Observations of currents and near-surface temperatures from Lake Superior reveal a surprisingly rich field of eddies that extended throughout the water column and were present throughout the lake and during all seasons. Vertical profiles of horizontal were measured with a 150 kHz vessel-mounted acoustic Doppler current profiler (RD Instruments) currents in a coordinate system moving with the ship. Vessel motion and position information are obtained using a TSS POS/MV320, which can achieve +/-0.05 degree accuracy in roll, pitch and heading, and sub-meter horizontal resolution using a fully integrated system of inertial sensors and survey grade DGPS receivers. Currents in mid-lake were surface intensified with speeds reaching as much as 20 cm/sec in a layer bounded from below by the thermocline. Velocities near the bottom of the lake had magnitudes of approximately 5-10 cm/sec. Surface temperature data were used to characterize the distribution of the eddies and to address how the temperature anomalies were generated by the turbulent dynamics. A spectral slope was calculated from averaged surface temperature spectra in a range of wavelengths between 4.5 and 32 kilometers. During all time periods, the spectral energy density decayed at rates between $k^{-1.5}$ and $k^{-2.4}$. The shapes of mid-summer surface temperature anomaly spectra were consistent with a spectrum expected for a passive tracer within geostrophic turbulence.

OS41A HC: Hall III Thursday 0830h

Quantification and Regionalization of Benthic Flux Rates: Implications for Ocean Budgets II

Presiding: **C Hensen,** Fachbereich Geowissenschaften Universitt Bremen **; M Zabel,** Fachbereich Geowissenschaften Universitt Bremen **; C E Reimers,** Oregon State University

OS41A-01 0830h POSTER

Ba Preservation and Re-dissolution in Surface Sediments of Different Oceanic Regions in the South Atlantic

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Barium in the form of $BaSO_4$ (barite) is used as a geochemical sediment proxy to reconstruct present and past primary production. The knowledge of the burial efficiency of the proxy is crucial in this approach and there is a strong variation in estimates for barite preservation given in the literature.

Dissolved Ba concentrations were measured in the pore waters of the sediment at locations on the continental slope of the northern Angola, the Cape and the Argentine Basin. All measured concentration profiles exhibit a Ba release in the upper centimetres. Below this subsurface maximum dissolved Ba concentrations are on a constant level. This 'equilibrium concentrations' are approximately equal for the profiles measured in each of the oceanic regions. Differences exist between the three basins. The concentrations increase in the order: Angola Basin (ca. 185 nmol l^{-1}), Cape Basin (ca. 220 nmol l^{-1}) and Argentine Basin (ca. 245 nmol l^{-1}) corresponding to the Ba concentrations measured in the bottom water. Additionally, we calculated the biogenic Ba content and the accumulation rate of biogenic Ba from the measured total Ba concentration in the solid phase.

The transport and reaction model CoTReM was used to simulate the redissolution flux of Ba into the bottom-water, the amount of Ba buried in the sediment and the flux of biogenic Ba to the sediment surface for the assumed boundary conditions (sedimentation, bioturbation). By this approach we determined the burial efficiencies of biogenic Ba for the different oceanic regions to identify possible mechanisms which effect the Ba preservation in the sediment (e.g. organic matter mineralisation, saturation state of the bottom-water with respect to barite).

OS41A-02 0830h POSTER

Characterisation of Benthic Biogeochemical Provinces - An Approach for Reliable Budgeting of Flux Rates on the Global Scale

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A huge number of studies have frequently shown that benthic oxygen, carbon and nutrient flux rates depend on a complex interplay of different control parameters such as the primary and/or export productivity, the rain ratio, or the sediment composition. Especially the last one includes the important physical effects of lateral advection by currents which are often underestimated. Unfortunately, data give also evidence that these connections predominately do not have global validity. The weighting between the factors influencing transformation and exchange rates at the sea floor is rather determined by oceanographic conditions and seems to be specific for each component additionally. On the other hand, its no question that benthic flux rates play an important role for ocean budgets. Because field studies are very expensive and time-consuming they cannot be carried out ocean-wide which makes obvious the necessity of global estimates.

Inspired by Longhurst et al. (1995), who have defined provinces for the primary production, in this project we try characterize biogeochemical processes in the deep sea. Geostatistical methods and Geographic Information Systems (GIS) were used both to formulate specific spatial functions describing the relationship between the benthic release and control parameter(s) and to optimise the construction of regional distribution maps. The first is mostly restricted to regions with high data density. Applications of the transfer functions on areas with comparable oceanographic and sedimentary conditions but sparse benthic results, give first very promising results (please cf. Seiter et al. at this session).

Longhurst, A., Sathyendranath, S., Platt, T., Caverhill, C. (1995): An estimate of global primary production in the ocean from satellite radiometer data.- J. Plankton Res., 17(6), 1245-1271.

URL: http://www.geochemie.uni-bremen.de/

OS41A-03 0830h POSTER

Assessing Sediment-Water Nutrient Exchange Processes in the North Sea.

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Inorganic macro nutrient species are often thought to be a major limiting factor for primary producers in marine systems; ultimately, therefore, production is dependent on the amount of new and regenerated nutrients. It is generally held that greater than 90 percent of marine primary production is remineralised within the marine system. However, the contribution to this figure from benthic remineralisation and exchange processes is poorly understood. Areas of high fishing intensity typically exhibit a proliferation of smaller benthic organisms, and receive elevated amounts of organic matter in the form of offal and discards. Smaller benthic organisms are more productive yet less effective at turning over the sediment. This effectively reduces bioturbation activity, thereby altering sediment redox state and nutrient dynamics. This study examines the potential impact of bottom fishing on early diagenetic transformations and benthic nutrient exchange in coastal seas, using a number of observational and experimental approaches. Insitu measurements (benthic nutrient profiling) as well as laboratory based experiments (chamber flux measurements) were used. Bioturbation contribution and benthic disturbance were accounted for. Mesocosm experiments were used to isolate flux contributions from different assemblages of benthic organisms and bottom fishing. Benthic coring was used to obtain nutrient pore water profiles for flux rate modelling. These data were modelled to give an annual benthic flux rate for the North Sea, for nitrate, nitrite, ammonium and phosphate. The implications of the findings for Bioturbation and other biogeochemical implications are discussed and evaluated.

OS41A-04 0830h POSTER

Quantifying Pore Water Exchange Across the Sediment-Water Interface in the Deep Sea With In Situ Tracer Studies

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Benthic flux chambers have been widely used to measure the in situ fluxes of nutrients and oxygen in biogeochemical studies. In many cases, an inert tracer such as NaBr is injected at the start of the incubation and monitored throughout the experiment. A linear extrapolation of the tracer data has been used in the past to estimate the initial chamber concentration and water volume. Here we interpret the exchange of NaBr tracer between chamber waters and underlying pore waters in several in situ experiments conducted at four deep sea locations: the California margin, North Carolina margin, Ceara Rise, and Cape Verde Plateau. We examine the accuracy of previous chamber volume and flux estimates and assess sediment-water solute exchange rates.

A centered finite difference scheme was developed to simulate NaBr transport. Model results reveal an initial period of rapidly decreasing tracer concentrations that is missed by the widely-spaced sampling intervals generally employed during in situ experiments. The results suggest that the linear extrapolation scheme previously employed overestimates chamber volumes and hence benthic fluxes. The magnitude of the effect depends on sampling interval and effective solute exchange rate. At locations where interface exchange is dominated by molecular diffusion and reasonable sample intervals are used, chamber volumes are generally overestimated by 10 - 50 percent. At locations where exchange is enhanced by the activities of macrobenthic organisms and/or widely spaced sampling intervals are employed, larger overestimates can occur. The model is also used to estimate overall solute interfacial exchange rates. At locations where rates of organic matter remineralization are low, exchange is consistent with molecular diffusive rates. At locations where organic matter remineralization is rapid, exchange can be significantly faster than molecular diffusion alone, but may be controlled by the presence of macrofauna and hence bottom water oxygen concentrations. These observations are consistent with previously reported correlations between benthic solute exchange and respiration rates.

OS41A-05 0830h POSTER

Porewater Exchange in Permeable South Atlantic Bight Continental Shelf Sediments

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South Atlantic Bight continental shelf sediments are characterized by high permeabilities, substantial benthic microalgal photosynthesis, and rapid tidally-driven bottom current velocities. These factors restrict the utility of conventional benthic chambers for estimating benthic remineralization. Intact sediment core incubations from a 27 m depth station were employed ten times over an annual cycle to evaluate the relative contributions of diffusional and advective pore water exchange on the benthic flux of dissolved constituents. Replicate sediment cores recovered at each sampling period were incubated in circulating seawater in the dark at in situ temperatures for 9 -15 days depending on season, and porewaters were collected at 1-cm intervals periodically throughout the incubation. Replicate cores were incubated with and without surface pistons to evaluate diffusive losses from surface sediments into the overlying incubation waters. Using the observed rate of silicate concentration increase at each depth interval as a measure of opal dissolution, the rate of pore water exchange required to achieve the initial pore water silicate distribution was calculated. Results were incorporated into computer models describing exchange processes as combinations of molecular diffusion/nonlocal exchange or molecular diffusion/enhanced diffusion. Given the large natural variability, no seasonality was observed in the magnitude of porewater exchange. When represented as a

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nonlocal exchange process, estimated rates average 6 d-1 and are occasionally as large as 20 d-1 for the upper 5 cm of the sandy shelf sediments. Conversely, when exchange is represented as a diffusional process, rates within the upper 5 cm must average 80 times molecular diffusion and occasionally exceed 300 times molecular diffusive rates.

OS41B HC: Hall III Thursday 0830h

Synthesis of Pacific Ocean Carbon Cycle Research III

Presiding: **M Lamb,** NOAA/PMEL**; C Cosca,** University of Washington

OS41B-06 0830h POSTER

Dynamics of Dissolved Trace Metals During the Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS)

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During the first iron-enrichment experiment in the subarctic Pacific (SEEDS) in 2001, the dynamics of dissolved trace metals were studied. Iron was released in a patch of water (80 km^2) with a mixed layer depth of 10 m. Seawater samples were collected from the upper water column (5-70 m) of In- and Out- patch stations. Immediately after the collection, a portion of seawater was filtered with a 0.2 μm filter and acidified with HCl. In our laboratory, dissolved trace metals (Fe, Co, Ni, Cu, Zn, etc.) were concentrated using a chelating column technique and determined by ICP-MS.

At the In-patch station, the concentration of dissolved Fe in the surface layer was 0.8-0.9 nM on day 2-4 after the iron release and decreased exponentially to < 0.15 nM (the detection limit) on day 11. The dissolved concentration of Co, Cu and Zn in the surface layer on day 2 was 0.040, 1.7 and 2.2 nM, respectively. They also decreased exponentially to 0.014, 1.2 and 0.86 nM on day 13. The concentration of Ni was 5.0 nM and did not show significant decrease. The mole ratio in the concentration difference between days 2 and 13 was SiO_4 : NO_3 : PO_4 : Zn : Fe : Cu : Co = 27 : 16 : 1 : 1.2 $\times$ 10^{-3} : 6.5 $\times$ 10^{-4} : 4.3 $\times$ 10^{-4} : 2.6 $\times$ 10^{-5}. These are the first data showing that the mesoscale iron fertilization affects the dynamics of dissolved Zn, Cu and Co.

OS41B-07 0830h POSTER

Biological Processes During the Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS)

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The first iron-enrichment experiment was carried out in the Western Subarctic Gyre (48.5°N, 165°E) during the summer of 2001. Iron and SF6 were added in a patch of water (8 x 10 km) with a mixed layer depth of 10 m. As a result, surface dissolved iron concentration was 1.9 nM after 1 day from the enrichment (D1). The first biological response to the iron enrichment was the increase in photochemical quantum efficiency (*Fv/Fm*) of algal photosystem II on D3. Chlorophyll-a increased from D6 and reached 20 mg m^{-3} on D10. The maximum differences between outside and inside of iron patch were 19.5 mg m^{-3} in chlorophyll-a, and 13.5 μM in nitrate during the experiment. Dominant phytoplankton species before the fertilization and outside of the patch was pennate diatom Pseudoniztschia pungens, but rapidly increased phytoplankton in the iron-patch was large-sized (>10 μm) centric diatoms, mainly Chaetoceros debilis. The growth rate of C. debilis was much faster (>1.9 d^{-1}) than the other phytoplankton from D4 to D7. From D11 to the end of our observation on D14, *Fv/Fm* decreased, but chlorophyll-a concentrations kept rather constant. Nitrate did not deplete until D14, and shallower euphotic layer depth than the mixed layer observed on D12 suggested that phytoplankton was stressed by light at the end of the experiment. Gut-pigment contents of dominant copepods (*Neocalanus* spp. *Eucalanus bungii* and *Metridia pacifica*) increased 4—18.4 times in the patch and the maximum value was observed on D11. Abundance of salmons and small squids collected using trawl, did not change between inside and outside of the iron patch, but northern mackerels were abundant in the iron patch. These biological responses showed that the western subarctic Pacific might be the most sensitive to iron enrichment in the world HNLC regions.

OS41B-08 0830h POSTER

Variation in Iron(III) Solubility and Iron Concentration in the Northwestern North Pacific Ocean

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Vertical distributions of Fe(III) hydroxide solubilities (<0.025 μm) and dissolved Fe (<0.2 μm) concentrations at 0-250 m depth were studied inside (HP) and outside (LP) a high production (phytoplankyon bloom) patch area in the northwestern North Pacific Ocean during May 1999. In the surface mixed layer, the Fe(III) solubility values at HP were much higer (2-4 nM) than those (0.3-0.9 nM) at LP, and strongly correlated with chlorophyll *a* and nutrient concentrations. The high Fe(III) solubility observed in the surface mixed layer was probably due to a higher concentration or stronger affinity of natural organic Fe(III) chelators. In the surface waters, the dissolved Fe concentrations were generally lower than the Fe(III) solubility values, resulting from the active biological removal of dissolved Fe and excess concentration of Fe-binding organic ligands. The Fe(III) solubility minima (0.2-0.4 nM) were present in a narrow depth range (40-125 m) below the surface mixed layer at all stations. The subsequent Fe(III) solubility levels appeared to increase up to 0.6-0.8 nM with depth at 100-250 m in association with the increase in nutrient concentrations. The strong linear correlations between Fe(III) solubility values and nutrient concentrations in middepth waters suggest that the formation of organic Fe(III) chelators may be related to microbial decomposition of sinking biogenic organic matter. In middepth waters, the dissolved Fe concentrations were generally higher than the Fe(III) solubility values, suggesting that the small colloidal iron phases may be present in the dissolved Fe (<0.2 μm) fraction.

OS41B-09 0830h POSTER

The effect of boundary scavenging and circulation on the distribution of 230Th and 231Pa in the North West Pacific

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230Th and 231Pa are natural radionuclides produced uniformly throughout the water column from the decay of dissolved U. Both are particle-reactive and removed from the water column to the underlying sediment by adsorption on settling particles, a process also known as scavenging. 231Pa is less particle-reactive than 230Th and has a longer residence time in the water column (100-200 y vs 20-40y). As a result, 231Pa is more effectively transported to regions of high particle flux where it is preferentially removed, a process called "boundary scavenging". In addition, because adsorption on settling particles is a reversible process, large-scale upwelling and downwelling also affect the vertical distribution of 230Th and 231Pa, producing convex and concave profiles, respectively, which can be interpreted in terms of deep-water circulation patterns. We have measured dissolved and particulate 230Th and 231Pa concentration profiles at two stations off the Kamchatka Peninsula in the N. W. Pacific, an area characterized by very high opal fluxes. We combine these data with earlier profiles obtained further south to quantify boundary scavenging in the N.W. Pacific and to document the impact of intermediate water formation and deep-water upwelling on the radionuclide profiles.

OS41B-10 0830h POSTER

Carbon Fluxes from the Sepik River into the Bismark Sea and the New Guinea Coastal Undercurrent

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The Sepik River is a major contributor of water, sediment and associated organic loads to the coastal waters of northern New Guinea. We compare dissolved and particulate organic carbon data from September 1997 during an extremely dry year with that from 1999/2000 during wet season discharges. Estimated source flux of DOC is 32 x 10^9 to 101 x 10^9 moles/yr and POC is 13 x 10^9 to 38 x 10^9 moles/yr. The Sepik DOC flux is equal to that from all four major rivers combined that enter the Gulf of Papua on the south coast of PNG. The Sepik inorganic PIC flux is low (0.2 x 10^9 moles/yr) as the river does not drain carbonate soils. With a narrow continental shelf, and strong coastal currents, much of this exported material is available for long distance transport into the Bismarck Sea and beyond.

CTD casts and associated instrument data showed that the river signature was visible in optical measurements in deep profiles taken in the Sepik Canyon. Pulses of suspended sediments are carried offshore in the water column at the interface between density layers. At depths where the 25-cm path-length transmissometer and optical backscatter sensor instruments showed significant deflections, discrete water samples were taken in clean Niskin bottles for organic analysis. Additional high volume samples for lipid classes were taken with Infiltrex samplers deployed on a floating mooring along with two sediment trap arrays set at 100 and 260 m depths. The Infiltrex samplers were set at 55, 180, 200 and 220 m depth in an effort to target the surface layers and those of westward flowing water in the New Guinea Coastal Undercurrent (NGCUC) which tracks along the coast at a depth of 200 m and at a speed of 0.5 m sec-1 (Cresswell, 2000).

Analyses of lignin phenols, hydrocarbons, fatty acids, sterols and n-alcohols in these samples were used to estimate the degradation and dispersion of this organic input to the coastal waters and possible entrainment in the NGCUC.

Cresswell, G. R. 2000. Coastal currents of northern Papua New Guniea, and the Sepik River outflow. Marine and Freshwater Research 51, 553-564.

URL: http://www.aims.gov.au/pages/research/projects/project05/tropics.html