Work Package II

Spatial and Seasonal Fluxes and Biogeochemical Processes in the Water Column

Executive Summary of Scientific Achievements

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WP2 scientists have made excellent progress during this first year, aided by three management meetings in Vigo (16th May 1997), Paris (27th/28th November 1997) and Lisbon (27th/28th April 1998), and running nine scientific cruises for OMEX II-II on the N.W. Iberian Margin.

WP 2 Cruise	*Dates*	*Science*
Charles Darwin 105 A	29/05/97 – 09/06/97	Swath bathymetry; kasten and box coring; trial deployment of POL echosounder mooring
Charles Darwin 105 B	10/06/97 - 22/06/97	Mooring deployment; biogeochemical surveys; underway measurements; Belgica intercalibrations
Belgica B	18/06/97 – 20/06/97	Underway measurements; intercalibration with Charles Darwin
Belgica C	21/06/97 - 08/07/97	Biogeochemical survey during upwelling season
Belgica D	02/07/97 – 07/07/97	Biogeochemical study of La Chapelle Bank.
Almeida Carvalho	06/12/97 – 15/12/97	Hydrological study of particulates along the Iberian Peninsula
Charles Darwin 110 A	23/12/97 – 05/01/98	Cycling of carbon, nutrients and other trace elements on the NW Iberian Shelf and Slope.
Charles Darwin 110 B	06/01/98 – 19/01/98	Mesoscale spatial variability of water transport, particles, carbon and nutrients in shelf and slope waters of the Iberian Margin
Poseidon PS237-1	26/02/98 – 16/03/98	Cross- and along-slope gradients in water column properties; recovery and deployment of OMEX-II sediment trap and current meters.

The WP2 First Annual Report is divided into 2 parts. The first concerns Executive Management in which the responsibilities of partners who are given as partner numbers and acronyms, are reported on a Task-by-Task basis. The second is a series of syntheses covering Physics (Tasks 1-3), Nutrients & Particulates (Tasks 4-6), Primary Production and Remote Sensing (Tasks 7, 8 & 12) and Fate of Production (Tasks 9-11) in which our scientific achievements are integrated into short papers.

Task II.1: Moorings, currents, circulation and flow fields

Task 1.1. Review of Historic Current Meter and Hydrographic Data: Three historical databases have been set up:. i) a current meter database, containing 40 current meter years from the mid-latitude Northeast Atlantic Ocean (7 UCG)and archived data from 1986 from three slope and one shelf mooring plus a set of Argos drifter tracks (6a UWB-a) ; ii) a hydrographic database based upon data obtained since 1897 for water masses of the Northwest Iberian margin (5b NIOZ-b), and iii) an AVHRR SST image archive in weekly and monthly composite form for the Iberian Peninsular for 1993-1997 and available on http://www.npm.ac.uk/rsdas/composite/ (9 NSS). In addition to this, data from a key 1986 cruise has been re-examined to allow detailed T/S analyses to be carried out (6a UWB-a). A comparison between real and modelled historical current data is underway (11 IST, 7 UCG). For the Portuguese waters, current meter data obtained by IH in previous years have been

produced. Two data sets have been analysed, one obtained during the summer and fall 1987 and comprising three current meter moorings along a cross-shore section offshore Porto (41º 05'N), the other corresponding to the SEFOS current meter moorings maintained from May 1994 to September 1996 over the continental slope (900 and 2300m depth) off S.Pedro Muel (39º 45'N). As an extension of the 87 data set, including coastal wind measurements and two hydrographic surveys, a process oriented study was conducted to describe the dominant dynamical features of the upwelling season of 1987 and to search the nature of the low-frequency flow variability. Methods used included rotational spectral and coherence analysis, dynamical mode decomposition and EOF decomposition (8a IH-a). To complete the data set, access to MORENA current meter data is eagerly awaited (7 UCG & 6b UWB-b) and this is required before the data report can be written and the task is completed (7 UCG & 8a IH-a).

Task 1.2. Deploy Current Meters and Traps on Moorings: A series of moorings have been deployed. Two trap moorings were deployed on the NW Iberian slope in July 1997, and then recovered and redeployed in March 1998 (17 IfM). These were sited on the basis of analyses of historical current meter data and remote sensing. The moorings (for configuration and positions see below) form a pair of three moorings along a transect normal to the slope, with a third current meter (7 UCG) mooring. Five current meters are placed adjacent to the 5 sediment traps. Mooring IM 2 is situated at42°38.75'N 09°41.86'W in water depth of 1453 m. The following gear is situated at the 600m (Sed. Trap), 620m (RCM+Transm), 1050m (Sed. Trap), 1070m (RCM+Transm). Mooring IM 3 is situated at 42°37.72'N 10°01.67'W in a water depth of 2238 m. The following gear is situated at 600m (Sed. Trap), 620m (RCM+Transm). 1080m (Sed. Trap), 1100m (RCM+Transm), 1720m (Sed. Trap), 1740m (RCM+Transm) (17 IfM). Remote sensing images were provided for the Charles Darwin during which the moorings were deployed (9 NSS). POL deployed 2 current meter moorings for UCG in 160 m and 700m water depth in June 1997 on CD105. These moorings have had a chequered history since they have been moved about 1km up-slope and have been hit 4 times, presumably by fishing activity!! Although the ADCP was lost, it has now been recovered. The sub-surface mooring has yet to be recovered, but will be redeployed when ship time permits (7 UCG). In Portuguese waters, one current meter mooring was deployed in February 97 over the mid shelf (84m) off Leixões (41º 05'N) with 4 current meters at 25, 50, 70 and 80m depth, 1 current meter 79m depth and 1 electromagnetic current meter at 18m depth. The current meter mooring is located close to the mooring site of a WAVEC wave buoy and will extend the data already obtained by a similar mooring maintained at the same location during part of the winter 96 (November 96 to January 97). Data from this OMEX mooring is complemented by the two SEFOS moorings that IH still maintains at 900 and 2300m depth off S.Pedro de Muel (new moorings position from September 1996 to present: 39º 55'N), and by coastal wind data measured in weather stations maintained by IH. In the future, the OMEX mooring will be replaced during early June by an identical mooring complemented (possibly) with a bottom electromagnetic current meter which will be measuring in a burst mode at 2m from the bottom (measurements with a sampling rate of 2 Hz in burst of 10 minutes every hour). By September the moorings will be replaced by one mooring over the mid-shelf including a bottom ADCP and possibly a bottom electromagnetic mooring and by a second mooring over the upper slope (including RCM's 7 and one RCM9) (8a IH-a). Remote sensing objectives have been completed (9 NSS).

Task 1.3 Current Meter Data Analyses: Trap current meters and those in Portuguese waters have been successfully recovered (17 IfM & 8a IH-a) . No data recovered as yet from UCG moorings (7 UCG). Data from a current meter mooring maintained off Leixões (41º 19' N) between November 96 and January 97 has been analysed. This mooring was deployed during the cruise CORVET96 and was planned to provided data relevant to the objectives of IH contribution to OMEX II - II. Data analysis methods included basic statistics, rotational spectral analysis, dispersion diagrams for different bands of variability (tidal, inertial and subinertial). A technical report is being produced and data/statistics will soon be send to BODC (8a IH-a).

Task 1.4 Shipboard ADCP for Upper Ocean Currents: ADCP data from CD 105 and 110 have been received and are at an advanced stage of processing despite shipboard data logging problems (6a UWB-a & BODC). Analysis of vertical current structure from a 1986 cruise has been completed and is on course for publication (6a UWB-a).

Task 1.5 Sourcing Currents: Although this work is only scheduled for the final year, a start has been made already (NIOZ). Historical currents processed by UCG will be compared with virtual time series of currents produced by the model in the same locations and for the same period. Locations and periods to do the comparisons were choose having in mind available atmospheric data to force 3D ocean circulation model. Virtual time series will be analysed as if they are real (computation of mean, standard deviation, etc.) and comparison is made in that way (11 IST). Chelsea Instruments Plc "Aquapacks" have been fitted to CPRs and have recorded temperature, salinity and fluorescence. Six of nine tows (to the end of March 1998) returned successful data. All 1997 data are banked at BODC (12 SAHFOS).

Task 1.6. Detection, Typology and Statistics of Seasurface Temperature and Colour: Filament transport detection was discussed at Vigo, Paris and Lisbon WP2 meetings. Four Horizon Marine mixed layer drifters have been purchased. In relation to AVHRR and SeaWIFS, remote sensing monitoring has been set up on schedule (4a PML-a) with ongoing discussion of implementation of automated approaches to detection, classification and statistical analysis of SST and ocean colour features (6a UWB-a). Algorithms have been implemented for detecting oceanic fronts on SST maps, and this has been applied to OMEX II-II data for 1997. Weekly composite front maps have been found to provide a good basis for statistical analysis of fronts, eddies and filaments and ware on track for completion by month 18 (9 NSS).

Task II.2: Water Mass Analysis by Conservative and Transient Tracers

Task 2.1 Classical Hydrography & Water Masses: Hydrographic and hydrochemical (oxygen and nutrients) data from Pelagia 108 and 109 have been quality controlled, processed and the resulting data files have been sent to BODC (5b NIOZ-b). Cruises CD105 (June 1997) and CD110 (December 1997 - January 1998) carried out an array of CTD stations, and supplementary XBT casts on CD110. The June cruise completed the full array of planned stations. However, the winter cruise was conducted in atrocious conditions and XBT casts could only be carried out at half the stations and most sampling was limited to the surface (2 POL & 4a PML-a). CTD hydrographic data from the cruise CORVET96 as been quality controlled and data analysis is on course. This IH lead cruise, held during November 1996, included a "local study" designed to fulfil some IH objectives to OMEX II-II. Observations during this local study included 72 CTD/SPM casts with a Neil Brown MKIIIC equipped with a 12-bottle rosette and a nephelometer, water samples for CTD calibration, SPM evaluation and nutrients, and bottom sediment samples with a multicorer. A cruise report is being written and data will soon be sent to BODC. A second OMEX cruise (CLIMA 97) was held by IH between 6 to 15 December 1997. During the cruise 120 CTD/SPM casts were made using a coupled system including a Neil Brown MKIIIC CTD (equipped with a nephelometer) and a Hidronaut CTD (equipped with an OBS, O2, pH and Redox sensors and an ultra-sonic current meter). Water samples for CTD calibrations, for SPM evaluation and for nutrient analysis have been collected. The data from the Neil Brown CTD has been quality controlled and data analysis is on course. Nutrient samples have been analysed. A cruise report is being prepared and data will soon be sent to BODC. Near future work: To complete data quality control and analysis for the CLIMA 97 cruise. An OMEX cruise will be held by the end of the summer 98 (possibly September). Observation will include CTD/SPM measurements, water samples for CTD, SPM and nutrients and bottom sediment samples (8a IH-a).

Task 2.2 Tracers & Mixing End Members The end-members of the deep-water mass have been described using the historical database (see 1.1), and the contributions of the deep water masses calculated. This has resulted in a completed manuscript (5b NIOZ-b). The following have been achieved: a) redefinition of the Hydrodynamic model layout, b) development of the 2-Way nested model, c) improvement of the turbulent closure of the model and d) development of the interface to couple the hydrodynamic and ecological models (11 IST). Water samples for $\delta^{13}C$ and $\delta^{18}O$ measurements were collected on Belgica 97-14 and Poseidon 237-1 and carbon isotope analyses from Belgica 97-14 are currently ongoing at the Leibniz Laboratory, University of Kiel. The oxygen isotopes will be analysed in Fall, 1998. Analysis of the methane and collection of radiocarbon samples will take place on board R/V Meteor in January 1999. All targets are being met (24A GEOMAR-A).

Task II.3: Spatial Distribution of Turbulence & Mixing

Task 3.1 Deploying Free Falling YOYO: The FLY probe, tested in November, was deployed successfully several times on the CD110 cruise in January. High turbulence was recorded in the top 20m of the water column. Post-processing software was also successfully used at sea. This research is ahead of schedule since it is timetabled for Years 2 & 3 of the project. (6b UWB-b).

Task 3.2 Map 3-D distribution of Turbulence Kinetic Energy: Climatological data have been used to run models for testing turbulence closure and a major challenge, that of reconciling the consistent relative warming of the upper ocean by the model, has been identified (11 IST). Data obtained by UWB-b have been banked at BODC and preliminary results, reported above; show the work is on target (6b UWB-b). Preparations are being made to order and process SAR data coincident with cruise CD114 (4d PML-d [ex 9 NSS]).

Task 3.3 Provide parameters for comparison with turbulence in closure models: Preliminary turbulence parameters were reported to the modellers at the Lisbon workshop. The work is on target (6b UWB-b). The 1-D vertical model used by IST during OMEX I has been used experimentally to test turbulence closures and coupling with biogeochemical models. During OMEX I, the model was used to reproduce the vertical variability of temperature, phytoplankton and nutrients in the Goban Spur region using atmospheric forcing and sea surface temperature (SST) measured at K1 buoy made available by BODC. In that work it was noted that SST tends to diverge from observed SST after the end of August with the higher temperatures being obtained in the model. A similar run was made for the OMEX II-II region using climatological data and SST Levitus data. The results showed a very similar problem. Further investigation revealed an error heat fluxes in both cases leading to a consistent warming in the upper ocean. A technique for correction of heat fluxes was developed using observed SST producing more accurate results for temperatures and for turbulence parameters such as turbulent kinetic energy, turbulent viscosity and turbulent diffusivity. UCW-b will made available profiles of temperature, kinetic energy and turbulent viscosity as well as atmospheric forcing for comparison with 1D and 3D correspondent profiles in order to validate more accurately the turbulence closure used in MOHID3D (11 IST).

Task II.4: Nutrient Distribution, Speciation, Upwelling & Fluxes.

Task 4.1 Nutrient Oceanography: Nutrient distributions were carried out in real time on Darwin 110 and on preserved samples on Belgica 9714 (13 IIM). Preserved samples were taken for nutrient intercalibrations (1b ULB-b, 4c PML-c, 13 IIM & 23 VUB). Nutrient data from earlier cruises (GALICIA 7, GALICIA 8, GALICIA 9, GALICIA 11, GALICIA 12 and MORENA I) have been sent to BODC for integration into the OMEX database (13 IIM). Nutrient samples were collected on Belgica 97/14 by ULB-b (1b) at reference stations and dispatched for intercalibration (13 IIM, 4c PML-c and 23 VUB). At the beginning of the same cruise, the Belgica and Charles Darwin (CD110) met in the coastal area near Vigo. CTD casts were performed and nutrient samples were exchanged for intercalibration exercise. Results of dissolved phosphate and silicate on these samples were transmitted by ULB-b to PML-c who prepared a report on this intercalibration exercise. Nutrient samples were also taken on board the Belgica from the CTD bottles for dissolved nitrate/nitrite, phosphate and silicate. One set of samples was analysed manually on board for phosphate and silicate, and the data have been banked at BODC (1b ULB-b). Another set of samples was kept frozen to be analysed for nitrate/nitrite in the laboratory (1b ULB-b). Nutrient intercalibration on preserved samples taken during OMEX cruises and the results for NO_3 and Si concentrations are available. Other nutrient samples were taken and preserved during both cruises. The analysis is in progress. Shipboard nutrient distributions were carried out using underway acquisition of NO_3/NO_2 and dissolved Si during BG9714. 21 stations were sampled for the vertical distribution of nutrients. Concentrations of NO_3/NO_2, Si, NH_4 and urea are available (23 VUB). Nutrient samples (NO_3+NO_2, NH_4, Urea and $Si(OH)_4$) along vertical profiles have been collected on BG9714 Belgica cruise. The samples have been analysed and intercalibration exercise for nutrient determination was performed at

the BODC site O2IC1 (1b ULB-b, 23 VUB). Nutrient intercalibration on fresh and frozen samples taken during CD110B cruise on January 1998 has been continued (13 IIM). Results have been sent to PML-c to be included in the database. Analysis of 5 nutrients (NO_3, NO_2, NH_4, PO_4 and Si) on fresh samples has been done during the CD110-B cruise from 5 to 16 January 1998. A total of 112 samples have been analysed (55 from underway sampling) and the data have been submitted to BODC (13 IIM). Analytical systems have been serviced and successfully commissioned in preparation for the shipboard sampling programmes. Staff have been appointed jointly by PML and Univ. Plymouth to measure DOC/TDN distributions in WP2. Axel Miller led Charles Darwin cruise CD110B and organised shipboard total dissolved nitrogen (TDN) analyses. The data obtained are currently being processed and quality controlled (4a PML-a).

Task 4.2 Conserved Nutrient Tracers: -Historic NO_3 & PO_4 data are included in the data that have been sent to BODC (13 IIM). From the historic database, nutrients and oxygen have been extracted, and quasi-conservative pre-formed nutrients have been constructed. These data are used in the water mass analysis in WPII.2 and the research is proceeding according to plan (5b NIOZ-b). AOU data was obtained during the Belgica 97/14 (June 1997) and the CD 110B (January 1998) cruises; data processing is complete (22 ULg).

Task 4.3 Nutrient Boundary Fluxes: From the water mass analysis and the use of nutrients and pre-formed nutrients, an increase towards the European continental margin of mineralization of organic matter in the deep water has been established qualitatively (5b NIOZ-b).

Task 4.4: Nitrate Remote Sensing Algorithms: OMEX 2-2 cruise data transferred to BODC are being used to extract SST and nitrate data extracted for developing nitrate remote sensing algorithms. Deliverables are on target (4d PML-d [ex 9 NSS]).

Task II.5: Source Markers of Particulate Matter

Task 5.1: Biomineral and Lithogenic Composition. Surface suspended samples were collected on board the Belgica 97/14 cruise by centrifugation during month 1. Particulate material was also sampled by *in-situ* filtration of large volume of water at various depths using Stand Alone Pumps (SAPs) during the Belgica 97/14 and CD110B cruises (1b ULB-b). The analyses of these samples for major and minor elements are close to completion (1b ULB-b). An intensive water column sampling programme was conducted during Feb./March 1998 on the POSEIDON cruise to characterise the composition and gradients of suspended particulate matter using both CTD transmissometers and water samples. Samples are currently being analysed (for dry weight, carbonate, POC, PON, opal and $\delta^{15}N$) and the results will contribute to a good seasonal coverage of SPM at the Iberian Margin. SAPS were deployed on the moorings for the first time and samples will be available in Jan 1999. Except for the delay in deploying the SAPS due to technical problems from the manufacturers, work is on schedule (17 IfM).

Task 5.2: Stable isotopic signatures. 100 samples from sediment traps and approx. 220 water column SPM samples are available for analyses of $\delta^{15}N$. Sediment trap samples are currently being treated and analyses of water column samples are underway (17 IfM). 22 samples collected by centrifugation of surface waters from 3m depth during BG9714 were taken for $\delta^{15}N$ and POC/PN determinations. Analyses are rescheduled during the second year because of the availability of our mass spectrometer (23 VUB).

Task 5.3. Particle Residence Times: Large seawater volumes for radionuclide measurements were collected on WP2 cruises. During CD105 and CD110 cruises, the sampling was focused on the euphotic layer, during PE109 on intermediate and bottom nepheloid layers. All ^{234}Th and ^{228}Th measurements have been achieved (27 CFR).

Task 5.4. Pigment Biomarker: Chlorophyll *a* samples were taken for intercalibration exercise when Belgica and Charles Darwin met (1b ULB-b). Samples of chlorophyll *a* were also collected on shallow CTD casts down to 150-200m during the Belgica 97/14 cruise; they have been analysed by fluorimetry method and the data have been banked at BODC (1b ULB-b). ULB-b also collected

chlorophyll *a* samples during the CD110B cruise, the analyses of which are in progress. Samples have been collected from three WP II cruises to date including CD105 (June 1997): 330 samples - 41 vertical profiles + underway (includes intercalibration exercise with Belgica), CD 110 (January 1998): ~ 80 samples - 6 vertical profiles + underway, Poseidon (February - March 1998): >100 samples - 12 vertical profiles. Analysis of chlorophyll and carotenoid pigments in samples from CD105 has been completed. Data has been quality controlled and banked with BODC (including intercalibration data) facilitating chemotaxonomic interpretation; use in calibration of in situ optical and fluorimetric sensors and development of ocean colour remote sensing algorithms and. Analysis of samples from CD110 and Poseidon cruises is presently underway. Data generated is directly relevant to both WPI and WPII objectives. All targets have been met (4a PML-a).

Task 5.5: Biomass Carbon: Samples for bacteria and for microzooplankton have been collected on WP2 cruises and are undergoing microscopical analyses in the lab (4b PML-b, 14a UAL-a). Microzooplankton biomass has been determined for some samples collected during March 1998 (4b PML-b). SAHFOSS contribution is dependent on the data collected under 10.1 and 10.2 (12 SAHFOS). Samples have been collected on CD105b and CD110b using vertically integrative net hauls and the LHPR system. These samples are currently being analysed with respect to body length measurement (prosome length). Length-weight equations have been compiled. In addition total mesozooplankton biomass measurements are also been made using destructive (dry weight) methods (16 SOC).

Task II.6: Dissolved Organic Carbon

Task 6.1 Seasonal and Spatial Distribution of DOC: Intercalibration and optimisation of HTCO-DOC has now been started by 4a PML-a and all the DOC data from IIM has been delivered to BODC. Samples from two shallow profiles (a total of 9 samples) in the Ria de Vigo, during September 97 have been collected to continue with intercalibration exercise (13 IIM). Replicates of these samples have been passed to 4a PML-a (and to ULB-b - for opportunistic participation in the intercalibration exercise), for subsequent analysis (13 IIM). Analytical systems have been serviced and successfully commissioned in preparation for the shipboard sampling programmes. A PhD student has been appointed to measure DOC distribution. A number of measures have been and continue to be taken as a matter of course, to ensure consistency between the analytical facilities at IIM and PML. These include preparation of a joint-authorship DOC/TDN methodological manuscript, analyses of common samples from the OMEX Box, and on-going participation in an international DOC intercomparison exercise, funded by US oceanographic agencies (4a PML-a). Investigation of DOC remote sensing algorithm is expected to be undertaken in years 2 and 3 of OMEX as data become available at BODC. No deliverables required at present (4d PML-d [ex 9 NSS]).

Task 6.2. Plankton Production of DOC: To deliver Technical Annex requirements, two activities were completed during Year 1 of the project: The method for the determination of DOC production rates by plankton was optimise and a detailed protocol has been developed. Shipboard measurements of DOC production by plankton were measured at a series of stations during two cruises: CD105 (29 May to 22 June 1997) and CD105 (5-19 January 1998) on board RV Charles Darwin. The data set corresponding to CD105 has been processed and is ready for data banking. Data corresponding to CD105 are currently being worked out and data quality control is being undertaken. Experiments designed to quantify the relationship between grazing rates and DOC production are being discussed and the experimental set up is currently the object of active debate among the three institutions involved. Experiments will be carried out before next autumn. (21 UVi). During this first year of the project the methods for measuring DOC production have been optimised in collaboration with UVI (partner 21). The first measurements in the sea, coupled to DON production and zooplankton grazing will be obtained during the cruise OMEX-0898 scheduled for August 1998 (20 IEO).

Task 6.3. Bacterial Utilisation of DOC: Plans are well advanced for large bottle experiments with different filtration and dilution treatments to estimate the rate of bacterial biomass increase and DOC uptake on the August 1998 WP2 cruise (14a UAL-a).

Task II.7: CO_2 Drawdown and Ventilation.

Task 7.1 CO_2 Partial Pressures and Upper Ocean Biogeochemistry: Quality control & integration of historical IIM data from the Galicia and Portugal area into OMEX database has been started (13 IIM). A limited number of PO_4 and chlorophyll samples were taken on board the Belgica 97/14 cruise which will be used by ULg for their underway pCO_2 measurements (1b ULB-b). pCO_2 data was generated on the first WP2 cruise (Belgica cruise 97/14, June 1997). Surface mapping of pCO_2, pH, O_2 was accomplished during Belgica 97/14 and CD 110B cruises covering upwelling and downwelling situations; data processing is complete. Two more cruises are planned for the near future on board the Belgica in July 1998 and the Meteor in January 1999 (22 ULg).

Task 7.2 Air-Sea Exchange of CO_2: Preliminary calculations of air-sea exchange, in collaboration with RISØ, started in May using the Belgica 97/14 data set (22 ULg).

Task 7.3 Marine versus Anthropogenic CO_2: Water samples for analysis of the $\delta^{13}C$ of total dissolved CO_2 have been collected on two cruises, Belgica 9714 and Poseidon 237-1. Carbon isotope analyses from Belgica 97-14 are currently being analysed at the Leibniz Laboratory, University of Kiel, and are 70% complete. The intercalibration of continuous underway pCO_2 measurements with the University of Liege, originally planned to take place within the first year, has been delayed because of a logistical conflict. The intercalibration was originally planned for Belgica cruise 98/15 in July, 1998, but the GEOMAR equilibrator is needed on another project at that time. The intercalibration has been rescheduled for the Meteor M43/2 cruise in January 1999. Samples for radiocarbon analysis will also be collected at that time. Except for the delay in the pCO_2 survey, all targets are being met (24A GEOMAR-A). Intercalibration with GEOMAR of underway pCO_2 systems will be carried out during the Meteor cruise in January 1999 (22 ULg).

Task II.8: Primary, New and Size-fractionated Primary Production

Task 8.1: Spatial & Temporal Distribution of Phytoplankton and their Pigments. Phytoplankton samples were obtained on Belgica 9714 and Darwin 110 cruises (13 IIM). Microphytoplankton counts of samples taken during Belgica cruise BG9714 are already finished and will be submitted to BODC soon (13 IIM). Phytoplankton samples have been collected on CD110-B cruise and are currently being analysed by microscopy (13 IIM). Chlorophyll samples were taken for intercalibration exercise when the Belgica and Charles Darwin met. Shallow samples down to 150-200m during the Belgica cruise have been analysed by fluorometry method (1b ULB-b). Samples from two CTDs were collected for the determination of chlorophyll during CD105's intercalibration exercise with Belgica. Analysis of chlorophyll in samples by HPLC is complete with quality control currently being undertaken before data is banked (4a PML-a). On CD105, > 330 samples were collected from 41 vertical profiles and from an underway sampling programme on CD105. Analysis of chemotaxonomic pigments in these samples by HPLC has been completed with quality control currently being undertaken before data is banked (4a PML-a). The chemotaxonomy of phytoplankton pigments will be applied to data from CD105 to determine the distribution and abundance of the major phytoplankton taxa and their contribution to total phytobiomass in the study region (4a PML-a). Seven CPR tows were collected in 1997 and all samples have been analysed for phytoplankton species relative abundance. Three further tows have taken place in 1998 and analysis is in hand. Monthly tows will continue until month 30 of the project (12 SAHFOS). SeaWiFS ocean colour data have been processed daily since 19th September 1997, and presented on the OMEX remote sensing web site. HPLC data have been obtained for early OMEX cruises and will be compared with SeaWiFS in order to develop and validate pigment remote sensing algorithms. No deliverables required at present (4d PML-d [ex 9 NSS]).

Task 8.2: Intercalibration of Primary and New Production: It has still not been possible to organise an intercalibration of ^{14}C, ^{15}N and $^{32/33}P$ methodologies. There will be an opportunity for comparisons of ^{14}C fixation between PML-c and IIM in August 1998 (4c PML-c).

Task 8.3: Parameterisation of Primary Production: Photosynthesis as a function of irradiance have been determined during the BG9714 cruise by performing ^{14}C uptake experiments on water samples collected at two depths and incubated under an artificial light gradient ranging from 0 to 600 $\mu Em^{-2}s^{-1}$ (1b ULB-b). The potential production was also investigated at various stations by measuring the ^{14}C incorporation during incubation experiments under constant light conditions (80, 188 and 530 $\mu E\ m^{-2}\ s^{-1}$); size fractionation was performed on the incubated samples by filtering the water through 0.2, 2 and 20 µm porosity filters (1b ULB-b). ^{14}C P vs I relationships were also measured on this cruise together with underwater light field, spectra of phytoplankton absorption coefficients, chlorophyll, and phytoplankton (13 IIM). Experiments were carried out at 55 samples on 14 stations where the spectral light attenuation was measured also at depth of 5, 10, 15, 20, 30, 40, 50 and 60 m. Chlorophyll, pico and nanoplankton, spectra of light absorption by phytoplankton and detritus, and spectra of water column light attenuation have already been sent to BODC. Phytoplankton counts are needed to complete the analyses (13 IIM). Photosynthesis-irradiance relationships (P vs. I curves), underwater light field and spectra of phytoplankton absorption coefficients has been determined on CD110-B cruise and data are being analysed (13 IIM). Primary production was measured during the Poseidon cruise in March 1998; data analysis is complete. Comparisons will be made primary production estimated by in situ and by P vs I relationships in August 1998 (4c PML-c).

Task 8.4: New Production: Eight stations were sampled to assess the nitrogen uptake regime. The following experiments were carried out: $^{15}NO_3$ and $^{15}NH_4$ PvI curves using short time incubations on an artificial light gradient up to 600 $\mu E\ m^{-2}\ s^{-1}$. $^{15}NO3$, $^{15}NH_4$ and ^{15}N-urea uptake experiments with a constant light of 200 $\mu E\ m^{-2}\ s^{-1}$. $^{15}NO_3$, $^{15}NH_4$ uptake kinetics at 200 $\mu E\ m^{-2}\ s^{-1}$ to assess Michaelis-Menten parameters and inhibition of nitrate uptake by ammonium. $^{15}NH_4$ isotope dilution experiments to assess the rate of ammonification. The samples are currently being analysed by emission spectrometry and all targets are being met (23 VUB). New production measurements were done on the Poseidon cruise in March by incubating water samples with $^{15}NO_3$ and $^{15}NH_4$. Analysis of these samples is underway but not yet complete (4c PML-c). This task is awaiting *in situ* data to be lodged in the BODC data base, with progress towards deliverables as planned (4d PML-d [ex 9 NSS]).

Task 8.5: Assimilation of Phosphorus: The rate of size-fractionated (0.2µm and 2µm) assimilation of ^{32}P by phytoplankton was determined during the BG9714 cruise at two depths (surface and chlorophyll maximum) at 9 stations under well controlled conditions similar to those for ^{14}C (1b ULB-b). Samples were additionally incubated with the addition of various inhibitors (sodium azide, antibiotics) in order to evaluate the fraction of ^{32}P uptake due to abiotic processes such as passive adsorption and to heterotrophic activity (1b ULB-b). The results are being analysed and interpreted (ULB). Phosphate uptake was measured during the Poseidon cruise in March 1998. The data analysis is complete (4c PML-c).

Task 8.6: Spatial and Seasonal Distribution of Primary and New Production. The data collected on CD 105 and on the March cruise on Poseidon have been plotted in relation to geographical location and provide estimates of primary and new production for the early summer period, prior to significant upwelling events. The data will be lodged at the OMEX data centre in the near future (4c PML-c).

Task II.9: Microbial Populations as Pelagic Sinks

Task 9.1 Distribution of bacteria and microzooplankton: Samples have been collected for bacteria and for microzooplankton on all WP2 cruises. Bacterial samples were collected in the Charles Darwin cruise 110b (January 1998). A total of 30 samples were fixed on board and later processed for bacteria counts (Acridine Orange Direct Count) and cell sizing using epifluorescence microscopy. Bacteria biomass was calculated as a non-linear function of cell volume. Bacteria counts and biomass will be further estimated for samples in the two WP2 summer cruises which UAL-a will participate in (Belgica 98/15 & Antonio Bode August 98). This will give us some idea of seasonal (winter & summer) variation in bacteria distribution (14a UAL-a). Preliminary analysis of Lugol's fixed samples show microzooplankton to be abundant during March particularly at the shelf stations with abundance of 20-200µm size class ranging from 0.6 to 10 cells ml^{-1} in surface samples. Lowest abundance was found at oceanic deep-water stations. There was a distinct shift in the microzooplankton community

composition which appeared to be as a result of changes in the composition of the phytoplankton community. In shelf waters, where diatoms were the main phytoplankton, heterotrophic dinoflagellates comprised 60% of the total biomass. In deeper water stations the phytoplankton community was dominated by smaller picoplankton and the microzooplankton community comprised smaller oligotrich ciliates and very few heterotrophic dinoflagellates (4b PML-b).

Task 9.2 Nitrogen and CO_2 regeneration by bacteria micro- and mesozooplankton: Nitrogen and CO_2 regeneration by bacteria, micro and mesozooplankton. Methods for measuring DON excretion by microplankton have been optimised. The first measurements in the sea, coupled to DON production and zooplankton grazing will be obtained during the cruise OMEX-0898 scheduled for August 1998. The planning of this cruise (which will be responsibility of IEO) has taken most of the time-effort during the last six months. A detailed review of DON data collected in the area in the past was made to determine the concentrations that can be expected, and the relationships between DON and other variables (20 IEO). The respired fraction of ^{14}C-leucine will be measured directly in samples after incubation for bacterial production. UAL-a will participate in two cruises this summer (Belgica 98/15 & Antonio Bode August 98) where this task will be performed on board (14a UAL-a). AOU data was obtained during Belgica 97/14 and CD 110B cruises and preliminary calculations of air-sea exchange, in collaboration with RISØ, started in May using the Belgica 97/14 data set (22 ULg).

Task II.10: Mesozooplankton Distribution and Production Processes.

Task 10.1 Zooplankton Distribution & Seasonality: Historical CPR data has been analysed to show seasonal cycles of abundance and horizontal species distributions for selected dominant taxa (see science report). Other taxa can be similarly processed as required. CPRs have been successfully deployed seven times in 1997 and a further 3 times in 1998 (to the end of April). All 1997 samples have been analysed for zooplankton species abundances. Data will be banked at BODC by the end of year 1 (12 SAHFOS). Samples have been collected on CD105b and CD110b using vertically integrative net hauls and on CD105b using the LHPR system. These samples are currently being analysed with respect to taxonomic composition, abundance and biomass. Plans are underway for samples to be collected for SOC on the forthcoming Belgica (98/15) cruise, and Andrew Hirst will be participating on CD114b, when more samples will be collected (16 SOC).

Task 10.2. Zooplankton Grazing, Exudation & Faecal Production. Cruise samples of preserved mesozooplankton have been obtained from June 1997, January 1998 and March 1998 for length/dry weight measurements of dominant taxa. June 1997 samples have been processed and measurements have been obtained for 22 of the 28 key taxa (12 SAHFOS). The flux of faecal pellets in sediment traps will be determined microscopically from samples that are currently being picked and split. Data will be available by month 24 (17 IfM). Zooplankton excretion and respiration was measured on CD110 and gut passage times in Appendicularia have been determined (19 UOv). Size distributed herbivorous grazing protocols have been decided upon in collaboration with UITØ-b. Inter-calibration with UITØ-b will take place in Tromsø prior to the August CD114b cruise on which this work will be undertaken. Egg production experiments to be used to determine weight-specific growth were to have been conducted on CD110b, however, this work was disrupted severely because of the bad weather conditions. It may be possible if time allows for Andrew Hirst to continue this work on CD114b. A model that allows prediction of weight-specific growth and egg production has been completed and been accepted for publication in the journal Marine Biology ('Towards a global model of *in situ* weight-specific growth in marine planktonic copepods' AG Hirst & RS Lampitt). The appendix used in the construction of this empirically driven model has been lodged with BODC. The accuracy of the model is currently being examined with the aim of allowing errors bars to be placed on predictions from data collected within the Galician box. Empirical relationships that allow indirect estimates of respiration and faecal pellet production have been completed using published materials (16 SOC). Zooplankton grazing, exudation and export. Methods for measuring DON excretion by microplankton have been optimised. The first measurements in the sea, coupled to DON production and zooplankton grazing will be obtained during the cruise OMEX-0898 scheduled for August 1998. A joint experiment with partner 19 (UOV) and 21 (21 UVI), designed to determine the role of zooplankton

grazing in DON and DOC in controlled laboratory conditions, was scheduled for autumn 1998 to help in the interpretation of the results obtained during the OMEX-0898 (20 IEO). Formulation of the pelagic model has begun. Various pelagic model routines, including new phytoplankton routines, a routine describing bacterial dynamics and dissolved organic matter, and several implementations for sediment-water exchange processes have been developed. Other routines (zooplankton, nitrate and ammonium dynamics) were already available from the OMEX-I project. These submodels are currently being tested, all targets have been met (15a NIOO-a).

Task II.11: Sedimentation, suspended material and the 'Carbon Depocentre'

Task 11.1. Deployment of sediment traps for estimation of vertical particle flux. Two moorings, IM2 and IM3 that were deployed at the Iberian Margin slope in August 1997 were successfully recovered during the POSEIDON cruise in March 1998. With the exception of the sediment trap in 1753m on IM3 that malfunctioned due to corrosion and flooding of the motor, a full set of samples and complete record of current meter data were obtained. *In-situ* pumps, that were tested extensively and successfully on the ships wire were also deployed on the moorings. Mooring recovery will be in January 1999. Details of the moorings are given in the science report. Sediment trap samples are currently being processed in the laboratory. It is foreseen that splits will be ready for distribution to partners within 6 months. Work is on schedule in this task (17 IfM). SST were presented on the web site to support mooring deployment during month 1-3: no further NSS deliverables required at month 12 (4d RSDAS – ex 9 NSS).

Task 11.2. Seasonal vertical fluxes from biogeochemical and morpholgical analyses of suspended material: The necessary hard-shelled plankton data are being collected as described in II.8.1. Comparisons will be made with sediment trap material when this has been processed by IfM (12 SAHFOS). Progress in this task will be achieved when sediment trap and SPM samples are analysed (see above) and data will be delivered for dry weight, carbonate, POC, PON, opal, microscopic phytoplankton and faecal pellet counts, algal pigments and $\delta^{15}N$ in suspended and sinking particles. Data are expected to be available for suspended particles by Sept. 1998 and for trap samples by April 1999 (17 IfM). Seasonal vertical fluxes from biogeochemical & morphometric analyses of suspended and sediment trap material. We are still waiting for trap samples (27 CFR). SOC's contribution will follow later into the project once results are available (16 SOC).

Task II.12: Remote Sensing & Biogeochemicals Algorithms

Task 12.1: Archived and Real-time Remote Sensing Data: Individual AVHRR-SST and thermal-IR images (to show clouds) have been produced and placed in a hierarchical structure e.g. 1997/12/15 on the WWW since the start of OMEX under http://www.npm.ac.uk/cgi-bin/cgiwrap/wwwrsdas/browser/AVHRR/omex2/ (4d PML-d [ex 9 NSS]). Real-time acquisition of SeaWiFS started on 19 September and chlorophyll & ocean colour images covering the OMEX 2 area are available in a hierarchical structure at http:// www.npm.ac.uk/cgi-bin/cgiwrap/wwwrsdas/browser/SeaWiFS/omex2 (4d PML-d [ex 9 NSS]). Individual AVHRR SST and thermal infrared images, and SeaWiFS ocean colour images, are being continuously processed in near-real time, and disseminated to OMEX scientists via the web site. Progress, data, and applications are presented in the science report. All deliverables have been met. Cruises supported with near-real time data include: Charles Darwin CD105 (29/05/1997-22/06/1997); Belgica BG9714 (18/06/1997- 07/07/1997), Charles Darwin CD110 (23/12/1997-19/01/1998), Poseidon PS237-1 (26/02/1998-16/03/1998) (4d PML-d [ex 9 NSS]).

Task 12.2: Algorithm Development and Validation: No analysis has yet been done in relation to this Task (4c PML-c). An empirical model for the assessment of new production using nutrient distribution data (i.e. NO_3 and NH_4) has been designed for OMEX 1 (Elskens *et al.*, submitted to Deep-Sea Research January 1998). Results of the uptake and inhibition kinetics (Task 8) are currently used to refine the model for the Iberian Margin zone (23 VUB). Surface water samples from throughout the OMEX Grid have been analysed during CD110B. Similar measurements will be made during the forthcoming summer cruise (R.V. Cornide de Saavedra / Russian Vessel) and the winter

cruise (R.V. Meteor). Quality controlled data will be made available for the potential development of remotely sensed Gelbstoff algorithms (RSDAS) through BODC (4a PML-a). Novel remote sensing algorithm development will be undertaken when appropriate data-sets are available via the BODC database. All remote sensing data required for the task are already available. Progress on this task is as expected with deliverables on target for months 24, and 36 (9 NSS). Surface mapping of pCO_2 was accomplished during Belgica 97/14 and CD 110B cruises and preliminary correlations between pCO_2 with *in-situ* SST were attempted and discussed with NSS (22 ULg).

Physics (Tasks 1, 2 & 3) Synthesis

Martin White (University College Galway, Ireland)

To understand the currents and flow fields, some 40 current meter years of archived data for the Iberian margin region have been analysed this year, as well as some satellite tracked buoy data. The data has been obtained from BODC, SISMER (Bord-est data set) and from OMEX Partners. Unfortunately no data from the MORENA experiment has been received as yet but this situation is undergoing review. The existing SEFOS (EU FAIR project Shelf Edge Fisheries and Oceanography Study) current meter data has been re-analysed and time-series show the seasonal pattern of southward shelf/slope flow during summer upwelling conditions and a poleward flow in autumn/winter when southerly winds weaken or reverse. Variability and magnitude of flows across the shelf are considerably smaller than those in the along-slope direction. At the depth level of influence for the Mediterranean Water (MW), a topographically constrained poleward flow of ~5 cm s^{-1} is found. A data report documenting the statistics is under construction.

Re-analysis of data collected for the upper layer of the Iberian margin indicates the variable structure in the temperature/salinity signal within both the poleward flow of warm water and filament structures. Analysis of the shipborne ADCP, for upper layer circulation patterns, has not started as yet but the data from CD105 and CD110 is being banked/quality controlled at BODC before analysis is due to start this year. Pattern recognition techniques have been used to quantify the variability in the upper layer circulation and the features in the OMEX region, such as eddies and frontal structures. Analysis of the archive AVHRR satellite imagery, for the time 1993-present, has been completed, with monthly SST composites available on the web. These images show that the autumn/winter poleward flow of warm saline water can pass the NW corner of Spain and flow along the shelf edge into the Cantabrian Sea and this is consistent with measured buoy tracks. At the recent WP2 meeting, it was agreed that some quantification of the balance between the density and wind forcing, driving the two different dynamical regimes, should be made.

The first stage of mooring deployments is underway, with the establishment of the OMEX line near 42^{o} 40'N and the deployment of a mooring on the slope. The OMEX line was decided with the help of the swath bathymetry collected on CD105a. A bottom mounted ADCP was deployed on the shelf and a 700m sub-surface mooring on CD105 (June 1997) and were due for recovery on CD110 (January 1998). Unfortunately the 700m mooring was interfered with by fishing activity and has not, as yet, been recovered. A replacement mooring, recovery of the existing mooring and re-deployment of the ADCP may be possible in the summer. The two trap moorings completing the OMEX line were deployed in summer of 1997 and recovered in March 1998 and STABLE was deployed for 17 days during CD110 to measure near seabed turbulence. The Portuguese mooring is to be recovered in May 1998. Analysis of these data will commence early in the 2^{nd} year.

To analyse water masses, CTD data has been collected on all WP2 cruises this year, along with bottle samples for temperature/salinity calibration and other water properties such as nutrients, oxygen and sediment concentrations. CTD stations have been made in a grid of cross slope sections between 41.25N-43N, with stations located 10km apart. Stations are categorised in an order of importance and hence priority for occupation. Additionally, water samples for carbon and oxygen isotope analysis have been collected on two cruises - Belgica 97/14 (summer 1997) and Poseidon 237/1 (winter 1998).

CTD data collected on WP2 cruises in the first year have been quality controlled including the CD105, CD105 and Pelagia (1997) data sets.

Water mass characteristics for the region have been identified from archive CTD data from the whole NE Atlantic region in conjunction with work carried out for the WOCE experiment. Characterisation of the deep and intermediate water masses is completed and two manuscripts have been prepared. Classification of the thermocline level is ongoing. A salinity minimum centred at 500m depth west of the Iberian margin represents a water mass formed by winter convection to the north of the region. Analysis of the salinity maximum associated with MW shows the trapping of the high salinity water near the slope in the northern Iberian margin.

Spatial determination of turbulence and mixing using the FLY turbulence probe, has measured vertical profiles of current shear from which the turbulent dissipation and vertical turbulent diffusivity may be inferred using assumptions about the distribution of the turbulence in the water. Seven stations, consisting of between 5-15 individual profiles down to 300m depth, were made on the winter CD110b cruise, forming a 2-D section across the slope. High dissipation rates (0.1-1 m^2 s^{-1}) were found in the surface layer but it is unclear if these values are valid or if the measurements have been affected by outside processes like bubbles or ship wake effects. Lower values (0.0001-0.001 m^2 s^{-1}) were measured at the level of the thermocline, but values increased to 0.01 m^2 s^{-1} at a station close to the shelf break. Interestingly a suppression of the turbulent dissipation was observed at the near coast station where high riverine input generated a strong pycnocline. A summer deployment of the probe during the WP1 cruise is planned.

Modeling activities underpins all three tasks outlined above. During the first year the 3d hydrodyamical model used in OMEX I has been refined to focus on individual processes that occur at the Iberian margin, namely the slope current and upwelling filaments. Ultimately the model will be used to quantify fluxes through the OMEX box. Two experiments were performed to establish a slope current driven by the changes in density along the Iberian margin, including the effect of a front known to exist at 39.6°N and extending for a length of 100 km. A slope current was generated with similar characteristics to that previously measured. Volume transports, calculated at different latitudes, increased further north and were similar in magnitude to geostrophic estimates reported in the literature.

For the model run to generate filaments, an idealised bathymetry was used together with a horizontally uniform density field (to isolate the effect of the windstress). Wind stress imposed was climatological but simplified to allow realistic generation of an undercurrent coastal jet. Model results show the generation of filaments along the coast approximately 150km apart with a vertical extension in signature to 300m depth, consistent with spatial scales measured.

Work for the coming year will include significant validation exercises through comparison of archived current meter data with that generated by the model at same locations/timeframes and with realistic wind forcing. The 1D vertical turbulence closure model will be compared to turbulence data measured using the FLY probe.

Nutrients & Particulate Matter (Tasks 4, 5 & 6) Synthesis

Francisco G. Figueiras (Instituto de Investigaciones Marinas, Vigo, Spain)

Nutrient conditions in the recurrent poleward-flowing slope current during the winter (coined ‘Navidad’) were studied during cruise CD110-b. The ~150m deep mixed layer of subtropical warm and salty water carried by this surface flow - which occupied from the deep ocean to the middle shelf - was characterised by low nutrient concentrations. Nutrients increased sharply below the upper mixed layer, in accordance with the levels expected for the water masses in the area. The poleward flow confined the low-salinity continental waters outwelled from the Rías Baixas in the inner shelf, where surface nutrient concentrations were much higher than in surface ocean waters. Similar distributions

were also observed in total dissolved nitrogen TDN. Satellite imagery (RSDAS – ex NSS) supported the view from the hydrographic variables. 'Navidad' was clearly visible from the SST images, whereas the true-colour image from SeaWiFS shows the increased concentrations of suspended material in the inner shelf.

The available information of dissolved organic nitrogen (DON) concentration in the area was extensively studied. High concentrations of DON (up to 10 μM) were found in coastal areas associated to elevated chlorophyll concentrations. The positive correlation observed between DON and POC and PON, chlorophyll and primary production as well as the negative relationships between DON and DIN suggests that they can be used to estimate how DON evolves in surface waters during upwelling episodes.

Nutrient concentrations measured in deep waters during CD110-B and the apparent oxygen utilisation (AUO) calculated with data from the cruises BG9714 and CD110-B indicate that the nutrient end-member concentrations of deep and intermediate waters are not significantly different from those previously defined for the study area.

The Panorama methodology, developed during OMEX I project, has been applied to all historical AVHRR images for the study region. An algorithm for the detection of hydrographic features such as fronts, upwelling, filaments and eddies has also been implemented. As a result of all of this, weekly SST maps from 1993 to 1997 have been generated together with information concerning to averaged position and timing of fronts, upwelling, filaments and eddies, which are now used to assist in planning future cruises in the area. The SST maps are being used to derive algorithms in order to predict the distributions of nutrient concentrations in the area starting from historical and nutrient data obtained during the project.

Particle dynamics and fluxes in the Galician waters were studied during cruises CD105, CD110 and PE109 by means of the radionuclide ^{234}Th. In summer (CD 105), a gradual increase in particulate ^{234}Th activities existed from the slope to open waters, with no clear differences along the coast. The large scatter in particulate ^{234}Th activities that was found in shelf waters, probably due to the higher dynamism of these waters, preclude to infer any definitive conclusion about vertical particle flux in the shelf at this stage of the project. A higher variability in ^{234}Th activities was observed during the winter (CD 110) when compared with summer conditions. Sometimes deficit and equilibrium situations were found and higher levels of ^{234}Th activity were observed in shelf waters when compared with the summer values. The resuspension of shallow sediments caused by high winter mixing could be the reason for that. Moreover, in summer particulate ^{234}Th activities were associated to the thermocline, which was better developed in open waters than in the slope. Particle residence time, which is derived from the deficit in ^{234}Th activities, indicates that there was an increase in the residence time from 10 days in the slope to 30 days in the open ocean that could be caused by stratified conditions.

Preliminary results on bacteria biomass during the winter cruise CD110-B revealed small cell volumes and low total bacterial numbers with a decreasing trend in surface waters away from the coast and from North to South. There is also some evidence that bacteria in deep Mediterranean waters have a larger volume and a higher frequency of dividing cells than those from winter surface waters. During the spring (Poseidon 237/1) higher microzooplankton biomass was found at shelf stations than in open waters. The relatively high value of 6.8 mg C m^{-3} for this shelf waters suggests that the spring bloom had already begun, as indicated by the high chlorophyll concentrations and the high diatom abundance found at the same stations.

Dissolved organic carbon (DOC) distributions during winter cruise CD110-B, at the time of the poleward flow 'Navidad', showed that average DOC concentration was higher in shelf waters than in poleward domain. However, DOC content of poleward waters was significant higher than below This means that the poleward transport DOC from the subtropical Atlantic to the north along the Iberian Margin.

Experiments performed during cruise CD110-B showed that DOC production by phytoplankton was higher in shelf than in oceanic waters. A high rate of DOC released that accounted for up to 40-50%

of the total incorporated carbon by phytoplankton was found in oceanic and shelf waters too. Nevertheless, sharp variations were detected between stations with some places where DOC released did not reached 10% of the total carbon fixation.

Production and Remote Sensing (Tasks 7, 8 and 12) Synthesis

Ian Joint (CCMS Plymouth Marine Laboratory, UK)

The aim of this component of OMEX II is to quantify phytoplankton production and to determine how much of that production results from the utilisation of nitrate (new production) rather than ammonium or organic nitrogen compounds (regenerated production). Since the annual flux of nitrate into the euphotic zone is largely balanced by sedimentation of organic nitrogen into deep water, new production also gives an indication of the quantity of carbon which may be transported from the euphotic layer into deeper water (since the C:N ratio of planktonic and organic matter is relatively constant). Therefore, the aims of the groups studying phytoplankton and new production are to quantify on a seasonal basis the rates of primary production and the utilisation of nitrate, ammonium, urea and phosphate. Hence, the amount of carbon which is fixed by phytoplankton will be known and will be compared with the carbon requirements of the heterotrophic community; in addition, the new production estimates will indicate how much of the carbon which is fixed by phytoplankton might sediment into deep water. These estimates of carbon and nitrogen flux through the phytoplankton will complement and contrast with measurements on seasonal and regional variations in the partial pressure of CO_2 and with estimates of flux of CO_2 across the air-sea interface. The use of satellite remote sensing allows all the measurements made at sea to be placed in larger spatial and temporal scales.

Progress has been good in achieving these aims. Primary and new production have been measured by *in situ* or on-deck incubations on 3 cruises: Charles Darwin CD105 and Belgica 97/14 in June 1997 and Poseidon 237 in February/March. In addition, both IIM and ULB-b have measured photosynthesis-irradiance (P-E) relationships on Belgica 97/14, and IIM on CD110-B; estimates of primary production can be modelled if the P-E characteristics of a phytoplankton assemblage are known. In both June and March, the smallest phytoplankton (picoplankton <2µm) were found to contribute most to the primary production rate and the rates were comparable in the two cruises. However, significant differences in the P-E characteristics were found, with high values in summer for the maximum chlorophyll-specific, carbon fixation rate (P^B_m) and light saturation parameter (E_k); the phytoplankton from 60-70m were adapted to low light and had low values of E_k. In contrast, winter populations were adapted to low light in summer but showed no photoinhibition at high light, indicating that the adaptation was a consequence of the well-mixed water column in winter.

New production was found to be low in June with little utilisation of nitrate giving low F-ratios of 0.05 to 0.5. Nitrate concentrations in the surface mixed layer were low and phytoplankton growth depended on regenerated nitrogen. Up to 78% of the nitrogen requirement of the phytoplankton was met by the utilisation of urea. Kinetic experiments showed that the maximum uptake rates of nitrate and ammonium co-varied but that phytoplankton was more efficient at utilising ammonium in this nitrogen limited environment. Data on nitrate and ammonium assimilation in February/March are not yet available but very low nitrate concentrations were found throughout the shelf region as a result of the poleward 'Navidad' slope current bringing warm water from the south of the region; F-ratios are again expected to be low.

Phytoplankton has an effect on the partial pressure of CO_2, which is reduced as a result of photosynthesis. However, other processes influence pCO_2. In June, the distribution of pCO_2 was very heterogeneous with strong undersaturation in those regions where phytoplankton was most active. The spatial distribution was complex because oversaturation was observed in upwelling waters; furthermore, the transition from oversaturated to undersaturated waters occurred over a few days as a consequence of phytoplankton photosynthesis. In winter, pCO_2 was controlled by water cooling and

by vertical mixing and there was a significant influence of the freshwater input from the rias. Measurements have been made to determine the atmospheric exchange of CO_2; the method exploits differences in $^{13}C/^{12}C$ ratio in the ocean and atmosphere, since there is a decrease of $\delta^{13}C$ in the atmosphere. Samples for stable carbon isotope analysis have been taken on Belgica 97/14 in June 1997 and on Poseidon in March 1998. All $\delta^{13}C$ profiles show strong gradients in the upper part of the water column. Samples taken from 1500m on the Poseidon 237 cruise will be used to reconstruct the $\delta^{13}C$ anomaly due to anthropogenic invasion because anthropogenic effects on $\delta^{13}C$ are not yet seen in deep water.

All partners have benefited from the processing of remote sensing images by RSDAS. Real-time satellite images of sea surface temperature (SST) and chlorophyll concentration have been made available on the OMEX web page and are routinely transmitted to research ships to aid the OMEX scientists in their work at sea. There is now a vast archive of SST images available for the OMEX II region and the data have been assimilated into weekly and monthly SST maps. In addition, an algorithm developed for detecting oceanic fronts and weekly composite maps has proved to be a good basis for the statistical analysis of fronts, eddies and filaments. All these developments in remote sensing are providing valuable information to extend the spatial coverage of measurements made at sea.

Therefore, in this first year of OMEX II, good progress has been made in a wide front. Data are available on primary and new production, on nutrient assimilation rates, on pCO_2 distribution and on $\delta^{13}C$ vertical profiles, and remote sensing is proving to be an extremely valuable tool in the OMEX study of the Iberian shelf and shelf break.

Fate of Production (Tasks 9, 10 & 11) Synthesis

Avan N. Antia (Institut für Meereskunde, Kiel, Germany)

The fate of organic matter fixed photosynthetically in the euphotic zone plays a key role in the drawdown of atmospheric CO_2 and determining its fluxes is a central focus of the OMEX II-II project. Seasonally strong upwelling at the Iberian Margin and the accompanying nutrient enrichment of surface waters makes it a region of high productivity with strong spatial gradients in pelagic properties. Counteracting elevated productivity and thus the potential for CO_2 drawdown is the reversal of the ocean-atmosphere gradient in pCO_2 by upwelled waters over-saturated in CO_2, reaching the surface. Determination of the net effect of these antagonistic processes requires estimation of the main sources and sinks of carbon in the surface mixed layer on appropriate time and space scales.

The primary fate of phytoplankton is to be grazed within the euphotic zone, with a small though variable proportion of organic matter being exported below the mixed layer. Utilisation of organic matter is primarily by bacteria, micro- and macrozooplankton, all of which form the focus of investigations within Work Package 2. Grazing has differing effects on the fate of organic matter in dependence on grazer type; bacterial production contributes primarily to nutrient retention in the epipelagial, microzooplankton also rapidly recycle nutrients but additionally form a link to higher grazers through the microbial loop, whereas macrozooplankton can both remineralise nutrients and, through formation of rapidly sinking faecal material, contribute significantly to flux. Seasonal and spatial abundances and activities of zooplankton and bacteria can thus be expected to follow those in phytoplankton biomass and productivity. Seasonally, the imbalance between growth and grazing, such as during the spring bloom and possibly during strong upwelling (through a shift in species composition) makes autotrophic material available for export.

Gradients in the distribution of bacteria and microzooplankton during winter and spring show gradients in abundance and biomass with decreasing values further offshore. During Feb./March 1998,

a shift in the composition of the microzooplankton assemblage between shelf and outer slope is seen to be related to the community structure of their prey, indicating a functional response of the grazers to prey type. Additional seasonal resolution will be available within the next year. Experimental determination of the rates of bacterial respiration and DOC uptake and of microzooplankton herbivory will provide quantitative estimates of the impact of bacteria and protozoa on phytoplankton stocks.

A retrospective analysis of CPR data from routes at the Iberian Margin dating from 1958 highlights the significant relationship between copepod abundance and species composition and the degree of upwelling, based on monthly means of data. Spatial trends show concentration of zooplankton biomass around the shelf break for individual taxonomic groups. Continuous recordings of temperature, salinity and fluorescence from sensors now attached to the CPR are been obtained on each tow and these will be used to interpret the distribution of zooplankton in relation to water mass characteristics. Seasonal values of zooplankton biomass from net samples within the upper mixed layer will become available after sample analyses and these will be used in collaboration with SAHFOS to determine seasonal factors for the conversion of CPR counts to biomass using empirically derived length/weight to carbon values for the dominant taxa.

Estimation of zooplankton grazing rates will be determined on a summer cruise and through conversion of CPR-determined biomass using established biomass/ingestion parameters. A novel method of determination of appendicularian feeding rates and faecal production has been developed and work is underway to link these to environmental variables such as temperature, food concentration or body size. Identification of the faecal pellets of appendicularia and other dominant zooplankter and their enumeration in sediment trap samples will be conducted to estimate the seasonal role of zooplankton in export fluxes.

Most of the primary production grazed is respired within the surface mixed layer within which dissolved inorganic carbon can equilibrate with the atmosphere during deepest annual mixing, and thus does not contribute to net export. It is only that proportion of organic material that is exported below the depth of maximal mixing that is capable of sequestering carbon over climatically relevant time scales. A second focus in determining the fate of production thus concentrates on measurements of the flux of suspended and sinking particles on the mid and outer slope. Time-series measurements from sediment trap and *in situ* pump deployments will provide one of the 3 near-continuous recordings within OMEX and will be linked to the other time-series measurements within OMEX (CPR and remote sensing) to provide resolution over seasonal and upwelling cycles. Deployment and recovery of long-term moorings with sediment traps, in situ pumps and current meters have been successful, and samples covering the time period from July 1997 to March 1998 are currently being processed. Data and interpretation will be available in the second year of OMEX II-II. Expected source areas for particles collected by the traps will be determined and, using remote sensing, the degree of upwelling determined within these areas over the duration of trap deployment. Biochemical, isotopic and morphometric analyses conducted on the samples obtained by a number of OMEX partners will enable delineation of the seasonal fluxes of different elements.

Further progress will be made within the coming year in providing seasonal coverage of the biomass and activity of secondary producers during forthcoming OMEX cruises. These will be linked to seasonal productivity measurements and annual patterns of export flux, facilitating parameterisation for input into ecological models being developed within OMEX.