Team Name: KSSOWLSB

Chosen Theme: Life on Earth

Organization Name: École Kelowna Secondary School

Country: Canada

Introduction

As the International Space Station (ISS) passes over mountains and valleys, the gravitational pull of Earth fluctuates. Consequently, this changes the orbit and velocity of the ISS slightly. These changes can be measured using a method known as satellite gravimetry (Figure 1). On Earth, this is used to effectively measure the shift in ice levels around the world.

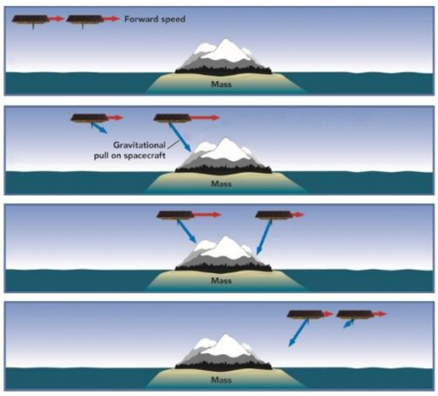

Figure 1: The method currently used for satellite gravimetry

The objective of our experiment was to develop a model that can map the terrain of a planet by interpolating the slight changes in the velocity of an orbiting satellite.

We were compelled to investigate this topic since it would potentially allow us to predict the geological structures of any planet. The uses of these findings can extend far beyond our Solar System, furthering the mapping of foreign landscapes using a satellite retrofitted with little to no specialized equipment.

Through our experiment, we expected to find fluctuation increases within a few km/hr in the speed of the ISS when it traverses over large mountain ranges.

Method

Our initial program used the Skyfield library to record the latitude and longitude of the ISS every 5 seconds. Then, the program calculated the velocity ($v = \Delta d/\Delta t$) travelled between readings. Every third iteration, an image was taken. In the end, we used the Coral TPU and an Image Classification Model trained using Teachable Machine to sort the images into the following classes: Day, Night, Twilight.

In Phase 4, we wrote a program using the Open-Elevation API to collect elevations. A disadvantage of Open-Elevation was its lack of ocean data, removing lots of potential for analysis.

To normalize our datasets, we used:

$$Normalized\ X = ((b - a) * (X - y)/(z - y)) + a$$

Looking at the velocity, we noticed a pattern that we believe was caused by the gravity of the Sun and Moon.

To cancel this pattern, we took each velocity point, got the average of its four neighbouring numbers and subtracted the average from the datapoint. Those with differences greater than 140m were graphed (Figure 3). This method reduced our accuracy because if there was an anomaly in any neighbour point, the four-point average decreased, allowing some normal points to make their way into the unusual section.

Finally, we created Figures 2, 3, 4, and 5 using MatPlotLib and BaseMap.

Results

Once we got the results, we noticed an unexpected pattern in the velocity (Figure 2). We believe the oscillating pattern is associated with the gravitational pull of the Sun and Moon. It's consistent with how a satellite would react when facing the gravity of three major bodies; the pull of the Moon is stronger because the Sun is further away. The cycle repeats twice, matching the number of orbits in 3 hours. The oscillations also appear to be the same the length regardless of program run time, further supporting our hypothesis.

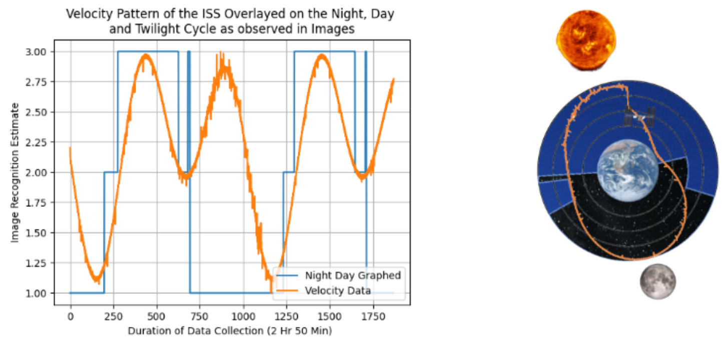

Figure 2: Velocity overlayed on the data collected from the night cycle; merged with an illustrated orbital representation

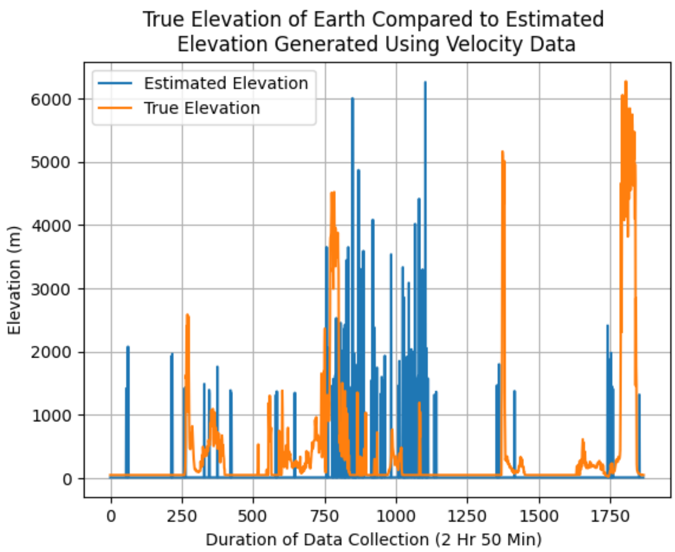

Figure 3: Real elevation overlayed on estimated elevation

Figure 3 shows that our method may have partially worked. The predicted elevation often rose at the same time as the true elevation. Looking at datapoint 262, we can see the predicted elevation rose only three datapoints, or 103km before the true rise. This was also repeated in datapoint 1362, which rose seven datapoints or 242km before.

Though the locations of the peaks often match, the heights do not. In Figure 4, we can see that the deviation scarcely reaches 0%, and where it does, it is because the true elevation was 0m. The average deviation calculated was -9.6846%. This indicates that often, the true elevations rose but went unmatched by our predictions.

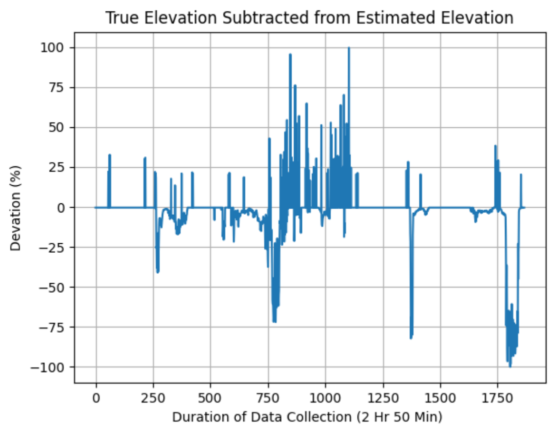

Figure 4: Deviation from accurate prediction

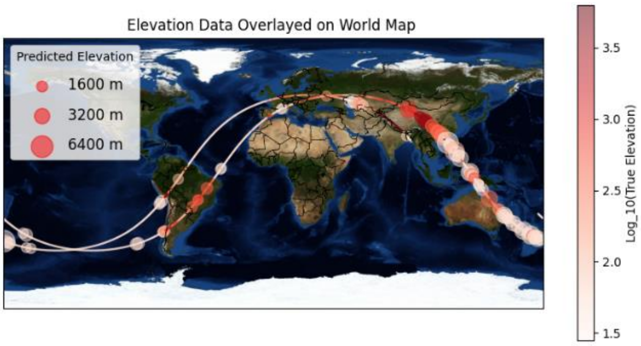

Figure 5: True elevation (colours) compared to prediction (circle size)

This diagram demonstrates the shortcomings of our predictive model. It often wrongfully predicts the presence of large mountains in the middle of the ocean. The effectiveness of our model can be further questioned by its lack of response over the Himalayas. The radius of the circles should be huge, but they are completely unaffected!

Learnings

Throughout our experiments, our team faced a variety of unexpected obstacles. We learnt a great deal about teamwork and problem-solving.

One issue was the difficulty producing Figure 4. Approaching this problem was challenging in its own right. However, learning how to effectively research through Google and keywords made the process easier. Eventually, we found what we needed through the BaseMap documentation. This taught us the importance of keywords when researching and the BaseMap functions.

Though the previous hurdle was difficult to solve, the chaos in our organizational structure was much harder. Initially, we communicated through numerous social channels because in-person meetings were nearly impossible with scheduling conflicts. To solve these issues, we trimmed our communication down to just Discord. Next, we assembled a spreadsheet that listed all members' availability and assigned tasks on an organizational tool called Taskade (Figure 6). Soon, we saw significant improvements; our communication was effective, and our to-do list shrank.

These setbacks allowed us to grow to a degree we didn't think possible. Our team is now more responsible, and capable. In future competitions, we will implement these strategies earlier since they allowed us to be efficient and practical with our time.

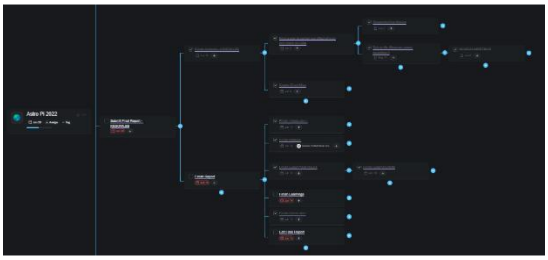

Figure 6: Taskade Flowmap

Conclusion

While our initial expectations for our experiment didn't align with our results, we still collected validating data. Our hypothesis that the velocity would differ by a few kilometres was supported.

One question we remain unable to solve is why our calculated velocity was in the range of 6.85-6.95km/s. According to the European Space Agency, the ISS orbits at a speed of 7.6-7.7km/s.[1] Regardless, we didn't spend too much time attempting to solve this as it didn't interfere with our calculations.

One explanation to why our predictions were incorrect may have to do with the original program. We relied on the accuracy of the sleep function, but it can differ by up to 10 milliseconds.[2] This variation was miniscule, but combined with the delay in the Skyfield GetLocation method, created an inconsistent time gap anywhere between 5.2 to 5.7 seconds. This inconsistency may also explain why our calculated velocities weren't in the range of the true velocity (7.6-7.7km/s).

In the future, rather than using a constant in the velocity calculations, we will use the time spent between calculations. This will allow us to create an algorithm that can more accurately predict terrain.

GitHub Repo: https://github.com/Hashoo27/KSSOwlsB2022

[1] https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/ISS_International_Space_Station
[2] https://codehunter.cc/a/python/how-accurate-is-pythons-time-sleep