Research Design

1. Data Sources

The primary data source for the project is described in Csatho, et al. (2014), but including updated data through 2017. The data is a collection of LIDAR data obtained from several NASA satellite and overflight missions to collection ice sheet elevation data. The raw data has been processed to produce around 150,000 time series of elevation changes over time. Some of the time series have upwards of 50 observations over the span of around 15 years, while others are shorter, having observations from only more recent missions. Among the ways that the data has been processed is to attempt to account for seasonal changes. An ice sheet model has been used to remove those seasonal effects in order to tease out the dynamic ice loss relative to 2006 (Csatho, Schenk, Veen, & Angelen, 2014).

Supporting data for the analysis will come from the PROMICE project mapping ice sheet velocities over time (Solgaard, et al., 2021) and digital elevation maps (Bamber, Ekholm, & Krabill, 2001). In addition, data on Greenland's catchment basins will also be incorporated (Mouginot & Rignot, 2019).

2. Source Evaluation

The primary data set of dynamic ice loss from Csatho, et al. (2014) is a high-quality data set collected from NASA missions. The processing of the data has been published in a peer reviewed journal. Some potential areas for caution with this data set lie in the error size at elevation as the LIDAR methods used are more problematic on steep rather than shallow slopes. In addition, the removal of the seasonal patterns from ice sheet models rather than observed weather data may be introduce its own errors (Csatho, Schenk, Veen, & Angelen, 2014). However, presumably the model has been tested against past observations, and it is not being used in this context to predict future seasonal patterns, only model past ones. Comparing the data in this data set to other digital elevation models of the same area can help to account for any possible uncertainty arising here.

Inland regions have the fewest observations since they are the most difficult to survey in person, and so these are the regions that also have the shortest time series along with potentially largest errors. It may be necessary to limit the analysis to the most recent years in the data set in order to provide the best error estimates.

3. Data Collection

One of the challenges of the dynamic ice loss data set is that it is compiled from multiple missions and then combined in a single data set. This can also be a strength of the data, but it does present certain challenges. The technology changed over time, meaning that older data may have larger errors than more recent data. Older data was confined more to the coasts to monitor glacial retreats, so inland data covers a shorter period of time. Some of the missions overlapped, or had breaks in them making the time series irregular, which makes analyzing the data more challenging with traditional time series methods (Csatho, Schenk, Veen, & Angelen, 2014).

4. Research Method

Individual time series can be analyzed with a variety of nonlinear regression methods including polynomial regression, LOESS regression, spline regression and Gaussian process regression. Given the possible autocorrelation of the data, Gaussian process regression may be the best choice here. For the spatial domain, a LOESS two-variable model is possible using a package in R, however, to get a full spatial-temporal model, Gaussian process regression remains the best choice. The difficulty here is that Gaussian process regression (kriging) is computationally intensive and so breaking up the data space into smaller chunks may be necessary to model all the variables simultaneously. Another possible solution is to employ spatial sampling methods. Both methods can be employed in order to compare the results.

In addition to modeling the dynamic ice loss, models of the elevations and errors included in the same data set will be done. The results of the elevation model can be compared to other elevation models in order to assess their quality and change over time. The dynamic ice loss model can be adjusted to the same resolution as the ice velocity model, and a correlation analysis will be conducted to assess the relationship between ice loss and ice flow rate. Overlaying the data on the catchment basins may also provide additional insights into the impact on dynamic ice loss.

5. Visualizing Research

In order to visualize the result, several maps of the analysis can be created. A map of Greenland showing the locations of the time series included in the analysis. Maps of the dynamic ice loss model for a selection of years, maps of the ice velocity model for the same years, maps of elevation and error for comparison.

In addition to the maps, graphs of individual time series models may also be included for a more localized analysis of the difference between coastal data and interior time series. Since the ice sheet velocity models are also available over an extended period of time, it may be worth extracting time series for similar locations for direct comparison.

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