Science Objectives of the Ozone Monitoring Instrument

Pieternel F. Levelt, Ernest Hilsenrath, Gilbert W. Leppelmeier, *Member, IEEE*, Gijsbertus H. J. van den Oord, Pawan K. Bhartia, Johanna Tamminen, Johan F. de Haan, and J. Pepijn Veefkind

***Abstract*—The Ozone Monitoring Instrument (OMI) flies on NASA's Earth Observing System AURA satellite, launched in July 2004. OMI is an ultraviolet/visible (UV/VIS) nadir solar backscatter spectrometer, which provides nearly global coverage in one day, with a spatial resolution of 13 km × 24 km. Trace gases measured include O_3, NO_2, SO_2, HCHO, BrO, and OClO. In addition OMI measures aerosol characteristics, cloud top heights and cloud coverage, and UV irradiance at the surface. OMI's unique capabilities for measuring important trace gases with daily global coverage and a small footprint will make a major contribution to our understanding of stratospheric and tropospheric chemistry and climate change along with Aura's other three instruments. OMI's high spatial resolution enables detection of air pollution at urban scales. Total Ozone Mapping Spectrometer and differential optical absorption spectroscopy heritage algorithms, as well as new ones developed by the international (Dutch, Finnish, and U.S.) OMI science team, are used to derive OMI's advanced backscatter data products. In addition to providing data for Aura's prime objectives, OMI will provide near-real-time data for operational agencies in Europe and the U.S. Examples of OMI's unique capabilities are presented in this paper.**

***Index Terms*—Air quality, atmospheric composition, ozone monitoring, satellite measurements.**

I. Introduction

THE Ozone Monitoring Instrument (OMI), a contribution of the Netherlands Agency for Aerospace Programs (NIVR) in collaboration with Finnish Meteorological Institute (FMI) to the Nationa Aeronautics and Space Administration's (NASA) Aura mission, is orbiting the Earth on the Aura spacecraft. Aura is part of NASA's long-term Earth Observing System (EOS) mission and was launched in July 2004 from Vandenberg Air Force base in California into a polar sun-synchronous orbit.

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P. F. Levelt, G. H. J. van den Oord, J. F. de Haan, and J. P. Veefkind are with the Royal Dutch Meteorological Institute (KNMI), KS/AS, 3730 AE De Bilt, The Netherlands (e-mail: levelt@knmi.nl; oordvd@knmi.nl; haandej@knmi.nl; veefkind@knmi.nl).

E. Hilsenrath was with NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA. He is now with the Joint Center for Earth Systems Technology, University of Maryland Baltimore County, Baltimore, MD 21250 USA (e-mail: Ernest.Hilsenrath@nasa.gov).

G. W. Leppelmeier is with G&S Associates Oy, 02360 Espoo, Finland (e-mail: gwl@GandS.pp.fi).

P. K. Bhartia is with NASA Goddard Space Flight Center, Greenbelt, MD 20771 USA (e-mail: Pawan.Bhartia@nasa.gov).

J. Tamminen is with the Finnish Meteorological Institute, Earth Observation, FIN-00101 Helsinki, Finland (e-mail: Johanna.Tamminen@fmi.fi).

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The OMI instrument [1] has capabilities derived from its predecessors, the Total Ozone Mapping Spectrometer (TOMS) [2], the Global Ozone Monitoring Experiment (GOME) [3], and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) [4] with advanced viewing capabilities, which includes global coverage with high spatial resolution. OMI works synergistically with the other three Aura instruments to collect data in support of Aura's three mission objectives: detecting and explaining ozone trends, the global impact of pollution, and the connections between atmospheric chemistry and climate. With regard to the first objective, OMI continues the TOMS record of high-quality, total ozone measurements and monitoring of stratospheric ozone recovery predicted by chemical models [5]. This imposes rigorous pre- and postlaunch instrument calibration requirements. OMI continues mapping the polar regions to track changes in high-latitude ozone depletion events. OMI acts as a bridge for monitoring ozone until the ozone measurements on the National Polar-orbiting Operational Environmental Satellite (NPOESS) and METOP become operational. OMI's ozone profile measurements will complement those made by the Microwave Limb Sounder (MLS) [6], Tropospheric Emission Spectrometer (TES) [7], and the High Resolution Dynamic Limb Sounder (HIRDLS) [8], the other Aura instruments, but with a denser coverage using its cross track capability. OMI's high spatial resolution is used to detect key tropospheric pollution parameters, which include four of the U.S. Environmental Protection Agency's criteria air pollutants. OMI also measures surface ultraviolet (UV) irradiance, which is an important factor for air quality predictions, as well as a human health and agricultural productivity. Finally, OMI studies aerosols, which are major contributors to climate forcing, but remain the most uncertain contribution in the Earth's radiation budget.

This paper provides an overview of OMI's science objectives, which are related to the Aura mission goals. A brief overview of the instrument is given, demonstrating how its design enables meeting science objectives. The data products are described along with the algorithms that produce these. More detailed descriptions of these topics appear as accompanying papers in this special issue.

II. Science Objectives

OMI's unique capabilities for monitoring the Earth's atmosphere includes daily global coverage with high spatial resolution for all its data products. The 13 km × 24 km ground pixel size is the highest resolution ever achieved for an ultraviolet/visible (UV/VIS) backscatter spectrometer. This results in far more

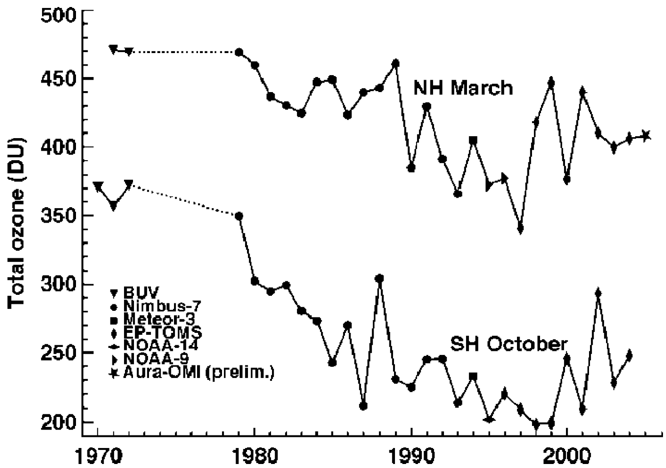

Fig. 1. Average column ozone poleward of 63° latitude in the springtime of each hemisphere (March for the Northern Hemisphere and October for the Southern Hemisphere), in Dobson units (DUs), based on data from various satellite instruments as indicated. The horizontal dotted lines show the pre-1982 averages, based on data points from 1971, 1972, 1979, 1980, 1981, and 1982. The data point from OMI is preliminary. The figure is updated from [14], courtesy of NIVR (Netherlands), KNMI (Netherlands), FMI (Finland), and NASA (U.S.). Source: [13].

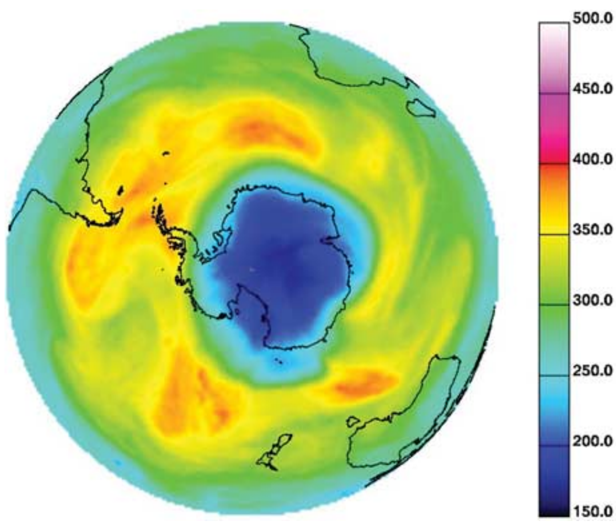

Fig. 2. Antarctic ozone hole measured by OMI on November 1, 2004. Scale in Dobson units.

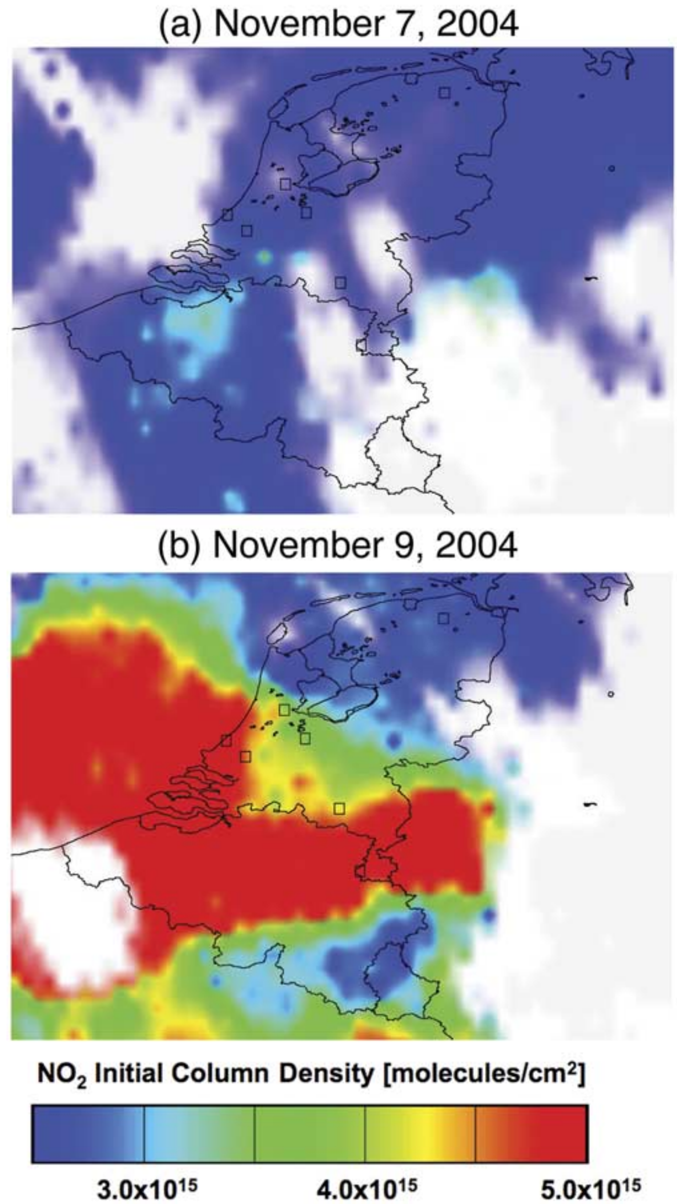

Fig. 3. NO_2 columns measured by OMI above The Netherlands on (a) November 7 and (b) November 9, 2004. In the red areas is the pollution by nitrogen dioxide 5 to 10 times larger than in the clean, blue areas. White areas are covered with clouds.

cloud-free scenes than previous backscatter measurements (e.g., TOMS, the Solar Backscatter Ultraviolet (SBUV) instrument, GOME, and SCIAMACHY).

OMI complements Aura's three main objectives [9] with its own questions as follows.

- Is the ozone layer recovering?
- What are the sources and distribution of aerosols and trace gases that affect global air quality?
- What are the roles of tropospheric ozone and aerosols in climate change?
- What are the causes of surface UV-B change?

A. *Is the Ozone Layer Recovering?*

The Montreal Protocol [10] was signed in 1987 by the world community because of the concern about ozone depletion and the subsequent increase in UV surface irradiance. The aim was to reduce the release of chlorofluorocarbons (CFCs) into the atmosphere. At that time ozone was being measured by satellites as diagnostic of stratospheric dynamics. The discovery of the Antarctic ozone hole led to the Protocol amendments that, through international treaties, would lead to elimination of CFC production. Satellite ozone measurements were then dedicated to monitoring global ozone trends, and the depth and extent of the Antarctic ozone hole. Photochemical models predict that by reducing the CFCs, thereby reducing chlorine and fluorine radicals that destroy ozone, the spring ozone hole above Antarctica as well as the general worldwide reduction of the ozone layer would slow down and will lead to a complete recovery in the second half of the 21st century [11]. Decades of very precise total ozone measurements, preferably on a global scale, are therefore needed in order to be able to monitor the ozone layer and its predicted recovery. The longest satellite record of any trace gas existing to date is the 30-year TOMS/SBUV total ozone record [12]. OMI total ozone measurements are used to extend this record as well as the GOME and SCIAMACHY data record. Determining this long-term ozone trend is a difficult task as this trend is relatively small compared to natural variations.

Therefore, OMI's total ozone measurements have to be very precise over the long term with high accuracy in order to make composite trends with other ozone monitoring instruments. OMI data for the Northern Hemisphere spring high latitude has been added to the Intergovernmental Panel on Climate Change's (IPCC) report on safeguarding the ozone layer [13], which tracks ozone depletion from satellite data at high latitudes. OMI data along with the historical data from the IPCC report are shown in Fig. 1.

Finally, OMI's high spatial resolution may help in determining the relative roles of chemistry and dynamics in the evolution of the Antarctic ozone hole and ozone depletions in the Northern Hemisphere during winter/spring. Fig. 2 illustrates the Antarctic ozone hole measured by OMI on November 1, 2004.

The accuracy of OMI's data products relies on the instrument's calibration accuracy and on the accuracy of the retrieval algorithms. An extensive long-term in-flight calibration effort is underway. As part of the effort to produce an accurate, long-term ozone record, we will continue to improve the total ozone algorithm using OMI's hyperspectral capabilities.

B. What are the Sources and Distribution of Aerosols and Trace Gases That Affect Global Air Quality?

OMI provides data on ozone, NO_2, aerosols, SO_2, and HCHO in the troposphere. These are all-important tropospheric pollutants, produced by industrial and electric power plants, traffic, and biomass burning. OMI's high spatial resolution increases the incidences of cloud-free scenes, resulting in better coverage. Clouds are a notorious disturbance in UV/VIS satellite measurements, since they scatter the solar radiation, preventing the measurement of the atmosphere below the cloud. In the presence of clouds, the amount of trace gas below the cloud is taken from another source, such as climatology or model calculations. Clouds also interfere severely with aerosol retrievals. With OMI's increased ability to observe cloud-free scenes, daily maps of troposphere and pollution are possible. The daily global coverage enables OMI to monitor global transport of pollution.

Fig. 3 illustrates total NO_2 columns measured by OMI above The Netherlands for November 7 and 9, 2004. Large, day-to-day variation of NO_2 can be clearly seen. These changes are attributed to the troposphere and most likely within the boundary layer, since stratospheric amounts change little from day to day. On November 7, 2004, the NO_2 load in the troposphere is about 5 to 10 times lower than on November 9, 2004. These day-to-day variations in NO_2 are well known from ground-based measurements but have never been observed by a satellite instrument before. GOME and SCIAMACHY are limited to monthly or yearly averages of NO_2 pollution because of their low spatial resolution and limited coverage. Also high regional dependency of pollution can be seen by OMI, as is shown on November 9.

C. What are the Roles of Tropospheric Ozone and Aerosols in Climate Change?

Ozone and aerosols in the troposphere influence the temperature on Earth and therefore the climate. Important climate parameters of these constituents are the amount and distribution as a function of height, and for aerosols, also its composition (which determine their radiation properties). OMI measurements of tropospheric ozone, which is also a greenhouse gas, and aerosols, in particular the UV-absorbing aerosols, will reduce the uncertainty in their contribution to climate forcing. Fig. 4 illustrates OMI measurements of aerosols above Australia that result from biomass burning. The aerosol optical thickness is a measure of the amount of aerosols, and the aerosol single-scattering albedo is related to the absorbing properties of the aerosols. OMI aerosol algorithms can differentiate between sulfate, smoke and dust, which contribute differently to climate forcing. Fig. 4(d) shows that for the aerosols above Australia different values of the single-scattering albedo occur, which indicates that the aerosols originate from different sources.

D. What are the Causes of Surface UV-B Change?

Excessive doses of UV radiation are known to cause health effects, such as skin cancer, eye problems and immunosuppression. However, changes in UV-B are not only a human health concern, but a concern to the entire ecosystem. UV-B can affect plant productivity and also the rate of atmospheric pollution production. Pollution, in turn, also affects the health of the plants, animals and humans. Therefore, UV-B plays a duel role in the environment. Surface UV-B amounts are determined from overhead ozone, clouds and aerosols, and their properties. OMI measures all of these parameters simultaneously.

III. OMI Instrument

The OMI instrument is a nadir-viewing imaging spectrometer that measures the solar radiation backscattered by the Earth's atmosphere and surface over the entire wavelength range from 270–500 nm, with a spectral resolution of about 0.5 nm. The spectral sampling distance ranges from 0.15–0.3 nm/pixel, depending on wavelength. In OMI a scrambler is used to depolarize the radiation. The 114° viewing angle of the telescope perpendicular to the flight direction corresponds to a 2600-km-wide swath on the Earth's surface, which enables measurements with a daily global coverage. In the normal operation mode, the OMI pixel size is 13 km $\times$ 24 km at nadir (along $\times$ across track); however, in the zoom mode the spatial resolution can be reduced to 13 km $\times$ 12 km.

OMI was built by Dutch Space and the Netherlands Organisation for Applied Scientific Research (TNO) TPD in cooperation with Finnish subcontractors VTT and Patria New Technologies Ltd. The Royal Netherlands Meteorological Institute(KNMI) is the Principal Investigator Institute. Overall responsibility for the OMI mission lies with the Netherlands Agency for Aerospace Programmes (NIVR) with the participation of the Finnish Meteorological Institute (FMI). A more detailed description of the instrument appears as a companion paper in this special issue [1].

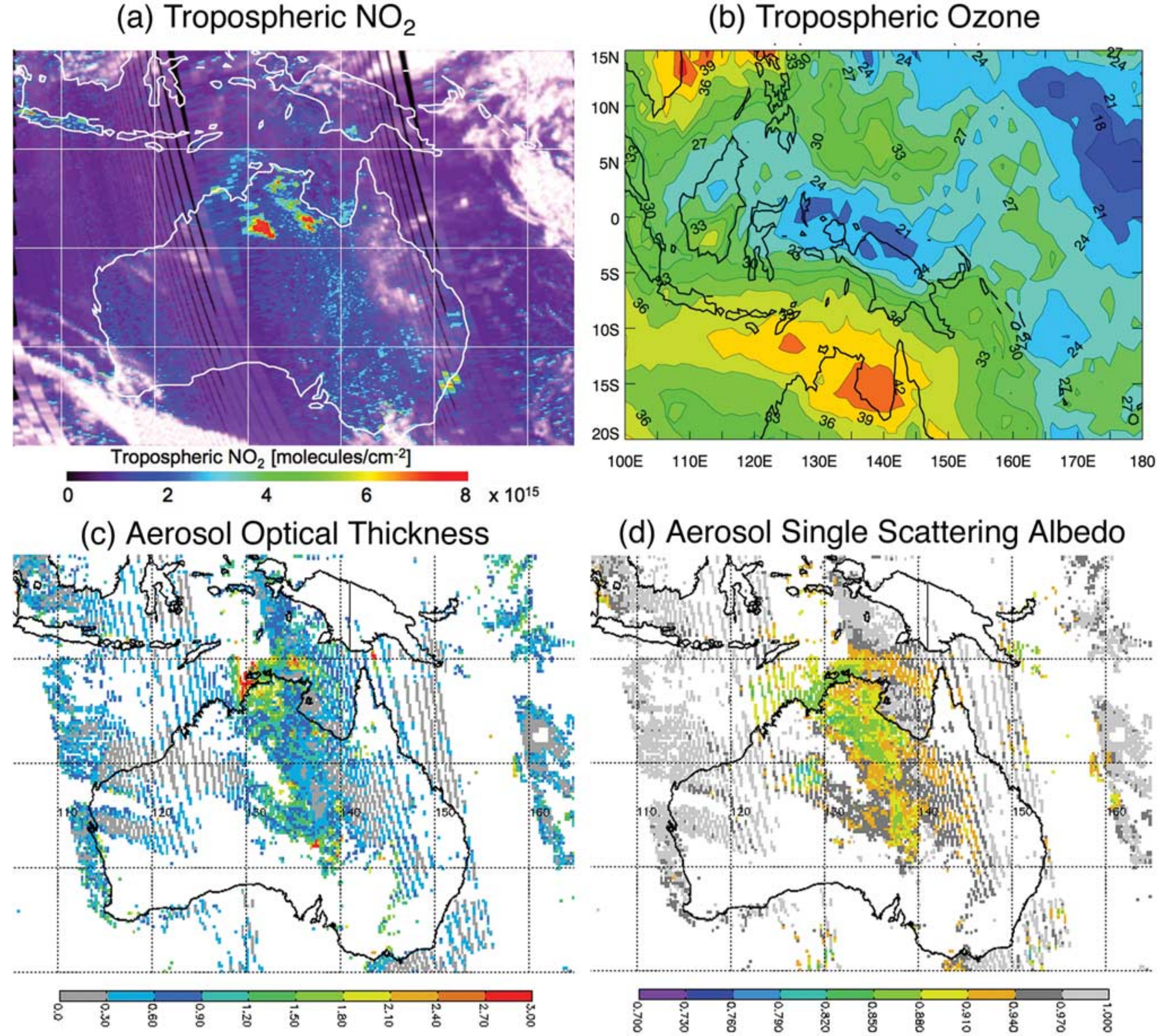

Fig. 4. OMI measurements of tropospheric NO_2, tropospheric ozone, and aerosols, resulting from biomass burning above Australia on October 11, 2004. (a) OMI tropospheric NO_2 columns. Courtesy of E. Bucsela (NASA GSFC). (b) OMI tropospheric ozone (in Dobson units). The method called "cloud slicing" was used to determine column ozone amounts. Blue regions are around 25 DU, while orange regions exceed 40 DU. The orange region north of Australia coincides with intense biomass burning aerosols detected by OMI over much of north central Australia on this date [i.e., (c) and (d)]. Courtesy of J.R. Ziemke (NASA GSFC). (c) Aerosol optical thickness measurements. The aerosol optical thickness is a measure of the amount of aerosols and is derived at a wavelength of 380 nm. Courtesy O. Torres (NASA GSFC and UMBC JCET). (d) Aerosol single-scattering albedo measurements. The single-scattering albedo is derived at a wavelength of 380 nm and is related to the absorbing properties. Different values indicate that the aerosols originate from different sources. Courtesy of O. Torres (NASA GSFC and UMBC JCET).

IV. OMI Algorithms and Data Products

OMI algorithms rely heavily on experience gained from TOMS, SBUV, GOME, and SCIAMACHY. Algorithms were developed, and continue to be improved, by science team members in Europe and the U.S. Some algorithms are produced separately, while some are produced jointly by the Dutch, Finnish, and U.S. teams.

A. Total Ozone

OMI ozone data are retrieved using both the TOMS technique developed by NASA and a differential optical absorption spectroscopy (DOAS) technique developed by KNMI. Both algorithms provide OMI ozone data of the same quality as TOMS ozone data in order to ensure continuity of ozone trends detected to date. The long-term goal is to eliminate any bias between the two algorithms. Experience with TOMS and DOAS suggests that the algorithms are capable of producing total ozone with an rms error of about 2%, though these errors are not identical and necessarily randomly distributed over the globe.

The NASA OMI algorithm is the TOMS Version 8 algorithm applied to OMI [2]. This version uses only two wavelengths (317.5 and 331.2 nm) to derive total ozone. Four other TOMS wavelengths are used for diagnostics and error correction. V8

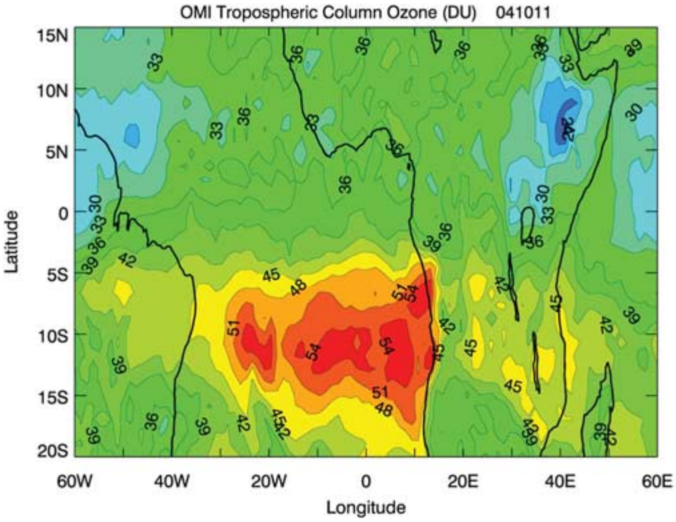

Fig. 5. OMI tropospheric column ozone (in Dobson units) for October 11, 2004 over the South Atlantic. The method called "cloud slicing" was used to determine column ozone amounts. Blue regions are around 25 DU, while red regions exceed 50 DU. Courtesy of J. Ziemke (NASA GSFC).

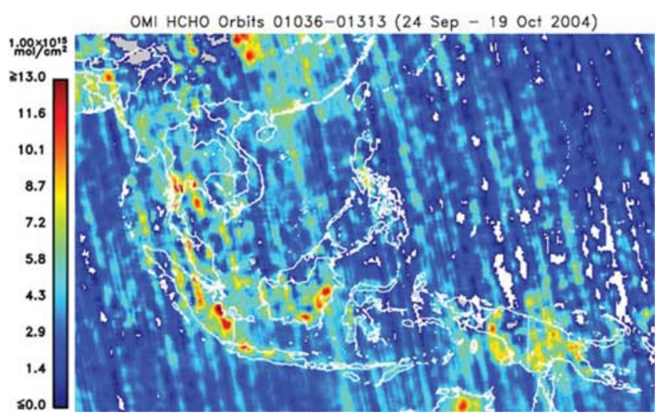

Fig. 6. Preliminary average vertical columns (geometric AMF) of HCHO over Southeast Asia during September 24 and October 19, 2005, showing events of biomass burning over Sumatra, Borneo, and New Guinea as well as anthropogenic activity in Jakarte (Java) and the RedBasin (China). Courtesy of T. Kurosu and K. Chance (SAO).

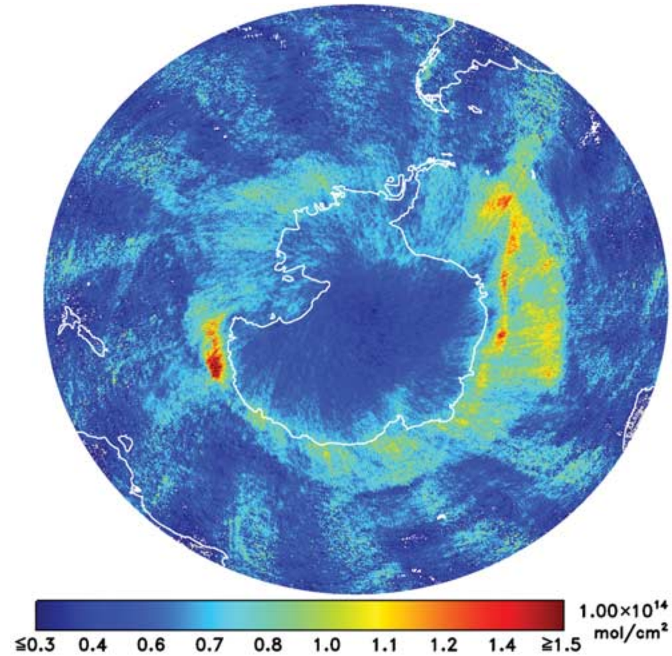

Fig. 7. OMI BrO total column measurements over the Antarctic made on September 29 and 30, 2004. Courtesy of T. Kurosu and K. Chance (SAO).

was used to reprocess all SBUV and TOMS total ozone data taken since April 1970. Therefore, it is being applied to OMI to ensure continuity of the data record. This algorithm will remain in operation until an algorithm is developed that is demonstrated to be more accurate because it uses the enhanced capabilities of OMI.

The KNMI total ozone algorithm is based on the DOAS technique [15] that has been widely used to measure trace gases from ground. It has been applied successfully to process data from the GOME and SCIAMACHY instrument that are currently flying on the European Remote Sensing 2 (ERS-2) and ENVISAT satellites. This ozone column is estimated from longer wavelengths than those used in the TOMS algorithm. In principle, DOAS is less sensitive to disturbing effects by absorbing aerosols, SO_2, and calibration errors than the TOMS algorithm. The OMI DOAS algorithm uses a different spectral window (331.6–336.6 nm) to GOME and SCIAMACHY, chosen such that the retrieval does not depend on external information of atmospheric temperatures.

B. Ozone Profiles

The OMI profile algorithm is based on the optimal estimation technique [16] that has become standard in the field. It will take advantage of the hyperspectral capabilities of the OMI instrument to improve the vertical resolution of the ozone profile below 20 km compared to those from the SBUV instruments that have flown on NASA and National Oceanic and Atmospheric Administration (NOAA) satellites since 1970. It uses new approaches to calculate the required radiances and Jacobians in an efficient manner and to correct for rotational Raman scattering. In principle, this algorithm should be able to provide more accurate total O_3 estimates than the two algorithms discussed above, for it uses a broader range of OMI wavelengths that includes those that are used for total ozone.

C. Tropospheric Ozone

Tropospheric column ozone will be produced using an improved version of the tropospheric ozone residual (TOR) method developed for TOMS [17]. In this algorithm one uses a high vertical resolution O_3-profiling instrument to determine the stratospheric ozone column, which is then subtracted from total column ozone. EOS Aura has two instruments, HIRDLS and MLS, which are designed to produce the stratospheric O_3 profile at a high vertical resolution. The TOR algorithm will also use the "cloud slicing" technique developed for TOMS, which is less sensitive to calibration but only works best in the tropics. Work is presently underway to extend this method to higher latitudes. First preliminary tropospheric ozone retrievals have been shown to be successful and showed enhanced tropospheric ozone levels over Australia and the South Atlantic [see Figs. 4(b) and 5]. Biomass burning is one of the major sources for generating tropospheric ozone. It is not uncommon to have increases of 10–15 DU in tropospheric O_3 caused just

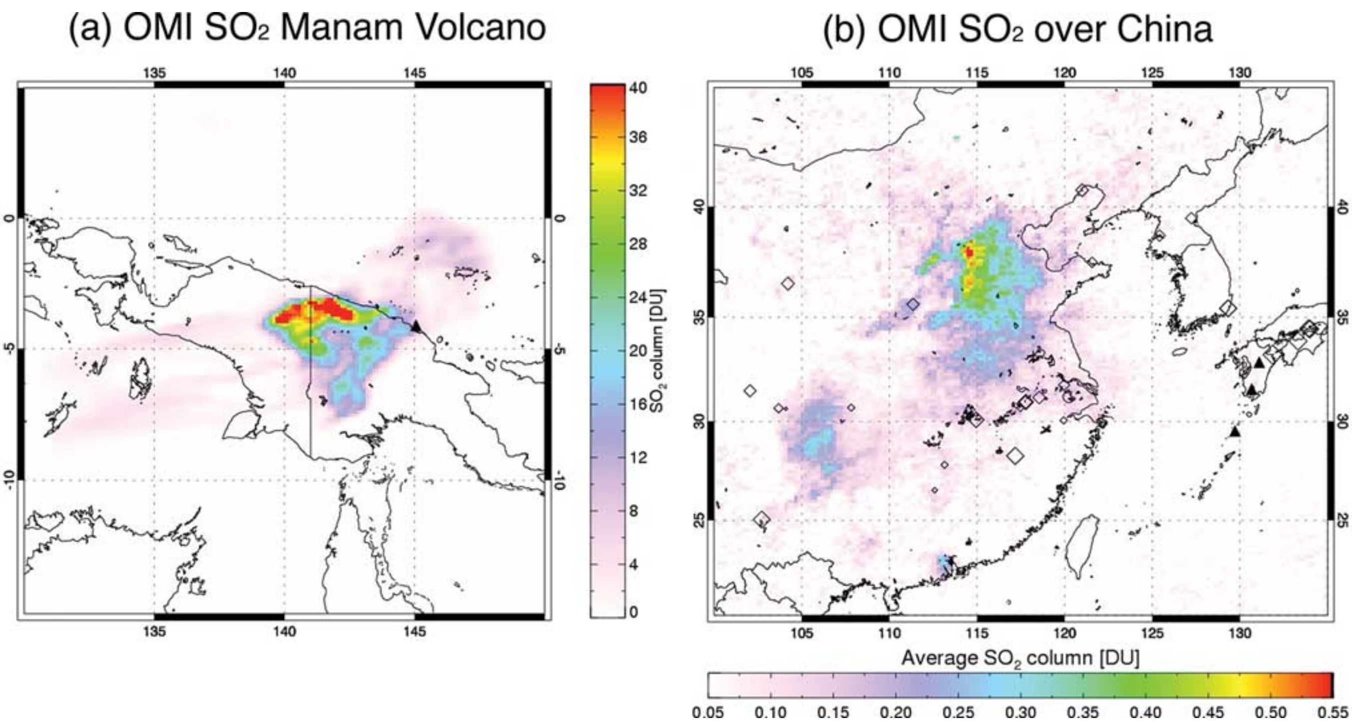

Fig. 8. (a) OMI SO_2 image of an explosive eruption cloud from Manam volcano (Papua New Guinea) on January 28, 2005. The triangle symbol marks the location of the volcano. This SO_2 cloud reached stratospheric altitudes (21–24 km) and hence was a significant aviation hazard. (b) Average SO_2 column amount measured by OMI over eastern Asia in December 2004. Diamonds indicate the locations of copper smelters. Several SO_2 source regions in China can be identified. The principal source of SO_2 emissions in China is coal-fired power plants. For further details on the OMI SO_2 product see [21]. Courtesy of S. Carn and A. Krueger (UMBC).

from biomass burning alone. Other sources including industrial pollution, lightning NO_x, and stratospheric injection, which can also produce large enhancements in tropospheric O_3.

D. Trace Gases

Apart from O_3, the atmospheric trace gases NO_2, SO_2, BrO, HCHO, and OClO also have absorption features that fall in the OMI wavelength range. Because of OMI's hyperspectral capability these gases can be retrieved using DOAS or similar algorithms. DOAS algorithms have been successfully employed for GOME and SCIAMACHY and have been also applied to ground-based measurements. The method involves fitting the spectroscopic features in the measured Earth albedo and accounting for Fraunhofer structures due to rotational Raman scattering (the Ring effect). From the fit, slant columns are derived that are converted to vertical columns using radiative transfer models and a general assumption for the measured constituent's vertical profile. This method is applied to BrO, HCHO, and NO_2. For OClO, only slant columns are possible because its profile is poorly known. Formaldehyde (HCHO) biomass burning events above South America, South Africa, and Indonesia, as well as BrO above ice fields at the South Pole, have been detected by OMI (see Figs. 6 and 7).

For NO_2, further analysis is used to separate the troposphere and stratosphere based on the fact that NO_2 stratospheric features are generally zonal while the features in the troposphere have distinct patterns related to NO_2 sources. An alternative approach to extracting tropospheric amounts is to remove the stratospheric column using HIRDLS data. These tropospheric NO_2 columns will provide the information needed for air quality

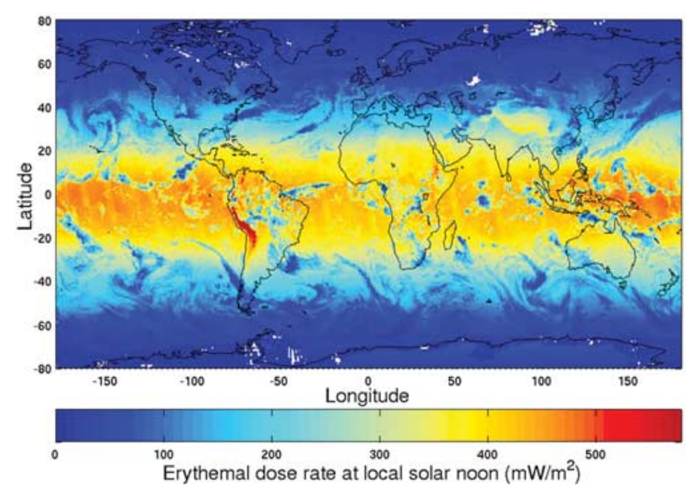

Fig. 9. Cloud-corrected erythemal dose rate at local solar noon (milliwats per square meter) on March 14, 2005. Courtesy of Aapo Tanskanen (FMI).

studies. The total column NO_2 measurements (see Fig. 3), indicate that the tropospheric information is available. In Fig. 4 first preliminary tropospheric NO_2 retrievals are shown above Australia, based on the assumption that stratospheric NO_2 data are generally zonal [18], [19].

Implementation of the full spectral fitting (SF) SO_2 algorithm [20], has been delayed. In lieu of SF, OMI science team members have developed a fast retrieval algorithm that produces SO_2 column amounts using residuals from the operational TOMS version ozone code at four wavelengths corresponding to maxima and minima in the SO_2 absorption cross-section. This is called the band residual difference (BRD) algorithm [21].

TABLE I
OMI SCIENCE REQUIREMENTS

Product Name	Units	Accuracy Abs::Rel (1)	Temporal Resolution	Horizontal Resolution::Cover (2)	Vertical Resol.:: Cover
Radiances	Watts/cm^2/sr	3%::1%	once/day	13 × 24 km::G D	NA
Total Ozone	DU (3)	3%::1.5%	once/day	13 × 24 km::G D	Column
Ozone Profile	ppmv	10%::10%	once/day	13 × 48 km::G D	6 km::20-45 km
Tropospheric Column Ozone	DU (3)	25%::10%	once/day	52 × 48 km::60S-60N D	Column
Surface UVB Flux	Watt/m^2	10%::10%	once/day	13 × 24 km::G D	Surface
Cloud Scattering Layer Pressure (4)	hPa	100hPa::30hPa	once/day	13 × 24 km::D	Surface
Aerosol Optical Thickness (5)	Dimensionless	0.1::0.05 30%::10%	once/day	13 × 24 km::G D	Column
Aerosol Single Scattering Albedo	Dimensionless	0.1::0.05	once/day	13 × 24 km::G D	Column
SO_2	molecules/cm^2	3 10^{16} (50%)::2 10^{16} (20%) non-volcanic 30%::20% volcanic	once/day	13 × 24 km::G D	Column
NO_2	molecules/cm^2	2x10^{14}::2x10^{14} background 30%::20% polluted	once/day	13 × 24 km::G D	Column
HCHO	molecules/cm^2	35%::25%	once/day	13 × 24 km::G D	Column
BrO	molecules/cm^2	25%::25%	once/day	13 × 24 km::G D	Column
OClO	molecules/cm^2	15%::10%	once/day	26 × 48 km::V	Slant Column

(1) Absolute accuracy is given at the horizontal and vertical resolution indicated in the last two columns, and represents the root sum of square of all (1σ) errors, including forward model, inverse model, and instrument errors, calculated over the covered area, as indicated in the 6th column. Relative accuracy represents a component of the absolute error that varies at the frequency indicated in the 5th column. When multiple values are given, the larger value applies.

(2) G represents global coverage, D daylight, and V polar vortex conditions. (3) 1 DU = 2.687 × 10^{16} molecules/cm^2.

(4) Cloud products are limited to optically thick cloluds. (5) Aerosol products are limited to cloud-free pixels.

The BRD algorithm provides unique observations of SO_2 in volcanic and polluted regions. Noise levels are higher than can potentially be achieved by using the SF method, but are still five times better than EP TOMS, allowing for robust detection of lower tropospheric SO_2. Using the BRD technique measurements of passive SO_2 degassing from several volcanoes on a daily basis have been obtained. Explosive volcanic eruption clouds can be tracked for a longer time than was possible with TOMS, providing critical data for aviation hazard mitigation [see Fig. 8(a)]. Anthropogenic SO_2 has been detected over eastern China [see Fig. 8(b)], South America, and Europe.

E. Clouds and Aerosols

In addition to trace gases, OMI derives information on clouds and aerosols. The cloud parameters are essential for the retrieval of other OMI products, particularly for the troposphere. OMI cloud information includes both the effective cloud coverage and effective cloud pressure, which employs absorption by O_2-O_2 [22] and the rotational Raman scattering [23]. The retrieved cloud cover and pressure are used to estimate, and correct for, the amount of trace gas hidden below the clouds. There are plans to combine both algorithms, which makes it possible to determine a more accurate cloud albedo and coverage, and thereby reduce the errors for trace gases in the boundary layer. Both cloud algorithms have been shown to work according to expectations.

A cloud mask is needed for accurate retrievals of aerosol optical thickness both over land and ocean. The spectral aerosol optical thickness contains information on the aerosol concentration and on the size of the aerosol particles. From the wavelength dependence of the radiances measured by OMI the aerosol optical thickness and the single-scattering albedo are derived. The aerosol optical thickness and single-scattering albedo are retrieved using the TOMS UV algorithm [24] and the OMI UV/VIS multiwavelength algorithm [25]. The algorithms are applied to (nearly) cloud-free pixels. First aerosol retrievals using the TOMS UV algorithm have shown biomass burning detection above, for example, Australia (see Fig. 4) as well as dust events above the Sahara.

F. UV-B Algorithm

The OMI UV-B algorithm [26] inherits from the TOMS UV algorithm [24]. OMI measurements of ozone, aerosols, and clouds are used as inputs to the algorithm. Clear sky UV irradiance is first estimated using the total ozone column, derived with the TOMS algorithm, and additional geophysical data. By correcting the clear sky UV irradiance with the aerosol and cloud information, the surface UV irradiance is obtained.

The UV products that are produced are UV irradiances at four wavelengths (305, 310, 324, 380 nm), noontime erythemal UV dose rate and the erythemal UV daily dose (see Fig. 9).

G. Near Real Time and Very Fast Delivery Products

OMI will also provide Near Real Time (NRT) products, which will be available 3 h after measurement, and Very Fast Delivery Products (VFD) [27], available within 30 min after measurement. The NRT products will have daily global coverage and will initially include total ozone and possibly other TOMS type products. NRT NO_2 products are also planned. NRT total ozone data will be used by ECMWF and NOAA in their weather forecasts. Total ozone data will improve the medium range weather forecast by providing wind field information at altitudes where little information is currently available. OMI is able to make an UV-B forecast for a few days ahead based on the NRT total ozone data. Other applications of OMI NRT include volcanic SO_2 and ash mapping for aircraft avoidance control. Testing is underway to use OMI's NRT tropospheric NO_2 data for air quality forecasts.

The Direct Broadcast OMI data received at Sodankylä in northern Finland is used to produce the OMI VFD products. The products include clear-sky UV index, erythemally weighted daily UV dose and total ozone. The Direct Broadcast data and hence also the VFD products are regional, covering most of Western Europe. Distribution maps of the UV and ozone products will be made publicly available through the Internet.

Table I is a summary of the OMI Standard Data products, including requirements for accuracy and coverage. The OMI Science Requirement Document [28] describes the relationship between the required accuracies as shown in Table I and the science questions discussed in this paper. Some algorithms are still under development; therefore schedules for public release depend on the data product. Public released OMI standard data products will be available via the NASA Goddard Space Flight Center Earth Sciences Distributed Active Archive Center at http://daac.gsfc.nasa.gov.

V. Conclusion

OMI is the first of a new type of nadir looking UV/VIS spectrometers, and is performing according to expectations. First results are shown for Ozone, NO_2, SO_2, BrO, HCHO, UV-B, and aerosols. Therefore, OMI will contribute significantly to study of the ozone layer, air quality, and climate change. Near Real Time products of OMI can be used for UV-B, weather and air quality forecasts, and aircraft avoidance control.

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Pieternel F. Levelt received the M.S. degree in physical chemistry and the Ph.D. degree from the Free University of Amsterdam, Amsterdam, The Netherlands, in 1987 and 1992, respectively. Her Ph.D. work consisted of the development of a XUV spectrometer-based nonlinear optical technique and performing XUV spectroscopy on small diatomic molecules.

In 1993, she started working at the Royal Netherlands Meteorological Institute (KNMI), De Bilt, in the Atmospheric Composition section at the Research Department of KNMI. There, she worked on chemical data assimilation of ozone in two-dimensional and three-dimensional chemistry transport models and on the validation of the European satellite instruments GOME and SCIAMACHY. She was a Member of the Algorithm and Validation subgroups of GOME and SCIAMACHY. She was strongly involved in the validation program of both instruments. Since July 1998, she has been Principal Investigator of the OMI instrument and is responsible for the scientific program of OMI and managing the international OMI Science Team. She is also the Project Manager of the OMI Program at KNMI and responsible for the development of algorithms, validation, and data processing of OMI products and in-flight calibration and operational planning of the OMI instrument. She is managing the OMI team at KNMI consisting of 15 to 35 people. As Principal Investigator, she is advising NIVR on OMI instrument requirements and performance.

Ernest Hilsenrath was with NASA's Goddard Space Flight Center from 1965 to August 2005. He was Deputy Project Scientist for the EOS Aura mission and is Co-Principal Investigator for the Ozone Monitoring Instrument flying on Aura. In the 1970s, he developed a unique rocket payload to measure ozone profiles in the stratosphere and lower mesosphere. He also conducted ozone and water vapor measurements from rockets, balloons, and aircraft. He was the Principal Investigator of the Shuttle-borne SBUV instrument, flown eight times, to calibrate the SBUV/2 series of instruments in the NOAA polar orbiting satellites. He managed the Goddard Space Flight Center's Radiometric Calibration and Development Facility. The laboratory provides calibrations for national international satellite ozone instruments and developed the first UV/VIS limb scattering instruments to demonstrate, from the Space Shuttle, the ozone monitoring capability for NPOESS. He served on and chaired several international panels for atmospheric composition observations including NPOESS and Eumetsat. He is Chairman of the CEOS Cal/Val Working Group's Atmospheric Chemistry Subgroup. He has authored more than 50 papers on atmospheric composition and calibration/validation in peer-reviewed journals. He is currently a staff member at the University of Maryland Baltimore County, Baltimore, at the Joint Center for Earth Systems Technology.

Gilbert W. Leppelmeier (M'72) has been involved in space research missions for 19 years, first at the Technical Research Centre of Finland and then at the Finnish Meteorological Institute. He was Co-Principal Investigator for the Ozone Monitoring Instrument onboard Aura from the start of the mission through 2004. Other space missions include Envisat, Odin, SOHO, Spectrum-Roentgen-Gamma, Cassini/Huygens, as well as a number of studies of atmospheric missions to Mars and Earth. Earlier research includes solid-state physics, nonlinear optics, laser fusion energy, and magnetic fusion energy. Since retirement from FMI in 2000 his continued activity in space and atmospheric sciences has been under the aegis of G&S Associates, Oy, Espoo, Finland.

Gijsbertus H. J. van den Oord is currently with the Royal Dutch Meteorological Institute (KNMI), De Bilt, The Netherlands. He has a 16-year-long background in both observational and theoretical astrophysics with emphasis on solar and stellar magnetic activity. On the theoretical side, he has worked in the fields of magnetohydrodynamics, plasma physics, beam electrodynamics, high-energy astrophysics, X-ray spectroscopy, and radiative transport. On the observational side, he has been an active user of (ground-based) radio and optical instrumentation, and spaceborne X-ray and (E)UV instrumentation. He has supervised two Ph.D. students and is author and coauthor of 72 papers. Since April 1999, he has been the Deputy Principal Investigator of the Ozone Monitoring Instrument. He has been a Visiting Professor at the University of Catania. He has been a member of numerous science advisory boards on both national and international level.

Dr. van den Oord received an award from Utrecht University for outstanding research accomplishments.

Pawan K. Bhartia received the the M.S. degree in computer science and the Ph.D. degree in physics from Purdue University, West Lafayette, IN.

He is currently the Project Scientist of NASA's Total Ozone Mapping Spectrometer satellite mission and the U.S. Science Team Leader of the Ozone Monitoring Instrument on EOS Aura. He has over 60 scientific publications, dealing principally with the measurement of the Earth's ozone layer.

Dr. Bhartia has received several NASA awards for his work, including the prestigious William Nordberg Medal in Earth Science from the NASA Goddard Space Flight Center.

Johanna Tamminen received the M.Sc. degree in mathematics, the Phil. Lic. degree in applied mathematics, and the Ph.D. degree in applied mathematics from the University of Helsinki, Helsinki, Finland, in 1993, 1999, and 2004, respectively.

She has been with the Finnish Meteorological Institute, Helsinki, since 1991, and has experience in data retrieval algorithms and statistical inverse problems. She has participated the European Space Agency's Global Ozone Monitoring by Occultation of Stars (GOMOS) satellite instrument project and was a member of the European Space Agency's (ESA) GOMOS Expert Support Laboratory during the instrument development and is currently a Member of ESA's GOMOS Quality Working Group. She is Co-Investigator of the SPICAM instrument onboard ESA's Mars Express satellite, and since the beginning of 2005 she has been Co-Principle Investigator of the Ozone Monitoring Instrument onboard NASA's EOS Aura satellite

Johan F. de Haan received the M.S. degree in physics and the Ph.D. degree from the Free University of Amsterdam, Amsterdam, The Netherlands, in 1978 and 1987, respectively. His Ph.D. thesis, entitled "Effects of aerosols on the brightness and polarization of cloudless planetary atmospheres" was defended successfully in 1987 (promoter: Prof. Dr. J. W. Hovenier). The thesis deals with the development of an improved adding/doubling code to calculate the degree of polarization of sunlight scattered by the atmospheres of the Earth and Mars. The code was applied to these atmospheres and effects of aerosols on the scattered light were investigated.

Between 1987 and 2003, he was involved in educating Ph.D. students in the Astronomy Department, Free University. He worked together with Ph.D. students on diverse subjects, such as light scattering by nonspherical aerosol particles, and the interpretation of measurements of polarized light scattered by the atmospheres of the Earth, Venus, and Jupiter. Between 1994 and 2000, he worked part-time at the Survey Department of Rijkswaterstaat, Delft, The Netherlands, on the interpretation of remote sensing images of coastal and inland waters. This included the development and application of schemes for atmospheric correction of those images and the improvement of retrieval algorithms for chlorophyll, suspended sediment, and yellow substance. In 2000, he began work at KNMI on OMI retrieval algorithms. He developed a scheme to improve the correction for rotational Raman scattering in the total ozone DOAS algorithm, thereby eliminating errors in the total ozone column of up to 10%. Currently, he is responsible for the OMI ozone profile algorithm, which is being extended to include rotational Raman scattering. Further, he is involved in the OMI cloud retrieval algorithm and is investigating ways to improve the current algorithm that is based on absorption by the O_2-O_2 collision complex at 477 nm. In general, specialized knowledge on radiative transfer and a good overall knowledge of numerical techniques are used to extend and improve retrieval algorithms. Special care is taken to ensure that the physics behind the algorithms is sound.

J. Pepijn Veefkind is an expert in the field of satellite remote sensing of aerosols and trace gases. He has experience in developing and validating retrieval algorithms for satellite based radiometers and spectrometers. During his Ph.D. research, he developed different techniques for the retrieval of aerosol optical thickness from GOME, ATSR-2, and AVHRR data and participated in several international field experiments. Since 1999, he has been working in the Ozone Monitoring Instrument (OMI) PI Team, which is part of the Atmospheric Composition Division, Royal Dutch Meteorological Institute (KNMI), De Bilt, The Netherlands. He is responsible for the development and implementation of retrieval algorithms for the OMI ozone column, ozone profile, NO_2, aerosol, and cloud products. He is chairing the Algorithms Working Group of the International OMI Science Team. His research interests include retrieval techniques, global monitoring of aerosols and trace gases, intercomparison of satellite measurements from different sensors, radiative forcing of climate, and satellite detection of air pollution.