

Quantifying spatial influences of infrastructure on snow melt

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FAIRBANKS



Impacts of infrastructure on the Arctic environment

- Expanding infrastructure/increasing infrastructure development in Arctic areas
- **Differences/changes in snow off/snow free dates**
- Impacts on e.g. vegetation, hydrology
- Road dust in winter and summer



Walker, D. A., and K. R. Everett. "Road dust and its environmental impact on Alaskan taiga and tundra." *Arctic and Alpine Research* 19.4 (1987): 479-489.

Raynolds, Martha K., et al. "Cumulative geoeological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska." *Global change biology* 20.4 (2014): 1211-1224.

Goals for this study:

- Quantify spatial/temporal patterns in snow free dates in the Prudhoe Bay area in relation to infrastructure
 - Demonstrate the potential of resources like the Sentinel-2 constellation to quantify and monitor snow melt patterns in Arctic industrial regions on a yearly basis
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- The impact of snow free timing on other variables such as e.g. NDVI (**vegetation**), NDWI (**surface hydrology**), surface temperature **for selected areas**

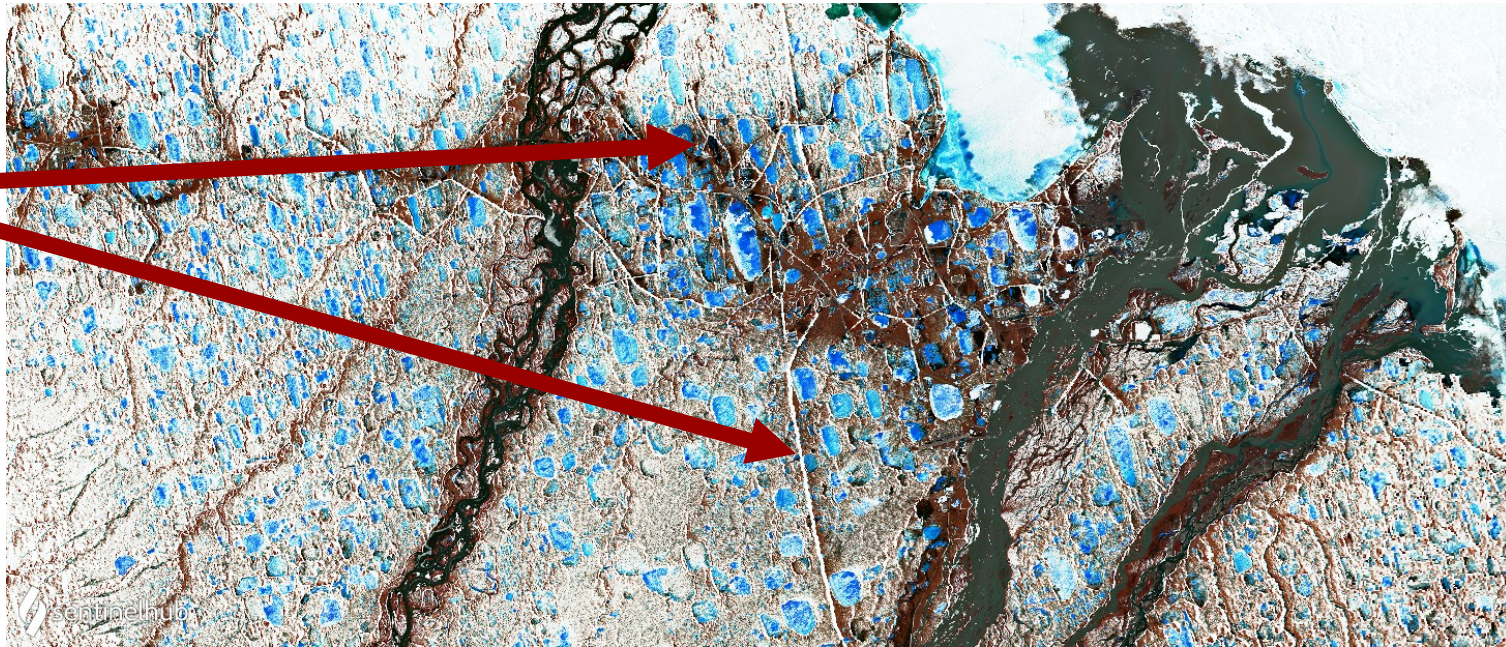


Photo: H. Bergstedt

Impacts of infrastructure on the Arctic environment

Sentinel-2 False colour composite 202005-29

Visible pattern of
infrastructure on the
snow covered
landscape





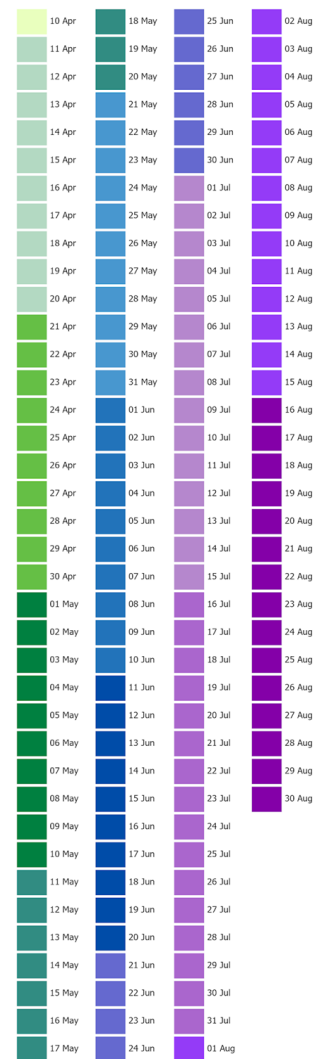
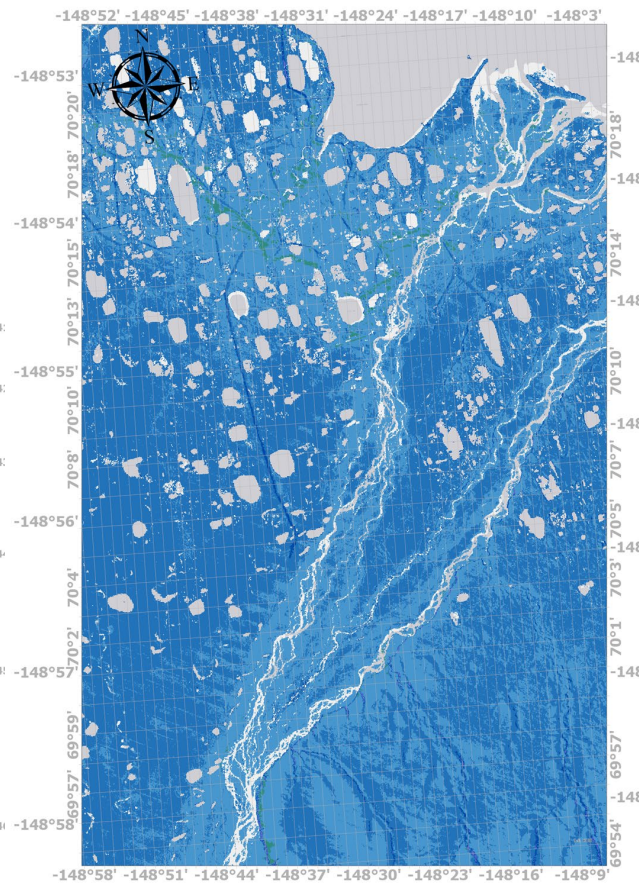
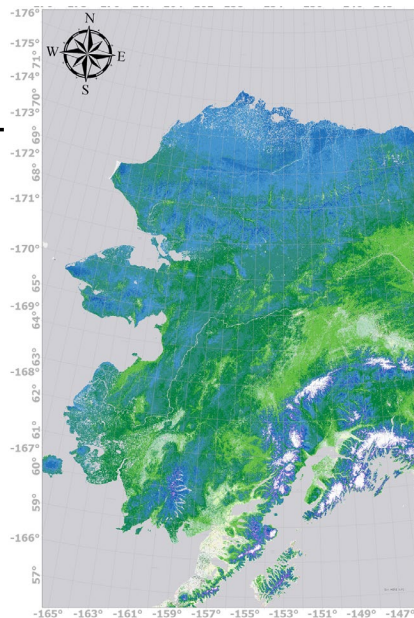
Typical snow free date for Alaska from existing data set



Macander, Matthew J., et al. "Landsat-based snow persistence map for northwest Alaska." *Remote Sensing of Environment* 163 (2015): 23-31.

- Based on Landsat
- 30m resolution
- Typical snow free date—no information about interannual variability

Other products based on microwave remote sensing available but coarse.

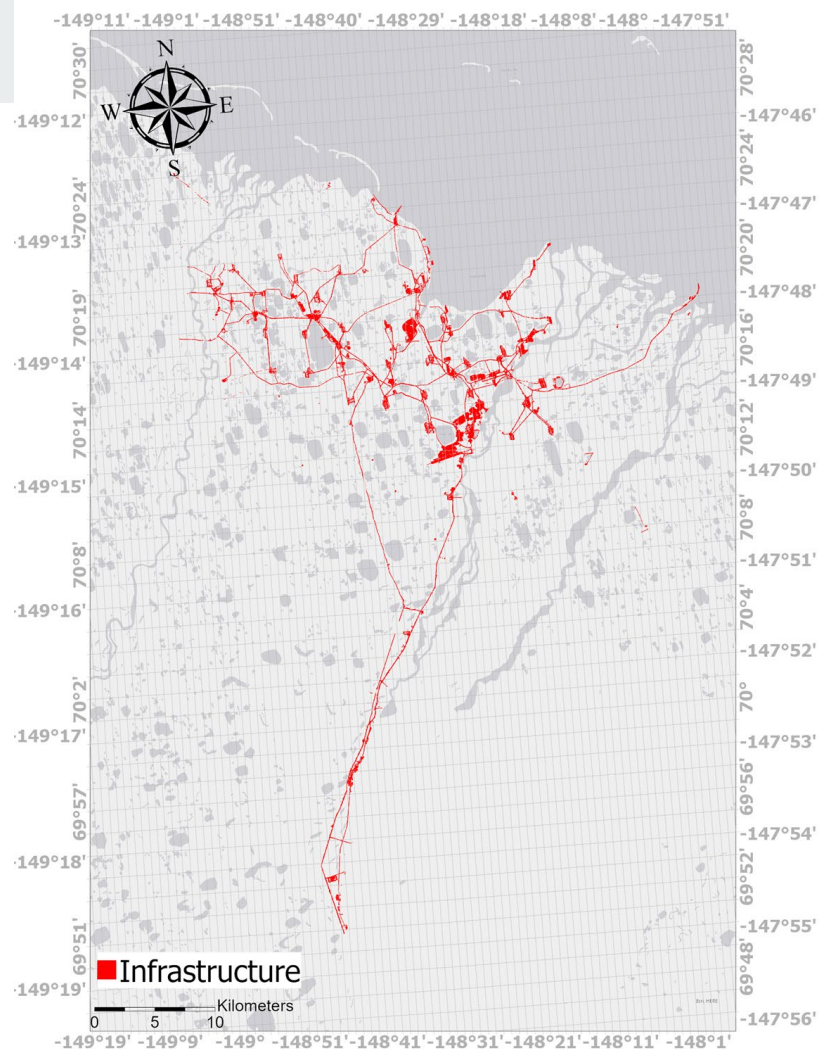




Infrastructure in the study area

- Infrastructure data set based on Sentinel-1 and Sentinel-2 data; described in Bartsch et al. 2020; Infrastructure shown here is a subset of a larger data set covering the circumpolar Arctic
- Data set covers different types of infrastructure, including roads, buildings, bridges, gravel pads, runways and oil/gas infrastructure

Bartsch, Annett, et al. "Towards Circumpolar Mapping of Arctic Settlements and Infrastructure Based on Sentinel-1 and Sentinel-2." *Remote Sensing* 12.15 (2020): 2368.

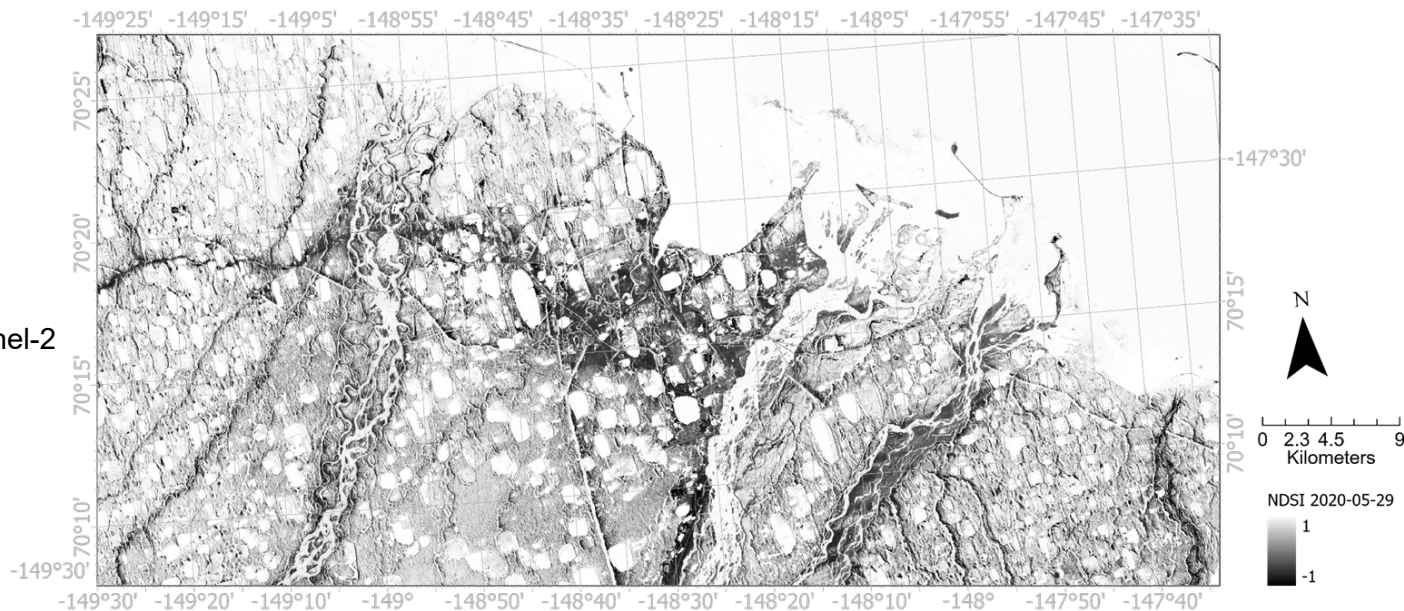


Snow mapping using Sentinel -2

- Creating Snow presence/absence maps based on Sentinel-2 multispectral imagery
- Spatial resolution 20m
- Temporal resolution 1-2 Sentinel-2 acquisitions per week
 - Cloud cover influences availability of imagery

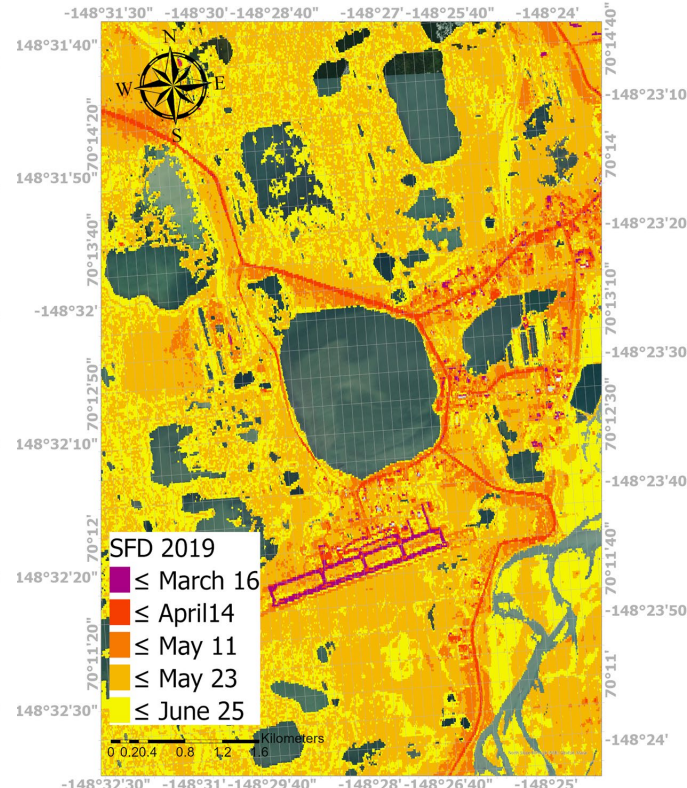
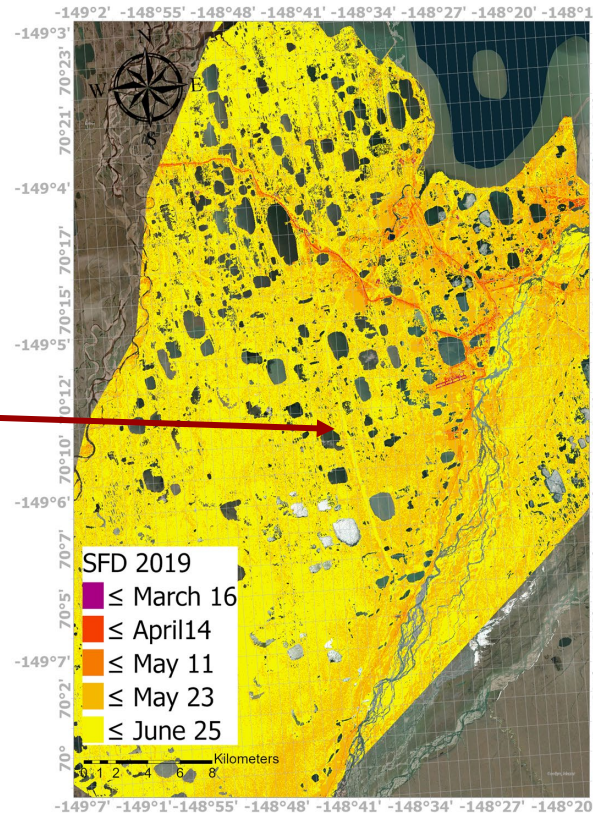
Mapping approach based on:
Normalized Difference Snow Index (NDSI)

$$\text{NDSI} = (\text{Band 3} - \text{Band 11}) / (\text{Band 3} + \text{Band 11})$$



Spatial patterns of snowmelt timing 2019

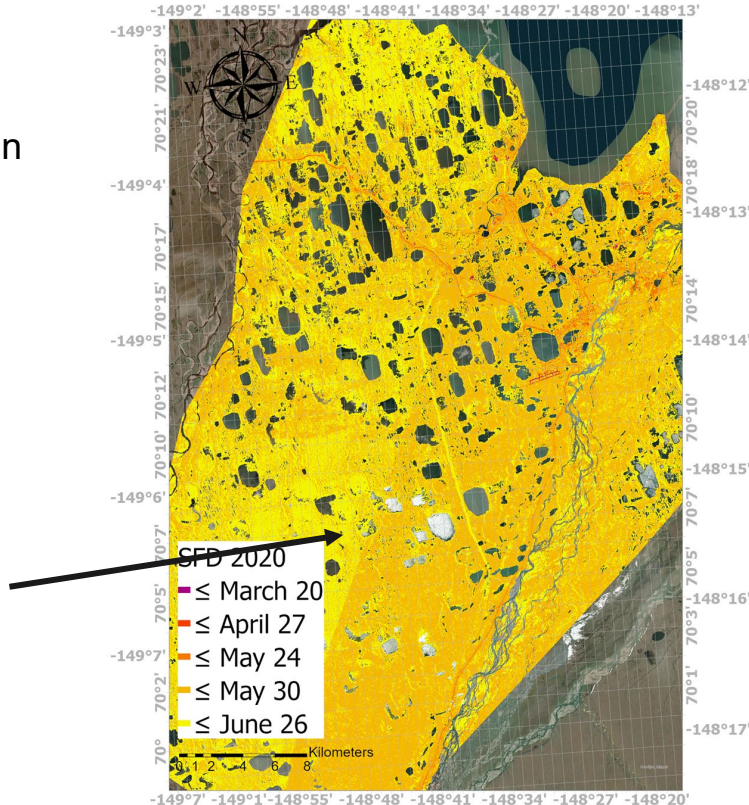
- Visible patterns in snowmelt timing across the landscape
- Early snowmelt near infrastructure (e.g. near roads)
- Delayed snowmelt along pipelines



Spatial patterns of snowmelt timing 2020

- Similar patterns as in 2019
- Less visible detail caused by fewer cloudfree imagery available

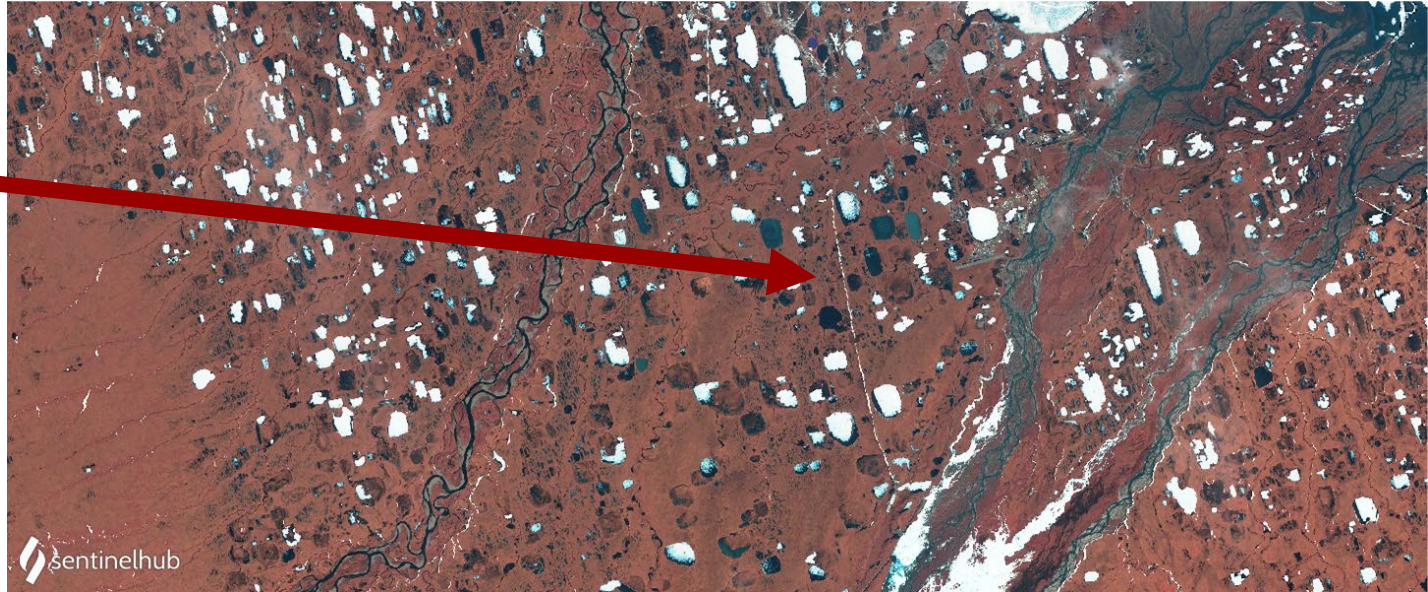
Linear artifacts based on differing acquisition dates



Delayed snow melt

Sentinel-2: 2016-06-11

- Lingering snow banks along pipelines
- Delayed snowmelt on the landscape caused by certain types of infrastructure

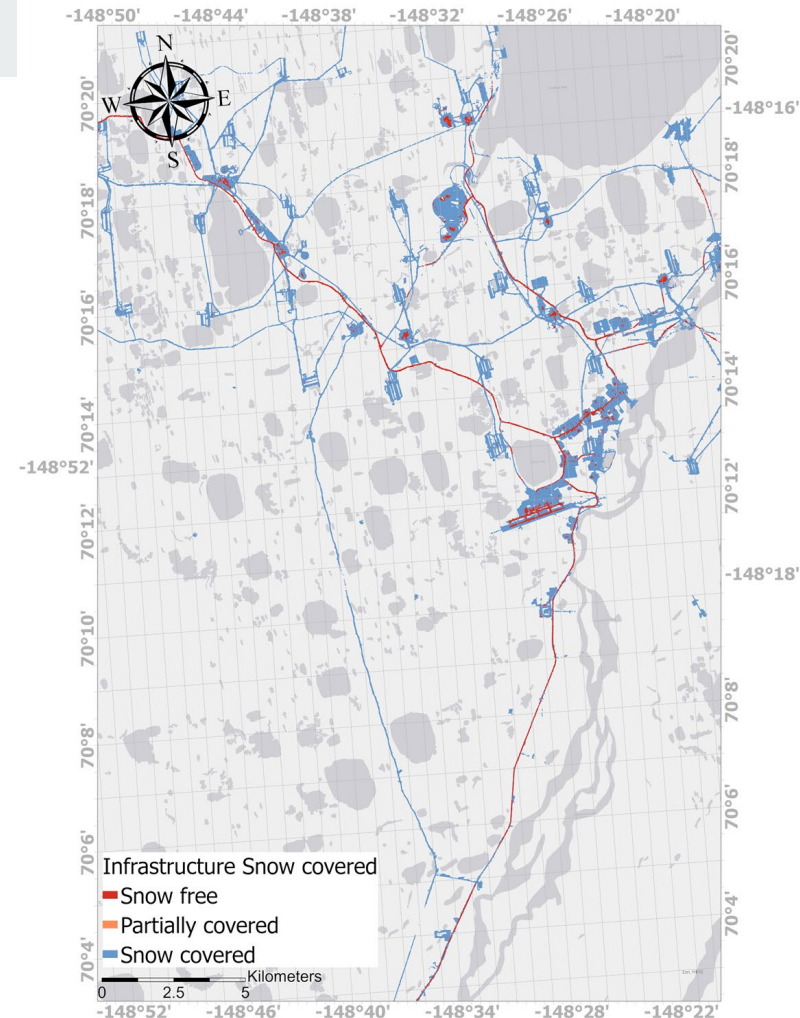


Snow cover of Infrastructure

Snow free infrastructure:

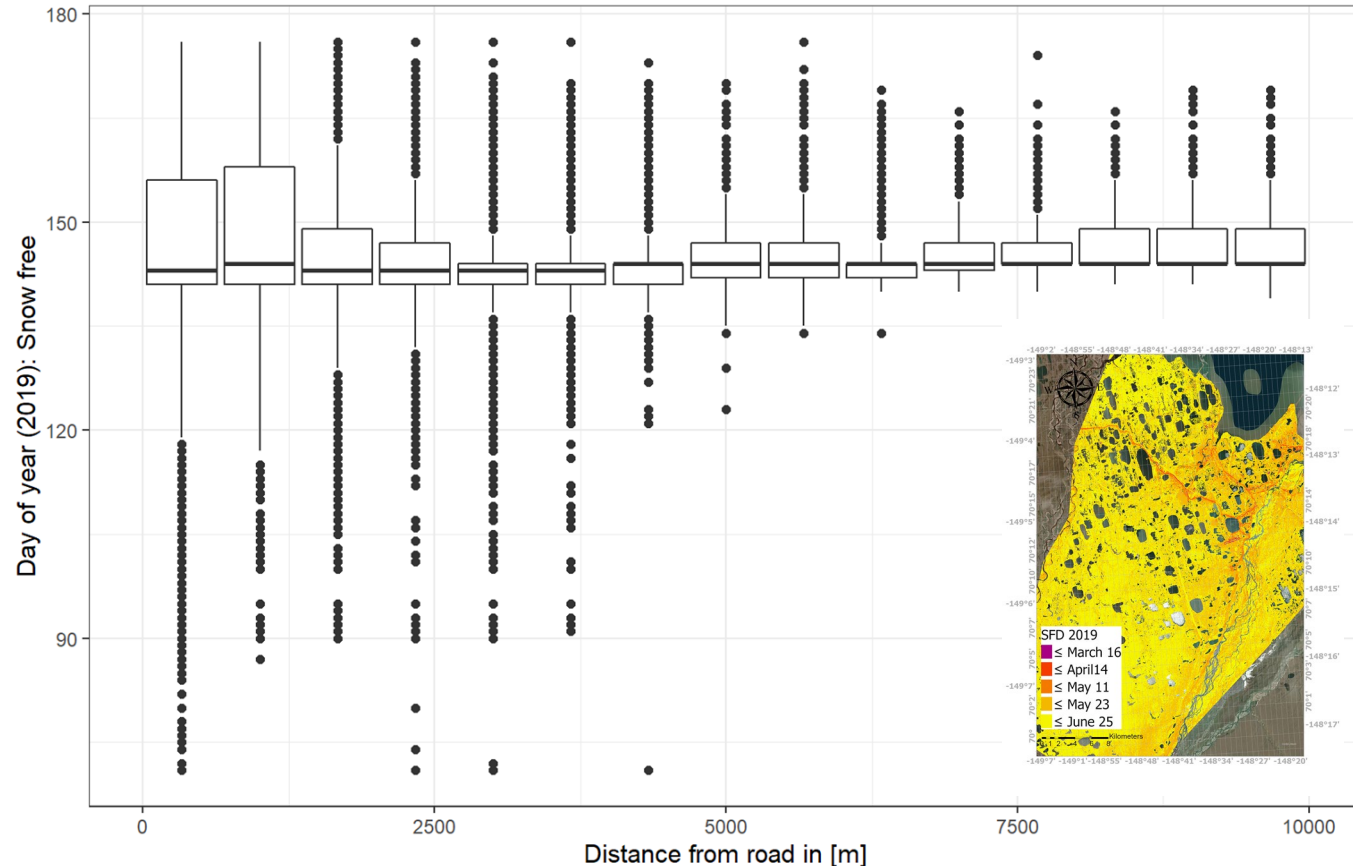
- Information extracted from Sentinel-2 NDSI Snow maps prior to snow melt
- High traffic areas visible in data as snow free
- Snow clearing efforts contribute to certain areas being snow free (e.g. airport runway)
- Snow free areas generate more road dust
- Snow accumulates near infrastructure (downwind)

Bartsch, Annett, et al. "Towards Circumpolar Mapping of Arctic Settlements and Infrastructure Based on Sentinel-1 and Sentinel-2." *Remote Sensing* 12.15 (2020): 2368.



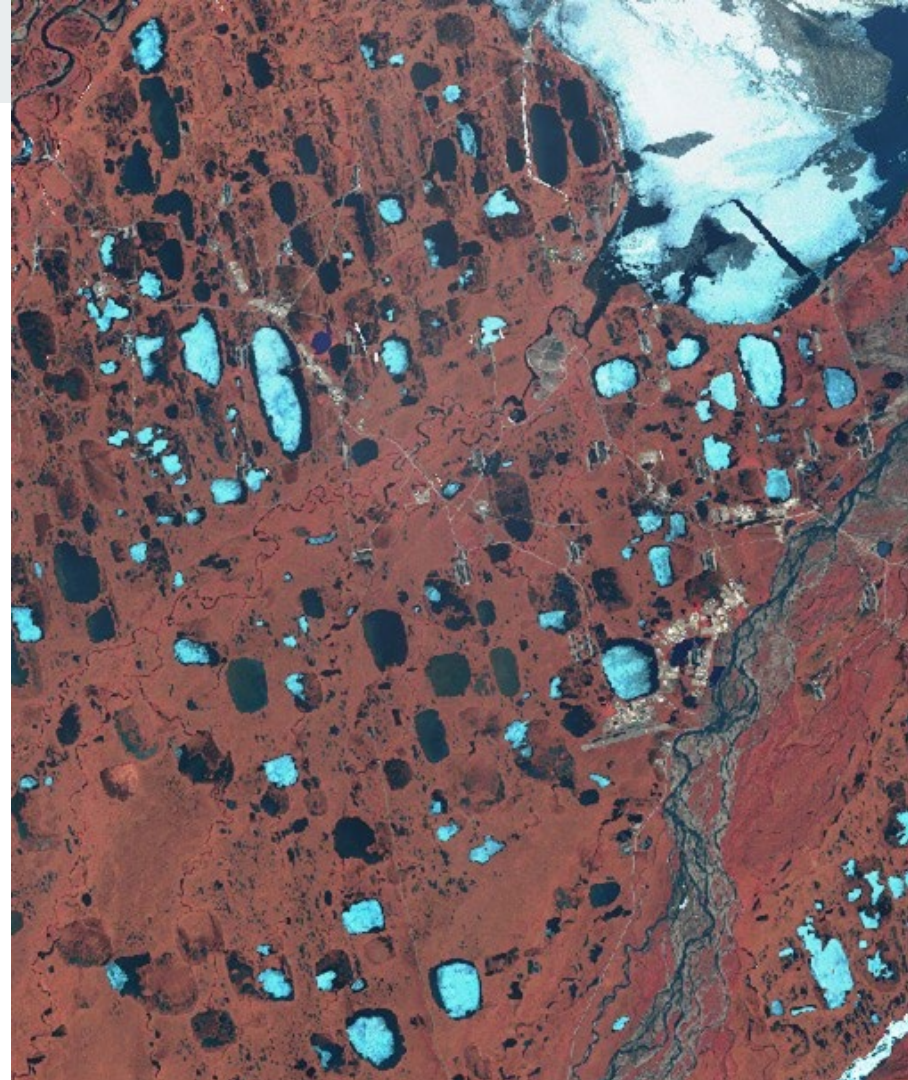
Snow free date vs. distance from roads

- Figure shows day of year a pixel becomes snow free (2019) vs. the distance from the nearest road for each pixel
- Median snow free dates similar for pixel near and far from the road
- Pixel near the road show high variability in snow free dates



Summary and Outlook

- Patterns in snow melt related to infrastructure are visible on the landscape
- Areas near infrastructure experience earlier and delayed snow melt
 - Different types of infrastructure have differing effects
- More work regarding quantifying these patterns and linking them to additional parameters ongoing





References

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- Gascoin, Simon, et al. "Estimating fractional snow cover in open terrain from Sentinel-2 using the normalized difference snow index." *Remote Sensing* 12.18 (2020): 2904.
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