POLREF: A NEW SIMULATOR FOR POLARIZED REFLECTION COEFFICIENT OVER OCEAN

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ABSTRACT

In the validation of the algorithm for the MERIS (MEdium Resolution Imaging Spectrometer) atmospheric corrections over ocean, the water reflectance derived from in-situ measurements represents a key element. The water-leaving radiance needs to be corrected for the sky dome reflection. In the standard protocol, this correction is achieved with an approximate value of the *Fresnel* reflection coefficient of sea surface applied to the measurement of the sky radiance. This standard correction ignores the polarized nature of both the atmospheric scattering and the *Fresnel* reflection of the water surface. The introduction of the polarization requires a vector radiative transfer code (RTC) in the coupled *«Ocean-Atmosphere»* system. The successive orders (SO) of the scattering code [1][2], offers a good opportunity to analyze the reflected sky dome over ocean when the incident angle corresponds to a significant polarization by reflection.

The main objective here is to describe a simulator of the polarized reflection coefficient of sea surface for MERIS. In other words, this simulator is perfectly in-line with the MERIS intrument facilities processor (IPF) for the level-2 processing [3], *i.e.*, using as inputs the same spectral bandset (or nominal wavelengths), the same set of illumination and viewing geometries, the same set of aerosols (models and aerosol optical properties) and the same boundary conditions [4].

1. INTRODUCTION

The standard protocol to correct the above water radiometry for the sky dome reflection consists in first, an in-situ acquisition of the atmospheric downwelling path radiance, and second, to apply to this measurement a *Fresnel* reflection coefficient that may depend on the wind-speed above the sea surface level. This protocol, widely used by the ocean-colour community, will be referred as the scalar approach insofar as it ignores the polarization of both the sky radiance and of the *Fresnel* reflection of the sea surface. Actually, the total sky radiance intensity to be removed from the above water radiance measurement combines the atmospheric radiance intensity and its polarized component.

In order to evaluate the impact of the polarization, we firstly need a RTC dealing with the *Stokes* parameters, with as outputs at the *minima,* the downwelling and upwelling radiance fields at bottom of the atmosphere (BOA). The ratio between the upward and downward radiances yields to the reflection coefficient of the sea surface to apply on the sky radiance measurement.

To fully analyze the impact of the polarization, the most direct approach should consist in two dual radiative transfer computations in the scalar and vector modes. Our main purpose will be to report the results of comparisons between the new reflection coefficients and the standard values found in the literature [5].

For allowing the operator to consider a large variety of situations in spectral, geometrical and atmospheric conditions, then the simulator has been based on a precomputed synthetic database with MERIS look-up tables (LUTs) of atmospheric scattering functions at BOA. This databse is described in Section 2.

As for the simulator of the polarized reflection coefficient of the sea surface, it is fully detailed in Section 3, with some examples of outputs.

2. GENERATOR OF RADIANCE FIELDS AT BOTTOM OF THE ATMOSPHERE

The simulator, namely POLREF (POLarized REFlection coefficient), is based on the radiative transfer theory. The successive orders (SO) of the scattering vector code [1][2], which was already employed for computing the MERIS LUTs over ocean, has been firstly adapted to output atmospheric functions (radiances and transmittances) at BOA. This modified version of the RTC/SO is then used to generate the MEROS database with BOA atmospheric LUTs, which will feed the POLREF simulator.

2.1. Modified version of the RTC/SO

The RTC/SO used to generate the *«Ocean-Aerosol»* LUTs for the MERIS level-2 processing, is a version dealing with three aerosol layers over ocean: a mixing layer (or boundary layer), an upper troposphere and a stratosphere. This code provides as standard outputs the normalized radiances at top of the atmosphere (TOA), on a specific angular grid in (SZA, VZA, RAA), defined by a set of 24 *Gaussian* angles plus the zenith or nadir direction for the Sun/view zenith angles (SZA, VZA) and by a set of 25 relative azimuthal angles (RAA) regularly spaced from 0 to 180 *deg.* with a step of 7.5 *deg.*

To estimate both the *Fresnel* reflection of the sky dome and the total downwelling flux at BOA some modifications have been reported in the current version of the RTC/SO in order to output:

- The upward and downward polarized atmospheric radiance fields at BOA (*Stokes* parameters: [I,Q,U], V being neglected);
- The total and direct downward atmospheric transmittances, including the coupling term between the *Fresnel* reflection and the atmospheric scattering.

2.2. Improvements and main features of the RTC/SO for the generation of the MEROS database

In order to generate the MERIS BOA atmospheric LUTs with this modified version of RTC/SO, three additional loops have been implemented in this code:

- a loop on the 15 MERIS spectral bands (or nominal wavelengths, *see* Tab. 2);
- a loop on the 17 values of the aerosol optical thickness at 550 *nm* (AOT550), from 0 (pure molecular atmosphere) to 0.8 by step of 0.05;
- a loop on the 25 solar zenith angles (24 Gaussians angles + zenith direction, *see* Tab. 1);

Table 1: Values of zenith angle (θ) derived from the Gauss quadrature for 24 discrete directions.

θ[deg.]	θ[deg.]	θ[deg.]	θ[deg.]
2.840906	25.058051	47.322394	69.588762
6.521063	28.768427	51.033390	73.299882
10.222955	32.479006	54.744420	77.011011
13.929756	36.189726	58.455477	80.722147
17.638419	39.900547	62.166556	84.433286
21.347983	43.611442	65.877652	88.144429

The RTC/SO solving the radiative transfer equation (RTE) under clear-sky conditions, no gaseous absorption is then accounted for in the generation of the MEROS database. However, in so far as the ozone layer is located above the aerosols and at a pressure level which makes negligible the coupling between the *Rayleigh* scattering and the gaseous absorption, the ozone absorption can then be treated separately and included in the POLREF simulator.

The *Rayleigh* scattering is described with a molecular optical thickness computed with the *Hansen and Travis* formulation [6] for a standard barometric pressure (P_s) of 1013.25 *hPa* (*see* Tab. 2), with a phase function characterized by a depolarization factor (δ) of 0.0279, and with a scale height (H_R) of 8 *kms* for the vertical distribution of the molecules.

Table 2: Rayleigh optical thickness in each of the 15 MERIS spectral bands for a standard barometric pressure.

λ	412.50	442.50	490.00	510.00	560.00
τ_R	0.315280	0.235910	0.155155	0.131714	0.089912
λ	620.00	665.00	681.25	708.75	753.75
τ_R	0.059433	0.044730	0.040562	0.034558	0.026944
λ	761.875	778.75	865.00	885.00	900.00
τ_R	0.025802	0.023617	0.015459	0.014099	0.013176

The 16 standard aerosol models (SAMs) from the climatology used to build the level-2 auxiliary data file (ADF) over ocean for the last 3rd MERIS reprocessing, have been selected to generate the MEROS database. These SAMs include the 12 models from *Shettle and Fenn* [7] (*i.e.*, maritime, coastal and rural models with four relative humidities: 50%, 70%, 90% and 99%) and the so-called blue aerosol models to account for the strong spectral dependence of the aerosol optical thickness (AOT). For the MERIS *«Ocean-Aerosol»* ADF, three blue aerosols have been extracted with an approach combining the micro-physical properties of these small particles with their inherent optical properties (IOPs) derived from CIMEL measurements acquired over ocean sites [8].

Above 20 *kms*, the atmosphere is considered as a free-aerosols layer, so as a pure molecular scattering layer.

The combination of the three models (aerosol layers) defines an aerosol assemblage. For MERIS, 15 standard aerosol assemblages have been defined with an optically fixed upper atmospheric layers, *i.e.*, with an AOT550 of 0.025 and 0.005, respectively for the troposphere and the stratosphere. For the last standard aerosol assemblage, the upper atmosphere has been characterized by a free of aerosols layer. For the mixing layer, its optical variability is described by the set of 17 AOT550 values (*see* Tab. 3).

Table 3: Structure of the atmosphere composed of three aerosol layers.

Layer	*Altitude (km)*	*Aerosol model*	*AOT550*
Boundary	[0; 2]	Among 12 SAMs and 3 Blue-IOPs	[0; 0.8]
Troposphere	[2; 12]	Continental	0/ 0.025
Stratosphere	[12; 20]	H2SO4	0/ 0.005

By assuming the water body as black whatever the MERIS wavelength, the boundary condition at the sea surface is given by the *Fresnel* reflection. The wave slopes spatially distribute the reflected beam composed with the direct solar irradiance and the sky radiance (*i.e.*, diffuse irradiance). The surface roughness is then described by the *Cox and Munk* model driven by a wind-speed (w_s) just above sea level [9]. A set of 3 wind-speeds has been selected for the roughness level of the sea surface state to generate the MEROS database (*i.e.*, w_s =1.5, 5.0 and 10 *m/s*).

2.3. The MEROS and SEAPOL databases

The modified version of the RTC/SO has been run over wind-roughened black sea surfaces both for a pure *Rayleigh* atmosphere and a maritime (*Rayleigh* + aerosols) atmosphere, in the 15 MERIS spectral bands, using a standard surface pressure. These SO computations have been conducted on the 16 SAMs, using the pre-defined set of 17 values of AOT550 which includes the pure molecular case for the first SAM only (free of aerosols layer for the troposphere and the stratosphere). Outputs provided by these runs consisted in a set of 2 binary LUTs of BOA atmospheric functions (coded in *«float with double precision»*), per SAM (*iaer*) and per wind-speed (w_s), as follows:

- LUT with upwelling/downwelling atmospheric path radiance fields at BOA,

$$I^{\uparrow}_{boa}, Q^{\uparrow}_{boa}, U^{\uparrow}_{boa}(\lambda, \tau_a^{550}, \mu_s, \mu_v, \Delta\phi),$$

$$I^{\downarrow}_{boa}, Q^{\downarrow}_{boa}, U^{\downarrow}_{boa}(\lambda, \tau_a^{550}, \mu_s, \mu_v, \Delta\phi).$$

- LUT with direct (t_{dir}) and total (T_{tot}) downward atmospheric transmittances,

$$t_{dir}(\lambda, \tau_a^{550}, \mu_s),\ T_{tot}(\lambda, \tau_a^{550}, \mu_s).$$

with λ, the MERIS nominal wavelength,
τ_a^{550}, the AOT at 550 *nm*,
μ_s, the cosine of SZA,
μ_v, the cosine of VZA,
$\Delta\phi$, the relative azimuthal angle.

The full MEROS database comprises 48 binary LUTs (16 SAMs x 3 w_s) with a total size of 2.85 *Gbytes*. In order to reduce the size of previous BOA atmospheric LUTs and to make easier their use as input to the POLREF simulator, an extraction of the atmospheric parameters strictly needed to compute both the polarized reflection coefficient of the sea surface and the total downwelling irradiance, has been achieved on the MEROS database. This yielded to a reduced database, namely SEAPOL, with a simple binary LUT (coded in *«float with single precision»*), per SAM (*iaer*) and per wind-speed (w_s):

- LUT with BOA upwelling/downwelling radiances and total downward transmittance.

The nomenclature of these LUT files is built as: *«LUT_BOA_**sam**_ws**yy**»*, where ***sam*** refers to the selected SAM among the list, hereafter:

{*mar00, mar50, mar70, mar90, mar99,*
coa50, coa70, coa90, coa99,
rur50, rur70, rur90, rur99,
IOP01, IOP02, IOP03}.

and ***yy*** is an index associated with the wind-speed:
{ *01, 05, 10*}.

where *mar00* corresponds to *mar99* with free of aerosols in the troposphere and stratosphere.

3. THE POLREF SIMULATOR

3.1. General flow chart

The general flowchart of the POLREF (POLarization REFlection) simulator is depicted on Fig. 1. It is described by the following steps:

• Step-1: A first block of inputs is related to the MERIS aerosol model (*iaer*, *AOT865*). The 16 SAMs used in the MERIS level-2 aerosol product, have been indexed (*iaer*) to make easier their selection by the operator. The AOT at 865 *nm* (AOT865) correspond to the integrated value for the whole atmospheric column. The latter represents a relevant information when the IOPs of the aerosols are extracted from the radiance measurements (*i.e.*, the solar extinctions and the sky radiances) acquired at surface level, as it was done to build the 3 blue-IOP models. This is not the case with the other SAMs insofar as the MERIS *«Ocean-Aerosol»* LUTs have been generated with a selected aerosol model in the mixing layer using a fixed upper troposphere and stratosphere. Thus, to get the MERIS BOA atmospheric functions (radiances and transmittances) from the LUTs stored in the SEAPOL database, we need to extract, for the user selected SAM (*iaer*), the AOT550 in the mixing (or boundary) layer ($AOT550_{ML}$).

• Step-2: A second block of inputs relies on the Sun/view geometrical condition corresponding to an eventual sequence of data acquisition with a field radiometer. This information allows to select the MERIS BOA atmospheric LUTs associated with the user's SAM (*iaer*). This selection is completed for each of the three wind-speeds used in the LUTs generation.

• Step-3: The input Sun/view geometry combined with $AOT550_{ML}$ extracted from *Step-1*, is then employed to look for the closest grid points by lower value in SZA, VZA, RAA and AOT550 used in the MERIS BOA atmospheric LUTs. This operation is achieved by the *«ClosestGridPoint (SZA,VZA,RAA,AOT550)»* box. A multi-linear interpolation is then applied to get values of the MERIS BOA upwelling/downwelling radiances and total downward transmittances at the user's angular geometry and extracted $AOT550_{ML}$ for the

SAM selected as input by the operator. The *«Linear Interpol (SZA,VZA,RAA, AOT550)»* box is perfectly in-line with the interpolation schemes implemented in the MERIS-IPF [3].

• Step-4: Using the user's input wind-speed (w_s) above sea level, a cubic spline interpolation in w_s is then employed to get the MERIS BOA upwelling/down-welling radiances and transmittances for the user selected roughness level. This step is completed with the user's input SAM by the *«SplineInterpol (w_s)» box*.

• Step-5: The input illumination geometry (*SZA*) combined with the user's input wind-speed (w_s), allows to compute the reflected direct Sun glint radiance by the wind-roughened black sea surface at BOA. For the user's input SAM (*iaer*), the total AOT at each MERIS wavelength is introduced to calculate the extinction of the direct solar beam at the sea surface level. This is completed with the *«SunGlint (L_{glint})»* box.

• Step-6: The user's input ozone amount (u_{O3}) allows to correct the MERIS BOA downwelling/upwelling radiances and the reflected Sun glint contributions at the 15 MERIS wavelengths, for the ozone absorption along the downwelling path.

• Step-7: At the end, the *«FresnelReflCoef (R)»* box allows to compute the new polarized reflection coefficients of the sea surface at the 15 MERIS wavelengths, accounting or not for the Sun glint contribution. The final outputs consist in the MERIS BOA upward/ downward radiances (L_{boa_up}, L_{boa_dw}), the MERIS reflected Sun glint radiances at BOA (L_{glint}), the MERIS downward atmospheric transmittances (T_{tot_dw}), and the MERIS *Fresnel* reflection coefficients with and without Sun glint (*resp.*, R and R_c). Moreover, the output radiances and transmittances account for the ozone absorption along the Sun path (*i.e.*, these physical quantities are multiplied by T_{O3_dw}).

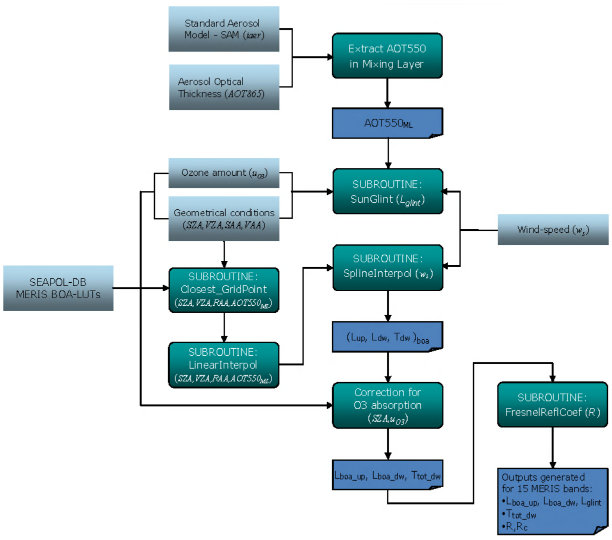

Figure 1: General flow chart of the POLREF simulator.

3.2. Description of the inputs

❖*Mixing or boundary layer*

A standard aerosol assemblage has to be selected by the operator, among a list of 16 SAMs (*see* Tab.4). Each SAM is referred by its index (*iaer*).

Table 4: List of indices (iaer) to select an aerosol model among the 16 MERIS SAMs.

iaer	*SAM*	*Comment about the 3 aerosol layers*
1	mar00	*Maritime model (RH=99%) + free- troposphere + free-stratosphere*
2	mar50	*Maritime model (RH=50%) + Continental + H2SO4*
3	mar70	*Maritime model (RH=70%) + Continental + H2SO4*
4	mar90	*Maritime model (RH=90%) + Continental + H2SO4*
5	mar99	*Maritime model (RH=99%) + Continental + H2SO4*
6	coa50	*Coastal model (RH=50%) + Continental + H2SO4*
7	coa70	*Coastal model (RH=70%) + Continental + H2SO4*
8	coa90	*Coastal model (RH=90%) + Continental + H2SO4*
9	coa99	*Coastal model (RH=99%) + Continental + H2SO4*
10	rur50	*Rural model (RH=50%) + Continental + H2SO4*
11	rur70	*Rural model (RH=70%) + Continental + H2SO4*
12	rur90	*Rural model (RH=90%) + Continental + H2SO4*
13	rur99	*Rural model (RH=99%) + Continental + H2SO4*
14	IOP01	*Blue IOP01 model (m=1.44, k=0.003; α=-1.95) in the 3 aerosol layers*
15	IOP02	*Blue IOP02 model (m=1.44, k=0.003; α=-2.10) in the 3 aerosol layers*
16	IOP03	*Blue IOP03 model (m=1.44, k=0.003; α=-2.25) in the 3 aerosol layers*

❖*Aerosol optical thickness at 865nm*

Next entry consists in the AOT for the whole atmospheric column. The operator has to provide the total AOT at 865 *nm* (referred by *AOT865*).

The acceptable values for *AOT865* are ranged in [0;0.8]. The minimum value of 0 corresponds to the pure *Rayleigh* scattering case for the first SAM (*iaer*=1) only. For the other SAMs, if the *AOT865* is smaller than the total AOT above 2 km (*e.g.*, 0.018 for any *iaer* in [2;13]), then the mixing layer will be assumed as free of aerosols.

As for the maximum value of 0.8, it corresponds to the limit of the expected performances of the MERIS atmospheric correction.

❖*Ozone amount*

In order to account for the ozone transmittance along the Sun path, the operator has to enter an ozone amount (u_{O3}) for the whole atmosphere. A standard value of u_{O3} is 0.32 *cm-atm*. A montly mean tabulated values of u_{O3} derived from ozone profile measurements with OMI (Ozone Monitoring Instrument from NASA) is available on the following web-site: *http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omto3_v003.shtml.*

Note that a separate box has been included in the POLREF simulator to compute the ozone transmissivity within each of the 15 MERIS spectral bands for the downwelling path.

❖*Sun/view geometry*

The inputs for the Sun/view geometry correspond to the Sun/view directions, defined by the solar/viewing zenith angles (SZA,VZA) and the solar/viewing azimuthal angles (SAA,VAA).

The validity domain for SZA/VZA is in [0;75] *deg.*, while SAA/VAA have to be ranged in [0;360[*deg.*

❖*Wind-speed*

The operator has to give a value of wind-speed above sea level (w_s), to get the MERIS BOA atmospheric functions (upward/downward radiances and transmittances) for his experimental condition of the sea surface state.

The validity domain of *ws* is within [1.5;10] *m/s*.

Moreover, the POLREF simulator assumes that the surface pressure is fixed to a standard value of 1013.25 *hPa* and that the water body is black whatever the MERIS wavelength.

3.3. Description of the outputs

The POLREF simulator provides as outputs:

(1) the full list of inputs selected by the operator,

(2) the MERIS BOA atmospheric LUTs used for the computations,

(3) the physical quantities simulated at the 15 MERIS wavelengths (λ), listed as follows:

- $\tau_R(\lambda)$, the *Rayleigh* optical thickness;
- $\tau_a(\lambda)$, the total aerosol optical thickness;
- $\tau_{O3}(\lambda)$, the total ozone optical thickness;
- $L_{boa\_dw}(\lambda)$, the BOA downwelling normalized radiance (sr^{-1});
- $L_{boa\_up}(\lambda)$, the BOA upwelling normalized radiance (sr^{-1});
- $L_{boa\_glt}(\lambda)$, the BOA reflected Sun glint normalized radiance (sr^{-1});
- $T_{tot\_dw}(\lambda)$, the total downwelling atmospheric transmittance;
- $R(\lambda)$, the *Fresnel* reflection coefficient (including the Sun glint);
- $R_c(\lambda)$, the *Fresnel* reflection coefficient (without the Sun glint);

Moreover, in the case where the AOT extraction in the mixing layer yields to a negative value of $AOT550_{ML}$, then the atmosphere is considered as a pure *Rayleigh* scattering medium (AOT550=0) to output the results.

All the radiances are given for an extraterrestrial spectral solar irradiance of 1 $W.m^{-2}.mic^{-1}$, and corrected for the ozone absorption along the Sun path. The total downward atmospheric transmittance includes the ozone absorption. Any other gaseous absorption are not accounted for in these computations.

3.4. Examples of output POLREF simulations

We have selected the viewing geometry as proposed by *Mobley* [5]: *i.e.*, a view zenith angle of 40 *deg.* and a relative difference in azimuth between the solar and viewing planes of 135 *deg.* Tab.5 gives the *Mobley*'s reflection coefficient estimated at this viewing geometry for three wind-speeds.

Table 5: Mobley's reflection coefficient estimated for a VZA of 40 deg., at 3 wind-speeds.

w_s (*m/s*)	1.5	5.0	10
R_{Mobley}	0.0263	0.0284	0.0329

For this geometry, we run the POLREF simulator using the inputs displayed in Tab.6.

Table 6: Example of an input data card to the POLREF simulator.

User's input card to POLREF	
Index of standard aerosol model	5
Total AOT @ 865 nm	0.0450
Total ozone amount (cm-atm)	0.3200
Sun zenith angle (deg.)	35.150
Sun azimuthal angle (deg.)	0
View zenith angle (deg.)	40.000
View azimuthal angle (deg.)	135.00
Wind-speed above sea level (m/s)	7.2

The selected maritime aerosol model corresponds to an *Angstroem* exponent (α) of -0.08. We clearly observe that the Sun glint contribution can be neglected and that at this wind-speed, the *Mobley*'s reflection coefficient is around 0.03 (Tab.5) while the POLREF simulator returns a reflection coefficient above 0.04.

Table 7: Example of outputs provided by POLREF for the input data card from Tab.6.

MERIS-BOA downward/upward normalized radiances, total downward transmittances & Fresnel reflection coefficients

wvl[nm]	tauR	tauA	tauO3	Lboa_dw	Lboa_up	Lboa_G	Ttot_dw	Rcoef	Rcoef_gc
412.500	.31528000	.07423429	.00006971	.03277581	.00128982	.00000024	.82645638	.03936015	.03935280
442.500	.23591030	.07108101	.00090037	.02563692	.00103478	.00000027	.85945552	.04037318	.04036279
490.000	.15515530	.06654112	.00641820	.01777711	.00073674	.00000029	.89087434	.04145946	.04144294
510.000	.13171380	.06478980	.01305874	.01533163	.00063859	.00000030	.89501162	.04167149	.04165190
560.000	.08991220	.06081293	.03327546	.01083792	.00045706	.00000031	.89371997	.04220048	.04217189
620.000	.05943340	.05661416	.03488968	.00781660	.00032829	.00000032	.90794424	.04204007	.04199879
665.000	.04472970	.05392202	.01616128	.00645158	.00026988	.00000034	.93719894	.04188381	.04183154
681.250	.04056210	.05302736	.01128253	.00602917	.00025227	.00000034	.94520968	.04189754	.04184092
708.750	.03455820	.05155259	.00601847	.00541258	.00022546	.00000035	.95484771	.04171918	.04165512
753.750	.02694380	.04932930	.00284691	.00457766	.00018905	.00000035	.96317993	.04137641	.04129946
761.875	.02580160	.04898724	.00212296	.00445441	.00018364	.00000035	.96473719	.04130586	.04122656
778.750	.02361670	.04823935	.00246186	.00419769	.00017249	.00000035	.96571627	.04117726	.04109284
865.000	.01545920	.04500000	.00070150	.00313649	.00013075	.00000036	.97313831	.04180182	.04168701
885.000	.01409880	.04437712	.00038743	.00296836	.00012360	.00000036	.97445546	.04176203	.04164038
900.000	.01317570	.04393545	.00048533	.00285237	.00011860	.00000036	.97500268	.04170701	.04158021

The outputs are saved in an ASCII text file making its use very easy to plot the results.

Fig. 2 displays the *Fresnel* reflection coefficient (R) computed with POLREF over 3 roughened black sea surfaces (1.5, 5 & 10 *m/s*) under a pure *Rayleigh* scattering atmosphere for a VZA of 40 *deg.* and 2 SZAs (50 and 70 *deg.*). Fig. 2*a* is for a RAA of 90 *deg.*, whereas Fig. 2*b* is for a RAA of 135 *deg.* Compared with the *Mobley*'s reflection coefficient (R_{Mobley}), it clearly appears that R is below for the viewing plane at 90 *deg.*, and above for the viewing plane at 135 *deg.* Accounting for the polarization may have a positive or negative value depending on the Sun/view geometry. More, the absolute difference between R and R_{Mobley} increases at large SZAs where the *Rayleigh* polarization is much more important. We can note also that a spectral dependence of R exists with a larger amplitude at RAA=135 *deg.* Finally, as expected, the increasing of the wind-speed (w_s) yields to larger R values.

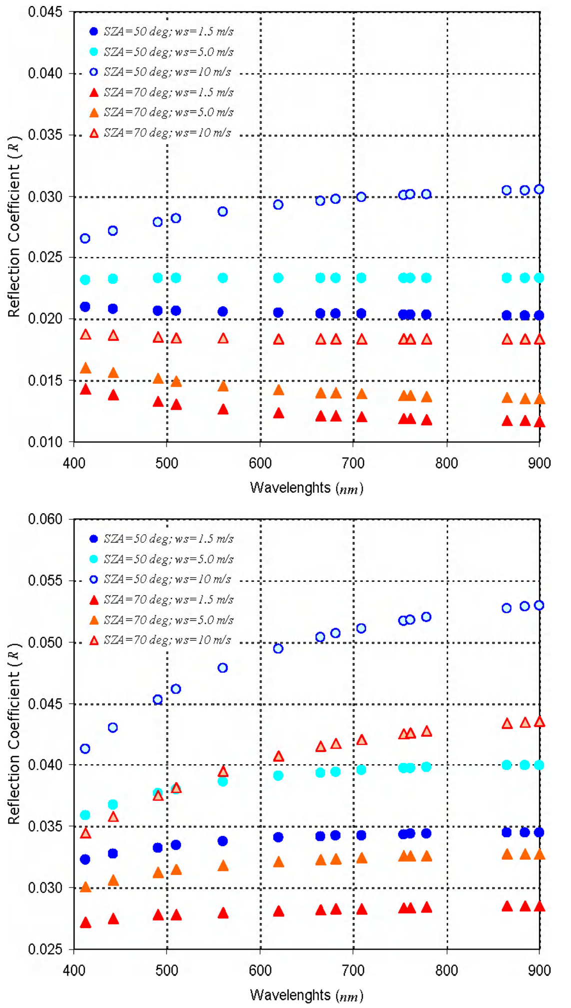

Figure 2: Spectral dependence of the reflection coefficient for the view conditions as described in the text and a pure Rayleigh case. The symbols inserted in the plots give the SZA and the wind-speed.

A more extensive use of the POLREF simulator is included in [10]. It allowed us to fully describe in the details the impact of the polarization in the correction for the sky dome reflection. If the polarization by the *Fresnel* reflection of the sea surface is well known, then the polarization by the atmospheric scattering is well illustrated by Fig. 3. Generally, the aerosols depolarize the *Rayleigh* scattering. This effect is more effective for the large AOTs and aerosol models with a predominance of large particles.

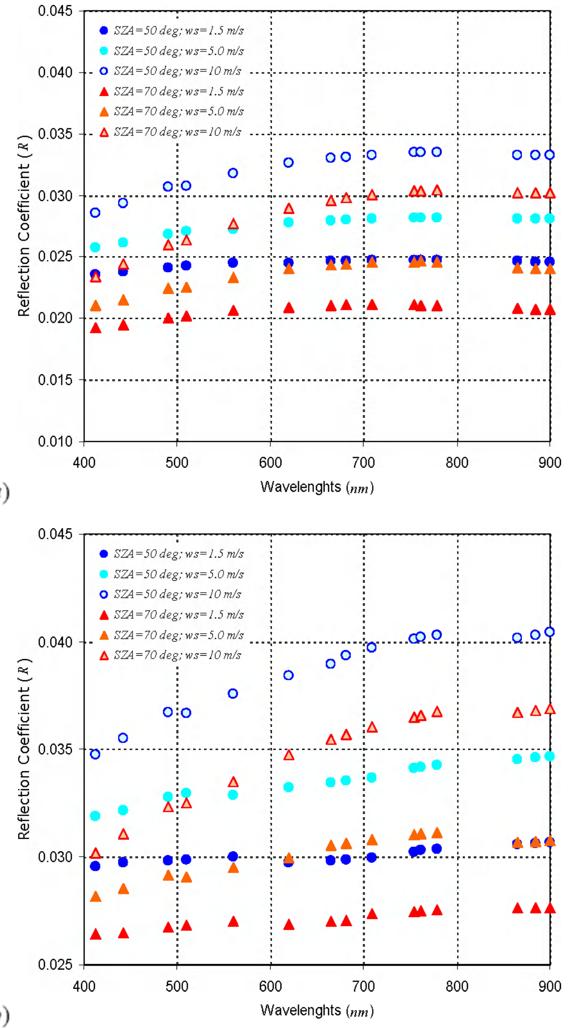

Figure 3: Same legend as Fig. 2 but by adding a maritime model with an AOT at 865 nm of 0.1

4. CONCLUSIONS & PERSPECTIVES

A simulator of the *Fresnel* reflection coefficient of sea surface has been developed. The latter, namely POLREF, is based on pre-computed LUTs of BOA atmospheric functions (upwelling and downwelling radiances, and total downward atmospheric transmittance), generated with a radiative transfer tool (RTC/SO) dealing with the polarization processes for both the sea surface reflection and the scatterers in the atmosphere (*i.e.*, molecules and aerosols). These LUTs are perfectly in-line with what is included in the MERIS-IPF in term of wavelengths, aerosols (SAM family), angular geometries and surface conditions (*i.e.*, a standard barometric pressure and a sea surface roughness).

The POLREF simulator presents two major roles:

- *Operational*: To develop a processing chain for sky dome correction of above water radiance measurements acquired by the SeaPRISM (SeaWiFS Photometer Revision for Incident Surface Measurements) and the TriOS/MUMM (Tri-Optical Sensors from the Management Unit of the North Sea Mathematical Models, Brussels - Belgium) field radiometers [11];
- *Educational*: To convince the ocean-colour community that the polarization plays an important role in the correction for the sky dome reflection in the above water radiance measurements.

Of course, the POLREF simulator could be also employed as a tool to evaluate the quality of field measurements such as the sky radiances and surface irradiances acquired at the MERIS wavelengths. Currently, POLREF uses as input the 16 SAMs from the «*Ocean-Aerosol*» ADF implemented in the third MERIS reprocessing, and consequently, this simulator and its associated SEAPOL database will need to be updated if the set of aerosol models changes for the next reprocessing. For the OLCI/S3 (Ocean & Land Colour Instrument onboard Sentinel-3), in addition to the aerosol models, we will have to include the new spectral bands (or wavelengths).

POLREF can be also improved to evaluate the bias induced on the reflected sky radiance at BOA when neglecting the polarization processes. This bias could be easily assessed for the specular case by using the *Stokes* parameters of the atmospheric radiance fields combined to the *Fresnel* reflection matrix of the sea water surface. In fact, for this particular geometry the scalar and vector reflection coefficients can be easily compared.

Because the simulator also provides as outputs the atmospheric radiance and irradiance, the direct comparison between these predictions and the in-situ measurements is potentially useful to evaluate the atmospheric model employed for the sky dome correction.

The POLREF simulator and its SEAPOL database represent the main ingredients to develop an operational processor to apply a vector sky dome correction of above water radiometry. The operationality of this new correction is fully described in [11]

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