OLCI Level 2

Algorithm Theoretical Basis Document

Alternative Atmospheric Correction

Document Ref: S3-L2-SD-03-C17-GKSS-ATBD

Deliverable Ref: SD-03-C17

Version: 1.1

Roland Doerffer
GKSS Research Center
Institute for Coastal Research
Max-Planck-Str. 1
D-21502 Geesthacht
roland.doerffer@gkss.de

Title: S3-L2-SD-03-C17-GKSS-ATBD_AlternativeAtmosCorr_v1.0-100406
Document Ref: S3-L2-SD-03-C17-GKSS-ATBD

	Name	Function	Company	Signature	Date
Prepared	Doerffer		GKSS		20090404
Approved					
Released					

Revisions:

Issue	Date	Subject	Author
1	20100406	First Version	Doerffer

Change Record

Issue	Date	Description	Change Chapters
1.0	06/04/2010	version 1	
1.1	19/07/2010	- equations in ch. 3 (RLtosa computation) errors corrected and numbered - clarification of radiance reflectance and water leaving radiance reflectance - validation and summary report provided with reference in chap. 11	3 1 11

Distribution List

Organisation	To	No. copies
ARGANS	S. Lavender	
ESA	P. Goryl	
ACRI	L. Bourg	

Table of Content

1 Introduction

This ATBD describes a procedure to derive the bi-directional water leaving radiance reflectances (RL_w) from top of atmosphere (TOA) radiance reflectance spectra RL_toa (L1b data) of the *Ocean Land Colour Imager* (OLCI) on Sentinel 3. The procedure is an alternative method to the standard atmospheric correction procedure for OLCI. Its main purpose is to improve the atmospheric correction over turbid and highly absorbing case 2 water and for areas of an image which are contaminated by sun glint. However, it can be applied also to case 1 water.

This part 1 of the ATBD describes how the procedure has to be implemented in the processor. Part 2 will describe the model used to simulate the training data set.

The procedure is mainly based on artificial neural networks with some pre-corrections. It delivers also information about spectra, which are out of the data set, which was simulated for training of the neural network and which determines the scope of the procedure. Furthermore, the path radiance reflectances (RL_path), the aerosol optical thicknesses and the angstrom coefficient are computed.

The neural networks are based on simulated bi-directional top of standard atmosphere radiance reflectances (RL_tosa). The simulations are performed for 15 bands of OLCI. The radiative transfer model includes an atmosphere with 50 layers with different aerosols and thin cirrus clouds, a wind dependent rough sea surface with specular reflectance of sky and direct sun radiation and white caps and a water body with different components of absorbing and scattering constituents. Furthermore, the water optical properties are temperature and salinity dependent.

The procedure consists of four parts:

1. Determination of top of standard atmosphere (TOSA) spectra (RL_tosa) from RL_toa spectra
2. Check if spectrum is in range and in scope by an auto-associative NN
3. Determination of RL_w, RL_path by a NN
4. Determination of tau_aerosol at 4 bands by a NN and calculation of the angstrom coefficient

Step 1 is used to perform a correction concerning (1) the deviation of the actual surface pressure from the standard pressure of 1013.2 hPa, (2) the correction of the deviation of the actual ozone column content from the standard value of 350 Dobson Units, (3) the correction for water vapour and other gases such as NO2(tbc).

The general outline is summarized in Fig. 1.

Note that the input of atmospheric gases is only necessary if these are not considered in the pre-correction step, which has to be performed elsewhere.

All reflectances are defined as bi-directional radiance reflectances, also called remote sensing reflectances,

$$RL\_x(\lambda, \theta_v, \varphi) = Lu(\lambda, \theta_v, \varphi) / Ed(\lambda, \theta_s),$$

where Lu is the upward directed radiance, Ed the downwelling irradiance, λ, the wavelength, θ_v, the viewing zenith angle, θ_s the solar zenith angle and φ the azimuth difference between sun and viewing direction.

The water leaving radiance reflectance RL_w is then accordingly the radiance leaving the water surface (without the specular reflected radiance above the surface), devided by the downwelling irradiance abouve the surface.

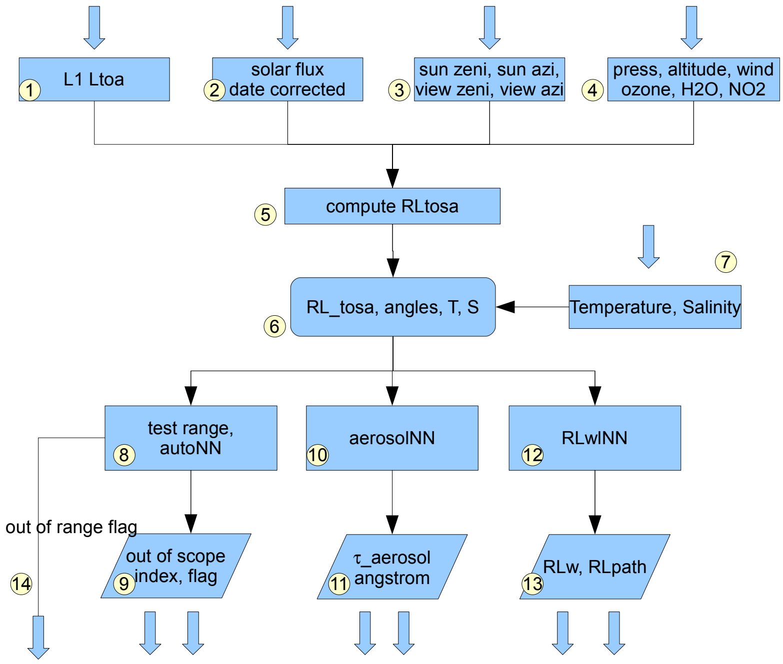

Fig. 1: Outline of atmospheric correction procedure

For the operation of the neural networks a routine to create/establish a network and a routine to execute a network are necessary. These routines have to be consistent with the structure of the provided nn-files. Furthermore, a routine must be available to read the minium and maximum values of the input neurons from the nn-file. These routines in form of a C-code can be provided.

2 Input Data

2.1 OLCI data (1)

L1b top of atmosphere radiances in 15 bands Oa 1-12 (400-753 nm), Oa 16, 17, 21 (778, 865,1020)

2.2 Auxiliary data (2), (3), (4)

View zenith angle (at pixel location): view_zenith

View azimuth angle (at pixel location): view_azimuth

sun zenith angle (at pixel location): sun_zenith

sun azimuth angle (at pixel location): sun_azimuth

solar flux for day of overflight at top of atmosphere: E_0

air pressure at sea level: press_act

altitude of water surface: alt

wind speed: wind

ozone column content in Dobson Unit: ozone_act (only necessary if not pre-corrected)

Water vapour column content: wv (only necessary if not pre-corrected)

NO2 column content: no2 (only necessary if not pre-corrected)

2.3 Supplemental data (7)

Sea surface temperature (celsius centigrates):sst

Sea surface salinity (ppt): sss

3 RLtosa computation (5)

To keep the dimension of the simulated data for training of the neural network as small as possible the radiance reflectance at top of standard atmosphere, RL_tosa, is defined. This is used as input to the NNs. The top of standard atmosphere assumes standard values for pressure at sea level and for ozone and no influence by water vapour and NO2.

Thus, the following fixed standard values are used in the simulations for training of the NNs:

- pressure at sea level: press_std (1013.25 hPa)
- ozone: ozone_std (350 DU)
- no water vapour
- no NO2

The deviation between the actual and the standard values are used to compute RL_tosa from RL_toa, with

Ed_toa = E_0 * cos(sun_zenith) *(Eq. 1)*

RL_toa = L_toa / Ed_toa *(Eq. 2)*

L_tosa = L_toa / (trans_u_ozone*trans_u_raylc*trans_u_wv*trans_u_no2) *(Eq. 3)*

Ed_tosa = Ed_toa* trans_d_ozone*trans_d_raylc*trans_d_wv*trans_d_no2 *(Eq. 4)*

RL_tosa= L_tosa / Ed_tosa *(Eq. 5)*

trans_u_ozone = exp(- (ozone_act _h- ozone_std)*a_ozone/cos(view_zenith)) *(Eq. 6)*

trans_d_ozone = exp(- (ozone_act_h - ozone_std)*a_ozone/cos(sun_zenith)) *(Eq. 7)*

trans_u_raylc = exp(-(press_act - press_std)*tau_rayl /2/cos(view_zenith)) *(Eq. 8)*

trans_d_raylc = exp(-(press_act - press_std)*tau_rayl /2*cos(sun_zenith)) *(Eq. 9)*

trans_u_wv = exp(-wv*a_wv/cos(view_zenith)) *(Eq. 10)*

trans_d_wv = exp(-wv*a_wv/cos(sun_zenith)) *(Eq. 11)*

trans_u_no2 = exp(-no2*a_no2/cos(view_zenith)) *(Eq. 12)*

trans_d_no2 = exp(-no2*a_no2/cos(sun_zenith)) *(Eq. 5)*

The actual air pressure is calculated for the altitude of the water surface (press_act_h) to include also lakes in high altitudes as possible targets for OLCI. To determine this pressure from the pressure at sea level the simple international barometric height formula for the standard atmosphere is used, which can be replaced by any more sophisticated formula if the required information is available. The standard formula assumes a surface pressure of 1013.25 hPa, a temperature at surface of 15 deg C and a temperature gradient of 0.65 deg C per 100 meter.

$$p(h) = 1013{,}25\left(1 - \frac{0{,}0065 \cdot h}{288{,}15}\right)^{5{,}255}\ \mathrm{hPa}$$ *(Eq. 13)*

To calculate the pressure at water surface we use:

press_act_h= press_act *(1-0.0065*h/288.15)**5.255 *(Eq. 14)*

with press_act the actual pressure at sea level and h the altitude of the water level in meter.

b_rayl is the scattering coefficient of the standard atmospheric gases ("Rayleigh scattering") at standard pressure. Due to the forward-backward symmetry of the scattering function b_rayl/2 is taken as the diffuse attenuation coefficient.

tau_rayl is the total attenuation of the specified layer caused by Rayleigh scattering.

a_ozone, a_wv and a_no2 are the specific absorption coefficients for ozone, water vapour and NO2 , i.e. per unit of column content.

Note: all above variables are wavelength dependent.

Remark 1: if the TOA radiances, which are provided as L1b / L1c data, are already corrected for the influence of water vapour and NO2, the corresponding actual values of these 2 variables can be set to the standard values. Alternatively the corresponding procedures can be omitted in the processor.

Remark 2: the atmospheric correction procedure of the case 2 regional (C2R) processor includes the so called smile correction (camera misalignment) in the TOSA preprocessor. Here we assume that this correction is not necessary for OLCI or is already performed in the L1c processor.

4 Supplementary data: water temperature and salinity (7)

Since the Fresnel reflection as well as the scattering and absorption properties of pure water depend on temperature and salinity, these data have to be provided as input to the neural networks. The data, which are not part of the auxiliary data set, may come either from actual measurements, climatological data or may be mean values, if no other data are available. The data are direct input to the neural networks.

5 Angles

All angles are defined for the position of the pixel. The viewing and sun azimuth angles are defined for the position of the sun and the satellite with respect to the pixel with North 0 degree, East 90, South 180, and West 270 degree: the observer stays on the pixel and looks to the sun or satellite.

The azimuth difference is then:

azi_diff = absolute(view_azimuth-sun_azimuth)

if (azi_diff > 180) azi_diff = azi_diff-180

with respect to the definition of the simulated data:

azi_diff = 180-azi_diff

The viewing and sun angles are transformed into Cartesian coordinates:

view_x = -sin(view_zenith)*cos(azi_diff)

view_y = sin(view_zenith)*sin(azi_diff)

view_z = cos(view_zenith)

6 Out of range / scope computation (8), (9), (14)

The scope of the atmospheric correction network is determined by the training data set. Thus, it its checked whether a measured spectrum (RL_tosa) is within this scope.

First the input values are checked against the minimum/maximum values of each input of the networks. If any value is outside the range, the out_of_range flag will be raised. Since all three networks are based on the same training data set, this test has to be performed only for one NN (i.e. the autoNN, (8)).

The minimum and maximum input values are included in and can be retrieved from the NN.

In a second step the type (form) of the RL_tosa spectrum is tested by using an auto-associative neural network. This NN tests if the input NN can be reproduced with an aaNN. The difference between the input RL_tosa and the output RL_tosa' can be used as an *out of scope index* and/or used to raise a flag if the index is above a certain threshold. The aaNN is trained with the same training data set. Output neurons are the RL_tosa' values. The central hidden layer of this NN is used as bottle neck layer, i.e. the number of neurons is kept to a small number, which is just sufficient to produce correct RL_tosa'.

out_of_range_flag = if for any i_band (RL_tosa(i_band) > RL_tosa_max(i_band) OR
RL_tosa(i_band) < RL_tosa_min(i_band))

out_of_scope_index= sqrt(sum((RL_tosa'(i_band)-RL_tosa(i_band)/RL_tosa(i_band))**2))/n_band

out_of_scope_flag = if(out_of_scope_index > out_of_scope_threshold)

Input to this NN are:

sun_zenith angle (degree)

view_x

view_y

view_z

water temperature

water salinity

wind

RL_tosa (15 bands)

Output of this NN are:

RL_tosa' (15 bands)

7 Computation of aerosol optical properties (10), (11)

The aerosol optical thickness, tau_aerosol, is computed for 4 wavelengths (443, 550, 778, 865 nm, OLCI bands 3, 16, 17) using the aerosolNN (11). The angstrom coefficient is computed from tau_aerosol_443 and tau_aerosol_865:

angstrom= log(tau_aerosol_443/tau_aerosol_865)/log(865/443)

Input to this NN are:

sun_zenith angle (degree)

view_x

view_y

view_z

water temperature

water salinity

wind

RL_tosa (15 bands)

Output of this NN are:

tau_aerosol_443

tau_aerosol_550

tau_aerosol_778

tau_aerosol_865

8 Computation of Water leaving radiance reflectance and path radiance reflectance (12), (13)

The bi-directional water leaving radiance reflectances (RL_w) and path radiance reflectances (RL_path) are direct output of the acNN (12). RL_path includes the specularly reflected sun and sky light (fresnel reflection) and, thus, the sun glint. Furthermore, wind dependent white caps are included in the simulation. The output RL_w together with the 3 angles is used in the waterNN.

Input to this NN are:

sun_zenith angle (degree)

view_x

view_y

view_z

water temperature

water salinity

wind

RL_tosa (15 bands)

Output of this NN are:

RL_w (15 bands)

RL_path (15 bands)

9 Output variables

In total the atmospheric correction procedure provides the following variables as output:

- Top of atmosphere radiance reflectances: RL_toa (15 bands)
- Top of standard atmosphere radiance reflectances: RL_tosa (15 bands)
- Path radiance reflectances: RL_path (15bands)
- Water leaving radiance reflectances: RL_w (15 bands)
- Tau_aerosol_443
- Tau_aerosol_550
- Tau_aerosol_778
- Tau_aerosol_865
- angstrom coefficient
- out_of_range_flag
- out_of_scope_index
- out_of_scope_flag

10 Interface to further processing

The water leaving radiance reflectances (RL_w) together with the three angles (sun_zenith, view_zenith, azimuth_difference) are input to the waterNN.

11 Validation

The atmospheric correction procedure has been qualified and validated for MERIS within the framework of two ESA contracts (C2R and glint correction). A detailed validation report and a summary report of the glint project are attached as Annexes.