Sympozjum Polarne BIS
Polar Symposium BIS
SOPOT 19 maja / May 2023

UMCS
WYDZIAŁ NAUK O ZIEMI I GOSPODARKI PRZESTRZENNEJ

New concept of permafrost degradation monitoring based on photonics technologies – case study from Calypsostranda (Bellsund, Svalbard)

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Project financed by European funds under the European Regional Development Fund and The National Centre for Research and Development: ‘Autonomous system of fibre optic quasi-distributed temperature sensor for ground temperature measurement’ (SPILOD) no. POIR.04.01.01-00-0031 / 19-00.

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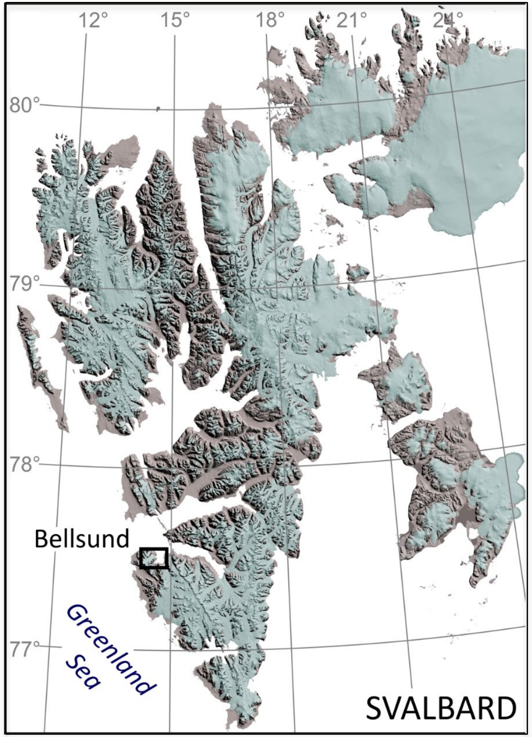
LOCATION

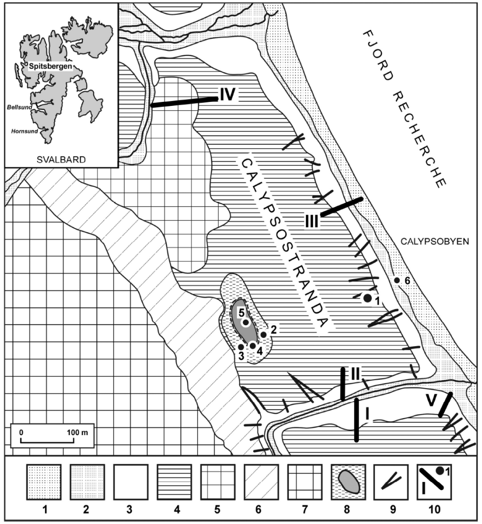
Svalbard
Bellsund
Calypsobyen
Calypsostranda



RESEARCH

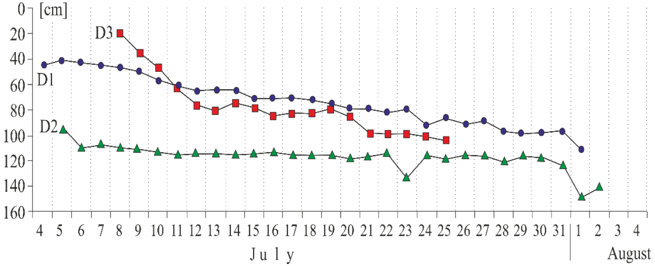
Main research topics

Sounding - steel rods of about a 1cm diameter and Danilin's soil frostmeter



Main sets of forms and location of measurement points of active layer of permafrost (Repelewska-Pękalowa & Pękala, 2004):

Year	Point / Site									
	1	2	3	4	5	6	I	II	III	IV
1986	90	125	120	-	60	-	120	-	145	122
1987	111	175	175	175	68	124	124	150	165	130
1988	108	163	168	193	70	148	121	180	177	135
1989	145	165	157	180	83	155	135	160	186	139
1990	130	165	165	165	56	137	118	135	170	122
1991	127	148	163	170	75	155	141	150	165	121
1992	140	170	165	180	70	145	140	180	155	125
1993	112	180	180	196	70	165	130	180	180	140
1995	125	176	180	174	68	174	135	170	160	140
1996	125	154	178	168	65	151	132	160	151	128
1998	130	124	121	170	75	150	-	-	160	-
2000	108	175	155	130	45	145	126	135	160	150
2001	116	131	180	165	73	154	150	170	132	155
2002	130	155	170	154	81	150	139	160	150	-
2005	150	225	220	210	115	160	157	195	200	145
2006	159	>217	>217	>217	180	178	215	>220	200	218
2007	166	>217	>217	>217	176	187	>217	>217	>217	>217
2008	156	>205	>217	>217	155	172	195	>205	>205	>205
2009	151	>203	>203	>203	>203	>203	>203	>203	>203	>203
2011	169	>202	>202	>202	>202	>202	>202	>202	>202	>202
2012	164	>202	>202	>202	>202	>202	>202	>202	>202	>202

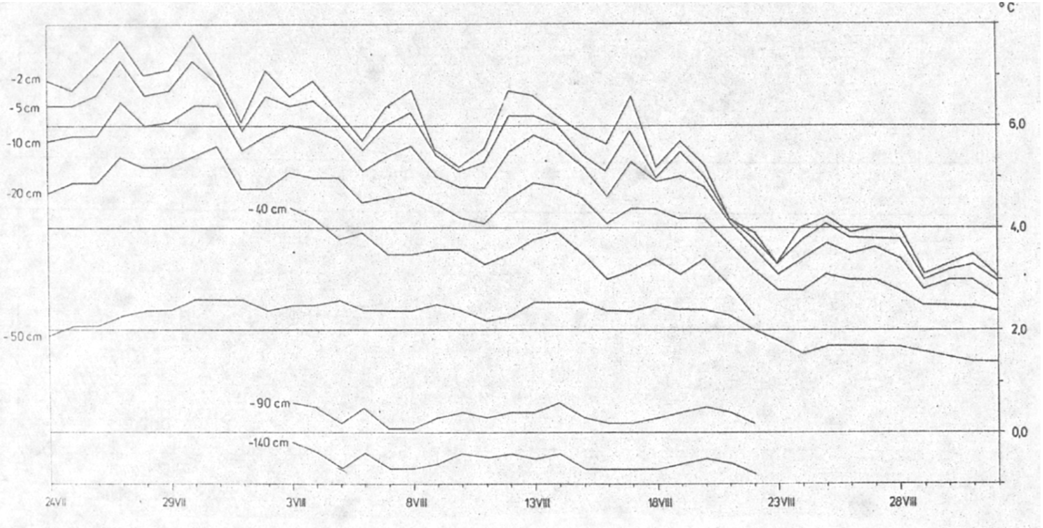


Daily changes of active layer thickness (Summer of 1996)

Repelewska-Pękalowa, J. & Pękala, K. (2004). Active-layer dynamics at the Calypsostranda CALM Site, Recherche Fjord region, Spitsbergen. *Polar Geography*, 28, 4, 326-343. https://doi.org/10.1080/789610209

RESEARCH

Main research topics



Ground temperature distribution (tundra)
Jule 24 – September 1, 1986

Measurements of ground temperatures
- mercury ground thermometer

Gradient temperature measurement probe

Repelewska-Pękalowa, J. & Gluza A. (1988). Dynamics of the permafrost active layer – Spitsbergen. In: K. Proceedings, Senneset (Ed.), 5th International Conference on Permafrost in Trondheim, 1, 448-453.

RESEARCH (2022)

Implemented projects (sources of financing):

SPILOD Project no. POIR.04.01.01-00-0031/19: ***Autonomous quasi-distributed optical fiber temperature sensor for ground temperature measurements***. The National Centre for Research and Development.

Consortium: InPhoTech- innovation photonics technology (lider)

Maria Curie-Skłodowska University in Lublin

- Institute of Earth and Environmental Sciences
- Institute of Chemical Sciences

Institute of Agrophisics Polish Academy of Sciecne in Lublin

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- **SPILOD** Project no. POIR.04.01.01-00-0031 / 19: ***Autonomous quasi-distributed optical fibre temperature sensor for ground temperature measurements***. The National Centre for Research and Development.

This project's aim is to develop a unique autonomous optical fibre based system for distributed ground temperature measurements that will enable remote sensing of this key parameter with unprecedented precision, resolution and range.

The goal of the project is to create and verify technology of ground temperature measurements with a dedicated device consisting of an opto-electronic system called an interrogator and a specialty optical fiber serving as a sensing element.

Innovative fiber design will provide better temperature sensitivity and measurement precision. Tasks proposed in this project also include designing and verification of the installation process, shields and safeguards against influence of unwanted environmental factors (strain, water ingression etc.), as well as formulation of measurements methodology and data analysis algorithms for proper description of ground's thermal dynamics.

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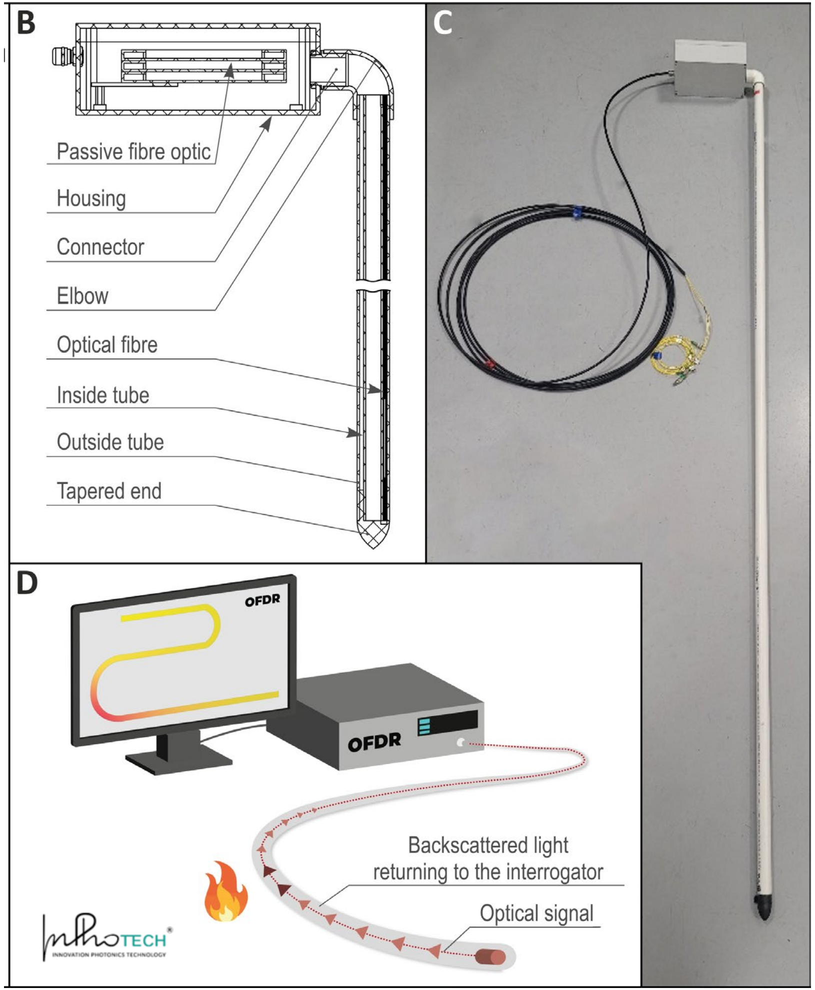
RESEARCH (2022)

Optical fibre based system

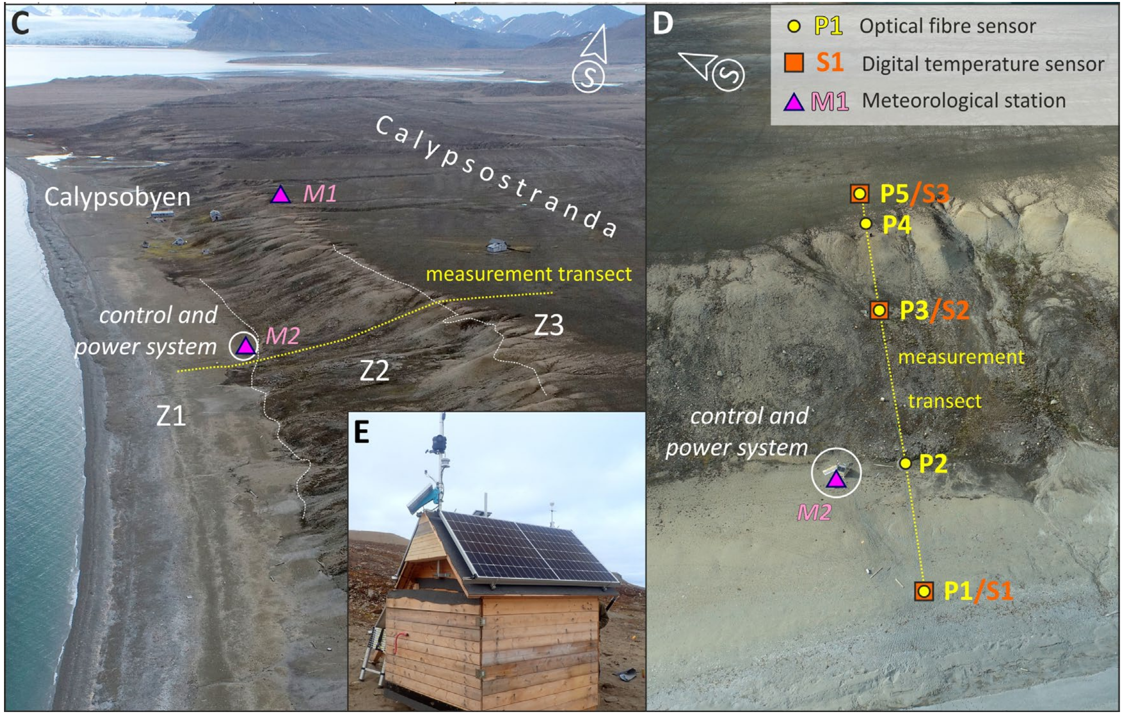
A measurement system uses an optical fibre along its entire length as a converter of the measured parameter - temperature. The optical signal is modified by the temperature at each point of the optical fiber. At the same time optical fibre works also as signal transmitter to a central unit, hence the measurement system does not posses any areas where the measurement cannot take place.

Thanks to that there are no blind points (where change of measured parameter, doesn’t change measured value) in the optical fibre sensor in contrast to the point sensors.



RESEARCH (2022)

Installation of optical fibre based system



- **Zone 1 (Z1)** – gravel beach; it is a zone with a width of 120-130 m with two storm ridges: contemporary transformed by marine processes and old wit hinterland. A thicker gravel layer (3-4 m) is deposited on the abrasion platform adjacent to the dead cliff of the 22-30 m a.s.l. raised marine terrace.

- **Zone 2 (Z2)** – solifluction slope; it includes the dead cliff. Its inclination is variable: lower and middle more gently sloping and muddy (clay, loam), varied with solifluction lobs, and upper – more sloping, built of gravel and dry.

- **Zone 3 (Z3)** – raised marine terrace (terrace III, 17-25 m a.s.l.). The old raised marine terrace of varied lithological structure, formed the turn of the Weiselian and Holocene.

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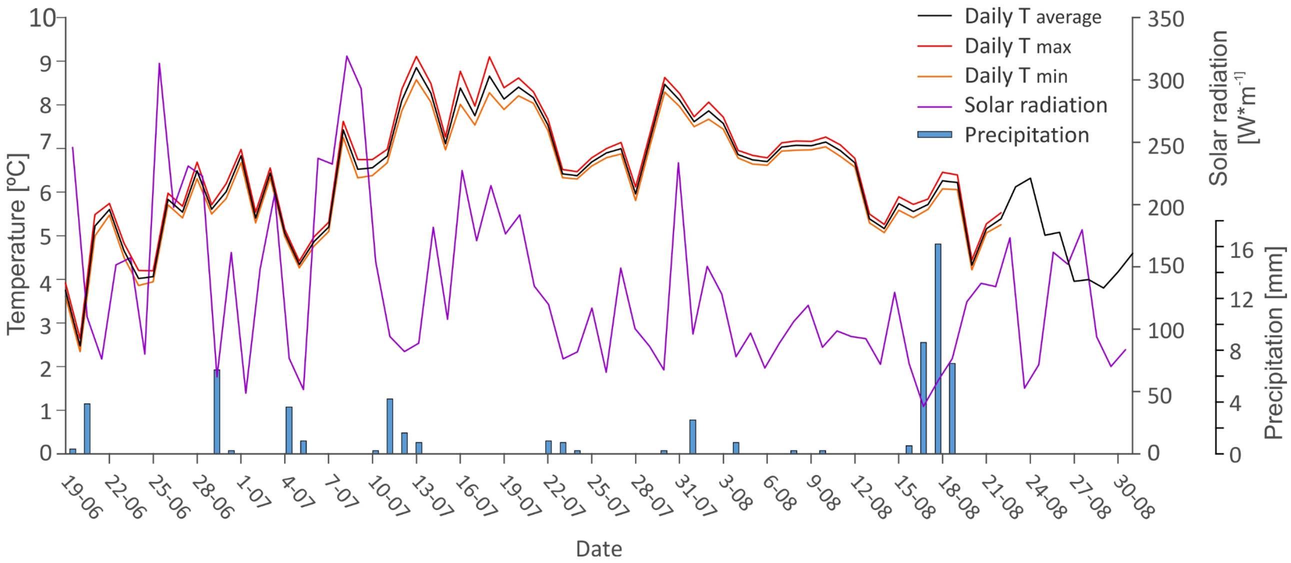
Meteorological observations

Two systems of weather station:

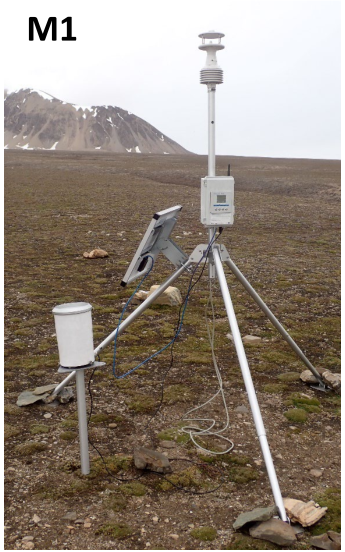
M1 – Delta OHM HD35AP

M2 – HOBO U30 and Lufft WS501

Measurement period:	19 June – 31 August
Daily T average	6.2°C
Daily T max	9.1°C (13 Jule)
Daily T min	2.5°C (20 June)
Precipitation (sum)	60.6 mm
Precipitation (max)	16.2 mm (18 August)
Radiation average	131.4 W*m^{-2}
Radiation max	319.1 W*m^{-2} (8 July)
Padiation min	38.0 W*m^{-2} (18 August)



M1



M2

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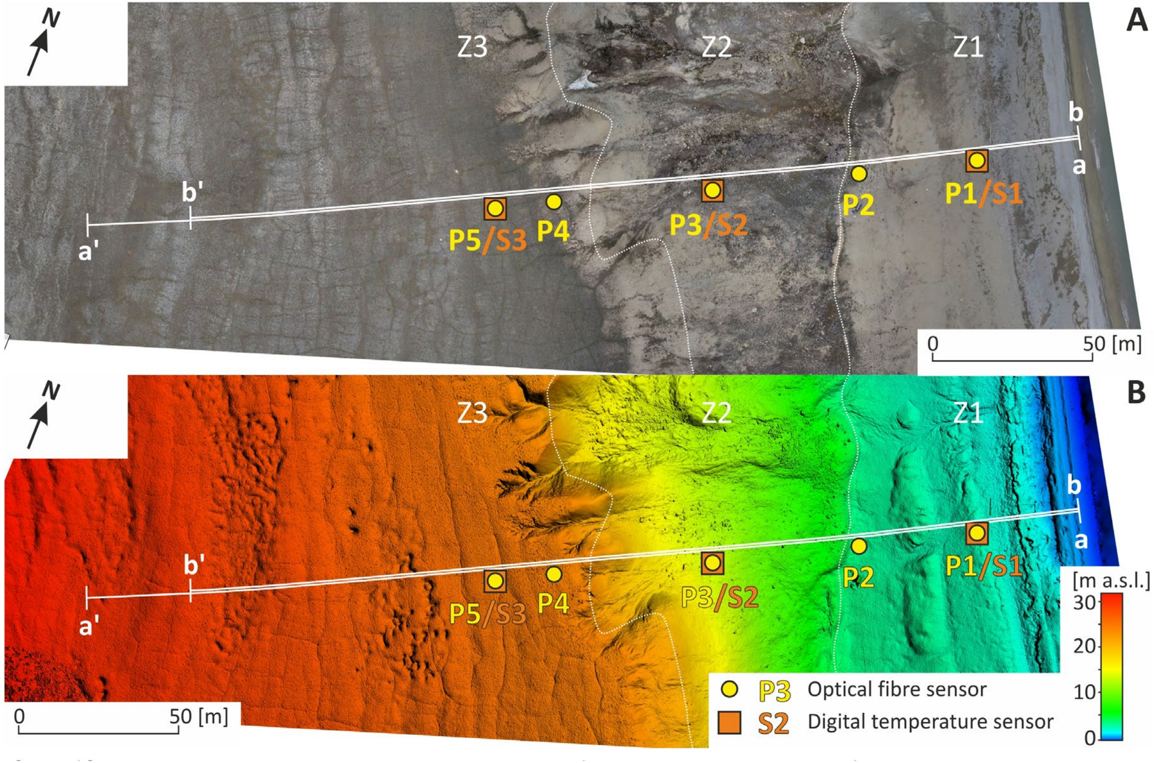
Installation of optical fibre based system

RESEARCH (2022)

SfM (Structure from Motion)

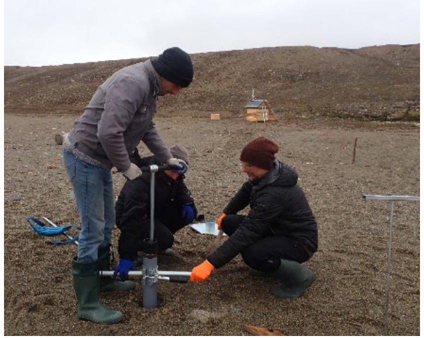
Phantom 4 DJI

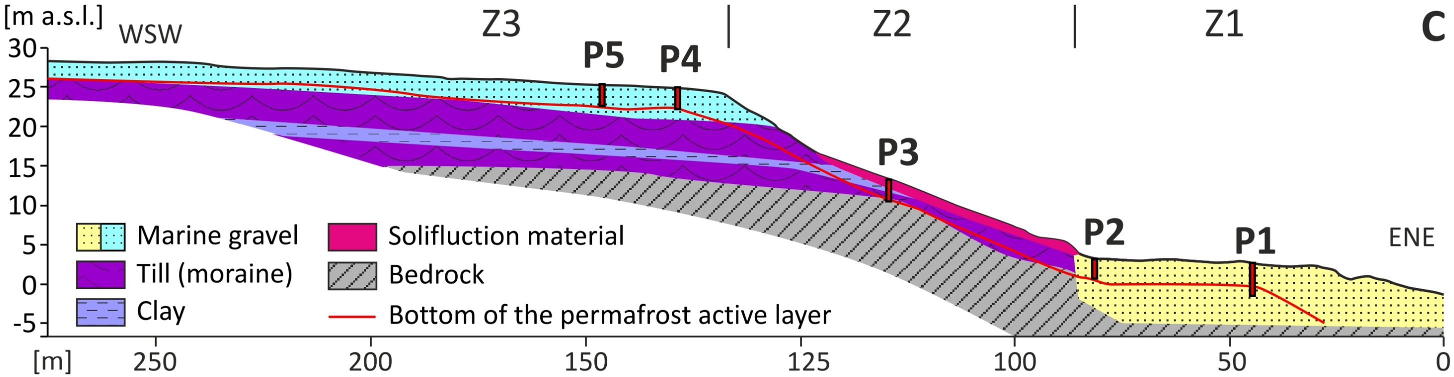


DJI Phantom 4 RTK

RESEARCH (2022)

Geological reconnaissance





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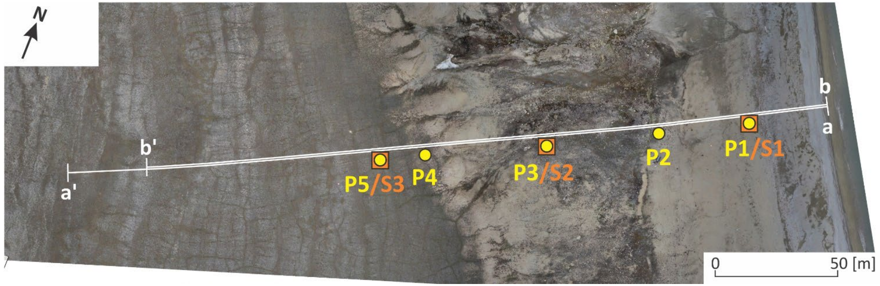
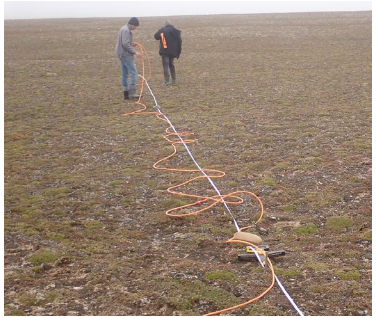
Electrical Resistivity Tomography (ERT)

ARES II (Advanced Multi-Channel Automatic Resistivity & System)



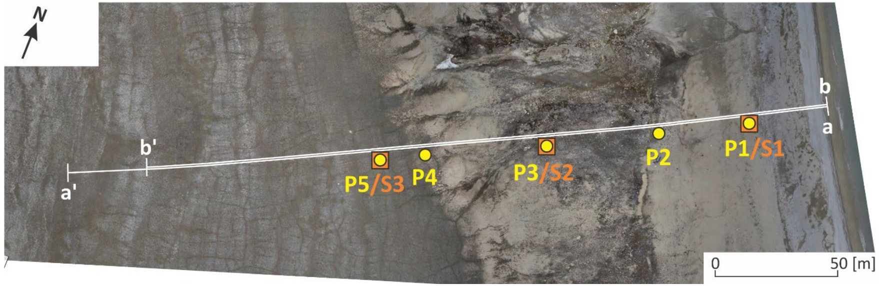
- Optical fibre sensor
- Digital temperature sensor (Geoprecision)



RESEARCH (2022)

Electrical Resistivity Tomography (ERT)

ARES II



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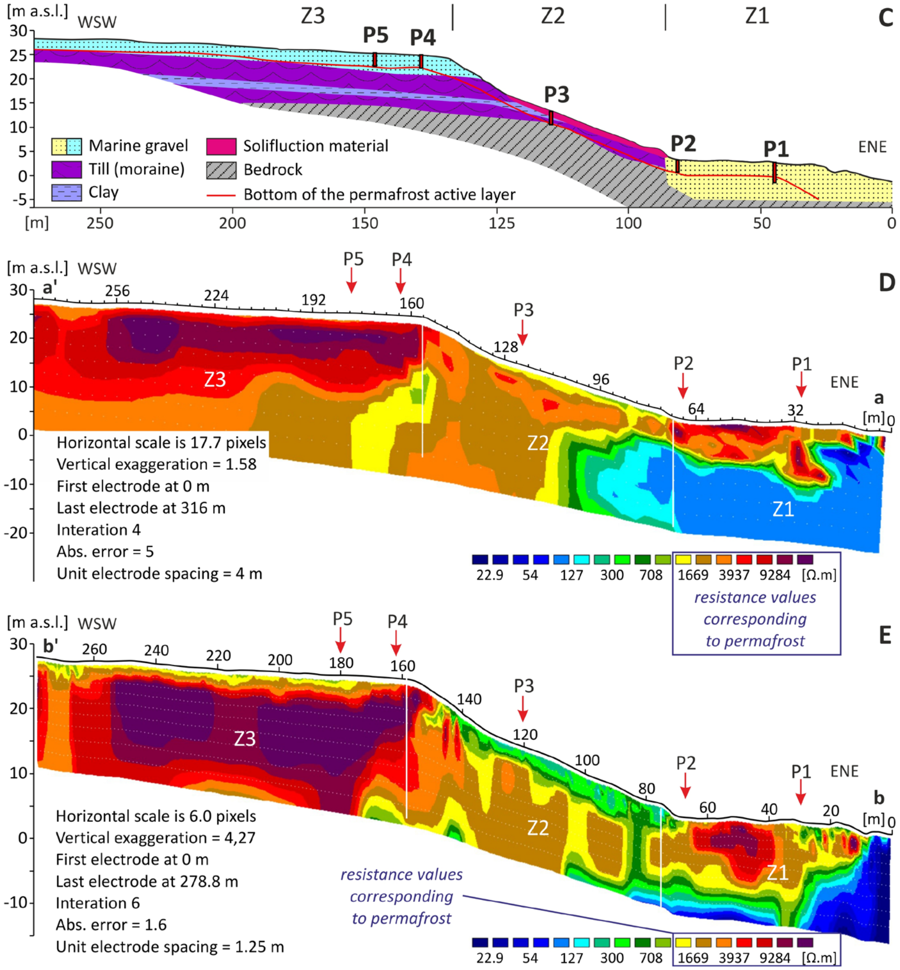
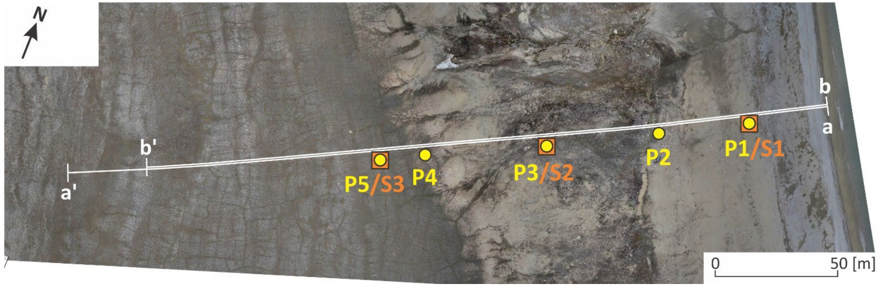


RESEARCH (2022)

Ground temperature measurements

Digital Temperature Sensor based on 2-Wire Bus (GeoPrecision)



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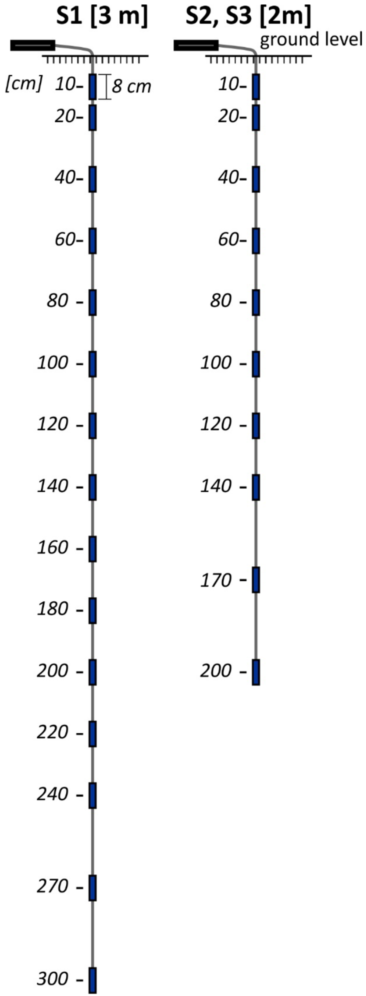

RESEARCH (2022)

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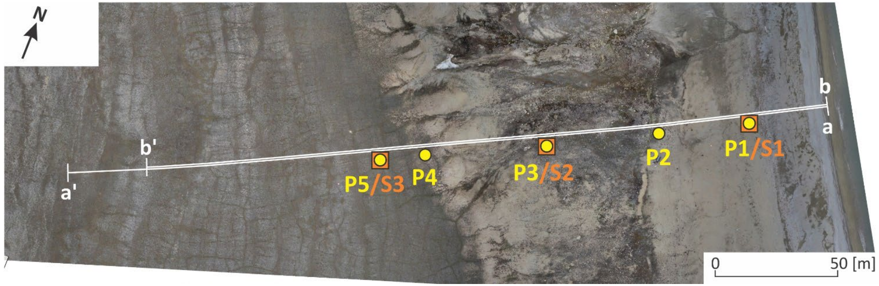

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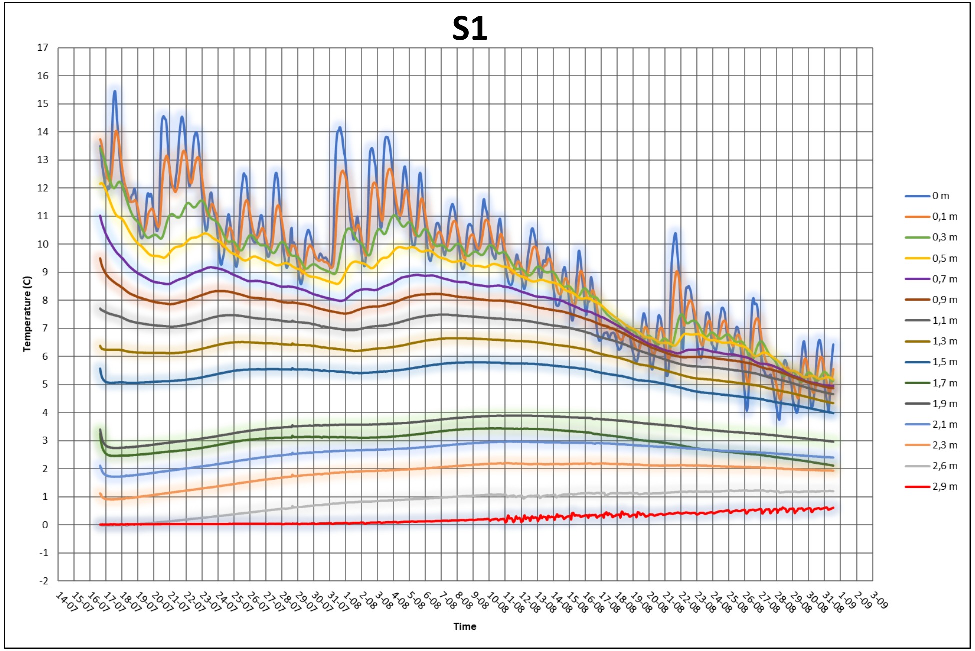

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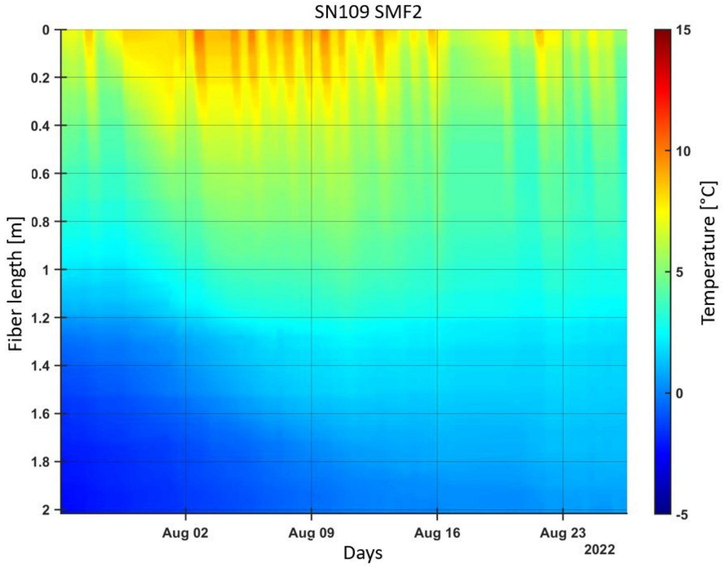
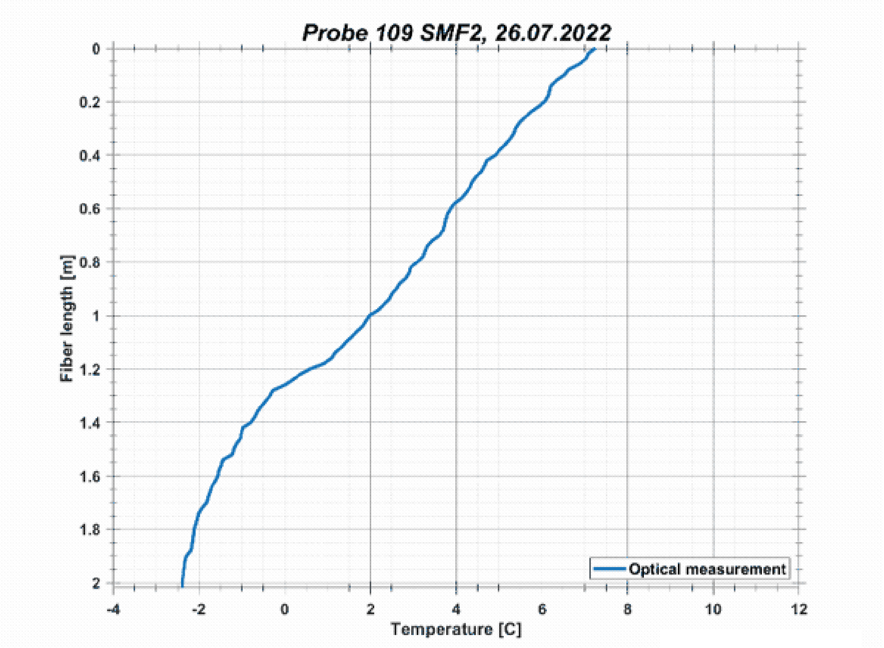
Optical fibre based system

The exemplary results

The map of temperature* profile in time as a function of fiber length



The temperature measured* by the optical fiber as a function of fiber length by days



*The temperature averaged from each day

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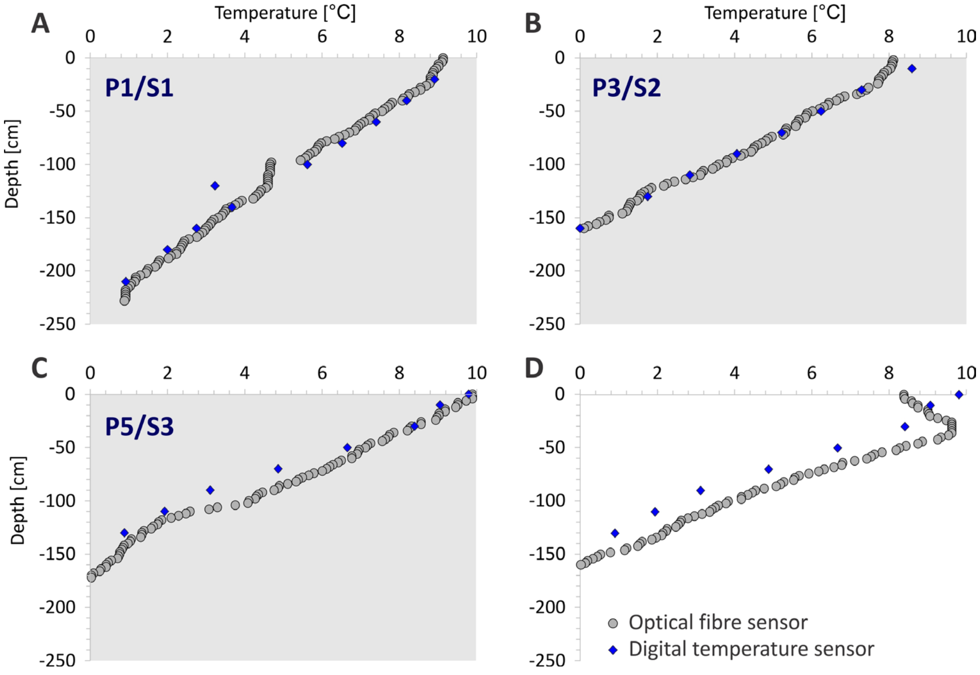
Optical fibre based system



Differences between readings from thermistor and fibre-optic sensors averaged over the vertical profile of investigated positions in the measurement transect.

Morphogenetic zones	The average value of the difference between the thermistor and optical fibre sensors [°C]	The average of the difference in absolute values between the thermistor and optical fibre sensors [°C]	sensor type impact significance p-value (one-way ANOVA)
Z1 gravel beach	-0.01	0.42	0.93
Z2 solifluction slope	0.07	0.24	0.96
Z3 raised marine terrace	-0.30	0.43	0.86

Sample results of temperatures in the ground profile. **05/08/2022 hours 1:00 p.m.** form optical fibre sensor comparison with the results of measurements from the digital temperature sensor:

A) P1/S1 installation point – beach

B) P3/S2 installation point – solifluction slope

C) P5/S3 installation point – raised marine terrace

D) example of 'temperature' readings from a fibre optic compared to temperature readings from digital temperature sensor when optic fibre is under uncontrolled stress.

CONCLUSION

Technical challenge

- Construction of a universal soil temperature sensor based on optical fibers.

Scientific challenges

- Measurements of soil temperature with high resolution.
- Determination of the direction and speed of heat stream movement in ground.
- Determining the interaction between sea water and land.

Problems to solve

- Enabling continuous power all year round - especially during the polar night. At the moment, the system will be off for the period from November to March - solar power.
- On-line connectivity - monitoring system operation on an ongoing basis.

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