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Towards circumpolar mapping of infrastructure based on Sentinel-1 and Sentinel-2

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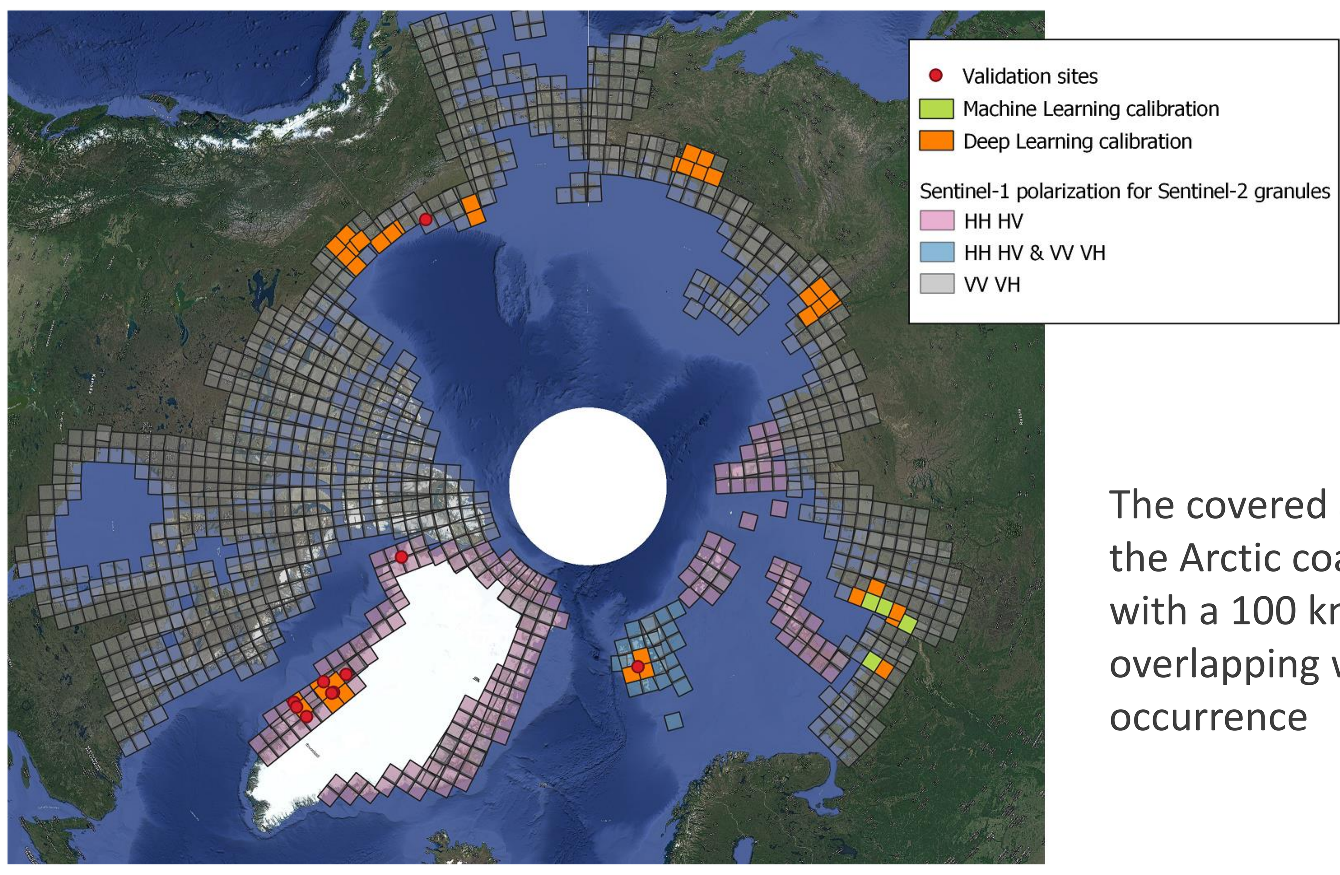
Introduction

- The growth of settlements and the associated increase of the exploitation of natural resources is an ongoing trend in the Arctic. Buildings and other infrastructure are endangered by destabilization and collaps due to the climate change induced thawing of permafrost in northern regions. The majority of human activity in the Arctic is located near permafrost coasts. Coastal settlements are additionally vulnerable because of coastal erosion, caused by rapid warming and thawing of coastal permafrost.
- The European Union (EU) Horizon2020 project "Nunataryuk" aims to assess the impacts of thawing land, coast and subsea permafrost on the climate and on local communities in the Arctic. One task of the project is to determine the impacts of permafrost thaw on coastal Arctic infrastructures and to provide appropriate adaptation and mitigation strategies. For that purpose, a circumpolar account of infrastructure is needed.
- We utilize the potential of combining Sentinel-2 multispectral data with Sentinel-1 (Synthetic Aperture Radar) data for mapping and characterizing Arctic infrastructure. Settlement characteristics (building properties, surface types) have been collected for sites in Greenland and Longyearbyen on Svalbard, Norway.
- First results based on machine learning methods show that the available resolution (10m) allows the identification of narrow features such as roads, which were not previously identifiable by commonly used data such as Landsat. Deep learning methods further improve the mapping with respect to errors of commission as well as distinguishing surface types.

Coverage



The covered area comprises the Arctic coastline with a 100 km buffer overlapping with permafrost occurrence

- More than 1200 Sentinel-2 granules are included in the analyses. For the majority, Sentinel-1 IW mode acquisitions in VV/VH polarization are available. Greenland and some high Arctic islands are covered in HH/HV or HH only.
- Calibration sites for both classification approaches are spread across the Arctic. Validation sites include settlements on the Greenland west coast, Longyearbyen and Prudhoe Bay.

Data & Methods

- The two polar-orbiting Sentinel-2 satellites of the Copernicus program of the EU are continuously providing multi-spectral images with high spatial and temporal resolution. Sentinel-2 data is of high value for mapping land cover. However, most traditional land cover classifications only contain one class for built-up areas. By using a multi-sensor approach, such as the combination of multispectral and Synthetic Aperture Radar (SAR) data, additional information can be derived that goes beyond the identification of built-up areas. Different types of infrastructure can be distinguished, as it is commonly needed.
- A challenge poses the variable availability of polarizations from Sentinel-1 (HH and HV versus VV and VH). All combinations are only available over Svalbard. So far, only normalization parameters have been published for HH and VV (Widhalm et al. 2018, Bartsch et al. 2020). Models still need to be calibrated for HV and VH.
- Two different approaches are tested:
  - Machine Learning: pixel-based classification using a Gradient Boosting Machine (Chen and Guestrin 2016)
  - Deep learning: a windowed semantic segmentation approach using the deep-learning framework keras (Chollet et al., 2015).
- Calibration data: OpenStreetmap
- Validation data:
  - dedicated observations within NUNATARYUK for several settlements on Greenland and for Longyearbyen
  - Prudhoe Bay Cumulative Impact Map, Alaskan North Slope

Dataset references

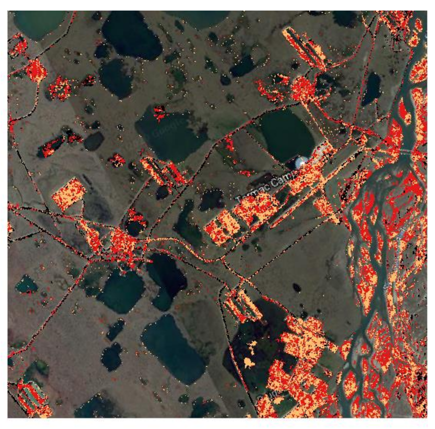
- Ingeman-Nielsen, Thomas; Vakulenko, Ivan (2018): Calibration and validation data for infratructure mapping, Greenland, link to files. PANGAEA, https://doi.org/10.1594/PANGAEA.895949
- Lu, Wenjun; Aalberg, Arne; Høyland, Knut; Lubbad, Raed; Løset, Sveinung; Ingeman-Nielsen, Thomas (2018): Calibration data for Infratructure mapping in Svalbard, link to files. PANGAEA, https://doi.org/10.1594/PANGAEA.895950
- Raynolds M.K., Walker D.A., Ambrosius K.J., Brown J., Everett K.R., Kanevskiy M., Kofinas G.P., Romanovsky V.E., Shur Y. & Webber P.J. (2014). Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology, 20, 1211-1224. http://arcticatlas.geobotany.org/catalog/entries/5470-prudhoe-bay-cumulative-impact-map-a-raynolds-2014
- Nitze, Ingmar (2018): Trends of land surface change from Landsat time-series 1999-2014. PANGAEA, https://doi.org/10.1594/PANGAEA.884137

Preliminary Results

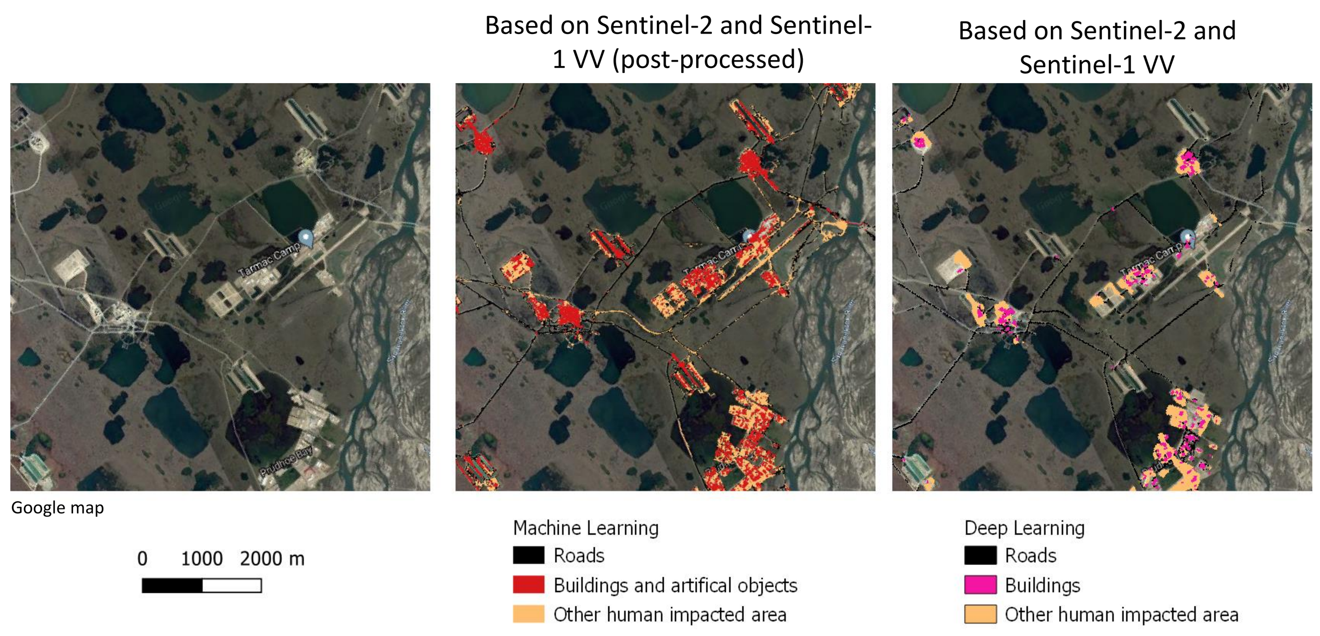
Prudhoe Bay

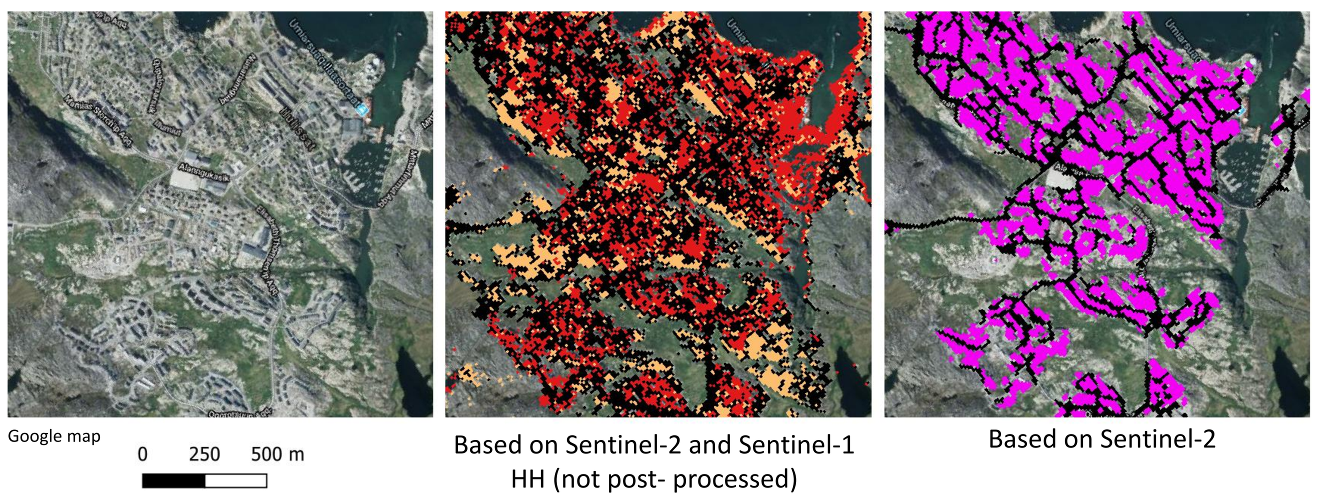
Background mostly tundra, some river beds

only Sentinel-1 VV/VH available



Based on Sentinel-2 only (not post-processed)

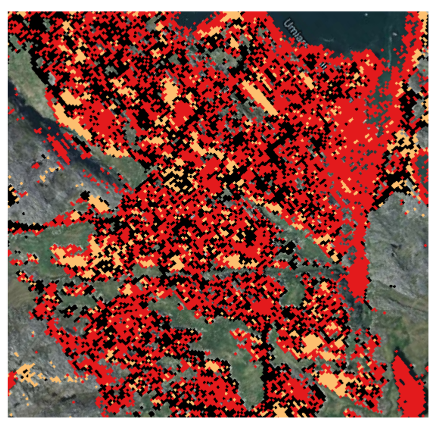




Illulisat

background mostly bedrock, only patches of vegetation

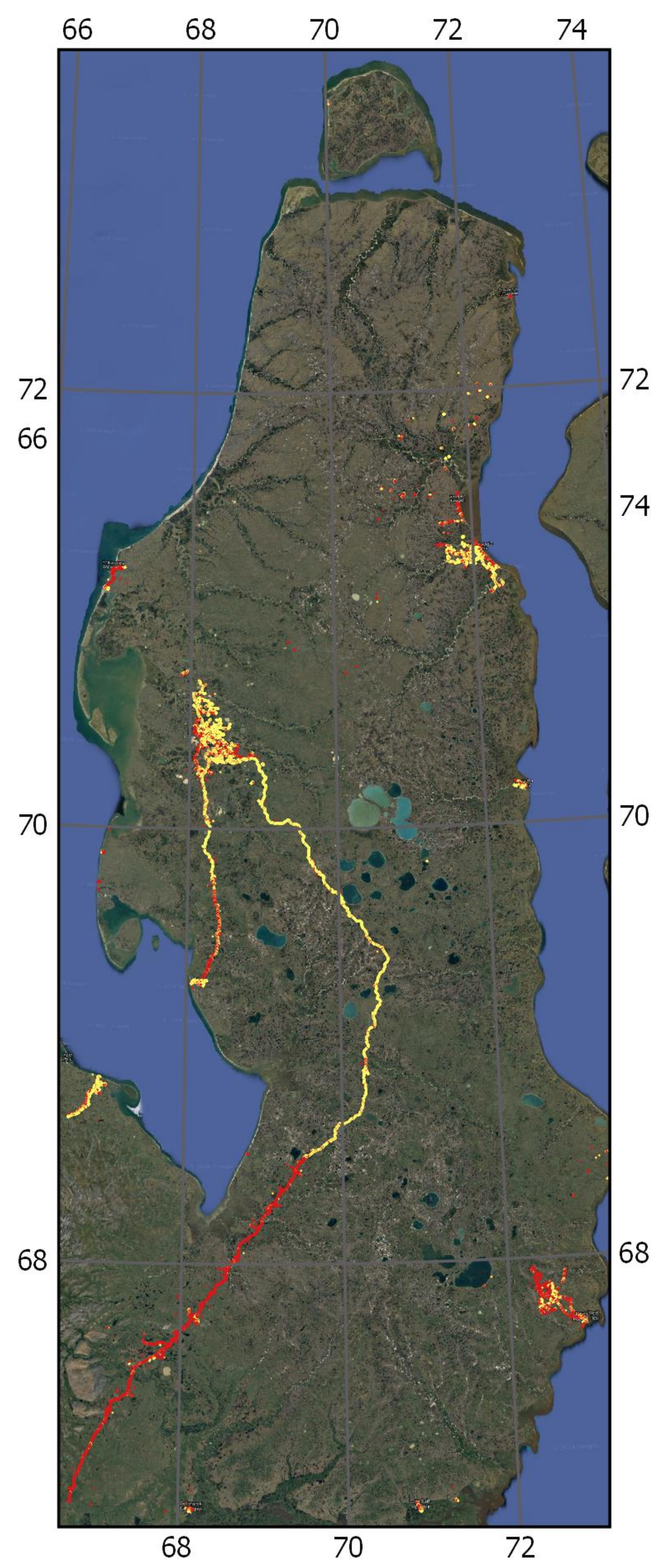
only Sentinel-1 HH/HV available



Based on Sentinel-2 only (not post- processed)

Yamal Peninsula

Background mostly tundra, some river beds and drained lake basins, deflation areas



Identified human impacted areas based on post-processed Machine Learning classification results. Yellow indicates new infrastructure after 1999, based on combination with Landsat trends available from Nitze et al. 2018 (background: google maps)

Summary and future work

- Both classification approaches provide useful information but differ strongly in error of omission and error of commission
- Both classification approaches require manual post processing
- The accuracy assessment needs to specifically consider surface material (roof and road properties) and implications with respect to their associated use in case of buildings (residential versus industrial)

References:

Widhalm, B., Bartsch, A., and Goler, R. (2018). Simplified normalization of C-band synthetic aperture radar data for terrestrial applications in high latitude environments. Remote Sensing. doi:10.3390/727rs10040551
Bartsch, A., Widhalm, B., Leibman, M., Ermokhina, K., Kumpula, T., Skarin, A., et al. (2020). Feasibility of tundra vegetation height retrieval from Sentinel-1 and Sentinel-2 data. Remote Sensing of Environment 237, 111515. doi:10.1016/j.rse.2019.111515Tianqi Chen and Carlos Guestrin (2016): XGBoost. In: Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining
Francois Chollet (2018): Deep learning with Python. Manning Publications, Shelter Island. ISBN 9781617294433; Chollet, F., et al. (2015). Keras. https://keras.io.

Nunataryuk: https://nunataryuk.org/