Definitions, Acronyms, Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEAM</td>
<td>Basic Envisat Tool for AATSR &amp; MERIS (<a href="http://envisat.esa.int/services/beam/">http://envisat.esa.int/services/beam/</a>)</td>
</tr>
<tr>
<td>BRF</td>
<td>Bidirectional Reflectance Factor</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>Environment Satellite (<a href="http://envisat.esa.int">http://envisat.esa.int</a>)</td>
</tr>
<tr>
<td>EO</td>
<td>Earth Observation</td>
</tr>
<tr>
<td>ERS</td>
<td>European Remote Sensing satellite</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency (<a href="http://www.esa.it/export/esaCP/index.html">http://www.esa.it/export/esaCP/index.html</a>)</td>
</tr>
<tr>
<td>ESRIN</td>
<td>European Space Research Institute (<a href="http://www.esa.it/export/esaCP/index.html">http://www.esa.it/export/esaCP/index.html</a>)</td>
</tr>
<tr>
<td>GMES</td>
<td>Global Monitoring for Environment and Security</td>
</tr>
<tr>
<td>L1, L2</td>
<td>Level 1, Level 2</td>
</tr>
<tr>
<td>MERIS</td>
<td>Medium Resolution Imaging Spectrometer Instrument</td>
</tr>
<tr>
<td>NIR</td>
<td>Near InfraRed</td>
</tr>
<tr>
<td>RR</td>
<td>Reduced Resolution</td>
</tr>
<tr>
<td>SoW</td>
<td>Statement of Work</td>
</tr>
<tr>
<td>TOA</td>
<td>Top of Atmosphere</td>
</tr>
</tbody>
</table>

Reference documents

R-1 MERIS DPM
1 INTRODUCTION
The objective of this report is to describe the principle of the ICOL processor implemented in BEAM. Following the ESA request, the ICOL processor returns a level 1 to be process in MEGS. §2 describes the algorithm with the key equations. §3 gives examples.

2 DESCRIPTION OF THE ALGORITHM

2.1 General flowchart

Inputs are level-1b images. Bands at 761 nm and 900 nm remain unchanged.

The “preparation” module transforms TOA radiance into TOA reflectance after correction of the gaseous transmittance.

The “Rayleigh” module corrects all the pixels from the Rayleigh scattering.

The “AE_RAY” module corrects the pixels in the vicinity of land (d>30 km) from the AE + FLM Rayleigh.

The “aerosol” module determines the aerosol model over these pixels.

The “AE_AER” module corrects from the AE+ FLM aerosol.

The “generation” module transforms, in 13 MERIS bands, the level 1c reflectance into radiance. For pixels not corrected from the AE and for 761 nm and 900 nm, level 1C is equal to level 1B.

The algorithm applies both on FR and RR data. The correction is applied even on sun glint contaminated pixels, even if the results are known to be wrong. The decision to exclude sunglint is taken downstream in the level 2 processor.

2.2 The TOA reflectance: Generate $\rho^*_{ng}$

All the pixels of the image are converted into TOA reflectance corrected from the gaseous correction $\rho^*_{na}$. The procedure is implemented in MEGS and described in (R-1).
2.3 The regular Rayleigh correction: Generate $\rho_{ag}^0$

This correction follows the 5S (R-2) formalism and applies to all the pixel of the image. It is based on the land Rayleigh correction implemented in MEGS (R-3). Over water, to the intrinsic Rayleigh reflectance $\rho_R^0$, the coupling term between scattering and Fresnel reflection:

$$\rho_R = \rho_R^0 \cdot (1 + r(\mu_s) + r(\mu_v)), \quad (1)$$

in which we introduce the Fresnel reflection coefficient $r$ respectively for the solar and view angles.

CF is the multiplicative factor to be applied to the intrinsic molecular reflectance to account for the coupling between Fresnel reflection and Rayleigh scattering. CF=1 over land and:

$$CF = (1 + r(\mu_s) + r(\mu_v))$$

over water.

The Rayleigh functions are computed as for the MERIS GS land processor. The Rayleigh correction is identical than for the MERIS GS land processor.

2.4 The level-1C Rayleigh

This correction is only applied only on the AEP’s which are pixels distant from the coast at less than 30 km.

*The land-Fresnel mask*

In Eq. (1), the coupling between scattering and Fresnel reflection is accounted for an open ocean. The vicinity of the land may reduce the direct to diffuse term if the solar plane crosses the coast line.

This correction is driven by the calculation of the maximum altitude of the atmosphere illuminated by the reflected direct solar beam. We detail below this computation for a nadir view (Figure 1).
Figure 1: (a) schematic representation of the distance \( l \) between the pixel \( P \) over water and the coast line at point \( S \) in the principal plane; (b) schematic representation of the maximum altitude of the atmosphere illuminated by the reflected direct solar beam.

Let \( l \) the distance between a pixel \( P \) over ocean surface and a pixel \( S \) over land at the coastline in the principal plane, \( Z_{\text{max}} \) is the maximum altitude reaches by the reflected solar beam. For a nadir view:

\[
Z_{\text{max}} = \frac{\tan(\theta_s)}{l}.
\]  

(2)

The vertical distribution of the molecules is described by the altitude dependence of the optical thickness:

\[
t_R(z) = \tau_R \cdot \exp(-z / H_R),
\]

(3)

with \( H_R \) the Rayleigh scale height.

Finally, Eqs. (7) and (17) yields to:

\[
\Delta \rho_R = \rho_R^b \cdot r(\mu_s) \cdot \exp(-Z_{\text{max}} / H_R).
\]

(4)

NB: The computation is a little more complex for off nadir view, but it is included in the ICOL processor.

**The traditional adjacency effect**

Following the 6S formalism (R-2), the contribution of the adjacency effects corresponds to:

\[
\Delta \rho_R^\text{AE} = \tau(\mu_s) \cdot (\langle \rho \rangle - \rho) \cdot T(\mu_s).
\]

(5)

The *Rayleigh* transmittances \((T, t)\) are pre-computed in LUT’s. Computation of \(\langle \rho \rangle\) requires the knowledge of the surface reflectance (here, the bottom of Rayleigh reflectance).

**Computation of \(\langle \rho_R \rangle\)**

We need to compute,
\[
<\rho_R> = \rho_o \cdot W_o^R + \sum_{d=1}^{n} \rho_d \cdot W_d^R ,
\]

where \( \rho_o \) and \( W_o^R \) are respectively the reflectance (after the Rayleigh correction) and a Rayleigh weighting function for the pixel \( P(i,j=0) \), and \( \rho_d \) and \( W_d^R \) respectively the mean reflectance and the associated Rayleigh weighting function at a distance \( d \). The weighting functions \( W \) are pre-computed in LUTs using the primary scattering approach described in (R-4).

2.5 The aerosol model

The vertical scale height is assumed to be 3 km. The aerosol models are the Junge models implemented in MEGS over land. The aerosol type is selected on the \( \rho_{ag} \) (BRR) ratio between 778 nm and 865 nm.

The aerosol AOT is determined at 865 nm with a signal formulation which includes the AE and the LFM. Water body is dark.

The intrinsic aerosol reflectance is first corrected for the coupling with the Fresnel reflection:

For the AEP, we first compute \( Z_{\text{max}} \). Default value is 999. \( Z_{\text{max}} \), which is used to correct for the Rayleigh and aerosol land Fresnel mask.

The land Fresnel mask correction is applied as described above, Eq. (4).

The specific AE Rayleigh correction is applied. \( <\rho_R> \) is computed through Eq. (6).
\[ \rho_a = \rho_a^0 \left[ 1 + \frac{P_a(\chi)}{P_a(\Theta)} \cdot \left( r(1) + r(\mu) \cdot (1 - \exp(-z_{\text{max}} / H_a)) \right) \right] = \text{CF}. \rho_a^0 \]  

We introduce here, the aerosol phase function \( P_a \) computed at the scattering angle \( \Theta \) and the one calculated at the scattering angle for the reflected solar beam \( \chi \).

Then, the AE is computed following Eq. (5) with:

\[ <\rho_a> = \rho_a \cdot W_a + \sum_{d=1}^{\infty} \rho_d \cdot W_d \]  

The corrective factor CF and \( W_\alpha \) are associated to a Junge model and are wavelength independent.

Spectral dependence of BRR is used to select the aerosol model. \( i_aer \) is the model number, between 1 to 26 (test on \( \alpha \) range (0-2.5) to be implemented).

\(<\rho_a>\) is computed through similar equation to Eq.(6). The aerosol functions are computed as for MEGS.

\( \rho_{a865} \) increases with AOT. The measured \( \rho_{a865} \) is bounded by two simulated values corresponding to two successive AOTs (\( \text{OAT}_{550\:\text{min}}=i_{aot}*0.1 \) \( \text{OAT}_{550\:\text{max}}=i_{aot}*0.1+0.1 \)).
2.6 The aerosol AE correction

The reduction of the aerosol reflectance due to the FLM is described by CF.

\[ < \rho_a > \] is computed as above.

The AE and FLM computations are similar than the above at 865 nm. They are conducted for the two bounded AOTs.

The AOT interpolation is done both on the total AE in all the MERIS bands.

The output is \( \rho_{1c}^* \) in 13 MERIS bands.

This reflectance is the relevant inputs for the BEAM level 2 routines.

2.7 The aerosol level-1C

The gaseous (O3) absorption is applied back except if we have stored from the first step the gaseous transmittance.

The reflectances are converted into radiances.

The outputs are the level 1C in 15 MERIS bands. The level 1C is different from the level 1B only where the AE and FLM apply.
EXAMPLE OF RESULTS

3.1 Numerical simulations

A nadir simulator has been developed based on exact computation with the SOS code (R-4) and a 5S like formalism to account for the AE. Between the forward and backward modeling, there are the following differences in the backward mode:

(i) The coupling between scattering and Fresnel reflection is approximated (Eqs. 5, 7).
(ii) The retrieve surface reflectance are approximated.

We consider here a nadir view and a SZA=44°, an aerosol model (associated to $\alpha$=-0.5) and AOT_{550}=0.2. Simulated results are for a straight coastline with no FLM; scene composition is vegetation over land and black water. $H_s=3$ km and the inversion uses this value. Figure 2 gives the TOA reflectance and its artificial increase due to the AE. Because here the land water contrast increases sharply with the wavelength in the near infra red, the AE appears significant in this spectral range. Therefore, in this case, the Rayleigh correction does not correct much, figure 4. When the correction with the aerosol is introduced, the AE are reduced by a factor 10 or so, figure 5.
Figure 2: (a) level 1C in 13 MERIS band versus the distance to the coast and (b) additional reflectance (x100) of the AE.
Figure 3: Same as figure 2 but after correction of the AE with a molecular atmosphere.
3.2 Illustration of the ICOL outputs

We selected a MERIS image acquired on 23/06/2005 on the south of Norway. On the RGB image, figure 5 was first added the AEF area and second a selected transect in red.
Figure 5: MERIS image on 23/06/2005

The level 1b is the regular MERIS level 1. The level 1C is after ICOL processing. It is obvious to see on figure 6 the adjacency effect in B13 (865 nm) on the level 1 with an artificial increase of the TOA reflectance at the coast line. This effect is corrected (may be a little over corrected) by ICOL. In B2 (442 nm), the contrast between land and sea is week and the ICOL processor returns small differences between the level 1B and the level 1N. But, at level 2, the artificial increase of the AOT will results in and over atmospheric correction in the visible bands. The 0.002 additional reflectance at 865 nm at the coast becomes an over correction of the water reflectance roughly of 0.005 ($\alpha$=-1 plus the amplification by the atmospheric transmittance).
LIMITATIONS

4.1 Sun glint

The presence of the sun glint biases the retrieval of the surface reflectance and therefore it impacts on the AE correction.

4.2 Spatial homogeneity of the atmosphere

We define a window of 60 km*60 km to compute $\langle \rho_R \rangle$ and $\langle \rho_a \rangle$. We apply then the atmospheric transmittances to evaluate the AE. On this macro window, we suppose that the atmosphere above each pixel has the same characteristics:

(i) Same barometric pressure.

(ii) Same aerosol model.

One major problem is certainly the presence of clouds within this window.
4.3 Estimation of surface reflectance

The reflectance of the land surface is needed to account for the AE. This surface reflectance is retrieved without taking into account the AE. To improve the results:

(i) The AE should be applied as well over land.
(ii) A second iteration may improve the results.

4.4 The aerosol vertical scale height

The vertical distribution of the aerosol directly impacts on the results. A standard value of 3 km will be implemented. A simple evaluation lies in the spatial variability of the aerosols which should not be correlated to the AE.

4.5 The off-nadir AE for the aerosols

The AE for the aerosols is in theory defined for a nadir view. Nevertheless, the algorithm applies for off nadir views. Again, a simple evaluation of the extension to larger view angles lies in the spatial variability of the aerosols which should not be correlated to the AE.