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ITR: A Computational Framework for Observational Science: Data Assimilation Methods and their Application for Understanding North Atlantic Zooplankton Dynamics

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Principal Investigator: Pershing, Andrew J. **Award ID:** 0732317

Organization: University of Maine

Submitted By:

Pershing, Andrew - Principal Investigator

Title:

ITR: A Computational Framework for Observational Science: Data Assimilation Methods and their Application for Understanding North Atlantic Zooplankton Dynamics.

Project Participants

Senior Personnel

Name: Pershing, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Graduate Student

Name: Azam, Sharmin

Worked for more than 160 Hours: Yes

Contribution to Project:

Ms. Azam completed a Masters of Engineering at Cornell in spring of 2007. For her thesis, she developed a multi-grid technique to interpolate satellite data. Her research was supported by this project.

Name: Stetson, Peter

Worked for more than 160 Hours: Yes

Contribution to Project:

This grant supported Mr. Steston's summer internship at the Gulf of Maine Research Institute in 2008. Based on this experience, Mr. Stetson applied to graduate school at UMaine. He is working on an MS in my lab, and this grant supported his first 6 months of study.

Undergraduate Student

Technician, Programmer

Name: Woodard, Linda

Worked for more than 160 Hours: Yes

Contribution to Project:

This project supported Linda Woodard at the Cornell Theory Center to implement the zooplankton model. Her funding has been transfered to U. Maine and her responsibilities have been transfered to Nicholas Record.

Name: Record, Nicholas

Worked for more than 160 Hours: Yes

Contribution to Project:

Mr. Record has assumed day to day responsibility for the technical aspects of the project. Mr. Record has also made important contributions to this project, notably taking the lead in developing the genetic algorithm and applying the MUSCL advection scheme. Mr. Record is now pursuing a Ph. D. part time, and the genetic algorithm work will appear in his thesis.

Other Participant

Research Experience for Undergraduates

Organizational Partners

Cornell University

This project began while I was employed by Cornell. Colleagues at Cornell, in particular, Linda Woodard in the Center for Advanced Computing, contributed over the whole course of the project.

Provincetown Center For Coastal Studies

Charles Mayo at PCCS provided zooplankton abundance data from Cape Cod Bay. We have used this data in high-resolution simulations of zooplankton in Cape Cod Bay.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

During the final year of our project, we focused on using ensemble methods to understand zooplankton dynamics. We explored how the genetic algorithm could be used to fit parameters in our copepod models. We began by conducting a series of twin experiments to develop a better understanding of the behavior of the genetic algorithm. Then, we used this understand to fit models for three copepod taxa in Cape Cod Bay. A manuscript on this work was recently submitted to the Journal of Marine Systems. We also implemented an ensemble Kalman smoother and used this procedure to produce operational forecasts for copepod abundance in Cape Cod Bay. We plan to submit a manuscript on this work later this year.

Findings:

We have developed a better understanding of how the genetic algorithm works when applied to parameters in a stage-resolved copepod model. This has provided insight into the kind of data that is most useful for model development and how parameters in the model interact. We have also produced, to our knowledge, the first operational forecasts of copepod abundance.

Training and Development:

During summer of 2008, this project funded undergraduate summer intern Peter Stetson. Peter implemented a particle tracking model in a 2D non-hydrostatic model of internal waves. He began applying this model to examine how internal waves create patches of krill and advect them on to shallow banks. Peter has continued this research as a graduate student. His first six months of graduate school were supported by this project.

Outreach Activities:

PI Andrew Pershing has delivered several lectures to non-scientific audiences. Most presentations used right whale management to motivate the discussion, but all of the presentations listed below included a discussion of copepod modeling and a brief introduction to data assimilation. Audiences ranged from K-12 science teachers to the general public.

In 2009, our lab began producing regular (~weekly) blog posts at our lab website:

www.seascapemodeling.org/seascape_projects . Our goal is to communicate how science works and to convey some of our enthusiasm for science. Blog posts have included presentations of modeling results, especially our operational work, discussions of climate change, and information on plankton and whales.

Public presentations:

Science in the ocean: finding, counting, and studying whales. National Science Teacher Association Annual Meeting, New Orleans, LA. March 18-22,2009
From weather to whales: Connections between climate, plankton, and right whales in the Gulf of Maine. Marine Environment Research Institute, Blue Hill, ME, January 15, 2009
Predicting right whale distributions from space. COSEE Teaching Workshop, University of New Hampshire, Durham, NH. July 8, 2008
Right whale, wrong time? A whaleÆs eye view of the changing Gulf of Maine. Presented at the Sandy Bay Yacht Club on July 12, 2007
Right whale, wrong time? A whaleÆs eye view of the changing Gulf of Maine. Presented at the Gulf of Maine Research InstituteÆs ôSea State 2.0ö Seminar Series, on April 12, 2007

Journal Publications

Record, NR and AJ Pershing, "Modeling zooplankton development using the monotonic upstream scheme for conservation laws", Limnology and Oceanography: Methods, p. 354, vol. 6, (2008). Published,

Pershing AJ, Record NR, Monger BC, Pendleton DE, Woodard LA, "Model-based estimates of Calanus finmarchicus abundance in the Gulf of Maine", Marine Ecology Progress Series, p. 245, vol. 378, (2009). Published,

Record NR, Pershing AJ, Runge JA, Mayo CA, Monger BC, "Improving ecological forecasts with genetic algorithms: an application to a copepod community model", Journal of Marine Systems, p. , vol. , (2009). Published,

Books or Other One-time Publications

S. Azam, " Efficient Belief Propagation for Preprocessing Near-Real-Time Satellite Data", (2007). report, Published
Collection: Masters in Engineering Report
Bibliography: Azam, S. 2007. Efficient Belief Propagation for Preprocessing Near-Real-Time Satellite Data, Masters in Engineering Report. Ithaca, NY, Cornell University.

Web/Internet Site

Other Specific Products

Product Type:

Software (or netware)

Product Description:

Medusa. Medusa is our zooplankton data assimilation system. At the heart of Medusa is a 2D advection-reaction-diffusion solver. The code has been engineered to facilitate its application to a wide range of problems. We have developed a reaction module to simulate Calanus finmarchicus populations dynamics. Other modules have been developed to simulate passive tracers and two interacting populations. Medusa contains an adjoint which can be used to estimate initial and boundary conditions responsible for a set of observations. We are currently implementing an ensemble Kalman filter.

Sharing Information:
We intend to distribute this software via the web.

Contributions

Contributions within Discipline:
This projects main contribution to date has been the development of a 2D model of Calanus finmarchicus dynamics in the Gulf of Maine. Through funding from NOAA and NASA, this model has been incorporated into an operational system to forecast right whale distributions.

This project also recognized the similarity between copepod development and advection and pioneered the use of advanced numerical schemes to overcome developmental diffusion. Based on this work, we recently submitted a proposal to NSF Biological Oceanography to develop a next-generation copepod model.

Contributions to Other Disciplines:
Our project examined three different algorithms: the genetic algorithm, the ensemble Kalman smoother, and the MUSCL advection scheme in the context of zooplankton models. While our main contribution is to advance the use of these procedures in oceanography, our studies are relevant to the application of these techniques in a variety of disciplines.

Contributions to Human Resource Development:
This project supported graduate training for three students (Sharmin Azam, Peter Stetson, and Nicholas Record). This project also supported three undergraduate summer interns: Yolanda Roberts (now in graduate school at U. Maryland), Patrick Meyers (graduate school at U. Miami), and Peter Stetson (graduate school at UMaine).

Contributions to Resources for Research and Education:
In addition to the public lectures and blog posts discussed previously, we presented our work to several audiences of middle school students at the Gulf of Maine Research Institute. GMRI has developed a unique educational experience for middle school students. As part of that experience, scientists at GMRI are invited to present brief descriptions of their research. Information from these presentations is then incorporated into the regular educational program. Members of this project have presented aspects of our work to these students. One well-received presentation related our computer modeling to video games. This idea was continued on the GMRI blog, 'Today in the Gulf of Maine' and was a topic of discussion in several classrooms.

Contributions Beyond Science and Engineering:
This project led to improved estimates of copepod abundance in right whale habitats in the Gulf of Maine. Through other projects, we are using these estimates to develop predictions for whale distributions. We are actively exploring with NOAA managers how these predictions could be used to reduce whale-vessel interactions.

Conference Proceedings

Categories for which nothing is reported:

Any Web/Internet Site

Any Conference