

GEOLAND2 - TOWARDS AN OPERATIONAL GMES LAND MONITORING CORE SERVICE; FIRST RESULTS OF THE BIOGEOPHYSICAL PARAMETER CORE MAPPING SERVICE

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ABSTRACT:

The European GMES initiative provides a political framework for future implementations of Services Centres related to environmental applications. The FP7/geoland2 project is the last brick towards the implementation of fully mature GMES Land Services, consisting of Core Mapping Services (CMS) and Core Information Services (CIS). Its goal is to build, validate and demonstrate operational processing lines and products on a user-driven basis. The CMS produce “basic” geo-information on the land state covering a wide variety of thematic content, spatial scales from local to global, and update frequency from sub-daily to several years. Besides being a valuable information source by their own, the “basic” products are input for the Core Information Services focusing on a broad variety of thematic fields, like water quality, forest management, spatial planning, agri-environmental issues, carbon cycle analysis, supporting the European environmental policies and international treaties on climate change, food security, and sustainable development. The Bio-geophysical Parameter (BioPar) CMS aims at setting-up operational infrastructures for providing regional, continental, and global variables describing the vegetation state, the radiation budget at the surface, and the water cycle, both in near real time and off-line mode. The concept, the objectives, and the structure of geoland2, and of the BioPar CMS, in the European GMES context are introduced. The research, development, production, and validation activities of the BioPar CMS are presented with a special focus on the first biophysical products available to the institutional users, and to the scientific community.

1. INTRODUCTION

With the ongoing climate change, the pressure on nature, biodiversity and our own living conditions increases steadily. To mitigate these trends by effective adaptation strategies and counter measures a frequent and area-wide monitoring of the environment is crucial to provide decision makers with accurate, up-to-date and reliable information on the changing conditions of our natural resources.

Within the GMES initiative (Global Monitoring of Environment and Security), led by the European Union (EU) and the European Space Agency (ESA), the Land Services provide cross-border harmonized geo-information at global to local scales in a time- and cost-effective manner. Building upon their results of a series of projects funded by the EU (geoland, Boss4Gmes, Cyclopes, VGT4Africa) and the ESA (GSE Land, GSE Forest Monitoring, DUE Globcarbon, DUE Globcover), geoland2 aims to organise a qualified production network, to build, validate and demonstrate operational processing lines and

to set-up a user driven product quality assurance process, to guarantee that the products meet the actual user requirements.

2. GEOLAND2

Geoland2 is a project of the 7th Framework Program which intends to constitute a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS). It addresses the three components (local, continental, global) of the LMCS.

The goal of geoland2 is:

- to prepare, validate and demonstrate pre-operational service chains and products that will underpin the LMCS
- to propose and demonstrate a concrete functional organisation of the LMCS

The architecture of geoland2 is made up of two layers (Figure 1): the Core Mapping Services (CMS) provide land cover, land use and land cover change, as well as a range of biogeophysical variables as an input to more elaborated products while the Core Information Services (CIS) offer specific information for European Environmental Policies and international treaties on climate change, food security and the sustainable development of Africa. The CIS are in direct contact with institutional end-users in charge of European policies, and Member State policies which have a generic pan-European character. They serve to estimate the added value of the CMS in comparison to existing approaches and to carry out a utility assessment of selected end-to-end service demonstrations.

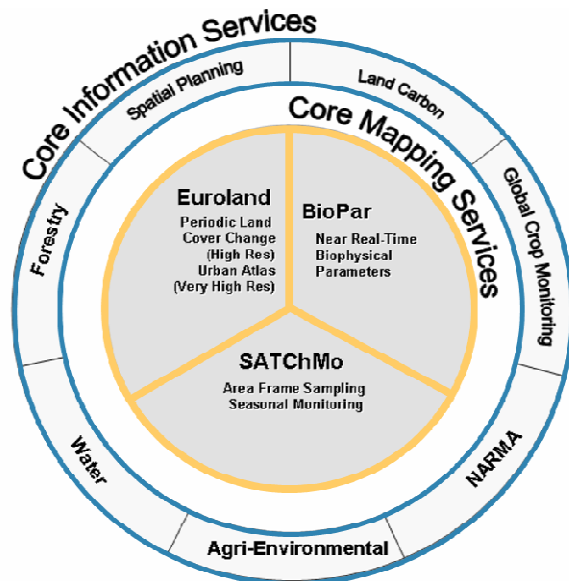


Figure 1. The geoland2 structure

The 3 Core Mapping Service tasks (Table 1) are:

- Land Cover & Land Use (Euroland): at local scale, Euroland produces VHR Urban Atlas inventory and change according to the specifications approved by DG REGIO in November 2007, on several tens of European cities. At continental scale, it produces over Europe and demonstration sites HR Land Cover inventory and change.
- Biogeophysical Parameters (BioPar): it produces in near real time (NRT) and off-line mode a series of biogeophysical variables describing the continental vegetation state, the radiation budget at the surface, and the water cycle. These products are derived mostly with Medium Resolution (MR) and Low Resolution (LR) data, at a global and continental scale, with a time frequency update from 3-hourly to 30 days.
- Seasonal & Annual Change Monitoring (Satchmo): it operates at continental scale over Europe and sub-Saharan Africa. It delivers: (i) a VHR/HR Area Frame Sampling over permanent samples representative for all European and African environmental/ecological conditions for annual statistics of land cover & land cover change; (ii) a complete MR continental coverage of seasonal and annual vegetation parameters to produce land cover change and agricultural land use. The time frequency of the product update is on the order of 3 -12 months.

Services	Scale	Portfolio Elements / Description	Area covered in geoland2
LMCS Infrastructure development and demonstration of production capacity			
LC / LCC (Euroland)	Local	VHR Urban Atlas Inventory VHR Urban Atlas Change	22 classes, 0.25 ha according to DG Regio definition 8 urban agglomerations 46 urban agglomerations
	Continental	HR Land Cover Inventory HR Land Cover Change	5 HR layers (quantitative layers), pixel-based and validated to 1 ha MMU Europe + demonstration sites
Seasonal / Annual Land Cover Changes (Satchmo)	Continental	VHR/HR Area Frame Sampling	Permanent Samples representative for all European and African environmental / ecological conditions for annual statistics and calibration & validation of Euroland and BioPar Europe (VHR) & Sub-Saharan Africa (HR) – continental coverage by local representative samples
		MR Seasonal Land Cover Dynamics	Complete continental coverage with medium resolution seasonal and annual vegetation parameters to support Euroland and agricultural monitoring Europe – sub-Saharan Africa
Biophysical Parameters (BioPar)	Global	HR / MR / LR Near Real Time and off-line monitoring of biophysical variables	Description of the continental vegetation, the radiation budget at the surface, and the water cycle Europe – Africa - Global

Table 1. The CMS portfolio

Services	Scale	Portfolio Elements / Description	Area covered in geoland2
Verification and Validation of LMCS Core Mapping Services			
Spatial Planning	Continental / Europe	Land take trends & Indicators, based on Euroland data, supporting spatial planning from regional to European scale	Europe + Demonstration sites
Agri-Environment	Continental / Europe	AgriEnv indicators based on Euroland and Satchmo for assessing the pressure and impact of agricultural management on the environment	Demonstration sites
Water	Continental / Europe	Assessing the status of water resources based on Euroland and BioPar by means of baseline & scenario modelling for efficient cross-border water management in support of the WFD	Europe + Demonstration sites
Forest	Continental / Europe	Forest (environmental) indicators based on Euroland in support of the reporting for MCPE, SEBI2010, UNCBD	Demonstration sites
Land Carbon	Global	Terrestrial carbon fluxes and the associated soil moisture, vegetation biomass and carbon storage	Globe
Natural Resources Monitoring	Africa	Contribution to building up the African environmental seasonal / annual change monitoring ("MONDE") component of the ACP observatory	Africa
Global Crop Monitoring	Global	Objective, real-time crop assessment and yield forecasts in support of EC policies in field Agriculture and Food Security	Europe + Globe

Table 2. The CIS portfolio

The 7 Core Information Services are being set-up with the following missions (Table 2):

- Spatial Planning: describe, explain and forecast urban land use change in Europe.
- Water: integrate EO derived LC/LU data in water quality models that can contribute to water management in Europe in flexible, sustainable and cost-efficient way.
- Forest: address specific user requirements from the European Environment Agency (EEA), DG JRC, and DG AGRI for improved forest class and biodiversity indicator information required for the LMCS and policy reporting requirements at a Pan-European level.
- Land Carbon: understand and assess the impact of weather and climate variability on terrestrial biospheric carbon fluxes, in the context of international conventions.

- Natural Resource Monitoring in Africa (NARMA): develop an environmental monitoring capacity over African countries for the needs of the EC services and for regional and continental EC partners in African countries.
- Global Crop Monitoring (GCM): provide objective, real-time crop assessment and yield forecasts in support to EC policies in the field “agriculture” (Common Agriculture Policy) and Food Security.

A cross-cutting Spatial Data Infrastructure (SDI) has been set-up with the aim to develop an operational service for the discovery, viewing, access, delivery and support of all products generated in the geoland2 project.

Altogether the geoland2 consortium, led by Astrium GmbH (Germany) and co-led by CNES (France), gathers 50 European partners from 21 European countries, and mixes three categories of private and public organisations: users, service providers and researchers.

3. THE BIOGEOPHYSICAL PARAMETER CORE MAPPING SERVICE (BIOPAR)

3.1 Introduction

The *Biogeophysical Parameter Core Service*, named in short BioPar, is a joint venture of 13 partners: HYGEOS, CNES, Infoterra France, INRA, and Météo-France (France), Université Catholique de Louvain (UCL), and VITO (Belgium), Institute of Meteorology (Portugal), Vienna University of Technology (Austria), EOLAB (Spain), University of Leicester, and ECMWF (United Kingdom), and Igik (Poland).

BioPar aims at setting-up validated operational infrastructure able to provide bio-geophysical variables describing the vegetation state, the radiation budget at the surface, and the water cycle at any scale of interest (regional, continental, and global), both in near real time and off-line mode, and that meets the users’ needs.

3.2 Concept

The BioPar concept relies on research and development activities, shared in 3 topics (vegetation, radiation, water), and on demonstration operations, shared in NRT and off-line processing (Figure 2). In particular, the R&D activities focus on parameters as LAI, FAPAR, albedo, burnt areas or soil moisture, which have been identified by the WMO/GCOS in the context of UNFCCC as Essential Climate Variables (ECV). The research teams define the retrieval algorithms based upon existing and validated methodologies, improve them to match as well as possible the user requirements, and initiate innovative actions to adapt them to the technical specificities of the next generation of sensors in order to ensure the continuity of the service. Effort will be put on the compatibility between historic and current products so that long-time series are available after the reprocessing of available EO archives. Independent teams perform the product validation, following a procedure established in close collaboration with the users and international bodies, relying on comparison with ground measurements collected over site networks, on inter-comparison with existing similar satellite products, and on data assimilation techniques, with the aim to guaranty the scientific relevancy of

the BioPar products. The development teams implement the algorithms in processing lines, and generate test data sets for user evaluation. The pre-operation centers perform the pre-operational production at regional, European and global scales, in NRT and in offline mode. Finally, the resulting biogeophysical parameters are disseminated by the Spatial Data Infrastructure cross-cutting issue, in a format in accordance with the INSPIRE directive.

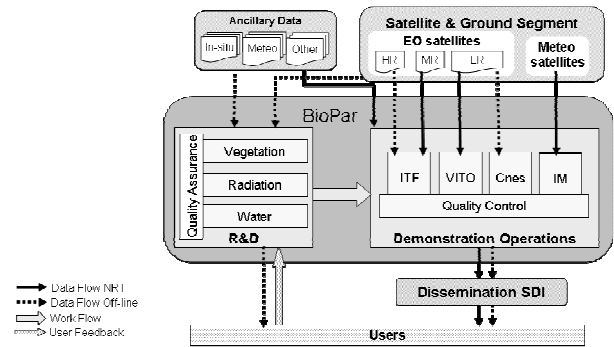


Figure 2. Main building blocks and generic data flow for BioPar processing lines

The BioPar CMS is a strongly user-driven service. The CMS portfolio has been designed from a careful analysis of the needs of CIS and other CMS, considered as good proxys of a large community of users including institutional users, future downstream services and the international science community. The study logic will be such that the products, their timeliness, and the R&D actions have been defined taking into account the users’ needs; the pre-operations, in NRT and in off-line mode, will start only with a user “green light”, given after they have successfully integrated test products into their current practices and working environment.

4. THE BIOPAR PRODUCTS

4.1 Service Portfolio

Product	NRT / Off-line	Spatial Resolution	Spatial coverage	Temporal Resolution	Sensor (Back-up)
Continental Vegetation					
LAI, FCOVER, FAPAR, DMP, NDVI, Phenology	NRT	1 km	Global	10-days	VTG (MODIS)
Times series of vegetation products	Off-line	4 km	Global	10-days	AVHRR + VGT
Burnt areas + seasonality	NRT	1 km	global	Daily	VGT
MERIS FR biophysical variables	NRT	300 m	Europe	10-days	MERIS
HR biophysical products	Off-line	10 m	Pilot Areas	4 times/year	SPOT
Energy Budget					
Downwelling Shortwave Surface Flux	NRT	~5 km	Global	3 hours	ΣGEO + AVHRR
Downwelling Longwave Surface Flux	NRT	~5 km	Global	3 hours, daily	ΣGEO + AVHRR
Land Surface Temperature	NRT	~5 km	Global	10-days	VTG
Surface Albedo	NRT	1 km	Global	10-days	ΣGEO + AVHRR
Surface Albedo	NRT	~5 km	Global	10-days	ΣGEO + AVHRR
Water cycle					
Water bodies + seasonality	NRT	1km, 250m	Africa	10-days	VTG, MODIS
Soil Moisture + Freeze/Thaw	NRT	0.1°	Global	Daily	ASCAT
Time series of soil moisture products	Off-line	25 km	Global	Daily	ERS-1&2 Scatt

Table 3. BioPar CMS Portfolio

The BioPar CMS portfolio includes vegetation (Leaf Area Index (LAI), Fraction of Absorbed PAR, Fraction of green cover, NDVI, Dry Matter Productivity, Phenology), burnt areas, downwelling shortwave and longwave radiation fluxes, land

surface temperature, surface albedo, burnt areas, soil moisture, products, provided at various spatial resolution depending on the sensor data used as input (Table 3).

Most of the products will be delivered in NRT in the sense of few days (less than one week), as requested by the final users who need to know the surface conditions within a few days of delay in order to react appropriately in case of anomaly, and to anticipate and manage the potential resulting problems. Detecting anomalies by comparing the current observation with a reference requires having consistent long time series. BioPar will provide such time series for some Essential Climate Variables (LAI, FAPAR, soil moisture) taking advantage of existing EO data archive, and developing sensor-independent methodologies.

4.2 LAI, FCover, FAPAR, NDVI derived from SPOT/VEGETATION sensor data

The leaf area index (LAI) is defined as half the total foliage area per unit of ground surface. The FCover is the fraction of ground unit covered by green vegetation. The FAPAR is defined as the fraction of photosynthetically active radiation absorbed by green vegetation for photosynthesis activity. The instantaneous FAPAR value at 10:00 solar time is used as a very good approximation to the daily integrated value under clear sky conditions. The Normalized Difference Vegetation Index (NDVI) corresponding to the SPOT-5/VEGETATION-2 sensor characteristics for its Red (B2) and NIR (B3) bands, is also provided.

The algorithm is based on already existing LAI, FAPAR, and FCover products to capitalize on the efforts accomplished and get a larger consensus from the user community. Following the published literature on products validation (Weiss, et al. 2007; Garrigues, et al. 2008), the best performing products were selected and combined to take advantage of their specific performances while limiting the situations where products show deficiencies. The selected products are re-projected onto the VEGETATION plate-carrée 1/112° grid, smoothed through time and interpolated at the 10 days frequency. Then the products are combined, and eventually scaled, to provide the fused product that is expected to give globally the ‘best’ performances. The fused products are generated for few years over the BELMANIP2 set of sites that is supposed to represent the possible range of surface types and conditions over the Earth (Baret, et al. 2006). Neural networks are then calibrated over this set of sites to relate the fused products to the corresponding atmospherically-corrected and directionally-normalized top of canopy SPOT/VEGETATION reflectances (Baret, et al. 2007).

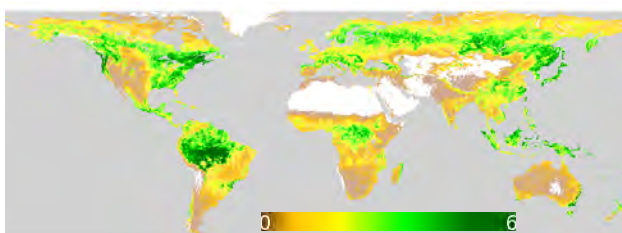


Figure 3: LAI derived from SPOT/VEGETATION, July 2002

Such methodology has been defined by INRA, and the processing line has been adapted by CNES, based upon an existing chain developed previously by Medias-France in the

framework of the FP5/CYCLOPES project. CNES has also generated two years of global, 10-daily products (example on Figure 3). Before the end of the year, the processing line will run in NRT at VITO. These vegetation products are being validated by EOLAB according to the protocol defined by the Land Product Validation (LPV) group of CEOS (Morissette et al., 2006).

The methodology will be adapted to the historical AVHRR surface reflectances made available by the LTDR project. The archive from 1981 will be processed to get a long time series (about 30 years) of vegetation variables fully consistent with the SPOT/VEGETATION products.

4.3 The set of biophysical variables derived from the FR MERIS sensor data.

The MERIS Full Resolution (FR) biophysical products, and the High Resolution (HR) biophysical products, contain a set of variables including estimates of the green, brown & soil cover fractions, the LAI, the FAPAR, the chlorophyll content, a canopy shadow factor, and the water & snow cover fractions.

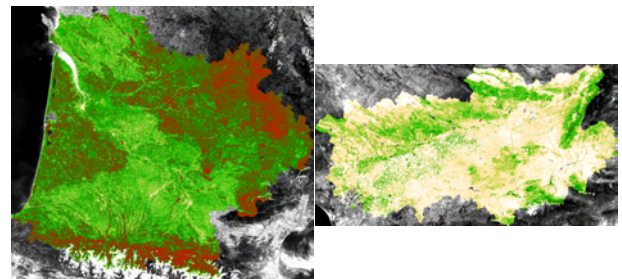


Figure 4. FAPAR over the Adour-Garonne river basin for June 2008 (left), and the Guadalquivir river basin for June 2006 (right) derived from MERIS FR data. The values vary from 0 (white) to 1 (red).

The baseline vegetation model developed for processing the MERIS data uses the SAIL/PROSPECT model as core component (Verhoef, 1984; Jacquemoud et Baret, 1990). This model was upgraded and completed in order to include the contribution of brown vegetation, the modelling of “rough” canopies, the computation of vegetation cover fractions in reference directional conditions, and the computation of FAPAR from the SAIL model. Then, to restore the heterogeneous nature of the MERIS pixels, a further modelling step is applied consisting in having a composite canopy model made of two components: 1) a main canopy component made of predominantly green vegetation, that may have all range of conditions from crops to forest/shrub canopies; 2) a second canopy component made of low brown vegetation, primarily designed to model either senescent crops/grasslands or bare soil conditions. Another important component of the developed model is the soil modelling, the soil reflectance being an input of the SAIL model. In this approach, the variation of soil brightness in relation with soil roughness and humidity is handled by performing an initial learning of the soil mean spectral signature in the MERIS bands at a regional level. Then, this signature is exploited through a physical model of soil variability, accounting for the soil shading and surface humidity effects. This scene model is then coupled with a model of the atmospheric transmission from Earth surface level to the sensor (Verhoef and Bach, 2003). The detection of water and snow covers is done through additional modelling of the

corresponding surfaces which are combined, as linear mixture, with the standard land model.

Infoterra France has elaborated the methodology above, developed the processing line, and ran it in off-line mode. Today, the existing MERIS FR (300m resolution) products covers some river basin across Europe (Rhine, Seine-Normandie, Guadalquivir, Adour-Garonne, Nemunas, Moselle-Sarre, Motala-Ström, Svetojci, Strymonas-Struma) for years of major interest for the final users (Figure 4). The production in NRT covering the whole Europe should start in the next weeks. These products are being validated by EOLAB, jointly with the products derived from SPOT/VEGETATION data (§4.2).

4.4 Soil Water Index (SWI) derived from ASCAT/Metop sensor data

The Soil Water Index is defined as the soil moisture content (in percent) in the soil profile. The retrieval algorithm uses an infiltration model describing the relation between Surface Soil Moisture (SSM) and profile soil moisture as a function of time. The algorithm is based on a two-layer water balance model (Wagner et al., 1999) to estimate profile soil moisture from SSM retrieved from scatterometer data. The remotely sensed topsoil represents the first layer and the second layer extends downwards from the bottom of the surface layer. In this model, the water content of the reservoir, whose depth is related to a characteristic time length (T), is described in terms of an index, which is controlled only by the past soil moisture conditions in the surface layer. A computational adaptation of the original SWI algorithm has been made based on a recursive formulation proposed by Albergel (2008). In this method, a gain factor is introduced that relates the past SWI measurements to the current measurements. The SWI processing algorithm uses ASCAT-25km SSM product as input to generate daily global SWI images, calculated for five different T values (1, 5, 10, 15, 20, 40, 60, 100) together with the respective quality flags.

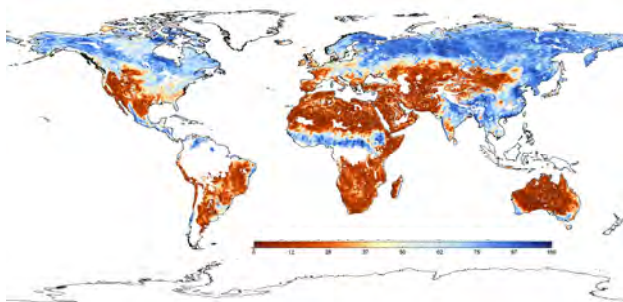


Figure 5. Global SWI derived from ASCAT/Metop data (25km resolution) for T=10 on 20th July 2007.

The retrieval algorithm is defined by Vienna University of Technology, the processing line is developed by CNES which has also generated the SWI products over the period from 1st June 2007 to the present (Figure 5). In few weeks, the processing line will run in near real time at the Institute of Meteorology of Portugal. The SWI products are being validated by Météo-France and ECMWF using in-situ observations, and operational, analyzed products from models running at global and regional scale.

A second version of the product is planned in the project life, including a more accurate detection of the freeze and thaw conditions of the surface. Then, the ERS/Scat data archive will

be re-processed in order to get a long time series of SWI fully consistent with the current ASCAT products.

4.5 The Surface Albedo derived from the SPOT/VEGETATION sensor data

The albedo is the fraction of the incoming solar radiation reflected by the land surface, integrated over the whole viewing directions. The BioPar albedo products include the directional albedo calculated for the local solar noon, and the hemispheric albedo, integrated over the whole illumination directions for 3 broad bands: visible [0.4, 0.7 μ m], near-infrared [0.7, 4 μ m], and the whole solar spectrum [0.3, 4 μ m]. The coefficients resulting from the inversion of a 3-kernels linear bidirectional reflectance model on the atmospherically-corrected SPOT/VEGETATION reflectances (Baret, et al. 2007) acquired during a period of 30 days are then combined with the pre-computed values of the directional kernels integrated over angular domains to estimate albedos. Finally, the broadband albedos are derived by linear relationships of spectral quantities.

This algorithm, and the processing line, have been previously set-up in the framework of the FP5/CYCLOPES project, by CNRM, and Medias-France, respectively. CNES has adapted the existing chain to the geoland2/BioPar specifications, and generated two years of global, 10-days products. Before the end of the year, the processing line will run in NRT at VITO. These SPOT/VEGETATION albedo products are being validated by EOLAB according to the protocol defined by the Land Product Validation (LPV) group of CEOS. An inter-comparison with the other BioPar albedo product (§4.6), derived by merging geostationary and polar sensors data, will be performed.

4.6 Other BioPar products

The radiation variables of the BioPar portfolio (Downwelling Shortwave Surface Flux (DSSF), Downwelling Longwave Surface Flux (DSLFL), Land Surface Temperature (LST), and albedo) will be generated by the fusion of geostationary and polar sensor data. The DSSF represents the short-wave fraction of the solar irradiance (0.3-4 μ m) reaching the soil background. The DSLFL is defined as the irradiance reaching the surface in the thermal infrared part of the spectrum (4-100 μ m). The LST is the radiative skin temperature of land surface. The albedo variables are the same as those retrieved using SPOT/VEGETATION data (§4.5). The Institute of Meteorology of Portugal is in charge of the algorithm definition, the processing lines development, and the production in near real time of the 4 products. These radiation variables correspond to an extension of those currently produced on an operational basis by the Satellite Application Facility on Land Surface Analysis (Trigo et al., 2010). While the latter are restricted to EUMETSAT sensors, Geoland-2 products make use of non-European geostationary satellites to increase area coverage. The demonstration DSLFL, and LST products shall be ready in the coming weeks, and the demonstration DSSF and albedo products shall be available by the end of the year.

The small water bodies product results from the fusion of two existing algorithms: the first one (Gond et al., 2004) was developed in the framework of VGT4AFRICA by the Joint Research Centre and is suited to arid and semi arid condition; the second one was developed for GlobalWatch project and was further developed in the context of Desert Locust prevention FAO product (Pekel, 2009). Both methods rely on different thresholds for the NDVI, the Normalized Difference Water

Index (NDWI), the Hue (from RGB to HSV transformation) and the reflectance in the middle infra-red of SPOT/VEGETATION data. The product includes also information about the seasonality, i.e. the date of filling and the date of drying. The Université Catholique de Louvain (UCL) is in charge of the methodology, whereas the processing line is developed and will run in NRT at VITO. The SPOT/VEGETATION water bodies product should be available before the end of the year. In a second step, the detection algorithm is being adapted to MODIS data (250m resolution) to identify smaller ponds.

The global burnt area product derived from the daily SPOT/VEGETATION data is still in development at the University of Leicester. Seasonality metrics (start, end and timing of maximum burning) are being added to the improved L3JRC algorithm (Tansey et al., 2008). At final, the processing line will be implemented and run at VITO. Further, in the project life, the methodology will be adapted to AATSR sensor data.

5. CONCLUSION

As geoland2 constitutes a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS), the BioPar CMS intends to bring a main brick to build the Global component of the LMCS. Through a global systematic monitoring service, the Global component of the LMCS aims to provide near real time bio-geophysical parameters at global scale, addressing primarily the 13 terrestrial ECVs, and describing the vegetation state and dynamic. The principal scope of the Global component of the LMCS is to deliver information products and services on the status and evolution of land surfaces in support to specific EU policies at international level and European commitments under international treaties and conventions, such as the three Rio conventions on Climate Change, Desertification and Biodiversity.

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7. ACKNOWLEDGEMENT

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