

# Validation of GMES Geoland-2 global biophysical variables (GEO VERSION1) products

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**Abstract - This study investigates the scientific quality of the first version of global biophysical products (FCover, LAI, FAPAR) developed in the Geoland-2 /BioPar Core Mapping Service, namely GEOV1. These products based on SPOT/VEGETATION data were built on MODIS and CYCLOPES products while reconciling their differences. The quality assessment strategy follows the CEOS/WGCV Land Product Validation guidelines. The spatial and temporal consistency of GEOV1 products is assessed by intercomparison with existing global products (MODIS C5, CYCLOPES V3.1, GLOBCARBON V2, JRC FAPAR) over a global network of homogeneous sites (BELMANIP-2) over two years period (2003-2005). The accuracy of GEOV1 is evaluated against a number of available ground truth maps. Several criteria of performance were evaluated, including spatial distribution, missing values, magnitude of retrievals, temporal variations, smoothness, precision and accuracy. Our results show that GEOV1 products present reliable spatial distribution, smooth temporal profiles, stable from year to year, reliable magnitude for bare areas and dense forest, and the best performance with ground-based maps. GEOV1 outperforms the quality of existing global products in most of the examined criteria, and constitutes a step forward in the development of global biophysical variables in the framework of Geoland-2.**

**Keywords:** Environment, Monitoring, Biophysical Parameters, LAI, FCover, FAPAR, SPOT/VEGETATION

## 1. INTRODUCTION

The FP7 Geoland-2 project constitutes a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS), and addresses the local, continental and global components of the LMCS. Within geoland-2 the BioPar Core Mapping Service is in charge of developing key biophysical variables at global scale (Lacaze et al., *this issue*). Accurate and stable biophysical variables (LAI, FAPAR, FCover) are requested from users involved in climate change research, forestry, global crop monitoring and environmental applications.

Current operational global products (MODIS, GLOBCARBON, CYCLOPES) present significant discrepancies, which are larger than users' requirements, partly due to the sensors and preprocessing steps but mainly coming from the assumptions embedded in the retrieval algorithms. These products mainly differ in term of magnitude, temporal continuity and smoothness, while consistent seasonality is generally observed. Based on these results, a consensus product based on SPOT/VEGETATION data is proposed in Geoland-2/BioPar, building on MODIS and CYCLOPES products while reconciling their differences. The resulting algorithm will be implemented at VITO to generate in near-real time the first collection of Geoland-2 biophysical variables over the globe at 1 km spatial resolution and 10 day frequency.

This paper describes the main results of the scientific quality assessment of the first version of geoland-2 biophysical

parameters at global scale, named GEOV1. The quality assessment has been performed in agreement with standards of the GEO/CEOS WGCV LPV group. Two years (2003-2004) of global products was analysed. The overall accuracy of retrievals was determined based on existing ground reference maps. The product spatial and temporal consistency (precision) was assessed with emphasis on spatial distribution of values, missing values and temporal smoothness. Finally, an inter-comparison with existing satellite products (MODIS, GLOBCARBON, CYCLOPES, JRC-FAPAR) is performed.

## 2. GEOLAND-2 BIOGEOPHYSICAL PRODUCTS

Geoland-2 BioPar version 1 (GEOV1) is derived from the SPOT/VEGETATION sensor at 1/112° (about 1 km at equator) spatial resolution and a 10 days temporal sampling, in a Plate Carrée projection. The algorithm is a neural network trained over a fused product based on CYCLOPES for low to medium LAI and MODIS for medium to high LAI values (for details see Baret et al., 2010). Thus, the LAI is close to an actual value for high values, but closer to an effective LAI for low values. The FAPAR corresponds to the instantaneous black-sky around 10:15h, which is a close approximation of the daily integrated black-sky FAPAR value. These products will be produced and delivered by VITO in near real time. Here, the original version is analysed; A smoothed and gap filled version will be also produced in Geoland-2/BioPar.

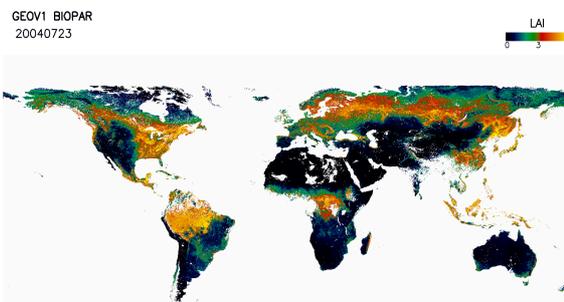


Figure 1. GEOV1 LAI global map corresponding to the 23 of July of 2004.

The version zero of Geoland-2 (GEOV0) BioPar LAI is derived from the CYCLOPES algorithm, whereas the FCover is based on a linear relationship between FCover and NDVI. The analysed data corresponds to a test dataset over Europe and Africa produced for the period 2003-2005.

## 3. VALIDATION PROCEDURE

This validation exercise was defined to be consistent with the best practices proposed by CEOS WGCV LPV subgroup (Morissette et al., 2006). First, an intercomparison with the existing global products was performed to examine the spatial and temporal consistency of GEOV1. Second, a direct validation approach was conducted using ground reference maps to quantify the overall performance of the products.

The reference global products used were: CYCLOPES v3.1 based on SPOT/VEGETATION observations (Baret et al., 2007),

Terra MODIS LAI/FPAR (MOD15A2) collection 5 (Yang et al., 2006), the GLOBCARBON LAI version 2 based on the combination of SPOT/VEGETATION and ENVISAT/AATSR data (Chen et al., 2006) and the JRC SeaWiFS FAPAR (Gobron et al., 2002).

### 3.1 Intercomparison Approach

The products were intercompared over the BELMANIP-2 (Baret et al., 2006) network of sites that was designed to represent globally the variability of land surface types. The land surface type is defined here using generic classes derived from the GLC-2000 classification. In this paper, the products are analysed for 5 generic classes, namely: Evergreen Broadleaf Forest, Evergreen Deciduous Forest, Needle-leaf Forest, Crops-Grasslands, Shrubs-savannas-bare.

The products must be compared over a similar spatial support area and temporal support period. They were thus resampled over Plate Carrée projection at  $1/112^\circ$  (about 1 km at equator) spatial resolution. The intercomparison was conducted using an average value over  $3 \times 3$  pixels to reduce coregistration errors between products and differences in their sensor Point Spread Function (PSF) which determines the actual footprint of the data. The temporal support period for the quantitative assessment is monthly as it is the lower temporal resolution. The original temporal sampling was used for compute missing values, histograms and the smoothness.

Intercomparison made at a monthly temporal support period was achieved selecting the central image of the month for GEOV1 and CYCV31, whereas for GEOV0 the first one was used (see table 1). In the case of MODIS products, with an 8 days temporal window, an average between the closest image to the reference date and the previous one is used for the scattering. Regarding JRC/FAPAR product, a monthly average was computed.

### 3.2 Direct validation

The quantitative performance of the products was evaluated against ground truth data. In-situ data processed according with CEOS/WGCV LPV guidelines accounting for up-scaling effects was compiled by Garrigues et al., (2008) coming from international initiatives such as VALERI, BIGFOOT, CRSS and others. Ground truth data is affected by different sources of uncertainties: (i) Foliage clumping is not characterised in many cases, leading to an underestimation of LAI (LAI<sub>eff</sub>). (ii) Optical measurements usually do not distinguish between photosynthetic active issues and other plant elements, leading to a positive bias in vegetation parameters, (iii) Understorey is not always characterised in forest sites.

Only those forest sites where the understorey was measured have been selected for the quantitative analysis. Those LAI maps where foliar clumping was not measured have been corrected using the clumping index values proposed by Chen et al., (2005) as a function of the biome type, these points are labelled as LAI<sub>eff</sub>/clumping. In addition, a few maps showing differences between the FAPAR and FCOVER greater than 0.15 are discarded. The scattering is carried out by comparing the field data with the closer product reference date. In-situ values for natural vegetation sites measured outside the period 2003-2004 are compared with satellite product estimates for the year in which the agreement was better.

## 4. RESULTS

### 4.1 Distribution of retrievals

Figure 2 shows the distributions of LAI retrieved values per biomes. Similar results for the different biomes were found with the exception of evergreen broadleaf forests where GEOV1 products present a distribution of values with its mode between CYCLOPES mode and MODIS mode. A positive bias for MODIS over shrublands and bare areas was found, as well as a negative bias of CYCLOPES for forest sites.

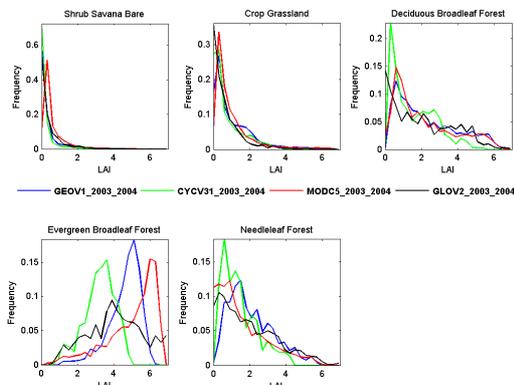


Figure 2. LAI histograms over BELMANIP-2 sites during 2003-2004 period.

Figure 4 shows the FAPAR histograms. A good agreement is found between MODIS and GEOV1 distributions for evergreen and deciduous forests. MODIS shows a clear positive bias over shrubs, savannas and bare areas. JRC FAPAR product shows a generalized underestimation as compared with other products.

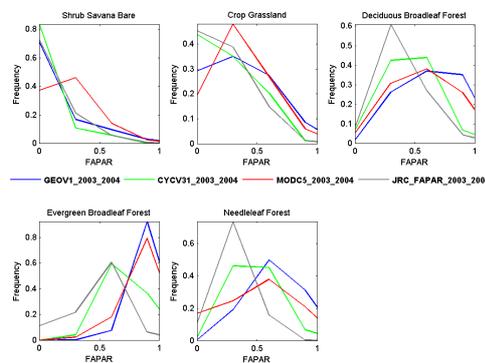


Figure 3. FAPAR histograms over BELMANIP-2 sites during 2003-2004 period.

Figure 4 shows the FCOVER histograms for CYC and GEOV1. The GEOV1 provides reliable distributions for forest, whereas CYCV31 shows a systematic underestimation.

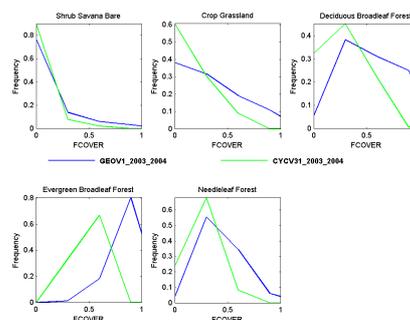


Figure 4. FCOVER histograms over BELMANIP-2 sites during 2003-2004 period.

## 4.2 Performance with reference products

The performance with global products was evaluated over BELMANIP-2 sites and 24 dates. Overall performance (RMSE), systematic deviations (bias) and correlations ( $R^2$ ) are shown in table 1.

	LAI			FAPAR			FCOVER	
	$R^2$	RMS	B	$R^2$	RMS	B	RMS	B
GEOV1-CYC	.95	.43	.15	.97	.07	.04	.15	.11
GEOV1-MODC5	.84	.62	.02	.90	.09	-	.05	-
GEOV1-GEOV0	.93	.38	.10	-	-	-	.10	-
GEOV1-JRC	-	-	-	.64	.23	.13	-	.03
GEOV1-GLOB	.80	.81	.34	-	-	-	-	-

Table 1. Intercomparison exercise: Performance of GEOV1 among the different global products.

GEOV1 is highly correlated with CYCV31 and GEOV0 for LAI (RMS<0.5,  $R^2$ <0.9), the performance with MODIS products is also good. Lower performances were found between GEOV1 and JRC FAPAR, GEOV1 and GLOBV2 LAI, and GEOV1 and CYCV31 FCover.

## 4.3 Temporal profiles

Temporal profiles of different products were displayed in order to evaluate their temporal consistency. Figure 4 shows an example over open woodland site in Mongu (Zambia). Field data symbols correspond to a different year (2000), acquired during SAFARI 2000 campaign. GEOV1 profiles show a good agreement with field measurements and a smooth trend over the period. GLOV2 present lower values and MODIS noisier profiles. For FAPAR, in-situ values were measured from two different instruments: TRAC and AccuPAR. The TRAC instrument estimates FAPAR from the gap fraction (FIPAR at SZA), whereas AccuPAR estimates FAPAR based on incident, reflected and transmitted PAR. As can be observed in Figure 5, ground estimates are within the error budget of the GEOV1 FAPAR.

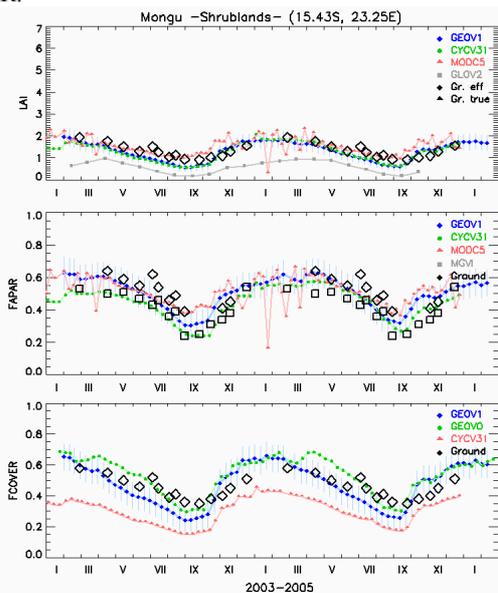


Figure 5. LAI, FAPAR and FCOVER temporal profiles at Mongu site in Africa.

## 4.4 Temporal smoothness

Figure 6 shows the cumulative histograms of the  $\delta$ FAPAR (smoothness). CYCV31 and GEOV1 present the lower delta values. The higher delta values for JRC FAPAR are due to daily product is more unstable.

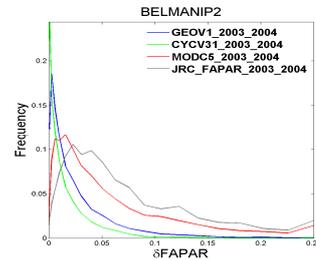


Figure 6. Temporal smoothness for the different FAPAR products. Note that the temporal sampling of JRC FAPAR is daily.

## 4.5 Direct validation

Figure 7 shows the scatter-plots of the comparisons of GEOV1 with in situ-based maps. For FAPAR and FCover correlation are better than 0.8, with an overall accuracy better than 0.1, and no systematic trends, which means that the target accuracy is achieved. For the LAI, overall performance is of 1 if only true LAI is used, and 0.85 when effective LAI corrected of clumping in-situ data is added. Correlation is better than 0.7, and minor systematic differences are found (bias<0.3).

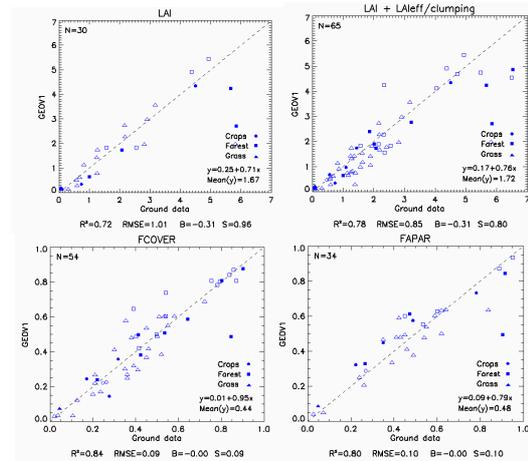


Figure 7. Comparison of GEOV1 products with ground-based estimates for LAI, LAI+LAIeff/clum, FAPAR and FCOVER. Filled symbols refers to coincident years, unfilled symbols refers to a different year.

For the other analysed products, the metrics are shown in table 2. In conclusion, GEOV1 presents the lowest RMSE with ground based data. The improvement is significant for the LAI (RMSE<1, lower bias, higher correlation), and for the FCOVER (RMSE<0.1, no bias). For the FAPAR the performance indicators of GEOV1 are identical to that of MODIS. The JRC FAPAR product presents systematic differences with the ground data, which should be partly explained by the different assumptions involved in the derivation of ground maps (i.e., black-leaves, daily integrated FAPAR) and satellite JRC product (i.e., instantaneous FAPAR at the time of acquisition)

Metric	CYCV31	MODC5	GLOBV2	GEOV0	JRC
<b>LAI (+LAIeff/clumping)</b>					
<b>R<sup>2</sup></b>	0.72	0.59	0.74		
<b>RMSE</b>	1.08	1.13	1.17		
<b>BIAS</b>	-0.54	-0.27	-0.80		
<b>FAPAR</b>					
<b>R<sup>2</sup></b>	0.78	0.80		0.89	
<b>RMSE</b>	0.12	0.10		0.18	
<b>BIAS</b>	-0.05	0		-0.14	
<b>FCOVER</b>					
<b>R<sup>2</sup></b>	0.82			0.80	
<b>RMSE</b>	0.19			0.13	
<b>BIAS</b>	-0.16			0.07	

Table 2. Direct validation results of global products.

## 5. CONCLUSION

In this study, a quality assessment of the first version of global biophysical products (LAI, FAPAR, FCover) developed in the framework of Geoland-2/BioPar, GEOV1, based on CYCLOPES and MODIS products, was performed. The methodology used follows the guidelines proposed by the CEOS LPV group for validation of remote sensing vegetation products. First, an intercomparison with current existing global products (MODIS C5, GLOBCARBON V2, CYCLOPES V3.1, JRC- SeaWiFS FAPAR) was performed over the BELMANIP-2 sites distributed around the world. Second, the uncertainties were quantified by direct comparison with ground-based reference maps. Several criteria of performance were evaluated, including spatial distribution, missing values, magnitude of retrievals, temporal variations, smoothness, accuracy and precision. The main conclusions are:

GEOV1 present reliable and consistent global spatial distribution of retrievals. The intercomparison with global products shows that GEOV1 LAI and FAPAR products present similar values than CYCV31 for sparse vegetation and crops, and is much closer to MODIS for forest sites. GEOV1 overcomes the positive bias of MODIS for low LAI/FAPAR values, and the negative bias of CYCV31 for forest sites. For the FCover, the GEOV1 overcomes the important underestimation of CYCV31, and improves also the quality of GEOV0. The magnitude of retrievals is reliable for low and high vegetation abundance.

The analysis of temporal consistency showed that GEOV1 present reliable inter-annual and seasonal variations, showing very smooth profiles. GEOV1 clearly outperforms the quality of MODIS or GLOBCARBON temporal profiles.

The comparison with ground truth shows that GEOV1 is the most similar product to the reference maps, reaching an overall performance (RMSE) better than 0.1 for FCover and FAPAR with no bias, and better than 0.8 for LAI with a slight negative bias. GEOV1 products reach the target accuracy required by users.

The main limitation is the lack of continuity at high latitudes and equatorial regions as in the other global products. This limitation will be solved with the smoothed and gap filled version of GEOV1 products which is currently under evaluation.

In summary, GEOV1 products have a good quality, showing a spatial consistent global distribution of retrievals. Temporal profiles are very smooth and are highly consistent from year to

year. Comparison with ground data shows that target accuracy is achieved, and no bias was detected.

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