GlobCorine – A joint EEA-ESA project for operational land dynamics monitoring at pan-European scale

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Abstract – Tracking land cover changes using remotely sensed data contributes to evaluating the impact of human activities on the environment. The first GlobCover map successfully demonstrated the usefulness of MERIS time series for operational land cover observation. Jointly supported by the European Space Agency and the European Environmental Agency, the GlobCorine project builds on the GlobCover findings and aims to make the full use of the MERIS time series for frequent land cover monitoring at the pan-European scale. Such an automated approach at 300 m will not identify landscape patterns as precisely as the Corine methodology, but it will significantly shorten the time response and expand the coverage. First, the automated GlobCover processing chain is adjusted towards a more land use oriented classification, compatible with the Corine typology. Second, an automated statistically-based algorithm is proposed to enable to monitor key land dynamics on a regular basis.

Keywords: MERIS, GlobCover, Corine Land Cover, land cover change monitoring, time series, automated

1. INTRODUCTION

Thanks to an efficient partnership led by the European Space Agency (ESA with JRC, FAO, EEA, UNEP, GOFC-GOLD and IGBP) and the GlobCover consortium (MEDIAS, UCL-Geomatics and Brockman Consult), the GlobCover project successfully delivered the very first 300m global land cover map thanks to ENVISAT MERIS time series (Arino et al. 2008). Following the success of the GlobCover project, the European Space Agency (ESA) decided to launch the GlobCorine project, in a joint initiative with the European Environment Agency (EEA).

Land use studies allow coupling the social and ecological systems and so, linking land cover changes with human activities and economic drivers (EEA 2006; GLP 2005). EEA has acquired a unique experience in land use database through the Corine Land Cover (CLC) project and the derived information. However, two major concerns need to be faced: the update frequency and the spatial extent of the CLC products (Defourny et al. 2008).

The CLC project currently covers the European Union countries and is updated on a 5-year basis with a delivery time of more than 2 years between the image acquisition and the derived results. Using MERIS time series would be highly complementary, allowing a more frequent monitoring of some major land dynamics. This would also result in a consistent mapping of the pan-European continent (i.e. the European Union countries extended to the European Russia and the whole Mediterranean basin), thus improving land monitoring and decision making on regional environmental issues.

The GlobCorine project attempts to address these EEA concerns building on the GlobCover findings. It aims at making the full use of the MERIS time series through two main activities dedicated to the pan-European continent: the land cover mapping and the land dynamics monitoring (Defourny et al. 2008).

First, the GlobCover classification module will be adjusted to provide a land cover product dedicated to the pan-European continent as compatible as possible with the CLC aggregated typology (EEA 2006). A more land use oriented typology will also be defined. Second, an automated change detection algorithm will be proposed in order to pinpoint changed areas. The change detection effort will be focused on three critical land dynamics: the urban sprawl, the agriculture conversions and the deforestation-afforestation processes.

2. GLOBCORINE DATA

The main source of data for the GlobCorine project is the MERIS Full Resolution Full Swath (FRS) composites as produced and delivered by the GlobCover processing chain (Vancutsem et al. 2007; Bicheron et al. 2008; Bicheron et al. 2009). In the framework of the GlobCover project, MERIS FRS data were collected by ESA from 1st December 2004 to 30th June 2006 over the world between 85° N and 56° S.

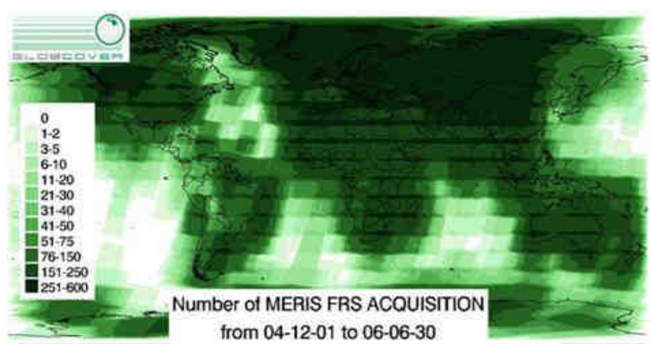

Figure 1. Number of MERIS FRS acquisitions from 1st December 2004 to 30th June 2006.

Figure 1 presents the density of MERIS FRS acquisitions over the world for this 19-months period (Arino et al. 2007). It shows a

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significantly better coverage over Europe than in many places of the world allowing further investigating this continent.

Clearly, the 300-m MERIS dataset will never provide a land cover product fully compatible with the current CLC products derived from Landsat and SPOT imageries, neither from the spatial nor from the thematic point of view. Nevertheless, it could potentially lead to some specific discrimination by characterizing the land cover phenology.

3. LAND COVER MAPPING

3.1 The GlobCover classification module

The GlobCover classification module has been designed to automatically interpret the MERIS surface reflectance composites into land cover classes at global scale.

An a priori stratification has been performed to split the world in 22 equal-reasoning regions from an ecological and remote sensing point of view. Such a regionally-tuned methodology indeed improves global maps accuracy by making it possible to tune the classification parameters according to regional characteristics.

The classification algorithm runs independently for each delineated equal-reasoning region and is organized into four steps, as shown in Figure 2. The key idea is to take advantage of the information contained by the multispectral composites and the temporal profiles. Spectral and temporal classification algorithms are combined (steps 1 to 3) to generate spectro-temporal classes, which are then labeled (step 4) into previously defined LCCS land cover classes. Class labels are assigned by cross-referencing the classification with a reference database of regional land cover maps and a set of decision rules (Arino et al. 2007). The classification chain is run and controlled by look-up tables (LUTs). For each equal-reasoning area, the LUTs indicate spectral band subsets, reference data, labeling decision rules and other classification algorithm parameters.

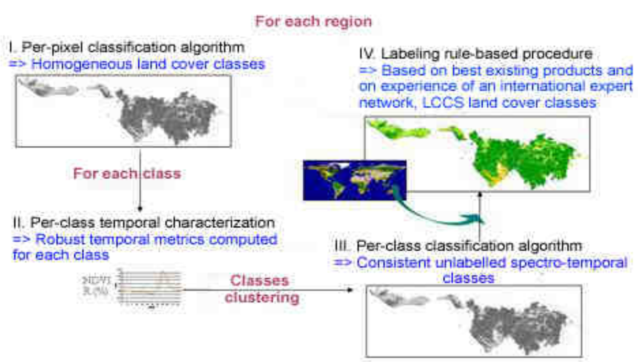

Figure 2. GlobCover classification module.

3.2 The GlobCorine adjustments

Some technical choices, which were made in GlobCover to deal with the global scale, limit the quality of the output for a given region. Working at a smaller scale may remove some constraints, thus improving the quality of the GlobCorine pan-European land cover map. The improvement is expected to come from three distinct areas. First, the classification algorithm should take advantage of the MERIS spectral resolution (15 bands). Only few spectral channels were used for GlobCover and thus, enhancing the spectral content of the signal should clearly improve the discrimination between specific classes of interest for EEA. Secondly, the stratification can be more specific. As a result, the delineated regions will gain in homogeneity and the classification parameters will be better calibrated. Third, the reference dataset currently used to label the spectro-temporal classes will be significantly enhanced to address specifically the EEA concerns, making the GlobCorine land cover map as compatible as possible with the CLC-aggregated typology.

3.3 The GlobCorine typology

As seen from the sky, land cover is a single image of both ecosystem and land use. Classification of land cover may address different purposes: importance can be given either to vegetation features, which are more related to habitats characteristics, or to landscape patterns, which reflect more land use. Typically, the GlobCover legend is of the first type, CLC of the second type.

There is no straightforward opposition between the two approaches as shown by several comparative analyses (Huettich et al. 2007; Herold et al. 2008). However, there are differences in purpose, enhanced by the classification methodologies. While GlobCover follows the UN Land Cover Classification System (LCCS) and automatically classifieds 300m pixels, CLC labels landscape objects that are visually identified from high resolution images. At the end, there are significant differences between the two maps and, more important, different visions of what land cover changes are. For instance, land and ecosystem accounts can hardly be derived from the current GlobCover product. It requires a more land use oriented typology, which should be made available by GlobCorine. The GlobCorine nomenclature will necessarily be a trade-off between the number of classes of key interest and their respective accuracy, constrained by the MERIS discrimination capabilities.

The intent is not to translate the GlobCover legend into something more “Corine looking” but to derive a different classification after the 3rd step of the GlobCover classification process. A new 4th “labeling” step will be set up using a new reference database and a new typology.

4 LAND COVER MONITORING

As just explained, CLC and GlobCover products promote two different visions of earth surface and land cover change. Furthermore, detecting change by comparing two existing land cover maps requires an actual change rate significantly higher than the error of the respective land cover maps. This is not the case in Europe as in most areas of the world.

The state of the art in change detection by remote sensing relies on alternative approaches either based on map-to-image or image-to-image analyses. In the framework of the GlobCorine project, the map-to-image has to be selected because only one MERIS FRS time series covering 2005-2006 is currently available.

The GlobCorine change detection algorithm is based on a method developed by Bontemps et al. (2008) which relies on a statistical analysis of the reflectance values distribution. First, homogeneous areas in terms of land cover and/or land use are delineated. In GlobCorine, it is done using the CLC maps corresponding to the previous epochs (CLC 2000). Second, statistical tests are performed to identify the outlying reflectance values in comparison to the reflectance distribution of the corresponding homogeneous class. These outliers are identified as land cover changes. The method is illustrated in Figure 3.

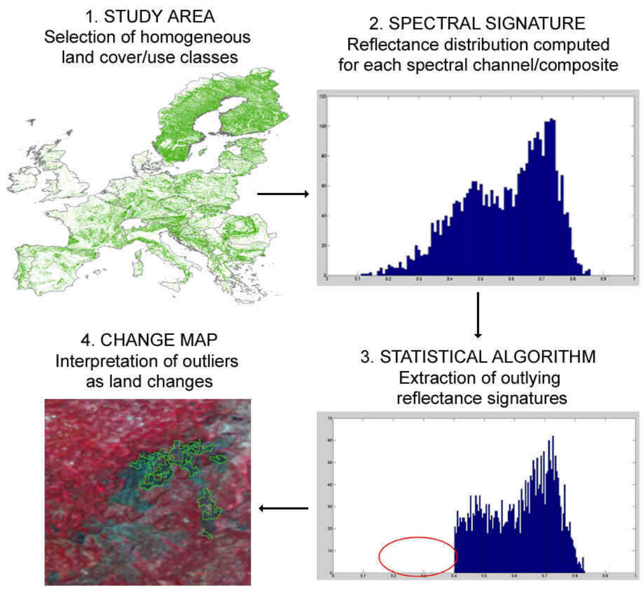

Figure 3. Change detection algorithm flowchart, illustrated with the case of forest dynamics

This method doesn't provide a binary "change no-change" output but a change probability map, i.e. a map where each detection is associated with a confidence level. This first originality enables to easily adapt the output map to the requirements of the users. In the case of GlobCorine, a comprehensive identification of all possible changes could constitute a prerequisite for further and finer detection through higher resolution data. A second originality of the proposed method is the possibility to work with objects rather than pixels. The advantage of a per-object approach is twofold: (i) objects are homogeneous and consistent analysis units, thus suitable for robust statistical analyses and automated procedures (Desclée et al. 2006) and (ii) objects may often be related to landscape patterns and constitute operational units for end-users (Pekkarinen 2002). The segmentation is applied to the time series, resulting in objects composed of pixels with similar spectral properties over time (Bontemps et al. 2008).

One should notice the compatibility of change detection as probabilities related to objects with the fuzzy logic assessments developed at the EEA from CLC (Land Accounts, op. cit. EEA 2006).

Through the change analysis between CLC1990 and 2000 and the production of land cover accounts (EEA 2006), EEA has demonstrated that not all possible changes take place in the real world and that a small number of changes make most of the picture. On the other hand, the number of land dynamics to monitor is restricted by the MERIS detection capacities, i.e. by its spectral and spatial resolution. This is why the change detection effort will be focused on three specific types of change: the urban sprawl, the afforestation and deforestation processes and the agriculture conversions. The change detection algorithm will be specifically tuned for each of these dynamics: per-pixel or per-object approach, segmentation parameters in the case of a per-object approach, dedicated spectral and temporal combinations…

5 RESULTS

5.1 The GlobCorine typology

The GlobCorine typology will focus on the CLC aggregated typology which has demonstrated its capacity to capture the most important land cover changes (EEA 2006). A first attempt of nomenclature is presented in Table 1.

Table 1. Preliminary GlobCorine nomenclature

Minimum legend	Detailed legend
1. Artificial areas	1. Artificial areas
2. Arable land and permanent crops	2.1. Non-irrigated arable land
	2.2. Irrigated or post-flooded agriculture
	2.3. Permanent crops and associations
3. Pasture and mosaic farmland	3.1. Pastures and grassland
	3.2. Mosaic farmland
4. Forest and transitional woodland shrub	4.1. Standing forest
	4.2. Transitional woodland and shrub
5. Heathland and sclerophyllous vegetation	5.1. Heathland and sclerophyllous vegetation
6. Open space with little or no vegetation	6.1. Beaches, dunes, sand plains and bare rocks
	6.2. Sparsely vegetated areas
	6.3. Glaciers and perpetual snow
7. Wetlands	7.1. Forested wetlands
	7.2. Low vegetation and bare wetlands
8. Water bodies	8.1. Inland water bodies
	8.2. Coastal water bodies

The contribution of each MERIS band is specifically investigated to enhance the discrimination performance, aiming at the 16 classes' typology with a minimum target of 8 classes.

5.2 The pan-European stratification

The GlobCorine stratification will be based on the biogeographical regions map of Europe (EEA 2002), presented in Figure 4. Spectral analyses will aid in determining if these new strata are (i) spectrally homogeneous, i.e. if they allow reduced spectral variability in comparison to the GlobCover strata, and (ii) spectrally specific, i.e. if the spectral signatures of the different GlobCorine classes in one stratum are significantly different than in other strata. Beyond the European countries, the stratification will be extrapolated from the WWF ecoregions (Olson et al. 2001).

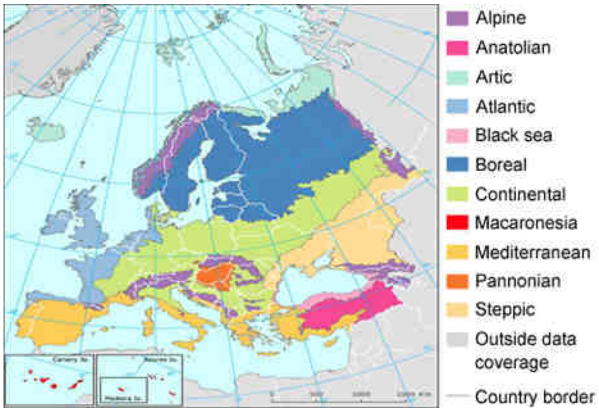

Figure 4. European biogeographical regions (2005) (Source: EEA Copenhagen 2007)

5. CONCLUSION

The challenging GlobCorine outputs are expected before the end of the year 2009 and include a pan-European land cover map for 2005 at 300m spatial resolution and a change map over the same region, pinpointing areas of urban sprawl, agriculture conversions and deforestation-afforestation processes.

The validation of the GlobCorine will be carried out by an independent team belonging to the European Topic Center on Land Use and Spatial Information in order to assess the actual performance of the products and their potential use for the European land community.

These two products are expected to demonstrate the potentialities of an automated operational system to provide some land information on a regular basis, also in the perspective of the Sentinel satellite series. Meanwhile, the GlobCorine products might become data sources for ongoing studies of land-cover and land-use dynamics and then help to improve our understandings of the environmental dynamics driven by land use change.

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ACKNOWLEDGEMENTS

The authors are grateful to ESA for his technical and financial support, to the GlobCover consortium for the availability of the MERIS dataset of the classification processing chain and to EEA for the scientific advices.