Eurasian warming – hydrography and biological productivity in the Arabian Sea

"THE PLOT THICKENS"

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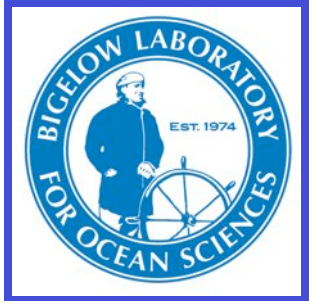
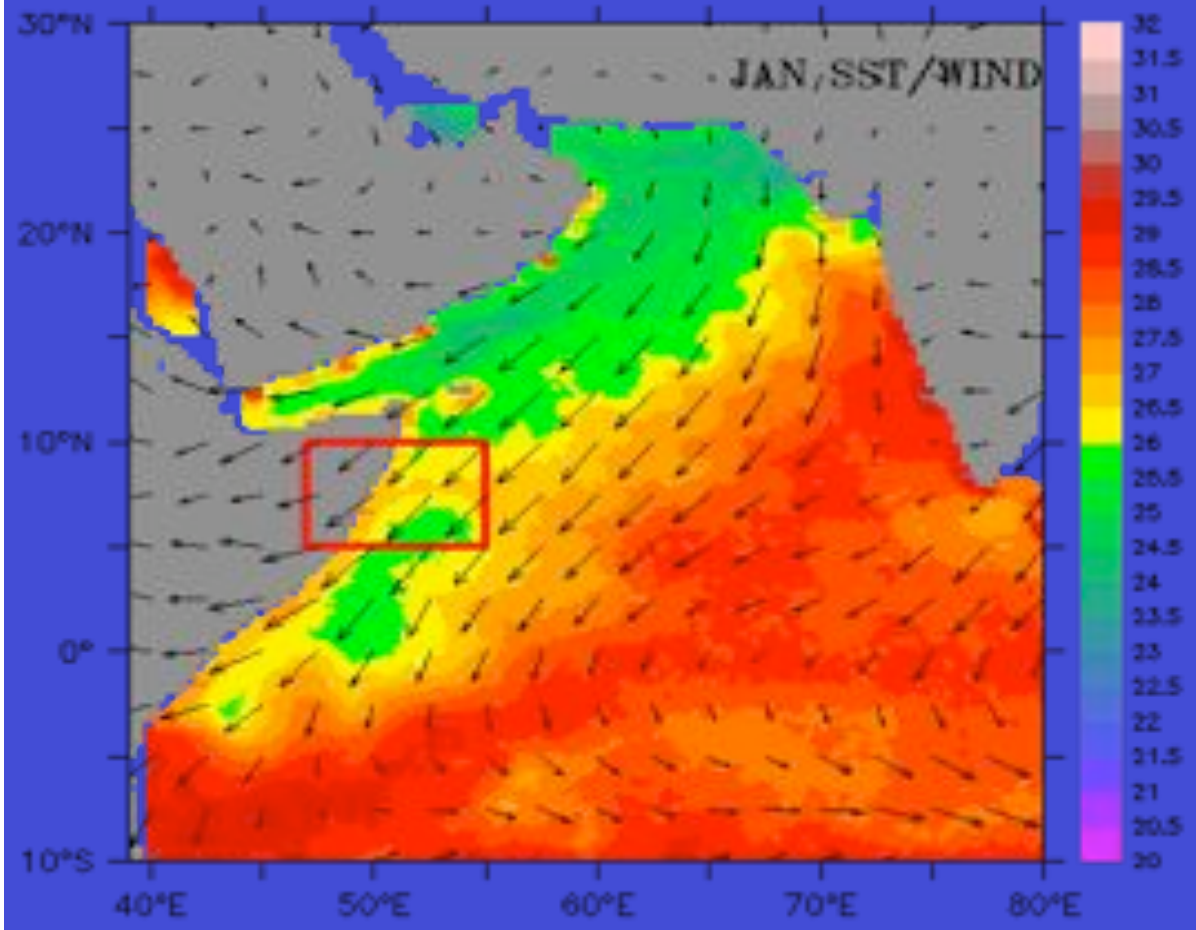
Sultan Qaboos University



ARABIAN SEA

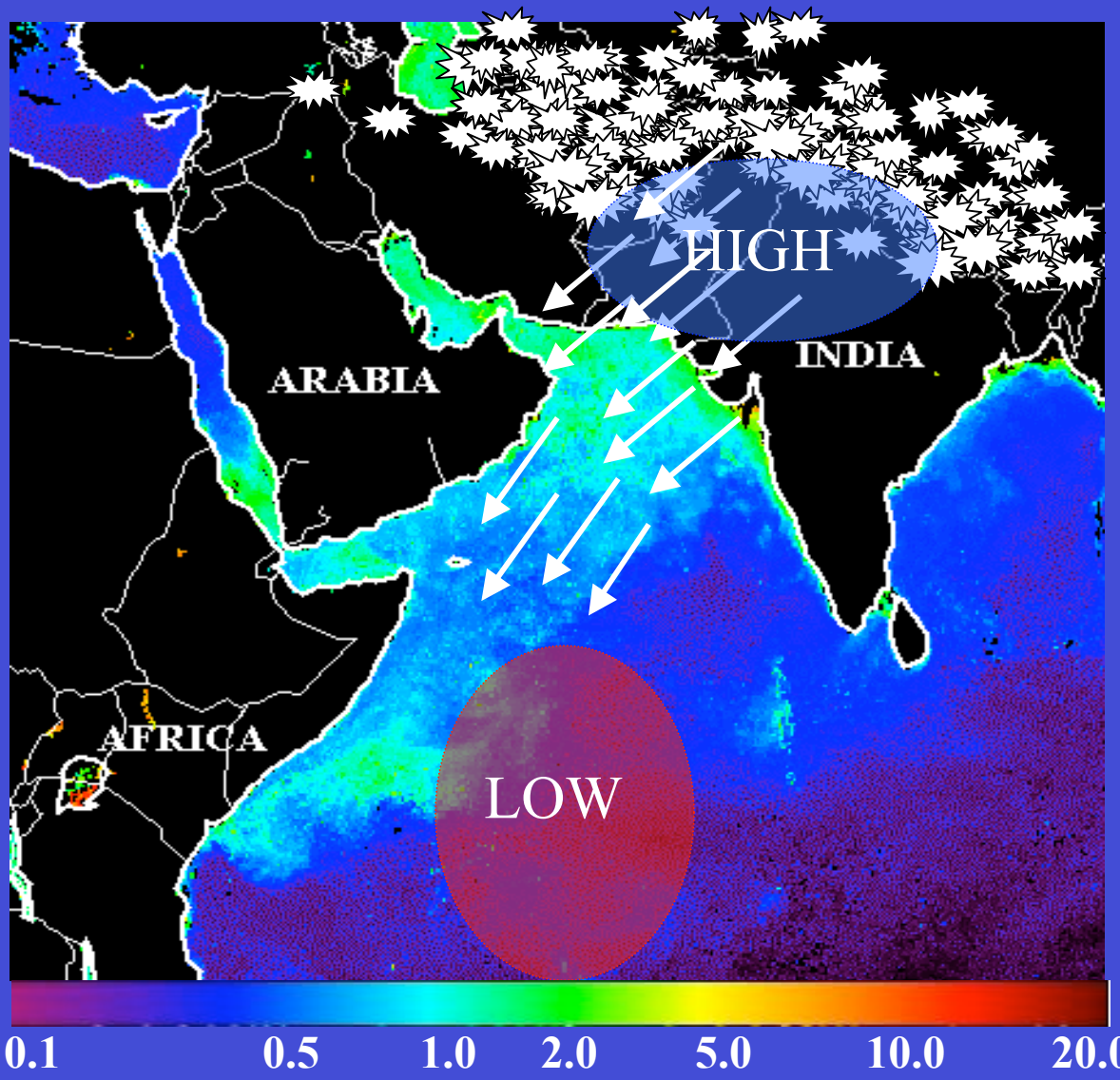


Landlocked to the north

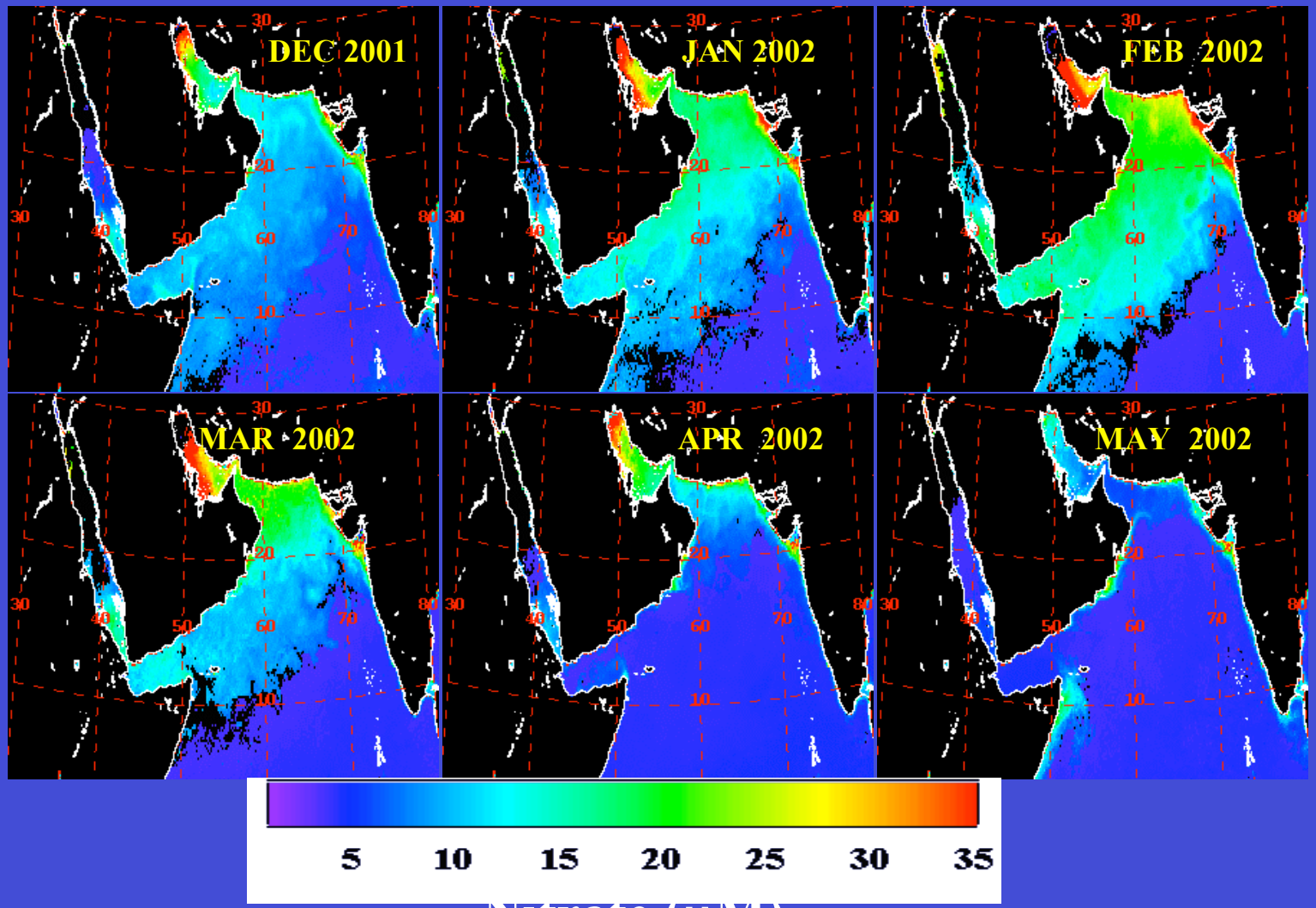
Comes under the influence of the monsoons which reverse direction seasonally driving one the most energetic currrent systems

Development and intensity regulated by thermal gradient between land and sea

WINTER MONSOON

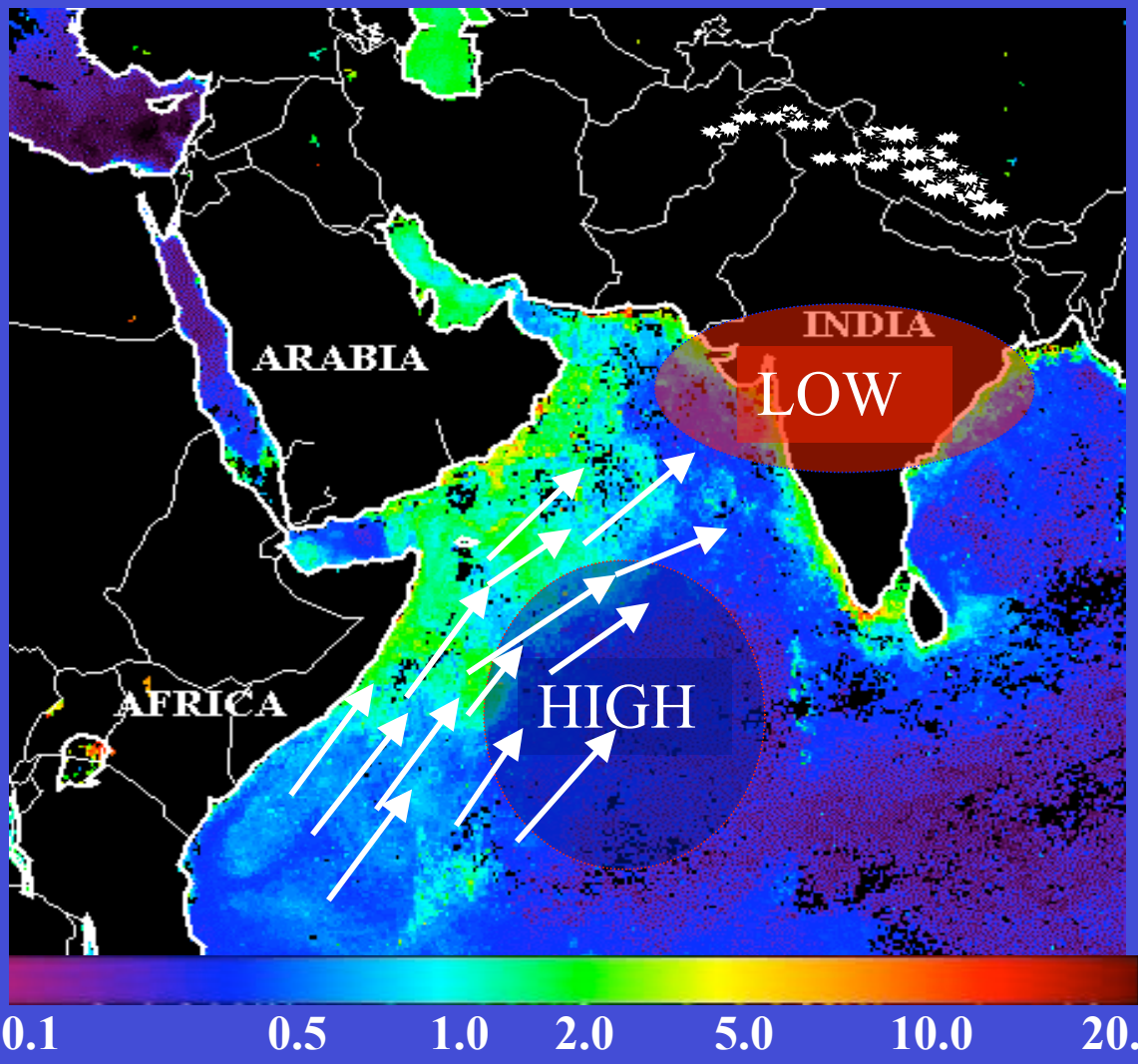


Schematic showing snow cover extent and wind direction superimposed on an ocean color chlorophyll image for the northeast monsoon season (Nov-Feb).

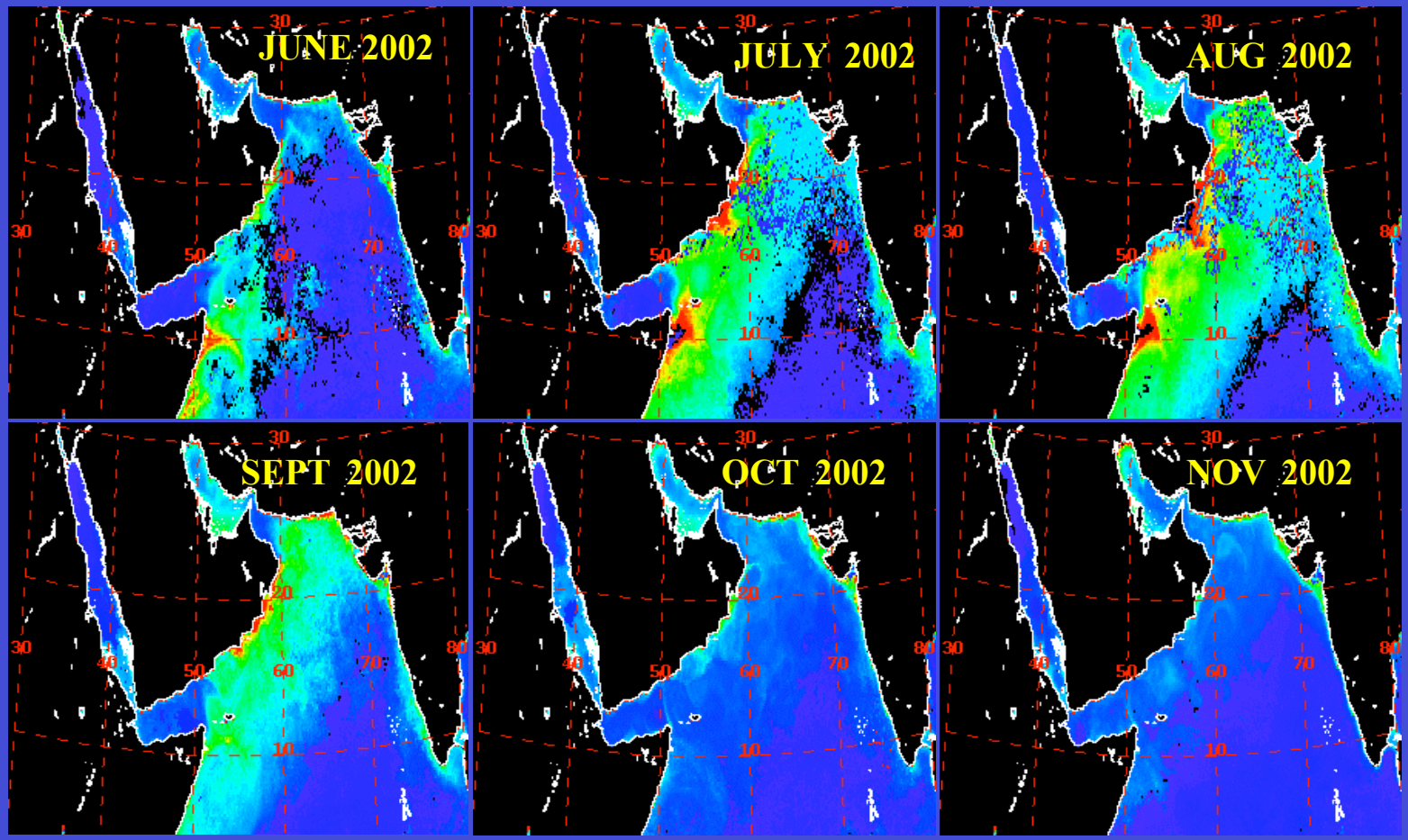


NITRATE INPUTS IN THE ARABIAN SEA DUE TO WINTER CONVECTIVE MIXING DURING NORTHEAST MONSOON

SUMMER MONSOON

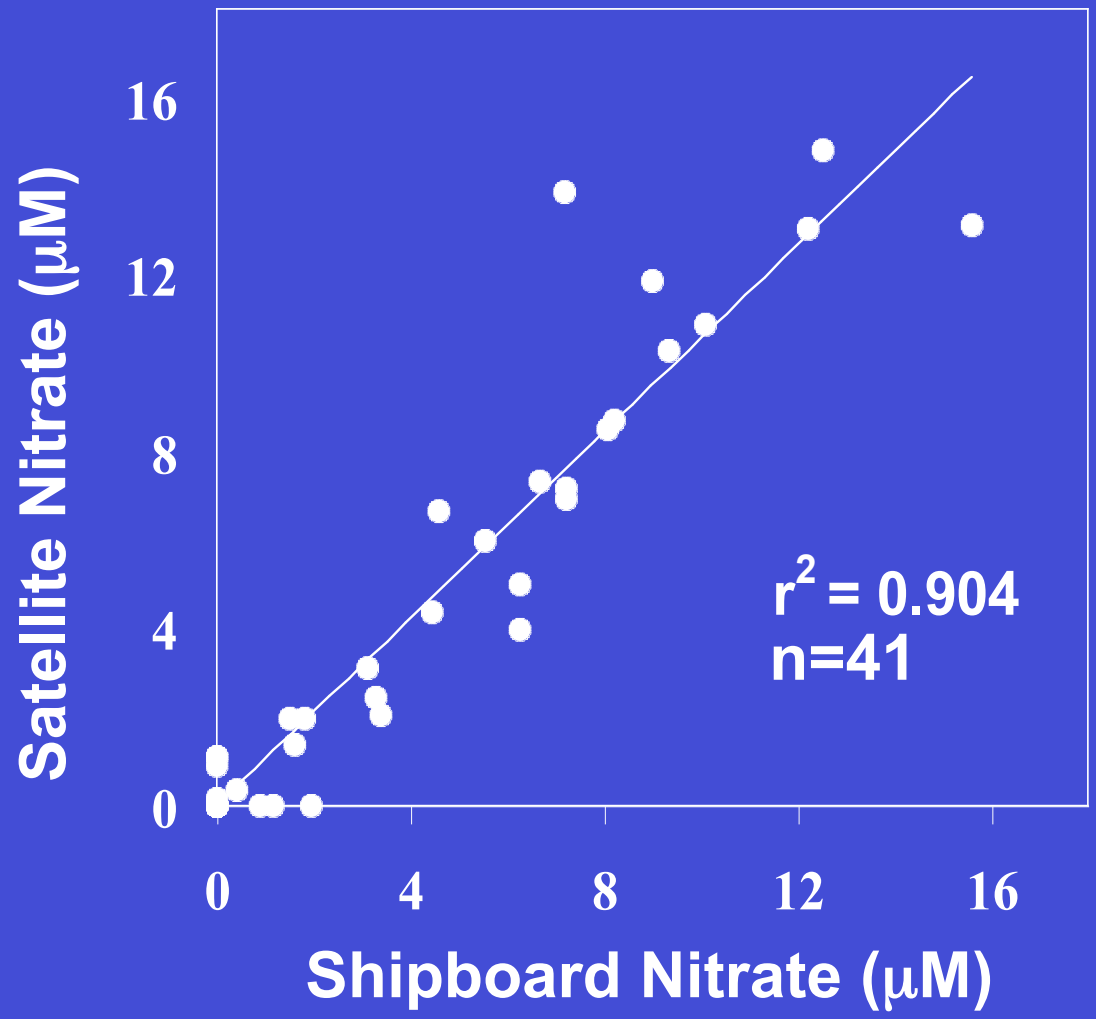


Schematic showing the reversal in wind direction during the southwest monsoon (Jun-Sept), superimposed on satellite derived chlorophyll fields

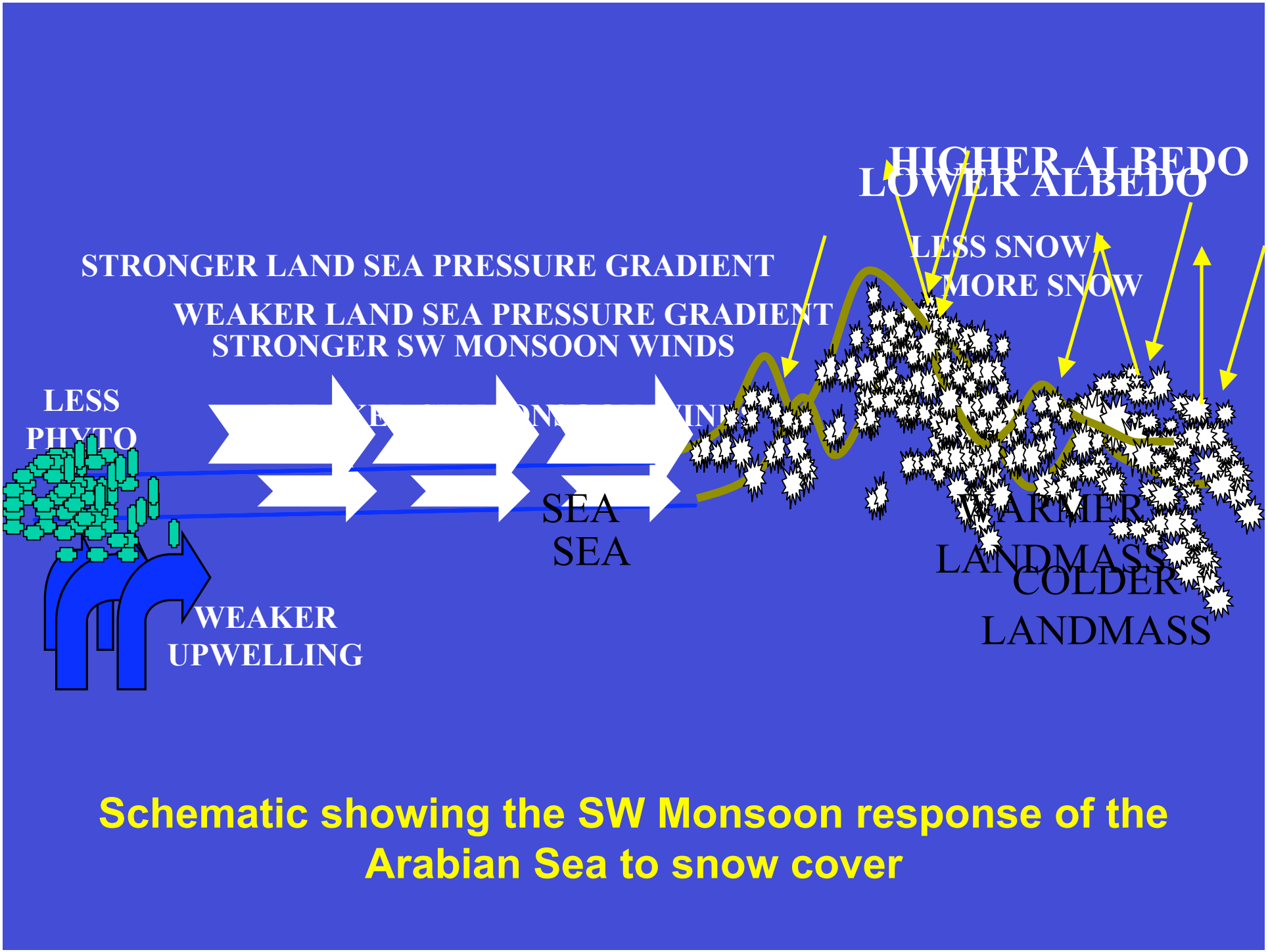


Nitrate (μM)

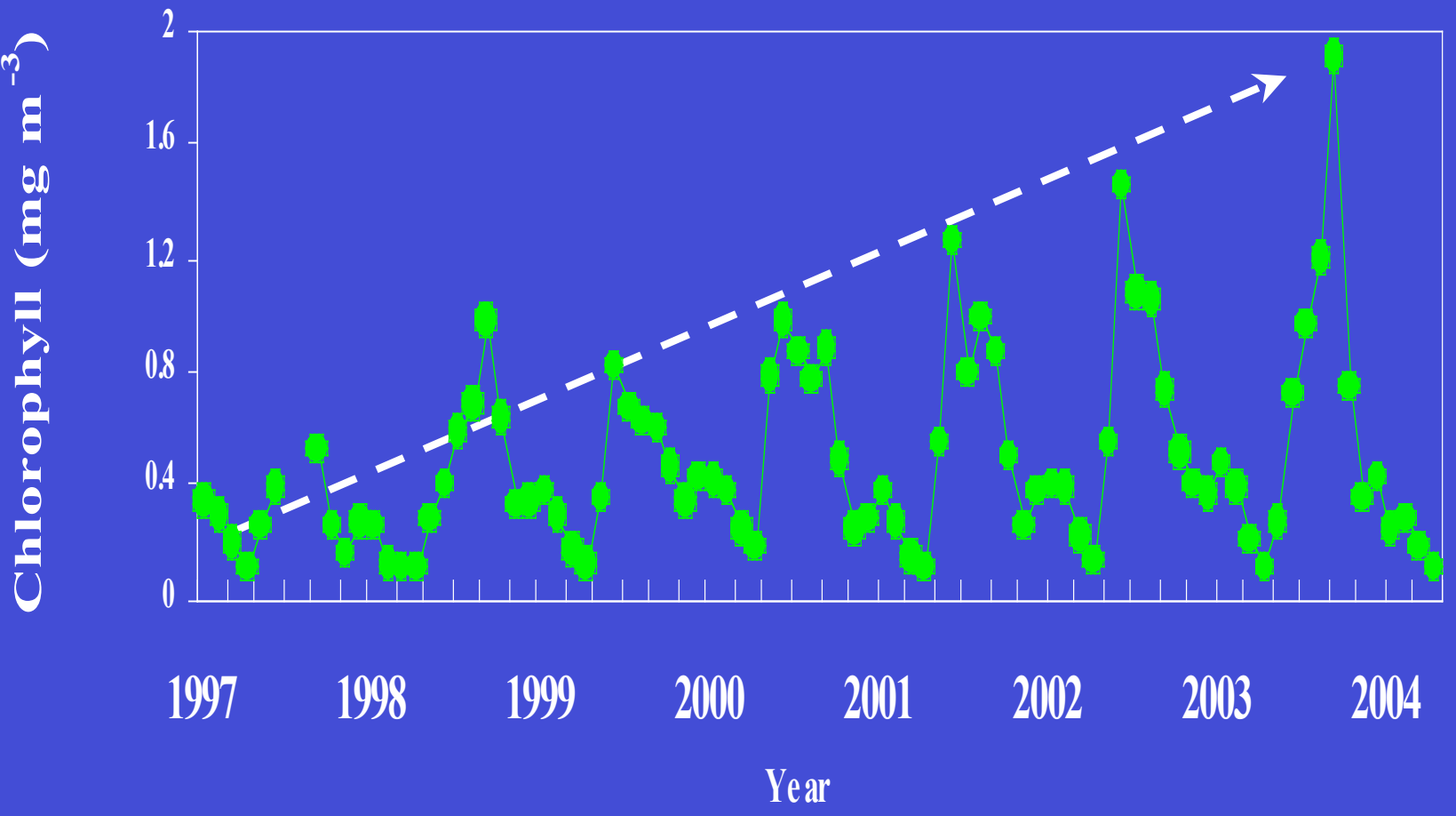
NITRATE INPUT DUE TO UPWELLING DURING THE SOUTHWEST MONSOON



Comparison between shipboard and satellite derived sea surface nitrate concentrations in the Arabian Sea



Schematic showing the SW Monsoon response of the Arabian Sea to snow cover

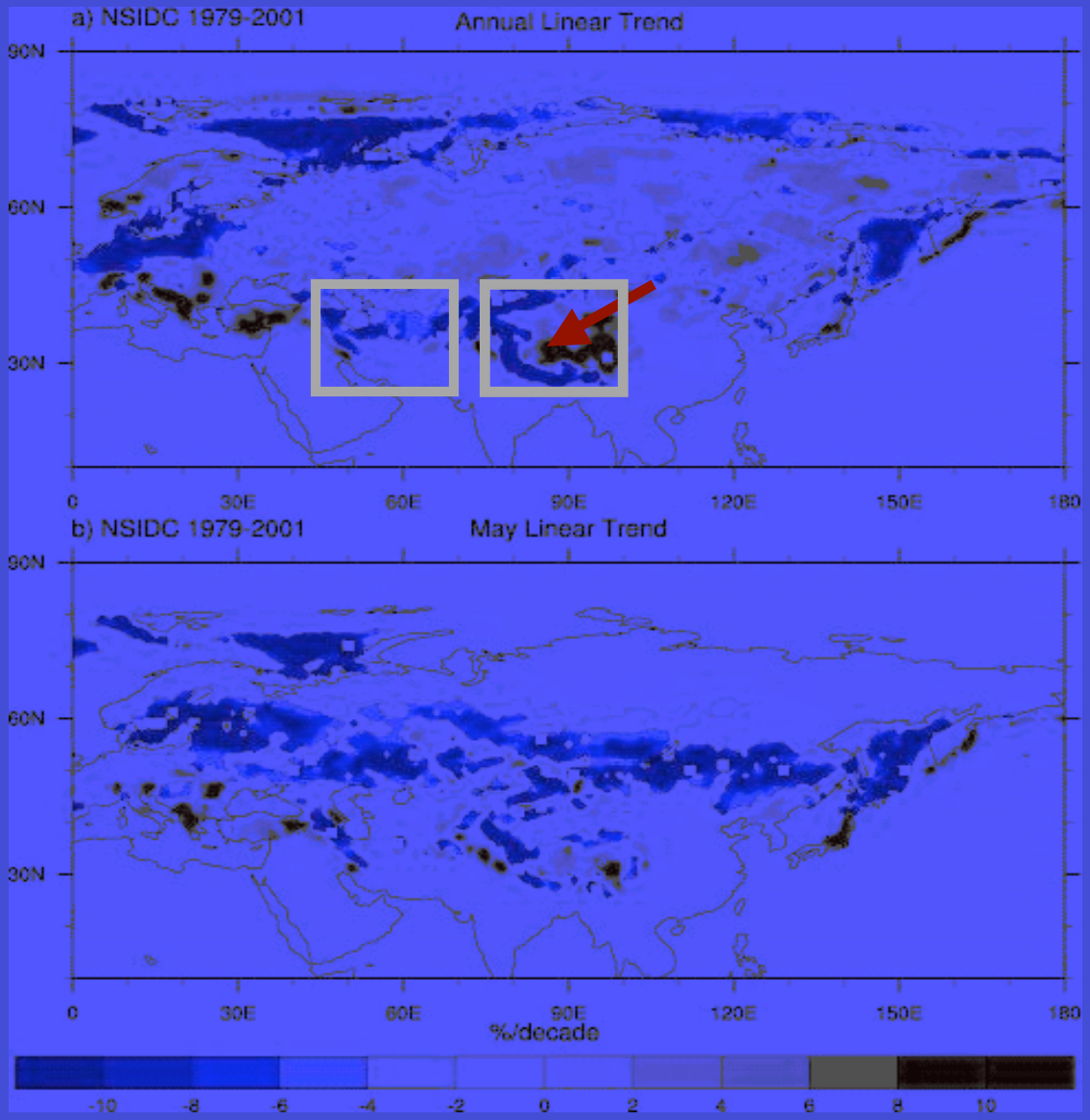


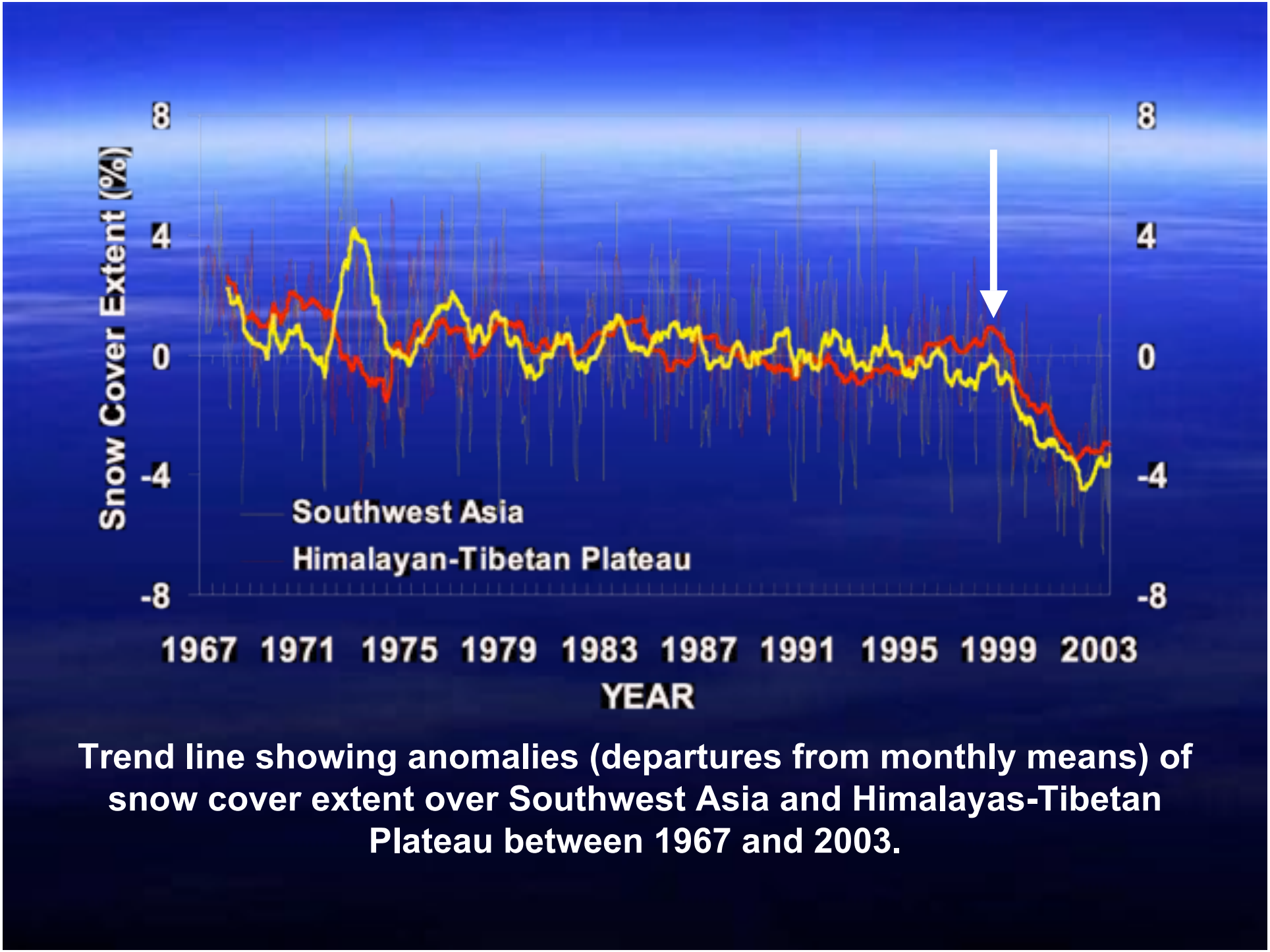
Interannual changes in chlorophyll along coast of Somalia since 1997

NSIDC SNOW COVER TRENDS

Annual snow cover trends suggest a marked decrease in snow accumulation north of the Arabian Sea.

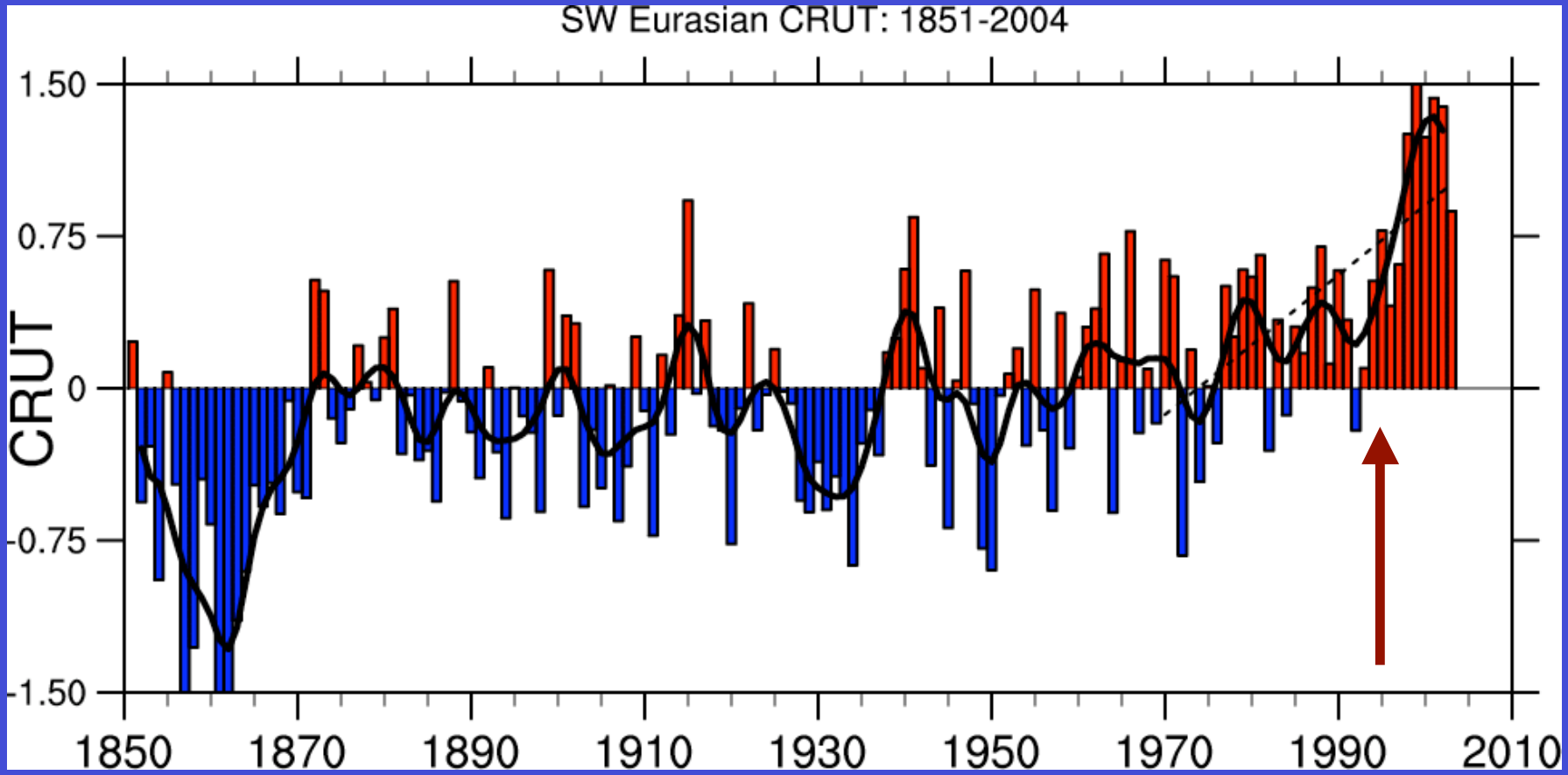
May snow cover trends are largely negative all over Eurasia reflecting an earlier and stronger spring melt-off.



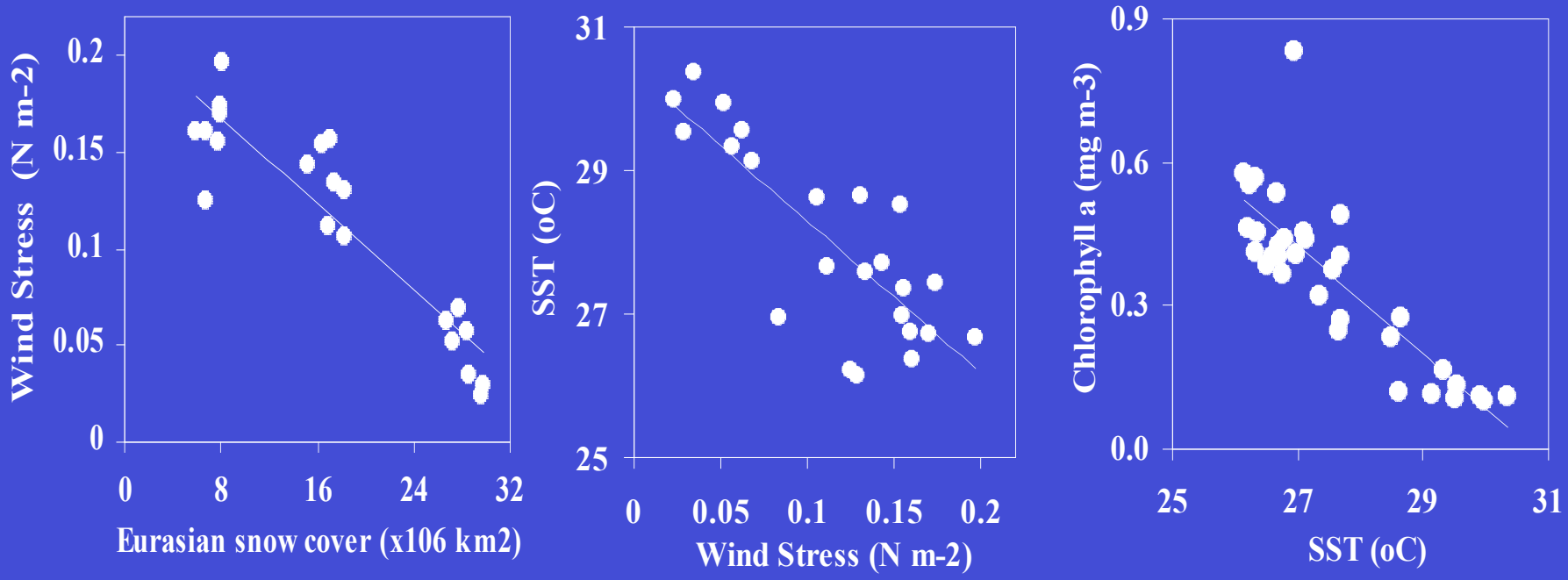


Trend line showing anomalies (departures from monthly means) of snow cover extent over Southwest Asia and Himalayas-Tibetan Plateau between 1967 and 2003.

Eurasian-Land Warming

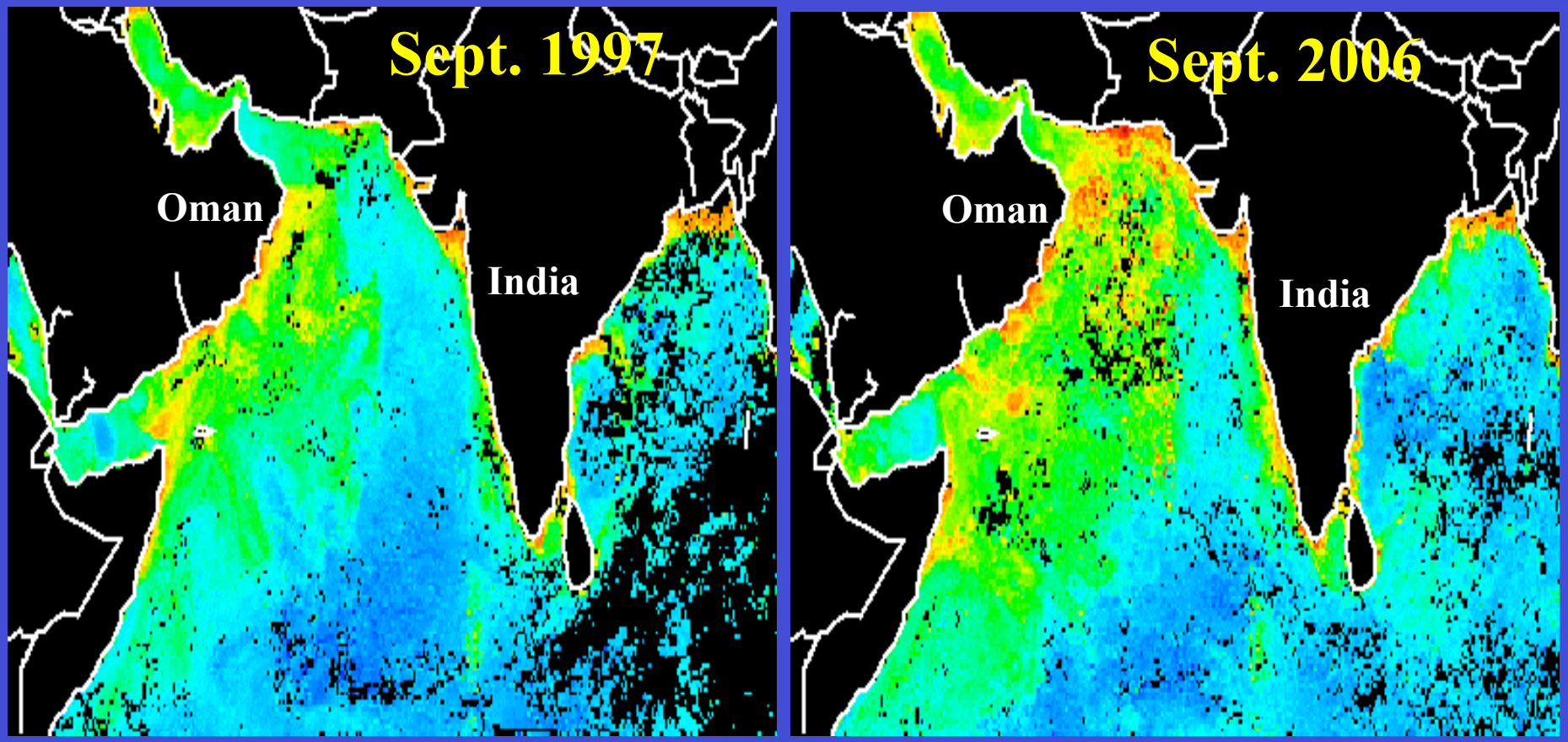


The warming of SW Eurasia mirrors the global-land signal, but recent warm anomalies are >50% larger than changes observed for global temperatures.

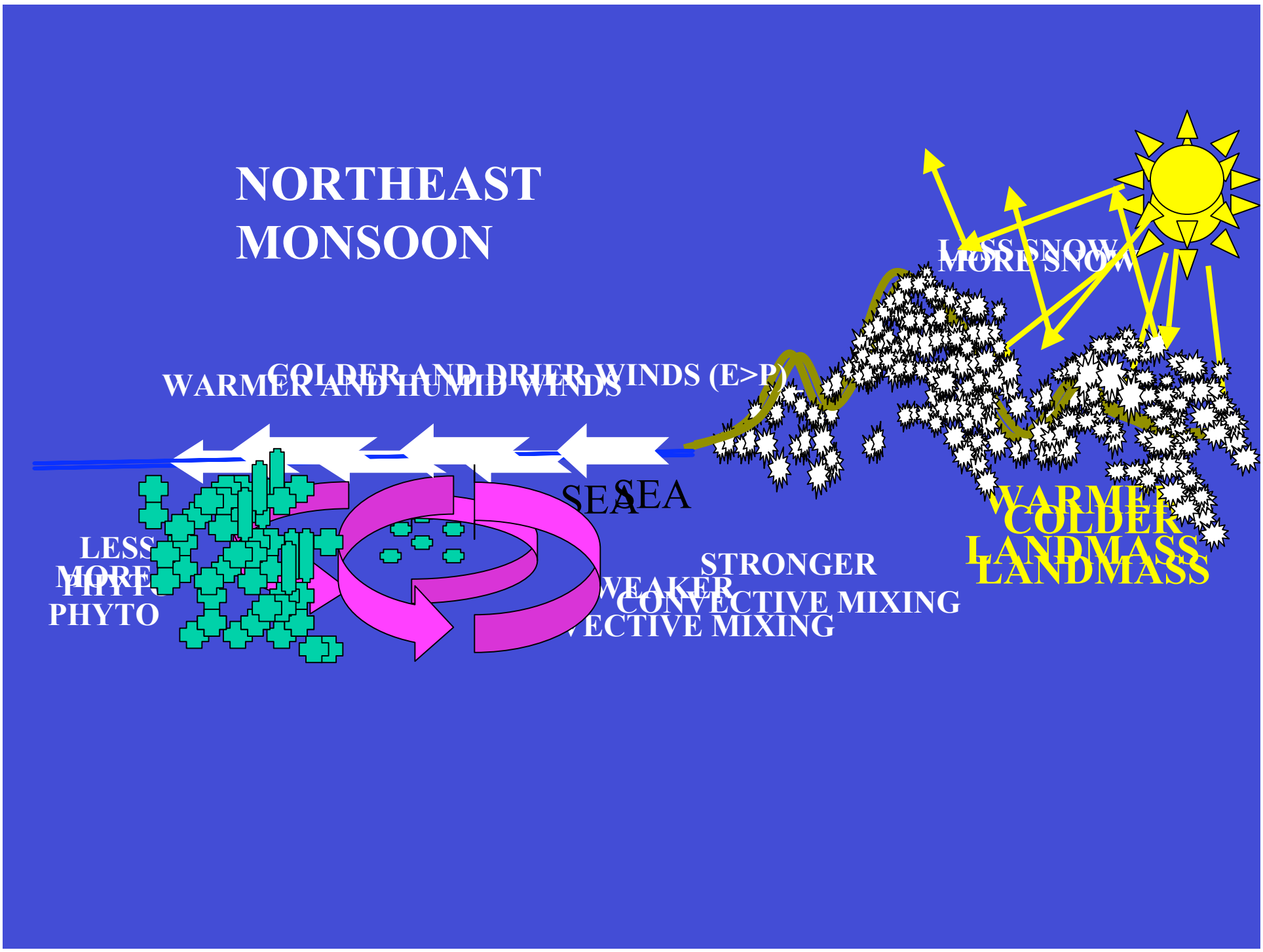


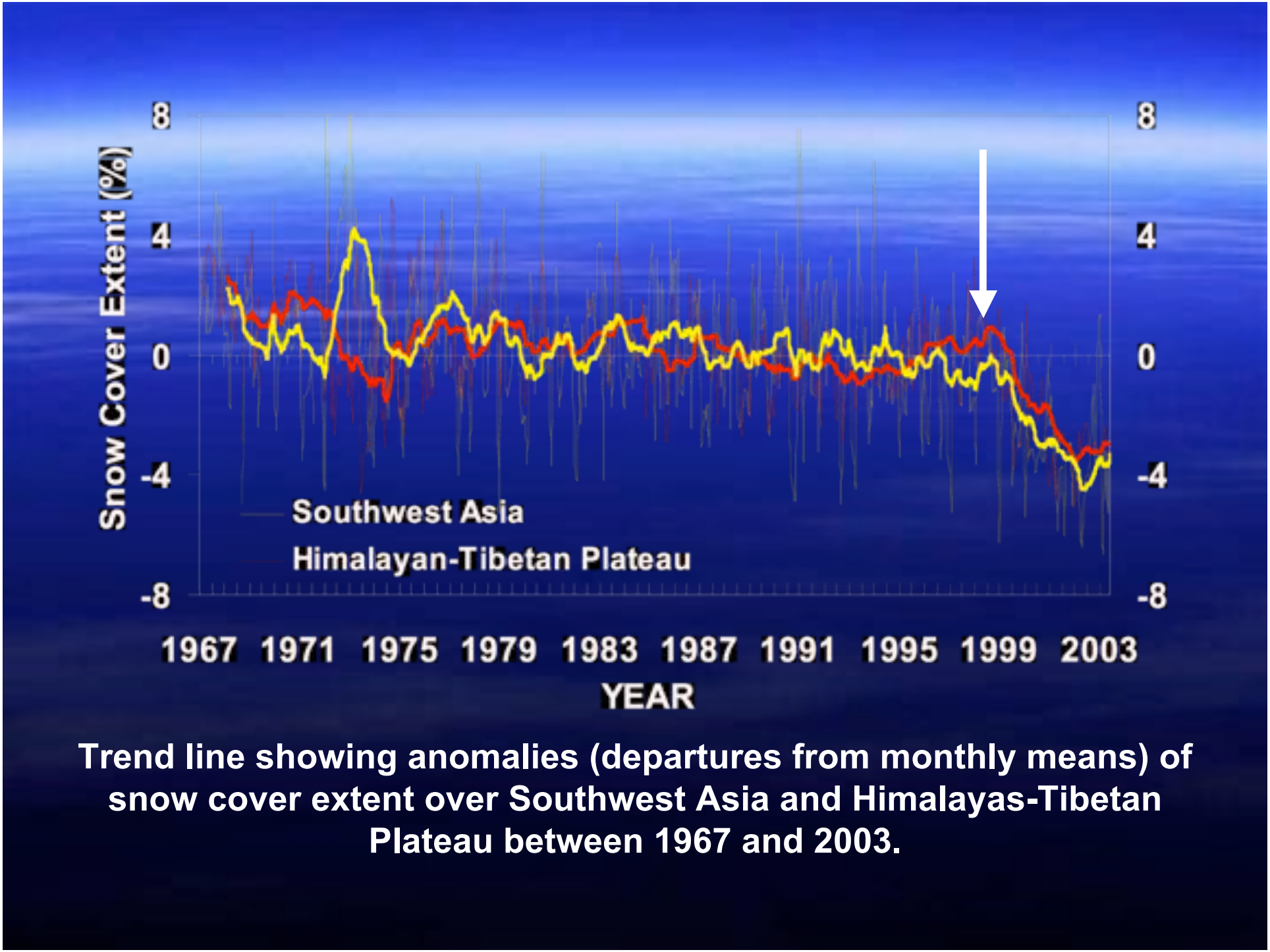
Scatter plots showing the impact of the decline in Eurasian snow on phytoplankton in the Arabian Sea

(Goes et al., Science, 2005)

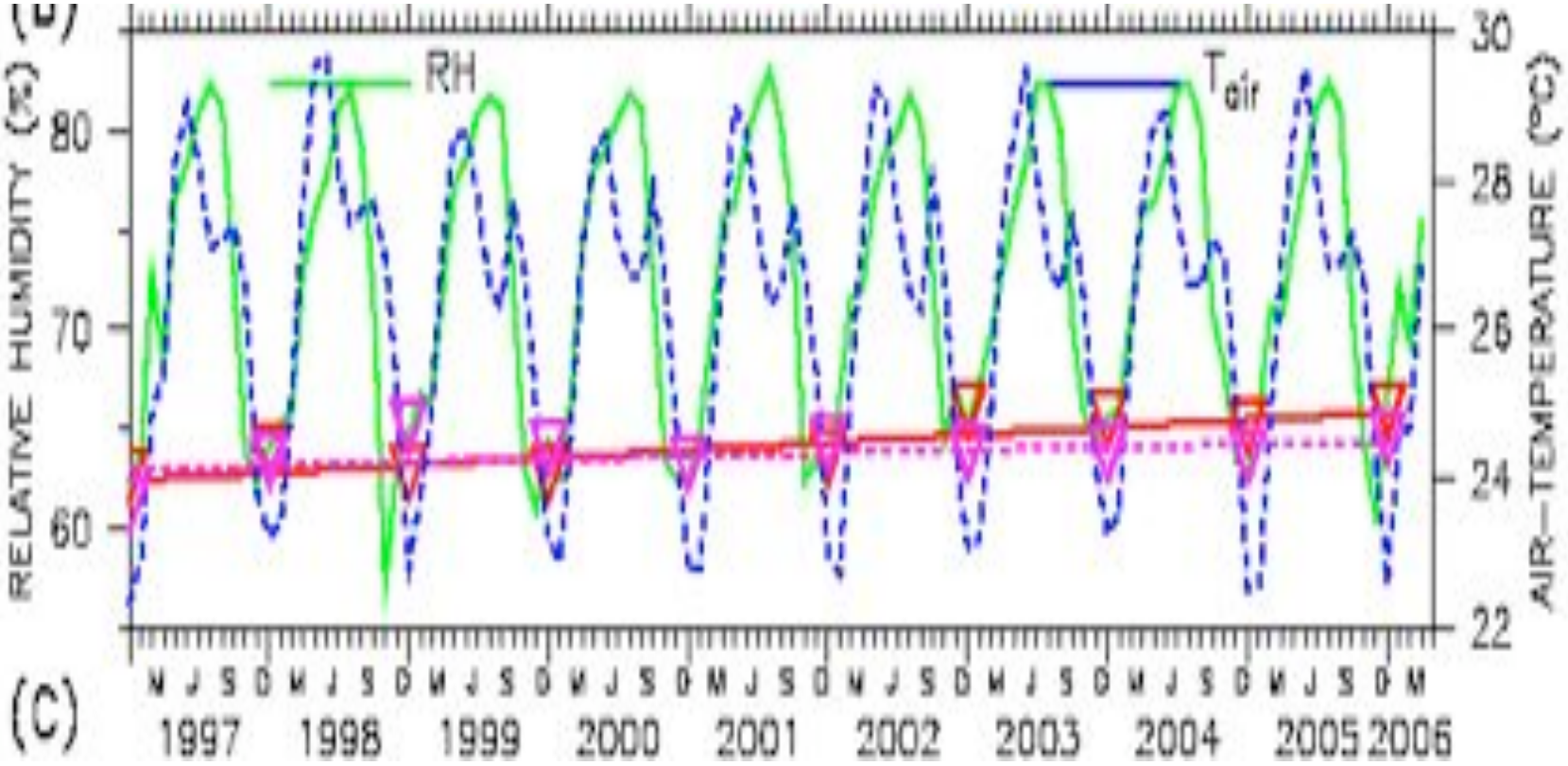


SeaWiFS derived chlorophyll fields during the peak southwest monsoon growth season of 1997 and 2006

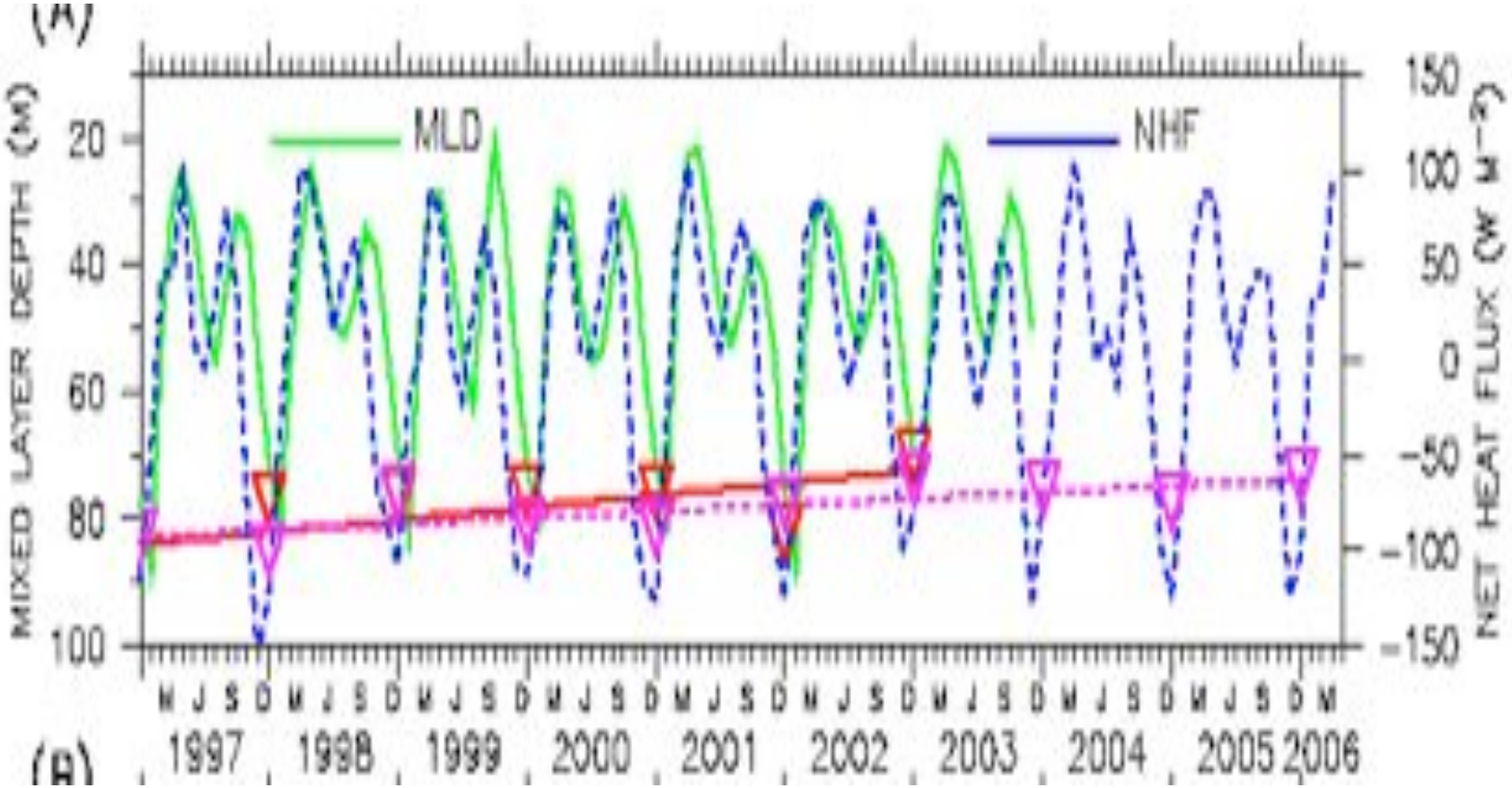

NORTHEAST
MONSOON
MORE SNOW
WARMER AND HUMID WINDS
COLDER AND DRIER WINDS (E>P)
SEA
SEA
LESS
PHYTO
STRONGER
CONVECTIVE MIXING
WARMER
COLDER
LANDMASS
LANDMASS



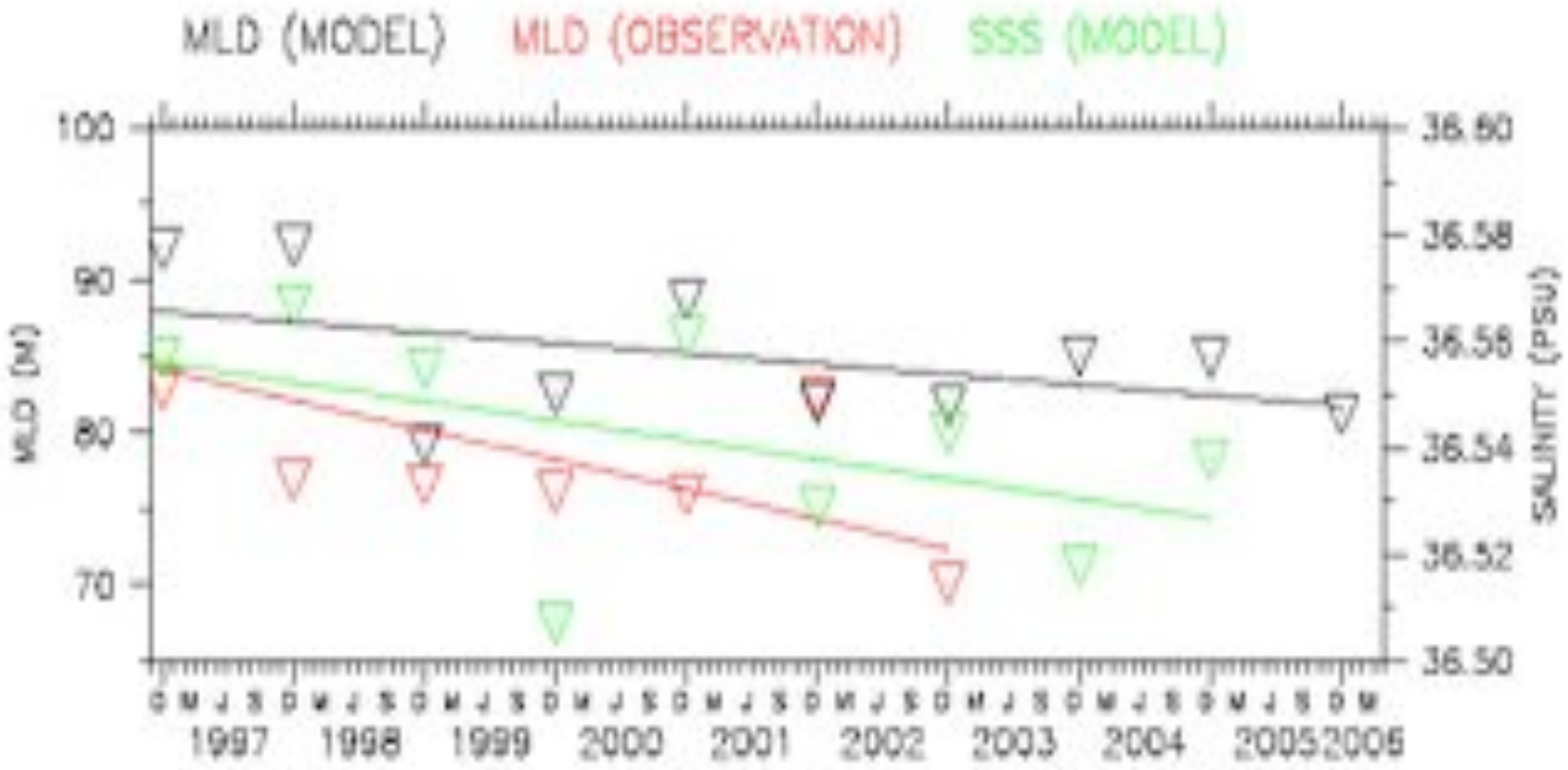
Trend line showing anomalies (departures from monthly means) of snow cover extent over Southwest Asia and Himalayas-Tibetan Plateau between 1967 and 2003.



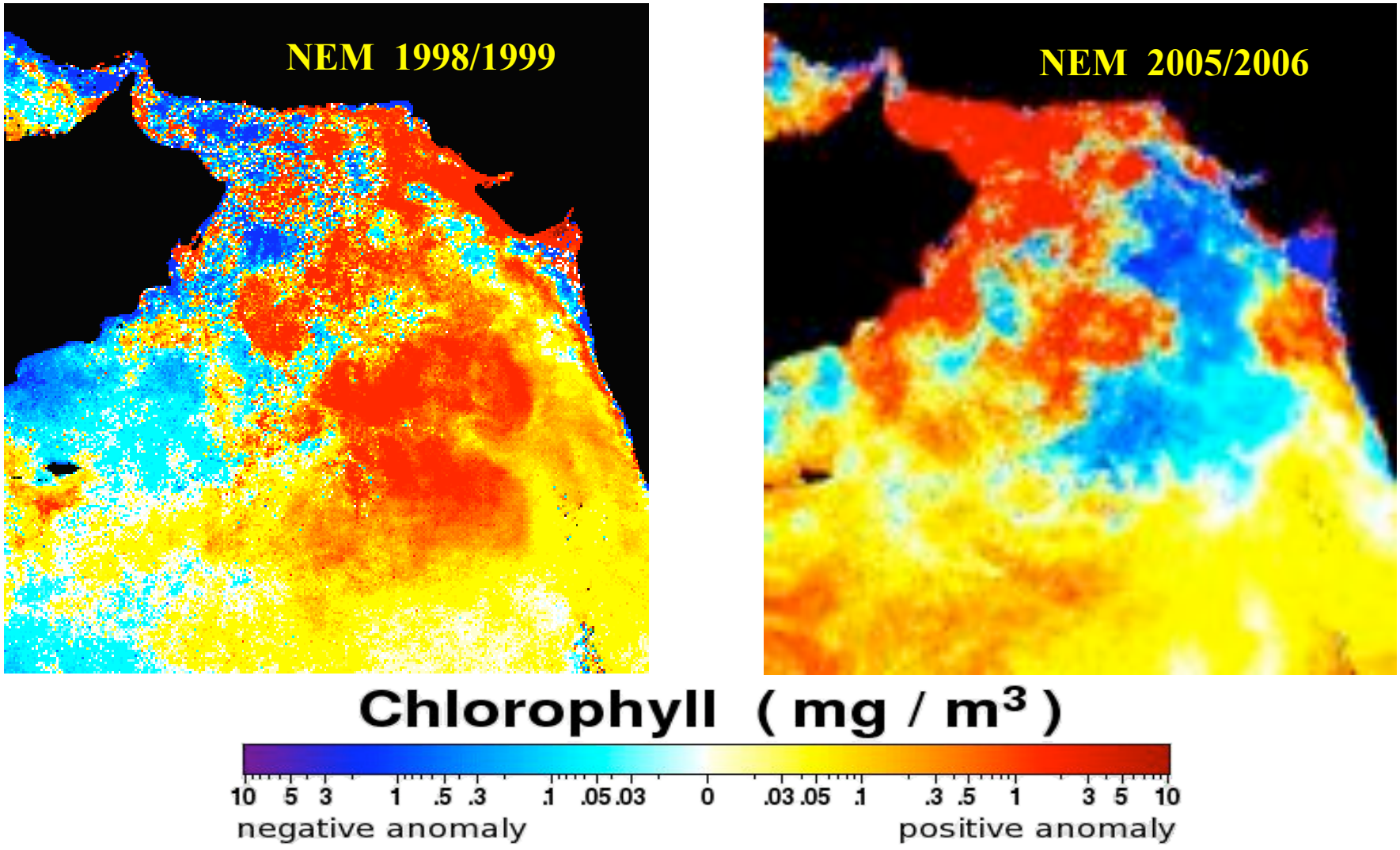
Air-temperature and Relative humidity for the northern Arabian Sea (60°E-70°E, 14°N-25°N).



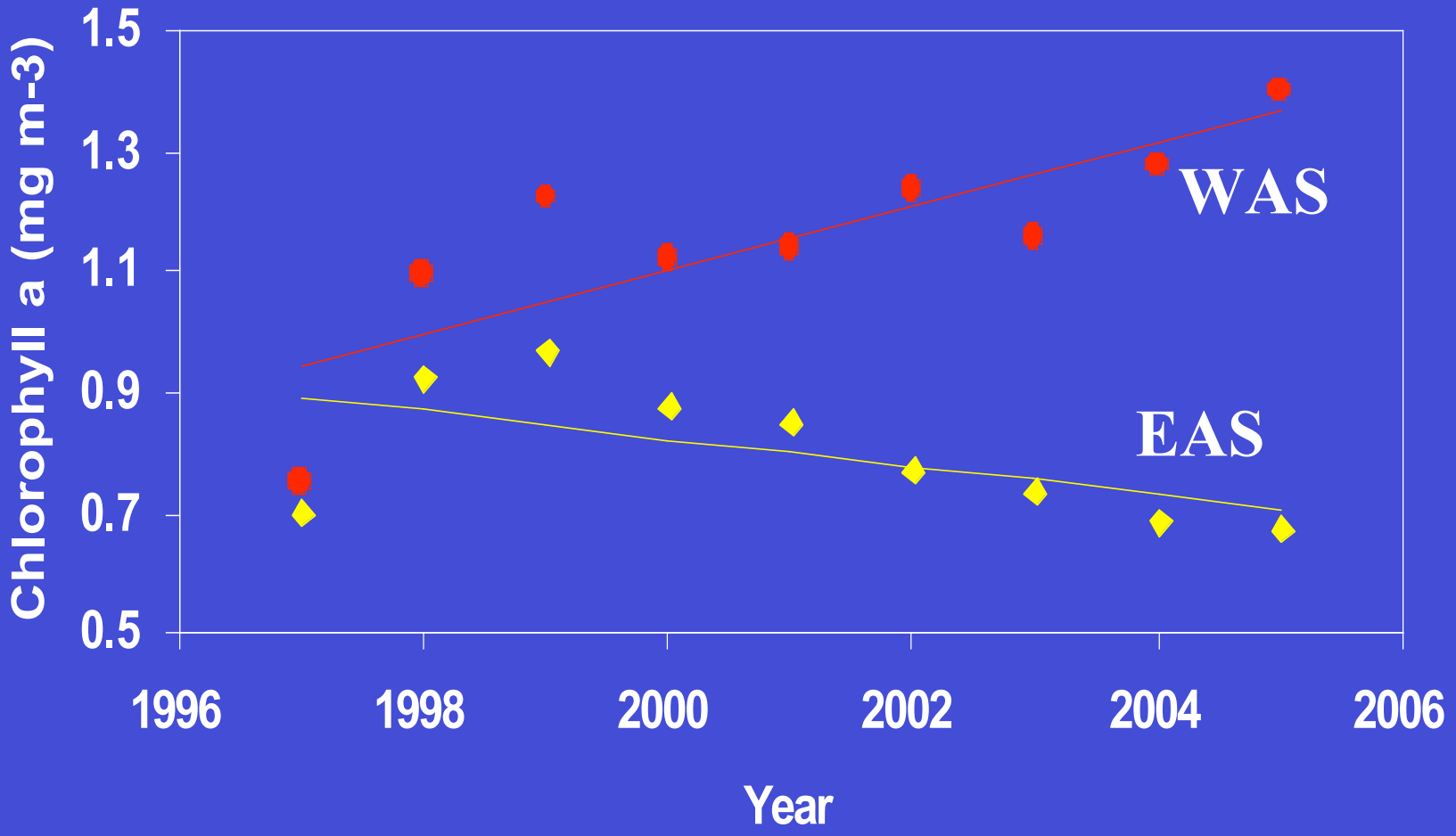
Annual trends of net heat flux (NCEP-NCAR) (60-70°E, 14°N-25°N) and Mixed Layer Depth (XBT, JEDAC, USA)



Comparisons of observed and model-derived MLD for winter (Jan – Feb), and model derived Sea Surface Salinity (SSS, psu) during Jan – May for the 60°E-70°E, 14°N-25°N. Model derived fields are obtained from the ECCO-JPL Kalman Filter Assimilation project.

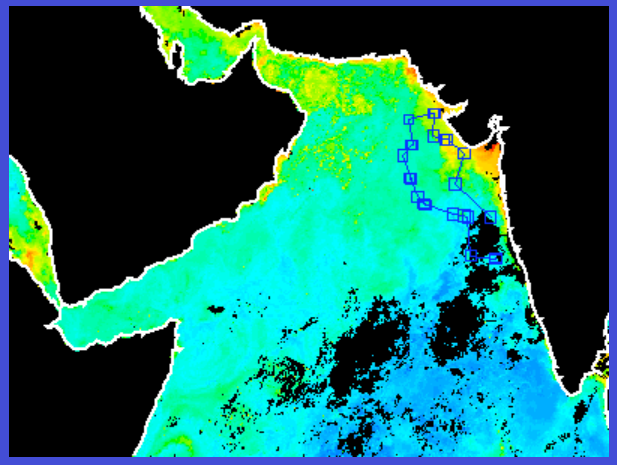


SeaWiFs derived chlorophyll anomaly plots for the winter monsoons of (A) Nov 2002 to Feb 2003 and (B) Nov 2005 to Feb 2006.

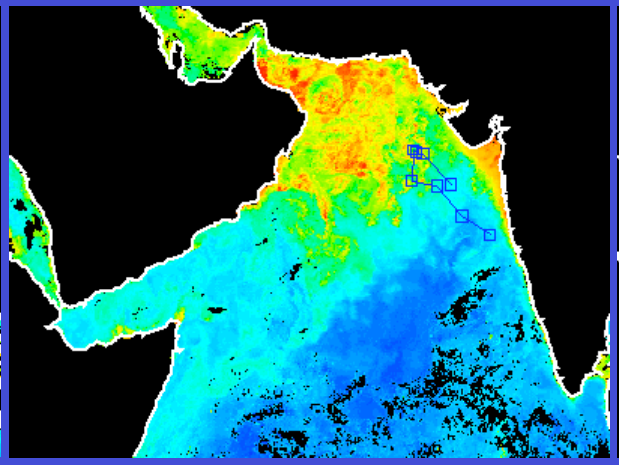


Winter mean SeaWiFS Chl *a* averaged over the Eastern Arabian Sea (EAS, 66°E-70°E, 15°N-24°N) and in the western Arabian Sea (WAS, 55°E-62°E, 17.5°N-22.5°N).

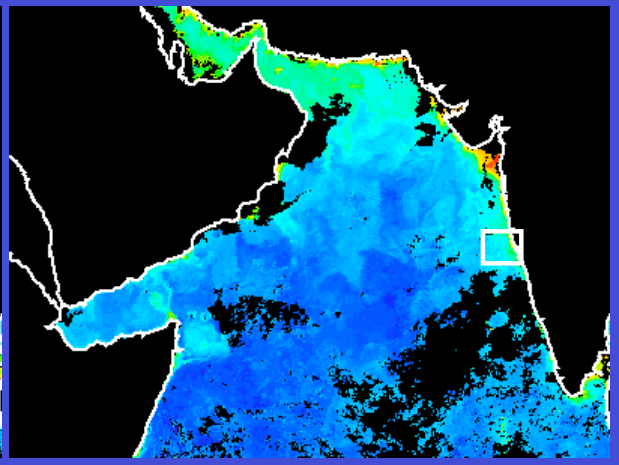
CRUISE TRACKS DURING THE NE MONSOON



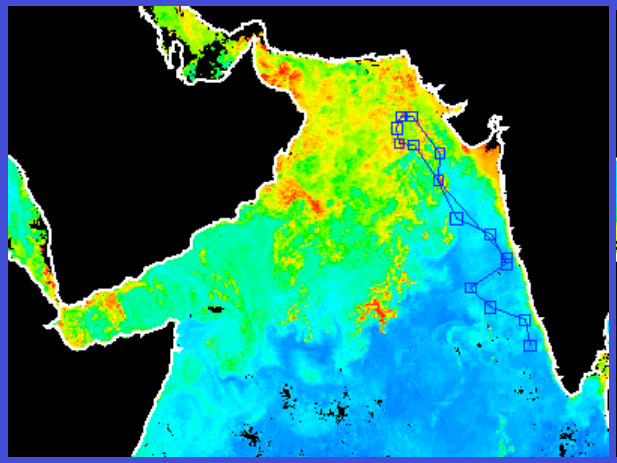
SK-186 (3rd-19th Jan 2003) Northeast monsoon



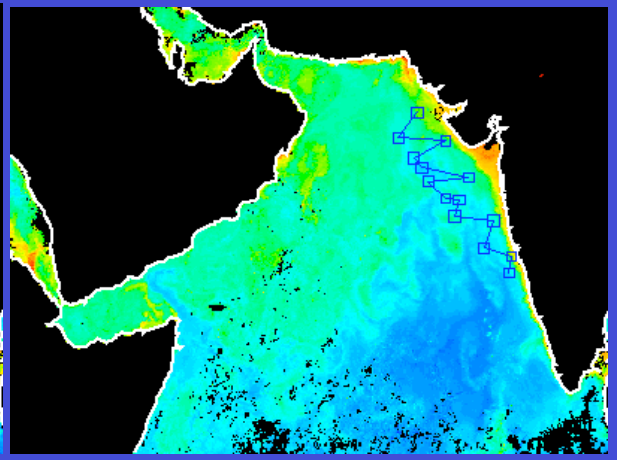
FORV 212 (27th Feb-5th Mar 2003) Spring Intermonsoon



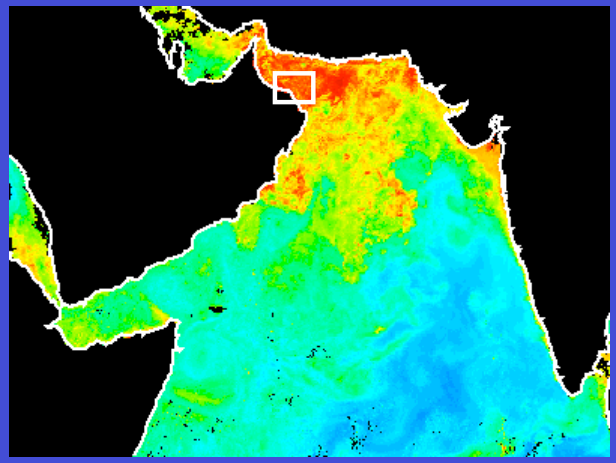
Cruise SASU-45 (2nd-5th May 2003) Late Spring



FORV 222 (22nd Feb - 8th Mar 2004) Spring Intermonsoon

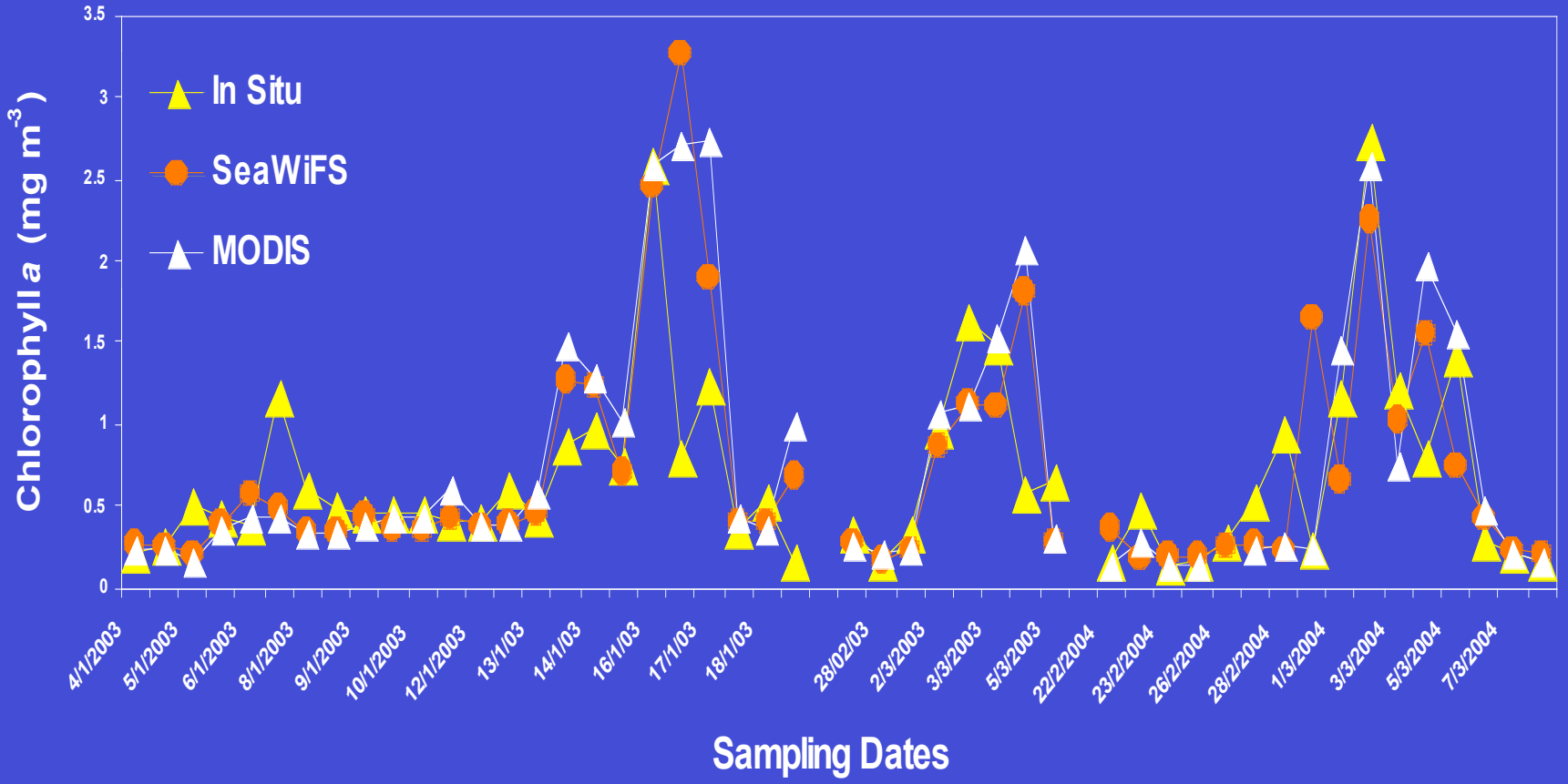


SK 214 (4th -17th Dec 2004) Northeast monsoon

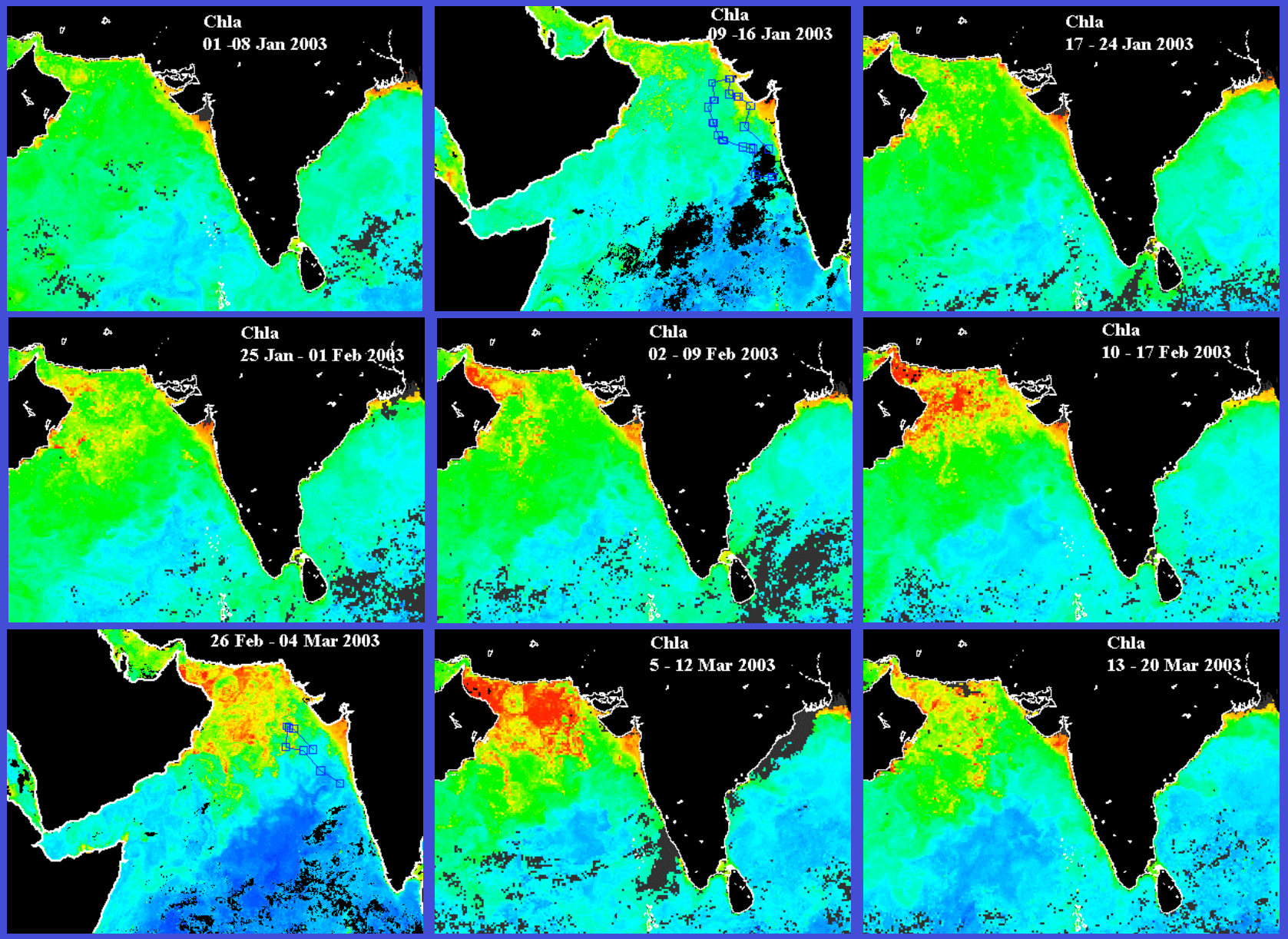


Fahal and OFF, Gulf of Oman (24th of Jan 2006)

Transport of desert dust over the Arabian Sea from surrounding desert regions during the NEM of 2005.

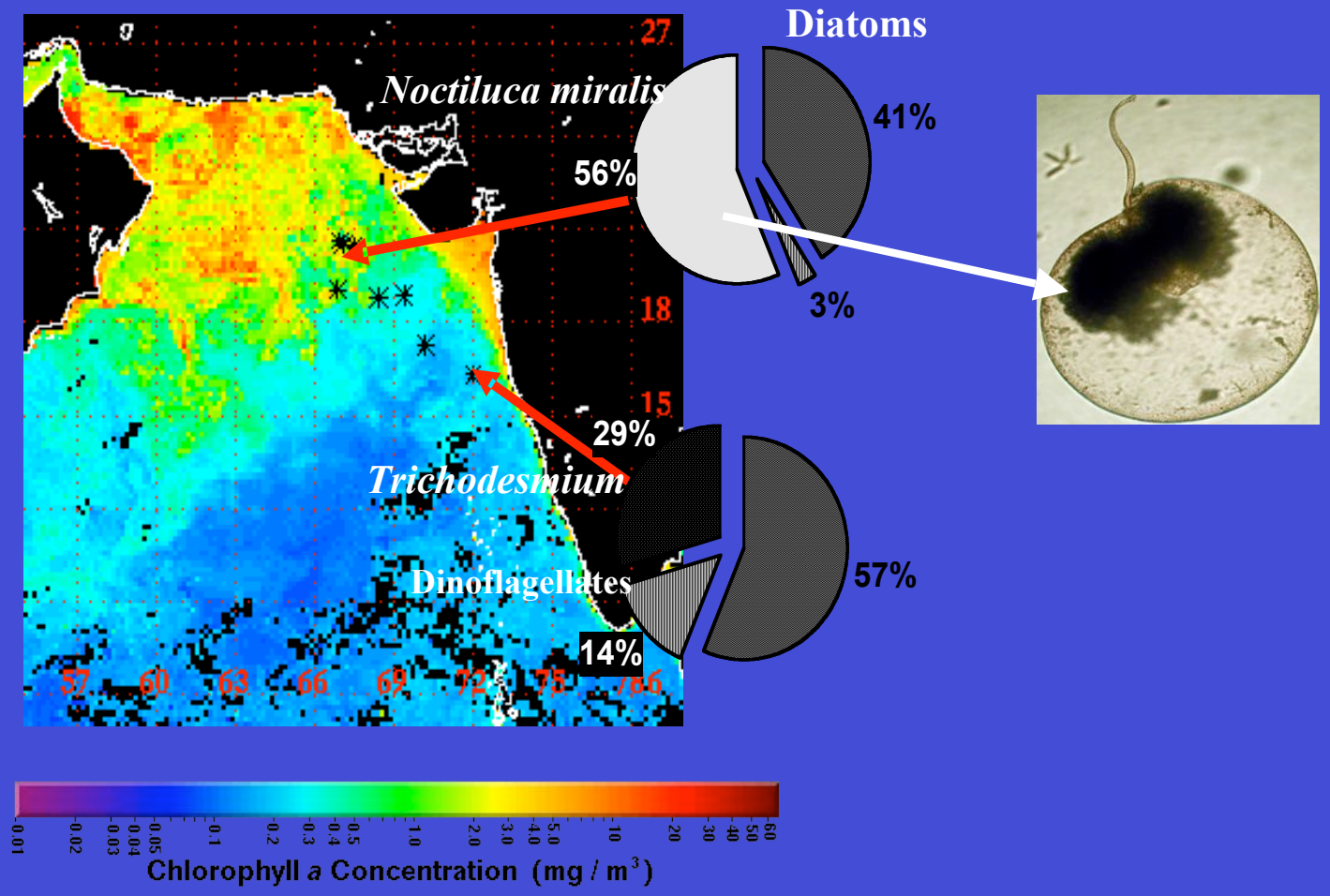


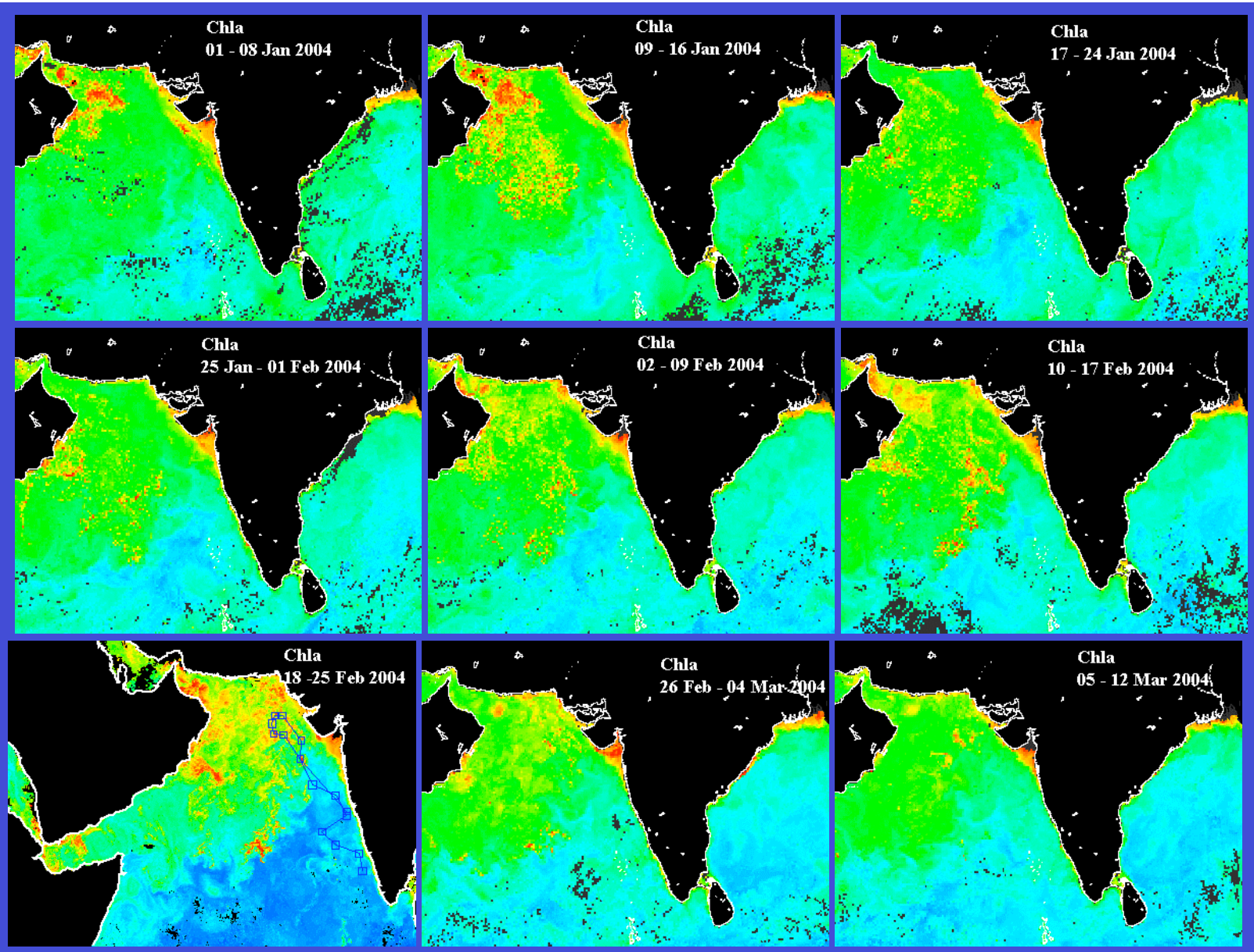
Comparison between ship and satellite data



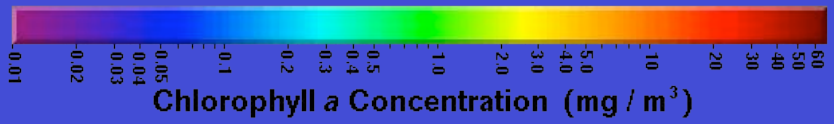
PHYTOPLANKTON BLOOM OF 2003

PHYTOPLANKTON TAXA ASSOCIATED WITH THE BLOOM OF 2003

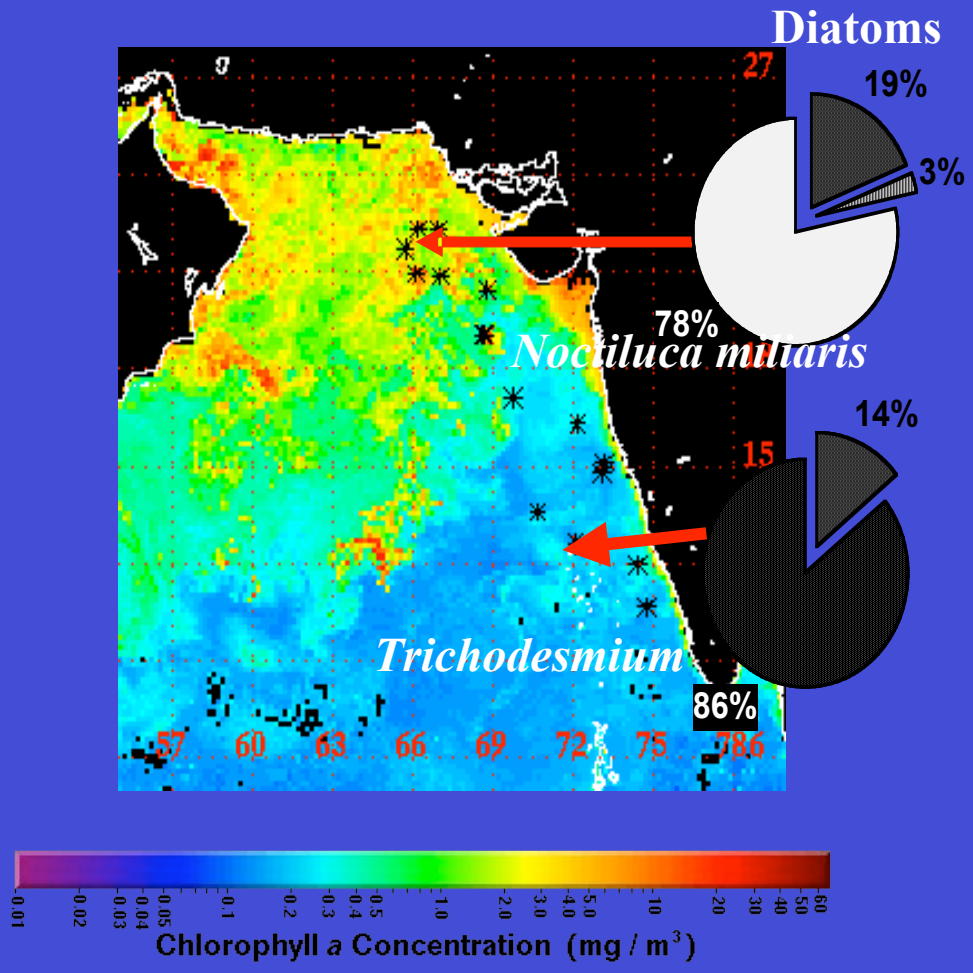


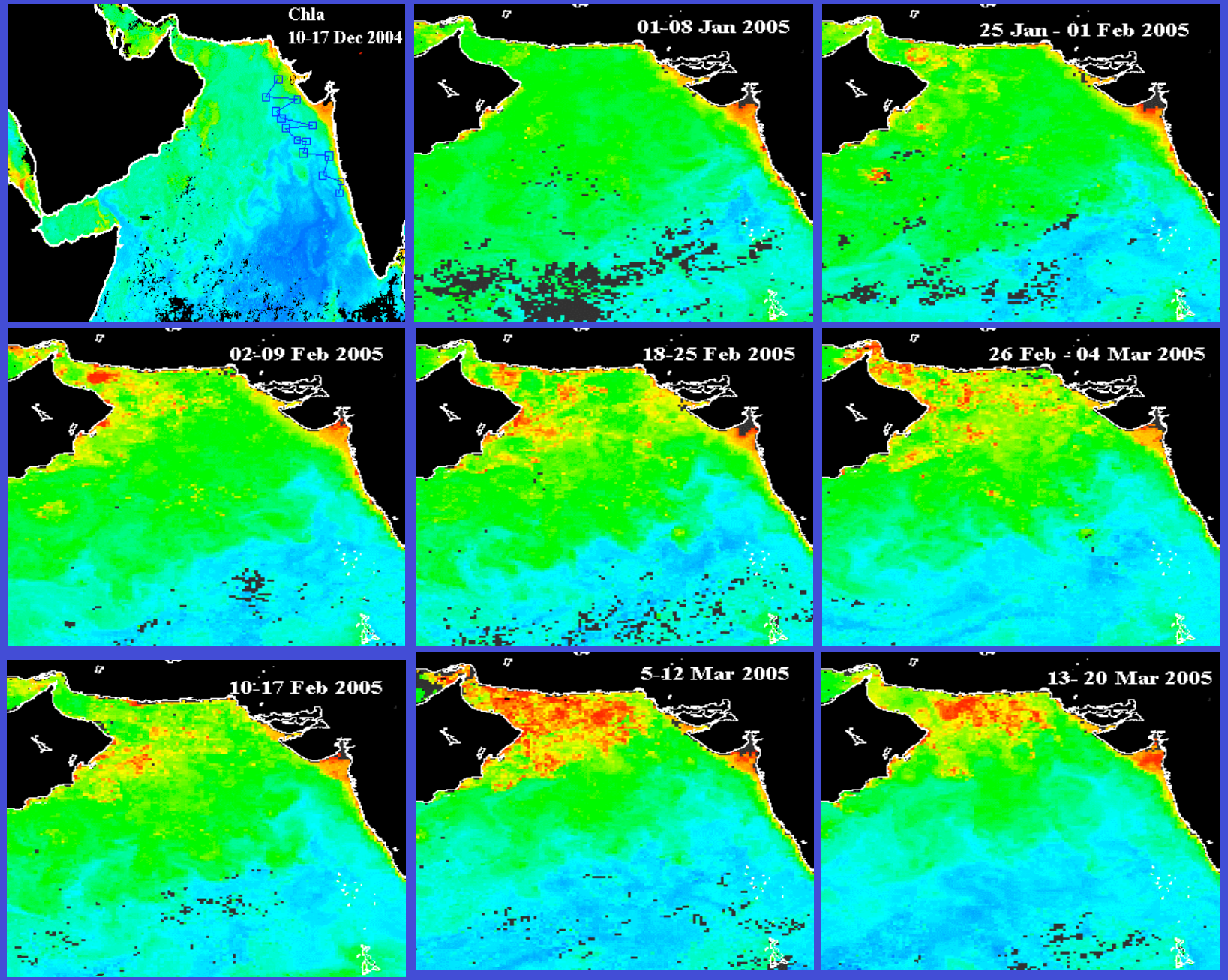


PHYTOPLANKTON BLOOM OF 2004



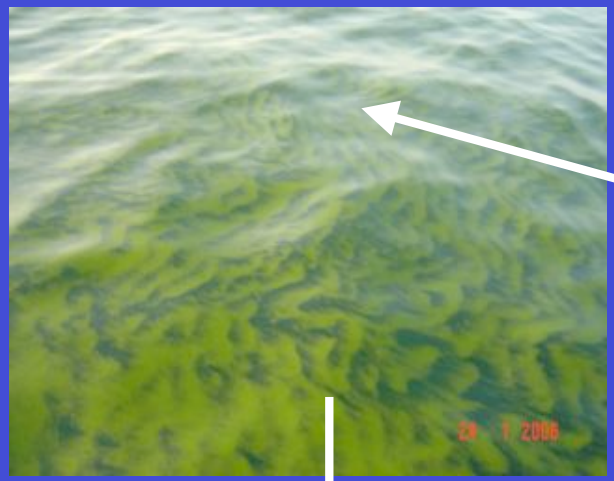
PHYTOPLANKTON TAXA ASSOCIATED WITH THE BLOOM OF 2004



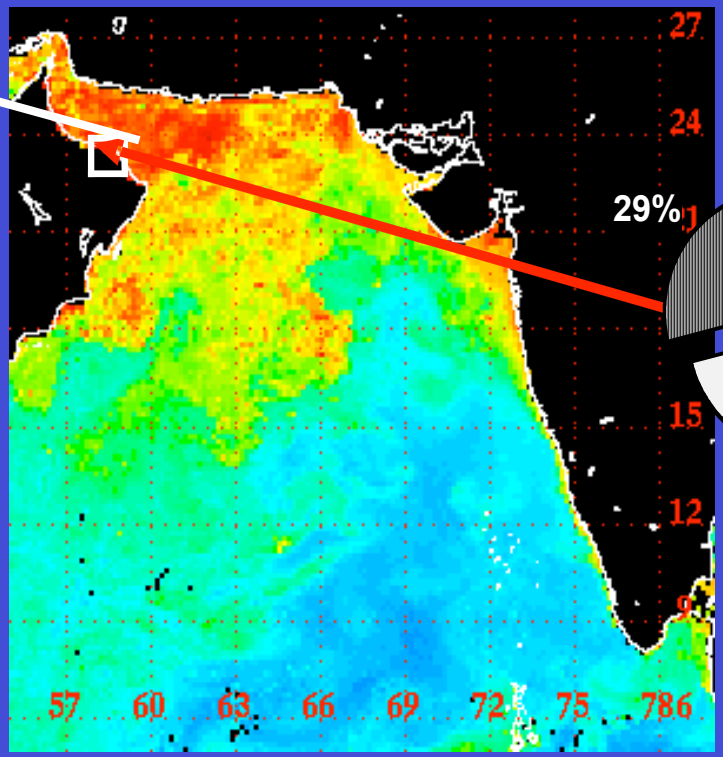


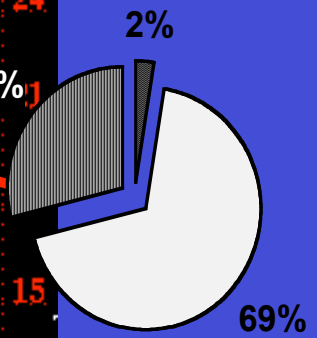
PHYTOPLANKTON BLOOM OF 2005

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

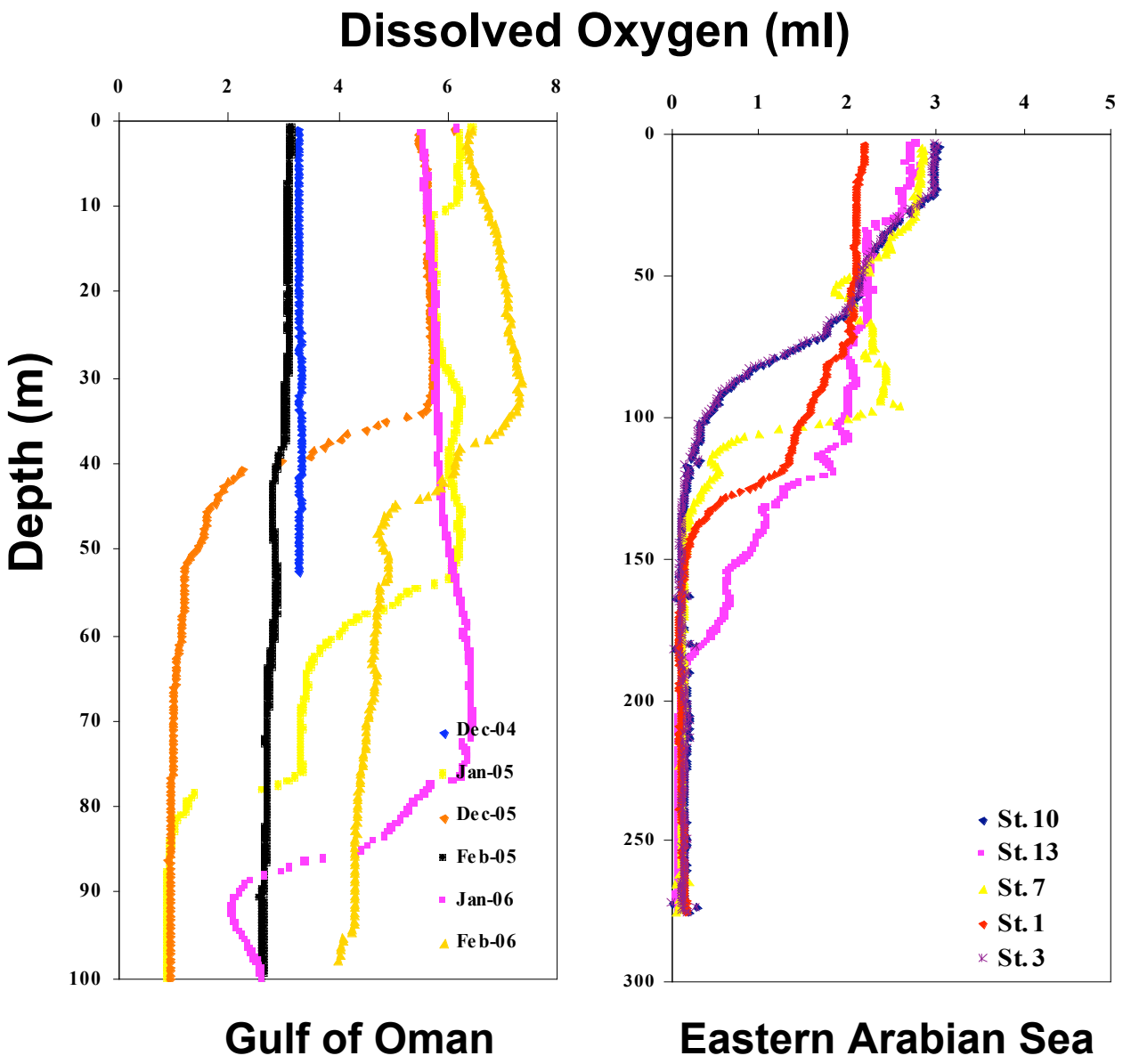


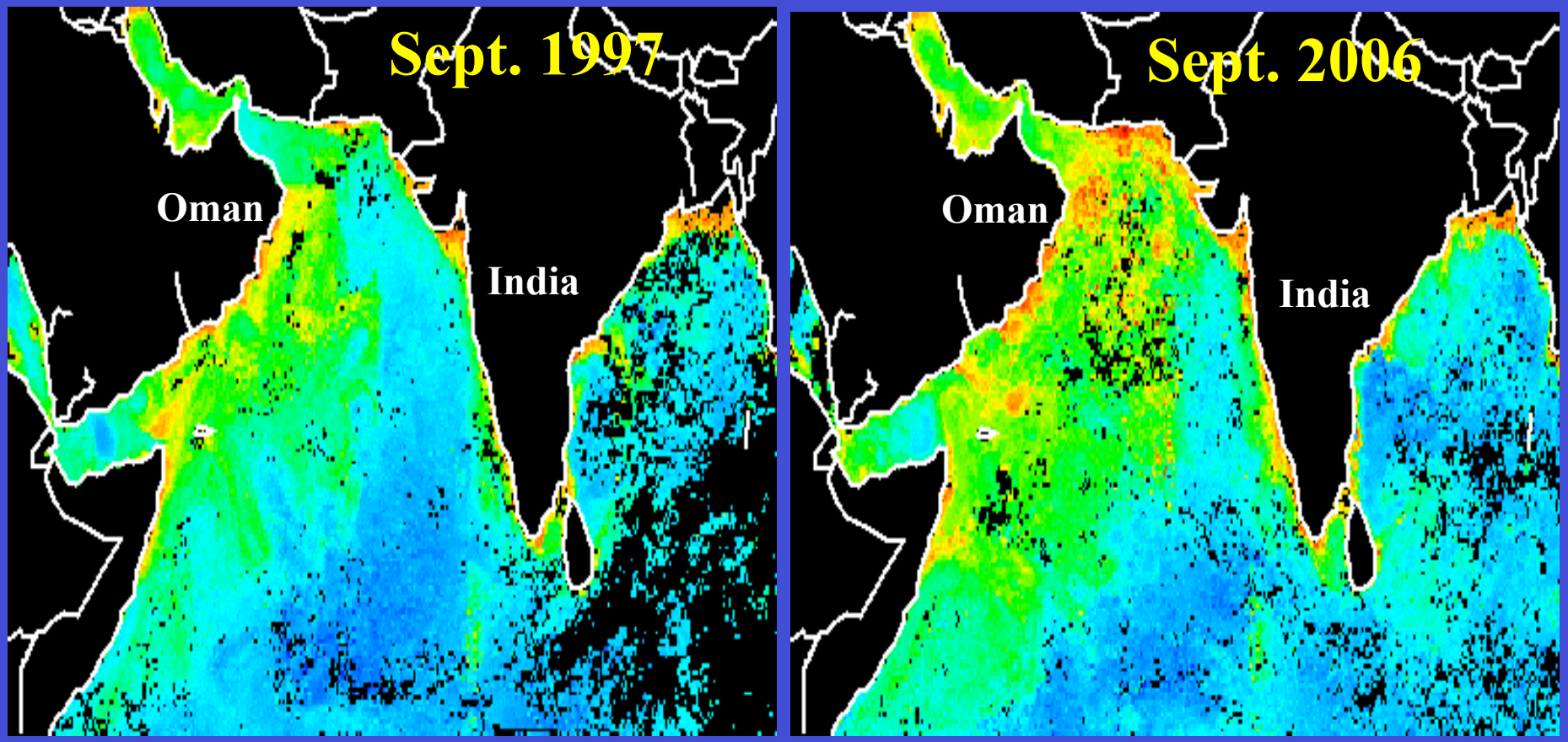
Pedinomonas noctilucae



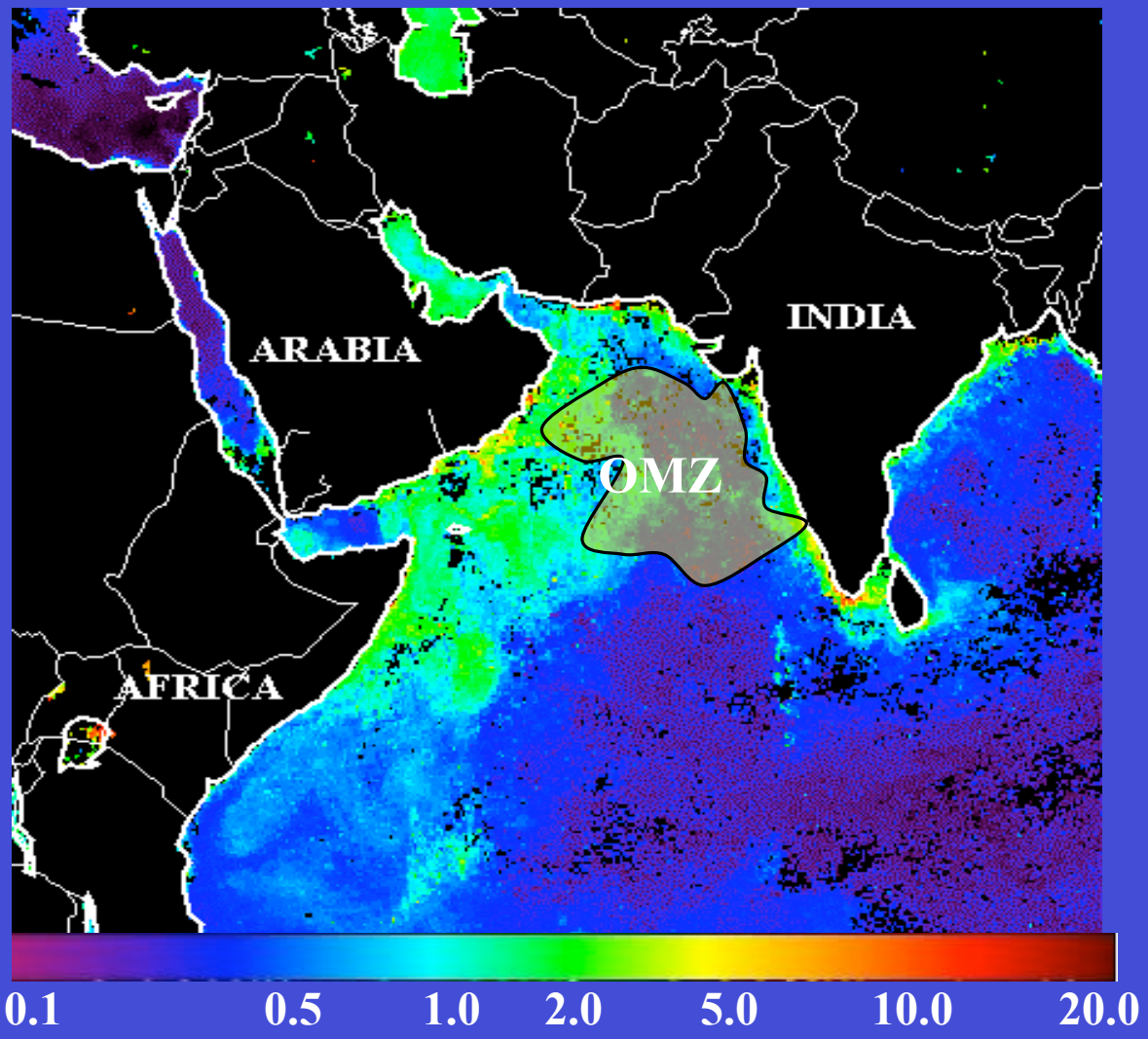


Dinoflagellate, which thrives in (cold) <22°C, nutrient rich and oxygen poor waters

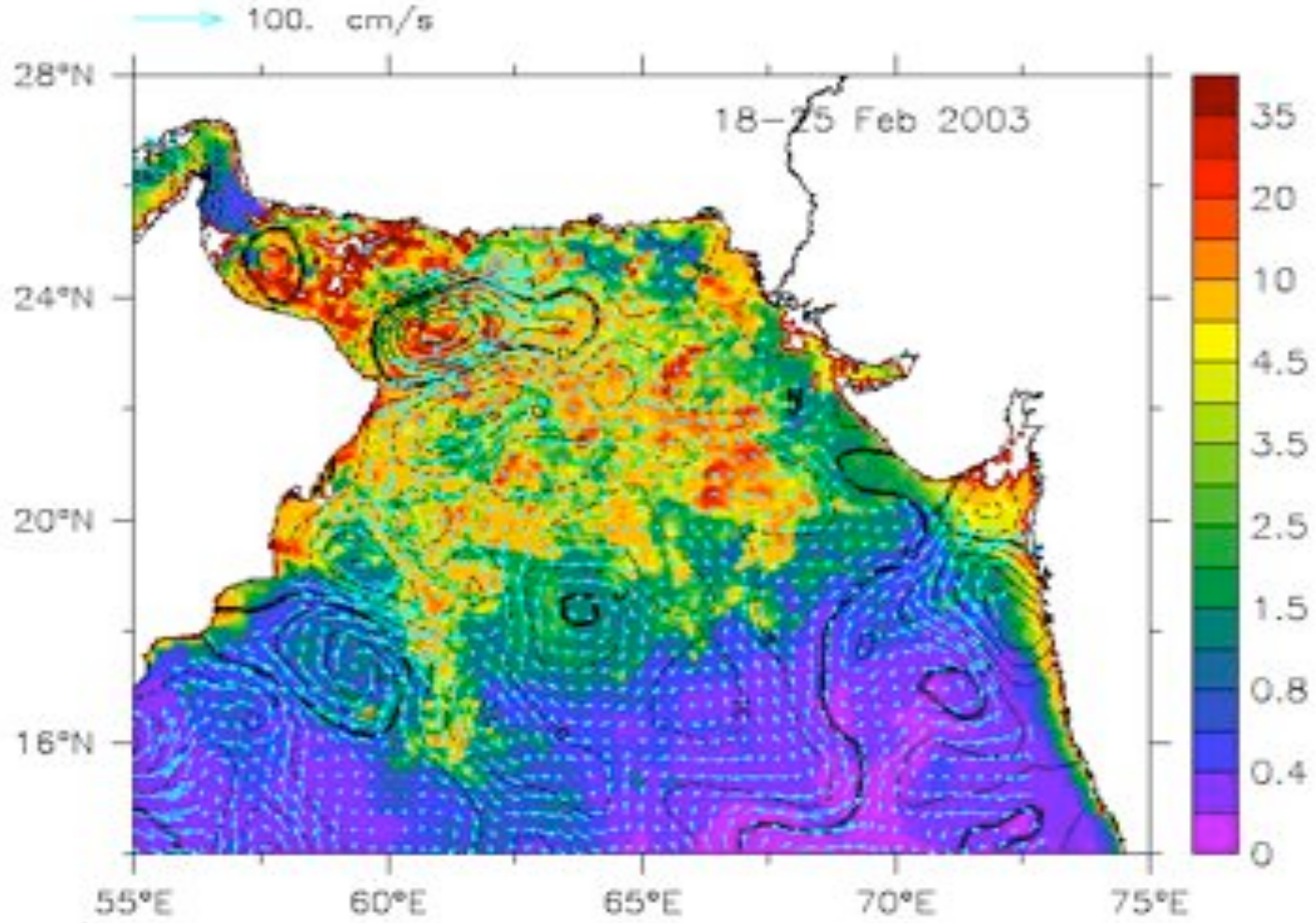

Dissolved Oxygen (ml)
Depth (m)
0
2
4
6
8
10
20
30
40
50
60
70
80
90
100
Dec-04
Jan-05
Dec-05
Feb-05
Jan-06
Feb-06
Gulf of Oman
0
1
2
3
4
5
50
100
150
200
250
300
St. 10
St. 13
St. 7
St. 1
St. 3
Eastern Arabian Sea



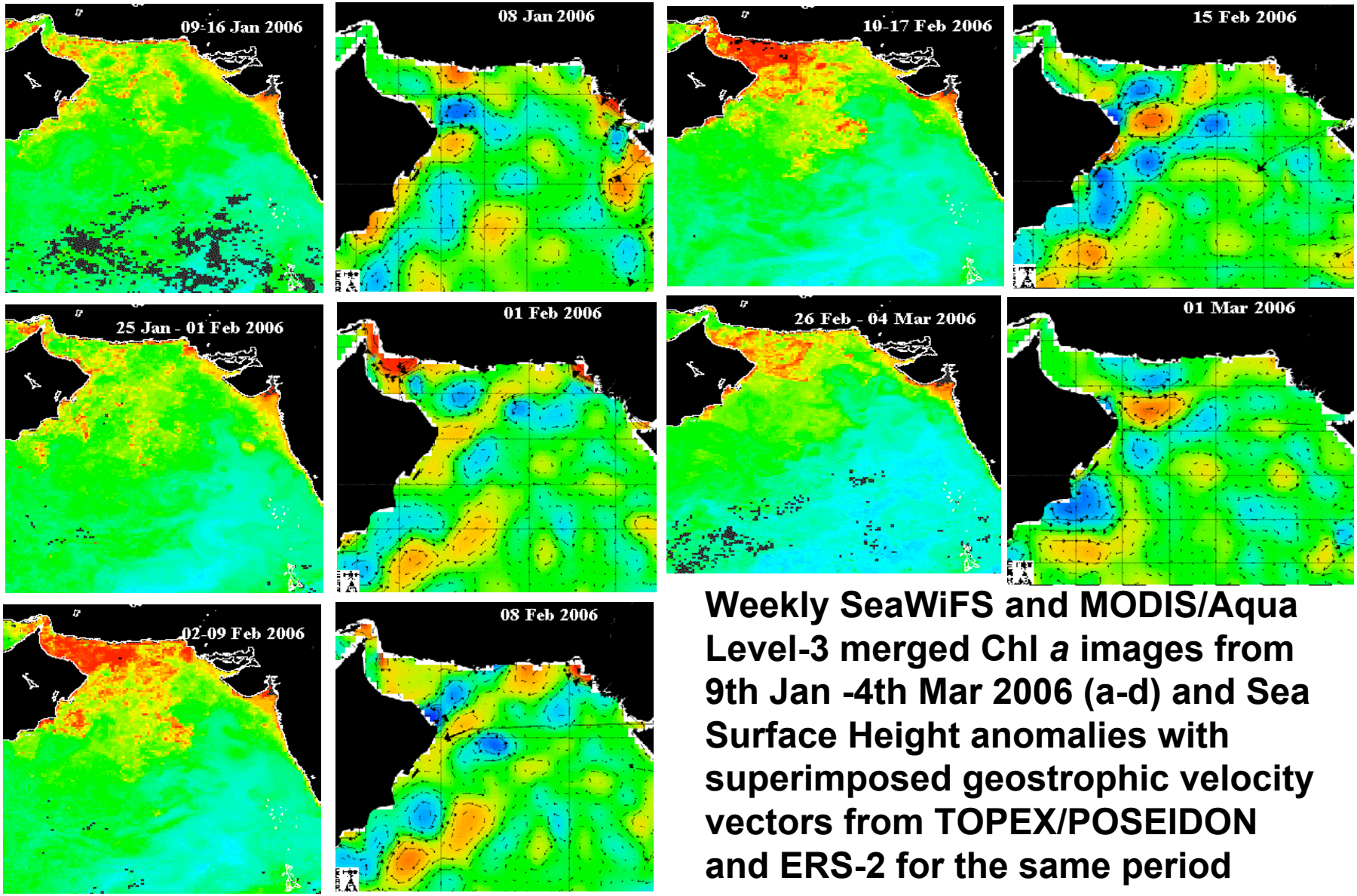
SeaWiFS derived chlorophyll fields during the peak southwest monsoon growth season of 1997 and 2006



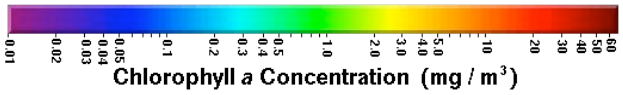
The Arabian Sea's permanent oxygen minimum zone

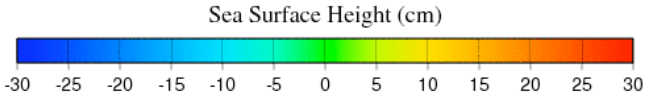


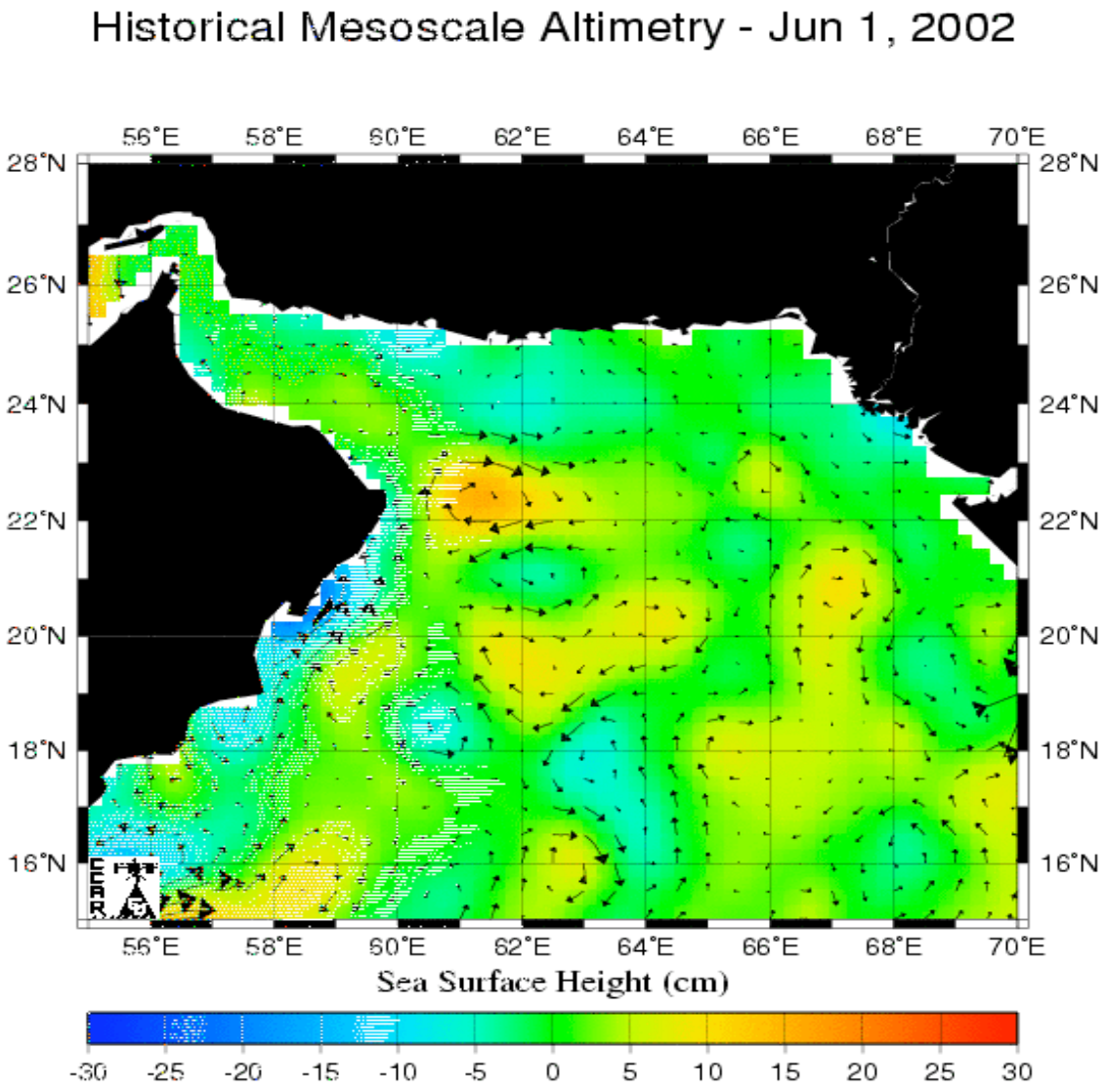
Sea Surface Height Anomalies (SSHA, cm, contours) and geostrophic current vectors computed from the SSHA for the period 22-25 February 2003 superimposed on a weekly (18-25 February 2003) averaged SeaWiFS chlorophyll *a* image.



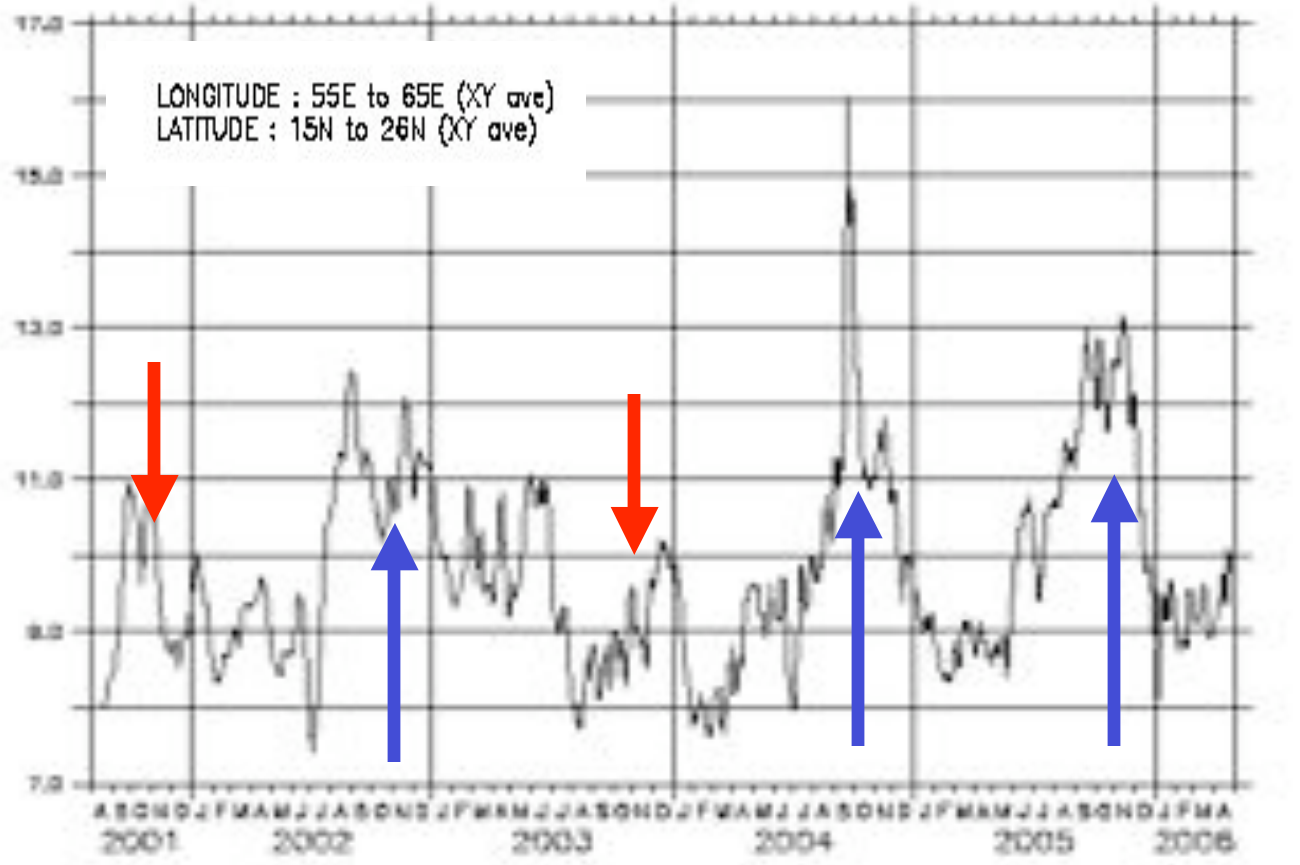
Weekly SeaWiFS and MODIS/Aqua Level-3 merged Chl *a* images from 9th Jan -4th Mar 2006 (a-d) and Sea Surface Height anomalies with superimposed geostrophic velocity vectors from TOPEX/POSEIDON and ERS-2 for the same period



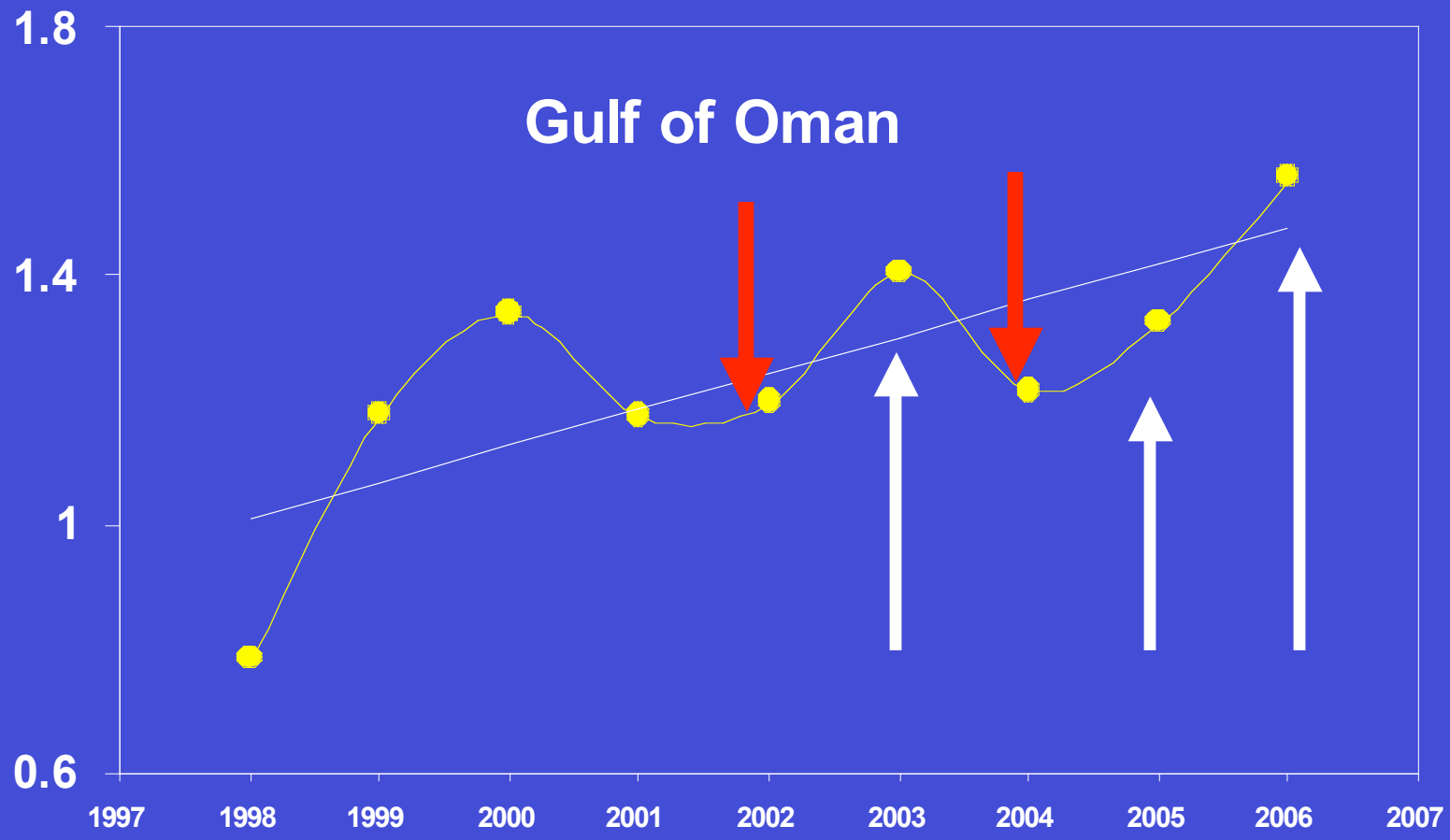




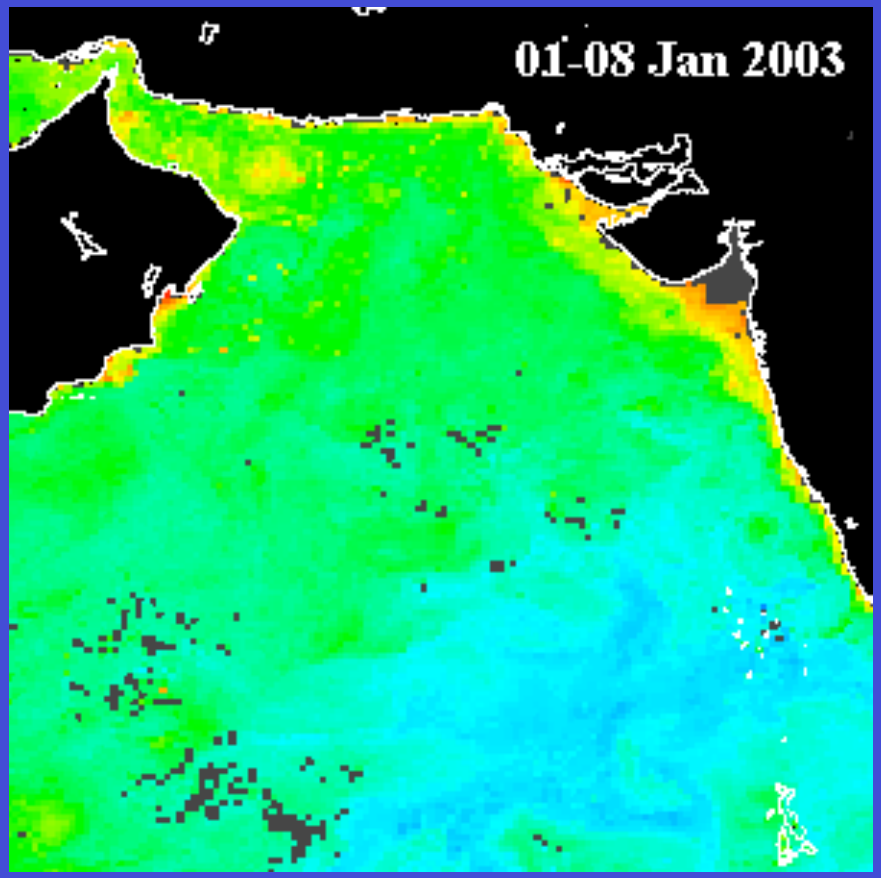
Geostrophic current vectors superimposed on Sea Surface Height Anomalies



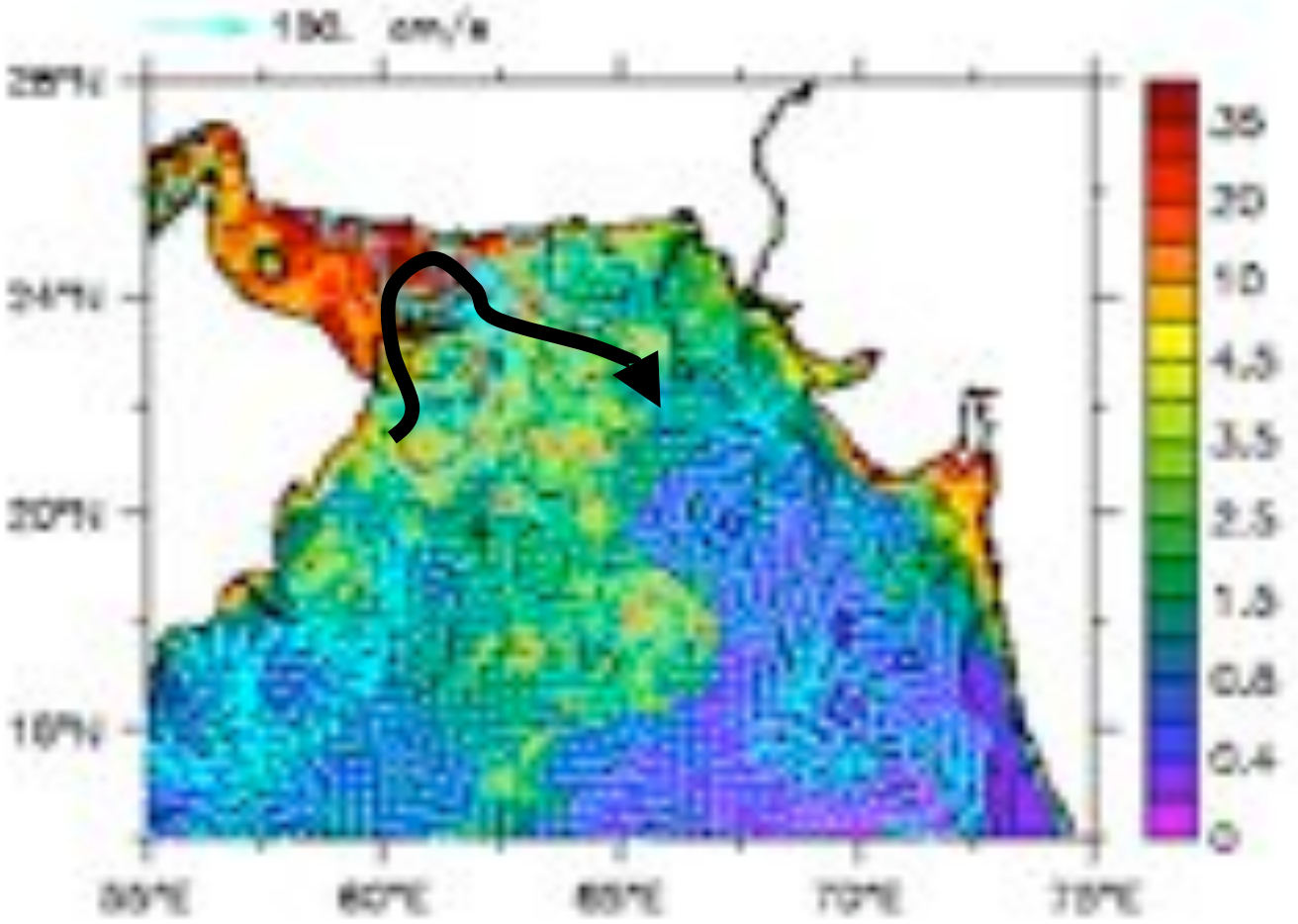
Eddy kinetic energy for the region off the coast of Oman for the period from 2001 to 2006.



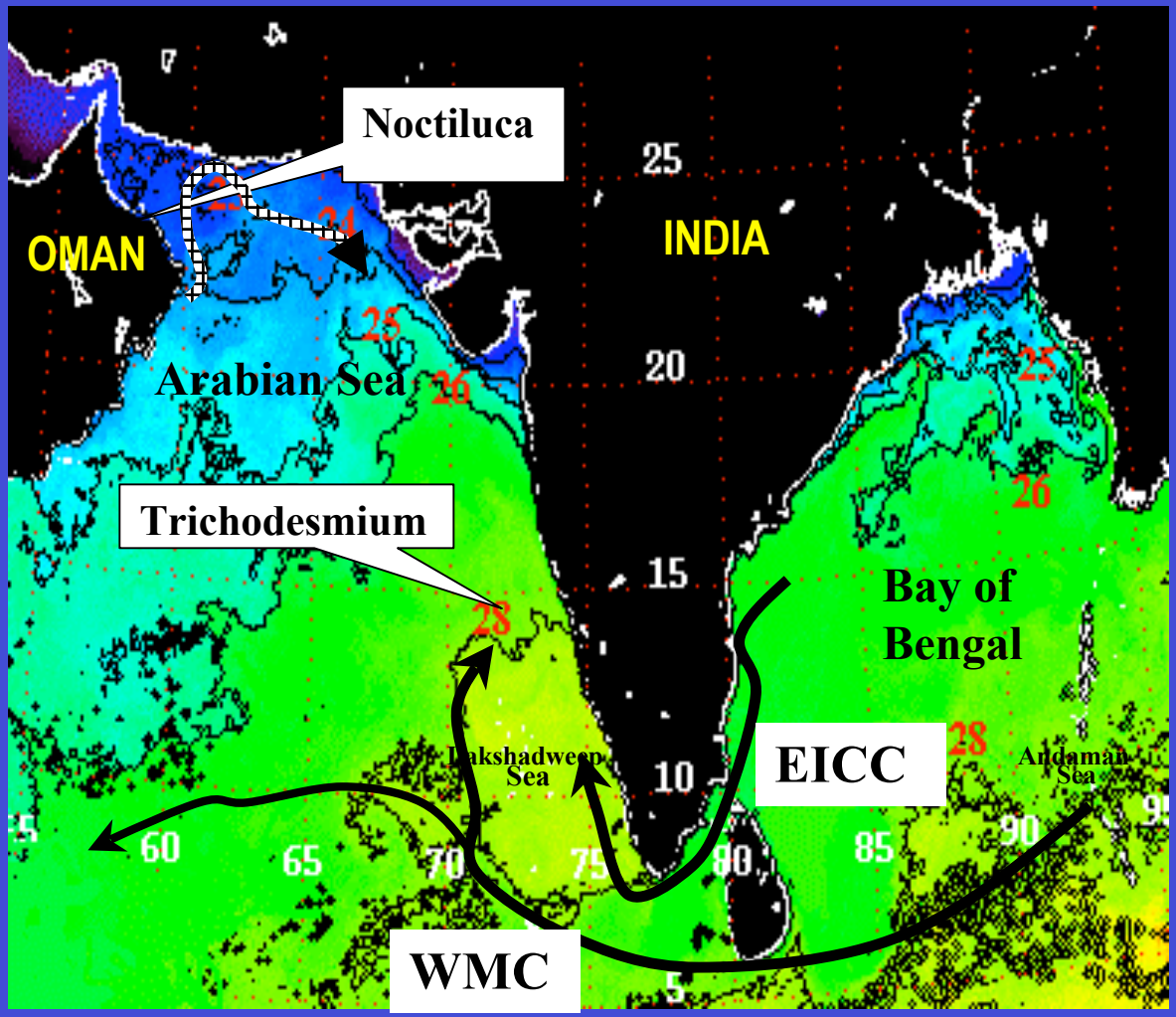
Area averaged chlorophyll for the Gulf of Oman



Evolution of phytoplankton bloom during the NE monsoon of 2003



Sea surface geostrophy superimposed on chlorophyll field of 24th Jan 2006



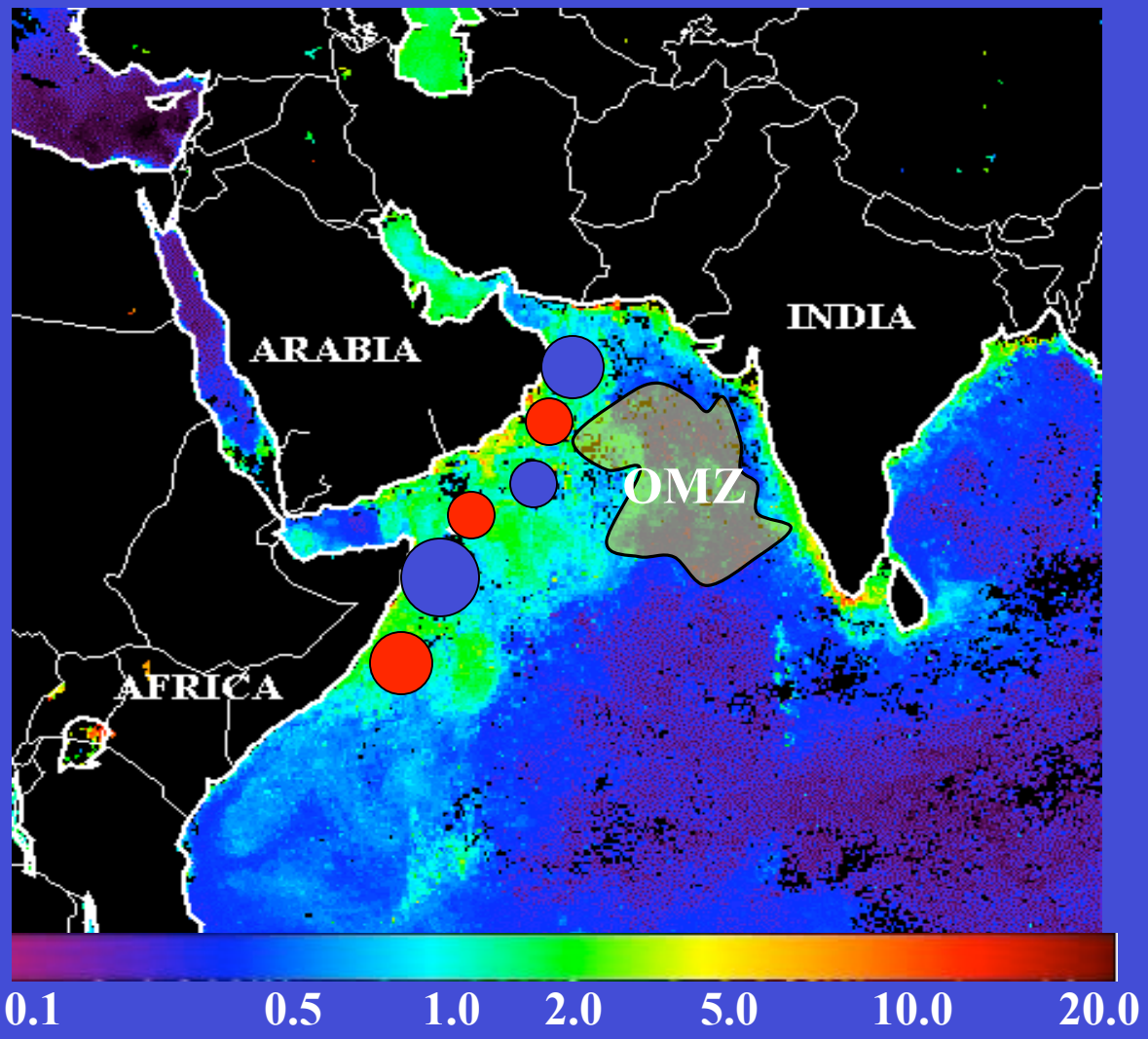
Potential route of dispersal of *N. miralis* bloom from the Gulf of Oman into the northern Arabian Sea (hatched line) and of *Trichodesmium* sp. from the Bay of Bengal and the Andaman Sea (solid black lines)

CLEAR SIGNS OF CHANGE IN BIODIVERSITY

- Pinpoint when changes in species diversity occurred and the rate and extent of this change
- Whether change is connected to large dust inputs
- How these changes are affecting biological productivity and carbon delivery to deeper layers of the Arabian Sea

1. Bacterial processes
2. Denitrification rates
3. The Oxygen Minimum Zone and
4. Coastal Fisheries

FISH MORTALITY OMAN – NOV 2005



What is the biogeochemical significance of eddies in the Arabian Sea?

Transport of desert dust over the Arabian Sea from surrounding desert regions during the NEM of 2005.

Global warming and Rainfall in India

Increasing Trend of Extreme Rain Events Over India in a Warming Environment

B. N. Goswami,[1]* V. Venugopal,[2] D. Sengupta,[2] M. S. Madhusoodanan,[2] Prince K. Xavier[2]

Against a backdrop of rising global surface temperature, the stability of the Indian monsoon rainfall over the past century has been a puzzle. By using a daily rainfall data set, we show (i) significant rising trends in the frequency and the magnitude of extreme rain events and (ii) a significant decreasing trend in the frequency of moderate events over central India during the monsoon seasons from 1951 to 2000. The seasonal mean rainfall does not show a significant trend, because the contribution from increasing heavy events is offset by decreasing moderate events. A substantial increase in hazards related to heavy rain is expected over central India in the future.

Goswami et al., Science Dec. 2006

Monsoon floods cause widespread damage, affecting millions in India 2005 and 2006

70 years of global warming?: Photograph of the Pindari glacier in the Himalayas taken on October 7, 1936, by then Deputy Conservator of Forests F W Champion. 70 years later at the exact spot, his grandson James Champion photographed the same glacier. (Source Sunday Indian Express, 29th Dec. 2006).

"The Study the Earth from Space to advance scientific understanding and meet societal needs"

THANK YOU