OS31T-08 1035h

Biogeochemical Properties of the Adriatic Sea Resulting From Ocean Color Data Assimilation

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This study aims to identify the controlling processes of phytoplankton distributions in the Adriatic Sea (eastern Mediterranean Sea). A three-dimensional primitive equations model (Ispramix), with realistic atmospheric forcing, is coupled with a three-dimensional biological model to simulate both the circulation and the biogeochemical variable distribution throughout 1998. We carry out data assimilation of chlorophyll concentrations derived from daily Sea-viewing Wide Field-of-view Sensor (SeaWiFS) maps to improve the description efficiency of the ecosystem model. The period of study spans from January to June 1998. This time interval includes bloom (late fall to early spring) and non-bloom regimes (late spring to early fall) in the Adriatic Sea. We discuss the impact of the river discharge and basin circulation on the biogeochemical conditions in both the productive (potentially eutrophic) shallow northern sub-basin and the oligotrophic deep central and southern sub-basins. The dominant processes fertilizing the basin are river discharge, seasonal destratification, advection of nutrients from the north to the south Adriatic sub-basins, and a limited in situ contribution of nutrients due to coastal upwelling (east coast). We estimate and compare these contributions during bloom and non-bloom regimes with the results from the coupled physical-biological model.

OS31T-09 1050h

Determining the Distribution of Chlorophyll a in Narragansett Bay, Rhode Island, With a Spectral Curvature Algorithm

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Chlorophyll a, a primary indicator of eutrophication in estuarine waters, varies enough in time and space to create spatial problems when monitored by satellite and temporal problems when measured with in situ field programs. Using aircraft to sense ocean color of locals waters, some of these problems can be resolved from the spectral characteristics. Spectral curvature algorithms have been developed and used to estimate chlorophyll a concentrations for the NY Bight, Nantucket Shoals, and the Chesapeake Bay, and incorporated in monitoring programs such as the Chesapeake Bay Program. The objective of this study is to develop an algorithm for Narragansett Bay, Rhode Island, from the biooptical properties of its West Passage. In its basic form, the algorithm calculates chlorophyll a as log10[chl] = a + b(-Log10 G), where G = [R1/(R2R3)], a and b are constants empirically derived from in situ concentrations of chlorophyll, and R is radiance from three spectral wavelengths. The constants for this study will be empirically determined, from in situ concentrations of chlorophyll a already collected during 32 weekly and biweekly cruises between May 1999 and June 2000. G will be determined from remotely sensed reflectances at 443, 490, and 555 nm measured during the same period. During this period, measurements were also made of light absorption due to colored dissolved organic matter (CDOM). The data indicated that CDOM is the dominant absorber at 443 nm and a major competitor at 490 nm. Consequently, a CDOM absorption term will be added to the algorithm. The algorithm coefficients will be tuned and model chl a estimates will be validated by comparing with in situ measurements from Narragansett Bay and other estuaries in Connecticut and Massachusetts. Spectral data will be gathered by the MicroSAS remote sensing system (Satlantic, Inc.) flown on a Cessna Skymaster. After validating the algorithm, the airborne remote sensing system will be used to create maps of the distribution of chlorophyll a in 30 estuaries in southern New England to support the USEPA Aquatic Stressors research program.

OS31T-10 1105h

Determining Suspended Particle Properties From In-Situ Measurements of the VSF With HydroBeta

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The Mie solution of Maxwells equations for light scattering by spherical particles provides the means for calculating the volume scattering function (VSF) given a particle size distribution (PSD) and the particle refractive index. This theory is widely used to calculate the VSF of oceanic waters since there has not been the means to routinely measure the VSF in situ. Conversely, the PSD and refractive index are exceedingly difficult to determine directly for natural distributions of marine particles. We have recently measured the VSF of a variety of oceanic waters in situ using a new instrument called HydroBeta, which measures continuous profiles of the VSF from 5 to 170 degrees at 12 angles simultaneously. We observed distinct variations in the shape of the VSF corresponding to different distributions of suspended particles. By using Mie theory and adjusting the PSD and particle refractive index, we were able to obtain excellent agreement with the VSF measurements, and hence obtained quantitative information on the natural marine particle distributions and their refractive indices. These results will be presented.

OS31T-11 1120h

Estimation of the Error Variance of Vector Wind Estimates From Fully Polarimetric Measurements of Ocean Surface Brightness Temperature

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The inversion of passive microwave radiometer measurements for the extraction of vector winds over the ocean involves the solution of a nonlinear system of equations. The form of the equations is derived from the Geophysical Model Function (GMF) for the dependence of the brightness temperature of the ocean surface on the local wind speed and direction. For the inversions examined here a physically based analytic model is used. We examine the accuracy of the inversion both by evaluating the theoretical limits on the variance of the estimates and through the use of simulations. The inversion process may be accomplished through the use of maximum likelihood estimation techniques, a special case of which is least squares minimization. The Cramer-Rao lower bound on the variance of the least squares solution is calculated using likely values for the measurement noise levels. This lower bound is composed of a sensitivity matrix that describes the dependence of the brightness temperature on the vector wind and bias terms that are due to the nonlinearity. The bias terms may lead to significant differences relative to the predictions of the sensitivity matrix alone. For example, errors may involve 180 degree abiguities not predicted by the sensitivity matrix. Since an analytic solution to the effects of the bias is not tractable, the problem is further investigated through Monte-Carlo simulation. Simulated brightness temperature measurements are inverted and errors in simulated vector wind measurement are examined in terms of their dependence on sea state and satellite parameters. In selection of satellite parameters, the WindSat instrument is given special attention. Results of the simulation analysis are presented along with the theoretical predictions based on the sensitivity matrix, and are expected to prove useful in characterizing and improving passive microwave vector wind inversion methods.

OS31U HC: 323 C Wednesday 0830h

Phytoplankton Growth and Physiology

OS31U-01 0830h

The Effects of Iron and Light Co-limitation on the Physiology of *Pseudo-Nitzschia* From Station P in the Northeast Subarctic Pacific

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Iron limits the production and growth rates of phytoplankton in 30-40% of the oceans. In high latitude iron-limited regions such as the NE subarctic Pacific and the Southern Ocean, iron limitation is confounded with light limitation in the winter. Light and iron interact through the process of photosynthesis. Because cells grown under low light require more photosynthetic units to increase light absorption, they have a large iron quota and are often iron deficient. Many laboratory studies document the effect of iron limitation on marine phytoplankton. However, the combined effects of iron and light on the physiology of native, oceanic phytoplankton are rarely studied. We investigate the effect of light and iron co-limitation on the physiology of the pennate diatom *Pseudo-nitzschia*, isolated from station P in the NE subarctic Pacific. These chain-forming diatoms dominate iron-enriched phytoplankton communities in the summer, and we know very little about their ecophysiology. In an effort to model the growth of this diatom, specific growth rates are calculated in response to iron and light. Cellular pigments, carbon, nitrogen and biogenic silica are measured under varying degrees of light intensity (between 7 and 166 $\mu molphotonsm^{-2}$ s^{-1}) and two treatments of iron (replete pFe 19.4 and limiting pFe 24-25). The ratio of biogenic silica to nitrogen, one of the most important indicators of iron stress in diatoms, is calculated. Photosynthetic efficiency is inferred using Pulse Amplitude Modulated (PAM) fluorescence. Potential and actual photosynthetic efficiencies, as well as photochemical and non-photochemical fluorescence quenching are measured. Careful application and interpretation of fluorescence signals may alleviate the need for radioactive isotopes in measuring primary production. This is one of few experiments on the physiology of oceanic pennates. In addition, *Pseudo-nitzschia* is an important species of diatoms in coastal temperate areas because its blooms are sometimes associated with domoic acid production. Results from these experiments are crucial to our understanding of ecological processes in the open ocean, and our interpretation of the results of large-scale iron enrichment experiments in the NE subarctic Pacific.

OS31U-02 0845h

Resource Limitation Alters Allometric Scaling of Metabolic Rates in Phytoplankton

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Allometric scaling of metabolic rates is a universal property of living organisms. Metabolic rate is often expressed as a power-law function of organism size with an exponent of 3/4, referred to as the 3/4 rule. Previous studies have found that metabolic rates often deviate from the 3/4 rule. We show that resource limitation can cause these deviations. Under resource limiting conditions, energy is diverted from growth to enhanced resource acquisition, leading to changes in chemical composition, which result in size-dependent changes in metabolic rate. Using a bio-optic model we show that under light limitation, optimal intracellular chlorophyll concentration is inversely proportional to cell diameter. As a result, the size scaling exponent associated with light-limited photosynthesis is closer to 1/2 than 3/4.

URL: http://marine.rutgers.edu/ebme/html_docs/staff/zfinkel.htm

WED

OS31U-03 0900h

Essential Trace Metal Quotas in Marine Phytoplankton

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Essential trace metal quotas (Fe, Mn, Zn, Cu, Cd and Co) in ten coastal and oceanic phytoplankton species were determined by high resolution inductively coupled plasma mass spectrometry (HR-ICPMS). These include 4 Bacillariophyceae, 2 Dinophyceae, 2 Haptophyceae, 1 Chlorophyceae and 1 Prasinophyceae. No Ti-EDTA-Citrate wash was necessary by reducing the inorganic Fe concentration in culture medium to 0.36 nM. Accuracy of the trace metal quotas was validated by an independent radioactive method for Fe and by measuring a planktonic reference material (CRM 414). The results showed that the essential trace metal quotas for individual elements all varied within one order of magnitude for nearly all of the species. The averaged metal quotas of all species were 5.0, 3.8, 0.9, 0.24, 0.21, and 0.16 (mmol/mol to P) for Fe, Mn, Zn, Cu, Cd, and Co, respectively. Detailed studies were also carried out to determine the quotas of Fe, Zn, Co, and Cd in Thalassiosira weissflogii (TW). The Fe quota ranged from 25 to 100 (umol/mol to C) when inorganic Fe in medium ranged from 0.1 to 36 nM in T. weissflogii. The replacement relationship between Zn, Cd, and Co were quantified at different Zn, Cd, Co, and CO2 concentrations in culture medium.

OS31U-04 0915h

Influence of Solar UV-Radiation on DMS Dynamics in Marine Phytoplankton

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Dimethylsulfoniopropionate occurs at high intracellular concentrations in many algal species, and is a significant cellular osmolyte. We have proposed that it may also function as part of a high-capacity cellular antioxidant system since DMSP and its breakdown products [dimethyl sulfide (DMS), acrylate, and dimethyl sulfoxide (DMSO)] all are effective scavengers of reactive oxygen species, particularly highly toxic hydroxyl radicals. As acrylate, DMS, and the DMS oxidation product DMSO all are 20 to 60 times more reactive with hydroxyl radicals than DMSP, the enzymatic lysis of DMSP to DMS and acrylate should greatly increase antioxidant protection within the cell. We hypothesize that this increased protection represents a primary biological function of this, otherwise, poorly understood enzymatic reaction. In support of these ideas, we observed that exposure of Emiliania huxleyi to natural solar UV-radiation, an important environmental oxidative stressor, increased DMSP to cell volume ratios by two-fold and increased the lysis of DMSP to DMS by up to 60-fold over that which occurred under UV-free fluorescent lighting. The stimulation of algal DMS release by UV-exposure may at least partly explain the observed increase in DMS in surface ocean waters during the summer, when exposure to solar UV-radiation is highest owing to higher solar UV intensity, longer day-lengths, and shallower surface mixed layers. This increase in DMS production under high solar radiation exposure has been proposed to help regulate global climate through negative feedback control of acidic sulfur species derived from atmospheric oxidation of DMS, which serve as significant cloud condensation nucleii.

OS31U-05 0930h

Influence of the Oxidant H_2O_2 and Oxidative Stressors (CO_2 Limitation and Cu Toxicity) on DMS Dynamics in Marine Algae

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Experiments with marine algae suggest that the algal osmolyte dimethylsulfoniopropionate (DMSP) and its breakdown products [(dimethyl sulfide (DMS), acrylate, and dimethyl sulfoxide (DMSO)] function as an important antioxidant system in marine phytoplankton. In support of this hypothesis we previously found that two oxidative stressors (iron limitation and solar UV radiation) increase cellular DMSP or DMSP cleavage to DMS in marine diatoms and prymnesiophytes. Here we report that the oxidant hydrogen peroxide and an oxidative stressor (toxic levels of cupric ions) both increase the cleavage of DMSP to DMS by 10- to 20-fold in the coccolithophorid *Emiliania huxleyi*, which contains constitutively high intracellular concentrations of DMSP (150-300 mmol/L). In addition, acute carbon dioxide limitation brought about by a short-term increase in pH (from 8.2 to 9.2), increased intracellular DMSP concentration by nine-fold in *Thalassiosira pseudonana*, a coastal diatom with an inducible DMSP system. Carbon dioxide limitation has been shown to promote oxidative stress in algae by inhibiting carbon fixation, thereby restricting the smooth flow of electrons within the photosynthetic apparatus. Taken altogether, these results support the hypothesis that DMSP, DMS, acrylate, and DMSO function within algal cells as an important antioxidant system, which, like most antioxidants, is inducible by increased oxidative stress.

OS31U-06 0945h

Differential UVR Responses of Taxonomic Pigmentation by Diverse Phytoplankton Assemblages Along Coastal California

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There is significant evidence that solar ultraviolet radiation (UVR, 280-400 nm) reaching and penetrating natural coastal waters has serious impacts on the biology and photoecology of diverse phytoplankton groups. In situ monitoring and field experimental studies are essential if the impact of natural variations in UVR on several aspects of biological oceanography is to be known. Few in situ water column studies exist which provide baseline data necessary for such assessments. This study presents data from the SUPACC (Solar Ultraviolet Productivity Algorithms for Coastal California) cruises, and focuses on UVRs short-term effects on phytoplankton community structure in diverse water masses. Changes in chlorophyll biomass and chemotaxonomic pigment markers, in response to different spectral UVR exposures, were utilized to estimate the UVR photosensitivity of different phytoplankton assemblages as a function of season, water mass characteristics, and several aspects of spectral light exposure. These analyses will include the examination of UVR effects on the total biomass as well as changes in the taxonomic composition. These short-term studies, with incubations of less than a day, indicate the UVR sensitivity for groups and communities at specific locations and times. By combining data from multiple locations and different seasons, it should be possible to provide an assessment of possible long-term consequences for coastal phytoplankton communities. The goal is to incorporate these findings into local, regional and global production and ecosystem models. These models are important in order to gain a more comprehensive understanding of the global carbon flux and potential consequences of past and future changes in UVR climatology related to changing concentrations of worldwide atmospheric ozone.

OS31U-07 1000h

PAM-Fluorescence Kinetics of 9 Marine Phytoplankton Species

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Chlorophyll *a* fluorescence provides information on the state of photosynthetic electron transport and its related processes in algae. This phenomenon is used by biological oceanographers for the determination of the physiological state of phytoplankton affected by nutrient limitation or photoinhibition. By using Pulse-Amplitude-Modulated (PAM) fluorometry, we measured different fluorescence parameters (Φ_M and Φ'_M, as the maximal and operational PSII photochemical yields and, Q_P and Q_N, as the photochemical and non-photochemical quenchings), which were useful in the determination of algal physiological state. However, there are no reports on the comparison of all the PAM-fluorescence parameters among various algal species. Hence, in this study we compared the PAM parameters among 9 phytoplankton species from 5 classes in order to obtain a better knowledge of the usefulness of fluorometry in field studies. We showed that for the species studied, $Q_{P(REL)}$ and $Q_{N(REL)}$, as the relative value of Q_P and Q_N, provided a better representation of the energy balance between photochemical and non-photochemical ways of energy dissipation by the photosynthetic apparatus. We found also that species such as *Emiliania huxleyi* and *Heterosigma akashiwo* have a lower photosystem II oxidation efficiency compared to *Pavlova lutheri*. Variation in fluorescence parameters between species (for example for Φ'_M: *Thalassiosira oceanica* = 0.178 vs. *Dunaliella tertiolecta* = 0.397) may be related to different processes linked to the organisation and function of the photosynthetic apparatus. However, we demonstrated that there is no clear trend in the parameter values among the species tested since many physiological factors may influence photosynthesis simultaneously. The relevance of our observations on these variations are discussed in terms of their implications for the interpretation of field results.

OS31U-08 1015h

Purificaton, Cloning and Sequencing of a Novel Cadmium Requiring Carbonic Anhydrase From the Marine Diatom *Thalassiosira weissflogii*.

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In vast areas of the open ocean, the concentrations of many biologically important trace metals are extremely low. In fact, recent oceanographic studies have shown that the low availability of a variety of trace metals may place a limitation on productivity in these marine environments. We are presently examining the strategies that photosynthetic microorganisms have evolved to compensate for low trace metal availability and in particular we are looking at mechanisms that have been developed to overcome Zn-limitation. The enzyme carbonic anhydrase (CA) is known to constitute the major use of intracellular Zn in a number of diatom species including our model organism, *Thalassiosira weissflogii* . At low Zn concentrations, such as those encountered in the open ocean, the ability of T. weissflogii to utilize HCO_3^- is impaired and consequently the growth rate is limited at low $_PCO_2$.

Work from our lab has shown that Cd can compensate for Zn-limitation in *T. weissflogii.* Addition of Cd to Zn-limited cultures of *T. weissflogii* enhances the growth rate at low $_PCO_2$, although the levels of the major CA, DCA1, remain low. These cultures express a novel, Cd-specific, CA which we now name CCA1. We have carried out initial characterizations of the regulation of CCA1 and have been successful in purifying this Cd-CA by standard chromatographic and electrophoretic techniques. Further, we have demonstrated that CCA1 is indeed distinct from DCA1. We have recently cloned and sequenced the cDNA encoding the Cd-CA, *cca1* , and have found that it encodes a novel protein consisting of three, very extensive, directly-repeated domains. The purification of the CCA1 protein and the cloning and sequencing of its cDNA will be discussed.