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The North Atlantic Current (NAC) Subpolar Front (SPF) current system serves as a conduit of warm salty waters into the northern North Atlantic. It is the upper limb of the thermohaline circulation of the Atlantic ocean, and plays a crucial role in the moderation of European Climate. Its transport and corresponding heat fluxes remain uncertain, mainly because the structure of the system is not well known. This paper presents a method to obtain the mean structure of temperature, specific volume anomaly, and velocity for the NAC-SPF region, using isopycnal float data combined with Gravest Empirical Mode (GEM) fields calculated from historical hydrography. A GEM field is a projection on geostrophic streamfunction space of hydrographic data, which captures most of the vertical structure associated with frontal regions. The performance of the float-GEM method is tested in two ways. First, two synoptic hydrographic sections (one across the NAC and the other across the SPF) are reconstructed from simulated isopycnal float pressure measurements. The baroclinic transports (relative to 1000db) are 24Sv for the NAC, and 11Sv for the SPF. The corresponding baroclinic temperature fluxes are 1.23PW and 0.39PW, respectively. The fluxes from the float-GEM generated sections are 23±2Sv and 10±1Sv for volume, 1.03±0.15PW and 0.34±0.03PW for temperature. Note that the relative errors are about 10%. These results show that the method proposed reproduces with high accuracy and precision the structure of specific volume anomaly and temperature associated to the NAC-SPF. For the second test, horizontal maps of pressure and temperature on the $\delta = -12.7 \times 10^{-8} m^3/kg$ specific volume anomaly surface ($\sigma_\theta \approx 27.5$) are produced, using RAFOS float data from two experiments taken place in the region between 1993 and 2000. These maps compare quite well with similar maps found in the literature, and establish the consistency of the method.

The good performance of the float-GEM method provides with a novel way of using isopycnal floats to obtain information on the structure of the ocean. We are particularly interested in studying changes in the absolute transports and heat fluxes along the NAC-SPF system. For this we are applying the float-GEM method combined with velocity measured by the RAFOS floats. Preliminary results of this application will be presented.

OS31S-09 1050h

Heat Budget in the Gulf Stream Region

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A simple three-dimensional thermodynamic model is used to study the heat balance in the Gulf Stream region (30 N - 45 N, 40 W - 75 W) during the period November 1992 to December 1999. The model is forced by surface heat flux derived from NCEP variables, with geostrophic surface velocity specified from sea surface height measurements from the TOPEX/POSEIDON altimeter and Ekman transport specified from NCEP wind stress. The mixed layer temperature and mixed layer depth from the model show good agreement with the observations on seasonal and interannual time scale. Although the annual cycle of the upper ocean heat content is underestimated, the agreement of the interannual variations in the heat content and the sea surface height are good; both are dominated by the large decrease from 1994 to 1997 and the increase afterward. As expected from previous studies, the surface heat flux dominates the seasonal variations in the mixed layer temperature and in the upper ocean heat content. The surface heat flux is also the largest contributor to the interannual variations in the mixed layer temperature. However, the interannual variations in the upper ocean heat content are dominated by the advection-diffusion term. Within the advection term itself, the largest variations are from the geostrophic advection anomaly. Both the advection of the mean temperature by the anomalous current and the advection of the anomalous temperature by the mean current are important to the anomalous advection. Other studies have shown that wintertime mixed layer temperature, or even better, upper ocean heat content, are more robust indicators of the potential contribution of the ocean to interannual heat flux anomalies. The analysis here shows that heat advection by geostrophic current anomalies is the dominant term in interannual variations in heat content in the Gulf Stream region.

OS31S-10 1105h

The Mediterranean Overflow and its Influence on the North Atlantic Circulation in a Global Ocean Model

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Observational studies based on climatological hydrographic data provided ambiguous pictures of the role the Mediterranean water plays in the global thermohaline circulation. Global ocean general circulation models ought to offer a valuable tool to resolve this uncertainty, but the narrowness of the Strait of Gibraltar and the complex dynamics that control the downslope evolution of the Mediterranean Overflow present great difficulties. Often crude parameterisation is used to represent the watermass in coarse resolution ocean models, to bypass the need to resolve the physical processes that determine the initial spread of the Overflow. Here we make an attempt to explicitly include the Mediterranean Overflow in a fully global ocean model with a horizontal resolution of 1/4 degree and the vertical coordinate discretised on geopotential levels. The Strait of Gibraltar is represented by a channel of approximately 50km wide, 85km long and a constant depth of 320m (10 model levels). Despite the poor resolution of the Strait and the stepwise topography, we show that the model produces a reasonable outflow flux (1 Sv) of the dense and saline Mediterranean water through the Strait, which then mixes intensely with the ambient watermasses while descending down the steps to increase its transport by a factor of 3 within a short distance of the Strait. The saline water spreads northward, westward and southward away from the Gulf of Cadiz, with the core at a depth near 900m, slightly shallower than but not significantly different from climatology. Making use of a parallel experiment in which the Strait of Gibraltar is closed, we will discuss the influence of the Mediterranean water on the large scale circulation of the North Atlantic.

OS31S-11 1120h

Investigating the Transport of Mediterranean Water in the Eastern North Atlantic Using Hydrographic and Model Data

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The influence of Mediterranean Water can clearly be seen at intermediate depths on maps of North Atlantic hydrography. It is presently undetermined how much of this water flows northwards along the Iberian continental slope and how much flows westwards into the ocean interior from its source in the Gulf of Cadiz. Our objective is to quantify this transport. We have used WOCE hydrographic sections at 41N, 20W and 24N to create a three sided box (the Med Box) around the Strait of Gibraltar, encompassing the Mediterranean Outflow. Mediterranean Water can be seen at mid-depths across the entire north edge of the box, concentrated in a northward flowing current close to the eastern boundary. In addition, a westward flowing current of Mediterranean Water crosses the western boundary between 35N and 40N. The overturning circulation within the Med Box produces a 4 Sv inflow of surface waters above 600 m, with a corresponding outflow of higher salinity intermediate waters between 600 and 1800 m. To assess the robustness of the circulation, comparisons are made between two realisations of the hydrographic Med Box, one from the late 1980s and one from the late 1990s, the seasonal Levitus climatology, and a fine resolution ocean general circulation model.

OS31S-12 1135h

Can We Observe and Study the Mediterranean Outflow and Meddies from Satellite Remote Sensing?

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Previous studies of the Mediterranean outflow and meddies (O&M) were limited by poor spatial and temporal resolution of the conventional observations. Little is known about meddies formation and transport, and the spatial and temporal variation of its trajectories. Generally speaking, most of the satellite observations are confined to the ocean's surface or its surface layer, while meddies were located, on an average, at a depth of 1000m. We developed a new remote sensing method to observe and study the O&M through unique approaches in satellite multi-sensor data integration analyses. Satellite altimeter, scatterometer, SST and XBT data were used to detect and calculate the trajectories and the relative transport of the O&M. Two experiments [A Mediterranean Undercurrent Seeding Experiment (AMUSE) and Structures des Echanges Mer-Atmosphere, Proprietes des Heterogeneites Oceaniques: Recherche Experimentale (SEMAPHORE)] from 1993 to 1995 were used to validate our method. Monthly mean features of the floats in meddies and our method were well agreed with each other. We found that more northwestward meddies occurred in the spring and more southward meddies occurred in the fall than previously thought. Streamfunctions using T/P altimetry and time-frequency energy distribution using Hilbert-Huang Transform (HHT) were computed to evaluate the meddy interactions with the sea surface. Since the O&M play a significant role in carrying salty water from the Mediterranean into the Atlantic and contribute to the North Atlantic Deep Water (NADW) formation, such new knowledge about their trajectories, transport and life histories is important to understand their mixing and interaction with the North Atlantic water, and hence, to lead to a better understanding of the global ocean circulation and the global change.

W E D

OS31T HC: 317 A Wednesday 0830h

Ocean Remote Sensing and Optics

Presiding: **R A Maffione,** Hydro-Optics, Biology Instrumentation Laboratories

OS31T-01 0830h

Estimation of Primary Production in Antarctic Coastal Waters: A Bio-optical Modeling Study

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Due to restricted accessibility and logistics, the Southern Ocean is a poorly sampled region in terms of bio-optical properties, which are an integral part of estimating primary production. In this study, the surface irradiance was estimated and parameterized at sites along the western Antarctic Peninsula and in the Ross Sea using a clear sky radiative transfer model. Application of the clear sky model included using an empirically-derived parameterization that corrects for cloud cover and multiple reflection effects between the ground and clouds (high albedo). Next, the inherent optical properties (IOP's), such as the absorption coefficient ($a(\lambda, z)$) and the backscatterng coefficient ($b_b(\lambda, z)$), were computed based on bio-optical constituents within the water column, and these inherent optical properties were combined to calculate the spectral diffuse attenuation coefficient, $K_d(\lambda, z)$, used for the construction of underwater light fields. Along with the constructed underwater light fields, different vertical biomass profiles and quantum yields were generalized to obtain primary production estimation at selected sites. The modeled primary production estimates are then compared with those obtained from *in situ* measurements. These comparisons show good agreement and indicate that this approach allows for development of regionally-based models for estimating primary production of Antarctic coastal waters.

OS31T-02 0845h

Validation of a Coupled Ocean-Atmosphere Shortwave Radiation Model Using CLAMS Measurements

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Intensive observations on the optical properties in the atmosphere and ocean were made during the Chesapeake Lighthouse and Aircraft Measurements for satellites (CLAMS) field campaign (July 10 - August 3, 2001) off the coast of Virginia. Spectral and broadband irradiances (upwelling and downwelling) measured from aircraft and from a rigid platform (the Chesapeake lighthouse), are used to validate a coupled ocean-atmosphere radiative transfer model. The model treats the absorption and scattering in both the atmosphere and the ocean explicitly; it treats slabs of ocean as additional atmospheric layers, but with significantly different optical properties. Key model input parameters, such as aerosol optical depth (airborne and surface-based photometers) aerosol optical properties (vertical profiles of single scattering albedo from in situ aircraft), precipitable water, wind speed, chlorophyll concentration and absorption coefficients for soluble and particulate materials in surface waters (in situ at the sea platform), are measured redundantly. We also employ model inputs from satellite data (i.e., SeaWiFS chlorophyll and MODIS aerosols). The objective is to test the model, the array of available model inputs, and the irradiance measurements for consistency; and then to show how the properties of the air and sea affect the spectral and broadband solar radiation and albedo, and the radiative interaction between the atmosphere and ocean.

OS31T-03 0900h

Inferring Surface Irradiance From Measurements Made at Depth

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When doing geolocation based on light measurements made aboard a diving animal, the first step is to infer the surface irradiance from measurements made at depth. The choice of optical pass band strongly affects the complexity of the problem, and a simple model of light absorption can elucidate the effects of various pass band choices.

Choosing a pass band that yields a simple problem leads to algorithms that first determine water properties from a days light and depth data, then recover an estimate of the surface irradiance during the day. These algorithms are both simple enough and robust enough to be implemented in the measurement platform aboard an animal. We illustrate the effect of algorithm choices using data obtained and processed aboard a free-swimming tuna.

OS31T-04 0915h

Do Aquatic Particles Absorb in the Near Infrared Spectral Region?

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We used a special geometry of spectrophotometric measurement with samples placed inside the integrating sphere to address the question whether significant absorption by aquatic particles exists in the near infrared (near-IR) spectral region from about 700 to 850 nm. Our tests with inorganic dyes and magnesium carbonate particles showed that placing a small sample (1-cm cuvette) inside relatively large integrating sphere (15 cm in diameter) reduces the scattering error to negligible level with no adverse effect on the absorption measurement. Our measurements of absorption by various particle suspensions suggest that absorption is generally negligible in the near-IR regardless of the type of particles. We examined 4 species of phytoplankton, phytodetritus derived from phytoplankton cultures, three samples of natural assemblages of mineral particles that show distinct reddish or brownish color, and finally three samples of aquatic particles from coastal and inland waters that have varying proportions of organic and inorganic particles.

OS31T-05 0930h

Measurements of the Volume Scattering Function of Oceanic Waters and Implications of its Variability

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Using a new instrument developed at HOBI Labs, called HydroBeta, we have measured in-situ profiles of the volume scattering function (VSF) in several coastal environments. HydroBeta was mounted on a profiling package that contained a variety of instruments for measuring additional optical properties, including the spectral absorption, beam attenuation and backscattering coefficients. HydroBeta measures continuous profiles of the VSF at 12 angles over the range 5 to 170 degrees. The specific angles are adjustable prior to deployment. Different sets of 12 angles were used on different deployments, sometimes concentrating on forward angles, or middle angles, or backward angles. These data sets are the first of their kind ever collected in oceanography and the results reveal the nature of the VSF of marine particles and its variability. In Monterey Bay, where many of the cruises were conducted, the water column often contains diverse distributions of organic and inorganic particles. Individual profiles often reveal astounding variability in the optical properties, with changes by more than a factor of 10 or more at different depths. Changes in the shape of the VSF as well as in the spectral optical properties indicate that the sources and characteristics of particle populations differ at different depths Because we also measured the backscattering coefficient with the HydroScat-6, we were able to investigate the conversion of the VSF at single angles in the backward direction to the backscattering coefficient. These results will be presented and the implications of the variability of the VSF discussed.

OS31T-06 0945h

Biogeo-optics: Predicting the Optical Properties of Coastal New Jersey at the LEO-15 Site

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The field exercise at LEO-15, during July 2000, was a remarkable gathering of marine scientists with interests in ocean optics and related coastal ocean dynamics. Our group did extensive water sampling and AC-9 measurements in Great Bay, New Jersey, the Mulicra River feeding into the bay, and outside into the Atlantic Ocean. On 24 and 25 July 2000 several researchers got together to take diverse data at the same stations. Sampling and instrument readings were done near the surface. The remarkable new Volume Scattering Function meter from the Ukraine was deployed along with an AC-9 meter and water samples were collected, all at the same time. The particle concentration and size distribution at the stations was measured with a Spectrex Instrument. The Spectrex is a laser-based instrument which measures mean optical cross section of particles. This information is converted to an equivalent spherical diameter to obtain a particle size distribution. The maximum equivalent particle diameter at the river mouth was about 30 mm as was also the case in the Atlantic just outside Great Bay. However, within the bay itself the maximum equivalent particle diameter was about 90 mm. This increase in maximum suspended particle size is no doubt indicative of resuspended bottom sediment The volume scattering functions recorded for the stations were integrated from 90° to 180° to give a value for the backscattering ratios at 532 nm. I utilized particle size distributions from 4 stations, in a transect from the river mouth to the Atlantic, to calculate the backscattering ratio from polydisperse Mie theory. I utilized 2 refractive indices for the calculations, one for quartz (1.157) which can be considered a"typical" mineral and one for a "typical alga." ($1.05 + i0.001$). Within Great Bay the particle size distribution is probably dominated by suspended mineral matter as the backscattering ratio is nearly predicted by the polydisperse Mie calculation with the quartz refractive index. The Milucca River station, however, shows indications of mixture with some suspended organic matter. The offshore station, however, indicates a backscattering ratio that is bracketed by the Mie calculations from the two refractive indices utilized here. Thus the offshore particle size distribution, which closely approximates that of the Mulicca River station, is probably partitioned into equal portions of inorganic and organic matter. These results indicate that the backscattering ratio, so important for remote sensing, can vary by one or two orders of magnitude depending on the nature, i.e. refractive index, of the suspended matter. However, the Mie calculations for total scattering utilizing the Spectrex particle size distributions and the two refractive indices did not bracket the AC-9 total scattering coefficients for these stations. More work needs to be done on particle shape and how this affects the size distributions inferred from instruments utilizing different physical properties of the suspended hydrosol.

OS31T-07 1020h

The remote sensing signature of Gulf of Mexico hydrocarbon seeps and implications for carbon flux

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Natural hydrocarbon seeps have been found across much of the northern Gulf of Mexico continental slope. Previous work has shown that oil rising from the seeps forms distinctive targets, called oil slicks, on the sea surface above the seeps and that slicks can be detected by satellite remote sensing. Hence, estimates of the number of seeps and their output might be obtained from satellite reconnaissance of an ocean basin. This paper describes work conducted to constrain such estimates. We acquired six RADARSAT wide and narrow scan SAR images between 9 and 21 July 2001 from a region of the Gulf of Mexico that contains numerous seeps. Synoptically, we collected up-looking ADCP data from an instrument on the seafloor and down-looking data from a ship-mounted instrument, as well as surface meteorological observations. We also imaged oil and gas rising through the water column with a 10-20 kHz chirp profiler. And we measured the size distribution and rise speeds of oil drops and gas bubbles at seafloor vents. These data were used to drive models of trajectory of oil and gas between the seafloor and sea surface and the gas flux to the water.

The seeps we studied comprised at most a few tens of individual streams of oil and gas that rise from discrete vents <1m in cross-section in a seafloor area <250m across. Volumetrically and as a mass-balance, gas is a larger fraction than oil, in the seeps we studied, by at least an order of magnitude. As they rise through the water, these streams are imaged as a solid column due to the properties of the acoustic beam. In the SAR images, traces of individual seeps were visible within a single oil slick. As a mass balance, gas phase dominates the oil phase by several times. The rise speed of the bubbles ranged from 12 to 40cm/s depending on where measurements were made–large bursts of bubbles had much higher rise speeds. Oil drop rise speeds were measured at about 5 cm/s. Modeling predictions of the trajectory of the hydrocarbon stream were consistent with the locations of oil slicks in the SAR images. The chirp data show streams rising all the way to the surface, however modeling results indicate that most bubbles should dissolve well below the thermocline, which was at ∼200m. This discrepancy may be due to the effect of oil-coatings on bubble dissolution rate. Weather had a dramatic effect on the number and sizes of oil slicks detected in the SAR images.

URL: http://www.bubbleology.com

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.

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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

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