Inter-campaign Bias and Data Noise Issues in the ICESat Satellite Series

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Background

As sea level rise becomes a more imminent threat, there exists a greater need to quantify and predict the climate models of the future using remote sensing technology.

Laser altimeter satellites periodically measure altitude across the globe and are valuable tools in estimating the changes in sea level.

ICESat (2003-2010) was the first of these satellites. It had a single instrument called GLAS (Geoscience Laser Altimeter System), which malfunctioned early on in the mission and caused data to be collected much less frequently; nevertheless, it had unprecedented accuracy and lasted longer than expected.

ICESat-2 launched in September 2018, with ATLAS (Advanced Topographic Laser Altimeter System). It functions by sending out 6 beams of photons, deliberately varying in strength, over a geographical footprint of about 17 meters.

Objectives

By the end of this project, we hoped to both be able to recommend locations for ICESat-2 researchers to analyze and prove the validity of ICESat-2 data based off of field data.
To narrow the areas to look at, we decided on three criteria for choosing locations: *rapid evolution, a presence of previous history/literature, and potentially something new to discover*.

Methods/Tools

We used various Python libraries to make our own tools and SRTM data to produce low-latitude elevation maps in QGIS.

Data Re-formatting:

We created programs with Python to extract columns and concatenate ICESat 1 and ICESat-2 csv data. These programs take command line input and accept regular expressions.

Plotting:

We designed tools for plotting 3D and 2D elevation maps. Both plotters process filepath inputs and create associated elevation scatter plots, using color to visualize more data.

Crossover Analysis:

ICESat-1 and 2 traversed the world on repeating, interweaving tracks, which meet at crossover points. Using linear regression and interpolation, we analyzed distribution of altitudes measured at given crossover points.

ICESat-1 had **inter-campaign bias** that exhibited associations with laser and orbital parameters; ICESat-2 presents issues surrounding **data noise.**

Possible sources of bias (largely in regards to ICESat-1) include ascending vs descending tracks, beta-angle, coelevation, laser energy, and rising sea-levels.

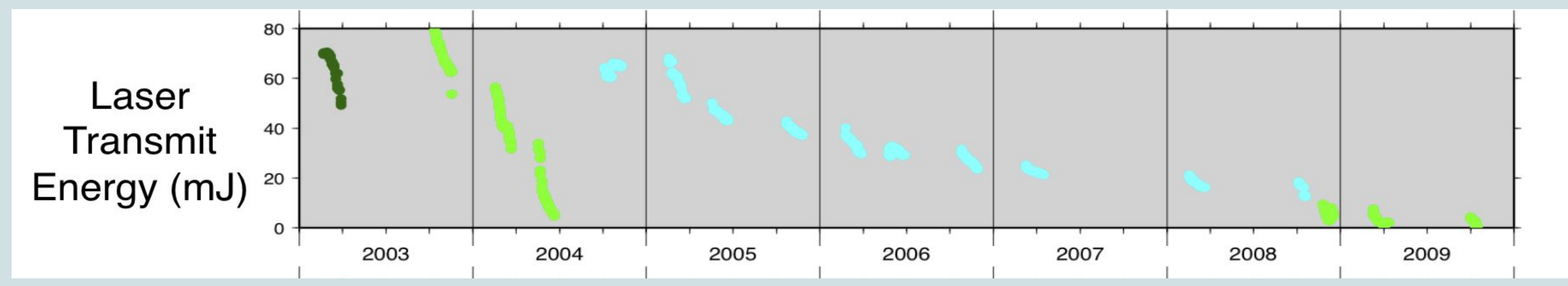
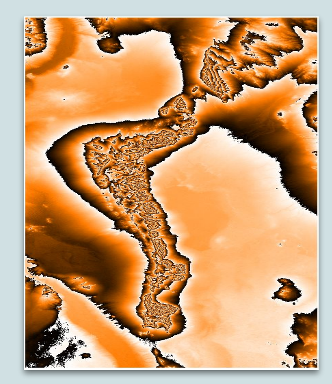


Figure 2: Example of discrepancies of laser energies between ICESat campaigns (credits, Dr. Urban CSR)

ICESat-2 has a massive and continuous data collection rate, causing it to avoid the basic issues of ICESat-1; the trade-off, however, is that there is significant noise in the data that presents issues when looking at canopies and high-aerosol areas, to the point that low quality returns lead to quasi-random determinations of elevation.

White Sands/Bastrop (Calibration)

- **White Sands, New Mexico**: site of the validation and calibration detector array for ICESat-1 due to it being positioned on the mission's reference groundtracks. We needed to observe land elevation data and White Sands was guaranteed to have this data.
- **Bastrop, Texas:** most destructive wildfire in Texas history in 2011. This was an ideal location to look at canopy and elevation differences.



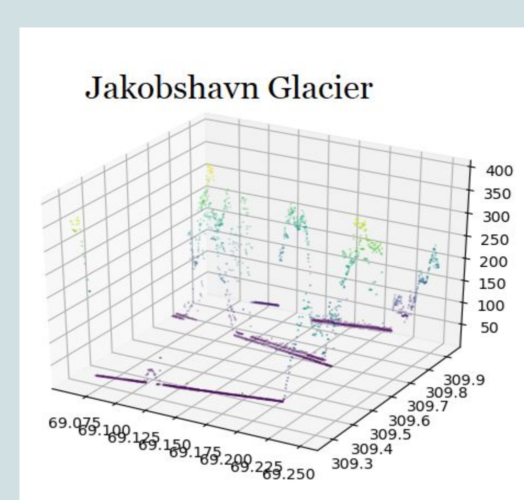
A shading scale is used for each location to depict varying elevations, where darker colors signify higher elevations and lighter ones signify lower ones.

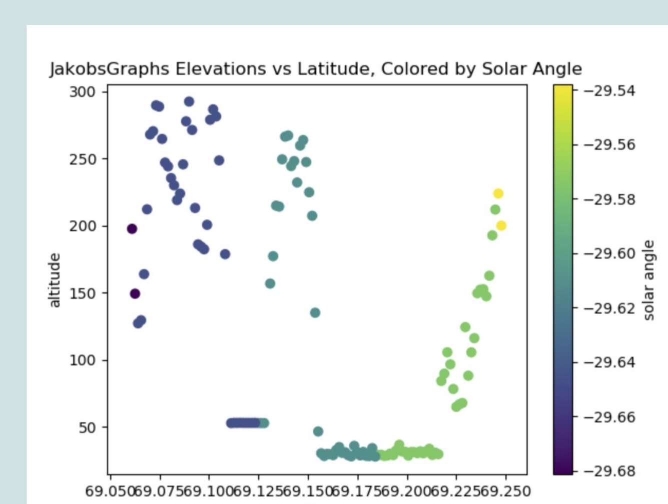
Image(**top**): White Sands, New Mexico.
Image(**bottom**): Bastrop, Texas.

Jakobshavn (Greenland)

Jakobshavn glacier in Greenland drains 6.5% of the Greenland ice sheet. It is the ice sheet's largest outlet glacier. Jakobshavn thickened substantially from 1991-97. However, after 1997, airborne laser altimeter data showed rapid thinning at peak rates reaching ~15 m/yr (Joughin et al.).

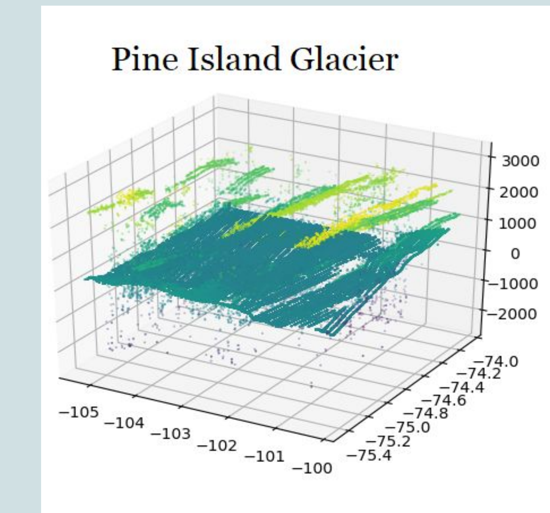
Image (**right**): Jakobshavn has multiple cracks that do not penetrate all the way through the ice, and are sensed as dips in the glacier, as exemplified by the graph on the right.



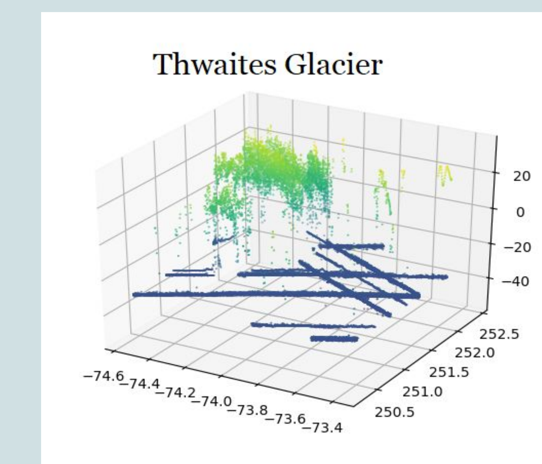


Pine Island & Thwaites (Antarctica)

Pine Island Glacier drains 69 cubic kilometers of ice each year from about 10% of the West Antarctic Ice Sheet. **Thwaites Glacier** is particularly vulnerable to warming temperatures, as it is considered one of the most unstable on the continent.



Analysis of satellite radar altimetry data and satellite radar interferometry data showed that the grounding line of Thwaites has retreated rapidly and that Pine Island glacier mass balance might well be negative (Rignot, 2001).



Future Recommendations

- A radar system that can do cloud penetrating measurements and give data in tandem with ICESat-2
- Reducing the pole hole further by changing the inclination
- Collecting less data in ICESat-2 to reduce noise and produce more precise data

Acknowledgements/Bibliography

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