POLREF: A New Simulator for Polarized Reflection Coefficients over Ocean

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INTRODUCTION

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 *Fresnel* 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. The latter ignores the polarized nature of both the atmospheric scattering and the surface reflection. The introduction of the polarization requires a radiative transfer code (RTC) which deals with the *Stokes* parameters, to compute the total radiance fields at bottom of the atmosphere (BOA). The successive orders (SO) of scattering code (*Lenoble at al., 2007*) was a good opportunity to analyze the impact of the polarization in the reflected sky dome radiance over ocean. This study has been fully reported in *Santer et al., 2012*.

A simulator, namely POLREF (POLarization REFlection coefficient), has then been developed to produce a new set of *Fresnel* reflection coefficients at the 15 MERIS wavelengths. It relies on a pre-computed synthethic database (SEAPOL), which includes MERIS look-up tables (LUTs) of atmospheric scattering functions at BOA. These LUTs have been generated with the SO vector code using as inputs, the same spectral bandset, the same aerosols, the same atmospheric and surface conditions, and the same set of Sun/view geometries, as for the «*Ocean-Aerosol*» auxiliary data file (ADF) used in the last 3rd MERIS reprocessing. Thus, the POLREF simulator is perfectly in-line with the MERIS intrument facilities processor (IPF).

MEROS Database

Modified RTC/SO:

The RTC/SO used for the generation of MERIS-ADFs over ocean (*Rayleigh* and aerosol LUTs), has been adapted to output the following atmospheric scattering functions:

- the upward/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.

Moreover, in order to allow the computations of MERIS BOA atmospheric LUTs, three additional loops have been implemented in this RTC/SO:

- a loop on the 15 MERIS spectral bands (*i.e.*, central wavelengths);
- a loop on the 16 values of the aerosol optical thickness at 550 *nm* (AOT550), from 0 (pure molecular scattering atmosphere) to 0.8 by step of 0.05;
- a loop on the 25 solar zenith angles (24 *Gaussian* angles + zenith direction).

Main features of RTC/SO:

- *No gaseous absorption:* However, because the ozone (O_3) 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 O_3 absorption is then treated separately and included in the POLREF simulator.
- *Rayleigh scattering:* It is described with a molecular optical thickness for a standard barometric pressure (P_s) of 1013.25 *hPa*, with a molecular phase function characterized by a depolarization factor (δ) of 0.0279, and with a scale height (H_R) of 8 *km* for the vertical distribution of the molecules.
- *Aerosol scattering:* It is structured in three optically homogeneous layers.

Layer	Altitude	Aerosol Model	AOT550
Boundary	[0-2] *km*	12 SAMs + 3 Blue-IOPs	[0;0.8]
Troposphere	[2-12] *km*	Continental	0 / 0.025
Stratosphere	[12-20] *km*	H2SO4	0 / 0.005

- *Boundary condition:* Water body is assumed to be black and the *Fresnel* reflection is described by a *Cox-Munk* wave slope distribution driven by a wind-speed (w_s). A set of 3 wind-speeds has been selected for the surface roughness (1.5, 5, 10 *m/s*).

MEROS Database:

This MERIS synthetic database has been generated with the modified version of the SO vector code. Outputs provided by these runs consist in 2 binary LUTs of BOA atmospheric functions per SAM (*iaer*) and per wind-speed (w_s), as follows:

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

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

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

- 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 central wavelength (15 spectral bands),
τ_a^{550}, the AOT at 550 nm (17 values),
μ_s, the cosine of solar zenith angle (SZA), (24 *Gaussian* angles + zenith direction),
μ_v, the cosine of view zenith angle (VZA), (24 *Gaussian* angles + nadir direction),
$\Delta\phi$, the relative azimuthal angle (RAA) between Sun/view directions (25 values).

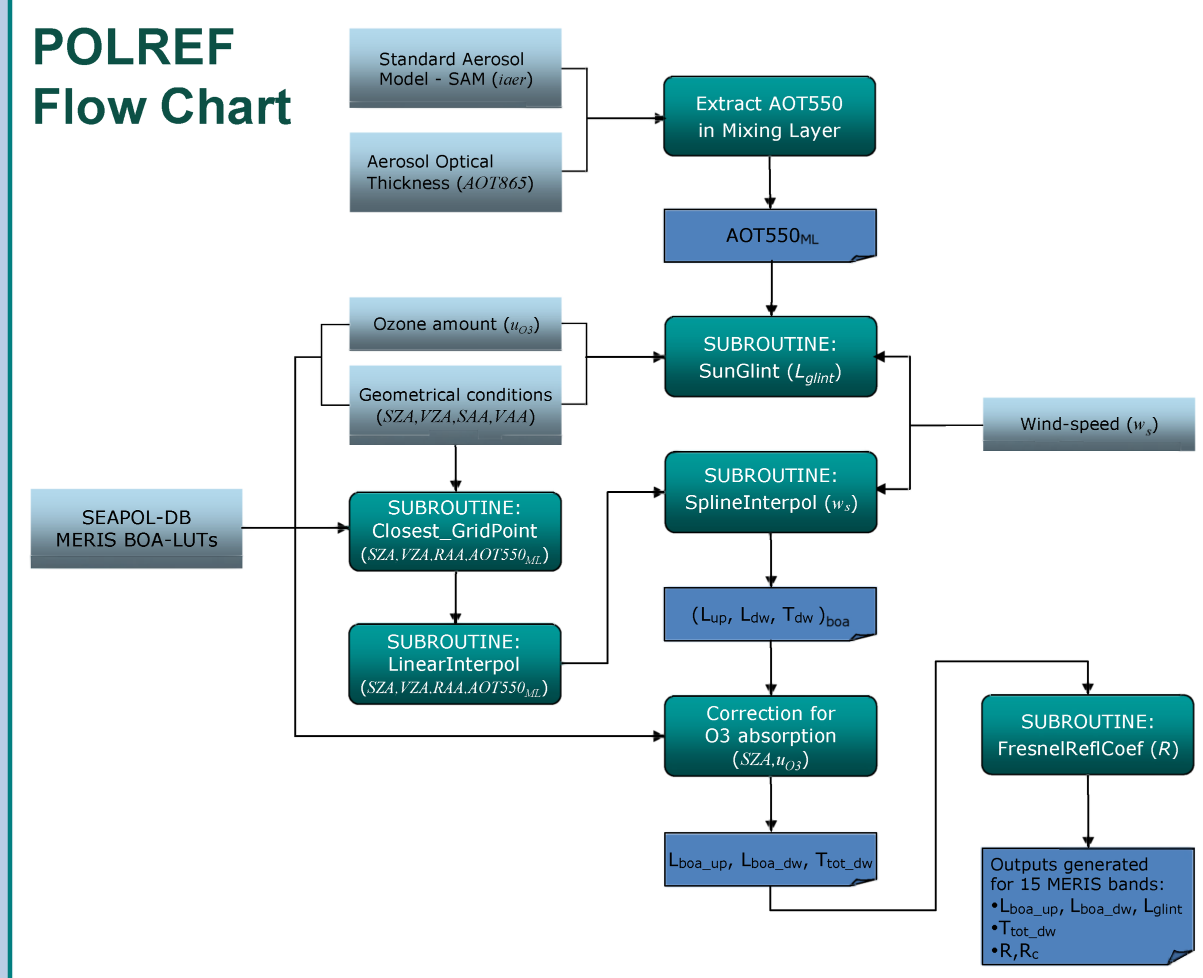
SEAPOL Database

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 strickly needed to compute both the *Fresnel* reflection coefficients 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 per SAM (*iaer*) and per wind-speed (w_s):

- LUT with BOA upward/downward 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'}.
'mar00' corresponds to 'mar99' with free-aerosols in troposphere and stratosphere.

POLREF Simulator



Some comments:

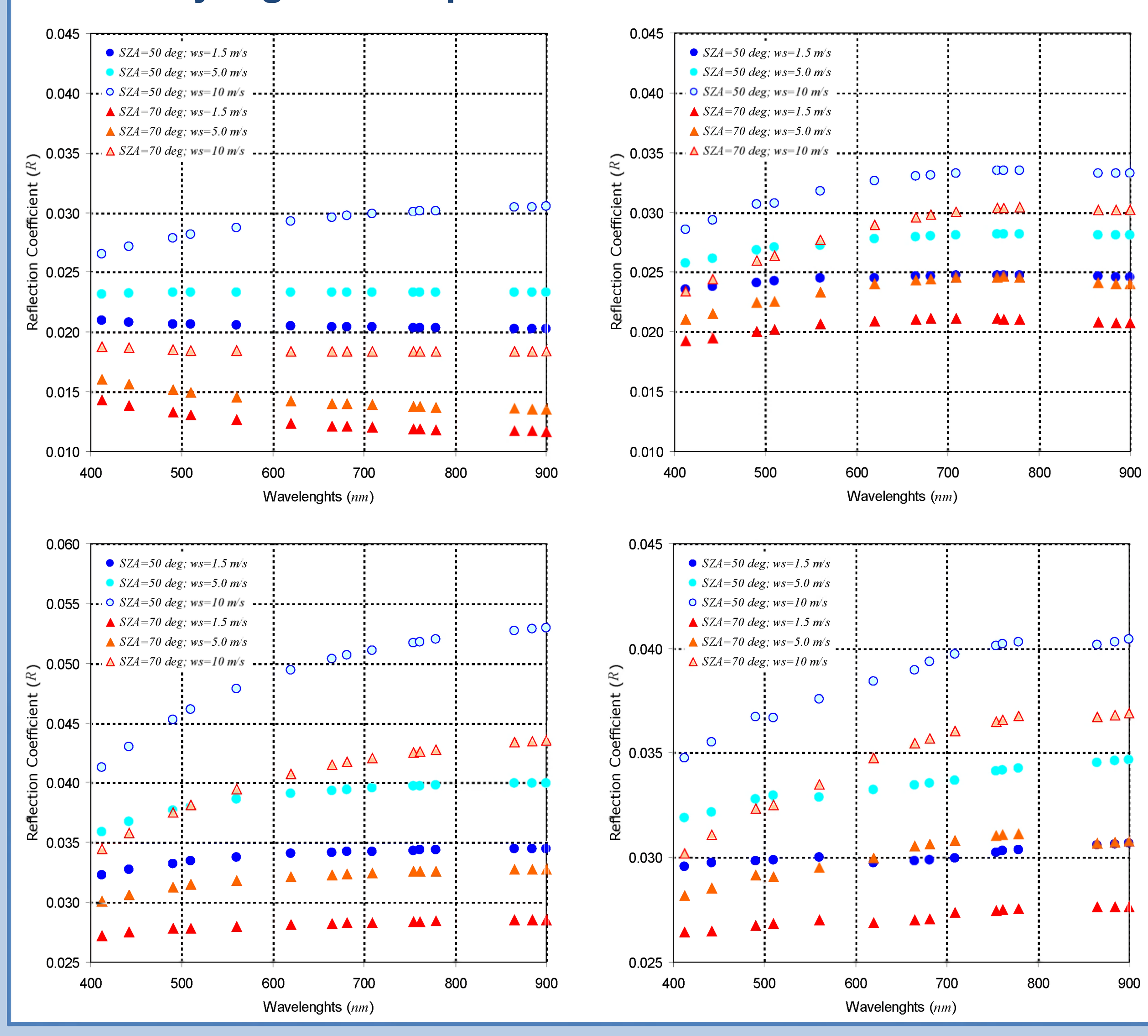
- 1st block of inputs is related to the MERIS SAMs (*iaer*, *AOT865*). The AOT865 is an integrated value for the whole atmospheric column.
- 2nd block of inputs corresponds to Sun/view geometry and O_3 amount
- The selection of MERIS BOA-LUTs is done with the user's input SAM (*iaer*), for each of 3 wind-speeds. The atmospheric functions are extracted from these LUTs at the closest grid points, with respect to the input Sun/view geometry and the AOT550$_{ML}$ (mixing layer) derived from the input AOT865.
- The multi-linear interpolations in (SZA,VZA,RAA,AOT550) and the cubic spline interpolation in w_s are in-line with the MERIS-IPF.

POLREF outputs:

- $\tau_R(\lambda)$, $\tau_a(\lambda)$, $\tau_{O3}(\lambda)$: respectively, the *Rayleigh* optical thickness, the AOT and O_3 optical thickness for the whole atmospheric column;
- $L_{boa\_dw}(\lambda)$, $L_{boa\_up}(\lambda)$: respectively, the BOA downwelling and upwelling normalized radiances (sr^{-1});
- $L_{boa\_glt}(\lambda)$, $T_{tot\_dw}(\lambda)$: respectively, the BOA reflected Sun glint normalized radiance (sr^{-1}), and the total downward atmospheric transmittance;
- $R(\lambda)$, $R_c(\lambda)$: respectively, the *Fresnel* reflection coefficients including or not the Sunglint contribution

Examples of Outputs from POLREF

Pure Rayleigh Atmosphere | **MAR90 - AOT865=0.2**



SEAPRISM Geometry (VZA=40°;RAA=90°)

w_s (*m/s*)	*1.5*	*5*	*10*
R_{mobley}	0.0263	0.0284	0.0329

Compared with R_{mobley}, the POLREF reflection coefficient (R_{pol}) is underestimated.

TriOS Geometry (VZA=40°;RAA=135°)

Compared with R_{mobley}, which is assumed to include the Sunglint contribution, R_{pol} is overestimated.

CONCLUSIONS

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 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.*, standard barometric pressure and sea surface roughness).

This POLREF simulator presents two major roles:

- Operational: To develop a processing chain for sky dome correction of above water radiance measurements acquired by the field radiometers (see *Barker et al., 2012*)
- 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 radiances measured with field radiometers. (Contact *Francis Zagolski* to get this POLREF simulator).

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Invest in our future

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