation, Validation and Application, GODIVA.

Work has started on the assimilation of retrieved ozone profiles from the GOME instrument in the transport model TM3, using the Kalman filter technique. The full Kalman filter proved to be very efficient in accurately describing the vertical distribution of ozone in the stratosphere and higher troposphere. A simplified version of the Kalman filter has been developed for the near-real time delivery of assimilated ozone profiles. This version is in the validation phase.

The retrieval of concentrations of trace gases with strongly varying vertical profiles from UV-visible satellite spectrometers like GOME is very sensitive to a-priori assumptions about the vertical distribution of the trace gas. Therefore, a combined retrieval-assimilation approach is developed for NO_2.

The EU DARE (Data Assimilation in Readiness for Envisat) project has explored the use of Envisat data, and has co-ordinated interactions between European groups working on Chemical Data Assimilation. The EU Spring-to-Autumn Measurements and Modelling of Ozone and Active species (SAMMOA) project studies the ozone decline in northern mid latitudes in the winter-spring period. The assimilation of ozone profiles is used to quantify the evolution of the vertical distribution of ozone. Data assimilation will be used in the validation phase of GOME-2 (Ozone SAF (Satellite Application Facility)) and Sciamachy.

Interpretation of ground-based and satellite observations

Allaart, Fortuin, Van Weele

A region of extremely low ozone passed over north-west Europe during November 30 and December 1, 1999 (figure 2). Total ozone in this so-called 'mini-hole' was measured with the Brewer Spectrophotometer at KNMI. This was the first time that accurate ozone values were measured in a mini-hole. The mini-hole has also been observed with the GOME satellite instrument. On December 1, an ozone-sonde was launched to measure the ozone profile in the hole. The results have been published in 'Geophysical Research Letters'.

The observations at Paramaribo station Research on Atmospheric Dynamics and Chemistry in Surinam (RADCHIS project) are being interpreted in various fields of atmospheric science (cf. highlights of this report). The observations consist of total ozone columns, ozone ('Umkehr') profiles and UV measurements from a Brewer instrument and of ozone soundings (The German word 'Umkehr' refers to a technique through which an ozone profile can be derived from zenith-sky irradiation measurements when the sun is skimming the

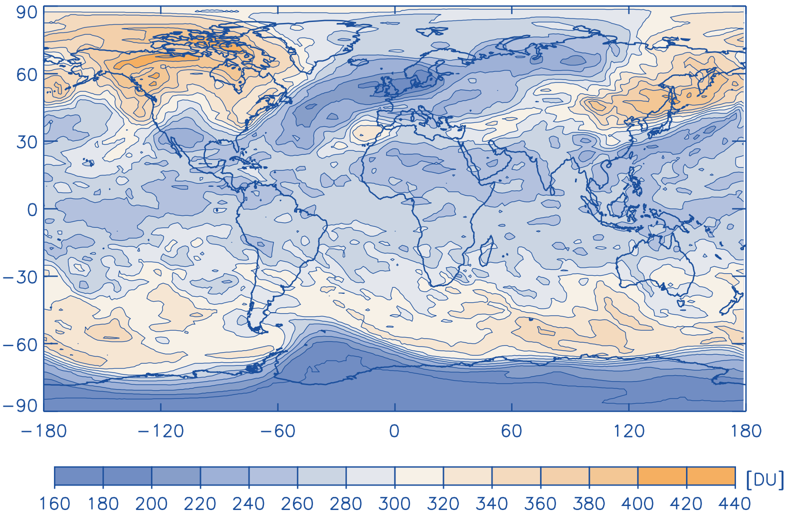

Figure 2. The global distribution of ozone based on assimilated Gome observations for November 30, 1999. Apart from the large ozone hole at the South Pole, typical nowadays for this time of the year, the figure shows very low ozone values above Western Europe and the Atlantic. With column values well below 200 DU these are the lowest ozone values observed in this region since the start of the observations in 1979.

horizon). The Umkehr profiles are appended to the sonde profiles above the burst level. On average, the correction factor obtained in this way was well within the WMO quality criterion.

A first analysis has been made of the spectral UV (Ultra-Violet) measurements. It is observed that the UV surface irradiance is fairly constant over the year, with a maximum measured UV Index ('Zonkracht') of about 18. The UV Index is a linear internationally agreed measure for the UV irradiance at the Earth surface, reaching values up to 8 in The Netherlands.

Within the SUVDAMA (Scientific Ultraviolet Data Management) project benchmark data for spectral UV surface irradiance were established. The benchmarks have an accuracy of a few percent and are now available to validate radiative transfer codes for spectral UV surface irradiance. In the follow-on project European Database for Ultraviolet radiation Climatology and Evaluation (EDUCE) the UV data will be used to address questions e.g., on European UV climatology and possible trends in UV doses.

The narrow-band radiometers measurements made in De Bilt in the period 1995-1996 have been used to study the effects of (partial) cloudiness on the incident UV irradiance. It was found that on partial-cloudy days the incident UV radiation regularly exceeds the irradiance on a cloud free day for prolonged time periods, while sunshine duration is found to be a better measure for the incident UV radiation than cloud cover.

Preparation of future atmospheric chemistry missions

Van der A, Kelder, Van Oss, Valks, Van Velthoven, Van Weele

The ozone satellite application facility (Ozone-SAF) project has been established by EUMETSAT in 1997. The Ozone-SAF project prepares for ozone and other trace gas retrievals for the Meteorological Operational satellites (METOP) and MSG satellites. For GOME-2 on board METOP-1, 2 and 3 the section has the responsibility for the retrieval of the ozone profile and aerosol operational data products, and for the validation of the total ozone product. For the total ozone validation data-assimilation techniques will be used.

ESA is planning an Atmospheric Chemistry Explorer (ACE) mission for the post-Envisat period. Under the co-ordination of our group scientific requirements have been established, based on the current perception of the main scientific issues in atmospheric chemistry research. It has been proposed that the mission objective of ACE should be 'to investigate atmospheric composition, its evolution under anthropogenic impact and its interaction with climate'. Emphasis will be put on sounding of the gaseous composition in the upper troposphere and lower stratosphere.
In autumn 2000 the ACE proposal was selected by ESA as a candidate core mission. In the coming year a 'Report for Assessment' will be written in preparation of the mission selection by ESA, scheduled for autumn 2001. If successful, the ACE mission is not likely to be launched before 2008.

The experience with GOME and Sciamachy has been used to assist the newly formed OMI working group in setting up the instrument requirements and retrieval algorithms for OMI.

Monitoring the atmospheric composition

Van der A, Allaart, Eskes, Fortuin, Piters, Valks

Chemically active gases such as ozone and methane play an important role in the Earth's climate system. Human-induced increases in the atmospheric concentrations of these gases have been identified and are shown to be a cause of detected changes in the global climate. Monitoring the distribution of the climate gases and their evolution is an essential task in climate research. Only remote sensing observations of atmospheric trace gas concentrations provide the global extend, spatial resolution and daily coverage that is required. The sequence of GOME, Sciamachy, OMI, GOME-2 and successor satellite instruments guarantee a long, uninterrupted and homogeneous time series of measurements.

Currently GOME ozone measurements are generated and archived by the division within the framework of ESA's Data Users Program (GOFAP project). These activities will be carried through in 2001. Furthermore, under the lead of our division an EU project has been defined which is specifically devoted to establish a coherent data set from the currently available five years of GOME observations.

Under the RADCHIS project, a Brewer MKIII spectrophotometer was installed on the premises of the Meteorological Service in Surinam (cf. article in highlights of this report). This happened in March 1999, and the Brewer has since been performing continuous total ozone and UV observations - along with ('Umkehr') profile observations during dusk and dawn. To this observation programme was added a balloon sonde station in September 1999. Since then sondes measuring profiles of ozone, temperature, humidity, and wind velocity plus direction are released weekly.

The ozone density distribution is measured with ozone sondes over De Bilt since 1992. These sondes are used for monitoring, the study of stratosphere-troposphere exchange, event studies, for international campaigns, and for validation of satellite data. In each winter we participated in the 'MATCH' campaign. The objective of these campaigns was to determine the role of fast chemical ozone depletion near the Polar Vortex. The ozone-sonde data are submitted to the European database at the Norwegian Institute for Air Research (NILU) and the WOUDC (World Ozone and UV Data Centre). Both Paramaribo and De Bilt have been accepted as NDSC stations for ozone soundings.

The ozone column density over De Bilt is measured continuously with the Brewer Spectrophotometer. Brewer ozone measurements are used for verification of ozone-sonde results, and the validation of satellite retrieval systems. The data are submitted to the World Ozone Mapping Centre in Greece and to the World Ozone and UV Data Centre (WOUDC). The data are also sent to RIVM (National Institute of Public Health and the Environment) to calculate UV impact on skin cancer incidence. The Brewer ultraviolet radiation spectra are being used to validate radiative transfer models.

Within the European Union project SUVDAMA a database for measured spectral UV surface irradiance in Europe has been developed. The Brewer spectral UV measurements from De Bilt for the period 1994-1997 were submitted into the database. The database will be extended in the follow-on project EDUCE (European Database for Ultraviolet radiation Climatology and Evaluation).

The OMI programme

Levelt, Van den Oord, Van Dijk, Acarreta Rodriguez, Boersma, Brinksma, Decae, Dobber, Dirksen, De Haan, Noordhoek, Veefkind, Voors

Introduction

Since 1998 KNMI is involved in the OMI programme. Centrepiece of this programme is the Ozone Monitoring Instrument (OMI) that will fly on the NASA AURA Mission that will be launched in 2003. A consortium of Fokker Space and the Institute for Applied Physics of the Netherlands Organisation for Applied Scientific Research (TNO-TPD) builds the instrument with contributions by the Finnish industry (VTT and Finavitec). For the management of the project NIVR (Netherlands Agency for Aerospace Programmes) and FMI (Finnish Meteorological Institute) have established a Project Office.

KNMI is the Principal Investigator (PI) institute. The PI is responsible for: defining the science requirements for OMI, managing the science team, safeguarding the performance aspects of the instrument, instrument calibration, algorithm development, data validation, the quality of the OMI data products, managing the Instrument Operations Team and instrument operations over the lifetime of the mission. Based on these responsibilities, three elements can be distinguished in the programme: the OMI Science Team, guidance of the industrial process, and the OMI Groundsegment. These elements are discussed below.

OMI on EOS-AURA

The OMI instrument will fly on the AURA mission that is part of the NASA Earth Observing System (EOS). Apart from OMI, the AURA payload consists of three other instruments: HIRDLS (High Resolution Dynamics Limb Sounder), MLS (Microwave Limb Sounder) and TES (Tropospheric Emission Spectrometer). The Earth Observing System will consist of three major scientific satellites (TERRA, AQUA and AURA) and a number of smaller satellites. The scientific objectives of the AURA mission are to study: 1) the ozone layer, 2) air quality and tropospheric chemistry and 3) climate change. OMI will contribute to these studies by providing information about ozone (columns and profiles), NO_2, aerosols, clouds, SO_2, BrO, HCHO, OClO and surface UV irradiance.

The OMI instrument will observe the wavelength range 270-500 nm. The instrument has various innovative features: a polarisation scrambler, a frametransfer CCD (Charge Coupled Device) and an extremely wide swath (114°). OMI will be launched into a sun-synchronous polar orbit and will provide daily global coverage with typical groundpixel sizes in the range 13×24 km^2 and 13×48 km^2. This implies that OMI will generate about 4,5 million spectra each day, divided over three channels.

The OMI science team

Over the past two years the OMI Science Team (OST) has been established. The core team consists of 33 scientists located at KNMI (9), FMI (4) and the US (20). Next to the core team there are several tens of scientists involved in the OMI programme as collaborators, co-investigators and associated scientists. The activities of the OST reside ultimately under the responsibility of the PI but are co-ordinated through the OMI Science Advisory Board (OSAB) consisting of the Dutch PI and the US and Finnish co-PI's. The US part of the OST is managed on a daily basis by the US Team Leader. On a working level the OST has been split into five Working Groups for algorithms, calibration, validation, data systems and operations. Apart from the calibration working group, these working groups are copied on AURA mission level. On mission level there is also an Education & Public Outreach working group. The current baseline is to review the Algorithm Theoretical Basis Documents for the OMI data products in the September 2001 timeframe.

Guidance of the industrial process

The industrial consortium will deliver three components of the OMI system: the instrument, the Level 0-1b processing (data processing from raw instrument data to Earth radiance and solar irradiance spectra) software and the command and telemetry database. In the light of the very tight schedule of the OMI programme, (the instrument delivery to NASA will be in March 2002), the major

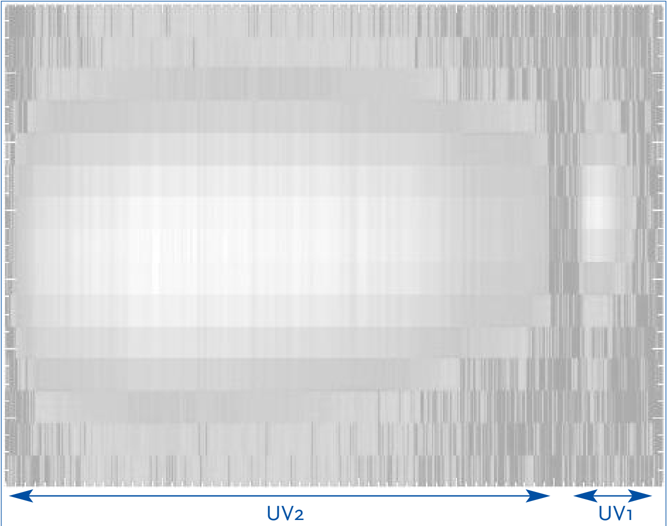

Figure 3. Zenith sky image obtained with the OMI Development Model. On the left the UV2 subchannel and on the right the UV1 subchannel. Clearly visible are the Fraunhofer lines and the ozone absorption lines. The UV1 signal is truncated because of the atmospheric cut-off.

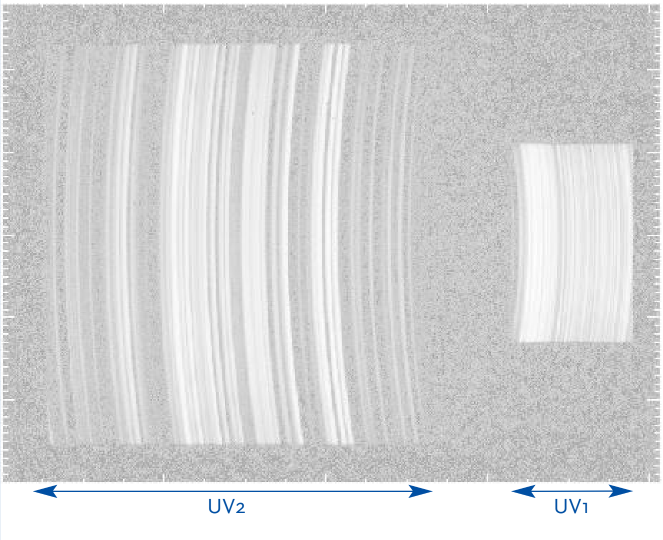

Figure 4. A spectral line source observed with the OMI Development Model. The horizontal direction gives the intensity as a function of wavelength. The vertical axis corresponds to the 260 km wide east-west swath as observed in orbit. The left side shows the UV2 sub channel (310 - 370 nm, left to right) and on the right side the UV1 sub channel (310 - 270 nm, left to right).

effort of KNMI has been to participate in industry-related activities. This includes participation in reviews of the hardware both on units and on system level as well as in various reviews related to the software development. On numerous occasions KNMI has advised the NIVR/FMI Project Office about performance issues.

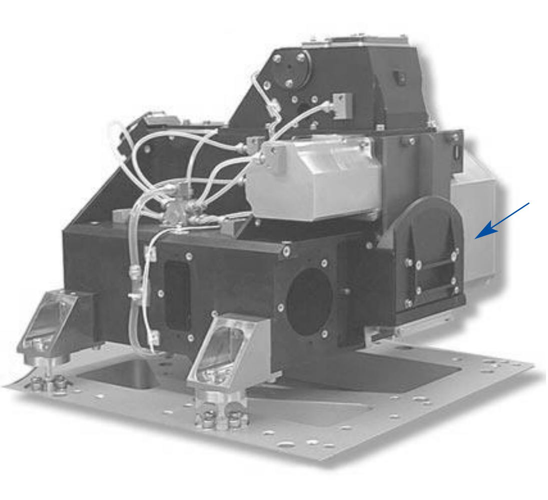

Figure 5. Optical Bench of the OMI instrument. The telescope entry is at the right hand side. Apart from the optical bench the instrument consists of two other small boxes, the Electronic Unit and the interface Adapter Module. The plastic tubes provide nitrogen flushing.

A milestone in the OMI programme was the test programme of the OMI Development Model in 2000 (see Figures 3-5). KNMI led an international team of experts that has been doing tests at the OMI facilities at TPD over a period of several weeks. The results of this programme indicate that the design of OMI is sound and that various performance aspects require further attention. After the Development Model the OMI Flight Model will be built. This Flight Model will be fully assembled in June 2001 after which an intense period of instrument characterisation and calibration will follow including measurements by the principal investigator.

The OMI groundsegment

Next to the OMI instrument in orbit, the OMI system also contains an OMI groundsegment. The groundsystem contains elements related to instrument operations and to data processing.

For instrument operations there will be a Flight Operations Team at Goddard Space Flight Center (GSFC) and an Instrument Operations Team at KNMI. The Instrument Operations Team will perform the actual commanding of the OMI instrument on a daily basis under supervision of the PI. The team will also be responsible for health checking of the instrument. To co-ordinate and plan all the operational aspects between NASA flight operations personnel and the PI-team a small Instrument Planning Group (three persons) has been established. The team at KNMI will use an Instrument Support Terminal to interact with the Flight Operations Team and the instrument.

For dataprocessing the OMI system will have the following elements: a Science Investigator Processing System (SIPS) at GSFC where the Level 0-1b processing (data processing from raw instrument data to Earth radiance and solar irradiance spectra) will take place and the Level 1b-2 processing (data processing from Earth radiance and solar irradiance spectra to the vertical column amounts or vertical profile of the dataproducts) of various joint US/NL dataproducts. At GSFC KNMI will have a small processing system for delivery of Near Real Time ozone column and profile. Near-Real Time dataproducts have to be available for end-users within three hours after observation. At KNMI there will be a Science Computing Facility for Level 1b-2 processing (data processing form Earth radiance and solar irradiance spectra to the vertical column amounts or vertical profile of the data products) of KNMI specific dataproducts. Finally, in Finland (Sodankyla) there will be a Science Computing Facility to produce regional ozone columns and profiles, and surface UV fluxes based on direct broadcast by the AURA spacecraft.

During the past biennium the KNMI team has been working on establishing all these operational elements of the OMI system. This work will continue till launch but in 2002 the system should have reached a large degree of maturity in order to be able to support the various end-to-end system tests after OMI will have been integrated on the spacecraft.

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