Universität Potsdam

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

Analysis of surface temperature data and topography from Yedoma complex of the Lena River delta

Internship report

Universität Potsdam

submitted by

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1 Introduction

As part of the M.Sc. degree program "Remote Sensing, Geoinformation and Visualization" at the Potsdam University is allowed and promoted to perform an Internship in the industry or at the research institution.

My motivation for the Internship was to participate in an ongoing research project and therefore to obtain the experience which is hard to get during University studies. Such experience to get familiar with the daily working life, to work as a team member in a corporate environment, and apply knowledge which I already obtained during my studies at Potsdam University.

Also, my goal was to broaden my knowledge of programming language Python, data pre-processing, and data analysis skills.

1.1 Presentation of the scientific research institute

I was working at the Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research (German: Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung). AWI is the center of polar and marine research in Germany which conducts research in the Arctic, the Antarctic, and the high and mid-latitude oceans. It was founded in the year of 1980 and named in honor of German meteorologist, climatologist, and geologist Alfred Wegener.

The institute is distributed over several cities in Germany: Bremerhaven, Potsdam, Sylt, Helgoland. It also has different research stations in Russia, Norway, Antarctica as well as ships and aircrafts.

I was a part of the SPARC research group lead by PD Dr. Julia Boike. The main focus of the research group is to explicate the two major cycles (water and heat) and to understand how changes in heat and water processes affect the balance and stability of the complex Arctic landscape.

1.2 Study area

Yedoma (Russian: Е́дома) is a type of Pleistocene age permafrost that was formed 1.8 million to 10,000 years before present. Characterized as organic-rich permafrost (around 2% carbon by mass) and ice-rich permafrost (50-90% by volume) (Walter KM et al., 2006).

Permafrost degradation and its contribution to climate change have been discussed by scientists for more than ten years (Mars and Houseknecht, 2007).

Global warming and increasing of land surface temperature have a positive effect on microbiological activity which leads to a faster thawing. It is estimated that there is about twice as much carbon stored in permafrost as already presented in the atmosphere (E.A.G. Schuur, et al. 2015). This is approximately 1460bn-1600bn tonnes of carbon. Released carbon turns into a greenhouse gas.

Thawing yedoma is a significant source of atmospheric methane. In order to perform proper climate research and to obtain reliable results, it is important to set up climate models properly and evaluate vital parameters such as land surface temperature and thawing.
Yedoma Ice-Complex landscapesare widely distributed in Northeastern Siberia, Northwestern Canada, and Alaska (see Figure 1).

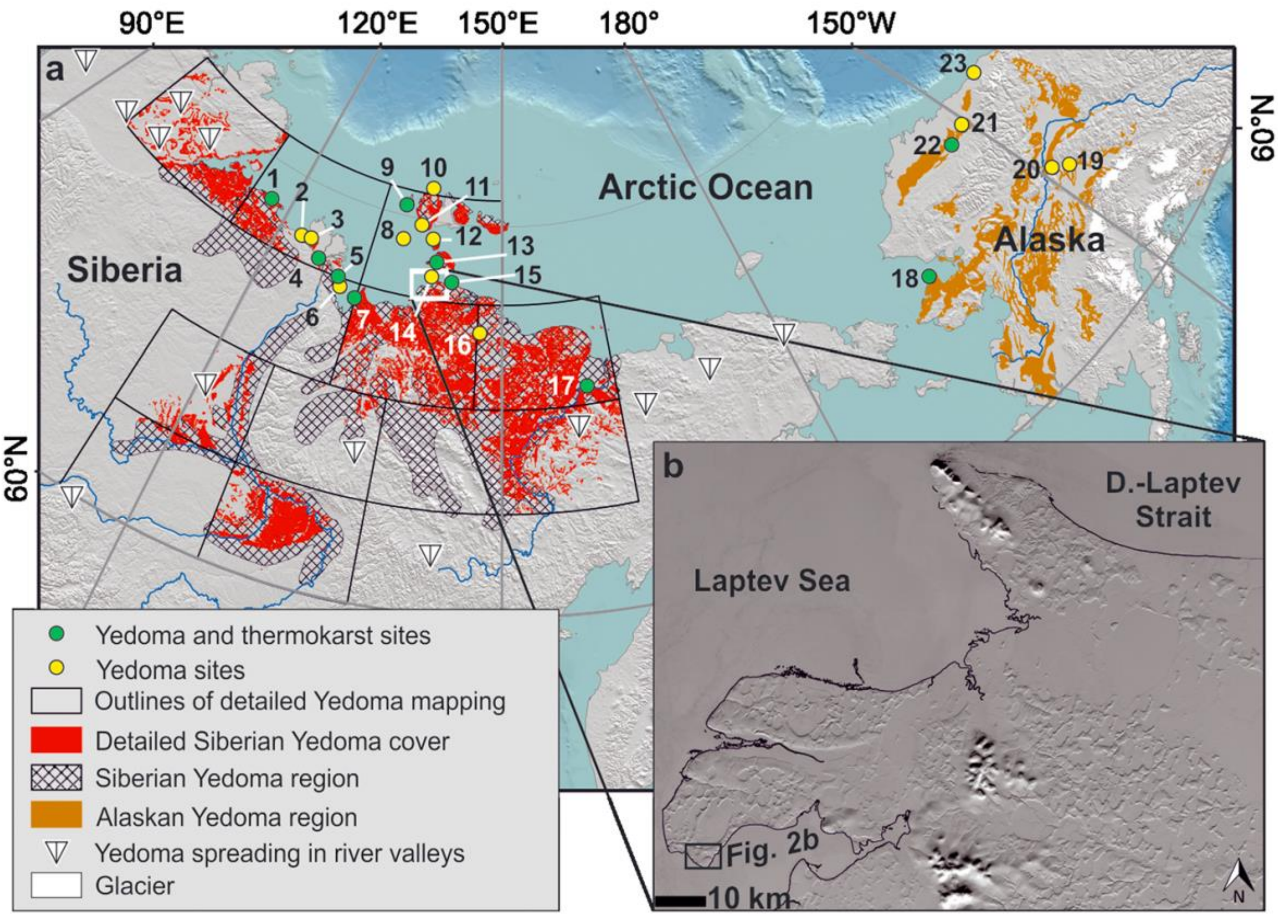


Figure 1: Distribution of Siberian Yedoma Ice Complex (Strauss et al., 2013)

The Lena river delta is one of the biggest in the world and the biggest delta in the Arctic. It is situated in the Northeastern part of Russia and covers an area of 25,000 km². The whole delta is consists of continuous permafrost (Brown et al., 1997).

Sites measurements were performed on the Kurungnak island in the delta of the Lena river which characterized by an arctic continental climate with a mean annual air temperature of -12.3°C.

Figure 2: Lena river delta landscape (Ph: N. Bornemann)

2 Site description

Three different sites (A, C, D) were dug and for each site, thermal properties, soil constituents, snow depth, and ground surface temperature were measured. For site B which is located near a first-order stream in a small valley, were taken only frozen core samples, snow depth, and ground surface temperature.

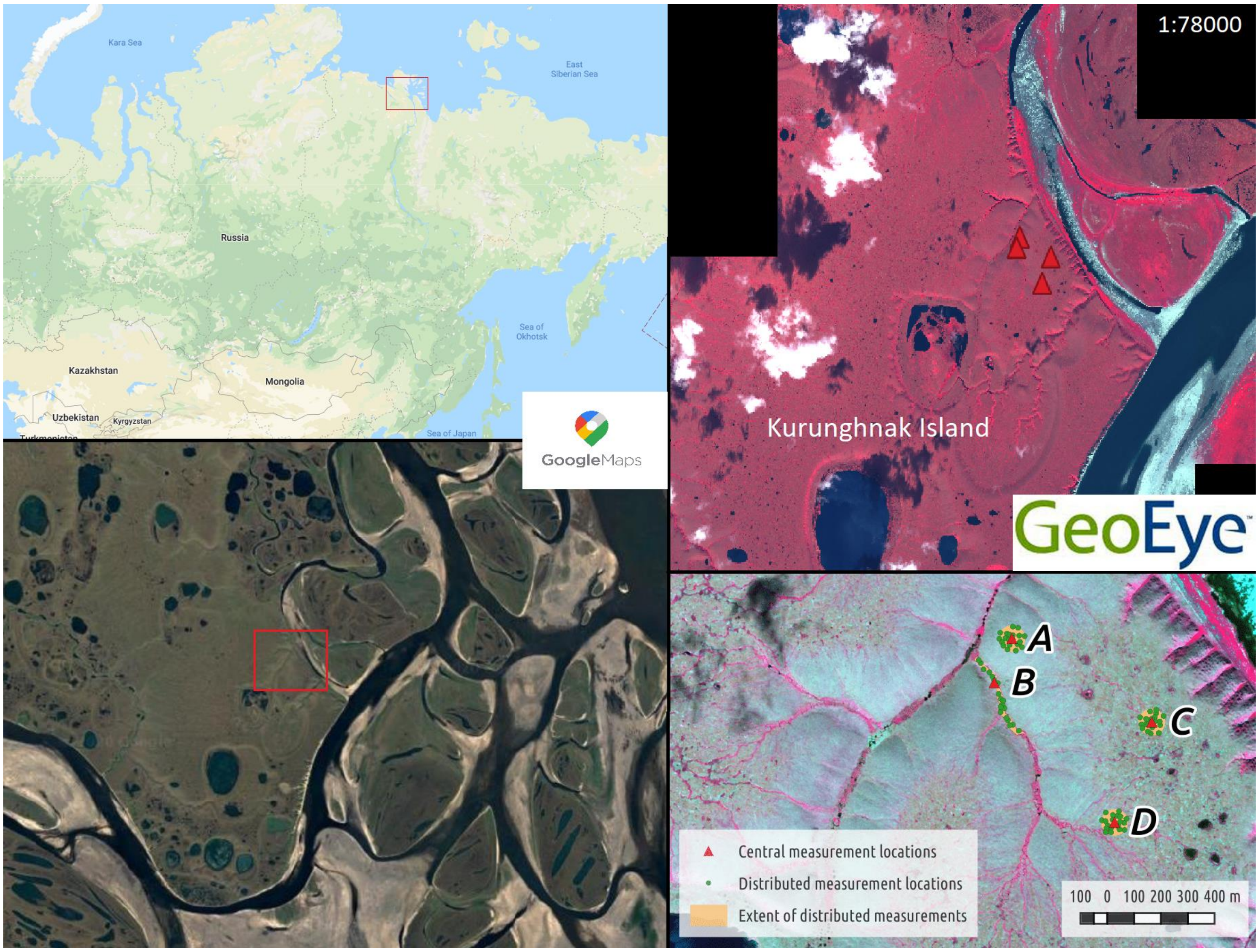


Figure 3: Overview map of the study region and sites. Image sources: top left, bottom left: Google Maps, top right: GeoEye, bottom right: adopted from Jan Nitzbon.

All sites were chosen in order to cover different topographical features:

- site A is situated on a slope,
- site B grass wetland in drainage valley,
- site C on the upland plateau,
- site D in an area where water assembles in small tracks that visibly starts to flow.

Coordinates of centers of all sites were measured with GNSS-equipment and around 20 supplementary profiles were randomly distributed in a 50 meters radius next to each site-center.

2.1 Site A

Site A (72◦ 22’ 6.7908" N, 126◦ 15’ 24.2316" E) is situated on a dry hillslope that is inclined to a first- to second-order stream.

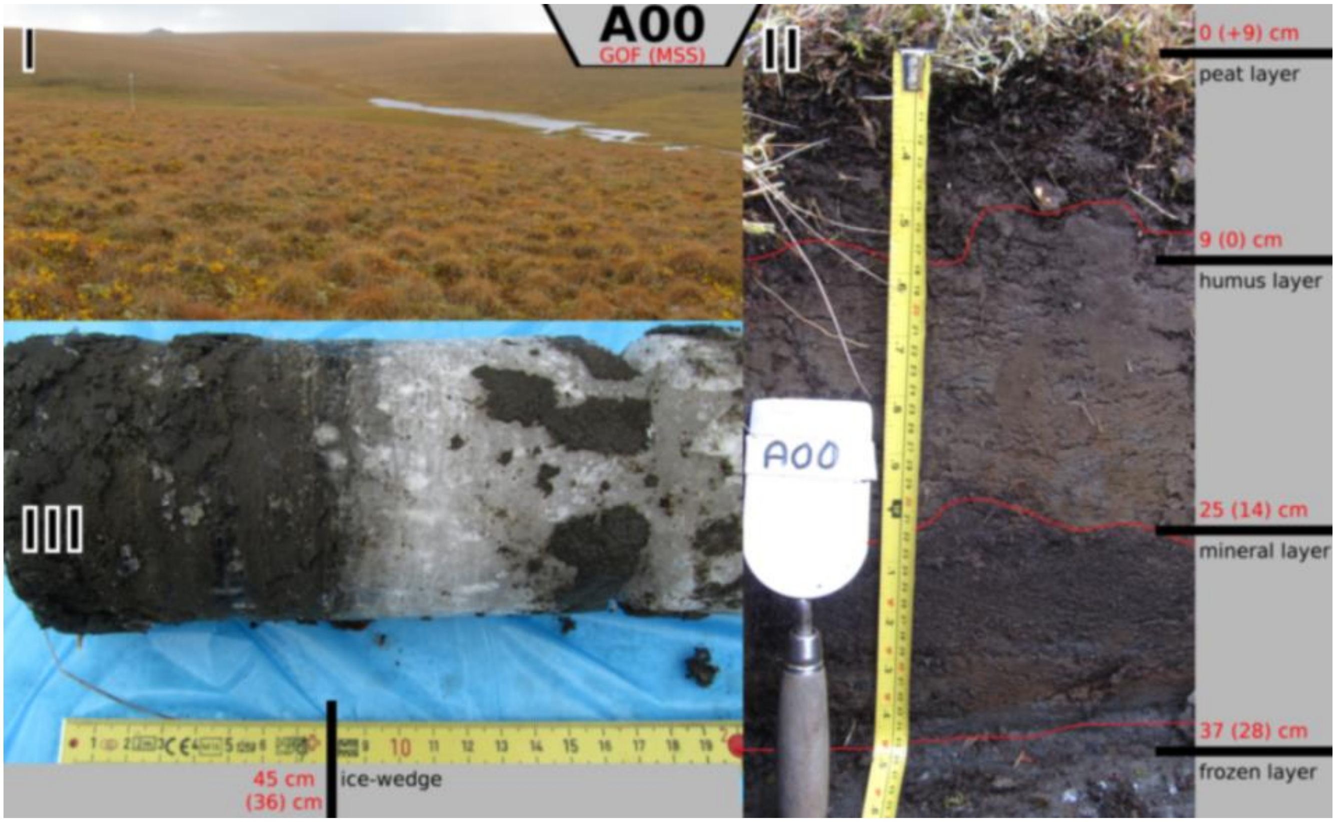


Figure 4: Site A profile. I: overview of the profile surroundings; II: active layer profile; III: transition of the frozen layer to ice-wedge (O. Kaufmann, 2018).

Overview of soil constituents for site A can be seen in Figure 5.

- **Frost table depth** (i.e. thaw depth) is the instantaneous level down to which the permafrost soil will normally thaw each summer in a given area. It was measured by pushing a steel rod into the thawed soil until denial.
- **Water table depth** is a depth of the level below which the pores and fractures of the ground are saturated with water. It was measured as a depth from the surface.
- **Moss layer depth** is the depth of a layer from the top of the surface and until the peat layer.
- **Peat layer depth** is the depth of a layer from the moss layer and until the mineral layer.
- **Snow depth** is the combined depth of old and new snow on the ground.

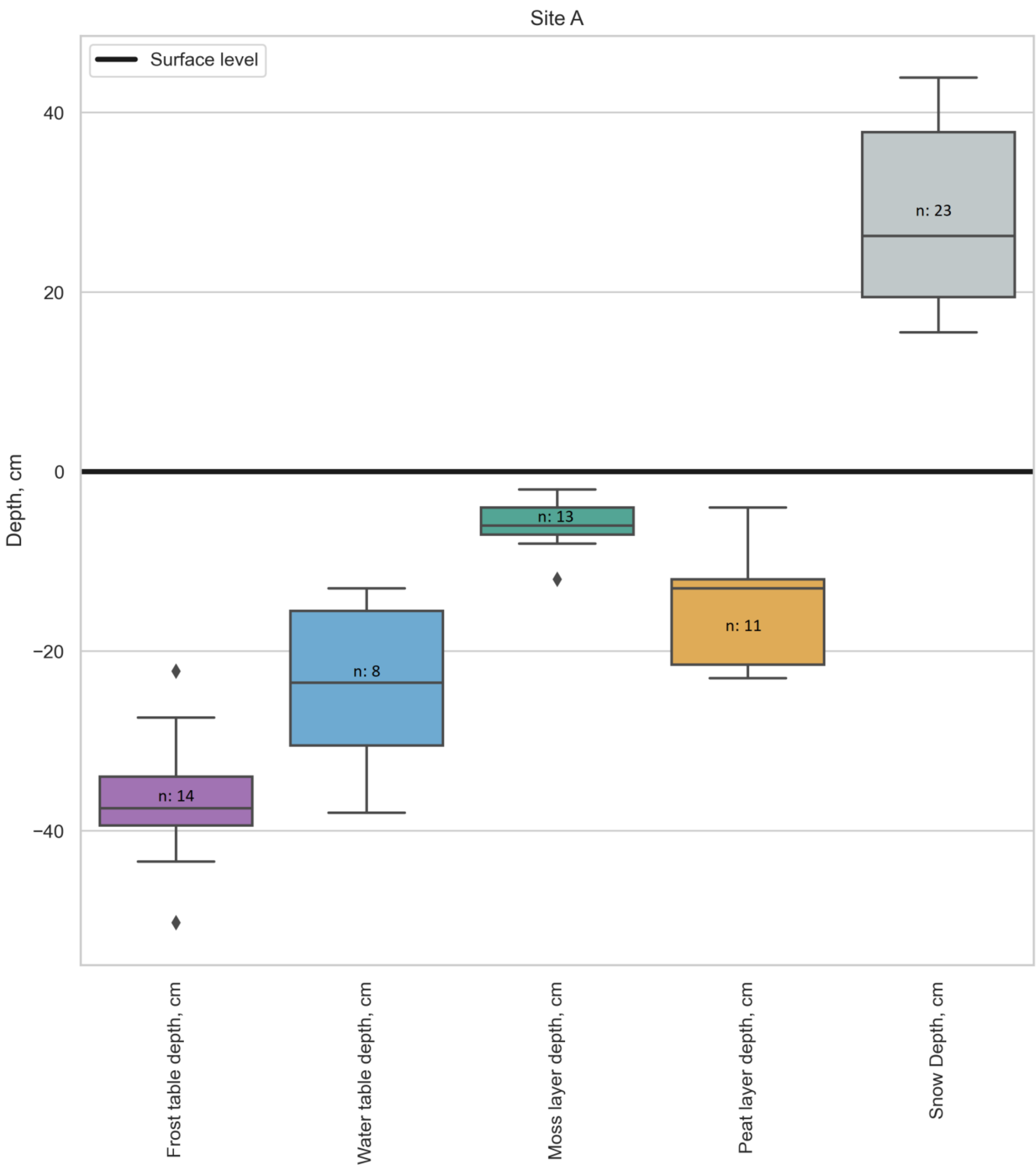


Figure 5: Soil constituents of site A

2.2 Site C

Site C (72◦ 21’ 57.5928" N, 126◦ 16’ 20.9856" E) is situated on an upland plateau with mostly undegraded permafrost. Since site C is situated on a plateau there is a little chance for water to run away or to store.

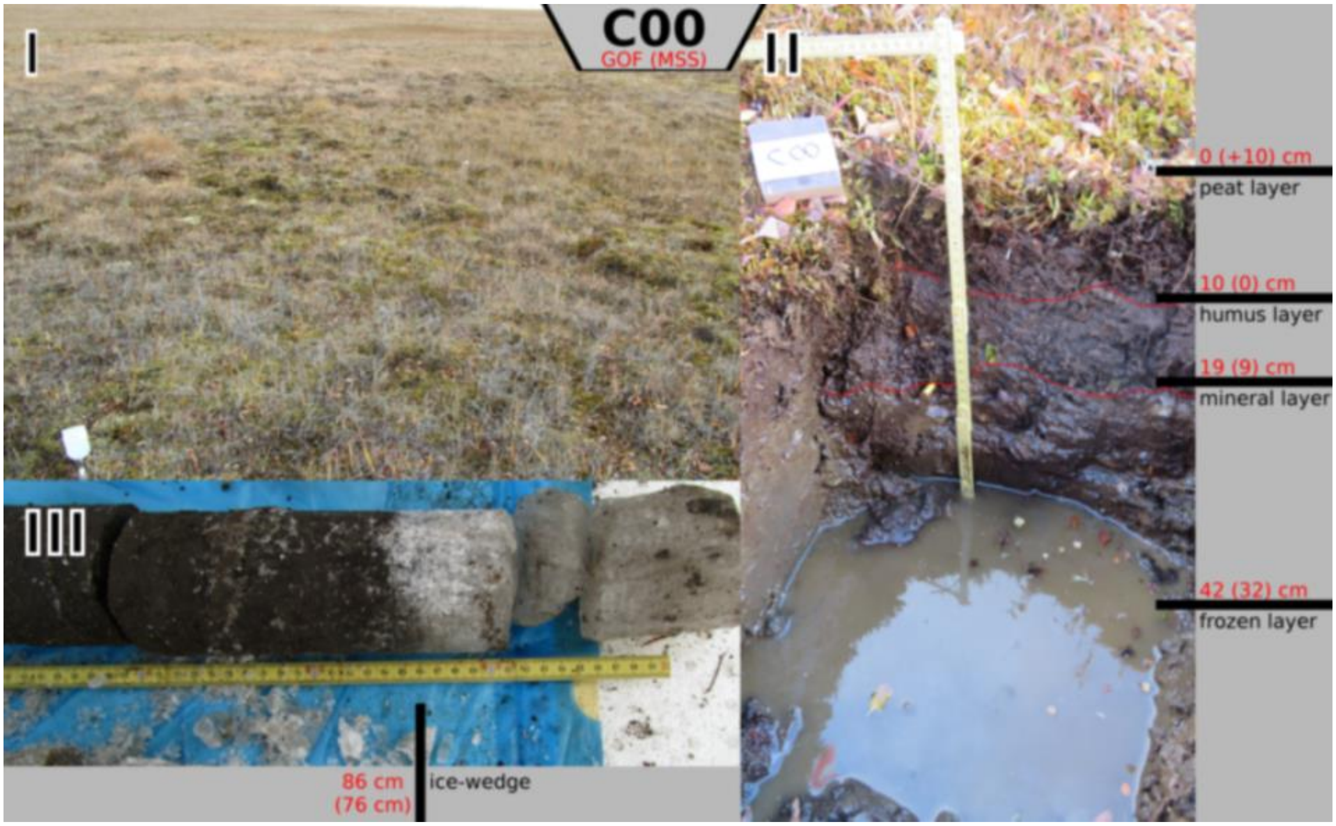


Figure 6: Site C profile. I: overview of the profile surroundings; II: active layer profile; III: transition of the frozen layer to ice-wedge (O. Kaufmann, 2018).

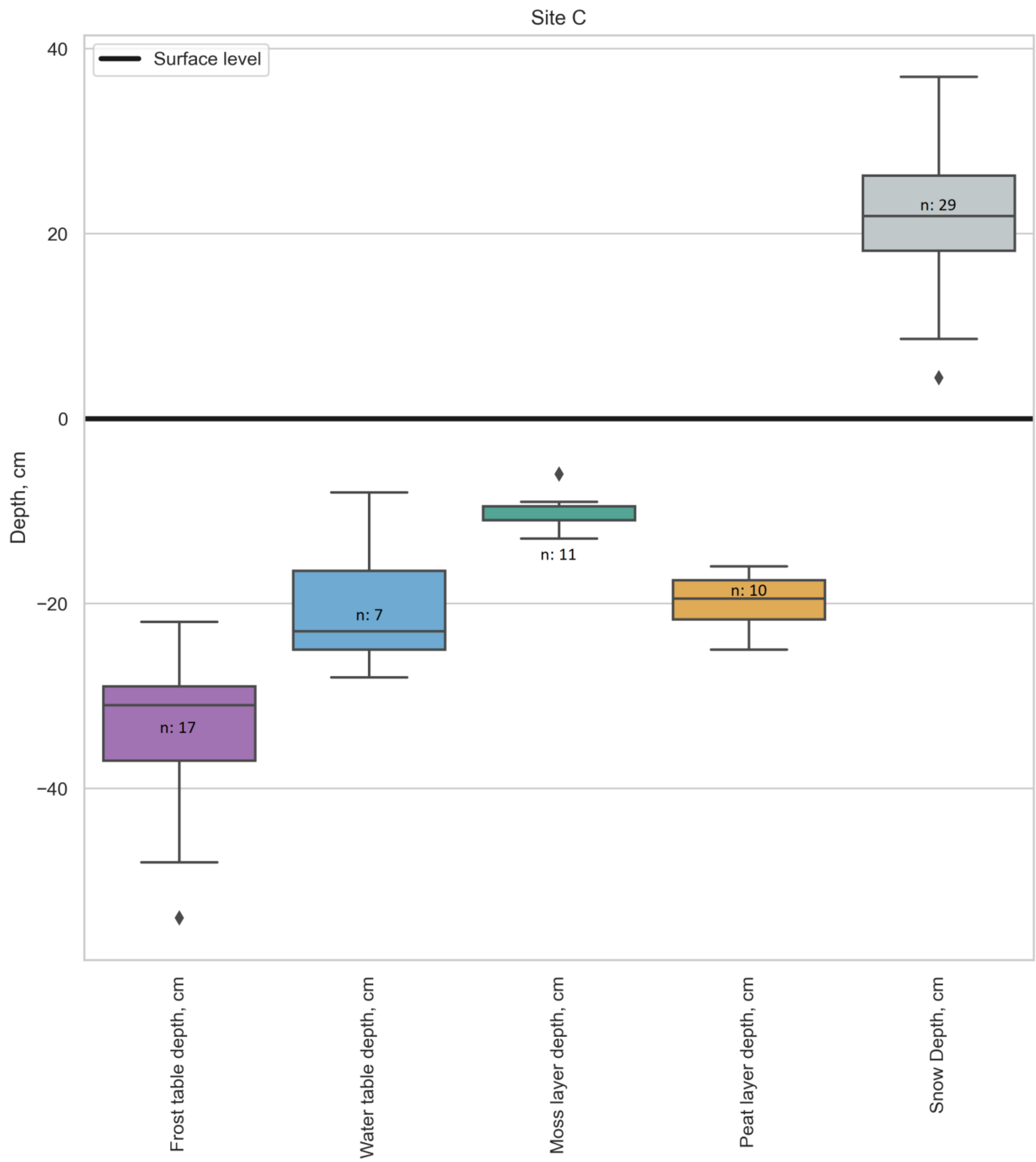


Figure 7: Soil constituents of site C

2.3 Site D

Site D (72◦ 21’ 45.2628" N, 126◦ 16’ 7.8492" E) is situated in an area where water assembles in small tracks that visibly starts to flow.

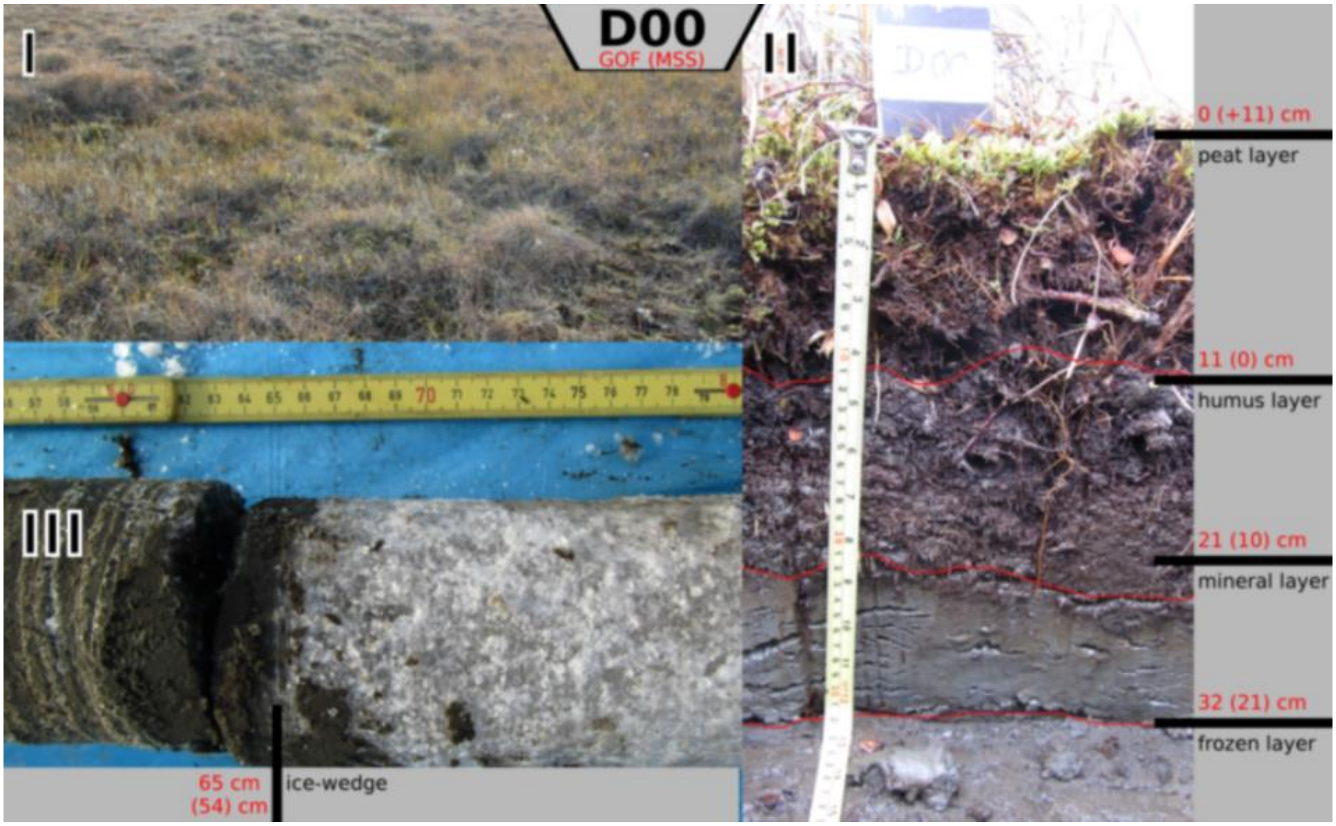


Figure 8: Site D profile. I: overview of the profile surroundings; II: active layer profile; III: transition of the frozen layer to ice-wedge (O. Kaufmann, 2018).

Water is blocked from runoff down because of the siltic composition. Vegetation is supported by flowing freshwater and cause a high amount of organic matter.
High water content is dominant in the peat layer.

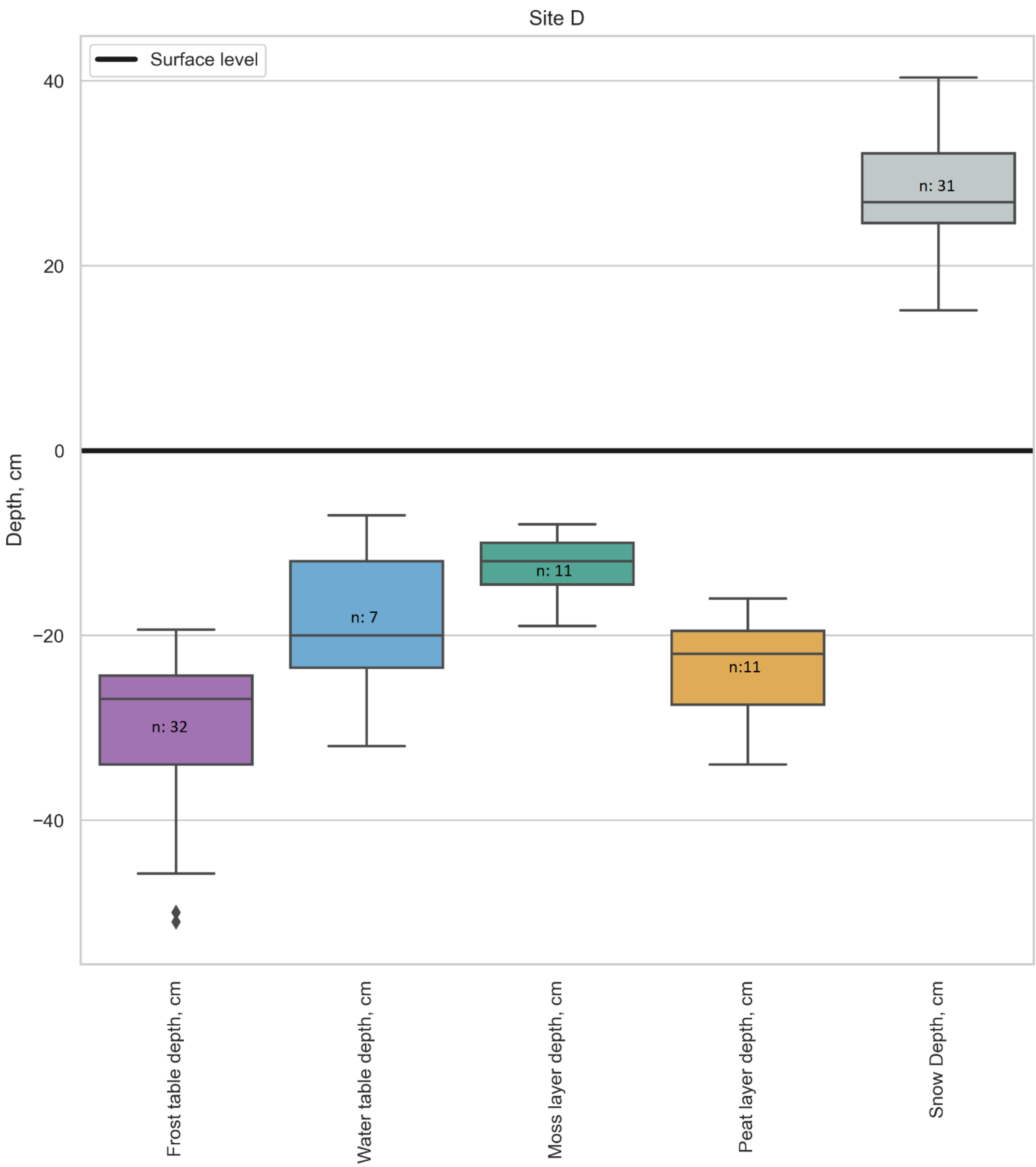


Figure 9: Soil constituents of site D

2.4 Soil constituents comparison

Measurements were made from 08.09.2017 to 15.09.2017.
Overall data points are situated clusterlike and tend not to spread (see Figure 10). Although it can be seen that datapoints for site A (slope) tend to have the smallest values, for site D (water tracks) tend to have the biggest values, and data points for site C (plateau) are mostly situated between them.

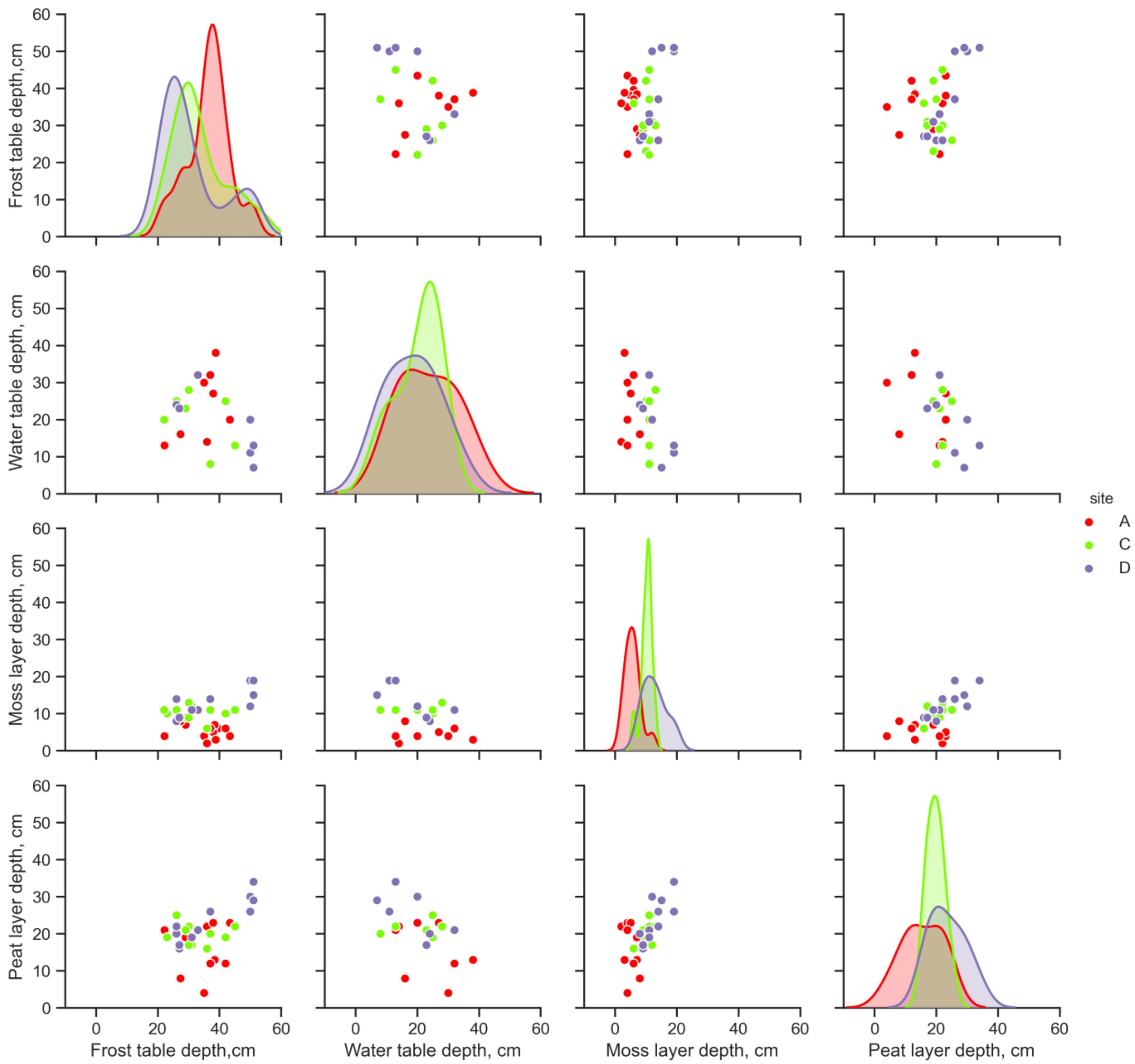


Figure 10: Paired comparison plot of soil constituents per site

Figure 11 serves a purpose to give a clear overview of soil constituents for all three sites that were measured.

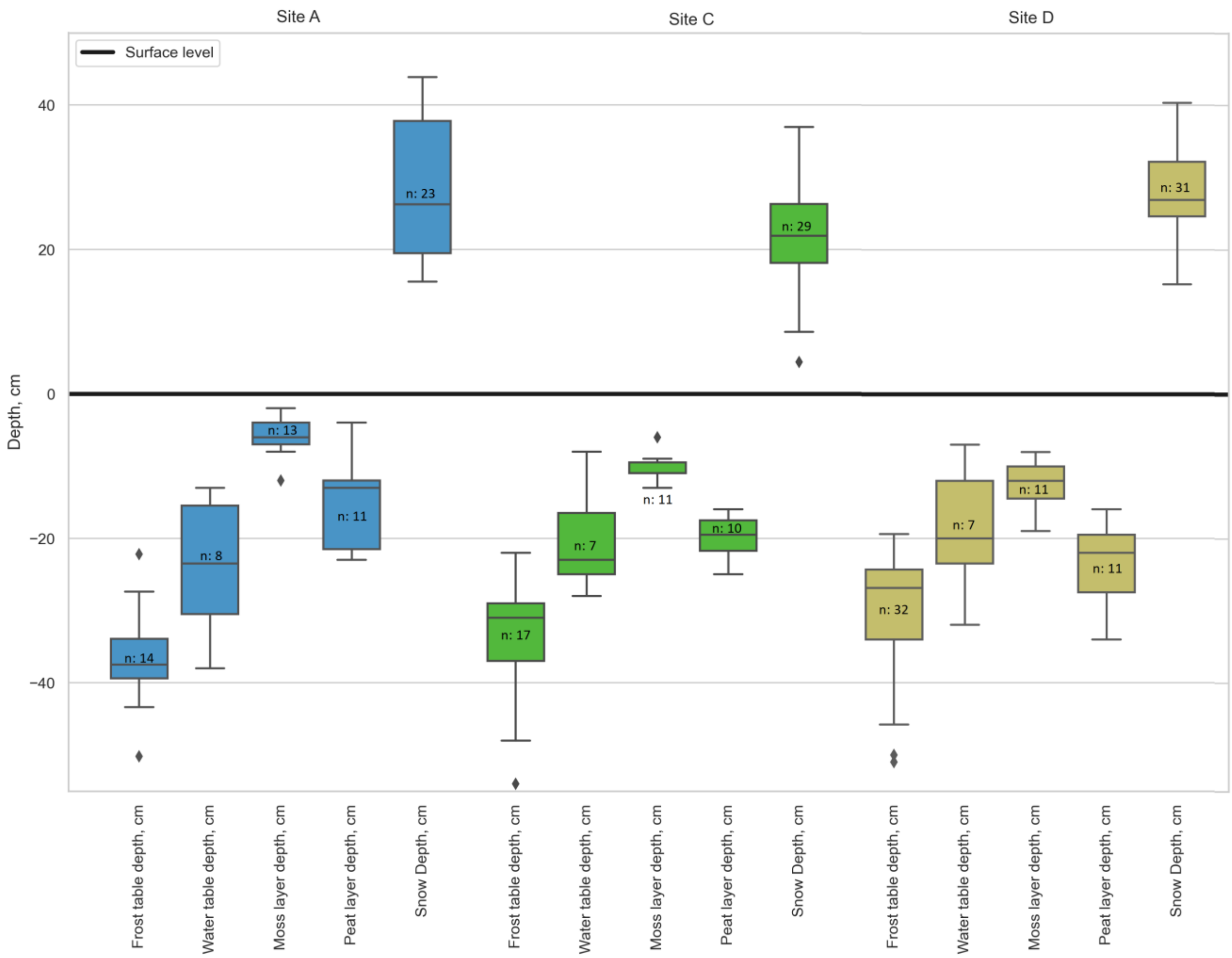


Figure 11: Soil constituents of sites A, C, D

2.5 Thermal properties

Three different kinds of thermal properties were measured with KD2 Pro Thermal Properties Analyzer [Decagon Devices, Inc., 2016] (see Figure 12). Thermal conductivity and heat capacity were determined by summarizing the share of each soil component. Soil should be non-frozen in order to perform a measurement.

Figure 12: KD2 Pro Thermal Properties Analyzer

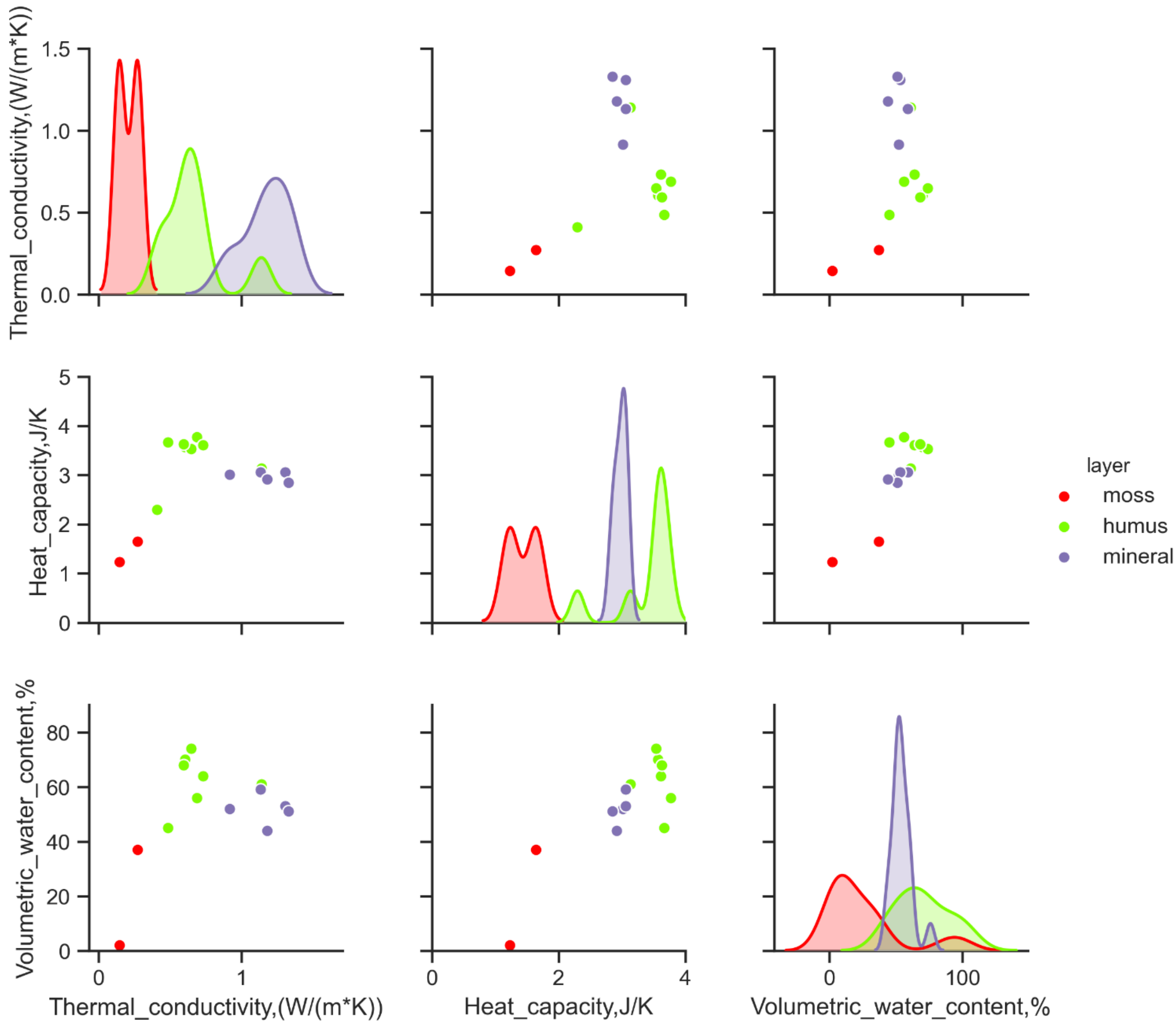


Figure 13: Paired comparison plot of thermal properties per layer

2.6 Correlation heatmap comparison

For a better understanding of the dataset, it is beneficial to visualize data and to look at possible correlations (see Figure 14). Each square represents the correlation between two independent features. Correlation ranges from -1 to +1, values which are close to +1 or -1 shows strong positive or negative correlations, it means as one increases so do the other or as one decreases so does the other respectively. Values which are close to zero means there is no linear trend between two variables.

The strong positive correlation is shown in red and strong negative correlation shown in blue. The diagonals are all 1/red since these squares are correlating each variable to itself.

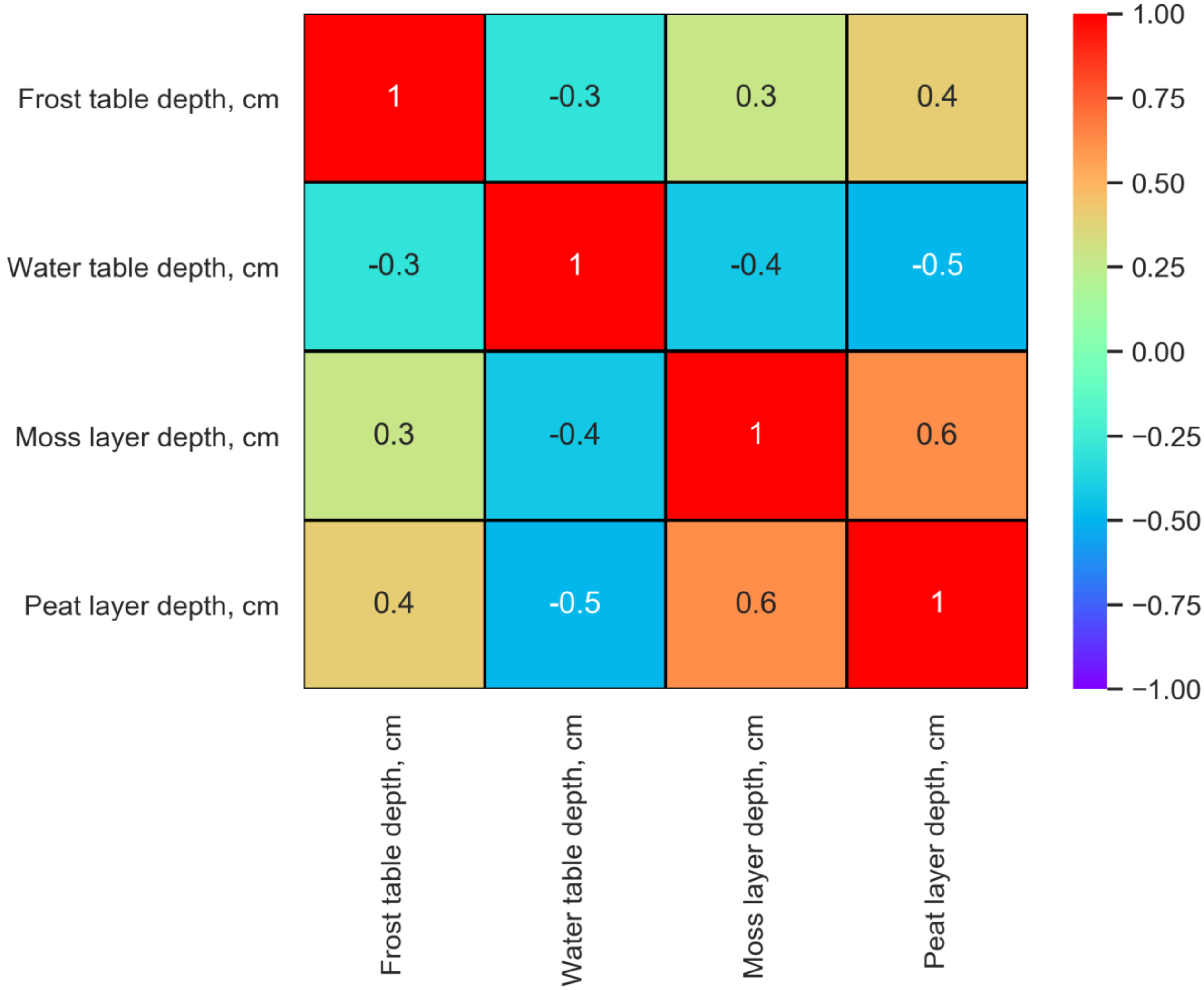


Figure 14: Correlation heatmap among soil constituents

For the current dataset, it can be seen that there is no strong correlation between soil constituents (see Figure 15). However, the strongest existing correlation is between Peat layer depth and Moss layer depth which is 0.6.

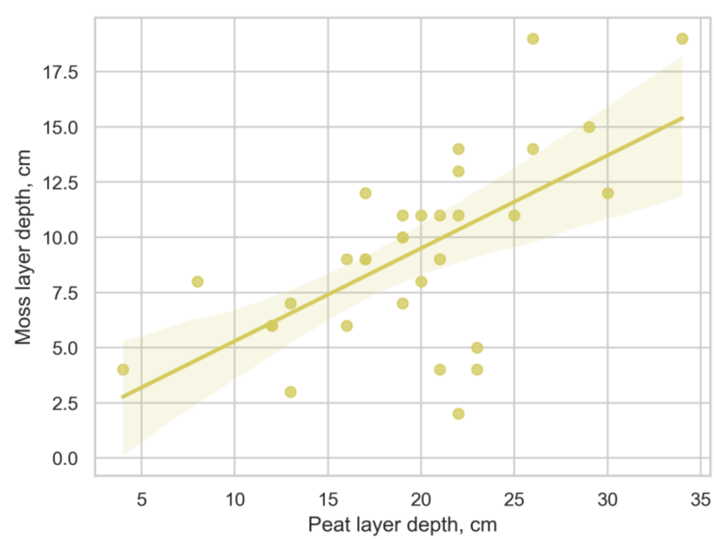


Figure 15: Positive linear relationship between Peat and Moss depth layers

3 Snow depth and ground surface temperature

The ground surface temperature measurements were made using iButton temperature loggers. The iButton temperature logger (DS1922L) is a self-sufficient system that measures temperature and records it in an internal memory section (see Figure 16). During the field campaign two iButtons were deployed in April 2018 and three were deployed in August 2018. The sample rate of deployed iButtons: 14400 seconds, i.e. temperature measurements were performed six times a day. All five iButtons were placed in places with different topographical features (see Figure 17).

Figure 16: iButton DS1922L (at.rs-online.com)

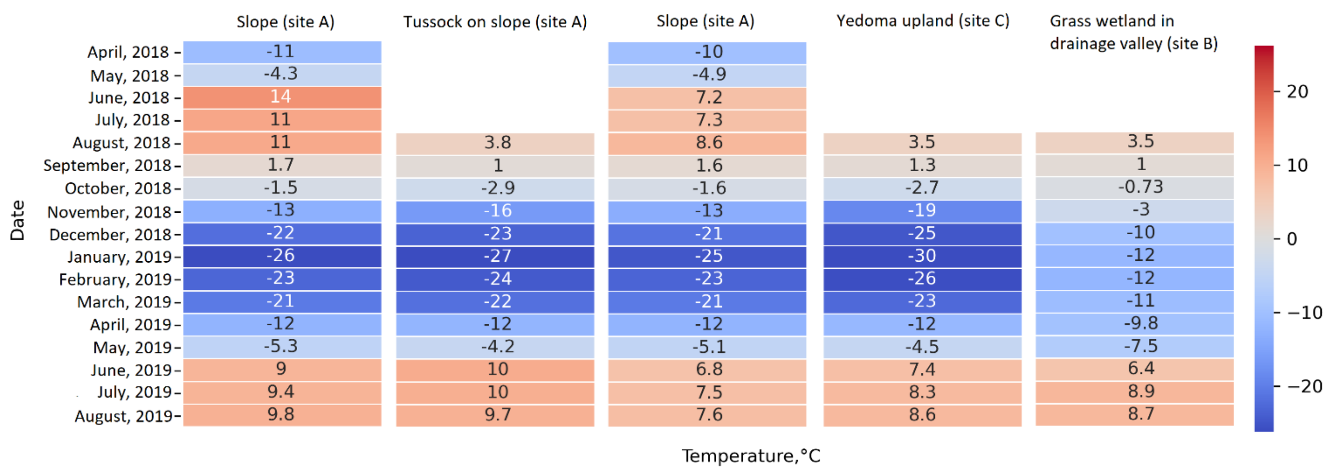


Figure 17: Overview of daily mean ground surface temperature

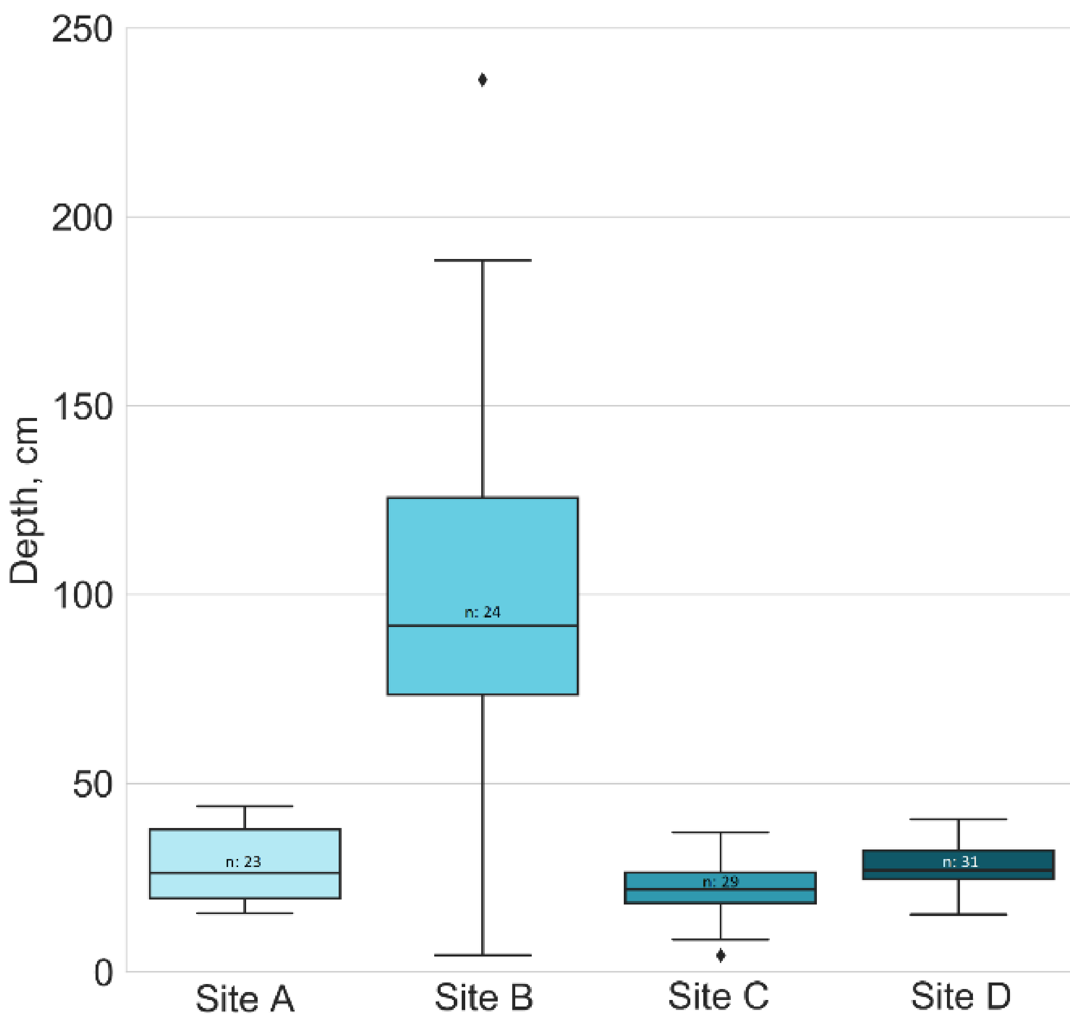
Snow depth measurements were taken by Frider Tautz during the spring 2019 campaign (see Figure 18). Measurements were made manually and at four different sites by calculating the distance between acrylic glass plate on the ground and the end of the rod.

Snow cover affects the temperature regime of the ground beneath it. Since snow has high albedo and emissivity it creates a cooling effect on the surface (for snow depths of all four sites see Figure 19).

In spring during the thawing season energy needed for ice melting impedes the fast warming of the ground below. During winter snow layer acts as an insulator.

Figure 18: Snow profile at manual subsidence rod (Ph: C. Wille)

Figure 19: Snow depth



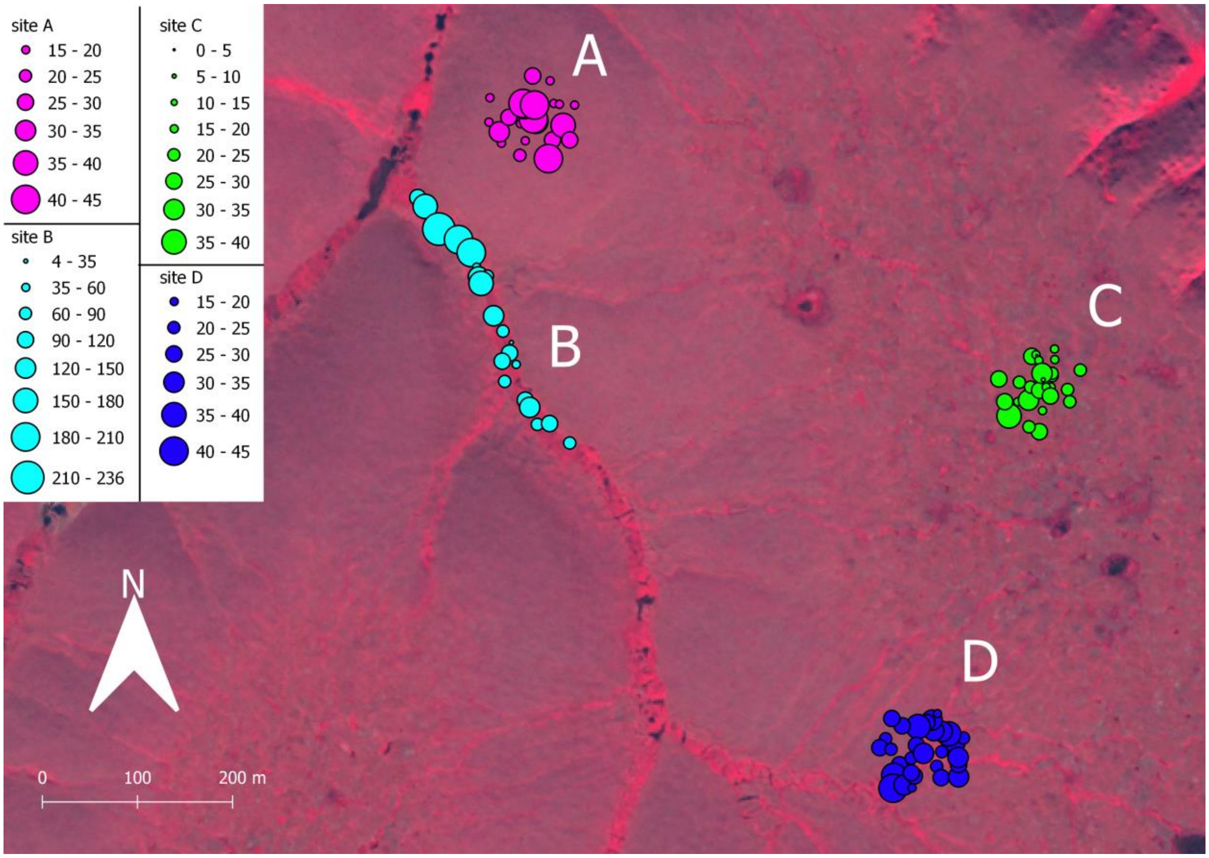


Figure 20: Snow depth distribution

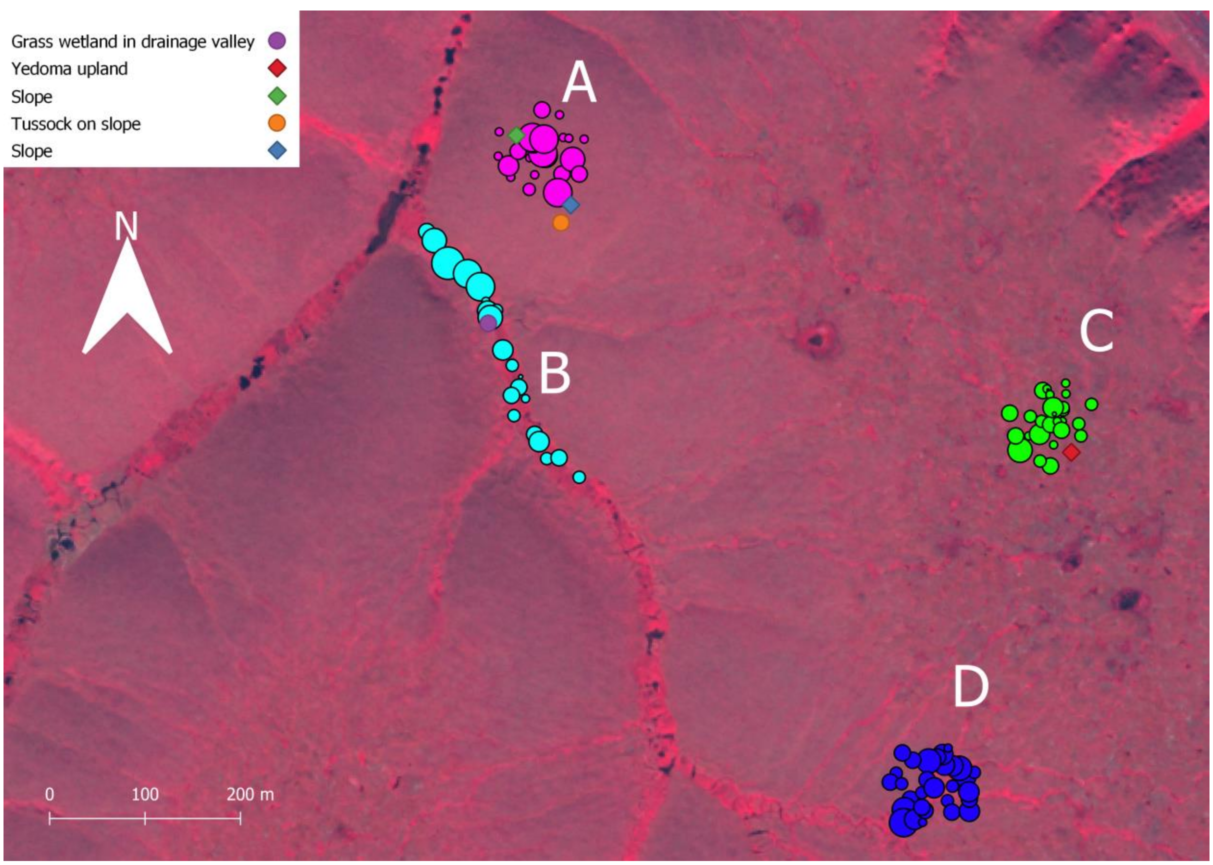


Figure 21: iButtons distribution

The purple line (grass wetland in drainage valley, site B) differ from four others during winter semesters (see Figure 22). This can be explained by increased snow depth compared to the other four places where iButtons where dug.

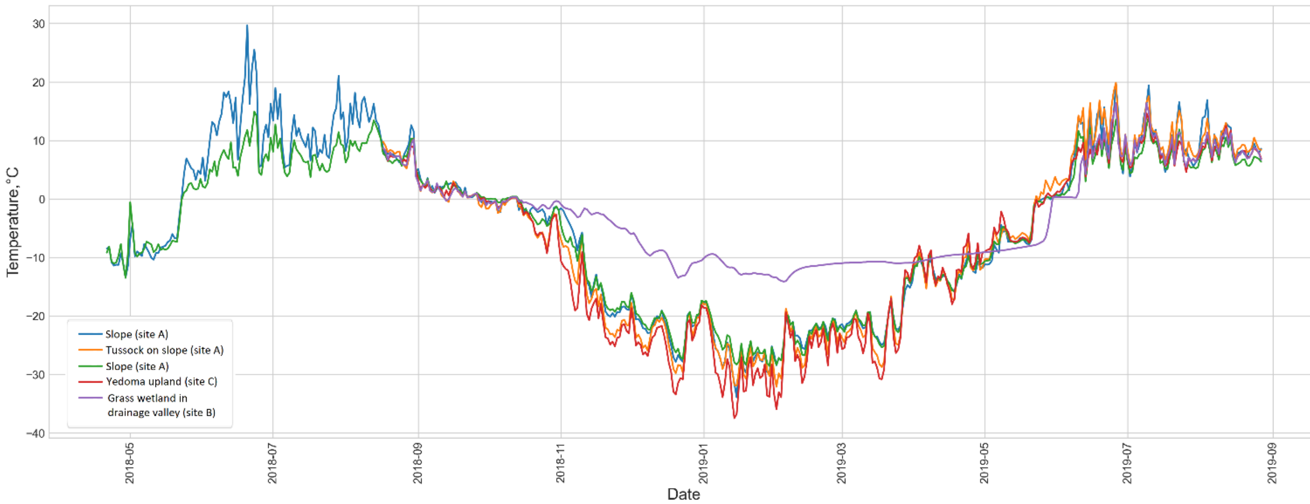


Figure 22: Time-series analysis of daily mean ground surface temperature

The same trend can be observed in Figure 23: during summer all five iButtons tend to follow one trend while during winter temperature at site B varies greatly.

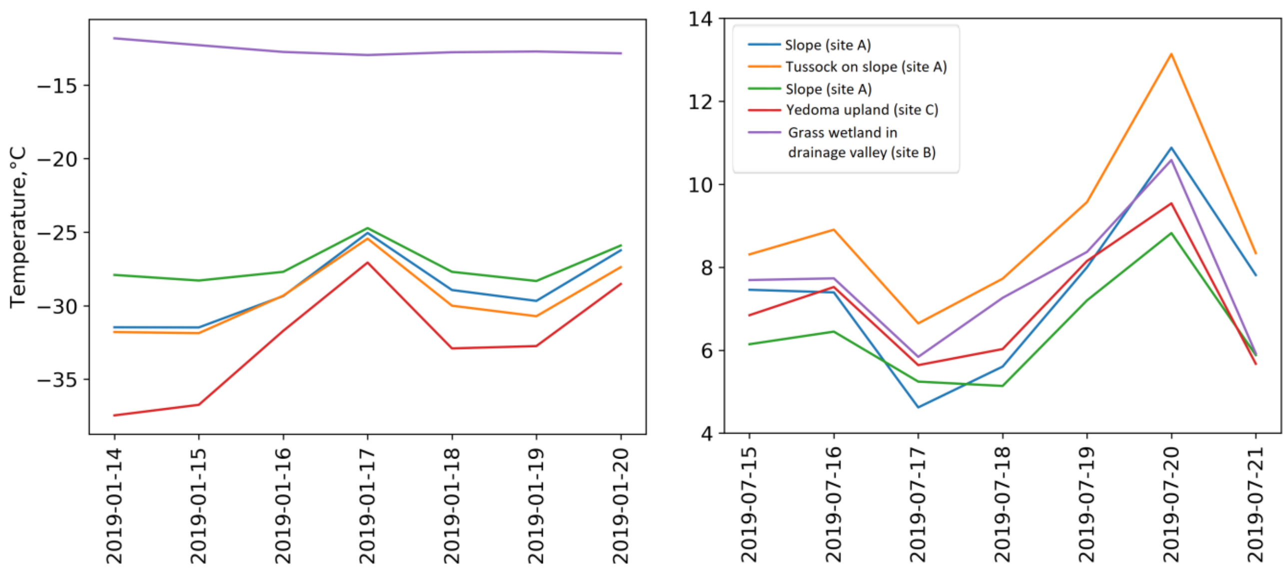


Figure 23: The weekly winter (14.01.2019-20.01.2019) and summer (15.07.2019-21.07.2019) temperature records

4 Sediment analysis

Overall 31 samples of sediment were taken (see Figure 24). Twelve of them were from the active layer and nineteen were from the frozen layer below the active layer. Six of those twelve are from the upper peat layer and the other six are from the mineral layer.

After that in the laboratory, organic material was destroyed, samples got centrifuged, and freeze-dried. Around one gram of the sample is weighted and dispensation agent and ammonia were added. Then everything was shaken automatically.

Subsequently, samples went through 1mm sieve into eight subsamples. After that samples were analyzed in the laser.

Figure 24: Packed sediment sample (Ph: J. Boike)

Following on grain size distributions of sand, silt, and clay have been calculated using GRADISTAT (Blott S. J., Pye K., 2001).

The result is the triangular diagram (see Figure 25) which shows that there is no fraction between 1-2 mm.

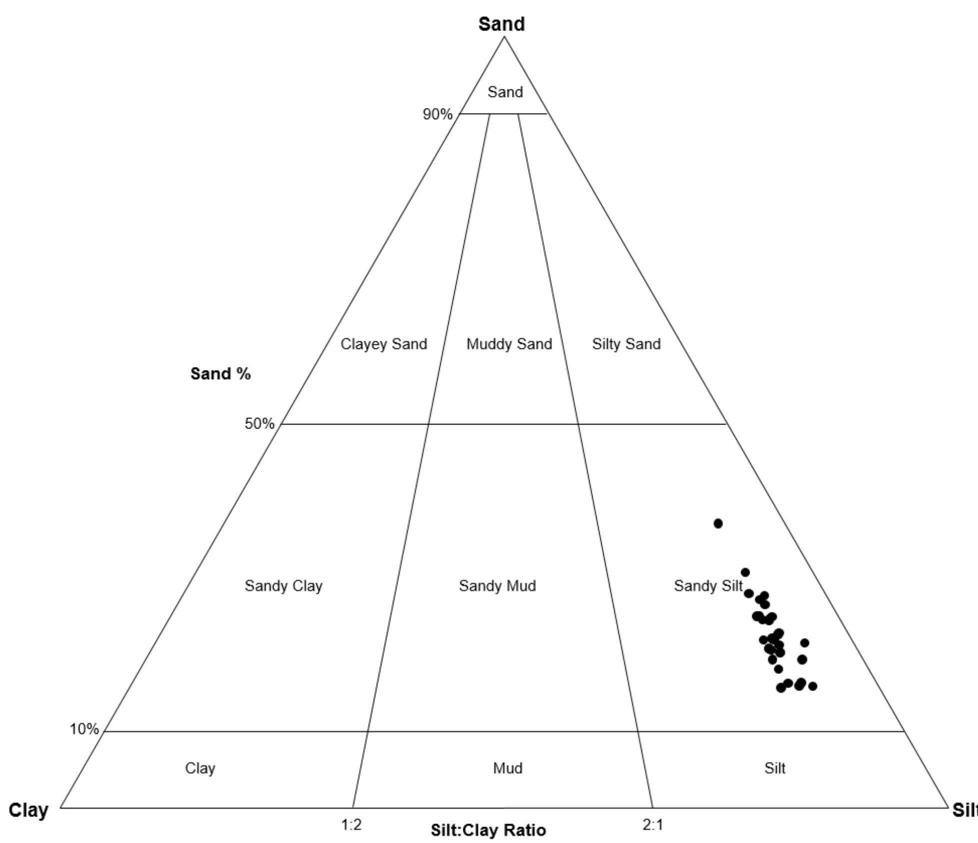


Figure 25: Sand-Silt-Clay diagram

Distribution of grain size and volume of all samples are shown in Figure 26.

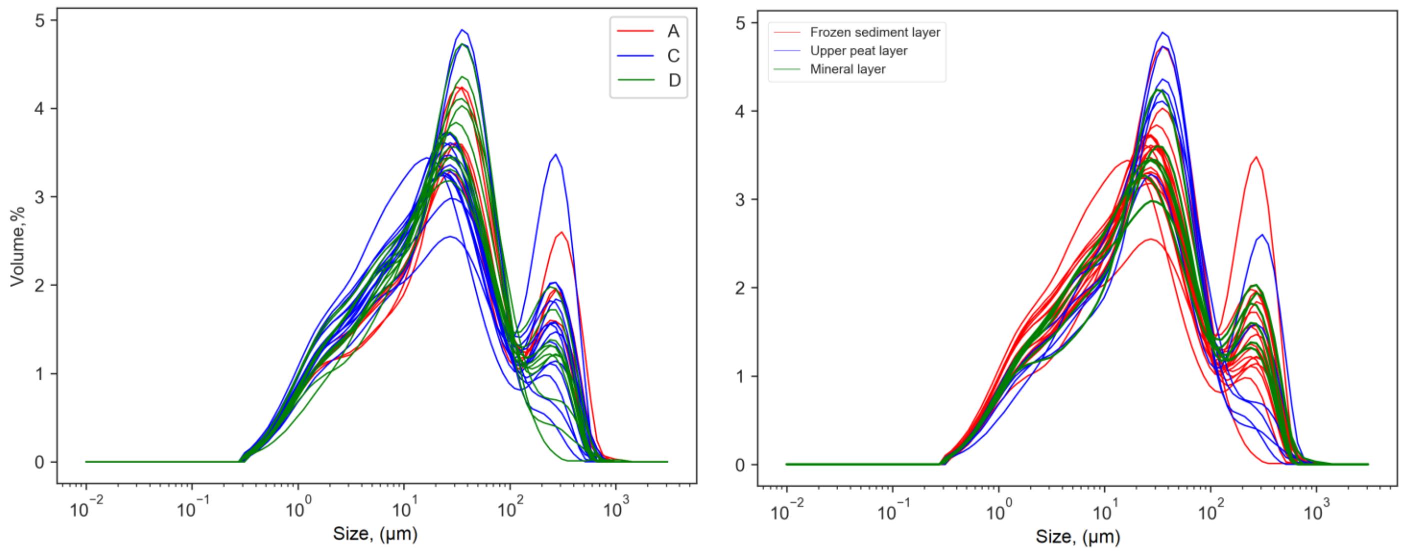


Figure 26: Distribution analysis of grain size for each site (left) and each layer (right). X-axis scaled logarithmically

5 Conclusion

Overall, I would describe my internship as a very positive and useful experience.
It was a great opportunity to improve my data processing and data visualization skills.
Also, it is my first experience of writing such a report. There is still a lot to discover and to improve but I see it as a good preparation before my master thesis.
However, I improved not just my hard-skills, discussions and general communication were also a great help. It was very beneficial for me to get insight into professional practice in a scientific institute.
Unfortunately, during the current coronavirus situation, I was working in the second part of this internship at home which obviously was less convenient. However, even in online-only mode, I was able to get all the data and all the help I need.
At last, this internship has given me new insights and motivation for my studies.

I would like to thank PD Dr. Julia Boike and Prof. Dr. Guido Grosse for being my advisors.
Also, I am particularly grateful for the assistance given by Jan Nitzbon.

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