Chapter 2 - Data and methods

2.1 Introduction

In order to understand the characteristics of the eddies in the BOB and address their origin and evolution, a suite of data sets, both in situ as well as remote sensing, were utilized. *In situ* data used in this study is collected on board Indian research vessel ORV Sagar Kanya (SK) during 2001-2003 under a national programme Bay of Bengal Process Study (BOBPS).

2.2 *In situ* data

The *in situ* data used in the present study is the temperature and salinity profiles collected at stations along 88°E in the central BOB from 7°N to 20°N, and along the western boundary from 11°N to 20°N (Figure 2.2.1 ) during 3 seasons - summer monsoon (SK166, 10-July-2001 to 1-August-2001), fall intermonsoon (SK182, 17-September-2002 to 11-October-2002) and spring intermonsoon (SK191, 16-April-2003 to 6-May-2003) intermonsoon . Temperature and salinity profiles up to 1000 m depth were taken at one-degree latitude interval along the central and western boundary tracks using a Seabird 9/11 plus CTD (Conductivity-Temperature-Depth) system. The station interval along the western boundary was, however more than one degree. The raw data was processed using the software ‘Seasoft’ version 4.2.17. CTD salinity was calibrated against water samples collected simultaneously by a rosette sampler fitted with 10/30-L Go-Flo bottles and analyzed with a Guildline 8400 Autosal. Using the temperature and salinity profiles
geostrophic currents were computed w.r.t 1000m using the temperature and salinity data following Helland-Hansen method [Pond and Pickard, 1978].

In addition to the in situ data from the above mentioned 3 cruises, monthly mean climatology of temperature and salinity on a 0.25 x 0.25 degree grid from World Ocean atlas (WOA) 2001 [Conkright et al., 2002] is also used for computation of heat and salt content anomalies (discussed in chapter 5).

From the surface meteorological parameters (air temperature, wet bulb temperature, pressure, and wind speed and direction) measured at stations along both central and western boundary tracks in all the 3 seasons, wind data were used for the computation of Ekman volume transport ($E_v$) using the following relationship.

$$ E_v = \tau/\rho f $$
where $\tau$ is the windstress at the surface, $\rho$ is the sea water density and $f$ is the Coriolis parameter. Windstress is computed using a constant drag coefficient of $1.3 \times 10^{-3}$ (see chapter 5 for more details).

The data on nitrate, phosphate, silicate and chlorophyll $a$ was taken from BOBPS data CD (Indian Oceanographic Data Centre product, National Institute of Oceanography, Goa, March 2007). The nutrient data (nitrate, phosphate and silicate) of BOBPS was generated from the water samples collected in the upper 1000 m from 19 discreet depths (near surface, 10, 20, 30, 40, 50, 75, 100, 125, 150, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 m) using 10/30L Go-Flo bottles attached to the CTD rosette and analyzed with a SKALAR auto-analyzer during summer and with spectrophotometer following Grasshoff et al. [1983] during fall and spring intermonsoons. In both cases, sensitivity for nitrate, silicate and phosphate was 0.1, 0.5 and 0.03$\mu$M respectively. The chlorophyll $a$ data of BOBPS was obtained from water samples collected in the upper 120 m from 8 discrete depths (near surface, 10, 20, 40, 60, 80, 100 and 120 m) and concentrations measured using a TURNER design fluorometer.

2.3 Remote sensing data

The spatial structure and the evolution of eddies were examined by analyzing 7-day snapshots of the merged sea-level anomalies of Topex-Posiedon/ERS 1/2 satellites obtained from AVISO live access server (http://las.aviso.oceanobs.com) having a spatial resolution of $1/3^{rd}$ of a degree during the period October 1992 to January 2004 [Le Traon et al. 1998].
This is a proven tool in studying the mesoscale features of the ocean [Le Traon and Dibarboure, 1999]. They show that the error associated with this amounts to about 3-6% of the variance of the signal. In the BOB the mean error is ~ 3 cm. Velocities from the sea-level anomalies were computed assuming the geostrophic relation

$$2\Omega \sin(\phi) V = g \tan(i)$$

where $\Omega$ is the earth's angular velocity, $\phi$ is the latitude, $V$ is the velocity and $\tan(i)$ is the slope of the sea surface [Pond and Pickard, 1978]. The error associated with the velocity computation amounts to ~ 20% of the variance [Le Traon and Dibarboure, 1999], which is small, but not negligible.

Twice daily Quik SCAT wind-stress (Large and Pond algorithm) obtained from PODAAC [JPL Publication, 2003] and Southampton Oceanography Center surface fluxes [Josey et al., 2002] was used to compute the curl of the wind-stress and is given by

$$\text{Curl}(\tau) = \frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y}$$

where $\tau_x$ and $\tau_y$ are eastward and northward components of wind-stress.

Eddies formed out of baroclinic instability processes tend to follow the typical length scale, Rossby deformation radius ($L_R$), a relative measure of stratification and the Coriolis force (discussed in chapter 3). $L_R$ is computed assuming a two layer ocean using the formula, $(\Delta \rho \rho_0^{-1} gh)^{0.5} f^{-1} [Kamenkovich et al., 1986]$ where $\Delta \rho$ is the density drop across the main pycnocline, $\rho_0$ a reference density, $h$ is the depth of the pycnocline, $f$ the Coriolis parameter.