Monitoring of natural hazardous objects of Antarctic oases: key results of the program implemented at the Larsemann Hills

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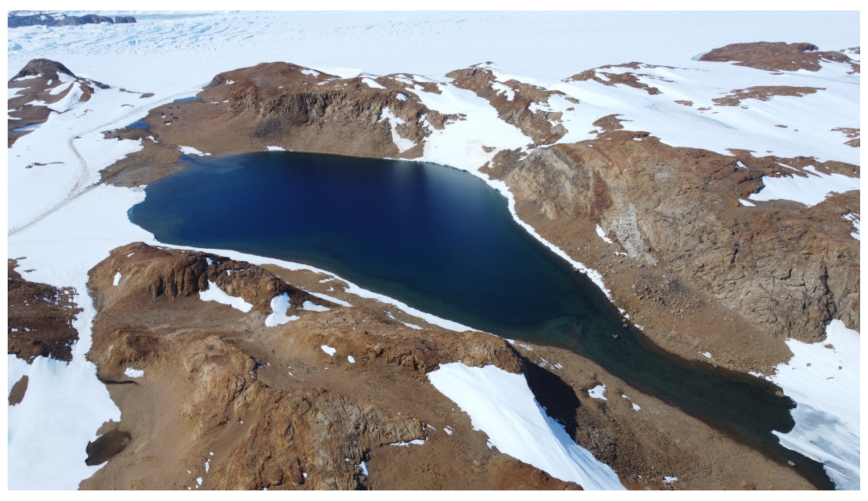
COMNAP · AARI Arctic and Antarctic Research Institute · RAE Russian Antarctic Expedition

Operating close to Antarctic oases often involves risks associated with hazardous natural objects and processes. Depending on the degree of danger, they can cause significant damage to the infrastructure of polar stations, seriously complicate logistical operations, or threaten the lives of people working in the field. Therefore, it is not surprising that one of the priority tasks of the Russian Antarctic Expedition in recent years has been to organise a programme to study and comprehensively monitor natural hazards. Such a programme was launched in 2017 in the area of the Russian Antarctic Progress Station (Larsemann Hills, East Antarctica).



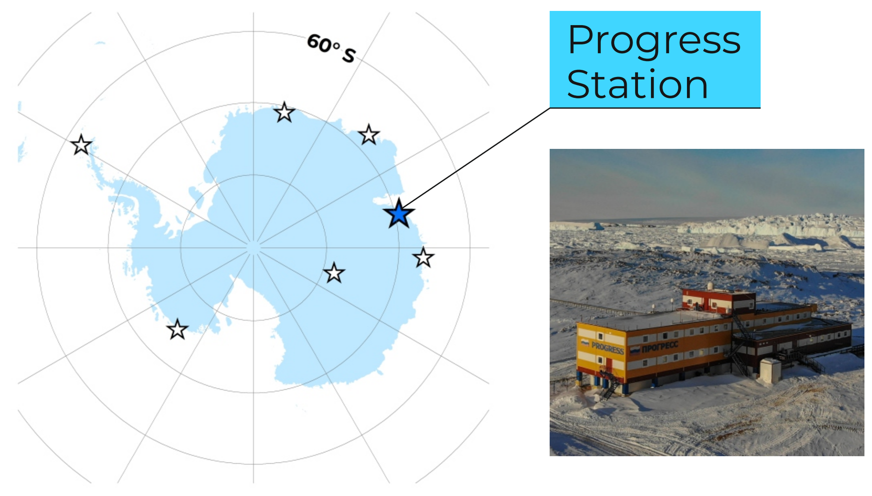
Larsemann Hills: typical view

Study area

- Coastal oasis, area ≈ 40 km²
- Surrounded by glaciers from the south and east
- Weather conditions: average air temperature -9,8°C, average annual precipitation 180 mm
- More than 150 freshwater lakes

Relevance

- 3 wintering stations and 3 field camps
- Supply of the intracontinental stations (Vostok, Kunlun)
- Snow runway
- The largest number of cargo operations within the Russian Antarctic Expedition
- Various scientific programs



Russian Antarctic stations and field bases

Natural hazards

Glacial crevasses

Potentially unstable hidden lakes

Glacial lake outburst floods

Aim of the program

to prevent any accidents resulted from natural hazards

Concept

Interaction with dangerous objects

1. detection
2. risk assessment
3. monitoring
4. explanation of the mechanisms

Methods

1. ground-penetrating radar (GPR)
2. land hydrology methods (water level observations, snow cover observations, bathymetric surveys)
3. aerial photography (UAV)
4. drilling
5. geodetical measurements
6. glaciological observations

Approach for ensuring the safety of transport operations

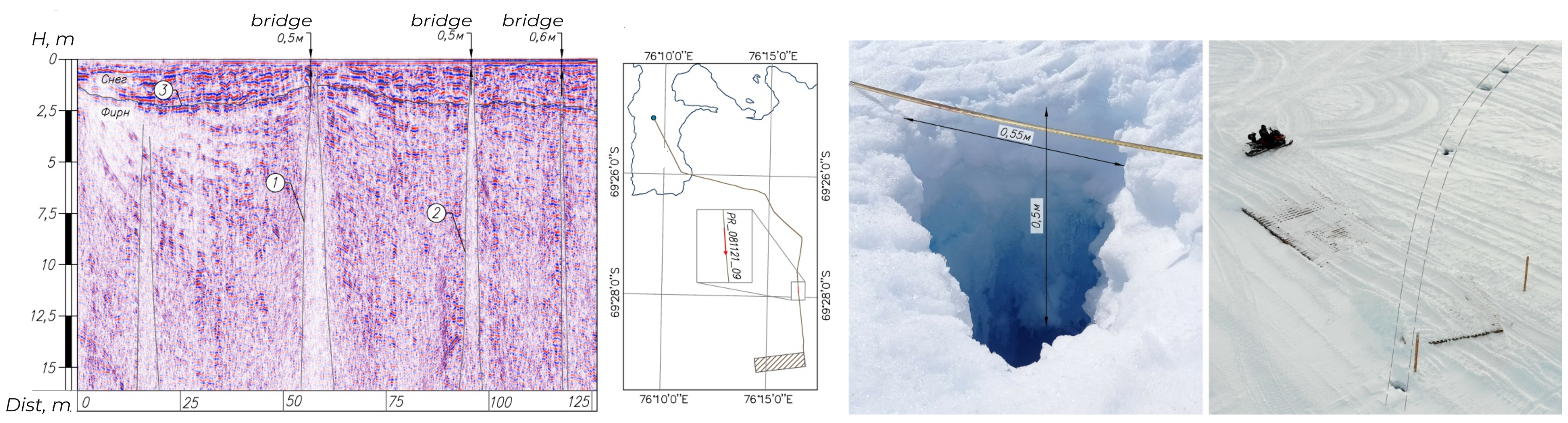
The need to organize a logistics facility → Selecting a pre-fit location → Presence assessment of dangerous objects → The location

is safe *or* **can be safe after additional measures are taken** *or* **unsafe**

Monitoring during the period of operation

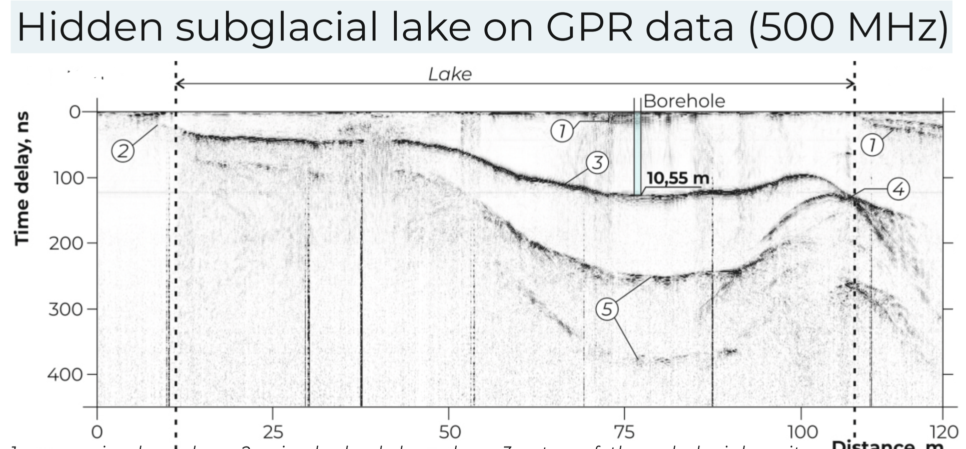
Another location

Examples: crevasses



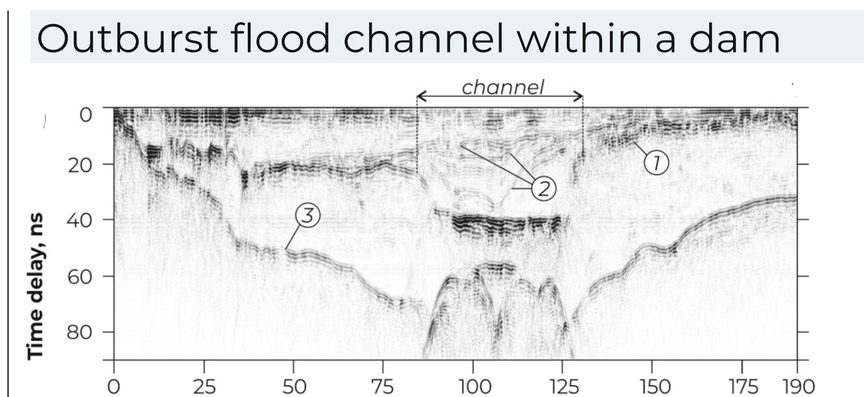
Examples: geophysical image of dangerous lakes

Hidden subglacial lake on GPR data (500 MHz)



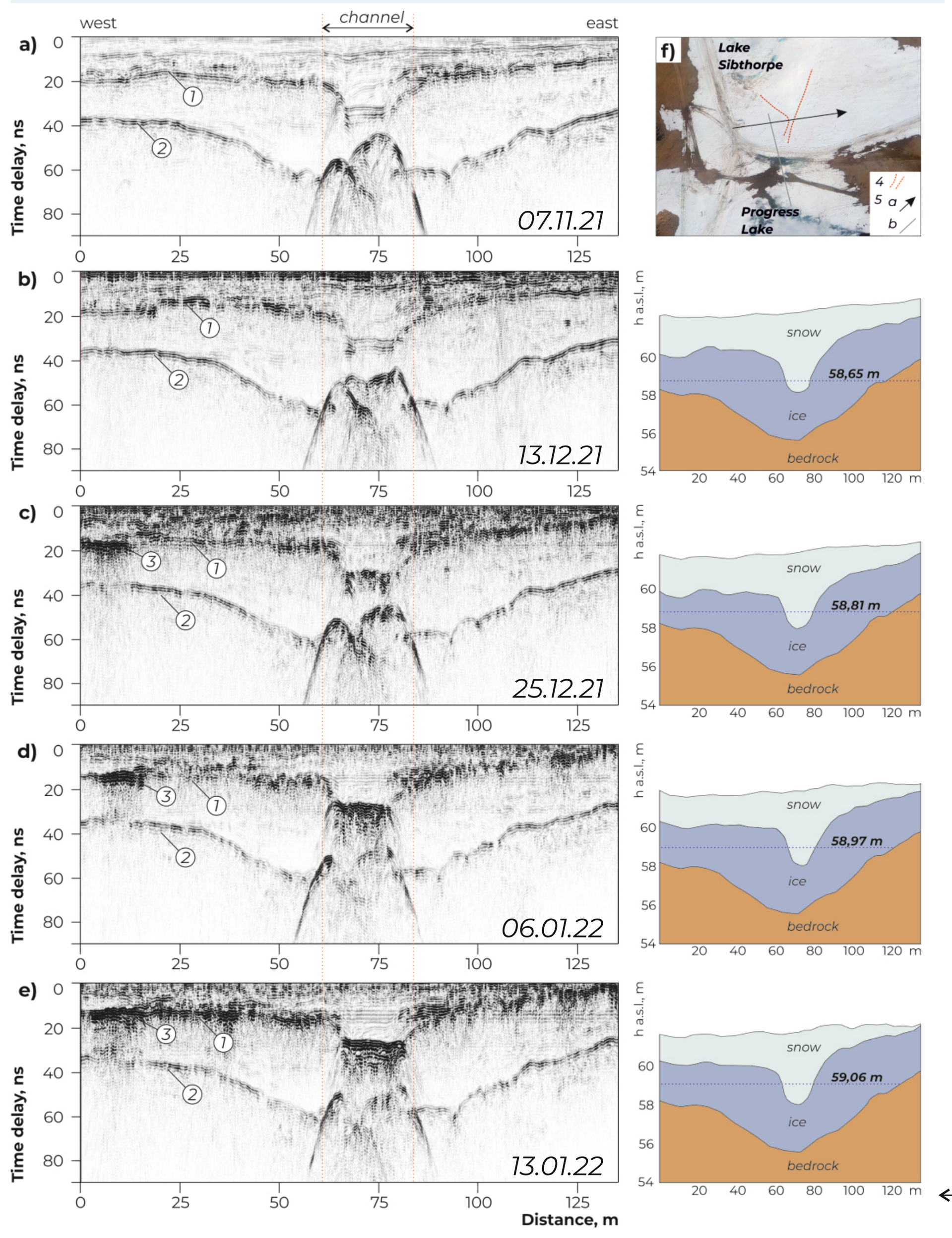
1 – snow-ice boundary; 2 – ice-bedrock boundary; 3 – top of the subglacial cavity; 4 – diffracted wave from the edge of the cavity; 5 – multiple waves formed with the top of the cavity

Outburst flood channel within a dam



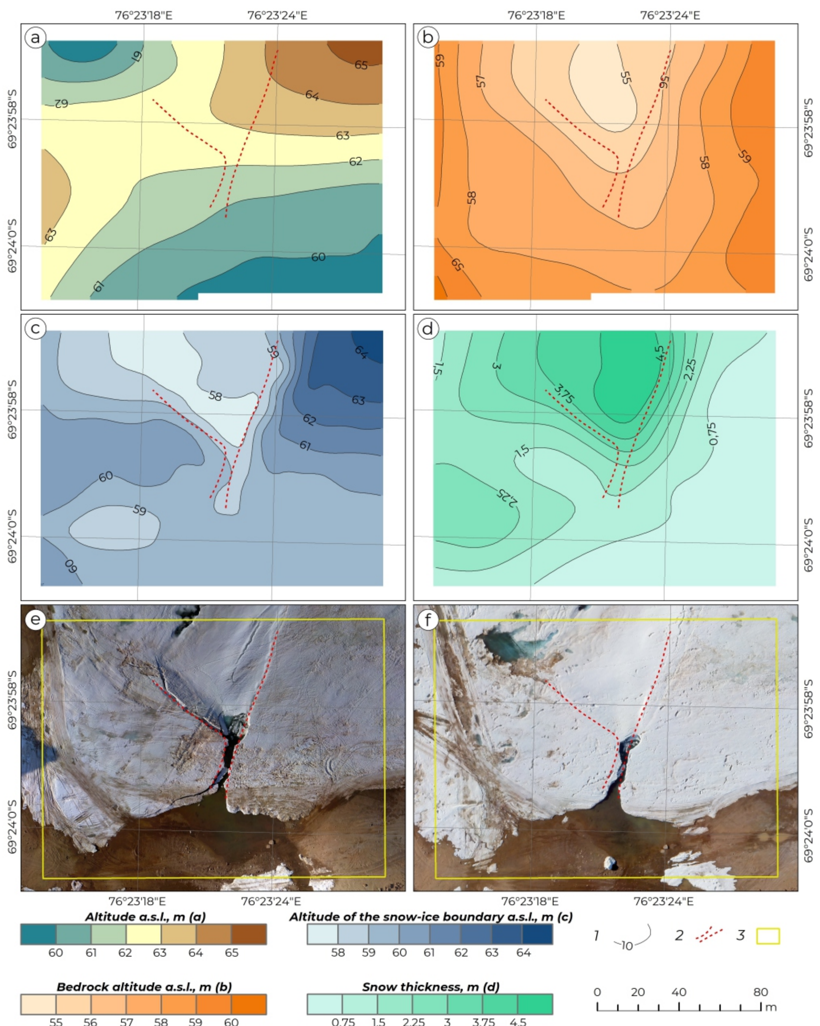
1 – snow-ice boundary; 2 – internal stratification of the snowpack; 3 – ice-bedrock boundary

Humidity monitoring within a dam (500 MHz)



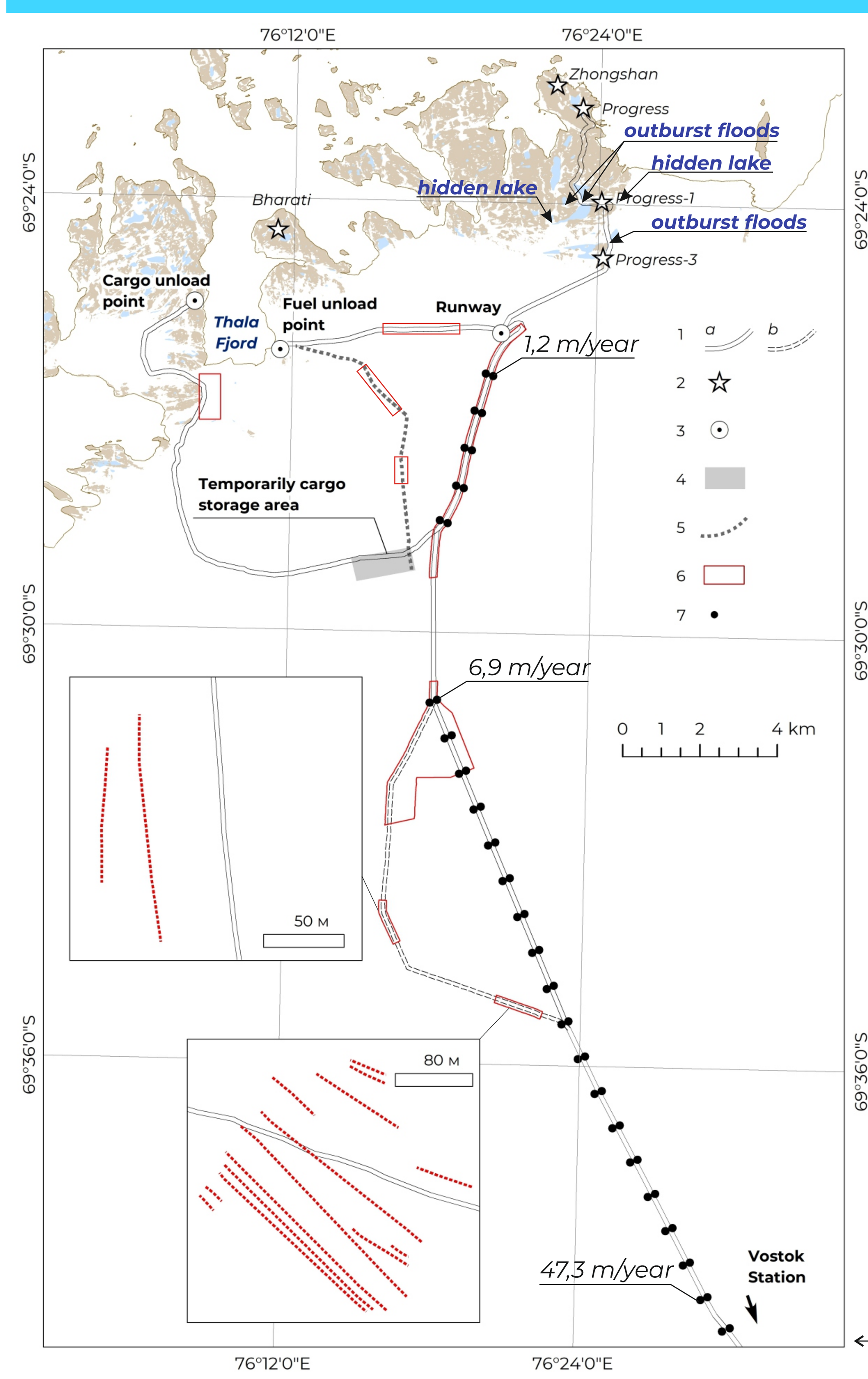
1 – snow-ice boundary; 2 – ice-bedrock boundary: 3 – snow swamp; for f: 4 – position of the old breakthrough channel; 5 – GPR lines

Internal structure of the snow-ice dam



a – chart of altitude of the surface; b – chart of the bedrock top altitude; c – chart of the altitude of the snow-ice boundary; d – chart of the snow thickness; e – orthophotomap of the site after the breakthrough in the season of the 64th RAE; f – orthophotomap of the site after the breakthrough in the season of 2019/2020
1 – isolines of the target parameters; 2 – position of the old channel; 3 – on sections e, f – boarder of the work site.

Main results and conclusions



1 – transport routes (a - existing, b - former); 2 - polar stations and field camps; 3 - points of logistics operations; 4 - area of temporarily cargo storage; 5 - temporarily line for fuel unloading; 6 - crevasse zones; 7 - glaciological stakes

To date, the main result of the program has been the completion of a **global inventory** of natural hazard sources within all the infrastructure facilities that are part of the RAE. **Lakes** have been identified and described in detail, the catastrophic outburst floods of which can affect the successful implementation of logistics operations, and monitoring activities are being carried out on them. **Crevasse zones** have been identified within existing routes. The capacity of snow bridges and the level of danger in a given field season are assessed annually. The design of **new infrastructure facilities** is carried out taking into account the results of a comprehensive survey and, as far as possible, directly in areas that are not affected by natural hazards and processes.

Recent articles

Grigoreva S.D., Kuznetsova M.R., Kiniabaeva E.R. **New data on Progress Lake (Larsemann Hills, East Antarctica): Recently discovered subglacial part of the basin** // Polar Science. – 2023 https://doi.org/10.1016/j.polar.2023.100925

Grigoreva S.D., Kiniabaeva E.R., Kuznetsova M.R., Popov S.V., Kashkevich M.P. **Structure of the snow-ice dams of the outburst lakes in the Broknes Peninsula (Larsemann Hills, East Antarctica) based on ground-penetrating radar data** // Ice and Snow. – 2021a. – V. 61. – № 2. – P. 291-300. [In Russian]

Boronina A.S., Popov S.V., Prykhina G.V., Chetverova A.A., Ryzhova E.V., Grigoreva S.D. **Formation of a large ice depression on Dålk Glacier (Larsemann Hills, East Antarctica) caused by the rapid drainage of an englacial cavity** // Journal of Glaciology. – 2021. – Vol. 67. – No 266. – P. 1121-1136.