Land Cover CCI

Product User Guide

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SYMBOLS AND ACRONYMS

(A)ATSR	: (Advanced) Along Track Scanning Radiometer
API	: Application Programming Interface
ASAR	: Advanced Synthetic Aperture Radar
ATBD	: Algorithm Theoretical Basis Document
AVHRR	: Advanced Very High Resolution Radiometer
BC	: Brockmann-Consult
CCI	: Climate Change Initiative
CCI-LC	: Climate Change Initiative Land Cover
CEOS	: Committee on Earth Observation Satellites
CEOS-WGCV	: CEOS Working Group on Calibration and Validation
CMC	: Climate Modelling Community
CMIP	: Coupled Model Intercomparison Project
CMUG	: Climate Modelling User Group
CRS	: Coordinate Reference System
ECV	: Essential Climate Variable
ERS	: European Remote Sensing Satellite
Envisat	: Environmental Satellite
EO	: Earth Observation
ESA	: European Space Agency
ET	: Evapotranspiration
fAPAR	: Fraction-Absorbed Photosynthetically Active Radiation
FR	: Full Resolution
Gamma-RS	: Gamma Remote Sensing
GCOS	: Global Climate Observing System
GCS	: Global Coordinate System
GDAL	: Geospatial Data Abstraction Library
GFED	: Global Fire Emissions Database
GIMMS	: Global Inventory Monitoring and Modelling System
GIS	: Geographic Information System
GMM	: Global Monitoring Mode
GRASS	: Geographic Resources Analysis Support System
IMM	: Image Mode Medium
IPCC	: Intergovernmental Panel on Climate Change
ISSI	: International Space Science Institute
LAI	: Leaf Area Index
Landsat	: Land remote sensing Satellite
LC	: Land Cover
LCCS	: Land Cover Classification System
LS	: Land Surface
MERIS	: Medium Resolution Imaging Spectrometer
MODIS	: Moderate Resolution Imaging Spectroradiometer
NDVI	: Normalized Difference Vegetation Index
NIR	: Near InfraRed
NLCD	: National Land Cover Database
OLCI	: Ocean and Land Colour Instrument

PFT	: Plant Functional Types
PROBA-V	: Project for On-Board Autonomy, with the V standing for Vegetation
PUG	: Product User Guide
RR	: Reduced Resolution
SAR	: Synthetic Aperture Radar
SLSTR	: Sea and Land Surface Temperature Radiometer
SPOT	: Satellite Pour l'Observation de la Terre
SPOT-VGT	: SPOT- Vegetation
SR	: Surface Reflectance
SRTM	: Shuttle Radar Topography Mission
SWBD	: SRTM Water Body Database
UCL	: Université catholique de Louvain
UN	: United Nations
UNFCCC	: United Nations Framework Convention on Climate Change
WB	: Water Body
WBP	: Water Body Product
WGS84	: World Geodetic System 84
WSM	: Wide Swath Mode

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Applicable documents

ID	TITLE	ISSUE	DATE
AD.1	Statement of Work for ESA Climate Change Initiative Phase II - CCI-PRGM-EOPS-SW-12-0012	1.2	07.06.2013
AD.2	ESA Climate Change Initiative Phase II - Land Cover ECV Technical baseline for the project (update of the technical proposal with clarification and negotiation items)	1.0	13.03.2014
AD.3	CCI System Requirements v1, CCI-PRGM-EOPS-TN-12-0031 Available on line at: http://46.137.76.174/?q=webfm_send/72.	1.0	13.06.2013
AD.4	CCI-LC URD Phase II. Land Cover Climate Change Initiative - User Requirements Document	1.1	30.11.2014
AD.5	CCI-LC PSD Phase II. Land Cover Climate Change Initiative - Product Specification Document	1.1	01.12.2014
AD.6	CCI-LC DARD Phase II. Land Cover Climate Change Initiative - Data Access Requirement Document	1.1	30.11.2014
AD.7	CCI-LC ATBD Phase II. Land Cover Climate Change Initiative - Algorithm Specification Document - Part I: Overview	1.1	03.12.2014
AD.8	CCI-LC ATBD Phase II. Land Cover Climate Change Initiative - Algorithm Specification Document - Part II: Pre-processing	1.1	03.12.2014
AD.9	CCI-LC ATBD Phase II v2. Land Cover Climate Change Initiative - Algorithm Specification Document - Part III: LC classification	1.2	13.01.2016
AD.10	CCI-LC ATBD Phase II. Land Cover Climate Change Initiative - Algorithm Specification Document - Part IV: LS seasonality	1.1	03.12.2014
AD.11	CCI-LC ATBD Phase II v2. Land Cover Climate Change Initiative - Algorithm Specification Document - Part V: WB classification	1.1	03.12.2014

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1 INTRODUCTION

1.1 Scope

The Product User Guide (PUG) is the reference product description, which describes data format, filenames, metadata and thematic content with the aim to familiarize users with the products.

The 1st phase of the Climate Change Initiative (CCI) generated a suite of products consisting of 3 consistent global Land Cover (LC) products corresponding to the 1998-2002, 2003-2007 and 2008-2012 periods, climatological 7-day time series representing seasonal dynamics of the land surface, Medium Resolution Imaging Spectrometer (MERIS) Surface Reflectance (SR) time series which served as input for generating the global land cover maps. In addition, a global Water Body (WB) product was derived from the Envisat Advanced Synthetic Aperture Radar (ASAR) archives. These products were described in a PUG [RD.6].

The 2nd phase of project, started in March 2014, led to a set of new and improved products: SR time series of Advanced Very High Resolution Radiometer (AVHRR) and PROBA-V, global annual and consistent LC maps from 1992 to 2015 and new versions of the global map of open water bodies and of the user tool.

This PUGv2 describes the available land cover products at the end of the second year of the CCI-LC project Phase II.

1.2 Background of the project

The European Space Agency (ESA) CCI projects will deliver the next generation of satellite derived geophysical parameters, with quantified uncertainties that will allow each parameter to be assessed against requirements from the Global Climate Observing System (GCOS) for Essential Climate Variables (ECV) and the Climate Modelling Community (CMC), represented within the CCI program by the Climate Modelling User Group (CMUG).

The objective of the CCI is to realize the full potential of the long-term global Earth Observation (EO) archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by United Nations Framework Convention on Climate Change (UNFCCC). The programme is organized in 2 phases.

The CCI Phase I provided a unique opportunity for the European EO science community to define and validate innovative approaches for continuously generating and updating a comprehensive and consistent set of ECV global satellite based data products in the long term – i.e. decades hence. The focus was on a major sustained, and coordinated scientific effort to review and improve underlying processing, retrieval and validation methods.

The CCI Phase II focuses on the generation of long-term, consistent, global data records for each ECV, exploiting the full range of available data sets from ESA and relevant European missions with the aim to issue extended and improved globally consistent ECV data sets from all CCI projects. Each project must make significant, further progress towards meeting the GCOS and related user requirements, exceeding the achievements of the Phase I CCI projects with quantifiable validated measure of performance.

This means the prototype ECV production systems implemented in CCI Phase I must be developed to a sustainable level, based on complete requirements specified and thoroughly validated by the competent science communities during Phase I [AD.3]. These system requirements must be updated to take account of the availability of new and upcoming missions (e.g. Landsat-8, Sentinels and PROBA-V) and evolution to meet industry level standards for operations, maintenance, evolution and configuration control. Phase II projects should follow an iterative life-cycle, of concurrent development and operations. Project activities must continue to be driven by climate science, traceable to documented user needs and CCI projects must engage the relevant science communities, working side-by-side with industry and data centers in Europe.

1.3 Structure of the document

After this introduction, the document is divided into 7 sections that are shortly described below:

- Section 2 briefly presents the CCI Land Cover (CCI-LC) project;
- Sections 3 to 6 describe the various products: land cover maps, land surface seasonality product, open water body product and surface reflectance time series;
- Section 7 presents the various tools that can be used to visualize and aggregate the products;
- Section 8 explains how to access the CCI-LC products and give their terms of use.

This document contains various appendices (sections 9 to 12) with additional detailed information.

2 CCI LAND COVER PROJECT

2.1 Revisited land cover concept

Considering the importance of land cover as an input in climate modelling, the development of a new global LC database was initiated during the 1st phase of the project. The specifications of this new database relied on an in-depth user requirement analysis conducted during the 6 first months of the Phase I project [RD.1].

This analysis revealed first the need to consider LC data under 2 aspects: ***stable*** in the form of land cover map and ***dynamic*** in the form of time series. In addition, the LC products should provide ***flexibility*** to serve different scales and purposes in terms of spatial and temporal resolutions. Their quality should also be transparent by using ***quality flags*** and controls.

From a remote sensing point of view, these requirements – and the first one in particular – led in rethinking the whole LC concept into ***LC state*** and ***LS seasonality*** components [RD.2]. The ***LC state*** concept refers to the set of LC features remaining stable over time which define the LC independently of any sources of temporary or natural variability. It is agreed that the LC state is well described using the United Nations (UN) Land Cover Classification System (LCCS) [RD.8], which is also quite compatible with the Plant Function Types (PFT) concept of many models [RD.1]. The ***LS seasonality*** concept relates directly to the temporary or natural variability of LC features that can induce some variation in land surface over time without changing the LC in its essence. This LS seasonality is typically driven by biogeophysical processes. It encompasses different observable variables such as the green vegetation phenology, snow coverage, open water presence, and burned areas occurrence, etc.

Furthermore, the need to generate successive LC state products consistent over time resulted in the development of a new original classification approach. Most often, LC maps were generated from few instantaneous observations of the land cover state. As a result, classification outputs are sensitive to the date(s) of observation and can reflect temporary conditions (e.g. map savannahs as burnt scars, boreal forest as snow, croplands as bare soils, etc.). The developed alternative consisted in describing the LC state ***from multi-year observation dataset***. In this case, assuming that no LC change – even temporary – has occurred over this multi-year period, the LC is expected to be mapped in a consistent way over time. This approach was successfully implemented in the 1st phase and continued in the 2nd phase.

2.2 Users' requirements

At the beginning of the 2nd phase of the project, a new user survey was conducted among the climate modelling partners of the CCI-LC project to analyze the fulfilment of the requirements defined in

Phase I and to identify target requirements for future LC products. The comprehensive user survey results of Phase I were reanalysed (excepted future modelling requirements) and consolidated through synthesizing new user needs from the scientific community from initiatives such as Terrabytes and International Space Science Institute (ISSI) special group, from Coupled Model Intercomparison Project (CMIP) 6 process and from the outcomes of the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC). The GCOS process has started to specify new ambitions for ECVs to meet the needs of the climate mitigation community – this also posed new requirements for the CCI-LC project. This activity is documented in details in [AD.4].

It resulted in a series of new requirements, which were organized into higher or lower priority categories:

1) Higher priority

a. Better description of LC characteristics in the context of PFT model requirements. As a follow-up of the Phase I work, the new requirement is to formulate LC – PFT conversion tables separately for different climatic regions. These regions are to be defined by the climate modeller users of the consortium, with PFT fractions per region identified using the land cover validation dataset.

b. In particular, the percentage ranges for LC – PFT conversion in the case of mixed classes, for example the class ‘mosaic tree and shrub (>50%) / herbaceous (<50%)’, should be better defined in order to provide the proportion (%) of tree, shrub, and herbaceous.

c. Longer temporal extent for LC maps (30 years and more) including datasets for the 1990’s and the 1980’s.

d. Higher temporal resolution: annual time steps in LC change.

e. More specific information of land cover/use change is required, at least in the context of the IPCC land categories (forests, agriculture, grassland, settlement, wetland, other land).

f. Additional attributes of the LC classes are required including vegetation height, minimum and maximum Leaf Area Index (LAI), clumping index and the distinction between C3 and C4 plants.

g. Move to 30 m (or better) scale LC and change assessments, at least for selected regions.

h. Provide the full time series for the Normalized Difference Vegetation Index (NDVI) LS seasonality.

i. Provide additional LS seasonality such as water and surface albedo for vegetation and soil LC classes.

j. Provide an improved water body product with at least a distinction inland water/ocean included.

2) Lower priority

a. Seek options for including land management (forestry, agriculture, livestock) with land cover datasets.

b. Provide additional relevant attributes of LC classes such as aboveground tree biomass, vegetation density, and permafrost fraction.

c. Improve the description of the results and products. Besides the detailed technical reports, short technical summaries highlighting important points should be provided.

d. Provide additional LS seasonality such as the FaPAR.

The requirements and their fulfillments are summarized in Figure 2-1.

	Threshold requirement Phase I	Target requirement Phase I	Threshold requirement Phase II	Target requirement Phase II
	Coverage and sampling			
Geographic Coverage	*Global* ✓	*Global with regional and local specific products* ✗	*Global with regional specific products* ✗	*Global with regional specific products* ✗
Temporal sampling	*Best/stable map and regular updates* ✓	*Monthly data on vegetation dynamics and change*	*5-10 year epoch maps with monthly vegetation dynamics(NDVI)* ✓	*1-year epoch maps. Monthly data on vegetation dynamics (NDVI)* ✓
Temporal extent	*1-2 years, most recent* ✓	*1990 (or earlier)-present* ✗	*1990 (or earlier) - present* ✓	*1980 (or earlier) - present* ✗
	Resolution			
Horizontal Resolution	*1000 m* ✓	*30 m* ✗	*300 m* ✓ *with regional 30 m products* ✗	*30 m* ✗
Vertical Resolution	–	–		
	Error/Uncertainty			
Precision	*Thematic land cover detail sufficient to meet current modelling user needs* ✗	*Thematic land cover detail sufficient to meet future model needs* ✗	*Thematic land cover detail (incl. conversion tables to PFT for climatic regions) sufficient to meet current and future model needs, incl. key land IPCC changes* ✓	*Thematic land cover detail (incl. conversion tables to PFT for climatic regions) and traits) sufficient to meet current and future model needs, incl. land changes and*

				land management ✗
Accuracy	*Higher accuracy than existing datasets* ✓	*Errors of 5-10% either per class or as overall accuracy* ✗	*Higher accuracy than existing datasets*	*Errors of 5-10% either per class or as overall accuracy*
Stability	*Higher stability than existing datasets* ✓	*Errors of 5-10% either per class or as overall accuracy* ✗	*Higher stability than existing datasets* ✓	*Errors of 5-10% either per class or as overall accuracy*
Error Characteristics	*Independent onetime accuracy assessment* ✓	*Operational and independent multi-date validation* ✗	*Independent multi-date validation* ✓	*Operational and independent multi-date validation*

Figure 2-1: Threshold (minimum) and target (optimal) requirements identified for LC products in the User Requirements Survey carried out in the CCI – LC project Phases I and II. Check–marks indicate fulfilled requirements (from [AD.4]).

2.3 Project outputs

The outputs of the CCI-LC Phase II project concern global SR time series, global annual LC maps, global LS seasonality products and a global WB product (hereafter named WBP), all of them being delivered along with metadata. The outputs also include software systems, products documentation and validation reports.

At the end of the 3-year long Phase II, the key global datasets for the end-users will be:

1) Global SR time series and associated metadata over different epochs and from different sensors:

   a. Time series of AVHRR 7-day composites[1] from 1992 through 1999;

   b. Time series of Envisat MERIS Full Resolution (FR) 7-day composites from 2003 through 2012;

   c. Time series of Envisat MERIS Reduced Resolution (RR) 7-day composites from 2003 through 2012;

[1] A 7-day compositing period is foreseen to be consistent with the other sensors, but this has to be confirmed according to the data coverage

   d. Time series of PROBA-V 7-day composites from 2014 and 2015 (and beyond);

   e. Time series of Sentinel-3 Ocean and Land Colour Instrument (OLCI) and Sea and Land Surface Temperature Radiometer (SLSTR) 7-day composites from 2016 (and beyond).

2) Global annual LC maps starting from the 1990s through 2015 based on the above AVHRR, SPOT-VGT, MERIS FR and RR, PROBA-V and associated metadata;

3) An updated global LC map for 2016 including the above Sentinel-3 OLCI and SLSTR composites and associated metadata[2];

4) Global LS seasonality products and associated metadata for the NDVI and water bodies;

5) Global map of permanent open WB for the 2010 epoch based on Envisat ASAR time series, associated with an additional data product detailing the dates of ice-free conditions over inland water bodies.

In addition, prototypes products are foreseen, which will demonstrate the pre-processing and classification algorithms developed for the Sentinel-1 and -2 missions and to expand historical time series. They include:

1) Sentinel-2 time series of regional SR composites from 2015 (and beyond) and associated metadata;

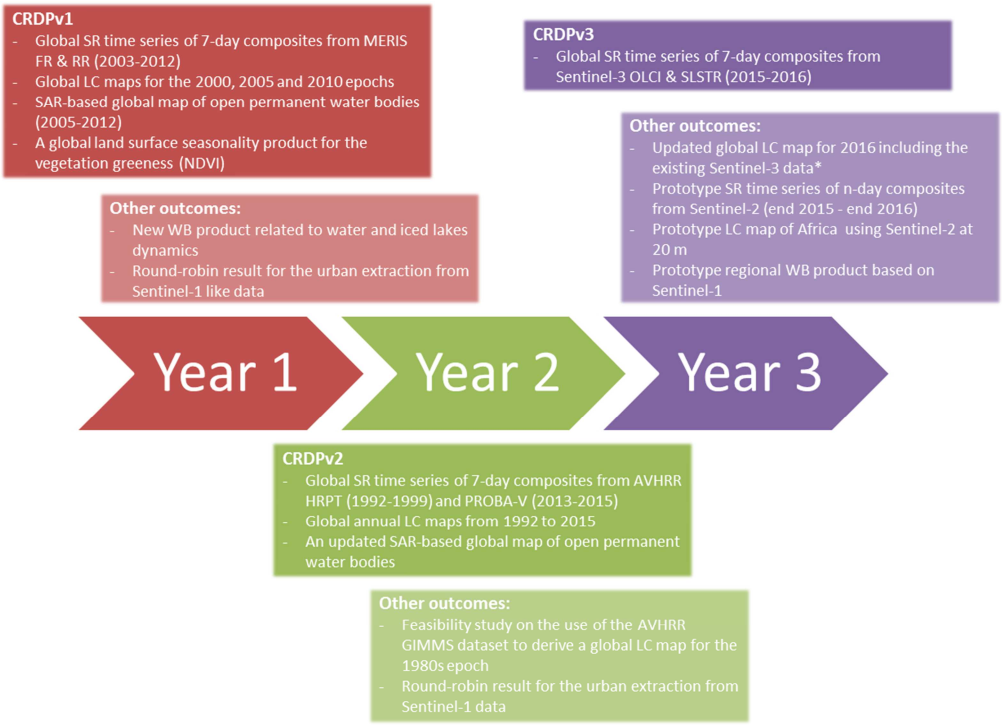
2) Africa-wide mosaic of Sentinel-2 cloud-free surface reflectances at 10 m;

3) Africa-wide LC map based on the above Sentinel-2 composites and associated metadata;

4) Prototype WB and urban products based on Sentinel-1 SAR data, tuned geographically to the regional LC maps obtained with Sentinel-2 data;

Those products will be generated throughout the project following a yearly planning. They will be delivered in the form of Climate Research Data Package (CRDP), versioned 1 to 3 for years 1 to 3, as illustrated in Figure 2-2.

[2] According to the availability of Sentinel-3 data in terms of quantity and timing with respect to the overall project planning



* According to the availability of Sentinel-3 data in terms of quantity and timing with respect to the overall project planning.

Figure 2-2: Planning of datasets to be produced in the CCI-LC Phase II (updated from [AD.5])

This version of the PUGv2 focuses on the products available in the CRPDv2. Their main specifications are summarized in Table 2-1.

Table 2-1: Summary of the CCI-LC products

PRODUCT	COVERAGE		RESOLUTION		SENSOR	PROJECTION	FORMAT
	SPATIAL	TEMPORAL	SPATIAL	TEMPORAL			
MERIS SR time series	Global	2003-2012	300 m 1000 m	7-day	MERIS FR MERIS RR	WGS 84	NetCDF
AVHRR SR time series	Global	1992-1999	1000 m	7-day	AVHRR	WGS 84	NetCDF
PROBA-V SR time series	Global	2014-2015 (and beyond)	300 m	7-day	PROBA-V	WGS 84	NetCDF
Annual LC maps	Global	1992-2015	300 m	1-year	MERIS FR/RR SPOT-VGT AVHRR PROBA-V	WGS 84	NetCDF & GeoTiff
NDVI LS seasonality	Global	1999-2012	1000 m	7-day	SPOT-VGT	WGS 84	NetCDF & GeoTiff
Water body	Global	2000-2012	150 m	13-year	ASAR WSM	WGS 84	NetCDF & GeoTiff

3 LAND COVER MAPS

3.1 Products description

The CCI-LC project delivers consistent global LC maps at 300 m spatial resolution on an annual basis from 1992 to 2015. The Coordinate Reference System used for the global land cover database is a geographic coordinate system (GCS) based on the World Geodetic System 84 (WGS84) reference ellipsoid.

Figure 3-1 presents the LC map from the year 2015 at global scale and Figure 3-2 shows the classification obtained throughout the years over a region of Argentina.

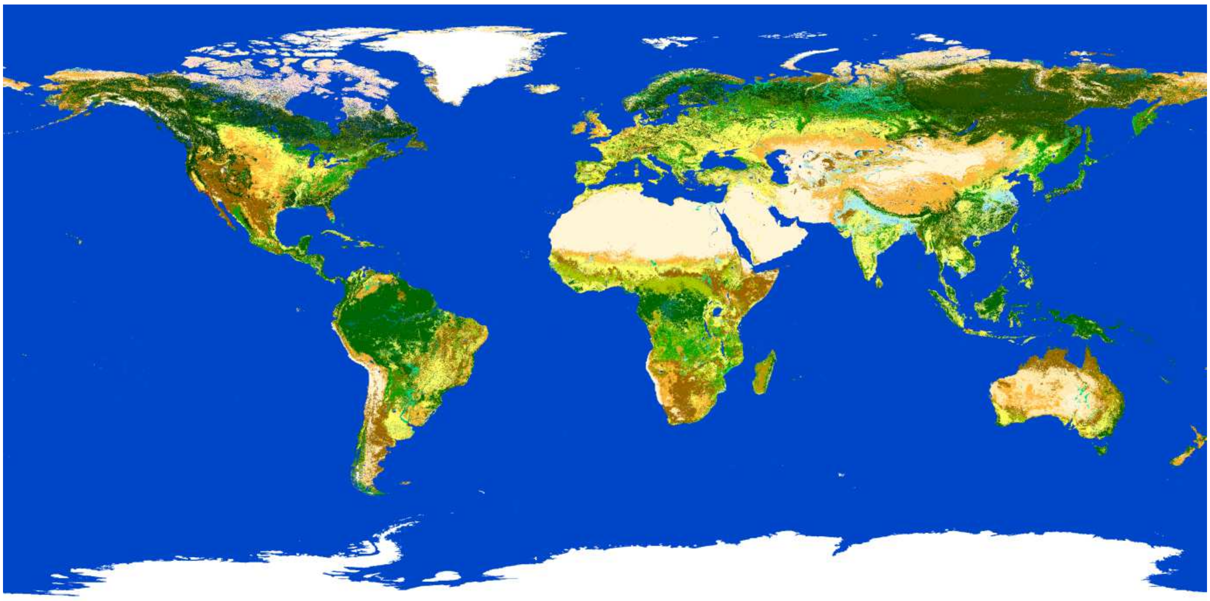


Figure 3-1: The most recent map from the LC map series from the year 2015, at 300 m spatial resolution.

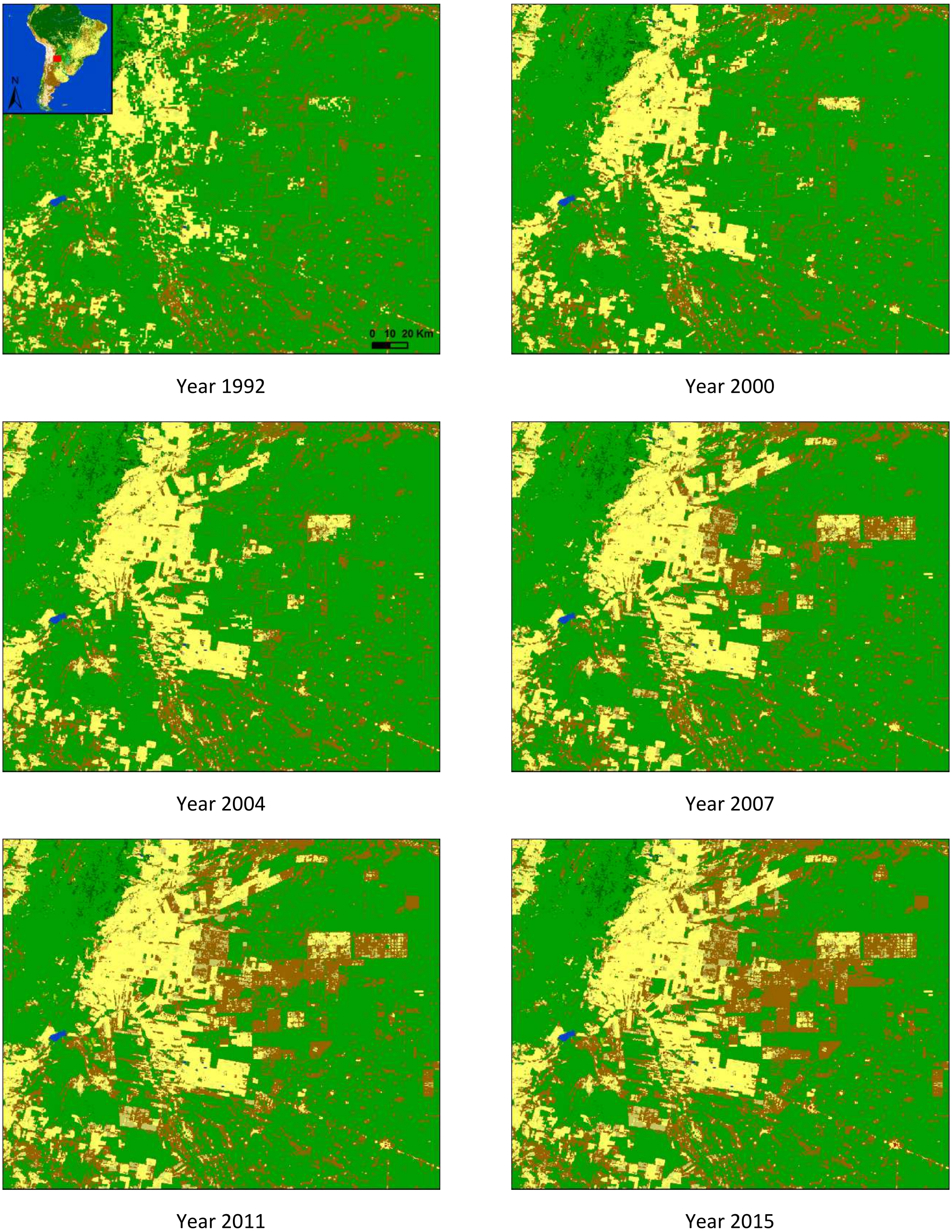


Figure 3-2: Illustration of a sequence of the CCI global annual land cover maps for years 1992, 2000, 2004, 2007, 2011 and 2015 for an area of the Salta Province in Argentina.

The following sections describe the legend of the CCI-LC maps, the processing chain including the classification and change detection modules and finally, the format of the maps and their four quality flags, valid for the full time series.

The project also delivers a user tool along with the land cover products, which allows users to aggregate LC maps to the spatial resolution, projection and format suitable for their models. This tool is described in Section 7.3 in detail.

3.1.1 Legend

The typology was defined using the Land Cover Classification System (LCCS) developed by the United Nations (UN) Food and Agriculture Organization (FAO), with the view to be as much as possible compatible with the GLC2000, GlobCover 2005 and 2009 products. In addition, the UN-LCCS was found quite compatible with the Plant Functional Types (PFTs) used in climate models [RD.1].

The UN-LCCS defines LC classes using a set of classifiers. The system was designed as a hierarchical classification, which allows adjusting the thematic detail of the legend to the amount of information available to describe each LC class, whilst following a standardized classification approach.

As the CCI-LC maps are designed to be globally consistent, their legend is determined by the level of information that is available and that makes sense at the scale of the entire world. The "level 1" legend – also called "global" legend – presented in Table 3-1 meets this requirement. This legend counts 22 classes and each class is associated with a ten values code (i.e. class codes of 10, 20, 30, etc.).

The CCI-LC maps are also described by a more detailed legend, called "level 2" or "regional". This level 2 legend makes use of more accurate and regional information – where available – to define more LCCS classifiers and so to reach a higher level of detail in the legend. This regional legend has therefore more classes which are listed in Appendix 1. The regional classes are associated with non-ten values (i.e. class codes such as 11, 12, etc.). They are not present all over the world since they were not properly discriminated at the global scale.

The explicit LCCS definition of each CCI-LC global and regional class is provided in Appendix 1.

Table 3-1: Level 1 (or global) legend of the CCI-LC maps, based on the UN-LCCS.

VALUE	LABEL	COLOR
0	No Data	
10	Cropland, rainfed	
20	Cropland, irrigated or post-flooding	
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	
60	Tree cover, broadleaved, deciduous, closed to open (>15%)	

70	Tree cover, needleleaved, evergreen, closed to open (>15%)	
80	Tree cover, needleleaved, deciduous, closed to open (>15%)	
90	Tree cover, mixed leaf type (broadleaved and needleleaved)	
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	
120	Shrubland	
130	Grassland	
140	Lichens and mosses	
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	
160	Tree cover, flooded, fresh or brakish water	
170	Tree cover, flooded, saline water	
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water	
190	Urban areas	
200	Bare areas	
210	Water bodies	
220	Permanent snow and ice	

Among these LC classes, four were largely identified thanks to external dataset: the “tree cover, flooded, saline water” (class value 170) class which is based on the global mangrove atlas [RD.11], the “urban areas” (class value 190) which relies both on the Global Human Settlement Layer [RD.30] and on the Global Urban Footprint [RD.35], the “water bodies” (class value 210) which have been inherited from the CCI global map of open water bodies (see Section 4) and the “permanent snow and ice” (class value 220) which comes from the Randolph Glaciers Inventory [RD.12] (to which the CCI-Glaciers project is one of the main contributors).

3.1.2 Processing chain

A key aspect of the CCI-LC maps consists in their consistency over time. As a result, the set of annual maps are not produced independently but they are derived from a unique baseline LC map which is generated thanks to the entire MERIS FR and RR archive from 2003 to 2012. Independently from this baseline, LC changes are detected at 1 km based on the AVHRR time series between 1992 to 1999, SPOT-VGT time series between 1999 and 2013 and PROBA-V data for years 2013, 2014 and 2015. When MERIS FR or PROBA-V time series are available, changes detected at 1 km are re-mapped at 300 m. The last step consists in back- and up-dating the 10-year baseline LC map to produce the 24 annual LC maps from 1992 to 2015.

The logical model underlying this processing chain is illustrated in Figure 3-3 and the EO data used to generate the global LC maps are summarized Table 3-2.

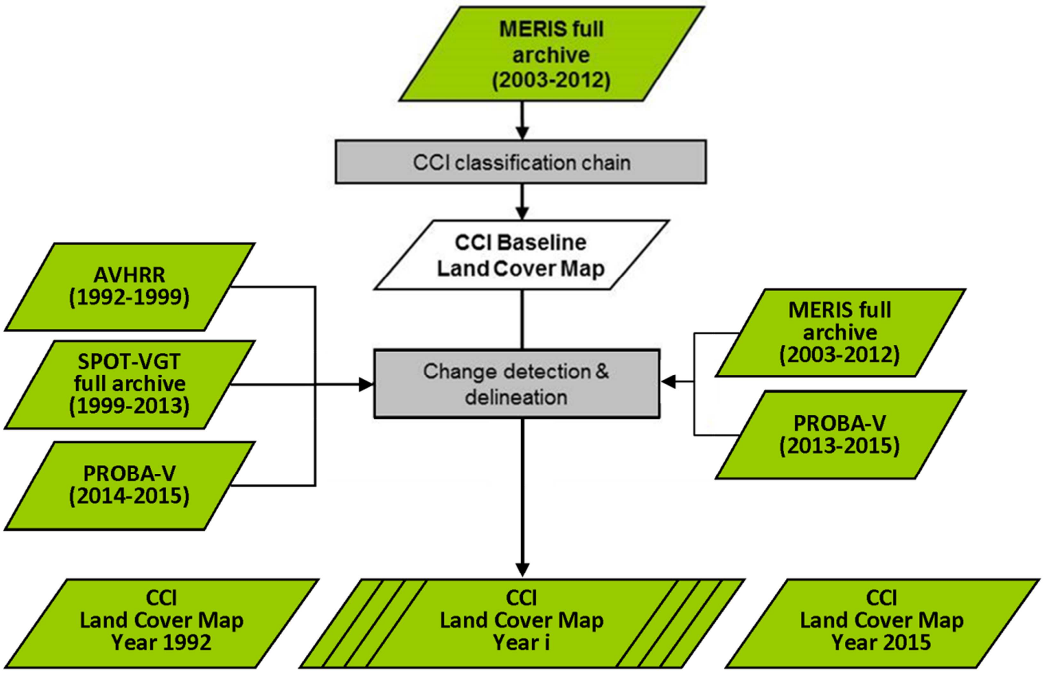


Figure 3-3: Schematic representation of the CCI-LC classification chain that generates global annual LC maps. The chain is made of 2 main processes and makes use of the entire archives of Envisat MERIS (2003 -2012), AVHRR (1992 - 1999), SPOT-VGT (1999 - 2013) and PROBA-V data for 2013, 2014 and 2015.

Table 3-2: Satellite data sources used to generate the global LC maps.

GLOBAL LC DATABASE	REFERENCE PERIOD	SATELLITE DATA SOURCE
Baseline 10-year global LC map	2003-2012	• MERIS FR/RR global SR composites between 2003 and 2012
Global annual LC maps	1992-1999	• Baseline 10-year global LC map • AVHRR global SR composites between 1992 and 1999 for back-dating the baseline
	1999-2013	• Baseline 10-year global LC map • SPOT-VGT global SR composites between 1999 and 2013 for up and back-dating the baseline • MERIS FR global SR composites between 2003 and 2012 to delineate the identified changes at 300 m spatial resolution • PROBA-V global SR composites at 300 m for year 2013 to delineate the identified changes at 300 m spatial resolution
	2014-2015	• Baseline 10-year global LC map • PROBA-V global SR composites at 1 km for years 2014 and 2015 for up-dating the baseline • PROBA-V time series at 300 m for 2014 and 2015 to delineate the identified changes the LC map spatial resolution

The classification module that generates the baseline map was developed by the Université catholique de Louvain (UCL). It was designed to be globally consistent while regionally-tuned. It capitalized on the GlobCover unsupervised classification chain [RD.9] while also relying on a machine learning algorithm and on a multiple-year strategy [RD.10]. In this way, it combined both the spectral and temporal richness of the MERIS FR time series.

The change module works independently from the above-mentioned classification module. It consists of 2 consecutive steps: change detection at 1 km and change delineation at 300 m.

The first step of the change module consists in mapping the dynamics of the land surface by analyzing, on a per-pixel basis, annual time series of 1-km global classifications from 1992 to 2015 [AD.9]. These annual classifications are derived from AVHRR time series between 1992 to 1999, SPOT-VGT time series from 1999 to 2013 and PROBA-V time series from 2014 to 2015. With their 1 km resolution, they allow capturing the dominant land cover transitions. Yet, in order to avoid false change detections due to the inter-annual variability in classifications, each change has to be confirmed over more than two successive years in the classification time series. An exception is made for changes occurring in 2014 and 2015. They are allowed with only one or two years of confirmation but conversely, they are limited to forests changes that are well detected.

In the most dynamic regions of the world, more than one land cover change can be detected between 1992 and 2015. Most of the pixels are associated with 0, 1, 2 or 3 land cover changes, knowing that each change needs to last at least two years to be detected. For instance, a forest loss to shrubland during two years followed by a forest recovery is too short to be detected as LC change.

Examples of annual classification time series analyses are given in Figure 3-4.

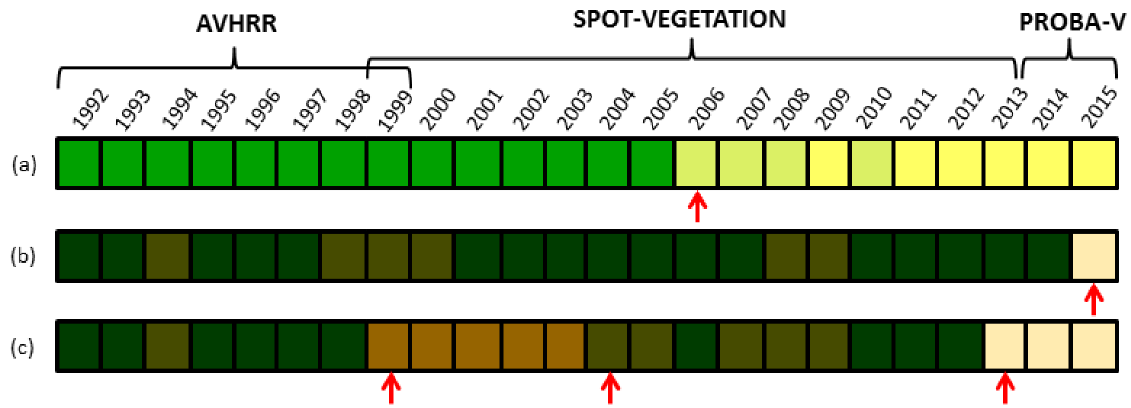


Figure 3-4: Change detection on a pixel basis from a time series of 24 annual 1-km global classifications (1992 to 2015: AVHRR, SPOT-VGT and PROBA-V). Red arrows indicate years of change detected along the time series.

The change is detected between CCI land cover classes grouped into the six IPCC land categories, i.e. cropland, forest, grassland, wetland, settlement and other land. This latter class is further split into shrubland, sparse vegetation, bare area and water. This grouping was a requirement expressed by the climate users. It also avoids false change detection between LC classes which are semantically close.

The correspondence between these IPCC land categories and the LCCS legend used in the CCI-LC maps is defined in Table 3-3.

Table 3-3: Correspondence between the IPCC land categories used for the change detection and the LCCS legend used in the CCI-LC classes.

IPCC CLASSES CONSIDERED FOR THE CHANGE DETECTION		LCCS LEGEND USED IN THE CCI-LC MAPS	
1. Agriculture		10, 11, 12	Rainfed cropland
		20	Irrigated cropland
		30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
		40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
2. Forest		50	Tree cover, broadleaved, evergreen, closed to open (>15%)
		60, 61, 62	Tree cover, broadleaved, deciduous, closed to open (> 15%)
		70, 71, 72	Tree cover, needleleaved, evergreen, closed to open (> 15%)
		80, 81, 82	Tree cover, needleleaved, deciduous, closed to open (> 15%)
		90	Tree cover, mixed leaf type (broadleaved and needleleaved)
		100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
		160	Tree cover, flooded, fresh or brakish water
		170	Tree cover, flooded, saline water
3. Grassland		110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
		130	Grassland
4. Wetland		180	Shrub or herbaceous cover, flooded, fresh-saline or brakish water
5. Settlement		190	Urban
6. Other	Shrubland	120, 121, 122	Shrubland
	Sparse vegetation	140	Lichens and mosses
		150, 151, 152, 153	Sparse vegetation (tree, shrub, herbaceous cover)
	Bare area	200, 201, 202	Bare areas
	Water	210	Water

The second step of the change module is the detailed delineation of the change detection 1-km hot spots and their surroundings (up to 5 km) at 300 m between 2004 and 2015 thanks to the MERIS and PROBA-V time series available at a spatial resolution of 300 m at this period.

3.1.3 Format

- **Naming Convention**

The filename convention of the global LC maps delivered by the CCI-LC project is the following:

Filename = <id>-v<version>.nc/tif

where <id> = <project>**-**<level>**-**<var>-<code>**-**<spatres>-<tempres>**-**<epoch>-<area>

The dash "-" is the separator between name components. The filename convention obeys NetCDF CF by using the postfix ".nc" and can be written as a GeoTiff file using the extension ".tif". The different name components are defined in Table 3-4.

Table 3-4. Components that make the name of the LC maps delivered by the CCI-LC project.

FIELD	SIGNIFICATION	VALUE
project	Project acronym	ESACCI- LC (constant)
level	Processing level	L4 (constant)
var	Unit of the LC product	LCCS (constant)
code	Product code identifier for CCI-LC products	Map (constant)
spatres	Spatial resolution	300 m (constant)
tempres	Temporal resolution	P1Y (constant)
epoch	Year of the product	[1992 ... 2015]
version	Incremental that follows the successive revisions of the CCI-LC Processing lines	Version of product revision, preferably major.minor, optionally with processing centre [a-zA-Z0-9._]*

An example filename of the global LC map for year 2010 would be: "ESACCI-LC-L4-LCCS-Map-300m-P1Y-2010-v2.0.nc/tif ».

- **Processing Level**

Level 4 (i.e. "variables that are not directly measured by the instruments, but are derived from these measurements" [RD.14])

- **Units**

Each pixel value corresponds to the label of a land cover class defined using UN-LCCS classifiers (see Table 3-1 in Section 3.1.1 and Appendix 1 in Section 9).

- **Spatial Extent**

All terrestrial zones of the Earth between the parallels 90°N and 90°S.

- **Spatial Resolution**

300 m

- **Temporal resolution**

Annual

- **Product layers**

The land cover maps are delivered along with 4 quality flags which document the reliability of the classification and change detection (Table 3-5).

Table 3-5: Quality flags of the LC maps.

NAME IN PRODUCT	DATA TYPE	DESCRIPTION
ESACCI-LC-L4-LCCS-Map-300m-P5Y-	byte	LC classification in LCCS (22 global classes + NoData

NAME IN PRODUCT	DATA TYPE	DESCRIPTION
YYYY-vx.x.nc/tif		coded as 0)
ESACCI-LC-L4-LCCS-Map-300m-P5Y-YYYY-v1.0_qualityflag1.nc/tif	byte	Indicates if the pixel has been processed (1) or not (0) 0 - pixel not processed 1 - pixel processed
ESACCI-LC-L4-LCCS-Map-300m-P5Y-YYYY-v1.0_qualityflag2.nc/tif	byte	Indicates the pixel status as defined by the pre-processing: 1 - Pixel flagged as “clear land” 2 - Pixel flagged as “clear water” 3 - Pixel flagged as “clear snow and ice” 4 - Pixel flagged as “cloud” 5 - Pixel flagged as “cloud shadow” 6 - Pixel flagged as “filled”
ESACCI-LC-L4-LCCS-Map-300m-P5Y-YYYY-v1.0_qualityflag3.nc/tif	byte	Indicates the number of valid observations available to derive the classification
ESACCI-LC-L4-LCCS-Map-300m-P5Y-YYYY-v1.0_qualityflag4.nc/tif	byte	Provides the number of LC change observed during the period 1992-2015 (ranging from 0 to 5) per pixel

- **Projection**

The projection is a Plate-Carrée with a geographic Lat/Long representation based on the WGS84 ellipsoid (Figure 3-5). The Coordinate Reference System (CRS) used for the global LC products is a geographic coordinate system (GCS) based on the World Geodetic System 84 (WGS84) reference ellipsoid and using a Plate Carrée projection.

The projection makes use of an equatorial radius (also called semi-major axis) of 6378.14 km and of a polar radius (also called semi-minor axis) of 6356.76 km. The inverse flattening parameter is of 298.26 m. The coordinates are specified in decimal degrees. A complete description of the CRS is given in as an ISO 19111 WKT representation.

```
GEOGCS["GCS_WGS_1984",
    DATUM["D_WGS_1984",
        SPHEROID["WGS_1984",6378137.0,298.257223563]],
    PRIMEM["Greenwich",0.0],
    UNIT["Degree",0.0174532925199433],
AUTHORITY["EPSG",4326]]
```

Figure 3-5: Description of the coordinate reference system defining the global LC products.

- **Format**

The LC maps are delivered in NetCDF-4 and GeoTiff format. The NetCDF files specification follows CF conventions [RD.16].

- **Metadata**

The metadata for the LC maps are provided as global attributes in the NetCDF file and are included in the GeoTiff raster. It follows the CCI guidelines [RD.17].

- **Estimated size**

The size of one global land cover map is around 260 MB. The size of the quality flags varies between 80MB and 2GB. These estimations take an internal LZW compression into account.

3.2 Qualitative assessment

The following figures present the annual LC products, with a focus on the year 2015 which is the most recent one of the map series. This presentation is done, through snapshots and visual comparison with reference datasets and with the previous version of the CCI-LC map for the 2010 epoch (v1.6.1), in various regions of the world. These comparisons show the accomplished progress.

The high level of thematic detail present in the CCI-LC maps is illustrated in Figure 3-6, Figure 3-7 and Figure 3-8. Figure 3-6 illustrates the increased representativeness of CCI-LC map 2015 for the Boreal zone with a reduction of the bare areas class.

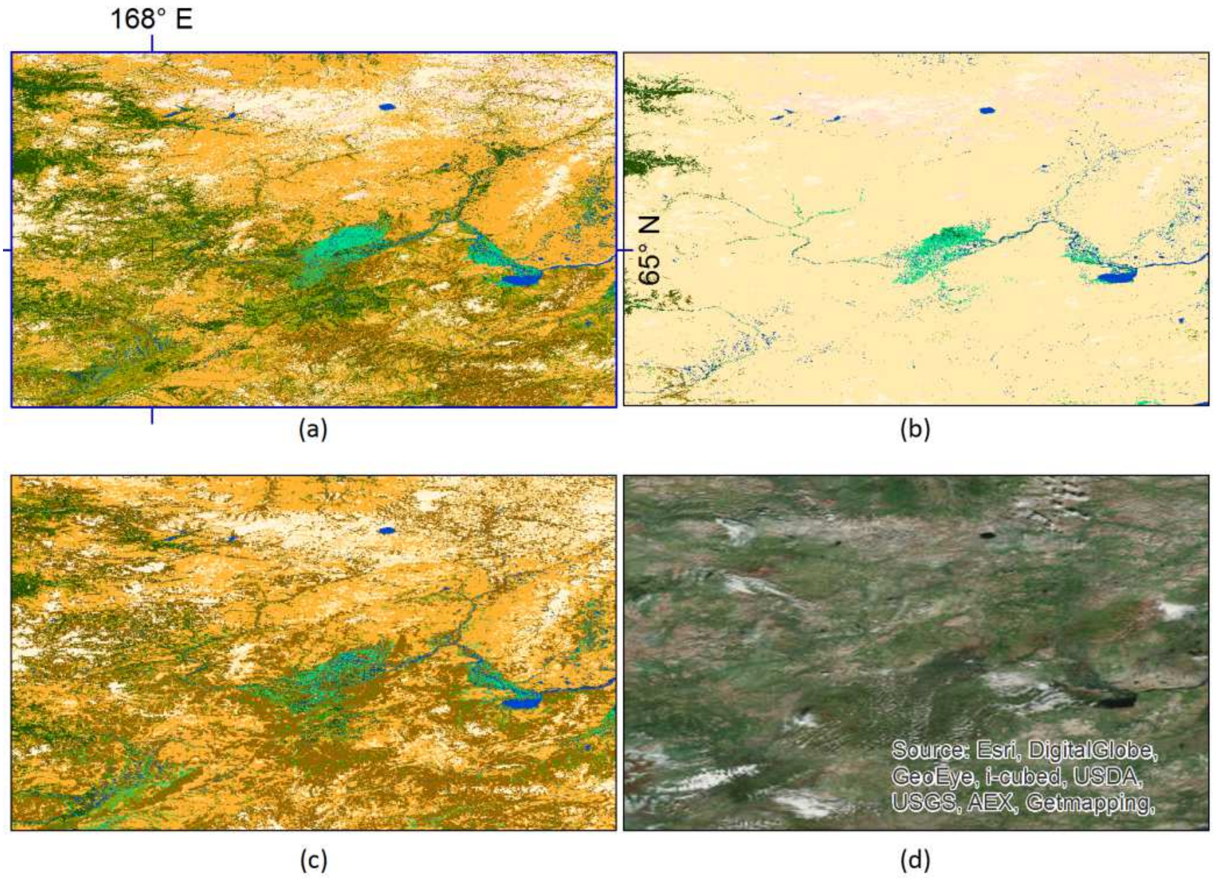


Figure 3-6: Comparison, over Russia, between the 2015 LC map (a), the CCI LC v1.6.1 from the 2010 epoch (b), the Northern Eurasia Land Cover database [RD.31] (c) and the ESRI high resolution base map layer (d).

In general, good agreement between the CCI-LC map 2015 and other existing reference maps is also observed, even if these reference datasets are of higher spatial resolution. This is the case with the SERVIR datasets [RD.34], as illustrated over Zambia in Figure 3-7.

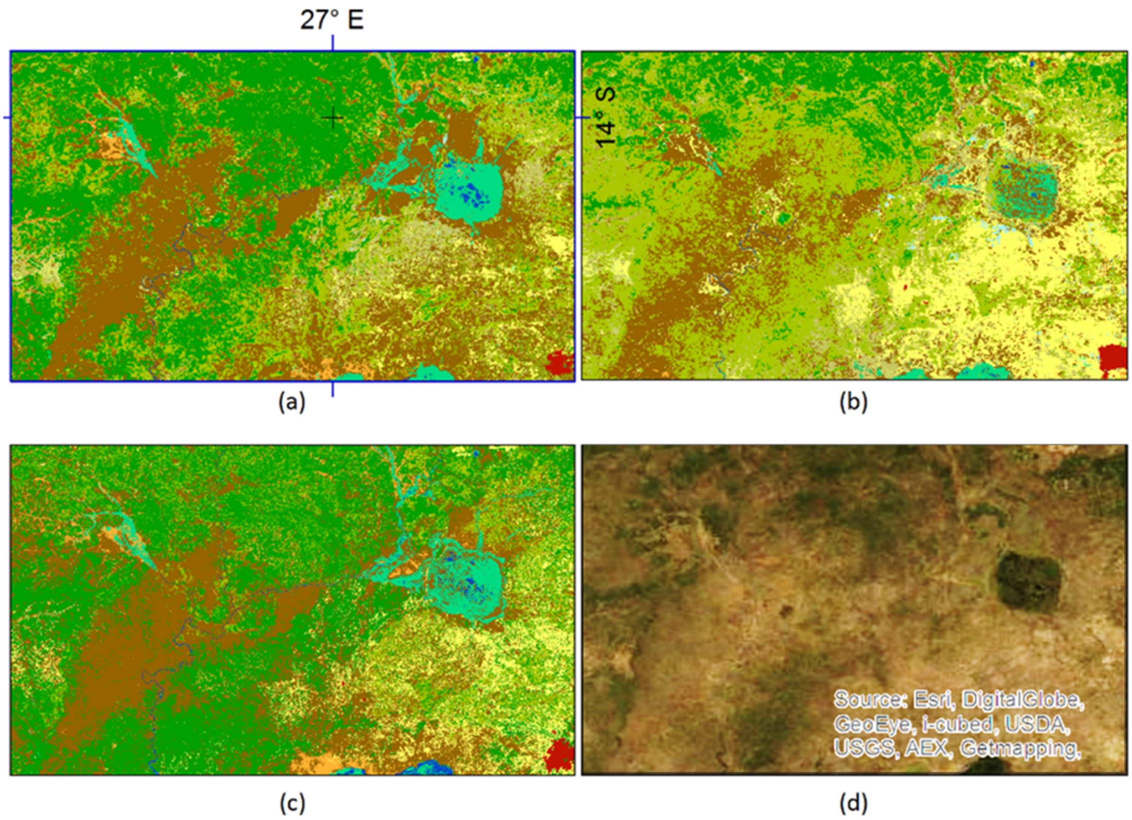


Figure 3-7: Comparison, over Zambia, between the 2015 LC map (a), the CCI-LC v1.6.1 from the 2010 epoch (b), the SERVIR land cover of Zambia (c) and the ESRI high resolution base map layer (d).

Good agreement is also observed with lower spatial resolution datasets, as illustrated in Figure 3-8 in Angola.

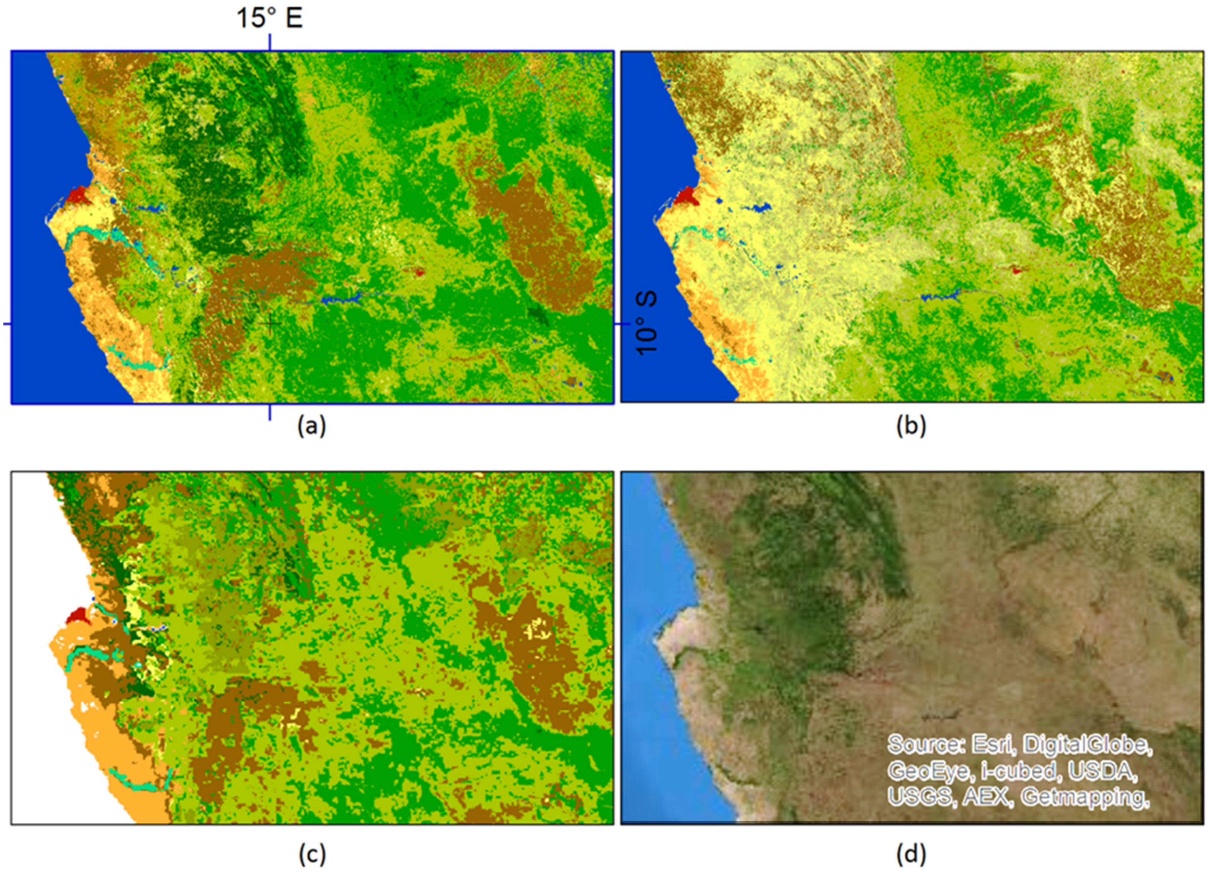
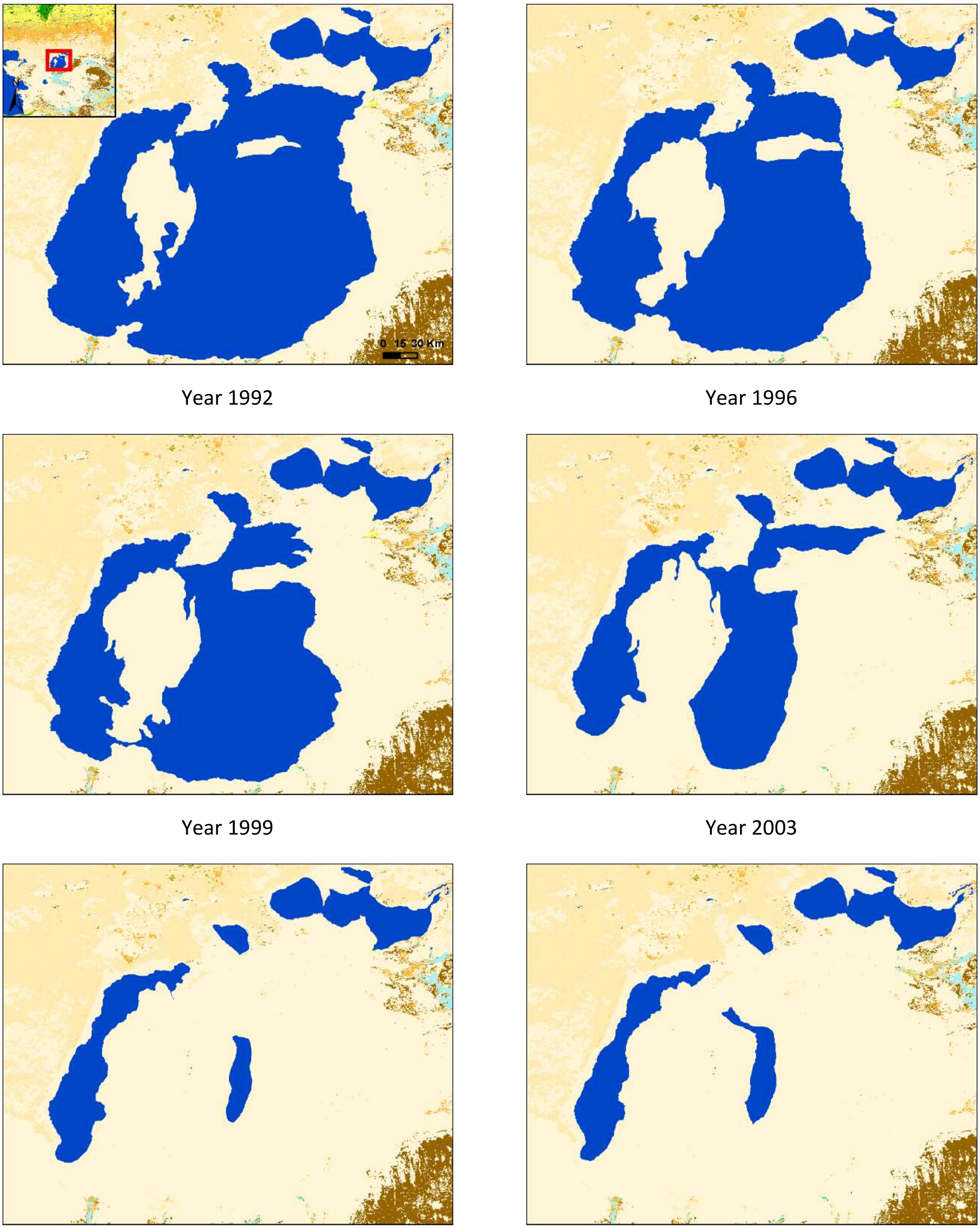


Figure 3-8: Comparison, over Angola, between the 2015 LC map (a), the CCI-LC v1.6.1 from the 2010 epoch (b), the regional GLC2000 for Africa [RD.32] (c) and the ESRI high resolution base map layer (d).

Figure 3-9 and Figure 3-10 illustrate the land cover dynamics of major LC changes captured in the annual CCI-LC maps from 1992 to 2015 over an area in Brazil and over the Aral Sea, respectively.

In Brazil, the evolution of the deforestation patterns is consistent with what is observed in the Landsat imagery from the Timelapse Google Earth Engine [RD.33]. The slight underestimation of croplands in 1992 is explained by the use of the 1-km AVHRR in the 1990s. The drying up of the Aral Sea is in agreement with recent published research [RD.42].

Figure 3-9: Comparison of deforestation patterns in Brazil between annual LC maps for years 1992, 1997, 2000, 2005, 2010 and 2015 (a) and the corresponding Landsat imagery from Timelapse Google Earth Engine (b).



Year 1992 | Year 1996
Year 1999 | Year 2003
Year 2009 | Year 2015

Figure 3-10: Dynamics of the Aral Sea illustrated by the CCI global annual land cover maps for years 1992, 1996, 1999, 2003, 2009 and 2015.

3.3 Validation

A critical step in the acceptance of the CCI-LC maps by the user communities is providing confidence in their quality through validation against independent data such as ground-based reference measurements or alternate estimates from other projects and sensors.

The main objective of the validation is to allow a potential user determining the "map's fitness for use" for his / her application. There are several definitions of validation available from various agencies, and it was agreed that the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (CEOS-WGCV) definition would be adopted within the CCI program:

> *"The process of assessing, by independent means, the quality of the data products derived from the system outputs".*

The validation process independence has been ensured (i) using validation datasets that were not used during the production of the LC maps and (ii) being carried out by external parties, i.e. by staff not involved in the production of the LC maps.

As a preliminary validation process, the accuracy of the CCI-LC map of year 2015 was assessed using the GlobCover 2009 validation dataset such as in the GlobCover validation exercises [RD-3] [RD-4]. Due to the fact that the GlobCover and CCI-LC legends are not fully identical, not all the points of the GlobCover 2009 validation database could be used.

Contingency matrices were built and overall accuracies were not only calculated based on the diagonal cells of the matrix but also accounted for other cells which mark agreement between the product and the validation dataset. Table 3-6 presents a first contingency matrix calculated by comparing the CCI-LC map from 2015 with all the points interpreted as "certain" by the experts, whether "homogeneous" (i.e. made of a single LC class) or "heterogeneous" (i.e. made of several or mosaic LC classes). A second contingency matrix is derived using only the "homogeneous" and "certain" points of the GlobCover 2009 validation set, which is presented in Table 3-7. These two matrices indicate that the accuracy level is found to be 71.45% in the first case and 75.4% in the second case.

Table 3-6: Adjusted contingency matrix that considers the CCI-LC 2015 map and the "certain" ("homogeneous" and "heterogeneous") points of the GlobCover 2009 validation dataset. Green cells mark diagonal cells while yellow cells represent other samples that also mark a clear agreement between the product and the reference.

		REFERENCE: GLOBCOVER 2009 VALIDATION DATASET																							
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**	**210**	**220**	**SUM**	**User Acc. (%)**
PRODUCT: CCI-LC 2015 MAP	**10**	342	50	0	0	7	0	0	0	6	0	0	9	13	0	1	0	0	3	7	4	0	0	442	**89**
	20	9	16	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	28	**89**
	30	22	2	21	0	3	2	1	0	4	0	0	5	1	0	0	0	0	0	1	0	0	0	62	**73**
	40	15	0	0	13	3	2	0	0	0	0	0	2	4	0	2	0	0	0	0	0	0	0	41	**59**
	50	9	2	0	0	257	2	1	0	15	0	0	1	1	0	0	0	0	0	0	0	0	0	288	**94**
	60	13	1	0	0	21	74	2	5	43	0	0	26	8	0	1	0	0	3	0	1	2	0	200	**59**
	70	3	0	0	0	3	3	63	3	57	0	0	13	14	7	2	0	0	7	0	7	3	2	187	**64**
	80	0	0	0	0	0	2	0	37	3	0	0	2	1	3	1	0	0	0	0	2	0	0	51	**78**
	90	0	0	0	0	1	9	11	1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	34	**35**
	100	20	0	0	0	3	2	3	0	2	5	0	6	8	3	2	0	0	0	2	2	0	0	58	**36**
	110	1	0	0	0	1	0	0	0	0	0	2	1	2	0	2	0	0	2	0	0	0	0	11	**36**
	120	20	2	0	0	4	5	2	0	5	0	0	118	24	3	11	0	0	1	1	12	1	2	211	**56**
	130	33	3	0	0	0	0	1	1	4	0	0	19	99	2	12	0	0	0	4	23	1	2	204	**49**
	140	0	0	0	0	0	0	1	0	0	0	0	0	4	10	0	0	0	5	0	4	0	2	26	**38**
	150	3	0	0	0	0	0	0	1	0	0	0	10	9	6	33	0	0	0	2	28	0	2	94	**35**
	160	1	0	0	0	8	1	0	0	0	0	0	0	1	2	0	6	1	3	0	0	0	0	23	**26**
	170	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	8	**75**
	180	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	8	0	0	2	0	15	**53**
	190	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	25	**88**
	200	1	1	0	0	0	0	0	0	1	0	0	1	2	1	4	0	0	0	2	160	2	6	181	**88**
	210	0	2	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0	1	1	0	102	1	111	**92**
	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	28	29	**97**
	SUM	493	81	21	13	312	102	85	48	153	5	2	215	195	39	72	7	7	33	43	245	113	45	2329	
	Prod. Acc (%)	**76**	**84**	**100**	**100**	**84**	**76**	**78**	**77**	**86**	**100**	**100**	**59**	**54**	**26**	**46**	**86**	**86**	**24**	**51**	**65**	**90**	**62**		**71.45**

Table 3-7: Adjusted contingency matrix that considers the CCI-LC 2015 map and the "certain" and "homogeneous" points of the GlobCover 2009 validation dataset. Green cells mark diagonal cells while yellow cells represent other samples that also mark a clear agreement between the product and the reference.

	REFERENCE: GLOBCOVER 2009 VALIDATION DATASET																								
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**	**200**	**210**	**220**	**SUM**	**User Acc. (%)**
PRODUCT: CCI-LC 2015 MAP	**10**	245	27	0	0	4	0	0	0	1	0	0	6	7	0	0	0	0	2	5	0	0	0	297	**92**
	20	5	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	12	**83**
	30	18	2	0	0	2	1	0	0	1	0	0	2	1	0	0	0	0	0	1	0	0	0	28	**71**
	40	12	0	0	0	3	1	0	0	0	0	0	2	3	0	2	0	0	0	0	0	0	0	23	**39**
	50	4	2	0	0	224	2	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	241	**96**
	60	5	0	0	0	18	44	1	4	31	0	0	16	3	0	1	0	0	2	0	0	1	0	126	**60**
	70	1	0	0	0	2	2	35	2	28	0	0	8	5	1	1	0	0	5	0	2	2	1	95	**66**
	80	0	0	0	0	0	0	0	12	2	0	0	2	1	0	0	0	0	0	0	0	0	0	17	**82**
	90	0	0	0	0	1	6	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	13	**31**
	100	5	0	0	0	3	1	0	0	1	0	0	3	6	1	1	0	0	0	1	1	0	0	23	**35**
	110	1	0	0	0	1	0	0	0	0	0	0	1	2	0	2	0	0	2	0	0	0	0	9	**22**
	120	15	2	0	0	4	4	1	0	1	0	0	92	10	0	10	0	0	1	1	7	0	1	149	**62**
	130	25	1	0	0	0	0	1	1	1	0	0	13	48	0	8	0	0	0	2	2	1	1	104	**46**
	140	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	1	0	2	0	1	9	**33**
	150	3	0	0	0	0	0	0	0	0	0	0	7	4	1	9	0	0	0	1	17	0	0	42	**21**
	160	0	0	0	0	4	1	0	0	0	0	0	0	1	1	0	5	1	1	0	0	0	0	14	**36**
	170	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	7	**71**
	180	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0	3	0	0	1	0	9	**33**
	190	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	21	**86**
	200	0	1	0	0	0	0	0	0	1	0	0	1	2	1	4	0	0	0	1	135	1	6	153	**88**
	210	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	78	0	81	**96**
	220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	25	26	**96**
	SUM	340	43	0	0	267	62	41	19	79	0	0	154	99	10	38	6	6	18	30	168	84	35	1499	
	Prod. Acc (%)	**79**	**79**	**N/A**	**N/A**	**86**	**74**	**85**	**63**	**94**	**N/A**	**N/A**	**63**	**54**	**30**	**24**	**83**	**83**	**17**	**60**	**80**	**93**	**71**		**75.38**

According to the CEOS recommendations, overall accuracy values weighted by the area proportions of the land cover classes are also calculated. The surfaces of the various land cover classes were determined based on the CCI-LC 2015 product itself, projected in an equal area projection. Using the 1499 “certain” and “homogeneous” points, the weighted-area overall accuracy figure of the 2015 CCI-LC map is of 71.1%, while with the 2329 “certain” points (without homogeneity constraint), it is of 71.7%. In the first case, accounting for the LC classes area decreases a little bit the overall accuracy while in the second case, it does not modify it the value significantly. These figures are higher than the ones of GlobCover 2009 product.

Attention should also be paid to the producer and user accuracy values, which give more information about the accuracy of the different thematic classes and which can also explain the effects observed when weighting the overall accuracy values by the land cover class areas.

The highest user accuracy values[3] are found for the classes of rainfed cropland (class value 10; 89-92%), irrigated cropland (class value 20; 89-83%), broadleaved evergreen forest (class value 50; 94-96%), urban areas (class value 190; 88-86%), bare areas (class value 200; 88-88%), water bodies (class value 210; 92-96%) and permanent snow and ice (class value 220; 97-96%). This is generally not surprising as these classes are homogeneous, unambiguous and recognisable. What is more unexpected - and therefore a highly positive result - is the high accuracy associated with the cropland classes. These classes are of paramount importance for food security [RD.38, RD.39, RD.40] but which are unfortunately often poorly captured in global land cover products due to their dynamic nature and the large variety of agro-systems [RD.41].

Conversely, mosaic classes of natural vegetation (class values 100, 110) are associated with the lowest user accuracy values, as well as the three classes of lichens and mosses (class value 140), sparse vegetation (class value 150) and flooded forest with fresh water (class value 160). The class of mixed broadleaved and needleleaved forest (class value 90) has also a low user accuracy value, but all errors relate to confusion between this class and other forest classes, which very much limits the impact of this low value.

Finally, it shall be mentioned that the quality of the map varies according to the region of interest. Looking at the number of valid observations available over a region (information provided in the quality flag 3) can give a first indication about the input data quality and the expected classification reliability.

This validation based on the GlobCover 2009 validation dataset is to be seen as a preliminary validation process. A more detailed validation is currently undergoing based on a new validation dataset collected in the framework of this project and which should allow capturing better the complexity of the landscape and also validating the LC changes.

[3] The figures given into brackets correspond to the ones given in Table 3-6 first (certain points, homogeneous and heterogeneous) and in Table 3-7 second (certain points, homogeneous only)

3.4 Limitations

- ***Classification accuracy related to the number of observations in the MERIS archive***

As already mentioned, users have to know that the quality of the map varies according to the region of interest. Looking at the number of valid observations available over a region (information which is provided in the quality flag 3) can give a first indication about the input data quality and the expected classification reliability. Areas affected by a lower MERIS FR coverage are the western part of the Amazon basin, Chili and the southern part of Argentina, the western part of Congo basin as well as the gulf of Guinea, the eastern part of Russia, the eastern coast of China and Indonesia.

- ***Classification accuracy in the light of the contingency matrix***

The overall accuracy figures presented in the previous section must be balanced by the fact that the LC maps quality varies according to the thematic class. In particular, land cover classes such as rainfed and irrigated croplands, broadleaved evergreen forest, urban areas, bare areas, water bodies and permanent snow are found quite accurately mapped. On the other hand, classes such as lichens and mosses, sparse vegetation and flooded forest with fresh water can be affected by errors. The mosaic classes of natural vegetation have also lower user accuracy values, such as the class of mixed broadleaved and needleleaved forest. Yet, in this latter case, most of the errors occur between this class and other forest classes, which very much limits the thematic impact of this lower accuracy value.

- ***Not all possible changes between the 22 LC classes are captured in the dataset***

Given the methodology to detect the change (section 3.1.2), it is of paramount importance to highlight that the CCI-LC dataset does not capture all the possible changes between the 22 LCCS land cover classes.

The 22 LCCS land cover classes are indeed grouped into the 6 IPCC land categories, with the consideration of the subcategories shrubland, sparse vegetation, bare area and water (forming the "Other" IPCC main land category), as explained in Table 3-3. Consequently, any change occurring between LCCS classes being part of the same IPCC land category is not captured by the CCI-LC dataset. More precisely, the CCI-LC dataset does not provide information on:

- the conversions between rainfed (class values 10, 11 and 12) and irrigated agriculture (class value 20). As a result, the agriculture intensification through the irrigation will not be detected as a change;
- the conversion between forest classes (e.g. conversion of broadleaved to mixed forests, flooded forest dewatering or salinization of a forest flooded with fresh water);

- the conversion between sparse vegetation (class value 150) and lichens and mosses (class value 140);
- the conversion between a "pure"[4] class and a mosaic class (e.g. forest degradation characterized by the evolution of a pure forest (class values 50 to 90) to a mosaic of natural vegetation (class values 100 and 110); cropland intensification characterized by the conversion of a mosaic of cropland and natural vegetation (class values 30 and 40) to a rainfed or irrigated cropland (class values 10 to 20); forest regeneration characterized a mosaic of natural vegetation (class values 100 and 110) to a pure forest (class values 50 to 90).
- the conversion between "level 2" or "regional" classes (see section 3.1.1), whatever the IPCC land category. This corresponds to any dynamics specific to herbaceous vs woody cropland (class values 11 and 12), to the density of the forests (depicted in the level 2 of the forest classes 61, 62, 71, 72, 81 and 82), to the phenology of the shrubland (class values 121 and 122), to the type of the sparse vegetation (class values 151, 152, 153) or the type of bare area (class values 201 and 202).

- ***Abrupt changes better captured than gradual ones***

To allow the detection of a change from a class X to a class Y, the developed method needs to observe the new class Y during at least 2 consecutive years. This was explained in detail in section 3.1.2, Figure 3-4. As a consequence, abrupt changes are better captured than gradual ones.

Abrupt changes are characterized by sudden LC transitions from one IPCC class to another that most often last more than 2 years (e.g. a forest loss to an agriculture class in Figure 3-2).

Conversely, gradual changes that can be understood as slow transitions between two IPCC classes by going through intermediate mosaic classes are not so well detected. An example of gradual change would be transitions from shrubland (class value 120) to bare area (class value 200) by going through successive land cover states such as mosaics and grasslands classes lasting during maximum 2 years.

- ***Change delineated at 300 m based on hot spots of change detected at 1 km***

All annual CCI-LC maps are delivered at 300 m spatial resolution but it is to be reminded that the change detection is performed at 1 km spatial resolution, based on the AVHRR, SPOT-VGT and PROBA-V missions. It means that only land cover changes visible at 1 km are detected. These hot spots of change and their surroundings (up to 5 km) are then further delineated at 300 m starting 2004 onwards thanks to the availability of the 300 m MERIS and PROBA-V time series at this period.

As a result, several cases of change omissions are observed in the annual LC maps. First, changes of low intensity and/or surface below 1 km² are not detected. Second, changes are not delineated at 300

[4] "pure" is here expressed as opposed to "mosaic" or "mixed" class, which have the values 30, 40, 100 and 110

m if it does not occur in the surroundings of a hot spot of change detected at 1 km. In other words, if the change occurs at a distance greater than 5 km away from the 1 km change hot spot. Finally, changes will not be delineated at 300 m if they occur before year 2004 as no MERIS and PROBA-V time series exist at 300 m before 2003.

- ***Changes along the coastlines and of permanent snow and ice class not included in the CCI-LC products***

Changes along the coastlines are not captured with a change detection algorithm based on 1-km observations. Yet, an exception is made for changes related to the Saudi Arabia manmade islands.

In addition, the permanent snow and ice (class value 220) remains constant over time and relies solely on the Randolph Glaciers Inventory [RD.12].

- ***Changes occurring in the 2014 - 2015 period***

Changes occurring in the 2014 - 2015 period are limited to forests changes. This is a consequence of the methodology that needs to have confirmation of the land cover change during at least 2 years. During this period, this confirmation cannot be ensured and so, only the forest changes – which are the easiest to detect – are included in the maps.

- ***Change during the AVHRR 1992 - 1999 period***

The performance of the change detection is highly dependent on the input data quality and availability. The general lower quality of AVHRR surface reflectances and georeferencing implies a less reliable change detection. In addition, the lack of AVHRR data in year 1994 reduces the change detection reliability for this particular year.

4 LAND SURFACE SEASONALITY PRODUCTS

4.1 Products description

To meet the climate modeling community needs and describe the natural variability of the land surface, two climatological variables, also named “LS seasonality”, have been produced: the NDVI LS seasonality, representative of the vegetation greenness and the WB LS seasonality, representative of the the water occurrence. Three climatological variables were produced in Phase I (the NDVI, burned areas and snow seasonality products).

On a per pixel basis, the NDVI LS seasonality reflects, along the year, the average trajectory and the inter-annual variability of a land surface feature over the 1999-2012 period. It is built from existing long-term global datasets with high temporal frequency and moderate spatial resolution (1 km). It is a result from a compilation of 13 years of 7-day instantaneous observations into 1 temporarily aggregated profile depicting, along the year, the reference behaviour for the vegetation greenness. These measurements are described in Table 4-1.The methodology underlying the generation of these products was developed by the Université catholique de Louvain (UCL).

Table 4-1: Main characteristics of the LS seasonality products.

Climatological dataset	Measurements	Data sources	Spatial coverage and resolution	Temporal coverage	Temporal resolution	Total Data Volume
NDVI	- Mean - Standard deviation - Number of valid weekly composites - Status	14 years of daily S1 SPOT-VGT surface reflectance time series	Global 1000m	1999-2012	Weekly	~ 30GB

4.2 NDVI seasonality product

4.2.1 Description

The NDVI seasonality product describes globally the yearly reference dynamic of the vegetation greenness characterizing the 1999-2012 period. It is therefore a valuable reference dataset for phenology studies and phenological metrics extraction at global scale [RD.15]. It is built from 14 years of SPOT-VGT daily top of canopy SR syntheses (S1 products) and of related quality flags.

It comprises 4 measurements in total. The annual behaviour of the vegetation is characterised by two time series of 7-day composites, corresponding first to the NDVI smoothed average and second to the inter-annual variability over the aggregation period (14 years). In addition, 2 quality flags are provided at the pixel-level: the number of valid and cloud-free weekly composites used to generate the NDVI average and the status qualifying the pixel. These items are described thoroughly in Section 4.2.3.

The average component of the resulting NDVI seasonality is illustrated for the 4 seasons of the year in Figure 4-1. As it can be seen, the product clearly captures the spatial pattern of many land features, including the ones situated in the cloudiest regions of the world like the equatorial areas.

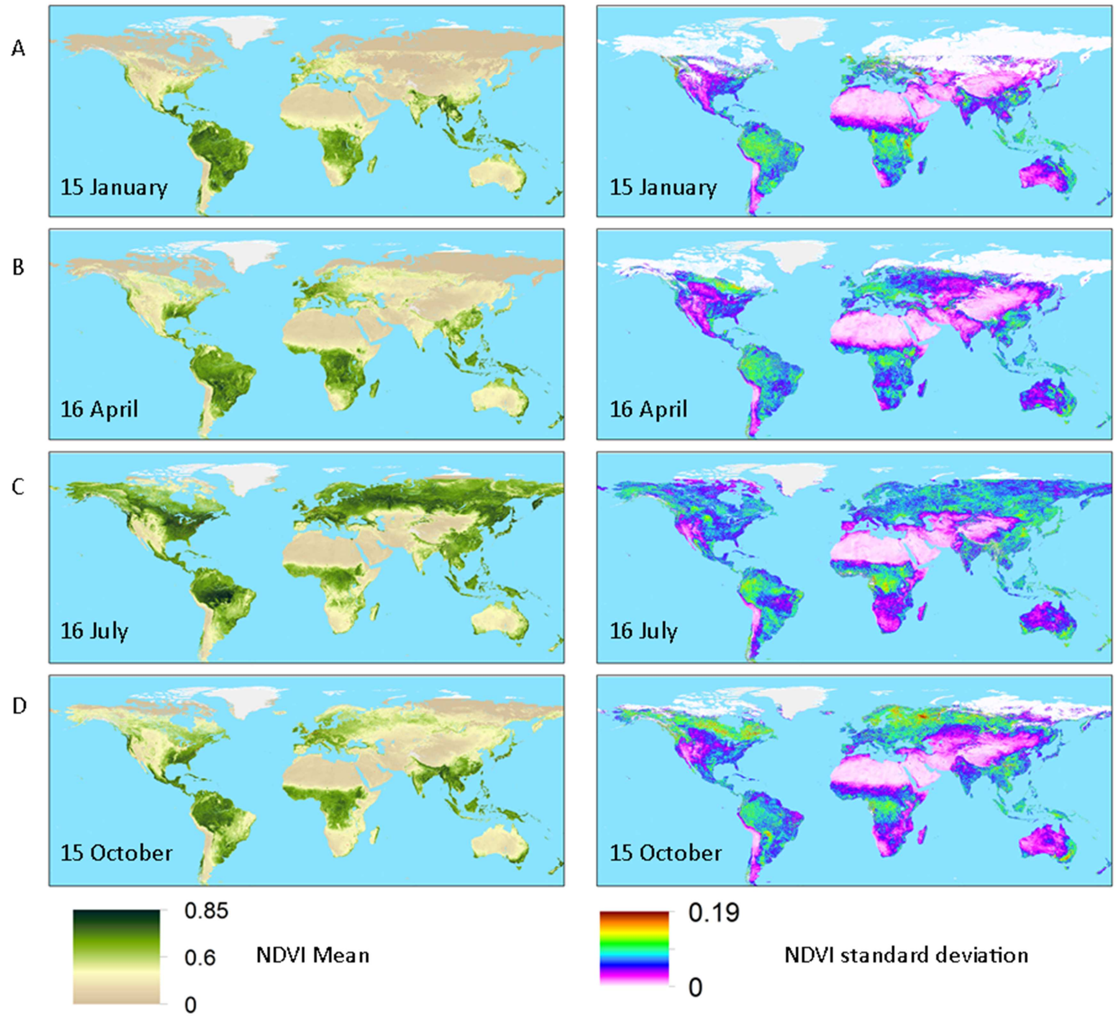


Figure 4-1: Average (left) and standard deviation (right) components of the NDVI Seasonality Product at 4 weeks of the year. The dates indicated in Figure A, B, C and D correspond to starting day of the 7-day composite period. White colour situated in high latitudes corresponds to NaN values [RD.15]

The SPOT-VGT 1-km spatial resolution associated with a high geometric accuracy allows producing meaningful profiles, even in highly fragmented areas such as in Africa (Figure 4-2). The 3 NDVI profiles, extracted on (i) a mosaic class of different cropland areas, (ii) a mosaic class of tree and shrub cover types and (iii) a land cover class made of broadleaved deciduous trees, demonstrate the spatial consistency of the product and its capacity to depict the intra-annual variability of the vegetation greenness.

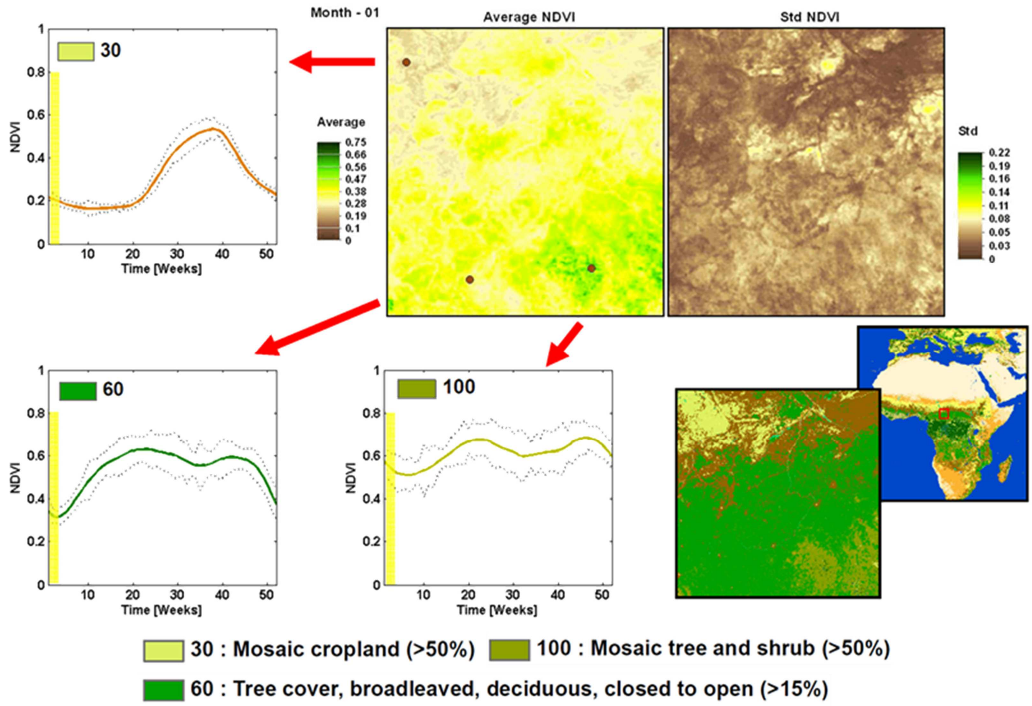


Figure 4-2: Detailed spatial example of NDVI seasonality profiles - average (plain line) and standard deviation (dotted line) - extracted in the region of Central Africa. The profiles are extracted from 3 pixels belonging to 3 classes of the 2010 LC state map product. The variety of the dynamic of vegetation is clearly captured.

4.2.2 Products evaluation

The potentialities for the NDVI seasonality were highlighted in the contexts of cropland diversity (intensity of agricultural practices, crop cycles), thematically close land cover classes diversity (bare areas, grassland and shrubland), vegetation seasonalities and leaf types.

Yet, it shall be mentioned that the reliability of the products is spatially variable and dependant on the number of valid and cloud-free weekly composites which is to be used as a quality indicator. The lowest numbers of valid and cloud-free observations are found over the western coast of central Africa and extreme latitudes.

One of the drawbacks with using optical time series for global mapping is the inconsistency of the valid coverage along the year. Data are missing over high latitudes during winter time when there is no solar illumination.

The lack of validation and uncertainty estimates is also a limitation.

4.2.3 Format

The global NDVI seasonality characterizing the 1999-2012 epoch includes 4 series of measurements distributed in the form of 52* 7-day layers for a total compressed data volume of 30 GB. Two of the series represent variables describing the yearly reference dynamic of the vegetation greenness and its inter-annual variation: the smoothed averaged NDVI and the standard deviation. The other two layers are the number of valid and cloud-free weekly composites and the status of the pixel.

Each layer has a spatial resolution of 1km and a geographic Lat/Long WGS84 projection (see Section 3.1.3 for a complete description).

The layers are delivered in NetCDF-4 and GeoTiff format. The NetCDF files specification follows CF conventions [RD.16].

- **Science dataset**

Table 4-2 summarizes the description of each 52* 7-day layers in terms of variable description, valid values range, scaling factor, NaN value and pixel depth.

Table 4-2: The description of the 4 series layers included in the global NDVI seasonality product.

NDVI Seasonality Series	Description	Valid values range	Scaling factor	NaN value	Pixel depth
AggMean	Smoothed NDVI values corresponding to the averaged NDVI over the 1999-2012 period. It gives the yearly reference dynamic of the vegetation greenness at a 7-day frequency.	[-10000 to 10000]	0.0001	32767	Int16
Std	Standard deviation of the averaged NDVI over the 1999-2012 period. It represents the inter-annual variability of the average NDVI for each 7-day period.	[0 to 10000]	0.0001	32767	Int16
NYearObs	Number of valid and cloud-free weekly composites contributing to each 7-day period of the AggMean and Std series. It is a quality indicator of the average and std estimates.	[0 to 14]	None	None	Int16
Status	Status of the pixel; 0: invalid, 1 : land , 2 : water , 3 : snow, 4 : cloud , 5 : filled ice	[0 to 5]	None	0	Int16

- **Metadata**

The metadata of the global LS seasonality products is described in Appendix 3.

- **Naming convention**

The file name convention of the global LS seasonality products is as generic as possible. All seasonality products follow this structure:

File name = <id>-v<version>.nc/tif

where <id> = <project>-<level>-<var>-<prod>-<spatres>-<tempres>-<epoch>-<date>

The dash "-" is the separator between name components. They are defined in Table 4-3.

Table 4-3: Naming convention in the NDVI seasonality filenames.

FIELD	SIGNIFICATION	VALUE
project	Project Acronym	ESACCI-LC (constant)
level	Processing level	L4 (constant)
var	Variable identifier for the LS seasonality	NDVI-Cond (constant)
prod	Product identifier for LS seasonality	AggMean, Std, Status, NYearObs
spatres	Spatial resolution	1000m (constant)
tempres	Multi-year period of the product defined by the number of years + Temporal resolution of the product	P14Y7D (constant)
epoch	Multi-year epoch of the product, defined by the start and end years	[YYYY-YYYY] where the two "YYYY" are the first year and the last year of the period. This field is 1999-2012 for the NDVI Seasonality product.
date	Start date of the compositing period	[yyyymmdd] where "yyyy" is the starting year of the epoch, "mm" is the month and "dd" is the day
version	Incremental that follows the successive revisions of the CCI-LC Processing lines	Version of product, major-minor

An example file name of the global LS seasonality product related to the 1999-2012 NDVI standard deviation variable between the 1st to 7th January would be: "ESACCI-LC-L4-NDVI-Cond-Std-1000m-P14Y7D-1999-2012-19990101-v2.0.tif".

5 GLOBAL MAP OF OPEN WATER BODIES

5.1 Product description

The CCI global map of open water bodies (WBP v4.0) [RD.24] is an updated version of the CCI-LC WBP v3.0. Improvements originate from a revisit of commission and omission errors with high resolution WB products and auxiliary datasets, which also serves to improve the delineation of the SAR-based water bodies. Figure 5-1 illustrates the improvement of network connectivity in rivers achieved in the WB v4.0 product, compared to the previous version.

In addition to the SAR Water Body Indicator, the precursor of the CCI-LC WB v3.0, the CCI-LC WBP v4.0 relies on 6 external datasets. The 30-m optical GFC-datamask [RD.27] and Global Inland Water (GIW) v1.0 WB products [RD.28] were selected for their finer resolution and their strong complementarities. The Shuttle Radar Topography Mission (SRTM) [RD.21] was used exclusively to include islands below 60°N. In order to remove commission errors over glaciers, extend the CCI-LC WBP v4.0 to 90°S and distinguish inland water from oceans, the following auxiliary products were also selected, respectively: the Randolph Glacier Inventory (RGI) [RD.12], the Scientific Committee on Antarctic Research Antarctic Digital Database (SCAR ADD) [RD.23] and the Global Self-consistent, Hierarchical, High-resolution Shoreline (GSHHS) [RD.22]. The methodology to build the CCI-LC WBP v4.0 is fully described in [AD.11].

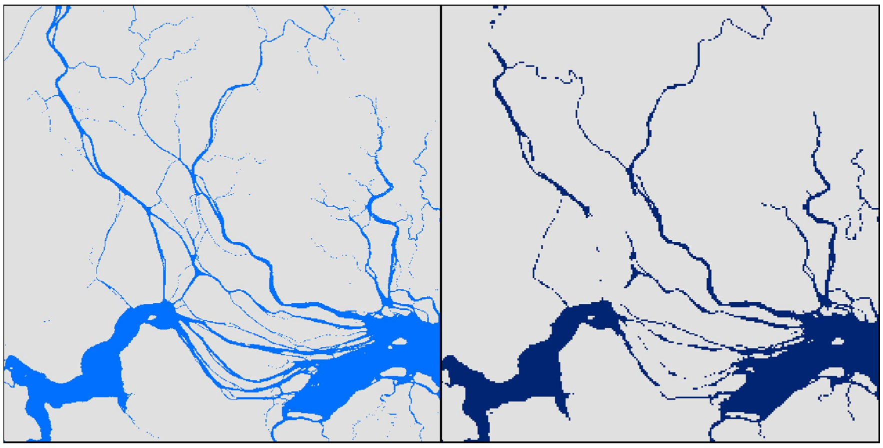


Figure 5-1: River network continuity has drastically improved in the CCI-LC WBP v4.0 (left, compared to the WBP v3.0 on the right), adding high resolution WB dataset as inputs.

The CCI-LC WBP v4.0 is a fully global and precise map of open permanent WB and coastlines (Figure 5-2) that includes two separate layers: a land/inland water/ocean repartition at 150 m spatial resolution and an inland water fraction, in percent of the 150 m grid cell.

Although the CCI-LC WBP v4.0 is delivered as a separate layer at 150 m, it forms class "Water Bodies" of the global annual LC Maps v2, after resampling to 300 m using an average algorithm.

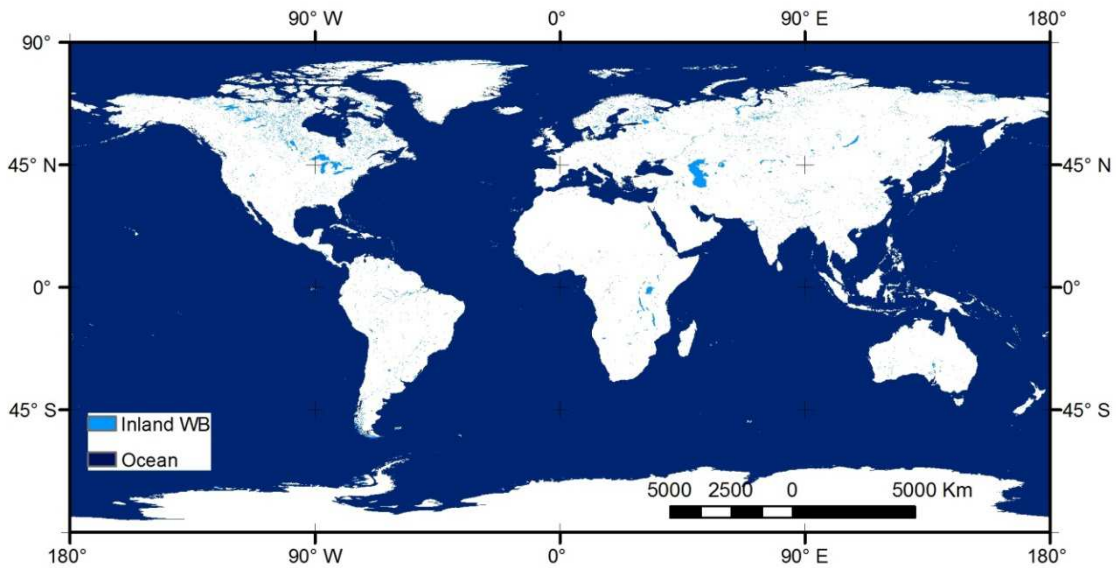


Figure 5-2: Illustration of the CCI-LC WBP v4.0 with distinction of the inland water from oceans.

5.2 Validation

In the same way as for the global land cover maps, the validation process included three different steps: elaborating the sampling strategy, collecting reference data sources and assessing the products accuracy.

The overall accuracy of the CCI-LC WBP v4.0 and its constitutive inputs was performed at global scale. In this document, only the accuracy results of the CCI-LC WBP v4.0 are shown but more detailed information can be found in [RD.24].

5.2.1 Sampling strategy

A validation reference database was built using 2400 samples of 150 m x 150m footprints, based on a two-fold stratified random sampling biased towards areas where errors are most expected (coastlines, river and lake banks, sand dunes, ice-covered regions, etc.). The rationale behind this design is to avoid assessing major parts of the Earth surface covered by large permanent WB (oceans, lakes) or land that coincide with areas of highest classification performances.

First, the samples were distributed proportionally to the surface of 21 equal reasoning regions (polar areas excluded) defined by bioclimatic and remote sensing criteria [RD.25]. This ensured that the whole Earth surface was homogeneously covered. Second, as surface water corresponds to a marginal class w.r.t. global land cover, the location of samples was further distributed according to areas typically mapped as land or water by independent WB products and zones where disagreements generally occur. Samples were selected according to the following class repartition: half of the samples in areas of disagreement between independent WB products, a quarter in areas of land agreement and a quarter in areas of water agreement. The location of validation samples are illustrated in Figure 5-3.

Forcing half the samples in areas of disagreement between WB datasets biased the distribution towards challenging areas of WB mapping. Resulting biased validation figures allowed to be more sensitive to the performances of the different WB products but were only meaningful in relative terms. This bias was eventually corrected to derive overall accuracy figures by weighting them by the actual surface of the land and water classes of each stratum among land agreement, water agreement and discrepancies.

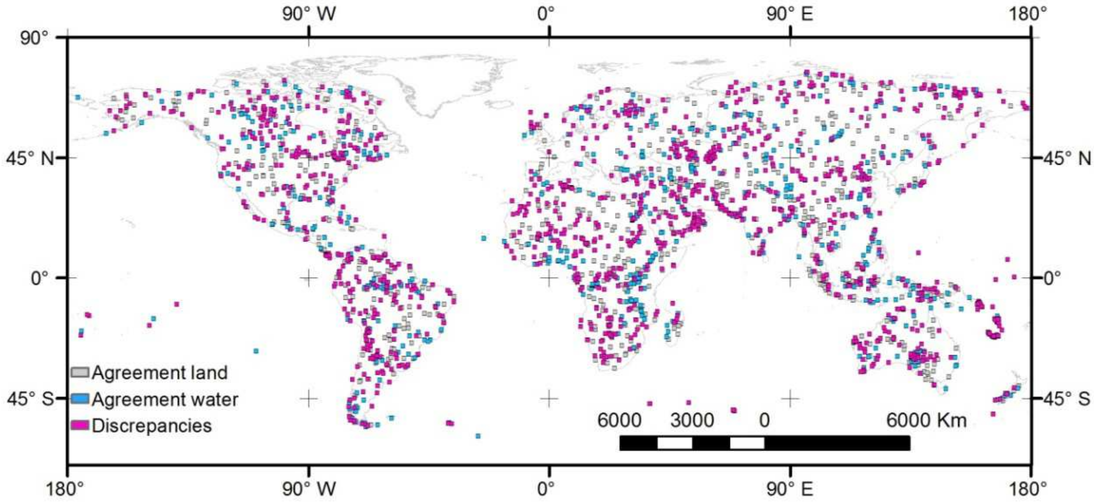


Figure 5-3: Location of the samples of 150 m x 150 m of the validation reference database and distribution in the stratification (agreement land, agreement water and discrepancies) based on the three other independent WB sources.

5.2.2 Reference data collection

The validation samples were visually interpreted independently from the CCI-LC WBP v4.0 using high resolution imagery provided by Google Earth. Samples were labelled as water when at least half the sample was covered with open surface water.

Attention was paid to the temporal aspect of environmental events such as temporary snow cover or water evenly across the globe. The temporal character of an event relied on a careful use of the historical imagery of Google Earth. Samples, covered with temporary snow or water, were labelled as land systematically.

In addition, the date of high resolution imagery, seasonal or permanent character of WB and snow, the potentiality of being inundated, wetlands and swamps were recorded per sample.

5.2.3 Results

The overall accuracy of the CCI-LC WBP v4.0 was performed at global scale. Only reference samples intersecting valid areas of the CCI-LC WBP v4.0 and its constitutive inputs were retained.

Table 5-1 summarizes the accuracy figures resulting from the comparison between the CCI-LC WBP v4.0 and the validation reference samples weighted by the actual surface of the land and water classes. The spatial completeness, defined as the percentage of valid data in the product, the coverage, expressed in upper and lower latitudes and longitudes are also indicated.

Table 5-1: Spatial completeness, coverage and accuracy results of the WBP v4.0.

Spatial completeness	Spatial coverage		Non-Water			Water		
(%)	(LAT)	OA (%)	PA (%)	UA (%)	F-Score (%)	PA (%)	UA (%)	F-Score (%)
100	90° N - 90° S 180° W - 180° E	99	99	100	100	92	86	89

The CCI-LC WBP v4.0 provides the best F-score performances in spite the fact that it tends to very slightly overestimate the permanent water area. The representation of the water class of the CCI-LC WBP v4.0 is clearly of higher accuracy than its constitutive inputs (see [RD.24] for more details). The completeness and spatial coverage of the CCI-LC WBP v4.0 are of 100% and 90° N - 90° S and 180° W - 180° E, respectively.

A second accuracy assessment focused on error-prone areas in WB mapping such as shoreline, lakes and rivers banks, yielded a wider range of accuracy results for the different classes and brought additional information. It is fully described in [RD.24].

5.3 Format

- ### Science dataset

The CCI-LC WBP v4.0 includes two separate layers: a land/inland water/ocean repartition at 150 m spatial resolution and an inland water fraction, in percent of the 150 m grid cell. It has a LAT/LONG WGS84 projection. Table 5-2 gives the layers variable description, valid values ranges, units, fill value and pixel depth.

Table 5-2: The description of the layers included in the CCI-LC WB v4.0 product.

Layer Names	Description	Valid values range	Units	Fill value	Pixel depth
Map	Land/ inland water/ocean classification at 150m spatial resolution. Legend : 1-Land, 2-Inland Water, 3-Ocean	[1 to 3]	None	None	Byte
IWF	Inland water fraction, in percent of the 150 m grid cell	[0 to 100]	Percent	None	Byte

- ### Naming convention

The layer is delivered at the global extent in GTiff format. The file name convention is as generic as possible and follows this structure:

File name = <type>-v<revision>.(tif/netcdf) **where <type>** =

<project>-<level>-<code>-<var>-<spat res>- <period+ temporal res.>-< epoch>

The dash "**-**" is the separator between name components. They are defined in Table 5-3.

Table 5-3: Naming convention in the CCI-LC WB v4.0 dataset.

FIELD	SIGNIFICATION	VALUE
project	Project Acronym	ESACCI-LC (constant)
level	Processing level	L4 (constant)
code	Product code identifier for CCI-LC products	WB (constant)
var	Variable code identifier for the LC conditions	Variable name of the product: Map or IWF
spat res	Spatial resolution	150 m
period+ temporal res.	Multi-year period of the product defined by the number of years + Temporal resolution of the product	P13Y
epoch	Multi-year epoch of the product, defined by the start and end years	[YYYY] where "YYYY" is the first year of the period. This field is 2000 for this product.
version	Incremental that follows the successive revisions of the CCI-LC Processing lines	Version of product, preferably major-minor , optionally with processing centre [a-zA-Z0-9._]*

- **Metadata**

The following attributes are included in the CCI-LC WBP v4.0.

```
Driver: GTiff/GeoTIFF
Size is 259200, 129600
Coordinate System is:
GEOGCS["WGS 84",
    DATUM["WGS_1984",
        SPHEROID["WGS 84",6378137,298.257223563,
            AUTHORITY["EPSG","7030"]],
        AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0],
    UNIT["degree",0.0174532925199433],
    AUTHORITY["EPSG","4326"]]
Origin = (-180.000000000000000,90.000000000000000)
Pixel Size = (0.001388888800000,-0.001388888800000)
Metadata:
  AREA_OR_POINT=Area
  Copyright =ESA 2015 - UCLouvain and Gamma-RS
```

```
  Dataset =Static map of open water bodies at 150 m spatial resolution resulting
from a compilation and editions of land/water classifications: the Envisat ASAR
water bodies indicator, a sub-dataset from  the Global Forest Change 2000 - 2012
and the Global Inland Water product. This product was resampled to 300 m using an
average to form the class "Water Bodies" of the CCI-LC Maps.
  Description =
   Layer 1 = Water classification; 1: Land , 2: Inland Water, 3: Oceans
   Layer 2 = Percentage of inland water inside the 150 m grid cell
  Scaling Factor =none
Image Structure Metadata:
  COMPRESSION=LZW
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (-180.0000000,  90.0000000) (180d 0' 0.00"W, 90d 0' 0.00"N)
Lower Left  (-180.0000000, -89.9999885) (180d 0' 0.00"W, 89d59'59.96"S)
Upper Right ( 179.9999770,  90.0000000) (179d59'59.92"E, 90d 0' 0.00"N)
Lower Right ( 179.9999770, -89.9999885) (179d59'59.92"E, 89d59'59.96"S)
Center      (  -0.0000115,   0.0000058) (  0d 0' 0.04"W,  0d 0' 0.02"N)
Band 1 Block=256x256 Type=Byte, ColorInterp=Gray
```

6 SURFACE REFLECTANCE PRODUCTS

6.1 Products description

The SR products delivered by the CCI-LC project consist in different global SR composite time series covering the period 1992-2015 that are the input for the classification algorithms. The pre-processing module was developed by Brockmann-Consult (BC), capitalizing on the GlobCover and GlobAlbedo projects. The SR products delivered by the CCI-LC project are in detail:

1) Time series of AVHRR 7-day composites from 1992 through 1999;
2) Time series of Envisat MERIS FR 7-day composites from 2003 through 2012;
3) Time series of Envisat MERIS RR 7-day composites from 2003 through 2012.
4) Time series of PROBA-V 7-day composites from 2014 through 2015 (and beyond);

Table 6-1 details the satellite dataset that are planned to be used in order to generate the global SR composite time series.

Table 6-1: Satellite data that are planned to be used to generate the CCI-LC SR time series

Global SR composite time series	Reference period	Satellite data source	Technical specifications of the satellite data source
AVHRR global SR composite time series	1992-1998	AVHRR 2	• 1km spatial resolution • 5 spectral bands in visible and infrared • Global coverage
MERIS global SR composite time series	2003-2012	Envisat MERIS FR & RR	• 300-m or 1000- m resolution full swath • 15 spectral bands in visible and near infrared (NIR) • Global coverage
PROBA-V global SR composite time series	2014-2015 (and beyond)	PROBA-V	• 300m spatial resolution • 4 spectral bands in visible and infrared • Global coverage

The time series are made of temporal syntheses obtained over a 7-day compositing period. The exact schema for the 7-day periods is to start at January 1 and go on 7-day by 7-day periods until the end of the year. In this way, it should be noted that the last period of December comprises 8 days. As for leap years, the 7-day period including February 29 comprises 8 days. There are separate time series for MERIS FR and MERIS RR, PROBA-V and AVHRR.

In order to simplify the handling and analysis of 300m spatial resolution global datasets, the 7-day SR time series are being delivered in tiles. Global products are subdivided into 72 x 36 tiles (Figure 6-1) following the tiling system already used in the GlobCover project ([RD.9] and [RD.13]). Tiles are 5 degrees by 5 degrees. The tile coordinate system starts at (0,0) (85N180W) (horizontal tile number, vertical tile number) in the upper left corner and proceeds right (horizontal) and downward (vertical). The tile in the bottom right corner is (71, 35) (90S175E). A tile is physically represented by a single file whose file name also indicates the tile south-west corner (see Section 6.2 for a complete description of the naming convention). In addition, tiles having no land contribution are not delivered.

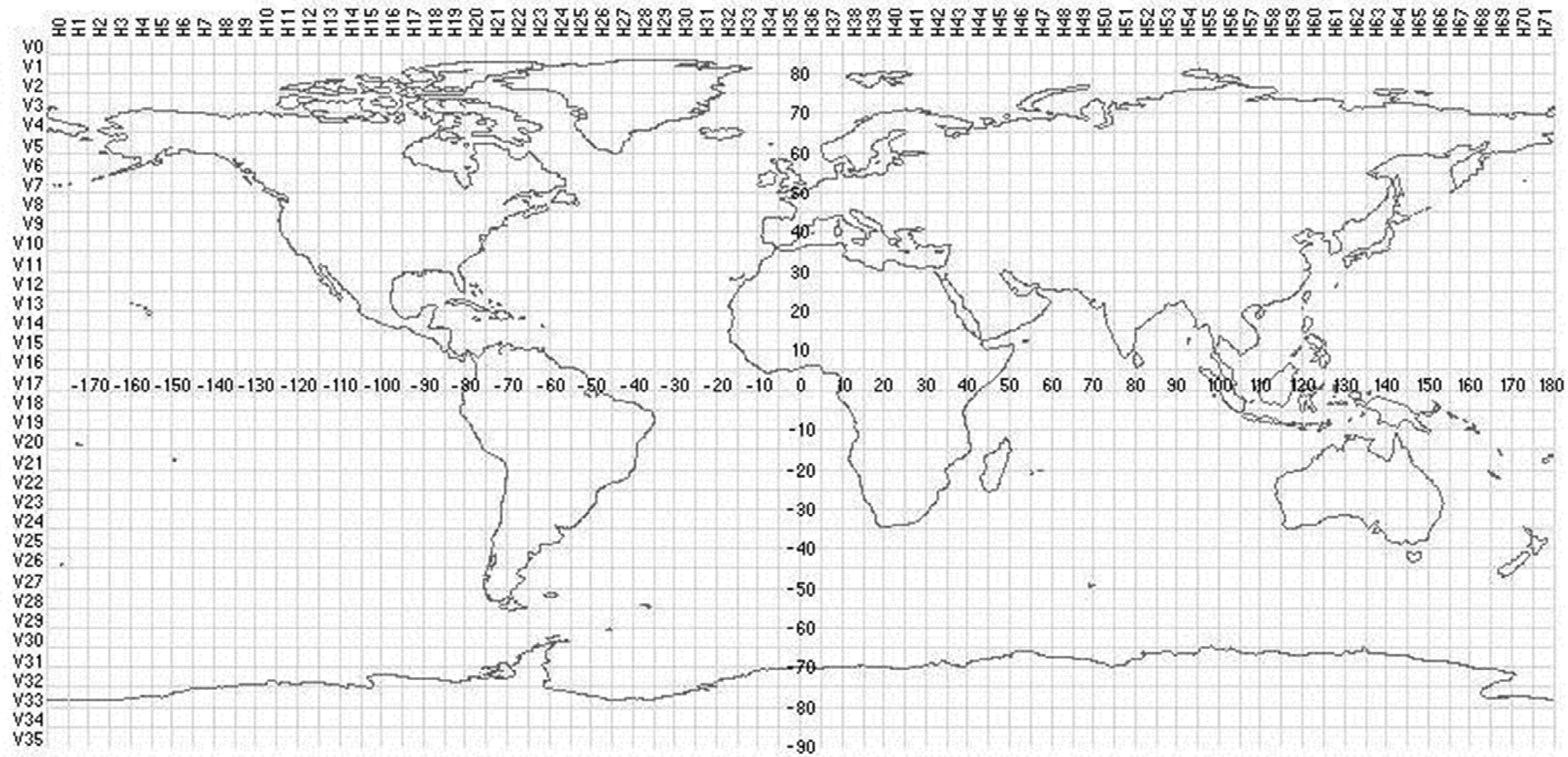


Figure 6-1: Description of the tiling system used for the SR products (from [RD.9] and [RD.13])

6.1.1 MERIS SR time series

The MERIS FR and RR SR time series were already produced in Phase I. Improved versions have been generated during this Phase II. The spectral content encompasses 13 of 15 MERIS spectral channels – bands 11 and 15 being removed - (Table 6-2) and the spatial resolution is of 300m for the Full Resolution (FR) and 1000m from the Reduced Resolution (RR).

Table 6-2: MERIS spectral channels.

BAND NUMBER	BAND CENTRE (NM)	BAND WIDTH (NM)	USE
1	412.5	10	Yellow substance and detrital pigments
2	442.5	10	Chlorophyll absorption maximum
3	490	10	Chlorophyll and other pigments
4	510	10	Suspended sediment, red tides
5	560	10	Chlorophyll absorption minimum
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption and fluorescence reference
8	681.25	7.5	Chlorophyll fluorescence peak
9	705	10	Fluorescence reference, atmospheric corrections
11	760.625	3.75	O2 R-branch absorption band
10	753.75	7.5	Vegetation, cloud
12	775	15	Atmosphere corrections
13	865	20	Vegetation, water vapour reference
14	885	10	Atmosphere corrections
15	900	10	Water vapour, land

Figure 6-2 shows the individual RGB image of tile h37v12 of CCI-LC MERIS FR SR 7-day composite from 2005-07-02 at 300m spatial resolution.

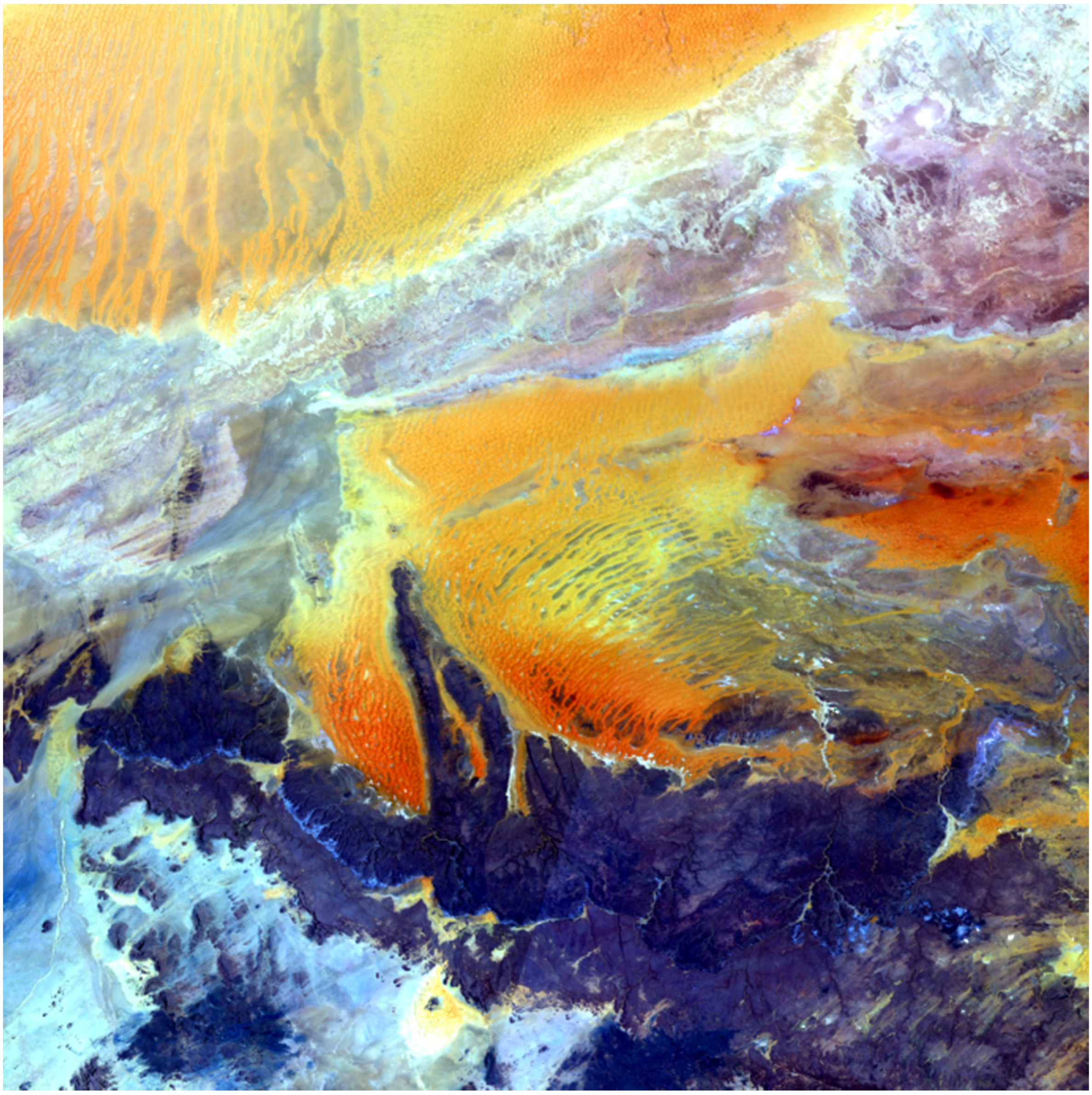


Figure 6-2: Example of CCI-LC MERIS FR SR 7-day composite, at 300m spatial resolution and tile h37v12 - ESACCI-LC-L3-SR-MERIS-300m-P7D-h37v12-20050702-v1.0.nc (RGB with channels 7, 5, 2).

Two examples of the global RGB image of CCI-LC MERIS FR SR 7-day composites are illustrated in Figure 6-3 (2009-04-02) and Figure 6-4 (2003-01-15). The different coverage of the Earth is clearly visible and is mainly influenced by the different number of available input daily data.

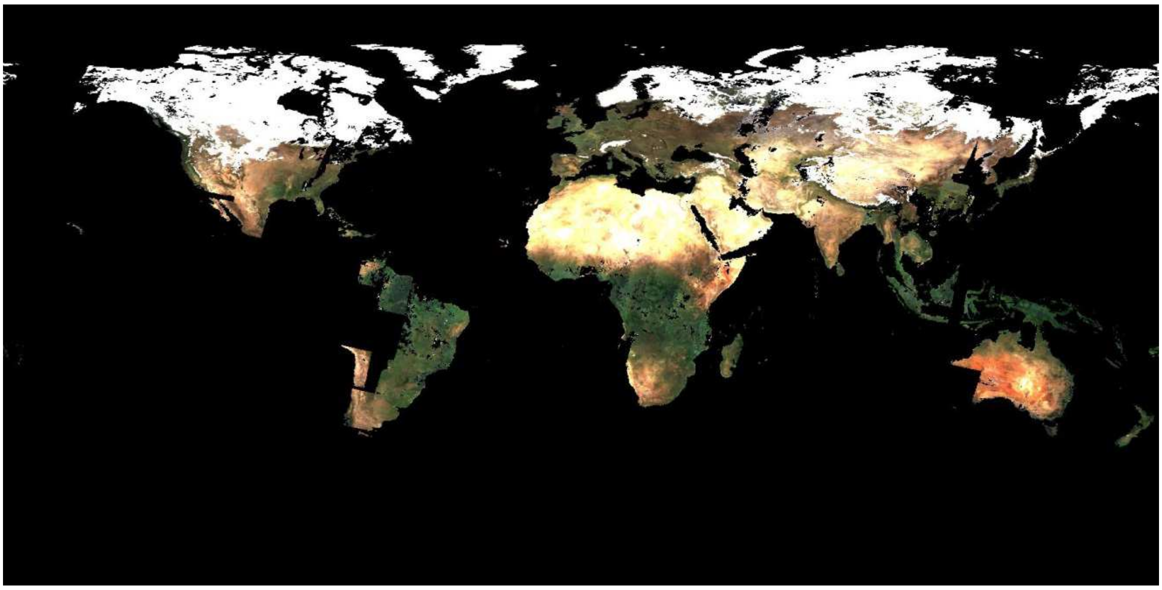


Figure 6-3: The CCI-LC Global Surface reflectance MERIS FR 7-day composite from the 2009-04-02 through 2009-04-08 at 300m spatial resolution (RGB with channels 7, 5, 3).

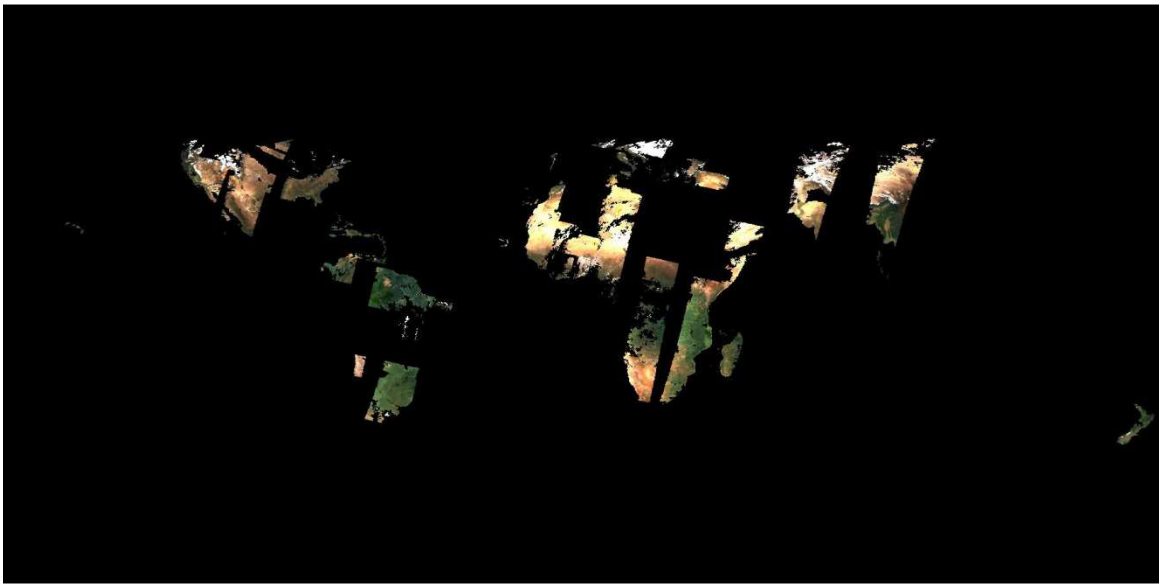


Figure 6-4: The CCI-LC Global Surface reflectance MERIS FR 7-day composite from the 2003-01-15 through 2003-01-21 at 300m spatial resolution (RGB with channels 7, 5, 3).

Figure 6-5 shows the average of all MERIS FR SR 7-day composites related to the 2010 epoch (i.e. the 5 years from 2008 to 2012) at 300m spatial resolution.

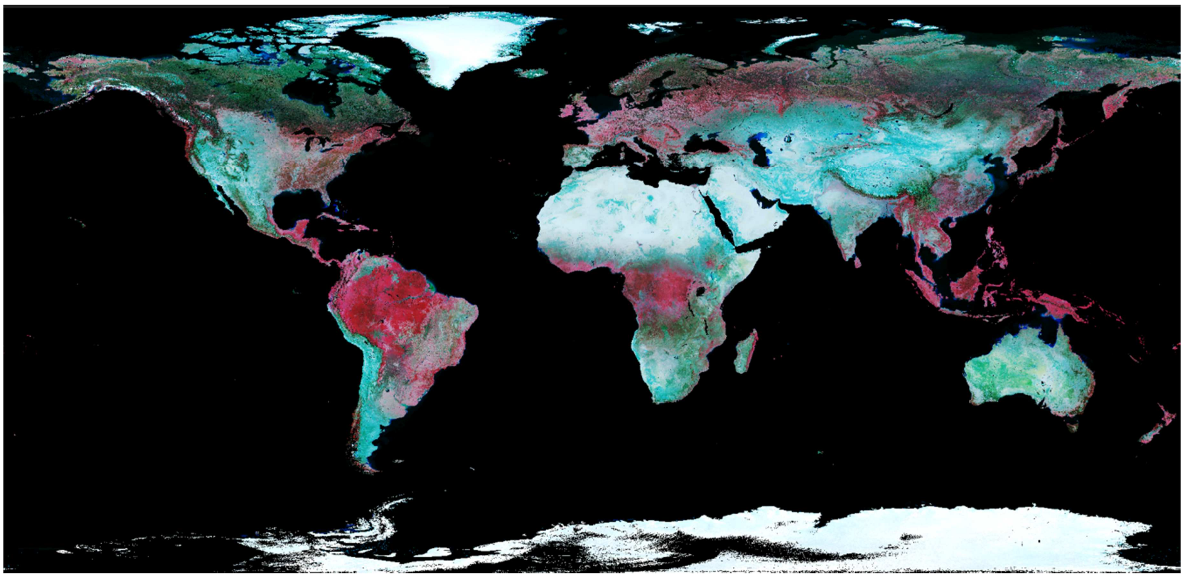


Figure 6-5: The CCI-LC Global Surface reflectance composite from all MERIS FR SR 7-day composites from the 2010 epoch (2008-2012), at 300m spatial resolution (RGB with channels 14, 7, 5).

6.1.2 AVHRR SR time series

The AVHRR SR time series have been generated during this Phase II. The spectral content encompasses the 2 VIS-NIR spectral channels as well as the 3 InfraRed spectral bands (Table 6-3) and the spatial resolution is of 1000m.

Table 6-3: AVHRR-2 spectral channels.

BAND NUMBER	BAND CENTRE (µM)	BAND WIDTH (µM)	COMMENT
1	0.63	0.05	Surface reflectance
2	0.9125	0.1875	Surface reflectance
3	3.74	0.19	Brightness temperature
4	11	0.5	Brightness temperature
5	Ch4 rep.	Ch4 rep.	Brightness temperature

Figure 6-6 shows the individual RGB image of tile h26v18 of CCI-LC AVHRR SR 7-day composite from 1993-05-21 at 1000m spatial resolution.

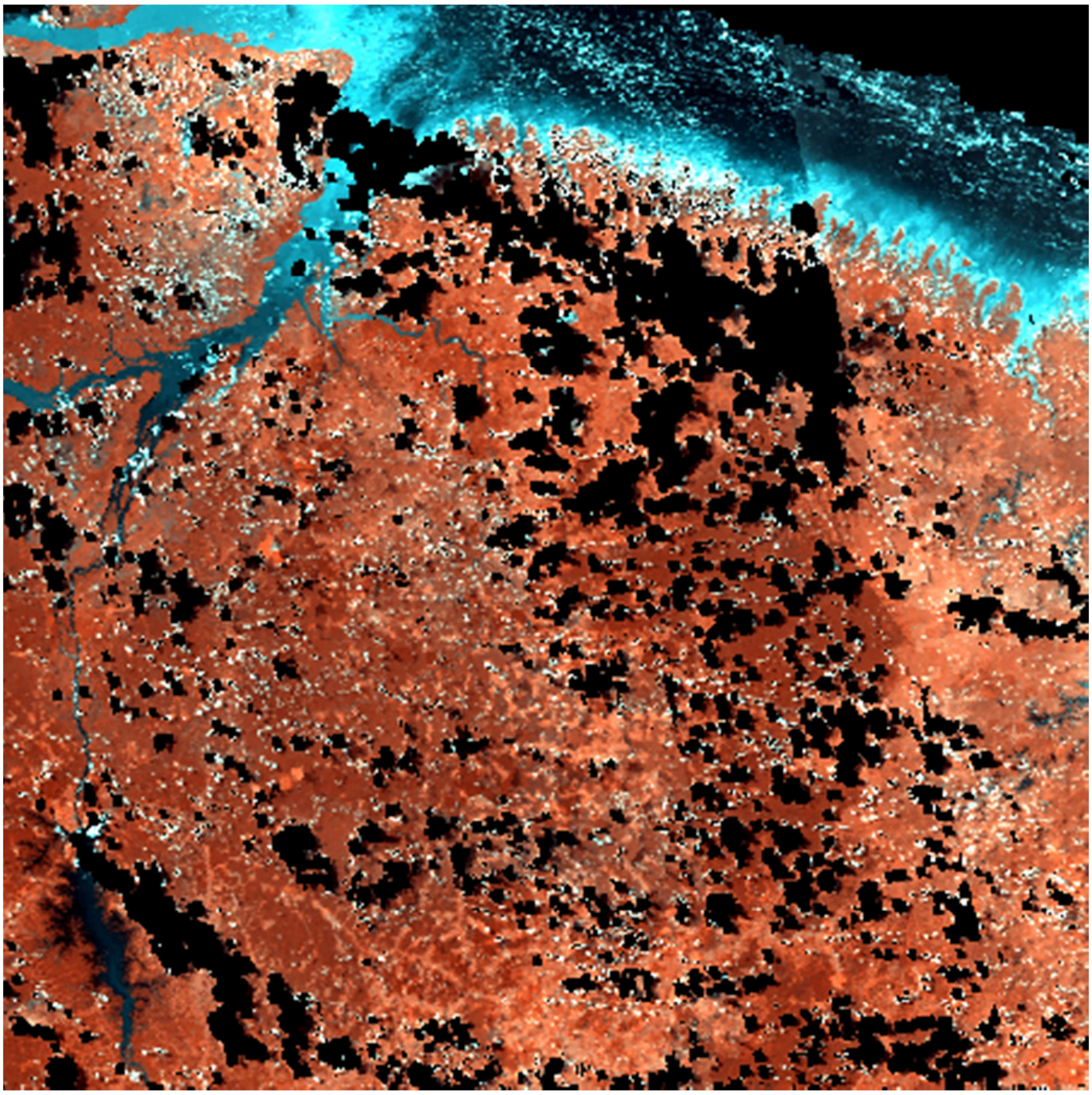


Figure 6-6: Example of CCI-LC AVHRR SR 7-day composite, at 1000m spatial resolution and tile h26v18 - ESACCI-LC-L3-SR-AVHRR-1000m-P7D-h26v18-19930521-v2.2.nc

Figure 6-7 shows the CCI-LC global surface reflectance composite from all AVHRR SR 7-day composites from 1996-05-21, at 1000m spatial resolution.

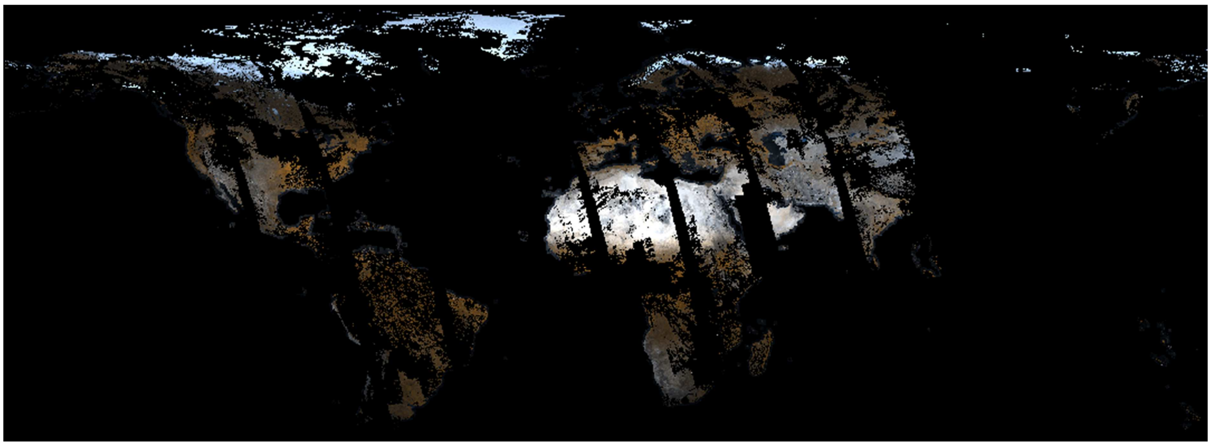


Figure 6-7: The CCI-LC Global Surface reflectance composite from all AVHRR SR 7-day composites from 1996-05-21, at 1000m spatial resolution (ESACCI-LC-L3-SR-AVHRR-1000m-P7D- h00-71v00-35-19960521-v2.2.nc)

6.1.3 PROBA-V time series

The PROBA-V SR time series have been generated during this Phase II. The spectral content encompasses the 4 VIS-NIR-SWIR spectral channels (see Table 6-4) and the spatial resolution is of 300 m.

Table 6-4: PROBA-V spectral channels.

BAND NUMBER	BAND CENTRE (NM)	BAND WIDTH (NM)	COMMENT
1	464	47	Surface reflectance for the Blue
2	655	82	Surface reflectance for the Red
3	837	130	Surface reflectance for the NIR
4	1603	65	Surface reflectance for the SWIR

Figure 6-8 shows the individual RGB image of tile h36v13 of CCI-LC PROBA-V SR 7-day composite from 2015-03-19 at 300m spatial resolution.

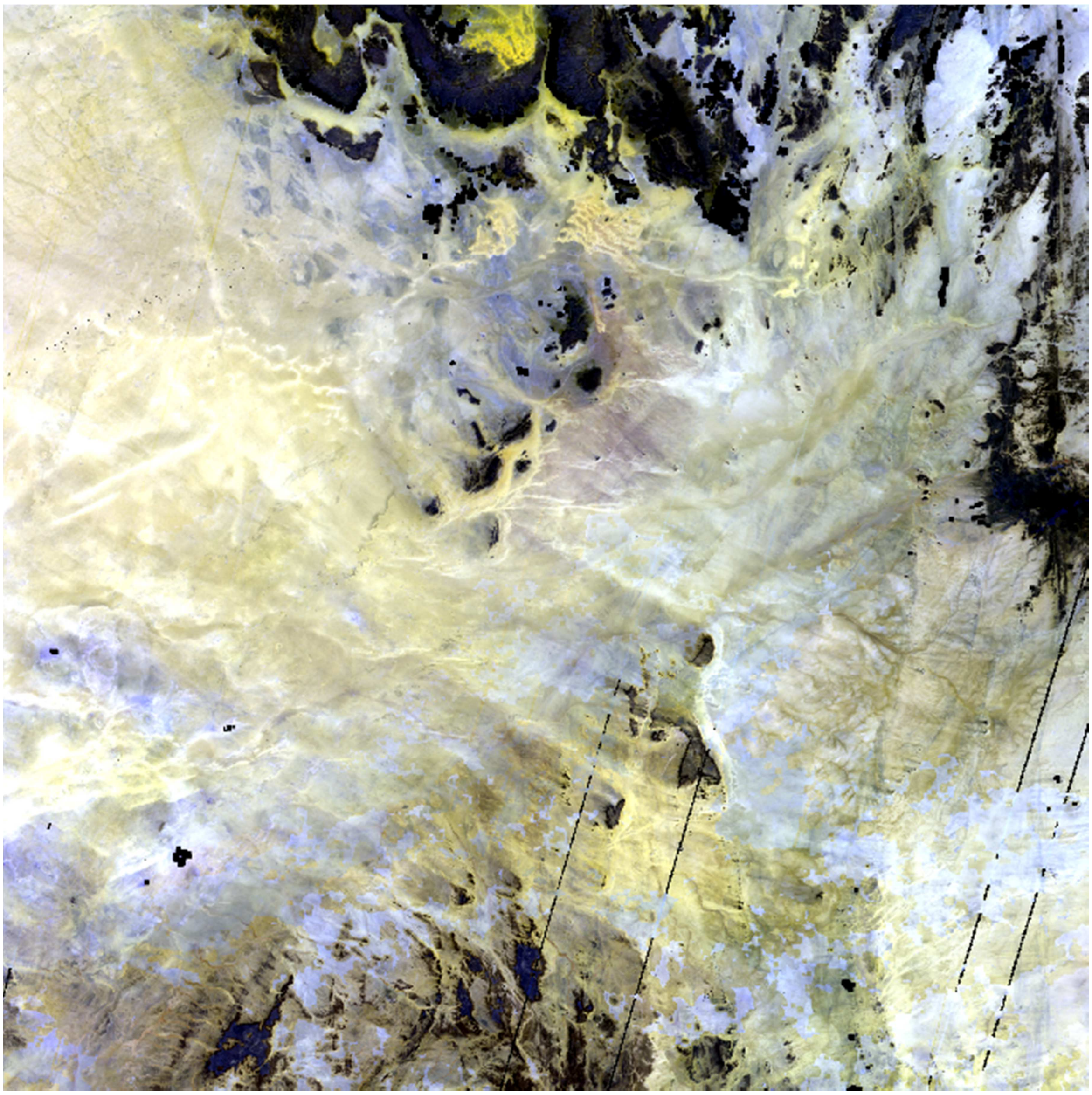


Figure 6-8: Example of CCI-LC PROBA-V SR 7-day composite, at 300m spatial resolution and tile h36v13 - ESACCI-LC-L3-SR-VEGETATION-300m-P7D-h36v13-20150319-v2.0.nc

Figure 6-9 shows the CCI-LC global seven-week seasonal surface reflectance composite from all PROBA-V SR 7-day composites from 2014-07-16 to2014-09-02, at 300m spatial resolution.

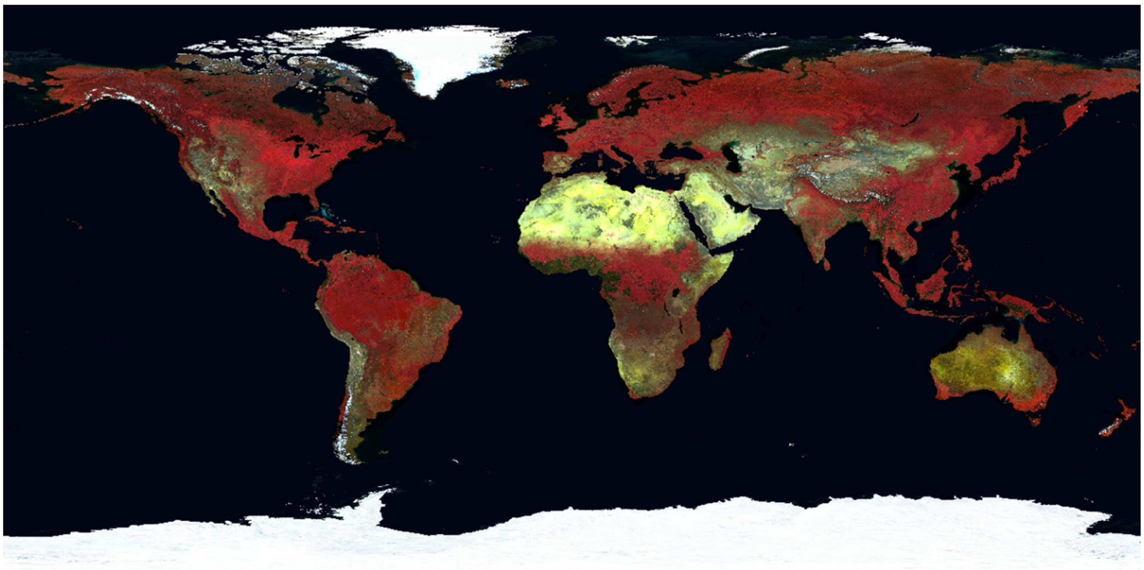


Figure 6-9: The CCI-LC Global Surface reflectance AVHRR composite from all SR 7-day composites from 2014-07-16 to2014-09-02, at 300m spatial resolution (ESACCI-LC-L3-SR-Vegetation-300m-P7D- h00-71v00-35-20140716-201400902-v2.1.nc)

6.2 Products format

- ### Naming convention

The file name convention of the global SR composite time series delivered by the CCI-LC project is the following:

File name = <id>**-**v<version>.nc

where <id> = <type>**-**<tile>**-**<start time>

where <type> = <project>[-<level>]-<code>**-**<sensor>**-**<spatres>**-**<tempres>

The dash "-" is the separator between name components. The filename convention obeys NetCDF CF by using the postfix ".nc". The different name components are defined in Table 6-5.

Table 6-5: Components that make the name of the SR products delivered by the CCI-LC project.

FIELD	SIGNIFICATION	VALUE
project	Project Acronym	ESACCI-LC (constant)
level	Processing level	L3 (constant)
code	Product code identifier for CCI-LC products	SR (constant)
sensor	Mission, platform and sensor identifier	MERIS, PROBA-V, AVHRR
spatres	Spatial resolution	300m or 1000m
tempres	Compositing period	P7D (constant)
tile	Tile of the Plate Carrée grid (see Figure 6-1)	Tile name in format hXXvYY where XX is the

FIELD	SIGNIFICATION	VALUE
		column and YY is the row e.g. " h71v27" - tile in column 71 and row 27 of the Plate Carrée grid (see Figure 6-1)
start time	Start time of the interval mentioned in the field "period"	"yyyyMMdd" where: "yyyy" is the start year of the composite "MM" is the start month of the composite "dd" is the start day of the composite
version	Incremental that follows the successive revisions of the CCI-LC Processing lines	Version of product, preferably major.minor , optionally with processing centre [a-zA-Z0-9._]

An example file name of the first 7-day MERIS FR SR composite for the year 2008 located at the tile h40v13 would be: "ESACCI-LC-L3-SR-MERIS-300m-P7D-h40v13-20080326-v1.0.nc"

- **Processing Level**

Level 3 (i.e. "data or retrieved environmental variables which have been derived from level 1 or 2 products and which have been spatially and/or temporally resampled" [RD.14])

- **Units**

Top of Canopy Reflectance values (no unit, provided as a fraction) coded in 16-bits

- **Spatial Extent**

All the terrestrial zones of the earth between the parallels 90°N and 60°S. The SR products are provided in tiles as defined in Section 6.1.

- **Spatial resolution**

300 m or 1000 m

- **Temporal resolution**

7 day

- **Product layers**

The CCI-LC global 7-day SR products description is based on the structure of the NetCDF files. The global attributes of the composites are described in the Appendix 2.

- **Projection**

The projection is a Plate Carrée with a geographic Lat/Long representation based on the WGS84 ellipsoid (see Section 3.1.3 for a complete description).

- **Format**

All the SR time series are delivered in NetCDF-4 format using the "classic model" of NetCDF with compression. The file specification follows CF conventions [RD.16].

- **Metadata**

The metadata for the SR products is provided as global attributes in the NetCDF file. It follows the CCI guidelines [RD.17].

- **Estimated size**

The size of a global 7-day 300-m MERIS FR/RR SR composite is estimated at ~70 GB/ ~8 GB (compressed) and the size of the one tile is estimated at ~0.3 GB/~0.02 GB (compressed).

The size of a global 7-day 1000-m AVHRR SR composite is estimated at ~4 GB (compressed) and the size of the one tile is estimated at ~3 MB (compressed).

The size of a global 7-day 300-m PROBA-V SR composite is estimated at ~40 GB (compressed) and the size of the one tile is estimated at ~90 MB (compressed).

7 SOFTWARE TOOLS

A set of tools to browse and view the content of the CCI-LC products are available.

7.1 Software tools for viewing and using the CCI-LC SR 7-day composite products

7.1.1 BEAM

Since the CCI-LC SR 7-day products are in NetCDF format, these products can be opened with all NetCDF compatible software packages. We particularly recommend using the BEAM toolbox, which is specifically developed by ESA for the exploitation of EO data products. BEAM, for example, features the interpretation of flag-codings, provides image interpretation information, handles missing data gracefully and allows band arithmetic using a fast expression language.

BEAM is the Basic European Remote Sensing Satellite (ERS) & Envisat (Advanced) Along Track Scanning Radiometer ((A)ATSR) and MERIS Toolbox and is a collection of executable tools and an Application Programming Interface (API) which have been developed to facilitate the use, viewing and processing of data of various sensors. Furthermore, BEAM is open source and freely available from http://earth.esa.int/beam.

Regarding the CCI-LC products, BEAM could for example be used to:

- view the images and metadata;
- create regional subsets;
- investigate the products by creating statistics, histograms, and scatter plots;
- perform image analysis (e.g. clustering);
- validate data by comparison with in-situ or any other kind of reference data.

The components of the BEAM software are the following ones:

- VISAT - an intuitive desktop application to be used for visualization, analysis and processing of remote sensing raster data. Figure 7-1 gives an impression of how VISAT looks and feels like;
- a set of scientific tools running either from the command line or invoked by VISAT, also entirely written in Java;
- a rich Java API for the development of new remote sensing applications and BEAM extension plug-ins.

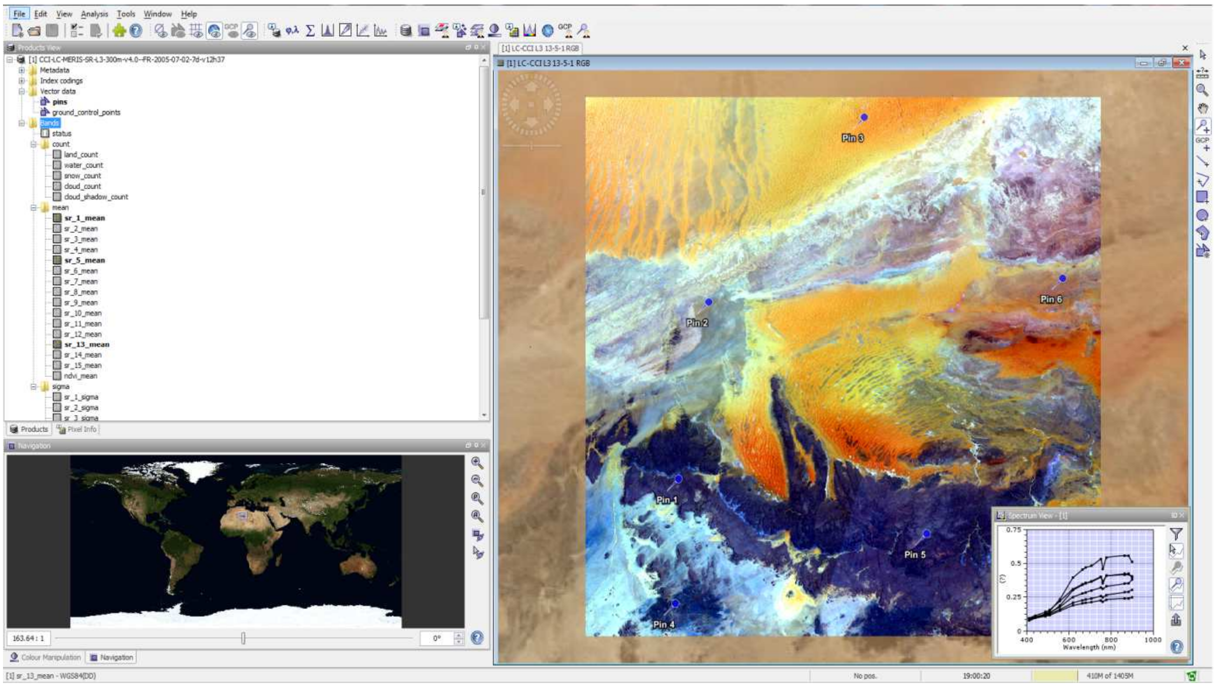


Figure 7-1: Screenshot of VISAT.

7.1.2 Panoply

The Panoply data viewer provided by for free (available at http://www.giss.nasa.gov/tools/panoply/) can also be used. It is illustrated at Figure 7-2.

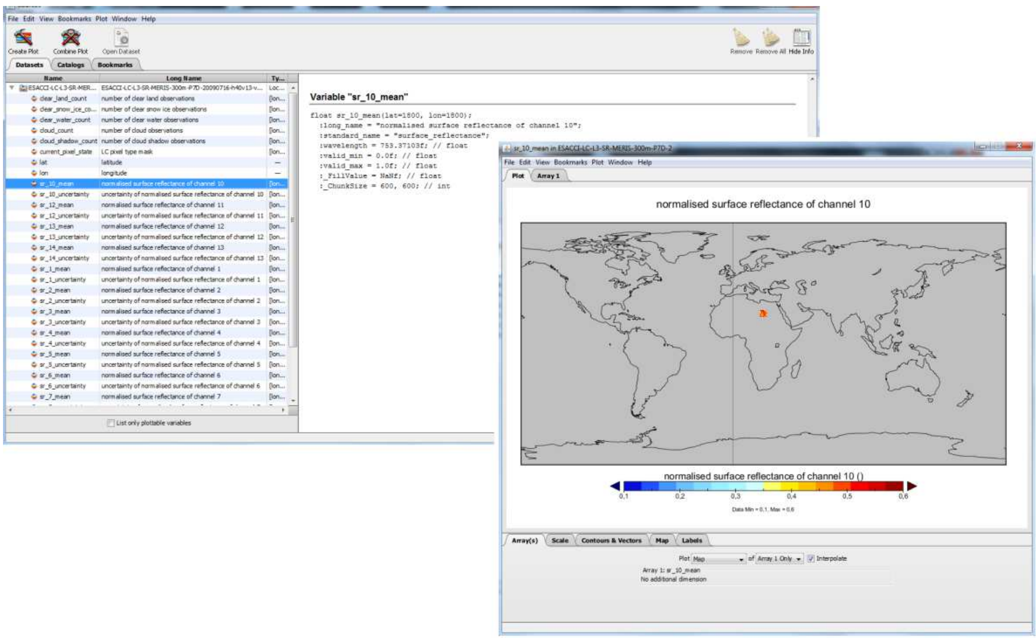


Figure 7-2: Screenshot of Panoply.

7.2 Software tools for the CCI-LC maps and seasonality products

The CCI-LC map and seasonality product are delivered both in the NetCDF and GeoTiff formats.

The GeoTiff format is supported by many softwares such as ArcGIS, Erdas and ENVI. These softwares can be used simply to visualize the data or to cross LC information with other spatial sources (vector or raster layers), extract temporal series on the seasonality products, compute statistics, etc.

Several Open Source softwares also support the GeoTiff format, such as the Geospatial Data Abstraction Library (GDAL [RD.18]) and the Geographic Resources Analysis Support System (GRASS GIS [RD.19]).

GDAL is a library for reading and writing raster geospatial data formats. It is built with a variety of useful command-line utilities for data translation and processing. This software allows easy access to the metadata and statistics of the files via the gdalinfo command. Regional subsets can also be created with the gdal_translate function.

GRASS GIS is a free Geographic Information System (GIS) software used for geospatial data management and analysis, image processing, graphics/maps production, spatial modelling, and visualization.

7.3 CCI-LC user tool

The LC map and seasonality products are delivered at spatial resolution of 300 m and 1km, respectively. All products are delivered in a Plate Carrée projection as global files. However, climate models may need products associated with a coarser spatial resolution, over specific areas (e.g. for regional climate models) and/or in another projection. In order to face the variety of requirements, the CCI-LC project has developed a tool that allows users to adjust these three parameters of the LC products in a way which is suitable to their model.

The climate users of the CCI-LC project have established a minimum list of possibilities in terms of spatial resolution and projection that the tool shall - and does - offer. They are presented in Table 7-1.

Table 7-1: Minimum set of projections and spatial resolutions that need to be included in the re-projection, aggregation and subset tool developed by the CCI-LC project.

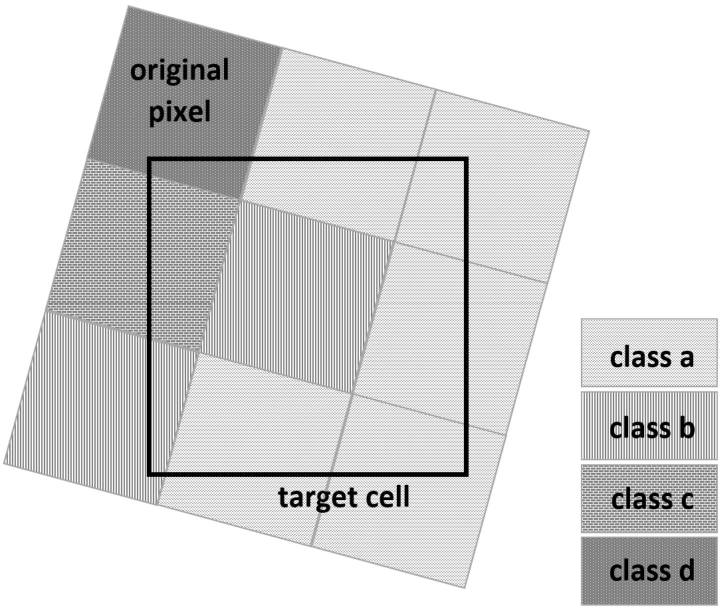
PARAMETER THAT CAN BE ADJUSTED	POSSIBILITIES OFFERED BY THE TOOL
Regional subset ID	Predefined regional subset
	Free specification of regional subset (4 corner coordinates)
Spatial resolution	Original resolution
	0.25 degree
	0.5 degree
	1 degree
	1.875 degree

PARAMETER THAT CAN BE ADJUSTED	POSSIBILITIES OFFERED BY THE TOOL
Projection	Original projection (Plate-Carrée)
	Gaussian grid
Conversion of CCI-LC classes to PFT	CCI-LC standard cross table
	User defined cross table Additional classification map

In case of re-projection and aggregation of the CCI-LC products the applied resampling algorithms are different depending on the type of product and on the included bands and are described in the following.

- **Re-sampling algorithm for the CCI-LC Map products**

The aggregated CCI-LC map product includes following bands: the fractional area of each CCI-LC class, the majority classes and the fractional area of each PFT as well as the accuracy. The majority class n is defined as the CCI-LC class which has the rank n of sorted list of CCI-LC class by fractional area in the target cell (see also Figure 7-3). The number of majority classes is a parameter which can be defined by user. The rules for the resampling are specified in consultation with the users. So each original pixel contributes to the target cell according to its area percentage but the value of a pixel will only consider if the flag -processed flag- has the status processed and the flag -current_pixel_state- has the status clear land, water or snow and ice. Then the accuracy is calculated by the median of the values of the band -algorithmic_confidence_level-.



	Area	Majority class
class a	~ 8/16	1
class b	~ 5/16	2
class c	~ 2/16	3
class d	~ 1/16	4

Figure 7-3: Visualization of the pixel aggregation from the spatial resolution of original LC-CCI Map product into the user defined spatial resolution of the aggregated LC-CCI Map product.

- ## Re-sampling algorithm for the CCI LS seasonality product

In case of the aggregation of the NDVI CCI LS seasonality product, the mean of NDVI and the sum over all valid NDVI observations are included in the aggregated product. The rules for the resampling are also specified in consultation with the users. As well as for the CCI-LC map products, each original pixel contributes to the target cell according to its area percentage but the value of a pixel will only consider if the flag -current_pixel_state- has a dedicated status w.r.t. the type of seasonality product.

- ## LCCS to PFT conversion

Furthermore, it is very important that the modellers can use the aggregation tool to apply the conversion from the LC legend to their user-specific PFT list in order to deliver an appropriate PFT product. The conversion of CCI-LC classes to PFT is based on a look-up table, which has been confirmed by the climate modellers and is shown in Table 7-2. The users have the possibility to define their own look-up tables. Additionally, the user can also apply the conversion of the LCCS classes to PFT including additional information, like world map of Köppen-Geiger climate classification (v3.10 and see Figure 7-4, [RD.20]).

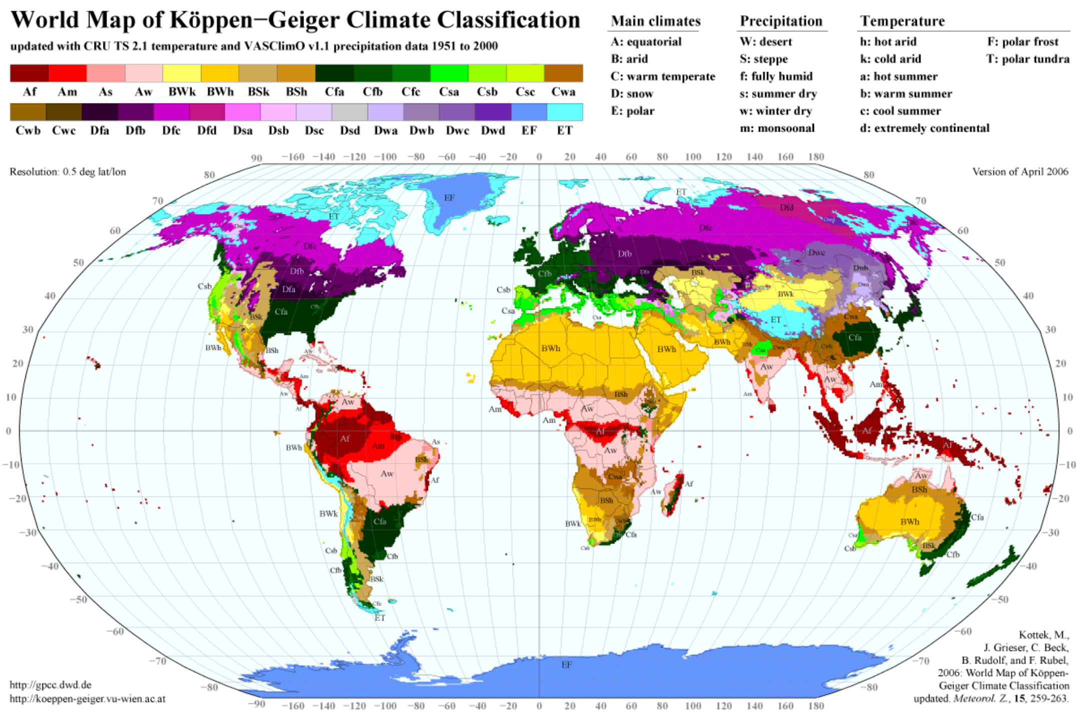


Figure 7-4: Köppen-Geiger climate classification [RD.20].

Table 7-2: Look-up table - conversion of CCI-LC classes to PFT.

- **Examples**

Figure 7-5 gives an example of the global land cover map aggregated at a cell size of 9.8 km and the pixel value represents the majority class 1 w.r.t. the LC class, according to Table 3-1.

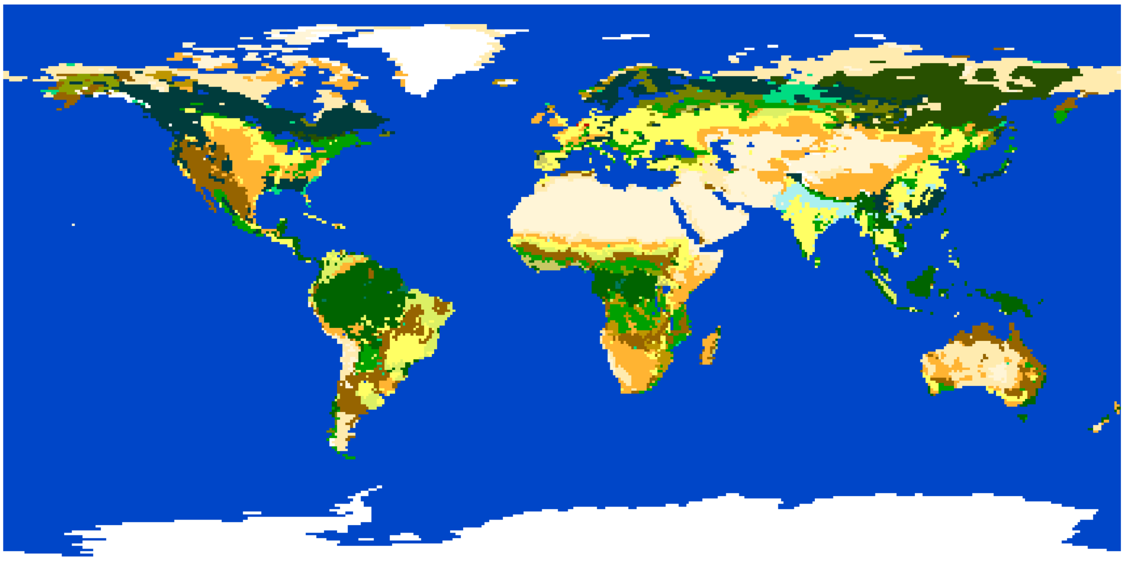


Figure 7-5: Example of the aggregated global land cover map V1 obtained with the user tool. Its pixel size is 9.8 km, the majority class is 1 and the pixel value represents the LC class according to Table 7-2.

Figure 7-6 shows an example of the global land cover map aggregated at a cell size of 9.8 km and the pixel value represents the area of the LC class 130 - grassland. Figure 7-7 gives an example of the global land cover map aggregated at a cell size of 9.8 km and the pixel value represents the area of the PFT – natural grass.

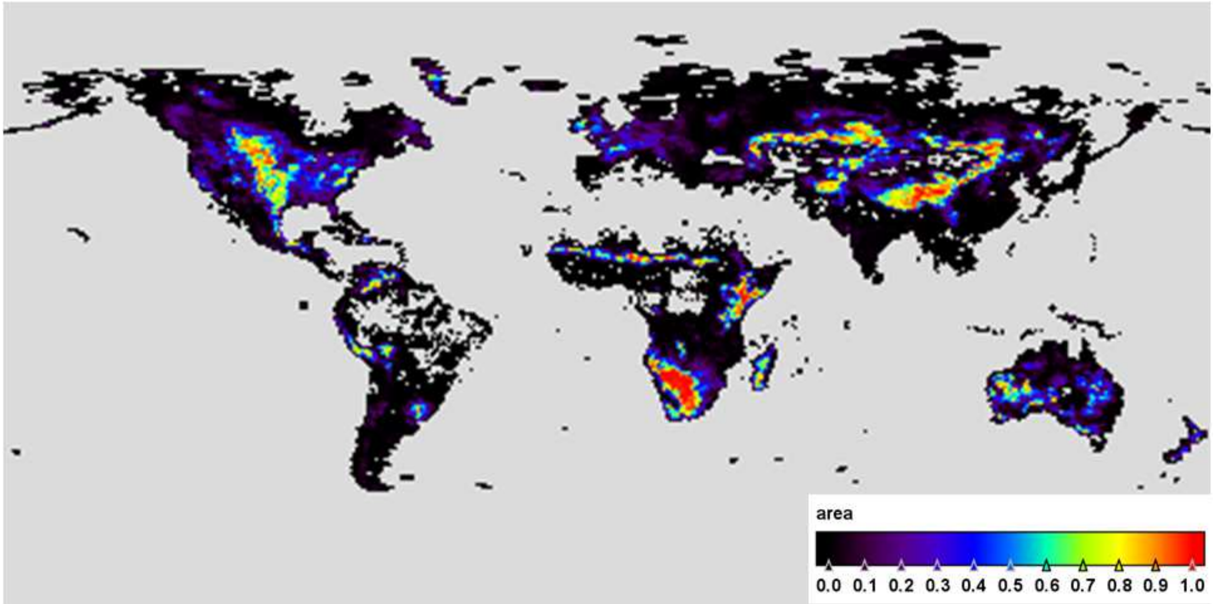


Figure 7-6: Example of an aggregated CCI Global Land Cover Map V1 obtained with the aggregation tool. Its pixel size is 9.8 km, area of CCI-LC class – 130 – grassland.

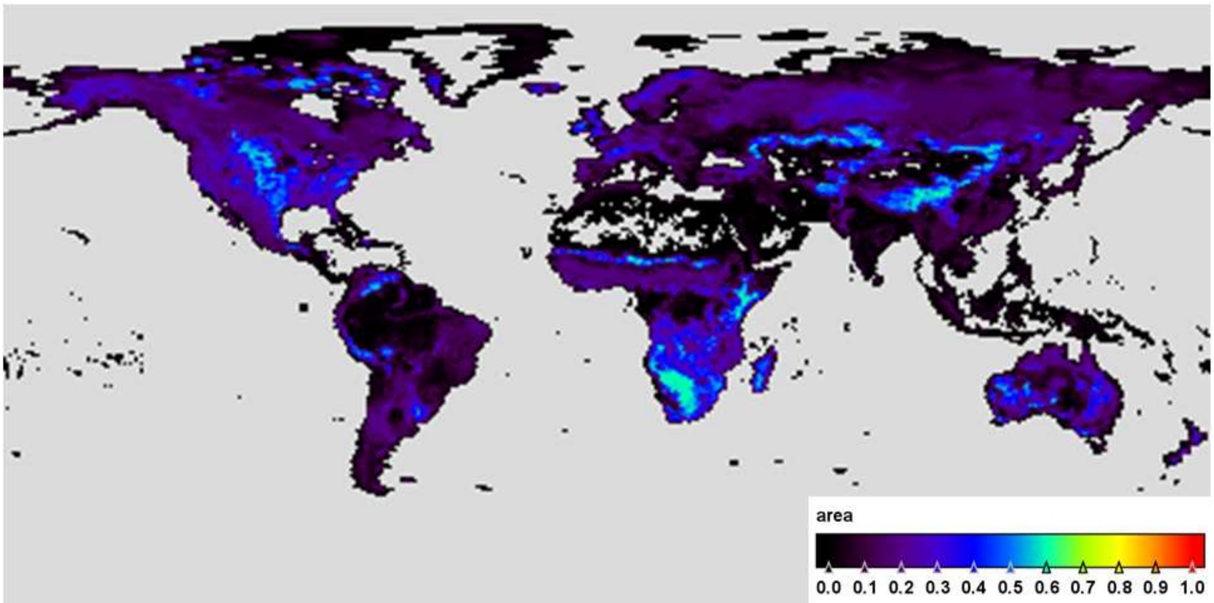


Figure 7-7: Example of an aggregated CCI Global Land Cover Map V1 obtained with the aggregation tool. Its pixel size is 9.8 km, area of CCI-LC PFT – natural grass.

The instruction manual of the aggregation tool can be found in the Appendix 4 of this document.

7.4 Software tools for CCI-LC dataset visualization

Considering the heavy download related to the full CCI-LC products dataset, a web interface was developed to mainly visualize and interact with data. It is accessible at the following address: http://maps.elie.ucl.ac.be/CCI/viewer/index.html. Figure 7-8 illustrates the home page of the visualization interface

It includes two main compartments: the map environment (right) and the information panel (left). The information panel includes the description of the LC-Map legend (1) and the functionality to download pdf documents describing the products: this actual product user guide, summary user guides for the CCI-LC Maps and seasonality products and the CCI-LC Maps legend (2).

The "+ O -" button (3) can be used to adapt the zoom, such as the mouse wheel and to set the visualization extent to global. By default, the base layer displayed in the map environment corresponds to the CCI-LC map of year 2015 but it can be changed by selecting one of the products available in (4): a 10-year global MERIS surface reflectance product composite, the annual CCI-LC maps from 1992 to 2015 and the water body product.

The base layer is interactive (5). A left click, anywhere on the layer, highlights the LC-Map label of the selected pixel in the legend description of the left panel. A right click activates the display of the CCI LS NDVI seasonality profiles reference behaviour.

Finally, the download data button (6) redirects the user to a new web page where the products are available for download:

- The CCI-LC maps and their corresponding quality flags (see Section 3.1.3);
- The SAR WB layer from the WB product v3.0 (see Table 4-2) and v4.0 (see Table 5-2);
- The NDVI and water seasonality products can be extracted according to LAT/LONG coordinates or simply downloaded;
- The user tool.

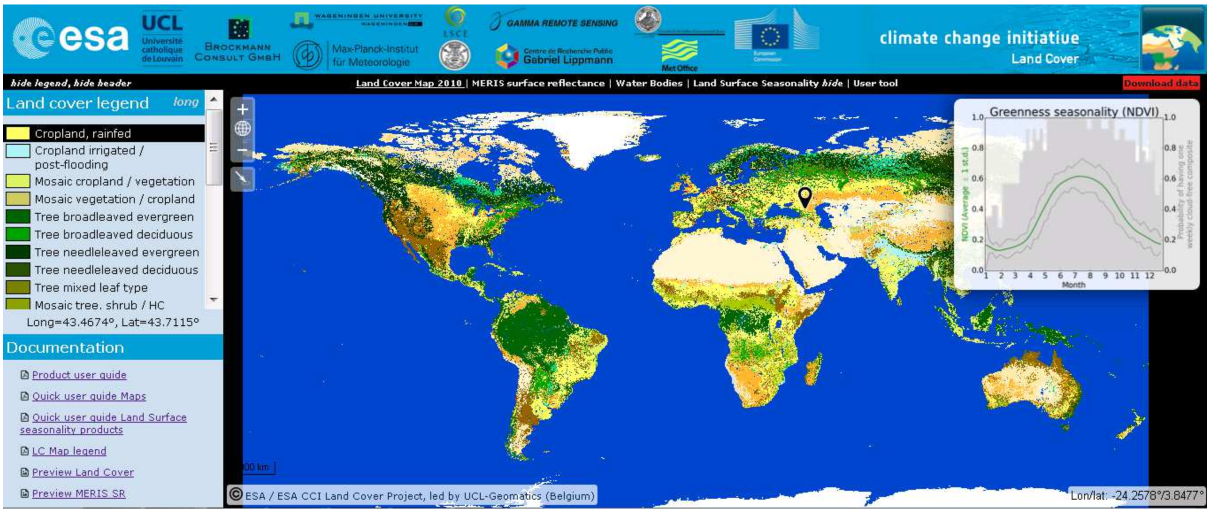


Figure 7-8: Main page of the CCI-LC products visualization tool, with the following functionalities: top-left) LC-Maps legend description; bottom-left) download of documents describing the CCI-LC products; top-left) tools box to control the zooms (+ and -), to set the view to the global extent (O) and to reach particular coordinates; top) products available for visualization; centre) visualization panel. A right click on the map activates the apparition of the LS seasonality profiles (NDVI) and highlights the LC-Map label on the left panel; top right) redirection to data download web page. Please note that a right click also shows additional profiles of the dynamics of land cover regarding the snow and burned areas occurrence.

8 DATA ACCESS AND POLICY

The CCI-LC products are made available through the viewer presented in Section 7.4:

CCI-LC visualization interface (http://maps.elie.ucl.ac.be/CCI/viewer/index.html)

For the time being, the data delivered in the CCI-LC database are the following ones:

- MERIS FR and RR time series version 1.0;
- AVHRR time series version 1.0;
- Annual LC maps from 1992 to 2015 (v2);
  - Legend (csv)
  - Symbology for ENVI (.dsr), for ArcGis (.lyr) and for QGis (.qml)
- NDVI seasonality products v2.0;
- WB product v3.0 (300 m) and v4.0 (150 m);
- The User Tool v3.12.

This CCI-LC database has been processed by the CCI-LC consortium led by UCL-Geomatics (Belgium). They are made available to the public by ESA and the consortium. You may use one or several CCI-LC products land cover map for educational and/or scientific purposes, without any fee on the condition that you credit the ESA Climate Change Initiative and in particular its Land Cover project as the source of the CCI-LC database:

Copyright notice: © ESA Climate Change Initiative - Land Cover project 2017

Should you write any scientific publication on the results of research activities that use one or several CCI-LC products as input, you shall acknowledge the ESA CCI Land Cover project in the text of the publication and provide the project with an electronic copy of the publication (contact@esa-landcover-cci.org).

If you wish to use one or several CCI-LC products in advertising or in any commercial promotion, you shall acknowledge the ESA CCI Land Cover project and you must submit the layout to the project for approval beforehand (contact@esa-landcover-cci.org).

9 APPENDIX 1 – CCI-LC LEGEND

9.1 Hierarchical global and regional legends

LABEL		VALUE		COLOR
GLOBAL	REGIONAL	GLOBAL	REGIONAL	
No Data		0		
Cropland, rainfed		10		
	Cropland, rainfed, herbaceous cover		11	
	Cropland, rainfed, tree or shrub cover		12	
Cropland, irrigated or post-flooding		20		
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)		30		
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)		40		
Tree cover, broadleaved, evergreen, closed to open (>15%)		50		
Tree cover, broadleaved, deciduous, closed to open (>15%)		60		
	Tree cover, broadleaved, deciduous, closed (>40%)		61	
	Tree cover, broadleaved, deciduous, open (15-40%)		62	
Tree cover, needleleaved, evergreen, closed to open (>15%)		70		
	Tree cover, needleleaved, evergreen, closed (>40%)		71	
	Tree cover, needleleaved, evergreen, open (15-40%)		72	
Tree cover, needleleaved, deciduous, closed to open (>15%)		80		
	Tree cover, needleleaved, deciduous, closed (>40%)		81	
	Tree cover, needleleaved, deciduous, open (15-40%)		82	
Tree cover, mixed leaf type (broadleaved and needleleaved)		90		
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)		100		
Mosaic herbaceous cover		110		

(>50%) / tree and shrub (<50%)				
Shrubland		120		
	Evergreen shrubland		121	
	Deciduous shrubland		122	
Grassland		130		
Lichens and mosses		140		
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)		150		
	Sparse tree (<15%)		151	
	Sparse shrub (<15%)		152	
	Sparse herbaceous cover (<15%)		153	
Tree cover, flooded, fresh or brakish water		160		
Tree cover, flooded, saline water		170		
Shrub or herbaceous cover, flooded, fresh/saline/brakish water		180		
Urban areas		190		
Bare areas		200		
	Consolidated bare areas	201		
	Unconsolidated bare areas	202		
Water bodies		210		
Permanent snow and ice		220		

9.2 LCCS coding of the CCI-LC legend

VALUE	LCCS ENTRY	LCCS LABEL	LCCCODE	LCCLEVEL
10	A11 Cultivated Terrestrial Areas and Managed Lands	Rainfed shrub crops // Rainfed tree crops // Rainfed herbaceous crops	11494 // 11490 // 11498	A2XXXXXXD1 // A1XXXXXXD1 // A3XXXXXXD1
11		Rainfed herbaceous crops	11498	A3XXXXXXD1
12		Rainfed shrub crops // Rainfed tree crops	11490 // 11494	A1XXXXXXD1 // A2XXXXXXD1
20		Irrigated tree crops // Irrigated shrub crops // Irrigated herbaceous crops // Post- flooding cultivation of herbaceous crops	11491 // 11495 // 11500 // 11499	A1XXXXXXD3 // A2XXXXXXD3 // A3XXXXXXD3 // A3XXXXXXD2
30		Cultivated and managed terrestrial areas / Natural and semi-natural primarily terrestrial vegetation	0003 / 0004	A11 / A12
40		Natural and semi-natural primarily terrestrial vegetation / Cultivated and managed terrestrial areas	0004 / 0003	A12 / A11

50	A12 Natural and Semi-natural Terrestrial Vegetation – Woody / Trees	Broadleaved evergreen closed to open trees // Broadleaved semi-deciduous closed to open trees	21496 // 21497-15048	A3A20B2XXD1E1 // A3A20B2XXD1E2-E4
60		Broadleaved deciduous closed to open trees	21497	A3A20B2XXD1E2
61		Broadleaved deciduous closed (100-40%) trees	21497-121340	A3A20B2XXD1E2-A21
62		Broadleaved deciduous open (40-(20-10)%) trees	20132-3012	A3A11B2XXD1E2-A13
70		Needleleaved evergreen closed to open trees	21499	A3A20B2XXD2E1
71		Needleleaved evergreen closed (100-40%) trees	21499-121340	A3A20B2XXD2E1-A21
72		Needleleaved evergreen open (40-(20-10)%) trees	20134-3012	A3A11B2XXD2E1-A13
80		Needleleaved deciduous closed to open trees	21500	A3A20B2XXD2E2
81		Needleleaved deciduous closed (100-40%) trees	21500-121340	A3A20B2XXD2E2-A21
82		Needleleaved deciduous open (40-(20-10)%) trees	20135-3012	A3A11B2XXD2E2-A13
90		Broadleaved closed to open trees / Needleleaved closed to open trees	21495 / 21498	A3A20B2XXD1 / A3A20B2XXD2
100	A12 Natural and Semi-natural Terrestrial Vegetation	Closed to open trees / Closed to open shrubland (thicket) // Herbaceous closed to open vegetation	21445 // 21449 / 21453	A3A20 // A4A20 / A2A20
110		Herbaceous closed to open vegetation // Closed to open trees / Closed to open shrubland (thicket)	21453 / 21445 // 21449	A2A20 / A3A20 // A4A20
120	A12 Natural and Semi-natural Terrestrial Vegetation – Shrubs	Broadleaved closed to open shrubland (thicket)	21449	A4A20
121		Broadleaved Evergreen Closed to Open Thicket // Needleleaved Evergreen Closed to Open Thicket	21517 // 21520	A4A20B3XXD1E1 // A4A20B3XXD2E1
122		Broadleaved Deciduous Closed to Open Thicket // Needleleaved Deciduous Closed to Open Thicket	21518 // 21521	A4A20B3XXD1E2 // A4A20B3XXD2E2
130	A12 Natural and Semi-natural Terrestrial Vegetation – Herbaceous	Herbaceous closed to very open vegetation	21453	A2A20
140		Closed to open lichens/mosses	21465	A7A20

150	A12 Natural and Semi-natural Terrestrial Vegetation	Sparse trees // Herbaceous sparse vegetation // Sparse shrubs	20052 // 20055 // 20058	A3A14 // A4A14 // A2A14
151		Sparse Trees	20052	A3A14
152		Sparse Shrubs	20055	A4A14
153		Herbaceous Sparse Vegetation	20058	A2A14
160	A24 Natural and Seminatural Aquatic Vegetation	Closed to open (100-40%) broadleaved trees on temporarily flooded land, water quality: fresh water // Closed to open (100-40%) broadleaved trees on permanently flooded land, water quality: fresh water	41638-R1 // 41724-R1	A3A20B2C1D1-R1 // A3A20B2C2D1-R1
170		Closed to open (100-40%) broadleaved trees on permanently flooded land (with daily variations), water quality: saline water // Closed to open (100-40%) broadleaved trees on permanently flooded land (with daily variations), water quality: brackish water // Closed to open (100-40%) semi-deciduous shrubland on permanently flooded land (with daily variations), water quality: saline water // Closed to open (100-40%) semi-deciduous shrubland on permanently flooded land (with daily variations), water quality: brackish water	41638-4891-R2 // 41638-4891-R3	A3A20B2C1D1-C5-R2 // A3A20B2C1D1-C5-R3
180		Closed to open shrubs on permanently flooded land // Closed to open herbaceous vegetation on permanently flooded land // Closed to open shrubs on temporarily flooded land // Closed to open herbaceous vegetation on temporarily flooded land // Closed to open shrubs on waterlogged soil // Closed to open herbaceous vegetation on waterlogged soil Water quality: fresh, brackish or saline water	41897 // 41983 // 42069 // 42347 // 42348 // 42349	A4A20B3C1 // A4A20B3C2 // A4A20B3C3 // A2A20B4C1 // A2A20B4C2 // A2A20B4C3
190	B15 Artificial Surfaces	Artificial surfaces and associated areas	0010	B15
200	B16 Bare Areas	Bare areas	0011	B16
201		Consolidated Material(s)	6001	A1
202		Unconsolidated Material(s)	6004	A2
210	B28 Inland Waterbodies, snow and ice	Natural water bodies // Artificial water bodies	7002 // 8002	A1B1 // A1B1
220		Artificial perennial snow // Artificial perennial ice // Perennial snow // Perennial ice	7005 // 7008 // 8006 // 8009	A2B1 // A3B1 // A2B1 // A3B1

10 APPENDIX 2 – NETCDF ATTRIBUTES

- **Surface reflectance product**

The CCI-LC global 7-day SR products description is based on the structure of the NetCDF files. The global attributes of the composites are described in Table 10-1.

Table 10-1: Global attributes of the global 7-day SR products delivered by the CCI-LC project, according to the structure of the NetCDF files.

Attribute Name	Format	Value	Description
title		ESACCI-LC-L3-SR-MERIS-300m-P7D-h40v13-20080326-v1.0	Product identifier (see “naming convention” see 6.2)
summary		This dataset contains a tile of a Level-3 7-day global surface reflectance composite from satellite observations placed onto a regular grid.	
project		Climate Change Initiative - European Space Agency	
references		http://www.esa-landcover-cci.org/	References that describe the data or methods used to produce it.
institution		Brockmann Consult GmbH	Where the data has been produced
contact		info@brockmann-consult.de	
source		e.g. MERIS FR L1b	Method of production of the original data
history		e.g. MERIS FR/RR: amorgos-4.0 lc-sdr-2.0 lc-sr-2.0	List of applications that have modified the original data, with time stamp, processor and parameters
comment			Miscellaneous information about the data or method used to produce it
Conventions		CF-1.6	Name of the conventions followed
standard_name_ vocabulary		NetCDF Climate and Forecast (CF) Standard Names version 18	

Attribute Name	Format	Value	Description
keywords		satellite,observation,reflectance	
keywords_ vocabulary		NASA Global Change Master Directory (GCMD) Science Keywords	
license		ESA CCI Data Policy: free and open access	
naming_authority		org.esa-cci	
cdm_data_type		grid	
platform		e.g "ENVISAT"	
sensor		e.g "MERIS"	
type		sr- 300m-7d	Product type
id		e.g "ESACCI-LC-L3-SR-MERIS-300m-P7D-h40v13-20080326-v1.0"	
tracking_id		e.g "2521cb70-348f-4676-9d7c-c0311a8118ac"	
tile	hXXvYY	e.g. " h71v27"	Example for the tile in row 27 and column 71 of the Plate Carrée grid (see Figure 6-1)
product_version	major.minor	e.g " 1.0"	Product revision (see here above)
date_created	yyyy-MM-dd'T'HH:mm:ss'Z'	e.g " 20130424T124732Z"	Creation time of product
creator_name		Brockmann Consult	
creator_url		http://www.brockmann-consult.de/	
creator_email		info@brockmann-consult.de	
time_coverage_start	yyyy-MM-dd'T'HH:mm:ss'Z'	e.g" 20080326T000000Z"	Start of aggregation period e.g. 2009-01-01T00:00:00Z
time_coverage_end	yyyy-MM-dd'T'HH:mm:ss'Z'	e.g" 20080402T000000Z"	End of aggregation period e.g. 2009-01-11T00:00:00Z
time_coverage_duration	0 ... 1382400	P7D	aggregation period
time_coverage_resolution		P7D	
geospatial_lat_min	-90.0 ... 90.0		South border of the bounding box
geospatial_lat_max	-90.0 ... 90.0		North border of the bounding box
geospatial_lon_min	-180.0 ... 180.0		West border of the bounding box
geospatial_lon_max	-180.0 ... 180.0		East border of the bounding box
spatial_resolution		300	Resolution of the product in meters
geospatial_lat_units		degrees_north	
geospatial_lat_		e.g " 0.002778 "	

Attribute Name	Format	Value	Description
resolution			
geospatial_lon_units		degrees_east	
geospatial_lon_ resolution		e.g " 0.002778 "	
TileSize		600:600	

The global 7-day SR NetCDF file for a tile has two dimensions that define the spatial raster, as described in Table 10-2.

Table 10-2: Information related to the spatial dimension of the global SR products delivered by the CCI-LC project

Dimension	Value	Description
lat	1800	Dimension that distinguishes different lines
lon	1800	Dimension that distinguishes different columns

The variables and variables' attributes of the global 7-day SR NetCDF file are presented in Table 10-3.

Table 10-3: Variables and variables' attributes of the global 7-day SR products delivered by the CCI-LC project, according to the structure of the NetCDF files.

Variable	Attribute	Format	Value	Description
crs		int	0	Coordinate reference system attribute container
	wkt		GEOGCS["WGS84(DD)" DATUM["WGS84", SPHEROID["WGS84", 6378137.0, 298.257223563]], PRIMEM["Greenwich", 0.0], UNIT["degree", 0.017453292519943295], AXIS["Geodetic longitude", EAST], AXIS["Geodetic latitude", NORTH]]	
	i2m		0.002777777777777778,0.0,0.0,-0.002777777777777778,20.0,25.0	
lon		float (lon)	-180.0 .. 180.0	Longitude coordinate of pixel column
	standard_name		longitude	
	long_name		longitude coordinate	
	units		degrees east	
	valid_min		-180.0	

Variable	Attribute	Format	Value	Description
	valid_max		180.0	
lat		float (lat)	-90.0 .. 90.0	Latitude coordinate of pixel row
	standard_name		latitude	
	long_name		latitude coordinate	
	units		degrees north	
	valid_min		-90.0	
	valid_max		90.0	
sr_<n>_mean n = 1 .. 10, 12 .. 14 (MERIS) n=B0,B2, B3, MIR (PROBA-V) n=1,2 (AVHRR)		float (lat,lon)		Mean of SR values of channel <n>[5]
	long_name		normalised (averaged) surface reflectance of channel n	
	standard_name		surface_bidirec-tional_reflectance	
	wavelength_nm		MERIS: 412.5, 442.5, 490, 510, 560, 620, 665, 681.25, 708.75, 753.75, 778.75, 865, 885 nm PROBA-V: 463, 655, 845, 1600nm AVHRR: 630, 912.5 nm	Centre wavelength of channel
	valid_min		0	
	valid_max		1	
	_FillValue		NaN	
	ancillary_variab-les		sr_n_uncertainty current_pixel_state clear_land_count clear_water_count clear_snow_ice_count cloud_count cloud_shadow_count	
bt_<n>_mean n=3,4,5 (AVHRR)		float (lat,lon)		Mean of top-of-atmosphere brightness temperature values of channel <n>6
	long_name		top-of-atmosphere brightness temperature of channel n	

[5] valid for current pixel_state 1 or 3

[6] valid for current pixel_state 1 or 3

Variable	Attribute	Format	Value	Description
	standard_name		toa_brightness_temperature	
	wavelength_nm		AVHHR: 3740, 11000, 11000nm	Centre wavelength of channel
	valid_min		0	
	valid_max		400	
	_FillValue		NaN	
	ancillary_variab-les		current_pixel_state clear_land_count clear_water_count clear_snow_ice_count cloud_count cloud_shadow_count	
sr_<n>_uncertainity n = 1 .. 10, 12 .. 14 (MERIS) n=B0,B2, B3, MIR (PROBA-V) n=1,2 (AVHRR)		float (lat,lon)		uncertainity of normalized surface reflectance values of channel <n>[7]
	long_name		uncertainity of normalized surface reflectance values of channel n	
	standard_name		surface_bidirec-tional_reflectance standard_error	
	wavelength_nm		see above	Centre wavelength of channel
	valid_min		0.0	
	valid_max		0.5	
	_FillValue		NaN	
vegetation index_mean		float (lat,lon)		Mean of vegetation index, e.g. NDVI
	long_name		mean of vegetation index	
	standard_name		normalized_difference_ vegetation_index	
	valid_min		-1	
	valid_max		+1	
	_FillValue		NaN	
	ancillary_variab-les		current_pixel_state clear_land_count clear_water_count clear_snow_ice_count cloud_count cloud_shadow_count	

[7] The uncertainity values of the SR values are to less due to a calculation failure regarding the error propagation of the uncertainty of the SDR values.

Variable	Attribute	Format	Value	Description
clear_land_ count		short (lat,lon)		Number of contributing observations over clear sky land in aggregation period
	long_name		Number of contributing of observations over clear sky land	
	standard_name		surface_bidirectional_ reflectance number_of_observations	
	valid_min		0	
	valid_max		150	
	_FillValue		-1	
clear_water_ count		short (lat,lon)		Number of observations with water coverage in aggregation period
	long_name		number of clear_water observations	
	standard_name		surface_bidirectional_ reflectance number_of_observations	
	valid_min		0	
	valid_max		150	
	_FillValue		-1	
clear_snow_ ice_count		short (lat,lon)		Number of contributing observations with snow and ice coverage in aggregation period
	long_name		number of clear_snow_ice observations	
	standard_name		surface_bidirectional_ reflectance number_of_observations	
	valid_min		0	
	valid_max		150	
	_FillValue		-1	
cloud_count		short (lat,lon)		Number of observations with cloud coverage in aggregation period
	long_name		number of cloud observations	
	standard_name		surface_bidirectional_ reflectance number_of_observations	
	valid_min		0	

Variable	Attribute	Format	Value	Description
	valid_max		150	
	_FillValue		-1	
cloud_shadow_count		short (lat,lon)		Number of observations with cloud shadow coverage in aggregation period
	long_name		number of cloud_shadow observations	
	standard_name		surface_bidirectional_ reflectance number_of_observations	
	valid_min		0	
	valid_max		150	
	_FillValue		-1	
current_pixel_state		byte (lat,lon)		Status of surface associated with the surface reflectance in the aggregation period: "invalid" = 0 "clear_land " = 1 "clear_water" = 2 "clear_snow_ice" = 3 "cloud" = 4 "cloud_shadow"=5
	long_name		LC pixel type mask	
	standard_name		surface_bidirectional_ reflectance status_flag	
	flag_values		0 ... 5	
	flag_meanings		invalid clear_land clear_water clear_snow_ice cloud cloud_shadow	
	valid_min		0	
	valid_max		5	
	_FillValue		-1	

- **Land cover products**

The CCI-LC global land cover products description is based on the structure of the NetCDF files. The global attributes of the land cover maps are described in Table 10-4.

Table 10-4 : Global attributes of the global LC maps delivered by the CCI-LC project, according to the structure of the NetCDF files

Attribute Name	Format	Value	Description
title		ESACCI-LC-L4-LCCS-Map-300m-P1Y-2010-v1.0.nc/tif	Product identifier (see “naming convention”

Attribute Name	Format	Value	Description
			above)
summary		This dataset contains a global land cover map obtained from surface reflectance composites, placed onto a regular grid.	
project		Climate Change Initiative - European Space Agency	
references		http://www.esa-landcover-cci.org/	References that describe the data or methods used to produce it.
institution		UCL	Where the data has been produced
contact		Pierre.Defourny@uclouvain.be	
source		MERIS FR L1B, MERIS RR L1B,	Source of the original data
history		lc-mosaic-1.1 lc-compositing-1.0 lc-stratification-1.0 lc-classification-1.0 lc-labeling-1.0	List of applications that have modified the surface reflectance composites, with time stamp, processor and parameters
comment			Miscellaneous information about the data or method used to produce it
Conventions		CF-1.6	Name of the conventions followed
type		LCMap-300m	Product type
date_created	yyyy-MM-dd'T'HH:mm:ss'Z'	e.g " 20130424T124732Z"	Creation time of product
creator_name		UCL-Geomatics	
creator_url		http://www.uclouvain.be/elie.html	
creator_email		Pierre.Defourny@uclouvain.be	
epoch	YYYY	[YYYY] where the two "YYYY" are the year of the product	Year of the product,
geospatial_lat_min	-90.0 ... 90.0		South border of the bounding box
geospatial_lat_max	-90.0 ... 90.0		North border of the bounding box
geospatial_lon_min	-180.0 ... 180.0		West border of the bounding box
geospatial_lon_max	-180.0 ... 180.0		East border of the bounding box
geospatial_lat_min	-90.0 ... 90.0		South border of the bounding box
geospatial_lat_units		degrees_north	
geospatial_lat_		e.g " 0.002778 "	

Attribute Name	Format	Value	Description
resolution			
geospatial_lon_units		degrees_east	

The variables and variables' attributes of the global 7-day SR NetCDF file are presented in Table 10-5.

Table 10-5: Variables and variables' attributes of the global LC maps delivered by the CCI-LC project, according to the structure of the NetCDF files

Variable	Attribute	Format	Value	Description
crs		int		Coordinate reference system attribute container
	grid_mapping_name		Plate Carrée	
	semi_major_axis		6378137.0	
	inverse_flattening		298.257223563	
	false_easting		0.0	
	false_northing		0.0	
	longitude_of_central_meridian		0.0	
	scale_factor_at_central_meridian		1.0	
time		double(time)		Start time of the multi-year period
	standard_name		time	
	long_name		multi-year period	
	units		year	
lon		double (lon)	-180.0 .. 180.0	Longitude coordinate of image column
	standard_name		longitude	
	long_name		WGS84 longitude coordinate	
	units		degrees east	
	valid_min		-180.0	
	valid_max		180.0	
lat		double (lat)	-90.0 .. 90.0	Latitude coordinate of image row
	standard_name		latitude	
	long_name		WGS84 latitude coordinate	

Variable	Attribute	Format	Value	Description
	units		degrees north	
	valid_min		-90.0	
	valid_max		90.0	
lc_classif_lcss		byte (lat,lon)		LC classification in LCCS
	standard_name		land cover	
	long_name		LC class defined in LCCS	
	vocabulary		UN-LCCS 2005	
	valid_min		1	
	valid_max		240	
	_FillValue		0b	
lc_quality_flag_1		byte (lat,lon)		LC map quality flag 1: pixel processed or not
	standard_name		land_cover status_flag	
	long_name		LC map processed area flag	
	valid_min		0	
	valid_max		1	
	_FillValue		-1b	
lc_quality_flag_2		byte (lat,lon)		LC map quality flag 2: pixel status
	standard_name		land_cover status_flag	
	long_name		LC map area type mask	
	valid_min		0	
	valid_max		6	
	_FillValue		-1b	
lc_quality_flag_3		short(lat,long)		LC map quality flag 3: number of valid observations
	standard_name		land_cover number_of_observations	
	long_name		number of valid observations	
	valid_min		0	
	valid_max		32767	
	_FillValue		-1s	
	_FillValue		-1b	
	scale_factor		0.01f	

Variable	Attribute	Format	Value	Description
lc_quality_flag_4		byte(lat,long)		LC map quality flag 4: LC map confidence level
	standard_name		land_cover confidence_level	
	long_name		LC map confidence level based on product validation	
	valid_min		0	
	valid_max		100	
	_FillValue		-1b	
lc_quality_flag_5		byte(lat,long)		LC map quality flag 5: change confidence level
	standard_name		change confidence_level	
	long_name		Change confidence level based on change detection module	
	valid_min		0	
	valid_max		100	
	_FillValue		-1b	

11 APPENDIX 3 – METADATA

- **NDVI seasonality product**

The following attributes are included in all 4 series of products (AggOcc, Std, NYearObs and Status). Fields named “Files”, “Data set”, “Description”, “Scaling factor” and “Valid values range” vary according to the layer of interest. It follows the CCI guidelines [RD.17].

The following metadata concerning the NDVI status layer is proposed as an example.

```
Driver: GTiff/GeoTIFF

Files: ESACCI-LC-L4-NDVI-Cond-Status-1000m-P14Y7D-1999-2012-19990709-v2.0.tif

Size is 40320, 20160

Coordinate System is:

GEOGCS["WGS 84",

    DATUM["WGS_1984",

        SPHEROID["WGS 84",6378137,298.257223563,

            AUTHORITY["EPSG","7030"]],

        AUTHORITY["EPSG","6326"]],

    PRIMEM["Greenwich",0],

    UNIT["degree",0.0174532925199433],

    AUTHORITY["EPSG","4326"]]

Origin = (-180.000000000000000,90.000000000000000)

Pixel Size = (0.008928571400000,-0.008928571400000)

Metadata:

   Compositing period =7 days

   Copyright =ESA / ESA CCI Land Cover Project, led by UCL-Geomatics (Belgium)

   Data Set =Normalized Vegetation Index (NDVI) - Status

   Description =Status of the pixel; 1 : land , 2 : water , 3 : snow, 4 : cloud , 5
: filled ice

   NaN value =0
```

```
   Scaling Factor       =none
   Sensor =SPOT-VEGETATION
   Temporal coverage =1999 - 2012
   Valid values range =1 to 5
  AREA_OR_POINT=Area
Image Structure Metadata:
  COMPRESSION=LZW
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (-180.0000000,  90.0000000) (180d 0' 0.00"W, 90d 0' 0.00"N)
Lower Left  (-180.0000000, -89.9999994) (180d 0' 0.00"W, 90d 0' 0.00"S)
Upper Right ( 179.9999988,  90.0000000) (180d 0' 0.00"E, 90d 0' 0.00"N)
Lower Right ( 179.9999988, -89.9999994) (180d 0' 0.00"E, 90d 0' 0.00"S)
Center      (  -0.0000006,   0.0000003) (  0d 0' 0.00"W,  0d 0' 0.00"N)
Band 1 Block=256x256 Type=Int16, ColorInterp=Gray
```

- **Open water body product**

The following attributes are included in the layers of the product. It follows the CCI guidelines [RD.17].

The metadata of the WB-Map layer v3.0 is proposed as an example.

```
Driver: GTiff/GeoTIFF
Size is 129600, 64800
Coordinate System is:
GEOGCS["WGS 84",
    DATUM["WGS_1984",
        SPHEROID["WGS 84",6378137,298.257223563,
            AUTHORITY["EPSG","7030"]],
        AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0],
```

```
    UNIT["degree",0.0174532925199433],
    AUTHORITY["EPSG","4326"]]
Origin = (-180.000000000000000,90.000000000000000)
Pixel Size = (0.002777777700000,-0.002777777700000)
Metadata:
  AREA_OR_POINT=Area
  Copyright =ESA / ESA CCI Land Cover Project, led by UCL-Geomatics (Belgium)
  Dataset =Global Water Body Data Set from ENVISAT ASAR Data
  Description =Water classification; 1: Other , 2: Water
  Scaling Factor =none
Image Structure Metadata:
  COMPRESSION=LZW
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (-180.0000000,  90.0000000) (180d 0' 0.00"W, 90d 0' 0.00"N)
Lower Left  (-180.0000000, -89.9999950) (180d 0' 0.00"W, 89d59'59.98"S)
Upper Right ( 179.9999899,  90.0000000) (179d59'59.96"E, 90d 0' 0.00"N)
Lower Right ( 179.9999899, -89.9999950) (179d59'59.96"E, 89d59'59.98"S)
Center      (  -0.0000050,   0.0000025) (  0d 0' 0.02"W,  0d 0' 0.01"N)
Band 1 Block=256x256 Type=Byte, ColorInterp=Gray
```

12 APPENDIX 4 – INSTRUCTION MANUAL OF THE AGGREGATION TOOL

CCI-LC User Tools
~~~~~~~~~~~~~~~~~~
Version: 3.11
Release: 2017/01/11

Summary
~~~~~~~
This set of tools (conversion tool, aggregation tool, subset tool) prepares data for model computation.

General Note
~~~~~~~~~~~~~
The target files are always written in NetCDF-4 (enhanced model) file format.
If the NetCDF-4 Classic file format is needed the standard nccopy tool can be used for conversion.
When the REGULAR_GAUSSIAN_GRID is chosen as target grid and a regional subset which crosses the prime meridian is also defined the aggregation or the subsetting process will not work. This affects the predefined regions WESTERN_EUROPE_AND_MEDITERRANEAN and AFRICA.

Installation
~~~~~~~~~~~~~
As a prerequisite the CCI-LC User Tools require an installed Java SE 64Bit JRE version 7 or higher on the system. It can be obtained from the web page at http://www.oracle.com/technetwork/java/javase/downloads/index.html.

1) Unzip the zip-file in a directory of your choice.
2) Inside the unzipped directory you can find a folder which is named 'bin'.
   Inside you can find the windows and unix start scripts for the CCI-LC tools.

Execution
~~~~~~~~~~
All provided scripts are available in windows (*.bat) and unix (*.sh) versions.
The scripts need to be invoked from the command line. Navigate to the bin directory of the folder where you have unpacked the tools to. Write the command as described as follows.

Conversion Tool Usage (converts Tiff to NetCDF-4 files)
~~~~~~~~~~~~~~~~~~~~~~~~~~
convert(.sh/.bat) -PtargetDir=<dirPath> <pathToMapTifFile|pathToConditionTifFile>

In case of a CCI-LC Map file the corresponding flag files must be in the same directory as the Map file. They are automatically detected and added to the output NetCDF-4 file.
For an alternative map the corresponding QF1 and QF2 files, as well as the qualityflag3 and qualityflag4 files of the original Map must be in the same directory.
If a condition product shall be converted the AggMean tif file must be provided as source. All the associated variables (AggMean, Std, Status and NYearObs) are considered and integrated into the output NetCDF-4 file if they reside in the same folder as the source tif file.

Parameter Description:
-PtargetDir=<dirPath>
Specifies the directory where the target will be written. If this parameter is omitted the directory of the source file is used. The target is written as NetCDF-4 file.
If already a file with the same name/path exists, it will be overwritten.
(see "Output File Naming Convention")

Aggregation Tool Usage
~~~~~~~~~~~~~~~~~~~~~~

CCI-LC Condition Products
~~~~~~~~~~~~~~~~~~~~~~~~~

aggregate-cond(.sh/.bat) -PgridName=<name> -PnumRows=<integer>
-PtargetDir=<dirPath> <sourceFilePath>

Parameter Description:
-PgridName=<name>
Specifies the target grid of the resulting product. This is a mandatory parameter.
Valid parameters are: GEOGRAPHIC_LAT_LON and REGULAR_GAUSSIAN_GRID.
-PnumRows=<integer>
Specifies the number of rows for the specified grid.
Default ist 2160 rows. A grid with the default number of rows leads to a resolution of ~9.8km/pixel in the target product.
For a REGULAR_GAUSSIAN_GRID only the following values are valid:
32, 48, 80, 128, 160, 200, 256, 320, 400, 512, 640
-PpredefinedRegion=<regionName>
Specifies one of the available predefined regions. This is an optional value.
If a predefined region is given it has precedence over the user defined region (north, east, ...)
Valid Values are: NORTH_AMERICA, CENTRAL_AMERICA, SOUTH_AMERICA,
WESTERN_EUROPE_AND_MEDITERRANEAN, ASIA, AFRICA,
SOUTH_EAST_ASIA, AUSTRALIA_AND_NEW_ZEALAND, GREENLAND
-Pnorth=<degree>
Specifies north bound of the regional subset. This is an optional value
-Peast=<degree>
Specifies east bound of the regional subset. This is an optional value
-Psouth=<degree>
Specifies south bound of the regional subset. This is an optional value
-Pwest=<degree>
Specifies west bound of the regional subset. This is an optional value
-PtargetDir=<dirPath>
Specifies the directory where the target will be written. If this parameter is omitted the directory of the source file is used. It is written as NetCDF-4 file.
If already a file with the same name/path exists, it will be overwritten.
(see "Output File Naming Convention")
<sourceFilePath>
Is the path to the source NetCDF-4 file.

CCI-LC WB Products
~~~~~~~~~~~~~~~~~~~~~~~~~

aggregate-wb(.sh/.bat) -PoutputWbClasses=<boolean> -PnumMajorityClasses=<integer>
-PgridName=<name> -PnumRows=<integer> -PtargetDir=<dirPath> <sourceFilePath>

Parameter Description:
-PoutputWbClasses=<boolean>
~~~~~~~~~~~~~~~~~~~~~~~~~

Whether or not to add the WB class areas to the output. The default is true
-PnumMajorityClasses=<integer>
The number of majority classes generated and added to the output. The default is 2.
-PgridName=<name>
Specifies the target grid of the resulting product. This is a mandatory parameter.
Valid parameters are: GEOGRAPHIC_LAT_LON and REGULAR_GAUSSIAN_GRID.
-PnumRows=<integer>
Specifies the number of rows for the specified grid.
Default ist 2160 rows. A grid with the default number of rows leads to a resolution of ~9.8km/pixel in the target product.
For a REGULAR_GAUSSIAN_GRID only the following values are valid:
32, 48, 80, 128, 160, 200, 256, 320, 400, 512, 640
-PpredefinedRegion=<regionName>
Specifies one of the available predefined regions. This is an optional value.
If a predefined region is given it has precedence over the user defined region (north, east, ...)
Valid Values are: NORTH_AMERICA, CENTRAL_AMERICA, SOUTH_AMERICA, WESTERN_EUROPE_AND_MEDITERRANEAN, ASIA, AFRICA, SOUTH_EAST_ASIA, AUSTRALIA_AND_NEW_ZEALAND, GREENLAND
-Pnorth=<degree>
Specifies north bound of the regional subset. This is an optional value
-Peast=<degree>
Specifies east bound of the regional subset. This is an optional value
-Psouth=<degree>
Specifies south bound of the regional subset. This is an optional value
-Pwest=<degree>
Specifies west bound of the regional subset. This is an optional value
-PtargetDir=<dirPath>
Specifies the directory where the target will be written. If this parameter is omitted the directory of the source file is used. It is written as NetCDF-4 file.
If already a file with the same name/path exists, it will be overwritten.
(see "Output File Naming Convention")
<sourceFilePath>
Is the path to the source NetCDF-4 file.

CCI-LC Map Products
~~~~~~~~~~~~~~~~~~~~

```
aggregate-map(.sh/.bat) -PgridName=<name> -PnumRows=<integer>
            -PoutputLCCSClasses=<boolean> -PnumMajorityClasses=<integer>
            -PoutputPFTClasses=<boolean> -PuserPFTConversionTable=<filePath>
            -PadditionalUserMap=<filePath> -PoutputUserMapClasses=<boolean>
            -PadditionalUserMapPFTConversionTable=<filePath>
            -PoutputAccuracy=<boolean>
            -PtargetDir=<dirPath> <sourceFilePath>
```

Parameter Description:
For a description of the common aggregation parameters please have a look into the above section for the CCI-LC Condition Products. In addition for the aggregation of the CCI-LC Map Products the following parameters exist:

-PoutputLCCSClasses=<boolean>
Specifies whether the LCCS classes shall be added to the output. This parameter can be omitted. The default is true.
-PnumMajorityClasses=<integer>
Specifies the number of majority classes in the output. This parameter can be omitted, in this case the default (5) is used. A value of 1 will produce an output with
~~~~~~~~~~~~~~~~~~~~

just the majority class.
-PoutputPFTClasses=<boolean>
Specifies if a conversion to PFT classes shall be performed and the result added to the output. This parameter can be omitted. The default is true.
-PuserPFTConversionTable=<filePath>
Specifies the path to a user defined PFT conversion table. If not given the default CCI-LC conversion table will be used. For a description of the file format see further down.
-PadditionalUserMap=<filePath>
A map containing additional classes which can be used to refine the conversion from LCCS to PFT classes.
-PoutputUserMapClasses=<boolean>
Whether or not to add the classes of the user map to the output.
This option is only applicable if the additional user map is given too.
-PadditionalUserMapPFTConversionTable=<filePath>
The conversion table from LCCS to PFTs considering the additional user map.
This option is only applicable if the additional user map is given too.
-PoutputAccuracy=<boolean>
Specifies the computation of the accuracy shall be performed and the result added to the output. This parameter can be omitted. The default is true.
<sourceFilePath>
Is the path to the source NetCDF-4 file.

A real example might look like the following:

```
aggregate-map(.sh/.bat) -PgridName=REGULAR_GAUSSIAN_GRID -PnumRows=320
            -PoutputLCCSClasses=false -PnumMajorityClasses=3
            -PpredefinedRegion=AUSTRALIA_AND_NEW_ZEALAND
            -PtargetDir="/data/CCI-LC/output/"      "/data/CCI-LC/ESACCI-LC-L4-LCCS-Map-300m-P5Y-
2010-v2.nc"
```

The PFT (Plant Functional Type) conversion table
~~~~~~

The table, also known as Cross Walking Table, describes the conversion of the LCCS classes to PFTs. The file can start with an optional comment. If the comment is used the first line must start with '#' in order to indicate the comment. Multiple lines are not supported. The comment ('pft_table_comment') is included as an attribute into the NetCDF output file.
The actual PFT table starts with a table header. Each column of the header defines one PFT except the first. The first column is for the LCCS class indices.
The subsequent data rows, one for each LCCS class, define the conversion from corresponding class to the PFTs. Each cell specifies the percentage of the PFT, floating point values can be used. Zero percentage can be omitted. Columns are separated with the pipe ('|') symbol and the column header names are used as band names.

Example:

```
# An optional comment describing the conversion table
LCCS Class|Tree Broadleaf Evergreen|...|Managed Grass|Bare soil|Water|Snow/Ice|No data
0||...|||||100
10||...|100||||
11||...|100||||
12||...|50||||
20||...|100||||
30|5|...|60||||
40|5|...|25|40|||
...
220||...||||100|
```
~~~~~~

```
Subset Tool Usage
~~~~~~~~~~~~~~~~~~
   subset(.sh/.bat) -PpredefinedRegion=<regionName> -PtargetDir=<dirPath> <sourceFilePath>
        or
   subset(.sh/.bat) -Pnorth=<degree> -Peast=<degree> -Psouth=<degree>
                    -Pwest=<degree> -PtargetDir=<dirPath> <sourceFilePath>

   -PpredefinedRegion=<regionName>
      Specifies one of the available predefined regions.
      Valid Values are: NORTH_AMERICA, CENTRAL_AMERICA, SOUTH_AMERICA,
                        WESTERN_EUROPE_AND_MEDITERRANEAN, ASIA, AFRICA,
                        SOUTH_EAST_ASIA, AUSTRALIA_AND_NEW_ZEALAND, GREENLAND
   -Pnorth=<degree>
      Specifies north bound of the regional subset.
   -Peast=<degree>
      Specifies east bound of the regional subset. If the grid of the source product is
REGULAR_GAUSSIAN_GRID
      coordinates the values must be between 0 and 360.
   -Psouth=<degree>
      Specifies south bound of the regional subset.
   -Pwest=<degree>
      Specifies west bound of the regional subset. If the grid of the source product is
REGULAR_GAUSSIAN_GRID
      coordinates the values must be between 0 and 360.
   -PtargetDir=<dirPath>
      Specifies the directory where the target will be written. It is written as NetCDF-4 file.
      If already a file with the same name/path exists, it will be overwritten.
      (see "Output File Naming Convention" )
   <sourceFilePath>
      The source file to create a regional subset from.

   In order to create a regional subset of a map, condition or aggregated product the subset
   tool can be used. As parameter either one of the predefined regions can be selected or the
   outer bounds of the desired region can be specified. The target file is written into
   the directory of the source file.


Classes Remapping Tool Usage
~~~~~~~~~~~~~~~~~~~~~~~~~~~~

   remap(.sh/.bat) -PuserPFTConversionTable=<filePath>
                -PadditionalUserMap=<filePath>
                -PadditionalUserMapPFTConversionTable=<filePath>
                <sourceFilePath>

      -PuserPFTConversionTable=<filePath>
         Specifies the path to a user defined PFT conversion table. If not given the default
         CCI-LC conversion table will be used. For a description of the file format see further down.
      -PadditionalUserMap=<filePath>
         A map containing additional classes which can be used to refine the conversion from
         LCCS to PFT classes.
      -PadditionalUserMapPFTConversionTable=<filePath>
         The conversion table from LCCS to PFTs considering the additional user map.
```

This option is only applicable if the additional user map is given too.
<sourceFilePath>
The source file to create a regional subset from.

This tool splits up the information found in the band "lccs_class" into the PFTs given via look-up table files.
The basis for the look-up table is the csv file provided as userPFTConversionTable.
If additionally the additionalUserMapPFTConversionTable csv file is specified, it is used to improve the conversion to PFTs by using the also the additionalUserMap.

For an example of the userPFTConversionTable please have a look at the section 'Aggregation Tool Usage'.
The additionalUserMapPFTConversionTable has a similar structure.

```
# Koeppen-Geiger Map
LCCS_Class|Köppen_Geiger_Class|PFT_1|PFT_2|_PFT3|...|No_data
10|11||||||||14|86||||
10|12||||||||11|89||||
10|13||||||||10|90||||
10|14||||||||4|96||||
10|21||||||||6|94||||
10|22||||||||20|80||||
10|26||||||||13|87||||
20|11||||||||15|85||||
20|12||||||||21|79||||
20|26||||||||2|98||||
```

The first column is again the LCCS class, the second the class in the additional user map.
If one LCCS class, user class combination is missing the algorithm falls back to the userPFTConversionTable, if given or to the defaults of the CCI-LC conversion table

Output File Naming Convention
''

Conversion Tool Output:
~~~~~~~~~~~~~~~~~~~~~~~~

Map Product: ESACCI-LC-L4-LCCS-Map-{sRes}m-P{tRes}Y-{epoch}-v{versNr}.nc

Condition Product: ESACCI-LC-L4-{condition}-Cond-{sRes}m-P{tRes}D-{startY}{MonthDay}-v{versNr}.nc

Split Points:
~~~~~~~~~~~~~~

```
Map Product:     ESACCI-LC-L4-LCCS-Map-{sRes}m-P{tRes}Y-{epoch}-v{versNr}.nc
                                                 ^
                                                 |--- Split Position

Condition Pr.: ESACCI-LC-L4-{condition}-Cond-{sRes}m-P{tRes}D-{startY}{MonthDay}-v{versNr}.nc
                                                 ^
                                                 |--- Split Position
```

Examples Map Result:
~~~~~~~~~~~~~~~~~~~~~

Aggregation:
~~~~~~~~~~~~~~~~~~~~~

Input: ESACCI-LC-L4-LCCS-Map-300m-P5Y-2006-v2.nc

Output: ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-2006-v2.nc

Subset:
Input: ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-2006-v2.nc

Output: ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-EUROPE-2006-v2.nc
Output: ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-ASIA-2006-v2.nc
Output: ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-USER_REGION-2006-v2.nc

Examples Condition Result:
~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Subset:
Input: ESACCI-LC-L4-NDVI-Cond-300m-P9Y7D-20010101-v2.nc

Output: ESACCI-LC-L4-NDVI-Cond-300m-P9Y7D-EUROPE-20010101-v2.nc
Output: ESACCI-LC-L4-NDVI-Cond-300m-P9Y7D-ASIA-20010101-v2.nc
Output: ESACCI-LC-L4-NDVI-Cond-300m-P9Y7D-USER_REGION-20010101-v2.nc
~~~~~~~~~~~~~~~~~~~~~~~~~~~~