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PROVIDING PROCESSING LINES AND TEST DATA FOR THE 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), and to propose its specific functional organization. The architecture of 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. One CMS, called BioPar, is dedicated to the production in near real-time and off-line mode of biophysical variables describing the continental vegetation state, the radiation budget at the surface, and the water cycle.
We focus here on the following product lines: the Leaf Area Index, the Fraction of green Vegetation Cover, the Fraction of PAR absorbed by the vegetation, the NDVI, the surface albedo, and the Soil Water Index. Until 2012, the objective is to define, develop, validate, and run 2 versions of the processing lines. For each version, test data sets are generated: they are dedicated to the scientific validation performed by independent team, and to the product utility assessment carried out by the CIS users.
The talk will describe the organization setup to build the system, including the interfaces upstream with the team in charge of the algorithm definition, and downstream with the production centre which will perform the operation and dissemination. The emphasis will be put on the qualification procedure applied at each step of the development process. The test data sets, available during the
second quarter of 2010, will be presented. Furthermore, we will show the main results of the validation procedure which relies on comparison with ground measurements, and on inter-comparison with similar EO-based products, and the first feedback about the utility of these products for the users' applications.

1. THE GEOLAND2 PROJECT

1.1 Structure

The FP7 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), 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 (Figure 1). The 3 CMS deliver global or local maps at various temporal scales in the following areas of interest :

- Euroland : Periodic land cover change and urban atlas
- BioPar : near real-time and off-line biophysical parameters
- SATChMo : Area frame sampling for seasonal monitoring and global land cover change

The 7 Core Information Services (CIS) use the CMS products to provide high level analysis maps on the following topics :

- Land Carbon
- Global Crop Monitoring
- Natural Resource Monitoring in Africa (NARMA)
- Agricultural Environment
- Forest
- Water
- Spatial Planning.

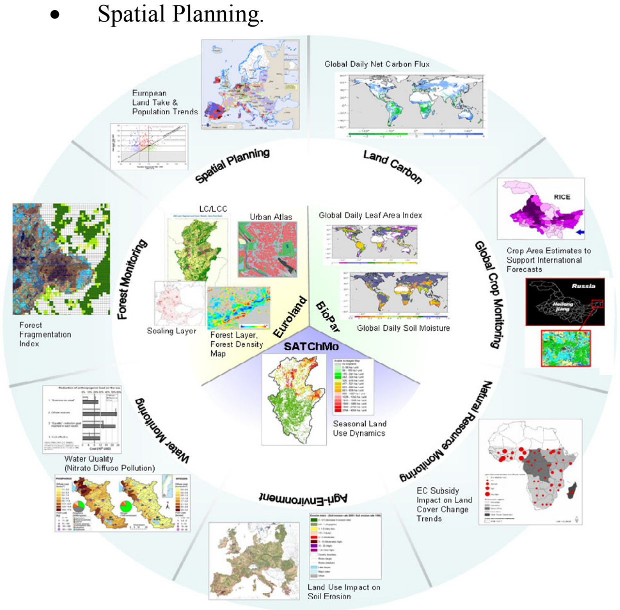


Figure 1 : GEOLAND2 project organization

Products and services provided by the GEOLAND2 project will be available to users to the Spatial Data Infrastructure (SDI) portal.

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. The bio-geophysical variables of the BioPar portfolio (see table 1) describe the vegetation state, the energy budget at the surface level, and the water cycle [1].

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	VGT (MODIS)
Climatology : LAI, fAPAR, fCover	Off-line	1 km	Global	Yearly	VGT
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 Downwelling Longwave Surface Flux	NRT	~5 km	Global	3 hours	ΣGEO + AVHRR
Land Surface Temperature	NRT	~5 km	Global	3 hours, daily, 10-days	ΣGEO + AVHRR
Surface Albedo	NRT	1 km	Global	10-days	VGT
Surface Albedo	NRT	~5 km	Global	10-days	ΣGEO + AVHRR
Water cycle					
Water bodies + seasonality	NRT	1km 250m	Africa	10-days	VGT, 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 1 : BioPar products characteristics

CNES is involved in the development of the following products (see table 1) :

- 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
- Soil Water Index (SWI) and Freeze / Thaw index derived from Metop/ASCAT data in NRT and from the ERS scatterometer archive
- Surface albedo derived from SPOT/VGT data in NRT

2. DEVELOPMENT OF PROCESSING LINES

2.1 Organization

The development concept relies on user product assessment and feedback : the development team implement algorithms specified by the definition team and generate test data sets for validation and user utility assessment. The user feedback is taken into account for the development of the second version.

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 existing EO archives.
Independent teams perform the product validation, following a procedure established in close collaboration with the users, 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. For such activity, we will test the usefulness of an innovative network of automatic sensors to monitor the vegetation variables on a long term basis.
The development teams implement the algorithms in processing lines, and generate test data sets for user evaluation.
The pre-operation centres 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 will be disseminated by the Spatial Data Infrastructure cross-cutting issue, in a format in accordance with the INSPIRE directive.

Table 2 shows the sharing of activities among the BioPar partner for the providing of vegetation and humidity products where CNES is involved. Definition, development, validation and production are shared between several European institutions from Austria, Belgium, France, Spain, Poland and Portugal.
INRA (F), HYGEOS (F) & TU Wien (A) define the product content and produce the specification set (documentation, prototype, reference products).
CNES (F) develop the processing lines and produces the test data set.
EOLAB (Sp), INRA (F), IGiK (Pl), Meteo-France & ECMWF validate the test data set and asses the scientific content of the product.
VITO (Be), CNES (F) & IM (P) perform the operational production disseminated through the SDI portal.

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), IGiK (Pl)	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)
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 : Activities sharing for vegetation and humidity product

2.2 Inputs

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

First the definition team provided Algorithm Theoretical Based Documents (ATBD) which describe in detail the algorithm to be implemented : methodology, 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, the vegetation products derive from an existing processing line named Cyclopes, developed and used by the former land surface thematic centre POSTEL [2 & 3]. This processing line has been used until 2009 to produce vegetation variable products from VGT instrument data until year 2007 (see figure 2). This issue of vegetation variables is named version 0 (V0).
CNES has taken over the former activities around Cyclopes and the version V0 is used as the baseline from the development of new vegetation variable processing lines.

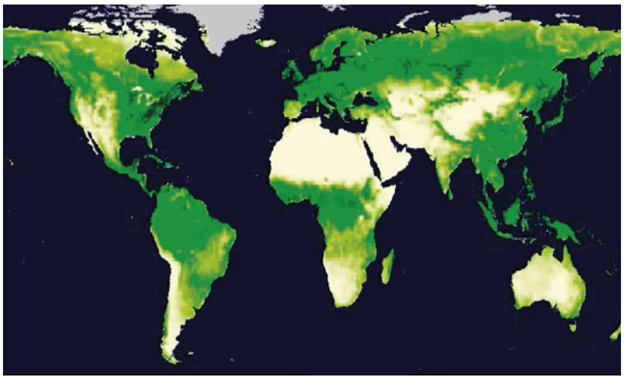


Figure 2 : FCover map (0 = white = bare soil, 1 = dark green = fully vegetated) from Cyclopes V0, © POSTEL/INRA

INRA 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.

2.3 Development process

During the design phase, CNES gathered requirement set (ATBD, operational interface, output format, …) and made a call for proposal for the development and test data phase. Vega Technologies company, based in Toulouse (Fr), has been selected in June 2009 and has developed the first versions of processing lines.

The development is performed in an industrial environment for two reasons.

The re-use of Cyclopes V0 needs a detailed and accurate knowledge of the existing processing line, in order to modify efficiently the six processing steps providing the albedo product (Level 3A) and the four vegetation products (Level 3B) from the VGT level 1 data.

More important, the industrial context includes a better quality frame by the use of external reviews at different steps of the development process. CNES has performed three reviews with its subcontractor, 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.

VEGA Technologies has shown his deep knowledge of the existing processing line of the vegetation variables and was able 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 is to assess and approve the preliminary design and assess the readiness to start the implementation phase. The purpose of the Critical Design Review is 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 address the result of the acceptance test (installation from scratch and testing of the processing line) performed at the sub-contractor premise and at CNES. 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, with a support of the subcontractor if needed. 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.

2.4 Outputs

2.4.1 Processing lines

The version 1 of vegetation variable processing line has been delivered to VITO in June 2010. After integration in the operational environment, expected before the end of the year, VITO will produce in NRT the vegetation variable and albedo product, and reprocess off-line the VGT archive to produce the time series of vegetation products.
CNES is currently developing the climatology processing line which will process this archive to provide, in 2011, the yearly climatology products (see tables 1 & 2).

The SWI processing line has been delivered to the Institute of Meteorology (IM) from Portugal in June 2010. After integration in the operational environment, expected before the end of the year, IM will produce in NRT the soil moisture product.

2.4.2 Demonstration products

Together with the processing lines, CNES delivers to the validation team and end users a test data set corresponding to the products that will be delivered by the operational processing line. All these data sets are available on the SDI web portal, with a Product User Manual document (PUM) describing their technical characteristics.

In 2009 CNES has generated 4 years of Cyclopes V0 vegetation products (2004 to 2007) which have been used by INRA to calculate the best neural network weights for the V1 vegetation processing line. These products are available on the Postel web server.
The vegetation variables test data set includes 10-day LAI, fAPAR, fCover & NDVI products from February 2003 to January 2005, issued from VGT2-P data provided by VITO.
The first test data sets have been delivered mid-April 2010 and analysed by INRA (Fr), who detected a large difference with former products (V0 Cyclopes, MERIS products). This difference came from the fact that the neural network had been calibrated on Cyclopes V0 L3A data, while these new neural network weight were applied on V1 L3A data.
During May 2010 the neural network has been calibrated on V1 L3A data and L3B test data have been re-produced with the new neural network weights.
The new vegetation test data sets have been delivered to the users beginning of June 2010.

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

The first delivery of SWI test data sets to TU Wien and Meteo-France took place end of March 2010, with a time length value of T = 10, 20, 40, 60 & 100. The analysis shown that above T = 20 the SWI values where the same, and a code mistake has been corrected.
More, after analysis, it has been decided to extend the product range to lower values of T= 1, 5 & 15, in order to have a better analysis depth by avoiding the figure stagnation due to the T exponential integration (see §3.3 SWI product characteristics).
The second version of test data sets have been delivered end of April 2010 and validated mid-May 2010. In order to have a service continuity with the end users until the product availability at IM (Pt), CNES produces monthly the SWI products and keep available the current archive, from June 2007 up to the present.

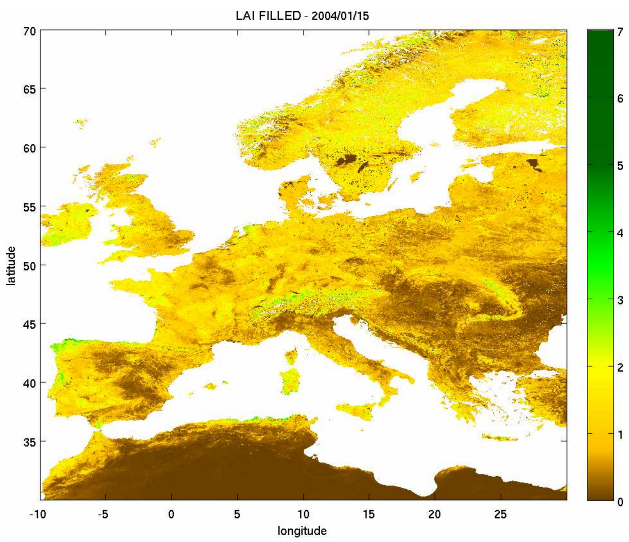
3. THE DEMONSTRATION PRODUCTS

3.1 LAI/fAPAR/FCover/NDVI from SPOT/VGT

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 (See [3]), 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. 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.

The product has the following characteristics (see the PUM document on SDI for more details) : variables values with error and quality flags, spatial resolution 1 km, temporal resolution 10 days, geometric accuracy < 300 m, thematic target accuracy 5% to 15%, global coverage by square tiles of 10°.



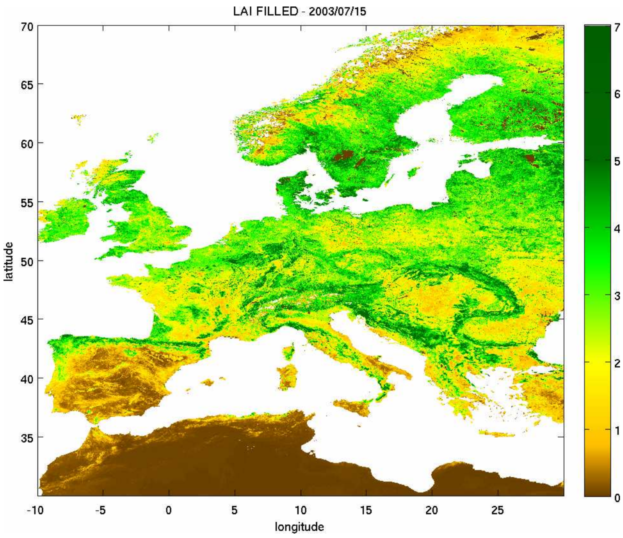


Figure 3 : LAI data sets, © CNES/INRA/HYGEOS/VITO.

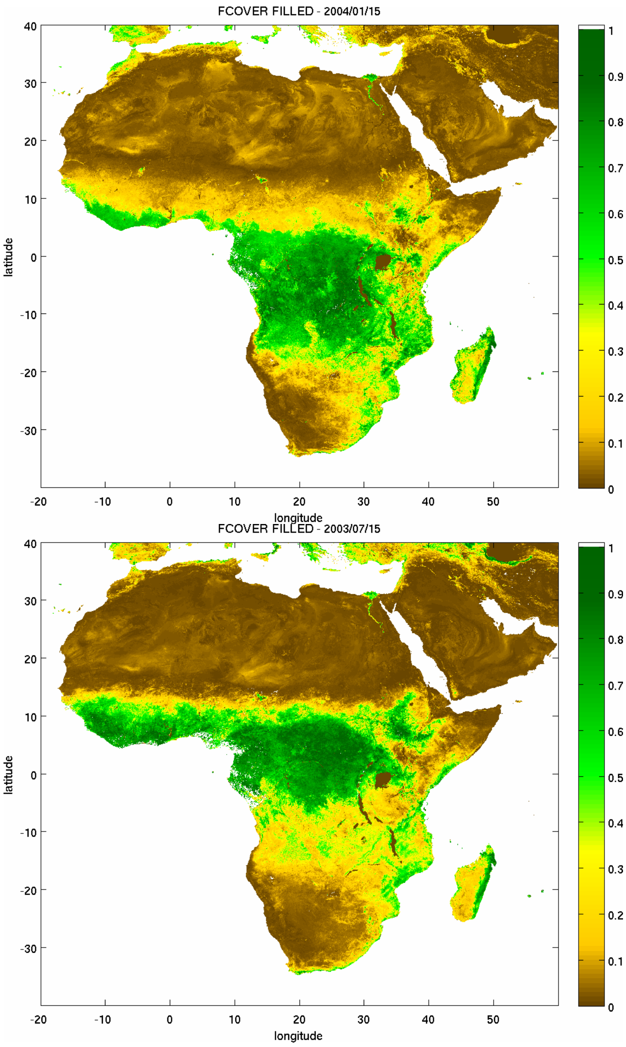
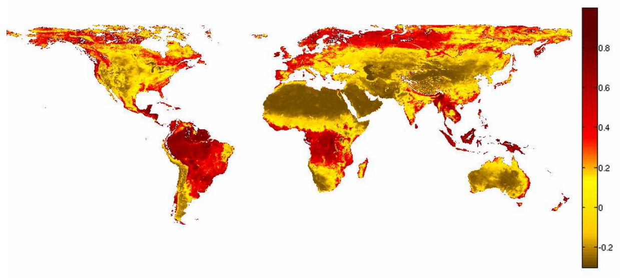
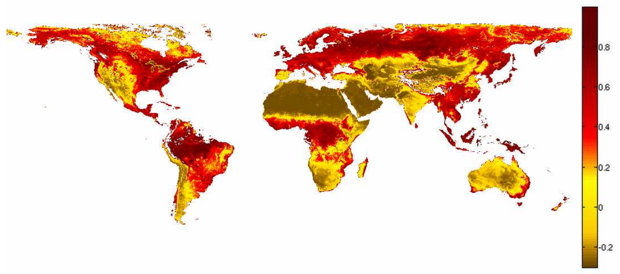


Figure 4 : fCover data sets, ©CNES/INRA/HYGEOS/VITO.



January 15th 2004



July 15th 2003

Figure 5 : fAPAR data sets, © CNES/INRA/HYGEOS/VITO.

3.2 Albedo from SPOT/VGT

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 (also called "black-sky albedo), and the hemispheric albedo, integrated over the whole illumination directions (also called "white-sky albedo") 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/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.

The product has the following characteristics (see the PUM document on SDI for more details) : reflectance values with error and quality flags, spatial resolution 1 km, temporal resolution 10 days, geometric accuracy 10%, thematic target accuracy 10%, global coverage by square tiles of 10°.

3.3 Soil Water Index (SWI)

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 and profile soil moisture as a function of time. The algorithm is based on a two-layer water balance model proposed by 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 Level 2 Soil Surface Moisture product as input to generate daily global SWI images, calculated for 8 different T values (1, 5, 10, 15, 20, 40, 60, 100) together with the respective quality flags.

The product has the following characteristics (see the PUM document on SDI for more details) : index values quality flags, spatial resolution 25 km, temporal resolution 1 day, geometric accuracy 4 km, thematic target accuracy 10%, global coverage.

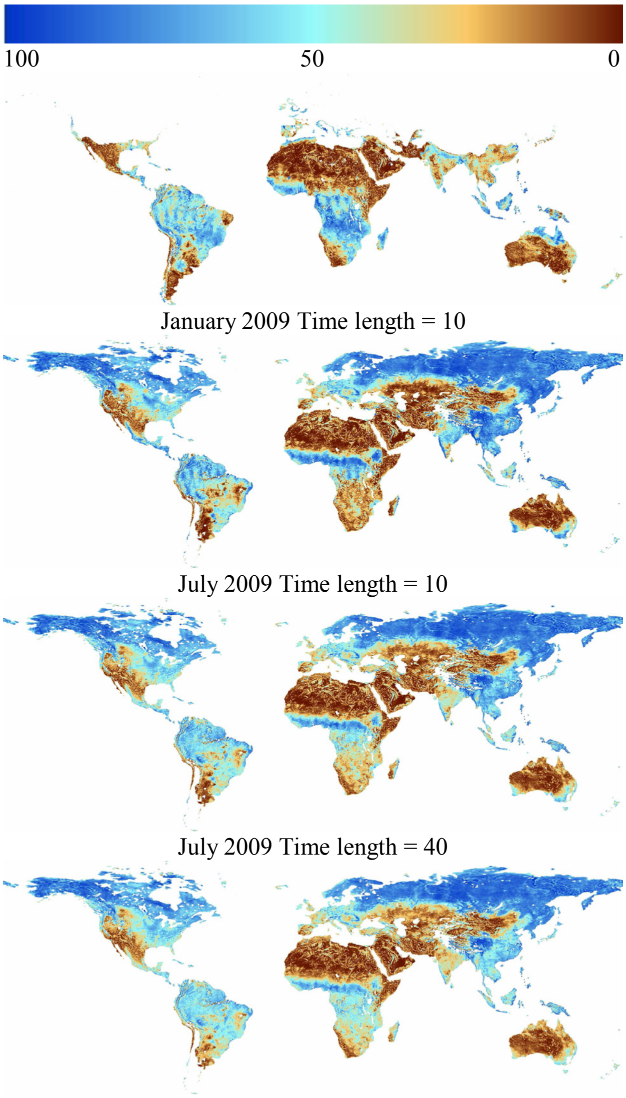


Figure 6 : Soil Water Index data sets, © CNES/TU Wien.

4. CONCLUSION

These first deliveries of BioPar test data show that vegetation and humidity variables products are know qualified and available for end users analysis. The product lines shall be operational for NRT processing in the production centres (VITO & IM) before the end of the year. All the products are available on the SDI web portal.

Development will continue on the same scheme and new versions are foreseen :

- Version 2 of vegetation variable processing line will improve the overall performance of the product line by applying directly the neural network to the VGT-P top of atmosphere reflectance. Products shall be available end of 2011.
- SWI & F/T Version 2 will improve the detection of freeze/thaw surface conditions and shall be available beginning of 2012.

CNES participate also to the SATChMo Core Monitoring Service (see figure 1) and will deliver end of 2011 a medium resolution land cover change map from MODIS data, on Europe and Africa. The development activities, shared with Université Catholique de Louvain in Belgium and the Institute of Geodesy and Cartography in Poland, will follow the same engineering cycle that BioPar.

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6. WEB SITES

Geoland 2 : http://www.land.eu
SDI portal : http://www.geoland2.eu/
POSTEL : Land surface thematic centre, http://postel.mediasfrance.org/
CNES : http://www.cnes.fr
VEGA Technologies : http://www.vegatechnologies.fr