The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2066-23

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2 - 10 November 2009

Unusual Blooms of the Green Noctiluca Miliaris (Dinophyceae) in the Arabian Sea during the Winter Monsoon

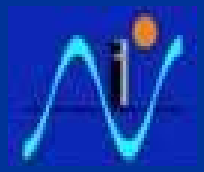
H.d.R. Gomes, Goes J.I., Matondkar Prabhu S.G., Roesler C., Parab S., Dwivedi R.M., Pednekar S., Basu S. and Werdell J.

Bigelow Laboratory for Ocean Sciences
ME
USA

UNUSUAL BLOOMS OF THE GREEN *NOCTILUCA MILIARIS* (DINOPHYCEAE) IN THE ARABIAN SEA DURING THE WINTER MONSOON

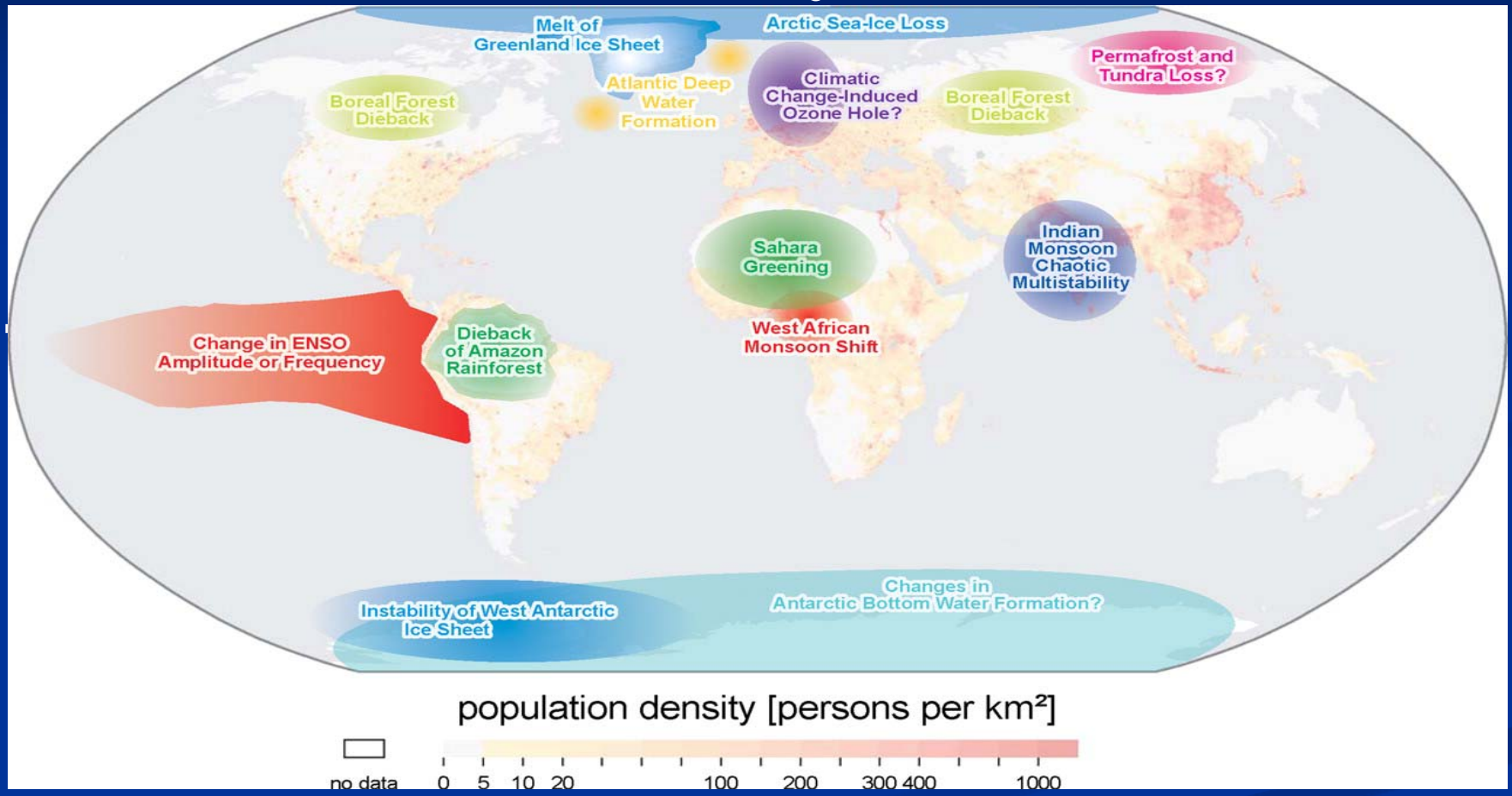
Helga do Rosario Gomes, Joaquim I. Goés[1], S. G. Prabhu Matondkar[2], Collin Roesler[3], Sushma Parab[2], R.M. Dwivedi[4], S. Pednekar[2], S. Basu[2] and Jeremy Werdell[5]

[1]Bigelow Laboratory for Ocean Sciences, ME, USA
[2]National Institute of Oceanography, Dona Paula, 403004 Goa, India
[3]Bowdoin College, Maine, USA
[4]Space Applications Centre, Ahmedabad, India
[5]NASA, Goddard Space Flight Center USA



WHY SHOULD WE CARE ABOUT THE ARABIAN SEA?

Tipping elements in the Earth's climate system



Tipping element = changes within the political horizon, significant population impact, policy relevant

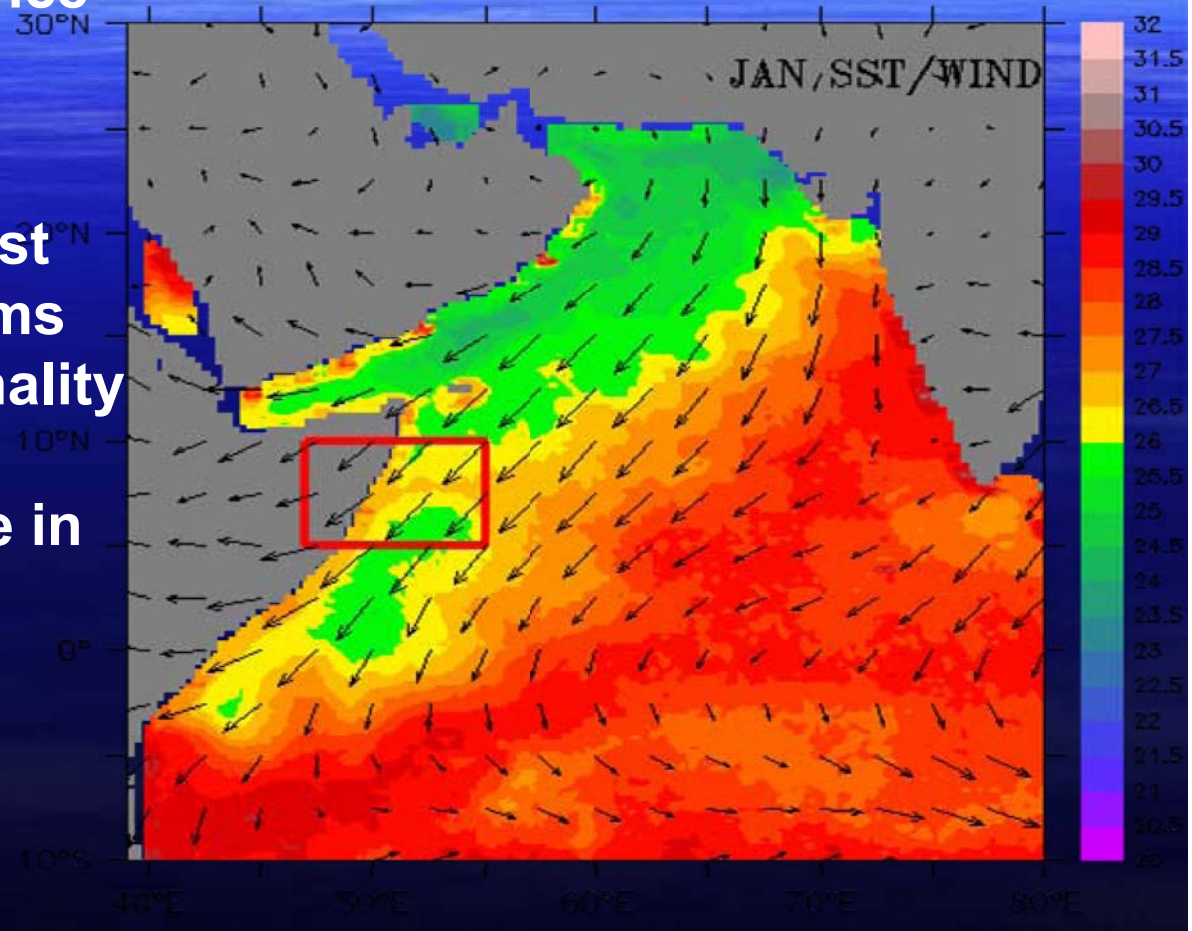
Lenton et al. 2008. PNAS. 155:1786-1793

ARABIAN SEA - A UNIQUE ECOSYSTEM

Comes under the influence of seasonally reversing monsoon winds

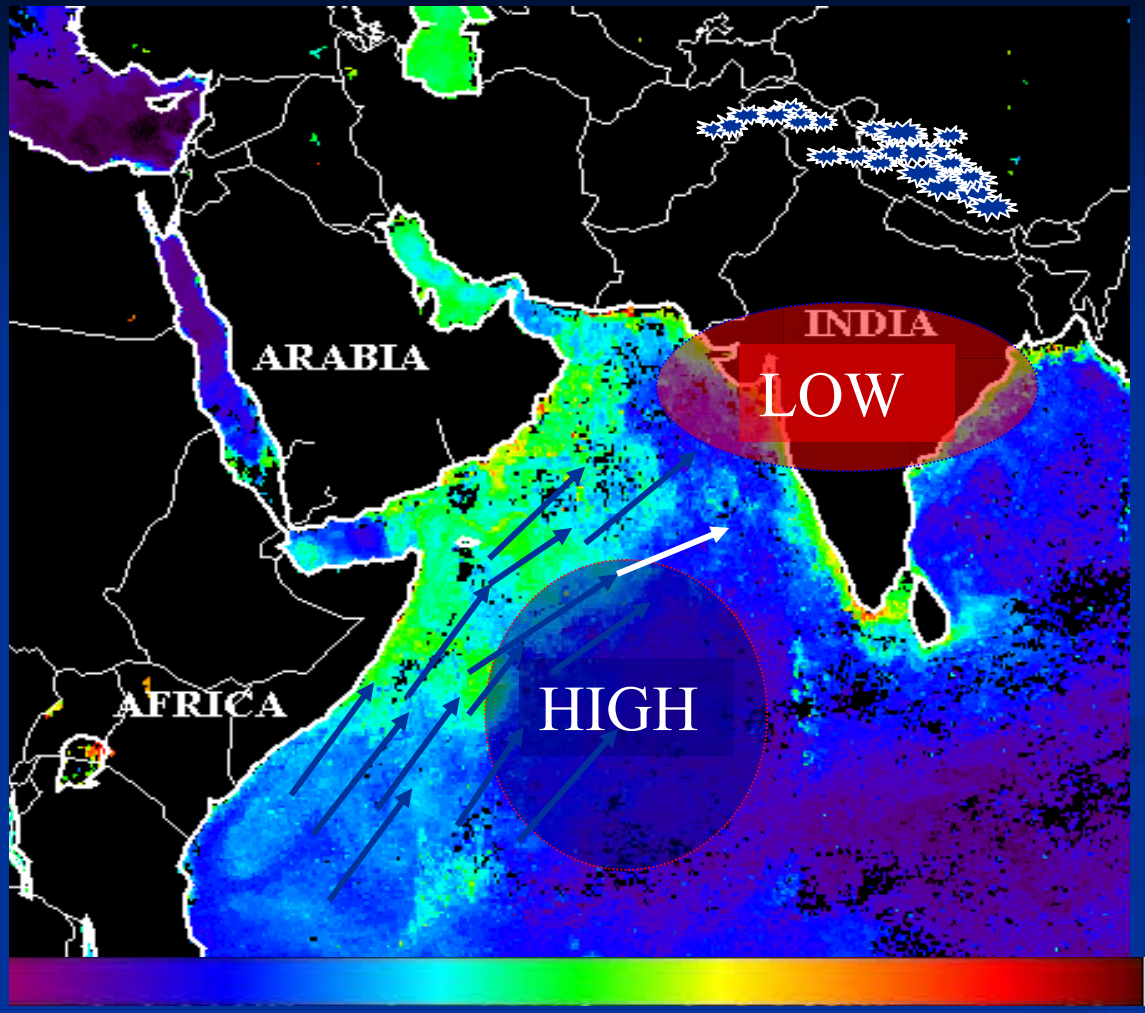
Winds drive one the most energetic current systems and the greatest seasonality in phytoplankton productivity observable in any ocean basin

Development and intensity regulated by thermal gradient between land and sea

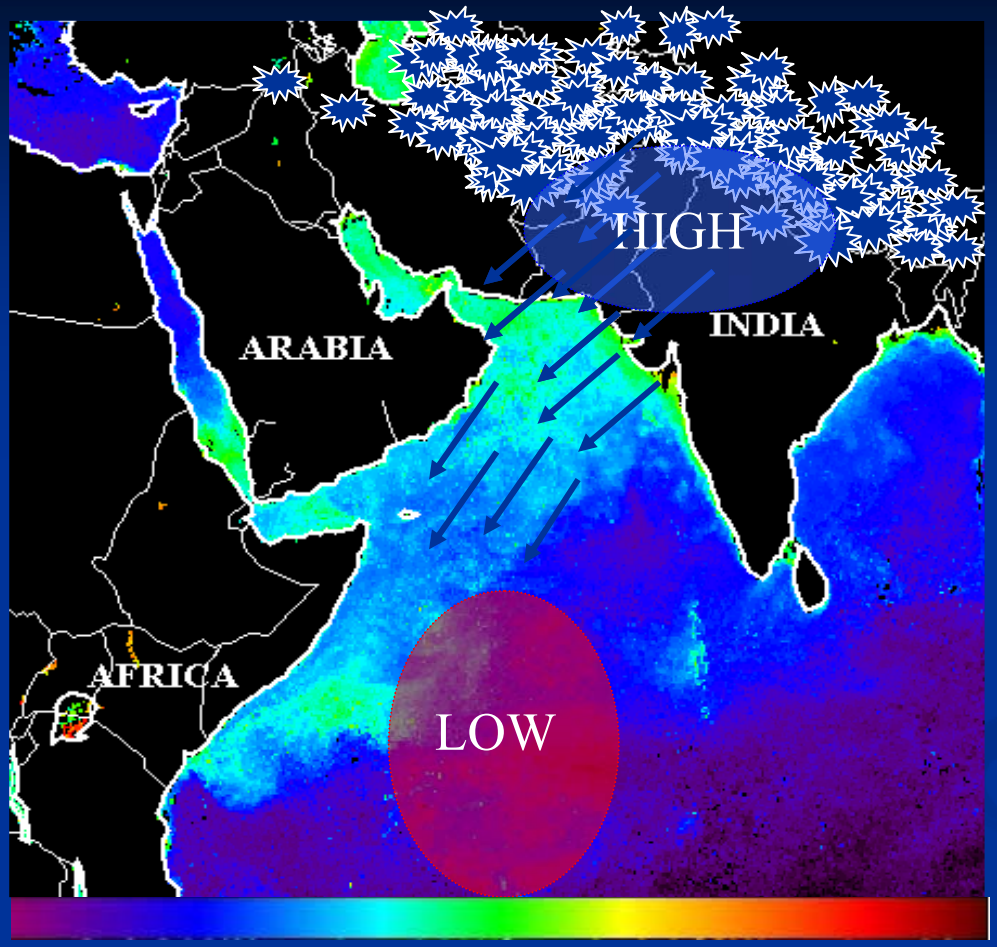


Between 1992-1996, the US spent ~$50M on the Arabian Sea JGOFS

SUMMER MONSOON



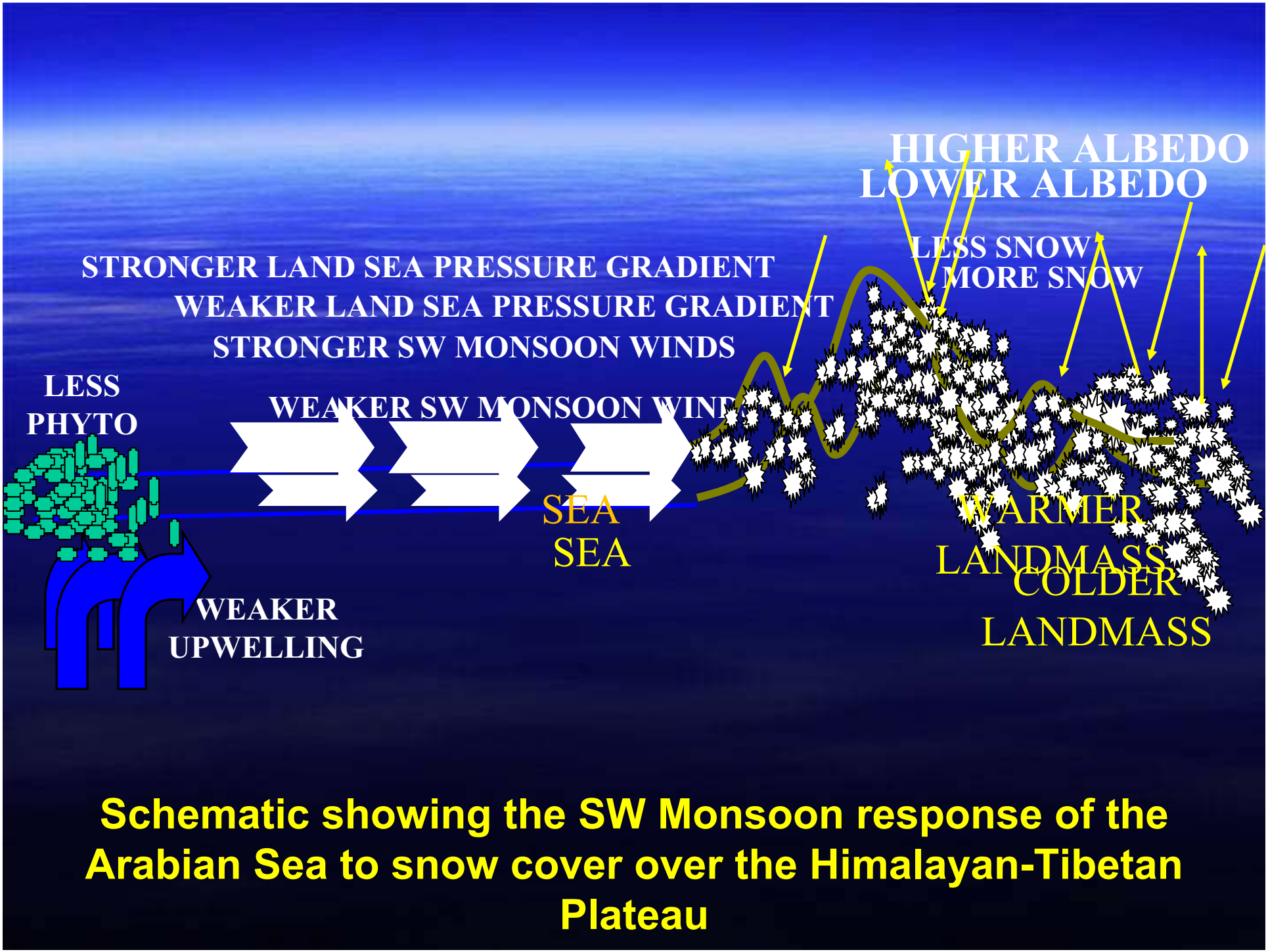
WINTER MONSOON



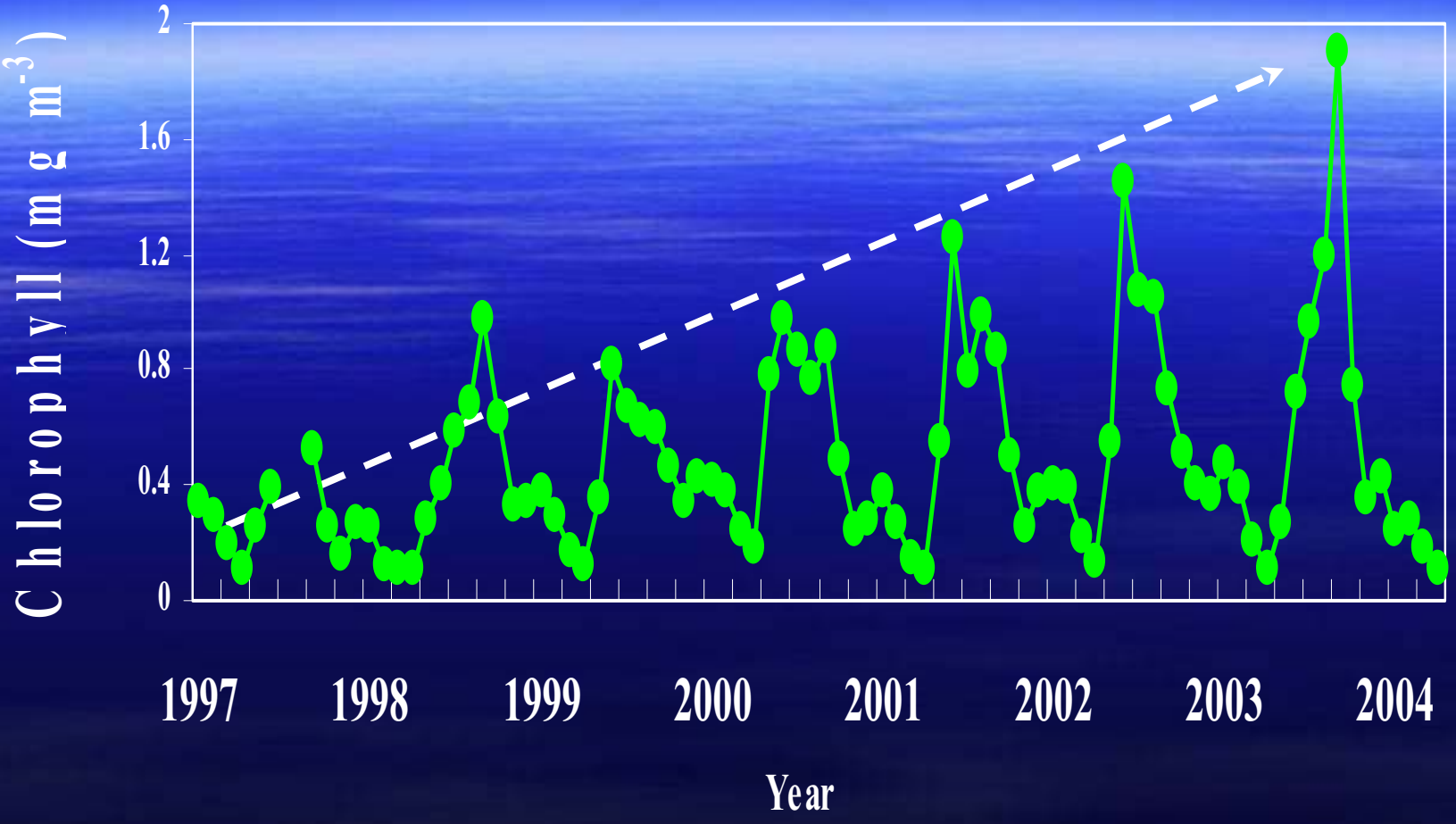
Winter cooling causes convective mixing and nutrient enhancement

Phytoplankton blooms

Predominance of diatoms

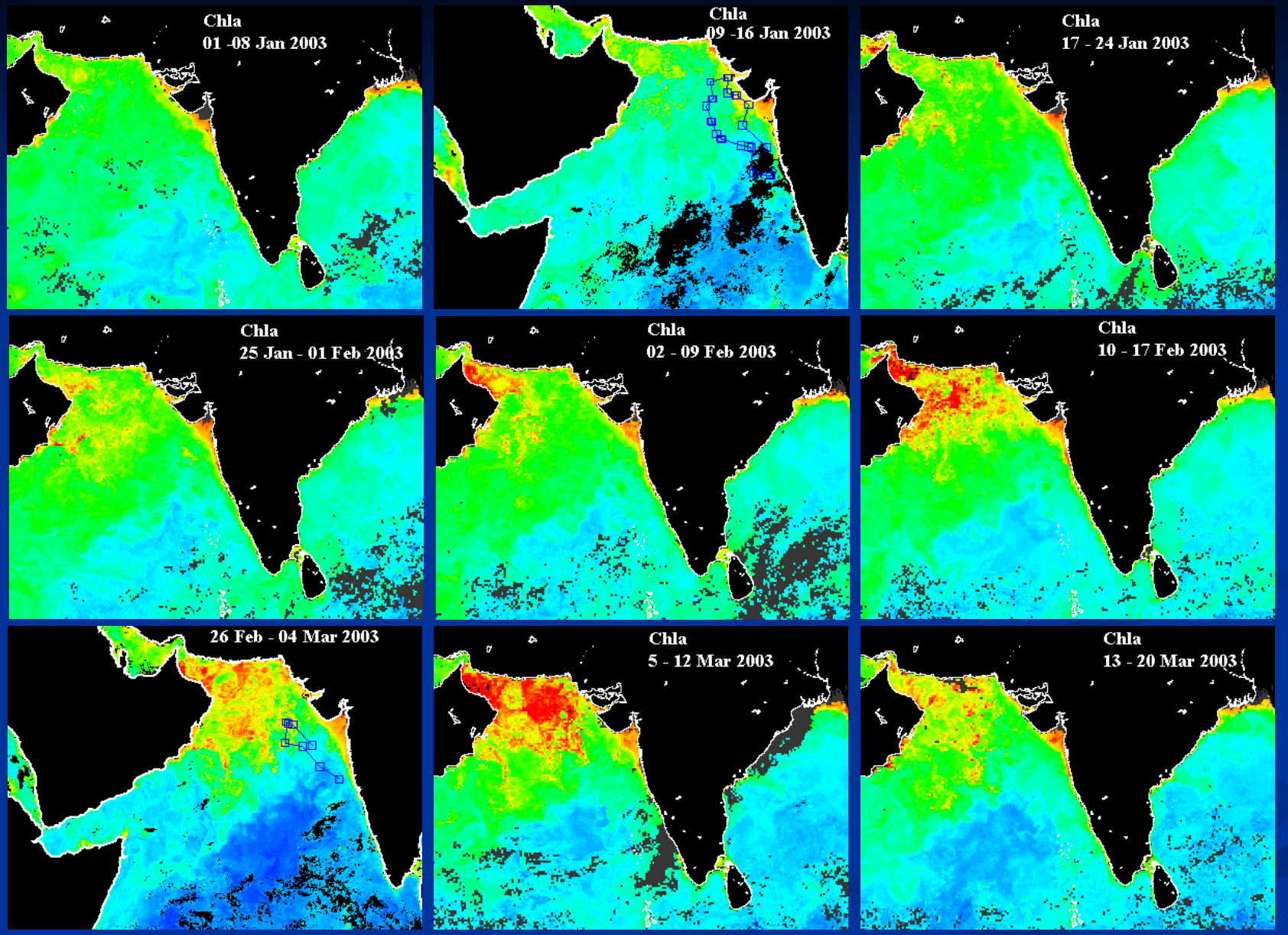


Schematic showing the SW Monsoon response of the Arabian Sea to snow cover over the Himalayan-Tibetan Plateau

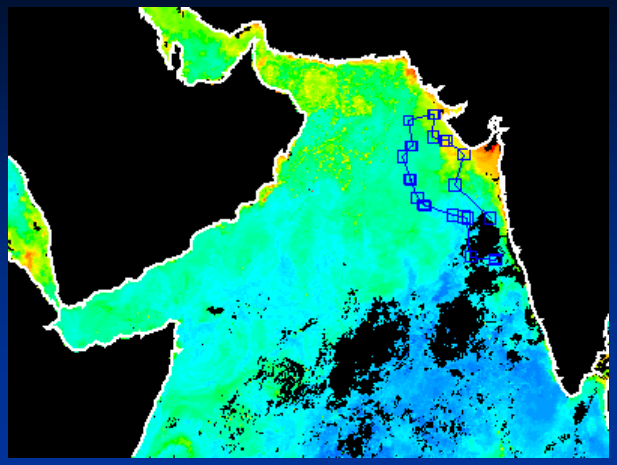


Interannual changes in chlorophyll along coast of Somalia since 1997

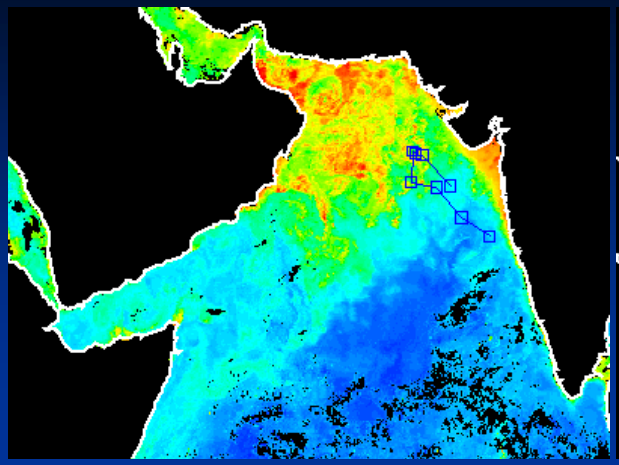
Goes et al. Science, 2005


Chla
01 -08 Jan 2003
Chla
09 -16 Jan 2003
Chla
17 - 24 Jan 2003
Chla
25 Jan - 01 Feb 2003
Chla
02 - 09 Feb 2003
Chla
10 - 17 Feb 2003
26 Feb - 04 Mar 2003
Chla
5 - 12 Mar 2003
Chla
13 - 20 Mar 2003

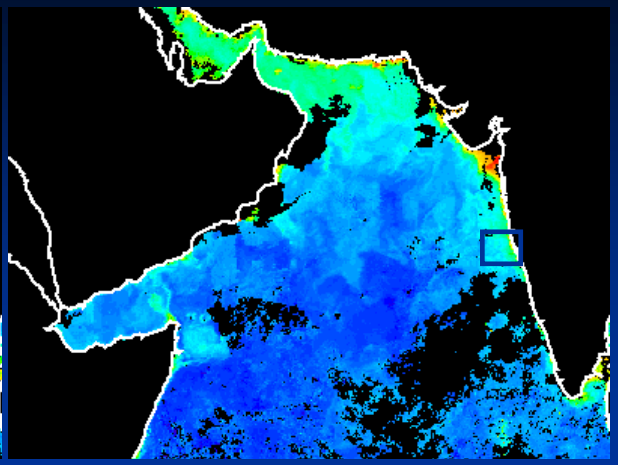
CRUISE TRACKS AND BLOOM SAMPLING



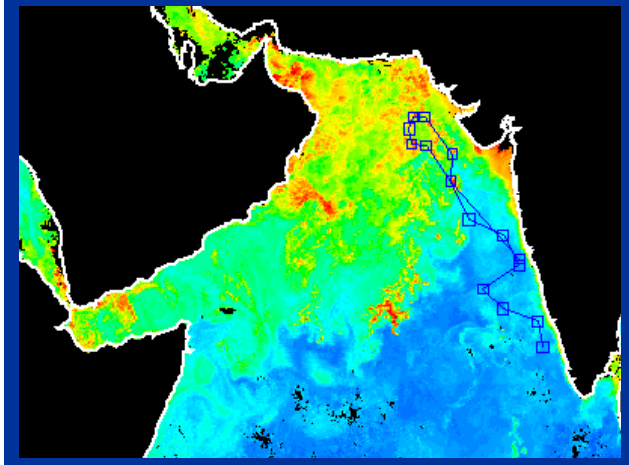
CR-1-JAN-2003 (3rd-19th Jan 2003) Northeast monsoon



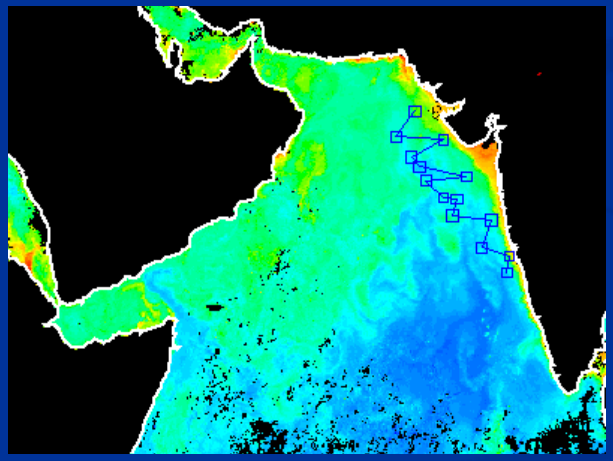
CR-2-MAR-2003 (27th Feb-5th Mar 2003) Spring Intermonsoon



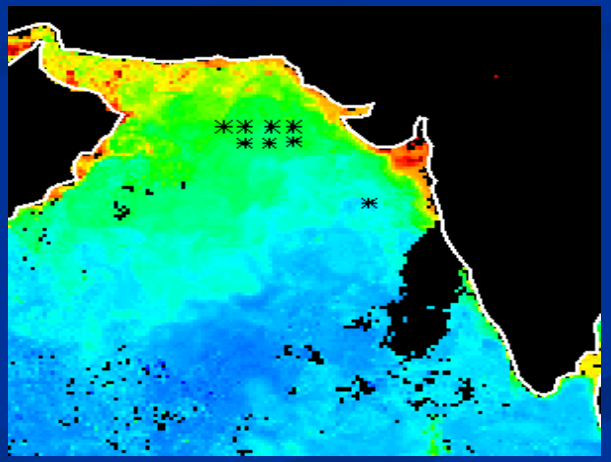
CR-3-MAY-2003 (2nd-5th May 2003) Pre-SW monsoon



CR-4-MAR-2004 (22nd Feb - 8th Mar 2004) Spring Intermonsoon



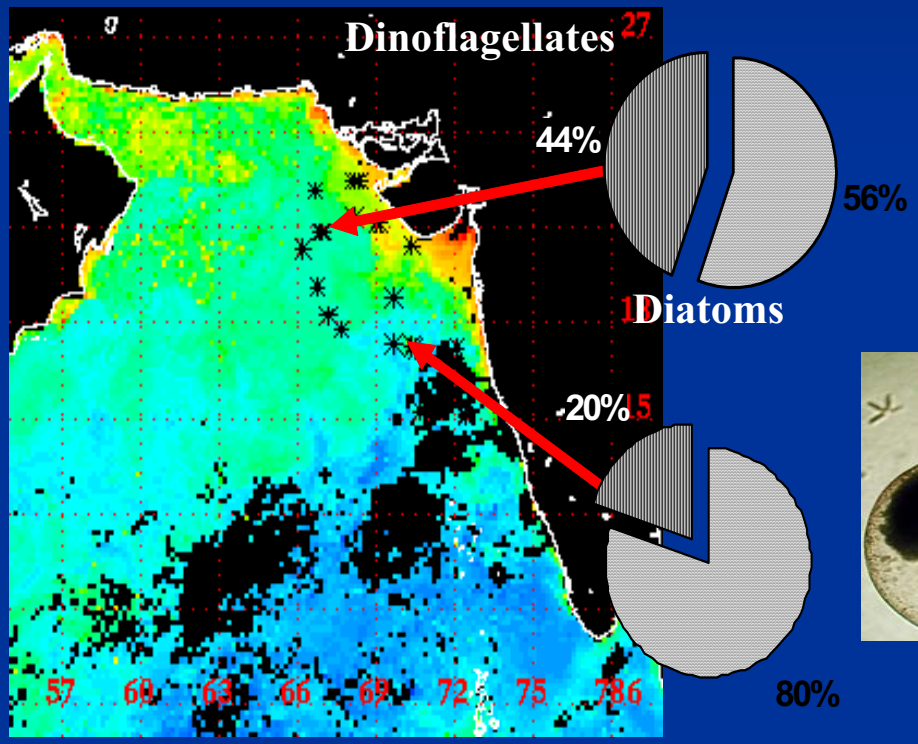
CR-5-DEC-2004 (4th -17th Dec 2004) Northeast monsoon



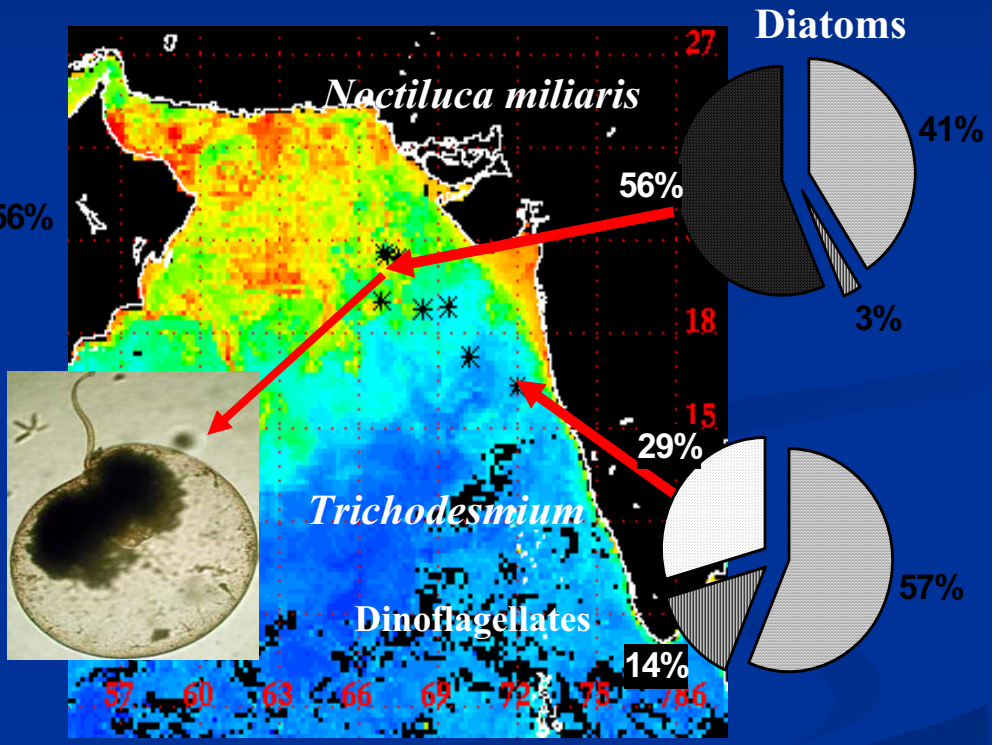
CR-6-MAR-2007 (1st - 15th March 2007) Spring Intermonsoon

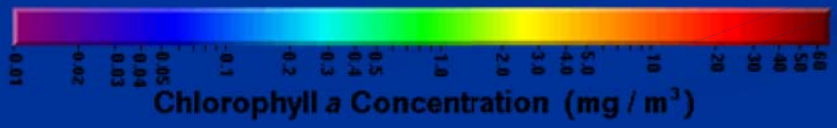
PHYTOPLANKTON TAXA ASSOCIATED WITH THE BLOOM OF 2003

WINTER MONSOON JAN 2003

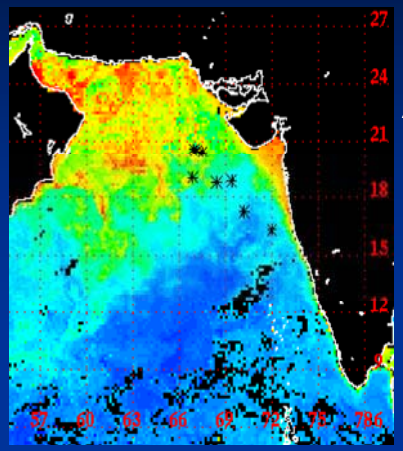


SPRING INTERMONSOON MAR 2003





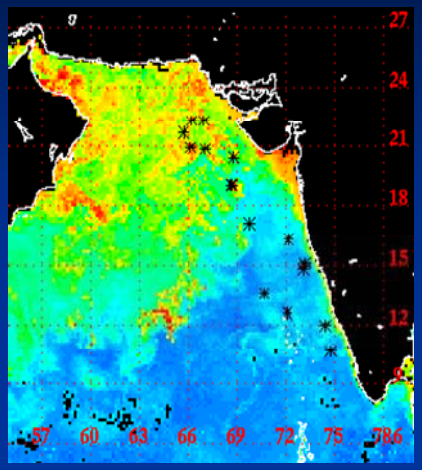
OCCURENCES OF *NOCTILUCA MILIARIS*



ARABIAN SEA MARCH 2003

Surface *N. miliaris*

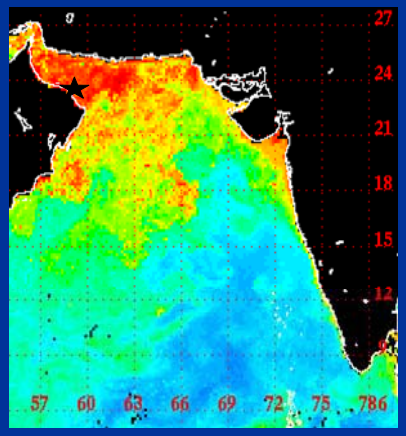
Ave 1794±1620 cells L^{-1}
Range 64 - 4128
Stations: 7 out of 8



ARABIAN SEA MARCH 2004

Surface *N. miliaris*

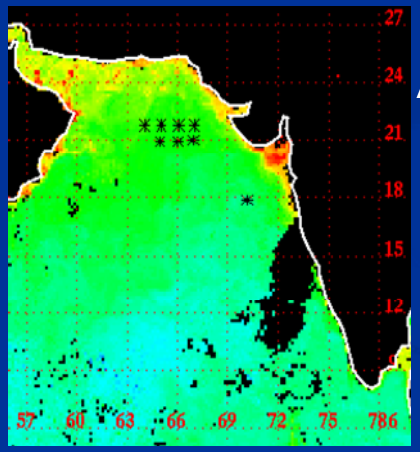
Ave 845±827 cells L^{-1}
Range 60 - 2494
Stations: 8 out of 16



GULF OF OMAN JAN 2006

Surface *N. miliaris*

Ave 1563±907 cells L^{-1}
Range 690 - 2500
Stations: 3

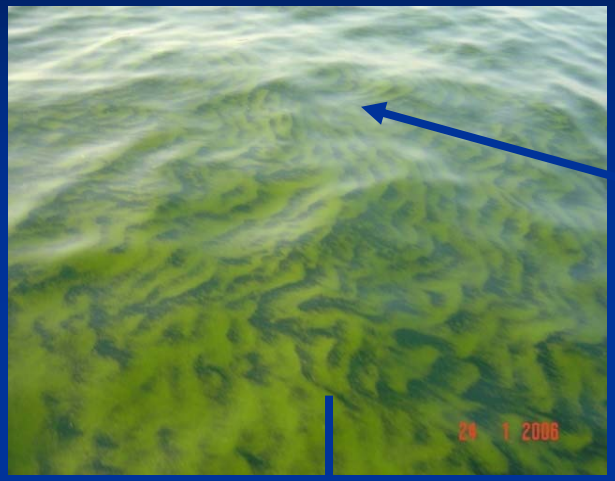


ARABIAN SEA MARCH 2007

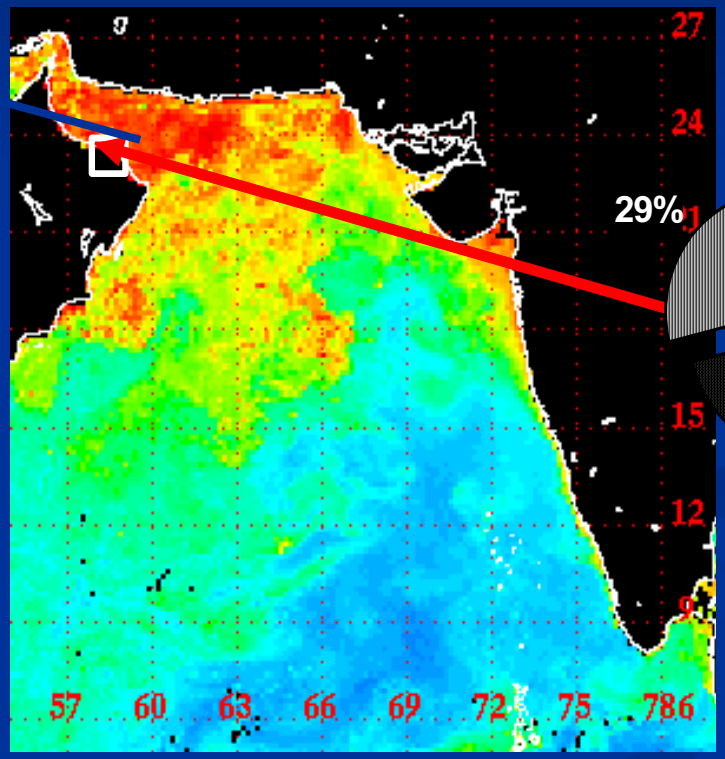
Surface *N. miliaris*

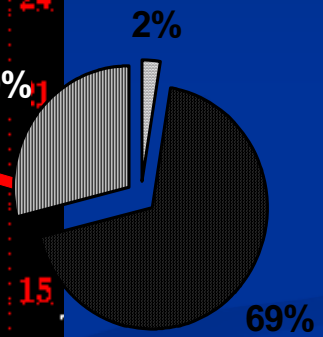
Ave *1*845±2801 cells L^{-1}
Range48 - 7200
Stations: 7 out of 8

NOCTILUCA MILIARIS BLOOM IN THE GULF OF OMAN, 24TH JAN 2006

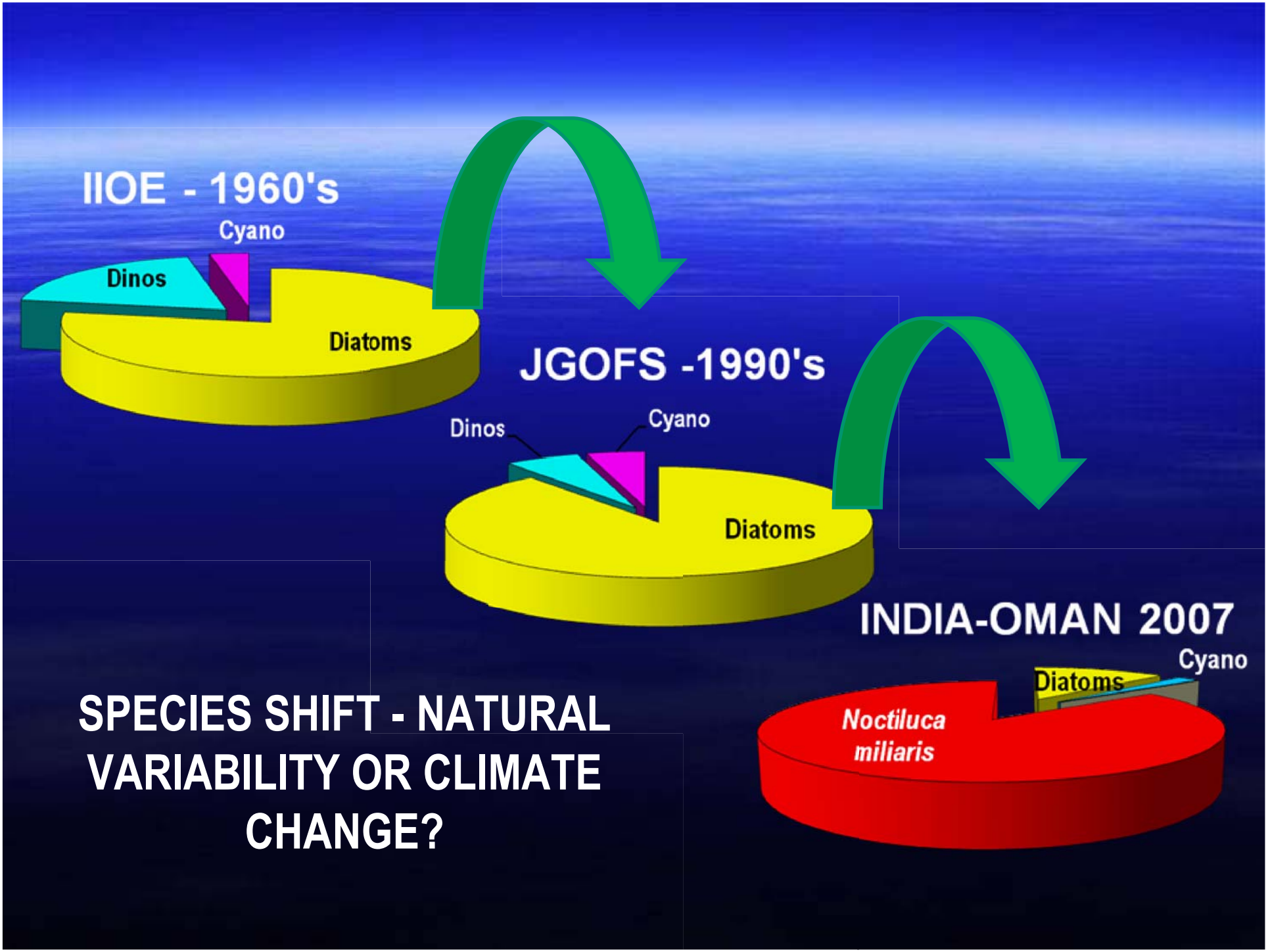


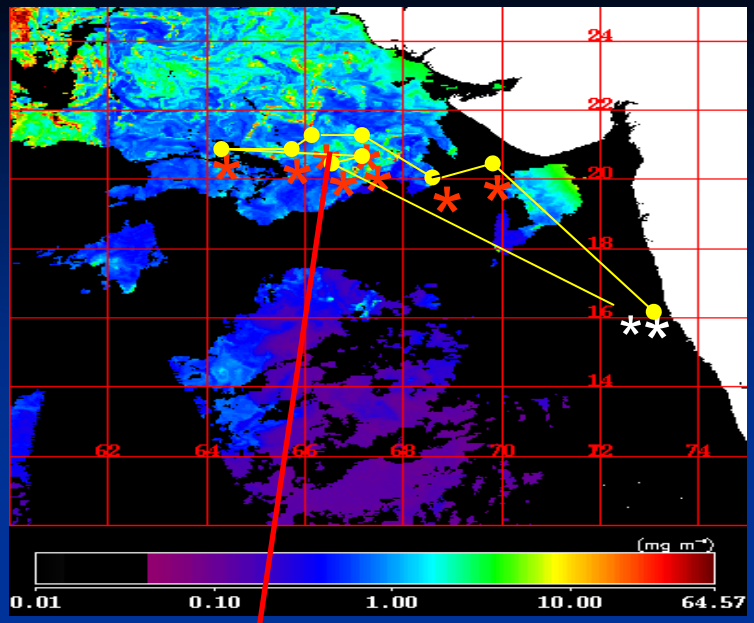
Pedinomonas noctilucae



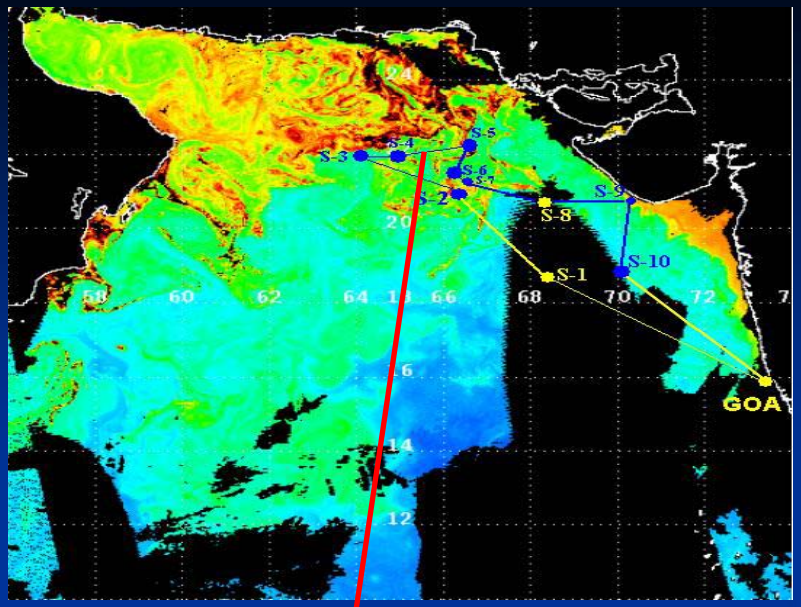


Dinoflagellate, which thrives in (cold) <22°C, nutrient rich and oxygen poor waters

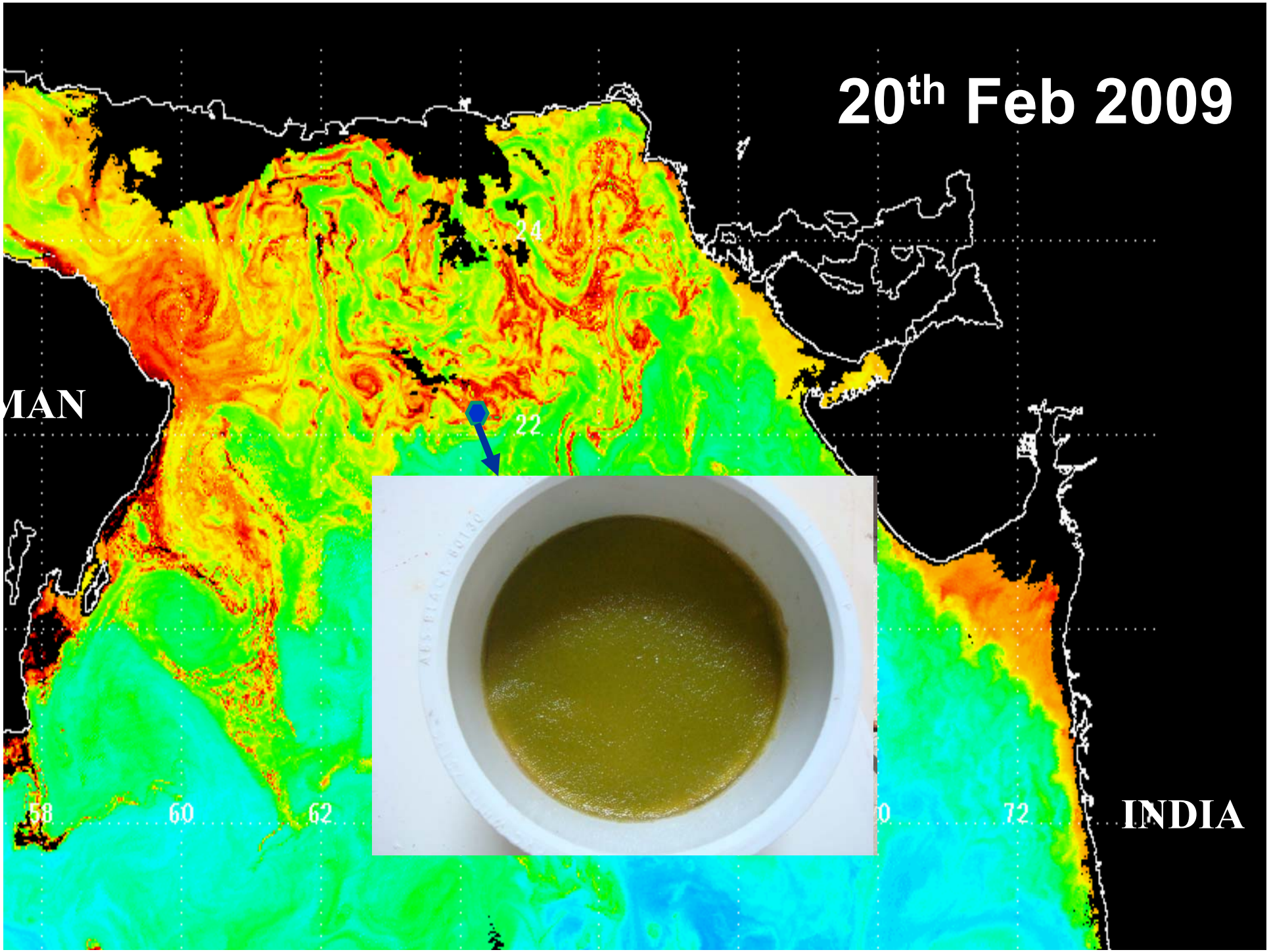

IIOE - 1960's
Cyano
Dinos
Diatoms
JGOFS -1990's
Dinos
Cyano
Diatoms
INDIA-OMAN 2007
Cyano
Diatoms
Noctiluca miliaris
SPECIES SHIFT - NATURAL VARIABILITY OR CLIMATE CHANGE?



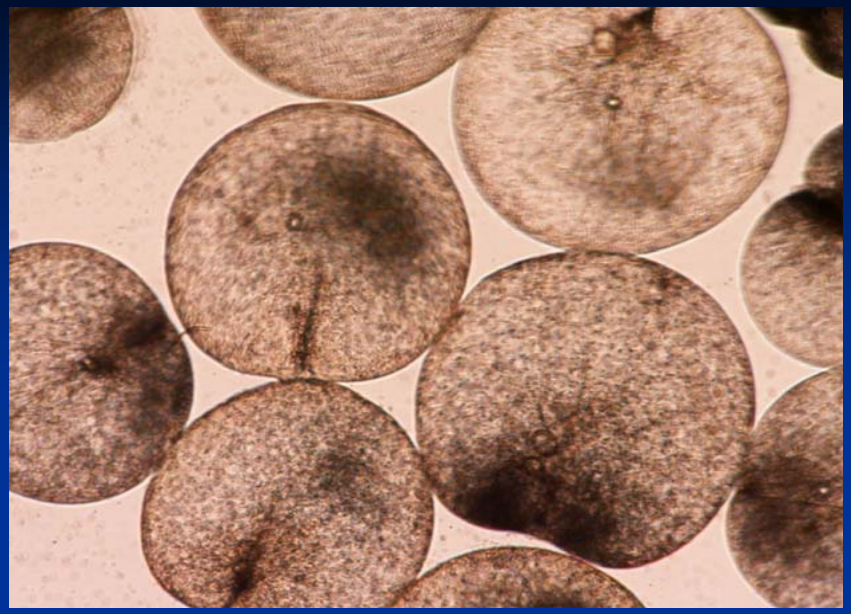
CR-7-FEB-2009 (9th - 23rd Feb 2009) Spring Intermonsoon

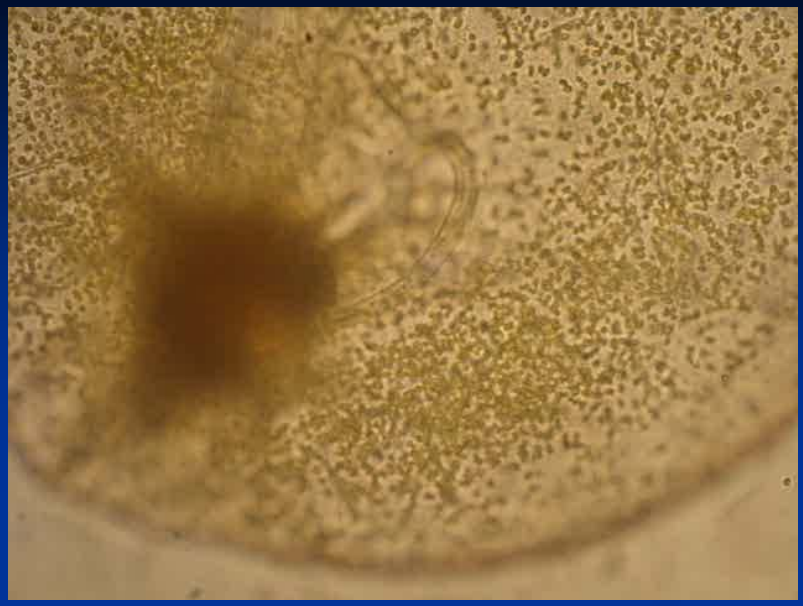


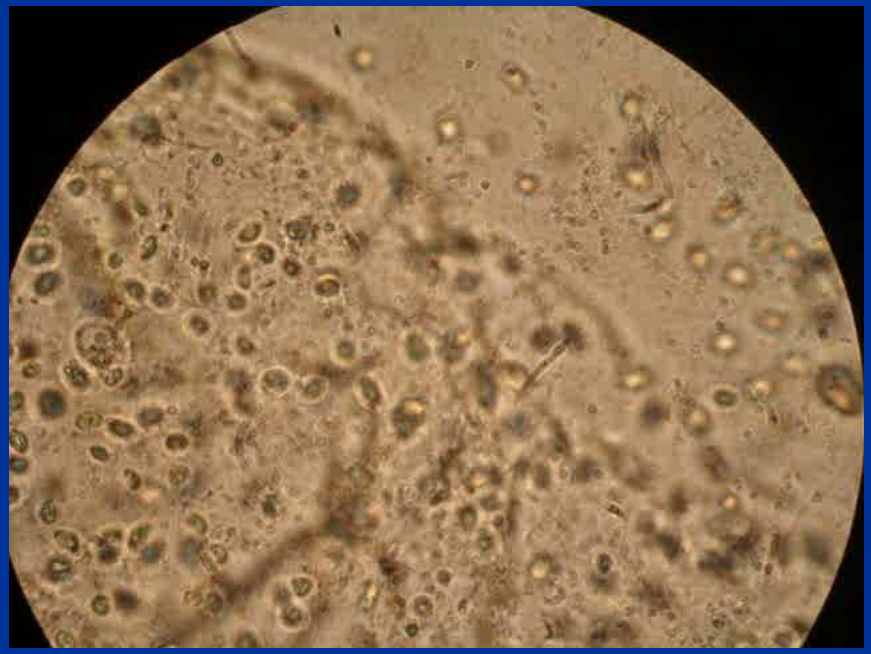
CR-8-MAR-2009 (27th Feb- 13th Mar 2009) Spring Intermonsoon

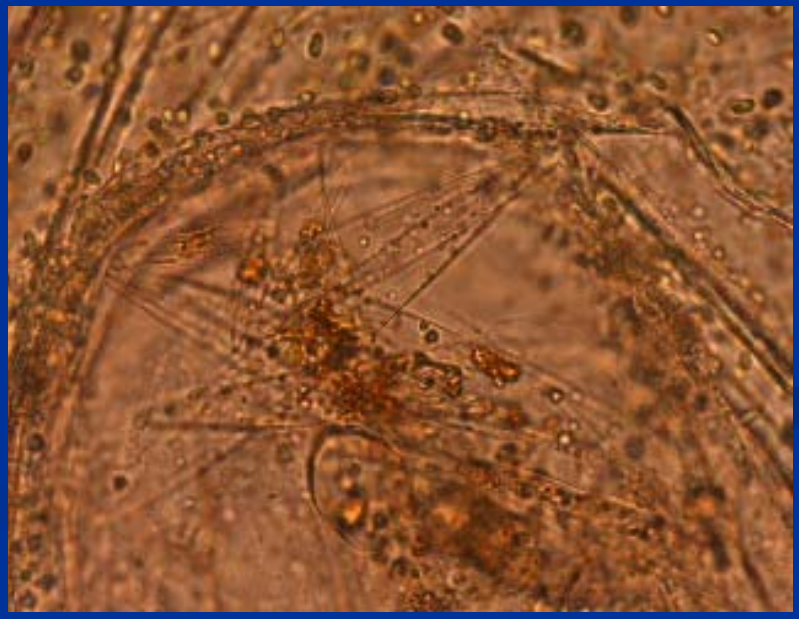

20th Feb 2009
MAN
24
22
58
60
62
72
INDIA

NOCTILUCA - MICROSCOPY

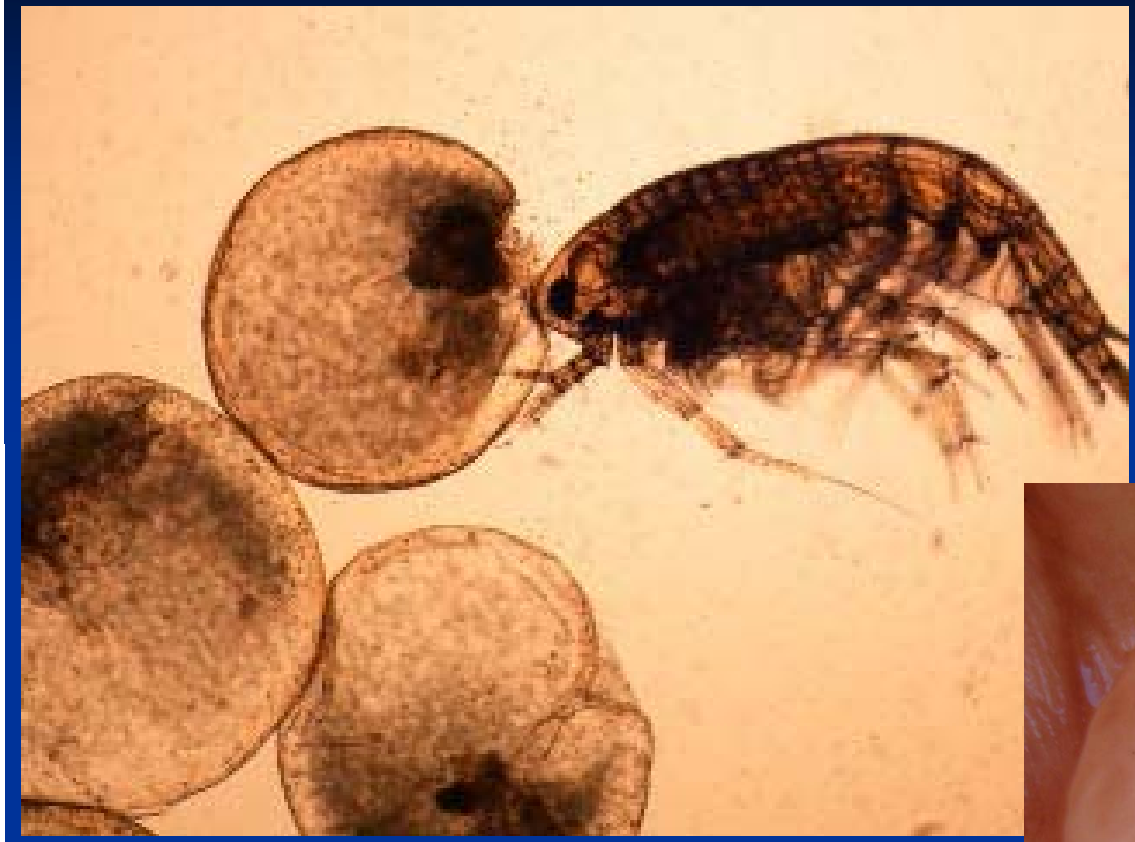








ALTERATIONS IN FOOD WEB STRUCTURE?



Summary Bacterial Counts

PEAK PHASE

AREA	Surface (10^8 cells L^{-1})		Column (10^{14} Cells m^{-2})	
	MAX	MIN	MAX	MIN
BLOOM	192	6.32	2.55	0.47
NON BLOOM	14.43	8.51	0.58	0.08

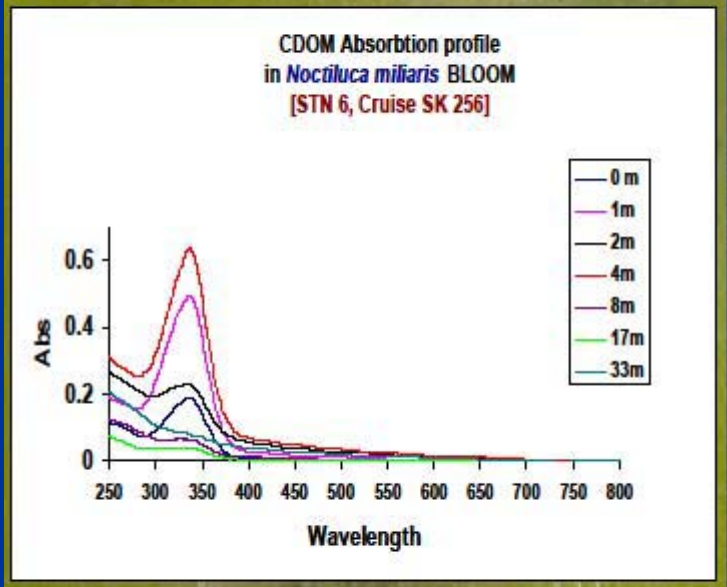
DECLINING PHASE

AREA	Surface (10^8 cells L^{-1})		Column (10^{14} Cells m^{-2})	
	MAX	MIN	MAX	MIN
BLOOM	33.6	5.62	2.04	0.25
NON BLOOM	20.6	4.29	0.39	0.28

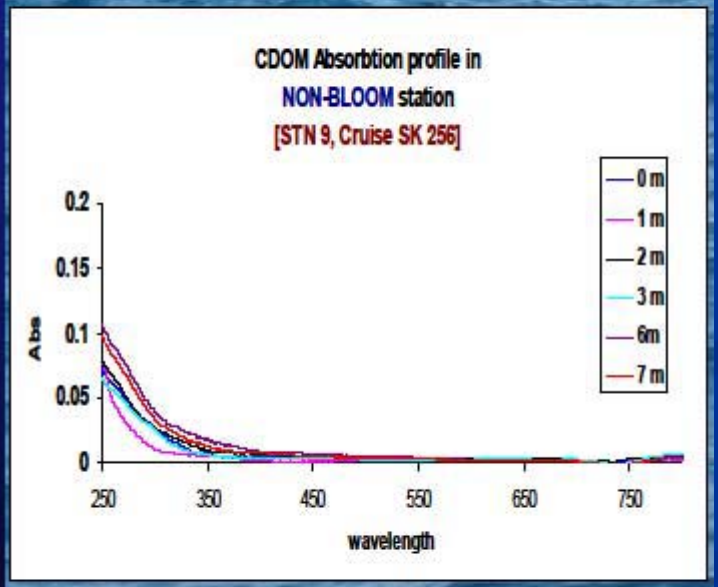
Key results:

1. Total Bacterial counts significantly higher in localized *Noctiluca* Bloom patches compared to the non-bloom areas of the N-E Arabian Sea
2. Bacterial counts from *Noctiluca* Bloom patches are the highest reported so far from the Arabian Sea.

CDOM PROFILES - BLOOM to NON BLOOM

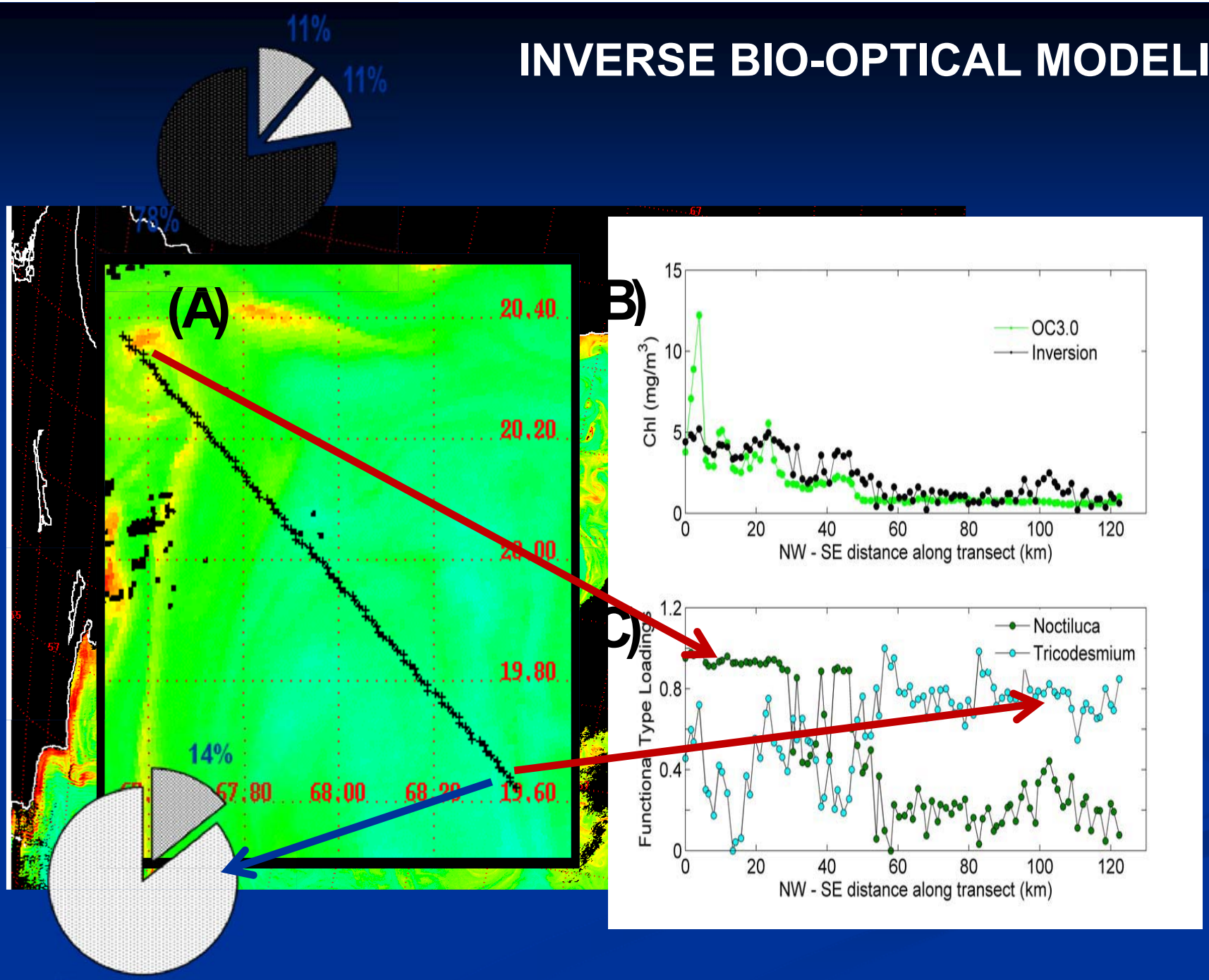


BLOOM



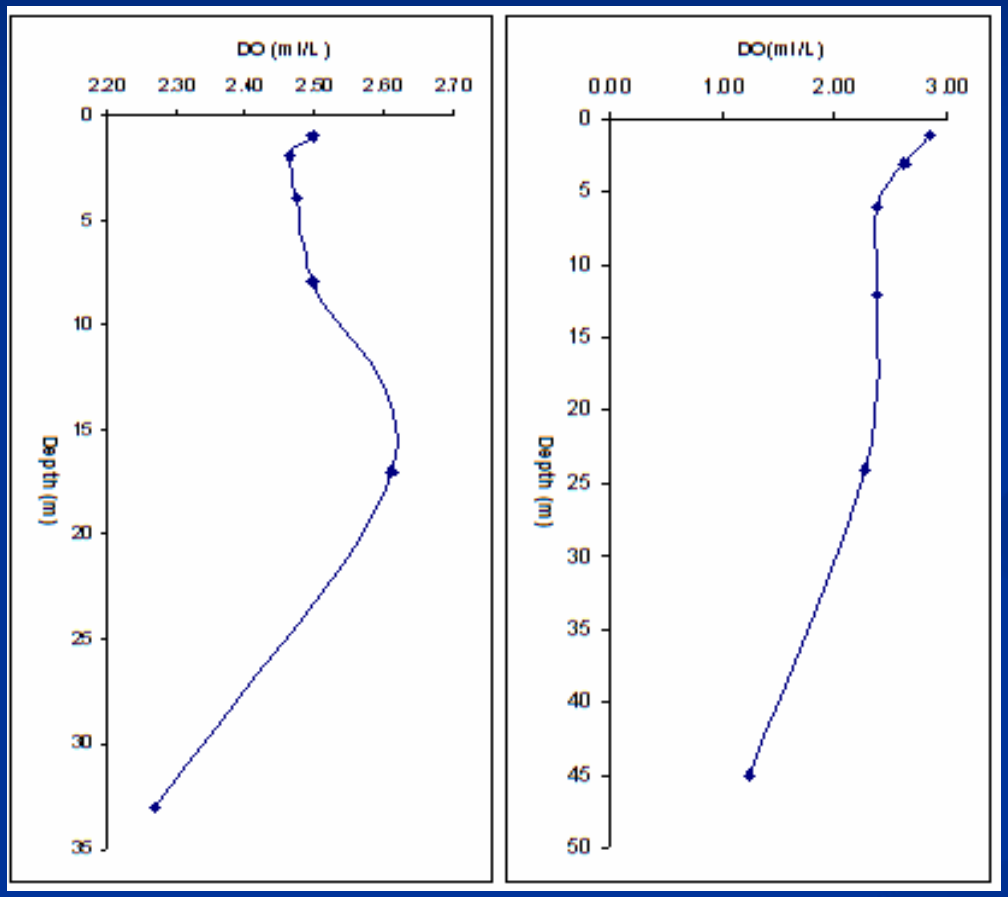
NON - BLOOM

INVERSE BIO-OPTICAL MODELING

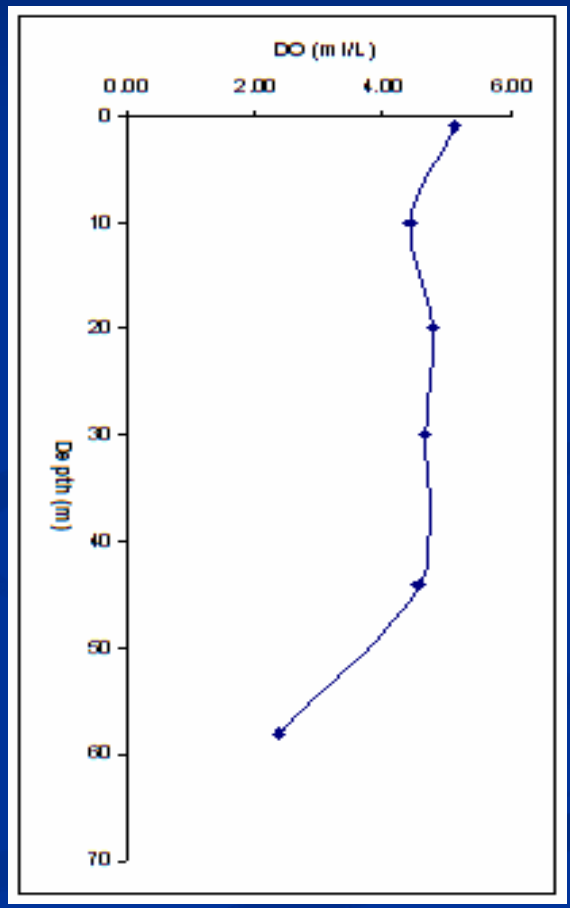


Dissolved Oxygen profiles in 2009

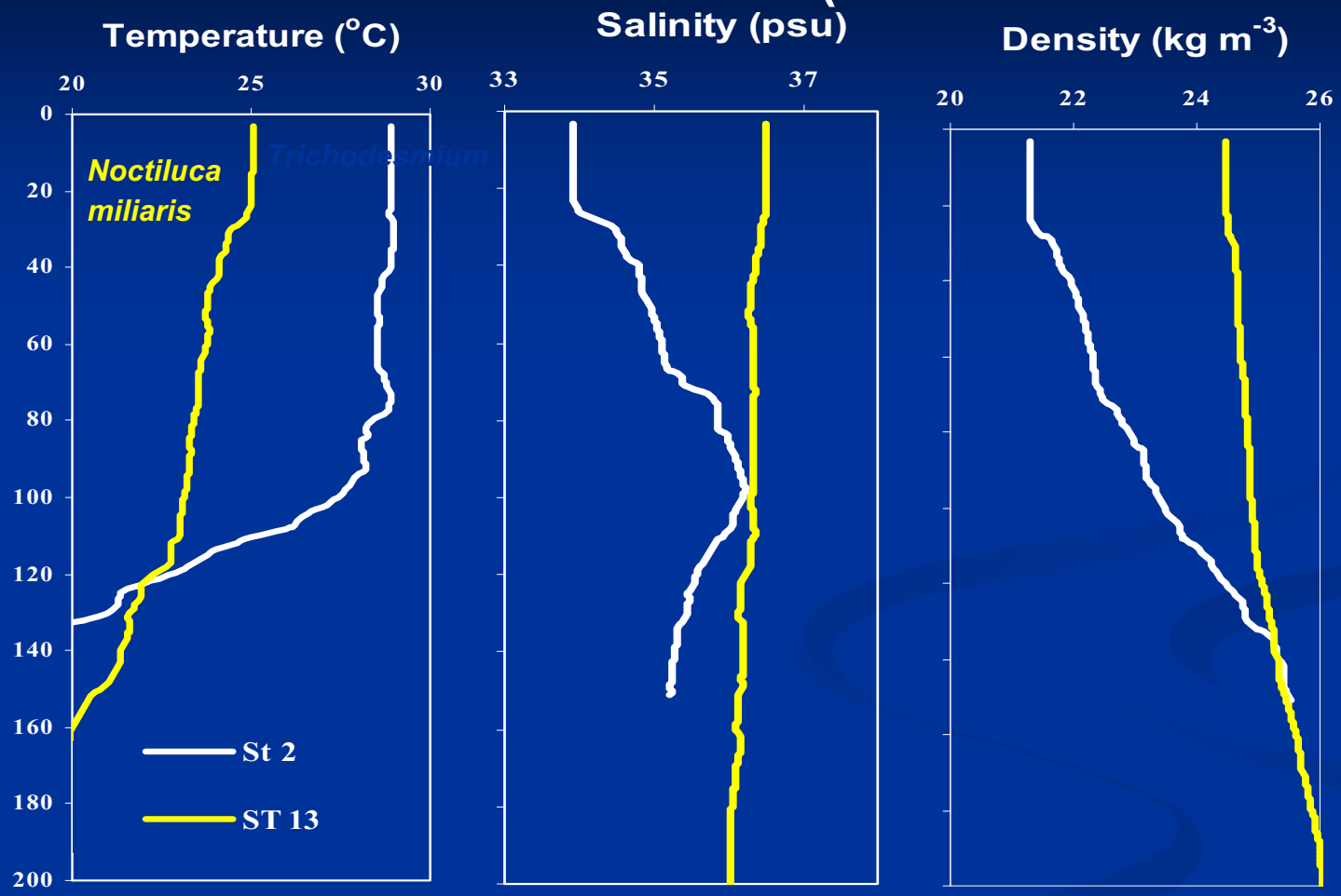
BLOOM AREA



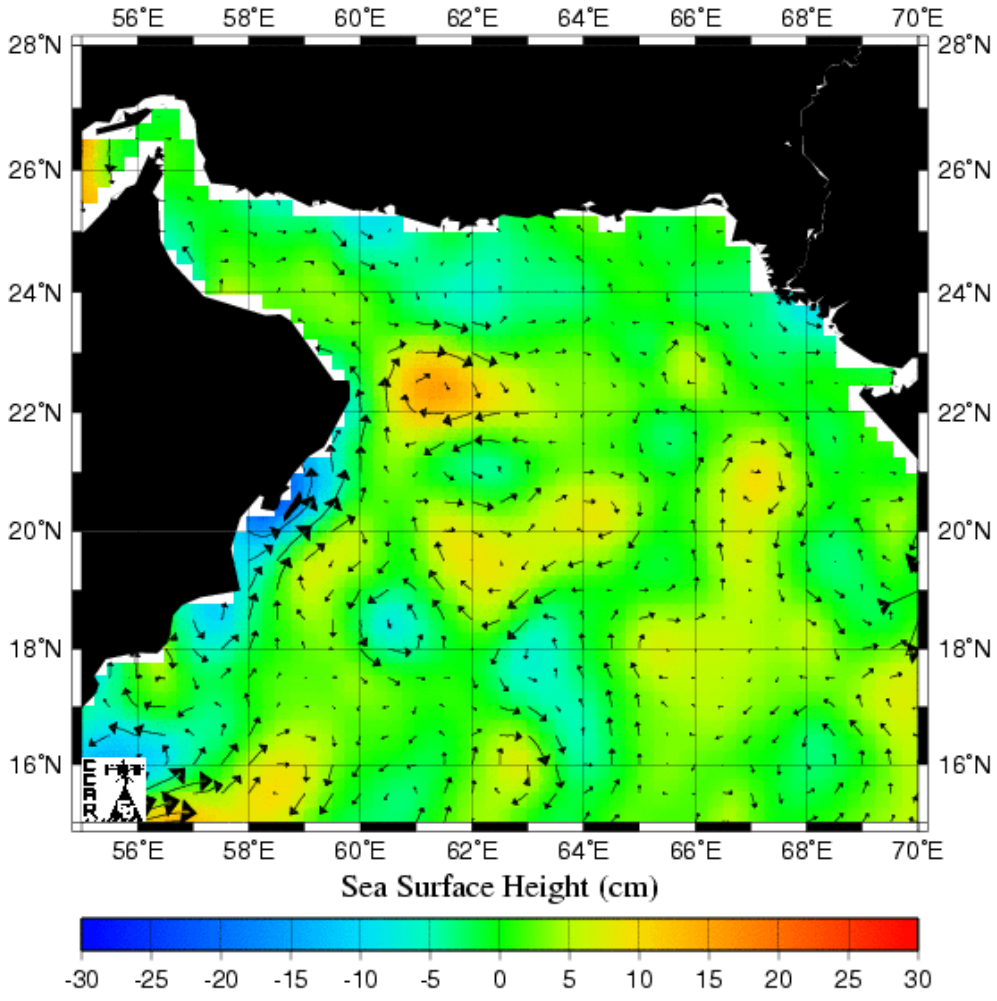
NON-BLOOM AREA

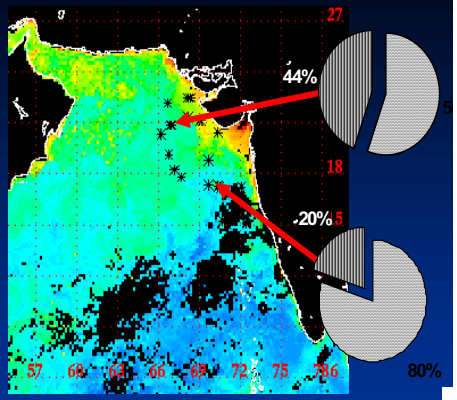


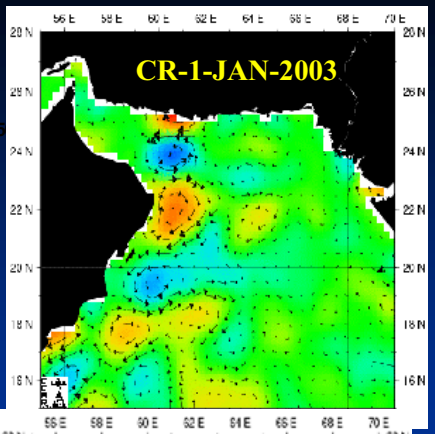
TYPICAL HYDROGRAPHY CONDITIONS AT TWO STATIONS SAMPLED ON CRUISE FORV 222 (22nd Feb-8th Mar 2004)

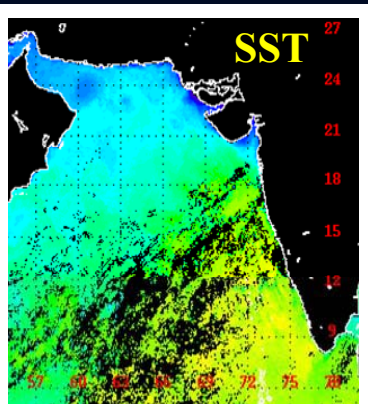


Historical Mesoscale Altimetry - Jun 1, 2002




44%
20%
80%


CR-1-JAN-2003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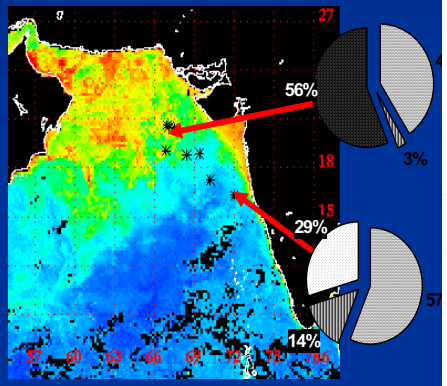
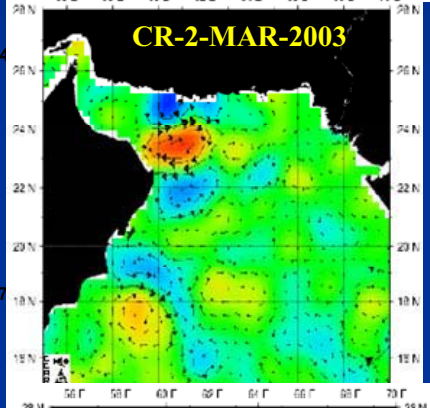
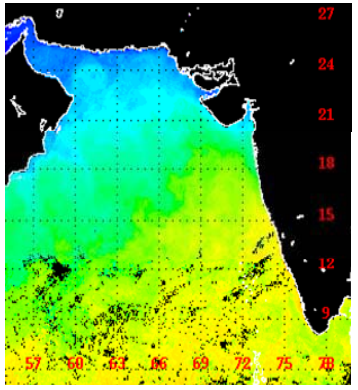
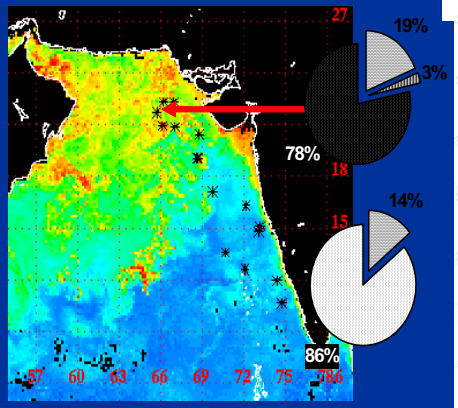
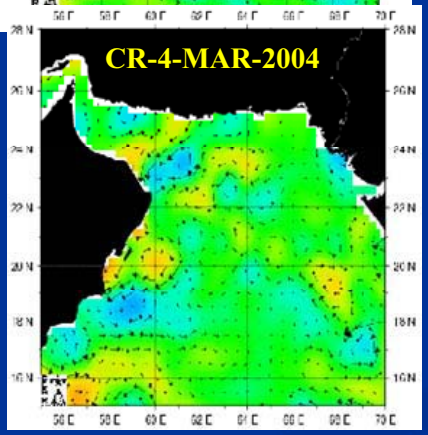
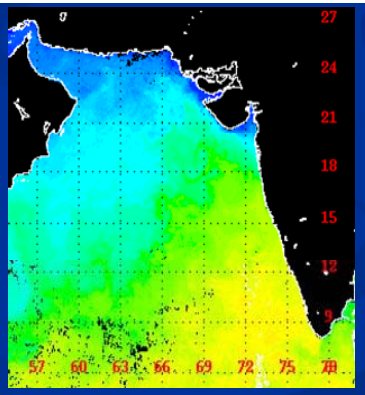

56%
3%
29%
14%

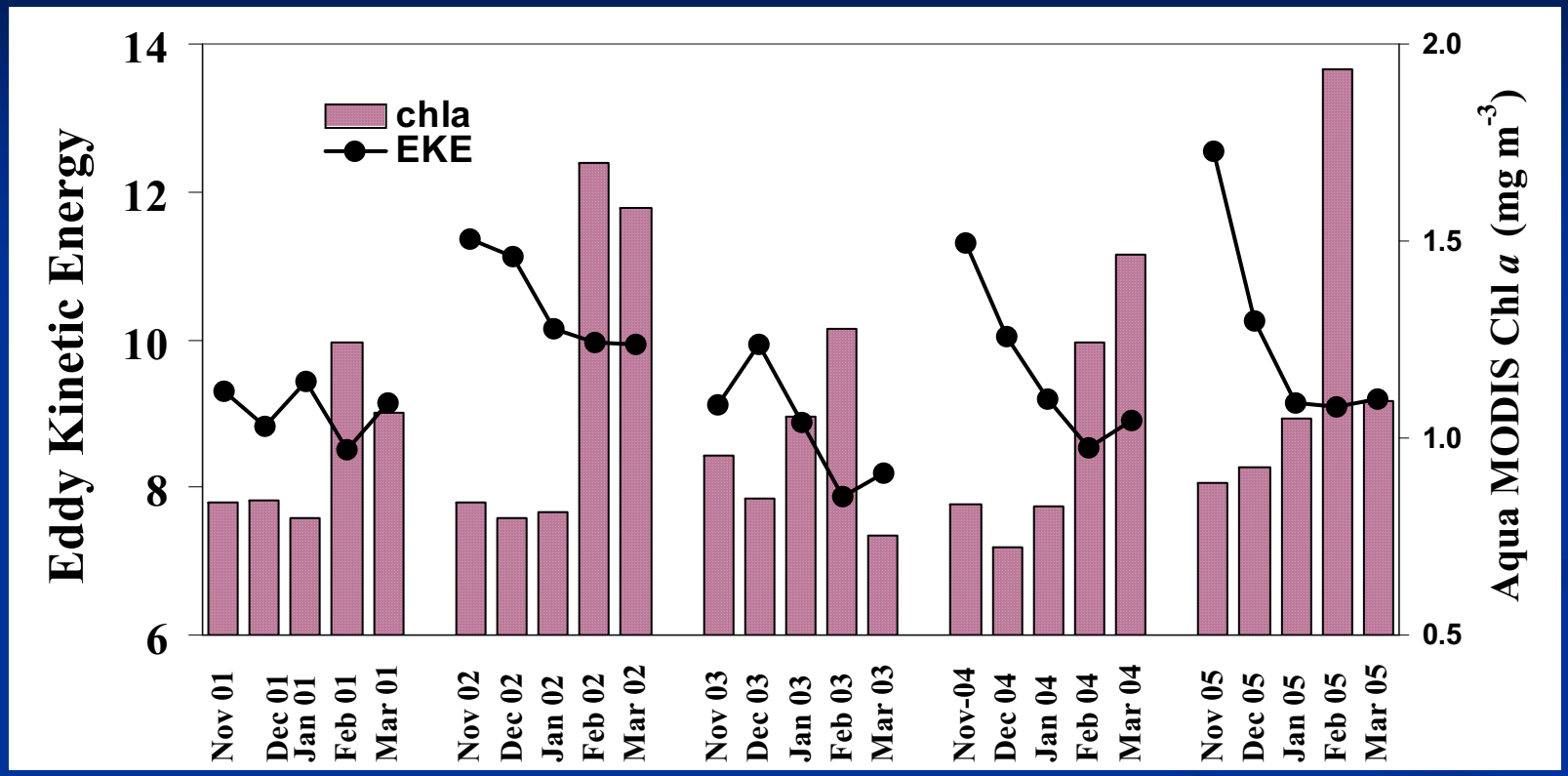

CR-2-MAR-2003




19%
3%
78%
14%
86%


CR-4-MAR-2004




Eddy Kinetic Energy
Aqua MODIS Chl a (mg m-3)
chla
EKE
14
12
10
8
6
2.0
1.5
1.0
0.5
Nov 01
Dec 01
Jan 01
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Mar 01
Nov 02
Dec 02
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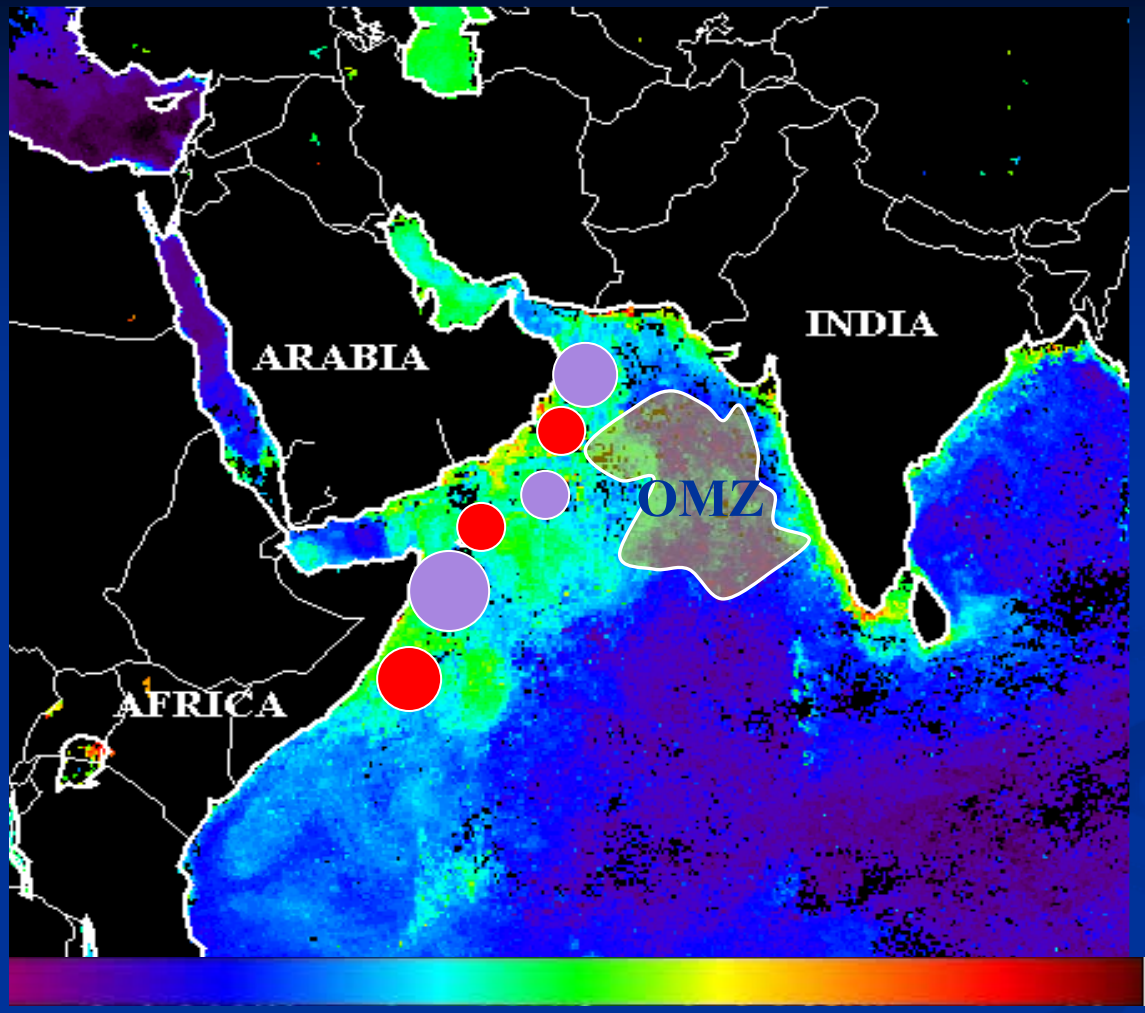
ARABIA
INDIA
OMZ
AFRICA

CONCLUSIONS

- **The appearance of *Noctiluca miliaris* in bloom proportions during the NEM is unprecedented as there are no previous reports of blooms of this organism during International JGOFS program (1992-1996) or during International Indian Ocean Expeditions of the 1960's**
- **Winter blooms of diatom-dinoflagellate assemblages are short lived and are replaced by widespread blooms of *Noctiluca miliaris* in spring**
- ***Noctiluca miliaris* is predisposed to cold, oxygen poor waters**
- ***Noctiluca miliaris* is a mixotroph, it harbors a autotrophic symbiont but also actively grazes on phytoplankton**
- **The emergence and dispersal of the bloom is tied to the cold eddies that populate the Western Arabian Sea and which possibly bring up low oxygen waters from deeper depths**
- **With support from field data, ocean color satellite data can provide us with means to identify *Noctiluca miliaris***

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