APPARENT OPTICAL PROPERTIES OF THE AEROSOLS FOR MERIS/OLCI-S3
- SELECTION OF BEST LUTS FOR ATMOSPHERIC CORRECTION OVER OCEAN -

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INTRODUCTION

In the aerosol remote sensing algorithm over ocean, the models are deduced from the spectral dependence of the path radiances in the near-infrared (NIR) region. Based on these derived optical properties, the atmospheric signal is then extrapolated from the NIR to the shorter wavelengths in the visible (VIS) domain. To perform such a classical atmospheric correction scheme requires a well defined climatology representative of the aerosols encountered in remote areas of oceans.

Different climatologies are candidate to be implemented as auxiliary data (*i.e.*, look-up tables) including radiative properties of the aerosols. In the MERIS (MEdium Resolution Imaging Spectrometer) atmospheric correction algorithm over ocean, we will consider: (*i*) the standard aerosol models (SAMs) [1] used in the 3rd MERIS reprocessing, (*ii*) the new set of AERONET (AErosol RObotic NETwork) derived models [2] characterized by their micro-physical properties, and (*iii*) the new set of AERONET derived models by WOPAER [3] described through their inherent optical properties (IOPs) [4]. All sets are processed with the MERIS Auxiliary data Tool (MERISAT) for generating these LUTs for the MEGS (MERIS-ESA Ground Segment) prototype.

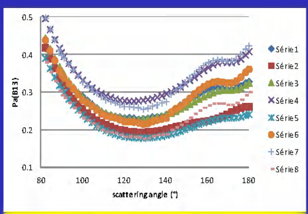
By using ODESA (Optical Data processor of ESA), the MERIS level-1 data extracted from MERMAID (MERis MAtchup In-situ Database) will be processed to get the level-2 data. AAOT (Acqua Alta Oceanographic Tower, Venice - Italy) being a reference station for MERIS Cal/Val activities, this site will be then selected to evaluate the MERIS level-2 aerosol product as well as the retrieved marine reflectance, obtained for each of the three sets of aerosol LUTs.

THE AEROSOL INHERENT OPTICAL PROPERTIES

The IOPs, required in 13 MERIS bands, are the extinction coefficient, the single scattering albedo (SSA) and phase functions P_a. For the SAMs, the IOPs are computed with the Mie's theory using the micro physical properties of the aerosols. For all the other IOPs, coming from AERONET, they are known in three spectral bands (440, 675 and 870 nm). This first step for the AAOT site is fully described in a companion paper [5].

These IOPs are then distributed in 16 classes which are organized around the values of the Angstroem exponent (α) computed in the NIR region between 675 and 870 nm. The first class starts at α=0 and the last one is centred at α=2.25, by using a step of 0.15 to get the others. For each class, we computed the mean, the minimum and the maximum values of at one sigma. A spectral interpolation has been finally achieved to get these IOPs at the 15 nominal MERIS wavelengths.

At the end, we get 8 sets of IOPs. Both for the SAMs [1] and the IOPA [4], these 2 sets are at a global scale. For the AAOT site, we refer the sets of IOPs as provided by AERONET [5] as AERO_mean, AERO_min and AERO_max, and for the sets of IOPs derived by WOPAER we call them as IOPA_mean, IOPA_min and IOPA_max.



		AERO			WOPAER		
IOPA	RUR70	mean	max	min	mean	max	min
1	2	3	4	5	6	7	8

Fig.1: Aerosol phase function at 870 nm versus the scattering angle for the 8 aerosol models and the class #11.

The MERIS aerosol reflectance ρ_a is extracted from the TOA reflectance. ρ_a is proportional to the aerosol phase function time the AOT: $\tau_a P_a$. We selected here the class #11 which is associated with α=1.5; this SAM is the RUR70 (rural with RH=70%). For this type of aerosols, we clearly see in Figure-1 that the aerosol phase functions in MERIS band #13 remain close to each other, when comparing what we got from AERONET at global scale (IOPA) or in AAOT from AEROPA and WOPAER. The rural P_a is substantially below mainly in the backward scattering. RUR90 is close to the minimum values of AEROPA and WOPAER. On a practical point of view, it means that MEGS should overestimate the AOT for these coastal aerosols.

The performance of the atmospheric correction (AC) has not to be judged on the retrieval of the AOT but on the possibility to predict,

$$\varepsilon(\lambda,\lambda') = \frac{\log(\rho_a(\lambda)/\rho_a(\lambda'))}{\log(\lambda/\lambda')}$$

the spectral dependence of ρ_a from the NIR to the blue region. More exactly, we extract the aerosol reflectance ρ_a in the NIR and we want to know it in the blue. In the primary scattering approximation, ρ_a is proportional to τ_aPa. Figure 2 gives the multiplicative factor we need to apply to ρ_a in B13 to get ρ_a in B2. Clearly the R70 model over estimates the atmospheric correction while the models derived from AERONET well compare.

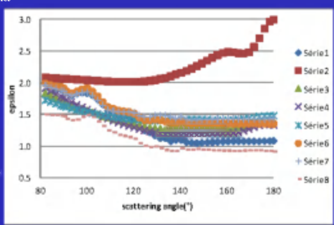


Fig.2: Ratio of MERIS B2/B13 versus the scattering angle for the 8 aerosol models.

THE AOP IN THE MERIS AUXILIARY DATA FILE(ADF)

The successive order of scattering (SO) code has been used to produce the aerosol apparent optical properties (AOPs): path radiances and transmittances for all of the 8 aerosol families in the MERIS bands for a set of 17 AOT550's (from 0 to 0.8 by a step of 0.05). The SO outputs have then been reformatted as auxiliary data files (ADFs) compatible with MEGS and ODESA.

THE ODESA -MERMAID PROCESS

The MERIS-RR L1 products are available in MERMAID. They correspond to the standard extraction of 5x5 pixels window around the AAOT. ODESA was applied on this L1 data set with the 8 new aerosol ADFs and without vicarious adjustment. The L2 outputs were merged with the MERMAID data to produce a new file which includes the *in situ* data and replaces the L2 products and break points by the ODESA outputs. This procedure was applied on all the 25 pixels of the window.

We then averaged the L1 and L2 on the 25 pixels keeping the flag setting used for the validation: no land, no cloud, no ice-haze, no white scatters, no glint, no PCD 13, no PCD 19. We also computed the rms values.

At the end, 126 matchups were selected. Table 1 displays a comparison between AOT measurements and MERIS MEGS-v8.0 retrieved values. First, the size of the aerosols is representative of coastal aerosols and not maritime ones. The spectral dependency in NIR is comparable because the MERIS aerosol reflectance does not depend much on the aerosol model. The dispersion on α is higher with AERONET because of its inaccurate determination at small AOTs. MERIS overestimates the AOT.

	AERONET		MERIS	
	AOT_870	ALP(670,870)	TAU_AER_13	ALPHA
mean	0.079	1.438	0.119	1.426
rms	0.050	0.863	0.061	0.343

Table 1 : Comparison between AERONET and MEGS: AOT at 870 nm and α: in mean and rms.

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EVALUATION OF THE AEROSOL PRODUCT

The aerosol product is the AOT at 865 nm and α(779,865). As a break point, the AOT550 is proposed. We generated the L2 product for the SAMs, IOPAs and the 3 regional AEROs (mean, min, max). The 3 regional IOPAs are similar to the AEROs.

The AERONET measurements correspond to the AOT at 440, 675 and 870 nm for 2 sets of measurements which bracket the time of the MERIS overpass. The AERONET data is matched with the MERIS AOT with: (*i*) a time interpolation at the time of MERIS overpass, (*ii*) a spectral interpolation on the AOT between 675 nm and 870 nm gives the AOT778 and AOT865, and (*iii*) a spectral interpolation on the AOT between 440 and 675 nm yields to the AOT550.

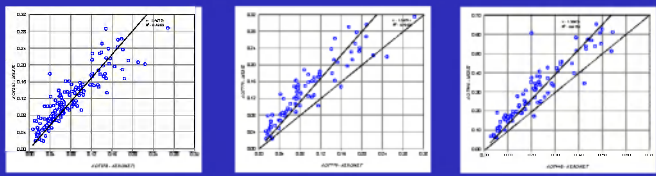


Fig. 3: AOT at 3 wavelengths. Comparison between in situ and MEGS-v8.0 for the SAMs.

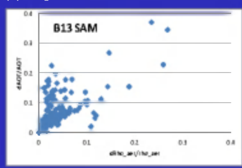
	SAM	IOPA global	AERO mean	AERO max	AERO min
N	157	156	153	154	155
mean	1.82	1.37	1.38	1.35	1.41
sigma	1.02	0.71	0.66	0.66	0.67
N	149	148	146	148	146
mean	1.5	1.48	1.17	1.14	1.21
sigma	0.5	0.54	0.29	0.29	0.3

Table 2: Number of matchups, mean ratio and sigma on the AOT between MERIS and AERONET at 865 nm (upper set) and 440 nm (lower set). A total of 5 different sets of aerosol ADFs are reported.

Clearly, with the SAMs MEGS overestimate the AOT both in the NIR and blue regions. Results are better with the aerosol models derived from AERONET both on the mean and on the dispersion, even if they are far to be perfect.

THE SPATIAL VARIABILITY OF THE AEROSOL PRODUCT

One indicator of the quality of the selected aerosol family is its ability to do not amplify the natural spatial variability of the signal. The inputs to aerosol remote sensing module are the aerosol reflectances at 779 and 865 nm. These values, obtained after gaseous correction and the BPAC, are independent on the aerosol ADF. The optical continuity of the aerosol models in a given family results in that the relative dispersion on the AOT should be comparable to the dispersion of the aerosol reflectance in MERIS B12 and B13.



In MEGS, 2 aerosol models bracket the aerosol reflectance in the NIR region. The optical discontinuity between these 2 models results in a noisy AOT. Here, we clearly stress that the IOPA models offer a better spatial homogeneity on the AOT compared to the SAMs

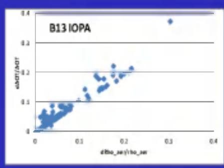
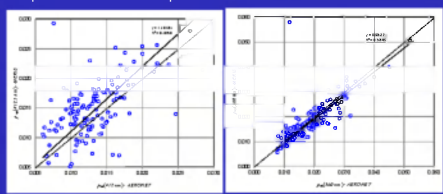


Fig. 4: Relative variation in the (5x5) pixels window of the AOT versus the relative variation of the aerosol reflectance in B13 for the SAMs and for the IOPAs.

EVALUATION OF THE WATER REFLECTANCE RETRIEVAL

The water reflectance is measured in 5 spectral bands centred at 412, 443, 490, 560 and 665 nm. We compare the 5 MERIS outputs in these bands.



The first comparison between *in situ* and MERIS water reflectances is achived in B2 and B5 with MEGS and SAMs without vicarious adjustment.

The MERIS water reflectance is above the *in-situ one* in B2 and very scattered. Results in B5 appear as more acceptable.

Fig. 5: Water reflectance at 2 wavelengths. Comparison between in situ and MEGS-v8.0 for the SAMs.

The choice of the criterion to intercompare the results is controversial. For each of the ADF, we report in this table, the number of matchups, the mean and the rms of the MERIS / *in-situ* ratio of the water reflectance in B2 and B5. We also display the difference '*in situ* - MERIS'. The salient point is the high dispersion which illustrates the difficulty to make the AC in the coastal region as well to interpret these results.

	ratio		difference	
	B2	B5	B2	B5
SAM	1.097	0.943	-0.001	-0.0020
129	0.354	0.333	0.004	0.0073
IOPA	0.878	1.073	-0.002	0.0000
129	0.358	0.459	0.005	0.0075
AERO_mean	1.545	0.778	-0.009	-0.0074
123	0.527	0.411	0.006	0.0110
AERO_min	1.546	0.732	-0.009	-0.0075
123	0.530	0.238	0.006	0.0074
AERO_max	1.517	0.767	-0.008	-0.0069
124	0.523	0.396	0.006	0.0073

Conclusion

We reported here for the AAOT data set a preliminary study on the influence of the aerosol models on some of the MERIS L2 products. What we clearly see for all the ADF candidates is a large dispersion on the AOT between *in situ* and MERIS. This dispersion is explained by the natural variability of the aerosol IOPs [4] but clearly this dispersion is reduced when the aerosol models are defined locally from their IOPs as for the AERO models. The spatial homogeneity is driven by the optical continuity of the aerosol models versus α, and the SAMs are the worst. For the water reflectance retrieval, we have no firm conclusion because of large error bars. With the algorithm as it is, we need to better identify the aerosol model and the only small hope we have is to use the relative humidity. Alternatively a combined retrieval of the aerosols and of the water colour is suggested.

This study needs to be consolidated and extended, starting by the AERONET Ocean Colour network. We need to process a large amount of matchups to be able to conduct an analysis for each type of aerosols (oceanic and costal) and for different scattering angle domains. It is clear than compared to MERIS, OLCI will go in the backscattering, a difficult region in terms of the variability of the IOPs.

References

[1] Antoine, D., and A. Morel, 1999. "A multiple scattering algorithm for atmospheric correction of remotely sensed ocean color (MERIS instrument): Principle and implementation for atmospheres carrying various aerosols including absorbing ones", *International Journal of Remote Sensing*, **20**: 1875–1916.

[2] Dubovik, O., and M. D. King, 2000. "A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements", *Journal of Geophysical Research*, **105**: 20673–20696.

[3] Santer, R., F. Zagolski, and O. Aznay, 2009. "Aerosol phase function derived from CIMEL measurements", *International Journal of Remote Sensing*, **31** (4), 969-992.

[4] Zagolski, F., R. Santer, and O. Aznay, 2007. "A new climatology for atmospheric correction based on the aerosol inherent optical properties ", *Journal of Geophysical Research, vol. 112, no. D14.*

[5] Santer, R., F. Zagolski, and O. Aznay, 2012. "Inherent optical properties of the aerosols for MERIS/OLCI-S3: From micro-physical properties to optical properties, *Proceedings of MERIS/AATSR & OLCI/SLSTR Preparatory Workshop*, Frascati (Italy), 15-19 October, 2012.