Astronomy 98 Final Project Report

Deacon Carreon
Olivia Silvia

April 29th, 2025

1   Simulation Hypothesis

The goal for this project was to model the tides of the Earth-Moon-Sun system. To do this, we simulated the positions of all three objects using equations of gravity and mechanics. With these distances we simulated the tidal wave heights at any inputted latitude on the Earth, ultimately putting it into an animation, based on the function parameter of time.

2   Mathematics

$$h_{wave} = \frac{3GM_m R_E^2}{2g_E D_{Em}^2} cos(\frac{2\pi t}{P_E * T_E})cos(\theta) \tag{1}$$

3   Project Steps

Code Via Github: `https://github.com/kombuchamushrooom/Astro98Project`

Libraries Used: math, numpy, matplotlib.pyplot, matplotlib.animation, Funcanimation, pandas

To start off with modeling the tides, we modeled the Earth, Moon, and Sun system with the parameters and equations described previously. The elapsed time was set in hours as a numpy array and allowed for precision in modeling. We were able to get lots of points for an ellapsed time that was 30 days. This parameter would help us simulate changing distances between the Earth, Moon, and Sun.
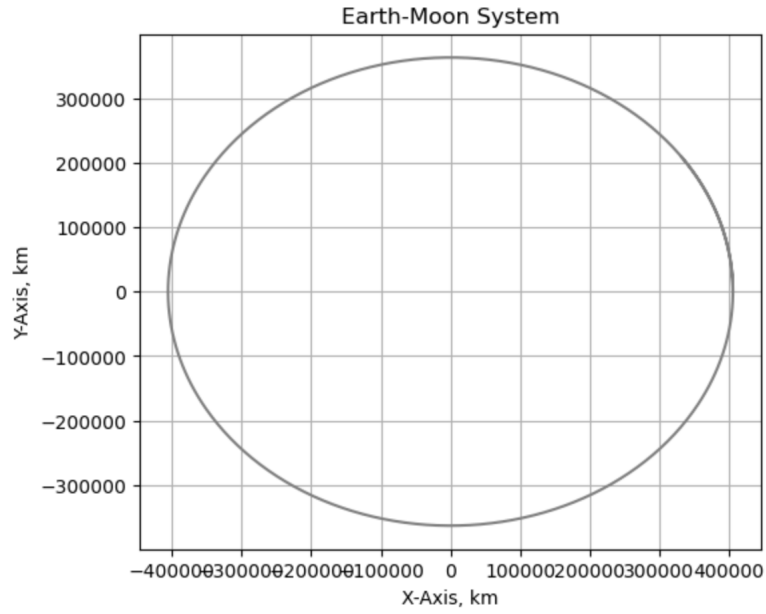
Figure 1: With equations (3), (4), and (5), we created a parametric representation of the elliptical path of the Earth-Moon orbit (origin (t=0) at right apogee).
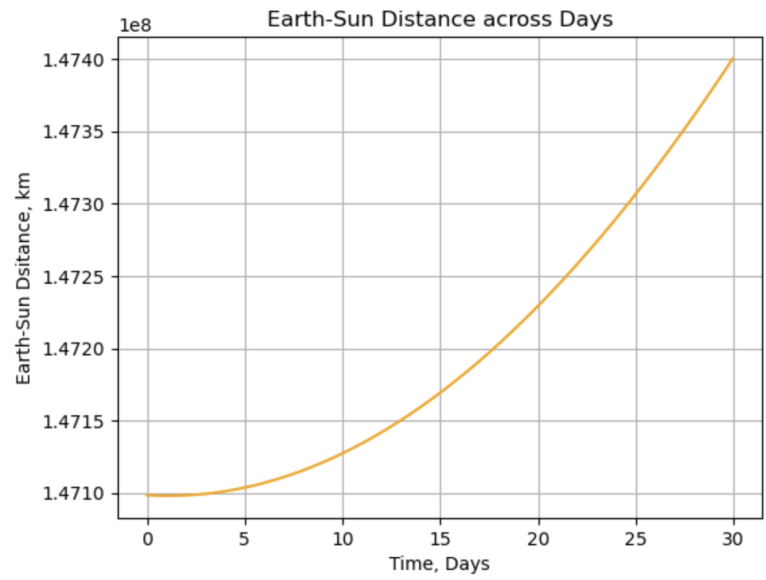

Figure 2: With equation (1), we created a parametric representation of the elliptical path of the Earth-Moon orbit (origin (t=0) on January 1st), so a little bit before aphelion.
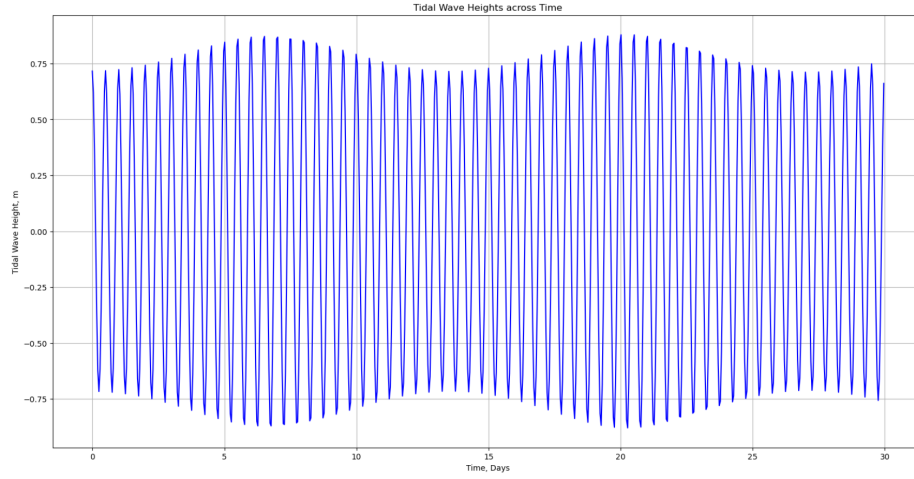
Figure 3: After establishing an hour-by-hour position of the Sun and Moon, with their live distances from Earth, we were able to use equation (4) to model the tidal wave heights as a function of time. We wanted to create an accurate depiction from data collected by our sources. As shown, our graph exhibits neap tide and spring tide phases.
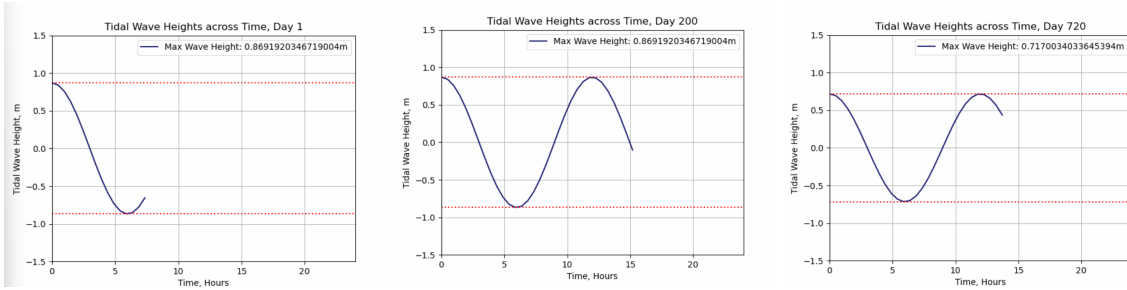
3.1   Animation

Figure 4: Animations of the tidal wave heights on days 1, 200 and 720 on Earth.
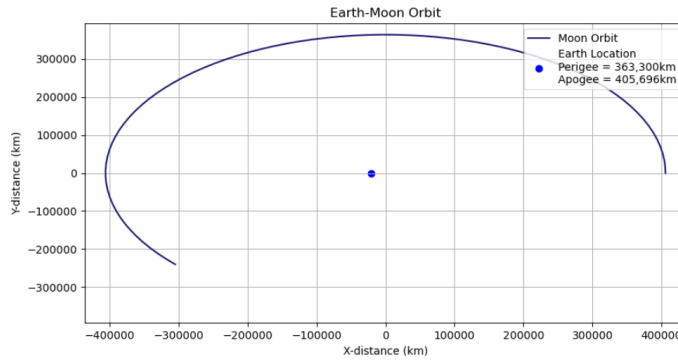

Figure 5: Extra Piece: One of our first sccessful animations was the Moon's orbit about the Earth. This was achieved via Matplotlib's FuncAnimation class.

4 Challenges

We initially faced difficulty learning Matplotlib's animation library and utilizing it for our project. Regarding the orbit, the primary issue was the fact that the ellipse equation was parametric. This was solved by initializing the x and y points as empty lists and appending points one-by-one in the update function. We also had trouble animating the Tidal Wave Heights Across Time function, which is likely due to a misunderstanding of the animation library rather than something completely unsolvable. We were able to troubleshoot the issue and found that it was largely due to the tides() function, which outputs the height of the waves on Earth as a function of time. Our guess as to why the animation couldn't work has to do with the fact that the update function was ultimately taking in one more parameter than it needed (we only want frames, but it was also taking in time because tides() takes that as an argument). This is consistent with the fact that the update function returned arrays rather than singular coordinate points. Unfortunately, due to time constraints, we resolved this by taking a sample of the wave heights as a function of time (hours) at various points along the orbit.

5 Conclusions

Despite being short on time, we had a lot of fun working on this project. We unfortunately had to cut some things that we planned on doing, such as modeling the tidal waves for multiple planetary bodies, we managed to get the tidal waves for Earth, in the end.

6 Works Cited

- Dr. Patrick Rynne. 2022. How the tides REALLY work. YouTube: Waterlust.
  `https://www.youtube.com/watch?v=bPhhYhNOFAc`

- Jim Branson. 2012. The Tides.
  `https://hepweb.ucsd.edu/ph110b/110b_notes/node13.html`

- Roger Williams University. Introduction to Oceanography. 11.1 Tidal Forces.
  `https://rwu.pressbooks.pub/webboceanography/chapter/11-1-tidal-forces/`