OS11J-09 1105h

Wind events and Benthic-Pelagic Coupling in Western Florida Bay

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We hypothesized that episodes of wind-induced mixing in Florida Bay (25.07°N, 81.01°W) contributed to biological processes in the water column by suspension of benthic dissolved and particulate materials, including benthic biota. Suspended particulate material, dissolved nutrients (NH_4^+, NO_2^-+NO_3^-, PO_4^{3-}, and SiO_2^{2-}), light, chl *a*, phytoplankton growth and meso and micro-zooplankton grazing were measured daily in Florida Bay from 5-13 March 2001. Initially strong N and NW winds (16 m s^{-1}) gradually diminished during our study. These strong winds resulted in a high degree of particulate material suspension, associated with low light penetration into the water column and enhanced nutrient availability. The highest concentrations of NH_4^+, PO_4^{3-}, and SiO_2^{2-} were observed during the strongest period of mixing, suggestive of a benthic source. Phytoplankton growth rates were light limited during the period of highest SPM concentration. As SPM settled and light transmittance increased, chl *a* concentration and phytoplankton growth increased. Elevated nutrient concentrations quickly diminished. Dilution experiments indicated phytoplankton growth exceeded losses to microzooplankton grazing by significant amounts during this event, with greatest differences during periods of highest SPM concentration. Mesozooplankton did not exert a strong grazing pressure on phytoplankton (<1% reduction in phytoplankton growth rate). Given the regular seasonal passage of northern air masses through Florida Bay during the October-April time period, we conclude that wind-driven suspension events are an integral component of material cycling in this system.

OS11J-10 1120h

Friction, Roughness, Turbulence and Nutrient Uptake by Coral Reefs

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Coral reefs are some of the roughest surfaces encountered in the ocean and maintain this roughness, against the effects of erosion, by their continuous growth processes. Such roughness creates extreme turbulence which is vital to many fundamental biological processes which are of prime importance to the health and ecology of coral reefs. The roughness of coral reefs exists on spatial scales extending from individual polyps (few centimeters) to the larger-scale complex topography of complete reefs (hundreds of meters) and so the conventional nearshore concept of smoothly-varying bathymetry is nowhere applicable to coral reefs. The hydrodynamic 'roughness length' is very large on coral reefs and varies not only with spatial scale but with bottom type, e.g. sand, rubble or living-coral. This paper discusses the important spatial scales for which roughness controls wave-forced currents, turbulence and nutrient uptake. Results are then presented for the variation of frictional stress, turbulent energy dissipation, and nutrient uptake with the height and period of waves on reefs. The paper proceeds to analysis the importance of roughness in controlling water flow across coral reefs, and the associated flushing of their lagoons, and also the dependence of these quantities on the height and period of incoming waves.

URL: http://www.ge.adfa.edu.au/SPECIES

OS11J-11 1135h

Export of Sediment and Nutrients to the Great Barrier Reef from Monsoonal Catchments of NE Queensland

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Monsoonal rivers in NE Queensland drain an average of 70 cu. km of runoff into the Great Barrier Reef (GBR) each year from a catchment of 422,000 sq. km. Most of the GBR catchment was covered by savanna woodland and is now used for cattle grazing. Substantial clearing of vegetation has taken place in some catchments. Intensive cultivation of sugarcane occurs on 4,000 sq. km in wetter portions of the coastal plain. Runoff dynamics are characterised by a high level of inter-annual, seasonal (wet-dry), regional (wet tropics dry tropics) and event-based (tropical cyclone) variability. Most freshwater runoff and export of sediment and nutrients occurs during brief wet-season flood events, which follow cyclones or monsoonal rain depressions. In this variable runoff regime, wet and dry catchments exhibit typologically consistent discharge volume-export relationships for sediment and nutrients (N, P). Dry-catchment rivers have low area-specific runoff rates, but high volume-specific sediment and nutrient loads. Wet-tropical rivers have high area-specific runoff, but lower volume-specific loads. These topological relationships have been used to estimate whole-catchment exports of sediment and nutrients to the GBR that take account of the considerable natural hydrological variability of NE Queensland rivers. Longitudinal sampling of nutrient concentrations within individual rivers indicates that sediment and nutrient exports to the GBR have increased several-fold in the last century as a result of land clearing and floodplain fertiliser applications.

OS11J-12 1150h

The Legacy of Historic Sewer Discharges: Here Today...Gone Tomorrow?

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In the early 1970's, monitoring of Palos Verdes infauna by the Los Angeles County Sanitation Districts (LACSD) revealed distinct effects from wastewater discharge, including low numbers of species diversity, abundance, and biomass in the areas around the outfalls. Since the 1970's, long-term monitoring of the area has allowed documentation of environmental and biotic recovery in response to improving effluent quality. Impacts related to the wastewater discharge were severe during the early years of the surveys, but have dramatically decreased over time. As a result, many adverse alterations to marine habitats have decreased in magnitude or disappeared altogether. Nevertheless, historically deposited contaminated sediments still remain on the shelf and slope. Physical and biological processes are mixing these sediments, and contaminants continue to be bioavailable from both surface and buried sediments. This process allows contaminants that have not been discharged in decades to continue to influence the local fish and invertebrate communities. Options for dealing with this situation will be discussed.

URL: http://www.epa.gov/region09/features/pvshelf/pilot.html

OS11K HC: 315 Monday 0830h

Multidisciplinary Ocean Observations and Observatories I

Presiding: **J Orcutt,** Scripps Institution of Oceanography**; R A Weller,** Woods Hole Oceanographic Institution

OS11K-01 0830h INVITED

Sea Change for the Ocean Planet

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Through development of new platforms, observational technologies, and modeling capabilities, the ocean and earth sciences are on the threshold of a revolution in ability to address fundamentally new scientific questions and to support a much broader community of users of information about the ocean. Specifically, advance in knowledge of the oceans has been severely limited by lack of sustained observations over extended periods and large areas. There is an immediate need for a new approach that effectively links basic research and operational oceanography to provide the data, information, and understanding required for more timely detection, understanding and prediction of change in all aspects of marine and estuarine ecosystems and the resources they support. New approaches are being developed to continuously visualize and assess environmental data that describe physical, biological, chemical, and geological processes operating in the four dimensions of space and time. To achieve expected new scientific insights at previously poorly-explored scales of observation and simultaneously serve national needs for better awareness of ocean processes, the GOOS (Global Ocean Observing System)and DEOS (Dynamics of Earth and Ocean Systems)international initiatives need to develop synergistically and become operational via the National Ocean Partnership Program (NOPP) and Ocean.US as soon as possible. A key premise of this approach is that hypothesis-driven basic research programs and the development of operational oceanography are critically dependent on each other. Basic research to be conducted via the DEOS initiative will be required to develop the full capabilities of the GOOS initiative, and the scales of observation and visualization made possible by use of GOOS, will increase the value and importance of more specifically-scientific inquiries.

URL: http://core.cast.msstate.edu/NOPPpg1.html

OS11K-02 0850h INVITED

The Coastal Module of The Global Ocean Observing System (Goos): an Assessment of Current Capabilities to Detect Change

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There is an immediate need to develop the coastal module of GOOS that will enable periodic ecosystem assessments and significantly improve the ability of participating nations to achieve the goals of international agreements and conventions for environmental protection, sustainable living marine resources, healthy marine and estuarine ecosystems, and safe and efficient marine operations. It is likely that, in the absence of a sustained observing system for improved ecosystem assessments and prediction of environmental changes and their effects on the environment and people, conflicts between commerce, recreation, development, environmental protection, and the management of living resources will become increasingly contentious and politically charged. The social and economic costs of uninformed decisions will increase accordingly.

Two related topics are addressed in this context. The first is the challenging task of producing scientifically credible quantitative assessments of the status, condition or health of coastal marine and estuarine ecosystems (ecosystem assessments) on regional to global scales. The second is the current capacity to provide the data required to produce such assessments in a routine and repeatable fashion (a purpose of GOOS).

The Program of Action for Sustainable Development (Agenda 21 agreed to at the UNCED conference in1992) calls for the establishment of a global ocean observing system that will enable effective and sustainable management and utilization of the marine environment and its natural resources. Effective and sustainable use of the marine environment and its living resources depends on the capability to routinely and periodically assess and anticipate changes in the status of coastal ecosystems and living resources on national to global scales. Recent attempts to produce such quantitative assessments have not been successful on either national (U.S.) or global scales. The reasons for this state of affairs and the status of the coastal module of GOOS are discussed in this context.

URL: http://www.hpl.umces.edu/cgoos/cgooshome.html

MON

OS11K-03 0910h INVITED

Evolution of LEO into a Shelf-Wide Ocean Observatory

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The integrated Long-term Ecosystem Observatory (LEO) was developed in the coastal waters off the central coast of New Jersey (USA) and has been operated since 1997. A major goal for the Long-term Ecosystem Observatory (LEO) was to develop a real-time capability for rapid environmental assessment and physical/biological forecasting in coastal waters. To this end, observational data was collected by satellites, shore-based radars, aircrafts, ships, fixed/relocatable moorings, and autonomous underwater vehicles in a 30 x 30 km research space and the data was provided real-time to a data assimilative ocean forecast model. Results of 4 coastal predictive skill experiments demonstrated that in this observationally rich research environment model forecast errors were dominated by uncertainties in the model physics or future boundary conditions rather than initial conditions. Therefore, ensemble forecasts with differing model parameterizations provided a unique opportunity for model refinement and validation. Currently the LEO system is being expanded into the New Jersey Shelf Observation System (NJ SOS) in order to develop an integrated system allowing for regional questions (300 x 300 km) to be addressed. New enabling technologies make this regional expansion possible. These enabling technologies include: (1) strategically located, long-duration physical/bio-optical moorings or cabled observatories for subsurface time series at fixed locations, (2) long-range shore-based high-frequency Coastal Radars (CODAR) that generate real-time surface current maps over 200 km distances, (3) a growing international constellation of high-resolution (spatial and spectral) ocean color satellites that can be used to generate surface temperature, chemical and biological maps, and (4) an emerging class of mobile subsurface oceanographic sampling platforms, the long-duration remotely-controlled Glider-type Autonomous Underwater Vehicles (AUVs) that provide guidance to short-duration propeller AUVs that can be steered into regions of scientific interest to underwater weather forecasters. NJ SOS will form part of the NorthEast Observatory System (NEOS), which is an ocean observatory consortium spanning from North Carolina to Maine.

URL: http://marine.rutgers.edu/cool

OS11K-04 0930h INVITED

The Dynamics of Earth and Ocean Systems (DEOS) Program

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Oceanography has been dominated for at least two centuries by an expeditionary approach and examples include the voyage of the Beagle in 1831-1836 and the Challenger Expedition in 1872 - 1876. In the U.S., the capabilities for expeditionary research were greatly amplified during and especially following WW II. Today the U.S. alone has established a research fleet of 28 vessels organized through UNOLS. While experimental oceanography has made enormous contributions over the decades and centuries, this approach has not been well-suited to investigating processes in which transients are important. The Dynamics of Earth and Ocean Systems (DEOS) program was developed in 1997 to promote the idea of making long-term observations in the oceans - to establish a long-term presence in the oceans.

DEOS, now under the sponsorship of the Consortium for Ocean Research and Education (CORE) with support from the NSF, advocates the collection of long-term time-series data with the recognition that this is the only viable approach to observe transients and changes and to enhance the signal-to-noise ratio of weak signals. Another talk in this session will expand upon the NEPTUNE component of DEOS. The authors believe that moored ocean buoys, including the Time-series Program, are a technically feasible approach for making sustained time series observations in the oceans and will be an important component of any long-term ocean observing system. Because of the broad spectrum of scientific needs identified during planning, it is clear that there is no single buoy or mooring design that will meet all of these needs while at the same time minimizing costs. Both the U.S. and Britain (B-DEOS) have completed design studies for these buoys and we will present these alternatives in light of realistic ocean environments. Ongoing experiments to demonstrate components of the mooring program will be discussed.

URL: http://igpp.ucsd.edu

OS11K-05 0950h INVITED

NEPTUNE: An Interactive Submarine Laboratory Network for Earth and Ocean Science at the Scale of a Tectonic Plate

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The Earth, Ocean, Planetary and Life Sciences are poised at the threshold of a new era of exploration, discovery, and understanding that will encompass a wide spectrum of globally significant planetary processes and the non-linear nature of their interactions. The convergence of innovative scientific concepts or insights, pressing societal needs, and rapidly evolving technological development compels us, and enables us, to begin entering ocean space with a globally distributed, continuous, real-time interactive presence. New intellectual drivers include: plate tectonic modulation of microbial productivity, documentation of the role that episodic Earth and ocean processes within the ocean basins play in the habitability of the planet, and the presence of other oceans in the solar system. Societal drivers include population loading of coastal regions, the need to educate the public regarding the planetary habitat, resource identification and assessment, and hazard recognition and mitigation. Parallel development among a number of key technologies is rapidly creating the potential for entire new approaches to studying planets; these include: power availability below sea level, rapid evolution in communication bandwidth, computational power, robotic sophistication, sensor diversity and endurance, and a growing interest in environmental genomics.

The NEPTUNE Program will provide a plate scale network of electro-optically cabled experimental nodes capable of delivering power and high-speed two-way communications to thousands of investigatorinitiated experiments on, below, and above the seafloor. Expected to be operational by 2006-7, this network of instrumented undersea laboratories will provide significant power (100kW), precise timing, and high-bandwidth (10 gigabits/second) communication capabilities to enable simultaneous operation of four dimensional (3D plus time) arrays of instruments and sensors located near 30 distributed experimental sites. Scientists, educators, students, and the general public will have ready access to many aspects of the system via a hard-wired Internet connection.

Scientific studies enabled by the NEPTUNE Facility will include: studies of erupting volcanoes and their microbial and mineral products, assessment and tracking of fish stocks in coastal and open ocean waters, comprehensive seismic studies of the dynamic deformation of a Pacific Rim subduction zone system including an assessment of the fluid expelled during major earthquakes, plate scale hydrologic studies using bore hole instrumentation put in place by the Ocean Drilling Program and it successors, decade-long studies of primary and secondary productivity in controlled and instrumented volumes of ocean space, airsea exchange studies during intense winter storms, testing of sensors and robots that will eventually be launched to other bodies in the solar systems in search of life, and sustained studies of deep-sea Benthic biological community dynamics over long periods of time. Each of these studies and many others will have the potential to adapt observational strategies and sampling protocols based on a full knowledge of the processes taking place at any time within the NEPTUNE System. Robotic sensor platforms will be responsive to changes in the environment and will allow experimental setups to be reconfigured at the discretion of the principle investigator. Finally, NEPTUNE will enable an entirely new view of the ocean environment be to shared with the general public, both in real-time and as an ever-growing archive that catalogues earth-ocean processes and their effects on life.

URL: http://www.neptune.washington.edu

OS11K-06 1030h INVITED

The Argo Project: Observing the Global Ocean in Real-time

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Argo Science Team

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The Argo profiling float project is a key global element in the emerging ocean observing system, measuring large-scale temperature and salinity (T/S) variability in the upper ocean. When fully implemented in 2005, Argo will include 3000 profiling floats drifting at 1-2 km depth, covering all of the worlds oceans. Each float will collect a T/S profile plus a measurement of ocean current every 10 days. Data are immediately transmitted ashore via satellite and made publicly available.

The ocean plays a fundamental role in the climate system of the Earth through the heat and hydrological cycles. The sea holds about 96% of the Earths water, and variability in ocean salinity reveals anomalous patterns of evaporation and precipitation. Over 90% of global warming observed in the past 50 years occurred in the oceans (e.g. Levitus et al, 2000, Science, 287, 2225-2229), and large interannual fluctuations in heat storage are seen regionally. In addition to providing vast reservoirs for storing heat and water, the ocean redistributes them and exchanges them with the overlying atmosphere.

Argo is an international program endorsed by the IOC and WMO, and is a part of WCRP/CLIVAR and GODAE. Large-scale deployment of Argo floats began in 2001. Floats are being contributed by 14 nations worldwide, including Australia, Canada, China, Denmark, the European Union, France, Germany, India, Japan, New Zealand, the Republic of Korea, Spain, the U.K. and the U.S., coordinated by the international Argo Science Team. The U.S. contribution to Argo is implemented by a consortium of institutions under the National Ocean Partnership Program. Other NOPP projects include development of multidisciplinary sensors for profiling floats.

Argo has many applications in basic oceanographic research and operational oceanography. Argo by itself will observe patterns of broadscale variability in upper-ocean temperature and salinity on a global basis, and will enable interpretation of the subsurface expression of sea surface height variability observed by the Jason satellite altimeter. Argo together with other elements of the observing system will reveal the role of the ocean in the climate system and will provide the necessary data for powerful new data assimilation and forecast models, to satisfy a broad range of applications.

URL: http://www.argo.ucsd.edu

OS11K-07 1050h INVITED

The Plan for a Global Array of Long-Term, Multidisciplinary Oceanographic Moorings

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An essential perspective on ocean variability is provided by moorings. Moorings provide platforms on which to mount instruments to sample the full ocean depth, from the surface to the bottom, with high vertical and temporal resolution. Diverse types of instruments are now being deployed on moorings, supporting studies of ocean biology, chemistry, geology, optics, acoustics, and physics, of air-sea interaction, and of climate variability. Progress on the technologies of building and designing moorings have increased their reliability and consequently our ability to deploy them successfully in more severe environments. At the same time, the lifetime of moorings has been improved, enabling effective occupation of specific sites for long periods. Developments of new sensors and instruments have added to the versatility of multidisciplinarity of moorings. Improved communications through the water, along mooring cables, and via satellite help provide data from moorings in real time.

Several examples of recent multidisciplinary moorings and the data they have collected are presented in revieiwng the rational for establishing long-term moorings. The central objective of the plan is to establish, in key regions and regimes in the ocean, long-term moored observatories. These observatories will provide new understanding of temporal variability and vertical structure, of atmosphere-ocean exchange processes, and of transports and storage of properties. They will provide anchor points for developing maps from complementary Lagrangian ocean platforms, ships, and satellites. They will provide the fixed point, accurate time series needed to validate and improve models of the ocean and of the atmosphere.

The locations identified to date and the strategy for moving forward to install and maintain these moored observatories will be presented. Feasibility and availability of national support and shiptime as well as scientific priority have been weighed. Some high priority sites are in severe environments, such as the Southern Ocean, so the plan includes in its initial phase mooring design and engineering studies needed to build the moorings to be used in those sites. With a number of sites already occuppied and plans for the extension and implementation of other sites, the prospect for a global array is promising.

OS11K-08 1110h INVITED

Monitoring the Ocean Acoustically: A Review and Strategy for the Future

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Since ideas for monitoring the oceans acoustically were first voiced in the mid-1970's, ocean acoustic tomography has evolved into an effective tool for remote sensing of the ocean interior on a wide variety of time and space scales. Regional tomographic arrays have been employed at scales of up to about 1000 km for measuring changes in integrated heat content, for observing regions of active convection, for measuring transports through the Strait of Gibraltar, for observing the evolving ocean mesoscale, for measuring barotropic currents, for directly observing oceanic relative vorticity, and for measuring barotropic and baroclinic tidal signals. Basin-scale tomographic arrays have been employed out to ranges of 5000 km for measuring large-scale changes in temperature and heat content in the North Pacific, Mediterranean, and Arctic oceans. At these ranges acoustic methods give integral measurements of large-scale ocean temperature that provide the spatial low-pass filtering needed to observe small, gyre-scale signals in the presence of much larger, mesoscale noise, offering a signal-to-noise capability for observing ocean variability with climate relevance that is not readily attainable by an ensemble of point measurements. In addition, tomographic methods rely on the measurement of acoustic travel times, which can be made without risk of calibration drift. The remote sensing capability has proven particularly suitable for measurements such as those in the Arctic and in the Strait of Gibraltar, where the application of conventional in situ methods is difficult.

The appropriate roles for acoustic tomography in an ocean observing system appear to be (1) to exploit the unique remote sensing capabilities for regional programs otherwise difficult to carry out, (2) to be a component of process-oriented programs in regions where integral or large-scale heat content or transport data are desired, and (3) to move toward deployment on basin to global scales as the acoustic technology becomes more robust and simplified. Tomography is naturally complementary to other ocean measurement techniques. Altimetry senses the ocean surface, while tomography senses the ocean interior. Profiling floats provide high vertical resolution of the upper ocean, while tomography suppresses internal wave and mesoscale noise and reaches the deep ocean. The operational costs of a tomographic network are low, making the amortized cost of the technique attractive. Permanent open-ocean stations (e.g., planned as part of the Integrated Ocean Observing System (IOOS) and the NSF Ocean Observatories Initiative) will provide supporting infrastructure for the application of acoustical techniques on basin to global scales.

OS11K-09 1130h

The Ocean Observatories Initiative: Providing a New Mode of Access to the Oceans for Research

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Recent workshop and commissioned reports have underscored a perceived trend in the types of proposals being submitted to the Ocean Science Division (OCE) of the National Science Foundation (NSF). There is increasing emphasis on research involving long-term experiments and sustained time-series observations. This trend requires substantially different infrastructure to continue into the new millennium the rapid rate of scientific progress that began in the early 1960's.

Just as the diversely capable academic research vessel fleet provides access to the world's oceans to support a wide spectrum of traditional research requirements, a diversely capable network of ocean observatories is required to address new and evolving sustained time-series requirements. Several pilot projects have successfully installed seafloor observatories using newly developed junction boxes and fiber-optic cable protocols. Technology development efforts have also advanced moored and relocatable buoys, instrumentation, sensors, and communication capabilities. In response to increasing demands by researchers for sustained observations, and capitalizing on recent advances in technology, an initiative has been developed by OCE for providing the basic infrastructure necessary for implementing an integrated system of ocean observatories.

The proposed Ocean Observatories Initiative (OOI) has three elements: 1) a lithospheric plate-scale observatory consisting of interconnected sites on the seafloor that span several geological and oceanographic features and processes, 2) several relocatable deep-sea observatories based around a system of buoys, and 3) an expanded network of coastal observatories. It is envisioned that this new system of research capabilities will be a substantial component of the U.S. Integrated Ocean Observing System. Funding for the OOI has been requested through NSF's Major Research Equipment (MRE) account, and it is approved for consideration in some future NSF budget request.

OS11L HC: 319 A Monday 0830h

The Cycle of Carbon in the Southern Ocean (S.O.) I

Presiding: **P Trguer,** Institut Universitaire Europeen de la Mer**; T Trull,** Antarctic CRC**; P Sedwick,** Bermuda Biological Station for Research**; A J Watson,** School of Environmental Sciences, University of East Anglia**; K R Arrigo,** Stanford University

OS11L-01 0830h INVITED

Bottom-up Control of Primary Production in the Southern Ocean: the Co-limitation Question With Regard to the Availability of Fe, Si, and Light

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Southern Ocean waters have long been considered paradoxical in terms of their biogeochemical properties, e.g. low primary production rates in a high nutrient environment, apparent high sedimentary opal burial efficiencies, and atypical phytoplankton ecophysiological characteristics. The functioning of the Southern Ocean ecosystems, which together represent the largest HNLC area of the World Ocean, has been studied in detail since the 1970's and most intensively during the S.O. JGOFS program between 1990 and 2000. The Antarctic opal paradox has largely been resolved, by establishing coherent budgets of biogenic silica production rates, opal rain rates in the water column and opal sediment burial rates; opal preservation efficiencies have now been revised downward and now appear to be no different than elsewhere in the sea. The new data on phytoplankton limitation indicate a significant influence of several potentially limiting factors. The first evidence of the control of primary production by iron was obtained in 1988/1989, and the importance of vertical mixing in controlling the underwater light climate was reinforced in 1991. These limiting factors are not independent. Iron availability has been recognized as a major factor slowing down or even preventing the photoadaptation of Southern Ocean phytoplankton via pigment synthesis control. The question of the nutritional requirements of diatoms with regard to silicon is still a matter of debate. Silicic acid limitation of silica production has been detected at what would otherwise be considered non-limiting silicic acid concentrations. The first estimates of very high K_S were obtained well before the development of isotopic tracer studies using stable (^{30}Si) and later on radioactive (^{32}Si) isotopes. More recent studies using these modern techniques have also indicated surprisingly high K_S values, at least in areas remote from coastal/shelf influence. Some shipboard studies have suggested a link between in situ low iron concentrations and high K_S values and it is thus tempting to hypothesize an iron-related control of the silicic acid uptake mechanism similar to that for nitrate utilization or nitrogen fixation. Only a few enrichment studies have hitherto been conducted, but some of them indicate a relationship between iron availability and the K_S values of natural assemblages. However there does not appear to be a single general mechanism relating Fe requirement and silicic acid utilization and other trace-elements could also be involved; specific experimental process studies on natural diatom communities are needed to investigate this problem. However it is now clear that the question of the "limiting factor" in the Southern Ocean and elsewhere cannot be considered simply in terms of von Liebig's law, but rather that the factors which control primary production are multiple and interrelated, which leads us to the present concept of co-limitation of phytoplankton growth by trace-elements, nutrients, and light.

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Effects of Iron Limitation on Southern Ocean Biogeochemistry and Phytoplankton Community Structure Assessed With a Natural Community Continuous Culture Incubation System

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Shipboard growout and open ocean addition experiments have been used to demonstrate that iron availability controls phytoplankton growth and carbon fixation in large areas of the Southern Ocean. These methods have provided strong evidence for iron control of primary productivity, but their application to understanding in situ processes is uncertain. Both growouts and open ocean fertilizations use unrealistically high single applications or multiple pulses of iron and are highly perturbed, non-steady state experiments. In contrast, natural communities usually receive their iron supplies from low-level, relatively continuous inputs from upwelling, mixing, or ice melting, and biomass removal processes are often in approximate balance with production. In order to understand the effects of iron at realistic supply rates and concentrations in a steady state system, we have adopted laboratory chemostat methods to shipboard use. Iron was supplied to phytoplankton communities from the Australian sector of the Southern Ocean continuously at low concentrations. Natural removal processes were simulated by losses through the chemostat outflows, resulting in a steady state experiment that closely reproduces the actual range of variability in iron inputs and biomass levels. Changes in phytoplankton community structure were monitored using microscopy, pigments analyses, and flow cytometry, and nutrient and carbon biogeochemistry were also followed. Shipboard chemostats are

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