OS32E HC: Hall III Wednesday 1330h

Biocomplexity/The PIRANA and MANTRA Programs and Marine Nitrogen Fixation

Presiding: **A Subramaniam,** ESSIC/University of Maryland University of Maryland**; D G Capone,** Biological Sci/Wrigley Inst.

OS32E-164 1330h POSTER

Effect of EDTA Additions on Natural *Trichodesmium* spp. Populations

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The marine, non-heterocystous cyanobacterium, *Trichodesmium*, is a globally significant nitrogen fixer and has recently gained widespread attention with the recognition of the importance of nitrogen fixation in the oceanic nitrogen cycle. *Trichodesmium* has been studied throughout the tropical and subtropical oceans of the world. Despite nearly two decades of intensive study, many questions of its physiology and ecology remain unresolved. *Trichodesmium* only fixes nitrogen during the day. One major impediment has been difficulty in maintaining the viability of natural populations for experimental studies. We note that EDTA (ethylenediaminetetraacetate) added in low concentrations (10 to 50 micromolar, final) to freshly collected colonies of *Trichodesmium* substantially prolongs the viability of these populations. Using nitrogenase activity as a measure of viability, we examined concentration dependence and the effects of time of collection, oxygen and iron addition. EDTA addition does not affect short-term rates of nitrogenase activity, compared to controls. Whereas control samples collected early in the day cease activity usually within about 6 h of assay initiation, samples treated with EDTA continue to fix at a constant rate through the day. Samples collected in the afternoon and held overnight rarely exhibit activity during the next light period; however, after treatment with EDTA, preincubation for extended periods (12-48h) is possible with the maintenance of competency in nitrogenase activity, allowing for comparison of diverse experimental treatments. The mode of action of EDTA is presently unknown.

OS32E-165 1330h POSTER

Variations of Labile Iron in Aerosols Collected Over the Tropical and sub-Tropical North Atlantic Ocean

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Atmospheric deposition is a major source of iron (Fe) to both high nutrient low chlorophyll (HNLC) and oligotrophic ocean regions where Fe may be a rate limiting nutrient for the growth of primary producers and nitrogen fixing organisms. The predominant source of iron to the atmosphere is from wind-derived (aeolian) suspension of dust from arid terrestrial regions. The chemical speciation of atmospheric Fe is believed to be a controlling factor for determining the fraction of Fe that is bioavailable. In this study, fine (<3um) and coarse (>3um) aerosol samples were collected during research cruises over the tropical and sub-tropical North Atlantic Ocean during 2001. Dissolved Fe(II), total dissolved Fe and reducible Fe concentrations were three species of labile Fe measured immediately after collection on board the ship. Reducible Fe was measured by using a chemical reductant. This reducible Fe provides a measurement of the total labile Fe that is available for reactions in seawater and cloudwater. Reducible labile Fe was also measured using a photochemical reductive dissolution method that gave similar results as the reducible labile Fe measured using the chemical reductant. Total reducible Fe was highly variable ranging from 0.19 ng m-3 to 68.7 ng m-3. These labile Fe results will be presented and discussed in terms of aerosol source regions, atmospheric processing of Fe during transport, deposition fluxes to the ocean and the release of atmospherically derived Fe to seawater.

OS32E-166 1330h POSTER

The Dissolved Inorganic Carbon System During the 2001 MANTRA/PIRANA Expeditions in the Western Tropical Atlantic

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The influence of the Amazon River on the carbon biogeochemistry of the western tropical Atlantic was examined during both slack and flood periods (MANTRA/PIRANA Biocomplexity Cruises 1 and 3; Jan-Feb and Jul-Aug 2001, respectively). Seawater samples from the water column were analyzed for total inorganic carbon using coulometry and for alkalinity using potentiometric titration. pCO_2 was calculated from these data using CO2SYS and the constants of Roy *et al.*

Winter sampling (MP1) occurred over an eastward transect (75-45°W) along 28°N, a southward transect (28-9°N) along 45°W, and a survey over an approximately triangular area (bounded by 11-6°N, 40-56°W) off the northeast coast of South America. For all stations sampled, we observed a 100-m mixed layer with a nearly constant DIC concentration (2050 μmol/kg) and an undersaturated surface pCO_2 relative to the atmosphere. Lower pCO_2 often corresponded with high *Trichodesmium* biomass. When scaled to a constant temperature and salinity, pCO_2 of the surface waters also showed an enhanced reduction at lower salinity stations, perhaps indicating the influence of Amazon River nutrient inputs. The southerly region showed more DIC variability below 100m. We also observed high salinity water (36-37 pss) just below the mixed layer (80-100m) in this region, indicating the presence of an advected subsurface layer from the South Atlantic subtropical gyre.

Summer sampling of the western tropical Atlantic (MP3) was performed over a roughly tetrahedral survey area off the northeast coast of South America (3-13°N, 42-56°W). At many stations, the Amazon plume created a thin (10 to 30m deep) lens of lower salinity water (28-31.5 pss) overlying a well-mixed layer up to 100m deep. Although the fresher Amazon water had a non-zero DIC and alkalinity signature, pCO_2 in the plume remained undersaturated.

Seasonal variations in the Amazon outflow affect the carbon biogeochemistry of the western tropical Atlantic. Preliminary analysis further suggests that physical parameters such as horizontal advection also influence the biogeochemical regime.

OS32E-167 1330h POSTER

Light Dependent Carbon and Nitrogen Fixation Characteristics of *Trichodesmium*

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Trichodesmium is a marine, diazotrophic, non-heterocystous cyanobacterium commonly found in tropical and subtropical waters. It has been suggested that *Trichodesmium* plays a large role in the biologically mediated net annual carbon export to the deep. However, there is considerable uncertainty in current estimates of global nitrogen fixation rates by *Trichodesmium*, as these have mostly been derived from extrapolation of shipboard measurements. There are efforts currently underway to model nitrogen fixation by this organism in order to better quantify the role of this organism in the global nitrogen cycle. This modeling requires a good understanding of the growth characteristics of *Trichodesmium* in terms of carbon and nitrogen fixation. However, to date, there have been few studies that fully characterize *Trichodesmium*'s light dependent carbon and nitrogen fixation.

We describe acetylene reduction assays and ^{14}C uptake measurements conducted using a 21-well photosynthetron during a winter and a summer cruise in the western tropical Atlantic Ocean. The data from these production versus irradiance (P vs. I) measurements were used to determine the maximum rate of carbon and nitrogen fixation ($P_{max}{}^{C}$, $P_{max}{}^{N}$), the initial slope (α_C, α_N), the index of light adaption (I_{kC}, I_{kN}) and the photoinhibition level (β_C, β_N) for each station. In addition, we derived local in situ carbon to nitrogen (C:N) fixation rate ratios. Preliminary analyses found an average P_{max} of 126 (± 95) pmol N colony^{-1} hr^{-1} at 792 (±187) μmol quanta and P_{max} of 5281 (±2264) pmol C colony^{-1} hr^{-1} at 826 (±200) μmol quanta.

OS32E-168 1330h POSTER

N2 Fixation in Coastal Waters of Northern Australia

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Large persistent blooms of the diazotrophic cyanobacteria, Trichodesmium, have been reported along the north coast of Australia and are readily evident in remote sensing images. During a research cruise in Nov 1999, we undertook a transit from Townsville to Broome paralleling this coast, examining the population densities of Trichodesmium, along with trends in the N:P ratios of its biomass and 14CO2 and 33PO4 uptake. Different methods for enumerating Trichodesmium were compared. We also analyzed chlorophyll and bulk plankton primary production as well as densities of and N2 fixation in the nanoplankton.

High surface densities (up to 10,000 trichomes per L) and visible blooms of Trichodesmium were encountered at many of the stations and N2 fixation could be directly measured on unconcentrated surface samples. Areal rates of N2 fixation in excess of 1 mmol N m-2 day were noted at several stations. The N:P ratios of Trichodesmium biomass were highly variable, ranging from 25 to 73 over the transect with no apparent spatial trend. Dinitrogen fixation was also detected in the nanoplankton fraction at many of the stations.

OS32E-169 1330h POSTER

Unicellular Cyanobionts of *Neostreptotheca* spp., *Ornithocercus* spp., *Spongostaurus* spp., and a Tintinnid Species: Immunolabelling of Nitrogenase and Phycoerythrin.

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Cyanobacterial symbionts (cyanobionts) of some species of tropical marine diatoms (*Neostreptotheca* spp.), dinoflagellates (*Ornithocercus* spp.), radiolarians (*Spongostaurus* spp.), and tintinnids (unknown species) were identified by LM-autofluorescence and investigated for the presence of nitrogenase and phycoerythrin. All samples were collected, isolated, and preserved during daytime. Immunogold-labeling techniques coupled with

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transmission electron microscopy verified the cyanobacterial affiliation of the cyanobionts as all showed a distinct phycoerythrin label significantly higher than the background. However only the cyanobacterium present in *Neostreptotheca* spp., labeled both phycoerythrin and nitrogenase. Nighttime samples are now needed to verify the absence of nitrogenase in the other. Distinct differences in ultra structure and size of cyanobiont cell diameter were apparent, and suggested that these open ocean symbioses have different cyanobacterial consorts. Cyanobacteria associated with *Neostreptotheca* spp. were largest, ranging 2.4 to 4.2 μm; those present in the *Ornithocercus* spp. had cell diameters ranging 2.8 to 3.3 μm, while the cyanobionts of the Tintinnid and *Spongostaurus* spp. were considerably smaller, being 1.0 to 2.1 μm and 0.3 to 0.8 μm, respectively. The cyanobionts of *Neostreptotheca* spp. were coccoid, and all other cyanobionts were oblong in shape. There were some patterns to the phycoerythrin localization. Labeling of phycoerythrin in the cyanobionts of *Ornithocercus* spp. was along their thylakoid membranes, which ran parallel throughout the cell. Phycoerythrin localization in the *Spongostaurus* spp. cyanobionts followed the same peripheral pattern as their thylakoid membranes. Clusters of 5-10 carboxysomes were apparent in the cyanobacteria residing in *Ornithocercus* spp., whereas all other cyanobionts had single carboxysomes scattered in their cell body. In addition to the cyanobionts, bacteria were also found between the girdle lists of the dinoflagellate (*Ornithocercus* spp.) host, suggesting this unlike the others to be a three-organism symbiosis. The cell diameter of the bacteria ranged from 0.2 to 0.5 μm approximately. No or few degrading cyanobionts were seen in the four symbioses and some of cyanobacteria associated with the Tintinnids were in the process of dividing, which suggests that they were all fully viable. The presence of phycoerythrin containing cyanobionts in non-photosynthetic hosts, *Ornithocercus* spp., *Spongostaurus* spp., and Tintinnids, implies that the cyanobacteria may rather function as an energy and carbon (nitrogen?) source for their protozoan hosts.

OS32E-170 1330h POSTER

Photoprotective Mechanisms of the marine planktonic cyanobacterium Trichodesmium spp.

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The genus Trichodesmium spp., a genus of non-heterocystous, marine, diazotrophic cyanobacteria of tropical and subtropical seas utilizes several mechanisms to protect itself from deleterious ultraviolet (UV) wavelengths. *Trichodesmium* possesses phycobilipigments with absorption peaks at 495 nm, 545 nm, and 565 nm, which absorb in the visible region of the spectrum, while it maintains numerous mycosporinelike amino acids (MAAs) to shield harmful ultraviolet-A (UVA) wavelengths. *Trichodesmium* colonies may serve as a photoprotective mechanism, shielding individual cells from UV while contributing to a general collection of MAAs, used by the entire colony. We observed evidence of production of MAAs in *Trichodesmium* colonies obtained from surface waters, while those collected at various depths in the water column had decreased production of photoprotective pigments.

OS32E-171 1330h POSTER

The PIRANA (Potential Influences of Riverine and Aeolian inputs on N2 fixation in the Atlantic) Paradigm: Preliminary observations from field studies

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As part of an NSF Biocomplexity in the Environment project, we are examining the major chemical and physical factors that affect phytoplankton populations of the Western Equatorial Atlantic Ocean (WEQAT) with particular reference to keystone N2 fixing phytoplankton and the roles of aeolian dust input from Africa and the Amazon River in providing Fe and Si to this ecosystem. We hypothesize that the WEQAT ecosystem switches between two states, a high dust, low river flow state in the winter that supports N2 fixation by Trichodesmium and a low dust, high river flow state in the summer that supports N2 fixation by the cyanobacteria Richelia intrarcellularis (an endosymbiont of some diatoms such as Hemiaulus hawkii) and that there are qualitative changes in the food web structure resulting from this switching.

Two field surveys were undertaken in February and August 2001. We found high dust input and relatively high surface salinities (35.3-36.7 PSS) in the winter. In summer, the Amazon outflow covered a vast area of WEQAT with surface salinity values of 30 PSS over 1000 km from the river mouth. The mixed layer depth and depth of maximum chlorophyll was deeper in the winter compared to the summer (90m in the winter vs 9 m in the river plume in the summer). While the Trichodesmium biomass was about twice as high in the winter (200-400 trichomes/L in the winter compared to 100-200 trichomes/L in the summer), the striking difference was in the Richelia population (virtually nonexistent in the winter vs 5000 cells /L in the river plume). Trichodesmium specific carbon and N2 fixation rates appear higher in the winter, while bulk phytoplankton carbon fixation rates were higher in the summer. Nutrient input from the Amazon River and Sahara dust appear to have a major influence in stimulating cyanobacterial N2 fixation in the Equatorial Atlantic Ocean.

OS32E-172 1330h POSTER

Interannual variability in mineral aerosol deposition to ocean regions from a 1979-2001 simulation

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Mineral aerosols contain trace amount of the micronutrient iron. Studies have shown that deposition to ocean basins is hetereogeneous in time and space. We show results from a 22 year simulation using the MATCH transport model, a desert dust module and NCEP/NCAR Reanalysis meteorological winds. Comparisons to available observations suggest that the model results are reasonable, but could be improved. Strong daily, seasonal and interannual variability is suggested. Budgets for different ocean basins are presented and compared with other available deposition estimates. In addition, we estimate the strong interannual variability in iron deposition to remote regions.

OS32E-173 1330h POSTER

Biocomplexity: Oceanic Nitrogen Fixation and Global Climate

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Oceanic N_2 fixation has recently been identified as a significant part of the oceanic nitrogen (N) cycle and the balance of nitrogen fixation and denitrification may directly influence the sequestration of atmospheric CO_2 in the oceans. Accumulating evidence indicates that iron (Fe) availability may be a key controlling factor for diazotrophy. The primary pathway of Fe delivery to the upper oceans is through dust deposition, a climate dependent process. N_2 fixers may therefore be directly involved in global feedbacks with the climate system and these feedbacks may also exhibit complex dynamics on many different time-scales.

The hypothesized feedback mechanism has the following component parts. The rate of N2 fixation in the worlds oceans can have an impact on the concentration of the greenhouse gas, carbon dioxide (CO_2), in the atmosphere on time-scales of decades (variability in surface biogeochemistry) to millennia (changes in the total NO_3 stock from the balance of N2 fixation and denitrification). CO_2 concentrations in the atmosphere influence the climate. The climate system, in turn, can influence the rate of N2 fixation in the oceans by controlling the supply of Fe on dust and by influencing ocean circulation. Humans also have a direct role in this cycle by our influence on agriculture at the margins of deserts and our effect on atmospheric CO_2.

We are studying each of the components of this system and then studying the hypothesized feedback processes in a set of models. The fieldwork has just started and involves a mix of ocean observations, direct experiments on mesocosm scales and the collection of sediment cores to probe the past earth history. We have made some exploratory model runs to help guide the field program. One key early question, the extent to which changes in nitrogen fixation will draw CO_2 out of the atmosphere and into the oceans shows that the ocean-atmosphere system (as modeled) is quite sensitive to the balance between nitrogen fixation and denitrification. Because of the interaction of the various parts of this system, simple models of this feedback cycle exhibit complex behaviors on a variety of timescales.

OS32E-174 1330h POSTER

Modeling Nitrogen Fixation in an Atlantic Coupled Ecosystem Ocean Circulation Model

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The focus of the modeling group in the Potential Influences of Riverine and Aeolian N_2 fixation in the Atlantic (PIRANA) Biocomplexity initiative has been: How important is the explicit representation in the plankton food web of a diazotroph functional group to the temporal and spatial patterns of productivity at regional scales?

Comparisons between model simulations with and without *Trichodesmium* demonstrate that feedbacks between functional groups are essential to capture the temporal and spatial patterns of biomass and production variability. Regional changes are linked to positive and negative feedbacks between phytoplankton (P) and nitrogen fixing (T) populations. As the ecosystem is perturbed by model physics a specific sequence of events follows which is determined by nonlinear interactions between P and T in the food web. (1.Negative feedback from P to T through competition for light. 2.Nutrient limitation of P reduces competition to a level where T begins to dominate. 3.Positive feedback from T to P through nutrient addition into the euphotic zone. 4.Return to process 1.) This sequence generates a secondary phytoplankton bloom (echo bloom) whose time and place is therefore dependent on food web structure.

Nitrogen fixation does not augment upwelled nitrate enough to bring phytoplankton production rates and new production up to remote estimates. However, increases are significant; basinwide production increases by 5% at observed nitrogen fixation rates. At fixation rates closer to geochemical estimates, production in the oligotrophic Atlantic is comparable to remote estimates

and 20 times the production rate of an eddy permitting NPZD model.

OS32E-175 1330h POSTER

Remote Sensing the PIRANA Paradigm

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The "Potential Influences of Riverine and Aeolian inputs on N2 fixation in the Atlantic" (PIRANA) project is examining the role of aeolian dust input from Africa and role the Amazon River in providing Fe and Si to the Western Equatorial Atlantic Ocean (WEQAT) region. We are interested in the response of phytoplankton, especially keystone N2 fixers, to chemical and physical forcings. We are using remotely sensed and modeled parameters such as chlorophyll (Chl - an indicator of phytoplankton biomass), absorption due to dissolved and detrital matter (Adg - an indicator of the Amazon River plume), aerosol optical thickness at 865 nm (Tau865 - an indicator of aerosol iron in dust from Africa), sea surface temperature, mixed layer depth, and wind speed to test our hypothesis that the WEQAT system switches between two states from winter to summer.

We have compiled a time series of these parameters derived from SeaWiFS and AVHRR satellites, NCEP and FNMOC model outputs, for three locations (11.5N 55W; 10N, 45W; and 6N, 47W) from 1997 to 2001. These variables were sea-truthed during two cruises in January/February and July/August 2001. We found relationships between parameters such as satellite-derived parameters such as Tau865, Adg and field measurements of total Iron concentrations and salinity, respectively. The seasonal signals for the various parameters are different at the three locations. For example, 10N, 45W has a Chl maximum in the winter while 11.5N, 55W has its Chl maximum in the summer, showing that the different forcing result in qualitative changes in the food web structure in this region.

URL: http://wrigley.usc.edu/bc/

OS32E-176 1330h POSTER

A New Reagent for the Quantification of Intracellular Iron in Marine Phytoplankton

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Laboratory and field studies have demonstrated that phytoplankton growth is limited by iron availability in some areas of the world ocean. However, the intracellular iron quotas of field populations of phytoplankton are still unknown. While laboratory studies have successfully used the titanium solution developed by Hudson and Morel (1989, Limnol. Oceanog. 34, 1113-1120) to distinguish between extra and intracellular iron in marine phytoplankton, its rapid reaction with oxygen makes it hard to manipulate. For that reason, we have developed a new reagent using oxalate as an inorganic reductant for dissolving extracellular iron in marine phytoplankton. Laboratory studies were conducted with cultures of 8 different phytoplankton species using 55Fe, 59Fe (for removal of extracellular Fe) and 14C (for cell breakage or lysis). Our preliminary results showed that reduction efficiency of extracellular iron using the new reagent (97 percent) was essentially indistinguishable from the titanium wash without any evidence of cell breakage or lysis. Furthermore, the removal efficiency of the oxalate solution was constant for up to 2 months (instead of a few days for the titanium solution).

For the quantification of extra and intracellular iron in natural samples we have also developed a method for removing the iron present in the oxalate solution. The cleaning protocol we used decreased the concentration of iron present in the reagent from 609 to 20 pmol per gram of solution. We are currently doing some preliminary work using the new reagent to differentiate intra versus extracellular iron in field populations of phytoplankton.

OS32E-177 1330h POSTER

The Dissolution of Eolian Iron in Surface Seawater and its Influence on Euphotic Zone Iron Distributions in the North Atlantic

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Eolian iron deposition to the surface ocean has a potential to alter phytoplankton growth and may play an important role in regulating earth climate through biological pump. Yet, the dissolution of eolian iron in the ocean euphotic zone and the subsequent mobilization (removal and cycling) of the released iron within this zone are poorly understood. Here we present new iron data (the iron passing through a 0.4 micrometer pore filter) to illustrate some features of these processes in the subtropical North Atlantic. These data include: (1) high resolution vertical profiles (every 2 m) and a surface horizontal transects (every 10 miles) of iron concentrations and (2) a time series dissolution of aerosol iron in surface seawater. Our results suggest that surface water iron concentrations are controlled by eolian iron deposition, vertical mixing and iron scavenging removal. More importantly, our data indicate that iron can be continuously released from aerosol particles over prolonged period (6-10 days) as these particles reside in the euphotic zone. Our results suggest that the cumulative percent solubility of eolian iron in surface seawater is much higher than previously thought.

OS32E-178 1330h POSTER

Phytoplankton Functional Groups and Oceanic Carbon Cycling

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A state of the art marine ecosystem model (Moore et al., 2001) that includes several key functional groups of phytoplankton and allows for multiple potentially limiting nutrients has been incorporated into the ocean component of the NCAR Community Climate System Model. The ecosystem model is coupled with a full biogeochemical module that includes carbonate system dynamics and air-sea gas exchange of oxygen and carbon dioxide. Phytoplankton growth rates are a function of available light, nitrogen, phosphorus, iron, and (for the diatoms) silicon. The inclusion of an explicit iron cycle, including the atmospheric source from dust deposition, allows the model to capture the observed High Nutrient, Low Chlorophyll conditions in the subarctic and equatorial Pacific, and in the Southern Ocean. Model results will be compared with global in situ nutrient and carbon system measurements and satellite-based estimates of surface chlorophyll concentrations and primary production. Controls on phytoplankton growth rates at the global scale will be examined. We will discuss the role of two key phytoplankton functional groups, the diatoms and the coccolithophores, in exporting carbon to the deep ocean and in driving air-sea fluxes of carbon dioxide. We will also examine spatial patterns in the rain ratio (CaCO3 sinking flux / organic C sinking flux) at the global scale.

OS32E-179 1330h POSTER

Availability of Iron for the Nitrogen Fixing Cyanobacteria, Trichodesmium, in the Sargasso Sea

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Phytoplankton productivity and biomass, especially of nitrogen fixing organisms, may be limited by the atmospheric input and bioavailability of iron in many regions of the ocean. Factors such as speciation during aeolian transport, the mode of deposition (wet versus dry), and solubility after deposition to surface seawater appear to affect the bioavailability of iron. In addition, nearly all soluble iron is bound to organic ligands such as siderophores and porphyrins, that may increase the bioavailability of iron. Experiments to determine the bioavailability of iron for the nitrogen fixing cyanobacterium, Trichodesmium, were conducted on transect cruises between Bermuda and Puerto Rico during the fall of 2000 and 2001. Iron concentrations were measured in rainfall events, aerosols, and within the surface seawater. Trichodesmium colonies were collected using a trace-metal clean plankton net to determine abundance and cell quota's (C:N:P:Fe), as well as nitrogen and carbon fixation rates. The iron uptake of Trichodesmium was measured during light and dark experiments using 55-Fe labeled ligands. It appears that the ligands ferrichrome, protoporphyrin IX, and desferal suppressed Fe uptake (decreased bioavailability) relative to inorganic iron. In contrast, a ligand from Synechococcus sp. PCC 7002 and Rhodotorulic acid (both di-hydroxy siderophores) seemed to have increased bioavailability compared to the tri-hydroxy siderophores and inorganic iron. Incubations in the dark resulted in significantly lower uptake rates than in the light for all forms of iron except desferal. Rather than the concentration of total iron or complexed iron, there is a need to characterize the ligand speciation to better understand iron utilization by Trichodesmium.

W E D

OS32E-180 1330h POSTER

Temperature and light requirements for growth and nitrogen fixation by Trichodesmium sp.

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Trichodesmium has been recognized as one of the most important nitrogen fixers in vast regions of the oceans. Because of its importance in the balance of the global nitrogen cycle, there is growing interest in incorporating the biochemical process of nitrogen fixation in ocean biogeochemical climate models (OBCM). The role of abiotic factors, such as temperature and light, in controlling nitrogen fixation rates by Trichodesmium are poorly understood, yet these parameters are integral parts of OBCMs. Field observations of Trichodesmium distribution suggest that nitrogen fixation in this species is limited to water temperatures above 20°C in the oceans and that distribution to higher latitudes is only due to drift rather then net growth. Blooms of Trichodesmium have been reported from regions with water temperatures as high as 35°C. Because the effects of light and temperature are difficult to separate from field observations, growth and nitrogen fixation tolerance and optima for these factors need to be established in controlled laboratory experiments. Since the synthesis, activity and degradation of nitrogenase in Trichodesmium is controlled by an endogenous cycle, which is set by illumination patterns, growth and nitrogen fixation rates as a function of temperature and light were assessed in a factorial experiment with these two factors as independent variables. An axenic Trichodesmium strain (IMS-101) was grown under different temperature and light regimes in a specially designed incubator. Nitrogen fixation rates and photosynthesis were determined using the acetylene reduction assay and pulse amplitude modulated fluorometry, respectively. Total protein measurements were used to assess biomass changes. Growth, nitrogen fixation rate optima and tolerance ranges for light and temperature will be presented.

OS32E-181 1330h POSTER

Nitrogen Nutrition of *Trichodesmium* in the Eastern Gulf of Mexico

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The non-heterocystous cyanobacteria, *Trichodesmium*, are considered the most important nitrogen fixers in the ocean. However, N_2 fixation is not the only mechanism used by these diazotrophs to meet their nitrogen requirements. Recent work has shown that *Trichodesmium* are also capable of taking up a number of other nitrogen substrates, both inorganic and organic. In cultures, N_2 fixation and nitrogen uptake vary with the physiological state of the cells. Similarly, as a bloom develops there may be changes in the uptake rates of various nitrogen compounds that are due to physiological changes in the *Trichodesmium* population or changes in the availability of nutrients. To investigate this further, the relative importance of inorganic versus organic nitrogen substrates to the nitrogen nutrition of *Trichodesmium* was quantified during a bloom in the eastern Gulf of Mexico in July 2001. A drogue was used to track the *Trichodesmium* bloom over a five-day period, thereby allowing some insight into the evolution of the bloom. Nitrogen uptake experiments were conducted on all five days by transferring 20 colonies of *Trichodesmium* into incubation bottles filled with filtered seawater and then amending these with ^{15}N labeled substrates. Uptake rates of inorganic nitrogen (ammonium and nitrate) and organic nitrogen (urea, dissolved primary amines, glutamate, alanine, and dialanine) were measured using traditional ^{15}N tracer techniques and compared with rates of N_2 fixation and ambient nutrient concentrations. Ambient nutrient concentrations were low, as would be expected of an oligotrophic area such as the eastern Gulf of Mexico. Preliminary results from uptake experiments indicate that ammonium uptake was 4-11 times higher (on a per colony basis) than the uptake of other forms of nitrogen. Nitrate uptake rates were very low compared to the others analyzed. These results are consistent with studies done in other oligotrophic regions.

OS32E-182 1330h POSTER

Fate of recently fixed nitrogen by *Trichodesmium* in the eastern Gulf of Mexico: results from dialysis experiments

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Unpublished research, anecdotal information and historical red tide monitoring data suggest a correlation between the timing and magnitude of blooms of the toxic dinoflagellate, *Karenia brevis* (formerly *Gymnodinium breve*), and the occurrence of the filamentous, dinitrogen (N_2) fixing cyanobacteria, *Trichodesmium* spp. in both the Gulf of Mexico and Atlantic coastal waters. We hypothesize that the correlation is due to a dependence of *K.brevis* on the regenerated nitrogen released from *Trichodesmium*. Relatively little is known, however, about the fate and significance of new nitrogen inputs derived from N_2 recently fixed by *Trichodesmium* or of the pathways of trophic transfer whereby this new nitrogen is transferred into planktonic food webs. As a first step to addressing this question, we performed a series of experiments to quantify the direct transfer of regenerated nitrogen, as dissolved organic nitrogen (DON) and/or ammonium, resulting from active dinitrogen fixation by *Trichodesmium*. Three sets of experiments were performed in July 2001 in the eastern Gulf of Mexico. In each experiment, *Trichodesmium* colonies were placed into dialysis bags that had pore sizes of 1K and 100K Daltons. The bags were filled with filtered seawater that was enriched with ^{15}N labeled dinitrogen gas. At the start of the experiment, the dialysis bags were immersed in whole surface water; ^{15}N labeled gas was added to whole water with no *Trichodesmium* as a control. In one set of experiments, copepods were added to determine the affect of grazers. After incubations of four to seven hours in on-deck flow-through incubators, the ^{15}N enrichment of cells in the whole water, *Trichodesmium*, and copepods were measured. Plankton in the whole water surrounding the dialysis bags were significantly enriched in ^{15}N in all treatments, except the controls, indicating release and subsequent uptake of regenerated nitrogen from *Trichodesmium*. Preliminary results indicate that uptake of recently released nitrogen in the <1K Dalton size range was 26 to 50% of the rate measured in the <100K Dalton treatment.

OS32E-183 1330h POSTER

N2 Fixation and N Regeneration by Trichodesmium in the Gulf of Mexico and in Cultures

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Trichodesmium spp. fix N2 and therefore are not N limited and contribute to new production in systems where they occur. However, the fate of new N from N2 fixation is unclear because N regeneration from N2 fixation has rarely been assessed. In the Gulf of Mexico, it has been hypothesized that the release and regeneration of recently fixed N2 from Trichodesmium fuels blooms of the red tide dinoflagellate Karenia brevis. In order to determine the rates at which N compounds are regenerated from Trichodesmium, and whether these are sufficient to fuel K. brevis blooms, we measured rates of 15NH4+ and DO15N release from 15N2 uptake in cultures of Trichodesmium IMS101 and in natural populations collected during a cruise in the Gulf of Mexico in July 2001. Because rates may vary as a function of physiological state, we measured N2 fixation and N regeneration over an entire growth cycle in cultures and over a 5-day period during which we followed a single population of Trichodesmium with a drogue in the Gulf of Mexico. N2 fixation was measured by acetylene reduction and 15N2 uptake. The former provided an estimate of gross N2 fixation while the latter measured net N2 fixation. Ammonium accumulated to concentrations of up to 1.6 uM in the culture medium during growth of Trichodesmium IMS101 and concentrations increased over the course of drogue study in the Gulf. More than 50% of the recently fixed N2 was released as NH4+, and rates of NH4+ uptake were 50 to 100% of the regeneration rates suggesting coupling between uptake and regeneration in Trichodesmium. The total amount of N regenerated from Trichodesmium was estimated using rate measurements and abundance data and these calculations suggest that N2 fixation is an important source of regenerated N in the Gulf of Mexico.

OS32E-184 1330h POSTER

Interactions Between Nitrate Uptake and Nitrogen Fixation in *Trichodesmium*

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Diazotrophic cyanobacteria can take up combined nitrogen when a source is present. However, the interaction between nitrogen fixation and combined nitrogen uptake is not well known. We studied the effects of combined nitrogen (nitrate) additions on nitrogen fixation rates in the cyanobacteria, *Trichodesmium*, maintained in continuous culture on a nitrogen-free medium (YBCII) and a 12:12 light-dark cycle. Following the addition of environmentally realistic concentrations of nitrate (2 to 10 μM) at the start of the light day, we measured acetylene reduction rates, nutrient concentrations, and biomass throughout the 12 hour illumination. Acetylene reduction is strongly inhibited (30 - 85%) by the presence of nitrate, with apparent saturation of the inhibition effect at initial nitrate concentrations of approximately 5 - 8 μM. The inhibition of acetylene reduction persisted through much of the light day as nitrate concentration in the culture vessel decreased, with full recovery between 7 and 9 hours following the nitrate addition, when the ambient concentrations had decreased to approximately 0.3 - 0.4 μM.

OS32E-185 1330h POSTER

Bio-optical algorithms for the remote detection of Trichodesmium

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Oceanic nitrogen fixation by Trichodesmium spp. has been shown to be potentially important to regional and perhaps, global biogeochemical cycling. Accurate estimates of their abundance and distribution require frequent, synoptic measurements, such as that provided by ocean color satellites. However, adequate algorithms relating remote sensing reflectance to Trichodesmium biomass do not exist for application on the global scale. In this work, we utilize an extensive dataset, the first of its kind, containing coincident bio-optical measurements and Trichodesmium abundance estimates in several ocean basins. We will use this dataset to evaluate existing Trichodesmium specific reflectance models and compare them to global climatologies (i.e., SeaBAM). Resulting differences will be used to improve our understanding of the remote detection of Trichodesmium in the world oceans.

OS32E-186 1330h POSTER

Nitrogen Fixation by Pico Cyanobacteria in the Tropical Atlantic Ocean

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Nitrogen fixation is a source of "new nitrogen" to oligotrophic marine environments. We present evidence of pico cyanobacteria as nitrogen fixers in the Tropical Atlantic Ocean. Immunolocalization on whole cells indicated the presence of nitrogenase in some pico plankton at night. We hypothesize that these unicellular cyanobacteria are able to fix carbon and nitrogen by separating these processes temporally; they photosynthesize during the day and fix nitrogen during the night. Furthermore, nifH expression was observed through RT-PCR at different depths in the water column. Amplified nifH and 16S rDNA cyanobacterial fragments were cloned and sequenced. Cultures of isolated pico cyanobacteria were examined for nitrogen fixation through the acetylene reduction method.