Project DIAPICNA -DIAzotrophic PIco-Cyanobacteria in the North Atlantic open ocean: their abundance and importance as a source of new nitrogen at the Azores Front/Current

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[1]MIO, Aix-Marseille Université, France, [2]ANCH, Vrije Universiteit Brussel, Belgium, [3]DOP, Universidade dos Açores, Portugal, [3]Marinha Portuguesa, Portugal

virginie.riou@univ-amu.fr
Phone: +33-491041605

V. Riou[1], A. Roukaerts[2], D. Batista[1,2], A.E.M Piniella[2], S.R. Prakya[3], C. Loureiro[3], M. Santos[3], A. Medeiros[3], S. Gomes[3], Lt A.V. Alves[4], M. Elskens[2], I.C. Biegala[1], A. Martins[3], F. Dehairs[2]

The Azores Front/Current

The Azores Front (**AF**) separates the saltier warmer 18°C Mode Water to the South (from the Sargasso Sea), from colder and fresher northern waters. Water mass structure changes markedly between 35°W and 20°W (**NW-** to **SE-AF**), with the **18°MW not penetrating further East than 30°W** [(1)].

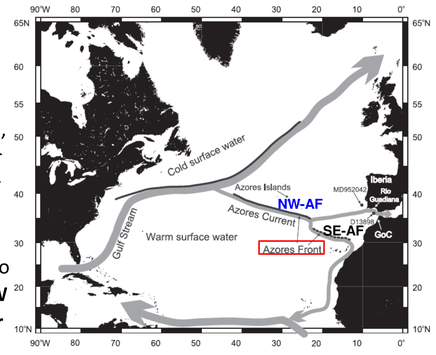


Figure 1: General surface circulation in the North Atlantic [(2)]

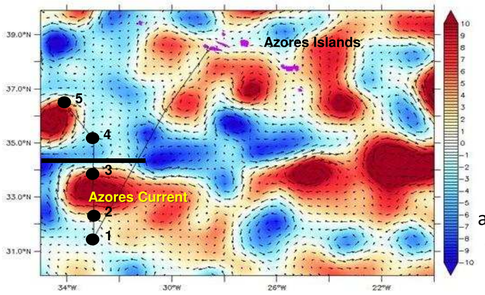
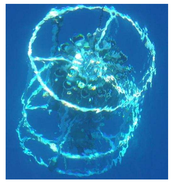


Figure 2: Sea surface height and geostrophic currents (AVISO) observed during the 2011 DIAPICNA cruise. Dots indicate the sampling stations.

The SW Azores area is one of **high mesoscale activity** and a possible source of eddies which may penetrate and influence the western basin of the North Atlantic (ridge topography) [(3)].

Oceanic N_2 fixation, currently mainly attributed to the activity of **Cyano-bacteria** (capable of fuelling such an energy expensive process), was estimated to account for up to **40 % of the CO_2 net export** from the surface waters to the deep ocean near the **SE-AF** (20-25°W) [(4)]. In this area, N_2 fixation was observed to be mostly performed by **<10µm** large particles [(5)]. Relatively abundant Group A diazotrophic unicellular cyanobacteria (UCYN-A) were detected in the North Atlantic subtropical gyre, up to the **NW-AF area** [(6)]. The **DIAPICNA** project intends to assess the extent of these UCYN abundance and of N_2 fixation in the **NW-AF area**.

Methods



DIAPICNA **sampling:**

5 stations

27/07-01/**08/2011**

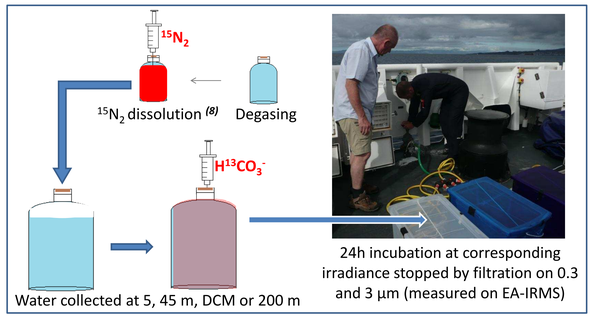
31.5°N-33.0°W to **36.2°N-33.9°W**

CTD - Nutrients concentrations

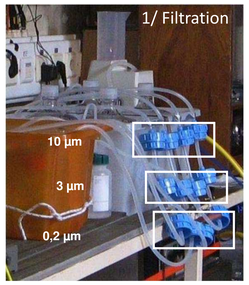
NO_3^- $\delta^{15}N$ and $\delta^{18}O$ analysis (denitrifier method [(7)])

Natural POC/PN concentrations, $\delta^{13}C$ and $\delta^{15}N$ signatures

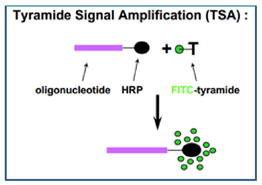
Tracer experiments to measure primary production and N_2 fixation



TSA-FISH with Nitro821 specific DNA probe [(9)] to count UCYN



2/ Hybridization



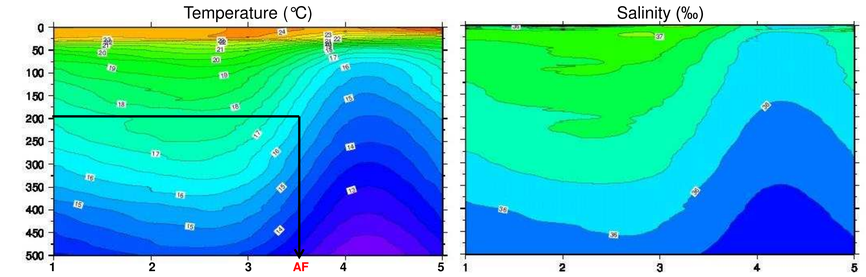
3/ DAPI general DNA labelling

4/ Eye microscopic counting

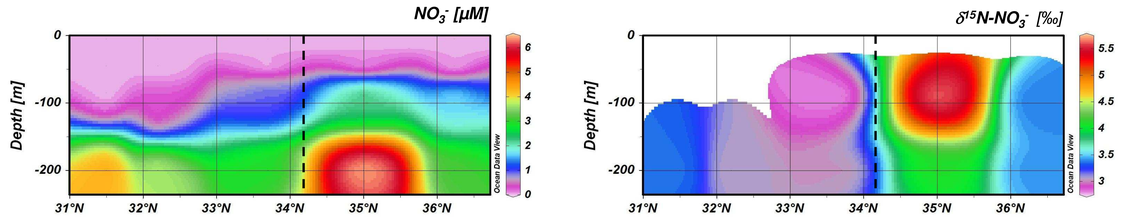
Results

The **Azores Front** was detected by the 16°C isotherm at 200m [(3)] between Stations 3 and 4 (Graph 1, left).

Geostrophic currents indicate that Station 5 was influenced by an **anticyclonic eddie** detached from the Azores Current (Fig. 2).



*Graph 1: **Temperature** and **salinity** depth profiles along the DIAPICNA transect (stations 1-5, AF = Azores Front)*



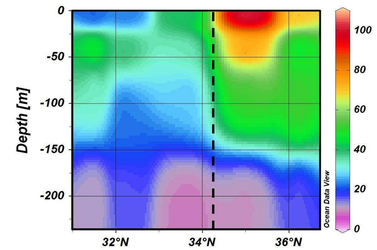
*Graph 2: **Nitrate concentration** and **$\delta^{15}N$ isotopic** profiles [(10)] for the first 200 m along the transect (black bar indicates the position of the Azores Front)*

Nutrient concentrations indicate an oligotrophic area with **nutrient bottom regeneration** at the North of the Azores Current Front (Station 4, 35°N, Graph 2, Left). Nitrate isotopes indicate **nitrate assimilation** at Station 4, while depleted signatures South of the Front might result from N_2 fixation (Graph 2, Right).

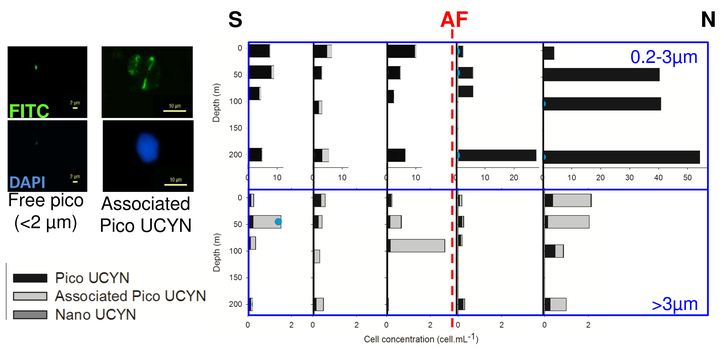
Total **primary production** in the euphotic zone (Graph 3) varied from **77** mg C/m²/d **South** of the **AF** to **131** mg C/m²/d in the **North**. It was particularly stimulated at Station 4.

Along the transect, the **>3 µm fraction** was responsible for 70% of the HCO_3^- uptake **above the DCM** (36-54% of total), while the **0.3-3.0 µm** fraction generally accounted for 53-69% of the total CO_2 fixation **200 m deep**, and at **Station 5**, for 57% within the DCM.

$^{15}N_2$ incorporation was detected mainly **in the DCM** in both particle size fractions, **on both sides** of the AF (except at Station 4), ranging from **1.8** ± 0.5 - **6.4** ± 1.7 **µmol N/m³/d**. **South** of the AF, **N_2 fixation** could also be detected at **5 m depth** in the **0.3-3.0 µm** fraction, and at **200 m depth** in the **>3µm** fraction. **North** of the AF, it was also observed in the **0.3-3.0 µm** fraction **5 m deep** at Station 5, and at Station 4, only at the 45 m depth.



*Graph 3: **Total primary production (µmol/m³/day)** measured from the $HC^{13}O_3^-$ incorporation in particles >0.3 µm*



*Graph 4: TSA-FISH **UCYN counts and observations***

DIAzotrophic **PI**co-**C**yanobacteria were detected at every depth of **all stations** (Graph 4). They were mainly found **free** (Graph 4, Left pictures) in the 0.2-3µm fraction, but also associated to inert or living particles (Graph 4, Right pictures: within a dinoflagellate).

Surprisingly, the highest counts of 25-50 cells/mL were recorded at the **North** of the Azores Front, 45-200 m deep, in cold oxygenated waters with temperatures ranging from 14.5-20.5°C and NO_3^- concentrations between 1-6 µM.

Conclusions

The marine N and global C cycles are closely linked by the primary production of the biological carbon pump, which can translocate atmospheric CO_2 to the deep sea, where it can be trapped for centuries [(11)]. In oligotrophic environments like the North Atlantic gyre, nitrate is often a limiting factor of this carbon sequestration [(12)]. The incorporation of atmospheric N_2 by diazotrophs is one of the main routes to compensate for this shortage [(13)], yet little is known about the importance of N_2-fixation to the primary production and carbon export.

The total primary production across the NW-AF measured from our incubations completely fits with the gross primary production estimated [(14)] in July-August 1997 in the same area. Our nitrate isotopic composition analyses show that, in addition to driving nutrient bottom regeneration stimulating primary production to the North, the NW-AF area is a place where N_2-fixation might be an important N source. $^{15}N_2$ incubations and specific UCYN counts support these observations, and further indicate that both the presence of pico-UCYN and N_2-fixation extend well below the surface and beyond the currently known physico-chemical limits set for such phenomena.

Mesoscale eddies detaching from the Azores Current following its interaction with the Mid-Atlantic Ridge may finally play an important role in modifying the abundance of pico-UCYN (Station 5) and associated rates of N_2 fixation as it was already suggested in the North Pacific [(15)].

Eurofleets Towards an Alliance of European Research Fleets

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