SATELLITE APPLICATION FACILITY ON OZONE AND ATMOSPHERIC CHEMISTRY MONITORING

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ABSTRACT

EUMETSAT's Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3M SAF) is a part of the EUMETSAT's Polar System (EPS) Ground Segment. The purpose of the O3M SAF is to produce a set of near real-time and offline products based on Metop data, together with dedicated validation services for the products. The near real-time products include GOME-2 total ozone, ozone profile and UV clear-sky fields. Offline products derived from GOME-2 data are total column amounts of ozone, NO2, BrO, ozone profile, aerosol index and optical depth, and offline UV fields. In addition, a total column ozone product is derived from HIRS/4 radiances. An important part of the O3M SAF activities has been the development of radiative transfer models and retrieval methods needed for the calculation of atmospheric products from GOME-2 and HIRS measurements. This paper describes the O3M SAF operational system and the status of the ozone and UV products.

1. OPERATIONAL SYSTEM AND PRODUCT DELIVERY

The O3M SAF products are processed and archived in a distributed system as depicted in fig. 1. The NRT products include total ozone (NTO), ozone profile (NOP) and UV clear-sky fields (NUV). The NTO and NOP products are delivered via EumetCast utilizing telecommunication satellites (Hot Bird) for the data transfer. The NUV product is based on assimilated total ozone (ATO) and is available at the DMI web site. The offline products include total ozone and trace gases (OTO), ozone profile (OOP), HIRS total ozone (HTO), aerosol product (ARS) and offline UV fields (OUV). The archived offline products are available to the users from the FMI and DLR archives. The products can be ordered directly from the archives or through the central product catalogue in the EUMETSAT's Unified Meteorological Archive and Retrieval Facility (UMARF).

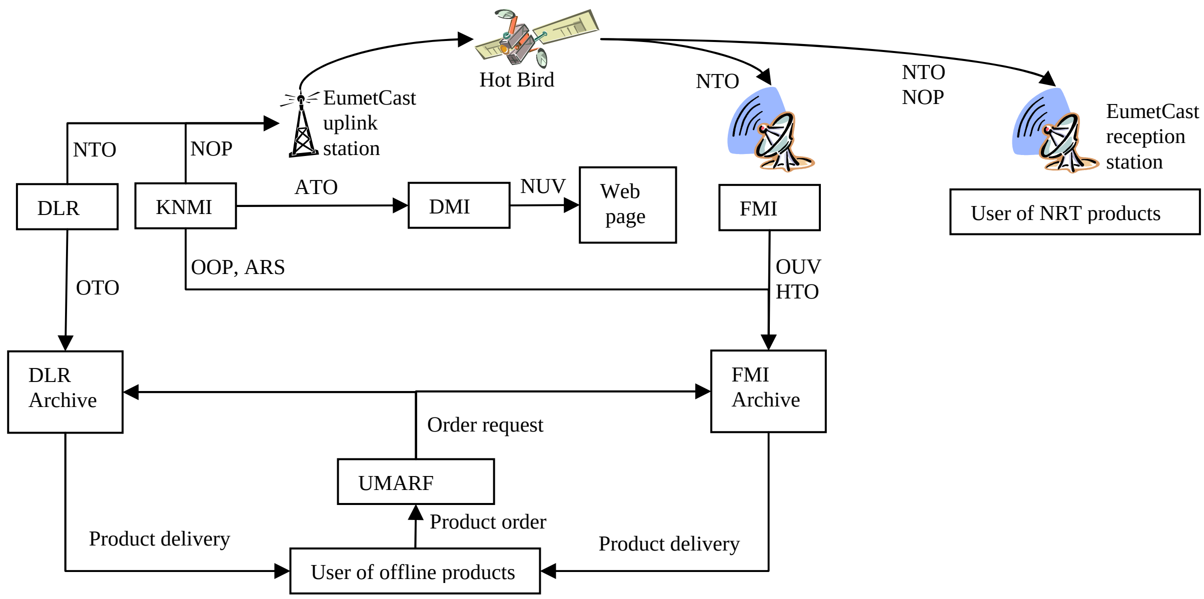

Fig. 1. An overview of the O3M SAF distributed processing and archiving system.

2. TOTAL OZONE AND TRACE GASES

Ozone is the most prominent absorber in the GOME-2 wavelength range. The absorption spectrum of ozone consists of a large-scale continuum (the Hartley, Huggins and Chappuis bands) and small-scale absorption features (with a width of a few nm). These features are prominent between 300 and 350 nm (Huggins band) and between 450 and 550 nm.

Other trace gases show significant spectral absorption structures between 300 and 400 nm (e.g., SO2, HCHO, BrO, and OClO) and above 400 nm (NO2). The retrieval of these minor species is more difficult because interferences of the spectral absorption features of different species occur and must be separated to retrieve the amount of the key component.

Trace gas slant columns from the GOME-2 instrument are retrieved along the line-of-sight of the instrument by application of the Differential Optical Absorption Spectroscopy (DOAS, Burrows et al., 1999)) fitting technique. The total ozone and trace gases provided by the O3M-SAF are being developed by DLR using the experience gained with the GOME Data Processor, the ground segment of the GOME/ERS-2 sensor (Loyola et al., 1997). The O3M-SAF will provide the following total column products:

- ozone total columns in near-real-time
- total columns of O3, NO2 and BrO in off-line
- experimental total columns of SO2, HCHO and OClO in off-line

The current accuracy of the operational GOME/ERS-2 ozone total column products using GDP 4.0 (Roozendael et al., 2004) is in the “percentage level” (Lambert et al., 2004). The GDP 4.0 algorithms was validated and the complete GOME/ERS-2 data set covering over 10 years measurements was reprocessed by end of 2004.

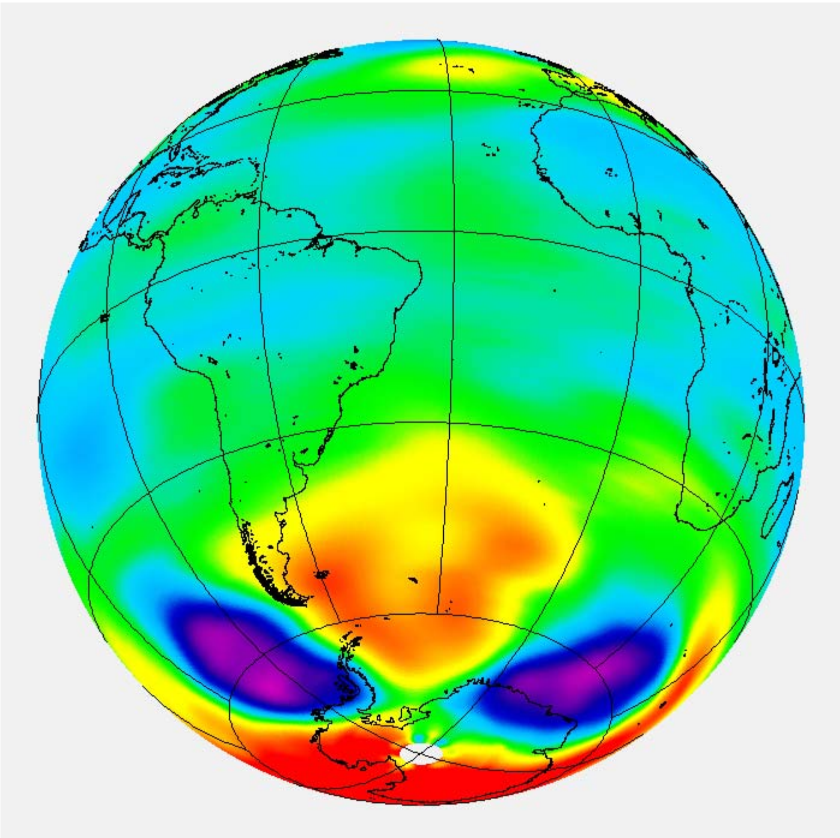

Fig. 2. Break down of the Antarctic ozone hole measured by GOME/ERS-2 on 25 September 2002.

The current accuracy of the operational GOME/ERS-2 NO2 total column products is of about 5% to 20%, further improvements for GOME-2 are foreseen, specially for the accurate retrieval during polluted conditions. The expected accuracy for other trace gases depends strongly on the geophysical conditions, for example sulphur dioxide can be retrieved with a good precision under volcanic eruption events, in the same way formaldehyde can be retrieved with good accuracy mainly under during biomass burning events.

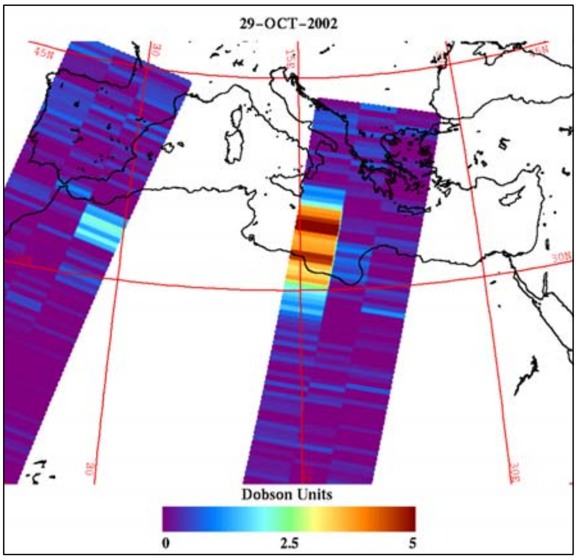

Fig. 3. Total sulphur dioxide content derived from GOME/ERS-2 on 29 October 2002 during Mt. Etna (Sicily) eruptions.

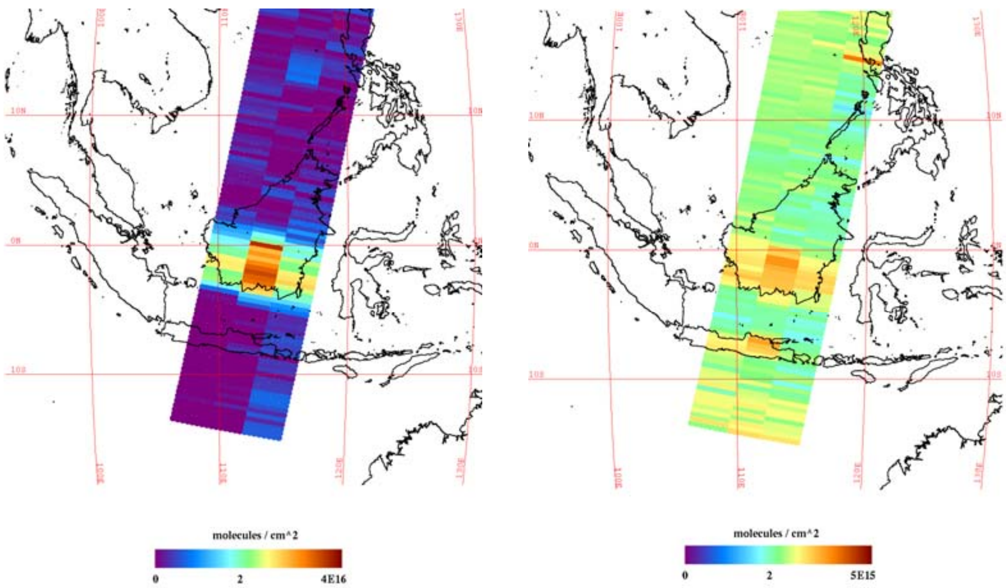

Fig. 4. Vertical columns of formaldehyde (left) and nitrogen dioxide (right) derived from GOME/ERS-2 during the biomass burning event in September 1997 in Asia. Fires were located on the Southern fringe of Borneo where HCHO- and NO2-levels are high.

3. OZONE PROFILE

An algorithm has been developed for the retrieval of the vertical distribution of ozone from GOME-2/METOP UV earthshine spectral observations. The method solves an inverse problem: the ozone profile determines the spectrum, but the spectrum is measured and the ozone profile is to be retrieved from it. Information on the vertical distribution of ozone is contained in the earth radiance measured from space in the wavelength range between about 260 to 340 nm. This is due to the strongly varying ozone absorption cross section in this range. The algorithm executes a formal retrieval: the spectral measurement is simulated using an on-line radiative transfer model and the ozone profile is adjusted so that the simulated and measured spectra agree. Since the actual amount of profile information contained in the measurement varies and the retrieval is performed on a fixed grid, the inversion is in general under-determined and therefore unstable. To remedy this, Optimal Estimation is used for the inversion. This involves the use of an a-priori ozone profile and error covariance to fill-in the missing profile information from the measurement. The balance between the two sources of information is described by the averaging kernel: this kernel gives the relation between the true profile relative to the a-priori and the retrieved profile, also relative to the a-priori. In case all information is extracted from the measurement, the kernel is the unit matrix and in case all information comes from the a-priori its elements are all is zero. A realistic averaging kernel is shown in the figure. It shows that the main profile information lies between 25 and 40 kilometres, where the kernel is highest. Above and below the kernel is broader and is more complicated in shape.

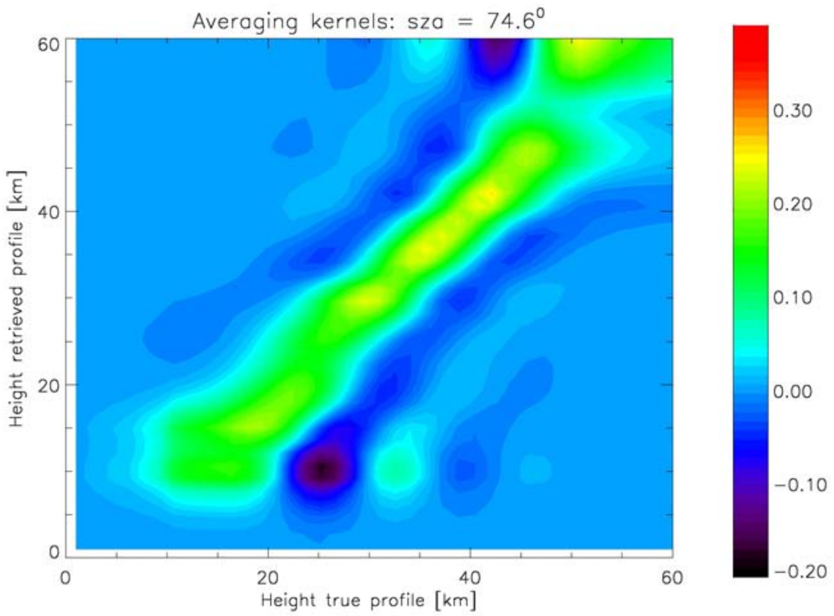

Fig. 5. Averaging kernel for a high value of the solar zenith angle (sza). The kernel is scaled with the a-priori profile.

The main part of the algorithm is the radiative transfer model. Since it is applied on-line, it should compute the UV earthshine spectrum as fast as possible to limit the run–time of the retrieval algorithm. Several measures have been taken to make the model faster, without compromising the required accuracy of the simulated spectrum. This includes: limitation of the number of wavelengths for which the model is run, limitation of the number of layers of the atmospheric model and limitation of the number of quadrature streams which govern the angular discretization of the radiation field.

The algorithm has been tested on the GOME instrument on ESA ERS-2 satellite. This is currently performed within the ESA project CHEOPS-GOME. The project has solved a number of Level 1 issues which used to limit the quality of the GOME profiles. As an example, fig. 6 shows differences between GOME and sonde ozone profiles. It is clear that the GOME profiles compare better than the a-priori. Furthermore, if the averaging kernel is taken into account a very good agreement is found, indicating a good quality of the Level 1 data and the forward model in the retrieval algorithm.

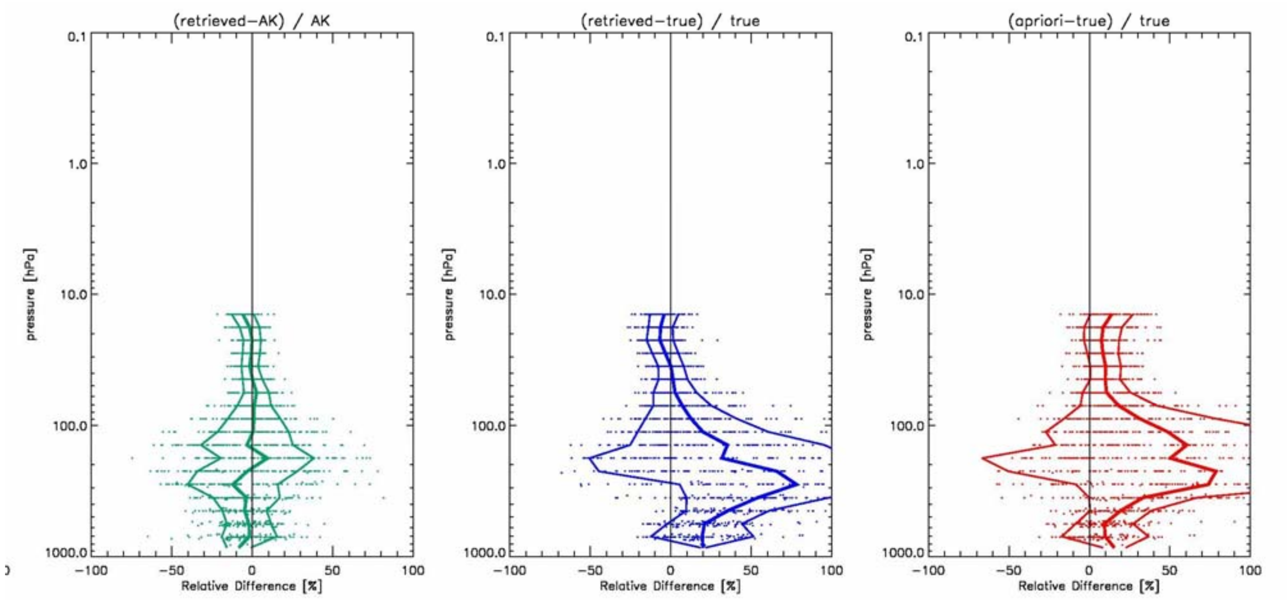

Fig. 6. Differences between GOME ozone profiles and collocated ozone sonde profiles (VMR, Hohenpeissenberg 1997, 105 colocations). The thick line denotes the bias, the thin lines the standard deviation of the difference; individual differences are denoted by dots. Right: Differences between sonde and a-priori, Middle: Differences between sonde and GOME, Left: differences between GOME profiles and sonde profiles on which the GOME averaging kernel has been applied.

For other comparisons with lidar and microwave ozone profile measurements also good comparisons for the middle and higher stratosphere have been found. Within the CHEOPS-GOME project a rigorous validation of Opera-Gome has been carried out whose results will be shortly available.
GOME2 on METOP has some differences with GOME on ERS2. The swath of GOME2 is larger to achieve global coverage in one day. This leads to large off-nadir viewing angles. The sphericity effects on the radiative transfer model has been taken into account in Opera Furthermore, GOME2 has a slightly different spectral resolution and improved spectral sampling.
A challenging project in the next phase of the O3MSAF is the combination of the infrared instrument IASI on METOP with GOME2. IASI measures ozone emissions lines in the thermal infrared at such a high spectral resolution that it contains information on the ozone profile, especially in the higher troposphere. A combined ozone profile retrieval using co-located GOME2 and IASI spectra delivers better vertically resolved ozone profiles, in particular in the troposphere.

4. SURFACE UV FIELDS

The off-line ultraviolet product is intended to provide global information on the surface UV radiation levels to support both environmental and human health impact assessments. The product is given in a 0.5 x 0.5 degree grid, and contains daily UV doses weighted with different biological action spectra, solar noon UV index and quality control flags. The user requirement for the product accuracy is 20%. The off-line UV product is derived from GOME-2 total column ozone product and AVHRR cloud data, therefore combining data from two different instruments onboard the Metop satellites. Sampling of the diurnal cloud cycle is improved by using additional AVHRR data from the NOAA satellites, available through the data exchange between EUMETSAT and NOAA. Fig. 7 shows a comparison of the prototype product with the corresponding ground-based Brewer spectrophotometer measurements in Northern Finland, Sodankylä, for a time period from 23 February 2001 to 1 September 2003. The rms error of the relative difference is 19.3 %, indicating that the user requirement for 20 % accuracy can be achieved with this method. However, the error is strongly dependent on the weather and surface conditions for a given day, for example the amount of clouds and snow, leading to large relative errors at low doses. The future developments of the UV product will therefore aim at reducing the error at these low dose conditions.

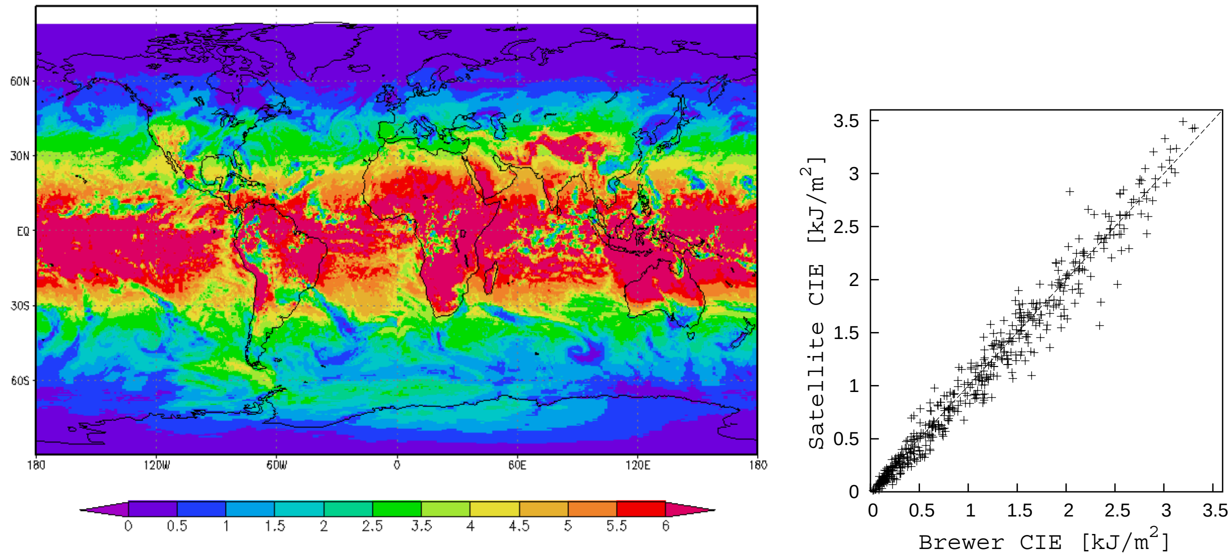

Fig. 7. (left) An example of the O3M SAF Off-line UV product derived from OMI data. A global map of erythemal daily UV dose [kJ/m2] for 7 October 2005, showing enhanced levels of UV radiation at the tip of South America due to the ozone hole. (right) A prototype product derived from EP TOMS total ozone and NOAA AVHRR data against ground-based Brewer spectrophotometer measurements in Sodankylä, Finland, from 23 February 2001 to 1 September 2003.

5. OUTLOOK

The O3M SAF project is now near the end of its development phase and will enter the next five year phase, the Continuous Development and Operations Phase (CDOP), in March 2007. After the launch of the first Metop satellite in June 2006, the products will be available in 2007.

6. REFERENCES

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