POSTER SESSION 1: TOPIC 3
Climatic Modulation of Organic Matter Fluxes

PS1: 3.1
Production and Exportation of Carbon : control by HEterotrophic organisms at small time scales (PECHE)

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PECHE is designed to examine pelagic ecosystems variability at small time scales in response to transient events. Biological structure is strongly coupled to physics and accordingly varies over a large range of time and space scales. A better understanding of processes at small time scales may be vital for calculating reliable budgets for the long term periods (seasons to years). Seasonal transition periods appear particularly critical in this context as they may influence both seasonal and interannual variability.
The project will examine short-term variabilities of primary production and export fluxes to depth. It focusses on the control by heterotrophic organisms (from bacteria to macrozooplankton) and on the response of the system to episodic events during a seasonal transition period, along depth. Field work will be done on two shorter cruises in April (maximum zooplankton abundance) and July 2003 (minimum downward flux) and during a one month time-series in September-October 2004. The specific objectives of the three observation periods are:
- Characterisation of the relative impact of zooplankton and bacteria in the mineralization of organic matter, taking into account their diversity and function.
- Quantification of this mineralization within the heterotrophic web as it varies with depth.
- Estimation of the response of the ecosystem to transient episodes of external forcing, such as wind events, at small time scales (hours, days) during the seasonal transition from summer to autumn. This will be studied during the multidisciplinary cruise DYNAPROC 2 that will also integrate the process studies performed during the other seasons.
This study will be conducted in the central zone of the Ligurian Sea (NW Mediterranean) where advective movements are negligible.

PS1: 3.2
Diatoms in control and at risk: climate feedbacks and anthropogenic forcing.

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Diatoms are the workhorses of the pelagic ocean, at the base of eutrophic food chains leading efficiently to higher trophic level productivity. The requirement for silica for construction of the diatom frustule makes this group uniquely subject to silicate limitation, as has been shown for the equatorial Pacific upwelling region. The flux of biogenic silica to sediments in the equatorial Pacific and the Southern Ocean decreased as atmospheric CO_2 decreased during the approach to glaciation, implying increased silicate limitation for diatoms. Model results suggest an active role for diatoms in the outgassing of CO_2 at the equator. This control by diatoms and the reduction in silicate input from rivers due to cooling and drying of the climate offers a feedback mechanism between climate variability, diatom productivity and CO_2 exchange. In addition to climate forced impacts, risk to diatoms also comes from anthropogenic sources. Reduced input of silicate due to damming of rivers and changes in water use patterns, and increased input of inhibitory levels of ammonium to estuaries and adjacent coastal waters affect diatom success. The high ammonium concentrations prevalent in some estuaries, a result of anthropogenic inputs from sewage treatment plants and agricultural runoff inhibit the uptake of nitrate by diatoms which draw primarily on nitrate for high growth rates. In San Francisco Bay diatom blooms occur when sufficient freshwater input reduces ammonium and allows nitrate uptake. In dry years, ammonium remains high and diatom blooms are absent. The role of climate in modulating diatom new production and sinking flux, both at the stimulatory and inhibitory levels is considered.

PS1: 3.3
Climate Modulated Carbon Export In The North Pacific Ocean The Role Of El-Nino Events

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The subarctic Pacific Ocean experiences strong climate-modulated seasonal, interannual to decadal variations in meteorological and physical oceanographic conditions, which can have a profound influence on biological processes and carbon cycling in the region. A five year satellite database beginning from 1997, provided us with evidence of strong interannual variations in the supply of inorganic nitrate and new production in the subarctic Pacific in association with the El Niño of 1997. Although this data allowed us to view and describe large changes in new production along the entire breadth of the subarctic Pacific basin, our accessibility to a 25-year database of shipboard measurements enabled us to better focus on the western subarctic Pacific. Thus, in addition to the primary motive of corroborating our results from satellites, this exercise allowed us to obtain a clearer picture of the mechanistic connections between the atmosphere and the oceans, and the biological response to these changes. The results from this study make a compelling case that the primary driver for interannual variations in biological production in the western subarctic Pacific is the strength of the wintertime monsoonal winds. These winds can be particularly strong during El Niño years, when the Aleutian Low intensifies and moves southeastwards. During this period oceanographic conditions undergo several changes, which in tandem, contribute to an increase in the supply of nutrients as well as an increase in the overall area of the North Pacific coming under influence of high nutrients. Unusually calm springs that follow these windy winters provide water column stability required for phytoplankton to benefit from the availability of nutrients. The transition to La Niña results in a reversal of these conditions.

PS1: 3.4
Assessment of the importance of the carbonate pump.

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Marine carbon research in the past decade has been mainly devoted to the understanding and quantification of processes controlling the fluxes of organic matter in the ocean. Little attention has been paid until now to the particulate inorganic carbon whose net fluxes to the sediments are comparable to those of the organic matter. There remains still a large uncertainty in the production and the fate of biogenic calcium carbonate in the oceanic carbon cycle. In the framework of the Belgian global change programme, we have developed a project devoted to the study of the inorganic carbon cycle in the Bay of Biscay where coccolithophorid blooms occur frequently. The study focuses on processes associated with the oceanic production and dissolution of calcium carbonate, by combining field investigations, laboratory experiments and modelling efforts. The rate of primary production and of calcification by phytoplankton is evaluated by 14C incubation experiments during a coccolithophorid bloom-forming period in the area of investigation. The relative production of organic matter and calcium carbonate in the photic zone along a transect from the continental shelf across the slope to deep waters will be presented. A tentative mass balance of the carbon fluxes for this area will be constructed. These preliminary results confirm the importance that the calcium carbonate pump may play in open ocean.

PS1: 3.5

Primary productivity and biomass of size-fractionated phytoplankton in a coastal upwelling area (Bahía Mejillones, 23ºS, Chile), during and after the 1997-1998 El Niño

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Coastal waters off Antofagasta (23ºS) are located in the Humboldt Current System, one of the major coastal upwelling region of the world. In this study we examine the temporal distribution of size-fractionated primary productivity and biomass in a coastal area, Bay of Mejillones (Antofagasta, Chile, 23ºS). We presented results obtained during 8 visits to the area over a 5-years sampling carried out between 1997 and 2002, that included El Niño of 1997-1998.
The mean values of primary productivity (integrated over the photic layer) estimated during the eight cruises ranged between 1116 to 8184 mg C m^{-2} d^{-1}. During Winter 1997 and Summer 1998, when El Niño took place, the observed primary productivity, 1800 mg C m^{-2} d^{-1}, was only third one of that estimated during Summer-Winter 2001. Primary productivity during Spring 2000, increased to a mean of 8000 mg C m^{-2} d^{-1}, an increase of 400% over the productivity during the Winter 1997 El Niño.
During El Niño, the pico and nanophytoplankton (< 20 um) were the dominant size classes, contributing more than 50% of chlorophyll *a* and primary productivity in coastal waters. After that period, almost always microphytoplankton dominated in total biomass and total primary production, even in low productivity and biomass seasons (Spring 2001 and Summer 2002). The flux rate of diatoms (dominant phytoplankton group) was very low during EL Niño conditions (January 1997-98) with values between 0.02 and 0.2 mg C m^{-2} d^{-1}). During February 2001 still low and increased two orders of magnitude during winter and spring 2001 (28 mg C m^{-2} d^{-1}).

PS1: 3.6

Organic carbon fluxes and paleoproductivity in the Eastern Barents Sea: responses to climatic changes during the Holocene and the last Millenium

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Variations in several paleoproductivity proxies including planktic and benthic foraminifer abundance and fluxes, TOC content and fluxes are studied in several deep-sea cores from the Eastern Barents Sea. As a result, we evaluated the impact of climatic variations on paleoproductivity changes during the Holocene with the time resolution of several hundreds of years, and during the last 800 years with decadal-to-century resolution based on AMS 14C dates. The high values of TOC and foraminiferal proxies generally correspond to the phases of increased sedimentation rates in the Early Holocene (about 11 to 6 cal ka BP.), thus reflecting a combined effect of enhanced productivity and intense terrigenous material supply from melting glaciers that resulted in the faster fresh organic matter burial. The high productivity events responded to a retreat of sea ice margin and longer ice-free seasons caused by climate warming and more intense Atlantic water inflow into the Barents Sea. Climatic changes also control the paleoproductivity and TOC fluxes in a Russkaya Gavan' (Novaya Zemlya) fiord during the last millenium. Maximum TOC fluxes occurred in 15th to 16th centuries (early Little Ice Age) when glacier front advanced into the fiord. A sharp decrease in productivity and organic matter fluxes at the beginning of 17th century corresponds to LIA culmination. The 20th century warming resulted in an intensification of bottom water exchange with the open sea and increasing trend of productivity.

PS1: 3.7
Limited Role of Export Production in Glacial-Interglacial CO_2 Cycles?

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Recent in situ experiments in the ocean have shown that marine productivity increases when iron availability increases. It has long been hypothesized that this effect may be responsible for part of the 80 ppm drawdown in atmospheric CO_2 at the Last Glacial Maximum (LGM), when atmospheric dust deposition was >2 times larger than it is today.
Results from models of varying complexity suggest that this effect is responsible for 8-40 ppm, and for large regional changes in biological export production in the ocean. Here we use observations and a model to assess whether or not the remaining CO_2 drawdown not related to dust increase is also associated to changes in export production. We study two time periods: the LGM where all physical, chemical and biological changes were at their maximum intensity, and Stage 5a-d (80 to 110 kyr ago) where atmospheric dust deposition had not yet started to increase but CO_2 had already gone down by 50 ppm. We compiled a global dataset of export production using 10 different indicators from over 140 deep-sea cores for the LGM, and from over 45 cores for Stage 5a-d. To investigate the mechanisms, we used a state-of-the-art ocean biogeochemistry model forced by LGM boundary conditions, with and without enhanced atmospheric dust deposition. The observations highlight distinct regional changes in export production. At the LGM compared to today: export production was reduced south of 50°S and in the eastern North Pacific, but increased in Subantarctic and northwest Pacific. During Stage 5a-d, export production south of 50°S was already reduced to near-glacial levels, but it had not yet increased to glacial levels in the Subantarctic. Furthermore, export production across the entire western Pacific was lower at Stage 5a-d compared with the LGM and today. The model can reproduce the patterns of export production during Stage 5a-d with changes in ocean circulation only. However, to reproduce the LGM patterns, increased iron deposition must be further imposed. The model suggests that increased export production only had an impact on atmospheric CO_2 between Stage 5a-d and the LGM. Based on observations in the Atlantic and western Pacific Oceans, our analysis suggests that the first 50 ppm of atmospheric CO_2 drawdown would not be caused by an increase in export production, but would be more consistent with changes in physical or chemical processes.

PS1: 3.8
Rapid Analysis of Carbon Isotopic Compositions of Sedimentary Algal Sterols

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We are developing a new procedure to produce highly resolved records of 13C in algal sterols. The procedure includes: (i) recovery of geolipids from dry sediments by extraction in organic solvents; (ii) chromatographic fractionation of the extract on silica gel; and (iii) removal of n-alcohols with Silicalite. Simplifications allow processing of 24 samples per day. Miniaturization has reduced the amount of sediment required to 300 mg. The 13C of the extract is measured using a moving-wire combustion system initially developed to accept the effluent of a liquid chromatograph (Brand and Dobberstein, 1996). Analyses are made at 25-sec intervals with an average standard error of 0.15‰ for samples ranging from 200 to 900 ngC. Comparison of the resulting records of the isotopic composition of algal lipids to parallel analyses of inorganic carbon allows calculation of the isotopic fractionation associated with primary production and thus provides information about conditions in the photic zone. It serves also to identify samples in which more detailed, compound-specific analysis would be worthwhile. A highly-resolved record of 13C in polar lipids from a sediment core collected on the Oman Margin (ODP 723B) indicates fractionations between 20 and 25‰. Increases in the fractionation could be caused by slowed rates of growth, an increase of the surface area/volume ratio of the community or an increase in the concentration of CO_2. Such changes could be related to varying strengths of upwelling, supplies of key nutrients, or to changes in the dominant population in the producer community.

PS1: 3.9

Seasonal and spatial Variability of the phytoplankton composition infered from photosynthetic pigments inventories: preliminary results from the GeP&CO experiment

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Marine primary production has different geochemical consequences depending on the species that dominate the phytoplankton. These species, or groups of species, have photosynthetic pigments that differ in nature or proportion from one to another. Identifying phytoplankton groups from pigments assemblages is a difficult task which requires a priori knowledge of the pigments ratios (i. e. abundance of a given pigment by reference to its chlorophyll a content) of the main groups in each provinces. We combine here a classification of pigments inventories and the CHEMTAX approach to derive the relative abundance of phytoplankton groups in samples collected in a large variety of oceanic conditions. These samples have been collected quarterly during three years at the sea surface along a shipping line from Le Havre (France) to Nouméa (New Caledonia), and are thus representative of the seasonal variability in the North Atlantic, Caribbean sea, Gulf of Panama, Equatorial Pacific, South Pacific Subtropical Gyre and Southwest Pacific. The results are compared to cells counts when these are available : flow cytometry counts of Prochlorococcus, Synechococcus and picoeucaryotes, and microscope counts and identifications of coccolithophorids. An attempt is made to establish relationships between satellite detected seawater reflectances and the average phytoplankton composition in oceanic provinces.

PS1: 3.10
Decadal Warming and Change in Annual Cycle of Phytoplankton Blooms in the Black Sea

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The basin-averaged, monthly AVHRR sea surface temperature data since 1985 together with the CTD data from various field surveys suggest that the Black Sea upper layer waters possess more than $2^{o}C$ warming during the last decade. The subsurface signature of warming is evident by a gradual depletion of the Cold Intermediate Layer (characterized by $T<8^{o}C$) throughout the basin. The warming trend accompanies with a shift at the timing of primary chlorophyll peak of the year. The satellite-derived phytoplankton pigment data since November 1996 indicate the strongest peak persistently taking place in autumn months, whereas it was used to occur in February-March prior to early '90s. Both warming and season-long, enhanced autumn phytoplankton production introduce favorable conditions for the growth and overwintering of small pelagic fishes, and thus contribute to the recovery of anchovy stocks after their dramatic collapse at the beginning of 1990s. This and other accompanying changes in the nutrient cycling and food web structure, characterizing impacts of natural climatic and anthropogenic forcings, suggest transformation of the Black Sea ecosystem to a new regime during the second half of the 90s. This new regime reflects a sign of considerable improvement from its heavily eutrophic state of the previous decade.

PS1: 3.11
Quantification Si and C decoupling in the world ocean

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Biogenic silica (opal) has a high potential as a paleoproductivity proxy. The deciphering of this sedimentary record, however, is complicated by spatial and temporal variations in opal preservation and by the decoupling between Si and C biogeochemical cycles. Within the EU-SINOPS project, data sets of Si and C production, water column fluxes and accumulation in sediments have been gathered. 9 regional budgets of Si and C fluxes have been built, for 5 sites located inside the Southern Ocean and for 4 sites outside. Within each reservoir, the highest Si:C flux ratios are found in the Southern Ocean. The mean values calculated for the 5 Southern Ocean sites are ca. 6-times higher than outside, in surface waters as in deep waters and in the sediments. Only during export, is this difference reduced because of higher Corg export efficiency in the Southern Ocean. Regional differences in Si:C production ratios encompass one order of magnitude and can be explained by silicic acid availability in the intermediate waters of the various basins considered, as modulated by growth conditions in surface waters. These differences are transported quasi-unchanged down to the sediment. At all sites, the strongest downward increases in the Si:C flux ratio are found between production and export (factor 6), and between the rain and the accumulation (factor 4). This highlights the importance of grazing in the relative enrichment of the biogenic particles with Si. During the transfer through deep waters, the Si:C flux ratio increases only slightly (factor 1.3). A unique equation has been formulated, which allows a good prediction of the fate of the Si:C flux ratio at each depth once the Si:C production ratio is known, and vice-versa. It is tested with a data set of sediment trap fluxes collected at ca. 90 sites, to reconstruct surface Si:C ratios from deep water ratios, and compare them with existing data and outputs of the Hamburg HAMOCC model.

PS1: 3.12
A Profiling Buoy System for real time monitoring of the Ocean Primary Productivity

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As a part of the Core Research for Evolutional Science and Technology (CREST) we are developing a profiling buoy system to measure ocean primary productivity in a real-time fashion, for the purpose of near-real time validation of the satellite derived estimate of primary productivity. The objectives of the project (POPPS: Project on Ocean Productivity Profiling System) is twofold; One is to develop a buoy system to obtain profiling measurements of optical parameter necessary calculate in situ primary productivity. The other is to develop an algorithm to estimate the daily net primary productivity in a unit area of the water column (the unit gC m-2 day-1) from the data obtained by the optical instruments.

The buoy system composes of an underwater winch unit, and a profiling buoy unit. The winch unit has capability of acoustic data transmission between the profiling unit and on-board controlling unit. The profiling buoy unit carries three optical sensors (FRRF, PRR800, PAR) in addition to CTD and a 3-D attitude sensor, and has capability of data processing, radio and acoustic data transmission. Field and laboratory tank test are being carried out, and the first operational model was delivered in the end of September 2002.

Our algorithm to estimate the net primary productivity utilizes measurements on photosynthetic properties of phytoplankton by an FRRF, chlorophyll a profile estimated from downward spectral radiance using a neural network, and a daily PAR insolation estimated by cloud amount detected by a geometeorological satellite. A validation program is now underway in Sagami Bay, Japan.

PS1: 3.13
Vertical distribution of the Dissolved Organic Carbon (DOC) in different areas of the Mediterranean Sea

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DOC vertical profiles in different areas of the Mediterranean Sea were studied during several oceanographic cruises carried out from January 1999 to September 2001. An accurate description of the DOC behavior, in relation to the hydrological structures occurring in the in the water column of the different areas, was performed by focusing similarities and differences. The study areas were located in key points for the water mass circulation in the Mediterranean Sea. They were: the Ionian Sea, where important change in the thermohaline circulation have been observed in the last ten years because of the formation of new Cretan waters, that have replaced the intermediate and deep layers previously occurring. The Sicily strait, the Sardinian Channel and Tyrrhenian Sea, where all the water masses, circulating in the Mediterranean have a route. In general DOC vertical profiles exhibit the highest values in surface waters and the lowest in the intermediate layers, while, in the deep waters, they show different trends. Important links were found between DOC distribution and the hydrological structure of the water column in the different areas. In particular, each water mass showed a characteristic concentration of DOC. This finding has been attributed to the age, origin and route of the different water masses. In particular, the Levantine Intermediate Water (LIW), that is the oldest water mass circulating in the Mediterranean, shows the lowest DOC concentrations in both the Ionian and the western part of the Mediterranean Sea. In contrast, the deep waters, younger than LIW, because derived by the sinking of surface waters of recent origin, exhibited higher DOC concentrations.

PS1: 3.14
228Ra/226Ra activity ratio in suspended matter to track barite formation and transport in the water column

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In recent years, several geochemical proxies were developed in order to better constrain past changes in the flux of organic matter exported from the euphotic layer. Among these proxies, barite (BaSO4) crystals appear to be very promising. These crystals are assumed to be precipitated within microenvironments formed during the decay of organic matter in the upper water column. However, a lack of understanding of the mechanisms of barite formation in undersaturated seawater has hindered rigorous application of the proxy.
Chemical analogues of barium, radium isotopes (i.e. 228Ra, T1/2=5.75 y, and 226Ra, T1/2=1602 y) are incorporated in barite and can be used to trace these crystals in the water column. In this work, we present 228Ra/226Ra activity ratios measured in suspended matter (that reflect the ratios in suspended barite) collected in oligotrophic regions using large volume *in situ* pumps. The profiles thus obtained are compared to those from the seawater and from the sinking matter collected using sediment traps. These results provide information on both the depth of formation and transport of barite within the water column, with implications for the use of barite as a proxy for productivity.

PS1: 3.15
Nutrient entrainment by storms in an oligotrophic ocean

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Nutrient flux to euphotic zone in an oligotrophic anticyclonic eddy has been observed in the northeast Atlantic, immediately after the spring bloom when surface nutrients were depleted. Before the storms, surface water nitrate concentrations in the eddy were below 0.1 micromol/kg. Increases in mixed layer nutrients were observed when large storms passed through the eddy. The maximum nitrate concentration during the major storm event reached 1 micromol/kg. The flux of nitrate to the euphotic zone depended on wind speed and duration of the storms. It is only for sustained wind speed higher than 15 m s-1 that a rapid increase in surface nitrate was observed. However, nutrient injection and biological uptake seem to be de-coupled in time due to unfavorable stormy weather for phytoplankton growth during the nutrient injection and the required time for phytoplankton to multiply as nutrients become available. There is a lag of about 24 hours between increased wind speeds and elevated nutrient level at the surface. The nitrate in the mixed layer disappeared within a couple days after the storms, suggesting a rapid nutrient uptake by phytoplankton. Biological community structure has been change from dinoflagellates dominated before storm to diatom dominated after storm. Although storm induced new production is episodic in nature it is two times larger than the daily diffusive flux. Increased storm intensity and frequency as predicted future global warming might act as a feedback to the climate change by increasing the carbon export through enhanced biological production.