7-14-2006

Collaborative Research: GLOBEC-01: Tidal Front Mixing and Exchange on Georges Bank: Controls on the Production of Phytoplankton, Zooplankton, and Larval Fishes

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Robert Houghton
Co-Principal Investigator; Columbia University

Final Report for Period: 09/2002 - 08/2006 **Submitted on:** 07/14/2006
Principal Investigator: Townsend, David W. **Award ID:** 0228943
Organization: University of Maine

Title:
Collaborative Research: GLOBEC-01: Tidal Front Mixing and Exchange on Georges Bank: Controls on the Production of Phytoplankton, Zooplankton, and Larval Fishes

Project Participants

Senior Personnel

Name: Townsend, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Name: Thomas, Maura
Worked for more than 160 Hours: Yes
Contribution to Project:
Data reduction and graphical presentation.

Other Participant

Research Experience for Undergraduates

Organizational Partners

Columbia University Lamont Doherty Earth Observatory
Lead PI of this multi PI collaborative research project is Dr. Robert Houghton of Lamont,

University of Massachusetts, Dartmouth
Collaborative research with Dr. Chengshen Chen, the lead modeller.

University of Southern Maine
Collaborative research with Dr. Lewis Incze, the zooplankton expert on our modeling team.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings:
Findings are incorporated in the previous section.

Training and Development:
The University of Maine was not funded to support any graduate students on this grant. However, we did at various times throught the course of this project, have undergraduate students working in our lab as volunteers, and conducting their 'Senior Capstone' research (on general plankton culture experiments, loosely related to the goals of this particular project.

Outreach Activities:
Outreach activities included:
-- Twice per year I ran an all-morning session on 'General Oceanography', with emphasis on the Gulf of Maine and Georges Bank, as part of the Marine Resource Education Program. The audience was commercial fishers and coastal and environmental managers in the New England region.

Journal Publications

Ji, R., C. Chen, P.J.S. Franks, D.W. Townsend, E.G. Durbin, R.C. Beardsley, R.G. Lough, and R.W. Houghton, "The impact of Scotian Shelf Water cross-over on the phytoplankton dynamics on Georges Bank: A 3-D experiment for the 1999 spring bloom.", Deep-Sea Research II., p. , vol. , ( ). Accepted

Ji, R., C. Chen, P.J.S. Franks, D.W. Townsend, E.G. Durbin, R.C. Beardsley, R.G. Lough, and R.W. Houghton., "Spring Phytoplankton Bloom and Associated Lower Trophic Level Food Web Dynamics on Georges Bank: 1-D and 2-D Model Studies.", Deep Sea Research II, p. , vol. , ( ). Accepted

Books or Other One-time Publications

Townsend, D.W. and W.G. Ellis, "Primary production and nutrient cycling on the Northwest Atlantic continental shelf.", (2006). Book, Accepted
Editor(s): Liu, K.K., L. Atkinson, R. Quinones, and L. Talaue McManus (eds)
Collection: Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis.
Bibliography: Springer Verlag New York.

Townsend, D.W.,A.C. Thomas, L.M. Mayer, M. Thomas and J. Quinlan., "Oceanography of the Northwest Atlantic Continental Shelf", ( ). Book, Accepted
Editor(s): Robinson, A.R. and K.H. Brink (eds).
Collection: The Sea, Volume 14
Bibliography: Harvard University Press

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Any Web/Internet Site
Any Product
Contributions: To Any within Discipline
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering

Final Report
National Science Foundation

Award Number: OCE-0228944

Project Title: Collaborative Research: GLOBEC-01: Tidal Front Mixing and Exchange on Georges Bank: Controls on the Production of Phytoplankton, Zooplankton, and Larval Fishes.

Award Period: 1 September 2002 to 31 August 2005;
No Cost Extension to 31 August 2006

Award Total: $149,964

1. Introduction:

The data and model development amassed by the U.S. GLOBEC Georges Bank program during the 1990s has provided a unique opportunity to advance our understanding of the ecology of the Bank. In particular the 1999 GLOBEC fieldwork provided high-resolution data in the vicinity of the tidal mixing front that encircles the Bank. The objective of our proposal was to use those data collected in 1999 by our Globec colleagues to build numerical simulation models that would allow us to test ideas about mixing and circulation in the tidal front with specific reference to the nature of nutrient fluxes to the biologically-productive Bank.

This project was a collaborative effort, lead by R. Houghton of Lamont-Doherty Earth Observatory of Columbia University. Other collaborators included: Chanshen Chen (University of Massachusetts Dartmouth), Lewis Incze (Bigelow Laboratory/University of Southern Maine), and R. Gregory Lough (NOAA/NMFS Woods Hole).

The University of Maine component (Townsend) focused on the development of an ecosystem model and design of numerical experiments to test the flux of nutrients onto Georges Bank. This report summarizes the main aspects of numerical experiments we designed and completed.

The underlying premise of our research was as follows:

Georges Bank supports a rich fishery because it is biologically productive and large enough to retain a significant portion of that production. It is biologically productive because: (1) the large crest area is shallow enough that light-limitation of phytoplankton is usually not important; (2) it is surrounded by deep waters rich in inorganic nutrients, which are in close proximity to, and readily available for mixing with, Georges Bank waters; (3) vigorous tidal mixing promotes the injection of these deep inorganic nutrients

onto the Bank, particularly in the north; and (4) subsequent dispersion and advection distribute the nutrients and ensuing production in a manner that coincides with larval retention mechanisms and biologically supports the early life stages of cod and haddock.

The University of Maine component of this project was to focus on the role of nutrient fluxes across the Bank in driving biological productivity. This modeling project was a natural follow-on to our earlier field studies in GLOBEC, where we conducted detailed measurements of nutrients and phytoplankton on the Bank, concentrating on the 1999 field seasons (January to June).

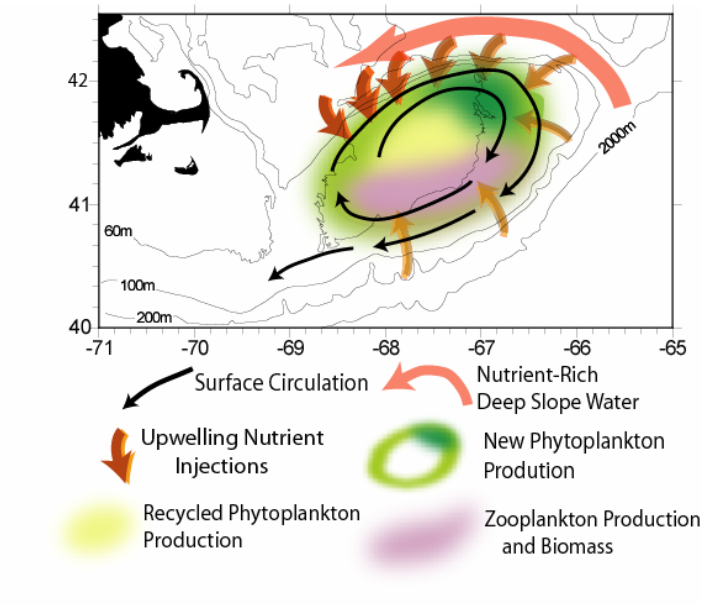

Fig. 1. Schematic representation of processes important to the biological productivity of Georges Bank illustrating the 'donut'-shaped procutive region around the perimeter of the Bank. (Townsend et al., 2006 [after Townsend and Petticgrew, 1997])

The oceanography of Georges Bank is dominated by several features and processes that impart important temporal and spatial constraints on the Bank's overall productivity. It has already been shown (Pastuszak et al., 1982; Townsend and Pettigrew, 1997) that nutrient injections occur around the periphery of the crest of the Bank (crest of Bank arbitrarily defined as 60m isobath; Fig.1). Those injections are most pronounced on the north flank, where the bathymetry is steepest and where nutrient-rich slope water resides nearby, having entered Georges Basin via the Northeast Channel (Fig. 1). Thus, we predicted that following the winter-spring phytoplankton bloom, Georges Bank would exhibit a "donut-like" band of elevated phytoplankton production, corresponding to the fluxes of new nutrients. Because primary production is driven by newly injected deepwater nutrients, this band would constitute "new" production which would then be available for transfer to higher trophic level biomass (zooplankton and fish).

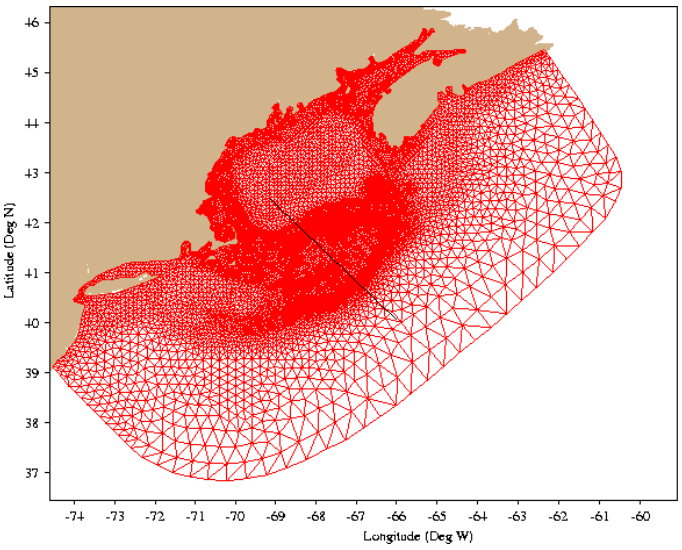

Fig. 2. FVCOM model domain. Line indicates cross-Bank transect.

2. Modeling Approach:

Our approach to addressing specific research questions to test various aspects related to the above conceptual model, were based on the FVCOM (Finite Volume Coastal Ocean Model) developed by C. Chen. The model domain is given in Figure 2 above.

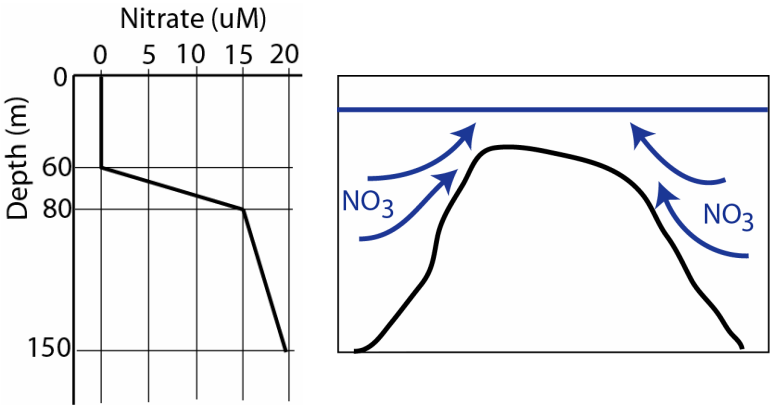

Figure 3. Nutrient profiles beyond the edges of the bank, and presumed fluxes onto Bank.

Figure 3 depicts schematically our experimental framework, which shows a summertime period of nutrient depletion, both on the top of Georges Bank, as well as in the surrounding deeper waters. Below a depth of 60 m (selected to coincide with the crest of the bank) nutrient concentrations begin to increase, from 0 µM NO_3 to 15 µM NO_3. We ran the physical model (no biological uptake or regeneration of nutrients; tides and density only, and without winds) in order to estimate the time required to "replenish" nutrients to the top of Georges Bank, which would give us an estimate of "new" primary productivity.

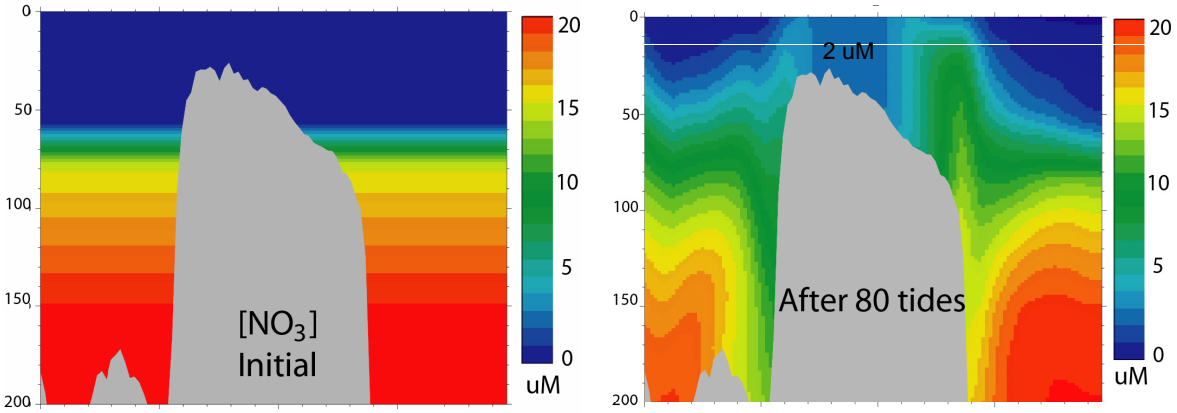

Figure 4. Left: Cross-section of initial nutrient field (nitrate) corresponding to transect in Fig. 2.; Right: same after model run simulating 80 tidal periods.

A major finding of this work has been that tides and density alone do not force the flux of nutrients onto Georges Bank. According to the model simulations, after 80 tidal periods (approximately 40 days) the concentration of nitrate on the crest of the Bank remains at only 2 µM. This flux rate corresponds to a very low rate of potential new primary production (less than half the rate we had calculated earlier), and likely does not represent the mechanism by which nutrients are brought to the Bank from deeper waters beyond

the Bank's edges – neither during the winter period of "recharge", nor during the warmer, productive months.

We thus began simulations to explore the role of wind mixing, which we hypothesized would advect in an Ekman layer those nutrients that were/are brought to the near-surface waters as a result of mixing processes in the tidal front region. The results of these numerical experiments using wind forcing from NE, SE, SW and NW at 10 and 20 m sec^{-1} (an example of which is given in Figure 5) demonstrated the importance of winds in redistributing newly upwelled nutrients in the tidal mixing front.

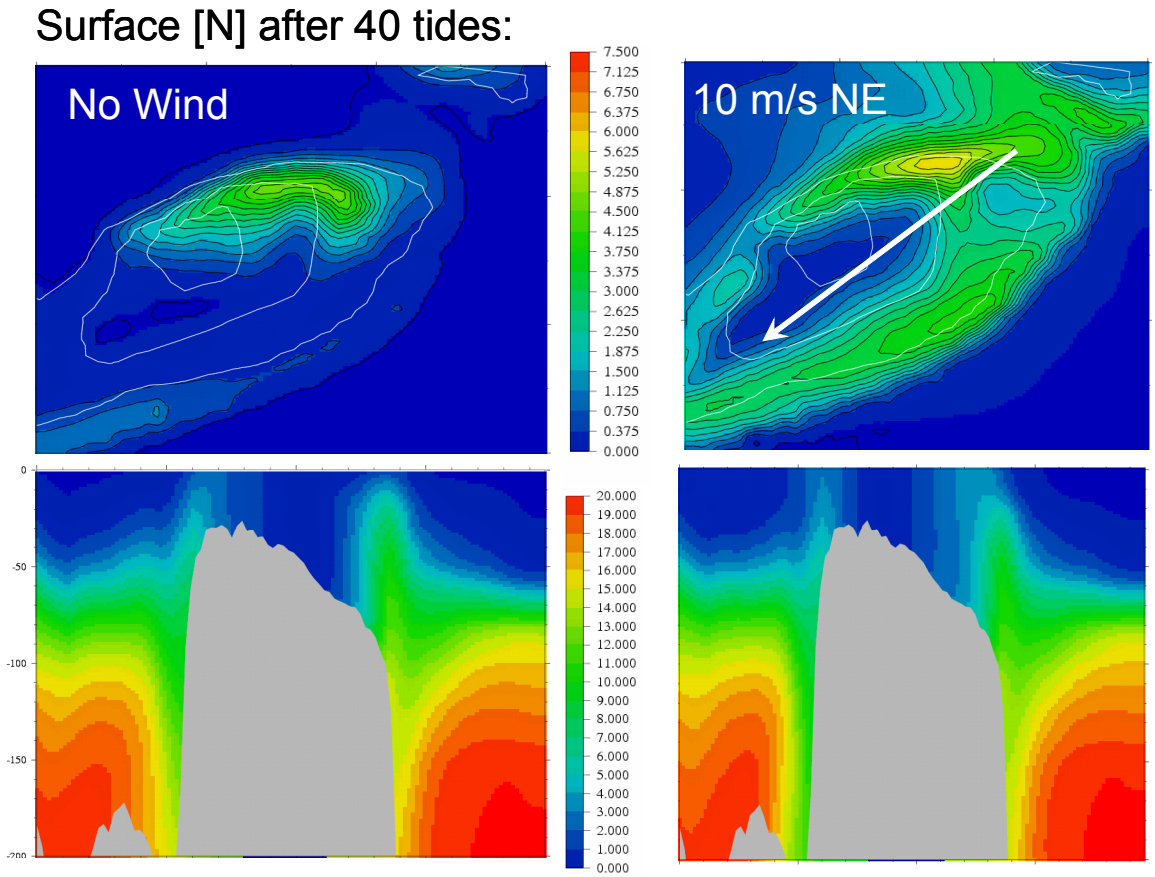

Figure 5. Areal contour plots and vertical cross sections of nitrate concentrations both before model simulations applying a NE wind of 10 m sec^{-1}.

Resulting Publications and Presentations:

Results of this research have been presented in GLOBEC workshops, as an invited talk at the 2005 Gordon Research Conference (Coastal Ocean Circulation), the 2006 Ocean Sciences Meeting. Several papers have also resulted which include major contributions from this work; they are all currently accepted for publication and are *In Press*.

D.W. Townsend, R.W. Houghton, C. Chen, S. Hu, L. S. Incze, R.G. Lough. 2006.

Modeling studies of cross-isobath nutrient fluxes and biological productivity of Georges Bank. AGU Ocean Sciences Meeting, Honolulu, February, 2006.

D.W. Townsend (invited). 2005. Physical Drivers of Biological productivity in the Gulf of Maine and Georges Bank. June, 2005. Gordon Research Conference, New Hampshire.

Ji, R., C. Chen, P.J.S. Franks, D.W. Townsend, E.G. Durbin, R.C. Beardsley, R.G. Lough, and R.W. Houghton. Ms. The impact of Scotian Shelf Water "cross-over" on the phytoplankton dynamics on Georges Bank: A 3-D experiment for the 1999 spring bloom. *Deep-Sea Research II* (In Press).

Ji, R., C. Chen, P.J.S. Franks, D.W. Townsend, E.G. Durbin, R.C. Beardsley, R.G. Lough, and R.W. Houghton. Ms. Spring Phytoplankton Bloom and Associated Lower Trophic Level Food Web Dynamics on Georges Bank: 1-D and 2-D Model Studies. *Deep-Sea Research II* (In Press).

Townsend, D.W. and W.G. Ellis. 2006. Primary production and nutrient cycling on the Northwest Atlantic continental shelf. *In:* Liu, K.K., L. Atkinson, R. Quinones, and L. Talaue-McManus (eds). *Carbon and Nutrient Fluxes in Continental Margins: A Global Synthesis.* Springer-Verlag New York. (In Press)

Townsend, D.W.,A.C. Thomas, L.M. Mayer, M. Thomas and J. Quinlan. 2006. Oceanography of the Northwest Atlantic Continental Shelf. pp. 119-168. *In:* Robinson, A.R. and K.H. Brink (eds). *The Sea,* Volume 14, Harvard University Press. (In Press)

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Townsend, D.W. and N.R. Pettigrew. 1997. Nitrogen limitation of secondary production on Georges Bank. *Journal of Plankton Research* 19: 221-235.

Townsend, D.W. and M. Thomas. 2002. Springtime nutrient and phytoplankton dynamics on Georges Bank. *Marine Ecology – Progress Series* 228: 57-74.

Townsend, D.W.,A.C. Thomas, L.M. Mayer, M. Thomas and J. Quinlan. 2006. Oceanography of the Northwest Atlantic Continental Shelf. pp. 119-168. *In:* Robinson, A.R. and K.H. Brink (eds). *The Sea,* Volume 14, Harvard University Press. (In Press)