Bathymetry of supraglacial lakes and streams on the Greenland Ice Sheet from high-resolution aerial photography

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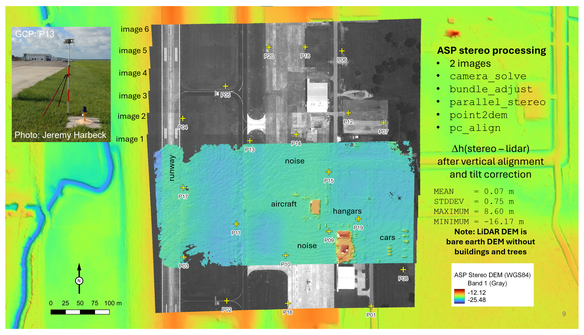
Background and Motivation

Advancing our understanding of the hydrological system connected to the Greenland Ice Sheet requires observational knowledge on a range of spatial scales with varying resolution and temporal coverage. Process-related studies generally require high-resolution observations over regional scales spanning hundreds of kilometers. While the resolution of spaceborne imaging is continually increasing, airborne imaging can provide complementary information at even higher resolution, often combining multiple sensors with coincident data acquisition. Here we use regional-scale, high-resolution (10×10 cm) aerial imagery collected by NASA's Airborne Topographic Mapper instrument suite (ATM) to derive topo-bathymetry of supraglacial lakes and streams using Structure from Motion (SfM) and stereo processing techniques. Supraglacial lakes appear as sapphire-blue features in natural-color imagery (Fig. 1A, right) with often clearly visible features at the lake bottom, making them ideal for SfM and stereo processing. The ATM airborne data also includes two short pulse, coincident green (532 nm) small footprint topobathymetric lidars providing a rare opportunity to compare lidar and imagery-based topo-bathymetry methods (Fig. 1B,C).

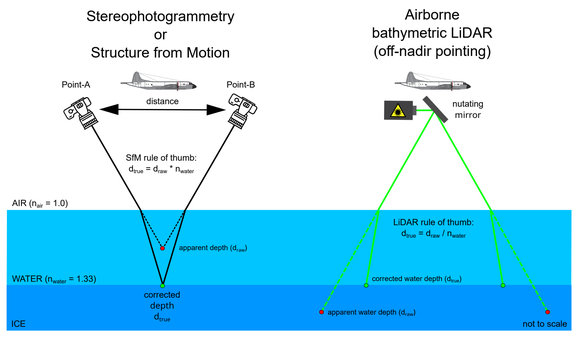
Approach

We use the **NASA Ames Stereo Pipeline (ASP)**, a powerful open-source processing toolbox with a long history, a broad user community, and active tool development. The aerial images are combined with differential GPS trajectories of the camera's position and high-accuracy attitude data from a commercial IMU system. Lens and camera parameters are derived using ground control points established for pre-deployment calibration flights. We compare the ASP stereo topo-bathymetry with lake depth estimates from an SfM-based commercial package (**Agisoft Metashape**) and topo-bathymetric estimates from our coincident ATM lidar data.

Instrument Calibration with Ground Control Points



Refraction Correction

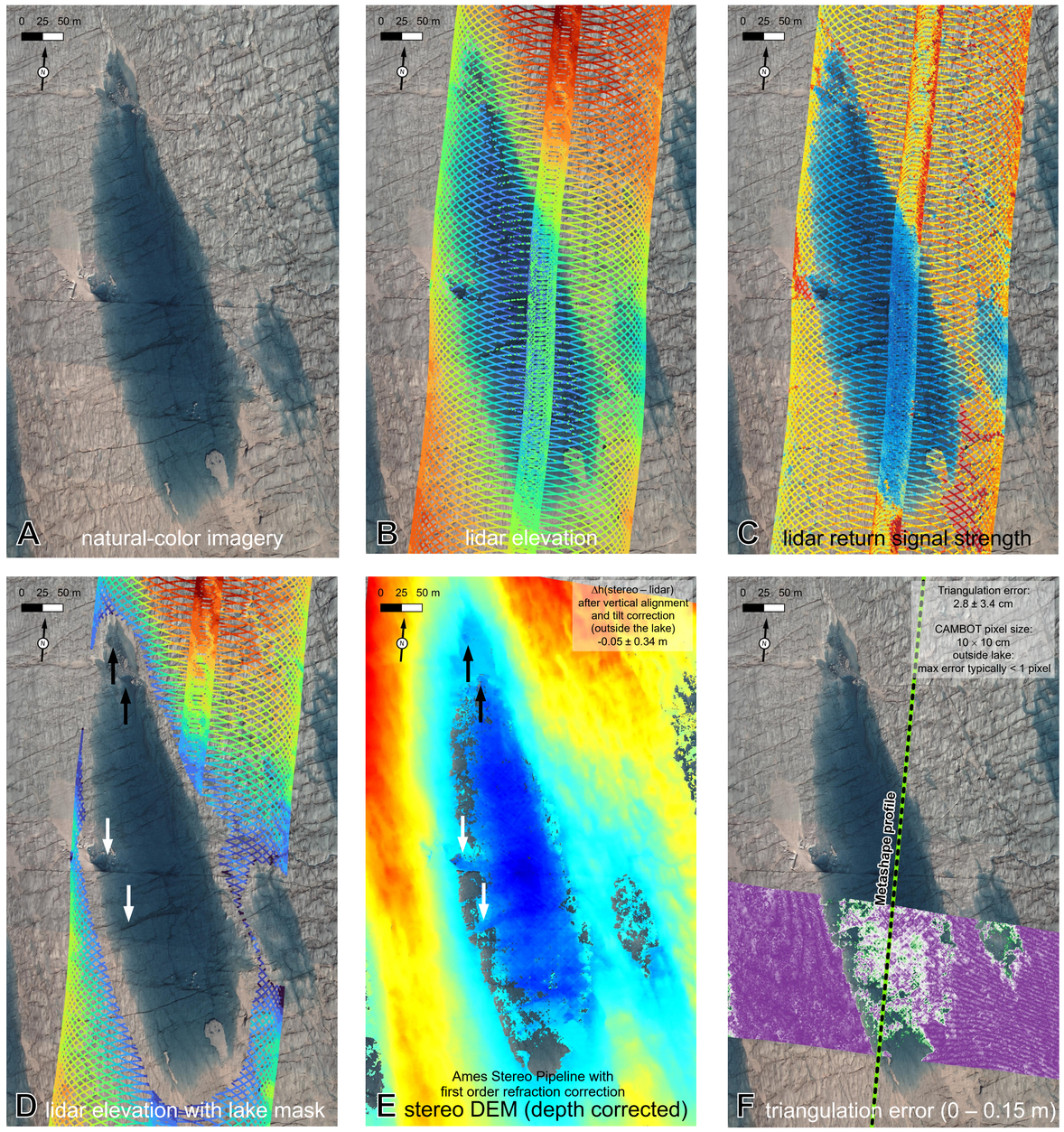


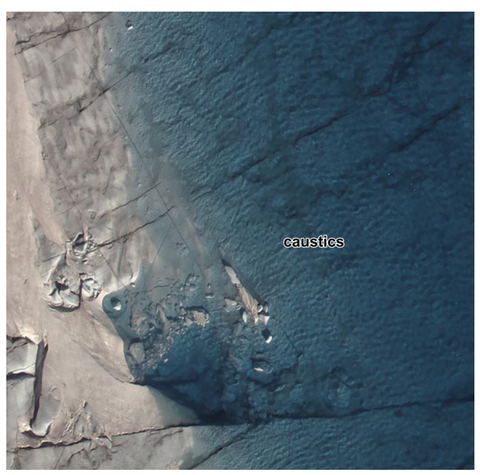
Challenges: Caustics and Lake Ice Cover

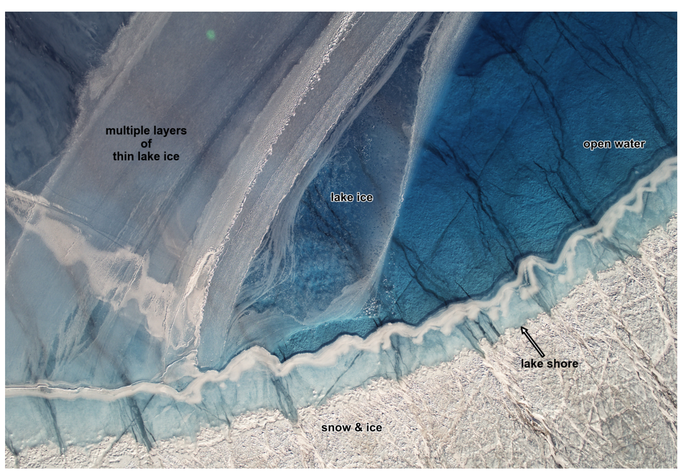
We find two main limitations for image-based topobathymetry estimates: thin **lake ice cover can obscure lake bottom texture** making lake bottom feature tracking between images impossible. The second limitation comes from caustics at the lake bottom caused by surface waves. These **caustics are not stationary features and can move thus changing the texture in the 0.5 secs between successive image acquisitions**.

Preliminary Results: Comparing SfM, ASP and LiDAR Bathymetry

We compare the ASP stereo topo-bathymetry with lake depth estimates from an SfM-based commercial package (Agisoft Metashape) and topo-bathymetric estimates from our coincident ATM lidar data.





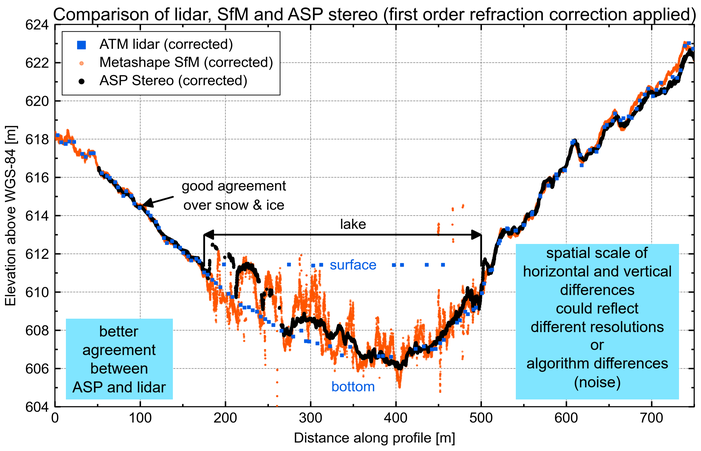


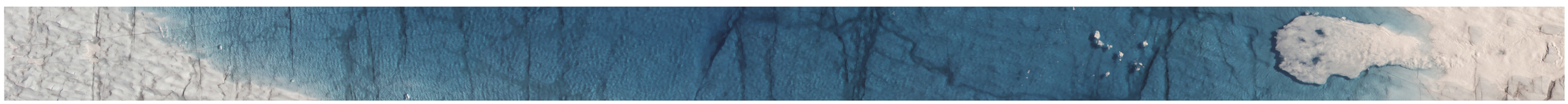
Ongoing Work

1) Evaluate different treatment of non-stationary features (noise) in SfM and stereo algorithms.
2) Use lake without caustics for comparison.

Consider other possible reasons for differences in lake bathymetry across methods:
• penetration of green laser light into ice at lake bottom? (difficult to pin down)
• lidar elevation bias caused by sloping lake bottom? (difficult to pin down)

Results may have broader impacts and might be relevant for future spaceborne missions.





Open Science Project Implementation

This project has been implemented within the spirit of NASA's Transform to Open Science (TOPS) program with the goal of transforming communities to an inclusive culture of open science.
An active GitHub repository with project information (including this poster), open-source code and tools is available at: https://github.com/mstudinger/ATM-SfM-Bathymetry