ESA Climate Change Initiative – Fire_cci
D1.4 – Data Access Requirement Document (DARD)

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Summary

This document is the Data Access Requirements Document (DARD) for the Fire_cci project and it refers to the Task 6, Work Package 6400. The document includes a full list of data sources that are necessary for the generation of the BA maps, namely input images (with the detailed level of required processing), information auxiliary data, and validation data.

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Accepted	ESA - Technical Officer	Stephen Plummer	30/11/2017

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Document Status Sheet

Issue	Date	Details
1.4	22/02/2011	First Document Issue
1.5	03/05/2011	Upgraded issue
1.7	13/05/2011	Minor adaptations
2.0	01/12/2015	New version, first corresponding to Phase 2 of Fire_cci
2.1	01/02/2016	Minor corrections requested by ESA
2.2	11/08/2016	Minor adaptations
2.3	30/12/2016	Addressing ESA comments according to CCI-FIRE-EOPS-MM-16-0130
2.4	30/09/2017	Update of the document
2.5	30/11/2017	Addressing ESA comments according to CCI-FIRE-EOPS-MM-17-0089

Document Change Record

Issue	Date	Request	Location	Details
1.5	03/05/2011	UAH	Whole version	Revision following receipt of review comments from Stephen Plummer (ESA) and CCI-fire team members
1.7	13/05/2011	UAH	Whole document	Minor adaptations
2.0	01/12/2015	UAH	Whole document Page 2 Whole document	New format and layout Inclusion of team members of Phase 2 Whole re-writing of the document
2.1	01/02/2016	ESA	Sections 1, 2.1, 3.1, 3.2, 3.3, 3.4, 4, 4.3, 4.4, 5.1.1, 5.2.1, 5.2.2, 6.2, 6.3, 6.4 Sections 3.1 Annex 1	Minor changes in the text New paragraph added at the end of the section. New acronyms were added
2.2	11/08/2016	UAH	All document Section 2.1 Section 2.4 Section 3.2	Update of hyperlinks. Reference to Landsat 8 removed. Section deleted Inclusion of MOD09GA and MYD09GA in the list, and information on the tiling system

Issue	Date	Request	Location	Details
				of the images. New figure added.
			Section 3.3	Minor changes in the text.
			Section 3.4	New SLSTR products added.
			Section 4.1	Sentinel-1 status and product to use updated.
			Section 4.3	Reference to the use of L8 images for the small fire dataset deleted, as S2 images are already available.
			Section 5.1.1	Minor changes in the text.
			Section 5.2.1	Deleted repeated hyperlink.
			Section 6.3	Land Cover CCI acronym changed to LC_cci. New text added.
			Section 6.5	New reference added.
			Section 7 Acronyms	New acronyms added.
2.3	30/12/2016	ESA	Sections 2.1, 3.3, 3.4, 4.1, 5.1.1, 5.1.2	Minor changes in the text.
			Section 3.1	The information was re-organized.
			Section 3.2	Updated text.
			Section 6.2	Last paragraph deleted.
			Sections 6.3 and 6.5	Information added to explain the use of the auxiliary data in the BA production.
			Section 7	References updated.
			Annex 1	Acronyms added.
2.4	30/09/2017	UAH	All document	Hyperlinks updated
			Sections 1, 2.1, 4, 4.1, 5.2.3, 5.2	Minor changes in the text
			Section 3.2	Removed reference to the use of Aqua products
			Section 3.5	New section added to address the use of the AVHRR-LTDR data
			Section 6.2	Minor changes in the text, and figure removed.
			Section 6.3	Section updated
			Section 6.5	Last paragraph removed
			Section 7	References added
2.5	30/11/2017	ESA	Sections 2.1 and 2.3	Changed from applicable document to reference document
			Section 3.2	Corrected missing reference
			Sections 3.3 and 3.4	Updated the characteristics of the products used in Fire_cci.
			Section 3.5	Included new information on the product. Sub-section on the product used in Fire_cci added.
			Section 4.1	Clarified the product used within the project.
			Section 4.2	Included more information explaining the characteristics of the available products. Added sub-section on the products use within the project.
			Section 4.3	Information related to the use of other Landsat missions apart from L8 has been included. Description of the data expanded.
			Sections 4.4 and 6.5	Updated information on product used for Fire_cci.

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1. Executive Summary

The DARD describes all data (input, reference and auxiliary data) necessary to perform the Fire_cci Phase 2 project. The document compiles in a systematic manner sources of data, data characteristics, ordering and delivering mechanisms, identification of access conditions and pricing.

The input satellite data for the Fire_cci Phase 2 project are ENVISAT MERIS FRS, MODIS TERRA, Landsat-8 OLI, PROBA-V, Sentinel-3 OLCI and SLSTR, Sentinel-2 MSI and Sentinel-1 SAR. For Option 2, LTDR from NOAA-AVHRR sensors is used as well. For European sensors, raw data are previously pre-processed, i.e. geometrically, radiometrically and atmospherically corrected (for NASA sensors, our process starts from corrected reflectances). Land-sea masking, cloud masking and snow and ice detection is applied to data using auxiliary information (e.g. digital elevation model, land covers, water masks, etc.).

The reference data consist mainly of Landsat TM/ETM+ and OLI obtained from the USGS database. In addition, fire perimeters from national forest services, when available, are used as a preliminary validation exercise when calibrating the algorithms. However, reference fire perimeters for validation are only extracted from multitemporal satellite imagery, following CEOS CalVal standards (Padilla et al., 2014).

2. Introduction

2.1. Overview

Following the Fire_cci project goals (RD-1), algorithms are being developed and validated to generate consistent, stable, multi-sensor, and error-characterized global burned area (BA) products. The BA products are developed at two levels of spatial detail:

- Coarse resolution, global coverage, continuous time series, based on Envisat MERIS, Terra MODIS sensor and Sentinel-3 OLCI and SLSTR data.
- Medium resolution, continental coverage, short time series (starting from 2016), based on Sentinel-2 MSI, Sentinel-1 SAR and PROBA-V 100-300 m resolution.

The pre-processing chain is being developed for European sensors to provide the best possible geometrical and radiometric accuracy. The production of BA products includes global coverages of the full time series of MERIS and MODIS sensors (2001-to present).

2.2. Purpose of the document

The Data Access Requirements Document (DARD) identifies data and conditions under which these data are made accessible. Accordingly, each data source includes information about the originating system, identification of the data class (e.g. in-situ, EO, model), specification of the sensor type and key technical characteristics, information about data availability and coverage (time-scale, geographic, temporal), source data product name & reference to product technical specifications documents. It also includes a description of the ordering and delivery mechanism, identification of access conditions and pricing.

2.3. Applicable Documents

(RD-1)	Phase 2 of the Climate Change Initiative (GMECV) Request for Quotation RFQ/3-14286/15/I-NB ECV Fire Disturbance, Proposal prepared by University of Alcala (UAH, Spain) on July 24, 2015, in association with UAH's project partners.

3. Input satellite data for producing coarse resolution Burned Area products

This section describes the input data for the pre-processing chain including the source of data, the ordering and delivering mechanisms as well as the access conditions.

3.1. MERIS

The Medium Resolution Imaging Spectrometer (MERIS) formed part of the core instrument payload of ESA's environmental research satellite ENVISAT, which was active between March 2002 and April 2012, when the satellite was unexpectedly lost. ENVISAT flew on a sun-synchronous orbit with a mean altitude of 799.8 km and an inclination of 98.55º. The orbit time was 100.6 minutes with a repeat cycle of 35 days. MERIS crossed Equator at 10:00 solar time.

The MERIS sensor was originally conceived for oceanographic applications, particularly to retrieve ocean colour. For this reason, the sensor incorporates several bands in the blue and green regions of the electromagnetic spectrum, as they are closely related to chlorophyll content. As MERIS was mainly designed for ocean monitoring, the instrument is capable of detecting the low levels of radiation emerging from the water constituents. However, at the same time the instrument has a high dynamic range in order to detect bright objects (clouds, snow).

MERIS was a wide field-of-view push-broom imaging spectrometer with a swath width of 1150 km (field-of-view (FOV) = 68.5°) measuring the solar radiation reflected by the Earth in 15 spectral bands from 412.5 nm to 900 nm. All bands were programmable in width (variable between 1.25 and 30 nm) and position, but were fixed before launch in response to the recommendations of the Science Advisory Group (SAG) for the main period of the mission (see Table 1). MERIS allowed global coverage of the Earth in 3 days. Each MERIS pixel had a field of view of 0.019 degrees, which implied that pixel size varied in the across track direction, between 0.26 km at nadir and 0.39 km at swath extremities. Along-track sampling was close to 0.29 km. MERIS had the capability to output data sampled at the Full Resolution (FR) with the spatial sampling described above, and Reduced Resolution (RR) data sub-sampled at 1.2 km. The following products are available at ESA:

- MERIS Reduced Resolution Geolocated and Calibrated TOA Radiance (MER_RR_1P)
- MERIS Full-Resolution Geolocated and Calibrated TOA Radiance (MER_FR_1P)
- MERIS Full Resolution Full Swath (MER_FRS_1P)

Product used in Fire_cci:

For the Fire_cci Phases 1 and 2, the FRS format is the source of MERIS data. The generation of the Full Resolution Full Swath product (MER_FRS_1P) was introduced in

the processor IPF version 4.10, installed in January 2005. This new product was made of 4481 pixels per line. The resulting file size was 500 Mbytes.

Multiple kinds of MERIS data are available on the online data storage of Brockmann Consult GmbH (BC), who is responsible for the system engineering of the Fire_cci Phase 2 project. These are:

- MER_FSG_1P – geo-corrected Full-Resolution Level-1
- MER_RRG_1P – geo-corrected Reduced-Resolution Level-1
- MER_RR__1P – 3rd re-processed Reduced-Resolution Level-1

The MER_FSG_1P is the source of MERIS data for the Fire_cci Phase 2 project. This product is obtained from the MER_FRS_1P official ESA product, using the Accurate MERIS Ortho-Rectified Geo-location Operational Software (AMORGOS) available from ESA. The 8 and 10 bands of MERIS from Table 1 are used for the BA algorithm following conclusions gained from Fire_cci Phase 1.

Table 1: Specification of the 15 MERIS channels recommended by the Science Advisory Group (SAG)

MERIS Band Number	Centre Wavelength (nm)	Bandwidth (nm)	Application
1	412.5	10.0	Yellow substance and detrital pigments
2	442.5	10.0	Chlorophyll absorption maximum
3	490.0	10.0	Chlorophyll and other pigments
4	510.0	10.0	Suspended sediment, red tides
5	560.0	10.0	Chlorophyll absorption minimum
6	620.0	10.0	Suspended sediment
7	665.0	10.0	Chlorophyll absorption and fluorescence reference
8	681.5	7.5	Chlorophyll fluorescence peak
9	708.75	10.0	Fluorescence reference, atmospheric corrections
10	753.75	7.5	Vegetation, cloud
11	760.625	3.75	Oxygen absorption R-branch
12	778.75	15.0	Atmosphere corrections
13	865.0	20.0	Vegetation, water vapour reference
14	885.0	10.0	Atmosphere corrections
15	900.0	10.0	Water vapour, land

More information on MERIS is available at: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/meris, last access September 2017.

3.2. MODIS VNIR

The Terra and Aqua platforms are part of the NASA Earth Observing System (EOS) programme (Parkinson et al., 2006), which includes several other platforms for terrestrial observations. Terra was launched in December 1999, and it is located in a near-polar, sun-synchronous orbit, crossing the equator at around 10:30 am. The orbital height is 705 km, with a period of 98.88 min and a repeat cycle of 16 days. It carries five sensors (MODIS, CERES, MISR, MOPITT, and ASTER) designed for global observations of critical land, oceans, and atmospheric variables. Aqua was launched in May 2002, and it has similar orbital characteristics as Terra, but with a lag period of 3 h and, therefore, crosses the equator at 1:30 pm. This satellite carries six sensors (AIRS,

AMSR-E, AMSU-A, CERES, HSB, and MODIS), with an instrument configuration oriented toward oceanographic studies.

The main sensor on board the two platforms is the Moderate-Resolution Imaging Spectroradiometer (MODIS). It acquires worldwide daily data from 36 different spectral bands, at different resolutions, from 250 to 1000 m. Bands 1 and 2 have finer spatial resolution (250 m) and include the red and NIR spectral wavelengths (Table 2). Another five bands are acquired at 500 m resolution, covering the visible and SWIR spectrum. All the other bands have 1000 m resolution and cover additional wavelengths in the visible, middle and thermal infrared spectral bands. The swath covered by MODIS is 2300 km, and observation frequency is daily (twice when the two satellites are accounted for). The MODIS programme was built around a wide range of scientists working together to obtain both calibrated radiances and final products. These products are grouped in three domains: Atmosphere products, including aerosol, total precipitable water, clouds, and atmospheric profiles; Land products: surface reflectance, surface temperature, land cover, vegetation indices, active fires, incoming radiation, evapotranspiration, plant productivity, albedo, burned areas, snow cover, and sea ice; and Ocean products, which include sea temperature, chlorophyll-a concentration, particulate carbon, fluorescence, and incoming photosynthetic radiation (http://modis.gsfc.nasa.gov/ last access in September 2017). MODIS images are free and can be accessed through the data distribution network of NASA (http://modis.gsfc.nasa.gov/tools/ last access September 2017).

Table 2: Specification of the MODIS VNIR channels

MODIS Band Number	Bandwidth (nm)	Spectral domain
B1	620-670	Red
B2	841-876	Near Infrared

Products used in Fire_cci:

Among the standard products, the Fire_cci project uses the reflectance for the visible and near infrared channels at 250 m, to have a similar spatial and spectral resolution to the MERIS data. Also, although there are currently some burned area products from MODIS developed at a spatial resolution of 500 m, such as the MCD64A1 (Giglio et al., 2009) and the MCD45A1 (Roy et al., 2008), there is no BA product at 250 m. Hence the objective of creating a product derived from MODIS but at this finer resolution.

Complementary to the 250 m data, some 500 m data will also be utilised: the bands corresponding to the solar and sensor angles, and the quality flags of the 250m-product, which are only available in the 500m-product.

From the standard list of NASA products for these channels, the following products will be used:

- Surface Reflectance Daily L2G Global 250m: MOD09GQ (Terra).
- Surface Reflectance Daily L2G Global 500m: MOD09GA (Terra).

These products are provided in a sinusoidal grid consisting of 460 non-overlapping tiles of approximately 10 degrees x 10 degrees in size (Vermote et al., 2011). Each tile is assigned a horizontal (h) and vertical (v) coordinate ranging from 0 to 35 and 0 to 17 respectively (Figure 1). The tile in the upper left corner is designated as h0,v0.

These products are freely available at https://lpdaac.usgs.gov/data_access/data_pool (last access September 2017). The standard geometric, radiometric and atmospheric corrections applied by the NASA MODIS team are used as input for the BA algorithm. Information on the pre-processing methods of these datasets can be found in each of the products webpages (all last access September 2017):

- MOD09GQ: https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod09gq_v006
- MOD09GA: https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod09ga_v006

The MODIS data is processed on third-party hardware (CEMS), under the responsibility of BC.

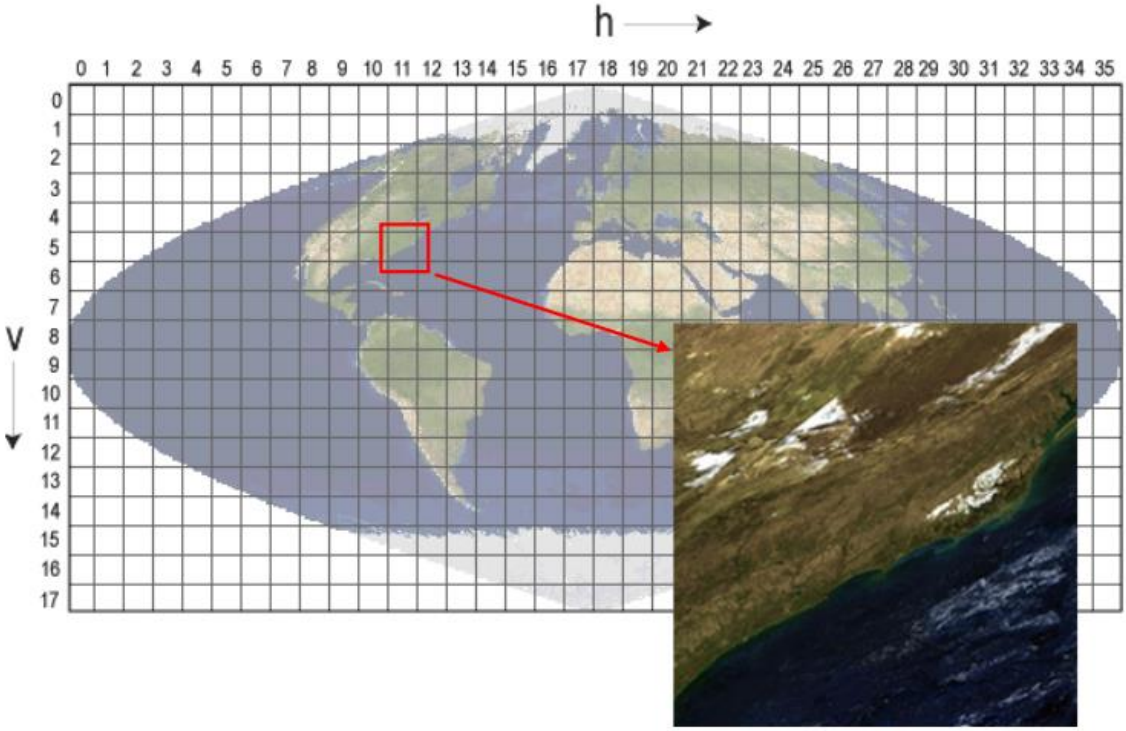

Figure 1: MODIS sinusoidal grid and an example tile (tile h11v05), extracted from Vermote *et al.* 2011

3.3. OLCI

The Ocean and Land Colour Instrument (OLCI) sensor is part of the Sentinel-3 (S-3) satellite. S-3 is primarily an ocean mission, but it is able to provide atmospheric and land applications, providing data continuity for the ERS, ENVISAT and SPOT satellites. The first Sentinel-3 (A) was launched on 16 February 2016, with a second satellite to be launched in 2018, on the same orbit but flown 180° out of phase. The orbit is sun-synchronous, with a height of 814.5 km, an inclination of 98.65° and a repeat cycle of 27 days, crossing the equator at around 10:00 am. Besides the OLCI sensor, Sentinel-3 includes 6 other instruments: SLSTR (see Section 3.4), SRAL, MWR, DORIS, LRR and GNSS.

The OLCI sensor is a follow up version of ENVISAT MERIS, and it includes the bands that were defined for the MERIS sensor. It is a push-broom instrument with 5 camera modules sharing the FOV, each one with a FOV of 14.2° and 0.6° with its neighbours.

The whole FOV is shifted across track by 12.6° away from the Sun to minimise the impact of Sun glint. It has a swath of 1270 km, and a native resolution of ~300 m, and it provides global coverage at the equator in 2-4 days with one satellite and in less than 2 days with two satellites.

The sensor has 21 bands, which characteristics are listed in Table 3. The FR product is computed with the native resolution of the sensor, with a RR processing mode also available with a resolution of ~1.2 km.

Different product types are distributed to the public (all links accessed in September 2017):

- Level-1B product: provides TOA reflectance for each pixel in the instrument grid, each view and each OLCI channel, both in full and reduced resolution, plus annotation data associated to OLCI pixels. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci/product-types/level-1b.
- Level-2 land products: provides land and atmospheric geophysical parameters computed for full and reduced resolution. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci/product-types/level-2-land.
- Level-2 water products: provides water and atmospheric geophysical parameters computed for full and reduced resolution. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci/product-types/level-2-water.

Table 3: Band characteristics of the Sentinel-3 OLCI

OLCI Band Number	Centre Wavelength (nm)	Bandwidth (nm)	Application
Oa1	400	15	Aerosol correction, improved water constituent retrieval
Oa2	412.5	10	Yellow substance and detrital pigments (turbidity)
Oa3	442.5	10	Chl absorption max., biogeochemistry, vegetation
Oa4	490	10	High Chl, other pigments
Oa5	510	10	Chl, sediment, turbidity, red tide
Oa6	560	10	Chlorophyll reference (Chl minimum)
Oa7	620	10	Sediment loading
Oa8	665	10	Chl (2nd Chl abs. max.), sediment, yellow substance/vegetation
Oa9	673.75	7.5	For improved fluorescence retrieval and to better account for smile together with the bands 665 and 680 nm
Oa10	681.25	7.5	Chl fluorescence peak, red edge
Oa11	708.75	10	Chl fluorescence baseline, red edge transition
Oa12	753.75	7.5	O2 absorption/clouds, vegetation
Oa13	761.25	2.5	O2 absorption band/aerosol corr.
Oa14	764.375	3.75	Atmospheric correction
Oa15	767.5	2.5	O2A used for cloud top pressure, fluorescence over land
Oa16	778.75	15	Atmos. corr./aerosol corr.
Oa17	865	20	Atmos. corr./aerosol corr., clouds, pixel co-registration
Oa18	885	10	Water vapour absorption reference band. Common reference band with SLSTR instrument. Vegetation monitoring
Oa19	900	10	Water vapour absorption/vegetation monitoring (max. reflectance)
Oa20	940	20	Water vapour absorption, atmos./aerosol corr.
Oa21	1 020	40	Atmos./aerosol corr.

Also, in combination with the SLSTR sensor (see Section 3.4), a group of Synergy (SYN) products will be created. These aim to combine the information of the OLCI and SLSTR instruments. The products that will be distributed to the public are (all links accessed in September 2017):

- Level-2 SYN product (SY_2_SYN): will contain surface reflectance and aerosol parameters over land, provided on the OLCI image grid, similar to the OLCI Level-1B product (~300m), for the sun-reflective channels of SLSTR (both in nadir and oblique view) and for all OLCI channels except bands Oa14, Oa15 and Oa20. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-synergy/product-types/level-2-syn.
- Level-2 VGP product (SY_2_VGP): will contain TOA reflectances at 1 km spatial resolution, provided on a regular latitude-longitude grid (called 1 km VEGETATION-like product) https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-synergy/product-types/level-2-vgp.
- Level-2 VG1 product (SY_2_VG1): will contain daily synthesis of surface reflectance, with the spatial resolution of the 1 km VEGETATION-like product, based on information of same channels of SPOT-VGT (B0, B2, B3 and MIR) produced with OLCI and SLSTR data. It will also contain NDVI information. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-synergy/product-types/level-2-vg1-v10.
- Level-2 VG10 product (SY_2_VG10): similar to the VG1, but with a 10-day synthesis surface reflectances and NDVI.

Products used in Fire_cci:

For Fire_cci the Level-2 SYN product were planned to be used. However, since at the end of 2017 this product is not yet fully tested neither publicly available, and considering the time frame of the Fire_cci phase 2 project, it was recently decided (telecon 15.11.2017) to start implementing the OLCI algorithm on TOA reflectances (L1), but also request from ESA the surface reflectances, at least from the equivalent bands to those used for the MERIS BA algorithm (B10 and B8).

Further information on the sensor can be found at https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci (last access September 2017).

3.4. SLSTR

The Sea and Land Surface Temperature Radiometer (SLSTR) is a dual view (near-nadir and backward views) conical imaging radiometer aboard Sentinel-3 satellites, which provides continuity to the ENVISAT AATSR instrument. Its dual view scan has a swath width of 1420 km at nadir and 750 km backwards.

The SLSTR has 6 bands in the visible and SWIR bandwidths with a resolution of 500 m, and another 3 bands in the medium and thermal infrared with 1000 m of resolution. Also, F1 and F2 fire bands are based on the same detectors as S7 and S8 but with an increased dynamic range to minimise saturation over fires.

Table 4 lists the characteristics of the bands. Further information on the sensor can be found at https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr (last access September 2017).

Table 4: Band characteristics of the Sentinel-3 SLSTR

SLSTR Band Number	Centre Wavelength (µm)	Bandwidth (µm)	Application	Resolution (m)
S1	0.555	0.02	Cloud screening, vegetation monitoring, aerosol	500
S2	0.659	0.02	NDVI, vegetation monitoring, aerosol	500
S3	0.865	0.02	NDVI, cloud flagging, Pixel co-registration	500
S4	1.375	0.015	Cirrus detection over land	500
S5	1.61	0.06	Cloud clearing, ice, snow, vegetation monitoring	500
S6	2.25	0.05	Vegetation state and cloud clearing	500
S7/F1	3.74	0.38	SST, LST, Active fire	1000
S8/F2	10.85	0.9	SST, LST, Active fire	1000
S9	12	1	SST, LST	1000

Different product types are distributed to the public (all links accessed in September 2017):

- Level-1B product: provides TOA radiances and brightness temperatures for each pixel in the instrument grid, each view and each SLSTR channel, plus annotations data associated with SLSTR pixels. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/product-types/level-1b.
- Level-2 WST product: provides L2P sea surface temperature, following the Group for High Resolution Sea Surface Temperature (GHRSST) specifications. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/product-types/level-2-wst.
- Level-2 LST: provides land surface parameters generated on the wide 1 km measurement grid. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/product-types/level-2-lst.
- Level-2 FRP and AOD products: provides fire radiative power and aerosol optical depth. https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-slstr/product-types/level-2-frp-aod.

Products used in Fire_cci:

As there is no SLSTR 500 m product that will provide surface reflectance (the Level-1B product is TOA and not TOC), Fire_cci planned to use the SY_2_SYN product described in Section 3.3. However since at the end of 2017 this product is not yet fully tested neither publicly available, and considering the time frame of the Fire_cci phase 2 project, it was recently decided (telecon 15.11.2017) to start implementing the SLSTR algorithm on TOA reflectances (L1), but also request from ESA to compute the surface reflectances.

3.5. AVHRR-LTDR

Option 3 complements the baseline project by backward extending BA products to the early 80's using AVHRR data. The Advanced Very High Resolution Radiometer (AVHRR) has been on board the NOAA satellites since 1979 (Cracknell 1997). It includes five bands (red, near infrared, middle infrared and two thermal infrared) at 1.1 km resolution (at nadir), acquiring two images everyday globally (actually four, since two satellites have been working simultaneously most of the mission life). At the beginning of the NOAA mission, the AVHRR full resolution data were only available for certain areas with their own receiving antennas, and not always digitally recorded. For this reason, there are not reliable archives to build global mosaics for the first ten

years of the AVHRR acquisition period (1979-1989). However, in addition to the full resolution mode, the AVHRR sensor acquired a degraded version (4 km), named global area coverage (GAC), which does have global coverage since almost the beginning of the mission.

Based on GAC data, NASA created a global-full time series of AVHRR at 0.05° resolution (approx. 5 km), named the long-term data record (LTDR) dataset. Since the LTDR includes systematic geometric and radiometric corrections, Option 3 of the Fire_cci project proposed to base the detection of BA from this dataset. There are various others long-term coarse AVHRR data series (GIMMS or Pathfinder), whose strengths and weaknesses have been cross validated, as reported in the literature (Alcaraz-Segura et al. 2010; Tucker et al. 2005).

The pre-processing includes radiometric in-flight vicarious calibration for the visible and near infrared channels and inverse navigation to relate an Earth location to each sensor instantaneous field of view (FOV). Atmospheric corrections for Rayleigh scattering, ozone, and water vapour are undertaken, with aerosol correction being implemented. The LTDR also produces a surface reflectance product for channel 3 (3.75 µm).

Version 5 is the latest product available, released on August 2017. This version improves the previous one regarding BRDF correction, flagging of band scans in the QA, the compositing of the images, and gas transmission correction coefficients. This version also solves a temporal instability in the product, caused by the change from the use of AVHRR2 prior to 2001 and AVHRR3 from that day on.

The AVHRR-LTDR V5 products for the 1981-2016 time period are:

- Surface reflectance:
  - SREFL_CH1 (0.5 – 0.7 µm)
  - SREFL_CH2 (0.7 – 1.0 µm)
  - SREFL_CH3 (3.55 – 3.93 µm)*
- TOA brightness temperature:
  - BT_CH3 (3.55 – 3.93 µm)*
  - BT_CH4 (10.3 – 11.3 µm)
  - BT_CH5 (11.5 – 12.5 µm)
- View zenith angle (VZEN), Solar zenith angle (SZEN).
- Relative azimuth (RELAZ).
- Quality Assessment Field (QA).
- Satellites used to generate the LTDR dataset are the following:
  - N07: 1981 – 1985
  - N09: 1985 – 1988
  - N11: 1988 – 1994
  - N14: 1985 – 1999
  - N16: 2000 – 2005
  - N18: 2005 – 2009
  - N19: 2009 – 2017

A detail of the availability of data is shown in Figure 2. Most of the data gaps that existed in version 4 have been solved, and now very few data gaps remain.

Further information on the product is available at https://ltdr.modaps.eosdis.nasa.gov/cgi-bin/ltdr/ltdrPage.cgi (last access November 2017).

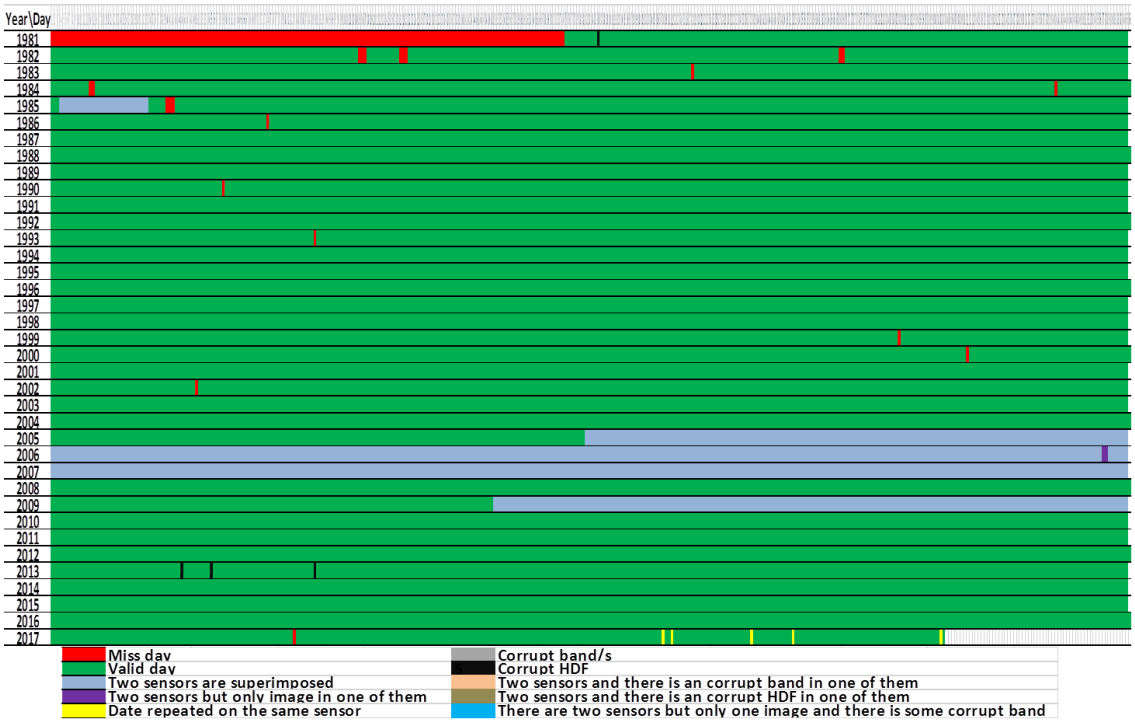

Figure 2: Availability of LTDR v5.0 daily images for the full time series

Products used in Fire_cci:

Due to the characteristics described above, the AVHRR LTDR version 5 data series was chosen and proposed as the baseline data set for Option 3. This product can be freely downloaded from ftp://ltdr.nascom.nasa.gov/allData (last access November 2017).

4. Input satellite data for producing medium resolution Burned Area products

The generation of the small-fire database requires access and processing of medium resolution data, which will be primarily acquired by ESA sensors (Sentinel-2 and, for cloud regions, Sentinel-1). The geographical location of the data corresponds to the African Continent.

4.1. Sentinel-2 MSI

The Sentinel-2 (S-2) satellite is part of the Copernicus initiative of the ESA/European Commission (previously called GMES - Global Monitoring for Environment and Security). The satellite was launched in June 2015, as a continuation of the Landsat and SPOT series. This satellite is designed for applications such as land cover use and change detection, geophysical variables analysis, risk mapping and disaster relief. A second satellite (Sentinel-2B) was launched March 2017.

S-2 has a sun-synchronous orbit at 786 km mean altitude and an inclination of 98.62°, crossing the equation at 10:30 am at descending node. S-2B has the same orbit but phased at 180°, to give a revisit frequency of 5 days at the equator with both satellites. It provides land coverage between -56° and +83° latitude, with a geo-location of 20 m without ground control points.

S-2 carries the MultiSpectral Instrument (MSI), a push broom medium-resolution sensor with 13 spectral bands of different spatial resolution, and a swath of 290 km. The characteristics of the bands are detailed in Table 5.

There are several product types available for public use:

- Level-1B product: TOA radiances in sensor geometry. One granule represents the sub-image one of the 12 detectors in the across track direction (25 km), and contains a given number of lines along track (approximately 23 km). Each Level-1B granule has a data volume of approximately 27MB.
- Level-1C product: TOA reflectances in fixed cartographic geometry (combined UTM projection and WGS84 geodetic system). Level-1C images are a set of tiles of 10.000 km^2 and approximately 500 MB, and contain applied radiometric and geometric corrections (including orthorectification and spatial registration).
- Level-2 product: Bottom-of-atmosphere reflectances delivered in UTM WGS84 coordinates. It provides 100x100 km^2 tiles with a data volume of approximately 600 MB. This product is currently made available at the user's side via a Sentinel-2 ESA toolbox (http://step.esa.int/main/download/, last access September 2017).

Table 5: Band characteristics of the Sentinel-2 MSI

MSI Band Number	Centre Wavelength (nm)	Bandwidth (nm)	Resolution (m)
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	783	20	20
8	842	115	10
8a	865	20	20
9	945	20	60
10	1380	30	60
11	1610	90	20
12	2190	180	20

Products used in Fire_cci:

Level-1C user products are available through the Sentinel Scientific Data Hub (https://scihub.copernicus.eu/, last access September 2017) free of cost. This data is being systematically downloaded by BC for pre-processing and use in the Small Fires Database algorithm. BC uses an API Hub application for machine-to-machine downloading of MSI data to speed up the connections. The full 2016 MSI available data will be processed for Sub-Saharan Africa.

4.2. Sentinel-1 SAR

The ESA continued Radar observations after the launch of the Sentinel-1A (S-1) satellite in 2014, which is part of the Copernicus Operational Services being developed by the agency. S-1 orbits at 693 km with an inclination of 98.18° and a repeat cycle of 12 days at the equator, crossing the equator at 6:00 pm at ascending node. A second satellite with the same instruments, Sentinel-1B, was successfully launched on April 25th 2016, in the same orbit but separated by 180° from Sentinel-1A, reducing the global repeat viewing cycle to 6 days.

S-1 includes a C-Band SAR instrument with a centre frequency of 5.405 GHz and polarizations VV, VH, HH and HV. It has an incident angle of 20°-45°, and a radiometric accuracy of 1 dB.

There are four nominal operational modes designed for inter-operability with other systems:

- Strip Map Mode with 80 km swath and 5x5 m (range x azimuth) spatial resolution
- Interferometric Wide-Swath Mode with 250 km swath, 5x20 m (range x azimuth) spatial resolution and burst synchronisation for interferometry
- Extra-Wide-Swath Mode with 400 km swath and 20x40 m (range x azimuth) spatial resolution
- Wave Mode with 5x5 m (range x azimuth) spatial resolution leap-frog sampled images of 20x20 km at 100 km along the orbit, with alternating 23º and 36.5º incidence angles.

S-1 products are provided for download via HTTP in .ZIP archive file format through the Sentinels Scientific Data Hub (https://scihub.copernicus.eu/, last access September 2017) free of cost. The products available there are Level-0 and Level-1 for Strip Map Mode, Interferometric Wide Swath Mode and Extra Wide Swath Mode, and Level-2 for Wave Mode, Interferometric Wide-Swath Mode and Extra Wide Swath. The general characteristics of each level are:

- Level 0: consist of the sequence of Flexible Dynamic Block Adaptive Quantization compressed unfocused SAR raw data. For the data to be usable, it will need to be decompressed and processed using focusing software.
- Level 1 are produced as:
    - Single Look Complex (SLC): consist of focused SAR data geo-referenced using orbit and attitude data from the satellite and provided in zero-Doppler slant-range geometry. The products include a single look in each dimension using the full TX signal bandwidth and consist of complex samples preserving the phase information.
    - Ground Range Detected (GRD): consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Phase information is lost. The resulting product has approximately square resolution pixels and square pixel spacing with reduced speckle at the cost of reduced geometric resolution.
- Level 2 are ocean products, and include components for Ocean Swell spectra, Ocean Wind Fields and Surface Radial Velocities.

Products used in Fire_cci:

Level-1 products are used within the Fire_cci project. Images from 2016 are used for the SFD test in the Northern Hemisphere Tropical Africa. For the CCN1 test over Indonesia, images from 2015 and 2016 will be used, to better analyse the impact of the important El Niño event of 2015. For option 3, images from 2017 will be used, as images from Latin America are scarce for 2016. In all cases, the data used is Interferometric Wide-Swath Mode. For Africa, SLC data is used to obtain coherence data, while GRD data is used for the South American and Indonesian algorithms.

4.3. Landsat

The Landsat mission has been the most widely used remote sensing mission for land applications since the first launch in 1972. The most recent platform, Landsat-8 (L-8) was developed to serve as a continuity mission of previous satellites, and therefore incorporates similar characteristics to the sensors on board Landsat-5 to 7. The satellite was launched in February 2013. L-8 orbits the earth at 705 km, with a revisit frequency of 16 days.

L-4 and L-5 carried the Thematic Mapper (TM) sensor, and images consist of six spectral bands with a spatial resolution of 30 meters for Bands 1-5 and 7, and one thermal band (Band 6). The Enhanced Thematic Mapper Plus (ETM+) sensor is carried on Landsat 7, and images consist of seven spectral bands with a spatial resolution of 30 meters for Bands 1-5, and 7. The resolution for Band 8 (panchromatic) is 15 meters. The approximate scene size is 170 km north-south by 183 km east-west for both sensors. A summary of the characteristics of the bands is shown in Table 6.

Table 6: Landsat 4-5 TM and 7 ETM+ characteristics

Band number	Spectral region	Landsat TM sensor		Landsat ETM+ sensor	
		Wavelength (µm)	Spatial resolution (m)	Wavelength (µm)	Spatial resolution (m)
1	Blue	0.45-0.52	30	0.45-0.52	30
2	Green	0.52-0.60	30	0.52-0.60	30
3	Red	0.63-0.69	30	0.63-0.69	30
4	Near infrared	0.76-0.90	30	0.77-0.90	30
5	SWIR1	1.55-1.75	30	1.55-1.75	30
6	Thermal	10.40-12.50	120* (30)	10.40-12.50	60* (30)
7	SWIR2	2.08-2.35	30	2.09-2.35	30
8	Panchromatic	-	-	0.52-0.90	15

* Band 6 was acquired at the lower resolution shown in the table, but products are resampled to 30-metre pixels.

L-8 includes two sensors on board, the Operational Land Imager (OLI) and the Thermal InfraRed Sensor (TIRS) (Table 7). The former is a successor of the ETM+, although it includes the push-broom technology and two additional bands, with a swath of 185 km, while the TIRS is also a push-broom instrument and contains two bands in the thermal infrared at lower spatial resolution than the other bands (100 versus 30 m for the multispectral and 15 m for the panchromatic). Both sensors have a high signal-to-noise ratio and have a radiometric resolution of 12-bits. The sensor incorporates two new bands over the TM/ETM+: a deep-blue band (#1) for better discrimination of coastal waters and aerosol studies, and a cirrus cloud band (#9) to improve atmospheric correction.

The Landsat standard data products comprise the:

- Level-1 standard data product: processed to standard parameters, and distributed as scaled and calibrated digital numbers (DN). The data are radiometrically calibrated and orthorectified using ground control points and digital elevation model data to correct for relief displacement. For further information see https://landsat.usgs.gov/landsat-level-1-standard-data-products (accessed November 2017).
- Level-2 Surface Reflectance: atmospherically corrected Level-1 products. For further information refer to https://landsat.usgs.gov/landsat-surface-reflectance-data-products (accessed November 2017).

Table 7: Landsat-8 OLI and TIRS characteristics

Sensor	Band number	Wavelength (µm)	Spectral region	Spatial resolution (m)
OLI	1	0.43-0.45	Deep blue	30
	2	0.45-0.51	Blue	
	3	0.53-0.59	Green	
	4	0.64-0.67	Red	
	5	0.85-0.88	Near infrared	
	6	1.57-1.65	SWIR1	
	7	2.11-2.19	SWIR2	
	8	0.50-0.68	Panchromatic	15
	9	1.36-1.38	SWIR3	30
TIRS	10	10.60-11.19	Thermal Infrared1	100
	11	11.50-12.51	Thermal Infrared2	

Products used in Fire_cci:

The Surface Reflectance Level-2 data of L-8 were downloaded by EHU for calibrating the Sentinel-2 algorithm. UL used the same Level-2 data corresponding to L-4 to L-8 for the validation dataset (see Section 5.1.1). All products are freely available, and there are different sources of data, listed in Section 5.1.1.

4.4. PROBA-V

The PROBA-V satellite is an ESA satellite launched on May 2013, and it was designed to bridge the gap in space-borne vegetation measurements between SPOT-VGT (March 1998 – May 2014), ENVISAT (March 2002 - April 2012) and the Sentinel-3 satellites (the first launched in February 2016). The PROBA-V mission objective is to ensure continuity with the SPOT-VGT mission heritage. The PROBA-V mission had a design life time of 2.5 years, but the platform performance is well within requirements and in May 2015 it was decided to extend the mission with another 2.5 years. PROBA-V flies at an altitude of 820 km in a sun-synchronous orbit, with an inclination of 98.7° and a local overpass time at launch of 10:45 am (10:50 am as of August 2015, and as the satellite has no on board propellant, the overpass times are expected to gradually differ from the at-launch overpass time).

The VEGETATION instrument on board PROBA-V has a FOV of 102°, with a swath width of 2295 km. This swath width ensures a daily near-global coverage (90%), full global coverage at 300m resolution is achieved every 2 days. The central camera observes at 100 m nominal resolution, which covers a swath of about 517 km that ensures global coverage every 5 days. The instrument has four bands, detailed in Table 8.

The PROBA-V products available are:

- Segment products (L1C TOA): include geometric and radiometric processing.
- Synthesis products: include mapping and SWIR mosaicking onto WGS84 geographic projection, cloud and cloud shadow detection, snow/ice detection, atmospheric correction and compositing:
  - S1 (1-day syntheses): TOA and TOC
  - S10 (10-day syntheses): TOC, with starting days at the 1st, 11th or 21th day of a month. For months having 28, 29 or 31 days the S10 of the third synthesis comprises the remaining days of that month.

- S5 TOA and TOC: available for the 100 m product. PROBA-V 100 m S5 products are comparable with full-coverage 300 m S1 products and are not real syntheses. Due to the narrow swath of the 100 m camera, there is only overlap in observations for latitudes > 40°. This means that only poleward of this latitude compositing rules can be applied and that within ~40° S – 40° N the reflectances at one of the five days are given. The TIME grid dataset in the S5 files provides information at which day observations over
- S1 and S5 TOC NDVI for the 100 m product
- S10 TOC NDVI for the 300 m and 1 km product

PROBA-V products can be downloaded from the Product Distribution Portal at http://www.vito-eodata.be/PDF/portal/Application.html#Home (last access September 2017). The available products are:

- Segment products
- 1 km Synthesis products
- 300 m Synthesis products
- 100 m Synthesis products

The 1-km Synthesis and the older-than-1-month data are free of charge. The data is available in GeoTIFF and HDF5 format. More information of the PROBA-V processing steps can be found at http://proba-v.vgt.vito.be/en/product-types (last access September 2017).

Table 8: PROBA-V spectral and radiometric characteristics

PROBA-V Band NAME	Centre Wavelength (µm)	Bandwidth (µm)	SNR @ TOA [W $m^{-2}sr^{-1}$ μm^{-1}] at 300 m resolution
BLUE	0.464	0.440 – 0.487	177 @111
RED	0.655	0.614 – 0.696	598 @110
NIR	0.837	0.772 – 0.902	574 @106
SWIR	1.603	1.570 – 1.635	720 @20
Radiometric performance			
Absolute accuracy [%]		< 5	
Inter-channel accuracy [%]		< 3	
Stability [%]		< 3	
Geometric performance			
Geolocation mean accuracy (standard deviation) [m] for January-June 2015		BLUE: 60.69 (49.94) RED : 60.46 (50.78) NIR : 61.30 (50.52) SWIR: 61.86 (50.03)	

Products used in Fire_cci:

The data used for the Fire_cci project will be the S5-TOC product for the 100m resolution images for certain areas where MSI results are available, as a way to scale from the medium to the coarse resolution products. They will be downloaded from the Product Distribution Portal by BC for the same period and area of the Sentinel-2 data to be used for the generation of the Small Fires Database. BC will also be in charge of pre-processing the data.

5. Reference Data

5.1. Introduction

5.1.1. Sources of BA reference perimeter

To obtain the BA reference perimeters for the spatio-temporal validation of the BA products, multitemporal Landsat-TM/ETM+/OLI images are being used following the CEOS Cal/Val protocols that were used in the Fire_cci Phase 1 (Padilla et al., 2011; Padilla et al. 2014; Padilla et al. 2015).

The Surface Reflectance High Level Data Products (see Section 4.3) have been downloaded from the USGS given its availability and access (http://glovis.usgs.gov or http://earthexplorer.usgs.gov, both last accesses in September 2017). Images available can be listed and bulk downloaded. Those two characteristics are necessary for an appropriate sampling and efficient reference data generation.

No other archive has been found to have those characteristics. Special efforts have been made with the ESA Landsat archive from the Online Dissemination portal (https://earth.esa.int/web/guest/data-access/, last access September 2017), but all available images could not be retrieved as there is a limit (2000) in the number of images that can be listed, and hence it was not used. In any case the USGS database was found enough to retrieve the sampled areas designed by the statistically design sample.

5.1.2. Sample areas

A stratified random sample selected reference data from 2003 to 2015 at global scale. Specific details of the sampling strategy are included in the PVR and have been recently published (Padilla *et al.* 2017). As a summary, the strata were defined at three levels: yearly, according to the biomes and according to the level of BA extents. The sampling allocation was proportional to the BA in each stratum to maximise the efficiency of the sampling design. The final selection of reference sampling sites is included in Figure 3.

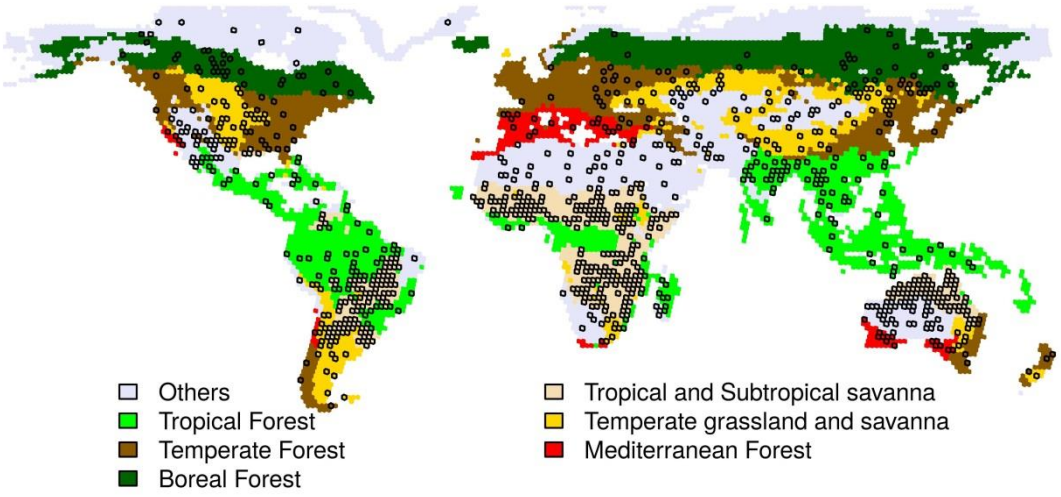

Figure 3: Spatial distribution of sampled units

5.2. Other sources of fire perimeters

As already mentioned, in addition to the high resolution satellite data fire perimeters when and where available were also used for comparison purposes. Although they

cannot be reliably used for strict validation, this information was useful to calibrate the BA algorithms in different ecosystems.

In the following sections source, means of acquisition and location of fire perimeters are described. All the data mentioned is free of charge.

5.2.1. Canada

Fire perimeters for the study site of Canada are obtained from the Canadian Wildland Fire information System, which includes the Canadian National Fire Database (CNFDB). Data consist on annual shape files, covering the whole area and are in Lambert Conformal Conic projection and in the geographic coordinate system GCS_North_American_1983.

The CNFDB (http://cwfis.cfs.nrcan.gc.ca/ha/nfdb, last access September 2017) contains annual fire perimeter data from 1980 to 2010 as submitted by the Canadian fire management agencies, including provinces, territories, and Parks of Canada. The data set includes fires of all sizes, and it is based on digitized and mapped wildfire reports collected from the agencies, based on field observations, aerial photography and Landsat imagery. It is worth noting that completeness and quality of data depend strictly on the agencies, which means that they vary from one agency to another and between years. The CNFDB is compiled and maintained by the Canadian Forest Service, a sector of Natural Resources Canada.

5.2.2. California (USA)

The California Department of Forestry and Fire Protection (CAL FIRE) provides the perimeters of fires occurred in the State of California through the Fire and Resources Assessment Program (FRAP). It consists of a GeoDatabase updated annually, with the latest release being Version 14_2, released in July 2015. The data covers fires back to 1878 and fires 10 acres (~4 ha) and greater. The GeoDatabase contains separate feature classes for wildfires, and for prescribed burns/fuel treatments. Detailed metadata is provided for each individual feature class. The database includes the fire perimeters contributed by CAL FIRE, USDA Forest Service Region 5, the Bureau of Land Management, the National Park Service, Contract Counties and other agencies, based on wildfire reports. The data can be downloaded from http://frap.fire.ca.gov/data/frapgisdata-sw-fireperimeters_download (last access September 2017).

5.2.3. EFFIS

Since 2004 the forest fire data provided each year by individual EU Member States and other European countries are checked, stored and managed by the Joint Research Centre (JRC) within the European Forest Fire Information System (EFFIS). At present the database contains fire data from 40 countries in European, Middle East and North Africa countries.

Data of the latest burned season can be obtained via Web Map Server (WMS) at http://forest.jrc.ec.europa.eu/effis/applications/data-and-services/ (last access September 2017), and the historical information is available upon request. Information from the European Fire database is available after approval of a data request. Maps on the number of fires for a selected year and for the countries for which data are available can be obtained from this service. BA perimeters are obtained by the rapid response database generated by EFFIS personnel, based on automatic and visual interpretation of MODIS R-NIR 250m images.

5.2.4. Australia

The North Australian Fire Information (NAFI) website (http://www.firenorth.org.au/nafi3/, last access September 2017) displays information about northern bushfires on a web-based map for north Australian fire managers. The bushfire information includes hotspots (locations of burning fires), fire scars (recently burned country), and other information such as fire weather, fire history, etc. The data is sourced largely from government agencies such as Landgate (Western Australia), Geoscience Australia and the Bureau of Meteorology. The fire scar mapping has been produced by the Cooperative Research Centre for Sustainable Development of Tropical Savannahs, Bushfires Northern Territory, the Darwin Centre for bushfires research, at Charles Darwin University (for Northern and Western fire patches) and the Cape York Peninsula Development Association (for Queensland). BA was obtained from multi-temporal comparison of 250 m MODIS imagery, using segmentation and visual interpretation.
The data for download are 250 m pixel size fire scars that extend across the whole of north Australia, dating back to the year 2000 and up to 2014. Two types of data are available, with and extent that covers the Kimberley, the Northern Territory and Queensland:

- Fire History data which covers (a) Years burned, (b) Years Late Burned and (c) Years last burned for recent years.
- Fire Scar data which displays the annual fire scar maps for each year for northern Australia.

Both datasets are available as either GeoTIFF images or shapefiles.

6. Auxiliary input files

6.1. GETASSE DEM

In the pre-processing of MERIS data, the AMORGOS software was used in order to do the geo-correction. Accurate geo-location information about longitude, latitude, and altitude for each MERIS pixel was generated, with accuracy up to 4.0 m starting from a MERIS Full Resolution product. For the Fire_cci pre-processing, AMORGOS was used with the Global Earth Topography And Sea Surface Elevation (GETASSE) DEM, which is a 30 arc second spatial resolution elevation model. GETASSE30 is a composite of four other DEM datasets: the SRTM30 dataset (http://www2.jpl.nasa.gov/srtm/, last access September 2017), ACE dataset (http://www.cse.dmu.ac.uk/EAPRS/products_ace_overview.html, last access September 2017), Mean Sea Surface data (http://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mss.html, last access September 2017) and the EGM96 ellipsoid (http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.html, last access September 2017) as sources.

This product can be freely obtained via ESA services: http://earth.esa.int/services/amorgos/download/getasse/ (last access September 2017), as 15° x 15° tiles, which are 12 MB in size each.

6.2. SRTM Water Body Data (SWBD)

The Shuttle Radar Topography Mission (SRTM) Water Body Data files were used in the pre-processing of the MERIS images to obtain sub-pixel accuracies. This same mask was also used for the pre-processing of the LC_cci products.

These files are a by-product of the data editing performed by the National Geospatial-Intelligence Agency (NGA) to produce the finished SRTM Digital Terrain Elevation Data Level 2 (DTED® 2). In accordance with the DTED® 2 specification, the terrain elevation data have been edited to portray water bodies that meet minimum capture criteria. Ocean, lake and river shorelines were identified and delineated. Lake elevations were set to a constant value. Ocean elevations were set to zero. Rivers were stepped down monotonically to maintain proper flow. After this processing was done, the shorelines from the one arc second (approx. 30-metre) DTED® 2 were saved as vectors in ESRI 3-D Shape file format.

The SRTM Water Body Data are available as 1° x 1° cells between 60 S and 60 N. There are 12,229 zipped (*.zip) files, which contain the entire SRTM Water Body Data (SWBD) set. Only those DTED® cells that contained water have a corresponding SWBD shape file. The continental codes and the number of zipped files for each continental region are: a = Australia (888), e = Eurasia (5,388), f = Africa (1,809), i = Islands (141), n = North America (2,268), s = South America (1,735). Around 3.5 GB are necessary for all unzipped files.

This description in more detail and all zipped files are available at no charge from http://dds.cr.usgs.gov/srtm/version2_1/SWBD/ (last access September 2017).

6.3. Global Land cover map

The land cover maps are used as auxiliary data in the BA algorithm development, since the fire characteristics are closely linked to the type of vegetation. ESA's CCI Land Cover (LC_cci, http://www.esa-landcover-cci.org/, last access September 2017) is used to mask non burnable classes within the BA detection algorithms, as well as to report burned land cover both in the pixel and grid products. At the same time, the Fire_cci BA product will be used by LC_cci for the burned area seasonality product. In this way, consistency will be assured between the different CCI projects.

The LC_cci products use the UN Land Cover Classification System (LCCS) legend organized in two levels, and includes 3 additional global land surface seasonality product, characterizing the vegetation greenness, the snow and the burned area dynamics.

Two products have been or are being used by the Fire_cci project. For the MERIS Fire_cci v4.1 and MODIS Fire_cci v5.0 products, the LC_cci v1.6.1 was used (Kirches et al. 2013), as it was the latest available product at the moment of burned area processing. This product includes three epochs: LC_cci of the period 1998-2002 (designed LC_cci 2000), LC_cci of the period 2002-2007 (designed LC_cci 2005), LC_cci of the period 2008-2012 (designed LC_cci 2010). The remaining BA products will use LC_cci v2.0.7 (Santoro et al. 2017), which consists in annual land cover maps from 1992 to 2015.

The LC_cci products are available at BC, which is responsible for the system engineering of the LC_cci project. Figure 4 shows the CCI Land Cover map version 1.6.1 corresponding to the epoch 2003-2007.

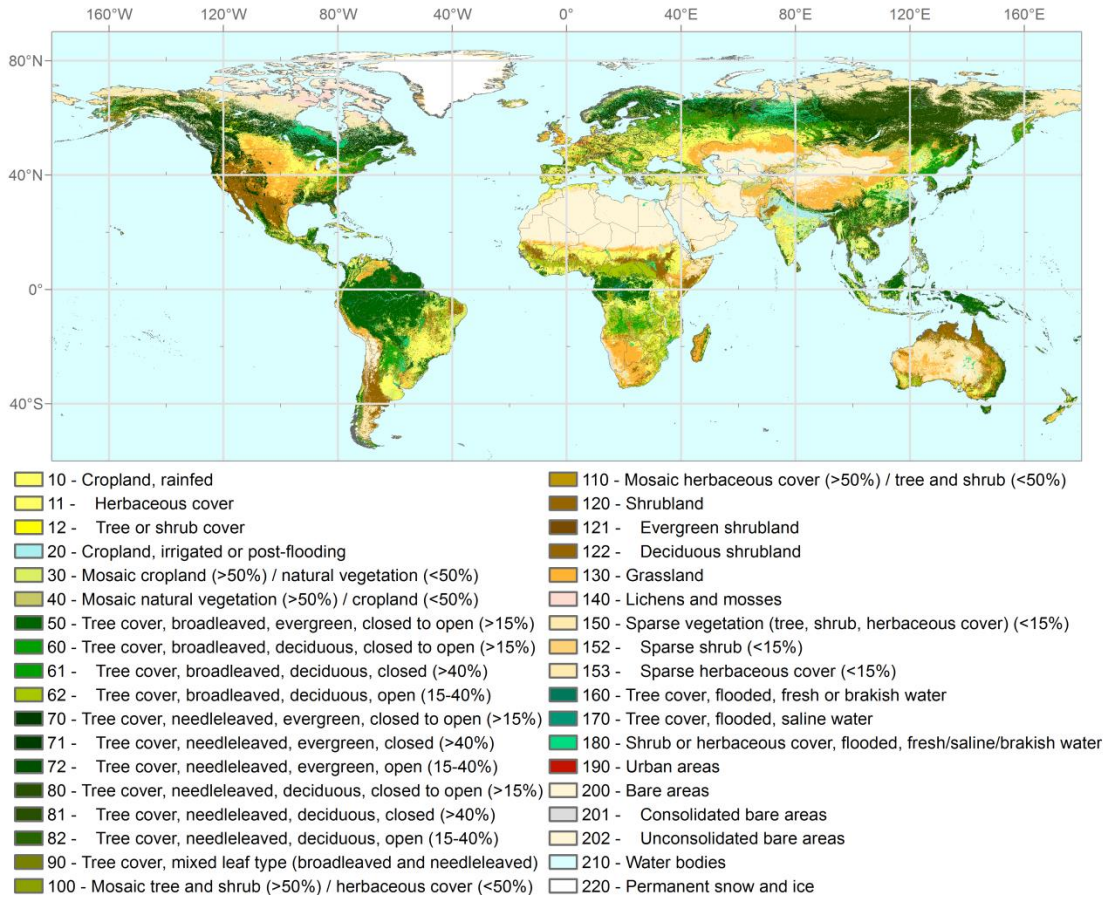

Figure 4: Land Cover CCI global map for the period 2003-2007 of version 1.6.1.

6.4. WWF Ecoregions

Over the past years WWF's Conservation Science Program (CSP) has developed a biogeographic regionalization (ecoregions) of the Earth's terrestrial biodiversity.

According to WWF CSP, for a global ecoregion map to be a useful tool in conservation planning, it must have biogeographic units delineated at a scale useful for regional conservation planning, and each unit should be categorized within a standardized classification of biomes and realms. Accordingly, ecoregion is defined as a relatively large unit of land or water containing a distinct assemblage of natural communities sharing a large majority of species, dynamic and environmental conditions (http://www.worldwildlife.org/biomes, last access September 2017). In this sense, ecoregions define areas within which one would expect to find a particular set of encounter probabilities of different biodiversity features, whether they are species, habitats or phenomena.

The WWF Terrestrial Ecoregions of the World (Olson et al. 2001) are used as one of the stratification categories in the selection of samples for the validation exercise (see Padilla et al. 2014).

6.5. Active Fires

Active fire information is used in the MERIS and MODIS algorithms as the first step of burn area detection, for the identification of burned seeds and dates of burn.

The MODIS active fires product detects fires at 1 km resolution, using a contextual algorithm, where thresholds are first applied to the observed middle-infrared (MIR) and thermal infrared brightness temperature. False fire detections are later rejected by comparison of the brightness temperature relative to the neighbouring pixels (Giglio *et al.* 2003)

The MODIS active fire product is available in several formats (see http://modis-fire.umd.edu/pages/ActiveFire.php, last access September 2017):

- Level 2 Fire Product MOD14 (Terra) and MYD14 (Aqua): identifies active fires as well as other thermal anomalies (e.g. volcanoes). It is defined in the MODIS orbit geometry covering an area of approximately 2340 by 2030 km in the across- and along-track directions respectively and contains a set of metadata information.
- Level 2G Day-time and Night-time fire products MOD14GD/MOD14GN (Terra) and MYD14GD/MYD14GN (Aqua): provides geocoded data structure for storing granules and may be temporal composited and reprojected.
- Level 3 8-Day Daily composite fire Product MOD14A1 (Terra) and MYD14A1 (Aqua): is tile-based and is a 1-km gridded composite of fire pixels detected in each grid cell over each 24-hour compositing period. Eight days of data are then packaged into a single file.
- Level 3 8-Day Summary fire Product MOD14A2 (Terra) and MYD14A2 (Aqua): is very similar to the daily Level 3 fire product, but it refers to an 8-day compositing period.
- MODIS Global Daily Fire QA Products: consists on coarse resolution (5 and 20 km) global summary fire imagery indicating areas where active fires have been detected and is generated by Land Discipline QA.
- Climate Modelling Grid Fire Products: are daily and monthly gridded summaries of fire pixels with application in regional and global modelling.
- MCD14ML Fire Location Product: consists of ASCII files containing the geographic location, date, and some additional information for each fire pixel detected both by Terra and Aqua sensors on a monthly basis.

For the Fire_cci MERIS BA product, MCD14ML Collection 5 was used. This product is freely downloadable from the ftp server at University of Maryland ftp://fuoco.geog.umd.edu (last access September 2017), and is also available from the Fire Information for Resource Management System (FIRMS, https://firms.modaps.eosdis.nasa.gov/download/, last access September 2017), transformed into a SHP file. These data were downloaded at UAH premises. In the case of the MODIS and OLCI algorithms, Collection 6 of the MODIS MCD14ML active fire products is used.

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Annex 1: Acronyms and abbreviations

AATSR	Advanced Along-Track Scanning Radiometer
AD	Applicable Document
AIRS	Atmospheric InfraRed Sounder
AMORGOS	Accurate MERIS Ortho-Rectified Geo-location Operational Software
AMSR-E	Advanced Microwave Scanning Radiometer - EOS
AMSU-A	Advanced Microwave Sounding Unit
AOD	Aerosol Optical Depth
API	Application programming interface
ARP	Application Related Product
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATBD	Algorithm Theoretical Basis Document
AVHRR	Advanced Very High Resolution Radiometer
BA	Burned Area
BC	Brockmann Consult GmbH
CAL FIRE	California Department of Forestry and Fire Protection
Cal/Val	Calibration and Validation
CCI	Climate Change Initiative
CDED	Canadian Digital Elevation Data
CEOS	Committee on Earth Observation Satellites
CEMS	Climate, Environment and Monitoring from Space
CERES	Clouds and the Earth's Radiant Energy System
CLASS	Comprehensive Large Array-data Stewardship System
CNFDB	Canadian National Fire DataBase
CSP	WWF's Conservation Science Programme
DARD	Data Access Requirements Document
DEM	Digital Elevation Model
DN	Digital Number
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DTED	Digital Terrain Elevation Data
EFFIS	European Forest Fire Information System
ENVISAT	Environmental Satellite
EO	Earth Observation
EOS	Earth Observation System
ERS	European Remote sensing Satellite
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
EU	European Union
FIRMS	Fire Information for Resource Management System
FOV	Field Of View
FR	Full Resolution
FRAP	Fire and Resources Assessment Program
FRS	Full Resolution, full Swath
GAC	Global Area Coverage
GCS	Geographic Coordinate System
GeoTIFF	Tag Image File Format
GETASSE	Global Earth Topography And Sea Surface Elevation
GHRSST	Group for High Resolution Sea Surface Temperature

GIMMS	Global Inventory Monitoring and Modeling System
GLCF	Global Land Cover Facility
GLS	Global Land Survey
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GRD	Ground Range Detected
HDF	Hierarchical Data Format
HH	Horizontal transmit and Horizontal receive polarization
HSB	Humidity Sounder for Brazil
HTTP	HyperText Transfer Protocol
HV	Horizontal transmit and Vertical receive polarization
INPE	Instituto Nacional de Pesquisas Espaciais
IPF	Instrument Proccesing Facility
JRC	Joint Research Centre
L-4	Landsat-4
L-5	Landsat-5
L-7	Landsat-7
L-8	Landsat-8
LAADS	Level 1 and Atmosphere Archive and Distribution System
LC_cci	Land Cover CCI
LCCS	Land Cover Classification System
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LLR	Laser RetroReflector
LTDR	Long-term data record
MERIS	Medium Resolution Imaging Spectrometer
MISR	Multi-angle Imaging SpectroRadiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPITT	Measurements of Pollution in the Troposphere
MSI	MultiSpectral Instrument
MSS	Multispectral Scanner
MWR	MicroWave Radiometer
NAFI	North Australian Fire Information
NASA	National Aeronautics and Space Administration's
NDVI	Normalized Difference Vegetation Index
NED	National Elevation Dataset
NGA	National Geospatial-Intelligence Agency
NIR	Near Infra-Red
NOAA	National Oceanic and Atmospheric Administration
NPP	National Polar-orbiting Partnership
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land Imager
PVP	Product Validation Plan
QA	Quality Assessment
RELAZ	Relative Azimuth
RMSE	Root Mean Squared Error
RR	Reduced Resolution
S-1	Sentinel-1
S-2	Sentinel-2
S-3	Sentinel-3

SAG	Science Advisory Group
SAR	Synthetic Aperture Radar
SHP	Shapefile
SLC	Single Look Complex
SNR	Signal-to-Noise-Ratio
SPOT	Satellite Pour l'Observation de la Terre
SLSTR	Sea and Land Surface Temperature Radiometer
SRAL	Synthetic Aperture Radar Altimeter
SRTM	Shuttle Radar Topography Mission
SWBD	SRTM Water Body Data
SWIR	Short-Wave Infra-Red
SYN	Synergy products from Sentinel-3
SZEN	Solar zenith angle
TIRS	Thermal InfraRed Sensor
TM	Thematic Mapper
TOA	Top Of Atmosphere
TOC	Top Of Canopy
UL	University of Leicester
URL	Uniform Resource Locator
USA	United States of America
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VGT	Vegetation
VH	Vertical transmit and Horizontal receive polarization
VIIRS	Visible Infrared Imaging Radiometer Suite
VNIR	Visible and Near InfraRed
VV	Vertical transmit and Vertical receive polarization
VZEN	View zenith angle
WGS	World Geodetic System
WMS	Web Map Server
WSM	Wide Swath Mode
WWF	World Wildlife Fund