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Russian-German Cooperation: Expeditions to Siberia in 2018

Edited by

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with contributions of the participants

HELMHOLTZ

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Titel: Das Vegetationsuntersuchungs-Team der Expedition "Chukotka 2018" blickt auf seinem Rückweg zum Feldlager auf den See Ilirney, Tschukotka, von dem lange Sedimentkerne geborgen werden konnten (Foto: Luise Schulte, AWI).

Cover: On its way returning to the field camp, the vegetation survey team of the expedition "Chukotka 2018" is looking at the lake Ilirney, Chukotka, of which long sediment cores could be retrieved (Photo: Luise Schulte, AWI).

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Expeditions to Siberia in 2018

Research Station Samoylov Island and Lena Delta 05.04. - 15.09.2018

Expedition to Chukotka and Central Yakutia 29.06. - 21.08.2018

Chief scientists

Dmitry Bolshiyanov (AARI), Svetlana Evgrafova (SIF), Alexey Fage (IPGG, NSU), Mikhail Grigoriev (MPI, IPGG, NEFU), Birgit Heim (AWI), Ulrike Herzschuh (AWI), Annelen Kahl (EPFL), Christian Knoblauch (UHH), Liudmila Lebedeva (MPI), Anne Morgenstern (AWI), Luidmila Pestryakova (NEFU), Aline Plötz (AWI), Lasse Sander (AWI), Nikolay Sennikov (IPGG, NSU), Jens Strauss (AWI), Sebastian Wetterich (AWI)

2.22 Permafrost research on Sobo-Sise Island (Lena Delta)

Sebastian Wetterich [1], Alexander Kizyakov [2], Michael Fritz [1], Aleksey Aksenov [3], Lutz Schirrmeister [1], (Thomas Opel [1,4]: not in the field)

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Fieldwork period and location
From July 11th to July 25th, 2018 (on Sobo-Sise; eastern Lena Delta)

Objectives
The part of the LENA 2018 expedition on Sobo-Sise Island in the eastern Lena Delta took place from July 11th to July 25th 2018. The field team consisted of three AWI colleagues from the AWI Permafrost Research section and two Russian colleagues; Alexander Kizyakov from the Moscow State University and Aleksey Aksenov from the Arctic Antarctic Research Institute (Figure 2.22.1).

Figure 2.22.1: *Participants of the Sobo-Sise expedition 2018: S. Wetterich, A. Aksenov, L. Schirrmeister, M. Fritz, A. Kizyakov (from left to right)*

Sobo-Sise Island belongs to the third geomorphologic terrace of the Lena Delta. According to a landform classification by Fuchs et al. (2018) 43% of the land surface are occupied by Yedoma uplands and Yedoma slopes, 43% are thermokarst basins and 14% are lakes. The cliff is remarkable for its fast shore line retreat of up to 20 m/yr based on Landsat data (2000-2013; Nitze and Grosse 2016) and for substantial elevation change due to thaw subsidence of up to −2 cm/yr (based on Sentinel-1 InSAR, 2017) and up to −3.4 cm/yr (based on on-site rLiDAR) both indicating ongoing and fast permafrost degradation (Chen et al. 2018; Guenther et al. 2018).
In continuation of previous work on the island in 2014-16 the 2018 campaign focused on three major aims:

1. Cryolithological description and extensive sampling of the Yedoma Ice Complex (IC) and adjacent alas profiles to deduce paleoenvironmental information and organic matter (OM) data;

2. Geochemical characterisation, surface waters pathways by means of dissolved organic carbon (DOC), coloured dissolved organic matter (cDOM), hydrochemistry and stable water isotopes;
3. Active layer and thaw subsidence measurements in continuation of previous studies.

Methods and fieldwork summary

Permafrost sampling

Yedoma IC and alas profiles were taken at different positions of the river shore including both, vertical sediment profiles and horizontal ice-wedge profiles (Figure 2.22.2) to cover the entire exposed permafrost archive.

Figure 2.22.2: *Location of sediment and wedge-ice profiles on Sobo-Sise Island (GeoEye-1 image of July 8th, 2014, synthesis of NIR+Red+Green)*

The Yedoma IC exposed up to about 25 m above river level (arl) was cryolithologically described and sampled on rope by A. Kizyakov using hammer and axe to document and to obtain the material. Three overlapping 'windows' of sedimentary polygon fillings of the IC were sampled (SOB18-01: 24.1 to 15.7 m arl, SOB18-03: 18.2 to 10.2 m arl and SOB18-06: 13.4 to 0.9 m arl). The sampling totaled in 61 samples (Appendix A.2.21). Additionally, at profile SOB18-06 we took samples for detailed radiocarbon dating at 2.5 m arl within one peat horizon (samples SOB18-06-40 to SOB18-06-58). At profile SOB18-01 a core (SOB18-07) was drilled down to 1.7 m depth below surface (bs) using the SIPRE permafrost corer (Figure 2.22.3).

Profiles of alas deposits were sampled at three locations – east of the cliff (SOB18-04: 3.6 to 1.1 m arl, SOB18-05: 2.15 to 0.65 m arl) and west of the cliff (SOB18-10: 1.35 to 0.7 m arl). Sampling positions are shown in Figure 2.22.4. Detailed cryolithological descriptions are given in Appendix A.2.22.
The sedimentary material of the IC and alas profiles will be subject to sedimentological, OM, biomarker, paleo-bioindicators, ancient DNA analyses complemented by radiocarbon dating and stable isotope analyses of the intrasedimental ice. Ground ice content was already estimated in the field as weight difference of the sample after oven-drying (Appendix A.2.21).

Figure 2.22.3: *Yedoma IC profiles studied at the Sobo-Sise cliff shown as (a) overview with the thermoerosional valleys incising the Yedoma cliff and draining into the Lena River, (b) detail of SOB18-06, (c) detail of SOB18-01 and SOB18-03 and (d) drilling of SOB18-07*

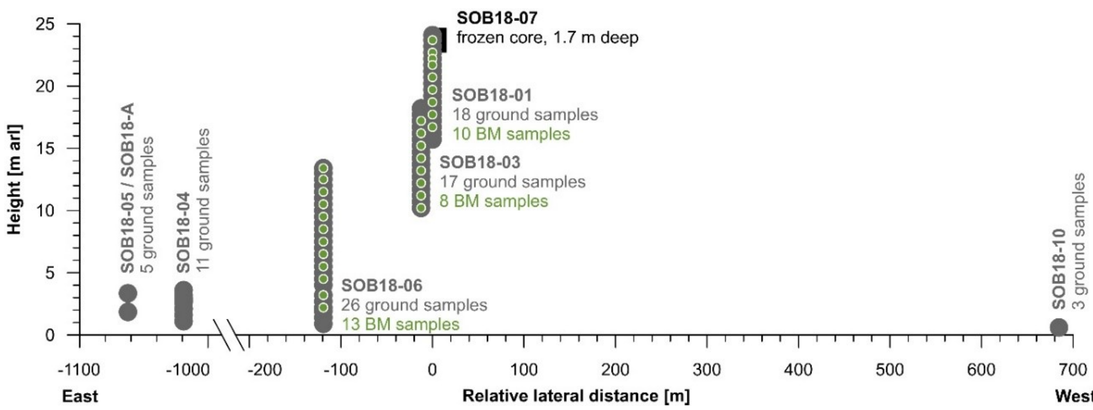

Figure 2.22.4: *Sampling locations of sediment profiles on Sobo-Sise Island (BM – biomarker samples)*

Three Yedoma IC ice wedge profiles were obtained at different heights above the river (Figure 2.22.5). SOB18-02 was taken at 19.7 m arl on rope by ice screw between the sediment profiles SOB18-01 and SOB18-03. The ice wedge profiles SOB18-08 and SOB18-09 were taken by chainsaw at 9.4 m arl and 2 m arl, respectively.
The detailed horizontal ice wedge profiles amounted to 250 samples and will be analysed for stable water isotopes (Appendix A.2.23). Additionally sampled ice blocks from the Yedoma IC profiles will be analysed for DOC and CO_2 radiocarbon ages.
The ice wedge SOB18-02 was sampled on rope by ice screws at 4.5 m bs between sediment profiles SOB18-01 and SOB18-03 (Figure 2.22.5a) over a width of 4.5 m with sample distance of 0.15 m. Single ice veins were 1 to 2 cm wide and contained numerous rounded bubbles (diameter 1 mm), partly elongated.
The ice wedge SOB18-08 was exposed between 0.4 and 1.6 m bs over a width of 4.6 m (Figure 2.22.5b) and covered by the active layer (0 to 0.2 m bs) and protective layer (0.2 to 0.4 m bs).
The ice wedge SOB18-09 was situated below a thermoerosional valley and sampled from the Lena River bank about 2 m arl over an apparent width of 3.9 m (Figure 2.22.5c). The wedge ice contained numerous rounded bubbles (diameter 1 to 2 mm) but elongated bubbled (diameter 1 mm) in its central part.
The approximately 2 m high and 1.2 m wide ice wedge was sampled in the profile SOB18-04 (Figure 2.22.5d). This ice wedge had several lateral shoulders that merged into ice-rich sediment layers. The ice contained numerous small air bubbles (>1 mm in diameter). Individual ice veins were difficult to recognize. Nine samples at 10 cm intervals were taken at 1.7 m bs. Left and right 10 cm distance from the ice wedge edge were left. In addition, a large sample was taken in the middle of the ice wedge at 1.9 m depth with the axe (Appendix A.2.23).

Figure 2.22.5: *Ice wedge profiles studied at the Sobo-Sise cliff shown as (a) detail of SOB18-02, (b) detail of SOB18-08, (c) detail of SOB18-09 and (d) detail of SOB18-04.*

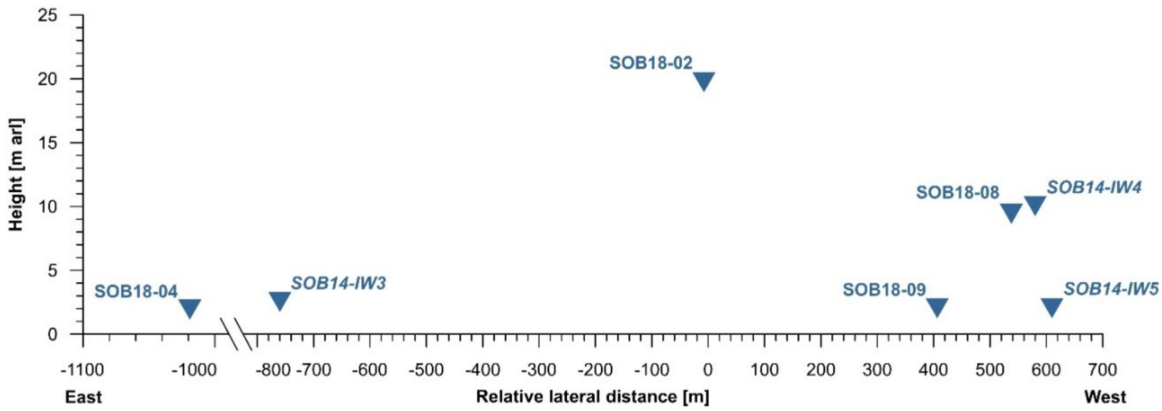

Figure 2.22.6: *Sampling locations of wedge-ice profiles on Sobo-Sise Island (IW – ice wedge). Profiles samples in 2014 are indicated in italics. Note differing x-axis if compared to Figure 2.22.4.*

Yet unpublished ice wedge sampling on Sobo-Sise Island conducted in 2014 by Thomas Opel is reported here to complement the study. The major aim of the ice-wedge studies during the expedition was to generate new ice-wedge stable-water isotope ($\delta^{18}O$, δD, d excess) datasets for the reconstruction of past winter climate variability. Additional ice-wedge samples have been taken to test and compare different dating approaches for ground ice by $^{36}Cl/Cl^-$ as well as radiocarbon dating of organic macro remains, DOC, and CO_2 from air bubbles. In total, nine ice wedges have been studied and sampled in detail (blocks, slices). All ice-wedge blocks and slices were transported to Germany in frozen state for further sub-sampling in the cold lab. Additional ice-wedge samples were taken from several sediment cores along transects in the study areas. Several modern ice veins from recently growing ice wedges have been sampled as modern endmember. To characterise the general stable-isotope environment, precipitation as well as water from rivers, creeks, lakes, active layer have been sampled. In the following, it will be focused on the detailed ice-wedge studies.

On Sobo-Sise Island, ice wedges were studied in different landscape types and stratigraphic units: (1) Yedoma IC deposits (SOB14-IW3), late Glacial to Holocene thermokarst basins (SOB14-IW1, 2 and 5) and slope from Yedoma IC uplands and thermokarst basin (SOB14-IW4).

Two ice wedges SOB14-IW1 and SOB14-IW2 (Figure 2.22.7a, N 72.5219°, E 127.8572°) were studied directly beside sediment profile SOB14-01 of Jens Strauss in a thermokarst basin (alas) about 8 m arl. The ice-rich host sediments were grey sandy silts with table lenticular cryostructures and peat inclusions.

Ice wedge SOB14-IW1 was a syngenetic ice wedge mirroring the polygonal surface. It was up to 1.6 m wide. The wedge ice was milky white with clearly detectable ice veins of 0.5 to 1.5 cm width and many air bubbles. Two kinds of air bubbles have been found: small (up to 1 mm) round bubbles and vertically elongated bubbles up to 2 mm long. The wedge ice contained little amounts of sediments and organics. The ice wedge was cut perpendicular to its growth direction. In total, 7 blocks were cut from the ice wedge with a chain saw, five in a 1.2 m wide horizontal profile 1 m below surface (active layer depth 44 cm) and two additional blocks from below for dating purposes (Figure 2.22.7a).

Ice wedge SOB14-IW2 was a smaller ice wedge (about 20 cm wide), preliminary interpreted as second-order ice wedge dissecting the polygon. It was partly degraded. In the milky white wedge ice single ice veins (0.5 to 1 cm wide) could be clearly identified. Small spherical air bubbles of 0.5 to 1 mm in diameter as well as vertically elongated (up to 1 cm) were found. The ice was characterized by little amounts of sediments and organics. Two samples were taken by chain saw, representing the ice wedge itself and most likely refrozen standing water above.

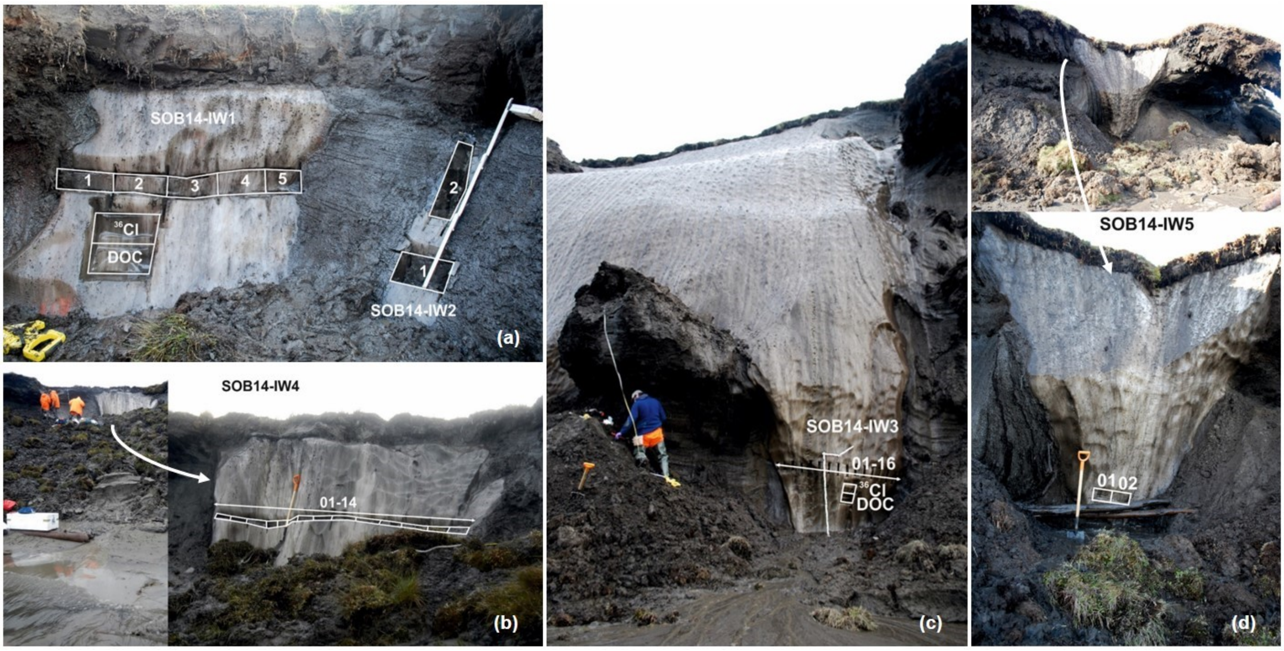

Figure 2.22.7: *Ice wedges of the Sobo-Sise expedition 2014 (a) SOB14-IW1 and 2 in a thermokarst basin, (b) SOB14-IW3 in the lowest accessible part of the Yedoma IC, (c) SOB14-IW4 at the slope from Yedoma IC upland to thermokarst basin and (d) SOB14-IW5 at the lowest slope from Yedoma IC upland to thermokarst basin*

Ice wedge SOB14-IW3 (Figure 2.22.7b, N 72.53581°, E 128.30054°) was studied directly beside sediment profile SOB14-02-A about 2.5 m arl. The ice-rich host sediments belong to the lowest accessible part of the Yedoma IC and were brownish to grey silts to sandy silts with structureless cryostructure at the bottom, lenticular cryostructure in the middle and ice bands and lenticular structure in the upper part of the profile. This profile was overlain by a distinct peat layer. At the left side of the ice wedge a vertical sand lense could be identified, likely pressed upwards due to ice-wedge growth. Ice wedge SOB14-IW3 was a syngenetic ice wedge of the Yedoma IC. It was about 2.7 m wide. The wedge ice was milky grey. Partly, single ice veins were clearly detectable and 0.5 to 1.5 cm wide. Very few sand veins could be found. The ice exhibited many air bubbles: (1) very small bubbles in the centre of single ice veins, (2) spherical bubbles 0.5 to 2 mm in diameter, and (3) elongated bubbles up to 1 cm long (diameter 0.5 to 2 mm). The amount of sediment and organics was low. 17 samples (vertical slices of 2 to 8 cm width, resolution 15 to 20 cm) in a horizontal profile were cut by chain saw, complemented by two blocks (Figure 2.22.7b).

Ice wedge SOB14-IW4 (Figure 2.22.7c, N 72.54262°, E 128.26814°) was studied directly beside sediment profile SOB14-03 at the slope from Yedoma IC upland to thermokarst basin. The ice-rich host sediments consisted of grey sandy silt in the lower part and silt in the upper part with peat lenses and a peat horizon. In the lower part a lenticular cryostructure was found and in the upper part a layered cryostructure. Ice wedge SOB14-IW4 was interpreted as syngenetic ice wedge. It was covered by 40 cm of sediment, whereof 35 cm represented the active layer. The ice was milky white with clearly detectable and partly cross-cutting ice veins up to 1 cm wide. The content in sediments and organics was very low whereas many elongated air bubbles up to 3 cm long could be found. About 1.6 m below surface 14 blocks were sampled in a horizontal profile of 3.6 m width (Figure 2.22.7c). As such an ice-wedge width is rather unlikely, we observed and sampled most likely an ice-wedge junction that appeared to be wider due to cutting and erosional (flowing water) effects. The stable-isotope data will help to solve this issue.

Ice wedge SOB14-IW5 (Figure 2.22.7d, N 72.54284°, E 128.26775°) was studied at the lowest part of the slope from Yedoma IC upland to thermokarst basin. The host sediments were grey silts and sands with ice bands, that were bend upwards in the immediate vicinity of the ice wedge and include woody remains as well as distinct peat layers.

Ice wedge SOB14-IW5 was sampled in its about 1 m wide lower part about 30 cm above the ice-wedge

toes, representing the initial ice-wedge stage (Figure 2.22.7d). Two blocks were cut. The wedge ice was milky white with very little organics and little sediment inclusions. Partly sand grains were found in the clearly detectable ice veins up to 1 cm wide and cross-cutting each other. The wedge ice was characterised by a lot of air bubbles that occurred in three types: (1) very tiny clouds of bubbles, (2) elongated bubbles (1.5 to 2.0 cm long, and 1 mm in diameter, and (3) spherical bubbles of about 1 mm in diameter.
Five additional samples were taken from modern ice veins from recently growing ice wedges in different locations of a huge thermokarst basin. Additional ice-wedge samples were taken from boreholes in transects from the Yedoma IC uplands to thermokarst basins (profiles SOB14-T1 and SOB14-T2).

Geochemical investigations
Permafrost thaw and rapid erosion mobilize large quantities of sediment, carbon and nutrients into the aquatic ecosystem and ultimately into the nearshore zone of the Laptev Sea. The high Yedoma cliffs together with the Holocene cover deposits, exposed along the channels of Lena River Delta, export large volumes and masses of material into the aquatic environment. However, an integrated assessment of organic matter stocks, their lateral fluxes due to thaw and erosion and on the fate of eroded material in the aquatic environment is still missing and hampers our ability to quantify the contribution of lateral OM fluxes to the Arctic carbon cycle.
Hydroecological elements of the Lena Delta comprise the Lena River including its channels, the coastal waters, lakes and ponds, creeks and thermoerosional gullies, and meltwater streams from thawing permafrost cliffs (Figure 2.22.8, Figure 2.22.9, Figure 2.22.10). This study focused on creating the link between OM stocks and fluxes from the Yedoma cliff towards one of the main Lena River channels.

Figure 2.22.8: *Location of surface water sampling on Sobo-Sise Island (GeoEye-1 image of July 8th, 2014, synthesis of NIR+Red+Green)*

Figure 2.22.9: *Examples of thermoerosional valleys showing (a, b) creek water ca. 50 m before it flows over the cliff into the Lena channel; valley at east end of Yedoma island (SOB18-SW-04, July 14th, 2018, 17:51), (c, d, e) a thermoerosional valley draining western edge of eastern alas right before it flows in the Lena channel; little creek ca. 100 m east of Yedoma cliff (SOB18-SW-10, July 17th, 2018, 14:51), (f, g, h) a thermoerosional valley of alas west of camp; central outflow right at the edge of alas into the Lena River (SOB18-SW-02, July 14th, 2019, 12:30) and (i, j, k) a thermo-erosional valley between the camp and the first permafrost sampling site above SOB18-01 (SOB18-SW-01, July 14th, 2018; 12:12)*

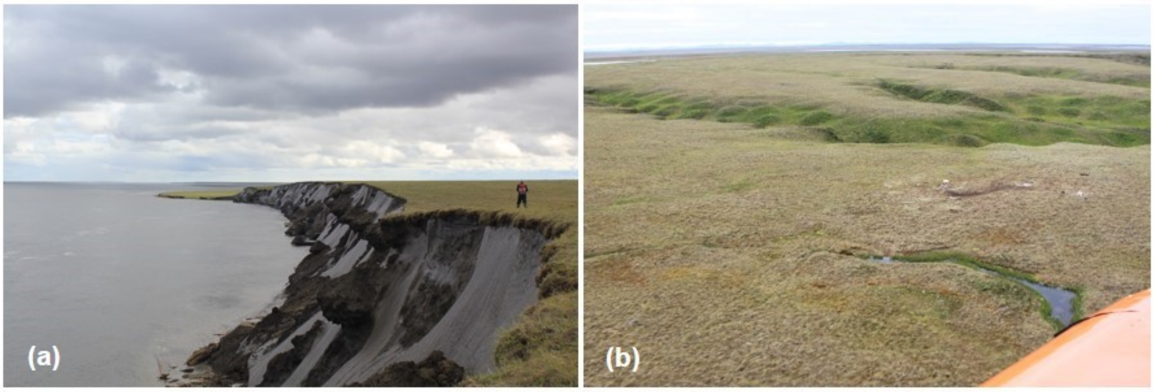

Figure 2.22.10: *Examples of sampling sites and water bodies showing (a) the permafrost cliff, where permafrost outflow samples and river water samples have been taken directly at and below the headwall and (b) the interpolygonal pond at camp as seen from the helicopter (SOB18-SW-16, July 23th, 2018).*

Preliminary results

One major goal of this expedition to Sobo-Sise Island was to quantify OM stocks in (i) permafrost deposits and (ii) surface water bodies and to characterize the quality of the OM for a better understanding of the fate of OM from terrestrial permafrost towards the Arctic nearshore environment. Expected results are:

- particulate and dissolved carbon and nitrogen stocks of the late Pleistocene Yedoma and Holocene cover deposits on Sobo-Sise Island;
- biogeochemical characteristics of the late Pleistocene Yedoma and Holocene cover deposits on Sobo-Sise Island;
- dissolved organic carbon stocks in surface water bodies on Sobo-Sise Island;
- annual OM fluxes from Sobo-Sise Island based on erosion rates and OM stocks;
- quantitative information on OM degradation in surface water bodies.

Permafrost sampling of the Sobo-Sise cliff is described elsewhere in this report chapter (see section "Permafrost samping"). Frozen samples were left to thaw overnight and supernatant water was decanted for the following analyses in descending order of priority depending on water availability: stable water isotopes, DOC concentration, cDOM, major anions and cations, pH and electrical conductivity (Appendix A.2.24). For surface water 250 mL glass bottles (Schott©) were used for sampling polygonal pond, creek water from thermoerosional valleys and Lena River water. Sample bottles were rinsed three times with sample water before sample collection. Nalgene HDPE bottles (1 l) were used for sampling permafrost meltwater from the headwall. A larger sample volume was required due to the high sediment load of sometimes greater than 50% in the suspension. Samples were filtered, split and chemically preserved for the different analyses directly in the field lab (Figure 2.22.11).

For stable water isotope analyses ($\delta^{18}O$, δD) unfiltered samples were directly filled in sample bottles. For DOC and cDOM analyses samples were filtered through pre-rinsed 0.7 µm GF/F glass fiber filters attached to a rubber-free syringe. The liquids were filled in clear glass vials with screw caps and PTFE septum and amber glass vials for DOC and cDOM, respectively. DOC samples were acidified with HCl (30% suprapur). For major ion analyses samples were filtered through 0.45 µm CA syringe filters and filled into sample bottles. HNO_3 (65% suprapur) was added to cation samples. All samples were stored cool and dark. If possible and if enough sample material was available pH and electrical conductivity were determined in the field directly using a portable WTW multimeter.

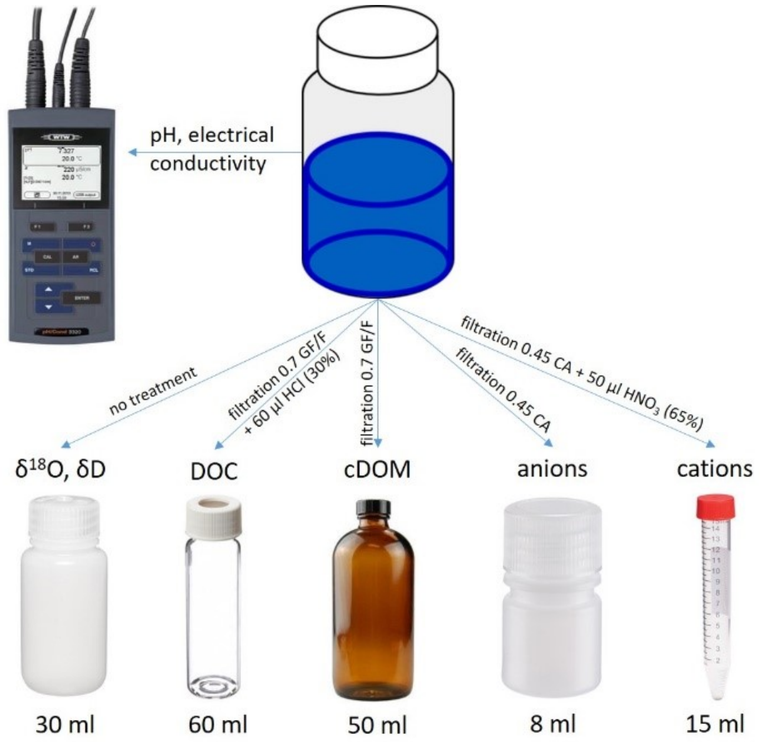

Figure 2.22.11: *Scheme of water sample treatment and preservation*

Field work resulted in:

- Four rain samples at different days for stable water isotopes to characterize modern precipitation;
- 16 surface water samples for pH, electrical conductivity, stable water isotopes, DOC concentration, cDOM, anions, cations:
  - polygonal pond (n=2)
  - creek water from thermoerosional valleys (n=5)
  - Lena River water (n=6)
  - Permafrost meltwater from headwall (n=3)
- meltwater samples from thawed permafrost samples for pH, electrical conductivity, stable water isotopes (n=102), DOC concentration (n=33), cDOM (n=21), anions (n=21), cations (n=21)
- meltwater from thawed ice wedge samples for stable water isotopes (n=84)

Active layer and thaw subsidence measurements

In continuation to active layer and thaw subsidence measurements in 2015-16 on Sobo-Sise Island (ref. F. Günther) in course of the PETA-CARB project, repetitions were undertaken on July 19th, 2018 (Figure 2.22.12).

Figure 2.22.12: *Location of active layer profiles and thaw subsidence benchmark measurements on Sobo-Sise Island (GeoEye-1 image on July 8th, 2014, synthesis of NIR+Red+Green)*

The benchmark measurements of relative heights above the vegetation surface are shown in sketches and photographs in Figure 2.22.13. For benchmarks #1 a small depression around was observed and captured in two measurements of 13.0 and 20.5 cm relative height above surface. Benchmark #2 revealed a value of 9.4 cm. Benchmark #3 was surrounded by a small water pool; the measure was 12.2 cm. Benchmark #4 was almost at the surface with values of 0.0 and 1.1 cm. Benchmark #5 was on one side surrounded by moss higher than the benchmark leading to a value of −3.0 cm and on the other side above the benchmark with 4.0 cm. Benchmark #6 was also from one side surrounded by water with 12 cm above the ground of the pool and 7.7 cm above the vegetation surface. The moss surrounding benchmark #7 was higher than the benchmark top resulting in a value of −3.0 cm.

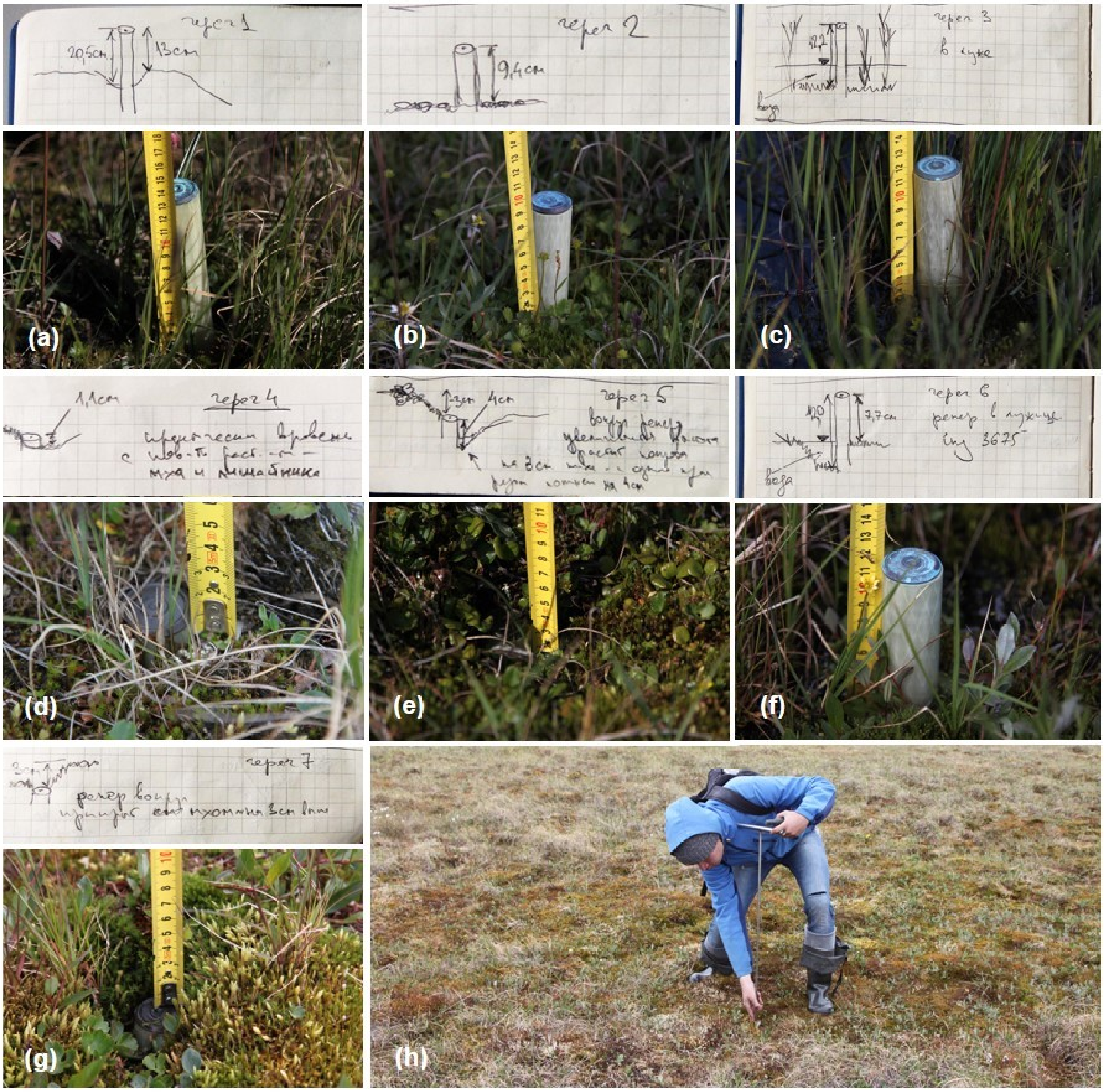

Figure 2.22.13: *Thaw subsidence measurements on Sobo-Sise Island of (a) benchmark #1, (b) benchmark #2, (c) benchmark #3, (d) benchmark #4, (e) benchmark #5, (f) benchmark #6 and (g) benchmark #7. Figure (h) illustrates active layer depth measurements along the profiles shown in Figure 2.22.12.*

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