A Math Student's Journey to Antarctica

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There are two things that have always been a part of my life. The first is mathematics. Ever since I was in preschool and I first saw numbers, I have always enjoyed thinking about them and looked for ways to manipulate them. The second is ice. I was born during a blizzard that dumped three feet of snow in Salt Lake City over a twenty-four hour period and I love to ski. I would have never thought that the two things coexisted until my sophomore year when I began to explore the mathematics of sea ice. Last year I was fortunate enough to be invited by Professor Golden to participate in a research expedition to Antarctica, as part of the National Science Foundation sponsored Research Experiences for Undergraduates program. I can say with certainty that nothing I have ever experienced here in Utah can compare with what I experienced in Antarctica.

Antarctica feels like a completely different world. There is limited communication with the rest of the world and there is definitely no cell phone service. The temperature of the air and water can be cold enough to kill you in a matter of minutes without proper gear. It is an isolated, frozen landscape. The vast amount of sea ice in Antarctica during the winter is nearly inconceivable from a human perspective and accounts for as much area as the continent itself.

The first time I saw Antarctic sea ice was about six o'clock in the morning of September 10, 2007, seven days after our ship had departed from Tasmania, Australia. The top of the ocean was about -2 degrees Celsius and ice was starting to form into disks called pancake ice. There were probably millions of these disks surrounding the ship for miles. It was an incredible sight to see. While the ship was still close enough to the sea ice edge, these perfect waves generated in the nearby open ocean propagated through the pancake ice. Instead of the seemingly chaotic movement that the ship had been undergoing in the open ocean, the ship now moved up and down in a pleasant sinusoidal motion.

Figure 1: Ocean swells moving through fields of pancake ice off of east Antarctica.

As the ship traveled further into the sea ice pack, the pancakes got bigger and bigger until they gradually formed into gigantic sea ice flows that were on the kilometer scale. The ship would pull along side these flows, a brow would be put out from the port side, a team would go check the sea ice for safety hazards, and finally the scientists would be allowed to go onto the sea ice to perform experiments and collect data. The goal of our work was to collect empirical data to help develop mathematical theories on sea ice and to verify mathematics that had already been developed. Sea ice is a composite material that consists of pure ice surrounding brine inclusions, air pockets, and solid salt inclusions. The two primary data sets that we collected investigated the correlation between the brine volume fraction and transport properties of sea ice.

Figure 2: The *Aurora Australis* alongside a sea ice floe at night.

The first primary data set collected each day was permeability data. Roughly speaking, sea ice is impermeable for brine volume fractions less than 5% and is permeable for brine volume fractions greater than 5%, which corresponds to critical temperature of -5ºC for a typical sea ice bulk salinity of 5 parts per thousand. To observe this “rule of fives,” holes of different depths were drilled into the sea ice and the rate at which fluid filled the hole was measured. Using the cores that had been drilled out, we took salinity and temperature measurements of the sea ice, which allowed us to create a brine volume profile. The rate at which fluid filled the hole allowed data to be collected on the permeability of the sea ice. To our knowledge, the data we collected was the first permeability data ever obtained in the Antarctic sea ice pack. It was an incredible experience to be able to use my knowledge of mathematics and apply it to a real world situation.

The second primary data set collected each day was the conductivity of the sea ice. Using a 1960’s era piece of equipment with four probes, an earth resistance tester, Wenner array measurements and direct vertical conductivity measurements were conducted. Wenner array measurements had previously been taken using this equipment, but we adapted this equipment to take direct vertical conductivity measurements, which we believe are the first of their kind. Already knowing the brine volume fraction profile of the sea ice in the location of the conductivity measurements, the dependence of the vertical conductivity on the brine volume fraction and was obtained, which gave excellent results when analyzed back home.

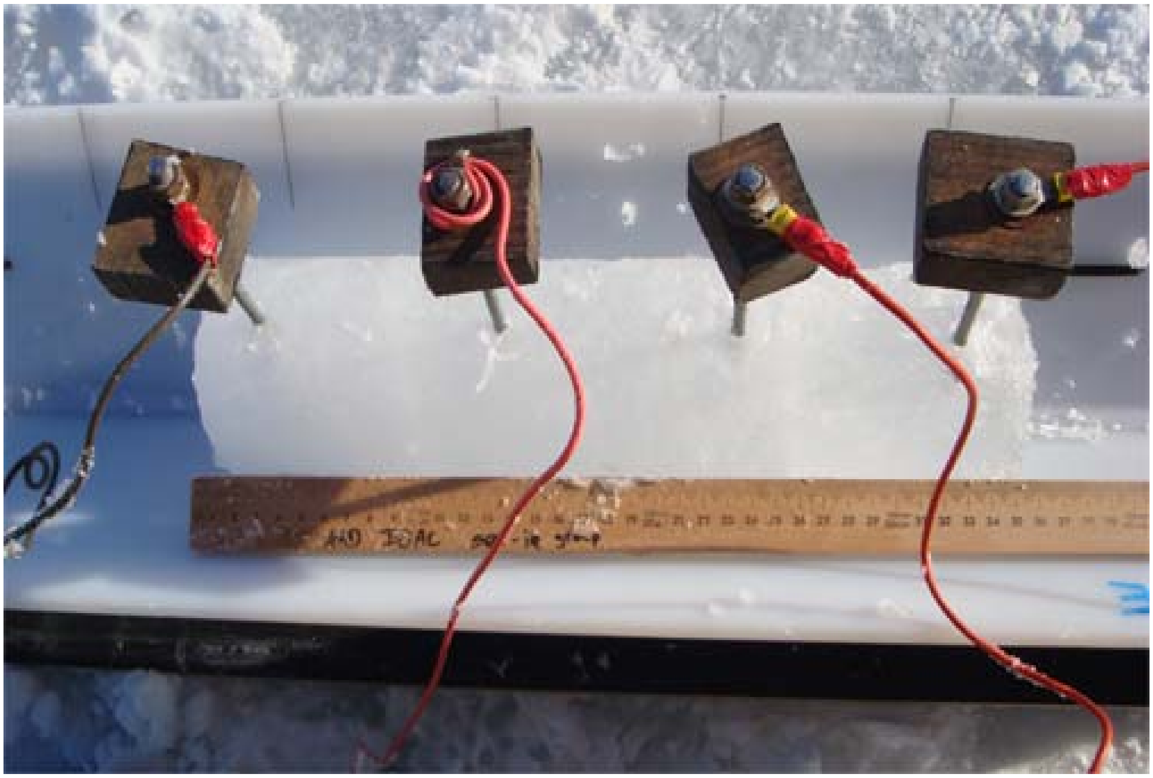

Figure 3: Modified Wenner array with four electrical probes inserted into a sea ice core to take direct vertical conductivity measurements of sea ice.

Sea ice is an indicator and regulator of climate change, with ice thickness being a major component in helping determine the effects of global warming. Current satellites and algorithms can sufficiently detect sea ice extent. However, the microwaves normally used by satellites often cannot sufficiently penetrate the sea ice, making thickness difficult to obtain. Both of the primary data sets that we collected and analyzed will help scientists to better estimate sea ice thickness. It was an amazing feeling that the research I participated in could have an impact helping scientists better understand the effects of global warming.

My adventure to Antarctica was something that I will never forget. To be able to experience Antarctica while using mathematics to do research was a truly incredible adventure. Mathematics and sea ice continue to be a large part of my life.

See video of our expedition at http://ucomm.utah.edu/current/antarctic.html