Understanding Our Changing Climate Unit 2: Global Sea-Level Response to Temperature Changes

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In this unit students plot global averaged sea surface temperature (SST) anomaly data to create time-series plots spanning 1880–2018 and conduct linear trend analysis to assess SST change during this period. The anomalies are calculated based on the average temperature 1901–2000. Thus below-zero temperature anomalies show temperatures lower than the twentieth-century average and above-zero anomalies are higher temperatures than that period. Based on the calculated SST change, students will calculate how much sea-level rise occurred during 1993–2015 due to thermal expansion of the oceans. Students compare their thermal expansion–calculated sea-level rise results to observed sea-level rise from radar altimetry and assess how much sea-level rise is attributable to thermal expansion.

Two types of data will be utilized in this unit:

1. Sea surface temperature (SST) data. Techniques for measuring sea surface temperature have changed over time. The earliest data (1800s) were collected by measuring the temperature of a water sample collected by lowering a bucket from the side of a ship, whereas today SST is collected more systematically from ships and stationary and drifting buoys.

2. Sea-level satellite altimetry data. Altimetry is a technique for measuring height. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield sea-surface heights.

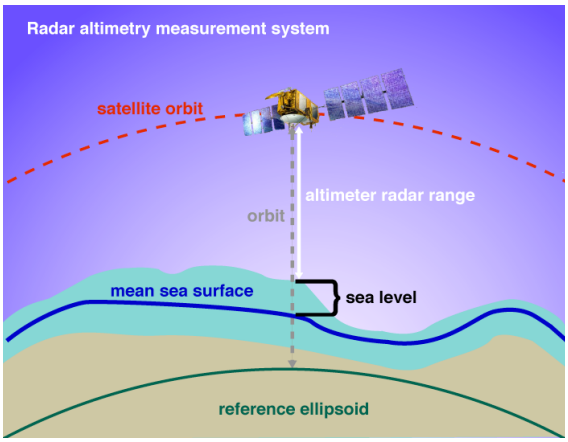

Figure 1. Radar altimetry measurement system. https://www.star.nesdis.noaa.gov/sod/lsa/SeaLevelRise/LSA_SLR_background.php

The following requires you to create graphs of data sets. Ensure that the axes on all graphs are labeled and include correct units. For the questions requiring quantification, please identify the methodology you used to obtain your answer, including the equations used.

Part I. Assessing Changes in Sea Surface Temperature

1. Access the student data spreadsheet. This data shows how the average surface temperature of the world's oceans has changed since 1880, and is represented as anomalies (deviations from the average) relative to the period 1901–2000. From the tab SSTanomaly1880–2018 create a plot of annual sea surface temperature anomaly data from 1880 to 2018. Include a plot of the data here (3 points).

2. Based on the graph you created, how much have SST increased over the period of the record? Describe how you assessed the SST increase (Which years did you compare? What was your methodology?). (3 pts)

3. Next you will examine the trends in SST for the period 1993–2015. This is the period that overlaps with the satellite altimetry measurements. From the same spreadsheet, access the tab SSTanomaly1993–2015. This data set is similar to the annual anomaly data included on the graph that you just made, but the base period for this data is 1971-2000. This data also includes data bracketing the upper and lower 95% confidence intervals (meaning that there is a 95% certainty that observed SST falls in this range). Create a graph that includes the following features, and paste a copy of the graph below (3 pts):
    a. SST anomalies from 1993 for the three data sets (annual SST anomaly, and the upper and lower 95% confidence interval SST anomalies.
    b. A linear trend line for each of the data sets
    c. The equation for the linear trend line for each of the three data sets.

4. Apply the linear equations to calculate how much sea surface temperature increased during the period 1993–2015, and insert the results into the table below (3 pts):

Parameter	Annual SST Anomaly	Lower 95% confidence interval Annual SST anomaly	Upper 95% confidence interval Annual SST anomaly
SST Temperature change (Celsius) between 1993 and 2015 based on linear equations			

Part II. Assessing Sea-Level Rise Due to Thermal Expansion

Sea-level rise due to thermal expansion can be estimated using the relationship that 100 mm of sea-level rise is expected for each Celsius degree increase in temperature. This applies for the top well-mixed 500 meters at the surface of the oceans. For the calculations that follow, assume that the SST increase that you calculated in Part I applies to the top 500 meters of the surface of the ocean. (This value was extrapolated from the IPCC 2014 report)

5. Based on the SST temperature increase that you calculated above in Question 4, calculate how much sea-level rise would have occurred during 1993–2015 due to thermal expansion of the sea water. Include the equation that you used to calculate sea-level rise due to thermal expansion, and enter your results into the table below (3 pts):

	based on annual SST anomaly	based on lower 95% confidence interval Annual SST anomaly	based on upper 95% confidence interval Annual SST anomaly
Calculated Sea-level rise (mm) 1993–2015 due to thermal expansion and based on SST linear equations			

6. Now you will compare your calculated sea-level rise due to thermal expansion results with observed changes in mean sea level. Sea-level data can be accessed in the SeaLevelData1993-2020 tab from the spreadsheet. Plot the observed radar altimetry sea-level data. On your graph include the linear trend line and the equation for the trend line (3 pts). Paste a copy of your graph here.

7. Based on the radar altimetry sea-level data that you just plotted, and the linear trend line equation, how much did sea level increase between 1993 and 2020 (3 pts)? Be sure to include your equation and show your calculation.

Part III. Synthesis: What is the role of thermal expansion in observed sea-level rise?

8. Compare the observed sea-level data (Question 6) to the sea-level rise that you calculated due to thermal expansion (Question 5). How much greater is observed sea level compared to your estimate of sea-level rise due to thermal expansion? (3 pts)

9. Why do/don't the values agree? Can observed sea-level rise be attributed solely to thermal expansion? (3 pts)

10. What other sources may be contributing to sea-level rise besides thermal expansion? (3 pts)

11. **Reflection:** What have you learned through this analysis? What do you know now about the role of thermal expansion in sea-level rise that you didn't know prior to completing this activity?