

AEROSOL REMOTE SENSING OVER OCEAN IN GLINT CONTAMINATED REGIONS USING AATSR AND MERIS

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1. INTRODUCTION

The Medium Resolution Imaging Spectrometer MERIS and the Advanced Along-Track Scanning Radiometer AATSR instruments, both onboard ESA's Environmental Satellite ENVISAT, provide similar spatial resolution and swath, but complementary information, encompassing different spectral domains and viewing geometries. Recent geophysical algorithms do not take advantage of a synergetic use of the measurements of both instruments, although the benefits in cloud and aerosol retrieval are obvious. This paper presents one example for a synergistic use of MERIS and AATSR imagery: The retrieval of aerosol optical thickness and Angstrom coefficient over the ocean, in particular in sun glint contaminated regions. Later we will extend the focus on the potential of the estimation of aerosol absorption by means of its single scattering albedo.

2. MERIS AND AATSR IN SHORT

MERIS is an imaging spectrometer with 15 programmable spectral bands in the range 400nm – 1050nm. The operational band setting positions of the 15 bands are between 412.5nm and 900nm, including one narrow channel at 761.375nm in the O₂ A-band absorption band, two bands to estimate the integrated water vapour content, and three bands to retrieve aerosol properties. The MERIS swath covers 1150km across track. The original pixel size is 260m x 300m in nadir with a slight increase towards the edge of the swath. The full resolution data (FR) are spatially integrated (4x4 pixel) to the reduced resolution (RR) pixel with a 1040m x 1200m pixel size.

AATSR is a scanning radiometer with 7 spectral channels at visible, reflected infra-red and thermal infrared wavelengths with two ~500 km wide curved swaths, with 555 pixels across the nadir swath and 371 pixels across the forward swath. The nominal pixel size is 1km² at the centre of the nadir swath and 1,5 km² at the centre of the forward swath. This unique feature provides two views of the surface and improves the capacity for atmospheric correction and enables observations of the ocean surface under a tilt angle of ~46.9° in forward direction. The first 3 AATSR bands cover MERIS channels, however, the bandwidth of the AATSR channels is significantly larger.

2. THE ALGORITHM IN SHORT

The aerosol retrieval algorithm consists of three parts. **The first part** is the estimation of the ocean specular reflection at 3.7 micron, whereby an estimation of the thermally emitted part at 3.7 from the brightness temperatures at 11 and 12 micron is used. The thermal emitted radiance is subtracted from the top of atmosphere radiance and corrected for water vapour, resulting in the specular reflectance at 3.7 micron. **The second part** is the propagation of this reflectance a) to the MERIS channel wavelength (taken into account the wavelength dependence of the water refractive index) and b) to the corresponding MERIS observation geometry, which is necessary to account for the different scanning methods of MERIS (line scanner) and AATSR (conical scanner). **The third part** is the estimation of the aerosol optical properties (AOT at 550nm and Angstrom coefficient) utilizing the sea surface reflection as the lower boundary condition in a physical inversion.

2.1. Solar portion and specular reflection at 3.7 μ m

The top of atmosphere radiance at AATSR channel at 3.7 μ m top of atmosphere radiance consists of reflected and scattered solar radiation as well as emitted radiation from the atmosphere and the surface. For cloud free conditions the amount of molecular scattering is negligible ($\tau < 0.00005$), the amount of aerosol scattering is very small and, compared to the amount of reflected and emitted radiation, negligible as well. (Under special conditions, in particular for high aerosol loadings due to desert outbreaks or for undetected clouds, this may be different, but it is not considered here). Therefore we can assume the following equation:

$$L_{TOA} = L_{surf,E} + L_{atm,E} + L_{surf,S}$$

With $L_{TOA,E} = L_{surf,E} + L_{atm,E}$, the top of atmosphere radiance without any solar radiation, as it is observed e.g. during night, the sum can be further simplified and the equation can be rearranged to:

$$L_{surf,S} = L_{TOA} - L_{TOA,E}$$

The estimation of $L_{TOA,E}$ is done by a linear regression of the measured brightness temperature at 11 μ m and 12 μ m (BT11 and BT12) to the brightness temperature at 3.7 μ m (BT3.7):

$$BT_{3.7} = a + b \cdot BT_{11} + c \cdot (BT_{11} - BT_{12})$$

The regression coefficients are: $a = 4.91348$ $b = 0.978489$ $c = 1.37919$. The coefficients have been found by analyzing cloud free sea surface night scenes. The intensive quantity $BT_{3.7}$ is converted into the extensive radiance $L_{TOA,E}$ by a simple linear interpolation in an appropriate look up table $L_{TOA,E} = LUT [BT_{3.7}]$. Finally $L_{surf,S}$ is corrected for water vapor transmission $T_{3.7}$ and solar irradiation to obtain the bottom of atmosphere reflectance at $\gamma_{3.7} = L_{surf,S} / (E_0 T_{3.7})$

2.2. Geometrical and spectral conversion of the glint at 3.7 μm

The glint at MERIS wavelengths and MERIS viewing geometry is not equal to $\gamma_{3.7}$ because i) the refractive index of water is different at the visible and 3.7 micron and more important and more difficult to solve ii) the azimuth difference of the AATSR observation is different to the azimuth difference of the MERIS. The main quantity for this geometrical conversion is the **effective wind-speed** ws . It is assumed that there exists a unique relationship CM between the glint γ at a specific wavelength λ , the observation geometry (ϑ_{sun} , ϑ_{view} , φ_{diff}), the refractive index of sea water at that wavelength n and the wind-speed ws .

$$\gamma = CM(\vartheta_{\text{sun}}, \vartheta_{\text{view}}, \varphi_{\text{diff}}, n, ws)$$

But studies have shown, that this relation does not exist, at least not precisely. In particular the wind direction, existing (cross) swell and the history of the waves modulate the relationship and lead to different parameterizations of sea surface roughness. The task of the wind-speed ws is solely to act as a consistent parameter for the sea surface glint. Since ws is the only unknown in the upper simplified relationship, there could be an unique inverse solution:

$$ws = CM^{-1}(\vartheta_{\text{sun}}, \vartheta_{\text{view}}, \varphi_{\text{diff}}, n, \gamma)$$

Under the assumption that the unique inverse CM^{-1} exists, the geometrical conversion is straight forward and consists of the following two steps:

i) Calculation of the effective wind-speed

$$ws = CM^{-1}(\vartheta_{\text{sun}}, \vartheta_{\text{view}}, \varphi_{\text{AATSR}}, n_{3.7}, \gamma_{3.7})$$

ii) Calculation of the glints γ_{MERIS}

$$\gamma_{\text{MERIS}} = CM(\vartheta_{\text{sun}}, \vartheta_{\text{view}}, \varphi_{\text{MERIS}}, n_{\text{MERIS}}, ws)$$

The forward operator CM is implemented and approximated by a look up table. The inverse operator CM^{-1} could not be approximated by an analytic function, because under some conditions or geometries it is not unique, but twofold (two effective wind-speeds can produce the same sun glints). Instead a simple and fast search algorithm was implemented, that gives the possible wind-speeds.

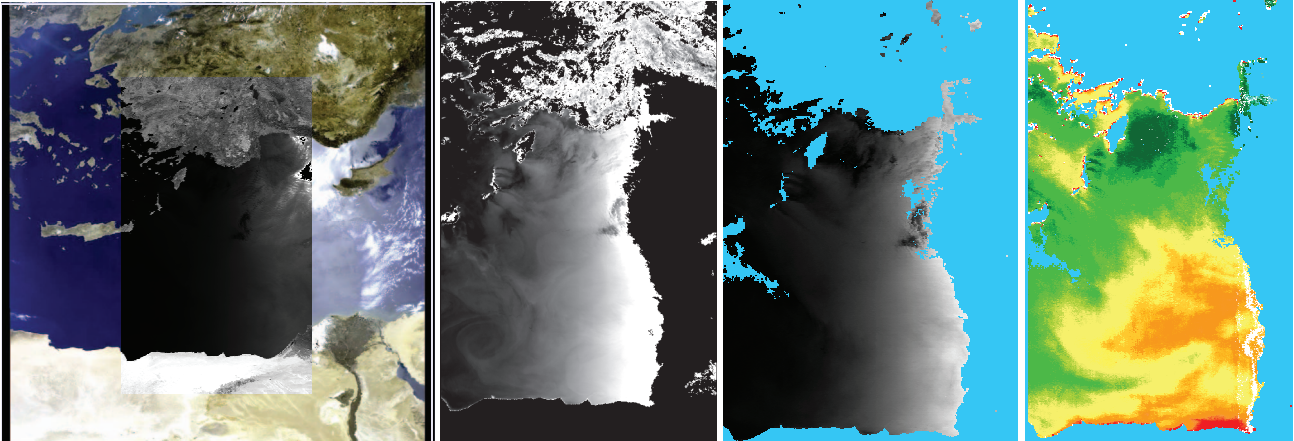
2.3. Estimation of aerosol properties

The estimation of the aerosol optical properties (AOT at 550nm and Angstroem coefficient α) is a physical inversion using the estimated sea surface reflection as the lower boundary condition. Eventually it is a simple LUT search where AOT and α are the search dimensions. The LUT was filled with radiative transfer calculations using the radiative transfere code MOMO (Fell and Fischer 2003).

From theoretical investigations we know that for high and medium glint situations (see e.g Kaufmann et al 2003) the aerosol absorption is to some extend separable from aerosol optical thickness and aerosol asymmetry. We will search for a quantitative measure to identify such situations and apply an absorption retrieval (extension

of the LUT search dimension to single scattering albedo) to these situations. However, this is not implemented yet (writing this extended abstract).

3. EXAMPLES



From left to right. 1.) True colour composite of a glint affected scene of the Mediterranean on the 13.Jun 2003 observed by MERIS and a black white overlay of AATSR 1.6 μm nadir view. 2.) The same scene measured by AATSR 3.7 μm . Due to the high reflectivity of the glint and some land surfaces this channel is partly saturated. 3.) The estimated sea surface glint at 0.89 μm for the MERIS viewing geometry. 4.) The estimated aerosol optical thickness at 550nm (dark red = 0.4, dark green = 0.1)

4. REFERENCES

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