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Diatoms are the only primary producers that utilize silicon and function as key exporters of organic matter and silica to the deep ocean. Recent studies showed that the open ocean around Antarctica accounts for a much higher fraction (10-15%) of global silica production than previously estimated. These high production rates give rise to the opal-rich band of sediments that circle the Antarctic continent south of the Polar Front. The marine silicon cycle needs to be studied in greater detail throughout the world oceans. Natural variations in the abundance of silicon isotopes provide a tool to carry out such widespread studies.

Application of silicon isotopes as tracers for temporal and spatial variations in silica production requires an understanding of the mechanisms underlying variations of silicon isotope abundances in seawater silicic acid and diatom opal. Changes in the silicon isotopic composition of opal in sediment cores can then be better interpreted and combined with other proxies for reconstructing past biogeochemical conditions.

We measured the silicon isotopic composition of silicic acid in surface waters on samples collected along 170°W in the vicinity of the Antarctic Polar Front during four cruises (October 1997 to March 1998) as part of the US JGOFS AESOPS program. δ^{30}Si values decreased southward from +2.9 to $+1.8^{o}/_{oo}$ along the strong meridional gradient in dissolved silicon. δ^{30}Si values were inversely correlated with silicic acid concentration and imply an enrichment factor, ϵ, of $-0.8^{o}/_{oo}$ similar to the value of $-1.1^{o}/_{oo}$ obtained for cultured diatoms. These are the first data that document changes in the δ^{30}Si value of silicic acid as it is consumed by diatom growth in a natural system; thus they provide direct evidence that silicon isotope fractionation in the sea conforms to a simple Rayleigh model.

δ^{30}Si of particulate silica from a sediment trap located in the Polar Front at 1031 m depth from November 1996 to January 1998 increased sharply from +0.6 to $+1.5^{o}/_{oo}$ during the course of a diatom bloom, after which the δ^{30}Si signal dropped to pre-bloom conditions. The increase in the δ^{30}Si values of particulate silica in the trap paralleled that of silicic acid in surface waters with an offset of approximately $-1.1^{o}/_{oo}$.

The results support the use of natural variations in silicon isotope abundances in surface waters as a proxy for dissolved silicon utilization and support the use of the δ^{30}Si of diatom opal recovered from sediments to reconstruct the history of relative silicic acid use in surface waters.

OS21L-09 1050h

Ge:Si Fractionation in Continental Margin Sediments: Balancing the Ge Budget

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While the modern oceanic silica budget is reasonably well-constrained, the sink term for the germanium budget is poorly defined. This lack of fundamental geochemical information limits our ability to interpret glacial-interglacial Ge:Si variations observed in biogenic opal. While opal burial is certainly one important sink for Ge, budget calcuations suggest that there is at least one additional significant sink. Recently our group showed that at several stations along the California continental margin, germanium is fractionated from silica in iron-rich sediments, with germanium being sequestered in an unidentified sediment phase (GCA, 2000, 64 : 2453 - 2465). We present here sediment porewater data from the Peru-Chile continental margin and additional in situ benthic incubation and sediment core incubation data from the California continental margin. These additional results show that the magnitude of this diagenetic fractionation is 50% in reducing, iron-rich margin sediments. At abyssal depths, the Ge:Si benthic regeneration ratio is consistent with no fractionation from the ratio in opal. Calculations indicate that fractionation in the depth range 0.1-1 km is sufficient to balance the Ge budget. We conclude that sequestering of Ge in iron-rich continental margin sediments is the "missing" Ge sink. Temporal variation in the strength of this sink could be sufficient to drive fluctuations in the glacial-interglacial Ge:Si oceanic ratio.

OS21L-10 1105h

The Effect of Ocean Temperature on the Ge/Si Ratio of Seawater

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Although the water column cycling of inorganic Ge and Si in sea water are remarkably similar, the ratio of Ge/Si in opal has varied through time in concert with changes in global climate. Results published by Froelich, Mortlock, Shemesh, and their colleagues have demonstrated that ratios have ranged from the present value of 0.7 RU (1 RU = 10e-6 atoms Ge/atom Si), to 0.5 RU during the last glacial maximum, to approximately 0.9 RU during the mid-Miocene. Weathering (approximately 0.5 RU) and hydrothermal (approximately 11 RU) sources provide the two largest inputs of these elements, and the temporal variation of the ratio in opal has often been interpreted to reflect variations in their relative importance. The recent discovery and quantification of a substantial sink for Ge in anoxic, iron-rich sediments provides an alternative explanation for the temporal variation of seawater Ge/Si. The importance of this newly discovered Ge sink depends on the rate at which opal reaches the sea floor in margin environments.

Water column temperature is a key factor in determining the fraction of opal produced that reaches the sea floor. Based on the temperature dependence of water column opal dissolution determined in situ by Erez et al. (EPSL 59,1982), a decrease of 3°C in surface water in the CA margin should increase the opal rain at 1 km by 1.4-2.0 times; an increase in T of 2°C should decrease it by 0.4-0.7 times. These temperature changes are published estimates of changes during the last glacial maximum and the mid-Miocene, respectively, and the calculated changes in opal reaching the sea floor at 1 km are sufficient to account for the temporal variation in oceanic Ge/Si. The range in the calculated flux reflects different scenarios for the water column temperature structure. Other important factors, such as weathering rates, dust dissolution, opal production, changes in the methylgermanium cycle, or the areal extent of iron-rich anoxic sediments could also vary, but it appears that their effects might be secondary. One implication of these results is that the effective depth of opal regeneration in the ocean varies in response to climate. Whether this might influence the rate or oceanic distribution of diatom production is unknown at present.

OS21L-11 1120h

New Insights Into the Mechanism of Barite Formation in Seawater and Implications for Paleoproductivity Reconstruction

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Ba accumulation in marine sediments has often been used as a proxy for past changes in ocean productivity, but a better understanding of the mechanism of barite formation in seawater is necessary to develop the approach as a quantitative method.

To this end, we have conducted time-series decay experiments of cultured and coastal plankton. Barite crystals, monitored by SEM, were produced during each experiment. Chemical leaching was applied to the coastal plankton before and after decay. The results show that plankton accumulates a relatively large pool of labile Ba, which is rapidly released during decomposition and acts as the main source of Ba for barite formation in supersaturated microenvironments. This contrasts with earlier suggestions that barite saturation in microenvironments might be achieved by increasing sulfate concentration. Since mass balance indicates that only a small fraction (2 to 4 percent) of the labile-Ba pool is converted to barite, the availability of microenvironments that could locally concentrate Ba released by plankton decay seems to be the main controlling factor for barite precipitation. This may explain the higher barite yield that is typically observed in the field, and the seasonal and geographic changes that have been observed in the Ba/Corg ratio of settling particles collected with sediment traps.

Since Ba uptake by phytoplankton seems to be the initial step for barite formation, these results are encouraging for realizing the potential of the approach, but they also caution against a simplistic interpretation of the Ba sedimentary record. Barite formation yield can vary between 3 percent in high productivity margin areas to 30 percent in open ocean sites. Using Ba as a quantitative paleoproductivity tool will thus require that we understand the factors controlling this yield and that we quantify the processes involved.

OS21L-12 1135h

Barium Benthic Fluxes Over a Range of Oceanic Environments: Testing the Utility of Barium as a Paleoproxy

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Observed biological associations of Ba in seawater plus correlations between fluxes of sedimentary barite and bio-Ba with organic carbon and/or opal fluxes in sediment traps and sediments have been used and tested by paleoceanographers as algorithm-driven paleoproductivity proxies. The details of this mechanism and its links to productivity, diatom shells and the sinking flux of organic carbon have not been firmly established. A second Ba-paleoproxy employs the current oceanic relationship between Ba and alkalinity to interpret Ba/Ca ratios in benthic foraminifera as a paleo-alkalinity proxy. However, the Ba:Alk relationship is not mechanistic but rather depends upon spatial coherence of parallel carriers and over-printing by thermohaline circulation. This leads to questions of whether the current Ba:Alk relationship in seawater is constant. Studies employing benthic landers to compare Ba and Alkalinity fluxes from sediments are one way to solve some of these problems. To this end, Ba-fluxes from benthic lander chamber samples have been determined for a wide variety of global environments. These fluxes have then been compared to the regeneration fluxes of bioactive constituents (carbon, alkalinity, silica), and to bottom water and sediment redox state to deconvolve the multivariate relationships with benthic Ba-fluxes. Our preliminary data extends the Ba-flux range several fold over previous data sets, and covers sites with high and low alkalinity fluxes, above and below the lysocline, high and low carbon- and opal-rain, and greatly differing bottom water oxygen concentrations. From this data, a Ba:Alk relationship from benthic fluxes of approximately 1:4500 is observed, significantly different from the ratio of 1:1500 observed from modern deep waters. This suggests the possibility that the paleo-Ba:Alk relationship in seawater may have differed from that observed today. Additionally, there are strong correlations between the Ba benthic flux and both the silica and TCO2 fluxes, as well as with depth.

TUE

OS21M HC: 315 Tuesday 0830h

Oceanic Time-Series Measurements: Assessment of the Past and Planning for the Future II

Presiding: **M W Lomas,** Bermuda Biological Station for Research, Inc.,**; N R Bates,** Bermuda Biological Station for Research, Inc.,**; J Dore,** University of Hawaii

OS21M-01 0830h INVITED

Time Versus Space: the Problems of Scale

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It is received wisdom that, as time scales increase, the space scales expand. It is appropriate to consider frequency/ wave number scenarios and in this format there are three different problems: (1) the organisms distribute their activities along the diagonal at all scales from min/mm to millenia/global. Thus prey predator interactions are also interactions across scales. (2) Theoretical approaches prefer to fix quite narrow upper and lower bounds to the wave number:frequency space. So we have a jumble of non intersecting boxes. Thus, in physics: turbulence, eddy resolving, basin scale. With comparable distinct ecological contexts. (3) For logistic reasons, sampling tends to be "horizontal" (large, one-off, surveys; WOCE); or "vertical" (HOT/BATS); or small "boxes" for specific models (eddies; routine fish stock surveys). In planning future time series, I suggest these three aspects need to be explicitly included; particularly the need to couple models of different space time regimes. This is more than a desire for larger simulations. We have been successful at physical/biological coupling within each space/time box; but we do not seem to have incorporated the ecological coupling between scales (microbial loop/days - carnivores/years). Similarly, there are now a range of techniques for spatial description; from AUV's to remote sensing. But there are problems at the intermediate scales and trophic levels. For example do we assume a "continuous" spatial ocean or one with discrete "Longhurst" provinces?

OS21M-02 0855h

Changes in Phytoplankton Pigment Structure at BATS: Causes and Implications for Ecosystem Functioning

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The phytoplankton community structure in the Sargasso Sea near BATS has been sporadically documented over the past 4 decades, with the general conclusion being that phytoplankton community structure is relatively invariant and dominated by prokaryotes and picoeukaryotes. The 10+ year record of phytoplankton pigment data collected at BATS, however, suggests that during the past 5 years, there have been significant changes in phytoplankton community structure. The spring phytoplankton bloom at BATS is due to increases in all pigment-based taxonomic groups to some extent. From 1996 to the present, the relative importance of prymnesiophytes (as indicated by 19'-hexanoyloxyfucoxanthin) has apparently increased from ~10% of total chlorophyll to ~20% of chlorophyll, with the most significant changes occurring during the spring bloom period in 1996. In addition, the normally important chlorophyte/prochlorophyte component (as indicated by chlorophyll b) was conspicuously absent from early 1997 to early 1998.

These changes in phytoplankton pigment composition correspond in time to marked changes in the phase of several dominant modes of climatic variability, namely the North Atlantic Oscillation and the Southern Oscillation Index. This correlation should not imply cause and effect, but it has long been known that species competition can be controlled by changes in environmental regimes that may be associated with changes in large-scale climate patterns. This instability in phytoplankton community structure appears to have had other impacts on the functioning of the Sargasso Sea ecosystem. The last 5 years has seen an increase in the baseline flux of particulate organic matter at BATS of nearly 2-fold, and a 4-fold decrease in the accumulation of DOC during the spring bloom period. This apparent change in the partitioning of organic carbon between particulate and dissolved phases has a large potential impact on the functioning of the biological pump in the Sargasso Sea. The decade of observation at BATS hints at the strong dynamic links between physical forcing, phytoplankton response in the oceanic gyres, and biogeochemical cycling of key nutrients. Understanding of these links is the challenge for the next decade of time-series research.

OS21M-03 0910h

Temporal Variability of Light Penetration Depth at Station ALOHA: Potential Effect in Productivity and Phytoplankton Community Structure in the Lower Euphotic Zone

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Nearly monthly deployments of a Profiling Reflectance Radiometer (PRR) made since February 1998 at Station ALOHA (22°45'N, 158°00'W) document 40 m excursions of isolume surfaces between winter and summer months. While the 1% light level for summer months (~0.53 mol quanta $m^{-2}day^{-1}$) reaches on average 125 m, this photon flux shoales to 85 m during winter. The seasonal cycle of light depth penetration results from the combined effect of changes in sea surface solar irradiance and light attenuation (absorption and scattering) in the upper water column. Superimposed on this seasonal cycle, we observed short-term change in light attenuation in the mixed layer resulting from sub-surface diatom blooms during summer months of years 1998 and 2000. Colored Dissolved Organic Matter (CDOM) and chlorophyll (Chl) solar-induced fluorescence (683 nm) profiles derived from PRR data also display seasonal patterns in the lower euphotic zone. For a given isolume flux smaller than 0.53 mol quanta $m^{-2}day^{-1}$, the CDOM and Chl -specific fluorescence signals appear to increase between August-November and decrease between December-February. Since the photon flux is constant along a given isolume, this variability is attributed to physiological changes within the phytoplankton community in the lower euphotic zone. Because the temporal vertical displacement of the nutricline is forced by the displacement of isolumes we suggest that some of these fluorescence and CDOM trends result from successional patterns driven by the seasonal penetration and subsequent retreat of light into the nutricline. The difference in nitrate concentrations profiles in the upper water column between winter and summer months indicates that the lower euphotic zone contributes at least 30% of the annual new production in this area of the North Pacific subtropical gyre and the majority of the euphotic zone nitrate uptake.

URL: http://picasso.oregonstate.edu/ORSOO/hawaii/PRR/

OS21M-04 0925h

The Cariaco Time Series Study: Climate Forcing, Particle Fluxes, and Sediment Accumulation

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The anoxic Cariaco Basin has long been a favorite site of marine geochemists for the study of organic matter remineralization and other redox sensitive processes. The scientific community also has come to appreciate the Cariaco Basin as an exceptional archive of past global climate changes. The basin experiences significant changes in upper ocean conditions and upwelling intensity during the course of a year due to seasonal migrations of the ITCZ and its impact on the trade winds. In November 1995, we initiated a time series study in Cariaco Basin with the major goal being to understand how contemporary sedimentation patterns reflect climatic and oceanographic variability in the tropical western Atlantic Ocean. To achieve this, we are examining the relationships between regional hydrography/climatology, productivity, particulate flux, and input to the sediments. The field program consists of monthly hydrographic and primary productivity measurements, coupled with bi-weekly sediment trap measurements of particle fluxes at four depths (275, 450, 930 and 1250 m).

Primary productivity and the resultant carbon fluxes display a distinctive seasonal cycle related to upwelling. Depth-integrated (0-100 m) primary production varied by an order of magnitude over the five year period of 1996-2000 from a low of 448 gC m^{-2} d^{-1} in October 1999 to a high of 6858 gC m^{-2} d^{-1} in May 1996. On average, the carbon flux measured at 275 m is ~5% of primary production and less than 2% at 1250 m, indicating considerable remineralization within the anoxic water column. Intense bacterial activity and carbon cycling occurs in the region of the oxic/anoxic interface, but it is unclear if bacteria at this interface represent a significant source of new carbon to the total carbon flux. Additionally, episodic high flux events associated with transient forcing result in significant delivery of material to the sea floor.

OS21M-05 0940h

Climate Modulation of Physical and Biogeochemical Features at CaTS

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The biogeochemistry of Caribbean Surface Water (CSW) at Caribbean Time Series Station (CaTS) is largely controlled by nutrient input through lateral advection. Near surface phytoplankton biomass is seasonally enhanced in response to advection of low salinity river plumes from the Orinoco River. Climatological monthly mean CSW salinity is correlated to rainfall over the Orinoco River basin at a lag of 3-4 months (r = -0.6), a lag consistent with satellite imagery-derived northward displacement of the Orinoco River plume. CSW salinity and temperature anomalies are correlated to variations of the Southern Oscillation Index (SOI) at lags of 5-6 months (r = -0.38) and 8 (r = - 0.59) months respectively. Our observations coincide with published analyses relating rainfall over Northern South America to SOI variability. Interannual rainfall variability and the consequent transport of nutrient-bearing particulate and dissolved humic material may thus be responsive to global scale tropical climate variability as indicated by the SOI. Similar analysis yielded a very weak relation between salinity anomalies and the higher latitude North Atlantic Oscillation index (NAO).

Subsurface Tropical Atlantic and Caribbean waters are particularly nutrient depleted. Levitus'94 climatology indicates intrusion of a southwestward flowing highly saline water mass (Subtropical Underwater, SUW) formed in an area centered at 24N, 42W and entering the Caribbean Sea through the Mona and Anegada passages. This intrusion coupled to limited influence from equatorial upwelling results in a distinct subsurface nutrient depletion extending, at a depth of 125m, from its formation area to 80W and from 12 to 30N. Observations at CaTS indicate that although average nitrate concentrations in the SUW core are substantially lower than those found at high and low latitudes, increases in nitrate concentration coincident with deepening of the core and lower temperatures are frequent. Such events are also reflected in enhancement of the subsurface chlorophyll maximum. Climatological monthly means of SUW core properties at CaTS show seasonal minimum temperatures and maximum depth during the summer and minimum mean depths and maximum temperature during the first months of the year. SUW core depth and temperature yield significant correlations, r^2=0.30 and r^2=0.18 with the North Atlantic Oscillation index (NAO), at temporal offsets of 45 and 43 months respectively. Such time offset implies an average southwestward transport velocity of 2.3 to 2.4 cm.sec $^{-1}$ for the SUW, which agrees with previous transport estimates for this water mass. Analogous correlation analyses with the SOI yields a significant correlation with core depth (r^2= 0.22) with a temporal offset of 40 months but not with core temperature at a similar timescale.

Upper water masses in the Caribbean exhibit teleconnections with tropical and extratropical climatic oscillations. While CSW responds mainly to tropical forcing, the SUW appears to respond to atmospheric pressure gradients of the North Atlantic (NAO). The susceptibility of Caribbean and Tropical Atlantic physical and biogeochemical processes to climate change stress the need for acquiring a deeper insight into mechanisms leading to the observed teleconnections.

OS21M-06 1015h

Changes in the Oceanic Sink of CO_2 in Subtropical Mode Water of the North Atlantic Ocean

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The magnitude and interannual variability of uptake of carbon dioxide (CO_2) into subtropical mode waters (STMW's) are poorly quantified. In the North Atlantic Ocean, STMW ventilates the shallow depths (~200-400 m) of the subtropical gyre, and interannual variability of STMW formation is primarily associated with climate variability (i.e. North Atlantic Oscillation, NAO). Long-term ocean CO_2 records in the western North Atlantic indicate a recent divergence in the

rates of CO_2 uptake, with CO_2 increasing in STMW at a rate double that of the surface layer. The non-conservative increase of CO_2 does not result from remineralization of organic matter or density variability, but rather, weak wintertime mixing and lack of STMW reventilation, which appear associated with an NAO positive phase. Since 1988, ~0.6-1.7 Pg (10^{15} g) of CO_2 has accumulated within the gyre STMW, representing a long-term oceanic sink of CO_2 (>10 years). The accumulation of CO_2 in STMW should continue until winters with stronger mixing (associated with a NAO negative phase), when entrainment of STMW CO_2 into surface waters ultimately release CO_2, stored in STMW, to the atmosphere over short timescales (<2-3 years). Interannual variability in the uptake of CO_2 into STMW thus provide another factor and feedback controlling the global ocean uptake of CO_2.

OS21M-07 1030h

Carbon, Nitrogen, and Phosphorus Biogeochemistry at Station ALOHA: Redfield and Variable Stoichiometry Models

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The biogeochemical cycles of carbon, nitrogen, and phosphorus are tightly coupled in the upper ocean, but observations from the HOT and BATS time-series programs have shown that a simple assumption of a fixed stoichiometry is untenable. The coupling of carbon cycle to the nitrogen and phosphorus cycles in microbially-mediated biogeochemical processes affects the net air-sea exchange of CO2, "burial" of carbon in the meso- and bathypelagic ocean, and the relative importance of biotic and abiotic terms in the carbon cycle. We have conducted multielemental model simulations of Station ALOHA with models that treat C-N-P ratios as variable for both production and remineralization of organic matter, and models that treat remineralization ratios as variable while phytoplankton production occurs in Redfield ratio. The results suggest that non-Redfield stoichiometry of both production and remineralization of organic matter is necessary for accurate simulation of all of the observed pools of C, N, and P as well as rate processes such as primary production. Results from a variable ratio model of phytoplankton growth agree with field observations that primary production is significantly underestimated by radiocarbon measurements of the particulate fraction only, and suggest that there is a large flux of labile organic carbon to the heterotrophic microbial community, uncoupled from fluxes of organic N and P. This may in part explain the apparent selection of heterotrophic Bacteria for growth on inorganic rather than organic forms of N and P. Adaptation of the heterotrophic bacterial community to this abundant source of substrate may explain interannual changes in bulk dissolved organic matter.

OS21M-08 1045h

A new Paradigm for the Formation of the Primary Nitrite Maximum

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The Primary Nitrite Maximum (PNM) is found throughout the oceans at the base of the mixed layer, slightly shallower than the beginning of the nitracline. The current paradigm for the production of the feature is differential inhibition by ultraviolet light of ammonium oxidation compared to nitrite oxidation. More recent evidence from cultures of nitrifiers contradicts the assumptions of this paradigm, with lower inhibition of nitrite oxidation than ammonium oxidation. In contrast to the putative bacterial source, phytoplankton have long been found to produce nitrite, especially under low light conditions characteristic of the PNM. Combining recent results from phytoplankton cultures, with the presence of the chlorophyll maximum, permits a "back of the envelope" calculation suggesting that phytoplankton are the dominant source of nitrite forming the PNM. In addition to the year-round PNM, substantial amounts of nitrite are present the Sargasso Sea throughout the mixed layer during the winter mixing period, at times nearly equaling the nitrate concentration. We will present estimates again suggesting the phytoplankton are responsible for this feature rather than bacteria.

OS21M-09 1100h

Monitoring Interannual Variability in a Southern California Upwelling System

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An important link between physics and biology in marine upwelling ecosytems such as the California Current is the mechanism by which ocean currents and eddies supply nutrients to the euphotic zone. Net fluxes of mass, heat, salt, nutrients, oxygen, and chlorophyll into a control volume defined by the modern CalCOFI region were computed from data collected on 55 cruises over a 14-year period, 1984-1997. Significant low-frequency variability was observed in the net property flux convergences and was related to low-frequency (interpentadal and ENSO time scale) changes in the dominant wind and circulation patterns. The results demonstrate the importance of horizontal flux convergences to nutrient cycling and point out the inadequacy of 1-D vertical exchange models in regions such as upwelling zones where residence times are short. Although the nutrient fluxes were consistently positive, their magnitude varied by more than 100% both seasonally and interannually, in concert with environmental changes in the atmosphere and ocean.

Long time series such as CalCOFI are essential for observing interannual variability, yet such time series are expensive in both human and ship resources. Autonomous underwater vehicles such as seagliders hold great promise for sampling ocean variablity with less expense and greater frequency than is practical from ships, yet there are some measurements for which shipboard sampling will still be required. A challenge in planning for the future is in defining the appropriate mix of traditional and autonomous sampling to resolve the physical, chemical, and biological signals of interest.

OS21M-10 1115h

San Pedro Ocean Time Series (SPOTS): A Study of Opal Cycling in the Water Column and Sediments off Southern California

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This time series study is an investigation into the fate of opal produced in the upper ocean, as it falls through 900 m of water column, and within the sediment column. Various time-series measurements (water column surveys, sediment traps, repeat benthic flux measurements) were used to study changes in opal reactivity within these zones. An ocean time series has been established off Southern California between Los Angeles and Catalina Island; surface to 500 m profiles of nutrients have been measured on a monthly basis from 1998-present. From the change in dissolved Si inventory in the upper 50 m during the spring-to-summer seasons and diapycnal gradients, a production flux of biogenic particulate Si has been estimated as 2-7 mmol Si/m2d. The role of advection in these signals is unknown. Sediment trap collectors from 120, 200, 500 and 860 m indicate that biogenic Si rain rate declines from 1.8 to 1.3 mmol Si/m2d through this depth range. The change in opal rain vs. depth is described by a function and modeled such that the dissolution rate constant for opal at a given depth is dependent on particle settling rate. At particle settling rates of 50, 100, 200 m/d, the rate constant for opal dissolution at 900 m is 0.01 to 0.04 /day. We also have a time series of opal dissolution flux measurements from the sea floor (at 900 m) beneath the time series location. The pattern of opal dissolution flux is systematic with season, the highest dissolution rate occurs during the mid-summer months and the lowest in the winter months. There is an offset of several months between the timing of maximum opal delivery to the sea floor and the maximum rate of benthic dissolution. These patterns of rain and remineralization have been modeled and results indicate a rate constant for opal dissolution of 0.005 to 0.01 /day. Either particles are settling at the slow velocity of 50 m/d through 900 m of water column or opal solubility characteristics change between particles in the water column and particles in the sediment column.

OS21M-11 1130h

Variation of Stable Carbon Isotopes in Sinking Organic Matter over Three Seasonal Upwelling Cycles (1997-1999) Collected as Part of the CARIACO Time Series

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Sinking organic matter was collected at bi-monthly intervals by sediment traps over a 4 yr period as part of the CArbon Retention In A Colored (CARIACO) Time Series Program. The sediment trap array consists of four cone shaped traps along one wire at depths of 275m, 455m, 930m and 1255m. Concurrent measurements of productivity, $[CO_{2aq}]$, chlorophyll and temperature collected on monthly cruises aboard R/V Hines allow for comparison of surface water processes that influence the stable carbon isotopes of settling organic matter ($\delta^{13}C_{org}$). $\delta^{13}C_{org}$ for three complete upwelling cycles (1997-1999) ranged as low as -22.56 $^{o}/_{oo}$ during periods of water column stratification and as high as -17.75 $^{o}/_{oo}$ during seasonal upwelling. There was little variation of $\delta^{13}C_{org}$ between different depths collected at the same time interval with standard deviations ranging from only 0.6 $^{o}/_{oo}$ to 0.02 $^{o}/_{oo}$ indicating that there is little diagenetic alteration of the $\delta^{13}C_{org}$ signal through the water column. There is a strong relationship ($r^2 = 0.67$) between decreasing water column temperature and increasing values of $\delta^{13}C_{org}$ and a somewhat weaker relationship between $\delta^{13}C_{org}$ and productivity ($r^2 = 0.28$). This suggests that there may be a link between seasonal upwelling, biological productivity and the $\delta^{13}C_{org}$. Contrary to previous laboratory and field studies $\delta^{13}C_{org}$ and , ϵp are positively correlated with $[CO_{2aq}]$ indicating that a decrease in $[CO_{2aq}]$ may not be a controlling factor of $\delta^{13}C_{org}$ in the Cariaco Basin. Possible mechanisms for this positive relationship between $\delta^{13}C_{org}$, ϵp and $[CO_{2aq}]$ include a diffusion limiting Rayleigh distillation effect, non-diffusing flux of CO_3^- species into phytoplankton cells, internal carbon concentrating mechanisms in phytoplankton and phytoplankton species composition.

OS21M-12 1145h

Nitrogen and Oxygen Isotopomeric Constraints on the Origins and Sea-to-Air Flux of N_2O in the Oligotrophic Subtropical North Pacific Gyre

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Although the oceans are a significant source of the greenhouse gas nitrous oxide (N_2O) to the atmosphere, its magnitude and characteristics are poorly constrained. We present here stable isotope and isotopomer (intramolecular distribution of ^{15}N within the linear NNO molecule) results for N_2O from Station ALOHA in the subtropical North Pacific gyre near

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Hawaii. The results indicate shallow (~100-300 m) *in situ* N_2O production. Results of isotope mass balance models constrain the rate of N_2O production and the sea-to-air flux of N_2O. Results of an isotope mass balance model that takes into account the ratios of the vertical gradients in the isotopic abundances of N, O, N^a (central N) and N^b) (terminal N) of N_2O and the measured gradients of N_2O concentration through the thermocline, indicate that *in situ* production contributed 40% to 65% of the sea-to-air flux of N_2O. This model also predicts that the net sea-to-air flux of N_2O was at least 0.4 μmoles m^{-2} d^{-1} and most likely exceeded 0.7 μmoles m^{-2} d^{-1}. We present a new method for calculating N_2O production using the difference between the site preference (= $\delta^{15}N^a$ - $\delta^{15}N^b$) of atmospheric and dissolved oceanic N_2O and the rate of air-sea N_2O exchange. These results suggest a rate of N_2O production of 2.9±1.2 μmoles m^{-2} d^{-1} and indicate that shallow production contributed about 50% of the net sea-to-air flux of N_2O. These results can be used to better constrain the global N_2O budget.

OS21N HC: 316 C Tuesday 0830h

Coupled Biophysical Processes, Fisheries Resources, and Climate Variability in Coastal Ecosystems of the Northeast Pacific Ocean III

Presiding: **P T Strub,** College of Oceanic and Atmospheric Administration**; R M Letelier,** College of Oceanic and Atmospheric Sciences

OS21N-01 0830h

Characteristics and Forcing of the Spring Transition off California

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Fortuitously timed physical observations on a grid of stations off California during March 1995 and repeated the following month captured a dramatic shift from late-winter to spring conditions. The initial period was characterized by a broad coastal zone with weak eddying flow, while the main California Current jet meandered approximately 300 km offshore. While the same dynamic pattern persisted in the offshore region in April, a well-organized equatorward coastal jet had developed, creating strong zonal gradients in temperature and salinity. These observations suggest that the California Current along this part of the coast is regenerated in spring as a coastal upwelling jet that subsequently broadens to join or supplant what had been the main jet. The evolution of this pattern due to local and large-scale wind forcing is examined, and the implications for the offshore and alongshore transport of biological material are explored.

OS21N-02 0845h INVITED

Mesoscale Structure in the Northern California Current System

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During spring and summer 2000, two mesoscale mapping cruises were carried out in the northern California Current System between 41.9 and 44.6N and offshore for 150 km. The primary measurement platform was a towed undulating vehicle equipped with a CTD, fluorometers, a multi-wavelength light absorption and attenuation instrument, and a PAR sensor. A shipboard ADCP measured water velocities and a bio-acoustics instrument measured multi-frequency (38, 120, 200, 420 kHz) backscatter. Surface drifter trajectories and satellite SST imagery provide context for the mesoscale maps. A variety of wind regimes were encountered from strong upwelling to strong downwelling. The data provide good examples of flow-topography interaction including the influence of a major submarine bank and a large coastal promontory on the eastern boundary current circulation. Early in the season the upwelling front and jet followed the bottom topography fairly well. There was cold water inshore of the shelfbreak all along the coast with pockets of elevated biomass (chl up to 4 mg m^{-3}) near the coast. Mesoscale activity was minimal. During the summer cruise, the upwelling front and jet were much more convoluted including major meanders offshore associated with Heceta Bank and Cape Blanco. High levels of phytoplankton biomass (chl in excess of 10 mg m^{-3}) were found over Heceta Bank and near the coast south of Cape Blanco. The large offshore meander near Cape Blanco carried cold, nutrient-rich, high phytoplankton biomass (chl of 2-4 mg m^{-3}) away from the coast over 100 km offshore. Details of the physical and biological structure of the meanders will be presented.

URL: http://damp.oce.orst.edu/globec/nep

OS21N-03 0910h

Bio-Optical Patterns Within the Mesoscale Structure of the Northern California Current System

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Mesoscale mapping of the hydrographic and bio-optical properties of the Northern California Current System was conducted during spring and summer 2000 between 41.9N and 41.6N off the Oregon coast. A towed, undulating vehicle carried a CTD, two fluorometers, a multi-wavelength absorption and attenuation meter (ac-9), and a PAR sensor. In addition, an ac-9 and a Fast Repetition Rate fluorometer (FRRf) collected bio-optical data on surface waters throughout the mesoscale surveys. Multiple onshore-offshore transect lines provided repeated crossings of velocity jet and frontal boundaries, and allowed resolution of physical and bio-optical parameters on horizontal scales of 1km or less and on vertical scales of 1-2m. Our results permit assessment of the linkages and the degree of coupling between physical and bio-optical patterns during strong upwelling and strong downwelling events, as well as during low-wind relaxation intervals. The location of the coastal jet and the upwelling front fluctuated considerably under the variable forcing regime, with more extensive mesoscale structure in all parameters in late summer relative to spring, as current meanders developed around subsurface topography (Heceta Bank) and moved offshore near Cape Blanco. Sharp horizontal gradients in autotrophic biomass were observed across the boundaries of the coastal jet and the upwelling front, with chlorophyll levels often in excess of 5 mg m^{-3} on the inshore side of the fronts. Horizontal gradients also were observed in the spectral slope of particulate absorption and attenuation as well as in the physiological properties of the autotrophic assemblages (as determined with FRRf). Details of the spatial correlations of physical and bio-optical parameters will be presented.

OS21N-04 0925h

Mesoscale zooplankton distribution and its correlation with physical and fluorescence fields in the California Current in 2000

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Surveys of zooplankton distribution were conducted in the California Current between 42.5N and 44.7N in spring and fall 2000 as part of the US GLOBEC Northeast Pacific Study to understand the effects of climate variability and climate change on the marine ecosystem. The study focuses on understanding how physical forcing affects the spatial and temporal distribution of zooplankton, and their correlation with physical and other biological fields. The survey was conducted using an Optical Plankton Counter (OPC) and a fluorometer mounted on a vertically undulating vehicle (SeaSoar). The processed OPC data provide a resolution of 4 m in the vertical, and 50 size classes of the Equivalent Spherical Diameter (ESD) between 250 mm and 16 mm. The results show the heterogeneity in zooplankton distribution. Zooplankton are highly abundant in nearshore areas where upwelling was the dominant physical feature, and less abundant in offshore regions. The correlation between zooplankton abundance and chl-a concentration is poor both horizontally and vertically. Taking advantage of zooplankton size spectra provided by OPC measurements, analyses of zooplankton sizes and productivity of zooplankton were conducted to further explore the correlation between physical fields, zooplankton size distribution and productivity.

OS21N-05 0940h

The Recent Northwest Baitfish Boom and Increased Salmon Ocean Survival

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Historical datasets indicate that Northwest baitfish abundance has fluctuated widely over the last 50 years and probably more. Salmon ocean survival has also fluctuated widely since records began. Since 1999 we have noted a marked increase in the number of baitfish (smelt, Northern anchovy, Pacific herring, and Pacific sardine) off Washington and Oregon. This increase appears to be related to decreasing ocean temperatures, changing zooplankton species and abundance, and decreased predator abundance. We hypothesize that baitfish abundance directly affects salmon ocean survival by acting as "alternative prey" for predators and thus decreasing predation rates. Long- and short-term fluctuations in oceanographic conditions that affect baitfish recruitment may be the mechanism that controls baitfish abundance and thus salmon marine survival. Global warming and other anthropogenic factors could directly affect future baitfish recruitment and thus the abundance of Northwest salmonids.

OS21N-06 0955h

Distribution, Growth, Origin, Trophic and Species Associations of Juvenile Salmonids in the Northern California Current Ecosystem

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Information is summarized on juvenile salmonid distribution, size, growth, stock origin, and trophic and environmental associations from the June and August 2000 GLOBEC cruises with particular emphasis on differences related to the regions north and south of Cape Blanco off Southern Oregon. Juvenile salmon were more abundant during the July-August cruise as compared to the June cruise and were distributed northward from Cape Blanco. There were distinct differences in distribution patterns between salmon species with chinook found close inshore in cooler water all along the coast. Coho salmon were rarely found south of Cape Blanco. The nekton assemblages differed significantly between cruises. June samples were dominated by juvenile rockfishes, rex sole, and sablefish, which were almost completely absent in August. The forage fish community during June was comprised of herring and