



permafrost
cci

**CCI+ PHASE 1 – NEW ECVS
PERMAFROST**

D1.2 PRODUCT SPECIFICATIONS DOCUMENT (PSD)

VERSION 2.0

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PREPARED BY

b·geos



GAMMA REMOTE SENSING



UiO : University of Oslo



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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 Permafrost_cci Product Specification Document (PSD) corresponding to the year 1 dataset of Phase 1 of the Permafrost_cci project. It describes the product specifications of the Permafrost products. The product specifications address the main requirements expressed by the users in the User Requirements Document (URDv1.1, RD-3) including those expressed by the Permafrost_cci climate research group (CRG). Since the range of potential user communities of a Permafrost product 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, while considering current technical constraints.

The PSD includes a glossary of permafrost relevant terms, the product specifications and formats, including details of meta data.

Ground temperature and active layer thickness are considered the primary variables that require climate-standard continuity as defined by GCOS. Permafrost fraction and zone are secondary parameters, but of high interest to users. Annual averages of ground temperature and annual maxima of thaw depth (active layer thickness) will be provided at 1km spatial resolution during year 1 of Permafrost_cci. Product level is 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 product specifications in order to obtain a permafrost product that is consistent, stable and error-characterised. The purpose of this document is to present the structure, syntax and file naming conventions used to describe the different permafrost products. It provides all the necessary data needed by permafrost algorithm developers and users to write and read the permafrost products respectively.

1.2 Structure of the document

This document contains a glossary of permafrost specific terms in section 1.7. 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., Westermann, S., Heim, B., Wiczorek, M., Pellet, C., Barboux, C., Kroisleitner, C., Strozzi, T. (2019): ESA CCI+ Permafrost Data Access Requirements Document, v1.0

[RD-3] Bartsch, A., Matthes, H., Westermann, S., Heim, B., Pellet, C., Onacu, A., Kroisleitner, C., Strozzi, T.(2019): ESA CCI+ Permafrost User Requirements Document, v1.1

[RD-4] Westermann, S. Bartsch, A., Strozzi, T. (2019): ESA CCI+D2.1 Product Validation Algorithm Selection Report (PVASR). V1.0

[RD-5] Heim, B., Wieczorek, M., Pellet, C., Barboux, C., Delaloye, R., Bartsch, A., Kroisleitner, C., Strozzi, T. (2019): D.4.1 Product validation and intercomparison report (PVIR), v1.0.

1.5 Bibliography

A complete bibliographic list that support arguments or statements made within the current document is provided in Section 5.1.

1.6 Acronyms

A list of acronyms is provided in section 5.2.

1.7 Glossary

The list below provides a selection of terms relevant for the parameters addressed in Permafrost_cci [RD-7].

active layer

The layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost.

In the zone of continuous permafrost the active layer generally reaches the permafrost table; in the zone of discontinuous permafrost it often does not. The active layer includes the uppermost part of the permafrost wherever either the salinity or clay content of the permafrost allows it to thaw and refreeze annually, even though the material remains cryotic ($T < 0^{\circ}\text{C}$).

The active layer is sometimes referred to as the "active zone"; the term "zone," however, should be reserved for the zones of discontinuous and continuous permafrost.

In Russian and Chinese literature, the term active layer covers two distinct types: (1) the seasonally thawed layer overlying permafrost, and (2) the seasonally frozen layer overlying unfrozen ground inside or outside permafrost areas.

REFERENCES: Muller, 1943; Williams, 1965; Brown, 1971; van Everdingen, 1985.

active-layer thickness

The thickness of the layer of the ground that is subject to annual thawing and freezing in areas underlain by permafrost.

The thickness of the active layer depends on such factors as the ambient air temperature, vegetation, drainage, soil or rock type and total water content, snowcover, and degree and orientation of slope. As a rule, the active layer is thin in the High Arctic (it can be less than 15 cm) and becomes thicker farther south (1 m or more).

The thickness of the active layer can vary from year to year, primarily due to variations in the mean annual air temperature, distribution of soil moisture, and snowcover.

The thickness of the active layer includes the uppermost part of the permafrost wherever either the salinity or clay content of the permafrost allows it to thaw and refreeze annually, even though the material remains cryotic ($T < 0^{\circ}\text{C}$).

Use of the term "depth to permafrost" as a synonym for the thickness of the active layer is misleading, especially in areas where the active layer is separated from the permafrost by a residual thaw layer, that is, by a thawed or noncryotic ($T > 0^{\circ}\text{C}$) layer of ground.

REFERENCES: Muller, 1943; Williams, 1965; van Everdingen, 1985.

continuous permafrost

Permafrost occurring everywhere beneath the exposed land surface throughout a geographic region with the exception of widely scattered sites, such as newly deposited unconsolidated sediments, where the climate has just begun to impose its influence on the thermal regime of the ground, causing the development of continuous permafrost.

For practical purposes, the existence of small taliks within continuous permafrost has to be recognized. The term, therefore, generally refers to areas where more than 90 percent of the ground surface is underlain by permafrost.

REFERENCE: Brown, 1970.

continuous permafrost zone

The major subdivision of a permafrost region in which permafrost occurs everywhere beneath the exposed land surface with the exception of widely scattered sites.

Taliks associated with rivers and lakes may occur in the continuous permafrost zone.

REFERENCE: Brown, 1970.

depth of zero annual amplitude

The distance from the ground surface downward to the level beneath which there is practically no annual fluctuation in ground temperature .

A change of no more than 0.1°C throughout the year is arbitrarily considered as "practically no annual fluctuation". The temperature at the depth (or level) of zero annual amplitude ranges from about -0.1°C at the southern limit of the permafrost region to about -15°C in the extreme polar reaches of the zone of continuous permafrost. The depth of zero annual amplitude varies widely but generally lies between 10 and 20 m below the ground surface, depending on climatic and terrain conditions such as amplitude of annual surface temperature variation, vegetation, snowcover and characteristics of the soils and rocks including thermal diffusivity (see thermal properties of frozen ground).

SYNONYMS: (not recommended) zone of minimum annual amplitude, zone of zero annual amplitude.

REFERENCE: Muller, 1943.

discontinuous permafrost

Permafrost occurring in some areas beneath the exposed land surface throughout a geographic region where other areas are free of permafrost.

Discontinuous permafrost occurs between the continuous permafrost zone and the southern latitudinal limit of permafrost in lowlands. Depending on the scale of mapping, several subzones

can often be distinguished, based on the percentage (or fraction) of the land surface underlain by permafrost, as shown in the following table.

<u>Permafrost</u>	<u>English usage</u>	<u>Russian Usage</u>
Extensive	65-90%	Massive Island
Intermediate	35-65%	Island
Sporadic	10-35%	Sporadic
Isolated Patches	0-10%	-

SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.

REFERENCES: Brown, 1970; Kudryavtsev, 1978; Heginbottom, 1984; Heginbottom and Radburn, 1992; Brown et al., 1997.

discontinuous permafrost zone

The major subdivision of a permafrost region in which permafrost occurs in some areas beneath the exposed land surface, whereas other areas are free of permafrost.

The zone of discontinuous permafrost lies between the continuous permafrost zone and the southern latitudinal limit of permafrost in lowlands. Near its northern boundary, discontinuous permafrost is extensive, where-as near its southern boundary it occurs as isolated patches of permafrost, and sporadic permafrost. There is no sharp distinction, or boundary, between the continuous and discontinuous permafrost zones.

REFERENCE: Brown, 1970.

disequilibrium permafrost

Permafrost that is not in thermal equilibrium with the existing mean annual surface or sea-bottom temperature and the geothermal heat flux.

REFERENCE: Mackay, 1972a.

equilibrium permafrost

Permafrost that is in thermal equilibrium with the existing mean annual surface or sea-bottom temperature and with the geothermal heat flux.

SYNONYM: contemporary permafrost.

REFERENCE: Mackay, 1972a.

extensive discontinuous permafrost

1. (North-American usage) Permafrost underlying 65 to 90 percent of the area of exposed land surface.

2. (Russian usage) Permafrost underlying 70 to 80 percent of the area of exposed land surface.

It is suggested that this term be used as a replacement for "widespread" discontinuous permafrost, because the word "widespread" can mean either "extensively distributed" or "widely spaced".

SYNONYM: widespread discontinuous permafrost.

REFERENCE: Heginbottom and Radburn, 1992.

ground ice

A general term referring to all types of ice contained in freezing and frozen ground .

Ground ice occurs in pores, cavities, voids or other openings in soil or rock and includes massive ice. It generally excludes buried ice, except in Russian usage. Ground ice may be epigenetic or syngenetic, contemporaneous or relict, aggrading or degrading, perennial or seasonal. It may occur as lenses, wedges, veins, sheets, seams, irregular masses, or as individual crystals or coatings on mineral or organic particles. Perennial ground ice can only occur within permafrost bodies.

REFERENCES: Mackay, 1972b; Pollard and French, 1980.

ice content

The amount of ice contained in frozen or partially frozen soil or rock.

Ice content is normally expressed in one of two ways:

1. on a dry-weight basis (gravimetric), as the ratio of the mass of the ice in a sample to the mass of the dry sample, expressed as a percentage, or
2. on a volume basis (volumetric), as the ratio of the volume of ice in a sample to the volume of the whole sample, expressed as a fraction.

The volumetric ice content cannot exceed unity whereas the gravimetric ice content can greatly exceed 100 percent.

REFERENCES: Penner, 1970; Anderson and Morgenstern, 1973; Johnston, 1981.

isolated patches of permafrost

Permafrost underlying less than 10 percent of the exposed land surface.

Individual areas of permafrost are of limited areal extent, widely separated, and are completely surrounded by unfrozen ground.

SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.

REFERENCES: Heginbottom and Radburn, 1992.

mean annual ground-surface temperature (MAGST)

Mean annual temperature of the surface of the ground.

Permafrost exists if the mean annual ground-surface temperature is perennially below 0°C. Although the mean annual surface temperature may be below 0°C, the surface temperature will fluctuate during the year, causing a layer of ground immediately beneath the surface to thaw in the summer and freeze in the winter (the active layer). Small changes in the annual range of surface temperature and in the mean annual surface temperature from year to year, or over a period of a few years, may cause a layer of ground between the bottom of the active layer and the permafrost table to remain at a temperature above 0°C, creating a talik or residual thaw layer.

[RD-1]

mean annual ground temperature (MAGT)

Mean annual temperature of the ground at a particular depth.

The mean annual temperature of the ground usually increases with depth below the surface. In some northern areas, however, it is not uncommon to find that the mean annual ground temperature decreases in the upper 50 to 100 metres below the ground surface as a result of past changes in surface and climate conditions. Below that depth, it will increase as a result of the

geothermal heat flux from the interior of the earth. The mean annual ground temperature at the depth of zero annual amplitude is often used to assess the thermal regime of the ground at various locations [RD-1]

n-factor

The ratio of the surface freezing or thawing index to the air freezing or thawing index.

At any site, (standard) air temperatures are seldom the same as surface (air/substrate boundary) temperatures. Because air temperatures (measured at weather stations) are usually available and surface temperatures are not, the n-factor (an empirically determined coefficient) is used to relate air temperatures to surface temperatures in order to establish the thermal boundary condition at the surface, particularly for engineering purposes.

The difference between air and surface temperatures at any specific time and location is greatly influenced by climatic, surface and subsurface conditions (e.g., latitude, cloud cover, time of day or year, relative humidity, wind speed, type of surface--wet, dry, moss, snow, natural vegetated te-rain, mineral soil, pavements-- and thermal properties of the ground). The average surface temperature and n-factor may vary significantly from year to year, even for a given surface and location, as well as for different sites, surfaces and soil systems.

Values of the freezing and thawing n-factors have been determined for a large number of sites and surfaces and are widely used for predicting sur-face temperatures and the thermal regime of the ground. The data vary widely, however, and indicate that a rigorous value of n for a given site cannot simply be chosen from these data. Direct determination of the n-factor for a specific location is much better and requires concurrent observations of air and surface temperatures throughout at least one and prefer-ably several complete freezing and thawing seasons.

REFERENCES: Carlson and Kersten, 1953; Lunardini, 1978, 1981.

permafrost

Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years .

Permafrost is synonymous with perennially cryotic ground: it is defined on the basis of temperature. It is not necessarily frozen, because the freezing point of the included water may be depressed several degrees below 0°C; moisture in the form of water or ice may or may not be present. In other words, whereas all perennially frozen ground is permafrost, not all permafrost is perennially frozen. Permafrost should not be regarded as permanent, because natural or man-made changes in the climate or terrain may cause the temperature of the ground to rise above 0°C. Permafrost includes perennial ground ice, but not glacier ice or icings, or bodies of surface water with temperatures perennially below 0°C; it does include man-made perennially frozen ground around or below chilled pipelines, hockey arenas, etc.

Russian usage requires the continuous existence of temperatures below 0°C for at least three years, and also the presence of at least some ice.

SYNONYMS: perennially frozen ground, perennially cryotic ground and (not recommended) biennially frozen ground, climafrost, cryic layer, permanently frozen ground.

REFERENCES: Muller, 1943; van Everdingen, 1976; Kudryavtsev, 1978.

permafrost boundary

1. The geographical boundary between the continuous and discontinuous permafrost zones.
2. The margin of a discrete body of permafrost.

permafrost degradation

A naturally or artificially caused decrease in the thickness and/or areal extent of permafrost.

Permafrost degradation may be caused by climatic warming or by changes in terrain conditions, such as disturbance or removal of an insulating vegetation layer by fire, or by flooding caused by a landslide-blocked stream, or by human activity. It may be expressed as a thickening of the active layer, a lowering of the permafrost table, a raising of the permafrost base, or a reduction in the areal extent or the complete disappearance of permafrost. [RD-1]

permafrost region

A region in which the temperature of some or all of the ground below the seasonally freezing and thawing layer remains continuously at or below 0°C for at least two consecutive years.

The permafrost region is commonly subdivided into permafrost zones. [RD-1]

permafrost zone

A major subdivision of a permafrost region.

A permafrost region is commonly subdivided into permafrost zones based on the proportion of the ground that is perennially cryotic. The basic subdivision in high latitudes is into zones of continuous permafrost and discontinuous permafrost.

REFERENCES: Muller, 1943; Brown, 1967, 1978; Washburn, 1979; Pewe, 1983.

sporadic discontinuous permafrost

1. (North-American usage) Permafrost underlying 10 to 35 percent of the exposed land surface.
2. (Russian usage) Permafrost underlying 5 to 30 percent of the exposed land surface.

Individual areas of permafrost are completely surrounded by unfrozen ground.

SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.

REFERENCES: Muller, 1943; Brown, 1967; Heginbottom and Radburn, 1992.

talik

A layer or body of unfrozen ground occurring in a permafrost area due to a local anomaly in thermal, hydrological, hydrogeological, or hydrochemical conditions.

Taliks may have temperatures above 0°C (noncryotic) or below 0°C (cryotic, forming part of the permafrost). Some taliks may be affected by seasonal freezing. Several types of taliks can be distinguished on the basis of their relationship to the permafrost (closed, open, lateral, isolated and transient taliks), and on the basis of the mechanism responsible for their unfrozen condition (hydrochemical, hydrothermal and thermal taliks):

1. closed talik - a noncryotic talik occupying a depression in the permafrost table below a lake or river (also called "lake talik" and "river talik"); its temperature remains above 0°C because of the heat storage effect of the surface water;
2. hydrochemical talik - a cryotic talik in which freezing is prevented by mineralized groundwater flowing through the talik.

3. hydrothermal talik - a noncryotic talik, the temperature of which is maintained above 0• °C by the heat supplied by groundwater flowing through the talik;
4. isolated talik - a talik entirely surrounded by perennially frozen ground; usually cryotic (see isolated cryopeg), but may be noncryotic (see transient talik);
5. lateral talik - a talik overlain and underlain by perennially frozen ground; can be noncryotic or cryotic;
6. open talik - a talik that penetrates the permafrost completely, con-necting suprapermafrost and subpermafrost water, (e.g., below large rivers and lakes).

It may be noncryotic (see hydrothermal talik) or cryotic (see hydro-chemical talik).

SYNONYMS: (not recommended) through talik, penetrating talik, perforating talik, piercing talik;

7. thermal talik - a noncryotic talik, the temperature of which is above 0°C due to the local thermal regime of the ground;
8. transient talik - a talik that is gradually being eliminated by freezing, e.g., the initially noncryotic closed talik below a small lake which, upon draining of the lake, is turned into a transient isolated talik by permafrost aggradation (see also closed-system pingo).

REFERENCES: Williams, 1965; Washburn, 1973; van Everdingen, 1976.

2 KEY REGIONS FOR STUDY

2.1 Global Permafrost distribution

Permafrost is a phenomenon of the subsurface thermal state across vast areas. Permafrost underlies approx. 24% of the terrestrial Northern Hemisphere (Figure 1). Southern hemisphere permafrost occurs in the Andean mountains, in the Southern Alps in New Zealand and ice-free areas of the Antarctic continent and neighbouring islands. All regions where permafrost can occur will be covered in Permafrost_cci.

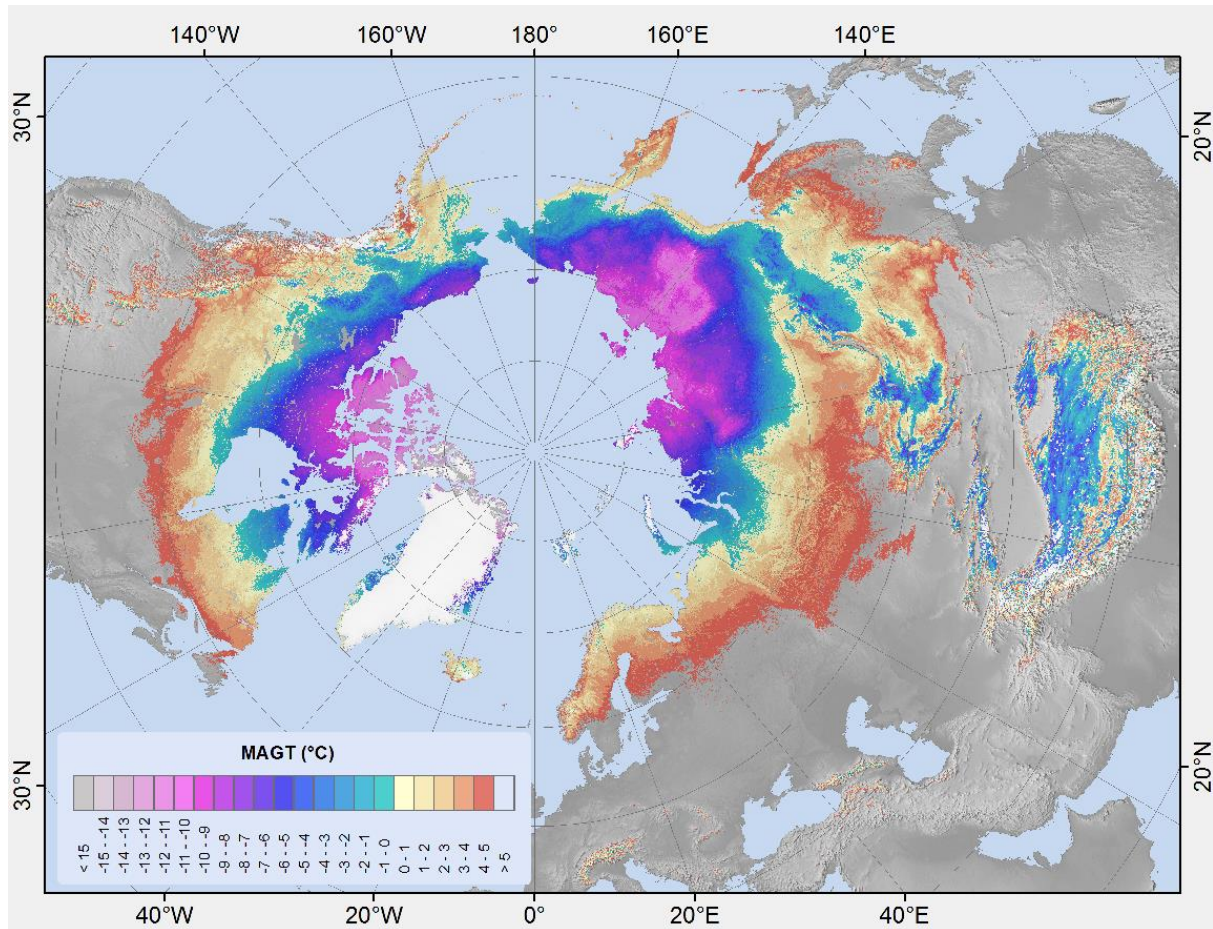


Figure 1: Modelled Mean Annual Ground temperature in regions with permafrost probability larger than zero (GlobPermafrost). Data: Obu et al., 2018

2.2 Regions for evaluation

In situ data and maps are utilized as benchmark for the round robin in phase 1 and for validation throughout the project. All available maps and data are documented in the Data Access Requirements Document (DARD, [RD-2]).

In situ data obtained from GTN-P, Roshydromet RHM, Nordicana-D, PANGAEA and the Arctic Data Centre are used for validation. Especially GTN-P borehole sites in Alaska are investigated in comparison to GIPL2 runs (Dmitry Nicolsky, University of Alaska Fairbanks, USA) and the ESA

DUE GlobPermafrost map (equilibrium model) for benchmarking [RD-4, RD-5]. Further regional comparisons are made for mountain regions in the European Alps (PERMOS and to a high-resolution permafrost map generated by Toposcale-Geotop; J. Fiddes, SLF Switzerland). Evaluation also considers rock glacier inventories where available [RD-5].

3 PRODUCTS SPECIFICATIONS

3.1 Ground temperatures, active layer thickness and permafrost fractions

3.1.1 Product description

This product includes the ECV state variables ground temperature and active layer thickness, derived from a thermal model driven and constrained by EO data. In addition, the product provides a yearly fraction of permafrost-underlain and permafrost-free area within a pixel, as well as the areal fraction underlain by a talik (permafrost-free zone on top of degrading permafrost, which is the result of near-surface permafrost degradation). Classification according to the IPA permafrost map delivers the well-known permafrost zones, distinguishing sporadic, discontinuous and continuous permafrost.

3.1.2 Temporal compositing

The temporal resolution of the final product of year 1 is one year, which corresponds to average annual ground temperatures, as well as the maximum depth of seasonal thaw, which corresponds to the active layer thickness.

3.1.3 Spatial resolution

The Spatial resolution of the Permafrost product will be linked to the best available resolution of the input sensor. Here, the spatial resolution is limited to 1km, which is the spatial resolution of remotely sensed LST. However, we apply ensemble-based modelling of subpixel variability, i.e. different ensemble members represent different ground stratigraphies and snow depths found within 1km pixels. This is required for computation of permafrost and talik fractions.

3.1.4 Pixel attributes

ECV variable	unit	property	values provided	Product string
ground temperature at certain depth (maximum 5 m)	degree C	annual average	median and standard deviation of the ensemble	GTD
active layer thickness	m	annual maximum	median and standard deviation of the ensemble	ALT
permafrost fraction	0-1	annual minimum		PFR
permafrost-free fraction	0-1	annual maximum		PFF
fraction underlain by talik	0-1	difference of the above		PFT
permafrost zone	four classes: no permafrost or isolated, sporadic, discontinuous, continuous			PZO

3.3 Product accuracy

With respect to the threshold user requirements documented in [RD-3] the following accuracy is targeted in year 2/3 of phase 1:

- Ground temperature: 2.0 degree C compared to GTN-P boreholes
- Active layer thickness: RMSE <0.25m for ALT < 1.0m and RMSE <0.5m for ALT >1.0m

Product accuracy of the year 1 dataset is documented in [RD-5]. The threshold requirements for ground temperature has been already met in year 1 with an RMSE of 1.98 °C if calculated pairwise in the bulk data set, and RMSE of 1.84 °C if calculated in depth-specific data collections. Active layer thickness of the year one dataset (without enhanced stratigraphy) is characterized by a model bias of ~ 0.35 cm and a RMSE of ~ 1 m if calculated for the bulk data collection.

3.4 Data dissemination for all products

All datasets are distributed via the CCI portal, published on PANGAEA and delivered to the Permafrost Information System hosted by AWI.

3.5 Data documentation

The data documentation is available on the ESA CCI webpage (<http://cci.esa.int/Permafrost>).

4 PRODUCT FORMATS

4.1 Product projection system

The Coordinate Reference System (CRS) used for the global permafrost products in year 1 will be Polar Stereographic projections (Arctic and Antarctic) based on the World Geodetic System 84 (WGS84) reference ellipsoid. The coordinates are specified in meters. In year 2, the projection will be changed to the specifications of the `lst_cci` datasets, as they will be used as input. Information on product projection, ellipsoid and pixel size will be included in the NetCDF.

4.2 Subsets

Generation of subsets for America and Eurasia will be considered for year 2.

4.3 File formats

All datasets are provided in NetCDF format.

4.4 Product file naming conventions

The naming of the products follows the ECV naming convention.

The files for each parameter and month will be named as follows:

ESACCI-<CCI Project>-<Processing Level>-<Data Type>-<Product String>[-<Additional Segregator>]-<Indicative Date>[<Indicative Time>]-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.

<Product String>

GTD, when the parameter is ground temperature at a certain depth, ALT, if the parameter is active layer thickness, PFR if the parameter is permafrost extent (fraction), PFF if the parameter is permafrost-free fraction, PFT if the parameter is fraction underlain by talik and PZO if the parameter is permafrost zone.

<Additional Segregator>

This should be `AREA_<TILE_NUMBER>` being the tile number the subset index: 1- global, 2-North America, 3-Eurasia, 4-Northern hemisphere

<Indicative 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. For monthly products DD=01. Annual averages are represented with year only.

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 fv1.0 (released in May 2019).

<Layer>

In case that the individual layers of the pixel product are provided as different NetCDF files, the code of each layer will be detailed as follows:

- PP: layer 1, corresponding to the Julian day, or day of the year of detection of the permafrost parameter.
- CL: layer 2, corresponding to the confidence level
- LC: layer 3, corresponding to the ground stratigraphy
- LS: layer 4, corresponding to the LST source.

Example:

ESACCI-PERMAFROST-L4-MODIS-ALT-AREA4_PP-2003-fv01.0.nc

4.5 File meta data - NetCDF

The following attributes will be included in the NetCDF file:

Global Attribute	Content
title	ESA CCI permafrost <parameter name>
institution	University of Oslo
source	<text>
history	YYYY-MM-DD HH:MM:SS
references	http://cci.esa.int/Permafrost [and publications]
tracking_id	<xxxxxxxx-yyyy-zzzz-nnnn-mmmmmmmmmmm> a UUID (Universal Unique Identifier) value
Conventions	CF-1.7
product_version	<number>
summary	<text>
keywords	<text>
id	<filename>
naming authority	University of Oslo
keywords_vocabulary	NASA Global Change Master Directory (GCMD) Science Keywords

Global Attribute	Content
cdm_data_type	Grid
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	University of Oslo
creator_url	https://www.uio.no/english/
project	Climate Change Initiative - European Space Agency
geospatial_lat_min	-90
geospatial_lat_max	90
geospatial_lon_min	0
geospatial_lon_max	360
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	NetCDF Climate and Forecast (CF) Metadata Convention version 67
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 v2.1

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5.2 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
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)
PPF	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
SLF	Institut für Schnee- und Lawinenforschung, Davos
SU	Department of Physical Geography Stockholm University
TSP	Thermal State of Permafrost
UAF	University of Alaska, Fairbanks
UNIFR	Department of Geosciences University of Fribourg
URD	Users Requirement Document
WGS 84	World Geodetic System 1984
WUT	West University of Timisoara