BLOOMS OF *NOCTILUCA MILIARIS* IN THE ARABIAN SEA – AN *IN SITU* AND SATELLITE STUDY

Helga do Rosario Gomes[1], Joaquim I. Goes[1], S.G. P. Matondkar[2], Sushma G. Parab[2], Suraksha Pednekar[2], Adnan Al-Azri[3], Prasad G. Thoppil[4]

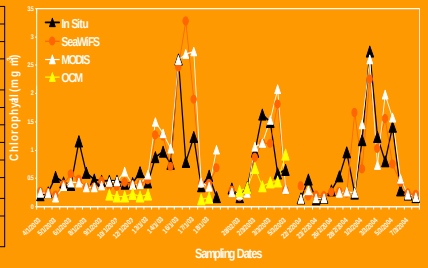
[1]*Bigelow Laboratory for Ocean Sciences, ME, USA (hgomes@bigelow.org), [2]National Institute of Oceanography, Goa, India [3], Sultan Qaboos University, Oman, Stennis Space Center, MS, USA*

ABSTRACT

Phytoplankton cell density, Chlorophyll *a* (chl *a*) concentration and pigment data collected during a series of 5 cruises in the northern Arabian Sea in the Northeast Monsoon (NEM, Nov- Jan) and the Spring Intermonsoon (SIM, Mar-May) since 2003 onwards contradicted the established notion that winter blooms are comprised of diatom communities. Recent data shows that following the NEM and well into the SIM, phytoplankton populations are dominated by the dinoflagellate *Noctiluca miliaris* Suriray (synonym *Noctiluca scintillans* Macartney). In the SIM they were often in association with the well known blooms of the diazotroph *Trichodesmium* sp. Large blooms of *N. miliaris* have also begun making their appearance annually in the Gulf of Oman and off the coast of Oman. This study uses NASA's recently developed product of merged SeaWiFS and Aqua-MODIS chl *a* data to investigate the temporal evolution and spatial extent of these taxonomically validated blooms. Satellite chl *a* in relation to Aqua-MODIS SST and altimetry data suggest that mesoscale eddies that populate the western Arabian Sea during the NEM contribute to the genesis and dispersal of these blooms from the Gulf of Oman into the central Arabian Sea.

CRUISE AND SATELLITE IMAGERY DETAILS

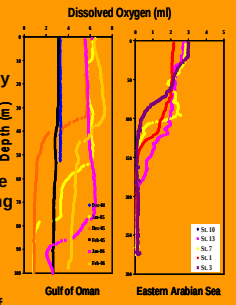
ARABIAN SEA SAMPLING		
CRUISE NOMENCLATURE	DATE	MONSOON
CR-1-JAN-2003	3rd -19th Jan 2003	NEM-2003
CR-2-MAR-2003	27th Feb – 5th Mar 2003	SIM-2003
CR-3-MAY-2003	2nd - 5th May 2003	PSWM-2003
CR-4-MAR-2004	22nd Feb-8th Mar 2004	SIM-2004
CR-5-DEC-2004	4th -17th Dec 2004	NEM-2005
CR-6-MAR-2007	1st -15th March 2007	SIM-2007
GULF OF OMAN SAMPLING		
FAHAL (23.67ºN, 58.5ºE)	From 2004 and ongoing	FORTNIGHLY
OFF (23.62ºN, 58.65ºE)	From 2005 and ongoing	FORTNIGHLY
BHANDAR KHAIRAN (23.51ºN, 58.72ºE)	From 2006 and ongoing	FORTNIGHLY



Satellite data: Recently (March 2006) produced Level-3 Chl *a* product from NASA which merges SeaWiFS and Aqua-MODIS data was used. This product ameliorates problems associated with missing data due to cloud cover and bad pixels. For 8-day composites of 9 km resolution, the merged product gives a 20.6% increase in coverage over SeaWiFS and a 24% increase over Aqua-MODIS. Surface Temperature (SST) was obtainedfrom Aqua-MODIS as a 4 km resolution, 4 µ, night time product. Both merged chl *a* and SST products were downloaded from http://oceancolor.gsfc.nasa.gov/ Weekly, near-real time high-resolution gridded data (1/3º x 1/3º on a Mercator grid) of SSHA and geostrophy vectors (merged product of T/P, ERS-1&2, and Jason satellites) were obtained from the AVISO satellite altimetry web page at http://www.aviso.oceanobs.com and superimposed on Aqua-MODIS merged chl*a*.

MAJOR FINDINGS

- ***N. miliaris*** **is a large heterotrophic dinoflagellate that harbors thousands of free-swimming cells of the prasinophyte *Pedionomonas noctiluca***
- **Blooms of *N. miliaris* are a recent phenomenon as the JGOFS study of 1994-1996 and the IIOE reported the dominance of diatoms in winter blooms of the N. Arabian Sea**
- **Satellite altimetry data suggest a strong coupling between these blooms and mesoscale eddy activity in the Western Arabian Sea**
- **Cyclonic cold eddies could be bringing up oxygen poor subsurface waters from the Oxygen Minimum Zone at mid-depth and facilitating the genesis and evolution of the *N. miliaris* blooms in the Gulf of Oman**
- **Warm cyclonic eddies may aid in their dispersal out of the Gulf of Oman into the northern Arabian Sea. The anticyclonic arc-like swaths of the bloom in the ocean color images may be evidence of this**



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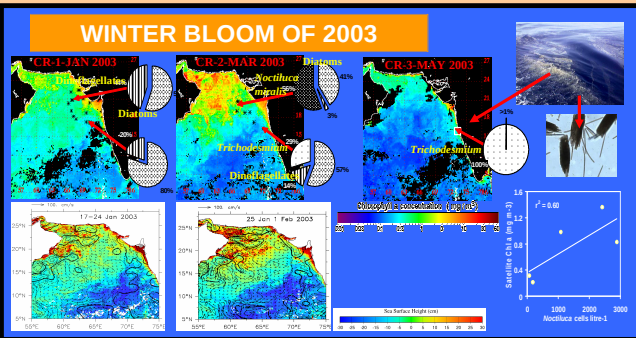
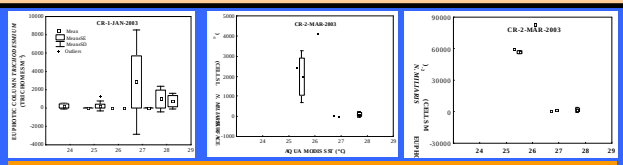
WINTER BLOOM OF 2003



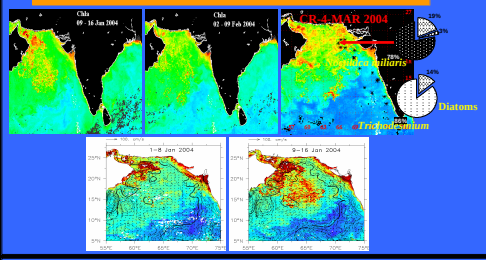


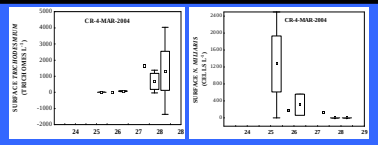
CR-1-JAN2003
- Dominance of diatoms and dinoflagellates
- No *N. miliaris* was found

CR-2-MAR2003
- Large blooms of *N. miliaris* at all stations sampled. Surface populations comprised 5-60% of the phytoplankton population and averaged 34%.
- *N. miliaris* was found in the north in association with colder waters
- *Trichodesmium* was associated with warmer waters in the south
- Satellite derived Chl *a* correlated significantly (r^2 =0.6) with *N. miliaris* cell counts.

(CR-3-MAY2003)
- In May *N. miliaris* blooms were replaced by blooms of the diazotroph *Trichodesmium*

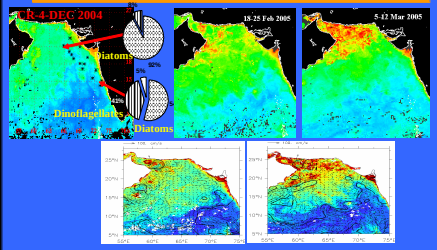
WINTER BLOOM OF 2004

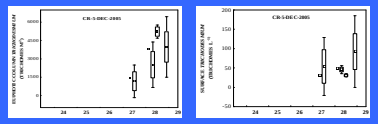




CR-4-MAR2004
- *N. miliaris* blooms were observed again with surface counts making up 38 – 65% of the total phytoplankton. Again, *N. miliaris* cell counts correlated significantly (r^2= 0.8) with satellite Chl *a* concentrations
- The two species followed a distinct geographic pattern with *N. miliaris* in the north between 21º and 22.5ºN, a mixture *N. miliaris* and *Trichodesmium* between 17 and 20ºN and *Trichodesmium* between 11-17ºN.
- *N. miliaris* was associated with colder waters (<26.5ºC), while *Trichodesmium* was seen in warmer (>26.5ºC) waters along the southwest coast of India.

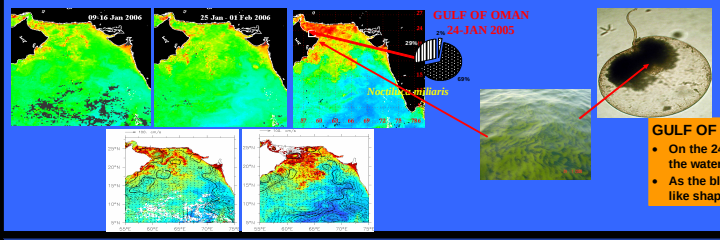
WINTER BLOOM OF 2005





CR-5-DEC2004-JAN2005
- Diatoms and dinoflagellates dominated the winter bloom of 2005
- A bloom appeared in the Gulf of Oman in late Jan 2005 and spread all over the N. Arabian Sea by Feb 2005
- Once again *Trichodesmium* was seen in warmer (>27°C) waters along the southwest coast of India.

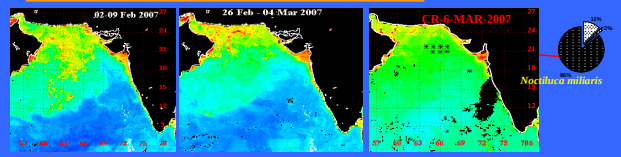
WINTER BLOOM OF 2006



Date	BHANDAR KHAIRAN	OFF	FAHAL
	N. miliaris cells L^{-1}		
12/17/2005	30	40	347
12/27/2005	485	34	200
1/7/2006	1742	24	2000
1/22/2006	690	1500	2500
2/22/2006	842	104	No Data

GULF OF OMAN JAN2006
- On the 24th Jan 2006 a distinct bloom of *N. miliaris* was detected in the Gulf of Oman which streaked the waters green and persisted until Feb 2006.
- As the bloom extended from the Gulf of Oman into the open ocean, its edges resembled large arch-like shapes suggestive of the outer fringes of anticyclonic structures

WINTER BLOOM OF 2007



CR-6-MAR2007
- A bloom developed in early Feb 2007
- *IN. miliaris* made up 86% of the phytoplankton populations while other diatoms comprised 12%