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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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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⁾.

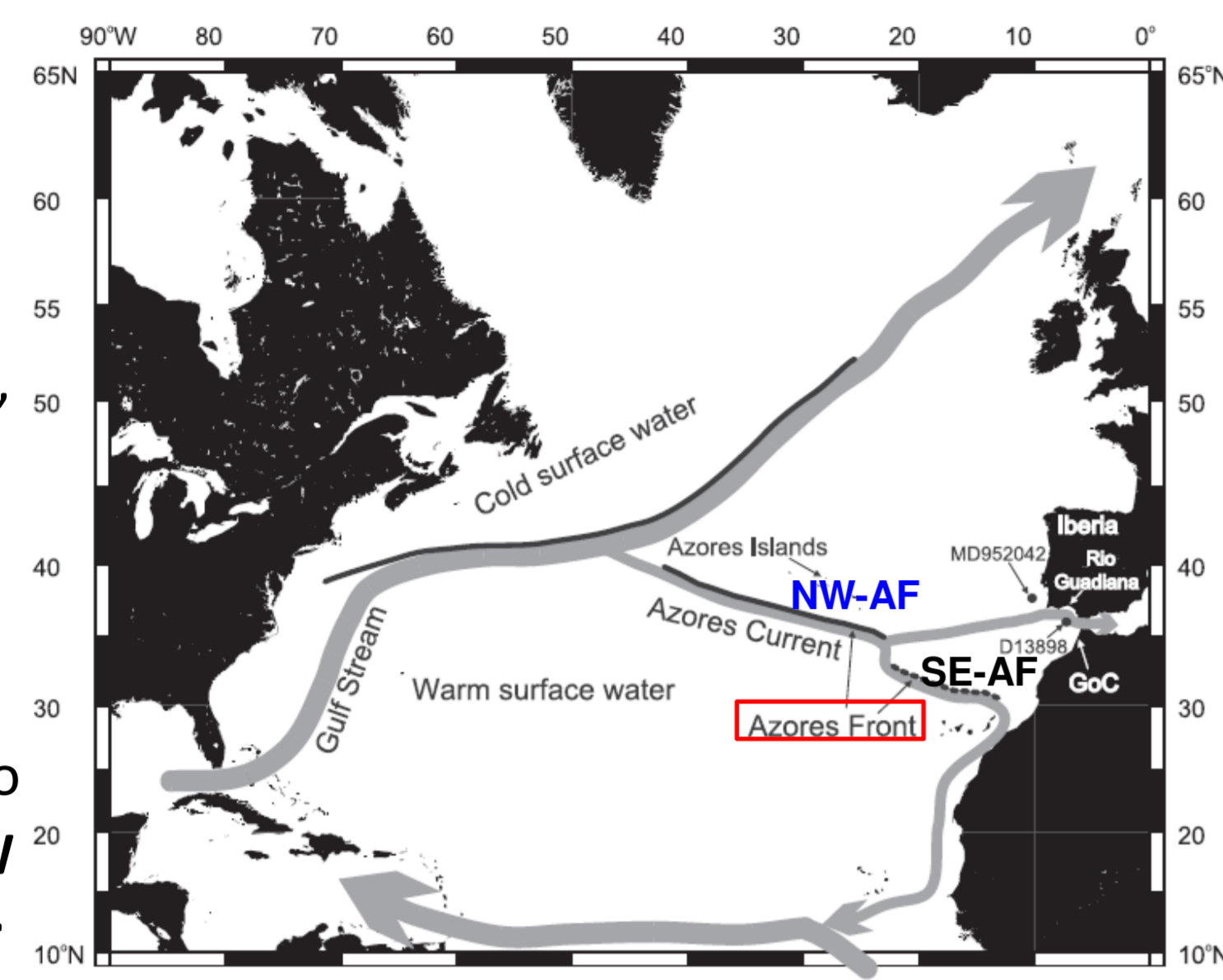


Figure 1: General surface circulation in the North Atlantic⁽²⁾

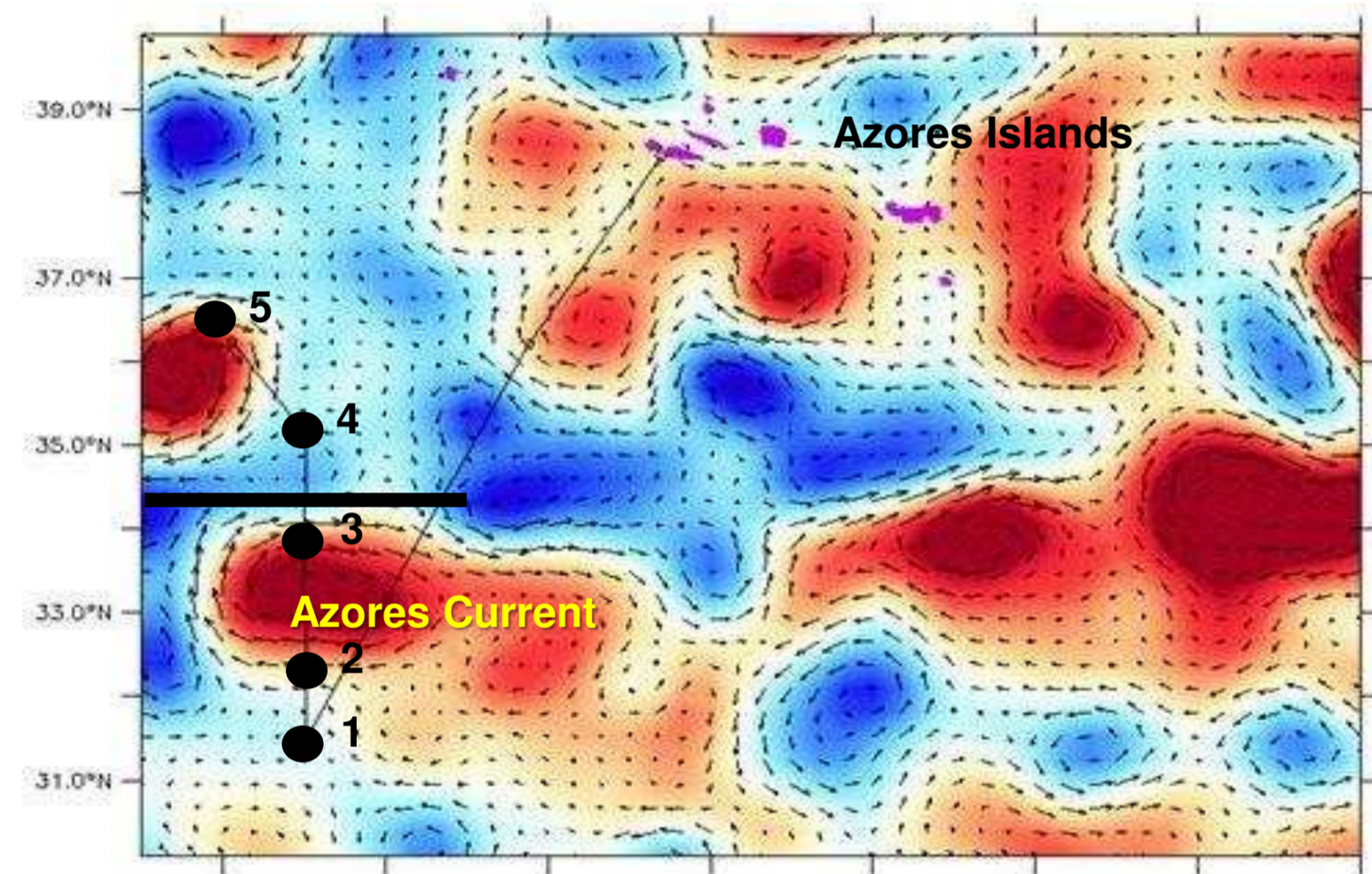
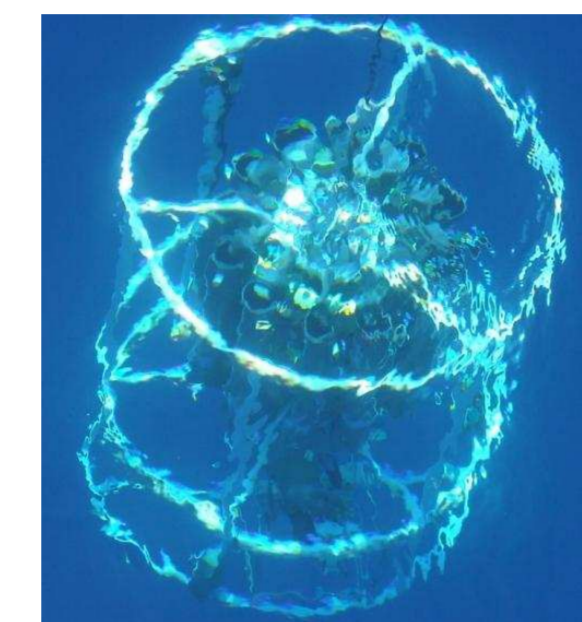


Figure 2: Sea surface height and geostrophic currents (AVISO) observed during the 2011 DIAPICNA cruise. Dots indicate the sampling stations.

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 N₂ 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 CO₂ net export** from the surface waters to the deep ocean near the SE-AF (20-25°W)⁽⁴⁾. In this area, N₂ 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 N₂ fixation in the NW-AF area.

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⁾.

Methods



DIAPICNA sampling:
5 stations
27/07-01/08/2011
31.5°N-33.0°W to 36.2°N-33.9°W

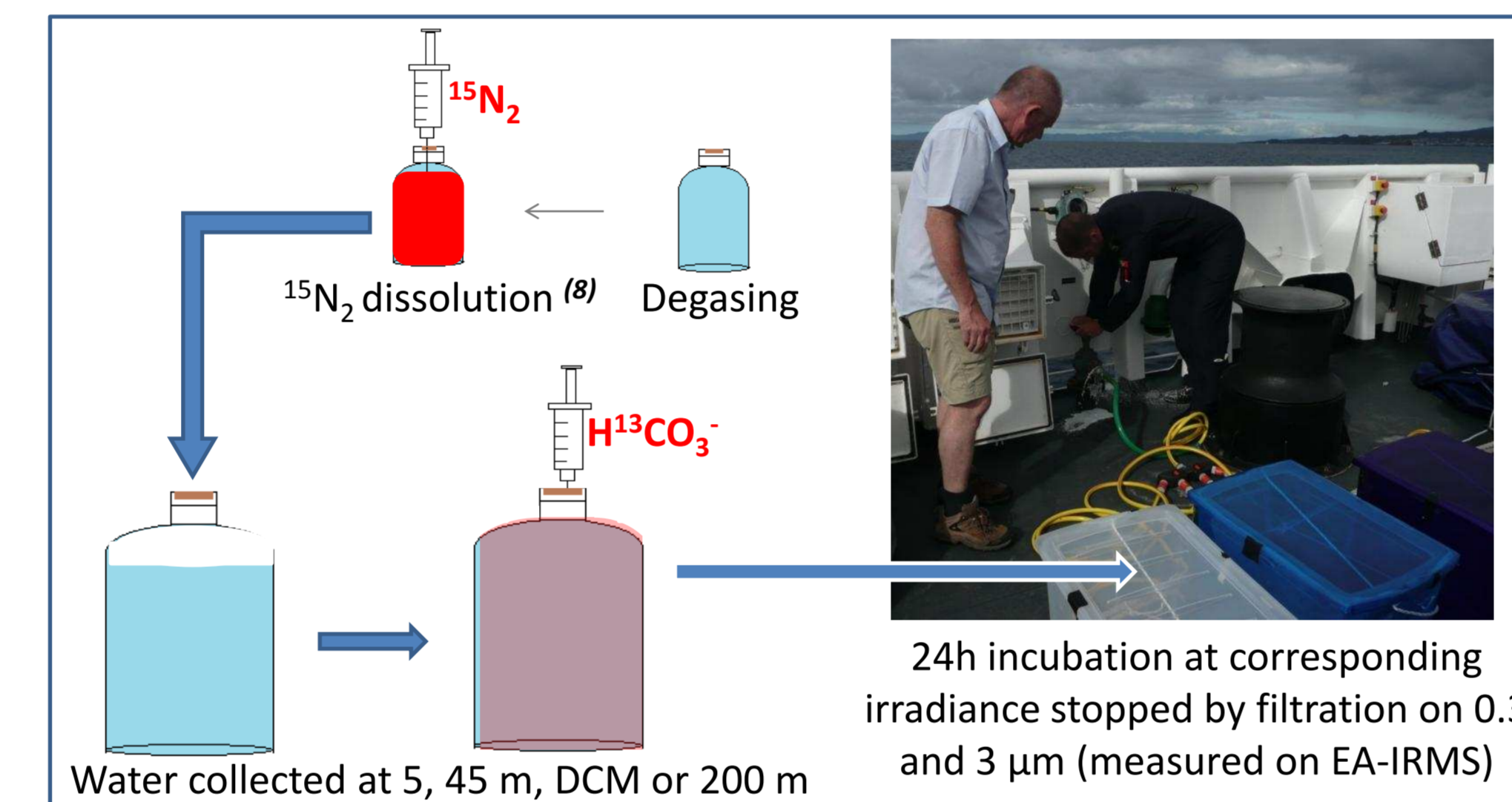


CTD - Nutrients concentrations

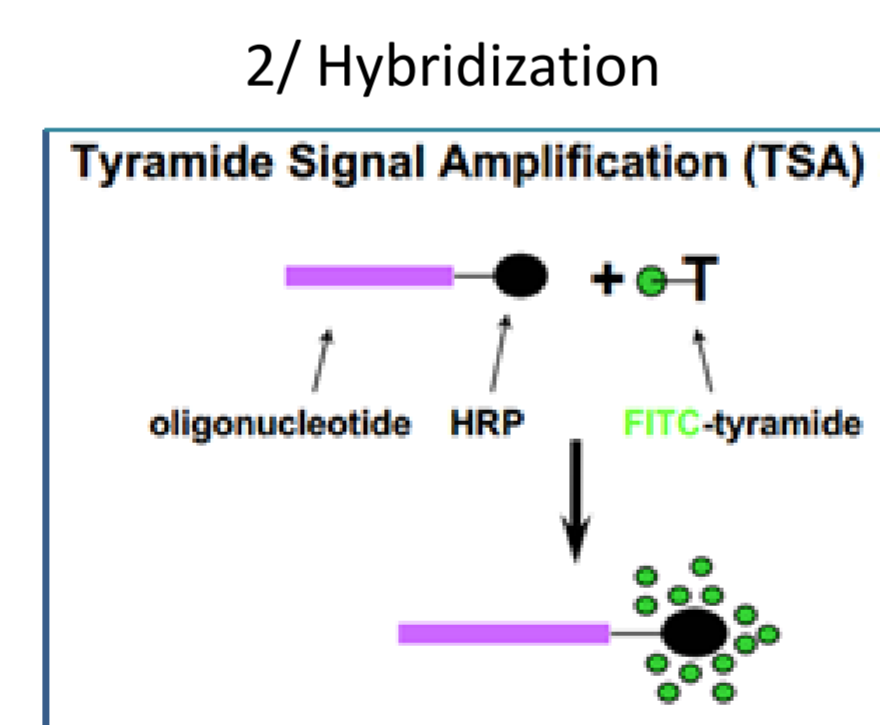
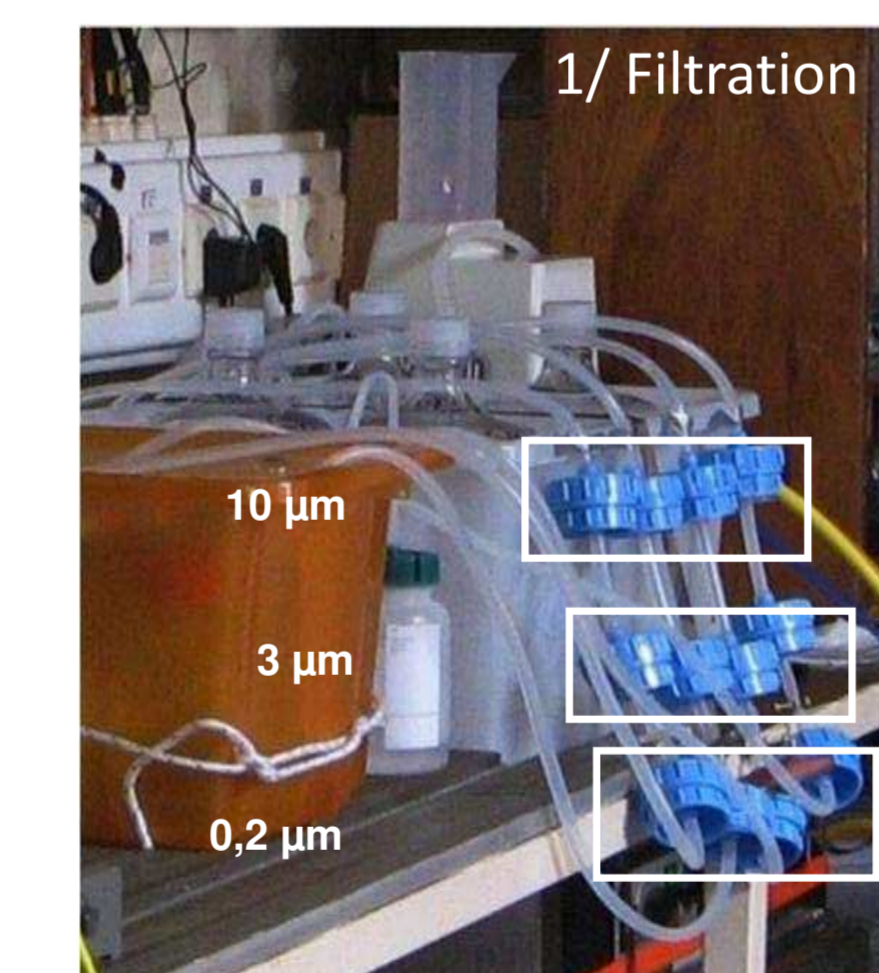
NO₃⁻ δ¹⁵N and δ¹⁸O analysis (denitrifier method⁽⁷⁾)

Natural POC/PN concentrations, δ¹³C and δ¹⁵N signatures

Tracer experiments to measure primary production and N₂ fixation



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



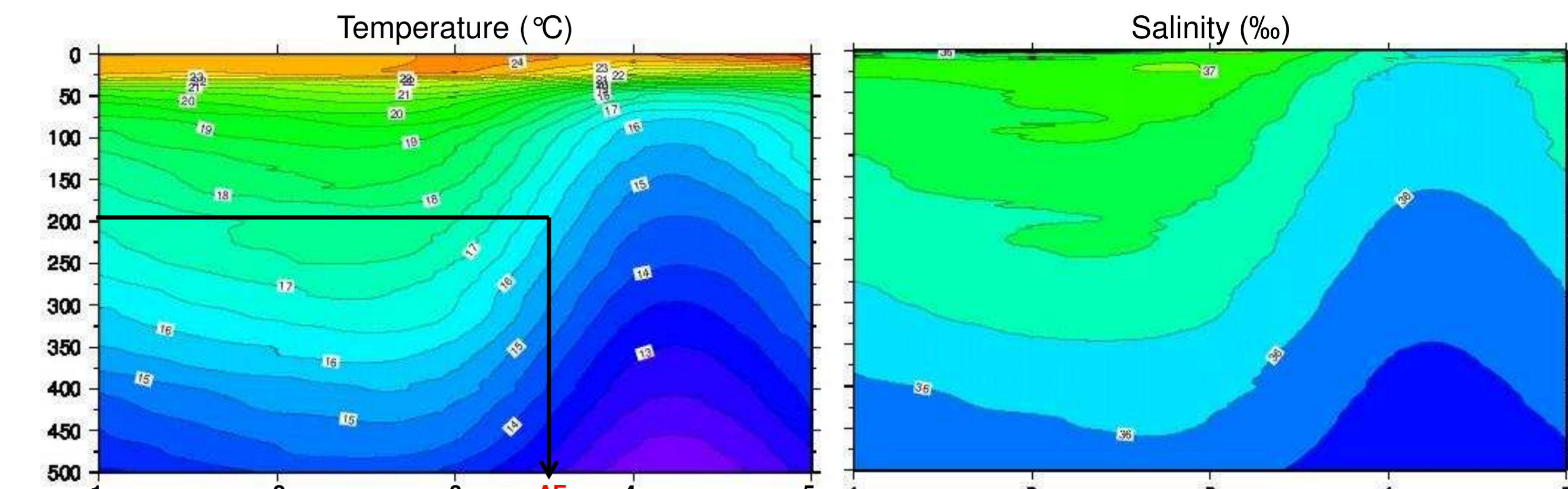
3/ DAPI general DNA labelling

4/ Eye microscopic counting

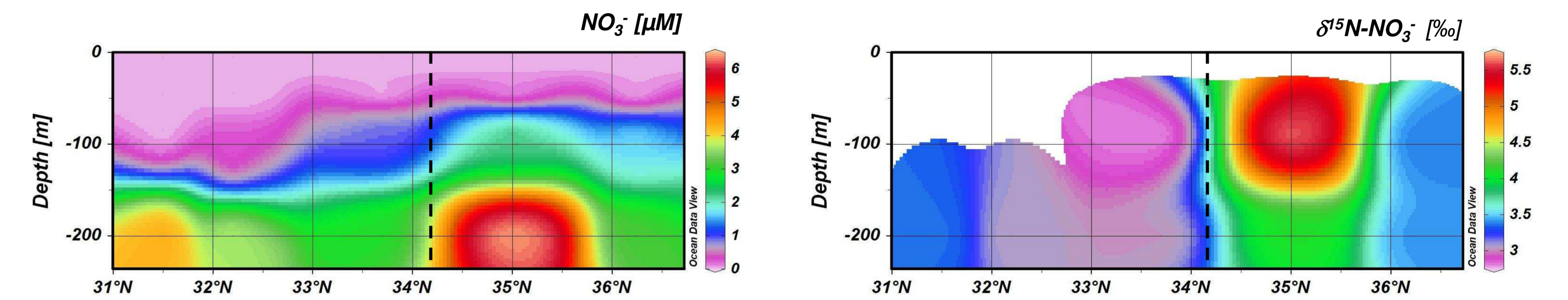
Results

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)



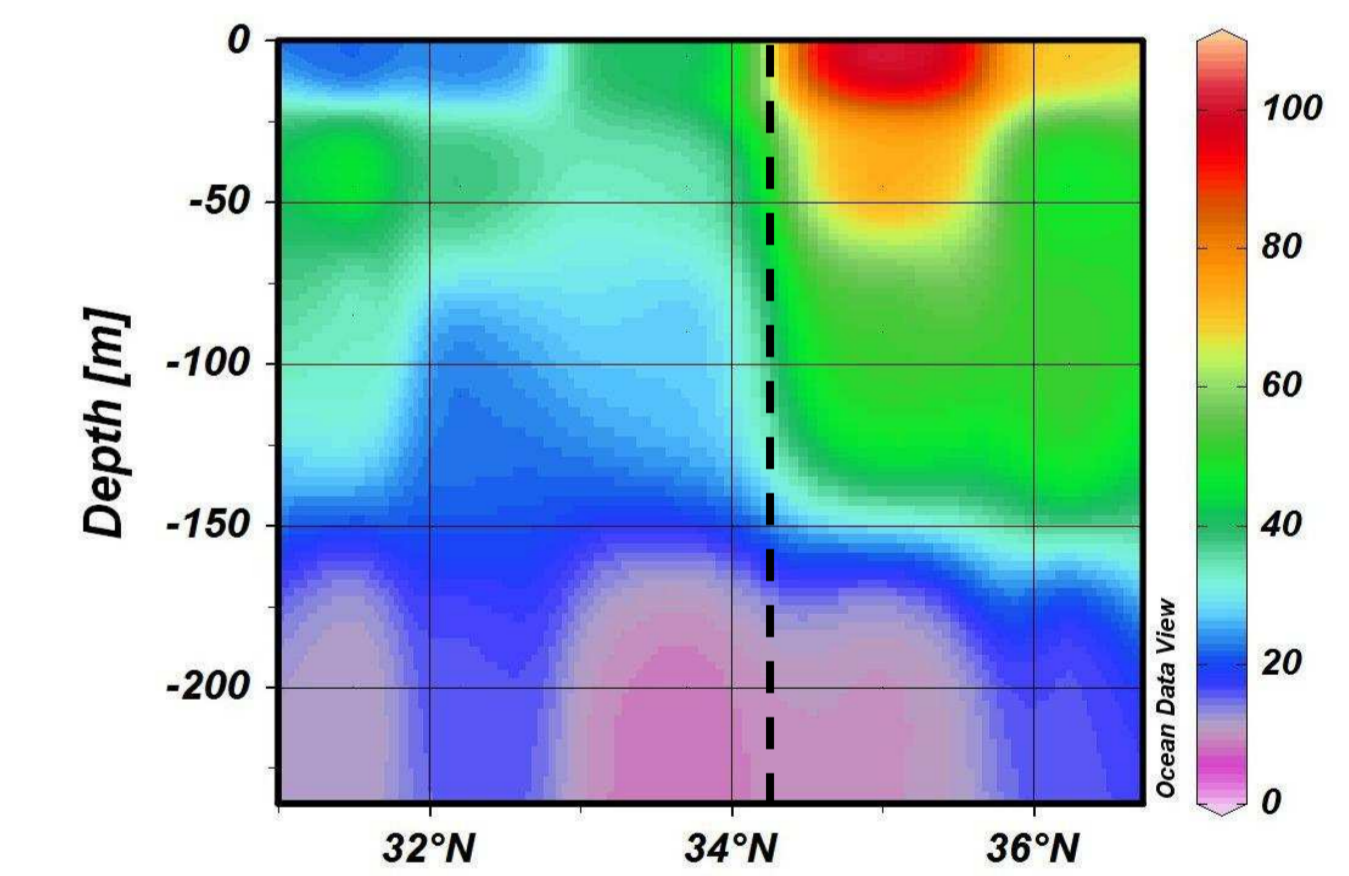
Graph 2: Nitrate concentration and δ¹⁵N isotopic profiles⁽¹⁰⁾ for the first 200 m along the transect (black bar indicates the position of the Azores Front)

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 N₂ 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 HCO₃⁻ uptake **above the DCM** (36-54% of total), while the **0.3-3.0 µm fraction** generally accounted for 53-69% of the total CO₂ fixation **200 m deep**, and at **Station 5**, for 57% within the DCM.

¹⁵N₂ 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**, N₂ 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.



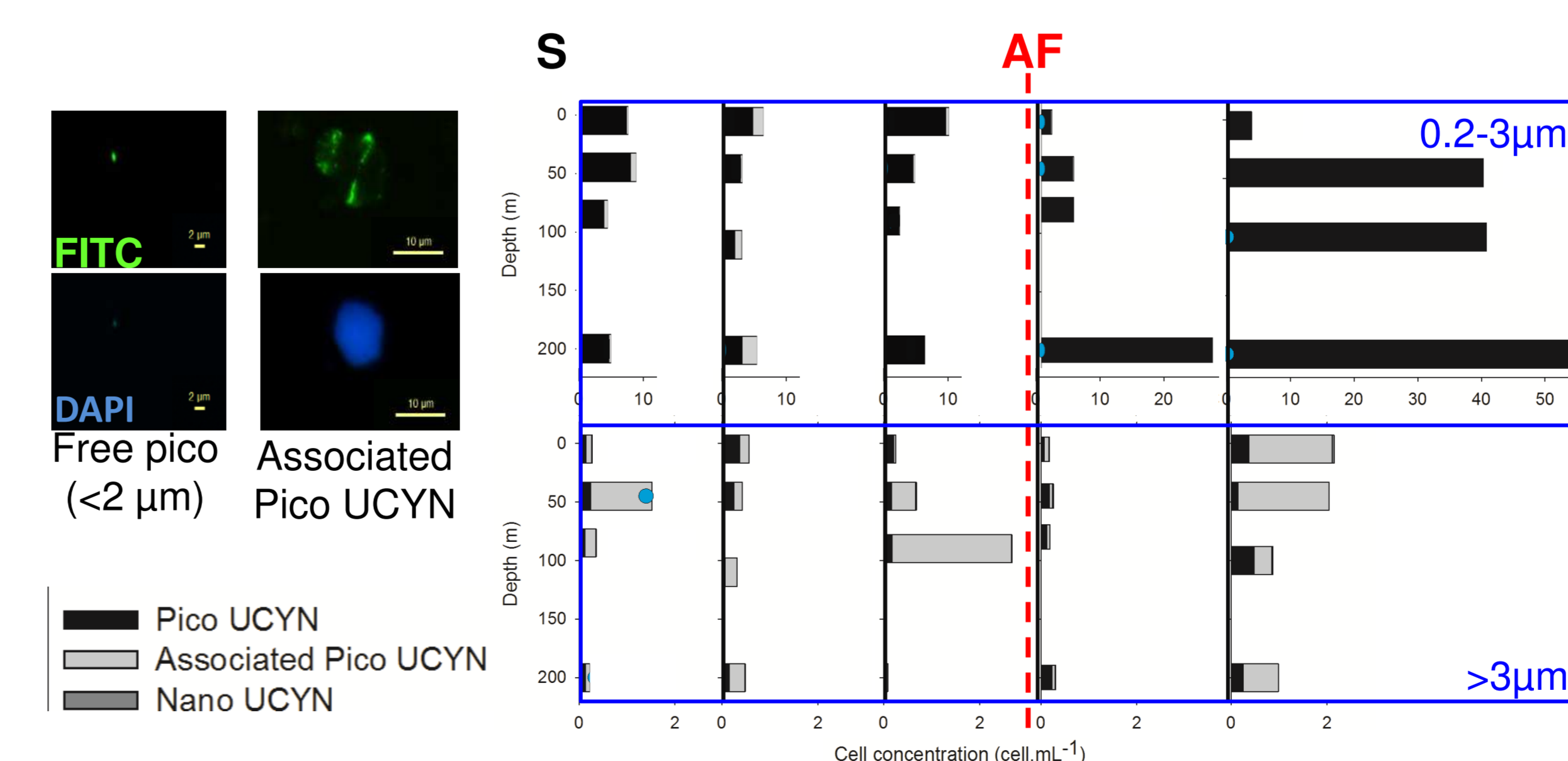
Graph 3: Total primary production (µmol/m²/day) measured from the HC¹³O₃ incorporation in particles >0.3 µm

Conclusions

The marine N and global C cycles are closely linked by the primary production of the biological carbon pump, which can translocate atmospheric CO₂ 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 N₂ by diazotrophs is one of the main routes to compensate for this shortage⁽¹³⁾, yet little is known about the importance of N₂-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 N₂-fixation might be an important N source. ¹⁵N₂ incubations and specific UCYN counts support these observations, and further indicate that both the presence of pico-UCYN and N₂-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 N₂ fixation as it was already suggested in the North Pacific⁽¹⁵⁾.



Graph 4: TSA-FISH UCYN counts and observations

DIAzotrophic Pico-Cyanobacteria 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 NO₃⁻ concentrations between 1-6 µM.

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