OS21D HC: Hall III Tuesday 0830h

The Cycle of Carbon in the Southern Ocean (S.O.) III

Presiding: **P Trguer,** Institut Universitaire Europeen de la Mer**; P Boyd,** Institut Universitaire Europeen de la Mer**; S Blain,** Institut Universitaire Europeen de la Mer**; R Sempere,** LMM, CNRS UMR 6117

OS21D-55 0830h POSTER

δ^{13}C of Surface and Deep Organic Matter in the Subantarctic and Polar Frontal Zones of the Southern Ocean South of Australia.

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To identify water column processes that control $\delta^{13}C_{org}$ in the Southern Ocean and determine whether surface patterns are preserved as organic matter sinks to the deep ocean, seasonal cycles of the carbon isotopic composition of organic matter ($\delta^{13}C_{org}$) were determined from surface particles (from six north-south cruises between September 1997 and March 1998) and moored sediment traps (at 1060, 2050 and 3850 m in the Subantarctic Zone at 47°S, 3080 m under the Subantarctic Front at 51°S and 830 and 1580 m in the Polar Frontal Zone at 54°S). $\delta^{13}C_{org}$ of surface water organic matter was up to 4.5$^o/_{oo}$ higher in the SAZ (between -26 and -22$^o/_{oo}$) than the PFZ (-27 to -25$^o/_{oo}$) and underwent a seasonal increase of ~4 and ~2$^o/_{oo}$ in the SAZ and PFZ respectively. This seasonal increase is consistent with biological draw down of $[CO_2]_{aq}$ and associated ^{13}C enrichment of dissolved inorganic carbon. $\delta^{13}C_{org}$ of material collected in deep sediment traps was also higher in the SAZ (~-22$^o/_{oo}$) than PFZ (~-24.5$^o/_{oo}$), but there was little seasonal change in either region. The $\delta^{13}C_{org}$ of organic matter reaching deep sediment traps in the spring was enriched (by ~4 $^o/_{oo}$ in the SAZ and ~2$^o/_{oo}$ in the PFZ) compared to the surface waters in both the SAZ and PFZ, suggesting that preferential export of some components of surface organic matter occurs or that the extent of remineralisation of sinking materials varies seasonally.

OS21D-56 0830h POSTER

Inorganic Carbon Changes in two Southern Ocean Iron Release Experiments: Effects of Iron, Hydrography and Meteorology

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In two *in situ* iron enrichment experiments we tested how iron supply affects inorganic carbon chemistry in the Southern Ocean. The Southern Ocean Iron Release Experiment (SOIREE) was initiated in early February 1999 in polar waters at 61°S 141°E. In cruise ANT 18-2 of R.V. *Polarstern* iron was added to the centre of a subantarctic eddy at 48°S 21°E on 7-8 November 2000. The iron additions enhanced algal growth in both studies, which promoted a decrease of dissolved inorganic carbon (DIC) and the fugacity of carbon dioxide (fCO_2) after 4-5 days. In SOIREE biological carbon uptake gradually lowered surface water fCO_2 from then onwards, while wind speed remained below 16 m s^{-1}. After 13 days the fugacity had decreased by 35 μatm (10% of its initial value) and DIC by 18 μmol kg^{-1} (0.8%). In ANT 18-2 recurring storm induced mixing and algal carbon uptake resulted in a sawtooth pattern of surface water fCO_2 with a maximum decrease of 20 μatm after 12, 18 and 20-22 days. The areal extent of the fCO_2 patch was much larger than in SOIREE. Both iron enriched patches became sinks for atmospheric CO_2. The longterm uptake of atmospheric CO_2 resulting from the iron additions would have been less than the amount initially fixed by biological activity. The experiments demonstrate beyond doubt that iron supply influences phytoplankton growth in the Southern Ocean. Meteorological and hydrographic conditions and possibly grazing pressure strongly affect the evolution of inorganic carbon upon iron enrichment.

OS21D-57 0830h POSTER

Role of Algal Coagulation in Carbon Export During Iron Fertilization Experiments.

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The SOIREE experiment involved the fertilization of a large area of the Southern Ocean with soluble iron. The addition did increase the growth rate and accumulation of phytoplankton, principally diatoms, but did not enhance particle removal from the surface mixed layer. Coagulation theory can help explain these trends in particle removal. The application of a simple coagulation model to the SOIREE experiment successfully predicts observed particle sedimentation patterns. The results suggest that there was no enhanced particle removal because of physiological changes in algal settling, decreased algal settling velocities, and because the specific rate of algal accumulation was too low to accelerate aggregate formation. The removal of additional carbon from the upper ocean by iron fertilization need to consider coagulation and the factors regulating it account for this effect.

OS21D-58 0830h POSTER

Assessing the Collection Efficiency of Ross Sea Sediment Traps Using ^{230}Th and ^{231}Pa

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Annual fluxes of particulate ^{230}Th and ^{231}Pa collected by sediment traps deployed at two locations in the Ross Sea are compared to expected fluxes, derived by combining the seasonal depletion of ^{230}Th and ^{231}Pa in surface waters with the steady-state production of each nuclide by radioactive decay of its respective dissolved uranium parent. Conservative (minimum) estimates of the expected ^{230}Th flux are greater than the flux collected by sediment traps deployed at 200m by factors of three and six at the two sites. The actual discrepancy may be much larger. The discrepancies between expected and measured fluxes of ^{231}Pa are slightly smaller, but comparable in magnitude to those for ^{230}Th. The discrepancies between expected and measured fluxes for these natural radionuclides are similar in magnitude to those determined previously, using the same sediment traps, for particulate organic carbon, which suggests that the sediment traps undercollected the actual flux of sinking particles.

OS21D-59 0830h POSTER

Anomalously low Zooplankton Abundance in the Ross Sea: An Alternative Explanation

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This study utilizes a 3D ecosystem model to examine the spatial and temporal dynamics of zooplankton in relation to phytoplankton stocks in the southwestern Ross Sea (Antarctica). Previous work in this area suggests that although grazer populations appear low, biomass is highly variable spatially, even in waters with similar phytoplankton standing crops and rates of primary production. Waters of the Ross Sea polynya support a large bloom of the haptophyte Phaeocystis antarctica which is impacted minimally by the meager zooplankton population, whereas within Terra Nova Bay, diatoms dominate the phytoplankton and zooplankton contribute much more to the vertical carbon flux. This difference in grazing pressure has frequently been explained by a reduced susceptibility of P. antarctica to grazing due to mechanical and/or chemical defenses. However, ample evidence from both the field and laboratory show that Phaeocystis spp. are readily grazed by both meso- and macrozooplankton. Our goal was to determine if alternative explanations to the mechanical and/or chemical defense hypothesis might explain the observed low zooplankton abundance in waters dominated by P. antarctica. To this end, the ecosystem model was parameterized so that diatoms and P. antarctica were grazed with equal ease (i.e. no prey selectivity) and the resulting phytoplankton and zooplankton dynamics were compared to observations. The model correctly simulated the rapid bloom and decline of P. antarctica in the Ross Sea polynya, with zooplankton stocks remaining low throughout the season. In contrast, zooplankton in Terra Nova Bay reached much higher levels, despite a maximum phytoplankton biomass that was similar to that in the central Ross Sea. The slower growth of phytoplankton in Terra Nova Bay resulted in a higher degree of phytoplankton/zooplankton coupling, exhibiting an grazing:algal growth ratio near unity. Conversely, the extreme boom/bust character of the P. antarctica bloom in the Ross Sea polynya resulted in much greater decoupling from higher trophic levels. This indicates that the low zooplankton abundance observed in the Ross Sea polyna may simply be a consequence of their inability to match the high growth rates of P. antarctica. Thus, the true adaptation by P. antarctica to resist grazing may reside in its high growth rate, rather than any other defense mechanisms. The different degrees of zooplankton/phytoplankton coupling between the Terra Nova Bay and the Ross Sea polynya regions may have important implications for food web structure and carbon export.

URL: http://ocean.stanford.edu/atag/os2002/

OS21D-60 0830h POSTER

Organic Carbon, Biogenic Silica and Diatom Fluxes in the Marginal Winter sea ice Zone and in the Polar Front Region: Interannual Variations and Differences in Composition

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Particle fluxes and composition were examined over five years at two mooring sites in the Polar Front Region (site PF) and in the marginal winter sea ice zone (site BO) in the eastern Atlantic Sector of the Southern Ocean. Seasonality, interannual variability and the magnitude of total mass fluxes were higher at site BO compared to PF. Five-year averages and standard deviations of total mass fluxes were 19.6±18.5gm^-2 and 24.8±29.9gm^-2 at PF and BO, respectively. Peak fluxes at site BO occurred in January 1995 but the highest peak was measured in February 1990 (almost 1300 mg m^-2 d^-1) followed by post-bloom sedimentation in March through May. At site PF, highest fluxes of about 500 mg m^-2 d^-1 were found between December and March. Blooms at site BO, influenced by sea ice as indicated by diatom species composition, seem to occur more sporadically (e.g. in 1991, 1995). During deployment PF3, *Fragilariopsis kerguelensis* and *Thalassionema nitzschioides* fo1 dominated diatom flux, while *F. kerguelensis* and sea ice related algae were the main contributors to total diatom flux at site BO. During deployment BO1, the bloom collected in February was characterized by a very high molar Si:C ratio of 8.8 which decreased almost continuously during

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the post-bloom phase reaching a value of one in May. We obtained a significant linear increase of biogenic opal fluxes with organic carbon fluxes at site PF and a highly significant but exponential relationship at site BO. Higher annual total mass fluxes were recorded at site BO, primarily due to elevated opal and lithogenic fluxes, corresponding to a higher silicate availability in the southern Antarctic Circumpolar Current. In contrast, higher mean organic carbon fluxes were obtained at site PF in accordance with elevated primary production and biomass. We obtained a three-fold higher molar Si:C ratio (Five-Year mean) for sinking particles collected with the upper BO traps (Si:C=4.0) compared to the PF (Si:C=1.3) consistent with the general pattern of Si and Fe availability.

OS21D-61 0830h POSTER

Physical control of chlorophyll a, POC, and TPN distributions in the pack ice of the Ross Sea, Antarctica

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Pack ice algae and environmental conditions were investigated along a 1470 km north-south transect in the Ross Sea during the spring 1998 oceanographic program Research on Ocean-Atmosphere Variability and Ecosystem Response in the Ross Sea (ROAVERRS). Snow and sea ice thickness along the transect varied spatially, with thinner snow and ice at the northern ice edge and thin new ice in the vicinity of the Ross Sea polynya. Relative to springtime observations in other sea ice regions, algal chlorophyll a (Chl *a*) concentrations were low. In contrast, POC, TPN and POC:Chl *a* were all high, indicating either that the ice contained substantial amounts of detritus or non-photosynthetic organisms, or that the algae had a high POC:Chl *a* ratio. The abundance of Chl *a*, POC and TPN in the sea ice was related to ice age and thickness, as well as to snow depth: older ice had thinner snow cover and contained higher algal biomass while new ice in the polynya had lower biomass. Older pack ice was dominated by diatoms (particularly *Fragilariopsis cylindrus*) and had vertical distributions of Chl *a*, POC and TPN that were related to salinity with higher biomass at the ice-water interface. Fluorescence-based measurements of photosynthetic competence (Fv/Fm) were higher at ice-water interfaces, and photosynthesis-irradiance characteristics measured for bottom ice algae were comparable to those measured in pack ice communities of other regions. Nutrient concentrations in extracted sea ice brines showed depletion of silicate and nitrate, depletion or regeneration of phosphate and nitrite, and production of ammonium relative to conservation of seawater chemistry; however, concentrations of dissolved inorganic nitrogen, phosphorous and silica were typically above levels likely to limit algal growth. Modeled light penetration levels implied that in the thickest pack ice and thickest snow cover, light levels could be limiting to algal photosynthesis. Enrichment of δ^{13}C-POC in the sea ice was correlated with the accumulation of POC, suggesting that carbon sources for photosynthesis might shift in response to decreasing CO_2 supply. Comparisons between new ice and underlying waters showed similar algal species dominance (*Phaeocystis antarctica*) implying incorporation of phytoplankton, with substantially higher POC and TPN concentrations in the ice.

OS21D-62 0830h POSTER

Organic Matter Fluxes and Preservation in the Southern Ocean: Role of Diatoms

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Amino acid and pigment compositions can be used to trace the source and diagenetic state of organic matter in sinking particles and sediments. We investigated these compounds in sediment trap material (collected ~1300m below the surface and 1000m above the seafloor) and sediments from the Southern Ocean between 56°S - 66°S along 170°W during November 1996 - March 1998 as part of USJGOFS AESOPS. In the Southern Ocean, productivity of large diatoms reaches a peak in austral spring and summer, resulting in a large flux of sinking particles. Throughout this area, diatom-source indicators are enriched during high flux periods relative to low flux periods. Diatom indicators include glycine, serine, and fucoxanthin in total trap material and diatom frustule-bound amino acids. Organic compound compositions also indicate that organic matter in sinking particles in the Antarctic Polar Front (~60°S) and north of the front was more degraded than organic matter at other stations, and more degraded during summer when the flux was highest. This suggests that at and north of the Front and during peak flux periods, diatom-derived organic matter was more highly processed by grazing relative to more southern stations and lower flux periods. At the Antarctic Circumpolar Current station (~63°S), the region of highest flux, the composition of sinking organic matter suggests that diatoms even more strongly dominate the summer peak flux period, but are less degraded, than at northern stations. This suggests that in this region ungrazed diatoms may be a more important component of the flux than at other stations.

Within diatom frustules, glycine and threonine were enriched relative to the total amino acid content in trap samples, more so during high flux periods than at times of lower flux. Since these amino acids are encased in opal, they are protected from degradation; thus species composition, nutrient status or extent of dissolution are greater influences on the composition of these bound amino acids. The composition of frustule-bound amino acids in bottom sediments is more similar to trap material collected during high flux rather than the low flux periods. This suggests that diatoms, and their associated organic matter, settling during high flux (and not low flux) periods are preferentially preserved in the sedimentary record, likely because diatoms with the most robust frustules sink during this period.

OS21D-63 0830h POSTER

Estimates of Net Community Production Using Dissolved Inorganic Carbon Deficits and δ^{13}C Enrichments in the Upper Water Column of Prydz Bay, Antarctica

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Primary production in the Southern Ocean plays an important, yet largely unknown role in the in the global carbon cycle. This study presents results from a recent cruise to the East Antarctic Margin, including Prydz Bay. In March of 2001, we observed normalized (S = 34.5) surface concentrations of total dissolved inorganic carbon (DIC) ranging from 2070 to 2160 μmol kg^{-1}, compared to winter values of ~2222 μmol kg^{-1}. Surface water DIC depletion results from the seasonal uptake of CO_2 by phytoplankton. By integrating the DIC deficit over the depth of the mixed layer we estimate seasonal net community production (NCP) in Prydz Bay of 33 to 60 g C m^{-2}. Measurements of pCO_2 in surface seawater and the overlying atmosphere indicate that exchange with the atmosphere has replaced a portion of the carbon taken up by phytoplankton, thus making these values of NCP minimum estimates. Over the same area, we also observed enrichments in the δ^{13}C of DIC throughout the mixed layer, due to preferential uptake of ^{12}C by phytoplankton. By constructing an isotopic mass balance, we derive separate estimates of NCP, with values falling within the range above, indicating that δ^{13}C may be a useful adjunct tool for estimating NCP and export. We discuss the caveats associated with this method and provide a comparison of rates of primary production derived from net seasonal nutrient depletions as well as satellite-based ocean color observations. In addition we use inventories of particulate organic matter in the water column to estimate minimum export of organic C from the mixed layer. These values of NCP are low compared to the values reported for the Ross Sea and portions of the Antarctic Peninsula, but do indicate that Prydz Bay is an important region for carbon uptake and recycling on the Antarctic Continental Shelf.

OS21D-64 0830h POSTER

Changes in Phytoplankton Community During the Southern Ocean Iron Fertilisation Experiment "EisenEx 1" Based on Marker Pigments

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In early austral spring 2000 (October/November) the first iron experiment in the Atlantic sector of the Southern Ocean (Eisenex 1) was carried out. Approximately 500 square kilometers were fertilized with iron to test the hypothesis concerning the role of iron as growth-limiting factor for marine phytoplankton in this region. During the course of the 3 weeks of the experiment water samples were taken inside the and outside the iron-fertilized patch. The samples were analyzed by high performance liquid chromatography to determine changes in phytoplankton biomass and group composition inside and outside the patch, using chlorophyll a and a variety of marker pigments. Group composition was estimated using the Chemtax program.

Chlorophyll increased fourfold inside the patch within the 3 weeks of the experiment. The increase in biomass was mainly attributable to diatoms, which contributed about 75 % of the biomass at the end of the experiment, demonstrating a preferential growth of this algae due to the iron fertilization. Although less important in terms of biomass, pronounced shifts in haptophytes and chlorophytes were found. Results indicate a preferential growth of Phaeocystis-type over Emiliania huxley-type haptophytes and of prasinophyceae over chlorophyceae. In addition autotroph dinoflagellates, pelagophytes, cryptophytes and cyanophytes were present. Strong wind mixing during the entire experiment inhibited the development of a stratified water column. Therefore, phytoplankton biomass and the different phytoplankton groups were almost evenly distributed over the upper 100 m of the water column.

OS21D-65 0830h POSTER

Effects of Ice Drift on the Productivity of Sea Ice Microbial Communities in the Weddell Sea, Antarctica

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Several attempts to estimate the primary production of sea ice algae and its contribution to the total Southern Ocean production have been made during the last 10 years, with values ranging from 35 Tg C year^{-1} [Arrigo et al. 1997] to 70 Tg C year^{-1} [Legendre et al. 1992] associated mainly to the seasonal pack ice zone. Simplifications of physical and biological processes in sea ice models are the main causes of the variability in production numbers.

In order to investigate the effects of ice dynamics on the sea ice primary production in the Weddel Sea, a high resolution thermodynamic sea ice model was coupled with a microbial food web model in a Lagrangian scheme, where ice floes containing microbial communities move in time and space following the large scale ice drift. Ice velocities are taken from the Bremerhaven Regional Ice Ocean Simulations (BRIOS) coupled ice-ocean model [Timmermann et al. 2001]. The thermodynamic sea ice model has a vertical resolution of 2 cm and is integrated by a leap-frog finite difference method. It includes a full isotopic fractionation scheme for salt and tracers. Desalination process and accumulation of biological material are determined by the rate of thermodynamic sea ice growth. Subsequent biological production is simulated by a physiological adaptive cell quota model of microalgae and protozooplankton growing under light, temperature, nitrogen and silicon co-limitation conditions inside the brine channels. The photosynthetically active spectral radiation

in sea ice was calculated with a coupled atmosphere-sea ice bio-optical model. A time-splitting technique is used to couple the different time scales of model components.transport of biological material during sea ice drift in the Weddell Sea plays a key role in the distribution of microalgal standing stock, showing higher biomass values in the western than in the eastern Weddell Sea. The main drift direction of ice floes accompanying the Weddell Gyre induces a southward transport of floes in the eastern Weddell Sea and consequently degradation of light and temperature conditions during the onset of sea ice growth season. On the other hand, northward drift of ice floes in the western Weddell Sea improves light conditions inducing sea ice microalgal primary production. These factors have a major impact on sea ice biology, showing values of primary productivity up to 5-fold greater than previous estimates. The sea ice drift also proved to be of major importance determining the variability in thermodynamic sea ice growth patterns due to differences in the physical boundary conditions. Characteristic salinity and tracer profiles inside the sea ice obtained by the model correspond well with observed features found in sea ice cores collected in the Weddell Sea. Model results suggest that coupling dynamic-thermodynamic ice growth and biological processes is essential to better represent observed spatial patterns of Antarctic sea ice microalgal standing stocks and primary production.

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Legendre, L., S. F.Ackley, G. S. Dieckmann, B. Gulliksen, R. Horner, T. Hoshiai, I. Melnikov, W. S. Reeburgh, M. Spindler and C. W. Sullivan, Ecology of sea ice biota. 2. Global Significance, Polar Biol., 12(3-4), 429-444, 1992.

Timmermann, R., A. Beckmann and H. H. Hellmer, Simulation of ice-ocean dynamics in the Weddell Sea. Part I: Model description and validation, J. Geophys. Res., in press, 2001.

OS21D-66 0830h POSTER

Seasonal Particulate Export Below the Polar Front in the Southern Indian Ocean Sector of Prydz Bay, East Antarctica

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Timeseries sediment traps were deployed between 1000m and 3300m at 62^{o}S, 73^{o}E between 1999 and 2001 as part of a field research collaboration between the US and China. The scientific focus of the collaboration was aimed at measuring the production and export of POC in the offshore Prydz Bay/Cooperation Sea region of the Southern Indian Ocean where seasonal and annual particulate export data is lacking. Results from geochemical analyses of the trap samples are intriguing in that they indicate that POC export in this region is substantially higher than expected from either ocean color or previously published primary productivity data. The annual total mass flux, seasonal peaks in biogenic components, and the mole ratios of organic carbon and biogenic silica to inorganic carbon of these samples are highly comparable to the AESOPS station MS5 sediment trap data sets obtained in the Marginal Ice Zone at 66^{o}S 170^{o}W. Unique to both the trap data sets, collected from two distinctly different sub-polar frontal regions, is that they exhibit extremely high mole ratios of organic C/inorganic C of >10 compared with the more frequently observed values of approximately 1. Additionally, both of the sites display particulate biogenic Si/organic C mole ratios that are much higher by over a factor of 4 compared to that reported for the silica-rich North Pacific. Implications of these results for understanding particle export in the Southern Ocean will be discussed. Preliminary results of stable isotope analyses and diatom and foramanifera studies completed by Australian colleagues on the Prydz Bay samples will also be presented.

OS21D-67 0830h POSTER

A Southern Ocean Comparison of CFC 11-Age Derived Estimates of Anthropogenic CO_2 to Multi-Parametric Linear Regression

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The change in anthropogenic CO_2 from 1968 to 1996 was estimated using a CFC-age method for three WOCE sections (P12, P14, P15) in the Southern Ocean and directly compared to values obtained using a Multiparametric Linear Regression method over the same period. The agreement in anthropogenic CO_2 concentrations between the two independent methods was very good (less than ±8%) for waters younger than 30 years. The good agreement provides confidence that either method can estimate multi-decadal changes in anthropogenic CO_2 in the ocean. In all three sections, the greatest inventory of anthropogenic CO_2 occurs in the Sub-Antarctic Zone with detectable penetration to a depth of 1500 m. South of the Polar Front the penetration of anthropogenic CO_2 shallows and by 60°S it is generally confined to the upper 200m of the ocean. The exception was along 140°E where we observed high concentrations (11-12 umol/kg) in Antarctic Bottom Water(AABW) and along 170°E where the AABW signal was detectable (6-8 umol/kg) below 2500 m. Further east along 170°W we were unable to detect an anthropogenic CO_2 signal in AABW.

OS21D-68 0830h POSTER

Spatial Structure of Physical and Bio-Optical Distributions Across the Antarctic Polar Front

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Mesoscale surveys to examine the relationship between the physical processes and biological response along the Antarctic Polar Front (PF) were conducted as part of the US JGOFS Southern Ocean Program (October/November 1997). Multiple crossings of the PF near 170 W, using a towed undulating instrumented vehicle, revealed regions of high chlorophyll within a large meander of the PF. Cross-correlation analysis of temperature, salinity, and chlorophyll suggests that the spatial separation between the steepest meridional gradients in physical and biological features decreased as phytoplankton biomass increased during the early stages of the spring bloom. Oceanographic sections across the PF that possessed the strongest horizontal temperature and salinity gradients displayed spatial offsets of 15-35 km between the physical and biological manifestation of the front. In contrast, those cross-front sections with weaker physical gradients displayed spatial offsets of 10 km or less between the physical and biological manifestation of the front. Correlations between water mass properties and bio-optical indices suggest that phytoplankton assemblages in the PF are advected eastward within discrete bands of horizontal velocity, and the bio-optical signature of the PF in austral spring changes in response to meander-generated upwelling in the PF and to increasing daylength. Mesoscale spatial variability in PF position (meandering) and dynamics (upwelling and downwelling) thus interact with variability in light and nutrient availability to create time- and space-dependent spatial offsets between the physical and biological frontal boundaries.

OS21D-69 0830h POSTER

Modelling Mesoscale Processes and Nutrient Limitation Impact on the Biological Pump in the Frontal Zone of the Austral Ocean

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A set of three-dimensional coupled physical and biological models is used to ascertain mesoscale dynamical activity process on primary production in the frontal zone of the Southern Ocean. Recent studies, in different oceanic regions, have shown that mesoscale dynamics have a real impact on biological activity in the surface layer. Most of these studies was dedicated to oligotrophic systems. The area under our focus is clearly non-oligotrophic and the goal of this study is to identify the effects of mesoscale dynamics on such a system. This study is a process modelling study taking into account the nonlinear dynamics of a zonal front at the equilibrium, and a simplified representation of the local ecosystem. The physical model is a Primitive Equations model with a channel zonally periodic geometry. Two biological models are used : firstly a classical NPZD model with nitrogen as a potential limiting nutrient, and secondly a model with an iron type nutrient limitation which we call XPZD model.

Primary production reproduced by the NPZD coupled model is strongly constrained by the horizontal advection in the frontal zone. Limitation is mainly induced by the spatial structure of the mixed layer. In this case nutrient limitation is generally low and vertical velocities associated with mesoscale dynamics have low impact. At the north of the frontal zone, a low primary production is reproduced by the model, according to observations. But in the southern part of the domain higher production is observed revealing a too low primary production limitation. When a simple parameterization of the impact of iron on phytoplankton growth rate is included in the XPZD coupled model, firstly primary production in the southern part of the domain becomes low, as in the northern part. In addition, in the frontal zone, althought the poduction is weaker than in the NPZD model as a consequence of strong iron type limitation, diagnostics reveal a stronger impact of vertical velocities on primary production. Effects of a time varying wind forcing are also studied revealing a strong effect on vertical velocities and consequently on nutrient uptakes in the mixed layer.

TUE

OS21D-70 0830h POSTER

An Arctic Ocean Time Series of Dissolved Inorganic Carbon.

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This paper presents the first ever, yearlong DIC time series in a polar ocean. Polar oceans are critical to the global carbon cycle for several reasons including strongly seasonal, short-term but high rates of biological productivity and the nearby formation of deep water. Since the mid 1980's modeling studies have suggested that polar oceans act as a window between the atmosphere and the deep sea, and that global atmospheric CO2 levels depend on the relative rates of upwelling of carbon-rich deep water and biological utilization of DIC in high-latitude surface waters. While these models are typically invoked for the Southern Ocean, this project aimed to determine if the Arctic Ocean might also play a role.

This project was part of a collaborative effort to evaluate seasonal patterns of biological production and respiration in the central Arctic Ocean. We collected weekly depth profiles and experimental samples from the yearlong SHEBA field station (October 1997-1998) in the central Arctic Oceans Canadian Basin. We also collected simultaneous springtime DIC measurements "upstream" in the Chukchi Sea during a USCG Science of Opportunity (SOO) cruise, AWS98. Over 1200 seawater samples for DIC and alkalinity were collected and transported to UGA for analysis. High-precision DIC measurements were made with a SOMMA linked to a coulometer; alkalinity was measured by potentiometric titration. Estimates of short-term repeatability on duplicate samples (DOE, 1997) are excellent (0.6 mol/kg or about 0.03 % for DIC). Accuracy is also excellent (assessed using Dicksons certified reference material).

Key results from this study include: (1) Seasonal changes in sea-ice melt, riverine flux, and biological activity all have strong quantifiable influences on surface DIC concentrations in the Arctic Basin.. (2) The Mackenzie River outflow (traced by high levels of salinity-scaled alkalinity) greatly influenced Arctic Ocean surface properties during Fall 1997. (3) Seasonal changes in salinity-scaled DIC concentrations concur with other net community production estimates, and suggest that the annual carbon cycle in the perennially-ice-covered Arctic is balanced over the upper 50 m. (3) A layer of very high DIC waters (greater than 2200 mol kg-1) existed year-round in the Canadian Basin (100 - 200 m), although it thinned significantly during the summer as SHEBA drifted northward. The concentration of DIC in these waters is the same as near-bottom shelf waters in the springtime Chukchi Sea, consistent with an advective link between the shelf and basin. (4) At SHEBA, near-surface pCO2 (under-ice) was supersaturated with respect to the atmosphere during winter, but undersaturated during summer. (5) Springtime under-ice algal blooms in the seasonally ice-covered Chukchi Sea draw pCO2 concentrations below equilibrium with the atmosphere before summer ice melt, con-

firming the springtime component of the seasonal rectification hypothesis (Yager et al., 1995) suggesting that the Arctic is a climate-sensitive sink for atmospheric CO2.

OS21D-71 0830h POSTER

Colloidal Fe accounts for a significant part of dissolved organic Fe-Complexes in the Southern Ocean

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Previous studies have shown that the chemical speciation of dissolved iron (Fe) is dominated, at the thermodynamic equilibrium, by the organic complexation in the oceanic waters (Rue and Bruland, 1995, 1997; Gledhill and van den Berg, 1994; Wu and Luther, 1995 ; Witter and Luther, 1998; Boye et al., 2000; Gledhill et al., 1998; van den Berg, 1995; Witter et al., 2000). In those studies, the organic speciation of iron was determined either in 0.45, 0. 3 or 0.2 microm filtered waters, currently defined as the dissolved pool. But it is not known whether the Fe-binding organic ligands (L) and the organic iron (FeL) are trully dissolved (soluble <200 kDa) or are small organic colloids (>200 kDa - <0.2 microm). This was investigated in this study with, for the first time, concomitant determinations of the organic speciation of Fe in both the soluble and the small colloidal fractions. Distributions at depth (0-1000 m) of the size-fractionated Fe and organic Fe-binding ligand were established in the ambient seawater at 4 stations located in the Atlantic sector of the Southern Ocean during the late austral spring [ANT18-2, RV Polarstern, Nov. 2000]. The physical speciation of iron showed that dissolved Fe (<0.2 microm) occurs predominantly in the smallest size-fraction, with soluble-Fe representing about 62% of dissolved-Fe. However, this fraction tends to decrease with depth to the benefit of colloidal-Fe (colloidal Fe = 15-83% of dissolved Fe below the euphotic layer). The size-fractionation of the dissolved organic ligand was dominated by soluble ligands at all depths, with 84.0% of dissolved-ligand concentration being smallest than 200 kDa. But the small colloidal organic ligand (>200 kDa-<0.2 microm) represented a significant fraction of the dissolved pool (about 4 to 35%), and this fraction tends to increase with depth (13 to 35% of the dissolved-L below 100 m). The organic speciation of dissolved iron as calculated at the thermodynamic equilibrium was dominated by the organic complexation, 99.6% of dissolved-Fe being complexed by the dissolved organic ligand. Separate calculations of the organic complexation of soluble and colloidal Fe also showed that soluble and colloidal Fe occured predominantly in organic complexes with soluble and colloidal organic ligand respectively. The size-fractionation of dissolved-Fe and its organic speciation are discussed in terms of geochemical impact and bioavailability of Fe for the antarctic biomass.

OS21E HC: Hall III Tuesday 0830h

Multidisciplinary Ocean Observations and Observatories III

Presiding: **S Riser,** University of Washington**; J Delaney,** University of Wasington

OS21E-100 0830h POSTER

Freak Waves in the Ocean - We Need Continuous Wave Measurements!

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Freak waves, sometimes also known as rogue waves, are a particular kind of ocean waves that displays a singular, unexpected, and unusually high wave profile with an extraordinarily large and steep trough or crest. The existence of freak waves has become widely known while it invariably poses severe hazard to the navy fleets, merchant marines, offshore structures, and virtually all oceanic ventures. Multitudes of seagoing vessels and mariners have encountered freak waves over the years, many had resulted in disasters. The emerging interest in freak waves and the quest to grasp an understanding of the phenomenon have inspired numerous theoretical conjectures in recent years. But the practical void of actual field observation on freak waves renders even the well-developed theories remain unverified. Furthermore, the present wave measurement systems, which have been in practice for the last 5 decades, are not at all designed to capture freak waves. We wish therefore to propose and petition to all oceanic scientist and engineers to consider undertaking an unprecedented but technologically feasible practice of making continuous and uninterrupted wave measurements. As freak waves can happen anywhere in the ocean and at anytime, the continuous and uninterrupted measurements at a fixed station would certainly be warranted to document the occurrence of freak waves, if present, and thus lead to basic realizations of the underlying driving mechanisms.

OS21E-101 0830h POSTER

Shore-based Mapping of Ocean Surface Currents at Long Range using 5 MHz HF Backscatter

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Increasing use has been made of HF radio-wave techniques to remotely sense ocean surface currents, from the Doppler shift they impose upon backscatter. Radio frequencies of 11-26 MHz have been most commonly used in commercial instruments such as SeaSonde, OSCR, and WERA; these typically allow current mapping to ranges of O(50km).

Recently, we have been operating an array of three SeaSondes designed for lower frequencies, near 4.8 MHz, between Winchester Bay, Oregon (43.7N) and Pt. St. George, California (41.8N). This mode of operation results in greatly extended range, to O(180km). Preliminary comparisons with data from upward-looking ADCPs show a strong correlation at subinertial frequencies; the SeaSonde, measuring the upper 2m, shows somewhat higher energy in the tidal/inertial band than the ADCP data, measured at 9m. Contrary to expectation, these locations have not shown a strong diurnal modulation in range.

Intermittent signal degradation of a type not seen at 11-28 MHz affects a fraction of the data. This degradation appears to be due to scattering from the lower layers of the ionosphere, and results in distinctive distortions of the cross-spectra. Data screening techniques based on these distortions are being tested.

OS21E-102 0830h POSTER

Coupled Physical/Bio-Optical Model Experiments at LEO-15

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A coupled Atmosphere-Ocean-Ecosystem high resolution model is used to study the inherent and apparent optical properties (IOPs and AOPs) associated with recurrent summer upwelling events off of the New Jersey Coast. The physical and bio-optical data gathered by the observational network at the Long-Term Ecosystem Observatory (LEO-15) is used to initialize, update, and validate the coupled system (COAMPS/ROMS/EcoSim). A series of real-time, atmosphere-ocean nowcasting and forecasting experiments were carried during July 2001 as part of the HyCODE adaptive sampling program. The forecasting schedule was tuned to the data sampling strategy which required a three-day forecast twice a week. The overall predictive skill of the atmosphere-ocean system was improved by increasing the horizontal resolution of the atmospheric model (COAMPS) to 5km, when compared to previous year resolution of 40km. The bio-optical simulations using EcoSim were done in hindcast mode.

URL: http://marine.rutgers.edu/cool/hycode2/hycode2.html

OS21E-103 0830h POSTER

Use of time derivative and local velocity in mapping a 2-D field

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A near-continuous measurement from a stationary observation platform allows estimation of the time derivatives. Additional co-measurement of the current velocity can lead to a constraint on the local spatial derivatives, as well. The effects of these derivative estimates on spatial structures of the measured field is investigated in this presentation. Twin experiments are conducted for the evaluation, and methods based on a simple spatial interpolation and a Kalman-filter assimilation are considered. Sensitivity of the derivative estimates to high-frequency variations (e.g., noise) is examined.

OS21E-104 0830h POSTER

Microwave SSTs: Current Achievements and Future Expectations

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The TRMM Microwave Imager (TMI) has produced passive microwave observations at 10.7, 19.4, 21.3, 37.0, and 85.5 GHz since December 1997. Accurate retrievals of sea surface temperature (SST) can be made in all weather conditions except rain. Microwaves penetrate clouds with little attenuation, giving an uninterrupted view of the ocean surface. This is a distinct advantage over infrared measurements of SST, which are obstructed by clouds. Comparisons with ocean buoys show a root mean square difference of about 0.57°C, which is partly due to the satellite-buoy spatial-temporal sampling mismatch and the difference between the ocean skin temperature and bulk temperature. The combination of 1-micron (infrared), 1-mm (microwave) and 1-meter (buoy) SSTs is yielding a better understanding of the ocean skin layer. Microwave SST retrievals are of adequate resolution and accuracy for a high-quality, long-term dataset for climate studies. Future missions (ADEOS-II, AQUA) will include microwave radiometers also capable of SST retrieval. Furthermore, an additional channel at 6.9GHz will increase accuracy, especially at temperatures below 10°C.

URL: http://www.remss.com

OS21E-72 0830h POSTER

ANAIS : Autonomous Nutrients Analyzer In Situ

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The ANAIS instrument is devoted to an autonomous, long-term in situ monitoring of the ocean. We are particularly interested in measuring dissolved nutrients, key players of the oceanic carbon cycle. This led us to develop a chemical analyzer ANAIS, able to measure simultaneously dissolved nitrates, silicates and