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RES ice thickness and frontal ablation of outlet glaciers in the Russian Arctic

Andrey Glazovsky*, Ivan Lavrentiev*, Evgeny Vasilenko** and Nelli Elagina*

* Institute of Geography RAS, Department of Glaciology, Moscow, Russia, ** Institute of Industrial Research 'Akadempribor', Uzbekistan Academy of Sciences, Tashkent, Uzbekistan

INSTITUTE OF GEOGRAPHY
Russian academy of sciences
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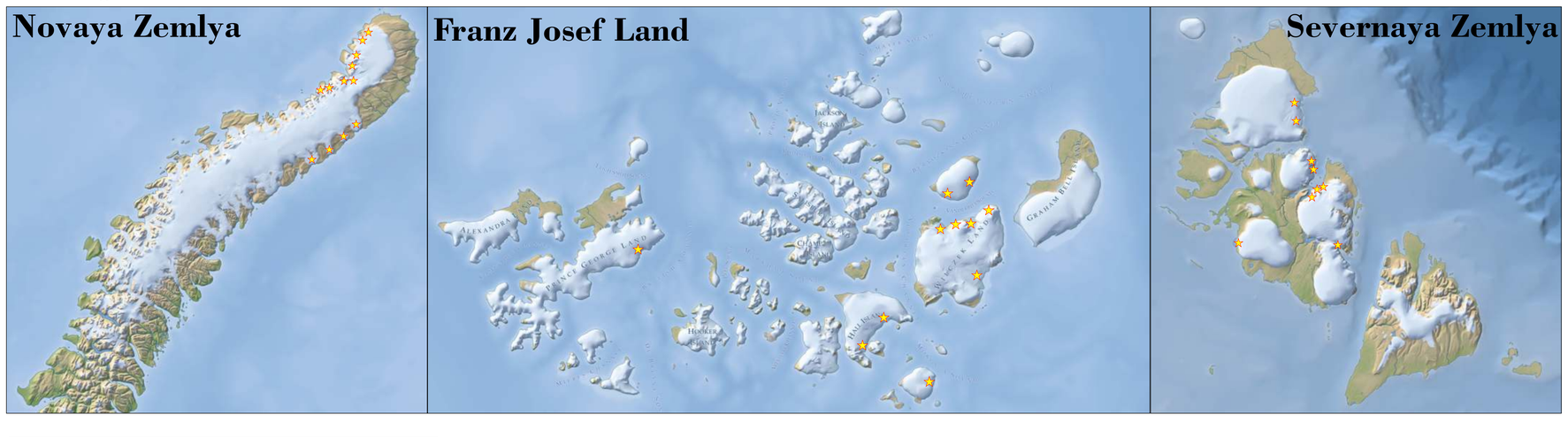
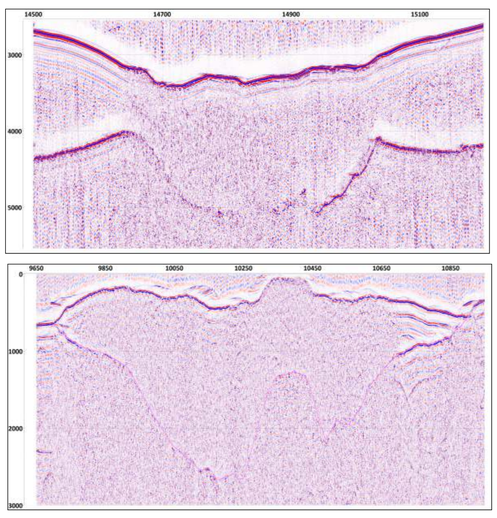
Introduction Frontal ablation of tidewater glaciers and ice caps in the Russian Arctic is poorly known. Meanwhile it is an important component of their mass balance, and its knowledge is strongly required when considering the iceberg risk in off-shore industrial activities.

Study area is located in three archipelagos of the Russian Arctic with total glacerized area 51591 km^2, including **Novaya Zemlya** (NZ) 22,128 km^2; **Franz Josef Land** (FJL) 12,762 km^2, and **Severnaya Zemlya** (SZ) 16,701 km^2 [1].

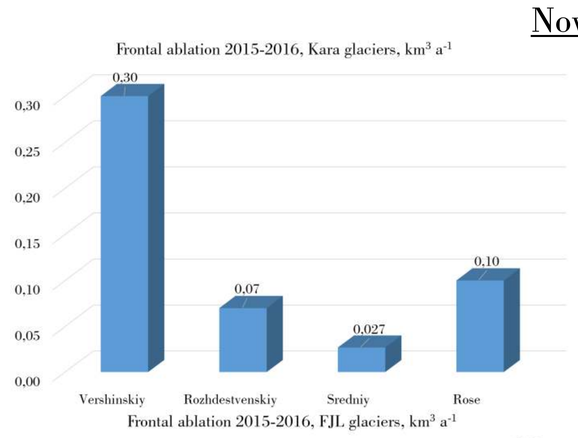


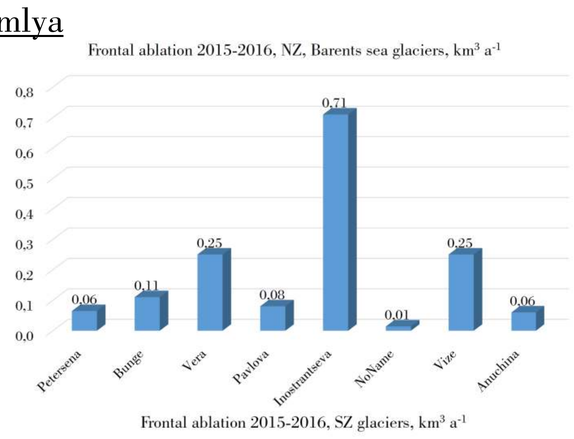
Data · Data on ice thickness of 31 glaciers (12 on NZ, 11 on FJL, and 8 glaciers on SZ) were obtained during our airborne 20 MHz GPR RES campaigns in 2014–2016;
· Data on variations of glacier fronts from 2001 to 2016 were extracted from Landsat satellite imagery;
· Glacier surface velocities from 2014 to 2016 were based on feature tracking on repeat Landasat-8 imagery using COSI-Corr package and from GolIVE v.1 [2] data set combined with continuous records from seven GPS beacons installed on five glaciers;
· ArcticDEM data on glacier ice surface combined with RES ice thickness data were used to compile glacier bedrock maps and transects.



Approach Frontal ablation is estimated for each glacier as a sum of the ice flux through a fixed fluxgate above the position of the calving front, and the ice volume change in the terminus below the fluxgate due to advance or retreat. The spatially fixed fluxgate is defined approximately perpendicular to the ice flow, 250–1500 m upglacier from the actual calving front. The depth-averaged speed is extracted from the surface velocity field in increments of 25 m along the fluxgate and weighted by a correction factor 0.9. The ice thickness is extracted in the same points from the ice thickness maps or transects. Radar two-way time data were converted to ice thickness using radio wave propagation speed 168 m mcs^{-1}.
Besides all glaciers without RES data, we also do not include in our estimations the surging western basin of the Vavilov Ice Cap and disintegrating Matusevich Ice Shelf (both SZ).

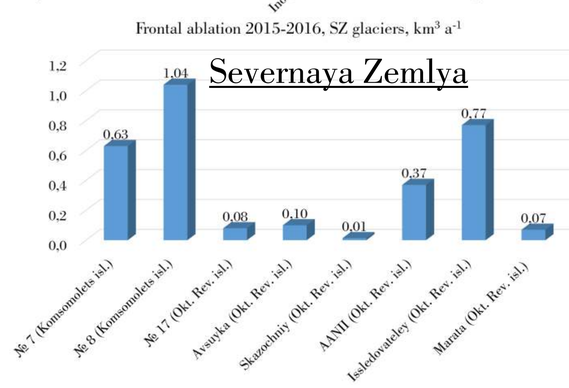
Novaya Zemlya



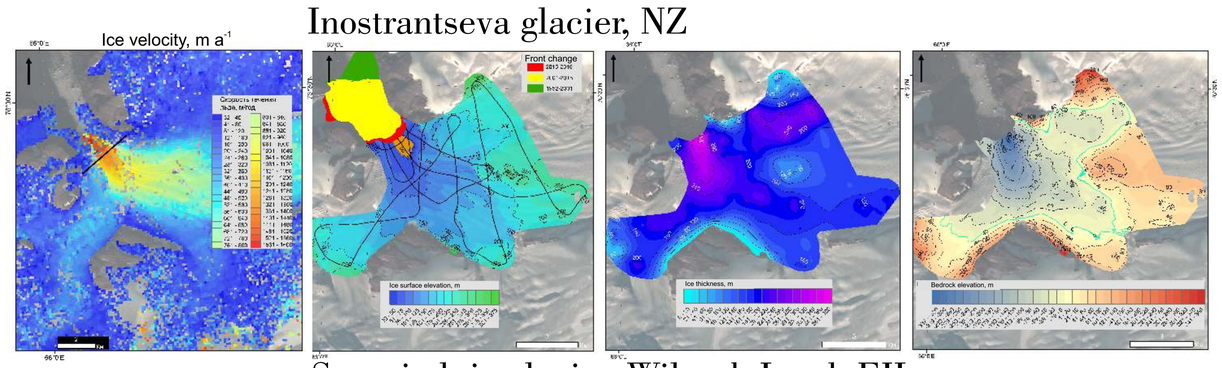


Franz Josef Land

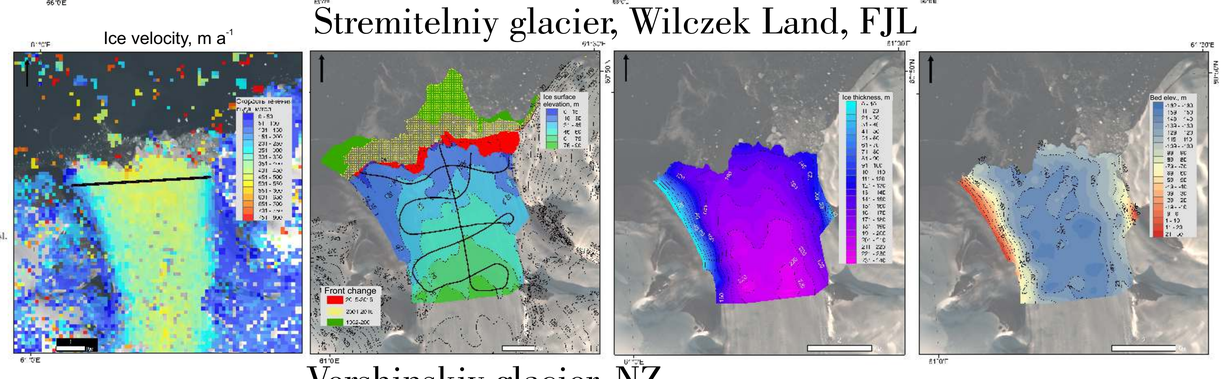
Severnaya Zemlya



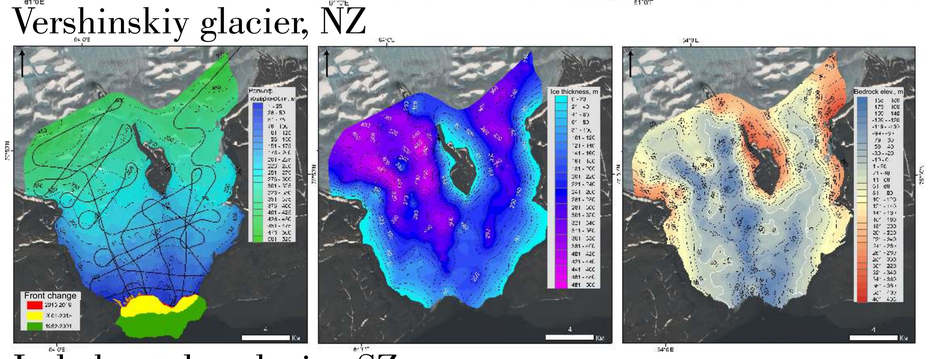
Inostrantseva glacier, NZ



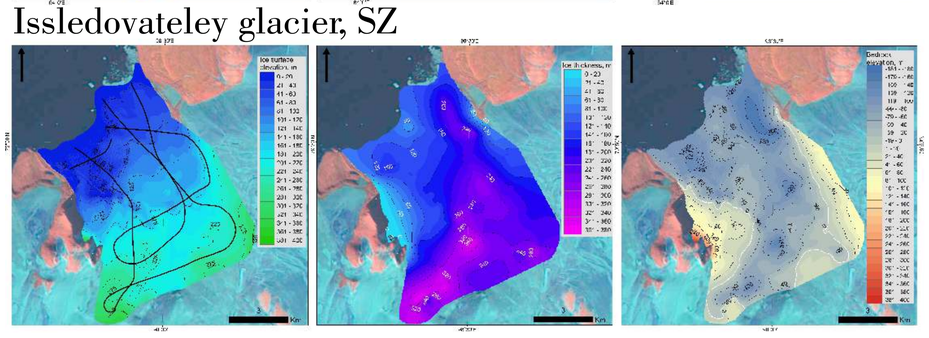
Stremitelniy glacier, Wilczek Land, FJL



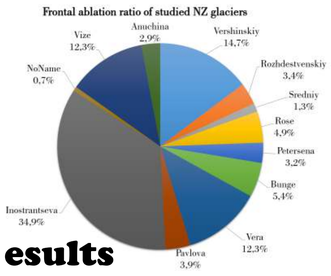
Vershinskiy glacier, NZ

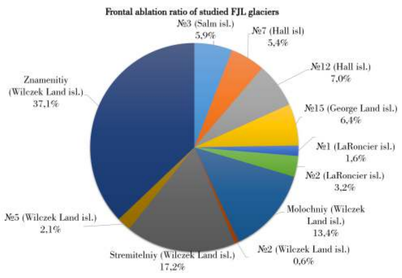


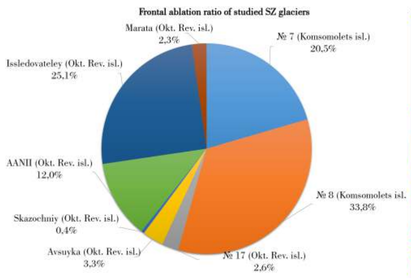
Issledovateley glacier, SZ



Results







Ice thickness · Mean ice thickness at glacier fronts is in average: from 60 m at eastern coast to 105 m at western coast **on NZ**; 107 m **on FJL**; and 117 m **on SZ**. · Maximum ice thickness at glacier front has the Inostrantsev Glacier on NZ: 216 m in average (maximum ~400 m).

Frontal ablation · Frontal ablation rate of RES surveyed glaciers is assessed as: **2.04 km^3 y^{-1} on NZ** (12 glaciers) including **0.5 km^3 y^{-1}** on eastern coast (4 glaciers) and on **1.54 km^3 y^{-1}** on western coast (8 glaciers); **1.86 km^3 y^{-1} on FJL** (11 glaciers), and **3.07 km^3 y^{-1} on SZ** (8 glaciers). · Share of terminus position changes in frontal ablation is: **28 % on NZ** (32 % eastern coast and 26 % western coast), **27 % on FJL**, and **24 % on SZ**.

Conclusions · **Our assessment of annual frontal ablation of outlet glaciers in the Russian Arctic as 7 km^3 of ice is a minimal one**, because it based on the data set of only 31 RES-surveyed glaciers. This set covers less than a quarter of calving glaciers on NZ and SZ, and even less on FJL. But a simple increasing of our assessment in proportion to the number or area of all calving glaciers will not give the correct overall estimate.
· **Input of studied glaciers in our assessment is very unequal. The following 6 glaciers provides nearly 60 % of frontal losses** in our estimate: N 8, N 7 and Issledovateley Glaciers on SZ, Inostrantseva and Vershinskiy Glaciers on NZ, and Znamenitiy Glacier on FJL (1.04, 0.63, 0.76; 0.71, 0.3; and 0.69 km^3 y^{-1}, respectively).
· **Terminus retreat is an important component, constituting near a quarter of the frontal ablation** of studied glaciers.

References 1. RGI Consortium, 2017, Randolph Glacier Inventory (RGI) – A Dataset of Global Glacier Outlines: Version 6.0. Technical Report, Global Land Ice Measurements from Space, Boulder, Colorado, USA. Digital Media. DOI: https://doi.org/10.7265/N5-RGI-60.
2. Scambos T., Fahnestock M., Moon T., Gardner A., Klinger M. Global Land Ice Velocity Extraction from Landsat 8 (GoLIVE), Version 1. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. 2016. doi: http://dx.doi.org/10.7265/N5ZP442B Accessed on June 14, 2017.

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