Template product information package

Product	**Albedo**
Participant ID	**MEDIAS-France**

1. General Information

It corresponds to the amount of solar energy reflected by a surface and provides information on the radiative balance, thus on temperature and water balance. The required quantity for these models is the spectrally integrated albedo over 300-3000 nm spectral domain also called broadband albedo:

$$a=\frac{\int_{300nm}^{3000nm} E(\lambda).a(\lambda).d\lambda}{\int_{300nm}^{3000nm} E(\lambda).d\lambda}$$

where $a(\lambda)$ is the spectral albedo and $E(\lambda)$ is the spectral down flux. The spectral albedo corresponds to hemispherical reflectance of the canopy, i.e. the bidirectional reflectance integrated over the hemisphere with regards of the view directions:

$$a(\lambda)=\frac{1}{\pi}\int_0^{2\pi}\int_0^{\pi/2}\rho_\lambda(\theta_s,\theta_v,\phi).\cos\theta_v.\sin\theta_v.d\theta_v.d\phi$$

where $\rho_\lambda(\theta_s,\theta_v,\phi)$ is the spectral bidirectional reflectance and θ_s, θ_v, and ϕ are respectively the view zenith, sun zenith and relative azimuth angles. The albedo depends obviously on the irradiance conditions, i.e. the directional distribution of the incoming radiation that varies constantly throughout the day. Models that use albedo are running either at the daily time step, or at finer time steps. Therefore, the pertinent product definition should be consistent with the temporal resolution of the models used in the applications targeted.

A simple approach consists in estimating two sorts of albedo: the directional-hemispherical albedo corresponding only to the direct radiation coming from the sun, and a bihemispherical albedo corresponding roughly to the diffuse radiation assumed isotropic

(Strahler and Muller, 1995). The directional hemispherical albedo is computed for the local solar noon.

2. Application of the product

The albedo is one of the most interesting variable required required as a primary input for global circulation models used to forecast short term weather and long term climatic change (Dickinson 1983). It is also mandatory for local to regional estimates of energy and mass exchanges between the earth surface and the atmosphere as described by soil vegetation atmosphere transfer models (SVAT). Most GCMs are still using prescribed field of surface albedo that are often 5%-15% in error from place to place and time to time (Sato et al., 1989)

This product is currently not yet provided operationnally from the VEGETATION instrument but it already exists from another sensor (MODIS). It is also well adapted for real time processing due to possible strong temporal variations.

3. Algorithmic methodology

The employed approach for albedo calculation follows a corollary from the general strategy of directional normalisation using a kernel-based BRDF model which was adopted for the CYCLOPES project.

First, CYCLOPES algorithm removes clouds and their shadows, based upon thresholds depending on classes of a landcover map, and correct the effects of atmospheric absorption and scattering to get surface reflectances from daily VEGETATION P products. Then the linear reflectance model of Roujean et al. (1992) is inverted to normalize the surface reflectances and removes the bidirectional effects due to changes in sun and viewing angular configurations during the synthesis period. This model describes the bidirectional reflectance as a linear combination of three terms, themselves weighted by three parameters :

$$\rho(\theta_s,\theta_v,\phi) = k_0 + k_1 f_1(\theta_s,\theta_v,\phi) + k_2 f_2(\theta_s,\theta_v,\phi)$$

θs, θv, ϕ are respectively the solar zenith, view zenith and relative azimuth angles, while f1 and f2 are the geometric and volume scattering functions respectively, and ki are the weighting parameters of the fi functions.

The compositing method is improved using an a priori information (Hagolle et al., 2004): a confidence interval for the parameters of the Roujean model is used to constrain the least-squares fit. As a result, the cost function is modified as follows :

$$C=\left(\sum_{i=1}^{N}\frac{(\rho_i-\hat{\rho}_i)^2}{\sigma_i^2}\right)+\frac{(k1-C1(\lambda))^2}{\sigma_{k1}^2}+\frac{(k2-C2(\lambda))^2}{\sigma_{k2}^2}$$

where $1/\sigma_{k1}^2$ and $1/\sigma_{k2}^2$ are the weights of the constraints and $1/\sigma_i^2$ the error associated to reflectance. C1(λ) and C2(λ) have been empirically determined.

Having constrained the BRDF model, it is easier, in most cases, to detect and discard cloud contaminated pixels. The detection is done using B0 band. If the standard deviation of errors σ of the model fit is above a threshold, our algorithm discards all the observations that are greater that the adjusted model values plus σ. At this stage, many previously undetected cloudy pixels are discarded. Then a second fit and a new σ value is computed (smaller than the previous one) ; all the pixels that have a difference to the model greater than 1.5* σ are discarded whatever the sign of the difference. This last stage is iterated until no pixel is discarded anymore, or until the number of remaining pixels is lower than 3.

In the operational D10 method (Duchemin et al, 2002), pixels with a strong deviation from the model fit were also discarded but with no distinction between higher and lower values. The improvement in this new method is illustrated hereafter (figure 1). The current algorithm is applied at a 10-day frequency on surface reflectances acquired during a sliding period of 30 days to generate directional parameters for each spectral bands. Normalized reflectances are then assessed with a sun zenith angle corresponding to a solar position observed at 10h00 local time and a viewing observation at nadir.

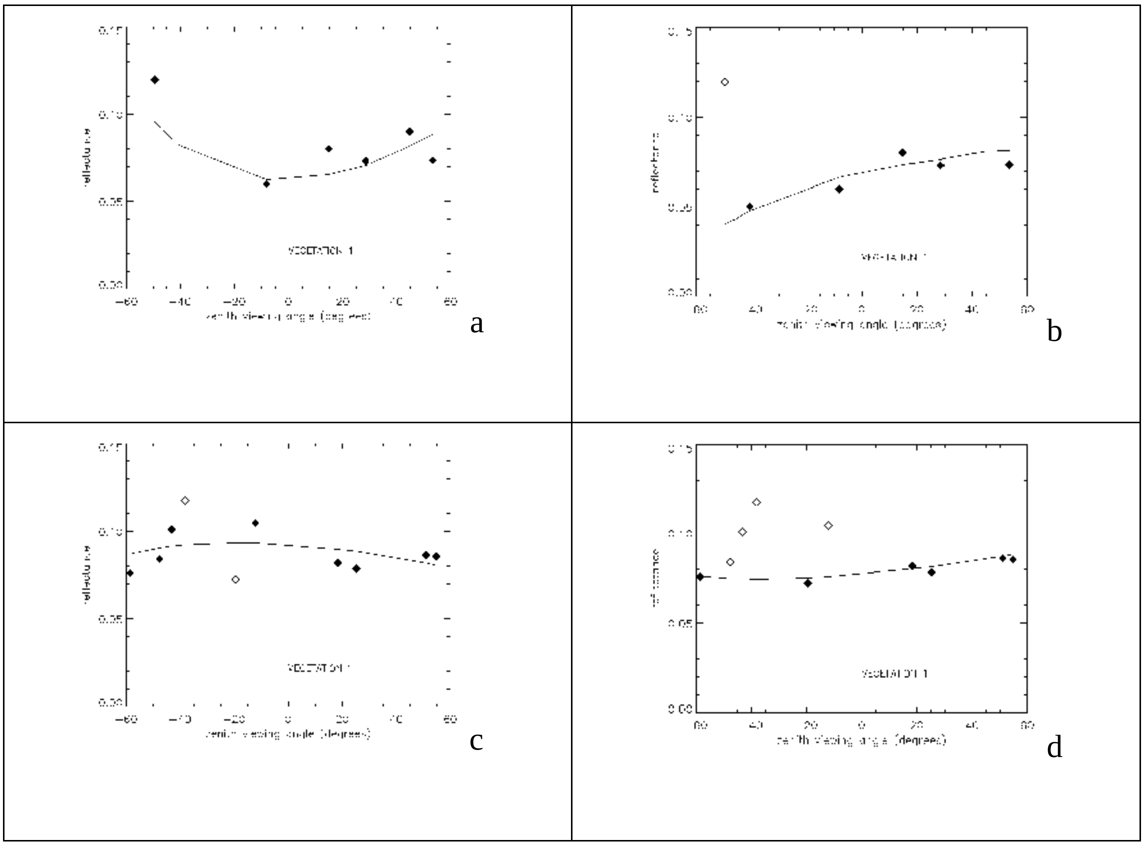

Figure 1 Left column, reflectances (triangles) and the retrieved BRDF model (solid lines) for two different pixels (Côte d'Ivoire, Dec 2002) in spectral band B2, during a test period of 15 days, using the D10 method. Right column, retrieved model using the new proposed method that uses a priori information. In all plots, unfilled symbols correspond to observations that were discarded by the iterative process described in the text.

Inserting the reflectance model in the equation gives the expression

$a_{\lambda}^{dh}(\theta_{s\_n})=k0.I_0^{dh}(\theta_{s\_n})+k1.I_1^{dh}(\theta_{s\_n})+k2.I_2^{dh}(\theta_{s\_n})$ and
$a_{\lambda}^{bh}(\theta_{s\_n})=k0.I_0^{bh}(\theta_{s\_n})+k1.I_1^{bh}(\theta_{s\_n})+k2.I_2^{bh}(\theta_{s\_n})$ where
$I_i^{dh}(\theta_{s\_n})=\frac{1}{\pi}.\int_0^{2\pi}\int_0^{\frac{\pi}{2}} f_i(\theta_s,\theta_v,\phi).\cos(\theta_v).\sin(\theta_v).d\theta_v.d\phi$ et $I_i^{bh}=2.\int_0^{\frac{\pi}{2}} I_i^{dh}.\cos(\theta_s).\sin(\theta_s).d\theta_s$ are the respective angular integrals of kernel fixed function which are preprocessed and stored in look up tables.

The broadband albedo is defined as the integral of spectral albedo over a certain wavelength interval weighted by the spectral irradiance. Since the integral can be approximated as a weighted sum of the integrand at discrete values of the integration variable, broadband albedo may be expressed as a linear combination of the spectral albedo valuex in the available spectral channels

First, Van Leeuwen and Roujean (2002) determined coefficients for the conversion from spectral or rather narrow band albedo to various broadband albedo ranges in the case of AVHRR and SEVIRI. These authors used the SAIL radiative transfer model (Verhoef, 1984) to generate an extensive data set of synthetic spectral canopy reflectances for different surface types. For vegetation, the leaf optical properties were extracted from the ASTER spectral library (Hook, 1998). After calculating the narrow band albedo values in the instrument's spectral bands and the broadband albedo values in the range of interest, they applied a linear regression analysis and determined the corresponding transformation coefficients.

Samain (2004) extended that work to VEGETATION instrument in the CYCLOPES project framework using a wider range of soil and leaf optical properties. A data set comprisin 11 representative soil and 108 vegetation types was constituted from the ASTER and USGS spectral librairies, the LOPEX'93 experiment (Hosgood et al., 1995) and the BOREAS and HAPEX-Sahel field campaigns. Simulations with the PROSPECT model (Jacquemoud and Baret, 1990) complete the dataset to represent senescent leaves.

Following this approach, the broadband albedo are derived from the spectral quantities by applying the linear transformation

$$a_{\gamma}^{xh}=c_{0\gamma}^{xh}+\sum_j c_{j\gamma}^{xh}.a_j^{xh} \qquad \text{with “x” = “d” or “b”}$$

4. Ancillary data

The current CYCLOPES version 2 uses several ancillary data mainly for the inputs in the atmospheric correction and cloud detection:

- monthly mean aerosol MODIS products. In the persective of a real time processing chain, this ancillary data should be removed and replaced by a climatology previously processed (monthly mean derived from previous years)
- water vapor estimate and pressure at sea level derived from meteorological data downloaded from Météo-France. The 2 files immediately anterior and posterior to the orbit. The resolution is 1° x 1°. These data are already available at VITO for operational processing of VEGETATION P products
- ozone concentration derived from the TOMS instrument. In this case too, this ancillary data should be removed and replaced by a climatology previously processed
- the DTM issued from GTopo30 at a 2km spatial resolution
- the GLC2000 landcover classification

5. Examples

The figure 3 presents a broadband bihemispherical albedo over Africa in April 2003. The highest values are logically observed for different parts of Sahara desert.

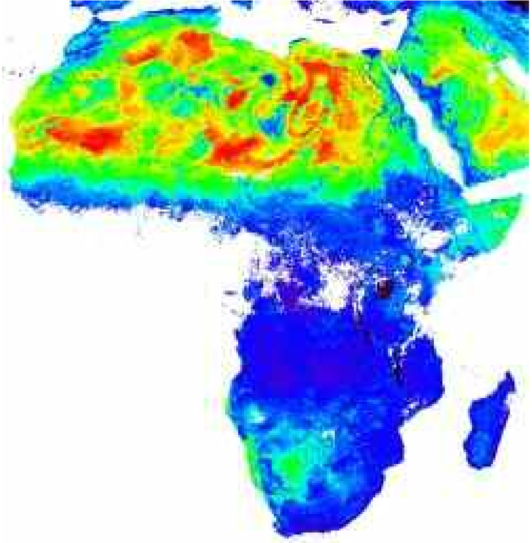

Figure 3 Broadband Bihemispherical Albedo over Africa in April 2003. The white pixels correspond to invalid pixels.

6. Validation evidence

Two comparison exercises are currently lead by Météo-France. One consists in comparing CYCLOPES albedo products with similar spatially MODIS products. It will provide a statistical analysis (error bar, bias, standard deviation) between co-registered MODIS and CYCLOPES products for the three broadband albedos (visible, near infrared, total). The second exercise will compare the same CYCLOPES products with in-situ measurements from BSRN sites (Baseline Surface Radiation Network). High frequency measurements (each 1 or 3 minutes) of down-welling and up-welling solar fluxes (in clear and partially clouds situations) are operated the whole year. An example is given in figure 4 for the Payerne site in Switzerland.

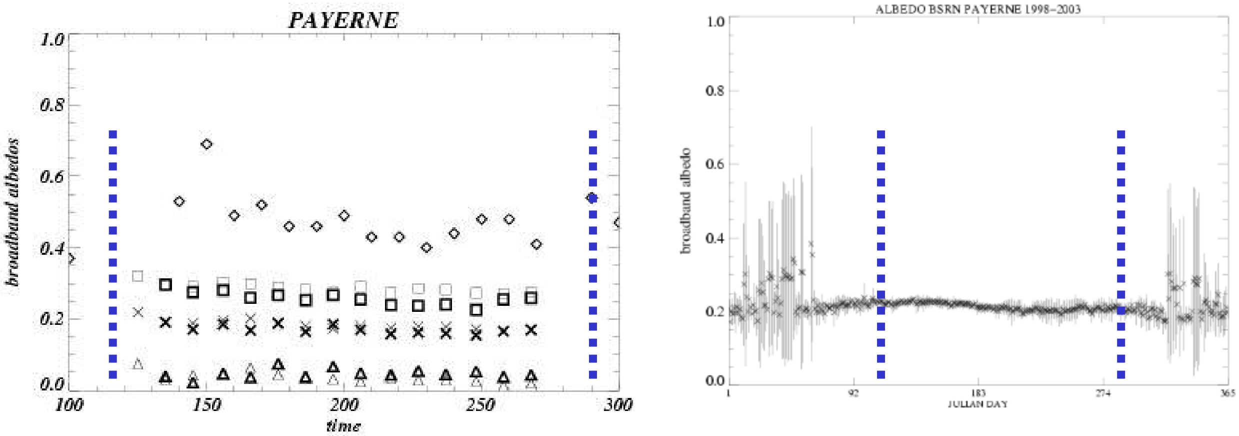

Figure 3 Temporal profile for Broadband Bihemispherical Albedo (visible: triangle; near infrared: square) for year 2002 and 2003 (bold) on the left and field measurements on the right where the bold line corresponds to a daily mean

7. Estimated cost from 'pre-operational' to 'operational'

The current processing chain implemented in the CYCLOPES project is operational. Products are delivered in a Plate Carre projection. A clear documentation exists describing Input Output Data Definition, Products Validation, End Users Information Guide.

The project objectives imply that the CYCLOPES processing chain is not a real time processing chain. It means that modifications will have to be brought in the framework of VGT4AFRICA project concerning the compositing method. Work will be achieve to generate a composite on day *j* relying on measurements only acquired before this day. These modifications concern minor methodological aspects (modifications of temporal weighting, sliding compositing period, aerosol and ozone climatology) which will have no impact on processing time.

The IPR for CYCLOPES external users are governed by the Consortium Agreement signed by the different parties.

8. References

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9. Technical product sheet

Product name *Broadband Albedo (Directional Hemispherical or Bihemispherical)*
Algorithmic Methodology *Products derived from an angular and spectral integration of directional parameters of a kernel model*
Geometric Resolution *1 km*

Product Accuracy

An error file at the same spatial resolution exist for each product

Frequency Delivery

Every ten days

Ancillary data

- *Monthly mean aerosol MODIS product, daily ozone TOMS product, but they could be replaced by climatology*
- *DTM (Gtopo30)*
- *GLC2000 Land Cover classification*

Delivery time

After the last P product acquisition, about one day (TBC)

Archive

Full year 2002 and 2003 (situation on 04/18/05). It will be extended to years 1998 until 2001 in Summer 2005.