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Significance of Wind-Pressure Relation during Bay of Bengal Cyclones

Mohammedali Nellayaputhenpeedika, V Radhakrishnan

Abstract: - Cyclone is a natural disaster that blows Over Bay of Bengal (BoB) and makes masses of devastation. Assessment of its characteristics and prediction of its mobility are extremely difficult tasks. Wind and pressure are the most significant factors that decide cyclone genesis, propagation and intensity. Physical understanding of the relation between two significant parameters during cyclone is very complicated and is elusive through modelling and prediction. Data sourced from International Best Track Archive for Climate Stewardship (IBTrACS) were analyzed to know wind and pressure relation and cyclone tracking. Cyclone spatial wind pattern is determined using the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2). Analysis shows that wind and pressure are related inversely and is complex in nature. Spatial analysis using MERRA-2 demonstrates asymmetric wind pattern. IBTrACS data (from 2005 to 2016) show the majority of the cyclone intensity is concentrated on north-eastern side of BoB which fact could be attributed to high subsurface heat storage. Inter comparison of different cyclones during the period 2005-2016 was also made and found in support of the wind pressure relation.

Keywords: Tropical cyclone, wind-pressure, cyclonetrack, asymmetric wind, radial wind.

I. INTRODUCTION

The oceanic region of BoB and Arabian Sea (AS) of North Indian Ocean is one among the warm oceans favorable for formation of cyclones and accounts for the 7% global cyclones [7]. The BoB records highest number of cyclones compared to other regions; its semi enclosed geographic setting and its funnel shape make intensive striking in coastal area. Highly dense coastal populations of low lying areas face lot of vulnerabilities due to cyclones. Temporal trend of cyclone is very much related to maximum wind speed [11]. In most of the tropical cyclone (TC) forecasts, cyclone intensity represents maximum sustained wind or the minimum sea-level pressure. Warnings of the potential wind destruction near the TC centre [3] are issued based on the predicted tracks of the TC. As destruction of TC occurs in larger area and sudden changes in intensity are not always as expected, the horizontal distribution of wind across the cyclone core is important for an accurate forecasting. But, lack of accurate wind data over ocean and surface pressure make this task difficult.

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***** Correspondence Author

Mohammedali Nellayaputhenpeedika, Department of Marine Science, Bharathidasan University,Trichy, India.

V Radhakrishnan*, Department of Marine Science, Bharathidasan University,Trichy, India..

With its wide swath (~1800km) and higher horizontal resolution (12.5 km latitude/ longitude resolution), QuikSCAT satellite, launched in 1999, overrides some of the previous limitations in horizontal wind analysis during cyclones. As outer core wind distribution can change without any changes in inner core, relationship between them is very important to understand complete structure of TC [10].

Tropical cyclone intensity is influenced by the magnitude of pressure and wind i.e., the maximum wind speed and minimum sea level pressure near the cyclone centre at standard height of 10m (MSLP) [2]. Analysis of cyclone track data from IBTrACS data revealed characteristic wind-pressure setting during different cyclones. Realization of relation between wind and pressure is very important for physical understanding of tropical cyclone. Still it is an unresolved problem for scientific community [5]. While TC size and intensity are related to maximum surface wind (Vmax) its intensity change is related to radius of Vmax (Kieu et al., 2010). Energy required to create low pressure system and high wind speed is provided by warm water; cyclone forms when water body is over 26.5^{0}C. Warm water extends up to a depth of 600m; Warming trend in eastern BoB makes it a favorable place for cyclogenesis [13]. Tropical cyclones are mostly active during pre and post monsoon periods when high air-sea interaction prevails. It is a favorable condition for the formation cyclone. Observation of recent changes in tropical cyclone activities show that there is a notable increase in frequency and duration of cyclone intensity; most of them have wind speed >64 knots, beyond that a longitudinal eastward shift of intense cyclone observed, which is supported by sea surface temperature (SST) and upper ocean heat content data analysis [1]. TC size is the measure of radial extent of surface wind, where azimuthally averaged wind is used for the measure of size. Azimuth averaging eliminates asymmetry connected with TC motion [7]. The widest swath and large horizontal resolution capacity of Quick Scatterometer (QuikSCAT) help derive radial spectrum of wind magnitude [2]. Magnitude of cyclone represents relationship between pressure deficit, maximum wind speed and its radius. Analysis of all these parameters gives an idea about cyclone character. Parameters include Coriolis acceleration changes due to surface friction, terrestrial effects and heat convection [12].

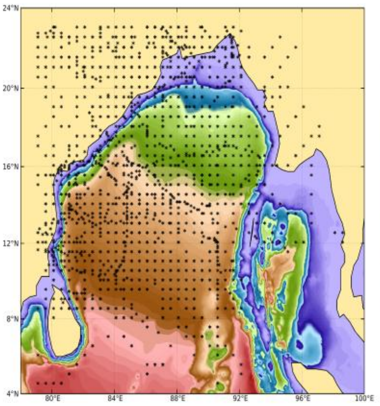

Fig.1. Daily locations of all cyclone tracks over Bay of Bengal during the period of 1986-2016.

II. DATA AND METHODOLOGY

Cyclone track data was tapped from IBTrACS (http://www.ncdc.noaa.gov/ibtracs/) whose contents viz., cyclone information such as maximum wind speed, location and minimum pressure are precise. It provides idea regarding maximum sustained wind (MSW), and distance of various wind speed extended out of the storm centre and minimum sea level pressure (MSLP). For a variety of causes such as warning, post-cyclone resilience measures, etc., cyclones necessitate to be characterized in terms of its physical properties and tracks. Precise and continuous data on cyclones are unavoidable for forecast to protect people and property. National Climatic Data Centre of NOAA makes available free the data sourced from public and private agencies under its International Best Track Archive for Climate Stewardship (IBTrACS) programme. It is a data warehouse of world cyclones holding time-series of hourly data of several variables of all recorded cyclones. Optimally, best-track data are the result of post-season reanalysis of a storm's position and intensity acquired from all accessible data sources like ship, surface and satellite observations (although the level of reanalysis will vary by agency). IBTrACS provides high accuracy track data of cyclones since 1848. IBTrACS data variables are location of the storm centre (lat/lon), maximum sustained surface wind speed (Vmax, or else known as 'Intensity'), minimum central pressure (Pmin).

Wind speed and its azimuthal and radial vector records at 10 m level obtained at ocean near surface (http://tropicalcyclone.jpl.nasa.gov/) are available with QuikSCAT for the period from 1999 to 2009. It is an optimized version of Version 3 of the complete global QuikSCAT dataset. It is optimized particularly for tropical cyclone and subset global data in to storm centred files which sensor passed sufficiently close to the storm centre, optimization adopted neural network algorithm to increase accuracy and avoid rain contamination. QuikSCAT data with 0.25^0 spatial resolution have accurate coverage around the globe which was active during 1999-2009 for a continuous swath of 1800 km. Data are accurate in all weather conditions for the winds up to 40 m/s, and hence it is a cyclone wind speed repository.

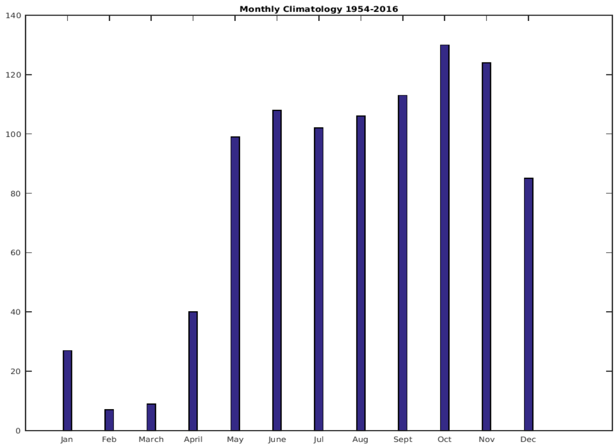

Fig. 2. Month wise cyclone frequency analysis during the period 1986-2016.

III. RESULT AND DISCUSSION

Climatology of number of cyclones shows most cyclone take place during October and November and least observed on February, Table.1. Gives an idea about intensity and maximum wind speed observed during the period of 2005-2016. In 2015, there is no cyclone observed and apart from that all years observed cyclone with varying intensity. Intensive cyclone observed during 2013, *Phailine* was observed as highest category of cyclone-5. Cyclone *Nilam* was in the category of tropical cyclone with maximum wind magnitude of 23.5 m/s. Cyclone intensity grade was based on Saffir-Simpson Scale range (Table.2.).

3.1 Wind pressure relation

Most of the instances cyclone track data of wind and pressure show inverse proportionality. Magnitude of wind speed and low pressure system shows intensity and character of the cyclone. In most of the occasions, cyclones get intensified in open ocean and strength of wind speed decreased when it reach to coastal area as wind speed intensification is controlled by energy stored in ocean. Most of the cyclone wind speed continuously increase and when its reach to maximum wind, it's gradually decrease its strength,

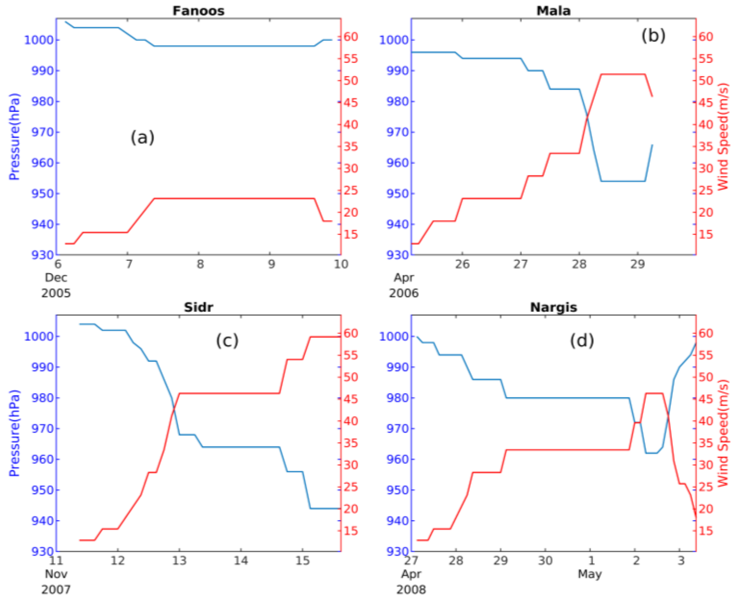

Fig.3. Minimum pressure and maximum wind along the cyclone track.

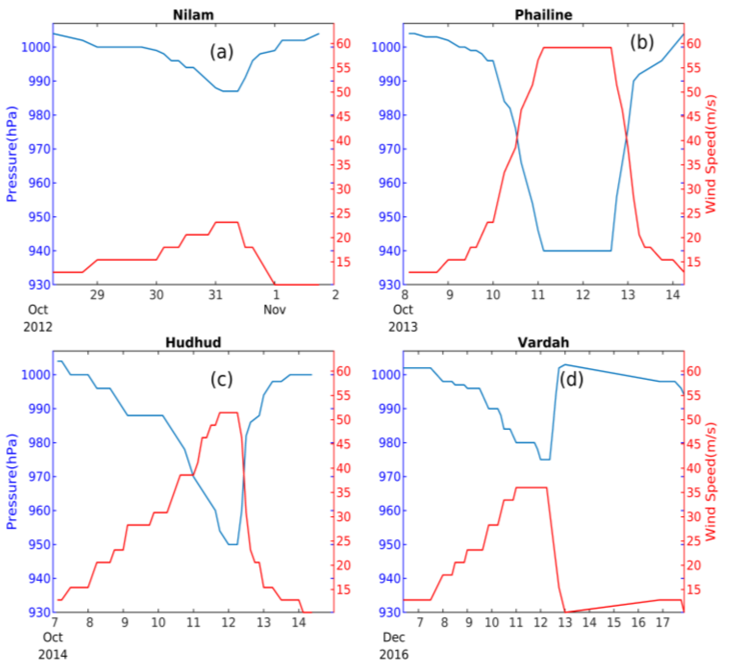

Fig. 4. Minimum pressure and maximum wind along the cyclone track.

after reaching maximum sustained wind its hold the same strength for while without changing its strength, most of the time it occur when cyclone intensity reached to higher category, in the case of cyclone Phailin maximum wind speed attained was 59.17m/s. Fig. 3. Illustrates time series of maximum wind and minimum pressure of cyclones occurred during the period 1990-2016. Data obviously support that high wind speeds are linked with low wind pressure resulting in cyclones. It is evident from the inverse relationships between maximum wind speed and minimum wind pressure shown by plots of cyclones, viz., *Nargis*, *Phailin* and *Vardha*, (Fig. 3d, Fig. 4 (b & d)). Time series of cyclone data are plotted with wind pressure along primary y-axis and wind speed along secondary y-axis. Graphs of wind pressure and wind speed are indicative of common relations for different selected cyclones (Fig. 3 & Fig.4).

During the initial stage of cyclone there is a decrease in the trend of pressure and having reached the minimum the pressure shoots up to a maximum (blue graph of plot a). At the same time red graph representing wind speed takes a mirrored shape of wind pressure. Gradually increasing wind speed upon attaining maximum suddenly dips to very low wind speed. Similar pattern of trends are noticeable in plots constructed for rest of the cyclones. Low pressure and high wind speed are inversely proportional which is explicit from the plots. Pressure decreases until middle of the cyclone duration and then again start to increase, similarly wind speed also inversely behaves (Fig. 4a).

Table 1. List of cyclones considered in the study and their characters

Cyclone	Year	Category	Maximum wind (m/s)	Minimum pressure
Fanoos	2005	CYCLONE-1	23.15	998
Mala	2006	CYCLONE-4	51.45	954
Sidr	2007	CYCLONE-4	59.17	944
Nargis	2008	CYCLONE-4	46.29	962
Ward	2009	TROPICAL STORM	23.15	996
Laila	2010	CYCLONE-1	28.29	986
Giri	2010	CYCLONE-4	54.01	950
Thane	2011	CYCLONE-1	38.58	969
Nilam	2012	TROPICAL STORM	23.15	987
Phailin	2013	CYCLONE-5	59.17	940
Hudhud	2014	CYCLONE-4	51.45	950
NA	2015	No considerable cyclone		NA
Vardah	2016	CYCLONE-1	36.02	975

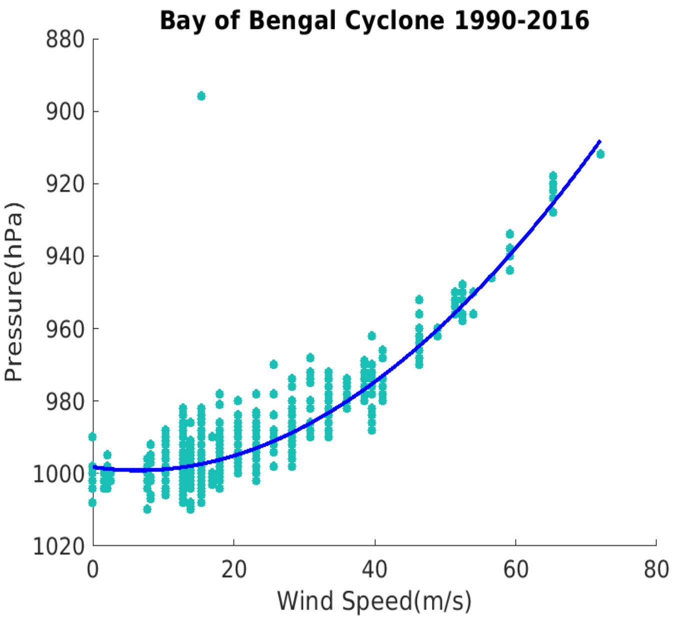

Fig.5. Pressure-wind speed scatter plot from 1990-2016, over Bay of Bengal Cyclone frequency.

Table 2. Saffir-Simpson Scale for cyclone category

Type	Category	Pressure (mb)	Wind (knots)	Wind (m/s)
Depression	td	----	< 34	<17
Tropical Storm	TS	----	34-63	17-32
Cyclone	1	> 980	64-82	33-42
Cyclone	2	965-980	83-95	43-48
Cyclone	3	945-965	96-112	49-57
Cyclone	4	920-945	113-135	58-69
Cyclone	5	< 920	>135	>70

3.2 Cyclone spatial distribution

To analyse spatial variability of wind speed, track data of 12 cyclones were screened out from IBTrACS (representing) and used. The data were in such way that it represented tropical storm to cyclone-5 categories and of the period 2005-2016. The given spatial plot is processed after interpolation and regridding to 0.5 degree resolution. The outcome was the spatial picture of cyclones over BoB. Spatial pattern shows most cyclones occurred in north-eastern side and central part of BoB, intensive cyclones are observed in eastern side and warm subsurface water in eastern side makes most favorable place for intensification [13]. Noticeably there is no intense cyclonic activity observed in southern side of BoB and many cyclone originated or propagated through Andaman Sea which is less deeper than other places. Spatial pattern shows that many of the intensive cyclone either landfall or pass through along Myanmar and Bangladesh coast.

3.3 Asymmetric wind pattern

Fig. 7 and Fig. 8 are spatial plots of cyclone *Phailin* originated in Andaman Sea in October 2013 whose maximum wind speed was 59 m/s and the observed lower pressure was 940 m/s. In intensity it was rated as cyclone-5. Magnitude of cyclone and area of intensity increased when cyclone floated above open waters of north eastern flank of the Sea. Wind direction was inward from outer to centre from both north and south sides and outward movement were towards east and western sides. When cyclone reached coastal side wind direction was towards centre of ocean and wind movement was from coastal area. Spatially wind pattern is asymmetric close to cyclone centre where low wind pressure prevailed. Outer region of the cyclone was with high asymmetric wind pattern. Strength and variability varied based on location and low pressure system. The winds in the outer core region play a critical role in modifying TC size [2]; size change is much more sensitive to the dynamics in the outer-core region compared to that in the inner-core region.

Cyclone wind speed appeared as different fronts of varied magnitude approximate circular or semi circular depends on the magnitude and intensity of the cyclone. Less magnitude wind shows in the direction of track and high magnitude observed opposite direction of track. When cyclone intensity increased its shows magnitude front size is increased. When cyclone reached near coastal area, its magnitude decreased and when it made landfall its magnitude decreased to lower values. During landfall magnitude of wind concentrated parallel to coastal areas; it increased devastation of cyclone.

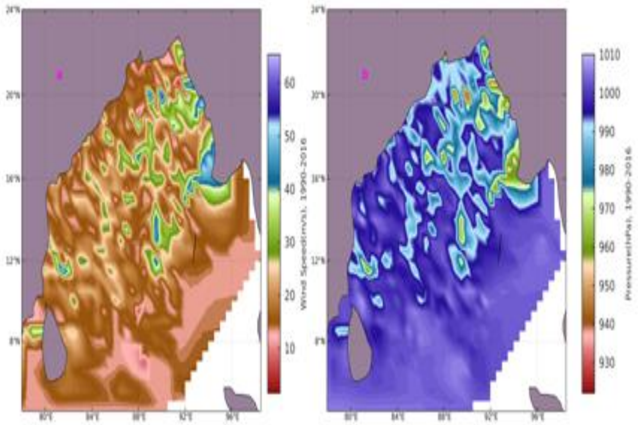

Fig. 6. Spatial distribution cyclone low pressure and maximum wind speed during the periods 2005-2016, over BoB.

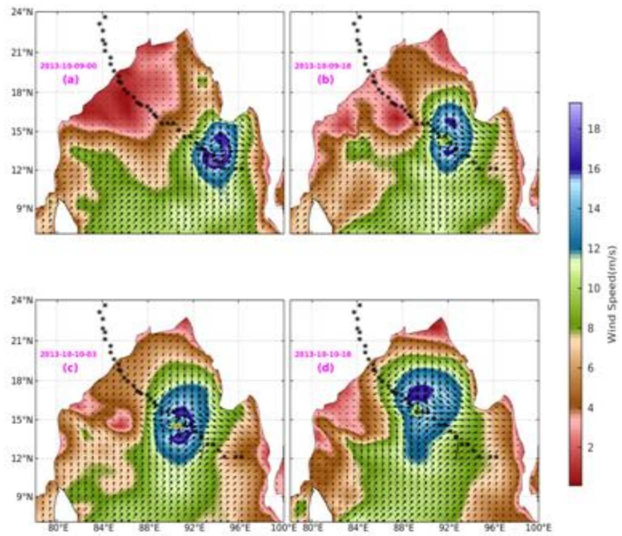

Fig. 7. Spatial magnitude of cyclone *Phailin* , 2013.

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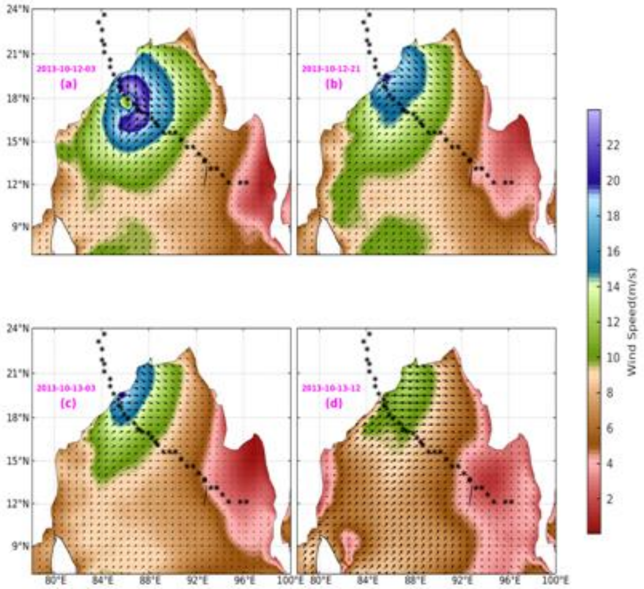

Fig.8. Spatial magnitude of cyclone *Phailin*, 2013.

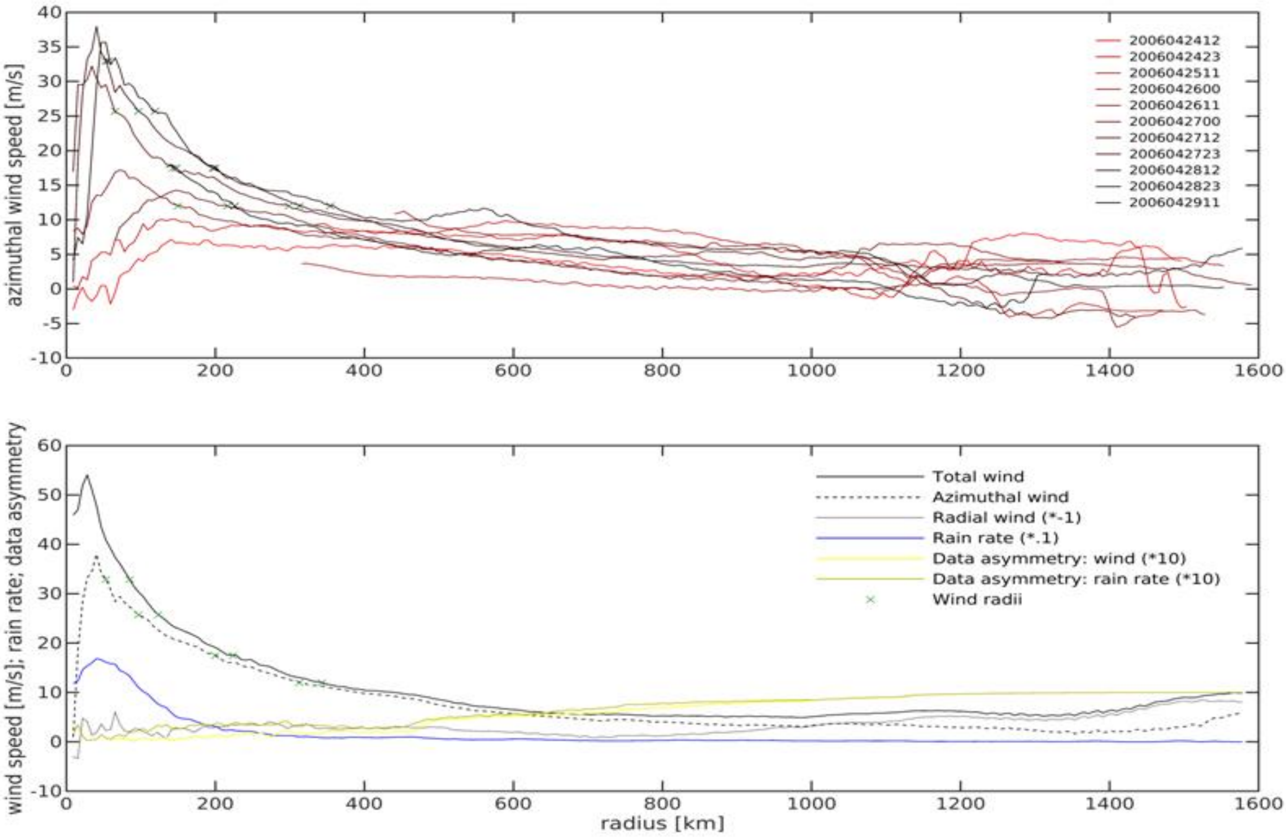

Fig.9. Radial profile wind magnitude during cyclone Mala on 2006.

3.4 Radial Wind Profile

Analyses showed that magnitude of wind parameters follow rise-peak-fall-level pattern with increasing distances from the centres of cyclones. Cyclone Fanoos started over BoB with designated intensity of cyclone1 whereas cyclone Mala was categorized as 4. Fig. 9 show magnitude of wind low in cyclone centre and when radius is around 30km its magnitude of wind and rain reached to maximum and after maximum wind profile, it started decreasing. When air masses were away from the cyclone centre approximately around 600km, they showed not much change in magnitude. But when cyclone moved away from its origin its asymmetry increased. There are no considerable changes in asymmetry from cyclone centre to 30km. Radial figure (Fig. 9) show total wind magnitude and azimuthal wind showing symmetric pattern and parallel magnitude changes. Also noticeable is the impact of cyclone even though very far from cyclone centre.

IV. CONCLUSIONS

Wind-Pressure inverse relation during a cyclone is expounded through the analyses of 12 cyclones occurred during the period 1999-2016.

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Further studies on 12 cyclone cases (2005-2016) revealed maximum wind and minimum pressure relation and the intensification of cyclones in north eastern part of BoB. Inverse relationships between maximum wind speed and minimum wind pressure in specific cyclones viz., *Vardha*, *Nargis*, *Phailin* and *Laila* are presented. Radial analyses of cyclone data showed that cyclone centers were with less magnitude and around 30km distance winds were at its peaks. Beyond that distance winds were decreasing in speed increasing distances towards cyclone periphery. Nomadic cyclones acquire asymmetric pattern around its centre from initial circular shapes with more asymmetry observed far from cyclone centre.

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REFERENCES

1. Balaji, M., Chakraborty, A., & Mandal, M. (2018). Changes in tropical cyclone activity in north Indian Ocean during satellite era (1981–2014). International Journal of Climatology, 38(6), 2819-2837.
2. Chan, K. T., & Chan, J. C. (2012). Size and strength of tropical cyclones as inferred from QuikSCAT data. Monthly Weather Review, 140(3), 811-824.
3. Chan, K. T., & Chan, J. C. (2018). The outer-core wind structure of tropical cyclones. Journal of the Meteorological Society of Japan. Ser. II.
4. Chavas, D. R., Emanuel, K. A., & Vigh, J. (2014). QSCAT-R: The QuikSCAT tropical cyclone radial structure dataset. NCAR Tech. Note TN-5131STR.
5. Chavas, D. R., Reed, K. A., & Knaff, J. A. (2017). Physical understanding of the tropical cyclone wind-pressure relationship. Nature communications, 8(1), 1360.
6. Choi, J. W., Cha, Y., Kim, H. D., & Lu, R. (2016). Relationship between the maximum wind speed and the minimum sea level pressure for tropical cyclones in the western North Pacific. J Climatol Weather Forecast, 4(180), 2.
7. Gray, W. M. (1985). Tropical cyclone global climatology. WMO Technical Document WMO/TD, 72(1), 3-19.
8. Kieu, C. Q., Chen, H., & Zhang, D. L. (2010). An examination of the pressure–wind relationship for intense tropical cyclones. Weather and Forecasting, 25(3), 895-907.
9. Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., & Neumann, C. J. (2010). The international best track archive for climate stewardship (IBTrACS) unifying tropical cyclone data. Bulletin of the American Meteorological Society, 91(3), 363-376.
10. Kossin, J. P., Knaff, J. A., Berger, H. I., Herndon, D. C., Cram, T. A., Velden, C. S., ... & Hawkins, J. D. (2007). Estimating hurricane wind structure in the absence of aircraft reconnaissance. Weather and Forecasting, 22(1), 89-101.
11. Landsea, C. W., Harper, B. A., Hoarau, K., & Knaff, J. A. (2006). Can we detect trends in extreme tropical cyclones?. Science, 313(5786), 452-454.
12. Olfateh, M., Callaghan, D. P., Nielsen, P., & Baldock, T. E. (2017). Tropical cyclone wind field asymmetry—Development and evaluation of a new parametric model. Journal of Geophysical Research: Oceans, 122(1), 458-469.
13. Sahoo, B., & Bhaskaran, P. K. (2016). Assessment on historical cyclone tracks in the Bay of Bengal, east coast of India. International Journal of Climatology, 36(1), 95-109.

AUTHORS PROFILE

Mohammedali Nellayaputhenpeedika received his Master degree in Physical Oceanography from Cochin University of Science and Technology (CUSAT), Cochin, Kerala. The author has published six internationals journals. He is currently pursuing his Ph.D in Department of Marine Science, Bharathidasan University, Trichy. His area of research interest is data mining and analysis in Physical Oceanography for extreme event such as cyclone.

Dr. V Radhakrishnan: I have had my graduation and post-graduation in Geology from Presidency College, Chennai (University of Madras). I am an alumnus of PhD Geology of Kerala University, Thiruvananthapuram, Kerala.My teaching career has started in 1981 as Assistant Professor of Geology in V.O. Chidambaram College, Thoothukudi, Tamil Nadu. Having put 34 years of academic and research experience I retired as Professor and head from the Department of Marine Science, Bharathidasan University, Tiruchirappalli. I continuedthe research on marine microlitter of Chennai Marina Beachunder the UGC's Emeritus Professor Fellowship. I have completed a few research projects funded by UGC and Department of Science and Technology, New Delhi. I have also conducted a few training programmes and seminars. I have taught graduate and post-graduate courses in geology and marine science. I have guided 6 Ph.D. scholars and several M.Sc. and M.Phil. Students.

I have published a Text book on General Geology (1987) for University Students of Geology and another one on soft skills: "Feeling Good". I have published about 70 research and general articles in journals of national and international repute. I have also released several proceedings volumes and CDs. I have written several popular science articles in Tamil and also presented radio talks. I have also featured in UGC's country wide class room telecast through its GD4 Higher Education Channel with 4 episodes of educational telecasts. Poetry.com has published two of my poetries in English.

Under administrative themes, I have served coordinator for Internal Quality Assessment Cell (VOCC for NAAC) and Chief of Examinations (VOCC) and Chief Coordinator of Public examinations (TNPSC and Hindi Prachar Sabah Examinations). I have been instrumental in organizing World Ocean Day, and Coastal Cleanup Day, matching global trends.