permafrost
cci

CCI+ PHASE 1 – NEW ECVS
PERMAFROST

CCN3 OPTION 6
IMPROVED SOIL DESCRIPTION THROUGH A LANDCOVER MAP DEDICATED FOR THE ARCTIC

D1.1 User Requirement Document (URD)

VERSION 1.0

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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 modelling 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). As part of the Permafrost_cci baseline project, ground temperature and active layer thickness were considered the primary variables that require climate-standard continuity as defined by GCOS. Permafrost extent and zonation are secondary parameters, but of high interest to users. The ultimate objective of Permafrost_cci is to develop and deliver permafrost maps as ECV products primarily derived from satellite measurements. Algorithms have been identified which can provide these parameters ingesting a set of global satellite data products (Land Surface Temperature LST, Snow Water Equivalent SWE, and landcover) in a permafrost model scheme that computes the ground thermal regime. Annual averages of ground temperature and annual maxima of thaw depth (active layer thickness) were provided at 1km spatial resolution during three phases of Permafrost_cci. The data sets were created from the analysis of lower level data, resulting in gridded, gap-free products. EO data sets are employed to determine the upper boundary condition of the differential equation, while its coefficients (e.g. heat capacity and thermal conductivity) are selected according to landcover information. Subgrid information on landcover must be used to generate ensembles of input parameters for permafrost modelling.

CCN3 option 6 addresses the need for landcover information of relevance for Permafrost monitoring and modelling. The specific aim of this CCI+ Permafrost subproject is to implement a circumpolar landcover description with sufficient thematic content. It utilizes prototypes of ESA DUE GlobPermafrost, i.e. traditional landcover classification, vegetation height maps and surface roughness maps.

This document describes the user requirements and product specification for the landcover characterization. The specific activities of the user requirement analysis include in particular the revision of user questionnaires that were made in the framework of GlobPermafrost and in the first year of the Permafrost_cci baseline project. They have been reassessed as part of an internal workshop for needs of the transient version of the permafrost model CryoGRID and the regional climate model HIRHAM.

Requirements related to the landcover include circumpolar coverage and consideration of improved thematic content (incl. differentiation of tundra shrub types, peatlands, artificial landcover). The prototype spatial resolution has been deemed sufficient.

1 Introduction

The user requirement document ascertains specific user requirement for the use of EO derived landcover products for the Arctic. It provides an overall summary of main findings. User requirements are established by the clear definition of a number of attributes.

1.1 Purpose of the document

This document provides the user requirements for CCN 3 OPTION 6 (option led by b.geos). The URD assesses the requirements of relevant organisations from the Climate Research Community and the Permafrost_cci baseline project. The requirements will be used to guide the product specifications of the Permafrost_cci project. In this document, where specific user requirements are identified they are concisely stated and assigned a requirement ID reference code named 'URq_XX'. This allows cross-referencing and traceability between multiple CCI documents.

1.2 Structure of the document

In Section 1.7, this document contains a glossary of terms specific to lowland permafrost. Section 2 of this document details the user community and potential use of the Permafrost_cci service in the Arctic. Results from user survey and related documents are summarized in Section 3. This also includes the results of the Permafrost_cci baseline survey, which targeted climate modellers and specific use cases. Key issues to fulfil these requirements are discussed in Section 4. A summary of the requirements is presented in Section 5.

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. 2016. The Global Observing System for Climate: Implementation Needs. GCOS Implementation Plan, WMO.

1.4 Reference Documents

[RD-1] Bartsch, A., Matthes, H., Westermann, S., Heim, B., Pellet, C., Onacu, A., Kroisleitner, C., Strozzi, T. 2021. ESA CCI+ Permafrost User Requirements Document, v2.0

[RD-2] National Research Council. 2014. Opportunities to Use Remote Sensing in Understanding Permafrost and Related Ecological Characteristics: Report of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/18711

[RD-3] GlobPermafrost team. 2016. Requirements Baseline Document. ESA DUE GlobPermafrost project. ZAMG, Vienna

[RD-4] Bartsch, A., Westermann, Strozzi, T., Wiesmann, A., Kroisleitner, C. 2019. ESA CCI+ Permafrost Product Specifications Document, v1.0

[RD-5] 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-6] Bartsch, A., Widhalm, B., Pointner, G., Ermokhine, Ks., Leibman, M. and B. Heim (2019): DUE Globpermafrost Product documentation: Land cover prototype III – landcover classes https://download.pangaea.de/reference/98451/attachments/ESA_GlobPermafrost_PD_LCP_LANDC_20190128_v1.0.pdf

1.5 Bibliography

A complete bibliographic list that support arguments or statements made within the current document is provided in Section 6.1.

1.6 Acronyms

A list of acronyms is provided in section 6.2.

1.7 Glossary

The list below provides a selection of terms relevant for the parameters addressed in Permafrost_cci [RD-5]. A comprehensive glossary is available as part of the Product Specifications Document [RD-4].

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 ($T < 0°C$).

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 ($T < 0°C$).

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 ($T > 0°C$) layer of ground.

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

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 perma-frost; 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 un-common 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]

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, 1985; Kudryavtsev, 1978.

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]

2 Users of landcover underlain by permafrost and related initiatives

The new landcover map is primarily developed for applications considered within the ESA Permafrost_cci project. This includes permafrost modelling for production of the climate data records as well as use cases targeted on improvements of Earth System Models. The user requirements discussion has been also extended to projects and groups using similar models outside of Permafrost_cci. This includes for example activities in the HORIZON2020 CHARTER and ERC Q-Arctic projects.

Previous surveys on Arctic landcover in the framework of ESA DUE GlobPermafrost [RD-1] have addressed a wide range of potential users in permafrost research what has been reassessed. In addition, requirements by application related to upscaling of soil and flux properties are considered. Of relevance are initiatives such as RECCAP2-Permafrost as well as the ESA/NASA AMPAC initiative. Interests by groups involved in habitat and biodiversity research (e.g. HORIZON2020 CHARTER) also need to be considered as potential users of such data.

3 Users requirements

Landcover in the Arctic is very heterogenous and cannot be represented at coarse resolution as used for global landcover maps (Bartsch et al. 2016a). In the context of permafrost monitoring landcover descriptions are of interest as proxy for soil properties. Various local scale studies have demonstrated the utility of satellite data (e.g. Hugelius et al. 2011; review in Bartsch et al. 2016). Target applications are upscaling of soil properties and fluxes. Information on soil properties is key for modelling of subground temperatures. The required parameterization for Permafrost_cci relevant permafrost models is described in Westermann et al. (2017) and Obu et al. (2019). A circumpolar map which serves the needs of the model parameterization is, however, still lacking to date. A prototype landcover based on Sentinel-1 and Sentinel-2 which offers a wider thematic content and spatial detail than global maps has been developed within the framework of ESA DUE GlobPermafrost (Bartsch et al. 2019). It has been evaluated within the context of a subsidence studies for common tundra classes (Bartsch et al. 2019). Results indicated the representativeness of the landcover classes for different soil types.

Consolidated requirements for permafrost research in general are available through [AD-2, 2014] and [RD-2,2014]. For soil physical characteristics a target resolution of 1-5 m (regionally) and threshold resolution of 100-1000 m (circumpolar) are suggested. These requirements need to be reviewed in the context of recent developments and considering various applications including permafrost modelling and carbon cycle studies.

The landcover map shall also be of utility for permafrost related climate modelling as well as other applications such as habitat and biodiversity studies. Users within Permafrost_cci and collaboration activities have been consulted for detailed requirements.

3.1 Currently available products

Currently available datasets at circumpolar scale lack thematic content and spatial resolution (e.g. Bartsch et al. 2016). Also HR_Landcover_cci complies with the thematic content (number of classes relevant for the Arctic) of global maps and can therefore not supply the required information for the regions to be covered. Most advanced is the CAVM (circumarctic vegetation map), which has been recently revised (Reynolds et al. 2020) but has a spatial resolution of 1km, is based on observations from AVHRR SWI 1982–2003 combined with AHVRR and MODIS maximum summer NDVI (2000–2009) and has a focus on vegetation communities. Prototypes of GlobPermafrost have higher spatial resolution and have been developed based on a dedicated survey but are currently only regionally available.

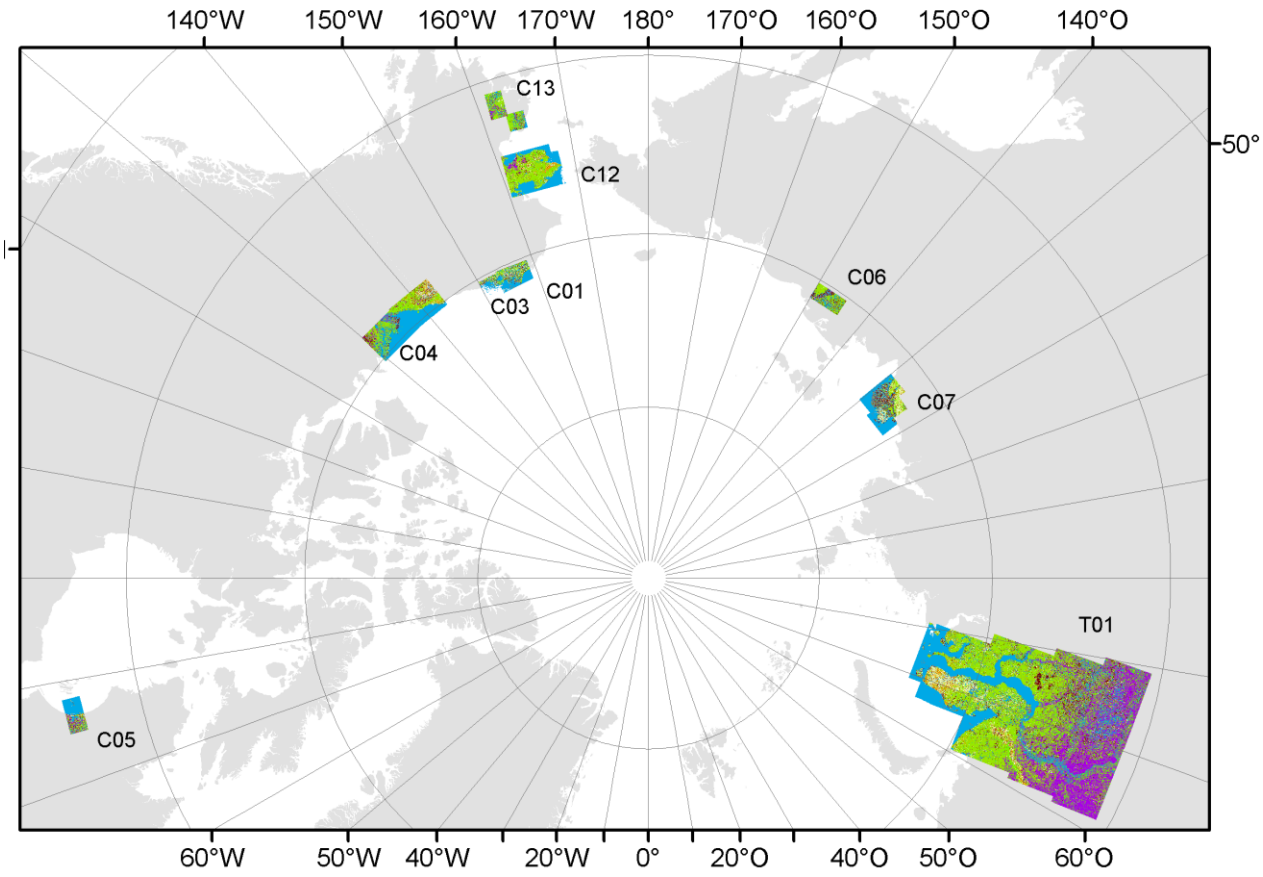

Figure 1: Extent of ESA DUE GlobPermafrost landcover prototype maps [RD-6]

Soil organic carbon content (SOC) as well as wetland distribution has been shown to be detectable from C-band SAR data (Bartsch et al. 2016b). But it has been so far only derived at 500m resolution. CCI_Landcover (300m) was evaluated for global SOC prediction, but the available thematic content was found insufficient (Mishra et al. 2021;): '... as the land cover map that we used was prepared for global applications and the stocks do not represent a separate land cover type for peatlands. Future effort to conduct separate analyses for peat and no-peat lands could decrease the uncertainties in SOC stock estimates such as demonstrated by Siewert …'

Specifically, the representation of wetland types for the Arctic has been discussed recently. The C-band SAR based retrievals have been integrated for global methane budget determination (Saunois et al. 2020) as well as for a global wetland map (Zhang et al. 2021). However, a range of wetland types need to be represented. Olefeld et al. (2021) prepared a map based on existing sources including the GL30-WET classes (Wetlands: marshes, floodplains, shrub wetland, peatlands). The target classes have been Bog, Fen, marsh, permafrost bog, tundra wetland. This information has been aggregated to 0.5×0.5˚ grid cells. Issues are therefore inherited from the input datasets and the spatial detail is insufficient for e.g. the scale addressed in Permafrost_cci (1km).

3.2 Permafrost_CCI specific user requirements survey in lowland permafrost areas

A user consultation was carried out as part of the baseline project of GlobPermafrost in 2016. It included questions targeted at the landcover prototype development. This has been revised and a project internal workshop targeted the needs for permafrost and climate modelling.

The discussion focused on the threshold and target requirements:
:

- Threshold requirement (minimum: "must have"): the limit at which the observation becomes ineffectual and is not of use for your application.
- Target requirement (optimal: "nice to have"): the maximum performance limit for the observation, beyond which no significant improvement would result for your applications.

Further consultation with collaboration partners pointed to the following aspects:

- Human impacted areas (roads, settlements) need to be separated for the ‘bare’ class
- A representation of dry, moist and wet is important and is reflected in the current classes
- The class disturbed needs to be split up into subcategories. Especially areas with vegetation need to be separated from areas without vegetation.
- The spatial resolution is sufficient

Table 1: List of r_k-factors assigned to landcover class groups in Landcover_cci clase to create landcover class groups for CryoGRID (source: Obu et al. 2019)

Landcover class group	r_k-factor	CCI Landcover classes
Bare areas	0.95	140, 150, 152, 153, 200, 201, 202
Grasslands and croplands	0.75	10, 11, 12, 20, 130
Shrubs	0.8	30, 40, 100, 110, 120, 121, 122
Deciduous forest	0.95	50, 60, 61, 62, 80, 81, 82, 90
Evergreen forest	0.9	70, 71, 72
Wetlands	0.55	160, 170, 180
Urban	0.7	190

A database of Arctic in situ soil data is currently prepared in order to enable (Palmtag et al. in prep) improved parameterization of the in Permafrost_cci used model CryoGRID. Classes as listed in Table 2 are currently considered reflecting availability of information.

Table 2: Currently considered classes in the soil dataset developed for CryoGRID parameterization

TIER I		**TIER II**	
1	Forest	1.1	deciduous forest

		1.2 1.3	coniferous forest deciduous needleleaf forest
2	Tundra	2.1 2.2	Shrub tundra herb / graminoid tundra
3	Wetland	3.1 3.2	Permafrost wetlands Non-permafrost wetlands
4	Water bodies	4.1 4.2	Lakes Streams
5	Barren	5.1	Barren
6	Snow / Ice	6.1	Snow / Ice

Especially important is the separation of peatlands. Their survey can be comparably dry. Ideally, areas with organic layer > 40 cm (and more than 30% of SOC weight) should be separated from areas with an organic layer less than 40 cm. A coarse resolution peatland map is existing (Hugelius et al. 2020) which can serve as guidance. For the climate modelling organic layer in the first 50 cm is crucial.

Shrub tundra is required to have shrubs with at least 40 cm height. This is of relevance for heat and radiation transfer and snow.

In general, the classification needs to be compatible with Landcover_cci. An extent including also non-forest areas in the boreal domain would be ideal, more important that representing dynamics (but tundra coverage only).

3.1.1 Summary of user requirements

Table 1. Requirements for landcover in permafrost lowland areas

	Threshold requirement	**Target requirement**
	Coverage and sampling	
Geographical coverage and sampling [URq_01]	Pan-Arctic tundra.	Pan-Arctic with extension to taiga biome (none-forest in landcover_cci).
Temporal sampling [URq_02]	Static	Dynamic
Temporal extent [URq_03]	Last decade	1979 - present
	Resolution and Uncertainties	
Horizontal resolution [URq_04]	100 -1000m (previous user survey)	< 10m (previous user surveys including GlobPermafrost)

	CMUG/CCI 300-1000m CryoGrid 100-300 m for fraction GCOS global 250m-1000m	CryoGrid 20 m
Accuracy [URq_05]	better accuracy than available so far GCOS: (max. error for individual classes) 15% omission /commission per class	<10% error, see Landcover_cci URD CMUG (climate modelling use) for landcover_cci 10-15 %
Error characteristics [URq_6]	Confusion matrix, overall accuracy, Kappa	Confusion matrix, overall accuracy, Kappa
	Thematic content	
Wetlands [URq_06]	Consideration of high latitude types	Separation of peatlands
Soil properties [URq_07]	Optional	Organic horizon >40m

3.1.2 Coverage and sampling

The landcover map should specifically cover the Arctic tundra (threshold). As target all non-forest areas underlain by permafrost in high latitudes should be included. The temporal extent represents Permafrost_cci baseline product requirements [RD-1].

3.1.3 Horizontal resolution

Figures 3 to 4 document the responses to the GlobPermafrost user survey [RD-3]. They are in line with results from [RD-2]. Target resolution should be 10m or better for general use, a 20 m resolution has been suggested foro CryoGRID in order to best characterize subgrid variability for the 1 km resolution.

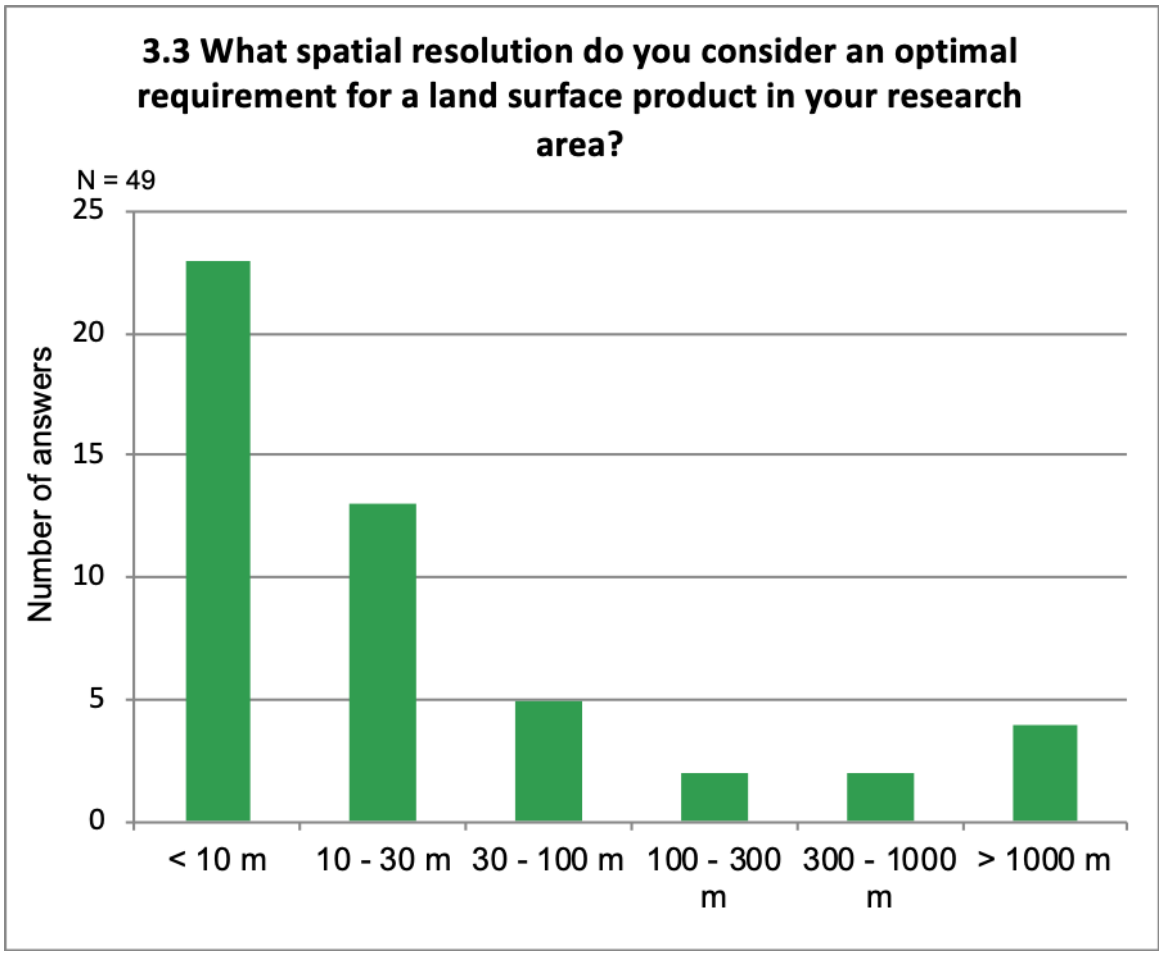

Figure 2: Question 3.3 results of DUE GlobPermafrost user survey [RD-3]

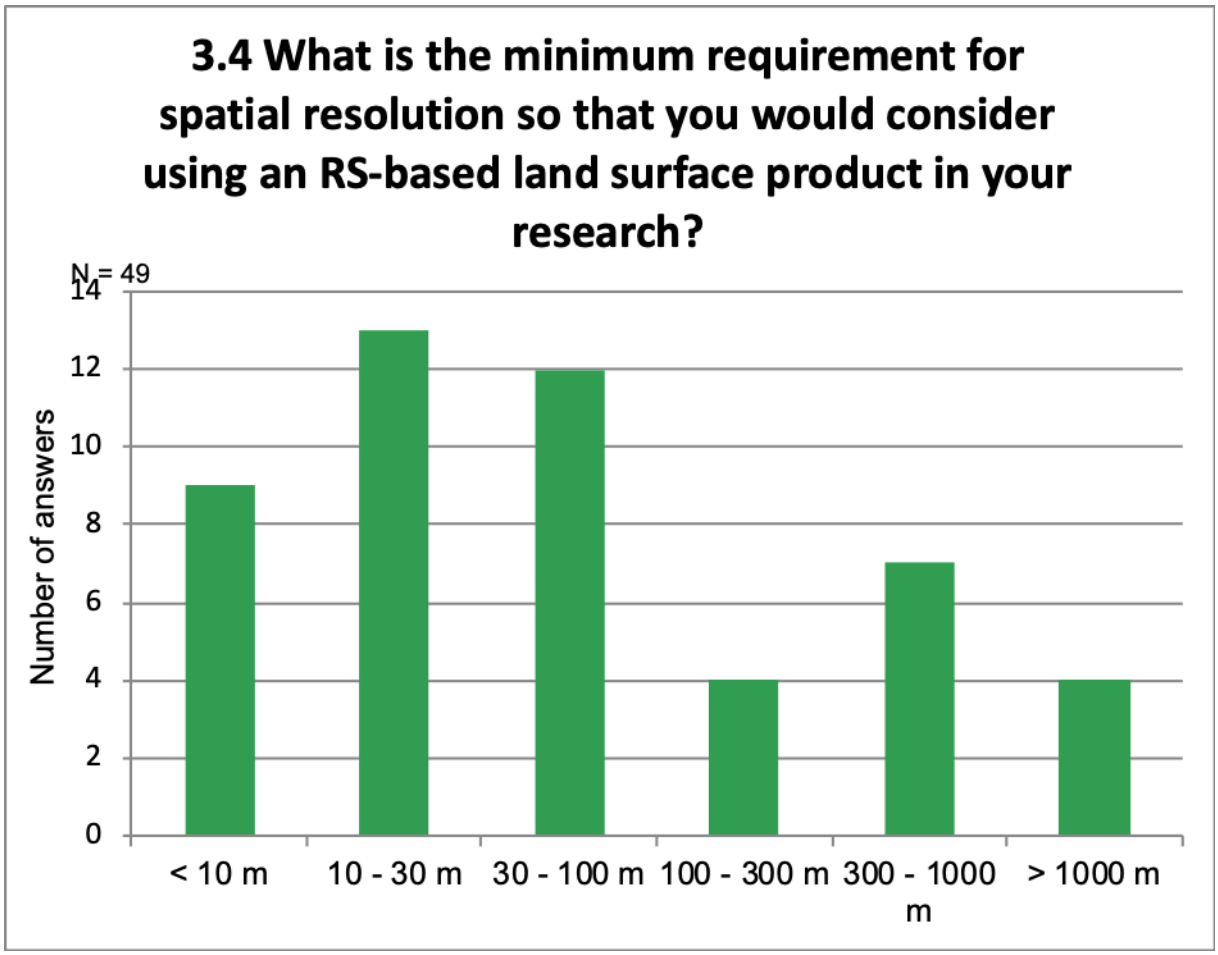

Figure 3: Question 3.4 results of DUE GlobPermafrost user survey [RD-3]

3.1.4 Thematic content

88% of survey participants of [RD-3] indicated an interest in from subgrid information on landcover units (e.g. fractions of different landcover classes for each grid cell). Landcover information is used by the majority as proxy for subsurface conditions (Figure 5). Half of the detailed responses to the thematic content (Table 3) relate to the need of soil properties.

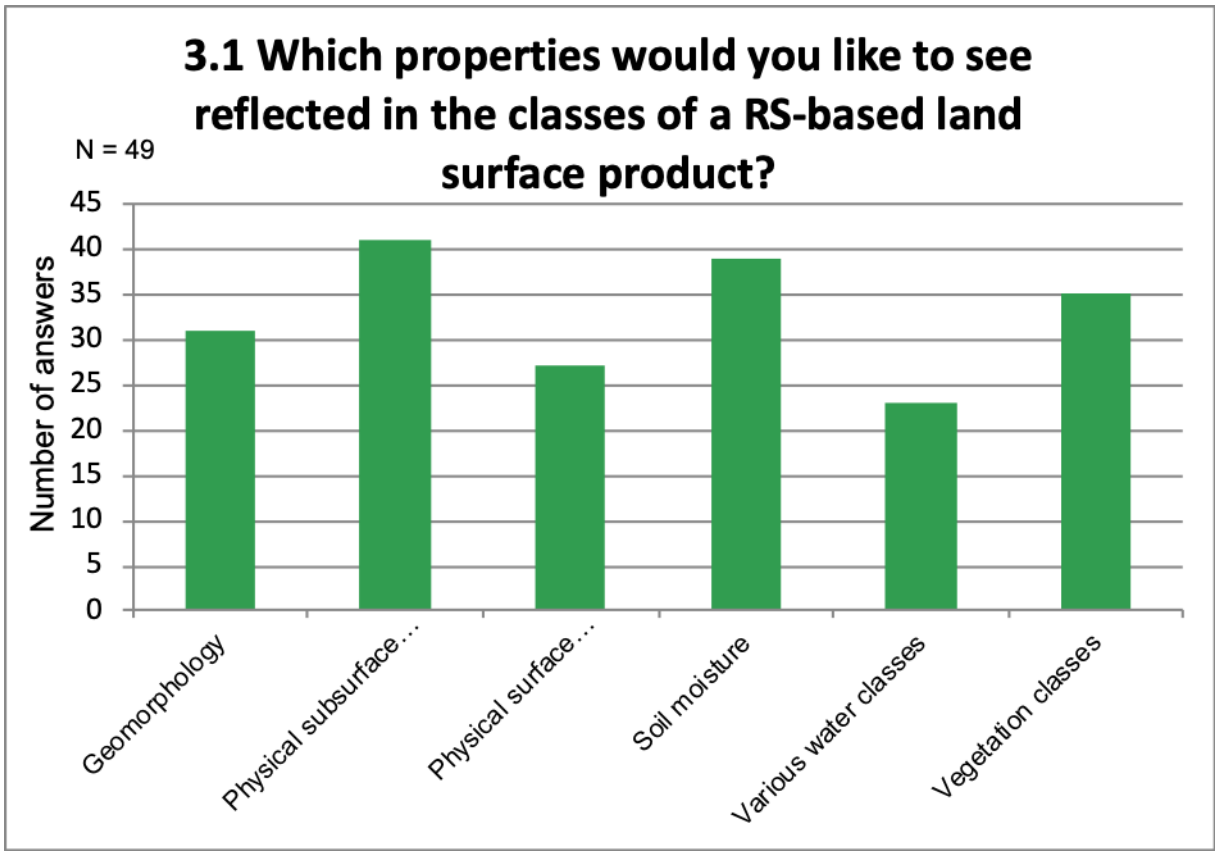

Figure 4: Question 3.1 results of DUE GlobPermafrost user survey [RD-3]

Table 3: Survey [AD-3] responses to question 3.2 Which landcover/surface type classes would you like to see distinguished in a RS-based land surface product for your research area?

#	Survey response	Potential of Landcover Prototype
1	Physical surface properties	-
2	vegetation, LAI	Communities are reflected
3	active/inactive permafrost vs rocks and scree vs vegetation	Mountain specific features to be tested
4	Yedoma, Peatlands, Barren, etc...	To be revised for target requirements
5	water, vegetation	complies
6	sand, forest	Sandy soils considered in subclasses, to be revised
7	ice-rich, very ice-rich, ice-poor, unfrozen	-
8	Vegetation products	Communities are reflected
9	Pine forest, larch forest, sparse forest, open areas, burned areas	Deciduous versus needleleaf included, others in subclasses
10	Ice soil rock vegetation	To be revised for target requirements
11	Polygons	Polygonal tundra as subclass
12	gravel (manmade), tundra	Can be combined with Bartsch et al. 2021

13	woody, non-woody, open water	Reflected in classes
14	Debris slopes and rock glaciers	Mountain specific features to be tested
15	Different vegetation classes, lithology of the upper part, soil moisture	To be revised for target requirements
16	peatlands	To be revised for target requirements
17	Tundra/Peatland	To be revised for target requirements
18	not clear, classes are expected to evolve as results of more use of RS data	- [comment from ESM related user]
19	All the above would be useful but I low confidence in products that claim they can accurately predict subsurface properties.	-
20	bedrock, coarse debris (talus slopes, rock glaciers), fine debris / soil	Mountain specific features to be tested
21	ideally a nested hierarchy but otherwise akin to latest CAVM-CBVM	Communities as in CAVM are reflected
22	Several vegetation classes, several water classes	Reflected in classes
23	fine debris, coarse debris, vegetation, bedrock	Mountain specific features to be tested
24	bedrock (if possible, bedrock type), sediment (if possible, coarse, fine), glacier, snow, fruticose lichens, mosses, graminea, perennial lake, temporary lake, infrastructure (buildings, airfield, other)	Mountain specific features to be tested Other features reflected currently in some classes
25	thermokarst landforms	-
26	Minimum requirement: Trees, Grasses, Shrubs, Bare Soil, wetlands, lakes/rivers, ocean	Reflected in classes
27	different types of forest, grassland, wetland, peatland, bareground, ice/snow	To be revised for target requirements
28	Snow physical metamorphic status	-
29	vegetation cover, soil	To be revised for target requirements
30	Geomorphology and land cover combined	-
31	tree density, shrub density, vegetation communities	Partially reflected in classes
32	vegetation communities (focus on shrubs), shrub density	Partially reflected in classes

4 User requirements feasibility

The following subsections highlight and revise the user requirements that are judged to be not fully feasible or that need refinement within the scope of the CCN3 option 6.

4.1 General

For landcover, we identify the following user requirements that are not fully feasible:

URq_09 and 10: Temporal sampling: The main data sources will be Sentinel-1/2 to meet the spatial resolution requirement. Therefore no full decade can be covered and also no dynamics (not in all cases a cloud free image available per year).

4.2 Class specific

For landcover, we identify the following user requirements that are not fully feasible:

URq_05 Separation of peatlands, areas with > 40 cm organic layer – Specific quantitative assignments for soils are not feasible by using landcover as proxy. An indication for SOC beyond typical values of mineral soils will be tested.

URq_07 Compatible with Landcover_cci. The spatial resolution differs apart from thematic content. Scale dependencies in the tundra-taiga transition zone (potential fusion zone) therefor need to be analysed first.

5 Summary

All specific user requirements are listed in Table 8. It provides a summary of the identified user requirements that is organised by EO data product. For each user requirement, the source and the type of work it will address are identified. We aim to meet as many of these requirements as possible in the course of the project time frame, taking into account data availability and workload constraints.

Table 8: *Summary of user requirements. Background (BG) means that this is a continuous activity, production (P) means that the related requirement has to be considered during production.*

ID	PARAMETER	REQUIREMENTS	TYPE
URQ_01	GENERAL	Representation of dry, moist and wet	P
URQ_02	CLASS	Subcategories of prototype class ‚disturbed'	P
URQ_03	GENERAL	Spatial resolution 20 m	BG
URQ_04	CLASS	Separation of artificial landcover (roads, settlements)	P
URQ_05	CLASS	Separation of peatlands, areas with > 40 cm organic layer	P
URQ_06	CLASS	Separation of shrub tundra higher than 40 m	P
URQ_07	CLASS	Compatible with Landcover_cci	P
URQ_08	GENERAL	Coverage threshold: pan-arctic , target extension to none forest taiga	BG/P
URQ_09	GENERAL	Temporal sampling threshold static, target dynamic	BG
URQ_10	GENERAL	Temporal extent threshold last decade, target 1979 - present	BG

6 References

6.1 Bibliography

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6.2 Acronyms

CCI	Climate Change Initiative
CCN	Contract Change Notice
CRS	Coordinate Reference System
DARD	Data Access Requirement Document
DEM	Digital Elevation Model
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
GST	Ground Surface Temperature
GTOS	Global Terrestrial Observing System
IPA	International Permafrost Association
MAGT	Mean Annual Ground Temperature
MAGT	Mean Annual Ground Surface Temperature
NSIDC	National Snow and Ice Data Center
PSD	Product Specifications Document
RD	Reference Document
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
URD	Users Requirement Document