Assignment 2

FYS-3023

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Task 1: CryoSat-2 Echogram

Task 1.1

In the first task, we are asked to display the echogram as an image, from the LRM track. The echogram can be seen in Figure 1 below.

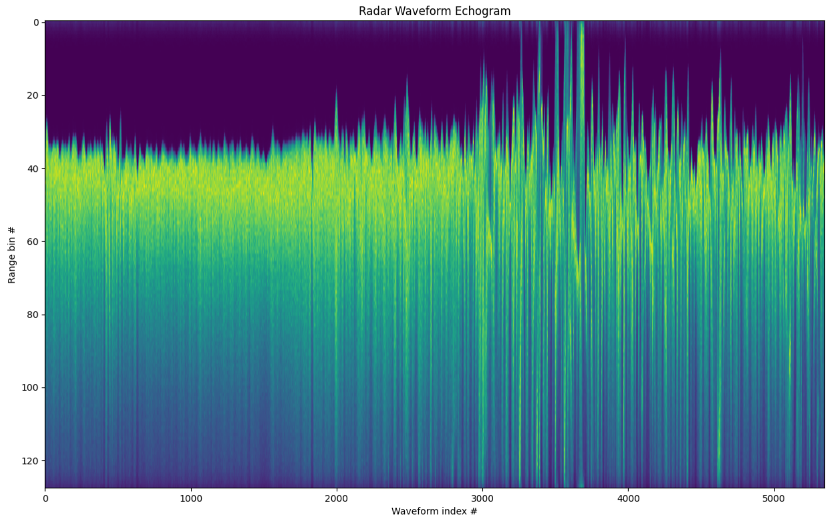


Figure 1: Echogram with sensor in LRM

Task 1.2

We are now going to plot one random waveform with the power normalized from zero to one, this comes out like in Figure 2 below.

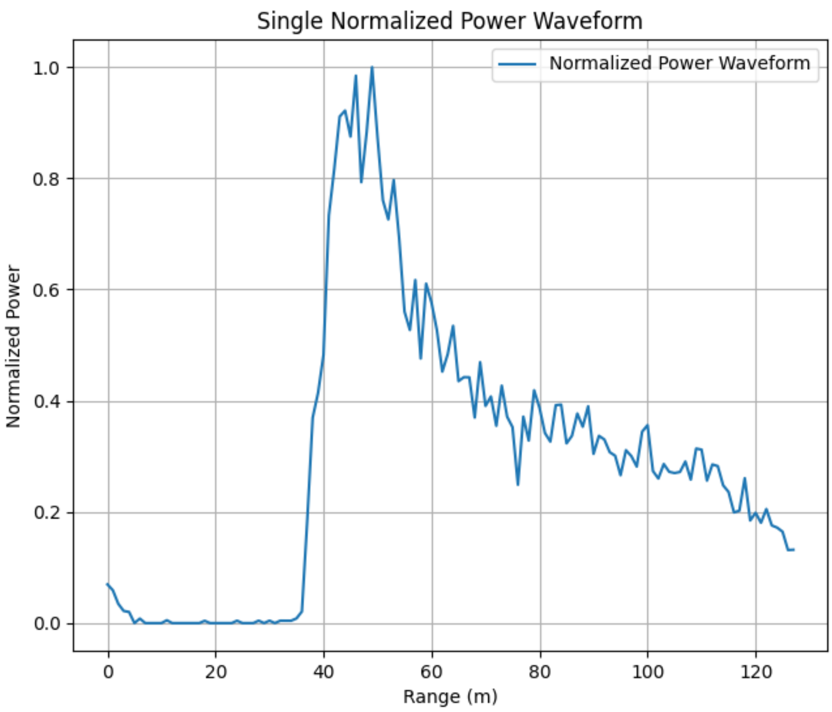
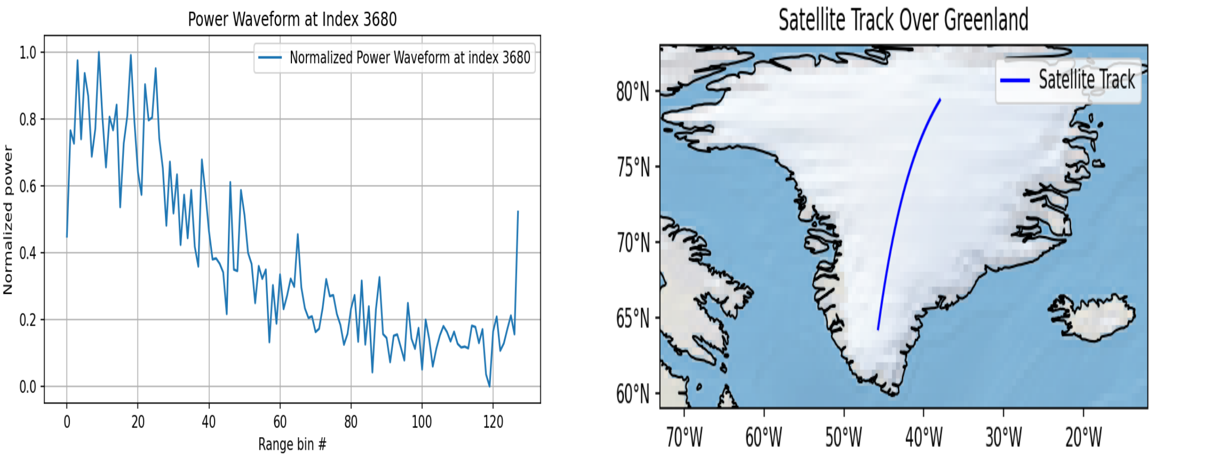


Figure 2: One random waveform with the power normalized from zero to one

Task 1.3

In this task, we are going to plot the waveform at index 3680 as seen in Figure 3a. The reason for this is described in the task description. After this, we were asked to plot the satellite track to see where we are looking and where we "loses lock" this plot can be seen in Figure 3b.



(a) Waveform at index 3680 (b) Satellite track over a base map of Greenland

Task 2: Waveform Retracking

Task 2.1

Now, we are going to design our own TFMRA (Threshold First-Maximum Retracking Algorithm) to identify the point on the leading edge of the waveform that we assume represents the mean ice sheet surface elevation. The code will include five main steps that we are given, by completing this we obtain a plot of the retracting points on top of the echogram as shown in Figure 4. From the TFMRA, the total number of discarded waveforms is 1140. This seems to be a bit high, which is also evident by the plot below where we see some missing re-tracking points. I will assume that reason for this lays in the code, and not in the data as we are informed that there should be up to a 1000 discarded waveforms and not above.

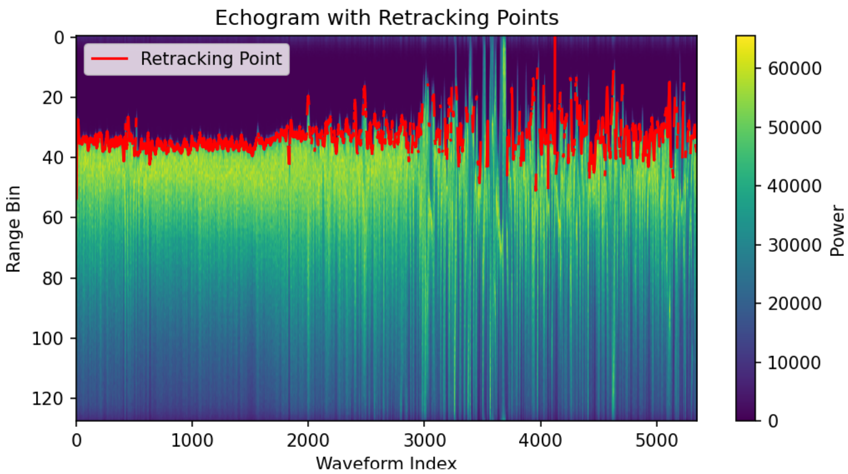


Figure 4: Echogram with retracking points

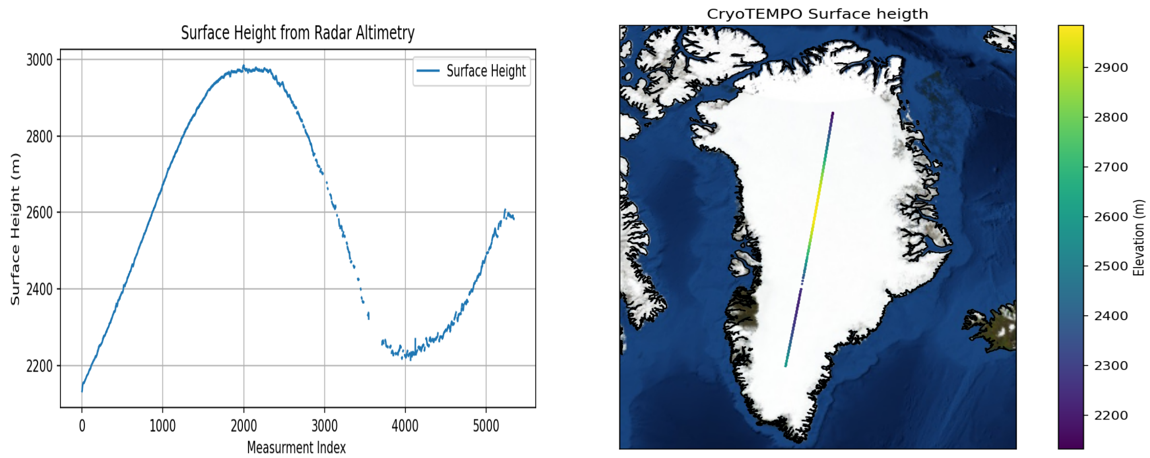
Task 3: Finding the Surface Elevation

Task 3.1

On page 46 of the CryoSay Handbook we are given the equation for calculating the range from the satellite to the central bin of the range window, for implementing this we load the two-way time delay and use the number of samples for LRM mode.
For calculating the surface height we take the satellite altitude minus the range, but first, we need to account for various geophysical corrections, and the corrections are found in Table 5 in the handbook. The corrections are available in the L1B product, but only at 1 Hz sampling, whereas the waveform data is at 20 Hz. We therefor need to associate the 1 Hz corrections to the 20 Hz measurements based on the instructions on page 52 in the Handbook. (most of these two section is from the task description)
Know as we where given the clear instructions above, we will have five key steps in our code.

1. Basic range calculation
2. Geophysical corrections mapping
3. total geophysical corrections
4. Corrected range calculation
5. Surface height calculation

By following these steps, we obtain the following plots shown in Figure 5 with a surface height profile (Figure 5a) and the surface height on a basemap of Greenland (Figure 5b).



(a)

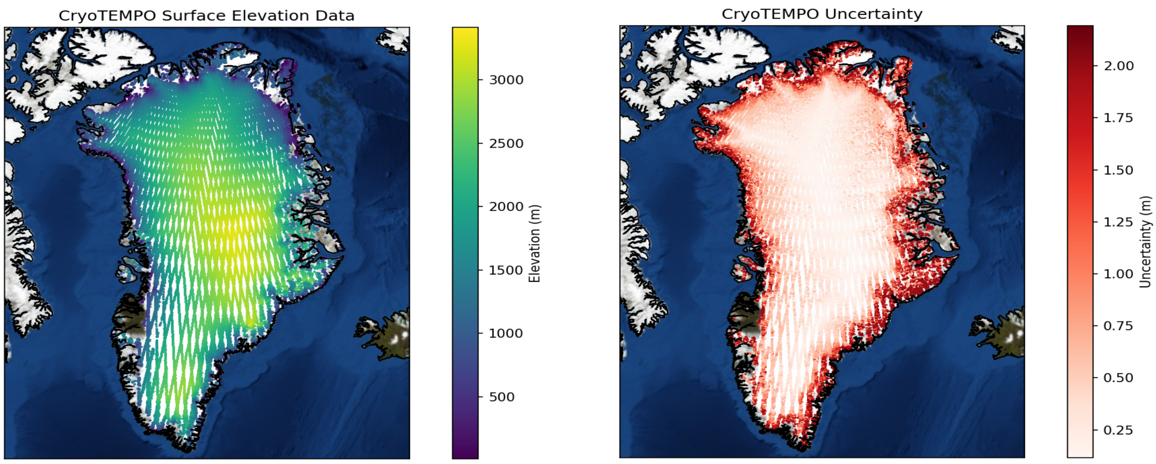
(b)

Figure 5: **(a)** shows the surface height profile. **(b)** shows the surface height on a basemap of Greenland.

Task 4: Creating a Monthly Map of the Surface Elevation

Task 4.1

For this task, we are going to load all the CryoTEMPO netcdf files and convert the latitude and longitude data to a projected coordinate system where we choose the Polar Stereographic North (PSN) projection. Including this we are also going to only retain samples with surface type = 1, "grounded ice" and Remove the samples where the elevation or uncertainty is *NaN*. When this is completed we obtain the following Figures 6, showing the elevation (Fig 6a) and the uncertainty (Fig 6b) on a basemap of Greenland. By comparing this to the figures for elevation and uncertainty at the "CryoTEMPO" webpage [1], we see that figures goes well with what we obtained.



(a) (b)

Figure 6: **(a)** shows the elevation. **(b)** shows the uncertainty

Task 4.2

In the next task, we are going to plot the elevation as a 3D model including our own processed track, atop of each other for us to compare. Hence, here we will plot our processed track from Task 3.1 and combine it with our down-sampled CryoTEMPO data from the last task. We then obtain the 3D model shown in Figure 7, from the plot there is no clear indication that we have any outliers, and our tack lines up well with the CryoTEMPO data.

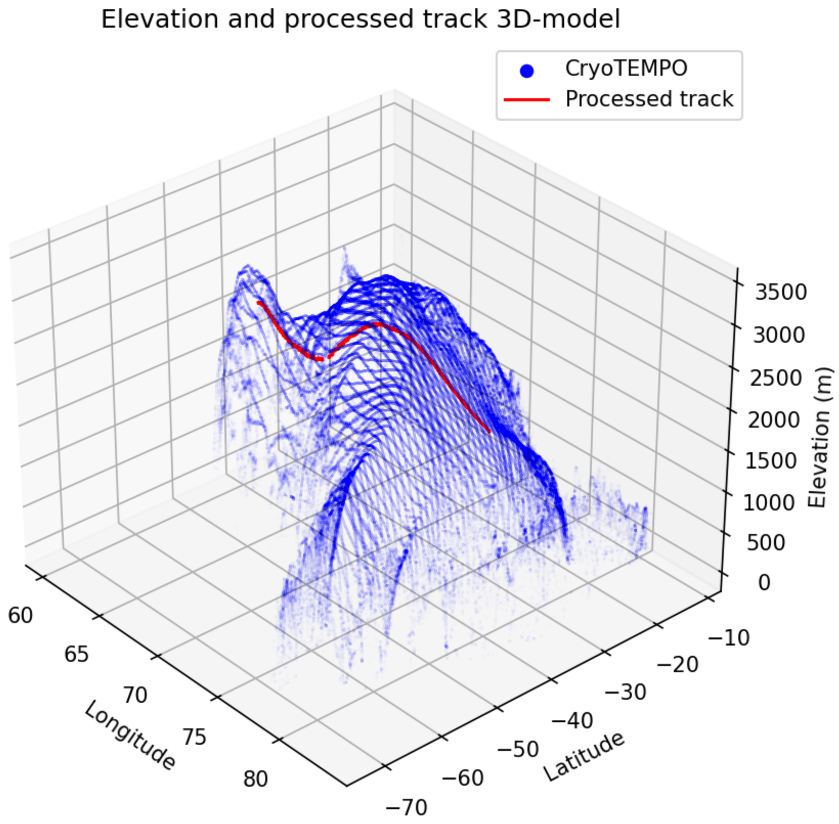


Figure 7: Caption

Task 5: Long-term Surface Elevation Change

Task 5.1

Now we are going to resample the CryoTEMPO data to the same 5-km grid as used by Zhang et al, this is done by using *cKDTree* from `scipy.spatial`. We then obtain the following plot shown in Figure 8.

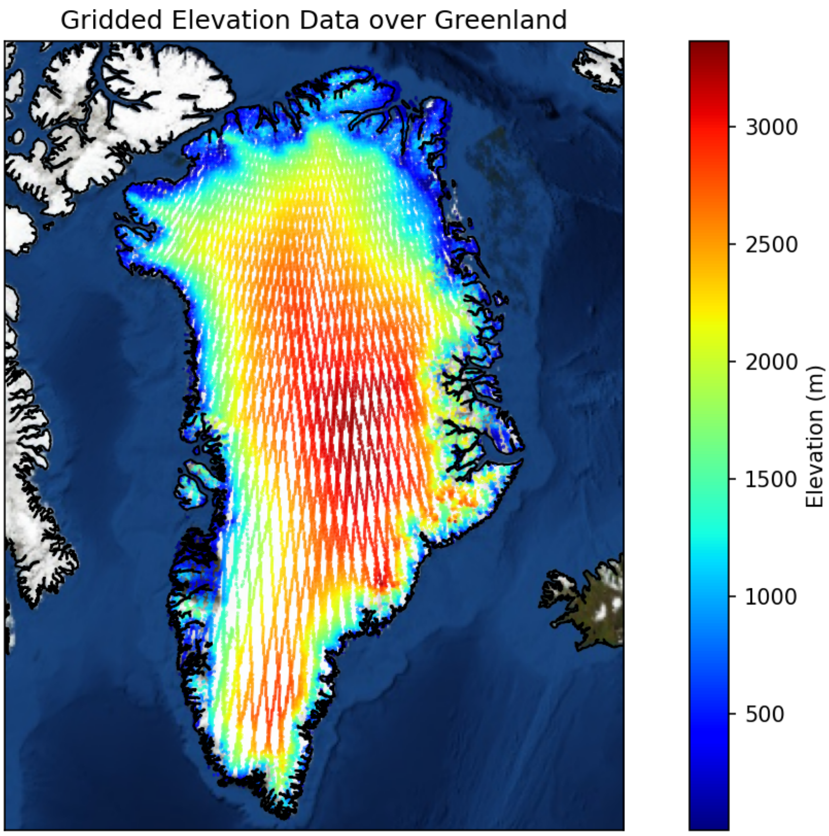


Figure 8: Resampled CryoTEMPO data to 5 km grid

Task 5.2

For the first part of this task, we asked to show the different drainage basins, which led to the plot below where we have identified 8 different basins.

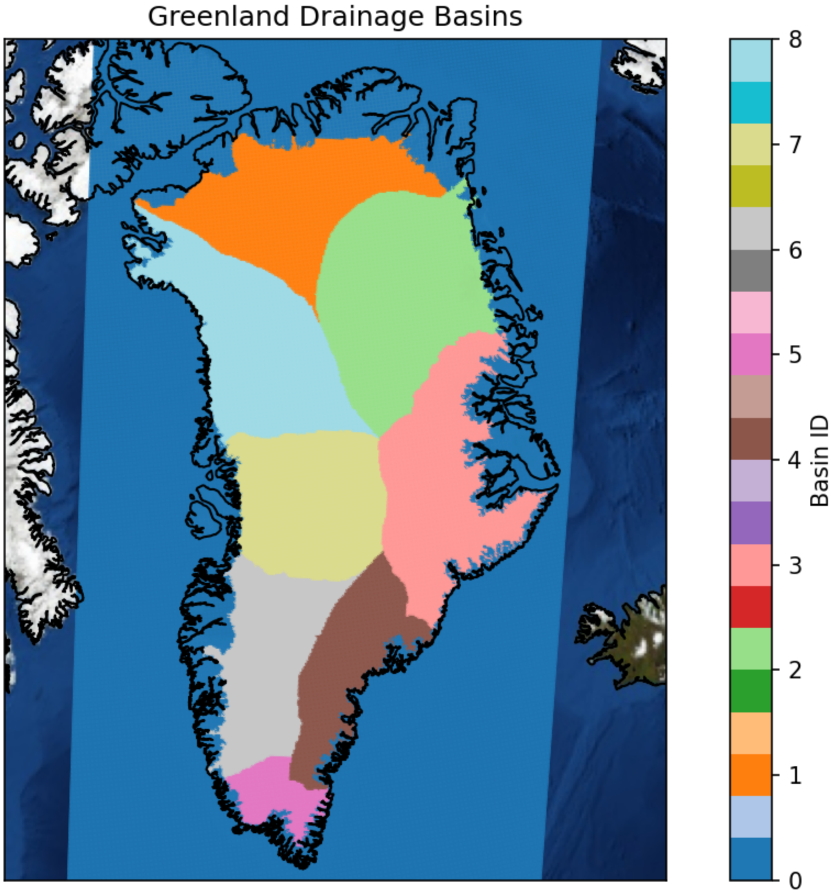
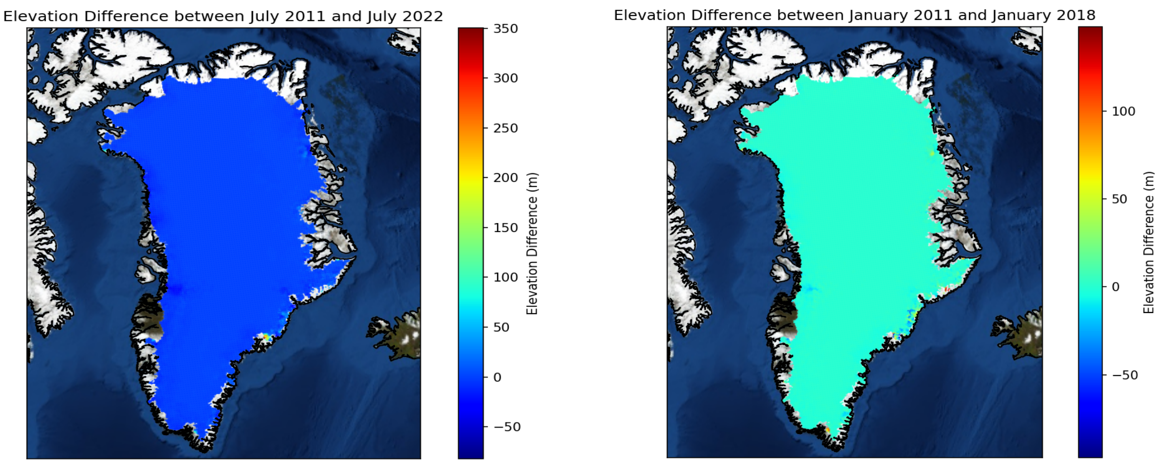


Figure 9: Different drainage basins at Greenland

We are than ask to add our July 2022 grid to the end of the Zhang et al gridded record. In Figure 10a, we have a plot of the elevation difference from July 2011 to July 2022. From this, it appears that over these few years, the overall ice elevation has decreased. In Figure 10b we have a plot of the election difference from January 2011 to January 2018, and the differences are smaller.



(a)

(b)

Figure 10: 3D elevation plot, before and after processing.

Task 5.3

For the last task, we plotted (shown in Figure 11) a times series of the mean elevation for all the measurements within region 8 of the ice sheet. Due to many missing grid cells in the July 2022 data, this data is discarded from the times series to avoid biasing the results.
From the plot in Figure 11, we see an overall fluctuation due to seasonal variability. But from the plot, we observe a downward trend, which strongly suggests the thinning of the Greenland ice sheet. The places are seen to have the most changes, are in the regions south. These regions are influenced by warmer ocean water, leading to increase in melting and retreat i.e. mean elevation has a faster downward trend.

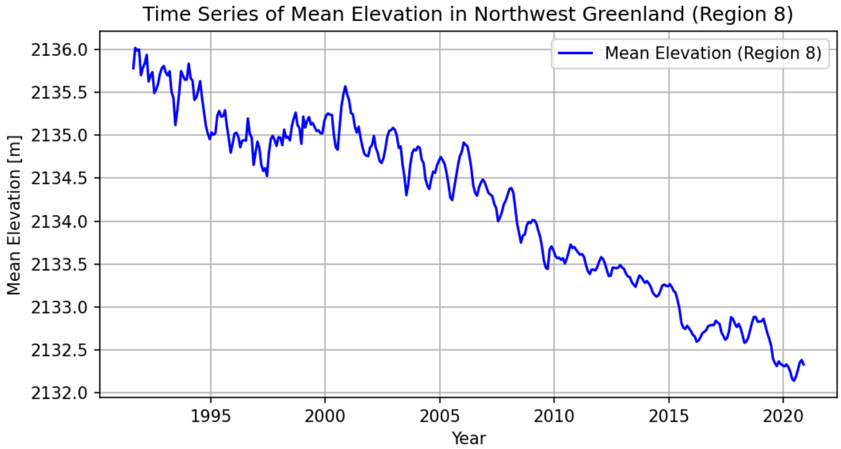


Figure 11: Mean elevation in region 8

The strength of satellite altimetry for ice sheet monitoring is that it provides frequent observations which enable us to monitor monthly. Also, one great factor which is obvious, is that we can cover remote and large areas remotely. We also have data from the early 90s, which gives us data for long-term trends and seasonal variations. Some drawbacks are that due to cloud cover, sensor limitations, and the orbit of the satellite, there are often missing cells in the satellite data. Another drawback is that satellite altimetry has limitations in areas with complex surfaces, e.g. near ice cliffs and crevasses.

Bibliography

[1] Cryo-TEMPO, November 2024. [Online; accessed 4. Nov. 2024].