permafrost
cci

CCI+ PHASE 2 – NEW ECVS
PERMAFROST

CCN4 OPTION 7
ICEINSAR: INFERRED ACTIVE LAYER WATER/ICE CONTENT AND FREEZE-THAW PROGRESSION FROM ASSIMILATING INSAR IN PERMAFROST MODEL

D3.1 SYSTEM SPECIFICATION DOCUMENT (SSD)

VERSION 1.0

30 SEPTEMBER 2024

PREPARED BY

b·geos GAMMA REMOTE SENSING

NORCE UiO : University of Oslo

Document Status Sheet

Issue	Date	Details	Authors
1.0	30.09.2024	First version	LR, LW, SW, AB, TS

Author team

Line Rouyet and Lotte Wendt, NORCE

Sebastian Westermann, UiO

Annett Bartsch, B.GEOS

Tazio Strozzi, GAMMA

ESA Technical Officer

Frank Martin Seifert

EUROPEAN SPACE AGENCY CONTRACT REPORT

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the authors or organizations that prepared it.

TABLE OF CONTENTS

Executive summary

Within the European Space Agency (ESA), the Climate Change Initiative (CCI) is a global monitoring program which aims to provide long-term satellite-based products to serve the climate modelling and climate user community. The two main products associated to the ECV Permafrost are Ground Temperature (GT) and Active Layer Thickness (ALT). GT and ALT are documented by the Permafrost_cci project based on thermal remote sensing and physical modelling.

The Permafrost_cci models take advantage of additional datasets, such as snow cover and land cover, to estimate the heat transfer between the surface and the underground. However, several challenges remain due to spatially variable subsurface conditions, especially in relation to unknown amounts of water/ice in the active layer that modify the effective heat capacity and the thermal conductivity of the ground. In complex terrain with large spatial heterogeneities, coarse and partly inadequate land cover categorisation, the current results show discrepancies with in-situ measurements, which highlight the need to assimilate new data sources as model input. Although the ground stratigraphy is not directly observable from space, it impacts the dynamics of the ground surface. The seasonal thawing and refreezing induce cyclic subsidence and heave of the ground surface due to ice formation and melt in the active layer, and can therefore be used as indirect indicator of the ground conditions.

Synthetic Aperture Radar Interferometry (InSAR) based on Sentinel-1 images can be used to measure the amplitude and seasonal progression of these displacements. The movement amplitude is related to the amount of water/ice that is affected by a phase change, whilst the timing of the displacement patterns reflects the vertical progression of the thawing/freezing front. Considering the fine to medium spatial resolution of Sentinel-1 images, InSAR time series therefore have the potential to enhance the characterisation of subsurface hydrogeologic and thermal parameters and adapt the existing Permafrost_cci models to improve their performance at the local to regional scale. The *IceInSAR* pilot project (Option 7) will develop a prototype for permafrost model adjustment by assimilating Sentinel-1 InSAR surface displacement maps and time series into the model to constrain stratigraphy parameters. *IceInSAR* will provide pilot products, expected to be used for adjustment of the ECV processing chain of the baseline project in a next phase.

This System Specification Document (SSD) provides the reference documents describing the Processing System (PS) applicable for the *IceInSAR* Option 7.

1 Introduction

1.1 Purpose of the document

This report is the System Specification Document (SSD) required by the Permafrost_cci State of Work (SoW) [AD-1]. It provides the necessary references describing the Processing System (PS) applicable for the *IceInSAR* Option 7.

1.2 Structure of the document

Section 2 describes the system specification of the *IceInSAR* Option 7. Section 3 includes a bibliography and a list of acronyms. A glossary of the commonly accepted permafrost terminology can be found in RD-4.

1.3 Applicable Documents

[AD-1] ESA. 2022. Climate Change Initiative Extension (CCI+) Phase 2 – New Essential Climate Variables – Statement of Work. ESA-EOP-SC-AMT-2021-27.

[AD-2] GCOS. 2022. The 2022 GCOS Implementation Plan. GCOS – 244 / GOOS – 272. Global Observing Climate System (GCOS). World Meteorological Organization (WMO).

[AD-3] GCOS. 2022. The 2022 GCOS ECVs Requirements. GCOS – 245. Global Climate Observing System (GCOS). World Meteorological Organization (WMO).

1.4 Reference Documents

[RD-1] Westermann, S., Bartsch, A., Strozzi, T. 2023. ESA CCI+ Permafrost. D.2.2 Algorithm Theoretical Basis Document (ATBD). Version 4.0. European Space Agency.

[RD-2] Wiesmann, A., Bartsch, A., Westermann, S., Strozzi, T. 2023. ESA CCI+ Permafrost Phase 2. D.3.1 System Specification Document (SSD). Version 4.0. European Space Agency.

[RD-3] Rouyet, L., Wendt, L., Westermann, S., Bartsch, A., Strozzi, T. 2023. ESA CCI+ Permafrost Phase 2. CCN4 Option 7. IceInSAR: Inferred Active Layer Water/Ice Content and Freeze-Thaw Progression From Assimilating InSAR in Permafrost Model. D.2.2 Algorithm Theoretical Basis Document (ATBD). Version 1.0. European Space Agency.

[RD-4] van Everdingen, Robert, Ed. 1998 revised May 2005. Multi-language glossary of permafrost and related ground-ice terms. Boulder, CO: National Snow and Ice Data Center/World Data Center for Glaciology (http://nsidc.org/fgdc/glossary/; accessed 23.09.2009).

1.5 Bibliography

A complete bibliographic list that supports arguments or statements made within the current document is provided in Section 3.1.

1.6 Acronyms

A list of acronyms is provided in Section 3.2.

2 System Specification

The *IceInSAR* Option 7 is a pilot project building on the Processing System (PS) developed in the Permafrost_cci baseline project. The theoretical basis of the Permafrost_cci algorithms is described in the ATBD of the baseline project [RD-1]. The system design is described in the SSD of the baseline project [RD-2]. Adjustments made to the processing lines are described in the ATBD of the *IceInSAR* Option 7 [RD-3].

3 References

3.1 Bibliography

-

3.2 Acronyms

AD	Applicable Document
ADP	Algorithm Development Plan
ALT	Active Layer Thickness
ATBD	Algorithm Theoretical Basis Document
B.GEOS	B.Geos GmbH
CAR	Climate Assessment Report
CCI	Climate Change Initiative
CRDP	Climate Research Data Package
ECV	Essential Climate Variable
EO	Earth Observation
ESA	European Space Agency
E3UB	End-To-End ECV Uncertainty Budget
GAMMA	Gamma Remote Sensing AG
GCOS	Global Climate Observing System
GMS	Ground Motion Service
GT	Ground Temperature
GTN-P	Global Terrestrial Network for Permafrost
UIO	University of Oslo
INSAR	Synthetic Aperture Radar Interferometry
IPA	International Permafrost Association
NORCE	Norwegian Research Centre AS
PE	Permafrost Extent
PF	Permafrost Fraction
PSD	Product Specification Document
PUG	Product User Guide
PVASR	Product Validation and Algorithm Selection Report
PVIR	Product Validation and Intercomparison Report
PVP	Product Validation Plan
RD	Reference Document
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SD	Surface Displacement
SSD	System Specification Document
URD	Users Requirement Document
URq	User Requirement
WMO	World Meteorological Organisation