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CONTENTS

SYMBOLS AND ACRONYMS

(A)ATSR	(Advanced) Along Track Scanning Radiometer
ALOS	Advanced Land Observing Satellite
ASAR	Advanced Synthetic Aperture Radar
AOD	Aerosol Optical Depth
ATBD	Algorithm Theoretical Basis Document
CCI	Climate Change Initiative
CCI-Biomass	Climate Change Initiative – Biomass
CEOS	Committee on Earth Observation Satellites
CEOS-WGCV	Committee on Earth Observing Satellites Working Group on Calibration and Validation
CMC	Climate Modelling Community
CMUG	Climate Modelling User Group
CRS	Coordinate Reference System
DARD	Data Access Requirements Document
DEM	Digital Elevation Model
DLR	Deutsches Zentrum für Luft- und Raumfahrt
ECV	Essential Climate Variables
EEA	European Environmental Agency
ENVISAT	ESA Environmental Satellite
EO	Earth Observation
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESM	Earth System Model
FAO	Food and Agriculture Organization
GCOS	Global Climate Observing System
GCS	Geographic Coordinate System
GDAL	Geospatial Data Abstraction Library
GFED	Global Fire Emissions Database
GlobCover	ESA DUE project
GLWD	Global Lakes and Wetlands Database
GTOS	Global Terrestrial Observing System
HH	Horizontal-Horizontal
HV	Horizontal-Vertical
ICESAT GLAS	Ice, Cloud, and land Elevation Satellite Geoscience Laser Altimeter System

IIASA	International Institute of Applied Systems Analysis
IMS	Interactive Multisensor Snow and Ice Mapping System
JAXA	Japan Aerospace Exploration Agency
JRC	Joint Research Centre
L1, L2, L3	Level 1, Level 2, Level 3 etc.
LC	Land Cover
LCCS	Land Cover Classification System
MERIS	Medium Resolution Imaging Spectrometer
MMU	Minimum Mapping Unit
MVC	Maximum Value Composite
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NSIDC	National Snow and Ice Data Center
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PFT	Plant Function Type
PSD	Product Specification Document
PUG	Product User Guide
PVASR	Product Validation and Algorithm Selection Report
PVP	Product Validation Plan
S1, S2	Sentinel-1, Sentinel-2
SAR	Synthetic Aperture Radar
SLC	Single Look Complex
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 Dataset
TM	Thematic Mapper
UNFCCC	United Nations Framework Convention on Climate Change
UR	User Requirement
USGS	United States Geological Survey
WGS84	World Geodetic System 84
WSM	Wide Swath Mode
WWF	World Wildlife Fund

1. Introduction

1.1. Purpose and scope

This document provides a summary of the products from the CCI-Biomass project. Its main content is contained in two summary tables relating to a) Above Ground Biomass (AGB) and Growing Stock Volume (GSV) products and b) the AGB change product. Although the AGB products are well-specified, there has been no in-depth discussion about the desired properties of the change product or what it should comprise. Hence this document should still be regarded as an interim summary.

2. The AGB product

Table 1 summarises our current understanding of the AGB products to be generated in CCI-Biomass. These are consistent with the major recommendations from the climate and carbon cycle modelling communities as expressed during the First User Workshop and set out in the User Requirements Document (D1.1). The spatial resolution required for the REDD+ community is not a target for CCI-Biomass, though in most other respects the proposed products are acceptable to them.

A potentially difficult issue for the AGB products is provision of information on bias (which is a concern for almost all ECVs). This is strongly related to the validation component of the project and cannot be considered independently of spatial resolution, since bias could vary with resolution. The precision of the products is easier to estimate but is of less concern to the modellers since many of them are principally interested in grid-cell values, in which case pixel averaging can be used to provide more precise estimates of the mean. Note that for most modellers, the locations of sub-grid-cell AGB estimates within a grid-cell are not needed. However, for models using age or biomass cohorts, the histogram of AGB values within a grid-cell is of major interest. Currently we have no specification of how accurate the histogram would need to be, or what the appropriate accuracy measure would be.

Table 1: Product specifications for AGB products.

Product	Map of forest aboveground biomass (AGB; Mg ha^{-1}). Maps of precision for both products
Spatial Coverage	Global
Pixel spacing	100 m x 100 m
Temporal Extent	Three time periods: 2010, 2017 and 2018

Reference System	Lat-Long, WGS-84
Accuracy	Accuracy should be higher than existing maps. AGB estimates should be unbiased but if this cannot be achieved with current sensors, information on likely bias will be provided.
Data format	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer
Delivery mode	CCI Open Data Portal
Product support	• Fully documented mapping methods (i.e., the ATBD) • Robust and standardised validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate AGB and validation • Free and open access

3. The AGB change product

Changes in AGB are of major importance for climate as increases are associated with carbon sinks and sources respectively and hence changes in the overall amount of atmospheric carbon. However, measurement of change using any form of remote sensing data (including Synthetic Aperture Radar; SAR) is not well developed because of sensor, data and algorithm deficiencies. For SAR, two suggested approaches are to (i) generate and difference AGB maps and (ii) measure differences in the SAR signal and establish a link with AGB change.

Differencing AGB maps was studied during the GlobBiomass project where it was noted that quantifying the error statistics in the AGB difference product is crucially dependent on knowledge of the distribution of the error statistics of the AGB product itself. The precision of the AGB difference will be given by the square root of the sum of the variances of the individual AGB measurements, so will be larger than the precision of either of the two input AGB values. The bias will be the difference of the biases in the two AGB measurements, so can be larger or smaller than either of the two individual biases. The ability to calculate confidence intervals on the AGB difference depends on whether the precision in the individual AGB measurements varies with AGB. Hence progress with describing the accuracy of AGB change measured using AGB differencing relies on the findings from the validation element of CCI-Biomass.

Measuring differences in the SAR signal and establishing a link with AGB change is statistically much more firmly grounded, as there has been extensive work on detecting and measuring changes in both single and multi-channel radar signals. The difficulty is then to attribute change to AGB change and the size of that change, and these issues have not been extensively studied.

Changes in AGB over annual (2017 to 2018) and decadal (2010-2017 or 2018) can be associated with a range of **events and processes** that have occurred over these periods. Based on a change taxonomy being developed that supports CCI Biomass, **AGB gains** are associated with increases in the amount of vegetation, such as those linked to afforestation, reforestation (both natural and plantations), recovery from wildfires, revegetation, vegetation encroachment and restoration and succession. Most of these processes take place over fairly long time-scales and are often difficult to discern in annual comparisons of Earth observation data or derived products. **AGB losses** are decreases in the amount of vegetation, which can be natural (wind damage, prescribed burns, wildfires, or dieback following storms) or human-induced events (e.g., deforestation, selective logging, thinning). These are sometimes followed by recovery and hence increase in vegetation. Processes causing AGB reduction include dieback (from storms, sea level fluctuation, inundation, droughts, insects, pathogens or herbivory) and desertification. In general, events are easier to detect through annual comparisons (i.e., 2017 to 2018 in the context of CCI Biomass) but longer term processes may be best detected through multi-annual or decadal comparisons (i.e., 2010 to 2017/18). Each of these change events and processes (whether leading to a loss or gain in AGB) will be detectable to differing degrees using SAR data and current efforts aim to better define these and the extent to which they can be mapped.

In the above, AGB change has been treated as a quantity to be estimated at each pixel, but for modelling it may be more useful to consider changes in the histogram of AGB values within a grid-cell. Such an approach has attracted little attention up to now and its development needs both provision of methods and interaction with the modelling community to establish the best way forward.

It is against this background that Table 2 summarises our current understanding of the AGB change products to be generated in CCI-Biomass.

Table 2: Current product specifications for AGB change products.

Global AGB change product specifications		
	Threshold (minimum) Requirements	Target Requirements
Product	Maps of forest AGB change (Mg ha^{-1})	Maps of forest AGB change
Spatial Coverage	Global	Global
Pixel spacing	1 km x 1 km or at grid-cell level	100 m x 100 m or at grid-cell level
Temporal Extent	Changes for two time intervals: between 2010 and the 2017-2019 period and between 2017-2018 and 2018-2019	As for threshold.
Reference System	Lat-Long, WGS-84	Lat-Long, WGS-84
Accuracy	Currently not specified and may need different specifications for pixel values and grid-cell histograms.	As for threshold, but validated products are required.

	Estimates of AGB change should be unbiased, which has different meanings for pixel values and grid-cell histograms. Methods to validate the product are currently undefined.	
Data format	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer
Delivery mode	CCI Open Data Portal	CCI Open Data Portal
Product support	• Fully documented change mapping methods (i.e., the ATBD) • Validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate validate biomass change. • Free and open access	• Fully documented change mapping methods, • Robust and standardised validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate validate biomass change. • Free and open access • Access to underlying data

4. Conclusions

The properties of the CCI-Biomass AGB product are well specified but characterisation of possible bias continually improves as the algorithm development and validation components become more consolidated. The specification of the AGB change product is less clear, as currently the meaning of AGB change (i.e., whether based on pixels or grid-cell histograms) in the context of climate and carbon models needs more discussion and interaction with the modellers. This will have major impact on the methods to be adopted and the description of error metrics. For the pixel-based approach, there is still uncertainty about whether approaches based on differencing AGB estimates or measuring signal change and attributing this to a quantitative value of AGB change will be more effective. Information from the validation WP of the CCI-Biomass project will be crucial for specification of the accuracy of both AGB and AGB change products.