Princeton University

Honors Faculty Members Receiving Emeritus Status

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The biographical sketches were written by staff and colleagues in the departments of those honored.

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Faculty Members Honored in 2019
for Receiving Emeritus Status

Jorge Sarmiento

Jorge Sarmiento, the George J. Magee Professor of Geosciences and Geological Engineering, is transferring to emeritus status on July 1, 2019. With his 18 Ph.D. students, 58 (!) postdoctoral fellows, and many accomplished collaborators, he has published 250 papers that have founded and defined the fields of ocean biogeochemistry and chemical oceanography, and form a pillar of climate science.

Jorge studies and models ocean circulation, biological processes in the ocean, and the impacts of circulation and metabolism on the oceanic distribution of those elements involved in biological cycles (primarily CO_2, O_2, nitrogen, phosphorus, and iron). Jorge has used his models to study rates of biological processes in the oceans, responses of ocean biology to global change, and the dynamics of fisheries. He has tracked transfers of fossil fuel CO_2 from human activities into the atmosphere and oceans. By deciphering the factors that partition fossil fuel CO_2 between the atmosphere and the ocean, Jorge has arguably contributed more towards understanding the fate of fossil fuel CO_2 than any other person.

Jorge did his undergraduate work at Swarthmore College and received his Ph.D. at Columbia University. His early research focused on the fundamental and challenging question of how fast waters mix within the oceans. Jorge identified radioactive isotopes released from sediments to the "bottom waters" of the ocean. He then measured the distribution of these isotopes in seawater to determine the rates of mixing from the sea floor to shallower depths, and from the ocean margins to the interior.

Jorge spent a two-year postdoctoral fellowship at the Geophysical Fluid Dynamics Laboratory, NOAA, and in 1980 he joined Princeton's Department of Geosciences as an assistant professor. In 1984, he published a seminal paper with J. R. Toggweiler that would have a profound influence on his career and beyond, to this day. Their work was stimulated by the discovery that, during the last ice age (which ended about 10,000 years ago), the atmospheric CO_2 concentration was about one-third lower than the "preindustrial" value (i.e., around 1800, before mankind starting adding CO_2 to air by burning fossil fuels). This low ice-age CO_2 concentration was understood to reflect the transfer of CO_2 between the atmosphere and the deep ocean, which contains the lion's share of CO_2 on Earth's surface (ocean+atmosphere+biosphere). The great insight of this paper was to recognize that the Southern Ocean is the window through which the deep ocean communicates with the atmosphere. The Southern Ocean is the main region where the surface water gets cold and dense enough that it can mix with cold deep waters; elsewhere surface waters are warmer, and thus buoyant, and float on the denser waters below. Rapid communication between atmosphere and deep ocean, through the Southern Ocean "window", would raise the CO_2 concentration of the atmosphere by releasing CO_2 that had been produced by metabolism and accumulated in the deep ocean. Diminishing the window would retain metabolic CO_2 in the deep ocean and lower the atmospheric CO_2 burden. The search for insight into glacial-interglacial CO_2 change then centered on understanding how and why the Southern Ocean was more open during warm times, and more closed during ice ages.

Another important feature of the Southern Ocean concerns its exceptionally high nutrient levels. The deep ocean accumulates CO_2 and nutrients (mainly nitrogen and phosphorus, but also iron) because organisms use nutrients to build biomass, which forms in the sunlit upper ocean and eventually sinks and decays at depth. In the Southern Ocean, mixing between deep and shallow waters raises the nutrient concentration of the local sunlit layers, enabling the rapid growth of single-celled phytoplankton. This growth supports the food resources and megafauna of the Southern Ocean, and influences the biology of the global ocean in other ways. Perhaps most important is that mixing in the Southern Ocean transfers nutrients from nutrient-rich deep waters to nutrient-poorer shallower waters. These shallower waters flow north with their increased nutrient content and supply most of the nutrients reaching the euphotic zone beyond the Southern Ocean. This supply fertilizes much of the biological activity of the global ocean.

Throughout Jorge's time at Princeton, the Geophysical Fluid Dynamics Laboratory has developed ocean circulation models of increasing complexity and realism. These models use the basic equations describing the motion of fluids on a rotating sphere to describe ocean physics, i.e., circulation and mixing. In 1991, Jorge and colleagues published the first paper that represented biological fluxes of carbon and other elements within a global circulation model. Much of Jorge's effort since that time involves improving the physical and biological models by challenging them with data, and using these improved models to characterize rates of biological processes in the ocean. A particularly important project involved mapping the distribution of nitrogen fixation and denitrification, processes that transfer nitrogen between N_2 and the more biologically useful forms (nitrate and ammonia).

Burning fossil fuel raises the CO_2 concentration of air, which in turn drives atmospheric CO_2 into the ocean. This flux is extremely important for human well-being, because it attenuates the increase in atmospheric CO_2 that arises from burning fossil fuels. Jorge has led the effort to understand ocean uptake of fossil fuel CO_2, using both measurement and modeling approaches. Jorge showed that, just as the Southern Ocean mediates transfer of CO_2 between ocean and atmosphere on glacial-interglacial timescales, it also largely controls the transfer of anthropogenic CO_2 between the atmosphere and the subsurface ocean on timescales of decades.

Around 2005, Jorge expanded the scope of his work to project the future health and yield of fisheries. This work involves using models described above to predict changes in primary production (the growth of the phytoplankton at the base of the food chain), and the effect on of these changes on fisheries. The work grew to encompass the influence on fisheries of future decreases in subsurface dissolved oxygen concentrations. This work showed that ocean warming, a decrease in primary production, and lower O_2 would all lead towards compressed habitats and lower fisheries yields. This work, coupled with improved fish physiology models, enabled predictions of how fisheries yields would evolve for different fish in different geographical regions. One important finding was that declines would be greatest in tropical areas that are socioeconomically most vulnerable.

Around 2014, Jorge expanded his Southern Ocean interests by founding, shaping, and directing a major new national research initiative. Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) involves scientists at eight American institutions, with multiple foreign collaborators. SOCCOM members are engaged in observing and modeling the physical circulation of the Southern Ocean and the large-scale processes linking biological carbon fluxes and ocean chemistry. The heart of the program is a set of 126 robots, dispersed throughout the Southern Ocean at 2000 m water depth. Every eight days, each robot rises up through the water column to the surface, measuring properties reflecting ocean physics and the rates of biological processes. This work is tracking the physical and biological state of the Southern Ocean, improving our knowledge of Southern Ocean uptake rates of fossil fuel CO_2, and providing information about the nature and activity of Southern Ocean ecosystems.

For about 40 years, Jorge has been the leading scientist engaged in analyzing and modeling the fundamental, interconnected processes of ocean chemistry, biology, and climate. During that time, the models became more realistic, and came to encompass many new properties. Jorge's group pioneered almost all these developments.

In addition to founding and directing SOCCOM, Jorge has been involved in myriad leadership positions in the ocean community, both at Princeton and beyond. His widely used textbook, *Ocean Biogeochemical Dynamics* (2006), is on every oceanographer's bookshelf and dog-eared copies have traveled far in nearly every geosciences student backpack. In over 30 years of teaching at Princeton, he trained many generations of future oceanographers, via his seminal chemical oceanography class for graduate students. He also attracted many students to the geosciences major by teaching his introductory general oceanography course. He was the long-time director of the Atmospheric and Ocean Sciences Program at Princeton and the long-serving director and scientific leader of the Cooperative Institute for Climate Science at NOAA. Many of his students and postdocs are now working at other research universities including eight in foreign countries, and are assuming leadership positions for the next generation. Jorge was on the steering committees and led working groups for major international research programs, including Joint Global Ocean Flux Study (JGOFS) and World Ocean Circulation Experiment (WOCE). He was a leader in writing the U.S. Carbon Cycle Science Plan. Among other honors, in 2009 he won the Roger Revelle Medal from the American Geophysical Union for "outstanding contributions in atmospheric sciences, atmosphere-ocean coupling, atmosphere-land coupling, biogeochemical cycles, climate, or related aspects of the Earth system."