Water body distributions across scales: a comparison of three Arctic wetlands

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S. Muster[1], B. Heim[1], A. Abnizova[2], J. Boike[1]

[1]Alfred Wegener Institute for Polar- and Marine Research, Potsdam, Germany; [2]York University, Toronto, Ontario, Canada

Motivation and Goals

A changing Arctic climate may alter the aerial extent of wetlands as well as the number and occurrence of water bodies, affecting high-latitude carbon, water and energy fluxes. Ponds, i.e. water bodies with a surface area smaller than 1 ha, dominate by far the number of water bodies in Arctic wetlands. The impact of ponds on regional and global carbon emissions, both current and future, is hard to quantify since little information is available regarding their number and occurrence throughout the Arctic.

Goals were to compare three Arctic wetlands regarding

I. their water body size and abundance,
II. the effect of spatial resolution on water body mapping, and
III. the potential of medium-scale Landsat surface albedo to show the subpixel fraction of water cover (SWC).

I. Water body size distributions

of water bodies ≥ 5m²

based on high-resolution water body maps from

- near-infrared aerial imagery at 0.3 m resolution
- TerraSAR-X imagery (HH polarization) at 2 m resolution
- Kompsat-2 near-infrared imagery at 4 m resolution

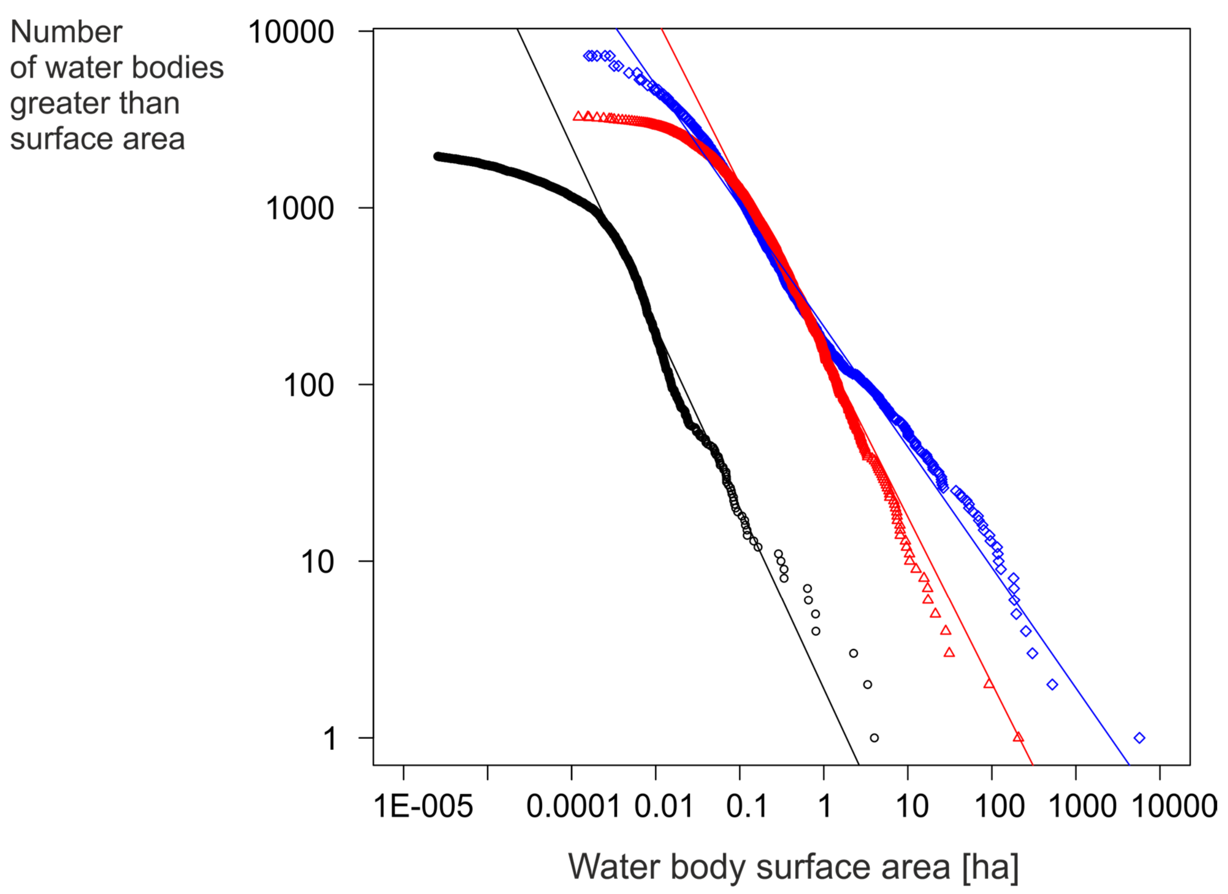


Fig. 1: Size distributions of water bodies for Samoylov Island (black), Polar Bear Pass (red) and Barrow (blue) on a double logarithmic scale (base 10). Linear regressions based on the upper tail of the distribution overestimate the abundance of smaller water bodies.

Key findings I

- Ponds contribute more than 95% to the total number of water bodies in each study area.
- The upper tail of the size-distribution fits well a Pareto distribution but cannot be used to extrapolate the abundance of smaller water bodies.

II. Multi-scale mapping of water bodies

- High-resolution imagery at 0.3 to 4 m resolution
- Landsat-5 TM band 4 at 30 m resolution
- MODIS water mask (MOD44W) at 250 m resolution

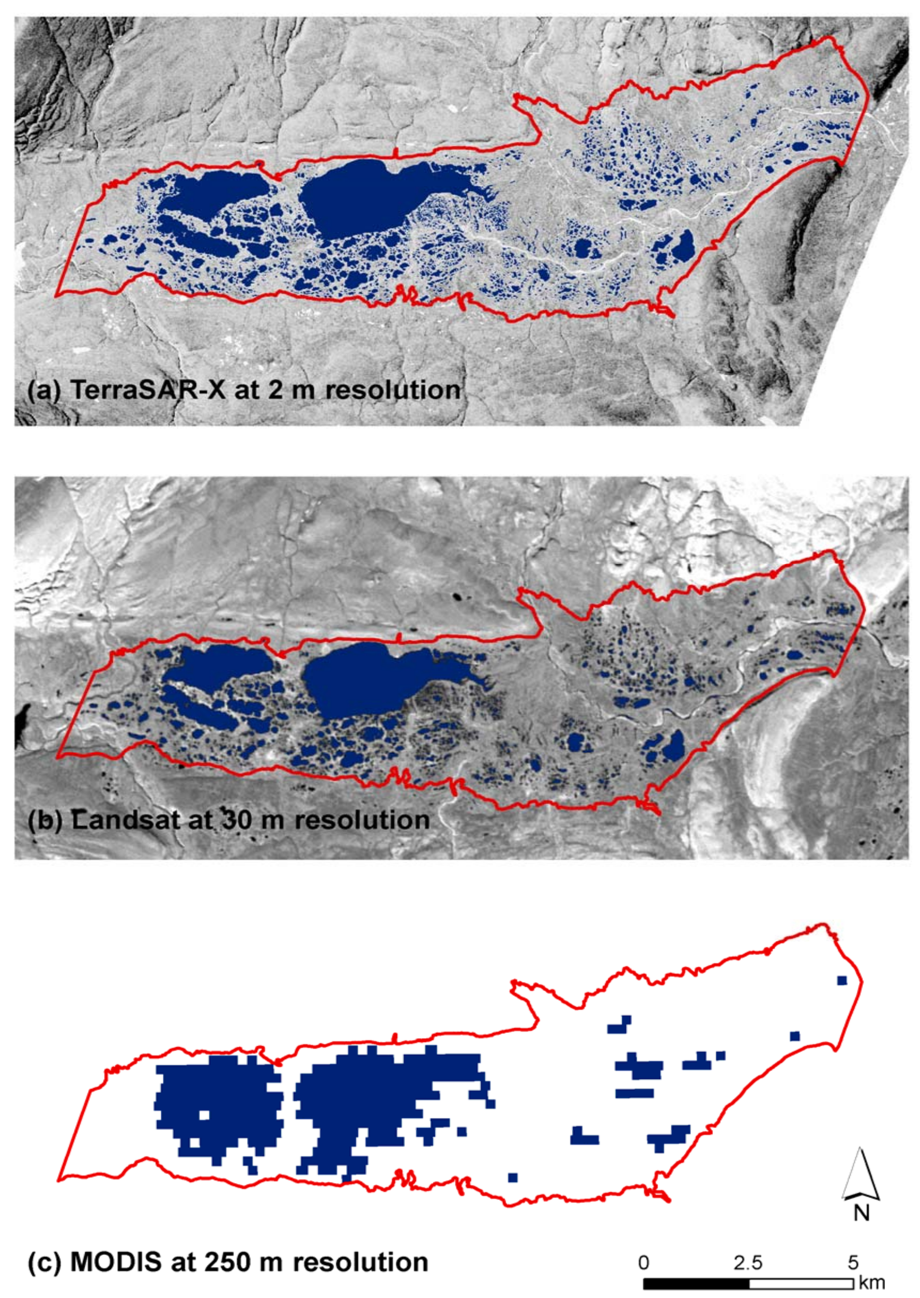


Fig. 2: Multi-scale water body mapping at Polar Bear Pass.

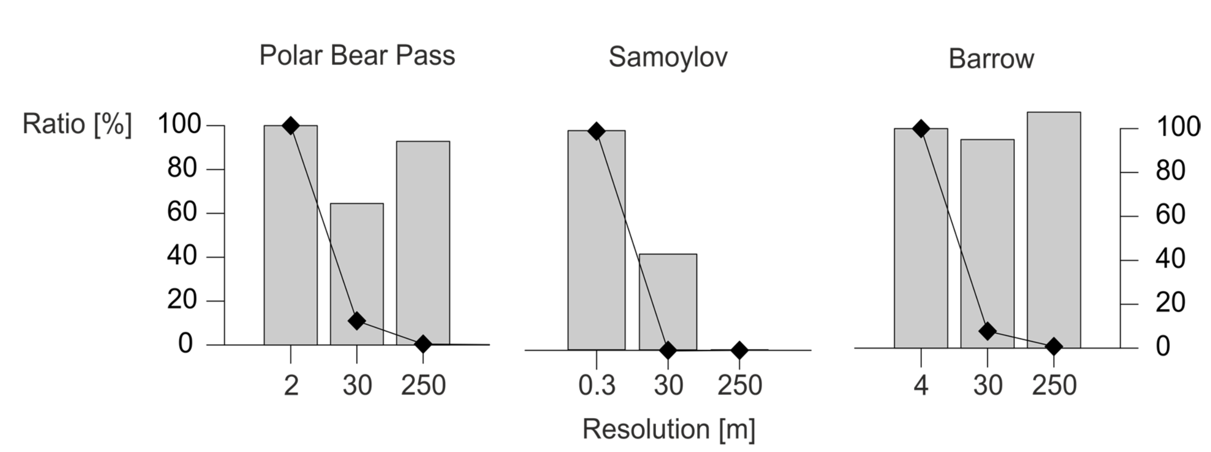


Fig. 3: Water body surface area and water body number mapped at different resolutions. Bars show the ratio of water surface area to the total water body surface area mapped at the highest resolution. Lines show the ratio of water body number to the total number mapped at the highest resolution.

Key findings II

- With decreasing resolution, clusters of small water bodies converge to large water surfaces, locally overestimating the water surface area.
- Underestimation of the water surface area due to the loss of small water bodies at coarse resolution may be counterbalanced by the local overestimation of the water surface area.

III. Subpixel analysis of Landsat albedo

Including all water surfaces

Albedo, α, is defined as the fraction of incident radiation that is reflected by a surface integrated over all sun-view geometries. Landsat surface albedo was calculated after Duguay and Ledrew (1992) using the surface reflectance, ρ:

$$\alpha = 0.526_{\rho\ band2} + 0.362_{\rho\ band4} + 0.112_{\rho\ band7}$$

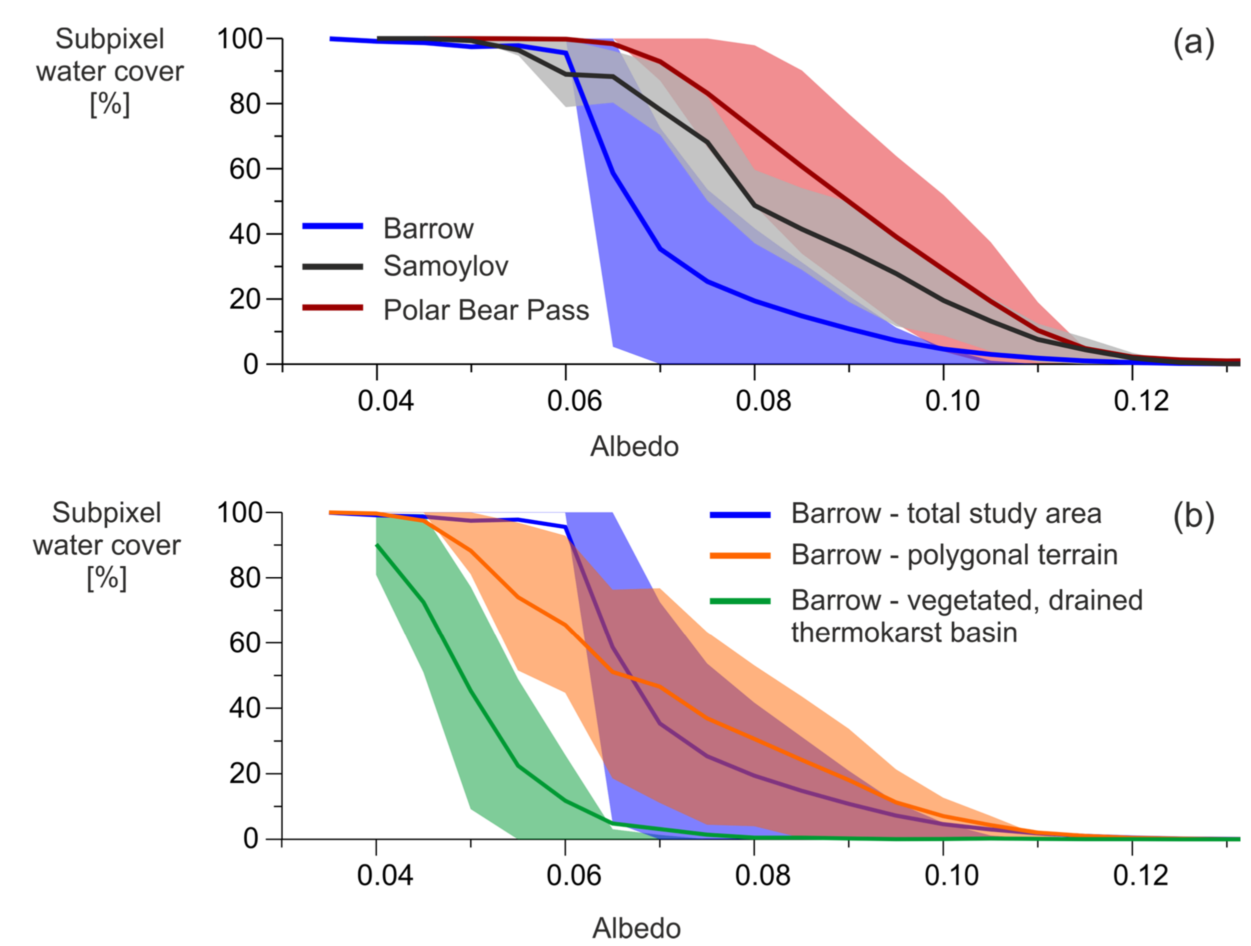


Fig. 4: Mean subpixel proportion of open water cover (SWC) per Landsat albedo for (a) the total study areas, and (b) landscape subtypes at Barrow.

Key findings III

- The darker the Landsat pixel, the more open water cover it contains.
- The albedo-SWC function appears strongly linear for mixed pixels, i.e. pixels with less than 95% and more than 5% SWC.
- Albedo-SWC functions should be derived separately for distinctly different surface types.

Conclusions

- All three wetlands showed similar properties regarding size-abundance data of water bodies, scaling errors, and retrieval of subpixel water cover via Landsat albedo.
- Common scaling functions can be applied to similar wetland regions across the Arctic for implementation in regional and global ecosystem and climate models.
- Scaling schemes need to incorporate not only the total water surface area but also the ratio of ponds versus lakes.

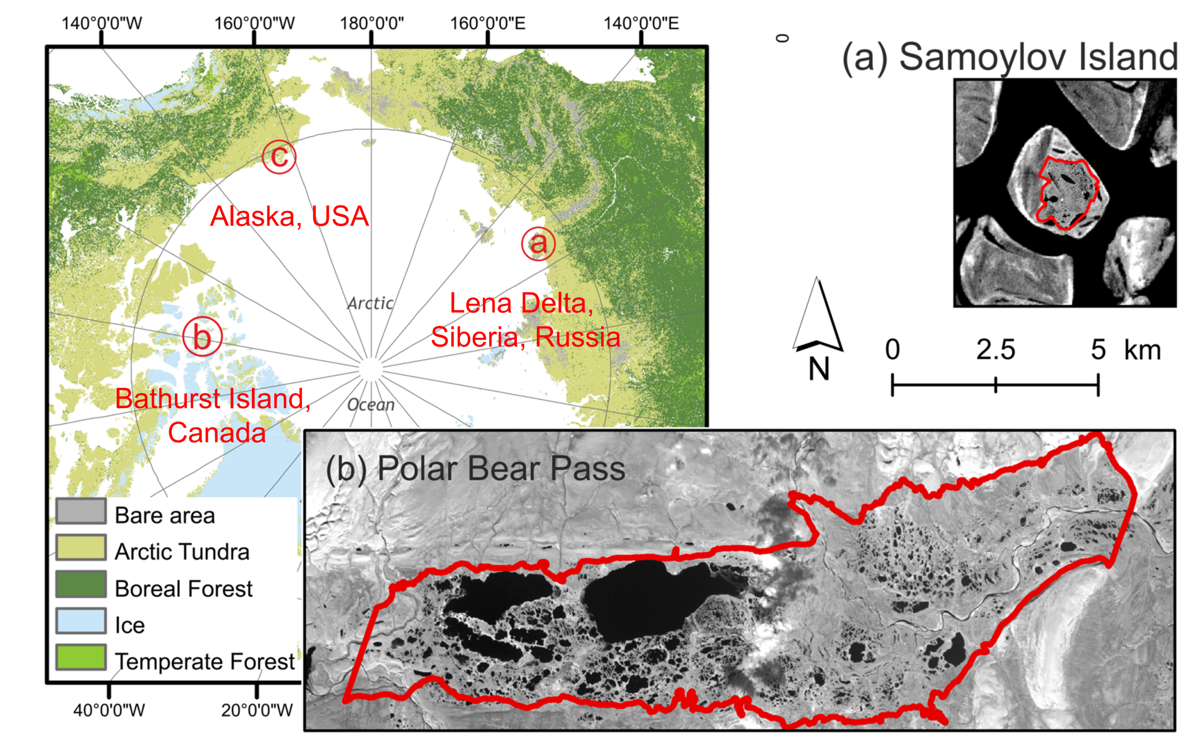
Site characteristics

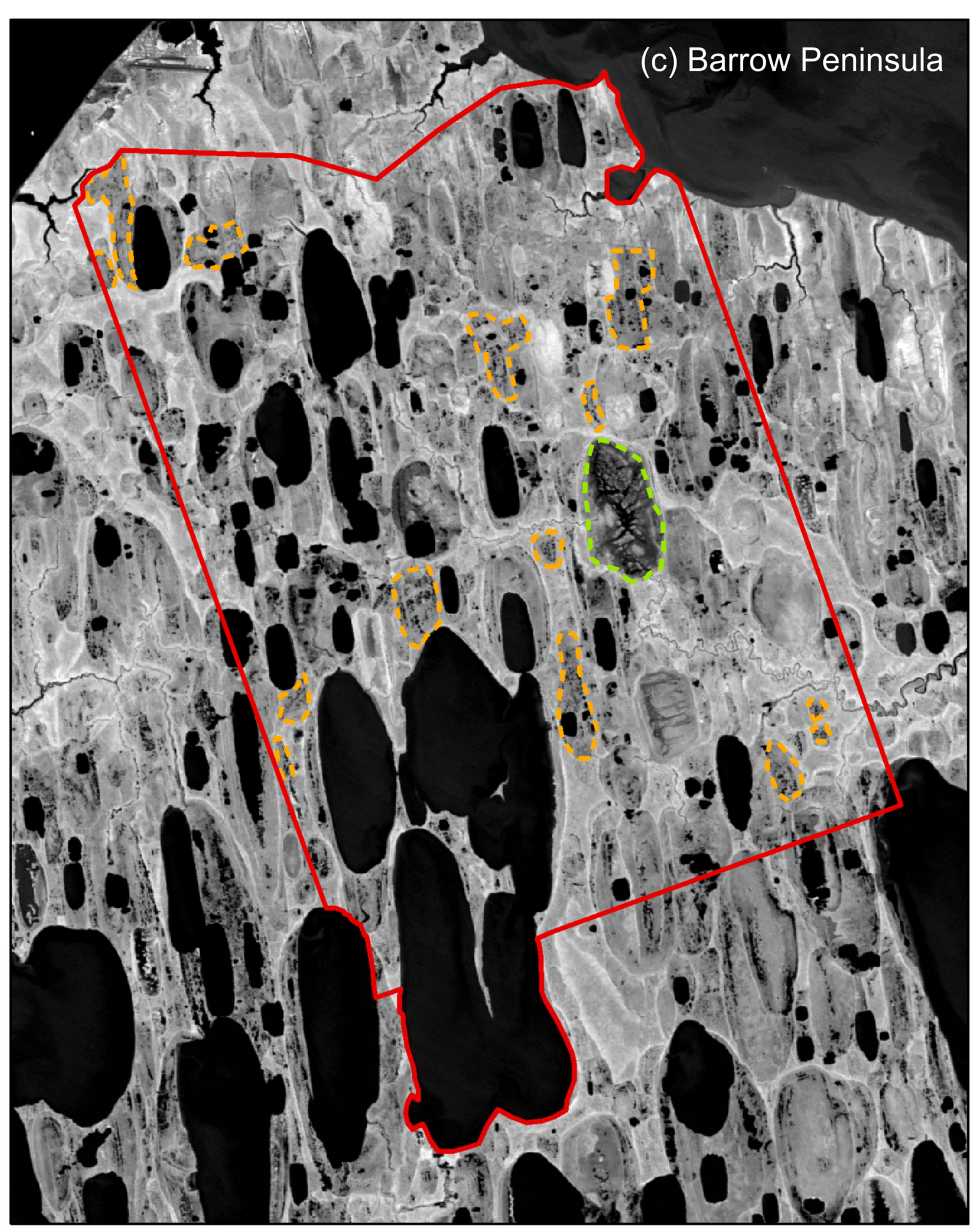
- Peat-forming lowland wetlands
- Underlain by continuous permafrost
- Predominantly wet tundra with an abundance of sedges, grasses, mosses and dwarf-shrub
- Long, dry, cold winters and short, moist, cool summers

Terrain Types

- Samoylov Island: low-centered ice-wedge polygonal tundra
- Polar Bear Pass: shallow ponds and thaw lakes, limited extents of ice-wedge polygons and sedge meadows
- Barrow: polygonal terrain, shallow, oriented thaw lakes, and drained thaw lake basins

Location of study areas





References: Duguay, C., Ledrew, E., 1992. Estimating surface reflectance and albedo from landsat-5 thematic mapper over rugged terrain. Photogrammetric Engineering and Remote Sensing 58, 551–558.

Corresponding author: Sina Muster, Alfred Wegener Institute, Potsdam, Germany
Sina.Muster@awi.de, www.awi.de/en/go/spac

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