



Role of eddies in the Bay of Bengal circulation and hydrography and in the distribution of nutrients and chlorophyll

Thesis submitted to Goa University  
for the degree of

*Doctor of Philosophy in  
Marine Sciences*

by

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Goa, India.*

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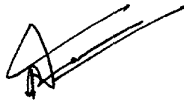
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## Statement

As required under the University ordinance 0.19.8(vi), I state that this thesis entitled "Role of eddies in the Bay of Bengal circulation and hydrography and in the distribution of nutrients and chlorophyll" is my original contribution and it has not been submitted on any previous occasion.

The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed off.



Nuncio Murukesh

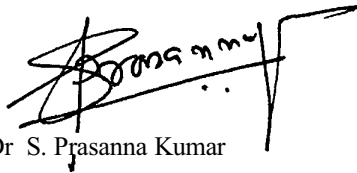
National Institute of Oceanography  
Dona Paula, Goa

Place: Dona Paula

Date: 13-Jul-2007

## Certificate

This is to certify that the thesis entitled "The role of eddies in the Bay of Bengal circulation and hydrography and in the distribution of nutrients and chlorophyll" submitted by Shri. Nuncio Murukesh for the award of the degree of Doctor of Philosophy in Marine Science is based on original studies carried out by him under my supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma in any institution.



Dr S. Prasanna Kumar

Research Supervisor

National Institute of Oceanography

Dona Paula, Goa

Place: Dona Paula

Date: 13-July-2007

All corrections suggested by him earlier  
have been incorporated

R R R  
7 Feb, 08

## **Acknowledgements**

Though I encountered eddies in one of the data analysis and synthesis session of MR-LR programme, I had no idea whether it would make it into this volume. But plans were working out differently. Soon I came to know that Dr Prasanna Kumar is ready to take a student and by that time I received a decent fellowship from Council of Scientific and Industrial research, which have been my all means of living through these years, and I happily boarded the train to Goa. Even after, this was only one of the topics under consideration, before he finally showed the green signal. The Head of the Department, HRDG and the Director, NIO forwarded my proposal with out any delay and permitted to utilize the institute's resources. During these years Dr Prasanna has not only been a good supervisor but a good friend and a great motivator who thinks about me more than I ever would. The interactions we had, leapfrogged my insight on how oceans function as a single entity. He allowed me to use the BOBPS data set which forms the basis of the present study and instilled courage to go ahead in difficult times. After a year, Goa University kindly permitted to register my study under the Marine Science Department and offered their services and Dr. Ramesh Pai was appointed as co-guide. His comments and suggestions have made me to go that extra mile and his presence has ensured an efficient link between me and the university. Dr G.N. Nayak, HOD Marine Science has been prompt in the university related matters and critically monitored the progress of my work.

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## **Abstract**

Eddies are ubiquitous in the ocean and are products of geophysical turbulence. They develop from the hydrodynamic instabilities and are known to alter the physical and biochemical properties of the ocean. In the north Indian Ocean (NIO), these changes in the hydrodynamical and biochemical properties are a response to the seasonal reversal of monsoon winds. Off the twin seas of the NIO, the Arabian Sea (AS) responds to this seasonal reversal more directly, whereas its eastern counterpart the Bay of Bengal (BOB) deviates from the norm. Apart from the seasonal reversal of the monsoon winds, BOB is influenced by the remote forcing via Rossby waves and coastally trapped Kelvin waves. Though the presence of eddies were reported in the BOB as early as 1950's, their genesis and evolution have not been subjected to intense scrutiny. Present study is an attempt in this direction and to decipher their role.

Recently concluded Bay of Bengal Process Studies (BOBPS) had two observational transects, along the central as well the western boundary of BOB, which was repeatedly sampled for 3 seasons during summer 2001, fall intermonsoon 2002 and spring intermonsoon 2003. Analysis of the thermohaline structure showed many undulations which can be characterized as eddies along both transects. They altered the ambient temperature by 2-6°C and salinity by 0.2 to 1 psu. Eddies observed along the western boundary and along the central BOB are found to have different origins.

Along the western boundary the cyclonic eddy designated as northern coastal eddy (NCE) was found to be a robust feature occurring every year. Satellite derived sea-level anomaly data during 2001 and 2003 showed that the NCE was formed in February from an instability in the northward flowing western boundary current. This instability was governed by a local positive wind-stress curl close to the western boundary and offshore negative wind-stress curl, and remote forcing via the westward propagating Rossby waves. NCE had a life span of about 5 months.

Eddies encountered along the central BOB appeared to have a different origin. It has been found that a gradient in sea-level anomaly, which is a manifestation of the horizontal density gradient, was generated out of a variety of physical processes (viz, large scale circulation, westward propagating Rossby waves and the wind forcing), which drives a vertical shear and baroclinic instability. However, this explanation does not hold good for all the eddies observed, especially those found during spring intermonsoon. The life cycle of these eddies is marked with splitting and coalescing. Evolution of these eddies studied using the satellite sea-level anomalies showed that they have a life span of about 1-5 months.

Analysis of heat and salt content showed that the heat content is dramatically influenced by the presence of eddies and was about 2-3 times the seasonal variability. The impact of eddies was not pronounced in the salt content. In the Bay of Bengal winds are comparatively weak hence the Ekman transport computed from the observed winds were found to be smaller ( $<1\text{Sv}$ ) than the geostrophic transport which was about 2-8 Sv when

integrated in the upper 150 m depth. The geostrophic transport also was dominated by eddies. Enhanced heat and salt transports was noticed near these eddies which reached up to  $600 \times 10^{12}$  J/m/day and  $200 \times 10^{12}$  Kg/m/day respectively. This resulted in enhanced east-west and offshore-onshore transport of heat and salt.

Eddies not only influenced the thermohaline characteristics of the BOB, but showed its influence in the distribution of water-column nutrients as well as chlorophyll concentrations. Eddy-pumping supplied the much needed nutrients to the upper layers which in turn enhanced the chlorophyll concentrations by 2 to 6 times the ambient values in the BOB. Thus, the study show that eddies are ubiquitous in the BOB in all the seasons and play a key role in altering the physical, chemical and biological characteristics of this basin. The eddy-induced enhanced biological productivity in the BOB provides an explanation to the paradox of comparable rates of annual organic flux to the deeper ocean between biologically low productive BOB and a high productive Arabian Sea.