Satellite Altimeter Demonstration Experiments for Outreach and Education

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ABSTRACT

Classroom demonstrations of satellite altimetry are described that are suitable for outreach demonstrations to the general public and classroom instruction for high school students. Nadir altimetry is introduced using an ultrasonic rangefinder and a programmable microcontroller. Demonstrations of radar, SAR imaging, and altimetry are being developed using a short-range radar demonstration kit.

Model Altimeter

A model altimeter can be easily and inexpensively constructed from an Arduino microcontroller and an ultrasonic range finder (Figure 1). The rangefinder incorporates a simple ultrasonic sensor with a microcontroller. The sensor sends out a burst of ultrasound and then listens for the echo when it bounces off an object. The working range of this rangefinder is between 2 centimeters and 3 meters. The microcontroller is connected to a laptop, and the data from the sensor can be read into MATLAB for data visualization and analysis. This inexpensive rangefinder can be used for a variety of simple experiments, such as making range measurement of students walking towards and away from the sensor. A nadir altimeter can be modeled by making range measurements to the surface of water in a container.

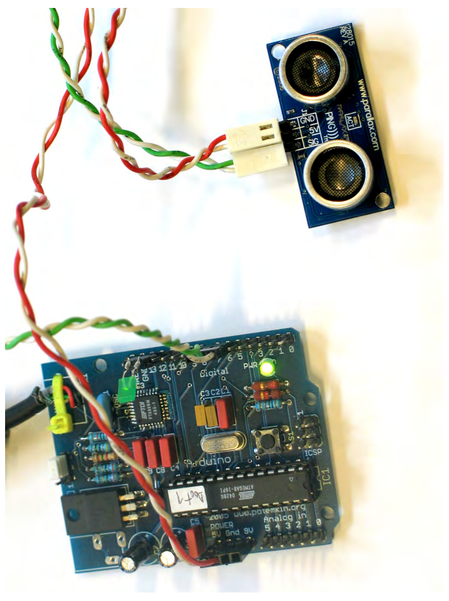


Figure 1: Model altimeter constructed from an Arduino mini controller and an ultrasonic rangefinder.

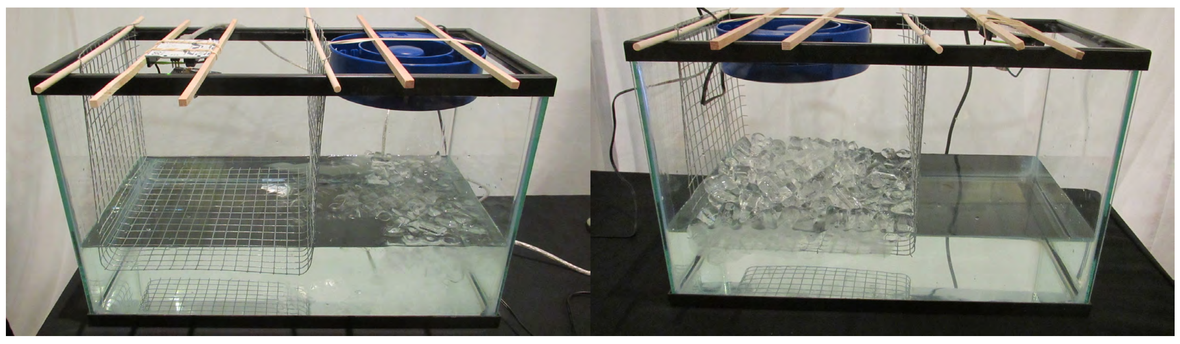


Figure 2: Experimental setup to compare the differences between the contribution of melting sea ice (left) and melting continental ice (right) to sea level rise.

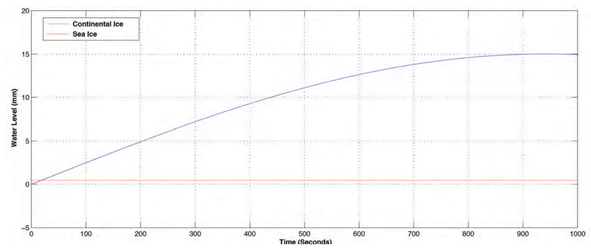


Figure 3. Results of ice experiment that show that melting "continental ice" (blue) contributes significantly more to sea level rise than melting "sea ice" (red).

Contribution of Melting Sea Ice and Continental Ice to Sea Level

The model altimeter can be used to explore the difference between melting sea ice and melting continental ice in terms of their contribution to sea level change. The increase of water level in two separate containers, one container where ice is floating in tap water to simulate sea ice (Figure 2, left panel) and one where ice is suspended just above the surface of the tap water to simulate continental ice (Figure 2, right panel). A fan is used to expedite the melting of the ice. The experiment is run for 20 minutes, and the results are read directly into MATLAB for further analysis. Once the experiment has been completed MATLAB is used to analyze the results to determine whether sea ice or continental ice contributes more to sea level rise when it melts. The results (Figure 3) show that melting "continental" ice causes the water level to change significantly more than melting "sea" ice. This classroom lectures accompanying this experiment, the experiment itself, and statistics describing the educational outcomes are described in Hamlington and Leben (2012).

Contribution of Melting Sea Ice to Sea Level

It was common lore that the melting of floating ice does not change sea level until Noerdlinger and Brower (2007) correctly pointed out that the melting of floating ice actually raises sea level. A more advanced experiment exploring this "halosteric" contribution of melting sea ice to sea level can be performed based on a similar experiment described in Noerdlinger and Brower (2007).

The demonstration uses a saturated solution of sodium chloride with blue dye added and a 1000 ml graduated cylinder with an adhesive metric ruler attached. The saturated salt solution, which is 26% salt by weight, was made by adding 3 lbs. of sea salt to one gallon of heated distilled water. Various recipes for making the solution can be found with a web search of "how to make a saturated salt solution". Ice cylinders slightly smaller than the diameter of the graduated cylinder were made using forms made from PVC tubing and end caps available a local hardware store.

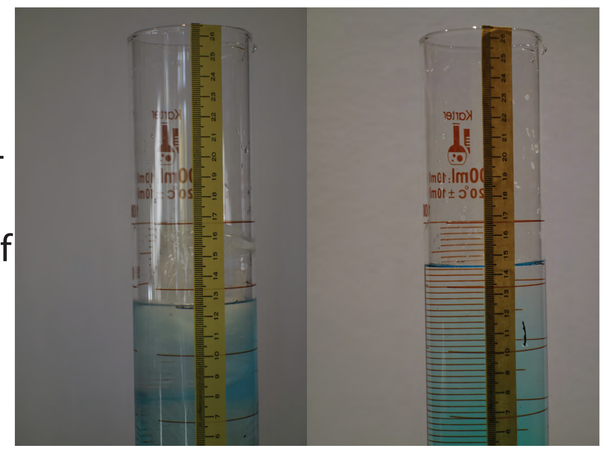


Figure 4. The initial experiment was performed starting with approximately 600 ml of salt solution in the graduated cylinder and a reference height of 3.3 cm on the metric ruler. A total of 333 grams of ice was added to graduated cylinder, increasing water level to 12.5 cm (left). Melting overnight raised the water level to 14.4 cm (right).

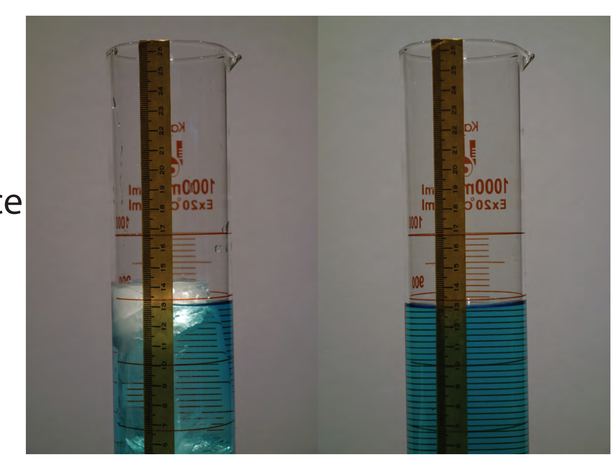
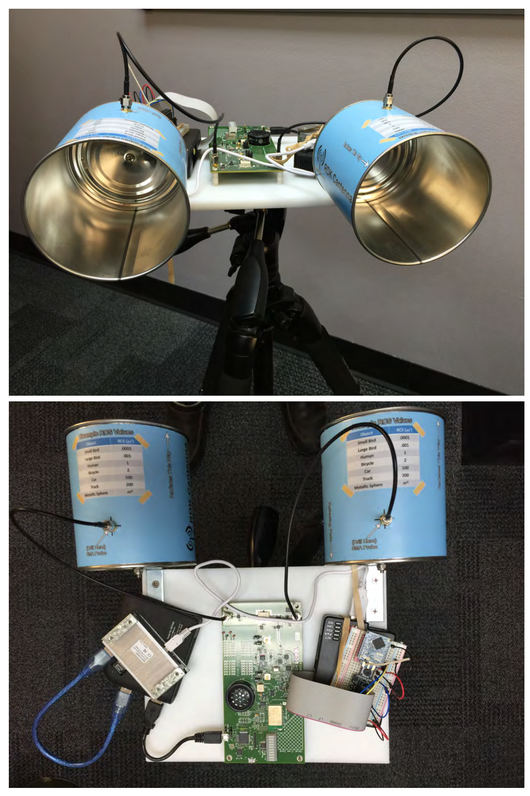


Figure 5. The experiment was repeated, this time using distilled water instead of the saturated salt solution. A total of 290 grams of ice was added to graduated cylinder, increasing water level to 13.9 cm. Melting overnight resulted in no change in water level from the initial height of 13.9 cm.

The "halosteric" contribution of melting ice floating in a saline solution is clearly shown. The effect for salinity values in the earth's ocean is such that the increase in ocean volume when floating sea ice melts is equal to 2.6% of the seawater volume initially displaced by the ice.

Radar Demonstration Kit

We are also exploring the use of a radar demonstration kit available from Quonset Microwave (2014). This system is based on a small radar system used in an course published on the MIT OpenCourseWare website titled "Build a Small Radar System Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging" (MIT OCW, 2014). The "coffee can" radar system is shown to the right along with additional a Raspberry Pi for data collection and wireless radio for data transmission.



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Noerdlinger, P. D., and K. R. Brower (2007): The melting of floating ice raises the ocean level, Geophys. J. Int., 170, 145–150, doi:10.1111/j.1365-246X.2007.03472.x.

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