Mapping Multi-scale Surface Changes on Negribreen Glacier, Svalbard, during Surge using ICESat-2, Sentinel-1 and Airborne Field Data

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Abstract

The Negribreen Glacier System on the east coast of Spitsbergen, Svalbard, has been actively surging since 2016, i.e., during the entire lifetime of ICESat-2 (launched in September 2018). The progression of Negribreen's surge throughout the glacier system has resulted in large-scale elevation changes and wide-spread crevassing, which is ideally mapped and analyzed using ICESat-2 measurements processed by the Density Dimension Algorithm for Ice (DDA-ice) (see Herzfeld et al. 2016, IEEE TGRS, and Herzfeld et al., 2022, Science of Remote Sensing).

In this analysis, we quantify how Negribreen has been evolving in its mature surge phase over the course of 2019 and 2020. Using ICESat-2 data, together with airborne field data and Sentinel-1-derived velocity data, we quantify large-scale effects such as elevation-change and mass transfer through the system, as well as smaller-scale effects afforded by high-resolution data products of the DDA-ice such as crevasse characterization, surface roughness and changes thereof.

Results show the expansion of the surge in upper Negribreen where increased crevassing has occurred along with height change rates nearing 30 m/year. In addition, fresh surge crevasses formed along the margin between the surging ice of Negribreen and non-surging ice of neighboring Ordonnansbreen. Finally, increased surge activity found on inflowing glaciers from the Filchnerfonna accumulation zone suggest that surge effects may continue to expand up glacier leading to further disintegration of the ice system with continued mass loss.

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Negribreen Glacier System and ICESat-2 RGTs

The Negribreen Glacier System (NGS), a large glacier system in Arctic Svalbard, surged in late 2016 reaching speeds of 21m/day during its peak in July 2017, equivalent to 200 times its normal quiescent velocity. The NGS consists of Negribreen, where the majority of the surge activity occurs, Rembebreen, a southern tributary glacier in the upper glacier system, and two main tributary glaciers flowing in from the north: Akademikarbreen feeding Negribreen in the upper glacier, and Ordonnansbreen further down-glacier. The NGS receives large amounts of inflowing ice from the Filchnerfonna accumulation zone above the NGS to the west.

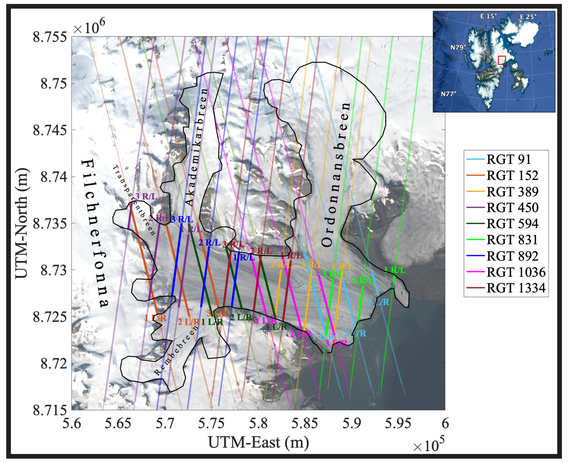

Figure: ICESat-2 survey lines over the Negribreen Glacier System. The survey lines for each of ICESat-2's three beam-pairs are color coded by their Reference Ground Track (RGT) while the NGS borders are given by the black line. Left/Right (L/R) beam-pairs are separated by ∼90 m on-ice.

Imagery from Field Campaign in August 2019

In response to the sure, the Geomathematics, Remote Sensing and Cryospheric Sciences Group at the University of Colorado, Boulder, conducted three airborne survey campaigns of the glacier system in the summers of 2017, 2018 and 2019, collecting laser altimeter, IMU and GPS measurements together with imagery (see Herzfeld et al., 2022, Remote Sensing).

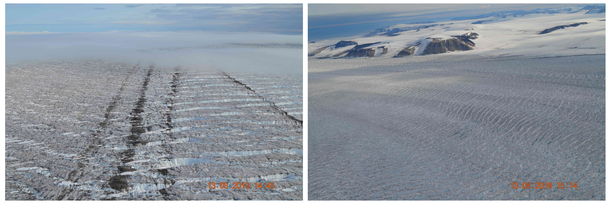

Figure. (Left) Low-lying clouds covering the lower glacier and terminus (photo looking downglacier. (Right) Young surge crevasses in upper Negribreen.

Figure. (Left) Large and complex crevasses exceeding 30 m depth in the center-front of the glacier just above the terminus. (Right) Snow-bridged crevasses seen most clearly in the left-foreground with the white, fresh snow covers the top of the open crevasses.

Figure. (Left) Water-filled crevasses. (Right) Crevasses near the Negribreen-Akademikarbreen Medial Moraine (NAMM) are filled with water indicating a disruption in the local englacial drainage system. Fresh crevassing through surge expansion affected this area along the northern NAMM in early 2020, shortly after this photo was taken.

Contact Info, Acknowledgements and Reference

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Paper Preprint: Trantow, Thomas and Ute C. Herzfeld, Progression of the surge in the Negribreen Glacier System from two years of ICESat-2 measurements, Journal of Glaciology (in review), doi.org/10.31223/X5NT1Z (Earth ArXiv preprint)

Sentinel-1 Velocity Maps

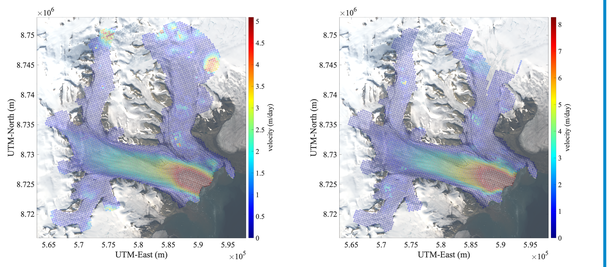


Figure. (Left) Mean surface velocities between 2019-08-11 to 2019-08-23 (m/day). This baseline spans the 2019 airborne campaigns in August 2019. (Right) Mean surface velocities between 2020-07-10 to 2020-07-22 (m/day) with peak surge speeds exceeding 8 m/day. July typically sees the fastest ice-surface speeds in Negribreen.

Elevation and Roughness Change

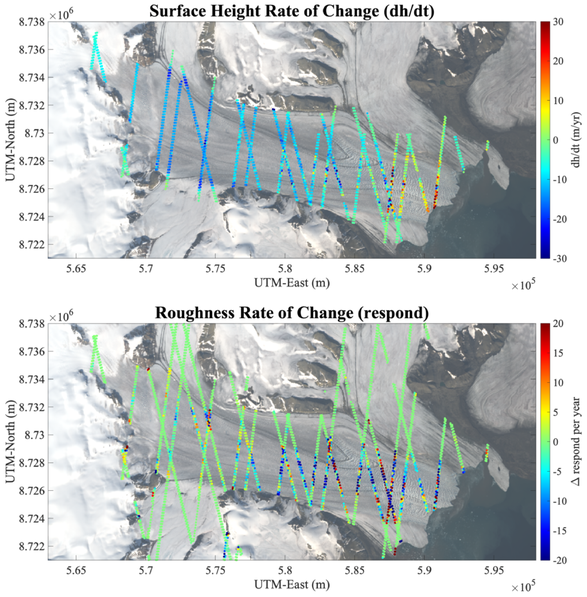
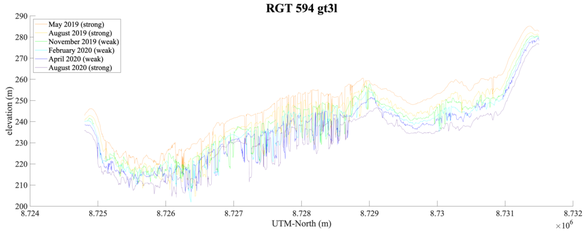
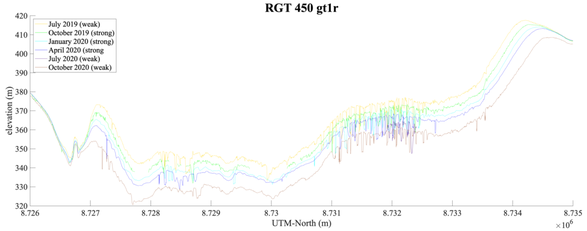


Figure. (Top) Rates of change of glacier surface height during the 2019-2020 part of the recent Negribreen surge (m/yr). (Bottom) Rates of change of roughness during the 2019-2020 part of the recent Negribreen surge. Roughness (lrespond) change rate in Δrespond per year.

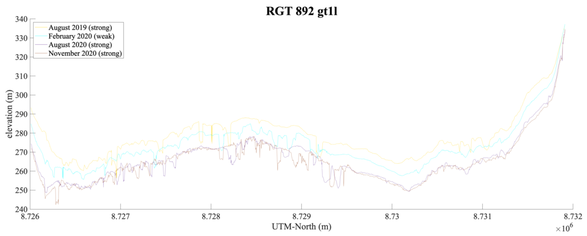
ICESat-2 RGT Time Series Results over Negribreen

(1) Detection of New Surge Crevasses and Changes in Existing Crevasse Fields in Upper Negribreen:





(2) Crevasse Expansion Along and Across the Shear Margin (NAMM):



(3) Disintegration of the Ordonnansbreen Tooth: