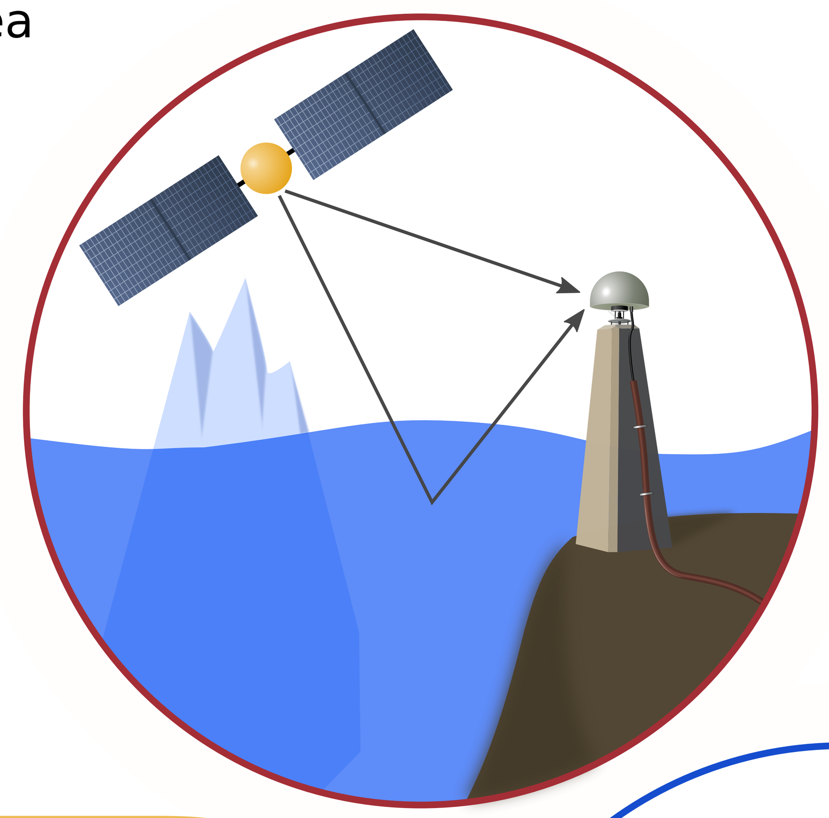
Sea level in Thule measured with tide gauge, GNSS-IR and Satellite Altimetry

Trine S. Dahl-Jensen, Shfaqat Abbas Khan, Simon D.P. Williams, Ole B. Andersen and Carsten A. Ludwigsen

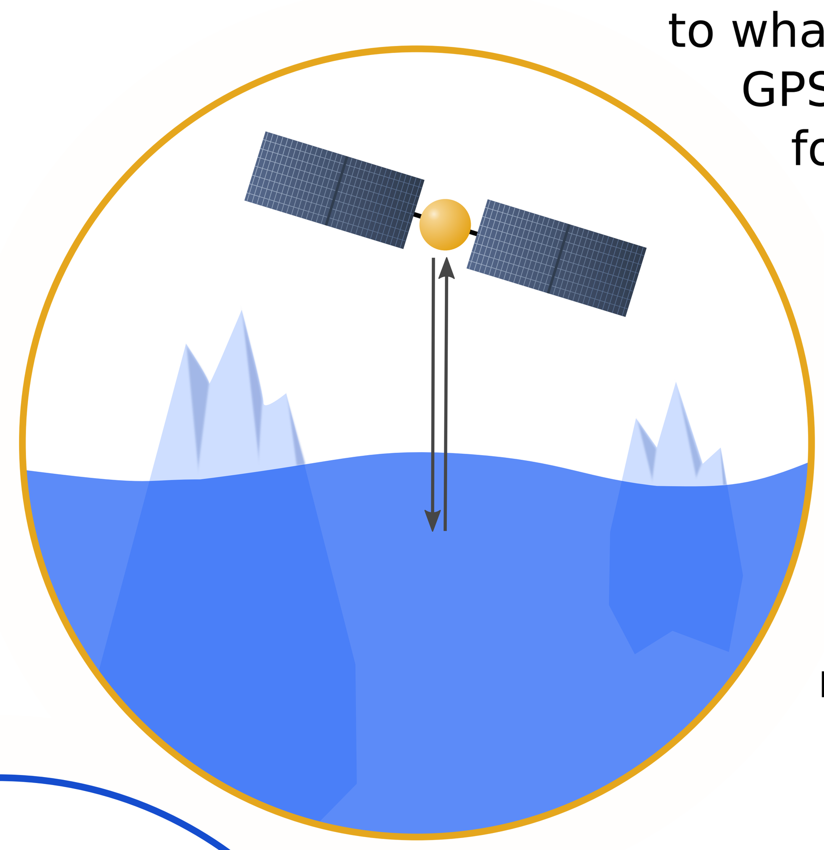
1. Introduction

Recent studies show that relative sea level can be measured by GNSS interferometric reflectometry (GNSS-IR) a using geodetic GPS. Here we will compare annual measurements of sea level in Thule, Greenland, from GNSS-IR, tide gauge (TG) and satellite altimetry. The sea level change is compared with Sea Surface Temperatures (SSTs) and modeled gravitational sea level variations.



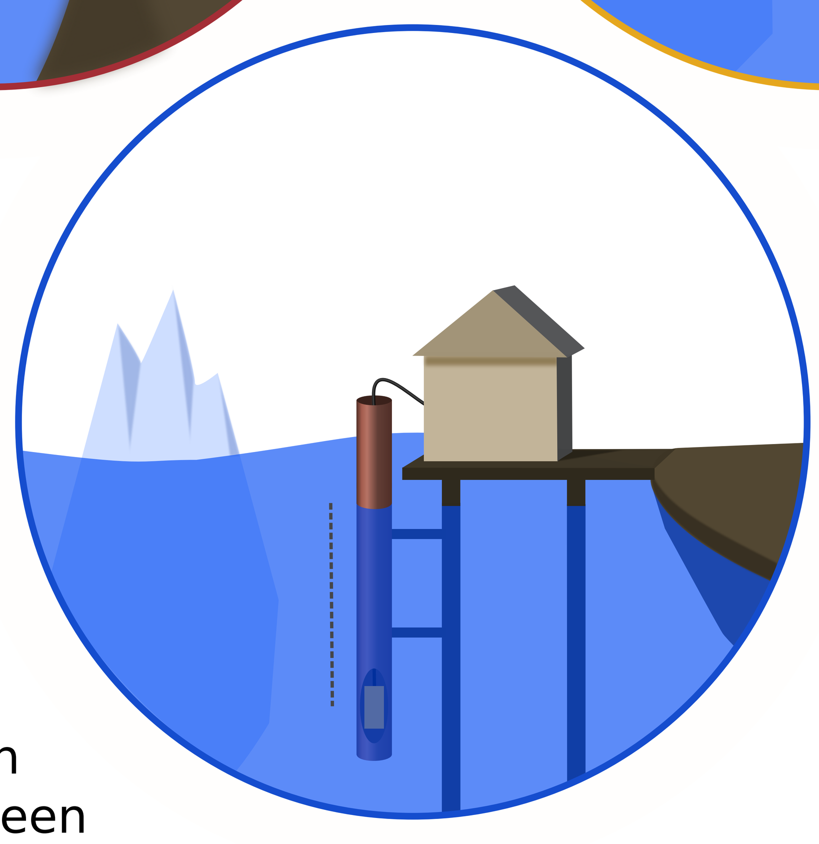
2. Data and method

Thule is the only place in Greenland where we can directly compare inter annual changes in sea level measured with a TG and using GNSS interferometric reflectometry (GNSS-IR). We use the GNET GPS station in Thule which is is located approximately 60 m from the water.
The tide gauge (TG) at Thule is locates less that 1.5 km from the GPS station and measures sea level every 5 minutes. Unfortunately, the tide gauge in Thule is not datum controlled.
Sea level is extracted from the GPS station using the method similar to what is described in [1].
GPS positions are used to correct GNSS-IR and TG for uplift for comparison with altimetry.
Cryosat-2 data is used to extract sea level from altimetry.
Average Sea Surface Temperatures (SSTs) are calculated from daily HadISST1 SSTs over an area of approx. 70,000 km^2.
Before calculating annual average sea levels, ocean tides and annual and biannual signals are modeled and removed.



3. Results

The annual average sea level anomaly from each method is shown in figure 1. GNSS and TG results are corrected for vertical land movement measured with GPS for comparison with altimetry. The estimated uncertainty on the yearly average sea level using TG and GNSS varies between 4 and 6 mm. In contrast, it is between 23 and 31 mm for the altimetry. Though the three time series show similar variations they differ more than would be expected from the estimated errors. This is not unexpected between altimetry and the other methods.
The significant deviations between TG and GNSS may partly be due to the TG not being datum controlled. Furthermore, sea ice during winter will result in differences in the measurements using the two methods. If we compare daily values of sea level from GNSS and TG the linear correlation between the two is 0.88.



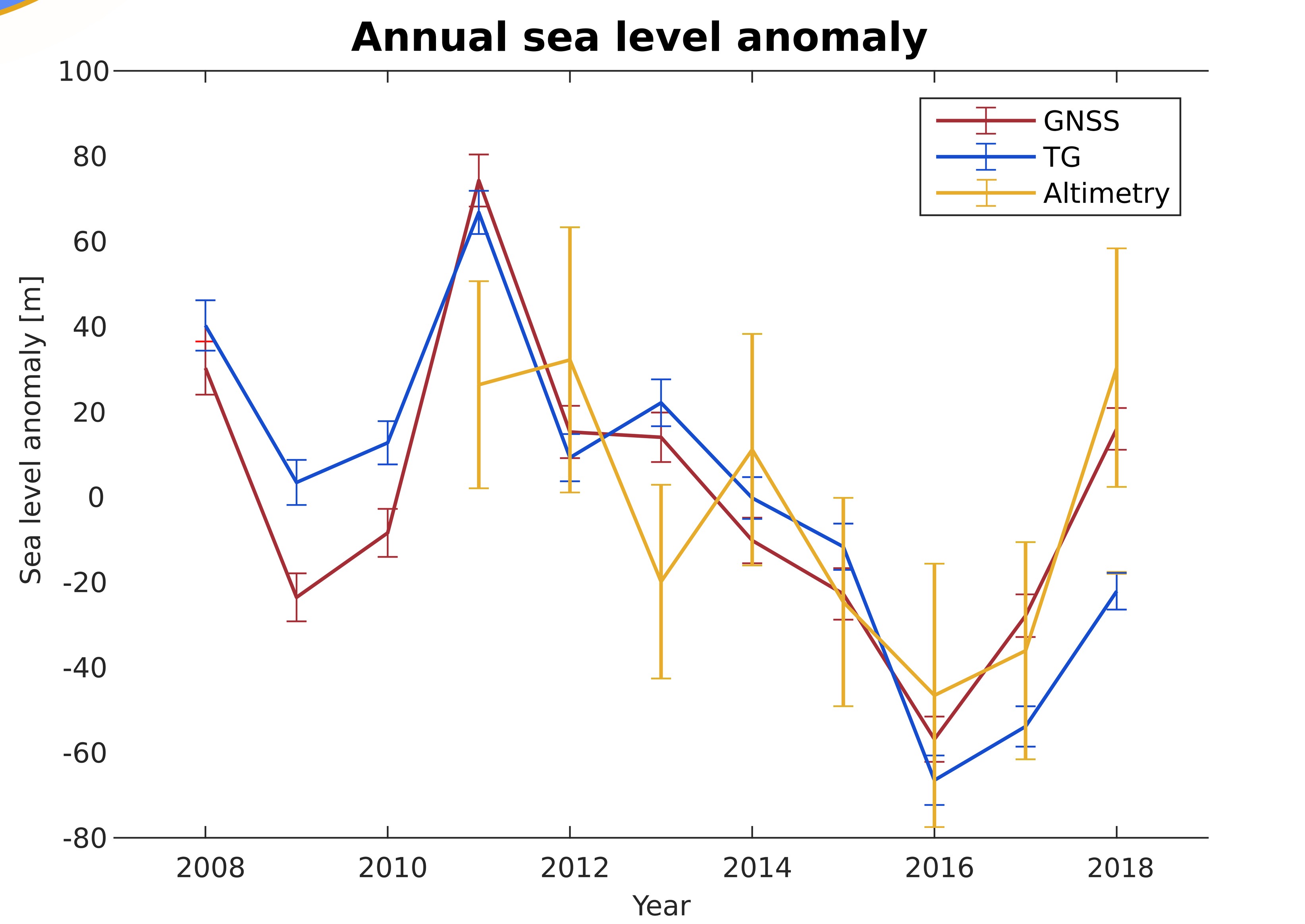


Figure 1: Sea level measured using GNSS-IR, tide gauge and Altimetry

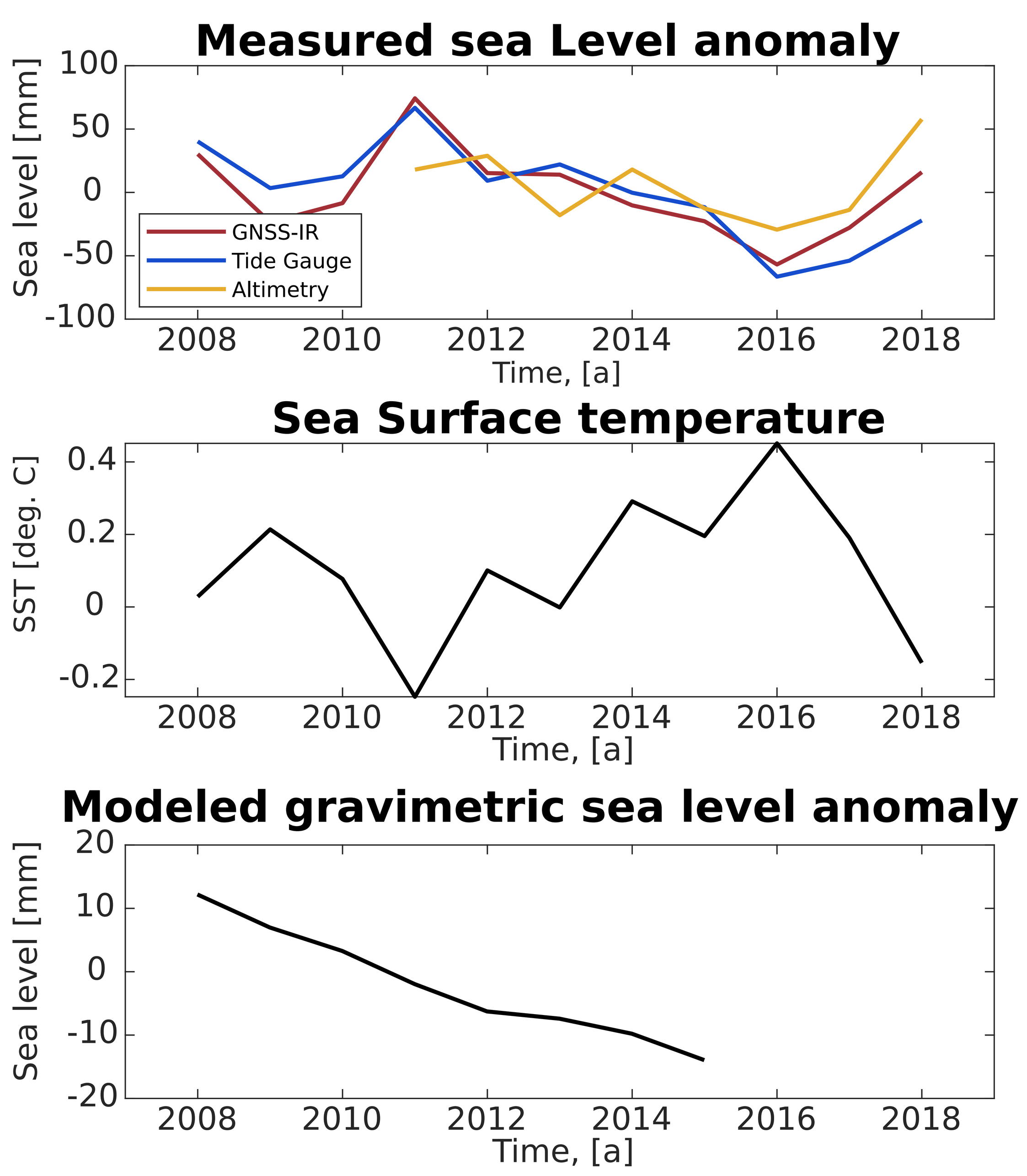


Figure 2: Sea level, SST and gravimetric sea level anomaly.

Figure 2 shows the measured sea level change along with Sea Surface Temperature (SST) and modeled gravimetric sea level rise.
The trend in the modeled gravimetric sea level is -4 mm/yr, while the linear trend in the yearly average sea level measured by GNSS and TG is -4 and -5 mm/yr, respectively. The trend in SST is negligible compared to the yearly variations.

If the trend is removed from the data the gravitational sea level change is an order of magnitude smaller than the measured sea level and thus cannot explain the variations.
Comparing SST with the measured sea level we get a correlation between SST and GNSS-IR and TG sea levels of -0.9 and -0.8.

4. Conclusion

Sea level measured with GNSS and TG show comparable interannual variations though deviations are larger that would be expected from error estimates.

Likely origins of deviations are sea ice and the lack of datum control on the TG.

Models suggest that gravimetric changes in sea level are reason for a significant part of the sea level trend.

Annual variations of sea level correlate well with local SST while annual variations from detrended gravimetry is an order of magnitude smaller than for measured sea level.

[1] Roesler, C. and K.M. Larson, 2018. Software tools for GNSS interferometric reflectometry (GNSS-IR).