



Surface albedo and toc-r 300 m products from PROBA-V instrument in the framework of Copernicus Global Land Service

Jean-Louis Roujean^{a,*}, Jonathan Leon-Tavares^b, Bruno Smets^b, Patrick Claes^b,
Fernando Camacho De Coca^c, Jorge Sanchez-Zapero^c

^a UMR3589-CNRM, CNRS/METEO-FRANCE, 42 avenue Coriolis, 31057 Toulouse, France

^b VITO, Boeretang 200, 2400 Mol, Belgium

^c EOLAB, Valencia, Spain

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ABSTRACT

PROBA-V instrument launched in 2013 is offering a global daily coverage at pixel resolutions of 333 m and 1 km in three spectral bands (BLUE, RED, NIR) and 600 m for shortwave infrared (SWIR). The PROBA-V mission is the follow-on of the VEGETATION program started in 2000, which allowed generating long-term series at 1 km pixel resolution. The PROBA-V products belong to the Copernicus Global Land Service portfolio (<http://land.copernicus.eu/global/>). The sensor design of PROBA-V with oriented cameras offers a wide field of view (FOV) for sampling the BRDF (Bidirectional Reflectance Distribution Function). This paper details the methodology implemented at the premises of VITO (Flemish Institute for Technological Research) with the aim to disseminate routinely from PROBA-V daily observations for both surface albedo (SA) and top-of-canopy corrected reflectance (TOC-R) products. The method classically operates a selection of cloudless scenes, performs atmospheric corrections, and finally applies a correction of directional effects on a pixel per pixel basis. The synthesis period is the decade and the composite period is 20 days. Such choice is a pointwise sampling as being a trade-off between the availability of clear scenes and the timescale for phenology. Regarding the albedo catalogue, a narrow-band to broadband conversion is stipulated. A recurrent technique serves for gap-filling based on the spread of weighed a priori data. Additional information concerns the quality flag and the age of the product. Preliminary accuracy assessment is performed through a comparison with the Moderate Imaging Spectroradiometer (MODIS) Collection 6. Dependable spatial consistency is reached except for wintertime with deviations in terms of rmse (root mean square errors) about 0.03 for visible and shortwave domains, and 0.04 for near infrared. Besides, both PROBA-V and MODIS C6 exhibit close time profiles, marked by smoothness or rapid transitions. Results over 10 confidence sites reveals rmse values of 0.032 and bias of 0.01 over the 2014 full annual cycle.

1. Introduction

Land surface albedo is the cornerstone for characterizing the energy balance in the coupled surface-atmosphere system and also constitutes an indispensable input quantity for soil-vegetation-atmosphere transfer models. It yields an Essential Climate Variable (ECV) as established by the Global Climate Observing System (GCOS) (GCOS, 2016) with given guidelines for its long-term validation (<http://www.qa4ecv.eu/ecv/albedo>). Knowing the surface albedo, the net radiation at the surface can be estimated and besides the whole energy budget. Heretofore, three spectral broadband ranges, namely the solar spectrum (400–3000 nm), the visible (400–700 nm) and the near- and shortwave-infrared (700–3000 nm), were deemed the relevant quantities. Actually,

any change in the short-wave (solar) albedo can be tenuous because of the counter-balancing between broadband visible and near infrared surface albedo. This fully justifies the dissemination of the three broadband albedo products although one could be derived from the two others. Noteworthy, the spectral range for visible broadband is matching with PAR (Photosynthetically Active Radiation) range to depict the carbon budget. As vegetation absorbs most of the PAR radiation, therefore PAR albedo is particularly sensitive to greenness. On the other hand, near-infrared albedo is high for leafy vegetation and low for woody material comparatively to visible albedo.

Actually, there exists variant definition of albedo products according to the domain of directional integration (Schaeppman-Strub et al., 2006). It notably places a regard to the fraction of direct versus

* Corresponding author at: UMR-5126, CESBIO, 18 avenue E. Belin, bpi 2801, 31401 Toulouse, France.
E-mail address: jean-louis.roujean@cesbio.cnes.fr (J.-L. Roujean).

diffuse solar radiation. The salient albedo products are the Directional-Hemispherical Reflectance (DHR) – also called Black Sky Albedo (BSA) – and the Bi-Hemispherical Reflectance (BHR) – also called White Sky Albedo (WSA). Their combination relative to the ratio of sky irradiance leads to the so-called Blue Sky Albedo. Actually, the Blue-Sky Albedo is the true albedo to be measured in situ.

The resolution of 333 m offered by PROBA-V sensor will prompt new applications in domains encompassing agriculture, forestry, land use, land cover, hydrology and weather forecasts areas. The point-wise spatial-temporal resolutions of PROBA-V is also prone to leverage geo-engineering activities in order to dampen the effects of a changing climate. The Copernicus Global Land Service (CGLS) operates “a multi-purpose service component” that offers a series of bio-geophysical products on the status and evolution of land surface at global scale (<http://land.copernicus.eu/global>). Timely production and delivery of set of parameters exacerbate the constitution of long term series of satellite-based products elaborated in a coherent manner. The primary objective of CGLS is to continuously monitor the status of land territories and to supply reliable geo-information to decision makers, businesses and citizens to define environmental policies and take right actions. ImagineS (Implementing Multi-scale Agricultural Indicators Exploiting Sentinels) project from FP7 (Framework Program Seventh) was at the root of the development of cutting-edge retrieval methods of key biophysical variables, amongst which the land surface albedo. The algorithm to measure the land surface albedo from PROBA-V is a trimmed methodology previously implemented in operational for Meteosat Second Generation (MSG) (e.g. Geiger et al., 2008). The insurance of the continuity with past product from SPOT/VEGETATION at 1 km is enacted by the follow-on dissemination of 1 km PROBA-V product, owing to CGLS. The algorithm has been fine-tuned with time for the purpose of an enhanced efficient computation and service requirements.

The paper first reviews the background theory about the kernel-driven BRDF (Bidirectional Reflectance Distribution Function) approach. The BRDF model parameters serve to estimate both spectral albedos and TOC-R. A narrow- to broadband conversion is then performed. If most satellite projects adopted the kernel-based approach, a variant was operated for MISR (Multi-angle Imaging Spectro-Radiometer), further assessed in terms of noise (Lucht and Lewis, 2000), then of added-value for MODIS (Jin et al., 2002) and also in virtue of its potential to map snow albedo (Stroeve and Nolin, 2002). Whilst a surface albedo product is useful for surface energy balance and radiation forcing at surface level, TOC reflectance normalized to geometry of reference is more inclined to serve for the monitoring of the surface resources and the derivation of vegetation indices. Section 2 presents the instrument, the calibration accuracy, the levels of data processing and quality. Section 3 tells about the methodology implemented. Section 4 details the tools and criteria for products evaluation. Section 5 provides a preliminary assessment of the products quality. Section 6 concludes the study and stresses future prospects.

2. Characteristics of PROBA-V instrument

2.1. Principle of measurement

PROBA-V payload named VGT was launched in 2013 for 7 years and is fully comparable to the previously VEGETATION sensor embarked on SPOT (Satellite Probatoire d'Observation de la Terre). It is a multi-spectral push-broom spectrometer. The payload consists of three identical cameras, equipped with a very compact Three Mirror Anastigmat (TMA) telescope. Each TMA has a FOV of 34° with four spectral bands. The limit of view zenith angle is 75° (e.g. http://proba-v.vgt.vito.be/sites/proba-v.vgt.vito.be/files/Product_User_Manual.pdf). Three spectral bands belong to the visible range (460 nm for Blue, 658 nm for Red and 834 nm for NIR) plus a SWIR band (1610 nm). VGT is restricted to imaging land and dedicated calibration zones. Each camera owes its own land sea mask that allows removing the sea pixels. About 14 near

polar orbits per day are registered. PROBA-V flies at 820 km altitude. The swath width of 2250 km ensures a daily coverage of land masses above 35° latitude with however a limitation to 75° North and 56° South. About 90% daily coverage is obtained in the equatorial zones. The Ground Sampling Distance is 100 m (VNIR) and 200 m (SWIR) at nadir and 360 m (VNIR) and 690 m (SWIR) at the edge of the swath.

2.2. Data preprocessing and performances

The images are projected in the grid plate carrée for Level 1-b and the geodetic datum is WGS84. The pixel co-ordinates are given for the center of the pixel. For details on the radiometric performances of PROBA-V, we will refer the reader to the dedicated link (<https://earth.esa.int/web/sppa/mission-performance/esa-3rd-party-missions/proba-v/products-and-algorithms/products-information>). To be outlined here that the PROBA-V S1 Top of Canopy (TOC) reflectance values are synthesis of the pixels from the three cameras having harmonized spectral responses functions. Daily PROBA-V composites (S1) of TOC reflectance, at a spatial resolution of 333 m, are the primary sensor data serving as input for both TOC-R and surface albedo algorithms. Note that official references to PROBA-V products indicate 300 m although the true resolution is 333 m. In case of multiple observations per day, the maximum of Normalized Difference Vegetation Index (NDVI) enacts a criterion of selection. The current PROBA-V cloud detection method (implemented in collection 1, C1) identifies the presence of clouds based on land cover class, climatology background surface reflectance per pixel and a set of decision rules (Sterckx et al. (2014), Dierckx et al., 2014, Wolters et al., 2017). The cloud mask is majorly inherited from VEGETATION. The Digital Elevation Model is from GTOPO30 (U.S. Geological Survey). The columnar water vapor and ozone contents, also the atmospheric pressure, are input fields issued from the numerical weather prediction model of the European Centre for Medium-Range Weather Forecasts (ECMWF). The ground segment of PROBA-V applies an atmospheric correction on a pixel-per-pixel basis for cloud-free pixels. The atmospheric correction is performed using the SMAC (Simplified Method for Atmospheric Correction) software (Rahman and Dedieu, 1994). SMAC considers linear parameterizations for the absorption and scattering components of molecules and aerosols based on the physics of the 6S code. These relationships include tunable coefficients depending on aerosol type and PROBA-V channels. However, a continental type is taken everywhere whereas the aerosol optical depth (AOD) at the wavelength of 550 nm is prescribed as a function of latitude. The S1 TOC PROBA-V reflectance is distributed with the Status Map (SM), which tells about the quality of the product (radiometry quality, cloud mask, etc.) (see Table 1). A land sea mask (LSM) is used to delineate the coastline. Note that for time being, the inner water bodies are not masked by the application of LSM.

3. Methodology description

3.1. Algorithm overview

The operational processing scheme of the land surface albedo and TOC-R algorithm is depicted in the flow chart of Fig. 1. It encompasses three successive steps: the spectral TOC reflectance values serve as the input quantities for the inversion of a linear kernel-driven BRDF model, which allows taking into account the angular dependence of the reflectance factor. A well-established approach for an operational computation of the surface albedo is based on semi-empirical BRDF kernel model. Such category of models has received a great deal of attention and effort from the optical remote sensing community in the last decades (Roujean et al., 1992; Barnsley et al., 1994; Wanner et al., 1995; Strahler, 1994; Hu et al., 1997). The approach is based on a decomposition of the bi-directional reflectance factor into a number of kernel functions which are associated to the dominant light scattering processes, e.g. geometric and volumetric effects, a separation between the

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