OPERATING THE COPERNICUS GLOBAL LAND SERVICE

B. Smets [(1)], R. Lacaze [(2)], S.C. Freitas [(3)], A. Jann [(4)], J.-C. Calvet [(5)], F. Camacho [(6)], F. Baret [(7)], C. Paulik [(8)], R. d'Andrimont [(9)], K. Tansey [(10)], A. Verger [(11)]

[(1)] *VITO, Boeretang 200, 2400 Mol, Belgium – bruno.smets@vito.be*
[(2)] *HYGEOS, Euratechnologies, 165 avenue de Bretagne, 59000 Lille, France - rl@hygeos.com*
[(3)] *IPMA, Rua Cao Aeroporto de Lisboa, 1749-077 Lisboa, Portugal – sandra.coelho@meteo.pt*
[(4)] *ZAMG, Hohe Warte 38, 1190 Vienna, Austria – alexander.jann@zamg.ac.at*
[(5)] *CNRM/Météo-France, 42 avenue G. Coriolis, 31057 Toulouse Cedex, France – calvet@meteo.fr*
[(6)] *EOLAB, G.V. Marques del Turia, 20-9, 46 005 Valencia, Spain – camacho@eolab.es*
[(7)] *INRA, EMMAH UMR1114, site Agroparc, 84914 Avignon, France – baret@avignon.inra.fr*
[(8)] *Vienna University of Technology, Gusshausstrass 27-29/122, 1040 Vienna, Austria – christoph.paulik@geo.tuwien.ac.at*
[(9)] *Université Catholique de Louvain, Croix du sud 2 - L7.05.16, B1348 Louvain-la-Neuve, Belgium – raphael.dandrimont@uclouvain.be*
[(10)] *University of Leicester, LE1 7RH, Leicester, United Kingdom – kevin.tansey@le.ac.uk*
[(11)] *CREAF-CEAB-CSIC-UAB, Cerdanyola del Vallès 08193, Barcelona, Spain – verger@creaf.uab.es*

ABSTRACT

From 1st January 2013, the Copernicus Global Land Service is operational, providing continuously a set of biophysical variables describing the vegetation conditions, the energy budget at the continental surface and the water cycle over the whole globe. Essential Climate Variables like the Leaf Area Index (LAI), the Fraction of PAR absorbed by the vegetation (FAPAR), the surface albedo, the Land Surface Temperature, the soil moisture, the burnt areas, the areas of water bodies, and additional vegetation indices, dry matter productivity and TOC reflectance, are generated every hour, every day or every 10 days on a reliable and automatic basis from Earth Observation satellite data. The service and its products are continuously checked on technical and scientific quality. In view of service continuity, the existing retrieval methodologies are being adapted to new sensors (e.g. Proba-V and the Sentinels), taking the benefit of the increased resolution.

1. INTRODUCTION

Our natural environment is increasingly under pressure. A growing global population fuels the need for food, natural resources and land. Ecosystems are under threat and the climate is changing rapidly. Environmental information is of crucial importance to help us understand how our planet and its climate are changing, the role played by human activities in these changes, the influence to our daily lives and to the decisions being made today on environmental policies.
The Group on Earth Observations (GEO) initiative is a clear manifestation of the desire by the international community to secure a permanent and long term watch over the resources and environment of the Earth. The European Union has set up the Copernicus initiative (former Global Monitoring for Environment and Security, GMES) to provide this information. Policy-makers and public authorities use the information to prepare environmental legislation and policies.

Copernicus is based on three main components : (i) the Component Space, run by the European Space Agency's space infrastructure contributes to the development of Sentinel satellites and ground segments, (ii) the Component In-Situ, run by the European Environment Agency (EEA), which coordinates information networks provided by in-situ sensors and (iii) the Component Services, run by the European Commission (EC), which coordinates amongst others the implementation of a systematic monitoring of the state of the Earth's land subsystem.

In connection with the Land Monitoring Service , there are three components : (i) the Local component (e.g. , protected areas, coastal , urban atlas) , (ii) the Continental component (rankings at European level) and (iii) the Global component responsible for the continuous generation of biophysical variables on a global scale and providing consistent time-series. The latter component, the Copernicus Global Land Service, intends to promote specifically the European contribution to GEO, to international policies (e.g. climate change) and / or international treaties (e.g. UN " Rio " and climate conventions). The main topics are: (i) agriculture, crop monitoring and food security, (ii) biodiversity, protected areas, and monitoring of forest cover, (iii) drought and desertification, (iv) coal flows, land use and changes in use, (v) support for programs in Africa (e.g., AMESD , MESA).

The Copernicus Global Land Service, has been developed from the research and development performed for over 10 years, mainly in several

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Framework Program (FP) projects as Geoland-2/BioPar and VGT4Africa and through EUMETSAT's Land Surface Analysis Satellite Application Facility (LSA-SAF). Currently, the Global Land Service is operated by a consortium led by VITO, through a framework agreement with the Joint Research Centre (JRC) in the context of the GMES Initial Operation (GIO).
The main components of the Global Land Service are: (i) production of biophysical variables at global scale in near real-time (NRT), (ii) quality control according to scientific protocols, (iii) reprocessing of the data archive (up to 15 years of Earth observation data) and (iv) dissemination and user support.

2. PRODUCTION AND TIME-SERIES

All products from the Global Land Service come with a Product Manual for the User (PUM), the Algorithm Theoretical Basis document (ATBD) and a Validation Report (VR) that can be downloaded from the website [3].
Table 1 summarizes the products provided by the Global Land Service.

Product	Sensor	Resolution	Frequency	Period
LST	Σ Geos	5 km	1 hour	2009-NRT
SA	VGT	1 km	10 days	1999-NRT
TOC_R	VGT	1 km	10 days	2013-NRT
BA	VGT	1 km	10 days	1999-NRT
DMP	VGT	1 km	10 days	2009-NRT
FAPAR	VGT	1 km	10 days	1999-NRT
fCover	VGT	1 km	10 days	1999-NRT
LAI	VGT	1 km	10 days	1999-NRT
NDVI	VGT	1 km	10 days	1999-NRT
VCI	VGT	1 km	10 days	2013-NRT
VPI	VGT	1 km	10 days	2013-NRT
SWI	ASCAT	0.1°	1 day	2007-NRT
WB	VGT	1 km	10 days	1999-NRT

Table 1. Product catalogue Copernicus Global Land Service. Σ Geos means that LST is derived from many geostationary sensors data.

The Global Land Service provides products in NRT which are compatible with 10+ years of archive from the Geoland2 and VGT4Africa projects and offers the option to reprocess the full time-series when required.
The following sections introduce the products through the three defined categories: (i) the energy budget, (ii) the vegetation state and (iii) the surface water.

2.1. Energy budget

The Top of Canopy reflectance (TOC_R), the Surface Albedo (SA), and the Land Surface Temperature (LST) all contribute to describe the energy budget at the continental surface.

The TOC-R is the fraction of irradiance reflected by the continental surface, in a standard sun-view configuration, after removal of the atmospheric contribution while the Albedo is the fraction of irradiance reflected by the surface and integrated over all viewing directions . (directional albedo, also known as the black-sky albedo) (Figure 1), and integrated over all viewing and solar directions (hemispherical albedo, also known as white-shy albedo). Both are also provided in three broadband spectral ranges: visible [0.4, 0.7μm], near infrared [0.7, 4μm] and the solar spectrum [0.3, 4μm]. All the pre-processing steps (calibration, cloud and shadow screenings, atmospheric correction) , the time compositing method over 30 days of SPOT/VEGETATION (VGT) observations, and the albedo retrieval algorithm , defined by CNRM / Météo-France, have been developed in the FP5/CYCLOPES project [13].

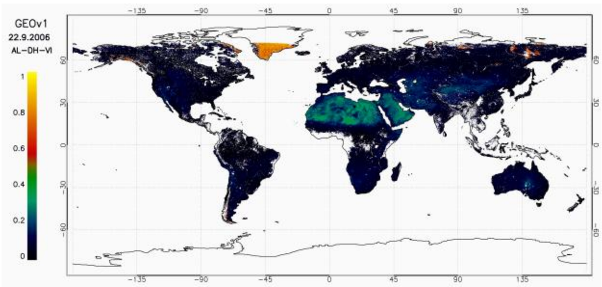

Figure 1. Surface albedo derived from SPOT/VGT, September 2006

The validation has shown that the product of SPOT / VGT Albedo has a very similar performance to that of MODIS C5 with a RMSE for BELMANIP-2 sites of only 0.03. Comparison with in-situ data shows a RMSE between 0.04 and 0.03 if we filter pixels with snow. Details are available in the Validation Report [3].

The global land surface temperature (Figure 2), developed by IPMA, is obtained by combining LST products obtained from various geostationary sensors such as Meteosat Second Generation/SEVIRI (provided by LSA-SAF), GOES and MTSAT. It is generated with an hourly frequency.

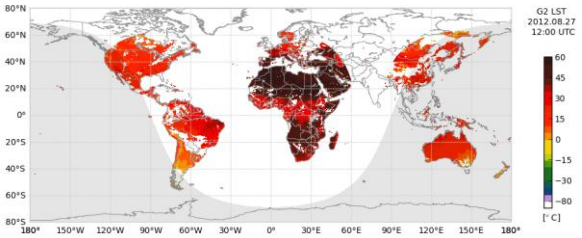

Figure 2. LST (°K), from merging GOES, MSG, and MTSAT data, August 2012.

The LST is obtained from semi-empirical regressions of TOA brightness temperature using split-window methodology or dual algorithms depending on the information available in the thermal infrared channels of geostationary sensors [4]. Product validation with in-situ data networks (e.g. SURFRAD, BSRN) have shown biases around 2 to 3° Celsius. The main value added through products based on geostationary sensors is the hourly rate to describe the diurnal cycle of LST and improve the frequency of observation areas are often covered by clouds. Details are available in the Validation Report [3].

2.2. Vegetation state

Products that describe the state of vegetation, developed by INRA, include leaf area index (LAI), the daily fraction of PAR radiation absorbed by vegetation (FAPAR), and the fraction of vegetation cover (fCover).

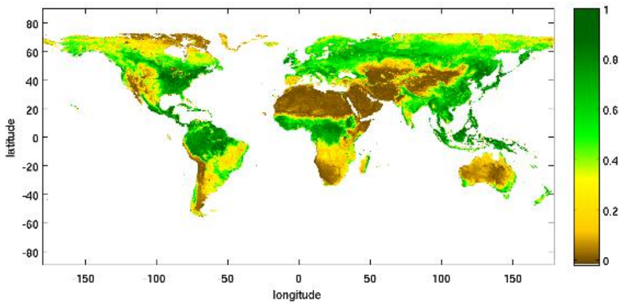

Figure 3. FCover derived from SPOT/VGT, August 2004

The algorithm for estimating the GEOV1 version products, is based on neural networks trained with the existing CYCLOPES V3.1 and MODIS C5 products which were fused to improve the variable estimates by benefiting of the respective advantages of each product. The inputs of the neural networks are the TOC-R SPOT/VGT reflectances (§2.1) and the median value of the sun zenith angle over the compositing window of 30 days.[1]. Validation results show that these products improve most validation criteria evaluated [2]. The comparison with in-situ data reaches an overall performance (RMSE) better than 0.1 for Fcover and FAPAR with no bias, and between 0.8 and 1 for LAI depending the ground dataset used with a slight negative bias, which is very close to the uncertainty level of the ground based maps. Details are available in the Validation Report [3]. A further adaptation of the algorithm, known as the GEOV2 version products, is currently under review which further improves the smoothness of the product and provides a better real time product.

Moreover, two additional vegetation indices were developed by VITO, starting from the time series of the Normalized Difference Vegetation Index (NDVI). The Vegetation Condition Index (VCI), expressed in % reports the status of the vegetation compared to the same period in previous years, and the Vegetation Productivity Index (VPI) (Figure 4) reflecting the probability of observing a similar value of NDVI time series [7].

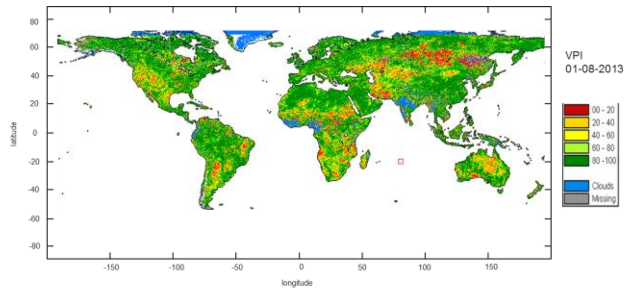

Figure 4. Vegetation Productivity Index from SPOT/VGT, 1^{s} dekad August 2013

The Dry Matter Productivity (DMP) product, developed by VITO, estimates the daily growth of the biomass. It is equivalent to the net primary productivity (NPP), but DMP is customized for agricultural applications and is expressed in kilograms of dry matter per hectare per day. The algorithm for estimating the DMP is based on the classical approximation of Monteith [5], which relates vegetation productivity by combining the incident solar radiation (~ PAR) , the FAPAR and the efficiency for the conversion of biomass radiation which depends on the temperature.

The Burned Areas (BA) product, developed by the University of Leicester, is based on the algorithm of Tansey et al. [8], optimized to fit a real-time production. It also introduces a seasonality metric to estimate the beginning, maximum and end of a fire station.

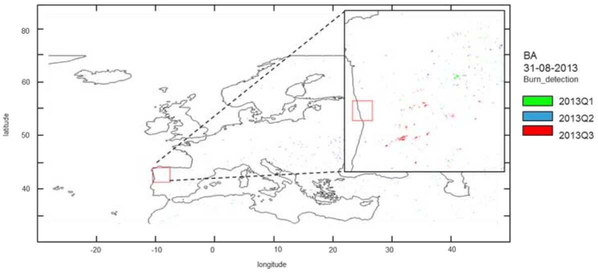

Figure 5. Burnt Area from SPOT/VGT, 2013, Europe and North-Portugal

The BA product has participated in a round robin exercise organised in the framework of the ESA Climate Change Initiative (CCI) Fire [10]. The validation was performed by comparing with high-resolution data Landsat TM, for thirty-five study sites, located across the Earth's surface and representing different biome types, using pre and post-fire analysis. The results show that an amount of both omission and commission errors were seen, however the product yields reasonable and sensible maps in regions of significant and concentrated fire activity over multiple years. The details are in available in the Validation Report [3].

2.3. Surface water

The Soil Water Index (SWI), developed by Vienna University of Technology, is estimated using a two-layer water balance model [9] relating the Surface Soil Moisture (SSM) to the soil moisture profile (SWI) as a function of time (T). The algorithm calculate the daily global maps of SWI (Figure 6) for 8 different values of T (T=1, 5, 10, 15, 20, 40, 60, 100) from the Metop/ASCAT SSM using a recursive formulation [12] . In addition, a surface state flag indicates the state of the surface (frozen, unfrozen, melting).

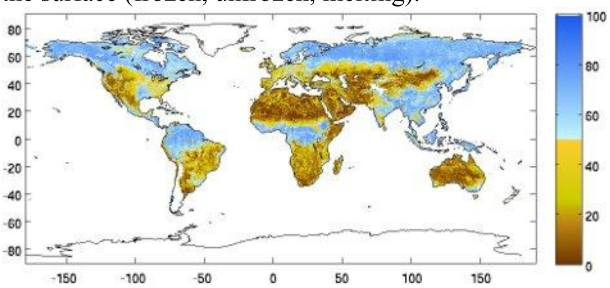

Figure 6. Global SWI (%) derived from Metop/ASCAT data for T=10 on 15th July 2007.

The validation has been performed with in-situ data and two different SVAT models: the ISBA-A-gs model (Météo-France), and global CTESSEL model (ECMWF). The results show that the best absolute and anomaly correlations where obtained for the T parameter value T=15 over France. This result is in agreement with findings using in situ soil moisture observations at a depth of 0.3m. Details are available in the Validation Report [3].

Finally, the area of Water Bodies (WB) identifies the pixels covered by water. They are the result of the fusion of two algorithms, realized by the Université Catholique de Louvain: (i) a detection algorithm developed in the context of the JRC VGT4AFRICA project, and suitable for arid and semi-arid areas over Africa [11], and (ii) an algorithm developed for the project GlobalWatch and used for the prevention of locusts [6]. The product includes information on seasonality, e.g. date of filling and drying.

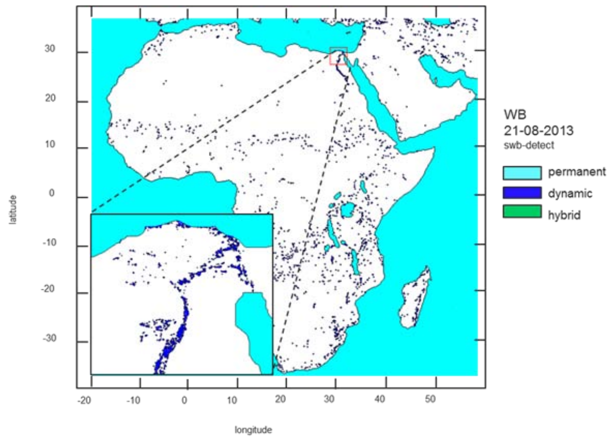

Figure 7. Water Bodies from SPOT/VGT, August 2013, Africa and Nile river delta

The validation was performed based on a reference datasets derived from ENVISAT Advanced Synthetic Aperture Radar (ASAR) and ESA Globcover 2009 and has shown that, over Africa, the combination of algorithms returns accurate results for permanent water bodies covering an area of at least 10km^2. Details are available in the Validation Report [3]. The validation across sites outside Africa is ongoing.

3. QUALITY MONITORING

The Global Land Service monitors the quality of the service through different levels: (i) checking for unreliable product values by means of statistical variables at the temporal frequency of the products, (ii) scientific validation of the NRT products every six months or of a time-series before releasing new product versions and (iii) an independent evaluation and review process.

The first two steps are under the responsibility of the consortium, represented by a Science & Technology Manager of HYGEOS, while the latter is implemented by a separate entity providing a high quality and independent reviewing process to all aspects, both from engineering and scientific points of view of the operational activities. This entity, led by Spacebel N.V., also manages a technical user group to provide feedback at technical level on the use of the Global Land Service.

For a specific time slot and geographical region, a set of statistical parameters (the quartiles, the 5% and 95% percentiles, the minimum / maximum values excluding lower / higher outliers, the median value, the percentage of land pixels that were effectively processed) are calculated. By means of visualizing the statistical parameters in dynamic charts, the behaviour of the product is analysed in near-real time (Figure 8).

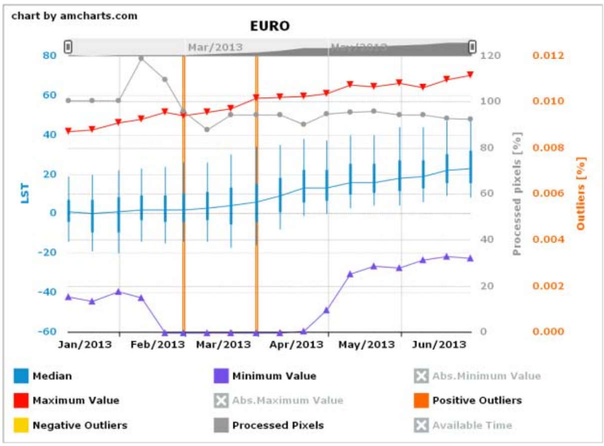

Figure 8. Technical quality monitor statistics LST, 1st half 2013 over Europe continent.

Scientific quality assessment and continuous quality monitoring constitute the means of guaranteeing the compliance of generated products with international requirements from GCOS (Table 2) through (i) an exhaustive scientific evaluation of new products before to be implemented operationally, (ii) a checking of the quality of operational products along the time. Both are based on existing guidelines, protocols and metrics defined by the Land Product Validation (LPV) group of the Committee on Earth Observation Satellite (CEOS). In complement of the above product-by-product validation, a cross-cutting analysis is performed by integrating many variables into a Land Data Assimilation System (LDAS) to assess the consistency between products.

Product	Target Accuracy
LST	2°K
SA	10% (SA>0.15 for snow-free targets) or 0.03 (AL<0.15)
TOC_R	Same as SA
BA	NA
DMP	NA
FAPAR	0.05 for FAPAR < 0.2; 10-15% for FAPAR > 0.2
fCover	0.05 for fCover < 0.2; 10-15% for fCover > 0.2
LAI	0.5 for LAI <1; 20% for LAI > 1
NDVI	NA
VCI	NA
VPI	NA
SWI	10%
WB	90% for detection

Table 2. Product target accuracies

4. DISSEMINATION AND USER SUPPORT

The data is distributed through (i) internet and (ii) Digital Video Broadcast (DVB). The internet [3] provides a Spatial Data Infrastructure (SDI) compliant to widely accepted international Open Geospatial Consortium (OGC) standards, in line with the INSPIRE directive. The system provides the following services to the user: (i) a catalogue discovery service to query for product availability, (ii) a Web Mapping Service for viewing, (iii) an ordering service to automate the actual dissemination of a product requested on demand or to disseminate large amounts (e.g. full archive) of products and (iv) a subscription service to get automated notifications whenever a new NRT product becomes available. The infrastructure is based on a de-centralized model, providing a single-point web enabled catalogue and a decentralized back-end per production centre (VITO, IPMA, ZAMG), serving the actual transfer of data to the user. The DVB channel broadcasts the continental products over Africa and South America through the GeoNetCast system in Near Real Time. Through this means, users with a small internet bandwidth are able to receive and store the global land products. Access to the data is free and open, without any restrictions.

The Global Land Service includes also a helpdesk to provide user support, through telephone, e-mail and (soon) a ticketing system.

5. FUTURE PROSPECTS

On the short term, within the GIO framework, the service is continued through evolution tasks by adapting the existing algorithms to the PROBA-V 1 km data-set while safeguarding consistency with the available time-series. On top the temporal consistency of products will be further aligned by offering also a 10-daily LST and SWI products. Through the FP7 Imagines (2012-2016) project, a consortium of institutions is preparing processing chains to pass to 300m resolution, first using PROBA-V data and later fuse the data with Sentinel3. Products that will first benefit from this improved

resolution are the vegetation state variables. The techniques used and experience gained to pass to 300m are assumed to be deployed to the other products in a later stage.
To safeguard sustainability of the service at any time, a closer cooperation is explored with the LSA-SAF to align products providing the option to offer a degraded backup service (1km) using products derived from meteorological satellites, e.g. Metop/AVHRR, in case of disruptions in the data flow of the prime satellite.
On the longer term, the new capabilities of the Sentinels and contributed missions will be further exploited through results of research and development activities from EC programs as well as national initiatives. It is assumed that the available portfolio will evolve into (i) a regular monitoring of the globe at medium resolution (300m, 100m), while introducing (ii) hot spot monitoring at high resolution (30m, 10m using Sentinel-2 data) across e.g. major protected areas, ACP countries, and (iii) integration of new products as outlined in the specification and identified by the user community (e.g. phenology, water level, permafrost, …). It is important to receive the Earth-Observation data timely within 24 (max 48) hours with a daily (near) global coverage to sustain the 1km and 300m service.

6. ACKNOWLEDGEMENTS

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