Geoland2 : Operational Delivery of Biophysical Products and Services for GMES Land Monitoring Core Service

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Abstract - Geoland2 project is part of the GMES EU-lead initiative and intend to prepare, validate and demonstrate pre-operational service chains and products of the Land Monitoring Core Service (LMCS). The LMCS is made of 3 Core Mapping Services (CMS) providing "basic" land products, and 7 Core Information Services (CIS) which generate more "elaborated" information. One CMS, called BioPar, provides near real-time and off-line biophysical variables describing the continental vegetation state, the radiation budget at the surface, and the water cycle.

Several BioPar product lines have been developed by CNES and are currently under operational integration by VITO and IM, which will provide operational products beginning of 2011.

The paper describes the organization set-up to build the system with the team in charge of algorithm definition, validation, production and dissemination. The emphasis will be put on the qualification procedure and on the content of the free operational products.

Keywords: Environment, Monitoring, Land, Parameters, Services, Production, Near-real-time, Global

1. THE GEOLAND2 / BIOPAR PROJECT

1.1 Geoland2 Overview

The FP7 geoland2 project is part of the GMES EU-lead initiative and intends to prepare, validate and demonstrate pre-operational service chains and products of the Land Monitoring Core Service (LMCS), and to propose its specific functional organization. The Geoland2 consortium includes 50 European partners: private companies, public institutions, service providers, research laboratories, etc .

Geoland2 is made of 3 Core Mapping Services (CMS) providing "basic" land products, and 7 Core Information Services (CIS) which are thematic elements using the CMS products to generate more "elaborated" information addressing specific European policies. The 3 CMS deliver global to local maps at various temporal scales in the following areas of interest : land cover change and urban atlas, biophysical parameters, seasonal monitoring and global land cover change.

1.2 The BioPar Core Mapping Service

The goal of the Biogeophysical Parameters Core Mapping Service (BioPar CMS) is to set up pre-operational infrastructures for providing an extensive range of bio-geophysical parameters on regional, European, and global scale, both in near-real-time (NRT) and off-line mode (See [1]). The bio-geophysical variables of the BioPar portfolio describe the vegetation state, the energy budget at the surface level, and the water cycle.

1.2.1 Concept and objectives

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 is put on the compatibility between historic and current products so that long-time series are available after the reprocessing of existing EO archives.
The development teams implement the algorithms in processing lines, and generate test data sets for for validation and user utility assessment. Independent teams perform the product validation, following protocols established at international level, with the aim to guaranty the scientific relevancy of the BioPar products. The user feedbacks are taken into account before starting the operational NRT production, and for the development of the second version.
The operation centres integrate processing lines in their production infrastructures, and perform the pre-operational production at regional, European and global scales, in NRT and in offline mode, with the periodicity required by the users.
Finally, the resulting biogeophysical parameters are disseminated by the Spatial Data Infrastructure (SDI) in a format in accordance with the INSPIRE directive.

1.2.2 Porfolio

Product	NRT Off-line	Spatial resolution	Spatial coverage	Temporal resolution	Sensor (Backup)
Continental vegetation					
Vegetation variables : LAI, fCover, fAPAR, DMP, NDVI, Phenology	NRT	1 km	Global	10-days	VGT
Climatology : LAI, fAPAR, fCover	Off-line	1 km	Global	Yearly	VGT
Time series of vegetation products: LAI, fAPAR, fCover, NDVI	Off-line	4 km	Global	10-days	VGT, AVHRR
Energy budget					
Surface albedo	NRT	1 km	Global	10-days	VGT
Water cycle					
Soil moisture & Freeze / Thaw	NRT	25 km	Global	Daily	ASCAT
Time series of soil moisture & F / T	Off-line	25 km	Global	Daily	ERS1&2 Scatt

Table 1 : BioPar products characteristics

CNES is involved in the development of the following products:

- The Leaf Area Index (LAI), fraction of vegetation Cover (fCover), fraction of Absorbed Photosynthetically Active Radiation (fAPAR), Normalized Density Vegetation Index (NDVI) derived from SPOT/VGT data in NRT
- The long time series of these vegetation variables derived from AVHRR and SPOT/VGT archives
- The climatology of LAI, fAPAR and fCover variables
- The Surface Albedo derived from SPOT/VGT in NRT
- The Soil Water Index (SWI) and Freeze / Thaw index derived from Metop/ASCAT data in NRT and from the ERS scatterometer archive

2. PROJECT ORGANIZATION

2.1 Partnership and role breakdown

Table 2 shows the breakdown of activities among the BioPar partners for providing vegetation and soil moisture products. Definition, development, validation and production are shared between several European institutions from Austria, Belgium, France, Spain, Poland and Portugal.

Product	Type	Definition	Development & test data	Product validation	Production
Vegetation variables : LAI, fCover, fAPAR, NDVI	NRT	INRA (F) HYGEOS (F)	CNES (F)	EOLAB (Sp), INRA (F)	VITO (Be)
Climatology : LAI, fAPAR, fCover, NDVI	Off-line	INRA (F)	CNES (F)	EOLAB (Sp)	CNES (F)
Time series of vegetation products	Off-line	INRA (F)	CNES (F)	EOLAB (Sp)	VITO (Be)
Surface albedo	NRT	HYGEOS (F)	CNES (F)	EOLAB (Sp)	VITO (B)
Soil moisture & Freeze / Thaw	NRT	TU Wien (A)	CNES (F)	Meteo-France, ECMWF	IM (Pt)
Time series of soil moisture & Freeze / Thaw	Off-line	TU Wien (A)	CNES (F)	Meteo-France, ECMWF	CNES (F)

Table 2 : Project organization for vegetation and soil moisture products

INRA (F), HYGEOS (F) & TU Wien (A) define the product content and produce the specification set (documentation, prototype, reference products). CNES (F) develops the processing lines and produces the test data set. EOLAB (Sp), INRA (F), Meteo-France & ECMWF validate the test data set and assess the scientific content of the product. VITO (Be), CNES (F) & IM (P) perform the operational production disseminated through the geoland2 SDI portal and through EUMETSAT's EUMETCast satellite based dissemination system.

2.2 Development logic

2.2.1 Inputs

There are several inputs needed by CNES for the development phase and test data production.

First the definition team provides an Algorithm Theoretical Based Document (ATBD) which describes in detail the algorithm to be implemented: methodology, physical assumptions, formulas, input data description, processing steps, flowcharts, …
For the vegetation products INRA provided the vegetation variable ATBDs and HYGEOS provided the albedo and filtering/gap filling ATBDs. For the soil moisture product, TU Wien provided the SWI ATBD.

Secondly, the operational centres expressed their interfaces requirements.
VITO provided the coding specification document, which explains the software convention that shall be used (general coding rules, computer platform issues, filename and directory structure conventions) and the Product Output Format document, which specifies the format used at VITO and gives a detailed description of files contents and name conventions.
IM provided the Algorithm Plugging Interface Document (APID), which includes their software conventions, and their Product Output Format document.

Thirdly, TU Wien delivered to CNES an IDL prototype used for the development of the SWI V1 product line. This prototype has been used as an example of algorithm implementation and for the technical qualification of the product by cross-checking of prototype output and test data, before delivery of them to the validation team.

Fourthly, CNES has taken over the processing line developed for the CYCLOPES project ([2], [4]) by the former land surface thematic centre POSTEL. This processing line has been used until 2009 to produce vegetation variable products from VGT instrument data until year 2007. This processing line is the baseline for the development of improved vegetation variables. INRA has delivered to CNES a Matlab prototype of the Neural Network used at the last stage of the processing line, in order to verify the implementation of the new structure and weights.

2.2.2 Reviews

During the design phase, CNES gathered requirement set (ATBD, operational interface, output format, …) and to perform the development in an industrial environment because it includes a better quality frame by the use of external reviews at different steps of the development process. CNES has performed three reviews where experts from the BioPar partners were present.

The System Requirement Review took place in July 2009 and demonstrated how far:

- the Service Specification answers to the User Requirements Document (URD)
- the processing line design answers to the Service Specification requirements
- the external interfaces and operation requirements are taken into account during the development
- the Service Validation Plan (SVP) implements the necessary verification steps to validate the requirements of the URD and the commitments of the Service Specification.

This review has shown a deep knowledge of the existing vegetation processing line, a capability to propose discerning changes to match the specifications and the requirements of the production centres, and also a rigorous methodology of validation based upon unit & integration tests, and upon scientific analysis of the output using tools including visual control, and statistic data analysis

Due to the huge reuse of Cyclopes processing line, the Preliminary and Critical Design reviews have been merged in one review which took place in October 2009. The purpose of the Preliminary Design Review was to assess and approve the preliminary design and assess the readiness to start the implementation phase. The purpose of the Critical Design Review was to assess and approve the detailed design of the processing lines and the detailed definition of the interfaces.
The P-CDR review raised 50 questions & answers from the review group, which have been analyzed and discussed. The P-CDR concludes that all the objectives are fulfilled, excepted for BUFR interfaces of the SWI product (lack of detailed format).

The Industrial Acceptance Review addresses the result of the acceptance test (installation from scratch and testing of the processing line). The IAR has been performed and accepted for the vegetation variables and is currently performed for the SWI product.

After this milestone, CNES delivers the processing lines to VITO and IM. Then VITO and IM will organize the Validation Readiness Review (VARR) and the Operational Readiness Review (ORR) of their processing line. CNES will participate in these reviews.

2.2.3 Demonstration products

2.2.3.1 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, 0.7µm], near-infrared [0.7, 4µm], and the whole solar spectrum [0.3, 4µm]. The coefficients resulting from the inversion of a 3-kernels linear bidirectional reflectance model on the atmospherically-corrected SPOT/VGT reflectances ([2]) 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.

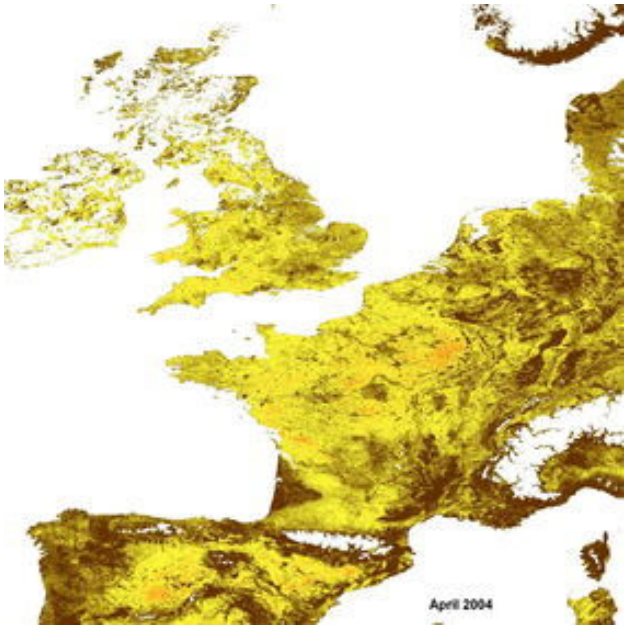

Figure 1 : Surface albedo derived from SPOT/VGT, April 2004

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

The leaf area index (LAI) is defined as half the total green area per unit of horizontal ground surface. The FCover is the fraction of ground unit covered by green vegetation. The FAPAR is defined as the daily fraction of photosynthetically active radiation absorbed by green vegetation considering 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. Following the published literature on products validation ([4], [5]), the best performing products were selected and combined to take advantage of their specific performances while limiting the situations where products show deficiencies. The detailed description of the methodology, based upon neural network calibrated over the BELMANIP2 set of sites to relate the fused products to the corresponding atmospherically-corrected and directionally-normalized top of canopy SPOT/VEGETATION reflectances, is given in [6].

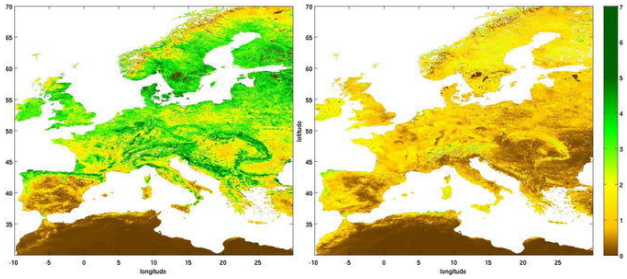

Figure 2 : LAI on Europe, July 2003 - January 2004

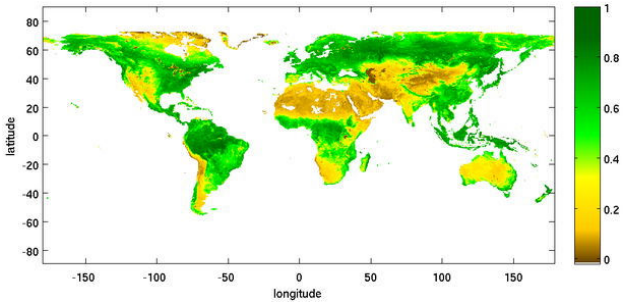

Figure 3 : Global NDVI data set, July 2004

The albedo and vegetation variables test data set includes 10-day products from February 2003 to January 2005, issued from VGT2-P data provided by VITO.

2.2.3.3 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 (T). The algorithm is based on a two-layer water balance model ([7]) to estimate profile soil moisture from SSM retrieved from scatterometer data. A computational adaptation of the original SWI algorithm has been made based on a recursive formulation proposed by [8]. 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.

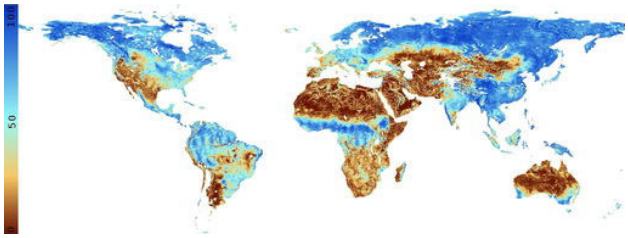

Figure 4 : Global SWI data set, July 15th 2003, T = 10

The SWI test data set includes data from June 2007 up to the present.

2.2.4 User utility assessment

The surface albedo product and the vegetation products (LAI, FCover, FAPAR & NDVI) have been validated by EOLAB according to the protocol defined by the Land Product Validation (LPV) group of CEOS ([3], [9]). Conclusions are that vegetation products have a good quality, with smooth

temporal profiles and high temporal and spatial consistency. The data filtering does not introduce significant improvements and the gap filling shall not exceed 8 consecutive observations.

The user utility assessment has been performed until October 2010. SWI products have been analysed by Land Carbon CIS represented by Météo-France. Product content has a good quality and some improvements have been decided: implementation of an improved detection of freeze/thaw conditions in version 2 and product reprocessing with the new calibrated SSM data.
Vegetation products have been validated by Land Carbon, Global Crop Monitoring (GCM) and NARMA CIS. They authorized the product distribution after some minor format adaptations, and recommended that the products represent really the present state of the surface. This will be taken into account in Version 2 with a new compositing approach. NARMA suggested that the product shall be more user-friendly. To deal with that, a tool, called VGTExtract, allowing format conversion, tile sticking, and area cropping, is provided with the products through the SDI Expert portal.

2.2.5 Processing lines

The version 1 of vegetation variable processing line has been delivered to VITO in June 2010. A new release, which takes into account the improvements requested by the users utility assessment, has been delivered in January 2011.

The SWI processing line has been delivered to the Institute of Meteorology (IM) from Portugal in June 2010. A new release, including Freeze/Thaw index and input format adaptation, shall be delivered in February 2011.

2.3 Operational production

The production teams (VITO and IM) integrate the processing lines in their automated pre-operational systems. These systems demonstrate production in NRT and in off-line mode, to archive and distribute the products to users. The processing lines are optimized to ensure operational management with permanent quality control, optionally including a backup service.
CNES is currently developing the climatology processing line which will process the vegetation archive to provide, in 2011, the yearly climatology products (see table 1 & 2).

3. CONCLUSION

CNES received feedback from users and from the validation team. Some change requests considered relevant to the entire community have been implemented in a new version of both processing chains. The operational production implementing the user requests will begin in 2011.
All the demonstration products are freely available, with a Product user Manual document (PUM), on the Geoland2 SDI Expert portal.
The methodology is being to be adapted to the historical AVHRR surface reflectances made available by the LTDR (Long Term Data Record) project. The archive from 1981 will be processed to get a 30-years time series of vegetation variables fully consistent with the SPOT/VGT products.

Development will continue on the same scheme and new versions are foreseen. Version 2 of vegetation variable processing line, available end of 2011, will improve the overall performance of the product line by applying directly the neural network to the VGT-P top of atmosphere reflectance. Soil Water Index & Freeze/Thaw Version 2 will improve the detection of freeze/thaw surface conditions.

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6. QUESTIONS

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7. WEB SITES

Geoland 2 : http://www.gmes-geoland.info
SDI Expert portal : http://www.geoland2.eu/
CNES : http://www.cnes.fr
POSTEL: http://postel.mediasfrance.org