White Paper on OMI Science Goals and Validation Needs

		Date	Signature
Author:	R. McPeters, P.K. Bhartia, J.F. de Haan, and P.F. Levelt	11 December 2002	
Checked:	OSAB	11 December 2002	
Approved:	OSAB and US Team Leader	11 December 2002	
Archive:	R. Noordhoek	11 December 2002	

Distribution list:

To:	Mike Kurylo	NASA/HQ
CC:	Phil DeCola	NASA/HQ
	James Gleason	NASA/HQ
	Mark Schoeberl	NASA/GSFC
	Richard McPeters	NASA/GSFC
	PK Bhartia	NASA/GSFC
	Ernie Hilsenrath	NASA/GSFC
	Gilbert Leppelmeier	FMI
	Anssi Mälkki	FMI
	Ellen Brinksma	KNMI
	Johan de Haan	KNMI
	Pieternel Levelt	KNMI
	Harry Förster	NIVR

Change status:

Issue	Date	Comments	Affected pages
1.0	11 December 2002	First issue	All

White Paper on OMI Science Goals and Validation Needs

R. McPeters, P.K. Bhartia, J.F. de Haan, and P.F. Levelt

The validation needs of OMI are covered in detail in the Aura Validation Plan. The purpose of this white paper is to briefly review the OMI science goals as part of the Aura mission and show how they lead to specific validation requirements. The validation requirements discussed here are an update to those in Aura Plan and highlight those validation capabilities that need development. A summary of OMI validation needs appears at the end of this document.

OMI Background

OMI is an advanced hyperspectral instrument that measures backscattered radiation in the UV and visible. It will be flown as part of the EOS Aura mission and provide data on atmospheric chemistry that is highly synergistic with HRDLS, MLS, and TES. OMI has an imaging swath of 114 degrees and a nadir ground pixel of 13 x 24 km^2 when measuring total ozone, aerosols, cloud information, and UV irradiances. Its hyperspectral capability enables measurements of trace gases such as SO_2, NO_2, HCHO, BrO, and OClO, but with a ground pixel of about 26 x 48 km^2 because of the higher measurement precision required. Stratospheric ozone profiles will also be measured with this size ground pixel. OMI will obtain daily global coverage.

OMI Science Goals

While the purpose of the original TOMS instrument was simple, namely the mapping of global ozone, the scientific goals of OMI, the successor to TOMS, are far more ambitious. OMI will address each of the major questions to be investigated by the Aura mission. With the other Aura instruments it will answer the following questions:

1) *Is the ozone layer recovering as expected?*

OMI will measure total column ozone on a global basis, continuing the long term TOMS ozone data record and serving as a bridge to the NPOESS ozone monitoring instruments that (OMPS) will be flown by the US late this decade. In order to understand the cause of observed ozone change it is important to distinguish the altitude at which the change is occurring. Recovery of total column ozone and lower stratospheric ozone will be complicated by the effects of global warming. Ozone near 40 km, which is controlled mostly by gas phase chemistry, might be a more reliable indicator of ozone recovery. It will be important to connect the OMI observations to other data sets (SBUV/2, GOME, SCIAMACHY, OMPS) to produce a long-term ozone data record for trend detection.

2 *What are the sources of aerosols and trace gases that affect global air quality and how are they transported?*

OMI, in conjunction with other Aura instruments (particularly HRDLS and TES), will provide global mapping of several key tropospheric constituents including aerosols and some EPA (Environmental Protection Agency) criteria pollutants and other radicals. These include tropospheric ozone, NO_2, SO_2, BrO, and HCHO in the planetary boundary layer. Air quality change has now become a major environmental issue because of intercontinental transport of urban pollution and biomass burning products. It has been shown that satellite measurements in conjunction with photochemical models can provide knowledge on the sources, sinks and transport of these gases and of aerosols.
OMI will certainly be able to measure SO_2 from volcanic eruptions, but the detection of SO_2 in the boundary layer is more difficult. If OMI can detect the pre-eruptive release of volcanic SO_2 it might even provide warning of an impending volcanic eruption.

3) *What are the roles of tropospheric ozone and aerosols in climate change?*

Aerosols increase the sunlight backscattered to space, and ozone is a greenhouse gas through its infrared absorption at 9.6 microns. The importance of aerosols to climate change is well known, and OMI will contribute by measuring both absorbing and non-absorbing aerosol. The sensitivity of surface temperature to changes in ozone is a maximum for ozone changes occurring near the tropopause. TES will obtain tropospheric profiles at a limited number of locations around the globe. OMI total ozone measurements will be combined with HIRDLS and MLS measurements of the stratospheric profile to obtain daily maps of the total tropospheric ozone content. Together these measurements will provide a new and unique picture of the amount and variability of tropospheric ozone. The combination of measurements leads to new validation requirements over and above those for the individual instruments.

4) *What are the causes of surface UVB change?*

The atmospheric constituents that most affect ultraviolet reaching the surface are total column ozone, clouds, and aerosols. OMI is designed to measure the first two of these with very high long-term accuracy. But aerosols, particularly aerosols that absorb in the UV (smoke, dust, black carbon, and exotic nitrated and aromatic aerosols found in urban smog) are important for deriving the amount of UVB radiation penetrating to the Earth's surface. OMI data, combined with data from ground-based instruments (AERONET and UV shadowband radiometers), and other satellite instruments on the A-train (MODIS and CALIPSO) should provide great improvement in our knowledge of the UV absorbing properties of aerosols, resulting in improved estimates of the surface UVB flux.

OMI Validation Requirements

OMI has a unique capability among the Aura instruments in that it maps key atmospheric constituents including aerosols. OMI is also a monitoring instrument; therefore maintaining its long-term accuracy is essential. Its capabilities must be tested and assured using a variety of validation techniques, particularly for its tropospheric products. OMI's validation requirements may be considered in terms of the products it measures.

A) Total Column Ozone and Ground Level UVB

OMI is designed to measure total column ozone with very high long-term accuracy. The existing network of ground-based Dobson and Brewer instruments in conjunction with data from SBUV, TOMS, GOME and SCIAMACHY instruments can meet the basic validation requirement for ozone as well as for surface UVB. However there must be an assurance that the ground-based networks are maintained and data quality assured. To supplement the existing network it would be very desirable to acquire a few double Brewer instruments to serve as reference instruments to verify how well the different ozone algorithms perform under difficult conditions (ozone retrieval under high aerosol loading conditions, retrievals in the Antarctic, etc.). The Brewer instruments would be used on a campaign basis to investigate situations where OMI retrievals are difficult.

Similarly, there is an informal network of UVB measuring instruments around the world that could be used for direct validation of the UVB product. These validations are in a long-term average sense because the strong dependence on clouds leads to small scale inhomogeneity. Such data are routinely archived at the WOUDC in Toronto. It would be desirable to also investigate inhomogenieties inside an OMI ground pixel with multiple low cost inter calibrated instruments.

B) Tropospheric Ozone

Tropospheric ozone can be derived from OMI by various techniques, but they are all differential measurements and require high precision. Because this is a more difficult measurement than total column ozone, the validation requirements are likewise more stringent.

The simplest method of validating the tropospheric ozone column is to use ozone-sondes. A small network of ozone-sonde stations has operated for many years and is expected to continue. For several years NASA has provided funding to augment this network by providing sondes for stations in the southern hemisphere tropics under the SHADOZ program. We recommend that this network be expanded to include a few northern tropical stations. It is also important to add low cost total ozone measuring instruments (Microtops or similar) at these stations in order to alleviate the 10% or so calibration uncertainties sometimes seen in the ozone-sonde measurement.

An aircraft lidar system that can measure ozone and aerosols below (and above) flight altitude is needed. The lidar should also be capable of measuring SO_2 for validation and to avoid the significant error possible in a polluted atmosphere. The lidar should fly on the planned Aura validation/chemistry research missions (INTEX, TC3, etc.) as well as the proposed WB-57 AVE missions. This should be supplemented by a DOAS instrument that covers the OMI wavelength range that can look both up and down in order to derive the ozone column above and below the aircraft.

Finally, it would be highly desirable to have tropospheric ozone lidars in at least a few locations where pollution events occur regularly. In contrast to sonde stations, which usually provide only one measurement per week, tropospheric ozone lidars can capture day-to-day and hour-to-hour variations. Measurements on such short time scales are needed for OMI validation in polluted areas.

C) Ozone near 40 km

Umkehr measurements, NDSC lidars, and solar occultation instruments like SAGE can provide all the information OMI needs to validate ozone change near 40 km. Currently the Umkehr data processing effort for satellite comparison is fully supported by NASA's SBUV/TOMS project. It will be highly desirable to continue this effort to support validation of OMI. It is important to note that Umkehr measurements are conceptually very similar to the space-based OMI measurements, but they are self-calibrating, like SAGE, which makes them extremely valuable for OMI validation. Since ozone near 40 km is also affected by temperature changes, temperature data will also be needed to interpret trends there.

For detecting ozone trends, the key uncertainty is instrument long-term calibration. Comparisons via derived ozone columns and profiles may still contain algorithm issues, which may hide calibration problems. Validating satellite radiances could overcome this problem and should be pursued. Validation of GOME radiances was successfully accomplished using ozone data from SBUV/2 and ozone sondes and radiative transfer codes to compute expected radiances. There is on-going research to attempt radiance validation using ground based observations of zenith sky radiances.

D) Aerosols

The global AERONET network, partially funded by the EOS project, provides very useful data to validate aerosol measurements from space. However, the CIMEL instrument used in the network currently doesn't measure aerosol absorption at wavelengths shorter than 440 nm. For OMI validation, it will be highly desirable to augment this network so that measurements can be extended down to 340 nm. This could be done either by modifying the CIMEL instrument itself or by adding commercially available UV shadow-band radiometers to the network. Aerosol lidars are needed at some sites to provide altitude information.

E) Cloud height

Cloud height will be derived from OMI by looking at Raman scattering and O_2-O_2 absorption, The effective cloud top pressure derived can be validated from the ground with combined radar and lidar measurements, but only for a limited range of conditions. Such measurements are performed at ARM sites and at several sites in Europe (Cloudnet). The algorithms must be validated for a broad range of conditions. For example, Raman scattering in the ocean will affect the UV cloud algorithm, since this algorithm relies upon a theoretical model to compute the ocean Raman contribution. This model could be validated using an aircraft-borne DOAS instrument, one similar to OMI in spectral range and resolution, that would measure both the up-looking and down-looking radiance near the ocean surface. It is desirable that this instrument also provide spectral coverage in the oxygen A-band in order to establish a measure of consistency for this alternative cloud pressure technique. It is also desirable for the aircraft instrument to make measurements above cloud, ocean, and land at high spatial resolution in order to assess the effects of subpixel variability. Data from other instruments on A-train satellites, such as the Cloudsat radar and CALIPSO lidar, will be compared with OMI cloud products. Therefore, it is important for OMI that these instruments also be validated. An aircraft lidar instrument that would be used for validating other OMI products (aerosol and perhaps trace gases) could be used for this purpose.

F) Other Trace Gases

It is expected that OMI will measure several trace gases other than ozone - SO_2, NO_2, and HCHO, and possibly BrO and OClO. With the exception of SO_2 from large volcanic eruptions, these are all difficult measurements that require high accuracy, particularly for species in the boundary layer. Ground based DOAS instruments with their detailed spectral information are the best means of validating these trace gas measurements. Several DOAS sites have been established by European groups, but there are none in North America. Methods for measuring column NO_2, HCHO, and SO_2, both background levels and in polluted areas, are not established and urgently need development for validation purposes and atmospheric chemistry research. An aircraft based DOAS instrument (possibly the OMI simulator) viewing up and down to derive the columns above and below the aircraft may help. It will also potentially solve problems of ground pixel size mismatches with ground based measurements and provide data in regions of interest where there are no ground measurements. As the OMI column measurements for both ozone and trace gases depend on the altitude profile of these trace gases, particularly in polluted regions, aircraft measurements (DOAS, lidar and in-situ) can help to verify the climatology of the altitude profiles that are used in the retrieval algorithms. Validation of passive volcanic emissions may require development of small DOAS spectrometers for UAV (Unattended Aircraft Vehicle) or manned aircraft. In-situ measurements of all trace gas measurements should also be made on board the aircraft.

Ground based NO_2 lidars are being developed in Europe. Support for these efforts should be strongly encouraged by the Aura validation team.

G) Mobile Ground Station

For the purpose of verifying OMI measurements and algorithms in problem areas, in polluted or heavy aerosol environments for example, a mobile ground station is needed, since most ground stations are located in pristine environments. This would consist of a suite of instruments to measure all the parameters needed for closure, i.e., all the parameters needed to fully characterize the radiative properties of the atmosphere. For ozone and other absorptive gases this would require an accurate total column measurement and a profile measurement. For aerosols this would require measurements of the size and altitude distribution and the index of refraction and absorptive properties. The instruments needed might vary depending on the problem being addressed, but would likely include a Brewer instrument, mobile lidars, DOAS instruments, UV instruments, and aerosol instruments. The suite of instruments needed obviously overlaps the instruments required for product validation discussed above, and indeed could be the same instruments provided they could be available for use in the mobile ground station as needed.

Summary of OMI Validation Needs

1) Data from Existing Networks

Network	Purpose
Dobson / Brewer network	Total column ozone
sonde / SHADOZ network	Ozone and temperature profiles
Aeronet	Aerosols
UVB instruments	Surface ultraviolet
NDSC network	Ozone and trace gas profiles
ARM sites and Cloudnet	Clouds

2) Ground based Instruments

Instrument	Purpose
Double Brewer instrument	Targeted studies of ozone algorithm accuracy and UV measurements
Support for enhanced ozone-sonde network	Tropospheric ozone
Simple total ozone instruments (Microtops or similar)	Normalization of ozone-sonde data
Ground-based DOAS instruments in North America	O_3, SO_2, NO_2, HCHO, BrO, OClO column and tropospheric validation
Modified CIMEL instruments or shadowband instruments	Aerosol parameters (visible and UV)
Aerosol lidar	Aerosol vertical profile
Tropospheric ozone lidar in polluted areas	Monitoring of tropospheric ozone changes
NO_2 lidar / SO_2 lidar	NO_2 and SO_2 vertical distribution
Support for umkehr research	Monitor ozone vertical profile (near 40 km), satellite radiance calibration
Mobile ground station	Various measurements in polluted areas

3) Aircraft based Instruments

Instrument	Purpose
Look-up / look-down DOAS instrument (or OMI engineering model)	Ozone and trace gas column above and below aircraft, cloud height, sub pixel information
Aircraft-based ozone lidar (with SO_2 and aerosol band)	Ozone (and SO_2 and aerosol) profile below (and above) aircraft
In-situ SO_2 instrument	Air pollution / volcano monitoring
In-situ NO_2, HCHO, O_3, BrO, OClO instrument	Air pollution