Evaluation of supraglacial lake depth estimation techniques using Sentinel-2, ICESat-2, TanDEM-X, and in situ data, along with an analysis of rapid drainage events over Northeast Greenland

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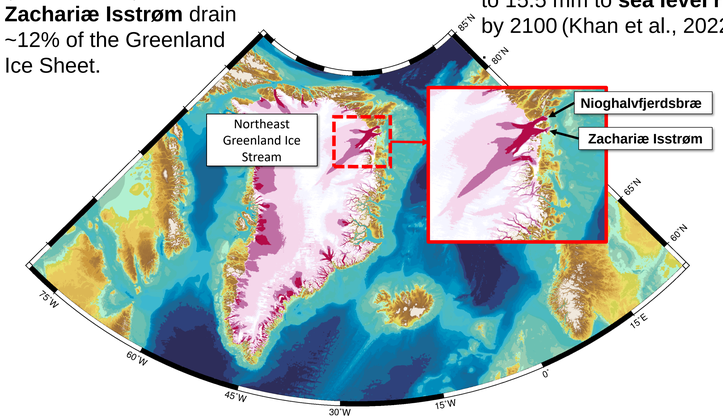
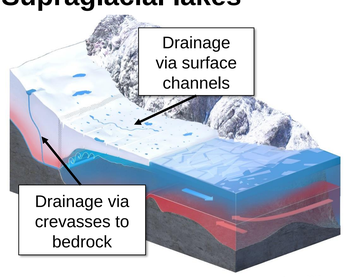
Northeast Greenland

Nioghalvfjerdsbræ (79°N Glacier) and **Zachariæ Isstrøm** drain ~12% of the Greenland Ice Sheet.

The Northeast Greenland Ice Stream could contribute 13.5 to 15.5 mm to **sea level rise** by 2100 (Khan et al., 2022).



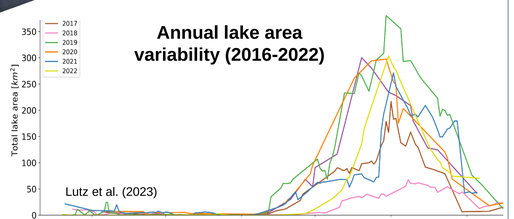
Supraglacial lakes



Supraglacial lakes form annually during periods of warm temperatures, high rainfall or thick snowpack (Turton et al., 2021).

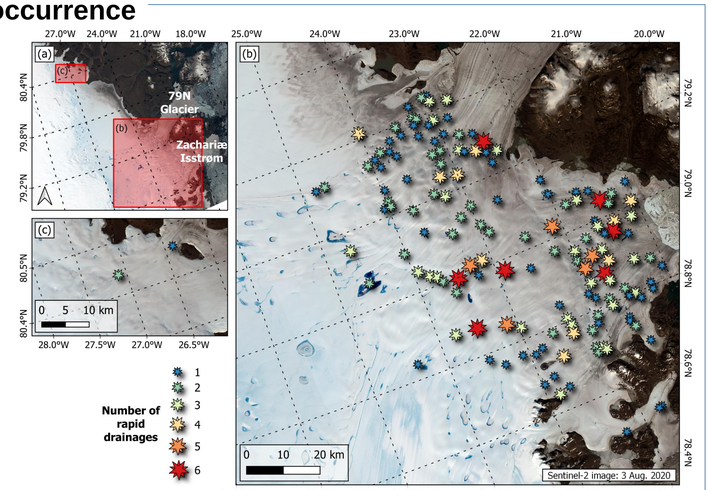
Through **rapid drainages**, large volumes of meltwater are directly transported to the glacier bed, where it is then discharged to the ocean.

The discharge of supraglacial lakes to the glacier bed increases basal sliding, which causes temporary **speed-ups** in glacier velocity.



Rapid drainage occurrence

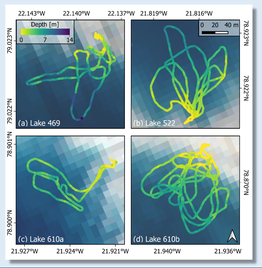
- Over the seven analyzed years (2016 – 2022), six lakes drained every year except one.
- Frequent drainage is not necessarily limited to highly crevassed areas.
- While glacier margins see many infrequent drainages, not all lakes toward the central flow line of the glacier experience highly frequent drainages.



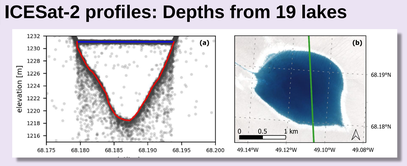
Lake depth methods

1 Digital Elevation Model post-drainage (TanDEM-X)

2 In situ sonar: Depths from 4 lakes in NE Greenland



3 ICESat-2 profiles: Depths from 19 lakes



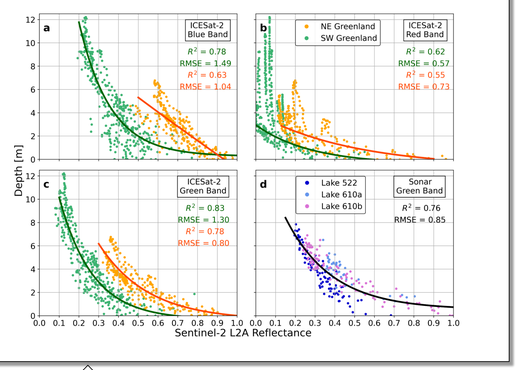
4 Radiative transfer model (Sentinel-2)

$$z = \frac{\ln(A_d - R_\infty) - \ln(R_w - R_\infty)}{-g}$$

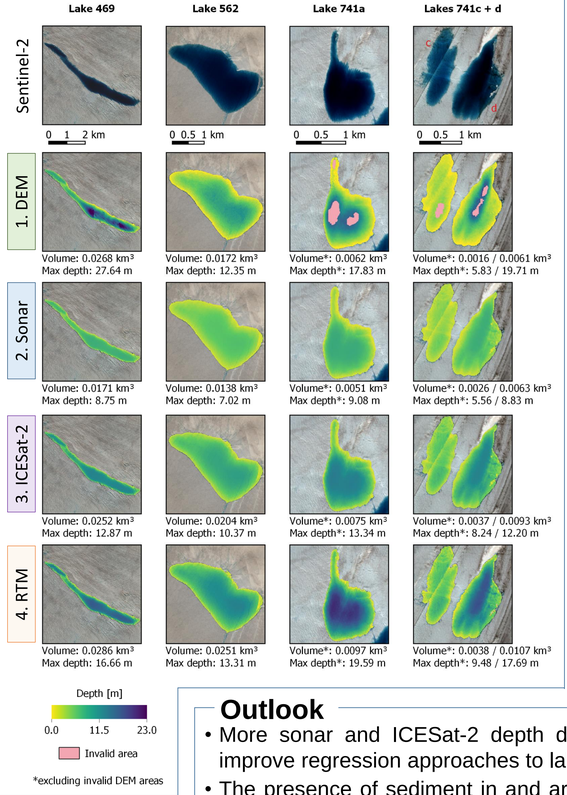
Philpot (1989)

z = lake depth
A_d = lake bed albedo
R_∞ = optically deep water reflectance
R_w = water pixel reflectance
g = two-way attenuation coefficient

Correlation of ICESat-2 depths (a-c) and sonar depths (d) to Sentinel-2 reflectance values



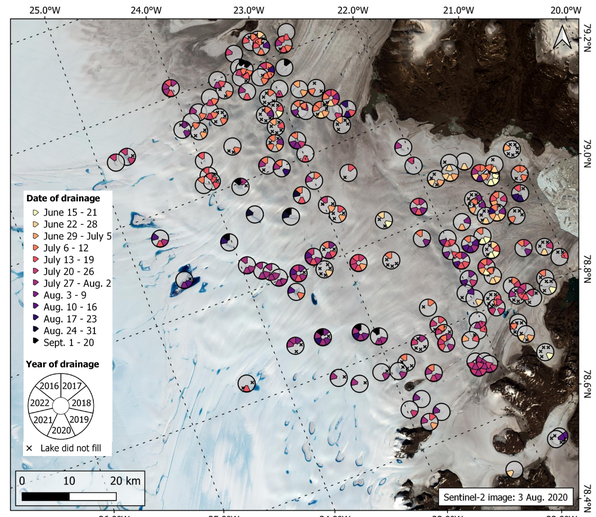
- The sonar and ICESat-2 depth data are correlated to Sentinel-2 reflectance values to create regressions applicable to other scenes.
- Distinct behavior seen between ICESat-2 data gathered in Northeast Greenland vs. Southwest Greenland.
- Larger presence of sediment in Southwest Greenland causes shift toward lower reflectance values.
- The RTM method tends to overestimate depths most strongly due to the sensitivity of its parameters.



*excluding invalid DEM areas

Rapid drainage seasonal patterns

- The simultaneous drainage of several adjacent lakes can be often seen, highlighting the influence of ice dynamics on drainage timing
- The total number of rapid drainages is not necessarily correlated to the total amount of meltwater present in the melt season.
- In the cool year of 2018, fewer lakes underwent rapid drainages, particularly in higher altitudes.
- Individual lakes do not necessarily drain at the same time every melt season, but in general, lakes at higher elevations drain later in the season.
- A drainage hole can remain open for more than one melt season, draining continuously instead of filling up.



Outlook

- More sonar and ICESat-2 depth data, especially of deeper depths, would help improve regression approaches to lake depth estimation.
- The presence of sediment in and around the lake can strongly influence the depth results and needs further investigation.
- Ice velocity along with the movement and development of crevasses needs to be further investigated to better understand precisely how these glacier mechanics influence rapid drainages.

References

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SCAN ME

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