Space Lasers and the Pursuit of Flatness

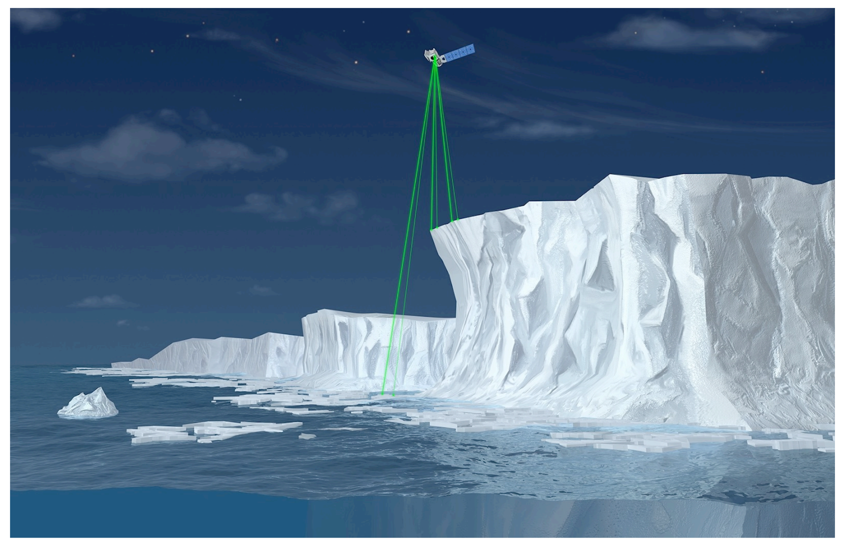
[1]Hannah Besso, Jarrid Nakata, & Julien Butwin
[1]Department of Chemical Engineering, Department of Civil and Environmental Engineering

CHEMICAL ENGINEERING
UNIVERSITY of WASHINGTON

Background

Most snow-dominated watersheds do not contain spatially or temporally representative measures of snowpack, thus leading to uncertain spring and summer streamflow predictions. In 2018, NASA launched a new spaceborne lidar instrument (ATLAS) aboard the satellite ICESat-2, which measures the elevation of the Earth's surface at high resolution (**Figure 1**). It was originally launched with the goal of measuring changes in mass of relatively flat icesheets at the poles, but it also provides an exciting opportunity to measure snow depth from space in understudied, snow-dominated watersheds.

However, previous work has shown that the accuracy of each point decreases with increased terrain slope and roughness (**Figure 2**).



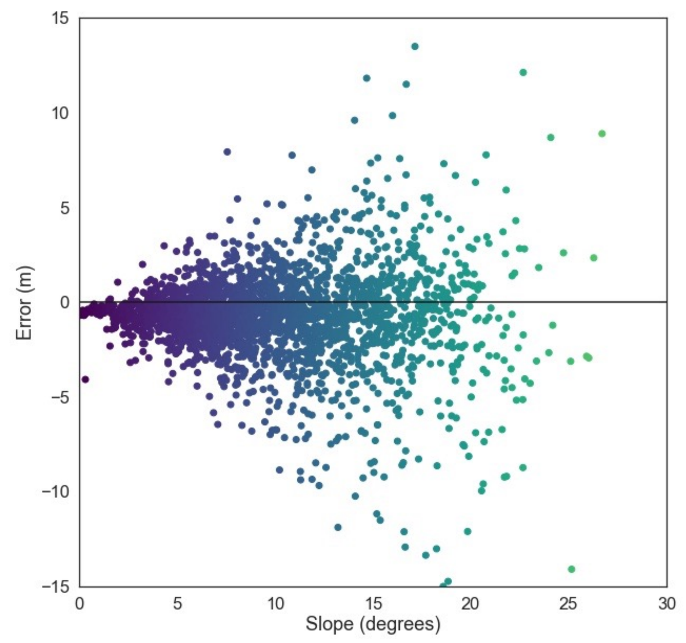
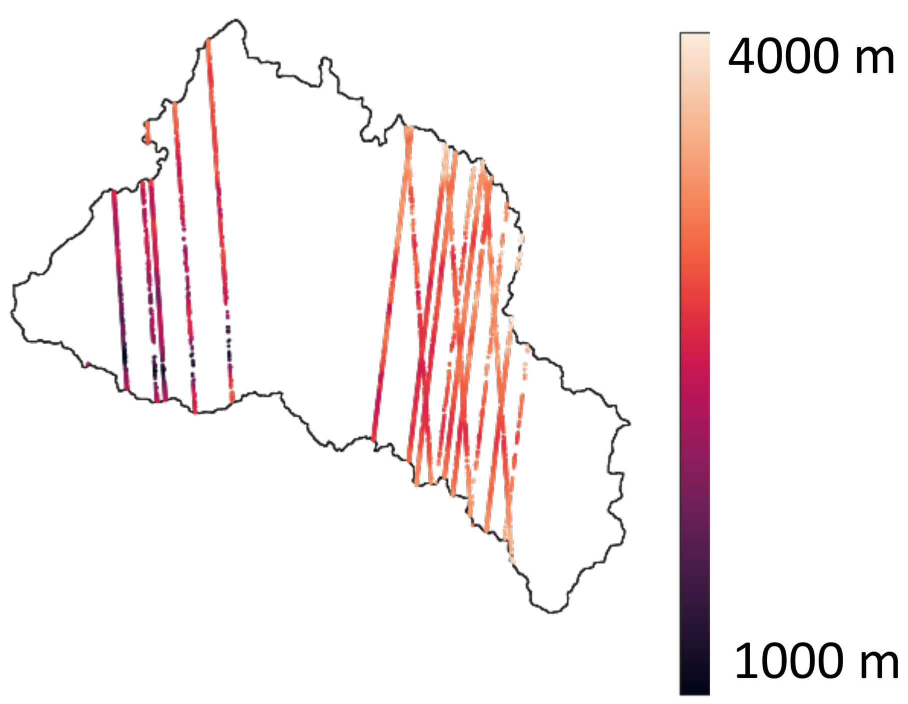


Figure 1. An illustration of the 6 lasers onboard ICESat-2 measuring ice height [1].
Figure 2. Differences between elevations of the Earth's surface between the new ICESat-2 satellite and high-resolution aerial LIDAR. Differences get much bigger in areas with greater terrain slope.

Aim 1: To use a moving window standard deviation analysis paired with slope analysis to best identify flatness below a certain threshold for an elevation image dataset

Aim 2: To develop tiling and stitching functions to reduce the size of the image being worked with if necessary

Aim 3: To maximize throughput by decreasing computing requirements of workflow, allowing analysis of larger regions.



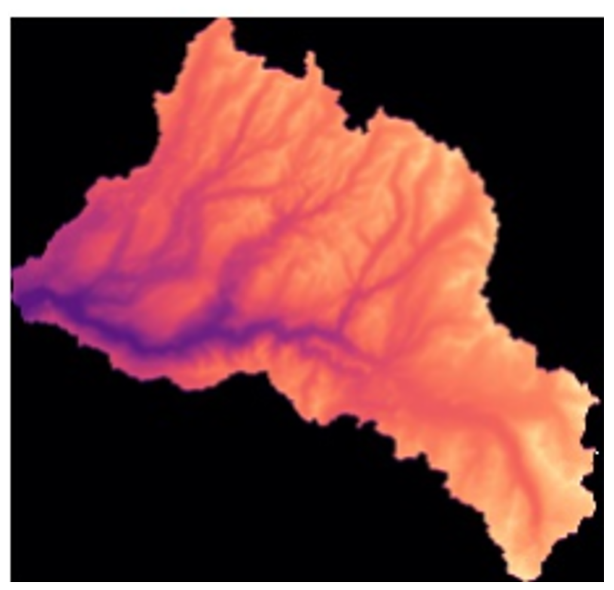


Figure 3 (Left). All of the ICESat-2 elevation data from the summer of 2020.
Figure 4 (Right). The Upper Tuolumne Watershed, with elevation displayed.

Slicing, Dicing, and Stitching

To reduce computing power, two functions were created. One slices a large image into uniform tiles of specified shape that could then be analyzed. The function returns a dictionary of locations as keys and images as values, in addition to the original locations of the tiles. The other function stitches those images back together after analysis using the preserved locations (**Figure 5**). A function was also developed that would pad an image to a desired shape and direction with NaN values but was deemed unnecessary for this project.

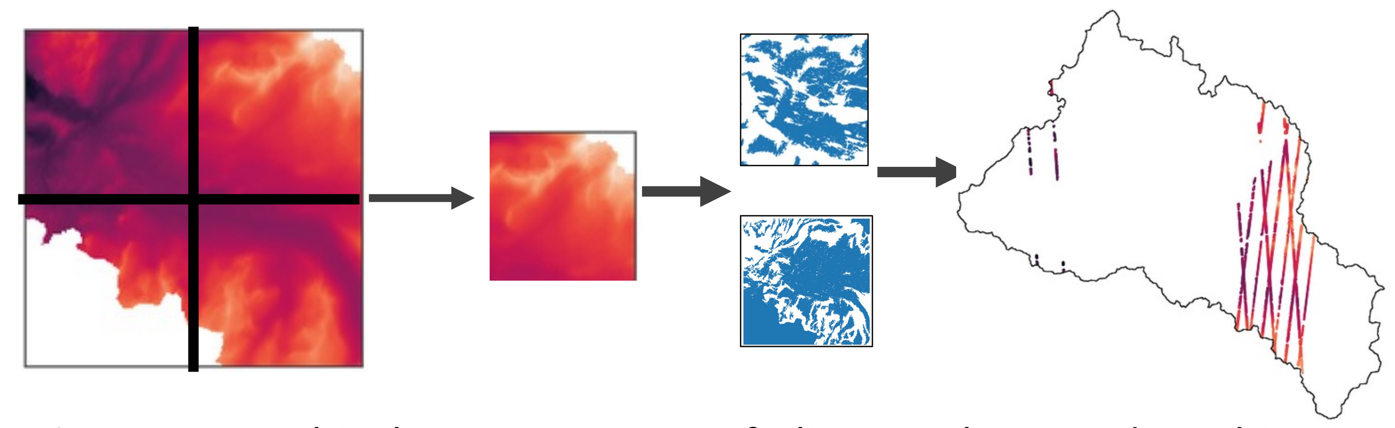
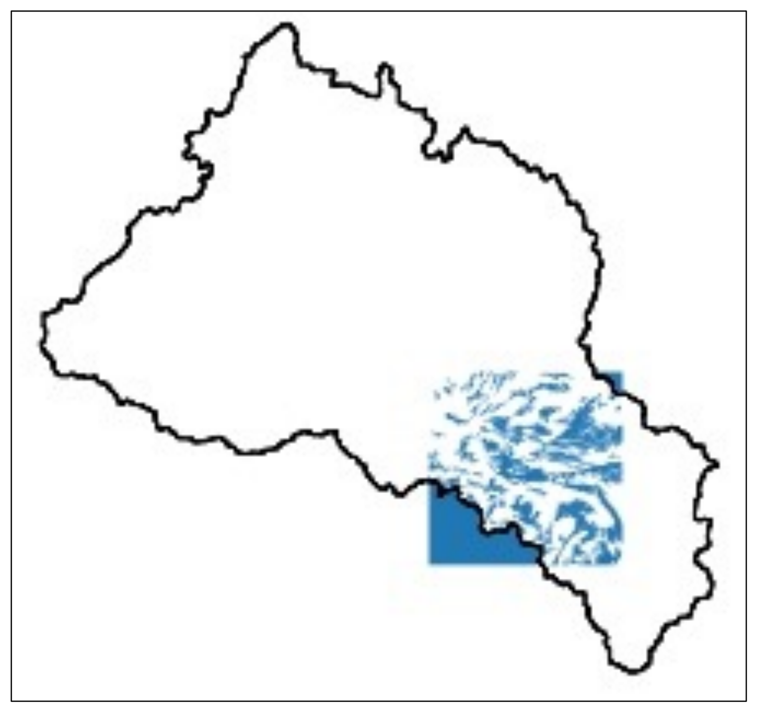


Figure 5: Graphical representation of tiling, analysis, and stitching process.

Results

Our chosen study area was not the entire Tuolumne Watershed, but in fact a small subset of the watershed chosen for increased probability of smooth, flat terrain. This bounded area is shown below in **Figure 6.**



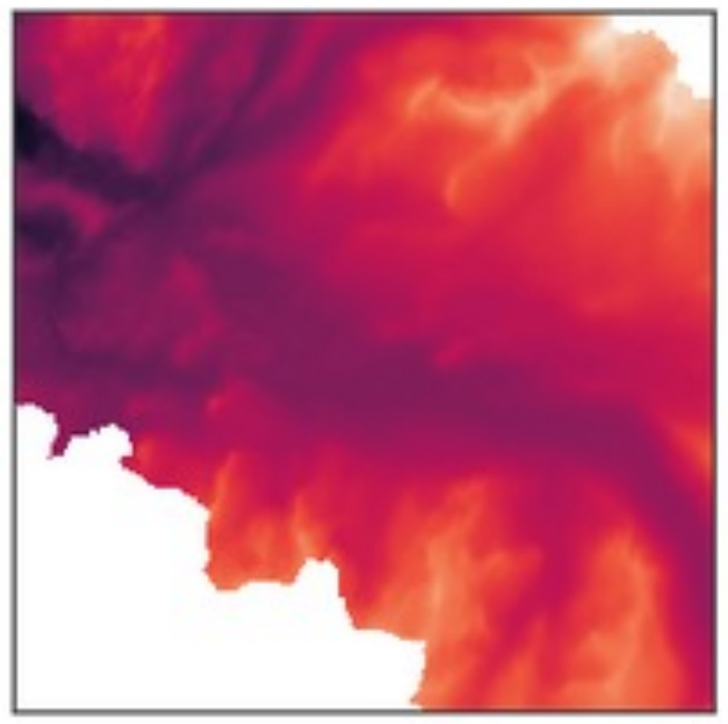
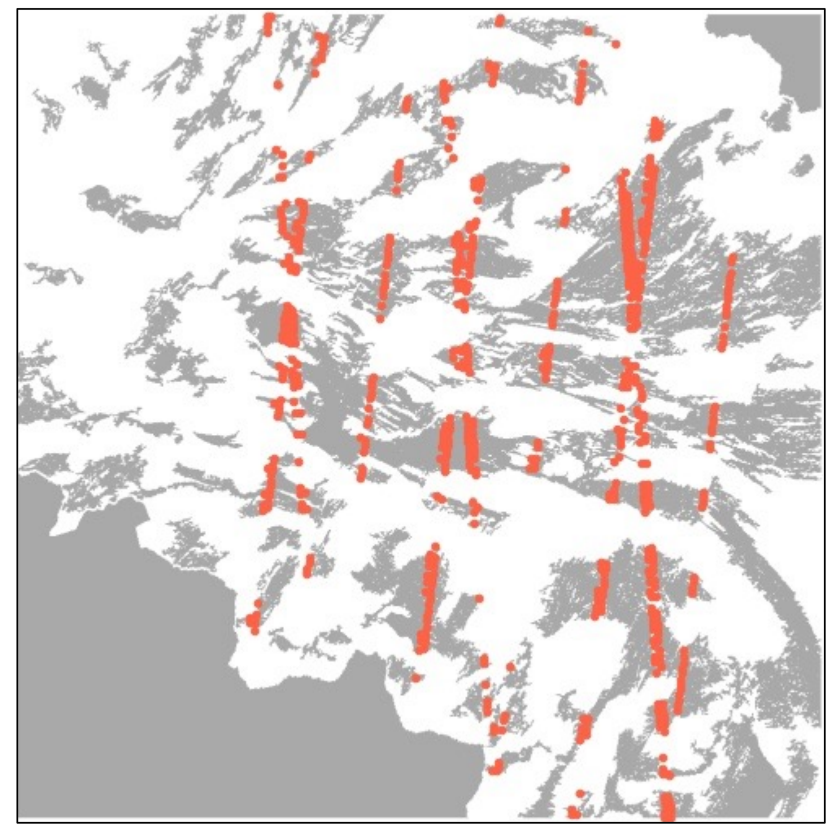


Figure 6 (Left). The entire Tuolumne watershed, with the chosen study area shown in the blue boxed region.
Figure 7 (Right). The watershed subset chosen as the study image.

Surface roughness was determined through standard deviation calculation over 12x12 pixel sections. Slope was determined using a pre-made function from the Geospatial Data Abstraction Library (GDAL).

Two masks were developed by setting a threshold for maximum terrain slope and surface roughness. The overlapping regions between these two masks indicate locations where ICESat-2 data will be least accurate. Quality data accuracy in single-mask regions may indicate too liberal a threshold. In such a scenario, the threshold should be decreased to produce a new mask.

Regions with low-quality data were removed by cropping the high surface roughness and high slope regions from the ICESat-2 tracks. As can be seen in **Figures 8 & 9,** the region in Tuolumne Meadows with accurate ICESat-2 data is limited.



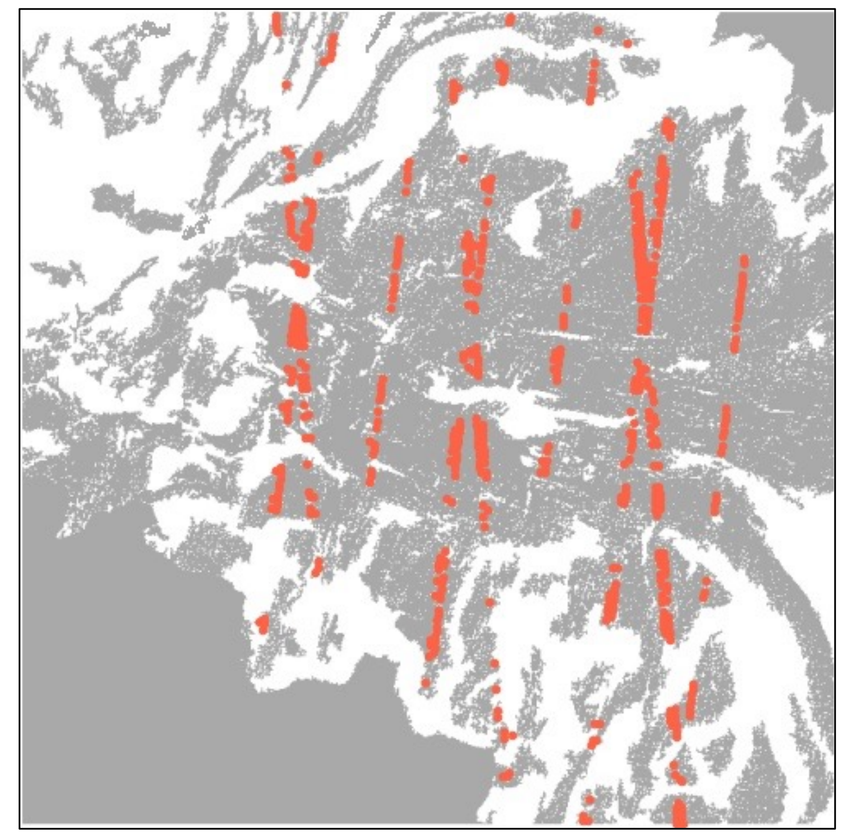


Figure 8 (Left). The thresholded standard deviation (mask in white) elevation map analysis marked by the tomato-red lines (ICESat-2 tracks).
Figure 9 (Right). The thresholded slope (mask in white) elevation map analysis marked by the tomato-red lines (ICESat-2 tracks).

Uncertainties: Due to time constraints we were unable to compare different slope functions fully. However, the algorithm selected for slope calculation was apparently robust to surface roughness according to documentation.

Future Direction: Moving forward, we would like to analyze the rest of the watershed to see if the subsection is representative of the watershed as a whole or if this is, in fact, a relatively flat region.
We would also like to make a function that will combine our slope and standard deviation masks for easier use.

References and Acknowledgements

[1] Nasa.(2020). ICESat-2 Illustration. Nasa.gov/press-release
[2] Perry, M., et al. (2021). gdaldem programs documentation.

We would like to thank David Shean and Chad Curtis for their guidance through this project.