RELATIVE SEA LEVEL CHANGE: A GLOBAL PROBLEM IN YOUR BACKYARD

Scott A. Sinex
Department of Natural Sciences
Prince George's Community College
Largo, MD 20774
sinexsa@pgcc.edu

Abstract

Using authentic mean sea level data for a local site from the PSMSL website, we will use tide gauge data to address the question, "Is sea level changing?" and determine the rate of relative sea level change for the site. Students will need to be able to produce a scatter plot of the data and perform a linear regression and display the equation and r-square on the plot. Google Sheets will be used here; however, the task could be accomplished in Excel.

Introduction

Can we bring a global problem home to your own coastal backyard or to a coastal vacation site close to where you live such as Myrtle Beach in South Carolina? Are you looking for a data-driven project? Using data from local tide gauge data, which is measured regularly at well over 600 gauges worldwide, we can determine the relative rate of sea level change! This is a data analysis project that can demonstrate how a global problem can influence your local backyard.

The objectives of this activity are listed below:

1. examine tide gauge data in your own coastal backyard to address the question, "Is sea level changing?", plus investigate the causes of relative sea level change;
2. select a tide gauge location from the PSMSL website and download the annual mean data in Google Sheets or Excel;
3. plot a graph of relative height as a function of year, examine for possible trend, perform a linear regression, and judge goodness of fit via r-square;
4. interpret the regression model to determine the average rate of sea level change; and,
5. address how sea level is changing at your local site.

We will explore the global databank at the Permanent Service for Mean Sea Level (PSMSL), downloading data for your site, and getting it into Excel or Google Sheets. We will examine a prebuilt interactive Excel spreadsheet to enhance the factors that influence relative sea change, explore models for some tide gauges worldwide, and look at how the slope (gradient) of the land influences the inundation (flooding) of land. Resources will be provided to participants to allow them to develop an activity around their local location modeled on "Paradise Lost: Chesapeake Bay and Sea Level Change" and the accompanying Excelet. The average annual tide gauge data for most gauges show fairly decent trends for scattered data, which is a good thing for students to see. This has been referred to in the recent literature (Gould & others 2014, Schultheis & Kjelvik 2020) as messy data. This author prefers to call it scattered data. Sinex (2005) discusses scatter in linear models. The average worldwide sea level change from tide gauges is 1.8 mm/year or 18 cm/century (Jevrejeva & others 2014), which allows comparison to local values and aids in considering the multiple factors that influence relative sea changes. See the Classroom Resources section at the end of this article.

This should not be your first mathematical modeling activity! Stacking Oreo cookies and examining errors is a great start. See Sinex (2013) for a hands-on manipulative approach, and Sinex (2017, 2018) for adding more science processes.

What is a Tide Gauge?

A calibrated pole that is secured in the underwater sediment to measure the changes in sea level relative to a datum, a reference height on land. Newer versions have an encased float and recording device for graphing data as a function of time. For more information and history of the tide gauge, see Dusto (2014). An example of an historical site in Anchorage, Alaska is given in Figure 1.

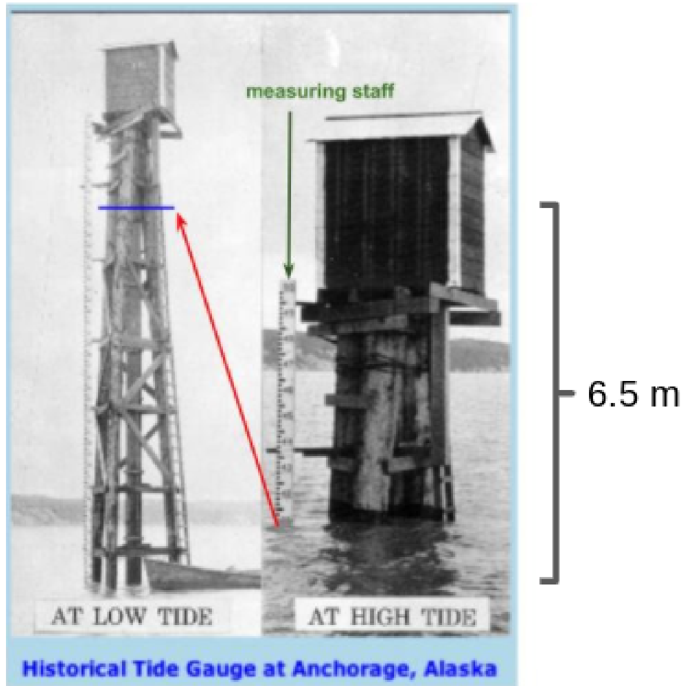
Relative Sea Level Change

A tide gauge measures relative sea level change, which depends on two basic factors:

- Change in the volume of seawater (melting/forming glaciers, which is ice covering land and/or thermal expansion of seawater); and,

- Geological factors that change the local land elevation of the tide gauge (glacial rebound from ice removal, subsidence due to fluid removal from sedimentary rock such as groundwater or petroleum).

These factors are illustrated in Figure 2, along with the resulting change in relative sea level.



Modified from NOAA

Figure 1 - Historic Tide Gauge in Anchorage, Alaska

Relative sea level change can be explored; hence, can be discovered by students using the Paradise Lost: Chesapeake Bay and Sea Level Change interactive Excel spreadsheet (tide gauge tab).

Retrieving the Tide Gauge from the Permanent Service for Mean Sea Level

A YouTube video on how to find a tide gauge site, download the data into Google Sheets, and then separate the data into columns for analysis is provided in the Classroom Resources section at the end. This video was designed as instructions for students.

St. Petersburg FL Tide Gauge - An Example

Here is an example for St. Petersburg, FL showing the annual mean sea level measured over 72 years (Figure 3). The slope of the regression line is the average rate of change uf relative sea level, 2.78 mm/year or 27.8 cm/century. The goodness-of-fit or r-square is also fairly high. The rate is influenced by increased seawater volume and subsidence due to ground water withdrawal.

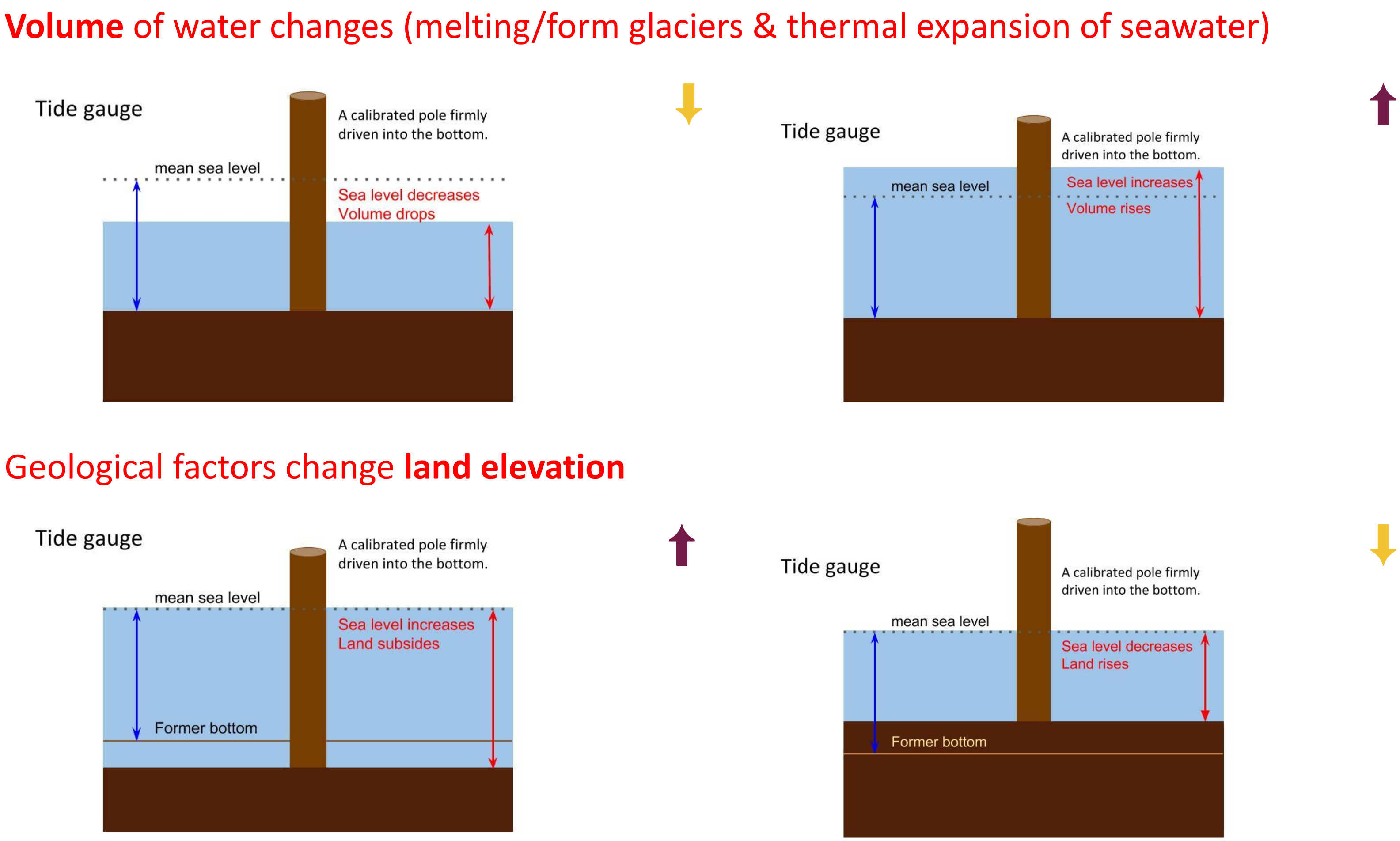


Figure 2 - Tide Gauges and Relative Sea Level Change - What causes the change?

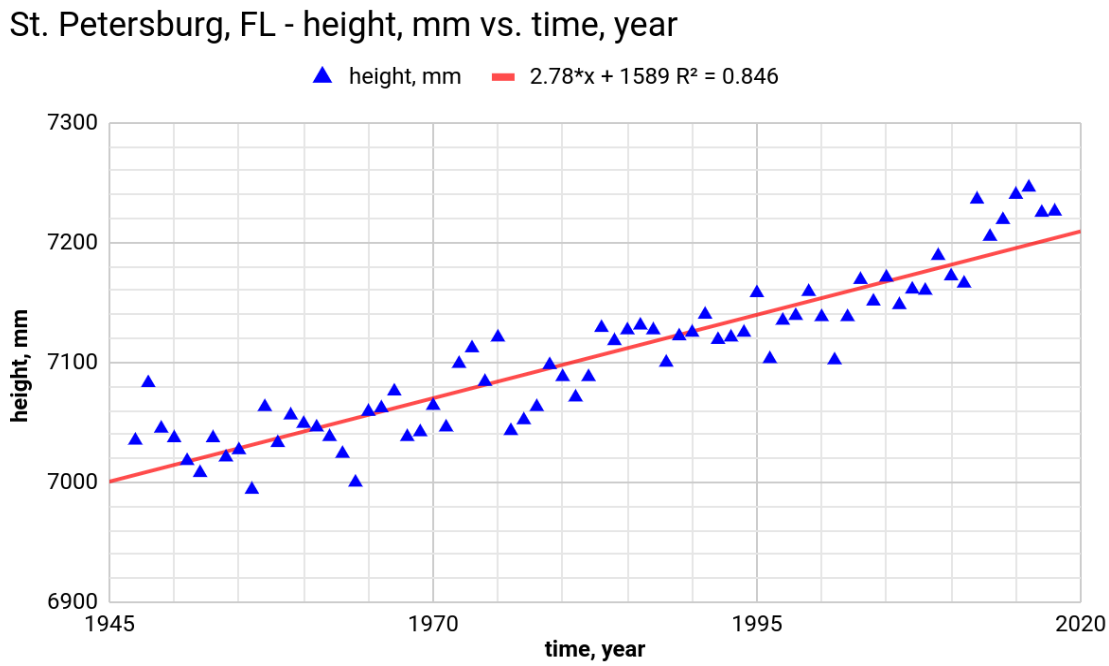


Figure 3 - Tide gauge data for St, Petersburg, FL

This activity could be done at the level of Algebra I or above as students need to be able to graph data and understand slope. The regression line is just the line of best fit.

Can you have a negative slope? Yes, this is an area where sea level is decreasing over time such as Stockholm, Sweden (Figure 4). Stockholm was ice covered by glaciers in the last ice age and the land is now slowly rebounding (uplifting) due to the loss of the ice mass. This factor overrides any increase in seawater volume to give Stockholm an overall decrease in relative sea level.

Using the Paradise Lost: Chesapeake Bay and Sea Level Change interactive Excel spreadsheet mentioned earlier (now see the inundator tab) , students can explore how the slope of the land (gentle low lying vs. steep) influences the amount of inundation of water flooding the land. Loss of small islands in the Chesapeake Bay has increased over the last century. See Come High Water: Sea Level Rise and Chesapeake Bay (2014) for more information.

If multiple sites are available for your locale, they can be assigned to groups and a discussion of results can ensue. A downloadable Google Sheets spreadsheet to pool tide gauge results is provided in the Classroom Resources section at the end. Have students use the Comments feature to have a discussion (instructor may need to seed to get started).

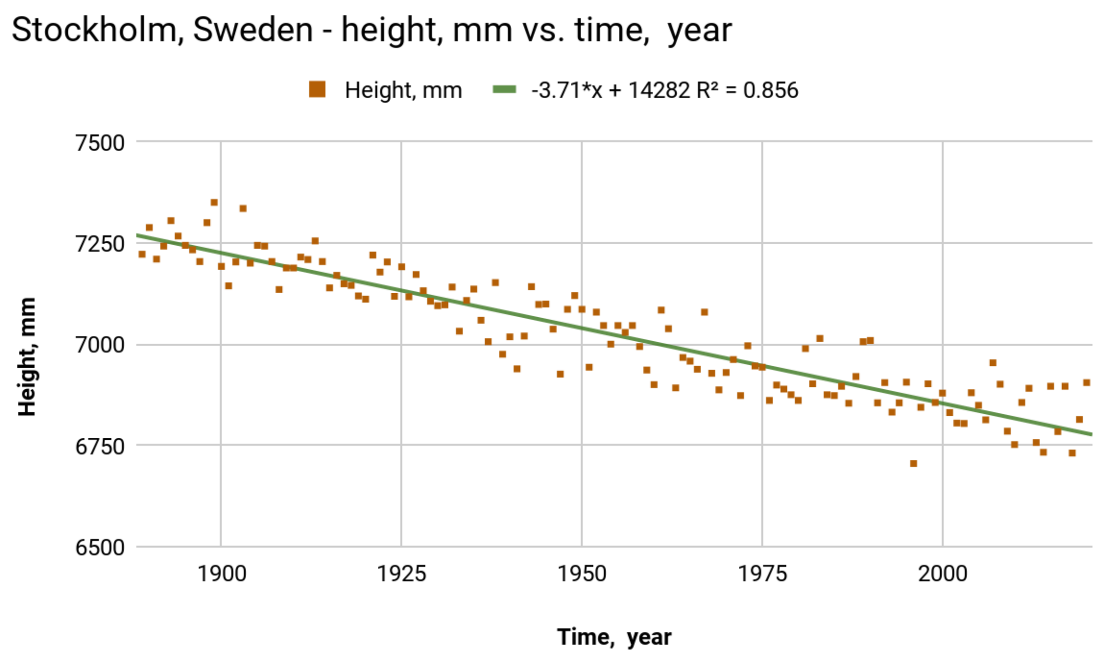


Figure 4 - Tide gauge data for Stockholm, Sweden (influenced by glacial rebound)

Some Final Thoughts

What do students get out of this activity? Here is a list of outcomes:

- Deal with real-world authentic data;
- Download with data handling into the spreadsheet;
- Examine a trend and data analysis to determine relative sea level change for the site
- See scatter in real data!;
- Address: Is this global problem in their own background?; and,
- With multiple sites, discuss differences or similarities and can consider possible causes.

Bringing a global problem to your local backyard is not an easy task. From here a further discussion of why sea level is rising is in order to investigate. Here are two papers to consider if you want more detailed information, see DeJong and others (2015) and S. Jevrejeva and others (2014).

Keep an eye on the author's "Sea Level Change: Real-world Data Analysis and Mathematical Modeling Spreadsheet Projects" website as it develops. Satellite altimetry data and discussion is coming soon as this is a nice big data project. Data projects examining the causes of sea level rise will appear shortly down the road.

Acknowledgements

The author wishes to thank Catherine Mejia Sinex, retired mathematics teacher, for providing invaluable comments on this paper.

References

Come High Water: Sea Level Rise and Chesapeake Bay in **Chesapeake Quarterly 13** (2-3) (2014) at http://www.chesapeakequarterly.net/sealevel/index.php (accessed September 2021).

B.D. DeJong and others (2015) Pleistocene relative sea levels in the Chesapeake Bay region and their implications for the next century, **GSA Today 25** (8), 4-10. https://www.geosociety.org/gsatoday/archive/25/8/pdf/i1052-5173-25-8-4.pdf

A. Dusto (2014) Reading between the tides: 200 years of measuring global sea level, https://www.climate.gov/news-features/climate-tech/reading-between-tides-200-years-measuring-global-sea-level (accessed September 2021).

R. Gould, S. Sunbury, and M. Dussaul (2014) In Praise of Messy Data: Lessons from the Search of Alien Worlds, **The Science Teacher 81** (8), 31-36.

E.H. Schultheis and M.K. Kjelvik (2020) Using Messy, Authentic Data to Promote Data Literacy & Reveal the Nature of Science, **The American Biology Teacher 82**, (7) 439–446. https://online.ucpress.edu/abt/article/82/7/439/111771/Using-Messy-Authentic-Data-to-Promote-Data

S. Jevrejeva and others (2014) Trends and acceleration in global and regional sea levels since 1807, **Global and Planetary Change 113**, 11-22. https://core.ac.uk/download/pdf/191605011.pdf

NASA Global Climate Change - Sea Level at https://climate.nasa.gov/vital-signs/sea-level/ (accessed September 2021).

S.A. Sinex (2005) Exploring the Goodness of Fit in Linear Models, **Convergence** (MAA, March 2005).

S.A. Sinex (2013) Investigating and Visualizing Measurement Error for Novice "STEM" Learners in **Proceedings of the Spring 2013 Mid-Atlantic Section Conference of the American Society of Engineering Education**, pp. 222-234.

S.A. Sinex (2017) Multivariable Spreadsheet Modeling and Scientific Thinking via Stacking Bricks in **Electronic Proceedings of the ICTCM Conference**, Vol. 28, pp. 381-390.

S.A. Sinex (2018) Algebraic and Scientific Thinking via Spreadsheets: The Unstacking Coins Model in **Electronic Proceedings of the ICTCM Conference**, Vol. 29, 14pp.

NOAA What is a tide gauge? at https://oceanservice.noaa.gov/facts/tide-gauge.html (accessed September 2021).

Classroom Resources

Sea Level Change: Real-world Data Analysis and Mathematical Modeling Spreadsheet Projects, https://sites.google.com/view/ssinex/home/sea-level-change

PSMSL Data Coverage at https://www.psmsl.org/products/data_coverage/
Getting Tide Gauge Data from Permanent Service for Mean Sea Level (PSMSL)
http://academic.pgcc.edu/~ssinex/excelets/getting_tide_data.pdf (for loading into Excel)

Paradise Lost: Chesapeake Bay and Sea Level Change
Activity: http://academic.pgcc.edu/~ssinex/excelets/inundator_act.pdf
Excelet: http://academic.pgcc.edu/~ssinex/excelets/inundator.xls (must view in Excel!)

Getting tide gauge data from PSMSL into Google Sheets, a YouTube video at https://youtu.be/X2ur5z99lcM

Sharing Pooled Results in a Google Sheets spreadsheet, https://docs.google.com/spreadsheets/d/1B6Ng5NGZ3RSHXUXTN35ozVUEnTzOyo3ucvGm9rTdlX4/edit#gid=0