HICO Data User's Proposal
Titles of Proposals

1. ***Amazon iNfluence on the Atlantic: CarbOn export from Nitrogen fixation by DiAtom Symbioses (ANACONDAS)***

2. ***Characterization of large and unusual Noctiluca blooms in the northern Arabian Sea and their role in carbon cycling during the winter monsoon***

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Amazon iNfluence on the Atlantic: CarbOn export from Nitrogen fixation by DiAtom Symbioses (ANACONDAS)

Abstract/ - Project - 1:

The tropical North Atlantic Ocean has generally been considered a net *source* of ~30 TgC y^{-1} to the atmosphere (*Takahashi et al.* 2002; *Mikaloff-Fletcher et al.* 2007), but our recent results from the region suggest a biologically mediated atmospheric carbon drawdown of a similar magnitude (28 TgC yr^{-1}) by diatom-diazotroph symbiotic assemblages (DDAs) (*Subramaniam et al.* 2008). These organisms possess a unique capacity for fixing nitrogen in the Amazon plume itself, and can represent a regionally significant carbon sink in offshore riverine plume waters that are devoid of inorganic nitrogen. Because these DDAs have also been found in other tropical river systems, it has been speculated that they represent a globally significant, yet previously overlooked carbon sink mechanism. However, present knowledge about the magnitude, spatial extent, and fate of this new production is limited due to the difficulty in sampling these regions by traditional shipboard means. One of the goals of this project is to investigate the possibility of using ocean color remote sensing to detect communities of DDAs and other phytoplankton functional types in river plumes from space. We believe that the distinct optical signatures of these phycobilipigment-rich DDAs affords us the possibility to detect them from space. We believe that HICO hyperspectral data offers us the advantage over multi-spectral ocean color sensors such as MODIS-Aqua and MERIS in detecting DDAs from their unique optical signatures. In addition we believe that HICO data will provide us with the means to detect other phytoplankton functional types as well as other in-water constituents such as CDOM, Chl, Total suspended matter, etc because of their unique optical signatures. Our overarching goal in this project is to combine satellite derived fields of DDAs with shipboard environmental data on nutrients, PAR etc. to provide answers to the following questions: 1) What is the spatial extent and activity of DDAs and how does this relate to other diazotrophic species such as *Trichodesmium* sp. and phytoplankton succession in the Amazon River plume? 2) What physical, biogeochemical and ecological factors regulate the distribution, growth and ultimately the fate of DDAs?

Statement of work/project description:

Because the Amazon River flows through the world's biggest and most densely forested river basins, it carries with it massive amounts of sediments, nutrients as well as particulate and dissolved organic material. These constituents together impart a unique color to the freshwater outflow, which is visible from space as a greenish-brown plume stretching several thousands of miles in the WTNA. The gradient of environmental conditions (light, nutrients, colored dissolved organic matter (CDOM), salinity, temperature, mixed layer depths etc.) that evolve as this plume mixes with the

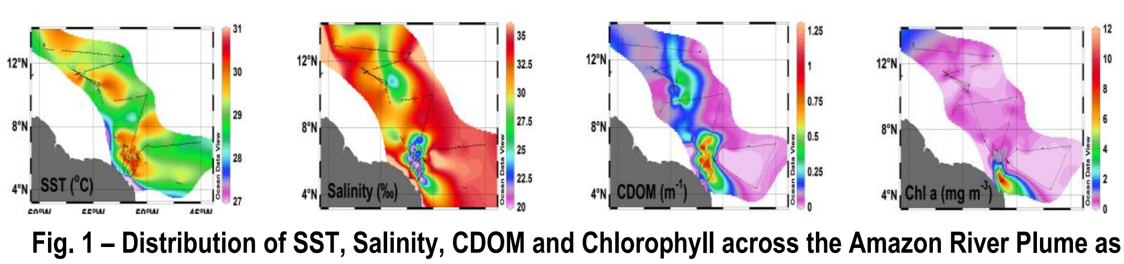

Fig. 1 – Distribution of SST, Salinity, CDOM and Chlorophyll across the Amazon River Plume as obtained from the shipboard underway system

waters of the WTNA creating unique niches (Fig. 1), that have a profound influence on the composition and magnitude of phytoplankton communities within and outside of the plume (Carpenter et al.,2004).

During our most recent cruise to the Amazon River Plume in May-June 2010, we used a combination of high frequency water sampling for phytoplankton microscopy with a state-of-the art underway automated laser fluorescence sampling method to demonstrate the existence of these unique niches within the Amazon River plume as it moved from the mouth of the river to the offshore regions (Fig. 2). We believe that the unique gradients of phytoplankton functional types and the variability of several in-water constituents such as CDOM, TSM would be reflected in remotely sensed hyperspectral water leaving radiances. Given this, we would like to propose investigating the possibility of using hyperspectral HICO data to study the distribution of phytoplankton functional types and in-water constituents in the Amazon River Plume

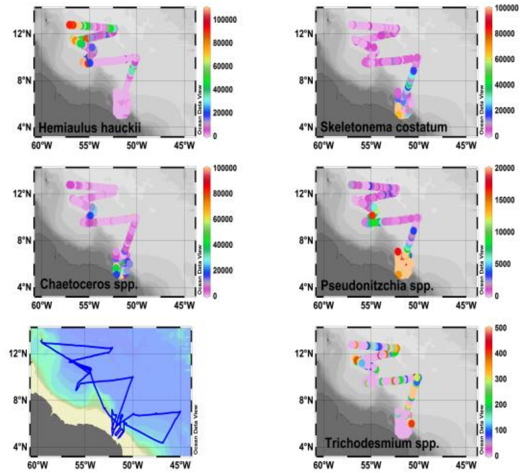

Fig. 2 – Distribution of major phytoplankton species within the Amazon River Plume

2. Biographical sketch and available facilities

We the Principal Investigators Joaquim I. Goes and Helga do Rosario Gomes are well versed in the use of in-water optical techniques and remote sensing for ocean ecosystem and biogeochemical studies. We have extensive cruise experience, experience in the deployment of optical instruments and have published several papers using satellite ocean color data.

During the upcoming cruise in the Amazon River Plume scheduled from 1st Sept. to 9th Oct. 2011 on board the *R/V Melville* (Fig. 3 for proposed cruise track) we will deploy a Satlantic Micropro-multispectral radiometer, a Wet-Labs, ac-s, a Wet Labs bb7fl2 and a suite of other sensors to map the underwater light field within and outside the plume. An underwater profiling Fast Repitition Rate Fluorometer (FRRF), and laboratory based Photosynthethrons and spectrophotometers will be used to investigate the bio-optical properties of phytoplankton communities and their ability to photosynthesize under different conditions of light. Throughout the cruise as we transect through the plume, we will monitor the diversity and size structure of phytoplankton communities with the help of an underway Advanced Laser Fluorometer (ALF) and phytoplankton pigment measurements. We will also make aerosol optical depth measurements with a sunphotometer. All these

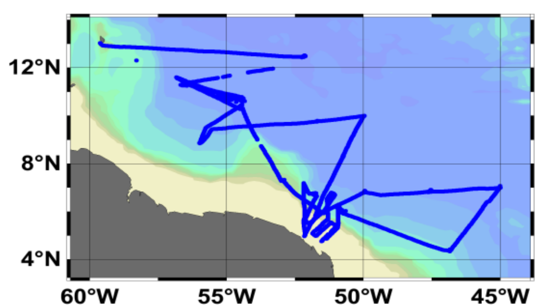

Fig. 3 Proposed cruise track for ANACONDAS cruise 2011 on board the R/V Melville from the 1st of Sept to 9th Oct 2011.

datasets will be utilized to understand how various constituents of the plume waters including phytoplankton communities influence the color of the ocean from space.

Our goal is to utilize these datasets is two fold:

1) To validate remotely sensed products that are available from NASA's ocean color satellites.
2) To develop inverse bio-optical modeling techniques that would allow us to identify various functional types from ocean color data.

Project – 2 Characterization of large and unusual Noctiluca blooms in the northern Arabian Sea and their role in carbon cycling during the winter monsoon

Abstract- Project 2

Until the late 90's *Noctiluca miliaris*, a large dinoflagellate, with a flagellated green-pigmented endoysmbiont, *Pedinomonas noctilucae* was a minor component of phytoplankton populations in the northern Arabian Sea, appearing in bloom form only sporadically in coastal regions predisposed to upwelling and deep slope water intrusions during the Southwest monsoon. Since then however, *N. miliaris* blooms have increased in frequency, intensity and distribution, but with the majority of blooms being observed following the Northeast monsoon. Large blooms of these organisms have now become pervasive in the Gulf of Oman and more widespread over large parts of the western Arabian Sea in association with waters that are nutrient-rich and undersaturated with respect to oxygen (*Gomes et al., 2006, 2009*). There is particular concern that the spread of *N. miliaris* blooms may be indicative of eutrophication of the Arabian Sea ecosystem. Such concerns are consistent with recent indications that the Arabian Sea is becoming more productive (*Goes et al., 2005; Goes et al in review*) and that its permanent oxygen minimum zone is intensifying due to increased organic matter export from the euphotic zone. Off the coast of Oman, *N. miliaris* blooms have been observed in association with cold water cyclonic eddies and with diatoms, but in the eastern Arabian Sea, *N. miliaris* blooms are frequently encountered along with blooms of the diazotroph *Trichodesmium* sp. Here, we propose to carry out a targeted program aimed at developing the capacity to identify and quantify *N. miliaris, Trichodesmium* sp. blooms and other phytoplankton functional types from space using satellite ocean color data. By applying the method to historical ocean color datasets from SeaWiFS, we will attempt to pinpoint when *N. miliaris* blooms first began making their appearance in the Arabian Sea. In addition, we will integrate fields of phytoplankton functional types with ship-based ecophysiological information to investigate: i) the implications of these blooms on carbon cycling and biogeochemical processes in the Arabian Sea. Finally we will consolidate this information and interpret it with other satellite data to understand: 1) the environmental conditions facilitating large *N. miliaris* blooms in the Arabian Sea; 2) the oceanographic and meteorological conditions contributing to their enhanced frequency and 3) possible climatic connections. Our field study has been devised in consultation with colleagues at the National Institute of Oceanography & the Space Applications Centre in India and the Sultan Qaboos University, Oman, who have pledged access to their shipboard and laboratory facilities.

Statement of work: Project description:

In this proposal we will investigate environmental conditions and climatic connections related to the emergence of *N. miliaris* blooms in the NAS, and its associated ecological and biogeochemical consequences by addressing the following questions:

- Has there been a fundamental shift in phytoplankton communities of the NEM and if so when and where did it occur?
- How do the rates of carbon fixation (and respiration) and systemic carbon fluxes associated with *N. miliaris* blooms compare with those of other PFTs more typically associated with the NEM?
- Does upwelling associated with the prevalent cyclonic mesoscale eddies in the western Arabian Sea contribute to the formation of an environmental niche that favors *N. miliaris*?
- Is the recent climate trend leading to a greater prevalence of *N. miliaris* blooms?

Each year depending on the availability of ship-time we participate along with our Indian colleagues on board their research vessels in their winter monsoon cruises. For the past 3 years we have participated in 4 cruises to the Arabian Sea.

On board measurements on these cruises include the following:

ADCP measurements of ocean currents, CTD profiles that include dissolved oxygen (DO) and photosynthetically available radiation (PAR), beam attenuation and passive fluorescence using sensors mounted on the CTD rosette.

i. Water samples from 8 discrete depths within the water column using Niskin bottles mounted on a CTD rosette. These samples are analyzed onboard for inorganic nutrients (nitrate, nitrite, ammonia, phosphate and silicate) using an auto-analyzer *(JGOFS 1996)*, dissolved oxygen (Automated Amperometric Oxygen Titration (AAOT), *Culberson & Huang, 1987)* and Chl using fluorometry (*Holm-Hansen and Riemann 1978).* HPLC phytoplankton pigments *(Claustre et al., 2004; Parab et al., 2006)* and microscopic phytoplankton cell counts (*Tomas, 1992)* and species composition analysis *(Claustre et al., 2004; Parab et al., 2006).*

ii. Deck incubations for phytoplankton production (PP) rates (^{14}C-technique) in samples from 6 depths within the euphotic zone at the survey stations (*JGOFS, 1996; Fitzwater et al. 1982*) and short term production versus irradiance incubations to assess photosynthetic parameters.

iii. Size fractionated HPLC pigments and production rate measurements in bulk phytoplankton and in carefully sorted cells of *N. miliaris* and *Trichodesmium* sp.

iv. On-board analysis of spectral absorbance of size fractionated phytoplankton, *N. miliaris* and *Trichodesmium* sp. and detrital particles *(Kishino et al., 1985)* and CDOM using an onboard scanning double-beam spectrophotometer *(D'Sa et al., 2002)*.

v. Suspended matter and CHN analysis of particulates collected on pre-combusted GF/F filters (*JGOFS, 1996*) at NIO.

3. Output and deliverables (Project 1 and Project 2)

Assuming a successful outcome, what are the products that will be produced? How will using HICO data advance the mission of the program? What will the investigator return to the HICO program (algorithms for new products, validation of HICO products for an additional site or region, etc.)? All HICO data users will be asked to attend an annual

HICO team meeting topresent their results and discuss HICO data and their uses and applications. One deliverable is the commitment to attend this annual meeting.

Our goal is to utilize these rich in-situ optical datasets with HICO hyperspectral datasets to develop algorithms for CDOM, TSM, Chlorophyll, DDAs and other functional types for the Amazon River Plume and for the Arabian Sea. In addition we plan to attend the annual HICO meeting to present the findings from our work.

4: References

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