C-MORE BULA:
Biogeochemistry of the Upper ocean: Latitudinal Assessment

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Goals of the BULA cruise

Utilize a latitudinal transect to conduct a multidisciplinary, multi-institution assessment of the upper ocean in the oligotrophic South Pacific, the equator, and the North Pacific Subtropical Gyre. Among the many goals of the cruise were:

1. Study the distribution, production, and loss rates of dissolved hydrogen and its relationship to nitrogen fixation.
2. Survey the distribution of trace gases in the Pacific.
3. Examine the coupling between nutrient gradients and rates of primary production and respiration.
4. Identify prominent trends in plankton biomass, biomass structure, and elemental stoichiometry.
5. Identify and isolate new *Prochlorococcus* strains.

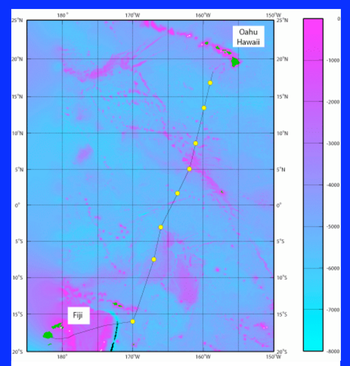

Figure 1: BULA cruise track

Hydrography of the BULA transect

The cruise crossed three distinct regions, two oligotrophic gyres and the equatorial upwelling region. The black line indicates the mixed layer depth, and points show stations where CTD casts were conducted. The Western Pacific Warm Pool is evident from the temperature contour. Both oligotrophic gyres exhibit deep chlorophyll maxima. The dissolved oxygen profiles show oxygen production under the mixed layer in the gyres, while the salinity contour illustrates the physical regional boundaries (Figure 2).

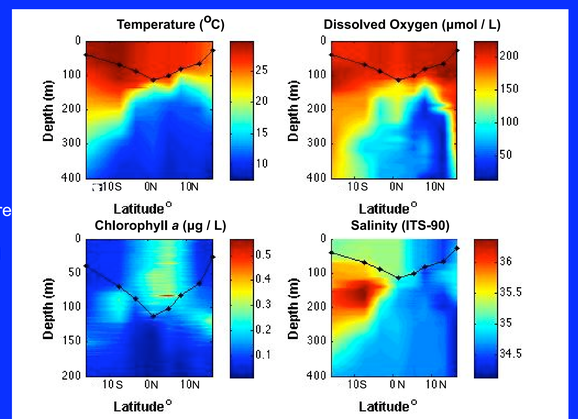

Figure 2: Biogeochemical variables measured during BULA

Nutrient Concentrations and Distributions

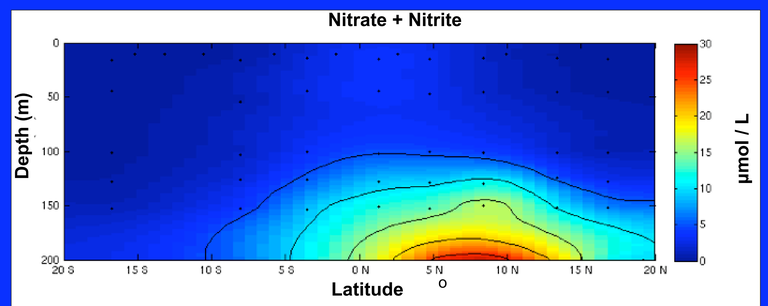

Figure 3: Nitrate + Nitrite concentrations along the BULA transit

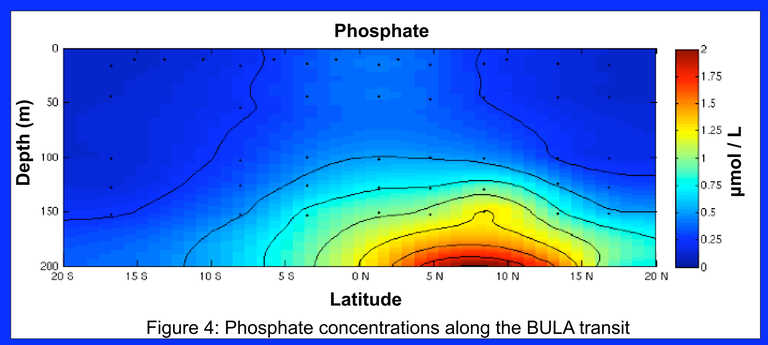

Figure 4: Phosphate concentrations along the BULA transit

The nutrient gradient across the equator can be seen in the concentrations of nitrate and nitrite (Figure 3) and in phosphate concentrations (Figure 4). Maximum nutrient upwelling was between 5 and 10 N.

Dissolved and Greenhouse Gas Concentrations

Surface dissolved gas concentrations were measured across the transect (Figure 5, CO_2 pending). With the exception of dissolved oxygen at the equator, all the gases were supersaturated with respect to atmospheric equilibrium, however they display unique characteristics with regard to their profiles along the transect. Nitrous oxide concentrations increased at the equator to reach a maximum concentration of 140 % supersaturated at Station 4, which coincides with the equatorial upwelling (Figure 6). Methane is consistently supersaturated (Figure 7). Dissolved hydrogen displays the most variation, ranging from 120 % to almost 1500 % supersaturated. Concentrations of dissolved hydrogen at the surface were positively correlated with rates of nitrogen fixation (data not shown).

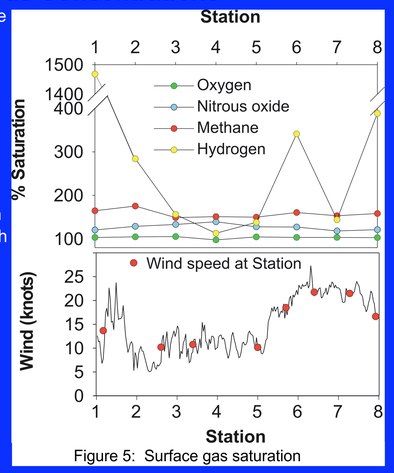

Figure 5: Surface gas saturation

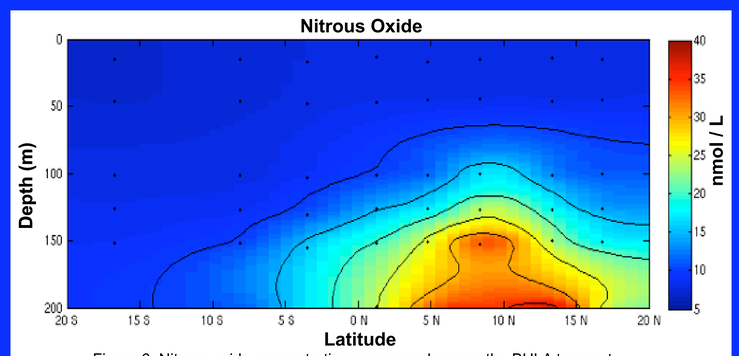

Figure 6: Nitrous oxide concentrations measured across the BULA transect

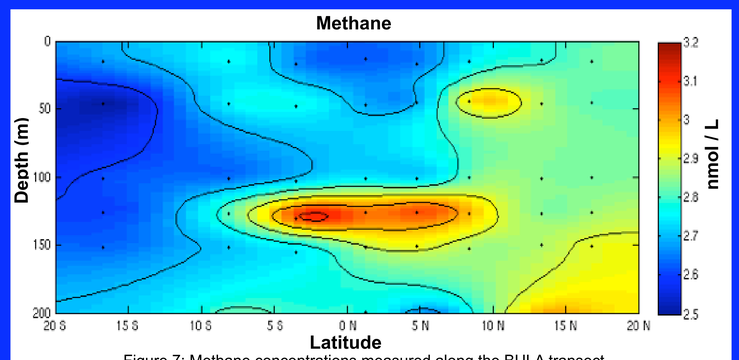

Figure 7: Methane concentrations measured along the BULA transect

Metabolic Balance

Gross Primary Production (GPP), Net Community Production (NCP) and Respiration (R) rates were measured in near surface waters along the transect. GPP represents the total oxygen evolved, R represents the amount of oxygen consumed by metabolic processes, and NCP represents net oxygen production per unit volume, per unit time. Oxygen concentration was measured by Winkler titration. NCP and GPP increased (Figure 8) with nutrient concentrations. Net autotrophy was observed from 5 S to 8 N.

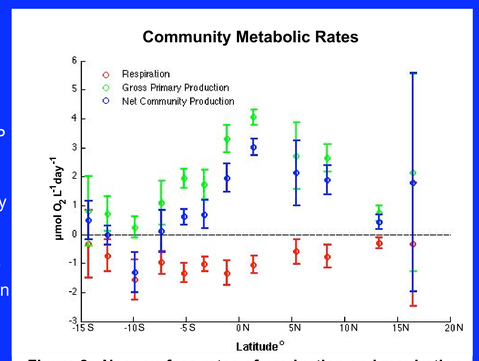

Figure 8: Near surface rates of production and respiration

Microbial Populations Changing Across the Transit

Flow cytometry was used to enumerate picophytoplankton populations (Figure 9). Depth integrated autotrophic populations showed clear patterns: *Prochlorococcus* was more abundant in the oligotrophic gyres, while both *Synechococcus* and picoeukaryote abundances increased with increasing nutrient concentrations.

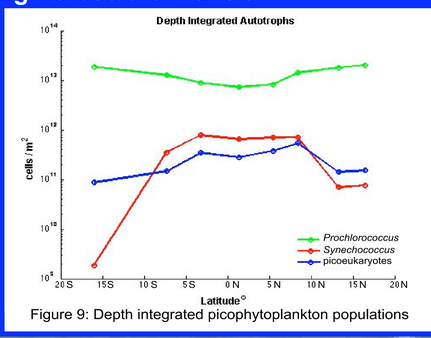

Figure 9: Depth integrated picophytoplankton populations

New *Prochlorococcus* Groups Discovered

Neighbor-joining tree of ITS sequences isolated from tropical South Pacific surface waters at Station 2 (Figure 10). The tree was constructed from ITS of sorted single cells, plus ITS sequence from isolates with sequenced genomes. ~50% of single cells were e9312, ~25% of single cells were either HLIII or HLIV. No MED4 or Low Light clades found in library. Strong boot strap support for the clades (shown in red). Stars mark sequences from cultured isolates with sequenced genomes. These provide reference points for tree construction and analysis. Amplified genomic DNA from several representative HL3 and HL4 ecotypes have been sent to Pennsylvania State University for sequencing.

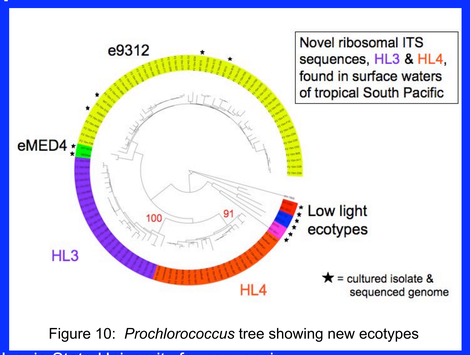

Figure 10: *Prochlorococcus* tree showing new ecotypes

HL3 & HL4 Depth Distribution

Both new high light ecotypes were approximately evenly distributed above 100 m (Figure 11). These populations drop off rapidly below that depth.

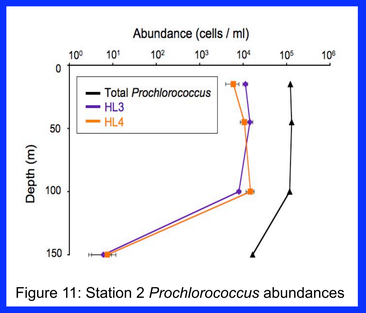

Figure 11: Station 2 *Prochlorococcus* abundances

Results

- Hydrogen saturation in the mixed layer was high in the gyres and decreased near the equator, while dissolved oxygen saturation fell below 100 % at the equator. Mixed layer nitrous oxide was highest at the equator.
- The nitrous oxide maximum was offset from the equator, similar to nutrient distributions. Methane concentrations showed a different pattern, with a maximum located closer to the surface and not distributed symmetrically across the equator.
- Net Community Production and Gross Primary Production showed more variability than Respiration. Net autotrophy (NCP > 0) was observed in near surface waters in conjunction with increased nutrients.
- *Synechococcus* and picoeukaryote populations increased as nutrient concentrations increased, while the total *Prochlorococcus* abundance declined nearer the equator. Picoeukaryote and *Synechococcus* population increases were correlated with increased rates of NCP and GPP.
- Two new high light ecotypes of *Prochlorococcus* were identified from low nutrient waters in the Western Pacific Warm Pool.

Acknowledgements

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