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	

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
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 mission
TUDr	Technische Universität Dresden
UCL	University College London
UL	University of Leeds
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 1, 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 above parameters are inherited from the AIS_cci project (phase 2015 – 2018). The URD document is part of Task 1 Requirements Analysis deliverables, with deliverable id: D1.1. The URD will be updated at the beginning of the third review-design-produce-assess cycle as described in the SoW [AD2]. This version of the URD is the initial cycle 1 version.

1.1 Purpose and Scope

The URD document is part of the Task 1 Requirements Analysis deliverables, with deliverable id: D1.1-1. The URD will be reviewed and updated once after 2 years from the start of the project (at the beginning of the 3rd cycle) as described in the Technical proposal [RD1]. This version of the URD is the cycle 1 version.

The URD for the Antarctica_Ice_Sheet_cci+ project is updated based upon the current ECV requirements according to the GCOS 2016 Implementation Plan [GCOS (2016)]. The documents from the previous CCI Ice Sheets project, specifically on the URD and the CAR compiled in the Antarctic_Ice_Sheet_cci (AIS_cci) project included in phase 2 of ESA's CCI ([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 Antarctica_Ice_Sheet_cci+ project the ECV parameters are the same as in AIS_cci. Therefore in preparation of this URD, we have not performed an independent user survey within the community, but we have relied on previous user survey performed in 2013 as part of AIS_cci [RD2]. 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, thereby preparing for this URD. The user involvement has been done through 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 on-line data archives to assess requirements within different user groups, and finally, the CRG have 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. xxxxxxxxxx/18/I-NB, and its Appendix 2	CCI+ PHASE 1 - NEW R&D ON CCI ECVS, for Antarctica_Ice Sheet_cci		
AD2	ESA-CCI-EOPS-PRGM-SOW-18-0118 Appendix 2 to contract.	Climate Change Initiative Extension (CCI+) Phase 1, New R&D on CCI ECVs Statement of Work	2018.05.31	Issue 1 Revision 6

Table 1.2: List of Reference Documents

No	Doc. Id	Doc. Title	Date	Issue/ Revision/ Version
RD1	ST-UL-ESA-CCI+-PI-AIS-TROP	Antarctic Ice Sheets cci+ Technical Proposal (TPROP)	2018.09.14	1.0
RD2	ST-UL-ESA-AISCCI-URD-001	User Requirements Document (URD)	2017.11.01	3.0
RD3	ST-UL-ESA-AISCCI-CAR-001	Climate Assessment Report (CAR)	2018.07.05	3.0
RD4	ST-UL-ESA-AISCCI+-PVP-001	Product Validation Plan	2019-11-13	1.0

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

Table 1.3: List of Other References

[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.

Joughin, Ian et al. (2012). Ice-Sheet Response to Oceanic Forcing. Science Vol. 338. 1172-6. 10.1126/science.1226481.

Konrad, H. et al (2018) Net retreat of Antarctic glacier grounding lines, Nature Geoscience, 11, pp.258-262. doi: 10.1038/s41561-018-0082-z

McMillan, M., et al (2014) Increased ice losses from Antarctica detected by CryoSat-2, Geophysical research Letters, 41 (11), pp. 3899-3905.

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.

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

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 and Shepherd, in Press) which allow for an additional 10-20 cm of mean global sea level rise by 2100 (Church et al., 2013). 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+ are 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 parameterization 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+ programme is a step forward into 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 easy 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 United Nations Framework Convention on Climate Change (UNFCCC) and 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

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 [RD2]. The summary of the Antarctic Ice Sheet product properties generated during the AIS_cci project 2015 – 2018 are summarized below.

Table 3.2: Summary of the AIS_cci 2015 – 2018 products.

Product	EO Input Data	Temporal Range	Temporal Frequency	Spatial Coverage	Geographic Location	Spatial Resolution
SEC	ERS-1/2, ENVISAT & CS-2 RA	1991 – present day	monthly	Full AIS	AIS	5km grid
IV - AIS product	Sentinel-1	2015-present day	Annual to triannual	Full AIS (minus polar gap)	AIS	200m grid
IV - Time series product	Sentinel-1	2015-present day	6 to 12 days	Key ice streams	AIS	200m grid
IV – Getz Ice Shelf	ERS-1/2, ALOS PALSAR, S1	1995-present day	Annual	Zwally Basin 20	WAIS	200m grid
GMB – Gridded product	GRACE	2002 – present day	monthly	Full AIS	AIS	50km grid
GMB – Basin product	GRACE	2002 – present day	monthly	Full AIS	AIS	1 change time series per drainage basin
GLL	ERS-1/2, TerraSAR-X, Sentinel-1 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:

"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 technical requirements (TR) to the user requirements analysis [AD2]:

[TR-13] The analysis shall use the GCOS expressed requirements for Ice Sheet ECVs by involving the key science bodies as conduits for community consensus and establish active interaction with the ice sheet and climate research communities.

- We are delivering products in standard formats required by the science community, we are also ready to provide obs4MIPS data formats.
- AIS_cci+ consortium members participate in various Antarctic related cryosphere activities. The PI of the proposal is the lead of IMBIE project.

[TR-14] As an update from CCI Phase 1 and 2, the Contractor shall identify potential new users who represent the broad variety of applications over ice sheets and survey their requirements for satellite-based Ice Sheet ECV products.

- This will be carried out as part of the User Requirements work package in two cycles.

[TR-15] User requirements for ECV product uncertainties shall be re-assessed and updated if needed. This includes how the uncertainties should be expressed in the ECV products.

- The uncertainty representation developed and implemented in the former AIS_cci will be continued into the AIS_cci+ products.

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 in a later stage of the project. 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 (see **Table 3.3**). These specifications are based on users requirements resulted previously to phase 2015-2018. In the current phase the temporal range is extended and the EO data availability is completed with new sensors.

Table 3.3 Overview of the Antarctica cci+ Phase 1 data products

Product	EO Input Data	Temporal Range cci/cci+	Temporal Frequency	Extent	Spatial Resolution
SEC	Cryosat-1, Sentinel-3, ICESat-2 altimetry	1991 - 2021	monthly	AIS	5 km grid + basins
IV	Sentinel-1 A/B	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

4 Download status 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 1 the number of visitors on each of the above mentioned partner website is plotted, while Figure 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. Also on the cci data portal (http://cci.esa.int/data) the amount data accessed has a positive trend (Figure 3).

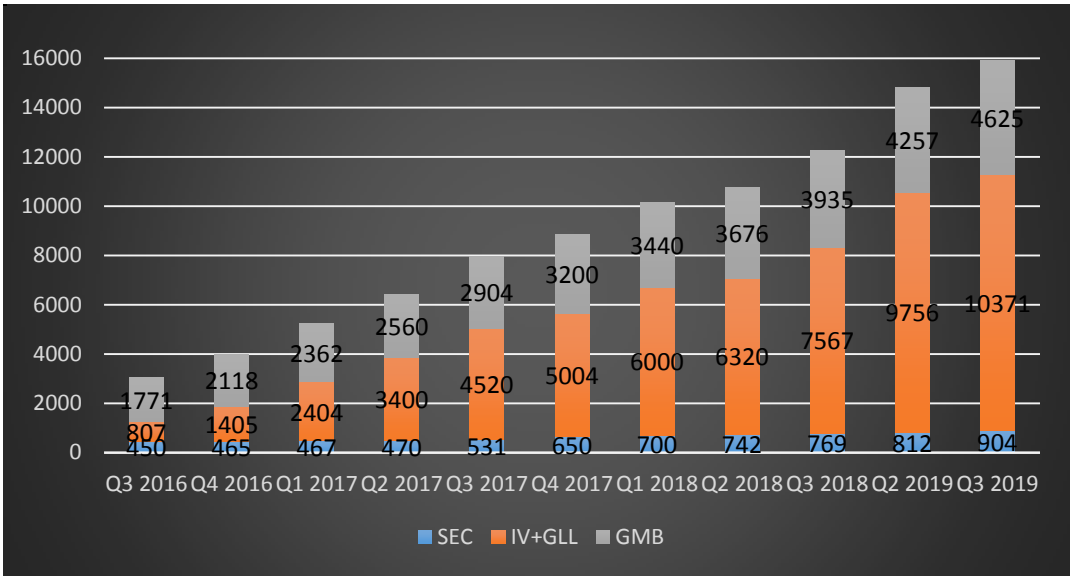

Figure 1. Accumulated number of visitors of AIS_cci products on the partner's websites.

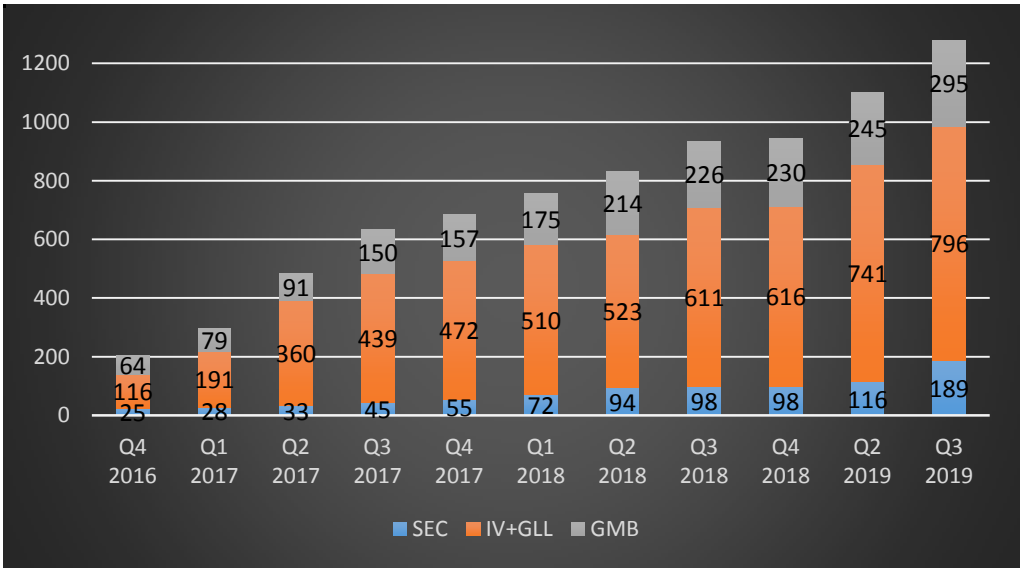

Figure 2. Accumulated number of AIS_cci product downloads on the partner's websites.

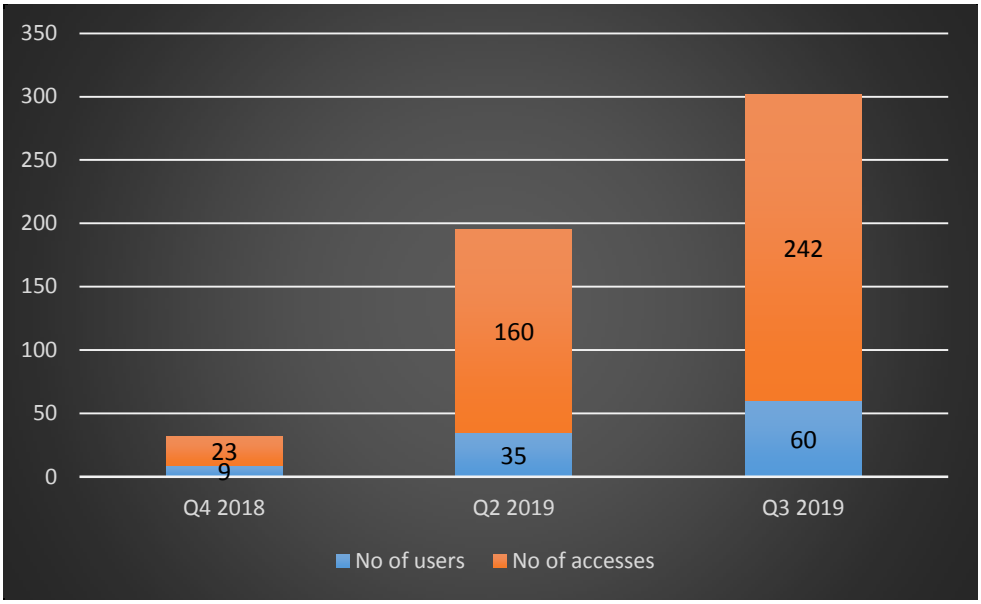

Figure 3. Number users and accesses of AIS_cci data products on CCI data portal.

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.

End of document