Assessing the Impacts of Ocean Acidification on Phytoplankton Functional Types – A Case Study for the Amazon River Plume

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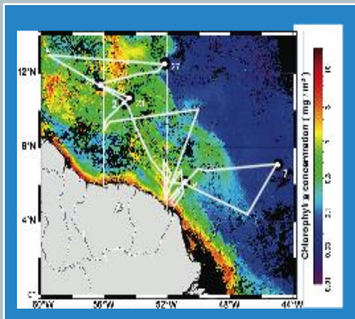
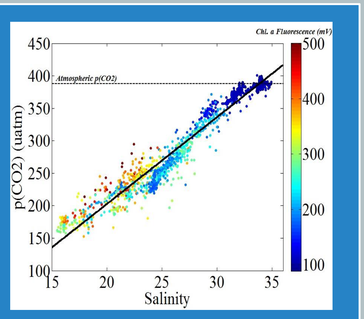
As human activities continue to raise the levels of atmospheric and oceanic CO_2, we require a clearer understanding of the responses of plankton to these increases and better ways to detect the global impacts of anthropogenic change on marine ecosystems. The Amazon River plume which contains the surface ocean's largest environmental gradient of pCO_2 (~100 ppm and ~1300 µmol C kg^{-1}), provides the perfect natural laboratory for making critical progress on these challenges. Our recent ship-based bio-optical measurements along the plume's gradient of salinity, CDOM, nutrients and pCO_2, together with on-deck and laboratory - CO_2 manipulation experiments, suggest that phytoplankton community structure and metabolic activity may be in large part controlled by DIC concentrations and to a lesser degree by dissolved inorganic phosphate and nitrate availability. These observations allow us to postulate that 1) coastal-estuarine phytoplankton, which are typically exposed to a wider range of pH than their truly oceanic counterparts, are as susceptible to ocean acidification as their oceanic counterparts and 2) changes in the carbonic acid system will fundamentally alter the community structure and function of tropical marine primary producers. We also discuss our findings in the context of their potential application to ocean acidification studies using satellite data.

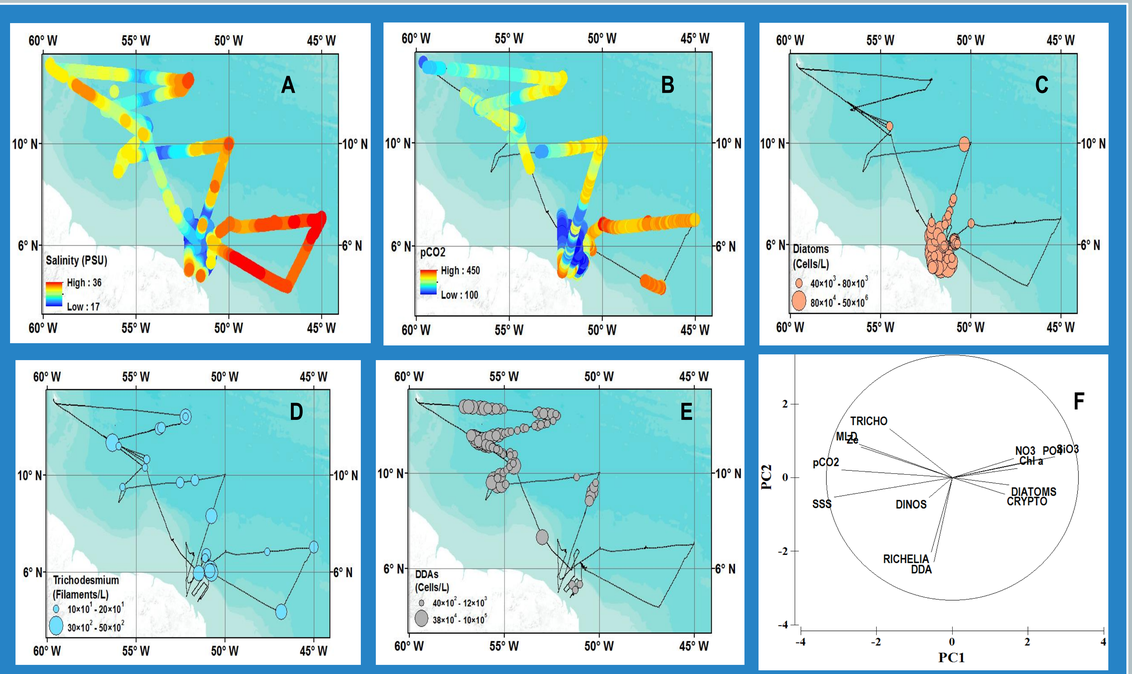


Cruise track and station locations of May-June 2010 cruise in the Amazon plume. Background is satellite Chlorophyll *a*

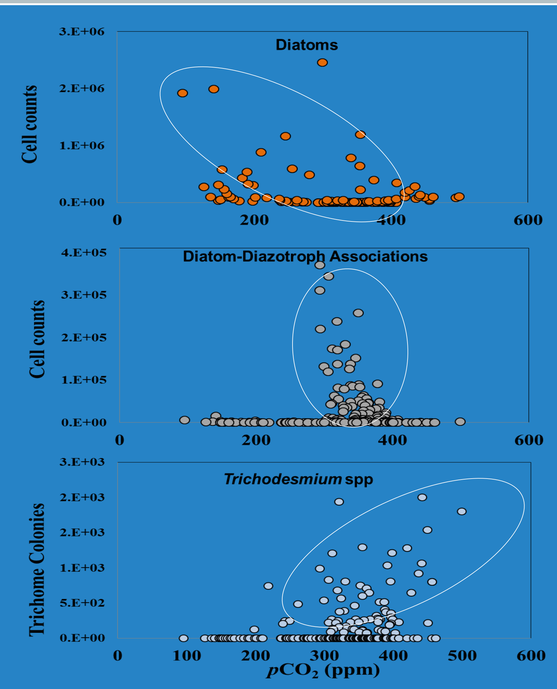


Chl *a* fluorescence (color scale, mV) plotted on pCO_2 vs salinity (x-axis) in the Amazon plume (May 2010) Range of pCO_2 on y axis can be observed. The line denotes the least squares fit, not a mixing line.

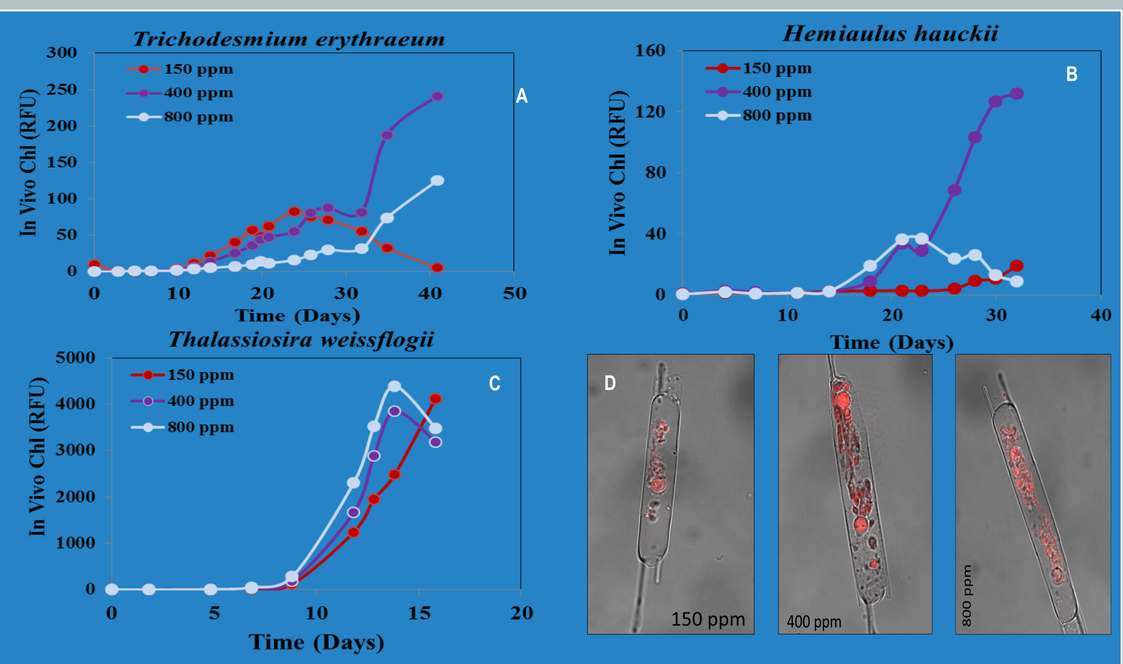
During the May-June of 2010 cruise , we utilized an Advanced Laser Fluorometer (ALF) and microscopy to map the distribution of phytoplankton communities in the Amazon River Plume. When examined in the context of the physical and chemical environment of the plume, these high resolution measurements of phytoplankton revealed that the interaction of freshwater from the Amazon River Plume with high salinity waters of the Western North Atlantic Ocean, creates extreme variability in hydrographic conditions and a complex mosaic of habitats that have a huge bearing on the spatial patterns of phytoplankton communities in the plume. Results from ship-based bio-optical measurements along the plume's gradient of salinity, CDOM, nutrients and pCO_2, together with on-deck CO_2 manipulation experiments, suggest that the phytoplankton community structure and metabolic activity may be in large part controlled by pCO2 concentrations and to a lesser degree by dissolved inorganic phosphate and nitrate availability. These data along with results from recent laboratory experiments confirm the notion that the inorganic carbonate system of the Amazon River Plume has a huge bearing on the distribution of phytoplankton functional types.



Along-track variations in A) salinity, B) pCO_2, and phytoplankton abundance: C) asymbiotic diatoms, D) *Trichodesmium*, and E) Diatom-Diazotroph Associations (DDAs) during May-June 2010 Amazon plume expedition. F) PCA showing the affinity of Diatoms and Cryptophytes for low pCO_2 waters, DDAs (including its endosymbiont *Richelia intracellularis*) for intermediate pCO_2 waters and *Trichodesmium* spp. for high pCO_2 waters.



Distribution of major phytoplankton in relation to *p*CO2 concentrations along the cruise track



Results from laboratory experiments showing the growth response of A) *Trichodesmium* B) *Thallasiosira* sp. (Diatom) and C) *Hemiaulus hauckii* (DDA) to varying concentrations of pCO_2. Confocal microscope changes in intracellular *Richelia* populations within *Hemiaulus hauckii* when exposed to different CO_2 levels

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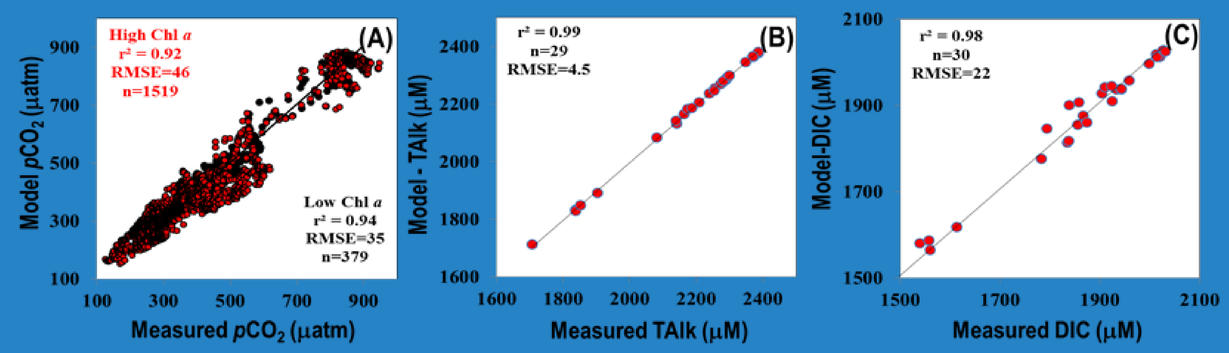
ASSESSING OCEAN ACIDIFICATION USING SATELLITES

The availability of a large database of carbonate chemistry and hydrographic and biological variables collected during our cruises provides us with an excellent opportunity to test the feasibility of deriving seasonally and regionally stable empirical relationships that could be applied to satellite imagery to monitor the carbonate system from space. pCO_2, TAlk and DIC obtained from empirical relationships derived using different combinations of SST, SSS and Chl *a* as the predictor variables, when compared against independent datasets (pCO_2, TAlk and DIC) from the plume give us immense confidence that it will be possible to derive satellite data products that are relevant to enable measurements of ocean acidification from space data.

Our broad objective is to move forward, building upon our previous results in the Amazon River plume and repurposing our large datasets of bio-optical properties from the plume for developing novel algorithms for phytoplankton functional types (PFTs). Our plan is to make use of these valuable data sets in combination with existing and new experimental, remote sensing and coupled physical-biological modeling data to answer the following questions:

- How does the carbonate chemistry gradient along the Amazon River Plume influence the distribution and community structure of phytoplankton?
- Do changes in river discharge impact the pCO_2 gradient across the Amazon River Plume and if so, does it have a bearing on the structure of phytoplankton communities?
- How will the projected changes in the gradient of pCO_2 alter the structure of phytoplankton communities and therefore C cycling in the WTNA?



Comparisons of shipboard measured and modeled estimates of A) near surface pCO_2 obtained as a function of SSS, SST and Chl *a* B) DIC obtained as a function of SST and SSS and C) TAlk obtained as a function of SSS and SST).