

geoland data and products for GMES

HALO
report

Draft

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1 Introduction

The report gives an overview on data requirements and production of the geoland integrated project. Prepared as part of the HALO¹ activities, it intends to meet the need for a description of Geoland's data flow and dissemination relevant to the interaction between Land, Atmosphere and Ocean IPs in GMES².

Geoland is funded under FP6 (Thematic Priority Space/GMES) and runs for three years (2004-2006). Geoland organises the broad range of "land applications" addressed by European Directives and Policies as well as by global policies and conventions. Geoland priorities are regional monitoring of land cover change and environmental stress in Europe and global vegetation monitoring. Geoland tackles the issues of regional monitoring and reporting for nature protection, water and soil issues, spatial planning, and strategic information on food security and crop monitoring, global land cover and forest change, and natural carbon fluxes.

Geoland's observatories and core services are currently (10/2004) in a consolidation and demonstration phase which will (i) lead to a final set of products defined according to user demands and (ii) prove the transferability of test-sites studies.

Geoland's subprojects, which are called observatories, have either only regional coverage focussing on selected test sites or a continental to global area of interest. From an HALO point of view, only the global observatories have to be predominantly covered by HALOs activities due to their strong interaction with atmosphere and ocean IPs and their more developed operational maturity. The report will firstly provide a brief overview of all geoland services & observatories, but subsequently its main focus will be put on global observatories & services.

Many strong links exist between atmosphere, ocean and the land & vegetation. HALO wants to identify the links and coordinate the respective data transfer between the integrated projects, each covering a dedicated part of the earth system. Examples of interactions concerning the land surface and vegetation are:

- Vegetation and land surface control the atmospheric fluxes of moisture, heat, radiation and CO₂
- Precipitation and atmospheric conditions (Temperature, Clouds) influence the state of vegetation and land surface
- Human activities (agriculture, foresting, urbanization) change land surface and vegetation status, and, in return, land surface and vegetation affect human activities (food supply, forest fire etc.)

¹ HALO is a GMES specific support action (SSA), which will be responsible for the harmonized coordination of the interaction between the atmosphere, land and ocean integrated projects of the GMES backbone. The objective of HALO is to enable an efficient and coherent data exchange between the relevant IP's of GMES. HALO will provide agreed recommendations for the data architecture of GMES in its operational phase starting in 2008.

² GMES is a joint initiative of the European Commission and the European Space Agency, designed to establish a European capacity for the provision and use of operational information for Global Monitoring of Environment and Security. Besides the ocean theme, GMES's thematic priorities are land & vegetation, atmosphere, water resources, natural risks and security.



The information sources used for preparing this report are the Geoland Reference Document “Detailed Observatories Description”³ and current version of the service portfolios⁴ of the global observatories and the core service of bio-geophysical parameters. Further, valuable discussion with and comments from geoland people has been an important input to the report. Finally, web based documentation of space agencies and international research bodies (ESA, EUMETSAT, NASA, NOAA, GTOS, IGOS, ICOS) have been consulted.

The report starts in chapter 2 with a general overview of the project compiled from the Reference Document. The rest of the report predominantly focuses on the global observatories and services. The thematic analysis of data relevant to land and vegetation theme is given in chapter 3 and chapter 4 provides an overview of satellite instruments for monitoring land and vegetation. The inventory of the current Geoland products is content of chapter 5.

³ 2_ITD0350_geoland_RefDoc_4.0 , and ITD0350_geoland_Annex-I_I4.00

⁴ ONC-0350-RP-0005-ServicePortfolio-I2.01, CSP-0350-RP-0005-ServicePortfolioWP8210-I1.00, OFM-0350-RP-0005-ServicePortfolio-d1.02, OLF-0350-RP-0005-ServicePortfolioOLF-I2.01

2 Project Overview

Geoland aims to provide and establish geo-information products and services to support GMES, utilising available Earth Observation resources, and integrating them with existing models into preoperational end-user applications. The geoland products and services aim at the monitoring of land cover and vegetation addressing the GMES priorities “Land Cover Change in Europe”, “Environmental Stress in Europe”, and “Global Vegetation Monitoring”.

Geoland provides an interdisciplinary integration of 56 partners comprising user organisations, private and public service providers and researchers from 15 European member and accession states.

The project is organized into three regional and three global sub-projects, called observatories, and core services, which support the observatories with cross cutting products.

- **Regional observatories:**
 - **Nature Protection Observatory** addressing the Habitats and Bird Directive, the Ramsar Convention, the Convention on Biological Diversity;
 - **Water and Soil Observatory** addressing the Thematic Strategy for Soil Protection, and the Water Framework Directive,
 - **Spatial Planning Observatory** addressing the European Spatial Development Perspective, and the European Spatial Observatory Network,
- **Global or continental observatories**
 - **Natural Carbon Fluxes Observatory** addressing the UN Framework Convention on Climate Change
 - **Global Land Cover and Forest Change Observatory** addressing the UN Forum on Forest, and the Forest and Development Communication of the Commission, supporting environmental measures in developing countries,
 - **Food Security and Crop Monitoring Observatory** addressing the council regulations on Food Aid Policy,
- **Core Services**
 - **Generic Land Cover** supporting the regional observatories with cross-cutting land cover and land cover change products
 - **Bio-geophysical Parameters** supporting global observatories with cross-cutting biogeophysical data

The regional part of GEOLAND will develop and improve methodologies rather than establishing operational services or delivering products. Their work focuses on representative European test sites and will not cover the whole or large parts of Europe. However, the transferability of products & services to European test sites will prove readiness to provide products for much larger areas.

From an operability point of view, the global observatories are considered to be more mature than regional observatories. The development of regional and global services is mainly based on test sites, with the final aim to demonstrate the possibility of extending the services to the full European/global scale.

2.1 Core Service generic land cover

The associated core service “generic land cover” will provide land cover information from satellite observations in with a specification which has been consolidated and agreed with the dedicated Observatories. Thematic “value-adding” per application area will be done in the Observatories. The production chain will generate standard, agriculture, forest and infrastructure land use data of the test sites in scale 1 : 100,000 and 1 : 25,000.

Products:

- CSL-I-1: generic land cover (CLC classes 1 – 2); scale 1 : 100,000 thematic masks to improve observatory work (=specialisation along value chain)
- CSL-I-2 – 4: Integration of thematic classes (CLC 3 to n) from observatories for special LULC
- CSL-I-5 – 8: Hot spot mapping for special applications / in core test sites (scale 1 : 25,000)

Test sites:

- Sweden: ~ 29,000 km²
- Germany: ~ 7,000 km²
- Austria: ~ 14,000 km²
- Greece: ~ 20,000 km²
- France: ~ 100,000 km²

The core service generic land cover is aiming for multi-purpose land cover products at more detailed level than CORINE land cover as well as specific land cover products (e.g. selected thematic classes). Geoland will work on methodological improvements to provide cheaper, faster and more automated methods compared to CORINE land cover. The development and demonstration of services is mainly based on test sites, with the final aim to demonstrate the possibility of transferring the services (role out concept) to the full European/global scale.

2.2 Regional observatories

The development of observatories is based on a limited number of test sites. Further, a clear road-map and service development cycle has been developed to shift from methodological studies to full European scale.

The Observatory on Water and Soil (OWS) will be split into two (sub-) observatories, one with focus on water, the other with focus on soil.

- Water abstraction pressure by irrigation map
- Water pollution map
- Source apportionment map
- Soil erosion risk maps

Geolands Observatory Spatial Planning will provide information on the spatial development of regions. LU/LC information will be used to generate indicators, representing the former and actual urban-rural relationship of the region. Thus two types of products will be developed:

- A LC/LU base product, representing the spatial distribution of urban, agricultural and (semi-)natural land cover types.
- Indicator products in the urban-urban, urban-rural and rural-environmental domain, that will be derived from the basic LC/LU product and additional information (e.g. demographic data): population density, proportion of built-up area, degree of land consumption, size, shape and distribution of landscape elements, landscape fragmentation, etc. and their development over time

Geolands Observatory on Nature Protection will generate the following products for the main European ecozones:

- Alpine monitoring
- status and change in protected forests
- wetland monitoring
- Alpine vegetation types
- ecotone characterisation maps.

The methods will take advantage of specific sensors for specific applications; e.g. exploiting vegetation phenology with optical imagery or SAR data for mapping forest cover change (e.g. the effects of storm damage on particularly protected areas or burnt areas).

2.3 Core Service Service Bio-Geophys. Parameters

The “Bio-Geophysical Parameters” (CSP) core service will sustain the 3 global observatories “Global Land Cover & Forest Change” (OLC), “Food Security & Crop Monitoring” (OFM) and “Natural Carbon Fluxes” (ONC) that support policies that require monitoring activities on a continental to global scale. These observatories provide strategic information (e.g. on carbon, forests, and food security) for decision-making processes on European and international level.

The provided biogeophysical parameters are:

- Vegetation activity: Leaf Area Index, fraction of Photosynthetically Absorbed PAR, fraction of soil covered by vegetation,
- Radiative budget at surface level: down-welling flux (short-wave and long wave), albedo, temperature,

- Fires (active fires and burned areas),
- Soil moisture,
- Precipitation.

A list of the all CSL products and their temporal and spatial resolution and coverage is given in Table 1.

The CSP aims at reaching a pre-operational production and validation of the above-mentioned products. The CSP will mainly be built on existing operational efforts (VITO and Land SAF / Eumetsat) and on existing projects (FP5 Cyclopes, ELDAS and ESA Globcarbon). The complete information chain: algorithmic research – development of processing lines – operational production context will be set up and validated.

Description of the CSP portfolio

Product	Coverage Area	Time Period	Space Resolution	Time Resolution	Input satellite data	Availability of first products
Leaf Area Index (LAI)	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
FCover	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
FAPAR	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
Surface Albedo	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
	Europe - Africa	1993 - 2003	5 km		METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Surface Reflectance	Africa Boreal Eurasia	1998 - 2003	1 km	1-month	VGT	Sept 2004
Down-welling Shortwave Radiation Flux (DSR)	Global	2000	50 km	4 time/day	Geo-stationary + AVHRR	May 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Down-welling Longwave Radiation flux (DLR)	Europe - Africa	1997 - 2003	50 km	4 times/ day	METEOSAT	Jan 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2000			GMS	Jul 2005
Land Surface Temperature (LST)	Europe - Africa	1997 - 2003	5 km	½ hour 10-day 1-month	METEOSAT	Jul 2005
	Europe - Africa	1993 - 2003	5 km	1 day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005



Soil moisture	Global	1992 - 2000	50 km	10-day 1 month	ERS	Mar 2004
		2003 - 2004	100 km	1 week	AMSR	Jul 2005
Rainfall	Global	1997 - 2003	1°	1 day	Multi-sensor	Jan 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Evapo- transpiration	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Burned areas	Africa Boreal Eurasia	2000 - 2003	1 km	1 month	VGT	Jan 2005
Water Bodies	Africa Boreal Eurasia	2000 - 2003	1 km	10-day	VGT	Jan 2005

Product	Code	User in Geoland	Temporal Resolution	Spatial Resolution	Spatial Coverage	Temporal Coverage
Surface reflect-ance	CSP-F-4	OLF	3 months	1 km	Africa & Boreal Eurasia	period: 2000 2nd period: 2001-2003
SW radiation	CSP-F-5	ONC, OFM	4 to 10 times/day	50 km	Europe Global	1st period: 3 months of 2000 2nd period: whole 2000
LW radiation	CSP-F-6	ONC, OFM	4 times/day	50 km	Europe & Africa	period: 2000 2nd period: 1997-2003
Tem-perature	CSP-F-7	ONC, OFM, OLF	10 or 30 days 1 day	10 km 3 km	Europe & Africa	period: 2000 2nd period: 1997-2003
Burned surface	CSP-F-8	OLF	30 days	1 km	Africa & Boreal Eurasia	period: 2000 2nd period: 2001-2003
Water bodies	CSP-F-9	OLF	10 days	1 km	Africa	period: 2000 2nd period: 2001-2003
Soil Moisture	CSP-F10	ONC, OFM	8 day	100 km	Global	1st period: 2003 for years 1992-2000 2nd period: 2002
Precipita-tion	CSP-F-11	ONC, OFM	1 day	1°	global	period: 2000 2nd period: 1997-2003

Table 1 List of the products provided by the Core Service Bio-geophysical Parameters. (ONC: Obs. Natural carbon, OLF: Obs. Land Cover & Forest Change, OFM: Obs Food & Crops Monitoring.)

2.4 Food Security & Crop Monitoring

The factors that determine the food security situation are the availability of sufficient food of good quality throughout the year, access to that food for all people and good utilisation of it. The final test on adequate food security is on the food situation of the poorest and most vulnerable people in society, at household and individual level. The Observatories contribution to GMES in analysing the global food security situation lies in the field of monitoring food supply at regional level world-wide. The ambition of the Observatory is to make a next step towards an independent European Global Yield and Production Forecasting System that provides information on yield and production of arable crops and pasture production for animal husbandry over the whole world. This system will make optimum use of Earth Observations by integrated use of data from ground observations, plant production statistics, and satellites.

The methodology behind the yield component of the global observatory for production & yield is based on combining, integrating and extending the results from several existing European systems for deriving yield indicators. These methodologies are based on different techniques: agro-meteorological modelling based on weather variables (MARS yield forecasting system), remote sensing-based estimation of vegetation production through a Monteith-type production model (VITO-DMP), remote sensing-based estimation of crop evapotranspiration (EARS-EWBMS), statistical correlation with vegetation indices (IgiK) and a methodology based on a drought index calculated from satellite-based soil moisture estimates (ScatYield).

Within the geoland project, these existing methodologies will be improved by using intermediate-level products that will be delivered by the geoland core services.

The yield component of the observatory will integrate these approaches ranging from relatively simple to more complex biophysical indicators by bringing them together in a common analytical framework, and making a comparative study of their performance in a few pilot regions.

The methodology behind the area component of the global observatory for production & yield is based on the use of the new generation of intermediate resolution (250 m.) satellites (ENVISAT-MERIS, TERRA-MODIS, ADEOS2-GLI) for estimating cropped areas. Several techniques will be applied to this data in order to derive crop area estimates. These techniques will include spectral unmixing, fuzzy classification techniques, partial unmixing with preliminary classification of mixed and pure pixels and simple classification for areas with large field size and low diversity in crop types.

The proposed activities are split into two themes: yield estimates and area estimates, and in two phases:

- Phase 1: yield: Intercomparison and validation study of yield forecasting methodologies in European countries (Poland, Belgium, Spain);
- Phase 1: area: Methodology and validation study on European sites (Belgium, France, Russia);

- Phase 2: yield: Transfer of integrated methodology to other regions outside Europe (Central Asia, Northern China);
- Phase 2: area: Intercomparison of the area estimate methodologies on the Belgium study area and a study on production estimates by combining yield and area estimates on suitable regions.

Overview of input data sets:

- Multi-temporal satellite data (MERIS , VEGETATION, NOAA-AVHRR)
- fAPAR, LAI & NDVI (Core Service)
- ECMWF meteo data / meteo parameters of LANDSAF
- Geostationary satellite data sets (EARS / Core Service)
- Global ancillary maps/data (global land cover, soil map, official yields etc.)
- MARS-STAT database on the project European pilot areas
- Soil moisture indicators from scatterometer (topsoil soil moisture ms & profile soil moisture SWI)
- Land cover data (PELCOM-GLC2000 for Russia) / Agronomic data (crop varieties, crop calendars for pilot areas) and yield statistics

2.5 Observatory Global Land Cover & Forest Change

The Observatory will provide global spatial data on land cover and forest change, addressing international concerns according to the global environmental protection and global change issues.

The geographic area covered will be of continental size, namely Africa and Boreal Eurasia, as indicated in the annex of the GMES/EC strategic plan (COM 2001/609). Table 2 provides a list of input data of the observatory which are process in the following kinds of data analysis:

In the “**temporal change analysis**” work package the attention will be focussed on the identification and production of indicators of the temporal behaviour of the growing season, and the inter-annual and inter-seasonal comparison. The input data will include 10-day observations of fractional cover as well as surface temperature at 1km ground resolution. Output data will include 10-day de-livery of environmental indicators at full as well as at reduced resolution (typically 1°*1°).

In the “**multispectral change analysis**” a method will be put in place to assess environmental status from seasonal multispectral synthesis with change detection tools to identify areas of possible vegetation degradation by comparison with a reference status provided by a reliable land cover map, i. e. the CSL 2000 map. The output will be typically a seasonal map depicting spectral disturbances, to be further qualified as environmental degradation with external validation. In addition the exploitation of medium resolution satellite data (250-300 m) will be streamlined to identify changes in the spatial extension of two key land-cover categories: forest and the agricultural do-main. This specific action will be carried out on sub-continental windows of interest.

In the “**fire disturbance analysis**” automated analysis of seasonal patterns of fire and burnt surfaces will be developed. A particular attention will be given to data recalibration. It is indeed note-worthy that the identification capacity of available low-resolution space sensors to active fires and burned surfaces is very much governed by the specific conditions of the ecological unit under analysis. Recalibration must thus be applied accordingly.

In the “**seasonal water resource analysis**” work package the attention will be focussed exclusively on the semi arid regions of Africa. The application will be built on the consolidation of an existing and tested methodology and will aim at providing indication of surface water availability in temporary water bodies.

The two other work packages: “**assessment on environmental status – Africa**” and “**assessment on environmental status – Boreal Eurasia**” are similar in substance. The objective is to integrate; using GIS tools the parameters delivered by the previously described work packages, ancillary environmental information such as rainfall, air temperature, etc... where necessary, and key elements of ecological mechanisms and human activity. The output will be identified by key ecosystem categories, such as: boreal forests, tundra, tropical forests, woodlands, rangelands, relevant biodiversity sites, protected areas with special legal status. It will typically be provided on a yearly basis.

Parameter	Freq.	Res.	Comments
FCover	10 day	1 km	from core service CSP
NDVI	10 days	1 km	for Africa from VEGETATION
Averaged calibrated surface reflectance	2-3 month	1 km	from core service CSP
Averaged surface reflectance	2-3 month	300 m	from MODIS or MERIS
Active fire	1 days	1 km	from ATSR / Globcarbon
burned surface	10 days	1 km	from core service CSP, VEGETATION Globcarbon
Temperature	10 days	1 km	from core service CSP
Waterbodies	10 days	1 km	from core service CSP, VEGETATION semi-arid Africa

Table 2 Input data of the observatory Global Land Cover & Forest Change

2.6 Observatory Natural Carbon Fluxes

The main objective of the carbon observatory is to deliver an improved scientific understanding of the current terrestrial carbon fluxes, in support of the implementation of the Kyoto protocol. More specifically, the building a global full carbon accounting modelling system is envisioned, treating the impact of weather and climate variability on ecosystem fluxes and carbon stocks. The product of the system will be a near real-time analysis of biospheric CO₂ fluxes, globally at 1° resolution, released every 3 or 6 months. The other products of the service will consist of water and energy fluxes, biomass and soil moisture estimates that are fully compatible with CO₂ exchange.

The land remote sensing products to be assimilated will be processed by ECMWF, together with the required in situ meteorological observations. The ECMWF



operational data processing system will be used to perform this task. The remote sensing products will be provided by the core service.

ONC will develop a model and data assimilation system for the estimation of natural carbon and water fluxes over land. The land surface model will have

- a photosynthesis-based evaporation,
- a prognostic equation for leaf biomass,
- with growth and mortality as source terms.

This will be complemented by a simplified treatment of the other carbon pools (woody biomass, and soil respiration). Such a system will run globally, at a resolution tbd between 40km and 125 km. The system will become operational in 2007-2008 at ECMWF.

In order to control the drifts in the model above, data assimilation will be developed. A forward operator linking leaf biomass to LAI, will be developed. The assimilation system will run with an assimilation window of 2-3 weeks. The observations in such a system are:

Bio-geophysical observations estimated from remote sensing, aggregated by tiles in the model grid.

- LAI
- fAPAR

Observations to drive the assimilating model, including

- hourly surface solar and thermal radiation downward;
- Daily precipitation.

Solar radiation is probably of good quality and could beat the quality of model products. Longwave radiation is more questionable, and almost certainly of lower quality than model products.

The only product available in near-real time is a gauge-based precipitation over the coterminous USA, based on a high-density gauge network. No such product is available or planned in Europe. One exception is the ELDAS precipitation fields, covering the 15-month period October 1999-December 2000, based on 36,000 raingauges in Europe. This product has also been merged with radar data, and there are currently two versions, 3-hourly and daily values.

Remote sensing estimates over land might be of usable quality once GPM is launched; but not demonstrated yet. In the absence of measurements there is no alternative to using climatology or short-term forecasts.

3 Data and Products in Geoland

The general idea of the data flow structure in geoland is that the two core services provide the main input data sets of the observatories. The input data of the global observatories are mainly based on satellite observations whereas in-situ observations are mainly used for the validation purposes.

Meteorological forcing data, in a way in-situ information, is provided by the meteorological forecast and analysis and further EO data. It is either directly obtained from ECMWF or in a process form via the core services.

Geoland's thematic priorities span from spatial planning issues to the global carbon cycle. The diversity of addressed issues and the different status of operational maturity make it difficult to find a common summary of the used and exchanged data and products. Consequently, the HALO work will have to focus on the global observatories, especially the one on Natural Carbon Fluxes (ONC).

Figure 1 depicts the spatial and temporal resolution covered by geoland's observatories and core services. The data of the global observatories have an update frequencies from days to month together with a spatial resolution of in the range of kilometres. In contrast, the regional observatories, which focus on test sites only, require much higher spatial resolution of about 10 m together with slow update rates of several years. Only the snow cover observation within the observatory nature protection has a time scale of days.

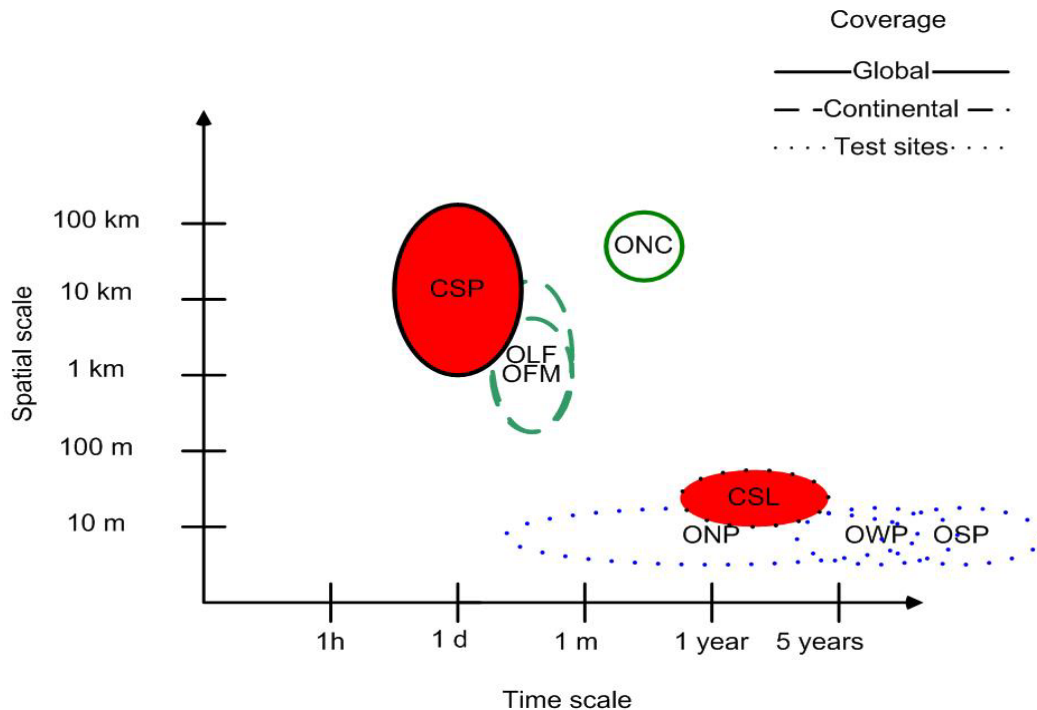


Figure 1 Time and spatial resolution of the data in Geoland's Core services (CS) and observatories (O). CSL ...Geophysical parameters, CSL ... Generic land cover, ONC ... Natural Carbon, OLF... Land Cover & Forest Change, OFM ...Food Security and Crop Monitoring, ONP ... Nature Protection, OSP ...Spatial Planning.



The spatial data sets in Geoland differ in many respects. They are either

- Categorical of land use & cover data
 - Land cover, which is concerned the nature of features
 - Land use, which is concerned with the socio-economic function
- Numerical as in the case of the bio-geophysical parameters and meteorological data.
 - Spectral Vegetation indices
 - Biomass properties LAI, Biomass production
 - Surface radiation budget
 - Soil moisture & Precipitation
 - Land Surface temperature

Geoland's data is either directly or indirectly (satellite) measured by instruments or it is "collected" by surveys and from other information sources. The data is represented in different projections on regular grids (rasters), in pixel or in vector formats (polygons) for administrative units.

Most of the data in Geoland are provided in GIS (Geographical information system) formats. However, GIS applications are not very common in the meteorological and oceanographic community since they are not the best tool to handle temporally changing data. Due to the temporal dimension, environmental data are likely to have higher data volumes compared to conventional geographical data.

3.1 Land cover characteristics data sets

Land cover is more concerned with the bio-geophysical nature of earth surface features (crops, water etc.) whereas land use describes more their socio-economic function.

Land cover data is categorical information provided to a certain minimum mapping area representing the spatial resolution of the data. The spatial resolution dealt with in Geoland varies from a couple of meters for the regional observatories to about 100 km (1°) in the global observatories. The tiles or fraction approach provides additional information to what percentage certain land characteristics cover the minimum mapping area or grid box with extent of the resolution.

The time scale of land cover and use changes is mostly longer than 1 year. The vegetation and agriculture growth cycle, expressed in different seasons has a typical time scale of weeks but is repeated every year in different proportion. Biomass burning and foresting change the land cover characteristics in are much more irregular temporal patterns.

Important land cover data sets are Corine and ECOCLIMAP:

CORINE Land Cover (CLC) is a geographic land cover/land use database encompassing most of the countries of the European Community (except Sweden and Finland for which the inventory will be finalised in 2000-2002) and the majority of the Central and East European countries. CLC describes land cover (and partly land

use) according to a nomenclature of 44 classes organised hierarchically in three levels. The first level (5 classes) corresponds to the main categories of the land cover/land use (artificial areas, agricultural land, forests and semi-natural areas, wetlands, water surfaces). The second level (15 classes) covers physical and physiognomic entities at a higher level of detail (urban zones, forests, lakes, etc), finally level 3 is composed of 44 classes. CLC was elaborated based on the visual interpretation of satellite images (SPOT, LANDSAT TM and MSS). Ancillary data (aerial photographs, topographic or vegetation maps, statistics, local knowledge) were used to refine interpretation and the assignment of the territory into the categories of the CORINE Land Cover nomenclature.

ECOCLIMAP is a new global dataset at a 1km resolution. It is intended to be used to initialize the Soil-Vegetation-Atmosphere-Transfer schemes (SVATs) in meteorological and climate models (at all horizontal scales). The database supports the 'tile' approach, which is utilized by an increasing number of SVATs. 215 ecosystems representing areas of homogeneous vegetation are derived by combining existing land-cover maps and climate maps, in addition to using the AVHRR satellite data. Then, surface parameters used in SVATs, (as LAI, vegetation fraction, roughness length, minimal stomatal resistance, albedo and emissivity) are computed using look-up tables.

3.2 Vegetation variables

Leaf Area Index (LAI one-sided leaf area per unit area of ground) and Net Primary Production (NPP) are important variables to describe and model the vegetation dynamics in global and regional scale. The simulation of crops yields as well as water flux by evapotranspiration, CO₂ - fluxes and carbon storage due to photosynthesis and respiration, and leaf litter-fall make use of LAI data.

Remote sensing provides a means to make repeatable, consistent measurements over large areas that can be related to LAI. Generally, LAI has been estimated from remotely sensed data by developing relationships between ground-measured LAI and spectral vegetation indices (SVI). Most SVIs are sensitive to the differences between visible and near-infrared reflectance, so they can be used to distinguish green leaves from many other materials in the landscape. However, many factors other than LAI can affect the value of SVIs, so their use has some limitations.

The most common example of the SVI is the normalised vegetation index (NDVI), which is the difference between the signal of AVHRR's NIR and VIS channels divided by their sum.

A radiation quantity of vegetation dynamics and therefore more related to remote sensing than LAI is the fraction of absorbed PAR fAPAR. fAPAR (the fraction of absorbed PAR) = APAR/PAR incident at the canopy top. The amount of PAR incident at the top of a vegetation canopy varies with latitude and local topography, and throughout the day with changing sun angle, variations in cloud cover, and atmospheric properties (such as moisture and particulates).

3.3 Geophysical Land parameters

Vegetation dynamics and the interaction between land and atmosphere are governed by radiation, heat and water budget. Important quantities are surface albedo and reflectance, long and short wave radiation, precipitation and soil moisture.



All parameters tend to have rather non-homogenous spatial and temporal pattern. In-situ measurements of the variables are therefore difficult to map (i.e. analyse) into a regular field representation with a certain resolution. Except precipitation which is operationally observed at many sites at least in Europe and North America, the variables are only observed in selected research campaigns or sites.

Retrieved satellite data provide almost full global coverage but only geostationary platforms can provide radiation data which resolves the diurnal cycle. Cloud cover and may hamper the observation of the earth surfaces.

Precipitation and soil moisture can be retrieved from active micro wave instruments (radars) but with unknown quality. A merged precipitation product of satellite, rain gauge and model data would be the best way to provide global or continental data in near real time.

4 Satellite Missions for Land and Vegetation

This chapter briefly reviews the use for satellite observation to infer information about the land surface and the vegetation status. It intends to introduce present and future satellite missions which will be used in geolands global observatories and services and which might be also used in the GMES ocean and atmosphere IPs covered by HALO. A product specific summary of present and future satellite data used in geoland global observatories and services, and possibly in other GMES IPs, has still to be worked out in cooperation with the observatories and services. So far, only an availability schedule of global satellite vegetation product till 2030 has been compiled.

Satellites based instrument are the most common way to obtain geospatial data. The radiation received from earth surface is measured by instruments, and it is used to infer the required earth surface properties. The resolution of the instrument determines the resolution of the map.

Land cover/ use and vegetation data is mostly retrieved from optical imaging instruments in the visible (VIS) and near infrared (NIR) range. Vegetation properties are observed by considering the radiation absorbed due to photosynthesis. The application of the VIS and NIR imagers is limited to cloud free day time conditions, which may limit the availability of the pictures.

Microwave instruments are less affected by clouds. Multi-frequency and multi polarization Synthetic Aperture Radars (SAR) are used to provide high resolution (10 - 30 m) images of land cover. Active MW instruments (Scatterometer and SAR) and passive MW radiometers are capable of observing soil moisture.

Examples of present instruments often used for land cover and vegetation imaging are ETM+ onboard Landsat - 7, HRVIR, HRG and Vegetation onboard SPOT 4 and 5, AVHRR onboard NOAA-series satellites, Modis and AMSR-E onboard Aqua and Terra and Meris and ASAR onboard Envisat.

All of the above mentioned instruments are carried by polar orbiting satellites, which means that a certain point at the earth is revisited in several days depending on the swath width. Instrument with a high spatial resolution and small swath (10 - 30 km) are not suitable to get global coverage in a reasonable time frame.

Due to their orbit position (fixed in relation to earth and 45 times farther away than polar orbiters), geostationary satellites provide data with very high temporal (< 30 minutes) and lower spatial resolution. Geostationary missions of operational meteorological satellites ensure a reliable long-term data supply.

Table 3 List of current satellite instruments for land and vegetation monitoring. (* in image mode, a wider field of view with coarser resolution is possible) list a selection of current satellite instruments which supply observations of the earth surface's land cover and vegetation. The operational production of Geolands observatory on natural carbon (ONC) requires a sustainable supply of global LAI data beyond 2008. Table 4 provides a list of possible data providers for either LAI or spectral vegetation indices. The following paragraphs briefly describe current and future missions, which are relevant to Geoland.



Instrument	Mission (launch date)	Expected lifetime	Spectral Range	Spatial resolution at nadir	Swath width	Temporal resolution
TM	Landsat-5 (1984)	exceeded but still working	VIS NIR TIR	30 m	185 km	2 weeks
ETM+	Landsat-7 (1999)	till 2005	VIS NIR TIR	15 m	185 km	2 weeks
HRVIR	SPOT 5 (2002)	till 2010	VIS NIR	5 m	60 km	26 days
HRG	SPOT 4 (1998)	till 2005	VIS NIR	10 m	60 km	26 days
VEGETATION	SPOT 4 /5	till 2010	VIS	1.1 km	2200 km	1 day
AVHRR/3	NOAA-14-17 (1994- 2002) MetOp (2005)	to be continued	VIS NIR	1.1 km	2500 km	3 h in constellation
MODIS	Aqua (2002) Terra (1999)	till 2008	VIS NIR	250 m	2300 km	1 - 2 days
MERIS	Envisat (2002)	till 2008	VIS NIR	300 m	1100 km	3 days
SAR	ERS-2 (1995)	in 2003 recorder fault	MW active	28 m*	100 km	35 days
ASAR	Envisat (2002)	till 2008	MW active	28 m*	400 km	3.5 days
Scatterometer SCAT	ERS-2 (1995)	till 2008	MW active			
AMSR-E	Aqua	till 2008	passive MW			
SERVI	MSG -1 (2004).	till 2011 continued by MSG2	VIS - IR	1 km	earth-disk	15 min
VISSR	Meteosat-7 (1997)	continued by MSG	VIS - IR	2,5 km	earth-disk	30 min
Seawifs	Orbview-2	1997-2002	VIS - NIR	4.5	2800 km	2-3 days

Table 3 List of current satellite instruments for land and vegetation monitoring. (* in image mode, a wider field of view with coarser resolution is possible)

	year										
Instrument Mission	1981 -85	1986 -90	1991 -95	1996 00	2001 -05	2006 -10	2011 -15	2016- 20	2021- 25	2026- 30	2031 -35
AVHRR NOAA	NDVI -NOAA series										
AVHRR METOP							Possible NDVI- METOP / EUMETSAT				
VEGETATIO N- SPOT					NDVI						
SEAWIFS ORBVVIEW				NDVI							
MERIS ENIVISAT					MGVI						
MODIS- TERRA					LAI						
MODIS- AQUA					LAI						
VIIRS NPP & NPOESS						NDVI					
VIIRS NPP & NPOESSS						LAI					

Table 4 Availability of vegetation products from satellite data

4.1 Landsat

The Landsat series started 1972 and continues with Landsat 7 launched in 1999. The Landsat Program is part of the NASA's global change initiative - the Earth Observing System. Landsat 7 is operated by USGS. The images are a important resource for global change research and applications in agriculture, geology, forestry, regional planning, education and national security.

The earth observing instrument on Landsat 7, the Enhanced Thematic Mapper Plus (ETM+), replicates the capabilities of the Thematic Mapper instruments on Landsats 4 and 5. The ETM+ also includes new features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment, and large area mapping than its design forebears. The primary new features on Landsat 7 are a panchromatic band with 15m spatial resolution and thermal IR channel with 60m spatial resolution.

4.2 SPOT

SPOT (Satellite Pour l'Observation de la Terre, French for "Earth observation satellite") is a high-resolution, optical imaging system operating from space. Starting



The SPOT series is run by CNES (France) and further European Partners. The latest satellite of the series, SPOT 5 (launched 2002), will be operational through 2007; Spot 4 (launched in 1998, lifetime 3-5 years) and SPOT 2 (launched 1990, data recorder fault) are still in operation.

SPOT-4 carries 2 HRVIR (High Resolution Visible and InfraRed) instruments and the vegetation monitoring unit VEGETATION with a wider field of view. HRVIR sensors have a special spectral channel in the middle-infrared (1.58-1.75 μm), useful for improved vegetation monitoring and mineral discrimination. VEGETATION has a spatial resolution of 1.165 km, while data are re-sampled to a 1 km grid resolution. The swath width is 2250 km, providing global coverage every day. VEGETATION uses the same spectral bands as HRVIR with an additional “blue” spectral band (0.43-0.47 μm) for atmospheric correction (assessment of aerosol load), whose usefulness for oceanographic applications was demonstrated later. SPOT 5 carries VEGETATION and two improved HRVIR instrument called HRG and a spectroscopic unit HRS to provide 3-D images.

4.3 NOAA-AVHRR

The AVHRR (Advanced high resolution radiometer) instruments onboard the polar orbiting NOAA / NPOES series has the longest service history and widest data distribution in the field of meteorology, climatology and vegetation monitoring. A further benefit of the AVHRR data lies in their high temporal frequency of global coverage since 2 satellites are simultaneously run in operational mode.

A new series of NOAA satellites (POES) carrying AVHRR/3 began with the launch of NOAA-15 in 1998. NOAA operates four satellites (14 - 17) in mid 2004 but only NOAA-16 and 17 are classified as the operational satellites. An AVHRR/3 instrument will be part of the payload of the European MetOp series. The first out of 3 MetOp satellites will be launched 2005.

The AVHRR/3 instrument is a 6 channel imaging radiometers which detect energy in the visible and infrared (IR) portions of the electromagnetic spectrum. The instrument has an instantaneous spatial resolution of 1.1 km and swath width of about 2700 km. It provides day and night imaging of land, water and clouds, measures sea surface temperature, ice, snow and vegetation cover.

4.4 ESA Missions Envisat and ERS-2

ESA environmental research satellites ERS-2 (launched 1996) and Envisat (launched 2002) carry instruments with land and vegetation applications. Envisat continues the operation of many ERS-2 instruments. The MERIS, AATRS / ATRS and ASAR / SAR instruments are of special importance for GEOLAND satellite data demands. The envisaged lifetime of Envisat and ERS-2 will last no longer than 2008 which is before the GMES operational phase is going to start.

The MEdium Resolution Imaging Specrometer Instrument **MERIS** measures the solar radiation reflected by the Earth in 15 spectral bands, programmable in width and position, in the visible and near infra-red. Meris produces images with a surface area of 650 km x 650 km with a resolution of 300 m or 1150 km x 1150 km with a resolution of 1.2 km. The primary mission of MERIS is the measurement of sea colour in the oceans and in coastal areas but MERIS can also measure vegetation parameters on land. The MGVI (MERIS Global Vegetation Index) is development of

an NDVI which uses information from the blue part of the spectrum. The correlation between MGVI and fAPAR seems to be better than for the NOAA NDVI.

The **ASAR** (Advanced Synthetic Aperture Radar, Envisat) and **SAR** (ERS-2) are active MW instruments. Applications for this sensor include the study of ocean waves, sea ice extent and motion, and land surface studies such as deforestation and desertification. ASAR can operate in several observing and polarisation modes. The respective resolutions reach from 100 m in 400 km swath in global monitoring mode to about 30 m in image mode.

AATSR (Advanced Along Track Scanning Radiometer) onboard Envisat is an imaging radiometer operating in three visible and four infrared channels. The main purpose of AATSR is the accurate measurement of SST, of top of the atmosphere brightness temperatures and land surface detection of fires and burnt area. AATSR spatial resolution is about 1 km with swath width of 500 km.

4.5 NASA Earth Observing System (EOS)

Terra (launch 1999) and Aqua (launch 2002) missions are a part of the NASA-centered international Earth Observing System (EOS). Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.

MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard both satellites with many capabilities related to land and vegetation processes. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands between 0.4 and 3.0 μm .

MODIS retrievals include surface radiation budget variable (Albedo etc), ecosystem variables (vegetation indices, LAI and FPAR, Vegetation Production, NPP, Evapotranspiration & Surface Resistance) and land cover characteristics. The AMSR sensor on Aqua may provide soil moisture information.

4.6 Geostationary Missions

The system of present and future geostationary meteorological missions is a sustainable source of operational data provision. Currently five satellites from Europe (METEOSAT 5/7), US (GOES 9/10/12) and Japan (GMS) build the geostationary observation systems. The new generation of European satellites MSG (MSG-1 launched 2002, MSG-2 to be launched 2005) will operationally provide data until at least the year 2012. MSG main instrument SERVIRI works with 12 channels in the VIS to IR range. The GERB instrument (Solar and total band) onboard MSG for earth radiation budget studies.

Besides the meteorological purpose, SERVIRI measurements can be used to derive vegetation indexes and fire detections. SERVIRI observes the earth in a 15 minutes interval and - depending on the channel, spatial resolution is in the range of 1 - 3 km at Nadir.

The first of three MSG spacecraft will be launched late in the year 2000, allowing Europe to maintain its leading role in gathering global weather data. Meteosat transmits HRI data at 1694.5 MHz, at a data rate of 166.66 kbits/s. Further information on Meteosat can be found at EUMETSAT's web site

4.7 Future Missions

The operational phase of GMES will start in 2008 when the lifetime of the major European environmental satellites Envisat and ERS-2 will have reached its end. In order to ensure operational services, the new data of new satellites have to be used which are partly not available in the development of the services. A larger risk for a lack of continuity seems to be in the high resolution sensors for regional applications. Continuous service seems to be provided by the operational meteorological geostationary (MSG) and EUMETSAT Polar System (EPS) of MetOp - satellites.

EUMETSAT has no plans to provide biogeophysical products from METOP.

The following section lists briefly future satellite mission with capabilities and the fields of land and vegetation monitoring.

The **PLEIADES** programme is intended to replace SPOT but its satellites will have 10 times less coverage capabilities. The first satellites of this programme will be launched by the end of 2006.

An AVHRR/3 instrument will be part of the payload of the European **MetOp** series but EUMETSAT has no plans to provide biogeophysical products from METOP. The first out of 3 MetOp satellites will be launched 2005. The **SERIVI** instrument will be the payload of the next **MSG** satellites.

POESS Preparatory Project (**NPP**) of NASA starting 2006 will provide a continuation of global change observations after Earth Observing System (EOS) Terra and Aqua. Onboard **VIIRS** (Visible/Infrared Imager/Radiometer Suite) is a follow-up of AVHRR and MODIS instruments. NESDIS has firm plans to provide bio-geophysical products such as Vegetation Indices and Leaf-Area Index from NPP and NPOESS.

Soil Moisture and Ocean Salinity Mission (**SMOS**) by ESA is the second Earth Explorer Opportunity mission scheduled for launch in early 2007. The instrument on-board is the **MIRAS** (Microwave Imaging Radiometer using Aperture Synthesis) passive L-band 2D-interferometer capable of measuring soil moisture.

5 Inventory of Geoland Products

The following listing is a inventory of inter mediate products as defined in the Geoland proposal and current version of available product portfolios. Geolands observatories and core services are currently (10/2004) in a product consolidation phase which will lead to final set of products which are defined according to user demands.

The three regional observatories provide products for selected test sites in Europe only. Each Observatory has defined its own sites. The observatory food security and crops monitoring provides products for selected European countries (Belgium or France, Russia). The observatory on forest monitoring and land cover change aims at continental coverage (Russia, Africa) and the observatory on natural carbon provides its products in global coverage.

Core Service Generic Land Cover (test sites)

- Generic Land Cover 1:100 000
- Generic Land Cover 1:25000

Observatory Nature Protection (Test sites)

- Alpine Monitoring System
- Protection Forest Monitoring
- Wetland Monitoring
- Habitats and Biotopes
- Mountain Vegetation Types
- Ecotone Characterisation Map

Observatory Water & Soil (Test sites)

- Water shortage risk mapping
- Water pollution map
- Source Apportionment model
- Soil Erosion and Desertification

Observatory Spatial Planning (Test sites)

- Spatial Indicators
- Urban Growth Scenarios
- Landscape Transformation Scenarios



Observatory Food Security & Crop Monitoring (France or Belgium, Russia)

- Early assessment of crop yield
- Early assessment of acreage

Observatory Global Land Cover and Forest Change (Africa, Russia, Boreal Eurasia)

- Temporal Change Analysis
- Spectral Change Analysis
- Fire Disturbance Analysis
- Seasonal Water Resource Analysis
- Assessment on Environmental status
- Assessment on Environmental Status

Observatory Natural Carbon Fluxes (global coverage at 1/2° resolution, every 3 - 6 month)

- Terrestrial biospheric CO₂ flux
- Water flux
- Vegetation Biomass
- Leaf Area Index
- Root-zone Soil Moisture
- Carbon Storage

Core Service Geo-biophysical Parameters (global or Africa or Boreal Eurasia)

Product	Coverage Area	Time Period	Space Resolution	Time Resolution	Input satellite data	Availability of first products
Leaf Area Index (LAI)	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
FCover	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
FAPAR	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
Surface Albedo	Global	1998 - 2003	8 km	10-day	VGT	June 2004
	Europe – Africa Boreal Eurasia		1 km			Sept 2004
	Europe - Africa	1993 - 2003	5 km		METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Surface Reflectance	Africa Boreal Eurasia	1998 - 2003	1 km	1-month	VGT	Sept 2004
Down-welling Shortwave Radiation Flux (DSR)	Global	2000	50 km	4 time/day	Geo-stationary + AVHRR	May 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Down-welling Longwave Radiation flux (DLR)	Europe - Africa	1997 - 2003	50 km	4 times/day	METEOSAT	Jan 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2000			GMS	Jul 2005
Land Surface Temperature (LST)	Europe - Africa	1997 - 2003	5 km	½ hour 10-day 1-month	METEOSAT	Jul 2005
	Europe - Africa	1993 - 2003	5 km	1 day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Soil moisture	Global	1992 - 2000	50 km	10-day 1 month	ERS	Mar 2004
		2003 - 2004	100 km	1 week	AMSR	Jul 2005
Rainfall	Global	1997 - 2003	1°	1 day	Multi-sensor	Jan 2005
	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Evapo-transpiration	Europe - Africa	1993 - 2003	5 km	10-day	METEOSAT	Oct 2004
	Asia	1999 - 2003			GMS	Jul 2005
Burned areas	Africa Boreal Eurasia	2000 - 2003	1 km	1 month	VGT	Jan 2005
Water Bodies	Africa Boreal Eurasia	2000 - 2003	1 km	10-day	VGT	Jan 2005

Table 5 CSP products

6 Links to documentations on the web

GMES:

- GMES general information: <http://www.gmes.info/>
- GMES and ESA <http://earth.esa.int/gmes/>
- GMES cross - cutting assessment team <http://www.gmes-cca.co.uk>
- Geoland project <http://www.gmes-geoland.info>
- MERSEA project <http://www.mersea.eu.org/>
- GEMS project http://www.ecmwf.int/research/EU_projects/GEMS/
- HALO specific support action
http://www.ecmwf.int/research/EU_projects/GEMS/
- GSE FM Forest Monitoring <http://gafweb.gaf.de/gse/index.htm>
- GSE GMSF (Global Monitoring for Foss Security) <http://www.gmfs.info>

Land cover data sets:

- CORINE land cover classification <http://reports.eea.eu.int/COR0-landcover/en>
- ECOCLIMAP
http://www.cnrm.meteo.fr/gmme/PROJETS/ECOCLIMAP/page_ecoclimap.htm

Satellite missions for land and vegetation monitoring

- Landsat <http://landsat.usgs.gov/>
- SPOT http://www.cnes.fr/html/455_461_1415_.php
- VEGETATION on SPOT <http://www.spot-vegetation.com/>
- NOAA AVHRR <http://edc.usgs.gov/products/satellite/avhrr.html>
- MODIS on Aqua and Terra <http://modis.gsfc.nasa.gov/>
- MODIS vegetation products from Boston University
<http://cliveg.bu.edu/modismist/>
- MERIS on Envisat <http://envisat.esa.int/instruments/meris/>
- MSG and MetOp <http://www.eumetsat.de>
- SMOS http://www.esa.int/export/esaLP/SEMIM51P4HD_smos_1.html

International Bodies and Programmes on the Land and Carbon theme

- Global Terrestrial Observing System GTOS <http://www.fao.org/gtos/>
- IGOS (Integrated Global Observing System) Carbon Theme IGCO (Integrated Global Carbon Observation) <http://ioc.unesco.org/igospartners/Carbon.htm>
- CARBOEUROPE <http://www.bgc-jena.mpg.de/public/carboeur/>
- Global Carbon Project http://www.globalcarbonproject.org/about_the_gcp.htm