Land Cover CCI

PRODUCT USER GUIDE

VERSION 1.1

DOCUMENT REF:	CCI-LC-PUGv3
DELIVERABLE REF:	D3.3
VERSION:	1.1
CREATION DATE:	2017-06-28
LAST MODIFIED:	2017-08-21

This page is intentionally blank.

Document Signature Table

	NAME	FUNCTION	COMPANY	SIGNATURE	DATE
PREPARED	Santoro M.		Gamma RS		
PREPARED	Kirches G.		BC		
PREPARED	Wevers J.		BC		
PREPARED	Boettcher M.		BC		
PREPARED	Brockmann C.		BC		
PREPARED	Lamarche C.		UCL		
VERIFIED	Defourny P.	Science leader	UCL		

Document Versions Record

VERSION	DATE	DESCRIPTION	APPROVED
1.0	2017-07-17	First version, based on Year 2 document (version 2.2)	
1.1	2017-08-21	Updated regarding ESA RIDs	

Document Change Record (to version 1.1)

RID	SECTION	COMMENTS
FR-01	Page 6 / Applicable Documents table	The correct link could not be found on the web. The link was removed.
FR-02	Page 8 / Reference Documents table	The Reference Documents list was updated to reflect the current content of the PUGv3
FR-03	Page 9 / Reference Documents table	
FR-04		
FR-05	Table 2-1	The coverage of S2 seasonal and 366-day SR composite at 20m spatial resolution has been corrected.
FR-06	Page 23 / Table 3-1	The RGB combinations have been updated
FR-07	Section 5.3	The spectral content of Sentinel 2 has been corrected.
FR-08	Figure 5-3	Typo corrected
FR-09	Figure 5-4	Typo corrected
FR-10	Section 5.2.1	The example file name of the 366-day surface reflectance composite for the year 2015/2016 located at the tile h47v15 has been corrected.
FR-11	Section 5.2.1	Coverage has been included - Africa
FR-12	Estimated size	Product type and estimated size has been corrected.

Document Diffusion List

ORGANIZATION	NAME	QUANTITY
ESA	O. Arino, F. Ramoino	

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
Envisat : Environmental Satellite
EO : Earth Observation
ERS : European Remote Sensing Satellite
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
GTOS : Global Terrestrial Observing System

IMM : Image Mode Medium

IPCC : Intergovernmental Panel on Climate Change

ISSI : International Space Science Institute

JRC : Joint Research Centre

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

RF : Random Forest

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

UTM : Universal Transverse Mercator

WB : Water Body

WBP : Water Body Product

WGS84 : World Geodetic System 84

WSM : Wide Swath Mode

REFERENCE DOCUMENTS

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	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
AD.12	CCI-LC ATBD Phase II v3. Land Cover Climate Change Initiative - Algorithm Specification Document - Part IV: WB classification	1.0	11.07.2017
AD.13	CCI-LC ATBD Phase II v3. Land Cover Climate Change Initiative - Algorithm Specification Document - Part III: LC classification	1.0	11.07.2017

Reference documents

ID	TITLE
RD.1	CCI-LC URD Phase I. Land Cover Climate Change Initiative - User Requirements Document. Issue 2.2. Date 23.02.2011.
RD.2	CCI-LC PSD Phase I. Land Cover Climate Change Initiative - Product Specification Document. Issue 1.11. Date 03.07.2014.

ID	TITLE
RD.3	CCI-LC PUG Phase I. Land Cover Climate Change Initiative - Product User Guide. Issue 2.4. Date 02.09.2014.
RD.4	Di Gregorio A., 2005, UN Land Cover Classification System (LCCS) – Classification concepts and user manual for Software version 2. Available at: http://www.fao.org/docrep/008/y7220e/y7220e00.htm. Date 1.06.2016
RD.5	Committee on Earth Observation Satellites, 2008, Working Group on Information Systems and Services - Interoperability Handbook, February 2008 Issue 1.1. Available at: http://www.eohandbook.com/
RD.6	Pesaresi M., Ehrlich D., Ferri S., Florczyk A.J., Freire S., Halkia S., Julea A.M., Kemper T., Soille P. and V. Syrris. Operating procedure for the production of the Global Human Settlement Layer from Landsat data of the epochs 1975, 1990, 2000, and 2014. Publications Office of the European Union, EUR 27741 EN, 2016. doi: 10.2788/253582.
RD.7	Global Urban Footprint, GUF; DLR 2016
RD.8	Pekel J-F., Cottam A., Gorelick N., Belward AS. High-resolution mapping of global surface water and its long-term changes. Nature. 540, 418–422 (15 December 2016). doi:10.1038/nature20584
RD.9	Bicheron, P., Defourny, P., Brockmann, C., Schouten, L., Vancutsem, C., Huc, M., Bontemps, S., Leroy, M., Achard, F., Herold, M., Ranera, F., Arino, O. GlobCover: products description and validation report, ESA GlobCover project. Available at: http://due.esrin.esa.int/page_globcover.php
RD.10	Bontemps, S., Defourny, P., Van Bogaert, E., Kalogirou, V. and Arino, O., GlobCover 2009 □ Products Description and Validation Report (2010). Available at: http://due.esrin.esa.int/page_globcover.php
RD.11	Committee on Earth Observation Satellites, 2008, Working Group on Information Systems and Services. Interoperability Handbook, February 2008 Issue 1.1. Available at: http://www.eohandbook.com/
RD.12	http://step.esa.int/main/toolboxes/snap/

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Scope

The Product User Guide (PUGv3) 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 year 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 year 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.

The 3rd year of project is dedicated to prototype products characterizing the land cover and the water bodies from Sentinels 2 and 1 acquisitions, respectively. This PUGv3 describes those products, delivered to ESA at the end of this 3rd 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 centres 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 5 describe the various products: the S2 prototype map of Africa at 20 m, the S1 map of open water bodies and the S2 surface surface reflectance time series;
- Section 6 presents the various tools that can be used to visualize and aggregate the products;
- Section 7 explains how to access the CCI-LC products and give their terms of use.

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*	*Errors of 5-10% either per class or*	*Higher stability than existing*	*Errors of 5-10% either per class or*

	datasets ✓	*as overall accuracy* ✗	*datasets* ✓	*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;
    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;

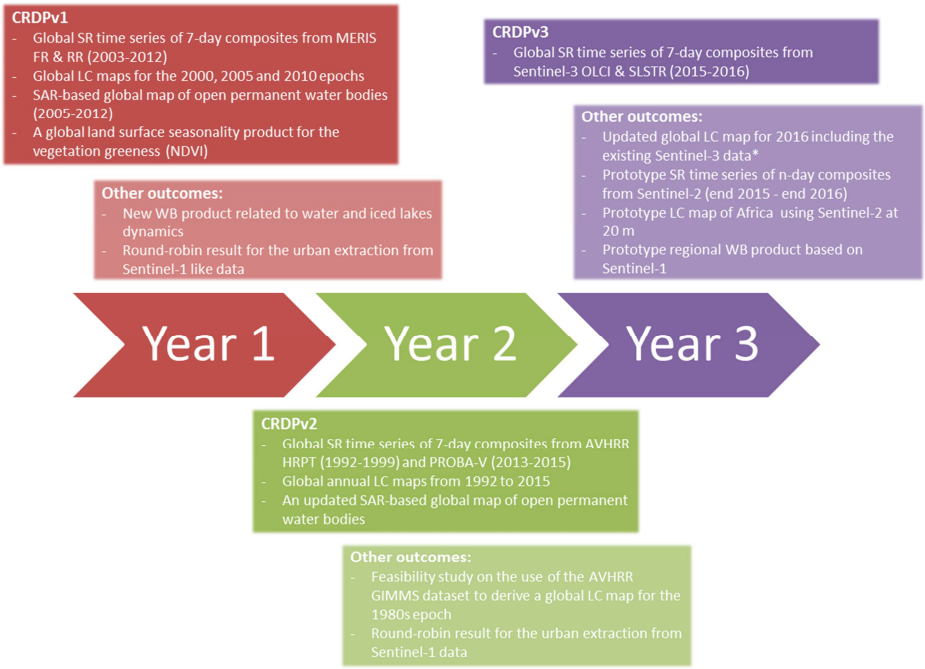
[1] A 7-day compositing period is foreseen to be consistent with the other sensors, but this has to be confirmed according to the data coverage
[2] According to the availability of Sentinel-3 data in terms of quantity and timing with respect to the overall project planning

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.



* 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 PUGv3 focuses on the products available in the CRPDv3. 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			
Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution	Africa	2015/ 2016	20m	bimonthly and 366-day	Sentinel 2	PlateCarée/ WGS 84	GeoTiff
Sentinel 2 Surface directional reflectance product at native spatial resolution	3 countries (Botswana, Zambia, and Zimbabwe)	2016	10 m	10-day	Sentinel 2	UTM/ WGS84	Archive (zip) of GeoTiff files
20m Sentinel 2 LC map	Africa	2015/ 2016	20 m	1-year	Sentinel 2	WGS 84	GeoTiff
Water body	Global	2000-2012	150 m	13-year	ASAR WSM	WGS 84	NetCDF & GeoTiff

3 S2 PROTOTYPE MAP OF AFRICA AT 20 M

3.1 Product description

For this third year, the CCI-LC project delivers a prototype map of Africa at 20 m based on 1 year of S2 observations from December 2015 to December 2016. 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 illustrates the S2 prototype map of Africa at continental scale in its current state.

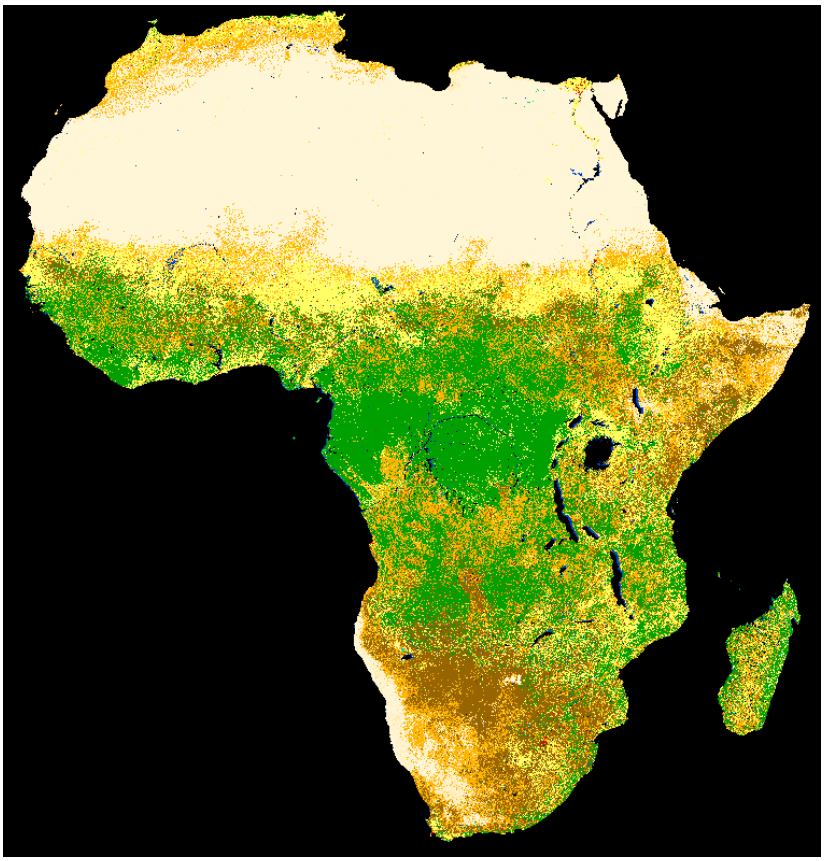


Figure 3-1: The Sentinel-2 prototype map of Africa at 20 m.

The following sections describe the legend of the S2 prototype map of Africa, an overview of the classification modules and finally, the format of the map.

At present state, the user tool, which allows users to aggregate LC maps to the spatial resolution, projection and format suitable for their models, has not been updated yet. Section 6 therefore describes the functionalities that such tool will have in the future.

3.1.1 Legend

The legend of the S2 prototype map of Africa was built after reviewing various existing typologies (e.g. LCCS, LCML…), global (e.g. GLC-share, GlobeLand30) and national experiences (Africover, SERVIR-RMCD).

The legend includes 10 generic classes that appropriately describe the land surface at 20 m spatial (see Table 3-1). Seven of them are generic land cover categories recommended in the Global Terrestrial Observing System (GTOS) guidelines (2009): trees cover areas, shrubs cover areas, bare areas, built up areas, snow and/or ice and open water. Building on the GLC-share approach, the GTOS herbaceous class was further distinguished into cropland and grassland. Finally, these classes were completed by the "vegetation aquatic or regularly flooded" and "lichen and mosses / sparse vegetation" classes because of their importance in climate modelling.

Table 3-1: The legend used for the S2 prototype map of Africa.

VALUE	LABEL	R	G	B
0	No data	0	0	0
1	Trees cover areas	0	160	0
2	Shrubs cover areas	150	100	0
3	Grassland	255	180	0
4	Cropland	255	255	100
5	Vegetation aquatic or regularly flooded	0	220	130
6	Lichen Mosses / Sparse vegetation	255	235	175
7	Bare areas	255	245	215
8	Built up areas	195	20	0
9	Snow and/or Ice	255	255	255
10	Open water	0	70	200

Among these LC classes, two were largely identified thanks to external datasets: the "open water" class was based on the Global Surface Water product [RD.8] and the "urban areas" relied both on the Global Human Settlement Layer [RD.6] and on the Global Urban Footprint [RD.7].

3.1.2 Processing chain

The classification modules that generate the S2 prototype map of Africa at 20 m were developed by the Université catholique de Louvain (UCLouvain-Geomatics, Belgium). It builds upon the state-of-art established for the production of the global annual maps from 1992 to 2015 at 300 m [AD.9]. More details are available in [AD.13].

The classification module is articulated to the pre-processing one as illustrated in Figure 3-2. The pre-processing module converts S2 L1C Top-of-Atmosphere (TOA) values to S2 L2A Top-of-Canopy (TOC) cloud screened surface reflectance (SR) values at 20 m spatial resolution in all S2 bands.

These reflectances values are eventually aggregated into composites with periods and bands varying according to a pre-defined stratification of Africa. Composites of one year and 3 months constitute the main inputs to the classification module, which interprets them into a land cover map. The reference module consists in bringing refinements to the 20-m reference layer used to produce the global annual LC maps at 300 m. The reference layer is then used as a-priori and a training dataset in the classification modules.

Two classification algorithms, the Random Forest (RF) and Machine Learning (ML), were chosen to transform the cloud-free reflectance composites generated by the pre-processing module into a land cover map. The two maps resulting from both approaches are then combined either to select the best representation of a land cover class which will be part of the final S2 prototype map of Africa or, in case of unreliable LC class delineation, the reference layer is used to consolidate the land cover classification. The final step of the production consists in translating the original legend in 22 LCCS classes into the final S2 legend including 10 classes.

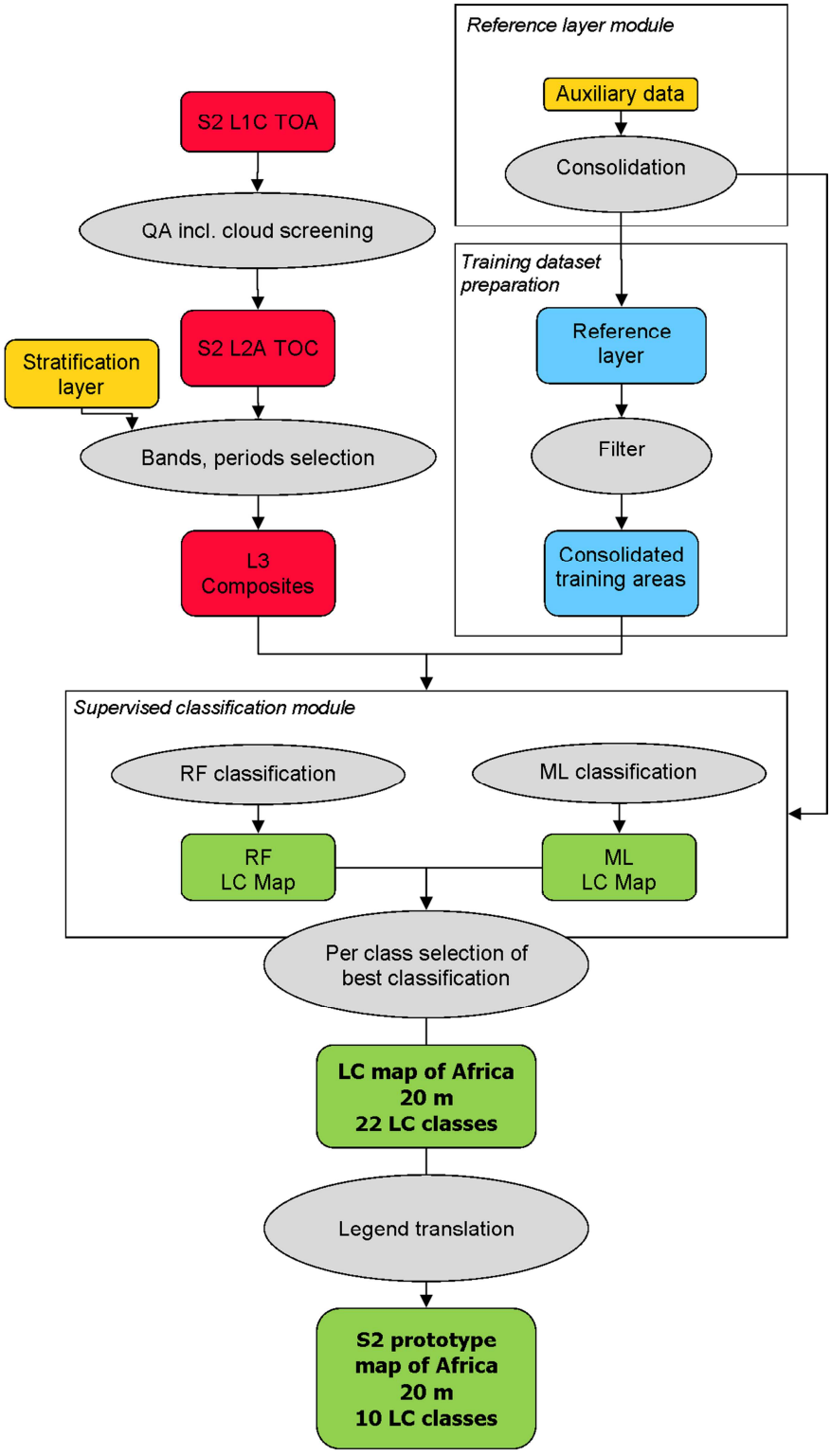


Figure 3-2: Schematic illustration of the pre-processing, reference layer and classification modules that generate the S2 prototype map of Africa.

3.1.3 Format

- **Naming Convention**

The filename convention of the S2 prototype map of Africa at 20 m 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 3-2.

Table 3-2. 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	20 m (constant)
tempres	Temporal resolution	P1Y (constant)
epoch	Year of the product	2016
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._]*

The filename of the S2 prototype map of Africa is therefore: "ESACCI-LC-L4-LCCS-Map-20m-P1Y-2016-v1.0.tif».

- **Processing Level**

Level 4 (i.e. "variables that are not directly measured by the instruments, but are derived from these measurements" [RD.5])

- **Units**

Each pixel value corresponds to the label of a land cover class (see Table 3-1 in Section 3.1.1).

- **Spatial Extent**

Africa

- **Spatial Resolution**

20 m

- **Temporal resolution**

Annual

- **Product layers**

The S2 prototype map of Africa at 20 m is delivered as a unique file, described in Table 3-3.

Table 3-3: Layer that makes the S2 prototype map of Africa at 20 m.

NAME IN PRODUCT	DATA TYPE	DESCRIPTION
ESACCI-LC-L4-LCCS-Map-20m-P1Y-2016-v1.0.tif	byte	LC classification in LCCS (22 global classes + NoData coded as 0)

- **Projection**

The projection is a Plate-Carrée with a geographic Lat/Long representation based on the WGS84 ellipsoid (Figure 3-3). 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 3-3: Description of the coordinate reference system defining the global LC products.

- **Format**

The S2 prototype map of Africa at 20 m is delivered in GeoTiff format.

- **Metadata**

The metadata for the LC maps are provided as global attributes in the NetCDF file and are included in the GeoTiff raster.

- **Estimated size**

The size of the S2 prototype map of Africa at 20 m is around 50GB. These estimations take an internal LZW compression into account.

3.2 Qualitative assessment

The qualitative assessment is done through comparisons with VRH resolution imagery, the original reference database of Phase 2 Year 2 and the CCI-LC map at 300 m of 2015. It still a work in progress but already show the accomplished progress.

The following figures present the S2 prototype map of Africa, with a focus on a natural area in Angola (Figure 3-4) and a structured urbanized area in South Africa (Figure 3-5).

In Angola, and most often, forest areas are well defined. Patches of grassland are also correctly delineated but confusion exists between grassland and cropland. This was foreseen as only one yearly composite could be used in this region to overcome the lack of valid and cloud-free observations. Flooded herbaceous cover could not be detected in this region.

In all areas, a salt and pepper effect is visible, pleading for post-classifications strategy like object-based aggregation.

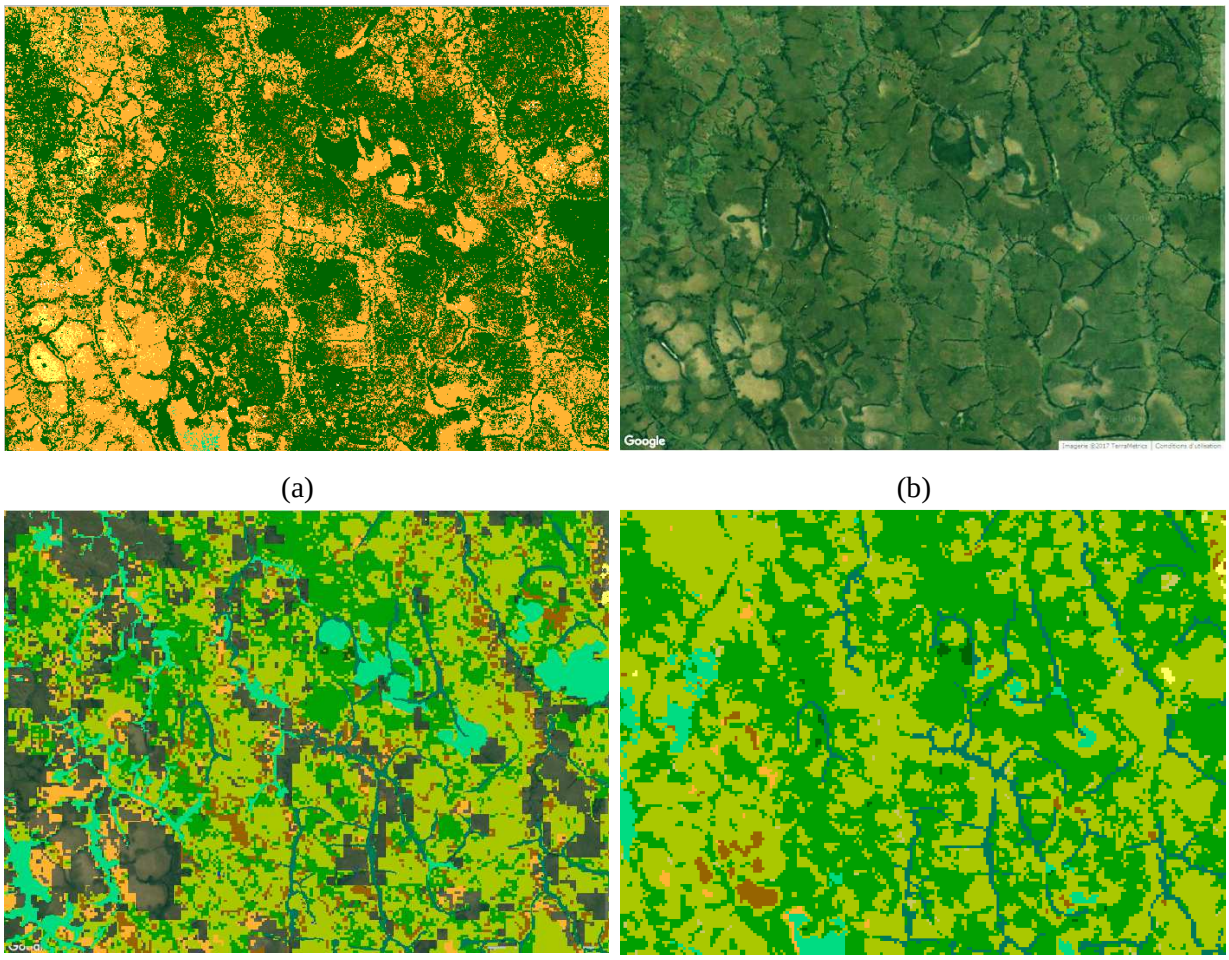
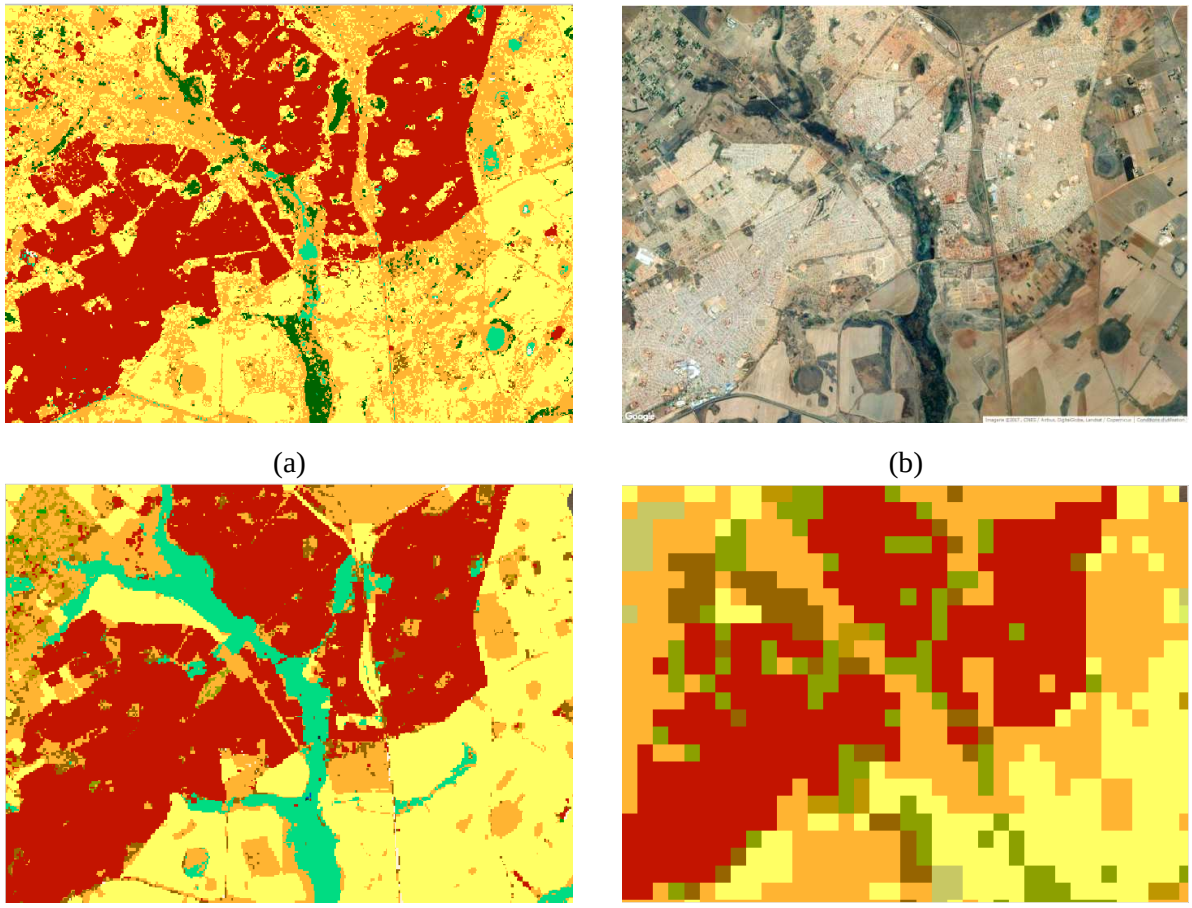


Figure 3-4: Comparison, over Angola between the S2 prototype map of Africa (a), VRH resolution imagery (Terra Metrics)(b), the original reference database of Phase 2 Year 2 (c) and the CCI-LC map at 300 m of 2015 (d).

In more structured areas like in South Africa and with a reference layer of high quality, the S2 prototype map of Africa offers a good representation of the landscape. Forest, along the river is better detected than in the reference layer that misclassifies forest as flooded herbaceous cover (turquoise). The urban class is also better delineated than in the reference as some houses at the top left of the image could be mapped.



(a) (b)

(c) (d)

Figure 3-5: Comparison, over South Africa between the S2 prototype map of Africa (a), VRH resolution imagery (CNES/Airbus, digital globe)(b), the original reference database of Phase 2 Year 2 (c) and the CCI-LC map at 300 m of 2015 (d).

3.3 Validation

A critical step in the acceptance of the any map 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".*

No validation was performed on the S2 prototype map of Africa at 20 m.

4 S1 MAP OF OPEN WATER BODIES

4.1 Product description

The Sentinel-1 water body product (WBP) is a self-standing dataset, prototyping the use of Sentinel-1 C-band SAR data to map water surfaces. The WBP covers West Africa between -18° and 8° E, 17° and 4° N, thus including the major catchments and basins of the region (Figure 4-1). The WBP relies on multi-temporal observations of the SAR backscatter acquired between January 2015 and May 2017. The WBP portrays open water bodies in their maximum extent within the time frame of the SAR dataset. The dataset has a spatial resolution of 20 m. The original detection of water bodies obtained with the SAR data only has been refined with the Sentinel-2 land cover map to remove commissioning errors due to the confusion between water and other flat planar surfaces with similar backscatter characteristics as water. For details on the procedure implemented to generate this prototype product, it is referred to [AD.11].

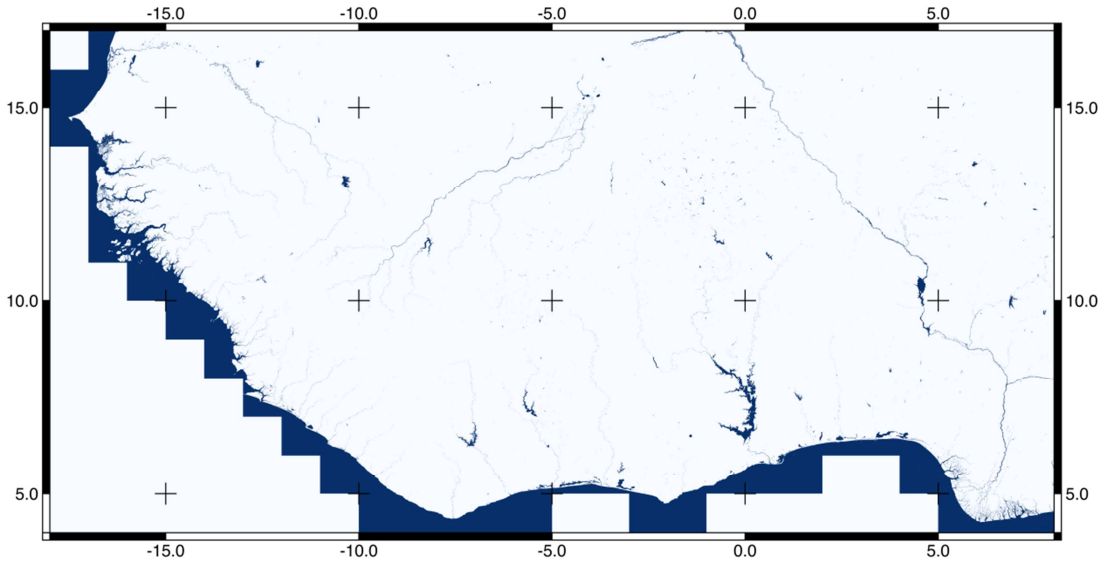


Figure 4-1: Sentinel-1 Water Body Product for West Africa.

Figure 4-2 and Figure 4-3 show details of the water body product for the delta of the Senegal river and the Volta Lake. To indicate the high level of detail in the water body product, panels have been added with the Google Earth coverage of the same area.

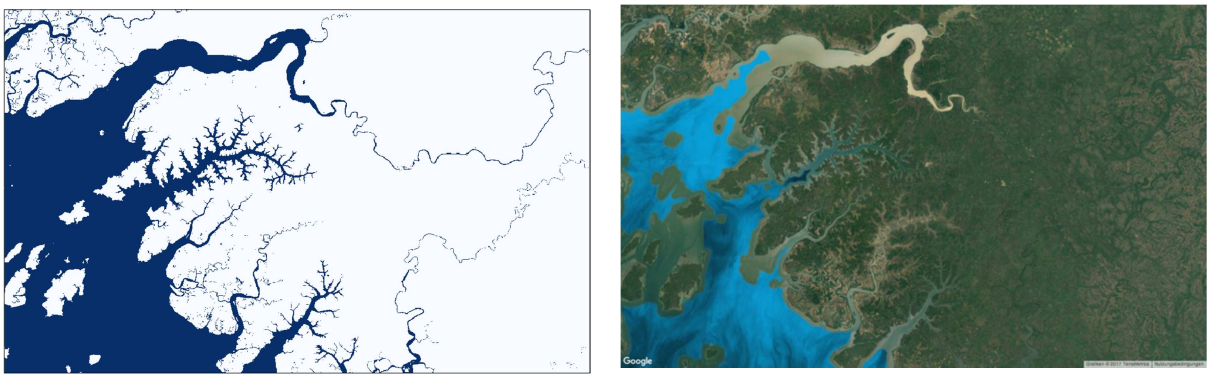


Figure 4-2: Detail of the delta river system in Guinea Bissau: Sentinel-1 Water Body Product (left), Google Earth imagery (right).

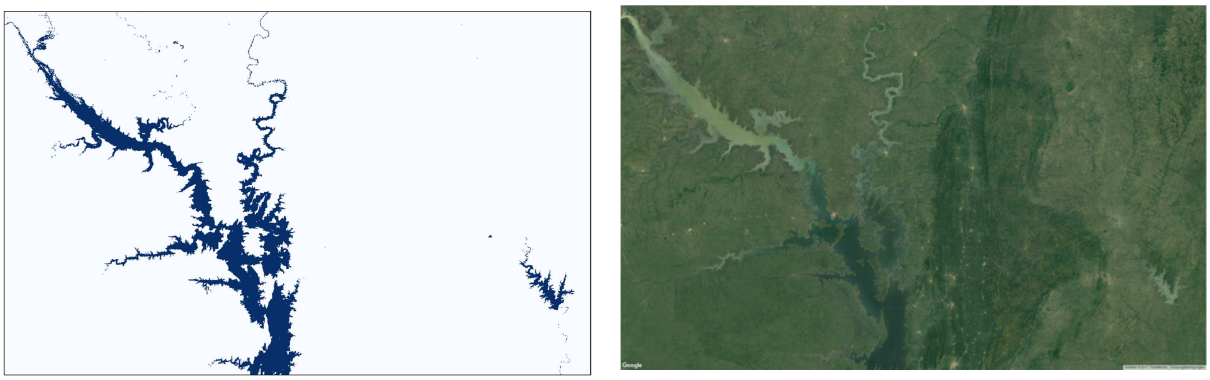


Figure 4-3: Detail of Lake Volta, Ghana, in the water body product (left) and in Google Earth imagery (right).

4.2 Validation

The Sentinel-1 map of water bodies for West Africa was based on a two-stage approach. First, an intermediate data product depicting water and land was created by classifying SAR multi-temporal metrics and corresponding incidence angles. Then, the intermediate product was refined with morphology filters and masking with an auxiliary dataset for large-scale water commission errors. The C-band Sentinel-1 SAR backscattered intensity is indeed sensitive to water surfaces but other surfaces (deserts, arid terrain, permanent ice cover and shadows) behave similarly. The classification was performed with a 5 folds cross-validation, resulting in approximately 93% overall accuracy (5% water commission error, 10% water omission error), evaluated on more than 5'000 samples (pixels) almost similarly distributed into the classes "land" and "water". For details, it is referred to the Algorithm Theoretical Basis Document of this data product [AD.11]. This is not to be taken as the true accuracy of the classification, though. Large-scale detection of water in desert and arid areas in the northern part of the study area were certainly responsible for a much higher water commission error than the result obtained with cross-validation. A proper validation of the intermediate product from the classification has not been undertaken.

The Sentinel-1 water body product has not been validated either. In this Section, we provide a qualitative assessment of the strengths and limitations of the dataset. For comparisons, other water

body products with similar spatial resolution are considered. It is referred to the JRC water occurrence dataset for 2014-2015 in order to allow for an analysis using nearly simultaneous datasets.

The Sentinel-1 water body data product captures small details of major water bodies thanks to the 20 m spatial resolution of the Sentinel-1 datasets. The well-known issue of imperfect delineation of water bodies (mixed pixels are typically allocated to land) has been solved with the use of morphological filters.

With respect to existing water body datasets based on 30 m Landsat data, the delineation is often slightly more precise; also artifacts seem to be better handled. In Figure 4-4, the western branch of the Barrage de Selengue presents repeated horizontal striping, which is assumed to be caused by artifacts in the input remote sensing data.

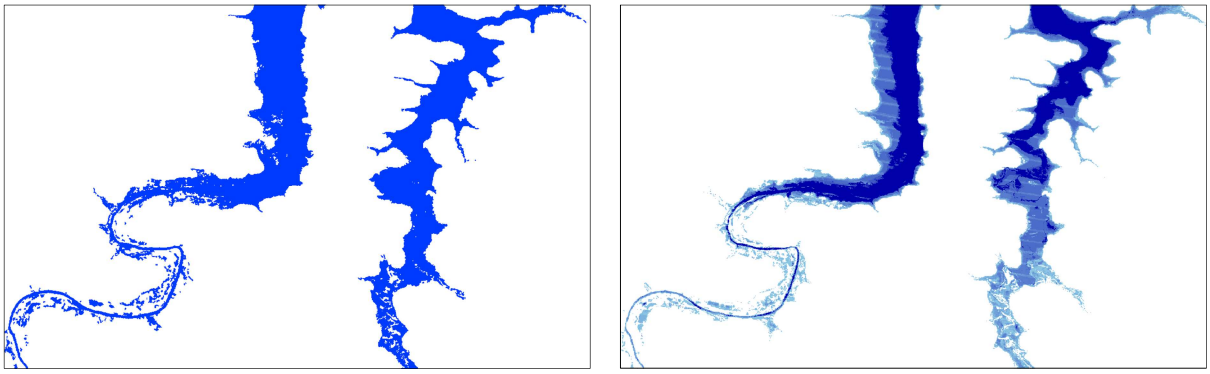


Figure 4-4: Water body maps for the southern part of the Barrage de Selengue, Mali: Sentinel-1 water body product (left), JRC water occurrence 2014-2015 (right). The Sentinel-1 map is a binary water/land classification. The JRC water occurrence uses shades of blue to represent occurrence in months (light to dark blue: 1 to 12 months occurrence).

The capability of Sentinel-1 to acquire regardless of solar illumination and cloud cover guarantees for the thematic precision of the water detection throughout the entire study area. Figure 4-5 shows the water bodies detected with Sentinel-1 and by JRC with optical data for a region in Sierra Leone with at least 10 months in the year with precipitation > 150 mm. The JRC dataset presents significant water omission due to the almost permanent cloud cover. The two major rivers in the area are instead well identified in the Sentinel-1 water body data product.

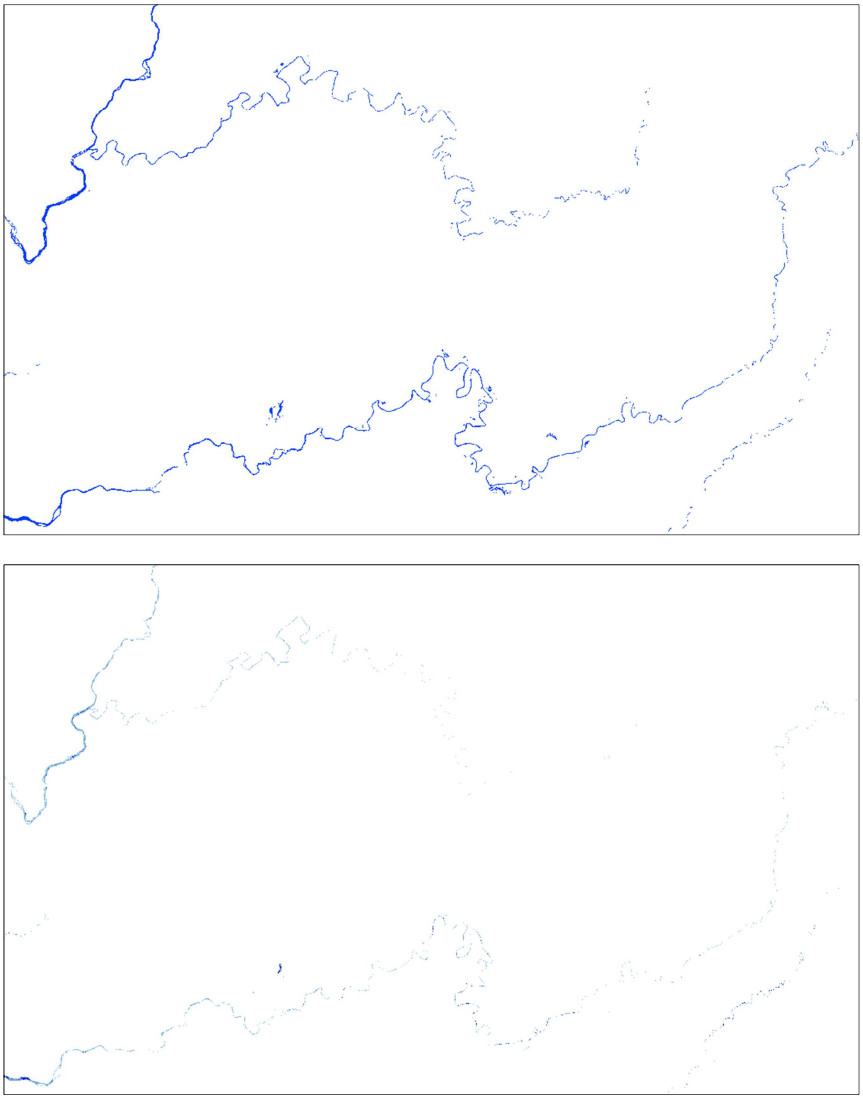


Figure 4-5: Water body maps for a region west of Port Loko, Sierra Leone, depicting the Bankasoka River (north) and the Rokel River (south). Top panel: Sentinel-1 water body product. Bottom panel: JRC water occurrence 2014-2015.

The major weakness of the Sentinel-1 water body product is the omission of water bodies narrower than twice the pixel size. Water omissions could not be compensated for with morphological filters if the water body was not detected in first place. The possibility to explore algorithms to connect segments based on the input SAR data (where often very narrow rivers are visible) should be explored to obtain a higher precision of the detection As a result, narrow rivers remain either undetected or appear fragmented. The issue is exacerbated by the solution implemented to reduce large-scale water commission errors. A mask depicting the potential extent of water bodies was derived from the 150 m CCI Water Body Product. The spatial detail of this dataset is high but still missing small details like narrow river which in the end caused removal of correctly classified water pixels when the CCI WBP did not detect water. This is a major flaw of the classification that needs to be revised in the future.

Figure 4-6 shows an example of discontinuity in the detection of a river. The rivers are approximately 40-50 m wide, with frequent embankments of sand. The discontinuities are not as visible in the SAR data. It is assumed that the classification approach was too conservative in the detection of water, causing omissions; in addition, masking with a dataset derived from a 150 m spatial resolution water body map added water omissions to the map.

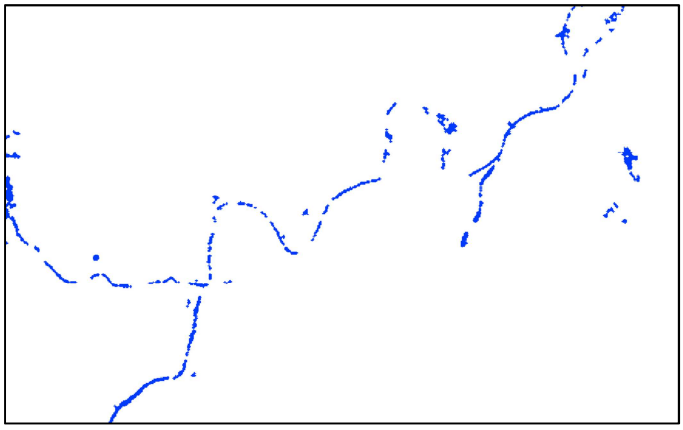


Figure 4-6: Example of fragmented rivers in the Sentinel-1 water body product. The area is located west of the town of Koubi, Mopti region, Mali.

Finally, the reliability of the information of maximum extent can be questioned considering that data within a time frame of 29 months has been used to generate the Sentinel-1 water body product. Being this a prototype product, it was preferred to maximize the number of Sentinel-1 observations using all available at the time of data production and obtain stable multi-temporal metrics to feed to the classification algorithm. As a result, inundations might have been captured as water bodies. A proper validation should be undertaken to better characterize the definition of such areas in the context of the product here developed.

4.3 Format

- **Science dataset**

The Sentinel-1 water body product represents a binary classification of land and water with a spatial resolution of 20 m. It has a LAT/LONG WGS84 projection. Table 4-1 gives the layers variable description, valid values ranges, units, fill value and pixel depth. The dataset does not differentiate between inland water and ocean water.

Table 4-1: Description of the layers included in the Sentinel-1 WB product.

LAYER NAMES	DESCRIPTION	VALID VALUES RANGE	UNITS	FILL VALUE	PIXEL DEPTH
Map	Land/water classification at 20 m spatial resolution. Legend : 1-Land, 2 Water, 0-Void	[0 to 2]	None	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 **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 4-2.

Table 4-2: Naming convention in the CCI-LC Sentinel-1 Water Body 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
spat res	Spatial resolution	20 m
period+ temporal res.	Multi-year period of the product defined by the number of years + Temporal resolution of the product	P3Y
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 2015 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 Sentinel-1 WBP.

```
Driver: GTiff/GeoTIFF
Size is 143000, 71500
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",0.00018181818],
    AUTHORITY["EPSG","4326"]]
```

```
Origin = (-18.000000000000000,17.000000000000000)
Pixel Size = (0.0001818181818,-0.0001818181818)
Metadata:
  AREA_OR_POINT=Area
  Copyright =ESA 2017 - UCLouvain and Gamma-RS
  Dataset =Static map of open water bodies at 20 m spatial resolution resulting from a classification of Sentinel-1 SAR data and refinement with the CCI Water Body Product.
  Description =
   Layer 1 = Water classification; 1: Land , 2: Inland Water, 0: no data
Scaling Factor =none
Image Structure Metadata:
  COMPRESSION=LZW
  INTERLEAVE=BAND
Corner Coordinates:
Upper Left  (-18.0000000, 17.0000000) (18d 0' 0.00"W, 17d 0' 0.00"N)
Lower Left  (-18.0000000, 4.000000) (18d 0' 0.00"W, 4d 0' 0.00"N)
Upper Right (8.000000, 17.0000000) (8d 0' 0.0"E, 17d 0' 0.00"N)
Lower Right (8.000000, 4.00000) (8d 0' 0.0"E, 4d 0' 0.0"N)
Center      (-5.000000,  10.500000) (5d 0' 0.00"W,  10d 30' 0.00"N)
Band 1 Block=256x256 Type=Byte, ColorInterp=Gray
```

5 SURFACE REFLECTANCE PRODUCTS

5.1 Products description

The Sentinel 2 Surface reflectance products delivered by the CCI-LC project consist in

- Sentinel 2 seasonal and 366-day surface reflectance composite based on SR time series of one year at 20 m spatial resolution over Africa
- Sentinel 2 surface directional reflectance product of one year at native spatial resolution over selected sites (Botswana, Zambia, and Zimbabwe)

that are the input for the classification algorithms. The pre-processing module was developed by Brockmann-Consult (BC), capitalizing on the GlobCover, GlobAlbedo and Timeline projects. Table 5-1 details the satellite dataset that are used in order to generate the Sentinel 2 Surface reflectance products.

Table 5-1: Satellite data that are planned to be used to generate the Sentinel 2 Surface reflectance products

SENTINEL 2 PRODUCTS	REFERENCE PERIOD	SATELLITE DATA SOURCE	TECHNICAL SPECIFICATIONS OF THE SATELLITE DATA SOURCE
Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution	2015 - 2016	Sentinel 2	• 10m, 20m and 60m spatial resolution • 13 spectral bands in visible and infrared • Africa
Sentinel 2 surface directional reflectance product at native spatial resolution			

The Sentinel 2 seasonal surface reflectance composite are made of temporal syntheses obtained over a 60-day compositing period. The Sentinel 2 Surface reflectance products have been generated during this Phase II. The spectral content encompasses 11 of 13 Sentinel 2 spectral channels – bands 9 and 10 being removed - (Table 5-2).

Table 5-2: Sentinel 2 spectral channels.

BAND NUMBER	BAND CENTRE (NM)	BAND WIDTH (NM)	SPATIAL RESOLUTION [m]	USE
1	443	20	60	aerosol
2	490	65	10	aerosol, land use, vegetation
3	560	35	10	land use, vegetation
4	665	30	10	land use, vegetation
5	705	15	20	land use, vegetation
6	740	15	20	land use, vegetation
7	783	20	20	land use, vegetation
8	842	115	10	water vapour, land use, vegetation
8a	865	20	20	water vapour, land use, vegetation

BAND NUMBER	BAND CENTRE (NM)	BAND WIDTH (NM)	SPATIAL RESOLUTION [m]	USE
9	940	20	60	water vapour
10	1375	20	60	cirrus cloud
11	1610	90	20	land use, vegetation
12	2190	180	20	aerosol, land use, vegetation

In order to simplify the handling and analysis of Sentinel 2 Surface reflectance products, the products are being delivered in tiles or granules and each band is being delivered in an separate file.

The composites products are subdivided into 72 x 36 tiles (Figure 5-1) following the tiling system already used in the GlobCover project [RD.9, RD.10]. 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). In addition, tiles having no land contribution are not delivered.

The surface directional products are delivered in granules like the L1C granules, which are100x100km2 ortho-images in UTM/WGS84 projection. The tiling grid is available in KML format[3] and tile naming convention is described in the 'Tiles and UTM Tiled Grid' section of the Sentinel 2 product specification document (PSD)[4].

[3] https://sentinel.esa.int/documents/247904/1955685/S2A_OPER_GIP_TILPAR_MPC__20151209T095117_V20150622T000000_21000101T000000_B00.kml

[4] https://sentinel.esa.int/documents/247904/685211/Sentinel-2-Product-Specifications-Document

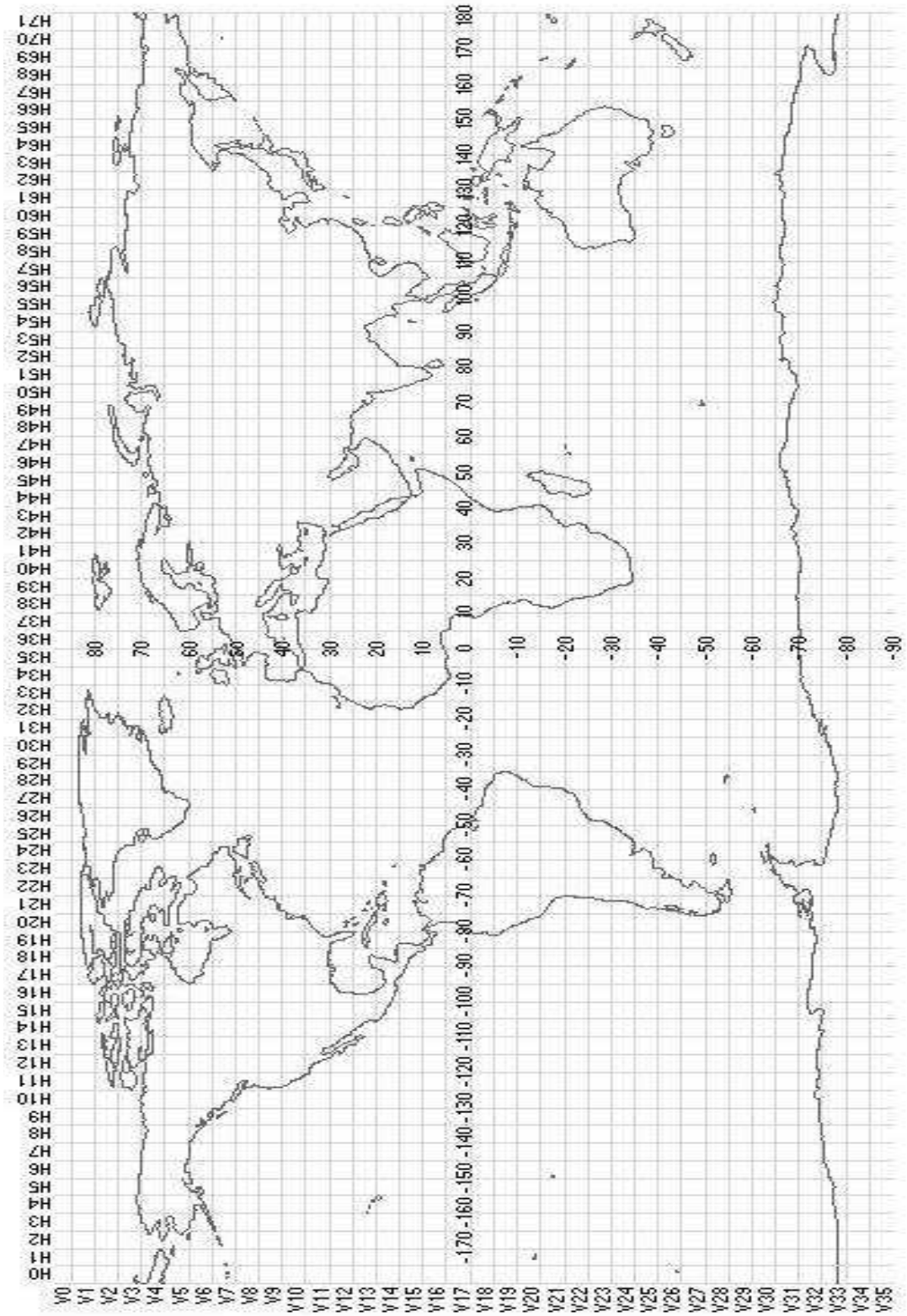


Figure 5-1: Description of the tiling system used for the SR composites products [RD.9, RD.10].

5.1.1 Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution

Figure 5-2 shows the individual image of tile h37v12 of CCI-LC Sentinel 2 seasonal surface reflectance composite from 2015-12-02 at 20m spatial resolution.

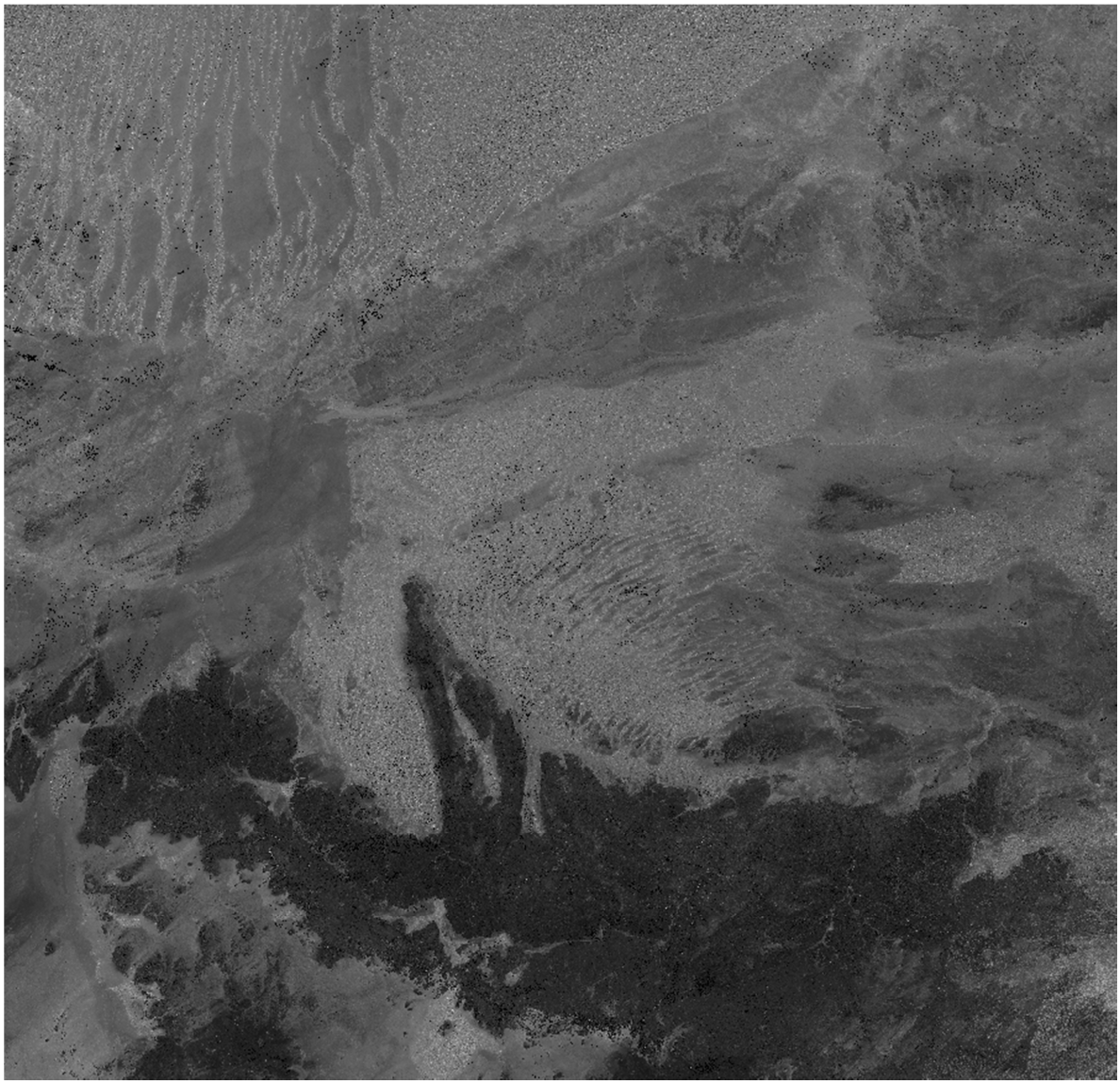


Figure 5-2: Example of CCI-LC Sentinel 2 seasonal surface reflectance composite, at 20m spatial resolution and tile h32v12 - ESACCI-LC-L3-SR-MSI-20m-P60D-sr_xxx_mean-h37v12-20151202-v1.4 (xxx =4,3,2; RGB with channels 4, 3, 2).

Furthermore, an example of the RGB image of CCI-LC Sentinel 2 seasonal surface reflectance composite at 20m spatial resolution over Africa is illustrated in Figure 5-3 (2015-12-02).

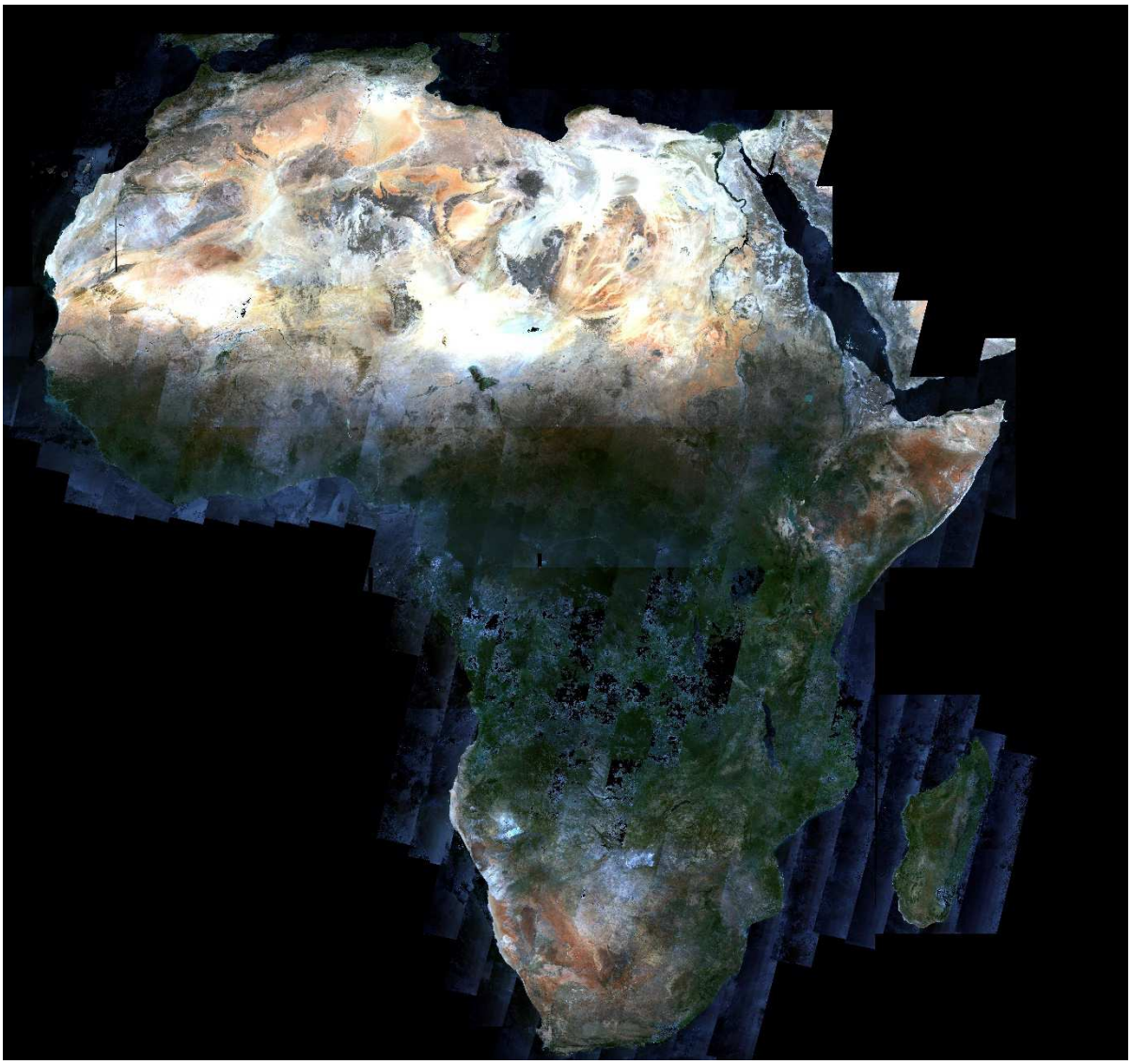


Figure 5-3: The CCI-LC Sentinel 2 seasonal surface reflectance composite at 20m spatial resolution over Africa (2015-12-02) (RGB with channels 4, 3, 2).

Figure 5-4 shows the RGB image of CCI-LC Sentinel 2 366-day surface reflectance composite at 20m spatial resolution over Africa (2015-12-02).

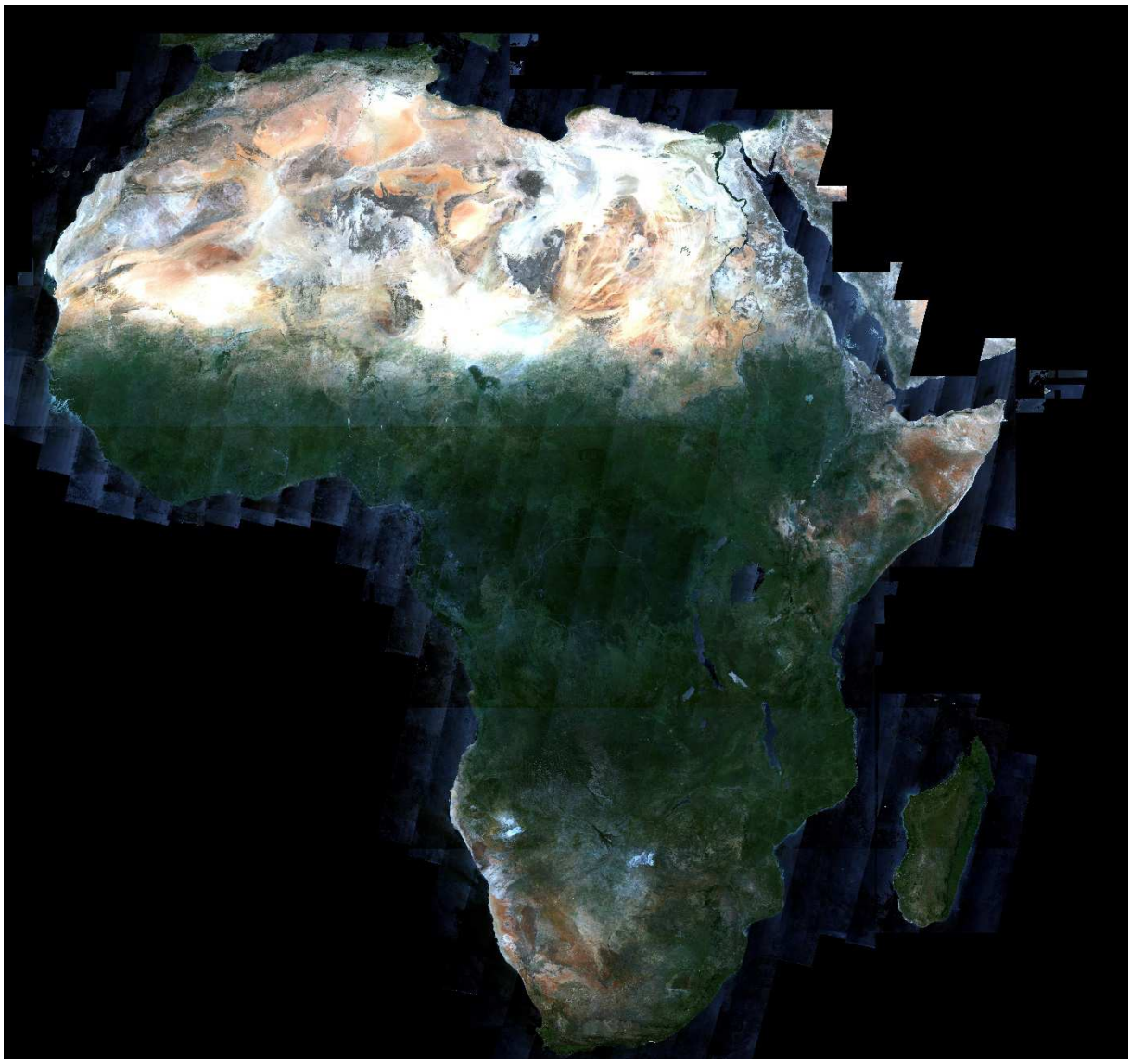


Figure 5-4: The CCI-LC Sentinel 2 366-day surface reflectance composite at 20m spatial resolution over Africa (2015-12-02, RGB with channels 4, 3, 2).

5.1.2 Sentinel 2 surface directional reflectance product at native spatial resolution

Figure 5-5 shows the individual RGB image of Sentinel 2 surface directional reflectance product at native spatial resolution (2016-06-25, T34KGD, RGB with channels 4, 3, 2)

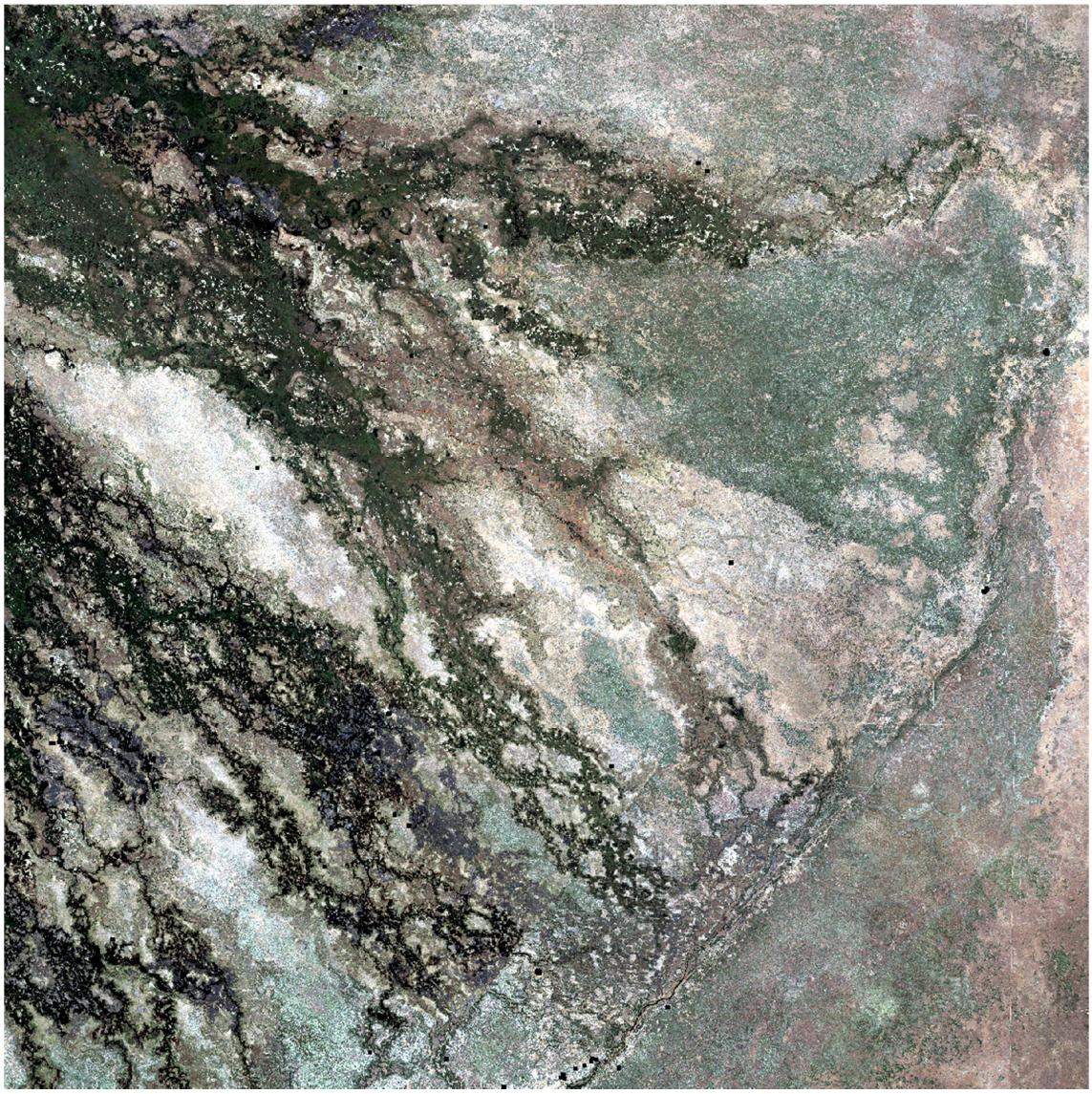


Figure 5-5: Example of CCI-LC 5.1.2 Sentinel 2 surface directional reflectance product at native spatial resolution (2016-06-25, T34KGD, RGB with channels 4, 3, 2)
S2A_OPER_PRD_MSIL1C_PDMC_20160625T152634_R121_V20160625T084528_20160625T084528_T34KGD

5.2 Products format

5.2.1 Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution

- **Naming convention**

The file name convention of the seasonal and 366-day surface reflectance composite 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>-<band>

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

Table 5-3: 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	MSI
spatres	Spatial resolution	20m
tempres	Compositing period	P60D or P366D
Band	Band name	sr_1_mean sr_2_mean sr_3_mean sr_4_mean sr_5_mean sr_6_mean sr_7_mean sr_8_mean sr_9_mean sr_10_mean sr_11_mean obs_count status status_count vegetation_index_mean

FIELD	SIGNIFICATION	VALUE
tile	Tile of the Plate Carrée grid (see Figure 5-1)	Tile name in format hXXvYY where XX is the column and YY is the row e.g. " h71v27" - tile in column 71 and row 27 of the Plate Carrée grid (see Figure 5-1)
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 366-day surface reflectance composite for the year 2015/2016 located at the tile h47v15 would be: "ESACCI-LC-L3-SR-MSI-20m-P366D-sr_5_mean-h47v15-20151202-v1.4.tif "

- **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.5])

- **Units and datatype**

The Top of Canopy reflectance values and the corresponding additional values are coded in different data types – see Table 5-4.

Table 5-4: Properties for the bands of the Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution .

BAND	BAND	UNITS	SCALE FACTOR	DATA TYPE
sr_1_mean	surface reflectance for band 1 (443 nm)	no unit	0.001	int16
sr_2_mean	surface reflectance for band 2 (490 nm	no unit	0.001	int16
sr_3_mean	surface reflectance for band 3 (560 nm)	no unit	0.001	int16
sr_4_mean	surface reflectance for band 4 (665 nm)	no unit	0.001	int16
sr_5_mean	surface reflectance for band 5 (705 nm)	no unit	0.001	int16
sr_6_mean	surface reflectance for band 6 (740 nm)	no unit	0.001	int16
sr_7_mean	surface reflectance for band 7 (783 nm)	no unit	0.001	int16

BAND	BAND	UNITS	SCALE FACTOR	DATA TYPE
sr_8_mean	surface reflectance for band 8 (842 nm)	no unit	0.001	int16
sr_9_mean	surface reflectance for band 8A (865 nm)	no unit	0.001	int16
sr_10_mean	surface reflectance for band 11 (1610 nm)	no unit	0.001	int16
sr_11_mean	surface reflectance for band 12 (2190 nm)	no unit	0.001	int16
obs_count	number of observations	no unit	-	int16
status	Current pixel state 0 = invalid 1 = clear_land 2 = clear_water 3 = clear_snow_ice 4 = cloud 5 = cloud_shadow 11 = haze 12 = bright 14 = temporal_cloud 15 = dark	no unit	-	int16
status_count	Number of observations related to the status	no unit	-	int16
vegetation_index_mean	normalized difference vegetation index	no unit	0.1	uint8

- **Spatial Extent**

All the terrestrial zones of the earth over Africa. The products are provided in tiles as defined in Section 5.1.

- **Spatial resolution**

20 m

- **Temporal resolution**

60-day or 366-day

- **Projection**

The projection is a Plate Carrée with a geographic Lat/Long representation based on the WGS84 ellipsoid. 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.

- **Format**

All the corresponding product files (geotiff) are delivered in folders with the following structure – tile and date – see also Figure 5-6.

Figure 5-6: Folder structure and files for the Sentinel 2 seasonal and 366-day surface reflectance composite at 20m spatial resolution

- **Estimated size**

The size of a Sentinel 2 seasonal or 366-day surface reflectance composite at 20m spatial resolution composite over Africa is estimated at ~4 TB and the size of the one band per one tile is estimated at ~0.7 GB.

5.2.2 Sentinel 2 surface directional reflectance product at native spatial resolution

- **Naming convention**

The file name convention of the surface directional reflectance products delivered by the CCI-LC project is the following:

File name = <original L1C granule name>-<ac-sdr>.zip

The dash "-" is the separator between name components. An example file name of the surface directional reflectance product for the 25-06-2016 located at the tile T34KGD would be:

"S2A_OPER_PRD_MSIL1C_PDMC_20160625T152634_R121_V20160625T084528_20160625T084528_T34KGD-ac-sdr.zip "

The zip archive file includes the individual geotiff files per band.

- **Processing Level**

Level 2 [RD.5])

- **Units and datatype**

The Top of Canopy reflectance values and the corresponding additional values are coded in different data types – see Table 5-5.

Table 5-5: Properties for the bands of the Sentinel 2 surface directional reflectance product at native spatial resolution

BAND	BAND	UNITS	DATA TYPE
B1_ac	surface directional reflectance for band 1 (443 nm)	no unit	uint16
B2_ac	surface directional reflectance for band 2 (490 nm	no unit	uint16
B3_ac	surface directional reflectance for band 3 (560 nm)	no unit	uint16
B4_ac	surface directional reflectance for band 4 (665 nm)	no unit	uint16
B5_ac	surface directional reflectance for band 5 (705 nm)	no unit	uint16
B6_ac	surface directional reflectance for band 6 (740 nm)	no unit	uint16
B7_ac	surface directional reflectance for band 7 (783 nm)	no unit	uint16
B8_ac	surface directional reflectance for band 8 (842 nm)	no unit	uint16
B8A_ac	surface directional reflectance for band 8A (865 nm)	no unit	uint16
B11_ac	surface directional reflectance for band 11 (1610 nm)	no unit	uint16
B12_ac	surface directional reflectance for band 12 (2190 nm)	no unit	uint16

BAND	BAND	UNITS	DATA TYPE
pixel_classif_flags	IdePix flags 1 = Invalid pixels 2 = Pixels which are either cloud_sure or cloud_ambiguous 4 = Semi-transparent clouds, or clouds where the detection level is uncertain - cloud_ambiguous 8 = Fully opaque clouds with full confidence of their detection - cloud_sure 16 = A buffer of n pixels around a cloud 32 = Pixels is affect by a cloud shadow 64 = Cirrus clouds, or clouds where the detection level is uncertain 128 = Cirrus clouds with full confidence of their detection 256 = Pixels at a coastline 512 = Clear snow/ice pixels 1024 = Clear land pixels 2048 = Clear water pixels 4096 = Land pixels 8192 = Water pixels 16384 = Bright pixels 32768 = White pixels 65536 = Brightwhite pixels 131072 = High pixels 262144 = Pixels with vegetation risk 524288 = Sea ice pixels	no unit	uint32
status_10m	Current pixel state 0 = invalid 1 = clear_land 2 = clear_water 3 = clear_snow_ice 4 = cloud 5 = cloud_shadow 11 = haze 12 = bright 14 = temporal_cloud 15 = dark	no unit	uint8
surface_pressure	surface pressure	Pa	float32
AOD	aerosol optical depth at 550 nm	no unit	float32

BAND	BAND	UNITS	DATA TYPE
aerosol_type_index	aerosol type 0 = Rural aerosol type 1 = Maritime aerosol type 2 = Urban aerosol type 3 = Desert aerosol type	no unit	uint8
TC_Ozone	Total ozone content	kg/m²	float32
TC_WV	Total column water vapour content	kg/m²	float32
aot_flags	AOT Flags 1= AOD from climatology only 2= AOD spatially interpolated	no unit	uint8
sun_azimuth	sun zenith angle	degree	int16
sun_zenith	sun azimuth angle	degree	int16
view_zenith	view zenith angle	degree	int16
view_azimuth	view azimuth angle	degree	int16

- **Spatial Extent**

All the terrestrial zones of the earth over the Botswana, Zambia and Zimbabwe. The products are provided in tiles as defined in Section 5.1.

- **Spatial resolution**

native resolution (see Table 5-2)

- **Temporal resolution**

observation date

- **Projection**

The projection is a UTM/wGS84 projection. The UTM (Universal Transverse Mercator) system divides the Earth's surface into 60 zones. Each UTM zone has a vertical width of 6° of longitude and horizontal width of 8° of latitude.

- **Format**

All the corresponding product files (geotiff) are delivered in zip folders with the following structure - see also Figure 5-7.

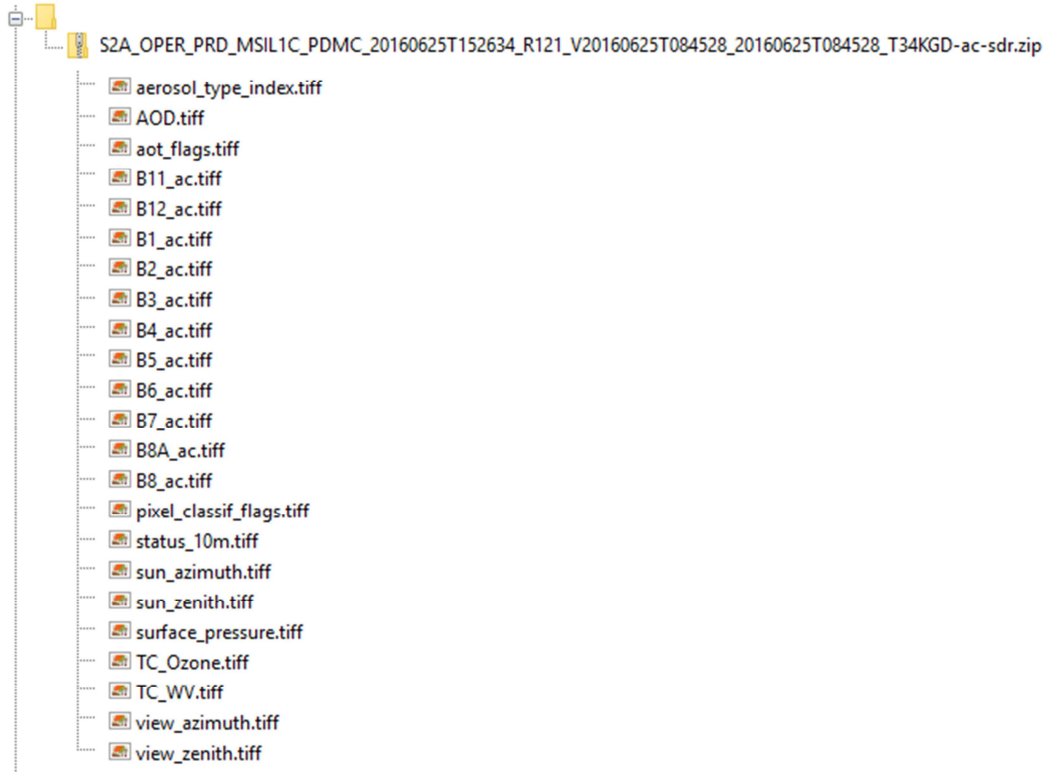


Figure 5-7: Folder structure and files for the Sentinel 2 surface directional reflectance products at native spatial resolution

- **Estimated size**

The size of a Sentinel 2 surface directional reflectance products at native spatial resolution is estimated at ~2 GB and the size of the one band per one tile is estimated at ~50-500 MB.

6 SOFTWARE TOOLS

A set of tools to browse and view the content of the CCI-LC products are available. The CCI-LC surface reflectance products and CCI_LC map product are delivered both in the 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]) and the Geographic Resources Analysis Support System (GRASS GIS) and SNAP [RD.12].

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.

“The SNAP architecture is ideal for Earth Observation processing and analysis due the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework” [RD.12].

Feature Highlights

- Common architecture for all Toolboxes
- Very fast image display and navigation even of giga-pixel images
- Graph Processing Framework (GPF): for creating user-defined processing chains
- Advanced layer management allows adding and manipulation of new overlays such as images of other bands, images from WMS servers or ESRI shapefiles
- Rich region-of-interest definitions for statistics and various plots
- Easy bitmask definition and overlay
- Flexible band arithmetic using arbitrary mathematical expressions
- Accurate reprojection and ortho-rectification to common map projections,
- Geo-coding and rectification using ground control points
- Automatic SRTM DEM download and tile selection
- Product library for scanning and cataloging large archives efficiently
- Multithreading and Multi-core processor support

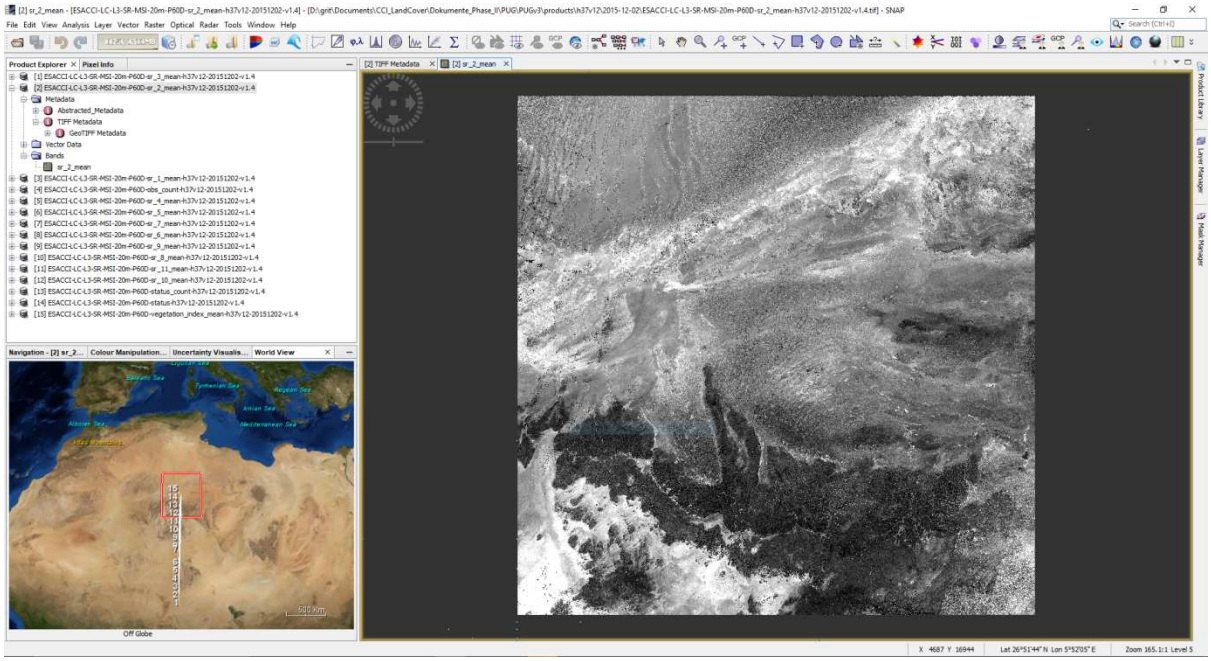


Figure 6-1: Screenshot of SNAP.

7 DATA ACCESS AND POLICY

The CCI-LC products documented in this PUGv3 are not to be delivered, by any means, outside of the consortium until common agreement between ESA and prototype producers is concluded.