Nutrients and organic matter distributions in the NW Iberian margin

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INTRODUCTION

It is well-known that the seasonal variability in the surface circulation within the OMEX box is governed by the large-scale climatology of the NE Atlantic. The contrasting dominance of downwelling-favourable southerly winds during the autumn-winter and upwelling-favourable northerly winds during the spring-summer (Wooster *et al.*, 1976; Fraga, 1981) is usually observed. The meso-scale variability of nutrients, phytoplankton and photosynthesis-irradiance (P-E) relationship under downwelling-favourable conditions were presented in the 1st annual report, after completion of cruises *BG9714C* (21 to 30 June 1997) and *CD110B* (5 to 16 January 1998).

During the 2nd year of OMEX II-II, IIM have participated in two upwelling-favourable summer cruises. **1**) The WP II cruise *BG9815C* (27 June to 7 July 1998), mapping phytoplankton and nutrients. **2**) The WP I cruise *CD114* (1 to 11 August 1998), following the short-time-scale variability of nutrients, dissolved and particulate organic matter, phytoplankton and (P-E) relationships during a Lagrangian experiment in the upwelling filament off Vigo.

METHODS

Nutrients

Analyses of nutrient salts (ammonium, nitrite, nitrate, phosphate and silicate) were performed on board during cruise *BG9815C*. Samples were directly drawn from the Niskin bottles into 50-ml polyethylene containers, and preserved at 4°C until subsequent analysis. During cruise *CD114A*, samples were filtered through Whatman polypropylene filters (0.45 µm) and collected into 50 ml polyethylene containers, They were preserved at –20°C until analysis in the base laboratory. Nutrients were determined colorimetrically with an 'Alpkem Corporation' auto-analyser (Perstorp Analytical, Wisonwille, USA), working under the principle of segmented flow analysis.

Dissolved organic matter

Samples were filtered through Whatman GF/F filters (ashed 450°C, 4 hours) in an all-glass filtration system. The filtrate was collected into 10-ml ampoules (ashed 450°C, 12 hours). After acidification with phosphoric acid to pH < 2, ampoules were heat-sealed and preserved in the dark at 4°C after analysis in the base laboratory. A Shimadzu TOC 5000 analyser was coupled in-series with an Antek 7020 chemiluminescence detector for the simultaneous determination of dissolved organic carbon (DOC) and total dissolved nitrogen (TDN). High temperature (680°C) catalytic (Al_2O_3 impregnated with 0.5% platinum) oxidation quantitatively produces CO_2 and NO• from DOC and TDN, respectively. CO_2 is determined with an NDIR gas analyser and NO• with an N-specific chemiluminescence reaction (Alvarez-Salgado and Miller, 1998).

Particulate organic matter

Samples were collected from the Niskin bottles in 2 litre polycarbonate flasks. They were immediately filtered with an oil-less vacuum filtration system (filtration pressure <0.3 kg cm^{-2}) to collect the particulate organic matter content in 25 ∅ mm Whatman GF/F filters (ashed 450 °C, 4 hours). The filters were dried on silica gel and frozen to -20ºC until analysis in the base laboratory. Measurements were carried out with a 'Perkin Elmer 2400 CHN' analyser.

RESULTS AND DISCUSSION

Task II.4.1 *Nutrient Oceanography*

During cruise *BG9815C*, a narrow band of cold upwelled ENAW along the Galician shelf (<15°) was observed in association with the dominant northerly winds. On the contrary, surface temperatures >17°C were recorded in the stratified waters of the adjacent ocean. During the upwelling cruise the salinity, temperature and nutrient distributions along the OMEX line P (Figure 1) clearly contrasted with the distributions observed during the downwelling cruise. Salinity and temperature allow us to identify three well-defined domains in the upper water column (<200 m). **1**) the cold (<15°C) and relatively mixed upwelled waters on the shelf. **2**) The warm (>17°C) and stratified surface waters (<40 m) of the adjacent ocean. **3**) The subsurface (50-100 m) high salinity core (>35.85 pss) of subtropical water which provokes the isotherms bowling observed at the slope stations. This high salinity core seems to be the remains of the massive poleward slope current observed during the winter, which acts as the compensation undercurrent of the NW Iberian upwelling system during the summer. This view is quite similar to the seasonal variability of surface current described in the upwelling of California and Oregon, at about the same latitude than the Iberian upwelling.

The contrast between cold upwelled waters over the shelf and warm stratified waters in the adjacent ocean affects surface nutrient distributions. They range from >1.0 to <0.1 $\mu mol \cdot kg^{-1}$ nitrate, >0.10 to <0.02 phosphate and >1.5 to <1.0 silicate. Therefore, whereas nitrate and phosphate are depleted in the stratified waters of the oceanic domain, silicates still maintains a relatively high concentration, probably above the threshold concentration to initiate diatoms division. Surface nutrients over the shelf increased from south (off the Ría de Vigo) to north (off Cape Finisterre), where 7 $\mu mol \cdot kg^{-1}$ nitrate, 0.5 phosphate and 3 silicate were recorded after strong upwelling.

Nutrients supplied from the continent to shelf surface waters are negligible (surface salinity >35.6 pss, <0.4% of freshwater) for the cases of nitrate (< 3.4%) and phosphate (< 0.9%) whereas it represents ~18% for the case of silicate. In any case, the upwelling of cold (<13 °C) and nutrient-rich (> 7 nitrate, >0.45 phosphate and > 2 silicate) ENAW is the main source of nutrients for the autotrophic populations on the shelf, with N/P and N/Si ratios of 16 and 3.5 respectively, indicating potential silicon limitation for a diatom population growing with a N/Si silification ratio of 1.

The distributions along the OMEX line P also shown nutrient enrichment of upwelled ENAW by mineralisation on the shelf, a well-described phenomenon in the NW Iberian margin (Alvarez-Salgado *et al.*, 1997). Mineralisation increases from north to south and mainly affects SiO_4H_4.

Task I.3 *Nutrient dynamics, primary production, biomass and phytoplankton*

Our main objective during cruise *CD114* was to evaluate the size and quality (C/N ratio) of the dissolved (<1 µm ∅) and particulate organic (<200 µm ∅) matter pools transported by the filament.

Figure 2a summarises all the relevant information regarding the organic carbon and nitrogen levels in ENAW upwelled over the shelf and the thermocline waters of the filament outwelled to the adjacent ocean. Three contrasting domains are defined: **1**) upwelled ENAW; **2**) thermocline waters (>15°C) of the coastal-start of the filament; and **3**) thermocline waters (>16°C) of the ocean-end of the filament. With these numbers in mind, the average TOC excess (ΔTOC) in the filament coastal-start represents 23.7 µMC (61% as DOC, 39% as POC), with a surprisingly low C/N molar ratio of 7.0, suggesting that the filament is transporting labile materials recently formed on the shelf (time scale of a few days). The average ΔTOC maintains 21.3 µMC (65% DOC, 35% POC) with a C/N molar ratio of 6.9, pointing to the persistence of the material formed on the shelf during transport to the ocean. It should be highlighted the dominant contribution of DOC to the organic carbon excess observed in thermocline waters (~2/3 of ΔTOC), which has to be considered in any assessment of carbon export mediated through filaments. In this sense, the horizontal export of primary production is mediated through DOC whereas the vertical export is mediated through sinking particles.

The DOM transported by the filament can be roughly partitioned into refractory, semi-labile and labile fractions (Figure 2b) under the following assumptions. **a**) Organic matter in ENAW is refractory and, it is not going to undergo any transformation (biological or photochemical) during upwelling to the surface and subsequent outwelling to the adjacent ocean. **b**) The POM accumulated in thermocline waters of the filament (C/N = 6.8) can be considered as labile materials. **c**) There is a significant correlation between POC and DOC changes in thermocline waters of the coastal start of the filament (*r* = +0.65). The correlation between PON and DON is good (*r* = +0.70) as well. We consider that the fraction of DOC, which covaries, with POC (slope 1.1±0.2) —and the fraction of DON which covaries with PON (slope 1.0±0.1)— contribute to the labile fraction. We obtained that the 81 µMC exported across the self-edge consist of **1**) 57 µMC of refractory DOC (70%, C/N ratio 19.0); **2**) 5 µMC of semi-labile DOC (6%, C/N ratio of 10.0); **3**) 10 µMC of labile DOC (12%, C/N ratio of 7.4) and; **4**) 9 µMC of labile POC (11%, C/N ratio of 6.8).

REFERENCES

Alvarez-Salgado X.A., Castro C.G., Pérez F.F., Fraga F. (1997). Nutrient mineralisation patterns in shelf waters of the western Iberian Upwelling. Cont. Shelf. Res. 17: 1247-1270

Alvarez-Salgado X.A., Miller A.E.J. (1998). Simultaneous determination of dissolved organic carbon and total dissolved nitrogen in seawater by high temperature catalytic oxidation: conditions for accurate shipboard measurements. Mar. Chem. 62: 325-333

Fraga F. (1981) Upwelling off the Galician coast, Northwest Spain. In: Richards F.A. (ed.) Coastal Upwelling, American Geophysical Union, pp 176-182

Wooster W.S., Bakun A., Mclain D.R. (1976) The seasonal upwelling cycle along the eastern boundary of the North Atlantic. J. Mar. Res. 34: 131-141

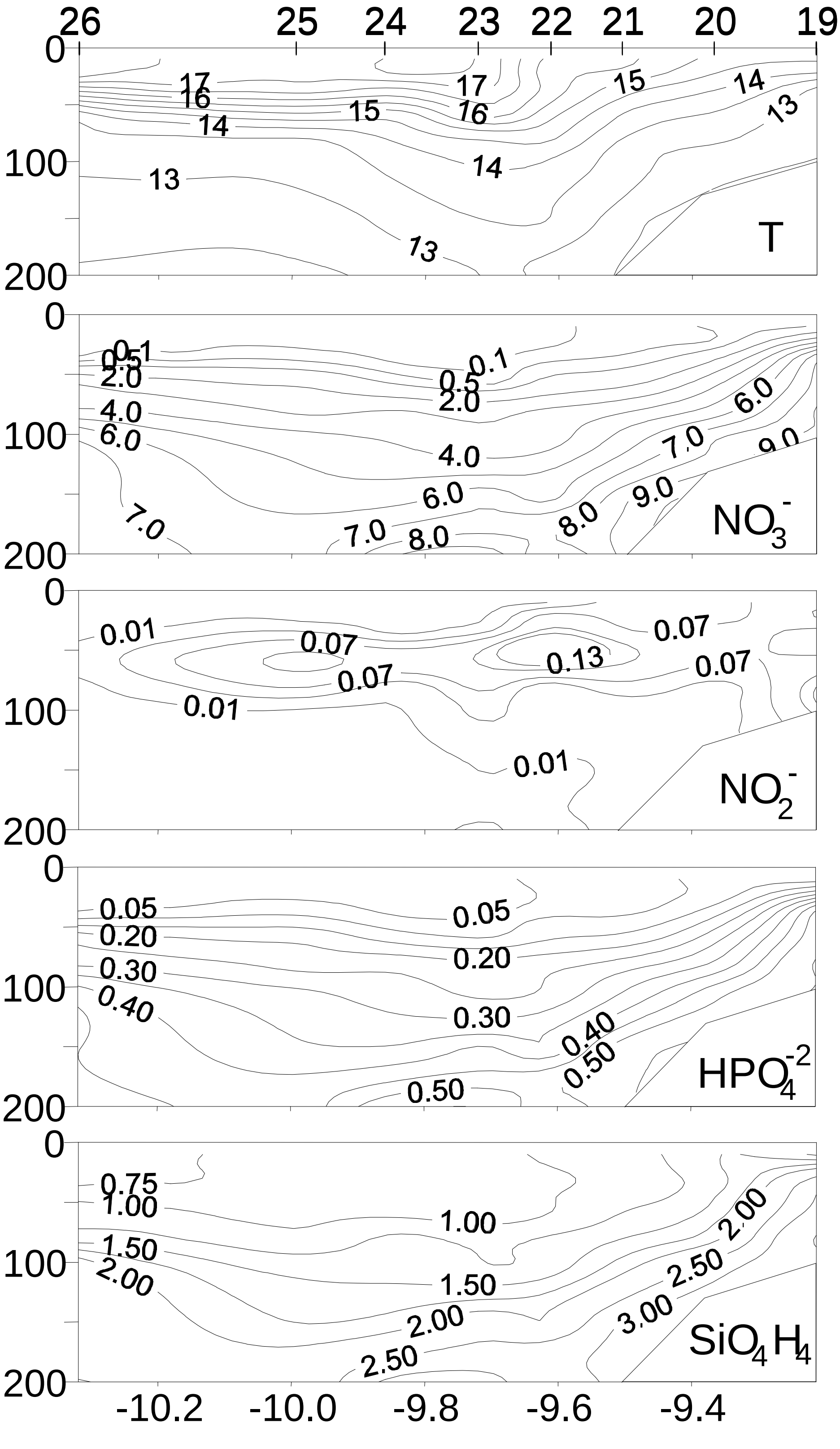
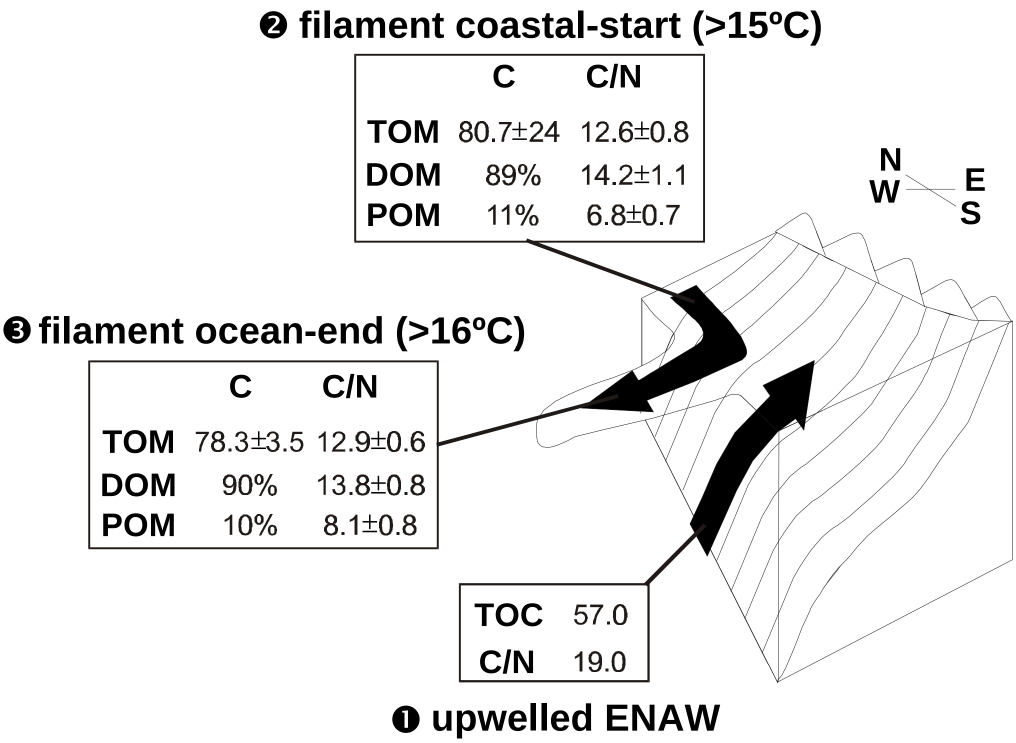
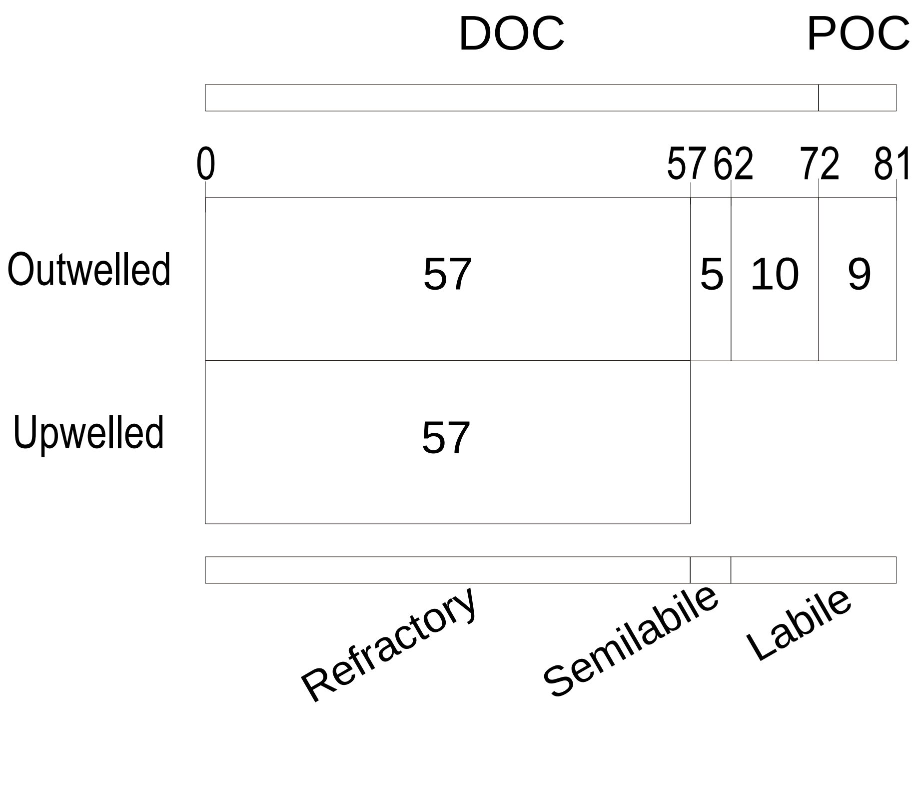


Figure 1. Distributions of temperatute (°C), nitrate, nitrite, phosphate and silicate (µmol kg^{-1}) in the upper 200 m along the OMEX line P during the WP II summer cruise *BG9815C*.



(a)



(b)

Figure 2. Particulate and dissolved organic carbon and nitrogen stocks in upwelled ENAW, the coastal-start and the ocean-end of the filament (a); and tentative partition of refractory, labile and semi-labile organic matter in waters upwelled into and outwelled from the shelf (b).