International Journal of Convergent Research 1(1) July - December (2024)

IJCR International Journal of Convergent Research

International Journal of Convergent Research

Journal homepage: International Journal of Convergent Research

Relationship between Precipitation and Cyclones in the Bay of Bengal India during 2015-2019: Using Tropical Rainfall Measurement Mission (TRMM)

Anupama Sahoo [1], Ghulam G. Zahid [1], Nepal Singh[2], Usman Aarif Chaudhary[2], Mohammad Zahbi[3], Ajhar Hussain [2*]

[1] Department of Atmospheric and Ocean Sciences, Indian Institute of Technology, Bhubaneswar Orissa India -752050, India

[2] Department of Geology, Aligarh Muslim University Aligarh India -202002, India

[3] Faculty of Earth and Environmental Sciences and Engineering, University of Miskolc, Hungary

***Corresponding Author:** glyazhar@gmail.com

Citation: Sahoo, A., Zahid, G. G., Singh, N., Chaudhary, U. A., Zahbi, M., & Hussain, A. (2024). Relationship between precipitation and cyclones in the Bay of Bengal India during 2015-2019: Using Tropical Rainfall Measurement Mission (TRMM). *International Journal of Convergent Research*, 1(1), 72-78.

ARTICLE INFO

Received: 3rd October 2024
Accepted: 16th November 2024

ABSTRACT

The Bay of Bengal (BoB) is a cyclone hotspot as it's warmer than the Arabian Sea. The North Indian Ocean, according to Neumann, was home to 7% of all worldwide Tropical Cyclones (TCs) (NIO). TCS was relatively common in the Bay of Bengal (BoB), accounting for 5% of all worldwide TCs. May, October, and November were the months with the greatest TC activity, while January, April, and July had the weakest TC activity. To evaluate the distribution of TC rainfall throughout an inter-annual and monthly timescale, rainfall data from the Tropical Rainfall Measurement Mission (TRMM) were employed (i.e., how much TC contributed to total rainfall). Using TC best track data from the Indian Meteorological Department, this article initially examined TC activity in this region from 2015 to 2019 (January–December) (IMD). The present study describes the role of cyclones in seasonal rainfall over the period from 2015 to 2019. The precipitation does not depend upon any stage of cyclones, it sometimes peaks higher value at the D stage, sometimes also at its mature stage. The study also concludes that the maximum rainfall does not have to be proportional to the intensity. The rainfall areas of a TC are not proportional to its intensity; Therefore, TC categories with higher intensities do not generate excessive rainfall.

Keywords: (BoB) Bay of Bengal, TRMM, tropical cyclone, precipitation, SST.

INTRODUCTION

According to Neumann (2019), the North Indian Ocean accounts for 7% of all Tropical Cyclones (TCs) worldwide (NIO). Each year, only five to six tropical cyclones develop in the basin. Tropical cyclones form between March and June and between October and December, with May and November being the busiest months. The Bay of Bengal is where the largest of these storms develop. Tropical cyclones (TCs) that make landfall Rodgers et al. (2000, 2001) in the Bay of Bengal (BoB) area usually dump a lot of rain, sometimes causing coastal flooding and a lot of damage. Tropical cyclones can bring a lot of rain, which is one of the most dangerous hazards they can bring. Most rain is produced by tropical cyclones that are large, slow-moving, and not sharing. Rainfall is observed to be strongest within a degree latitude of the eyewall or central thick overcast of a tropical cyclone, with smaller amounts farther out. Thakur et al. (2018) evaluated the distribution of TC rainfall using inter-annual and monthly rainfall data from the Tropical Rainfall Measurement Mission (TRMM) (i.e., how much TC was involved in overall rainfall). The amount of TC precipitation in the BoB region varies substantially from one TC to the next, and even from time to time within the same TC. Now, we're looking at the TC rainfall distribution in the BOB region using TRMM satellite data from 2015 to 2019. Because the BoB basin had more than three times the number of TCs at the time, we concentrated on it and ignored the AS basin. We also calculate the total precipitation and how many days the cyclone stays over BoB, and at that time how many precipitation rates change. Jiang and Zipser (2010) discovered that the TC rainfall distribution (i.e., how much TC was responsible for the overall amount of rainfall) in the North Atlantic, east-central Pacific, western North Pacific, NIO, south Indian Ocean, and South Pacific were 8-9 per cent, 7 per cent, 11 per cent, 5 per cent, 7–8 per cent, and 3–4 per cent, respectively.

Total column water vapour (TCWV), relative humidity (RH), lower tropospheric temperature (LTT), sea surface temperature (SST), and upper ocean heat content (UOHC), all these variables were higher in the BoB than in the AS, making it an active basin for cyclone generation. Dhar (1980) investigated the depression's effects or tropical storms on monsoon rainfall over specific months. As a result, we investigate the TC rainfall distribution in this region by applying TRMM satellite data over the BoB area from 2015 to 2019 and analysing TC activity and its rainfall distribution over BoB, and how they are dependent on each other. The present work aims to study the role of cyclones in seasonal rainfall and the dispersion of rainfall within the rain-receiving zones of the environment.

DATA AND METHODOLOGY

Study Domain

The Study Region that has been chosen for study is extended from 76°E – 100°E and 4°N –24°N. This region is a part of the North Indian Ocean (NIO). For the cyclonic study, we took the BoB region, in the period of pre-monsoon month (April-May) and post-monsoon months (October–December).

TCS Best Track Data Set

We have used the IMD best track dataset to know the path of the cyclone that is residing over the Bay of Bengal region. (http://www.rsmcnewdelhi.imd.gov.in).

Rainfall Data

In this paper, we used TRMM (Tropical Rainfall Measurement Mission), Daily accumulated precipitation (ir) with HQ calibration (mm), and 25 km resolution. Source: https://disc.gsfc.nasa.gov/datasets/TRMM_3B42_Daily_7/summary. The Tropical Rainfall Measuring Mission, or TRMM, was a research satellite that was operational from 1997 until 2015 and was meant to assist us in gaining a deeper comprehension of the distribution and variability of precipitation in tropical regions as an element of the water cycle that is a component of the present climate system. TRMM provided much-needed information on rainfall over the sea surface and by spanning the tropical and subtropical parts of the Earth; it serves to fuel the global atmospheric circulation, which affects both weather and climate, by releasing heat. The Tropical Rainfall Measuring Mission (TRMM) improved our understanding of the relationships between water vapour, clouds, and precipitation that are essential to the regulation of Earth's climate by collecting a significant quantity of information on precipitation using many space-borne sensors in collaboration with other satellites in NASA's Earth Observing System. TRMM provides crucial data on rainfall and the heat release associated with it that serves to fuel the global atmospheric circulation that determines both the weather and climate by covering tropical and subtropical parts of the Eart.

RESULTS AND DISCUSSION

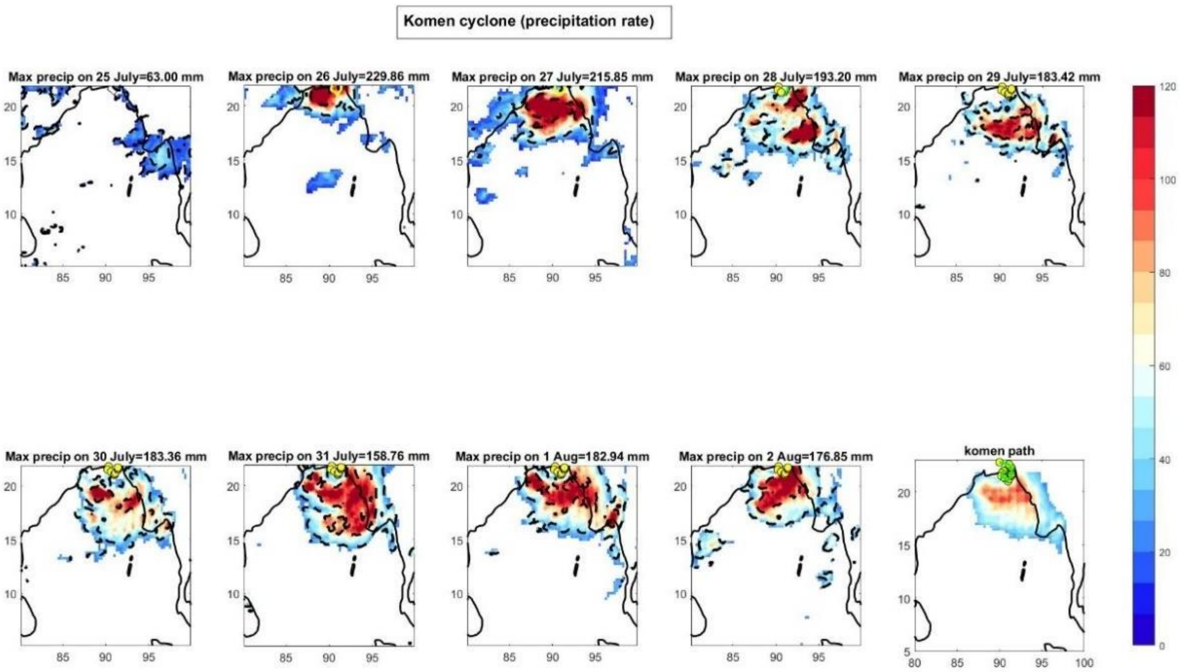
We have listed some of the cyclones that occurred between 2015 and 2019 in Table 1 so that we can easily identify the changes in rates of precipitation during different cyclones and know how they are relatable with each other over the Bay of Bengal region.

Table 1: List of Tropical cyclones, Date of formation, and Lifetimes

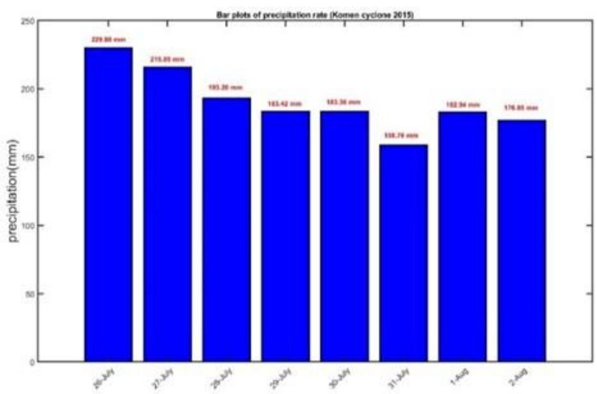
Cyclone Name	*Duration*	*Lifetime in No. of days*
KOMEN (2015)	26 July – 2 Aug	8
ROANU (2016)	16 May – 22 May	6
KYANT (2016)	22 Oct – 28 Oct	8
MAARUTHA (2017)	15 Apr – 17 Apr	3
TITLI (2018)	8 Oct – 12 Oct	5
BULBUL (2019)	5 Nov – 11 Nov	7
FANI (2019)	26 Apr – 4 May	9

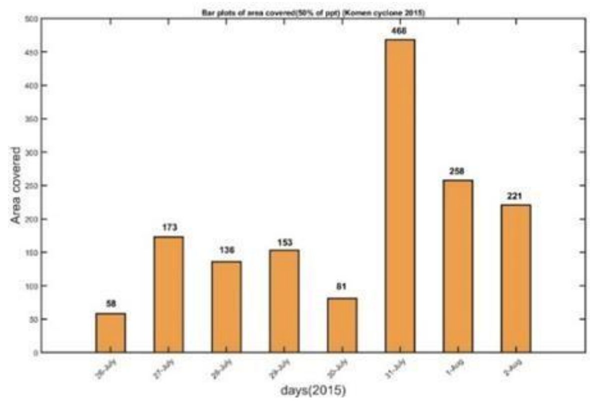
Here we mainly examined the KOMEN, ROANU, and BULBUL cyclones to identify the rates of precipitation during the different stages of these cyclones.

Figure 1: *(a) Spatial distribution of rainfall in the KOMEN cyclonic period by TRMM, (b) Bar plots of precipitation rate in KOMEN cyclone, (c) Bar plots of Area covered by rainfall in the KOMEN cyclone period.*



(a.)





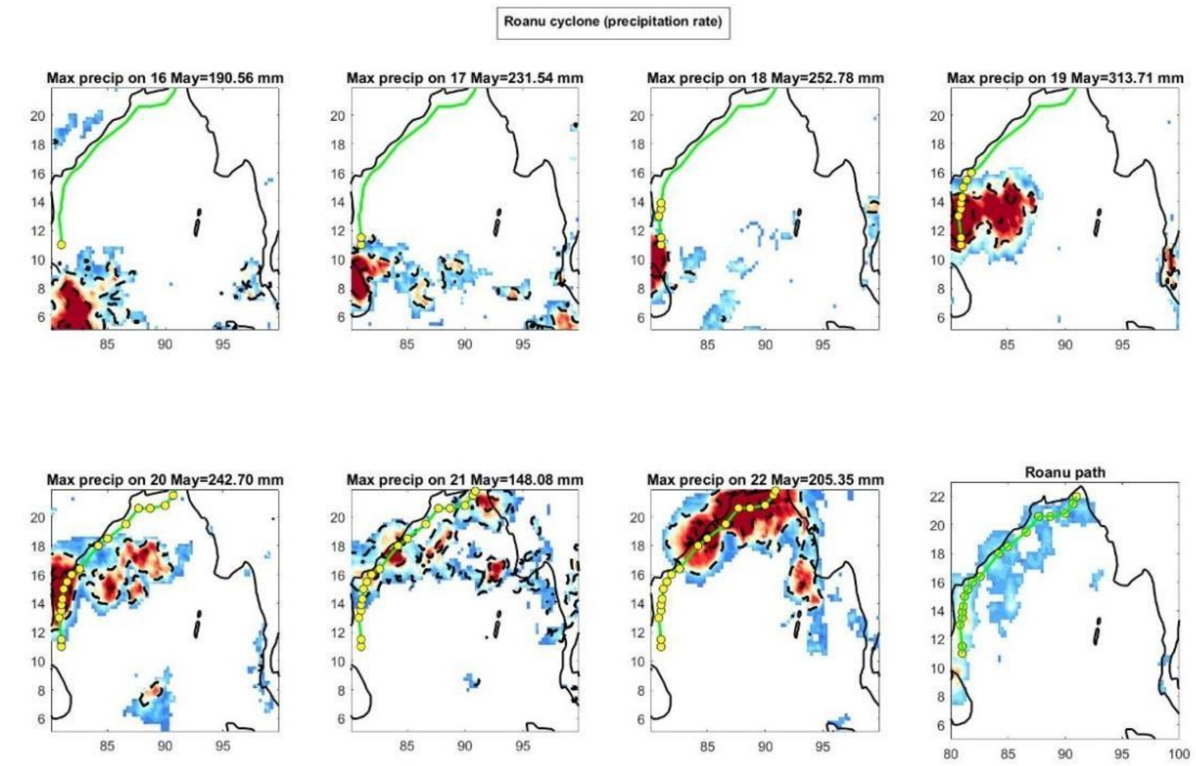
(b.) (c.)

The cyclonic rainstorm (CS), KOMEN, emerged over the Bay of Bengal (BoB) on July 25th evening from a trough of low pressure that passed through north-eastern BoB and abutting Bangladesh and Gangetic West Bengal and then formed into a storm over the same area on July 26th morning. During 1400 and 1500 UTC on July 30th, it flew in a semi-circular path above the northeast Bay of Bengal, and after that, it travelled through the Bangladeshi coastline between Hatia and Sandwip at latitude 22.50N and longitude 91.40E. It travelled north-northwestward, then west and west-south-west after making landfall, moving across Bangladesh, Gangetic West Bengal, and Jharkhand. Around 1200 UTC on August 2, it quickly degraded into a distinct low-pressure region that covered Jharkhand and the neighbouring states of north Odisha and north Chhattisgarh. The cyclonic storm Komen caused heavy to heavy rainfall over the Bay of Bengal at that time.

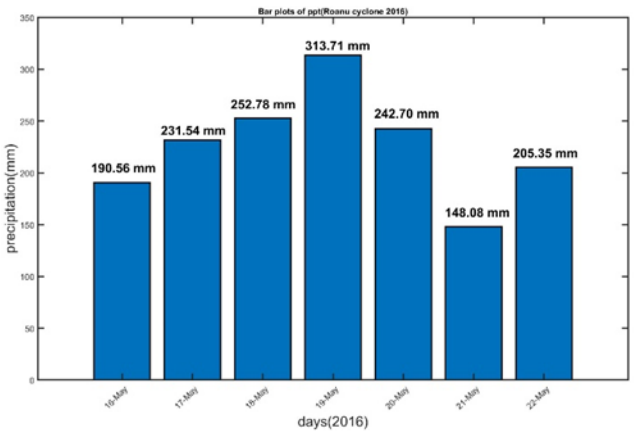
In Figure 1 (a), we can see how precipitation changes during the development stages of cyclone Komen. We see that during the developed stage of cyclones on 26th July the precipitation is maximum i.e. 229.86 mm compared to the mature stage of the cyclone. However, in the CS stage, the precipitation rate is 183.42 mm. Here we take the area of 50% of the maximum area covered by the cyclone, so precipitation is measured in that area. Figure (b) shows the precipitation amount during different stages of the Komen cyclone and figure (c) shows the area covered means the number of grids covered by cyclone Komen in that life period. It covered the maximum area i.e. 468 grid points on the 31st of July, at that time the precipitation amount was

158.76 mm. During the developed stage of the cyclone depression stage on 26 July the precipitation rate was very high but it covered very little area.

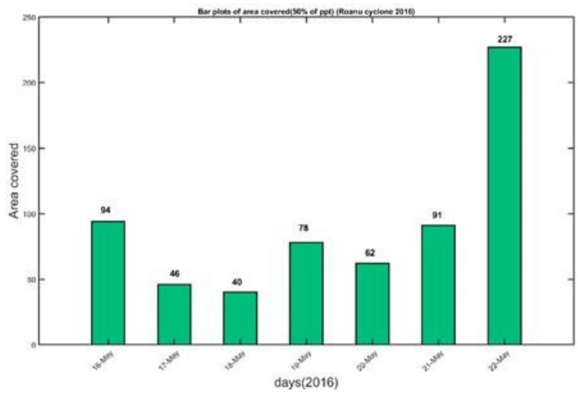
Figure 2: *(a) Spatial distribution of rainfall in ROANU cyclonic period by TRMM, (b) Bar plots of precipitation rate in ROANU cyclone, (c) Bar plots of Area covered by rainfall in ROANU cyclone period.*



(a.)



(b.)

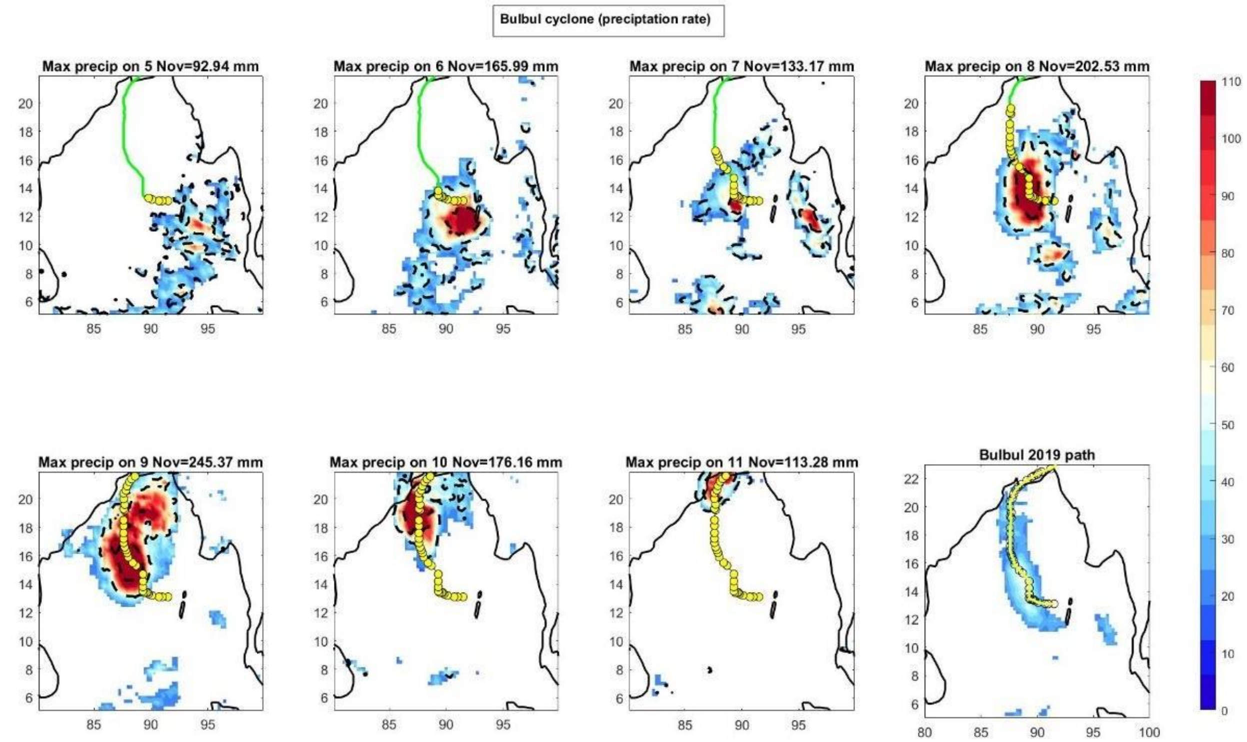


(c.)

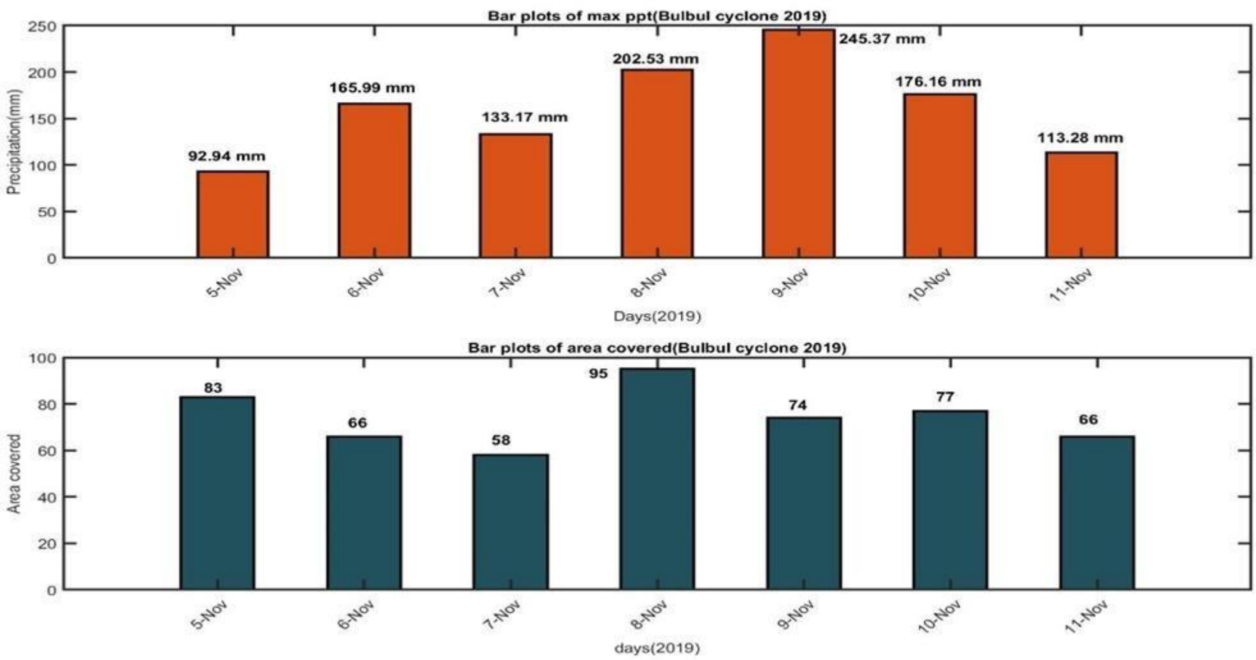
At 0300 UTC on May 15, 2016, a low-pressure region appeared over Southwest Bay and neighbouring locations off the coast of Sri Lanka. At 0900 UTC on the same day, it deepened into a well-marked low over the same zone. At 0600 UTC on May 17, 2016, the system proceeded north-northwestward before condensing into a Depression over Southwest Bay and the adjacent areas (Latitude 11.0°N, Longitude 81.0°E). The system then drifted north, intensifying into a Deep Depression over West-Central Bay and neighbouring Southwest Bay around 1200 UTC on May 17, 2016 (Latitude 13.5°N, Longitude 81.0°E). Later, it became stronger and moved across West-Central Bay and nearby Bay, becoming Cyclonic Storm (CS) "Roanu." (Latitude 15.0°N, Longitude 81.2°E). In conjunction, cyclone 'Roanu' has made landfall.

Their cyclonic storm (CS), reaches its maximum amount of total rain falling around 313.71mm on 19th May. After that, the total rainfall of 50% of the area that the cyclone covered is starting to decrease. The minimum amount of total rainfall of that 50% of the total area covered by the cyclone is very low around 148.08mm on 21st May at their depression stage. But when the intensification of cyclones is getting low means of 22 May it covers a large area around 227 grid points but precipitation is lower than its CS stage.

Figure 3: *(a) Spatial distribution of rainfall in BULBUL cyclonic period by TRMM, (b) Bar plots of precipitation rate in BULBUL cyclone, and Bar plots of Area covered by rainfall in BULBUL cyclone period*



(a.)



(b.)

On October 28, a Very Severe Cyclonic Storm (VSCS) called "BULBUL" developed over the western Pacific Ocean. On November 2, it moved into the north Andaman Sea. It erupted as a low-pressure system over the northern Andaman Sea early on November 4th. In the afternoon of November 4th, It developed into a low-pressure region that was centred over the northern Andaman Sea and its environs. In the early morning of November 5th, it intensified into a Depression (D) over east-central and bordering southeast Bay of Bengal (BoB) due to favourable climatic circumstances. In the early hours of the morning of November 6th, it deepened into a deep depression (DD) across east-central and neighbouring southeast BoB, moving almost west-northwestwards. On 6th November it moved north-northwestward and developed into a severe coastal storm on the evening of November 7th. It further intensified into VSCS on the morning of 8th November. It continued to move northwards until 9th November, and it weakened into SCS on the night of 9th November further it weakened into CS in the early morning of 10th November. It then moved east northward and weakened into DD and then D in the morning of 11th November.

We see that during the developed stage of cyclone Bulbul on 5th November 2019, the precipitation was low at 92.94 mm. But in the DD stage, the precipitation rate started to increase to around 165.99 mm on 6th November. But in its VSCS stage, it peaks its maximum total precipitation at around 202.53mm on 8th November and precipitation peaked maximum on 9th November at around 245.37mm. Fig (b) shows the precipitation amount during different stages of the BULBUL cyclone and also shows the area covered means the number of grids covered by cyclone BULBUL in that life period. It covered the maximum area, i.e. 95 grid points on the 8th of November in its VSCS stage, at that time the precipitation amount was very high. During the weakened stage of a cyclone the D stage on the 11th of November the precipitation rate was getting low also it covered less area than its intensified stage.

CONCLUSION

Using the rainfall data collected by TRMM, this study investigated the impact that tropical cyclones had on the dispersion of precipitation in the Bay of Bengal between the years 2015 and 2019.

Table 2: *List of Cyclones, Date of formation, and Precipitation*

Cyclone Name	*Duration*	*Peak Value of Precipitation*	*Stages of peak precipitation*
KOMEN (2015)	26 July – 2 Aug	229.86	D (26th July)
ROANU (2016)	16 May – 22 May	313.71	CS (19th May)
BULBUL (2019)	5 Nov – 11 Nov	245.37	SCS (9th Nov)

Table 2 shows at what stage of the cyclone the precipitation is maximum and how it varies. We here can see that precipitation does not depend upon any stage of cyclones, it sometimes peaks higher value at the D stage, sometimes also at its mature stage. The greatest increase in precipitation was observed on average at the separate cyclone centres throughout the Bay of Bengal area during the passage of the storm. In addition, the maximum rainfall does not have to be proportionate to the intensity, according to the study. Because a TC's rainfall area is not proportionate to its intensity, higher-intensity TC categories do not produce more rain. Over the vastness of the ocean and the TC's track region in general, the biggest rainfall volume and contribution of a TC were discovered. The quantity of rain and contribution provided by TCs diminished considerably as they progressed inland and made landfall. More intense tropical cyclones produce significantly more rainfall over the ocean. According to Prat and Nelson, intense TCs are not necessarily connected with significant rainfall, even though they often produce torrential rain over large areas in a short period. A TC's strongest rainfall volume and contribution were frequently reported over the ocean and along the TC's track zone. The quantity of rain and contribution provided by TCs diminished considerably as they moved inland and made landfall. So The study concludes that the maximum rainfall does not have to be proportional to the intensity. The area of rainfall of a TC is not proportional to the intensity of cyclones, hence more rain doesn't come from higher-intensity TC categories.

ETHICAL DECLARATION

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper.
Financing: This research received no external funding.
Peer review: Double anonymous peer review.
Acknowledgement: We express our sincere gratitude to the TRMM project for providing the valuable datasets used in this research.

REFERENCES

Cerveny, R.S. and Newman, L.E., 2000. Climatological relationships between tropical cyclones and rainfall. *Monthly Weather Review*, 128(9), pp.3329-3336.

Chen, L., Li, Y. and Cheng, Z., 2010. An overview of research and forecasting on rainfall associated with landfalling tropical cyclones. *Advances in Atmospheric Sciences*, 27(5), pp.967-976.

Cheung, K., Yu, Z., Elsberry, R.L., Bell, M., Jiang, H., Lee, T.C., Lu, K.C., Oikawa, Y., Qi, L., Rogers, R.F. and Tsuboki, K., 2018. Recent advances in research and forecasting of tropical cyclone rainfall. *Tropical Cyclone Research and Review*, 7(2), pp.106-127.

Cong, C.H., Chen, L.S., Lei, X.T. and Li, Y., 2011. An overview of the study of tropical cyclone remote rainfall. *J Trop Meteorol*, 27(2), pp.264-270.

Dhar, O.N.; Rakhecha, P.R.; Mandal, B.N. Influence of tropical disturbances on monthly monsoon rainfall of India. *Mon. Weather Rev*. 1980, 109, 188–190.

Jiang, H.; Zipser, E.J. Contribution of Tropical Cyclones to the Global Precipitation from Eight Seasons of TRMM Data: Regional, Seasonal, and Interannual Variations. *J. Clim*. 2010, 23, 1526–1543.

Khouakhi, A., Villarini, G. and Vecchi, G.A., 2017. Contribution of tropical cyclones to rainfall at the global scale. *Journal of Climate*, 30(1), pp.359-372.

Li, Q., Lan, H., Chan, J.C., Cao, C., Li, C. and Wang, X., 2016. An operational statistical scheme for tropical cyclone-induced rainfall forecast. Chapter, 10, pp.217-232.

Molongwane, C., Bopape, M.J.M., Fridlind, A., Motshegwa, T., Matsui, T., Phaduli, E., Sehurutshi, B. and Maisha, R., 2020. Sensitivity of Botswana Ex-Tropical Cyclone Dineo rainfall simulations to cloud microphysics scheme. *AAS Open Research*, 3(30), p.30.

Neumann, C.J. Global Guide to Tropical Cyclone Forecasting; *World Meteorological Organization: Geneva, Switzerland*, 1993. Available online: https://library.wmo.int/doc_num.php?explnumid=9598 (accessed on 2 November 2019)

Rodgers, E.B., Adler, R.F. and Pierce, H.F., 2000. Contribution of tropical cyclones to the North Pacific climatological rainfall as observed from satellites. *Journal of Applied Meteorology*, 39(10), pp.1658-1678.

RSMC. Best Track Data of Tropical Cyclonic Disturbances over the North Indian Ocean. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.176.8143&rep=rep1&type=pdf (accessed on 2 November 2019).

Schumacher, R.S., Galarneau, T.J. and Bosart, L.F., 2011. Distant effects of a recurving tropical cyclone on rainfall in a mid-latitude convective system: A high-impact predecessor rain event. *Monthly Weather Review*, 139(2), pp.650-667.

Sengupta, D., Bharath Raj, G.N. and Shenoi, S.S.C., 2006. Surface freshwater from the Bay of Bengal runoff and Indonesian throughflow in the tropical Indian Ocean. *Geophysical Research Letters*, 33(22).

Sengupta, D., Goddalehundi, B.R. and Anitha, D.S., 2008. Cyclone-induced mixing does not cool SST in the post-monsoon north Bay of Bengal. *Atmospheric Science Letters*, 9(1), pp.1-6.

Thakur, M.K., Lakshmi Kumar, T.V., Dwivedi, S. and Narayanan, M.S., 2018. On the rainfall asymmetry and distribution in tropical cyclones over the Bay of Bengal using TMPA and GPM rainfall products. *Natural Hazards*, 94(2), pp.819-832.

Uddin, M., Li, Y., Cheung, K.K., Nasrin, Z.M., Wang, H., Wang, L. and Gao, Z., 2019. Rainfall contribution of tropical cyclones in the Bay of Bengal between 1998 and 2016 using TRMM satellite data. *Atmosphere*, 10(11), p.699.

Utsumi, N. and Kim, H., 2022. The observed influence of anthropogenic climate change on tropical cyclone heavy rainfall. *Nature Climate Change*, 12(5), pp.436-440.