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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⁾.

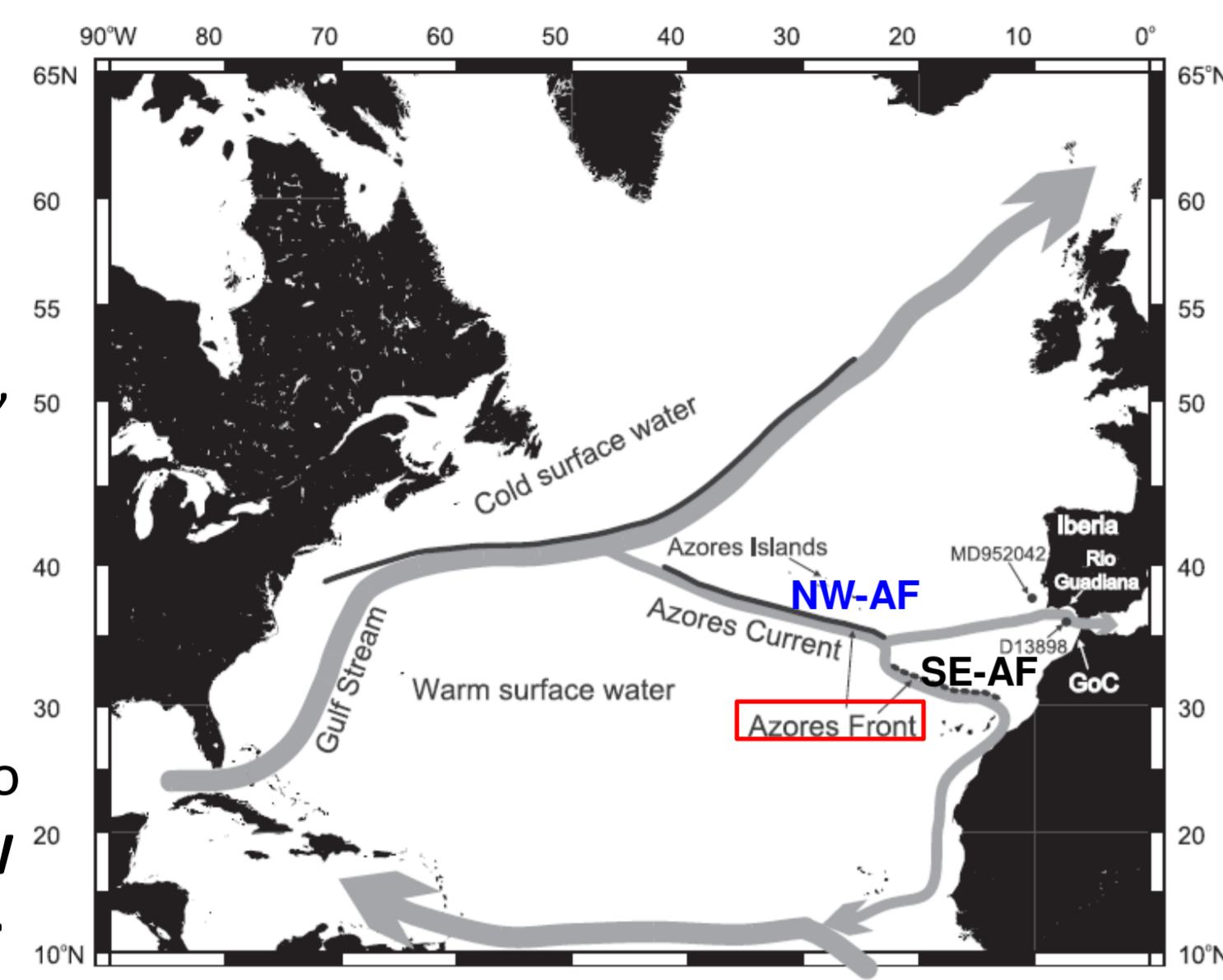


Figure 1: General surface circulation in the North Atlantic⁽²⁾

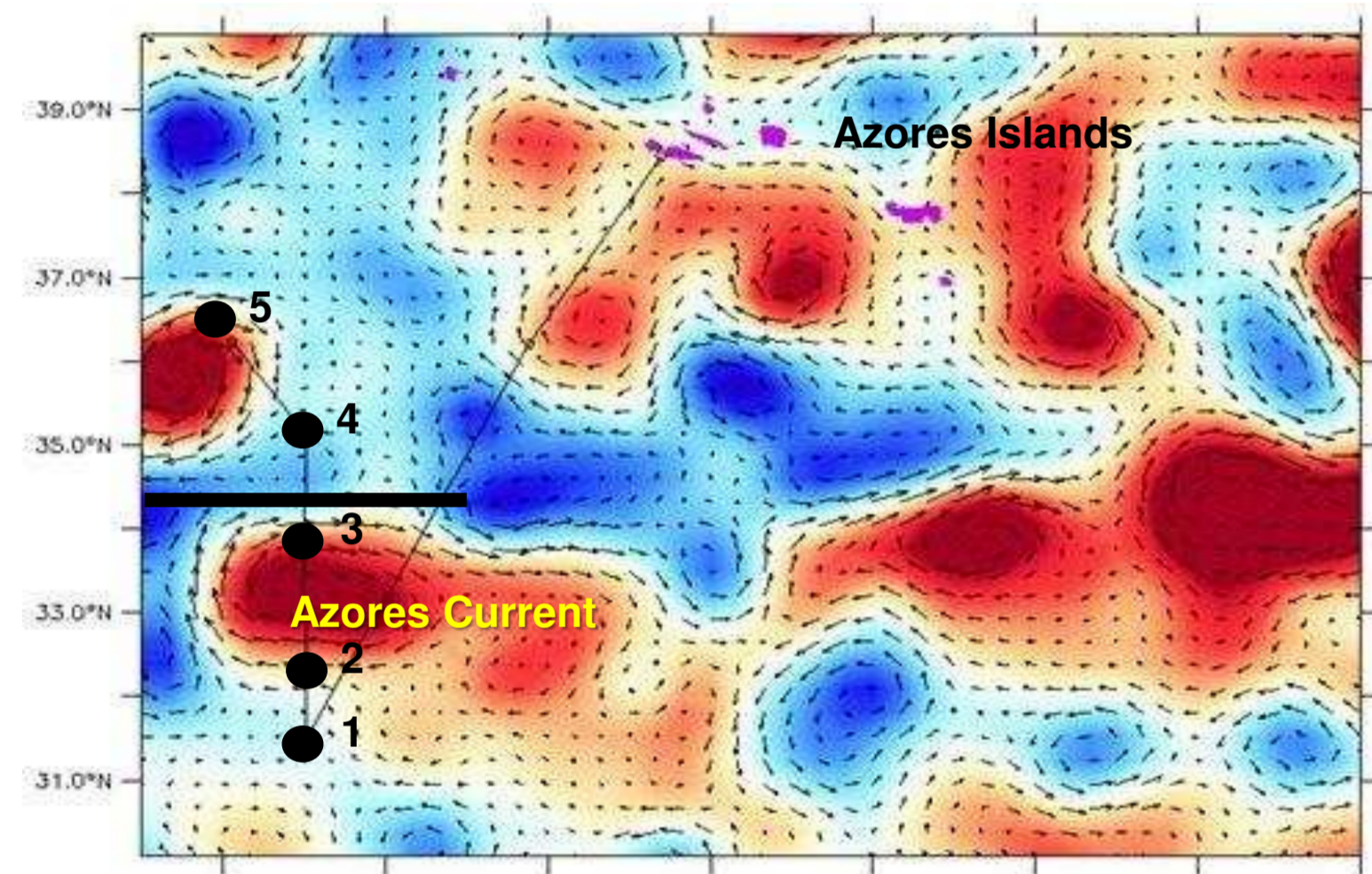
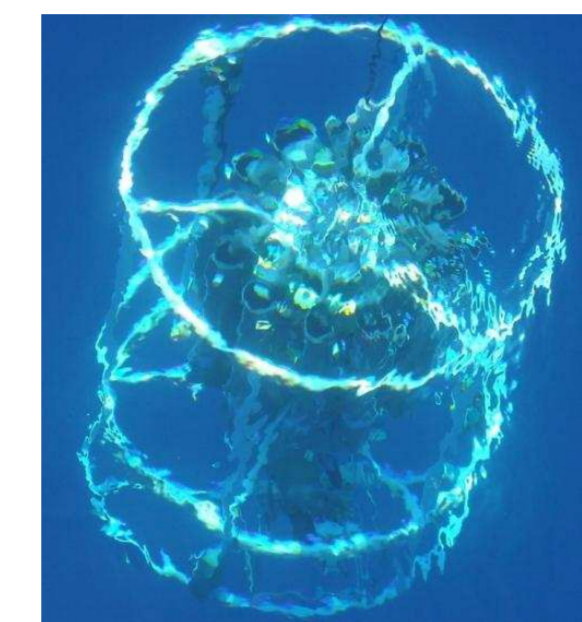


Figure 2: Sea surface height and geostrophic currents (AVISO) observed during the 2011 DIAPICNA cruise. Dots indicate the sampling stations.

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 Cyanobacteria (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

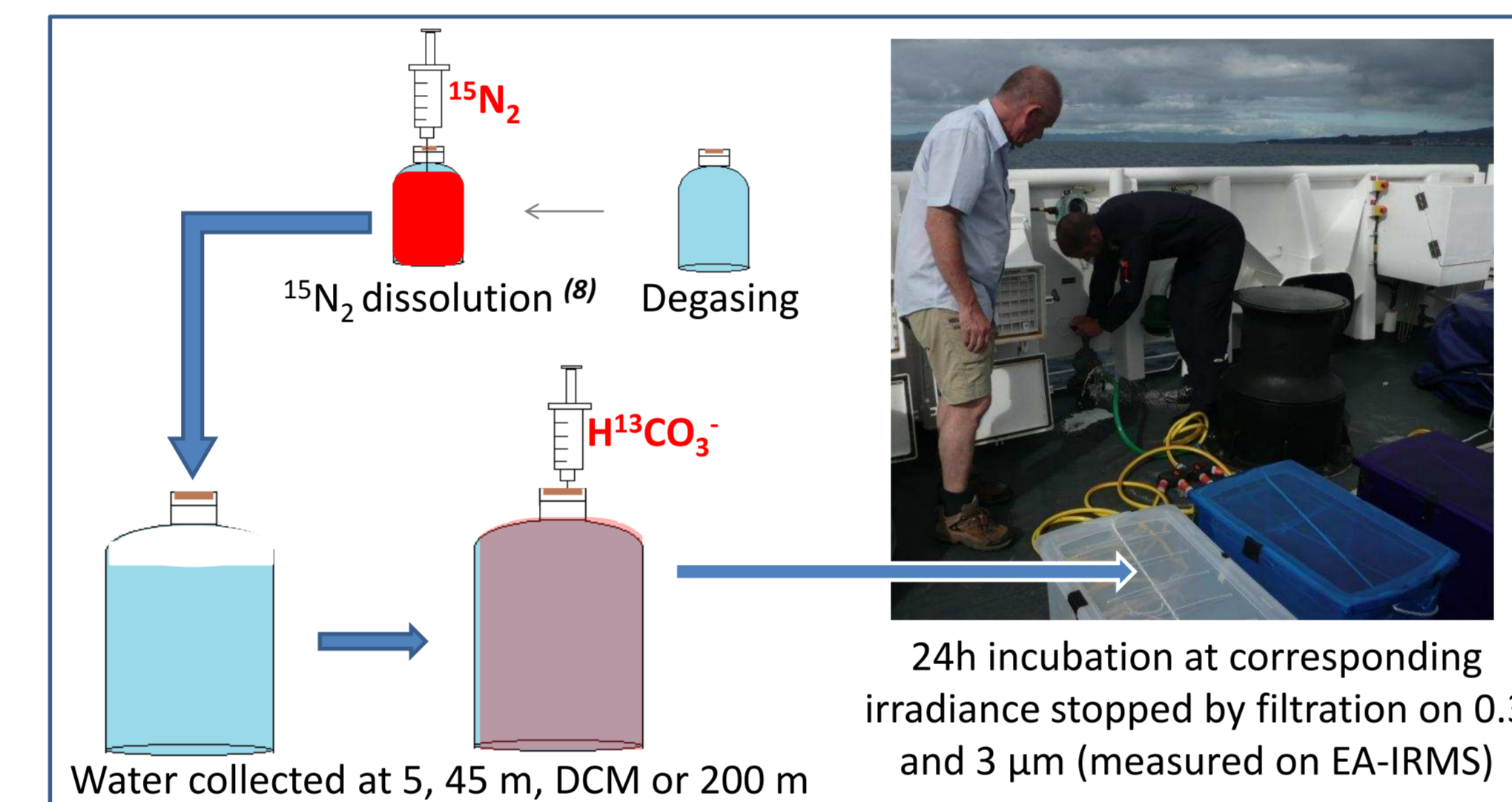


CTD - Nutrients concentrations

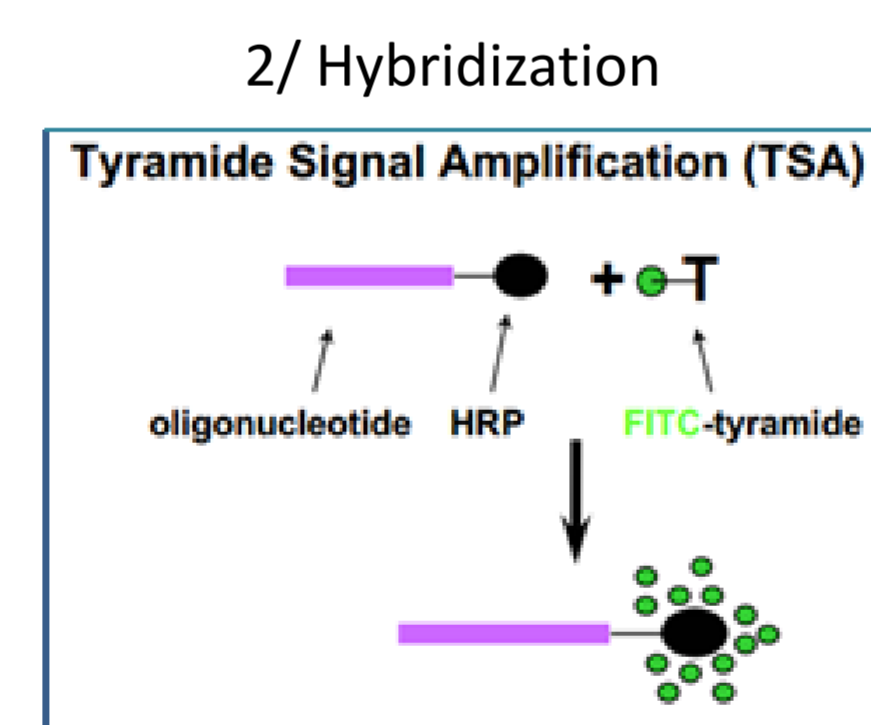
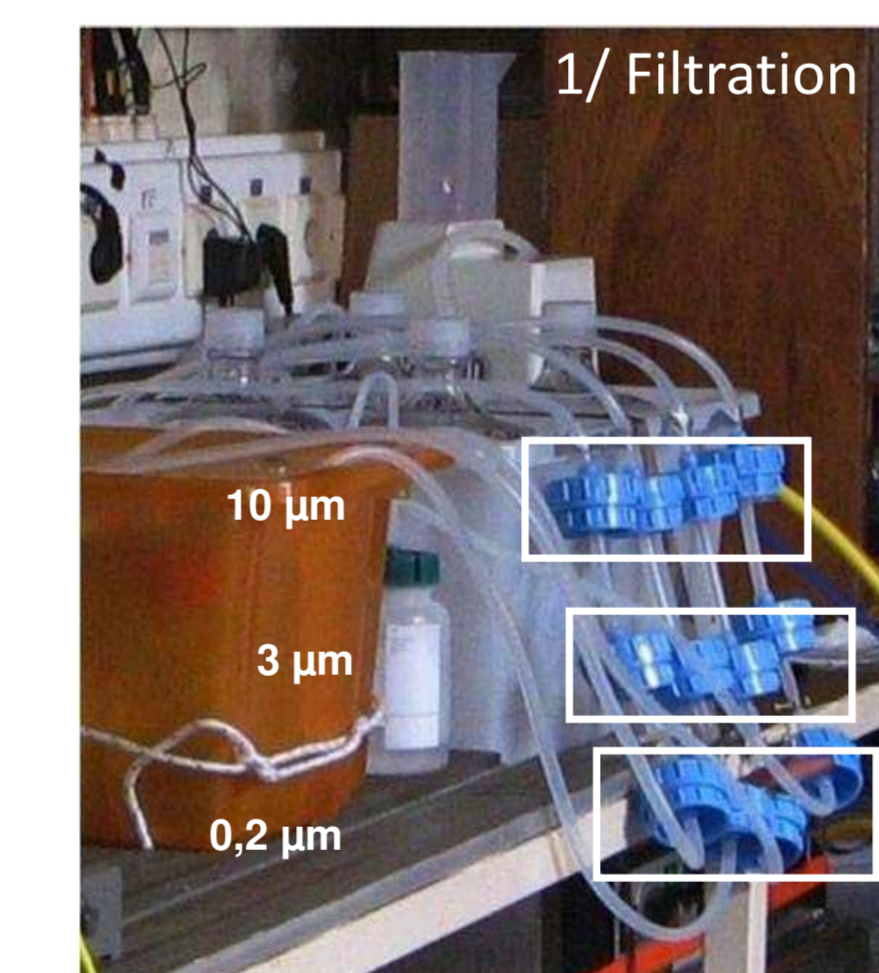
NO₃⁻ δ¹⁵N and δ¹⁸O analysis (denitrifier method⁽⁷⁾)

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



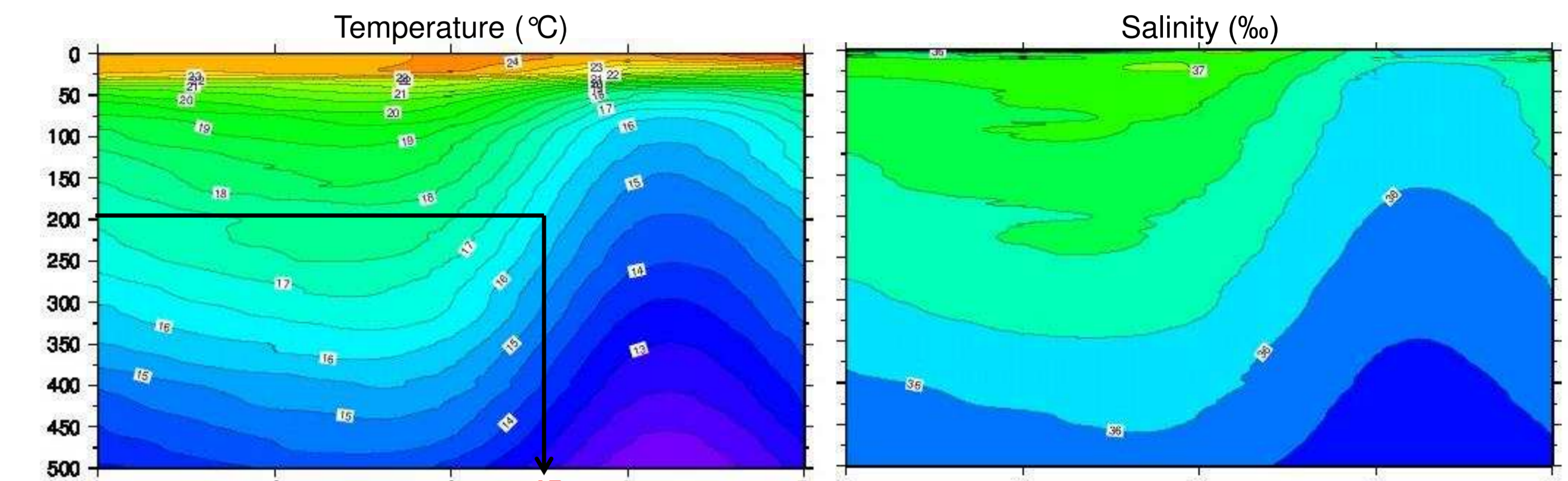
3/ DAPI general DNA labelling

4/ Eye microscopic counting

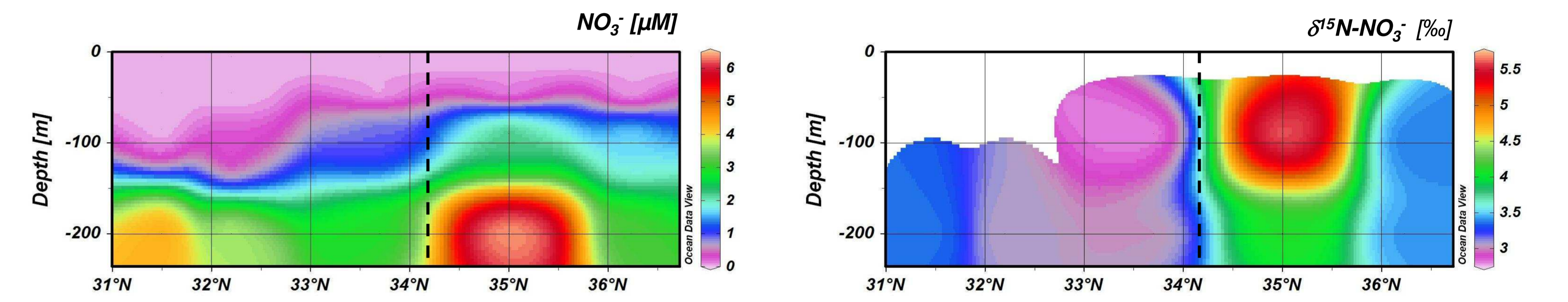
Results

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)



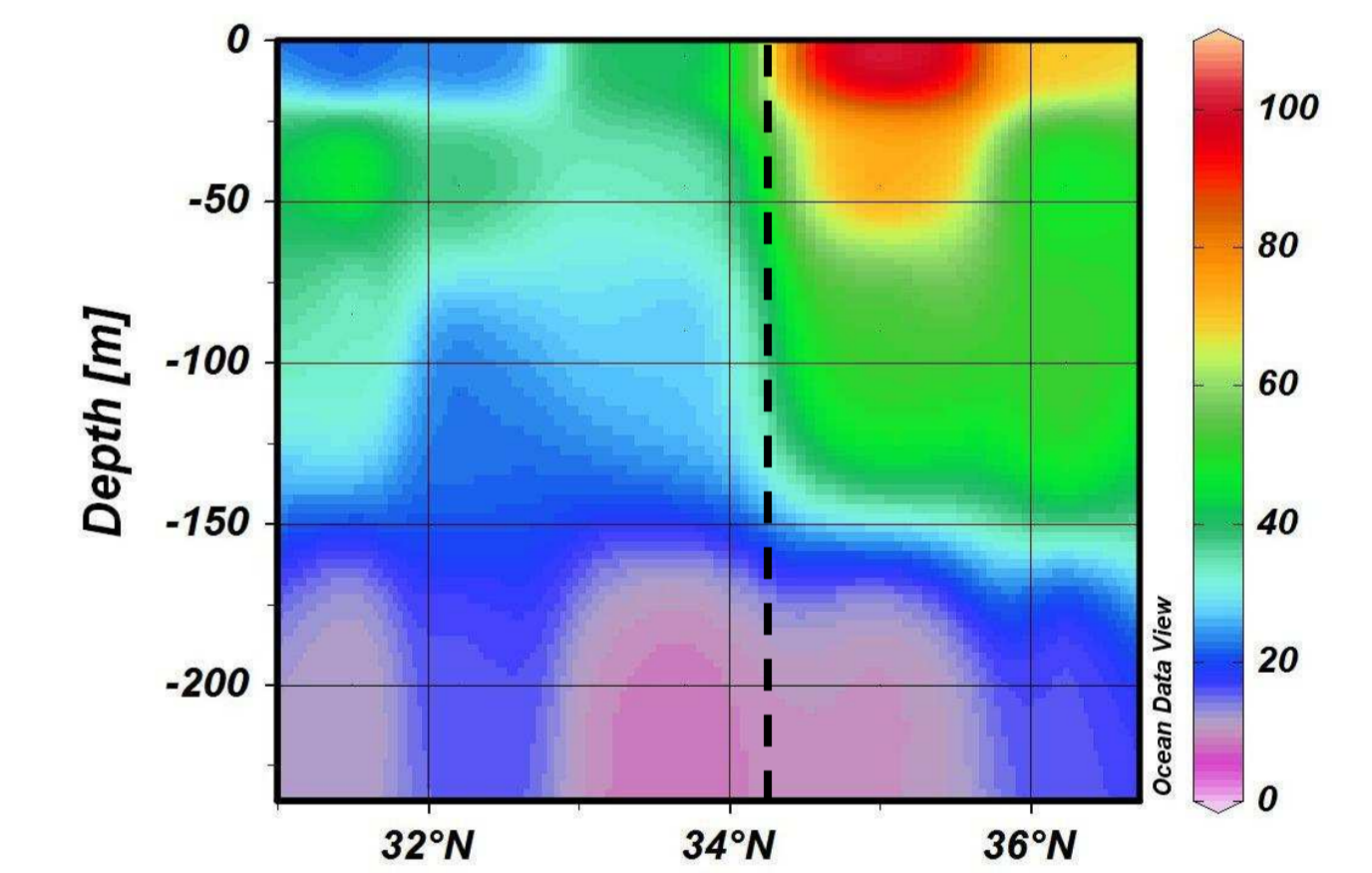
Graph 2: Nitrate concentration and δ¹⁵N isotopic profiles⁽¹⁰⁾ for the first 200 m along the transect (black bar indicates the position of the Azores Front)

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.



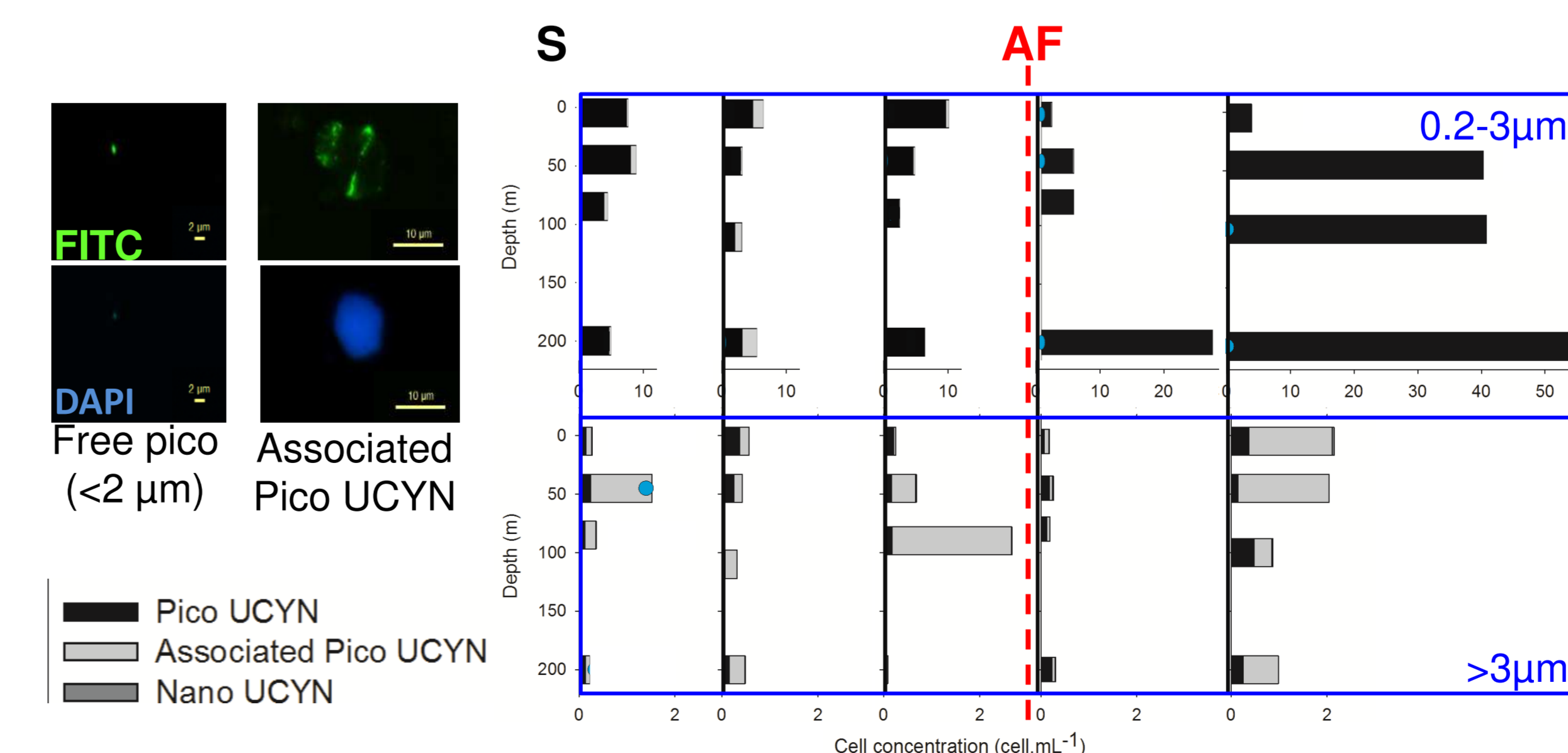
Graph 3: Total primary production (µmol/m²/day) measured from the HC¹³O₃ incorporation in particles >0.3 µm

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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