Characterizing lowland permafrost mires in Sub-artic Sweden

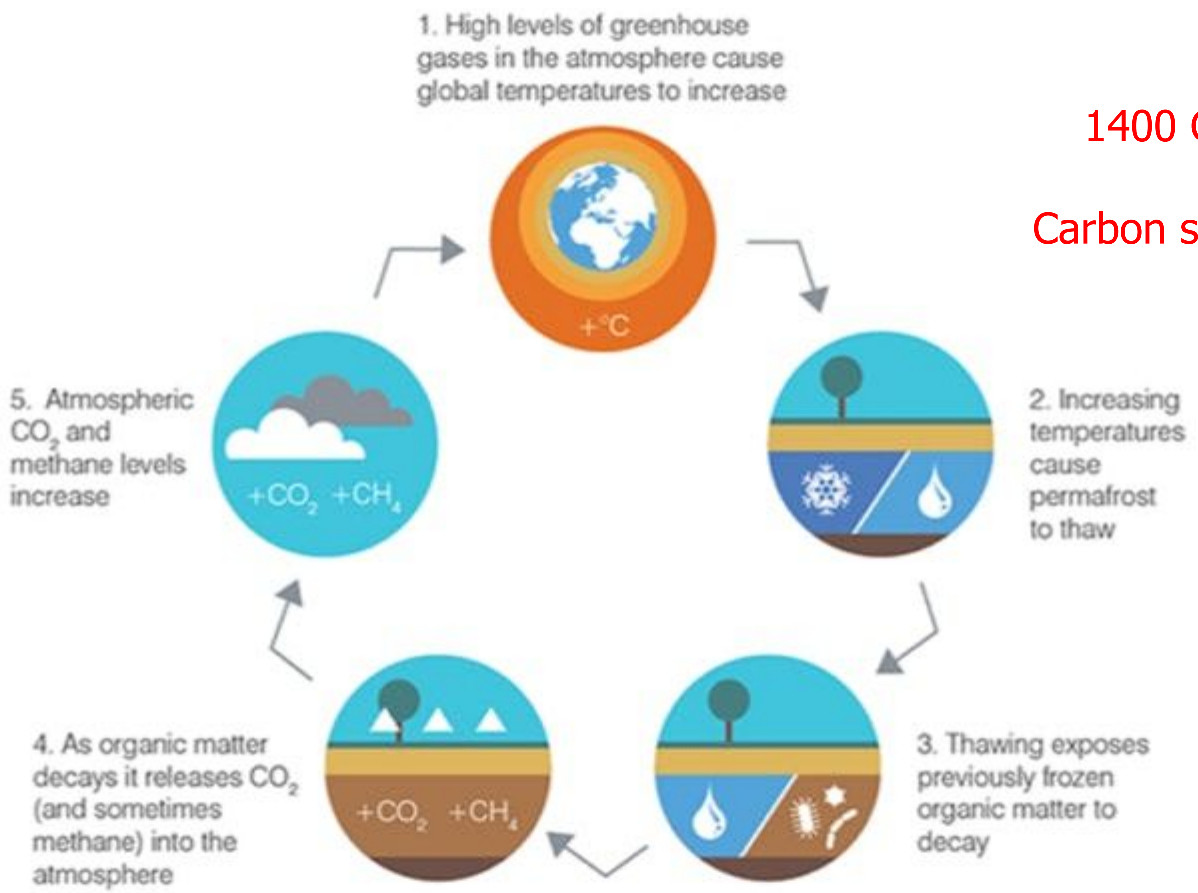
Motivation – „Gateway to the underworld“

The crater appeared in the 1960s after forest in the area was cleared.

Increasing 12 – 14 m in diameter per year

Source: https://www.themoscowtimes.com/2020/08/04/siberias-gateway-to-the-underworld-expands-amid-record-smashing-heat-wave-a71055

Motivation – Co_2 and methane emissions



1400 Gigatons of Frozen carbon!

Carbon source instead of carbon sink?

Source: https://www.thearcticinstitute.org/wp-content/uploads/2021/02/Permafrost-positive-feedback-loop.jpg

Motivation – Impacts of permafrost degradation on infrastructure

Source: Hjort, Jan, et al. (2022)

Land subsidence

30–50% of the critical circumpolar infrastructure is thought to be at high risk by 2050

Motivation – Permafrost degradation in the Abisko region

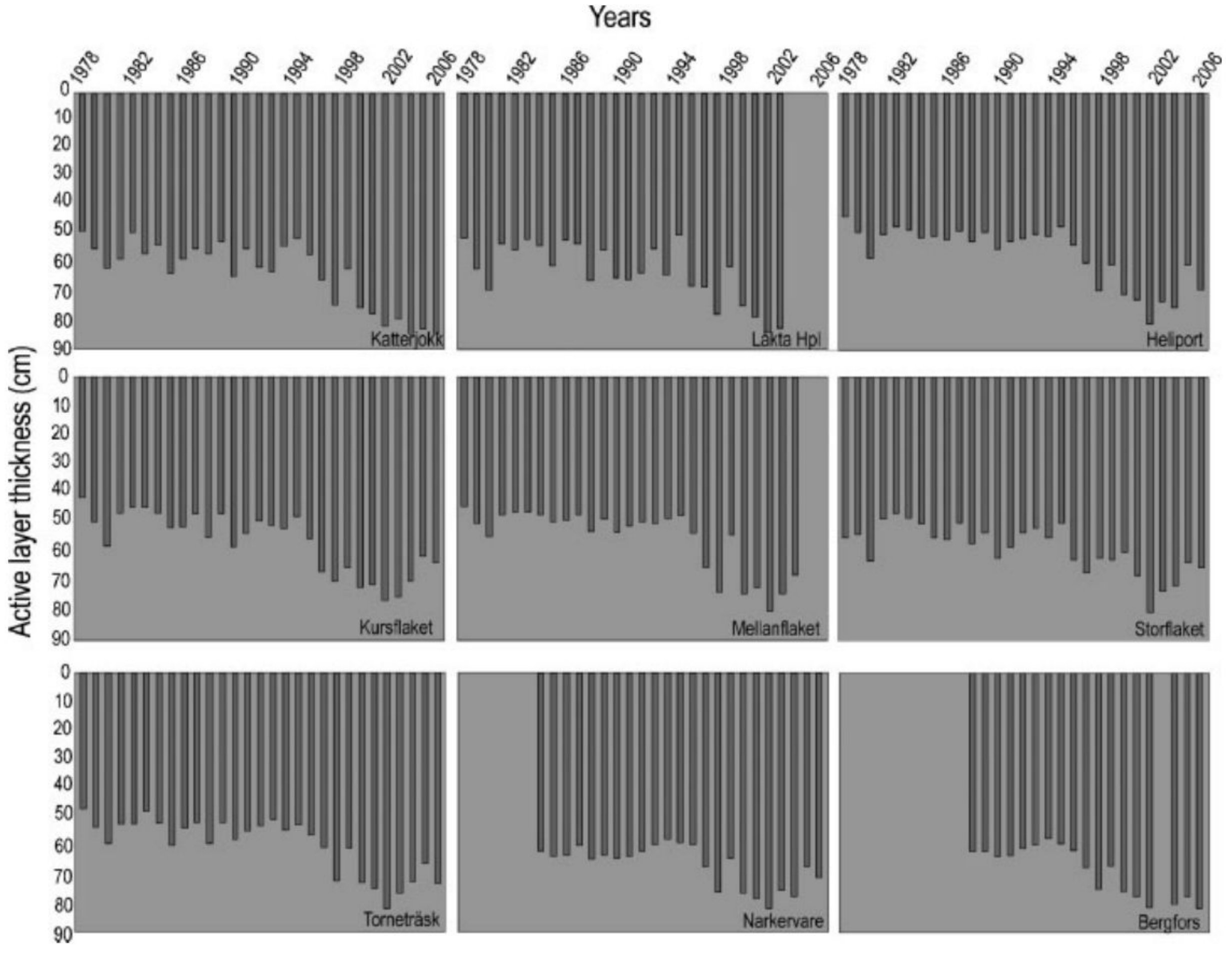


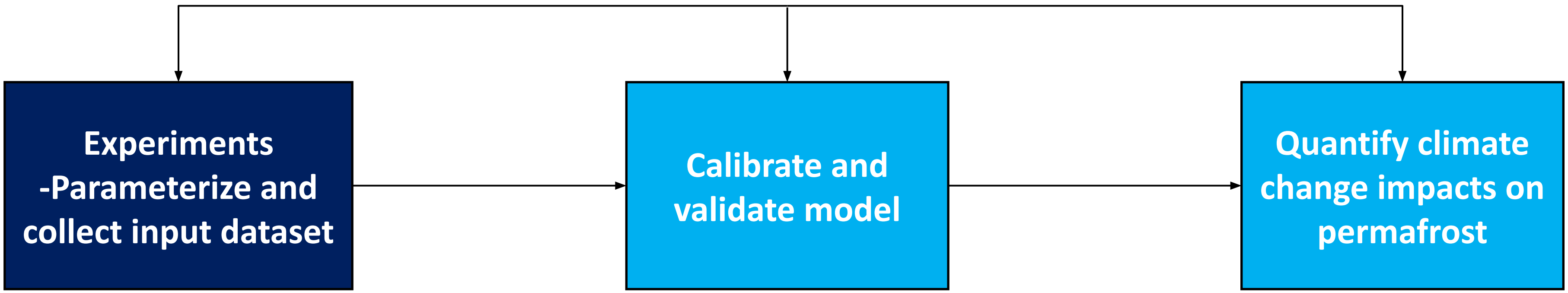
Figure 4 Active-layer thickness from 1978 to 2006 at the nine sites. The active layer has become thicker over the monitoring period, especially during the last decade.

Source: Akerman et al. 2008

81% of permafrost melted

ALT increases by 0.7 – 1.3 cm/yr

Overall research goals

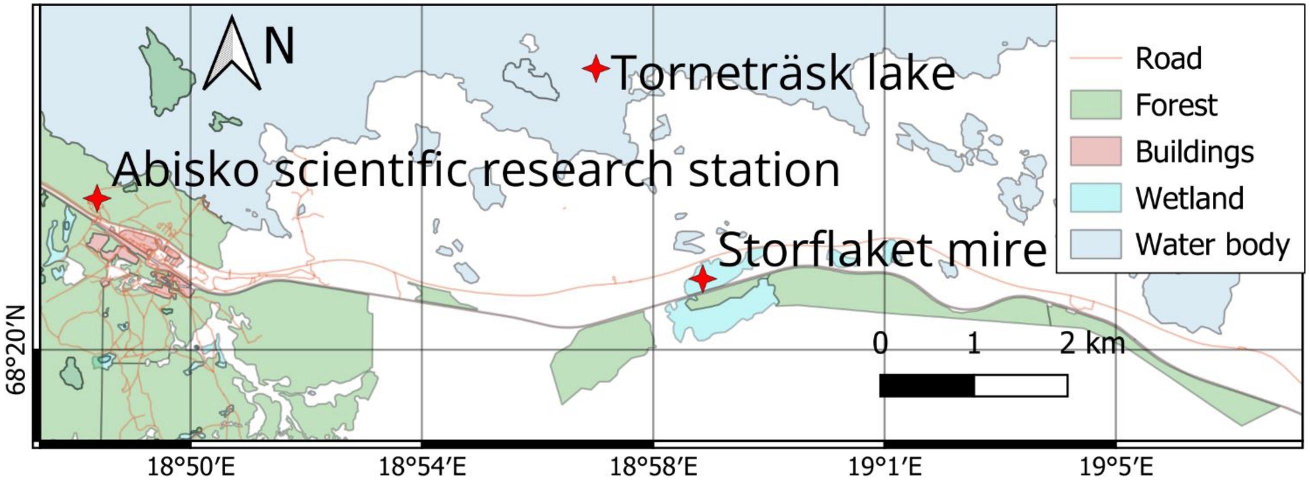


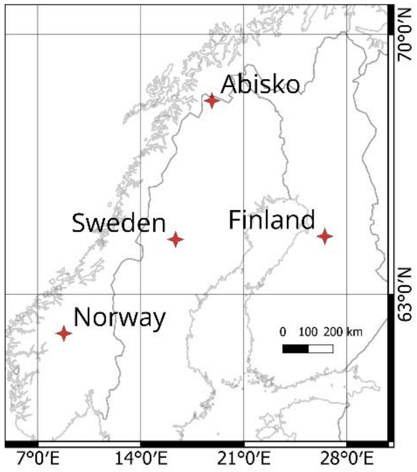
Experimental research goals

- Establish a methodology for the **near-surface** characterization of permafrost mires

  - input and calibration datasets for numerical models

General background – Abisko region





- Along the southern boundary of permafrost occurrence in Eurasia
- Maritime to continental climate
- Ombrotrophic peatland mires

- Lowland Discontinuous/Sporadic permafrost
- Abisko – Rain shadow region
- Storflaket mire
- Data availability: Measurements made since 1913

Satellite image of Abisko region

Source: Google earth image

Satellite image of Storflaket mire

Source: Zentra cloud dashboard map - https://zentracloud.com/#/dashboard_map

Characterization of permafrost mires

Pedological properties

- Porosity
- Bulk density
- Visual soil properties

Thermal properties

- Temperature loggers
- Thermal conductivity
- Heat capacity

Hydrological properties

- Soil moisture sensors
- Variably saturated properties
- Field and In-situ Hydraulic conductivity
- Active layer depth

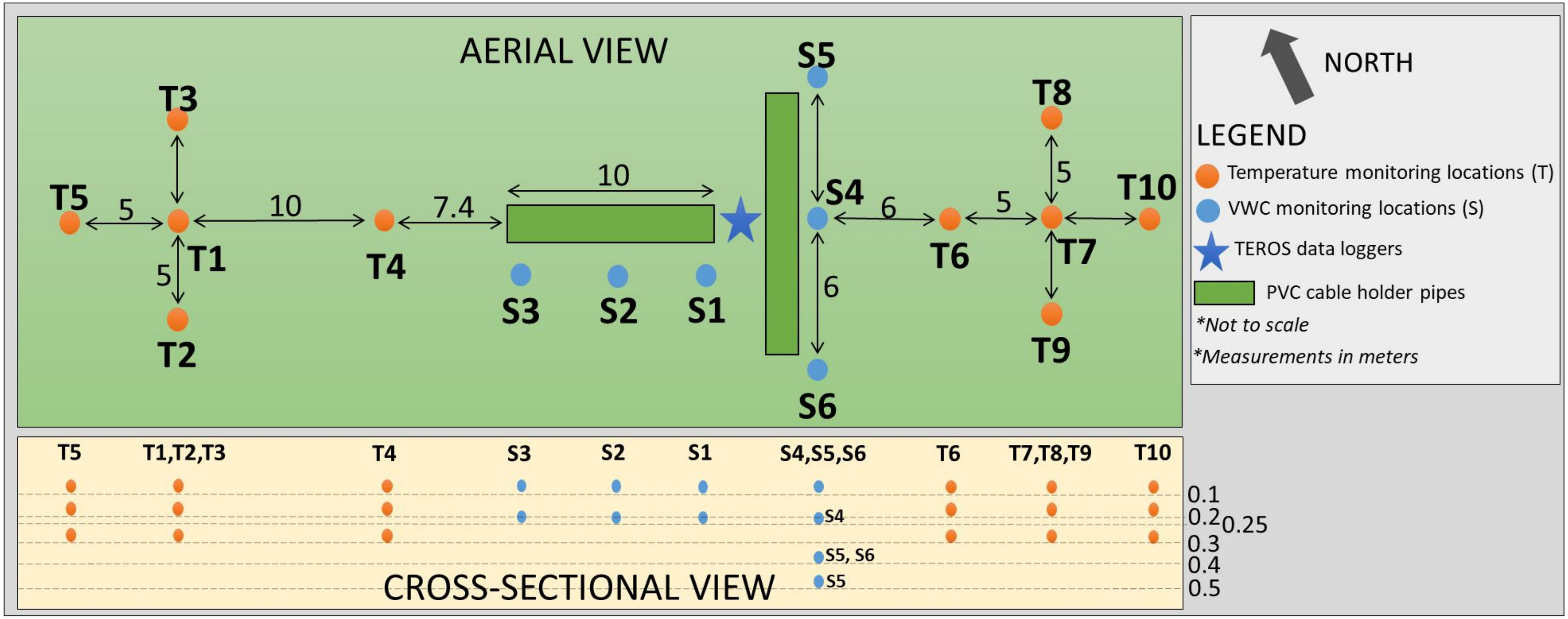
Biological properties

- Land type
- Vegetation type
- Organic carbon
- Organic nitrogen

1. Soil properties

Characteristics	Details
Plant type	Rosemary heath, Dwarf birch, Black crowberry, Dewberry, Cranberry, Cloudberry, Sheath cotton grass, Narrow-leaved sphagnum moss, Brown sphagnum moss
Porosity [from field soil samples close to the surface]	0.65 - 0.82 [0.78]
Dry bulk density [g/cm3] = Dry soil/Volume of soil	0.1018 - 0.365 [0.1852]
Field wet bulk density [g/cm3] = Wet soil/Volume of soil	0.6601 - 1.135 [0.95]
Distance to permafrost table from surface in June [cm]	30 - 40 [35]
Vegetation depth [cm]	1 - 20 [8.5]

Sensor installation layout



2. Soil moisture sensor – TEROS 12

- Mesurements: Volumetric water content, Temperature, Electric conductivity
- In-situ, Single point continuous
- Dielectric permittivity, Capacitance technology
- ZL6 Data logger – Cloud-based service, Battery/solar power driven
- 12 sensors installed at 6 locations and 5 depths

TEROS 12 sensor

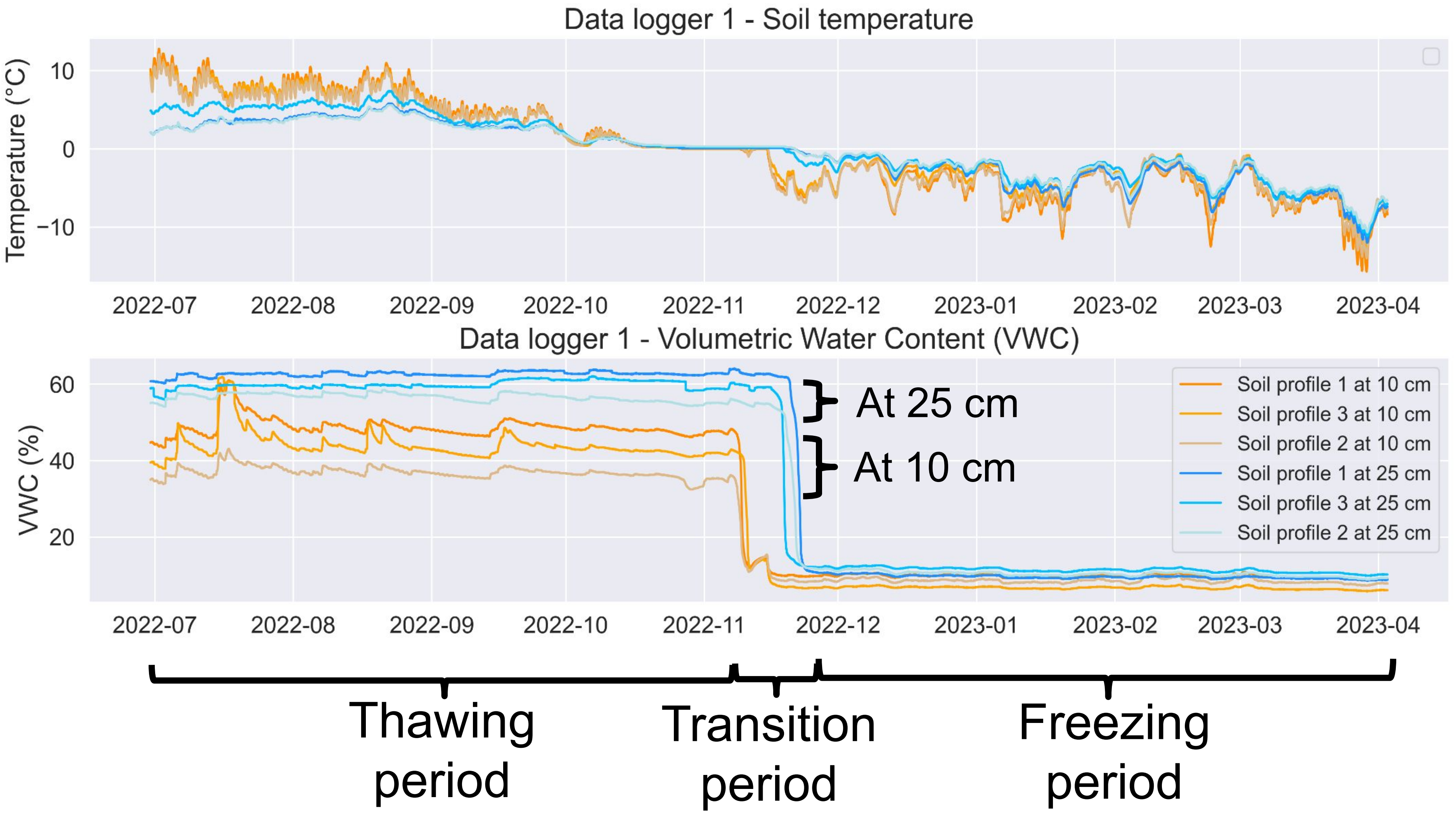
Source: https://www.metergroup.com/

ZL6 Data logger

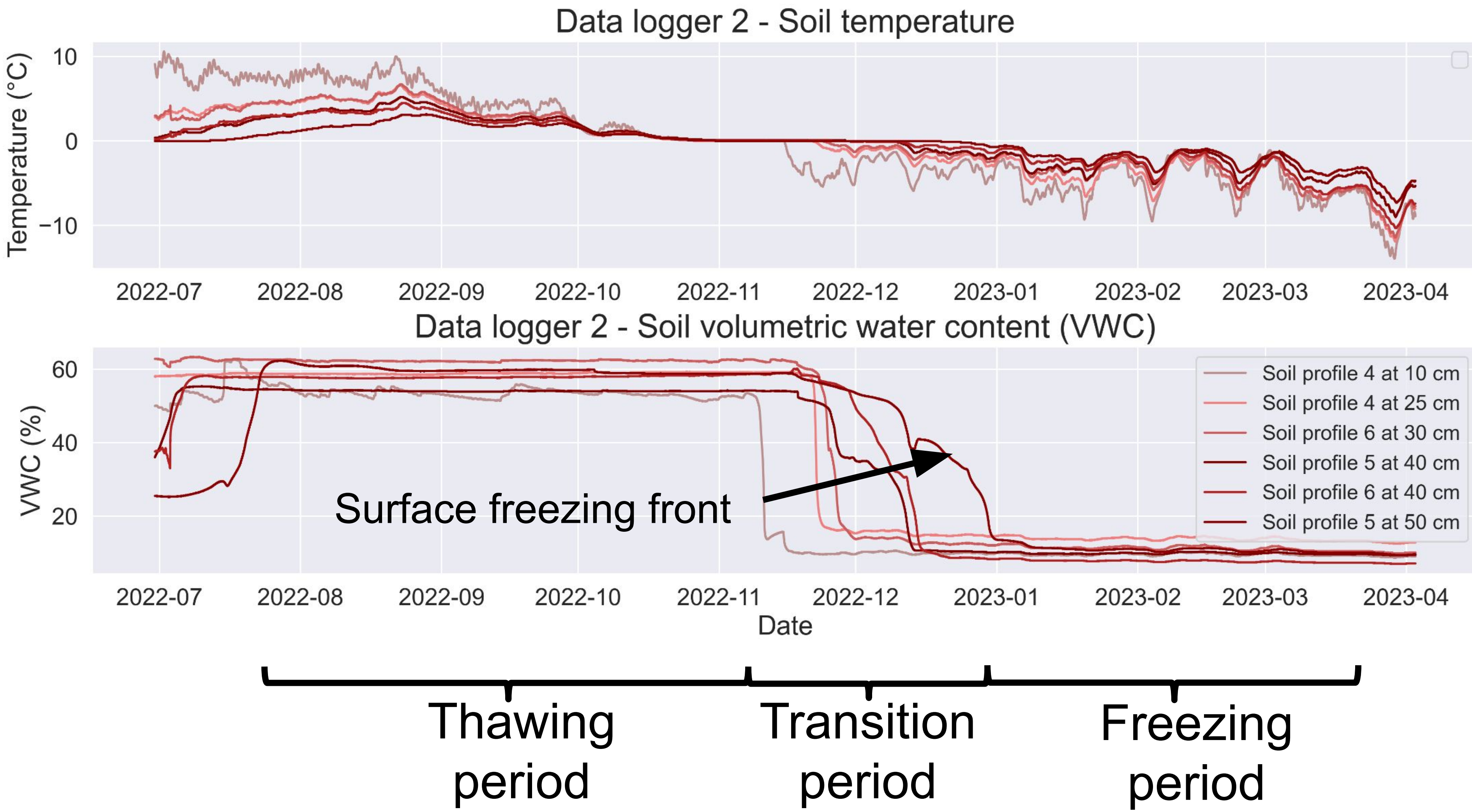
Source: https://www.metergroup.com/


SP4

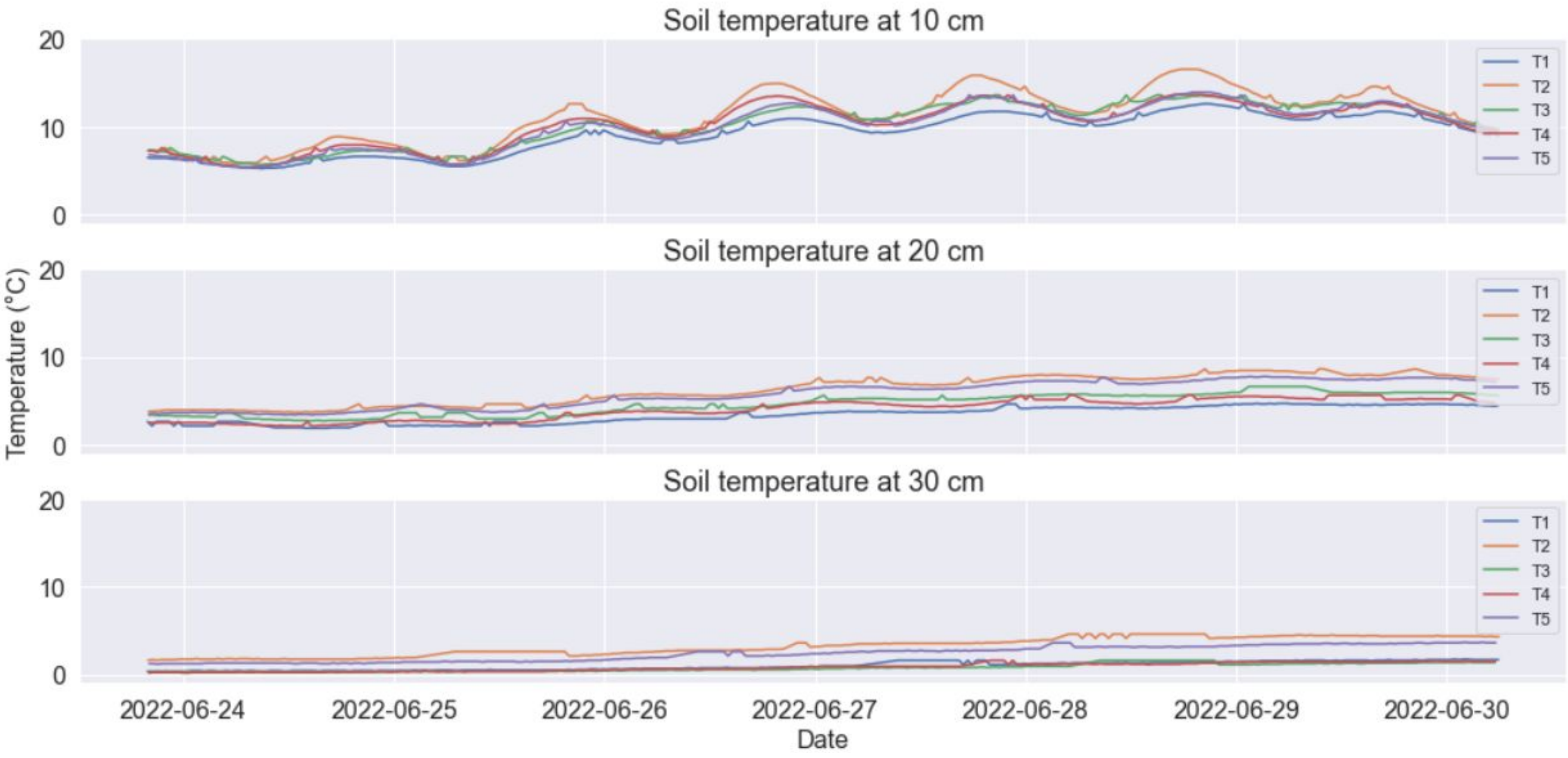
TEROS 12 sensor – Results



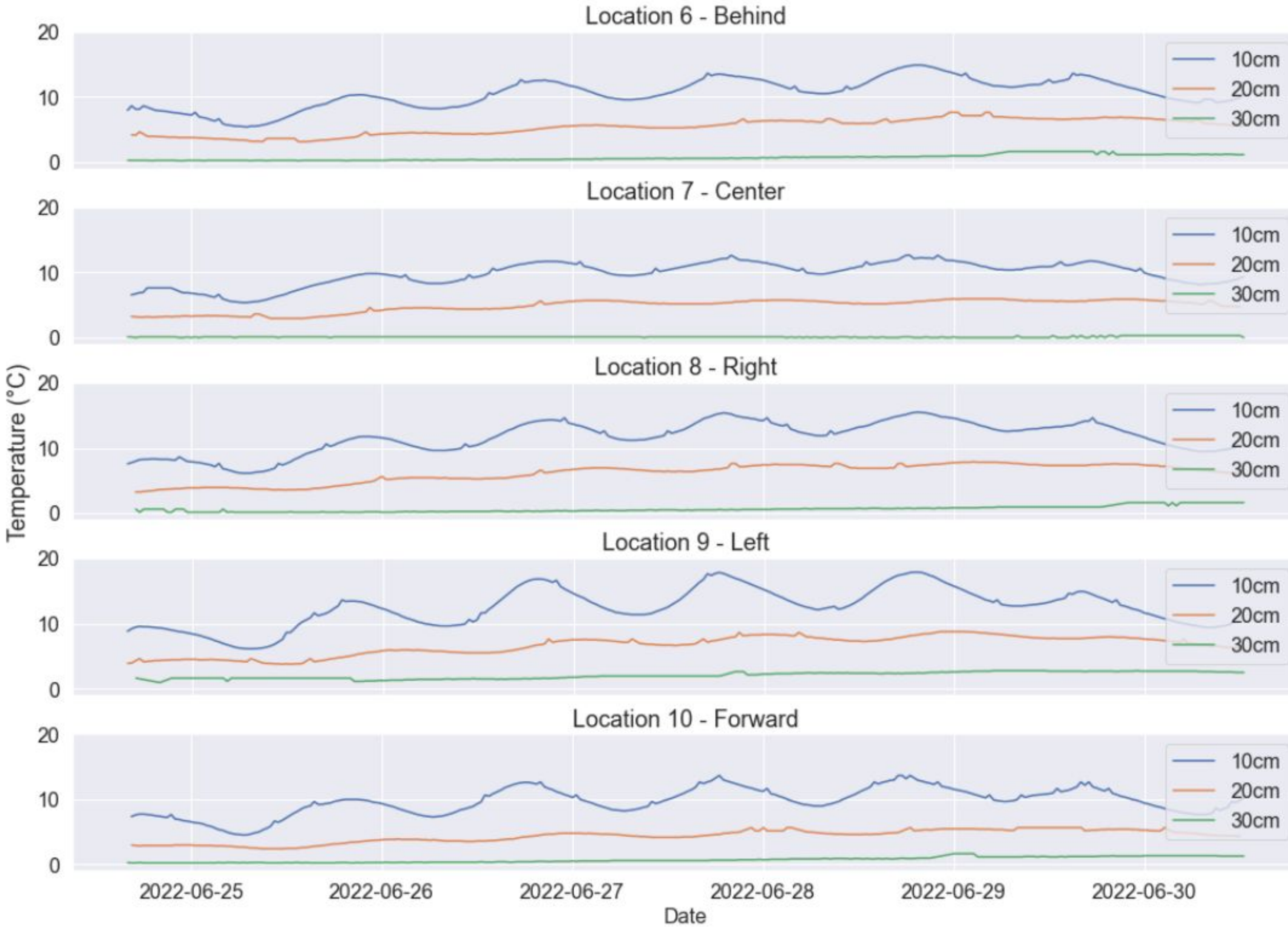
TEROS 12 sensor – Results



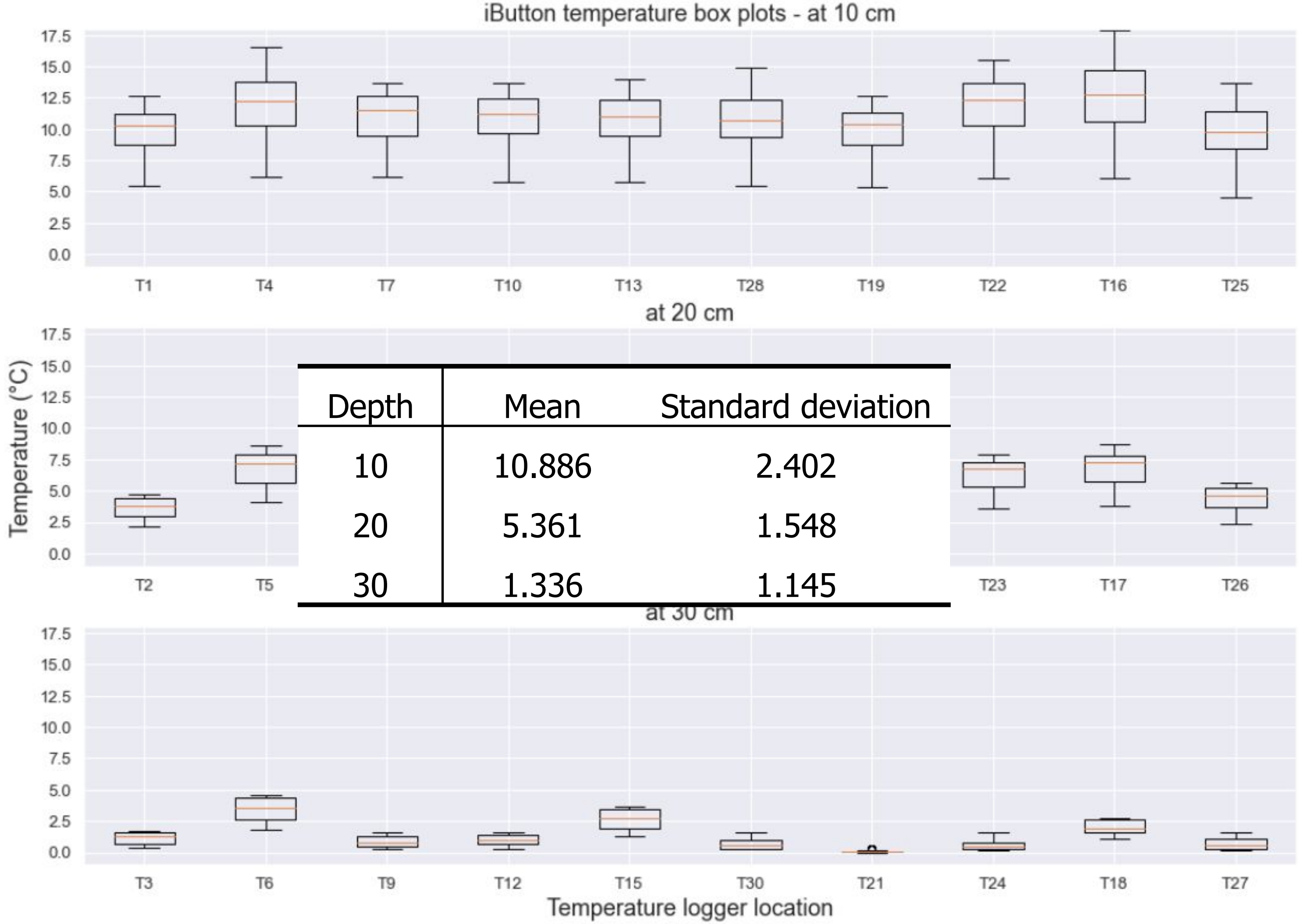
iButton temperature loggers – Spatial variability



iButton temperature loggers – Spatial variability



iButton temperature loggers



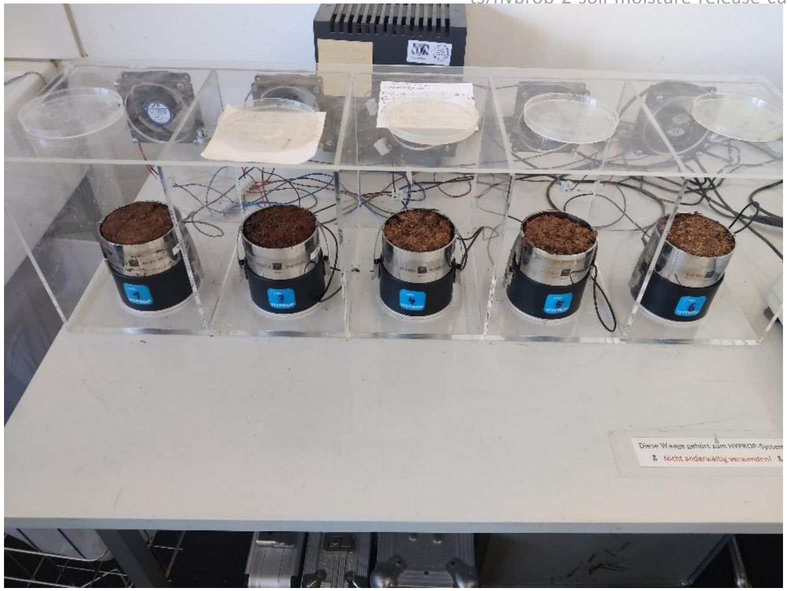
Depth	Mean	Standard deviation
10	10.886	2.402
20	5.361	1.548
30	1.336	1.145

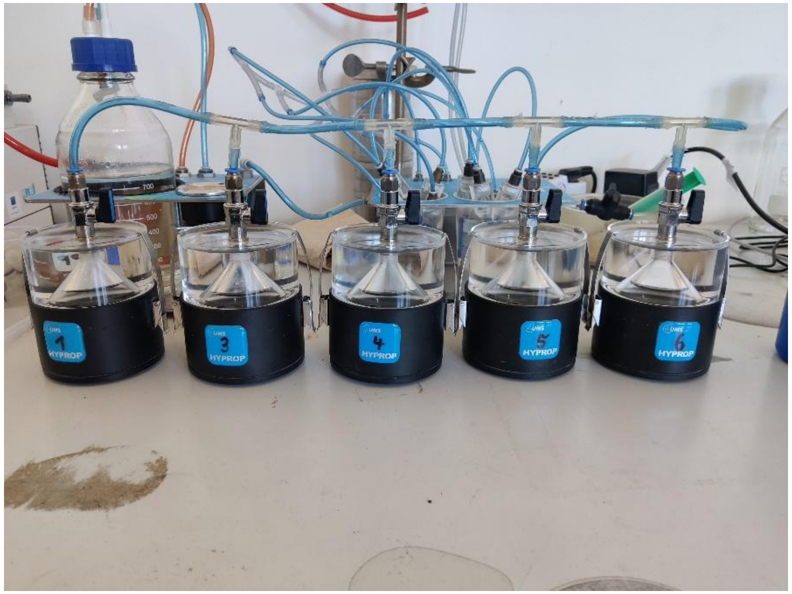
4. HYPROP

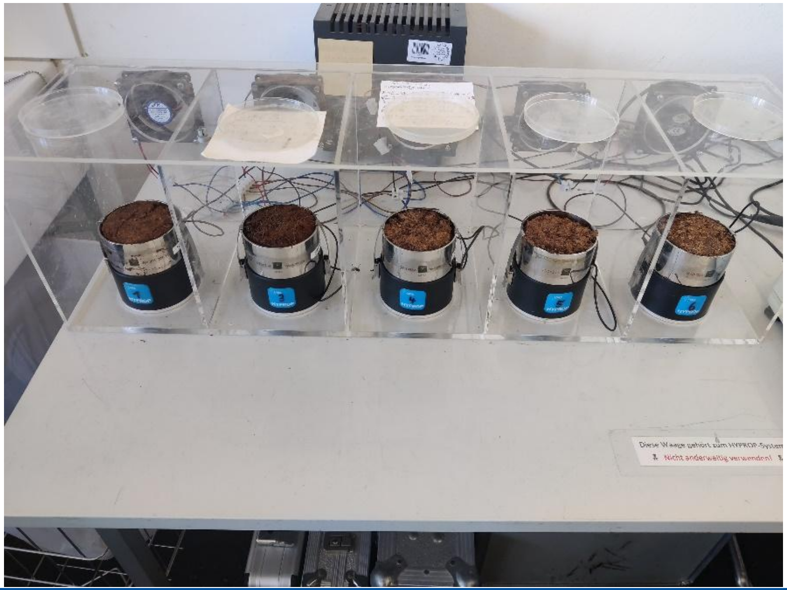
- Variably saturated properties - Soil moisture release curves
- Based on the Evaporation method
- 12 soil samples taken at 6 locations and two depths

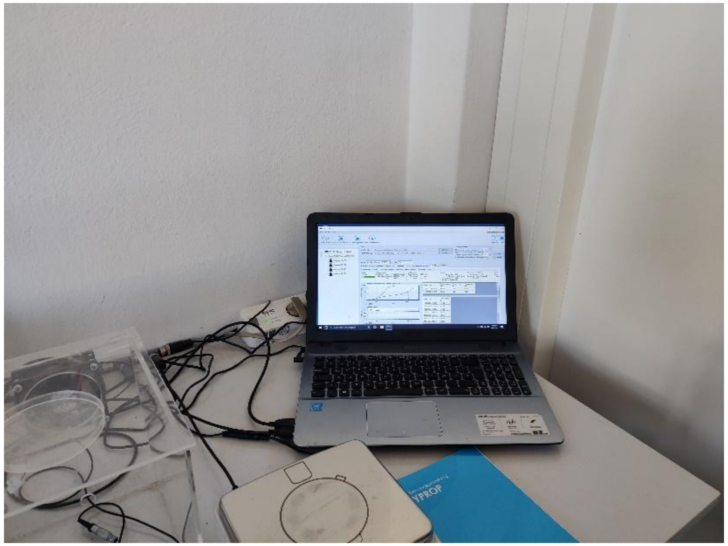
HYPROP device

Source: https://www.metergroup.com/en/meter-environment/products/hyprop-2-soil-moisture-release-curves

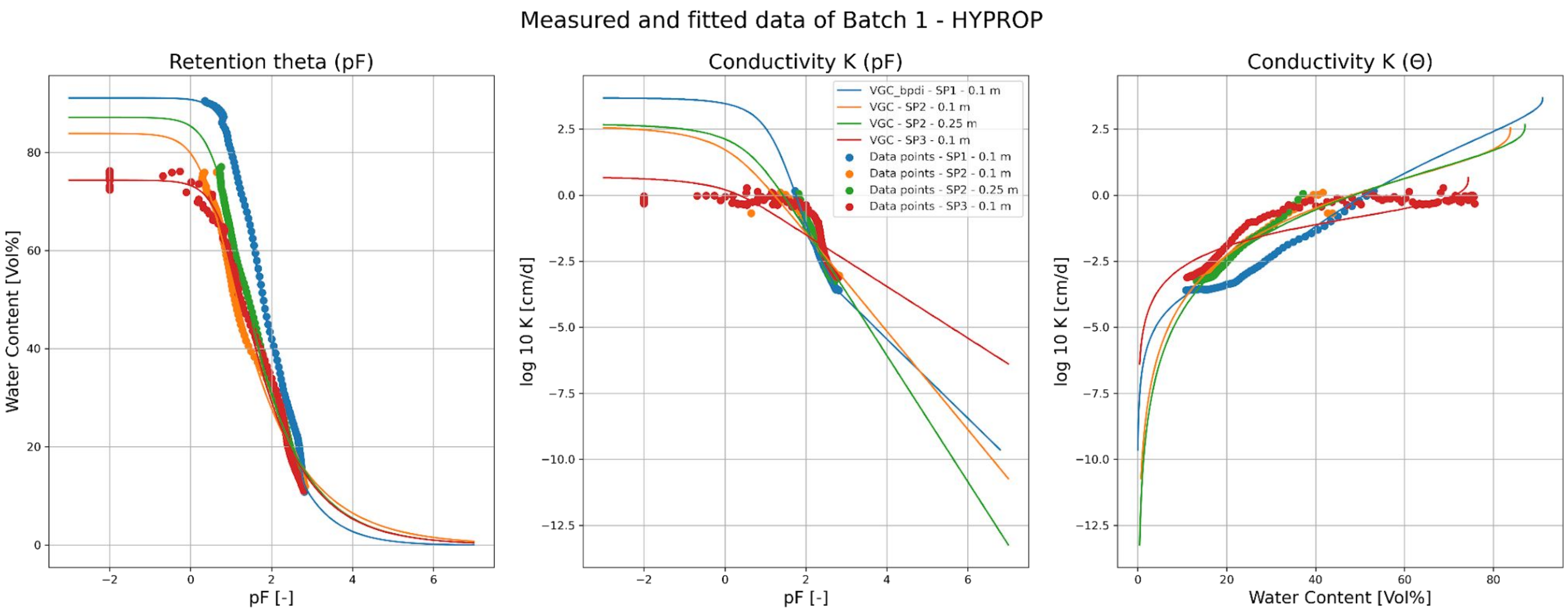



HYPROP



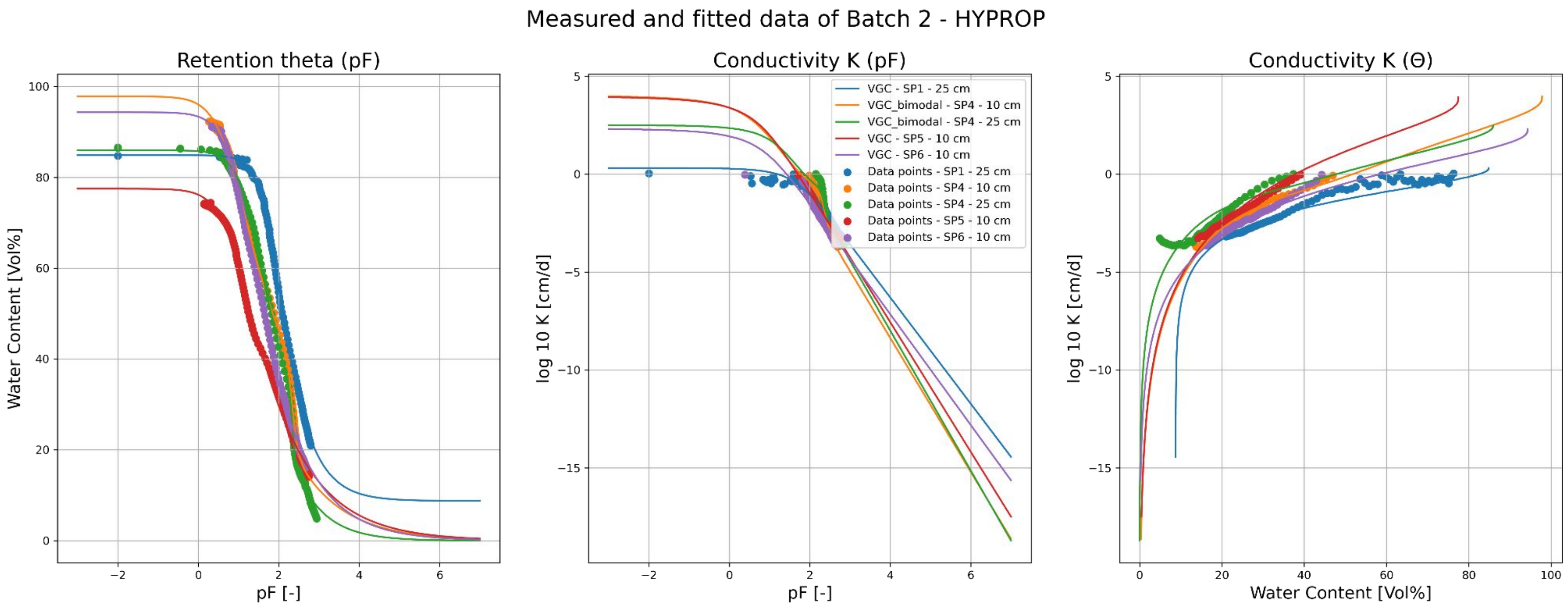


HYPROP Results – Batch 1



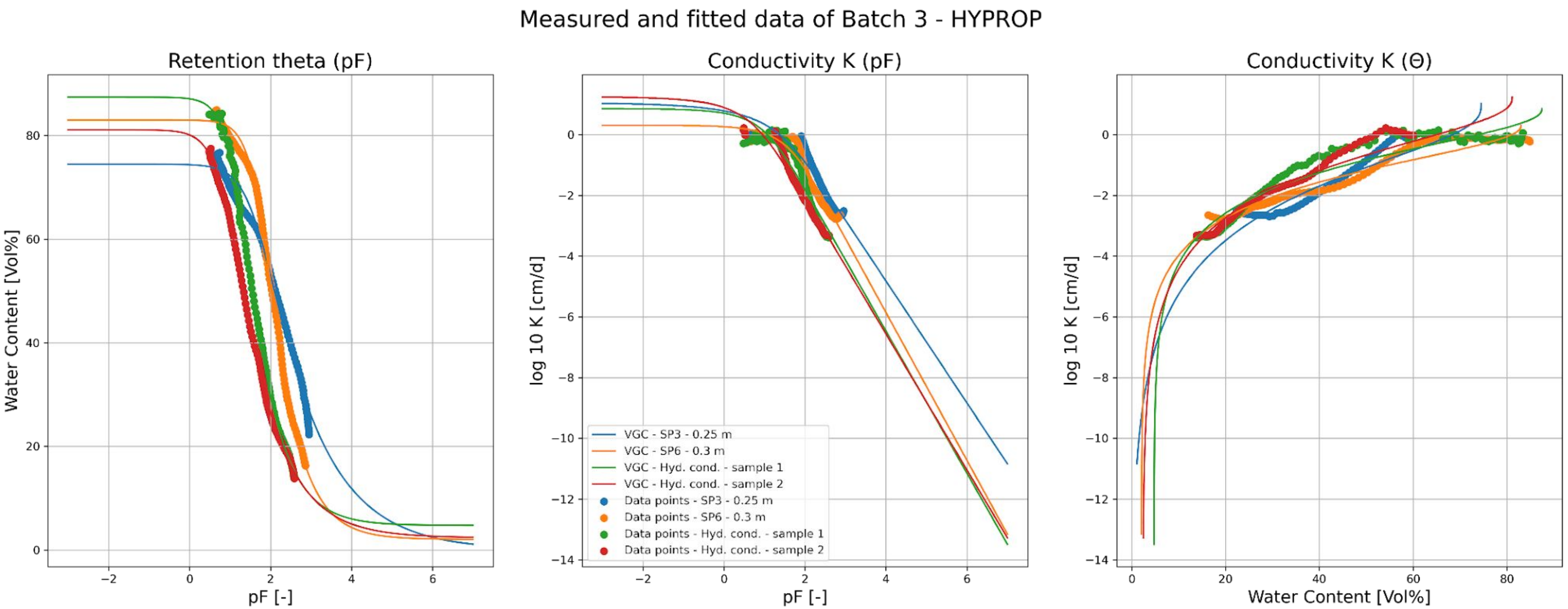
- Traditional Van Genuchten model
- Bimodal PDI variant - Van Genuchten model

HYPROP Results – Batch 2



- Traditional Van Genuchten model
- Bimodal constrained van Genuchten model (Durner)

HYPROP Results – Batch 3



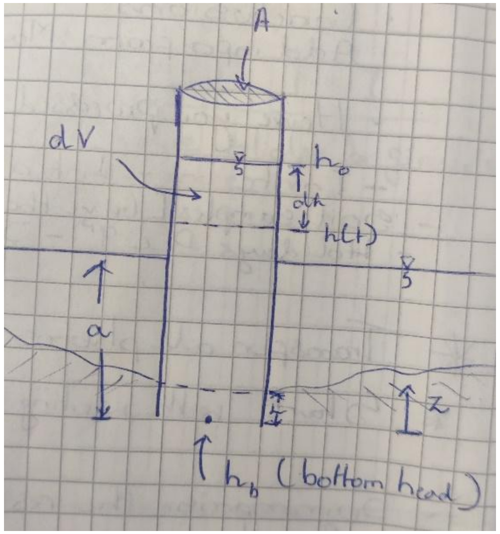
- Traditional Van Genuchten model

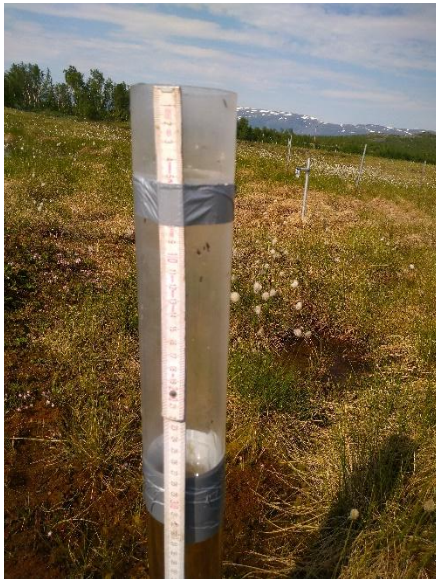
5. Field Hydraulic conductivity

- Falling head permeameter test
- Requires a constant head – Thermokarst pond

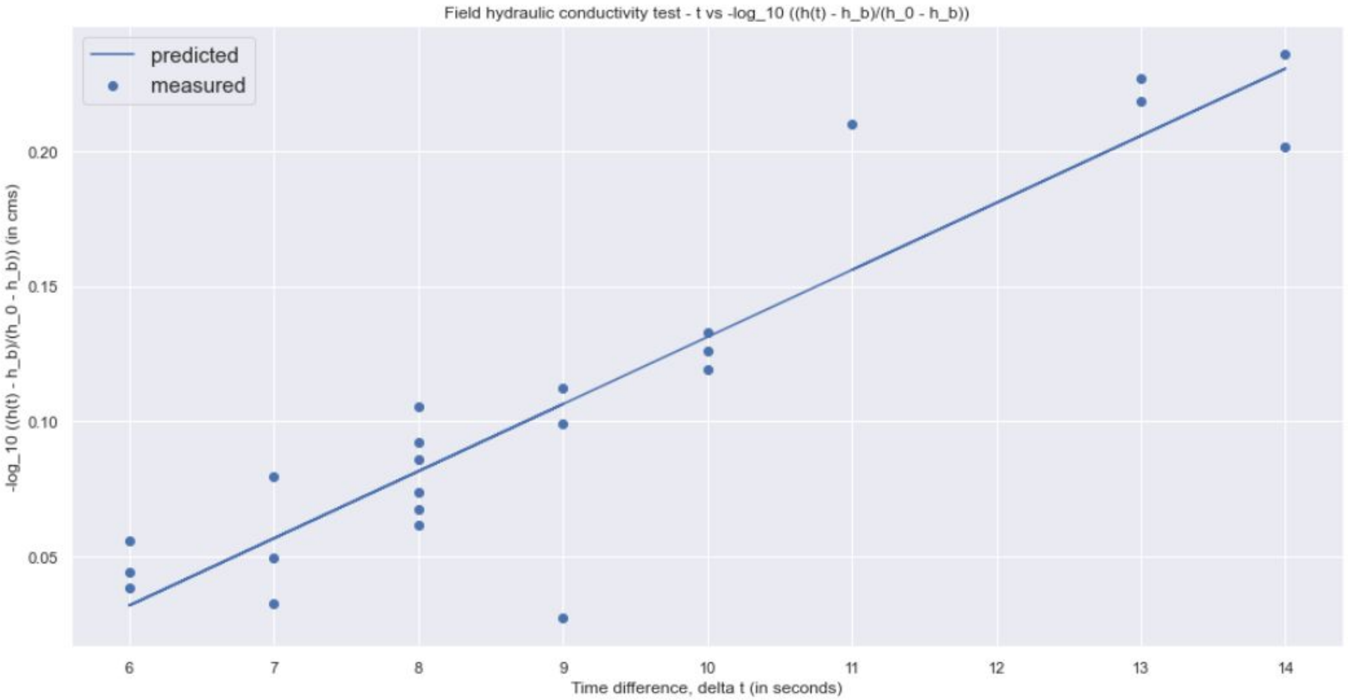
$$y = \log \frac{h(t) - h_b}{h_0 - h_b}, \; m = \frac{-K}{2.3l}, \; x = t$$

$$y = mx$$





Field Hydraulic conductivity results



	K (m/day)	m	r
0	370.745176	-0.024876	0.923565
1	186.943337	-0.015679	0.896852
2	-128.017157	0.011713	0.548940

$$y = \log \frac{h(t) - h_b}{h_0 - h_b},\ m = \frac{-K}{2.3l},\ x = t$$

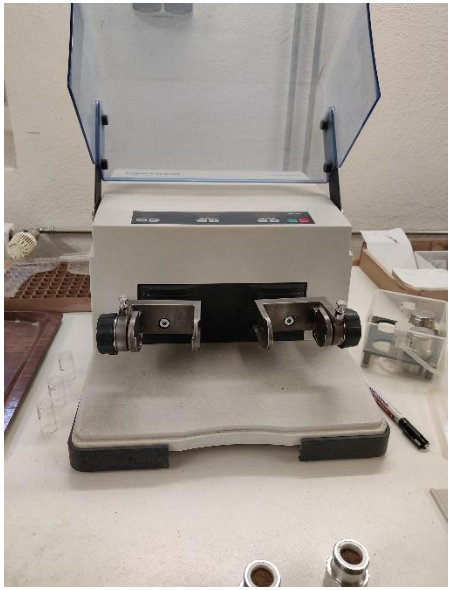
$$y = mx$$

6. Carbon, Nitrogen [CN] Estimation

1. Loss on ignition test: 80% Soil organic matter
2. Vario ISOTOPE CN analyzer: 1% Soil Organic Nitrogen and 50 % Soil Organic Carbon
3. SOM/SOC ~ 1.4 – 2.5

Soil sample in crucibles

Thermolyne furnace



Mixer Miller MM 400

Vario ISOTOPE CN analyzer

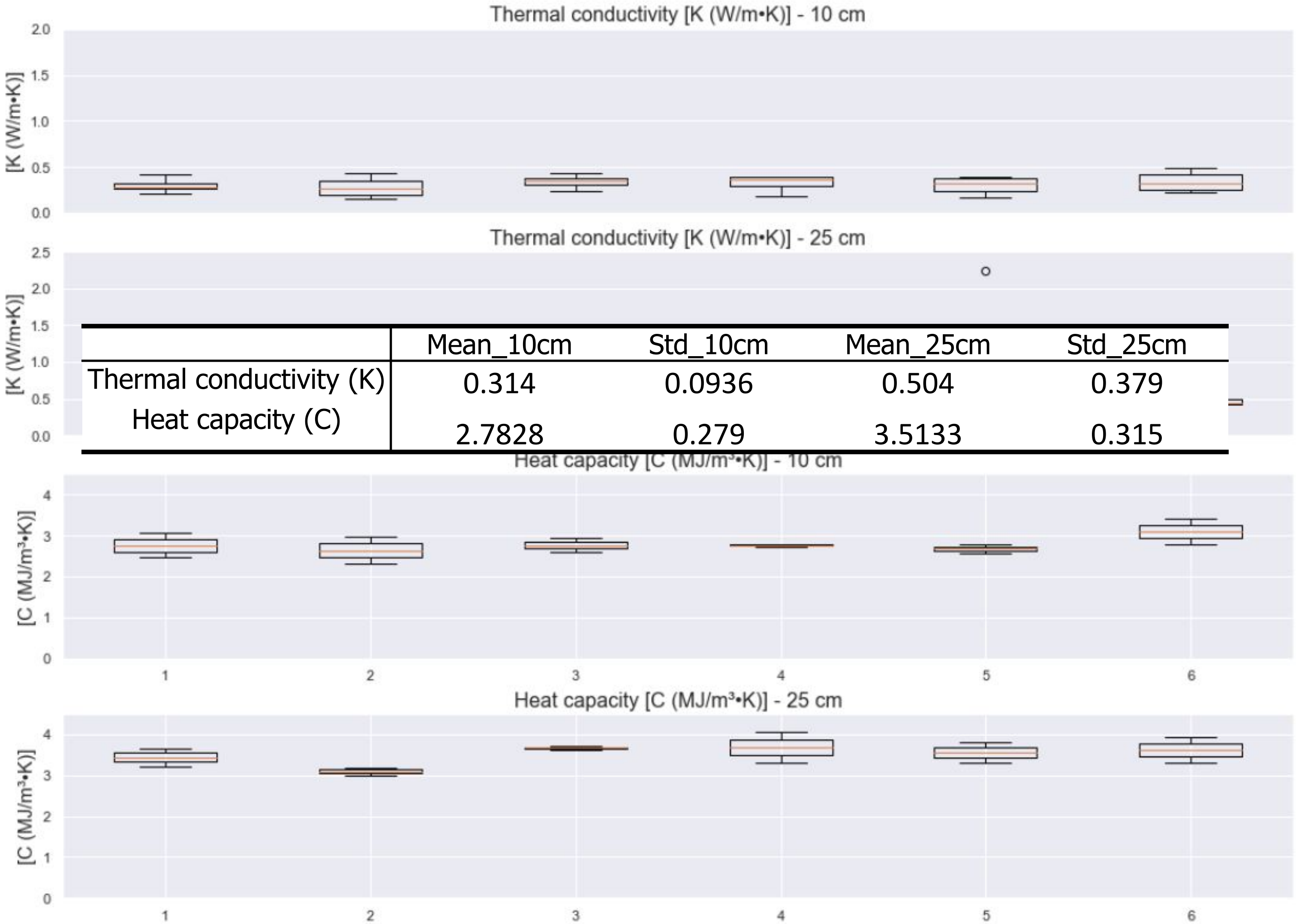
7. TEMPOS

- Thermal properties analyzer
- Transient line heat source method
- Measures thermal conductivity, and heat capacity
- At 6 soil profile locations

TEMPOS device

Source: https://www.metergroup.com/en/meter-environment/products/tempos-thermal-properties-analyzer?creative=593909765701&keyword=&matchtype=&network=g&device=c&gclid=CjwKCAjwh4ObBhAzEiwAHzZYU6139OBiNHK5T1r9YtMWoh745QazOjfG6v4-8UaNDROE5DQSf0cAXBoC1XEQAvD_BwE

TEMPOS – Results (at 10 cm and 25 cm)



	Mean_10cm	Std_10cm	Mean_25cm	Std_25cm
Thermal conductivity (K)	0.314	0.0936	0.504	0.379
Heat capacity (C)	2.7828	0.279	3.5133	0.315

Conclusion

- Highly porous, organic-rich soil with variable vegetation depth [Microtopographic heterogeneity]
- Soil moisture and temperature sensors are functioning well!
- Measured parameters are within range.
- Data collected are suitable as input into numerical models.

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Thank you 😊