# Thermo-insulation effect of a seasonal snow-cover on permafrost soil in Bayelva, Svalbard (1998 - 2017)

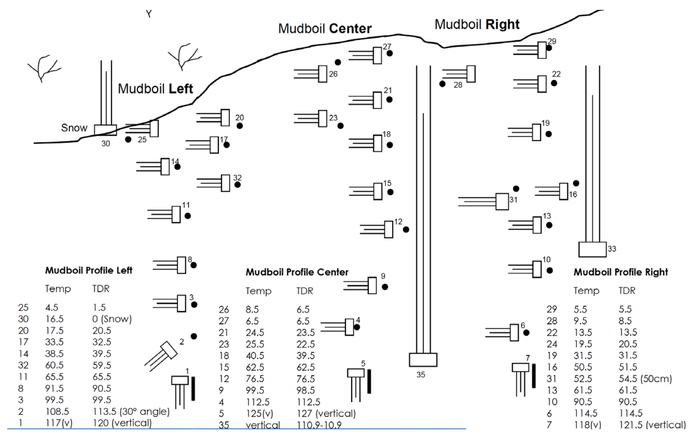
S.Ebenhoch[1,4,5], M. Maturilli[2], B. Höfle[1,5], K. Roth[4], J. Boike[2,3]

[1] Department of Geography, University of Heidelberg, Germany [2] Alfred-Wegener-Institute for Polar and Marine Research, Potsdam, Germany [3] Institute for Geography, Humboldt University, Germany [4] Institute for Environmental Physics, University of Heidelberg, Germany [5] Heidelberg Center for the Environment, Heidelberg, Germany
Contact: ebenhoch@iup.uni-heidelberg.de

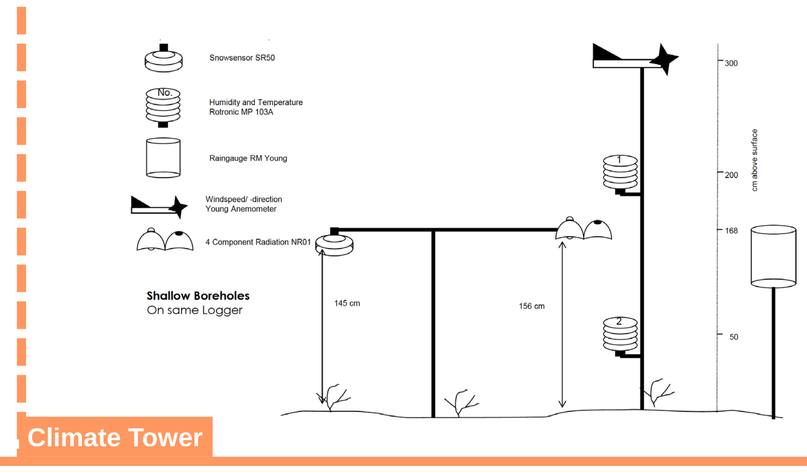
## Introduction

At the High-Arctic research site Bayelva (78.5 ° N, 11.5 ° E) on Svalbard soil, climate and snow components are recorded since 1998 by the Alfred-Wegener-Institute. Long-term analyses of air, radiation, soil, and snow characteristics were examined to gain better understanding of the thermo-insulation effect of the seasonal snow-cover. The Stefan-Model was applied to estimate the annual maximum thaw depth of the active layer, the active layer thickness (ALT). To account for different magnitudes of insulation, the Effective Snow Depth was calculated for each cooling season (Oct – Mar) and correlated to air and soil temperature amplitudes [Slater et al. 2017].

## Set Up



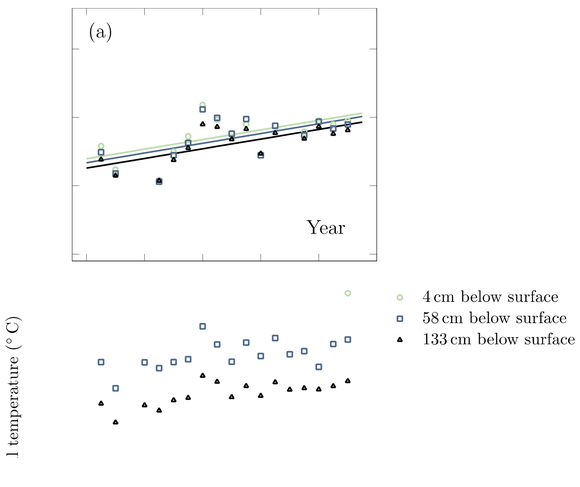

Soil Profile



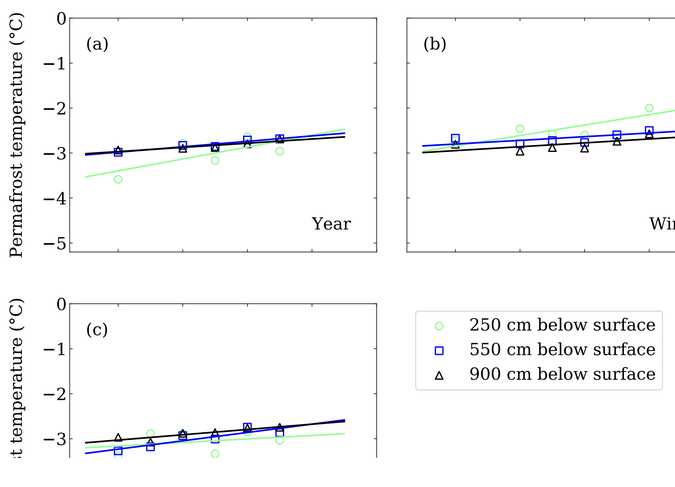

Climate Tower

## Soil Properties

**Active Layer Temperatures**: recorded in high-resolution soil profile from 1998 to 2017. Mean annual, winter (DJF), and summer (JJA) temperatures were aggregated.



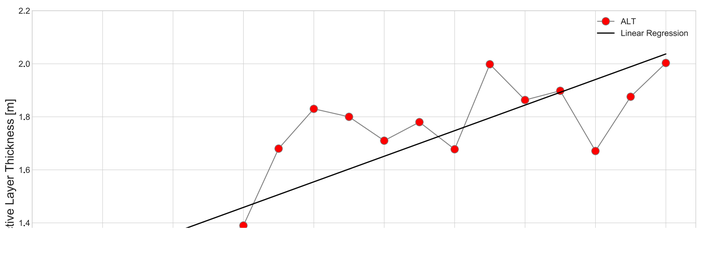

**Permafrost Temperatures**: recorded in borehole, installed in 2009. Mean annual, winter, and summer temperatures were aggregated.




**Active Layer Thickness**: maximum annual thaw depth estimated by Stefan-Model.

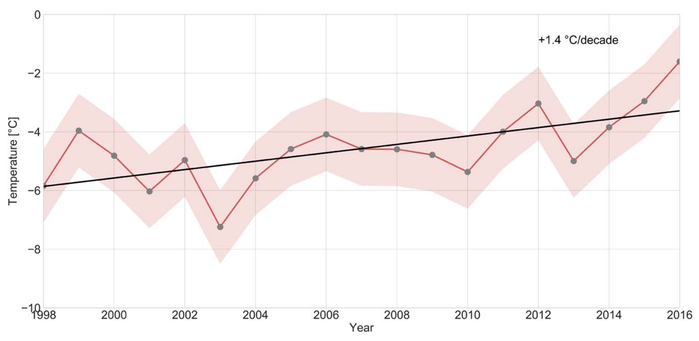
$$Z_{thaw} = \sqrt{\frac{K_h |TDD(t)|}{\rho_w L_{sl} \theta_w}}$$

$K_h$ being the bulk thermal conductivity [W/m K], TDD the thawing degree day Index, and the volumetric latent heat in the denominator.

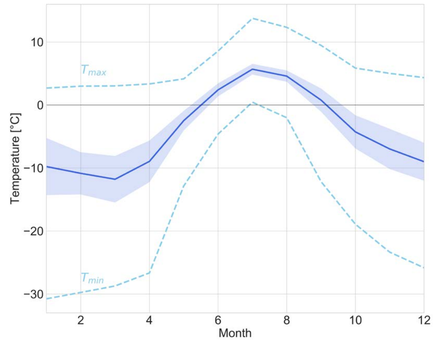



## Air Temperature

**Mean annual air temperature**: from 1998 to 2016. Data-gaps were filled with air temperatures recorded in Ny-Ålesund, 2.7 km east of Bayelva.



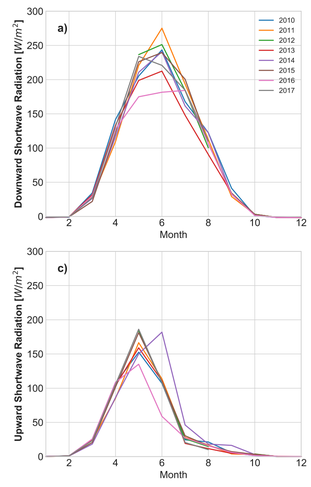

**Mean monthly temperature**: from 1998 to 2016. Absolute minimum and maximum values, and the mean value of all months.




## Radiation

**Mean annual net radiation**: from 1998 to 2016. Large data-gaps excluded from annual mean aggregation.

**Mean monthly shortwave radiation**: upward and downward components from 2010 to 2017.

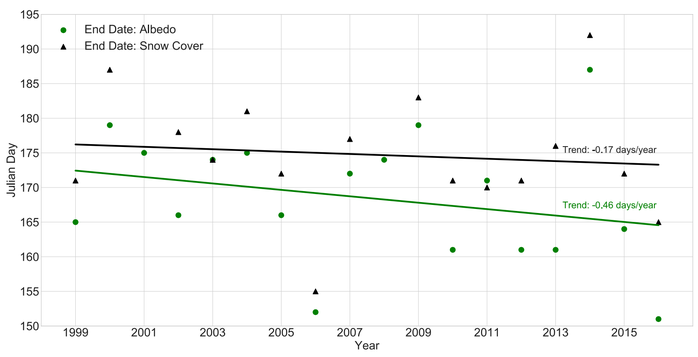




## Snow Properties

**End of snow-cover:** final day of snow-cover was determined using two different approaches:

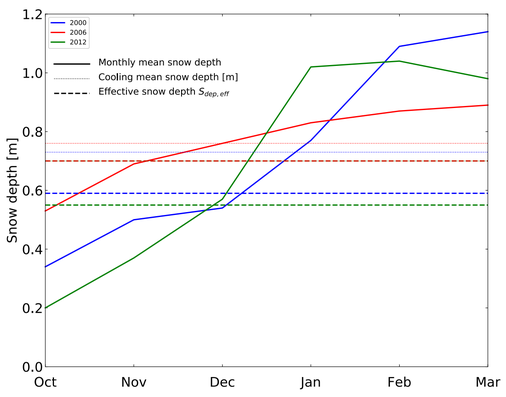
1) Day of year when daily maximum **snow depth** stays below 0.05 m for the rest of the summer. Values above 0.05 m in summer are classified as vegetation.

2) Relation of upward and downward shortwave radiation gives the Albedo of a surface. **Albedo** values below 0.2 represent tundra/rock surface and were used as threshold to determine the last day with snow.




**Effective Snow Depth**:

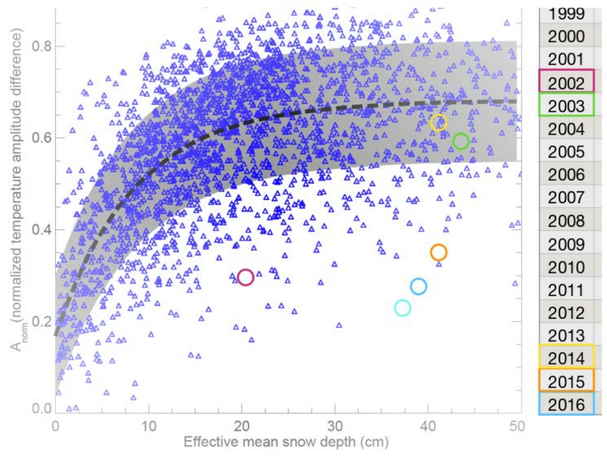
$$S_{\text{depth,eff}} = \frac{\sum_{m=1}^{M} (S_m \cdot (M+1-m))}{\sum_{m=1}^{M} m}$$




**Normalized Temperature Amplitude**:

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

**P:** temporal offset between air and soil temperature amplitudes
**Q**: temporal nature of snow accumulation
**R**: effective damping depth




## Conclusions:

- Warming active layer and permafrost temperatures
- Deepening of annual maximum thaw depth
- Warming air temperatures
- Increasing net radiation
- Earlier melt-off of snow-cover
- Effective Snow Depth represents snow-pack with high insulation effects
- Correlation of Effective Snow Depth to air and soil temperature amplitudes difficult

References:
- Boike, J., I. Juszak, S. Lange, S. Chadburn, E. Burke, P. P. Overduin, Ku. Roth, O. Ippisch, N. Bornemann, and L. Stern (2017). A 20-year record(1998–2017) of permafrost, active layer, and meteorological conditions at a High Arctic permafrost research site (Bayelva, Spitsbergen): an opportunity to validate remote sensing dataand land surface, snow, and permafrost models, Earth Syst. Sci. Data Discuss. In: EarthSystem Science Data Discussions 1, p. 86.
- Roth, K. and J. Boike (2001): Quantifying the thermal dynamics of a permafrost sitenear Ny-Ålesund, Svalbard. In: Water Resources Research 37.12, pp. 2901–2914. issn:0043-1397. doi: 10.1029/2000WR000163
- Slater, Andrew G., David M. Lawrence, and Charles D. Koven (Apr. 2017). Process-levelmodel evaluation: a snow and heat transfer metric. en. In: The Cryosphere 11.2, pp. 989–996. issn: 1994-0424. doi: 10.5194/tc-11-989-2017