PCCH-Arctic – Polar Climate and Cultural Heritage – Preservation and Restoration Management

Project presentation and current results

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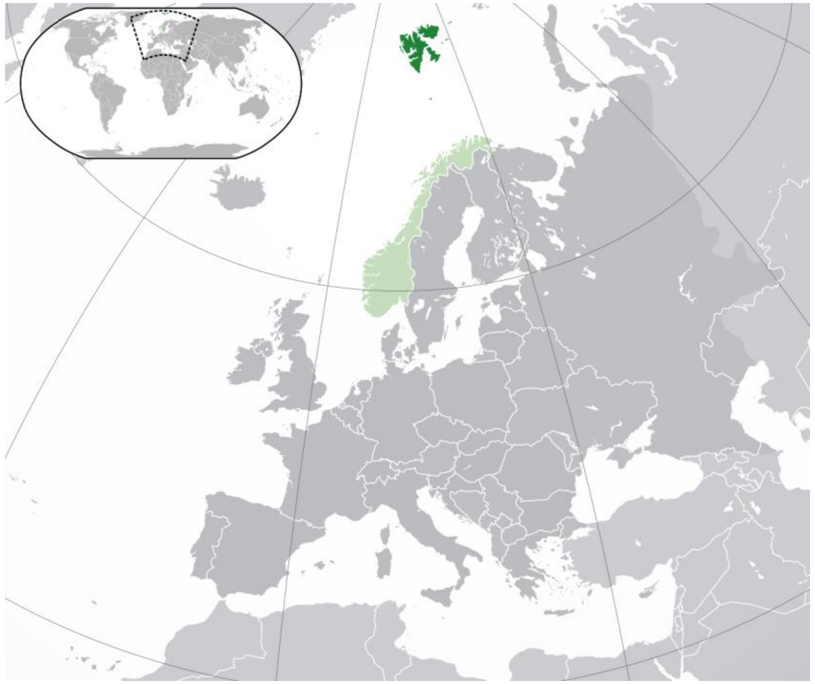
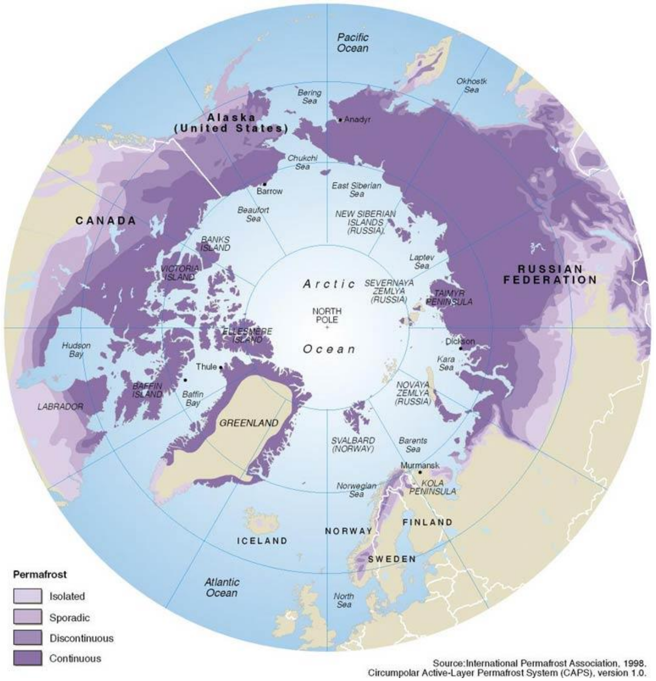
Study location



Reference: Wikipedia

Reference: https://toposvalbard.npolar.no/



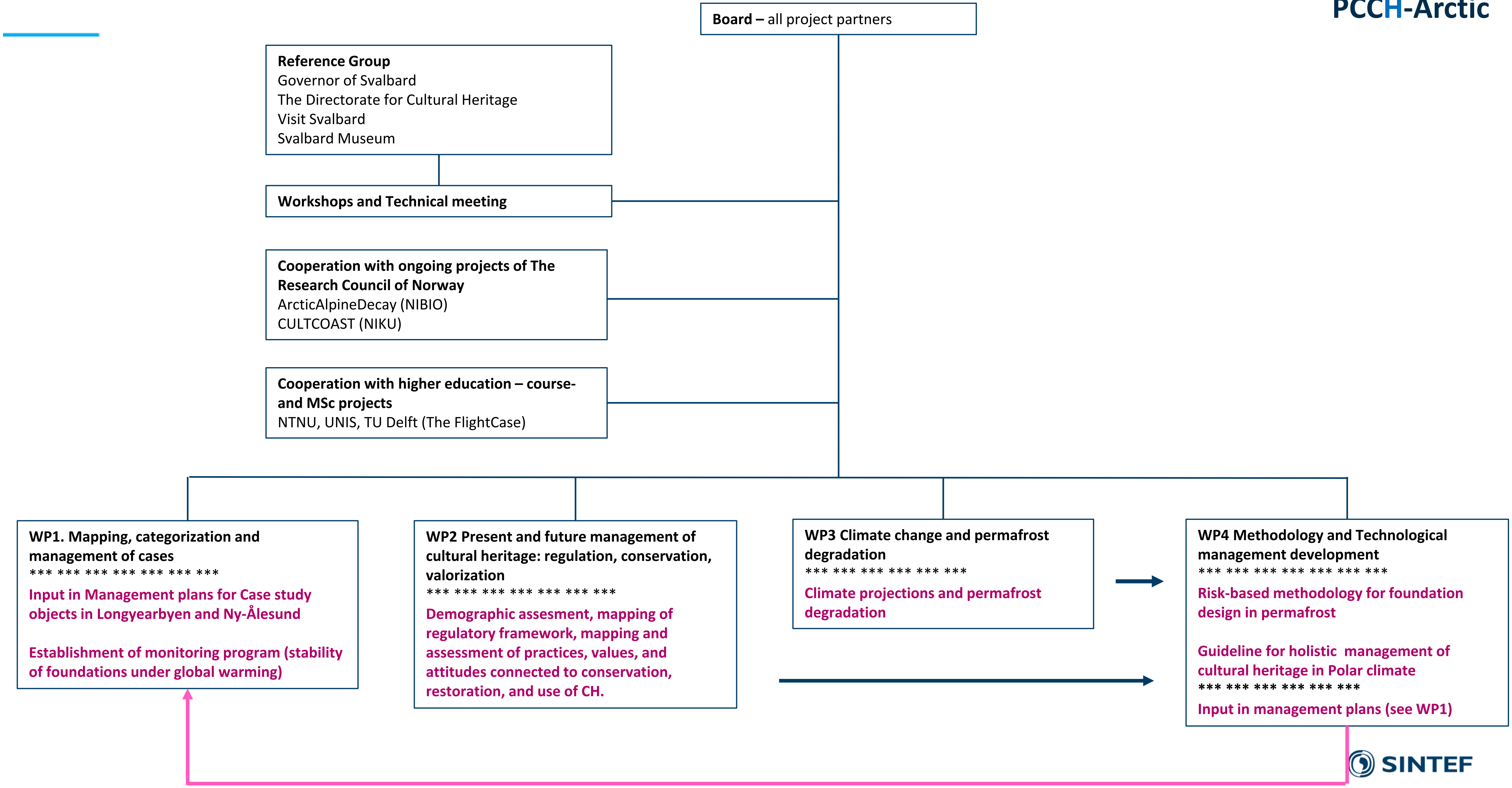
Permafrost in Northern Hemisphere. Reference: Circumpolar Active-Layer Permafrost System (CAPS), version 1.0. International Permafrost Association, 1998

PCCH-Arctic – Polar Climate and Cultural Heritage – Preservation and Restoration Management

- **Objectives:** to create a knowledge base for sustainable safeguarding and future use of cultural heritage in the Arctic in conditions of changing climate and demography
- **Project period:** 2021–2024
- **Funding:** The Research Council of Norway and User Partners, 10 MNOK (Cash) + 1.08 MNOK (InKind), i.e. ~1 MEuro.
- **Project type:** collaboration project to meet challenges in society and buisness (KSP)
- **User Partners:** Longyearbyen Lokalstyre, Store Norske Spitsbergen Kulkompani (SNSK) AS and Kings Bay AS
- **Research Partners:** Sintef, The Norwegian Meteorological Institute, UiO, UNIS and UniVie
- **Reference group:** Governor of Svalbard, The Directorate for Cultural Heritage, Visit Svalbard, Svalbard Museum
- **Web-page**: https://www.sintef.no/prosjekter/2021/pcch-arctic/
- **Research Council of Norway project number:** 320769, **SINTEF project number:** 102024999

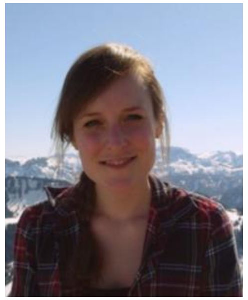
Outline of PCCH-Arctic

PCCH-Arctic



SINTEF

Researchers



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Research hypotheses

RH1: Costs of maintaining and restoring cultural heritage objects are quite high and the volume of objects is staggering. New technological solutions may be applied or developed to both lower the costs and improving the quality of the work.

RH2: Conservation of cultural heritage in the Arctic (objects, monuments, sites) faces a double challenge from the warming climate and increasing human activity. At the same time, cultural heritage can play an important role in sustainable development of the North. **Management plans** that take **socio-cultural** as well **environmental** and **technical** factors into account will make sustainable use of cultural heritage possible.

RH3: Expected climate change impact on cultural heritage in permafrost environments should be accounted via **risk-based management**, which is linked to probabilistic approaches for hazard assessment and geotechnical and foundation design in permafrost.

RH4: Definition of **permafrost temperatures**, currently based on historical data, n-factors and field investigations **should be substituted by the surface energy balance models**.

RH5: Currently used analytically and empirically based tools for geotechnical and foundation design in permafrost should be substituted with **emerging numerical tools**.

Research questions

RQ1: Can new technological solutions, applied or developed by the project, lower the cost and improve the quality of the work?

RQ2: How do changing preferences, patterns and levels of tourist traffic combined with local demographic development impact on cultural heritage in Svalbard?

RQ3: How can we take expected climate change impacts into account in risk-based management of cultural heritage in permafrost environments?

RQ4: Is the definition of permafrost temperatures based on historical data, n-factors, and field investigations suitable for geotechnical and foundation design in permafrost in rapidly changing climate?

RQ5: Can emerging numerical tools for geotechnical and foundation design in permafrost replace currently used analytical and empirical solutions?

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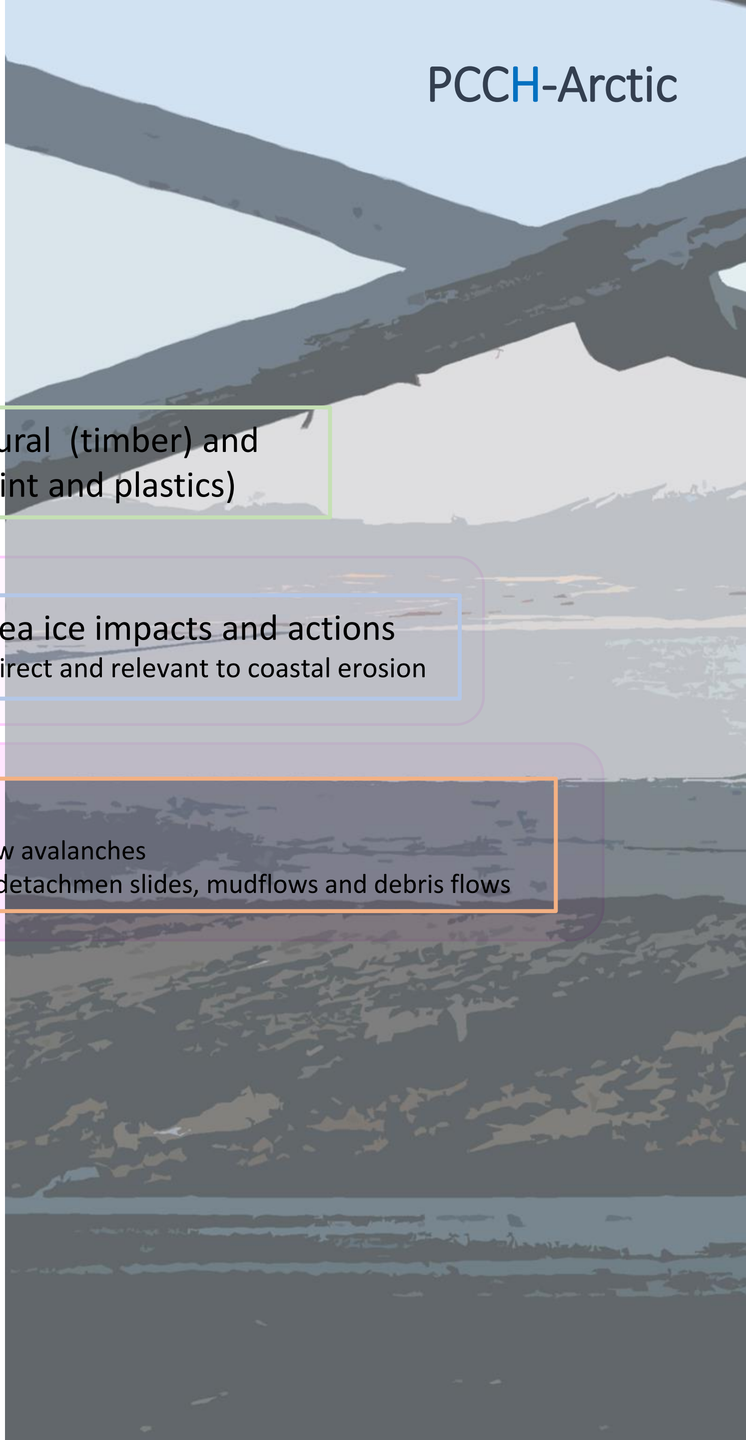
Some natural hazards in cold regions, which may be relevant to cultural heritage

May be intensified by the climate change

Degradation of materials	Bio-degradation of timber; Corrosion of metal; UV-degradation of natural (timber) and syntetic polyments (paint and plastics)
Hydrodynamical actions and sediment transport	Coastal erosion and sea flooding; Riverine erosion and riverine flooding; Sea ice impacts and actions Direct and relevant to coastal erosion
Geo-hazards	**Degradation of permafrost** Increases in seasonal thaw depth (active layer), warming of permafrost at depth, development of residual thaw zones **Slope hazards** Landslides, rockfalls, snow avalanches Solifluction, active-layer detachmen slides, mudflows and debris flows
Special site-specific hazards	Flooding due to sudden drainage of glacial lakes, large ("mega") landslides
Sequences of catastrophic events	Riverine flooding + landslides (blocking rivers); avalanches + riverine flooding



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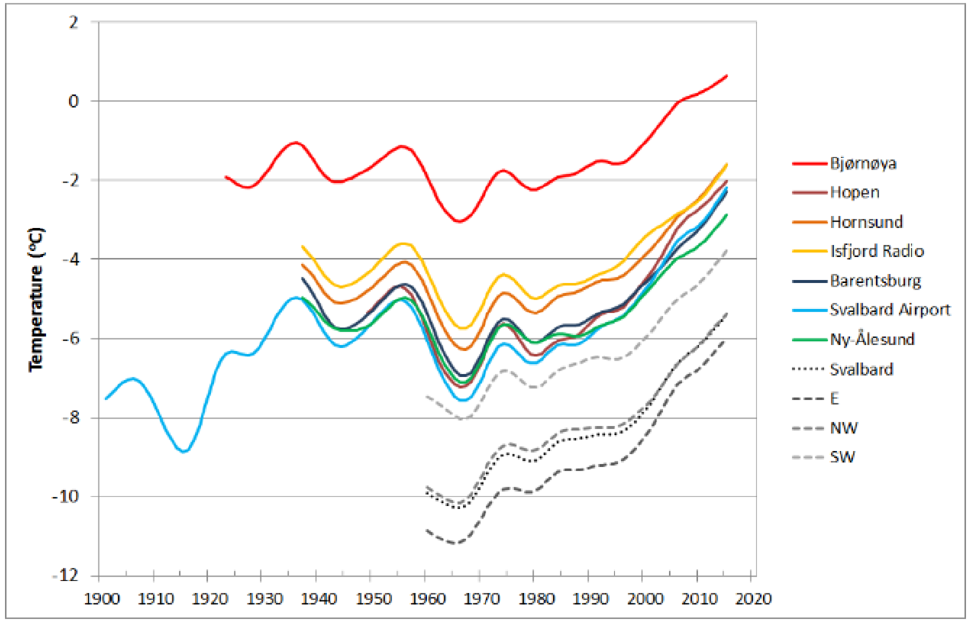
Other impacts on cultural heritage

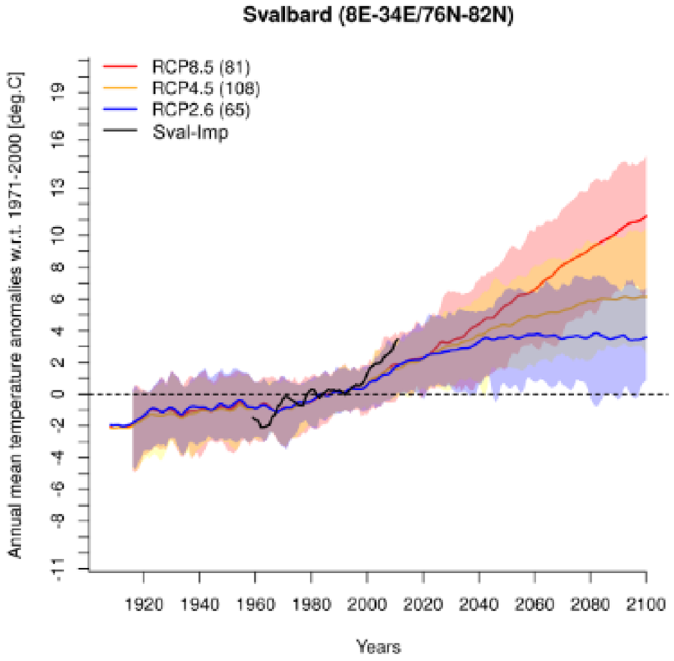
- Direct impacts due to the use
- Impacts on the cultural heritage sites
- Urban developments
- Pollutans (?)
- ++?

- "Wear and tear" due to use
- Impacts on vegatation, land surface, etc.

Climate change – air temperature in Svalbard: 1900–2100



Annual mean temperature for weather stations and regions in Svalbard. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljødirektoratet



Annual mean temperature anomalies. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljødirektoratet

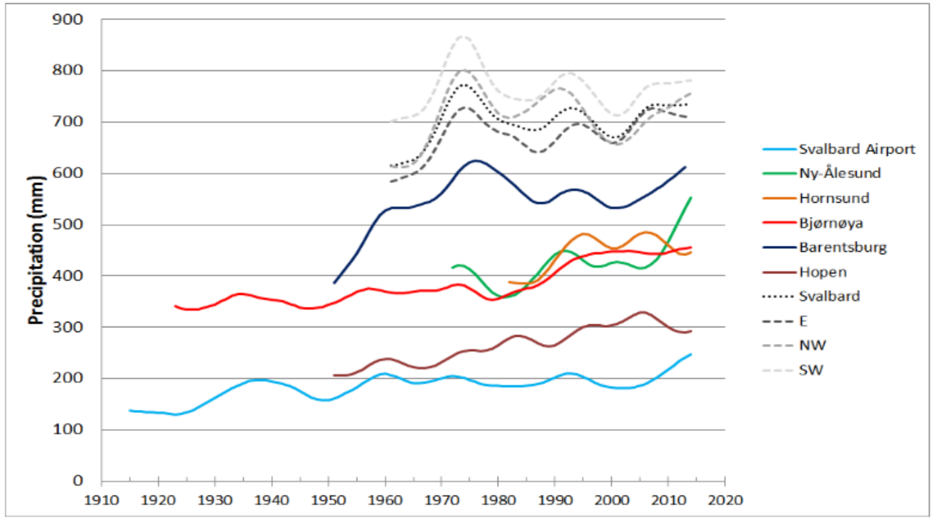
The Arctic is warming faster than the rest of the world

In Svalbard, most of the warming is in the winter season (which will prevent maintaining permafrost regime in the ground)

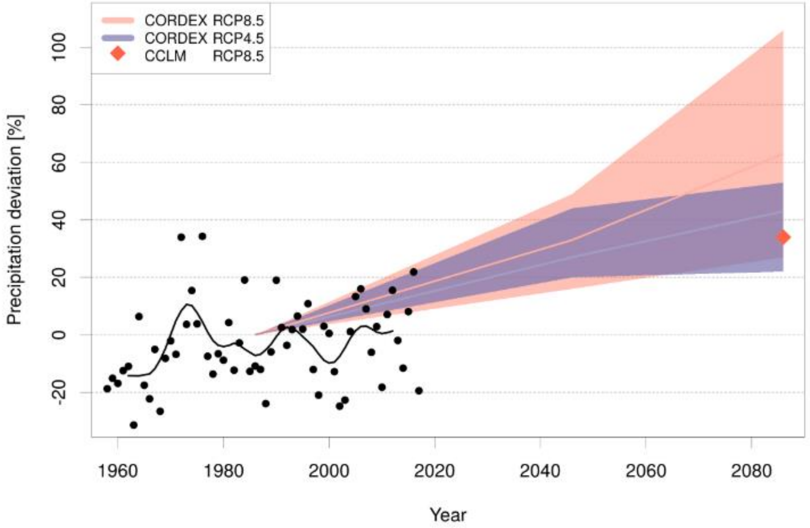
Climate models show strong future temperature increase for Svalbard.

Differences between socio-economic scenarios are naturally larger by the end of the century.

Climate change – precipitation: 1900–2100



Annual mean precipitation for weather stations and regions in Svalbard. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljødirektoratet.



Annual mean precipitation for Svalbard area as deviation (%) from the reference period 1971-2000. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljødirektoratet.

Warming means less snow and more rain.
Wind causes undercatch (negative bias) of snow.

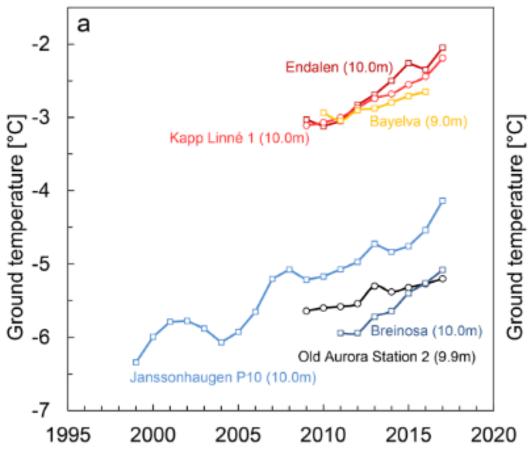
Many stations show increase in precipitation, but part of this is due to less undercatch.

Model simulations show future increase in precipitation.

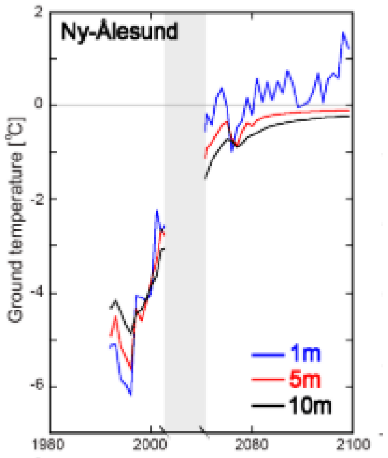
Impacts of global warming on permafrost in Longyearbyen and Ny-Ålesund

		2016-17				2008-2009	
Location	Borehole name/ ID	MAT (°C)	MGST (°C)	MGT (°C)	ALT (cm)	MGT (°C)	ALT (cm)
Adventdalen	Old Aurora Station 2	-1.9	-1.3	-5.2(9.9 m)	94	-5.6 (9.9 m)	90
	Endalen	-1.9		-2.7 (19 m)	190	-3.2 (15 m)	120
	Breinosa	-3.8	-4.1	-5.1 (10 m)	49	n/a	n/a
	Janssonhaugen/ P10	-3.8	n/a	-5.0 (20 m)	n/a	-5.5 (20m)[µ]	170
	Janssonhaugen/ P11	-3.8	-3.7(0.2 m)	n/a	185	n/a	170
Ny-Ålesund	Bayelva	-2.3	-3.6	-2.8 (9 m)	200	-2.9 (9 m)[π]	180
Kapp Linné	Kapp Linné 1	-1.2	-1.6	-2.6 (20 m)	300	-3.1 (15 m)	250
	Kapp Linné 2	-1.2	-1.6	-2.8 (20 m)	190	-3.2 (15 m)	180

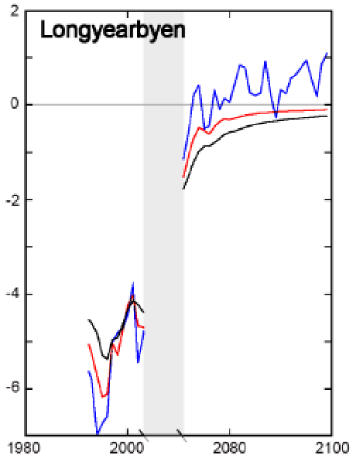
Permafrost monitoring sites with mean ground temperatures near or at the depth of zero annual amplitude. Reference: Christiansen et al., 2019 and Christiansen et al., 2010



Annual mean ground temperatures (MGT) at selected monitoring sires in Svalbard. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljødirektoratet. Data series are updated from Isaksen et al. 2007a, Christiansen et al. 2010 and Boike et al. 2018.

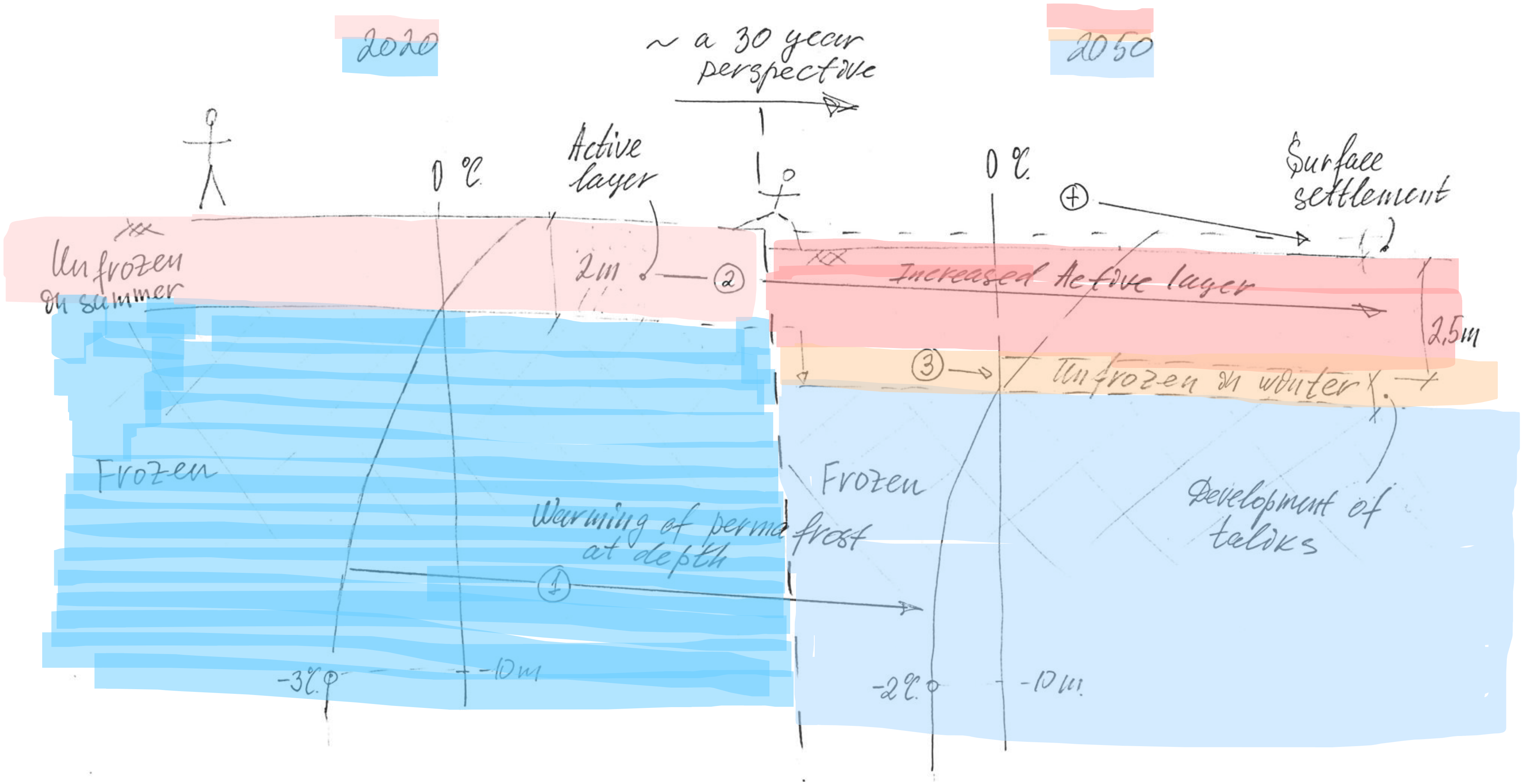


Permafrost modelling results for Ny-Ålesund. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljø-direktoratet.

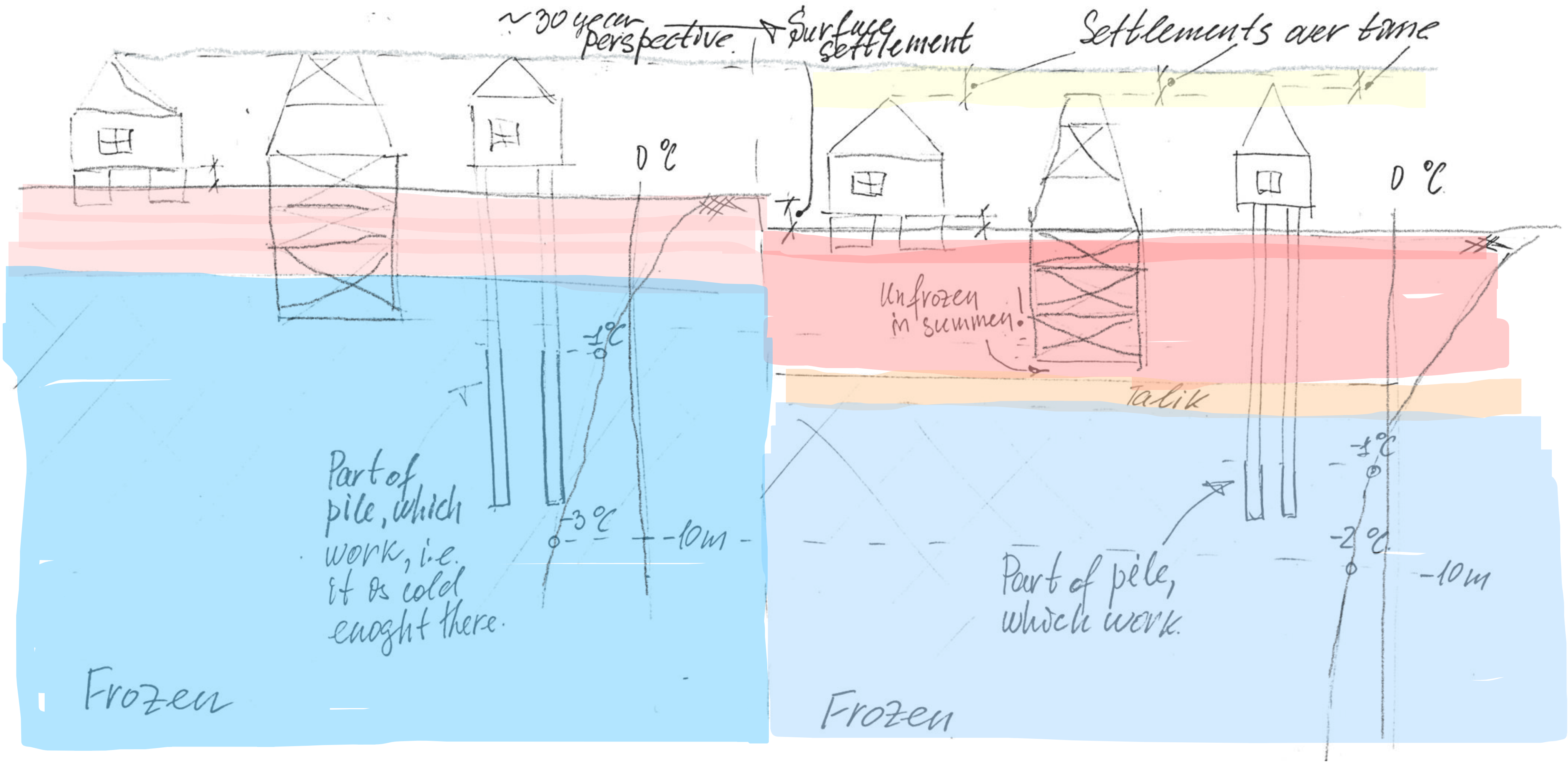


Permafrost modelling results for Longyearbyen. Reference: Hanssen-Bauer, et al., 2019 Report "Climate in Svalbard 2100". NCCS report no. 1/2019. Commissioned by Miljø-direktoratet.

Impacts of global warming – **degradation of permafrost**



Impacts of degrading permafrost on structures – **settlements and stresses**

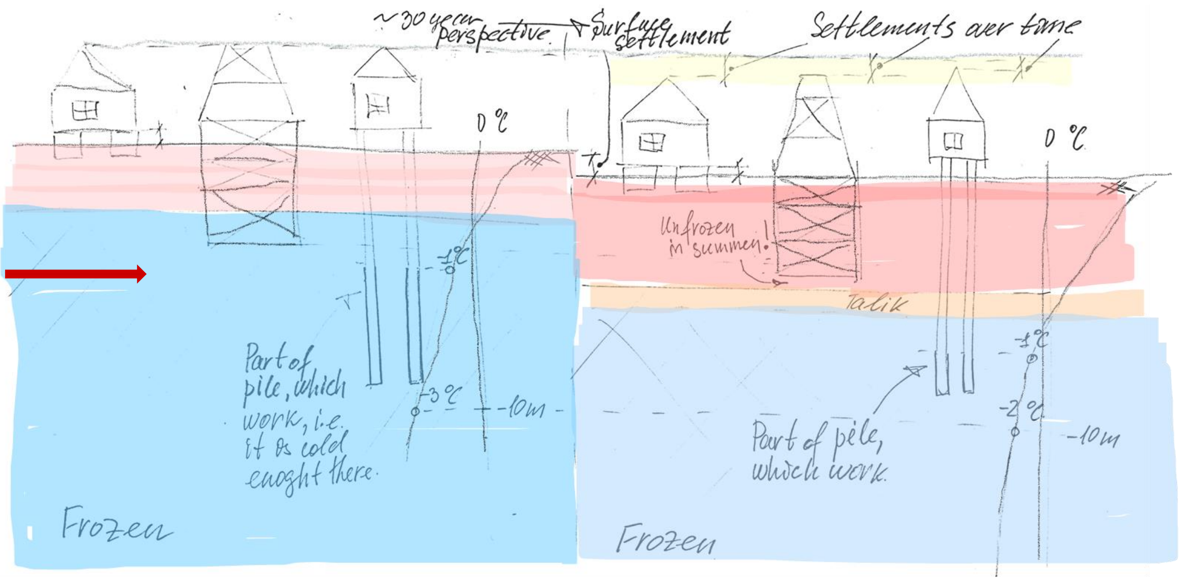


Engineering concerns related to degradation of permafrost

Engineering concerns, Instanes et al. (2005) after Esch et al. (1990):

- **Warming of permafrost body at depth**:
  - a. Increase in creep rate of existing piles and footings.
  - b. Increased creep of embankment foundations.
  - c. Eventual loss of adfreeze bond support for pilings.
- **Increases in seasonal thaw depth (active layer):**
  - a. Thaw settlement during seasonal thawing.
  - b. Increased frost-heave forces on pilings.
  - c. Increased total and differential frost heave during winter.
- **Development of residual thaw zones (taliks):**
  - a. Decrease in effective length of piling located in permafrost.
  - b. Progressive landslide movements.
  - c. Progressive surface settlements.

Relevant to cultural heritage



Handling of engineering concerns related to degradation of permafrost, Instanes et al. (2005): **Sensitive vs insensitive infrastructure → use of different approaches**

Sensitive infrastructure: large sensitivity and large consequences → detailed analysis … that may require more detailed geotechnical investigations (including local measurements of ground temperatures) and monitoring, detailed measurements of ground temperatures

Built technical-industrial cultural heritage: may be not that sensitive (when presented by simple structures as small houses), but consequences may extremely hight (due to extremely hight value)

Engineering concerns related to degradation of permafrost

1. Sensitivity of different structures to climate change is a function of:

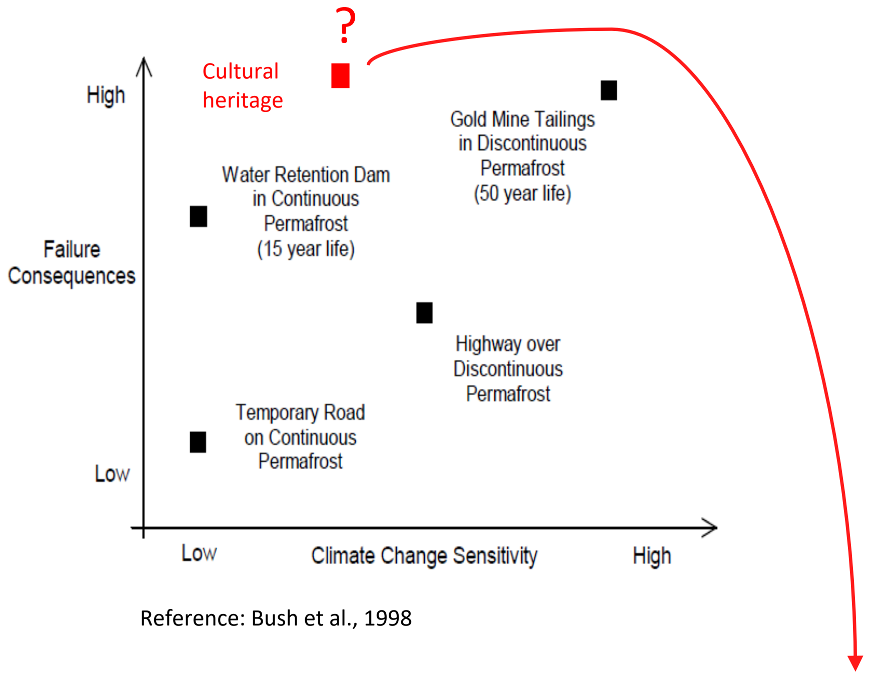
- Type of structure (structural aspects)
- Geo/cryological conditions
- Magnitude of climate change

2. Cultural and historical value

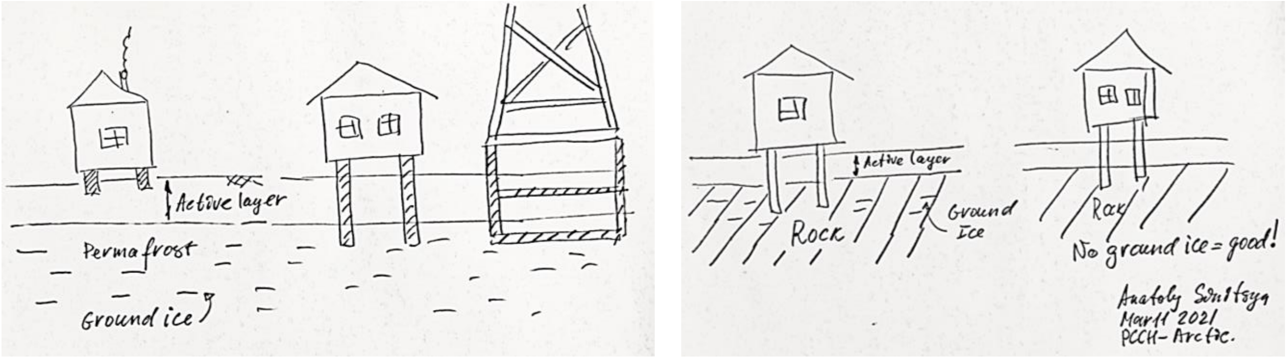
- There are different classes of value, including a class of a highest priority

Soil Type	Permafrost Temperature Zone			
	Zone 4 T < -7°C	Zone 3 -7°C ≤ T ≤ -4°C	Zone 2 -4°C ≤ T ≤ -2°C	Zone 1 -2°C ≤ T ≤ 0°C
Any soil with massive ice	M	H	H	H
Peat and organic	L	M	H	H
Silt or clay	M	M	M	H
Till	L	L	L	M
Marine soils with salinity	M	M	H	H
Sand or gravel	L	L	L	M
Frost-shattered rock	L	L	M	M

Temperature change sensitivity of permafrost by soil type and temperature zones Bush, E., et al. (1998).



Reference: Bush et al., 1998



Unlithified vs lithified permafrost – different sensitivity to climate change

Cultural heritage of high significance – where we are, compared to the gold mine tailings?

What types of consequences we should consider?

More towards practicalities for Handling of Engineering concerns related to degradation of permafrost

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Arctic Climate Impact Assessment. Support Systems, and Industrial Facilities, Instanes et al. 2005, [2]

Sensitive and insensitive infrastructure – different approaches

Sensitive infrastructure – large sensitivity and large consequences → detailed analysis is required.

Design:

- Recommended methodology – risk-based analysis (one of the project aims)
- Design is based on projected air/permaforst temperatures

Practicalities:

- **Piles foundations** – longer piles, extra measures (thermosyphon cooled pilings).
- **Very light buildings** funded directly on permafrost – adjustable mechanical systems, adjustable foundations (issues with water supply/sewage lines)
- **Elevated buildings:** importance of solar radiation shading and snow removal
- **Slab-on-grade foundations** with cooling systems – efficiency of passive systems (thermosyphons and air ducs) will decrease.

+ wider use of artificial cooling systems?

[+

Synthesis of the North American practice on stabilizing foundations on permafrost, McFadden 2001, [11]:

NB! Tacking into accound site-specific geo-cryological conditions is very important.

- Placement of new piles
- Relevelling an existing the building
- New post and pad foundations to distress foundation of small buildings
- Introduction of air-forced cooling system in the crawl space
- Buildings with heated basements:
  - Sacrificing of basement and introduction of air-forced cooling system
  - Installation of natural-convection devices under existing buildings (incl. drilling of inclined holes)
  - Insulation in the heated basement
  - Refrigeration cooling of the foundation (cooling system is installed under the floor)
- Buildings with a slab-on-grade-foundation:
  - Passive cooling with natural convection devices
  - Cooling with a forced-convection crawl space
- Three dimensional truss foundation

Solutions, marked in green which might deem to be acceptable (at a different degree) from historical and cultural points of view.

Towards defining the acceptable solutions for restoration of foundations of cultural heritage

Recommendations for restoration of foundations of historical buildings in Ny-Ålesund are presented in Hoem and Paulsen (2008):

- Foundations resting directly on the terrain:
  - To keep original solutions
  - Replacement of rotten elements
  - Avoiding direct contact of foundation with the ground (to place stones under the foundation
- Wooden piles:
  - Position to be corrected if necessary
  - Replacement of rotten elements
  - New piles can be placed **slightly further** down in the terrain to provide better stability
- Wooden posts:
  - Regular inspections to checking functionality and adjustments
  - Replacement of rotten elements
- Shallow concrete foundations:
  - Regular inspections to checking functionality and adjustments
  - Replacement of weathered elements
  - Use of local sand from Zeppelinhavna for production of new concrete blocks ☺☺

Boligbrakke G in Hiorthhamn, Svalbard (summer 2021) with temporal foundation solution as described in (Boro and Flyen, 2021). This temporal solution is in place for 18 years as for 2021.

May the following **solutions deem as acceptable from historical and cultural points of view, especially when taking into account ethical and socio-cultural aspects?**

- Longer pile foundations and deeper shallow foundations
- Snow management (elevated structures)
- Introduction of air-forced cooling system in the crawl space
- Insulation in the heated basement
- Refrigeration cooling of the foundation (cooling system is installed under the floor)

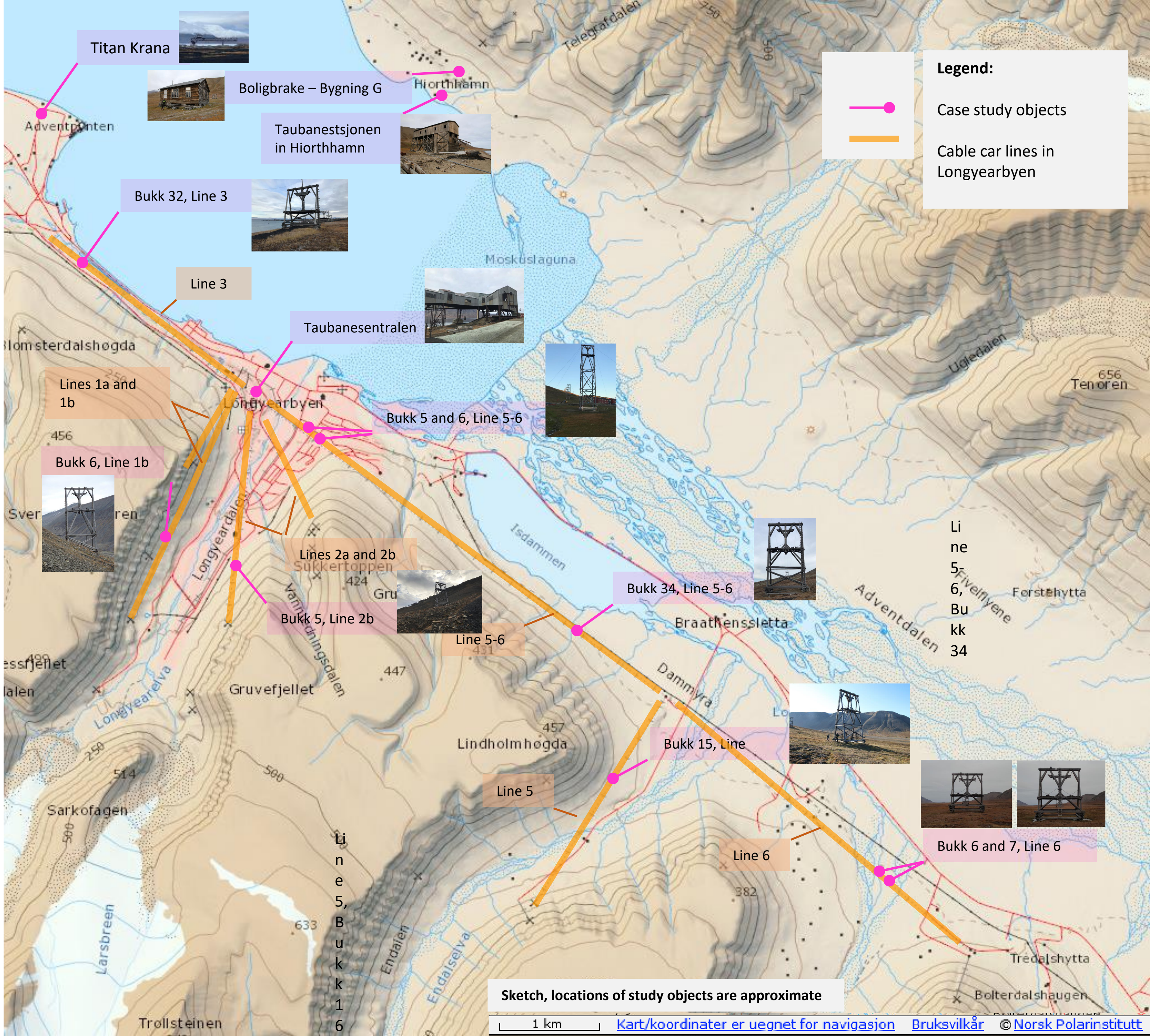
- Should improved foundation solution **require low frequency of inspections** (that would be beneficial for the cases at with the Boligbrakke G in Hiorthhamn, see picture above)?

WP1. Input in the management plans of the case study objects

Table. The case study objects in PCCH-Arctic

	Longyearbyen	**Object ID in Askeladden***
1.	System of the cableway posts, 1907–1960 (*Taubanebukker*, Norwegian): • Cable car line 1b (*Taubanelinje 1b*) • Cable car line 2b (*Taubanelinje 2b*) • Cable car line 3 (*Taubane 3)* • Cable car line for mines 5 and 6 (*Taubane delstrekning gruve 5 og 6*)	158657 158986 158619 87889
2.	The Titan crane, 1953 (*Titankrana*, Norwegian)	NA
3.	The old coal cableway centre in Longyearbyen, 1957 (*Taubanesentralen i Longyearbyen*)	87889-6
4.	The coal cableway station in Hiorthhamn, 1917 (*Taubanestasjonen i Hiorthhamn*, Norwegian)	93040-6
	Ny-Ålesund	
1.	The airship mast in Ny-Ålesund, 1926 (*Luftskipsmasta*)	158506-2
2.	The White house, 1919 (*Hvitt hus*)	159 781
3.	The Tronderheimen house, 1945 (*Trønderheimen*)	159 772
4.	The London houses, 1912/1950 (*Londonhusene*)	159807-1 159804-1 159806-1 159802-1
5.	The Green Harbour-house, 1909 (*Green Harbour-Huset*)	159759-1

Case-study objects in Longyearbyen



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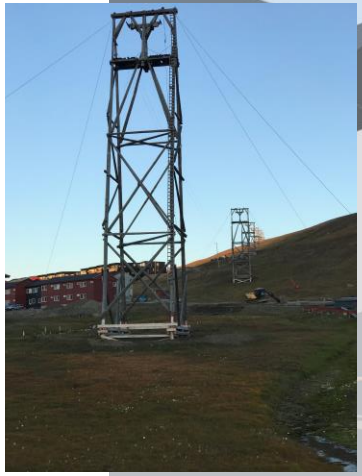
Case-study objects in Longyearbyen and Hiorthhamn

Taubanesentralen in Longyearbyen

Line 3, Bukk 33

Line 1b, Bukk 6



Line 5-6, Bukk 6

Line 5-6, Bukk 34

Taubanestasjonen in Hiorthhamn

Line 2b, Bukk 5

Line 5, Bukk 16

Line 6, Bukk 7

Titankrana

Boligbarakke G in Hiorthhamn

Line 6, Bukk 8

Case-study objects in Ny-Ålesund

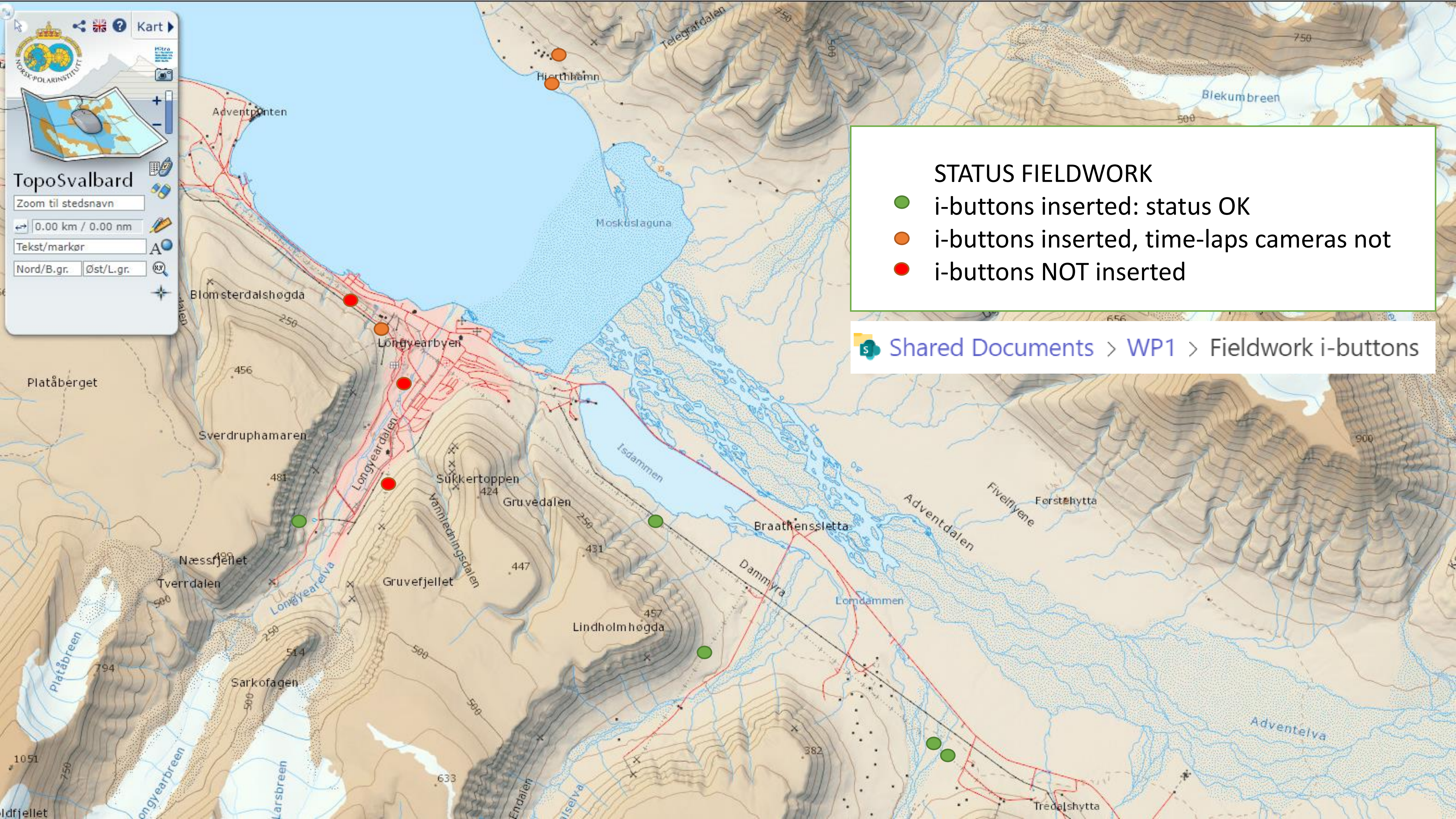
Case-study objects in Ny-Ålesund

The Green Harbour house

Luftskipsmasta

The London houses

The White house (Managers house)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i-buttons inserted: status OK
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TopoSvalbard
Zoom til stedsnavn
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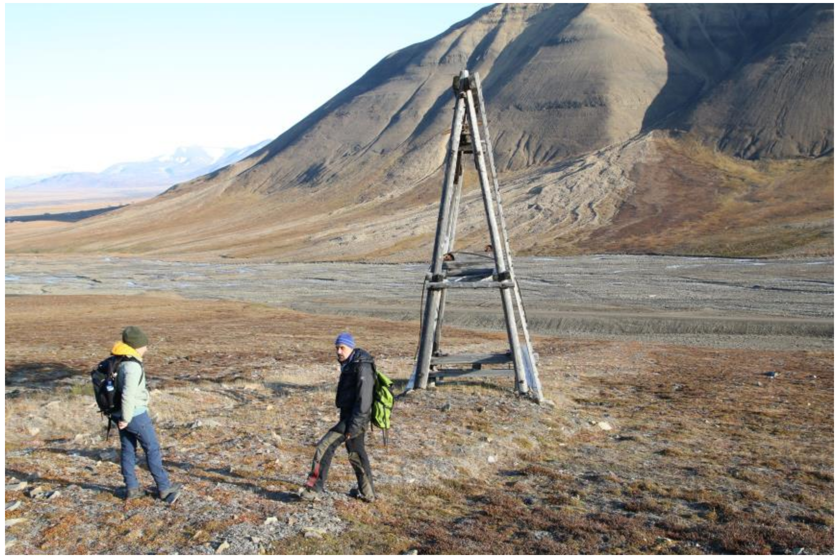
Tekst/markør
Nord/B.gr.
Øst/L.gr.
Kart
Adventpynten
Hiorthhamn
Telegrafdalen
Blekumbreen
Moskuslaguna
Blomsterdalshøgda
Longyearbyen
Platåberget
Sverdruphamaren
Sukkertoppen
Gruvedalen
Isdammen
Braathensletta
Adventdalen
Fivelflyene
Førstehytta
Dammyra
Lomdammen
Næssfjellet
Tverrdalen
Longyearelva
Gruvefjellet
Vannledningsdalen
Lindholmhøgda
Sarkofagen
Platåbreen
Longyearbreen
Larsbreen
Endalen
Adventelva
Tredalshytta
Longyeardalen

Pictures from fieldworks



Field excursion in Endalen (September 2021). Picture: Sinitsyn, A.

Installation of i-buttons. Picture: Enevoldsen, K. (winter 2022)

dGPS survey at Tital Krana (September 2022). Picture: Sinitsyn, A.

An i-button. Picture: Enevoldsen, K.

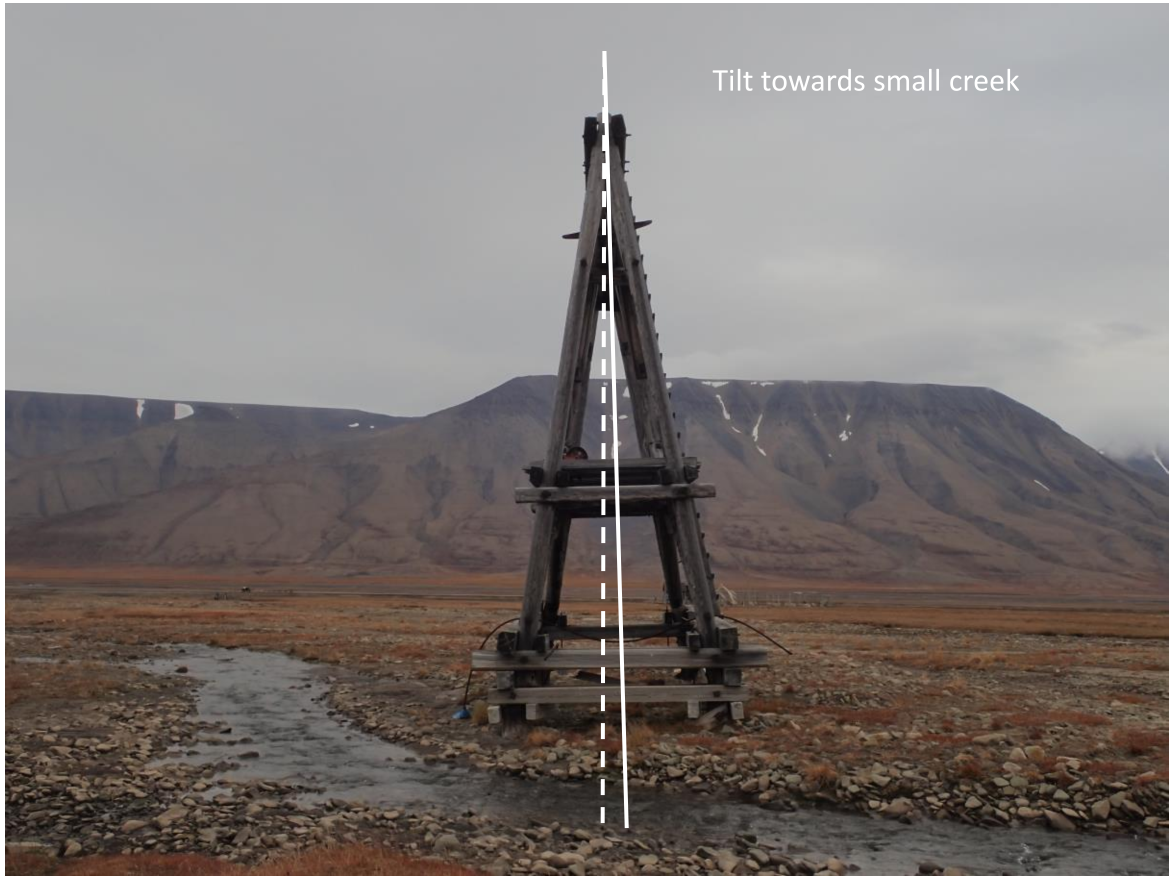
An i-button installed and marker with a shield. Picture: Enevoldsen, K.

Indicators of changes in microclimate – **changes in vegetation** under and around the structures – different vegetation species (are those typical for a warmer climate?) and much richer vegetation compared to surrounding tundra: 1) grass instead of moss; 2) much denser grass cover; 3) much greener grass cover.

Line 3, Bukk 22 (pictures 22_13 and 22_11) – changes in vegetation under the structure compared to surrounding terrain

Line 6, Bukk 27 (pictures 27_5 and 27_7) – changes in vegetation and depressions around foundations, spin-off effect – ponding of water

Influence of running water on permafrost degradation



Line 6, Bukk 10 (pictures 10_1 and 10_2) – running water in seasonal creek warms up permafrost, tilt of structure towards a creek.

Preliminary inventory of cableway posts

Types of natural hazards	Number of cases, approximately
Permafrost degradation	110
Solifluction	43
Gravitational slope processes	34
Surface wash and gravitational processes	2
Snow avalanches	4
"Special" cases	1
Additional evaluation is needed	8

Several various natural hazards are normally present at a particular location

Inventory of taubanebukker

	Object ID in Aksenladen	Need in restoration, number of structures						
		Destroyed/Absent	Restored/Prepared for restoration	Further analysis is needed	Further analysis is Needed/Needed	Needed	Needed/ Urgent	Urgent
Cableway post's lines								
Taubanelinje 1a	159054	11						
Taubanelinje 1b	158657	3	1	6	1	6	2	3
Taubanelinje 2a	158987	5						
Taubanelinje 2b	136716	5	2	3		4	2	
Taubane 3	158619	1		17	22	1		
Taubane delstrekning gruve 5 og 6	87889	4	8	14		8	1	9
Taubane delstrekning gruve 5	87889	4	1	8	2	1	1	5
Taubane delstrekning gruve 6	87889			14	3	13	7	3
Total number of different cases		**33**	**12**	**62**	**28**	**33**	**13**	**20**
Total number of surveyed cableway posts and their previous locations								**201**

Estimations of future air temperatures in Longyearbyen, based on exiting climate projections

Air thawing and freezing indexes

MSc thesis of Kristin Enevoldsen, UNIS/NTNU/SINTEF

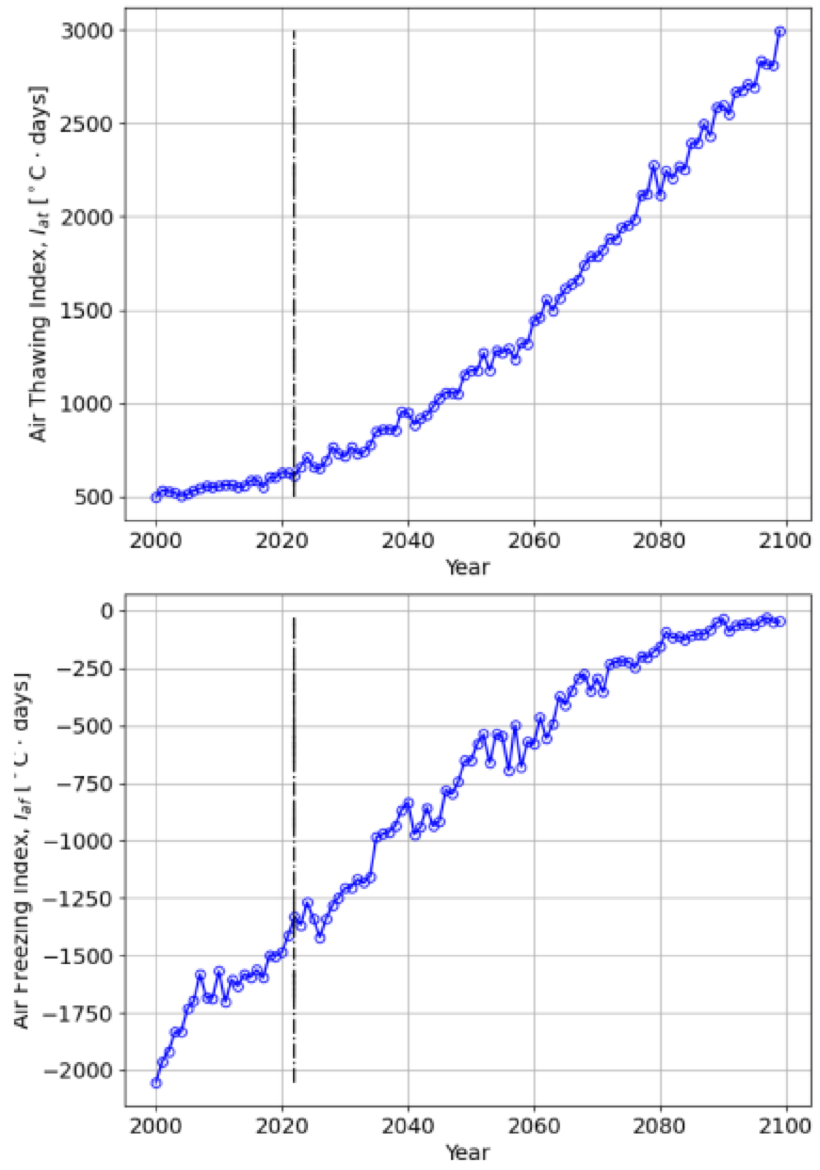


Figure 4.8: This plots show the estimated air thawing index I_{at} and air freezing index I_{af} in the period from 2000 to 2100. The vertical line indicates 2022. The future scenarios are based on predicted future temperatures from MET.

Future ground temperatures under foundations (numerical simulations) – preliminary analysis based on existing climate projections

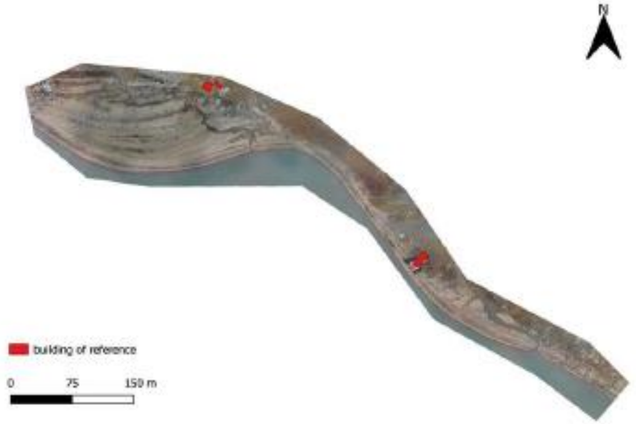
	Ground temperature [θ]								
	d_f 1.5m			d_f 2.0m			d_f 2.5m		
	SAND	SILT	CLAY	SAND	SILT	CLAY	SAND	SILT	CLAY
2030	>0	-0.4	-0.6	-0.2	-0.8	-1.1	-0.7	-1.2	-1.6
2040	>0	-0.4	-0.5	>0	-0.8	-1.1	-0.3	-1.2	-1.4
2050	>0	>0	>0	>0	-0.2	-0.8	-0.2	-0.4	-0.4
2060	>0	>0	>0	>0	>0	>0	>0	>0	>0

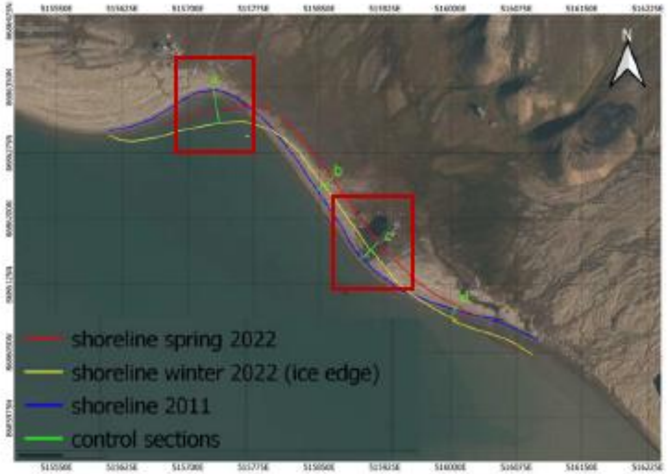
Table 4.11: Temperatures below footings from Temp/W for foundation depth d_f 1.5 m, 2.0 m and 2.5 m fot the three soil types.

Reference: MSc thesis of Enevoldsen, K. UNIS/NTNU/SINTEF

Modelling of coastal erosion at Hiorthhamn

MSc thesis of Carlo Antonello, UNIS/NTNU/SINTEF





Reference: MSc thesis of Antonello, C. UNIS/NTNU/SINTEF

Modelling : Results

Constant Sea Level Rising rate

Storm Condition increased by n% over the wave data set

20 anni

	$K[10^6 m^{9/4}s^{2/3}]$	S [%]	s [mm/y]	storm conditions	EROSION from 2020 to 2042 [m]	Increase in Recession [%]
Model 1 - 20 years	8.1	60	0.5	10% increase	9.4	1.2
Model 1 - 20 years	8.1	60	0.5	20% increase	11.5	23.5
Model 2 - 20 years	8.25	60	1	10% increase	9.3	1.0
Model 2 - 20 years	8.25	60	1	20% increase	11.8	28.6

40 anni

	$K[10^6 m^{9/4}s^{2/3}]$	S [%]	s [mm/y]	storm conditions	EROSION from 2020 to 2062 [m]	Increase in Recession [%]
Model 1 - 40 years	8.1	60	0.5	10% increase	18.9	17.4
Model 1 - 40 years	8.1	60	0.5	20% increase	22.5	39.8
Model 2 - 40 years	8.25	60	1	10% increase	18.6	17.0
Model 2 - 40 years	8.25	60	1	20% increase	22.9	44.0

	EROSION from 1927 to 2062 [m]	EROSION from 2022 to 2062 [m]	erosion rate [m/y]
Model 1	86.9	16.1	0.644
Model 2	86.7	15.9	0.642

Model was able to reproduce historical erosion rates, based on this the effects of stronger wave climate (observed increase from reference locations across the Arctic was used) were modelled. The latter provided up to 44% higher erosion rates.

Suggested solutions for handling the hazard of erosion at the site:

- Groin at the structure (to get accumulation rather then erosion by the structure)
- Headland breakwaters
- Beach nourishment/smoothing accumulative profile NW from the structure
- Combination of beach nourishment and protective structures
- Relocation of structure uphill (the currently considered approach)

WP2. Present and future management of cultural heritage: regulation, conservation, valorization

Main hypothesis (RH2):
Conservation of cultural heritage in the Arctic (objects, monuments, sites) faces a double challenge from the warming climate and increasing human activity. At the same time, cultural heritage can play an important role in sustainable development of the North. Management plans that take ethical and socio-cultural as well environmental and technical factors into account will make sustainable use of cultural heritage possible.

Research question (RQ2):

How do changing preferences, patterns and levels of tourist traffic combined with local demographic development impact on cultural heritage in Svalbard?

Task 2.1 Scenario-based demographic assessment of future developments in tourism and local communities

Task 2.2 Mapping and assessment of the regulatory framework surrounding conservation, restoration, and use of cultural heritage

Task 2.3 Mapping and assessment of practices, values, and attitudes connected to conservation, restoration, and use of cultural heritage

WP2. Present and future management of cultural heritage: regulation, conservation, valorization

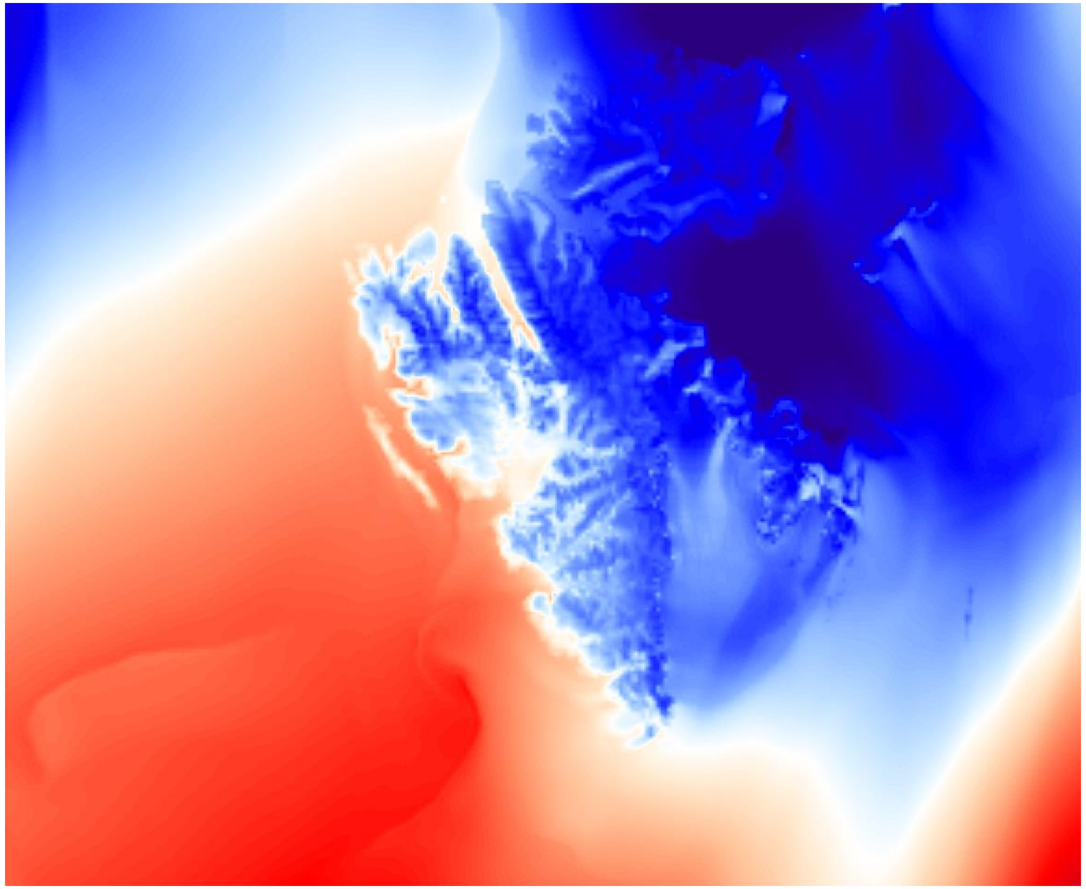
Task 2.3 Mapping and assessment of practices, values, and attitudes connected to conservation, restoration, and use of cultural heritage

Qualitative research methods – interviews & ethnographic fieldwork

- Mapping of different **values** connected to cultural heritage
- Identification of main types of **attitudes** towards heritage preservation
- Exploration of **dilemmas** related to use/protection of cultural heritage

Need for communication, dialogue, and transparency in the cultural heritage field on Svalbard

WP3. Climate change and permafrost degradation



Interaction between atmosphere and permafrost:

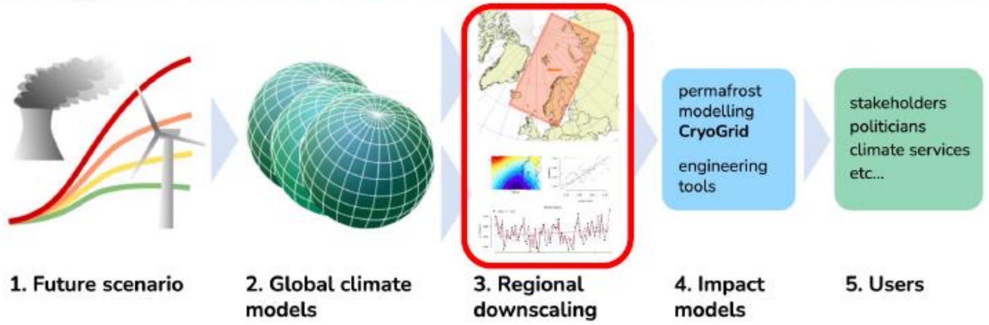
- Snow acts as an insulator
- Rain can melt snow, or refreeze

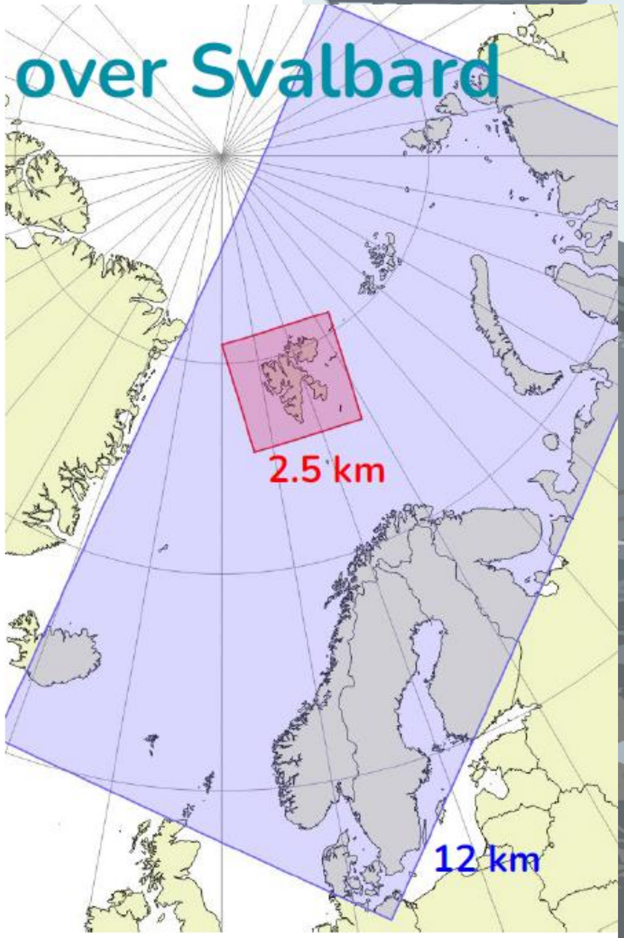
In PCCH-Arctic, new high-resolution simulations + hybrid downscaling can provide a better description of local weather:

- Changes in statistics over time
- Input to permafrost and engineering models

WP3. Climate change and permafrost degradation

High-resolution climate simulation over Svalbard





Production of regional climate simulation with the HCLIM model:

- 2.5 x 2.5 km resolution over Svalbard
- Period: 1991-2060 (historical + SSP5-8.5 *~business as usual*)
- Input data from global climate model NorESM2-MM
- ~70 output variables at 3-hourly resolution (land & atmosphere)
- Post processing tailored to provide data to CryoGrid permafrost model (UiO)
- Evaluation against historical climate (observations from e.g. Ny-Ålesund and Longyearbyen and CARRA reanalysis)
- Supplement with hybrid downscaling of CMIP6 (statistical + dynamical) to quantify ensemble spread

Oskar Landgren & Julia Lutz, Norwegian Meteorological Institute

Norwegian Meteorological Institute

PCCH-Arctic

Simulating permafrost evolution under cultural heritage on Svalbard

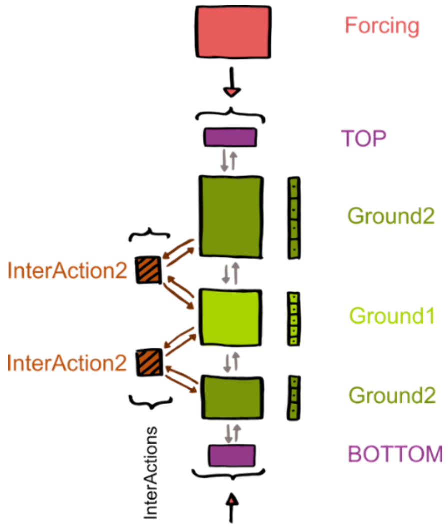
PCCH-Arctic – Polar Climate and Cultural Heritage
WP3 – Climate change and permafrost degradation

Simulation

- Snow?
- Building type?

→Progress:

- Forcing data
- Model setup with CryoGrid



Validation

iButtons

→Progress:

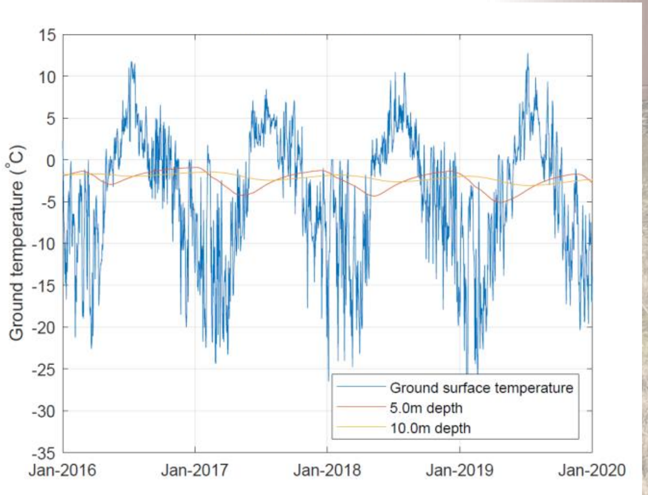
Installation of iButtons

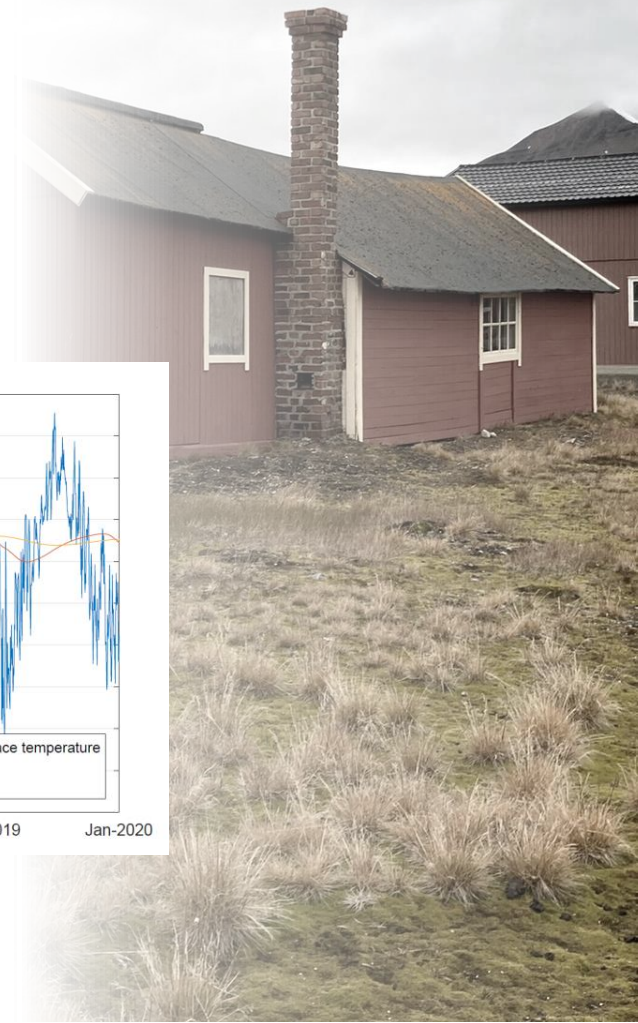
Results

- Ground temperatures
- Water content
- Ice content

→Progress:

Yet to come





WP 4. Methodology and Technological management development

- Recommendations (a set of best practises) for holistic management of cultural heritage in Polar climate

- Input in the *Recommendations*: PCCH-Arctic methodology for decision making (climate risk to permafrost are included):
  - Coarse analysis – screening for possible natural hazards and evaluating risk
  - Fine analysis – probabilistic geotechnical analysis

- Specific solutions for the needs of user-partners, widely applicable in the pan-Arctic (probably we will look at the solifluctions slopes)

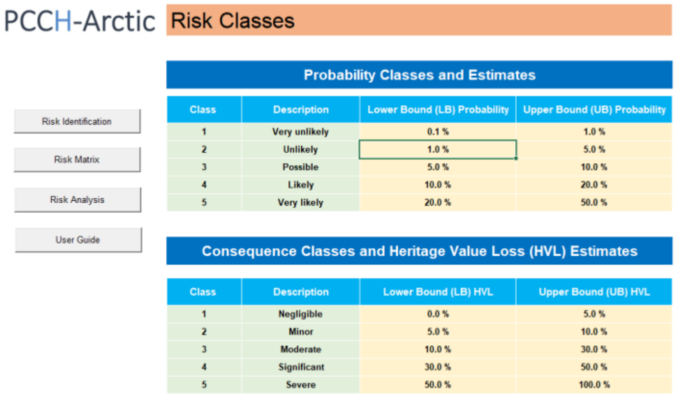
- Monitoring methods for support of management and maintenance plans

WP 4. Methodology and Technological management development

PCCH-Arctic methodology for decision making:

- Coarse analysis – screening for possible natural hazards and evaluating risk based on existing hazard maps.
  Based on NS5815.
- Fine analysis – probabilistic geotechnical analysis based climate projections that include statistical parameters (RCP 8.5 scenario only).

WP 4. Methodology and Technological management development – an example of Coarse analysis

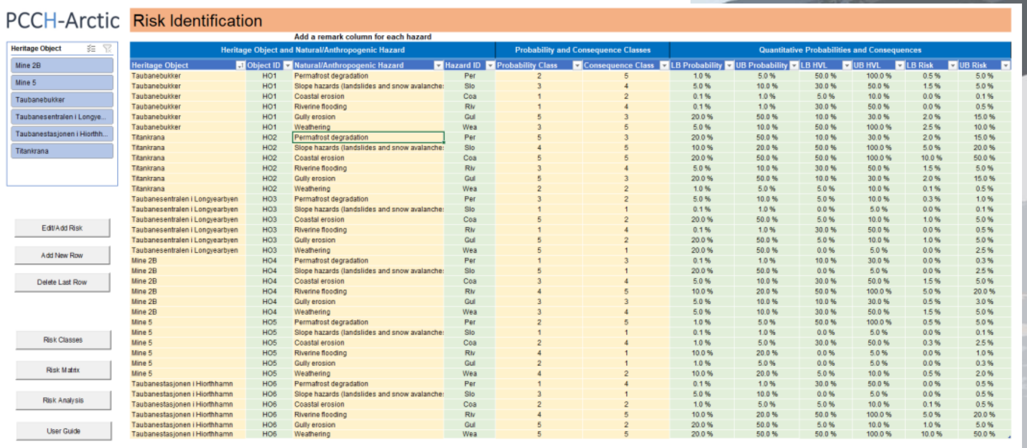


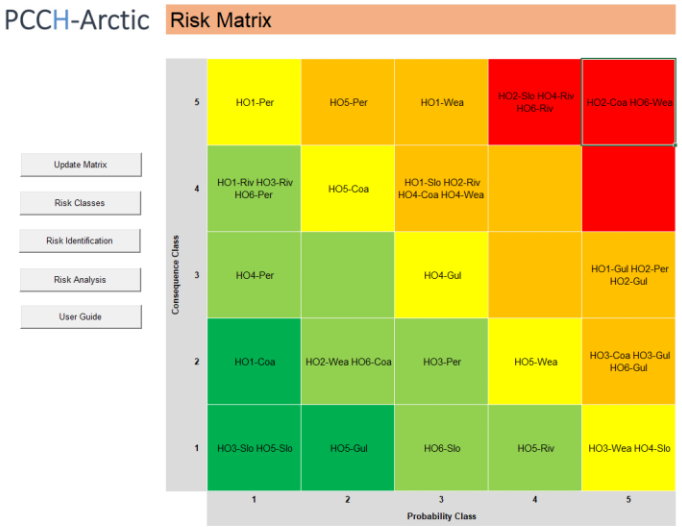
Probability Classes and Estimates

Class	Description	Lower Bound (LB) Probability	Upper Bound (UB) Probability
1	Very unlikely	0.1 %	1.0 %
2	Unlikely	1.0 %	5.0 %
3	Possible	5.0 %	10.0 %
4	Likely	10.0 %	20.0 %
5	Very likely	20.0 %	50.0 %

Consequence Classes and Heritage Value Loss (HVL) Estimates

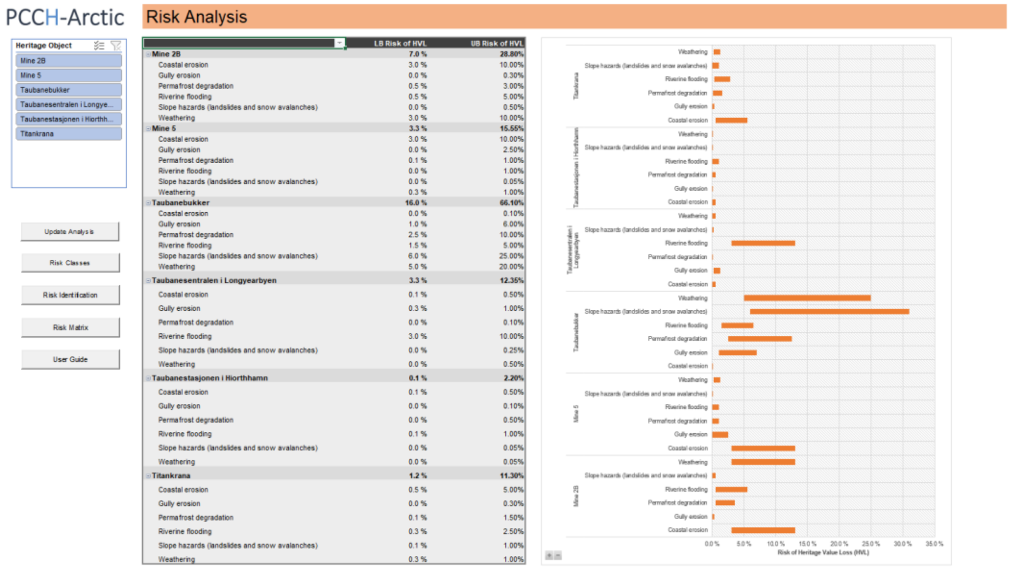
Class	Description	Lower Bound (LB) HVL	Upper Bound (UB) HVL
1	Negligible	0.0 %	5.0 %
2	Minor	5.0 %	10.0 %
3	Moderate	10.0 %	30.0 %
4	Significant	30.0 %	50.0 %
5	Severe	50.0 %	100.0 %





Consequence Class	1	2	3	4	5
5	HO1-Per	HO5-Per	HO1-Wea	HO2-Slo HO4-Riv HO6-Riv	HO2-Coa HO6-Wea
4	HO1-Riv HO3-Riv HO6-Per	HO5-Coa	HO1-Slo HO2-Riv HO4-Coa HO4-Wea		
3	HO4-Per		HO4-Gul		HO1-Gul HO2-Per HO2-Gul
2	HO1-Coa	HO2-Wea HO6-Coa	HO3-Per	HO5-Wea	HO3-Coa HO3-Gul HO6-Gul
1	HO3-Slo HO5-Slo	HO5-Gul	HO6-Slo	HO5-Riv	HO3-Wea HO4-Slo

Probability Class



References

1. Esch, D. C. and T. E. Osterkamp (1990). "Cold regions engineering: Climate warming concerns for Alaska." Journal of Cold Regions Engineering 4(1): 6-14.
2. Instanes, A., et al. (2005). Ch. 16 Infrastructure: Buildings, Support Systems, and Industrial Facilities. ACIA, 2005. Arctic Climate Impact Assessment. ACIA Overview report. Cambridge University Press: 1022.
3. Andersland, O. B. and B. Ladanyi (2004). Frozen Ground Engineering, 2nd Edition. Hoboken, New Jersey, John Wiley & Sons.
4. van Everdingen, R.O., Muli-Language Glossary of Permafrost and Related Ground-Ice Terms. 2005, International Permafrost Association: The Arctic Institute of North America, The University of Calgary, Calgary, Alberta, Canada T2N 1N4.
5. McFadden, T. (2001). Design Manual for Stabilizing Foundations on Permafrost.
6. Christiansen HH, B Etzelmüller, K Isaksen, H Juliussen, H Farbrot, O Humlum, M Johansson, T Ingeman-Nielsen, L Kristensen, J Hjort, P Holmlund, ABK Sannel, C Sigsgaard, HJ Åkerman, N Foged, LH Blikra, MA Pernosky and R Ødegård (2010). The thermal state of permafrost in the Nordic area during the International Polar Year. Permafrost and Periglacial Processes, 21:156-181.
7. Christiansen HH, GL Gilbert, N Demidov, M Guglielmin, K Isaksen, M Osuch and J Boike (2019a). Permafrost thermal snapshot and active-layer thickness in Svalbard 2016-2017, 18 p. First SIOS SESS report: https://sios-svalbard.org/SESS_Issue1
8. Boike J, I Juszak, S Lange, S Chadburn, E Burke, PP Overduin, K Roth, O Ippisch, N Bornemann, L Stern, I Gouttevin, E Hauber and S Westermann (2018). A 20-year record (1998–2017) of permafrost, active layer and meteorological conditions at a high Arctic permafrost research site (Bayelva, Spitsbergen), Earth Syst. Sci. Data, 10, 355-390, https://doi.org/10.5194/essd-10-355-2018.
9. Hanssen-Bauer, I., et al. (2019). Climate in Svalbard 2100 - a knowledge base for climate adaptation.
10. Bush, E., D.A. Etkin, D. Hayley, E. Hivon, et al., Climate Change Impacts on Permafrost Engineering Design., in Environment Canada. 1998, Downsview, Ontario: Environmental Adaptation Research Group.
11. Sysselmannen på Svalbard, Hoem, S. and .Paulsen, B., 2008. Ny-Ålesund. Forvaltningsplan for de fredete bygningene i tettstedet (Ny-Ålesund. Management plan for the listed buildings in the settlement).
12. Riksantikvaren. Flyen, A.-C., Boro, M. (2020). Svalbard: Hiorthhamn Kulturmiljø. Kulturminner og klima – risikovurdering og planlegging av tiltak. En del av prosjekt Adapt Northern Heritage 2020: 29.