Climate Modelling User Group

Deliverable 2.3

Suitability of CCI ECVs for Climate Science and Services

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

Also contributions from Vrije Universiteit Brussels and members of the Glaciers_cci CRG

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
1.5	05 July 2021	Contribution on Ice Sheets from VUB
2.0	11 Aug 2021	First draft of v2 submitted to ESA
2.0_RID	10 Sep 2021	RIDs received from ESA
2.1	10 Sep 2021	RIDs addressed, resubmitted to ESA
3.0	28 Mar 2022	First draft of v3 submitted to ESA

CMUG CCI+ Deliverable 2.3

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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 a previous phase of CMUG was entitled the Technical Note 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 third for CMUG in CCI+ Phase 1, will focus on the User Requirements Document (URD), the Product Specification Document (PSD), the Product User Guide (PUG), the Climate Assessment Report (CAR) and either the Product Validation Plan (PVP) or the Product Intercomparison and Validation Report (PVIR) for each CCI project, with other documents reviews on an *ad hoc* basis. The URD is reviewed for all 23 of the current CCI projects, the PSD is reviewed for the 9 ECVs new in Phase 1 of CCI+, the PUG is reviewed for 21 of the CCI projects, the CAR for 22 the PVP for 6, the PVIR for 15 and the PQAR, CECR and PVASR for one each.

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?
- Usefulness of the PUG to a new user
- Assessment on the approach and validity of the CAR
- Opinions on the validation methods laid out in the PVP or PVIR
- Feedback on the format and readability of all documents
- 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] https://climate.esa.int/documents/644/CMUG_PHASE_2_D2.3_Product_Assessment_v3.1.pdf

Versions of Documents Reviewed

The comments in this report refer to the relevant documents available to CMUG as of 25 January 2022 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 is not considered here, for the new ECVs established in the CCI+, both URD, PVIR/PVP, PUG 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, PUG, CAR, PVIR/PVP 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.

Table 1. Version of documents reviewed.

ECV	URD	PSD (for ECVs new at CCI+ only)	PUG	PVP	PVIR	CAR	Others	CMUG lead / last update
Aerosols	V4.5 (28/08/2020): Pers comm Thomas Popp	N/A	V1.1 (22/04/2020) https://climate.esa.int/documents/81/Aerosol_cci_PUG_v1.1.doc	V2.1 28/08/2020https://climate.esa.int/documents/619/Aerosol_cci_PVP_v2.1_final.pdf	N/A	V2.0 31/03/2021: pers comm Thomas Popp	V1.2 28/08/2020: pers comm Thomas Popp	Angela Benedetti (ECMWF)/ May 2021
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	V2.0 (07/10/2020) https://climate.esa.int/documents/617/Biomass_D4.3_CCI_PUG_V2.0.pdf	V1.1 (03/03/2019) http://cci.esa.int/sites/default/files/biomass%20D2.5%20Product%20Validation%20Plan%20%28PVP%29%20V1.0.pdf	V2.0 (17/12/2020) https://climate.esa.int/documents/616/Biomass_D4.1_Product_Validation__Intercomparison_Report_V2.0.pdf	V3.0 14/07/2021: pers. Comm Heather Kay		Debbie Hemming (Met Office) / May 2021
Cloud	V3.0 (14/07/2017): Pers. Comm. Simon Pinnock	N/A	V5.1 (16/01/2020) https://climate.esa.int/media/documents/Cloud_Product-User-Guide-PUG_v5.1.pdf	N/A	V6 (03/02/2020) https://climate.esa.int/media/documents/Cloud_Product-Validation-and-Intercomparison-Report-PVIR_v6.0.pdf	V3.1 18/09/2017 https://climate.esa.int/media/documents/Cloud_Climate-Assessment-Report-CAR_v3.1.pdf	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) Apr 2021

Fire	**V7 (27/11/2019): https://climate.esa.int/documents/224/Fire_cci_D1.1_URD_v7.0.pdf**	**N/A**	**FireCCI51 - MODIS (v1.0; 21 April 2020), FireCCISFD11 Sentinel-2 Sub-Saharan Africa (v1.2, 12 February 2019), FireCCILT11 - AVHRR-LTDR (v1.0, 7 December 2020) FireCCIS1SA10 - Sentinel-1 South America (v1.0, 12, July 2019)**	**v1.1 (15/10/20): https://climate.esa.int/documents/623/Fire_cci_D4.1_PVIR_v1.1.pdf**	**v2.1 (16/11/20): https://climate.esa.int/documents/Fire_cci_D5.1_CAR_v2.1.pdf**	**Pablo Ortega (BSC) Feb 2022**
Glaciers	**V1 (01/10/2016): https://climate.esa.int/documents/456/glaciers_cci_ph2_d11_urd_v1.pdf**		**V1.5 (25/10/2016): pers comm Frank Paul**			
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**	**CO2_OC2_FOCA v3.0 (26/01/2021): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PUGv3_GHG-CCI_CO2_OC2_FOCA_v09_20210126.pdf CH4_S5P_WFMD v3.0 (8/01/2021): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PUGv3_GHG-CCI_CH4_S5P_WFMD.pdf**	**v2.1 (19/03/21): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PVIR_GHG-CCIp_v2p1.pdf**	**V2.0 09/03/2021: https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/GHG-CCIp_CARv6_v2.pdf**	**Angela Benedetti (ECMWF) March 2022**

			CO3_TAN_OCFP v2.0 (10/02/2021): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PUGv2.1_GHG-CCI_CO2_Tan_OCFP_v1.pdf CO2_GO2_SRFP & CH4_GO2_SRFP v1.1 (4/02/2021): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PUGv1.1_GHG-CCI_CO2_GO2_SRFP_v2.pdf CH4_GO2_SRPR v1.2 (3/12/2020): https://www.iup.uni-bremen.de/carbon_ghg/docs/GHG-CCIplus/CRDP6/PUGv1.1_GHG-CCI_CH4_GO2_SRPR_v2.pdf					
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	v1.1 (4/05/2020): https://climate.esa.int/media/documents/CCI_HRLC_Ph1-D4.3_PUG_v1.1.pdf		v1.4 (4/02/2021): pers comm Francesca Bovolo	V2.0 20/10/2021: pers comm Francesca Bovolo		Enza di Tomaso (BSC) Apr 2021

Ice Sheets (Greenland and Antarctic)	Antarctic V1.0 (10/12/2019): https://climate.esa.int/media/documents/ST-UL-ESA-AISCCI-URD_v1.0.0.pdf Greenland v2.1 (15/01/2021): https://climate.esa.int/documents/637/ST-DTU-ESA-GISCCI-URD-001_v2.1.pdf	N/A	Antarctic v1.0 (03/06/2021): https://climate.esa.int/documents/1243/ST-UL-ESA-AISCCI-PUG-0001.pdf Greenland v1.0 (14/10/2020): https://climate.esa.int/documents/276/ST-DTU-ESA-GISCCI-PUG-001_v1.0_6Z3mTw8.pdf	N/A	Antarctic v1.3 (04/05/2018): https://climate.esa.int/media/documents/ST-UL-ESA-AISCCI-PVIR-001_v1.3a.pdf Greenland v1 (14/10/2018): https://climate.esa.int/documents/1250/ST-DTU-ESA-GISCCI-PVIR-001_v1.0_9S3FM3F.pdf	Antarctic v3.0 05/07/2018: https://climate.esa.int/media/documents/ST-UL-ESA-AISCCI-CAR-001_v3.0.pdf Greenland v4.3 12/01/2021: https://admin.climate.esa.int/documents/1251/ST-DTU-ESA-GISCCI-CAR_v4.2_signed.pdf		Philippe Huybrechts and colleagues (VUB) / March 2022 Clara Henry (MPI-M) / March 2022 (Antarctic only)
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	V1.1 (15/05/21): https://climate.esa.int/documents/360/CCI-LAKES-0029-PUG_v1.1_signed_CA.pdf	V1.0 (24/04/21): https://climate.esa.int/documents/988/CCI-LAKES-0030-PVP_V1.2.pdf		V2.1 29/10/2021: https://climate.esa.int/media/documents/CCI-LAKES-0044-CAR_v2.1.pdf		Grace Redmond (Met Office) / Nov 2020 Erasmo Buonomo (Met Office) May 2021
Land Cover	V1.0 (16/09/2019): https://transvol.sgsi.ucl.ac.be/download.php?id=afff326017409fd6	N/A			V1.1 21/08/2017: https://www.esa-landcover-cci.org/?q=webfm_send/138	V1.0 11/07/2017: https://climate.esa.int/documents/96/ESACCI-LC-Ph2-CARv3-1.0.pdf	PUGS v1.3 (31/08/2020): https://datastore.copernicus-climate.eu/documents/satellite-land-cover/D3.3.12-v1.3_PUGS_ICDR_LC_v2.1.x_PRODUCTS_v1.3.pdf	Enza di Tomaso (BSC) Apr 2021

Land Surface Temperature (LST)	**V1.1 (21/02/2019): pers. Comm. Simon Pinnock**	**V1.11 (17 June 2020): pers comm. Simon Pinnock**	**v1.2 (22/10/2020): https://admin.climate.esa.int/media/documents/LST-CCI-D4.3-PUG_-_i1r2_-_Product_User_Guide.pdf**		**v1.2 (23/09/2020): https://admin.climate.esa.int/media/documents/LST-CCI-D4.1-PVIR_-_i1r2_-_Product_Validation_and_Intercomparison_Report.pdf**	**V2.0 20/12/2021: pers comm Darren Ghent**		**Jean-Christophe Calvet (Météo France) Nov 2020** **Rob King (Met Office) Apr 2021**
Ocean Colour	**V1.0 (31/07/2019): https://docs.pml.space/share/s/lg8js7hFSOaaZrtbtFGbmQ**	**N/A**	**V1.0 (12/10/2020): https://docs.pml.space/share/s/okB2fOuPT7Cj2r4C5sppDg**		**V1.0 18/02/2021: https://docs.pml.space/share/s/xztLpM-NRka9rqoeSQFw5A**	**V1.1 10/02/2022: https://docs.pml.space/share/s/vS7lSM2DRBqrM9APK-PJkw**	**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) / Apr 2021**
Ozone	**V3.1 (01/09/2020): pers. Comm. Michel Van Roozendael**	**N/A**		**v2.1(06/12/2020): https://climate.esa.int/documents/409/Ozone_cci_PVP_2.1_20201206.pdf**		**V1 draft 24/11/21: pers comm Michel Van Roozendael**	**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) May 2021**

[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

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**	**v2.2 (03/03/2021): https://climate.esa.int/documents/596/CCI_PERMA_PUG_v2.2.pdf**	**V2.1 (14/01/2021): https://climate.esa.int/documents/627/CCI_PERMA_PVIR_v2.1.pdf**	**V3.0 (30/09/2021): pers comm Tazio Strozzi**	**Jean-Christophe Calvet (Météo France) Jan 2022**
Sea Ice		**V2.0 (20/03/2020): https://climate.esa.int/documents/78/Sea_Ice_User_Requirements_Document_2.0.pdf**	**N/A**	**SIT v1 (10/02/2017): https://climate.esa.int/documents/75/Sea_Ice_Thickness_Product_User_Guide_1.0.pdf** **SIC v1.1 (20/09/2017): https://climate.esa.int/documents/70/Sea_Ice_Concentration_Product_User_Guide_1.1.pdf**	**SIT v1.1 (23/07/2018): https://climate.esa.int/documents/76/Sea_Ice_Thickness_Product_Validation_and_Intercomparison_Report_1.1.pdf** **SIC v1.1 (23/07/2018): https://climate.esa.int/documents/71/Sea_Ice_Concentration_Product_Validation_and_Intercomparison_Report_1.1.pdf**	**v2.1 (29/03/21): https://climate.esa.int/documents/681/SeaIce_CCI_P1_CAR_D5.1_Issue_2.1_accepted.pdf**	**Andreas Wernecke (MPI-M) / May 2021** **Pablo Ortega (BSC) / Feb 2022**
Sea Level (previously Sea Surface Height)	**Global**	**V1.6 (22/10/2014): http://www.esa-sealevel-cci.org/webfm_send/235**	**N/A**	**v2.2 (13/12/2016): https://climate.esa.int/documents/477/SLCCI-PUG-029-2-2.pdf**	**V2.0 (09/12/2016): https://climate.esa.int/documents/478/SLCCI-PVIR-073_SL_cciV2-1-1.pdf**	**2.1 (22/11/17): https://climate.esa.int/documents/476/SLCCI-CAR-079-2-1.pdf**	**Pablo Ortega (BSC) Feb 2022**

coastal	V1.2 (16/06/2020): http://www.esa-sealevel-cci.org/webfm_send/640	N/A	v1.3 (11/06/2020): https://climate.esa.int/documents/605/SLCCI_PVP_006_ProductValidationPlan_v1.3.pdf		V1.0 (05/10/2020): https://climate.esa.int/documents/606/SLCCI_PVIR_018_ProductValidation_v1.0.pdf	V2.0 16/03/2021: https://admin.climate.esa.int/documents/1127/SLCCI_CAR_023_ClimateAssessmentReport_v2.0.pdf	V2.0 (22/11/2017) https://climate.esa.int/en/projects/sea-level/key-documents/	David Ford (Met Office) Jan 2022
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	v1.0 (17/01/2020): https://climate.esa.int/documents/884/Sea_State_cci_PUG_v1.0-signed.pdf		V1.0 (22/06/2020): pers comm David Cotton	V2.0 18/10/2021: Pers comm Ellis Ash	V2.0 (18/10/2021) pers comm Ellis Ash	David Ford (Met Office) / Jan 2022
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	v1.2 (5/03/2020): http://cci.esa.int/sites/default/files/SSS_cci-D4.3-PUG-v1.2-signed_0.pdf	V1.1 (04/12/19): http://cci.esa.int/sites/default/files/filedepot/SSS_cci-D2.5-PVP-v1.1-signed.pdf	V3.0 12/09/2021 https://www.dropbox.com/t/Rm55kmONeKN1cpKD	V3.1 22/07/2021 https://www.dropbox.com/t/aXI2nsh5QiyJ1ydb		Andreas Wernecke (MPI-M)/ Feb 2022 Pablo Ortega (BSC)/Feb 2022
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	v2 (8/04/2019): https://climate.esa.int/documents/267/SST_cci_PUG_v2.pdf		V1.0 16/06/2019 https://climate.esa.int/documents/268/SST_cci_CAR_v1.pdf	V1.0 16/06/2019: https://admin.climate.esa.int/documents/268/SST_cci_CAR_v1.pdf	Product Quality Assessment Report (PQAR) v4.1 (27/10/2020): https://datastore.copernicus-climate.eu/documents/satellite-sea-surface-temperature/v2.0/D2.SST.2-v2.2_PQAR_of_v2SST_products_v4.1_APPROVED_Ver1.pdf	Andreas Wernecke (MPI-M) / Feb 2022

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	v2.0 (09/11/2020): https://climate.esa.int/documents/287/Snow_cci_D4.3_PUG_v2.0_r2MH0hU.pdf		V2.0 (25/11/2020): pers comm Gabriele Schwaizer	V3.0 (15/12/2021): pers comm Gabriele Schwaizer		Jean-Christophe Calvet (Meteo France) Jan 2022
Soil Moisture (SM)	V2.1 (19/11/2020): pers comm. Richard Kidd	N/A	v2 (16/04/2021): https://admin.climate.esa.int/media/documents/ESA_CCI_SM_D4.2_v2_Product_Users_Guide_v06.1_i1.0.pdf		V2 (16/04/2021): https://admin.climate.esa.int/media/documents/ESA_CCI_SM_D4.1_v2_PVIR_v6.1_issue_1.0.pdf	V2.0 (04/11/2021): pers comm Richard Kidd		Frederique Cheruy (IPSL) & Amen Al-yaari (Sorbonne University) May 2021
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	V1.1 (13/10/2020): pers. Comm. Pauline Cocevar	V1 (24/02/2021): Pers. Comm. Pauline Cocevar		V1.1 03/11/2020: https://admin.climate.esa.int/media/documents/Water_Vapour_cci_D5.1_CAR_v1.1.pdf	V2.1 30/09/2021: pers. Comm Pauline Cocevar	Axel Lauer (DLR) May 2021

Comments on CCI project documentation

The CCI ECV projects 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

The following documents are reviewed below:

- User Requirements Document (URD) version 2.0 dated 28 August 2020
- Product Validation Plan (PVP) version 2.1 dated 28 August 2020
- Product User Guide (PUG) version 1.1 dated 22 April 2020
- Climate Assessment Report (CAR) version 2.0 dated 31 March 2021

User Requirement Document

This document has undergone several revisions and is now in a very mature form. However, there are now new aerosol variables proposed for climate monitoring and assimilation and user requirements for these should be 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

Product Validation Plan (PVP)

This is a solid validation plan, set out in a concise and effective manner. No improvements can be recommended.

Product User Guide (PUG)

This is a well written document. As a user, I know that the CCI+ AER products are easy to download and use. I would suggest expanding the section related to the product limitations and strengths in connection to SLSTR. It is now known from the verification that SLSTR performs less satisfactorily that AATSR due to the specific viewing geometry. I think the users should know more about this. At the moment, to the best of my knowledge, the SLSTR dataset cannot be considered to be continuing the AATSR climate data record, is this correct? Please add a comment specifically to address this in the document.

Climate Assessment Report (CAR)

This document assesses Aerosol_cci data sets that have been processed with the Swansea algorithm until the end of 2020, part of a second climate research data package. It describes two user case studies,on radiative forcing and data assimilation, and some initial results. . These case studies are of great interest for the climate and reanalysis research community, and, therefore, for CMUG. The description of the case studies are preceded by an evaluation of the data sets at different spatial and temporal resolution. In the first case, averages values of AOD and AODf at a monthly, 1 by 1 degree gridded resolution are considered for three years (1998, 2008 and 2020, based respectively on ATSR2, AATSR and SLSTR on Sentinel-3 A and B) and compared to MODIS and MACv3 climatology. In the second case, level 3 SLSTR monthly mean AODs are compared to CAMS reanalysis AODs for one year (2019), while for data assimilation purposed SLSTR level 2 values are used for a month of the same year. We list here some suggestions to improve future versions of the document.

General comments: No description is given of the major reprocessing of the retrievals that was done in late 2020 with the Swansea algorithm. It would be good to have a very brief summary of the main changes or improvements achieved, and, most importantly, to state the algorithm version that has been used. Also, it is not completely clear if the data used in the data assimilation case study have also undergone this major reprocessing since the introduction mentions years 1998, 2008, 2020 and not 2019. The introduction also mentions the CISAR algorithm applied to SLSTR. The reader is left curious to know whether there are plans for it to be assessed through the user case studies. Additionally, there are no links between the evaluation/comparison section and the analysis of the results of the two case studies. One would expect that some results could be explained or linked to the evaluation part, but maybe this will happen when further analysis is done of the case studies. In future versions, if would be good to have a summary of the evaluation/comparison part in the final summary section, and also to have a description of the results of the case studies in the executive summary.

Comments specific to case study 1: A comparison between SLSTR retrievals from Sentinel-3A and 3B highlights retrieval limitations at wider swath angles. It would be useful to know if this limitation has been discussed with the retrieval team and, as a consequence, a correction should be applied to the retrieval (function of the angle) or data at wider swath angles should be discarded. Difference of retrievals between the different years and sensors points to retrieval differences and biases that jeopardize any attempt to analyze decadal trends. It would be useful to specify if, and at which extent, those differences also affect the conclusions drawn in the rest of the case study. Very minor comment: there are not details about which collection and data set of MODIS retrievals has been used.

Comments specific to case study 2: It would really help the reader to have a short summary of the main finding of the comparison against the CAMS reanalysis, beside listing the details of the results for each analyzed month. Also, it would be good to provide more details about the following: the spatial resolution of the model simulations, any explanation on why the assimilation changes the sign of the bias with respect to the control, how PMAP data are bias-corrected. Also, the description in table 4.1 of the experiment hju4 is not clear: it is called "Control (analysis)" but it seems rather a forecast with no data assimilation. In the same table please consider adding the following as continuation of the experiment description: "SLSTR over ocean in the operational configuration" for hjf2, "in the operational configuration" for hjlc, “over ocean in the operational configuration” for hjxo, “over ocean and land in the operational configuration” for hjxq.

2.2 Biomass

The following documents are reviewed below:
- 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,
- Version 1.1 of the Product Validation Plan (PVP) dated 03 March 2019,
- Version 2.0 of the Product User Guide (PUG) version 2.0 dated 07 October 2020,
- Version 2.0 of the Product Validation and Intercomparison Report (PVIR) version 2.0 dated 17 December 2020.
- Version 3.0 of the Climate Assessment Report (CAR) version 3.0 dated 14 July 2021

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 500 m 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?

Product User Guide (PUG)

The PUG provides a very useful and comprehensive summary of the algorithms, thematic content, limitations, and technical specifications (format, file names and metadata) of the Biomass_cci data products available at the end of the second year of the project. This is supported by appendices of information on the datasets that are helpful for interpreting the AGB map and map data format. To help understand the extremes in the datasets CMUG would find it useful if extreme categories could be included in the figure scales where relevant, e.g. for figure 3-1 it would be helpful to include a discrete category for the highest AGB estimates 350-?? Mg ha^{-1}. The visual comparison of AGB with Google Earth maps is useful for communicating the detail available from the AGB estimates to wider audiences. Further, the comparison with higher resolution airborne laser scanning (ALS) data for selected regions (figure 3-6 to 3-11) is helpful for demonstrating very high-resolution model-observation based assessments.

Product Validation and Intercomparison Report (PVIR)

The PVIR assesses the quality of the three Biomass_cci products (global AGB for epochs 2017, 2018 and a refined 20210 product) and their uncertainty measures, relative to plot observations and LiDAR campaign data. The potential errors in all datasets and harmonisation steps are well explained and it is useful that both observation-based and model-based uncertainties are considered. The spatial and ecoregion assessments are helpful for comparing with comparable model output, although variations in biome / ecoregion categories may provide a limitation on this. CMUG would welcome the use of additional datasets to extend the error associated with using small plot data for AGB map assessment.

Climate Assessment Report (CAR)

General comments

The CCI Biomass Climate Assessment Report (CAR, year3, version 3.0) provides a clear and comprehensive review of the literature relating to the current understanding and modelling of biomass. The report gives a good account of the difficulties involved in evaluating biomass production in land-surface / earth system models (from observational and modelling perspectives) and identifies the allocation of net primary production (NPP) to woody and soft tissue pools (and associated turnover time) as a particularly important process to represent more realistically within models.

It would be helpful to include a short definition of the CCI Biomass AGB at the start of the document, so the reader is aware of how this estimate compares with others in the literature. It would also be worth considering a glossary of terms at the end of the document for the key vegetation pools and exchanges discussed in the review.

The evaluation of biomass in carbon cycle models (section 3) using the Trendy v8 S3 simulations is interesting and informative, highlighting a wide range in simulated AGB across models. Possible reasons for the differences between model and CCI Biomass AGB are suggested and would need further study to understand. It is beyond the scope of this review but would be valuable future research to assess how much the differences in model-specific plant functional types contribute to the spatial differences with CCI Biomass AGB. This would help modellers to prioritise improvements in plant functional type definitions relative to other carbon cycle processes.

The studies described in sections 4 to 8 are very helpful to understand responses and suitable modelling approaches of biomes to different pressures. It would be really useful if the studies that focus on tropical biomes could be extended to temperate and boreal ecosystems so global land surface / earth system models could also be informed by a consistent approach across these biomes.

Specific comments

2.3. Allocation of net primary productivity to biomass pools

- It would be useful to include a short sentence regarding the paper by Jones et al (2020), which presents a modelling approach to improve the representation of carbon storage in land-surface models and demonstrates its application to drought response in tropical forests within the JULES land-surface model. The paper 'highlights the need for future research into carbon storage and allocation in plants, particularly in response to extreme climate events such as drought'.

3.1.1. Modelling biomass in global climate/carbon process-based models

- Page 23 '…total biomass outputs from all models are first remapped to the same spatial resolution…'. To enable replication, it would be helpful to include the method used for the remapping, e.g., nearest neighbour, inverse distance interpolation?
- It would be helpful to know how sensitive the spatial estimates of AGB are to the biome-specific ratios of total:AGB carbon used from Liu et al (2015). For example, if the ratios for each biome type are varied to the extremes of their plausible range, how would this change AGB for each biome?

4. Towards an evaluation of carbon allocation and turnover times in models

- This is an impressive study using 2011-2016 biomass, NPP and LAI data to constrain key vegetation carbon cycle processes across tropical regions, including carbon allocation and turnover time. It would be very interesting to extend this study to temperate and boreal regions to assess if canopy height is as important to wood and leaf carbon allocation in sub-tropical ecosystems. There is great potential of such satellite and field-based studies to inform improvements in land surface / earth system models.

5. Tropical biomass change. Case study of impacts and legacy from the 2015-16 El Niño event

- This is a very detailed and impressive study of the responses and recovery of tropical vegetation to drought during 2015-16. Understanding and modelling the resilience of tropical biomes to drought is vitally important to reasonable future carbon cycle projections and this work is very useful for this modelling. It would also be useful to provide case studies to help understand the resilience of temperate and boreal biomes to extreme events.

8. Preliminary global estimates of AGB changes combining SMOS passive microwave data and CCI Biomass high resolution maps

- Page 69, end of paragraph. Another missing representation of disturbance in TRENDY models would be pests and pathogens…which would have been particularly relevant to British Columbia (see https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/forest-health/forest-pests/bark-beetles/mountain-pine-beetle/responding-to-the-1999-2015-outbreak).

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 documents reviewed in this section for the Cloud_cci project are:

- User Requirements Document (URD) version 3.0, 14/07/17
- Product User Guide (PUG) version 5.1, 16/01/20
- Comprehensive Error Characterisation Report (CECR) version 4.1, 01/04/2018
- Product Validation and Intercomparison Report (PVIR) version 6.0, 03/02/20
- Climate Assessment Report (CAR) version 3.1, 18/09/2017

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 take advantage of the uncertainty information could be a possible improvement. This could include guidelines on:

- 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 during the day. 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.

Product Validation and Intercomparison Report (PVIR)

General comments / ideas

- Using a wider than single-spaced line spacing would improve readability of such an extensive document.
- The tables are very useful, enabling quick search of the document.
- As an idea for future versions of this document: where available, the per-pixel uncertainties might possibly be used to check how much of the deviations found between the Cloud_cci data and the reference datasets in section 4 can be explained within these uncertainty estimates and possibly also to distinguish between systematic and random differences.
- Usage of ERA-Interim data could be replaced with ERA5.
- Evaluation of seasonal differences is not part of the evaluation (and that's fine). But whenever striking differences are found in particular seasons, this could be mentioned as a precaution for users of the data.

Specific Comments

- ***Section 2:***
  - Other key documents mentioned in introduction (e.g. ATBDv5, etc.) might not be straight-forward to find for the inexperienced user. Giving a reference or a website could help with this. Maybe simply insert hyperlinks into the document.
- Section 3.3:
  - SIS and SDL are not defined in the text / figure captions but only in the list of acronyms.
  - Do numbers given for standard deviation include both, temporal and spatial (different stations) variation?
- Section 4:
  - I like the "general findings" summarized as bullet points
  - From a user's point of view, I would find it more convenient to have the evaluation results sorted by variable instead of separating into morning/afternoon, i.e. I would prefer going through all variables and read about morning/afternoon results in sections directly following each other or maybe even side-by-side in the same section.
  - Figures showing climatological means (e.g. figure 4-1): it would be a bit easier to gauge the differences between the different satellite products when showing the absolute values of the reference dataset only and difference plots for all other datasets instead.
  - Discussions: whenever possible, a more quantitative language would be helpful, e.g. providing a measure/number/estimate (or a reference to a table) for statements such as "has worsened", "slightly decreased trend", "a bit lower", etc. (examples taken from the section on total cloud cover, but this applies to other discussion sections as well).
  - Captions of figures showing standard deviation ("…standard deviation of […] averaged…"): not sure I understand the term "averaged" as I thought this would be simply the temporal standard deviation calculated from a time series of monthly means for the given time period.
  - Tables: I would rather speak of e.g. "evaluation metrics" than "evaluation scores" as the quantities given here are (in my opinion) not really "skill scores" in the sense of combined metrics but rather simply individual metrics.
  - Page 31, second bullet point ("with all datasets being with approx."): being with → being within?
  - The footnotes on pages 38/74/101 are repeated on the following pages. Not sure that's needed. Probably enough to only put the footnotes on pages where they are actually referenced.
  - Page 44, third line from bottom: "relative" → "relatively"
  - Page 57, line 2: "tropic" → "tropics"
- Section 5:
  - Page 100: not sure the term "blacklisted" is the best option, maybe rather something like "masked as missing"?
- Section 6:
  - The introductory parts for the individual variable are a bit repetitive. The common parts such as the formulas and explanation of the terms could be summarized in the beginning of section 6.

 - Uncertainty estimates for the reference datasets could be summarized in a table as this would help to quickly find the key information.
- Section 7:
    - A table summarizing the numbers for the different variables would be great.
    - The tables "Recommendation on the usage" are great and could be put in a more prominent position (e.g. a separate subsection) so they are easier to find when looking through the table of contents.
    - Page 131: "heavy aerosol" → e.g. "high aerosol concentrations"
    - Caption of table 7-2: not sure what is meant by "tractability" in this context.

Climate Assessment Report (CAR)

The document is nicely structured and well written. Please find below some general and some specific comments.

General comments / ideas

- Maybe add links to documents such as, for instance, "ATBDv5", "PUGv3.1", etc., mentioned in the text to make access more convenient.
- Throughout the whole document: it would be nice to have (where possible) more quantitative statements, e.g. section 2.1.2: "slightly better", "worse", "great difficulties", etc. or e.g. section 2.1.3: "correlations […] are good", "relatively good agreement", etc.
- Wherever possible, fuzzy statements such as, for instance, "a hint of bimodality appears", "seems to amplify the problems" or "much overestimated" (sect. 2.1.4) could be avoided or rephrased to be more specific and precise.
- Section 2.3
    - The section reads rather as a summary than conclusions.
    - It would be nice to have some quantitative measures of the agreement / disagreement of the datasets, maybe in the form of a table.
    - If possible, recommendations on which dataset to use could be given for specific regions / applications to guide users, particularly for climate analyses.
- For updated versions of this document: consider switching from ERA-Interim to ERA5
- Model evaluation (e.g. sections 5.1.4, 5.1.5): might be good to introduce some metrics (e.g. RMSD, correlation, bias, etc.) to measure model performance; I am not sure some of the conclusions e.g. about ice sedimentation in the model or the importance of increasing the spatial resolution can actually be drawn from this analysis without showing or discussing additional results.
- At the moment I am not fully convinced of the added value of presenting evaluations of selected models including brief descriptions of the models and model setups. A brief comparison as an example is certainly fine but I would rather be interested in general methods including e.g. recommendations or do's and don'ts or a discussion of strengths and limitations of the CCI data for certain model evaluation applications. Except for the message that a cloud simulator should be used for comparisons with the CCI data, I think I did not get too much out of these sections…

Specific Comments

- ***Acronym CFC is missing in the list of acronyms and I would find it helpful if explained at its first occurrence in the executive summary (p. 11).***
- ***p.12, 1), "***development of a carefully" → delete "a" or alternatively "s" in "data sets".

- p. 22, “For each latitudinal/longitudinal grid box the mean GEWEX cloud assessment reference value is estimated as well as the rms of its variability among its datasets.” → it is not clear to me, what is meant here by “variability”. If possible, be more specific. E.g. does variability include the day-to-day variability and seasonal variability or are you talking about anomalies?
- p. 25, “shown in the other figures” → if possible, specify which figures.
- p. 27, “Correspondingly, one should expect that the instantaneous radiation fields calculated with these datasets will be sometimes out of phase despite the fact that their averages can be coherent with reality.” → as a user it would be nice to know what is meant by “can be coherent with reality”. Are the fields (when averaged) usable, what are expected uncertainties?
- p. 30, “The Cloud_cci MERIS-AATSR dataset presents a distribution continuing at all pressures towards very high and thin clouds.” → I do not understand this statement, maybe consider rephrasing.
- p. 32, “the following conclusions is drawn” → change “is” to “are”
- Table 3-1: Add units (%) to caption or table header.
- Figure 4-1: I found it a bit confusing to see two entries of “Cloud_cci AVHRR-PM ice” in the legend → maybe remove second entry
- Section 4.3.1, “general climate models” → general circulation models (typically also simply climate model)
- Section 4.3.3: how are CTP mean values calculated? Are cloud-free cases treated as missing values and ignored? I am not completely sure what to get out of this section. Some more interpretation would be helpful.
- Figure 5-13: I find it very hard to distinguish “NaN” from the actual values (similar gray shades)
- p. 59: “clt” has not been defined yet
- p. 60: “CCIu” has not been defined yet
- Fig 5-18: Would be nice to have the CCI uncertainty as e.g. a shaded area or as error bars directly with the CCI curve instead of separate at the bottom of the plot

2.4 Fire

This section reviews the following documents:
1) The PUGs of the 4 ongoing (not deprecated) datasets:

- FireCCI51 - MODIS (v1.0; 21 April 2020)
- FireCCISFD11 Sentinel-2 Sub-Saharan Africa (v1.2, 12 February 2019)
- FireCCILT11 - AVHRR-LTDR (v1.0, 7 December 2020)
- FireCCIS1SA10 - Sentinel-1 South America (v1.0, 12 July 2019)

2) The PVIR of all datasets version 1.1 dated 15 October 2020
3) User Requirement Document version 7.0 dated 27 November 2019
4) Climate Assessment Report (CAR) version 2.1 dated 16 November 2020

MODIS / AVHRR-LTDR / Sentinel-2 Sub-Saharan Africa (SFD) / Sentinel-1 South America (S1SA) - PUG

The four documents provide a very detailed up-to-date account and relevant information for the users for the four datasets that are currently supported by the Fire_cci. The format is consistent and very well structured in all the documents, which are at the same time tailored to the particularities of each of the products. We value the level of detail in each of the sections, which include clear and concise explanations and high-quality figures that nicely illustrate the information provided in each of the product layers and attributes. The first three documents also include a clear description of how uncertainty is characterised in the corresponding products and provide recommendations on product use, both of which are of great value. Neither the description of uncertainty nor the recommendations on product use have been included in the last document (Sentinel-1 South America), which would be desirable. The first two documents also have a section of known issues, not present in the other two (S1SA and S2SA). For coherence across documents, we suggest including it in all of them, as it is not clear if no issues are known for the last two, or if they are simply not reported. Another section that is only included in two of the documents and we recommend adding to the other two (S1SA and SFD) is product validation. We also note that for the last one there is a mismatch between the name of the database used in the document (Small Fire Database), and the one reported in the Fire_cci key document section (Sentinel-2 Sub-Saharan Africa).

D4.1 product - PVIR

This document assesses the quality of the burned area global and regional products, describing the methods and some preliminary results. The validation protocol is thoroughly detailed and its implementation is well supported with a nice selection of very illustrative figures. However, we have noted that some of the figures, especially some of the first ones (2 to 9), are blurred and would benefit from improved definition. Considering several accuracy metrics to evaluate the products is also valuable, as is the inclusion of the equations used to derive them. However, as not all readers of the document will be familiar with these metrics, we recommend providing some short explanation on how to interpret them and the nuances between them. We have also noted that this document does not cover all the burned area Fire_cci products (e.g. Sentinel-2 Sub-Saharan Africa or the Small Fire Database are not included). It would be good to acknowledge that some datasets are not included, justify why, and refer to other documents (if available) describing how they have been evaluated.

User Requirements Document (URD)

The latest Fire_cci 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. More importantly, it explains 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.

Climate Assessment Report (CAR) Fire CCI+ v2.1

This CAR document provides a detailed study case focused on Africa that nicely illustrates how observational uncertainties in different burned area products affect the representation of fire emissions, through the use of a regional atmospheric model with a chemistry module. The report is very well documented, from the choice of products employed, with particular emphasis on the aspects/limitations that are associated to each dataset that could explain differences between them, to important methodological aspects, including how the data needs to be pre-processed to overcome the main limitations previously described. The document is also well supported by a nice selection of figures and tables.

There are some aspects that could be taken in consideration to improve future CAR documents, targeting the African or other application studies. The first concerns the document title, which is too generic and does not reflect the specificity of the study. This can be particularly important if future CAR documents are focused on other study regions. Specifying this clearly either in the title or in a subtitle would allow interested users to identify the CAR document that is more useful for their needs. The motivation for the choice of Africa as a study region was also not very clear (is it a region where observational uncertainties are more prominent? Or is it a region for which more products are available?). A second point that could be improved is the balance between the part of the document that describes the products and methodological aspects (24 pages) and the actual evaluation (3 pages), which is rather short and mostly focused on some preliminary results for the reference experiment (using the FINN burned area product, the default climatology in the atmospheric chemistry model, which is not a product produced by the CCI). The report also mentions that a more thorough evaluation will follow but it's unclear where nor when it will be published. As a final minor recommendation, given that the CAR document focuses on a particular region, it would be beneficial to include a final paragraph extrapolating whether and how the main lessons learned would apply other study areas.

2.5 Glaciers

For the Glaciers ECV, members of the Glaciers_cci Climate Research Group (CRG) have evaluated two documents, the User Requirements Document (URD) for Year 3 of Phase 2 dated 1.10.2016 and the Product User Guide (PUG) version 1.5 dated 25.10.2016. These former versions were selected as they provide the most complete overview of the consortium activities. However, the URD is outdated now. The Algorithm Theoretical Basis Document (ATBD) and the Product Validation and Intercomparison Report (PVIR) have not been directly evaluated, but the Glaciers_cci team compiled the essentials of both documents in two separate journal publications that were reviewed by peers and are both well cited.

User Requirements Document (URD)

The document is still an adequate overview of user requirements, with a focus on satellite- based possibilities, but the document is also partly outdated as it is more than 5 years old and does not reflect some of the recent progress in the field. Depending on future use, the document could be updated to represent the situation today. As one example, the Sentinel-1 and 2 satellites launched from 2014 and 2015 with a higher spatial and temporal resolution that are very useful for glacier outline mapping and deriving velocity fields are not mentioned in this document.

The text in 3.1.3 on IPCC could be updated to include the latest assessments report. The text and title in 3.1.6 on the IACS RGI working group is now outdated. The text should be updated in a new version to reflect that, including names of leaderships (e.g. replace late Graham Cogley) and mention some of the current objectives and deliverables. The Section 4.2 elevation change-DEM differencing can be updated with the recent progress on dense ASTER time series on a much larger scale (Urq-15). In 4.4, much progress has been made using Sentinel-1 data to derive velocity fields. The summary list needs to be updated to reflect the current situation.

(Liss M. Andreassen, President of the International Association of Cryospheric Sciences, IACS)

Product User Guide (PUG)

The Glaciers CCI Product User Guide (PUG) describes well the nature, format, and use of the different data products from the Glaciers CCI project. Products on glacier area, elevation change from altimetry and DEM differencing, and velocity are all described. Ample tables and illustrations provide examples and detailed documentation of the proper use of the products, as well as known issues.

The document also describes software tools, both proprietary and open-source, that can be used to work with the data.

Users of these data sets will naturally need to know what sources of error exist, the error magnitudes, and under what conditions the data sets should be used. The PUG discusses limitations in the different data sets and includes figures that illustrate potential problems for some applications. For example, Figure 2.3 shows the complications that arise when digitizing outlines for debris-covered glaciers. As another example, Figure 3.1 shows the potential effects of varying coverage and time ranges on altimetry measurements in Antarctica.

Finally, the PUG includes 25 references to relevant documentation in the literature. In this reviewer's opinion, the PUG adequately covers all the information and metadata users will likely need to make effective use of the Glaciers CCI data sets.

(Bruce H. Raup, Director of Global Land Ice Measurements from Space, GLIMS)

Algorithm Theoretical Basis Document (ATBD)

The essentials of the ATBD are published in a peer-reviewed journal (161 citations, 21.1.22): Paul, F. and 24 others (2015): The Glaciers Climate Change Initiative: Algorithms for creating glacier area, elevation change and velocity products. Remote Sensing of Environment, 162, 408-426. (https://doi.org/10.1016/j.rse.2013.07.043)

Product Validation and Intercomparison Report (PVIR)

The essentials of the PVIR are published in a peer-reviewed journal (56, citations 21.1.22): Paul, F., T. Bolch, K. Briggs, A. Kääb, M. McMillan, R. McNabb, T. Nagler, C. Nuth, P. Rastner, T. Strozzi, J. Wuite (2017): Error sources and guidelines for quality assessment of glacier area, elevation change, and velocity products derived from satellite data in the Glaciers_cci project. Remote Sensing of Environment, 203, 256-275. (https://doi.org/10.1016/j.rse.2017.08.038).

2.6 Greenhouse gases (GHG)

The documents reviewed for the GHG_cci project are:

- User Requirement Document (URD) version 3.0 dated 17 February 2020
- Product Validation and Intercomparison Report (PVIR) version 2.1 dated 19 March 2021
- Product User Guides (PUGs) for the 5 latest products:
  - *CO2_OC2_FOCA version 3.0 dated 26 Jan 2021*
  - *CH4_S5P_WFMD version 3.0 dated 8 Jan 2021*
  - *CO3_TAN_OCFP version 2.0 dated 10 Feb 2021*
  - *CO2_GO2_SRFP & CH4_GO2_SRFP version 1.1 dated 4 Feb 2021*
  - *CH4_GO2_SRPR version 1.2 dated 3 Dec 2020*
- Climate Assessment Report (CAR) version 2.0 dated 9 March 2021

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.

Product Validation and Intercomparison Report (PVIR)

This document is an excellent and detailed validation document with impressive results, particularly for CO2. Please expand the executive summary with some key points that go together with the three tables presented, referring to the page numbers of the document in which more detailed information can be found. It’s hard for the reader to go through 100 pages of report, so signposting to the most relevant information would be welcome.

Product User Guides (PUGs)

Designed to provide information for each individual CO2 or CH4 retrieval/dataset and brief enough to be readable, I found them useful. In particular, it was useful that all documents had a similar structure (although some were missing a brief introductory summary, which is always welcome), including a section on known issues and recommended data usage. I would recommend including a short executing summary for all retrievals in future versions of the PUG documents.

Climate Assessment Report (CAR)

This is an exhaustive and well-written document. A very good executive summary explains the main findings and is noted as a particularly good feature.

CMUG recommend adding a short section on "What's new with respect to previous editions of the document". There is a mention in the Change log that the current version (CRDP#6) includes methane, whereas the previous version did not. This should be highlighted more prominently as it's a major aspect of novelty.

Other than this suggestion the document is mature and fit for purpose.

2.7 High Resolution Land Cover (HRLC)

The documents reviewed for the HRLC_cci project are

- User Requirement Document (URD) version 2.0 dated 3 January 2020
- Product Specification Document (PSD) version 2.0 dated 3 January 2020
- Product User Guide (PUG) version 1.1 dated 4 May 2020
- Product Validation Plan (PVIR) version 1.4 dated 4 February 2021
- Climate Assessment Report (CAR) version 2.0 dated 20 October 2021

The URD and PSD are found to be useful with clear explanations and sufficient detail. However, the PUG would benefit from some editing and clarification and the PVIR was less easy to read with many figures and little explanation. The CAR is an early stage document and will improve in the next version when the product is more mature and can be assessed fully. Below are some recommendations for improving the documents. Recommendations for CCI+ Phase 2 specific to HRLC_cci 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, there seems not to have been user-consultation about the plan of providing data in Universal Transverse Mercator projection. It could well be that users might prefer a regular grid or Gaussian 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*". The year chosen should be clarified.

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.

Product User Guide (PUG)

This document provides information on the products that are currently being developed for the HRLC new Essential Climate Variable (ECV) including a general description of the products, the planned format, naming convention for the product files, delivery methods, the availability of quality flags and plans for an independent validation. Four products are envisaged: a static HRLC map for a specific year (2019), historical HRLC maps every 5 years, historical HRLC change detection maps every year, NDVI/EVI indexes every 4 months. The latter three products will cover the period from 1990 to 2015.

With HRLC being a new ECV, certain aspects of the products are yet to be determined in the current version of the document (for example, it is stated that "*delivery projection and data organisation [...] will be discussed at the time of the first delivery*", or that "*ERS-1, ERS-2, ENVISAT-ASAR will also be considered*", or that "*The change map will be produced on the basis of Landsat acquisitions of 1 year*" - which year?). If updated information is available at this stage into the project, those aspects could be revised.

Additionally, here are some suggestions are for aspects to be expanded in the document.

- It would be useful to add information for the users about the tile schemes, either the Sentinel 2 MGRS tiling scheme or the Landsat Path/Row tiling scheme that will be used by the HRLC products.
- There is no explanation on how the pixel-wise uncertainty will be characterized.
- Some explanation of the field "probability" would be useful as it is not clear what it represents, and also the definition of the six status used to characterize a pixel in the pre-processing phase ("Filled" status?).
- Some products are declared Level 4, another L3P, and another L3, it would be good to clarify it.
- Three products are named "MERGED". It would be useful to explain briefly the reason.
- There is a mention of a delivery of a product, called VRT file, consisting of the merge of all the tiles. It would be useful to have more details about this format and it should be included in the table in section "2.1 Products summary" (the table has no title or number) where currently only the delivery of multiple files is present.
- Regarding the NDVI/EVI index product, the statement that "*there is no confidence information, since it is a simple mathematical product that does not depend on any further process from our side*" does not encourage its use. It would be good to provide more explanation for it.
- Section 8 on User Tool does not introduce the user tool that is mentioned in other documents (a user tool similar to the LC_cci user tool to do re-sampling, re-projections, …). Are there still plans to create one?
- In general, the document will benefit greatly of some re-editing, in particular Section 1 and 2: different typos are present and some sentences do not read well.

Product Validation and Intercomparison Report (PVIR)

This document provides quality and quantitative assessment on Round Robin prototypes of the HRLC new ECV products. It also inter-compares the products with reference data.

We list here some suggestions to improve the document:

- Section 3.1 should briefly explain the validated products.

- Table 2 is not useful without some explanation of all the acronyms used and briefly of the algorithms behind them. The SAR maps are not in the table.
- The visual assessment highlights only issues with the products without providing examples of good performance that are listed in Table 3.
- In the quantitative assessment section suddenly the name "processing chain" is used to identify the different products/algorithms, this might be confusing for the user as it was not used before.
- The two assessment methods (per stratum and unbiased) are not easy to follow, it would be useful to have a clear explanation of what they calculate.
- Given the many plots, the sections on quantitative assessment would benefit from more extensive conclusion sections explaining the findings obtained in the various assessments, also with the use of summary tables.

Climate Assessment Report (CAR)

This document describes preparation work to assess the CCI HRLC product. Being a new ECVs, the initial work has been done mainly with MRLC maps and other satellite products with the aim to develop tools to assess the HRLC in the near future. In parallel, the assessment teams are working also on improving modelling aspects in order to better describe land cover heterogeneity and integrate the new HRLC information. A full assessment of the HRLC product is expected to be provided in the next version of the document.

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.

2.8 Ice Sheets – Antarctic and Greenland

The documents reviewed in this section are

- Antarctic Ice Sheets User Requirements document version 1 dated 10/12/2019
- Greenland Ice Sheets User Requirements document version 2.1 15/01/2021
- Antarctic Ice Sheets Product User Guide version 1 dated 03/06/2021
- Greenland Ice Sheets Product User Guide version 1 dated 14/10/2020
- Antarctic Ice Sheets Product Validation and Intercomparison Report version 1.3 dated 04/05/2018
- Greenland Ice Sheets Product Validation and Intercomparison Report version 1 dated 14/10/2018
- Antarctic Ice Sheets Climate Assessment Report version 3 dated 05/07/2018
- Greenland Ice Sheets Climate Assessment Report version 4.3 dated 12/01/2021

User Requirement Documents (URDs)

The URD (User Requirements Document) for the GrIS (Greenland Ice Sheet) and AIS (Antarctic Ice Sheet) appear comprehensive and useful documents. They are publicly available for download from the ESA-CCI website and contain contact information. The documents have a reference ID and a time of release, indicating that the report history is documented. A list of acronyms and abbreviations is also included.

The documents are a useful addition to the datasets, as they sketch the background, the need and the usefulness of the ECVs that are provided by ESA-CCI. The documents state that feedback is acquired and integrated into the datasets and their guidance documents, which significantly improves the data quality. The summary of the GCOS (Global Climate Observing System) and user requirements hereby enable the user to draw conclusions with respect to the quality assessment of the datasets. Furthermore, future plans are also included, from which the users can derive expected products.

Product User Guides (PUGs)

The Product User Guides for the GrIS (Greenland Ice Sheet) and AIS (Antarctic Ice Sheet) are mature, user-friendly, extensive and comprehensive documents that are publicly available from the ESA-CCI website. Both reports contain contact information of the authors and project leaders, and also references to scientific publications are included in case the user requires more in-depth information. The documents have a reference ID and a time of release, indicating that the report history is documented. As such, users can make sure that the latest version has been selected. The documents are an added value to the datasets and guide the users towards correct usage and interpretation of the datasets. It must be said, however, that jargon is regularly used, which may not always be understandable for non-expert users. A list of acronyms and abbreviations is included in both documents and aids the comprehensibility of the text.

In the documents, each ECV (Essential Climate Variable) is treated in separate paragraphs. For both the AIS and GrIS these are the surface elevation change, the ice velocity and the gravimetric mass balance. For GrIS, also ice discharge and supraglacial lakes are included, while for AIS, the grounding line location is discussed additionally. All paragraphs include information about the product data content, the data format, file naming convention, the grid projection, the known limitations and a suggestion for software tools to visualize the data. An additional open software GIS (Geographic Information System) tool, QGIS, may be added as a suggestion, as it allows for easy visualization. It may be useful to add some specific applications for each ECV (e.g. ice discharge calculations from ice velocities, global sea level change contribution from the gravimetric mass balance or surface elevation change, etc.). Below, we furthermore add some suggestions for additional remarks, by using the examples of the 3 different ECVs that are present in both PUGs (ice velocity, surface elevation change and gravimetric mass balances). These can then be integrated in the document for better usage and interpretation of the data.

For the ice velocity ECV, it may be useful to spatially indicate some regions over the ice sheet where relatively lower quality data are generally found. For example, spatially filled data gaps are not flagged in the dataset and hence are not detectable. Furthermore, there is no information given related to the time of the year during which valid pixels for the velocity estimate were acquired. Also, without clipping with an ice mask, non-ice-covered pixels have values that are not NaN. A suggestion for a data-matching ice mask may therefore be useful. Another aspect is that products contain ‘stripes’ or ‘streaks’ in slow flow areas due to ionospheric disturbances, which can be seen from visual inspection, and this phenomenon is not mentioned in the document. Next, for AIS, no figure or map is included that shows the velocity data. However, a map of ice sheet-wide AIS velocities is shown on the referred CryoPortal download page (http://cryoportal.enveo.at/), but these data are not available for download (i.e. only data for some individual glaciers are available). In the PUG, also no information is given related to the spatial extent of the AIS IV data.

With respect to the surface elevation change ECV, it can be noted that the variable name of the SEC in the downloaded files is “rate of surface elevation change” with units meter year-1. This choice of words may confuse users in thinking that it is a trend with units meter year-2. The listing of discussed paragraphs is also not always consistent (e.g. for the AIS PUG, no product known limitations are discussed for the SEC ECV).

It may furthermore be useful to state that also other processes than surface melt and accumulation can contribute to surface elevation change, and that SEC does not necessarily equal mass change. From the examples of the metadata that are included in the PUG, it can be deduced that the global attributes and variables in the AIS and GrIS data files are not similar. For example, for AIS, a parameter that quantifies the total number of contributing radar altimeter measurements used to calculate dh/dt is mentioned, while it is absent in the GrIS PUG. This may be useful information for data quality assessment. It may be useful to state that peripheral ice caps and glaciers are not all included in the GrIS file. For AIS, there is no link to download the SEC data is included on the website (https://climate.esa.int/en/projects/ice-sheets-antarctic/data/).

For the gravimetric mass balance ECV, the information with regards to the gravimetric mass balance (GMB) ECV is rather compact in the GrIS PUG. Product known limitations are, for example, not included for this ECV. It may be useful to state, for especially non-expert users, what the definition of the mass balance of an ice sheet is and how users can convert the data to global sea level contributions. From the data, no gridded error and uncertainty characterization can be found.

Product Validation and Intercomparison Reports (PVIRs)

As with the PUG, also the PVIR (Product Validation and Intercomparison Reports) for the GrIS (Greenland Ice Sheet) and AIS (Antarctic Ice Sheet) appear as user-friendly documents. They are publicly available for download from the ESA-CCI website. The reports contain contact information and references to scientific publications. The documents have a reference ID and a time of release, indicating that the report history is documented by a change log. Also here, the regular use of expert terminology is noted, which may affect the comprehensibility of the text for non-experts. Although a list of acronyms and abbreviations is also included. It can be said that the documents are an added value to the datasets, as a comprehensive description of validation procedures significantly improves the data quality. As before, each ECV (Essential Climate Variable) is treated separately in the documents, including information about sources of independent validation data (including references), the validation procedure, the validation outcome and recommendations for product improvement.

With respect to velocity, the product is evaluated against multiple publicly available products covering the same area. The overall conclusion shows good results, as the statistics of validation outcome exhibit good agreement between ESA-CCI data and external independent datasets. The discussion of the results is, however, rather compact. In the AIS PVIR, some text is furthermore still shown in red, which gives the document a rather incomplete impression.

For the surface elevation change data, a possible suggestion may be broadening the spatial and temporal extent of the validation procedure and to elaborate more on how the different surface characteristics, data acquisition methods and data processing methods may influence the interpretation and outcome of the validation procedure. As of now, data seem to be validated only to airborne laser altimetry data, which implies low spatial coverage. The discussion and interpretation of the results is also rather compact. Differences between ESA-CCI radar altimetry and other independent datasets may, for example, be allocated to slope-related error, differences in subsurface penetration of the signal, and/or the modeling and processing/editing component. Furthermore, differences related to spatial/temporal coverage and sensitivity to weather conditions play a role in explaining the remainder of the observed variance.

Finally, in the section on issues of validation of GMB some text is shown in red, which gives the document a rather incomplete impression.

Climate Assessment Report, Greenland Ice Sheet (CAS_GrIS)

The CAR (Climate Assessment Report) for the GrIS (Greenland Ice Sheet) is a mature, user-friendly, extensive and comprehensive document that is publicly available from the ESA-CCI website. The report contains contact information of the authors and project leaders, and also references to scientific publications are included in case the user requires more in-depth information. The document also has a reference ID and a time of release, indicating that the report history is documented. As such, users can make sure that the latest version has been selected. The documents discuss a range of ECVs (Essential Climate Variable), including the surface elevation change (SEC), the ice velocity (IV), the gravimetric mass balance (GMB), grounding line location (GLL), calving front location (CFL), mass flow rate ice discharge (MFID), and supraglacial lakes (SGL). An overview of these ECVs and their potential usage in determining the current state of the ice sheets, including their benefits and limitations, is thereby discussed. The documents are surely an added value to the datasets and guide the users towards correct interpretation and the potential usage of the datasets. A list of acronyms and abbreviations furthermore aids to the comprehensibility of the text. However, jargon terminology is still regularly used, which may not always be understandable for non-expert users. For the gravimetric mass balance, for example, it may be useful to state, especially for non-export uses, what the definition of the mass balance of an ice sheet is and how users can convert the data to global sea level contributions. Furthermore, future plans and recommendations are also included, from which the users can derive expected products. All in all, it is clear that the document significantly improves the data quality.

We add some suggestions for additional remarks, which are especially related to the data quality. It may, for example, be useful to spatially indicate some regions over the ice sheet where relatively lower quality data are generally found. A clear reference to the PVIR (Product Validation and Intercomparison Report) and/or End-to-end Uncertainty Budget Document (E3UB) in the appropriate sections of the text can, in that aspect, be included to refer the user to more information concerning the uncertainty characterization and validation of the datasets. In our opinion, elaborating more on how the different surface characteristics, data acquisition methods and data processing methods may influence the results and their interpretation, would add further value to the documents. A comparison of the data characteristics to the GCOS (Global Climate Observing System) may also enable the user to draw conclusions with respect to the quality assessment of the datasets. It should also be stated whether peripheral ice caps and glaciers are or are not included, as well as whether spatial and/or temporal gaps in the data exist(ed) and how they are treated. Mentioning whether data only comprise gridded or time series products, or whether their spatial scale includes only regional or ice sheet-wide areas, may also be of use. For the ice velocity ECV, information related to the time of the year during which valid pixels for the velocity estimate were acquired (summer season acquisitions, all-year round) and how this may affect the eventual data, should also be clearly stated. The last sentence on page 21 stops incompletely.

We conclude that the CAR document appears relatively user-friendly and mature, but some slight improvements can still be made, which are especially related to the product quality and how this influences the eventual results and their interpretation.

Climate Assessment Report, Antarctic Ice Sheet (CAR_AIS)

The CAR (Climate Assessment Report) for the AIS (Antarctic Ice Sheet) is a mature, user-friendly, extensive and comprehensive document which is publicly available from the ESA-CCI website. The report contains contact information of the authors and project leaders, and also references to scientific publications if a user requires more in-depth information. The documents have a reference ID and a time of release, indicating that the report history is documented. As such, users can make sure that the latest version has been selected.

The Climate Assessment Report comprises of a short introduction followed by an in-depth case study of the Getz and Sulzberger Sector, West Antarctica. Four climate variables are discussed, namely the Surface Elevation Change (SEC), the Gravimetric Mass Balance (GMB), the Ice Velocity (IV) and the Grounding Line Location (GLL), with greater emphasis on the last two. The case studies give an excellent example of the useability of the variables, which can be applied to other areas in Antarctica.

Section 2 gives an overview of the CRG assessment approach and provides a context for the subsequent sections. It may be worth emphasising in the first few paragraphs that the concentration of the report is on specific case studies, because a broader, Antarctica-wide assessment was expected from the table of contents. Alternatively, the table of contents could be altered.

An overview of the Surface Elevation Change (SEC) and Gravimetric Mass Balance (GMB) products is given in Section 3. The SEC product uses a 5x5km grid and captures the ice thinning in the vicinity of the grounding line. The GMB product is of lower resolution (50x50km), but captures the negative mass balance in the case study region. The authors note that a higher resolution would be advantageous.

In Section 4, an overview of the Ice Velocity (IV) and Grounding Line Location (GLL) products is given. The authors note that data are missing, probably due to a lack of surface features necessary for the tracking algorithm. A superposition of two flow regimes is observed in the data and the source of this feature is not clear. The authors acknowledge the ambiguity in identifying the grounding line location due to various factors. Despite this, in areas where there are multiple grounding line observations available, there is little difference between observations.

In Section 5, the authors examine the processes responsible for the glaciological changes observed in the Getz and Sulzberger sector. The authors recommend using models in addition to observations in order to fill data gaps. Using observations (2005-2017) and the BICICLES model, the authors demonstrate that dynamics instability in the region studied is at least partially responsible for mass loss in this region. This work shows the potential for similar studies to be performed for other regions in Antarctica.

In Section 6, the authors provide a context for the results of the study. The focus is on the grounding line and ice velocity, as these have been found to be of greater interest in the Getz region. The accuracy of the grounding line position was determined using a combination of SAR datasets and an optical approach to identify the break in surface slope. The authors acknowledge that differences in grounding line identification techniques may result from an inadequate estimation using the optical technique. The authors find the generated ice velocities to be consistent using different techniques and compare well with externally acquired results. Useful project recommendations were included in Section 6.3.

The document adds value to the datasets and guides the users towards correct interpretation and the potential usage of the datasets. A list of acronyms and abbreviations furthermore aids to the comprehensibility of the text. However, jargon terminology is still regularly used, which may not always be understandable for non-expert users. For the gravimetric mass balance, for example, it may be useful to state, especially for non-export uses, what the definition of the mass balance of an ice sheet is and how users can convert the data to global sea level contributions. Future plans and recommendations are included, from which the users can derive expected products. All in all, it is clear that the document significantly improves the data quality.

General comments: From the table of contents, an overview of SEC, GMB, IV and GLL was expected, followed by a case study of the Getz & Sulzberger Sector, whereas the case study was in fact incorporated into the text throughout the document. A thorough read-through to correct minor grammatical errors and repetitions would improve the text. Some figures were not referred to in the text (Fig. 8 and Fig. 9) and Fig. 9 was missing an (a) and (b) part. Section 6 could have a more precise title or include more citations.

We also add some suggestions for additional remarks, which are especially related to the data quality. It may, for example, be useful to spatially indicate some regions over the ice sheet where relatively lower quality data are generally found. A clear reference to the PVIR (Product Validation and Intercomparison Report) and/or End-to-end Uncertainty Budget Document (E3UB) in the appropriate sections of the text can, in that aspect, be included to refer the user to more information concerning the uncertainty characterization and validation of the datasets. In our opinion, elaborating more on how the different surface characteristics, data acquisition methods and data processing methods may influence the results and their interpretation, can additionally add value to the documents. A comparison of the data characteristics to the GCOS (Global Climate Observing System) may also enable the user to draw conclusions with respect to the quality assessment of the datasets. It should also be stated whether peripheral ice caps and glaciers are or are not included, as well as whether spatial and/or temporal gaps in the data exist(ed) and how they are treated. Mentioning whether data only comprise gridded or time series products, or whether their spatial scale includes only regional or ice sheet-wide areas, may also be of use. For the ice velocity ECV, information related to the time of the year during which valid pixels for the velocity estimate were acquired (summer season acquisitions, all-year round) and how this may affect the eventual data, should also be clearly stated. The font type and size should match over the entire document for improved appearance.

We conclude that both the CAR document appears relatively user-friendly and mature, but some slight improvements can still be made to the readability of the document and related to the product quality and how this influences the eventual results and their interpretation.

2.9 Lakes

The documents reviewed for the Lakes_cci project are:

- User Requirement Document (URD) version 1.1 dated 5 September 2019
- Product Specification Document (PSD) version 1.2 dated 15 May 2020
- Product User Guide (PUG) version 1.1 dated May 2020
- Product Validation Plan (PVP) version 1.2 dated 24 April 2020
- Climate Assessment Report (CAR) version 2.1 dated 29 October 2021

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.

Product User Guide (PUG)

The PUG is useful and clear. Table 1 captures our requirements (basic ones are daily frequency and 10 year length), but it doesn't capture the real life incompleteness (sometimes sparsity) of these datasets, which is an issue for application to climate modelling.

Section 3.3.1 on lake ice cover (LIC) includes a CMUG relevant application in point 4) of the user application list, however, it would probably be useful to include numerical weather prediction studies as a separate item here. NWP could reasonably be done with these datasets as well as climate modelling evaluation studies. For this there will be the same issue with data gaps raised above and from our contribution to this WP, i.e. the need for a spatial and temporal complete dataset at daily frequency (and for at least 10 years), in order to produce reasonable climatological estimates even from a Regional Climate Model (RCM) driven by reanalysis.

LSWT, section 3.4: potential use in NWP and climate modelling is not mentioned, and LSWT is even more relevant to these applications than is LIC.

Product Validation Plan (PVP)

This document is clearly laid out and easy to read. The plan of validation through comparison of the products with in situ data and other products, for case studies based on field work and for combined verification to look at consistency between variables is sound. The sections on constraints of the validation are welcome, although it could perhaps be made clearer how some of the issues described might be addressed.

The statement "*when the climate data records are released for external use, project scientists will be collecting feedback from data users and improving the data production chains accordingly*." is good in theory, and CMUG would encourage pursuing this process fully. We would be interested in being part of the round robin process outlined in Sections 5 and 6.

At a recent Climate Science Working Group (CSWG) meeting it was noted NWP models using data assimilation can supply information useful for gap filling, and such a dataset would also be useful for evaluation. Currently no European Meteorological services assimilate lake data, but as work progresses using the FLake model some data may become available in the near future and making early use of this might be of benefit to Lakes_cci.

An acronyms list would be a useful addition.

Some specific queries and comments are recorded below:

- In section 2.4 both validation method 1 and method 2 rely on in situ data with the limitations described in detail. The statement "*validation only allows providing general overview of errors budget (for in site Calibration / Validation experiment) and comparisons against in situ data give another overview*" seems contradictory as all validation described uses in situ data and it is not clear what the "regular external validations" mentioned are. This section could be made clearer.
- Section 3.1: references for the hypsometric method could be given
- Section 3.2: S1 and S2 are not defined
- Figure 3 needs map reference (lat/lon on axes) and text should be larger
- Figure 7: "Locations of 113 in 43 lakes" → "Locations of 113 observations in 43 lakes"
- Section 4.1: Unfortunate that all observations are in the northern hemisphere
- Section 4.4: "The principal constraint is that the number of remotely-sensible lakes with in situ data, which is limited." → "The principal constraint is the number of remotely-

sensible lakes with in situ data, which is limited." Or "The principal constraint is that the number of remotely-sensible lakes with in situ data is limited."

- Section 5.4: It seems unlikely that there are no constraints to the validation of the 250 m LIC product?

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 Lakes_cci 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 Lakes_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.

Climate Assessment Report (CAR)

The Climate Assessment Report D5.1 includes a basic description on the five available ECV datasets and the first case studies using them, with an emphasis on the use of multiple ECVs and other factors (including meteorological variables from reanalysis) to understand existing trends. Probably a more thorough review might have been useful, e.g., my understanding of figure 6-10 is that the x axis scale repeats the colour scale and there is no indication on the frequency of this distributions, but the overview of the potential use of this dataset is very interesting and, considering the initial stage of these activities, also very promising.

From the point of view of the climate modelling community, all the ECVs variables should be of interest, two of them as directly accessibly from models with lake components (LIC and LWST, although the former is very likely to be a binary value for each grid box, two other variables as integrated measures of the local hydrological cycles (LWE and LWL), and the other one (LWLR) relevant for Earth system models, although they tend to be very coarse in resolution, i.e. not too many lakes can be represented. On the other hand, high resolution models and regional climate models do not usually match the complexity of the Earth system models, in particular the inclusion of the carbon cycle, but they are likely to include a lake component (usually FLAKE) because of its importance for local climate processes. The length of the reconstructions are very good, the resolution very high and the associated uncertainties should not be a problem in a climate model context. However, even regional climate models tend to cover wide areas, therefore the issue of temporal frequency mentioned as a problem in two cases studies (Greenland and Danube delta) is very likely to be relevant in all climate model work, it is very likely that even the limited areas used by RCMs will have regions affected by similar problems.

This issue is recognised in the discussion on users' requirements, in the context of climate modelling this is clearly a priority for the future development of these datasets.

2.10 Land cover

The following documents are reviewed below:

- User Requirement Document (URD) version 1.0 dated 16 September 2019
- Product User Guide and Specification (PUGS) version 1.3 dated 31 August 2020
- Climate Assessment Report (CAR) version 1.0 dated 1 July 2017
- Product Validation and Intercomparison Report version 1.1 dated 21 August 2021

Feedback on the quality and maturity of the data product was also supplied

User Requirement Document (URD)

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)

Product User Guide and Specification (PUGS)

This document provides information on the C3S LC Intermediate Climate Data Record for 2016-2019, a continuation of the LC_cci maps for 1992-2015. Consistency is maintained between the two data sets consisting of global, yearly LC maps at 300m spatial resolution. The document explains the specifications of the products (format, filenames, metadata, content) and how to access them. The document is very clear and a useful reference for users.

We have some suggestions for some aspects that could be improved. A complete validation is not yet presented in this version of the document, it would be useful to know what the plans are for this and where the results will be reported. There is no observational uncertainty characterization associated with the maps, some users may be interested in this. There is no mention in Section 2.1 of the “User Tool” that prepares data for model computation doing conversions, aggregations, subsets and which is available through the LC_cci visualization interface. It would be useful to know if this is still maintained and further developed. Minor comments for Table 5: a green tick should maybe be used for the target requirements in Phase II for the geographic coverage; the meaning of black diamonds is not explained.

Climate Assessment Report (CAR)

This document assesses the Land Cover product or Land Cover surface reflectance and NDVI by means of 3 different land surface models, ORCHIDEE, JSBACH and JULES, either by using the new land cover maps (at 300 m resolution) in the model or by estimating and comparing annual land cover changes (from 1992 to 2015). The impact of the new land cover change product is jointly assessed by the 3 models.
The reports is extensive. It requires an update, since it dates back in 2017, which is planned for March 2022. We list here some suggestions to improve the future version. It would be very useful to have an executive summary before the introduction describing in one or two pages the main features, results, and recommendations. It would be appreciated also to have a conclusions section of the main results achieved at the end of Section 2 (LSCE assessment) and at the end of Section 3 (MPI-M assessment), in the latter by expanding the recommendation section. Minor comment: please review in Section 2 the cross-reference to other subsections (currently there are some “section 0”).

Product Validation and Intercomparison Report (PVIR)

This document assesses the quality of two products generated during the first and second year of Phase II: the global surface reflectance composite time series (LC-CCI SR) and the annual global Land Cover (LC-CCI) maps.
We list here some suggestions to improve it. The documents has 374 pages, 288 pages excluding the Appendix. Please consider moving more plots and tables (in particular for Section 3) to the Appendix section and leave in the main sections the most relevant ones. How it is structure now it is difficult to read since the text is lost among a big number of plots and tables. It would be very useful to have an executive summary before the introduction. It is not clear what the authors mean by “users accuracy values” in the concluding remarks. Minor comment: please review cross-references to sections (there is at least one “section 0”). The documents dates back in 2017, the release of a new PVIR is planned for March 2022, but under the CS3 contract (if we understood correctly).

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 LC_cci 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 LC_cci 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 2 300 m 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 < 5 km 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.

2.11 Land Surface Temperature (LST)

The documents reviewed for the LST_cci project are:

- User Requirements Document (URD) version 1.1 dated 21 February 2019
- Product Specification Document (PSD) version 1.11 dated 17 June 2020
- Product Validation and Intercomparison Report (PVIR) version 1.2 dated 23 September 2020
- Product User Guide (PUG) version 1.2 dated 22 October 2020
- Climate Assessment Report (CAR) version 2.0 20 December 2021

The standard of the LST_cci documentation is very variable, while the format and length of the PUG and PVIR are good, the PSD and URD, however, are disappointing, they 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 LST_cci product specification. A substantial amount of raw data are provided from the requirements gathering process. These data coming from a wide range of user cases means that the LST_cci 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 LST_cci 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 LST_cci 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)

The PSD provides a comprehensive guide to the file formats, metadata and variables contained in the LST_cci 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 URD. 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 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 URD 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 LST_cci 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.

Product User Guide (PUG)

This document begins with a quick start guide to the LST data products. This is a welcome addition so that the user can immediately see what variables and from what sensors data are available and have a short outline to the file format. This helpful format continues through the rest of the documents, with section 3 “How do I use the ESA LST cci data?” chapter being clearly presented and laid out. The use of questions as headings means the user can quickly find and relate to the explanations and information given.

The use of a FAQ style for a makes it simple to find most things the user needs to understand before using the product. There will be some information that is difficult to find as a result but this will be limited to more advanced questions in which the user will be probably be best directly contacting the LST_cci team directly anyway; so this keeps this PUG in a user friendly format.

It is a welcome addition that file headers and contents examples are given in appendices to the document. This gives the user a clear guide to whether they are correctly loading the data and obtaining the correct product. Information and examples on how to use the uncertainty information in the product is missing from the document. That is not necessary a bad thing because the theory and mathematics behind that can get quite involved but references to the documents where this information is recorded is recommended.

Product Validation and Intercomparison Report (PVIR)

This document provides a comprehensive review of the techniques and results from the validation preformed on the LST_cci dataset. Two methods of validation are presented, one using ground station data, the second comparing to existing satellite products. This is useful methodology for the CCI data user because it gives both a measure of the accuracy of the product and allows the user to have confidence in using CCI products over existing products.

For the first method, each ground site is individually presented. The plots for these results are clear and the user can very quickly get an understanding of the performance of each platform in the CCI product across different biomes and climate regions. The report explains how some features plotted arises, from cloud cover issues, vegetation etc… and these can then be investigated by the user if they need to,

The second comparison allows the CCI product to be compared over wide areas at the continental length scale. This is an important result because of the lack of ground weather stations and research sites in some parts of the world, and to show how spatial consistency across the product set. Again the results are clearly presented by the given plots. The text and accompanying tables provide the full details.

The conclusion is the dataset performs well in both tests. The report points to differing performance from different platforms depending on the biome/region the validation is being performed. This is good information to highlight because the user can choose to use LST_cci data from differing platforms depending on their region of interest.

Climate Assessment Report (CAR)

This report highlights six main user case studies of the CCI_LST data and a further couple of reports using the dataset. The report begins by summarising how these case studies have been used to improve the CCI_LST product. This includes cold bias of Greenland, improvements to cloud processing, and improvements to how the data is delivered. Other ancillary and metadata issues have been discovered by these case studies and the CCI_LST team are now aware of them and looking into them.

Some of the case studies are reviewed in the following.

Case study one looks at the relationship between LST and the 2 meter near-surface air temperature. This is an important relationship because near-surface temperature is used an indicator in climate change. The study finds the anomalies between the air temperatures (taken from the EUSTACE project) correlate well to the CCI LST product anomalies. The approach uses a comparison of maximum, minimum and mean air temperatures. The result shows that the CCI LST data are performing as expected in this setting. They highlight that the combined multisensor IR and MW product shows discontinuities associated with changes of sensors; the otherwise good scientific performance allows these issues to be confidently highlighted so the product can be further improved for V2.

Case study 3 looks at urban heat islands and how the CCI LST product can be used to detect surface urban heat islands, the difference between the urban and rural LST behaviours and values. The study considers cities in differing climate conditions. The result shows the CCI LST product captures the heat islands in the LST values and hence is capturing the water and heat balance differences between the urban and rural areas. The study highlights some of the ancillary land cover data in the product is incorrect and should be corrected in future versions of the product.

This is an important point as land use driven by climate change, and urban expansion, will mean this this value will likely not be constant through the whole product. This is something that should be highlighted to users, and also taken into account with the processing to create the dataset as quantities such as emissivity could vary more than expected.

Case study 5 is another good investigation into urban heat islands. The results from cities in Romania show very good correlation between the CCI LST and the observed near-surface air temperatures. This means the LST can be used to infer the effect instead of air temperatures. All the urban results in this document give a good advertisement to the technique and the dataset in this regard. Again, cloud contamination is flagged a limiting factor; this is something the CCI LST now have several pieces of evidence to investigate further.

In the additional case studies, from Hemming and King, they show how the CCI LST data can be used with near-surface temperature as opposed to instead of the near-surface temperature in the above cases. This is then used to understand the different temperature behaviours in different vegetation types. This has applications in land cover classification, climate model evaluation, phenology and vegetation stress detection. Their work also documents the use of the CCI LST data in ESMValTool.

Niclòs' study gives an evaluation of the CCI product against the existing operation MODIS LST product. They note a warm bias compared to operation MODIS in the CCI product, maybe attributable to the resolution differences in the versions of data used, and hence issues concerning the homogeneity of the land.

In conclusion, the case studies in the CAR give a good representation of the CCI LST product. Several different applications have been explored and all reported favourable results. There are some common themes around cloud contamination and ancillary data noted. This is good feedback to the CCI team so they can further improve what is already a good product.

2.12 Ocean Colour (OC)

The documents reviewed for the OC_cci are:

- User Requirements Document (URD) version 1 dated 31 July 2019
- Product Validation and Algorithm Selection Report (PVASR)[6] version 3.0 dated 23 December 2015 (Pt1) and 15 January 2016 (Pt2)
- Climate Assessment Report (CAR) version 3.0 dated 29 June 2017
- Product User Guide (PUG) version 1.0 dated 12 October 2020
- Product Validation and Intercomparison Report (PVIR) version 1.0 dated 18 February 2021
- Climate Assessment Report (CAR) version 1.1 dated 10 February 2022

User Requirements Document (URD)

The Phase 3 OC_cci 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 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.

[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

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 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.

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: URD). 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.

Climate Assessment Report (CAR)

The range of applications for the OC_cci data 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 are 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 continues to be regular reprocessing 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.

[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

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.

Product User Guide (PUG)

The OC PUG is a helpful document with an appropriate level of detail and provides a good introduction to the products for users. It is a mature document and has evolved well from earlier versions previously reviewed by CMUG. This current review therefore focusses on a few additions and clarifications which might be useful.

Arguably, sections 5 and 6 on the scientific and technical overview of the products would sit more intuitively earlier in the document, perhaps between the current sections 1 and 2. The current structure is also valid though, so this is merely being raised as a thought to consider.

The discussion of uncertainties and detailed instructions on how to use and interpret them are very useful, and necessary for users. Worth adding though is advice on when to unbias the data, and when to use the data values as provided. This is not currently clear and may mean some users are not using the data in the most appropriate way.

Also lacking is any mention of what depth the ocean colour data represent, and to what extent it is appropriate to treat them as purely surface values. This is not straightforward, so definitive guidance is not expected, but some mention and signposting to the literature would be helpful.

The overview of previous versions in section 9 is useful, but omits to mention that v4.2 corrects an issue in the chlorophyll product as well as kd. It would be worthwhile making clearer the differences between v4.0, v4.1, and v4.2.

Figure 6 shows the bias in v5.0 to be near-zero, in contrast to v4.2. The text just reads “The magnitude of the bias has been across most of the global oceans” – presumably the word “reduced” should be added – but it would be interesting to know the reason for this improvement.

Finally, some minor comments:

- Some acronyms, such as QAA and AD4, are used without explanation – a table of acronyms might help.
- The “Where can I get detailed information?” subsection of section 1 references the old-style CCI website.
- The Python code in section 3 should be updated from “print nc.variables[“chlor_a“][:].mean()” to “print nc.variables[“chlor_a“][0,:].mean()” to reflect the time dimension added from v2 onwards.
- The caption to figure 8 states “monthly and 8-day composites” were used, but the figure only appears to use 8-day composites.
- In the “Specific elements of the sinusoidal product” subsection on page 38/39, the alignment of variables in the example NetCDF header could be improved.

Product Validation and Intercomparison Report (PVIR)

The PVIR compares the v5.0 OC-CCI dataset to the previous v4.2, to the GlobColour merged ocean colour product, and to a database of *in situ* matchups compiled by OC-CCI. Results are a combination of automated validation performed by PML, and independent validation performed by CNR. The conclusion is that v5.0 is superior to v4.2, and a better product for climate studies than GlobColour.

The overall methodology and conclusions are sound, some minor technical comments are detailed below.

The introduction states "The OC-CCI project provides ocean colour ECV data, with a focus on case 1 waters but also comprises also regions with case-2 data, which can be used by climate change prediction and assessment models." This implies that data in case 2 waters are suitable for use by (some) models, but maybe not for solely observation-based studies. This may or may not be the intended interpretation, either way it would be worth clarifying briefly the recommended suitability of case 2 data for different uses. This could be enhanced by splitting some of the later validation against in situ data into case 1 and case 2 waters, as well as giving overall values, so the relative performance can be seen.

The development of an in situ database, and making it public, is a very positive achievement coming out of OC-CCI. There's an ambiguity over version numbers though. The PVIR consistently states that v7 is used. But the version cited (Valente et al., 2019) is labelled as v2 on PANGAEA, and the most recent version under review (Valente et al., 2022), is only v3, not yet v7.

A trivial point, but the formatting errors in section 3 made it confusing to read at first, as much of it looked like table captions rather than main text.

The caption to figure 3 states: "the V5 data is generally more noisy (greater extremes in product values)". Should this read v4.2 rather than v5? The statement seems to contradict the figure having larger y-axis scales for v4.2, and the statement in the text that "the V5.0 data has a smaller range of values". If the caption is correct, then reconciling the statements merits further discussion.

When comparing v4.2 and v5.0 to in situ data, it would be worth also calculating only common matchups, as is done for the later GlobColour comparison, before concluding which is better. The difference in n is small enough that it would be unlikely to change conclusions, but this would be worth confirming. Furthermore, consideration of the relative uncertainties in the v4.2 and v5.0 products, and in the in situ database if available, would be informative.

Also trivial, but the ordering of the v4.2 and v5.0 subplots is different in figure 4 than in figures 2 and 3, and the subplots themselves are not labelled, which could be confusing.

It is stated that "The coverage of v5.0 is very slightly reduced compared to v4.2 during the SeaWiFS years due to an enhanced masking scheme used in the v5.0 production, but the inclusion of OLCI provides a significant boost to coverage from 2016 onwards." A difference is also apparent in the period 2012-2016, which would be worth commenting on.

Climate Assessment Report (CAR)

The v5 CAR is split into three sections. Section 1 gives an overview of the v5 products and compares to previous versions. Section 2 compares the products to GlobColour. Section 3 is a copy of Sathyendranath et al. (2019), a publication in the journal Sensors describing the OC-CCI products. The material in Section 2 is common with the v5 PVIR, and has been reviewed under that heading. Section 3 has already been peer-reviewed and appeared in the scientific literature. This review will therefore concentrate on Section 1.

The CAR gives a useful and informative overview of the processing, in particular what has changed since the previous version 4.2. In many cases the reasons behind decisions have been discussed, which is useful and interesting from a user perspective. The comparison to GCOS requirements, with discussion around different ways this can be calculated, and the comparison to previously-identified requirements, are also useful.

Two minor suggestions for clarification, mostly out of personal interest. Firstly, do the project team have ideas about why POLYMER is so much worse for SeaWiFS? Secondly, in Figure 1.10 chlorophyll concentrations appear higher near the coast in the v5 climatology than for v4. However, this may just be due to how the coastlines are plotted. It would be worth plotting them in the same way, and commenting if there has been a change.

2.13 Ozone

The following documents are reviewed below

- User Requirements Document (URD) version 3.1 dated 01 September 2020
- Comprehensive Error Characterization Report (CECR) version 2 dated 22 December 2016
- Product Validation Plan (PVP) version 2.1 dated 06 December 2020
- Climate Assessment Report (CAR) version 1.0 dated 24 November 2021

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.

Product Validation Plan (PVP)

This is an excellent and complete document. CMUG would recommend close collaboration with WMO bodies which oversee the ground-based ozone measurement network (GAW) in matters related to requirements. It is also important that ESA CCI groups are involved in WMO panels (for the example the Scientific Advisory Group on Reactive Gases).

Climate Assessment Report (CAR)

The document reads as if it has undergone already several revisions and is now in a very mature form 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 many past and recent studies, particularly model/observation comparisons related to the ozone hole and its expected future behaviour.

The conclusions make a reference to an old CMUG report which should be updated. I also think that the discussion about the CMUG contribution to the O3 CCI work, which has been instrumental for the use of several CCI datasets in the ERA5 reanalysis (Hersbach et al 2020 and Dragani 2016, see comment in the CAR) should be reported in a separate section and not the conclusions. Moreover the O3 CCI data were also used in the CAMS reanalysis (Inness et al 2019, ACP - The CAMS reanalysis of atmospheric composition (copernicus.org)). Specifically, CCI SCIAMACHY, MIPAS data and GOME-2. The CCI MIPAS data will also be used in the CAMSRA2, while other O3 datasets are still under discussion (Inness, private communication). This should also be reported.

As a general comment which should be applicable to all ECVs, it would be useful to have an executive summary of the CAR which highlights main points of the current version as well as indicating which are the updates with respect to previous versions. This is particularly helpful to review documents that have been revised over many years so that the reviewer can focus mostly on the new aspects of the report.

2.14 Permafrost

The following documents are reviewed below:

- User Requirement Document (URD) version 1.1 dated 12/02/2019
- Product Specification Document (PSD) version 2.0 dated 30/11/2019
- Product User Guide (PUG) version 2.2 dated March 2021
- Product Validation and Intercomparison Report (PVIR) version 2.1 dated 14 January 2021
- Climate Assessment Report (CAR) version 3.0 dated 30 September 2021

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.

Product User Guide (PUG)

The permafrost Product User Guide (PUG) document issued in March 2021 describes the general properties of the products (e.g. file format) and defines the permafrost variables that are produced: ground temperature, active layer thickness, and permafrost extent. This is a clear and concise document.

A short chapter lists known limitations of the products. Each variable is illustrated by a map but no time series is shown. This would be helpful and should be considered for future versions of this document. The novelty with respect to previous versions is a more complete description of known issues, which is welcomed by CMUG.

Figure 1 presents a map of the mean annual ground temperature (MAGT) at 1 m depth in 2005. This may lead users to think that MAGT at 1 m is to be considered in priority for some reason. Is MAGT at 1 m depth really representative of permafrost or should values at deeper soil layers be considered?

More generally, examples of potential applications based on the use of each sub-product could be indicated: since this product is quite new, this would be useful to users not familiar with such variables. For all sub-products, an indication of the statistical distribution of values (e.g. percentiles, or at least min, max, mean and standard deviation) would be useful to complete the figures.

Multi-year time series (1997-2018) could be shown for all variables at one location representative of the permafrost area. In the "known limitations" section, "ground stratigraphies" and "Yedoma" should be defined because all users may not understand these terms.

It is mentioned that the quality of the product is reduced over the Siberian Yedoma permafrost type. Users could be interested in an updated version of the Siberian Yedoma since this permafrost type is particularly vulnerable to climate warming (https://doi.org/10.1016/j.earscirev.2017.07.007). Is this planned?

Product Validation and Intercomparison Report (PVIR)

The permafrost product validation and intercomparison report (PVIR) is an extensive document of 81 pages. A more concise document would be more convenient.

The permafrost variables are defined, together with the independent observations and metrics used to produce validation scores. Two versions of the products corresponding to two projection systems (POL and SIN) are considered. This is surprising because in the PUG, only the POL projection system is described. Why complicate the PVIR with unnecessary material about the SIN products? Focusing on the POL products would clarify the PVIR document. The authors may only show the final result corresponding to the product available to the users. If there is any good reason to show results for the SIN products, it should be explained.

Figure 3.13: it seems that the content of the Figure is different from the caption.

Tables 3.12 and 3.14: units should be consistent (replace cm by m).

Figure 3.14: why is g-score that bad at 0 and 2 m for year 2017?

Overall, this document contains a lot of information. Both executive summary and summary sections are quite long but do not provide the key messages the users need in order to decide whether they can use these products or not.

Climate Assessment Report (CAR)

The permafrost climate assessment report (CAR) document issued in September 2021 describes three use cases of several permafrost variables (ground temperature, active-layer thickness, permafrost probability). The consortium organized a user workshop from which a clear recommendation was to work on improving spatial and temporal resolution of the products. In use case 1, climatic simulations are made to assess the impact of integrating ESA-CCI LC and PERMAFROST geographical information (vegetation spatial distribution, mineral and organic components of the soil) into the land component of the climate model. While land cover has a small impact, soil composition markedly influences ground temperature. In particular, the cold model bias in Siberia is reduced. The simulated air temperature is improved. In use case 2, the consistency between PERMAFROST products and the ESA-CCI HRPC GlobPermafrost disturbance product is evaluated. Lake surface change and fires are considered. The loss of lake surfaces is more pronounced in areas presenting warmer ground temperatures. A specific fire event in Alaska seems to trigger a marked trend toward larger active-layer thickness values (Figure 5). It appears that more work is needed to demonstrate the impact of fires on permafrost variables. In use case 3, coastal erosion data from the H2020 Nunataryuk project are compared with PERMAFROST ground temperature over Canadian and Russian areas. Increase in erosion seems to be consistent with increasing ground temperature. The mechanism linking the two processed is not explained. Is ground temperation the only driver of coastal erosion? Finally, the comparison with pre-existing in situ observations show that permafrost probability is overestimated in relation to a cold bias of 1.5°C of the PERMAFROST ground temperature.

General comments:
The document is well structured but the text sometime needs to be improved (see below). Recommendations were obtained from a user workshop but use cases did not produce clear recommendations. The amount of work presented is quite impressive but user cases are not always very conclusive. This can be explained by the relatively low maturity of this ECV in comparison to other ECVs. At this stage, user uptake has a rather exploratory nature. More frontier research is probably needed to progress in the production and in the validation methods. Finally, focusing on key results and on “lessons learned” could improve the readability of the document.
Particular comments:

- P. 4: “fore and non-fire”?
- P. 11: Caption of Table 1 is not complete. Obu et al. reference should be given. The methodology should be explained with some text (e.g. meaning of pM vs. pE, SOO vs. sFO, etc.).
- P. 11: “Biases and root mean square errors are shown in Table 1.” Not in Table 1.
- P. 13: MAGT at which soil depth?
- P. 15: Figure 4 is not cited in the text.
- P. 17-18: Figures 6-9 are not cited in the text.
- P. 21-23: Figures 13-15 are not cited in the text.

2.15 Sea Ice

The following documents are reviewed below:

- User Requirements Document (URD) version 2.0 dated 20 March 2020
- Climate Assessment Report (CAR) version 2.1 dated 29 March 2021

Sea Ice Thickness (SIT)

- Product Validation & Intercomparison Report (PVIR) version 1.1 dated 23 July 2018
- Product User Guide (PUG) version 1 dated 10 February 2017

Sea Ice Concentration (SIC)

- Product Validation and Intercomparison Report (PVIR) version 1.1 dated 23 July 2018
- Product User Guide (PUG) version 1.1 dated 20 September 2017

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 researchers. 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.

Climate Assessment Report (CAR)

This report, although limited in scope and extent, assesses a series of useful aspects of the main sea ice data products, both of sea ice concentrations and thickness that can determine their suitability for different climate research purposes. These include the identification of spatiotemporal inconsistencies, to problems in the metadata and the netcdf files produced that can emerge when used with a selection of the most common analysis and monitoring tools used in climate research (cdo, ncview, python,...).

However, in several of the sections the discussion and/or analyses are rather superficial, leaving the reader with a feeling of incompleteness. As three prominent examples, it's worth highlighting (1) the section on the regional patterns, based exclusively on visual inspection (which can be deceiving and subjective, and should be complemented by some objective automatised criteria), (2) the section on comparison with climate models, that includes a figure that is not referenced nor discussed, and (3) the last section on maturity matrix, which simply states that is a work will be done later on. This, together with the lack of a final section with the main conclusions/lessons learned/recommendations, leaves an overall feeling that this is preliminary instead of a final version of the report.

Sea Ice Thickness

Product Validation and Intercomparison Report (PVIR-SIT)

PVIR-SIT compiles a very large set of reference data products to thoroughly analyse the SIT quality.

At times in section 3.1 (Product inter-comparison) it is not clear whether statements about lowering the uncertainties are conclusions from figures shown or are based on additional (not shown) analysis (e.g. based on the provided product uncertainty estimates). If there is no additional analysis, I do not understand how an inter-product comparison can identify an uncertainty reduction (since we do not know the real state), in particular since the figure colour bar extents (+/-0.25 m) are most of the time smaller than the claimed uncertainty reduction (~0.5 m, ~0.6 m, ~1 m). For this it might be interesting to repeat the following validation (using in-situ data) for preview1 data and check whether the preview2 is better in reproducing those measurements.

Again, the validation with independent data is fairly advanced and appreciated. I do wonder, however, why the correlations between SI_cci SIT and reference data shown, which are frequently quite small (in about 1/3 of the comparisons the R^2 values are below 0.1) receive comparably little attention. Some SI_cci SIT distributions agree indeed very well with the validation data distributions but show close to no correlation. Could the distributions be right for the wrong reasons?

It is not clear to me how well the reported errors are represented in the product uncertainty estimates. For many applications it is as important to have a reliable uncertainty estimate as it is to have a good SIT estimate, so that we are not over-confident in the SIT values. It would be very helpful to validate the provided uncertainties alongside the SIT values.

Can you comment on the possibility to make the compiled validation data set publicly available?

Specifics:

- You mention the Sea of Okhosk on page 15 and 17 but in the figures show only the very north of that sea, with no more than two or three valid data points in total. Is that correct?

- Similarly, the Lincoln Sea is mentioned on page 16 but is virtually not covered by ENVISATs orbit, please check.

Product User Guide (PUG-SIT)

The Sea Ice Thickness (SIT) Product User Guide gives a good and precise staring point into the use of the SI_cci SIT product. The technical description is well done and product properties are well described.

It should be considered to highlight the existence of biases between missions more clearly, these exist not only in regions with significant surface type mixing (P11) (see e.g. Figure 9c in PVIR). Similarly, it should be mentioned that the data has to be sanitised by the users (e.g. filtering of negative SIT).

Could you clarify what snow data is used for the southern ocean since for the OSI-SAF data: 'coverage is incomplete for the Envisat observation period and non-existent for the ERS-1&2 period' (P12)?

ENVISAT SIT appear to be biased low in the PVIR, is this not a known limitation?

CMUG would like to see more examples of how the data can be used, e.g. the toolboxes/programs/scripts used to create the figures in the guide.

Sea Ice Concentration

Product Validation and Intercomparison Report (PVIR-SIC)

The Sea Ice Concentration (SIC) Product Validation and Intercomparison Report investigates the SI_cci SIC quality predominantly with (less continuous but high quality) MODIS data. This is done for several years, followed by an analysis of the regional quality disparity.

The product evaluation focuses on locations with nearly 100% and 0% SIC. This might be necessary for technical reasons, but I am not sure how representative the resulting findings are for the dataset in general. Considering that dynamic tie-points are found in a comparable way (correct me if I am wrong), most of the validation efforts shown here appear to be tie-point validations only. Should we expect the algorithm errors to be larger for fractional (0<SIC<100) sea ice coverage? If so, how much? CMUG would suggest expanding on the method used here and explaining the reasoning behind using the extreme value points.

Do I remember correctly (from the SI_cci progress meeting) that the reasons for strongly asymmetric distributions for the SICCI3RELF (e.g. figure 4.2.2. lower right panel) have been found? If not, it would be good to investigate why this algorithms behaves so differently.

Since there is the possibility of errors in the validation data (i.e. locations with real SIC<100% being included in the SIC=100% ground truth data, which would explain the increased lower tails in those distributions), the median (in addition or instead of the mean) could be considered to calculate the bias.

It is great that the validation and intercomparison results are published in the scientific literature. Would it be possible to quickly summarize the main results of those papers for this report?

It is not clear how well the reported errors are represented in the product uncertainty estimates. For some applications it is at least as important to have an reliable uncertainty estimate as it is to have a good SIC estimate, so that we are not over-confident in the SIC values. It would be very helpful to validate the provided uncertainties alongside the SIC values.

Can you say anything about the temporal stability of the product?

Can you comment on the possibility to make the compiled validation data set publicly available?

Product User Guide (PUG-SIC)

The PUG gives a good overview of the underlying sensors and algorithms. It also provides a good entry point into the file content and limitations.

CMUG would like to see more examples on how the data can be used, e.g. the toolboxes/programs/scripts used to create the figures in the guide. It could also be useful to have an example how the status flag can be decomposed into its bits or how raw and sanitised data can be combined to gain a complete field of raw data (including locations which have been changed and which have not been changed).

When discussing the influence of melt ponds, it is indicated that the SIC product aims to represent the sea ice fraction excluding melt ponds and open ocean. I understand that melt ponds are virtually impossible to distinguish from ocean with this data, but what is the target of the product? Some further explanation on this point would be welcome.

Advice on which algorithms should be used in which circumstances should be added.

2.16 Sea Level

Sea level products are split into those relating to global sea level and those relating to coastal sea level. The documents for each set of products are addressed separately here.

Global Product

The following documents are reviewed below:

- User Requirements Document (URD_global) version 1.5 dated 22 October 2014
- Product User Guide (PUG_global) version 2.2 dated 13 December 2016
- Product Validation and Intercomparison Report (PVIR_global) version 2.0 dated 9 December 2016
- Climate Assessment Report (CAR_global) version 2.1 dated 22 November 2017

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 worthwhile to include these requirements on the new URD.

Global Product User Guide (PUG_global)

The document gathers essential information for the users of the global Sea Level_cci products, including an overview of the instruments used, the altimetric standard applied, and other relevant aspects like the nomenclature, format, variable attributes, NetCDF headers and map projections used. It also reports the changes with respect to the earlier version (1.1). The document is therefore useful and fulfils its purpose.

Some suggestions are now listed of aspects in the document that could be improved:

- In Section 5.4 it would be desirable to include a figure illustrating the Cartesian projection and the level of detail provided by the spatial resolution. Sections describing the different variables and their attributes could also benefit from similar figures.
- No information on the observational uncertainties of the different variables is currently provided and would be desirable, as it can be critical for some users. For this, including a reference to relevant documents that describe them in detail would suffice.
- A similar suggestion is made regarding the validation of the different products, which is not addressed nor mentioned in the document.
- Also desirable is information on the continuity (or lack of continuity) of the products. The document mentions that the v2.0 of the global SL product would be extended until December 2015, but 5 years have passed since then and is not clear if this happened or the extension reached more recent years. It would be important to update this information, mentioning also if the product has been extended further, and if there is any plan to do so. If the products are discontinued, it should be mentioned too, explaining the reason (e.g. lack of new satellites to provide continuity, identified issues, priority for the production of new products based on refined techniques/data).
- A final suggestion is to include a section reporting potential problems/caveats in the products that the users should be aware of: e.g., data gaps, specific temporal periods or regions with higher uncertainty or reported problems.

Global Product Validation and Intercomparison Report (PVIR_global)

This document provides a comparison of the two global SL datasets produced by the Sea Level_cci, describing their similarities and also their differences, and providing explanations of the reasons behind some aspects where they disagree. It also includes a comparison of both datasets with two other independent observation-based estimates, and documents which one of the two CCI products is in better agreement with them. As such, the document nicely fits its purpose, and is a useful reference for potential users of the CCI products.

We now provide a list of recommendations of several aspects that can help to improve the usefulness of the document:

- The two CCI datasets compared (v2.0 and v1.1) exhibit identical long-term trends over the whole period addressed in the document (1993-2014) which suggests that this is a robust estimate. However, they also show some significant discrepancies in terms of temporal variability, which are particularly evident in Figure 3. It would be good to quantify the level of agreement between the two datasets with correlation metrics, not only for the global mean time series but also at the grid point level, to identify regions with important differences (which would attest of higher observational uncertainties). For these correlations, removing the long-term trend would be desirable, to focus on the month-to-month variations. It would also be important to indicate when correlations are significantly different, and where that happens, if it can be explained by methodological differences.

- Another recommendation is to explain, in the annual signal section, how the phase and magnitude are defined, as a proper definition is currently lacking.
- Similarly, it is not clear in Figure 10 how the variance for each temporal step is computed. Does it represent a spatial variance? Or does it represent a temporal variance over a moving window? More details are needed for clarity.
- The final section on validation could be improved by providing some metrics of agreement (e.g. root mean square errors, correlations) between the two ECV products and the two independent datasets from tide gauges and ARGO floats, for global averages and if possible too at the regional level. That information is essential for the users to give preference to one dataset over the other, depending on their final application.

Global Product Climate Assessment Report (CAR_global)

This is a comprehensive and dense report, assessing and comparing the suitability of the different global sea level products for different application purposes.

However, some parts are a bit arid to read, and the whole report could benefit from some synthesis and homogenization effort and better structuring. The report indeed reads as an unbalanced collection of four distinct and rather independent blocks (with their separate reference and conclusion sections) that have very different focus, level of detail and length. This, connected to the fact that the main sections refer to specific work packages, leaves the impression that instead of a climate assessment report the document is just a final deliverable reporting on different activities performed within the CCI project, which can deter the interest of readers that have not followed the project closely.

It would be desirable if future CAR documents for this CCI use a more standardised structure with its own identity, including well-defined sections that are conveniently introduced at the beginning of the document, a single reference section, and a final section summarizing the main conclusions from all the sections.

Coastal Product

The following documents are reviewed below:

- User Requirements Document (URD_coastal) version 1.2 dated 16 June 2020
- Product User Guide (PUG_coastal) version 1.3 dated 11 June 2020
- Product Validation and Intercomparison report (PVIR_coastal) version 1.0 dated 5 October 2020
- Climate Assessment Report (CAR_coastal) version 2.0 dated 16 March 2021

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.

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.

Coastal Sea Level Product User Guide (PUG_coastal)

The coastal sea level PUG provides a concise technical introduction to the products. It contains useful information, but could be expanded to be more helpful to users from a range of backgrounds.

It seems to be written for an audience already familiar with using SLA products in NetCDF format. Inexperienced users, who arguably are most in need of a PUG, would benefit from the PUG being expanded to include a simple introduction to the variables in SLA products, and more detail on how to interpret them and common applications. For instance, exactly what sea level anomaly, mean sea surface, and mean dynamic topography represent, and how to use them for different applications. Comparison to tide gauge data may be a common one, as would validation of and assimilation into ocean models. The examples provided are a good start, particularly the inclusion of sample code in section 3.6.

Missing is any discussion of uncertainty information, and appropriate ways to calculate uncertainties. Also useful would be a brief overview of how the coastal products compare to the global product.

Coastal Sea Level Product Validation and Intercomparison Report (PVIR_coastal)

The coastal sea level PVIR is a well-written and accessible document, providing plenty of information of interest to users. The methods are well explained, as are uncertainties and caveats with the approaches taken, particularly for section 4 on the comparison with tide gauge data.

Section 5 on characterisation of uncertainties at regional scales is comparatively brief, and more detail on the methods and results could be usefully included. The document states that a manuscript is in preparation, so presumably further results will become available in the future.

Very intriguing are the results shown in figure 5, suggesting little significant difference in coastal and open ocean trends. It will be interesting to see the community explore this further in future.

Coastal Sea Level Climate Assessment Report (CAR_coastal)

The Coastal SL-CCI CAR v2.0 is relatively short, though it is noted at the end that the main contribution to the Climate Assessment work package was only just getting underway at the time of writing, so this brevity is understandable at this stage of the project.

The work presented is interesting, beginning by discussing coastal trends, with a focus on a case study at Senetosa. This case study is well explained, giving a good overview of the possible reasons for what is observed. The initial section 2.1 could benefit from an extra paragraph or two though, just to give a brief overview of the main conclusions globally.

In section 4.1 potential comparison with ocean reanalyses is discussed, with the issue highlighted that models do not typically have sufficiently high resolution for a meaningful comparison. It should be noted that the table of available reanalyses is incomplete, for instance it is missing the global ORAS5[6], the CMEMS Iberia-Biscay-Ireland[7] and Northwest European Shelf[8] products, and the Australian BRAN[9] and eReefs[10] products. Admittedly none of these has sufficient resolution either, so this is a bit of a moot point. But there may be more sources of model data out there which could be of use.

The forthcoming work using JERICO data looks promising, it will be interesting to see the results of this once available.

[6] https://www.ecmwf.int/en/research/climate-reanalysis/ocean-reanalysis
[7] https://resources.marine.copernicus.eu/product-detail/IBI_MULTIYEAR_PHY_005_002/INFORMATION
[8] https://resources.marine.copernicus.eu/product-detail/NWSHELF_MULTIYEAR_PHY_004_009/INFORMATION
[9] https://research.csiro.au/bluelink/global/reanalysis/
[10] https://research.csiro.au/ereefs/ereefs-data/

2.17 Sea State

The documents reviewed for the Sea State _cci are:

- User Requirements Document (URD) version 1.0 dated 06 February 2019
- the Product Specification Document (PSD) version 1.0 dated 05 February 2019
- the Product User Guide (PUG) version 1.0 dated 17 January 2020
- the Product Validation and Intercomparison Report (PVIR) version 1.0 dated 22 June 2020
- the Climate Assessment Report (CAR) version 2.0 dated 18 October 2021

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 resolution 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 Sea State_cci 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 20 Hz to 1 Hz, 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

Product User Guide (PUG)

The sea state PUG is a useful combination of accessible overview and technical information. It is important to have an easily readable introduction for new users, and that has largely been achieved.

Something which could usefully be added, perhaps in section 3, is a high-level overview of the difference between swh, swh_adjusted, and swh_denoised. This would help new users to determine which variable(s) more quickly and accurately they should be using for their specific applications.

Similarly, some discussion of best practice in using the uncertainty information, and any pitfalls in doing so. For instance, how to calculate the uncertainties over an aggregated region or global time series, particularly for cases where a simple averaging of uncertainties is not the correct approach.

While it is unlikely to be necessary for users experienced with NetCDF data, the PUG for some other ECVs contains instructions on how to work with the products in different applications or languages, sometimes with sample code. This is something that could be considered, or at least link to tutorials elsewhere.

Product Validation and Intercomparison Report (PVIR)

The Sea State_cci PVIR provides a good initial validation and intercomparison, including many worthwhile plots and comparisons. It feels like just a starting point though, and given the list of future work in section 5, the authors evidently agree. CMUG look forward to seeing how the document evolves accordingly over the course of the project.

In the results shown, further comment on some of the most interesting features would be appreciated. For instance, section 2.3.2 shows the CCI climatology to be consistently higher than that of ERA5 or RY2019, but makes no comments on possible reasons why or potential consequences. This would be extremely interesting to know more about. There is some discussion of this in the published paper of Timmermans *et al*. (2020), that could be usefully included in the PVIR. Similarly for other results and discussion in Timmermans *et al*. (2020) and Dodet *et al*. (2020), particularly as this work has already been performed.

Validation of L2 and L3 products will be very important, and this is included under future work. A detailed validation and comparison to other products will definitely be of interest to users.

Climate Assessment Report (CAR)

The Sea State CCI CAR v2.0 comprises a series of case studies followed by user feedback.

The first case study looks at how extremes at the coast are captured in the v1 and v2 sea state products. The conclusion is that these are broadly consistent between the two versions. CMUG would echo the recommendation that “future Sea State CCI products endeavour to incorporate data from earlier satellite altimeter missions to extend the time series and enable climate studies”.

The second case study looks at extreme wave heights, focusing on the worthwhile question of whether those present in the CCI products can be believed. Given the uncertainties and the differences between v1 and v2, the recommendation of updating the quality flags for v3 seems sensible. It’s good to make sure users take appropriate care when using these data.

The third case study takes an interesting look at decadal variability and the relationship with climate indices like the NAO. The final case study focusses on the marginal ice zone, and the stated engagement with users in this area is to be encouraged.

The second half of the report gives an overview of user feedback from various meetings and workshops. Arguably this information would fit better in the URD, but user engagement is always important so it’s good to see it being a focus.

2.18 Sea Surface Salinity (SSS)

The documents reviewed for the SSS_cci project are:

- User Requirements document (URD) version 1.4 dated 03/01/2019
- Product Specificaiton document (PSD) version 1.6 dated 24/04/2019
- Product User Guide (PUG) version 1.2 dated 5 March 2020
- Product Validation Plan (PVP) version 1.1 dated 4 December 2019
- Climate Assessment Report (CAR) version 3.1 22 July 2021

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 what 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 months 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 using 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. 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)

Product User Guide (PUG)

The document summarises indispensable information for the users of the two first Level-4 SSS datasets produced in the first-year exercise of the CCI+: a monthly mean product and a 7-day running mean product. It also includes a full list of references to other key documents expanding on some aspects of the dataset production and their evaluation. The document is therefore a useful reference in which potential users of the SSS products can resolve their concerns or be redirected to other documents where they can be clarified.

An important caveat conveniently stated in the document is that both products are preliminary versions that have not been fully validated, thus warning the users of potential problems that could be encountered, flagging also already identified issues, and providing in addition an appropriate channel to communicate them and/or provide feedback to the product producers (Mngt_CCI-Salinity@argans.co.uk). Also important for potential users is the information that is provided on how the errors and biases are computed in each product. For the weekly dataset, it is, however, unclear what the term “variability” represents in the equation (section 2.3.2.3). Is it the variance? Or the standard deviation? Similarly, it should be clarified what the term error_L2OS stands for. We also note that not all the acronyms in section 1.6 are used in the document (e.g. UCR/CECR, SRAL), and thus recommend the list to be revised.

Another aspect of potential interest to users, that is currently not addressed in the document and could lead some users to prefer the SSS_cci products over other datasets, is the mid-term/long-term sustainability of the dataset. We thus recommend providing information on the current plans to extend the datasets further in time (how long are the current missions expected to continue? will there be other missions providing continuity to the datasets?), and also on the additional improvements that are being considered for future product versions.

Product Validation Plan (PVP)

This document describes the validation protocol for the Sea Surface Salinity (SSS) products obtained in the course of ESA SSS_cci project, including a list of the independent SSS datasets that will be used as ground truth measurements. The protocol is well explained, providing a detailed account of the different types of underlying uncertainties (accuracy vs representativity) that need to be addressed during the validation, which ones have been estimated and how, and which ones haven’t and why (e.g. vertical representativity errors). It also provides clear unambiguous definitions of key concepts, like traceability or uncertainty, as well as of the quality metrics that are considered to perform the validation, explaining the different relevant information that can be derived from each of them. To complement the final list of products that will be used as ground truth measurements provided in section 4, we suggest specifying which other observational products have been considered to calibrate/generate the SSS_cci datasets, and to clarify as well if they are completely independent from the ground truth references, and if not, to explain the potential impact on the validation results.

Product Validation and Intercomparison Report (PVIR)

The CCI+ SSS PVIR is well structured, easy to follow as very comprehensive by covering a large range of aspects. Please find below a number of thoughts.

While the summary of main results upfront is very well intended, this summary (Section 2.2) is in parts hard to follow and would strongly benefit from more explanations. I would advice to use full sentences (e.g. 'CCI data is limited in...' instead of 'Limited CCI data in..', also: is the data availability or quality limited?) to improve readability. I included a list of more specific comment on this section at the end of the document.

I am a little surprised by the match-up procedure. From a user perspective a monthly SSS product is considered the best estimate of the averaged monthly field and I expected the validation numbers to indicate how far high-quality point measurements diverge from this. Restricting the match-up to only the central 15 days of the month could lead to misunderstandings. I assume this time has been chosen due to the biweekly repetition rate, but each Argo measurement could be matched to more than one CCI grid estimate (since they are overlapping in time) or equivalently the match-up could be started on the CCI data side to find Argo data as match-up.

On this note, I am really happy to see that the spatial representativeness error is taken into account, is there a possibility to do a similar analyis about the temporal representativeness or to have a (back of the envelope) estimate of its size?

Figure 3: The fitted PDF using traditional mean+std is such a poor representation of the histogram that I wonder how far off the outlier have to be to cause this (surely they have be outside of the shown +/- 1 pss range, no?). Are these outliers more likely to be caused by the Argo data (despite what seems like a rigorous filtering) or in the CCI data? Is there any way they can be systematically identified and flagged as low quality (if not the case already)? I agree that this is a strong case for using robust measures, however this should not suggest that the challenges which outliers/heavy tails pose for applications do not need to be taken into account. For this it might be even more interesting to look at the tails of dSSS distribution, normalized by uncertainties.

I am fascinated by some aspects of the L4 OI. First, none of the contributing products show a peak around 34 pss (Fig. 6) but the interpolated version does (Fig. 3). Secondly, the quality of the L4 product seems to be uneffected of the satellite missions available (Fig. 12). Neither the L4 median dSSS nor the std* dSSS seems to improve with the addition of Aquarius in 2011. The same is true at the end of the smap contribution in 2019, is there actually a benefit in using this multi sensor approach or is SMOS all we need? Put differently, why do we not see existing benefits in Figure 12? There might be easy answers to this which I simply missed, I am just sharing my thoughts here.

Specifics:
Section 2.2:
Bullet point (BP)1: avoid repetition of BP2, BP3: remove one of the 'details', BP4 remove 'of' BP5: can you give a number here? BP8: What is 'coherent variability' referring to? Correlations between CCI SSSv3 and Argo data (I do not think that they have been analyzed globally)? Similar variability statistics (e.g. Fig. 18)? Variability which is coherent in space (as sub-BP1

could be understood)? It would be useful to provide more explanation of what you mean and reference the section you base this statements on. Sub_BP3 could be written more clearly. BP10-SubBP2: for this area and period the peak-to-peak difference seems to exceed 0.1 every single year. BP11: move up to BP9 'long-term stability'? BP13 'within 30%': good to give values, but what do these 30% mean? Argo(?) observations are typically within a range of 30% of the provided uncertainty? This would mean that CCI uncertainty is overestimated.

Section 2.4 BP1, could you clarify whether there issues are represented in the quality flag?

Some of the documents referred to more often are not publicly available or hard to find (e.g. RD05: PVIR v2). In some cases the key result/value which is referred to could be repeated here for the readers convenience (e.g. top of page 26)

Section 3: Thanks fore making the validation data available.

Page 43 "Figure 15 represents [...] with a yearly running average applied": Please clarify, is this figure not used to discuss the seasonality? Why are there clear seasonal cycles after applying a yearly running mean?

When describing trends/long-term stability it is sometimes not clear what the time unit is (e.g. top of page 44, "+/- 0.04 pss" per year/decade/product lifetime?

Some internal references did not work (page 23 first paragraph)

Again, I want to highlight that this is a very compelling validation report and that this is complaining on a high-level.

Climate Assessment Report (CAR)

The SSS CAR is very well presented and covers a large range on aspects. It includes a very useful summary of previous documents which allows the CAR to be read as a stand-alone report. It includes among other things the relation of measured SSS with relevant climate indexes, the relevance of salinity for horizontal density gradients in the tropical Atlantic and the main fluxes in the salinity budget.

Specifics/minor:

Why are sections 6.3.2, 6.3.3, 6.3.8 and 6.3.9 not considered case studies? I understand that there is a reasoning in the order of the case studies, but it would be more intuitive if the case studies numbers would be adjusted accordingly, i.e. section 6.3.1 - case study 1, 6.3.2 -case study 2 etc.

The summaries of previous documents are quite useful to make this a stand-alone climate assessment. More of a note to the original questionnaire for the URD is: My understanding is that the trade-off between temporal resolution and uncertainty should be a reduced precision, not accuracy. Basically, higher resolution will create more spread (lower precision) but not necessarily introduce more biases (equal accuracy).

In some cases it seems like units are missing (page 24 top: long-term stability, is this per year/decade/record length?

Some in text labels/cross-references do not work (page 34 top, 42, referenct to Fig. 6-16 odd, same page 54 bottom, page 60 and 61 bottom, the reference to Figure 6-6 on page 61 probably refereing to another figure

The section about "Small scales, stratification and river plume in the Gulf of Guinea"(page 48 to 53) would benefit from being discussed with a stronger link to the climate assessment (instead of product validation). The same is true for the Summary (Section 7)

2.19 Sea Surface Temperature

The following documents are reviewed below:

- User Requirements Document (URD) version 2.1 dated 2.1 13 January 201
- Product Quality Assessment Report (PQAR) version 4.1 dated 27 October 2020[11]
- Product User Guide (PUG) version 2 dated 8 April 2019
- Climate Assessment Report (CAR) version 1.0 dated 16 June 2019

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 require dense temporal sampling with more flexibility on the spatial resolution. In this hypothetical case an 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.

[11] https://datastore.copernicus-climate.eu/documents/satellite-sea-surface-temperature/v2.0/D2.SST.2-v2.2_PQAR_of_v2SST_products_v4.1_APPROVED_Ver1.pdf

If applicable, would it be of interest to check in future with users if there are in-situ datasets 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.

Product Quality Assessment Report (PQAR)

The SST Product Quality Assessment Report provides an in-depth evaluation of the SST product. The thorough comparison with in-situ measurements is well structured and covers an assessment of the provided product uncertainties, latitudinal aspects and the temporal development of data quality, which renders it a very useful resource.

Below are some minor points which might or might not be helpful to the team.

- I am not clear what the differences between this document and a Product Validation and Inter-comparison Report would be.
- I am not sure about one aspect of the validation plots (which I like in general very much). They always show the discrepancy RSTD centered at 0 (instead of mean/median). This might or might not be the standard way to produce this kind of plots. In any case, users will assume that the provided uncertainty (green dashed lines) incorporates biases and (unbiased) signal noise. In one case (Figure 2.2.2.1, AVHRR-M02) the median is outside of the discrepancy RSTD. So in the rare case of large biases, would it not be more appropriate to center the RSTD on the median to see how large the overlap of the two distributions would be?
- The Figures in Section 2.2 also do not follow the same numbering system as those in the previous sections.
- Regarding the target of 0.1 K and limited availability of in-situ data with this precision: I think you do a better job in evaluating whether the product reaches this target than you state. For example, the two leftmost bins in Figure 2.2.5.2 top row (and 2.2.6.1) show discrepancies towards drifter measurements below 0.2 K, which indicates that (1) the drifter uncertainty might be overestimated, and (2) that the satellite products add close to no additional discrepancy to this. In other words, even if drifter uncertainty is 0.2 K, if the satellite to drifter discrepancy is not significantly larger you have shown that the satellite uncertainty is <0.2 K.
- Can you comment on the possibility to make the compiled validation data set publicly available?
- P44 (2.2.2 Level 2 against GTMBA): ' ATSR and daytime AVHRR are well estimated.' I think you mean nighttime here.
- P46 (2.2.3 Level 3U against drifters) 'The uncertainties of daytime ATSR-1 (2 channel data) are slightly over-estimated' I think you mean under-estimated here
- P52: '2.2.7 Level 4 against GTMBA' I think this section is about Level 3C data instead of Level 4?

Product User Guide (PUG)

The SST Product User Guide provides a good entry point to the SST product. The 'which product could I use' section (3.1.3) is a great addition to point the user to the most appropriate datasets. Also, the PUG puts a focus on technical guidance for the users (the use of toolboxes etc.) which is very helpful.

At times it might be possible to condense the content (e.g. I am not sure section 4.2.4 is necessary) and be a little more specific. For example, L3C data files are introduced several times but it has initially not been clear to me whether the data from all orbits is provided as different variable layers or combined to a single field. That is in part because it is not explicitly stated how data is combined if measurements from different orbits for the same location are available. In Table 14 it does say that the file contains the 'best available skin SST', however, the exact same words are used in Table 12 with regards to L3U files. CMUG would request that these definitions are rewritten to be clearer.

It should be checked whether a restructuring of some parts of the guide could help the reader to find the relevant information more easily and quickly. For example,
- the important 'Limitations' (section 3.5.6.2) is a subsection of 'Why use ESA SST CCI data (and why not)?' which is in turn a subsection of the 'Frequently asked questions'. 'Limitations' could be placed more prominently.
- similar considerations apply to section 3.5.6.1. (Key features of ESA SST CCI data)

Regarding the highlighted periods of increased noise in AVHRR data (1982 and 1983), it is not clear to me whether this is represented in the provided uncertainties (flag)?

The different levels of spatially correlated uncertainties (including section 7.5) are great, it would be even more beneficial to propagate those uncertainties (ideally also accounting for uncertainty due to interpolation) to L4 data.

Side note: The x-axis label in the figures in Table 4 is a little confusing, are these values of the RSTD or the discrepancy which is shown here?

Climate assessment report (CAR)

The SST CAR is well written and structured. Particularly useful are the short summaries and 'key points' throughout the report. A large number of aspects are addressed in great detail, from the global to regional scale. I hope that the following remarks help to spark new ideas (e.g. for the next phase) and are understood as coming from someone outside of the satellite SST community.

My main concern is that substantial parts of this report read like a PVIR so that I see potential to extract parts of this document into a PVIR and streamline the remaining to highlight the insights which the new version of the CCI SST product reveals of the climate system. In particular the multi product inter-comparison in Section 4 (with the exception of subsection 4.4) and most of the trailblazer user reports could be used for a separate PVIR or would otherwise benefit from a stronger discussion of the climate assessment. The key results in the beginning of most sections are very much appreciated but would benefit from accompanying brief motivation of how this particular study contributes to the objectives of the CAR.

Let me illustrate with the use of an example. Section 5.2.3.3 shows what impact the new CDR has on atmospheric simulations for different SST resolutions. While I believe that this study is very valuable, it reads like its purpose is to validate the SST dataset through its impact on known biases in atmospheric models. Of the summary (5.2.3.3.6), only the last paragraph is directly related to a better process understanding (local vs. remote impact of SST on clouds in Western Boundary Current regions). Similarly in Section 5.2.3.5, I would consider an investigation of whether the SST is causing a precipitation bias an validation exercise, while the investigation of the origin of atm. moisture for the south asian summer monsoon is an assessment of the climate.

More focus could for example be put on the analysis of the spatial SST variability which appears (Figure 4.4) to be substantially better resolved in the SST CDR2.0 then in previous versions and the comparison datasets. For example, the new insights of this improvement on the cascade of mixing energy from large to small spatial scales could be investigated. Is there a reason why this is done only for model results (Figure 5-4) instead of a purely observational based assessment of the system? More generally, what is the (small scale) spatio-temporal variability and how is this improving our understanding of the surface ocean dynamics (e.g. regarding ocean fronts)?

In addition to showing SST anomaly time series (Section 3) it could be interesting to calculate the strength of teleconnections of the climate system, such as the correlation of Nino3.4 with SOI.

As stated for example on page 144, the ENSO provides a good opportunity for coross-assessment of several satellite records and for model evaluation. It is further noted that "Climate models capture the basic ENSO features but the amplitude, life cycle and frequency are not properly reproduced and most models' variability extends too far into the Western Pacific. To further understand model
performances and biases, evaluating models with observational constraints derived from
multiple variables can give new perspectives." (Page 144). Even though some statistics are clearly limited by the length of the timeseries, would it be possible to provide intervals of (for example) nino3.4 amplitude, life cycle and frequency which are in agreement with the CCI SST CDR? In other words, values of some statistics, like the decadal variability, are very uncertain but it might nevertheless be possible to identify values which can be ruled out to be realistic.

I really like the concept of including case studies in this type of report (section 6). As mentioned, in some cases it is not clear to me how the studies go past product validation and contribute to the climate assessment.

Would an assessment of global ocean heatwaves and change of heatwave frequency over time be possible with the CCI SST product?

Minor/Specifics:

The executive summary (page 10/11) could be more precise by providing some numbers. E.g. Bullet Point (BP) 3: "much improved", BP 8: "found to be cooler than"

Page 6: the paragraphs starting with "Section 4" and "Section 5" refer in fact to Section 6 and Section 7, respectively.

Page 16: AVHRR SST is used as comparison dataset but AVHRR is also contributing to the CCI SST. Can you mention the main differences in processing in the comparison data and CCI?

The text in section 3 often refers to individual events (eruptions), could these be extracted from the time series and shown for all areas, or as a map, in one plot? This is in addition to time series plots, of course.

Figure 3-20 and 3-21: Are the anti-correlations in high latitudes for the CCI analysis with long lag significant? Can you explain the related process and what new insights the CCI SST version provides regarding the strength of this process?

Figure 4.1: Is the central panel the mean (as the caption states) or the median (as the text, page 47, states)? What is the nominal measurement uncertainty of Argo data?

Could you clarify who performed the work in Section 5? My understanding is that it is from within the CCI SST team, but section 5.2.6 sounds like being from outside the team. This might just be my associations with the word 'recommendations'. Maybe 'lessons learned' could be an alternative?

Figure 5-5 shows, for my understanding, the fraction of the earth surface (including land?) covered by sea ice. It is much more common to show sea ice coverage in million km².

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 100 km scale an accuracy of 0.1 K with the CCI data is not quite achieved being closer to 0.15 K. Areas with persistent cloud cover are particularly challenging in terms of achieving accuracy requirements.

2.20 Snow

The following documents are reviewed below:

- User Requirements Document (URD) version 2.0 dated 17/12/2019
- Product Specification Document (PSD) version 2.0 dated 19/12/2019
- Product User Guide (PUG) version 2.0 dated November 2020
- Product Validation and Intercomparison Report (PVIR) version 2.0 dated November 2020
- Climate Assessment Report (CAR) version 3.0 dated 15 December 2021

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 algorithm’s 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.

Product User Guide (PUG)

The snow Product User Guide (PUG) document issued in November 2020 describes the general properties of the products (e.g. file format) and defines the snow variables that are produced: snow cover fraction (SCF, several options) and snow water equivalent (SWE). This is a clear and concise document.

For each variable, a short chapter lists strengths and known limitations of the products. Each variable is illustrated by a map but no time series is shown. Multi-year time series could be shown for all variables at one location to be defined. This location should be representative of an area with seasonal snow cover and with a significant seasonal and interannual variability of snow cover and snow water equivalent (e.g. in northern Germany). This would be particularly useful for the AVHRR SCF time series because AVHRR sensors had no onboard calibration. The users need to figure out to what extent time series are homogeneous in time.

Product Validation and Intercomparison Report (PVIR)

The snow product validation and intercomparison report (PVIR) is a document of 53 pages issued in November 2020. Landsat satellite images are used together with in situ snow depth observations for performing the validation.

Information seems to be duplicated in Tables 3.13 and 3.14 (exactly the same figures in (a) and (b)). Presentation of these Tables could probably be simplified.

Figures 3.5, 3.6, 3.9, 3.10: to which subfigures are Dozier, Klein and Salomonson related? Could score changes in time be explained? This validation exercise is quite convincing. However, indirect validation through a comparison with the NOAA IMS SCF product would have been interesting since SCF users are familiar with the IMS product.

Climate Assessment Report (CAR)

The snow climate assessment report (CAR) document issued in December 2021 describes five use cases of the SWE product (Snow Water Equivalent).

In use case 1, a trend analysis is performed. A discontinuity can be observed in all SWE product in 1988. This is due to the transition from SMME to SSMI. Attempts to improve the radiometric calibration of SMMR did not solve the problem, that could also be caused by the poorer sampling time of SMMR. SWE can be used to estimate snow cover fraction and monthly mean decreasing trends for the northern hemisphere do not change much from one product version to another. A similar result is found for the Artic only. The lack of data in mountain areas is an issue. In use case 2, SNOW products are used to evaluate CMIP6 simulations. Results are available in two papers published in 2022 and 2021. It is envisaged to produce a low-resolution product that could easily be used by non-expert users. In use case 3, the products are used by SnowMIP to close the scale gap with in-situ observations. This exercise has revealed some inconsistencies in the SWE product. In use case 4 the SWE is used together with snow cover fraction (SFC) to validate simulations of changes in the hydrological regime of the Artic land masses. The large fraction of SCF missing data is an issue. Efforts to gap-fill SCF are needed. In use case 5, the assimilation of the IMS product in the ECMWF model from 2004 onward triggers a marked discontinuity in the simulated SWE. This shows the potential of assimilating longer SWE time series.

General comments:
The document is well structured and very well written. Convincing key results are presented in a very clear way. Five useful recommendations are made to the CCI-SWE consortium.

2.21 Soil moisture

The following documents are reviewed below:

- User Requirements Document (URD) version 2.0 dated 19 November 2020
- Product User Guide (PUG) version 2 dated 16 April 2021
- Product Validation and Intercomparison Report (PVIR) version 2 dated 16 April 2021
- Climate Assessment Report (CAR) version 2.0 dated 04 November 2021

It would be useful if the SM_cci key document web pages (https://climate.esa.int/en/projects/soil-moisture/key-documents/) followed the same format as the other CCI projects, especially as the number of documents increases as the project matures.

User Requirements Document (URD)

This document is very well written and structured. It helps better understand the SM_cci 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 SM_cci products 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.

Product User Guide (PUG)

This document is well prepared and structured as well as very helpful for final users.

In section 2: Soil Moisture within the environment an update to references would be encouraged, the most recent reference is from 2011. Since then much work on the role of soil moisture in the climate has been done for instance

- on the coupling between soil moisture and convection (e.g. Taylor *et al*., 2012 DOI: 10.1038/nature11377 , Guillod *et al*., 2015 DOI: 10.1038/ncomms7443),
- on the impact on the nocturnal cooling and the amplitude of the diurnal cycle (Cheruy *et al*., 2017, https://doi.org/10.1002/2017MS001036),
- on the temperature biases in climate model (e.g. Al-Yaari *et al*., 2019, https://doi.org/10.1038/s41598-018-38309-5),

Some specific comments are listed below:

- There is a problem with the citations: "Error! Reference source not found."
- Al-Yaari et al., 2019, could have been referred in "ESA CCI-SM in Earth system applications".

Product Validation and Intercomparison Report (PVIR)

This document is also well prepared and structured.

The authors focus mainly on the comparison between products/CCI versions but very rarely interpret the origin of the differences. The comparison is mostly limited to the diagnostics of agreement or disagreement. It seems essential to us that the scientists who know the data best suggest possible cause of disagreement. For instance, there are opposite trends between the CCI passive, active, and combined products, which is quite surprising. The authors should help the end-user to decide which dataset is trustworthy for different applications and what the pros and cons are.

Minor points:

- p 18 “Error! Reference source not found”
- p 22 that that
- p 22: ERA5 observation. As far as I know ERA5 SM is a model product not an observation.
- A few words on the meaning of “break adjusted” might help the end-users, does the change go in the expected direction?
- Concerning the in-situ measurement, are the values of the soil moisture assimilated in ERA product?
- p. 32 Comment on Fig. 22: The increase in correlation is mostly for the absolute value.
- p.41 (in particular, its temporal dynamics), could the authors be more specific, as for instance they show that there is not agreement in the tendencies between the various sets.

Climate Assessment Report (CAR)

This document is well prepared and structured. It shows numerous examples in the peer review literature confirming the added value of satellite derived SM products (ESA-CCI). The “ESA CCI SM at a glance” is particularly welcome and well equilibrated. The main concern I have deals with the use of ESA CCI SM products to derive trends, this is mentioned several times in the document. For instance p 8 “… . Long temporal coverage is essential for robust trend and driver assessment.” In the PVIR document that we previously reviewed, authors showed opposite trends between CCI passive, active and combined products. Is this issue solved? If not, the user has to be warned if they want to use ESA CCI SM to seek robust trends.

P 11: “ESA CCI SM shows a strong similarity with related terrestrial water cycle components such as terrestrial water storage, precipitation, the self-calibrating PDSI, and terrestrial evaporation”: the meaning of this sentence is unclear to me. Could the authors develop a little?

The literature review is very extensive and already impressive. I can indicate some additional work that is not mentioned yet. Al-Yaari et al (2019) have used CCI in their work: “Satellite-based soil moisture provides missing link between summertime precipitation and surface temperature biases in CMIP5 simulations over conterminous United States”, https://doi.org/10.1038/s41598-018-38309-5. Recently Cheruy et al., have used CCI data together with GLEAM data analyse the land-atmosphere interactions in the IPSL-CM6 climate model used for the production of the simulations for CMIP6, “Improved near-surface continental climate in IPSL-CM6A-LR by combined evolutions of atmospheric and land surface physics” https://doi.org/10.1029/2019MS002005

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 SM_cci 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 SM_cci product and this hampers the full use of CCI soil moisture over these regions. The SM_cci team decided to flag data over these regions. We recommend providing this information and let final users decide whether they are useful or not.

2.22 Water Vapour (WV)

The documents reviewed for the WV_cci project are:

- User Requirement Document (URD) version 2.0 dated 18 November 2019
- Product Specification Document (PSD) version 2.1 dated 27 November 2019
- Product User Guide (PUG) Version 1.1 dated 13 October 2020
- Product Validation Plan (PVP) version 1 dated 24 February 2021
- Climate Assessment Report (CAR) version 1.1 dated 03 November 2020

Some suggestions are also 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 (URD)

- 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 (PSD)

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

Product User Guide (PUG)

General comments

- The use of many acronyms makes the text difficult to read for anyone not very familiar with the topic. Defining the ones in the text that are used repeatedly would make reading the text easier as going back and forth between the text and the glossary is somewhat breaking the flow.
- The numbering of the subsections is sometimes a bit too detailed (e.g. 3.2.2.2.1.1). At least for me this makes it rather more difficult to remember the main context than it helps to structure the document. After a while I start feeling a bit “lost” in the document.
- In many cases, no details are given but only references to other documents. This is of course fine but I would find it helpful to have wherever possible at least a few keywords

or a 1-2 sentences summary so it would be possible to get the basic idea without having to go through a number of external documents.

- I like the "fact sheets" (e.g. tables 3-4, 3-5, 3-6) as this allows for a quick overview. I find this very helpful.
- It would be nice to have some context (e.g. an introductory paragraph in the beginning of the section) for the software tools presented in section 5. E.g. who is the target group (scientists, students, interested public, etc.)? What are the main applications of the tools (visualization, analysis, website, etc.)? What is the context within ESA CCI? What is the motivation for choosing the tools shown?
- Not sure there is a large added value from the listings in section 11 as people will have to check the actual content of the files they downloaded anyway as any printed table might be outdated.

Specific Comments

- Caption of figure 2-2: not sure what is meant by "Symmetric system". Maybe add brief explanation.
- The processing chain (section 3.1.2) could be outlined in a few sentences instead of only referring to other documents. Without any further explanation, I find figure 3-1 difficult to understand.
- Input products (section 3.1.3.1.1): it would be nice and helpful to have the products used explicitly listed here.
- Page 16: there are several empty subsections "3.1.3.1.2" on the page
- Page 17: empty subsection "3.1.3.1.2.3"
- Section 3.1.3.1.2.4: what is meant by "24 NetCDF products per year"? 24 netCDF files per year, i.e. one file per month and product?
- Page 18: empty subsections "3.1.3.2.1", "3.1.3.2.2" and "3.1.3.3"
- Section 3.1.3.2.1: there are empty parenthesis at the end of the first paragraph. Is there anything missing?
- Section 3.1.3.3.1.1: I am not familiar with the term "final flag bands". Maybe add a brief explanation.
- Table 3-1: given the content of the table, I guess the caption should rather read something like "variables and coordinates in Level-3 TCWV land product"?
- Table 3-1: the variables time, lat, lon are usually not called "bands" as suggested in the caption of the table but rather "coordinates". Variables ending in "_bnds" are usually (in climate modelling at least) referred to as "bounds" and not "bands".
- Table 3-1, time_bnds: maybe rather simply speak of "time bounds"?
- Page 21, last line: "merge products" → "merged products"?
- What is the difference between figure 3-5 and figure 3-6? Both look the same to me.
- The caption of figure 3-5 says "CDR-3" but the figure says "CDR-4".
- Section 3.2.2.2.1.1, "The missing values are set to NaN": while there is technically nothing wrong with this approach, it makes it more difficult to process the data with some programming languages. It would be more common to define a "missing value" (e.g. netCDF attribute "_FillValue") and use this value instead of setting data points to NaN as this is approach widely used and therefore supported by most programming / scripting languages.

Product Validation Plan (PVP)

General comments

- The use of many acronyms makes the text difficult to read for anyone not very familiar with the topic. Defining the ones in the text that are used repeatedly would make reading the text easier as I find going back and forth between the text and the glossary is somewhat disruptive.
- A summary of the different processing / validation steps e.g. as schematics would be helpful and make it easier for those not familiar with the process to get an overview more quickly and more easily.
- Colocation criteria are given (e.g. $\Delta t \leq 24h$, $\Delta r \leq 1000\ km$) but not explained. What is the rational for these criteria?
- I am missing a section on how the results of the evaluation will be put into context / rated, e.g. in terms of fitness for purpose, recommended applications, meeting the goals of ESA CCI, etc.

Specific Comments

- I am not sure I fully understand the purpose of the list of references in the beginning of section 1.2 without any further explanation. I would either give one or two keywords per reference to make it clearer which reference is addressing which definition or remove the list and add the references (as needed) to the list in Appendix 1.
- The first paragraph about the lack of interactions between tropospheric and stratospheric communities in section 1.3 seems a bit out of place. Maybe connect with CDR requirements or remove?
- Section 2 (p. 15), 3rd paragraph: "references" → "reference datasets"
- Section 2.2 (p. 16): for the sake of completeness, it would be nice to have a 1-2 sentence summary of the CDR-2 dataset (similar to the ones for CDR-1 on p. 15 and for CDR-3 on p. 17)
- Schematic of the workflow shown in fig. 4-2 is great and really helpful; similar schematics for the other steps would be great.

Climate Assessment Report (CAR)

The document is nicely structured and well written. Please find below some general and some specific comments.

General comments / ideas

- I understand why this document is split into part 1 and part 2 but eventually, i.e. once part 2 is available, it would be nice to have only one document.
- I think the document would be easier to read if acronyms would be defined in the text instead of having to go back and forth between the glossary and the text.
- Whenever possible, quantitative measures would be helpful instead of purely qualitative ones such as, for example, "Largest absolute biases", "distinct bias" (p. 15) or "good degree of correlation" (p. 22)

- Maybe add links to additional documents such as “CAR v3.0”, “DARD v3.2” or “PVP v3.2” to make access to these documents more convenient for the reader.
- As an idea, the “all-sky” product could also be mentioned as this product is particularly interesting to model evaluation.

Specific Comments

- Section 2.1: I would find a table providing an overview on all datasets used including the main reference and/or doi number very helpful. Simply referring to DARD is not very convenient.
- Figures 3-1, 3-2, 3-2: there is no legend or color bar for the scatter plots explaining the different colors.
- Figures 4-6, 4-7, 4-12: the color bars could be labeled e.g. with “density of data points”.
- Caption of fig. 4-2: maybe add reference and/or doi for LandCover CCI. The meaning of the color scale is not clear to me and could be explained here as well.
- Figure 4-4: I found the color scale slightly confusing as this is – as I understand - a binary mask, so maybe remove the color scale from this figure?
- Table 5-1, ERA5 step size: did you mean 1.45 instead of “0l.45”?
- Figures 6-1, 6-2, 6-3: not sure I understand why some bars in the upper panel and in the lower panel of the figures seem to be shifted.
- Table 7-1: CMUG recommends that this summary table be placed earlier in the text to provide an overview on the evaluation sections before discussing the details.

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

Summary

Overall, 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 readability. The LST_cci URD and PSD are examples where document length is excessive and reorganization would be helpful, although the LST_cci PUG is much better structured. The Permafrost_cci project also provides a number of examples of well-organized documents.

While at times it is useful to summarise key points and conclusions from other project documents, detailed descriptions and text should not be duplicated, e.g. a short summary and a reference to the URD from within the PSD is sufficient, without wholesale duplication. This will allow the reader to grasp the main point being made without finding the referenced document but at the same time allow them to follow up for more detail if necessary.

Some specific 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 consideration for what might be of use. More stringent guidance from ESA on expected content and length for each document would be welcome, as well as a more coherent review process across CCI projects.

CMUG recommends that all products, datasets and documents are citable with a DOI. This is available for many of the CCI ECVs already and should be rolled out to cover them 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 access to the most recent versions of documents through the new CCI web site and the layout of the “key documents” page for each project could be standardised. Is there some central system in place to ensure these pages are kept up to date?

The format and content of the URDs varies considerably between the CCI projects, some merely collect requirements while others provide detailed discussion of their feasibility. This second approach is useful information for climate modelers and CMUG would encourage all projects to include a section covering physical limitations of the observations. A wider and more representative range of contributors to the URDs is encouraged, in terms of application, but also in terms of geography so that users outside Europe might have some input. CMUG would be keen to work closely with each CCI ECV project when the next round of requirements gathering begins.

For the PVIR CMUG would like to encourage a more standardised approach to uncertainty analysis. A lot of work has been done to assess the datasets, but assigning uncertainties to the data provided to users has not always followed through (e.g. SI_cci SIT).

The PUGs are generally clear and well formatted. However, as for the PVIR, the amount of uncertainty information included varies greatly from one product to another. Guidance could be provided by ESA on what information to include in each document, so that this can be standardised. CMUG would suggest that the process for calculating uncertainty is included in the PVIR together with the results, these results can then be summarized in the PUG and the PVIR referenced. The PUG can then go on to give recommendations about what these results mean in practice for the user. Some projects do this well already Cloud_cci, Fire_cci and Ocean Colour_cci are good examples.

It is recommended that the PUG should be aimed at a new user and with this in mind CMUG particularly liked the "FAQ" style layout of the LST_cci PUG. The fact sheets included in the WV_cci PUG for each product were also well received and including these in appendices to the PUG for all projects is recommended.

A succinct list of the information CMUG would like to see in a PUG is given below.

- Descriptions of sensors
- Technical specifications of data (format, filenames metadata)
- Guide to method of access
- Guide to any preprocessing required by user
- Product strengths and limitations/known issues (i.e. regions or time periods where data is poor)
- Uncertainty characterisation and recommendations for use/best practice/guidelines and validation documents referenced (PVP/PVIR)
- Recommended applications for products and examples of existing applications
- Description of code/toolboxes/algorithms for using data and guidance on when to these should be used
- Maps and time series of data to be included
- Information on the continuity of each product (e.g. when moving from one instrument to another)
- Citation information

Overall CMUG recommendations for all documents are given below

Specific recommendations on the document structure:
- All documents to include an executive summary
- Standardized contents and recommended length
- Information to be grouped by application (e.g. when included in tables)
- Table of acronyms, but acronyms also expanded in text on first use (and subsequently if not used for a number of pages)

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 are given for each ECV in the relevant sections above. Some points which apply to all CCI projects are listed here:

- New instruments providing additional products should be considered in the URDs for future phases. 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 useful too, but this should be the minimum
- Some thought could be given in the next versions of CCI project 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

Acronym list

AGB	Above Ground Biomass
ATBD	Algorithm Theoretical Baseline Document
BA	Burned Area
CAMS	Copernicus Atmospheric Monitoring Service
CAR	Climate Assessment Report
CCI/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

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