ESA Climate Change Initiative (CCI+)

Essential Climate Variable (ECV)

Antarctica_Ice_Sheet_cci+ (AIS_cci+)

User Requirements Document (URD)

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Change Log

Issue	Author	Affected Section	Change	Status
1.0	Dana Floricioiu	All	Document creation and written draft	Released to ESA
2.0	Dana Floricioiu	All	Updated at the beginning of phase 2	Released to ESA

Acronyms and Abbreviations

AIS	Antarctic Ice Sheet
AMAP	Arctic Monitoring and Assessment Programme
ATBD	Algorithm Theoretical Basis Document
ATLAS	Advanced Topographic Laser Altimeter System
CAR	Climate Assessment Report
CCI	Climate Change Initiative
CEOS	Committee on Earth Observation Satellites
CFL	Calving Front Location
CMUG	Climate Modelling User Group
CPROP	Contractual Proposal
CR	Cardinal Requirement
CRDP	Climate Research Data Package
CRYOVEX	CryoSat Validation Experiment (airborne and in-situ campaigns)
CRG	Climate Research Group
CS2	CryoSat-2
C3S	Copernicus Climate Change Service
DARD	Data Access and Requirements Document
DEM	Digital Elevation Model
DInSAR	Differential Interferometric Synthetic Aperture Radar
DLR	German Aerospace Center
DTU-S	DTU Geodynamics Group
DTU-N	DTU Microwaves and Remote Sensing Group
ECV	Essential Climate Variable
EO	Earth Observation
ENVEO	ENVironmental Earth Observation GmbH
ESA	European Space Agency
E3UB	End-to-End ECV Uncertainty Budget
FCDR	Fundamental Climate Data Record
FPROP	Financial Proposal
GCOS	Global Climate Observation System
GEUS	Geological Survey of Denmark and Greenland
GCP	Ground Control Point
GIA	Glacial Isostatic adjustment
GLL	Grounding Line Location
GMB	Gravimetry Mass Balance
GrIS	Greenland Ice Sheet
IGOS	Integrated Global Observing Strategy
IMBIE	Ice Sheet Mass Balance Inter-comparison Exercise
InSAR	Interferometric Synthetic Aperture Radar

IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel of Climate Change
IPP	Interferometric Post-Processing
IPROP	Implementation Proposal
IPY	International Polar Year
IV	Ice Velocity
IW	Interferometric Wideswath
MPROP	Management Proposal
NBI	Niels Bohr Institute, University of Copenhagen
NERSC	Nansen Environmental Research Institute
NU	Northumbria University
PARCA	Polar Areas Regional Climate Assessment project (NASA)
PM	Progress Meeting/ Project Management
PMP	Project Management Plan
PROMICE	Danish Program for Monitoring of the Greenland Ice Sheet
PSD	Product Specification Document
PUG	Product User Guide
PVIR	Product Validation and Intercomparison Report
RA	Radar Altimetry
RFQ	Request For Quotation
S&T	Science and Technology AS
SAR	Synthetic Aperture Radar
SLBC cci	Sea Level Budget Closure cci project
SEC	Surface Elevation Change
SOW	Statement of Work
SSD	System Specification Document
SVALI	Stability and Variability of Arctic Land Ice (Nordic project)
SWIPA	Snow, water, Ice and Permafrost in the Arctic
SVR	System Verification Report
TBD	To Be Decided
TPROP	Technical Proposal
TSX/TDX	TerraSAR-X/TanDEM-X SAR satellites
TUDr	Technische Universität Dresden
UCL	University College London
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URD	User Requirement Document
WBS	Work Breakdown Structure
WMO	World Meteorological Organization

1 Introduction

This document contains the User Requirements Document (URD) for the Antarctica_Ice_Sheet_cci+ project for CCI+ phase 2, in accordance to contract and SoW [AD1 and AD2].

The purpose of the URD is to document the user requirements of climate science and climate services for the development of the AIS ECV data products. The geophysical parameters of AIS in the AIS_cci+ project are:

- Surface elevation change (SEC)
- Ice velocity (IV)
- Grounding Line Location (GLL)
- Gravimetric Mass balance (GMB)

All the above parameters are inherited from the AIS_cci project (phase 2015 – 2018) and were continuously generated in the AIS_cci+ phase 1 (2019 – 2022). The URD document is part of Task 1 Requirements Analysis deliverables, with deliverable id: D1.1.

1.1 Purpose and Scope

The URD document is part of the Task 1 Requirements Analysis deliverables, with deliverable id: D1.1.

The URD for the Antarctic_Ice_Sheet_cci+ (AIS_cci+) phase 2 project is updated based on the current ECV requirements according to the GCOS 2022 Implementation Plan [GCOS (2022)]. The documents from the previous CCI Ice Sheets project, specifically on the URD and the CAR compiled in the AIS_cci+ phase 1 project ([RD2] and [RD3]) are also considered. The update is done through engagement with the user community, as well as consultation with the CRG.

In the AIS_cci+ phase 2 project the ECV parameters are the same as in AIS_cci and AIS_cci+ phase 1. Therefore in preparation for this URD, we have not performed an independent user survey within the community, but we have relied on an initial user survey performed in 2013 as part of AIS_cci. The survey provided a consistent overview of user groups and user requirements which is adapted for the current project in Chapter 2 below.

We have continuously involved the user community in the previous CCI project phases, thereby preparing for this URD. The user involvement has been done through the project's website, newsletters and by presentation of CCI data products at scientific conferences and at other meetings. In addition, we have here surveyed the literature and online data archives to assess requirements within different user groups, and finally, the CRG has been consulted for feedback on the user requirements.

The user requirement analysis for the Antarctica_Ice_Sheet_cci+ was performed on this basis.

1.2 Document Structure

This document is structured as follows:

- Chapter 1 describes the purpose and structure of the document
- Chapter 2 describes the background and the user groups for the Antarctica_Ice_Sheets_cci+.
- Chapter 3 analyses the user requirements using various sources.
- Chapter 4 provides the download statistics of the released products.
- Chapter 5 concludes the document and provide an overview of user requirements.

1.3 Applicable and Reference Documents

Table 1.1: List of Applicable Documents

No	Doc. Id	Doc. Title	Date	Issue/ Revision/ Version

AD1	ESA/Contract No. 4000143397/23/I-NB CCI+ PHASE 2 - ANTARCTIC ICE SHEET.	CCI+ PHASE 2 - NEW R&D ON CCI ECVS for AIS CCI	13.02.2024	NA
AD2	ESA-EOP-SC-AMT-2023-12 and its appendix 2.	STATEMENT OF WORK, ESA EXPRESS PROCUREMENT – EXPRO CCI+ phase 2 – Theme II – Antarctic Ice Sheet (AIS)	14.07.2023	1.2

Table 1.2: List of Reference Documents

No	Doc. Id	Doc. Title	Date	Issue/ Revision/ Version
RD1	UN-ESA-AIS-CCI+-P2-CCN-TPROP	Antarctic Ice Sheets cci+ Technical Proposal (TPROP)	2023.09.27	1.0
RD2	ST-UL-ESA-AISCCI+-URD-001	User Requirements Document (URD)	2019.12.10	1.0
RD3	ST-UL-ESA-AISCCI+-CAR-001	Climate Assessment Report (CAR)	2022.05.03	1.0
RD4	ST-UL-ESA-AISCCI+-PVP-001	Product Validation Plan	2019-11-13	1.0
RD5	ST-DTU-ESA-GISCCI+-URD-001	GIS CCI User Requirements Document (URD)	2023-07-05	3.1

Note: If not provided, the reference applies to the latest released Issue/Revision/Version

Table 1.3: List of Other References

Church, J.A., et al (2013), Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. doi: 10.1017/CBO9781107415324.026

[GCOS (2016)] - GCOS-200 - The Global Observing System for Climate: Implementation Needs. Available online at https://library.wmo.int/opac/doc_num.php?explnum_id=3417.

GCOS (2022) - GCOS-244 - The 2022 GCOS Implementation Plan. Available online at https://library.wmo.int/records/item/58104-the-2022-gcos-implementation-plan-gcos-244.

GCOS (2022) - GCOS 245 - The 2022 GCOS ECVs Requirements © World Meteorological Organization, 2022. Available online at https://library.wmo.int/records/item/58111-the-2022-gcos-ecvs-requirements-gcos-245

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Rignot E., J. Mouginot, B. Scheuchl, (2011) Ice Flow of the Antarctic ice sheet, Science Vol. 333, pp. 1427-1430, DOI: 10.1126/Science.1208336.

Scambos, T. A., et al (2004) Glacier acceleration and thinning after ice shelf collapse in the Larsen B embayment, Antarctica, Geophys. Res. Lett., 31, L18402, https://doi.org/10.1029/2004GL020670, 2004.

Slater, T., Hogg, A.E. & Mottram, R. Ice-sheet losses track high-end sea-level rise projections. Nat. Clim. Chang. 10, 879–881 (2020). https://doi.org/10.1038/s41558-020-0893-y.Shepherd, A. et al (2012) A reconciled estimate of ice-sheet mass balance, Science, Vol. 338 (6111), pp. 1183-1189.

Shepherd A; et al (2018) Trends and connections across the Antarctic cryosphere, Nature, 558, pp.223-232. doi: 10.1038/s41586-018-0171-6

Mark E. Tamisiea, Jerry X. Mitrovica, James L. Davis, (2003) A method for detecting rapid mass flux of small glaciers using local sea level variations, Earth and Planetary Science Letters, Volume 213, Issues 3–4, pp 477-485, ISSN 0012-821X, https://doi.org/10.1016/S0012-821X(03)00301-7.

van den Broecke, M. et al (2009) Partitioning Recent Greenland Mass Loss, Science Vol. 326 (5955), pp 984 – 986.

2 Background

2.1 The need for Antarctic Ice Sheet ECV products

Changes in ice sheet mass are societally relevant because they contribute to global sea level rise (0.59 +/- 0.20 mm/yr over the period 1992 to 2011 in Shepherd et al, 2012). Both ice sheets, Greenland (GrIS) and Antarctica (AIS) are losing ice mass at accelerating rates (e.g. McMillan et al., 2014; Rignot et al., 2011) in response to atmospheric (van den Broeke et al., 2009) and oceanic forcing (Joughin, 2012). Rates of ice loss from the AIS have increased, significantly, during the past decade (The IMBIE Team, 2018), and are now tracking towards the upper range of the IPCC's projections made in AR5 (Slater et al, 2020) which allow for an additional 10-20 cm of mean global sea level rise by 2100 (Church et al., 2013). Recently, a new record of the Earth's polar ice sheet mass balance was produced by aggregating 50 satellite-based estimates of ice sheet mass change. This new assessment shows that the ice sheets have lost 7563 Gt of ice between 1992 and 2020, contributing 21 mm to sea level rise (Otosaka et al, 2023). The principal AIS mass losses are due to changes in ocean forcing (Shepherd et al., 2018) which have triggered ice dynamical imbalance through ice shelf collapse (e.g. Scambos et al., 2004) or grounding line retreat (e.g. Konrad et al., 2018). Where the ice sheet bedrock deepens inland, this promotes instability (Thomas et al, 1979) which is of particular concern for future sea level rise. Ice sheet mass fluctuations also cause non-uniform variations in sea level due to their changing gravitational attraction (Tamisiea et al, 2003), and a consequence of this effect is that mass losses from Antarctica are of greater importance for Northern hemisphere sea level rise, providing a strong impetus for European nations to study the region.

Consequently, continuing to generate the geophysical products mentioned above over Antarctica within AIS_cci+ is crucial for ice sheet monitoring and modelling, glaciological research and climate modelling. These data sets will contribute to the understanding of the current AIS mass loss including the involved contributing processes as well as to the understanding of the consequences of the present and future climate changes on AIS mass change and to the improvement of the predicted sea level change contribution. Dense temporal series of high spatial resolution IV products over outlet glaciers are of interest for reducing the currently large uncertainty of their contribution to the sea level rise. Long time series of high-resolution SEC and IV products are required for ice sheet models which are currently evolving through increasing their resolution towards that of the satellite-based data products. Coupled climate and ice sheet models increased also their resolution as well as the complexity of their parameterisation and therefore can benefit from the remote sensing products too.

2.2 Users of Antarctic Ice Sheet ECV products

The ice sheet user community was outlined in the AIS_cci URD (RD2) and this information is repeated here for the sake of completeness within the AIS_cci+ project documentation.

Users of the Ice Sheets CCI data products can generally be divided into:

- **Ice sheet modellers** who are using the ECV parameters to validate and/or initialize their models, e.g. comparing modelled and observed SEC, CFL or GLL, or using the ECV parameters to constrain model parameters, e.g. constrain basal drag and ice viscosity by fitting modelled and observed IV.
- **Remote sensing scientists** who are deriving volume and mass changes from satellite observations.
- **Surface mass balance modellers and glaciologists**, who are interpreting satellite observed volume and mass changes, e.g. deriving mass change from observed volume changes by using firn densification models, or comparing observed mass loss with estimates from surface mass balance models based on climate models and observations.
- **Climate and Ocean modellers**, who are interested in the ice sheet component of the climate system and its interactions with other parts of the climate system, e.g. freshwater fluxes from ice sheet on shorter timescales or orographic forcing of wind patterns on longer timescales.
- **Authorities and organizations** who are interested in monitoring of the ice sheets for political or practical decisions.

The direct users of the AIS_cci+ data products over ice sheets are thus a relatively broad group covering several scientific communities. They are working with different approaches and at different levels, and their data needs are not the same. However, for all groups, it is often a significant problem to collect relevant data from various sources and to transform them into a standard format and the CCI/CCI+ program is a step forward in offering relevant and reliable data in standard formats.

Experience from earlier phases of the CCI program has demonstrated a strong interest from the user communities in long-term records of ice sheet ECVs from satellite observations to be available in user-friendly formats and from easily accessible platforms.

3 Analysis of users' requirements

3.1 GCOS requirements for the primary ECV parameters

The Global Climate Observing System (GCOS) represents the scientific and technical requirements of the Global Climate Observing System on behalf of the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC).

According to GCOS [GCOS (2016)], efforts should be made to:

(a) understand the processes related to the increase in mass loss of both ice sheets through improved observations and in situ measurements;

(b) reduce uncertainties in estimates of mass balance by improving measurements of ice-sheet topography and velocity and ice-sheet modelling to estimate future sea-level rises.

The GCOS definition for the Ice Sheets and Ice Shelves ECV states:

"The understanding of the timescale of ice-sheet response to climate change has changed dramatically over the last decade. Rapid changes in ice-sheet mass have surely contributed to abrupt changes in climate and sea level in the past."

The GCOS product requirements for the Antarctica_Ice_Sheet_cci+ parameters are given in the Terrestrial ECV Product requirements of [GCOS (2016)]:

Ice sheets and ice shelves requirements:

Table 3.1: GCOS requirements 2016 [GCOS (2016)] of ice sheets and ice shelves ECV.

Product	Frequency	Resolution	Required measurement uncertainty	Stability
Surface elevation change	30 days	Horizontal 100m	0.1m/year	0.1m/year
Ice Velocity	30 days	Horizontal 100m	0.1m/year	0.1m/year
Ice mass change	30 days	Horizontal 50 km	$10km^3$/year	$10km^3$/year
Grounding line location and thickness	yearly	Horizontal 100 m; Vertical 10m	1m	10m/decade

The latest of the GCOS Implementation Plans series (GCOS-244, 2022) and the revised requirements for ECVs (GCOS-245, 2022) were released in 2022. The ECV requirements were publicly reviewed in 2020 and the entire report was publicly reviewed in May 2022. Here we give the update of the ECV Ice Sheets and Ice Shelves product requirements.

For consistency, we list below the five criteria used to express the 2022 requirements:

1. Spatial Resolution - horizontal and vertical (if needed).
2. Temporal resolution (or frequency) – the frequency of observations e.g. hourly, daily or annual.
3. Measurement Uncertainty – the parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand (GUM)1. It includes all contributions to the uncertainty, expressed in units of 2 standard deviations unless stated otherwise.
4. Stability – The change in bias over time. Stability is quoted per decade.
5. Timeliness - The time expectation for accessibility and availability of data.

In the current Implementation Plan (GCOS-245, 2022), for each of these criteria, a goal, breakthrough and threshold value are presented. These are defined as:

- Goal (G): an ideal requirement above which further improvements are not necessary.
- Breakthrough (B): an intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses.
- Threshold (T): the minimum requirement to be met to ensure that data are useful.

Regarding the evolution of the ECV parameters, the table below illustrates the changes in the Ice Sheets and Ice Shelves ECV (which belongs to the terrestrial category) in the 2016 and 2022 implementation plans:

Terrestrial			
ECV	**ECV Product 2016**		**ECV Product 2022**
Ice Sheets and Ice Shelves	Surface Elevation Change		Surface Elevation Change
	Ice Velocity		Ice Velocity
	Ice Mass Change		Ice Volume Change
	Grounding Line Location and Thickness		Grounding Line Location and Thickness

The requirements for the ECVs and their products are presented in 3 different sections Atmospheric, Ocean and Terrestrial. Here we reproduce the tables concerning the Ice Sheets and Ice Shelves ECV. A definition and units are provided together with the requirements.

Requirements of the ECV Product: Surface Elevation Change in (GCOS-245, 2022)

Name	**Surface Elevation Change**				
Definition	Measurements of the change height above a reference (geoid or ellipsoid) of the snow-air surface or uppermost firn layers.				
Unit	Annual change in elevations above sea level measured in meters (m y^{-1})				
Note					
Requirements					
Item needed	**Unit**	**Metric**	**[1]**	**Value**	**Notes**
Horizontal Resolution	m	Spacing of measurements	G B T	 100	
Vertical Resolution			G B T	- - -	N/A. One value per point of Earth's surface.
Temporal Resolution	month		G B T	1 12	
Timeliness			G B T		
Required Measurement Uncertainty	m a^{-1}	error of measured in-situ using the geodetic method and remotely sensed surface elevation	G B T	 0.1	
Stability	m a^{-1}	as above	G B T	 0.01	
Standards and References					

Requirements of the ECV Product: Ice Velocity in (GCOS-245, 2022)

Name	**Ice Velocity**
Definition	Surface-parallel vector of the surface ice flow.
Unit	m y^{-1} (average speed in grid cell of surface ice flow)

Note					
	Requirements				
Item needed	**Unit**	**Metric**	**[1]**	**Value**	**Notes**
Horizontal Resolution	m	Grid cell size	G	50	
			B	100	
			T	1000	
Vertical Resolution			G	-	N/A. One value per point of Earth's surface.
			B	-	
			T	-	
Temporal Resolution	month	time	G	1	
			B		
			T	12	
Timeliness			G		
			B		
			T		
Required Measurement Uncertainty	m y^{-1}	error of measured in-situ using the geodetic method and remotely sensed surface elevation	G	10	
			B	30	
			T	100	
Stability	m s^{-1}	as above	G		
			B		
			T	10	
Standards and References	Hvidberg, C.S., et al., 2021. User Requirements Document for the Ice_Sheets_cci project of ESA's Climate Change Initiative, version 1.5, 03 Aug 2012.				

Requirements of the ECV Product: Ice Volume Change in (GCOS-245, 2022

Name	**Ice Volume Change**				
Definition	Direct measurement of local volume changes or inferred volume change from combining measurements.				
Unit	$km^3 y^{-1}$				
Note					
	Requirements				
Item needed	**Unit**	**Metric**	**[1]**	**Value**	**Notes**
Horizontal Resolution	km	Size of grid cell	G		
			B		
			T	50	
Vertical Resolution			G		N/A. One value per point of Earth's surface
			B		
			T		
Temporal Resolution	d	Time	G	30	
			B		
			T	365	
Timeliness			G		
			B		
			T		
Required Measurement Uncertainty	$km^3 y^{-1}$	error of measured in-situ using the geodetic	G		

Stability		method and remotely sensed surface elevation	B		
			T	10	
	$km^3 y^{-1}$	as above	G		
			B		
			T	1	
Standards and References					

Requirements of the ECV Product: Grounding Line Location and Thickness in (GCOS-245, 2022

Name	Grounding Line Location and Thickness				
Definition	Location of the line (zone) where ice outflow to an ocean begins to float, and thickness of ice at that location.				
Unit	m (thickness), coordinates of location				
Note					
Requirements					
Item needed	Unit	Metric	[1]	Value	Notes
Horizontal Resolution	m		G	100	
			B		
			T	1000	
Vertical Resolution			G	-	N/A
			B	-	
			T	-	
Temporal Resolution	y		G		
			B		
			T	1	
Timeliness			G		
			B		
			T		
Required Measurement Uncertainty	m		G	1	
			B		
			T	10	
Stability	m		G		
			B		
			T	1	
Standards and References					

3.2 Users requirements from Antarctic_Ice_Sheet_cci

The previous phases of the Antarctic_Ice_Sheet_cci had four geophysical parameters: SEC, IV, GLL and GMB. These parameters were selected together with their spatial and temporal coverage as a result of a user survey conducted in 2013 during the AIS_cci scoping study and preserved during the AIS_cci+ phase 1[RD2]. The summary of the Antarctic Ice Sheet product properties generated during the AIS_cci project 2015 – 2018 and AIS_cci+ phase 1 are summarized below.

Table 3.2: Summary of the AIS_cci 2015 – 2018 products and AIS_cci+ project 2019 - 2022.

Product	EO Input Data	Temporal Range	Temporal Frequency	Spatial Coverage	Geographic Location	Spatial Resolution

SEC	ERS-1/2, ENVISAT & CS-2 RA, Sentinel-3 SRAL	1991 – present day	monthly	Full AIS	AIS	5km grid
IV - AIS product	Sentinel-1 SAR	2015-present day	Monthly, Annual	Full AIS (minus polar gap)	AIS	200m grid
IV - Time series product	Sentinel-1 SAR	2015-present day	6 to 12 days	AIS margins	AIS	200m grid
GMB – Gridded product	GRACE, GRACE- FO	2002 – present day	monthly	Full AIS	AIS	50km grid
GMB – Basin product	GRACE, GRACE- FO	2002 – present day	monthly	Full AIS	AIS	1 change time series per drainage basin
GLL	ERS-1/2, TerraSAR-X, Sentinel-1 A/B SAR	1992 – present day	6 days to > 20 years	24 key ice streams	AIS	< 250m shapefile

3.3 SoW Requirements

The SoW [AD2] states that:

AIS_cci+ phase 2 will continue the development and production of Ice Sheet ECV data products building upon the success of the previous CCI programme and AIS_cci+ phase 1, realising the full potential of ESA's long-term Earth Observation data archive, established over the last 30 years. The project will develop and validate algorithms towards GCOS requirements to generate long-term, consistent, stable and uncertainty-characterised ECVs. AIS_cci+ phase 2 will document a coherent and continuous suite of actions that encompasses all steps necessary for the systematic generation of the ECVs set out in this proposal, continuing the achievements of the CCI programme.

"The purpose of the Ice_sheets_Antarctica_cci project is to provide users with high quality, stable and consistent ECV data records for use in science and for the development of services. GCOS provides a high-level specification of the requirements for Ice Sheets and Ice Shelves ECV products in the GCOS Implementation Plan (2016, [RD-1]). However, it is recognised that there is a spectrum of different user requirements within climate and ice sheet science, depending on different specific applications of the ECV."

The SoW has specific technical requirements (TR) to the user requirements management [AD2]:

[TR-15] To ensure the AIS_cci user requirements specification has high credibility, the Contractor shall collect requirements from leading glaciologists, climate scientists and leading climate science organisations, as well as projects monitoring the Antarctic ice sheets

- We are consulting the latest versions of documents related to climate assessments and the existing ice sheet requirements of GCOS, the results of the GCOS public review of requirements for ECVs (from May 2022) and CMUG CCI+ deliverable "Suitability of CCI ECVs for Climate Science and Services" and the CRG recommendations from phase 1 [RD-3].

[TR-16]
As an update from earlier CCI and CCI+ phases, the Contractor shall identify potential new users who represent the broad variety of applications over the Antarctic ice sheets, and survey their requirements for satellite-based Ice Sheet ECV products, paying particular attention to:
• Large international climate model intercomparison exercises, including CMIP6 and ISMIP6.
• Developers of climate services (e.g., Copernicus Climate Change Service).
• Upcoming requirements for GCOS climate indicators related to Ice Sheets and Ice Shelves.
• Potential requirements from other CCI projects for AIS_cci ECV products, for example for easing cross-ECV studies.

- We are revising the list of potential users of the data products and their applications over Antarctica.
- We are revising the specific user requests of the AIS_cci data products.
- We are consulting the user requirements from Greenland Ice Sheet ECV (GrIS_cci).

[TR-17] User requirements for ECV product uncertainties shall be included in the analysis, including how the uncertainties should be expressed in the AIS_cci ECV products (e.g., how should the uncertainties be broken down into their random and systematic components).
User requirements for the specification of spatial and temporal error-correlation characteristics of the products shall be analysed.

- The user requirements for the AIS_cci+ products with their associated uncertainties are going to be updated.

3.4 Requirements from the international research community

The Climate Modelling User Group (CMUG) is ESA's climate modelling expert group in the Climate Change Initiative (CCI) project. CMUG is a consortium comprising the Met Office Hadley Centre, the Max Planck Institute for Meteorology, the European Centre for Medium-Range Weather Forecasts (ECMWF) and Météo-France.

The Climate Research Group (CRG) is the Ice_Sheets_cci expert group who are engaged in the project and involved in understanding climate dynamics specifically related to the Ice Sheets ECV.

The CMUG and the CRG were invited to participate in the user survey during the 2015 - 2018 phase of the project [RD3]. In preparation of the user requirements analysis, the CRG were consulted for feedback and input.

As part of the cooperation with the international research community outlined in the technical proposal [AD2], a user workshop is planned during the 2024 European Polar Science Week which will be held in Copenhagen from 3 to 6 September. Here users of ECV data and stakeholders will present and discuss research related to the ECV products.

3.5 Overview of planned data products

The [RD4] presents an overview of the planned data production in phase 1 of the project (**Table 3.3**). These specifications are based on user requirements resulted previously to phase 2015-2018, while the extended temporal range and adjusted EO data availability were added in phase 1. During phase 2 additional EO data will be used for some of the parameters taken over from phase 1: ICESat-1 altimetry for SEC and SAOCOM SAR for IV. The specifications of the new data products planned for phase 2 (**Table 3.4**) will be updated after the user workshop.

Table 3.3 Overview of the Antarctica cci+ phase 2 data products taken over from phase 1.

Product	EO Input Data	Temporal Range cci/cci+	Temporal Frequency	Extent	Spatial Resolution
SEC	Cryosat-2, Sentinel-3, *ICESat-2*[1]	1991 - 2021	monthly	AIS	5 km grid + basins
IV	Sentinel-1 A/B, *SAOCOM*[1]	2014 - 2021	Annual, monthly & sub-monthly	AIS margins (incl. ice shelves)	200 m grid
GMB	GRACE/GRACE FO	2002 - 2021	monthly	AIS	50 km grid, basins
GLL	Sentinel-1 A/B, TSX SAR	1992 - 2021	decadal	20 ice streams	< 250 m

[1]additional EO data to be used in phase 2.

Table 3.4 Overview of the new data products in Antarctica cci+ phase 2. The requirements will be updated after the user consultation meeting.

Product	Product Description	EO Input Data	Temporal Range cci/cci+	Temporal Frequency	Extent	Spatial Resolution
IVC	Ice Velocity Change	Sentinel-1 A/B, TerraSAR-X, ERS-1, ERS-2, ENVISAT	TBD	TBD	TBD	TBD
GLM	Grounding Line Migration	Sentinel-1 A/B, TSX SAR	TBD	TBD	TBD	TBD
ISCL	Ice Shelf CoastLine	Sentinel-1 and Cryosat-2	TBD	TBD	TBD	TBD

4 Status of Downloads of data products

The AIS_cci/cci+ data products are released to the users for download at the three partners' data product websites and from the CCI Data Portal. The partners's websites are:

- http://www.cpom.ucl.ac.uk/csopr for SEC
- https://data1.geo.tu-dresden.de/ for GMB
- http://cryoportal.enveo.at/ for IV and GLL

The download status provides important information on the interest and usage of the products. In Figure 4.1 the number of visitors on each of the above-mentioned partner websites is plotted, while Figure 4.2 shows the numbers of the product downloads. They show how the interest of the science community for the AIS_cci products was still increasing even during the temporal gap between the cci/cci+ projects. Samples of the products are also available on the CCI data portal (http://cci.esa.int/data).

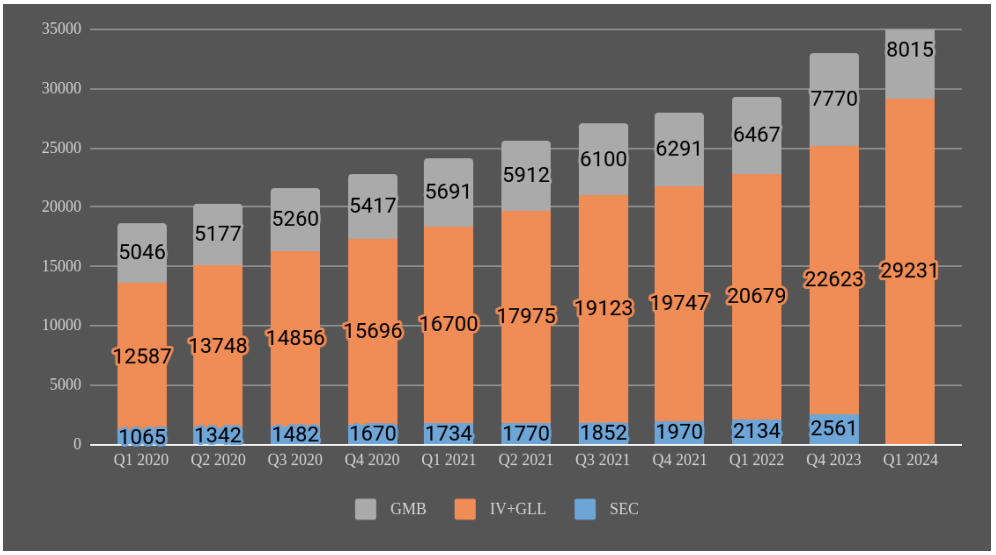

Figure 4.1. Accumulated number of visitors of AIS_cci products on the partner's websites.

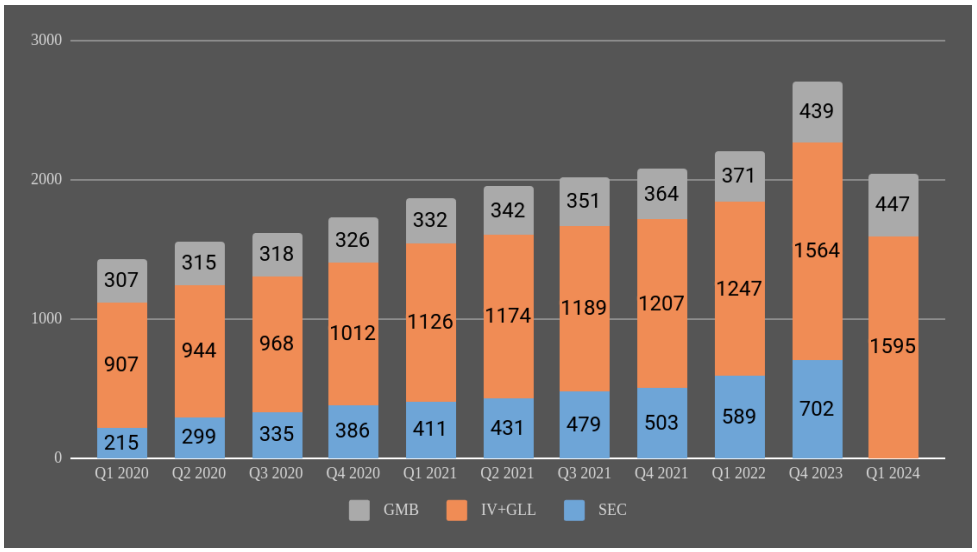

Figure 4.2. Accumulated number of AIS_cci product downloads on the partner's websites.

5 Conclusions

The user requirements for the Antarctica_Ice_Sheet_cci+ parameters have been reviewed and updated from previous phase (the AIS_cci project). For all four parameters the temporal range of the processed products is extended to currently available EO data at the same temporal frequency as in AIS_cci. SEC and GMB - both continent wide - will have monthly products. The GLL generation will be continued on selected ice streams to insure the required decadal resolution. The high frequency of Sentinel-1 A/B acquisitions on certain areas will allow also investigations of short term GLL changes. The IV products will cover the margins of the continent and will include also the ice shelves. IV will exploit the Sentinel-1 data acquisition plan as well and will have an increased temporal resolution aiming at resolving seasonal changes which are of high scientific interest.

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