Template product information package

Product	**Cover Fraction**
Participant ID	**MEDIAS-France**

1. General Information

The cover fraction fCover is the fraction of green vegetation covering a unit area of horizontal soil. It corresponds to the gap fraction in the nadir direction. It is generally close to fAPAR with the advantage of being defined independently of illuminations conditions making it an intrinsic canopy attributes. For these reasons, fCover is a very good candidate for substitution of classical vegetation indices. Note that fCover is also independent on leaf and soil optical properties although it is defined with reference to green elements. FCover typically varies from 0 (bare soil) to 1 (full cover). The required accuracy should be consistent with that proposed for fAPAR and should be around 0.05. Similarly, the maximum encoding step should be 0.01.

2. Application of the product

FCover is used to decouple vegetation and soil contributions in energy balance processes wih particular attention to temperature and evapo-transpiration. Its inter-annual variations allow to monitor the changes in land-use.

3. Algorithmic methodology

Among the several retrieval algorithms of biophysical parameters such as fCover, those that are based on the minimisation of the distance in the space of canopy variables appeared to be optimal from the accuracy of the retrievals while being very efficient computationally wise. Therefore a neural network has been built with normalized reflectances in 3 spectral bands (B2, B3, MIR), sun zenith angle and fAPAR as inputs and fCover as output. We briefly describe the key steps to generate the normalized reflectances. Then we focus on the physical basis of the radiative transfer model represented by the neural network.

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 :

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

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.

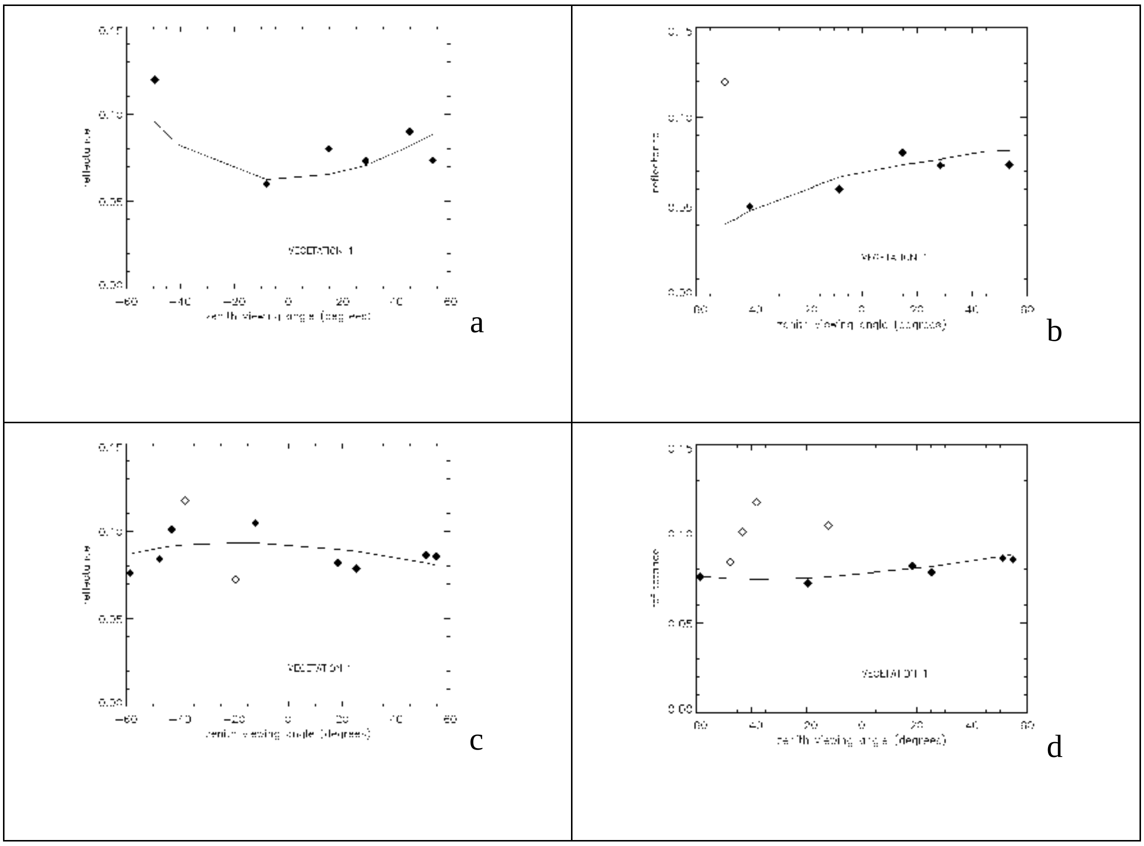


Figure 1 Left column, reflectances (triangles) and the retrieved BRDF model (solid lines) for two different pixels (Côte d'Ivoire, Dec 2002) in spectral band B2, during a test period of 15 days, using the D10 method. Right column, retrieved model using the new proposed method that uses a priori information.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

The basic idea here is to derive fCover by inversion of a unique, physically based vegetation reflectance model, irrespective of surface type. The canopy is modelled as an horizontally homogeneous turbid medium, limited by a soil layer also homogeneous. It may seen irrealistic to consider that canopies are homogeneous on scales larger than a few tens of meters, and a fortiori on scales of 1 kilometer. It may also seem irrealistic to use the turbid medium concept, a priori adapted to some cover types (grasslands, cultures), in area where vertical structures are prominent such as forest covers for example. This approach has, however, several advantages: i) it is simple, ii) it provides a sound physical representation of the average properties of the soil + vegetation layer, and iii) it should provide a sensitive improvement relative to the use of semi-empirical relationships generally calibrated on specific targets using specific geometric configurations, and therefore hardly extrapolable to the generality of possible terrestrial surfaces and geometric configurations.

The radiative transfer SAIL model is modified with the integration of PROSPECT (Jacquemoud and Baret., 1990) and an empirical soil background description. The present model uses an updated version of leaves spectral properties (Fourty and Baret, 1996). It predicts the canopy BRDF at any wavelength and sun view geometry, as a function of parameters describing the canopy structure, leaf biochemistry and spectral soil properties. The structural parameters are the leaf area index (LAI), the average leaf angle (ALA), and the hot spot parameter (HOT), ratio of leaf size to cover height (Kuusk, 1994). The leaf biochemical parameters are the pigment concentrations representing the chlorophyll A and B and carotenoids (C_{ab}), the water equivalent thickness (C_w), the brown pigments (C_{bp}), the dry matter (C_m). A leaf structure index (N) represents the effective number of layers inside a leaf. The optical soil properties are tackled with 10 standard soil spectra, 1 snow spectrum and 1 water spectrum. A brightness parameter (B_s) independent on wavelength allows to take into account various moisture and roughness. The proportion between soil and vegetation is explained with the fCover variable.

First, radiative transfer model simulations are made to generate a large database (several thousands simulations). It is mainly made within following steps. The ECOCLIMAP database (Masson et al., 2003) is used to drive the distribution of LAI as a function of location and date. The sun position is determined depending on location and date. The distribution of the background soil is driven by latitude and season. Finally, the distribution of the other input variables is derived from prior knowledge of their distribution. Once this database is generated, it is split in three parts: a training part containing 50% of the simulations to assess weights and bias of the various neurons of the network, an hyperspecialization part and a testing part to validate the network (both 25% of the simulations). The neural network once trained is run in operational mode to generate fCover with normalized VEGETATION reflectance as main inputs. A complementary step provides an estimate of the associated uncertainty.

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

This part presents an example of fCover product over Africa in April 2003 using measurements from VEGETATION sensor at 1km spatial resolution (fig. 2). The largest fCover values are observed in the equatorial belt and high plateau of Ethiopia. The figure 5 focuses on North Egypt and Middle East. The high fCover values for the Nile Delta are clearly distinguishable.

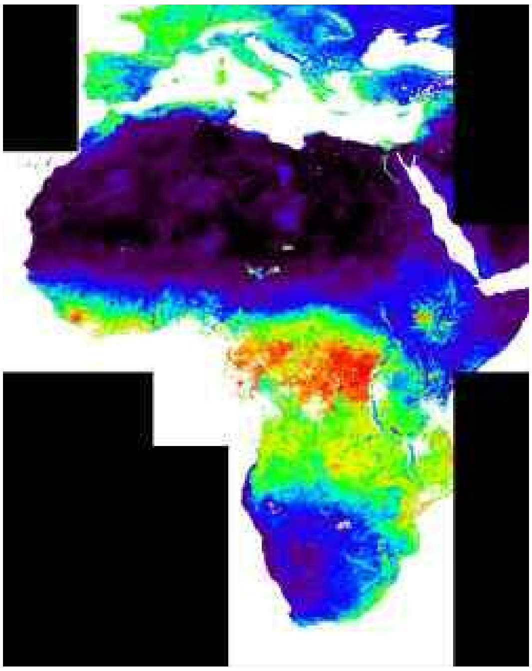


Figure 2 fCover over Africa in April 2005. The white pixels correspond to invalid values. The color scale is between 0 (black) and 1 (red)

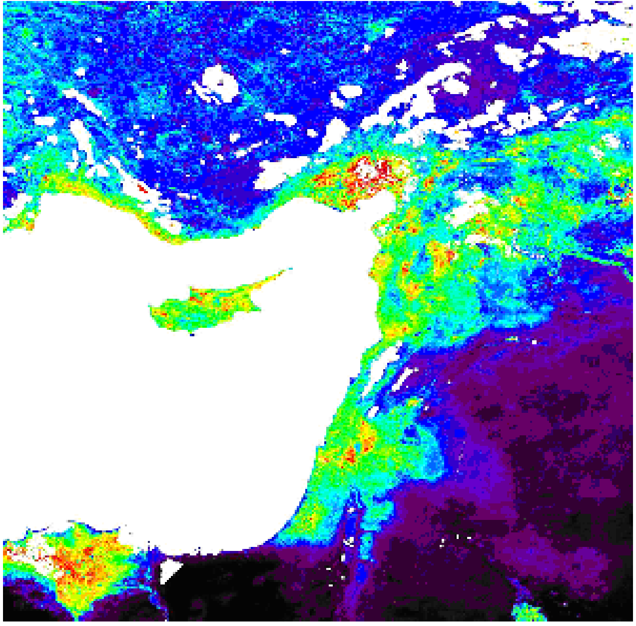


Figure 3 fCover over North Egypt and Middle East in April 2005. The color scale is between 0 (black) and 1 (red). The white pixels correspond to invalid values.

6. Validation evidence

Validation exercises have been carried out through comparisons with ground validation sites derived from VALERI experiment (Baret et al., 2005) but also with similar products derived from MODIS sensor. VALERI encompasses 27 sites located all around the world in order to take into account the various terrestrial biomes, including both natural and cultivated vegetation. Within VALERI, a dedicated methodology has been set up to estimate the value of the considered biophysical variables at the spatial resolution of large swath satellites from ground measurements. Each individual ground measurement site, an area of 3×3 km² flat and relatively homogeneous at the 1km scale, is sampled by selecting elementary sampling units (ESUs) that represent the variability observed within the whole site. Over each ESU, which is around 20×20m², gap fraction measurements are performed either with LAI2000 or hemispherical photographs. A concurrent (±7 days) SPOT-HRV image is then used to up-scale the ground measurements performed over the ensemble of ESUs to the whole site, thanks to a transfer function and co-kriging techniques. This processing allows to compare directly products derived from low resolution sensors and ground VALERI measurements. Examples of fCover temporal profiles are presented hereafter with VALERI points if available (and its associated error) for sites located in Mali (fig. 4), Morocco (fig. 5) and Burkina Faso (fig. 6).

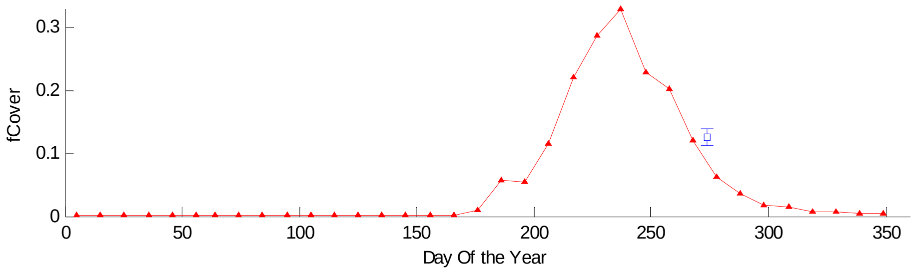
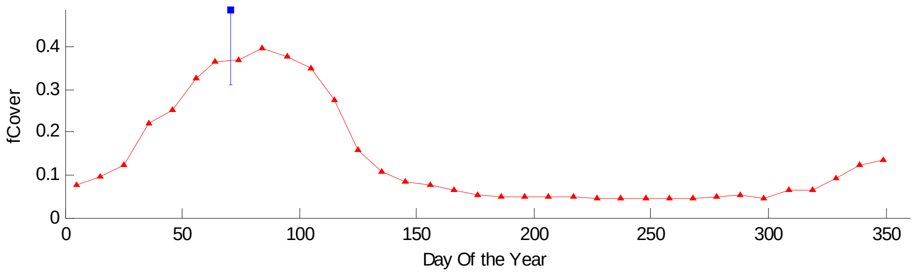
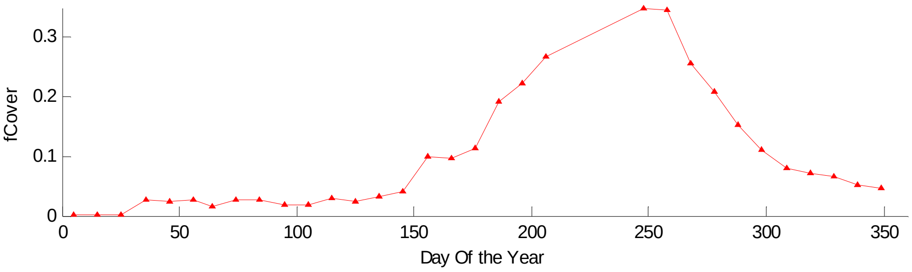


Figure 4 fCover temporal profile for the Gourma site (50% bare soil, 50% grass). The blue point correspond to VALERI measurement



<u>Figure 5</u> fCover temporal profile for the <u>Haouz site</u> (56% bare soil, 2% deciduous broadleaf, 42% grassland)



<u>Figure 6</u> fCover temporal profile for <u>Ouagadougou site</u> (21% bare soil, 16% deciduous broadleaf, 63% grassland)

7. <u>Estimated cost from 'pre-operational' to 'operational'</u>

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. <u>References</u>

Baret, F., M. Weiss, M. Leroy, D. Allard, S. Garrigue, H. Bohbot, R. Bosseno, C. D. Bella, M. Espana, V. Gond, J.-P. Guinot, D. Guyon, C. Lelong, E. Mougin, T. Nilson, and R. Vintilla, "VALERI: a network of sites and a methodology for the validation of land satellite products", *Rem. Sens. Env.*, submitted, 2005.

Duchemin B., B. Berthelot, G. Dedieu, M. Leroy, Ph. Maisongrande, « Normalisation of directional effects in 10-day global syntheses derived from VEGETATION/SPOT : Validation of an operational method on actual data sets », *Rem. Sen. Env.*, 101-113, 2002

Hagolle O., A. Lobo, P. Maisongrande, F. Cabot, B. Duchemin, A. de Pereyra, "Quality assessment and improvement of temporally composited products of remotely sensed imagery by combination of VEGETATION 1 and 2 images", *Rem. Sen. Env.*, 94, 172-186, 2004.

Kergoat L., « A model for hydrologic equilibrium of leaf area index on a global scale », J. Hydrology, 212-213, 267-286, 1999.

Knorr W., and M. Heimann, « Impact of drought stress and other factors on seasonal land biosphere CO2 exchange studied through an atmospheric tracer transport model », *Tellus*, 47B, 737-746.

Kuusk A., “A multispectral canopy reflectance model”, *Rem. Sens. Env.*, 50, 2, 75-82, 1994

Kohlmaier G.H., F.W. Badeck, R.D. Otto, et al., « The Frankfurt Biosphere Model. A global process oriented model for the seasonal and long term CO2 exchange between terrestrial ecosystems and the atmosphere, Part 2 : Global results for potential vegetation in an equilibrium state », 8, 61-87, 1997.

Lambin E. et al., “ Land Use and Cover Change “ *IGBP Report-48*, 1999.

Masson V., J.L. Champeaux, F. Chauzin, C. Mériguet, and R. Lacaze, “A global database of land surface parameters at 1km resolution in meteorological and climate models “, *J. of Climate*, vol. 16, n°9, 1261-1281, 2003.

Neilson R.P. and R.J. Drapek, « Potentially complex biosphere responses to transient global warming », *Global. Bio. Cycles.*, 4, 505-521, 1998.

Prince S.D., and S.N. Goward, “Global net primary production : a remote sensing approach “, *J. Biogeography*, 22, 815-835, 1995.

Roujean J.L. and R. Lacaze, ”Global mapping of vegetation parameters from POLDER multiangular measurements for studies of surface-atmosphere interactions: a pragmatic method and its validation”, *J. of Geo. Res.*, vol. 107, D12, 2002.

Warnant P., L. François, D. Strivay, J-C. Gérard, « CARAIB : a global model of terrestrial biological productivity », Global. Bio. Cycles., 8, 255-270, 1994.

Weiss M., F. Baret, R. Myneni, A. Pragnère, and Y. Knyazikhin, “Investigation of a model inversion technique for the estimation of crop characteristics from spectral and directional reflectance data”, *Agronomie*, 20, 3-22, 2000

9. Technical product sheet

Product name *Cover fraction*
Algorithmic Methodology *Product derived through a neural network approach using normalized reflectance in B2, B3 and MIR, fAPAR as inputs*
Geometric Resolution *1 km*
Product Accuracy *An associated file contains for each pixel the fCover uncertainty*

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.