Work Package IV

Integrated Margin-Exchange Product

Executive Summary of Scientific Achievements

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Of the six scientific tasks of Work Package IV, tasks 4 to 6 only commence at month 13 or later and will be commented on only as regards prior modelling progress.

Task IV.1: Water budget and circulation

The only year-1 deliverables (month 9) are current meter statistics from historical data. For this, partner 7 (UCG) has collected over 40 current meter - years of "historical" pre-OMEX data in the region of north-west Iberia and statistics have been calculated. However, these will be augmented on receipt of more data, eg. from MORENA. The report of these statistics is expected shortly but has been slightly held up by delayed data acquisition.

Partner 8a (IH) has produced basic statistics at different time scales, and further analyses (dispersion diagrams for different bands of variability, spectra, coherences), for historical current meter data sets obtained by partner 8 (IH). These include data from (i) inner- shelf, mid-shelf and upper slope moorings off Oporto (41°05′N) for May-October 1987 accompanied by coastal wind measurements at Ferrel (39°55′N) and data from two hydrographic surveys (these data have been used in a study of low-frequency flow variability during the upwelling season) and (ii) SEFOS moorings in 900m and 2300m off S. Pedro de Muel (39°45′N), May 1994 - September 1996. Statistics being assembled will be sent to partner 29 (BODC) soon.
These statistics will feed into flux estimates (IV.2) and model validation.

Partner 17 (IfM) measurements of currents, temperature and salinity are available from five current meters deployed on the two sediment trap moorings near 42°39′N. The recording interval is 2 hours; the measurements span the period August 1997 to March 1998. CTD data are available from the Poseidon cruise at the Iberian margin (26 February to 16 March 1998) and have been submitted to partner 29 (BODC). Deliverables are on schedule.

Partner 5b (NIOZ) has assembled a historical set of hydrographic data with emphasis on the European ocean margin, specifically the area in 31° to 53°N and east of 21°W. These data sets comprise (i) CTD(O_2) data and (ii) hydro-chemistry data. Sets (ii) contain records of pressure, temperature, salinity, dissolved oxygen, phosphate, nitrate and silica. Hydrographic data from OMEX II cruises have been processed and quality control has been performed. Based on the historical data set the applicability of quasi-conservative nutrient tracers for multi-parameter water mass analysis has been evaluated. Preformed nitrate and phosphate gave more independent information than Broeckers "PO" and "NO" and are further used in the quantitative water mass analysis. Multi-parameter analysis of the deep and intermediate water masses in the north-eastern Atlantic Ocean has resulted in identification and description of the source water types which set up this water mass. Analysis of the central water in the permanent thermocline is ongoing.

The deep water mass in the Northeast Atlantic (NEADW) can be described adequately by a linear mixing model with four endpoints. Iceland-Scotland Overflow Water (ISOW) from the Iceland Basin, Labrador Sea Water (LSW), Mediterranean Sea Overflow Water (MSW), and Lower Deep Water (LDW) of Antarctic origin form the source water types. Analysis of bio-geochemical parameters supports a cyclonic re-circulation of ISOW and LDW in the mid-latitude eastern north Atlantic, as proposed by van Aken and Becker (1996). Re-circulation of ISOW and LSW in the NEADW core extends southwards from the Iceland Basin to the Madeira Abyssal Plain. A meridional oxygen trend observed in the near bottom LDW must be due to ageing during the flow of LDW to the north.

At intermediate levels over the southern Porcupine Abyssal Plain, sub-surface salinity minima appear to derive their water from winter convection in the Porcupine Sea Bight and northern Bay of Biscay. After formation in the Gulf of Cadiz, two MSW cores can be discriminated along the west Iberian ocean margin extending to the latitude of Cape Finisterre. Further from the source these separate cores decay and form a single MSW core, characterized by relatively low AOU and (preformed) nutrient concentrations.

Analysis of the North-East Atlantic Central Water (NEACW) in the permanent thermocline has just begun. Similarly to the water in the sub-surface salinity minimum, isopycnal analyses indicate that the thermocline waters off Galicia are formed in the northern Bay of Biscay, where they enter the permanent thermocline by subduction. This requires a southward transport mechanism in the eastern North Atlantic.

The hydrographic analyses performed hitherto all indicate an enhanced diapycnal mixing near the ocean margin in the Bay of Biscay at intermediate and deep levels. This boundary mixing is probably driven by breaking internal waves of tidal origin. Off the west Iberian margin enhanced diapycnal mixing is less evident, possibly masked by a more complicated hydrographic structure. Enhanced knowledge of the internal wave statistics and turbulent regime as planned in WPI, II may clarify this.

Reference

Van Aken, H.M. and G. Becker (1996) Hydrography and through-flow in the north-eastern North Atlantic Ocean: the NANSEN project. Progress in Oceanography, 38, 297-346.

Task IV.2: Carbon sources, cycling and fates

The year-1 deliverables are intercalibrations (month 6) and conclusions about practical applications of techniques (month 12). These are subsumed in the intercalibrations listed in task IV.3. Nevertheless, many measurements have been made on WPII and WPIII cruises that will eventually contribute to this unifying task. Some examples follow; more detail may be found in the WPII and WPIII reports.

Partner 13 (IIM) made measurements on cruises BG9714 and CD110B and Partner 1b (ULB-b) on BG9714, to establish a Primary Production – Irradiance relationship. Earlier IIM data in the area have been processed and banked at IIM. Parter 13 (IIM) also collected samples for phytoplankton determinations during these two cruises. Earlier phytoplankton data for the area are available from IIM.

Partner 17 (IfM) successfully recovered the two sediment trap moorings in March 1998; 100 trap samples are currently being processed. Progress in task IV.2 will be made once flux data are available.

Partner 8b (IH) has obtained preliminary results on POC in the water column (especially in nepheloid layers, from a cruise in November 1996 between 41° and 42°N) allowing estimation of carbon sources for the continental shelf and upper slope of the Portuguese margin. POC in SPM has the following patterns:

- its proportion is inverse to SPM concentration
- the POC fraction ranged from 3% to 29% in surface waters, being generally higher in the northern part of the area and further offshore, less in the middle and inner shelf to the south
- values were between 3% and 12% in the bottom nepheloid layer on the shelf
- over the outer shelf and upper slope (depth > 200 m) POC values range from 13% to 19% of total SPM and do not differ between surface and deeper layers.

Task IV.3: Nutrients, trophodynamics and fertility

Nutrients (Partners 4c, 1b, 13; PML-c, ULB-b and IIM)
Two nutrient intercalibration exercises have taken place. The first intercalibration took place in June 1997 and the data have been fully worked up. The second was in January 1998; some data are still preliminary and will be worked up in the coming months.

June 1997
During the OMEX II cruise on *RRS Charles Darwin* (CD105), water samples were taken at three stations in water depths of 90m, 200m and 2250m and distributed to partners 4c, 1b, 23 and 13 (PML-c, ULB-b, VUB, IIM). The depths sampled were 10, 20, 30, 40, 50 and 70m at station S90 (90m water depth), 10, 20, 40, 60, 80, 100, 120, 200m at station S200 and 10, 20, 50, 100, 200, 500, 750, 1000, 1250 and 1500m at station S2250. The water samples were filtered and frozen for subsequent analysis by partners 4c, 1b, 23, 13 (PML-c, ULB-b, VUB, IIM). In addition, partner 4c (PML-c) analysed another replicate set of samples immediately, *i.e.* without freezing and storage.

A second intercalibration exercise was done when the *RRS Charles Darwin* and the *RV Belgica* met on 20 June 1997. In this case, CTD casts were done by each ship and water samples were taken from 12 depths. Replicate samples were exchanged between the two ships and either analysed immediately or stored frozen for subsequent analysis.

Excellent agreement was found between the nitrate measurements made by partner 4c (PML-c) on unfrozen samples and by partner 13 (IIM) on frozen and stored samples. The comparison of phosphate determinations is slightly more variable but still shows good agreement between the two determinations; there is some divergence in the measurements at highest concentrations.

The silicate analyses showed the value of intercalibration exercises. When analyses at sea were first compared, the PML-c values were significantly less than the IIM values. When the PML-c frozen samples were analysed, an error was discovered in the calculations at sea and the PML-c values have now been corrected. However, there continue to be differences between silicate in fresh and frozen samples.

A regression of the nitrate concentrations determined by the two laboratories shows almost perfect agreement with a slope of 1.04 for the fitted line, an intercept of zero and an R^2 value of 1.00. The phosphate intercalibration is also good with R^2 of 0.85. However, the slope is no longer unity and the IIM estimates are higher than those of the PML-c. The R^2 value for the silicate determinations suggests that the precision of both laboratories is good – the regressions yield a straight line with R^2 value of 0.98 – but there is a problem with accuracy; that is, the relative changes in silicate concentration are well described by both laboratories but there is doubt about the absolute value of silicate concentration, with the PML-c consistently measuring lower concentrations than the IIM. The analysis of ammonium shows wide variations and IIM estimates higher than PML-c estimates; both precision and accuracy are suspect. This may be a consequence of storage of samples or of contamination on board ship, which is a recognised problem in ammonium determinations.

Comparison of phosphate and silicate concentrations measured by partners 4c, 1b, 13 (PML-c, ULB-b and IIM)
The second intercalibration involved exchange of samples between the two ships. All data have now been worked up. An intercomparison of phosphate determination shows excellent agreement between the measurements made by the ULB-b and the PML-c. The slope of the fitted line is 1.09, the intercept is –0.01 and R^2 is 0.99. That is, precision and accuracy are both excellent in these measurements. The silicate data also show a perfect linear trend with R^2 value of 1.00. However, as with the intercalibration of the PML-c and the IIM, the slope is not unity and the PML-c estimates are consistently below those obtained by ULB-b. It is clear that the PML-c standard silicate solution was not correct.

January 1998

The data from the intercalibration exercise in January 1998 have not all been analysed. However, a comparison of nitrate measured by partner 13 (IIM) on the cruise and by partner 4c (PML-c) on frozen samples again gave good precision, but the slope of the fitted line is 1.10. The PML analysis of frozen samples is giving higher values than the IIM analysis of fresh samples. In fact, although the PML-c values at high nitrate concentrations are higher than those of IIM, in the near surface water, IIM find nitrate concentrations of 1.2µmol l^{-1} and the PML-c analysis is 0.23µmol l^{-1}. This requires further investigation and any discrepancies may be obvious when the ULB-b and VUB data are analysed.

Conclusions

Both intercalibration exercises in OMEX II found excellent agreement in nitrate determinations made by the PML and the IIM; phosphate and silicate determinations are also good. There appear to be no problems in precision of any of the determinations but accuracy could be improved. The ammonium determinations show wide variation between the PML-c and the IIM and will require further analysis at sea on fresh samples to resolve the observed differences.

DOC Methods Intercalibration

A revised manuscript: “Simultaneous determination of dissolved organic carbon and total dissolved nitrogen in sea water by high temperature catalytic oxidation: conditions for precise shipboard measurements”, by Xosé A. Álvarez-Salgado & Axel E.J. Miller (partners 13 & 4a; IIM & PML-a), has been accepted by *Marine Chemistry* for publication. This details work carried out by the authors during the period of OMEX I; as a result, much valuable collaboration and common experience in the analytical methodologies will be employed during OMEX II-II.

Both partners 4a (PML-a) and 13 (IIM) are part of an on-going international DOC intercomparison programme, organised by Jonathan Sharp (Univ. Delaware) and Dennis Hansell (Bermuda BSR). This programme collects and circulates ampoules of deep Sargasso sea water, of known DOC concentration, to all registered members of the international community, with formal analytical and reporting protocols. This is an extremely important move towards wide-scale analytical consistency, and will be included at all stages of the OMEX DOC measurement programmes.

Xosé A. Álvarez-Salgado (partner 13; IIM) has collected samples from two shallow profiles (a total of 9 samples) in the Ria de Vigo, during September, 1997. Replicates of these samples have been passed to partner 4a (PML-a; and to partner 1b - ULB-b - for opportunistic participation in the intercalibration exercise), for subsequent analysis. Results from this exercise are not yet available.

Representatives from partners 4a and 13 (PML-a, IIM) both participated in the Charles Darwin cruise CD110-LegB, 6th-19th January, 1998. This provided another opportunity for collection of samples for intercalibration. Samples were analysed on-board and in the laboratory (PML-a), and preserved aliquots will subsequently be analysed in the home laboratories of partners 4a and 13 (PML-a, IIM) with further opportunity for participation by partner 1b (ULB-b).

The combined results from these activities will result in repeatedly intercalibrated methodologies, producing data sets from WP1 and WP2.

Pigments and primary production

With respect to investigating the vertical profiles of chemotaxonomic chlorophyll and carotenoid pigment biomarkers of phytobiomass and degradation fates, samples from two CTDs were collected for the determination of chlorophyll during the CD105 intercalibration exercise with Belgica. Sample analysis is complete with quality control currently being undertaken before data are banked.

Due to the time constraint, it was not possible to conduct an intercalibration exercise on primary and new production between partners 1b/4c (ULB-b/PML-c) and partners 23/4c (VUB/PML-c) when the *Belgica* and RRS *Charles Darwin* met in June 97. However, partner 13 (IIM) participated in the Belgica 97/14 cruise. Primary production measurements were performed at certain stations by partners

1b (ULB-b) and 13 (IIM) using different methodologies; the results can be compared for intercalibration purposes.

Partner 13 (IIM) has analysed chlorophyll samples from BG97/14 and CD110B. Partner 1b (ULB-b) collected chlorophyll *a* samples in the upper 150-200m of the water column during BG9714 cruise. These samples have been analysed and data banked at BODC (ULB-b). Chlorophyll *a* samples collected by partner 1b (ULB-b) during CD110B are being analysed. Partner 4a (PML-a) has obtained samples to analyse for pigment biomarkers from three WPII cruises to date: CD105 (June 1997), CD110 (January 1998) and Poseidon (February-March 1998). For spatial and temporal distribution of phytoplankton biomass, species, pigments and their remote sensing, samples have been collected from the same three cruises. Analysis of chlorophyll and carotenoid pigments in samples from CD105 by high resolution HPLC has been completed; data have been quality controlled and banked with BODC. Analysis of samples from CD110 and Poseidon cruises is presently underway.

Otherwise, these determinations have not been intercalibrated; this must await a WP I cruise, the first of which is now planned for August 1998 and was the subject of extensive discussion at WPI workshops (Paris, November 1997; Lisbon, April 1998).

Nutrient uptake, nutrient regeneration and grazing methodology
These determinations similarly await a WPI cruise (August 1998) where rate process studies will be emphasised.

Conclusion
Maximum advantage has been taken of cruise opportunities to date, but several intercomparisons await the opportunity of the WPI cruise in August 1998 (RRS *Charles Darwin* 114).

Task IV.6: Integrated Margin Exchange Model

Partner 11 (IST) has continued model developments that will form a basis for the integrated model. The 3-D prognostic physics model has been used to investigate
- processes related to slope current generation and structure
- filament structure and dependence on wind stress variability
- parameterisation of turbulence: investigation of the seasonal cycle of vertical structure has shown an error in heat fluxes leading to consistent excessive warming in the upper ocean; a correction technique using observed surface temperature produces more accurate results for temperature and turbulence parameters
- tidally induced circulation.

One-way nesting has been implemented, information passing only from the larger-scale to the finer-resolution model. In a test, the nested area had 30 x 30 grid cells, the linear reduction factor in grid size being 1/3. This nesting is available for partner 18 (SINTEF) to couple with a biochemical model.
Coupling between hydrodynamics and biochemical models has also been investigated, implementing a biochemical module. The model uses a trophic structure approach; energy flows from autotrophic to heterotrophic producers. State variables are nitrogen (ammonia, nitrate, nitrite; refractory and non-refractory DON, PON), primary and secondary production. Equations are described in Miranda (1998). A prototype of the hydrodynamics-biochemical interface has been developed. The biochemical model is "zero-dimensional"; each property knows only the values of the local controlling state variables. A specific module updates the state variables, using hydrodynamical information from the circulation model, internal transformations from the biochemical model and fluxes across boundaries. Simulations have been carried out using both Eulerian and Lagrangian approaches to transport, with similar results.

Reference
Miranda R., 1998: Nitrogen biogeochemical cycle on the North Atlantic Ocean. M.Sc. Thesis, Instituto Superior Técnico, Lisboa.