Response of phytoplankton biomass to seasonally varying physical forcing along the coast of Oman.

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The response of phytoplankton biomass to seasonally varying physical forcing was investigated from a long time-series study to describe the factors that control phytoplankton population densities and biomass in the coastal waters of Oman.

Surface temperature, salinity, nutrients, dissolved oxygen, chlorophyll a (Chl a), and phytoplankton and zooplankton abundance of seawater were measured as far as possible from February 2004 through February 2006, at two stations along the southern coast of the Sea of Oman. The highest concentrations of Chl a (3 mg m-3) were recorded during the southwest monsoon (SWM) when upwelling is active along the coast of Oman. However, results from our study reveal that the timing and the amplitude of the seasonal peak of Chl a exhibited interannual variability, which might be attributed to interannual differences in the seasonal cycles of nutrients caused either by coastal upwelling or by cyclonic eddy activity. Monthly variability of SST and concentrations of dissolved nitrate, nitrite, phosphate, and silicate together explained about 90% of the seasonal changes of Chl a in the coastal ecosystem of the Sea of Oman. Phytoplankton communities of the coastal waters of Oman were dominated by diatoms for most part of the year, but for a short period in summer, dinoflagellates were dominant.

Impact of mesoscale variability on mixed layer depth and phytoplankton bloom in Kerguelen region.

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The Kerguelen Plateau is a shallow submarine plateau of great meridional extent (□16◦ between 46◦ S and 62◦ S) located in the Indian sector of the Southern Ocean and surrounded by deep basins. This plateau forms a natural barrier to the Antarctic Circumpolar Current (ACC) which exhibits strong meandering and eddy activity. A phytoplankton bloom, with a strong interannual variability is observed downstream Kerguelen plateau. The large scale circulation pattern of this area is well known from recent field campaigns but little is known about the impact of mesoscale activity on the spatial and temporal variability of Kerguelen phytoplankton bloom. In particular, mesoscale activity is likely to strongly control the spatial patterns and the interannual variability of mixed layer depth downstream the plateau and therefore affect the phytoplankton bloom properties.

Here, we investigate the impact of mesoscale dynamics on mixed layer depth and phytoplankton bloom downstream Kerguelen plateau. To this purpose, a regional modelling study of the South Indian Ocean dynamics and biogeochemistry is carried out. Two model experiments based on NEMO-PISCES are run over the period 2000-2011 : one at low resolution (0.5◦) and one at higher eddy-resolving resolution (1/12◦). First, the impact of model resolution on the simulated surface circulation is evaluated against available observational datasets. Second, the changes in mixed layer depth spatial distribution and temporal variability with increasing model resolution are investigated. Finally, we discuss how phytoplankton bloom onset and duration are affected by changes in mixed layer depth due to model resolution. These results will help understanding the mechanisms controlling the interannual variability of Kerguelen bloom.

Primary production of phytoplankton and chlorophyll concentration in waters of the Canary Upwelling

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There were analyzed the long-term data on primary production (PP) and chlorophyll "a" concentrations (Chl), which were obtained during 14 research cruises in the area of Canary Upwelling (16-36° N; 6-18° W) in 1994-2008. Chl and PP were investigated on the shelf in depths from 15 to 1000 m. PP was measured at 428 stations, and Chl at 1194 stations. PP was measured according to the radiocarbon method using short-term exposition. Bottles were placed in flowing incubator where light intensity was simulated in accordance with the sampling depths (100, 69, 46, 25, 10, 3, 1% of subsurface light intensity). The Chl were determined measuring fluorescence. At stations where PP was measured, the Chl was determined at the same 7 depths (100-1%) and at the depth of 100 m. At other stations Chl was determined at 7 depths (0, 10, 20, 30, 50, 75, 100 m).

The area of Canary Upwelling is one of the most highly productive areas of World Ocean. The highest values of PP and Chl were observed in areas of all-the-year-round upwelling (21-24° N) and location of Senegalese-Mauritanian thermal front (to the south 21° N). Contact of these zones results in formation a continuous highly productive zone from 24 to 19° N, in the summer. The waters of eutrophic and hypertrophic status predominate (PP – 1.3-4.2 $gC \cdot m^{-2} \cdot d^{-1}$), Chl "a" in the layer of 0-100 m - 100-370 mg / m^2). Northward of 24° N the upwelling is of seasonal nature. The most intensive coastal upwelling occurs in summer, causing higher values of PP and Chl (up to 2 times) comparing with winter. Northward of 24° N, highly productive areas have local character, and their distribution may change yearly. Usually they are located at a coast (in area of Agadir bay and capes Bojador, Juby, Ghir), where the strongest upwelling is observed (PP – 1.3-4.0 $gC \cdot m^{-2} \cdot d^{-1}$, Chl in photic zone - 75-220 mg/m^2). Southward of the Senegalese-Mauritanian front (16-19° N in the summer) upwelling is almost absent, the waters oligotrophic and mesotrophic status predominate (PP- 0.3-1.3 $gC \cdot m^{-2} \cdot d^{-1}$, Chl in photic zone 5-50 mg/m^2). For all the area the regularity of gradual transition from eutrophic and hypertrophic waters in a coastal zone, to mesotrophic and oligotrophic waters, in places of penetration on a shelf of oceanic waters, was observed.

Southward of 21° N (EEZ Mauritania) the spatial distribution of PP and Chl corresponds to surface concentration of phosphate (*P*) and temperature of water (*t*). The highest values of PP and Chl "a" were observed in areas of lower surface *t* and higher concentration of phosphate that was caused by lifting of waters from intermediate depths. E.g., in 2004 the zones of intensive phytoplankton development and high PP precisely corresponded *t* below 26°C and *P* higher 0,2 µmol/l. The *t* was the indicator of the border dividing the rich with nutrients eutrophic and hypertrophic waters which are formed in zone of intensive upwelling and location of Senegalese-Mauritanian thermal front, and mesotrophic and oligotrophic warm (>25° C) tropical waters. The good equations relating average and integrated in water column values Chl and PP to the surface *t* (R^2 = 0.60-0.84) and surface *P* (R^2 = 0.56-0.79 in different years) were derived. Northward of 21° N (EEZ Morocco) the highest values of PP and Chl also were observed in zones coastal upwelling, where the *P* was higher 0.2 µmol/l, but good correlations with surface concentration of phosphate and *t* was't derived.

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Use of the surface chlorophyll concentrations for calculation of depth-integrated values of primary production and chlorophyll in water of the Canary Upwelling and the Atlantic Part of Antarctica

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The data on chlorophyll “a” concentrations (Chl) and primary production (PP) allow to estimate the biological productivity of waters and to carry out the analysis of food web dynamics. Shipboard direct measurements of depth-integrated values of PP and Chl are limited in duration and the area of the field observation. Use of the satellite data is limited because they do not allow to obtain the data on PP directly, and estimations of Chl pertain to surface waters only, whereas research of productivity of waters requires information on depth-integrated values of PP and Chl.

There were analyzed the long-term data on PP and Chl, which were obtained AtlantNIRO during 13 research cruises in the area of Canary Upwelling (16-36° N; 6-18° W) in 1994-2004 and 6 research cruises in the Atlantic part of Antarctica (52-68° S; 18-60° W) in 1984-2000. In waters of the Antarctic Region PP was measured at 229 stations, and Chl at 314 stations. In the area of Canary Upwelling PP was measured at 402 stations, and Chl at 1121 stations. PP was measured according to the radiocarbon method using short-term exposition. Bottles were placed in a deck flowing incubator where light intensity was simulated in accordance with the sampling depths (100, 69, 46, 25, 10, 3,1% of subsurface light intensity). The Chl were determined measuring fluorescence. At stations where PP was measured, the Chl was determined at the same 7 depths (100-1%) and at the depth of 100 m. At other stations Chl was determined at 7 depths (0, 10, 20, 30, 50, 75, 100 m).

The large areas, where PP and Chl were measured, are formed by the various water masses which considerably differ in hydrological, hydrochemical and biological parameters. It is the reason for large range of obtained values of PP and Chl, corresponding to waters of the variability from distrophic to hypertrophic (PP – 0.02-4.64 gC/(m^2·day), Chl “a” – 3-241 mg/m^2 in a layer of photosynthesis and 5-698 mg/m^2 in layer of 0-100 m). For these areas the excellent equations relating surface Chl “a” to the average in a layer of photosynthesis PP (R^2 = 0.77-0.81), average Chl “a” in a layer of photosynthesis (R^2 = 0.91-0.95) and a layer of 0-100 m (R^2 = 0.80-0.86) were derived. Also the good equations between surface Chl “a” and the integrated for water column values of PP (R^2 = 0.64-0.69), Chl “a” in a layer of photosynthesis (R^2 = 0.72-0.91) and a layer of 0-100 m (R^2 = 0.64-0.86) were derived. These equations allowed to calculate a level and spatial distribution depth-integrated values of PP and Chl “a” for all surveys data since 1984 to 2004. The calculated values of PP and Chl “a” differed from shipboard direct measurements in waters of the Antarctic Region by 1-11 % and 6-25 % and waters of the Canary Upwelling by 1-37% and 2-34%. High accuracy of estimation was observed, taking into account that the mean area values of PP and Chl varies in waters of the Antarctic Region by 400-800% and waters of the Canary Upwelling by 200-400% in different years. So these dependencies, which were calculated on the base of long-term investigations of large areas of Atlantic ocean with waters of various trophic status (from distrophic to hypertrophic), confirm possibility of calculations of the depth-integrated values of PP and Chl “a” and their spatial distribution using shipboard or satellite measurements of the surface Chl “a” concentrations.

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First inventory and richness of the benthic community of the Gulf of Arzew.

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Abstrat

The Distribution's study of the macrobenthic community in the of Arzew's gulf, has enabled to inform us about the macrobenthos living in an area close to the largest industrial area in Algeria. The study of 46 selected stations between-16m to 96m was collected using the grab Aberdeen. A subsample of sediment was used for the study of sedimentary texture funds Gulf TWINSPAN classification (Two Way Indicator Species of ANalysis) based on the abundance of each species allows us to approach the description of the benthic fauna. The dominant species are those that have the biological characteristics and ecological preferences are most appropriate for different types of habitats of the Gulf. The faunal analysis serves to highlight the one hand the main species, characteristics, indicative of pollution and major dominant ecological stocks. Regarding data processing AFC gives the same results, a collection of stations and species according to similarities between them and their ecological preference to the sedimentary cover of the Gulf. This approach provides a parallel observation biological environment, to develop a functional richness of aquatic ecosystems and considered to offer an integrated management to the problems of pollution of the industrial zone of Arzew.

Keywords: Macrobenthic community – Arzew's gulf – Sedimentary texture –TWINSPAN – Ecological preference – Integrated management

The structure of planktonic communities under variable coastal upwelling conditions off Cape Ghir (31°N), in the Canary Current System (NW Africa)

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Cape Ghir (31°N) is an area of permanent coastal upwelling with maximum intensity in summer-autumn, when a stronger across-shore thermal gradient and increased mesoscale activity are also present. The effects of spatial (a coastal-ocean transect with 7 stations) and temporal (5 dates: from December 2008 to October 2009) variations in upwelling conditions on the structure of planktonic communities was investigated. Two main upwelling phases were identified: weak and moderate. These phases were mostly influenced by nutrient concentration (space), and by sea surface temperature and number of days favourable to upwelling (time), largely influencing plankton biomass and community structure. Total chlorophyll-a (Chl-a) was dominated by the nanoplankton fraction (flagellates and dinoflagellates), whereas microplanktonic diatoms and dinoflagellates were the main contributors to the autotrophic carbon (C). This implies that constant C:Chl-a conversion factors usually used for estimations of autotrophic biomass and, eventually, for primary production, are not appropriate for this region. The relatively lower contribution of microplankton to Chl-a might result from a suboptimal physiological state in the case of diatoms (Si or N limitation) or a significant contribution of mixotrophic forms in the case of microplanktonic dinoflagellates and ciliates. The mean heterotrophic(H):autotrophic(A) biomass ratios were mostly ≤ 1 when the contribution of mixotrophs was considered in the calculations but >1 (inverted pyramid) without it. This result points out that biomass estimates of autotrophs in coastal and oceanic regions not dominated by diatoms need to evaluate more properly the inclusion of mixotrophs.

Parameterization of vertical chlorophyll a in the Arctic Ocean: Impact of the subsurface chlorophyll maximum on regional, seasonal and annual primary production estimates

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Predicting water-column phytoplankton biomass from near-surface measurements is a common approach in biological oceanography, particularly since the advent of satellite remote sensing of ocean color (OC). In the Arctic Ocean, deep subsurface chlorophyll maxima (SCMs) that significantly contribute to primary production (PP) are often observed. These are neither detected by ocean color sensors nor accounted for in the primary production models applied to the Arctic Ocean. Here, we assemble a large database of pan-Arctic observations (i.e. 5206 stations) and develop an empirical model to estimate vertical chlorophyll a (chl a) according to: (1) the shelf-offshore gradient delimited by the 50 m isobath, (2) seasonal variability along pre-bloom, post-bloom and winter periods, and (3) regional differences across ten sub-Arctic and Arctic seas. Our detailed analysis of the dataset shows that, for the pre-bloom and winter periods, as well as for high surface chl a concentration ($\mathrm{chl}\,a_{\mathrm{surf}}$; 0.7-30 mg m^{-3}) throughout the open water period, the chl a maximum is mainly located at or near the surface. Deep SCMs occur chiefly during the post-bloom period when $\mathrm{chl}\,a_{\mathrm{surf}}$ is low (0-0.5 mg m^{-3}). By applying our empirical model to annual $\mathrm{chl}\,a_{\mathrm{surf}}$ time series, instead of the conventional method assuming vertically homogenous chl a, we produce novel pan-Arctic PP estimates and associated uncertainties. Our results show that vertical variations in chl a have a limited impact on annual depth-integrated PP. Small overestimates found when SCMs are shallow (i.e. pre-bloom, post-bloom >0.05 mg m^{-3} and the winter period) somehow compensate for the underestimates found when SCMs are deep (i.e. post-bloom <0.05 mg m^{-3}). SCMs are, however, important seasonal features with a substantial impact on depth-integrated PP estimates, especially when surface nitrate is exhausted in the Arctic Ocean and where highly stratified and oligotrophic conditions prevail.

Variability in primary production, carbon stocks and fluxes, plankton community structure and metabolic balance, along the Cape Guir filament (NW Africa): A lagrangian approach

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We have studied the variability in dissolved and particulate organic matter, plankton biomass, community structure and productivity, vertical carbon fluxes and the plankton metabolic balance, at 6 stations along the Cape Guir filament, following a lagrangian drifter. The study was carried out during a weak to moderate upwelling phase, following an intense upwelling period during the two previous weeks. The filament was revealed as a complex and variable system, with low inorganic nutrient concentrations and offshore decreasing trends in total chlorophyll, particulate organic carbon (POC), labile organic substances and heterotrophic production. The high POC:PON ratios in the water column suggest the presence of a large detrital component in the POC. Primary production (as carbon uptake) was variable but low along the filament. Nano- and picophytoplankton co-dominate both in terms of chlorophyll, cell abundances and metabolism, with little influence of larger forms. Community respiration (R) and heterotrophic production were high, shifting the oxygen metabolic balance to heterotrophy (R>Gross Production) at some of the stations. Carbon and nitrogen fluxes of particles, collected with drifting sediment traps, yielded values similar to previous studies in the same region, with a clear offshore decreasing trend. Overall, the filament behaved as a source of carbon to the atmosphere, due to both the thermodynamic effect of temperature on seawater carbon and the heterotrophic processes at surface. The strong mesoscale and submesoscale eddy fields interacting with the filament would help to recirculate organic matter towards the core of the filament and increase R, as observed in other NW Africa filaments. Our results suggest that during transient periods between strong upwelling events, remineralization processes dominate along the Cape Guir filament, reducing the effective transport of organic matter from the coastal upwelling to the open ocean.

An integrative view of the biological carbon pump: from the surface ocean to the deep sediment

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The importance of the global ocean as a carbon sink (or source) and thus its role during past, present and future climate change strongly depends on the efficiency and functioning of so-called 'biological carbon pump' – the complex set of interlinked processes involving the transfer of carbon fixed by primary producers in the euphotic zone to the deep ocean below, followed by its degradation, dissolution or burial in the sediments. Therefore, quantifying the efficiency of this biological carbon pump and understanding its response to and its feedbacks on global climate change is key to advancing our understanding of the global carbon cycle. Such quantitative understanding inevitably requires an integrative and fully coupled consideration of the different pelagic and benthic components that comprise the biological carbon pump. \ This presentation provides an integrative overview of the biological carbon pump that accounts for the complex interplay of transformations and fluxes from the surface ocean to the deep sediment. In addition, the spatial and temporal variability of the pump's efficiency will be explored and its impact on benthic fluxes assessed. Earth system models represent ideal tools to quantify this variability and to explore its response and feedbacks to carbon cycle perturbations. However, existing models often include highly simplified representations of the biological carbon pump that limited their prognostic and diagnostic use. Therefore, a better quantitative understanding of the biological carbon pump and its role in the Earth system will require a mechanistic "cradle-to-grave" description.

Estimating global-ocean primary production, and nutrient-light colimitation by combining remote-sensing data with an optimality-based phytoplankton model

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The concept of constant "Redfield" phytoplankton stoichiometry is still widely used in oceanography, e.g., for estimating the respective nutrient that limits phytoplankton growth in the surface ocean. Culture experiments, on the other hand, show a strong relation between nutrient limitation and cellular stoichiometry with often substantial deviations from Redfield stoichiometry particularly when one nutrient is limiting. Here we investigate to what extent both views can be reconciled by applying an optimality-based model of phytoplankton growth, which had been calibrated against culture studies, with remote-sensing and in-situ data in order to infer global and seasonally varying patterns of colimitation by light, nitrogen and phosphorus in the world ocean. Our joint model-data analysis suggests permanent nitrogen limitation in the tropical ocean, while northern-hemisphere high latitudes display seasonal nitrogen-light colimitation. The Southern Ocean is strongly limited by light, and we presume this limitation may be further intensified by accounting for iron effects in the model. Limitation by phosphorus appears unimportant throughout most of the world ocean. Based on these findings, we also seek to calculate global primary production rates using the optimality-based model and forcing environmental conditions (nitrogen and light) estimated via satellite data. We asses to what degree the spatial and temporal variability of the optimality-based model results compare to primary production rates derived from ocean color algorithms.

Synoptic scale variability of phytoplankton community uptake rates in the southern Benguela upwelling system.

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Understanding the mechanisms that control the proliferation of certain species or groups of species that share functional traits, is key to advancing our understanding of the structure of phytoplankton communities, including harmful algal blooms. Many biogeochemical models use uptake kinetic parameters that are scaled allometrically and generally assumed constant within functional groups or size class, throughout changing ambient conditions. This research aims to identify when deviations from the generally assumed size scaling exponent can be attributed to the particular responses of certain functional groups to their ambient environment and physiological state. The uptake of nitrogen from different sources is assessed as a functional trait that dictates the response, at a physiological level, of communities to their physical and chemical environment. During upwelling-downwelling cycles, blooms dominated by either Myrionecta rubra or Prorocentrum triestinum are analyzed in conjunction with the associated environmental data in order to establish the influence of controlling forces on their performance criteria.

Effects of photo-acclimation and variable stoichiometry of phytoplankton on production estimates from 1D and 3D marine ecosystem modelling

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The aim of this study is to evaluate the consequences of accounting for variable Chl:C (chlorophyll:carbon) and C:N (carbon:nitrogen) ratios in the formulation of phytoplankton growth in biogeochemical models.

First, we compare the qualitative behaviour of a suite of phytoplankton growth formulations with increasing complexity under oligotrophic regime: 1) a Redfield formulation (constant C:N ratio) without photo- acclimation (constant Chl:C ratio), 2) a Redfield formulation with diagnostic chlorophyll (variable and empirical Chl:C ratio), 3) a quota formulation (variable C:N ratio) with diagnostic chlorophyll, and 4) a quota formulation with prognostic chlorophyll (dynamic variable). These phytoplankton growth formulations are embedded in a simple marine ecosystem model in a 1D framework at the Bermuda Atlantic Time-series (BATS) station. The model parameters are tuned using a stochastic assimilation method (micro-genetic algorithm) and skill assessment techniques are used to compare results. The lowest misfits with observations are obtained when photo-acclimation is taken into account (variable Chl:C ratio) and with non-Redfield stoichiometry (variable C:N ratio), both under spring and summer conditions. This indicates that the most flexible models (i.e., with variable ratios) are necessary to reproduce observations. As seen previously, photo-acclimation is essential in reproducing the observed deep chlorophyll maximum and subsurface production present during summer. Although Redfield and quota formulations of C:N ratios can equally reproduce chlorophyll data the higher primary production that arises from the quota model is in better agreement with observations. Under the oligotrophic conditions that typify the BATS site no clear difference was detected between quota formulations with diagnostic or prognostic chlorophyll.

Second, the Redfield and quota formulations (both with variable Chl:C ratio) are compared at the scale of an oceanic basin with contrasted regimes. The aim is to describe the spatial and temporal variations of the phytoplanktonic C:N ratio at basin-scale and its impact on primary production. Here the ecosystem model is coupled to a 3D eddy-resolving model representing a double gyre circulation at basin-scale. Realistic values of C:N ratios for phytoplankton and production are simulated, with mesoscale, seasonal, and zonal variations, and are in agreement with previous *in situ* measurements. Taking into account phytoplanktonic plasticity through a variable C:N ratio (flexibility) smoothes the spatio-temporal variability of phytoplankton concentration and production compared to Redfield model (damping effect). Especially, production is increased in the southern low-productive oligotrophic gyre and decreased in the northern high-productive gyre (of +39% and -34%, respectively, for the production in carbon).

Low latitude export production and its high latitude nutrient sources: interannual variability

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Compared to high latitudes, export production at low latitudes (30N-30S) exhibits a high degree of interannual variability relative to its mean. A significant proportion of this tropical export production, 33-75%, is thought to be fueled by nutrients subducted in Subantarctic Mode Waters (SAMWs) 30-40 years prior. In this study we use hydrographic data from WOCE/CLIVAR to investigate interannual variability in SAMW nutrient loads and its potential drivers. We find that periods of increased upwelling (as approximated by wind stress curl (WSC)) south of the Polar Front and in the Antarctic Circumpolar Current are associated with increased nutrients in SAMWs at lag times of about 1 year. This implies that any high latitude biological response to the increased nutrient supply is insufficient to consume it before it becomes entrained and subducted in SAMWs. A one standard deviation change in WSC is associated with a 5-15% change in SAMW nutrient concentrations, which may be expected to induce corresponding variability in downstream tropical export production.

Biogeochemical Inferences from the Diel Variability of Optical Properties in the NW Mediterranean

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Characterisation and quantification of primary and community production remains a central theme of biological oceanography. Observed similarities between diel cycles of photosynthesis and inherent optical properties allows for quantification of biogeochemical variability with unprecedented temporal resolution. Yet observations of IOPs such as the beam attenuation coefficient (c_p) and the backscattering coefficient (b_{bp}) remain scant and of limited duration. This research aims to exploit a six-year high frequency measurement IOP time series at the BOUSSOLE site in the Mediterranean, to derive information on the diel, seasonal and interannual variability of particulate production at this site. The use of empirical relationships between c_p and particulate organic carbon to calculate net community production was examined. Results show that strong diel signals in c_p, and to a lesser extent b_{bp}, reflect diel patterns in carbon fixation. A morning maximum in the specific rate of variation of c_p was related to a higher rate of production. Distinct diel cycles were evident for different trophic states and across seasons (oligotrophy, mixing, bloom development and collapse), whilst interannual variability is shown to be relatively weak. Characteristic vertical profiles of IOPs are used to extend the methodology to allow determination of depth-integrated production. Comparisons are made between IOP-based methods and 'traditional' chlorophyll-based approaches used at the same high frequency to derive proxies of primary production. These results lend credence to the belief that c_p in particular may be used to infer biogeochemical properties; whilst the importance of a non-intrusive, high frequency methodology to characterise particulate productivity on a global scale should not be underestimated.

On the small range of net community production rates in the open ocean

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Over the past 20 years, the community has collected a large array of data constraining net community production (NCP) in the deep ocean away from coastal areas. Sources of data include studies of 15NO3- assimilation, seasonal variations in the distribution of nutrients and DIC in the upper ocean, and biological fluxes of O2 from sea to air as constrained by mixed layer O2/Ar ratios and gas transfer velocities. On seasonal and longer timescales, NCP is much greater than organic carbon accumulation in the upper water column, so that NCP must approximate carbon export production. Therefore NCP is an important rate term in ocean biogeochemistry as well as a key characteristic of the state of an ecosystem.

We summarize values of NCP where the density of measurements is sufficient to characterize the rate on a seasonal or annual timescale. Such regions include the boreal oceans, the north Atlantic and North Pacific subtropical gyres, the equatorial Pacific, and the Southern Ocean. This global summary of NCP shows that, in most regions, the rates fall within the range of 1-4 moles C m-2 yr-1. This range agrees with estimates of export production based on nutrient distributions in the dark ocean and seasonal variations in the O2/N2 ratio of air.

This modest variability in time-integrated NCP is surprising given the large variations in light fields, iron supply, and nitrogen and phosphorus concentrations in the different study regions. We do not completely understand the limited variability but can recognize some of the contributing factors. First, light penetrates more deeply when chlorophyll concentrations are low, increasing NCP integrated throughout the euphotic zone. Second, organisms migrate vertically to acquire deep nutrients for production at shallower depths. Third, N2 fixation provides N where NO3- concentrations in the water column are low. Fourth, the growing season is short in nutrient-replete waters of the subpolar and polar oceans. Fifth, the ratio of carbon export/gross photosynthesis is lower in warmer waters with higher productivity.

Using gliders to measure seasonal variability in dissolved oxygen at a time series station in the North Atlantic.

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Measurements of primary production have to cope with several challenges (such as costs, temporal and spatial limits, patchiness) that hamper scientists in their effort of obtaining valuable and comparable data.This raises the need of in situ surveys able to cover large time spans and geographical ranges with reasonable costs. The OSMOSIS project aims to collect a year-long data series using Seagliders, i.e. autonomous underwater vehicles that can dive up to 1 km of depth, communicate via Iridium satellite and are equipped with sensors for different parameters (temperature, conductivity/salinity, oxygen, chlorophyll a fluorescence, photosynthetically-active radiation) [Eriksen et al., 2001]. Three pairs of Seagliders are going to be deployed for missions of about 4 months' duration each around the PAP site in the Porcupine Abyssal Plain/North Atlantic between September 2012 and September 2013. A mooring array supplements the data with meteorological and oceanographic measurements. As part of the OSMOSIS project, we will use dissolved oxygen measured by Aanderaa 4330F optodes to study variations in net community production over an annual cycle. We want to explore different hypotheses about what causes phytoplankton blooms, what parameters influence their vertical extent and intensity, related to variations occurring at the mesoscale and their triggering factors (eddies, upwelling, atmospheric input of nutrients). The oxygen sensors are calibrated in situ using collocated CTD casts, when Seagliders are deployed and recovered. Here, we report on initial calibration results from the first deployment and recovery between September 2012 and January 2013. We describe our calibration strategy using Winkler samples to calibrate high-resolution, ship-board CTD profiles. These are then used in turn to calibrate the glider optodes, by matching O2 data according isopycnals as in previous studies [Frajka-Williams et al., 2009; Alkire, 2012].

What is the upper limit for primary production in the Southern Ocean?

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In the Southern Ocean the biological pump of CO2 is inefficient. This is revealed by the large amount of unused major nutrients still present in the surface waters that reach the northern boundary of the Southern Ocean. It is now well recognized that this results from iron-limitation of primary production. This situation was, however, likely different in the past (glacial era) and might be also altered in the future due to climate change. Therefore, how much primary production can sustain the surface waters of the Southern Ocean emerges as a critical issue. The regions that are naturally fertilized with iron offer a unique environment to address this question. In this communication I will focus on one of this region extending around the Kerguelen Plateau. Based on the results coming from two oceanographic cruises (KEOPS1(Jan-Feb 2005) and KEOPS2 (Oct-Nov 2011), recurrent observation from ship (OISO observing service) and in situ measurement using elephant seals, I will propose a description of the seasonal cycle of key factors in a highly productive Southern Ocean. The seasonal dynamics revealed how light, mixing regime, availability of silicon contribute to impose an upper limit to the efficiency of the biological pump in an iron fertilized Southern Ocean.

Particulate and size-fractionated dissolved primary production derived from Emiliania huxleyi

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Extracellular release of dissolved organic carbon (DOC) as well as concentration and composition exudates are highly variable in marine phytoplankton and suggested to be strongly affected by environmental conditions such as temperature, nutrient- and CO_2 concentrations. As substrate for heterotrophic turnover or as pre-cursor for particle aggregation, DOC plays a central role in the global carbon cycle. In order to improve our understanding on the fate of DOC in the future ocean, we conducted a phosphorus controlled (N:P=28, growth rate of μ=0.2 d^{-1}) chemostat experiment to characterize exudates derived from Emiliania huxleyi (strain B 92/11) grown at present day (380 µatm) and elevated CO_2 (750 µatm). ^{14}C incubations were accomplished to determine primary production (PP), comprised by particulate ($PO^{14}C$) and dissolved organic carbon ($DO^{14}C$) production. Chemical analysis included the amount and composition of particulate combined carbohydrates (pCCHO) and of high molecular weight dissolved combined carbohydrates (>1 kDa, HMW-dCCHO). Additional information on DOC derived from E. huxleyi was obtained by investigating different size classes of $DO^{14}C$ and HMW-dCCHO in molecular weight sub-divisions <1000 kDa, <100 kDa and <10 kDa.

The size fractionation of $DO^{14}C$ revealed different contributions of tested size classes of averaged 24.2±7.4 % in <0.40 µm-1000 kDa, 14.7±5.4% in <1000-100 kDa, 25.8±9.0% in <100-10 kDa and 35.4±4.0% in <10 kDa. The size fractionation of HMW-dCCHO also showed highest shares of averaged 38.8±7.4% to be smaller than 10 kDa (>1 kDa). The composition of pCCHO clearly differed from the composition determined for HMW-dCCHO. Both fractions were dominated by neutral carbohydrates with 93.2±0.9% (pCCHO) and 86.8±4.4% (HMW-dCCHO). However, glucose was with 71.9±9.9% the most abundant component of pCCHO, while neutral HMW-dCCHO were comprised by comparable shares of arabinose, mannose/xylose and glucose. Most interestingly, proportions of glucose increased with fractions of decreasing molecular weight and yielded highest percentages of 64.4±9.6% in the size class <10 kDa.

Comparison of the cellular (pCCHO) and exuded (HMW-dCCHO) carbohydrates revealed clear differences between the particulate and the total dissolved fraction. However, a substantial proportion of exudates is <10 kDa and dominated by glucose which is, different to the dissolved size fractions >10 kDa, resembling the composition of cellular carbohydrates. The detailed characterization of different size classes and composition of DOC reveals information on amount, diagenetic state and reactivity of exudates, most likely improving our understanding of DOC dynamics in the ocean.

Seasonal and inter-annual variations of gross primary production, community respiration, and net community production of a i seagrass meadow

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We report gross primary production (GPP), community respiration (CR) and net community production (NCP) over Posidonia oceanica meadow at 10 m in Corsica (Bay of Revellata) based on the open water O2 mass balance approach from a data-set of hourly measurements with an array of three O2 optodes that was deployed from August 2006 to October 2009. The method was checked by the comparison with discrete measurements of metabolic rates derived from benthic chamber incubations also based on the diel change of O2. This comparison was satisfactory and actually highlights the potential caveats of benthic incubation measurements related to O2 accumulation in small sized chambers leading to photorespiration, and an under-estimation of GPP. Our data-set confirms previously established knowledge on community metabolism of P. oceanica meadows: these communities were characterized by intense GPP and CR values, with strong seasonal variations, and were net autotrophic at annual scale. However, the high resolution data-set we obtained reveals additional knowledge that was missed by discrete benthic measurements with a coarse resolution (at best monthly). There was a strong day-to-day variability of GPP and CR, probably linked to changes in light availability, and extremely high but transient GPP events were recorded. Strong inter-annual variability of community metabolic rates was evidenced, with lower GPP and NCP during the 2006/2007 yearly cycle characterized by a mild and less stormy winter compared to the 2007/2008 and 2008/2009 yearly cycles. This finding suggests that one possible future evolution of carbon flows in P. oceanica meadows would be the decrease of export organic carbon to adjacent communities and a decrease of GPP and NCP, since a decrease in frequency and intensity of marine storms is expected in future in the Mediterranean Sea, due to a northward shift of the Atlantic storm track.

Environmental Controls on Phytoplankton Photophysiology and Community Structure in Temperate Coastal and Shelf Waters

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The photosynthesis-irradiance curve is conventionally used in models of primary production to describe the photosynthetic response of phytoplankton to available light and can be described using two biomass-normalised parameters (Platt & Jassby 1976): the assimilation number and the initial slope. These so-called photosynthesis-irradiance or PE parameters are known to vary according to cell size, temperature, nutrient availability and light history (Geider & Osborne 1992). Our ability to estimate primary production from chlorophyll fields relies on our understanding of what environmental factors regulate their seasonal variability (Morel et al. 1996). In this study, we compare seasonal changes in the PE parameters in two temperate marine systems that are characterized by strong seasonal changes in chlorophyll biomass and phytoplankton community structure: Bedford Basin, Nova Scotia and the Scotian Shelf. Changes in the photosynthetic properties of the phytoplankton community as they relate to variation in physical forcing are examined. The implications of these findings for modelling primary production in coastal and shelf environments will also be addressed.

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Controls on the CO_2 system by benthic-pelagic coupling in the southern North Sea

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The shallowness of coastal seas permits close interaction between the sediments, the water column and the atmosphere. Furthermore, shallow coastal seas are regions of high primary production which leads to high fluxes of organic matter to the sediment. In the context of coastal oceans acting as a continental shelf pump, that is transferring CO_2 from coastal seas into the open ocean, the role of benthic processes are only partly understood.

Recent studies from the East China Sea and the North Sea show that sediments could play a more important role than previously anticipated. This so-called “benthic-pelagic alkalinity connection” states that anaerobic mineralization of organic matter in sediments are an important alkalinity source for coastal seas like the North Sea.

During a basin wide North Sea cruise in September 2011, we measured rates of sedimentary alkalinity (TA) generation within permeable and muddy sediments of the North Sea at 19 stations. Using closed sediment incubations, benthic fluxes of alkalinity, dissolved inorganic carbon, nutrients and oxygen were determined. In May 2012 we sampled an additional 7 stations in the Dutch coastal zone for the same parameters.

Here we present preliminary results from both cruises. In the northern North Sea benthic TA fluxes were zero. For the southern North Sea TA fluxes varied between 0 and 21 mmol m-2 d-1 (September 2011) and 3-19 mmol m-2 d-1 (May 2012). Fluxes for dissolved inorganic carbon (DIC) were generally higher than TA fluxes with a maximum of 29 mmol m-2 d-1 (September 2011). Furthermore, positive correlations between oxygen consumption rates and TA/DIC fluxes are showing significant higher TA and DIC fluxes in sediments with high oxygen consumption rates compared to sediments with lower oxygen consumption rates.

Our results show that benthic fluxes are an important source for the TA and DIC budgets in the southern North Sea. Benthic alkalinity fluxes can potentially alter the pCO_2 of the seawater and thus influence the CO_2 uptake from the atmosphere. Alkalinity generation in sediments can therefore play an important role in the pH dynamics and therefore acidification in coastal systems.

Light availability affects the ocean acidification response in coccolithophores

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Ocean acidification (OA) is predicted to profoundly affect biological processes that utilise inorganic carbon, such as calcification and photosynthesis. Much of the OA research upon phytoplankton has focused on the globally distributed calcifying coccolithophore species Emiliania huxleyi but the data between studies has been highly inconsistent, and often contradictory. Additional environmental factors, such as nutrient and light availability, that can influence the OA response, have not been fully considered. Here we examine for the first time the influence of light dose (daylength) on coccolithophores' response to OA. Under a 14:10h L:D cycle, the growth rates of E huxleyi strain NZEH decreased with elevated CO2 (from 1.07 d-1 at 385 ppm to 0.75 d-1 at 1000 ppm), but calcification remained unchanged (coccolith thickness). However, this response was reversed under continuous light, where growth rate was unaffected by CO2 concentration (0.93-0.94 d-1 for both CO2 treatments), but calcification was reduced at 1000ppm. We examined whether this model response applied to other E. huxleyi strains (different geographical locations and ages of isolation), as well as two other species of coccolithophore, Coccolithus pelagicus and Gephyrocapsa oceanica. All three of the E. huxleyi strains tested demonstrated a similar change in OA response with L:D cycle as the NZEH strain. Both G. oceanica and C. pelagicus showed depressed growth rates 1000ppm CO2 regardless of light regime, though calcification in G. oceanica decreased with CO2 only under continuous light. We are currently testing this aim more widely upon natural phytoplankton communities (often containing significant contributions from coccolithophores) in polar waters, i.e. areas of the world that experience natural extreme variation in daylength but predicted to be vulnerable to OA and climate change; these results will be discussed in the context of observations from the laboratory grown cultures.

Using diel cycles in O_2 and particulate organic carbon to estimate primary productivity from a Lagrangian mixed-layer float during the North Atlantic bloom

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The ability to estimate primary productivity (PP) from autonomous platforms could greatly increase the coverage of in situ PP estimates, which are critical for validation of satellite PP algorithms and ultimately our understanding of the functioning of marine ecosystems. Here we examine the link between PP and diel cycles in O_2 and particulate organic carbon derived from high-resolution measurements by an autonomous Lagrangian mixed-layer float in North Atlantic. The float was deployed for two months in the spring of 2008, spanning the rise and collapse of the spring diatom bloom. During periods of stable mixed-layer depths and low horizontal mixing, diel cycles in O_2 and particulate organic carbon were apparent, attributable to the difference between daytime net productivity and nighttime respiration. We use these diel cycles to estimate PP and compare these estimates with ^{14}C-based estimates.

Phytoplankton plasticity controls long-term variability: lessons from a lake

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Predicting interannual to decadal variability of ecosystems under changing forcing has become a key focus of aquatic biogeochemical research. Unfortunately, present-day models have little skill on these time scales. Evidence from the well-studied Lake Constance suggests that this lack of model skill stems from a limited ability to reproduce the physiological flexibility, species composition and biodiversity of phytoplankton. The large Lake Constance exhibits temperate-ocean-like seasonal variability as well as pronounced longer-term change in the form of a six-fold reduction in phosphate between 1980 and 2000. The ecosystem response to this change is counter-intuitive: first, a gradual reduction in nutrients has no effect on ecosystem dynamics for several years, after which rapid change occurs. Second, increased resource limitation triggers a period of enhanced grazer control of phytoplankton. These phenomena demonstrably result from luxury uptake of phosphorus (and variable C:P) on the one hand, and feedbacks between resource limitation, species diversity, and grazing pressure on the other. This has important implications for plankton models on all scales: while static parameterizations may reproduce seasonal change in plankton communities, longer-term predictability requires representation of the striking flexibility of phytoplankton.

Sediment-water column fluxes of carbon, oxygen and nutrients in Bedford Basin, Nova Scotia, inferred from 224Ra measurements

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Exchanges between sediment pore waters and the overlying water column play a significant role in the chemical budgets of many important chemical constituents. Direct quantification of such benthic fluxes requires explicit knowledge of the sediment properties and biogeochemistry. Alternatively, changes in water column properties near the sediment-water interface can be exploited to gain insight into the sediment biogeochemistry and benthic fluxes. Here, we apply a 1-D diffusive mixing model to near-bottom water column profiles of 224Ra activity in order to yield vertical eddy diffusivities (KZ), based upon which we assess the diffusive exchange of dissolved inorganic carbon (DIC), nutrients and oxygen (O2), across the sediment-water interface in a coastal inlet, Bedford Basin, Nova Scotia, Canada. Numerical model results are consistent with the assumptions regarding a constant, single benthic source of 224Ra, the lack of mixing by advective processes, and a predominantly benthic source and sink of DIC and O2, respectively, with minimal water column respiration in the deep waters of Bedford Basin. Near-bottom observations of DIC, O2 and nutrients provide flux ratios similar to Redfield values, suggesting that benthic respiration of primarily marine organic matter is the dominant driver. Furthermore, a relative deficit of nitrate in the observed flux ratios indicates that denitrification also plays a role in the oxidation of organic matter, although its occurrence was not strong enough to allow us to detect the corresponding AT fluxes out of the sediment. Finally, comparison with other carbon sources reveal the observed benthic DIC release as a significant contributor to the Bedford Basin carbon system.

Characterizing the ice algae biomass-snow depth relationship over spring melt using transmitted irradiance

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The nature of the ice algae chlorophyll a (chl a) - snow depth relationship was investigated on first-year sea ice in Allen Bay, Nunavut, from 27 April to 13 June 2011. A transmitted irradiance technique was used to remotely estimate ice algae chl a throughout the period at time series locations under a snow cleared site, and under a low, medium, and high snow depth cover. Furthermore, chl a was estimated along transects perpendicular to dominant snow drift orientation, and at short term snow clear experimental sites. The association between chl a and most snow depth categories changed over the spring bloom period from strongly negative to positive, before entering a period of snow independent decline. Algal biomass under areas cleared of snow was lower and experienced earlier termination (and at a faster rate) than snow-covered control sites likely due to changes in bottom ice temperature. Our results suggest that rain and warm weather events which serve to rapidly melt the snowpack, which are predicted to become increasingly common in the Arctic, could cause significant depletion of algal biomass and possibly early termination of the bloom if they occur late in the spring.

Introducing dynamic benthic fluxes in 3D biogeochemical model : an application on the Black Sea North-Western shelf

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While benthic and sediment processes are now recognized as major components of the shelf biogeochemical budget, their representation in 3D biogeochemical model has for long been oversimplified [*Soetaert et al.,* 2000].

These oversimplified formulations of the bottom boundary conditions prevent to account for the response of diagenetic processes to the environment. The consequent absence of spatial and temporal variability of benthic/pelagic fluxes may lead to mis-evaluation of important terms in the biogeochemical budgets (e.g. Oxygen, Nitrogen, Carbon, Phosphate). More importantly, feedbacks mechanisms within the ecosystem response to eutrophication may be overlooked, such as, for instance, the sensitivity of benthic denitrification to the oxygen content in the bottom waters.

The GHER-ECO 3D biogeochemical model is extended with a refined benthic component explicitly accounting for the effect of organic matter transport, deposition and resuspension and for the influence of the environmental conditions on the diagenetic pathways.

A semi-empirical approach allows to reproduce the variability and feedbacks driven by benthic diagenesis without the computational burden of a vertically resolved sediment layer. This simplification allows to use the coupled model for the long term runs (several decades) required to appreciate the slow dynamics introduced by the accumulation of organic matter in the sediment layer during the years of high riverine discharge.

The extended model has been implemented for the Black Sea North western shelf [*Capet et al.,* 2012]. After a presentation of the main assumptions used to construct the benthic module, results are analyzed with a focus on (1) spatial and seasonal variability of benthic diagenesis and consequent benthic/pelagic exchanges, (2) comparison to in-situ estimates of benthic/pelagic dissolved fluxes, (3) implication in biogeochemical budgets and eutrophication issue. Inherent limitations of the semi-empirical approach are discussed in the perspective of the current challenges addressed to biogeochemical models.

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Long-term variability in the primary production of the North Sea

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It is generally accepted that a regime shift occurred in the North Sea ecosystem in the late 1980s observed at different trophic levels (Alheit et al. 2005; Beaugrand 2004; Edwards et al. 2001 and 2002; McQuatters-Gollop et al. 2007; Pitois et al. 2012; Reid and Edwards 2001; Reid et al. 2001). In this study we aim to investigate long-term changes in pelagic primary production of the North Sea by examining whether chlorophyll concentration, sediment loads and the underwater light climate have changed. Light availability limits photosynthesis therefore primary production with consequences on higher trophic levels. In particular, we tested the hypothesis that the light penetration depth has decreased significantly in some areas of the North Sea over the last 100 years, with possible effects on primary production. As a first step a total of 51,483 estimates of light attenuation coefficient (Kd), from Secchi depth and from CTD profiles, from different sources and spanning from 1903 to 2012, were collated together with 75,393 in situ estimates of chlorophyll concentration (from 1970s until 2012), and 40,400 estimates of suspended solids (SPM) concentration (from 1989 to 2012). Observations were aggregated by season and in 5 hydrodynamic regions (permanently mixed, East Anglian turbidity plume, fresh water influence, seasonally stratified and intermediate regions), based on the length of vertical stratification of the water column, using the GETM model (Burchard and Bolding 2002). Smoothing functions were applied to the time series of Kd and chlorophyll for each hydrodynamic region, and used to determine estimates of annual primary production, applying simple models from Cole and Cloern (1984), and Joint and Pomroy (1981). The paper will discuss if there have been significant changes in the annual primary production of the North Sea in the last 3 decades, and how variations in primary production compare to variations in climate variables such as wind stress, cloud cover, precipitations and river run off.

Net ecosystem metabolism in the NW Iberian Upwelling System on an annual cycle

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The Galician coast, at the northern boundary of the Canary- Iberian Large Marine Ecosystem, constitutes the only coastal upwelling regime in Europe. This system has a unique set of physical and chemical characteristics. Between November 2008 and December 2009, a station off Cape Silleiro (NW Iberian Peninsula) was visited on a monthly basis to investigate the export of organic matter to the adjacent ocean. During these cruises, measurements of in situ gross primary production (GPP) and dark community respiration (DCR) with in situ 24h oxygen incubations and bacterial production with short lab-incubations were carried out. Besides, vertical fluxes of biogenic material from the euphotic zone were measured by means of 24h sediment trap deployments. Integrated plankton community production in the photic zone presented a seasonal variability in terms of gross primary production (GPP) and Net Community Production (NCP) with maxima during the spring bloom (86 and 60 mmol O2 m-2 d-1 for GPP and NCP respectively) and summer upwelling (615 and 318 mmol O2 m-2 d-1 for GPP and NCP respectively) and minimum values during winter (43 and 26 mmol O2 m-2 d-1 for GPP and NCP respectively). Integrated respiration rates for the euphotic zone ranged from 7 to 303 mmol O2 m-2 d-1 with maximum respiration rates reached during the summer upwelling. Bacterial production also reached maximum values during the summer upwelling (64.5 mmol C m-2 d-1) and minimum levels for the winter period (2.8 mmol C m-2 d-1). The vertical fluxes of organic carbon varied between a maximum of 0.88 gC m-2 d-1, just after the spring bloom and probably associated with the sinking of large diatom, and a minimum of 0.3 gC m-2 d-1 during the winter period. Based on primary production and respiration measurements and taking into account the pelagic fluxes, we assess that (1) NCP constitutes between 89 – 25% of GPP; (2) between 77 – 11% of GPP is respired in the photic zone and (3) vertical export represents 46% of NCP of the photic zone and (4) our results indicate that water column metabolic balance was in net balance in the continental shelf on an annual basis.

Biological production and the influence of vertical physical processes in the Bellingshausen Sea, Southern Ocean

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Mixed layer-net community oxygen production (*N*), from oxygen-to-argon ratios, and gross oxygen production (*G*), from triple oxygen isotope measurements, were estimated during late summer and early autumn (March-April) 2007 in the Bellingshausen Sea, west of the Antarctic Peninsula. In addition, O_2 profiles at 253 CTD stations complement our observations. Typically, *N* is approximated by the biological oxygen sea-to-air exchange flux (F_{bio}) (based on the O_2 / Ar supersaturation) and neglecting significant vertical and horizontal fluxes. Negative (F_{bio}) values are considered to represent net heterotrophy or vertical mixing. Here we show that vertical fluxes alone can account for the negative (F_{bio}) values in large parts of the Bellingshausen Sea and towards the end of the productive season. From this, improved estimates of mixed-layer *N* can be derived from the sum of (F_{bio}), (F_e) (entrainment from the upper thermocline during mixed-layer deepening) and (F_v) (diapycnal eddy diffusion across the base of the mixed layer). In the Winter Sea Ice Zone (WSIZ), the correction due to vertical effects results in a small change of F_{bio}= (30 $\pm$ 17) mmol m^{-2} d^{-1} to *N*= (34 $\pm$ 17) mmol m^{-2} d^{-1}. However, in the permanent open ocean zone (POOZ), the negative F_{bio} value of (-17 ± 10) mmol m^{-2} d^{-1} gives a corrected value for *N* of (-2 $\pm$ 18) mmol m^{-2} d^{-1}. We hypothesize that in the WSIZ enhanced water column stability, due to the release of freshwater and nutrients from sea-ice melt, may account for the higher *N*-value. Our results stress the importance of accounting for physical biases when estimating mixed layer-marine productivity from in situ O_2 / Ar ratios.

Primary production and potential for carbon export in naturally iron-fertilized waters in the Southern Ocean

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Since the recognition of the key-role of iron in the High Nutrient Low Chlorophyll Southern Ocean (SO), several expeditions have been conducted in natural iron-fertilized zones from the Subantarctic to the Antarctic Zones (Kerguelen Plateau, Crozet Plateau, southeast of Tasmania, South Georgia). During the productive season the surface waters in these areas show high chlorophyll contents (as derived from satellite observation). However, depth integrated productions and regimes of production lead to mixed observations in term of potential for carbon export. A global positive effect of natural iron fertilization on primary production and carbon export has been reported for the KEOPS 1 and CROZEX expeditions. However, this may not always be the case and results for the SAZ-Sense expedition south of Tasmania, for instance, reveal lower production and poor carbon export efficiency in the naturally iron fertilized area. Also, KEOPS 1 results suggest that increased export not necessarily results in increased efficiency of export relative to production. The KEOPS 2 expedition was carried out during early spring 2011 off Kerguelen Island and reveals quite a large spatial-temporal variability of export efficiency, with export production (EP) reaching the 700m horizon ranging between less than 1 and up to 20% of New Production (NP). Results from KEOPS 2 will be presented with reference to previous natural iron fertilization studies in the Southern Ocean. The questions of High Biomass Low Export system and winter primary production will be discussed.

Evaluating estimates of remote sensing Primary Productivity in the Gulf of Maine using a Slocum Glider

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Remote sensing estimates of net primary productivity (NPP) in the ocean are based on near-surface chlorophyll or carbon fields and assumptions about light and phytoplankton distribution in the water column. Models used to calculate light and phytoplankton budgets in the euphotic zone, although based on empirical relationships, often fail to replicate the distributions of these parameters in-situ, introducing errors in remote sensing based NPP. Here we use glider-based measurements of chlorophyll and light, collected during several field campaigns in the Gulf of Maine to calculate NPP input parameters. We compare parameters calculated from surface chlorophyll only (e.g. modeling light and phytoplankton distribution) with parameters calculated using the measurements from the whole euphotic zone. Differences between these two approaches are evaluated. In these datasets, the main portion of phytoplankton biomass shifts from the surface to the deeper portion of the water column, allowing us to derive uncertainly estimates for multiple case-scenarios.

Evaluation of gross primary production, community respiration, and net community production in various benthic communities (Posidonia oceanica seagrass meadow, Posidonia oceanica litter, epilithic macro-algae) in the Bay of Revellata (Corsica) using optodes.

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In the Bay of Revellata (Corsica, Mediterranean Sea), we investigate since late-2006 metabolic rates (gross primary production (GPP) and community respiration (CR)) related to various communities (Posidonia oceanica seagrass meadow, Posidonia oceanica litter, epilithic macro-algae) using optodes on benthic chambers over Posidonia oceanica seagrass meadow, Posidonia oceanica litter, epilithic macro-algae. Over the Posidonia oceanica seagrass meadow, these incubations allow to analyse changing rates of nighttime CR, and to evaluate the difference between daytime and nighttime CR. Over the Posidonia oceanica litter, these incubations reveal surprisingly highly variables GPP and CR values. Finally, these incubations also allow deriving GPP and CR values from epilithic macro-algae, the second most important benthic compartment of in the Bay of Calvi

Observating turbulence modulation of vertical distribution of Chl-a in northern South China Sea

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Using the in situ observation data in spring, 2010, the vertical distribution of Chl-a concentration, Nutrient concentration gradient, turbulent dissipation rate, and eddy diffusivity are studied, and the relations among them are explored. At the profiles nearby Luzon Strait , with the deep mixed layer and weak stratification, the turbulent dissipation rate and eddy diffusivity (in order of 0.001-0.00001) are strongest, however, the Chl-a concentration in vertical distribution at those profiles are weakest, though the flux of phosphate,nitrate and silicate are of largest value. At profiles nearby Hainan Island, with shallow mixed layer, and strong stratification, the turbulent dissipation rate and eddy diffusivity (in order of (0.000001) are weakest, but Chl-a concentration in vertical distribution at those profiles are strongest,though the flux of phosphate,nitrate and silicate are of small value. There is a high Chl-a concentration layer around 50-100m, coresponding to the depth with high nutrient concentration gradient. At sites with strong stratification and weak mixing, the high Chl-a concentration layer is thin, and the Chl-a value is strongest, suggesting plant plankton easily grow at weak mixing. But at profiles with weak stratification and strong mixing, the high Chl-a concentration layer is thick, and the Chl-a value is weakest, suggesting plant plankton easily move down and up by strong mixing, and strong mixing weaken plant plankton growth. The high Chl-a concentration layer are in thermocline layer at sites with weak stratification, since strong eddy diffusivity (mixing) may transfer enough nutrient upward to where the plant plankton easily growth. However, at sites with strong stratification, the high Chl-a concentration are below thermocline layer, since weak eddy diffusivity can not lift plant plankton upward and go in thermocline layer. Turbulence plays an important role in modulation of the vertical distribution of plant plankton , and influence the condition of plant plankton growth. The observation parameters and information are useful for bio-dynamic coupled model.

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Towards more accurate Greenland Sea primary production estimates: a parametrization of the chlorophyll vertical profile

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Current estimates of the global marine primary production range over a factor of two. At high latitudes, the uncertainty tends to be even larger than globally because here in-situ data and ocean color observations are scarce, and the phytoplankton absorption shows specific characteristics due to the low-light adaptation. The improvement of the primary production estimates requires an accurate knowledge on the chlorophyll vertical profile, which is the basis for most primary production models. Till date, studies describing the typical chlorophyll profile based on the chlorophyll in the surface layer have not included the Arctic region and in cases where it has been included, the dependence of the profile shape on surface concentration was neglected. The goal of our study was to derive and describe the typical Greenland Sea chlorophyll profiles, categorized according to the chlorophyll concentration in the surface layer and further monthly resolved. The Greenland Sea was chosen because it is known to be one of the most productive regions of the Arctic and is among the Arctic regions where maximum chlorophyll field data is available. Our database consisted of 1199 chlorophyll profiles from the R/Vs Polarstern and Maria S Merian cruises combined with data of the ARCSS-PP database (Arctic primary production in-situ database) for the years 1957-2010. The profiles have been categorized according to their mean concentration in the surface layer and then monthly median profiles within each category have also been calculated. By applying a Gaussian fit the mathematical approximations of median monthly resolved chlorophyll profiles of the defined categories have been determined. These were then used as the input to the satellite-based Antoine et al (1996) model for the analysis of the Greenland Sea primary production spatial-temporal patterns.

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Light-Mediated Release of Dissolved Organic Carbon by Phytoplankton: Implications for Carbon Cycling

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Dissolved organic matter (DOM) is one of the largest exchangeable reservoirs of carbon in the ocean. It is estimated that 50% or more of primary production is routed through DOM in the upper layers of the ocean. While satellites are indispensable in estimating the global ocean productivity, their sensors cannot 'see' this dissolved primary production. Much of the DOM is consumed by bacteria but some may be sequestered for long periods via further transformations, i.e., the newly described 'microbial carbon pump'. Although bacterial consumption represents DOM's primary fate, the connection between phytoplankton carbon supply and demand for that carbon by bacteria via DOM is anything but straightforward. Recent work carried out by our group, both with azenic laboratory culture and natural populations, shows that abrupt changes in irradiance (spectral, and intensity) lead to enhanced extracellular release (ER) of DOM from phytoplankton. Preliminary calculations reveal that it may be important component of ocean carbon flux, particularly in nutrient replete coastal waters. We conducted experiments to examine light-mediated ER and bacterial growth in daytime, time-course incubations, with water from coastal Florida. The results showed an increase in ER accompanying increases in irradiance. Bacterial uptake of DOC followed the general trend of ER, with bacteria preferentially taking up these light-mediated exudates. These and previous data (chemical analyses of DOC) suggest a strong dependence of DOC release on positive irradiance change and illustrate how transient bursts in primary production and DOC release may be captured in bacterial rather than phytoplankton biomass

Influence of the Pacific Decadal Oscillation on phytoplankton phenology and community structure in the western North Pacific

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Phytoplankton phenology and community structure in the western North Pacific were investigated for 2001–2009, based on satellite ocean colour data and the Continuous Plankton Recorder survey. We estimated the timing of the spring bloom based on the cumulative sum satellite chlorophyll a data, and found that the Pacific Decadal Oscillation (PDO)-related interannual SST anomaly in spring significantly affected phytoplankton phenology. The bloom occurred either later or earlier in years of positive or negative PDO (indicating cold and warm conditions, respectively). Phytoplankton composition in the early summer varied depending on the magnitude of seasonal SST increases, rather than the SST value itself. Interannual variations in diatom abundance and the relative abundance of non-diatoms were positively correlated with SST increases for March–April and May–July, respectively, suggesting that mixed layer environmental factors, such as light availability and nutrient stoichiometry, determine shifts in phytoplankton community structure. Our study emphasised the importance of the interannual variation in climate-induced warm–cool cycles as one of the key mechanisms linking climatic forcing and lower trophic level ecosystems.

Dynamics of primary production in the English Channel - Use of opportunity ships to access to high spatiotemporal scale.

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Hydrological and photosynthetic parameters were investigated monthly from November 2009 to July 2011 using opportunity ships, along two transects in the English Channel. A powerful statistical method, a Partial Triadic Analysis (PTA), was applied on the physicochemical data set and highlighted the functioning of different areas. The physicochemical and biological controls of primary production were investigated in these areas using PAM Fluorometer (Pulse Amplitude Modulated) at high frequency and 13C incubation methods. This approach allowed us to explore the various photoacclimation responses and the relationship between biodiversity and primary production and productivity in contrasted hydrological areas. We showed a parabolic relationship between the diversity and the maximal primary production but we did not found any correlation between the maximal productivity and evenness or richness. High levels of productivity were measured during the development of small phytoplankton cells, which highlights the importance of taking into account the dominant functional group rather than the diversity degree to explain the level of productivity at seasonal scale.

Seasonal variation, origin and fate of settling diatoms in the Southern Ocean tracked by silicon isotope record in deep sediment traps.

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Diatoms are major primary producers and key exporters of organic matter and silica in the Southern Ocean. As diatoms fractionate Si isotopes during formation of their siliceous frustules, the Si isotopic composition of opal is closely linked to the degree of silicic acid utilization in surface waters. In this context, comparison of the mass flux of biogenic silica captured in sediment traps with the silicon isotopic composition of that material provides key information concerning diatom dynamics in surface water, and how well the isotopic signature of exported opal is preserved from the euphotic zone to the underlying sediments.

Here we report measurements of stable silicon isotopes using MC-ICP-MS in sinking particles collected along a transect south of Tasmania. We compare d30Si seasonal variations with an unprecedented temporal resolution (generally 2 weeks to monthly), in 3 main areas of the Southern Ocean (Subantarctic Zone, Polar Frontal Zone and Antarctic Zone) at two different depths. We estimate an annual mean d30Si of exported diatoms. The results show that the isotopic signature is well preserved during settling along the deep water column which is indicative of a small impact of silica dissolution on exported material below 1000m. While d30Si of biogenic silica is getting generally heavier along the growth season, in accordance with a surface silicic acid nutrient pool getting consumed, the sediment trap record in the AZ some sudden lightening which are likely to result from nutrient resupply events in the mixed layer. In contrast, particles collected during winter display unexpectedly heavy d30Si signatures suggesting they originate from slowly settling detritic diatoms that have grown in late summer.

Overall this first study on a multi-record of d30Si signatures in sediment traps shows it is a useful proxy of surface processes controlling the seasonal variation of diatoms' productivity and its fate.

Physical drivers of interannual variability in phytoplankton phenology

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Every year, large areas of the world's oceans experience a significant seasonal cycle in phytoplankton biomass. Variability in the timing, or phenology, of these phytoplankton blooms affects ecosystem dynamics with implications for carbon export efficiency and food availability for higher trophic levels. Climate change is expected to alter phytoplankton seasonality through changes to the underlying physical drivers controlling bloom timing. For example, stronger and longer seasonal stratification will alter the availability of light and nutrients needed for phytoplankton growth. However, we must first quantify the current interannual variability in phenology and diagnose the major processes driving it before trying to understand future changes. Here we use satellite-derived ocean colour data to calculate seasonality metrics such as bloom initiation, peak and end. The relationships between variability in phytoplankton phenology and variability in physical drivers such as mixed layer depth, net heat flux and light is investigated. In the subpolar North Atlantic we find strong basin-wide phenological responses to variability in physical drivers though weaker links are seen in other ocean basins. In addition, variability in bloom initiation is more strongly linked to physical processes than the other seasonality metrics in subpolar regions.

Optimization and evaluation of a micronekton model with acoustic data

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The micronekton at the Mid-Trophic Level (MTL) of the pelagic food web is one of the less known components of the oceanic ecosystem, despite this fact they are a major driver of the spatial dynamics of their predators, many of them being exploited species (e.g., tunas). A modelling approach has been developed to represent the spatial dynamics of several MTL functional groups mainly driven by primary production (and physical variables such as temperature and oceanic currents). A key issue remains the parameterization of the energy transfer from the primary production to the functional groups. To optimize these parameters, in situ acoustic data providing indirect estimates of the micronekton biomass needs to be assimilated in the model. We present the parameter optimization approach based on Maximum Likelihood Estimation with an illustration using two transects of acoustic backscatter at 38 kHz collected during scientific cruises north of Hawaii. Similar transects collected in the south Pacific between Tasmania and New Zealand are used for the evaluation of the model and its new parameterization.

Phytoplankton phenology in shelf and slope waters of the upwelling region off central-southern Chile (35-38°S)

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Coastal upwelling in the central-southern region off Chile is a highly seasonal process known to influence the annual formation of phytoplankton blooms during the austral spring-summer period. This study describes the phenological indicators of phytoplankton biomass (onset, maximum rate of change, end, and duration) for the shelf and slope waters in the region between 35 and 38°S. Together with this, the extent to which these indicators are coupled to the annual cycles of zonal Ekman transport (ZET), wind stress curl (WSC), and sea surface temperature (SST), and their spatial and interannual variations were evaluated. For this purpose, time series techniques (harmonic analysis, EOF, wavelet analysis) were applied to satellite daily wind data (Cross-Calibrated Multi-Platform (CCMP) Ocean Surface Wind Components, ftp://podaac-ftp.jpl.nasa.gov/OceanWinds/ccmp/L3.0/fl; 25x25 km resolution; 2001-2011), and to satellite daily chlorophyll-a (Chl-a) and SST data (MODIS-A; http://oceancolor.gsfc.nasa.gov; 1x1 km resolution; mid-2002 to mid-2012). The annual Chl-a increase starts in early spring (September), attains a maximum rate of increase in summer (December-January), and ends 6 months later. The onset and end of this cycle take place 20 days earlier than those for ZET and WSC, and it starts 50 days earlier than the annual increase in SST. The phenological indicators (except the duration) for Chl-a display a large variability along the coast but no latitudinal trend was clear, as shown by ZET, WSC, and SST. In terms of interannual variability, the influence of El Niño Southern Oscillation (ENSO) cycle was noticeable for the 2002-2003 El Niño condition and 2007-2008 La Niña condition. The annual increase in Chl-a began later (23 d) in 2002-2003 compared with 2007-2008, and the cycle ended earlier (1 month shorter) under El Niño condition; a similar pattern was displayed by SST but not by ZET and WSC. Overall, these high-resolution data suggest that the timing of the annual increase in phytoplankton biomass in the region might be uncoupled from wind forcing; this does not mean that biomass variability is not responsive to upwelling conditions at smaller frequencies. FONDECYT 1120504.

Primary production and the carbonate system in the Mediterranean Sea.

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The validated 3D coupled transport-biogeochemical OPATM-BFM model [*Lazzari et al.*, 2012] is used to evaluate the impact of biological processes (i.e. primary production, respiration and recycling processes) on the temporal and spatial distribution of alkalinity and on the carbonate system dynamics in the Mediterranean Sea. The presented simulation, that covers the contemporary conditions, shows that primary production processes affects the carbonate system at the surface layers by fixing CO_2 into organic carbon that eventually sinks as particulate organic matter under the mixed layer. Organic carbon is then respired within the deeper layers, contributing to the carbon oversaturation especially in the western Mediterranean sub-regions. The carbon pump combined with the inverse estuarine Mediterranean circulation results in a net carbon export toward the Atlantic sea of about 45TgC per year. This net carbon loss is compensated by the sinking of atmospheric CO_2 through the water-air exchange (20TgC per year) and by the input from rivers (25TgC per year). Further, primary production processes, such as nutrient uptake, alter the alkalinity at surface and consequently the carbonate system equilibrium by increasing the solubility of CO_2 and the sinking of atmospheric CO_2. Results of the numerical simulation show that the most productive areas such as mixing and coastal areas (i.e. the Gulf of Lion, the Adriatic Sea and the Alboran Sea) present the highest seasonal variations of alkalinity (up to more than 20 μmol/kg) and the highest rate of atmospheric CO_2 sequestration.

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The role of freshening in controlling phytoplankton production in the Pacific sector of the Arctic Ocean

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The drastic sea ice decline in the Arctic Ocean triggered by global warming generates rapid changes in the upper ocean. Among physical changes produced by high melt in the water column, light availability, temperature increase and stratification strengthening are recognized to play a key role on primary producers. Another consequence recently evidenced concerned the increase of the freshening in the Canada Basin of the Arctic Ocean began in the 1992s and continued to at least the end of 2008. In this study we investigate the effects of reduced ice cover and subsequent freshwater accumulation (FWC) on primary producers. The Pacific sector of the Arctic Ocean explored during the summer 2008 from the Bering Strait (65°N) to the North Pole latitudes (86°N) provided a large in situ dataset, which were obtained during a year of record ice melt. The 2008 observation allows us to characterize the phytoplankton biomass and primary productivity together with a high freshening and for the first time over an open Canadian basin partially free of ice. The strong freshening occurring in 2008 in the upper layer of basins have a negative feedback on phytoplankton by deepening both the nutricline and the subsurface chlorophyll maximum (SCM). The phytoplankton growth appeared limited in surface and at SCM and presented primary production as low as 20 mg C m-2 d-1 in the areas strongly affected by freshening (FWC $>$ 6m) such as the Canada Abyssal Plain and the heavy ice covered Alpha Ridge. Conversely, a lower FWC ($<$ 3m) in the offshore Marginal Ice Zone (MIZ) near 80°N allows surface water nutrient repletion from the sub-surface Pacific Water (PW) and drives to biomasses and primary productivity two to five times higher than in the rest of the basin.

The effect of seasonality in phytoplankton community composition on carbon uptake on the Scotian Shelf, northwest Atlantic

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The short, but intense spring bloom, occurring late March to early April on the Scotian Shelf in the northwest Atlantic draws down approximately 50% of the total carbon fixed over the annual cycle in this region. In the spring and summer months following the collapse of the bloom, nutrient and chlorophyll levels plummet suggesting that further drawdown of carbon by phytoplankton will be severely limited. However, examination of the seasonality of the surface water partial pressure of CO2 (pCO2), measured by a CARIOCA buoy moored for several years on the Scotian Shelf, reveals that there is persistent net carbon drawdown throughout the nutrient poor, shallow mixed layer conditions of the warmer summer months at an order of magnitude comparable to that observed during the spring bloom. Using a combination of satellite ocean colour and a comprehensive in situ validation dataset consisting of phytoplankton absorption and cell counts, we employ a newly developed optical model to first accurately derive phytoplankton absorption spectra from satellite reflectance, and then to estimate the dominant phytoplankton size class from absorption spectral shapes. We show that despite the low chlorophyll concentrations throughout the summer (typically < 1 mg m-3), a phytoplankton community dominated by numerically abundant pico- (< 2 µm) and nano- (2-20 µm) sized cells is responsible for the net carbon drawdown evident in the pCO2 record, suggesting that, in this shelf system, chlorophyll concentration may be a poor proxy for biomass. We then consider seasonal patterns in net community production (NCP) in the context of the seasonality in phytoplankton size structure and suggest that more accurate estimates of carbon drawdown could be obtained through optically based approaches that move beyond simple chlorophyll-centred estimates of biomass.

Processes relevant for multi-decadal changes in primary production in the North Sea and Baltic Sea: hindcast and scenario modelling

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Despite their geographical vicinity, the North Sea and the Baltic Sea ecosystems exhibit very different characteristics in both physical and biological parameters. Nonetheless, since both ecosystems are characterized by the same general functional groups in phytoplankton and zooplankton and, their geographical distribution indicates comparable thermal adaptation of the plankton groups, we propose that the same ecosystem parameterization can be utilized to simulate the dynamics in both ecosystems simultaneously. Here we present results from an updated version of the 3d coupled ecosystem model ECOSMO valid for both areas. The model allows both multi-decadal hind cast simulation of primary production and specific process studies under controlled environmental conditions. Our results from a long-term hind cast (1948-2008) indicate incoherent "regime shifts" in the primary productivity (PP) between the North Sea and Baltic Sea. Correlation analysis between atmospheric forcing and PP indicates significant correlations for both solar radiation and wind, but cannot serve to identify causal relationship. Therefore additional scenario tests with independent atmospheric parameter perturbations were accomplished emphasizing specifically the role of solar radiation, wind and eutrophication. The results revealed that, although all parameters were relevant for the PP in North Sea and Baltic Sea, the dominant impact on long term variability was introduced by modulations of the wind fields.

Improvement and validation of a primary production model using remote sensing

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Phytoplankton forms the basis of the marine food web and constitutes about 48% of the global (terrestrial and marine) net primary production (Field et al. 1998). However, under certain circumstances, phytoplankton blooms cause severe ecological and economic damage to marine systems (Paerl and Huisman, 2008). The effects of phytoplankton blooms range from nuisance to beach recreation caused by foam accumulation, to shellfish and fish mortality due to local oxygen depletion in so called 'dead zones' (Peperzak and Poelman, 2008). In the latter case, the blooms are considered harmful algal blooms (HABs) (Peperzak, 2003). This paper focuses on modelling phytoplankton primary production in the North Sea in general, and nuisance blooms in particular. Phytoplankton blooms mainly occur in late spring or summer in the Dutch coastal zone, when environmental conditions for phytoplankton growth are optimal (Peperzak, 2003). Increased understanding of the driving forces behind phytoplankton growth in the North Sea and a reliable prediction system is of great interest. Computer models can hereby prove a valuable tool, as they take many of the factors on which the occurrence of phytoplankton growth may depend into account and allow for a large scale analysis. The results of updating the biochemical three dimensional model (DELWAQ) to produce net primary production (NPP) using remote sensing data of chlorophyll-a, the diffused attenuation coefficient and sea surface temperature as driving force is presented. New techniques such as the inclusion of remote sensing data (El Serafy, et al. 2011) as driving force could improve model performance. The first results of NPP estimates in the North Sea for the year 2007 will be presented and suggestions for improvements are discussed.

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Spatio-temporal distribution of nutrients at Oualidia lagoon (Atlantic Moroccan coast)

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This study we represent biogeochimical cycle of the water column of the Oualidia Lagoon (Moroccan Atlantic coast). Water samples were collected from March 2011 to August 2011, at six stations distributed throughout the Oualidia lagoon. The physico-chemical parameters measured (temperature, salinity, dissolved oxygen, conductivity) as well as nutrients (orthophosphate, nitrite and ammonium) result showed seasonal and spatial variation with a gradient of 1.18°C/km for the temperature and the range of variations 0.3 µmol/l/km for nitrites throughout the lagoon. The highest nutrient values (NH4=76.87 µmol/l in S4, PO43- =89.38 µmol/l in S4, NO2-=17.74 µmol/l in S5) generally from the middle to the upstream of the lagoon. The lowest (NH4=0.305 µmol/l in S1, PO43-=0.1µmol/l in S1, NO2-=0.025 µmol/l in S1) are located in the downstream. Keywords: Oualidia lagoon, Biogeochimical cycle, Nutrients

Data Assimilation on Numerical Simulation of Storm Surges along Bay of Bengal and Bangladesh Coast

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Bangladesh is situated at the northern tip of the funneling Bay of Bengal (BoB). The long continental shelf, shallow bathymetry, and complex coastal geometry with many kinks and islands with the overall funneling shape of the BoB are well-known features of the highest storm surge of the longest duration. IIT Kharagpur Model (2002) for storm surge is used for numerical simulation of storm surges near Orissa, West Bengal, and Bangladesh coasts. High resolution (Δx = 3.7 km, Δy = 3.5 km, Δt = 60 sec) IIT Model has been used for the simulation. Three or six hourly positional data of several severe storms that hit Bangladesh and West Bengal coasts have been used for making gradual changes in the storm surge scenario. A Generic Mapping Tool (GMT) has been employed with a view to imaging surges. 3D view of the peak surges during landfall has also been made by incorporating geo-referenced peak surge data into WinSurfer. Doppler Weather Radar (DWR) Data of Bangladesh Meteorological Department (BMD) are used to study the BoB cyclone through 3-dimensional variational (3DVAR) data assimilation technique within the WRF-ARW modeling system. The mean track error at the time of landfall of the cyclone is 66.6 km. The distribution and intensity of rainfall are well simulated by the model as well and were comparable with the TRMM estimates. Using this model, numerical experiments are performed to simulate the storm surge heights associated with past severe cyclonic storms which struck the coastal regions of Bangladesh. The model results are in agreement with the limited available surge estimates and observations.

Key words: simulation, funneling, bathymetry, storm surge, 3DVAR.

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Probabilistic estimate of the uncertainty due to physical forcings in phytoplankton models

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For decades the marine ecological models have sustained progressive developments and been subjected to an increasing degree of complexity in their processes, forcings and parameterization. In parallel, the validation techniques have evolved from visual to statistical comparisons, allowing fair estimates of the bias and correlations between model results and reference data. Still, it is difficult to estimate in advance what will be the uncertainty attached to any model prediction because of the complexity of the ecological models and the non linearity of their response to a change. Also, it is not trivial to determine the uncertainty of the model response due to one specific forcing. The uncertainty in an ecological model response is somewhat linked to the model sensitivity to a perturbation. Since the non-linear model responses to a perturbation may vary in wide ranges of possibilities, we chose to base our assessment on the probability theory, i.e. a "light" Monte-Carlo experiment. It consists in a reduced number of randomly-perturbated simulations where knowledge of the system allows narrowing the range of perturbations. The Belgian continental shelf (BCS; 51-52N and 2.5-3.5E; surface: 3600 km2) is a well-mixed and nutrient-enriched area where chlorophyll *a* spring bloom intensity and spatial distribution show interannual variations. These variations mainly depend on the river loads, the Atlantic water penetration through the English Channel, and the wind-driven advection. In this study, the uncertainty on modelled chlorophyll *a* prediction in the BCS is studied as a response to random wind perturbations. Statistical and probabilistic quantification of the results is being presented. That led to a better understanding of the model prediction capability.

Improving the estimation of primary production using remote sensing data in the Argentine continental shelf and shelf-break regions

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In order to estimate primary production on a synoptic scale using satellite information, four methods were tested to assign photosynthetic parameters that characterize the photosynthesis–irradiance relationships: (1) the nearest neighbor method (NNM), (2) static and, (3) dynamic partition into biogeochemical regions, and (4) average values of measured parameters. The required photosynthetic parameters were obtained during three oceanographic cruises conducted in the Argentine shelf and shelf-break regions during spring 2005, summer and winter 2006 by performing photosynthesis-light incubation experiments. Despite some variations in the performance according to the season, the NNM and the use of dynamic provinces emerged as the preferred methods for parameter assignment. Composite synoptic maps of primary production for each cruise were calculated, showing a high spatial variability within the region. Seasonal variability in the primary production for the whole continental shelf and for selected ecologically relevant regions, such as the shelf-break, were extracted from monthly images of primary production computed over an annual cycle using MODIS-Aqua derived chlorophyll-a concentration. The high mean primary production estimated over the shelf-break showed values comparable to other well-known productive zones of the world oceans, such as the Benguela system. A first estimation of the total amount of carbon fixed in the shelf-break area showed that the annual production of the Argentine shelf and shelf-break regions represent a large percentage of the mean production of the global ocean. Results will be compared to those obtained by previous global estimations for this region.

Phytoplankton primary production in shallow coastal ecosystems: a turbid estuary *versus* a multi-inlet lagoon (SE Portugal)

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Estuaries and coastal lagoons are among the most productive ecosystems in the world and they provide a wide range of ecosystem services and resources. Phytoplankton are usually the main source of organic matter to higher trophic levels and, in addition to their critical ecological function as primary producers, phytoplankton play pivotal roles in global biogeochemical cycles, thus affecting water quality and whole-ecosystem productivity. Phytoplankton are also sensitive indicators of environmental variability and have been extensively used as a gauge of ecological condition and change. Phytoplankton production and its relationship with environmental drivers are thus essential to understand ecosystem dynamics and to predict potential impacts of natural and anthropogenic stressors on ecosystem functioning. The main goal of this study was, therefore, to evaluate phytoplankton primary production, photosynthetic parameters and their environmental determinants in two confined coastal ecosystems located in southern Portugal: the turbid Guadiana estuary and the Ria Formosa lagoon.

Sampling campaigns were conducted in the Guadiana estuary throughout 2008 and in the Ria Formosa coastal lagoon during 2010-2012, in several locations covering a wide range of environmental conditions. Phytoplankton composition, abundance and biomass were determined using inverted and epifluorescence microscopy. Primary production was analysed using the ^{14}C incorporation and O_2 methods, under different light intensities. Abiotic environmental variables, such as nutrient and light availability, were also analysed.

Clear horizontal gradients were found in phytoplankton primary production for both ecosystems, with higher values usually registered at inner locations. In turbid regions, phytoplankton were the most efficient in utilising available resources, even under constant light limitation and occasional nutrient limitation. Overall, the less turbid Ria Formosa waters were more productive than the Guadiana estuary.

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The structuring role of horizontal stirring on primary production

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Primary production in the ocean is strongly affected by the horizontal mesoscale (10-100 km) and submesoscale (1-10 km) circulation. Eddies and filaments can create strong dishomogeneity, either amplifying small-scale diffusion processes (mixing) or creating tracer reservoirs. This variability has a direct effect on the biogeochemical budgets - controlling for instances tracer fluxes across climatological fronts, or part of the vertical exchanges. This variability also provides a challenge to in situ studies, because sites few tens of kms or few weeks apart may be representative of very different situations. Satellite data and Lagrangian tools are a powerful source of information for shedding some light on the mechanisms by which stirring can structure primary production and even the phytoplanktonic community. Such analysis unveils the presence of submesoscale domains which give rise to a mosaic of contrasted communities dominated by different functional types ("fluid dynamical niches"). Such domains can be exploited by in situ studies (in particular for natural and artificial iron fertilization experiments) as quasi-isolated environments, where biogeochemical processes can be monitored and quantified with high accuracy for a timescale comparable to the duration of a bloom.

Analysis of chlorophyll a concentration received with spectrofluorimeter FLUO-IMAGER M53b during the research cruise on April 2010

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The development of new algorithms for calculation of the chlorophyll a (Chla) concentration and dissolved organic matter (CDOM) with high accuracy is actual for remote sensing of the sea surface. It is known that the laboratory measurements are very different from those obtained by processing satellite maps. Different methods produce variety of errors. We present data from the Baltic research cruise in the open (Middle Shoal) and coastal zone (Gulf of Gdansk), in Spring. The measurements of Chl a in vitro and in vivo and CDOM concentrations, contained in a surface microlayer and in a layer of 15 cm, were made using standard method and SFS technology (spectrofluorimeters FLUO-IMAGER M53b (LDI, Estonia; SCALAR, The Netherlands)). This method allows to determine if the sample comes from the coastal zone or the open sea, and identify the main sample fluorescent pigments such as chlorophyll a, b, c2, CDOM, to determine their contribution and concentration, as well as using the library to select algae species, dominant in the sample. Analysis of the data showed not substantial differences between the concentrations of chlorophyll a in the water and a 15-cm layer. High concentrations of chlorophyll a and CDOM in the coastal zone related to the influence of the rivers.

Detection of global warming using satellite records of ocean productivity

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Detecting the climate change signal in satellite records of productivity would imply that ocean primary production has been affected by anthropogenic influences. Here, we demonstrate the use of the optimal fingerprint technique to detect anthropogenic climate change in satellite-derived ocean colour measurements. The methodology has previously been applied to detect and attribute greenhouse gas induced climate change in sea-surface temperature records, ocean heat content, atmospheric air temperature etc., but this is the first attempt to apply it to ocean productivity records. Monthly chlorophyll (Chl) values from Control (500 years) and Historical (1850-2005) runs of the Geophysical Fluid Dynamics Laboratory (GFDL) ESM-2G model were used to derive the pattern, or 'fingerprint', of the warming signal. Chl data (1997-2006) from NASA's Ocean Biogeochemical Model (NOBM), which assimilates SeaWiFS data, were projected onto the warming signal. Here, we test the hypothesis that the observed trends in the Chl data are due to anthropogenic climate change. The result of the application of the optimal fingerprint method to satellite records of Chl indicates that a global warming signal is not yet detectable. However, in future work we will introduce adaptations to the methodology, which may allow the fingerprint of global warming to be detected in the satellite ocean colour record.

Impact of nutrient limitation on the productivity of three functional groups of marine phytoplankton: experimental approach

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Phytoplankton has a major role on marine ecosystem functioning. As primary producer, phytoplankton produces a large amount of organic carbon and is a key component of trophic webs. These planktonic organisms depend directly on environmental conditions in particular in terms of nutrient concentrations. Anthropogenic nutrient enrichment of the coastal zone is now a well-established fact. This enrichment governs the distribution of phytoplankton and influence microalgae at multiple scales, from cells to community.

This study is integrated in the program ICCARE (région Nord/Pas de Calais-fédération de la recherche sur la biodiversité-France) whose objective is to study the Impact of Climatic Change and Anthropogenic effect on the pRoductivity of microalgae's community in coastal Ecosystems. Here we focused on the influence of phosphorus limitation on the productivity of three planktonic species. The prymnesiophyte Phaeocystis globosa, the diatoms Thalassiosira rotula and Ditylum brightwellii were chosen since they differ in term of size, resource use and timing of maximal abundance in English Channel. Semi-continuous cultures were carried out with three different phosphorus conditions. A multi factorial approach of productivity was applied, from photosynthesis, elemental composition to growth and exudates in order to better understand and quantify the effect of phosphorus limitation on phytoplankton's productivity.

Our results highlight the influence of phosphorus limitation on multiple physiological processes. Phosphorus depletion leads to a decrease of biomass production and negatively affect photosynthesis processes. The uptake and assimilation of phosphorus and nitrogen are also affected by phosphorus depletion resulting in difference in cell stoechiometry as a function of phosphorus concentration. Moreover, dissolved carbohydrates production and particular carbohydrates contents increase in phosphorus limited treatments. Phosphorus limitation leads to productivity changes which depend on species. For example photosynthetic activity is negatively impacted by a factor of 2.7 for Thalassiosira rotula, 1.8 for Phaeocystis globosa and 1.5 for Ditylum brightwellii in phosphorus limited conditions. These changes could have some repercussions on planktonic population and could also impact natural community through interspecific relation and trophic webs.

Interannual variability of primary production and air-sea CO_2 flux in the Atlantic and Indian sectors of the Southern Ocean

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As one of the major oceanic sinks of anthropogenic CO_2, the Southern Ocean plays a critical role in the climate system. However, due to the scarcity of observations, little is known about physical and biological processes that control air-sea CO_2 fluxes and how these processes might respond to climate change. It is well established that primary production is one of the major drivers of air-sea CO_2 fluxes, consuming surface Dissolved Inorganic Carbon (DIC) during Summer. Southern Ocean primary production is though constrained by several limiting factors such as iron and light availability, which are both sensitive to mixed layer depth. Likewise, the ratio of primary production to mixed layer depth controls the amplitude of the biological drawdown of DIC. Mixed layer depth is known to be affected by current changes in wind stress or freshwater fluxes over the Southern Ocean. But we still don't know how primary production may respond to anomalous mixed layer depth neither how physical processes may balance this response to set the seasonal cycle of air-sea CO_2 fluxes. In this study, we investigate the impact of anomalous mixed layer depth on surface DIC in the Atlantic and Indian sectors of the Subantarctic zone of the Southern Ocean (60°W-60°E, 38°S-55°S) with a combination of in situ data, satellite data and model experiment. We use both a regional eddy permitting ocean biogeochemical model simulation based on NEMO-PISCES and data-based reconstruction of biogeochemical fields based on CARIOCA buoys and SeaWiFS data. A decomposition of the physical and biological processes driving the seasonal variability of surface DIC is performed with both the model data and observations. A good agreement is found between the model and the data for the amplitude of biological and air-sea flux contributions. The model data are further used to investigate the impact of winter and summer anomalies in mixed layer depth on surface DIC over the period 1990-2004. The relative changes of each physical and biological process contribution are quantified and discussed.

MARINE RECORDS OFF THE COAST OF AFRICA: A CASE OF MECHANISMS AND CONSEQUENCES OF PAST AND PRESENT CLIMATE CHANGES OVER WEST AFRICA COAST AND ITS EFFECT ON PRIMARY PRODUCTION.

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The West African Coastal Regions houses 40% of the resources and it is the seat of intense economic activities, in addition, it contains the rich and varied ecosystems (Magrove, Lakes, Lagoons etc.) which offer ecological advantages of international significance. The Coastal Region of West Africa is prone to changes- resulting from a combination of natural factors (Sea level, Risk marked by climate changes) and human (increases puncture of natural resources, urbanization, construction of hydro-electric dams). Several areas of the West African Littoral Zones have experiences Coastal Erosion in order of 1-3 meters per annum with Ecological and Socio-economic repercussion.

The main objective of this Study is to produce a conceptual framework for developing contextually relevant response strategies and effective communication networks that are inter-disciplinary to past and present Coastal Sea Level changes and how it effect primary production, the impacts of past and present climatic changes on Coastal Level rise and ecosystem changes etc by addressing the following three themes: Detection, Prediction ,Adaptation and also determine the history of potentially important forcing factors and its effect on primary production.

The attempt in this study is to improve the understanding of the past and present coastal sea level changes, ecosystem changes and livelihood of human development in Africa: a case for West Africa and identify the important feedbacks which amplify or reduce the influence the effect of these forcings and its effect on primary production,

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The study revealed that barriers to successful information sharing must be managed to allow the delivery of accurate and timely information to those able to use it for greatest protection of those in coastal regions in West Africa and Nigerian coastline especially.

The research study conclude, over the last decades ,that there is lack of data and logistical difficulties for global change research in the coastline of West African region.

Descriptive and prediction models of phytoplankton in the Oualdia lagoon (Moroccan Atlantic)

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Abstract

The relative dynamics of phytoplankton complexes in the Oualidia lagoon (Moroccan Atlantic coast) ecosystem evolution was simulated by an ecological model. The system state in the model is described by: phytoplankton, zooplankton, dissolved organic matter, and dissolved mineral nitrogen. Two types of models were successfully elaborated, i.e. (1) the descriptive model to explain the dynamics of phytoplankton concentration in the Oualidia lagoon as a result of independent environmental variables, and (2) the phytoplankton concentration model prediction. The descriptive model for phytoplankton dynamics integrates and presents in a user-friendly way the knowledge collected through measurements over a period of two years (2011-2012) at six stations in the lagoon. Such presentation contributes to a better understanding of the ecosystem functioning. It is shown that the modeling results are adequately corresponding to the observation data.

Keywords: Oualidia Lagoon; Ecosystem model; Phytoplankton

New estimates of primary productivity and its limiting factors in the Central Arctic

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The Arctic Ocean is changing dramatically due to the rapid sea ice decrease. The reduction in ice thickness and cover leads to an increase in the amount of light penetrating through the ice. Thus changes in primary production are expected. Nevertheless, our knowledge about how other limiting factors such as nutrients might affect budgets and ratios of sea ice algae and phytoplankton productivity is still limited, especially in the central basins. This study presents recent results from the Central Arctic Ocean collected during late summer and early autumn 2011 and 2012. Primary productivity was measured using the 14C method in the water column, the sea ice and in the melt ponds through a wide variety of ice types and water masses. Additionally PI curves and nutrient enrichment experiments were performed at selected stations in order to infer primary productivity´s limiting factors at the end of the season. Aggregates of sea ice algae found in melt ponds and directly under the ice showed hardly any photoinhibition and presented the highest productivity on small scales . Nevertheless their contribution to the total primary production remains difficult to assess due to their patchiness. Regarding the different ice types, multi-year ice contained more algal biomass than first year ice at the end of the summer, but due to its much larger spatial extent and higher light transmission throughout the season, first year ice is likely to provide a higher proportion of overall sea ice algal productivity in a changing Arctic. The ice-covered water column had in general very low NPP rates probably due to both light and nutrient limitation, and the depth of the mixed layer in the Eurasian basins was limited to 15 m in 2012. Therefore in a summerly ice free Arctic Ocean, the proportional contribution of sea ice and sub ice algae compared to phytoplankton in highly stratified, nitrate limited surface waters is still difficult to predict, and will depend on nutrient transport and mixing processes.

Biological and physical triggers of the North Atlantic Spring Bloom

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There is a debate over what triggers phytoplankton blooms in the subpolar North Atlantic. The traditional explanation stems back to the seminal work of Riley and Sverdrup. According to their explanation, stirring by winter cooling and winds stir phytoplankton into deep waters, where there is too little light to prosper. In spring, when atmospheric forcing weakens and turbulent stirring subsides, phytoplankton experiences sufficient sunlight to grow and a bloom develops. Behrenfeld has recently turned the problem upside down suggesting that winter turbulence triggers blooms rather than preventing them. The hypothesis is that phytoplankton losses due to processes such as consumption by zooplankton and respiration are actually reduced by turbulent stirring that spreads biomass over deep mixed layers limiting encounter rates of phytoplankton and zooplankton.

We will present in-situ observations, collected with floats, and theoretical results, based on a simple NPZ mode, which suggest that the onset of the North Atlantic Spring Bloom goes through two distinct phases. In the first phase, a weak phytoplankton growth starts in response to a reduction in consumption by zooplankton and respiration as surmised by Behrenfeld. However the bulk of the population growth starts later in winter when turbulence in the upper ocean weakens as surmised by Riley and Sverdrup.

Estimating phytoplankton size-fractionated primary production in the NW Iberian margin: is mixotrophy relevant in pigmented nanoplankton?

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Size-fractionated primary production in the NW Iberian upwelling was estimated using the photophysiological parameterization firstly proposed by Claustre et al. (2005) and later improved by Uitz et al. (2008). The approach requires the knowledge of phytoplankton pigment composition to estimate the fraction of chlorophyll that is ascribed to each phytoplankton size-class: pico-, nano- and microphytoplankton. This chlorophyll fractionation is subsequently combined with the class-specific photophysiological properties to estimate size-fractionated and total primary production. When this procedure was applied to the phytoplankton pigment composition determined by HPLC in samples collected weekly over a year on the NW Iberian shelf, good agreement (P = 0.995, t-test for paired samples) was found between estimated and measured total primary production, suggesting that this size-fractionation procedure works well.

Total primary production varied between 0.14 and 1.8 g C m-2 d-1 with similar contributions of micro- (36±28%) and nanophytoplankton (35±18%) and a slightly lower contribution of picophytoplankton (29±14%). The highest variability occurred in primary production due to microphytoplankton (PPmicro = 0.35 ± 0.36 g C m-2 d-1) with PPmicro >1 g C m-2 d-1 during summer stratification and summer upwelling. In contrast, undetectable values of PPmicro were recorded in winter when oceanic water from the South is coastward advected by downwelling and the Iberian Poleward Current (IPC) flows northward on the slope. Primary production of nanophytoplankton (PPnano = 0.22 ± 0.17 g C m-2 d-1) and picophytoplankton (PPpico= 0.19 ± 0.13 g C m-2 d-1) was never undetectable, even during the IPC. Overall, variability of PPnano and PPpico was appreciably lower than PPmicro. Size-fractionated primary production contrasted with size-fractionated carbon biomass. While carbon fixed by micro- and picophyplankton (PPmicro and PPpico) frequently exceeded or equaled the respective standing stocks, resulting in turnover rates of 1.3 ± 1.3 d-1 and 0.71 ± 0.66 d-1 respectively, the turnover rates for nanophytoplankton were extremely low (0.09 ± 0.05 d-1). As nanophytoplakton accounted for 73 ± 16% of the total phytoplankton carbon biomass year-round, it is suggested that mixotrophic nutrition is significant for this phytoplankton class in this upwelling region. Without accounting for mixotrophy, the photosynthetic quotient (PQ = 2.8 ± 0.3 mol O2 : mol C) for phytoplankton photosynthesis was highly unrealistic. However, considering that nanophytoplankton can obtain 75% of their carbon requirements from heterotrophic nutrition (Crespo et al., 2011) the PQ = 1.78 ± 0.17 obtained was not significantly different from 1.4 (p = 0.76).

Seasonal and inter-annual dynamics of chlorophyll concentration and primary production in the Black Sea

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Spatial and temporal variability of chlorophyll concentration (Chl) in the sea surface layer and primary production in the Black Sea was studied using of SeaWiFS satellite color scanner data from 1998 to 2010 and the regional algorithms. It was revealed that seasonal chlorophyll dynamics in deep water is described with U-like form curve: maximum values were observed in winter-spring and fall periods and minimum ones in summer. By contrast, in the northwestern Black Sea maximum Chl was in summer and fall seasons. In the years with severe winters Chl was 3 -5 times higher than in the years with warm winters. The inverse relationship between mean Chl and December – March temperature was registered. The results of study of the photosynthetic characteristics of the Black Sea phytoplankton as well as vertical chlorophyll distribution were the base of the regional the low parametric regional model development for computation the Black Sea primary production values. The annual phytoplankton productivity cycle was shown to differ between sea regions and vary years-to-years due to climate changes. Annual phytoplankton production of the whole Black Sea basin varies from 59 to 71 being equal 64 $\pm$ 4 million tons organic carbon averaged.

Traits and trade-offs that shape diverse phytoplankton populations

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The phytoplankton community which performs primary production in the global ocean is inherently very diverse. We will discuss to what extent it is necessary to resolve this diversity to develop interpretive and prognostic models of global ocean productivity. The representation of diverse populations requires quantitative characterization of key traits and trade-offs which determine fitness in different environments. We will discuss a simplified but general framework with which to describe phytoplankton combining biophysical constraints related to cell-size and the costs and benefits of specific biogeochemical functionality.

Fixed-nitrogen and atmospheric N2 contribution to biological productivity along a North-South transect in the Eastern Atlantic Ocean

FONSECA BATISTA, DEBANY AND DEHAIRS, FRANK 1

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Marine primary production is limited by nitrogen availability over large areas of the world's ocean but especially in tropical and subtropical waters [Moore et al., 2009]. Nitrogen thus plays a critical role in the sequestration of atmospheric carbon into the deep ocean via the biological pump [Sohm et al., 2011]. The fixed-nitrogen budget in oceanic systems presently indicates that sources and sinks for nitrogen are not balanced. Biological nitrogen fixation provides the largest input of nitrogen to the oceans [Codispoti, 2007], while its removal through sediment and water column denitrification and anaerobic ammonium oxidation represents the loss function. The latter is generally considered to exceed the input via N2 fixation [Codispoti, 2007]. The past few years this condition has triggered several studies into the importance of N2 fixation as a source of new nitrogen to the ocean. We seized the opportunity offered by a scheduled north-south cross-Atlantic expedition to investigate the contributions of different N-nutrients (fixed nitrogen and atmospheric N2) to the biological production process and their variability between the different oceanographic provinces crossed.

The EUROPA cruise (European Universities & Research On board Polarstern in the Atlantic; [Auel et al., 2012]) took place on board R/V Polarstern sailing from Bremerhaven (Germany) to Cape Town (South Africa, ANT XXIX/1; Oct.-Nov. 2012). The cruise section followed the NW African coast, possibly affected by Saharan dust input, and crossed the area of marked nutrient doming (centered on the equator) and O2 depletion (on both sides of the equator) between 20°N and 20°S. At 17 stations, between 37.83°N and 26.26°S, we sampled the upper 700m of water column for nutrient distributions (ammonium, nitrate, phosphate) and for the natural isotopic composition of nitrate (δ15N and δ18O) to trace the major biological transformations of the nitrate pool, including N2-fixation [Großkopf et al., 2012]. We also conducted incubation experiments, using stable isotope enrichment techniques (15N2; 15NO3-;15NH4+; H13CO3-), for assessing primary production (PP) and the contribution of different N-sources, including atmospheric N2, NO3-, and NH4+, to the PP process over the euphotic layer (surface to 0.5 % PAR depth level). Shipboard data and first results of the enrichment experiments will be discussed.

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Optimal deployment of the BioArgo network: a modelling approach.

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In the last years, a new generation of biogeochemical marine sensors appeared (i.e. for chlorophyll, nitrate or oxygen concentration). Miniaturized and characterized by very low energy consumption, they are already successfully mounted on profiling floats, opening the way to imagine a global network of drifting autonomous platforms measuring biogeochemical parameters. Such a network will provide in a near future in situ estimation of ocean primary production at large scale. More than fifty of these floats should be deployed in 2013 in the North Atlantic region and in the Mediterranean sea. The aim of this study is to draw up guidelines for optimally define such deployments on the basis of past-recorded trajectories of existing floats and modelling/assimilation projections. To define a deployment strategy, a focus on the characterization of a given process through an optimal spatio-temporal sampling will be considered as the main criteria. The first step is to estimate the accuracy that could be expected in modelling of the sampling of biogeochemical quantities along realistic lagrangian paths. Float available trajectories are compared to trajectories computed with a lagrangian numerical model, based on velocity fields extracted from the NEMO model, in its ¼° configuration of the North Atlantic basin. Biogeochemical quantities (e.g. chlorophyll concentrations) sampled along real versus modelled float trajectories are then compared. A method, based on a cloud of numerical floats deployed at the same place and same time as a real float, is proposed. The idea is then to compare a biogeochemical parameters (e.g. variable of the biogeochemical model) sampled along the real float trajectory with the equivalent mean-averaged quantity sampled by the cloud of numerical floats. We show that this method helps in modeling more precisely the sampling of biogeochemical quantities (through the description of the spring bloom phenology) along lagrangian trajectories. Results show that the chlorophyll concentration sampled along a lagrangian path can generally be numerically-forecasted with a satisfying accuracy for a complete seasonal cycle. The model performances are nevertheless highly dependent of the deployment positions, with consideration to geographical and hydrodynamical conditions (subpolar jet, subpolar gyre, intermediate area). The perspectives of this work is the set up of data assimilation experiments aiming to quantify the amount of informations brought by a given network of drifting biogeochemical sensors.

Relationships between aerosols and surface chlorophyll concentration in the Mediterranean Sea.

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The Mediterranean atmosphere is subject to a continuous intrusions of Saharan and middle Eastern mineral dust particles. The deposition on surface waters of these particles may influence oceanic biological production. In this study, eight years (2000 to 2007) of weekly satellite chlorophyll and aerosol optical thickness data, and modelled dust deposition (BSC-DREAM8b) data are investigated to describe the geographical distribution and dynamics of the variables and to find potential relationships between them. SeaWiFS chlorophyll is corrected with an algorithm accounting for the greening of the Mediterranean.

Dust deposition correlates well with chorophyll, especially in the Eastern and Central Mediterranean (EM and CM respectively). Highest correlations are found in spring especially for the CM, but also extending somewhat into the EM and the southern Western Mediterranean (WM). When seasonally detrended data are used (which could be interpreted as events in the time series) correlation between dust deposition and chlorophyll is weaker and most significant for the CM and southern WM.

Dust deposition is mostly weakly related to AOT meaning that dust in the atmosphere may often travel at high altitudes without a chance of depositing over the ocean and distributions coincide with wind patterns over the Mediterranean. AOT is highest in spring and summer, while the highest deposition occurs mostly in autumn and winter and with a clear decreasing trend away from Africa

Chlorophyll is mostly anticorrelated with AOT at the annual scale while both variables are positively correlated in summer, with the exception of the northern WM, and also in spring for the CM and EM. Seasonally detrended data shows strong positive correlations especially for the CM and EM. This has been suggested to represent a satellite signal interference between dust in the atmosphere and chlorophyll and is certainly masking the results from the correlations between actual deposition and chlorophyll. But there is no easily identifiable general trend. For instance, the northern WM in winter shows some positive correlation between chlorophyll and deposition events while there is no relationship with AOT. At the DYFAMED site, chlorophyll relates well with SeaWiFS corrected chlorophyll ($\log DYF = 0.0129 + 1.0497 \cdot \log SW$; Adj. $R2 = 0.67$; $N = 91$; $p < 0.0001$) and is statistically unrelated to AOT. However, overall we cannot conclude that there is a positive relationship between deposition and chlorophyll because of the possible contamination of the chlorophyll signal from dust in the atmosphere in different areas.

Modeling the spring bloom in North and North West Iberia by means of a N2PZD2 model

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The NW coast of Iberia is characterized by high levels of primary production that result from relatively frequent and intense inputs of nutrients caused by upwelling, especially in spring and summer. Primary production sustains wealthy fisheries and aquaculture industries, which constitute a prime economic activity in the region.

The composition of phytoplankton in an upwelling system varies from the beginning of the bloom to its end. When nutrients and irradiance are high, diatoms are the dominant group, whereas flagellates become more important when upwelling relaxes and, consequently, nutrients and light intensity decrease. In the NW Iberian coast, it has been found that Chaetoceros socialis is the dominant diatom species during the spring bloom (Bode et al., 1996, 1998).

A high resolution (approximately 3 km) configuration of the ROMS physical model with atmospheric forcing coming from the regional agency Meteogalicia (http://www.meteogalicia.es), which has shown to represent the main features of the shelf and slope circulation in the area, was run coupled to the Fasham-type Fennel biogeochemical model (N2PZD2) in order to gain a better knowledge on the main processes acting during the spring bloom.

We will show comparisons of the model results for 2006 and 2007 with observations at weekly and daily time scales (MODIS chlorophyll-a images, in situ observations from the "Instituto Español de Oceanografía" Pelacus cruises).

We have decided to use parameters that are characteristic of plankton at the spring bloom. In particular, the parameters of Chaetoceros socialis have been considered for the unique phytoplankton class of the model. The spring bloom is reasonably reproduced both in the NW and N coasts both in time, space and intensity. Differences between the primary production in 2006 and 2007 in spring, summer and early autumn are obtained and can be related to the oceanographic conditions thanks the use of a numerical model.

The obtained results highlight once again the importance of a well validated hydrodynamic model to carry out ecosystem studies from a modeling perspective. Moreover, sensitivity analysis proved that a proper representation of the nutrient availability in the area is crucial as well as a reasonable choice of the phytoplanktonic species. The results are promising and encourage to move one step forward to consider at least two phytoplanktonic groups.

Data assimilation in a state-of-the-art physical-biogeochemical model of the North Atlantic: toward synergistic usage of Sea Level, SST and Ocean Colour observations

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In recent years, the assimilation of data into coupled physical-biogeochemical models of the ocean has been addressed primarily by investigating the potential of ocean colour observations to constrain the primary production and associated biogeochemical fluxes. In the framework of the MyOcean project, a prototype, sequential assimilation system was developed to monitor the biogeochemical state of the ocean during the SeaWiFS period, using a reduced-order state estimation scheme in a North Atlantic NEMO configuration at 1/4° (NATL025) coupled to a simple LOBSTER ecosystem (Fontana et al., 2013). In a companion study, the NATL4/LOBSTER platform was used to estimate the distribution of a number of key parameters of the biological model within biogeochemical provinces of the North Atlantic using the composite Globcolour data set (Doron et al., 2011; 2013). The implementation of those two assimilation approaches rely on the anamorphosis technique that is designed to account for the non-gaussian behaviour of errors on model variables (Brankart et al., 2012). In this poster, we will review the recent progress made with ocean colour data assimilation for applications in the context of NATL025. The complementarity between biological state and parameter estimation techniques will be discussed and assessed. In the framework of a new project funded by CNES, the biological modelling platform has been complexified by substituting LOBSTER with the more elaborated PISCES formulation to ensure consistency with both operational and research applications. A comparaison between these 2 models demonstrating their respective strengths and weaknesses in terms of operationnal development will be presented. Further, implications of the PISCES formulation will be analysed in terms of observation operators, diversity of satellite observations, and ocean colour derived products to be considered for future data assimilation studies.

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Regional Variability of the Observed Influence of Mesoscale Ocean Eddies on Near-Surface Chlorophyll

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At any given time, approximately 25 percent of the World Ocean's surface is within the interiors of mesoscale eddies. Mesoscale eddies influence biogeochemical cycling in the open ocean via the horizontal advection of marine phytoplankton and the vertical flux of nutrients into and out of the euphotic zone. Modern, eddy-resolving, coupled bio/physical global ocean circulation models provide a means by which the response of phytoplankton to eddies can be investigated. These models, however, must first be compared to observations in order to verify that the modeled ecosystem response to eddies indeed represents what is actually occurring in the ocean. The comparison of models to observations has been difficult in the past because a global analysis of the observed influence of eddies on marine phytoplankton has not been carried out.

We identify and track mesoscale eddies in altimetric sea surface height maps to explore the influence of eddies on phytoplankton. These eddy trajectories are used to investigate chlorophyll anomalies in an eddy-centric, lagrangian frame of reference, allowing for the construction of composite averages that represent the mean response of chlorophyll to eddies in any particular region. Our analysis reveals that the response of phytoplankton to eddy-induced horizontal and vertical fluxes varies regionally. This regional variability is likely a result of the differential entrainment of chlorophyll and nutrients into eddies during eddy formation and the influence of vertical eddy-induced nutrient fluxes. In this presentation we highlight specific regions of the World Ocean and attribute the observed response of chlorophyll within eddies to a particular mechanism. The results of this study provide a much needed observational baseline to which coupled, eddy-resolving bio/physical ocean circulation models can be compared.

The Turbulent Induced Biodynamical Interaction (TIBI) Effect

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In the late 1990s Allan Robinson developed a theory of NPZ interactions in a laminar upwelling flow field. His approach was to use the advection reaction (AR) equation in a Lagrangian coordinate system. Recently his theory was extended to turbulent flow by applying a probability density function to the solution of the AR equation. A review of this work is presented as well as new work examining the role of the Turbulent Induced Biodynamical Interaction (TIBI) effect, which is typically neglected in advection diffusion reaction (ADR) formulations for NPZ problems. The TIBI effect is associated with turbulence inducing fluctuations in nonlinear biological constituent interactions and is separate from the effect of turbulent mixing in dispersing the constituents. A simple example of the application of the theory -that of nutrient and phytoplankton fields being upwelled into a uniform optically active turbulent mixed layer- is presented. For this example, not including the TIBI term in an ADR formulation results in an overestimate of the primary production, increasing with decreasing turbulent Peclet number.

Impact of submesocale upwelling on phytoplankton production along an oligotrophic boundary current

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This work examines the role of meso/submesocale physics on the production of phytoplankton along the course of the Leeuwin Current in the southeast Indian Ocean. Using a high resolution numerical model that resolves sub-mesoscale physical processes, we find that relatively high concentrations of nitrate could be brought up from the deep ocean into the surface layer, through upwelling that occurs in the vicinity of mesoscale eddies. The nitrate concentrations are usually patchy and associated with steep density gradients across the fronts of the eddies. Similar patchiness has been observed from field measurements and we are now able to offer an explanation. The upwelling is strongest when the Leeuwin Current, and its associated eddy field, is most energetic during the austral winter months, suggesting that this process may also explain an observed correlation between current strength and phytoplankton biomass. Similar vertical motions in a lower resolution eddy resolving model are shown to be much weaker.

Parameterising primary production and convection in a 3D model

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In the recent past some few observational and modelling studies showed that the vertical displacement of water parcels and particles in regions of deep reaching convection plays a key role in late winter / early spring primary production (e.g. Backhaus et al., 1999; Wehde et al., 2001). The underlying mechanism describes how vertical convection cells capture living phytoplankton cells and exposure them recurrently to sun light. Most ocean models applied on large spatial areas use parameterisations of convection which neglect this mechanism. In the present study a parameterisation of primary production called 'phytoconvection' is applied which includes the effect of convective upward and downward motion on phytoplankton and the corresponding primary production. This parameterisation is implemented into the primary production module of the three-dimensional physical-biogeochemical model ECOHAM (Pätsch and Kühn, 2008). The new model system is applied to the northwestern European continental shelf and areas of the adjacent Northeast Atlantic. Parallel to this a reference simulation is made using a standard parameterisation of primary production. We focussed our analysis on a water column at a station in the eastern Rockall Trough to investigate the implications of the changed parameterisation of the primary production module for the ocean biology during the annual cycle. The credibility of the simulation results is also validated using observational data. Furthermore, the results of both simulations are compared within the whole model area to evaluate the regional differences and accordances between the two approaches - the standard type and the 'phytoconvective' type. The simulations show that the applied parameterisation of 'phytoconvection' produces deep-reaching living chlorophyll which compares reasonable to observed distributions of phytoplankton during late winter / early spring. Hence, the strong influence of deep convection during late winter / early spring on the primary production is demonstrated and, consequently, on the nutrients, the zooplankton and on the carbon export production. Regarding the comparison of the standard approach and the 'phytoconvection' approach, the two simulations show good accordance during summer and autumn in most regions of the simulation area while the productivity during late winter / spring is significantly higher in the 'phytoconvection' run in the regions governed by winter convection. In a last step the results of laboratory experiments dealing with phytoplankton growth during different light-dark cycles are implemented in the parameterisation and the according model outcome is presented.

Estimates of Net Phytoplankton Productivity (NPP) and Net Community Productivity (NCP) from a Lagrangian float

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During the North Atlantic Bloom study in the Iceland Basin in 2008, several types of productivity measurements were made in connection with autonomous tracking of changes in various parameters of a water mass. Net phytoplankton productivity (NPP) was assessed from ship-based measurements of 14C incorporation as a function of irradiance (photosynthesis vs. irradiance incubations; i.e., P vs. E experiments). Net community productivity (NCP) was derived from changes in biogeochemical inventories over a two-month period, April through May. The float measured PAR, chlorophyll fluorescence, particulate organic carbon from optics, oxygen, nitrate, temperature, and salinity along a mixed-layer Lagrangian trajectory. Times series of vertical profiles of PAR and chlorophyll biomass were constructed from float data. P vs. E parameters provided model coefficients to compute NPP and uncertainty estimates from the float time series, based on Jassby and Platt's (1976) tanh-equation, for hourly and one-meter bins integrated over the euphotic zone. Modeled NPP was compared with Alkire et al. (2012)'s estimates of NCP derived from changes in oxygen, nitrate, and POC for three specific periods – early bloom, main bloom and post bloom. NPP exceeded NCP for all three periods. During the early bloom, NPP and NCP were very similar, suggesting that most of the productivity was new production. During the main diatom bloom, NPP exceeded NCP by approximately 25%, suggesting that recycling of nutrients became more important. In the post-diatom bloom period, NCP was minimal suggesting that recycled nutrients dominated productivity in the period immediately after the termination of the diatom spring bloom. These results demonstrate that float observations, coupled with productivity model coefficients, can be used to assess and compare productivities.

The influence of biogeochemical processes on the pH dynamics in the seasonally hypoxic saline Lake Grevelingen, The Netherlands

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Coastal areas experience more pronounced short-term fluctuations in pH than the open ocean due to higher rates of biogeochemical processes such as primary production, respiration and nitrification. These processes and changes therein can mask or amplify the ocean acidification signal induced by increasing atmospheric pCO_2. Coastal acidification can be enhanced when eutrophication-induced hypoxia develops. This is because the carbon dioxide produced during respiration leads to a decrease in the buffering capacity of the hypoxic bottom water. Saline Lake Grevelingen (SW Netherlands) has limited water exchange with the North Sea and experiences seasonal bottom water hypoxia, which differs in severity interannually. Hence this lake provides an ideal site to study how coastal acidification is affected by seasonal hypoxia.

We examined the annual cycle of the carbonate system in Lake Grevelingen in 2012 and how biogeochemical processes in the water column impact it. Monthly measurements of all carbonate system parameters (DIC, pH, fCO_2 and TA), chlorophyll-a, oxygen and nutrients were accompanied by measurements of gross primary production and respiration using O_2 light-dark incubations. Gross primary production (GPP) was also estimated twice via high-resolution in situ O_2 monitoring. Finally, incubations to estimate nitrification and NH_4 uptake using ^{15}N-enriched ammonium were carried out seasonally.

Our results show that the hypoxic period was rather short but severe in 2012. During stratification and hypoxia, pH differed by 0.75 units between the oxic surface water and the hypoxic bottom water. The buffering capacity, expressed as the buffer factor $\partial TA/\partial[H^+]$, varied a factor 2 with season and up to a factor 5 with depth. Rates of GPP peak in summer and range up to 800 mmol $O_2/m^2/d$. Changes in $[H^+]$ due to net primary production, which are also highest in summer, are mainly driven by high primary production rates in the surface water and the low buffer factor at depth. Nitrification rates varied between 0 and 64.8 µmol/L/d and show a Michaelis-Menten type dependency on $[NH_4^+]$. Preliminary calculations of CO_2 fluxes indicate that on a yearly basis Lake Grevelingen is a sink for CO_2.

Constraints on values of biological parameters by observed turbulence in a quasi-2D phytoplankton model of the North Atlantic

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During the STRATIPHYT cruises in Summer 2009 and Spring 2011 in-situ plankton and nutrient concentrations as well as upper-ocean turbulence characteristics were measured from Las Palmas to Reykjavik [1,2]. The measurements agree with previous findings that the incoming light intensity and the stratification of the upper ocean set important conditions for the initiation of the phytoplankton bloom close to the surface and also for a possible shift to a deep chlorophyll maximum below the mixed layer. These strong characteristic spatial patterns and temporal cycles of phytoplankton surface concentration are also observed in satellite images of chlorophyll-a concentration in the Northern Atlantic. To understand the meridional depth (upper 200 m) variation of the phytoplankton distributions, a quasi-2D phytoplankton model was used. The results indicate that with the given profiles of the turbulent vertical mixing coefficient, only a very limited interval for the biological model parameters leads to the observed depth of the phytoplankton maximum.

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Quantifying competing carbon pathways in mesoscale upwelling filaments off NW Africa

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Upwelling regions play an important role in air-sea CO2 exchange and ocean productivity, but the balance between these competing carbon pathways is poorly quantified. Understanding this balance is confounded by the characteristic mesoscale variability of these regions. We describe a Lagrangian investigation of the carbon dynamics in two mesoscale upwelling filaments advected from the NW African coast. Both filaments produced strong CO2 effluxes, consistent with rates in other major upwelling regions. Biological production in the filaments exhibited a diurnal cycle which was used to determine net community production. The two filaments were characterised by different central water masses, phytoplankton community composition and net trophic state; these factors determined the extent to which carbon uptake by the biological community was able to modulate the air-sea flux of CO2. We contrast the carbon dynamics of these two filaments to assess the significance of this mesoscale variability to carbon cycling in upwelling regions.

THE INFLUENCE OF CLIMATE MODES ON PHYTOPLANKTON VARIABILITY IN THE INDIAN OCEAN AS REVEALED BY EARTH OBSERVATION

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The Indian Ocean plays an important role in the global carbon cycle, yet it is probably the most understudied ocean basin, especially regarding biogeochemical dynamics. It is known to display strong interannual modes of variability, particularly in response to the Indian Ocean Dipole (IOD), with consequences for carbon cycling. We examine the implications of these climate modes for phytoplankton variability in the Indian Ocean, using a decade of satellite ocean-colour observations and a model that links chlorophyll-a to the size of phytoplankton cells. Interannual anomalies in chlorophyll-a and phytoplankton size structure are correlated to those in sea-surface temperature (SST), sea-surface height (SSH) and stratification. In regions influenced by the Indian Ocean Dipole, we observe a tight correlation between phytoplankton size structure and these physical variables, such that interannual variations in the physical variables accounts for up to 70% of the total variance in phytoplankton size structure. For much of the Indian Ocean, low temperature, low SSH and low stratification (indicative of a turbulent environment) are correlated with higher chlorophyll and an increase in the fraction of larger size classes, consistent with theories on coupling between physical–chemical processes and ecosystem structure. However, the inverse result is seen in the southern basin, thus does not fit this mechanism. Rather warmer waters with a deeper mixed layer and elevated sea level correlate with higher chlorophyll and larger size classes. We propose an alternative mechanism: that nutrient rich water from the Australian continental shelf is advected into the interior Indian Ocean via warm-core eddies. Understanding the mechanisms underlying variability in marine phytoplankton is an important first step towards accurate prediction of change under a warming climate. We discuss the implications of these results in relation to potential climatic modification of the marine environment.

Biogeochemistry and carbon mass balance of a coccolithophore bloom in the northern Bay of Biscay (June 2006)

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Primary production (PP), calcification (CAL), bacterial production (BP) and dark community respiration (DCR) were measured along with a set of various biogeochemical variables, in early June 2006, at several stations at the shelf break of the northern Bay of Biscay. The cruise was carried out after the main spring diatom bloom that, based on the analysis of a time-series of remotely sensed chlorophyll-a (Chl-a), peaked in mid-April. Remotely sensed sea surface temperature (SST) indicated the occurrence of enhanced vertical mixing (due to internal tides) at the continental slope, while adjacent waters on the continental shelf were stratified, as confirmed by vertical profiles of temperature acquired during the cruise. The surface layer of the stratified water masses (on the continental shelf) was depleted of inorganic nutrients. Dissolved silicate (DSi) levels probably did not allow significant diatom development. We hypothesize that mixing at the continental slope allowed the injection of inorganic nutrients that triggered the blooming of mixed phytoplanktonic communities dominated by coccolithophores (Emiliania huxleyi) that were favoured with regards to diatoms due to the low DSi levels. Based on this conceptual frame, we used an indicator of vertical stratification to classify the different sampled stations, and to reconstruct the possible evolution of the bloom from the onset at the continental slope (triggered by vertical mixing) through its development as the water mass was advected on-shelf and stratified. We also established a carbon mass balance at each station by integrating in the photic layer PP, CAL and DCR. This allowed computation at each station of the contribution of PP, CAL and DCR to CO2 fluxes in the photic layer, and how they changed from one station to another along the sequence of bloom development (as traced by the stratification indicator). This also showed a shift from net autotrophy to net heterotrophy as the water mass aged (stratified), and suggested the importance of extracellular production of carbon to sustain the bacterial demand in the photic and aphotic layers.

RESPONSE OF CARBON FLUXES TO THE SOUTHERN ANNULAR MODE: THE ROLE OF EXPORT PRODUCTION AND SEASONALITY

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The predominant climate mode in the southern hemisphere is the Southern Annular Mode (SAM). In recent decades, the SAM showed a trend toward its positive phase, characterized by stronger westerlies. This trend is attributed to changes in the atmospheric composition (increase of greenhouse gases, ozone hole) and is predicted to continue in the future.

We analyze the response of the Southern Ocean carbon fluxes to the SAM trend in a hindcast simulation of a general circulation model (MITgcm) coupled to an ecosystem model with two phytoplankton classes (REcoM-2).

During a positive SAM event with stronger westerlies more Ekman pumping is observed. As a onsequence, more carbon- and nutrient-rich deep water is brought into the mixed layer. This leads to more outgassing of natural carbon, in line with previous model studies. On the other hand, the anomalous silicate and iron input favors primary production by diatoms and causes an overall increase of net primary production in our model. Accordingly, the export of organic carbon via the soft-tissue pump is increased. Primary production is responsible for a significant drawdown of the recently entrained carbon and its immediate return to the subsurface ocean, thereby reducing the amount of carbon available for sea-air gas-exchange.

The response of the carbon fluxes to a positive SAM event of the same magnitude is very different in different seasons. While the vertical advection anomalies are independent of season, primary and export production can only increase in summer, leading to a drawdown of natural carbon, opposite to the annual mean response. In winter, export production hardly changes, and outgassing of natural carbon occurs.

The positive trend in the SAM index is strongest in summer and it will be important for the future Southern Ocean carbon sink, how more vertical exchange caused by the SAM and more stratification caused by global warming will be balanced and whether the SAM effect will be dominant in summer.

The impact of global warming on seasonality of ocean primary production

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The seasonal cycle (i.e. phenology) of oceanic primary production (PP) is expected to change in response to climate warming. Here, we use output from 6 global biogeochemical models to examine the response in the seasonal amplitude of PP and timing of peak PP to the IPCC AR5 warming scenario. We also investigate whether trends in PP phenology may be more rapidly detectable than trends in PP itself. The seasonal amplitude of PP decreases by an average of 1-2% per year by 2100 in most biomes, with the exception of the Arctic which sees an increase of 1% per year. This is accompanied by an advance in the timing of peak PP by 0.5-1 months by 2100 over much of the globe, and particularly pronounced in the Arctic. These changes are driven by an increase in seasonal amplitude of sea surface temperature (where the maxima get hotter faster than the minima) and a decrease in the seasonal amplitude of the mixed layer depth and surface nitrate concentration. Our results indicate a transformation of currently strongly seasonal (bloom forming) regions, typically found at high latitudes, into weakly seasonal (non-bloom) regions, characteristic of contemporary subtropical conditions. On average, 36 years of data are needed to detect a climate change-driven trend in the seasonal amplitude of PP, compared to 32 years for mean annual PP. We conclude that analysis of phytoplankton phenology is not necessarily a shortcut to detecting climate change impacts on ocean productivity.

The role of light for phytoplankton distributions and productivity

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Light is fundamental to primary production. However, exactly where and to what degree light limits photosynthesis in the ocean remains unclear. To tackle this problem, we developed the irradiance component of a coupled MITgcm and ecosystem model similar to that of Follows et al. 2007 (Science), which includes many phytoplankton types. The degree of light limitation was quantified by the ratio of PAR and the light saturation parameter (Ek) for each phytoplankton, as predicted by the model. Light limitation was most pronounced in the high latitudes during winter and varied considerably across ocean basins. The degree of light limitation also differed between phytoplankton types. Phytoplankton with similar light absorption spectra to that of insitu PAR were likely to be less light limited than types with poorly-matched spectra. However, the amount of pigment in the cells (given by the chlorophyll-a to carbon ratio, Chla:C) was also important. In particular, the fact that diatoms are known to have higher maximum Chla:C compared to other species was important for their survival at the base of the euphotic zone and in regions with deep mixed layers. We use the model to consider how light acts as a limiting resource for both primary production and species competition, and explore the relative importance of light compared to other factors such as nutrient availability and temperature. We will also show real colour images for the surface ocean and consider the application of such models for satellite oceanography.

Using satellites to understand coccolithophore blooms

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The annual and inter-annual variability in phytoplankton bloom metrics can provide insights into the environmental factors that drive these blooms. The phenological characteristics of phytoplankton blooms have previously been explored using satellite derived chlorophyll-a as a proxy for phytoplankton biomass. However, we would like to assess phenology of different phytoplankton functional types separately in order to identify those factors that may specifically lead to the bloom formation of biogeochemically important coccolithophores and to use this information to determine whether these variables might affect the distribution of different coccolithophore morphotypes. As an initial step in this analysis, we use satellite derived Particulate Inorganic Carbon (PIC) measurements that allow us to decouple the bloom dynamics of coccolithophores (specifically Emiliania huxleyi) from the mixed phytoplankton signal. We present global maps of the annual and inter-annual variability in Emiliania huxleyi bloom characteristics, such as timing and magnitude, and investigate the environmental factors most likely to influence spatial and temporal patterns in coccolithophore blooms.

Nutrient pumping by submesoscale instabilities in the Mauritanian upwelling system

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Observations made within a cold filament in the Mauritanian upwelling system suggest that submesoscale frontal ageostrophic secondary circulations (ASC) at the peripheral edges of the filament sustained high levels of primary productivity by continuously resupplying nutrients to the euphotic zone. At the beginning of the experiment for which observations were made on the shelf and far from the front, primary production (PP) in the euphotic layer of 8.2 gC/m2/day was supported by nitrate concentrations (NC) of 8 mmol/m3. As the drifter marking the origin of the Lagrangian reference frame approached the front, PP dropped to 1.6 gC/m2/day whilst NC dropped to 5.5 mmol/m3. Thus, whilst the observed change in nutrients on the shelf accounted for 95-98% of the new PP, this value dropped to 50% near the front. These estimates take account of the observed f-ratio in the plankton community measured through nitrate uptake incubation experiments. We propose that the missing nutrients were supplied at the front by the ASC which were apparent as intense vertical velocities >100 m day-1 when measured by a drifting ADCP. Confluent flow sharpened the front on the northern edge of the filament leading to frontogenesis. The frontal circulations appear to have then been triggered by a wind-driven nonlinear Ekman buoyancy flux (EBF) generated by the persistent northerly wind stress that had a down-front component at the northern edge of the inshore section of the filament. The intense downwelling observed on the cold side of the front is accompanied by a weaker upwelling on the warm side that could have pumped nutrients across the front into the filament.

Variability of phytoplankton photosynthetic activity in a macrotidal ecosystem (the Strait of Dover, eastern English Channel, France)

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The dynamics and controls of phytoplankton photosynthetic activity were studied at different spatial and temporal scales in the coastal waters of the eastern English Channel. The photosynthetic parameters were investigated in situ between October 2008 and August 2010. They were related to physicochemical parameters (light, water temperature, salinity, nutrient concentrations) and phytoplankton community structure. The photosynthetic activity was obtained by measuring rapid light curves (RLC) using the Pulse Amplitude Modulated (PAM) fluorometry. The level of variability and factors influencing the photosynthetic activity depend on the scale considered. In space, no gradient of photosynthetic parameters was found between the coastal and offshore waters along a 10 km-transect. By contrast, within the water column along a depth gradient, variations of the maximum quantum yield (Fv/Fm), the maximum electron transport rate (ETRm) and the light saturation coefficient (Ek) were observed. At short time scales (from hour to the scale of a neap-spring tide cycle), the photosynthetic parameters were considerably variable. They were mainly influenced by light conditions, temperature and nutrient availability while phytoplankton community structure seemed to have a little importance. At longer time scales (from fortnightly to inter-annual scales), Fv/Fm, Alpha (the maximal light utilization efficiency) and ETRm varied without any clear seasonal cycle while Ek followed the seasonal variations of light. At these time scales, close interplays between shifts of phytoplankton communities and changes of light, temperature and nutrient availability controlled the variability of photosynthetic parameters. These results highlight the complexity of the control of phytoplankton photosynthetic activity in macrotidal ecosystems and the importance to investigate the photosynthetic parameters at different scales using a high sampling frequency.

Environmental control on phytoplankton size-fractionated primary production in the tropical and subtropical Atlantic, Indian and Pacific oceans

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Phytoplankton primary production and its distribution amongst different size classes play a critical role in the functioning of pelagic marine ecosystems both from an ecological and biogeochemical point of view. Around a quarter of global marine primary production occurs in tropical and subtropical latitudes of the world's oceans. Current knowledge about the variability of size-fractionated primary production in the open ocean is constrained because the limited number of cruises covering large temporal and spatial scales and using the same methodological approaches. Here we report estimates of pico-, nano- and micro-phytoplankton primary production obtained during the 2010 Malaspina circumnavigation Expedition. Size-fractionated carbon fixation rates were estimated with the 14C-uptake technique at 5 depths in 147 stations sampled along the tropical and subtropical Atlantic, Pacific and Indian oceans. The estimates carried out in the Indian and South Pacific oceans highlight because, as far as we know, not many direct observations of the size structure and metabolism of phytoplankton communities have been done before in these oceanic regions. The patterns obtained in phytoplankton size-fractionated primary production were related to changes in environmental forcings, including the input of nutrients into the euphotic zone through vertical diffusion. These results provide new insights about how nutrient supply dynamics to the upper ocean controls marine primary production and therefore influences global biogeochemical cycles.

Modeling of Primary Production in the Greenland Sea region

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Modeling of primary productivity in the Arctic region presents a unique set of challenges. These are predominantly focused around the poor validation of remote sensing and modeled data in the high latitudes, combined with an optically-complex environment. This study first examines the validity of input data sources and assumptions required for a high latitude spectral primary production model. Both the incident PAR and downwelling attenuation coefficient, key inputs for estimating light available for marine productivity, are considered. In-situ data from the ICE-CHASER 2010 cruise are used to validate modeled and remotely-sensed PAR. Our results show that thought remotely-sensed and modeled estimates of incident PAR are good they may not capture the full variation in light observed at high latitudes in summer months. A positive correlation between chlorophyll-a and light attenuation in the open ocean stations implies this region can therefore be classified as Case-I waters. We then investigate the relative importance of correctly estimating input parameters such as phytoplankton absorption spectra, phytoplankton absorption efficiency and CDOM contribution to total absorption. Finally we consider the importance of the level of complexity used in describing the vertical biomass profile for input into the primary production model. Common features of the Chlorophyll-a fluorescence profiles were near surface quenching and a sub-surface maximum. The sub-surface maxima is important in terms of relative production beneath sea-ice but it's contribution to annual integrated production may be less significant.

Potential for Improving Primary Productivity Estimates through Subsurface Chlorophyll and Irradiance Measurement

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A 26-year record of depth integrated primary productivity (PP) in the Southern California Current System (SCCS) is analyzed with the goal of improving satellite net primary productivity (PP) estimates. The ratio of integrated primary productivity to surface chlorophyll correlates strongly to surface chlorophyll concentration (chl_0). However, chl_0 does not correlate to chlorophyll-specific productivity, which appears to be a proxy for vertical phytoplankton distribution rather than for phytoplankton physiology. Modest improvements in PP model performance are achieved by tuning existing algorithms for the SCCS, particularly by empirical parameterization of photosynthetic efficiency in the Vertically Generalized Production Model [Behrenfeld and Falkowski, 1997]. Much larger improvements are enabled by improving the accuracy of subsurface chlorophyll and light profiles. In a simple vertically resolved production model, substitution of in situ surface data for remote sensing estimates offers only marginal improvements in model r^2 and total $\log_{10}$ root mean squared difference, while inclusion of in situ chlorophyll and light profiles improves these metrics significantly. Autonomous underwater gliders, capable of measuring subsurface fluorescence and irradiance on long-term, long-range deployments, increase PP model fidelity in the SCCS. We suggest their use (and that of other autonomous profilers such as Argo floats) in conjunction with satellites as a way forward for improved PP estimation in coastal upwelling systems.

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Three Improved Satellite Chlorophyll Algorithms for the Southern Ocean

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Remote sensing of Southern Ocean chlorophyll concentrations is the most effective way to detect large-scale changes in phytoplankton biomass driven by seasonality and climate change. However the current algorithms for the Sea-viewing Wide Field-of-view Sensor (SeaWiFS, algorithm OC4v6), the Moderate Resolution Imaging Spectroradiometer (MODIS-Aqua, algorithm OC3M) and GlobColour significantly underestimate chlorophyll concentrations at high latitudes. Here we use a long-term dataset from the Southern Ocean (20 - 160°E) to develop more accurate algorithms for all three of these products in southern high latitude regions. These new algorithms improve in-situ versus satellite chlorophyll coefficients of determination (r2) from 0.23 to 0.52, 0.29 to 0.53 and 0.03 to 0.27, for OC4v6, OC3M and GlobColour, respectively, while addressing the underestimation problem. This study also revealed that pigment composition, which reflects species composition and physiology, is key to understanding the reasons for satellite chlorophyll underestimation in this region. These significantly improved algorithms, and our knowledge of the effect of community pigment composition on them, will permit more accurate estimates of standing stocks and more sensitive detection of regional and temporal changes in those stocks, with consequences for derived products such as primary production and carbon drawdown.

Episodicity in Phytoplankton Dynamics on Regional and Global Scales.

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Most research to understand mechanisms controlling biological production focuses on certain domains in time and space. One example is the wealth of research that are being conducted on how biology and physics interact on mesoscales; another is the extensive effort to establish how biogeochemistry and ocean circulation control biological production on regional to global scales.

It is, however, challenging to include the results from different studies in a unified framework, and even more so to evaluate the relative importance between them. One possible approach to bridge processes in a range of temporal and spatial scales is by exploring how values of parameters such as Chl and NCP are distributed in time and space. The hypothesis is that divergences from a normal distribution can tell us something about the relative importance of different processes in controlling the biological production. In this project, we are focusing on how skewed the distributions are, and to what extent changes in phytoplankton biomass is episodic or more gradual.

We base our analysis on daily estimates of phytoplankton net production in the South California Bight. The input data are 1 year of daily MODIS satellite ocean color fields in conjunction with surface velocities from a high-resolution operational ocean circulation model (ROMS/JPL). Chlorophyll and light attenuation are combined with a carbon to chlorophyll model to estimate the phytoplankton carbon (PC) stock in the euphotic layer. A satellite-based productivity estimate in analogy with net community production (NCP), is derived by tracking changes in satellite-derived PC from one satellite image to the next, along water parcel trajectories calculated with surface velocities from the ocean circulation model. Such an along-trajectory analysis of satellite data discounts the effect of advection that would otherwise contribute to the temporal change between consecutive images viewed in the fixed reference frame.

These results are then used, in combination with sea surface temperature, to analyze how biological production varies in time and space on different temporal scales. Questions we address are such as how well changes in SST covary with biological production, what the typical spatial scales of events with biological production are, and how such events are distributed in space and time.

Finally, we expand the scope to the global scale by comparing our results from the South California Bight with distributions of Chl and SST from daily global MODIS satellite fields for the years 2002-2012. We calculate skewness and episodicity for each 9 km*9km grid cell in the global grid to identify regions with different characteristics.

The Sensitivity of the Seasonal Cycle of Phytoplankton Productivity to sub-Seasonal Mixed Layer Dynamics in the Sub-Antarctic Region

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In this study we initially provide an overview of Southern Ocean-scale spatial variability of the mean seasonal and sub-seasonal characteristics of phytoplankton biomass variability using a decade of ocean colour data. This analysis showed that there are not only strong contrasts between the main ocean basins but also that much of the elevated biomass regions are linked to strong intra-seasonal variability rather than a seasonal cycle (*Thomalla et al.*, 2011; *Fauchereau et a*l., 2011). We then examine the non-linear relationship between net community production and mixed layer variability using a high resolution multi-year data set of NCP derived from O2:Ar observations. The data show that, for an Iron limited system, not only is there an unexpectedly strong sensitivity to light variability but the regions of highest NCP were also the region with the highest variability in NCP. We propose a mixed layer physics mechanism that is consistent with both the non-linear relationship between NCP and MLD as well as with the high variability in the highest NCP region south of Africa (*Joubert et al,* 2013 in prep). Finally we use data derived from the deployment of 5 gliders in the SAZ south of Africa for the spring – later summer period of the austral summer in 2012 – 2013. These gliders were deployed between the Sub-Tropical and Polar Fronts from September 2012 to February 2013 as part of the South African Southern Ocean Seasonal Cycle Experiment (SOSCEx) (*Monteiro et al.,* 2011 *and Swart et al,* 2012). The gliders were equipped with CDTO, fluorescence and backscatter sensors and were programmed to do about 5 dives per day down to 1000m to provide a mean surface spatial resolution of 2 – 4km. The analysis of these data is presently underway but the focus of the analysis will be to test the validity of the proposed sub-seasonal mixing – stratification hypothesis proposed on the basis of the NCP-MLD relationships above.

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A 6-year study of pelagic primary production in a freshwater influenced sub-Arctic fjord system – with a view to the past

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Pelagic primary production varies greatly between Arctic regions. Seasonality in light and sea ice conditions are considered key parameters controlling the onset of production, but they also determine the length of the potential productive period. The level of primary production is generally considered to be more dynamic, also depending on other parameters such as nutrients concentrations and hydrographical conditions. Greenland is dominated area-wise by the Greenland Ice Sheet, the second largest terrestrial ice body in the world. Greenlandic fjord systems often depict a highly seasonal terrestrial freshwater input from glaciers and rivers, an input which is expected to increase in a warming climate. Seasonal sea ice predominates in the mid and northern coastal regions, while the coastal regions and fjords in southern Greenland (i.e. sub-Arctic) often show little or no sea ice cover. Hence, other factors such as the amount of incoming light and water column stability trigger the onset of phytoplankton production. This case study focuses on the Godthåbsfjord system located in SW Greenland (64N). This fjord covers an area of c. 2013 km2 and has an average depth of c. 250m (max. 600m) with an outer sill region. The ongoing monitoring program MarineBasis (part of Greenland Ecosystem Monitoring) has monthly measured pelagic primary production since 2005, along with a multitude of parameters on hydrography, benthos and higher trophic levels. Historical data on primary production and plankton composition exists from the same location from 1955-67. These time series, combined with intense research efforts in the area, constitutes one of the most extensive marine datasets from the Arctic. This case study examines the seasonality of primary production and the seasonal succession of parameters controlling primary production in the area, particularly the influence of seasonal freshwater input from rivers and glacial and local sea ice. Results also show an interannual stability of the system in terms of annual production and resilience in the species composition of the local phytoplankton community. This case study also compares the present day dataset (2005-11) with the historical data (1955-67) regarding annual productivity and seasonality – a view to the past.

Optimized multi-satellite merger to create time series of primary production estimates in the California Current

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We use a complex minimization process to satellite retrievals of bio-optical variables with an empirically tuned quasi-analytical algorithm (QAA) scheme to minimize the differences between match-ups between (1) satellite and in situ data and (2) between the respective bio-optical products of the overlapping satellite sensors (SeaWiFS, MODIS-Aqua, MERIS). We then apply the empirically tuned QAA model to standard satellite-derived remote sensing reflectance (Rrs) products from multiple satellite sensors (OCTS, SeaWiFS, MODIS-Aqua, MERIS) and derive optimized inherent optical properties, such as spectral absorption and backscattering coefficients, merged between multiple satellites. We then use the merged bio-optical variables as input to the phytoplankton absorption based primary production model (Aph-PP) of Lee et al. [2011] to create extended time series of satellite-derived primary production estimates for the time span of 1996-2012 in the California Current. We compare the output of the Aph-PP model with the outputs of the more traditional primary production models as well as with the 26-year record of in situ depth integrated primary productivity measurements in the Southern California Current System by the CalCOFI program. We evaluate the differences between the various models and ways to improve satellite estimates of primary production. Analysis of the surface chlorophyll-a time series in the same area [Kahru et al., 2012] shows an increasing trend off central California and a decreasing trend in the central North Pacific gyre and off Southern Baja California. Although this 16-year time series is too short to separate interannual and multidecadal cycles from climate trends, the observed trends are consistent with the predicted effects of global climate change.

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Metabolic balance of the Atlantic subtropical gyres

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The metabolic balance of the subtropical gyres is under debate [*Ducklow and Doney*, 2013]. Instantaneous rate measurements from oxygen (O_2) bottle incubations indicate net heterotrophy throughout large areas, but geochemical tracers and particle fluxes suggest net autotrophy or metabolic balance. We confirm this discrepancy by comparing O_2 bottle incubations with continuous measurements of surface oxygen-to-argon ratios (O_2/Ar) by membrane-inlet mass spectrometry to derive the mixed-layer metabolic balance of the subtropical gyres during AMT (Atlantic Meridional Transect) cruises (AMT16 and AMT17, both in 2005; AMT20, in 2010). The O_2/Ar results indicate net autotrophy throughout the Atlantic subtropical gyres. In contrast, bottle incubations show regions of net autotrophy alternating with heterotrophic patches. Generally, both methods give the same sign for the mixed-layer metabolic balance during spring, but opposite signs in autumn. Since the O_2/Ar data paint such a consistent picture in time and space, it is unlikely that the net biological O_2 flux is directed into the subtropical gyres, which would correspond to net heterotrophy. In turn, this means that bottle incubations are unsuitable to correctly represent the net metabolic balance in the subtropical gyres over larger temporal and spatial scales, which agrees with recent net community production extrapolations based on satellite ocean colour measurements [*Westberry et al.*, 2013].

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The Effect of Atmospheric Dust on Phytoplankton Growth in the Sargasso Sea

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This study investigated the effect of atmospheric dust on phytoplankton growth in the Sargasso Sea (Hydrostation S, North Atlantic, 32° 10.244 N, 64° 30.016 W) during spring in March 2011. Chlorophyll a, phaeopigments and phytoplankton taxa numbers were determined using flow cytometry and fluorometry. The aim was to determine the effect of two types of dusts; anthropogenic (NIST) and Saharan dust (TSD) on phytoplankton growth, by comparing different incubation treatments. Our data show that anthropogenic dust incubations have a negative effect on phytoplankton growth compared with Saharan dust. Chlorophyll a concentrations were consistently lower than initial values at the end of incubations and declined to the lowest levels with greatest amount of anthropogenic dust of 10 mg in 2.5 L. There was no big change in phaeopigments concentrations with different treatments. Flow cytometry measurements demonstrate that the response of phytoplankton growth to dust additions differ across phytoplankton species. Eukaryotes showed a large decrease in cell numbers compared with the predominance of Synechococcus and Prochlorococcus. The anthropogenic dust additions caused a significant decrease in Synechococcus growth in contrast to Saharan dust which stimulated growth. The results have implications for continued anthropogenic emissions influencing the health and ecology of the Sargasso Sea.

Net community production in the Western Bering Sea in 2010 and 2012

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The Western Bering Sea still remains one of the least studied proviences of the global ocean in terms of spatial and temporal variability of the primary production (PP). Annual research fishery surveys revealed high interannual variability of the Pacific salmon species distribution and abundance in the region which cannot be explained by climatic fluctuations and fish biology itself. Therefore the PP variability received greater attention as a base of marine food web, and as a possible key factor for the fish community temporal evolution. The objectives of our study are 1) development of an acceptable methodology for net community production (NCP) estimation based on autumn vertical nutrient profiles, and 2) NCP spatial – temporal distribution analysis for 2010 and 2012 aimed at determination of the main physical factors influencing NCP in the area. The future direction for this work is evaluation of the role of the NCP in nekton stocks variability in 2010 and 2012. Present work is based on data of two surveys carried out in the region in Sep-Oct 2010 (84 stations) and in Jul-Oct 2012 (90 stations). The surveys have included nutrient measurements which allow us calculating a proxy for NCP for the spring-summer 2010 and 2012. In order to estimate the nutrient consumption period duration, intensive nutrient consumption was assumed to start when net cooling shuts off. Thus, the mean diurnal NCP were evaluated as total NCP divided by period duration. Obtained results revealed high interannual variability of the NCP in the Western Bering Sea, which mainly controlled by the winter convective mixing and summer upper ocean layer stratification.

Importance of physical factors on spatial and temporal variability of primary productivity in the Arabian Sea.

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Marine net primary productivity is a key process in the global carbon cycle. Marine photosynthetic plankton are responsible for approximately 50 petagrams of carbon per year of net primary production, an amount equivalent to that on land. This primary production supports essentially all life in the oceans and profoundly affects global biogeochemical cycles and climate. The present work shows spatial and temporal distribution of primary production in the Arabian Sea, the processes that regulate this distribution, and how marine primary production is sensitive to climate variability and change. The scientific objectives of this paper are to determine seasonal variability of phytoplankton for a locale subject to strong seasonal wind-stress; understand how primary productivity: Chl-a changes with the advent of the SW monsoon; and determine whether the chlorophyll specific primary production is constant through the year in the Arabian Sea, where strong seasonal signals in nutrients are characteristic. Multi satellite data and SODA data is used to study the above tasks. Statistical approaches of ocean variability and their characteristic inter-seasonal to inter-annual time scales will be described. Satellite time-series of primary production can be clearly linked to interannual ocean variability. The phytoplankton increases in the western Arabian Sea (Somlia+Oman coasts) due to upwelling along the coast during southwest monsoon season; during the northeast monsoon season, phytoplankton abundance is large in the northern Arabian Sea. The Arabian Sea becomes productive in summer not only along the coastal regions of Somalia, Arabia and southern parts of the west coast of India due to coastal upwelling but also in the open waters of the central region. The central Arabian Sea resembles the stereotypic, unperturbed tropical ocean, with a thin oligotrophic mixed layer in the months of November and May. Both the northeast and southwest monsoons disrupt this typical feature through mixed-layer deepening and eutrophication in the central and northern Arabian Sea.

Automated FRRF measurements provide an alternative means to obtain seasonal and annual primary producton estimates in the Eastern and Western Scheldt Estuaries.

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In this presentation we describe how we measured primary production (PP) based on automated measurements using Fast Repetition Rate Fluorometry (FRRF). Since 2006 monthly to biweekly measurement of PP and FRRF were made at several station in two Dutch estuaries, the mesotrophic Eastern Scheldt estuary and the turbid eutrophic Western Scheldt estuary. The results show that the FRRF method accurately captures the seasonal dynamics in primary production at all stations visited. To obtain these results, we used three different ways to calculate C-fixation rates from FRRF measurements, where two methods were based on new algorithms developed by Oxborough et al (2012, LOM 10: 142-154). The largest challenge was to obtain and understand variability (if any) in the electron requirement for C-fixation (i.e. how many electrons produced in photosystem II are needed for CO2 fixation?). Values vary between 4-7 electrons/C for both estuaries. Estimates of annual primary production for the Eastern Scheldt estuary, based on a simple yearly average of the electron requirement for C-fixation, demonstrates that annual primary production can be estimated with more than 90% accuracy! These results demonstrate that our automated FRRF measurements provide an attractive alternative method to monitor primary production. The situation for the Western Scheldt estuary is more complex, as the electron requirement for C-fixation showed more interannual variability, and we are currently investigating the reason for this. This research was funded by the FP7 project PROTOOL.

Effects of upwelling on phytoplankton variability off SW Iberia

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Iberia Peninsula (IP) constitutes the northern sector of the Canary Current Upwelling System, one of the four Eastern Boundary Upwelling Systems of the world ocean. Cooler, nutrient-rich upwelled waters are known to promote primary production and consequently, biological production. The present study analyses the influence of upwelling on phytoplankton variability over a 14-year time series (1998-2011) off southwestern IP. To address the different coastal orientations, Atlantic (west) and Gulf of Cadiz (south) coasts, three polygons were delimited within the study area: west (WC) and south (SC) coasts and Cape São Vicente (CSV), the inflection point where coastline orientation changes. Phytoplankton descriptors were chlorophyll-a concentration (Globcolour MODIS-A, SeaWiFS, MeRIS Merged product) and net primary production (Eppley-Vertically Generalized Production Model from Oregon University) while two approaches, temperature and wind-based, were used to infer upwelling patterns. Indices were derived from offshore-onshore difference of sea surface temperature (UI^T – Pathfinder's AVHRR) and Ekman transport derived from wind-scatterometer data (UI^W – QuickScat and ASCAT).

For most of the years, upwelling favorable conditions extended from May to December for UI^T and April to September for UI^W. For both indices, a clear annual cycle depicted summer as the most upwelling-favorable season. Incidence of upwelling was higher for WC and CSV (~90%) than SC (~75%). Besides, upwelling was generally less intense in the former area. Chlorophyll-a (Chl-a) monthly climatologies presented similar patterns for WC and CSV, with the lowest values during winter and two peaks in late spring (April-May) and early summer (July-August), interspersed with a decline in June. In contrast, the highest Chl-a in SC was observed during early spring, typically March. In respect to primary production (PP), all areas exhibited maximum values during summer (July-September) and minimum in winter (December-February). Across the time series, both Chl-a and PP were significantly correlated with upwelling indices, although more strongly with UI^W. The relationship between phytoplankton and upwelling in southwestern IP presented a seasonal-dependence and area-specificity.

Contribution of micro-phytoplankton to total primary production in the Atlantic gyres

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Micro-phytoplankton play a major role in the export of organic carbon to the deep ocean, in the sequestering of anthropogenic CO_2 and therefore represent an important component of the carbon pump in the global ocean. By contrast, the pico-phytoplankton constitute a significant fraction of the total biomass in the oligotrophic ocean but contribute little to the export of carbon in the open ocean. Recent studies of the oligotrophic gyres have suggested that these areas are getting larger and less productive. In this paper we quantify the contribution of micro-phytoplankton (>10 µm) to total primary production in the North and South Atlantic gyres. From 1996 to 2012, 780 measurements of primary production were used from 142 sites on 8 Atlantic Meridional Transect Cruises (United Kingdom to the Patagonian Shelf). In addition, size fractionated photosynthesis-irradiance curves were made at 36 sites. From 2008 to 2012, micro- and pico-phytoplankton depth specific primary production (Pz) varied between the North Atlantic Gyre (NAG) and South Atlantic Gyre (SAG), but the percentage contribution of these size classes to total primary production did not change. In the NAG, micro-phytoplankton Pz from 0 to 50 m depth was on average 0.11 ± 0.24 mgC m^{-3} d^{-1} and 24% of the total Pz. In deeper waters between 50-300 m, micro-phytoplankton Pz was 0.02 ± 0.05 mgC m^{-3} d^{-1} representing 16% of total Pz . By comparison, in the SAG micro-phytoplankton Pz from 0 to 50m was lower (0.05 ± 0.09 mgC m^{-3} d^{-1}; 21% of total Pz) than the NAG, whilst in deeper layers (50-300 m) Pz (0.02 ± 0.04 mgC m^{-3} d^{-1}; 15% of total Pz) was similar in the gyres. Integrated primary production (PP) was also similar in the NAG (183.3 ± 93.1 mgC m^{-2} d^{-1}) and the SAG (179.6 ± 70.0 mgC m^{-2} d^{-1}), and there was no significant difference in the contribution of micro-phytoplankton production to total PP between Atlantic Gyres, which were on average 19% in the NAG and 17% in the SAG. Though micro-phytoplankton PP was similar between gyres, micro-phytoplankton chlorophyll normalized maximum photosynthetic rates (PmB) were higher in the SAG (PmB = 6.08 ± 11.00 mgC Chl^{-1} h^{-1}) compared to the NAG (PmB 3.11 ± 5.35 mgC Chl^{-1} h^{-1}), although not significant ($p=0.22$). The photosynthetic rates of pico-phyoplankton (<2 µm) were, however, similar between gyres. Micro-phytoplankton therefore contribute ~18% to the total integrated production in the Atlantic Gyres, which contrasts previous findings in the North Atlantic that suggest a contribution of 35-50% in oligotrophic regions of the Atlantic Ocean. The observed differences in the micro-phytoplankton photosynthetic rates between Atlantic Gyres suggest the need for a regional parameterization of size fractionated production models in different oligotrophic environments.

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Evaluation of phytoplankton functional types algorithms for the complex optical waters of Hudson Bay

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Hudson Bay is a complex inland sea located in subarctic central Canada. Due to the presence of many large rivers around its perimeter, light absorption is dominated by colored dissolved organic matter (CDOM) while phytoplankton is characterized by high values of the chlorophyll-a specific absorption coefficient that are related to the presence of protoprotective pigments. There is also some seasonal variability of the light absorbing compounds (chlorophyll-a, CDOM, non-algal particles) and pigments leading to a complex optical environment. Phytoplankton functional types algorithms have been developed using open ocean optical Type I data. To evaluate their capacity to provide information in the more complex Hudson Bay waters, we used a series of in situ measurements of size fractionated phytoplankton biomass and pigments composition derived from High-Pressure Liquid Chromatography analysis together with matchups satellite images. Two published algorithms were tested: PHYSAT [Alvain et al., 2005, 2008] that evaluates phytoplankton dominant groups and a three-component model [Brewin et al., 2010] that evaluates phytoplankton size class proportions. Preliminary results indicate that both approaches provide inaccurate results when compared with in situ measurements. Data analysis is ongoing to understand the cause of the algorithms failure and evaluate if it is possible to adjust their parameters to take into account the optical particularities of Hudson Bay. Complete results will be presented at the colloquium. REFERENCES Alvain, S., Moulin, C., Dandonneau, Y. and Bréon, F. M., 2005. Remote sensing of phytoplankton groups in case 1 waters from global SeaWiFS imagery. Deep-Sea Research I, 52, 1989-2004. Alvain, S., Moulin, C., Dandonneau, Y. and Loisel, H., 2008. Seasonal distribution and succession of dominant phytoplankton groups in the global ocean: A satellite view. Global Biogeochemical Cycles, 22, GB3001. Brewin, R. J. W., Sathyendranath, S., Hirata, T., Lavender, S., Barciela, R. M. and Hardman-Mountford, N. J., 2010. A three-component model of phytoplankton size class for the Atlantic Ocean. Ecological Modelling, 221, 1472−1483.

The biogenic silica cycle in relation with hydrodynamics in the area of interaction between the Antarctic Polar Front and the Kerguelen Plateau (KEOPS 2)

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Iron availability limits primary production in HNLC waters of the Southern Ocean. In some circumstances, recurrent seasonal blooms of phytoplankton are however observed in areas characterized by strong hydrodynamics, especially where the geostrophic fronts interact with large bathymetric discontinuities, such as ridges, islands and plateaux. In the Indian sector, the interaction between the Kerguelen Plateau and the Antarctic Polar Front (APF) generates a mechanism for iron enrichment that allows the development of large populations of diatoms. This can be seen on the ocean color composite images of the northeast of Kerguelen revealing the spatial extension of a phytoplankton-rich plume whose structure is strongly influenced by mesoscale activity. During the KEOPS 2 cruise (October-November 2011) the temporal evolution of biogenic silica production by diatoms was investigated in this area by using the isotope Si-30. The development of the bloom has been followed downstream of the area of interaction between the APF and the bathymetry. Preliminary results show that silica production fluxes are among the highest reported so far in the Southern Ocean (from 4.065 ± 0.005 to 51.249 ± 0.121 mmol.m^{-2}.d^{-1}). Comparison with a reference station (west of Kerguelen) located in deep waters and not influenced by the APF, confirms that the enrichment process is responsible for the spatial shift of the biogeochemical regime downstream of Kerguelen. Although significant, silica dissolution rates are generally much lower than production rates (6.261 ± 0.008 mmol.m^{-2}.d^{-1} in average). A budget of silicon in the core of the bloom enables identifying the roles of physical and chemical factors, and their interactions in maintaining the bloom throughout the summer season. These new data will be discussed in the general framework of Southern Ocean bloom dynamics related to natural iron fertilization.

Mixed layer depth variability and phytoplankton phenology in the Mediterranean Sea

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Oceanic phytoplankton phenology is undoubtedly affected by physical forcing, although the quantification of this influence is far from completely understood. Among the physical forcing factors, the Mixed Layer Depth (MLD) is historically considered the most impacting on phytoplankton dynamic. Focusing on the Mediterranean Sea, we explored the role of MLD variations in shaping the phytoplankton phenology. We merged a large database of in situ MLD estimations with satellite ocean color surface chlorophyll concentration ($[Chl]_{SAT}$) in order to generate concomitant annual MLD/$[Chl]_{SAT}$ cycles. Several indices were also calculated to quantitatively analyze each time-series and the interplay between $[Chl]_{SAT}$ and MLD. We specifically emphasized the relevance of indices, which summarize the match/mismatch between MLD and $[Chl]_{SAT}$ characteristics. Finally, a quantitative parameterization was developed to assess the relative role of light and nutrients in determining $[Chl]_{SAT}$ variations.

As previously observed, two dominant phenological regimes exist in the Mediterranean Sea. The first is marked by a typical spring bloom, like in temperate regions. The second is characterized by a low seasonality and by an absence of intense $[Chl]_{SAT}$ peak (i.e. bloom) and is related to the regimes observed in the subtropical areas. We demonstrated that the MLD plays a key role in determining the dominant phenological regime for different areas. We also showed that regions having low seasonality are characterized by concomitant MLD and $[Chl]_{SAT}$ maxima, whereas a delay of about 30 days was observed between MLD and $[Chl]_{SAT}$ peaks in the regions with strongest seasonality. Our analysis reveals a mismatch of one month between MLD and $[Chl]_{SAT}$ increase over the whole basin. Examining the impact of MLD on light and nutrients availability for phytoplankton, mechanisms were proposed to explain these matches and mismatches.

The effects of nitrogen limitation on the electron requirement for carbon fixation in marine phytoplankton

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Primary productivity is essential to describing structure and function of aquatic ecosystems. Development of bio-optical sensors, such as fast repetition rate (FRR) fluorometers, have opened up new avenues for deriving *in situ* primary productivity from measurements of electron transfer rates (ETR). Recent methods for the determination of the functional photosystem II (PSII) reaction centre concentrations [*Oxborough* et al., 2012] and the irradiance dependence of the quantum efficiency of photosynthesis [*Silsbe* et al., 2012] now enable researchers to use FRR fluorometers as stand-alone instruments for ETR measurements. This approach, however, still suffers from the limitation that FRR fluorometers determine productivity in a photosynthetic 'currency' of electrons produced by the splitting of water at PSII whereas most aquatic disciplines are interested in carbon-specific rates of primary productivity. Thus, ETR must be converted to carbon-specific primary productivity rates via the electron requirement for carbon fixation ($\phi_{e,C}$), that is the ratio of ETR:CO_2 fixation [units mol electrons (mol CO_2 fixed)$^{-1}$]. This variable is dependent upon the physiological status of phytoplankton and thus, on environmental conditions and taxonomic differences. Here, as part of the EU program PROTOOL, we present results of a comprehensive laboratory study examining the effect of nitrogen availability on the variability of $\phi_{e,C}$ in model phytoplankton species representing key functional groups (diatoms, chlorophytes, haptophytes, prochlorophytes, picocyanobacteria, and picoeukaryotes) in coastal and open ocean waters. With this knowledge, environmental-/taxonomic-based algorithms can now be developed and tested to more accurately derive high-resolution primary productivity rates from active fluorescence.

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Temporal and spatial variability of plankton chlorophyll and primary production in the Mediterranean Sea

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We present an analysis on the spatial and temporal variability of chlorophyll and primary production for the pelagic Mediterranean Sea areas. Estimates derived by 3-D transport reaction models are compared to satellite-based values and available in-situ measurements.

The ecosystem dynamics of different sub-regions are described by means of the extended Longhurst diagrams where in addition to chlorophyll, primary production and MLD, nutricline and grazing pressure are compared. On average the Mediterranean Sea can be classified as ”subtropical nutrient-limited winter-spring production period” domain. However significant differences emerge when considering specific areas.

The integrated net primary production highlights north-south gradients that differ from surface net primary production gradients and illustrates the importance of resolving spatial and temporal variations to calculate basin-wide budgets and their variability.

We show that, on a basin scale, the Mediterranean Sea is characterised by an high degree of spatial and temporal variability in terms of primary production and chlorophyll concentrations. The seasonal cycle signal dominates over the inter-annual variability when results are aggregated on large scale averages over the pelagic areas. Specific simulations that were designed to explore the role of external fluxes and light penetration were performed. The effects of atmospheric and terrestrial nutrient loads on the total integrated net primary production account for less than 5 % of its annual value.

On eddy permeability and the potential of horizontal eddy transport to affect primary production

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It has long been recognized that mesoscale eddies may impact primary production through horizontal transport of biomass and nutrients. The efficiency of this horizontal eddy transport depends on the ability of a given eddy to trap and transfer nutrient-rich waters across contrasted biogeochemical regimes. While marine eddies are commonly regarded as impermeable systems that are not subject to inward and outward fluxes of particle, recent studies based on dynamical systems tools, suggest this picture is an approximation, in principle only valid for eddies with no temporal variability.

Here we propose a Lagrangian satellite-based framework for evaluating the ability of a given eddy to trap and transport waters, by quantifying the rate of particles exchange between the eddy and its surroundings. The approach is based on advection of numerical particles by geostrophic surface currents from satellite altimetry data, and estimating the amount of particles located within the core of the eddy at a given time.

The approach is demonstrated for the case of an Agulhas ring that inhibited the south Atlantic for 2 years between 2006 and 2007. The eddy was identified as a quasi-isolated system (i.e. characterized by low rates of inward and outward fluxes of particle) that efficiently transported nutrient-rich waters from the flanks of the Agulhas retroflection to the interior of the south Atlantic subtropical gyre. Comparison with spatial distribution of satellite-derived surface chlorophyll, showed that throughout an 11 months period and along 1500km track, the eddy trapped a patch of high chlorophyll waters. The shape of the chlorophyll patch was consistently delimited by the horizontal transport barriers associated with the eddy. These observations emphasize the important role of horizontal eddy transport in sustaining biological production over the otherwise nutrient-depleted subtropical gyres.

On the magnitude of Primary Production Reynolds effects in the open ocean

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The oceanic circulation in the meso to submesoscale regime generates heterogeneity in the concentrations of plankton and nutrients at horizontal scales below 100 km. Due to the non-linear nature of primary production, this small-scale heterogeneity can create some departure from the mean field approximation, whereby primary production is evaluated from mean distributions at coarser-scale. Here we explore the magnitude of this biological Reynolds effect. This is done with a sub-mesoscale permitting biogeochemical model, representative of the seasonally varying subtropical and subpolar gyres. We found that biological Reynolds effects account for 5-20% of the biological fluxes, of which 2/3 are due to heterogeneities at scales 30-100 km and 1/3 at scales below 30 km. Moreover, the Reynolds fluxes for primary production are systematically negative, implying that primary production tends to be reduced by non-linear interactions at the mesoscale and smaller.

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Multiple use of light energy by open ocean keystone cyanobacteria: A modelling study

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The cyanobacteria genera Prochlorococcus are the most abundant carbon dioxide fixers in the largest biomes on Earth, the subtropical gyres of the Atlantic, Pacific and Indian oceans. How they achieve this dominance remains an open question. Where depleted concentrations of dissolved inorganic nitrogen would otherwise limit biological carbon dioxide fixation, the ability to use abundant light energy to enhance both carbon reduction and uptake of dissolved organic molecules (DOM) may provide a competitive advantage for Prochlorococcus. The first model to date capable of analysing the influence of multiple light use on carbon and nitrogen metabolism in a Prochlorococcus cell is presented, based on Dynamic Energy Budget theory. The model demonstrates that dividing light energy between carbon fixation and DOM uptake allows faster growth than could be achieved through specialist photoautotrophy or photoheterotrophy. The implications for how light energy influences growth of the keystone cyanobacteria at the base of the oceanic food web will be discussed.

Estimation of Large-scale Net Community Production Patterns based on *in-situ* O_2/Ar Measurements and Remotely Sensed Properties

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Export production plays a significant role in regulating atmospheric carbon dioxide (CO_2). At steady-state, surface export production is equal to net community production (NCP). We present preliminary results for a global mixed-layer NCP map based on statistical relationships between *in-situ* O_2/Ar-NCP measurements and remotely sensed properties. First, we determine which properties relate to NCP, including phytoplankton size fractions (PSF) derived based on a new algorithm, and estimate NCP through support vector machine (SVM) regression. Finally, we compare our algorithm's predictions to the ones of other well-established approaches.

PSF is believed to influence NCP through sedimentation rate and ecosystem structure. We develop a new algorithm to assess global PSF distribution from the remotely sensed spectral features reflectance (Rrs(λ)), normalized Rrs(λ), continuum removal spectra (CR(λ)), curvature spectra (CV(λ)) and band ratios (BR(λ_1, λ_2)). These features are ranked according to sensitivities to PSF. The most sensitive spectral features are used to estimate PSF through SVM regression. Validation results show that CR(λ) and CV(λ) are the most sensitive to PSF, and that our algorithm is effective in deriving PSF. Global spatial distributions of derived PSF are consistent with our current understanding of oceanic ecosystems. Although large-scale patterns in PSF can be identified, errors at smaller scales remain significant. We present some of the patterns and the spatial relation of PSF to *in-situ* O_2/Ar-NCP measurements.

We also assess the relation of *in-situ* O_2/Ar-NCP measurements to *in-situ* sea surface temperature (SST), and remotely sensed photosynthetically active radiation (PAR), particulate organic carbon (POC), particulate inorganic carbon (PIC), chlorophyll *a* concentration (Chl), net primary production (NPP), phytoplankton absorption coefficients ($a_{ph}(\lambda)$), particulate backscattering coefficients ($b_{bp}(\lambda)$), and the slope of particulate backscattering coefficients (η). Remotely sensed variables were derived from SeaWiFS 8-day 9km×9km products and matched with *in-situ* SST and O_2/Ar-NCP measurements from 1998 to 2009. We find that NCP observations are significantly correlated to SST, PAR, $a_{ph}(\lambda)$, $b_{bp}(\lambda)$, η, NPP, POC, Chl and PSF.

We develop an algorithm to estimate NCP through SVM regression which takes into the nonlinearities and the spatial variability in the relationship of NCP to these remotely sensed properties. Finally, we assess our statistical algorithm's performance by comparison to export production estimated with the new production and particle export ratio algorithms of Laws et al. (2000) and Dunne et al. (2005), respectively, applied to satellite NPP estimates (vertically generalized production model (VGPM) [Behrenfeld and Falkowski, 1997] and carbon-based production model (CbPM) [Behrenfeld et al., 2005]). Our predictions are generally consistent with those derived by these models, but with significant differences which will be further discussed.

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Influences of deep convection on phytoplankton winter dynamics

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In the North Atlantic, winter measurements have found considerable primary production in the absence of stratification. These observation cannot be explained by our classical understanding of bloom dynamics and have led to several mechanisms been put forward to explain different aspects of these findings. One hypothesis that gained support from model studies and field measurements, suggests that deep convection can sustain low primary production during winter by superimposing sinking rates, and thus frequently returning plankton cells into the euphotic zone. In this study we investigate the effects of deep convection on phytoplankton dynamics using a biological Individual-Based-Model (IBM), coupled to a non-hydrostatic convection model. Using realistic forcing the model results showed a homogeneous phytoplankton distribution within the mixed layer but also indicated the possibility that smaller blooms can form in the absence of stratification. The total phytoplankton biomass in the mixed layer did not show a clear trend in relation to the mixed layer depth, which indicates that the inter-seasonal variability of the total phytoplankton stock might be overestimated. This holds potentially important implication for the winter carbon budget in the North Atlantic. The findings underline the importance of deep convection for phytoplankton winter dynamics in the North Atlantic and demonstrated its connection to other concepts.

The role of mixotrophic and migrating protists in the production of microplankton community of the Gulf of Finland, Baltic Sea.

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Many protists play a dual role in marine ecosystems – they act as both primary (photosynthetic) producers and secondary (heterotrophic) producers. Mixotrophic protists may present a prominent component in the plankton community and hence have a great impact on marine biogeochemical cycles and ecosystem functioning. The photopigments (especially chlorophyll a) have been used as a measure of primary producers' biomass and indirectly as primary production in the marine environment. This approach excludes possible contribution of mixotrophic activity and hence possibly would misinterpret the nutrient recycling. Usually the pigment and protist concentrations in the upper 10 m layer only are taken into account neglecting the wide spread vertical migration ability of many protist organisms. Protists are neither uniformly distributed in the water column nor show the negative correlation with depth at all occasions. Very often the sub-surface (below 10 m) or deep (below euphotic zone) maxima of protists' biomass occur.

We have conducted extensive measurements using autonomous instruments and a towed vehicle, and sampling onboard the research vessel in the Gulf of Finland in spring and summer 2009-2012. The role of migrating mixotrophic organisms, such as the ciliate Myrionecta rubra in late spring and the dinoflagellate Heterocapsa triquetra in summer is presented and discussed.

BIOLOGICAL RESPONSE TO ALTERED STRATIFICATION DUE TO CLIMATE CHANGE IN THE SOUTHERN OCEAN

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The Southern Ocean (SO) is a key component of the global carbon cycle due to both physical and biological mechanisms. The biologically driven uptake of atmospheric CO2 occurs seasonally and is highest in regions where the limiting nutrient iron is available. While recent studies suggest that this region's capacity to take up CO2 is changing, in responses to changes in wind forcing and freshwater fluxes that affect stratification, the sign of these changes remains uncertain. In this work we examine the sensitivity of different biological indicators (primary production, surface chlorophyll-a, bloom timing) to changes in surface layer stratification using a biogeochemical model. Using idealized physical forcing (solar radiation, mixed layer depth and vertical mixing), we are able to reproduce the seasonal cycle of primary production under present SO conditions and assess the changes induced by possible future perturbation of the forcing. This sensitivity analysis is used to interpret the predicted century scale changes in Southern Ocean primary production in a suite of CMIP5 models.

Estimating Oceanic Export Production based on 3D coupled physical-biogeochemical modelling

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The study addresses various aspects of model-based estimating the oceanic primary production. In particular, we consider existent interpretations of the export fluxes; influence of implied conversions between modelled chlorophyll and biomass, expressed in nitrogen and/or carbon units, and, therefore, impact of decoupling the biogeochemical (N, C, Si) cycles and chlorophyll. Sensitivity of the export production estimates to the biological model parameters is also discussed.

Impact of meso- and submeso-scale dynamics on primary production

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Keynote:

In this talk, I will review ways in which primary production is affected by meso- and submeso-scale dynamics in various regions of the ocean. In nutrient depleted regions, the underlying dynamics leading to vertical motion serves to transport nutrients from the subsurface into the euphotic layer. In light-limited regions, which are replete with nutrients, submesoscale eddies can modulate the mixed layer stratification and availability of light, which triggers phytoplankton blooms. Both vertical and lateral motions are intrinsically linked in the way the dynamics contribute to production.

Influence of river discharge on plankton metabolic balance in the coastal Bay of Bengal

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Coastal regions receives significant amount of freshwater along with nutrients and organic matter from the terrestrial ecosystem. This is expected to modify plankton metabolic balance as the nutrients support phytoplankton production whereas organic carbon fuels heterotrophic activity. On the other hand, composition of the phytoplankton is also controlled by the concentration and ratio of nutrients received while quality of the organic matter (labile versus refractile) controls the respiration rates. The plankton metabolic balance is governed by the balance between these two processes. In order to examine the same, time-series experiments were conducted in the coastal Bay of Bengal, off river Godavari, in the east coast of India for one year. Discharge increased nutrients concentrations in the coastal Bay of Bengal with high N:P ratio (19) suggesting that waters are limited by phosphate as it is removed during estuarine mixing. Discharge also brought significant amount of suspended matter that inhibited light penetration depth. As a result, nanoplankton dominant during discharge period whereas microplankton contributed significantly to the total phytoplankton biomass during dry (no discharge) period. Nevertheless, enhanced nutrients triggered phytoplankton blooms resulting in increased gross primary production (P). Despite increase in gross primary production, heterotrophy was observed associating with river discharge whereas autotrophy prevailed during dry period. This suggests that organic matter brought by the river discharge supported heterotrophic activity lead to dominant heterotrophy. The P:R (gross production to respiration) ratios were 1.0 to 1.8 during dry period and were < 1 during discharge period suggesting that significant amount of terrestrial organic matter was utilized through heterotrophic activity. As a result, high pCO2 levels (500-620 uatm) were observed in the discharge plume in the coastal Bay of Bengal. This study suggest that though river discharge is a significant source of nutrients to the coastal region to support phytoplankton production, organic matter brought by the discharge supports heterotrophic activity and dominates the autotrophic production in the coastal Bay of Bengal.

The ratio of dark respiration to maximum photosynthesis and seasonal variability in two marine coastal waters

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Variability of primary production and planktonic dark community respiration were investigated during 2012 in the surface waters of two stations; Roskilde Fjord (RF) a closed and a shallow estuary and Great Belt (GB) a station in the North Sea-Baltic Sea transition zone with strong currents. Photosynthetic rates were determined by the 14C technique as a function of irradiance over 2 h of light incubation. Following light incubation, we determined dark respiration rates by continuous measurement of oxygen concentration for 12 hours with optodes (fiber-optic oxygen meter). The ratio of respiration to maximum photosynthesis (R/Pmax %) is considered to be a useful indicator of the trophic balance of the plankton community. This ratio varied from 10 to 218 % and 51 to 197 % at RF and GB respectively and is significantly correlated with chl-a values. Lowest ratios were observed during spring/autumn blooms where Chl-a values were highest (4-5 μg/L) at both stations. These results suggest that autotrophic respiration plays a key role in community respiration during phytoplankton blooms. The effect of previous light regime on dark respiration was also investigated in this study. Zero and first order functions were used to describe the respiration rates. Dark respiration and maximum photosynthesis will be discussed in relation to plankton succession.

Patterns in phytoplankton size structure: abundance, biomass and production in coastal and open-ocean waters

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The size structure of phytoplankton assemblages is a major determinant of trophic organization and biogeochemical functioning in pelagic ecosystems. While the study of the size distribution of phytoplankton abundance and biomass has a long tradition in biological oceanography, comparatively fewer efforts have been devoted to determine the size-scaling of phytoplankton growth and metabolic rates in the field. By combining measurements of abundance and biomass as well as primary production across the cell size spectrum it is possible to address questions such as: What are the carbon turnover rates of phytoplankton within different size classes in high- and low-production waters and how do they respond to environmental forcing? Is there a linkage between the size-scaling of abundance and the size-scaling of metabolic rate? Does phytoplankton metabolism follow the same allometric rules that have been observed in multicellular organisms? Which physiological mechanisms underlie the size-scaling of growth and what implications do they have to understand the ecological strategies of different functional groups? These topics are discussed through an overview of field data of phytoplankton abundance, chlorophyll *a*, biovolume and carbon fixation measured across the whole cell size range in contrasting marine environments, including coastal and open-ocean waters as well as cold, temperate and warm regions.

Some Perspectives on Oceanic Primary Production

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In this talk, I'll present some perspectives on the topic of primary production in the ocean from the standpoint of some 'rules' and highlighting recent progress. A few of the more notable rules have to do with phytoplankton physiology and growth, and one or two illustrate the structure of the ocean's ecosystem. They mostly express maximum values, and not variability. For example, a biophysical limit to the quantum yield for photosynthesis can be defined from the number of photons (8) required to evolve 1 molecule of oxygen. Similarly, the light-saturated rate (per hour) of photosynthesis normalized to the concentration of chlorophyll-a appears to have a maximum value of 25. We can say with some confidence that the growth of phytoplankton as a function of temperature will be less than that defined by a well-known relationship, the 'Eppley curve.' How environmental factors regulate the variability of these physiological parameters, at less than their maximum values, remains an active area of research. Regarding the structure of the ocean's ecosystem, there seem to be no rules regarding the relationship of phytoplankton to the other parts of the microbial food web, except perhaps for the muted biomass changes from day to day in much of the ocean. How much photosynthetic production is passed to the protozoans, zooplankton, and bacteria, in what form and over what time scales? A fundamental property of ocean ecosystems is the depth of the productive layer, the photic zone. The photic zone has a maximum, conventionally defined as the depth of penetration of 1% of the daily total of surface photosynthetically active radiation. The '1% light depth' criterion is almost everywhere used, and is almost certainly incorrect. The actual depth of the photic zone, where photosynthesis equals autotrophic respiration (the compensation depth) has not been resolved. More accuracy in its estimation, however, can provide another avenue to derive oceanic primary production from sensors aboard earth orbiting satellites.

Quantifying the mesoscale influence on primary production in the field

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It has been suggested that physical processes at the mesoscale, such as eddies and fronts, are responsible for delivering a substantial fraction of the nutrients required to fuel open ocean primary production, particularly in the subtropics. By far the majority of the work that has sought to test this hypothesis has been model-based, and results remain inconclusive. Furthermore, observational studies have often been confined to what might be viewed as special cases: individual features such as isolated eddies or frontal meanders. Consequently, the influence on primary production of mesoscale processes in any 'typical' square of ocean remains unquantified outside models. This talk will explore the reasons why such a crucial first order estimate is still lacking and uses results of fieldwork from the North Atlantic to explore how and, indeed, if such an estimate is possible in the foreseeable future.

Assessing bivalve's distribution as a response to phytoplankton/inorganic suspended particles ratio in the Belgian Coastal zone: a trait based model.

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Phytoplankton is generally assumed as the most important source of organic matter for bivalves in many estuaries and coastal zones. In particular, filter feeding bivalves pump seawater through their gills to retain suspended particulate matter (SPM), including inorganic particles. Since phytoplankton has a high energetic value, the higher its fraction in SPM, the higher the quality of the filtered material. In the Belgian coastal zone (BCZ) SPM concentration features a gradient from East to West due to a high turbidity area in front of the port of Zeebrugge. It has been observed that when SPM concentration increases, its organic fraction (phytoplankton plus detritus) decreases [*Fettweis et al*., 2008] as it becomes more and more diluted in the inorganic material: this implies a decrease in food quality for filter feeders.

In this study we show the development of a trait based model (TBM), which main goal is to find a mechanistic explanation to the bivalve's distribution in BCZ.

To capture enough food, the bivalves must filter high amount of SPM without clogging. Gills and palps are the organs responsible for two different food harvesting functions: particles filtration and particles selection respectively. Several studies have demonstrated that these two functions are related to the sizes of the organs [*Milke and Ward*, 2003]. A trade-off between the two functions is introduced, assuming that a fixed fraction of energy is invested in the food harvesting apparatus (gills plus palps), but that each species allocate it differently between the organs. Therefore the two biological functions for food harvesting can be reduced to one trait: the gills/paps mass ratio. The following hypothesis is formulated: bivalve communities in the BCZ are firstly structured by food availability and quality, i.e. SPM concentration and organic fraction of SPM, and the trait determining the fittest species is the gills-to-palps mass ratio.

This concept was designed into equations describing bivalve's growth, and then translated into a simple box model simulating the BCZ biogeochemical conditions. The gills-to-palps ratio allowing the fittest species to grow under varying conditions are compared with in situ measurements of gills-to-palps ratios in the BCZ. To our knowledge this is the first TBM for organisms other than primary producers

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Climate change projection of phytoplankton concentrations and primary production using an eddy-resolving ocean model

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Subtropical western boundary currents are warm, fast-flowing currents that form on the western side of ocean basins transporting tropical water to the mid-latitudes. Reconstructed sea surface temperature data since 1900 shows the surface ocean warming rate over the path of western boundary currents is 2 to 3 times faster than the global mean surface ocean warming rate. The Tasman Sea, where the East Australian Current (EAC) flows, is one of the western boundary current regions with a large historical surface warming trend. It is also a region that is projected to experience a large warming with climate change. Although climate change in the Tasman Sea is driven by large-scale changes in the Southern Hemisphere winds, all existing projections come from simulations that do not fully resolve either the boundary currents or eddies, which are important to the dynamical response of the Tasman Sea to the changes in winds. Using an Ocean Eddy-resolving Model (OEM) that captures the dynamics of the EAC and its eddies we show the response of the Tasman Sea to climate change is substantially different from what is projected with a coarse resolution Global Climate Model (GCM). In the OEM climate change projection the increase EAC and increased eddy activity in the Tasman Sea increases the nutrient supply to the upper ocean and causes an increase in the phytoplankton concentration and primary productivity in the oligotrophic Tasman Sea water. In contrast, non-eddy resolving ocean simulations project a reduction in phytoplankton and primary productivity with climate change. The study demonstrates the importance of resolving eddies to climate change projections in the western boundary current regions.

Enhancement of primary production at greater resolved scales

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The global marine biogeochemical system is an integral part of the Earth system and carbon cycle. Like many other fields, as computer power improves so also has the trend towards using higher resolution in an effort to capture a greater proportion of the real world in the models. In the framework of the EU-FP7 GreenSeas project we examine this approach by performing two simulations of the global marine biogeochemical system, one at 2 degree resolution (LO-res), and the other at 1/4 degree resolution (HI-res) using the PELAGOS model, a coupling between NEMO and the BFM. Both the LO-res and HI-res simulations are set up with the same initial conditions, forcing and biogeochemical parameterizations, allowing us to perform a direct inter-comparison of the two, with a special focus on the Atlantic ocean. We examine how resolving more of the physical features affects the biogeochemical system, in particular how differences in the resolved horizontal, vertical motions and the mixed layer depth are reflected in the plankton biomass, the nutrient availability and community structure. While the global large-scale oceanographic features (fronts, gyres, etc) are captured in both the LO-res and HI-res simulations, differences in the mesoscale flow structures, and in particular the resolved vertical physics in the HI-res simulation, drive very different behaviour in the biogeochemical system. These differences in the physics drive what is a spun-up biogeochemical system in the LO-res simulation into a new regime in the HI-res simulation where overall there is greater nutrient availability and a much higher total primary production, particularly at the Equator and in the subtropics. The exception is the Southern Ocean, where despite there being higher nutrient availability at the surface and a higher regulating factor for light, the overall growth is suppressed as a result of the enhanced vertical motions bringing plankton into deeper waters. Overall this approach identify the importance of resolving the vertical dynamics in marine biogeochemical models and opens up the question of the sensitivity of the parameterizations to the resolved scales.

The response of a Gulf estuary primary production to wind forcing and river discharge

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The primary production of the Perdido Bay Estuary (PBE), a typical bay on the Florida/Alabama coast along the Gulf, was simulated using an existing calibrated model (Xia et al., 2011). To better understand primary production dynamics in the PBE and similar bay systems, idealized sensitivity experiments were conducted to examine the influence of wind stress and river discharge on the 3-D primary production signature. The numerical model used in this study was based on a general-purpose three-dimensional Environmental Fluid Dynamics Computer Code (EFDC) hydrodynamic and water quality model. Results indicate that wind direction dominates surface orientation, while wind magnitude significantly influences 3-D primary production distribution. The surface primary production size was reduced under the effect of wind and increased wind forcing. A northerly wind could extend its length and duration at a lower wind speed (e.g 3 m/s), but primary production distribution's surface size will be smaller than with no wind forcing and its length and width will usually be decreased with the wind effect compared to no wind forcing. Westerly and southerly winds resulted in significantly larger areas of primary production conditions due to longer water-residence times that allowed continued surface primary production and subsurface microbial decomposition. Northerly and easterly winds, in contrast, promoted water transport toward the Gulf of Mexico, enhancing the freshwater discharge direction from Perdido River. The effects of the freshwater discharge to the primary production will also be discussed.

In situ and satellite based estimates of marine productivity: constraints on the seasonal cycle of the Southern Ocean surface pCO2

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We estimate in situ biological carbon production rates from high frequency measurements along the trajectories of 6 CARIOCA drifters in the Atlantic and Indian sector of the Southern Ocean during 2006-2009 spring-summer periods. Net Community production (NCP) integrated over the mixed layer is derived from the daily change of the dissolved inorganic carbon (DIC) combined with mixed layer depths estimated from Argo profiles. Daily values of NCP range from 30 to 140 mmol C m-2d-1. A satellite based ocean color model is used to compute depth integrated marine net primary production (NPP) for the same periods along the trajectories of the buoys. As already mentioned by other authors, the SEAWIFS chlorophyll are underestimated by a factor $\approx$ 2-3 in the Southern Ocean. Taking this into account, the export ratio NCP/NPP is included between 0.2 and 0.9 and decreases with increasing sea surface temperature. Monthly satellite based NPP are computed over the 38°S-55°S, 60°W-60°E area of the Southern Ocean. A seasonal budget of DIC and pCO2 in the mixed layer is assessed. We quantitatively separate all the physical and biological processes that control their monthly changes. A good agreement is found with pCO2 climatology of Takahashi (2009). On an annual timescale, mean NCP is $\approx$ 4-5 times greater than mean CO2 invasion, being respectively equal to -4.9 and 1.1 mol C m-2yr-1. Attention is drawn on key parameters that control the seasonal distribution of surface pCO2 and air-sea CO2 uptake that will have to be carefully monitored or modeled under changing environmental conditions.

Regulation of seasonal primary production in eastern boundary upwelling systems

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The seasonal cycle of satellite-derived primary production (PP) was investigated within a 150 km coastal box in four Eastern Boundary Upwelling Systems (EBUS): California, Peru, Northwest Africa and Benguela. Factors that are known to either increase or inhibit (hence regulate) primary production were compared with PP. They include: (1) Nitrate supply estimated from winds and nitrate concentration in the upwelling source waters; (2) Iron supply inferred from proxies (shelf width, dust deposition, river discharge); (3) Temperature; (4) Light and (5) Physical export consisting of offshore export, eddy-driven and wind-driven subduction. The ratio of potential new production (carbon-equivalent of nitrate supply) to satellite-derived primary production, termed the N-ratio, is shown to be an indicator of PP regulation by nitrate (low N-ratios) vs. other factors (high N-ratios). The factors regulating PP at the seasonal scale in EBUS are assessed by analyzing the N-ratios and computing spatial correlations between PP and each factor each month. The regulation of primary production was found to vary spatially, seasonally and from one EBUS to another. Paradoxically, macro-nutrient supply is only a strong regulator seasonally off California (winter) and Northwest Africa, and regionally in parts of the Benguela system. Light limitation is likely in all EBUS in winter but only effectively inhibits PP (high N-ratios) off Peru and Benguela. Iron regulation is suggested for all EBUS at varying levels and highest off Peru during austral winter when light regulation increases iron demand for phytoplankton. Rapid offshore advection combined with wind-driven and/or eddy-driven subduction may explain periods of lower PP than expected from nitrate supply off California and northern Benguela. These findings suggest that generalizations regarding the regulation of primary production in EBUS should be made with caution.

Upwelling and Algae Bloom events on the Romanian Black Sea Coast

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This paper is focused on the importance of the upwelling phenomena followed by the algae bloom on the Romanian littoral of the Black Sea in 2010-2012 years. The study area is Constanta – Mamaia site (44014'N and 28038'E) on the Romanian Black Sea Coast, with significant touristic and recreation importance. On the western Black Sea there are no permanent upwelling and downwelling events due to the high variability of the winds, although the prevailing once determines a north – south general flow. The western Black Sea is a rich nutrient area to which contributes the Danube River. Considerable amount of nutrients are preserved in the Shelf Cold Waters (SCW) during winter convection and the upwelling events result in a high bioproductivity of the sea water during summer. Low temperature and high salinity indicate strong upwelling conditions. The highest correlation is between sea surface temperature and the wind component normal to the coast. Taking into account the considerable special variability, the distribution of temperature and chll-a are analyzed. The data used are from the NIMRD (sea surface temperature, salinity, chll-a) and NMA (air temperature, wind) databases and the Modis–Aqua (http://oceancolor.gsfc.nasa.gov -4km resolution). Keywords: Shelf Cold Waters (SCW), upwelling, algae bloom, chlorophyll-a, Black Sea

Causes and effects of the long-term changes in the bottom vegetation of Kazachya Bay (Crimea, the Black Sea)

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An analysis of long-term changes in the bottom vegetation of Kazachya Bay, which has formed significant seagrass meadows and was the only field of unattached forms of Gracilaria gracilis and G. dura in the Black Sea. It showed an increased biomass and density of seagrass species Zostera marina, Z. noltii and Ruppia spp. to 3-16 times, and the reduction in almost the same amount for Gracilaria spp. and Stuckenia pectinata during the last quarter, despite their high tolerance to environmental conditions. A doubling of the area occupied by Z. noltii was found and reduction of Gracilaria spp. fields was almost an order of magnitude. Z. marina and Gracilaria gracilis phytocenosis have been replaced with a mixed community of Z. marina, Z. noltii and Ruppia spp., with a high share of the unattached form Cystoseira barbata var. repens.

Increased anthropogenic and recreational pressure in the coastal zone of Kazachya Bay influence on the ruderal species Z. noltii and Ruppia spp. and their biomass and density are risen, whereas these parameters are declined for the competitor Z. marina, which indirectly indicates a destruction of biotope. It is likely that the increase in the concentration of nitrogen and phosphorus in the coastal waters contributed to the development and competitive advantage Z. noltii, Z. marina and C. barbata var. repens; their specific surface and the ratio of production to biomass are 1.3-3 times higher than that of Gracilaria spp. Development of seagrasses could also contribute to the reduction or disappearance of Gracilaria spp. field, because some species of this genera have a negative effect on the metabolism of seagrasses. Probably one of the reasons for the disappearance of Gracilaria field in Kazachya Bay is to reduce wave activity with increased density and area covered by seagrass. In these conditions, we have found the destruction of Gracilaria spp. layers and the death of their thalli, what is also typically for some unattached agarophytes and their fields in the other parts of the World Ocean.

It was suggested that the development of seagrass meadows (Zostera marina, Z. noltii and Ruppia spp.) also contributed to the decrease in the degree of silting sediments due to low development of unattached Gracilaria spp. and S. pectinata, preferring muddy habitats.

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Partitioning Phytoplankton Carbon Biomass into Three Size Groups Using Satellite Ocean Colour Observations

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In the recent years, phytoplankton functional types (PFTs) have been added to the growing list of products of ocean colour remote sensing. PFTs are the groups of phytoplankton that play a specific prominent role in the biogeochemical cycling and the functioning of marine ecosystems. Methods for deriving PFTs from remote sensing differ both in what remotely sensed variable they are based on (e.g. absorption, chlorophyll concentration, particulate backscattering) and what criterion they use to define PFTs (taxonomy or cell size). Here, we employ a PFT method that uses particulate backscattering retrievals and Mie modelling to derive the parameters of particle size distribution [*Kostadinov et al.*, 2009, 2010] and retrieve three PFTs defined by the size of cells: picophytoplankton (having equivalent spherical diameter between 0.2 and 2 μm), nanophytoplankton (2–20 μm) and microphytoplankton (20–50 μm). *Kostadinov et al.* [2009, 2010] expressed the PFTs in terms of relative contribution to biovolume concentration (i.e. the total volume of cells per unit volume of seawater). However, a more useful way to express the PFTs would be to present them in terms of carbon biomass, since this quantity is more closely related to climate and is of great interest both for biogeochemical/ecosystem modellers and for deriving phytoplankton productivity from remote sensing [e.g. *Behrenfeld et al.*, 2005]. This motivates us to develop a procedure for recasting of the PFTs from the original method in the form of carbon biomass, using quantitative relationships between phytoplankton cell volume and cellular carbon content, reported by *Menden-Deuer and Lessard* [2000], after the initial effort by *Kostadinov* [2009]. We present the preliminary results of this carbon-based partitioning of the PFTs based on global data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS).

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Variability in photosynthetic reaction centre to chlorophyll ratios and electron-carbon coupling in natural phytoplankton populations: implications for Fast Repetition Rate fluorometry based productivity algorithms.

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Active fluorescence techniques such as Fast Repetition Rate fluorometry (FRRf) are frequently employed for in situ estimation of photosynthetic electron transport rates (ETR) through photosystem II (PSII) and hence inference of carbon fixation by marine phytoplankton. However, full reconciliation of ETR with carbon fixation is complicated by a range of factors. In particular, quantification of the number of PSII reaction centres is required to enable absolute ETR to be calculated, while the coupling between photosynthetic electron transport and carbon fixation potentially depends on environmental forcing. Here we present new evidence that variability in the ratios of ETR to carbon fixation and the ratio of chlorophyll to PSII, the latter quantified using immunoblotting, may both be related to nutrient availability in natural populations. Specifically, we demonstrate that variability in Chl:PSII is related to spatial-temporal patterns of iron stress in the high latitude North Atlantic and speculate that the electron requirement of carbon fixation may be related to nitrate flux in a stratified shelf sea system. Implications for FRRf productivity algorithms and more general interpretation of fluorescence data are discussed.

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High resolution time-space variability of satellite chlorophyll-a in the coastal and coastal transition zones off central-southern Chile (33-42ºS)

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This study focuses on the evaluation of the most significant scales of time-space variability in phytoplankton biomass in the coastal band (out to 100 km from the coast) and the adjacent coastal transition zone (CTZ, up to 76°W), and on its association to local wind forcing and sea surface temperature (SST) variations off central-southern Chile (33-42°S), the southern region of the Humboldt Current System. For this purpose, a decade (2002-2012) of daily and high spatial resolution data for satellite Chl-a and SST (MODIS Aqua mission, 1x1 km resolution) was used, together with surface wind data (wind stress and wind stress curl; Cross-Calibrated Multi-Platform Surface Ocean Wind product (CCMP; 25x25 km resolution). The main frequencies of time-space variability of Chl-a and the other variables were evaluated by Multi-Taper Method -Singular Value Decomposition- (MTM-SVD).The dominant frequency of Chl-a, wind and SST in the region was the annual; however, higher and lower frequencies were also significant for Chl-a. The annual phytoplankton cycle in the coastal band displayed the following patterns of spatial variability: i) a poleward propagation of the seasonal increase in Chl-a which followed wind stress variability, and ii) a strong latitudinal zonation of the annual Chl-a signal, with 3 breaks in continuity (at 37 and 40°S, two main upwelling centers), related to wind stress and wind stress curl variability. In the CTZ, the highest mean Chl-a (>0.5 mg/m3) extended out to 200 km offshore in the northern region (33-38°S) whereas it was about half that width in the southern region (38-42°S); this pattern was positively related to a strengthening of wind stress and wind stress curl in the former. In addition, a band of 60-80 km with no significant annual variability in the CTZ separated coastal from oceanic waters. The latter suggest that the annual increase in Chl-a in the coastal band does not propagates to offshore waters; this implies that Chl-a increases in the CTZ depend upon in situ growth of phytoplankton, a process that is most likely linked to upwelling of nutrient-rich waters in mesoscale eddies in the CTZ.

Internal tidal waves effects on near-surface chlorophyll concentration and primary production around Nazaré Canyon (western Portugal) and in the central region of the Bay of Biscay

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The present study describes the effect of large-amplitude internal tidal waves on near-surface chlorophyll concentration in the central region of Bay of Biscay and around the Nazaré Canyon (western Portugal). Internal wave propagation introduces vertical motions within the water column, especially near the pycnocline, forcing water particles to upward and downward motions. Since neutrally buoyant phytoplankton cells are usually passive, these cells can be significantly displaced in the vertical. Because light intensity decreases exponentially with depth, internal waves will expose phytoplankton cells to a larger light intensity on average. Satellite SAR data was used to characterize the signatures of internal solitary waves in the central Bay of Biscay (which are locally generated by internal tidal beams) and at the region of the Nazaré Canyon (presumably tidally-generated at the Estremadura Promontory). SAR and ocean colour satellite synergy support the occurrence of enhanced levels of chlorophyll spatially correlated with internal tides. It is shown, trough a primary production model and with satellite climatological chlorophyll data, that internal waves can increase the amount of carbon released in comparison with the nonexistence of internal tides. The results suggest that internal tidal waves represent an important mechanism that can play a significant role over biological processes, such as productivity, and thus may have a relevant regional ecological impact.

Estimation of primary production at high frequency using multi-parametric relationships between PAM measurements and carbon incorporation.

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Two methods of measuring primary production, modulated fluorimetry (PAM) and the traditional carbon incorporation method (13C) were compared in situ, in the central English Channel. The relationship between carbon incorporation (Pobs) and the electron transport rate (ETR) measured using PAM was not linear but logarithmic. This result can be explained by alternative electron sinks at high irradiance which protect the phytoplankton from photoinhibition. A multi-parametric model was developed to estimate primary production by ETR. This approach highlighted the importance of taking physicochemical parameters like incident light and nutrient concentrations into account. Using the multi-parametric model which we defined by Pobs and ETR measurements at low frequencies, the high frequency measurements of ETR enabled us to estimate the primary production capacity in the central English Channel between November 2009 and December 2010 at high temporal and spatial scales.

The summer phytoplankton along Oualidia lagoon (Atlantic-Morocco). Check-list.

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Samplings were carried by means of plankton nets in the oualidia lagoon (summer 2011 and 2012). Phytoplankton samples were collected twice a month, in order to obtain significant and nonhaphazard results. 126 species were identified, for the most part constituted by Diatoms (77 species); the most strongly represented genera are Chaetoceros, Navicula, Nitzschia. The Dinoflagellates amount to 49 species, with three genera dominant: Ceratium, Dinophysis and Protoperidinium. Other taxonomic groups, Silicoflagellea included, are not very well represented or completely absent.

Dissolved gas tracers of gross primary production and net community production: perspectives from a global ecosystem and biogeochemistry model.

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Two geochemical gas tracers, the triple isotopic composition of dissolved oxygen ($^{17}\Delta$), and O_2/Ar have been widely applied over the last decade for the assessment of gross photosynthetic production (GPP_{O2}) and net community production (NCP_{O2}). Together, these tracers provide a measure of the efficiency at which an ecosystem produces organic carbon available for export (NCP_{O2}/GPP_{O2}). As $^{17}\Delta$, and O_2/Ar have now been measured in all major ocean basins save the Indian (Juranek and Quay, 2013), the tracer system is ripe for interpretation on the global scale. We have incorporated oxygen isotopologs (^{16}O, ^{17}O and ^{18}O) and Ar into the ocean biogeochemistry and ecosystem component of the Community Climate System Model, Version 3.0 (CCSM 3.0). Model results compare well to field observations across diverse oceanic environments and are consistent with the canonical relationship between GPP_{O2} and net primary production of carbon (NPP_C) of GPP_{O2} :NPP_C = 2.7 (Marra, 2002). We demonstrate that $^{17}\Delta$, and O_2/Ar have exciting potential as new constraints on primary productivity and carbon export in ocean ecosystem models.

Metabolic rates (GPP_{O2} or NCP_{O2}), are generally calculated from field tracer measurements ($^{17}\Delta$, and O_2/Ar) using equations that assume a steady-state closed system mixed layer (Kaiser, 2011; Prokopenko et al., 2011). Using model simulations we assess the importance of physical transport and non-steady-state dynamics in accurately estimating GPP_{O2} and NCP_{O2} from $^{17}\Delta$ and O_2/Ar, respectively. Results indicate spatially and temporally predictable biases introduced when steady-state equations for GPP_{O2} or NCP_{O2} are applied. Steady-state equations overestimate GPP_{O2} and underestimate NCP_{O2} in upwelling regions, overestimate both GPP_{O2} and NCP_{O2} during fall in the subtropics and underestimate both GPP_{O2} and NCP_{O2} during spring blooms. Steady-state equations underestimate export efficiency (NCP_{O2}/GPP_{O2}) in almost regions and seasons. Model corrections could improve field-based estimates of ocean primary production from gas tracers.

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Primary production in the Southern Ocean: sensitivities to sub-mesoscale dynamics and sub-seasonal atmospheric forcing.

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The presence of cyclones in the Southern Ocean results in the strong modulation of wind stress at the sub-seasonal scale. These synoptic scaled events have the potential to impact upper ocean mixing through the associated stronger momentum flux inside the cyclone and a greater loss of sensible and latent heat in the surrounding ocean (Yuan et al., 2009). With the use of a physical-biogeochemical model we investigate the interaction of sub-seasonal forcing with sub-mesoscale dynamics on primary production in the Southern Ocean. The reference configuration is a reentry zonal channel model of the Antarctic Circumpolar Current (ACC), as described in Abernathey et al. 2011. We hypothesize that in the Southern Ocean, the effects of sub-mesoscale dynamics on the vertical mixing and stratification of the upper ocean will interact with bloom dynamics on sub-seasonal scales in turn effecting the seasonal cycle of primary production and carbon export. This research project investigates the sensitivity of the seasonal cycle of primary productivity and carbon export, to 1) the presence or absence of sub-mesoscale dynamics and 2) the interaction of sub-seasonal forcing with sub-mesoscale structures.

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Influence of light attenuation on the Spring Phytoplankton Primary Production in the northern East China Sea

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The East China Sea (ECS) is a large continental shelf located on the west rim of the Pacific Ocean between 25ºN and 32ºN, covering both subtropical and temperate regions. It is marked by the large amount of nutrients supplied from Changjiang river discharges and upwelling by Kuroshio Current in the continental margin which provides conditions for the ECS to be one of the most productive waters in the world's oceans. The northern ECS is especially characterized by high seasonal variation in primary production induced by physio-environmental changes and summer discharges from Changjiang river. Spring phytoplankton blooms and primary production in the northern ECS were studied during two research cruises conducted in April and May of 2011. Phytoplankton blooms and high primary production were observed in the eastern part of the northern ECS in April. In the western part of the northern ECS, however, low productions were observed and phytoplankton blooms were limited by high turbidity brought by strong water column mixing. In May, light extinction coefficient became low, and phytoplankton blooms and primary productions were increased in the western part of the northern ECS. Such shifting of phytoplankton blooms from east to west in the northern ECS can also be confirmed from the ocean color satellite images such as NASA Moderate Resolution Imaging Spectroradiometer (MODIS) data.

Retrieval of phytoplankton size classes from light absorption spectra using a multivariate approach

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Assessing phytoplankton group-specific contributions to global primary production is important because the various phytoplankton types have distinct and different roles in biogeochemical cycles of carbon and other elements. Current approaches link information on the size structure of algal communities to their photophysiological properties. They are open to improved performances if combined with algorithms that retrieve phytoplankton size classes from space-derived or in situ measured optical properties (IOPs and AOPs). Thanks to advances in these fields, several methods have been proposed to infer phytoplankton size structure and to analyse its temporal and spatial variations. Such analyses remain, however, a challenge. Here, new models based on the multivariate Partial Least Squares regression technique (PLS) are developed for the retrieval of three phytoplankton size classes (micro-, nano- and pico-phytoplankton) from a long time-series of in situ measurements of hyperspectral particle and phytoplankton absorption (BOUSSOLE site, Mediterranean Sea). The PLS models were trained using two different datasets of High Performance Liquid Chromatography (HPLC) pigment and filter-pad absorption measurements: 1) a regional dataset including data from the Mediterranean sea only; 2) a global dataset including various locations of the World's oceans. PLS models were established for quantification of the concentrations of total chlorophyll a, of the sum of 7 bio-marker pigments and of pigments associated with micro-, nano- and pico-phytoplankton separately. Good accuracy in the retrieval of pigment concentrations and size classes over the BOUSSOLE time series was observed for PLS models trained with the regional dataset. PLS models trained with either total particle or phytoplankton absorption spectra performed similarly, and both reproduced well seasonal variations of biomass and size classes derived by HPLC over the entire time-series. Satisfactory retrievals were also obtained using the global dataset, with however a lower accuracy. These results open the way to an application of this method to absorption spectra derived from inversion of radiance measurements (from either field or satellite observations), and to an improved evaluation of temporal and spatial variations in size-partioned primary production budgets at regional and global scale.

Recent advances in the methods used to analyse Fast Repetition Rate fluorometry (FRRf) data could significantly improve the routine estimation of gross primary production on wide spatial and temporal scales

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Although FRRf has long been applied to the estimation of phytoplankton primary productivity in situ, the requirement for an independent method to determine the concentration of functional photosystem II reaction centres ([RCII]) has limited the value of this method. A new approach to the analysis of FRRf data has allowed for estimation of [RCII] from dark FRRf data alone (Oxborough et al. 2012). This approach has also led to the development of an 'absorption algorithm' for estimating phytoplankton primary productivity which does not require determination of [RCII], is valid for a heterogeneous model of connectivity among RCIIs and provides a greatly improved signal to noise ratio under high photon irradiance. An additional potential benefit is the ability to generate wavelength-specific PSII absorption coefficients from dark FRRf measurements. To test the new approach, estimates of [PSII] have made from a diverse range of phytoplankton groups using a new multi-wavelength FRR fluorometer, with excitation centred at 450, 530 and 624 nm. These estimates were checked against more direct measurements of [RCII], using flash-oxygen release. Although these data, plus data from earlier studies, are entirely consistent with the new approach, it must be acknowledged that fluorescence from sources other than functional PSII reaction centres could introduce very significant errors. Methods for minimising these errors are currently being tested and will be reported on within this presentation.

Simulating the seasonal dynamics of a disrupted coastal environment using an NPZ Ecosystem Model

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The ”Shafdan” wastewater treatment plant treats sewage of 2 million residents, amounting to a Daily intake of 380,000 m3 of wastewater. Through several processes, this intake is filtered and then degraded by bacterial activity. 15,000 m3day-1 of access activated sludge (mainly consisting of dead Bacteria) is discharged into the sea, 5 km offshore, at 38 m depth. In the framework of the National Monitoring plan IOLR has been conducting seasonal surveys in the disturbed area since 1992, the collected data was rearranged into an ODV database in preparation of this study. Although sparse in terms of time distribution, the interannual analysis of this dataset demonstrates seasonal changes in the physical parameters and their impact on oxygen, nutrients and chlorophyll concentrations. The main objective of this study is to simulate these dynamics and investigate the coupling of an ecosystem model to physics. Key issues that will be addressed include the adequacy of climatologic data for the description of the system, discrepancies between the response time of the ecosystem model state variables and the hydrodynamic time resolution and attaining the proper representation of the effluent mixing with ambient water. For this purpose a simple NPZ numerical model (Peter J.S. Franks, 2002) is used. This model represents the nutrient-phytoplankton-zooplankton relations using three state variables which are defined in terms of their nitrogen content. In addition, the effects of temperature variations were introduced. Here we present the interannual analysis of the historical dataset together with preliminary zero-dimensional runs which were used to study the NPZ model dynamics and parameterization. In the future one-dimensional runs will introduce coupling to the physical processes. Finally, the model results will be evaluated using skill assessment techniques (Stow et al, 2009) and tested on the available datasets.

Distribution of phytoplankton functional types in high-nitrate low-chlorophyll waters in a new diagnostic ecological indicator model

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In this study, we combine the best of information obtained from remote sensing and a dynamic plankton model to design a new diagnostic ecological indicator model of phytoplankton functional types (PFTs). Our model is based on an artificial neural network which has the potential to interpret complex nonlinear interactions between PFTs and the environment – types of interactions characteristic of complex adaptive systems such as marine ecosystems. Using ecological indicators that fulfill the criteria of measurability, sensitivity and specificity, we model the spatial and temporal distribution of four PFTs: diatoms, coccolithophores, cyanobacteria and chlorophytes. The results of our diagnostic model reveal apparent PFT-specific ecological rules that are not always consistent with those inferred from a dynamic plankton model. Our model is sensitive to large seasonal and inter-annual shifts in phytoplankton community composition observed in many regions. Moreover, we demonstrate that in our model diatoms and coccolithophores can be co-dominant in the high latitude high-nitrate and low-chlorophyll regions, such as the North East Pacific and the Antarctic Atlantic Ocean. Though consistent with in situ and remote sensing observations, this result is in contrast to many if not all state-of-the-art dynamic plankton models which struggle to resolve the so-called paradox of plankton. We conclude that the ecological indicator approach can be used to potentially improve both past and future model estimates of PFT distributions, and thus also primary productivity, especially in the most remote and under-sampled parts of world's oceans.

A SHIP-BASED RECORD OF TEMPERATURE, SALT, NITRATE, CHLOROPHYLL AND PRIMARY PRODUCTION OVER 1989-2011 ASSOCIATED WITH NORTH PACIFIC CLIMATE INDICES

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Monterey Bay, California, has been sampled by ship at 2-3 week intervals since 1989. Here we examine time series of temperature, salt, sigma-t, spice, nitrate, chlorophyll and primary production in the upper 200m over the 23 year record and correlate the nonseasonal variability with Pacific basin climate indices.

Anomaly time series were constructed over 0-200m. The original data series are dominated by the seasonal cycle, but the anomalies highlight ENSO and additionally indicate that Monterey Bay has been cooler and saltier, with elevated subsurface nitrate and near-surface chlorophyll and primary production over the past decade.

To explore, anomalies for 0, 60, 100 and 200m were correlated against each other and Pacific basin climate indices. Within-parameter physical and nitrate anomalies are strongly coherent across depths with the largest variability near the surface; their cross-parameter correlations are also strong except for spice. The biological parameters are strongly intercorrelated, but are less strongly correlated to the physical variables with spice being the weakest predictor of biology. The 60 and 100m physical and particularly nitrate anomalies are better predictors of the biological variables than are the 0m anomalies. The climate indices representing ENSO, the Pacific Decadal Oscillation and the North Pacific Gyre Oscillation are strongly correlated to temperature, salinity, sigma-t and nitrate at all depths; El Niño Modoki is less strongly associated. The biological parameters are less strongly but still significantly associated with ENSO and the PDO and NPGO. The analysis provides an empirical demonstration of connection between a Monterey Bay time series and North Pacific basin nonseasonal variability.

Assessment of a global eddy-permitting biogeochemical hindcast of the ocean colour era.

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The combination of climate change and various anthropogenic drivers, such as e.g. changes in external nutrient inputs and exploitation of marine resources drive important changes in marine ecosystems. These changes occur against the background of natural variability. The retrospective analysis of global ocean biogeochemical state holds promise for identifying the response of marine ecosystems and biogeochemical fluxes to natural climate variability and, potentially, allows to detect trends driven by global climate change. Ideally, such a biogeochemical hindcast simulation should resolve the mesoscale and span multiple decades. Here, we present a biogeochemical simulation at 1/4° resolution for the period between 1994 to 2010 with NEMO/PISCES. The biogeochemical model PISCES was forced off-line by weekly fields provided by a physical simulation at 1/4° resolution (orca025) over the same period. The model was initialized with global climatologies. The spin-up involved 20 years of biogeochemical off-line simulation forced by a climatology of ocean physics. The inter-annual simulation (1994-2010) followed on the spin-up. The analysis of our spin-up strategy is presented with focus on the adjustment of model fields. The inter-annual simulation is evaluated by systematically comparing model fields to observations at global and regional scales. We draw on EOF (Empirical Orthogonal Functions) analysis to evaluate spatial/temporal variability. We focus on links between biogeochemical and physical variables in order to identify underlying common modes of variability for multiple variables. Finally, to complete the assessment, we compare EOF modes for Globcolour chlorophyll estimates (a merged Seawifs-Meris-Modis product) and model output over the period of observations.

The seasonal variability of chlorophyll with special emphasis in the Mediterranean

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The seasonal component accounts for an important part of the chlorophyll time series variability in temperate and subtropical seas. Seasonal mixing of nutrient rich deep water into the upper sunlit layers fuels much of this seasonality. Analyzing the geographic distribution of the importance of seasonality we may better understand ocean functioning and the factors influencing system production. We propose a Seasonality Index (SI) as the relative importance of the variance owing to annual recurrent trends with respect to total time series variance. The index is calculated either from spectral analysis or using a statistical cubic spline adjustment.

In general, areas with a larger annual mean chlorophyll tend to have a lower SI. Areas of high chlorophyll experience more irregular surface water nutrient enrichment such as upwelling or other phenomena. But there are exceptions such as equatorial and some tropical areas with low surface chlorophyll and also low seasonal contribution to chlorophyll variability. The HOT and BATS stations show similarly low annual chlorophyll averages but HOT has a very low SI (18%) while seasonal overturning gives BATS an SI of 76%. The very oligotrophic Mediterranean open ocean has an overall high SI of 77% or higher. Coastal areas heavily influenced by large river runoff (Rhone, Po, Nile), the Alboran Sea where Atlantic waters enter the Mediterranean, the northern Aegean Sea with the influence from the Black Sea through the Sea of Marmara or the Gulf of Gabes with a shallow shelf and coastal enrichment are all areas with a large chlorophyll signal and a local decrease in seasonality. The SI is slightly larger in the western basin than in the eastern basin because of a clearer annual mixing.

In the Catalan Sea (northwestern Mediterranean), the influence of the non-seasonal variability from the Gulf of Lions, produced probably by the discharge of the Rhone, is seen in the north with a fairly clear influence cutoff south of 41.3 N. The influence of the highly seasonal open Mediterranean waters is seen east of the Balearic Islands at ca. 4 E. Littoral waters and the influence of the Ebro discharge can also be seen reducing the seasonal component of chlorophyll variability. Transects perpendicular to shore show the increase in the SI.

The overall pictutre that emerges is one of system production depending presumably on the amount or the amplitude and on the variability of forcing new or limiting nutrients into the euphotic zone. However, the seasonal predictability of this forcing plays against annual mean chlorophyll. This may have important implications when analyzing trends in nutrient load in coastal areas and in global climate change scenarios.

Net Community and Gross primary production and carbon export in the transition zone between Peru Current and South Pacific Gyre, as determined with dissolved O2/Ar ratios and oxygen triple isotope composition of O2

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We report rates of Net Community and Gross Primary Production (NCP and GPP) within the mixed layer of the Eastern Tropical South Pacific (ETSP), a relatively understudied region of the Pacific ocean, during El Nino (January-February 2010) and La Nina conditions (March-April 2011). The study area included east-west transition from the High Nutrient Low Chlorophyll regime associated with upwelling to the oligotrophic conditions on the north-eastern limb of the South Pacific Gyre. NCP rates were derived from continuous underway measurements of O2/Ar ratios made along 10S and 20S latitudes between 80W and 100W, using an Equilibrator Inlet Mass Spectrometer (EIMS) system. GPP rates were estimated from the oxygen triple isotope (OTI) mass balance within the mixed layer at several hydrographic stations along the cruise tracks.

Excluding areas clearly affected by upwelling of the O2-undersaturated waters from below, the O2-based NCP rates (in mmolCm-2d-1) averaged along 10S were 4.7±1.8 during 2010 and 6.6±1.3 during 2011. The NCP along 20S was 3x lower in magnitude, averaging 1.3±0.4 during 2010 and 1.8±0.4 mmolCm-2d-1 during 2011. In 2011, we quantified the O2-based NCP rates at several locations within the upwelling-influenced waters by constraining the contribution of O2-undersatured, upwelled waters to the mixed layer using a box model. Upwelling velocity was based on a 7Be mass balance for the upper ocean. The estimates for NCP based on O2 budgets were comparable to the Corg export fluxes simultaneously determined at selected locations based on 234Th-deficit integrated over the upper 200 m of the water column.

GPP rates were derived from OTI. Along 10S, they were 113±30 and 198±99 mmolO2 m-2d-1 in 2010 and 2011 respectively. Along 20S, the GPP rates were lower, 75±22 and 121±39 mmolO2 m-2d-1 in 2010 and 2011. NCP/GPP ratios calculated based on the dual O2 tracer (O2/Ar supersaturation and OTI composition of dissolved O2) ranged from 0.05 to 0.15, with the highest ratios observed in the offshore region between 87º and 92ºW along 10S transect. We discuss spatial variability of the NCP and GPP rates, as well as NCP/GPP ratios in the context of the dynamic hydrography within the ETSP region, examining the links between observed patterns of biological production and physical transport of nutrients into the surface mixed layer.

Phytoplankton community effects on productivity changes in a global reduced mixing scenario

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Marine ecosystem models used to investigate how global change affects ocean ecosystems and their functioning typically omit pelagic diversity. Diversity, however, can affect functions such as primary production and their sensitivity to environmental changes. Using a global ocean ecosystem model that explicitly resolves phytoplankton diversity (the Darwin model) we present a first estimate of how phytoplankton diversity may affect primary production under global change.

An idealized scenario with a sudden reduction in vertical mixing causes diversity and primary production changes that turn out to be independent of overall diversity. Direct effects of diversity appear to be governed by responses of individual phytoplankton types differing in productivity. Changes in community composition have a minor impact. The relatively weak direct diversity effects are overwhelmed by tight coupling of primary productivity to physical forcing in this simplified model plankton community. Improved representations of phytoplankton including interactions with higher trophic levels, adaptation or evolution, may be needed to fully investigate and reveal diversity effects on ocean ecosystem functioning.

Zooplankton feeding traits and community composition in a global ecosystem model

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Global marine ecosystem models are widely being used to investigate plankton biogeography and its effects on ocean ecosystem functions. In these models, typically a fairly refined representation of phytoplankton functional types contrasts with an oversimplified implementation of zooplankton characterized by rigid plankton interactions. Top-down control by zooplankton, however, may govern simulated plankton community composition and diversity, and thereby affect ecosystem functions such as primary and export production.

In order to assess potential effects of an improved representation of plankton communities, we present a new trait-based model of plankton interactions. Focusing on zooplankton feeding strategies and their trade-offs, this model explicitly resolves variable top-down control of the phytoplankton community. Coupled to a diverse phytoplankton assemblage in a global ocean ecosystem model, it aims at exploring effects of community composition on plankton biogeography and ocean ecosystem functions. This setup allows us to directly quantify differences compared to more traditional zooplankton formulations and compare communities under different environmental regimes.

The Influence of Ocean Dynamics to Net Primary Production In The Banda Sea

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Distribution of Net Primary Production (NPP) is strongly influenced by the ocean dynamics. Seawater temperature and light penetration, which are influenced by the monsoon variations, play important role to the distribution of NPP, This study has tried to combine HAMburg Shelf Ocean Model (HAMSOM) to produce the variation of seawater temperature, Gauss equation and Lambert Beer Law to estimate chlorophyll-a and light intensity at each layer from satellite-derived data, and Carbon based Production Model (CbPM) to calculate the vertical and horizontal distribution of NPP in Banda Sea.

Results of this study show that upwelling and downwelling occurred during east and west monsoons respectively in the Banda Sea. During the upwelling period, sea surface temperature (SST) in the Banda Sea is decreased by around -4oC, while in downwelling period SST is increased by 2oC. A seasonal variation also occurred to the horizontal and vertical distributions of NPP. In the euphotic depth, total NPP is approximately 800 to 1800 mg C/m2/day. The highest NPP, around 250 - 450 mgC/m2/day, is found during the east monsoon (June – August) due to upwelled water mass to surface layer (0-6 meter). On the contrary, during west monsoon (November – February) NPP is decreased to around 130 - 160 mg C/m2/ day and moved to a deeper layer (around 30 – 40 meter) due to downwelling in this region.

Spatial structures of surface chlorophyll in the equatorial Pacific during recent El Niño events

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Four El Niño events occurred since the major 1997-1998 event. While warm SST anomalies were observed from the Central American coast to the central Pacific basin in 1997-1998, the warming pattern was confined in the central Pacific during the more recent events. In this study, we apply an Agglomerative Hierarchical Clustering to monthly maps of satellite-derived chlorophyll anomalies between September 1997 and December 2010 to analyze the surface chlorophyll signatures of recent El Niño-Southern Oscillation (ENSO). Other satellite measurements (sea level anomaly, wind) and satellite-derived surface currents allow suggesting processes at work during ENSO phases. We identify five clusters; the second and third structures represent La Niña, and the fourth one illustrates an intermediate period.

The strong 1997-1998 El Niño event is described in the first cluster. A large eastward shift of the oligotrophic warm pool, a deep nutrient pool (elevated SLA) and a reduction of equatorial upwelling (reduced trade winds) result in negative chlorophyll anomalies east of 170°E between 10°S and 10°N.

The four following El Niño events (2002-2003, 2004-2005, 2006-2007, and 2009-2010) are described in cluster five. Eastward advection of oligotrophic waters of the warm pool in the west combined to westward surface current in the east contribute to the confinement of the negative chlorophyll anomalies between 160°E and 160°W in the equatorial band. This negative anomaly core corresponds to a region of elevated SLA indicating deep nutrient (nitrate and iron) sources. Yet, this deep vertical structure is probably a second order factor on surface chlorophyll changes compared to the impact of horizontal advection. Negative chlorophyll anomalies that extend eastward from the equatorial anomaly core probably result from reduced upward iron fluxes linked to the deepening of the Equatorial Undercurrent. Two other thin bands of negative chlorophyll anomaly stretch from the anomaly core; one along 8-10°N to the Central American coast and the other one toward the Marquesas Islands at 140°W, 10°S. They follow the position of enhanced eastward countercurrents.

Comparison of photosynthetic efficiency using multi-colour fluorescence and carbon fixation by species of a light-stressed mixed phytoplankton community.

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Phytoplankton exist in dynamic communities shaped by variable environmental conditions. These microscopic photoautotrophs are the principal drivers of major biogeochemical cycles of carbon and other elements in oceanic and coastal systems. The contribution to overall carbon fixation differs between major functional types of phytoplankton, such as cyanobacteria, nitrogen fixers (diazotrophs), calcifiers (coccolithophores), silicifiers (diatoms) and DMS-producers (dinoflagellates and haptophytes), as does their response to environmental stressors such as limitation of light and nutrients. However performance indicators (such as photosynthetic efficiency) of the phytoplankton in response to their environment can be masked by taxonomic signals, reducing our ability to understand functional group responses. Here we use a recently developed multi-colour excitation Pulse Amplitude Modulated (PAM) fluorometer and a Fast Repetition Rate fluorometer (FRRF), to assess the response of a mixed population of cells containing the cyanobacterium *Synnechococcus* sp. and a small coastal diatom *Skeletonema pseudocostatum* grown at two light levels. Since the fluorescence signals of phytoplankton are highly dependent on the pigments packaged within the light harvesting complexes which change due to species composition and the regulation of photopigments in light-limited situations, we expected different fluorescence signals from mixed versus unialgal cultures and those at low and high light. Recent studies have shown that single-wavelength excitation fluorometry centered around 480 nm may lead to an underestimation of the photosynthetic efficiency of cyanobacteria, however this technology is more readily available for use in oceanographic studies. To resolve the taxonomic effect, we examined fluorescence derived using single turnover blue excitation (FRRF) and single turnover excitation at 400, 440, 480, 540, 590 and 625 nm (PAM), expecting to see higher photosynthetic efficiency of cyanobacteria under 590 and 625 nm versus blue, but the opposite for the diatom. We also compared fluorescence-based estimates of production with ^{14}C uptake and oxygen production to better understand the changes in carbon fixation, photosynthetic efficiency (absolute light absorption and electron transport rate) and pigmentation in a competing phytoplankton community when faced with light limitation. In particular, this presentation will explore light absorption and utilization at multiple wavelengths by a mixed light-saturated and light-limited phytoplankton community.

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Sensitivity of the ocean biological pump to parameterizations of the recycling matter

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Sensitivities in modeling the biological pump in the GISS climate model are explored here. Results are presented from twin control simulations of the natural CO2 gas exchange between the ocean and the atmosphere, in which two ocean models are coupled to the same atmosphere (modelE). The two ocean models (Russell ocean model and Hybrid Coordinate Ocean Model, HYCOM) use different vertical coordinate systems, and therefore different representations of column physics. Both variants of the GISS climate model -- modelE with the Russell ocean and modelE with the HYCOM ocean -- are coupled to the same ocean biogeochemistry module (the NASA Ocean Biogeochemistry Model, NOBM) which computes prognostic distributions for biotic and abiotic fields that influence the air-sea flux of CO2 and the deep ocean carbon transport and storage. In particular, the model differences due to remineralization rate changes are compared to differences attributed to physical processes modeled differently in the two ocean models such as ventilation, mixing, eddy stirring and vertical advection. The Southern Ocean emerges as a key region where the CO2 flux is as sensitive to biological parameterizations as it is to physical parameterizations.

The interplay between nutrient load, N partitioning and turbulence: three key factors in the dynamics of coastal plankton

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Two intensive surveys were conducted in the coastal waters of Barcelona (NW Mediterranean) to assess short term variations of biological parameters in relation to environmental conditions. Surveys lasted 1 week, with 3 to 4 samplings per day, and were carried out in autumn and spring. We focused on two attributes: wave height, as a proxy for mechanical energy entering the system, and nutrient inputs, whose variability in total load and relative composition is a central characteristic of coastal areas. The effects of the temporal coupling or uncoupling of both factors were examined. The interplay between nutrients and turbulence was also studied by means of 2 experimental simulations with natural planktonic communities. Experimental nutrient additions varied both in terms of total nutrient load and in the balance of elements, with a particular focus on N sources, since the various forms of N are closely related to different human activities and specific land uses.

In the experiments, shifts in community composition appeared to be mostly related to the interaction between turbulence and N partitioning: under still conditions, ammonium rich waters favoured small organisms and reinforced the microbial loop, whereas nitrate mostly favoured diatom growth. Turbulence added complexity to the final outcome, because mixing tended to favour large over small osmotrophs. Therefore, the results suggested that the rapid growth of small autotrophs and heterotrophic bacteria in ammonium rich waters could be partly counteracted by diatom increases if nutrient pulses were coupled with turbulent mixing, and diatom bursts after nitrate enrichments could be largely enhanced by concomitant turbulence.

This was consistent with the observations in the field, where a fine balance between moderate turbulent mixing and nutrient availability pushed our system toward diverse trophic pathways: sudden nutrient fluxes uncoupled from water motion tended to favour bacteria and heterotrophic nanoflagellates, while their concurrence with some water column mixing shaped a favourable scenario for large autotrophs. Ultimately, these two distinct biological responses pointed toward two main disturbance scenarios: Episodes of nutrient enrichment uncoupled from mixing, mostly related to episodic water spills from the nearby city that contributed to high relative loads of ammonium and organic compounds; episodes of increased wind caused by passing weather fronts that promoted some water column mixing and the entrainment of nutrients from bottom sediments or from adjacent water masses.

Nutrient uptake and primary production in the East Antarctic sea-ice zone (SIPEX 2 preliminary results).

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Covering approximately 40% of the Southern Ocean's surface during maximum extent in September/October, sea-ice is an important component of Earth's climate system and through a variety of feedback mechanisms acts as an agent and indicator of climate change [Thomas and Dieckmann, 2010]. Sea-ice is also a structuring force in Antarctic marine ecosystems and plays a crucial role in the primary productivity and biogeochemical cycling of the Southern Ocean [Thomas and Dieckmann, 2010]. Ice algae -mainly diatoms- primary production can contribute up to 25% to the overall production of ice-covered waters in the Southern Ocean [Arrigo and Thomas, 2004]. Gaining information about primary production and regime of production in the sea-ice is thus crucial to evaluate the role of such a continent/ocean boundary zone.

As a continuation of SIPEX 1 (2007), the SIPEX 2 expedition (Sept.-Nov.2012; R/V: Aurora Australis) took place in the East Antarctic sector (63–66°S, 115-125°E). The SIPEX purpose is to investigate relationships between the physical sea-ice environment, marine biogeochemistry and the structure of the Southern Ocean ecosystems. In this context, our work is focused on improving the understanding of nutrient cycling and primary production in the seasonal drift ice. Various nutrient uptake rates (HCO_3^-, NO_3^-, NH_4^+ and H_4SiO_4) are measured with in situ incubations. Therefore, we used the isotopic tool either by isotope dilution experiments using stable isotopes (^{13}C, ^{15}N, ^{30}Si-incubations) and natural isotopic signal measurement of nitrate ($\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^-). For nitrate isotopy both sea ice and the underlying water column were sampled. Preliminary results and details of our experimental designs will be developed and discussed.

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Evaluation of chlorophyll a response to the light and water column stratification variability in the temperate latitudes of the North Atlantic Ocean using autonomous underwater Seagliders

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Autonomous underwater Seagliders are designed to collect high-resolution simultaneous measurements of physical and biochemical properties over a long period of time, providing an opportunity to monitor bio-physical interactions in the upper ocean. Their ability to map phytoplankton distributions, throughout the water column, at any time of year makes them a powerful complement to surface limited satellite remote sensing in the study of primary production. In the framework of the Ocean Surface Mixing, Ocean Sub-mesoscale Interaction Study (OSMOSIS) programme two Seagliders were deployed in the temperate latitudes (49^0N, 16^0W) of the North Atlantic Ocean in September 2012 to measure temperature, conductivity, chlorophyll a (chl a) fluorescence, particulate optical backscatter and photosynthetically active radiation (PAR) up to 1000 m depth for one year. During the first four months of the deployment, significant variability in the chl a vertical distribution was observed. In autumn, a transition from non-uniform chl a profiles with a pronounced deep chlorophyll maximum (DCM) to uniform chl a profiles took place over the sampling area. Using the data from the Seagliders, we analysed the impact of light conditions and stratification/destratification events on the shape of the chl a profiles and integrated chl a concentrations. Measurements of particulate optical backscatter and chl a fluorescence were used to estimate the effects of fluorescence quenching. Understanding of factors controlling the DCM evolution and its erosion during mixing events is particularly important for interpretation of satellite ocean colour imagery.

TOWARDS UNDERSTANDING THE SPATIAL VARIABILITY OF BLOOM ONSET IN THE SOUTHERN OCEAN

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The annual cycle of phytoplankton growth is dominated by an intense population increase known as 'bloom', which leads to sinking of organic material and contributes to the carbon flux to the deep ocean. Bloom intensity and timing have large regional variability in the Southern Ocean. Due to its High-Nutrient Low-Chlorophyll characteristics, the Southern Ocean has relatively low blooms away from specific regions where the limiting nutrient iron is more available. Such biogeochemical variability couples with regional variability in the seasonal evolution of the mixed-layer depth and stratification, which also impacts the onset of the bloom. In this study we document the regional variations in the timing of the bloom onset in the Southern Ocean, based on a 13-year product of ocean colour measurements. In addition, we collocate more than 15,000 ARGO profiles to investigate the impact of mixed-layer dynamics onto the onset of the bloom. We find a series of distinct bloom regimes and discuss them in the context of the prevailing bloom onset theories: 'Critical Depth' (Sverdrup, 1952), 'Stratification-Onset' (Chiswell et al., 2011) and 'Dilution-Recoupling' (Behrenfeld, 2010) hypotheses.

Spatial and temporal variability in chlorophyll, implications for model-validation and interpretation of data

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When using biogeochemical models for long-term simulations (decades) it is important to know if they represent interannual variability in the system. However high spatial and temporal variability in marine phytoplankton represent a challenge for the interpretation of in-situ data. One option is to omit the spatial or temporal dimension by working in variable-space as suggested by Martin [2005]. But when we are interested in the actual spatial or temporal variability this is not possible. Specifically, when analyzing in-situ data, how do we know in the variability expressed is a result of actual interannual variability or just an artifact of the sampling? Furthermore, if it is an artifact of the sampling, which density of sampling is sufficient to represent the spatial and temporal scales that we are interested in?

In addition to in-situ data, remote sensing products and models can be used for their improved coverage, at least in space. Within the field of Geostatistics, the mismatch between the variability of two samples of a given variable measured on different spatio-temporal averaging volumes - called supports - can be quantified thanks to change-of-support models [Chilès and Delfiner, 2012]. Here we apply these statistical techniques to in-situ time series measurement and high-resolution satellite images. The aim of applying this method is to get some insight into the actual spatial and temporal variability of the chlorophyll and apply this knowledge to have a more realistic view of what the data represent and how much of the variability can be caused by poor sampling when performing the model-data comparison.

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Field measurements of bio-optical properties of phytoplankton types for use in primary production models

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Bio-optical properties of phytoplankton, including absorption spectra, pigment composition using High-Performance Liquid Chromatography (HPLC) and photosynthesis-irradiance parameters (initial slope of the photosynthesis-irradiance curve and the light saturation parameter) were measured on several cruises to different parts of the world ocean. The data were analysed to isolate samples in which different phytoplankton types were dominant, using a method based on HPLC pigments as described in Sathyendranath et al. (2009, Marine Ecology Progress Series; 383: 73–8). These samples were then analysed to examine the differences in the bio-optical properties of phytoplankton according to type. The phytoplankton types analysed are Prymnesiophytes, Prochlorococcus sp., diatoms, cyanobacteria and green algae.

Towards a 3D global climatology for chlorophyll-a based on a calibration of in situ fluorescence profiles using a neural network

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Recent technological advances in oceanographic instrumentation, led to integrating chlorophyll a fluorescence miniaturized sensors to autonomous platforms such as gliders and profiling floats. The high-frequency acquisition of fluorescence profiles requires developing innovative calibration methods, hence optimizing the utilization of such data. Firstly, we proposed a method for calibrating raw fluorescence profiles into profiles of chlorophyll a concentrations ([Chl]) based exclusively on the shape of the fluorescence profiles. Using the statistical iterative learning method of artificial neural networks (multi-layered perceptron), our approach is based on the analysis of a large database comprising profiles of fluorescence and HPLC-determined [Chl], collected in a wide variety of oceanic regions. Our approach is independent on any additional input data and thus can be applied to any fluorescence profiles regardless of sampling conditions. Secondly, our goal was to merge a global database of fluorescence profiles calibrated into [Chl] profiles. Prior to the calibration, we developed and applied a systematic quality control procedure. The resulting homogeneously calibrated database, that includes around 40,000 [Chl] profiles, is a first key element required for producing a 3D climatology of [Chl] in the global ocean. Different preliminary methods for aggregating the [Chl] profiles and generating such climatology are proposed.

Multi-year prediction of Marine Productivity in the Tropical Pacific

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An estimated $\sim$ 45 Pg of carbon are fixed every year by phytoplankton, the first level of the marine food web. This net primary production (NPP) sustains a large array of marine species across the trophic chain. In certain regions, e.g. the Tropical Pacific, NPP exhibits fluctuations at interannual to decadal time scales. The predictions of NPP fluctuations could be of major relevance to the science-based management of marine resources. At present, the predictive capacity is hampered by the ability of Earth system models to reproduce the phasing and the amplitude of NPP variations. Here, we use observed sea surface temperature as a simple approach to partly overcome this difficulty. We present the first retrospective prediction of NPP over the last decades (i.e., from 1997 to 2010) with an Earth system model. Our findings suggest that NPP, which is predicted 3 years in advance over the Tropical Pacific, exhibits higher predictive skill than physical ocean's fields. Predictability arises from poleward advection of surface nutrients and iron that imprint fluctuations of ocean productivity over years.

Influence of net community production and physical processes on surface oxygen and carbon distribution along a north-south section across the Australian Sector of the Southern Ocean

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Recently, broad-scale patterns in Southern Ocean productivity have been illustrated using measurements of the dissolved oxygen/argon ratio (O_2/Ar) obtained via Equilibrator Inlet Mass Spectrometry (EIMS) to estimate net community production (NCP). Here we present high frequency measurements of dissolved oxygen, O_2/Ar ratio, CO_2 partial pressure (pCO_2), and discrete observations of inorganic carbon, along a transect in the Australian Sector of the Southern Ocean (115°E, WOCE I9S repeat line). High quality measurement of dissolved oxygen provided total oxygen saturation, which was combined with an estimate of biological oxygen saturation (from O_2/Ar) yielding new insights into changes due to physical processes alone. In order to remove the influence of varying atmospheric pressure on the physical O_2 supersaturation, we present a new correction, which accounts for the varying barometric pressure history prior to the in situ observations. Variability in surface O_2 was thus partitioned into physical and biological drivers, and indicated significant spatial heterogeneity in the distribution of oxygen saturation. In the marginal ice zone, surface oxygen undersaturation was related to physical processes, associated with a combination of sea-ice melt, mixing with upwelled, oxygen-poor, circumpolar deep water, surface cooling, and gas exchange. This physical undersaturation ($O_{2,phys} \sim 1.5\ \%$) was coincident with biological supersaturation ($O_{2,bio} \sim 3\%$, i.e. surface production compensating for the upwelled undersaturated signal) and mixed-layer inorganic carbon drawdown on the order of 100 μmol kg^{-1} (relative to inferred winter conditions). Biologically-induced O_2 supersaturation and air-sea CO_2 disequilibrium were greatest between the southern boundary of the Antarctic Circumpolar Current (63.6°S) and southern extent of the Polar Front (58.6°S, $O_{2,bio} \sim 3\ \%$, $\Delta pCO_2 \sim 25$ μatm), and between the northern extent of the Sub-Antarctic Front (45.5°S) and the Sub-Tropical Front (39.8°S, $O_{2,bio} > 4\ \%$, $\Delta pCO_2 \sim 40$ μatm). Areas of enhanced NCP were correlated with shallow mixed-layer depths, consistent with light-limitation of production. We found good agreement between estimates of net community production from the O_2/Ar ratio and from seasonal inorganic carbon deficits in surface waters south of the Polar Front.

The estuarine phytoplankton community of Bangladesh

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Bangladesh has a 710 km long coastline, bordering an aquatic ecosystem characterized by constant mixing of freshwater with saltwater and sediment, at the northern Bay of Bengal. This estuarine environment provides the coastal community with an assemblage of resources, economic benefits and services, but little is known about the stocks, abundance and diversity of species therein, including the phytoplankton, which is an important foundation of aquatic living resources. A total number of 7 classes (i.e. Bacillariophyceae, Chlorophyceae, Chrysophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae and Xanthophyceae) of phytoplankton were identified with representative of maximum 107 species from the Karnaphuli River estuary of southeast coast, 55 species from the Meghna River of south-central coast, and 36 species from the Sundarban mangrove forests and 31 species from the Shibsha River of southwest coast. Studies suggest that highest abundance of phytoplankton occur in the summer months (April-June), Bacillariophyceae being the most common type. However, their distribution and composition in an estuary may be influenced by rainfall and upstream discharge, water temperature, wind direction and current affecting mixing, nutrient supply and concentration, and grazing. In this connection, the historical trends of water temperature showed an increase over time (i.e. 28.39, 28.86, 29.31 and 29.39°C during 1970-1979, 1980-1989, 1990-1999 and 2000-2010 respectively) and the pH had a decreasing trend (i.e. 7.8, 7.6 and 7.3 during 1970-1979, 1980-1989 and 1990-1999 respectively). The effects of warmer waters and declining pH conditions could significantly change the distribution, community structure and growth of populations of phytoplankton. These apparently subtle but untoward changes may potentially alter estuarine food chain leading to significant undesirable changes in fishery biodiversity which may threaten protein supply and food security of millions of peoples as well as affect the billion dollar fishing industry in Bangladesh – most of these issues are poorly understood and virtually nothing has been studied. Therefore, it is important to determine the spatial and temporal dynamics of phytoplankton community in estuaries, and their response to changing environmental gradients and climate.

Highly resolved measures of photosynthetic electron transport in European Coastal Waters

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Phytoplankton photosynthesis is chronically under-sampled across vast regions of the ocean. The complete absence of data across vast regions of the ocean has two critical ramifications. First, the contribution of net phytoplankton production (NPP) to the global C cycle is poorly constrained, and second how NPP varies with climate change is equivocal. If oceanographers are to address these critical issues, an alternative to ship-based photosynthetic assays must be found. Across the spectrum of earth sciences, stakeholders are now looking to autonomous sensor networks as a cost-effective measure to enhance the spatial and temporal resolution of environmental datasets. The Scientific Committee on Oceanic Research in particular, noting the unparalleled coverage afforded by commercial shipping, has started an ambitious plan (OCEANSCOPE) to equip vessels with unattended oceanographic instrumentation. Here we describe an autonomous platform that can be integrated into ships of opportunity to yield accurate and resolved measures of photosynthetic electron transport rates (ETR) through space and time. By continuously flushing sea water through an active fluorometer whose optical head is exposed to a programmable LED panel, our platform has allowed us to characterize light (E) dependent changes in ETR with unprecedented resolution in the Baltic and North Seas as well as North Atlantic Ocean. Across all ecosystems, this dataset demonstrates a spatially persistent diurnal periodicity in the E-dependency of ETR. This periodicity suggests that phytoplankton continuously adjust their photosynthetic apparatus in order to optimize the supply of energy and reductant for growth.

Biodiversity hotspots of primary producers at the global scale.

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Biodiversity of primary producers is a central issue to better understand the functioning of the marine ecosystem and for its implications in biogeochemical cycles. Nonetheless, current available information are based on in situ studies and their implementation at the global scale is particularly challenging, due to the ocean extent, its temporal variability, and the heterogeneity of the data sources on which compilations are built. Here we use coupled ecological and circulation models [*Barton, 2010*] and remote-sensing analysis to identify biodiversity hotspots of primary producers at the global scale. We define a Shannon entropy index, computed on a ~100km radius disk, which estimates a diversity using environmental patchiness of community composition. In the case of the remote sensing such heterogeneity is represented by the patchiness in ocean color bio-optical anomalies; in the case of the model the heterogeneity is represented by the patchiness of the phytoplankton dominant groups present in the area. This index is compared with the traditional Shannon entropy index, computed at each point, considering all the phytoplankton types in the model and large in situ datasets (AMT and OBIS). The relation between area-based and point-based diversity identifies as biodiversity hotspots for phytoplankton some of the most energetic areas of the global oceans -notably confluence zones- characterized by increased turbulence, mixing and the presence of mesoscale eddies. These oceanographic features may enhance local productivity by transporting nutrients into the euphotic zone and increase biodiversity by juxtaposing species typical of different water masses. Moreover, species richness can climb the trophic chain, in that marine hotspots often overlap for disparate trophic groups, from primary producer phytoplankton species to top predator species. Furthermore our index of diversity shows a relation to temperature and mid-latitude maxima in accordance with those previously evidenced in microbiological biodiversity model and observational studies.

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I express my preference for an oral presentation included in MJ Follows' section.
As a PhD student I also ask for the travel grant available for the Liege Colloquium.

Virect coupling of 600 m deep-water corals to surface productivity

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Deep-water Corals are amongst the most productive deep-water habitats. Although they obtain their nutrition from surficial waters, the hydrodynamic controls that enable growth of corals and associated fauna is not yet fully understood.

We combined a hydrodynamic, biogeochemical, habitat suitability and ecotrophic model to infer flows of organic matter in the Logachev deep-water coral mound province, (SW of Rockall Bank, NE Atlantic). A 3-Dimensional reactive transport model describing the transport and decay of organic matter (OM) in an area 80 * 60 km large, is driven by velocity fields generated by a hydrodynamic model. The habitat suitability model is used to estimate coral cover, and this is combined with food uptake rates inferred from a previously published ecotrophic model. The coupled model allows to estimate the origin and freshness of OM that reaches the bottom and the impact of corals on the OM degradation and distribution in the area. The model simulations show on several occasions a vertical and direct drawdown of fresh OM from the surface toward the coral mounds, more than 600 m deep. This OM delivery towards the coral mounds contrasts sharply with other, non-coral regions that exhibit a more regular down welling of shelf water.

Western Arctic Ocean Primary Productivity Changes over the Last Three Decades and in the Future: not a Simple Story.

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Significant changes in Arctic sea ice have been observed over the last three decades, characterized by unprecedented summer melt-back in recent years. As the summer sea ice extent shrinks to record low levels and the permanent ice thickness continues to decrease, there is increased evidence that the flow through the Bering Strait is increasing and the Beaufort Gyre intensifies. These changes in the Western Arctic Ocean (WAO) circulation are impacting directly the availability of nutrient and light to the phytoplankton in the upper water column. It is, however, not fully understood how these changes are and will be impacting primary productivity in the WAO. We use the coupled pan-arctic Biology/Ice/Ocean Modeling and Assimilation System (BIOMAS) to investigate changes in the physical system and productivity of the planktonic ecosystem between 1988 and 2011. Model simulations show that while WAO primary production has increased over the last three decades, some regions (e.g. Beaufort Gyre) have experienced a slight decrease over the recent years. Regional impacts of changes in the WOA circulation on primary productivity, nutrient flux and community structure will be analyzed in the context of climate changes in the past, present and future.

Rates of Summertime Biological Productivity in the Beaufort Gyre: A Comparison between the Record-Low Ice Conditions of August 2012 and Typical Conditions of August 2011

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The Arctic Ocean is changing rapidly as the global climate warms. Summer sea-ice extent is dramatically shrinking, with 2012 setting the record low in minimum sea-ice extent. The temperature is rising, the melt season is lengthening, and the freshwater storage and terrigenous input are increasing. How will these continuing changes affect biological productivity in the Arctic Ocean? The answer to this important question is not known. In order to predict future biological productivity and carbon cycling, we need, at least, to know the present-day rates of biological productivity in the Arctic Ocean and to understand what constrains them.

One way to gain such understanding is to quantify rates of Net Community Production and Gross Primary Production. Net Community Production (NCP) is defined as photosynthesis minus community respiration and thus is the net amount of CO2 taken up by the biological pump. Gross Primary Production (GPP) is defined as the total photosynthetic flux and thus is the carbon produced at the base of the food chain. By concurrently measuring rates of NCP and GPP, we can look separately at environmental effects on photosynthesis and respiration. This in turn allows a better mechanistic understanding of the processes controlling biological production.

We measured rates of NCP and GPP in the Beaufort Gyre region of the Canada Basin in the summer of 2011 and 2012 during the Joint Ocean Ice Studies (JOIS) expeditions. NCP rates were calculated from the in-situ gas tracer O2/Ar and GPP rates from the in-situ gas tracer triple oxygen isotopes. The record-low sea-ice coverage in summer of 2012 allows a tantalizing glimpse of how biological productivity might change in a seasonally ice-free Arctic Ocean. We find that, in the surface waters measured here, GPP rates in 2012 are significantly greater than in 2011. We hypothesize that this is because the lack of sea ice and warmer temperatures allows photosynthesis to increase in 2012. Lack of sea ice results in more light penetration; warmer temperatures increase reaction rates of photosynthetic processes. However, despite the increase in GPP, rates of NCP are similar between the two years showing that the heterotrophic community (zooplankton and bacteria) must have increased its activity as well and thus were able to respire the carbon due to increased photosynthetic production. Additionally, we show that, in 2011, rates of GPP in regions of actively melting sea ice (i.e. the Marginal Ice Zone) are larger than in the open water but that rates of NCP are similar. Once again, it seems that phototrophs are producing more, perhaps because of nutrient input from melting ice or from upwelling and mixing associated with the MIZ, but that the heterotrophic community increases as well, resulting in no net change in community productivity.

These results highlight that, although satellite chlorophyll records show an increase in summertime primary production in the ice-free areas of Arctic Basin, the net amount of carbon processed by the biological pump during summer may not change as a function of ice cover. Thus, a rapid reduction in summertime ice extent may not change the net community productivity or carbon balance in the Beaufort Gyre.

Do life cycles participate in the maintenance of diatom diversity?

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Trade-offs between traits on main ecological axes are frequently invoked when the seasonal structure of planktonic communities is addressed. The trait-based approach is mostly focused on factors regulating the ability to compete for resources and does not consider biological controls on net growth rates that may derive from chemical signalling among the cells or from specific life cycle features.

Notably, the paradigm of diatoms as the competition winners in nutrient replete conditions is based on experiments made with monoclonal cultures. In fact there are evidence that growth rate, even in culture, may change independently from resources, in different phases of the life history of a diatom.

We developed a numerical model of seasonal plankton diversity in the mixed layer to evaluate the impact of growth control on the seasonal succession of phytoplankton species. We observed a change in seasonal patterns of phytoplankton leading to community reorganization, when independent form resources availability growth rate control was included. Overall, the numerical exercise shows that life cycles traits impact the community structure and its time course, even considering control acting on a reduced set of species.

Our preliminary data suggest that biological processes other than resource acquisition do participate in the definition of the species ecological niches and thus have to be considered to fully describe and understand the mechanisms of diatom diversity maintenance, and of phytoplankton in general. We thus propose that biological traits, such as life cycles, must be included in the conceptual models of plankton succession.

Up or down - Modeling the fates and rates of phytoplankton carbon in the North Atlantic Ocean

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Plankton has a central role in the calculation of carbon and nutrient cycles in marine ecosystems since its biomass is either passed to the upper trophic levels or - if they die - sinks down to the deeper ocean. In recent years coupled physical/biological models have been developed to support these estimations on larger scales. We use the three-dimensional ocean dynamics model NEMO coupled to the biogeochemical model PISCES to investigate the carbon cycle in the North Atlantic Ocean. Phytoplankton in the model is divided into different functional groups (FG) to better address the pathway of carbon in different regions and seasons, which can be important, e.g. for calculating primary and secondary production. The validation of dominant FG using PhySAT estimates from satellite data confirms the simulated timing of phytoplankton production in different regions of the North Atlantic. One major question in our studies concerns the carbon sequestration: How much of the carbon is exported to the deep ocean? Estimates of carbon export at 1000 m was found to be ca. 22% of surface primary production. However, the relationship of primary production and carbon export on annual average varies between years and in different regions. We analyse what are the links that couple the export to the pelagic/surface processes on a regional and interannual basis for the years 1990 to 2010.

The impact of the Southern Annular Mode on Southern Ocean physics and biogeochemistry

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The Southern Annular Mode (SAM) is the dominant mode of climate variability in the southern hemisphere. In recent decades, its positive-trending phase has been associated with a strengthening and southerly migration of the westerly winds over the Southern Ocean. These winds drive the large-scale overturning circulation and therefore modulate vertical fluxes of nutrients and dissolved inorganic carbon, which fuel Southern Ocean productivity. The satellite ocean color data record is now long enough (1997 to present) to document circumpolar and regional trends in surface ocean productivity, in response to the SAM. This presentation documents interannual and spatial variability in winds, sea surface temperature (SST), mixed layer depths and surface chlorophyll as a function of the SAM.

The analysis indicates that the winds do indeed shift poleward and intensify during the positive phase of the SAM. In some regions this results in cool SST anomalies, which can be attributed to enhanced Ekman upwelling. The response in both satellite chlorophyll and satellite-based primary productivity is statistically significant in only a few small areas. A region of particular interest is the southeast Pacific, where the wind stress curl pattern is different to the Atlantic and Indian, and the cool SST anomalies appear to be caused by deeper mixing as opposed to enhanced upwelling. If so, this region could be trending in the direction of a source of CO2 to the atmosphere. Since this region is also the area of the ocean with the fewest observations of surface CO2, satellite proxies are employed to detect changes in air-sea CO2 fluxes.

Resolving the seasonal cycle of mixed layer physics and phytoplankton biomass in the Sub-Antarctic Zone using high resolution glider data

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The importance of understanding the scale sensitivity of the links between the dynamics of the surface boundary layer and the seasonal and sub-seasonal variability of ocean primary production has been highlighted in recent studies (Thomalla et al, 2011; Taylor and Ferrari, 2011; 2012; Lévy et al., 2012). This problem is particularly acute and interesting in the Southern Ocean where the lack of seasonal scale data is compounded with seasonal light and Iron limitation and a wide range of buoyancy forcing regimes associated with seasonal solar heat fluxes, eddies, fronts and sea ice. An analysis of SeaWiFS ocean colour data in the Southern Ocean shows that regions of elevated biomass are linked to either intra-seasonal variability or strong seasonal cycles (Thomalla et al., 2011). As part of the Southern Ocean Seasonal Cycle Experiment (SOSCEx; Monteiro et al., 2011; Swart et al., 2012), continuous high-resolution data (5-hourly, 1000m deep profiles at 2km horizontal resolution) from five autonomous gliders deployed between the Subtropical and Polar Fronts of Southern Ocean, are used to resolve the late-winter to late-summer variability in mixed layer physics and phytoplankton biomass. Preliminary results from the dataset allow us for the first time to diagnose the seasonal cycle of phytoplankton biomass over the austral spring-to-summer growing season of the Sub-Antarctic Zone.

Towards Reconciling Iron Supply and Demand in the Southern Ocean

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Iron is a key regulator of primary productivity (PP) in the Southern Ocean, which plays an important role in the global carbon cycle and moreover, is predicted to be especially vulnerable to climate change. Most all of the iron supplied to the Southern Ocean is via subsurface sources that are predominantly transported to surface waters via seasonal entrainment or year round diapycnal diffusion processes. The relative role played by each for iron remains poorly constrained, yet will ultimately govern the climate sensitivity of Southern Ocean PP. Here we use a data synthesis approach that combines 1) observations of iron, 2) physical properties of the ocean and 3) rates of phytoplankton utilisation to demonstrate the importance of winter entrainment in regulating iron supply to phytoplankton and to construct a comprehensive budget for Southern Ocean iron fluxes. Crucial to our results is the character of the vertical profile of iron, where weak vertical gradients downplay the importance of diapycnal diffusion that has been emphasised in prior studies over much of the region and necessitate deep entrainment to reach subsurface iron reservoirs. Hence only seasonal entrainment can provide enough iron to match large-scale estimates of phytoplankton demand. Accordingly, we suggest that future or past variability in Southern Ocean PP will likely be most sensitive to modifications to winter mixing rather than stratification. Attention should be placed on the vertical iron profile itself and mechanisms driving variability in winter entrainment in order to better constrain estimates of regional change suggested from models or observations.

Towards a quantitative understanding of sea ice biogeochemistry

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Sea ice biogeochemistry and its role in the whole ecosystem functioning remain still partly unknown due to the temporal and spatial patchiness of the available observations. Similar to the marine ecosystem, numerical models might contribute to enhance understanding and provide synthesis of the sea ice ecosystem. We present here some of the first efforts towards a quantitative understanding of the spatial and temporal distribution of sea ice biogeochemical properties, and of the impacts of sea ice shrinking and thinning on overall marine production and community composition. After shortly reviewing the stochiometrically flexible Biogeochemical Flux Model in Sea Ice (BFMSI, Tedesco et al., 2010, Ocean Modelling), we present the first preliminary results in a test case study area of the 3-D offline coupling configuration of the BFMSI with an ocean hydrodynamic model (OPA) and a sea ice dynamic-thermodynamic model (LIM) developed within the NEMO framework (http://nemo-ocean.eu).

Sea ice biogeochemistry: a guide for marine ecosystem modellers

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The role of sea ice biogeochemistry at large temporal and spatial scales is still largely unknown, mainly due to the temporal and spatial patchiness of the available observations. Quantitative tools, such as numerical models, have been so far mostly limited to process and local studies (e.g. Tedesco et al., 2012, Ecological Modelling). We present here a general methodology to implement from any pelagic biogeochemical model a new sea ice biogeochemical component, choosing among different levels of ecosystem complexity, vertical resolutions and adopting a strategy of coupling that ensures mass conservation. The aim is to encourage marine ecosystem modelers to add a new component to their modeling framework in ice-covered study areas. The benefits are manifold: modeling coupled sea ice and pelagic biogeochemistry e.g. ensures an adequate description of the ecosystem as a whole and the closing of the carbon cycle in polar regions.

Trait-based representation of diatom diversity in a Plankton Functional Type model

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Biogeochemical models often reduce biological complexity by assembling a large number of species sharing common ecological and biogeochemical functions into Plankton Functional Types (PFTs). In this approach, species diversity inside each PFT is generally not considered. Conversely, recent adaptive modelling approaches emphasize plankton diversity by letting communities self-assemble through competition amongst large numbers of species. Here, we combine adaptive and PFT approaches by introducing a trait-based description of diatoms in the existing MIRO model. The latter describes carbon and nutrient cycles in the Southern North Sea ecosystem with three autotrophic (diatoms, *Phaeocystis*, nanoflagellates) and three heterotrophic (bacteria, micro- and meso-zooplankton) PFTs. The new trait-based module relates fundamental properties of diatoms to their size: smaller diatoms have a higher maximum growth rate and nutrient affinity, while larger diatoms benefit from reduced grazing pressure and silicon needs. This trade-off makes optimal diatom size dependent on resource availability and predation pressure, favouring species succession in a variable environment. The diatom community is modelled as a continuum of sizes, which is represented by the total diatom biomass, their mean biovolume and its variance. The model is implemented in the Belgian coastal zone, where high quality observations allow a reconstruction of nutrients, PFT concentrations and diatom community structure for 1988-2000. The added value of the trait-based description of diatoms is evaluated by comparing outcomes from the original MIRO PFT model and the trait-based approach. Results are further analysed to identify the mechanisms driving diatom succession.

Understanding controls of diel patterns of biological CO2 fixation in the North Atlantic Ocean

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Much of the variability in the surface ocean's carbon cycle can be attributed to the availability of sunlight, through processes such as surface heat flux and photosynthesis, which regulate carbon flux over a wide range of time scales. The critical processes occurring on timescales of a day or less, however, have undergone few investigations, and most of these have been limited time spans of several days to months. Optical methods have helped to infer short-term biological variability, but corresponding investigations of the oceanic CO2 system are lacking. We employ high-frequency CO2 and optical observations covering the full seasonal cycle on the Scotian Shelf, Northwestern Atlantic Ocean, in order to unravel diel periodicity of the surface ocean carbon cycle and its effects on annual budgets. Significant diel periodicity ion the surface CO2 system occurs only if the water column is sufficiently stable as observed during seasonal warming. During that time biological CO2 drawdown, or net community production (NCP), are delayed for several hours relative to the onset of photosynthetically available radiation (PAR), due to diel cycles in Chlorophyll a concentration and to grazing. In summer, NCP decreases by more than 90%, coinciding with the seasonal minimum of the mixed layer depth and resulting in the disappearance of the diel CO2 periodicity in the surface waters. Ongoing work focuses on the transfer of these patterns to the individual -ideally remotely detectable- biological species, responsible for the CO2 fixation at the seasonal scale in order to predict vulnerability of the system due to climate change.

Spatial and temporal variability in satellite estimates of primary production over the Atlantic basin.

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The recent warming of the Earth system has important impacts on carbon cycling in the ecosystem. These are hard to quantify, both spatially and temporally, due to the sparseness of in situ observations. There has therefore been a concerted effort to derive accurate estimates of primary production from satellite to fill these gaps. In a dynamically changing ocean and contrasting ecological provinces, this requires continuous quantification. In this paper the accuracy of empirical and semi-analytical approaches to estimating primary production from satellite data are assessed in 15 provinces of the Atlantic Ocean, from the sub-Arctic waters of the North Atlantic to the South Atlantic Gyre. For the most accurate algorithm(s), a 14 year time series of primary production is generated to assess trends in and spatial and temporal differences between them. There was a consistent decrease in primary production in the North Atlantic sub-tropical and tropical Gyres from 1998 to 2005, suggesting that recent warming in these provinces is coupled to a decrease in phytoplankton production. In sub-arctic waters of the North Atlantic from 1998 to 2004, there was comparatively smaller variation in primary production followed by a consistent increase from 2005 to 2011. In these waters, high negative North Atlantic Oscillation index, coupled with warmer spring and summer temperatures, resulted in higher annual primary production suggesting a positive feedback between phytoplankton production warmer years. Satellite estimates of primary production were then coupled to models of new production to assess the variability in production driven by inorganic nutrients. For sub-arctic waters of the North Atlantic, new production was highest in 2009 (45 gC m-2 yr-1) and lowest in 2005 (35 gC m-2 yr-1) and were consistently higher along the Iceland Shelf, Reykjanes Ridge and sub-polar front and lower in the East Greenland and North Irminger basin. The sensitivity of these models to using satellite Sea Surface Temperature as an input parameter to describe photo-physiology, is also assessed.

Productivity estimates from hourly automated measurements at the Australian Southern Ocean Time Series site

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The Australian Integrated Marine Observing System maintains 3 moorings at the opem ocean SOTS site, in 4600m water depth, approximately 380 miles southwest of Tasmania near 140°E, 47°S. Oxygen and total gas tension measurements collected by the Pulse biogeochemistry mooring at 35 meters below the surface allow physical and biological contributions to surface water oxygen contents to be distinguished. Combining these with mixed layer depths from temperature loggers and wind-speeds from the SOFS air-sea flux mooring yields an hourly time series of net community production. The record shows oxygen undersaturation in late winter from deep ventilation of Subantarctic Mode Waters and then initiation of net community production in spring while mixed layer depths are still very deep. Seasonal warming drives relatively steady increases in physical oxygen supersaturation, but the biological production occurs in more discrete events, often associated with passage of distinct T-S water parcel compositions. Total net community production over the six month deployment from September 2010 to April 2011, amounts to approximately 60 gC/m2. In comparison, nitrate concentrations measured on seawater samples collected biweekly by the Pulse mooring suggest somewhat higher values of circa 90 gC/m2, and satellite biomass based algorithms suggest circa 70 gC/m2, but with different seasonality than the in-situ observations. Longer term observations from the SAZ deepwater sediment trap mooring reveal considerable interannual variability in both the magnitude and seasonality of export. These measurements emphasize the importance of distinguishing between mixing-layer and mixed-layer thicknesses in the integration of properties that determine production in the ocean and in models, particularly in regions with very deep winter mixing – which exceeds 400m at the Subantarctic SOTS site.

Chlorophyll a in Antarctic sea ice from historical ice core data

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Sea ice core chlorophyll a data are used to describe the seasonal, regional and vertical distribution of algal biomass in Southern Ocean pack ice. The Antarctic Sea Ice Processes and Climate - Biology (ASPeCt - Bio) circumpolar dataset consists of 1300 ice cores collected during 32 cruises over a period of 25 years. The analyses show that integrated sea ice chlorophyll a peaks in early spring and late austral summer, which is consistent with theories on light and nutrient limitation. The results indicate that on a circum-Antarctic scale, surface, internal and bottom sea ice layers contribute equally to integrated biomass, but vertical distribution shows distinct differences among six regions around the continent. The vertical distribution of sea ice algal biomass depends on sea ice thickness, with surface communities most commonly associated with thin ice ($<$0.4 m), and ice of moderate thickness (0.4--1.0 m) having the highest probability of forming bottom communities.

Future Arctic Primary Productivity from CMIP5 Simulations: Uncertain Outcome, but Consistent Mechanisms

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Net primary production (PP) in the Arctic should increase over this century, due to sea ice retreat, inducing an increase in available light, but could decrease if nitrate renewal is insufficient. Here, simulations performed with 11 Earth System Models from the CMIP5 exercise, covering 1900-2100, are analyzed using Arctic PP, surface nitrate and sea ice concentrations. Whereas the mean model well simulates Arctic-integrated PP at 511 TgC/yr for 1998-2005 and projects a 58 TgC/yr increase by 2080-2099, models neither agree on what limits PP today, nor on the sign of future PP change. However, the same mechanisms operate in all models. First, both sea ice and nitrate decrease over the 21^{st} century. Depending on the model, the strengthening nitrate stress is sufficient to overcome the effect of light increase. The inter-model spread stems from present nitrate stocks, poorly constrained by observations and characterized by an inter-model uncertainty of $>50\%$ of the mean. Second, virtually all models agree in the open ocean zones on more spatially-integrated PP and less PP per unit area. Where models disagree is the sea ice zone, where a subtle balance between light and nutrient limitations determines the change in productivity. Hence, it is argued that reducing uncertainty on present Arctic nitrate would render Arctic PP projections much more consistent. That is definitely required to understand the impact of climate change on the Arctic food webs and carbon cycle.

Modelling SST and chlorophyll patterns in a estuary-near coast system of Portugal: The Tagus case study

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Over the last years, the demand for coastal data on physical and biogeochemical variables has become an important issue, arising from fields like seawater monitoring programs and marine and coastal management. Water temperature and chlorophyll are among the variables referred as the top products on demand both by researchers and coastal managers. To support these needs state-of-the-art circulation and biogeochemical models are valuable tools, also sustaining the study and management of coastal systems. They can act like a supplement to observational programs, completing time and space limitations of observations, contributing to explain and understand processes and variability, as well as to study different scenarios.

In this contribution, a pre-operational biogeochemical nested model (www.mohid.com) implemented for the central region of Portugal, including the Region of Freshwater Influence (ROFI) of the Tagus estuary and also the near coastal system is presented. This product is the first of this kind in the region, and will provide free access to the biogeochemical simulated variables, being a final product of a national research project DyEPlume (PTDC/MAR/107939/2008). The main improvement here is the downscaling from a larger domain, as the whole Portuguese coast, to a local domain, as the Tagus estuary. The water temperature and chlorophyll results presented correspond to a simulation of the winter and early summer period (January-May 2007), which is characterized by strong freshwater inflow into the Tagus estuary, which in turn modulates the estuarine outflow to the Tagus ROFI. Therefore, the model is evaluated during a very dynamic and biologic productive period of the year.

The preliminary results address a general skill assessment rather than a thorough validation, which requires a great amount of data to perform the comparison with model results. The preliminary results of water temperature and chlorophyll reveal a proper reproduction of the vertical structure. The water temperature profiles show some thermal stratification at the study area. The average surface-to-bottom difference ranges from 1.3 ºC to 1.6 ºC. The chlorophyll vertical profiles reveal some differences between the model results and the measurements. In fact, the model results reveal higher values on the surface layers, as expected due to the possible light limitation in the water column, which decreases towards the deepest layers of the study domain.

The model implementation reveals promising results for studing water temperature and chlorophyll dynamics in the ROFI of the Tagus estuary. Consequently, is is considered that the model is a valuable tool able to reproduce the main features of the study region in seasonal and event time scales.

Ground-truthing variable-stoichiometry models

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Several pelagic ecosystem models now allow for flexibility in the elemental composition of the modelled plankton functional types. Often they are based on some variant of the model for phytoplankton photoacclimation by Geider et al. (1998) that has been shown to reproduce C:N and C:Chl ratios in laboratory experiments both for constant nutrient and light conditions, and for a transition to nutrient limitation well. Based on that success, the predicted stoichiometries in ecosystem models employing the Geider model or one of its competitors have not received much attention.

Here we first investigate how well the two physiologically-based models by Geider et al. (1998), and by Pahlow (2005) are able to describe observed changes in biomass stoichiometry in a laboratory experiment with a more dynamic nutrient regime, namely a sudden resupply of nitrogen after a bloom, as would be expected after a brief mixing event. We show that both the Geider et al. (1998), and the Pahlow (2005) model are able to describe shifts on C:N stoichiometry over the course of a bloom, albeit not equally well, but that both have problems describing the recovery from nutrient starvation.

We then discuss the patterns of phytoplankton stoichiometry and their sensitivity to some assumptions on physiology in a global ecosystem model. Our model allows for flexible stoichiometry in both non-diatoms and diatoms, with an extension of the Geider model for diatom Si:C variations. Globally, largest deviations of the C:N ratio from Redfield are modelled in the nutrient-depleted subtropical gyres, but they contribute little to vertical export. Lab-observed changes in C:Chl ratio are described well by the Geider model. Modelled global patterns in C:Chl are consistent with a number of field- and satellite-based observations. It remains a challenge, however, to distinguish between variations in stoichiometry due to physiological acclimation and to community composition.

In situ turbulence measurement and its relation to air-water gas exchange rate

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Turbulence in ocean upper layer is of great importance in mixing process and plays an intermediate role on atmosphere boundary layer and deep ocean dynamics. Random turbulent eddies upwell and renew the surface diffusive boundary layer and hence control the gas flux across the air-water interface. A free floating Particle Image Velocimetry (PIV) system and a floating chamber were employed to simultaneously measure near surface turbulence immediately below water surface and CO_2 flux across the air-water interface with very short temporal (seconds) and spatial (millimeters) resolution. Our in situ data indicate that small scale eddy model significantly overestimate gas exchange rate under weak turbulent dissipation condition. By adding a dissipation rate dependent factor in small scale eddy model, we improve the prediction of gas exchange rate by 25% in comparison with measured data. Moreover, near surface turbulence data confirm wave-turbulence interaction in surface layer resulting enhanced dissipation rate unbalanced with local shear production. We suggest that micro-breaking waves have significant effect on vertical turbulent structure in the enhanced turbulence layer sufficiently close to the water surface. A modified friction shear velocity was found to scale with dissipation rate in wave affect surface layer. Therefore, wave contribution on gas exchange should be added into conventional global CO_2 flux model (wind speed parameterization).

Spatio-temporal variability of inherent optical properties in Hudson Bay, Canada

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Hudson Bay is the world's largest inland sea. It is connected with the Labrador Sea through Hudson Strait and the Arctic Ocean through the Canadian Arctic Archipelago. Previous studies have shown that Hudson Bay has different optical properties (phytoplankton, dissolved and suspended matter absorption, photoprotective pigments, etc.) when compared to other Arctic regions. Bio-optical dataset including absorption and scattering, and biogeochemical parameters collected in fall 2005 and summer 2010 is analyzed in this region to investigate the spatio-temporal variability in inherent optical properties (IOPs). The following results are obtained: 1) The proportion of colored dissolved organic matter (CDOM) absorption in summer is relatively higher than in fall as a result of decreased phytoplankton absorption in summer. 2) Very low summertime phytoplankton specific absorption coefficients, among the lowest reported in the literature, are attributed to the high proportion of large size phytoplankton (micro-phytoplankton) and important packaging effect. 3) Both particulate absorption and scattering coefficients are higher in fall than in summer due to a relatively higher biomass in fall. 4) Most of the seasonal variability in light absorption and scattering is found to occur along the coast whereas little variability is observed in the central part of the Bay. These results emphasize that it is necessary to take into account the spatio-temporal variability in IOPs not only in bio-optical models and remote sensing applications, but also in primary production retrievals from space for Hudson Bay.

A preliminary assessment of use the VGPM models to estimate the ocean primary production in the China Sea

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We are trying to develop regional algorithms to estimate the ocean primary production (OPP) in the China Sea. First, we have four cruises' in-situ $PO^{14}C$ production measurement data in the East China Sea (ECS) and the Northern South China Sea (NSCS). The trophic state and seasonal temperature variation are different between the ECS and NSCS. The assessment is processed by using the in-situ surface chl$a$, surface temperature, the euphotic depth and the daily incident PAR to run the model, then comparing the model and measurement results (both converted to the logarithm form) with the model II linear regression. The Standard VGPM model , Eppley VGPM model and Gong&Liu's model are applied in the ECS. The Eppley VGPM model gives the best estimation with slope = 0.81, r^2 = 0.67; When the Standard VGPM model gives slope = 0.70, r^2 = 0.61, and the Gong&Liu's model gives slope = 0.56, r^2 = 0.62. The Standard VGPM model and Eppley VGPM model are applied in the SCS. The Standard VGPM model gives slope = 0.978, r^2 = 0.45, is better than the Eppley VGPM model with slope = 0.722, r^2 = 0.50, as the P_{opt}-SST relationship used in the Standard VGPM model gives the trend that OPP decline when the surface temperature is high as the same as what happen in the SCS because of its oligotrophic state in the summer season.

Primary production in Eastern Indian Ocean during spring intermonsoon period in 2012

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Phytoplankton biomass and primary production were studied to better understand the element cycle and energy flow in Eastern Indian Ocean. The Eastern Indian Ocean cruise was conducted by "MADIDIHANG 03""RV from April 25 to May 13, 2012, initiated by First Institute of Oceanography, State Oceanic Administration. The seawater surface temperature and the salinity in Eastern Indian Ocean were higher than that of the South China Sea. Stratification phenomena were prevalent in the water column during the study period. Dissolved inorganic nitrogen (NO-3 +NO-2) (<1μmol /L) were deficient in the upper layer, and increased intensively below the euphotic layer. Surface chlorophyll a concentration was lower than 0.15 mg /m3, and the maximum value were mostly appeared at 75m or 100m depth. Integrated chlorophyll a concentration in the water column ranged from 11.75 to 22.80 mg/m2, and the high value was found C Transect at adjacent area. Assimilation number in the water column was used to calculated Integrated primary production, with the mean value of 224.91 mgCm-2d-1. Integrated primary production ranged from 69.58~408.42mgCm-2d-1 in Eastern Indian Ocean during the study period, with the high value occurred at C Transect adjacent sea. Low values of DIN: P and DIN: Si indicated that nitrogen might limit the phytoplankton growth in the upper water of the Eastern Indian Ocean. In the Arabian Sea, both vertical mixing in winter and upwelling in summer carried the nutrients into the euphotic layer and could stimulate the phytoplankton growth. In the Eastern Indian Ocean, stratification impeded the nutrients moving upward, and the cloudy weather could also decrease the light penetration, so the primary production in the Eastern Indian Ocean was lower than that of the Arabian Sea.

Climate and ocean acidification impacts in an intermediate complexity global ecosystem model (MEDUSA–2.0)

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A major sink for atmospheric CO_2, and a key source of biological resources, the World Ocean is widely anticipated to undergo profound physical and via ocean acidification chemical changes as direct and indirect results of these emissions. Given strong biophysical coupling, the marine biota is also expected to experience strong changes in response to this anthropogenic forcing. Here we examine the response of an intermediate complexity global ecosystem model, MEDUSA–2.0, to climate and acidification impacts under scenarios for the 21st century. The primary impact of future change lies in stratification-led declines in the availability of key nutrients in surface waters, which in turn leads to a widespread decrease in ocean primary production. This impact has knock-on consequences for the abundances of the low trophic level biogeochemical actors modelled by MEDUSA–2.0, and these would be expected to similarly impact higher trophic level elements such as fisheries. MEDUSA–2.0 also permits the examination of potential acidification feedbacks to calcification, and finds that these may be significant for benthic communities.

The anthropogenic eutrophication of the Black Sea: quantitative evaluation, mechanisms and its role in the redistribution of organic matter among the main pelagic trophic chains.

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The work investigates the main aspects of the Black Sea eutrophication that have never been addressed before. Among the aspects addressed are the quantitative analysis of the eutrophication and eutrophication mechanisms in the shallow and deep parts of the sea, the main effect of eutrophication on marine ecosystems, namely its impact on the redistribution of incoming organic matter in the pelagic food web. The work shows that in the pre-eutrophication period (1960s) the annual primary production, the factor which is commonly used to evaluate the rate of organic matter income into marine ecosystems, was below 65 g C m^{-2} yr^{-1}, in most parts of the Black Sea including its deep regions. We are the first one to show that this low level of the annual production in the deep regions in that period were determined by the deep nitrates maximum localization and the presence of the highly-stratified zone of upper half of pycnocline which separates the nitrates from a photosynthetic layer and, thus prevents their penetration into a photosynthetic layer. It was shown that in the shelf regions affected by the Danube River nutrient loads, intensive eutrophication resulted in significantly increased levels of annual primary production, up to 250-350 g C m^{-2} yr^{-1}, having reached the eutrophic level. The rest of the regions and the Black Sea on average became mesotrophic with the annual primary production of ~145 g C m^{-2} yr^{-1}. Moreover, we are the first one to use the international oceanographic databases to comprehensively analyze the changes in hydrobiological, hydrochemical and hydrooptical parameters of eutrophication in the shallow and deep regions of the Black Sea and to demonstrate that in both regions the eutrophication developed in two phases (from the beginning of the 1970s to the mid of the 1980s and from the mid of the 1980s to the beginning of the 1990s), which differed from each other changes in functionally related eutrophication parameters. We further analyzed the role of various natural and anthropogenic factors in the bi-phasic nature of eutrophication. Finally, the work demonstrated that the eutrophication resulted in the dominance of a jellyfish-headed trophic chain, that, despite of the high levels of primary production, determined the low energy level of the present Black Sea ecosystem.

What is the impact of turbulent mixing on the formation, persistence and decay of thin phytoplankton layers?

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In the past two decades, observations of phytoplankton thin layers have become a common occurrence in the coastal ocean. Thin phytoplankton layers are key links in energy transfer from primary production to higher trophic levels in the coastal regions. However, their formation and persistence are still unclear, partially due to the lack of simultaneous and concurrent measurements of both physical and biological parameters at fine and microstructure scales. Utilizing an autonomous underwater vehicle (AUV), simultaneous and collocated spatial measurements of turbulence, fine structure, and chlorophyll a fields were made in Monterey Bay, CA. Using data collected in two years experiments, we examined and quantified the nature of turbulent mixing and its influence on the evolution of thin phytoplankton layers.

Results indicate that thin layers can occur and evolve in both an environment of strong and weak turbulence. Two cases were examined where a thermocline thin layer persisted in strong turbulence. In each of these two cases turbulence was generated by two different mechanisms, one from vertical straining associated with the trailing edge of an internal solitary wave train and one from direct shear instability generation due to the occurrence of a strong tidal current. For the former case the turbulence itself was confined to a thin layer by the large surrounding stratification of the local environment. The turbulence produced by the internal solitary wave train acted like a stratified wake eventually collapsing in the vertical. The phytoplankton thin layer was embedded within the turbulent field and behaving as a Lagrangian tracer also collapsed vertically. For the second case, the turbulence generated by shear from strong tidal flow, vertical diffusion gradually weakened the thin layer as it advected into the experimental site. We also examine the conditions under which turbulence has no discernable effect on thin layer evolution and develop criterion for this occurrence. During a time period of weak turbulence, the buoyancy Reynolds Number, Reb < 200 little diffusion occurs and the thin layer remains compact.

Sensing primary production from ocean color: Puzzle pieces and their status

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A core objective of satellite ocean color mission is to estimate primary production (PP) of global oceans from the measurement of ocean (water) color. Accurately estimating, or sensing, PP from color, which contains information of phytoplankton, is far from straightforward. It requires accurate quantification of various puzzle pieces that include light at sea surface, transmission from surface to deeper depth, phytoplankton index, as well as conversion of energy. In the past decades, there have been great efforts in improving our handling of these puzzle pieces. In this presentation we highlight the progresses that have been made, and discuss the challenges ahead of us for achieving the longstanding goal.