Aerosol retrieval algorithm for MERIS

European Geosciences Union General Assembly 2017
Vienna | Austria | 23–28 April 2017

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Introduction

The Aerosol_cci project aims to provide aerosol climate data records consisting of aerosol data sets retrieved from various European satellites. Within the project also an aerosol retrieval for MERIS was developed.

The Medium Resolution Imaging Spectrometer (MERIS) has been launched in 2002 onboard the ESA Envisat satellite and was providing data until Envisat's end in 2012. The MERIS spectrometer was designed primarily for surface and land scientific applications and measured reflected solar radiation in 15 channels from 400-900nm. An aerosol retrieval for MERIS was developed as part of the ESA Aerosol_cci project, where the basic scheme follows the algorithm by NASA (Sayer, 2012 and Hsu, 2012) for SeaWiFS.

In the following the main concept and key issues for the aerosol retrieval scheme for MERIS are highlighted.

Radiative Transfer

The Look-Up-Tables (LUT) are calculated using the radiative transfer code LibRadtran. The implementation within the creation of the MERIS-LUT is uvspecs default DISORT, in order to solve the radiative transfer equation.

- Plane parallel
- Mid-latitude standard atmosphere
- Fix NO2, O3 content
- 36 aerosol mixtures with varying AOD loading
- 6 different Albedi
- Varying viewing geometry

Mayer, B. & Kylling, A.
Technical note: The libRadtran software package for radiative transfer calculations - description and examples of use
*Atmospheric Chemistry and Physics, **2005**, 5, 1855-1877*

Aerosol model

The aerosol model on which the forward calculations are based, consists of 36 external mixtures of 4 aerosol components. The microphysical properties for these components are shown in the table below. The 36 mixtures should reflect a realistic range of aerosol compositions, from weak to strong absorbing,fine to coarse particles, as well as varying salt or dust fractions.

aerosol component	refractive index real part @550nm	refractive index imaginary part @550nm	effective radius [µm]	mode radius [µm]	comments	aerosol layer height
dust	1.56	0.0018	1.94	0.788	non-spherical	2-4 km
sea salt	1.4	0.	1.94	0.788		0-1 km
fine mode weak-absorbing	1.4	0.003	0.14	0.07	SSA=0.98 @550nm	0-2 km
fine-mode strong-absorbing	1.5	0.040	0.14	0.07	SSA=0.802 @550nm	0-2 km

Table 1: definitions for aerosol model

Cloud mask

Consists of 4 cloud-tests:

- convex-test on first 5 channels (412.5, 442.5, 490, 510 and 560 nm for thick clouds
- spatial coherences test at 412.5nm, sensitive to very small convective clouds
- derivative test between 620 and 560 nm, sensitive to thin clouds at the edge of big cloud bands
- R21 test (Klueser, 2015 and Kriebel, 2003) on channels at 412.5, 620 and 900 nm, to flag clouds, especially over very bright surfaces such as deserts

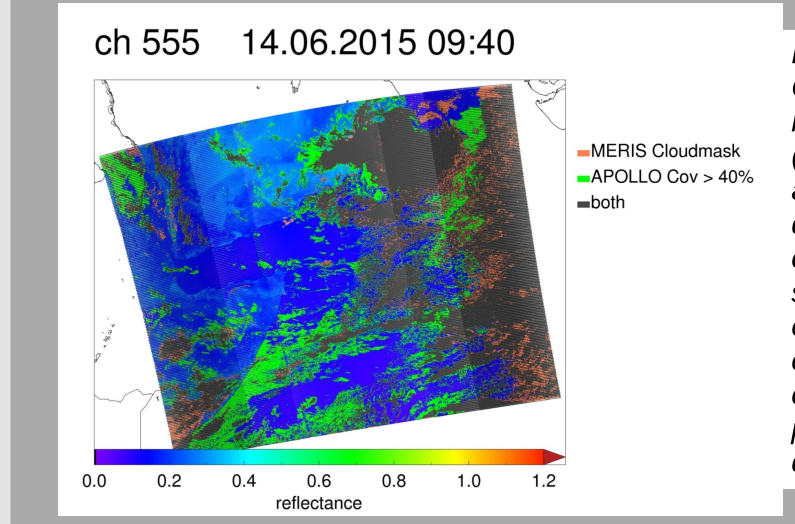

Fig.2: Comparisons between APOLLO (applied to VIIRS) and the newly developed MERIS cloud mask showed that especially thin clouds such as cirrus stay a problem in the detection

Klueser, L.; Killius, N. & Gesell, G.
APOLLO_NG; a probabilistic interpretation of the APOLLO legacy for AVHRR heritage channels
Atmospheric Measurement Techniques, 2015, 8, 4155-4170

Algorithm concept

The aerosol properties retrieved are the aerosol optical depth (AOD) at the wavelength 550nm; in best case also information on the aerosol type can be inverted, but its accuracy is dependent on the degrees of freedom within the measurement. Reflectance spectra at TOA computed by the forward radiative transfer model LibRadtran are fitted with Levenberg-Marquardt to the MERIS reflectance measurements. The cost-function over all 36 predefined aerosol models defines a probability density function to retrieve the most plausible AOD.

The retrieval is done on a 10x10 superpixel mode to provide appropriate run time. Cloudy pixels are rejected within the algorithm. Information content analysis suggested to use the channels 1,2,3,5,7 for the retrieval.

Current status is a land retrieval code only, but will be extended in the next versions to ocean too.

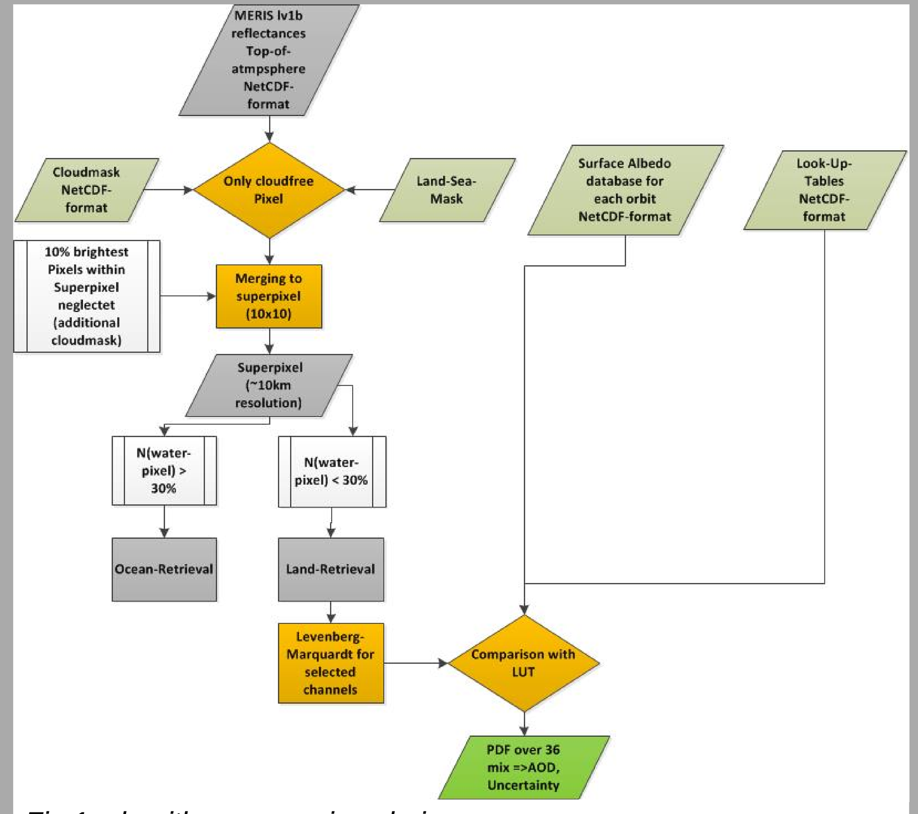

Fig.1: algorithm processing chain

BRDF effects

As the surface database includes Lambertian albedo only, a BRDF correction is added within the retrieval scheme. Two different surface types are included: Savannah for bright surface and coniferus forest for dark surface.
Based on the BRDF definition (Rahman, 1993) an indicatrix corrects the given surface albedo for selected pixel and viewing geometry.

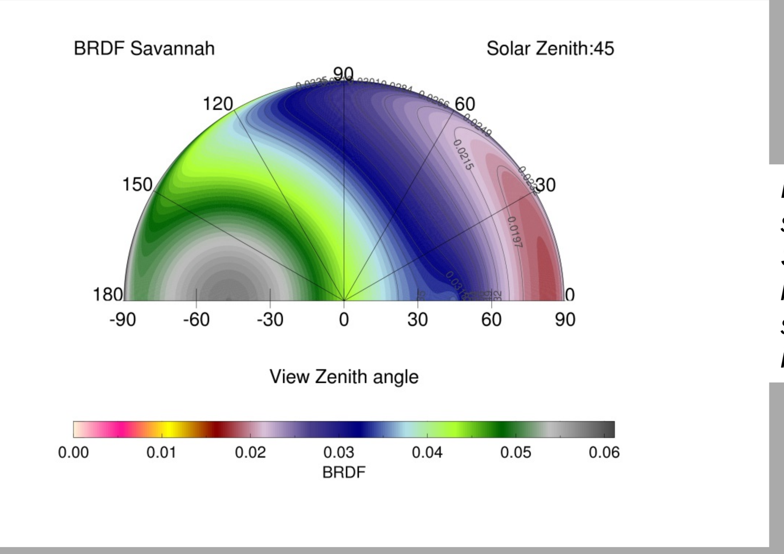

Fig.4: BRDF for surface type Savannah as basis for bright surface indicatrix

Rahman, H.; Pinty, B. & Verstraete, M. M.
Coupled surface-atmosphere reflectance (CSAR) model: 2. Semiempirical surface model usable with NOAA advanced very high resolution radiometer data, Journal of Geophysical Research: Atmospheres, 1993, 98, 20791-20801

Information content

In order to choose the most suitable channels for the retrieval a degree of freedom analysis (Rodgers, 2000) based on the forward calculation was applied.

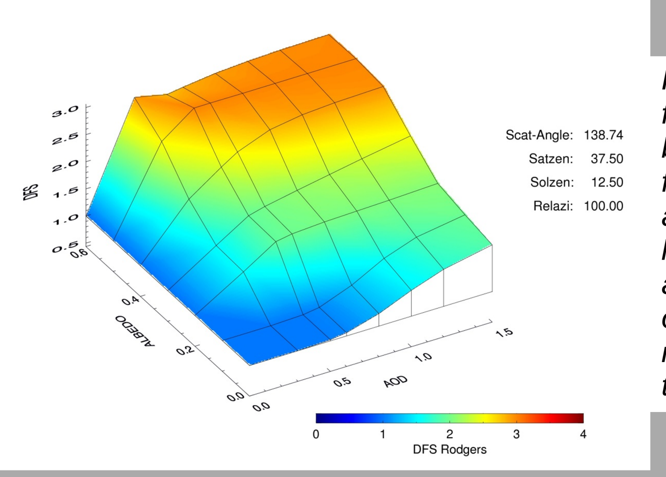

Fig.5: Degrees of freedom (DFS) based on Rodgers for varying surface albedo and aerosol loading. The assumed error on op-of-atmosphere reflectance was set to 0.001

Clive D. Rodgers, Inverse Methods for atmospheric sounding, Series om Atmospheric, Oceanic and Planetary Physics, vol2, 2000

Surface database

- level1 orbits are projected to a regular grid with a resolution of 0.05 degree
- Excludes cloud screened pixels
- 16 day window around each day of the year is selected for each land gridbox
- minimum reflectance within this time window
- Lambertian Equivalent Reflectance (LER) applied to aerosol-free LUT and retrieve then the corresponding surface albedo for the selected grid box

Herman, J. R.
Earth surface reflectivity climatology at 340-380 nm from TOMS data
Journal of geophysical research, 1997, 102, 28,003-28,011
Hsu, N. C.; Tsay, S.-C. & King, M. D.
Aerosol Properties Over Bright-Reflecting Source Regions
Transactions on Geoscience and Remote Sensing, 2004, 42, 557-569

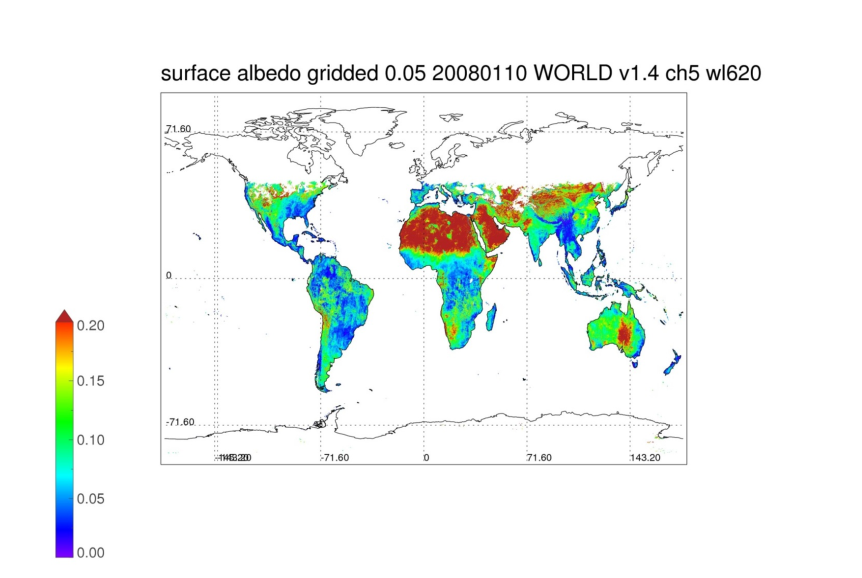

Fig.3 map of surface albedo from database for selcted day on red channel at 620nm, gridded on 0.05°

Summary

Within the Aerosol_cci project aerosol optical depth at 550nm is retrieved from MERIS measurements in 2008. The lv2 and lv3 products are available at ICARE (http://www.icare.univ-lille1.fr/archive/?dir=CCI-Aerosols). After successful testing the algorithm could be also applied to OLCI data in the near future.

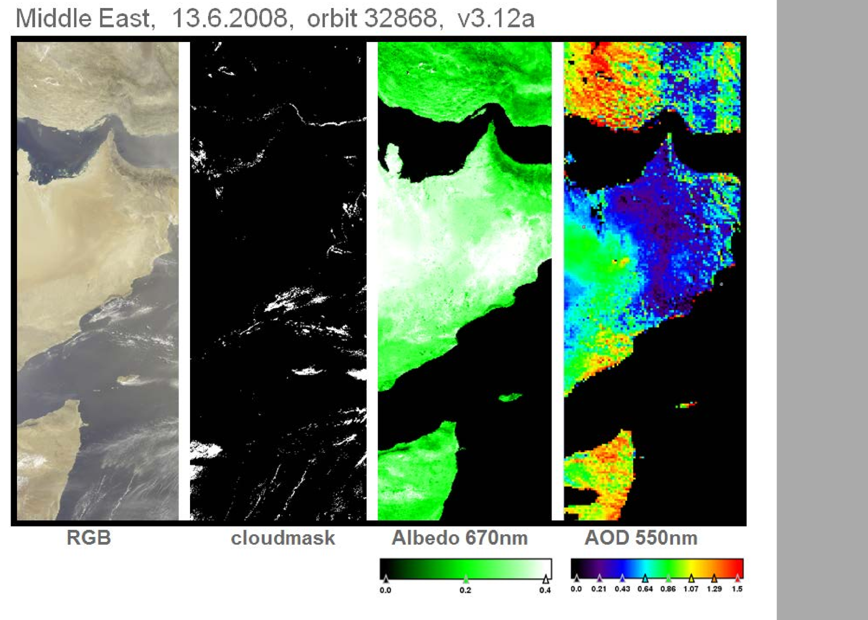

Fig.6 selected case study of aerosol optical depth retrieved from SeaWiFS4MERIS for 13.6.2008

acknowledgement : This work was supported by the European Space Agency as part of the Aerosol_cci project

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climate change initiative European Space Agency

Ref.:
Sayer, A.; Hsu, C.; Bettenhausen, C.; Jeong, M.-J.; Holben, B. & Zhang, J.
Global and regional evaluation of over-land spectral aerosol optical depth retrievals from SeaWiFS, Atmospheric Measurement Techniques, 2012, 5, 1761-1778
Hsu, C.; Gautam, R.; Sayer, A.; Bettenhausen, C.; Li, C.; Jeong, M.-J.; Tsay, S.-C. & Holben, B.
Global and regional trends of aerosol optical depth over land and ocean using SeaWiFS measurements from 1997-2010, Atmospheric Chemistry and Physics, 2012, 12, 8037-8053