East India Coastal Current induced eddies and their interaction with tropical storms over Bay of Bengal

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Eddies of about 10 to 500km in diameter, persisting for periods of days to months are commonly referred to as mesoscale eddies in oceanography. Energetic eddies are frequently found in the vicinity of faster flowing currents like the Gulf Stream and the Kuroshio. The present study deals with the role of eddies, occurring in the vicinity of the East India Coastal Current (EICC), particularly in the months of April to May and October to November, during the intensification of tropical cyclones in the Bay of Bengal. Although the Bay of Bengal is well known for mesoscale eddies, the role of these in the intensification/weakening of the storms is quantitatively unknown. In this study, an attempt has been made to conduct a quantitative analysis of the role of these eddies (warm/cold) in the intensification of the storms over the Bay of Bengal. It is found that in the case of a severe cyclone occurring over the period of 16 to 19 October, 1999 the intensity of the storm was enhanced by 260% due to its interaction with a warm eddy. This is much higher than that reported in case of, for example, Hurricane Opal (119%) and Typhoon Maemi (138%). The enthalpy fluxes (latent plus sensible) are much higher (lower) over warm (cold) eddies. The warm eddy opposes the cooling induced by the storm and helps the intensification through the supply of large amount of enthalpy flux. This emphasizes the importance of eddies in the intensification of storms over the Bay of Bengal, which is omitted by meteorologists in forecasting the intensification of storms.

INTRODUCTION

The western boundary coastal current in the Bay of Bengal, known as the East India Coastal Current (EICC) has been extensively studied[1,2,3,4]. Like the Somali Current in the Arabian Sea, the EICC reverses direction twice a year, flowing northeastward from February to September with a strong peak in March/April; and southwestward from October to January with the strongest flow in November. The EICC has depths extending up to 200m and has a transport of ~10Sv[1]. A change in the direction of EICC is observed just south of 18°N in the peak southwest monsoon period. Sea surface height and wind stress observations indicate that the strength and direction of the EICC follows closely the along-shore wind stress[5]. During the summer monsoon season (May-August), the EICC flows northward along the southern part of the Indian coast and equator-ward along the northern part[2] whereas, during October to December, the EICC flows equator-ward along the entire Indian coast[3] carrying low salinity water from the Bay of Bengal *en route*.

It was reasoned that the flow instabilities in the EICC lead to the formation of eddies in the vicinity of the EICC. It is worth noting that energetic rings and eddies are commonly found in the vicinity of faster flowing currents including the Gulf Stream and its North Pacific counterpart off Japan called the Kuroshio[6]. In their mature phase, the eddies may have mesoscale dimensions of about 100 to 200km in diameter and persist for periods of days to months. Although the EICC is not as strong as the Gulf Stream, it is also found to produce several cold and warm core eddies on both sides of the current during certain months (April and May, October and November) particularly when the EICC is very strong[7].

Over the northern Indian Ocean, the Bay of Bengal accounts for the majority (about 87%) of total pre- and post-monsoon tropical cyclones. Most of the severe cyclones in the Bay of Bengal during pre-monsoon (April to May) and post-monsoon seasons (October to November) make landfall on the east coast of India and cause colossal loss of life and property. The most severe super cyclone which occurred over the last 110 years hit Paradeep, Orissa, on 29 October 1999. The lowest central pressure was 926hPa and wind speed was greater than 200kmph. The storm surge of about 8m height traveled 30km inland. More than 10,000 people were killed and the total financial loss due to the damage was estimated at 4.5 billion US dollars[8].Hence advances in accurate prediction of the intensity and the track prediction of storm is very important to minimize the loss of life.

The interaction between tropical cyclones and ocean eddies has been identified as an important area of research in the tropical cyclone intensity change[9,10,11,12,13]. From the observational studies of various hurricanes like Opal, Mitch and Bret in the Atlantic, it has been generally found that rapid intensification (typically from Saffir–Simpson category 1 to 4 within 24 to 36hrs) was observed when these hurricanes passed over warm ocean features[10,11]. The intensification of a cyclone depends on a number of meteorological and oceanographic parameters. Leipper and Volgenau[14] first recognized the importance of ocean thermal structure in the tropical cyclone (TC) intensification. Goni *et al*[15] stressed the role of upper ocean thermal structure, since in most of the cases it is the upper ocean that supplies fuel for the movement and intensification of a cyclone. It has been generally established that tropical cyclones originate and intensify only in the oceanic regions where the sea surface temperature (SST) is above 26°C[15,16,17]. Although SST plays a role in TC genesis, the upper ocean heat content (UOHC) appears to play a vital role in the intensification of storms[10,18,19]. In the Bay of Bengal, the average value of UOHC and the depth of 26°C isotherm (D26) is 3 to 4 times higher in a warm eddy compared with that in a cold eddy[20]. Earlier studies suggest that the intensity of storms is underestimated by 26–30% if the eddies are not considered[21].

Sudden and unexpected intensification of tropical cyclones often occurs within 24 to 48hrs before striking the coast, upon passing over warm oceanic regimes such as the Gulf Stream or large warm core rings (WCRs) in the western North Atlantic Ocean and Gulf of Mexico. Although SST exceeding 26°C is a necessary condition for intensification of a cyclone, the Ocean Planetary Boundary Layer (OPBL) and the depth of the warm isotherm (D26) are equally important and represent regions of positive feedback to the atmosphere[22].For example, Hurricane Opal, that occurred in 1995, intensified rapidly from category-1 to category-4 status within 14 hours as it passed over a warm core eddy and encountered a deeper and warmer oceanic regime in the Gulf of Mexico[10]. Lin *et al*[21] have included the satellite altimetry data into a very simple coupled model to show that the presence of the warm ocean eddy can serve as an efficient insulator against the ocean's negative feedback, and helps to maintain, and even boost, the TC intensity.

Although the Bay of Bengal is well known for eddies, quantitative analysis on the role of these eddies in the intensification of storms is still lacking. Ali *et al*[23] discussed the importance of eddies in the case of May 2003 cyclones in a qualitative fashion. Lin *et al*[24] reported a sudden intensification of Nargis over a warm oceanic region, just before landfall. Sadhuram *et al*[20] showed that the intensity of Aila (24 to 26 May 2009) was enhanced by 43% when the storm encountered a warm eddy. Although these studies suggest the role of warm core eddies, a systematic quantitative assessment has not been done so far for Bay of Bengal cyclones. In the present study, the generation of eddies due to the EICC and their effect on the intensification/weakening of storms over the Bay of Bengal is addressed using remote sensing data.

MATERIAL AND METHODS

The merged products of altimeter data on dynamic heights, geostrophic currents and surface height anomaly (SHA) for the Bay of Bengal (78 to 99°E and 5 to 22°N) have been obtained for the period 1993 to 2009 from the NASA's Atlantic Oceanographic and Meteorological Laboraory (AOML) database in the netcdf format. After converting the netcdf data to ASCII, surfer software was used to plot the geostrophic currents, overlying the sea surface height anomalies taken from the AVISO live access server.

Data on cyclone tracks and the central pressure of the storms have been taken from the India Meteorological Department (IMD) and the Cyclone E- Atlas of IMD (2008). Argo data for locations (12.8°N, 81.1°E), (14.5°N, 85.7°E), (8.3°N, 84.2°E), (14.2°N, 82.21°E) and (8.59°N, 84.84°E) were taken from the INCOIS (Indian National Centre for Ocean Information services). To compute different oceanographic parameters that are necessary for this study, Argo data for every m depth interval were interpolated using spline interpolation technique.

UOHC from Argo data

UOHC is computed using the following equation

$$\text{UOHC} = \rho C_P \int_0^{D26} T\, dZ$$

In which ρ is the density of water column above 26°C isotherm, C_P is the specific heat of seawater at constant pressure; T is the temperature in excess of 26°C for a layer of depth increment dz and D_{26} is the depth of the 26°C isotherm.

A new method to compute UOHC from SSHA

Using RAMA buoy data and satellite SSHA from 2007 to 2009 in pre- and post-monsoon months at three locations (8°N,90°E; 12°N,90°E; 15°N,90°E) equations were developed to compute UOHC and D26 from SSHA (Fig 1).

SSHA is positively and significantly (>99% level) correlated with UOHC and D26. The regression equations are shown as:

Pre monsoon months (April to May):
UOHC = 2.55 ∗ SSHA + 75.58 (1)
D26 = 1.74 ∗ SSHA + 71.89 (2)
Post monsoon months (October to November):
UOHC= 2.09 ∗ SSHA + 75.03 (3)
D26 = 1.31 ∗ SSHA + 70.67 (4)

Eddy feedback factor for few cyclones

To quantify the contribution of any eddy, a dimensionless parameter called the eddy feedback factor has been introduced by Wu *et al*[25] which is defined as follows

$$F_{Eddy\text{-}T} = (\Delta p_{out} - \Delta p_{in}) / \Delta p_{in}$$

Where, Δp_{in} is the amount of the sea-level central pressure in hPa deepening when the storm encounters the ocean eddy and Δp_{out} is the central pressure in hPa when the storm leaves the eddy.

Sensible and latent heat fluxes and the meteorological parameters (zonal wind, relative humidity and air temperature) have been taken from the NCEP reanalysis. TMI SST has been taken from INCOIS database.

RESULTS AND DISCUSSION

EICC and eddies

Fig 2 shows the climatology of geostrophic currents for the months April and May and October and November and associated sea level anomalies (1993– 2009) during pre- and post-monsoon seasons in the Bay of Bengal. In the mean monthly pictures, the EICC appears to be a discontinuous flow with a few circulating loops along its path. The loops or mesoscale

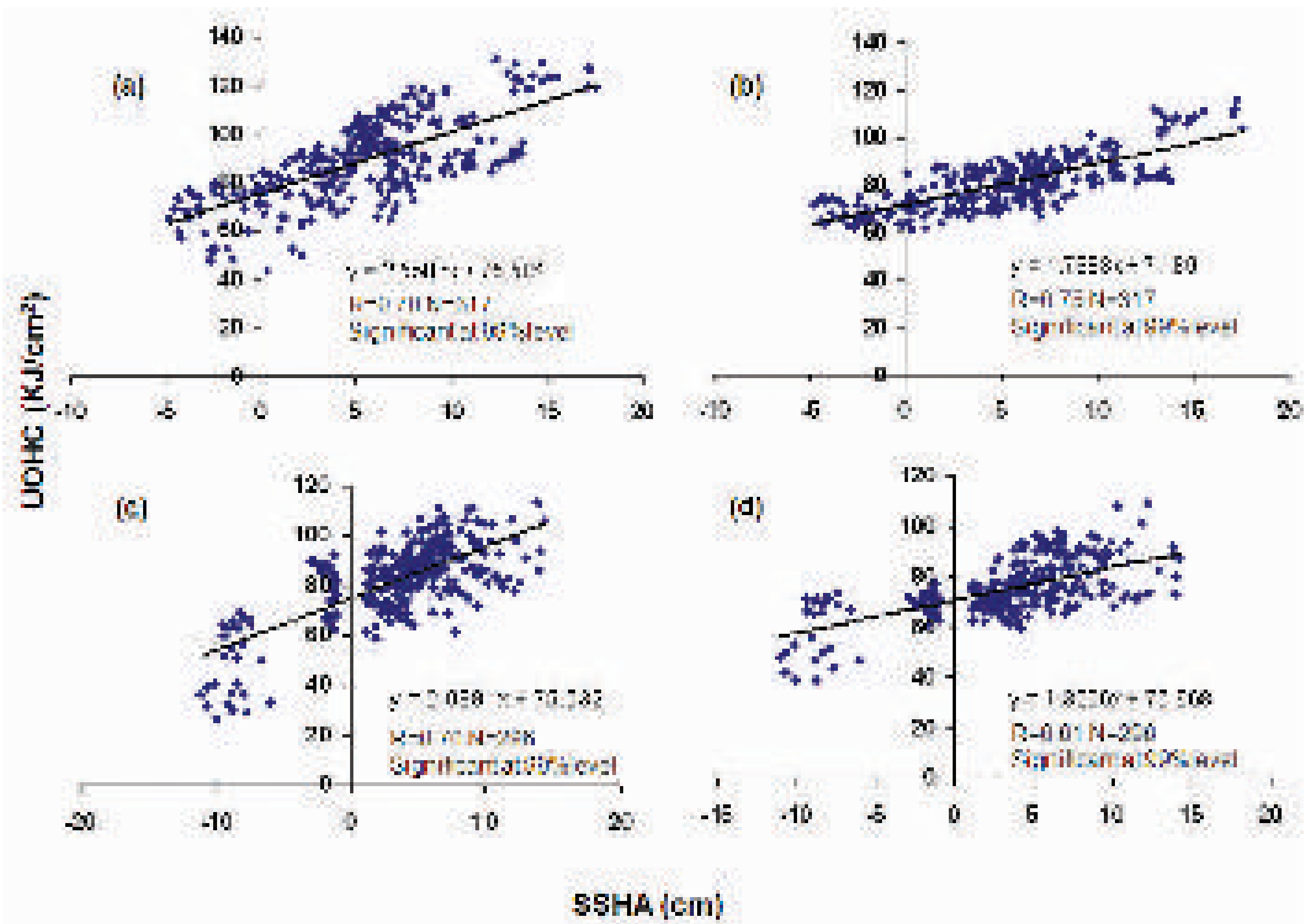

Fig 1. Scatter plot between SSHA and UOHC, D26 for pre- (a,b) and post- (c,d) monsoon months.

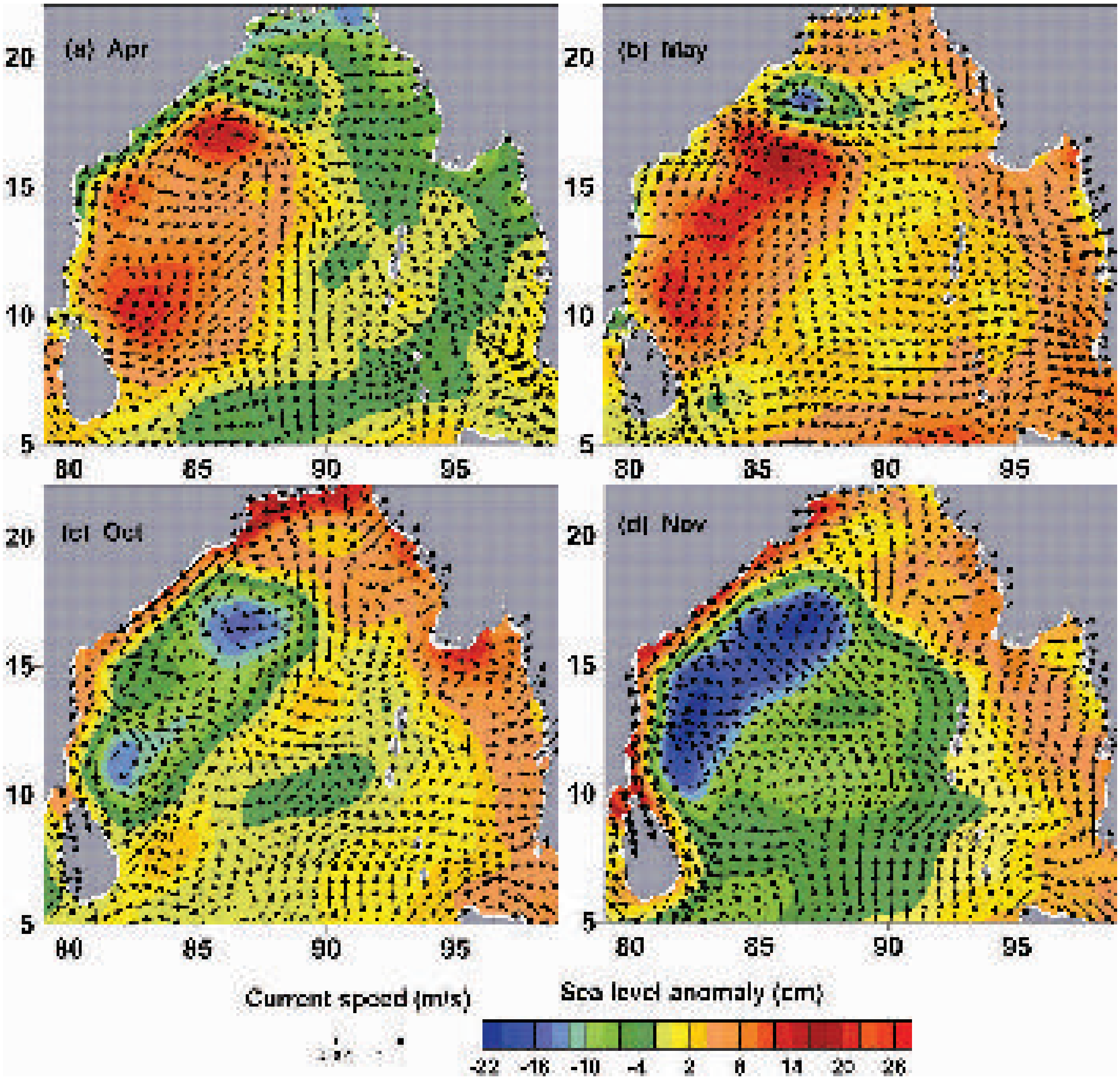

Fig 2. Climatology of geostrophic currents and sea level anomaly for the period 1993 to 2009 in (a) April (b) May (c) October and (d) November.

eddies are highly variable in direction at all timescales from intra-seasonal to inter-annual. The EICC is quite strong in the months of April to May and October to November leading to the formation of several eddies (cold and warm core) all along its path. These mesoscale features, associated with the EICC, have been studied previously[26].

Typical temperature and salinity profiles of warm and cold core eddies, compared to that of normal conditions (without eddies), are shown in Fig 3. A deeper mixed layer and higher SST values are clearly seen in the warm core eddy compared to cold core eddy or to that during normal conditions. In the warm eddies the warm waters are found to stretch significantly to deeper depths (>200m). Low Salinity was observed inside the warm core eddies. The positions of a few selected eddies and the dates of their occurrence along with the other computed oceanographic parameters like UOHC and D26 are presented in Table 1. All these parameters are generally higher in the warm core eddy compared to the other two cases. UOHC in the warm core eddy (156kj/cm^2) is almost 3 times higher to that of the normal condition (51kj/cm^2) and 4 times to that of cold core eddy (35kj/cm^2).

Eddies and the intensification of cyclones

The upper surface layer heat potential of the warm core eddy acts as a fuel for the intensification of a cyclone by giving a positive feedback to the cyclone. Whereas in the case of cold core eddy the heat potential is comparatively less and provides negative feedback to the cyclone. Cyclones entering the warm core eddies are usually intensified depending on the strength and size of the eddy while those passing

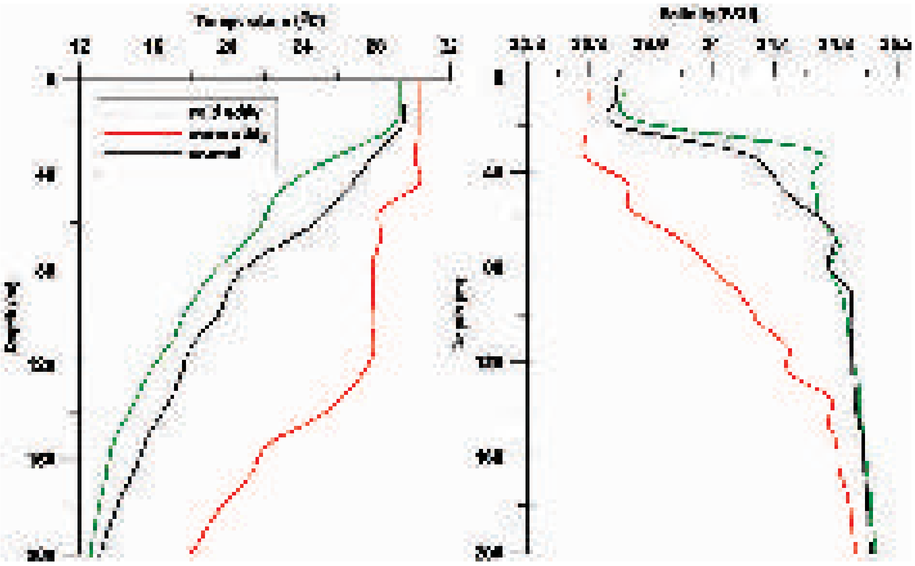

Fig 3. Variation of temperature and salinity profiles in a warm core eddy, a cold core eddy and under normal conditions.

Eddy location and date	SST(°C)	MLD (m)	D26(m)	UOHC(kj/cm²)
Cold eddy (8.3N,84.2E) (29/05/2009) Float ID 2900106	29.24	34	31	35
Warm eddy (13.9N,82.0E) (13/05/2009) Float ID 2901073	30.3	50	135	156
Normal condition (without eddy) (8.6N,84.8E) (28/05/2009) Float ID 4900670	29.43	28	49	51

Table 1: Comparison of oceanographic parameters for typical cold core and warm core eddies

through cold core eddies are generally weakened. The rate of intensification of a cyclone also depends on the translation speed (Uh) of the cyclone. Because of the inverse relationship between the UOHC and Uh developed for the northwest Pacific Ocean[24] and the Bay of Bengal[19] it is suggested that a slow (fast) moving cyclone can intensify over the region where UOHC is high (low). The eddy feedback factor (F_{EDDY-T}) could be positive (warm eddy) or negative (cold eddy). If F_{Eddy-T} is 0.6 it means that the cyclone is intensified by 60% on passing through the eddy. F_{EDDY-T} has been computed for eight cyclones with the results shown in Table 2. The tracks of eight selected cyclones which passed through warm/cold core eddies are shown in Fig 4. The images on the left hand side show the dynamic heights and the geostrophic currents of the sea surface in which the eddies can clearly be seen.

Similarly the pictures on the right hand side of Fig 4 show the sea surface height anomalies from which again the eddies can be identified. The severe cyclone which occurred during 15 to 18 October 1999 formed at 13.5˚N, 92.5˚E, intensified

S.No	Period/ name of the cyclone	Central pressure before entering the eddy (hPa)	Central pressure after coming out of the eddy (hPa)	Eddy feed back factor $F_{eddy\text{-}T}$	UOHC (kj/cm²)	D26(m)	Enthalpy Fluxes(kj/cm²)	
							Climatology	Observed (NCEP Reanalysis data)
1	15th to 19th oct 1999	994	968	260%	194	165	85	211
2	25th to 29th Nov 2000	992	976	160%	110	97	132	214
3	10th to 19th May 2003	998	982	75%	114	98	92	197
4	28th Nov to 2nd Dec 2005	998	1002	–60%	46	52	131	65
5	25th to 29th April 2006 (Mala)	964	954	30%	97	87	120	204
6	13th to 16th Nov 2008 (Khaimuk)	998	1004	–40%	58	60	149	70.5
7	23rd to 25th May 2009 (Aila)	984	974	43%	127	107	111	122
8	17th to 19th May 2010 (Laila)	993	978	100%	139	115	92	169
9	Opal (1995)			119%				
10	Maemi (2003)			138%				

Table 2: Oceanographic parameters and Enthalphy fluxes in eddies through which the cyclones passed

to category 4 and crossed the Orissa coast near Gopalpur on 18th Oct 1999. On 17 October the cyclone passed through the warm core eddy of size more than 200km as category-1 and became a very severe cyclonic storm of category-5

(http://weather.unisys.com/hurricane/n_indian/1999/4/track.dat).

The geostrophic currents (left panel) and the surface height anomaly (right panel) in Fig 4 show that the ocean eddy is very strong and considerably warm with a maximum SSHA of about +35cm. The eddy feedback factor ($F_{EDDY\text{-}T}$) as calculated from the central pressure variations of the cyclone is 2.6, which means that the intensity of the cyclone increased by 260% on passing through this warm core eddy on 17 October 1999 (Fig 4). On 26 November 2000 a tropical depression that formed at 8.5°N, 91.5°E moved westward, strengthening to become a tropical storm later that day. It intensified into a cyclone on 28 November by passing through a warm eddy eventually making landfall on 29 November. From Fig 4 it can be seen that the system belonged to category-1 on 26 November and was relatively weak before entering the warm eddy. However, on 28 November, after passing through the eddy, the cyclone intensified to category-4. Although the eddy was only moderately warm with SSHA of about 10cm the cyclone intensified significantly because it moved slowly and remained in vicinity of the eddy for a longer time. The eddy feedback factor for the cyclone is 160%. The cyclone which formed in the southern Bay of Bengal during 10 to 19 May 2003, entered an eddy with SSHA of 15cm, made re-curvature and intensified into a category-4 cyclone. The eddy feedback factor for the cyclone is 75%. Later it changed direction and crossed the Myanmar coast on 19 May. The severe cyclone

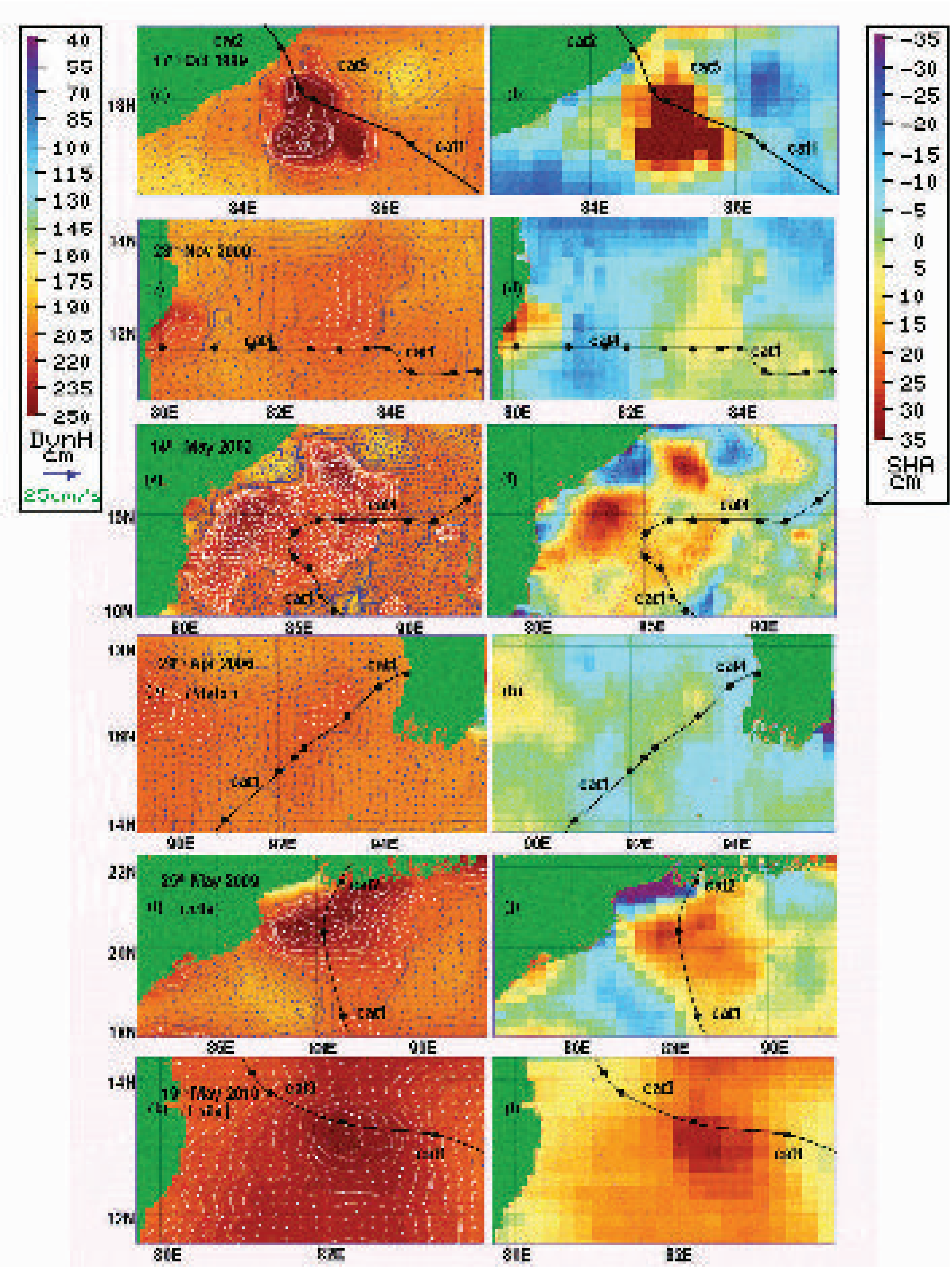

Fig 4. Tracks of cyclones which passed through warm core eddies in the Bay of Bengal during (a,b) 16 to 19 October 1999 (c,d) 25 to 29 November 2000 (e,f) 10 to 19 May 2003 (g,h) 25 to 29 April 2006 (Mala) (i,j) 23 to 25 May 2009 (Aila) (k,l) 17 to 19 May 2010 (Laila). Geostrophic currents (left panel) and SSHA (cm) (right panel) are overlaid.

Mala (24 April to 2 May 2006) intensified into a severe cyclonic storm on April 27 and transformed into a very severe cyclonic storm (category-4) on 28 April; but it weakened quickly after passing through a cold core eddy, made landfall on 29 April and quickly dissipated over Myanmar. Throughout Burma, the cyclone killed 22 people and caused damage to over 6000 houses, of which 351 were completely destroyed. Cyclone Aila formed on 23 May 2009 and crossed west Bengal on 25 May. It started as a deep depression and intensified into a category-2 cyclone as it passed through a warm eddy with SSHA of about 15cm. The eddy feedback factor for the cyclone has been calculated as 0.43. Although Aila was not a strong storm, it caused heavy rains and storm surges swamped the mouths of the Ganges River in Bangladesh and India and caused extensive damage. At least 50,000 hectares of agricultural land were lost during the storm, costing an estimated loss of about US$ 26.3 million. Cyclone Laila formed on 17 May 2010 at 11.6°N, 87°E and made landfall near Bapatla (15.8°N, 80.47°E). On May 17 it was located as a depression about 78km east-southeast of Chennai (13.08°N, 80.27°E). On May 18 it passed through a warm core eddy with SSHA of about 20cm and intensified into a cyclone, with the eddy feedback factor being 100%. On 20 May, it moved slowly and intensified further to a severe cyclonic storm of category-3 and made landfall near Bapatla, Andhra Pradesh. The cyclone caused heavy levels of destruction in the Prakasam, Krishna and Guntur districts and preliminary reports prepared by the State government estimated the loss at more than US$ 105.2 million.

In addition to the cases previously discussed, two more case studies of cyclones that passed through cold core eddies (Fig 5) are presented. On 29 November 2005 tropical cyclone Baaz began to form in the Bay of Bengal off the southern coast of India near the Island of Sri Lanka. It was predicted that the storm would move towards the east coast of India within the proceeding 48 hours and, as such, thousands of people were evacuated from the low-lying coastal strips of Tamil Nadu and Andhra Pradesh. However, it later passed through a cold core eddy of SSHA –25cm and thus weakened considerably.

The eddy feedback factor in this case is calculated as –0.60, meaning that the cyclone had weakened by 60% on passing through the eddy. By 30 November, it had turned into a depression, made slow progress towards land and then dissipated. This emphasizes the importance of eddies in forecasting the intensity and the track. If meteorologists conducting the forecasts had considered the location and impact of this cold core eddy, efforts undertaken up by the Government to evacuate people, could have been avoided. In 2008, a low pressure area was identified southeast of the Bay of Bengal. This was identified on 13 November and was then seen to concentrate into a depression east-southeast of Chennai. A few hours later IMD upgraded the system to a deep depression. It then intensified into a cyclonic storm Khai-Muk after passing through a

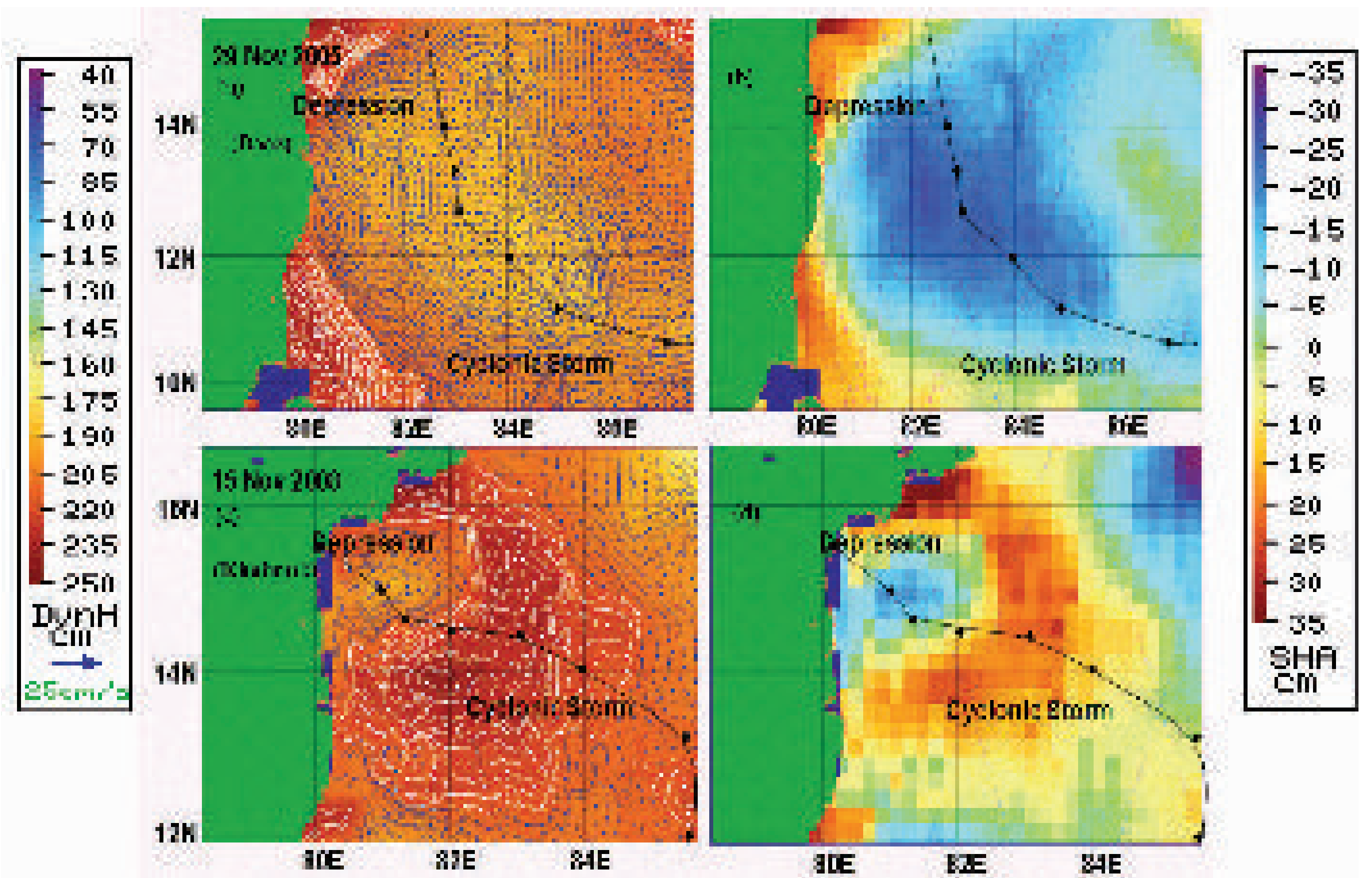

Fig 5. Tracks of cyclones which passed through cold core eddies in the Bay of Bengal during (a,b) 28 November to 2 Dec 2005 (Baaz) and (c,d) 13 to 16 November 2008 (Khaimuk). Geostrophic currents (left panel) and SSHA (cm) (right panel) are overlaid.

	SST-Air temperature (°C)			RH at 600 hPa			zonal wind difference (200–850 hPa) (m/s)			Zonal wind at 1000hPa (m/s)		
	Before	After	Climatology	Before	After	Climatology	Before	After	Climatology	Before	After	Climatology
15th to 19th oct 1999	2.91	–1.57	2.37	54	66	48	–1.02	–5.2	–1.32	–1.3	–2.74	-1.37
25th to 29th Nov 2000	3.49	–0.08	2.42	70	51	48	–4.45	–2.29	6.88	–2.76	–5.33	-4.30
10th to 19th May 2003	1.08	–0.3	1.08	82	68	32	–1.66	–1.86	6.29	4.79	4.45	3.5
28th Nov to 2nd Dec 2005	1.22	–0.13	2.76	27	74	48	6.75	–3.58	2.76	–5.92	–5.09	-4.30
25th to 29th April 2006 (Mala)	1.41	–0.55	0.52	32	44	25	2.22	–3.02	10.47	2.63	4	2.8
13th to 16th Nov 2008 (Khaimuk)	0.72	1.21	2.42	34	65	48	3.95	4.92	2.76	–4.92	–5.89	–4.30
23rd to 25th May 2009 (Aila)	1.02	–2.96	–1.57	78	66	50	–4.15	–4.03	9.68	0.16	0.03	1.8
17th to 19th May 2010 (Laila)	1.22	–1.93	0.05	25	56	38	–0.04	–12	–4.95	–0.67	0.47	1.13

Table 3: Meteorological parameters in eddies through which the cyclones passed.

warm core eddy. Later on 14 November, as the cyclone passed through a cold core eddy of SHA −15cm, the system became sheared to the western periphery and the IMD downgraded it back into a deep depression. The corresponding eddy feedback in this case is negative and amounts to –40% (Table 2).

What could be the reason for the intensification /weakening of storms due to these eddies? It is a known fact that normally a cyclone will intensify if the conditions from both atmosphere and ocean are favorable. If the conditions from the ocean are not favorable, the storm may not intensify even if the atmospheric conditions are favorable. The main requirements are the enthalpy flux (latent+sensible) and the ocean with warm and deep thermal structure. The cyclone Nargis (27 April to 2 May 2008) suddenly intensified over a warm ocean where the UOHC is 77–105kj/cm^2 and the enthalpy flux was 900w/m^2 (300% higher than climatological value) [24]. Similarly, Aila (24 to 26 May 2009) intensified over the warm eddy where UOHC and D26 were 146kj/cm^2 and 126m respectively[20]. In case of cyclone Sidr, the pre-storm UOHC and D26 were 84kj/cm^2 and 78m respectively[19]. For the presented 8 cases (Table 2) in which the cyclones passed through the eddies, the UOHC and D26 in the eddies was computed using the equations 1 to 4. High UOHC of 194 kj/cm^2, 139 kj/cm^2 and 127 kj/cm^2 were found in the warm core eddies during October 1999 (Aila and Laila cyclones respectively). D26 observed in the above warm eddies was high and varied between 100–150m. Enthalpy fluxes are also high in the warm core eddies with a maximum of 214w/m^2 which is double the climatological value. Overall, in the warm core eddies the enthalpy flux is 2 to 3 times higher than the climatological enthalpy flux. In cold core eddies, UOHC was < 60kj/cm^2 (1/3 of warm core eddy), D26 was < 65m and the enthalpy flux was 50% less than the climatological D26 where the November 2005 cyclone and Khaimuk (November 2008) weakened. The maximum drop of 26hPa in the cyclone central pressure during the October 1999 cyclone was due to the presence of a warm core eddy. There is a drop of 10 to16hPa in the remaining cyclones due to the presence of warm core eddies. There is a rise in the central pressure by 4 to 6hPa due to the cold core eddies. The UOHC and enthalpy fluxes are much higher over warm eddies compared with the cold eddies. Hence, the storms over warm (cold) eddy intensify (weaken) if the atmospheric conditions are also favorable. These results further support an earlier study[20] and emphasize the role of eddies and UOHC in the intensification of storms over the Bay of Bengal. The meteorological parameters, known to be important for the intensification or weakening of tropical storms, were also examined and these results are shown in Table 3. The difference between the SST and air temperature in all the cases is positive prior to the cyclone (favorable for the formation of cyclones) except during Khaimuk and is negative after the cyclone (not favorable for cyclone intensification). Highest of temperatures of 3.49° were observed in case of the November 2000 cyclone. Relative humidity (RH) at 600hPa is higher during all the cyclones compared to the climatological values. Kikuchi and Wang[27] showed the importance of RH at 600hPa for the intensification of tropical storms. Highest (82%) was observed during a May 2003 cyclone. Vertical wind shear between the 200 and 850hPa in all the 8 cases is also less compared to the climatological values, which is the favorable condition for the formation and intensification of cyclones[28]. Less shear was observed in the case of cyclone Laila (2010). Zonal wind at the 1000hPa pressure level is less compared to the climatological zonal wind with the exception of two cold core eddy cases. In the case of cyclone Aila a zonal wind of 0.16m/s was observed. The higher SST compared to the atmosphere at the surface and low wind seems in this case to be favorable for the storm vortex growth via wind induced surface heat exchange[28]. The contribution of different parameters for the intensification will vary from cyclone to cyclone. So, both the atmospheric and oceanographic conditions are equally important for cyclone intensification studies. But, without the supply of sufficient enthalpy flux from the ocean, storms may not intensify even though the atmospheric conditions are favorable.

CONCLUSION

Mesoscale eddies (warm core and cold core eddies) occur in the neighborhood of the EICC in the Bay of Bengal, particularly in the months of April to May and October to November when the EICC is strong. The intensification/weakening of cyclones due to their interaction with warm/cold eddies is possible in the Bay of Bengal, but is totally ignored in the storm intensification forecasting models. From the few cases studied, it can be observed that the eddy feedback factor ranges from –60% to 260 %. It is found that in case of a severe cyclone, for example, during the 16 to 19 October 1999 event, the eddy feedback factor is 260%- much higher than previously reported (Wu.et.al, 2007) and for Opal (1995) and Maemi (2003) (119% and 138% respectively) also. The high UOHC (>120kj/cm^2) and enthalpy fluxes (>400 w/m^2) in the warm core eddies are perhaps responsible for the intensification of storms in these cases. It is, therefore, suggested that modelers pay significantly more attention towards the role of these mesoscale eddies in the intensification or weakening of storms over the Bay of Bengal.

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