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Posters abstracts

Lateral mixing by submesoscale processes
BADIN, Gualtiero

We analyze the effect that submesoscale processes have on the diffusion of tracers both along isopycnals in the pycnocline and across surface mixed layer fronts. Submesoscale dynamics acts to enhance the diffusion of tracer along isopycnals, as measured by tracer variance. The study of the effective diffusion associated with the problem shows that the submesoscale dynamics enhance the eddy fluxes at the sides of filaments, while instead the centre of filaments act as barriers to transport. We believe that these results are important for the transfer and distribution of nutrients, and the export of particulate organic carbon.

Modulation of Carbon Export at the Submesoscale by Lagrangian Coherent Structures
CALIL, Paulo

The CMORE-OPEREX cruise (Jul 31-Aug 14 2008) was designed to investigate the formation and evolution of a bloom of phytoplankton around Station ALOHA and its impact on particle export. Low wind stress and high SST prior to the cruise favored the growth of N2-fixer Trichodesmium spp. . The study area was occupied by a mesoscale dipole, with a cyclonic eddy to the north and an anticyclone to the south. Two transects across these contrasting regions were performed at different resolutions (20 and 7 nm.). Although the mesoscale surface signal of the bloom was widespread, export production was very localized. Optical measurements from an Underwater Video Profiler (UVP) revealed that the highest concentration of large particles occurred in the region between the eddies and the particles were exported down to 300 m. Using Lagrangian techniques, namely the Finite-Size Lyapunov Exponents (FSLE's) calculated from geostrophic velocities obtained through remotely-sensed SSH, it was found that the specific regions where particle export occurred were coincident with regions of large horizontal stretching. These Lagrangian coherent structures (LCS's) are barriers to horizontal transport. In addition, local horizontal density gradients are enhanced in regions of large stretching, hence prone to surface frontogenesis. By using an expression derived from the omega equation we obtain good agreement between frontogenetically-generated downwelling and particle export in the region between the two eddies. Our results suggest that the stretching of the eddy field produces submesoscale features that strongly modulate the export of organic material from the surface layers into the interior ocean. This has implications for the sampling necessary to provide robust estimates of export rates.

SeaWiFS derived measurements of chlorophyll-a in the Scotia Sea: seasonal and interannual variability of phytoplankton blooms
BORRIONE, Inès

Data coverage in the Southern Ocean is a limiting factor for a full understanding of physical and biological processes. In these conditions remote sensing becomes a key tool, as high resolution is possible both in space and time. Analysis of a 10 year long time series of SeaWiFS ocean color images allows studying seasonal trends and inter-annual variability. Monthly averaged satellite imagery of chlorophyll a in the south-western sector of the Atlantic Ocean shows intense and recurrent blooms around the Antarctic Peninsula and the Island of South Georgia. Although specific areas show a regular pattern of low or high productivity, certain years appear to be more or less productive than the climatological average. Circulation patterns, continental shelves as well as the Antarctic Circumpolar Fronts are shown to be the major factors controlling extension of highly productive patches. However, the complexity of interactions between phytoplankton communities and the surrounding environment implies the need for more dedicated surveys and high resolution coupled physical-biogeochemical models; the latter would provide further information regarding nutrient fluxes and physical processes, especially during the under-sampled winter season and in the deeper layers not captured by satellite images.

Nutrients dynamics and trophic interactions between planktonic groups in a submesoscale anticyclonic eddy

CAMPBELL, Rose

The purpose of this study, carried out in the context of the LATEX programme, is to examine the biogeochemical properties of mesoscale eddies in the Gulf of Lions (NW Mediterranean) and to examine their impact on the structure of the plankton community. These structures were previously identified using wavelet analysis on the outputs of a 3dimensional hydrodynamic model, Symphonie. By adding to Symphonie a multi-nutriment, multi-functional groups of plankton, biogeochemical model, ECO3M-NWMED, we analyse the biogeochemical activity within these eddies. The outputs of the coupled model are compared to several different types of datasets (SeaWiFS images, in situ data) in order to fully verify its realism. A study of an anti-cyclonic eddy indicates a downwelling phenomenon which can be observed using various biogeochemical tracers such as nutriments, phytoplankton and bacteria. Decreasing concentrations of phytoplankton biomass throughout the period of the anticyclone are predicted and can be explained by predation by zooplankton and reduced availability of nutrients. Throughout the eddy episode, we observe various biogeochemical tracers rising up to the thermocline on the edge of the eddy and being advected from the coast to the edge of the shelf break.

Ocean surface observations of submesoscale processes: interactions between an anticyclonic vortex and a front

CHAVANNE, Cédric

We present observations of a submesoscale anticyclonic vortex and its interaction with a front, using high-frequency Doppler radio current meters and satellite radiometers. The vortex formed between two large cyclones to the southwest of O`ahu, Hawai`i. The radius of the core was 15 km, the azimuthal velocity reached 35 cm/ s, and the surface vorticity remained below -f for 9 days, reaching an extremum of -1.7 f. A tongue of surface water 0.7 degree C warmer became entrained northward between the vortex and the colder cyclone to the west. As the vortex strengthened, a sharper front formed along the eastern flank of the tongue than along its western flank. The flow was anticyclonic (-0.4 f) and divergent (0.1 f) on the warm side of the front, but cyclonic (0.6 f) and convergent (-0.2 f) on the cold side. This suggests an ageostrophic cross-frontal circulation maintaining along-front thermal wind balance in the presence of large-scale strain, sigma. Surface divergence, delta, was proportional to vorticity, zeta, during the 3-day frontogenesis: delta = - (sigma / f) zeta. This is consistent with a semi-geostrophic model of a front confined to a surface layer of zero potential vorticity.

Transport dynamics in the California Current System

CHENILLAT, Fanny (co-authors V. Combes, P. Rivière, E. Di Lorenzo, S.J. Bograd, M.Ohman, B.Blanke)

We investigate the low-frequency dynamics of cross-shelf and alongshore advection/mixing in the Central and Southern California Current System (CCS) over the period 1950-2008 using the Regional Ocean Modelling System (ROMS) with a 10km resolution. Our approach involves using an ensemble of passive tracers released in the numerical model to characterize the advection and mixing pathways associated with large-scale variability (e.g. ENSO, PDO, NPGO, coastally trapped waves) and with internal variability of the CCS (e.g. intrinsic variability of the mesoscale eddy field). We show here the mixing pathways and patterns that emerge from the passive tracers experiments and deduct the dominant forcing dynamics both in the surface and subsurface. In these numerical experiments, the coastal vertical transport and the subsurface coastal tracers' cross shore dynamics are strongly correlated with NPGO index and with the wind alongshore stress. This shows that the dynamic of the region is highly influenced by the coastal upwelling activity. A dynamic asymmetry North/South, in the studied zone, emerges and this is due to the mesoscale activity, higher in the South than in the North. California Under-Current (CUC), at about 200m depth, has been highlighted to play an important role in the alongshore transport and the mesoscale eddy activity affect the cross-shelf transport by spreading some subsurface tracers offshore from the CUC. We also discuss our findings in the context of the transport dynamics of important biogeochemical tracers such as oxygen and nutrients. The results suggest that the cross shelf transport of biogeochemical tracers should be linked to the NPGO index, index known to explain

variability of biological feature in this region. Also, an asymmetry North/South will influence the distribution and mixing of some phytoplankton and zooplankton species, hypothesis already proposed to explain plankton fluctuations observed in samples of CalCOFI cruises.

Submesoscale Seasonality in the North Pacific Subtropical Gyre
COLE, Sylvia

We present 16 observations of a section north of Hawaii along 22.75-34.5°N, 158°W taken with autonomous gliders from July 2007 to December 2009. We determine the horizontal variability of several physical and biological properties to address the seasonal modulation of submesoscale features. Above the winter mixed layer base, we determine the effects of restratification and vertical mixing on the horizontal structure of temperature and salinity fields. This region inherits its horizontal structure from the winter mixed layer, becomes isolated from the summer mixed layer, and is modified by several processes including horizontal mixing before being mixed back into the winter mixed layer. Below the winter mixed layer base, horizontal variability of the depth of the fluorescence maximum was seasonally modulated. Both the depth of the fluorescence maximum and mixed layer depth were most variable in March when the mixed layer was shoaling and least variable from August-November. Finally, we address the role of the subtropical front in submesoscale physics and biology. The deep fluorescence maximum shoaled by 25 m on average at the subtropical front and was sometimes mixed into the winter mixed layer in submesoscale patches to the north.

New information on the influence of mesoscale processes on ecosystems from top predators.
COTTE, Cédric

This study proposes a multidisciplinary approach for understanding how mesoscale and submesoscale processes influence marine food webs, from phytoplankton distribution to the foraging strategies of top predators. Since 2008, a new sensor measuring chlorophyll concentration is integrated within older devices (measuring temperature and salinity). These new devices equipped deep-diving elephant seals collecting unique 3D measurements from their dynamic environment while they forage. The purposes of this study are twofold; first, it aims to understand the foraging strategy of predators using satellite tracking and diving activity within their dynamic environment characterised using the automatic detection of eddies and filaments from satellites. Second, the oceanographic aim is to characterise physical and biological processes within eddies and filaments using in-situ measurements from devices.

Influence of a submesoscale eddy field on inertial waves generated by the wind
DANIOUX, Eric

Using a high resolution primitive equations numerical model, we study the propagation of wind generated inertial waves among a turbulent mesoscale and submesoscale oceanic eddy field. Results appear to follow analytical results by Klein et al. (2004): the inertial horizontal kinetic energy stays concentrated in the upper layers and is associated with the laplacian of the vorticity truncated at larger and larger scale as time goes by. This dispersion of the inertial horizontal energy along with the phase-shift induced by the vorticity generates two peaks on the profile on the r.m.s. of the vertical velocity: a peak in depth associated with the low vertical normal modes and a peak at the basis of the mixed layer associated with the high modes, with values reaching 30 m/day. These strong subsurface velocities, located at the gradient of the vorticity truncated, along with the vertical shear generated by horizontal motions, are believed to have an influence on the nutrients flux to the mixed layer.

Submesoscale community structure and interaction with fluid dynamics off Patagonia coast.
DE MONTE, Silvia

We investigate the structure of phytoplankton communities by combining multisatellite data, notably high resolution ocean-color maps of prevalent groups and altimetry-derived Lagrangian diagnostics of the surface transport. By addressing the spring bloom off Patagonia, we find the phytoplanktonic landscape organized in (sub-)mesoscale (tens of kms) patches of dominant types separated by physical fronts induced by horizontal stirring. These physical fronts enclose niches supported by water masses of similar history and whose lifetimes are comparable with the timescale of the bloom onset (few weeks). Within such ephemeral niches, best adapted types can become prevalent during a bloom, and then be distributed by small-scale mixing as niches are deformed into filaments. Our results suggest that by this mechanism, fluid dynamics can maintain local biomass dominance together with a broad distribution of planktonic types, affecting key ecological and evolutionary features such as regional bloom localization, the scale of dispersal and that of competition.

Interannual variability of air-to-sea CO2 fluxes and primary production in a high resolution, regional, coupled ocean circulation-biogeochemistry model of the Southern Ocean
DUFOUR, Carolina

The response of Southern Ocean dynamics and biogeochemistry, particularly air-to-sea CO2 fluxes, to the current climate trend in the Southern Annular Mode (SAM) is under debate. At the crux of that debate is the role played by mesoscale eddies in moderating air-to-sea CO2 fluxes. Eddies are a key feature of Southern Ocean dynamics, but they are poorly resolved in coarse-resolution ocean models that have been used to diagnose changes in these fluxes. Here, we examine the spatial and temporal variability of air-to-sea CO2 fluxes and primary production in a coupled ocean circulation-biogeochemistry model (NEMO-PISCES) forced by atmospheric reanalysis. A regional configuration including all ocean South of 300S is run from 1980 to 2004 at a resolution of 1/20. Our focus here is to understand the role of the SAM on the variability of air-to-sea CO2 fluxes, chlorophyll a and sea surface temperature. The mean state and annual cycle of these variables are thus examined using composite fields of these variables during SAM positive and negative phases. The simulation assessed in this presentation (i) is part of a series of coming simulations that will be run at higher resolutions to investigate the role of mesoscale eddies on air-to-sea CO2 fluxes response to the SAM and (ii) will be used as a reference simulation for a series of sensitivity experiments to changes in atmospheric forcing.

The effect of eddy – wind interactions on nutrient supply
FORRYAN, Alexander

Both theory and observations demonstrate that wind interacting with a mode-water eddy can result in the upwelling of water and hence of nutrients. However there is considerable debate with regards to the magnitude of the flux and the controls upon it. A high resolution primitive equation model of a mode-water eddy has been constructed and initialised using observations from a cruise in the Iceland Basin. The model has then been used to investigate the interaction between wind and the eddy and to quantify the effect of this interaction on nutrient supply. A range of different wind scenarios have been explored including, independent variation of wind speed and direction at different rates, and forcing using observed wind speed and direction sampled at half hour and six hour intervals.

Biological data assimilation, biological process experiments
FROLOV, Sergey

Our ability to construct trust-worthy ecosystem models is often limited by the paucity of the validation data. Recent developments in the field of sensors (flow cytometers, size-distribution counters, chemical sensors, and molecularfingerprint sensors) and platforms (gliders, floats, and AUVs) are promising to bring a new level of realism to models of ocean biochemistry. In this presentation, we investigate how to design a sampling array that integrates emerging sensors and platforms to detect the onset, distribution, and collapse of algal blooms on

coastal sub-mesoscale (features of less than 10km in size). The observation modes include a combination of satellite, moored, and autonomous platforms. We test the designed array in a twin data assimilation experiment using an NPZD model for Monterey Bay, California. Lessons learned from the twin experiment will be used to constrain upcoming CANON/BIOSPACE field program that aims at observing the dynamics of algal bloom patches and frontal zones.

Timing, sources and pathways for incorporation of larval fishes into a developing warm-core eddy of the Leeuwin Current, south-western Australia.
HOLLIDAY, David

Incorporation of planktonic biota into meso-scale eddies is well documented although there remains a paucity of direct examination of the timing and mechanisms of this process. Investigation of meso-scale circulation and cross-shelf transport associated with formation of an anticyclonic (warm-core) eddy of the Leeuwin Current was conducted during a month-long multidisciplinary research voyage off Western Australia. A suite of *in situ* oceanographic and biological measurements enabled elucidation of the timing, sources, and pathways for incorporation of larval fishes into the eddy. The eddy had physical, chemical and biological signatures reflecting strong mixing of its source waters. The horizontal distributions of neritic and oceanic larval fishes indicated strong onshore-offshore coupling. The Leeuwin Current was identified as the major transport route for the incorporation of neritic larval fishes into the eddy. Prior to this, mixing between Leeuwin Current and shelf waters occurs through upstream incursions of the current onto the shelf and this appears to be important for the initial entrainment of neritic larvae into the current. In contrast, high larval concentrations of meso-pelagic fishes (e.g. Myctophidae) in the eddy appear to be the product of localised spawning in or near the eddy. The ecological implications of meso-scale eddies relative to recruitment of coastal fish populations will be discussed.

Cross-frontal exchange within the upper ocean driven by submesoscale subduction
HOSEGOOD, Phil

Four-dimensional observations are presented of a submesoscale parcel subducting from the surface mixed layer (SML) at the North Pacific subtropical front. The measurements were obtained with high horizontal resolution using an undulating, towed CTD and vessel-mounted ADCP during repeated small-scale surveys around a drogued float. The float was initially deployed at outcropping isopycnals whose position corresponded to that of a large horizontal gradient in temperature and salinity whose effects on density were almost completely compensated. The parcel was distinguished as a coherent, isolated body of warm, saline, oxygen-depleted fluid that originated, and had completely detached, from the SML on the warm, cyclonic side of the front. The parcel had a horizontal and vertical scale of approximately 3 km and 40 m, respectively, and was centred on a depth of 80 m. It was therefore beneath the unusually shallow mixed layer base at 30 m which was due to the excessive rainfall during the measurement period. The replacement of the subducted parcel within the SML by cool, fresh, fluid with higher dissolved oxygen values from the intermediate layer between the SML base and permanent pycnocline indicates ageostrophic vertical circulation driving cross-frontal exchange. The horizontal ageostrophic velocity within the parcel was approximately 3-5 cm s-1 in a northward direction, advecting the fluid away from the front and commensurate with model predictions for cross-frontal exchange driven by frontogenesis. The origin of the parcel is discussed in terms of surface mixing events and the possible categorization of the parcel as a submesoscale coherent vortex.

Reconstruction of high resolution ocean dynamics satellite observations
ISERN-FONTANET, Jordi

More than 30 years of Earth observing satellites have provided a wealth of Sea Surface Temperature (SST) measurements. Although these data sets provide a lot of high quality information about ocean dynamics, it is difficult to extract quantitative dynamical information at high resolutions. To overcome this limitation, we investigate the capability of Surface Quasi-Geostrophic (SQG) equations to reconstruct subsurface fields, such

as horizontal velocities and density anomaly, in the upper 500 m of the ocean from a single SST snapshot. Furthermore, within this framework vertical velocities can also be diagnosed from SST. To demonstrate the feasibility of this approach, we have reconstructed the velocity field from high resolution SST images and successfully compared with independent high resolution satellite observations (roughness and Ocean Color) and in situ data (CTD and ADCP).

Small scale retrieval of ocean mean square slope and subsurface signal from space active remote sensing
JOSSET, Damien

The ocean-atmosphere exchanges are driven by the upper ocean boundary layer physical and biological properties. It is dependant of ocean surface state and roughness as well as subsurface biological composition. The ocean surface roughness increases with wind speed as it becomes an ensemble of small facets with a given distribution of slope orientation. This increases the area of ocean-atmosphere interface as well as injection of aerosol in the atmosphere and both sea-spray and CO2 uptake are changed accordingly. We have shown in our previous studies, ocean surface roughness can be retrieved from space lidar and radar. This retrieval is performed at the scale of the lidar and radar footprint (diameter of respectively 70 m and 2km) and at a high spatial resolution (each shot are spaced by respectively 330 m and 1 km), which will allow a better characterisation of ocean-atmosphere small scale exchange. Our study of ocean surface with lidar sensor also lead us to revisit the theoretical formalism for both ocean surface and subsurface lidar return. Our new formalism will allow using space lidar to determine the ocean subsurface return, critical for the retrieval of its biological composition. We will present our last results and perspectives on the use of space lidar and radar to ocean studies.

Biogeochemistry of the bay of Biscay: high resolution observations and modelling
LATHUILIERE, Cyril

The biogeochemical properties in the region of the Bay of Biscay are addressed. The long term objective is the prediction of the evolution of the biogeochemical properties, as a part of the PROTEVS program. For that purpose, the general circulation model HYCOM is coupled to a biogeochemical model and in situ observations are planned. The 2010 cruise aims at observing the transition between the coastal waters and open ocean waters. Two types of measurements are planned. The first one consists of CTD stations combined with sea water taking, in order to determine nutrients concentration. The second one is the in situ observation of the ocean using a SeaSoar, a towed undulating vehicle providing "quasi-synoptic" high resolution observations. This is well adapted to submesoscale observations of the 0100m surface layer. This poster has three objectives:
- Present the in situ measurements. This part will focus on the SeaSoar observations.
- Link the biogeochemical observations to the general circulation of the bay of Biscay. This part will focus on the transition between the coastal waters and the offshore waters, using in situ observations and biogeochemical high resolution modelling. The coastal band is mainly driven by the river discharges. The biogeochemistry of the shelf break is mainly determined by the vertical mixing associated with the baroclinic tide.
- Present the modelling platform.

The role of ocean transport on the distribution of plankton
McKIVER, William

In this work we studied how the distribution of plankton is affected by the ocean transport. To do this we performed numerical simulations using three different coupled fluid-ecosystem models, in which the biological processes are coupled to the 2D Navier-Stokes equations representing the ocean transport at large scales (> 100km). Our approach is to study how changes in relative timescales of the biological ecosystem to the fluid flow processes in order understand how the horizontal transport processes affect the ecosystem dynamics. We quantify the distribution of plankton using the spatial mean and the variance. Overall we find that there is a strong dependence of the dynamics on the timescale ratio. The particulars of these dependence's can be very different for different ecosystem models. For example in one model we find that the system undergoes a regime

shift, from a state where there is low average plankton concentrations to a state where there exists plankton blooms. Conversely for a different ecosystem model we find the average concentrations are not significantly affected by changes in the relative timescales, while the variance (and hence the spatial structure) has a strong dependence. Overall these results imply that the ocean transport processes play a crucial role in the dynamics of plankton ecosystems and we have found and analyzed various mechanisms through which it can affect the global plankton biomass, spatial heterogeneity (patchiness) or produce strongly nonlinear responses in the form of sharp regime shifts.

Watermass characteristics of the subpolar Mode Waters in the NE Atlantic: impact of the onset of the bloom and of the small and medium scales
MEMERY, Laurent

During the year 2001, the POMME programme was dedicated to the study of the subduction of Subpolar Mode Waters in the NE Atlantic (38-45°N, 18°W), and of the mechanisms driving their biogeochemical characteristics, with a specific emphasis on mesoscale processes. Numerical simulations at high resolution (5 km) using a thoroughly validated coupled dynamical – biogeochemical model are used to undertake a synthesis of this programme. The main results of this work will be presented: the subpolar Mode Waters have winter biogeochemical characteristics, as, at these latitudes, the bloom occurs after subduction; the small and medium scales increase the rate of subduction, the range of density of the subducted waters and modify the flux of tracers trapped in the main thermocline. This part of the NE Atlantic Ocean is, in agreement with observations, a carbon sink for the atmosphere.

Marine biogeochemical responses to the North Atlantic Oscillation in a coupled climate model
PATARA, Lavinia

This study investigates interannual-to-decadal marine biogeochemical responses to the North Atlantic Oscillation (NAO), the dominant mode of atmospheric variability in the North Atlantic sector. To this end, a coupled ocean-atmosphere general circulation model including interactive marine biogeochemistry is used to produce a 300-year simulation in which NAO-like variability is internally generated. NAO interannual fluctuations drive coherent anomaly patterns in ocean temperature and mixing through changes in local air-sea fluxes. These hydrodynamic changes affect the seasonality, magnitude, and spatial structure of the phytoplankton spring bloom through light and nutrient limitation mechanisms, and interact with the ability of the subpolar gyre of absorbing atmospheric CO_2. On decadal time scales, the adjustment of the ocean circulation to low-frequency NAO variability gives rise to ocean temperature and salinity anomalies which, thanks to ocean thermal inertia, persist for several years after their generation. Decadal ocean variability generated by persistent low-frequency NAO forcing causes a slight latitudinal shift of the phytoplankton subpolar bloom.

Impact of the topography on the shelf sea transport.
PENNEL, Romain

The impact of steep shelf topography may strongly modify the stability, the wavelength selection of unstable perturbation and therefore the size and trajectories of surface eddies along the coastal shelf. For instance, coastal currents in the southern part of the Mediterranean Sea (Algerian, Libyan currents) are characterized by a strong mesoscale activity above a complex bathymetry. Laboratory experiments were performed in a two-layer rotating tank configuration, to mimic a surface current above a deep ocean. We implemented an idealized configuration in the NEMO OGCM in order to reproduce the laboratory experiments. The numerical simulations resolves mesoscale features with 10 grid points by baroclinic deformation radius. We introduce a topographic parameter *To* as the ratio between the shelf slope and the isopycnal slope and we investigate the impact of this topographic parameter on the dynamics leading to eddy formation and mesoscale shelf-sea transport. For finite or large value of *To* the surface current tends to be stabilized above the steep shelf and smaller scale eddies are formed. The topography also changes the eddy trajectories inhibiting cross-shelf

transport. The impact on the shelf-sea transport is investigated by means of lagrangian particles put in the core of the current and tracked along their trajectory.

Validation of a biogeochemical-physical global coupled model
PERRUCHE, Coralie

The circulation model, NEMO in which sea surface temperature, altimetry data, in situ temperature and salinity are assimilated every week, is run globally at a resolution of 1/4° (Mercator reanalysis: GLORYS). A biogeochemical model (PISCES) is then embedded in offline mode in the simulated ocean circulation. To limit the computational resources necessitated by PISCES but to keep the impact of mesoscale processes, the physical fields are degraded from 1/4° to 1°. In this poster, we will present the biogeochemical fields resulting from a simulation of the 2002 - 2008 period and compare them to available observations and climatologies. The comparison with a simulation without assimilation will allow us to draw conclusions about the impact of assimilation. From these comparisons, we will diagnose the physical and biogeochemical parameters that could be tuned to improve the simulation. The final objective of this work is to operate this coupled system and provide global real time data of the biogeochemical parameters to the scientific community.

Mapping Submesoscale Nitrate Variability: A Novel Technique for Quantifying the Role of Mesoscale-Driven Processes in Upper Ocean Nutrient Supply
PIDCOCK, Rosalind

Despite growing evidence from modelling and theoretical perspectives of the potential contribution of processes at the mesoscale and submesoscale to nutrient cycling, mechanisms have remained poorly quantified in-situ due to the difficulties of collecting simultaneous hydrographic and nitrate data at the required time and space scales. We present results from an integrated deployment of a UV spectrophotometer, the SUV-6, on board a SeaSoar towed vehicle. Data were collected as part of a high-resolution mesoscale survey of a developing eddy dipole in the Iceland Basin during the summer of 2007. The combination of the SUV-6 sensor system and the SeaSoar vehicle as an instrument for in-situ data collection has allowed new and innovative observations of nitrate concentration at high resolution (4m vertically x 4 km horizontally), high-sensitivity (0.2 □M for a single measurement) and concomitantly with temperature, salinity and dissolved oxygen. The ability of this technique to resolve nitrate variability alongside physical processes at the required time and space scales for submesoscale analysis represents a significant advance in techniques used to observe processes of nutrient supply in the upper ocean. We demonstrate the potential of this integrated approach as a powerful new tool in quantification of the role of mesoscale and submesoscale vertical nutrient fluxes in annual new production. With estimates of this kind currently varying by an order of magnitude, this represents a potentially significant improvement to our understanding of the oceanic biogeochemical system on climatic timescales.

Fine scale vertical structure of the upwelling system off Pisco (14 S, Peru) as observed from glider data
PIETRI, Alice

The structure and dynamical mechanisms of an active upwelling cell in the Northern Humboldt Current System off Peru, has been observed by an autonomous underwater vehicle (glider) from October 3rd to November 24th 2008. The glider carried out 9 sections perpendicular to the continental slope from about 10 km to about 100 km from the coast, collecting about 1300 profiles, from the surface down to a maximum of 200 m depth. Data collected by the glider were calibrated and validated using CTD data from the overlapping coastal VOCALS-Rex cruise onboard the R/V Jose Olaya (October 2008).
Firstly, high resolution physical and biogeochemical data acquired by the glider are used to characterize the cross-shore structure and dynamics of the upwelling front. The 9 cross shore sections enable us to estimate the alongshore component of geostrophic currents and transports. Secondly, vertical structures at submesoscale showing localized vertical motions in the vicinity of the upwelling front are highlighted in temperature, salinity, and fluorescence. These submesoscale structures could be the result of interactions between the wind and the

ocean flow driving ageostrophic secondary circulations that have been generally underestimated up to now and are investigated here

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Impact of mesoscale processes on primary production in the Arabian Sea
RESPLANDY, Laure (co-authors M. Lévy; G. Madec; O. Aumont)

Satellite and in-situ observations have shown that mesoscale dynamics is ubiquitous over the Arabian Sea and that it greatly influences the chlorophyll seasonal distribution over the basin. We assess the impact of mesoscale processes on biological production by comparing an eddy-permitting (1/4° horizontal resolution) and an eddy-resolving (1/12° resolution) simulations of the same coupled biophysical model of the Arabian Sea. Most of the prominent dynamical and biogeochemical features are substantially improved by the simulation of mesoscale. In particular, the annual integrated primary production over the basin is increased by 40% in agreement with data-based estimates.
The nitrate supply at mesoscale is highly dependent on the large-scale circulation and therefore on the monsoon season. During the summer monsoon, the extra production induced by mesoscale dynamics is sustained by enhanced upwelling of nitrate off Somalia and the extension offshore the upwelling of Oman is largely explained by the horizontal mesoscale circulation. During the winter monsoon, the convective bloom in the central Arabian Sea is intensified by the vertical advection of nitrate within mesoscale eddies and by the nitrate surplus brought to the upper layer during fall.

Effects of Surface Quasi-Geostrophic turbulence on phytoplankton competition and coexistence
RIVIERE, Pascal (co-authors Coralie Perruche, Guillaume Lapeyre, Xavier Carton, Philippe Pondaven)

This work aims at studying the competition between two mutually exclusive phytoplankton species in a fully-turbulent field consisting of interacting mesoscale and submesoscale structures. A simple NPPZD ecosystem model is embedded in a Surface Quasi-Geostrophic model which is able to reproduce frontogenesis and the associated nutrient vertical pump. The two phytoplankton species differ by their size and their affinity for nutrients. In this study, we rationalize the role played by eddies and filaments in the distribution of the two phytoplankton species. We show that the SQG dynamics are responsible for the coexistence of the two phytoplankton species on a single limiting resource at statistical steady state. In addition, we show that as a result of strong vertical injections, filaments contain 64% of the phytoplankton biomass. The two phytoplankton species coexist in filaments but the large phytoplankton is predominant. By contrast, this latter is completely excluded from eddy cores where only the small phytoplankton develops. Since eddies are coherent structures (unlike filaments) and since their edges are almost impermeable to horizontal transport, the large phytoplankton can barely enter eddies. Therefore, eddies are ecological niches which shelter the small phytoplankton. Finally we show that interactions between eddies such as eddy merger can favor the survival of phytoplankton species within eddies on long time scales in the ocean.

Sea surface physical and biological parameters spectra from in-situ and modelled time-series. What do similarities and differences tell us?
SOMAVILLA CABRILLO, Raquel, Martin, A.P. and Lavin, A.

Variability of physical parameters and biogeochemical tracers in the ocean covers a wide range of scales, highly correlated in space and time. Typically, its study has been tackled from a spatial perspective, and so estimations of biogeochemical patchiness have been reported. Using intermittency as the temporal analogue of patchiness, comparison of physical and biogeochemical parameters spectra can be more feasible examined in the context of high frequency time-series, easier to obtain than high spatial resolution data. In this work, this possibility is explored finding similar results in terms of sea surface temperature and chlorophyll variability to those obtained from patchiness measurements, and a striking similarity between sea surface salinity and chlorophyll spectra. The relation between both is explored further using results of modelled time-series of these parameters. An NPZD model and an objective data assimilation and parameter optimization technique underlie modelled time-series presented. Besides giving insights into the coincidence of patchiness-intermittency found

for both variables, the comparison of observed high frequency time-series and simulation, results have shown that incapacity to reproduce phytoplankton variability at all timescales reduces drastically the estimation of the whole spring phytoplankton biomass. Thus, the proper reproduction of higher frequency variability in phytoplankton activity is crucial to evaluation of their effects in the population dynamics of higher trophic levels as well as the estimation of carbon pumping to the deep ocean throughout the year.

Meso-submeso coupling: Role of Baroclinicity below the mixed layer
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Persistent but weak upwelling forced by mesoscale processes, and short lived but intense fluxes due to sub-mesoscale mixed layer eddies (MLEs) both contribute to nutrient fluxes in the upper ocean. We posit that these processes may couple in surface fronts that have a deeper baroclinic structure. Indeed, MLEs arise both by instability of mixed layer fronts and surface fronts that have a deeper baroclinic signature, and the differences between these two scenarios remain unexplored. We explore on the coupling of mesoscale and submesoscale processes by genesis and evolution of sub-mesoscale motions in the presence and absence of baroclinicity below the mixed layer. A series of simulations using PSOM (Mahadevan 2006, Mahadevan and Tandon 2006) are being conducted. The genesis of sub-mesoscale eddies is quicker and grows to larger length scales when it is the baroclinicity extends deeper into the water column. In particular the role of vertical fluxes in these two scenarios is explored to examine whether effective coupling of MLEs with mesoscale eddies may lead to larger nutrient fluxes across the nutricline.