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DOCUMENT

Annex K: Fire Disturbance ECV (Fire_cci)

Prepared by	**EOP-SE**
Reference	
Issue	**1**
Revision	**4**
Date of Issue	**March 24th, 2015**
Status	**Approved**
Document Type	**SOW**
Distribution	

European Space Agency
Agence spatiale européenne

APPROVAL

Title Fire_cci Technical Annex	
Issue 1	**Revision** 4
Author EOP-SE	**Date** March 24th, 2015
Approved by	**Date**
Tender Evaluation Board	**March 27th, 2015**

CHANGE LOG

Reason for change	Issue	Revision	Date

CHANGE RECORD

Issue 1	**Revision** 4		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

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1 SCOPE

This Annex provides technical requirements that shall be used to develop the CCI Fire Disturbance ECV. The baseline requirement of this Contract covers the retrieval, verification and validation of satellite and in situ derived FCDRs and the production of user defined Fire Disturbance ECV data products including their verification, validation and use by the climate research community.

2 GCOS DEFINITION

The Fire Disturbance ECV is defined by GCOS [RD-2] as follows:

Product T.10: Maps of burnt area, supplemented by active fire maps and fire radiative power

- Burnt area, as derived from satellites, is considered as the primary variable that requires climate-standard continuity. To estimate emissions of trace gases and aerosols, burnt area can be combined with information on 1) available fuel load, 2) the fraction of the fuel loads that is also actually combusted (combustion completeness), 3) information about burning efficiency which, in combination with 4) emission coefficients, governs the partitioning of biomass burnt into the multiple trace gases and aerosols emitted.
- Ideally, satellite-derived information on vegetation, such as biomass density and vegetation productivity, is derived in concert with burnt-area measurements to facilitate the conversion of burnt area to emissions using computer models. Measurements of burnt area can also be used as a direct input (driver) to climate and carbon-cycle models, or, when long time series of data are available, to parameterize climate-driven models for burnt area simulation.
- The following is required for this ECV:
    - Burnt area (T.10)
    - Active-fire maps (supplemental to T.10)
    - Fire radiative power (FRP) (supplemental to T.10)

3 GCOS REQUIREMENTS

The **target** requirements for the primary variable, burnt area, for this ECV are stated in [RD-2] as:

Target Requirements Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Burnt area	250m	N/A	Daily detection	15% (error of omission and commission), compared to 30m observations	15% (error of omission and commission), compared to 30m observations

Rationale: Product requirements are driven by the need to estimate emissions from burnt area and for dynamic vegetation modelling. The requirements are close to original instrument resolution and, with high resolution in space (250 m) and time (daily), provide a basis for weekly and monthly (gridded) products for the various user communities. Error traceability in the provision of aggregated, gridded products is essential.
To achieve the target requirements the following elements are recommended by GCOS:

- FCDR of moderate-resolution optical multispectral imager radiances of the MODIS/MERIS-class, in particular those acquiring spectral radiances in the MIR/SWIR channel;
- Long time-series are needed to quantify the link between climate and burnt area and to detect climate change effects on burnt area;
- Validation of medium and coarse-resolution burnt area products through interpretation of multi-temporal high-resolution imager radiances (Landsat ETM-class) and field observations, in collaboration with local fire-management organizations and the research community following protocols for the validation of fire products by CEOS WGCV and GOFC-GOLD;
- Standardization of product format, meta-data, and reporting of uncertainty is needed so that modellers can easily understand the structure of the product;
- On-going development of 300m burnt-area products (MERIS-class) by ESA.

The **target** requirements for the supplementary variables, active fire maps and fire radiative power (FRP), for this ECV are stated in [RD-2] as:

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Active Fire Maps	1km	N/A	6h (all latitudes)	5% error of commission 30% error of omission compared to 30m spatial resolution detections (based on per-fire comparisons)	N/A
FRP (polar-orbiting platform)	1km	N/A	Sub-daily (e.g. 6h at all latitudes)	25% down to FRP of 10 MW	10%
FRP (Geostationary platform)	0.1° [1]	N/A	1h	25% down to FRP of 50 MW	10%

Rationale: The product requirements for active fires are set to allow the occurrence of new burnt areas to be more effectively recognized and those for FRP are driven by the need to improve estimates of greenhouse gas and aerosol emissions from fires.

[1] Note that the document [RD-2] indicates here 0.1 km which is unrealistic for a geostationary platform. This is considered as a typo and 0.1° has been indicated instead.

[TR-1]	The Fire Disturbance ECV project shall estimate burnt area with respect to the climate requirements. Active fire maps and Fire Radiated Power (FRP) are supplementary variables to burnt area and thus existing products will preferably be used. Any developments on Active fire or FRP shall only be performed where such products do not already exist.

4 PHASE 2 PRODUCT FRAMEWORK

4.1 CCI Phase-I Achievements

Considerable work was done in Phase I to develop new processing algorithms for the ATSR-series, VEGETATION and MERIS sensors given that the existing products e.g. L3JRC, GlobCarbon) are inconsistent both spatially and temporally and their intercomparison highlights issues with all approaches. This includes significant limitations in the preprocessing (including clouds, atmospheric correction, land-water masking, cloud shadow, geolocation). These previous products also do not feature global MERIS FRS products (300m) as recommended by GCOS. Significant re-evaluation of user needs was performed through the Climate Research Group to identify achievable requirements as those identified by GCOS are not achievable currently and are not compatible with the need for long time series.

The project focused on improving the preprocessing for each sensor, on development of improved burnt area algorithms, on merging of the products to produce a more consistent output complete with uncertainty information and on development of a comprehensive validation database. Products were produced for the temporal sequence 1995-2009 for ATSR-2. AATSR, VEGETATION and MERIS FRS for 10 500x500 km test sites distributed globally for key biomes. Global products for the period 2006-2008 for VGT, MERIS and a merging of the two sensors were generated and validated to check for consistency spatially and temporally, as a test of the processing system and to provide data for the CCI golden year (2008). The quality of these datasets for individual sensors is variable and hence only the results from MERIS have been released as final outputs. The MERIS Burned Area global datasets have been assessed by the climate researchers and found to be in good agreement with GFEDv4, the *de facto* standard for burned area, in terms of the total amount of burned area and the spatial and temporal distribution of fires with MERIS BA having been extensively validated. This increases the confidence in the quality for both products. The quality improvement in fire_cci MERIS data was found to be significant compared with former European burned area data (GLOBCARBON, L3JRC). The MERGED product, due to the inclusion of VGT data, showed significant over-reporting of burned area in the mid-to-high latitude regions and, overestimation of total burned area on the globe. This was primarily attributed to the misidentification of agricultural regions as being burned.

4.1.1 Products

The products produced by Fire_cci Phase I were:

Test sites
Full processing record (1995-2009) generated for 10 sites, each of 500kmx500km, distributed globally covering different fire regimes and biomes. Sites comprised Canada (boreal forest), Colombia (dry tropical savannah), Brazil (humid tropical rainforest and savannah), Portugal (dry temperate), Angola (humid tropical savannah), South Africa (dry temperate), Kazakhstan (agricultural steppe), Borneo (humid tropical), Russia (boreal forest) and Australia (dry tropical).

Single-Sensor Products
ERS-2 ATSR-2:
June 1995-June 2003

Envisat AATSR:
July 2002-Dec 2007

Envisat MERIS:
2004-2009 FR

SPOT VEGETATION:
1998-2009

Multi-sensor merged Products
1998-2009

Global products
Single-Sensor Products
Envisat AATSR: 2008
The results generated for the initial year did not prove satisfactory and the focus was thus changed to concentrate on MERIS FRS and SPOT VEGETATION only.

Envisat MERIS: 2006-2008
The results from MERIS proved to consistent with the existing de facto standard, GFED4, and were released to the Climate Research Group for assessment and subsequently to the wider research community through a data website.

SPOT VEGETATION: 2006-2008
As a result of the validation and CRG assessment activities, the results from VEGETATION proved to exhibit significant errors and were not consistent with the products from MERIS. These products were not therefore publicly released.

Multi-sensor merged Products

These comprised merging of the data from MERIS FRS and VEGETATION over the period 2006-2008. The inclusion of the VEGETATION data resulted in significant over-detection and the merged product was not therefore publicly released.

Validation Products
242 Pairs of Landsat TM/ETM+ images have been processed to generate validation files:

- 130 pairs for spatial validation.
- 112 pairs for temporal validation.

They include sample areas from different fire regimes and biomes, from 53 countries.
A total of 147.994 burnt patches were detected, affecting 126,180 km².
All files are documented following standard CEOS WGCV Fire guidelines.

4.1.2 Performance

The burnt area estimates generated in Phase I were tested against the validation products detailed above. Results are provided in the table below in comparison against the GCOS requirement and that generated from the User Requirement Analysis.

Data Source	Spatial Resolution	Temporal Resolution[2]	Accuracy[3]	Stability	Reference
GCOS Requirement	250 m	Daily	± 5%	± 5%	GCOS-154
Phase I User Requirement	300-1000 m Grid: 0.5 degrees	1-5 days	± 15% (minimum acceptable 25%) with balance in omission and commission	± 15%	Fire_cci URDv3.5
MERIS	Pixel 300 m Grid: 0.5 degrees	Daily accumulated in monthly files	**Global** Dice Coefficient[4]: 0.29±0.05 Omission: 76±5 Commission: 64±5 **Study Sites** Dice Coefficient: 0.46±0.03 Omission: 64±2 Commission: 36±10	Difficult to quantify given the highly variable nature of burning across time. No evidence found of temporal trends in slope for	Fire_cci PVIR I and II and PIR
VEGETATION	1000 m	Daily accumulated in monthly files	**Global** Dice Coefficient: 0.07±0.03 Omission: 94±4		

[2] Temporal resolution is the reporting accuracy for BA (GCOS target)
[3] Accuracy refers to the accuracy of the ECV product so in this case the BA

[4] Given that one classifier (product or reference data in our case) identifies a burned pixel, the Dice Coefficient is the conditional probability that the other classifier will also identify it as burned. Global analysis is based on 103 samples (Thiessen scene areas) covering the globe for 2008. Study Site analysis uses 112 image pairs over 10 sites distributed in the main biomes for the period 1997-2009. DC should be 1 for a perfect match (and while values are low those for MERIS are not too dissimilar from MODIS). Omission/Commission is given in percentage to equate to the GCOS values.

			Commission: 93±2 **Study Sites** Dice Coefficient: 0.36±0.09 Omission: 42±12 Commission: 74±8	any accuracy measure	
Merged product	Pixel: 300 m Grid: 0.5 degrees	Daily accumulated in monthly files	**Global** Dice Coefficient: 0.16±0.05 Omission: 79±5 Commission: 87±5 **Study Sites** Dice Coefficient: 0.46±0.08 Omission: 53±7 Commission: 55±11		Fire_cci PVIR I and II and PIR

4.1.3 Time

In Phase I the Fire_cci project had as its original objectives to produce:

- A full temporal sequence from 1995-2009 for ATSR-2. AATSR, VEGETATION and MERIS FRS for 10 small test sites distributed globally for key biomes.
- Global products for selected years in the sequence (1999, 2000, 2003, 2005, 2008)

These were subsequently modified to:

- A full temporal sequence from 1995-2009 for ATSR-2. AATSR, VEGETATION and MERIS FRS for 10 small test sites distributed globally for key biomes.
- Global products for years 2006-2008

After considerable assessment the Fire_cci produced MERIS FRS burned area products for 2006-2008 as its outputs. Results from the ATSR series and VEGETATION did not meet acceptable accuracy to justify their release. A merged product based on MERIS FRS and VEGETATION was produced but was not released because of the difficulties encountered with VEGETATION.

4.2 Phase 2 Requirements

4.2.1 Products

Following Phase I the objective of Phase II is to extend the time series of global BA estimates to the longest period possible using the best combination of satellite sensors for each given period with the emphasis on consistency of the record over the time series. This shall involve full characterisation of the uncertainty associated with the estimates at pixel level. While the emphasis is on the contribution of European sensors, appropriate other

sensors such as MODIS and AVHRR may be considered. The time series is also intended to cover the eventual contribution from the Sentinel series, specifically Sentinel-3.

In addition, given evidence from the Phase I and from other external research that all current BA estimates underestimate BA from small fires, the Fire_cci Phase II project will also produce estimates of small fire distribution at least for the African continent but also for other regions depending on data availability. The principal data sources for this work will be Landsat-8/OLI, Sentinel-2/MSI and Sentinel-1 SAR for very cloudy regions.

Thus the Fire_cci project shall:

[TR-2]	Produce a full temporal globally comprehensive and consistent record, which meets the requirements expressed by GCOS and the User community using the relevant sensors, with an emphasis on European sensors.
[TR-3]	Produce a small fires database for Sub-Saharan Africa and with extension to other key small fire regions dependent on data availability.

4.2.2 Performance

Phase-II is dedicated to generating a consistent, fully uncertainty characterised, long time series of burnt area covering periods when different satellite sensors provide data.

Phase-II shall therefore extend the work conducted in Phase-I to generate a full time series of global products that satisfy the requirements expressed by the user community. In doing so, there shall be an emphasis on improving consistency in processing within the project and across the programme through collaboration with other CCI project teams that are processing the same input data. This shall include a full assessment of the requirements for pre-processing for BA and the appropriateness of existing pre-processing schemes to meet these requirements. The need for additional pre-processing shall be evaluated. A priority shall be dedicated to improving consistency in product generation across different satellite sensors with the objective to extend as far as possible the BA record.

Phase-II shall also focus on generating a full characterisation of error from uncertainty in the input data through to the output products in a fully traceable and open manner. Finally, the objective of the Fire_cci project is to develop a sustainable system under configuration control which is capable of processing and reprocessing the products rapidly to incorporate improvements in the input data, improvements in algorithms both for pre-processing, if necessary, BA estimation, and incorporating data from new sensors as they become available, in particular Sentinel-3 OLCI and SLSTR.

Thus the Fire_cci project **shall**:

[TR-4]	Extend the work conducted in Phase-I to generate a full time series of global products with an emphasis on improving consistency in processing across the full time series.
[TR-5]	Produce a full characterisation of error from uncertainty in the input data through to the output products in a fully traceable and open manner.
[TR-6]	Develop a sustainable system that is capable of processing and reprocessing the products rapidly to incorporate improvements in algorithms and data from new sensors as they become available, in particular Sentinel-3 OLCI and SLSTR.

4.2.3 Time

In Phase II the objectives are to develop a system capable of processing and reprocessing efficiently the full global records for the period of the satellite archive and then the equivalent data streams coming from the Sentinel satellite series. This shall be supported by continued processing of Landsat, and optionally Sentinel-2 data, to develop a validation dataset that satisfies the requirements for CEOS Stage 3 validation.

Thus the Fire_cci project **shall**:

[TR-7]	Generate global spatially resolved estimates of BA for the period of the satellite data archive (nominally from 2000 to 2016 onwards with potential extension backwards to the 1980s from AVHRR records and forwards to 2017-18 to incorporate the Sentinel series of satellites)
[TR-8]	Generate a supporting dataset at higher resolution for validation of these products, dependent on data availability, to allow the validation to be achieved at CEOS Stage 3 level.

5 KEY ISSUES

5.1 Task 1: Requirements Updating

With the updating of the GCOS Satellite Supplement [RD-2] and the experience from Phase-I there is a need to thoroughly and critically assess the likelihood of being able to deliver products that approach the GCOS or User requirements, in particular considering the future provision of satellite data from the Sentinel series of satellites. This also means critically assessing the current system and its component parts, in particular the algorithms with the emphasis on continuous improvement and developing a roadmap to be implemented within the project for improvement towards User requirements.

It is also clear that to achieve the objectives to generate the Fire Disturbance ECV there is a need to continue to collaborate with international partners to ensure that the products generated by Fire_cci and by external groups are compatible, consistent and comparable.

Finally, there is a critical need, identified in [RD-3] to work on standardization of product format, meta-data, and reporting of uncertainty so that modellers [and other users] can easily understand the structure of the product. This, in particular, implies liaising closely with initiatives such as GCP-RECCAP, GFED and Obs4MIPS to ensure what is generated is understandable/compatible with their needs.

[TR-9]	The Fire_cci products **shall** be designed to match the users' requirements within the limits of technical and algorithmic feasibility. The user requirements **shall** be elaborated through detailed discussions with the climate research user community and contact with key organisations/initiatives for example those listed in Section 6-7.
[TR-10]	The Fire_cci **shall** work on standardisation of product format, meta-data and reporting of uncertainty as identified by GCOS and expressed in the CCI [RD-3].
[TR-11]	The URD, DARD and PSD from Phase I **shall** be revisited to incorporate requirements and updated annually based on issues identified by the consortium and as feedback comes from the user community on the products generated.

5.2 Task 2: Algorithm Development

In Phase-I advances were made on the geolocation (of AATSR in particular), atmospheric correction, cloud and snow and water body detection and on burnt area detection and processing using MERIS-FRS. However, there is a need to evaluate comprehensively the pre-processing procedures in relation to the impact on BA detection over time, the availability of appropriate pre-processing schemes from within and external to CCI and effort devoted to improvement on these issues where the impact is found to be significant.

In addition traceability of the processing schemes, in particular, where the data were not processed completely by the team needs to be improved and uncertainty characterisation of the data going into the BA algorithms needs to be handled more comprehensively.

Given the results achieved in Phase I and quality assessment of equivalent data products, there remains a need to improve the accuracy and robustness of the BA algorithms themselves. This requirement is the major component of the Phase II project and needs to be conducted comprehensively to identify the most appropriate combination of sensors and algorithms for each part of the satellite time series taking into account the need for consistency of the record across the time series and the estimation of uncertainty. This work should be conducted using Phase I as its basis but making a comprehensive assessment of other algorithms and data handling methods (including merging at different stages of processing). These approaches also need to be developed for the Sentinel series of satellites, specifically Sentinel-3.

In addition the recognition that small fires are generally not estimated well and potentially contribute up to 35% of global BA [RD-4] means there is a need to develop and test methods for the detection of small fires in particular in locations where these are the dominant fire type e.g. sub-Saharan Africa. Such development effort needs conducting using higher spatial resolution sensors than those used for the main processing but shall consider the consistency of any such dataset to this main processing. This means assessing at what fire size the main processing fails to capture the BA effectively and also how the small fire BA can be linked to the main processing.

Thus:

[TR-12]	The Fire_cci team **shall** evaluate the extent to which pre-processing affects the performance of the BA algorithms and hence quality of the BA estimate to determine if there are issues in pre-processing that need to be addressed in terms of improvement for each selected BA algorithm. This requires documentation of methods with full traceability. Typical examples of such assessment include: • Testing performance of algorithms with and without e.g. water bodies or snow, topographic shadow masking, cloud shadow masking. • Testing performance with and without cloud masking or BRDF correction.
[TR-13]	In considering the consistency of satellite products the Fire_cci team **shall** liaise closely with relevant other projects e.g. LandCover_cci and Aerosol_cci to maximise consistency within CCI. This includes consideration of ancillary data, application of static masks and cloud and atmospheric correction approaches. The choice of approach, for Fire_cci, **shall**, however, be driven by the needs for BA estimate quality.

[TR-14]	The Fire_cci team **shall** fully assess different options for BA detection algorithms including use of merging of sensor data at reflectance level and consideration of the availability of sensor records at different points in the time series. This **shall** be performed using a 'Round-robin' style inter-comparison of BA algorithms for a given year (nominally 2008) evaluating the impact of different sensors on product quality. This **shall** comprise an assessment using **modelling** of the performance of BA algorithms on individual sensors and by combining input data from multiple sensors to improve data availability taking account of the characteristics of the contributing sensors. This assessment **shall** consider the quality of BA estimates from different algorithms including those from Phase I and their potential improvement and **shall** take account of the uncertainty of the input data. This assessment **shall** be conducted to determine the potential contribution of individual sensors to BA estimation taking into account the availability of sensors at different points in the time series. The spatial and spectral resolution of data from the sensors **shall** be considered in this analysis e.g. AVHRR at different spatial resolutions. **All sensors** that potentially contribute **shall** be assessed to determine if they should be included in processing.
[TR-15]	Once the assessment in [TR-14] has been performed a limited demonstration of the performance of contributing sensors **shall** be performed using real data from one year (nominally 2008) and this **shall** be compared against existing records. The consortium **shall** propose the extent of this testing but it **shall** encompass the variety of environments and fire types found in biomes globally in a similar way to that used in phase 1.
[TR-16]	The Fire_cci team **shall** develop methods for the detection of small fires. This shall consider potential application at continental level, using medium-resolution sensors, such as Landsat-OLI or Sentinel-2. For those areas with high cloud coverage and no optical datasets, Sentinel-1 data will be alternatively used.
[TR-17]	The Fire_cci team **shall** adapt the MERIS BA algorithm to work with MODIS 250m VNIR data and consider extension to Suomi NPP VIIRS. This adaption shall be tested as part of the assessment in [TR-14].
[TR-18]	Fire_cci team **shall** adapt and develop their algorithms to Sentinel-3 OLCI and SLSTR.

The following algorithm development work may be proposed as OPTIONS to the Baseline Proposal:

[TR-19]	OPTION: The Fire_cci team **shall** develop an extension to the existing product to generate Combustion Completeness.
[TR-20]	OPTION: The Fire_cci team **shall** develop an extension to the existing product using AVHRR data (LTDR series) to extend backwards to the 1980s. This product **shall** be compatible and consistent with the baseline products to ensure a long time series that is unaffected by changes in sensor over time taking into account uncertainty estimates across the time series.
[TR-21]	OPTION: The Fire_cci team **shall** develop methods to include both FRP and hotspot information as fields within the product particularly focusing on SLSTR and existing geostationary and MODIS/VIIRS data for FRP and SLSTR and existing ATSR-2, AATSR, TRMM, MODIS/VIIRS and Geostationary data for hotspots

5.3 Task 3: System Implementation and Evolution

Phase II envisages the development of a sustainable processing system driven by the science that is capable of rapidly reprocessing the input data as upgrades in algorithms or new algorithms are generated. The system will be able to process the full long-time series in such a way that it will improve over the prototype system in user requirements terms. It will also need to be extendable to new sensor inputs as they become available e.g. Sentinel-3 OLCI and SLSTR. At least one full reprocessing is envisaged in Phase-II with this system.

The Phase-II system also needs to respond effectively and completely to the requirements identified in the SRD. This new processing system may be an evolution of the existing system taking full account of and respecting the need for data harmonisation, data standards, consistency and traceability. Thus:

[TR-22]	The Fire_cci team **shall** develop a sustainable processing system with the capability to process the entire record as listed in table 1 of chapter 8, from 2000-2016 and beyond, within 6 months of processing.
[TR-23]	The development of this system **shall** take as a priority the processing and reprocessing required (throughput and speed) to process/reprocess and assess quality on a cycle consistent with the annual review mechanism.
[TR-24]	The system **shall** be science-driven, modular to allow updating of all algorithm components, fully configuration controlled and with full tracking and resolution of all issues using System Verification approaches. It **shall** satisfy the requirements (updated for Phase-II) expressed in the Fire_cci SRD, taking account also of the CCI SRD.

[TR-25]	The Fire_cci **shall** establish a roadmap, for implementation within the project, of improvements in processing, algorithms and consistency to move towards achieving the User requirements, taking into account the updated User Requirements from Task 1 and shall take consideration of developments in other CCI projects. The consortium **shall** review this roadmap every 6 months to assess progress.
[TR-26]	The outputs of the system **shall** respect the CCI Data Standards and be accessible in a free and open manner to the Climate Science community (see SRD).

5.4 Task 4: Product Generation

The objective of Task 4 is a continuous cycle of improvement starting from the prototype products and evolving to the generation of consistent global results across the full time series under consideration. This will be achieved in stages across the 3-year duration of the project with review after every year to assess progress in the same manner as for all CCI projects. In this regard:

[TR-27]	In year 1: The Fire_cci team **shall** process the full MERIS_FRS record (2003-2011) to estimate BA at 300m using the algorithm established in Phase I. This **shall** consider data availability variation over the record in the uncertainty assessment.
[TR-28]	In year 2: The Fire_cci **shall** generate the full global multi-sensor time series from 2000-2016 using the processing system developed in Task 3. This reprocessing **shall** take into account algorithm developments in Task 2.
[TR-29]	In year 2: The Fire_cci **shall** generate a small fires database initially for Northern Hemisphere Tropical Africa using high resolution sensors namely Landsat 8 OLI and Sentinel-2 when it becomes available and Sentinel-1 radar for cloudy areas.
[TR-30]	In year 3: The Fire_cci **shall** generate the full global burned area time series as above with extension to 2017 and incorporating algorithm improvements identified in year 2.
[TR-31]	In year 3: The Fire_cci **shall** extend the small fires database to sub-Saharan Africa, where 70% of the total burned area occurs, for a single year and then extend across multiple years in sample sites, that cover the range of expected conditions for small fires, to check for temporal consistency.
[TR-32]	In year 3: Fire_cci **shall** extend the time series to include Sentinel-3 OLCI and SLSTR if these data products are available within the project lifetime.

[TR-33]	Year 1-3: The Fire_cci **shall** develop the validation data set using Landsat (and Sentinel-2 MSI when available) to generate a CEOS Stage-3 validation dataset, which is both temporally and spatially representative. Other satellites (e.g. SPOT and ASTER) **shall** also be considered to improve coverage in locations where the Landsat archive is limited.
[TR-34]	The Fire_cci **shall** provide the data products to the ESA data portal every time a major reprocessing or key update takes place.

5.5 Task 5: Assessment of Output Products by Climate Users

Since the assessment of outputs is a critical requirement for the success of CCI, in Phase-II the assessment of output products will be required from the start of the project and will be on a continuous basis to ensure involvement of the climate research community in product generation/development. Three phases of assessment are envisaged:

1. Assessment of the full MERIS_FRS record (2003-2011)
2. Assessment of the improved products generated with the first iteration of the sustainable processor, and
3. Assessment of the products generated with the upgraded sustainable processor.

Thus the specific subtasks in the project, which correspond to and are extended by Section 6-7, are:

[TR-35]	The Fire_cci **shall** through its Climate Research Group conduct assessments of the quality of the products extending that performed in Phase-I, namely assessment of the impact of the products for testing dynamic global vegetation models and assessing GFED in a variety of forms consistent with the generation of the products.
[TR-36]	The Fire_cci CRG **shall** feedback to the consortium on improvements to allow for upgrading the processor and regenerating the products. The products **shall** also be supplied to CMUG to allow them to conduct their assessment and feedback in the same way.
[TR-37]	Fire_cci **shall** ensure its quality controlled products are available to the climate science and carbon cycle research communities and shall work with these communities to ensure the products are taken up and used e.g. IBBI, RECCAP-2, CAMS, CCCS, Global Carbon Project for the World Carbon Atlas, CMIP-6/Obs4MIPS.

[TR-38]	The Fire_cci consortium **shall** organise user workshops during the project targeting specific user communities for whom the product has been developed to encourage uptake, and explore how to improve products. The consortium shall organise a workshop in year 1 and another one in year 3 of the project.
[TR-39]	The Fire_cci project **shall** work closely with other ESA projects to ensure and assess ECV product consistency and complementarity, and to make use of relevant external work that can contribute to the Fire_cci objectives, in particular in linking burnt areas to emissions.

6 INTERNATIONAL COORDINATION

6.1 Science Bodies

[TR-40]	Throughout the project close interaction with the climate and wider science community **shall** be established and maintained. Examples include: • With GOFC-GOLD to develop validation datasets to provide a fully stratified sampling of nature of fire activity over the globe (CEOS Stage 3) incorporating Sentinel-2, if available). • With the GFED community to ensure uptake of the products into the GFED calculations that are the de facto standard for fire emissions for carbon and climate research community. • With GCP-RECCAP community to promote the availability and access to BA estimates from Fire_cci including the work on small fires and on uncertainty characterisation.

6.2 Other International Frameworks

The success of the project depends on the products being made accessible and being taken up by the wider climate science and carbon cycle communities, beyond that strictly encompassed by the CRG and CMUG. Thus it is important for the consortium to be proactive, once the products are available in ensuring the products are taken up and used by these communities. Thus:

[TR-41]	Throughout the project, the CRG, in particular **shall** establish links to key groups to take up and use the Fire_cci products.

6.3 International Climate Assessments

[TR-42]	Fire_cci **shall** ensure delivery of its quality controlled products are available to the climate science and carbon cycle research communities and **shall** work with these communities to ensure the products are taken up and used in, for example: • International Biomass Burning Initiative (IBBI) • Second Regional Carbon Cycle Assessment and Processes (RECCAP-2) • CMIP-6/Obs4MIPS. The consortium shall additionally submit their data in Obs4MIPS format in the Earth System Grid.

7 USER ENGAGEMENT

In Phase-I the emphasis was on testing the prototype products against existing alternatives to determine their potential value and contribution. In Phase-II with the objective to have long time series of burnt area available updated on an annual basis the emphasis will be on assessing these products through the existing CRG, expanding beyond this group to other similar teams and working with the wider international climate and carbon research community.

7.1 Existing user Community

[TR-43]	The current CRG and CMUG **shall** be provided with long time series global products to allow them to conduct their assessment exercise and feedback to the Fire_cci team. Feedback received shall be incorporated into improvements in the processor.
[TR-44]	The results from the CRG and CMUG assessments **shall** be reported and discussed at the CCI collocations and the CMUG Integration meetings to allow wider feedback from the CCI Programme and projects to the improvement of the Fire_cci products.
[TR-45]	The products **shall** be assessed for their maturity against the CCI Maturity Matrix

7.2 Engagement of New Users

Once the first issue of the products has been generated and an internal assessment been conducted to ensure that the products are fit, in quality terms, for distribution then the Fire_cci team must proactively promote the products to other groups within the User community. This should be done through targeted community meetings e.g. with the wider DGVM community, carbon cycle community and climate/emissions community. Thus:

[TR-46]	The Fire_cci consortium **shall** organise user workshops during the project targeting specific user communities for whom the product has been developed. These include (in addition to the climate community): • the DGVM community, • carbon cycle community • atmospheric emissions community

7.3 Feedback and Actions that will be taken to include ESA products

It is vital for ESA (and other data providers) that issues identified in the processing, algorithm improvements generated and improved baseline products are fed back to ESA to allow improvements in the Ground Segment processing. This means for Fire_cci that the consortium must be in contact with the teams responsible for deciding on the content and scheduling of reprocessing exercises. Thus:

[TR-47]	The Fire_cci consortium **shall** liaise with the Ground Segment entities responsible for scheduling, upgrading and reprocessing input datasets e.g. ESA MERIS, PROBA-V and Copernicus Sentinels.

8 INPUT DATA SETS

It shall be the Contractor's responsibility to acquire all EO and in-situ data required to carry out the project tasks. This includes data from Sentinel-1 SAR, Sentinel-2's MSI and Sentinel-3's SLSTR and OLCI instruments.

The baseline datasets for the Fire_cci Phase 2 are shown in the following table:

Table 1 Baseline satellite datasets for the CCI Fire Disturbance ECV.

Agency	Satellite	Sensor	Period
ESA	ERS-2	ATSR-2	1995-2003
ESA	Envisat	AATSR	2002-2012
ESA	Envisat	MERIS	2002-2012
CNES/VITO	SPOT-4, SPOT-5	Vegetation	1998-2003, 2003-2014
ESA/EC	Sentinel-1	SAR	2014 to current
ESA/VITO	PROBA-V	Vegetation	2014 to current

EUMETSAT	METOP-A	AVHRR	2007 to current
EUMETSAT	METOP-B	AVHRR	2012 to current
NOAA	NOAA series	AVHRR	1981 to current
NASA	Terra	MODIS	2000 to current
NASA	Aqua	MODIS	2002 to current
NOAA	Suomi	VIIRS	2011 to current
NASA/USGS	Landsat-8	OLI	2013 to current
NASA/USGS	Landsat-7	ETM+	1999 to current
NASA/USGS	Landsat-5	TM	1984-2013

9 ESA REPROCESSING ROADMAP

Links to the reprocessing history of important ESA instruments are listed in the following table:

Table 2: ESA Reprocessing Roadmap.

Satellite	Sensor	Reprocessing history
ERS-2	ATSR-2	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/atsr-gridded-brightness-temperaturereflectance-product-5020?
Envisat	AATSR	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/aatsr-gridded-brightness-temperaturereflectance-1537?
Envisat	MERIS	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/meris-full-resolution-full-swath-4215?
PROBA-V	Vegetation	http://proba-v.vgt.vito.be/content/products
Sentinel-1	SAR	https://sentinel.esa.int/web/sentinel/home
Landsat	TM/ETM	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/landsat-7-etm-enhanced-thematic-mapper-plus-geolocated-terrain-corrected-systematic-processing-over-kiruna-and-masplomas?
Landsat	OLI	https://earth.esa.int/web/guest/data-access/browse-data-products/-/asset_publisher/y8Qb/content/landsat-oli-tirs-european-coverage?

10 KEY ASSOCIATED PROJECTS

[TR-48]	The Fire_cci project **shall** work closely with other ESA projects, especially those from CCI, to ensure and assess ECV product consistency and complementarity, and to make use of relevant external work that can contribute to the Fire_cci objectives.

11 REFERENCES

[RD-1] Implementation Plan for the Global Observing System for Climate in support to UNFCCC (2010 Update), GCOS-138, August 2010.

[RD-2] Systematic Observation Requirements for Satellite-Based Data Products for Climate - 2011 Update, GCOS-154, December 2011

[RD-3] Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements, GCOS Secretariat, GCOS-128, March 2009 (WMO/TD No. 1488). Available online at: http://www.wmo.int/pages/prog/gcos/index.php

[RD-4] Randerson, J. T., Y. Chen, G. R. van der Werf, B. M. Rogers, and D. C. Morton (2012), Global burned area and biomass burning emissions from small fires, J. Geophys. Res., 117, G04012, doi:10.1029/2012JG002128.

12 ACRONYMS

CCCS European Commission Copernicus Climate Change Service
CEOS Committee on Earth Observation Satellites
CMIP-6 Coupled Model Inter-comparison Project Phase 6
GCA Global Carbon Atlas
GCP Global Carbon Project (for the Global Carbon Atlas and RECCAP)
GFED Global Fire Emissions Database
GOFC-GOLD Global Observation for Forest Cover and Land Dynamics (Fire element)
IBBI International Biomass Burning Initiative
Obs4MIPS Observations for Model Inter-comparisons (CMIP-6)
RECCAP-2 Second Regional Carbon Cycle Assessment and Processes