A proposal to add two Slocum Gliders to the Gulf of Maine/North Atlantic Time Series (GNATS)

Executive Summary- We are proposing to acquire two autonomous underwater vehicles (AUVs), "Slocum Gliders", equipped with hydrographic and bio-optical instrumentation. They would be deployed across the Gulf of Maine, on a time series transect between Portland, Maine and Yarmouth, Nova Scotia. This sample line passes by 3 GOMOOS moorings, and the data will help with the interpretation of the GOMOOS data. The sample line also matches a long-term, Gulf-wide, NASA-funded transect (known as GNATS: **G**ulf of Maine/**N**orth **A**tlantic **T**ime **S**eries) that we have maintained since 1998 (now beginning our ninth year). Our measurements have been primarily hydrographic, biological, chemical and optical, with cruises spaced at roughly monthly intervals. The GNATS time series transect is the longest (315km) in the Gulf, and predates GOMOOS by 3 years. Since beginning GNATS, we have been looking for economical ways to increase the frequency of sampling in the Gulf to more than one trip per month, since the Gulf can change on faster time scales (e.g. harmful algal blooms, spring bloom, etc.). Moreover, our sampling platform has been primarily aboard a ship of opportunity, the *M/S Scotia Prince* ferry, which sampled between May and October. Following the departure of the *M/S Scotia Prince* from the Gulf in 2005, we have been chartering smaller (but more expensive) fishing vessels to continue our sampling. This prompted us to look for alternative means to sample the GNATS that can reduce the expensive ship costs and provide vertically-resolved data during times of year when we cannot be at sea.

The Slocum Glider is a state-of-the-art autonomous underwater vehicle (AUV) that moves up and down in the ocean by changing its buoyancy. Wings allow steerable gliding, thus horizontal propulsion. The vehicle traces a saw-tooth profile and can sample depth-resolved temperature, conductivity (salinity) plus bio-optical properties (such as radiance, irradiance, light scattering, chlorophyll fluorescence, dissolved organic matter fluorescence and beam attenuation. At the surface, the gliders fix their position via GPS, communicate the data and commands via ARGOS/Iridium satellite links, then adjust their course using dead reckoning before their next dive. The gliders carry an altimeter, thus they can collect data to within a few meters of the bottom before beginning their ascent. Slocum gliders can be deployed for ~1 month, after which they are commanded to stop at a pre-determined location for recovery (e.g. a near-shore location which is safer to reach in a small vessel).

Given the cost of ship time and inherent dangers of sampling the Gulf of Maine in the winter, this instrument could revolutionize our ability to sample the Gulf's physical and bio-optical properties. We are proposing for two gliders in order to alternate the glider deployments for check-up, testing, cleaning of bio-fouling organisms and recalibration prior to future deployments. Long-term measurements of the sort proposed here are essential for understanding the response of the Gulf and its primary producers (the base of its food web) to climate change. Slocum gliders are tried-and-tested technology; they have weathered Atlantic hurricanes and other significant weather events across the coastal waters of the Gulf of Mexico, mid-Atlantic Continental Shelf and even the busy, narrow Hudson River, without problems in deployment or data collection. We would make our data publicly available through GOMOOS, as well as several U.Maine and Bigelow researchers, particularly interested in these data because of their proximity to GOMOOS buoys. The State Bond Fund request for two gliders with sensors, plus ancillary equipment required to test the gliders and communicate with them via satellite would be about $282K. This should be compared to the cheapest ship time currently available; one round-

trip from Portland to Yarmouth (2.6d at sea) costs us about $13,000. In one 3-week deployment, a glider will do two round trips across the Gulf with a sample density 43X greater than in typical cruises. At minimum, each monthly glider deployment would save the equivalent of two ship trips (~ $26K) and the effective payback time for these gliders would be realized during the first year of this 5 year grant. Moreover, the gliders could be deployed in the winter, when ship operations are difficult due to rough weather.

We are fully aware of the possible risks in deploying an AUV in the Gulf of Maine given the plethora of fixed and drifting fishing gear. Given the specific requirement of this RFP for Maine Bond Funds that the equipment have a five-year lifetime, we have chosen to build in the cost of insuring the Slocum Gliders through MOAC (Marine Office of America, Corp, a division of CNA Maritime Underwriters). This company has extensive experience in maritime underwriting for a wide range of marine equipment. The insurance premium for keeping a glider in the water for twelve-24d deployments per year is $6638, with a $10,000 deductible. This cost is being provided in the Bigelow Match to the state request.

In terms of the selection criteria, we summarize our proposal as follows:
Proposed outcomes and measures- The measurable outcomes of this work would be a) a publicly-available, annual time series, including all the important seasonal events (e.g. the spring bloom, late fall overturn, deep winter convective mixing) and offers unsurpassed horizontal resolution, b) higher quality vertical sampling along the GNATS transect (including more bio-optical variables than we can sample now), c) reduced ship costs and d) a fundamental competitive edge for future NASA, Navy and NSF funding; these agencies are increasingly encouraging the use of AUV's to lower the ship time costs of oceanographic research.

Impact of instrument acquisition-The addition of two Slocum gliders to the GNATS program will convert our time series from a six-month sampling per year to a year-round program. This would also enhance the quality and quantity of the vertical profile data that we can collect, which will provide added scientific confidence (i.e. statistical resolution) on the Gulf's water properties and their variability. These tools also will be directly applicable to other oceanographic endeavors, increasing our capacity for R&D work in Maine, especially in the area of ocean observing, which is now receiving major infusions of funding. These instruments are cutting-edge marine technology that will allow us to address new and complex questions about Gulf-wide physical and biological oceanography as well as controls on ocean productivity and fisheries in the Gulf of Maine.

Scientific Merit-There is no doubt that questions about long-term climate change and its impact to the Gulf of Maine will require long-term data collection. It is easy to show that the climate of the Gulf of Maine responds to decadal cycles such as the North Atlantic Oscillation. The tough question is how this climate cycle (or an anthropogenically-induced climate change) affects the Gulf's circulation, turnover, primary/secondary production, fisheries, etc. We will reach a decade of sampling in just two years, which will allow us to begin to relate long-term, decadal scale climate forcing indices to Gulf-wide phenomena. Addition of the gliders will allow us to sample through the entire year, not possible when we sampled from the ferry. This is critical for a comprehensive time series record. Gliders will allow better spatial interpretation of the GoMOOS buoy data.

Collaboration-There are several areas of collaboration that will result from the funding of this proposal. The glider data will be made publicly available through GOMOOS which is the broadest form of shared collaboration with the public. There also will be collaborations with fellow researchers at Bigelow Laboratory and the University of Maine interested in our data as it

relates to the GOMOOS buoy data plus other glider-based research. There are associated costs for operating gliders that will be reduced by sharing with other users in the state. We will involve an undergraduate from Bowdoin College in our work.

Economic Growth and Benefit- The most important economic benefit of this work will be in our ability to leverage more funding from the Office of Naval Research, NASA and NSF to support our scientific studies. In these days of austere federal funding, these agencies have severely reduced precious ship funds. Moreover, the match funding that is part of this request will support a month of time each year for 3 Bigelow researchers to run the glider operation. The Maine State Office of Economic Development estimates that the impact of R&D funds in the local economy is about a factor of $8 return per dollar invested.

Relevance to Maine's research needs- Understanding long-term change of the physics and biology of the Gulf of Maine is clearly a research need in Maine, given requirements to predict future conditions in the Gulf. Long-term climate change can cause rippling effects through the ocean food web and human economy that are hard to predict without high quality ocean observing. Maine's economy is highly related to its coastal and ocean resources; it will require careful scientific monitoring of the sort proposed here in order to understand and predict long-term climate change.