

TOWARDS A EUROPEAN SERVICE CENTER FOR MONITORING LAND SURFACES AT GLOBAL AND REGIONAL SCALES : THE GEOLAND / CSP PROJECT

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ABSTRACT:

The European GMES (Global Monitoring of the Environment and Security) initiative provides a political framework for future implementations of Service Centers in charge of the provision of products and services related to environmental applications. The GEOLAND project targets the land cover and vegetation thematic area of GMES. The goal of GEOLAND is to demonstrate pre-operational capabilities by establishing strong and efficient producer / user relationships, with the objective of implementing GMES operational services in 2008 and beyond. One of the main goals of GEOLAND is to address global land surface monitoring issues to support related international and European policies. This activity has been structured in GEOLAND in one Core Service, the *Bio-geophysical Parameter Core Service*, and three Observatories related to carbon flux, crop production and land cover change estimates. The function of the Core Service is to provide value-added remote sensing products needed as input in the Observatories ; the latter provide end users (including policy makers) with appropriate thematic products. After a series of introductory statements on GMES and GEOLAND, the present paper focusses on the description of the *Bio-geophysical Parameter Core Service*. The team produces a number of bio-geophysical products at continental and global scales : leaf area index, vegetation fraction cover, downwelling radiation at surface level, surface temperature and humidity, burned areas, maps of water bodies, evapotranspiration, and precipitation. Multi-year, multi-sensor products will be produced in the project lifetime, from a variety of spaceborne instruments including VEGETATION, MERIS, POLDER, SEVIRI, METEOSAT, AVHRR, (A)ATSR, ERS / Scatt, and AMSR. The paper describes the team organisation, the generated products and associated methodological principles and sensors.

1. INTRODUCTION

There is an increasing need of environmental databases, not only for scientific purpose, not only for operational meteorology, but also for many emerging applications at all scales, e.g. early warning of food shortage, carbon flux assessment, monitoring land cover and forest degradation, urban and agricultural planning, water quality assessment, monitoring of protected areas, etc.

The GMES (Global Monitoring of Environment and Security) initiative led by the European Union (EU) and the European Space Agency (ESA) constitutes an adequate framework for providing not only space and ground segment infrastructures, assuring the operational continuity of space missions, but also the future implementation of Service Centers in charge of the provision of adequate products and services.

GMES can potentially be considered as a European component of a wider international initiative which was set up by the ad

hoc intergovernmental Group on Earth Observation (GEO) at the international summit of Washington in July 2003.

The GMES timeframe includes an implementation period, where the demonstration of pre-operational capabilities should be made, up to 2007, followed beyond 2008 by an operational period with the onset of operational services. In the implementation period, GMES actions are being undertaken by EU, through the 6th Framework Program of the Research General Directorate, and by ESA, with the onset of the so-called GMES Service Elements program.

The GMES initiative covers environmental issues related to the Ocean, the Atmosphere and Land Surfaces. For the latter, the GMES priorities are :

- Land Cover Change in Europe
- Environmental Stress in Europe
- and Global Vegetation Monitoring.

2. GEOLAND

GEOLAND is a GMES project of the 6th Framework Program covering the above priorities. It started in January 2004 for a 3-year duration. The goal of GEOLAND is to provide spatialized indicators and products in support of the implementation of European directives, and also of European policies and international conventions. Examples of directives include the Habitats, Natura 2000, Wetland, and Water Framework directives. Examples of international policies and conventions are UNFCCC (United Nations Framework Convention on Climate Change), UNFF (United Nations Forum for Forests), or the European Council regulation on Food Aid Policy, as well as the Kyoto Protocol.

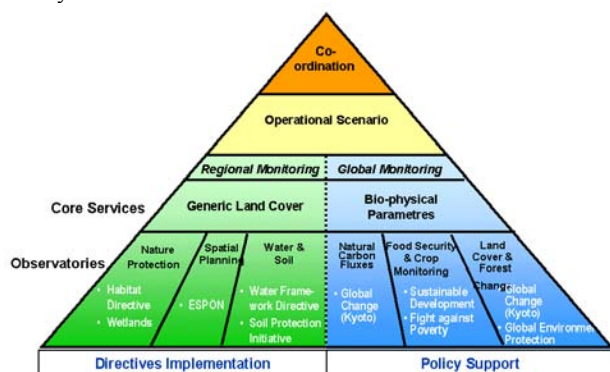


Figure 1. GEOLAND structure

GEOLAND has the ambition to provide a comprehensive coverage of land cover and vegetation GMES related issues. It has the goal to integrate existing heritage and link to other related GMES activities, develop and demonstrate pre-operational services for monitoring European as well as larger international areas, and develop a vision for an operational service infrastructure.

GEOLAND is structured to address regional monitoring in Europe as well as global monitoring (Figure 1). The activity is structured in two layers, a layer of so-called Observatories, which are the precursors of future GMES services, and a layer of Core Services, which provide in a mutualized way the Observatories with the value-added remote sensing products that they need.

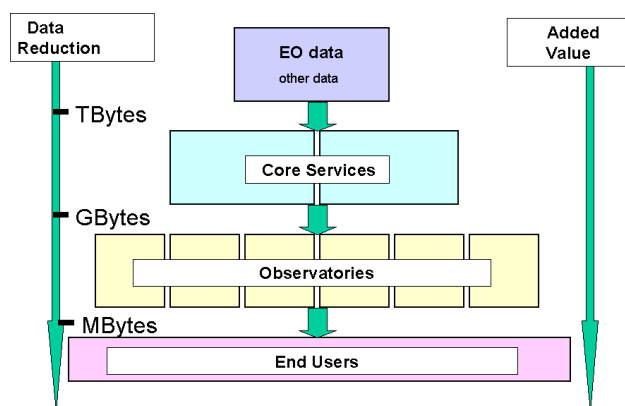


Figure 2. Information chain

With this structuration there are 8 sub-projects with 2 Core Services (*Generic Land Cover*, *Biogeophysical Parameter*), 3

regional Observatories (*Nature Protection*, *Spatial Planning*, *Water and Soil*) and 3 global Observatories (*Natural Carbon Fluxes*, *Food Security and Crop Monitoring*, *Land Cover and Forest Change*).

The information chain is shown in Figure 2. The "level 1" space data provided by the space agencies (that is, calibrated, geocoded, top of atmosphere radiances) are first processed in the Core Services, with a proper exploitation of synergies, and then processed in the Observatories with a late customization philosophy. Along the information chain the product value increases together with a significant decrease in data volume.

The envisaged products are quite numerous : 45 intermediate land cover and biogeophysical products from Core Services have been identified, and 28 final products, which span different integration levels from simple parameters to complex environmental assessments (Figure 3).

Core Service Generic Land Cover (CSL)		Observatory Spatial Planning (OSP)	
CSL-I-1 ... 8	General land cover and specialised land cover (agriculture, forest, urban infrastructure)	OSP-F-1	Spatial Indicators
CSL-I-2 ... 8		OSP-F-2	Urban Growth Scenarios
Core Service Bio-Geophysical Param. (CSP)		OSP-F-3	Landscape Transformation Scenarios
CSP-I-1 ... 14	LAI / FAPAR, Fcover, Albedo, Surface reflectance, SW radiation, LW radiation, Temperature, Active Fire, Burned surface, Water bodies, Soil Moisture, Precipitation	Observatory Land & Forest Cover Change (OLF)	
Observatory Nature Protection (ONP)		OLF-I-1 ... 11	Intermediate products, e.g. seasonal change detection, spatial fire pattern
ONP-F-1	Alpine Monitoring	OLF-F-1 ... 6	Annual patterns, e.g. vegetation growth, stress, disturbance, fire
ONP-F-2	Protected Forests	OLF-F-7 ... 8	Environmental Assessments of Africa & Boreal Eurasia
ONP-F-3	Wetland Monitoring	Observatory Food Security & Crop Mon. (OFM)	
ONP-F-4	Habitats & Biotopes	OFM-I-1 / 2	Crop Area, Crop Yield
ONP-F-5	Mountain Vegetation Types	OFM-F-1	Production estimates
ONP-F-6	Ecotone Characterisation Map	Observatory Natural Carbon Fluxes (ONC)	
Observatory Water & Soil (OWS)		ONC-F-1	Terrestrial biospheric CO ₂ flux
OWS-F-1	Water shortage risk map	ONC-F-2	Water flux
OWS-F-2	Water pollution	ONC-F-3	Vegetation Biomass
OWS-F-3	Source Apportionment Model	ONC-F-4	Leaf Area Index
OWS-F-4	Soil Erosion & Desertification	ONC-F-5	Root-zone Soil Moisture
		ONC-F-6	Carbon Storage

Figure 3. GEOLAND product overview

An operational scenario activity has also been set up with the objective to develop a vision for the future GMES infrastructure, including a space segment, with the key objective to lead to a sustainable availability of standard sensor series, a ground segment, and the implementation of GMES Services.

Many different user organisations, at regional, national, continental and international levels are associated to GEOLAND, being either part of the consortium or having shown interest in the project through letters of intent. The GEOLAND approach is definitely user-driven.

Altogether the GEOLAND consortium, led by Infoterra GmbH (Germany) and co-led by MEDIAS-France, gathers 56 European partners, and mixes three categories of organisations, users, service providers and researchers.

The rest of the paper describes in more detail the *Biogeophysical Parameter Core Service*.

3. THE BIOGEOPHYSICAL PARAMETER CORE SERVICE (CSP)

3.1 Introduction

The *Biogeophysical Parameter Core Service*, named in short CSP, is a joint venture of 10 partners, MEDIAS-France, Météo-France and NOVELTIS (France), VITO (Belgium), Institute of Meteorology (Portugal), University and Technological

University of Wien (Austria), EARS (the Netherlands), and Universities of Bonn and Karlsruhe (Germany).

CSP aims at demonstrating pre-operational capabilities of production of a series of biogeophysical parameters in several fields : vegetation, radiative budget at surface level, fire and water bodies, soil moisture, and precipitation.

There is a strong complementarity between CSP and the Land SAF (Satellite Application Facility) funded by Eumetsat. The Land SAF products are adapted to real time operational meteorology needs, and are centered on the operational application of meteorological sensors : MSG (Meteosat Second Generation), EPS (European Polar Platform). The service implementation is in progress at the Institute of Meteorology (Portugal). Whereas CSP products are adapted to GMES service needs (see below), with an emphasis on differed time products, including the production of historical series. Also, the multisensor character is an important feature of CSP. However, the location of the future service implementation of CSP is still to be defined.

3.2 Users

The main users of CSP are the GEOLAND global observatories.

Natural Carbon Flux is dealing with the global assimilation of remote sensing data for monitoring water & carbon fluxes on land. Its main products are the daily terrestrial biospheric CO₂ and water fluxes at the soil-vegetation-atmosphere interface, globally at 0.5° resolution. The end users are international organisations in charge of assessing the carbon balance and consulting political decision makers (IGBP, IGOS-P, PIK, GCP).

Food Security & Crop Monitoring produces crop production assessments for Europe and regions of Central Asia and China, as an input to Food Security Services and trade policies. The end users are FAO, and EU General Directorates for Agriculture and Aid in Cooperation (DG Aid Co).

Land Cover & Forest Change produces decadal-seasonal indicators for change and degradation of land cover & forests. The end users are international partners of the EU that implement their own environmental monitoring system (FAO, UNEP), and decision makers for services with responsibilities in policy orientation, project management and environmental reporting in the regions covered by the observatory (DG Aid Co, PUMA, IKI).

The other users of CSP belong to the science community. Contacts have been undertaken with a variety of groups, including LSCE, CNRM (France), MPI Jena, MPI Hamburg, PIK (Germany), CTCD (England), University of Louvain (Belgium), University of Valencia (Spain), and others.

In the mid-term, it can be envisaged that CSP could play a role analogous to the International Satellite Land Surface Climatology Project (ISLSCP) and beyond address large scientific organisation needs, such as IGBP, GEWEX or GTOS.

3.3 Structuration

CSP is built by integration of existing efforts, at the operational level, since the CSP consortium includes VITO and IM Portugal both experienced in operational processing, and at the

project level, since the results of previous and ongoing related projects such as FP5 / CYCLOPES, FP5 / ELDAS, ESA / DUP / GLOBCARBON are considered as assets in the CSP project.

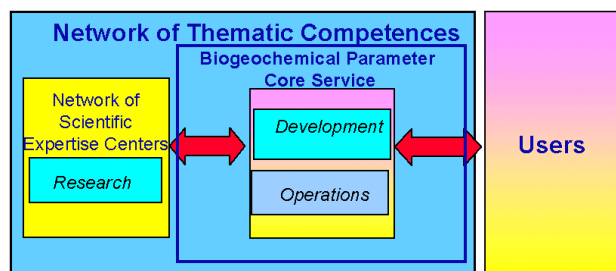


Figure 4. Network concept

The CSP consortium gathers both service providers (MEDIAS-France, VITO, EARS, NOVELTIS, IM Portugal) and research groups (U. Wien, TU Wien, U. Bonn, U. Karlsruhe, Météo-France).

The CSP project aims at prototyping a Network of Thematic Competences, including a Core Service tightly linked to upstream research, with fast and efficient feedback cycle loops between research and operations (Figure 4).

3.4 Development logic

The development plan (Figure 5) has been conceived in such a way that a product portfolio be available as soon as possible, so that the main users (global Observatories) and the providers can enter a feedback loop in the product development cycle.

The products offered by CSP have different levels of maturity. For the more mature products, the date of availability of a first version of the products has been set to the end of 2004. This date has been shifted to mid-2005 for products which necessitate more research and development activities.

At the end of the project, a demonstration of pre-operational capability for each product line should be made.

	List of products	2004	2005	2006
1 st suite of products	LAI – fAPAR – fcover	Development & Production of preliminary products	Consolidation & Validation & Extended production in time and space	Pre-operational service Demonstration
	Albedo Surface reflectance DLR flux Burned areas Water Bodies Soil moisture (ERS) Precipitation Evapotranspiration			
2 nd suite of products	LST DSR Soil moisture (AMSR)	Development & Production of preliminary products	Consolidation & Validation & Extended production in time and space	Pre-operational service demonstration

Figure 5. Development plan

4. CSP PRODUCTS

4.1 Service Portfolio

The CSP Service Portfolio, that is, the list of products delivered by the Core Service, including the delivery date, area and time period covered, space and time resolution, and user identification is shown in Figure 6.

Products	2004	2005	2006	Time Res.	Space Res.	Sensor	User
LAI, fAPAR, fcover	3 6 9 12	3 6 9 12	3 6 9 12	10-day	1 km	VEGT	ONC OLF OFM
Surface Albedo		GLOBAL, 2002 - 2003 GLOBAL, 1999 - 2003		10-day	1 km	VEGT	ONC
Surface Reflectance		GLOBAL, 2002 - 2003 EUROPE + AFRICA, 1999 - 2003 AFRICA + Boreal EURASIA, 2002-2003 AFRICA + Boreal EURASIA, 1998 - 2003		10-day 3 months	5 km sub-satellite 1 km	METEOSAT VEGT	OLF
Down-welling Short-wave Radiation (DSR) flux		EUROPE + AFRICA, 3 months 2000 GLOBAL, whole 2000 ASIA, 1999 - 2003		4 to 10 times per day 10-day	50 km 5 km sub-satellite	METEOSAT + FY-2 + INSAT + NOAA/AVHRR METEOSAT	ONC OLF OFM
Down-welling Long-wave Radiation (DLR) flux		EUROPE + AFRICA, 2000 EUROPE + AFRICA, 1997 - 2003 EUROPE + AFRICA, 1993 - 2003 ASIA, 1999 - 2003		4 times per day 10-day	50 km 5 km sub-satellite	METEOSAT+ NOAA/AVHRR METEOSAT	ONC

* The date of delivery is indicated by the left border of the coloured cell.

Products	2004	2005	2006	Time Res.	Space Res.	Sensor	Users
Land Surface Temperature	3 6 9 12	3 6 9 12	3 6 9 12	1/2 hour 10-day 1 month	0.05" (~5km)	METEOSAT	ONC OLF OFM
Soil Moisture		EUROPE + AFRICA, 2000 EUROPE + AFRICA, 1997 - 2003 EUROPE + AFRICA, 1993 - 2003 ASIA, 1999 - 2003		1 day 10-day 7-10-day 1 month 1 week	5 km sub-satellite 50 km grid 25 km 100 km	METEOSAT ERS AMS	ONC OLF OFM
Precipitation		GLOBAL, 1992-2000 GLOBAL, 2003 GLOBAL, 2000 GLOBAL, 2003 GLOBAL, 1997 - 2003 EUROPE + AFRICA, 1993 - 2003 ASIA, 1999 - 2003		1 day	1"	Multi-sensor	ONC OLF OFM
Evapotranspiration		EUROPE + AFRICA, 2000 EUROPE + AFRICA, 1993 - 2003 ASIA, 1999 - 2003		10-day	5 km sub-satellite	METEOSAT	OFM OLF ONC
Burnt Areas		AFRICA + Boreal EURASIA, 2000 AFRICA + Boreal EURASIA, 2000 - 2003		1 month	1 km	VEGT-ATSR AATSR-MERIS	OLF
Water Bodies		AFRICA, 2000 - 2003 AFRICA, 2000 - 2003		10-day	1 km	VEGT	OLF

* The date of delivery is indicated by the left border of the coloured cell.

Figure 6. CSP Product Portfolio

The Service Portfolio includes vegetation, albedo, surface reflectance, downwelling shortwave and longwave radiation fluxes, soil moisture, precipitation, evapotranspiration, burnt areas and water bodies products, which are briefly described below.

4.2 Vegetation : LAI, fcover, fAPAR

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 surface covered by vegetation (see an illustration in Figure 7). The fAPAR is defined as the fraction of photosynthetically active radiation absorbed by vegetation for photosynthesis activity. The fAPAR can be instantaneous or daily.

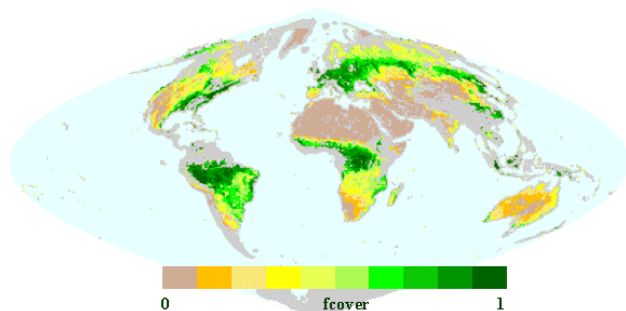


Figure 7. Global map of fcover derived from POLDER measurements, June 1997.

The production of these parameters will rely on the outputs of the current ESA / GLOBCARBON and FP5 / CYCLOPES projects, which are available, respectively, at VITO and MEDIAS-France.

The retrieval algorithm of LAI and fAPAR for GLOBCARBON is based upon a radiative transfer model and relationships with vegetation indices. Parameters are estimated using a look-up-table. In the CYCLOPES project, the inversion of a radiative transfer model to retrieve LAI, fcover and fAPAR is achieved using neural networks.

4.3 Albedo

The albedo is the fraction of the incoming solar radiation reflected by the land surface, integrated over the whole viewing directions. The albedo can be directional (calculated for a given sun zenith angle) or hemispheric (integrated over the whole illumination directions), spectral (for each narrow band of the sensor) or broadband (integrated over the whole solar spectrum).

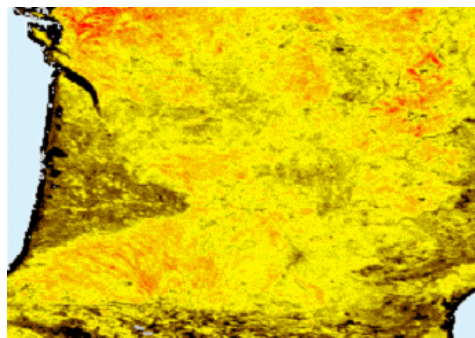


Figure 8. Surface albedo derived from VEGETATION data over South-West of France, August 2000.

The CYCLOPES albedo product is derived from VEGETATION / SPOT data. Observations acquired during a compositing period are first cloud-screened and corrected for atmospheric effects. Then, they are directionnally normalized by inversion of a 3-parameter linear bidirectional reflectance model, which yields three coefficients: a reflectance nadir-zenith, a geometric and a volumetric coefficient. These 3 coefficients are then used to simulate the reflectance over the whole viewing hemisphere, which permits to estimate the albedo.

The surface albedo is also a product of the EWBMS database provided by EARS. It is derived from METEOSAT visible (0.3-1.5 μm) images, so its spatial resolution is 5 km sub-satellite. The first step of the methodology consists of calibrating the noon visible METEOSAT image to obtain the daily planetary albedo. A darkest pixel method is then used to infer the atmospheric optical depth, which permits to infer the surface albedo from the planetary albedo.

4.4 Downwelling Shortwave Radiation Flux

The Down-welling Short-wave Radiation (DSR) flux (W/m^2) at the surface level represents the short-wave fraction of the solar irradiance (0.3-4 μm) reaching the soil background. The calculation of the DSR will be achieved on a hourly basis, at a global scale, and at 50 km spatial resolution.

The objective is to generate a global DSR product from the fusion of geo-stationary meteorological satellites and polar sensor systems. The global cover at mid latitudes will be ensured by all available geo-stationary satellites: METEOSAT-7 for Europe and Africa, METEOSAT-5 for the Indian Ocean, GMS-5 for Japan and Australia, GOES-10 over the Pacific Ocean, GOES-8 over Americas. The zonal gap between METEOSAT-5 and GMS-5 should be filled in by both the Indian INSAT satellite series and the Chinese FY-2 satellite

series. The sun-synchronous satellite NOAA/AVHRR covers the adjacent polar regions. The high frequency of measurements by the geo-stationary instruments allows to yield a product on the hourly basis.

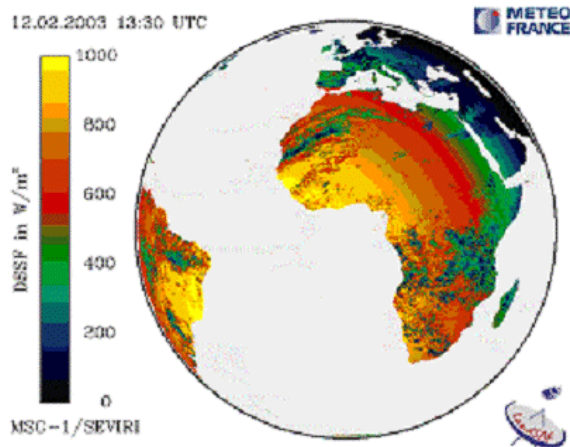


Figure 9. Simulated DSR flux over the MSG disk area.

4.5 Downwelling Longwave Radiation Flux

The Down-welling Long-wave Radiation (DLR) flux ($W \cdot m^{-2}$) is defined as the thermal irradiance reaching the surface in the thermal infrared spectrum ($4-100 \mu m$). It is determined by the radiation that originates from a shallow layer close to the surface, about one third being emitted by the lowest 10 meters and 80% by the 500-meter layer.

It is a particularly difficult parameter to retrieve since it cannot be directly measured by satellites. However, Radiative Transfer Models (RTM) may be used to estimate DLR from atmospheric profiles (temperature and humidity), if the cloudiness is known.

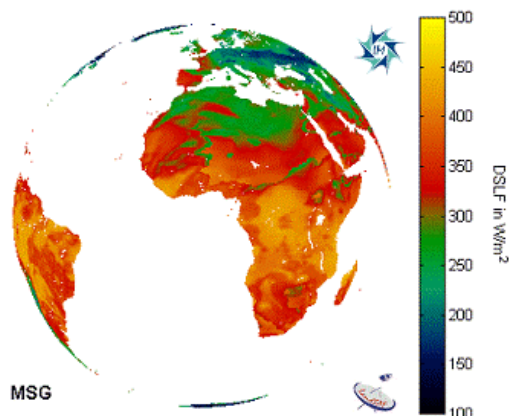


Figure 10. Land SAF DLR flux output product for MSG full disk 12.02.2003 - 12 UTC

The strategy consists in using conjointly satellite images from METEOSAT and NOAA to derive cloudiness, and two-meter air and dew point temperatures and precipitable water contents from ECMWF weather forecast data in RTM bulk empirical parameterizations.

4.6 Land Surface Temperature

The land surface temperature (LST) is defined as equivalent to the surface emitted radiance in the field-of-view of the sensor, according to Planck's law. The surface emitted infrared radiance is determined by "atmospheric correction" of the top of atmosphere radiance measured by the satellite in the $12 \mu m$ window range. The atmospheric correction takes the reflected part of the down-welling radiance and the attenuation of the up-welling radiance in the atmosphere into account.

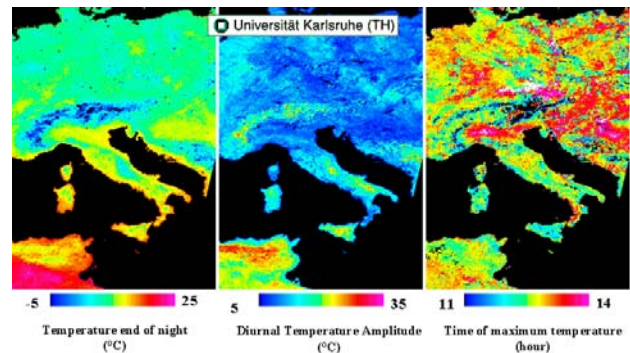


Figure 11. Land Surface Temperature indicators representatives for August 1996, derived from METEOSAT.

LST is retrieved from METEOSAT thermal infrared channel images using a neural network. METEOSAT is the only satellite that provides infrared measurements over Africa and Europe that resolves the diurnal wave of LST (Figure 11). The disadvantage of METEOSAT is that only one infrared channel is available. Thus established LST (and Sea Surface Temperature) determination methods like split-window technique can not be used and the atmospheric state can not be derived from METEOSAT data. The atmospheric situation (i.e. the temperature and moisture profiles) are taken from ECMWF. The physics of the atmospheric correction of a single infrared channel is the following: Calculate the expected satellite measurement for a reasonable range of land surface temperature, surface elevation and emissivity for the actual profiles and viewing angle – this constitutes the forward calculation of atmospheric radiances. The LST is then determined by interpolation to the actual satellite measurement (this is the inversion of the forward calculation) for profiles around the current pixel and horizontal interpolation of the atmospheric correction at the surrounding pixels.

4.7 Soil Moisture

A database of soil moisture products is derived from active microwave measurements (ERS-1/2 scatterometer). One parameter of the database is the topsoil moisture content (surface wetness). The topsoil moisture is a relative measure of soil moisture in the first 5 cm of the soil ranging between 0 and 100 representing the degree of saturation. The other parameter is the Soil Water Index (SWI). The SWI is a relative measure of the soil moisture content in the first meter of the soil layer, ranging between 0 and 100. If soil hydrologic soil properties are known (wilting level, field capacity and total water holding capacity) the SWI can be related to the volumetric soil moisture content.

An advanced change detection approach fully exploits the unique sensor design of the ERS scatterometers with three antennas simultaneously observing the Earth surface at different

look directions and the availability of 10 years of high quality backscatter data. The dependency of the reflected signal to the incidence angle depends on the amount of vegetation on the surface. For correcting vegetation effects, we use the fact that there exist an incidence angle, which varies with the moisture conditions, where the effect of vegetation is minimized.

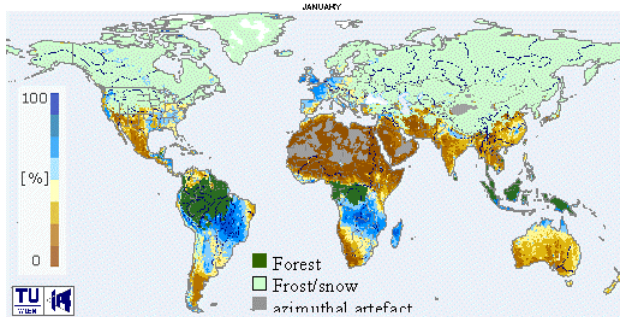


Figure 12. Global SWI derived from ERS scatterometer measurements in January (1992-2000 average).

Global soil moisture fields are also derived from passive microwave measurements (Aqua / AMSR). The parameter is here defined as the content of water within the uppermost meter of soil. The starting point of the analysis is to consider ground measurements from the former Soviet Union. The data set comprises soil moisture measurements of the upper 1 meter soil layer at 50 stations. Measurements are taken every 10 days during the period 1952 to 1985.

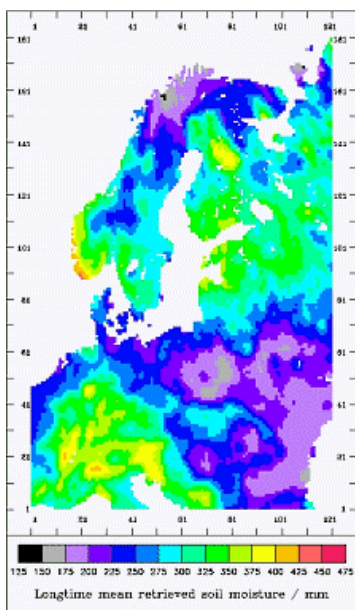


Figure 13. Multi-year mean soil moisture as derived from SMMR (1978-1987)

A two step methodology is then applied: first, the time averaged soil moisture at each grid point is calculated as a linear regression function of the long-time mean precipitation from GPCP (Global Precipitation Climatology Project), the vegetation density cover from the UMD-1km land cover map, and soil texture and terrain slope from FAO. The coefficients of the regression are calculated using the ground measurements.

In a second step, the remaining temporal variance of soil moisture can be inferred at each grid point using three temporally varying parameters. These are the precipitation

(again from GPCP), the air temperature, and the horizontally polarized 10 Ghz brightness temperature from AMSR. A further linear regression yields the temporal varying part of soil moisture.

4.8 Precipitation

The goal is to develop a global scale daily precipitation product based on existing multi-satellite products and bias-corrected precipitation gauge analyses. The objective is to improve the GPCP-1DD global multi-satellite product with a better calibration making use of bias-corrected rain gauge analyses based on about 6000 synoptic stations.

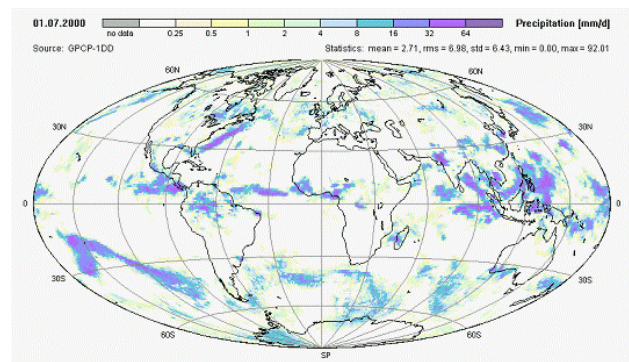


Figure 14. GPCP-1DD multi-satellite estimates of precipitation (mm) for July 01, 2000.

The GPCP-1DD multi-satellite product is derived from geostationary sensors data in the 40° north-south belt, and TOVS data from the polar orbiting NOAA 12/14. It is calibrated with monthly precipitation data being near-real-time available based upon reports from GPCP. Currently, there does not exist any operational global daily precipitation product, which is based on bias-corrected gauge analyses. The idea here is to collect global daily rain gauge data for the period 1997-2003, and to correct them for systematic measurement errors. The bias correction of the ground-based precipitation measurements is needed, because of the under-catch of operational rain gauges, which is on the order of 5-30 percent on average. Then, the rain gauge data will be interpolated to a global regular 1° longitude/latitude grid. GPCP satellite product and rain-gauge measurements will be co-kriged to estimate the final CSP precipitation product.

4.9 Evapotranspiration

The actual evapotranspiration in energy units represents the latent heat flux exchanged between the land surface and the atmospheric boundary layer.

The actual evapotranspiration is calculated as the difference between the daily net radiation and the daily sensible heat flux, under the assumption that the soil heat flux can be neglected. An additional correction for photosynthetic light use is carried out. The net radiation is estimated from the DSR flux, the surface albedo, the DLR and the up-welling long-wave radiation flux. The sensible heat flux is retrieved from the LST and the air temperature. This method can only be applied for clear sky conditions. As the LST is not estimated for cloudy pixels, the sensible heat flux and, consequently, the latent heat flux cannot be calculated in this way. In that case, it is assumed that the Bowen ratio (sensible heat flux versus latent heat flux) is

constant during the period of cloud cover, so it is the same as on the last cloudfree day.

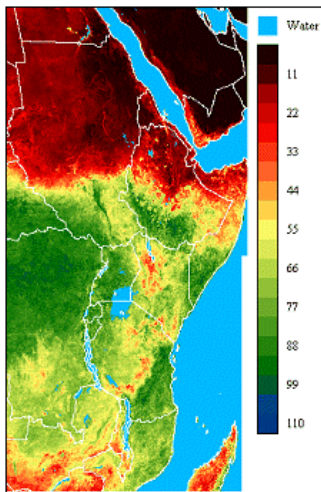


Figure 15.
Relative
evapotrans-
piration from
METEOSAT -
May 2002

4.10 Burnt Areas

Monthly global maps of burnt areas for the period 1998-2003 have been produced in the frame of the ESA-DUP2 GLOBCARBON project. The sensors for burn scar detection are ERS-2 / ATSR-2, ENVISAT / AATSR, and SPOT / VEGETATION. ENVISAT / MERIS is used to add confidence to the preliminary results.

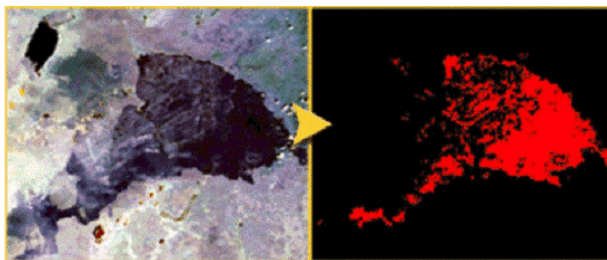


Figure 16. Burn scars detected in Mongolia on 11/5/2000, left: ATSR image (RED, NIR, SWIR) and right: burn scar map.

After a fire, two main physical variations can be detected in the remote sensing data over a vegetation layer. The first one is the strong top of atmosphere reflectance decrease: burnt areas have a lower reflectance in the near infrared channel than healthy vegetation. The second one is the LST increase that occurs over a burnt surface during day time, due to strong solar irradiance absorption and to the absence of evapotranspiration that normally transfers energy to the atmosphere in form of latent heat through water vapour. The presence of ash and carbon constitutes a dry layer that does not allow this cooling process, increasing the surface temperature by 7K.

4.11 Water Bodies

A method to map and monitor small ponds in arid regions using SPOT-VEGETATION 10-daily composites was developed in the frame of the GEOSUCCESS project. A small pond can be defined as a surface ranging between 1 km and few tens of km² of either free water or water with vegetation. Monitoring small ponds or water bodies is important for economic activities and

is of great environmental value. The method was applied for arid and semi-arid regions in northern Africa within GEOSUCCESS. The aim is to extend these calculations for CSP to the total African continent.

5. SCIENCE CHALLENGES

We conclude this paper by reviewing the present scientific limitations and the proposed approaches in the science field covered by CSP.

The key challenge today for vegetation and albedo parameters is to move from single sensor retrieval approaches to multisensor approaches. This is an important step forward in order to assure time continuity of retrieved variables, as well as to improve parameter accuracy using the spectral, directional, time and space synergies between sensors. This trend has been accounted for here, since the developments in GEOLAND / CSP largely rely on the progress undertaken in the FP5 / CYCLOPES and ESA / GLOBCARBON projects, for which the multisensor aspect has been very important.

Global fields of downwelling radiation, a key input parameter for vegetation functioning, are not yet available. Their retrieval in the long wave regime can now be envisaged using sounder radiances (i.e. TOVS) complemented with radiative transfer models. A multisensor approach with both polar and geostationary sensors has been undertaken in the short-wave. This should constitute a significant progress.

The land surface temperature, which plays a crucial role in the surface – atmosphere energy exchange, is difficult to derive due to inhomogeneities and rapid change in time. Advanced numerical methods in combination with growing storage capacities allow progress in this area. The provision of adequate ground based measurements for validation purpose remains however a challenging task.

For precipitation the major goal is to improve the satellite estimates with bias-corrected gauge data. The latter is needed, because of the under-catch of operational rain gauges (on the order of 5-30 % on average). Currently no operational global daily precipitation product, based on bias-corrected gauge analysis, is available.

The accuracy of global soil moisture products is currently well known only on a few regions. The scientific orientation is here to reinforce validation activities and to intercompare two different retrieval methods, based respectively on active and passive microwave sensing. The activities in the passive microwave represent an extension of progress made in the FP5 project ELDAS to the global scale.

The foreseeable evolution of the science field relevant to CSP is to move towards a generalization of multisensor approaches, possibly combining optical and microwave techniques. Some new parameters, such as vegetation biomass, chlorophyll concentration, or vegetation height should become progressively feasible through the maturation of retrieval techniques (i.e. biomass), and the upcoming of new sensors (i.e. vegetation height with new generation laser sensors). The accuracy should be more and more controlled thanks to algorithmic progress together with the development of validation facilities. The user requirements are expected to become more and more precise and will have a strong influence in this science field orientation.