Climate Modelling User Group

Deliverable 2.3

Suitability of CCI ECVs for Climate Science and Services

Centres providing input: Met Office, MPI-M, ECMWF, MétéoFrance, IPSL, SMHI, DLR, BSC

Version	Date	Status
0.1	30 July 2019	First CMUG assessment of CCI+ ECV product documents
0.5	9 August 2019	Input from Met Office; ECMWF, MPI-M, MétéoFrance, BSC, IPSL, DLR, SMHI
1.0	30 August 2019	Submission to ESA
1.1	11 December 2020	Update by MO, ECMWF, MPI-M, MétéoFrance, BSC, IPSL, DLR, SMHI
1.2	15 December 2020	Submission to ESA
1.3	15 December 2020	Resubmission of clean document to ESA
1.4	21 January 2021	Typo corrected

CMUG CCI+ Deliverable 2.3

Suitability of CCI ECVs for Climate Science and Services

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1. Purpose and scope of the Technical Report

The purpose of this report is to review the documentation of each ESA CCI+ project and provide feedback on both the products and documentation to ESA and the CCI teams. This feedback is provided from the point of view of users working in climate research and climate services who are represented by the ESA CCI+ Climate Modelling User Group (CMUG).

A previous version of this report from CMUG Phase 2 was entitled the Technical Report on Product Assessment[1] this provides comments and technical advice on the "Product Validation and Inter-comparison Report", "Climate Assessment Report" and "Uncertainty Characterisation Report" for 11 of the Phase 2 CCI ECVs. The versions of these documents reviewed then were the most recent at the date of the report (February 2017). Other CCI project reports were also assessed where found to be relevant.

This current report, the first for Phase 3 of CMUG, will focus on the User Requirements Document (URD) and Product Specification Document (PSD) for each CCI project, with other documents reviews on an *ad hoc* basis. The URD is reviewed for 20 of the current CCI ECVs and the PSD for the 9 ECVs new in Phase 1 of CCI+. The CCI projects on Glaciers and Antarctic and Greenland Ice Sheet ECVs are not considered in this document as they are not covered in the current phase of CMUG.

This report will cover

- The extent to which the URD captures requirements, from the perspective of the climate modellers and climate service users represented by CMUG
- Omissions from the ECV product described in the PSD
- Assessment of the utility of the PSD, does it contain all relevant information needed to start using the data?
- Ideas and recommendations for CCI+ Phase 2

The aim is to produce a concise report which will be useful when shared with the CCI+ projects.

The report starts with a table listing which version of the documentation has been reviewed, this is followed by a section on each ECV within which there are sub-sections for each document considered. The document reviews are then summarized with some overall recommendations from CMUG for the CCI+ projects and Phase 2 of the CCI+ given. Finally an acronym list and references are given.

[1] http://ensembles-eu.metoffice.com/cmug/CMUG_PHASE_2_D2.3_Product_Assessment_v3.1.pdf

2. Versions of Documents Reviewed

The comments in this report refer to the relevant documents available to CMUG as of 16th November 2020 when the CCI projects were contacted for latest versions. For the 14 CCI ECVs from Phases 1 and 2, the PSD was reviewed in the previous D2.3[1] so only the URD is considered, while for the new ECVs established in the CCI+, both URD and PSD are discussed. Other documents are reviewed in cases where the reviewer has used them in the course of their work, but the focus of this version of the report is the PSD and URD. The documents reviewed are listed in Table 1. Where the documents are available online, the URL is given in Table 1, if there is no URL then the documents were provided directly to CMUG by the ECV teams or ESA and the relevant contact is named.

CMUG recommends that the most up to date documentation should be made available on ESA's new CCI web pages and that naming conventions and document structure should be consistent between the CCI projects.

ECV	URD	PSD (for ECVs new at CCI+ only)	Others	CMUG lead / last update
Aerosols	V4.5 (28/08/2020): Pers comm Thomas Popp	N/A		Angela Benedetti (ECMWF)/ Nov 2020
Biomass	V1 (15/11/2018): http://cci.esa.int/sites/default/files/Biomass%20D1.1%20User%20Requirement%20Document%20V1.0.pdf	V2 (20/03/2020): http://cci.esa.int/sites/default/files/Biomass_D1.2_%20Product_Specification_Document_v2.pdf	PVP v2.0 (08/031/2020): https://climate.esa.int/sites/default/files/Biomass_D2.5_Product_Validation_Plan_V2.0.pdf	Debbie Hemming (Met Office / Dec 2020
Cloud	V3 (14/07/2017): Pers. Comm. Simon Pinnock	N/A	CECR v4.1 (03/04/2018): https://climate.esa.int/media/documents/Cloud_Comprehensive-Error-Characterisation-Report-CECR_v4.1.pdf CAR v3.1 (18/09/2017): https://climate.esa.int/media/documents/Cloud_Climate-Assessment-Report-CAR_v3.1.pdf	Ulrika Willen (SMHI) / Aug 2019 Axel Lauer (DLR) / Dec 2020

Fire	**V7 (27/11/2019): https://climate.esa.int/documents/224/Fire_cci_D1.1_URD_v7.0.pdf**	**N/A**		**Pablo Ortega (BSC)/ Nov 2020**
Green House Gasses (GHG)	**V3 (17/02/2020): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/URD/URDv3.0_GHG-CCIp_Final.pdf**	**N/A**		**Angela Benedetti (ECMWF)/ Nov 2020**
HRLC	**V2.0 (03/01/2020): https://climate.esa.int/media/documents/CCI_HRLC_Ph1-D1.1_URD_v2.0.pdf**	**V2.0 (03/01/2020): https://climate.esa.int/media/documents/CCI_HRLC_Ph1-D1.2_PSD_v2.0.pdf**		**Enza di Tomaso (BSC) / Nov 2020**
Lakes	**V1.1 (05/09/2019): https://climate.esa.int/sites/default/files/filedepot/incoming/CCI-LAKES-0019-URD-1.1.pdf**	**V1.2 (15/05/2020): https://climate.esa.int/sites/default/files/filedepot/incoming/CCI-LAKES-0016-PSD_V1.2_signed_CA.pdf**		**Grace Redmond (Met Office) / Nov 2020**
Land Cover	**V1.0 (16/09/2019): https://transvol.sgsi.ucl.ac.be/download.php?id=afff326017409fd6**	**N/A**		**Enza di Tomaso (BSC) / Nov 2020**
Land Surface Temperature (LST)	**V1.1 (21/02/2019): pers. Comm. Simon Pinnock**	**V1.11 (17 June 2020): pers comm. Simon Pinnock**		**Rob King (Met Office), Jean-Christophe Calvet (Météo France) / Nov 2020**
Ocean Colour	**V1.0 (31/07/2019): https://docs.pml.space/share/s/lg8js7hFSOaaZrtbtFGbmQ**	**N/A**	**PVASR v3.0 (Pt1 23.12.15; Pt 2 15.01.16)[2]** **CAR v2.0 (04.02.16): https://docs.pml.space/share/s/wZZzAxTJQkuC7wwdt3kJRQ**	**David Ford (Met Office) / Nov 2020**
Ozone	**V3.1 (01/09/2020): pers. Comm. Michel Van Roozendael**	**N/A**	**CECR v2 (22.12.16): http://cci.esa.int/sites/default/files/filedepot/incoming/Ozone_cci_KIT_CECR_02_01_02.pdf**	**Angela Benedetti (ECMWF) / Nov 2020**
Permafrost	**V1.1 (12/02/2019): https://climate.esa.int/documents/101/CCI_PERMA_URD_v1.1.pdf**	**V2.0 (30/11/2019): http://cci.esa.int/sites/default/files/CCI%2B_PERMA_PSD_v2.0.pdf**		**Jean-Christophe Calvet (Météo France) / Nov 2020**

[2] Reviews of these PVASR documents were included in an earlier draft of this report compiled by the previous CMUG management team, the documents referenced are not available to the current reviewer, but they are later versions than those currently linked from the CCI Ocean colour web pages, so the discussion is left in as it may be relevant

Sea Ice		**V2.0 (20/03/2020):** https://climate.esa.int/documents/78/Sea_Ice_User_Requirements_Document_2.0.pdf	**N/A**	**PVIR (SIT) v1.1 (23/07/2018):** https://climate.esa.int/sites/default/files/SeaIce_CCI_P2_PVIR-SIT_D4.1_Issue_1.1.pdf **PVIR (SIC) v1.1 (23/07/2018):** https://climate.esa.int/sites/default/files/SeaIce_CCI_P2_PVIR-SIC_D4.1_Issue_1.1.pdf	**Andreas Wernecke (MPI-M) / Nov 2020**
Sea Level (previously Sea Surface Height)	**Global**	**V1.6 (22/10/2014):** http://www.esa-sealevel-cci.org/webfm_send/235	**N/A**		**Pablo Ortega (BSC) / Nov 2020**
	coastal	**V1.2 (16/06/2020):** http://www.esa-sealevel-cci.org/webfm_send/640	**N/A**		**David Fort (Met Office) / Nov 2020**
Sea State		**V1.0 (06/02/2019):** http://cci.esa.int/sites/default/files/Sea_State_cci_URD_v1.0-signed.pdf	**V1.0 (05/02/2019):** http://cci.esa.int/sites/default/files/Sea_State_cci_PSD_v1.0-signed.pdf		**David Ford (Met Office) / Nov 2020**
Sea Surface Salinity (SSS)		**V1.4 (03/01/2019):** http://cci.esa.int/sites/default/files/SSS_cci-D1.1-URD-v1r4_signed-accepted.pdf	**V1.6 (28/01/2019):** http://cci.esa.int/sites/default/files/SSS_cci-D1.2-PSD-v1r6_signed-signed.pdf		**Andreas Wernecke (MPI-M) / Nov 2020**
Sea Surface Temperature (SST)		**V2.1 (13/01/2017):** https://climate.esa.int/documents/280/SST_CCI-URD-UKMO-201-Issue_2.1-signed.pdf	**N/A**		**Andreas Wernecke (MPI-M) / Nov 2020**
Snow		**v2.0 (17/12/2019):** http://snow-cci.enveo.at/documents/Snow_cci_D1.1_URD_v2.0.pdf	**V2.0 (19/12/2019):** http://snow-cci.enveo.at/documents/Snow_cci_D1.2_PSD_v2.0.pdf		**Jean-Christophe Calvet (Meteo France) / Nov 2020**
Soil Moisture (SM)		**V2.1 (19/11/2020): pers comm. Richard Kidd**	**N/A**		**Frederique Cheruy (IPSL) / Dec 2020**
Water Vapour		**V2.0 (18/11/2019):** http://cci.esa.int/sites/default/files/Water_Vapour_cci_D1.1_URD_v2.0-trackchanges_ms_tvuk.pdf	**V2.1 (27/11/2019):** http://cci.esa.int/sites/default/files/Water_Vapour_cci_D1.1_URD_v2.0-trackchanges_ms_tvuk.pdf		**Asel Lauer (DLR) / Dec 2020**

Table 1. Version of documents reviewed.

3. Comments on CCI project documentation

The CCI ECV projects for which the documentation has been reviewed (20 out of 23, excluding CCI Glaciers, CCI Ice Sheets (Greenland) and CCI Ice Sheets (Antarctic)) are considered here in alphabetical order. The comments and recommendations of the reviewers are split so that it is clear which comments refer to which document and which refer to the ECV product and documentation set overall.

2.1 Aerosols

Version 2.0 of the URD for the CCI Aerosols project, dated 28/08/2020, was reveiwed.

User Requirement Document

This document has undergone several revisions and is now in a very mature form. However, there are now new aerosol variables being proposed for climate monitoring and assimilation and it should be ensured that user requirements for these are covered by the new version of the document for CCI+ Phase 2. Profiles of backscatter and extinction (at several wavelengths) such those provided by lidar systems are good examples. Vertical profiles are mentioned throughout the document but no explicit requirement is set. In view of the current ESA operational and planned missions (Aeolus and EarthCARE) with lidar sensing capabilities, CMUG would like to see discussion of these variables in future versions of the document. Also, other variables are being considered by GCOS for inclusion as ECVs and these should be discussed. In particular surface (speciated) emissions have been flagged as extremely important.

In summary CMUG recommends for future versions of this document:

- New aerosol products such as profiles of backscatter and extinction should be mentioned, including any plans to include these in the ECV product in future
- New variables being considered for inclusion as ECVs should be mentioned, e.g. surface (speciated) emissions
- Requirements for vertical profiles should be outlined in detail

2.2 Biomass

Version 1.0 of the User Requirements document (URD) dated 15 November 2018, version 2.0 of the Product Specification document (PSD) dated 20 March 2020 and version 1.1 of the Product Validation Plan (PVP) dated 03 March 2019 were reviewed here.

User Requirement Document (URD)

User requirements defined in the URD reflect the needs of the two major communities that use AGB data: i) climate / carbon modelling, and ii) REDD+. While there is some overlap in requirements of these users, there are significant differences relating to scale. Climate / carbon modelling requires gridded data typically at 500m or coarser resolution, whereas REDD+ requires country based data at 1 ha or finer resolution. The requirements of these two communities are well defined in the URD.

Product Specification Document (PSD)

The PSD introduces a suitable range of products that meet the broad user requirements in the URD. Details on the uncertainties relating to spatial resolution and the accuracy are not currently defined, but will become clear as the product develops, which should not affect user applications at this stage. There are questions over how to calculate the AGB change product CMUG recommends further discussion with users of the product to resolve this.

Product Validation Plan (PVP)

The PVP provides a clear and comprehensive plan for the validation of AGB, and links to further relevant literature and datasets, CMUG would ask that it is made clearer if information on the seasonality (intra-annual timing) of AGB is available from the proposed datasets and analyses?

Suggestions for CCI+ Phase 2

If the details on uncertainties, and questions over how to calculate AGB change are not resolved by the end of Phase 1 then CMUG recommends that these are prioritised in Phase 2.

2.3 Cloud

The User Requirements Document (URD) version 3.0 dated 14 July 2017, the Product User Guide (PUG) version 5.1 dated 16 January 2020, the Comprehensive Error Characterisation Report (CECR) version 4.1 from April 2018 and the Climate Assessment Report (CAR) Version 3.1 from September 2017 are reviewed here.

The documents are nicely structured and well written. The product user guide is particularly nicely done. The URD could be further improved by providing tables grouped by application rather than by source as this would allow the reader to quickly find the required information. In the product user guide, an extension of Annex C on how to use the uncertainty information provided with the datasets would be very welcome. This could include information on error correlation lengths in space and time and possibly recommendations for best practices when averaging, regridding, etc. the uncertainty estimates for applications such as model evaluation. This could be an aim for CCI+ Phase 2.

User Requirements Document (URD)

Specific Recommendations

- Section 2.2.6: ERA-Interim is available from 1979-2019, so there is probably no need to use ERA40. ERA-Interim has now been replaced by ERA5, which is planned to cover 1950 to present.
- Section 2.2.1 (GCOS requirements on cloud radiative properties) could be transformed into a table.
- Table 4 summarizes the user requirements for climate monitoring. If possible, also other user requirements could be grouped by application (NWP, climate modelling, model evaluation, etc.) rather than by source (WMO, GCOS, CMUG, etc.). This would make the document easier to read.
- If possible, provide one "overarching" summary table for user requirements from different sources.

Product User Guide (PUG)

Specific comments

- Uncertainty information and known limitations for each group of variables is great, the bullet list format makes it easy to get a quick overview.
- An overview table on recommended applications or examples of existing applications for the different datasets would be welcome.
- The section on data access, citation, etc. is very helpful.

Suggestions for the PUG in CCI+ Phase 2

Propagation of Level-3 uncertainties into higher level products (Annex C) is a great addition and an excellent starting point for further analyses. Providing guidelines or best practice to help users taking advantage of the uncertainty information could be a possible improvement. This could include guidelines:

- error correlation lengths in space and time

- best practice for averaging, regridding
- how to compare with model data

Comprehensive Error Characterisation Report (CECR)

Suggested changes and additions to the CECR that would help the reader and user of the data:

- Add a specific description and validation of the CFC uncertainty
- Add which CALIOP time periods were used for the training and validation of CFC in CECR Table 5-1.

Climate Assessment Report (CAR)

- Cloud_cci data compares well with the GEWEX Cloud assessment data base, except for an underestimation of high level clouds especially at daytime. This might be improved by using the nighttime methods also at daytime in CC4CL.
- The Cloud_cci pixel based uncertainties show the user which areas should be carefully treated, e.g. polar and high altitude snow covered regions. However, the uncertainties were larger than the spread between the AVHRR datasets especially for the polar regions. According to the PVIR these uncertainties should not be used. That should be stated clearly at the site where the data can be downloaded.
- To improve the usability of Cloud_cci CFC in climate studies, a simple statistical method was developed for correcting CFC by bias correcting or “debiasing” the AVHRR-PM CFC data using synoptic observations. The corrected (debiased) dataset significantly outperforms the original one in terms of accuracy and precision, and standardizes performance among NOAA satellites. Therefore, debiasing can implicitly remove the inhomogeneity in CFC time series due to changing overpass times and unresolved diurnal cycle. The correction decreases the magnitude of trends but keeps their signs unchanged. This debiased dataset should be made available to users.

2.4 Fire

The User Requirement Document version 7.0 dated 27 November 2019 was reviewed.

User Requirements Document (URD)

The latest CCI Fire User Requirements Document gives an exhaustive account of the current burnt area products, their characteristics and identified limitations, their suitability for different uses, the ongoing initiatives and projects in which they are used and/or for which are relevant, and more importantly, how they meet (or will meet) the user requirements identified through different surveys and by different institutions. The document is also frequently revisited and updated with new inputs from different sources to keep it as relevant as possible to all users.

The document is very detailed and in some sections would benefit from some synthesis tables distilling the key information for the readers. For example, the main user requirements for each of the different applications, indicating if there are products that already meet them. Or the most important recommendations for each of the characteristics listed in Section 7.

Another suggestion for future versions of the document is to specify potential requirements that have been taken into account to meet the needs of other CCI+ projects, like RECCAP-2, in which fires (and their respective carbon emissions) play an important role.

2.5 Greenhouse gases (GHG)

User Requirement Document (URD) version 3.0 dated 17 February 2020 is reviewed here.

User Requirement Document (URD)

This document is quite exhaustive in many aspects related to column observations of GHG. The only element not sufficiently treated was the vertical resolution which is only briefly mentioned in section 5.3. It is undoubtedly true that the utility of column-average retrievals without any vertical resolution has been clearly demonstrated. However, with advances in modelling and assimilation of GHG it will be more important in the future to have also vertically resolved measurements, and requirements for those will have to be provided. CMUG suggests that for the next update of the URD document, experts are asked specifically about this aspect. The same comment applies to observing cycle (section 5.4). While this aspect is not relevant for regional flux inversions it might be relevant for assimilation of GHG concentrations.

As a general comment, the document is more geared toward the requirements for flux inversions at the regional level. In future revisions of the document this could perhaps be expanded to include also other applications such as data assimilation of GHG atmospheric concentrations.

2.6 High Resolution Land Cover (HRLC)

The User Requirement Document (URD) version 2.0 dated 3 January 2020 and the Product Specification Document (PSD) version 2.0 dated 3 January 2020, were reviewed. Both documents are found to be useful with clear explanations and sufficient detail. Below are some recommendations for improving the documents. Recommendations for CCI+ Phase 2 specific to CCI HRLC are also given.

User Requirement Document (URD)

CMUG would like to see more information on aggregation tools, the report states "*Visualization and aggregation tools like the ones developed within the ECV MRLC project as the HRLC products are expected to be quite large and should be easily aggregate at the model cell scale while compiling the distribution of the PFT within this cell. These tools will facilitate the use of HRLC data by climate and vegetation models usually working at lower spatial resolutions.*" Details should be provided of how this aggregation will be done. Will users benefit from high resolution information even after aggregation (since the HRLC should be consistent with the MRLC)?

Product Specification Document (PSD)

Users have been consulted on the desired format of data and metadata. Two preferences have been expressed by the users and potential users: GeoTIFF and NetCDF files with metadata included in the file. However, this has been translated in the PSD only in supporting GeoTIFF specifications with separate metadata in XML format. The product specifications in terms of data format do not seem to satisfy a considerable number of users preferring NetCDF format as standard, with metadata included within the product file, nor to satisfy the CCI Data Standards (ref. CCI-PRGM-EOPS-TN-13-0009, version 2.1)

Furthermore, the plan of providing data in Universal Transverse Mercator projection does not seem to have been consulted with users. It could well be possible that users might rather prefer a Gaussian or regular grid projection. It might be advisable to consult users further on this point.

In several places in the PSD it says "*The static map will refer to the year 2018*." but in one place it says "*year 2019 chosen for the static map*". It would be good to clarify the year chosen.

Minor details: some references or explanation is needed for the abbreviations GlobCover, SIGMA, RR in "*in the context of the GlobCover*", "*the recent SIGMA validation experiment*" "*HRLC mapping activities: RR, static maps and change detection.*", for readers who don't know what they are.

Recommendations for CCI+ Phase 2

CMUG would like to see engagement extended to more groups of users who would benefit from the impressive high resolution. Most climate modellers will aggregate at a coarser

resolution, but there might be more applications/users that can benefit from sub-grid information, some effort should be made to identify these.

2.7 Lakes

The User Requirement Document (URD) version 1.1 dated 5 September 2019 and the Product Specification Document (PSD) version 1.2 dated 15 May 2020 are reviewed here. Some feedback on data quality is also supplied.

User Requirement Document (URD)

The user requirements are well covered by this document. The survey carried out was comprehensive and minimum and target standards were identified which is useful.

One issue which was not addressed is the requirements for data quality, specifically for missing data and data gaps. These can make the data unusable if they are not addressed. Users require high frequency lake data without gaps and a preliminary assessment of what is currently available does not match this criterion. The GCOS climate monitoring principles are listed including regular assessment of data quality, and CMUG wonders if this is being carried out? Given the data gaps that currently exist in the product, there is a need for a tool to fill these in some useful way (see section on data quality below).

Product Specification Document (PSD)

While it is useful to keep the information at the highest granularity of information available there are cases (lake surface temperature) where the data are actually 5 km resolution but have been put on a 1/120 degree grid so that they matched with other products. This unnecessarily bloats the data size and can make it difficult to deal with, particularly when the user is not interested in most of the variables available. It would be useful for variables to be available on their native grid as well as the standard 1/120 degree grid.

Data size is a big issue, the total Lake CCI data set is near 2 Tb in size, it would be much easier to handle if there was an option to download variables individually as well as the full set.

One final point, the table in Section 6.3 in the PSD specifies a valid minimum temperature of -200 K. CMUG suggests that unphysical thresholds should be avoided.

Data Quality

CMUG WP3.7 is now underway. The goal was to use Lake Surface Temperature and Lake Ice products as ancillaries to a Regional Atmosphere only Climate model (RCM) in order to assess the impact of accurate lake information on the RCM's ability to represent Land Surface Temperature (using the LST ECV observations for comparison.)

However, the patchy nature of satellite data will make this impossible without a significant amount of post processing and interpolation. The RCM relies on coherent spatial data in time and space with no missing data present. WP3.7 plan to run an RCM over Europe, and during

some months, an average grid box only contains 3 days of non-missing data per month. CMUG are instead considering the use of the ARC3 dataset for an RCM experiment to test the effect of prescribed lake temperature on existing temperature biases over Europe. The ARC3 dataset is based on a physical reconstruction of lake data from satellite observations which requires specific scientific expertise for its completion, and which should be considered in projects aimed at producing data for general use, and a successful result from the RCM experiment would support this requirement.

In order for the CCI Lake data to be of most use to the climate community, reconstruction applying techniques similar to those applied to the ARC3 lake data set would make the data much more useful. Ideally, the reconstruction would go further than the ARC3 dataset and produce a daily spatially gridded data sets.

At the moment the amount of processing and observational expertise needed to use the Lake CCI datasets is a barrier to their use in the climate community, particularly for modelling. It would be our strong recommendation that observation scientists be given the resource to develop a reconstruction of Lake Ice and Lake Surface Water Temperature.

2.8 Land cover

Version 1.0 of the User Requirement document, dated 16 September 2019 was reviewed. Feedback on the quality and maturity of the data product was also supplied

User Requirement Document (URD Version 1.0 from September 2019)

A general re-editing/polishing of the document would be useful to make it clearer and avoid any misinterpretation: some paragraphs are hard to follow; some datasets, initiatives, models are mentioned without a reference or link. A detail: the link http://cci.esa.int/content/tablet-app provided in the document is not working.

There is ambiguity about the need for a high resolution product from the climate community: the document states that "*climate-modelling groups currently aggregate the CCI LC data to coarse resolutions. As such, they find that the current spatial resolution of 300m is a good balance between global coverage and detail*." It should be clarified if the community needs/uses a 300m resolution or only an aggregation to a coarser resolution.

The URD has a section on the "User Tool". It is not clear if the tool referred to is the CDF application. It is stated that "*The vast majority of users have not used the user tool (64%). Some users were not aware that it existed, or didn't have need of it. There appear to be some difficulties in installing the tool, or understanding how to use it*." CMUG would be keen to promote the tool to the research community, but more information is required e.g. links to the location of the tool.

A "tutorial to explain the use" of the user tool would useful in some form (it could be a video or a simple document)

Quality

The visual quality assessment of the LC CCI global SR-7day composites performed using SR composites from various satellite data sources (AVHRR, PROBA-V, MERIS FR and RR) show that the overall quality of the SR composite from FR and RR and PROBA-V data is very good and from AVHRR, is sufficient. 4 different issues were identified:

- Issue 1: missing lakes and island
- Issue 2: NoData (NaN value) in the desert over bright areas
- Issue 3: Cloud/snow ice discrimination
- Issue 4: Undetected semi-transparent clouds and clouds

The issues identified do not constitute a critical road block on the path forward, but should be addressed as time allows.

CCI Global Land Cover map V2

The Land Cover map results from a processing chain which uses the MERIS Full Resolution (FR) and Reduced Resolution (RR) multispectral SR 7-day composites as inputs. The map is a Level 4 product according to the CEOS definition. More specifically, the MERIS RR and SPOT-VGT data were used when needed to compensate for the lack of MERIS FR acquisitions.

CCI Global Land Cover Map V2						
Parameters	Sensors	Spatial coverage	Spatial grid	Temporal coverage	Temporal resolution	Total data volume
Land cover	MERIS SPOT-VGT	Global	300m*300m	1992-2015	annual	~350MB

- The quality of the map varies according to the region of interest. Areas with a lower MERIS FR coverage are:
  - Western Amazon basin
  - Chile and southern part of Argentina
  - Western part of the Congo basin
  - Gulf of Guinea
  - Eastern part of Russia
  - Eastern coast of China and Indonesia
- Not all possible changes between the 22 Land Cover classes are captured in the dataset because more emphasis was put on capturing carbon cycle changes. For instance:
  - Conversions between rainfed and irrigated agriculture
  - Conversions between forest classes e.g. broadleaved to mixed.
  - Conversion between sparse vegetation and lichens and mosses
  - Conversion between 'pure' class to a mosaic class (e.g. forest degradation characterised by the evolution of a pure forest to a mosaic of natural vegetation).
- Although CCI-LC maps are available at 300 m spatial resolution, change detection and therefore land cover changes can only occur at 1 km spatial resolution.
- Changes along the coastlines and of permanent snow and ice class are not included in the CCI-LC products.
- Changes occurring in the 2014-2015 period are limited to forest changes (as the methodology needs confirmation of the land cover over the last 2 years).
- Change detection performance is dependent on the input data quality and availability. The generally lower quality of AVHRR SR and georeferencing implies less reliable change detection.
- Occurrences of misclassification of the larger land cover classes exist. Similarly water is sometimes misclassified as another LC class.
- Also, certain small islands appeared to have been classified as water.

CMUG recommends that these issues are prioritised based on user needs and addressed as resource allows.

Suggestions for future development

Future opportunities for exploiting land cover change maps (also applicable to HRLC) could include:

1. **Easy transferability with other LCCS** such as IPCC, Corine, the International Union for Conservation of Nature (IUCN), the US Geological Survey's (USGS) National Land Cover Database (NLCD), International Geosphere-Biosphere Programme (IGBP) and MODIS. This would help a lot to update LC information in models with the use of the ESA product.
2. **Improving coarse resolution climate simulations**. High resolution land cover could inform improvements in understanding PFT fractions within the more detailed land cover classes found in LC_CCI Phase 2 300m products e.g. information about forest degradation (affecting carbon storage), roughness of vegetation canopy (affecting heat and moisture exchange in the atmosphere), and links between topography, land cover and soil (which may affect hydrological models).
3. **Climate impact and mitigation studies.** It is possible to use the output from higher resolution climate models to drive land surface model studies designed to investigate the impact of different land use management strategies on regional carbon budgets. For instance, studies like this could be done at < 5km for a large continental domain such as Africa for a period of decades. Some recent studies have highlighted the importance of vegetation productivity in tropical grasslands (related to interannual rainfall) as a key driver for interannual changes in atmospheric carbon dioxide.
4. **High resolution weather and climate modelling.** In addition to improving the understanding of PFT fractions, developing a better understanding of physical properties of the land surface such as canopy height, surface roughness and urban morphology. Urban morphology will be covered in the next round of Medium Resolution Land Cover. The availability of other satellite observations such as albedo, FaPAR, fire, and surface soil moisture would also allow better analyses of bias in models. Consistency between land surface parameters input to models is also important e.g. canopy height, LAI, land cover and albedo. Future planned development of weather and climate models on icosahedral grids will allow models to be run efficiently at very high resolutions. This further implies a significant need for high resolution land cover in the weather and climate community.
5. **Locations.** Results from a 2-year uncertainty study have highlighted several locations which could be treated as priority areas for understanding Earth system/climate processes and climate/weather effects:
   a. Europe & North America: Cross-walking uncertainty in bare soil in the agricultural belt (extending into Russia).
   b. SE Asia: Urban mapping (morphology of buildings), tree PFT fraction especially in Southern China. Important for simulating high impact weather impacts on populations
   c. Africa: Shrub vs grass cover in tropical savannahs, to understand LC class uncertainty.
   d. South America: Tropical savannahs are important for carbon fluxes because tropical grasses are very productive and they are very responsive to inter-annual variability in climate.
   e. Northern high latitudes: tree PFT vs bare soil uncertainty seems to contribute most to albedo uncertainty. This may be linked to thermokarst lakes, the northern extent of the tree line, or LC mapping of wetlands.

2.9 Land Surface Temperature

The User Requirements Document (URD) version 1.1 dated 21 February 2019 and the Product Specification Document (PSD) version 1.11 dated 17 June 2020 are reviewed here.

Overall the LST documents are disappointing. There is no ATBD and the PSD and URD documents are very long (160 pp each) and difficult to read (full of tables). It seems that the authors put all the material they had into these documents without thinking of their readability. The LST team should try to produce more concise new versions following the example of the Permafrost team.

User Requirement Document (URD)

This document provides a detailed insight to the process used to create the CCI LST product specification. A substantial amount of raw data is provided from the requirements gathering process. This data coming from a wide range of user cases means that the CCI LST can be created to be appropriate many applications. The full set of raw data exposes the user to ideas and concepts (given as requirements) that may be new to them. This also means that all users can fully understand why the product has certain specifications. Evidence for this is also given by the treatment of the GlobTemperature product in this document. An understanding of how the process used to generate the similar user requirements for GlobTemperature show how lessons have been learnt and how CCI LST can be produced to give users a noticeable improvement of the existing product.

This thorough treatment of the data allows users to consider new ideas and ways to understand the CCI LST data which has the potential to further improve their scientific work. However, the full set of information could be presented in a more accessible format. A full summary early in the document would allow the reader to decide what raw data is useful for their work without having to search for it, or read large sections of the document that might not be appropriate.

The URD states that a validation and user assessment will be carried out independently to data production to ensure that the products meet the requirements of the climate community. No details are specified yet on how such validation will be done. CMUG recommends inclusion of this information (e.g. signposting to relevant documents) within the URD.

Product Specification Document (PSD)

Section 8 of the PSD outlines the plan to provide an ATBD, CAR, UB, PUG and PVIR. Writing these documents is highly recommended to allow for a quality assessment, because a quality and uncertainty characterisation for this highly relevant ECV is important for the climate research community, especially with respect to impact studies, and for detection and attribution.

The PSD provides a comprehensive guide to the file formats, metadata and variables contained in the CCI LST files, it specifies LST uncertainty estimates, including information for different uncertainty components on a grid-point level and the total uncertainty derived

from the uncertainty components, which will both be in all LST_CCI products. This addresses the user requirements from the USD. Such information is needed to fully exploit the data and create systems that use the data files. The full account of the underlying data in each file (based on platform and processing level) is good because it allows an individual to select the most appropriate subset of the data. This information is complete and presented clearly. Differing levels of processing are clearly split and the user can see how the file attributes, metadata and underpinning raw data vary across such different versions of the product.

The PSD further provides an elaborated overview on the uncertainty components of the retrieval, covering random uncertainty, locally correlated atmospheric uncertainty, locally correlated surface uncertainty, systematic uncertainty, and total uncertainty. It further specifically accounts for the important differences in the terms uncertainty, error, accuracy and precision. The aim is to provide the uncertainty information with a clear documentation including descriptions of how to use the data and worked examples. The presented uncertainty characterisation is sophisticated and goes far beyond what other products provide. The USD further summarizes the results collected on the uncertainty information requirements of the users, the current use, and barriers of using uncertainty data. These findings are reflected in the PSD.

The exemplary uncertainty characterisation provides a solid basis for the missing CECR, UCR and UB. Missing information e.g., includes the measures of how the uncertainty should be quantified (standard deviation, root-mean square error, confidence intervals?).

The details of the user requirements and how CCI LST improves on existing products could be moved to a separate document or referred to in the User Requirements Document. This would make the information required to use the product easier to locate in the PSD.

2.10 Ocean Colour

The User Requirements Document (URD) version 1 dated 31 July 2019, the Product Validation and Algorithm Selection Report (PVASR)[6] version 3.0 dated 23 December 2015 (Pt1) and 15 January 2016 (Pt2) and the Climate Assessment Report (CAR) version 3.0 dated 29 June 2017 are reviewed here.

User Requirements Document (URD)

The Phase 3 Ocean Colour URD consists of a draft paper prepared for submission to Nature Scientific Reports, followed by the contents of the Phase 2 URD. The Nature Scientific Reports paper summarises the Phase 1 and Phase 2 user surveys, and so no extra substantive information appears to have been added compared with the Phase 2 URD. The CMUG review of the Phase 3 URD will therefore be kept brief, as the Phase 1[3] and Phase 2[4] URDs have been previously reviewed.

The user surveys conducted by the OC-CCI team have been comprehensive, and the discussion in the URD draws out many major points, discusses apparent contradictions, and puts them in context. As well as surveys conducted by OC-CCI, both CMUG requirements and those from other projects are drawn on and discussed. This results in a comprehensive piece of work. The format of the Phase 3 URD is perhaps a little unusual, and adds little to the Phase 2 URD, but all the necessary information is present, and the draft Nature Scientific Reports paper provides an accessible and readable overview, with more detailed information provided later on in the report.

One thing that stands out as meriting further discussion though is the quote "*Within the free field for this question, there were significant requests for providing primary production and Photosynthetically Active Radiation (PAR) with other requests for inorganic or calcite concentrations and particulate organic carbon. Additional parameters comparable with historical optical measurements were requested, such as Secchi disk depths and the Forel-Ule scale, alongside zooplankton estimates.*" Primary production in particular is widely used by climate modellers, and particulate organic carbon is increasingly used, but these requirements are not currently addressed by OC-CCI. That's not to say they necessarily need to be, given the derived nature and large uncertainties of such products, but the issue is an important one which merits further discussion. It is likely that climate modellers will continue to use primary production and other derived products, but go elsewhere to find them.

Product Validation and Algorithm Selection Report (PVASR)[5]

In the outlook of the v1 Product Validation and Algorithm Selection Report it is stated "*The auxiliary meteorology data should be harmonised. For SeaDAS processing SeaWiFS, MODIS*

[3] http://ensembles-eu.metoffice.com/cmug/CMUG_PHASE_2_D2.3_TechReportonProducts_v0.6.pdf
[4] http://ensembles-eu.metoffice.com/cmug/CMUG_PHASE_2_D2.3_Product_Assessment_v3.1.pdf
[5] These PVASR documents were reviewed by the previous CMUG management team, the documents referenced are not available to the current reviewer, but they are later versions than those currently linked from the CCI Ocean colour web pages, so the comments are left in as they may be relevant

and MERIS data NCEP is applied and but MEGS, POLYMER, Forward NN uses the ECMWF data in the MERIS product". What should have been made clear, is that the ERA-Interim fields MUST be used for the atmospheric water vapour correction in phase 2 of the CCI for all ocean colour products. This will avoid sudden discontinuities seen in the water vapour field of the operational ECMWF fields. CMUG made this point strongly at the beginning of the CCI project. According to the v2 report it appears that the choice was made to use NCEP instead, which at least is consistent, and the v3 and v4 reports do not appear to state what was used.

- While validation of the products is a continuous process, there are still concerns with regards to the under-sampling of the in-situ datasets particularly in the low and high productive (chlorophyll-a concentration) regions.

- Originally, the units of the chlor_a_rms_uncertainty and chlor_a_bias_uncertainty variables in the OC-CCI NetCDF files were not clear. These have since been renamed and the documentation improved, so this point has been addressed.

The OC-CCI team's proposition for periodic comparisons of algorithms when there is a significant change to either in-situ observations or retrieval methods, followed by mission re-processing, is commendable (Ref: UCD). However, there should also be a system (perhaps to be considered by ESA) to archive the previous version(s) with corresponding training and validation dataset to maintain backward compatibility and traceability.

The OC-CCI v2 dataset appears to be consistent with its precursors, including the v1 dataset. Like the v1 data set, the OC-CCI v2 data set was found to be most similar to SeaWiFS derived data, although generally, data records derived from single missions were closer to OC-CCI than other merged mission initiatives, and less biased by the inclusion of data from new OC sensors. For v3 comparison is just made with single sensor and in situ data, but the conclusions appear consistent.

Climate Assessment Report (CAR)

The range of applications is further expanded in v3 of the CAR, providing a comprehensive overview of the products, their accuracy, and examples of how they can be utilised for climate research. As well as a variety of improvements to the processing chain, and adding VIIRS data when available, two important user requirements have been started to be addressed for the first time in the v3 products. Firstly, the products are updated in delayed mode, so are available (at the time the v3 CAR was written, this has since been overtaken by NASA processing changes and the v4 product release) within a month of real time. The CAR rightly notes that the same quality as the initial time series cannot be guaranteed, but with this caveat, having a fully consistent set of products being continually updated should be of great use to a number of users. As long as there continue to be regular reprocessings of the entire time series, based on ongoing new research, CMUG very much encourage this approach.

Secondly, the v3 products begin to merge algorithms for Case 1 and Case 2 waters, in order to create a global product applicable for all water types. This is a major user requirement, which is not addressed by other ocean colour products, and requires substantial new research. The CAR notes that this has "been addressed to some extent in Phase 2 of OC-CCI, but requires sustained additional effort." CMUG welcome a product release that begins to address this, but

echo that sufficient resources need to be put in to addressing what is a novel and demanding, but extremely important requirement.

Despite the v1 and v2 OC-CCI products being specifically developed for Case 1 waters, the data assimilation sections mostly focus on Case 2 water studies using the v2 products. This is an important gap in the analysis. On the other hand, it is encouraging to see the utilisation of the error characteristics of OC-CCI data in data assimilation studies. Furthermore, even in Case 2 waters their use appears to be of benefit for reanalyses. For the v3 dataset, which promises greater accuracy for Case 2 waters, it would be interesting to see how their accuracy compares with v2, but this has not been detailed for data assimilation in the v3 CAR.

The OC-CCI dataset includes two GCOS variables: chlorophyll-a concentration and water-leaving radiances. The GCOS requirements for these two variables, as stated in the update to the satellite supplement to the GCOS Implementation Report (GCOS, 2016), is for an accuracy of 30% for chlorophyll-a concentration and of 5% for water-leaving radiances. In terms of stability, GCOS set their requirements as 3% for chlorophyll-a concentration and 0.5% for water-leaving radiances. The validation of these two OC-CCI v1.0 data products, against *in situ* observations, concluded that the GCOS requirement is met for most of the range in chlorophyll concentrations (except for concentrations lower than 0.1 mg $Chl.m^{-3}$) and for most water leaving radiances (with best results for the shortest wavelength of 412 nm), but slightly missing the GCOS target at longer wavelengths, as the frequency of higher relative errors increases with increasing wavelengths. These conclusions remain true for the v2 and v3 products. It appears that GCOS requirements are now being met for the full range of chlorophyll concentrations, although this does not seem to be explicitly stated. The subtropical gyres, where chlorophyll concentration is typically very low, and the highly productive coastal waters, where chlorophyll tends to be very high, are the geographical regions that exhibit the largest relative errors.

Whilst not GCOS variables, there is a growing user requirement for products such as phytoplankton functional types (PFTs). It is encouraging to see the OC-CCI team considering this issue, and presenting an initial demonstration of such an application. These and other novel products required by users should remain a focus.

In the first sentence of section 3.1 of the CAR, it states that SeaWiFS and MODIS are from ESA and that MERIS is from NASA: these affiliations should be reversed. This was noted in the review of v2, and remains uncorrected in v3. The v3 CAR ends by stating that “A major concern remains the stewardship and curation of the OC-CCI products once the present phase of the CCI product comes to an end.” CMUG echo the sentiments that further sustained research is still required in order to fully address user needs, particularly in relation to accuracy in Case 2 waters. The OC-CCI products to date have come a long way towards doing this, but much ground-breaking work still needs to be done before the potential contribution of ocean colour to climate studies is fully realised.

2.11 Ozone

The User Requirements Document (URD) version 3.1 dated 01 September 2020 and the Comprehensive Error Characterization Report (CECR) version 2 dated 22 December 2016 are reviewed.

User Requirement Document (URD)

This is a very mature document which reflects the fact that ozone is an "old" ECV and has been considered carefully by the scientific community for climate monitoring and reanalysis/ analysis applications. The authors offer a very detailed overview of the requirements, including comparisons with models. This part could be complemented and expanded with recent reanalysis from CAMS and C3S.

The authors also point out that vertically resolved information (ozone profiles) on longer time scales (decades) is rare and global coverage is weak, particularly in the Southern Hemisphere. This could be addressed in future satellite missions.

Finally they mention that no specific requirements for Level-1 data are set because users are interested in Level-2 and Level-3. While this may be true for climate applications, assimilation users may start using Level-1 data in the future. For the next update of the URD CMUG would recommend also including requirements for Level-1 data.

Comprehensive Error Characterization Report (CECR)

The CECR includes a new section discussing error characterization of the OMPS-LP USask 2D retrieval process, which only accounts for the random error component. Although the smoothing error is not included in the reported error estimate, they included representative averaging kernels in the product as diagnostic quantities, this should be explicitly described in the CECR

Please note that the ECMWF web-site is www.ecmwf.int and not www.ecmwf.eu as written in page 25. In addition, the final sentence of page 31 misses the subject, which I assume refers to the table that follows.

2.12 Permafrost

The User Requirement Document (URD) version 1.1, dated 12/02/2019, and the Product Specification Document (PSD) version 2.0, dated 30/11/2019, are reviewed here.

User Requirement Document (URD)

The user community is briefly described and a synthesis of past user requirement surveys is presented (e.g. OSCAR, GCOS, GlobPermafrost) together with a new original survey performed by the project. The latter is presented in detail, but the raw data should be included in an Appendix.

User requirements are also briefly described in the ATBD. Reading the ATBD is needed to fully understand the URD because the methods used have limitations that limit the feasibility of user requirements. These limitations are clearly described in the ATBD.

Product Specification Document (PSD)

This document contains a useful glossary giving the definition of 23 terms (e.g. talik) used to describe permafrost conditions. Data used for validation are also listed, which is essential information. Product specifications (temporal and spatial resolution, accuracy, etc.) and format are described. This is a concise and clear document.

Key atmospheric variables such as air temperature, wind speed, and precipitation are used. They are derived from the ERA5 atmospheric reanalysis. Wind speed is corrected for surface roughness and altitude. A simple spin-up procedure is applied and should be improved in the future. Since the considered ground layer is quite thick (100 m), a long spin-up of several decades (or even centuries) is probably needed. This should be clarified.

2.13 Sea Ice

The User Requirements Document (URD) version 2.0 dated 20 March 2020, the Product Validation & Intercomparison Report (PVIR) for Sea Ice Thickness (SIT) version 1.1 dated 23 July 2018 and the PVIR for Sea Ice Concentration (SIC) version 1.1 dated 23 July 2018 were reviewed. An assessment of the quality of data for the Sea Ice products is also given.

As part of the Sea Ice (SI) CCI, climate data record of both SIT and SIC have been developed. The former record is only available for the Northern hemisphere during winter, while the latter is available for both hemispheres all year round. Both records have a relatively large number of sources for observational uncertainty that are very coherently addressed.

User Requirements Document (URD)

The CCI+ Sea Ice User Requirements Documents (URD) (Reference: D1.1, Issue: 2.0 from March 20 2020) synthesizes user requirements from previous reports, a survey among users who have experience with previous SI ECV products and detailed discussions with individual researches. This multi-level approach avoids unnecessary repetitions of broad user surveys and allows insight into user needs at a high level of detail. The assessment of user needs is comprehensively discussed with regard to feasibility (from the product development teams) and bigger picture (from the climate user group). In addition the report identifies two primary types of users (expert and non-expert users) which further helps to take their needs into account. For example: this separation allows the authors to identify the need for a more general, easy to understand and prominently posted note on the uncertainties of L4 sea-ice thickness product, while at the same time less processed data would benefit more for comprehensive quantitative uncertainty estimates, distributed with the data.

The format of the presented document seems well suited to prepare the product specifications. The following comments could be considered for future versions of this (kind of) report.

Section 3 would be easier to follow if you would introduce the format (Requirements, Response by CCI Team, Conclusions by Climate User Group) and authors thereof more clearly in the beginning of Section 3 (in addition to the 'Scope' section)

The discussion of the use of radar freeboard for model applications in Section 3.1 is interesting. To my knowledge the transformation of model results to a radar freeboard is non-trivial since factors like radar snow-penetration depth, local ice/snow thickness distributions and radar re-tracker characteristics can play a role. The SIT product development team has much more expertise with these processes than most users will have, who would therefore benefit largely from any guidance. Would it be possible (though probably not as part of this project) to develop a radar freeboard observations operator? It would attempt to estimate the corresponding radar freeboard for a set of model variables like ice and snow thicknesses and snow temperature/liquid water content and probably other parameters which have a significant impact on the measurements. This operator could then be used by modelers to calculate radar freeboard based on model parameters in preparation for a comparison with the

measured radar freeboard. Even a simple regression and discussion of limitation would be of value for users of the radar freeboard data.

Considering the different needs of expert and non-expert users, it would be useful to provide a full user product handbook and a short/simple version for non-expert users. Maybe even boiling it down to a one page fact-sheet.

Did any of your discussions identify a need for a specific set of in-situ observations which should not be used as reference for the product development to remain independent? Or is the first priority to improve the data quality, utilizing all available data?

Discussions like those building the basis for Section 3, often do not follow a format which can easily be presented like more general questionnaires. However, any additional information would help the reader to understand the basis of the conclusions and allow for more transparency. This could include a list of questions/topics participants were asked, the number of participants in each group and maybe some overview of summary notes.

Sea Ice Thickness Product Validation and Intercomparison Report (PVIR-SIT)

The PVIR contains an extensive quantification of possible biases of the CCI SIT product relative to independent products. Compared to ground-based in-situ measurements and EM measurements, the CCI SIT product over-estimates ice thickness by typical 0.5 m to 1 m. Also compared to data from upward looking sonar (ULS), the ice-thickness biases are substantial.

The fact that uncertainties are quantified as part of the CCI Sea Ice products is useful. However, there is no systematic description of the individual contributions of the possible error sources to these discrepancies, which would be very helpful for any user of the data. The very large biases shown by this SIT record make the record currently not suitable for standardized use for either model evaluation or model initialization. Hence, the usefulness of this data for the climate-research community is still limited. A better characterization of the most likely underlying error sources is desirable.

For sea-ice thickness, the PVIR-SIT provides new estimates of uncertainties for the various methods that can be used to assess sea-ice thickness from space. The report first compares CryoSat-2 with Envisat, without dedicated links to the SI_CCI products (Section 3.0). The following sections (3.1-3.8) then specifically evaluate and check for consistency of the SI_CCI 2 SIT product against a variety of observations. This is done very carefully and comprehensively, largely meeting the essential requirements of the climate-modeling community. Albeit provided for the Southern hemisphere year-round, the uncertainty quantification for the Northern hemisphere is only available for winter.

Sea Ice Concentration Product Validation and Intercomparison Report (PVIR-SIC)

For sea-ice concentration, the PVIR-SIC describes the per-grid cell uncertainty estimates contained in the three SIC products of SI_CCI 2 with different grid resolutions (SI_CCI-VLF, 50km; SI_CCI-LF, 25km; SI_CCI-HF, 12.5km). The report comprehensively shows and discusses results from quantifying the SIC uncertainty for open water SIC, pack ice SIC, as

well as uncertainties in the times series and the seasonal cycle for both hemispheres. This is a very elaborated uncertainty analysis that goes beyond that of other products.

The uncertainty estimate that is contained in the actual SIC product itself provided by the SIC record only contains an estimate of those uncertainties that can be quantified for example by estimating differences between several over passes of the satellite. We appreciate that the report now also contains an analysis of the uncertainty from melt ponds by comparing the SI_CCI 2 SIC product with the climatological record of melt-pond occurrence from MODIS data.

Summary of Sea Ice product quality

For the uncertainties that can be quantified, the quality of the SI_CCI record is very high. In particular, the detailed description of the various error sources through the year and their inclusion into the actual record is a clear advantage of this record over existing ones. The quantifiable uncertainty of retrieved SIC for 100 % ice coverage is usually below 8 % in the Northern hemisphere, but at around 12 % in Southern hemisphere summer. For open water, the quantifiable uncertainty of retrieved SIC is up to 18 % in the Northern hemisphere, and around 5 % in the Southern hemisphere. These values are still acceptable for climate research, given the larger influence of less-known error sources such as melt ponds.

The description of these uncertainties in the PVIR-SIC and PVIR-SIT is sufficient and very helpful. No other existing satellite product has a similarly extensive assessment of quality and uncertainty.

As requested previously, the sources of uncertainty are now briefly mentioned in the PUG as well, complemented with a short overview on the quantified uncertainties available as maps in the SIC CDR product, namely the retrieval uncertainty, the smearing uncertainty, and the total uncertainty, each given as one standard deviation in percentage. The smearing uncertainty is caused by the insufficient representation of variations in SIC on spatial scales smaller than the grid resolution, while the retrieval uncertainty is based on tie point and brightness temperature uncertainties. Both sources of uncertainty are described in detail in the PVIR, and their impacts are discussed for both the Northern and the Southern hemisphere.

It is important to explicitly mention in both the PVIR's and the PUG that the sole inclusion of the quantifiable uncertainties might pretend a smaller uncertainty than there actually is. Otherwise there is a chance that users underestimate the possible error range of sea-ice concentration based on the uncertainty estimate that's included in the record, which does not include the sometimes large impact from melt ponds and thin sea ice on the total error.

For SIT, GCOS requires 25 km resolution, which is delivered by SI_CCI-2 for the Northern hemisphere, but not achieved for the Southern hemisphere with a grid resolution of 50 km. The SIT accuracy with biases of up to 1 m compared to in-situ observations, and 0.3 m compared to other SIT products is not compatible with the GCOS requirement of 0.1 m accuracy. The temporal resolution as required by GCOS is met by SI_CCI-2 SIT with its monthly resolution. There is no analysis of long-term stability of either SIC or SIT within SI_CCI, which should be addressed in phase 2 of the project.

2.14 Sea Level

The User Requirements Document for the Global Sea Level product (URD_global) version 1.5 dated 22 October 2014 and the User Requirements Document for the Coastal Sea Level product (URD_coastal) version 1.2 dated 16 June 2020 are reviewed here.

Global Product User Requirements Document (URD_global)

The document gathers input from different sources to provide a comprehensive view of the requirements and needs for a wide spectrum of users and groups, from the observational community to the broad climate research community, including for modeling and operational applications. It is therefore a useful reference document for many different user groups, in particular section 5 that provides a synthesis of the major requirements.

There are, however, a few aspects in the document that could be improved. The first relates to the reference documents used to extract the information. Because the current URD for Global Sea Level is from 2014, many of the documents it refers to are 10 years old, and have been superseded. For example, CMUG input was included from its phase-I requirement baseline document v1.2 (from 2010), but there are two newer documents from subsequent CMUG phases that reflect better the current modeling needs for the different ECVs: Deliverable 1.1 of CMUG-II (from 2016) and a first version of Deliverable 1.1 in CMUG-III (finalised in 2020). There is also a newer Implementation Plan with GCOS recommendations from 2016 (GCOS-200), which includes updated specifications for the Sea Level products with respect to those included in Table 2.1 of the current URD document. Similarly, tables 2.2 and 2.4 in the URD documents could also be updated with the latest WMO requirements (OSCAR/Requirements).

The URD could also be improved by including a section on the polar regions, for which remote sensing is crucial. The importance of this region was indeed highlighted in the URD, but no specific recommendations had been identified and therefore listed. Several documents exist now that could help to fill this gap, e.g., the user requirements study from WP1 of the Polar Monitoring project, and the user requirements for the Copernicus Polar Mission.

Likewise, the URD would be more complete if it included some specific information on the requirements for the sea level budget closure project (e.g. from the D1.1 Science Requirements Document), that is one of the most important ESA activities linked to the Sea Level ECV. The other major global research initiative involving sea level is the WCRP Grand Challenge (also a CLIVAR Research Foci) on "Regional Sea Level Change and Coastal Impacts", for which a Science and Implementation Plan exists that provides requirements for an optimal and integrated sea level observing system. It would therefore be worth it to include these requirements on the new URD.

Coastal Product User Requirements Document (URD_coastal)

The Sea Level in Coastal Areas URD provides a concise and useful summary of what will be done in the project to address various aspects of user requirements. Included is valuable discussion of the advantages and disadvantages of certain approaches, and potential

limitations given both the satellite and in situ data records. All the main points appear to be covered with no obvious omissions, though some aspects could use clarifying.

In particular, it is not clear how closely tied the proposed work is to surveyed user requirements, rather than simply what can be done with the available data. The general context is provided satisfactorily, but specific reference to user consultation is largely limited to a link to the global Sea Level URD. This does contain sections specifically addressing requirements for coastal products, but it would be useful to briefly synthesise these in the coastal URD. The proposed work can then be further discussed in this context. For instance, in the coastal URD it is unclear what the highest resolution near the coast will be, and within what distance of the coast this will be, as different numbers are mentioned in different places. Being clearer about this, and tying it to the needs of different applications, could be informative.

For the global merging, it is unclear whether open ocean and other coastal regions will use the standard SL-CCI algorithms, or ones designed for coastal areas. Would this product become a replacement for the existing global SL-CCI product, or always just be tailored to users interested in coastal regions?

The proposed validation against high-resolution ocean models will use a mixture of hindcasts and reanalyses, though the distinction that some runs include data assimilation and others do not is not made in the URD. For the hindcasts, the ensemble of 1/4° resolution simulations considered by Sérazin et al. (2015) will be used. Sérazin et al. (2015) also present two corresponding 1/12° simulations, it is not clear if these will also be used. For the reanalyses, a table is given describing available products, but this seems incomplete. For instance it does not include the CMEMS IBI simulation mentioned further down in the text. Nor is there mention of the CMEMS Northwest European Shelf (NWS) products, which cover almost all of the defined North East Atlantic region, include tides, and are available at 1.5 km resolution for near-real-time products and 7 km resolution for reanalysis. Furthermore, there is no discussion of the inclusion of data assimilation in these products and the ORAS5 reanalysis. Data assimilation will make these products more accurate, but the fact that they assimilate altimetry data means they are not independent of the Sea Level product being validated. This merits discussion.

It is also not clear if the validation against models and in situ observations will be the only error characterisation performed, or if other methods such as those suggested by Merchant et al. (2017) will also be employed. Again, this should be discussed in the context of specific user requirements.

2.15 Sea State

The User Requirements Document (URD) version 1.0 dated 06 February 2019 and the Product Specification Document (PSD) version 1.0 dated 05 February 2019 are reviewed here.

User Requirements Document (URD)

With regards to the User Requirements Document, it is satisfactory, but it is suggested that more explicit further information is provided on how the authors see the timetable for the planned roll out of key improvements to the dataset that they have indicated. Specifically:

- addition of variables representing period and direction (the text seems to imply these for Phase 1, but they are not presently described as alternatives in the PSD and are likely to need some substantial R&D to be completed)
- Is the proposed target coastal zone resolutions for a later phase? (CMUG suggests that the coastal zone is defined in the main body of text in addition to the caption for Table 2.3)

Product Specification Document (PSD)

The Product Specification Document (PSD) describes a data product where the quality of the Phase 1 SWH product will be as good as, or better than, the now discontinued GlobWave long term dataset. As such it will be useful for climate modelling (at different temporal and spatial scales), reanalyses and NWP assimilation. With regards to the PSD as it stands the main comments are:

- it would be good to definitively state the temporal processing applied to the data (I assume from 20Hz to 1Hz, but I couldn't see this explicitly) both in the documentation text and also in the netCDF file metadata
- it would also be useful to users to contrast these data to the CMEMS NRT product where there are overlaps

2.16 Sea Surface Salinity

The User Requirements document (URD) version 1.4 dated 03/01/2019 and the Product Specificaiton document (PSD) version 1.6 dated 24/04/2019 are reviewed here.

User Requirements Document (URD)

The Sea Surface Salinity (SSS) User Requirement Document version v1r4 (Ref.: ESA-CCI-PRGM-EOPS-SW-17-0032, Filename: SSS_cci-D1.1-URD-v1r4.docx) presents a set of user requirements for satellite SSS products in a clear and structured way. The document first gives a good overview of relevant applications for SSS data, followed by summarizing previous user requirement assessments as well as results of a new survey. These results are well summarized in a concise manner in the final section. We have nevertheless a few ideas for consideration of future versions of this document. These are listed below, followed by some minor specific comments.

The requirements from previous assessments (Section 2) and the new user survey (Section 3) are presented and discussed independently and are only compared and synthesized to a very limited extent (stating that they are not substantially different). If possible, it would be very interesting to discuss to which extent the new user survey supports previous findings and if they show differences, whether they can be interpreted as a change of user requirements. Can the two sources be synthesized into a single updated set of requirements?

This document does not discuss which requirements are possible to meet. While this might not be within the scope of this work, it could be worth to state this explicitly in Section 1.1 ('Scope') and/or to discuss e.g. the trade-off between resolution and accuracy in a bit more detail. For example do 78% of users ask for global mean accuracy of 0.2 or better (implying that for only 22% of users an accuracy of 0.3 or worse would be acceptable), but when given realistic (I assume) scenarios, the most popular option has a low accuracy of >0.3 (Figure 14). What are the implications of this? Should future surveys have more questions which visualize the expected retrieval trade-off between desirable properties? Would it be useful (and feasible) to develop a simple tool for users to select the optimal combination spatio-temporal resolution and accuracy? Only five participants (10%) in the presented survey are from outside Europe and North America. Am I correct that this number is too small to see whether these users have distinct requirements? The whole continent of Africa is not represented at all, neither is India despite its EO space program. How could future assessments be improved to be more representative? Considering the large range of applications and the fact that participants had no preference for any one (of 37) products (Page 17) it becomes clear that there is no single product to fit all requirements/applications. Different levels of processing are one approach to this problem, different averaging periods/bin sizes another. A comment on the (perceived) need for any further differentiations (if there are any) could be very valuable. Did you consider asking for the interest in satellite products which are fully independent from (specific) in-situ observations? Or should all available data be used to prioritize product quality?

Specific comments:

- Page 15: 'All respondents were asked about their general research interests and have cited mainly ocean circulation, freshwater fluxes and air-sea interaction (Figure 4)'.

According to Figure 4, interest in 'Trend and variability analysis' was larger than in Air-sea interaction.

- 'CATDS', 'BEC', 'RSS' and 'JPL' have not been specified.
- The Revision Date is 03/01/2019 (Cover page) which is nearly four month before the Revision following ESA comments (for v1r4, this issue, Page ii)
- Section 1.6 SISS: missing 'Salinity'?
- Page 28 last sentence: '(has been chosen 36 times in total, which is 32% of the answers)'. Did you consider to use the number of participants as reference here (instead of number of answers) since this question allows multiple selections?

Product Specification Document (PSD)

The Sea Surface Salinity (SSS) Product Specification Document (PSD) (Ref.: ESA-CCI-PRGM-EOPS-SW-17-0032, Filename: SSS_cci-D1.2-PSD-v1r6.docx) establishes the link between user requirements and SSS product specifications. It is convincingly showing how the user input has informed the product development and the structure of the developed product. Some minor comments can be found below.

While it is clear how the URD informed the product specifications for the first phase of the CCI+, this document could be improved by highlighting which requirements are not fully met and where further product developments should focus on. It is for example mentioned that bias corrected L2 and L3 are planned to be developed in the second phase of the project but the link of these to the URD could be made clearer.

The flow of the document might benefit from moving Section 2 past sections 3, 4 and 5. This would introduce the product variables before quoting the exact attributes which come with them.

The difference between spatial smoothing scales and grid size could be better explained. I assume this is based on the need for reduced uncertainty and required higher resolution for some applications. In this context I think that the attribute spatial_resolution (which I believe refers to the sensor footprint size, not the product grid resolution) would benefit from further explanation.

Specifics:
I compared the attributes given in the PSD with those of a data file I happened to have at hand. This file is version 1.8, instead of version 1.6 for which I have the PSD, that means that there is no need for those to agree on all cases. Below is a list of attributes which might have changed (with no aspiration to be complete) and should be kept in mind for updated versions of the PSD:

- ‘conventions’ in the PSD is called ‘standard_name_vocabulary’ in the v1.8 file
- ‘naming authority’ in the PSD is called ‘naming_authority’ in the v1.8 file
- The file contains a ‘creation_time’ attribute which is not the same as ‘date_created’.
- The attributes ‘spatial_grid’, ‘geospatial_vertical_min’ and ‘geospatial_vertical_max’ are provided in the file but not in the PSD
- The SSS variable does not have the following attributes: ‘coordinates’, ‘units’, ‘valid_range’, ‘scale_factor’, ‘add_offset’ (lines 211, 212, 216, 217, 218 in the PSD)
- AD01 is the User Requirement (instead of 'Reference') Document (URD)

2.17 Sea Surface Temperature

The User Requirements Document (URD) version 2.1 dated 2.1 13 January 2017 is reviewed. Some comments are also included on the maturity of the data.

User Requirements Document (URD)

The SST CCI Phase-II User Requirement Document (URD) (Document Ref : SST_CCI-URD-UKMO-201, Issue 2.1) constitutes a comprehensive collection of user requirements from a thorough assessment of the literature (including from earlier CCI phases), lessons learned documents/discussions, an extensive questionnaire and discussions from a user workshop on uncertainties. The results are presented in a structured and clear way and are well analyzed where appropriate (e.g. the questionnaire). Some points follow suggesting minor improvements to the document.

Of particular interest is the fact that the very long list of requirements from the thorough assessment of user needs are synthesized into 64 key requirements in preparation for the product specifications. Some of them seem to be impossible or cumbersome to be considered in a single product (e.g. SST_CCI-REQ-32 and SST_CCI-REQ-33; representation of uncertainties by covariance matrix vs. ensemble representation). A discussion of prioritization might be included in the URD as is the case for some other ECVs (e.g. Sea Ice_cci) although this may be intended to be covered by the PSD.

The questionnaire is well analyzed (which also means that it is not a big problem that the questions are not listed; Annex A is empty) and includes conditional examinations (i.e. how do requirements depend on type of user group/application). In addition it might be interesting to investigate the relationships between requested spatial resolutions, temporal resolution and accuracy. This could potentially reveal clusters in this three dimensional space which could provide more information for product candidates than analyzing requirements individually. For example: it could be imagined that one set of applications require high spatial resolution but is less stringent on the temporal resolution while most other applications requires dense temporal sampling with more flexibility on the spatial resolution. In this hypothetical case a SST product which attempts to satisfy high spatial and temporal resolutions at the same time would lead to unnecessarily high uncertainties.

Considering the great turnout of the survey, would it be possible to check the results of the survey for differences in user requirements by place of origin? It is shown (and I am sure it is difficult to avoid) that the majority of responses is from the US and Europe but it is not clear whether scientific interests are homogeneous or whether this predominantly western inquiry leads to a distortion of the focus of the product development.

If applicable, would it be of interest to check in future with the users whether there are some in-situ data-sets which should remain independent from the satellite product and its uncertainty estimates?

In section 2.2 accuracy and precision are defined, in 2.3 it is stated: 'The “Accuracy” target here is thought to represent the SST standard uncertainty at the stated spatial scale, rather than bias.' These appear to be conflicting definitions which should be clarified.

The executive summary is repeated in the introduction, which I do not think is necessary.

Maturity of data

A section on feedback from users was given with an issue of data download speeds being highlighted by several users following the v1 release. Also several minor issues with reading the data and treatment of associated flags. CMUG in D3.1v2 have highlighted problems with the time associated with the data which is different according to which depth of the data you are interested in. These issues are not mentioned in the corresponding section of the v2 CAR, so presumably have been improved, but this is not explicitly stated. Feedback from users seems generally positive, with some requesting extra products such as climatologies and monthly files to be available alongside the daily data.

Validation methods approved by the GHRSST science team and conforming to the guidelines under the QA4EO framework under the CEOS-WGCV were adopted. This international oversight of the validation plans is to be encouraged by all CCI teams. The GCOS stability requirement is met in the tropical Pacific and comparable to that of the pre-cursor ARC data. However in general for regions of 100km scale an accuracy of 0.1K with the CCI data is not quite achieved being closer to 0.15K. Areas with persistent cloud cover are particularly challenging in terms of achieving accuracy requirements.

2.18 Snow

The User Requirements Document (URD) version 2.0 dated 17/12/2019 and the Product Specification Document (PSD) version 2.0 dated 19/12/2019 were both reviewed.

A general comment is that this project is in its early phases and only the Snow Water Equivalent (SWE) product is available to the users at this stage. The ATBD was made available to the CMUG, but this document has not yet been published because the authors want to publish the algorithms once they are final. We suppose that the authors are aware of the upcoming special issue in Remote Sensing entitled "Remote sensing of global snow water equivalent"
(https://www.mdpi.com/journal/remotesensing/special_issues/snow_water_equivalent). This journal is known for publishing well written papers in about one month (from the day of submission to the actual open-access publication) and so would make a good vehicle for publicizing the final data set.

User Requirements Document (URD)

The user community is briefly described. A synthesis of past user requirement surveys is presented (e.g. IGOS, GCOS, OSCAR) together with a new original survey performed by the project. The latter is presented in detail.
Reading the ATBD is useful to understand the URD because the methods used have limitations that limit the feasibility of user requirements.

Product Specification Document (PSD)

A rather old reference for SWE (Takala et al. 2011) is given in the PSD together with a very brief description of the algorithms upgrades, more detail would be useful. Product specifications (temporal and spatial resolution, accuracy, etc.) and format are described adequately. This is a concise and clear document.

2.19 Soil moisture

The User Requirements Document (URD) version 2.0 dated 19 November 2020 is reviewed here.

User Requirements Document (URD)

This document is very well written and structured. It helps better understand the CCI soil moisture product and leads to better use by the final users. Latest updates and a state-of-the-art of the three datasets: the ACTIVE dataset from scatterometers, the PASSIVE product from radiometers and the COMBINED (scatterometers + radiometers) are well described going from algorithm development to product validation. This helps the user community to be updated along the ongoing development of the ESA CCI soil moisture product. However, the evaluation against ERA-5 could be misleading as it is still model dependent and this should be clearly stated.

While in some disciplines, the use of ESA CCI surface soil moisture is already widespread, in others, the soil depth mismatch between CCI and models' simulations is a problem and might limit the usefulness of the ESA CCI product for the evaluation of climate model simulations. As an example, while the soil depth of the CCI soil moisture product is (2-5) cm, the surface layer of CMIP models is 10 cm. Soil moisture at 10 cm starts to behave differently. It would be valuable to continue to explore the possibility to produce a root zone soil moisture.

Recommendations for CCI+ Phase 2

GLDAS Noah (v2.1) is used for scaling the datasets to each other. We think that the used model outputs (or any other intermediate information) should be explicitly included in the final CCI soil moisture product files. This could be useful for a detailed evaluation of some LSM.

Spatial and temporal gaps over densely vegetated regions is a well-known shortcoming of the CCI soil moisture product and this hampers the full use of CCI soil moisture over these regions. The CCI team decided to flag data over these regions. We recommend providing these information and let final users decide whether they are useful or not.

2.20 Water Vapour

The User Requirement Document (URD) version 2.0 dated 18 November 2019 and the Product Specification Document (PSD) version 2.1 dated 27 November 2019 are reviewed and some suggestions are provided for CCI+ Phase 2.

The documents are nicely structured and well written. The URD could be improved by providing tables grouped by application as this would allow the reader to find the information needed more quickly. In the product specification document, information on how to use the uncertainty information provided with the datasets would be very welcome. This could include information on error correlation lengths in space and time and possibly recommendations for best practices when averaging, regridding, etc. the uncertainty estimates for applications such as model evaluation. This could be an aim for CCI+ phase 2.

User Requirements Document (version 2.0 from 18 November 2019)

- Figure 2-2: units above panels indicate "gm/kg" but should probably be "g/kg"
- Many acronyms are not explained, e.g. GEWEX, SPARC, GAW, EE7, etc.
- If possible, group user requirements by application (NWP, climate monitoring, climate modelling, model evaluation, etc.) as this would make the document easier to read
- If possible, provide one "overarching" summary table for user requirements from different sources

Product Specification Document (version 2.1 from 27 November 2019)

- Some acronyms are not explained, e.g. PVP
- Page 15: paragraph starting with "Unphysical values are declared as […]" is appearing twice
- Product format and metadata: maybe mention that datasets will also be prepared for obs4MIPs

Suggestions for CCI+ Phase 2

Provide guidelines on how to use uncertainty estimate of gridpoint values:

- error correlation lengths in space and time
- best practice for averaging, regridding
- how to compare with model data

4. Summary

The format and content of the URDs varied considerably between the CCI projects, some merely collected requirements while others provided detailed discussion of their feasibility. Some feedback on document length and usability specific to individual projects is provided within the sections above, but it is in general requested that documents are written with an eye to both readability and usability, rather than including all available information without discernment for what might be of use. More stringent guidance from ESA on expected content for each document would be welcome as well as a more coherent review process.

It would also be good to make all products, datasets and documents citable with a DOI. This is available for some of the CCI ECVs but not all. CMUG understands that the provision of a DOI is available through CEDA and all projects should take advantage of this service if they have not already.

The CCI projects should also prioritise getting most recent versions of documents onto the new CCI web site. Is there some system in place to ensure these pages are kept up to date?

CMUG recommendations are for concise documents with clear contents. Large tables and data should be included in annexes, as the information they contain is relevant and useful to the user, but inclusion in the main body of the report can often detract from usability. CCI LST is an example where document length is excessive and reorganization would be helpful. CCI Permafrost is an example of a well-organized document. Also the contents of each of the project documents should not be duplicated, references to the URD from within the PSD are sufficient.

Specific recommendations on the document structure:

- Standardized contents and recommended length
- Information to be grouped by application (e.g. in tables)
- Summary organized by application of what products are available and which user requirements they meet

Specific recommendations on product and document storage and availability

- Links to all documents from the CCI web site
- DOI provided for all output (documents and datasets)
- Process in place to ensure web site and archives are kept up to date

Recommendations for Phase 2

Specific recommendations were given for each ECV in the relevant sections some points which apply to all CCI projects

- New instruments providing additional products should be considered in the URDs for Phase 2. Technology is progressing fast and CCI should take advantage of developments
- Unphysical values should be avoided
- All data products should be provided in CF compliant NetCDF format. Other formats may be advisable too, but this should be the minimum
- Some thought could be given in the next versions of PSD documents as to how to use the uncertainty information provided with the datasets. It would be helpful to include information on error correlation lengths in space and time and possibly recommendations for best practices when averaging, regridding, etc. the uncertainty estimates for applications such as model evaluation

5. Acronym list

AGB	Above Ground Biomass
ATBD	Algorithm Theoretical Baseline Document
BA	Burned Area
CAMS	Copernicus Atmospheric Monitoring Service
CAR	Climate Assessment Report
CCI+	Climate Change Initiative
CECR	Comprehensive Error Characterisation Report
CEDA	Centre for Environmental Data Analysis
CEOS-LPV	Committee on Earth Observation Satellites Land Product Validation Sub-group
CFL	Calving Front Location
CMUG	Climate Modelling User Group
DGVM	Dynamic Global Vegetation Model
DOI	Digital Object Identifier
ESA	European Space Agency
FR	Full Resolution
GLDAS	Global Land Data Assimilation System
GLL	Grounding Line Location
GMB	Gravimetric Mass Balance
IGBP	International Geosphere-Biosphere Programme
IUCN	International Union for Conservation of Nature MODIS
IV	Ice Velocity
JSBACH	The land surface component of the MPI-Earth Surface Model
JULES	Joint UK Land Environment Simulator
LAI	Leaf Area Index
LCCS	Land Cover Classification System
LSCE	Laboratoire des Sciences du Climat et de l'Environment
LSM	Land Surface Model
LPVS	Land Product Validation Subgroup
MCD45A1	MODIS Collection 5 Burned Area Product
MCD64A1	MODIS Collection 6 Burned Area Product
MERIS	MEdium Resolution Imaging Spectrometer Instrument
MODIS	MOderate Resolution Imaging Spectroradiometer
MOHC	Met Office Hadley Centre
MPI-M	Max Planck Institute for Meteorology
NLCD	National Land Cover Database
NVDI	Normalised Difference Vegetation Index
ORCHIDEE	ORganising Carbon and Hydrology in Dynamic EcosystEms
PAR	Photosynthetically Active Radiation
PFT	Plant Functional Types
PSD	Product Specification Document
PVIR	Product Validation Intercomparison Report
PVP	Product Validation Plan
RCM	Regional Climate Model

REDD+	Reducing Emissions from Deforestation and forest Degradation
RR	Reduced Resolution
SEC	Surface Elevation Change
SFD	Small Fire Databases Burn Product
SIC	Sea Ice Thickness
SIT	Sea Ice Concentration
SMAP	Soil Moisture Active Passive
SR	Surface Reflectance
SWE	Snow Water Equivalent
UCR	Uncertainty Characterisation Report
URD	User Requirements Document
URL	Uniform Resource Locator
USGS	United States Geological Survey

6. References

CMUG-PhaseII D1.1 Requirement Baseline Document v0.6 (http://ensembles-eu.metoffice.com/cmug/CMUG_PHASE_2_D1.1_Requirements_v0.6.pdf)

CMUG-PhaseIII D1.1 User Requirement Document (link tbc)

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