climate change initiative

→ PERMAFROST

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:

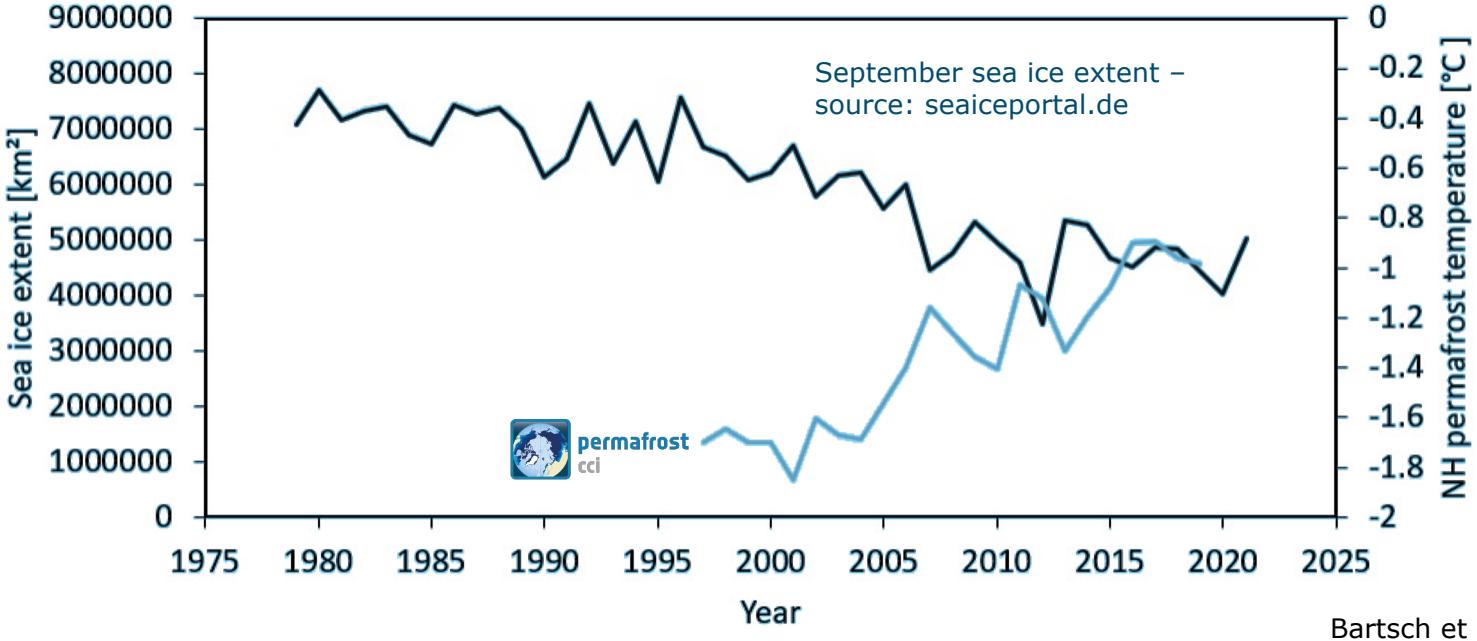
Phase I (2018-2021)

Phase II (2022-2025)

permafrost cci

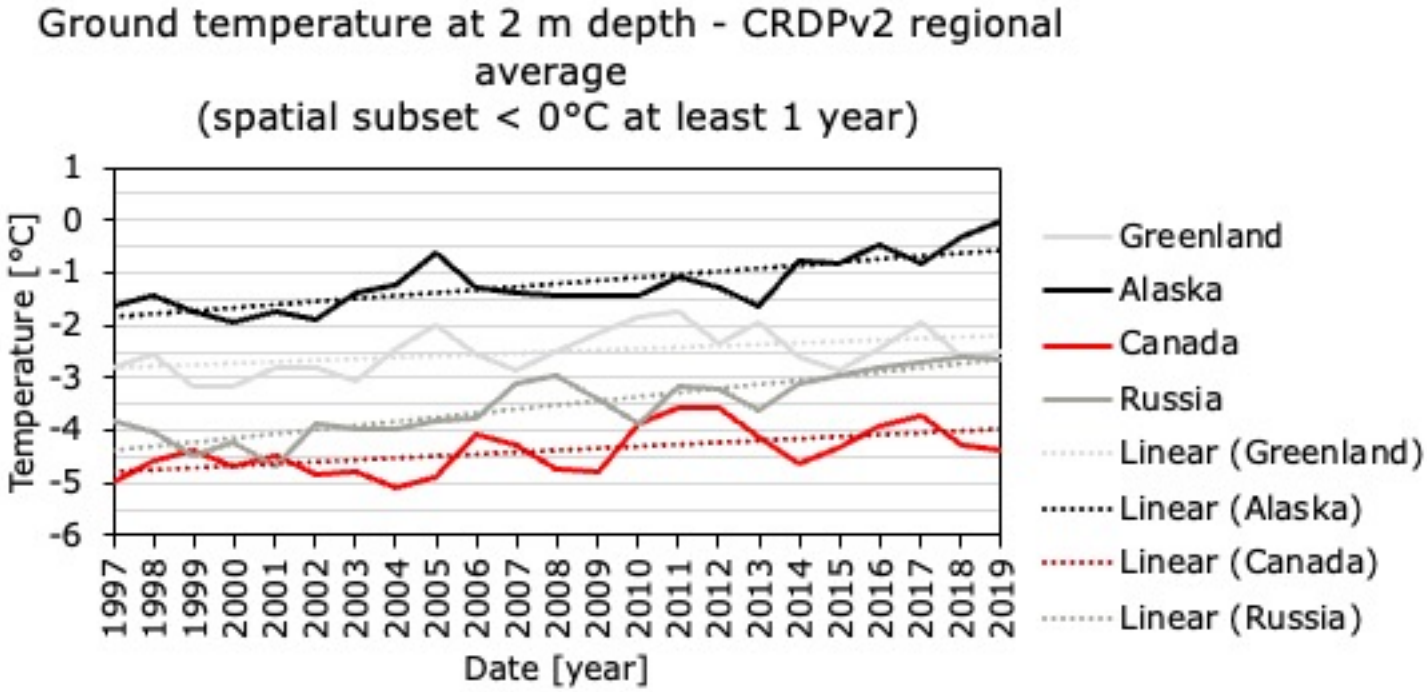
CCI+ Permafrost results

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

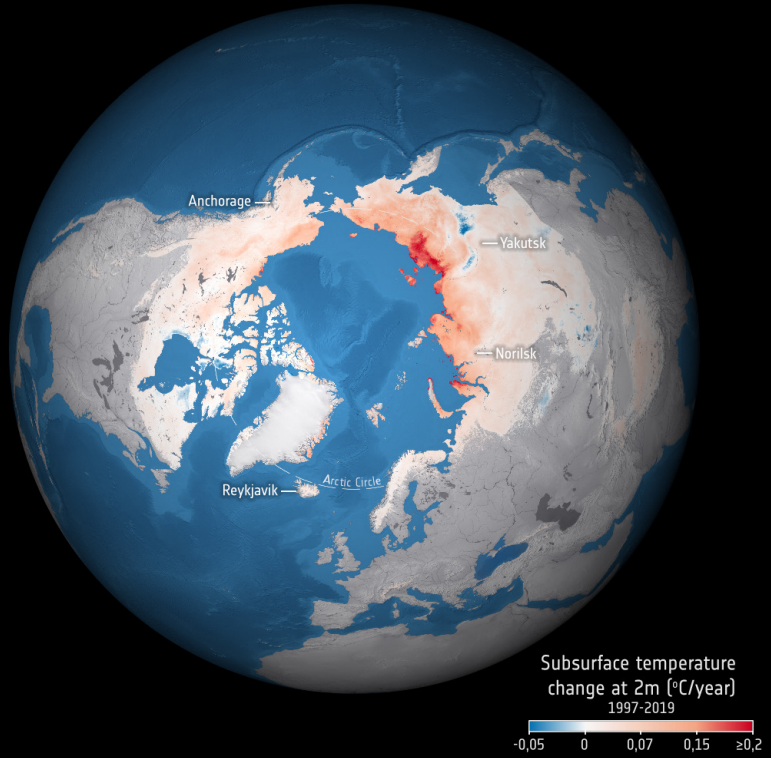


Bartsch et al. (2023)

CCI+ Permafrost results



permafrost
cci

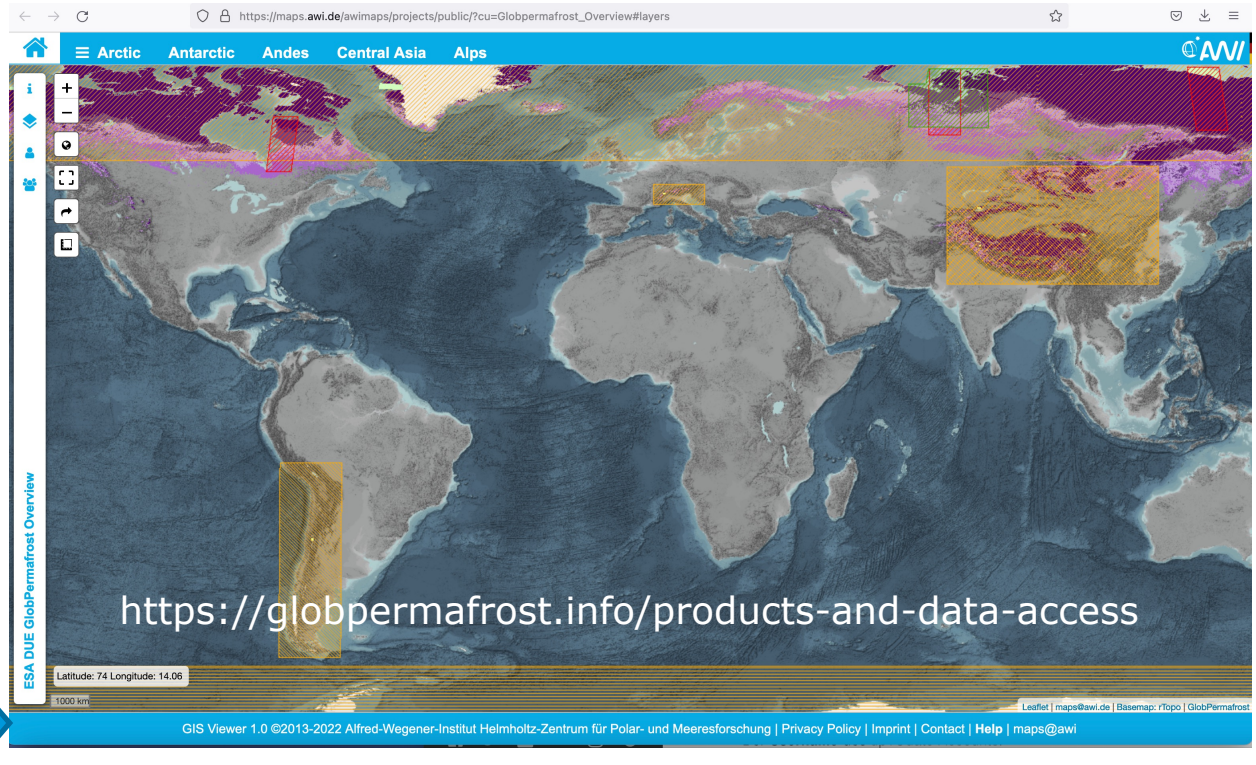


History & Status

GlobPermafrost (2016-2019)

J. Obu, S. Westermann, A. Bartsch, N. Berdnikov, H.H. Christiansen, A. Dashtseren, R. Delaloye, B. Elberling, B. Etzelmüller, A. Kholodov, A. Khomutov, A. Kääb, M.O. Leibman, A.G. Lewkowicz, S.K. Panda, V. Romanovsky, R.G. Way, A. Westergaard-Nielsen, T. Wu, J. Yamkhin, D. Zou (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



History & Status

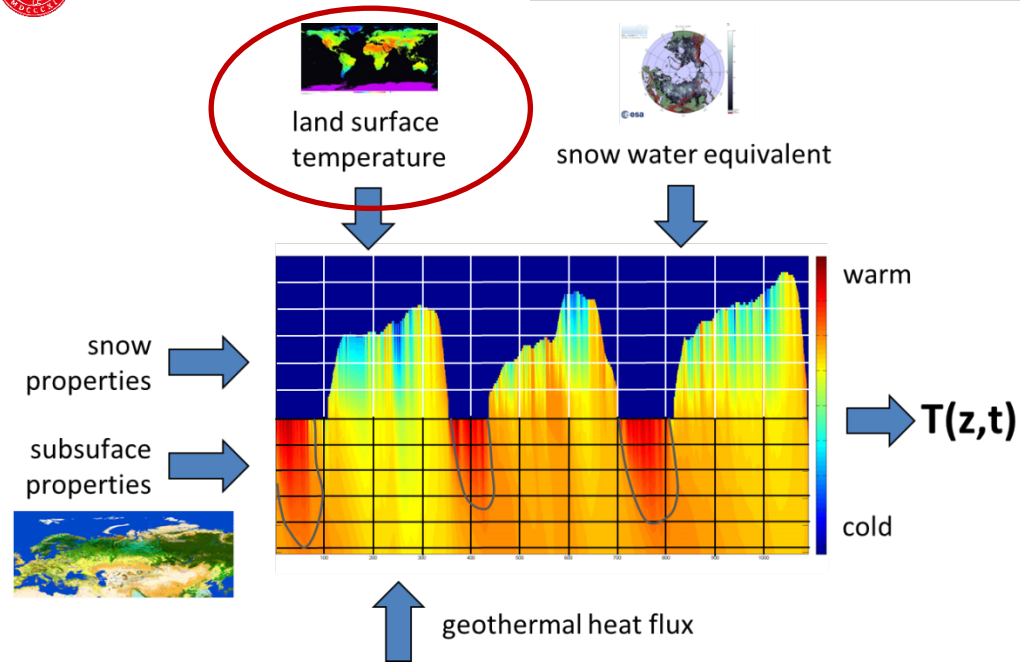
CCI+ Permafrost Phase I
(2019-2021)

S. Westermann
UiO : University of Oslo

CCI+ version CryoGRID

Transient modelling
is required to produce
time slices

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



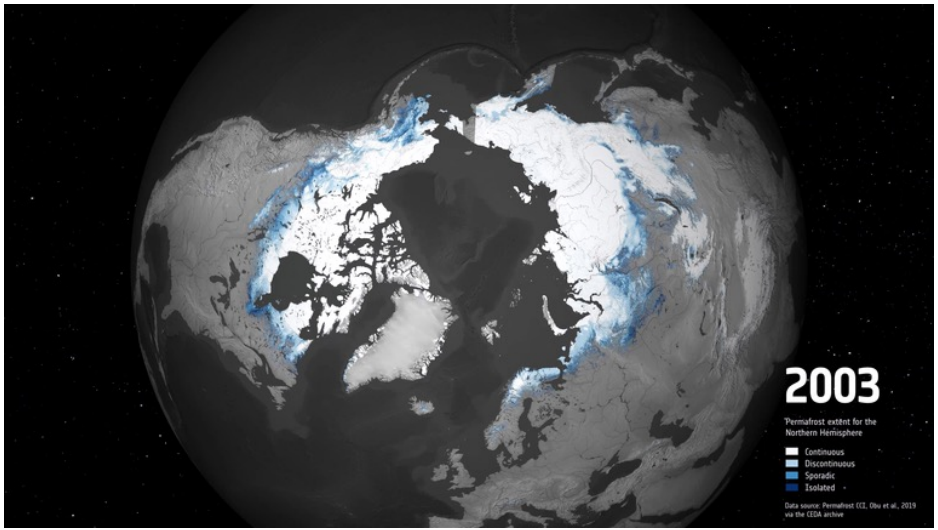
Overview CCI+ Permafrost products

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

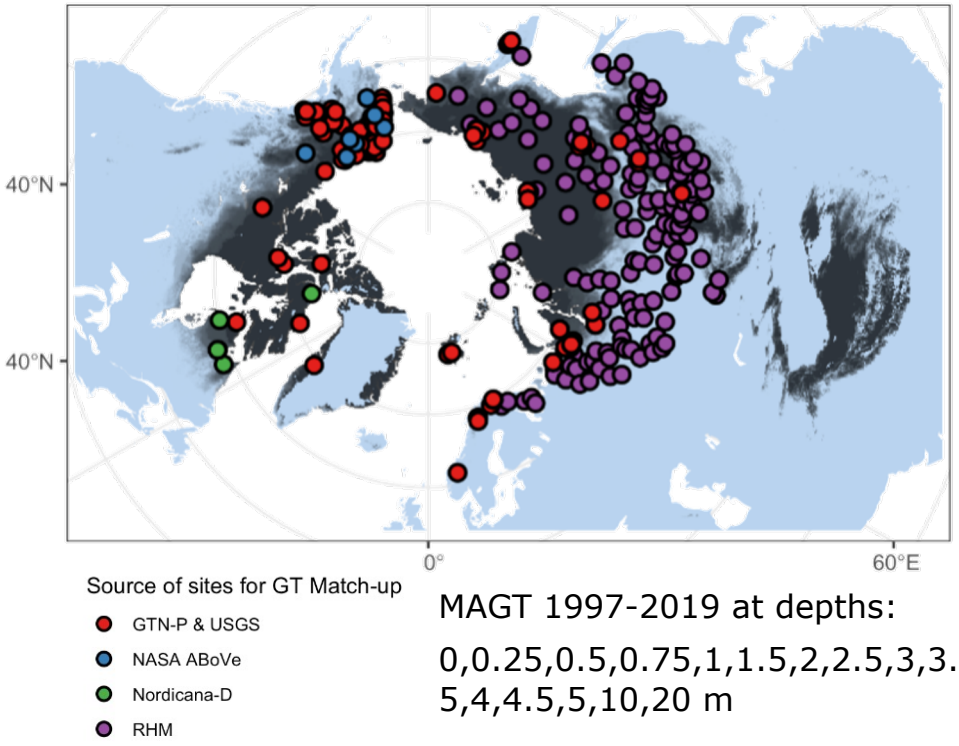
Overview CCI+ Permafrost products

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

- Permafrost Temperature
- Active Layer Thickness
- Permafrost extent

- Harmonized borehole temperature records database for calibration and validation

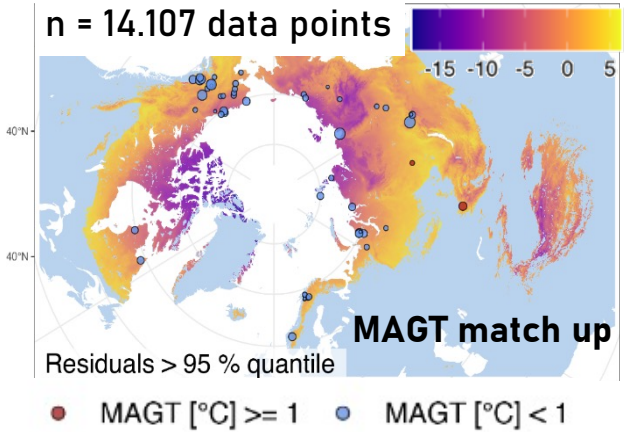
In situ data publication in preparation

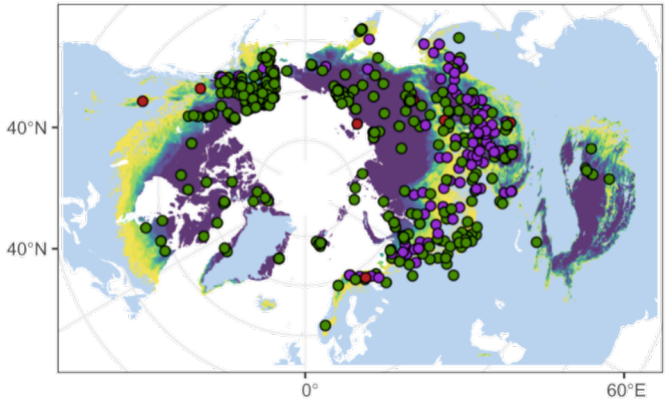


MAGT 1997-2019 at depths:

0,0.25,0.5,0.75,1,1.5,2,2.5,3,3.5,4,4.5,5,10,20 m

ESA Permafrost_cci validation





in-site TRUE, PE_cci FALSE

match

in-site FALSE, PE_cci TRUE

Permafrost extent PE match up

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 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

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)
+regional InSAR studies (Strozzi et al. 2018, Bartsch et al. 2019)
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Permafrost_cci Phase I (2018 - 2021) **Extensions Phase 1 (-2023)**
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Use: Comparison to lake change, landsurface model evaluation, trend extraction
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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)

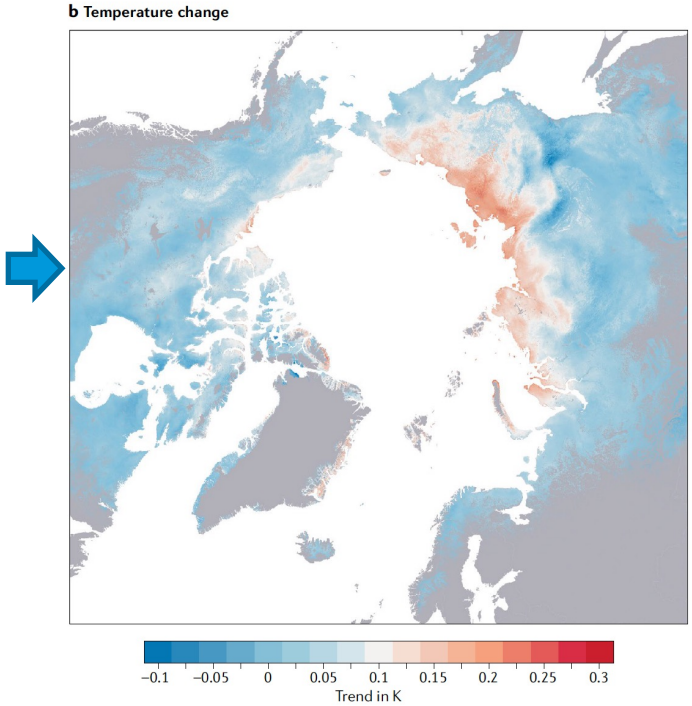
Obu et al. (2019)
Earth-Science Reviews

+ 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)	**Permafrost_cci Phase II (2022-2025)**
MODIS LST use as input for **transient** modelling	Adjustment to **LST_cci** (Sentinel-3) and **Snow_cci** as input
Use: Comparison to lake change, landsurface model evaluation, trend extraction	Higher level products generation for enhanced user uptake
Circumpolar implementation of GlobPermafrost landcover prototype (10m, ongoing)	Use of landcover for model parameterization, in situ evaluation
Comparison freeze/thaw	
Homogeneous inventories of **rock glaciers, kinematics from InSAR**	updates
Extension **of InSAR ground subsidence** for seasonal and long-term signals	R&D for InSAR use in CryoGRID
Dissemination via CEDA and AWI WebGIS	Dissemination via CEDA and AWI WebGIS
	Dedicated user workshops, 1st at EUCOP 2023

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 1ºC
- Brouillette (2021), Nature: ALT increased on average 2.5cm across NH during 2007-16 compared to the previous decade



Examples of site specific use

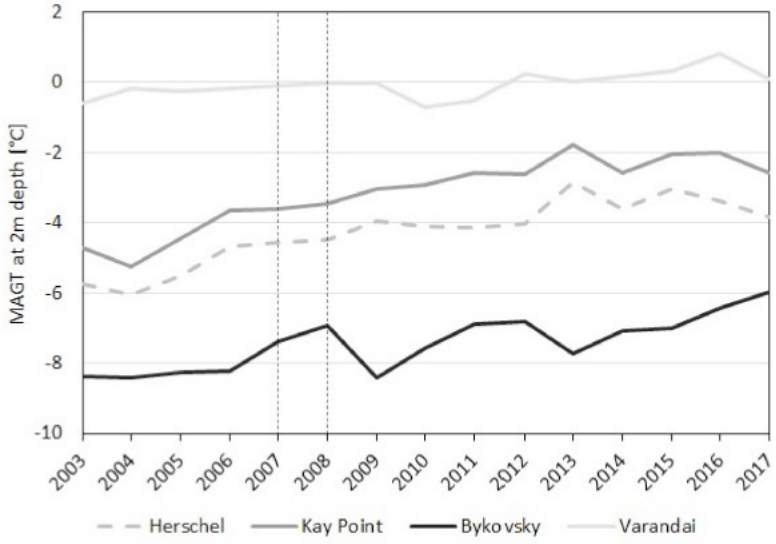


FIGURE 10 | Mean annual ground temperature (MAGT) at 2 m depth for 2003–2017 (source: Obu et al., 2019a). Vertical dashed lines indicate years with PALSAR acquisitions.

Change at sites with high coastal erosion rates

Bartsch A., Ley S. Nitze I., Pointner G., Vieira G. (2020): Feasibility Study for the Application of Synthetic Aperture Radar for Coastal Erosion Rate Quantification Across the Arctic. Frontiers in Environmental Science 8, 143

Examples of site specific use

Trends versus 2019 status at locations with infrastructure

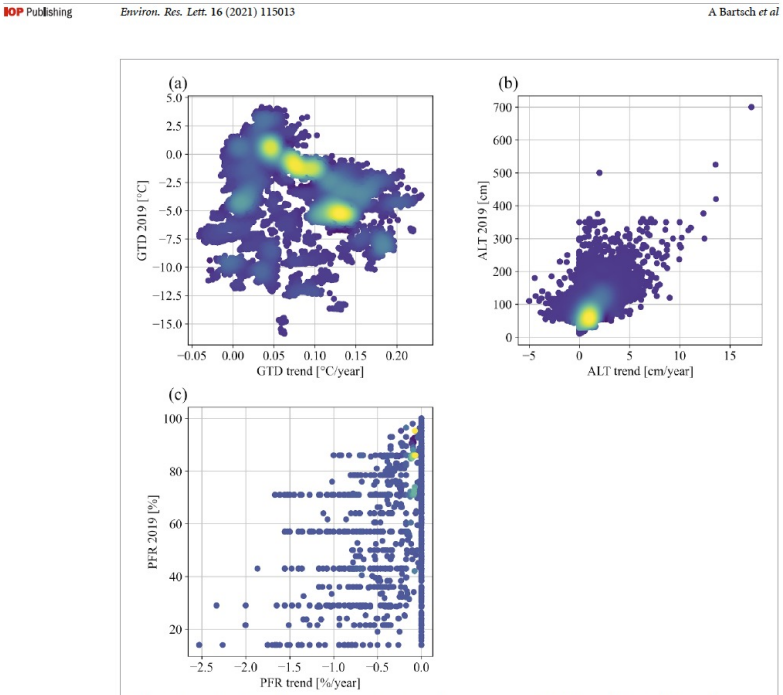
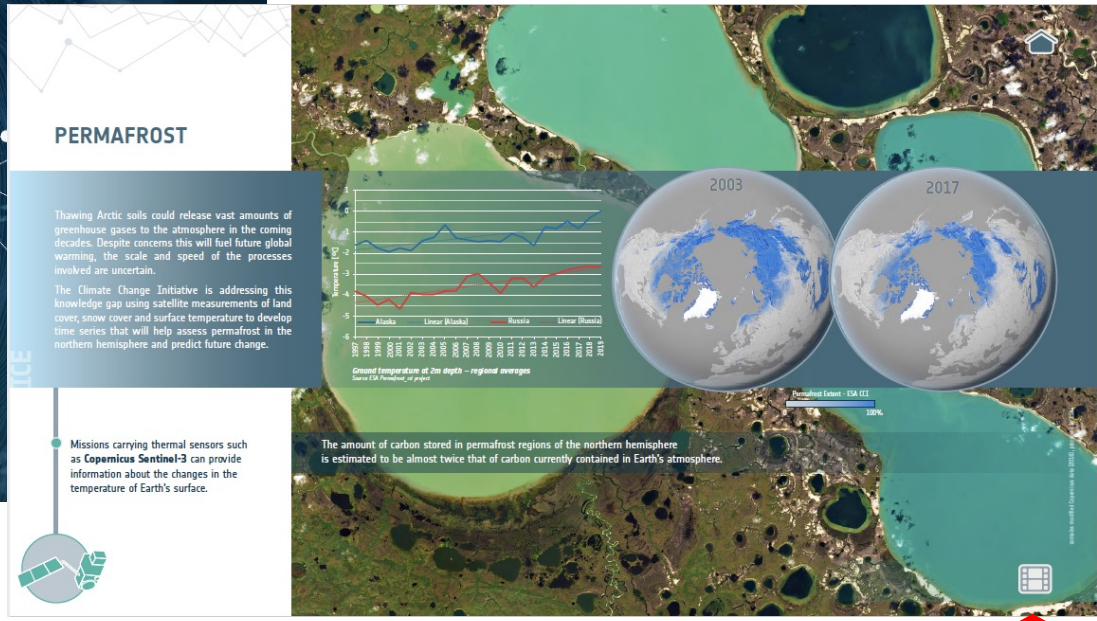


Figure 9. Scatterplots of trend versus 2019 status for (a) ground temperature at 2 m depth, (b) active layer thickness and (c) permafrost fraction. Each point represents the average for a distinct object (human impacted area) as mapped with Sentinel-1 and -2 (Bartsch *et al* 2021). Calculations are based on Obu *et al* (2021a, 2021b, 2021c) respectively.

Bartsch, A., G. Pointner, I. Nitze, A. Efimova, D. Jakober, S. Ley, E. Högström, G. Grosse, P. Schweitzer (2021): Expanding infrastructure and growing anthropogenic impacts along Arctic coasts. Environmental Research Letters. https://doi.org/10.1088/1748-9326/ac3176



Visualization of CRDPv0

Data access and use tutorial overview

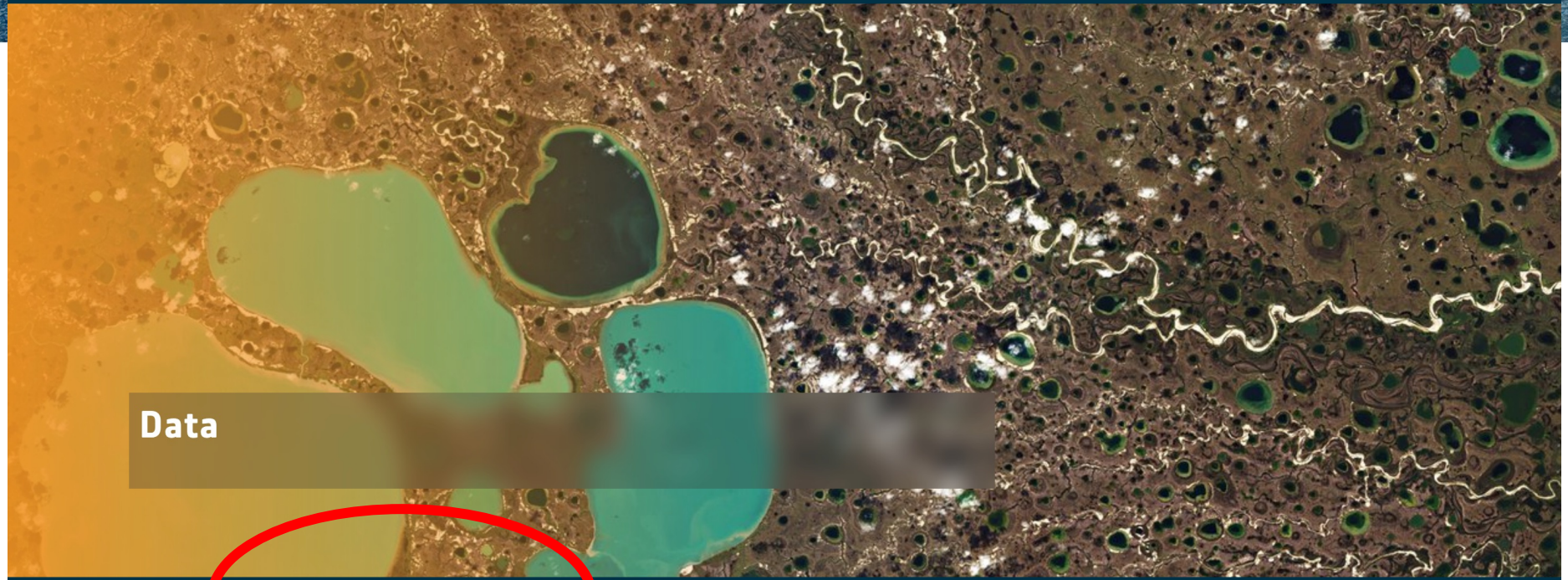
- Focus on CryoGRID results
  - There is one data download portal (CEDA)
  - There are two visualization options (AWI WebGIS and ESA ‘Climate from Space‘)

- 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/



Data

Permafrost Year 3 Climate Research Data Package (CRDP v2) on CEDA Archive and on the Climate Data Dashboard.

CryoGRID results

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:

Obu, J.; Westermann, S.; Barboux, C.; Bartsch, A.; Delaloye, R.; Grosse, G.; Heim, B.; Hugelius, G.; Irrgang, A.; Kääb, A.M.; Kroisleitner, C.; Matthes, H.; Nitze, I.; Pellet, C.; Seifert, F.M.; Strozzi, T.; Wegmüller, U.; Wieczorek, M.; Wiesmann, A. (2021): ESA Permafrost Climate Change Initiative (Permafrost_cci): Permafrost version 3 data products. Centre for Environmental Data Analysis, *date of citation*. http://catalogue.ceda.ac.uk/uuid/8239d5f6263f4551bf2bd100d3ecbead

Alternative 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

- Global permafrost properties (probability and mean annual ground temperature) based on equilibrium modelling (TTOP, 2000-2016) from GlobPermafrost (https://globpermafrost.info/products-and-data-access).

Key documents

Permafrost_CCI baseline project Phase 1

Document name	Version	Issue date	Download
D1.1 User Requirements Document (URD)	2.0	Nov. 30, 2020	
D1.2 Product Specification Document (PSD)	3.0	Nov. 30, 2020	
D1.3 Data Access Requirements Document (DARD)	2.0	Dec. 22, 2020	
D2.1 Product Validation and Algorithm Selection Report (PVASR)	3.0	Feb. 24, 2021	
D2.2 Algorithm Theoretical Basis Document (ATBD)	3.0	Nov. 30, 2020	
D2.3 End-to-End ECV Uncertainty Budget (E3UB)	3.0	Feb. 24, 2021	
D2.4 Algorithm Development Plan (ADP)	3.0	Nov. 30, 2020	
D2.5 Product Validation Plan (PVP)	3.0	Dec. 22, 2020	
D3.1 System Requirement Document (SRD)	3.0	April 8, 2021	
D3.2 System Specification Document (SSD)	3.0	April 8, 2021	
D3.3 System Verification Report (SVR)	3.0	April 8, 2021	
D4.1 Product Validation and InterComparison Report (PVIR)	3.0	Sept. 30, 2021	
D4.2 Climate Research Data Package (CRDP) Version 2	2	Sept. 25, 2021	
D4.3 Product User Guide (PUG)	3.0	April 13, 2021	
D5.1 Climate Assessment Report (CAR)	3.1	Jan. 19, 2022	

Permafrost_CCI baseline project Phase 2

Future updates here

Document name	Version	Issue date	Download
D1.1 User Requirement Document (URD)	3.0	Feb. 15, 2023	
D1.2 Product Specification Document (PSD)	4.0	Feb. 15, 2023	

Permafrost Year 3 Climate Research Data Package (CRDP v2) on CEDA Archive and on the Climate Data Dashboard.

CRDPv2 includes:

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ESA Climate Office
Home > Open Data Portal
Evidence | Explore | Educate | ESA & Climate
Climate Data Dashboard
of the ESA Climate Change Initiative
Climate Data Search interface
for the ESA Climate Change Initiative
Aerosol
Cloud
Greenhouse Gases
Ozone
Ocean Colour
Sea Ice
Sea Level
Sea State
Sea Surface Salinity
Sea Surface Temperature
Water Vapour
Antarctic Ice Sheet
Above-Ground Biomass
Fire
Glaciers
Greenland Ice Sheet
Lakes
Land Cover
Land Surface Temperature
Permafrost
Snow
Soil Moisture
1980
1990
2000
2010
2020

Climate Data Dashboard

of the ESA Climate Change Initiative

Permafrost

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: 6.6 GB
Number of files: 24

Dataset Information
Product Guide
Start date:01 Jan 1997
End date:31 Dec 2019
FTP Download
Additional Download Options

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 CDRP 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 downscaled 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

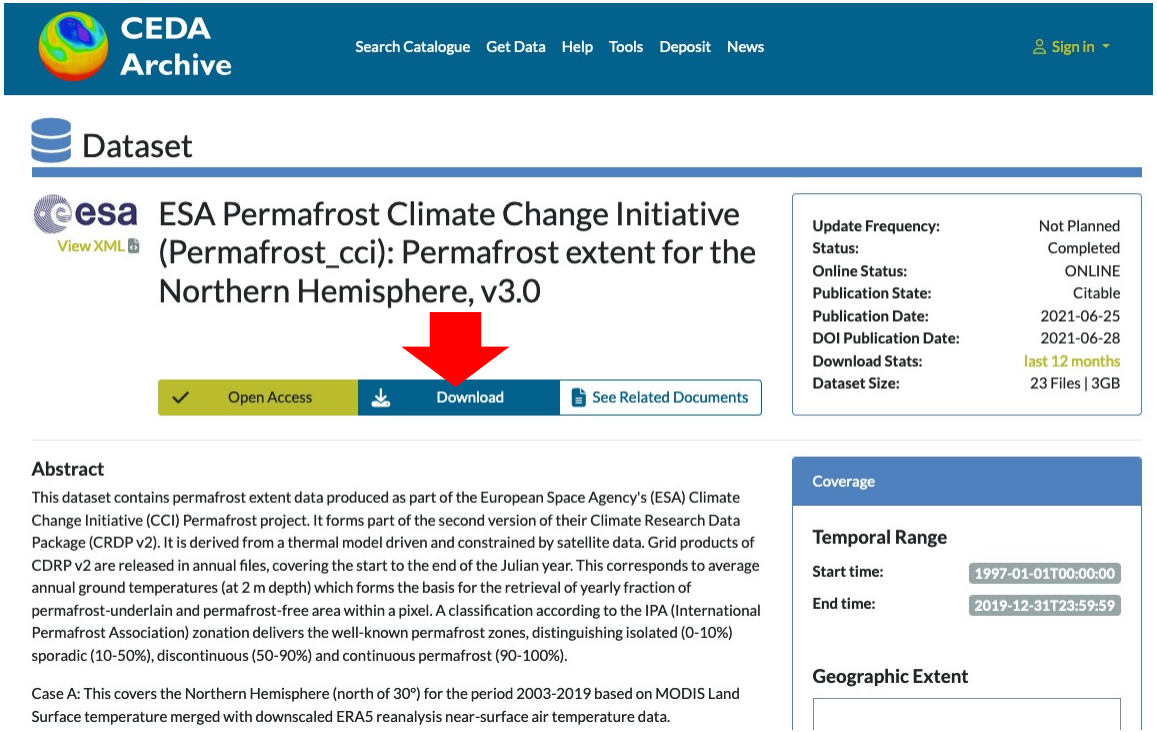
Link to CEDA

CRDP – Climate research data package

CRDPv0 is dataset v1.0

CRDPv1 is dataset v2.0

…

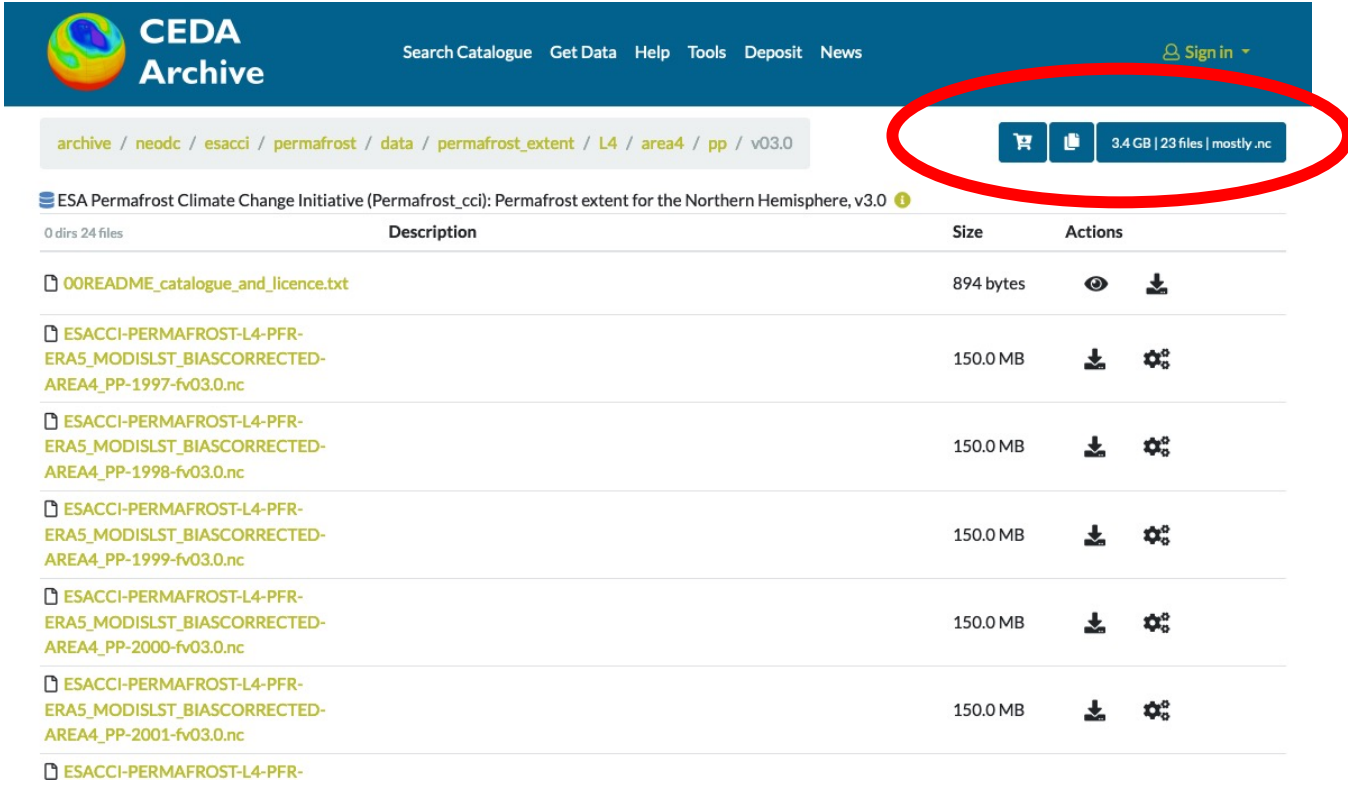


File naming

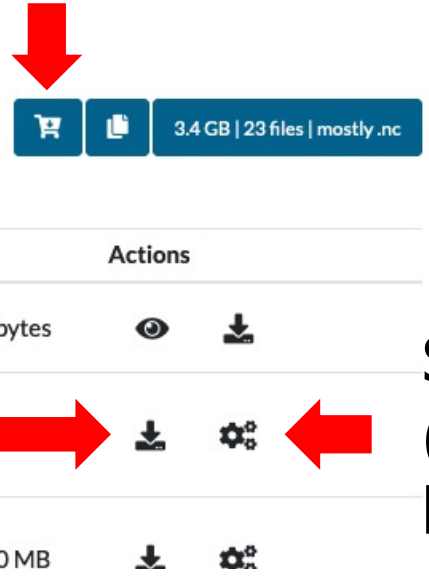
Level 4 - Data sets are created from the analysis of lower level data, resulting in gridded, gap-free products

Area 4 – Northern Hemisphere

One file – one year



Bulk download options

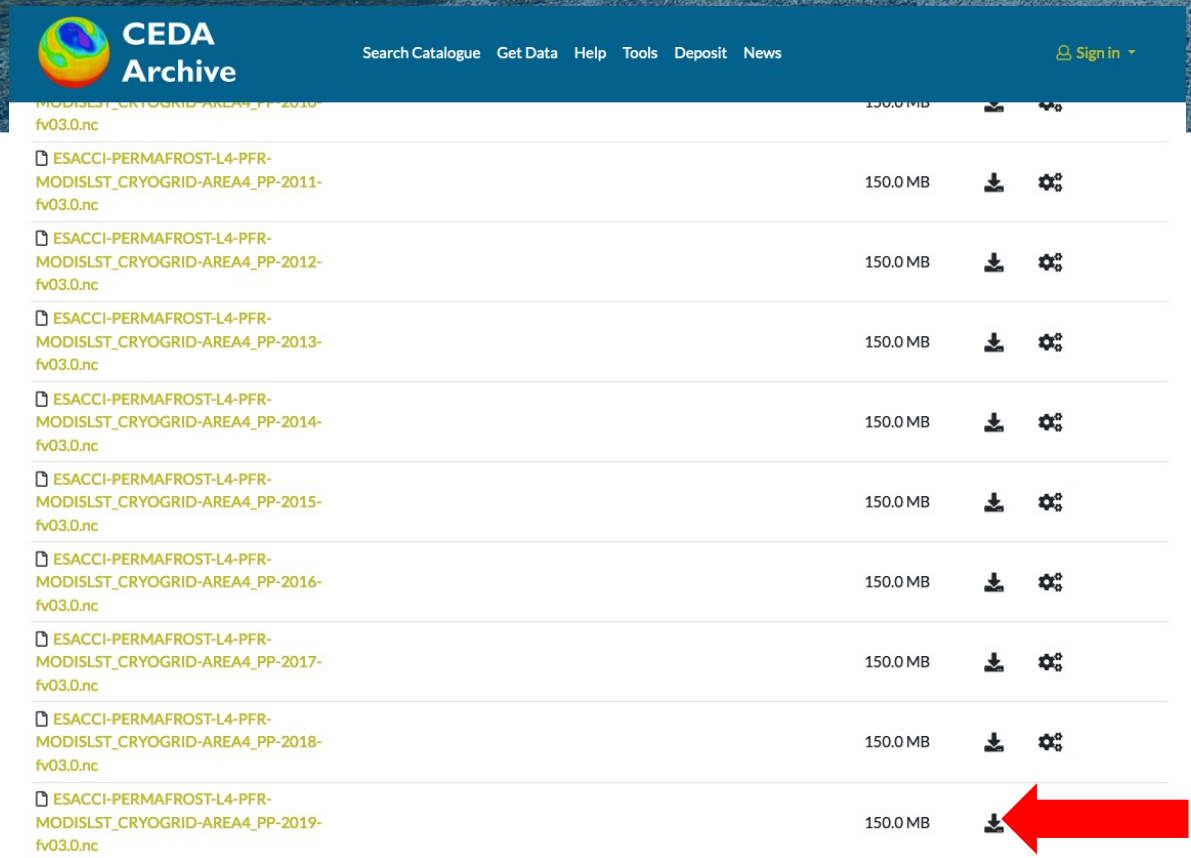


Manual download

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/ (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: `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/ 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 help page about interacting programmatically with the data
- JSON listing: Use json listing of this directory to script download.



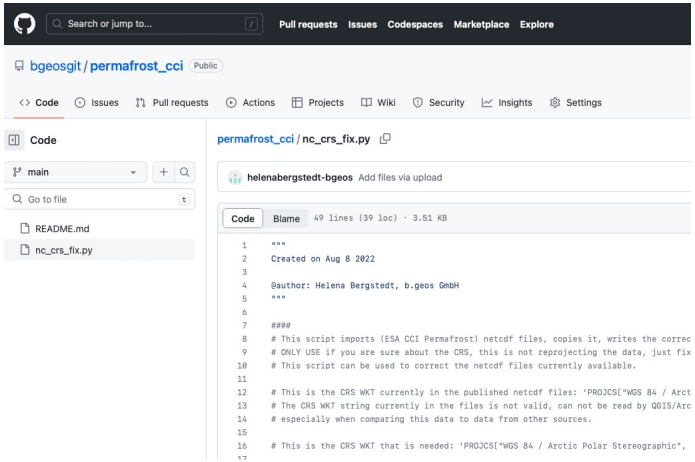
Permafrost extent

Example 1

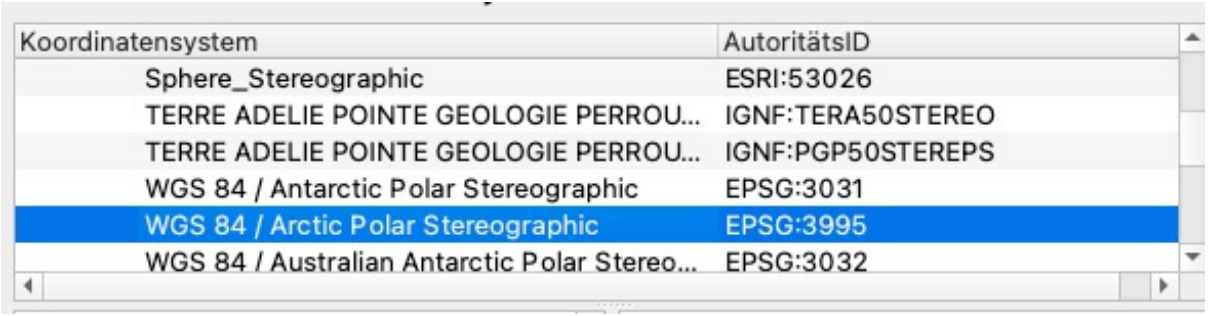
- Note, issue with NetCDF metadata projection information for all datasets in the current version on CEDA

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

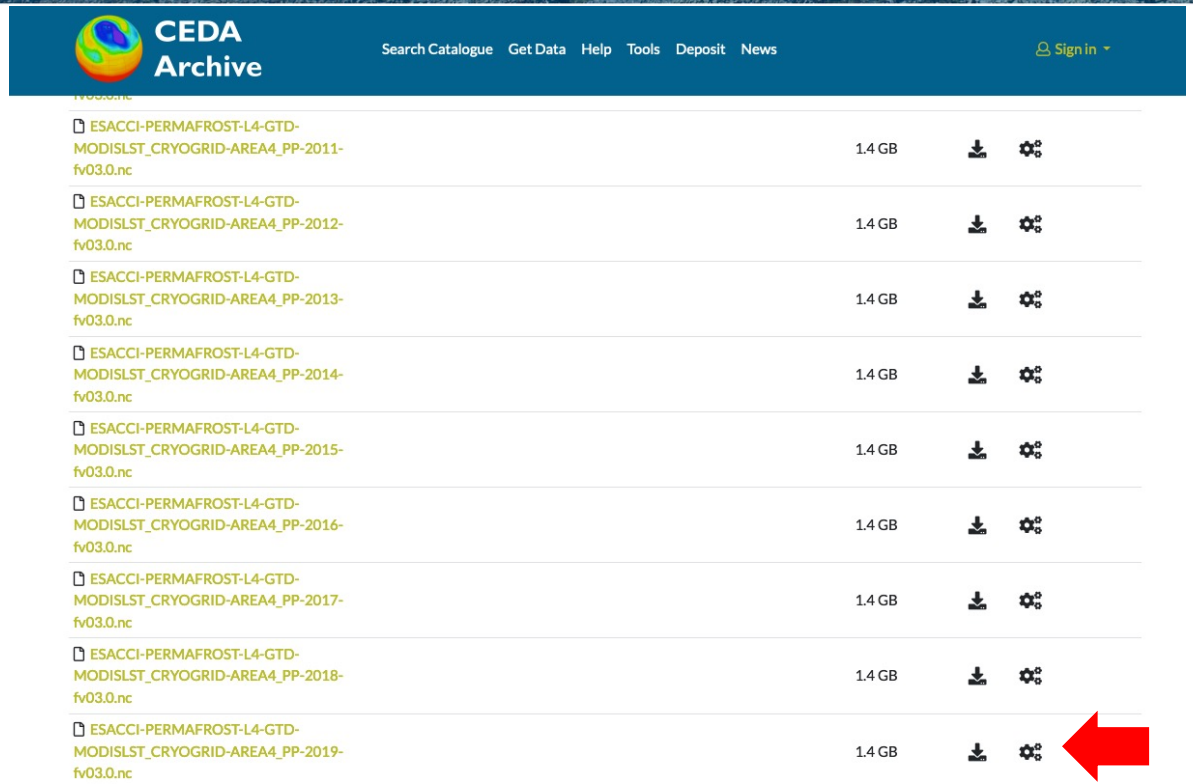
- will be solved in next upload later this year



Setting the layer coordinate system in QGIS, e.g. in version 3.12 for windows (not all versions work)



Koordinatensystem	AutoritätsID
Sphere_Stereographic	ESRI:53026
TERRE ADELIE POINTE GEOLOGIE PERROU...	IGNF:TERA50STEREO
TERRE ADELIE POINTE GEOLOGIE PERROU...	IGNF:PGP50STEREPS
WGS 84 / Antarctic Polar Stereographic	EPSG:3031
WGS 84 / Arctic Polar Stereographic	EPSG:3995
WGS 84 / Australian Antarctic Polar Stereo...	EPSG:3032


CEDA Archive
Search Catalogue
Get Data
Help
Tools
Deposit
News
Sign in
ESACCI-PERMAFROST-L4-GTD-MODISLST_CRYOGRID-AREA4_PP-2011-fv03.0.nc
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ESACCI-PERMAFROST-L4-GTD-MODISLST_CRYOGRID-AREA4_PP-2016-fv03.0.nc
1.4 GB
ESACCI-PERMAFROST-L4-GTD-MODISLST_CRYOGRID-AREA4_PP-2017-fv03.0.nc
1.4 GB
ESACCI-PERMAFROST-L4-GTD-MODISLST_CRYOGRID-AREA4_PP-2018-fv03.0.nc
1.4 GB
ESACCI-PERMAFROST-L4-GTD-MODISLST_CRYOGRID-AREA4_PP-2019-fv03.0.nc
1.4 GB

Example 2

OPeNDAP Dataset Access Form

Action: Get ASCII | Get Binary | Show Help

Data URL: http://dap.ceda.ac.uk/thredds/dodsC/neodc/esacci/permafrost/data/ground_temperature/L4

Global Attributes:

```
title: CCI Permafrost ground temperature
institution: University of Oslo
source: MODIS MOD11A1 and MYD11A1 level 3 Collection 6, ESA CCI Land
Cover dataset v1.6.1, ERA5 Reanalysis
history: 2021-02-24 11:21:13
```

Variables:

polar_stereographic: 32 bit Integer

polar_stereographic =

```
grid_mapping_name: polar_stereographic
straight_vertical_longitude_from_pole: 0.0
false_easting: 0.0
false_northing: 0.0
latitude_of_projection_origin: 90.0
```

x: Array of 64 bit Reals [x = 0..14761]

x:

```
standard_name: projection_x_coordinate
long_name: x coordinate of projection
units: m
axis: X
actual_range: -6111938.535111316, 7566906.108876757
```

y: Array of 64 bit Reals [y = 0..10352]

y:

```
standard_name: projection_y_coordinate
long_name: y coordinate of projection
units: m
axis: Y
actual_range: -5477994.701867972, 4115358.40741319
```

time: Array of 64 bit Reals [time = 0..0]

time:

```
axis: T
standard_name: time
long_name: time
calendar: standard
units: hours since 1950-01-01 00:00:00
```

GST: Grid

time: y: x:

```
standard_name: surface_temperature
grid_mapping: polar_stereographic
```

Resolution is 927m!

T2m: Grid

time: 0:1:0 y: 2282:1:2282 x: 5516:1:5516

```
standard_name: solid_earth_subsurface_temperature
grid_mapping: polar_stereographic
units: degrees celsius
conversion: to degrees celsius  x*0.01-273.15
scale_factor: 0.01
```

X -1.000.000
Y 2.000.000

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

Grid
X 5516
Y 2282
-> 'get ASCII'

OPeNDAP Dataset Access Form

Action: Get ASCII | Get Binary | Show Help

Data URL: http://dap.ceda.ac.uk/thredds/dodsC/neodc/esacci/permafrost/data/ground_temperature/L·

Global Attributes:

```
title: CCI Permafrost ground temperature
institution: University of Oslo
source: MODIS MOD11A1 and MYD11A1 level 3 Collection 6, ESA CCI Land
Cover dataset v1.6.1, ERA5 Reanalysis
history: 2021-02-24 11:21:13
```

Variables:

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```
grid_mapping_name: polar_stereographic
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false_northing: 0.0
latitude_of_projection_origin: 90.0
```

x: Array of 64 bit Reals [x = 0..14761]

x:

```
standard_name: projection_x_coordinate
long_name: x coordinate of projection
units: m
axis: X
actual_range: -6111938.535111316, 7566906.108876757
```

y: Array of 64 bit Reals [y = 0..10352]

y:

```
standard_name: projection_y_coordinate
long_name: y coordinate of projection
units: m
axis: Y
actual_range: -5477994.701867972, 4115358.40741319
```

time: Array of 64 bit Reals [time = 0..0]

time:

```
axis: T
standard_name: time
long_name: time
calendar: standard
units: hours since 1950-01-01 00:00:00
```

GST: Grid

time: y: x:

```
standard_name: surface_temperature
grid_mapping: polar_stereographic
```

Resolution is 927m!

T2m: Grid

time: 0:1:0 y: 2282:1:2282 x: 5516:1:5516

```
standard_name: solid_earth_subsurface_temperature
grid_mapping: polar_stereographic
units: degrees celsius
conversion: to degrees celsius x*0.01-273.15
scale_factor: 0.01
```

```
T2m.T2m[1][1][1]
[0][0], 26900
```

=-4.15° C

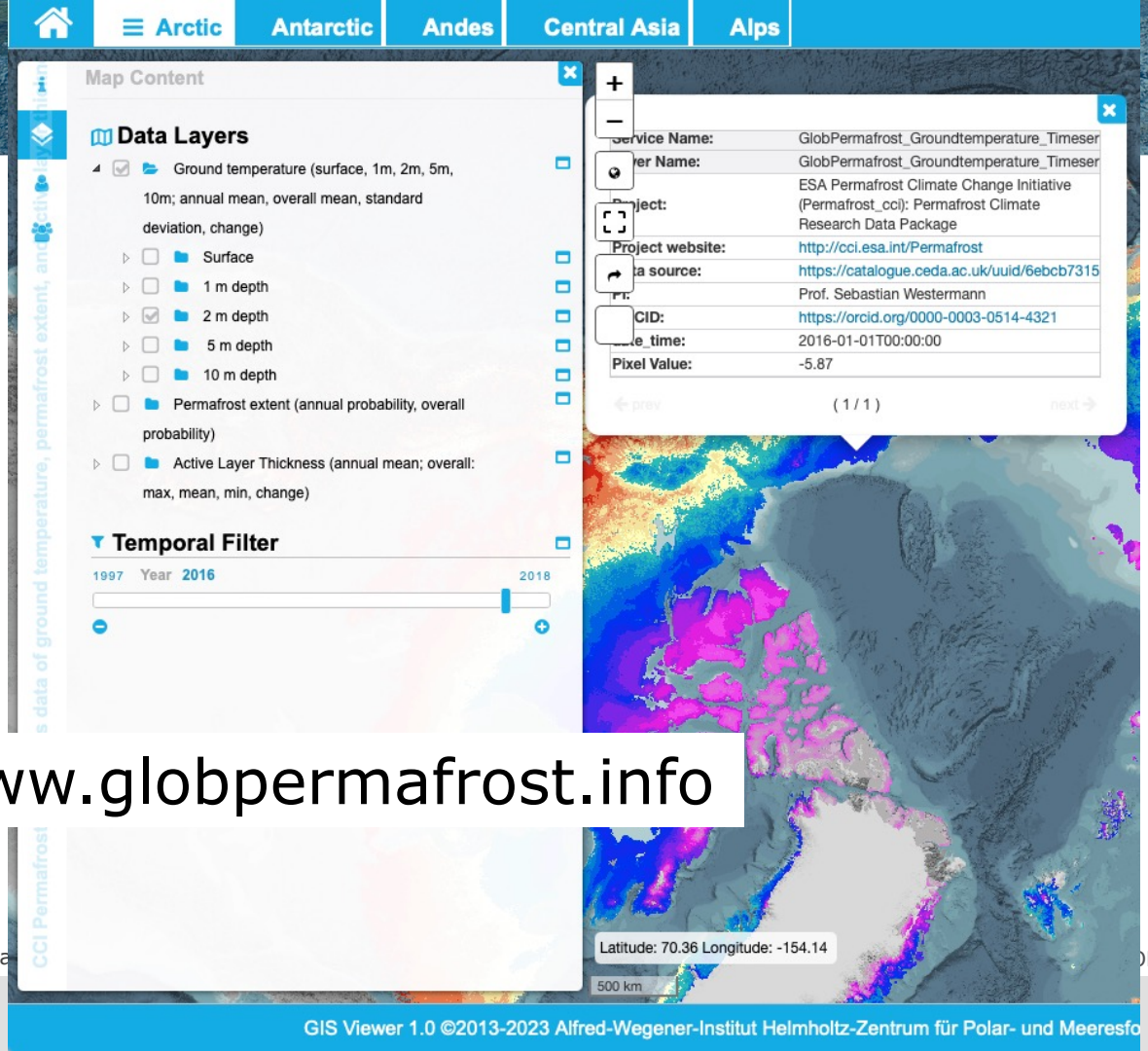
```
T2m.time[1]
604848.0

T2m.y[1]
2000335.8562749452

T2m.x[1]
-1000209.3332037004
```

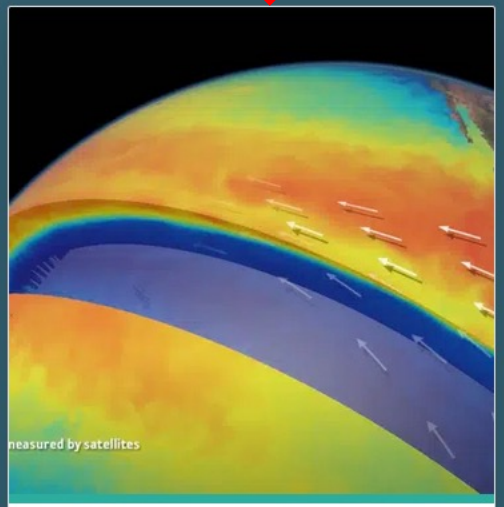
CRDPv1

(ends 2018)



e.g. via www.globpermafrost.info


ESA Climate Office
Home > Open Data Portal
Evidence | Explore | Educate | ESA & Climate
Climate Data Dashboard
of the ESA Climate Change Initiative
Climate Data Search interface
for the ESA Climate Change Initiative
Aerosol
Cloud
Greenhouse Gases
Ozone
Ocean Colour
Sea Ice
Sea Level
Sea State
Sea Surface Salinity
Sea Surface Temperature
Water Vapour
Antarctic Ice Sheet
Above-Ground Biomass
Fire
Glaciers
Greenland Ice Sheet
Lakes
Land Cover
Land Surface Temperature
Permafrost
Snow
Soil Moisture
1980
1990
2000
2010
2020



Climate from Space - interactive application

Explore the changing climate through the eyes of satellites with this interactive app

Learn more

Explore Climate Data

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

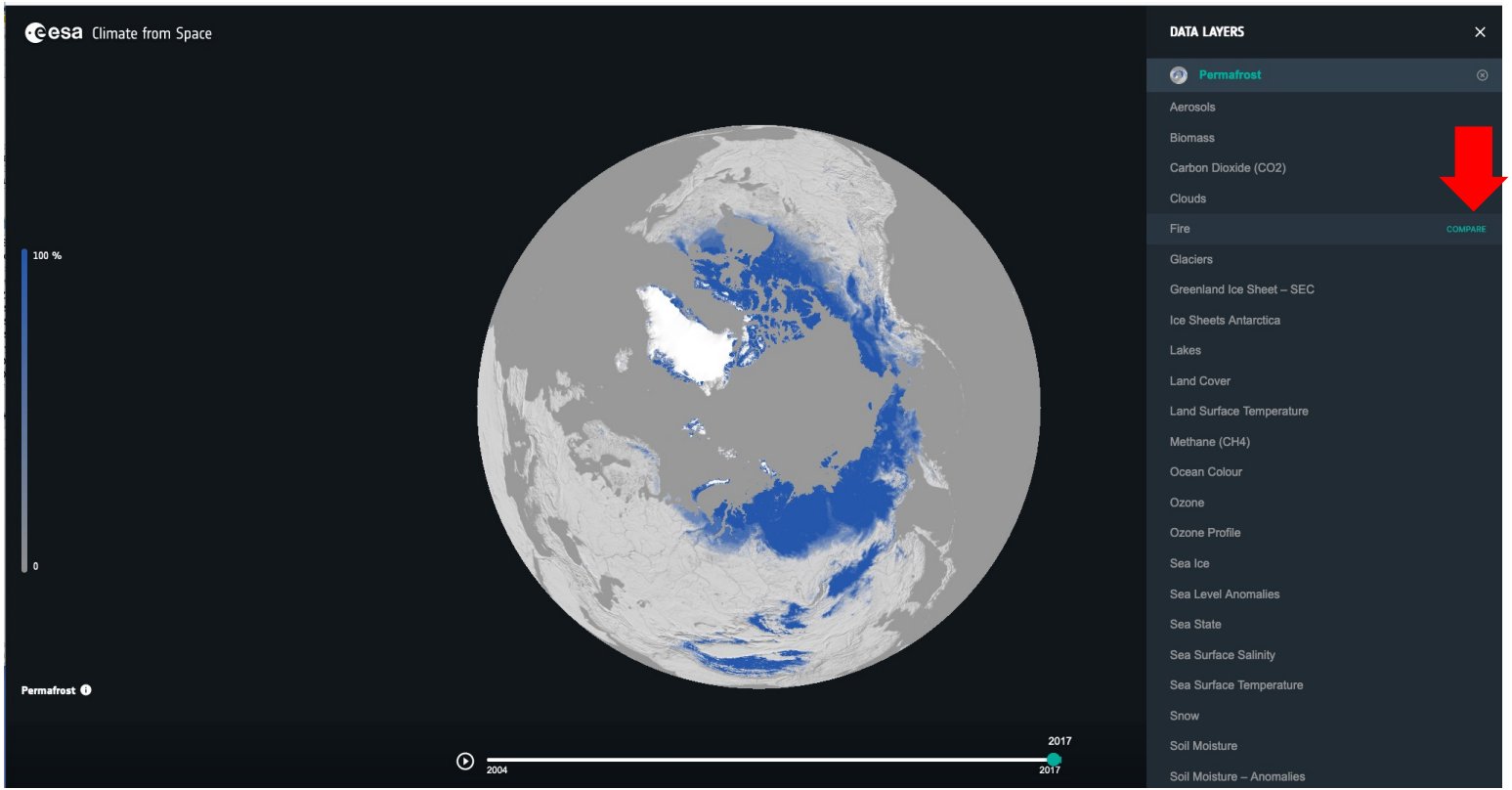
Learn more

CCI Open Data Portal

Free and open access to all CCI Essential Climate Variable data products

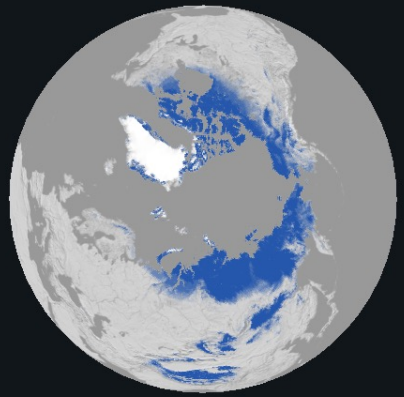
Learn more

CCI portal – Climate from Space

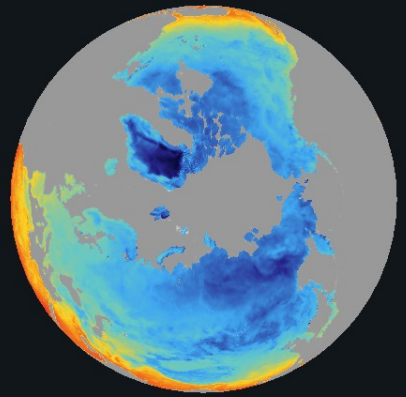


esa Climate from Space

Stories Data Layers



Permafrost



Land Surface Temperature

2017
1996
2020
January 2017

2D

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:

Obu, J.; Westermann, S.; Barboux, C.; Bartsch, A.; Delaloye, R.; Grosse, G.; Heim, B.; Hugelius, G.; Irrgang, A.; Kääb, A.M.; Kroisleitner, C.; Matthes, H.; Nitze, I.; Pellet, C.; Seifert, F.M.; Strozzi, T.; Wegmüller, U.; Wieczorek, M.; Wiesmann, A. (2021): ESA Permafrost Climate Change Initiative (Permafrost_cci): Permafrost version 3 data products. Centre for Environmental Data Analysis, *date of citation*. http://catalogue.ceda.ac.uk/uuid/8239d5f6263f4551bf2bd100d3ecbead

Alternative 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

- Global permafrost properties (probability and mean annual ground temperature) based on equilibrium modelling (TTOP, 2000-2016) from GlobPermafrost (https://globpermafrost.info/products-and-data-access).