MERIS LEVEL-2 PRODUCTS VALIDATION USING SIMBADA RADIOMETER NETWORK

Guislain Bécu, Pierre-Yves Deschamps, Jean-Marc Nicolas

Laboratoire d'Optique Atmosphérique, UMR CNRS 8518, Université de Lille I - 59655 Villeneuve d'Ascq - France,
pyd@loa.univ-lille1.fr
becug@loa.univ-lille1.fr
nicolas@loa.univ-lille1.fr

ABSTRACT/RESUME

The mission of the MERIS radiometer, launched on ENVISAT March 1, 2002 is to observe the Earth's surface, like the ocean color, i.e. the marine reflectance at ocean color wavelengths, and the Earth's atmosphere, like aerosol optical properties. The validation of the MERIS so called Level-2 products, which are the geophysical parameters derived from the TOA (Top Of Atmosphere) Level-1 radiance products, requires their comparison with in-situ measurements. We report here about this comparison using the network of SIMBADA radiometers that measure the two basic parameters for the validation of ocean color : marine reflectance and aerosol optical thickness.

1. SIMBADA RADIOMETER

The SIMBADA radiometer is an optical radiometer that measures at 11 wavelengths, from 350 to 870 nm. Most of these wavelengths fit the ones selected by MERIS in the operational mode. See Table 1 that gives SIMBADA and MERIS channels. The radiometer is manually operated from a ship deck and it has two measurement modes :

- a sun viewing mode to measure sun intensity, and derive atmospheric transmission then aerosol optical thickness
- a sea viewing mode to measure above water leaving radiance/reflectance

Table 1. SIMBADA and MERIS channels central wavelengths

SIMBADA bands (nm)	350	380	412	443	490	510	560	620	670	-	-	750	-	870	-
MERIS bands (nm)	-	-	412	443	490	510	560	620	665	681	705	754	775	865	890

The same optics is used for both modes thanks to a change of the electronic gain. A polarizer is used to reduce the sky reflection in the sea viewing mode. The radiometer is equipped with a GPS, a data acquisition and rechargeable batteries.

The radiometric calibration of the SIMBADA radiometers is obtained by means of a Langley plot of the sun intensity at an elevated site. Its relative accuracy is typically 1 %.

SIMBADA acquirements are processed and posted on the LOA web site (see http:\\www-loa.univ-lille1.fr\simbadA). After processing, the accuracy of the marine reflectance is typically 0.0005 absolute or 5 % relative, whichever is the greater. The accuracy on the aerosol optical thickness is 0.01.

2. SIMBADA NETWORK AND MERIS MATCH-UPS

18 SIMBADA radiometers have been built at LOA and have been operated from September 1, 2000. From then to September 13, 2002, they have delivered more than 1100 marine reflectance spectra, and 490 from April 29, 2002 which is the start of the continuous MERIS data acquisition. We identified either 320 potential match-ups with the MERIS instrument, i.e. the SIMBADA measurement is in the given MERIS swath on the same day, and obviously it is cloud free since the in-situ measurement of aerosol optical thickness has been done. Note that if we discard multiple measurements on the same day at motionless station, keeping only the nearest in time to MERIS overpass, we still have 140 potential match-ups. We received 23 scenes from ESA, corresponding to 53 coincident SIMBADA and MERIS

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measurements. We finally used 23 of them, after some glitter or partial cloud contaminated MERIS scenes have been rejected. Eventually we derive 23 spectrum match-ups (see Figs.1. for locations).

There are open ocean match-ups in the NW Atlantic, South Pacific, Indian Ocean and Red Sea that have been acquired thanks to the cooperation with Yves Dandonneau, LODYC, Paris.

Coastal sites have also been used in this study in the North Sea close to the Belgian coast, thanks to a cooperation with Kevin Ruddick, MUMM, Brussels, and in the Black Sea close to the Crimea coast, thanks to George Khomenko, LOCL, Wimereux, France.

The SIMBADA measurements have been done during the GeP&CO-K, GeP&CO-L, SKOGAFOSS, TOUCAN, Zeeleeuw 2002-240, Zeeleeuw 2002-252 and Black Sea Station cruises.

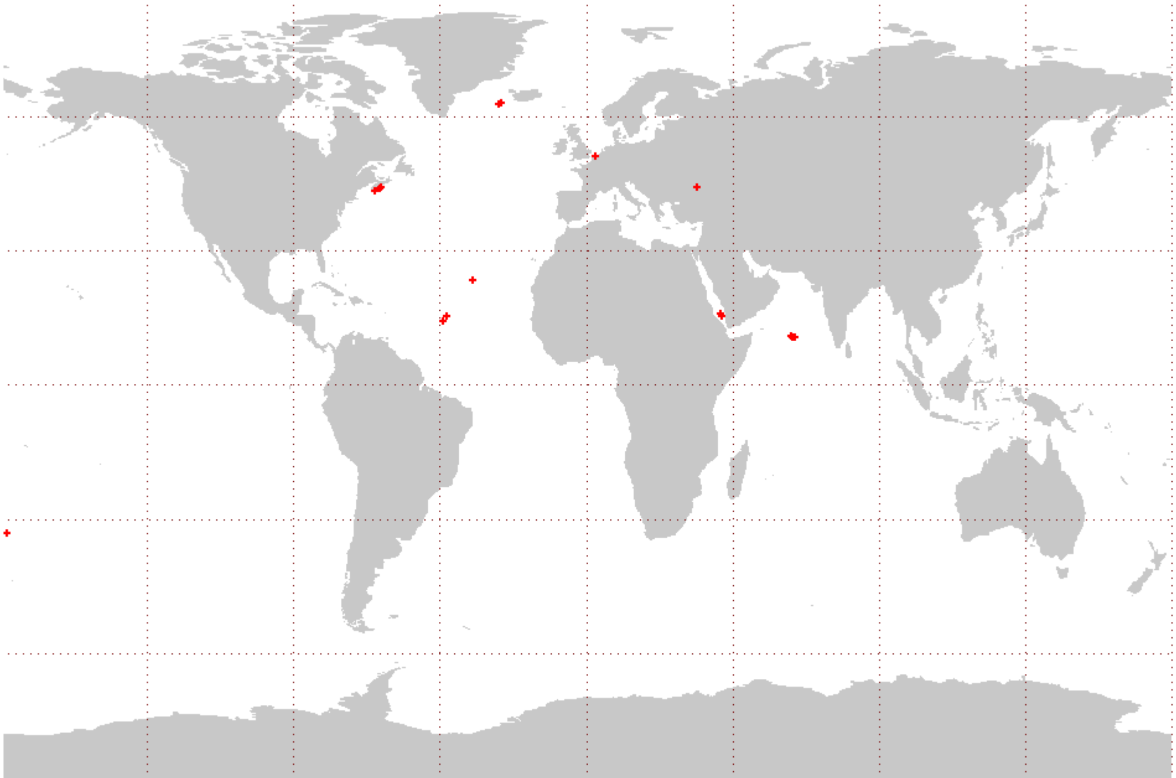


Fig.1. SIMBADA/MERIS match-ups locations

3. MARINE REFLECTANCE VALIDATION

Figs.2. to 6. present the results for some of the scenes.

Fig.2. is from the Pacific ocean and gives a window in the composite color of the MERIS (Level 1) image and the comparison between the MERIS derived Level 2 marine reflectance product and the SIMBADA in-situ measurement. It is under very clear conditions, and gives very good results for the comparison of the spectra.

Fig.3. is again an open ocean site but in the Red Sea with a high aerosol optical thickness. The comparisons of the spectra are not so very goods as in Pacific Ocean, and one can see that for the second match-up MERIS data are a little bit noisy (error bar are dispersion in a 3x3 box around the pixel). This is certainly due to near cloud contaminating the scene.

Fig.4. is a coastal site offshore Belgium, with two comparison spectra on the same day (4 spectra were recorded on this day, only the best and the worst cases are shown here). Despite the difficulties presented by the coastal highly turbid

and variable site, and local conditions reflected in the MERIS flags (dust like aerosols, turbid water, medium glint) the MERIS product is in good agreement with SIMBADA.

Fig.5. and Fig.6. are a coastal site offshore Crimea (2 different dates) . Spectra shown on Fig.2e. has been rejected from further analysis because we believe the MERIS spectral signature is strongly influenced by cloudy conditions. But the other spectrum comparison shows again a good result despite a rather high aerosol loading (τ = 0.3) and flags like offshore Belgium.

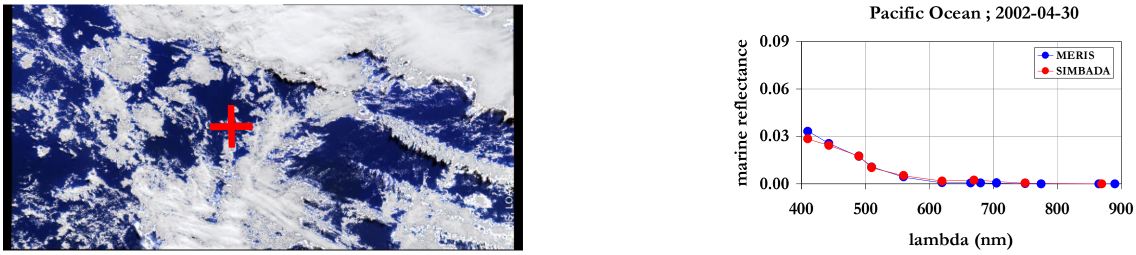


Fig.2. SIMBADA/MERIS spectral match-up in Pacific Ocean. MERIS image is L1 Rayleigh corrected true color composite.

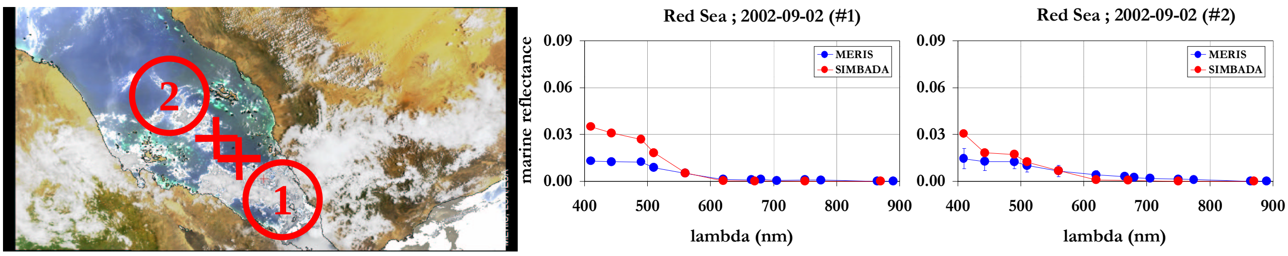


Fig.3. same as Fig.2. but in Red Sea.

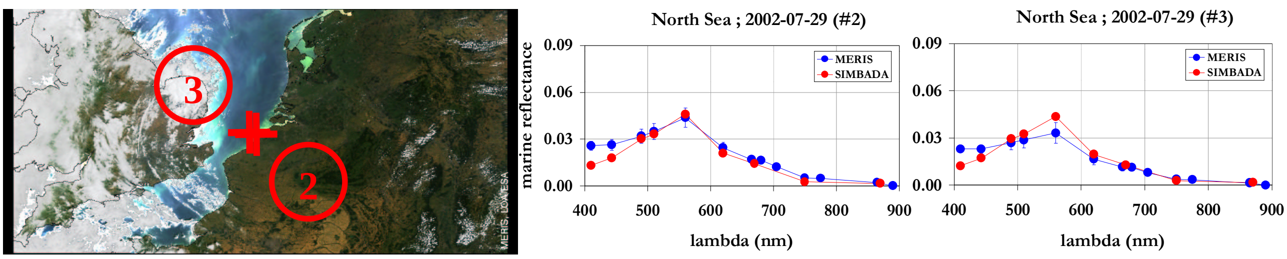


Fig.4. same as Fig.2. but offshore Belgium.

Fig.5. same as Fig.2. but at Black Sea station on Aug. 12, 2002.

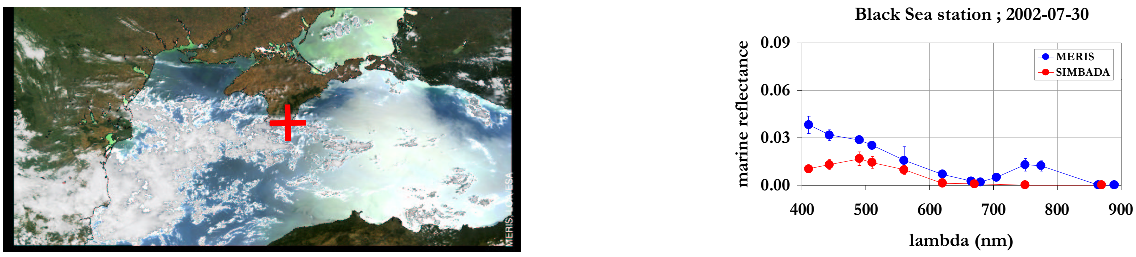


Fig.6. same as Fig.2. but at Black Sea station on Jul. 30, 2002.
This match-up was rejected because of near clouds and medium glint contaminating MERIS scene.

The comparison between the 23 reflectance spectra is summarized in a different way in Figs.7. that plot MERIS vs. SIMBADA reflectance at different wavelengths.

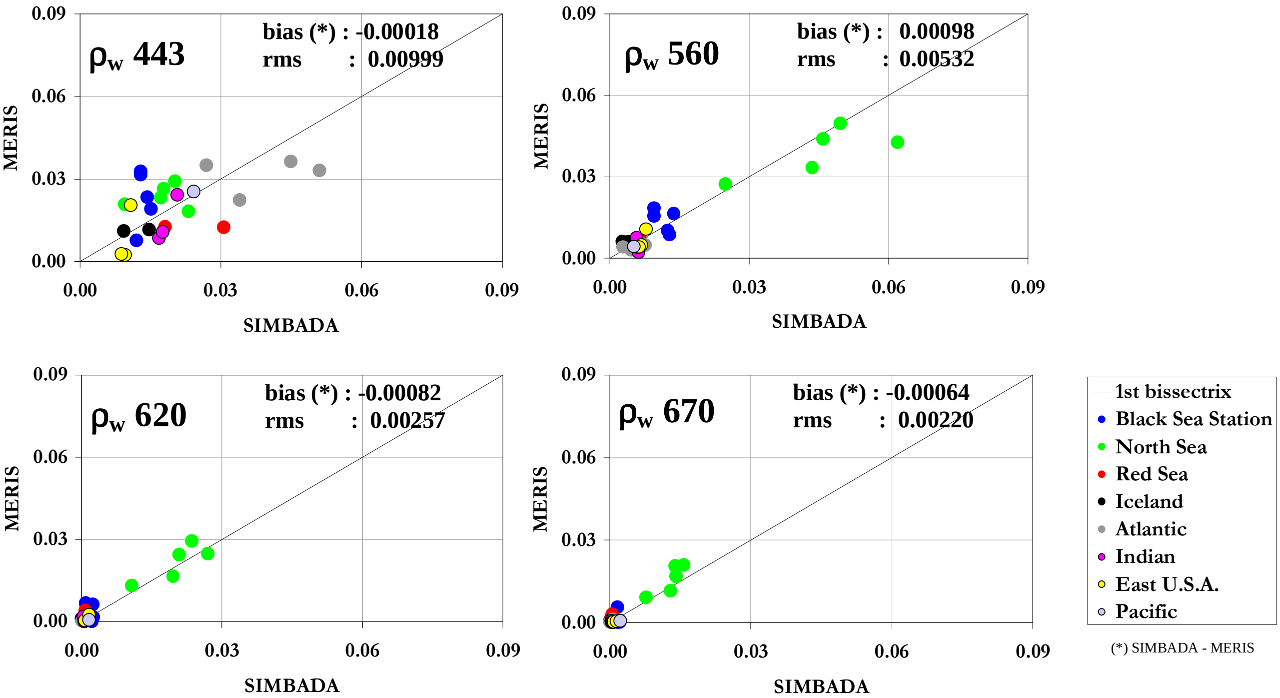


Fig.7. MERIS vs. SIMBADA reflectance at 443, 560, 620 and 670 nm.

Fig.8. is the final result for the reflectance comparison. It gives an averaged spectrum obtained from MERIS and SIMBADA from 412 nm to 865 nm. It strikingly shows practically no significant bias at any wavelengths. Also shown in Fig.4. as an error bar is the rms of the difference between MERIS and SIMBADA. This error increases gradually towards the shorter wavelengths. It is the sum of errors on MERIS and SIMBADA measurements. The SIMBADA error measurement is estimated to typically around 0.001 whatever the wavelength. Thus the given error bar seems to correspond mostly to the accuracy of the MERIS atmospheric correction as its difficulty increases towards to the blue region, and the difficulty of the spatial match-up in the coastal areas.

Fig.9. gives the estimated relative bias and relative rms error spectra of the MERIS/SIMBADA average comparison. It shows again small biases below 10 % except at 750 nm, and a relative error between 30 and 50 % on the MERIS derived reflectance. This result is fairly good but should be improved. If the marine reflectance are to be used in a ratio algorithm for chlorophyll concentration estimate, this would mean that the error on the chlorophyll concentration determination is a factor of more than 2.

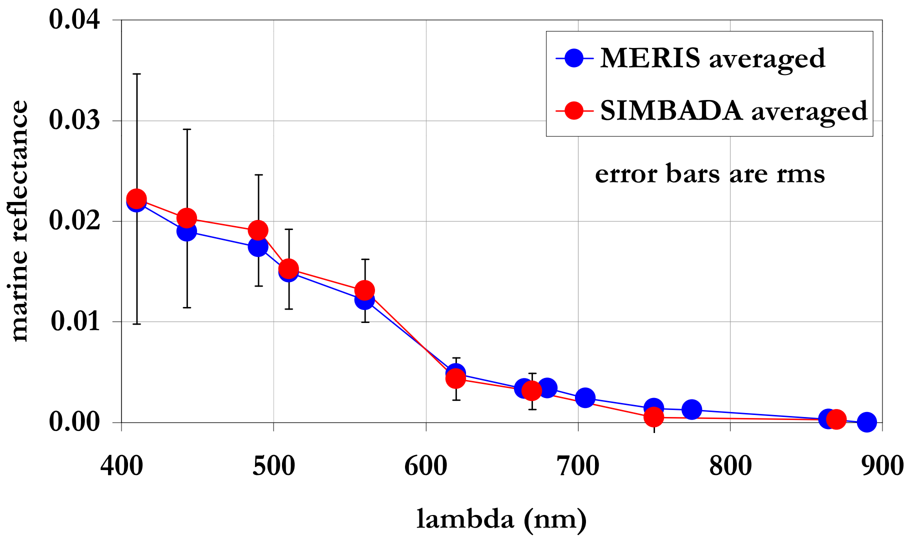


Fig.8. Averaged spectrum from MERIS and from SIMBADA to illustrate the bias. Error bars indicate rms between SIMBADA and MERIS measurements.

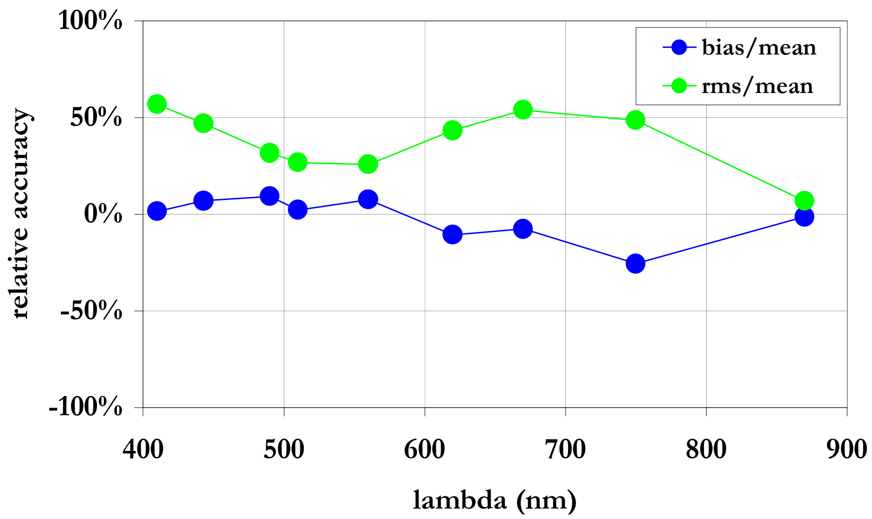


Fig.9. relative bias and rms error spectra of SIMBADA/MERIS average comparison.

4. CHLOROPHYLL CONCENTRATION VALIDATION

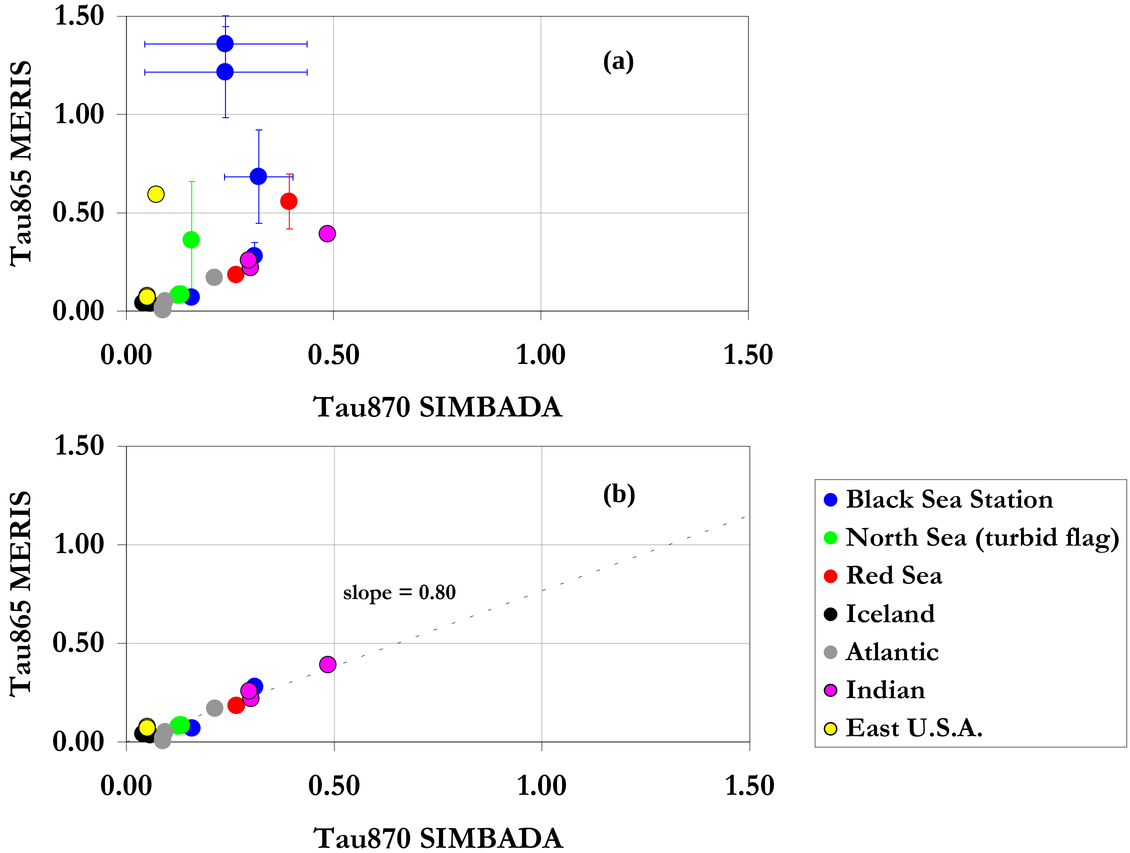
Unfortunately, by this time, we have got only 2 chlorophyll concentration measurement (derived from filtered water sample HPLC), courtesy of Yves Dandonneau, LODYC, corresponding to the MERIS match-ups. The 2 sites correspond to open ocean, case 1 water. Results of the comparison with MERIS Chl1 and Chl2 products are shown in Table 2. As expected a good agreement is obtained with MERIS Chl1 which is obtained using a case-1 water algorithm, while the Chl2 values obtained using a case 2 water algorithm is irrelevant for these sites. We cannot conclude on the accuracy of the MERIS retrieval of the chlorophyll concentration, but the two match-ups seem to show that it should be within a factor of 2 or better in the open ocean.

Table 2. First chlorophyll concentration comparisons (concentrations are given in $mg.m^{-3}$)

date	location	[Chl] in-situ	MERIS case1 [Chl]	MERIS case2 [Chl]	MERIS turbid flag
Apr. 30, 2002	SW Pacific Ocean	0.1440	0.0776	0.7621	0
Sep. 02, 2002	Red Sea	0.1870	0.3758	1.1143	0

5. AEROSOL OPTICAL PROPERTIES VALIDATION

Figs.10. show the comparison of MERIS and SIMBADA derived aerosol optical thickness. At the first glance the correlation is not good. We observe two grouping, one along a slope 1, the other one as a vertical dispersion of MERIS aerosol optical thickness above this slope. Our interpretation is that the vertical dispersion correspond to situations when a small cloudiness is present in the MERIS field of view, while the SIMBADA operator has taken aim to the sun between clouds. Confirmation of this comes from that the spatial variability of the MERIS derived optical thickness is rather large in these cases. After dropping what we believe are the partly cloudy cases, we obtained a rather good correlation between MERIS and SIMBADA for the aerosol optical thickness. The slope is 0.8, and corresponds to a slight underestimation of the aerosol optical thickness by MERIS.



Figs.10. MERIS derived aerosol optical thickness at 865 nm vs. SIMBADA derived aerosol optical thickness at 870 nm. (a) all match-ups – (b) cloudy scenes have been rejected. In the second case, the correlation is better ; MERIS under estimates by 20%.

Fig.11. show the comparison between MERIS epsilon factor (ε_M, deduced from measurements at 775 and 865 nm) and SIMBADA Angström component (α_S, deduced from measurements at 443 and 670 nm). On this figure, cloud contaminated and small aerosol amounts cases have been rejected (only 6 measurements in Red Sea, Indian Ocean and Black Sea remained). At the left hand side of the graph there is a second scale showing the corresponding MERIS Angström components (α_M). There is a slight correlation, but more points are needed to sort out realistic statistics.

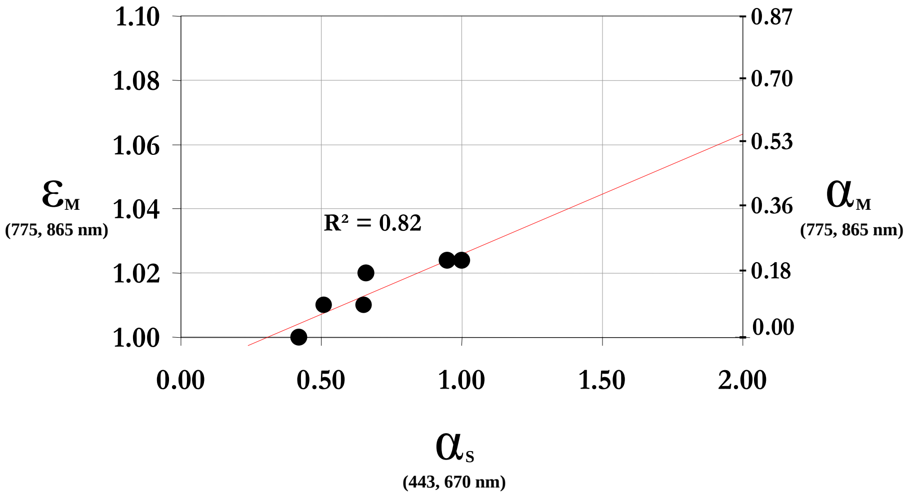


Fig.11. MERIS epsilon factor (ε_M) and Angström component (α_M) vs. SIMBADA Angström component (α_S). MERIS factors are deduced from measurements at 775 and 865 nm ; SIMBADA factor is deduced from measurements at 443 and 670 nm.

6. SUMMARY AND CONCLUSION

The in-situ measurements of marine reflectance and aerosol optical thickness by the SIMBADA network proved very valuable for the MERIS validation. 140 potential match-ups have been identified during the 6 months commissioning period, April to September 2002, and their analysis has been somewhat limited to 23 match-ups by the availability of MERIS data. The match-ups reflect very variable conditions, coastal and open seas, case-1 and case-2 waters, variable aerosol optical thickness.

Preliminary results show that marine reflectance retrieved by MERIS have no significant bias when compared to the SIMBADA ones. But the rms of the difference between the two measurements is rather large and increases to the shorter wavelengths ; it is likely to be attributed to the accuracy of MERIS atmospheric correction. As a result the relative accuracy on the estimate of marine reflectance is only 30 to 50 %, a figure that should be improved in order to retrieve the Chlorophyll concentration by a factor better than 2.

Two in-situ measurements of chlorophyll concentration have been compared to the MERIS ones retrieved using the case-1 water algorithm, and they are within a factor of 2. More measurements are necessary to conclude.

The MERIS estimate of the aerosol optical thickness shows a good correlation with in-situ SIMADA measurement when the analysis is strictly restricted to obvious cloud free situation. MERIS slightly underestimate the aerosol optical thickness by 20 %. We have not been able to find any correlation between the MERIS epsilon factor and the SIMBADA Angström coefficient, despite both measurements should be closely connected because they both reflect the influence of the aerosol type (size distribution) on the spectral dependence of the aerosol optical thickness.

This validation effort will be continued and we will keep on the operation of the SIMBADA network in 2003. We expect to obtain more MERIS scenes from 2002 and 2003. We also expect a fruitful comparison between MERIS and POLDER-2 successfully launched December 13, 2003. These are preliminary results based on a limited amount of MERIS data scenes, and we need more time and data to consolidate this analysis.

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