Assessing the Accuracy of ICESat-2 and CryoSat-2 Sea Ice Thickness Using SIDEx In Situ Data

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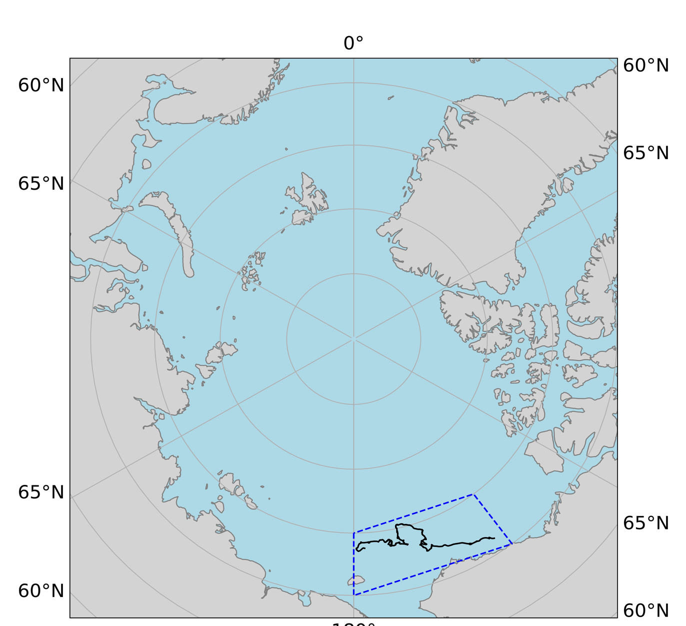
Abstract

The Arctic Sea ice plays a crucial climate role by influencing the Earth's energy balance. Its highly reflective properties block incoming solar radiation which prevents the absorption of sunlight and maintains ocean water temperatures. In this study, we aim to assess the accuracy of the ICESat-2 (IS2) and CryoSat-2 (CS2) sea ice thickness products by comparing them to in-situ data provided by the SIDEx Experiment. The IS2 and CS2 satellites have been taking measurements to determine sea ice parameters in the Arctic region since their respective launches. For IS2, we make use of its Level-4 Monthly Gridded Sea Ice Thickness Product (excluding May, June, July, and August) and for CS2 we utilize its Level-4 Sea Ice Elevation, Freeboard, and Thickness Product (excluding June, July, August, and September). With both products, the sea ice thickness is analyzed for each year available. To compare the data from the two satellites to the SIDEx Experiment data, we subset the grids to include data from the same area as the SIDEx Experiment data. To compare the satellite and SIDEx data, we calculated the mean sea ice thickness and their growth rates and compared it with the SIDEx Ice Mass Balance (IMB) buoy data. The agreement between the satellites and IMB data can help assess the accuracy of the IS2 and CS2 gridded sea ice thickness products.

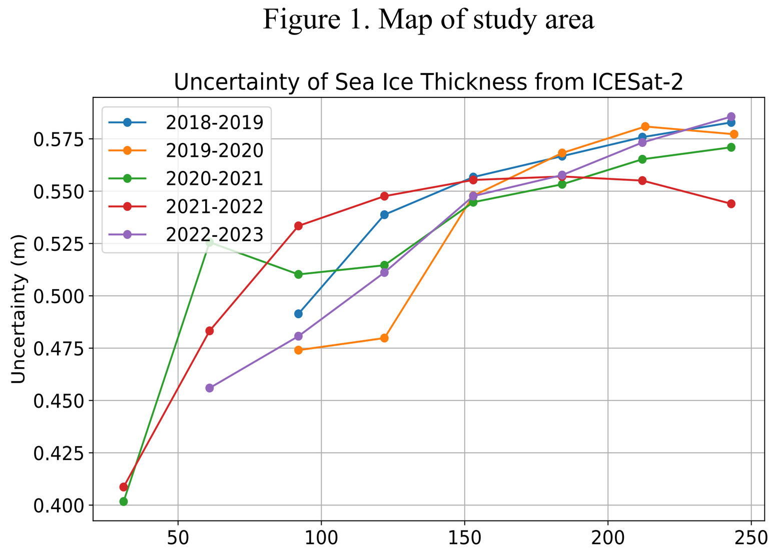
Background

- Sea ice plays a big role in maintaining the global temperature, as well as maintaining the ocean's temperature.
- Currently, IS2 and CS2 are being used in some studies to estimate Arctic snow depth.
- The goal of this project is to assess the accuracy of two satellites, IS2 and CS2 in measuring Arctic sea ice thickness.



This figure shows the track of the SIDEx IMB data (the black line). The grid shows the area that the gridded IS2 and gridded CS2 is constrained to. This allows for a more accurate interpretation of the IS2 and CS2 data in comparison to the IMB data.

Figure 1. Map of study area



This figure shows the uncertainties for the sea ice thickness from IS2. The uncertainties are fairly consistent between the years and generally increase as ice gets thicker in the winter months then begins to melt as summer approaches.

Figure 2. Uncertainties from IS2

Data

Three different products are used for this analysis: ICESat-2, CryoSat-2, and the SIDEx Ice Mass Balance buoys (IMB).

ICESat-2 (IS2):

- The IS2 satellite, using LiDAR, can detect the air-snow interface of the sea ice.
- We make use of the monthly gridded data (the sea ice thickness, and the sea ice thickness uncertainty) available spanning from 2018-2023.

CryoSat-2 (CS2):

- The CS2 satellite, using radar, satellite can detect the snow-ice interface of the sea ice.
- We make use of the monthly gridded data (sea ice thickness) available spanning from 2014-2024.

SIDEx IMB:

- The Sea Ice Dynamic Experiment, or SIDEx, uses Ice Mass Balance buoys (IMB) with thermistor chains to take precise measurements of Arctic sea ice thickness.
- The IMBs provided us with in-situ data that could be used to compare to the measurements taken with IS2 and CS2.

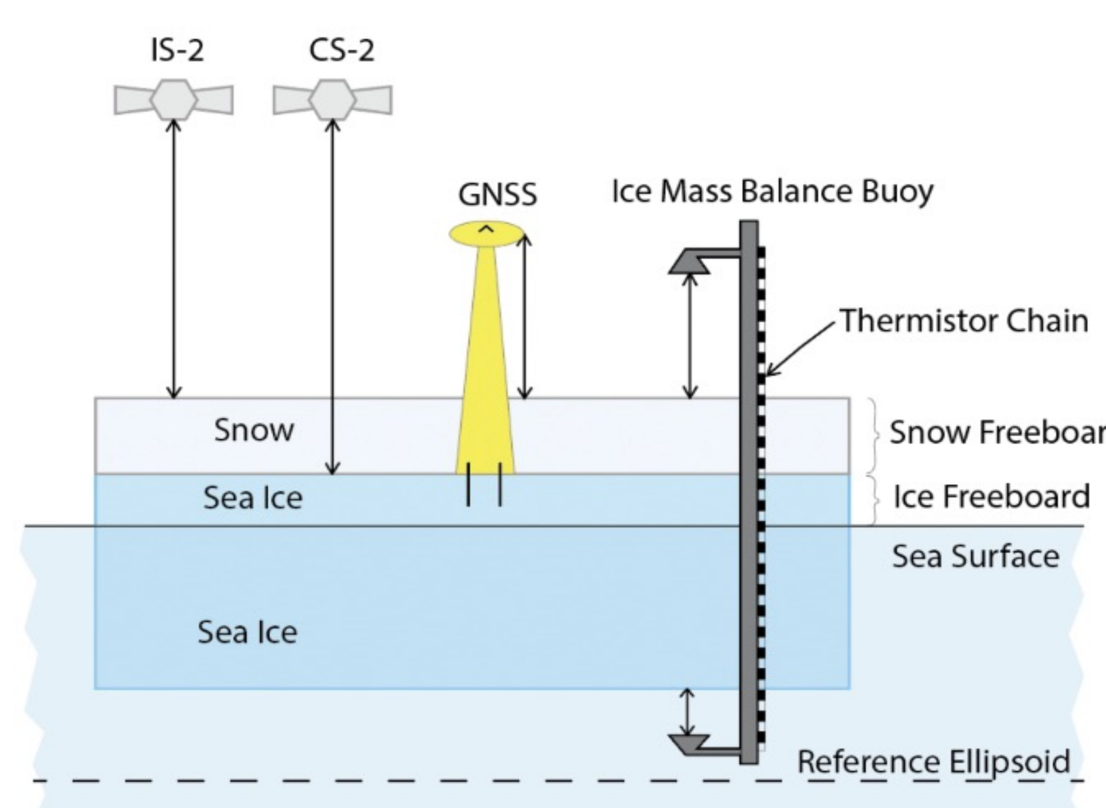


Figure 3. Diagram of the three products used: IS2, CS2, and SIDEx IMB

Methods

- A subset of both the gridded IS2 and CS2 data is taken to cover only the small region where the SIDEx IMB data is available.
- CS2 and IS2 ice thickness data are separated by season and plotted.
- A weighted mean and weighted offset is calculated for both the IS2 and CS2 data.
- The weighted mean and weighted offset are plotted against SIDEx IMB data to compare the growth rates.

Results

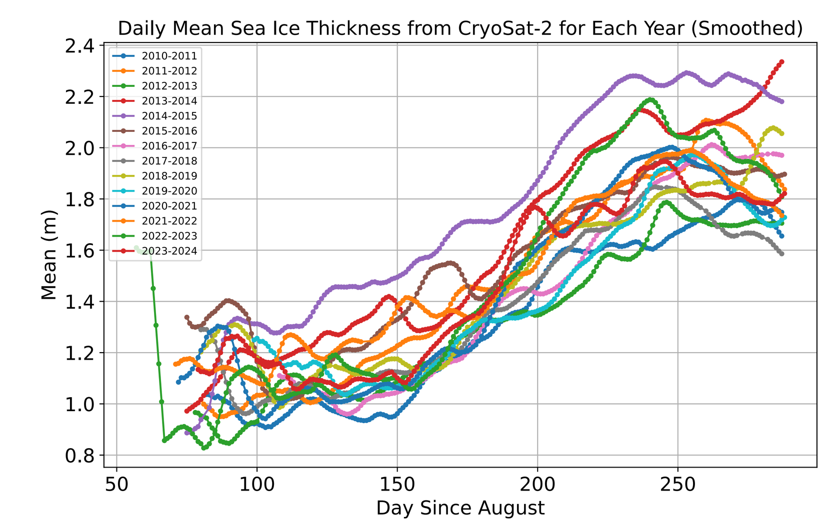


Figure 4. Daily Mean Sea Ice Thickness from the CS2 satellite in meters.

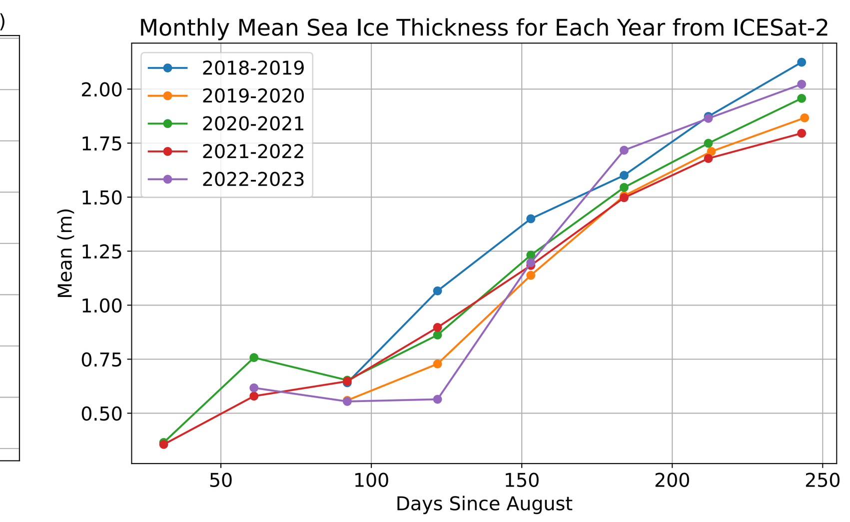


Figure 5. Monthly Mean Sea Ice Thickness from the IS2 satellite in meters.

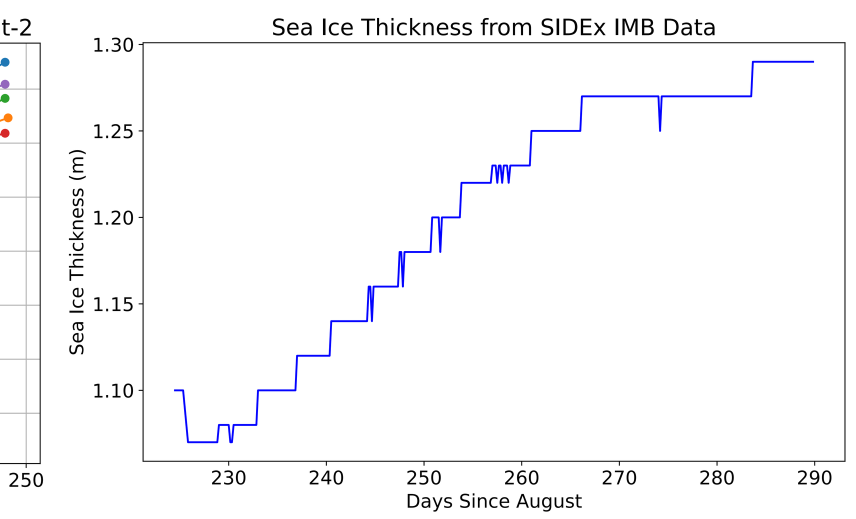


Figure 6. Sea Ice Thickness from the SIDEx IMB buoy in meters.

In these three figures the sea ice thickness for CS2, IS2, and IMB are shown for the available years (CS2 spans from 2014-2024, IS2 spans from 2018-2023, and IMB is from 2020-2021). In the three plots, each shows a general increase in sea ice thickness over the time period. However, there is more variation in the CS2 plot compared to the IS2 plot.

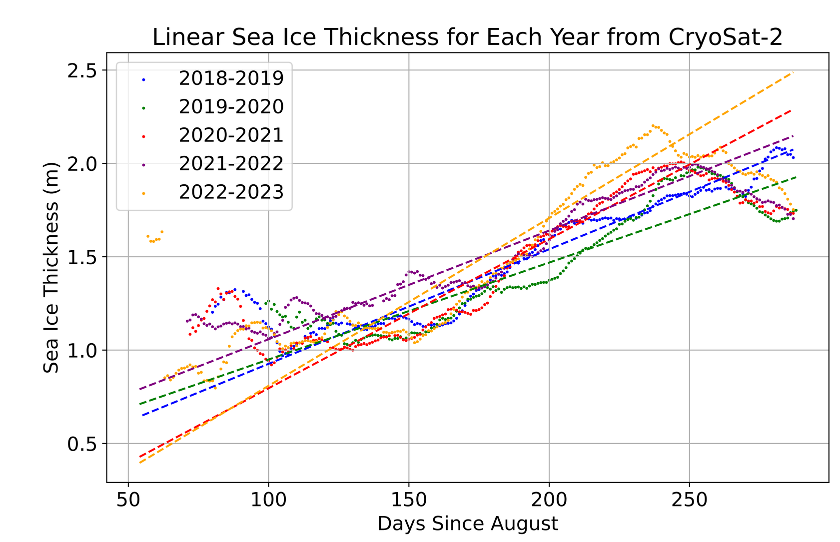


Figure 7. Linearization of the daily mean thickness from the CS2 Satellite.

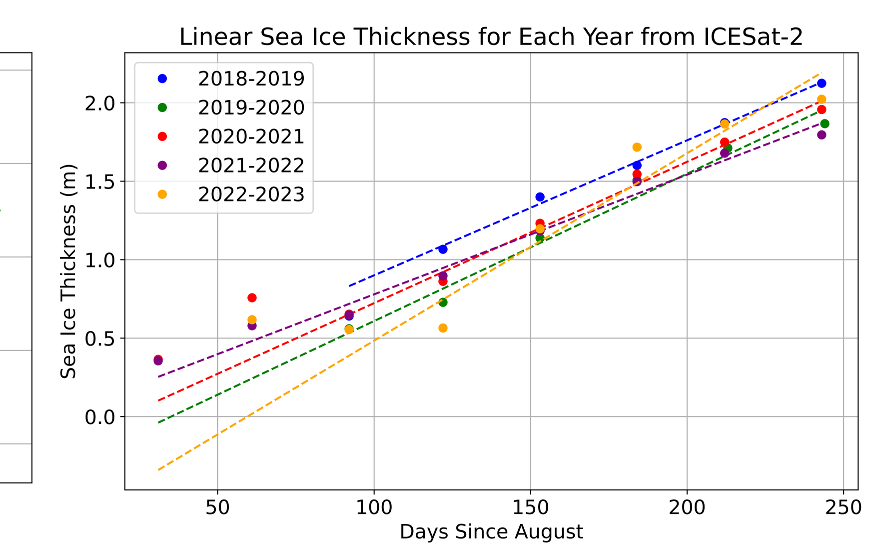


Figure 8. Linearization of the daily mean thickness from the IS2 Satellite.

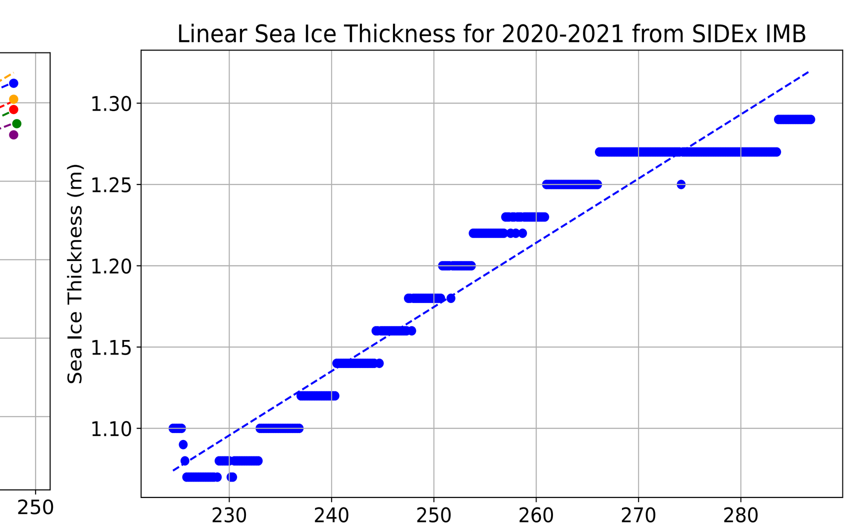


Figure 9. Linearization of the daily sea ice thickness from the SIDEx IMB buoy.

These three figures show the linearization of the sea ice thickness from CS2, IS2 and SIDEx IMB. Each has a general upward trend despite some points of decrease at certain times.

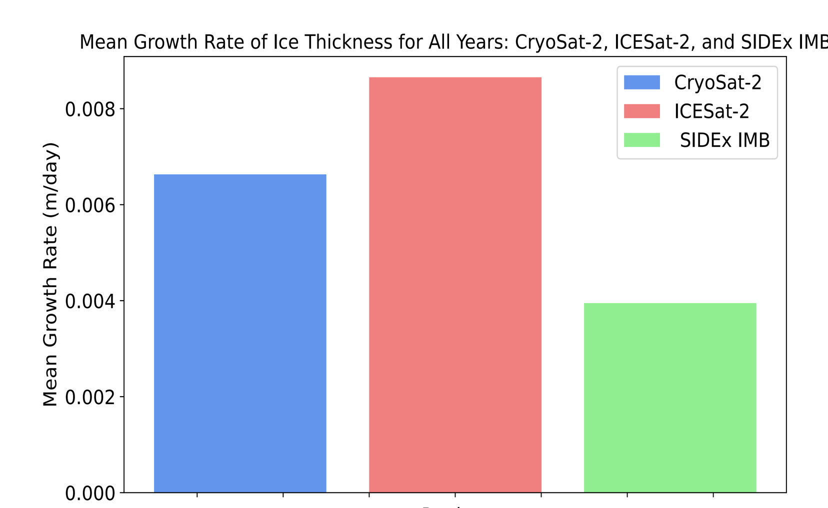


Figure 10. Comparison of the mean growth rate for all the available years of CS2 and IS2 data compared to the growth rate from the SIDEx IMB buoy.

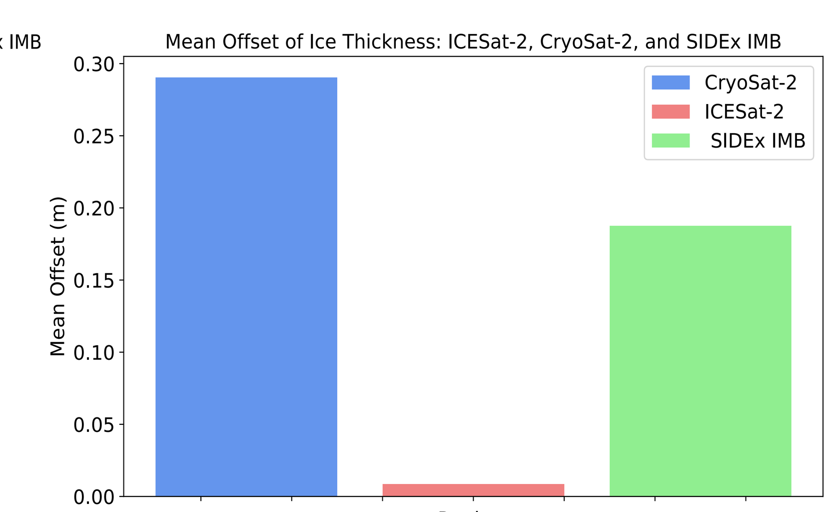


Figure 11. Comparison of the mean offset for all the available years of CS2 and IS2 data compared to the offset from the SIDEx IMB buoy.

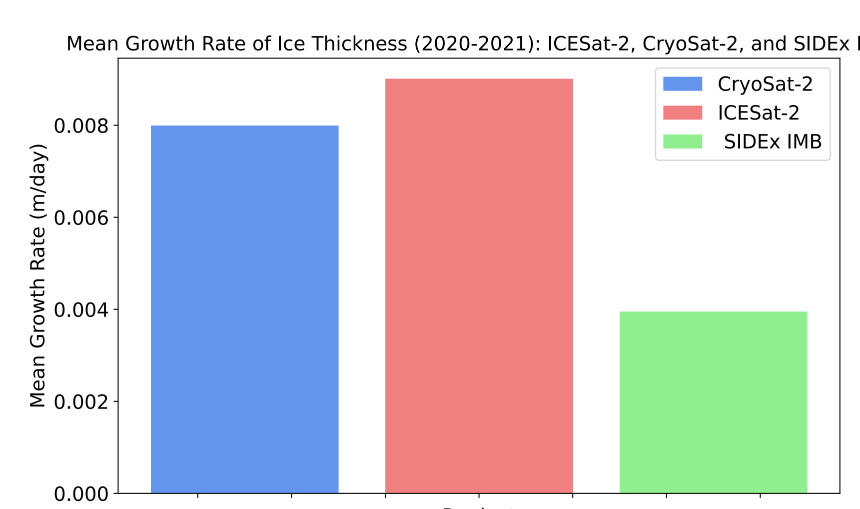


Figure 12. Comparison of the mean growth rate for only the years 2020-2021 from CS2 and IS2 data compared to the growth rate from the same years from the SIDEx IMB buoy.

These first figures show the weighted mean of the rate of growth and the weighted mean of the offset from all the years of available data. The weighted mean of the rate of growth is fairly similar, however, the weighted mean of the offset is much less for IS2 implying less variability. The third figure shows the growth rate only for the years 2020-2021 which are the only years that there is corresponding SIDEx IMB data. In this figure, both CS2 and IS2 overestimated the growth rate of the ice.

Summary

There are errors beyond the predetermined uncertainties in both CS2 and IS2 measurements of ice thickness. This could have an impact of current and future studies using this data to estimate sea ice thickness in the Arctic. Both the IS2 and CS2 satellites overestimate the sea ice growth rate compared to the in-situ data from the SIDEx IMB buoys, however further tests need to be ran to assess the extent of these errors.

Acknowledgements: This study was funded by the National Science Foundation (NSF) Research Opportunities for Undergraduates (REU) program at MIT Haystack Observatory award numbers **2243909**
This work is supported under the Office of Naval Research award N000141912605