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

Samuel Stettner (1), Hugues Lantuit (1), Annett Bartsch (2,3) , Birgit Heim (1) ,Guido Grosse (1), Achim Roth (4), Barbara Widhalm (2,3), Sofia Antonova (1), Simon Zwieback (5)
(1) Alfred Wegener Institute, Germany, D-14473 Potsdam Telegrafenberg A43; (2) Central Institute of Meteorology & Geodynamics, Austria, A-1190 Wien, Hohe Warte 38; (3) Department of Geodesy and Geoinformation, Vienna University of Technology, Austria, A-1040 Vienna Gußhausstr. 25-29;
(4) Department Land Surface, German Aerospace Center, Germany, Oberpfaffenhofen 82234 Weßling; (5) Institute of Environmental Engineering, ETH Zürich, Switzerland, 8093 Zürich Stefano-Franscini-Platz 5

Exploring the applicability of high temporal resolution SAR for monitoring permafrost landscapes

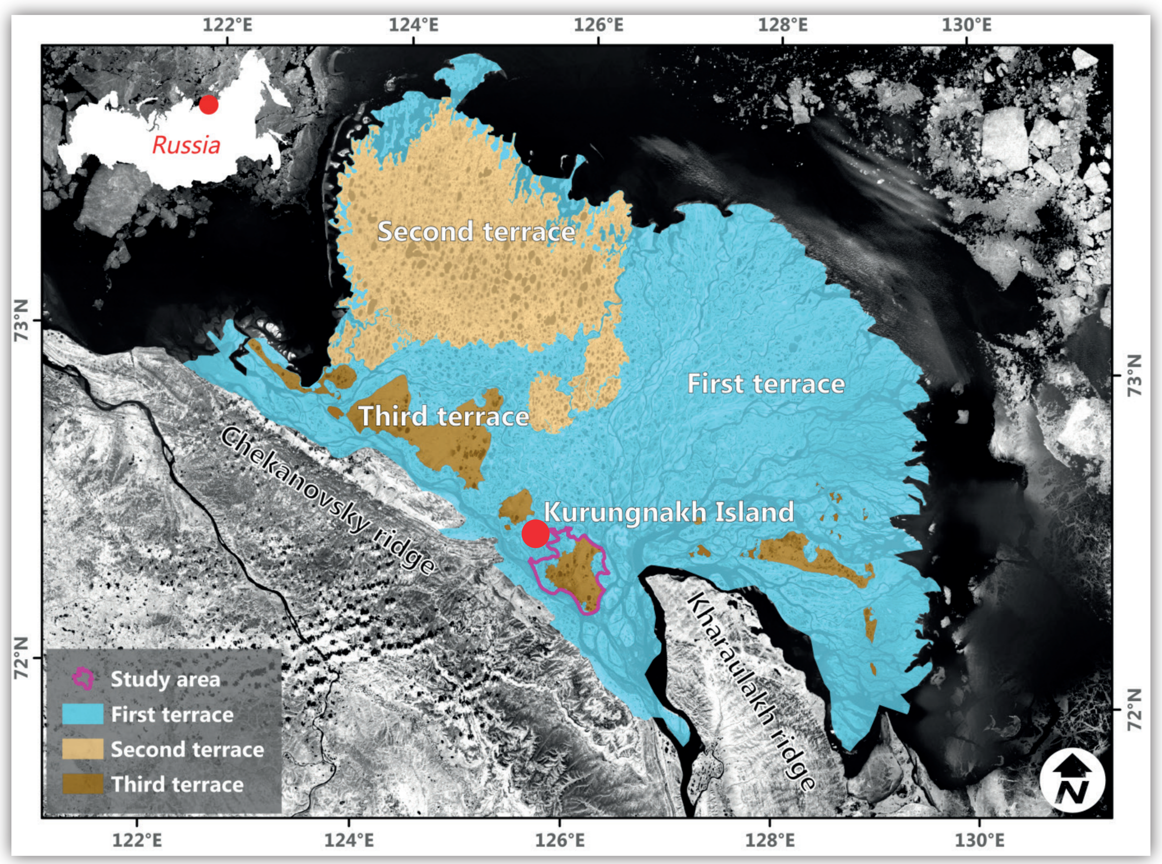
Background

Permafrost is an essential climate variable and an important physical landscape component of high-latitude environments. Rapid degradation of organic-rich permafrost sediments, near surface soil moisture changes as well as altering freeze thaw cycles have impacts on the release of carbon, on surface energy and water fluxes as well as on biogeochemical processes. Information in high temporal and spatial resolution is important for the understanding of permafrost landscapes in change. TerraSAR-X (TSX) synthetic aperture radar (SAR) operates independently of cloud coverage and polar night and provides imagery with high temporal (11 days) and spatial resolution (2,5m).

Objectives

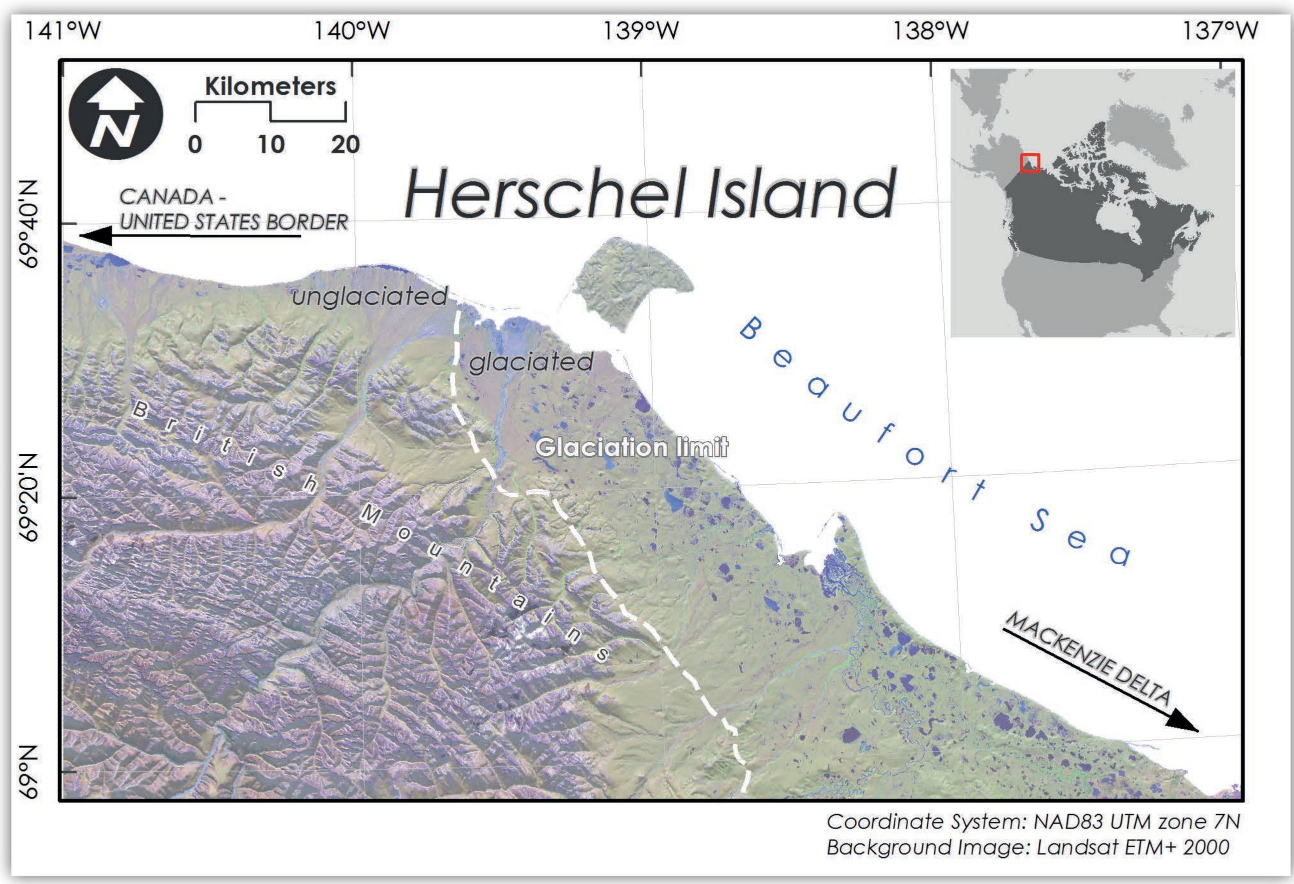
We use high-spatial and temporal resolution time-series of TSX in combination with optical very high resolution satellite and in-situ experimental setups in order to understand spatiotemporal patterns of permafrost landscape changes. We focus on two study sites in continuous permafrost Arctic tundra landscapes of Siberia and Canada. Our research questions are:

1) ***What is the intra-annual dynamic of riverbank erosion in ice-rich permafrost deposits?***
2) ***How are snow patches influencing near surface soil moisture dynamics on the catchment scale?***



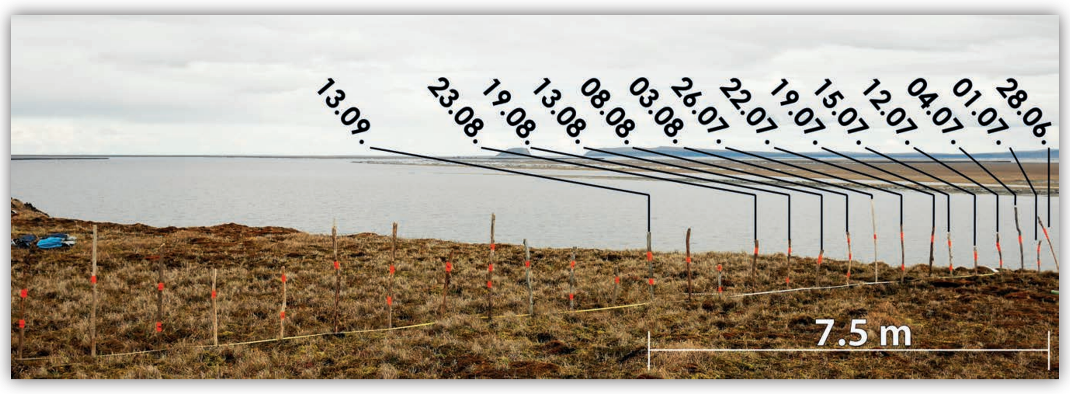
Study sites:

<-- Lena Delta & Herschel Island -->



1) Riverbank cliff top erosion

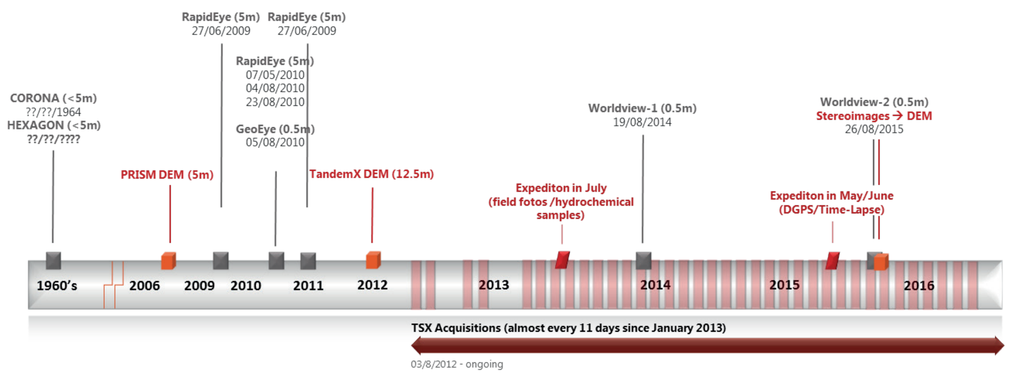
Field photo from 2013 showing the transition (cliff top) between undisturbed ice complex and the actively eroding cliff; red point = position of time-lapse camera



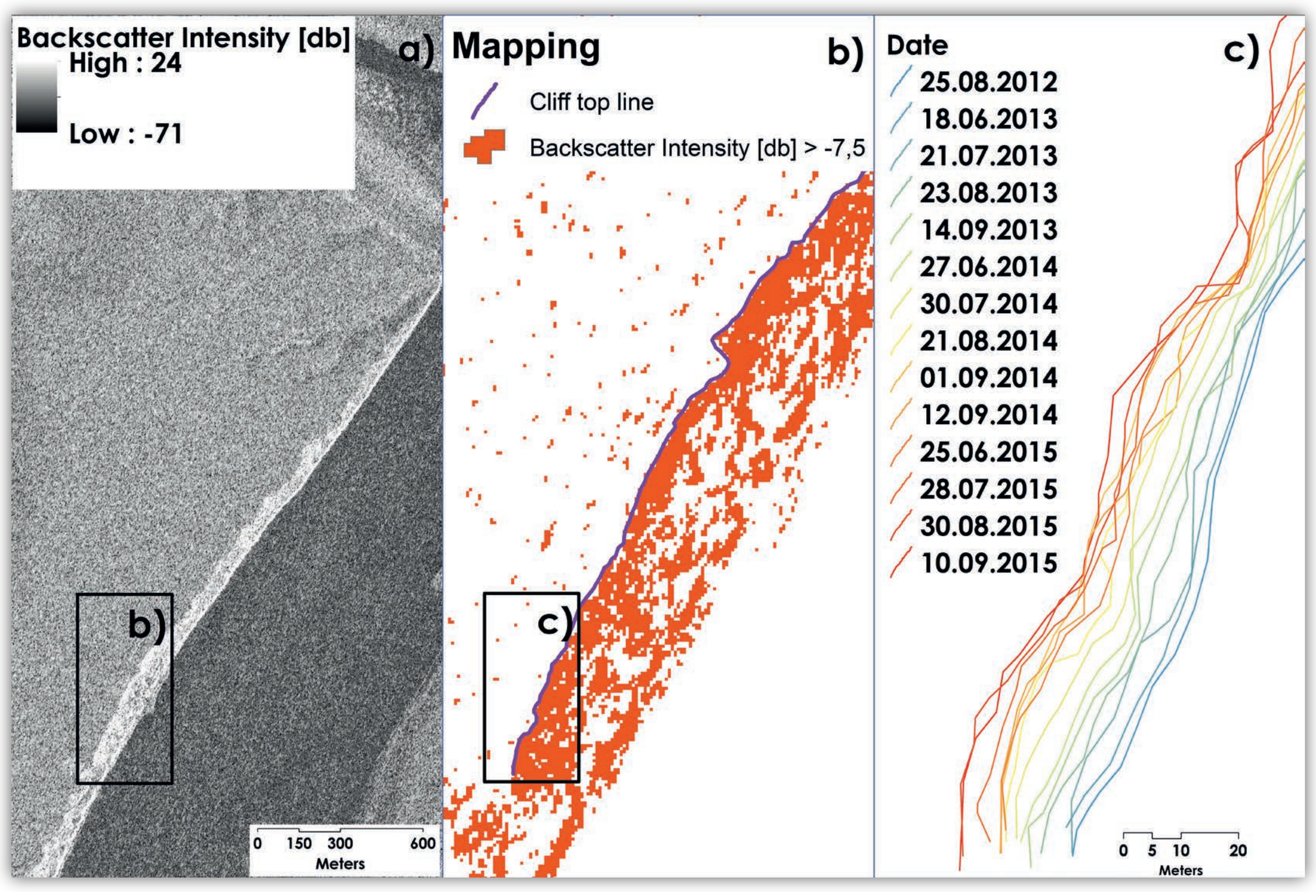
Time-lapse camera setup at the test site. We installed 29 wooden markers every 50 cm perpendicular to the cliff top and a Brinno TLC200 Pro time lapse camera viewing from South to North. Pictures were taken every four hours from 28.06.2015 to 13.09.2015. In that period 15 markers were eroded, equaling 7.5-m of cliff top retreat.

The majority of existing studies on riverbank erosion provide annual erosion rates and are based on optical imagery. Annual rates don't allow capturing intra-seasonal dynamics of cliff retreat.

Using a TSX time-series (2012 -2015) we analyze intra-seasonal dynamics of cliff top erosion between ice breakup and ice freeze up (late May to early October in the Lena Delta)[1] in order to understand the spatiotemporal pattern of rapid degradation of ice-rich permafrost



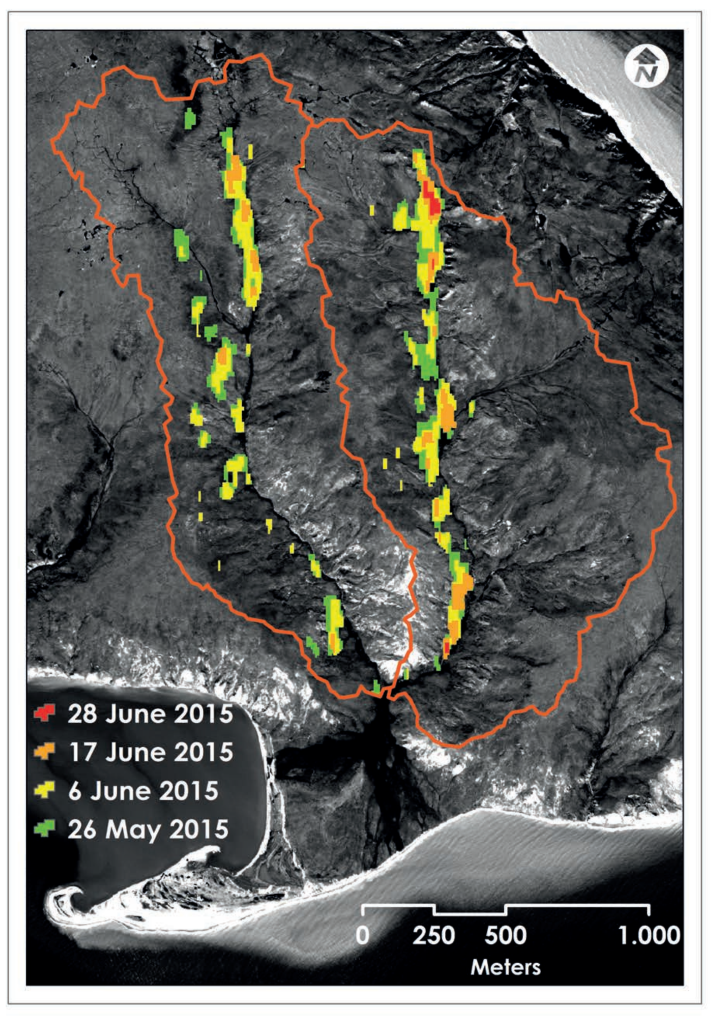
We use an HH polarized TSX time-series from 2012 to 2015 and compare the results with very high resolution optical reference data from 2010, 2014 and 2015. Stereo-photogrammetric DEMs are available for the years 2006 and 2015. On site we installed a time-lapse camera between June and September 2015.

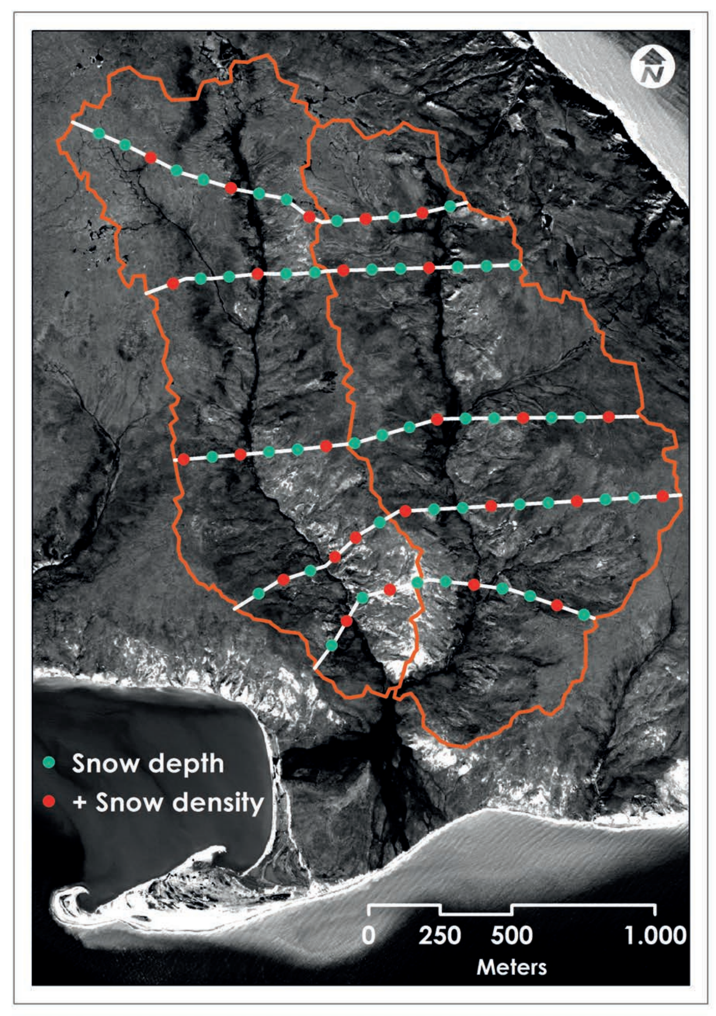


Monitoring cliff top retreat at the test site: a) TerraSAR-X scene from 21.08.2014 showing the test site; b) a threshold of -7.5 was defined by calculating the mean backscatter intensity within a ROI on the cliff. The threshold was applied to the TSX images prior to mapping of the cliff top; c) cliff top lines from TerraSAR-X images within the thawing season. Lines will be analyzed using the Digital Shoreline Analysis System developed from the USGS[2].

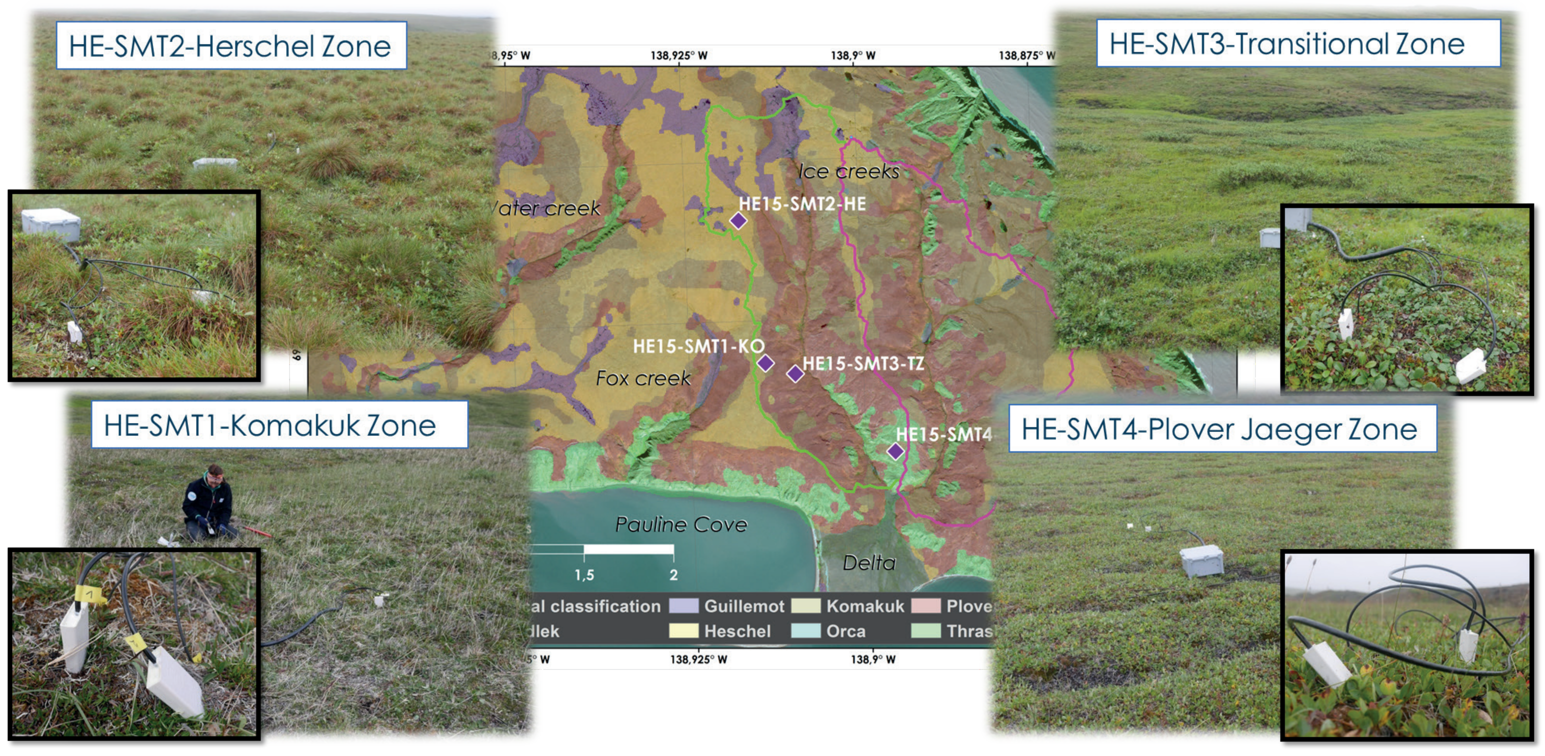
2) Snow patch distribution and soil moisture dynamics:

Snow is an important parameter in permafrost environments. It isolates the ground and generates runoff during snow melt, thus influencing near surface soil moisture and surface degradation. We use TSX time-series in order to identify the distribution of snow patches within two watersheds and to analyze the soil moisture dynamics afterwards during summer.





The left map shows first preliminary results of snow melt monitoring wihtin two small watersheds on Herschel Island. The HH polarized images from 2015 were compared to a snow free reference szene from 7 July 2015 and differences of the backscatter signal of more than 3dB [3] were extracted and filtered. Landsat images were used as a reference for the beginning of the snow free period. The right map shows locations of snow depth and snow density measurements that were taken in May 2016.



Four stations measuring soil moisture and temperature close to the surface were installed in July 2015 in four different landscape units to compare the influence of snow on the soil moisture dynamic. Each stations has two soil moisture and temperature sensors each that are installed vertically and diagonal. Animal attacks of the stations are a risk.

Acknowledgments

We thank the Helmholtz Alliance Remote Sensing and Earth System Dynamics (HGF-EDA) for funding this project. We thank the German Space Agency for kindly providing the TSX datasets. We thank the German Space Agency Division Land Surfaces and the ETH Zürich Institute of Environmental Engineering for hosting a research stay at their institutes.

Outlook

Field work on Herschel Island in July/August 2016:
- Hydrological investigations (discharge measurements)
- Surface soil moisture monitoring of snow patches, soil sampling, mapping

Ongoing TerraSAR-X acquisitions planned

References
1 Boike, J., Kattenstroth, B., Abramova, K., Bornemann, N., Chetverova, A., Fedorova, I., Frob, K., Grigoriev, M., Gruber, M., Kutzbach, L., Langer, M., Minke, M., Muster, S., Piel, K., Pfeiffer, E.M., Stoof, G., Westermann, S., Wischnewski, K., Wille, C. & Hubberten, H.W. 2013. Baseline characteristics of climate, permafrost and land cover from a new permafrost observatory in the Lena River Delta, Siberia (1998-2011). Biogeosciences 10 : 2105–2128. DOI: DOI 10.5194/bg-10-2105-2013
Nagler, T. & Rott, H. 2000. Retrieval of wet snow by means of multitemporal SAR data. IEEE Transactions on Geoscience and Remote Sensing 38 : 754–765. DOI: 10.1109/36.842004
Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L. & Ergul, A. 2009. Digital Shoreline Analysis System (DSAS) version 4.0— An ArcGIS extension for calculating shoreline change: U.S. Geological Survey Open-File Report 2008-1278

ETH Zürich TU WIEN DLR

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

Samuel Stettner
PhD Student
Samuel.Stettner@awi.de

Telegrafenberg A43
14473 Potsdam
Telefon +49 331 288-2126
www.awi.de/stettner