ESA Climate Change Initiative (CCI+)
Essential Climate Variable (ECV)

Antarctica_Ice_Sheet_cci+ (AIS_cci+)

Algorithm Development Plan

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Signatures page

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Change Log

Issue	Author	Affected Section	Change	Status
1.0	D. Floricioiu Lead author, DLR	All	Document Creation	Released to ESA?
1.1	D. Floricioiu Lead author, DLR	Sections 2.1. and 2.2	Update end of year 1	

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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
DMI	Danish Meteorological Institute
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
GIS	Greenland Ice Sheet
GLL	Grounding Line Location
GMB	Gravimetric Mass Balance
GIS	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
MFID	Mass Flux and Ice Discharge
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
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

1.1 Purpose and Scope

This document contains the Algorithm Development Plan (ADP) for the Antarctica_Ice_Sheet_cci (AIS_cci) project for CCI+ Phase 1, in accordance to contract and SoW [AD1 and AD2].

The purpose of the ADP is to outline the conceptual principles for algorithm development for novel products for the Antarctic Ice Sheet ECV which include [RD1]:

- ○ SEC from the new ESA altimetry mission Sentinel-3A/Sentinel-3B
- ○ IV extension to floating ice (ice shelves and ice tongues)

The first version of ADP [RD3] was delivered as an annex to the PMP [RD1]. The present document is the year 1 updated document based on the progress in algorithm development [RD4] due to the new data availability and in the product generation.

1.2 Document Structure

This document is structured as follows:

- Chapter 1 provides an introduction to the document
- Chapter 2 provides short descriptions of planned algorithm developments within each ECV parameter

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-AISCCI+-PMP-001	Project Management Plan		1.0
RD2	ST-UL-ESA-AISCCI-ATBD-001	Algorithm Theoretical Baseline Document	2017.11.01	3.0
RD3	ST-UL-ESA-AISCCI+-ADP-001	Algorithm Development Plan version 1.0	2019.10.17	1.0
RD4	ST-UL-ESA-AISCCI+-ATBD-001	Algorithm Theoretical Baseline Document for CCI+ Phase 1	2020.03.09	1.0

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

2 Planned Algorithm Developments

The core algorithms for all parameters of Antarctic Ice Sheet ECV have already been developed in the framework of the previous CCI phase or within earlier projects. In the current phase of the CCI+ project further developments of algorithms are foreseen for two parameters, SEC and IV, following the strategy described in the sections below.

2.1 Surface Elevation Change

For surface elevation change (SEC) parameter the primary new algorithm developments required for CCI+, in addition to the methods developed during the CCI project are:

○ to develop a new ingest algorithms for Sentinel-3A STM and Sentinel-3B STM using the latest available ESA L2 baseline for Sentinel-3. L2 baselines from Sentinel-3 will first be assessed for quality over the Antarctic ice sheet and in particular the ice sheet margins where there are currently known measurement problems and data quality issues due to sub-optimal ESA level-1 processing (configured for ocean and not sloping land ice surfaces).

○ to assess and develop new ingest algorithms for CryoSat-2 baseline-D, a new processing baseline that will be available during 2019.

○ to assess and develop new ingest algorithms for ENVISAT GDR v3.0, a new processing baseline that was released in July 2018 after the conclusion of the Antarctic CCI development phase.

○ to develop and tune new cross-calibration algorithms for the new altimetry missions (Sentinel-3A, Sentinel-3B) and new baselines (Cryosat, ENVISAT) available during the CCI+ project period.

○ to manage extending the time series of elevation measurements from the new contemporaneous operational mission phases of Sentinel-3A, 3B, Cryosat-2.

○ to calculate errors for the new missions and merged data products.

○ to develop methods for merging measurements of different contemporaneous missions. Previously (1991-2016) only one operational mission was available during any 5 year period (with short (< 2 year) periods of mission overlap). With the launch of Sentinel-3A (and subsequently S3-B) there will be up to 4 operational missions providing measurements of the ice sheet, providing the opportunity to increase temporal and spatial sampling.

2.2 Ice velocity

The key novel development for the ice velocity (IV) retrieval algorithm in CCI+ is the implementation of an Ice Velocity Tidal Correction Module (hereafter: IV-TCM). The IV-TCM corrects the ice velocity on ice shelves and floating extensions of outlet glaciers (e.g. ice tongues) for tidally induced vertical motion. The IV-TCM will be integrated in the IV processing chain which was already developed in the CCI phase. The algorithm development has three principal stages:

1. Round Robin: As stated in [RD3] a Round Robin (RR) was designed and conducted, in which experts in the field of IV retrieval were invited to participate, with the goal to intercompare and determine the most suitable approach for correction of ice velocities for ice shelves. The following activities were performed:

○ Selection of RR test areas and data sets and validation data.

○ Development of methods for validation and intercomparison of RR contributions and specification of evaluation criteria.

○ Compilation of RR package.

○ Announcement of RR experiment and invitation of specialists on ice velocity generation.

○ Collection and evaluation of contributions to RR experiments and documentation of RR results in Annex of ATBD [RD4].

2. Algorithm Selection: based on RR results the most suitable algorithm for tidal correction was selected [RD4].

3. Development & Implementation Phase

- Based on the outcome of the RR, the IV-TCM will be developed and integrated into the overall processing system for IV product generation. This phase involves designing and writing new routines. The IV-TCM will include different components, a tidal as well as an atmospheric pressure correction sub module.

- Development of uncertainty estimation for tidal correction will be studied and implemented. This also includes the evaluation of the different ocean tide models.
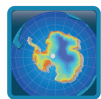
4. Testing & Validation Phase

- The implemented IV-TCM module will be rigorously tested and validated using in-situ data (e.g. GPS, where available) to ensure a robust tidal correction. Both corrected and uncorrected data will eventually be stored.

2.3 Grounding Line Location

No algorithm development activities are foreseen in the current phase of CCI+.

2.4 Gravimetric Mass Balance

No algorithm development activities are foreseen in the current phase of CCI+.

3 References

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