ESA CCI+ Phase 2 user workshop 4th June 2025

climate change initiative

PERMAFROST

Validation of Permafrost_cci II products using international and national monitoring networks

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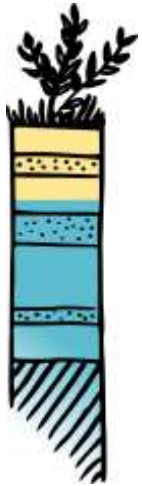
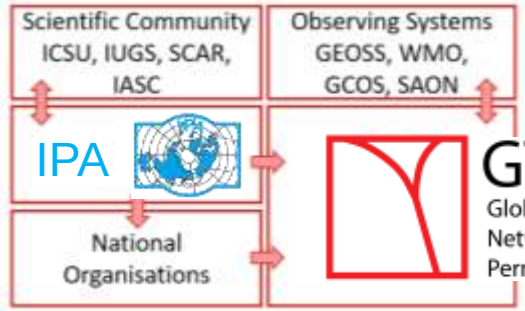
7 BGEOS, Vienna, Austria

permafrost cci

Permafrost: What is measured in-situ?





GCOS GTN-P / IPA + PERMOS (CH)

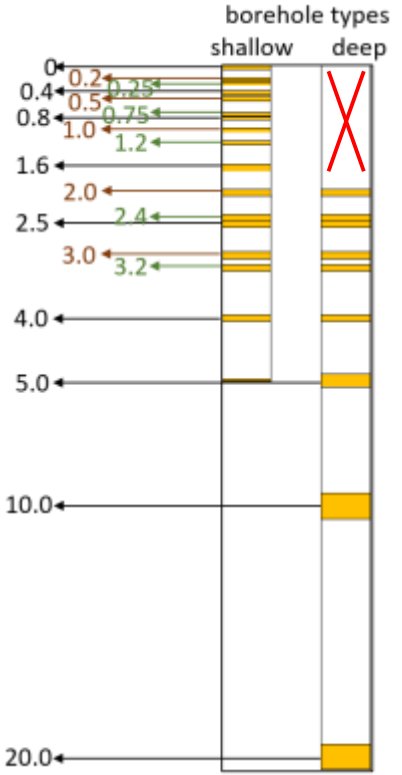
+ national & thematic monitoring networks

Ground that is at or below 0° C MAGT for at least 2 consecutive years

ECVs: Permafrost Temperature (PT), Active Layer Thickness (ALT), Rock Glacier Velocity (RGV)

Data Repositories

Ground Temperature GT Reference Data



Permafrost_cci GTD depth

Permafrost_ cci Ground Temperature per Depth (GTD) = Mean Annual GT (MAGT)

0 m

1 m

2 m

5 m

10 m

Permafrost_cci GTD time series at 0.0, 1.0, 2.0, 5.0, 10 m depth

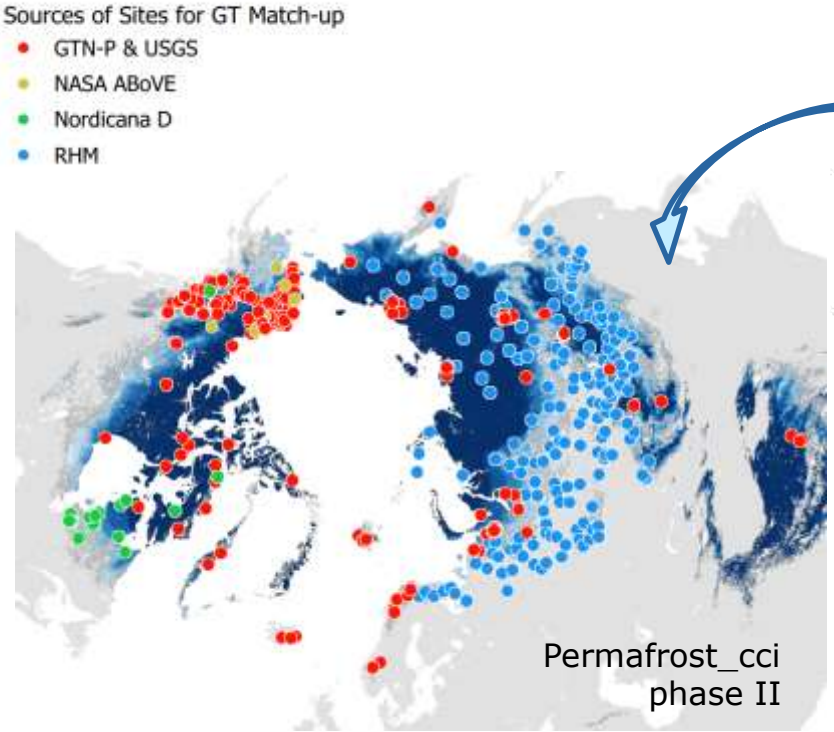
Permafrost_cci reference data collection for match-up analyses = in-situ MAGT time series from 1997 on

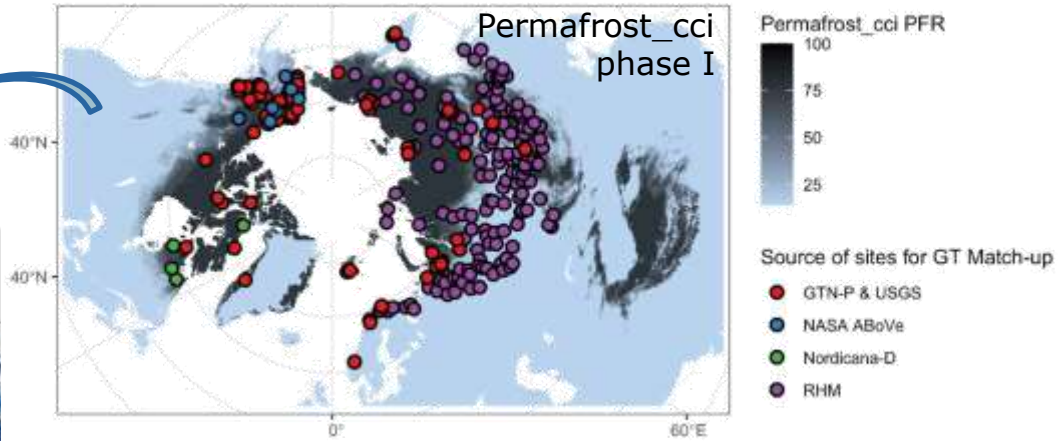
different depths per measurement programs, complemented by interpolation (depending on depth resolution)
Permafrost_cci product team simulates **GTD for all depths** to enable validation across all available in-situ depths

n = 13,614 match-up pairs (in time and depth) for 477 sites (1997 to 2021)
n = 27,389 match-up pairs for 477 sites for the interpolated dataset

Permafrost_cci standardised MAGT reference data FAIR Data Publication in PANGAEA (in submission)
ESSD manuscript (in preparation)

Ground Temperature GT Reference Data

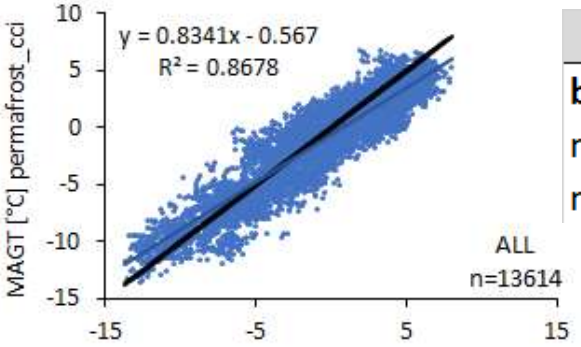




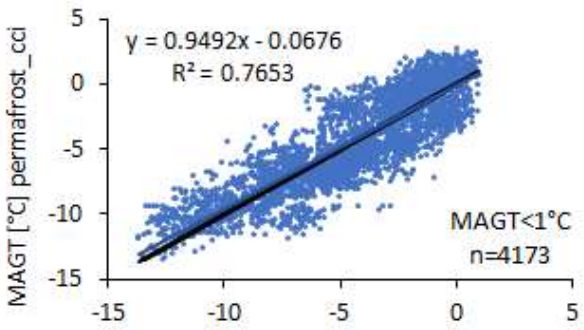
possible due to user feedback on Permafrost_cci workshops:

- additional GT depths for validation: 0.1 m + 1.50 m
- additional in-situ GT and ALT sites
  boreal North America (Alaska, Canada)

Assessment of Permafrost_cci GTDv4



	all	<1°C
bias		
mean±SD	-0.73 ± 1.55	0.15 ± 1.78
median	-0.89	0.38



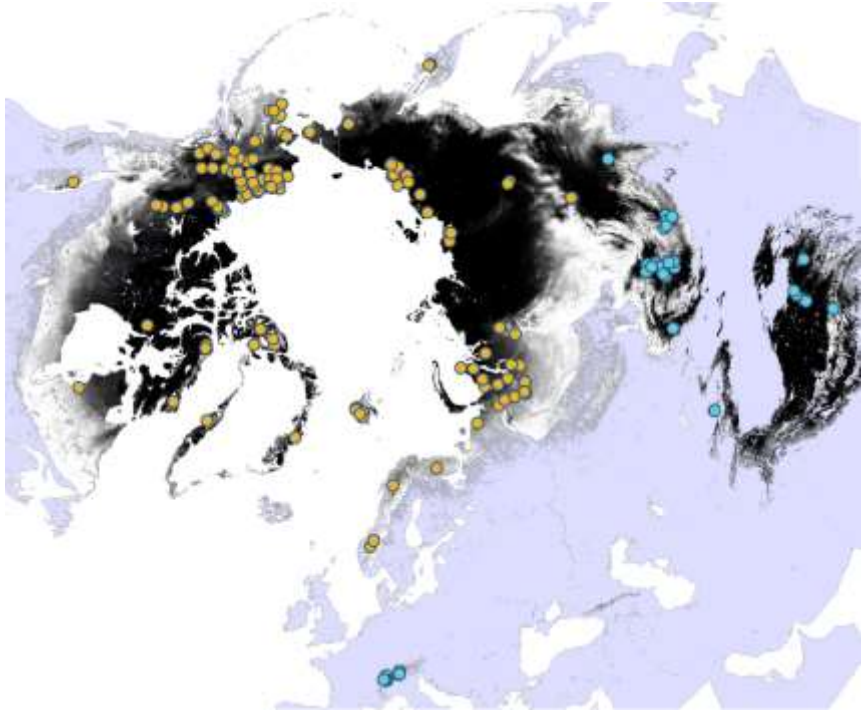
‚permafrost' = MAGT < 1°C

GTD median bias **-0.89 °C**, for ‚cold sites' GTD median bias is lower: **0.38 °C**.

without the surface temperature the quality is high with a **mean bias of 0.08 °C** for permafrost sites

stable GTD bias across depths with a larger negative mean bias in shallow depths (0 to 3m),
mainly caused by a negative bias in match-up pairs of the ‚non permafrost sites' (MAGT >= 1°C).

Active Layer Thickness ALT Reference Data

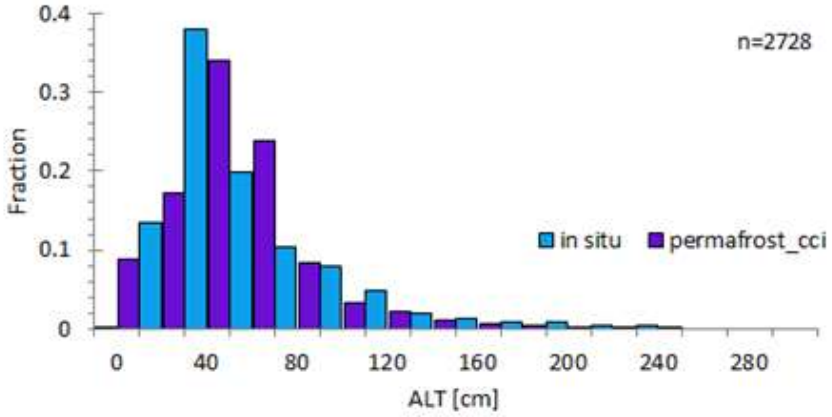


CALM

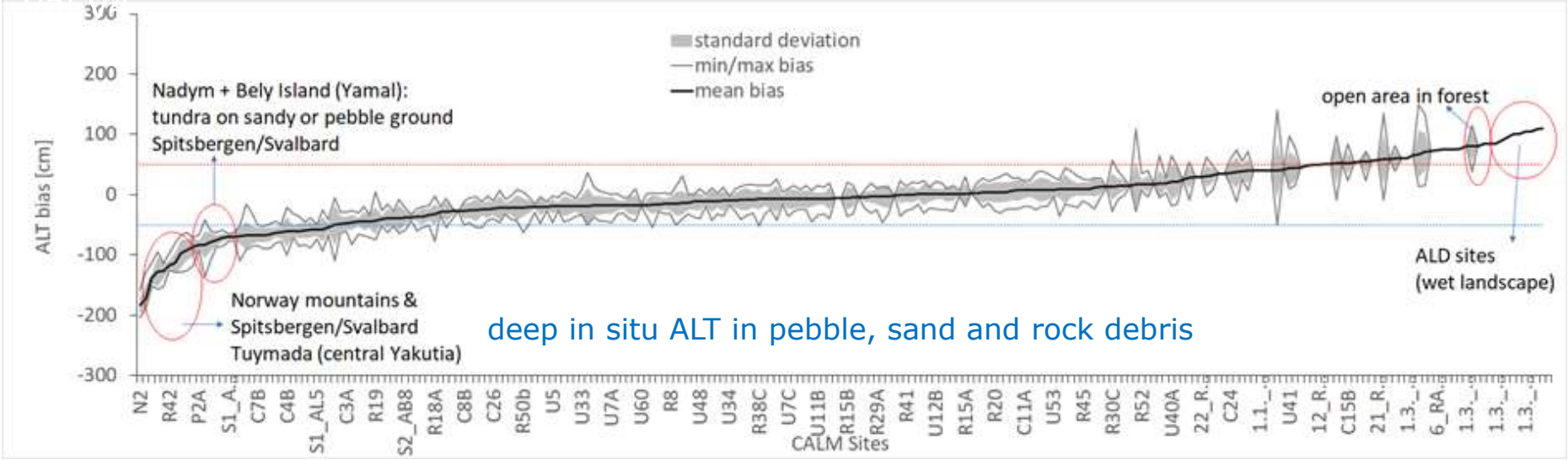
ALT sites for Match-Up analyses
- Region used or validation
- Region excluded from validation

Permafrost_cci PFR (year 2021)
100
0

both Permafrost_cci ALT and in-situ ALT show highest abundance in shallow ALT



Assessment of Permafrost_cci ALTv4

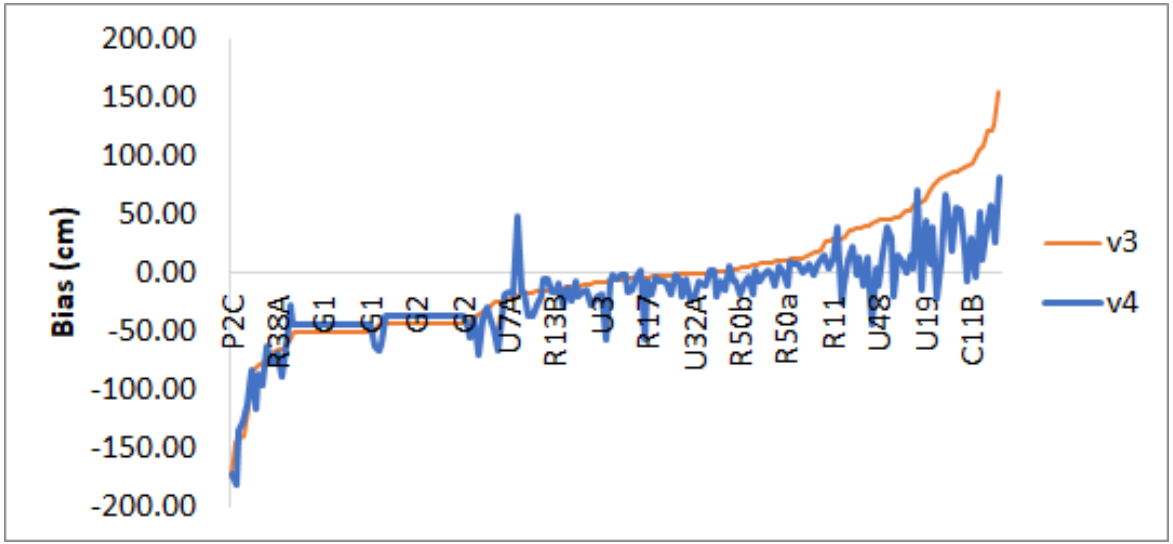


mean bias (Mongolia, China, Swiss Mountains excl.). x-Axis sorted by mean bias.

blue line = bias - 50 cm (Permafrost cci ALT too shallow)

red line = bias + 50 cm (Permafrost_cci ALT too deep).

Active Layer Thickness ALT Improvements phase II vs I



	bias		abs_bias	
Permafrost_cci	I	II	I	II
Canada	19.12	-18.68	55.17	45.33
Greenland	-44.70	-39.37	44.70	39.37
Svalbard	-119.05	-111.23	119.05	111.23
Russia	-7.29	-21.88	28.09	30.30
US	10.53	-2.75	23.33	19.82

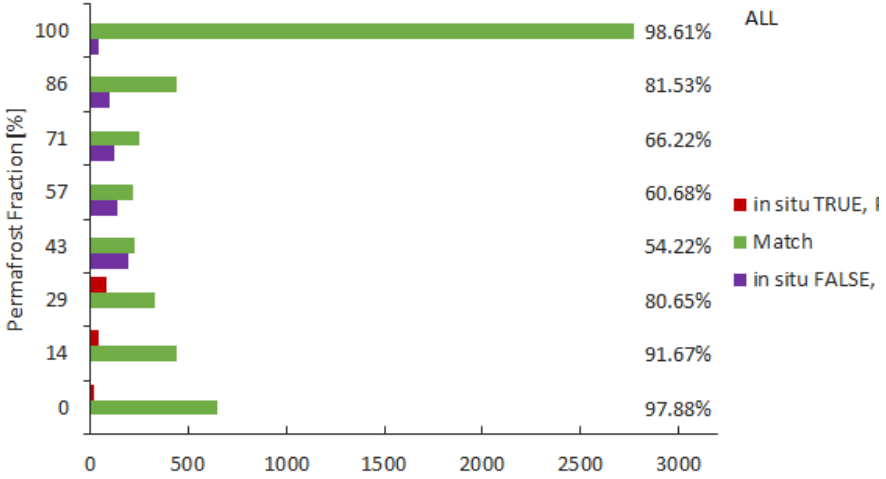
only sites available in both validation rounds are used for the comparison

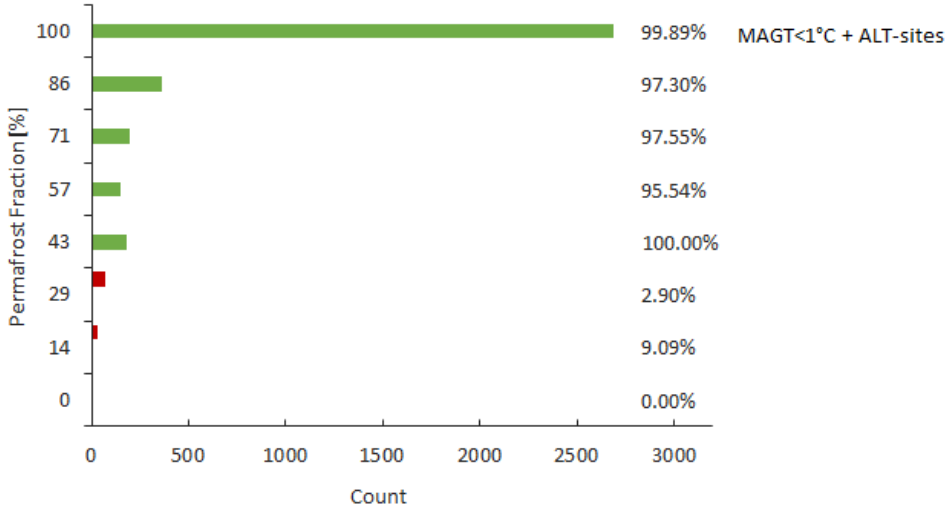
mean bias (Mongolia, China, Swiss Mountains excl.). x-Axis sorted by phase I mean bias.

blue line = phase II bias, orange line = phase I sorted bias

Permafrost Fraction PFRv4

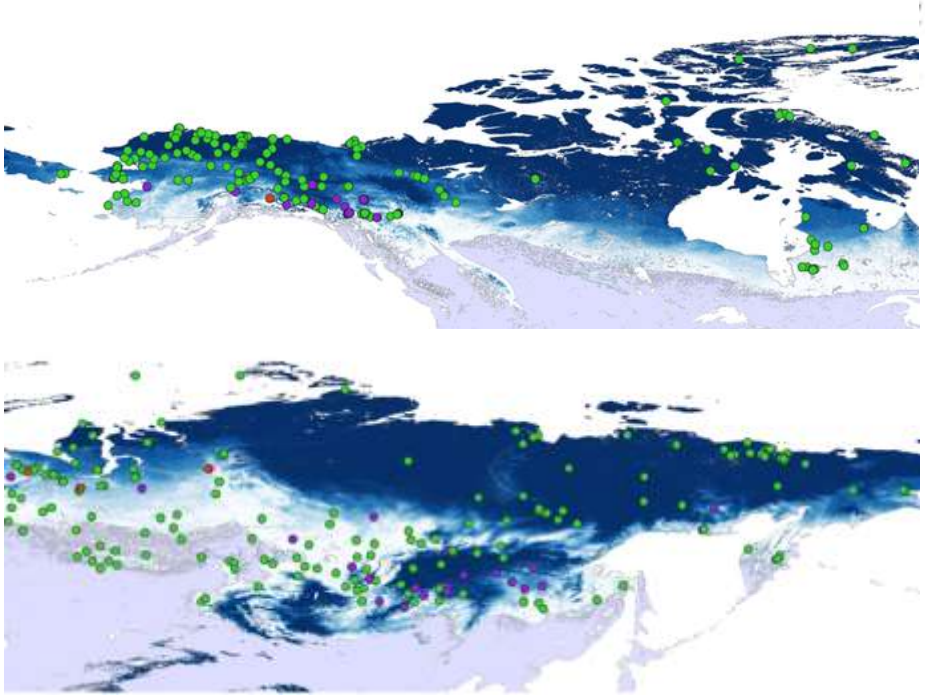
agreement of non permafrost for PFR<= 29 % and permafrost for PFR >=71%





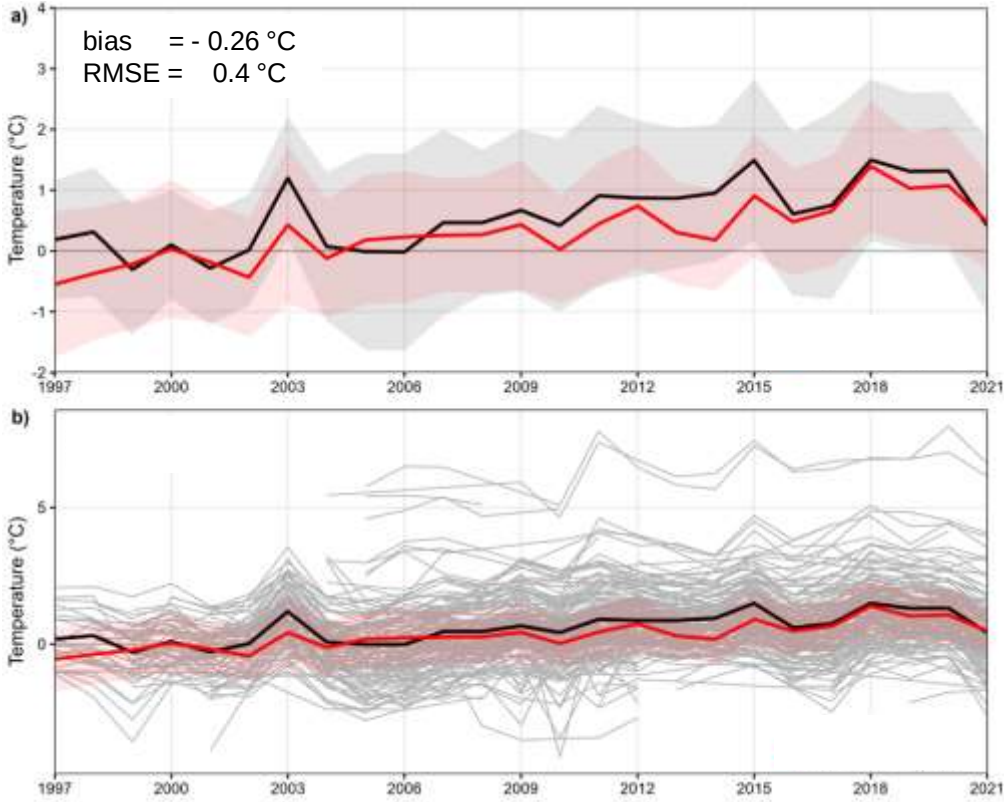
TRUE: PFR > 40 % AND (IN SITU MAGT (2 m depth)< 0.5°C AND/OR ALT)

Permafrost Fraction PFRv4



majority of PFR match-up pairs
(83.89 % PFR <=14 % and 87.99 % for PFR <= 29 %)
is in agreement between in-situ vs. Permafrost_cci abundance yes / no.
notably, the **100 % and the 0 % Permafrost_cci PFR show high percentage of agreement, with 98.61 % and 97.88 % match**.

PERMOS Assessment of Permafrost_cci GTDv4



Permafrost_cci GTD 1997 - 2021
PERMOS permafrost monitoring

a) Swiss Alps mean MAGSurfaceT (black)
b) MAGSurfaceT at each logger

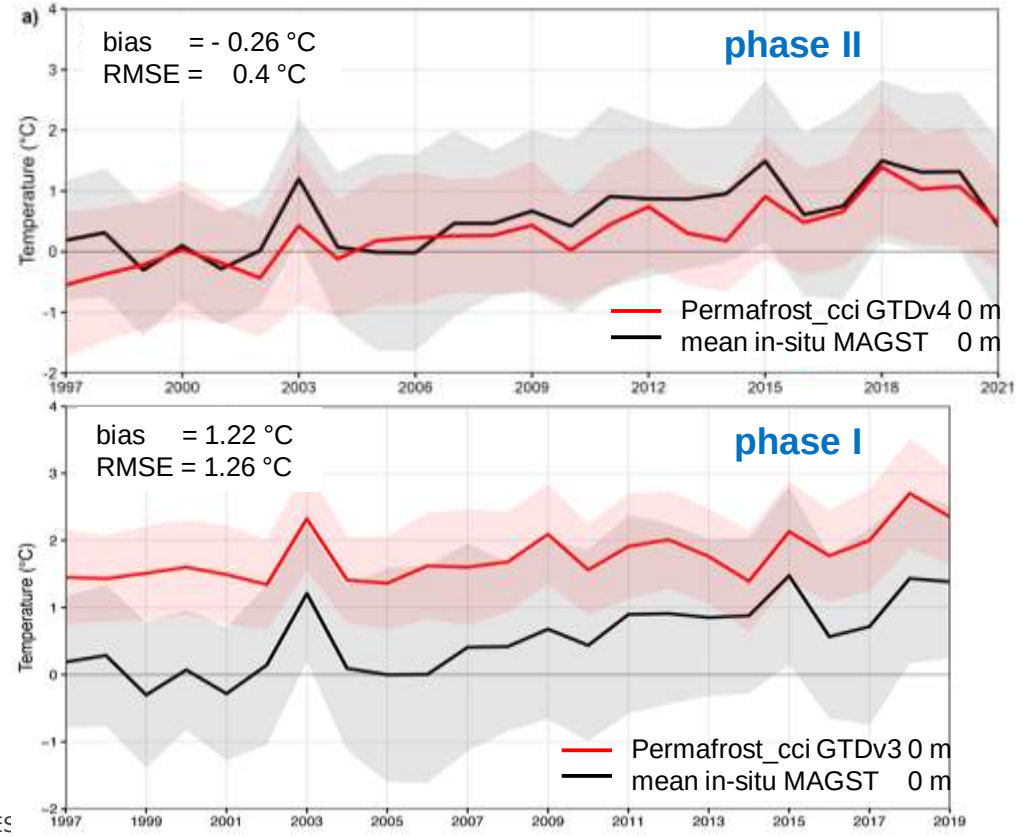
compared to **mean Permafrost_cci GTD at 0 m** (red) over the entire Swiss Alps between 2500 and 3000 m a.s.l. (shaded ± sdv.)

Permafrost_cci GTD 0 m cold bias -0.27 °C

Warming tendency observed in-situ well reproduced by Permafrost_cci GTDv4, as well as the inter-annual variability

- Permafrost_cci GTD 0 m
- in-situ MAGST/ site 0 m
- mean in-situ MAGST 0 m

PERMOS Assessment of Permafrost_cci GTDv4



Permafrost_cci GTD 1997 - 2021
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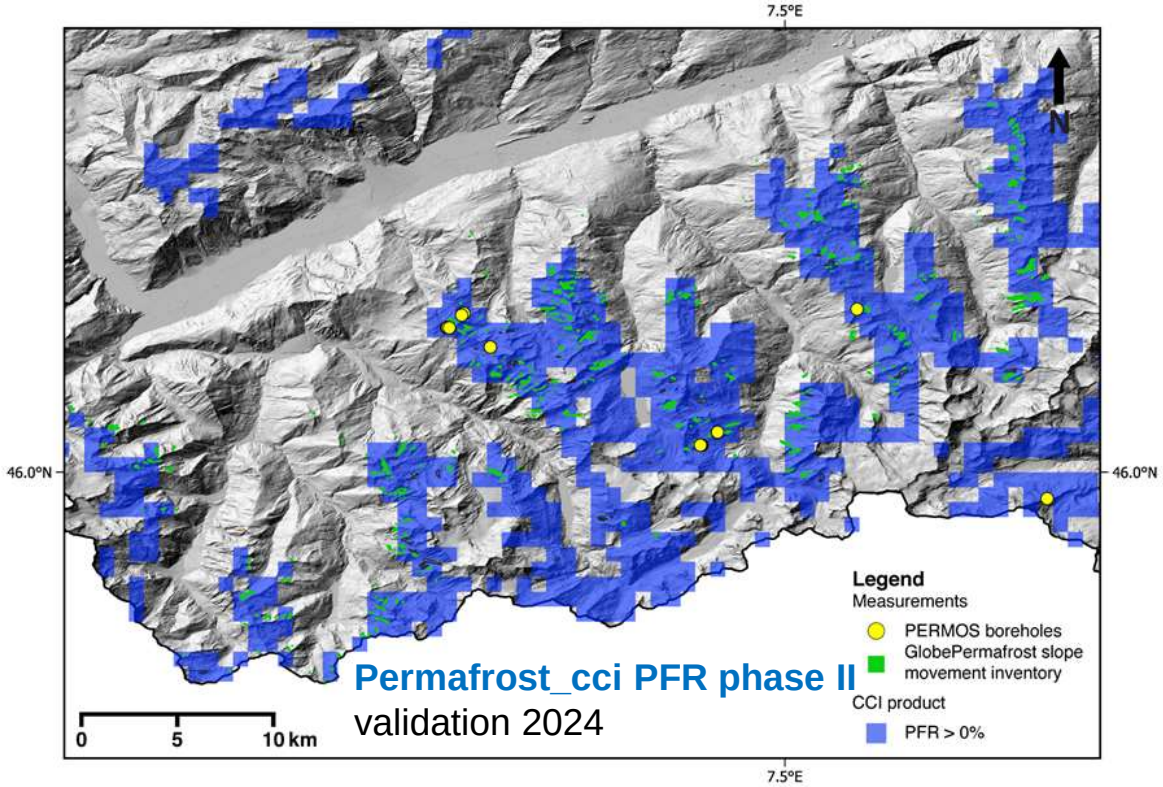
Permafrost_cci GTD phase II considerably better performance compared to phase I

warm bias +1.22°C became a slight cold bias -0.26°C

PERMOS Assessment of Permafrost_cci PFRv4

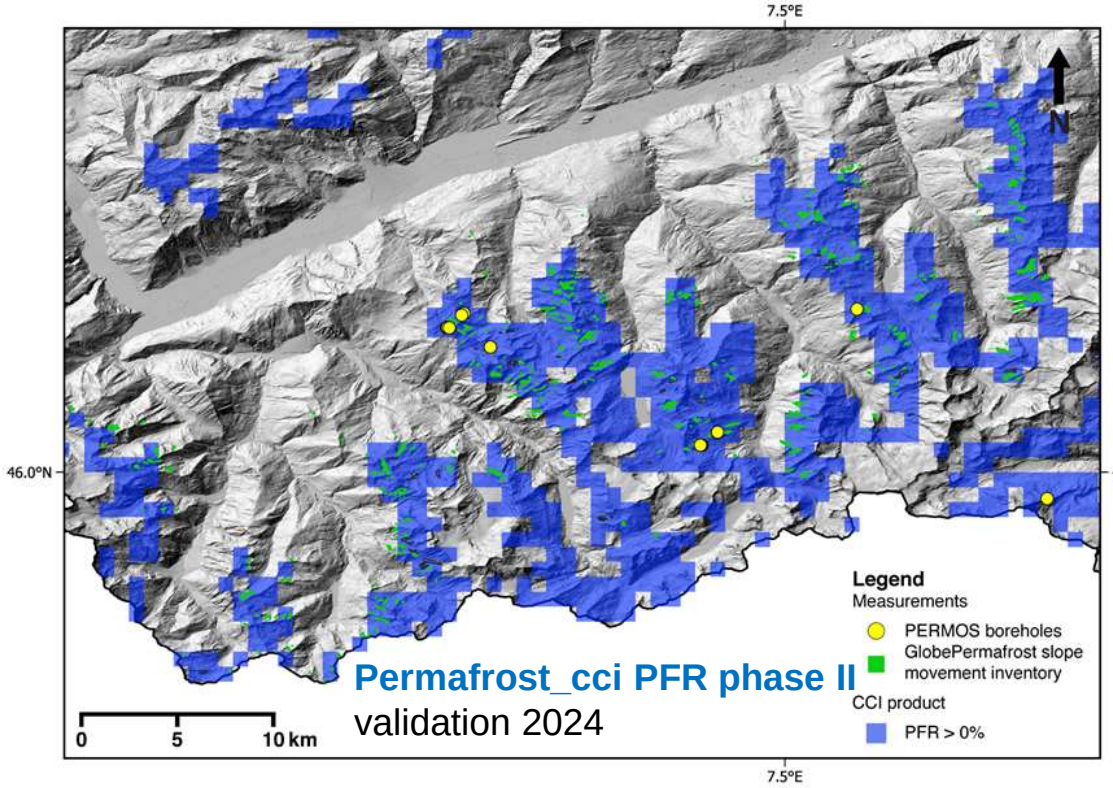


Permafrost_cci PFR 2021
Bas-Valais (CH)

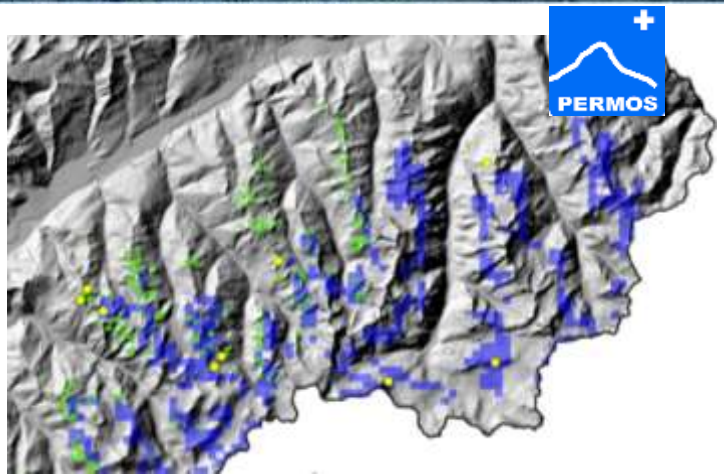
ESA GlobPermafrost slope movement inventory
(rock glaciers, push moraines)

PERMOS permafrost monitoring boreholes
11 from 12 PERMOS permafrost boreholes in permafrost
only one permafrost borehole incorrectly not in permafrost

PERMOS Assessment of Permafrost_cci PFR



Permafrost_cci PFR phase II
validation 2024



Permafrost_cci PFR phase I
validation 2021
majority of slope movement and PERMOS permafrost boreholes outside permafrost