

Current Research Projects in Computational Biogeochemistry

Scott Doney sdoney@virginia.edu

Dept. of Environmental Sciences (EVSC), University of Virginia (UVA)

<https://evsc.as.virginia.edu/people/profile/scd5c>

Group Website:

<https://uva.theopenscholar.com/scott-doney-computational-biogeochemistry-lab>

Prospective EVSC Graduate Students Information:

<https://evsc.as.virginia.edu/prospective-students>

The computational biogeochemistry group in UVA's Department of Environmental Sciences <http://www.evsc.virginia.edu/> tackles a wide range of interdisciplinary ocean and environmental science questions at the intersection of physics, chemistry, biology, and people. A particular focus is on natural and human-driven climate change and environmental impacts. The research spans from the open-ocean to the coasts and adjoining watersheds, from the shores of New England and the Virginia Eastern Shore to the Antarctic and Arctic, and from natural ecosystems to coupled human-natural dynamics. The group has a focus on marine science issues as well as global-scale questions connecting ocean-land-atmosphere.

The group's research is primarily computational, and we interact extensively with several field programs as described below. Students and postdoctoral researchers often do a fair amount of data analysis, remote sensing, and numerical modeling work to address a broad range of biophysical, biogeochemical, ecosystem, and human-system questions and themes. In several cases there are possibilities for students and postdoctoral research to participate in field work in conjunction with a primary computational research project.

A good place to start in developing some computational skills and background is a book that we developed from our hands-on graduate course (taught in Matlab)

Glover, D.M., W.J. Jenkins, and **S.C. Doney**, 2011: *Modeling Methods for Marine Science*, Cambridge University Press, Cambridge, UK, 592 pp., www.cambridge.org/glover
ISBN-13: 9780521867832 (note book is available electronically through UVA library)

Current Projects

UVA Environmental Institute <https://environment.virginia.edu/>

The UVA Environmental Institute is a pan-university effort bringing together folks from natural and social science, policy, law, engineering, architecture, and humanities to solve some of the toughest environmental problems. Our group focus within the

Environmental Institute is primarily on coastal and climate resilience, climate restoration, and linkages of water, food, energy and carbon cycles.

Carbon dioxide removal approaches (negative carbon technologies)

We are part of a collaboration at UVA with folks in engineering and policy/economics to explore the potential opportunities for and impacts of carbon removal approaches (e.g., bioenergy with carbon capture and sequestration; direct air capture; ocean carbon dioxide removal techniques). The work involves combining natural and social sciences utilizing as a framework an integrated assessment model of energy, technology, agriculture, and water systems.

Center for Chemical Currencies of a Microbial Planet (C-CoMP) <https://ccomp-stc.org/>

C-CoMP is a NSF-supported Science and Technology Center, a multi-institutional project examining chemical-microbial networks and the fate of labile organic molecules in the surface ocean. In addition to oceanography, the overall project spans from biochemistry and organic chemistry to system biology, molecular biology and bioinformatics with components in the lab, field, and informatics. The UVA component focuses primarily on numerical modeling to connect molecular and cellular scale dynamics to larger marine biogeochemical processes and climate change.

Virginia Coastal Reserve (VCR) LTER <https://www.vcrlter.virginia.edu/home2/>

The Virginia Coastal LTER program is based on the VA Eastern Shore and led by UVA Environmental Sciences faculty with collaborators across the region. We are spinning-up a research program on water-column modeling, data synthesis, satellite and drone remote sensing, and field measurements (e.g., nutrient dynamics; oxygen; inorganic carbon system and acidification; ocean color, plankton, and water clarity).

Arctic and Gulf of Alaska biogeochemistry and carbon cycle

Our group is collaborating with scientists at the U. Alaska, Fairbanks on numerical ocean biogeochemical models of the Gulf of Alaska and Arctic, focusing on how the regional ocean carbon system is impacted by changing climate, reduced sea-ice, altered freshwater input from land, and rising atmospheric CO₂.

Palmer, Antarctic LTER (Long Term Ecological Research): <http://pal.lternet.edu>

The Palmer LTER program explores the ecological impacts of changing climate and sea-ice along the Antarctic Peninsula. The program has generated a rich marine ecological and biogeochemical dataset from plankton to penguins and whales over more than three decades, with ship-based data and more recently mooring and robotic glider data and satellite remote sensing. Our group leads an active research component leveraging food-web, biogeochemical, and regional ocean-ice biophysical synthesis, modeling and remote sensing to address the program's overarching science questions.

Ocean Carbon Observatory (OCO-2 & OCO-3)

https://www.nasa.gov/mission_pages/oco2/index.html

We have a funded project to analyze and model data from the NASA OCO-2 & OCO-3 instruments, which measure the atmosphere column carbon dioxide (CO₂) concentration. The objective of the OCO-2 and OCO-3 missions is to improve estimates of CO₂ sources and sinks to the atmosphere including fossil fuel emissions and exchange with the land and ocean.

Linking marine fisheries and ecosystems

We are collaborating with folks in the UVA economics department to characterize the impact of marine fisheries on large-scale ecosystems. This is a “big-data” project combining ship-transponder data (fishing locations, intensity) with satellite ocean color. This work opens up many avenues for future study on coupled human-natural systems for the marine environment.

Ocean transient tracers

We are analyzing historical data and developing model simulations on tritium and helium isotopes (measures of ocean ventilation and circulation pathways) to better understand nutrient and oxygen dynamics. There is lots more to do on this project involving analysis of a new global data compilation and model simulations.

Other recent research areas

Ocean Acidification

We have a long-term interest in many aspects of ocean acidification from biogeochemistry and microbes to fisheries and socio-economics. One example is modeling studies of the US Northeast scallop fishery that link together water chemistry, scallop population dynamics, fishery operations, and physical and socio-economic drivers (e.g. climate change and acidification; human population and seafood demand; fuel prices).

Community Earth System Model (CESM) <http://www.cesm.ucar.edu/>

We have a long-standing involvement with the Earth system modeling and the ocean and biogeochemistry components of the CESM. Research opportunities span from development and testing of new model parameterizations (e.g. marine ecosystem plankton dynamics; zooplankton migration; etc.) to analysis of the existing model simulations.

Completed projects

North Atlantic Aerosols and Marine Ecosystems Study (NAAMES)

<https://naames.larc.nasa.gov/>

Our group led a marine ecosystem and biogeochemical modeling component of NASA funded NAAMES project, which aimed to better understand the controls on ocean

ecosystem dynamics over the annual cycle as well as ecosystem controls on biogenic aerosols in the marine troposphere. NAAMES completed four field campaigns combining ship-based, autonomous float, and airborne sampling. Our group is still involved in: 1) using NAAMES data to evaluate existing regional and global models, and 2) integrating field data, remote sensing, and numerical simulations to constrain plankton bloom dynamics.

Coastal Climate Change, Water Quality & Ocean Acidification

http://www.whoi.edu/sites/coastal_climate_change_solutions

We completed a field project working on Buzzards Bay, MA with a NGO-based citizen scientist program. There are still considerable opportunities for data analysis and modeling of water quality and its impacts (e.g., nutrient eutrophication, hypoxia, ocean acidification, water clarity, recreational shell-fishing and aquaculture). Recent projects include regional ocean warming, remote sensing of water clarity, drivers of shell-fishing trends, and acidification from freshwater inputs, eutrophication, and sewage discharge.

Marine Biodiversity Observation Network (MBON)

<http://www.marinebon.org/>

<http://www.marinebon.org/sanctuary-bon.html>

We were part of a large, multi-institutional effort trying to dramatically change how we observe the ocean and then use the wealth of new data to inform marine resource management and conservation.