Validation of Aerosol Properties Retrieved from GOME Measurements

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ABSTRACT

Aerosol optical thickness (AOT) values have been retrieved from radiances measured by radiometers and spectrometers such as METEOSAT, AVHRR (Advanced Very High Resolution radiometer), GOES (Geostationary Operational Environmental Satellite) and POLDER (Polarization and Directionality of the Earth's Reflectance). Early single-band methods are now superseded by bi- or multi-spectral algorithms that derive aerosol properties, i.e. optical absorbing and scattering properties and size distribution.

The Global Ozone Monitoring Experiment (GOME) Aerosol Spectral Processor (GASP) exploits the instrument's spectral coverage from Ultra-Violet to Near Infra-Red and its moderately high spectral resolution to derive AOT and type. The retrieval method is based on the fusion of the two types of GOME measurements: 1) radiance and solar irradiance spectra measured by the charge coupled device (CCD) arrays, presenting high spectral but low spatial resolution, and 2) the coincident reflectance measured by the Polarisation Measurement Devices (PMD), that have opposite characteristics. The generation of the AOT product is based on the processing of the GOME Level 1 data product distributed by Deutsche Forschungsanstalt fur Luft- und Raumfahrt (DLR) .

The synergistic use of PMD and CCD measurements allows for computing the AOT at the reference wavelength of 550 nm and the aerosol class at both spatial resolutions of 320x40 Km^2 (GOME pixel) and 20x40 Km^2 (PMD pixel). The main advantage is the increase of cloud-free pixels at the best spatial resolution.

The validation activity consists of three parts: i) A self-consistency check aimed to detecting suspicious spatial features or trends connected to the GOME observing geometry and spatial resolution; ii) Comparison with AOT and aerosol classes derived from ground-based sun-photometers; different scenarios have been chosen by selecting ocean or land surfaces and aerosol origin (desert, fires, background); iii) Co-location with different satellite-based aerosol retrieval products (AHVRR, POLDER, METEOSAT) allows for detecting differences related to the characteristics of each sensor and comparing time averages.

Recent results of the validation are presented together with feed-back on the processing algorithm, particularly on cloud identification and screening.

INTRODUCTION

The global analysis of aerosol load and radiative characteristics has become crucial during last years. Global maps of aerosol content based on rough assumptions on the aerosol model (pure scattering of direct solar radiation, uniqueness of particle size distribution and shape) cannot answer to questions arising about the aerosol role in the climate forcing and radiation balance: it has been stated that [1] even the sign of the top of atmosphere net aerosol forcing may be uncertain without a detailed knowledge of the aerosol content and type. Thus, several ongoing and future satellite missions have devoted many efforts in increasing our capability in global aerosol detection and characterisation (POLDER, Ocean Color Temperature Scanner - OCTS on ADEOS-I platform during 1996-97, Moderate Resolution Imaging Spectroradiometer - MODIS on TERRA platform since 1999, just to mention three examples) by exploiting narrow spectral band multi-wavelength measurements.

The GOME flies on-board the ERS2 satellite since 1995 and its main mission is the retrieval of total ozone at the nominal ground resolution of 320x40 km^2. The GOME instrument measures the earthshine radiance over a wide spectral range (0.240 – 0.793 μm) with high spectral resolution varying from 0.2 to 0.4 nm [2]. These characteristics are crucial for the determination of the aerosol optical properties over the ocean [3] avoiding gas absorption spectral regions that interfere with aerosols property retrievals.

Since 1997 a processor chain has been realised to derive the AOT and type from GOME CCD data [4]. In order to improve the low spatial resolution of AOT product a new data fusion technique has been applied [5] to GOME CCD and PMD data. PMDs consist of three broadband detectors at 295-397 nm, 397-580 nm and 580-745 nm respectively, and allow measurements of the earthshine reflectance over sixteen pixels (20x40 Km^2 wide) coincident in space and time with GOME CCD ground pixels. The fusion of the two different GOME observations presents the advantage stemming from the obtained spatial resolution, that is the drastic reduction of the cloud-contaminated cells, and hence the increase of the amount of valid data.

AEROSOL PROPERTIES FROM GOME AEROSOL SPECTRAL PROCESSOR (GASP)

AOT Product Description

The generation of the AOT product is based on the processing of the GOME level 1 data product distributed from DLR. Each product file includes the aerosol characterisation information relative to one orbit.

Aerosols classification and AOT evaluation is accomplished by the fitting of the measured reflectance spectra.

The AOT retrieval procedure is based on a one-step minimisation; the Rayleigh optical parameters are calculated using surface pressure data, while the reflectance fitting of the aerosol class and optical thickness is performed taking into account the relative humidity profile. In the two procedures meteorological information are used; when such data are not available, default values derived from the configuration parameter files are applied.

The AOT product gives the aerosol optical thickness at the reference wavelength of 550 nm, the aerosol classification, and the cloud fraction, both on the GOME and on the PMD spatial scale (the latter for no-cloudy PMD pixels only). It consists of a product header, the orbit geolocation, and general statistical information about the quality and the characteristics of processed data.

The following output data, produced by the GOME processor, are included in the AOT product:

- ✓ *Main result output: GOME aerosol optical thickness at the reference wavelength of 550 nm, Cloud fraction with respect to GOME ground pixel and associated error, PMD (if the PMD pixel is processed) aerosol optical thickness at the reference wavelength of 550 nm, PMD cloud coverage flag (0: cloud absence, 1: cloud presence; 2: partially cloudy).* The cloud flagging is based into a refined cloud clearing algorithm (CCA) [6] based on coincident ATSR (Along Track Scanning Radiometer) cloud maps and validated with METEOSAT derived cloud masks.
- ✓ Geolocation Information relative to the GOME and the PMD pixel: Ground pixel number and pixel subset counter, UTC time of the ground pixel at the end of the integration time, Ground pixel location coordinates (centre and four corners), PMD pixel location coordinates (centre and four corners).
- ✓ Intermediate output both on the GOME and the PMD spatial scale: Sun zenith angle computed with respect to the central point of the ground pixel, GOME surface albedo type, GOME aerosol class, Coefficients of the logarithmic fit polynomial of spectra for all wavelength windows (the implemented wavelength windows are three: 360-430 nm, 751-757nm, 775-785 nm), PMD sun zenith angle computed with respect to the PMD pixel central point (if the PMD pixel is processed), PMD surface albedo type (if the PMD pixel is processed), PMD aerosol class (if the PMD pixel is processed).
- ✓ Annotated output, extracted from the DLR DOAS Total Column of Ozone level 2 product: ICFA (Initial Cloud Fitting Algorithm) cloud fraction, CCA cloud fraction, CCA sub pixel trace

Definition of the AOT product fields to be Analysed/Validated

The main AOT fields that will be taken into account to be validated, both on the GOME and on the PMD scale, are:

- The AOT value retrieved at the reference wavelength 550 nm over sea
- The significance of the AOT retrieved values over land
- The Aerosol Class over sea and over land.

The aerosol classes, aimed to represent the main features of the real aerosol loaded scenarios, are listed in Tab.1. This definition could be upgraded at the end of the validation process by introducing different classes (e.g. biomass burning).

Tab. 1: Aerosol Classes Description

Aerosol Class	Description	Layer Position
1	Maritime polluted RH=0%	0-2 km
2	Not used	-
3	Not used	-
4	Not used	-
5	Urban LOWTRAN RH=0%	0-2 km
6	Urban LOWTRAN RH=70%	0-2 km
7	Urban LOWTRAN RH=90%	0-2 km
8	Urban LOWTRAN RH=99%	0-2 km
9	Maritime LOWTRAN RH=0%	0-2 km
10	Maritime LOWTRAN RH=70%	0-2 km
11	Maritime LOWTRAN RH=90%	0-2 km
12	Maritime LOWTRAN RH=99%	0-2 km
13	Tropospheric LOWTRAN RH=0%	12-30 Km
14	Tropospheric LOWTRAN RH=70%	12-30 Km
15	Tropospheric LOWTRAN RH=90%	12-30 Km
16	Tropospheric LOWTRAN RH=99%	12-30 Km
17	Rural LOWTRAN Rh=70%	0-2 km
18	Rural LOWTRAN Rh=90%	0-2 km
19	VOLCANIC 2	12-30 km
20	Desert Shettle 84	0-2 km

This work has been focussed on results obtained with the simplified radiative transfer model called GOMESIM [4] on the PMD spatial scale. Alternatively, the processor may exploit the ingestion of LookUp Tables (LUT) of reflectances computed with the MODTRAN model.

GASP DATA VALIDATION PLAN AND PRELIMINARY RESULTS

Inspection of Maps

A number of reasons can decrease the accuracy of the retrieved aerosol characteristics: among the others the radiative transfer model accuracy, the sun glint phenomenon and the cloud screening. All these topics may introduce biases and artificial variations of the AOT because they depend to some extent upon observation geometry and geolocation. For instance the scattering angle is a function of the latitude, so the uncertainties in the phase function could introduce a spurious patterns in the AOT. The cloud screening eliminates areas associated with clouds that might have enhanced aerosol optical thickness. The cloud screening procedure can thus bias both spatially and temporally the AOT distribution. Moreover areas affected by the frequent occurrence of clouds will have a smaller number of valid data resulting in poorer statistics. These artefacts can mask and distort the true AOT distribution.

It is nonetheless very difficult to detect and quantify these kind of effects. What we are proposing here is thus to carry out some experiments suitable to catch at least the effects that are mostly probably connected to some artefacts of the method or errors in its implementation:

- ✓ to analyse AOT distributions for the three GOME pixel types (East, West and Nadir). Systematic differences will imply a misinterpretation of the sun glint effect, poor cloud screening or some implementation errors.
- ✓ To draw AOT maps considering only one type of GOME pixels at time (i.e. AOT maps made only considering Nadir pixels, or East pixels, or West) and analyse the differences.
- ✓ To produce monthly mean AOT distributions; suspicious trends must be referred to some implementation errors.

Inspection of AOT over ocean monthly maps using the PMD cloud flag as unique filter demonstrates that the selection of fully cloud-free pixels leads to filter out the majority of aerosol events, whereas allowing partially cloudy pixels to be processed causes a strong overestimation of AOT, due to the cloud contamination. After some experiments, a filter has been proposed that takes into account the combination of retrieved aerosol class and AOT, and the cloud flag. Only data satisfying the conditions displayed in Tab.2 will be considered valid.

Tab. 2: Conditions on Aerosol Classes, AOT and cloud flag to consider the aerosol retrieval as valid.

Aerosol Class	Description	cloud flag	AOT
1	Mar.poll. RH=0%	0 or 2	< 2.0
2	Not used	-	-
3	Not used	-	-
4	Not used	-	-
5	Urban L. RH=0%	0 or 2	< 3.0
6	Urban L. RH=70%	0 or 2	< 3.0
7	Urban L. RH=90%	0 or 2	< 3.0
8	Urban L. RH=99%	0 or 2	< 3.0
9	Mar.L. RH=0%	0	< 0.8
10	Mar.L. RH=70%	0	< 0.8
11	Mar. L. RH=90%	0	< 0.8
12	Mar. L. RH=99%	0	< 0.8
13	Trop. L. RH=0%	0	< 0.8
14	Trop. L. RH=70%	0	< 0.8
15	Trop. L. RH=90%	0	< 0.8
16	Trop. L. RH=99%	0	< 0.8
17	Rural L. Rh=70%	0 or 2	< 0.8
18	Rural L. Rh=90%	0 or 2	< 0.8
19	VOLCANIC 2	0	< 0.2
20	Desert Shettle 84	0 or 2	3.0

In Fig.1 and 2 the AOT monthly mean over 1^{o} Lat. x 1^{o} Lon. grid has been displayed, for 1997, January and June.
Two features clearly become in evidence. The presence of the known Saharan dust transport over the North Atlantic Ocean in June. A seasonal pattern with highest values in the summer hemisphere, this latter too much high in magnitude with respect to previous satellite climatology [7]. Furthermore, the signature of the GOME orbits remains despite the space-time averaging, as a result of some artificial effects.
The retrieved AOT dependence from the observing geometry has been investigated by averaging separately East and West (with respect to the nadir viewing) pixels, that is taking into account only one third of the GOME swath. Results for June 97 (Fig.3 and 4) emphasise the AOT differences. It is clear that the difference is systematic, and it will be confirmed by the preliminary comparisons presented below. Note that in the "East scan" retrieved monthly mean most of the grid cells within the 20^{o}-30^{o} N belt has been mostly filtered out. It may be connected with the ocean glint that affects the East measurement. This situation can be easily explained by seeing the false colour (RGB) image obtained from PMD reflectances for selected orbits on June 97, 8. Fig.5 shows both the flat ocean glint, the Saharan dust transport and a problematic scenario into the successive orbit: the latitudinal position and the bigger reflectance East of the satellite nadir lead to consider the phenomenon as glint over a ruffled ocean surface. The filter proposed in Tab.2 seems to be already effective on both cases, even if it still need to be refined.
Finally, note that in Fig.4. the average pattern seems realistic considering previous results as those obtained for example from the POLDER mission [8], even is large areas with intermediate (around 0.5) AOT values instead of background (0.1, 0.2) values are still present. For a quantitative comparison with POLDER data, see below.

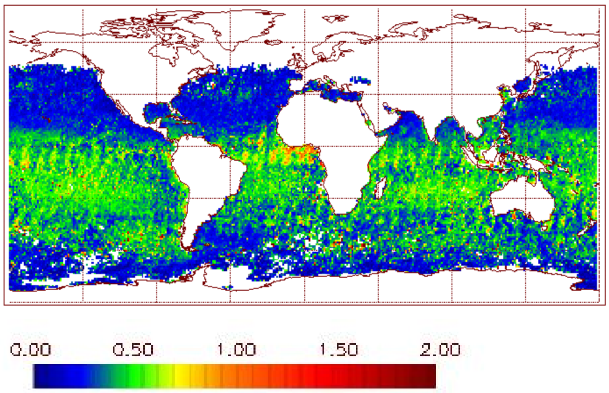

Fig.1. AOT monthly mean, January 1997.

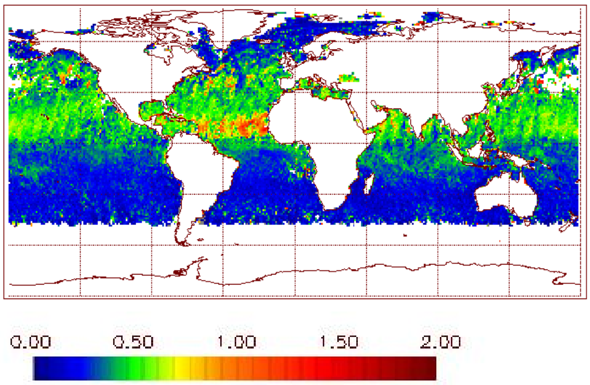

Fig. 2. As Fig.1, for June 1997

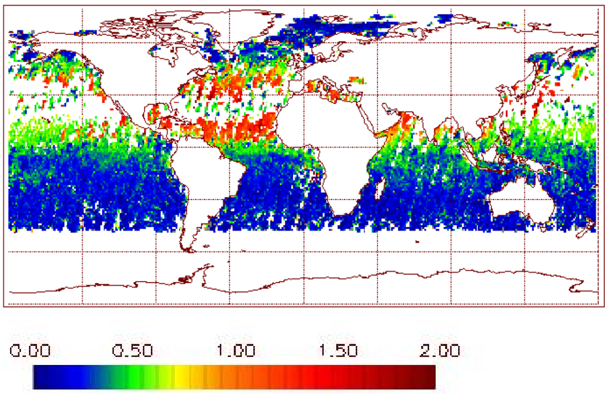

Fig.3. As for Fig.2, but only averaging “East” ground

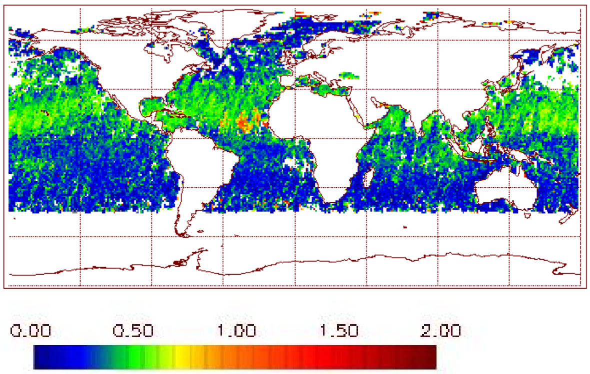

Fig.4. As for Fig.2, but only averaging “West” ground pixels.

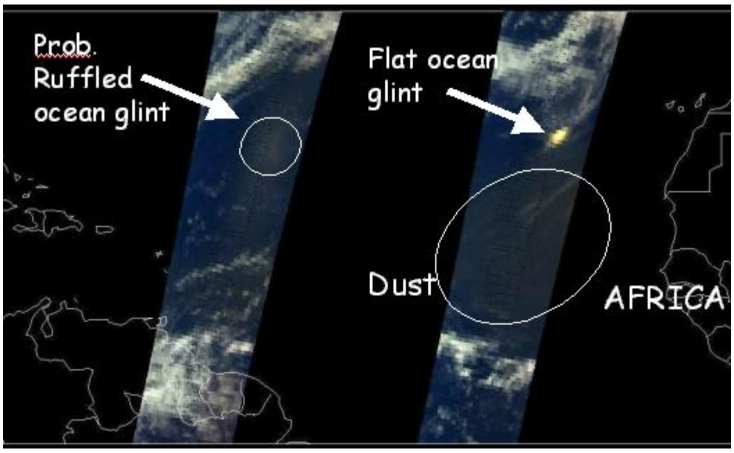

Fig.5 False colour image of GOME PMD reflectances over the Atlantic Ocean, June 1997, 8.

Comparisons with Ground Based Sun-Photometer Measurements

The AERONET network [9] with tens of sites deployed in many countries all over the world (though not evenly distributed and mainly covering the continental areas) offers an homogeneous and well documented source of spectral optical thickness. Data are available from 1993 and have been extensively used by many authors to validate/constrain retrievals. AERONET is an optical ground-based aerosol monitoring network and data archive supported by NASA's Earth Observing System and expanded by federation with many non-NASA institutions. The network hardware consists of identical automatic sun-sky scanning spectral radiometers owned by national agencies and universities. Data from this collaboration provide globally distributed near real time observations of aerosol spectral optical depths, aerosol size distributions, and precipitable water in diverse aerosol regimes.

The aerosol optical thickness is given at the reference wavelengths 440, 670, 870, 940 and 1020 nm. The uncertainty in AOT from a newly calibrated field instrument is less than 0.01.

The data undergo preliminary processing (real time data), reprocessing (final calibration ~6 months after data collection), quality assurance, archiving and distribution from NASA's Goddard Space Flight Center master archive and several identical data bases maintained globally. In 1997 more than 60 stations deployed overall the world contributed to the data-base. Because GASP derives AOT both over the ocean and land, we are largely interested in stations deployed over small islands..

After a preliminary analysis of the data-base available from AERONET the following items are to be considered relevant for the validation activity:

- ✓ The AERONET does not supplies a continuous source of data i.e. each ground station has its own periods of activity and of lack of data during the time.
- ✓ Not all the stations are measuring continuously during the day, so the available data can be restricted to some periods of the day with long intervals between a group of measurements and the next one.
- ✓ The automatic cloud clearing procedure is probably not in its final version and seems not able to separate cloudy

scenarios from dusty scenarios, as stressed also in [10].

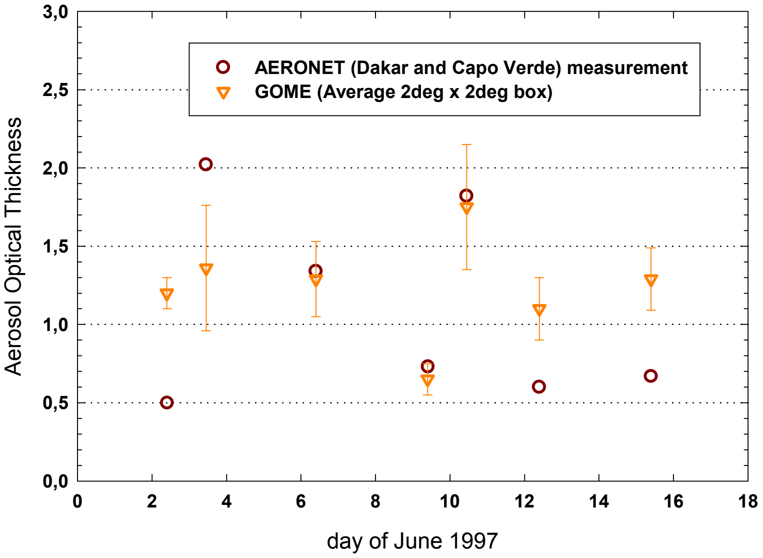

Fig. 6. Comparison among GASP AOT results and correspondent available AERONET AOT measurements, interpolated at 550 nm.. GOME GASP error bars refer to the standard deviation of the box averages.

Up to eight oceanic an coastal AERONET station will be screened within the conclusion of the validation activity, as to obtain tens of simultaneous measurements with GOME overpass, hopefully under different regimes of aerosol load and type. Furthermore, few selected stations over land will be devoted to check the significance of the AOT product over reflecting surfaces.

Fig.6 shows only few cases that has been derived by analysing June 1997; they has been registered over the Atlantic Ocean interested by desert dust outbreaks. No distinction between East and West GOME pixels has been adopted. Besides three good cases, also the overestimation of moderately aerosol loaded is in evidence in the three lowest AOT cases.

Comparisons with Other Satellite Data

The inter-comparison of GASP output with other satellite derived products on a pixel by pixel basis (i.e. without smoothing or averaging processes) has the advantage that the comparison is made with data that have a minimum of manipulation. The disadvantage is that the number of time-space coincident measurements decreases drastically. This is not really true for geostationary observations as METEOSAT's, for which the rapid repetition time allows to have time-coincident, reliable cloud-free data in a significant number of cases. For this analysis it is important:

- ✓ to analyse deeply the method applied by other investigators especially in connection with the adopted aerosol type, radiative transfer model, surface reflectance. That allows to interpret the difference and to direct ad hoc GASP processing trying to increase the agreement in the *a priori* hypothesis and inputs between the methods.
- ✓ to eventually adopt the same (or similar) input optical properties if they are especially suggested by the other investigators as suitable for specific conditions.
- ✓ to carefully analyse validation activities made by the POLDER, METEOSAT, AVHRR investigators to comprehend where and when the derived products have been considered most reliable.

A preliminary comparison has been performed by comparisons with POLDER derived AOT values, computed from CNES (Centre National d'Etudes Spatiales) data. Level 2 (aerosol parameters derived globally over ocean) aerosol optical thickness values at the reference wavelength of 865 nm and Angström coefficients have been extracted and geolocated by means of the *Mex* (v.4.0) software freely distributed with the product. More details on the POLDER operational algorithm can be found in [10]. Here it has been stressed that: i) despite the fact that both POLDER and GASP algorithms assume aerosol spherical particles, the POLDER one assumes a mono-modal particle distribution of aerosol particles, and LUT of radiances to be interpolated had been generated by varying the mode radius and the real part of the refractive index; ii) the imaginary part of the refractive index is equal to 0, so no aerosol absorption is considered; iii) AOT higher than 0.6 at 865 nm had been extrapolated: that leaded to a growing uncertainty for AOT greater than 0.7 [10]; iv) POLDER AOT data are carefully sun-glint free; v) accuracy of the Angström coefficient (α_{POLDER}) retrieval: in [10] a linear equation to correct the values with respect to sun-photometer data has been proposed, then used in the present comparison to transform POLDER AOT at 865 nm at the same wavelength of reference of GASP AOT.

$$AOT_{POLDER}(550) = AOT_{POLDER}(865) * (550/865) \wedge [-(\alpha_{POLDER}-0.08)/0.65] \tag{1}$$

On the other hand, GOME and POLDER offer a simply-obtained time-space coincidence, since thy are nadir-viewing instruments on board of polar satellites with rather the same Equator crossing time. Even the AOT "pixel" size is comparable, being around 20x20 Km^2 for the POLDER product, about half than the GASP one.

POLDER and GASP data have been co-located over a 1^ox1^o grid, during the 1 – 29 June 1997 period. Fig. 7 and 8 show the scatter-plot of the AOT averages, computed if more than 40% of the cell has been covered by measurements of both the instruments. The results has again split into West and East observing geometry.

Overestimation of GASP AOT is in again in evidence in "East" data. The number of occurrences is one order of magnitude less than for "West" data, due to the presence of glint. This analysis has been in fact restricted to a bounded area ($10^°/30^°$ N., $-10^°/-80^°$ W). Extension of the comparisons within glint-affected and glint-free areas will help in determining a definitive glint filter.

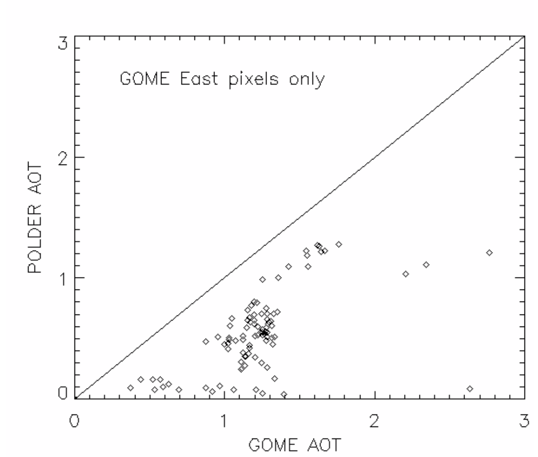

Fig.7. Scatter-plot of 93 co-located and spatially averaged (1^ox1^o) POLDER and GASP AOT values. Only East GOME pixels have been collected

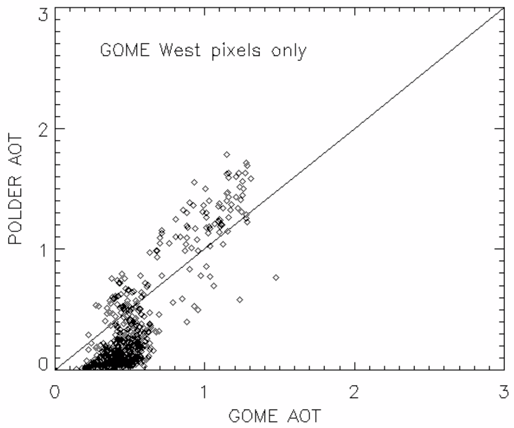

Fig.8. The same of Fig. 7, but for 927 occurreces generated from West GOME pixels.

AOT "West" data seems to be underestimated for high AOT values (from 1 to 2), and it seems do not succeed in evaluating correctly background regimes (AOT < 0.5), where POLDER data resulted excellently validated. At this stage, any definitive assessment seems anyway to be premature.

CONCLUSIONS

GASP exploits GOME spectral resolution and coverage in retrieving AOT and aerosol type and point toward considerably augmenting the number of valid data by combining CCD acquisitions with PMD reflectances. The wavelength selection allows to neglect gas absorption, and to detect a variety of aerosol classes. Obviously, the validation activity will determine also the remaining influence of the relatively big pixel size (that means mainly cloud contamination).

The started validation activity will be conducted on selected test cases, which cover aerosol regimes different in loading and type. Comparisons with sun-photometer derived data will make us able to assess bias and systematic differences especially in case of low AOT values, possibly due to residual cloud contamination and underestimated surface reflectance. Comparisons with different satellite data are promising to assessing the role of systematically different assumption in aerosol modelling (type, layer altitude, etc.).

Preliminary results have shown the need of a combined use of retrieved AOT and class with the cloud flag to filter out

cloud contaminated pixels to be distinguished by aerosol events. Furthermore, the sun glint over ocean need to be better identified, especially over no-flat sea surface. The systematic comparison of "East" and "West" pixels seems to be the most promising technique to test any improved filter.
Together with the scheduled computation of the absorbing aerosol index, feed-backs of the validation on the processor should regard the cloud clearing algorithm and the definitive selection of high quality data.

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REFERENCES

[1] A. S. Ackerman, O. B. Toon, D. E. Stevens, A. J. Heymsfield, V. Ramanathan, E. J. Welton, "Reduction of tropical Cloudiness by Soot," *Science*, vol.288, pp.1042-1047, 12 May 2000

[2] J. P. Burrows, M. Weber, M. Buchwitz, V. Rozanov, A. Ladstätter-Weiβenmeyer, A. Richter, R. DeBeek, R. Hoogen, K. Bramstedt, K.-U. Eichmann, and M. Eisinger, "The Global Ozone Monitoring Experiment (GOME): Mission concept and first scientific results," *J. Atmos. Sci.*, vol.56, pp.151-175, 1999.

[3] F. Torricella, E. Cattani, M. Cervino, R. Guzzi, and C. Levoni, "Retrieval of aerosol properties over the ocean using GOME measurements: Method and applications to test cases," *J. Geophys. Res.*, vol.104, pp.12,085-12,098, 1999.

[4] M. Mochi, A. Bartoloni, C. Serafini, M. Cervino, C. Levoni, E. Cattani, "GOME data processing at I-PAF: the aerosol optical thickness retrieval from GOME spectra. Proceedings of 3rd ERS Symposium *Space at the Service of our Environment*, Florence, Italy, 17-21 March 1997, Vol.II, pp 723-727. 1997.

[5] A. Bartoloni, P. Colandrea, B. Greco, R. Loizzo, M. Mochi, N. Santantonio, M. Silvestri, E. Zappitelli, "Improvement of the ERS-2 GOME Spatial Resolution for the Retrieval of Aerosol Optical Thickness by the Combined Use of the Spectral Array and the Polarisation Measurements Devices." Proceedings of the Third International Conference: Fusion of Earth Data, Sophia Antipolis, France, 26-28 January 2000, pp. 63-71, 2000.

[6] M. Cervino, V. Levizzani, C. Serafini, A. Bartoloni, M. Mochi, P. Colandrea, and B. Greco: "Cloud Fraction within GOME Footprint using a Refined Cloud Clearing Algorithm." *Adv. Space Res.*, Vol.25, n.5, pp.993-996. 2000

[7] R. B. Husar, J. M. Prospero, L. L. Stowe: "Characterization of tropospheric aerosols over the oceans with the NOAA advanced very high resolution radiometer optical thickness operational product," *J.Geophys.Res.,* Vol.102 (D14), pp.16,889-16,909, 1997

[8] J.L. Deuzé, M. Herman, P. Goloub, D. Tanré, A. Marchand: "Characterization of Aerosol over Ocean from POLDER-ADEOS-1," *Geopyhs. Res. Lett.*, Vol.26, n0.11, pp.1421, 1424, 1999. For the June 97 monthly mean AOT map, see http://www-projet.cst.cnes.fr:8060/POLDER/SCIEPROD/ae9706.htm.

[9] B. N. Holben, T. F. Eck, I. Slutsker, D. Tanré, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagan, Y. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak,: "Multi-band automatic sun and sky scanning radiometer system for measurements of aerosols," *Rem. Sens. Environ.*, Vol.66, pp.1-16, 1998.

[10] P. Goloub, D. Tanré, J.L. Deuzé, M. Herman, A. Marchand, and F.-M. Bréon: "Validation of the First Algorithm for Deriving the Aerosol Properties Over the Ocean Using the POLDER/ADEOS Measurements," *IEEE Trans. Geosci. and Remote Sens.,* Vol.37, n.3, pp.1586-1596, 1999.