Sea Level and Climate Change Outreach for High School Students

Ben Hamlington
Old Dominion University
Bob Leben
University of Colorado Boulder

Overview

- While great advances have been made in climate science in recent years, the lack of resources and attention given to this area of science at the K-12 level is cause for concern.
  - In the United States, climate science is generally not included in the public high school curriculum.
- Motivated by this, and as part of a NASA ROSES supplemental education proposal, in the past three years, we have sought to provide courses on sea level and climate science to high school students.
  - Collaborated with the Colorado Association of Black Professional Scientists and Engineers (CABPES) to provide an after-school sea level and climate science course to underrepresented and minority students in the Denver area.
  - Also, provided condensed single-day seminars (2-3 hours) at public libraries in the Denver area.

Overview

- In coordination with CABPES, we provided a course covering topics in climate with specific focus on sea level.
  - Course was offered twice a year, once in the Fall and once in the Spring, with each course consisting of 6 classes that are each 2 hours long.
  - Course introduces students to MATLAB and provides experience working with satellite altimetry data.
  - After each offering, course was evaluated with student feedback.
- Single-day seminars covered general topics in sea level, attempting to generate interest in additional studies.
- Primary goal of both offerings was to give students hands-on experience in the study of climate and sea level change → design of class-room experiments.
  - Early feedback from first iteration of course was that lecture-style teaching was not well-received.

Course Outline

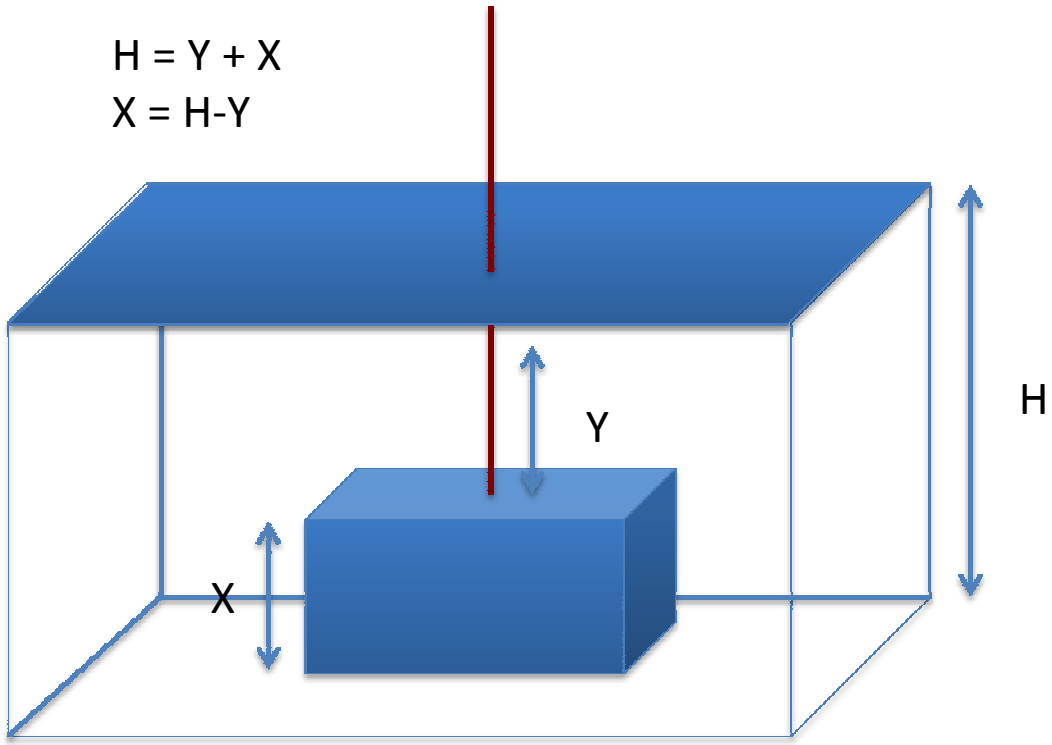
- Specific classes in the course were discussed in presentation at OSTST meeting in 2012 in Venice.
  - Class 1: Introduction to climate/sea level science
  - Class 2: MATLAB Tutorial
  - Class 3: MATLAB exercises with satellite altimetry data
  - Class 4: Introduction to satellite altimetry
  - Class 5: Experiment: Sea Ice vs. Continental Ice
  - Class 6: Climate Variability, Summary Wrap-up
  - Single-day seminars were derived from a synthesis of course topics.
- During the three-years of this project, four hands-on activities were designed for use during this course.
  - Class-room sea level science experiments are generally difficult to design given the large spatial scale and long time scale (relative to a 2-hour class!) of processes resulting in sea level change.
  - The remainder of this talk will be devoted to outlining the four experiments.

Sampling with Satellite Altimeters

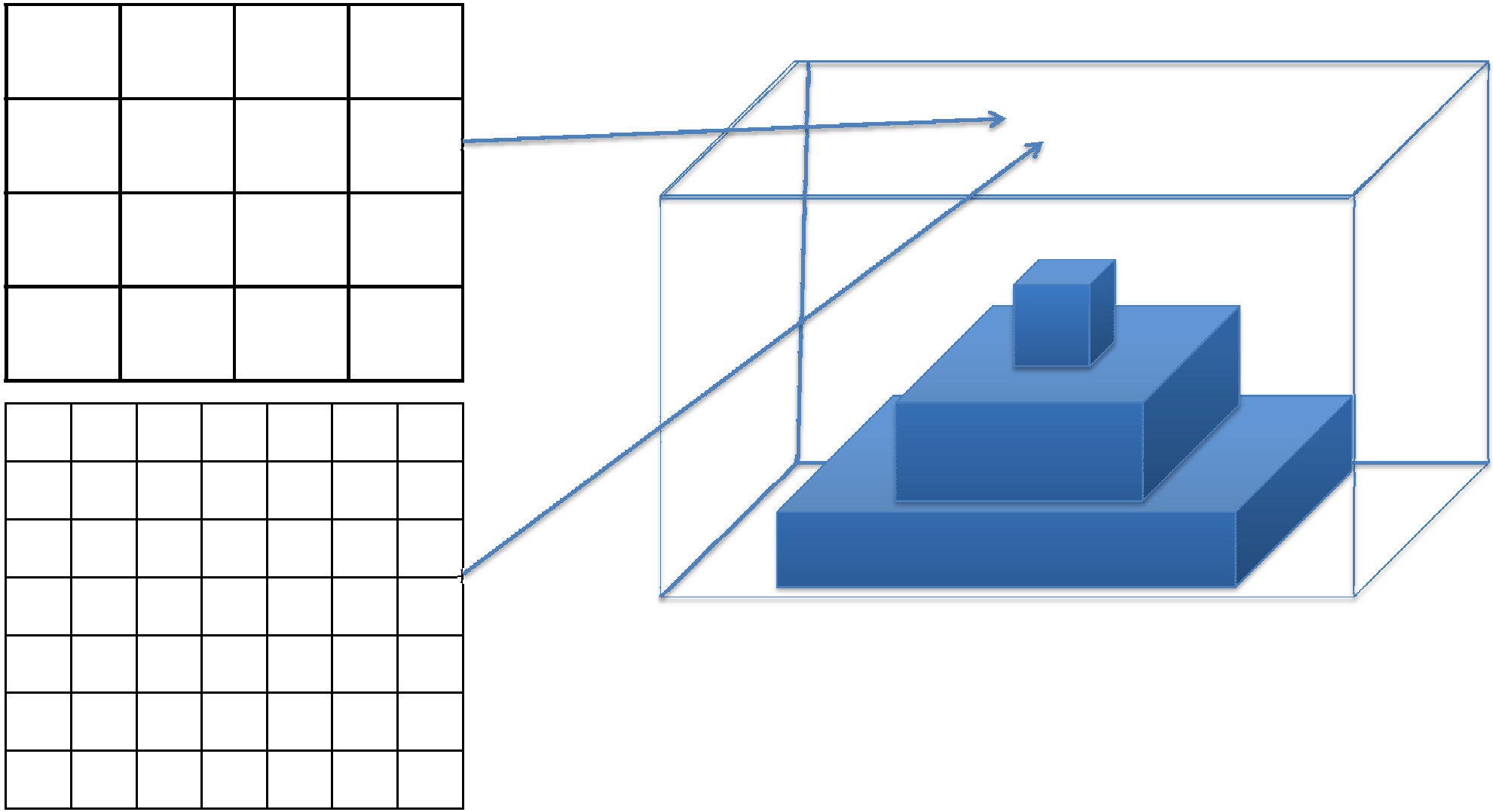
- To understand how satellite altimeters sample the ocean, a very simple experiment was designed.
  - Relayed the idea that satellite altimeters don't actually have to "see" the surface of the ocean to measure its height → frequently asked what kind of camera the altimeter used and how you could obtain height from a picture.
  - Also conveyed concepts regarding sampling resolution and aliasing.
- Experiment setup was as follows:
  - Boxes with an unknown object/shape/topography (to the students) were built and then sealed.
  - A "grid" of holes was drilled into the top of the box to simulate the locations where the altimeter was to take measurements.
  - Pieces of paper with different grids were taped on to the top of the box to specify which grid-points should be used.
  - Grid-points on the paper were colored according to the measured value and a color scale.
  - Total setup cost: ~$5 per box

Sampling with Satellite Altimeters

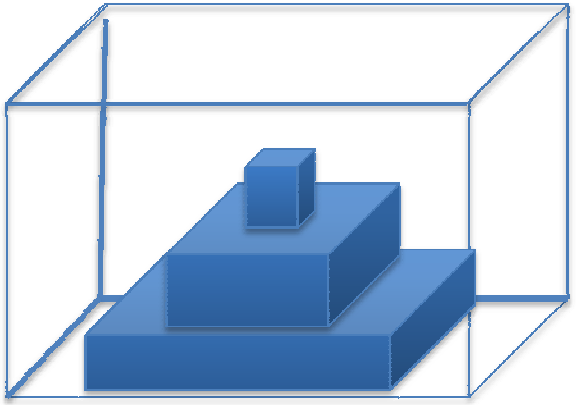
1. Put a wooden dowel into the drilled hole and push it down until it hits the object inside.
2. Pull the dowel out and measure how far it went in with a ruler (this will give Y).
3. Subtract Y from H, to give X.
4. Color in the box on the paper according to the provided color code.



Sampling with Satellite Altimeters

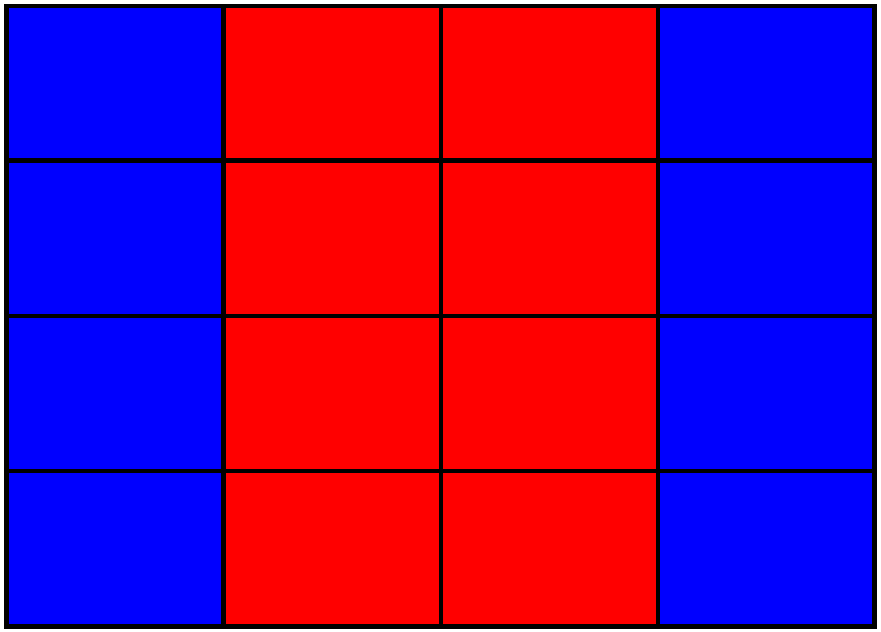


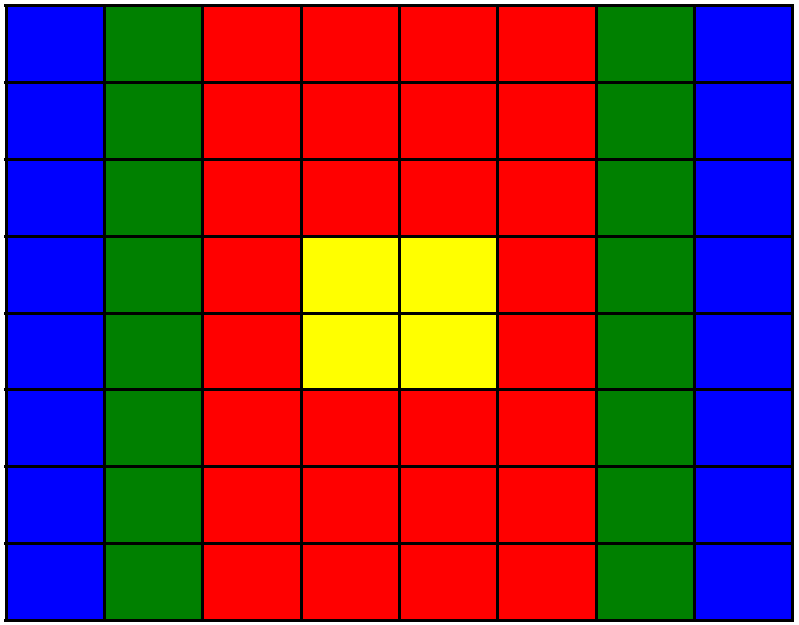
Sampling with Altimeters



Conveyed two main concepts:

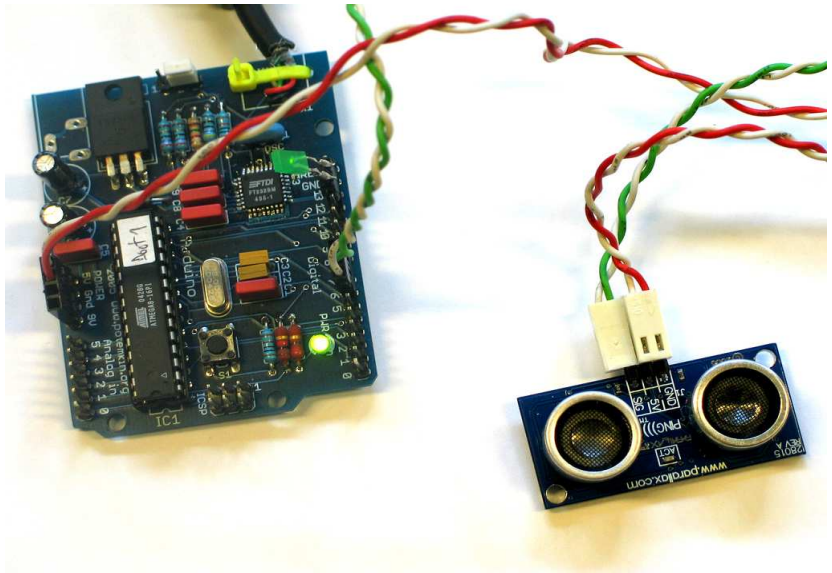
1. How satellites can observe and measure the ocean from space.
2. How satellite sampling affects how we study the ocean.





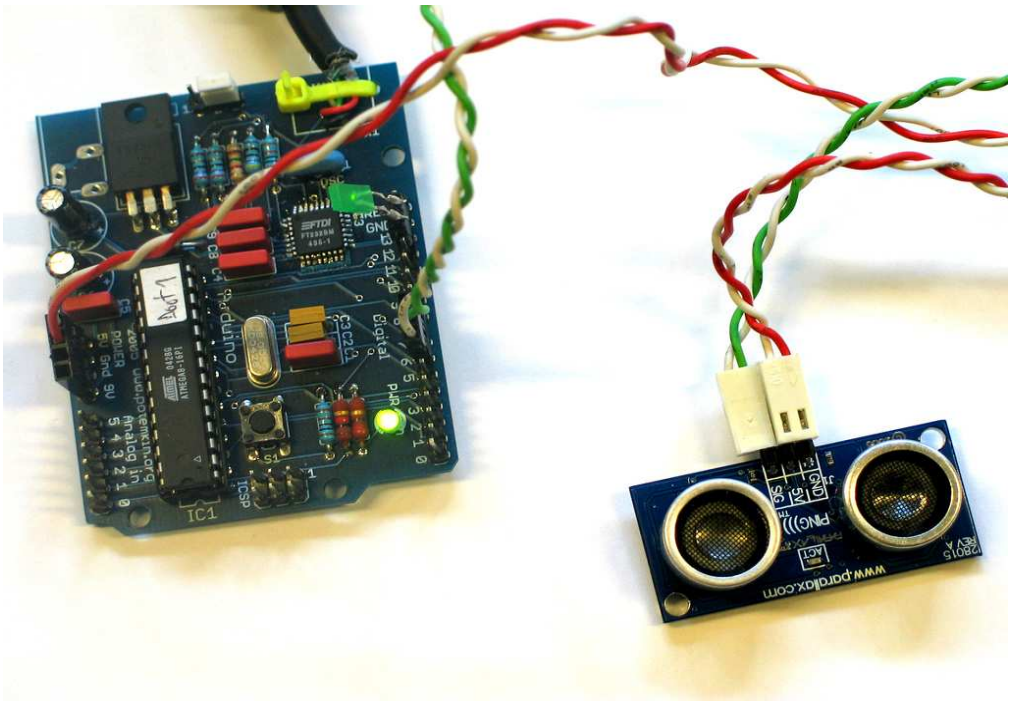
Designing a Model Altimeter

- In the next class, we discussed how the different parts of satellite altimeters work and how they measure the height of the ocean from space.
- Students explored sealevel.jpl.nasa.gov to learn more about satellite altimeters.
- Discussed past, present and future of satellite altimetry.
- We then created model satellite altimeters from simple ultrasonic rangefinder and programmable microcontroller.



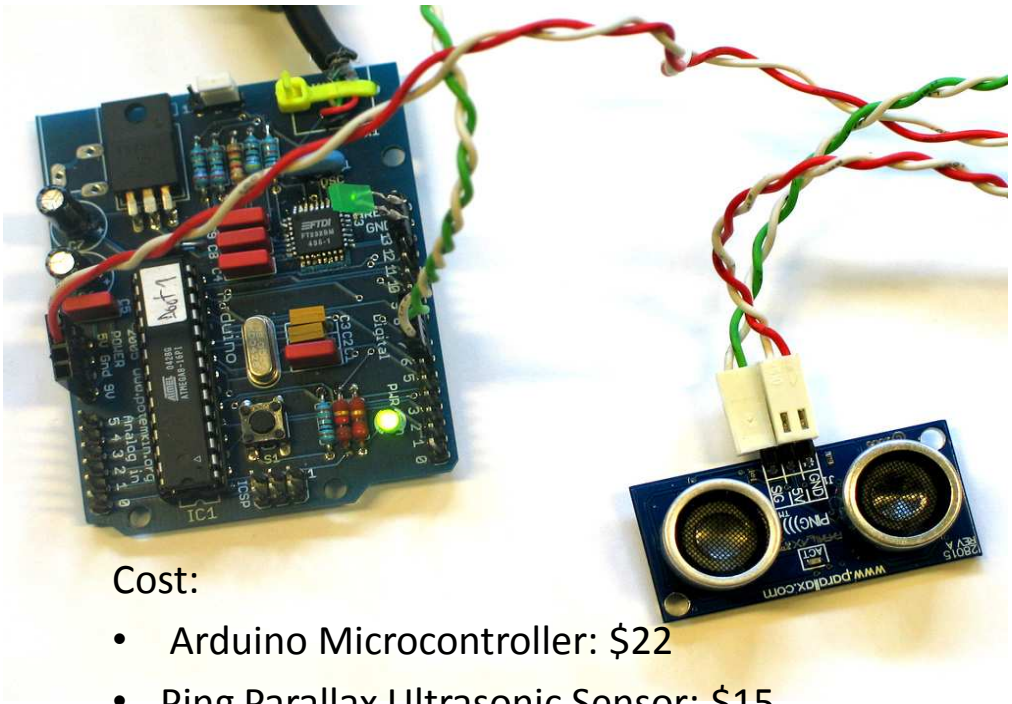
Model Altimeter

- We modeled a satellite altimeter by creating a simple ultrasonic rangefinder.
- The rangefinder incorporates an ultrasonic sensor with an Arduino microcontroller.
- The sensor sends out a burst of ultrasound and then listens for the echo when it bounces off an object (working range is between 2 cm and 3 m).
- Microcontroller is connected to a computer where it is programmed and measurements are output and read into MATLAB.
- Students used range-finders to measure distance to objects in the classroom, and measure the speed of someone walking.



Model Altimeter

- We modeled a satellite altimeter by creating a simple ultrasonic rangefinder.
- The rangefinder incorporates an ultrasonic sensor with an Arduino microcontroller.
- The sensor sends out a burst of ultrasound and then listens for the echo when it bounces off an object (working range is between 2 cm and 3 m).
- Microcontroller is connected to a computer where it is programmed and measurements are output and read into MATLAB.
- Students used range-finders to measure distance to objects in the classroom, and measure the speed of someone walking.

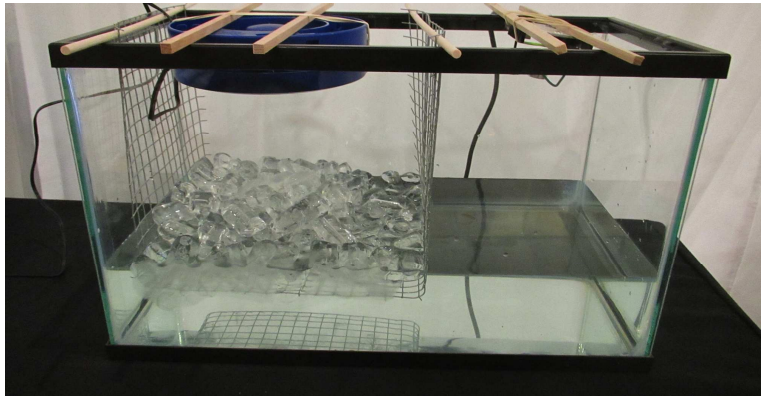


Cost:

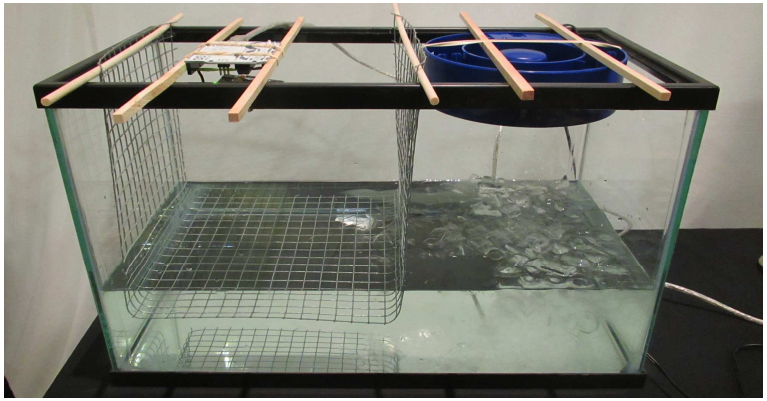
- Arduino Microcontroller: $22
- Ping Parallax Ultrasonic Sensor: $15
- Connectors: $1
- **Total Cost: $38**

Does the melting of floating ice raise sea level?

- **To make use of the model altimeters, we designed a simple experiment to better understand how melting ice affects sea level.**
- **Sea Ice vs. Land/Continental Ice:**
  - Students completed an experiment to understand the difference between melting sea ice and melting continental ice in terms of their contribution to sea level change.
  - Experiment runs for 20 minutes and results are output to MATLAB for further analysis.



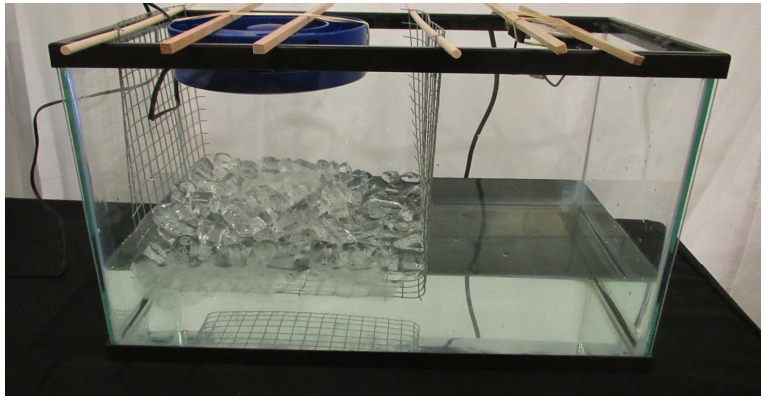
Continental Ice: To simulate melting continental ice (A), we positioned the ice in a wire mesh basket sitting slightly above the surface of the water, using a fan to improve air circulation and speed the melting of ice.



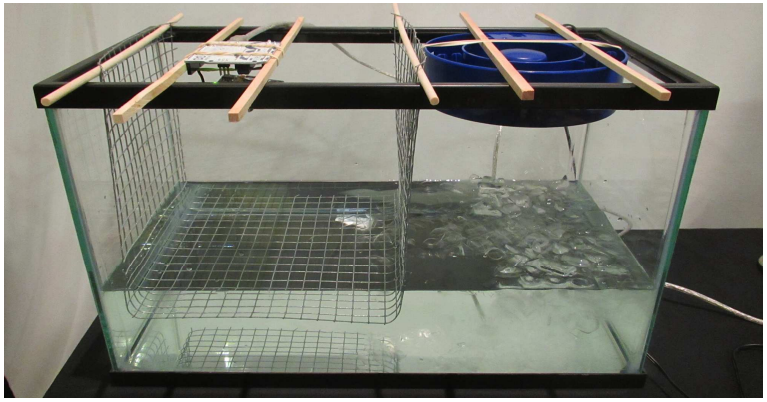
Sea Ice: To simulate melting continental ice (A), we positioned the ice in a wire mesh basket sitting on the surface of the water, using a fan to improve air circulation and speed the melting of ice.

Does the melting of floating ice raise sea level?

- **Cost:**
  - Aquarium - $15 , USB Fan - $5, Wire Mesh $2, Model Altimeter - $38
  - **Total Cost: $60**



Continental Ice: To simulate melting continental ice (A), we positioned the ice in a wire mesh basket sitting slightly above the surface of the water, using a fan to improve air circulation and speed the melting of ice.

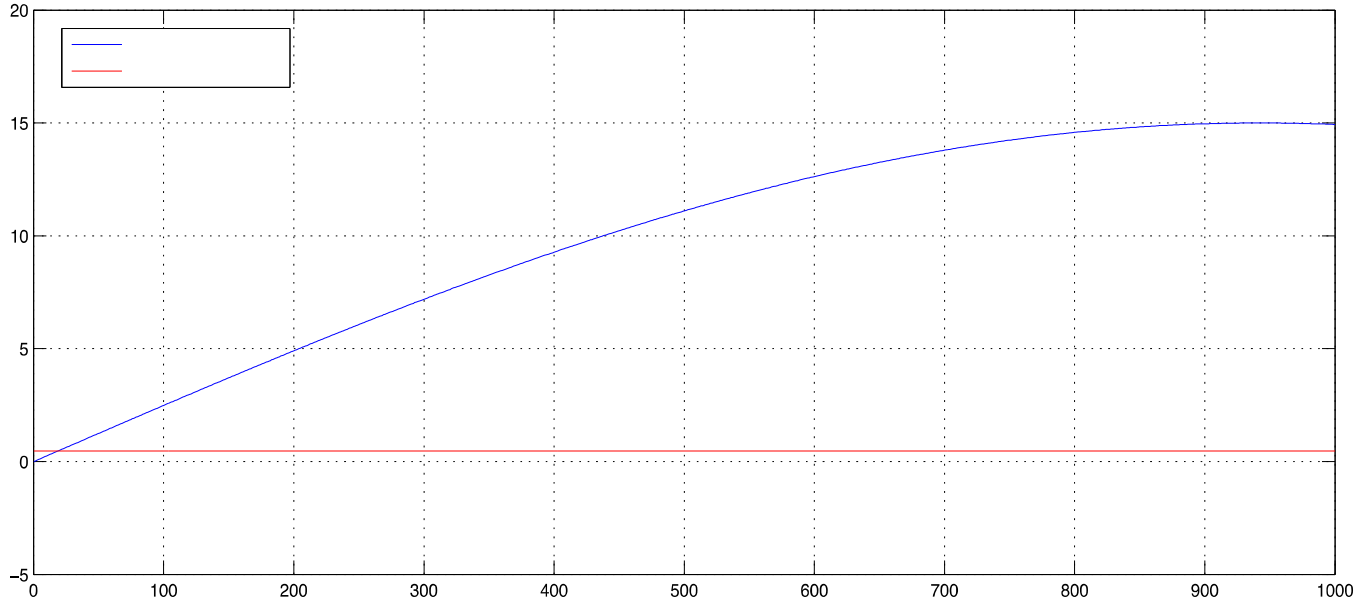


Sea Ice: To simulate melting continental ice (A), we positioned the ice in a wire mesh basket sitting on the surface of the water, using a fan to improve air circulation and speed the melting of ice.

Does the melting of floating ice raise sea level?

- **Sea Ice vs. Continental Ice:**

The results of the experiment show that the melting "continental" ice caused the water level to change significantly more than the melting "sea" ice. The students then used MATLAB to estimate the rate and acceleration of the changing sea level. (Note, the results have been smoothed to remove measurement noise).



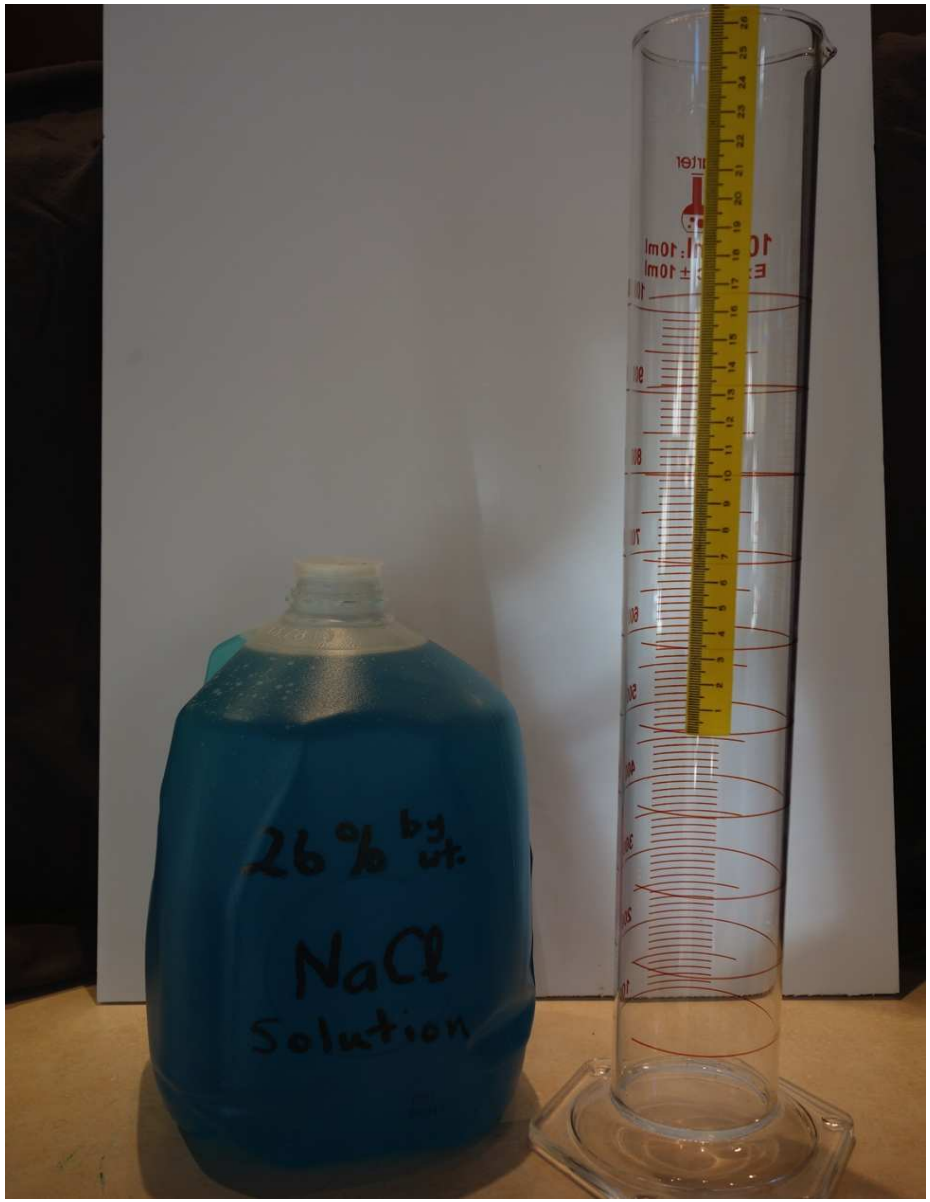
Does the melting of floating ice *really not* raise sea level?

- The results of the previous experiment can be a little misleading.
  - It is common lore that the melting of floating ice in the ocean does not change sea level.
  - In reality, salinity changes due to melting of sea ice do affect sea level.
- We have developed a simple demonstration comparing water levels of ice melting in a graduated cylinder containing distilled water or a saturated salt solution to test this hypothesis.

Experimental Setup

Materials & Setup

- 1000 ml graduated cylinder with adhesive metric ruler attached.
- Distilled water
- Saturated salt solution
  - 26% salt by weight
- Blue vegetable dye
- Frozen ice cylinders formed using 2” diameter PVC pipe and cap from local hardware store.
- Digital scale
- 600 ml calibration level
  - 3.4 cm.



Experiment #1: Ice Melting in Distilled Water

Water & Ice

Ice (290 g) added to 600 ml liquid

Water level: 13.9 cm

Ice Completely Melted

890 ml liquid

Water level: 13.9 cm

Experiment #2: Ice Melting Saturated Salt Solution

Saturated Salt Solution & Ice

Ice (333 g) added to 600 ml liquid

Water level: 12.5 cm

Ice Completely Melted

933 ml liquid

Water level: 14.4 cm

Does the melting of floating ice *really not* raise sea level?

- The “halosteric” contribution of melting ice floating in a saline solution is clearly seen.
  - Archimedes’ Principle states that an object immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces
  - Because freshwater is not as dense as saltwater, freshwater actually has greater volume than an equivalent weight of saltwater.
  - When freshwater ice melts in the ocean, it contributes a greater volume of melt water than it originally displaced.
  - For the Earth’s ocean salinity the increase in ocean volume when floating sea ice melts is equal to 2.6% of the seawater volume initially displaced by the ice.
  - This is 1/10 the sea level rise demonstrated using ice floating in a saturated salt solution.

Summary

- Four class-room activities were designed for the purpose of helping students understand climate and sea level change.
  1. Satellite altimeter sampling
  2. Model satellite altimeter using simple range-finder
  3. Sea Ice vs. Land Ice Experiment
  4. Halosteric contribution to sea level change
- As a supplement to their regular schoolwork, it was important to engage the students beyond lectures or PowerPoint presentations.
  - Feedback in early iterations was clear that hands-on experiments were the most useful in conveying important concepts.
  - In end-of-course surveys, students gave very high ratings to the conducted experiments.
  - Emphasizes the need for innovative approaches to teaching climate and sea level science in the absence of formal coursework in the high school setting.