climate change initiative

ESA CCI+ Permafrost – data access and use

Annett Bartsch + ESA project teams (>50 scientists directly involved)

DUE Permafrost (2009-2012)
DUE GlobPermafrost (2016-2019)

CCI+ Permafrost:

Phase I (2018-2021)
Phase II (2022-2025)
CCI+ Permafrost results

2 m depth ground temperature – derived based on Obu et al. 2021 (CEDA archive) using Landsurface temperature + CryoGRID model

September sea ice extent – source: seaiceportal.de

Bartsch et al. (2023)
CCI+ Permafrost results

Ground temperature at 2 m depth - CRDPv2 regional average
(spatial subset < 0°C at least 1 year)

Temperature [°C]

Date [year]


Greenland
Alaska
Canada
Russia
Linear (Greenland)
Linear (Alaska)
Linear (Canada)
Linear (Russia)
History & Status

GlobPermafrost (2016-2019)


Northern Hemisphere permafrost map based on TTOP modelling for 2000-2016 at 1 km2 scale. Earth-Science Reviews, Volume 193, Pages 299-316.

+ southern hemisphere → AWI WebGIS

https://globpermafrost.info/products-and-data-access
CCI+ Permafrost Phase I (2019-2021)

Transient modelling is required to produce time slices

- need of long-term records of
  - Land Surface Temperature,
  - Snow, and
  - suitable soil parameterization

S. Westermann
\[ \text{University of Oslo} \]

CCI+ version CryoGRID

land surface temperature

event

snow water equivalent

warm

cold

subsurface properties

geothermal heat flux

\[ T(z,t) \]
Overview CCI+ Permafrost products

Baseline products for **northern hemisphere (1km)**:
- Permafrost Temperature
- Active Layer Thickness
- Permafrost extent
- Harmonized borehole temperature records database for calibration and validation

Current version (May 2021): 1997-2019, CRDPv2

Animation: 2003-2017, CRDPv0
Overview CCI+ Permafrost products

Baseline products for **northern hemisphere** (1km):

- Permafrost Temperature
- Active Layer Thickness
- Permafrost extent

- Harmonized borehole temperature records database for calibration and validation

In situ data publication in preparation

Source of sites for GT Match-up:
- GTN-P & USGS
- NASA ABoVe
- Nordicana-D
- RHM

MAGT 1997-2019 at depths:
0, 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 10, 20 m
Permafrost_cci MAGT<1°C good performance bias 0.2°C (0,1,2,5,10,20m), stable across years.
Permafrost_cci MAGT discontinuous to non permafrost zones too cold, MAGT bias -1.47°C.
Majority of Permafrost_cci ALT trends match GTN-P ALT trends (60 %), large geographic data gaps.
Majority of Permafrost_cci PE match-up pairs in agreement (70 %), stable across years.
### CCI+ Permafrost Phase I

**GlobPermafrost (2016-2019)**

- Obu et al. (2019) Earth-Science Reviews
- + lake change along transects (Nitze et al. 2018)
- + regional InSAR studies (Strozzi et al. 2018, Bartsch et al. 2019)
- + AWI WebGIS
- + several user workshops

### Permafrost_cci Phase I (2018 - 2021)

#### Extensions Phase I (-2023)

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS LST use as input for <strong>transient</strong> modelling</td>
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<td>Use: Comparison to lake change, landsurface model evaluation, trend extraction</td>
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<td><strong>Circumpolar implementation of GlobPermafrost landcover prototype (10m, ongoing)</strong></td>
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<td>Extension of <strong>InSAR ground subsidence</strong> for seasonal and long-term signals</td>
</tr>
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<td>Dissemination via CEDA and AWI WebGIS</td>
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</tbody>
</table>

**Landcover data publication in preparation**
CCI+ Permafrost Phase I

GlobPermafrost (2016-2019)

Obu et al. (2019)
Earth-Science Reviews

+ lake change along transects (Nitze et al. 2018)
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+ AWI WebGIS
+ several user workshops

Permafrost_cci Phase I (2018 - 2021)
Extensions Phase 1 (-2023)

MODIS LST use as input for transient modelling

Use: Comparison to lake change, landsurface model evaluation, trend extraction

Circumpolar implementation of GlobPermafrost landcover prototype (10m, ongoing)

Comparison freeze/thaw

Homogeneous inventories of rock glaciers, kinematics from InSAR

Extension of InSAR ground subsidence for seasonal and long-term signals

Dissemination via CEDA and AWI WebGIS

Rock glacier inventory available (IPA action group)
**Phase II**

**GlobPermafrost (2016-2019)**

- Obu et al. (2019) *Earth-Science Reviews*
- + lake change along transects (Nitze et al. 2018)
- + regional InSAR studies (Strozzi et al. 2018, Bartsch et al. 2019)
- + AWI WebGIS
- + several user workshops

### Permafrost_cci Phase I (2018 - 2021) Extensions Phase 1 (-2023)

- MODIS LST use as input for **transient** modelling
- Use: Comparison to lake change, landsurface model evaluation, trend extraction

### Permafrost_cci Phase II (2022-2025)

- Adjustment to **LST_cci** (Sentinel-3) and **Snow_cci** as input
- Higher level products generation for enhanced user uptake
- Use of landcover for model parameterization, in situ evaluation

**Circumpolar implementation of GlobPermafrost landcover prototype (10m, ongoing)**

- Comparison freeze/thaw

**Homogeneous inventories of rock glaciers, kinematics from InSAR**

**Extension of InSAR ground subsidence** for seasonal and long-term signals

**Dissemination via CEDA and AWI WebGIS**

- R&D for InSAR use in CryoGRID
- Dissemination via CEDA and AWI WebGIS
- Dedicated user workshops, 1st at EUCOP 2023

**GlobPermafrost (2016-2019)**

**Obu et al. (2019)**

**Earth-Science Reviews**

+ lake change along transects (Nitze et al. 2018)
+ regional InSAR studies (Strozzi et al. 2018, Bartsch et al. 2019)
+ AWI WebGIS
+ several user workshops
Information gained based on CryoGRID

- Obu (2021), GRL: 15% of NH underlain by permafrost (based on GlobPermafrost dataset)
- Miner et al. (2022), NREE: ground temperature increase pronounced along Arctic coasts
- Bartsch et al. (2023): Since 2000, NH permafrost ground temperatures (2m) have increased on average by about 1°C
- Brouillette (2021), Nature: ALT increased on average 2.5cm across NH during 2007-16 compared to the previous decade
Examples of site specific use


Change at sites with high coastal erosion rates

Examples of site specific use


Trends versus 2019 status at locations with infrastructure

Figure 8. Scatterplots of trend versus 2019 status for (a) ground temperature at 7 m depth, (b) active layer thickness and (c) percent ice content. Each point represents the average for a distinct object (human impacted area) as mapped withSentinel-1 and -2 (Bartsch et al. 2021). Calculations are based on Obu et al. (2013a, 2014, 2016) respectively.
Visualization of CRDPv0
Data access and use tutorial overview

• Focus on CryoGRID results
  • There is one data download portal (CEDA)
  • There are two visualization options (AWI WebGIS and ESA ‘Climate from Space’)

• Access examples:
  1. Download of annual northern hemisphere dataset and use in QGIS
  2. Extraction of ground temperature for a specific coordinate from data portal
  3. Visualization of data and manual extraction of value for a specific site through WebGIS

Can be done with a mobile
Data access

- Search for CCI Permafrost
- https://climate.esa.int/en/projects/permafrost/data/
Permafrost Year 3 Climate Research Data Package (CRDP v2) on CEDA Archive and on the Climate Data Dashboard.
Permafrost Year 3 Climate Research Data Package (CRDP v2) on CEDA Archive and on the Climate Data Dashboard.

CRDPv2 includes:

- Mean Annual Ground Temperature in permafrost areas for the Northern Hemisphere, v3.0, 1997-2019, 1km; 0m, 1m, 2m, 5m and 10 m depth (University Oslo);
- Permafrost extent for the Northern Hemisphere, v3.0, 1997-2019, 1km, fraction, annual (University Oslo);
- Permafrost active layer thickness for the Northern Hemisphere, v3.0, 1997-2019, 1 km, annual maximum thaw depth (University Oslo).

Citation of complete dataset:


Additional access via WebGIS visualization at https://maps.awi.de.

Additional Permafrost_cci records:

- Rock glacier inventories at WebMAPS (University Fribourg).
- Days with potential alteration of ground temperature through rain on snow: mid-winter (Nov-Feb) snow thaw and refreeze, north of 65°N, MetopASCAT + SMOS at https://zenodo.org/record/7575927 (b.geos and FMI).

Heritage

### Key documents

**Permafrost_CCI baseline project Phase 1**

<table>
<thead>
<tr>
<th>Document name</th>
<th>Version</th>
<th>Issue date</th>
<th>Download</th>
</tr>
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<tbody>
<tr>
<td>D1.1 User Requirements Document (URD)</td>
<td>2.0</td>
<td>Nov. 30, 2020</td>
<td></td>
</tr>
<tr>
<td>D1.2 Product Specification Document (PSD)</td>
<td>3.0</td>
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<tr>
<td>D1.3 Data Access Requirements Document (DARD)</td>
<td>2.0</td>
<td>Dec. 22, 2020</td>
<td></td>
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<tr>
<td>D2.1 Product Validation and Algorithm Selection Report (PVASR)</td>
<td>3.0</td>
<td>Feb. 24, 2021</td>
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<tr>
<td>D2.2 Algorithm Theoretical Basis Document (ATBD)</td>
<td>3.0</td>
<td>Nov. 30, 2020</td>
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<tr>
<td>D2.3 End-to-End ECV Uncertainty Budget (E3UB)</td>
<td>3.0</td>
<td>Feb. 24, 2021</td>
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<tr>
<td>D2.4 Algorithm Development Plan (ADP)</td>
<td>3.0</td>
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<td>3.0</td>
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<tr>
<td>D3.1 System Requirement Document (SRD)</td>
<td>3.0</td>
<td>April 8, 2021</td>
<td></td>
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<tr>
<td>D3.2 System Specification Document (SSD)</td>
<td>3.0</td>
<td>April 8, 2021</td>
<td></td>
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<tr>
<td>D3.3 System Verification Report (SVR)</td>
<td>3.0</td>
<td>April 8, 2021</td>
<td></td>
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<tr>
<td>D4.1 Product Validation and InterComparison Report (PVIR)</td>
<td>3.0</td>
<td>Sept. 30, 2021</td>
<td></td>
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<tr>
<td>D4.2 Climate Research Data Package (CRDP) Version 2</td>
<td>2</td>
<td>Sept. 25, 2021</td>
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<tr>
<td>D4.3 Product User Guide (PUG)</td>
<td>3.0</td>
<td>April 13, 2021</td>
<td></td>
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<tr>
<td>D5.1 Climate Assessment Report (CAR)</td>
<td>3.1</td>
<td>Jan. 19, 2022</td>
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**Permafrost_CCI baseline project Phase 2**

<table>
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<th>Document name</th>
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<tbody>
<tr>
<td>D1.1 User Requirement Document (URD)</td>
<td>3.0</td>
<td>Feb. 15, 2023</td>
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<tr>
<td>D1.2 Product Specification Document (PSD)</td>
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**Future updates here**
Permafrost Year 3 Climate Research Data Package (CRDP v2) on CEDA Archive and on the Climate Data Dashboard.

CRDPv2 includes:

- Mean Annual Ground Temperature in permafrost areas for the Northern Hemisphere, v3.0, 1997-2019, 1km; 0m, 1m, 2m, 5m and 10 m depth (University Oslo);
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Heritage

The ultimate objective of Permafrost_cci is to develop and deliver permafrost maps as ECV products primarily derived from satellite measurements. The required associated parameters by GCOS for the ECV Permafrost are "Depth of active layer (m)" and "Permafrost temperature (K)."

Total catalogue size: 42.9 GB

Permafrost active layer thickness for the Northern Hemisphere, v3.0
Click here for data access

Catalogue size: 8.6 GB
Number of files: 24

This dataset contains permafrost active layer thickness data produced as part of the European Space Agency’s (ESA) Climate Change Initiative (CCI) Permafrost project. It forms part of the second version of their Climate Research Data Package (CRDP v2). It is derived from a thermal model driven and constrained by satellite data. Grid products of CRDP v2 are released in annual files, covering the start to the end of the Julian year. The maximum depth of seasonal thaw is provided, which corresponds to the active layer thickness. Case A: This covers the Northern Hemisphere (north of 30°) for the period 2003-2019 based on MODIS Land Surface temperature merged with downsampled ERA5 reanalysis near-surface air temperature data. Case B: This covers the Northern Hemisphere (north of 30°) for the period 1997-2002 based on downscaled ERA5 reanalysis near-surface air temperature data which are bias-corrected with the Case A product for the overlap period 2003-2019 using a pixel-specific statistics for each day of the year.

Data have been produced by the ESA CCI Permafrost project as part of ESA’s Climate Change Initiative programme.
CRDPv0 is dataset v1.0
CRDPv1 is dataset v2.0

ESA Permafrost Climate Change Initiative (Permafrost_cci): Permafrost extent for the Northern Hemisphere, v3.0

Abstract
This dataset contains permafrost extent data produced as part of the European Space Agency's (ESA) Climate Change Initiative (CCI) Permafrost project. It forms part of the second version of their Climate Research Data Package (CRDP v2). It is derived from a thermal model driven and constrained by satellite data. Grid products of CRDP v2 are released in annual files, covering the start to the end of the Julian year. This corresponds to average annual ground temperatures (at 2 m depth) which forms the basis for the retrieval of yearly fraction of permafrost-underlain and permafrost-free area within a pixel. A classification according to the IPA (International Permafrost Association) zonation delivers the well-known permafrost zones, distinguishing isolated (0-10%) sporadic (10-50%), discontinuous (50-90%) and continuous permafrost (90-100%).

Case A: This covers the Northern Hemisphere (north of 30°) for the period 2003-2019 based on MODIS Land Surface temperature merged with downscaled ERA5 reanalysis near-surface air temperature data.
File naming

Level 4 - Data sets are created from the analysis of lower level data, resulting in gridded, gap-free products.

Area 4 – Northern Hemisphere

One file – one year
Bulk download options

Manual download

Subset download
(only spatially, bands)
Bulk Download Options

- Raw HTTP downloads: [https://dap.ceda.ac.uk/neodc/esacci/permafrost/data/active_layer_thickness/L4/area4/pp/v03.0/](https://dap.ceda.ac.uk/neodc/esacci/permafrost/data/active_layer_thickness/L4/area4/pp/v03.0/) (Tip: If our file indexing is behind for some reason, then this service may show more recent changes that may not be displayed here)
- `wget -e robots=off --mirror --no-parent -r https://dap.ceda.ac.uk/neodc/esacci/permafrost/data/active_layer_thickness/L4/area4/pp/v03.0/` - `Wget` is great for bulk downloading.
- FTP: [ftp://ftp.ceda.ac.uk/neodc/esacci/permafrost/data/active_layer_thickness/L4/area4/pp/v03.0/](ftp://ftp.ceda.ac.uk/neodc/esacci/permafrost/data/active_layer_thickness/L4/area4/pp/v03.0/) - There are lots of tools that can use FTP to do bulk downloads (e.g. `Filezilla`)
- DAP: If you need to just get a subset of NetCDF files, have a look at the help page about interacting programatically with the data
- JSON listing: Use `json listing` of this directory to script download.
### Example 1: Permafrost Extent

The table lists permafrost extent data from MODIS-LST_CRYOGRID-AREA4 PP datasets for various years:

- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2011-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2012-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2013-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2014-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2015-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2016-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2017-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2018-fv03.0.nc**: 150.0 MB
- **ESACCI-PERMAFROST-L4-PFR-MODISLST_CRYOGRID-AREA4_PP-2019-fv03.0.nc**: 150.0 MB

These datasets provide permafrost extent information for the specified years.
• Note, issue with NetCDF metadata projection information for all datasets in the current version on CEDA

• Python fix available on GitHub
  • https://github.com/bgeosgit/permafrost_cci.git

• will be solved in next upload later this year
Setting the layer coordinate system in QGIS, e.g. in version 3.12 for windows (not all versions work)
<table>
<thead>
<tr>
<th>Description</th>
<th>Size</th>
</tr>
</thead>
</table>
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2011
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2012
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2013
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2014
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2015
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2016
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2017
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2018
f v03.0.nc | 1.4 GB |
| ESACCI-PERMAFROST-LA-GTDL-  
MODISLST_CRYOGRID-AREA4_PP-2019
f v03.0.nc | 1.4 GB |

Example 2
Resolution is 927m!

X -1.000.000
Y 2.000.000

(e.g. projection number EPSG:3995 in QGIS)

Grid
X 5516
Y 2282
-> 'get ASCII'
Resolution is 927m!

Resolution is 927m!

Resolution is 927m!

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Resolution is 927m!

Resolution is 927m!
CRDPv1 (ends 2018)

e.g. via www.globpermafrost.info
Climate from Space - interactive application
Explore the changing climate through the eyes of satellites with this interactive app

Explore Climate Data
Explore how our climate has evolved through 40 years of research-quality satellite data

CCI Open Data Portal
Free and open access to all CCI Essential Climate Variable data products
CCI portal – Climate from Space
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Heritage