Maine EPSCoR FY19-24 NSF EPSCoR RII Track-1
Proposal Development Process Phase I – Research Concept Papers

1) Proposed Research Focus:	***"Next-Generation Environmental Observatories – From Lakes to Rivers to the Sea: Protecting and Developing Maine's Natural Resource-based Economies in a Time of Rapid Change"***

2) Primary Contact Person:

Name:	Institution:	Title:	Dept.	E-mail:	Phone:
David Townsend	Univ. Maine	Professor	Marine Science	Davidt@maine.edu	581-4367

3) Suggested/Potential Key Senior Personnel:

Name:	Institution:	Title:	Dept.	E-mail:	Phone:
Neal Pettigrew	Univ. Maine	Professor	Marine Science	Nealp@maine.edu	581-4384
Cindy Isenhour	Univ. Maine	Assist. Prof.	Anthro & CCI	Cynthia.isenhour@maine.edu	303.807.6515
David Emerson	Bigelow Lab.	Senior Res. Sci.	N/A	Demerson@bigelow.org	315-2567
Nicole Price	Bigelow Lab.	Senior Res. Sci.	N/a	Nprice@bigelow.org	315-2567
Mohamad Musavi	Univ. Maine	Professor and Associate Dean	College of Engineering	Musavi@maine.edu	581-2218
Collin Roesler	Bowdoin	Professor	Biology	Croesler@bowdoin.edu	725-3842
Damian Brady	Univ. Maine	Assist. Prof.	Marine Science	Damian.Brady@maine.edu	563-8102
Larry Mayer	Univ. Maine	Professor	Marine Science	Lmayer@maine.edu	581-5118
Brian Beal	UM Machias	Professor	Mar. Ecology	Bbeal@maine.edu	255-1314
Brian Tarbox	SMCC	Professor	Biological Sci.	Btarbox@smccme.edu	741-5767
Andrew Pershing	GMRI	Res. Director	N/A	Apershing@gmri.org	228-1656
Caitlin Howell	Univ. Maine	Assist. Prof.	Ch. & Bio.Eng.	Caitlin.howell@maine.edu	581-2309

And Others: Numerous other investigators have agreed to participate in this project; U. Maine faculty include: *Aaron Strong, Teresa Johnson, Keith Evans, Josh Stohl, Andrew Thomas, Emmanuel Boss, Lee Karp-Boss, Sara Lindsay, Paul Rawson, Nishad Jayasundara, Ian Bricknell, Gayle Zydlewski, Mark Wells, Richard Wahle, Heather Hamlin, Kristina Cammen*, *Jeff Runge, Walt Golet*, *Fei Chai, Huijie Xue*, *Yong Chen,* and others we may have forgotten to list, just in the School of Marine Science;

Also: *Mike Kinnison*, School of Biology & Ecol.; *Katherine Allen, Joe Kelley*, School of Earth and Climate Science; *Sean Birkel, Paul Mayewski*, *Karl Kroetz*, Climate Change Institute (CCI); *Ivan Fernandez*, Forest Resources & CCI; *Kimberly Huguenard, Lauren Ross*, Civil & Env. Engineering. And, we are continue to engage other University of Maine engineering faculty, and Maine NGOs, such as the Friends of Casco Bay.

Intellectual Merit: (the research focus)

A. ***Need****: a brief statement of the research problem/need to be addressed, and why it is urgent for Maine to address this problem/need now (how it is currently limiting the state's capacity/research competitiveness).*

Our proposal is all about WATER – from *rain*, to our *lakes*, to our *rivers* and *estuaries*, to the *ocean* – and their connections with local and far-field forces that are driving both significant long-term changes and even more dramatic shorter-term increases in variability. Maine is unique among the lower 48 states in that it is geographically positioned at the confluences of major atmospheric storm tracks and two major western North Atlantic ocean currents. As a consequence, our water resources are more susceptible to, and are more greatly affected by, the accelerating trend of "environmental" (or climate) change – in some ways, Maine is the canary in the coal mine.

Because major North American storm tracks converge over Maine and the Gulf of Maine (GoM), it becomes all the more significant that northeast storm events (Nor-Easters) have been increasing in both frequency and intensity (*in just the past six weeks, two NE storms have "bombed out" over the GoM, fueled by the Gulf's abnormally warm ocean waters, producing hurricane-force winds offshore*). In addition, the GoM is situated at the point where cold, nutrient-poor waters (via the Labrador Current flowing south) meet and mix with warm, nutrient-rich waters (from the Gulf Stream flowing north). These offshore waters and, to a lesser extent, Maine's rivers, are the main source waters to the Gulf of Maine. In recent decades we have watched the relative proportions of these two ocean source waters alternate dramatically with one another on time scales of months to years, for reasons we are only beginning to understand. These *"alternating oceanographic states"* significantly affect the GoM's water temperatures, salinities, and nutrient regimes, thereby disrupting estuarine and marine ecosystem functions from plankton to fish.

The most obvious change that Maine and the Gulf of Maine are experiencing is warming. Not just air temperatures, but the waters of the GoM have been warming at an alarming rate. The fate of our record-setting landings

of lobsters (the most valuable fishery in the world) may hang in the balance. On land, we are seeing significant increases in precipitation (rain; snowfall is declining) and, more importantly, greatly increased variability in rainfall, meaning that extreme rain events are more common now. Freshwater runoff to the sea is therefore more variable, as is the delivery of pollutants, dissolved nutrients, suspended sediments, and low pH waters, thus impacting Maine's coast and coastal waters, in numerous ways. How all this influences the dynamics of our living marine resources is mostly a matter of speculation; we face more than a few unknowns. GoM warming trends, and large amplitude swings in hydrographic and nutrient properties, are likely affecting ocean acidification (pH, alkalinity and aragonite saturation states), the occurrence of red tides (by changing nutrient regimes), the health of our commercial fisheries (via population shifts), large swings in local steric sea level (promoting beach and salt marsh erosion), and our weather ─ all of which are of great economic importance to Maine, all of which are related to a changing climate, and all of which are only poorly understood if they are understood at all. Recent work is showing that ocean acidification may be the most important environmental issue facing the GoM and its estuarine and coastal waters, and all life forms that grow in those waters. For reasons still unknown, the buffering capacity and aragonite saturation state of the bulk waters of the Gulf of Maine proper are *the lowest* of any Atlantic coastal or shelf waters from Canada to Mexico. Maine's new and growing aquaculture industry (stimulated by SEANET) may be vulnerable, as might our capture fisheries, to the effects of, for example, spikes in acidification that stem from unpredictable, unmonitored, but frequent episodic inflows of those caustic offshore waters.

Maine's research activity on these issues is in its infancy and has yet to catch up with ongoing changes in its coupled marine and freshwater systems, changes that are happening before our eyes, in ways that no one understands. Numerous hypotheses fall out of the above discussion and cry out to be tested. The best approach: a next-generation observatory. But in the GoM we are dependent on an ageing ocean observing system and limited involvement of the best scientists in the state. It should be obvious that Maine is best positioned to lead the nation in the science of ocean, estuarine and freshwater observing, in order to protect and develop Maine's natural resource-based economies in the face of rapid change.

Where once the GoM observing system, developed here at UM, was the nation's envy, we rely today on an ageing infrastructure that needs to be updated and expanded to include Maine's lakes, rivers and estuaries, with the newest (and still-to-be-developed) sensors and capabilities, that meet the demands of a new clientele of users ─ with which not only to observe and document changes, but to conduct research into the effects of those changes, on living marine resources, on weather and climate, on local sea level fluctuations, and on the base of the marine food web. The proposed next-generation observatory, with new sensors and new data acquisition and communications systems, will increase the delivery of data and information by an order of magnitude.

B. *Research Goal & Objectives:* *describe the overall project goal to address this problem/need, and 1-3 key research objectives.*

We have two goals: **1)** To build a next generation observatory, as just described, and **2)** to develop the capability to package and deliver to users in different forms and at different scales the data and information they require *to understand and deal with extreme environmental variability in Maine and in our ocean*. Some information needs to be highly interpreted and may work its way into policy implementation on a time scale of decades, while some information may flow immediately to those in need for day-to-day decision-making. This project will clarify these connections and study/develop models and technologies to implement them.

Our objectives are: **1)** to update and expand the ageing observing system, its coverage (to include lakes, rivers and estuaries), its array of sensors (such as for nutrients, plankton and the carbonate system), and apply the broad expertise available in Maine and at UM in the development and marketing of new sensors and platform technologies. This is required if we are to meet the needs of not just mariners and oceanographers, but the growing needs of numerous other users and stakeholders, especially environmental mangers (fisheries, public health [PSP], coastal planners, etc.). **2)** We must develop a fundamental, mechanistic understanding of direct and indirect causes of, and impacts of, the dramatic environmental changes we see occurring. That is, we must begin to address the questions listed in the next section. **3)** We will leverage the existing capabilities produced by the current SEANET EPSCoR Program: The operation of their system of estuarine buoys and sensors will be extended into this project, leaving us to add/update/upgrade any sensors, and extend the system of sensors into the rivers and lakes.

C. *Research Actions:* *describe a few specific key research actions that could be implemented to meet the objectives.*

Our research actions will be targeted at answering the following questions (among others): How does a warming ocean influence the physics of mixing, stratification, currents? The acidity of ocean waters? The marine food web? Changes in physiology, distributions and abundances of commercially important species? How will increased variability in air temperatures and rainfall feed into these changes? How does warming relate to pH in the Gulf? Is the pH of Gulf of Maine waters stable? Is it Increasing? Why are the Gulf's alkalinity and aragonite saturation levels so dangerously low in the first place? How does pH affect phytoplankton? Their rates of primary production? Harmful algal blooms

(red tides)? Commercial species production? We should explore novel, innovative ways of addressing these questions, such as employing microbial genomics as a possible tool to track water masses (e.g., Bigelow Lab scientists), and, with our team of social scientists, we will expand the state's climate adaptive capacity through the development and implementation of a new state-wide framework for comprehensive, participatory stakeholder scenario-based planning built from observatory generated data products to provide actionable information to local and state decision-makers about how to prioritize policy and community responses to climate and environmental variability.

D. Priority: *indicate how this research would address NSF and state priorities in advancing the frontiers of knowledge and understanding (within a field and/or across different fields). Research*

The research directions alluded to here address two of Maine's Targeted Sectors (Nos. 2 and 6; Environmental Technology and Marine Technology and Aquaculture) and touch upon three of five NSF priority areas: *•Harnessing data for 21st century science and engineering…•Shaping the human-technology frontier… •Navigating the new Arctic.* With respect to these three: Environmental observatories are data-driven, and advances are dependent on new technologies and the people who understand them. As for Arctic connections: New shipping lanes to and from the Arctic will include safe passage to and from ports in the Gulf of Maine. And, alluded to above, the Gulf is already seeing evidence of, and environmental effects of, the arrival of Arctic melt waters.

Broader Impacts: (related to the research focus)

E. ***Impacts****: potential to benefit society and contribute to the achievement of specific, desired societal outcomes.*

Maine relies a great deal on its lakes and the sea for its livelihood and as a major component of its economy. End-users of these data and information include the Maine DMR and DEP, the commercial and recreational fishing and aquaculture industries, the coastal tourism and recreation industry, municipal and town officials, including planning offices and municipal water district operators, land trusts and watershed alliances, and property owners, and such state initiatives as the new Ocean Acidification Program launched by the Maine Legislature. While components of SEANET cover the immediate, nearshore zone, this project focuses on influences from upland freshwaters to offshore and afar (Arctic melt waters have arrived), which have already been shown to be important.

F. ***Impacts****: potential economic development as a result of this research.*

The economic value of the GoM to Maine is immense, from fisheries to shipping to tourism. Maine must be able to boast and market the cleanest and safest seafood products in the world, guarded by an ocean monitoring/observing system that is the best in the world. In the process, we will aim to develop and market new ocean observing sensors and technologies by teaming with our engineers and companies in Maine.

G. ***Impacts****: potential for statewide workforce development in this research area (faculty, postdocs, graduate and undergraduate students, and the professional workforce).*

Statewide workforce development will occur in a number of areas, all the while emphasizing diversity; Maine is an increasingly diverse state and is home to growing and vibrant refugee communities, and it is our goal to be proactively inclusive as we seek to build capacity. First, we will hire several new faculty in relevant areas. Second, we will support 1o to 20 new PhD students (housed with co-advisors state-wide) and 30 to 40 undergraduate students distributed among UMaine System campuses, the Gulf of Maine Research Institute, Bowdoin College, SMCC and other Maine institutions. We will also train students in our UMaine Professional Science Master's degree program in Marine Science; those students will work with faculty and stakeholders throughout Maine as part of their internship, which will focus in turn on relevant themes, preparing them for jobs in Maine marine-related industries.

H. ***Impacts****: potential to provide infrastructure that grows the state's academic research and education capacity.*

Natural resource-related industries comprise a major component of Maine's economy, which are in turn supported by a healthy environment that is Maine's hallmark. Our next-generation observatory will enable informed assessments of environmental changes now underway and their effects on our marine and aquatic environments' capacity to function as healthy ecosystems with myriad interconnecting parts. We will take advantage of, and build on. UMaine's SMART Program (Musavi et al.), sharing their goals to develop K-12 experiential and active learning models using real world environmental challenges, such as water, to engage students, especially female and under-served students, in engineering and science education. Grade school children, via GMRI's programs, will be exposed early to the needs of a healthy ocean.

Maine's research portfolio is already strong but is in critical need of infrastructural and personnel investments in order to stay strong and to capture the research and educational opportunities presented to us, ironically, by a rapidly changing environment. To remain competitive for the best students and keep pace with projected growth estimates, we must further develop our research capacity by building on and tapping the true potential of already-strong teams of scientists and educators.