Presenting land surface changes through the web-based Arctic Landscape EXplorer (ALEX) to permafrost communities – A permafrost service

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The EU-funded Arctic PASSION research project focuses on refining, improving and extending pan-Arctic scientific and community-based monitoring systems. The aim is to create a coherent and integrated Arctic observing system, tailored to the needs of the users or stakeholders. Within the project's Permafrost Service, we are developing a web-based portal, the 'Arctic Landscape EXplorer' (ALEX). In this online tool we present data on permafrost region land surface changes derived from remote sensing analysis. Using tailored visualizations and story maps as a means of more effectively communicating scientific observations of change, we specifically address non-scientific user communities, stakeholders, and rights holders in the Arctic.

Pan-Arctic land surface change data

Remote sensing analysis can be applied to detect and map permafrost disturbances at high spatial resolution over large regions to quantify landscape change, hydrological dynamics, and permafrost vulnerability. In the ERC PETA-CARB, ESA CCI Permafrost, and NSF Permafrost Discovery Gateway projects, a pan-Arctic time series of permafrost landscape change at 30m resolution and covering twenty years was produced using Landsat TM, ETM+, and OLI imagery (see Nitze and Grosse 2016).

To obtain robust trend parameters, the well-established Tasseled Cap transformation was applied to all cloud-free pixels in images with less than 80% cloud-cover for the months of July and August as part of the change analysis. Trends for each of the Tasseled Cap indices were calculated using a Theil-Sen regression (Sen 1968; Theil 1992), which considers the slope between each point in time and then calculates a median over the entire time period, which is defined as the master slope of the trend. The application of this approach is able to reliably detect and quantitatively assess key permafrost region disturbances such as lake drainage, coastal erosion, thermokarst lake expansion, retrogressive thaw slumps, fire scars, and infrastructure expansion, among many others, across continental-scale spatial domains (Nitze et al. 2018).

Within EU Arctic PASSION, the change algorithm and processing pipeline were further refined to provide even more robust results in areas where data sources are disrupted. The time series has also been updated to cover changes between 2003 and 2022.

The Arctic Landscape EXplorer (ALEX)

To make the scientific findings and the large remote sensing dataset more easily accessible, we have developed a tailored web-based portal, the Arctic Landscape EXplorer (ALEX, https://alex.awi.de, Figure 1). With the new portal, we provide interactive maps of recent information on land surface changes, hot spots of disturbance, and potential areas of active permafrost thaw and erosion.

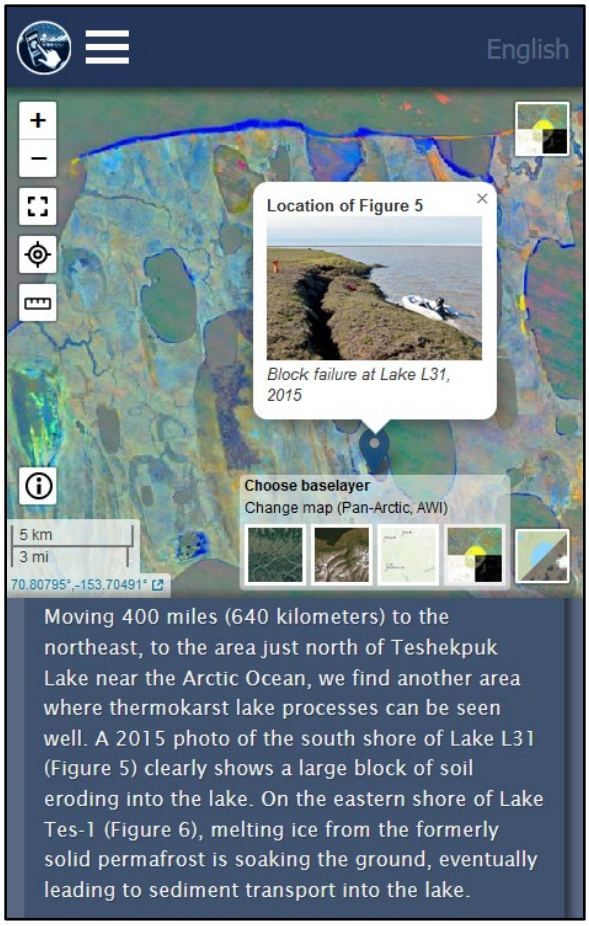

Figure 1. Screenshot of the Arctic Landscape EXplorer (ALEX) showing a story map in mobile device mode. In the change data (top), blue colors mark areas of lake expansion, coastal erosion, or flooding.

A series of short story maps are seamlessly integrated into the portal. This interactive approach combines map content with multimedia elements and narrative storytelling, encouraging users to engage more deeply with the map content. In a hands-on way, users are guided step-by-step to read and explore the map to gain a better understanding of the spatially explicit data. Tailored visualizations on topics such as coastal erosion, lake drainage, infrastructure expansion, and tundra fires are being implemented.

To ensure that user requirements are met, we build on mutually trusted collaboration with local permafrost communities. In recent consultations with local representatives and stakeholders from Alaska we received positive feedback and strong interest in the tool. The results of community evaluation and feedback are used to update the community-oriented maps.

Technical considerations and data dissemination

During the design and implementation of the tool, emphasis was placed on optimized page load times, the usability of the tool on mobile devices, and the ability to index the content. A set of simple to use controls helps the user to navigate to the current location and to compare different data sources. For the map component, we use the open source software library Leaflet, which is known to be one of the most popular open source JavaScript libraries for cartographic web applications (Edler & Vetter 2019). The library is very lightweight and offers an abundance of extensions that can be integrated to fulfill specific desired functionalities. For the layout, we use modern but well-established web standards such as the Cascading Style Sheets (CSS) Grid technology and Scalable Vector Graphics (SVG).

In addition to being visualized in the Arctic Landscape EXplorer, the surface change data can also be accessed via an OGC-compliant Web Map Service (WMS). Following the service-oriented architecture of a Spatial Data Infrastructure (SDI), publishing raster data via a WMS greatly facilitates data ruse. Using the appropriate service URL, a user can easily integrate the data into desktop geographic information systems (GIS; such as ArcMap or QGIS) as well as online map viewers based on standard map libraries (such as Leaflet or OpenLayers).

Conclusions

Publishing research data according to the FAIR data principles (Wilkinson et al. 2016) and by using open access information systems such as PANGAEA (Felden et al. 2023) can ensure that even large and complex scientific datasets are available in the long term and can be easily reused by the scientific community. However, these well-established information channels often do not reach local, regional, and state-level decision makers and community members living on permafrost.

With the ALEX tool, we strive to provide a permafrost landscape information tool that specifically addresses non-scientific audiences so that large and complex pan-Arctic permafrost change datasets become visible at the local and community level. The data presented through the tool can help to better understand the spatial explicitness of land surface changes and provide a valuable tool to support local decision making. Establishing a system to detect land surface changes caused by permafrost degradation is our contribution to a tailored, coherent, and integrated Arctic observing system.

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