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New and Export Productivity Regulation by Si and Fe in the Equatorial Pacific Ocean

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Principal Investigator: Chai, Fei . **Award ID:** 9802061
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Title:
New and Export Productivity Regulation by Si and Fe in the Equatorial Pacific Ocean

Project Participants

Senior Personnel

Name: Chai, Fei
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Jiang, Mingshun
Worked for more than 160 Hours: Yes
Contribution to Project:
Conducting 3D physical-biological model experiments.

Graduate Student

Name: Xu, Li
Worked for more than 160 Hours: Yes
Contribution to Project:
Testing 1D physical-biological model.

Name: Klein, Lawrence
Worked for more than 160 Hours: Yes
Contribution to Project:
Testing 1D physical-biological model.

Undergraduate Student

Research Experience for Undergraduates

Organizational Partners

Duke University Marine Laboratory
Richard Barber was supported by NSF to collaborate on this project.

University of Miami Rosenstiel School of Marine&Atmospheric Sci
Dr. T-H Peng was supported to collaborate on this project with contribution on the carbon modeling component.

San Francisco State University
Drs. Dugdale and Wilkersion were supported by NSF to collaborate on this project with contribution to silicate dynamics.

Other Collaborators or Contacts

R.T. Barber, R.C. Dugdale, F.P. Wilkerson, and T-H Peng are partners on this project.

Activities and Findings

Research and Education Activities:

This project incorporated the silicate pump hypothesis and Fe limitation into an ecosystem model to simulate CO2 fluxes in the equatorial Pacific. A first 1-D version of this model has been constructed and then embedded into a 3-D ocean circulation model for the equatorial Pacific. The 1-D model can be run and manipulated through a website with different parameters, and the 3-D model results can be accessed with the Live Access Server (LAS) (see Section 2 of the Project Decription for details). The ecosystem model includes 2 types of phytoplankton (diatoms and picoplankton), 2 classes of zooplankton, Si and N detrital fractions, NO3, NH4, Si(OH)4 and total CO2. It functions as a chemostat-like system with the loss rates, provided largely from zooplankton grazing, controlling growth rates of the phytoplankton. It was capable of reproducing the low Si(OH)4, high NO3 and low chlorophyll conditions in the equatorial Pacific. A typical run initialized with Levitus nutrients reproduces closely the vertical nutrient structure (and other data) at 140?W obtained during JGOFS TT011 cruise.

We have coupled this ten-component biological model with a 3-D ocean circulation model based upon on the Modular Ocean Model developed at Geophysical Fluid Dynamics Laboratory (GFDL) of NOAA with some modifications. The physical-biological model is forced with COADS (Comprehensive Oceanic and Atmospheric Data Set) monthly wind and heat flux. The initial conditions for NO3 and Si(OH)4 are from the processed NODC station data. Below the euphotic zone, sinking particulate organic matter is converted to inorganic nutrients by a regeneration processes, in which organic matter decays to ammonium, and then is nitrified to NO3. The flux of particulate material is specified using an empirical function. The Si(OH)4 regeneration is modeled through a similar approach but with a deeper regeneration depth profile. The biological model starts from year 1950 after the circulation model has integrated for 15 years.

04/01: ôModeling Carbon Cycle in the Pacific Oceanö. The Oceanography Society (TOS) 2001 Scientific Meeting, Miami, Florida.

12/00: ôModeling Carbon Cycle in the Pacific Oceanö. American Geophysical Union (AGU) Fall Meeting 2000, San Francisco, California.

11/00: 'Ecosystem and Carbon Cycle Modeling: Seasonal to Decadal Variability in the Pacific Ocean', School of Marine Sciences, University of Maine, Orono, Maine, USA.

10/00: 'Modeling Carbon Cycle in the Pacific Ocean', North Pacific CO2 Data Synthesis Symposium, Tsukuba, Japan.

08/00: 'Climate Change and Carbon Cycle in the Pacific Ocean', Second Institute of Oceanography, State of Oceanic Administration, Hangzhou, China.

05/00: 'Physical-Biogeochemical Modeling: Seasonal to Decadal Variability in the Pacific Ocean', National Center for Ocean Research (NCOR), Taipei, Taiwan.

04/00: 'Physical-Biogeochemical Modeling in the Equatorial Pacific Ocean', International JGOFS Open Science Conference, Bergen, Norway.

03/00: 'A Physical-Biological Model for the Pacific Ocean - Simulated Results from 1950 to 1990ö, Scripps Institute of Oceanography, La Jolla, California, USA.

01/00: ôEcosystem Modeling in the Equatorial Pacific Upwelling Regionö, Ocean Science Meeting, San Antonio, Texas, USA.

11/99: ôEcosystem Modeling in the Equatorial Pacific Upwelling Regionö, Old Dominion University, Norfolk, Virginia, USA.

03/99: 'Biogeochemical Modeling of the Equatorial Pacific Ocean' at Rosenstiel School of Marine and Atmospheric

Findings:

Between 5oS-5oN, 90oW-180o, the estimated sea-to-air CO_2 flux of 4.3 mol/m2/yr from the model is consistent with the observed results (1.0 to 4.5 mol/m2/yr). When source $Si(OH)_4$ concentrations are increased in the model diatoms increase, the picoplankton population and NO_3 consumption decrease, resulting in a maximum surface TCO_2 and increased CO_2 flux to the atmosphere at intermediate source $Si(OH)_4$ concentrations. The 1-D model considers the role of Fe implicitly through the parameters that determine the growth rate of diatoms, and Fe enrichment experiments conducted using the model matched the ecological behaviors observed during IronEx-2. Another result of the study was to evaluate the sources of $Si(OH)_4$ to the equatorial upwelling current which were found to be asymmetrical, with less $Si(OH)_4$ (only 30% of the total supply) entering from the south Pacific compared to the north. These results, suggest a coupling between Southern Ocean productivity, equatorial productivity, and the efflux of CO_2 to the atmosphere from the equatorial upwelling system.

For the three-dimensiaonal modeling, overall, the model captures the essential interannual variability shown by Barber and Chavez, (1983), Murray et al. (1994) and Feely et al (1997) and ENSO effects on phytoplankton dynamics. The total phytoplankton biomass decreases during all five El Ni±o events (1972-73, 1975-76, 1982-83, 1986-87, 1991-92), not just near the surface but also throughout the water column. The strongest reduction of the phytoplankton biomass occurred during the 1982-83 El Ni±o, followed by 1972-73 El Ni±o. The highest biomass was in 1987-88 and 1974, the La Ni±a periods. The phytoplankton biomass decreases due to the combination of $Si(OH)_4$ supply to the euphotic zone (decrease both in upwelling

and deepening of the nutricline) and decrease in Si(OH)4
concentration during the El Ni±o events, which results in
reduction of diatom growth.

These results are summarized in 3 lengthy manuscripts in press in Deep Sea Research and several other related publications.

Training and Development:

Two graduate students (Li XU and Lawrence KLEIN) have been involved in the 1D model development. Based upon their modeling activities and experinces, both of them are working on their MS thesis, which should be done within the next year.

Dr. Mingshun JIANG, a postdoc at the University of Maine, has been involved in the 3D modeling. Jiang had leanred how to run the MOM code combined with the 10-component ecosystem model on supercomputers. He is now working with the ocean modeling group as a research associate. He is working on a couple of manuscripts based upon the results from this project.

Outreach Activities:

The 1-D model has been implemented on the website, which allows 'non-moderlers' be able to run the 1D model interactively. This is very useful for people who do not know any computer language. We have put the 3D model resutls online, which can be accessed with the Live Access Server (LAS). These activities enhance a broder participation in understanding ocean ecosystem modeling.

Journal Publications

Chai, F., R. C. Dugdale, T-H Peng, F. P. Wilkerson, and R. T. Barber, "One dimensional ecosystem model of the equatorial Pacific upwelling system, Part I: Model development and silicon and nitrogen cycle", Deep Sea Research, p. , vol. , ( ). Accepted

Dugdale, R.C., R. T. Barber, F. Chai, T.H. Peng, and F.P. Wilkerson, "1-D ecosystem model of the equatorial Pacific upwelling system, Part II: Sensitivity analysis and comparison with JGOFS EqPac data", Deep Sea Research, p. , vol. , ( ). Accepted

Dugdale, R. C. A. G. Wischmeyer, F.P. Wilkerson, R.T. Barber, F. Chai, M. Jiang and T-H. Peng, "Meridional asymmetry of source nutrients to the equatorial upwelling ecosystem and itÆs potential impact on ocean-atmosphere CO2 flux: a data and modeling approach", Deep Sea Research, p. , vol. , ( ). Accepted

Books or Other One-time Publications

Chai, F., S.T. Lindley, J. R. Toggweiler, and R.T. Barber, "Testing the iron limitation and the role of grazing in the equatorial Pacific, a physical-biological model stu", (1999). Book, Published
Editor(s): R.B. Hanson, H.W. Ducklow, & J.G. Field (Editors)
Collection: The Changing Ocean Carbon Cycle: A midterm synthesis of the Joint Global Ocean Flux Study,
Bibliography: International Geosphere-Biosphere Programme Book Series 4. Pp. 156-186. Cambridge University Press.

Peng, T-H and F. Chai, "Modeling the carbon cycle in the Equatorial Pacific Ocean", (2001). Book, Published
Editor(s): C-T Arthur Chen
Collection: Marine Environment: the Past, Present and Future
Bibliography: p.240-255

Peng, T-H and F. Chai, "Modeling the carbon cycle in the equatorial Pacific Ocean", (1999). Book, Published
Collection: Proceedings of the 2nd International Symposium 'CO2 In The Ocean
Bibliography: 183-189

Web/Internet Site

URL(s):

http://athena.umeoce.maine.edu/1deco-new/1deco.htm

http://rocky.umeoce.maine.edu/las-public/

Description:

Other Specific Products

Contributions

Contributions within Discipline:

Predictive understanding of how iron, silicate and nitrate affect carbon partitioning in the equatorial Pacific. How the marine ecosystem and carbon cycle response to the physical forcing on interannual and decadal time scale.

Contributions to Other Disciplines:

The ecosystem mdoel developed from this project has been incorporated into other coastal physical models, such Gulf of Maine and Monterey Bay.

Contributions to Human Resource Development:

Research activities has helped to train graduate students and postdoc to learn about eocsystsme modeling and using supercomputers in ocean modeling.

Contributions to Resources for Research and Education:

Our interactive 1D modeling website and 3D model results online have been linked with US JGOFS website.

Contributions Beyond Science and Engineering:

none

Categories for which nothing is reported:

Any Product