GLOBCOVER : A 300 M GLOBAL LAND COVER PRODUCT FOR 2005 USING ENVISAT MERIS TIME SERIES

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ABSTRACT:
The objective of the ESA GLOBCOVER initiative is to develop a service which, in its first instance, will produce a 300 m global land-cover map, using as its main source ENVISAT-MERIS full resolution data acquired over the year 2005. The overall project includes the development of the pre-processing and classification chain, the production and the validation. Most of the global acquisition planning and the development of the entire processing chain are completed. The challenges of the geometric correction and of a regionally-tuned classification were successfully addressed. This unique global 300 m land cover product is expected to be made available to the international communities in the course of 2007.

1. INTRODUCTION

In the context of increasing concern for the future functioning of the Earth system global land cover maps are considered as key source of information with regards to GCM improvement (Solomon et al, 1993), land cover modeling, biodiversity habitat and tropical forest monitoring and global Carbon cycle change. To face up the changes and the degradation of natural resources which currently work on the biosphere, accurate and detailed information on the state and the evolution of the land cover is required. In particular, such information is necessary for a better understanding of the global cycles, for the monitoring of land cover changes and the climatic change simulation. It also has an impact on the environmental security (Kyoto protocol) and the biodiversity. Finally, it would contribute to a sustainable management of forest, agricultural and natural resources at regional, continental and global levels.

Early nineties the first global land cover map derived from remote sensing was produced by DeFries and Townshend (1994) using Advanced Very High Resolution Radiometer (AVHRR) (NDVI) data at 1° spatial resolution and then, at 8-km spatial resolution (DeFries et al., 1998). The international IGBP-DIS effort provided the first 1-km global map product derived still from AVHRR data (Loveland et al., 2000; Hansen et al., 2000). The main challenge was to acquire and put together the global data set. The legend and the accuracy were very much constrained by the poor AVHRR data quality (Loveland et al., 1999). However this definitively confirmed the needs for a consistent land cover map for the whole world and raised the validation issue of such 1-km global product.

With the launch of TERRA the MODIS land cover product was expected to fulfill the user's needs thanks to the advanced sensor capabilities. The MODIS land cover map (Friedl et al., 2002) has been generated with a supervised classification methodology that exploits a global database of training sites interpreted from high-resolution imagery in association with ancillary data. The procedure is automatic but supervised, what requires the definition of signatures for the final 17 classes. In this way, the results strongly depend on the quality of the identified signatures. While initially planned to be updated very regularly the global MODIS land cover product still faced major discrimination and confusion problem for various areas.
More recently, the Global Land Cover 2000 project (GLC2000) project produced a new Global Land Cover database for the year 2000 thanks to an international partnership of about 30 research groups co-ordinated by the European Commission's Joint Research Centre (Bartholomé et al., 2002). The project has adopted an ad hoc processing strategy for the different regions and relied on a multiple thematic resolution approach based on the FAO Land Cover Classification System (LCCS) (Di Gregorio & Jansen, 2000) to insure the consistency of the various outputs. This initiative took advantage of the great quality of the VEGETATION data to discriminate 22 different land cover classes at the global level.

The GLC2000 product presents a greater level of detail than MODIS product (22 classes for GLC2000 vs 17 classes for MODIS product) and a better accuracy. The overall accuracy of 68.6% (Mayaux et al., 2005) for the GLC2000 global product confirmed the critical role of the geometric and radiometric performance to build the annual time series. This product seems to be recognized as the current reference worldwide. For instance it has been endorsed by FAO and UNEP and selected for the Year 2000 Millenium Assessment.

Even if the production of a 1-km resolution global land cover map has been a challenge, most of the regions of the world would benefit from a finer space resolution, given the very large landscape heterogeneity. In that context the recent availability of the MERIS instrument, with its enhanced resolution (~ 300 m), offers a very interesting opportunity to improve the global land cover map product.

MERIS has been launched in March 2002 by the European Space Agency onboard ENVISAT, an advanced polar-orbit Earth observation satellite that provides with measurements of the atmosphere, the ocean, and the land and ice surfaces. MERIS is one of the ten ENVISAT on-board instruments. It is a push-broom imaging spectrometer that measures the solar radiation reflected by Earth surfaces in 15 spectral bands in the visible and near infrared spectral domain. The MERIS swath is 1,150 km and the global coverage is obtained in 3 days. The primary mission of MERIS is the measurement of sea colour and the retrieval of atmospheric parameters over the marine domain. The MERIS instrument can also be programmed to acquire data over land but the nominal geometric specifications was defined according to its primary mission.

2. OBJECTIVES

In that context, the objective of the GLOBCOVER project is to develop and demonstrate a service that will produce a global land cover map for the year 2005, using as main source of data the fine resolution (300m) mode data from MERIS to be acquired over the full year 2005. The thematic legend of the final product is intended to be compatible with the FAO LCCS used for the GLC 2000 map. The development is conceived such that the new product will update and complement the other existing comparable global products, in particular the global land cover map at 1 km resolution for the year 2000 (GLC-2000) produced by the JRC. It is also expected to improve such previous global products, in particular through a finer resolution (300m).

The GLOBCOVER aims not only to produce a global 300 m land cover map for the year 2005 but also to develop a software system made of two components, a first component dealing with the data pre-processing and a second component providing an automatic classifier, including the transformation of composites of surface reflectance into classes satisfying the LCCS nomenclature. Finally, the system and the products have to undergo a validation exercise, in order to reach the international standards in terms of geophysical quality.

3. GLOBCOVER CHALLENGES

This challenging project can only be foreseen because of the combination of various experiences previously acquired.. Indeed, from a thematic point of view, the experience gained in the GLC2000 appeared to be really mandatory to properly understand the GLOBCOVER issue and to tackle the main problem related to the production of a consistent land cover map at the global scale while the land cover reality is made of diversity, ambiguity and continuum.

Five main challenging areas are identified for the GLOBCOVER project:

(i) the data acquisition planning to insure the high temporal resolution of this global 300 m time series with 15 spectral bands;

(ii) the high standards pre-processing chain requires to produce consistent MERIS time series at 300m resolution. This includes: ortho-rectification of MERIS Level 1b products using AMORGOS tool, a land/sea classification using MERIS measurements instead of the static-land sea mask because of the 300 m resolution, a spectral normalisation of the bands most affected by the smile effect to the reference wavelength, an efficient cloud screening in the absence of SWIR and Thermal bands, a good compositing strategy to correct the BRDF effect and make use of most of the information available as the acquisitions are far from daily.

(iii) the handling and the processing of such a very large volume of data. The system is required to handle big data volumes in a short time span : the MERIS raw data volume is over 16 Terabytes, corresponding to 16 months of MERIS full resolution and full swath data from the 1st December 2004 to the 31st March 2006 between 85°N and 56°S, excluding ocean areas. This input data has to be fed into the pre-processing line. Besides the technical means necessary to physically transmit these data to the appropriate recipient, this implies a high level of collaboration between all the steps of the complete processing line. Dataflow can also become a bottleneck if data is not transmitted quickly enough from its repository to the required process.

(iv) the regionally-tuned land cover classification to be automatic, global and maintaining the 300-m resolution through the whole process. The global scale of this mapping exercise forces to encompass the whole diversity of land cover types while the temporal dimension of the data analysis requires an in-depth understanding of the related seasonality for the different bioclimatic regions. The key idea is to combine the spatial consistency of the classes delineation obtained from well selected multispectral composites with the discrimination power of the temporal profiles analysis. Before that, an a priori stratification of the world provides equal-reasoning regions to be processed separately. The great but much controlled flexibility of this classification strategy allowed defining an automatic process tackling both the regional diversity and the local heterogeneity of the land cover characteristics;

(v) the validation of the GLOBCOVER product to be completed in the course of this 2-year project. However, this can not afford to collect primary sources of information at global scale while relevant use of the GLOBCOVER map requires a detaited documentation on the geometric and thematic accuracies of the product.

4. OVERALL APPROACH

The overall project includes the development of the pre-processing and classification chain, the production and the validation. The figure shows an overview of the GLOBCOVER system.

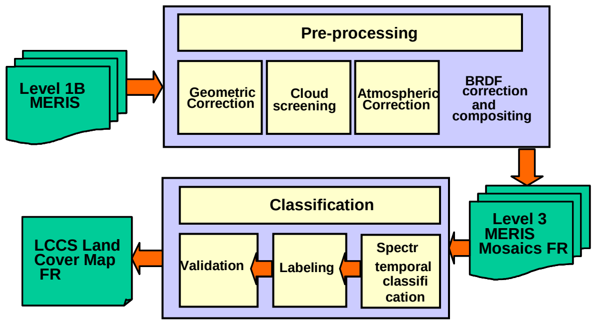

Figure 1. GLOBCOVER system overview

4.1 Pre-processing

The pre-processing includes the following steps: Geometric correction of the input data to achieve a geolocation accuracy of one third of pixel, cloud screening, land/water reclassification and a correction of the smile effect as a prerequisite for the subsequent atmospheric correction. The final BRDF correction and compositing step produces cloud-free syntheses.

4.2 Stratification

In order to deal with the diversity of ecological patterns at the global scale, the global stratification is a preliminary step to split the world in equal-reasoning areas from bioclimatic but also from a remote sensing point of view. This is the cornerstone for the regional tuning applied for all the consecutive classification steps as each region will be processed separately and mosaic into a single file afterwards. The areas have identified based on several criteria, including the vegetation seasonality, the snow cover, the burning period, the distribution of sun zenith angle, the cloud coverage and the data availability. On one hand, it reduces the land cover variability in the data set to process and so improve the discrimination efficiency of the classification algorithms. On the other hand, the classification parameters, i.e. temporal synthesis, specific band combinations, number of classes, etc, can be selected according to the characteristics of each equal-reasoning area.

The stratification delineation was completed in way to avoid inducing artificial limits in the final land cover product. They are based on natural limits directly derived from sharp boundaries observed in any remote sensing data set or through easy-to-classified and homogeneous land cover area. The most obvious limits are oceans and seas. It is also easy to derive well contrasted limits between biomes present in the annual composite, e.g. the equatorial forest / savannah interface.

4.3 Classification method

The land cover classification aims at the transformation of the surface reflectance's into a validated global land cover product. The overall classification performance relies on three steps:
(i) a classification algorithm to define homogeneous land cover objects based on one (or at most two) multispectral reflectance composite(s); (ii) a land cover discrimination algorithm made of iterative multidimensional clustering techniques;
(iii) a labelling procedure built on reference classifications such as the GLC2000 regional products and then adjusted to MERIS mapping capabilities with the support of international experts

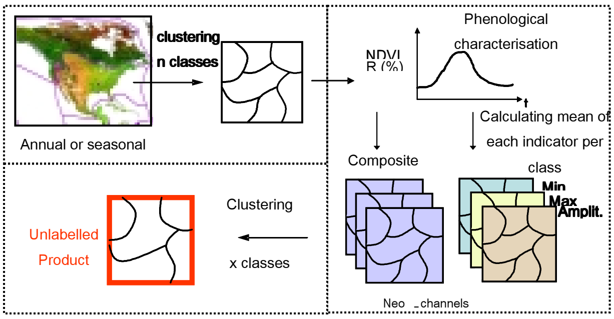

Figure 2. GLOBCOVER classification method.

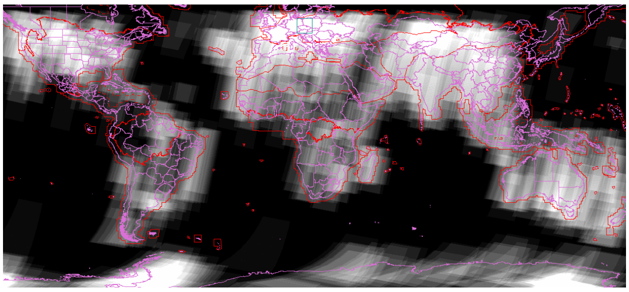

Figure 3. Current distribution of MERIS FR acquisition for the year 2005 (ESA) (from black to white according to the number of acquisition data).

A global stratification was completed to split the world into 22 equal-reasoning regions from bioclimatic, land cover and satellite observation conditions points of view. Very few limits were not obvious and required a particular attention. The figure 4 illustrates the GLOBCOVER stratification.

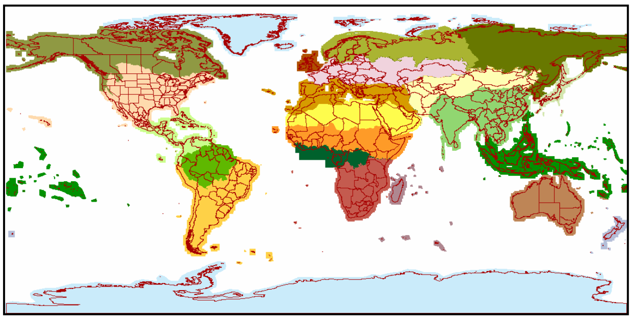

Figure 4. GLOBCOVER stratification delineating 22 equal-reasoning areas for the world.

The preliminary classification tests completed for several subsets built the confidence in the classification concept. The nominal GLOBCOVER legend has been defined using the FAO LCCS . This hierarchical typology includes 24 plain land cover classes and 38 classes when combined with bioclimatic zones. This was submitted to an international experts panel as well as to the land cover community. This land cover typology is also GLC2000 compatible in order to hopefully detect the change between 2000 and 2005.

Finally, a validation plan relying to an international network of regional land cover experts has been designed to validate independently the final land cover product. The experts will serve reference as they are supposed to provide the best information available based on their own experiences, the examination of existing maps and the interpretation of any other remote sensing imagery.

5. PRELIMINARY RESULTS

The time series actually acquired for the GLOBCOVER project provides a great coverage of the world but not yet uniform as shown in the figure 3.

As some areas have not been adequately covered during the nominal acquisition planning, the global MERIS FR acquisition has been further extended beyond March 2006 for GLOBCOVER.

The development of the GLOBCOVER pre-processing chain based on the AMORGOS module succeeded to reach the geometric accuracy required for time series analysis over land. For the relative accuracy, the analysis of 146 pairs of images widely distributed provided a RMSE value of 51,6 m. The absolute accuracy estimated from 10 Landsat-MERIS couples reached a RMSE value of 77 m.

5. PERSPECTIVES

Major steps of the GLOBCOVER initiative have been successfully passed, such as the building of a global MERIS FR data set and the significant improvement of the geometric accuracy of the MERIS data. The pre-processing chain is completed and the first tests of classification are going-on. The overall processing of this mass volume of raw data is not completed yet and the final validated land cover product is expected for June 2007.

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