Effect of the aerosol type uncertainty on the surface reflectance retrieval using CHRIS/PROBA hyperspectral images over land.

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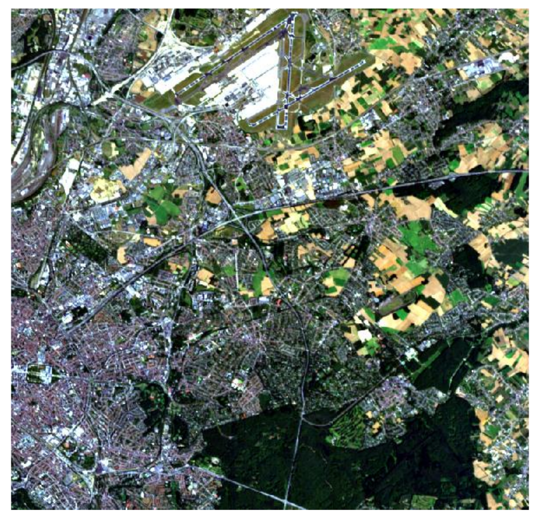
The surface reflectance is crucial for the quantitative analysis of land surface properties in geological, agricultural and urban studies. The first requirement for a reliable surface reflectance estimation is an accurate atmospheric correction obtained by an appropriate selection of aerosol loading and type. The aerosol optical thickness at 550nm is widely used to describe the aerosol loading. Recent works have highlighted the relevant role of the aerosol types on the atmospheric correction process defined by their micro-physical properties. The aim of this work is to evaluate the radiative impact of the aerosol type on the surface reflectance obtained from CHRIS (Compact High Resolution Imaging Spectrometer) hyperspectral data over land. CHRIS on PROBA satellite is an high resolution multi-angular imaging spectrometer, operating in the visible near-infrared spectral domain (400 to 1000 nm). As test case the urban site of Brussels has been selected. The physically-based algorithm CHRIS@CRI (CHRIS Atmospherically Corrected Reflectance Imagery) has been developed specifically for CHRIS data by using the vector version of 6S (6SV) radiative transfer model. The atmospheric data needed for the atmospheric correction were obtained from CIMEL CE-318 of the Brussels AERONET station. CHRIS images were selected if simultaneous AERONET data were available. Other specific requirements for imagery acquisition were high aerosol loading and high solar irradiation. The aerosol radiative impact has been investigated comparing the reflectance obtained by applying the CHRIS@CRI algorithm with different aerosol types: the three aerosol standard of 6SV and two characterized by specific microphysical properties provided by the AERONET station and calculated with FlexAOD code (a post-processing tool of the chemical transport model GEOS-Chem), respectively. The results show a clear dependence of the atmospheric correction results on the aerosol absorption properties.

URBAN SITE - BRUXELLES



CHRIS image

Target name: Wohrwe (Bruxelles)
Lat:50.84° N
Lon:4.46° E
Fly-by zenith angle: 0°

AERONET site – CIMEL CE-318

Bruxelles
Lat: 50.78° N
Lon: 4.35000° E
Elevation: 120.0 m

CHRIS (hh.mm) GMT	CIMEL (hh.mm) GMT	Solar zenith angle (degrees)	AOT @ 550 nm	Water Vapor (wv) gm^{-2}	Ozone (o3) gm^{-2}	AOT @ 550 nm FlexAOD
9.51	9.48 (Level 1.5)-8.48 (Level 2.0)	45	0.122	2.598	0.314	0.113

DATA

CHRIS

CHRIS (Compact High Resolution Imaging Spectrometer) on PROBA is an hyperspectral multiangular imaging spectrometer, It provides data from five observation angles during the same overpass.

Technical characteristics	
Spatial resolution (SR)	18 o 36 m
Number of spectral bands	19 canali (SR 18 m) 63 canali (SR 36 m)
Swath width	14 km
Spectral range	415-1050 nm
Image area	14 km X 14 km (748 X 748 pixels)

All CHRIS images in this work are acquired in Mode 3 (full swath, full resolution)

AERONET

The automatic tracking sunphotometer CIMEL measures the direct spectral solar irradiance and sky radiance for solar almucantar or principal plane scenario at six normal bands (440, 500, 670, 870, 940, and 1020 nm). It provides:

- the **aerosol optical depth** at the six nominal bands.
- the columnar content of **water vapor** (wv) and **ozone** (o3) from the direct component of the solar irradiance.
- the aerosol micro-physical and optical properties (aerosol **complex refractive index**, single **scattering albedo** and the scattering phase function as inversions products.

In the atmospheric correction algorithm :

- The AOD value at 550nm describes the aerosol loading
- The columnar content of water vapor (wv) and ozone (o3) define the atmospheric conditions.

MODELS

6SV: The Second Simulation of a Satellite Signal in the Solar Spectrum *Vector* radiative transfer code (Vermote et al, 2006), an improved version of the open-source code 6S (Vermote et al, 1997b).

FlexAOD: a post-processing tool for the calculation of the aerosol optical properties from the output of the chemical transport model GEOS-Chem. GEOS–Chem is a global 3-D model of atmospheric composition driven by assimilated meteorological fields.

ATMOSPHERIC CORRECTION ALGORITHM – CHRIS@CRI

The physically-based atmospheric correction algorithm CHRIS@CRI is based on the the vector version of the Second Simulation of a Satellite Signal in the Solar Spectrum (6SV) radiative transfer code. The algorithm for the atmospheric correction of CHRIS-PROBA images was implemented following the method reported in Bassani et al. (2010). For each CHRIS channel, the equation solved for the surface reflectance r_g (Bassani et al., 2010), is the following:

$$\rho_g = \frac{t_g \rho_{atm} - \rho_{TOA}}{S(t_g \rho_{atm} - \rho_{TOA}) - t_s t_g}$$

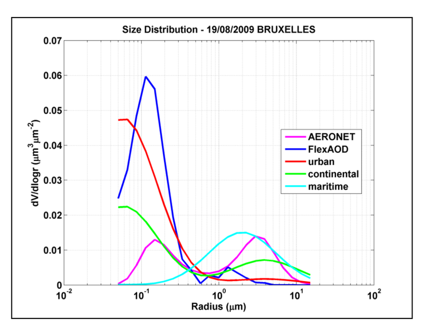
ρ_{TOA} = at sensor reflectance
ρ_{atm} = atmospheric reflectance
ts,tg= total and gas transmittance
S = surface albedo

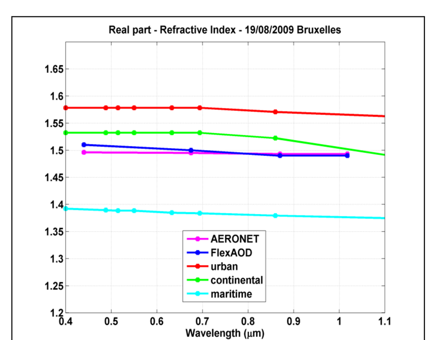
The surface reflectance is finally calculated applying the empirical formula used in atmospheric correction algorithms (Bassani et al., 2010; Guanter et al.,2007 & 2009a, Kotchenova et al., 2008; Vermote et al., 1997):

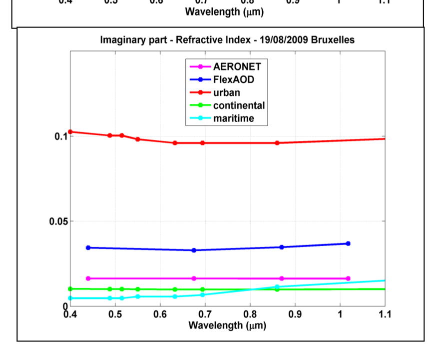
$$\rho(l) = \rho_{g+} \frac{t^u_{dif}}{e^{-\frac{\tau(l)}{\mu_v}}} [\rho_g - <\rho_g>]$$

t^u_{dif} = upward diffuse trasmittance
μ_v = zenith angle cosine
$\tau(\lambda)$= total optical depth

MICROPHYSICAL AND OPTICAL AEROSOL PROPERTIES







The CHRIS@CRI algorithm was instructed with 5 different aerosol types:

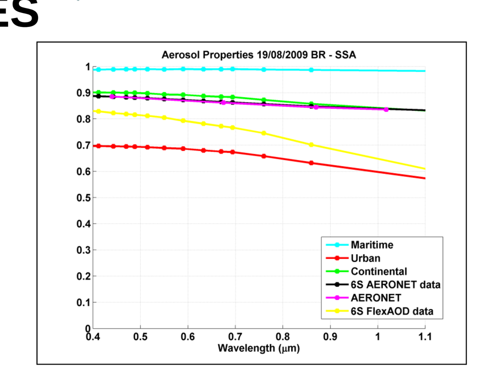
- AERONET data
- three 6SV standard aerosol (continental C, urban U e maritime M)
- FlexAOD (F) code data.

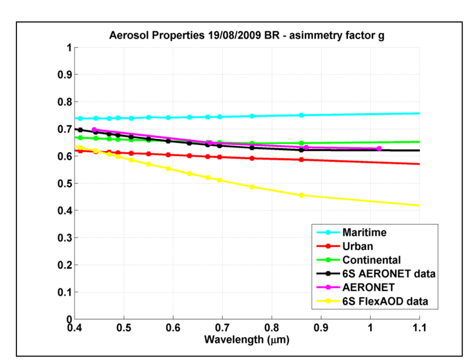
The micro-physical and optical aerosol properties are compared for all aerosol types.

6SV

Two aerosol optical properties were selected to compare the results obtained for different aerosol types:

- the single scattering albedo (SSA),
- the asymmetry parameter (g).



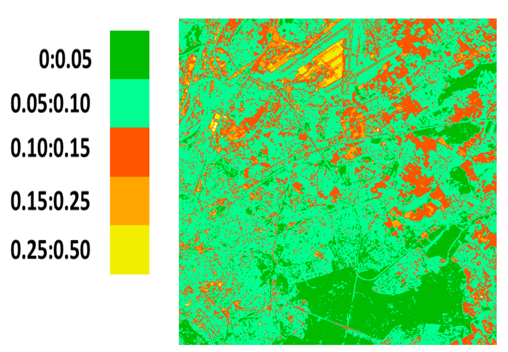


Comments:

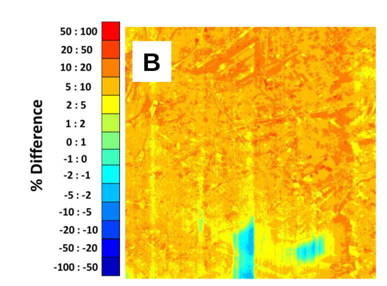
- The AERONET size distribution is bimodal and similar to a continental type. The FlexAOD and urban type show only the fine mode.
- The refractive index is similar for AERONET FlexAOD and continental.
- The SSA and g resulting from continental type are those in better agreement with AERONET.
- FlexAOD is the most similar to AERONET among the other models.

REFLECTANCE- Atmospheric algorithm product

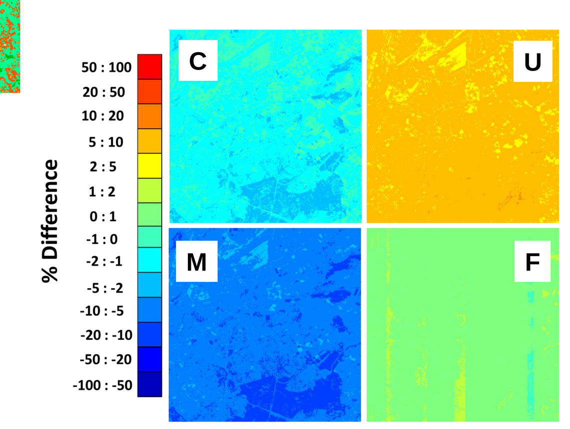
REFLECTANCE (AERONET) 550 nm



CHRIS@ CRI



PERCENTAGE DIFFERENCE 550 nm



BEAM comparison

The reflectance values obtained using the reference tool BEAM for the CHRIS image is compared to that obtained by applying the CHRIS@CRI algorithm using AERONET data for aerosol loading and aerosol properties.

The analysis of the percentage difference at 550nm shows a mean value of 8.7% with a standard deviation of 4.5% The percentage difference value varies from -10% to 10% for the other instrumental bands.

$$\frac{\rho\ AERONET - \rho\ BEAM}{\rho\ BEAM} x100$$

Different aerosol types comparison

The aerosol radiative impact has been quantitatively investigated comparing the reflectance obtained by applying the CHRIS@CRI algorithm with the five different aerosol types :

- the aerosol type defined by AERONET data is used as reference.
- the aerosol loading is described by AOD @ 550nm from AERONET data for all cases except that of FlexAOD. In this case it was used that from FlexAOD code

The analysis of the percentage difference value of reflectance obtained for different aerosol types show that the best agreement is achieved with continental and FlexAOD aerosol types

$$\frac{\rho\ (C,U,M,F) - \rho\ AERONET}{\rho\ AERONET} x100$$

CONCLUSIONS

- An atmospheric correction algorithm was applied to one scene from CHRIS-PROBA hyperspectral satellite instrument over Bruxelles on 19 August 2009.
- The surface reflectance calculated with the correction algorithm CHRIS@CRI (Bassani et al.,2010) is within10% of that calculated with the standard tool BEAM (**http://www.brockmann-consult.de/beam/doc/help/index.html**)
- The CHRIS@CRI algorithm was instructed with several alternative aerosol models: one using AERONET retrieval of size distribution and complex refractive index, three 6SV standard aerosol types (continental, urban, maritime), and one derived from comprehensive chemistry transport model (FlexAOD).
- The AERONET derived reflectance is chosen as reference .
- The AERONET size distribution is bimodal and similar to a continental type. The FlexAOD and urban type show only the fine mode. The refractive index is similar for AERONET FlexAOD and continental.
- The single scattering albedo and the asimmetry parameter resulting from continental type are those in better agreement with AERONET. Among the other models FlexAOD is the most similar to AERONET.
- The surface reflectance derived from continental type and FlexAOD are those in better agreement with the reflectance derived from AERONET model.

FUTURE WORK

- Evaluation of more case studies in order to understand the effect of different particular aerosol conditions (varying refractive index, size distribution and aerosol loading values) on the atmospheric correction algorithm (i.e on surface reflectance).
- Validation of FlexAOD fields with EUCARII campaign data

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