Ecoclimap 2: A new approach at global scale for ecosystems mapping and associated surface parameters database using SPOT/VEGETATION data

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Abstract

After a short presentation of ECOCLIMAP 1, the objective of this paper is to describe the methods used to derive surface parameters at 1km resolution using land cover maps, climate maps, and NDVI datasets. At global scale, the GLC2000 product and the associated regional legends is used and bring up improvement compared with previous maps made with AVHRR. A new concept of classification using the SPOT/ VEGETATION NDVI profiles, in order to define homogeneous ecosystems, is presented. The method is applied to Africa. Then, all surface parameters are derived for each of these ecosystems with look-up tables. The annual cycle of the Leaf Area Index (LAI) is constrained by the SPOT/VEGETATION information; an example over France is shown. Furthermore, a special emphasis will be made to the albedos fields produced in the framework of the SAF land and Cyclopes projects. This database can be used in meso-scale models, NWP models and GCM models.

1. Introduction

A good representation of land surface characteristics is necessary for meteorological models to reproduce realistically meteorological events and climatological patterns. The land-water mask, the soil-vegetation characteristics, and the urbanized area locations are required for the calculation of surface fluxes of heat, moisture, and momentum over continental and oceanic surfaces. The Soil vegetation atmosphere transfer scheme (SVAT), developed at Meteo-France (Noilhan et al, 1989) is implemented in operational numerical weather prediction (NWP) models, in climate models and in research meso-scale models; it requires a few parameters as inputs such as leaf area index, vegetation fraction, and albedo.

In 1999, Meteo-France has developed a first version of a global surface parameters database at 1km resolution (ECOCLIMAP I) using land cover maps, climate maps and NDVI datasets and mainly based on the IGBP 1-km AVHRR 10-day NDVI profiles (1992-1993).

The availability of updated and more accurate landcover maps (GLC2000 at global scale (Bartholomé et al, 2004) and CORINE2000 over Europe) and more precise sensors (such as SPOT/VEGETATION and MODIS) offers the opportunity of a substantial improvement of our database.

2. ECOCLIMAP 1

Ecoclimap 1 is a complete and global surface parameters dataset at 1km resolution (Masson et al, 2000). It is intended to be used to initialize the Soil-Vegetation-Atmosphere-Transfer schemes (SVAT) 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 AVHRR satellite data. This database is built using:

- A land cover map at a 1km resolution from the UMD (University of Maryland) landcover product (Hansen et al. 2000) at global scale, and from CORINE 1990 database over Europe.
- Climate maps: Koeppe and De Long (1958) over the globe and FIRS (EC 1995) over Europe.
- Normalized Difference Vegetation Index (NDVI) inferred from the IGBP 1km AVHRR monthly NDVI database for the period April 1992- March 1993.
- The FAO (1988) database at 10km resolution for soil texture.

The first necessary information which is used to assign conveniently the surface parameters is a basic distinction of the landscape units; so, each ecosystem is truncated into the fractions of woody vegetation, herbaceous vegetation and bare soil.

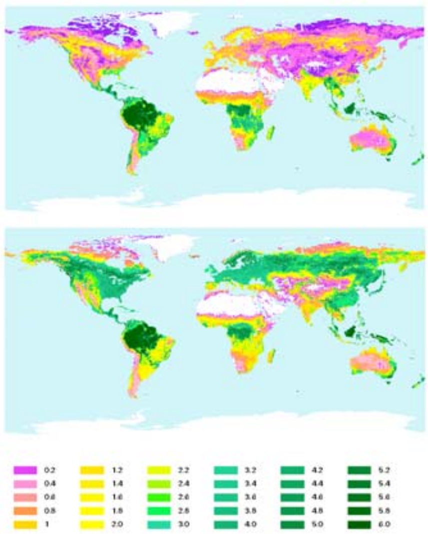

Fig. 1: Leaf Area Index for January (upper) and for july (lower)

Figure 1 Leaf Area Index for January (upper) and for July (lower)

vegetation type	total vegetation fraction	roughness length (m)	albedo of vegetation	minimal stomatal resistance (sm^{-1})	emissivity of vegetation
Bare soil	0	0.013			
Rocks	0	0.130			
Permanent snow & ice	0	0.0013			
C3 crops	$1-e^{-0.6LA}$	$0.13\min(1, e^{(LAI-3.5)/1.3})$	0.20	40	0.97
C4 & irr. crops	$1-e^{-0.6LA}$	$0.13\min(2.5, e^{(LAI-3.5)/1.3})$	0.20	120	0.97
Natural herbaceous (tropics)	0.95	$0.3^{LAI/6}$	0.20	120	0.97
Other herbceous	0.95	$0.3^{LAI/6}$	0.20	40	0.97
Needleleaf trees	0.95	$0.13\,h$	0.10	150	0.97
Evergreen broadleaf trees	0.99	$0.13\,h$	0.13	250	0.97
Deciduous broadleaf trees	0.95	$0.13\,h$	0.15	150	0.97

Table 1. Formulation of surface parameters for this database

Then, all surface parameters are derived for each of these ecosystems using look-up tables with the annual cycle of the Leaf Area Index (LAI) being constrained by the AVHRR NDVI profiles (Fig. 1). Table 1 defines the relations and the values used in Ecoclimap 1. The ECOCLIMAP LAI is validated against a large amount of in-situ ground observations (Fig 2.), and it is also compared to LAI derived from the ISLSCP2 database and the POLDER satellite. The comparison shows that this new LAI both reproduces values coherent at large scales with other datasets, and includes the high spatial variations owing to the input land cover data at a 1km resolution. In terms of climate modeling studies, the use of this new database is shown to improve the surface climatology of the ARPEGE climate model. This dataset is available to the research community (www1).

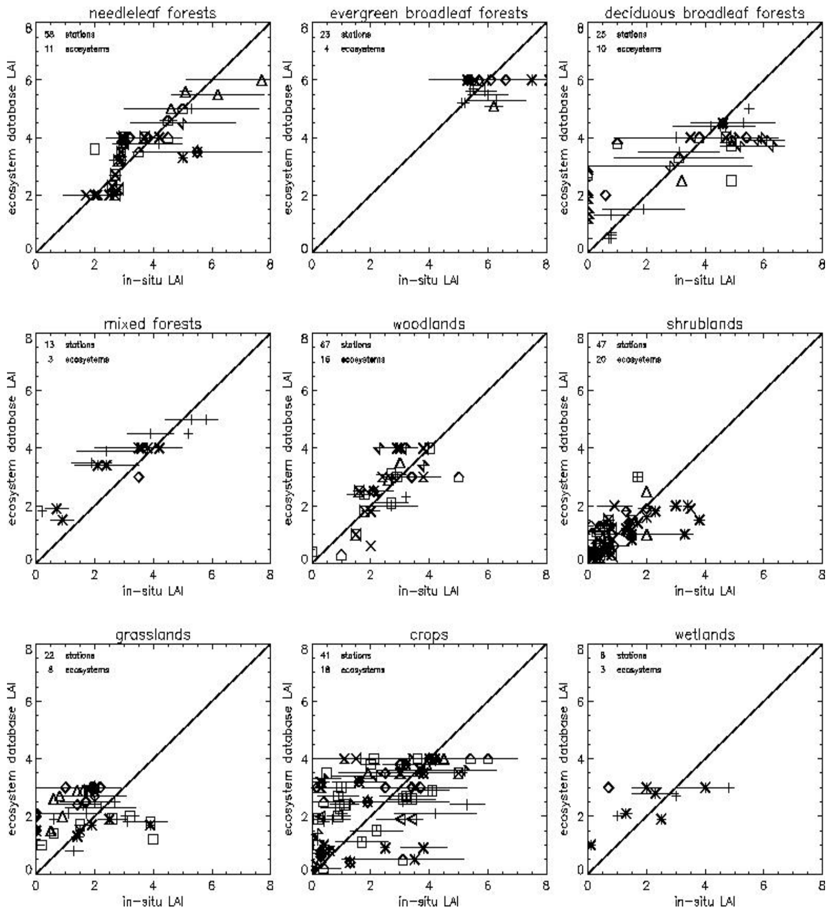

Figure 2: Comparison of the ecosystem LAI versus the observed LAI, for each month and ecosystem, arranged using 9 different land covers. For each graph, each symbol corresponds to the same ecosystem.

3. ECOCLIMAP 2

3.1. Ecosystem maps

3.1.1. Methodology

The large variability of the vegetation does not permit a straightforward derivation of the land surface parameters based uniquely on a general land surface inventory (Brown et al, 1993). For instance, for vegetation sharing the same nomenclature but located under different climates, different behaviours of the vegetation may however be obtained. In this regard, the forests of Northern Europe and the Mediterranean basin yield a typical illustration. This can also occur for the case of crops that present a time shift in their phenology. So, the first step is to split each land cover class of the regional maps in more homogeneous ecosystems using multi-temporal SPOT/VEGETATION data.

It is obvious that the new land cover maps such as GLC2000 and the MODIS landcover product lead to an important improvement in the definition of the major biomes compared to the previous land cover maps derived from AVHRR. At global scale our strategy for the GLC2000 product will be supported on the regional legends associated to the Land Cover Classification System (LCCS) developed by FAO that allows to characterize precisely the vegetation at 1km resolution (Bartholomé et al, 2003). Over Europe, the updated CORINE 2000 product will have a 250m resolution in phase with our needs for mesoscale models. In Ecoclimap 1, the main method was to cross land cover maps and climate maps which led to 225 biomes; however, the intra-class variability was still to high inside some classes. So, in Ecoclimap 2, a new strategy is defined: the idea is to use the information contained in multiannual S10 NDVI SPOT/VEGETATION profiles to split a land cover class in more homogeneous sub-classes. An unsupervised and/or hierarchical classification process, applied on multiannual (1999-2003) S10 NDVI SPOT/VEGETATION profiles, allows the discrimination of different behaviours inside of each land cover class. The classification is performed for each land cover class, each pixel being defined by its NDVI 10-day time-series (1999-2003). An automatic algorithm determines the optimised number of clusters for each GLC2000/CORINE class. In a second step, the mean NDVI profile is computed and analysed for each cluster. The spatial coherence of the classes is checked and, if necessary, a regrouping of the classes having a similar NDVI profile is carried out.

3.1.2. Application to Africa

This method is applied to the GLC 2000 land cover map of Africa (Mayaux et al, 2004). While the GLC2000 regional legend contains 24 classes, our methodology allows to define about 90 ecosystems. For instance, the class "closed evergreen forest" was exploded in 6 clusters (Fig. 3); the analysis of the associated mean multiannual NDVI profiles (Fig. 4) and the mean annual NDVI profiles (Fig. 5) shows differences which translate different behaviours of the vegetation. Furthermore, a substantial decrease of the variance of each sub-cluster is noticed; an example for the class "closed evergreen forest" is shown in Fig. 6. For the "open deciduous woodland", the classes follow the standard repartition of climates in latitude but also highlight more interesting meridian details (Fig. 7). Now, this strategy will be implemented for Europe and then applied to the other continents.

Figure 3: Clusters detected in the class "Closed evergreen forest" of the GLC 2000 map.

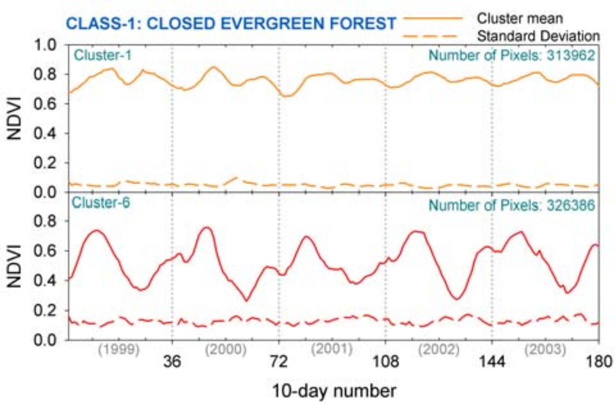

Figure 4: 5-year mean NDVI profile and associated standard deviation for clusters 1 and 6 of the class “closed evergreen forest”.

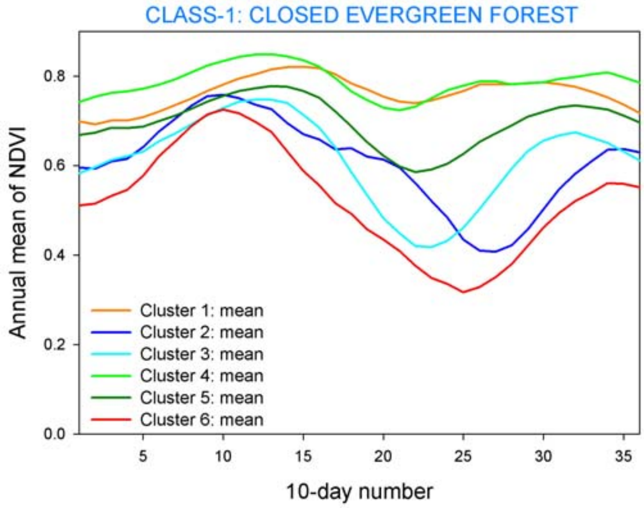

Figure 5: Annual mean NDVI profile for each sub-cluster of the class "closed evergreen forest".

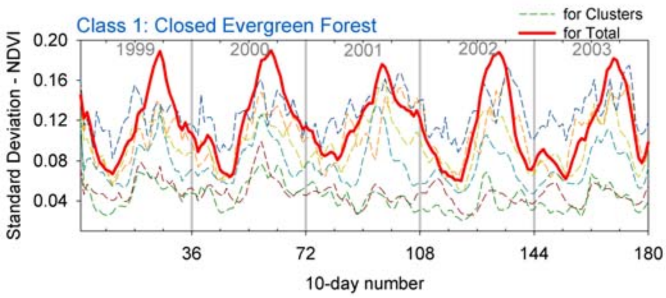

Figure 6: Figure 6. Standard deviations for the whole landcover class(in red) and for each sub-cluster of the class "closed evergreen forest".

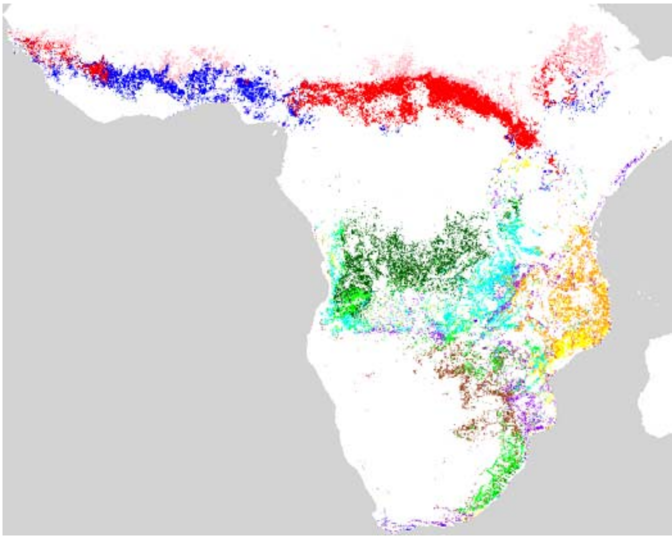

Figure 7: Clusters detected in the class "Open deciduous woodland" of the GLC 2000 map.

3.2. Surface parameters derived from the classification

3.2.1. Description of the database

In order to have a complete dataset, one needs to derive all the surface parameters needed in the SVATs. Orography and soil composition (e.g. clay and sand fraction) come from an independent source (e.g. F.A.O. for soil). Vegetation parameters are derived from the ecosystems defined in the paragraph 3.1. Over natural areas, each ecosystem is truncated into fractions of woody vegetation, herbaceous vegetation and bare soil.

The database must allow for both the surface 'tile' and the classical aggregated approaches. In the classical case (only one SVAT run per grid point), a parameter aggregation procedure is carried out (Noilhan et al, 1995) (see Fig. 8a). For sake of coherence, exactly the same procedure is used for aggregation at a coarser resolution (Fig. 8b). For LAI, typical values are selected for the maximum and minimum LAI for each class of vegetation; then, 10-days NDVI SPOT/VEGETATION values are used to impose a seasonality on LAI. It is possible to use either mean annual profile to derive climatological cycle or annual profile for a specific year. SVATs commonly use additional surface parameters, such as the vegetation fraction (the fractional area on the ground that is occupied by vegetation), the roughness length, the minimal stomatal resistance (that plays a role in the transpiration of plants), albedo and emissivity.

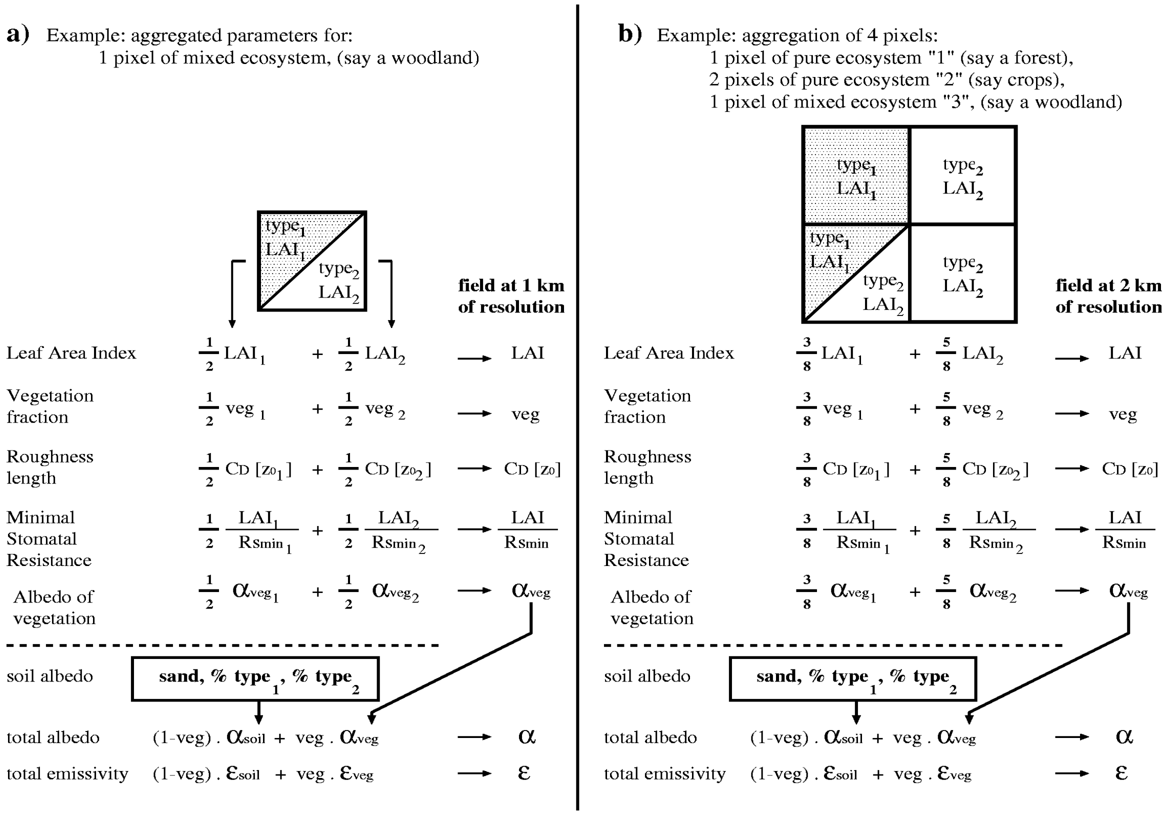

Figure 8: Aggregation rules to derive surface parameters: (a) aggregation of the surface characteristics of a mixed ecosystem pixel, and (b) aggregation towards a coarser resolution of the surface characteristics of several pixels, mixed or not.

3.2.2. Application to France

This methodology was applied for mapping LAI over France for the month of August from 1999 to 2003 using SPOT/VEGETATION profiles (Fig. 9). Large interannual differences appears. Particularly, the values of LAI for the month of August 2003 are lower of 20% in average with values higher than 50% on some regions; that corresponds to the severe dryness of the summer 2003 over France.

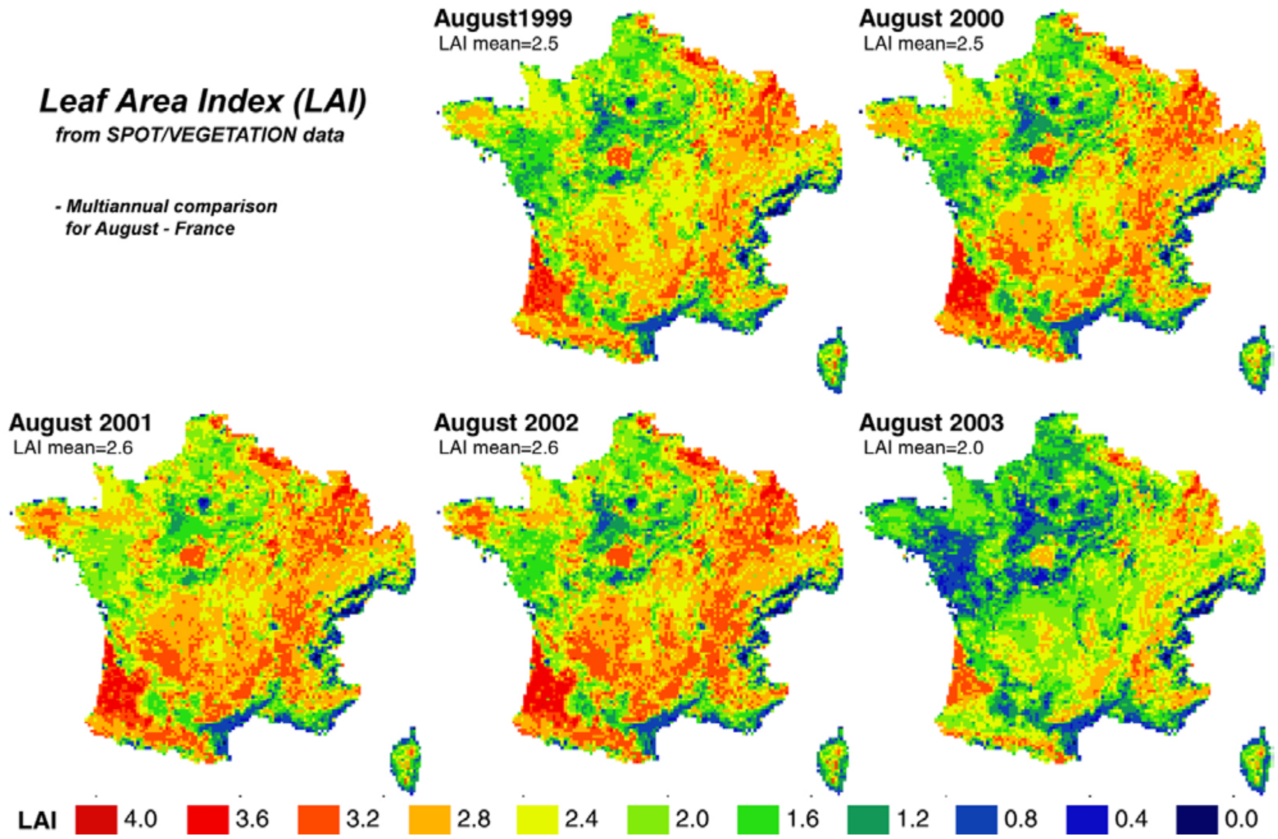

Figure 9: Multiannual comparison of LAI for August over France.

3.2.3. Improvements and validation of Albedo products

Special emphasis will be put on the albedo product using the results of the SAF Land and CYCLOPES projects.

In the framework of the EUMETSAT Satellite Application Facility for Land Surface Analysis (Land-SAF) we develop surface albedo and short-wave radiation products generated from observations provided by the SEVIRI instrument on board of the geo-stationary Meteosat Second Generation satellite.

For the albedo product cloud-free top-of-atmosphere reflectances in the instrument's $0.6\mu m$, $0.8\mu m$, and $1.6\mu m$ channels are atmospherically corrected with a simplified and fast radiative transfer code. The algorithm then exploits the diurnal variation of the illumination angle, which provides information on the angular variation of reflectance, in order to invert a linear kernel-based bi-directional reflectance model. Several albedo variants are derived by adequately integrating the constrained model functions.

The algorithm prototype is applied to a limited test data set comprising six SEVIRI scenes acquired between 6:00 UTC and 18:00 UTC on 28 July 2003. Figure 10 shows the resulting spectral albedo maps as well as a broadband albedo estimate obtained as a linear combination of the spectral quantities with regression coefficients.

The objective of the Cyclopes project is to provide coherent estimates of bio-physical variables such as land surface albedo and leaf area index at regional and global scales; an essential element of the project strategy is to provide sensor-independent estimates by exploiting the synergy of an ensemble of medium resolution imaging instruments (Fig. 11). The differences in the orbital configurations (angular sampling, frequency of observations) and sensor characteristics (spectral sensitivity, pixel size) potentially offer complementary information allowing us to increase the precision of the variable estimates.

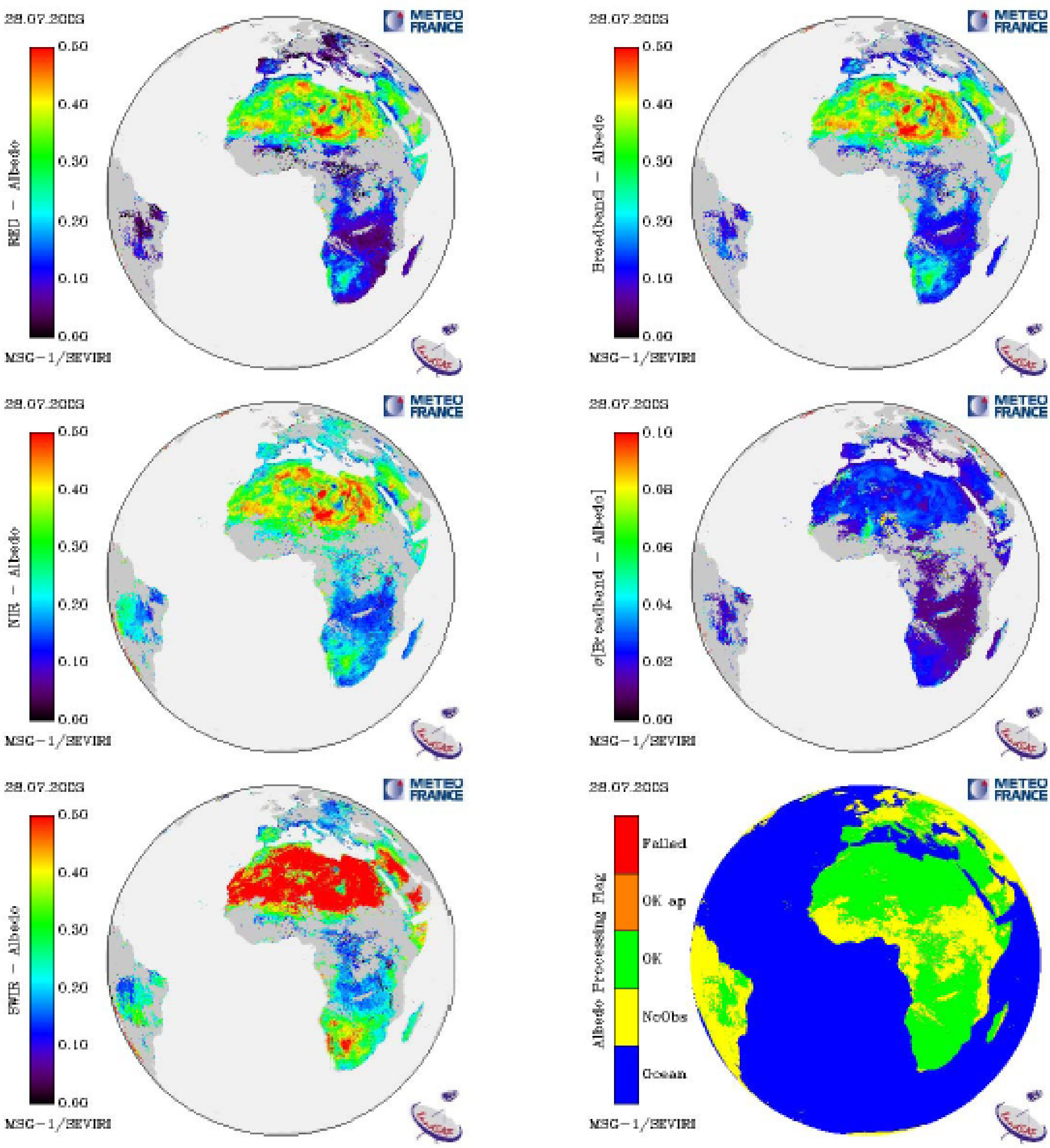

Figure 10: Directional-hemispherical albedo estimates calculated from a series of six MSG/SEVIRI images acquired on 28 July 2003. The images on the left depict (from the top to the bottom) the spectral albedo in the 0.6µm, 0.8µm, and 1.6µm instrument channels. The top right image shows the corresponding total broadband albedo ([0.3µm,4.0µm]), the middle right a provisional (theoretical) error estimate for the broadband albedo, and the bottom right a processing flag. In the latter the color code indicates if the algorithm was successfully applied (green) or if the inversion was not performed due to missing observations (yellow).

	spatial resolution	temporal resolution	spectral channels	observation angles	illumination angle	data availability
POLDER :	6km	~1 day	5	variable	~constant	1997, 2003
VGT :	1km	~1 day	4	variable	~constant	1998-
AVHRR :	4km	~1 day	4	variable	~constant	1982-
SEVIRI :	3km	15 min	3	constant	variable	2003-2018+
MERIS :	1km	~2 days	15	variable	~constant	2002-

Figure 11: Potential synergies between the instruments used in the Cyclopes project. The ellipses indicate particularly advantageous aspects of the respective sensors.

4. Conclusion

The contribution of the new global and regional landcover maps (GLC2000 and Corine 2000) associated with the SPOT/VEGETATION data allows us to define maps of homogeneous ecosystems.

In a second step, the seasonal cycle of the surface parameters can be derived from the temporal NDVI profiles of the SPOT/VEGETATION instrument.

Furthermore, the interannual variability of the surface parameters can be caught through the multi-annual database and so the climatic anomalies can be taken in account.

This complete and coherent surface data set is aimed to be used in meteorological and climate models at different resolutions. In particular, limited area models can obtain the greatest benefit. Furthermore, this dataset is very interesting for grid-nested models, because you will have a coherent surface between all the models.

5. References

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www1: http://www.cnrm.meteo.fr/gmme/PROJETS/ECOCLIMAP/page_ecoclimap.htm