# CCI+ PHASE 1 – NEW ECVS
## PERMAFROST

## CCN3 OPTION 6
## TOWARDS A MULTI-PURPOSE FREEZE/THAW CDR

# D1.2 PRODUCT SPECIFICATIONS DOCUMENT (PSD)

## VERSION 1.0

## 28 FEBRUARY 2022

### PREPARED BY

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# 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 modeling and climate user community. Permafrost has been selected as one of the Essential Climate Variables (ECVs) which are elaborated during Phase 1 of CCI+ (2018-2021).

This document is the Product Specification Document (PSD) of Option 3 within CCN3 of Phase 1 of the Permafrost_cci project. It describes the product specifications of a potential multi-purpose freeze/thaw CDR. The product specifications address the main requirements expressed by the users in the User Requirements Document (URDv1.0, RD-2) including those expressed by the Permafrost_cci Climate Research Group (CRG). Since the range of potential user communities of multi-purpose freeze/thaw CDR is very wide it is not possible to cover all those requirements. For this reason, the PSD establishes priorities between those requirements, putting in the first place those more sensible to climate researchers, specifically permafrost modelling, while considering current technical constraints.

The PSD includes the product specifications and formats, including details of meta data.

The multi-purpose freeze/thaw CDR shall be provided at 25km resolution, polar stereographic projection, covering the northern hemisphere (global as target) and representing 2010-2020 as threshold and back to 1979 as target. Product levels are 4: The data sets are created from the analysis of lower level data, resulting in gridded, gap-free products.

# 1 INTRODUCTION

## 1.1 Purpose of the document

This document describes in detail potential product specifications in order to obtain a northern hemisphere to global multi-purpose freeze/thaw product that is consistent and error-characterised. The purpose of this document is to present the structure, syntax and file naming conventions used to describe the different freeze/thaw product. It provides all the necessary data needed by developers and users to write and read the products.

## 1.2 Structure of the document

Section 2 describes the area covered for the service as well as regions of interest for evaluation. The remaining sections detail the product specifications and format.

## 1.3 Applicable documents

[AD-1] ESA 2017: Climate Change Initiative Extension (CCI+) Phase 1 – New Essential Climate Variables - Statement of Work. ESA-CCI-PRGM-EOPS-SW-17-0032

[AD-2] Requirements for monitoring of permafrost in polar regions - A community white paper in response to the WMO Polar Space Task Group (PSTG), Version 4, 2014-10-09. Austrian Polar Research Institute, Vienna, Austria, 20 pp

[AD-3] ECV 9 Permafrost: assessment report on available methodological standards and guides, 1 Nov 2009, GTOS-62

[AD-4] GCOS-200, the Global Observing System for Climate: Implementation Needs (2016 GCOS Implementation Plan, 2015.

## 1.4 Reference Documents

[RD-1] 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)

[RD-2] Bartsch, A., Wuite, J., Rautiainen, K. 2022): ESA CCI+ Permafrost CCN3 Option 3 - User Requirements Document, v1.0

## 1.5 Acronyms

AD                 Applicable Document

| | |
|---|---|
| ALT | Active Layer Thickness |
| AWI | Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research |
| B.GEOS | b.geos GmbH |
| CCI | Climate Change Initiative |
| CRG | Climate Research Group |
| CRDP | Climate Research Data Package |
| CRS | Coordinate Reference System |
| DARD | Data Access Requirements Document |
| ECV | Essential Climate Variable |
| EO | Earth Observation |
| ESA | European Space Agency |
| ESA DUE | ESA Data User Element |
| GAMMA | Gamma Remote Sensing AG |
| GCOS | Global Climate Observing System |
| GCMD | Global Change Master Directory |
| GIPL | Geophysical Institute Permafrost Laboratory |
| GTD | Ground Temperature at certain depth |
| GTN-P | Global Terrestrial Network for Permafrost |
| GUIO | Department of Geosciences University of Oslo |
| IPA | International Permafrost Association |
| IPCC | Intergovernmental Panel on Climate Change |
| LST | Land Surface Temperature |
| MAGT | Mean Annual Ground Temperature |
| MAGST | Mean Annual Ground Surface Temperature |
| NetCDF | Network Common Data Format |
| NSIDC | National Snow and Ice Data Center |
| PFR | Permafrost extent (Fraction) |
| PFF | Permafrost-Free Fraction |
| PFT | Permafrost underlain by Talik |
| PSD | Product Specifications Document |
| PSTG | Polar Space Task Group |
| PZO | Permafrost Zone |
| RD | Reference Document |
| RMSE | Root Mean Square Error |
| RS | Remote Sensing |

# 2 KEY REGIONS FOR STUDY

## 2.1 Arctic to global

The primary target application is permafrost. Permafrost is a phenomenon of the subsurface thermal state across vast areas. Permafrost underlies approx. 24% of the terrestrial Northern Hemisphere. It occurs also on the southern hemisphere but at low extent. The Northern hemisphere is therefore targeted. With respect to further applications, global coverage should be anticipated.

## 2.2 Regions for evaluation

Validation regions need to contain dense observation networks of surface state in order to investigate variations within the footprints of coarse resolution FT products. The assessment will also comprise comparison to Sentinel-1 C-band SAR observations. S1 coverage is therefore of relevance as well. Five primary sites have been selected (Figure 1). The Alaskan North Slope and Northern Finland region contain several key sites with distributed measurements. Three sites include continuous permafrost. One site discontinuous to continuous (Yamal) and the northern part of the Northern Finland region has isolated permafrost sites. Central Yamal, Lena Delta and the North Slope were also covered with the ESA DUE Permafrost FT product based on ENVISAT ASAR GM (see Figure 1 in Bergstedt et al. 2017[1])
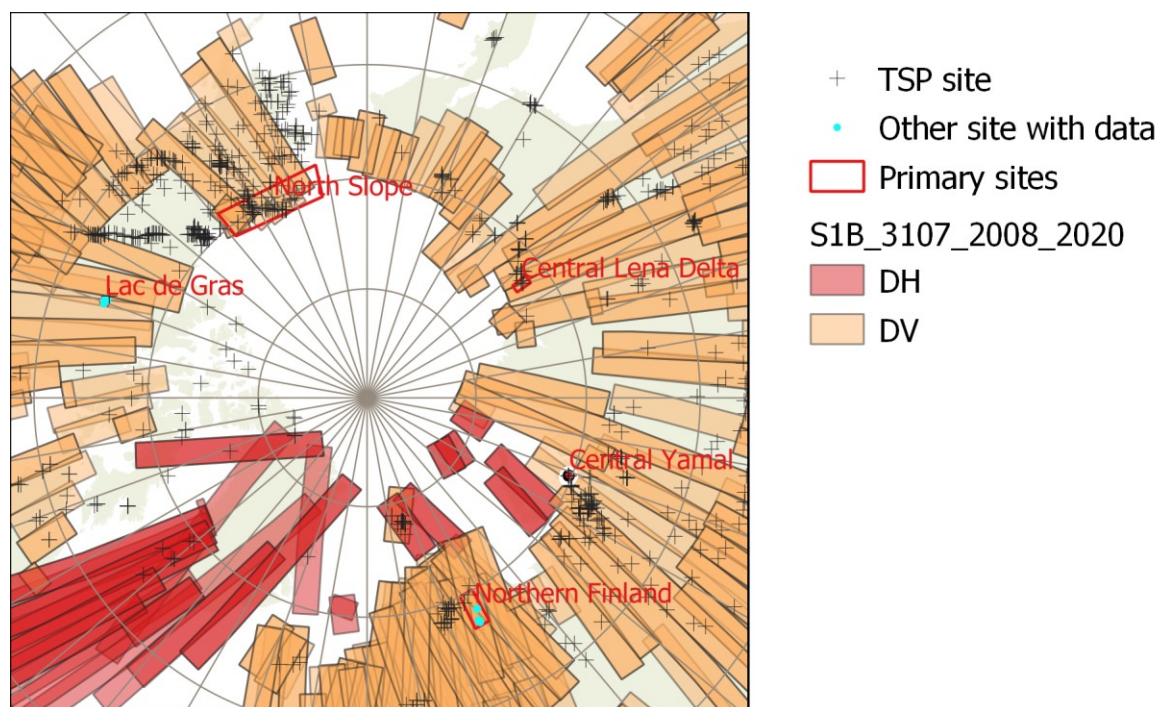


*Figure 1: Selected primary sites for development of benchmarking. August 2020 coverage for Sentinel-1B is shown as an example (DH – HH/HV, DV – VV-VH polarization). TSP – thermal state of permafrost boreholes. Other sites include published datasets and FMI sites.*

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[1] https://www.mdpi.com/2076-3263/7/3/65, https://doi.pangaea.de/10.1594/PANGAEA.779658

# 3 PRODUCTS SPECIFICATIONS

## 3.1. Product description

This product addresses snow as well as soil melt/thaw states.

## 3.2. Temporal compositing

The targeted resolution is daily, going back as far as 1979.

## 3.3. Spatial resolution

The Spatial resolution of the multi-purpose freeze/thaw product will be linked to the best available resolution of the input sensor. Here, the spatial resolution is limited to 25km for data going back until 1979, and approximately 10km for data available after 2000. However, information of subgrid state shall be included.

## 3. 4 Pixel attributes

| Product variable | unit | property | values provided[2] | Product string |
|---|---|---|---|---|
| Surface thaw/melt state | discrete classes | state of snow or soil surface | frozen melting thawed | STM |

## 3.4 Product accuracy

With respect to the threshold user requirements documented in [RD-2] the following accuracy is targeted:

- Threshold: better accuracy then available to far
- Target: <20% classification error

## 3.5 Data dissemination for all products

All prototype datasets are distributed via PANGAEA.

## 3.6 Data documentation

The data documentation will be available on the ESA CCI webpage (https://climate.esa.int/en/projects/permafrost/key-documents/).

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[2] initial definition, to be revised

# 4    PRODUCT FORMATS

## 4.1    Product projection system

The Coordinate Reference System (CRS) used for the multipurpose freeze/thaw product will be Polar Stereographic (Arctic) based on the World Geodetic System 84 (WGS84) reference ellipsoid. The coordinates are specified in meters.

## 4.2    Subsets

The prototypes will be developed over regions with in-situ data. They will be numbered complementing preceding definitions of Permafrost_cci project regions

## 4.3    File formats

All datasets are provided in NetCDF format.

## 4.4    Product file naming conventions

The files for each product type are named as follows:

ESACCI-<CCI    Project>-<Processing    Level>-<Data    Type>-<Product    String>[-<Additional Segregator>]-<Start Date>-<End Date>-fv<File version>.nc

<CCI Project>
PERMAFROST for permafrost_cci

<Processing Level>
L4 for Level 4; Data sets are created from the analysis of lower level data, resulting in gridded, gap-free products.

<Data Type>
STM – surface thaw /melt.

<Product String> : <source>_<algorithm>
    <Source>
          • To be defined.
    <algorithm>
          • To be defined

<Additional Segregator>
This should be AREA<TILE_NUMBER>_<Layer type>
<TILE_NUMBER>being the tile number the subset index: 1- global, 2-North America, 3-Eurasia, 4-Northern Hemisphere, 5-Romania 6-Switzerland, Western Swiss Alps; 7-Norway, Troms; 8-Norway, Finnmark; 9-Svalbard, Nordenskiöld; 10-France, Vanoise; 11-Italy, Sud Val Venosta, Sudtirol; 12-

Greenland, Disko Island; 13-Tien Shan; 14-Alaska, Brookes Range; 15-Argentina, Central Andes, 16-New Zealand, Central part of the Southern Alps, 17- Arctic tundra, 18- Northern Finland, 19-North Slope, Alaska, 20-central Lena Delta, Russia, 21 – Central Yamal, Russia, 22 – Lac du Gras, Canada

<Layer type>
- ST: layer type 1, corresponding to value of the surface state.

<Start Date> and <End Date>
The identifying date for this data set:
Format is YYYYMMDD, where YYYY is the four digit year, MM is the two digit month from 01 to 12 and DD is the two digit day of the month from 01 to 31.

fv<File Version>
File version number in the form n{1,}[.n{1,}] (That is 1 or more digits followed by optional . and another 1 or more digits). The most recent version is fv02.0 (released in May 2020).

Examples:
ESACCI-PERMAFROST-L4-STM-ASCAT-AREA18_ST-2015-2021-fv01.0.nc

## 4.5    File meta data - NetCDF

The following attributes are included in the NetCDF file:

| Global Attribute | Content |
|---|---|
| title | ESA CCI permafrost <parameter name> |
| institution | b.geos |
| source | <text> |
| history | YYYY-MM-DD HH:MM:SS |
| references | http://cci.esa.int/Permafrost [and publications] |
| tracking_id | <xxxxxxxx-yyyy-zzzz-nnnn-mmmmmmmmmmmm>    a    UUID (Universal Unique  Identifier) value |
| Conventions | CF-1.9 |
| product_version | <number> |
| summary | <text> |
| keywords | <text> |
| id | <filename> |
| naming authority | b.geos |
| keywords_vocabulary | NASA Global Change Master Directory (GCMD)    Science Keywords |
| cdm_data_type | Grid |

| Global Attribute | Content |
|---|---|
| comment | These data were produced at ESACCI as part of the ESA Permafrost CCI+ project Contract No 4000123681/18/I-NB |
| date_created | <file creation date> |
| creator_name | b.geos |
| creator_url | https://www.bgeos.at/ |
| project | Climate Change Initiative - European Space Agency |
| geospatial_lat_min | 55 |
| geospatial_lat_max | 90 |
| geospatial_lon_min | -180 |
| geospatial_lon_max | 180 |
| geospatial_vertical_min | 0.0 |
| geospatial_vertical_max | 0.0 |
| time_coverage_start | YYYYMMDDTHHMMSSZ |
| time_coverage_end | YYYYMMDDTHHMMSSZ |
| time_coverage_duration | P<number of years>Y |
| time_coverage_resolution | P<number><unit> |
| standard_name_vocabulary | CF Standard Name Table v73 |
| license | ESA CCI Data Policy: free and open access |
| platform | <name> |
| spatial_resolution | <number>< |
| geospatial_lat_units | none |
| geospatial_lon_units | none |
| geospatial_lon_resolution | <number>< |
| geospatial_lat_resolution | <number>< |
| key_variables | <name> |
| Format_version | CCI Data Standards v2.2 |