COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 08-1 **NSF 08-556** **07/03/08**	**FOR NSF USE ONLY** **NSF PROPOSAL NUMBER**
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **DGE - GRAD TEACHING FELLOWS IN K-12**	

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				071735252	

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
010211810	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE **University of New England**	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE **University of New England** **11 Hills Beach Road** **Biddeford, ME. 040059526**
AWARDEE ORGANIZATION CODE (IF KNOWN) **0020503000**	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)	☐ SMALL BUSINESS ☐ FOR-PROFIT ORGANIZATION	☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS	☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **The Interactions of Biology, Chemistry and Physics at the Land-Ocean Interface: A Systemic PARTnership Aimed at Connecting University and School (SPARTACUS)**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **2,965,008**	**60** months	**02/01/09**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.5) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☐ HUMAN SUBJECTS (GPG II.D.6) Human Subjects Assurance Number ________
Exemption Subsection ________ or IRB App. Date ________
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
____
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT **Department of Biological Sciences**	PI/PD POSTAL ADDRESS **11 Hills Beach Road** **Biddeford, ME 04005** **United States**
PI/PD FAX NUMBER **207-602-5956**	

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CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 08-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be dislosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME		

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

Project Summary

This project entitled The Interactions of Biology, Chemistry and Physics at the Land-Ocean Interface: A Systemic PARTnership Aimed at Connecting University and School (SPARTACUS), will form linkages among university researchers and their graduate students with the K-12 community.

Intellectual Merit. This project uses the hydrologic cycle in a coastal watershed as a focus to convey the importance of interdisciplinary efforts in addressing scientific and social issues to K-12 students, who will work with Graduate Fellows and their faculty advisors. It focuses on the interrelationships of physics, chemistry, biology, mathematics, and geology in studying a local watershed. This work uses local climate and weather to engage students in STEM activities to which they can relate. Specifically, it investigates how precipitation drives river discharge, which in turn, governs the coastal current, which influences coastal weather. However, feedback mechanisms along the way modify the type and amount of precipitation. These mechanisms include the interaction of solar radiation with the atmosphere and land/water surfaces, which is important because the amount of radiation influences weather patterns and precipitation. This project tries to disentangle the feedback loops to more clearly determine effects of population growth, land use, and climate change on the region. Questions to be addressed include how land cover influences precipitation and river discharge, how changes in discharge affect transport of nutrients and pathogens, and how the coastal ocean responds to these changes. While scientifically important, these phenomena are also tangible to students at all levels.

Broader Impacts. The Saco River watershed focus will engage K-12 students and teachers in authentic inquiry-based learning in STEM-related disciplines regarding biogeochemical cycling. In the process, Graduate Fellows will gain understanding of teaching and the educational process, and also develop skills in communication, collaboration and team building.

The Saco River watershed and the Saco River Coastal Observing System (SaRCOS) will be used for school projects designed through collaboration among University faculty, Graduate Fellows, and teams of teachers in six school districts. Place-based inquiry is a tool to engage students and may involve field data collection, real-time data acquisition from instruments in the river and offshore, laboratory analogues, and others. Students will participate in planning research, data gathering, and analysis in a grade appropriate manner. The interactions center on real scientific questions based in their local environs, so students engage in current research of relevance to them. This will make students more aware and interested in STEM disciplines, increase scientific literacy, aid in critical thinking skills, and enhance teacher comfort with STEM content and knowledge about STEM disciplines and careers.

The six participating school districts benefit from the partnership through professional development opportunities for teachers, and an enrichment of the learning environment in all of their schools. These districts encompass rural, suburban and urban settings, and also include the two largest and most ethnically diverse districts in the State of Maine. We expect that the relationships between university and K-12 faculty fostered during this project will continue after the project ends, resulting in a long-lasting impact on the region.

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For font size and page formatting specifications, see GPG section II.C.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

a. Results from Prior NSF Support:
No prior GK-12 funding.
Related Grants:
Students and Scientists: Together Advancing Science Knowledge
Award #: ESI-0222740 Amount: $565,014 Award Period: 9/1/2002-2/28/07
Henrietta List hlist@maine.edu (PI), Stephan Zeeman (Co-PI)
Partners: Maine Mathematics and Science Alliance, Univ. of New England
This project developed four new instructional units for GLOBE: a middle and high school unit on Urban Atmosphere and a middle and high school unit on Coastal Ecosystems. These units met the needs of school systems for standards-based instructional units and aided the research community in gathering data. In addition, the project developed an on-line tool, "Assemble an Inquiry," that coached educators through the process of developing their own customized, standards-based units with existing GLOBE materials.
Improving Biology Education for Non-science Majors: Environmental Change and Carbon Dynamics as the Focus of Inquiry-based Laboratories
Award #: DUE-9952305 Amount: $ 54,708 Award Period: 9/1/2000-8/31/02
Gregory Zogg gzogg@une.edu (PI), Stephan Zeeman (Co-PI), Mark Johnson (Co-PI)
To accomplish the goals of teaching non-science majors not only what we know from science (i.e., content), but more importantly how that knowledge is acquired (the process of science) and its relevance to real-world problems, we adapted the inquiry-based approach to laboratory investigation for use in our general biology course for non-science majors at the University of New England (approximately 150 students a year).
Phytopia: Showcasing Tiny Ocean Life in a Multimedia Environment
Award #: OCE-0085447 Amount: $ 88,834 Award Period: 9/1/2000-8/31/02
Annette deCharon annette.decharon@maine.edu (PI), Michael Sieracki (Co-Pl),
Stephan Zeeman (Co-PI)
Partners: Bigelow Laboratory for Ocean Sciences, University of New England
This award provided funding for scientists at Bigelow Laboratory for Ocean Sciences and the University of New England to collaborate with the Data Distribution Laboratory, a facility based at California Tech/JPL, to create a multimedia educational experience to bring the lower end of the marine food web "to life". Interaction with multimedia tools and data simulations enables students to discover why the marine ecosystem is critical to human existence. The program continues to be disseminated via CD ROMS and a website, and is aligned with efforts to create a Digital Library for Earth Science Education.
b. Goals and Objectives
The project uses the hydrologic cycle in a coastal watershed as a focus to convey the importance of interdisciplinary efforts to address scientific and social issues. Here we look at the interrelationships of physics, chemistry, biology, mathematics, and geology in studying phenomena that are tangible to students at all levels. In a nutshell, precipitation drives river discharge, which in turn, governs the coastal current, which influences coastal weather. However, along the way the interaction of solar radiation with the atmosphere and land/water surfaces modifies the type and amount of precipitation. This project tries to disentangle the feedback loops to more clearly determine effects of climate change.

We will use this focus to engage K-12 students and teachers in authentic inquiry-based learning about STEM-related disciplines focused on biogeochemical cycling. In the process, Graduate Fellows will gain understanding of teaching and the educational process, and also develop skills in communication, collaboration and team building.

The Saco River watershed and the Saco River Coastal Observing System (SaRCOS) will be used a for a myriad of projects which will be designed through collaboration among University faculty, Graduate Fellows, and teams of Teachers in six school districts. We will use place-based inquiry as a tool to engage students. K-12 projects will be tailored to each school's needs but will link back to the SaRCOS research. Projects may involve field data collections, real-time data acquisition from the SaRCOS instruments in the river and offshore, laboratory analogues, and others. Students will be engaged in planning research, data gathering, and analysis in a grade appropriate manner.

Participating school districts will benefit from the partnership through professional development opportunities for teachers and an enrichment of the schools' learning environment. Because the interaction centers on real scientific questions based in their local environs, students can engage in current scientific research that has relevance for them. The Graduate Fellows and their advisors will offer new opportunities for K-12 students to engage in critical thinking in science, and hopefully stimulate some to become STEM researchers themselves.

We anticipate the partnership to last well beyond the period of the grant, since continued support for linking Graduate Fellows to K-12 education will be aggressively sought as part of University of New England's commitment to support educational outreach.

c. Project Plan

Systemic Partnership Model Overview

The project plan incorporates three dimensions that collectively create the Systemic Partnership Model (see Figure 1). Each dimension relates to the essential facets of connecting the university and school together and reinforcing a systems approach, which mutually foster wider scope and more lasting impact.

The first dimension in the Systemic Partnership Model is the identification of district-wide needs. A needs assessment should be focused on the entire K-12 school district in order to actualize greater impact. Synergism will be cultivated as administrators and teachers across the district are involved in goal-setting with increased potential to impact multiple schools and classrooms. The second dimension is an appropriate scientific research project, which is systemic in allowing for the integration of the STEM disciplines, and locally-based so that the research can be tangible and real for K-12 students. The third and final dimension is a pedagogical framework that is based in inquiry but additionally has the systems-based lens of looking holistically at science.

Mutually these three dimensions build a systemic partnership, which include university and school components with an overlay of inclusive and extensive planning and delivery for greater impact.

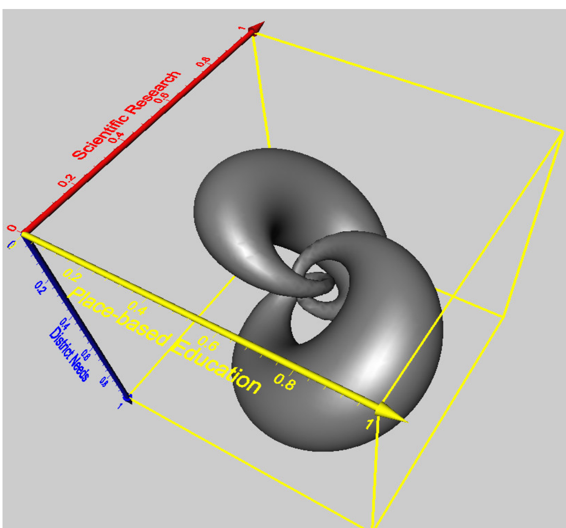

Fig. 1. Conceptual model of systemic partnership.

Actualizing Dimension One: Identifying District-wide Needs

To develop the framework for the university-school partnership and to identify areas of need and potential for collaboration, an extensive series of interviews were conducted in the spring of 2008 with school administrators and teachers. Prior to these meetings, university science faculty were interviewed as to their perspective on what could be offered to the schools and these ideas were shared with the school districts. Twenty school administrators and forty-one teachers from eight area school districts were interviewed.

All interviewees indicated that they would welcome collaborations with the University, so three additional questions were asked to focus on their needs: Who should the target audience be—students or teachers? Where should the programming occur? What programming is desirable?

In response to the first question, the K-12 stakeholders supported both audiences being targeted. With teachers as the audience, though, some cautions were offered. First, teachers' lives are full; consequently, whenever possible in-service training or workshops should be incorporated into the district's professional development days or built within the school day allowing for a substitute to relieve the teacher. Summer institutes should be intense and span a short number of days. If new curriculum is involved, it must be ready to go with suggested activities clearly outlined. Furthermore, any curriculum must be linked to the new *Maine Learning Results/Parameters for Essential Instruction* (Maine Department Education 2008), which directly reflects the national science standards.

With respect to the second question, the consensus was that having programming come to the schools would be preferred since transportation costs are becoming prohibitive; unless, of course, funding were available to underwrite these costs.

With the final question, K-12 stakeholders embraced many ideas identified by the university faculty, such as: the university maintaining a website with science lesson plans and resources, UNE scientists sharing their data with middle/high school students, offering hands-on teacher training modules such as how to set up an aquarium, supporting the National Science Ocean Bowl with UNE students serving as coaches, and maintaining a teacher resource room where materials can be borrowed. K-12 Stakeholders' additional ideas included: having their students involved in collecting data, having scientists visit schools to explore specific areas (e.g. anatomy and physiology, engineering, physics, water monitoring, greenhouses, biotechnology), sharing equipment (e.g. bringing microscopes to the classroom), shadowing a scientist, offering AP courses in aquatic sciences via video conferencing or distance education, hosting an "Ask a scientist" site in which questions could be sent to a scientist for a response, having UNE scientists come to a career day at the school district, facilitating the development of a science curriculum across K-12, developing a resource bibliography matched to units that are taught in the schools, and demonstrating experiments that then could be used in their classrooms.

Given this strong support for university-school collaboration, districts were asked whether they would be interested in participating in this grant proposal. Six school districts readily agreed including the two largest school districts in the state of Maine (http://www.maine.gov/education/enroll/enrlfacts.htm).

Each district participating in this project has a Science Vertical Team (SVT) composed of teacher representatives across grade levels. The SVT oversees the science curriculum, which includes identifying the K-12 scope and sequence and recommending curricular materials for the district. These teams will be central to the project.

Each spring a focused meeting of all SVTs will occur. At the meeting, the needs assessment conducted this year will be reviewed with particular focus on the programming ideas that were generated. The SVTs will identify those projects that they would like to earmark for the coming year, with the understanding that different projects might be identified across school districts. A range of projects will be accepted since it is important in developing systemic partnerships that a template is not imposed, but that we address a school district's needs.

From these selected projects, the SVTs will work with the university liaison and the faculty advisors to detail the components of the projects including identifying specific teachers or groups (for instance, it could be the SVT itself if the project entails school-wide or district-wide initiatives, such as offering teacher training modules), and job tasks for the school personnel as well as for the teaching fellows. Graduate Fellows will be assigned by district.

Actualizing Dimension Two: Scientific Research—the SaRCOS Project

STEM Background. Of central importance to a project such as this is an identifiable, charismatic, scientific project that will capture the imagination of K-12 students. We have chosen the effects of climate change on a local region, the Saco River watershed.

European settlement of North America has brought about many changes in the landscape including deforestation, agriculture, and alteration of the flow régimes of rivers (Foster *et al.* 1998, 2003, Poff *et al.* 1997). The full extent of these modifications may not yet be realized. For instance, Walter and Merritts (2008) show that streams in the Mid-Atlantic States were small and anabranching channels in pre-colonial time. The streams are now deeply incised channels cut into fill-terrace deposits and found behind thousands of former milldams that replaced the presettlement wetlands. The landscape of New England has also been thoroughly modified over the past 350 years (Williams 1982). The progression of changes went from deforestation and agriculture by colonists to subsequent farm abandonment and natural reforestation, in addition to population expansion and urbanization (Foster 1995, 1998, Whitney 1994). In Maine, the historical modification of the Kennebec River and estuary complex has been documented to show deleterious effects of dam building and industrialization (Köster *et al.* 2007). The current vegetation pattern is compositionally distinct from Colonial vegetation and shows little relationship to broad climatic gradients (Foster *et al.* 1998). While there have been documented changes in land use, the implications of these changes are not known.

Land use/Land Cover and Climate. Land use changes have been shown to alter regional climate and vegetation in adjacent natural areas, primarily through agriculture and urbanization (Stohlgren *et al.* 1998).The importance of land-use and land cover in climate change is related to a number of factors: changing surface albedo, effects on the hydrological cycle, and alteration of biogeochemical cycles (Carpenter *et al.* 2007). Worldwide there has been an observed increase of river runoff (Labat *et al.* 2004, Gedney et. al. 2006). The cause of the increased runoff has been attributed to the variability of global climate (Piao *et al.* 2007). But the picture is more complicated because of multiple interactions. For instance, the atmosphere-soil relationship (Figure 2) described by Enteckhabi, *et al.* (1996) contains a number of these poorly understood interactions.

Climate change has been linked to increasing risk of floods due to extreme weather patterns (Milly *et al.* 2002). Climate change has also been linked to local or regional increases or decreases of water availability (Vörösmarty, *et al.* 2000). The variability of runoff exists at different time scales, including monthly, annual, and multiannual fluctuations (Figure 3), which reflect extreme intensity events, wet and dry years, and global meteorological circulation, respectively (Labat *et al.* 2004). Brunsell (2006) points out that science has yet to produce a theory of temporal and spatial variability in land-atmosphere interaction with the roles of soil moisture and vegetation.

In the Northeastern U.S., increases in precipitation have been predicted by a number of research efforts (Christensen *et al.* 2007, Frumhoff *et al.* 2007, Hayhoe *et al.* 2007). Observational data also show that there have been both an increase in precipitation and an increase in extreme events over the last 70 years (Wake *et al.* 2006). Piao *et al.* (2007) found that land-use, particularly widespread deforestation, and structural changes such as leaf area index are important cognates in controlling runoff. A study of 145 experiments by Sahin and Hall (1996) showed that a 10% reduction in forest cover led to an increase of yield by 20-25 mm in conifer forest, and 17-19 mm increase in deciduous forest. Conversely they found that afforestation led to a 5 mm decrease in yield during conversion

4 *D. Entekhabi et al./Journal of Hydrology 184 (1996) 3–17*

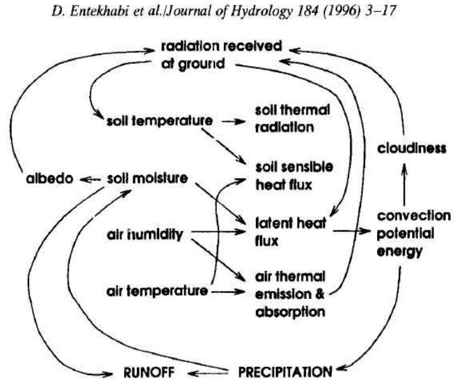

Fig. 1. Conceptual diagram of the pathways through which soil moisture affects and is mutually influenced by the overlying atmosphere (from Brubaker and Entekhabi, 1994).

Figure 2.

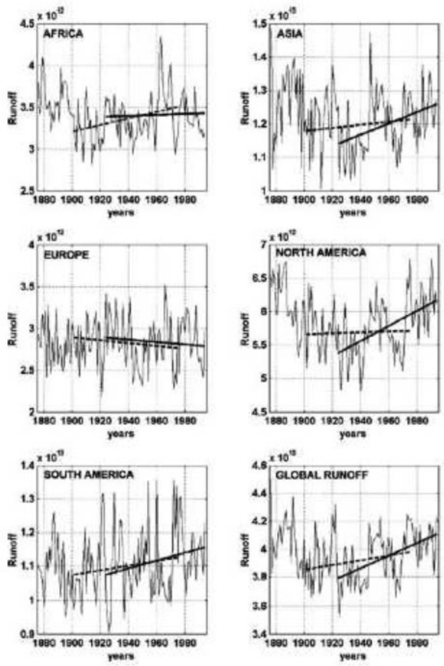

Figure 3. Regional runoff from Labat et al. 2004.

from scrub to forest. In the Northeast, studies indicate responses to climate change results in a range from a decrease in runoff to a 35% increase depending on the dominant species (Ollinger *et al. in press*).

The approach we use in this project is to quantify land use change in the region around the Gulf of Maine through image analysis both of aerial photographs and satellite imagery to identify land use change over the past 50 years. Preexisting satellite-derived data from national programs are used, specifically, the North American Landscape Characterization (NALC) data, which is Landsat Multi-Spectral Scanner (MSS) time-series image that were acquired in 1973, 1986, and 1991 (+/- one year) (http://edc.usgs.gov/products/satellite/nalc.html). This data set has a 60 m spatial resolution. A second data set is the 1992-2001 comparison of land use developed by the Multi-Resolution Land Characteristics Consortium (http://www.mrlc.gov/).

Relationship of River Discharge to the Coastal Ocean. The dynamics of the coastal ocean are inextricably linked to the terrestrial environment by rivers. River discharges affect coastal circulation patterns and may carry nutrients, sediment, and contaminants that affect coastal food webs. Buoyant river plumes often extend over large areas of the coastal ocean and affect transport and mixing for many miles downstream. Biological processes in the coastal ocean are closely coupled to the dynamics of freshwater plumes, so understanding the effects of river plumes on the coastal environment requires understanding both physical circulation and mixing processes and how those physical factors affect water chemistry, nutrients, phytoplankton, zooplankton, and eventually higher trophic levels. Because rainfall and snow melt are strongly seasonal and exhibit interannual variation, river plumes and the biological processes they influence are expected to be highly dynamic and vary on time scales of days, months, years, and decades (e.g., Yanagi & Hino 2005, Thomas & Weatherbee 2006). Understanding the causes and consequences of temporal variation is particularly critical for predicting the impacts of climate change on coastal oceans.

Climate and Coastal Waters. Climate change will alter the linkages between the land and ocean as shown above. Over the past century, temperatures regionally rose 3.4 ºF, and are predicted to rise further (USEPA, 1998). The HadCM2 model predicts an increase in precipitation of 10% ± 5 in spring and summer, and an increase of 30% ± 20 in winter (USEPA, 1998). Precipitation increases would lead to higher stream flow in winter and spring, leading to freshening of coastal waters. However, summer stream flows might be reduced because of increased temperature and evaporation. Higher temperatures might also lead to decreased oxygen concentration in estuarine waters. Superimposed on climate change will be effects of the North Atlantic Oscillation (NAO; Hurrell 1995, Hurrell & Dickson 2004). Positive phases of NAO indicate mild winter conditions and reduced snow cover for the eastern United States. Other NAO effects on include a possible higher incidence of harmful algal blooms (Stenseth *et al.* 2002), changes to terrestrial carbon and water cycles (D'Odorico *et al.* 2001) that will also impact coastal waters, and wave heights in the Northeast Atlantic are closely correlated to the winter NAO index (Bauer 2001), which would lead to changes in mixing and coastal erosion.

Saco River, Saco Bay, and the Maine Coastal Current. The Saco River is the fourth largest river (by discharge volume) in the State of Maine. Because two of the larger rivers (the

Androscoggin and the Kennebec) join before entering the Gulf of Maine, the Saco River is actually the third largest point source of freshwater. Discharge volumes are highly variable, but can exceed 600 $m^3 s^{-1}$ during spring run-off events.

The size of the Saco plume varies greatly with river discharge rates, peaking in late April through May (Fig. 4), with shorter-term events occurring in association with fall rain storms (typically Oct. and Nov.). Observations to date show that outside of the peak discharge season, the plume is restricted to an area around the river mouth, but during larger events can extend several kilometers from shore resulting in low salinity eddies that may become isolated at some distance. The plume is usually stratified (freshwater trapped near the surface), but mixing may reduce salinity much deeper in the water column. Most mixing events appear to be associated with increased wind stress (Fig. 4, red arrows), although at least one exception has been observed (Fig. 4, third arrow). The data has implications for introduction and distribution of nutrients, sediments, oxygen and pathogens.

Saco Bay has one of the few (2% of the coast) sandy pocket beaches on the coast of Maine (Slovinsky and Dickson, 2005). Despite their relative paucity, these habitats are important economically and environmentally. The sand budget for Saco Bay's beaches, the largest in the State of Maine, is also controlled by the Saco River discharge (Kelley *et al.*, 2005). Sediment transport is of great interest locally because of erosion at Camp Ellis.

After exiting the bay, the plume from the Saco joins the western segment of the Maine coastal current as it flows along the coast to the southwest (Fig. 5). It is a surface-trapped plume that is typically 10-20m thick, with velocity dependent on freshwater input, and cross-shelf structure and mixing thought to be largely controlled by wind forcing (Fong *et al.* 1997, Geyer *et al.* 2005). The Saco River plume is clearly a significant contributor during at least some discharge events, with a surface plume extending over many tens of square kilometers (Fig. 6).

Remote Observing Systems. Marine science has entered an era in which data collected by remotely deployed instruments is increasingly important in our understanding of physical transport and coupled biological processes. Projects like the Hawaiian Ocean Times Series (HOTS), Bermuda Atlantic Time Series (BATS), Rutgers University's LEO 15 and, locally, the Gulf of Maine Ocean Observing System (GoMOOS) have greatly expanded our understanding of temporal variation in spatial dynamics. Numerous large-scale ocean observing systems are either in place or under development, and significant federal funding is expected to flow into observing infrastructure (particularly through NOAA's IOS and NSF's ORION programs).

Implementation of SaRCOS. We developed a coastal observatory focused on Saco Bay and the discharge plume from the Saco River. The observatory consists of a core "Endurance" transect

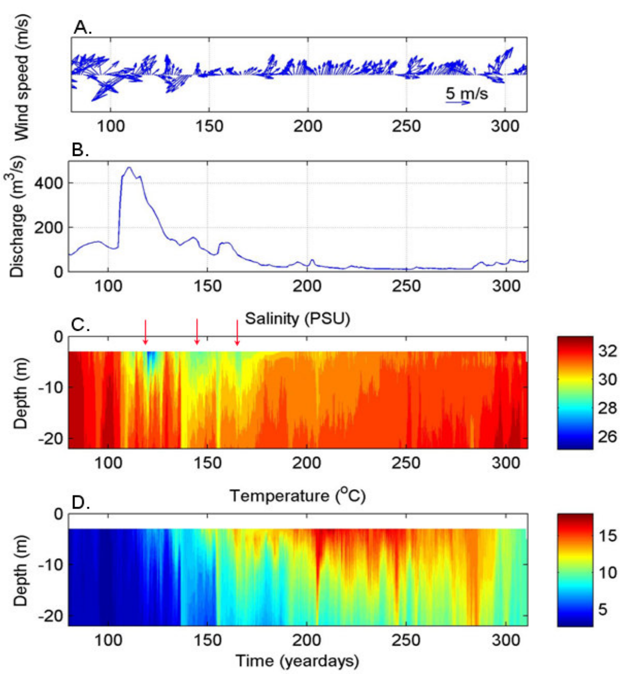

Figure 4. Temporal variation in wind, river discharge, salinity, and temperature within the Saco River and Bay during 2007. A.) Wind data from a nearby meteorological station. Arrows indicate wind direction and magnitude. B.) River discharge data from a USGS gauge in Cornish. C & D.) Depth profiles of salinity and temperature at the UNE buoy. Red arrows indicate 3 mixing events.

with two arrays of instruments that are permanently deployed, with data made freely available via the web in near real time, and a set of mobile or relocatable instruments that are deployed seasonally in support of specific projects. The Saco River is an important source of freshwater input to the western Maine coastal current, and a better understanding of dynamics within Saco Bay is important for assessing sediment transport patterns, salinity regimes for benthic invertebrates, and nutrient, phytoplankton (including blooms of toxic species), and food web dynamics.

Instrumentation. We have deployed a suite of instruments to collectively constitute a coastal observing system. The bulk of the instrumentation is deployed long term at two fixed position stations, and a separate set of moveable instruments for shorter-term deployment to address specific science questions. The two fixed position stations are located along a transect through the Saco River plume, with the shore station near the point of discharge and the buoy about 2 km out into the plume (inset aerial photo in Fig. 5). Sensors at the shore station measure chlorophyll, nutrient concentrations (nitrate, phosphate, and silica), salinity, temperature and water depth (at a single depth, because the river is so shallow). An acoustic Doppler current profiler measures the horizontal current profile across the river (horizontal rather than vertical

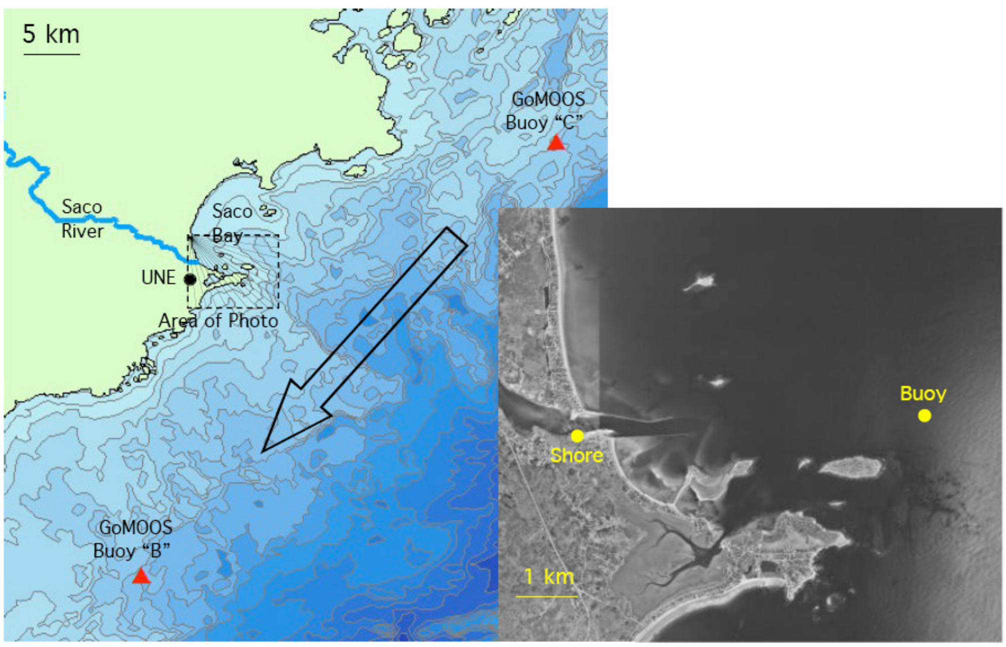

Figure 5. Map of area, with bathymetry (darker blue for deeper water), and inset aerial photo of a portion of Saco Bay showing approximate proposed locations of shore and buoy stations (yellow dots). Locations of GoMOOS buoys B and C are indicated for reference, and the general direction of the western coastal Maine current is represented by the outlined arrow.

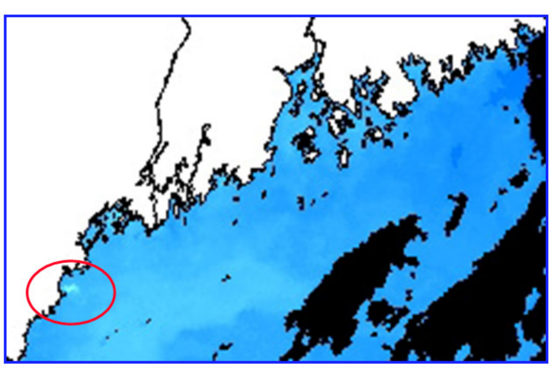

Figure 6. The plume from the Saco River (indicated by red ellipse) is apparent in AVHRR satellite data from May 6, 2004, as a plume of warmer water. This figure depicts the coast from New Hampshire to near the Canadian border, so the plume covers many square kilometers of sea surface.

salinity and temperature (at five different depths), the vertical current profile, various because of the shallow depth). Sensors on the offshore buoy (Fig. 7.) measure chlorophyll, wave parameters, and wind speed and direction. Two moveable equipment clusters can measure vertical current profiles, various wave parameters, and bottom salinity and temperature. Four surface GPS drifters use satellite links to telemeter their locations back to shore – the drifters let us operate within a Lagrangian, as well as Eulerian framework. Finally, a boat-deployed CTD- fluorometer-multichannel spectrophotometer unit measures salinity and temperature, as well as light absorption at various wavelengths. This unit will be used in targeted sampling to assess water mass characteristics and phytoplankton abundance when more detailed data on light scattering and attenuation are required. Data are transmitted in near-real time from the fixed stations and will be available for analysis by the scientific community as they come in through the GoMOOS network.

STEM Activities. The main STEM objectives of this project are to determine and quantify changes in the coastal ocean and watersheds of the Gulf of Maine due to climate change and varied land use. To achieve our objectives we use remote sensing, numerical modeling, and *in-situ* sampling of the Gulf of Maine watersheds, estuaries, and coastal ocean. These endeavors encompass the fields of physics, chemistry, biology, mathematics, and geology.

The following questions drive our research efforts:

1.) How do variations of land use modify precipitation and river discharge?
2.) How do changes in discharge result in alteration of coastal currents?
3.) Will changes in discharge and land use lead to increased pathogen loads and nutrients, and their transport in the surface waters of the region?
4.) What is the spatial extent of the Saco River discharge plume, and how does it vary temporally?
5.) How is sediment flux within Saco Bay and offshore transport related to river discharge?
6.) What are the biological consequences of mixing in Saco Bay, with respect to nutrient delivery and primary productivity?
7.) How do meteorological events affect mixing and plume behavior?
8.) Can wind or tide-driven mixing during a discharge event reduce bottom salinity sufficiently to kill benthic marine organisms in Saco Bay?
9.) How does variation in global climate affect the linkages between the river, the bay, and the coastal current?

The study will quantify changes in land use, runoff, and coastal circulation patterns, using predicted scenarios of climate change (Christensen *et al.* 2007, Hayhoe *et al.* 2007) and examine the effects of these changes on river discharge, pathogen loading, nutrient loading and what consequences these changes might have for rivers and the coastal ecosystem. This effort will use three existing research centers. The Joint NASA-University of New England Remote Sensing Center was funded by NASA to improve the capabilities of the region to use remote sensing. This past year UNE installed SaRCOS, which was funded through the State of Maine Marine Bond initiative. The Marine Mammal Rehabilitation Center at UNE is currently performing microbial source tracking on the Saco River to elucidate the sources of microbial pathogens– humans, dogs, livestock, or wild animals – within the Saco River watershed.

This project offers the opportunity for a number of smaller projects and in-depth collaboration of UNE scientists with K-12 students and teachers. Data analysis is relatively straightforward and ideally positioned for inter-disciplinary study. The examination of the mechanisms that govern the plume size and location are of interest to physicists and chemists as well as biologists. The effects of the plume on benthic populations due to salinity stress are of interest to physiological ecologists. Initial sampling indicates that fish larvae are non-randomly distributed with respect to plume boundaries. The relationship of the plume and larval fish are of interest to fisheries scientists. Higher nutrient concentration in the plume may affect phytoplankton dynamics and be of interest to biologists.

Actualizing Dimension Three: Pedagogical Framework—Place-based Education

Place-based education completes the Systemic Partnership Model. Place-based education is a term originated recently, but the idea is reflective of the pedagogy that John Dewey espoused in his lab school at the turn of the twentieth century, namely that student learning should be embedded in the local neighborhood context (Knapp 2005, Smith 2002). This pedagogical framework rests on the premise that in order to influence behavior, especially environmental stewardship and developing an understanding of the interactive, interdisciplinary nature of life, learning must occur within the context of the student's "place" or environs. Smith (2002) identified five common elements that define place-based education: 1) surrounding phenomena are the foundation for curriculum development, 2) students become the creators of knowledge rather than the consumers of knowledge created by others, 3) students' questions and concerns play central roles in determining what is studied, 4) teachers act as experienced guides, co-learners and brokers of community resources and learning possibilities, and 5) the wall between the school and community becomes more permeable and is crossed frequently (p. 593).
Place-based education can be multi-disciplinary using the environment as an integrating factor across all subjects, but generally the focus is on science initiatives (Ebersole & Worster 2007).

Research on the effectiveness of place-based education has shown gains in student achievement (American Institutes of Research 2005, Duffin *et al.* 2004, Emekauwa 2004, Powers 2004) and in positive student behaviors such as cooperation (American Institutes of Research 2005, Louv 2005, Powers 2004), critical thinking (Ernst & Monroe 2004), and achievement motivation (Athman & Monroe 2004). Additionally, students' self-reports reflect an increase in environmental stewardship behavior and time spent outdoors (American Institutes of Research 2005, Duffin *et al.* 2004). With short in-service training, teachers have indicated greater competency in implementing place-based strategies and documented use of field investigations and the integration of community resources in their classrooms (Meichtry & Smith 2007).

For this project, place-based education is selected as the pedagogical framework since it reflects a systemic approach to science learning centered in inquiry-based learning and focused on the local environment. Hence it is a natural fit in connecting a research project like SaRCOS to the area district's needs. Furthermore, place-based education is directly compatible with *The National Science Education Standards* (National Research Counci11996) and the *Maine Learning Results/Parameters for Essential Instruction* (Maine Department Education 2008) that recommend active learning through scientific inquiry. Graduate fellows, teachers, and thereby their students, will be involved in inquiry-rich projects that will based in the Saco River watershed, essentially the students' "backyard," utilizing and contributing to the research being conducted.

Prior to engaging with the K-12 community, Graduate Fellows will receive

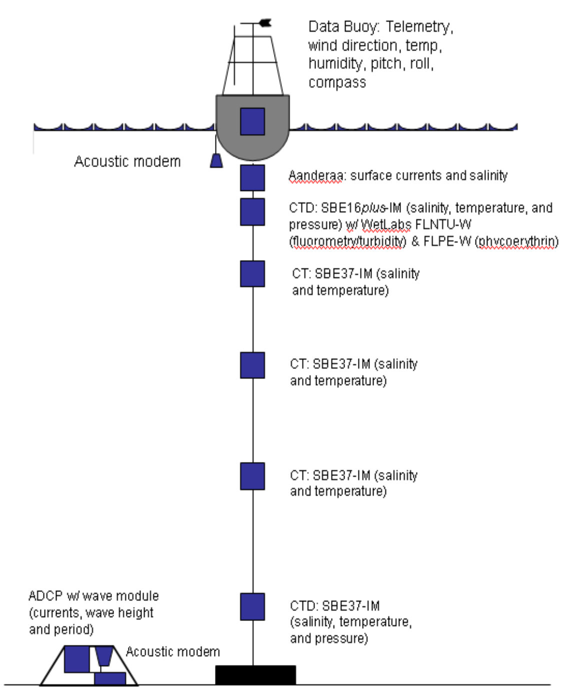

Figure 7. Schematic of the UNE buoy. Sensors measure temperature and salinity at six depths, with a fluorometer at the surface unit. Currents are measured throughout the water column. The data is telemetered to shore.

training in place-based and inquiry pedagogy as well as the national and state science standards.

Sample Projects - based on the spring 2008 needs assessment. *District-wide identified need—involving students in the collection of data.* Numerous entry points could be used connecting this need to the SaRCOS project. For instance, in determining river discharge and precipitation within the Saco watershed, historical runoff data will be used from USGS gaging stations around the region (**http://nwis.waterdata,usgs.gov/nwis**). Precipitation data can be obtained from the NCDC (**http://www.ncdc.noaa.gov/oa/climate/climatedata.html**). Students in collecting, organizing and analyzing these data will attain an appreciation that science is a collaborative endeavor with many technological and mathematical components. Another activity engaging more "classic" data collection would involve measuring pathogen loads in the Saco River and connecting it to health effects on animals and humans in the river and coastal waters, or sediment load and connecting it to beaches. In elementary classrooms, simple experiments could involve examining water salinity from different sites, first generating hypotheses and then explaining their findings determining whether their predictions were accurate. It is easily noted how these different-leveled projects emphasize the pedagogical framework of place-based learning steeped in inquiry while meeting districts' needs and connecting to the SaRCOS research.

District-wide identified need—offering hands-on teacher training modules such as how to set up an aquarium. While this could be a straightforward in-service workshop for teachers, the Graduate Fellows would consider how this need can be connected to the SaRCOS project and their research. For instance, while there is the logistical set-up of an aquarium, the Graduate Fellows will link this task with place-based activities that focus on the Saco River habitat. Connecting with local resources, the Saco River Salmon Club could provide fish eggs that classrooms then raise into fry and release. In short, the in-service module will explore examples of how an aquarium can reflect local habitats and be used with children to become stewards of the local environment. In this example, too, one sees how the three dimensions of the systemic partnership model are brought together—the district's needs for a teacher training module and positioning it within the pedagogical framework of place-based education utilizing the SaRCOS project focus.

Summary: The Systemic Partnership Model. This model provides a solid framework from which to support GK-12 activities that are systems-based in scope. District-wide needs have been accessed so impact can cut across many classrooms providing a richer experience for the Graduate Fellow. A scientific research project has been selected that is interdisciplinary in focus (biology, physics, chemistry, and geology) and can integrate all eight NSES content standards. Finally, the choice of place-based education provides a systems approach to explore how the local environment can be used to foster inquiry and scientific understanding.

Mentoring. In the summer the Graduate Fellows will be required to attend a 2-week intensive course covering place-based pedagogy, inquiry-based teaching, classroom management, and the national and state science and technology standards from faculty in the Education Department. Throughout the year, the University Liaison will provide additional pedagogical coaching for the graduate fellows, as will the SVT in their district.

Following the Graduate Fellows training in pedagogy and the national/state standards, they will be assigned to a District's established vertical science team, which will provide a direct link to the entire K-12 science curriculum. The choice of which SVT any Fellow will join will be dependent on the project chosen by the SVT, the Fellow's background and experience. The Fellows and the teachers to whom they are assigned will then meet for a week to identify projects in consultation with the faculty advisors, the university liaison, and the district SVT. Together they will create activities that actualize these projects as meaningful endeavors for students and engaging them in significant STEM research. These inquiry-based activities will be aligned with state and national standards using the SVT's guidance. This will allow the Graduate Fellows to gain insight into K-12 education that is rare for graduate students. Task analysis of each project will occur during this session, with timelines assigned, and evaluative measures set out.

This process will recur each spring to allow team members and projects to change as necessary. A focused meeting of all SVTs will be convened to review the projects that have been ongoing for the year and identify prospective goals for the following year, detailing the components needed to actualize the projects.

The Role of Graduate Fellows in the Schools. The Graduate Fellows will work closely with the SVT and teachers in the district to develop several school-wide projects that use the instruments, data and talents that are available either from the SaRCOS project or other available resources. Their training in place-based education and inquiry, and with help from the teachers, will allow them to play instrumental roles in the classroom and field by helping conduct the activities, lead discussion sessions, act as role models, provide disciplinary expertise, aid in curriculum development, and other useful tasks continuing to bring the systemic partnership model to actualization. It is anticipated that the Fellows will spend 2-3 days per week engaged in some aspect of K-12 work in the classroom or field. Fellows will also participate in the evaluation tasks to help them develop these skills. Fellows will bring with them a wealth of disciplinary expertise that they and their advisors will share with students and teachers in the schools.

Benefits to the Graduate Fellows. Fellows will be the recipients of pedagogical instruction that will help them in their future careers. They will also gain insight into the education process and be able to see strategies that have greater success. During their tenure, they will gain an appreciation for modes of communication that work with people outside of their disciplines, and with learners of all ages and abilities. Through their efforts at communicating their own research to lay persons, the Fellows will need to develop deeper understanding of their own fields so that they may convey the essence of their work, without relying on jargon. They will also gain a deeper appreciation for the incredible amount of work that teachers do. Perhaps most of all, they will learn how great an impact good teaching can have on the development of children into thinking and caring adults.

Benefits to Students and Teachers. K-12 students will benefit from enhanced learning opportunities, while their teachers will improve their content knowledge and skills. In particular, teachers will become comfortable incorporating field-based research, including activities using real-time online data and working collaboratively with university science faculty. Continued support for teachers and their students will be provided through web-based connections, and other electronic communications. This project reaches six school districts across the range from urban to rural settings, and includes lower socioeconomic groups and the most ethnically diverse population in the state.

Institutional Participation

The University serves as the facilitator for learning and conduct of STEM research activities. Several faculty are engaged in the SaRCOS project and additional faculty are involved in other endeavors that relate to the Saco River watershed and marine coastal ecology. In that regard, SaRCOS serves as the glue or focal point for faculty, Graduate Fellows, and K-12 teachers. UNE will serve to coordinate the activities around integration of faculty, graduate students and K-12 teachers. It will host a variety of activities such as workshops, meetings, and awards ceremonies for all the participants. It will also be responsible for conducting research on the efficacy of the project.

This project benefits the University by building bridges to the local communities. It also brings pedagogical expertise from the schools to not only the Graduate Fellows, but also their faculty advisors, most of whom have had little to no training in teaching.

The PIs in this project come from widely diverse backgrounds. Stephan Zeeman, Dept. of Biological Sciences, teaches Limnology, Oceanography, Remote Sensing and GIS. His interests lie in food web dynamics. Charles Tilburg, Dept. of Chemistry and Physics, teaches Physical Oceanography and General Physics. He also has a background in environmental engineering and hydrology. Dr. Susan Hillman, Dept. of Education, will supervise the outreach effort. Dr. Hillman is the former chair of the Department at UNE and at St. Joseph College (Connecticut) and currently teaches Science Methods and Math Methods courses.

Prior K-12 Involvement. The University of New England has a history of engaging the K-12 community through outreach activities including the NSF supported Phytopia (with Bigelow Labs), S2TASK using Project GLOBE (with Maine Mathematics and Science Alliance), and Access Earth (with University of Southern Maine), a project to engage students with disabilities in Earth Systems Science.

The School Districts. The Districts are the settings for the conduct of this work. While the school administrators serve a valuable role in implementing the work, the bulk of this task is the responsibility of the Science Vertical Team. The SVT selects the Fellows, guides the development and implementation of school projects, helps to mentor the Graduate Fellows, and critiques the results. The schools benefit by having outside experts come in to help clarify content, dispel misconceptions, bring new insight to processes, and having extra hands to do the business of teaching. Teachers would benefit by having disciplinary experts in the classroom and readily available when questions arise, thus increasing their confidence. The school districts would also see a benefit from increased participation in STEM courses as students become more curious and motivated. They would also see greater interest in students wanting to go on to higher levels of education.

Alignment to National and State Standards

In Maine the science curriculum must be aligned to the state science and technology standards, which directly reflect the national standards. Hence, all Graduate Fellows' activities that are identified from the district's needs must be aligned to national and state standards. Graduate Fellows, during their training, will be introduced to state and national standards. Once activities are assigned, we envision that the Fellows will be intimately involved in determining the alignment with the standards, under the supervision of the SVTs.

Implementation Plans for Special Populations

Graduate Fellows will be given special guidance during their 2-week course on pedagogy in regard to special populations. It is our aim to be as inclusive as possible, and to particularly reach out to underserved and underrepresented populations. Maine has codified the rights of individuals with disabilities in the Maine Unified Special Education Regulation Birth to Age Twenty, 05-071, Chapter 101, State of Maine Department of Education. As such, all necessary accommodations are provided for by the school districts, and where appropriate, assistive technology and other aids will be used.

Strategies for Sustainability.

As the project progresses, we will seek to involve more school districts as the benefits of participation become apparent. At the same time we will seek to continue these activities through involvement of the school boards, private foundations, and state and local funding sources. The UNE development office is already engaged in seeking the resources to enhance the K-12 outreach and nontraditional education efforts of the university.

Broader Impacts.

This project is grounded in the integration of research and education by advancing inquiry, understanding, and interest in STEM disciplines within the K-12 setting. The Graduate Fellows will be influenced to embrace K-12 outreach as an important part of academic life that they will carry forward in their careers. Furthermore, the Systemic Partnership Model is unique in bringing together school district's needs, scientific research, and place-based, inquiry education. Society will gain as a result, from a more scientifically literate and engaged populace. Regional, national and international venues will be sought to disseminate this model and the evaluative findings on its impacts to both the scientific community and to K-12 educators. Replication of the model is highly viable since it is grounded in the local environs in which science research occurs and thereby connects community, school and university effectively.

d. Recruitment and Selection Process

Graduate Fellows will be recruited nationally to join the overall project through advertising of the STEM projects and the GK-12 possibilities. Targeted letters to Department Heads of STEM Departments will aid recruitment. In these letters and advertisements we will emphasize the recruitment of underrepresented groups. We will especially target recruitment from minority institutions. We will also use our contacts to advertise these opportunities to students with disabilities.

For the selection process, we will ask potential candidates for letters of interest, a statement on educational philosophy, transcripts, and letters of support prior to being invited to interview for the Fellowship. A committee of faculty advisors will screen applicants and select those whose materials and interview support the sense that the candidate is academically qualified in their discipline, genuinely concerned about the educational process, and are competent in verbal and oral communication skills. The final choice of which Graduate Fellow will serve in a particular school or schools will be made by the SVTs in each district.

e. Organization, Management, and Institutional Commitment

The overall administration will fall to S. Zeeman. Oversight of the project will be managed through a tiered structure. A Management Team will consist of the PI, Co-PIs and the School Liaison. This group will set goals and coordinate the projects among the Graduate Fellows, SVTs, and Graduate Advisors.

The management team will make the first cut of selection of the Graduate Fellows, reviewing applications and conducting interviews. The Fellows will then be further vetted by the six SVTs as to fit with particular projects, schools and teachers. The Management Team along with the School Liaison and the Graduate Advisors are tasked with the guidance of the graduate fellows, including discussions of projects, STEM content, and appropriate training (classroom management, pedagogy, inclusiveness). The Fellows will receive further coaching from the SVTs, and will be mentored by the individual teachers.

f. Project Evaluation

Longitudinal Studies. We propose to assess the impact of the project by measuring several benchmarks. The Office of Institutional Research at the University will aid in these tasks. For Graduate Fellows, we will track applications to the program, their rate of successful completion of degree, time to degree completion, next career steps, and attitudes toward education and public outreach. We will follow faculty interest in participation and support for Gk-12 related practices. For teachers, we will assess their attitudes/comfort with STEM disciplines and numbers requesting participation in the program along with number of schools requesting participation. Finally, we will measure student interest in STEM disciplines.

External Evaluation. PEER Associates, a firm specializing in the evaluation of community-based educational programs, will collaborate with the project staff to implement a comprehensive formative and summative evaluation strategy over the life of the grant. PEER Associates is committed to using a multiple-methods, utilization-focused, participatory evaluation process. It is their intention to help organizations better articulate their vision, align their resources and their rhetoric accordingly, and improve their programs based on evidence of program functioning and outcomes. They also seek to help organizations build their own capacity to reflect on and internally evaluate programs.

Guiding Questions. The goal of the evaluation is to gather, analyze, and report on data that document the extent to which the project is effective in:

1. Building and enhancing a broad and transferable skill set in the graduate fellows, one that enables them to bring their local hydrologic research to K-12 schools and establish it as a meaningful and engaging integrating context for multidisciplinary teaching and learning.
2. Developing the personal and professional capacity of K-12 educators to use the local watershed as a resource for teaching a variety of disciplines, with emphasis in STEM instruction.

3. Establishing enduring and reciprocally beneficial partnerships between the university and the school districts which links the research of graduate schools and their faculty advisors with K-12 classrooms.

Overarching evaluation questions enumerated below are targeted at six areas of the program: program implementation, graduate fellows, K-12 teachers, K-12 students, faculty advisors, and K-12 administrators.

The evaluation design will focus on the following questions for program implementation:

- To what degree does program implementation correspond with program design (e.g. implementation fidelity)?
- To what extent does program implementation reflect established research-based best practices in place-based education, collaborative partnership, professional development, and other related fields?
- What are the primary challenges to program implementation and how are they resolved?

The evaluation design will focus on the following questions for Graduate Fellows:

- How does participation in the program help to prepare the Fellows for entry into the 21st century workforce?
- To what extent is Fellows' STEM research integrated into the school curricula?
- How does bringing their research to the school influence the Fellows' understanding of their own work?
- To what extent are the Fellows successful in implementing the principles and practices of place-based education and other related pedagogies?
- What do the Fellows accomplish in the classroom/school/district?
- What long-term impact does participation in the program have on the Fellows (e.g. graduate studies, career choices)?

The evaluation design will focus on the following questions for K-12 teachers (with emphasis on the Science Vertical Teams):

- How has teachers' practice changed as a result of participation in the program?
- How has teachers' STEM content knowledge changed as a result of participation?
- What are the teachers' perceptions of the program?
- What do teachers perceive as the benefits of participating in the program for their students?

The evaluation design will focus on the following questions for K-12 students:

- How have students' knowledge of and/or interest in STEM-related fields changed?
- How do program-related activities affect students' academic engagement?

The evaluation design will focus on the following questions for faculty advisors

- What do faculty advisors observe as the program impacts on the graduate fellows?
- To what degree does the program influence university faculty to continue partnering with K-12 schools?

The evaluation design will focus on the following questions for K-12 administrators:

- What have the administrators perceived as program outcomes for their teachers, students, and school culture?
- How has participation influenced administrators' decisions to continue partnering with STEM faculty and graduate students?

Data Collection. Data collected will include both quantitative and qualitative methods, including surveys, rubric scores, interviews, focus groups, on-site observations, and project tracking logs. Data will be collected from graduate fellows and faculty advisors, K-12 students, teachers and administrators, and project managers. The specifics of tasks, timelines, content, and responsibility for the data collection will be determined when the full project implementation and evaluation plans are established with participation from all stakeholders.

Data Analysis. Yearly pre/post surveys for participating graduate fellows, educators and students will be analyzed by comparisons of means. Control groups will not be established. Depending on the final scope of data collection and analysis, inferential statistical analysis may be used to explore the relationship between graduate fellow and teacher outcomes and extent of exposure to the program.

Interview, focus group, and on site observation data will be transcribed, then coded using qualitative analysis software. Relevant tracking log data will also be entered. Primary themes and key emergent issues will be identified to answer the evaluation questions. Program implementation quality and graduate fellow work will be assessed with rubrics.

By tracking implementation at the multiple sites, common elements will be identified and addressed, and where variation occurs among the sites, they will be able to assist the program staff in identifying underlying variables that might explain the variation. This evaluation data will be invaluable in using individual site successes to inform changes that might benefit sites that are encountering challenges, or in documenting key variables that impact program success. This cross-site evaluation effort will help to document the overall strategic value of the program and inform the educational community of site-specific nuances that might impact replication efforts.

Evaluation Timeline

The anticipated timeline for evaluation activities coincides with the major project activities and reporting deadlines. The formative evaluation will be ongoing throughout the project, and will monitor and document program implementation and activities. The summative evaluation will take place at intervals over the five year period to assess the extent to which the project is meeting its stated goals. This will provide quantitative and qualitative measures of the impacts on participating graduate fellows, their faculty advisors, and K-12 students, teachers, and administrators.

g. Faculty Participants

Dept. of Biological Sciences: A. Christine Brown, Timothy Ford (Vice President for Research and Dean of Graduate Studies), Markus Frederich, Kathryn Ono, James Sulikowski, Steven Travis, Philip Yund (Marine Science and Education Center), Stephan Zeeman, Greg Zogg. *Department of Mathematics:* Michael Arciero. *Department of Environmental Studies:* Jacque Carter (Provost). *Department of Education:* Susan Hillman. *Department of Chemistry and Physics:* Jerome Mullin, Charles Tilburg.

h. School District Involvement

We interviewed both administrators and faculty in eight school districts, and six have chosen to participate in this collaboration. Those are: Biddeford School District, Portland Public Schools, Bonny Eagle School District – Maine School Administrative District #6, Maine School Administrative District #57, Maine School Administrative District #71, and School Union #7. All have shown a keen interest in collaborating with the University and are looking forward to engaging their students in STEM disciplines through local scientific issues as stated in their letters of support. The participants include the two largest school districts in the state (SAD 6 and Portland). Within these districts there are 28 elementary schools, 7 middle schools and 8 high schools. The communities in which these school districts rest incorporate the range of urban, suburban and rural settings. Roughly 33% of the total 20,009 students enrolled in these districts qualify for free and reduced lunch, reflecting a low socio-economic population (http://portalx.bisoex.state.me.us/pls/doe_sfsr/eddev.ED534.ED534_report). Ethnicity data are difficult to attain in Maine because it is unavailable publicly. Since 96.3% of Maine's population is white, the Maine State government withdrew reporting student ethnicity by school district since this could be used to identify individual students. Turning then to overall population percentages, the U.S. Census data show that the city of Portland which is the largest urban area in Maine and one of the participating school districts, has a 10.4% minority population. Other larger towns in this region are not reported (http://quickfacts.census.gov/qfd/states/23/2360545.html).

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