Warming and thawing trends of permafrost at high Arctic site (Bayelva, Spitsbergen) 1998 - 2017

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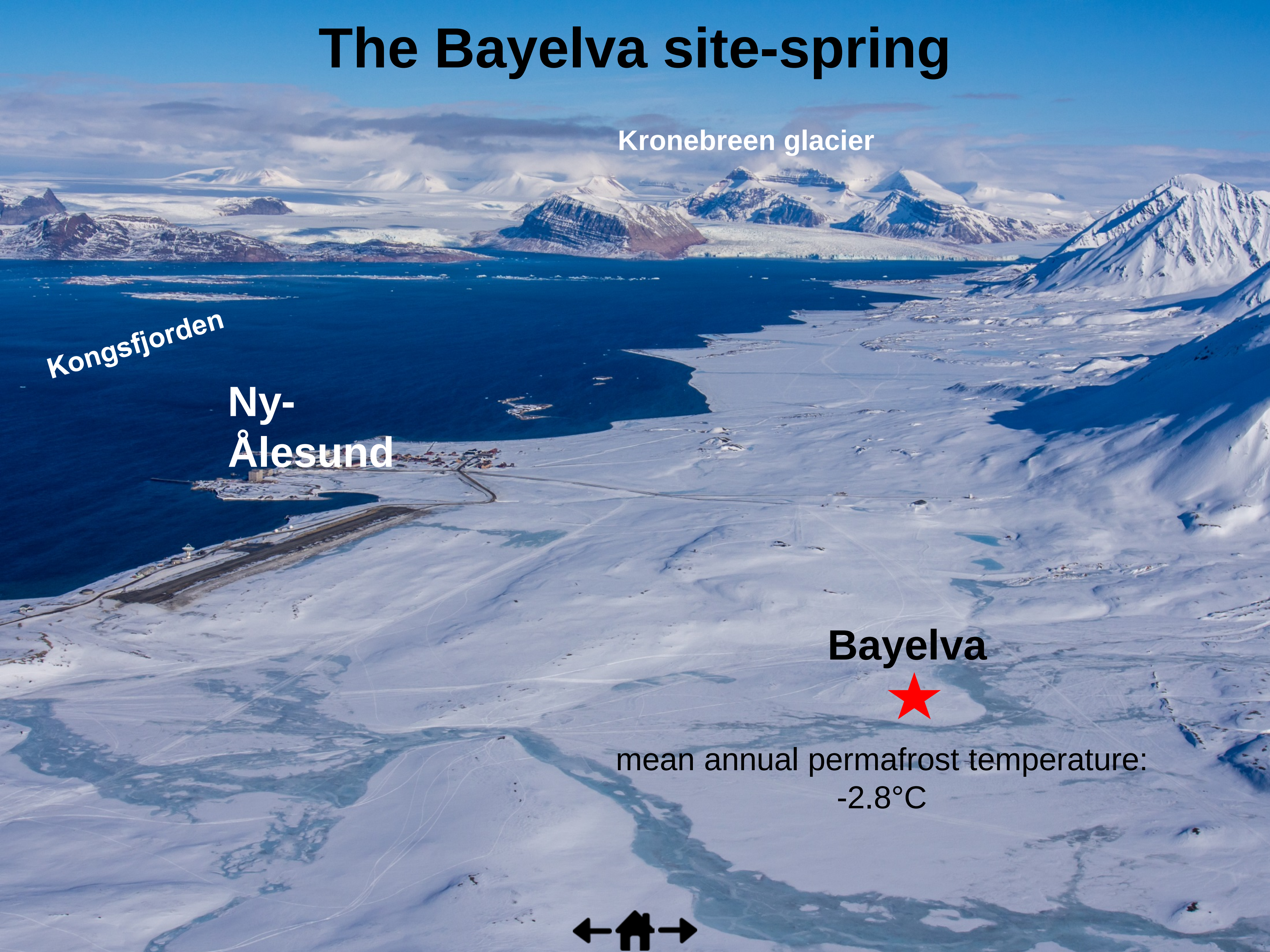
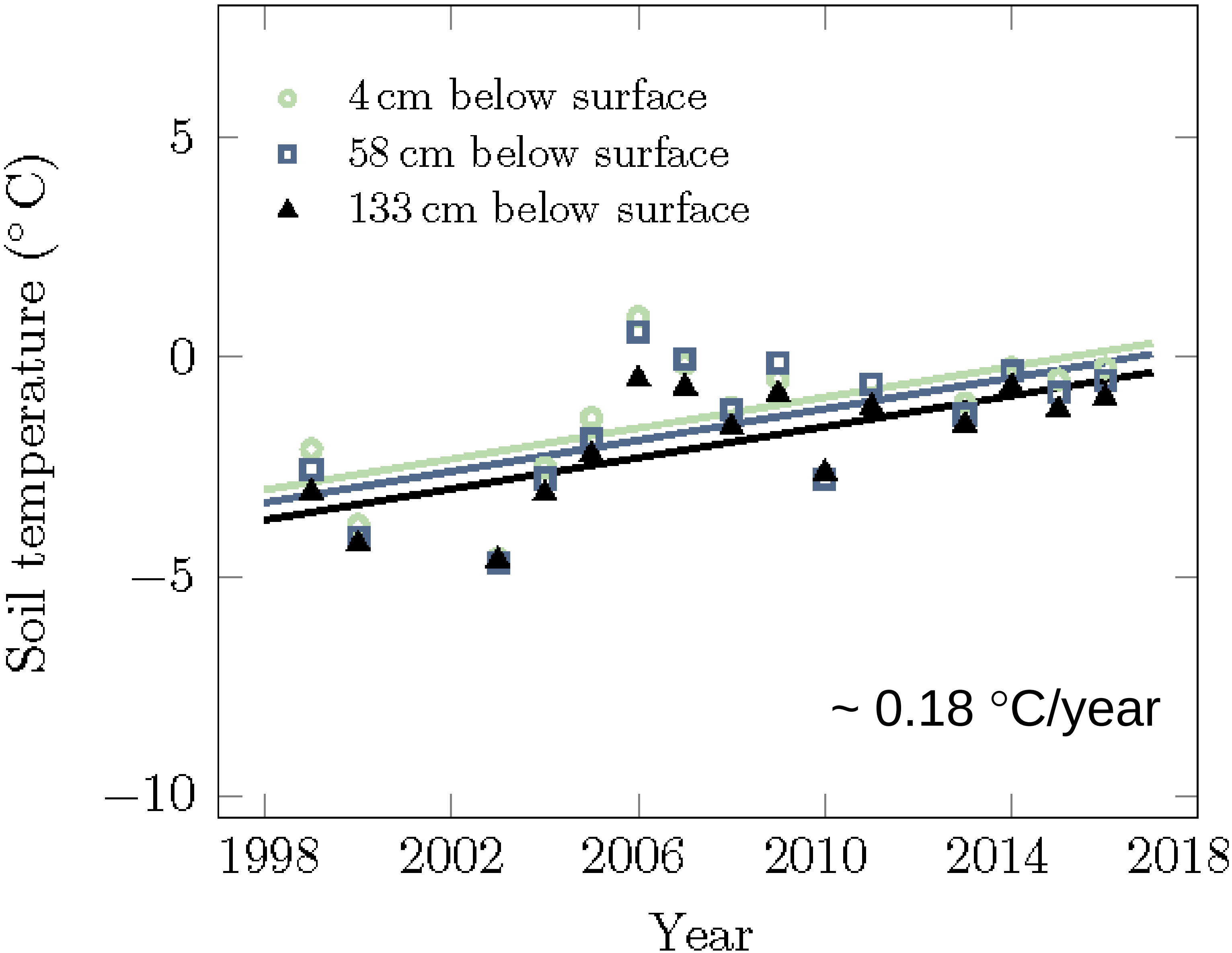
The Bayelva site-spring



Yearly trends: permafrost warming



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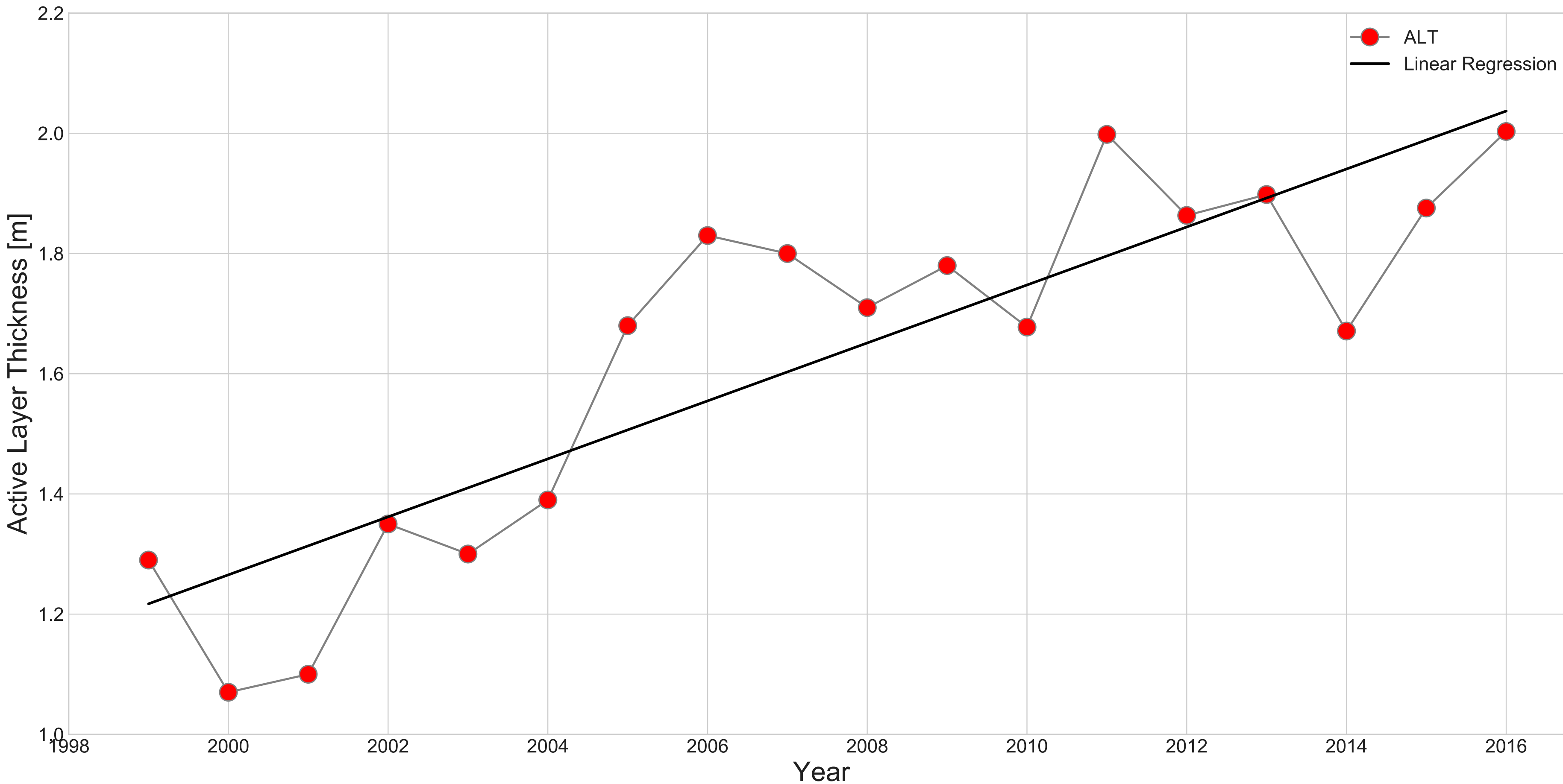
Yearly trends: active layer thickening



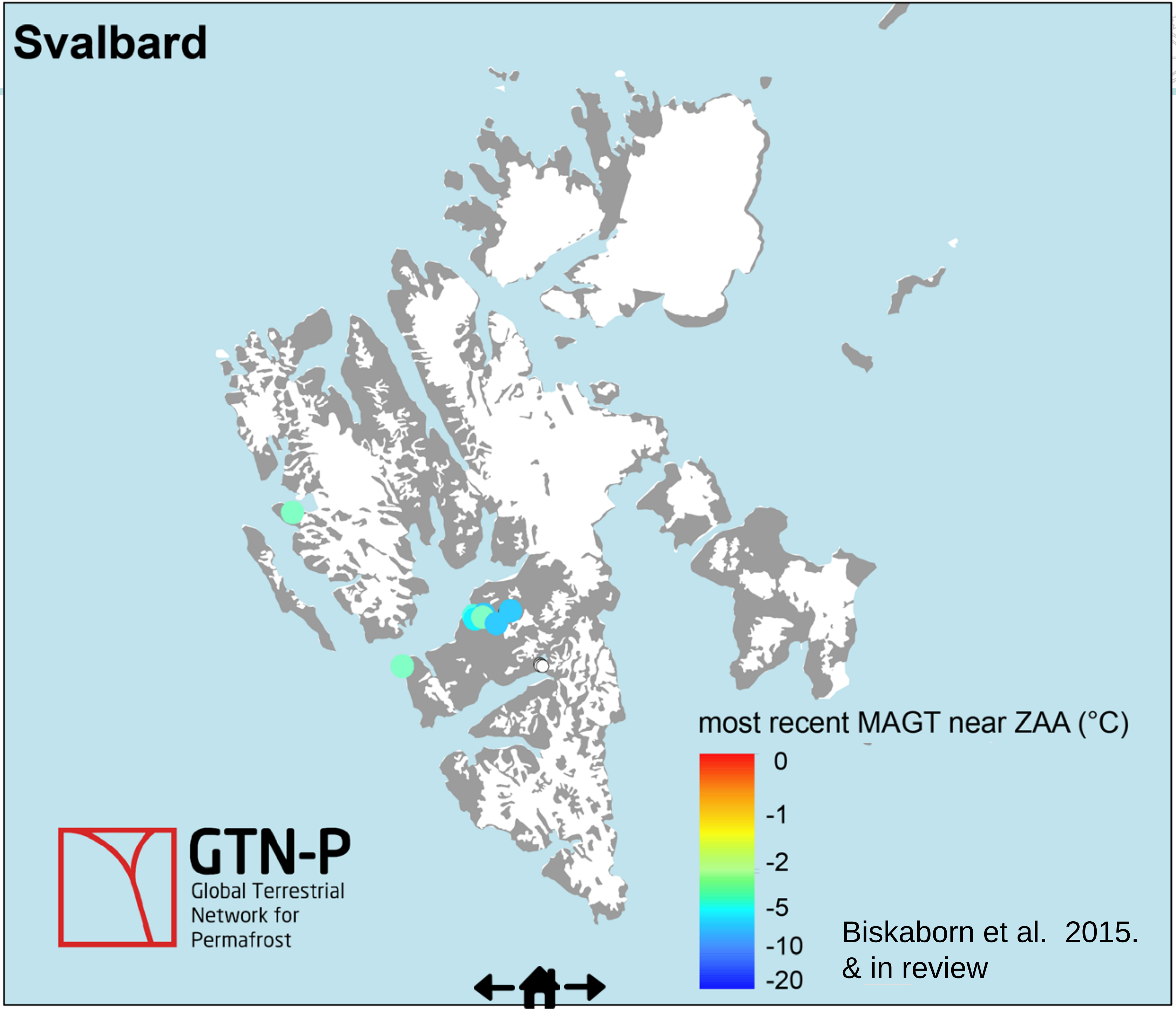
Maximum annual thaw depth estimated by Stefan-Model:

$$Z_{thaw} = \sqrt{\frac{K_h |TDD(t)|}{\rho_w L_{sl} \theta_w}}$$

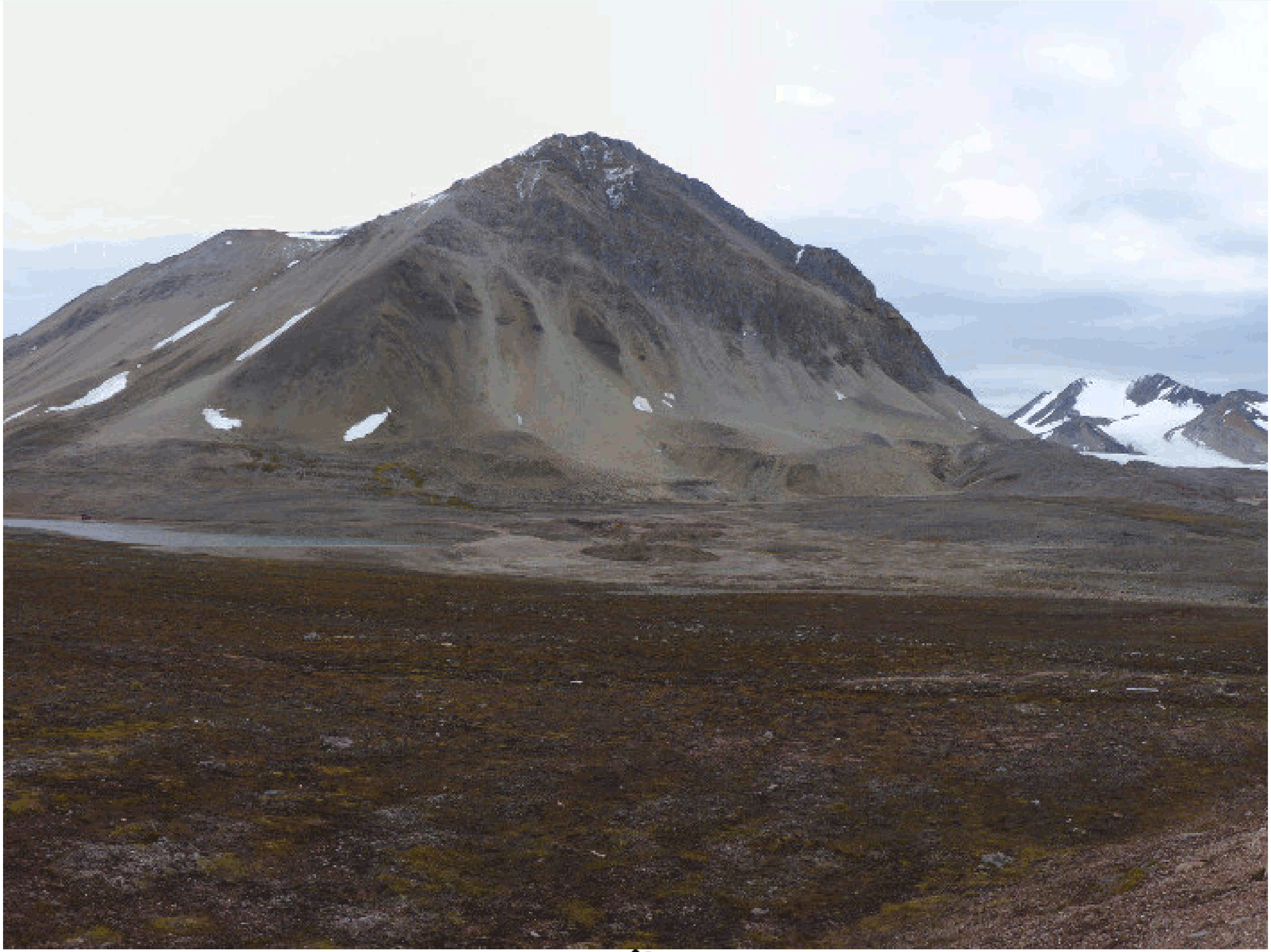
Interactive slides

Feel free to investigate on your own the following about Bayelva…

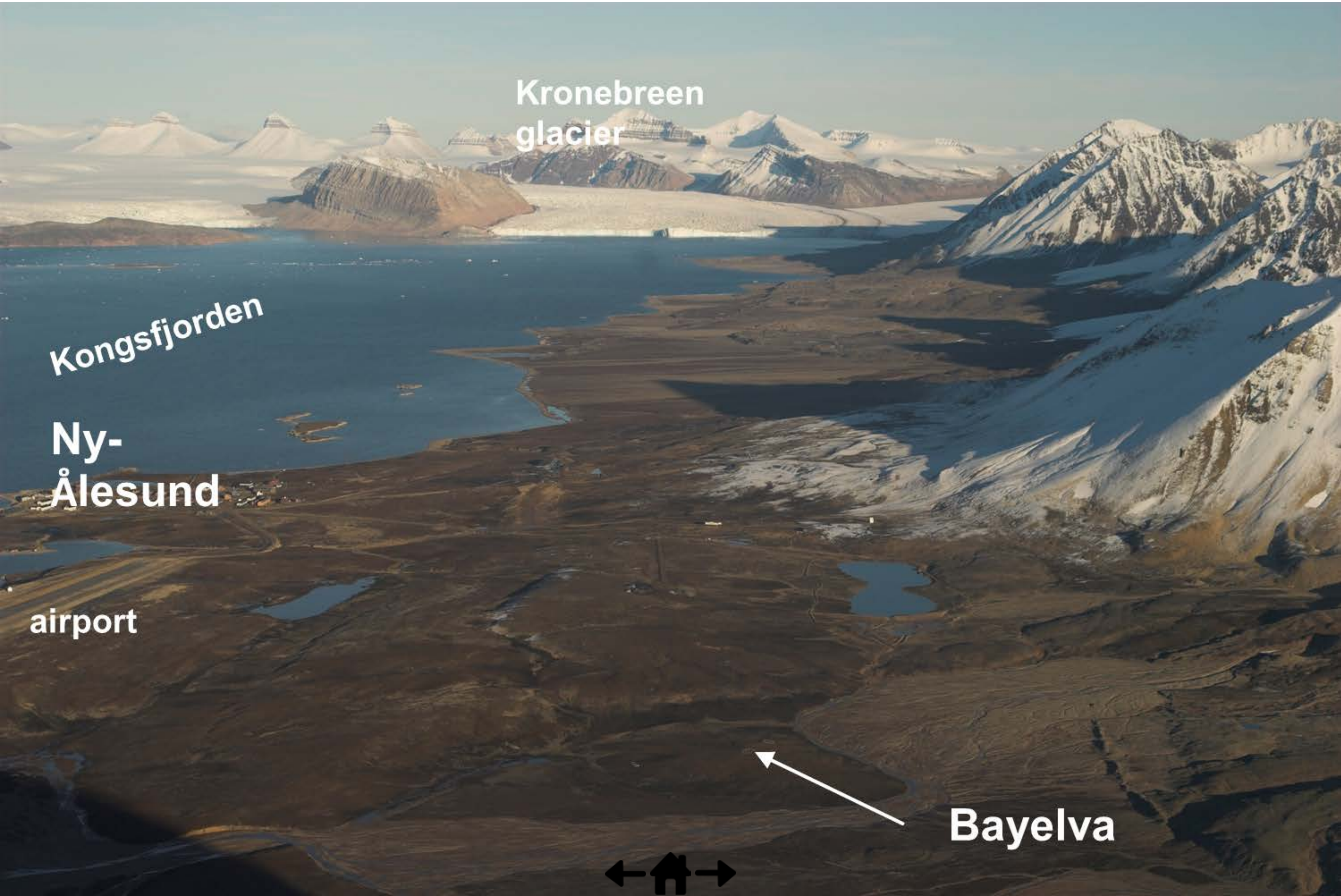
- Svalbard GTNP sites
- Landscape
- Instrumentation
- Snow cover characteristic and trends
- Permafrost warming & thawing trends
- C stocks and fluxes and comparison in earth system models
- Time series of soil temperature, water content, snow depth
- Pictures of our work at Bayelva
- Summary
- Publications


Svalbard
most recent MAGT near ZAA (°C)
0
-1
-2
-5
-10
-20
GTN-P
Global Terrestrial
Network for
Permafrost
Biskaborn et al. 2015.
& in review

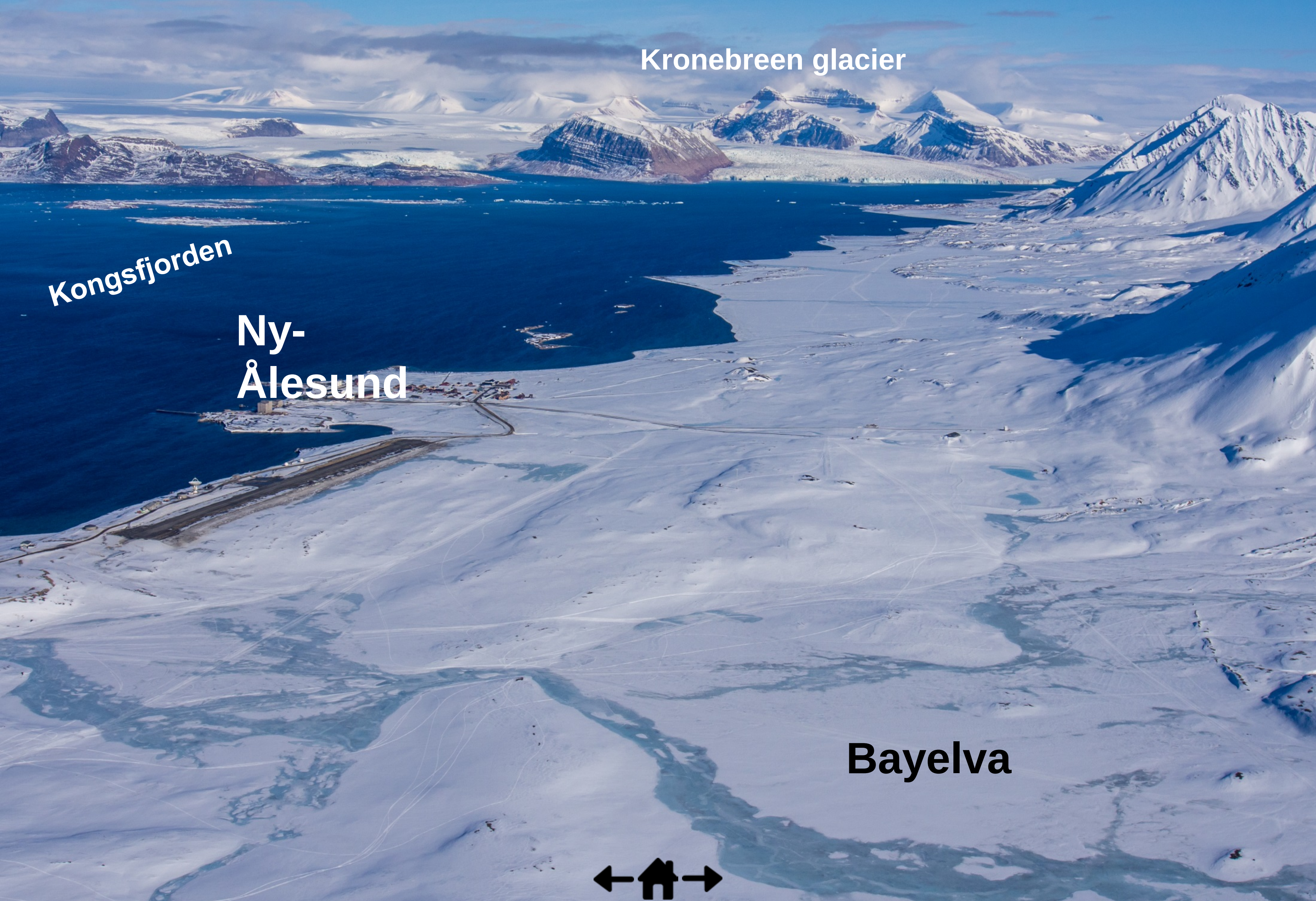
Landscape view

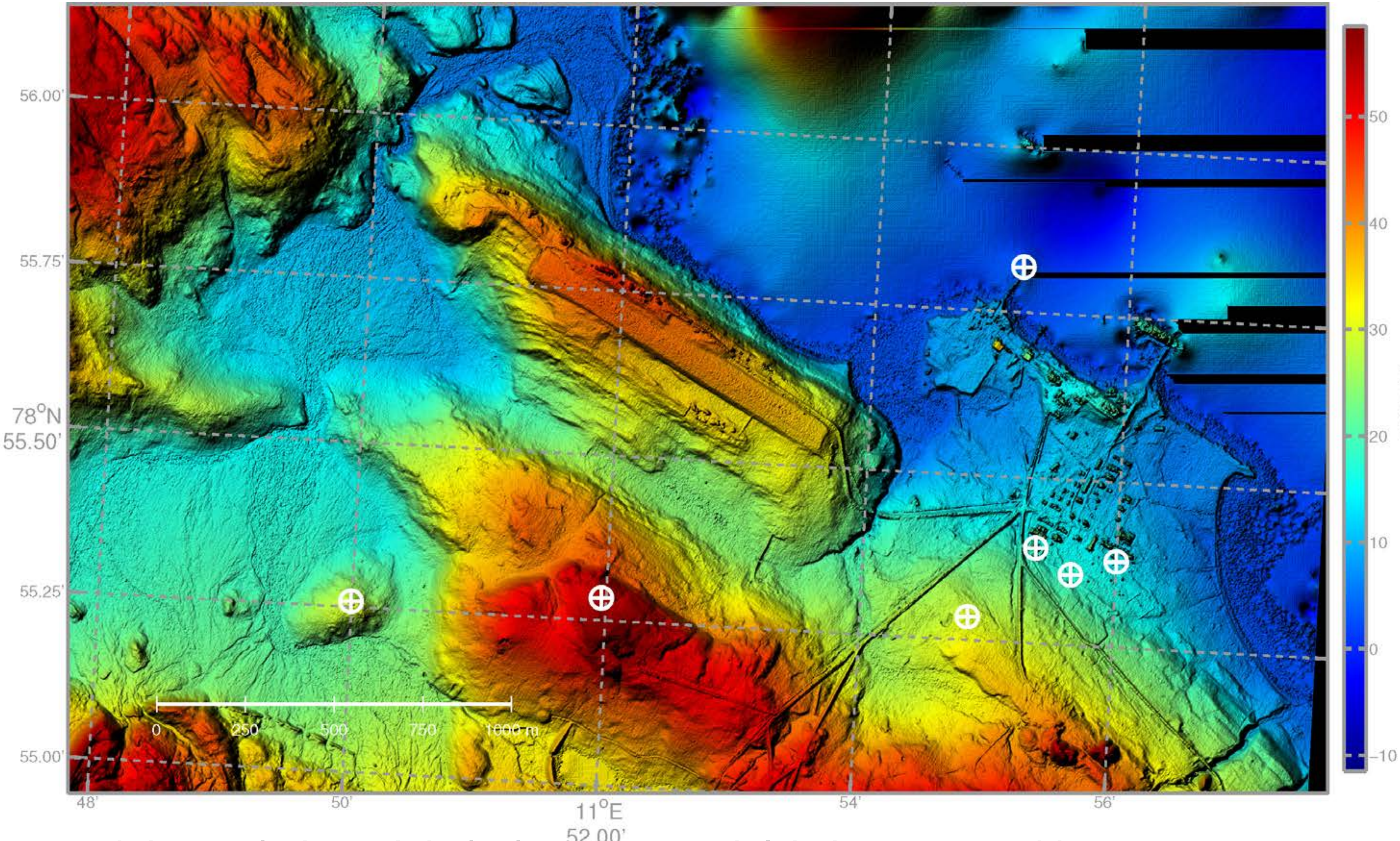


The Bayelva site-summer



The Bayelva site-spring

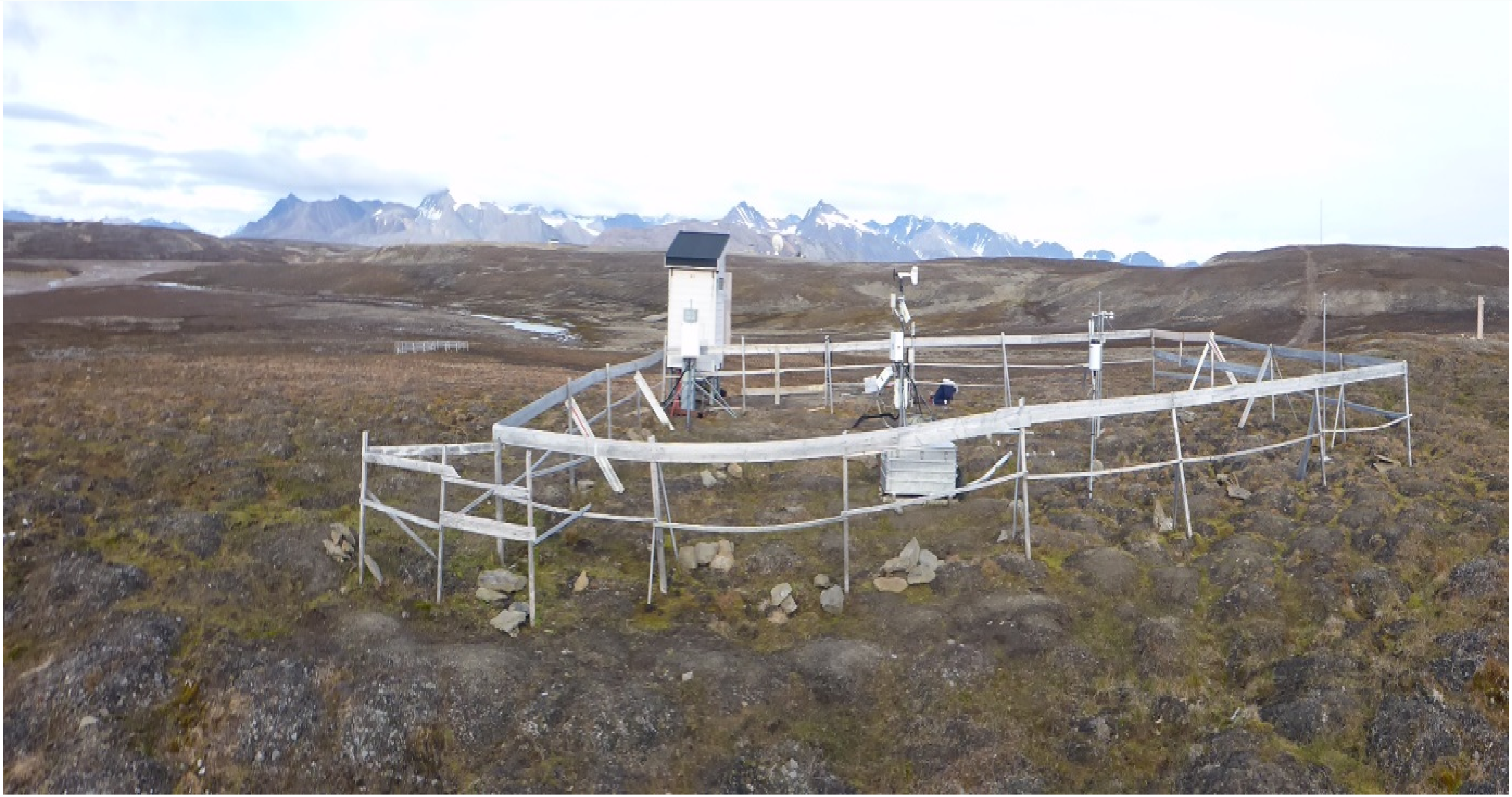




High resolution Digital Elevation Model (taken 2008 with HRSC camera), 20 cm/px, cell size 0.5 m
White markers indicate eddy covariance towers and/or meteorological stations in and around Ny-Ålesund

Boike et al. 2018

Instrumentation



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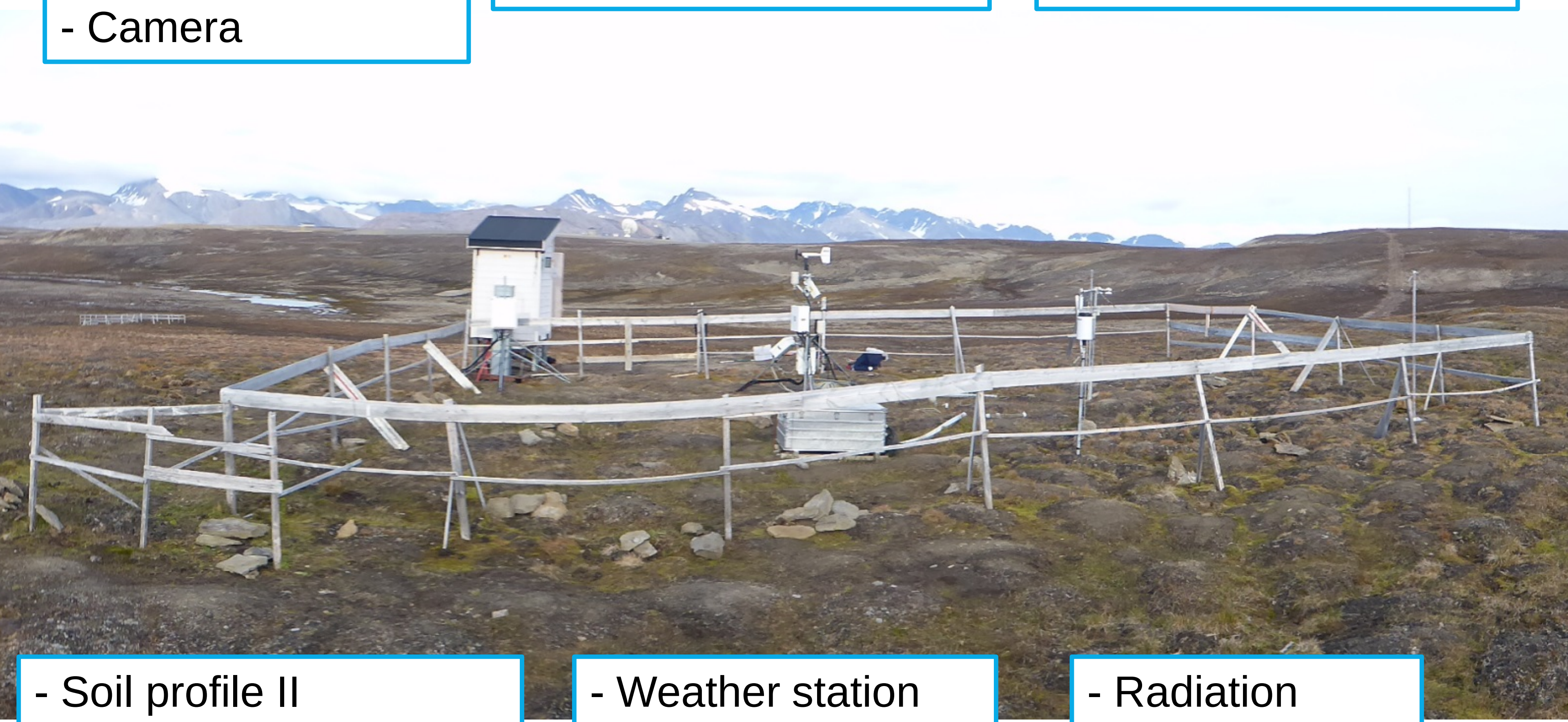
Instrumentation

- Electronics and data hub
- Camera

- Soil profile I (temperature, moisture)

- Permafrost borehole (9 m)



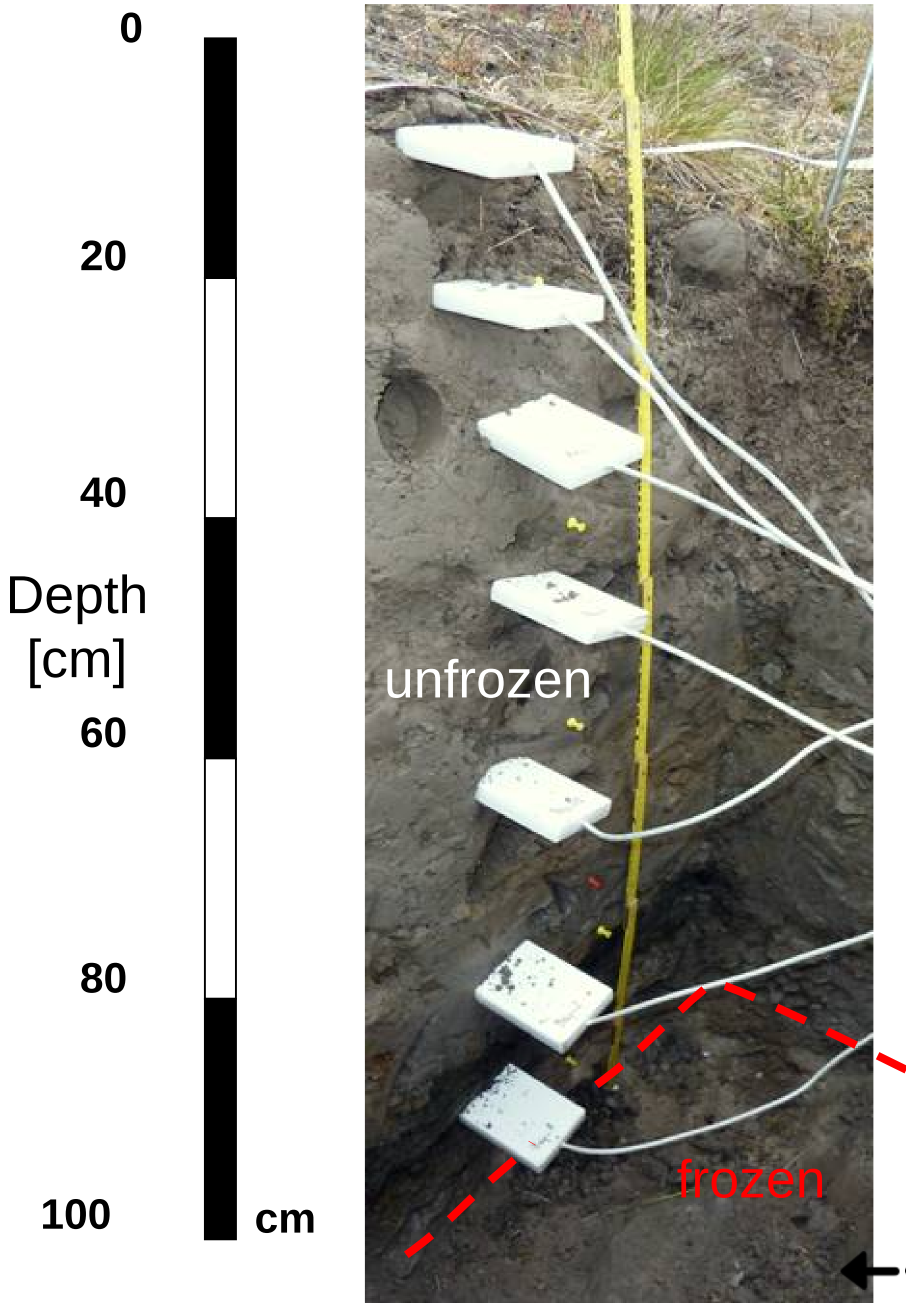
- Soil profile II (temperature, moisture)

- Weather station
- Snow profile

- Radiation
- Snow height II
- Rain

Boike et al. 2018

Soil characteristics

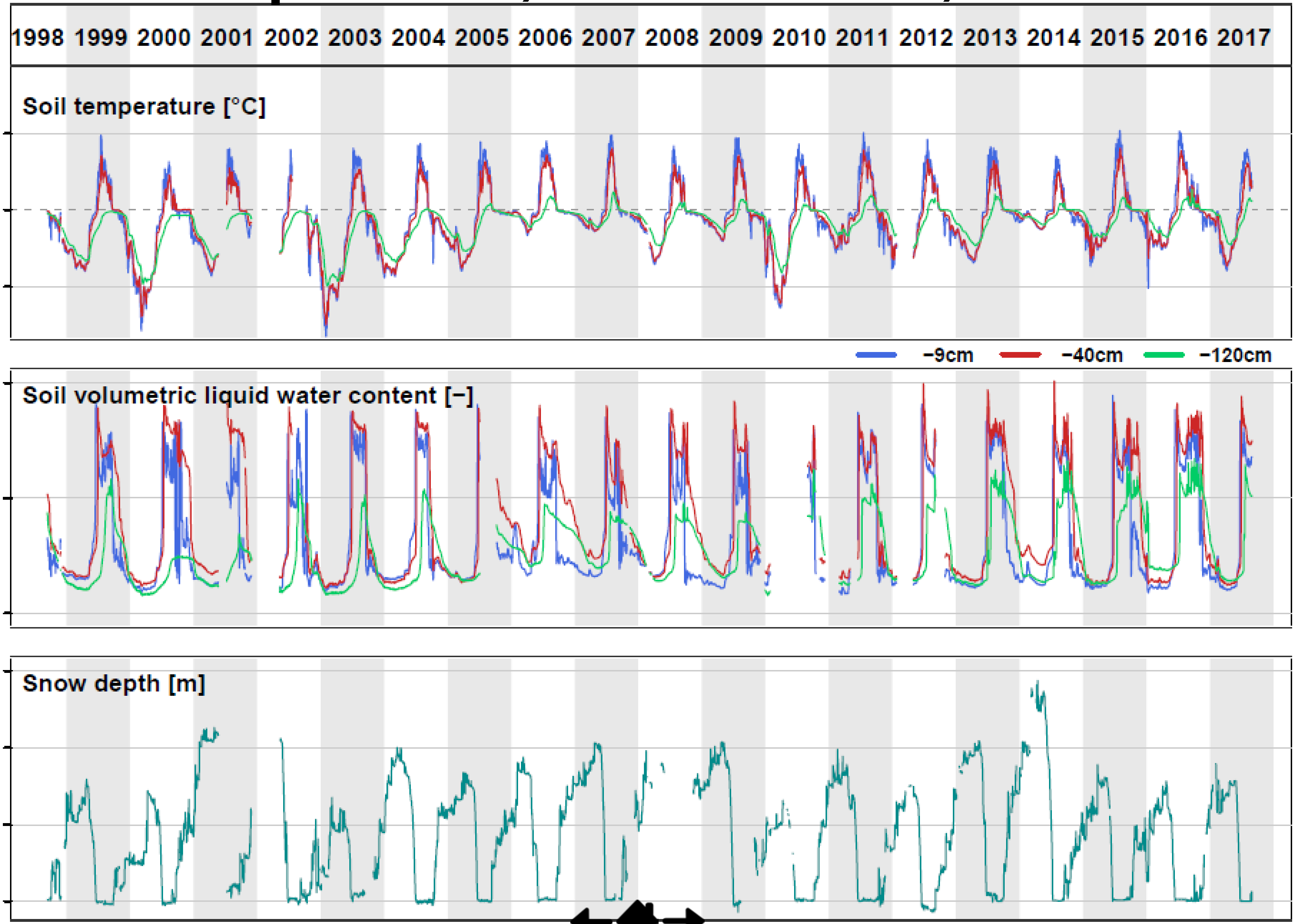


Measuring state variables in active layer (temperature and volumetric water content) for

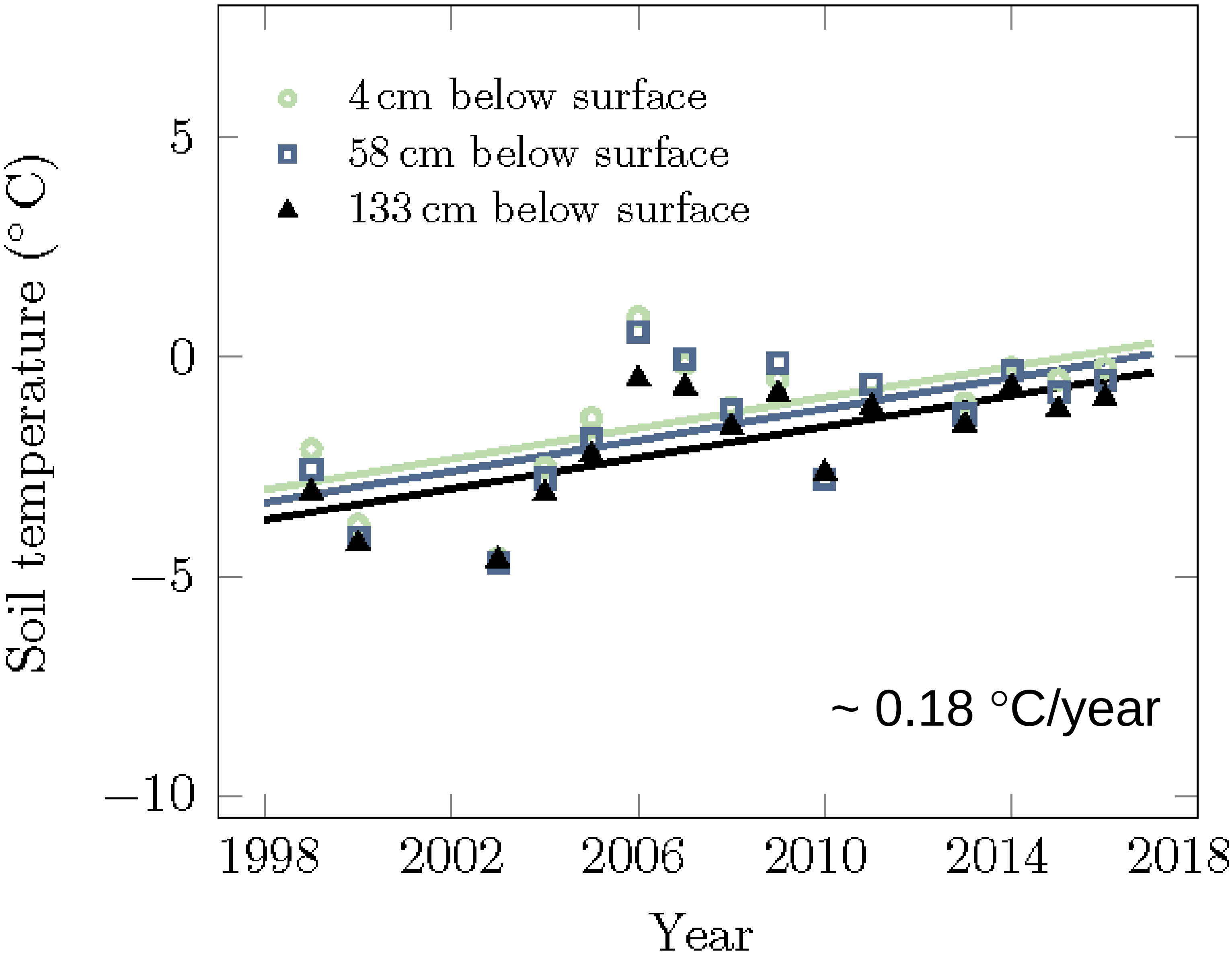
- Surface energy balance
- Biogeochemical processes
- Organic carbon storage/exchange

Boike et al. 2018

Temperature, water content, snow



Yearly trends: active layer



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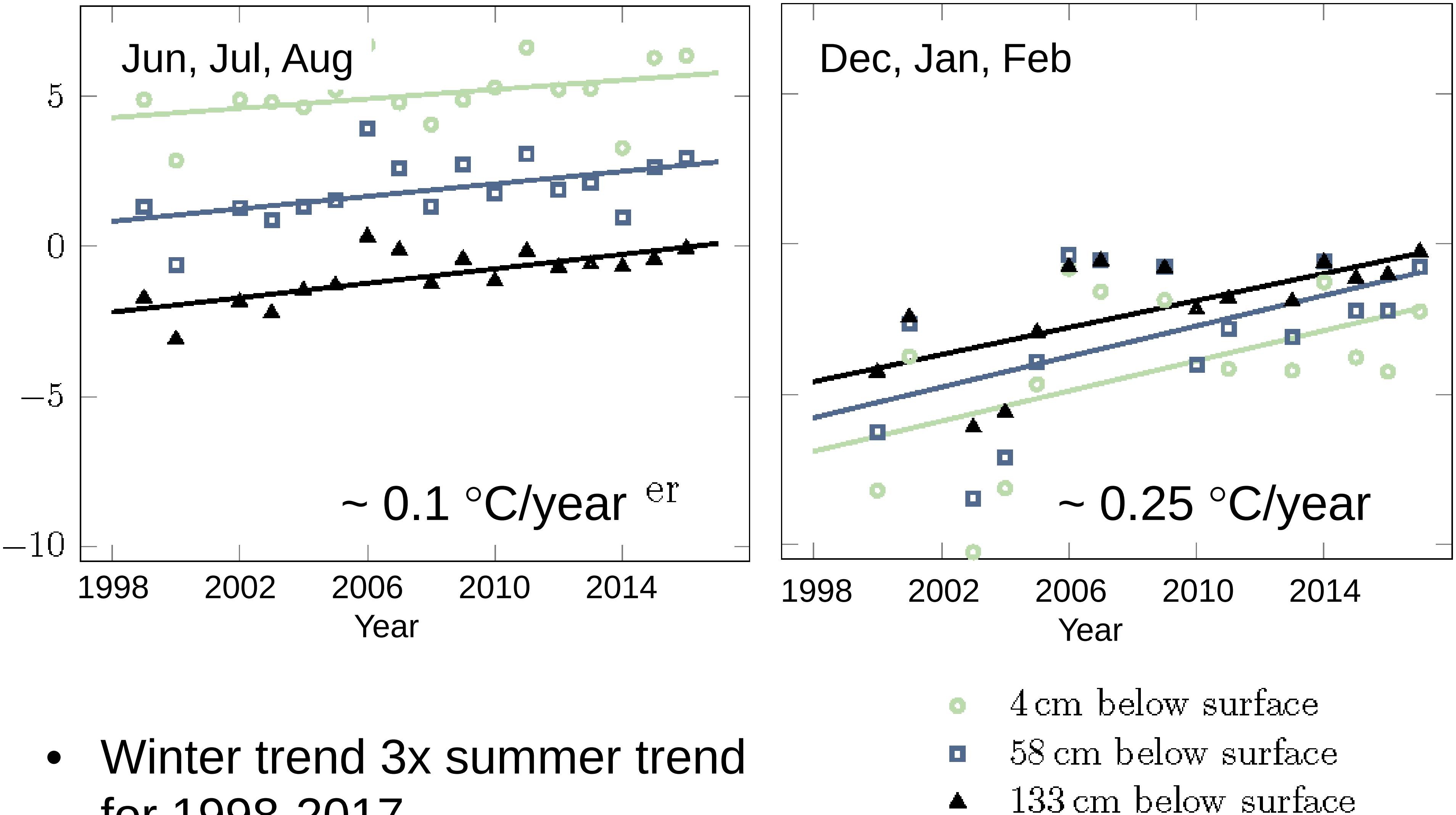
Seasonal trends: active layer



- Winter trend 3x summer trend for 1998-2017

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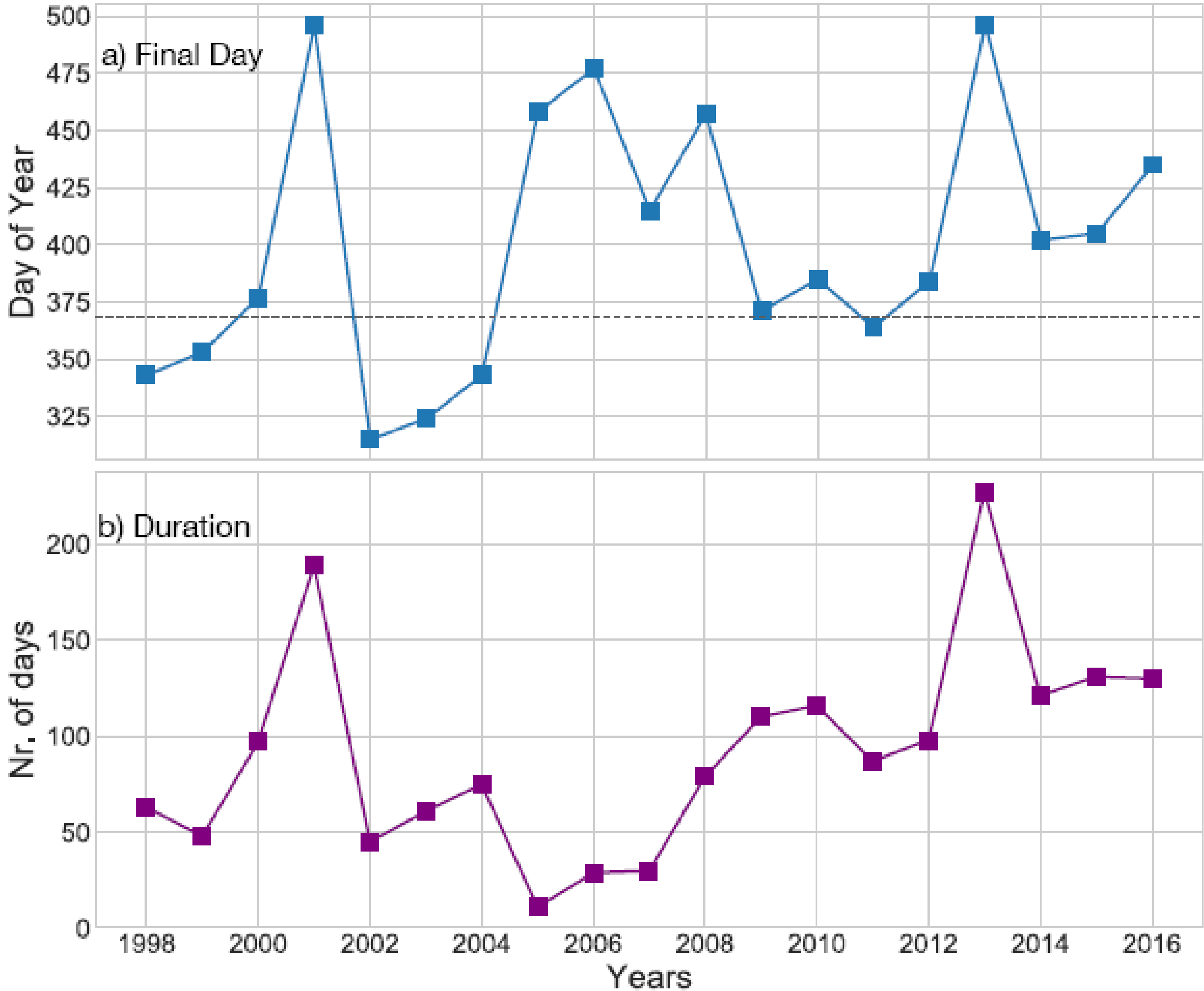
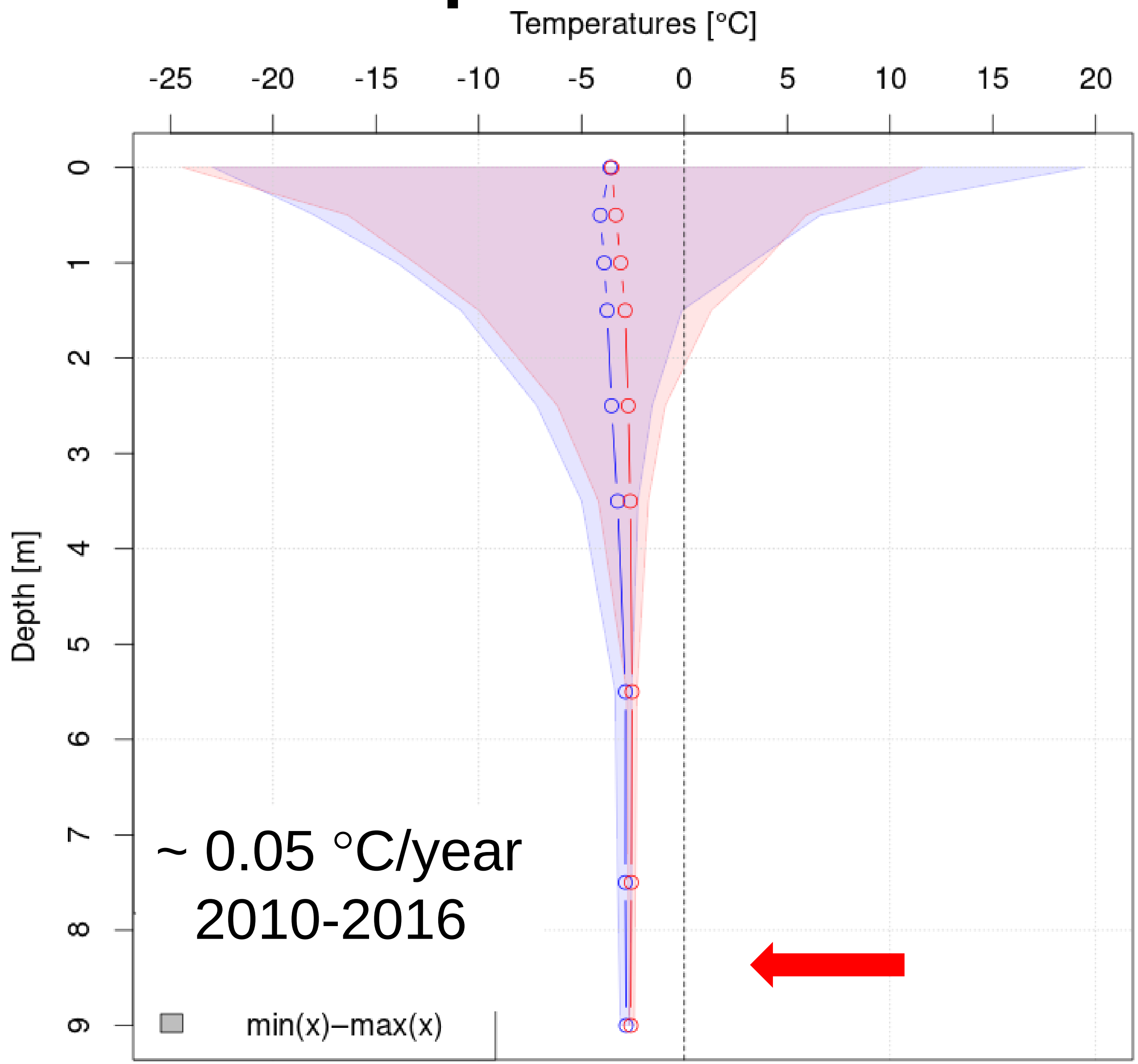
Seasonal trends: active layer

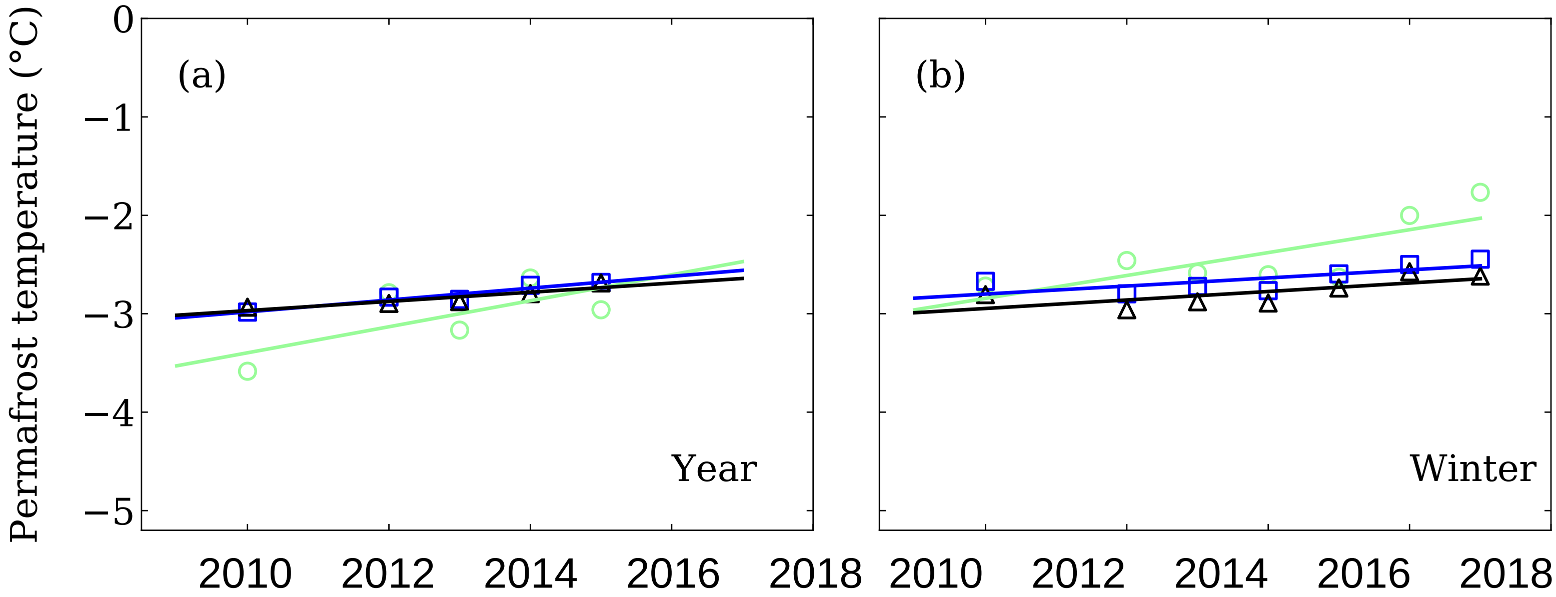


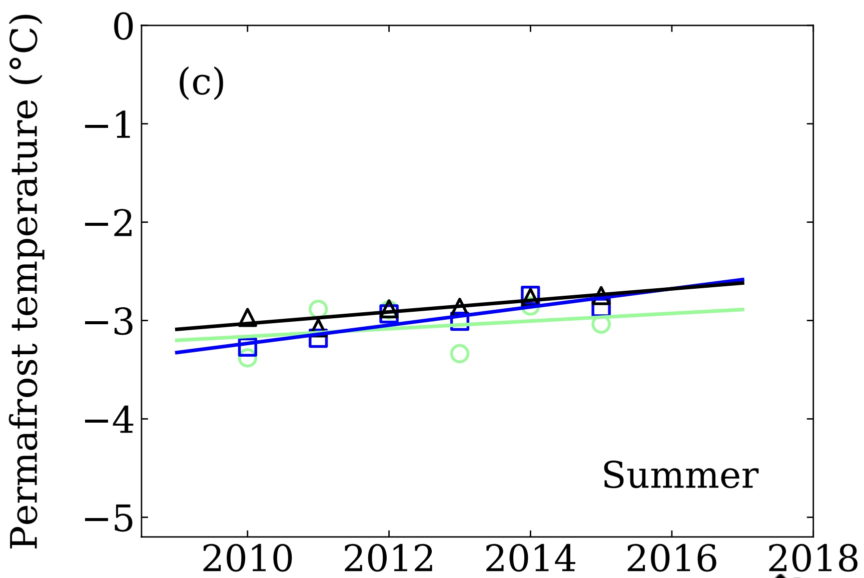
a) Final day of active layer freeze-up.
b) Number of days for freezing the active layer (0.01m to 1.41m depth).

Seasonal trends: permafrost



Seasonal trends: permafrost

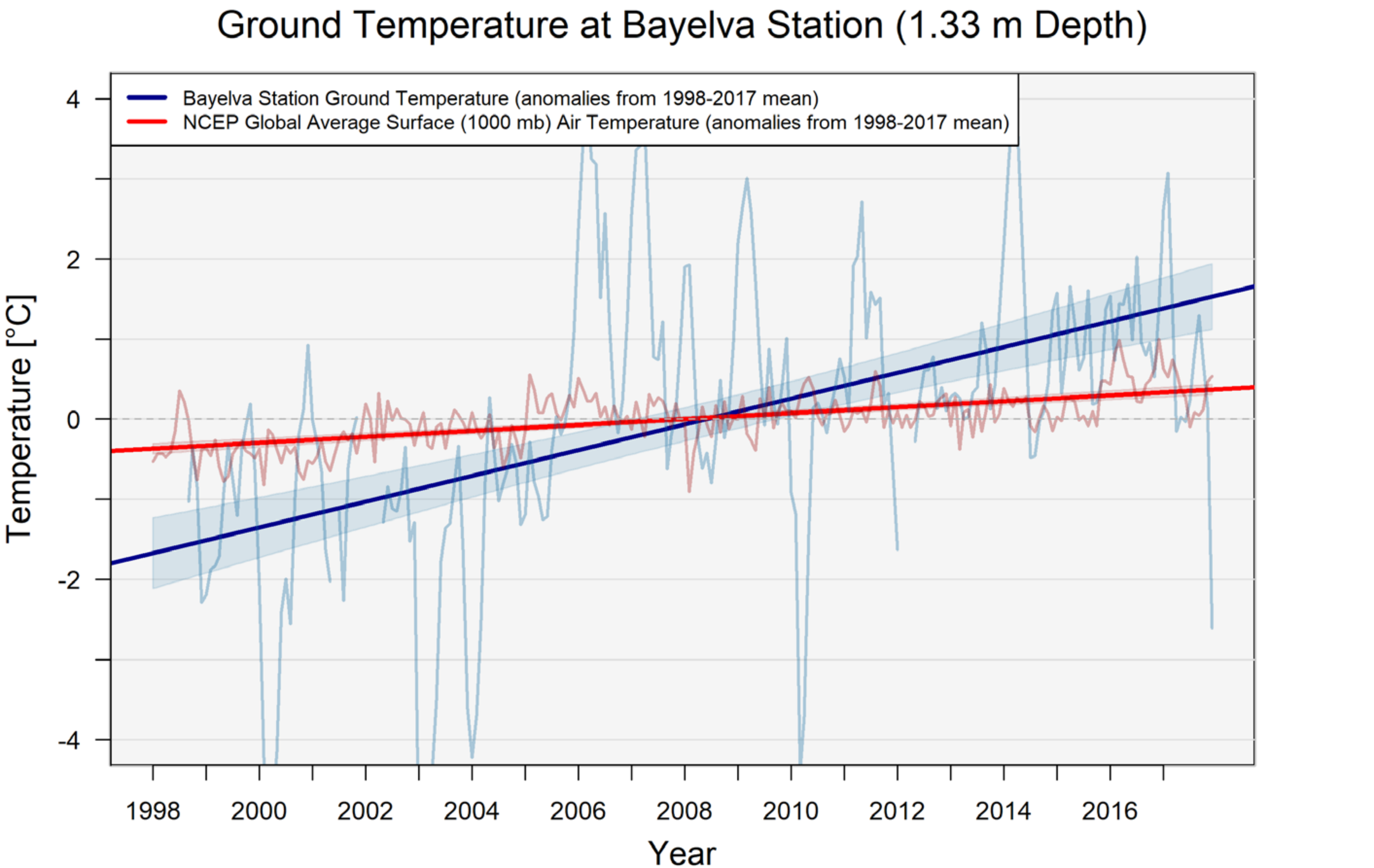




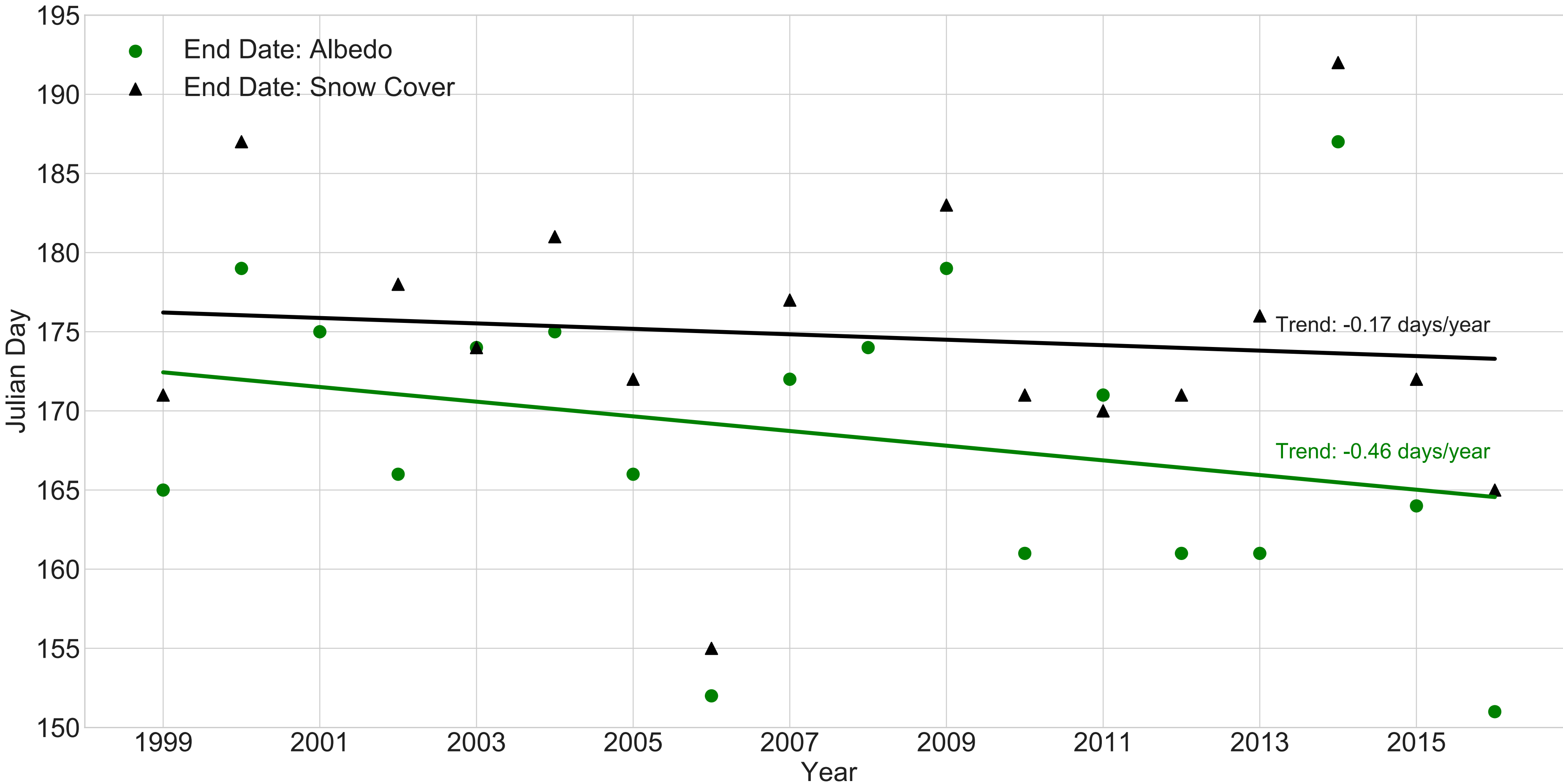
	4 cm	58 cm	133 cm
	below surface		
(a)	0.18±0.07	0.18±0.07	0.18±0.07
(b)	0.25±0.12	0.25±0.11	0.23±0.07
(c)	0.08±0.05	0.10±0.04	0.12±0.03

[°C/year]

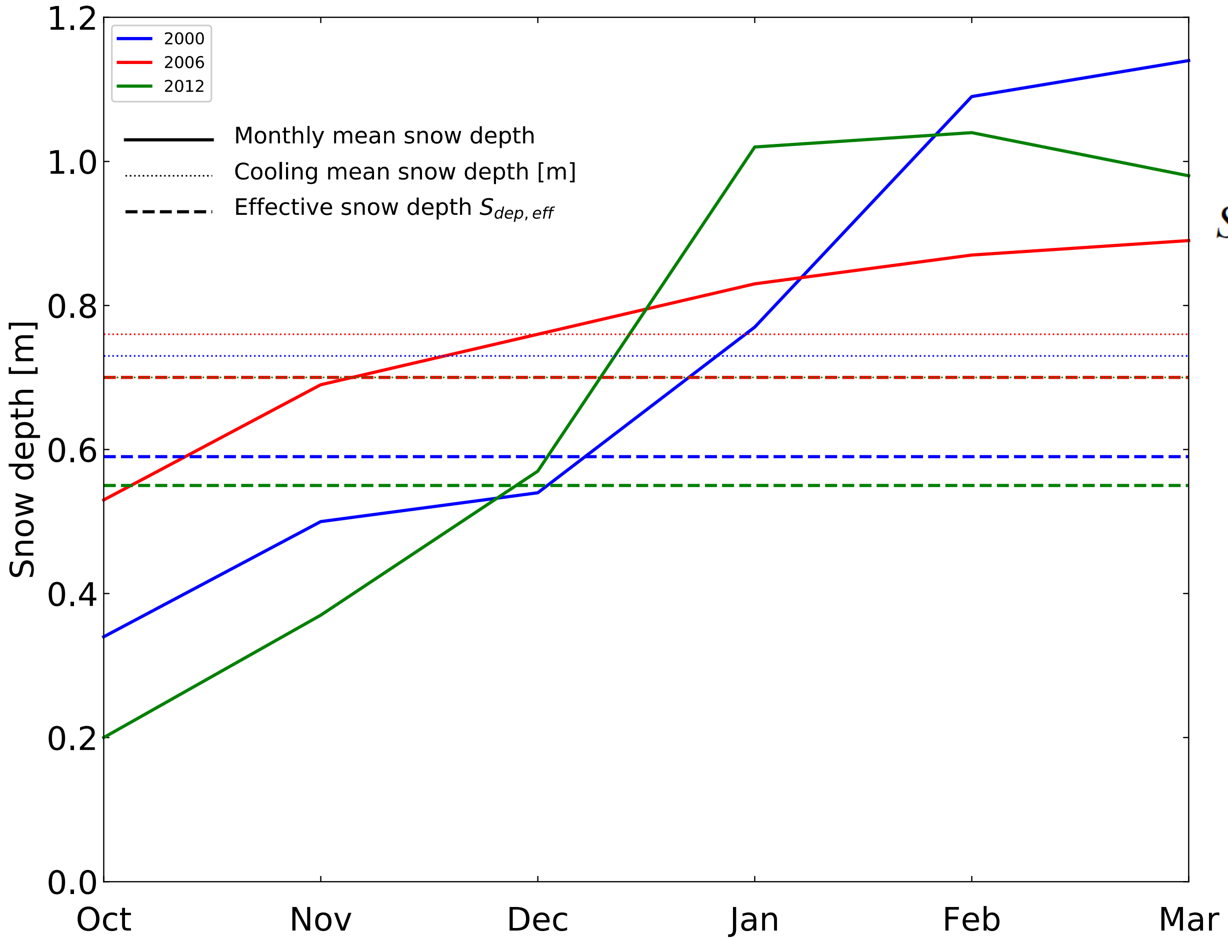
Bayelva compared to global temperatures



End of snow covered season



Effective snow depth: Bayelva



$$S_{\text{depth,eff}} = \frac{\sum_{m=1}^{M} (S_m \cdot (M+1-m))}{\sum_{m=1}^{M} m}$$

S_m: mean snow depth each month (m= 1–6)
M: total cooling period of 6 months (October–March)

Slater et al. (2017)

$S_{depth,eff}$ describes the insulation impact of snow and is an integral value such that the mean snow depth is weighted by its duration. Three different snow periods (2000, 2006, 2012) have similar mean values over the period October-May.

Normalized temperature amplitude

$$A_{\mathrm{norm}} = P + Q\left(1. - e^{-\left(\frac{s_{\mathrm{depth,eff}}}{R}\right)}\right)$$

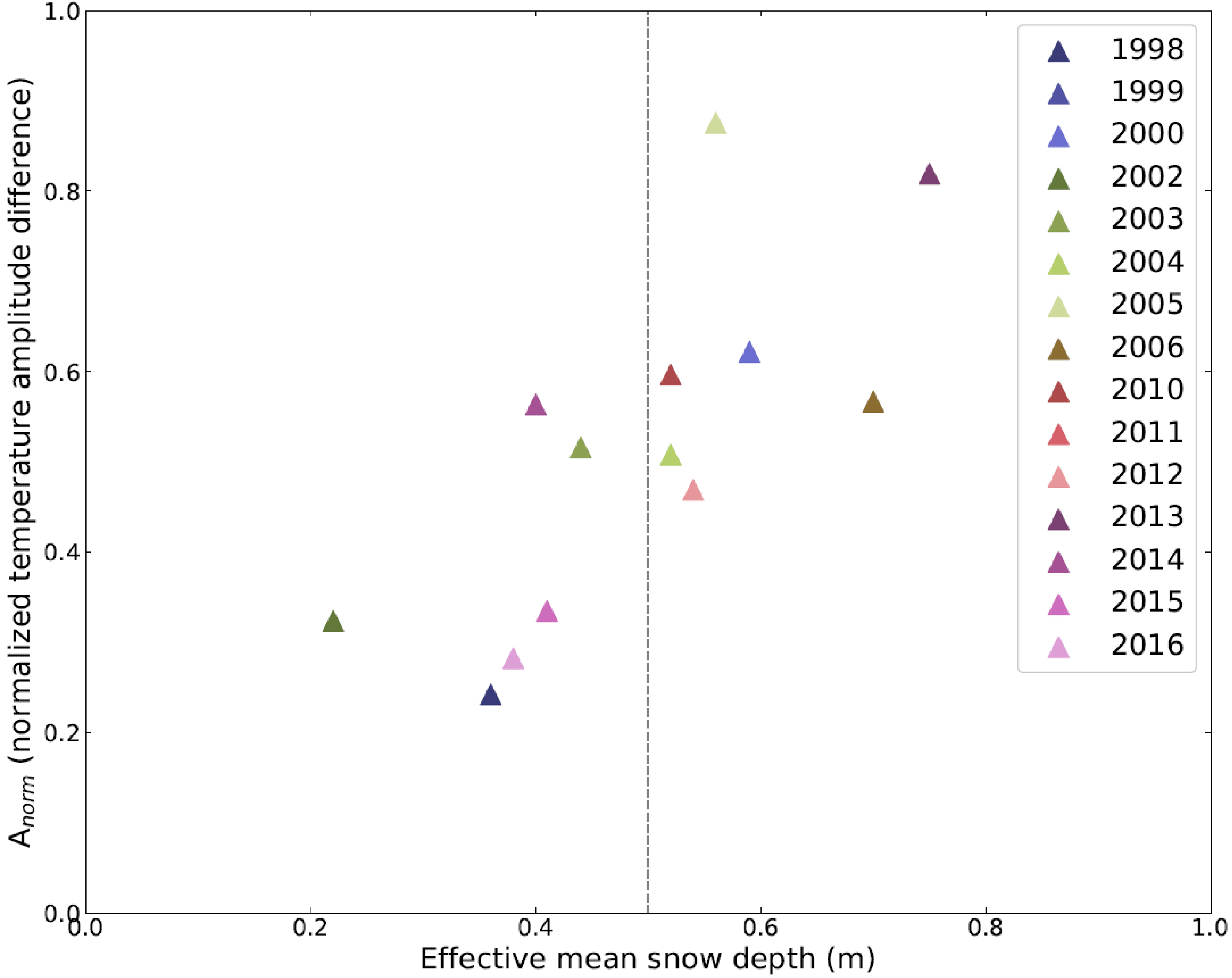
P: temporal offset between air and soil temperature amplitudes

Q: temporal nature of snow accumulation

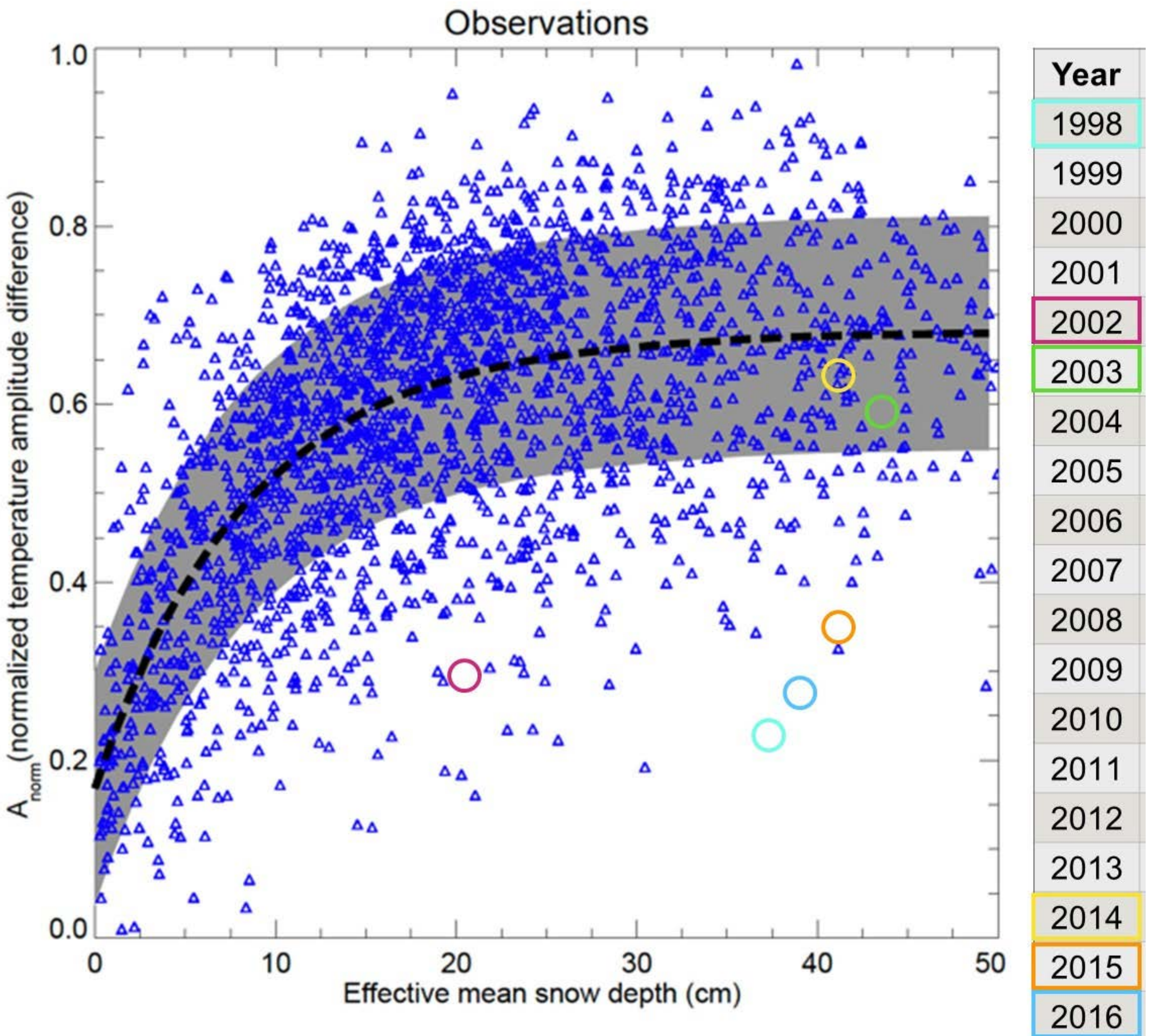
R: effective damping depth

Method based on the paper by Slater et al. (2017)

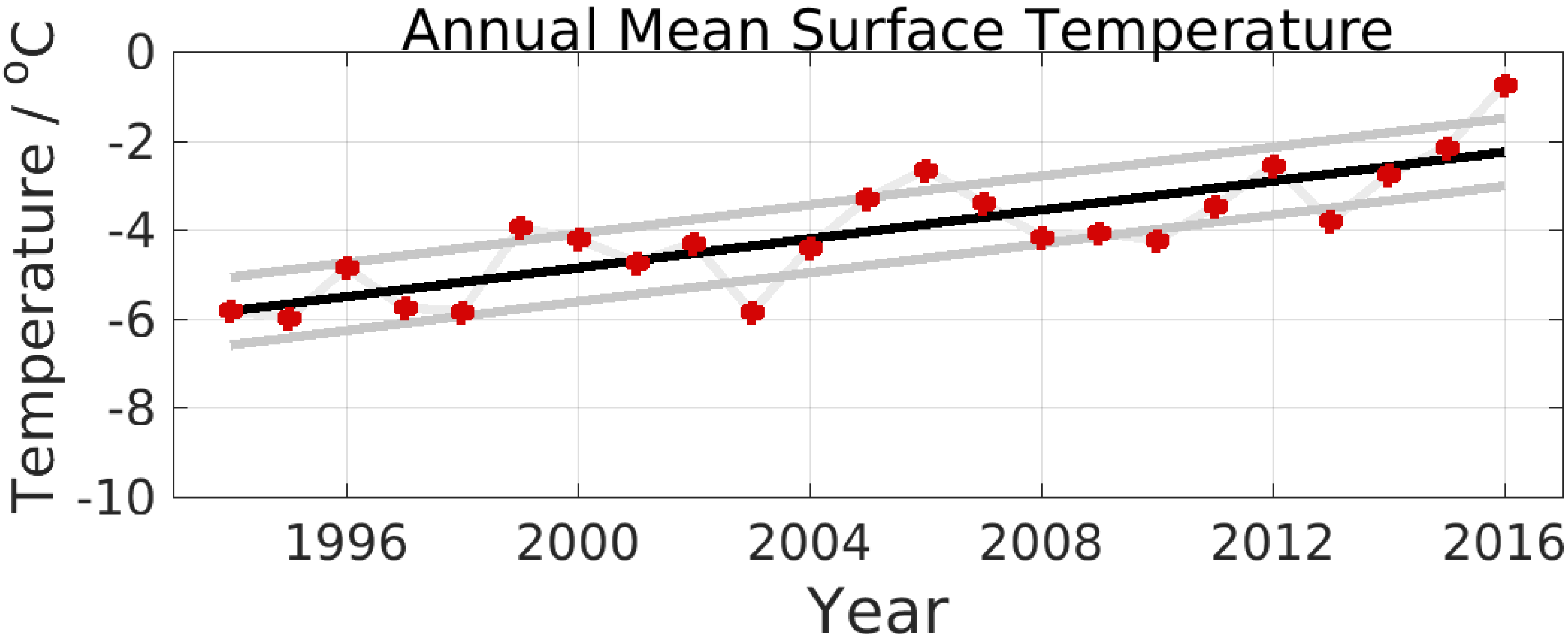
Effective snow depth: Bayelva



Normalized temperature amplitude: Bayelva



Warming in recent 2 decades, Ny-Ålesund



Mean warming : +1.6 (+/- 0.7) °C/decade

Strongest signal in winter: +3.2 (+/- 0.7) °C/winter

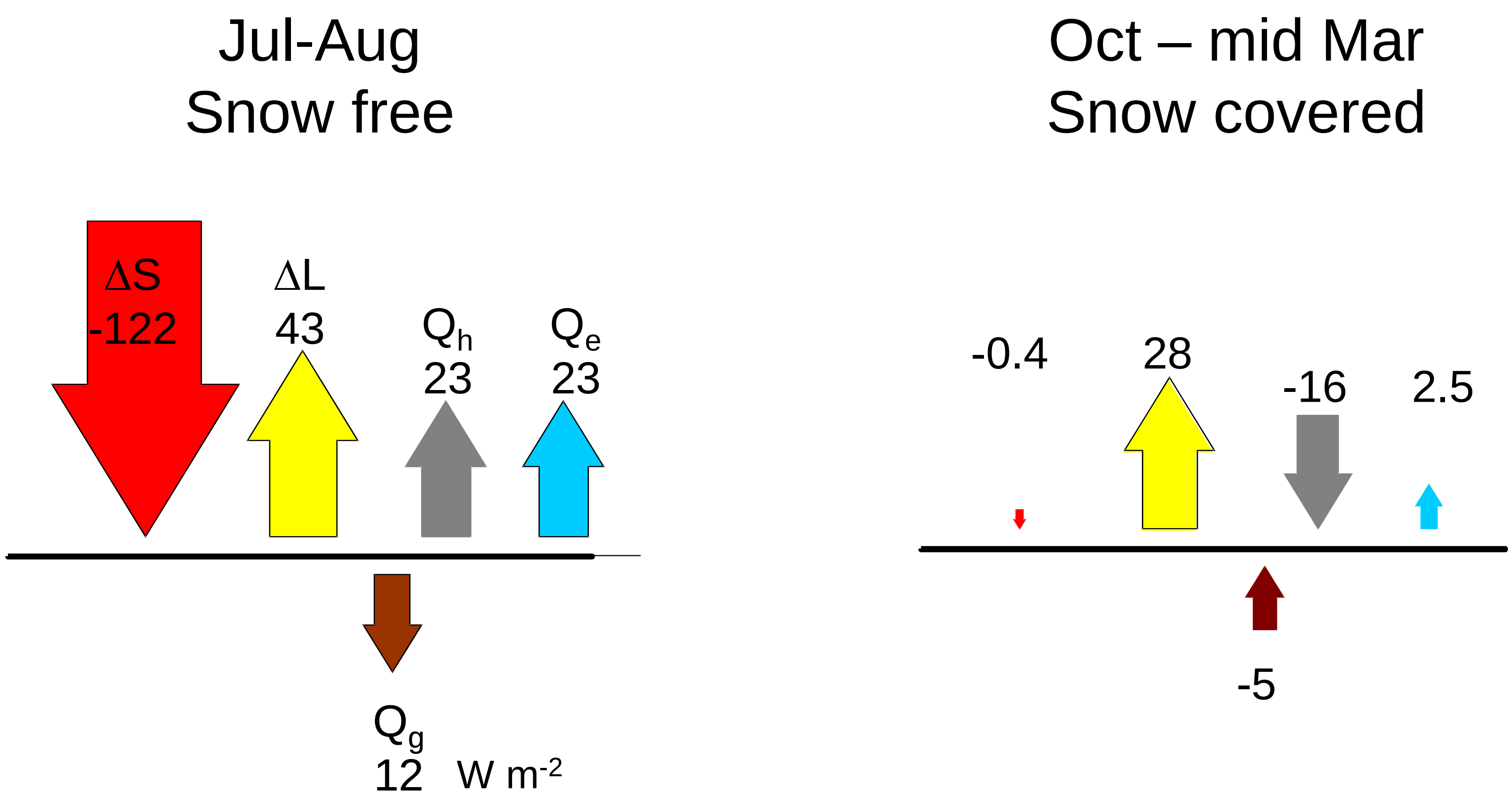
Update of Maturilli et al. 2013

Mean annual net radiation: Bayelva

Summary of 1998-2017 climate and permafrost at Bayelva

- Warming active layer and permafrost temperatures
- Deepening of annual maximum thaw depth
- Increasing air temperature and net radiation
- Earlier melt-off of snow-cover
- Effective Snow Depth represents snow-pack with high insulation effects
- No strong correlation of $S_{depth,eff}$ and air and soil temperature amplitudes
- Correlation (p-value of 0.7) between $S_{depth,eff}$ and final day of active layer freeze-back

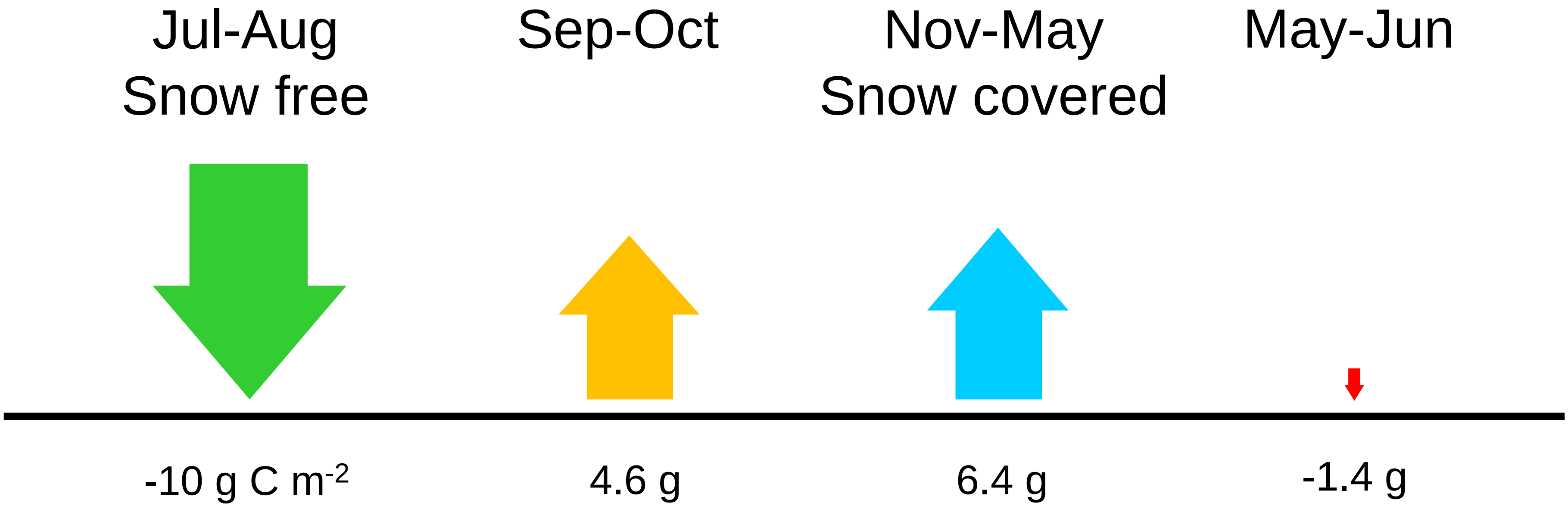
Surface energy budget 2008-09



- Most energy in summer lost to atmosphere
- Permafrost cooling in winter dominated by ΔL and Q_h

Westermann et al. 2009, Boike et al. 2012.
Data archived in FLUXNET, European fluxes database cluster, PANGAEA

Annual CO_2 budget

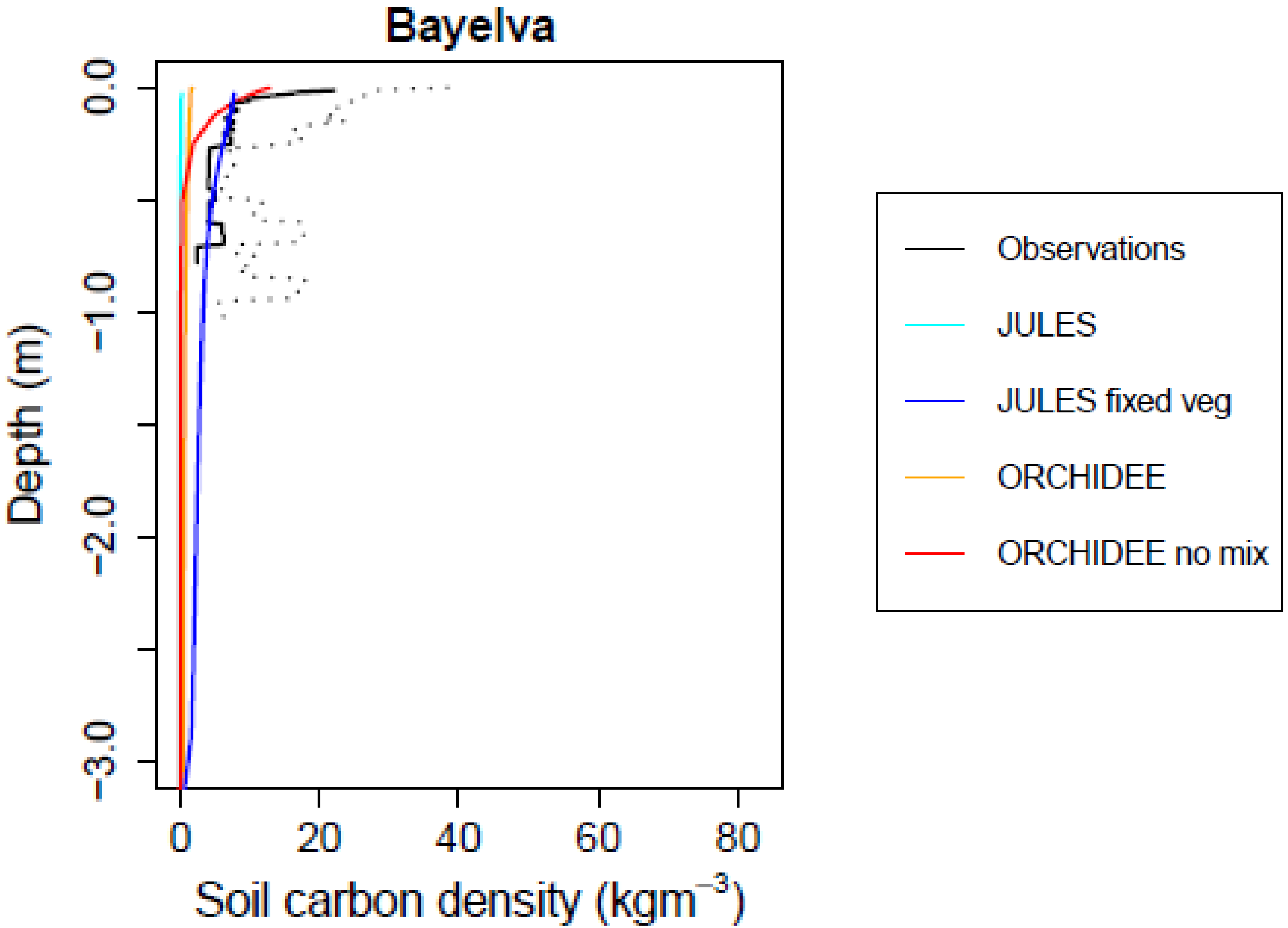


- At this site, uptake = emission (2008-2009)
- Shoulder and winter seasons are the unknowns!

Lüeers et al. 2014
Data archived in: FLUXNET, European fluxes database cluster, PANGAEA

Eddy data analysis 2007-2017 currently in process!

ESM model validation: SOCC



Chadburn et al. 2017

Publications

Biskaborn, B. K., Lanckman, J.-P., Lantuit, H., Elger, K., Streletskiy, D. A., Cable, W. L., and Romanovsky, V. E.: The new database of the Global Terrestrial Network for Permafrost (GTN-P), Earth Syst. Sci. Data, 7, 245-259, https://doi.org/10.5194/essd-7-245-2015, 2015.

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Slater, A. G., Lawrence, D. M., and Koven, C. D.: Process-level model evaluation: a snow and heat transfer metric, The Cryosphere, 11, 989-996, https://doi.org/10.5194/tc-11-989-2017, 2017.

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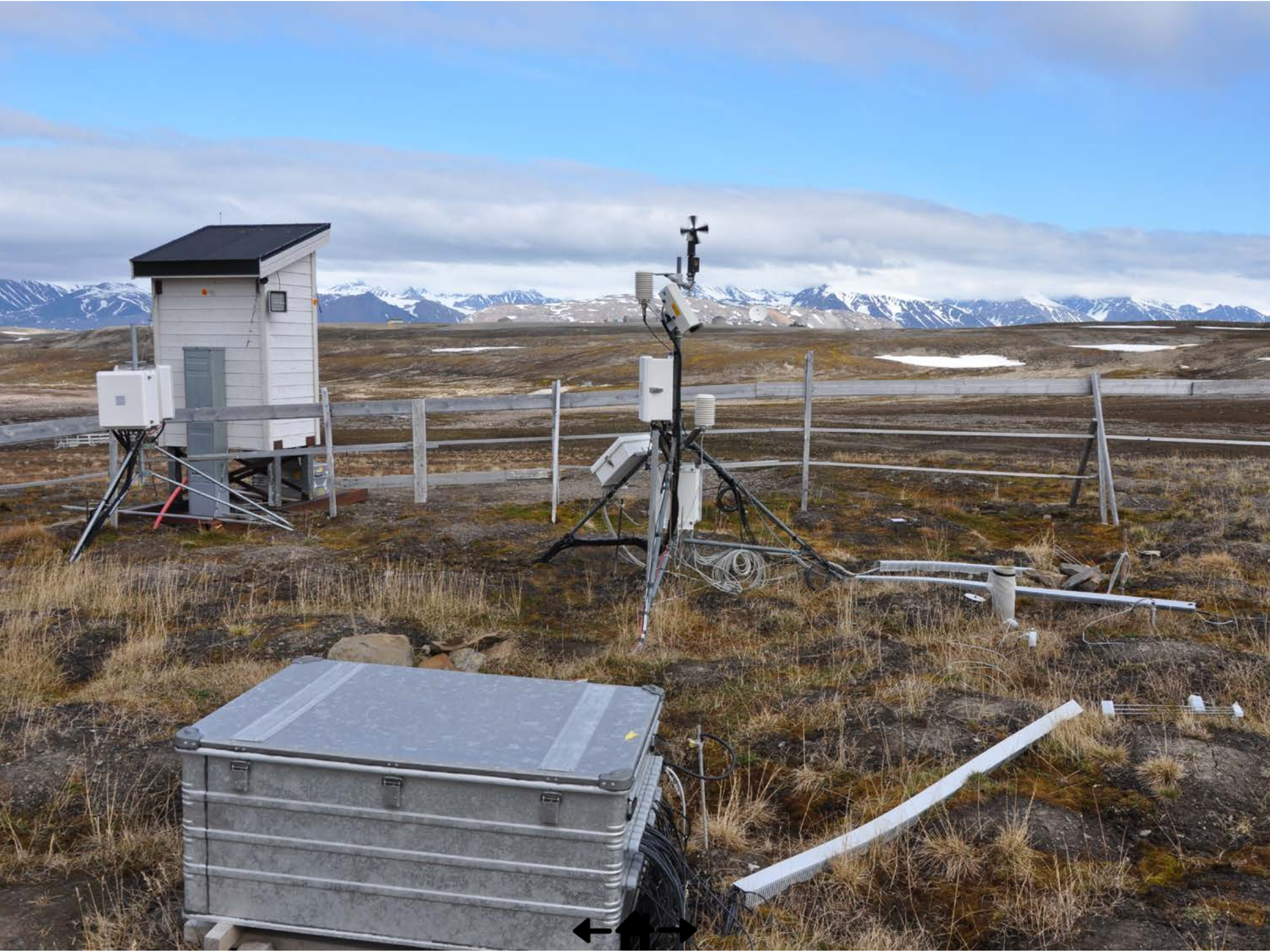


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