Abstract

Maine’s coastline has served as an economic and ecological resource for generations. From fisheries to shipping to tourism, the ocean is the lifeblood of this state. This is why understanding how the ocean changed in response to climate change in our past is paramount to the future of these fisheries and coastal cities. Recent work has shown that, for the past ~20 years, the Gulf of Maine has been warming faster than 99% of the world’s ocean (Pershing et al., 2015). However, direct observational records of ocean temperature in our region span less than 100 years, so it is difficult to distinguish natural long-term fluctuations from human-driven changes. This project aims to unravel some of the ocean-climate mysteries of the past several thousand years by analyzing marine fossils from sediment cores taken from the Gulf of Maine’s Jordan Basin. We intend to reconstruct sea surface temperatures during the mid- to late Holocene, which will provide insight to the Gulf’s long-term trends.

Project Description

Research Objectives

The primary objective of this study is to create a paleo record of Sea Surface Temperature (SST) in the Gulf of Maine’s Jordan Basin (see map in pdf attachment). This will be accomplished through chemical analysis of fossil shells produced by single-celled planktonic organisms called foraminifera, which are common in the Gulf of Maine. I will perform chemical analysis on the calcite in foraminiferal shells of the species N. imcompta to examine the ratio of the cations magnesium (Mg^{2+}) and calcium (Ca^{2+}). Using previously established calibrations, which demonstrate that higher water temperatures result in consistently higher Mg/Ca ratios in N. imcompta shells (Morley et al., 2017), the measured Mg/Ca ratio can then be used to calculate the temperature of water in which the organism grew.

The Gulf of Maine has only had a few paleo-climate studies done over limited time periods (Keigwin and Pilskaln, 2015; Wanamaker). This study hopes to expand the scope of these records in a region that is a key area in atmospheric and oceanographic circulation, as well as a region that has been tied to human communities for thousands of years. The current part of the sediment core that is being researched has already been radiocarbon dated, and has an age range of 6-0 ka, which is expected to experience a large change in temperature during the Holocene epoch. This is also a time of major cultural and fishing-strategy shift in Native communities on the Maine coast (Sanger, 2009).

Hypothesis 1: We hypothesize that sea surface temperature (SST) in the Gulf of Maine decreased steadily during the past 6,000 years, like much of the greater North Atlantic (Marcott et al., 2013), making the current warming trend observed in the past century highly anomalous relative to the long-term, natural trend. Alternatively, Gulf of Maine SSTs may have been highly variable during the past 6,000 years due to rapid changes in oceanic and atmospheric circulation, which would mean the current trends are within the realm of natural variability for this region.

Hypothesis 2: We also hypothesize that SST dropped below 16˚C at ~3.8 ka, contributing to the migration of Swordfish and the end of Swordfishing practices in New England (Sanger, 2009).

Importance to the Field

Sea surface temperature in Jordan Basin is a function of atmospheric heating/cooling as well as the relative mixture of incoming water from southern (warm) and northern (cold) latitudes(2; see Figure 1). Determining paleo SSTs will give us insight into how the Gulf of Maine responded to global changes on long (millennial to centennial) timescales, and provide a natural baseline against which we can compare the modern observed trends (past ~100 years).

In seawater, dissolved magnesium and calcium are present as ions with the same charge (2+) and a similar ionic radius. With increasing temperature, the magnesium more readily substitutes in for the calcium in carbonate shells (CaCO3). Therefore the Mg/Ca ratio of carbonates can be used as a “paleo-thermometer,” or a method for reconstructing past ocean temperatures. The general relationship with temperature is: the warmer the water, the higher the Mg/Ca ratio of fossil calcite. Mg/Ca of fossil shells can then be used to solve for past SST by using an already-established calibration (Mg/Ca=Be(AxT)), where A and B are species-specific constants, and T is the temperature at calcification (Morley et al., 2017).

How Project Will be Accomplished

This project will be accomplished by obtaining geochemical information from microorganisms in a sediment core. The sedimentological samples are from core KNR-198-CDH-9 collected by R/V Knorr from the Jordan Basin in 2010. Currently we have 32 wet samples with depths ranging from 717 cm to 1602 cm. This puts the age range between 6-3 ka. The Gulf of Maine provides open marine sedimentation free of ice cover from around 17 ka (2), giving us a rich, high-resolution sedimentological record. To supplement the samples we already have (covering 6-3 ka), we need to visit Woods Hole Oceanographic Institute’s core repository in Massachusetts to collect samples from the youngest part of the core, spanning 0-3 ka.

The foraminiferal samples will be extracted from the sediment core by being rinsed through a 63 micron sieve. This isolates the larger fossils from the mud-size sediment. Following the washing, the sample is dried, and the foraminifera are put through a 250 micron sieve, hand-picked and sorted under a microscope. Once the fossil samples have been sorted, the shells are cleaned chemically to remove any contaminating material (clays, organic matter, etc.). The sample is sonicated to remove any small adsorbed particles such as clays; reductive cleaning is performed to remove any metal oxides present in the shells, and finally the shells are oxidized (gently bleached) to remove any organic matter. The clean samples are then run through a mass spectrometer to establish Mg/Ca ratios. We plan to use a ThermoFisher Element II inductively coupled plasma mass spectrometer located in the Climate Change Institute's Sawyer building. Finally, Mg/Ca data will be translated into temperatures using a previously published calibration (Morley et al., 2017). We will compare our new temperature data to other records from the greater North Atlantic to test Hypothesis #1, and compare our data with existing archaeological records to test Hypothesis #2.

Relevance to Plan of Study

Currently, I am pursuing a dual degree in marine physical science and climate sciences. This study is in the area of paleoclimate, specifically paleoceanography, which allows me the unique opportunity to synthesize both degrees into a single project. If awarded this opportunity, I would have a research project that fits perfectly into my academic plan that allows me to develop new laboratory skills, further my scientific writing, expand my knowledge in both fields, and perform research on a topic that has the ability to expand to further work in the future. I am planning on graduating in May of 2020, where I would then like to move on to a masters program and continue researching climate related issues in the ocean.

Works Cited

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3. Morley, A., Babila, T. L., Wright, J., Ninnemann, U., Kleiven, K., Irvali, N., & Rosenthal, Y. (2017). Environmental Controls on Mg/Ca in Neogloboquadrina incompta: A Core-Top Study From the Subpolar North Atlantic. Geochemistry, Geophysics, Geosystems. doi:10.1002/2017gc007111

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5. Sanger, D. (2009). Foraging For Swordfish (Xiphias gladius) in The Gulf of Maine. Painting the Past with a Broad Brush: Papers in Honor of James Valtiere Write.

Budget Justification

Total Budget Requested: $3,000

Budget: Stipend Amount: $3,200

Budget: Materials and Supplies: 0

Budget: Travel: $611

Budget: MISC: $450

Budget Justification:

This grant will cover the majority of the cost associated with salary, chemical analysis, and travel to Woods Hole Oceanographic Institute totaling $4,261. The salary will pay for 8 weeks of full time summer work, 320 total hours at $10.00 an hour, totaling $3,200 This is broken into 5 weeks of sample preparation, 1 week for sample analysis, and 2 weeks for data processing and interpretation. All materials required for sample processing are currently in place in the Byrand Global Science Center's sedimentology Lab, and the materials required for the analysis are in the CCI's Sawyer building. The cost of the chemical analysis is ~$15 a sample and the number of samples required to get ~200 year resolution for the past 6,000 years is 30, totaling $450. Finally, travel to Woods Hole for the remainder of the samples is 706 miles round trip at $0.44 a mile, costing $311, and lodging for 2 people (2 rooms) costs $150 a night, totaling $300. This grant will cover all but $1,261 which will be covered by external funding sources that are currently being applied for, such as the Golden Fund, or mentor []'s start up funding.