A REVIEW PAPER ON TROPICAL CYCLONE CENTER DETECTION

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Abstract- **Tropical cyclones (TCs) are the most destructive weather systems that form over the tropical oceans, with about 90 storms forming globally every year. The timely detection and tracking of TCs are important for advanced warning to the affected regions. As these storms form over the open oceans far from the continents, remote sensing plays a crucial role in detecting them. Automatic weather forecasting is now achievable thanks to advancements in computer vision and satellite image technology. To prevent the loss of life and their assets, cyclone prediction is a major role because of directly related to the lives and household of human being. Satellite images provide an excellent view of clouds which can be used in weather forecasting and especially Infrared Red (IR) satellite images play in many environmental applications. To find the tropical cyclone (TC) center, the basic stage is to extract the main cloud of the cyclone. In manual segmentation, selection of the storm region is complicated, time consuming task and it also need the human experts for every time processing. In this article, a literature review is carried out to study various researches done by different scholars.**

Keywords: **Tropical Cyclone, Centre detection, Computer vision, optimization algorithm.**

I-INTRODUCTION

A TC is said to be a high-speed rotating storm, characterized by a low-pressure centre with a closed low-level atmospheric movement of winds which produces heavy rain. This may cause natural disaster, death and loss of property. A matured cyclone develops a centre called Eye associated with a ring of high intensity winds around it [1]. Since the launch of the first polar-orbiting meteorological satellite in the early 1960s, remote sensing techniques have proved to be a useful method for tropical cyclone analyses and forecasting. Satellite cloud images, acquired by passive remote-sensing instruments operating in the visible and infrared (IR) bands, vividly describe cloud-level tropical cyclone horizontal structures with large area coverage and frequently repeated observations [2].

As low pressure systems strongly govern our weather conditions, the ability of atmospheric models to predict cyclones is intensively studied by meteorologists and climatologists. A comprehensive overview of previous extra-tropical cyclone predictability studies focusing on short to medium-range forecasts. Nine global ensemble prediction systems (EPS) and their ability to forecast cyclones for a 6-month period was investigated. EPS produce multiple weather forecasts, which represent a sample of possible future atmospheric states. In accordance with previous findings it is shown that global deterministic models forecast the position of a cyclone with a higher accuracy than the cyclone intensity [3].

The techniques have been applied to general circulation model (GCM) output. For example, Murray and Simmonds (1991a) and König et al. (1993) investigated GCM output and compared it with reanalysis data. Raible and Blender (2004) applied the method of Blender et al. (1997) to simulated data and found that cyclone tracks and their corresponding variability are a sensitive measure to detect discrepancies between simulations with different ocean representations. Other studies have presented the role of cyclone-related variability on the generation of decadal variations of circulation patterns (Raible et al. 2004; Luksch et al. 2005). In climate change scenario simulations Schubert et al. (1998) found a northward shift of cyclone tracks in a warmer climate state. Leckebusch and Ulbrich (2004) confirmed this result and additionally investigated the intensity of cyclones. They found that North Atlantic cyclones intensify in projections of future climate compared with a control simulation for present day conditions, whereas no significant cyclone intensity changes were found in other studies (Kharin and Zwiers 2000, 2005) [4].

Most image processing problems using morphology such as merged and robust approach. Morphological pruning, thinning and filtering approaches are helpful techniques for preprocessing or post processing. The dilation, erosion, opening and closing operations are the most basic morphological operations for binary images [5].

As in the development of artificial intelligence (AI) technology in the last decade, machine learning algorithm has been successfully applied in the subjects of object detection and pattern recognition owing to its ability to efficiently extract imagery information. In the subjects of oceanography and meteorology, state-of-the-art machine-learning algorithms have been applied to recognize the circulating pattern in a spiraling fluid field. Moreover, deep convolutional neural network (DCNN) has been utilized to detect and classify objects in remote-sensing images. Based on DCNN, researchers have successfully developed object detection models for land-use and land-cover, vegetation, urban commerce, transportation vehicles, etc. Similarly, attempts are made to detect cyclones based on cloud images [6].

A TC revolved through irregular shapes at early phases of their development. When direct quantities of environmental variables such as temperature and pressure are not available, the detection of typical circular and curved patterns from remotely sensed data is a possible method to conclude the creation and development of tropical cyclones. The first complete pattern recognition technique for tropical cyclone intensity estimation from satellite images was developed by Dvorak [7]. The Dvorak technique (DT) is subjective, but it is still used as the primary intensity estimation and forecasting tool in many TC forecasting stations around the world [7]. The satellite-based technique is the only estimate of TC intensity available to tropical cyclone forecasters for ocean basins where there is no aircraft reconnaissance. An expert applies the technique to measure features of the clouds in satellite images by following a set of empirically determined rules.

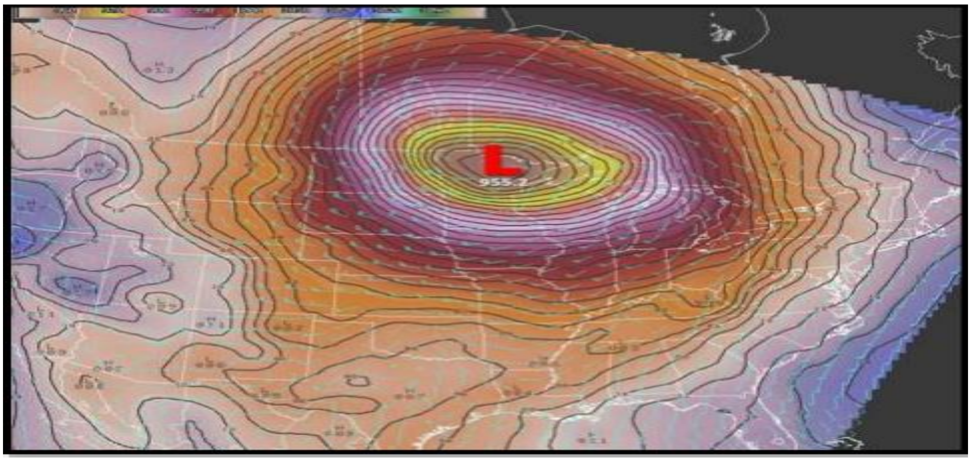

Figure 1: Typical Isobars in a Tropical Cyclone Development

1.2 CLASSIFICATION OF TROPICAL CYCLONES

The tropical cyclones are so diverse in size, characteristics and weather conditions that no two cyclones are similar and therefore, it is tough to categorise them in certain comprehensive classes. However, the tropical cyclones are normally classified into the following four types. **1.2.1 TROPICAL DISTURBANCE**

These are migratory wave-like cyclones which move east to west due to easterly trade winds. Thus, they are also popular as easterly waves. About 80 per cent of these disturbances occur between 50 and 200 N latitudes on the western side of the oceans. It is followed by occasional rainfall, and finally by moderate to heavy rainfall from heavy cumulus and cumulonimbus clouds occurs. Occasionally, due to intense instability they may emerge as hurricanes.

1.2.2 TROPICAL DEPRESSIONS

These are small size low pressure centres encircled by more than one closed isobars. The wind velocities are highly variable, but on an average remain about 40-60 km per hour. They occur most frequently in inter tropical convergence zone (ITCZ) and are rare in the zone of trade winds. They move in different directions. In summer season these disturbances influence the weather conditions of India and Australia. These depressions normally fail to attain the size of a storm and die out as weak disturbances.

1.2.3 TROPICAL STORMS

These are low pressure centres encircled by closely placed isobars and have wind velocities in the range of 63 to 118 km per hour. They are common in the Bay of Bengal, Arabian Sea, Caribbean Sea and in the vicinity of Philippines, especially during summer season. They are associated with heavy rainfall and storm surges in coastal areas. They frequently develop into more destructive type of tropical cyclones.

1.2.4 HURRICANES OR TYPHOONS

Tropical cyclones are warm vortex circulatory wind systems of tropical origin with closed circular isobars. They have sustained maximum winds of at least 119 kmph and torrential rains. They are known by different names in different parts of the world. Hurricane represents most powerful and destructive tropical cyclone. This term is used for tropical cyclones of the Caribbean Sea and Gulf of Mexico region. The pressure gradient is very steep and at centre isobaric value may be 950 mb and pressure variation between centre and fringe may be 50 to 60mb. Therefore, wind velocities are very high, with a minimum of 119 km per hour. The tropical cyclones of hurricane level force are called typhoons in the western North Pacific Ocean. They are known as willy willies in Australia, cyclones in Indian ocean, baguio in Philippines and taifu in Japan. Indian Meteorological Department (IMD) uses the term 'Severe Cyclone Storm' when the wind velocity exceeds 63 kmph and when above 119 kmph, it is called 'Severe Cyclone Storm with a core of Hurricane Winds'. Occasionally, when tropical cyclones have wind velocity above 200 kmph the term 'Super Cyclone' is used, for instance, the Super Cyclone of Odisha, October 29, 1999.

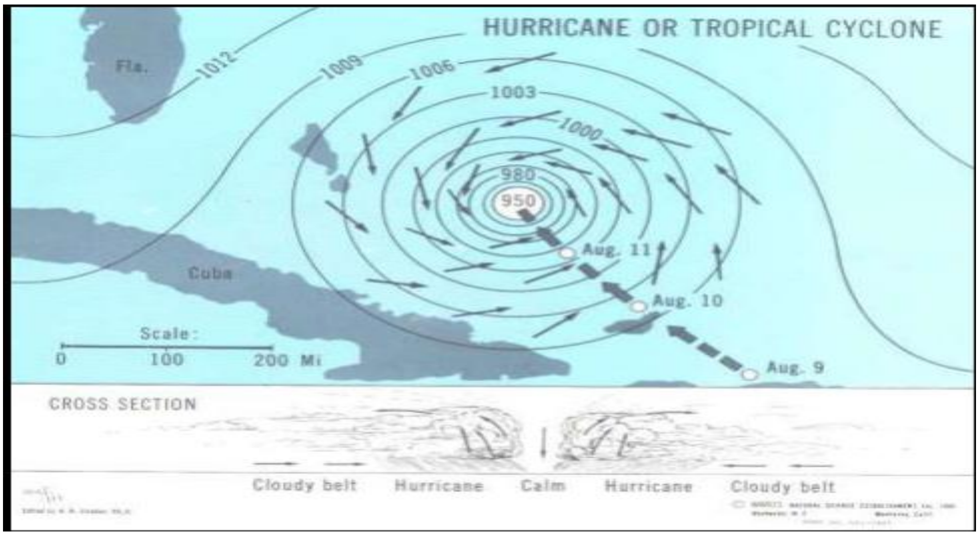

Figure 2: Hurricane

1.3.1 ORIGIN OF TROPICAL CYCLONES

The exact mechanism of origin and development of a tropical cyclone is still not well understood, but scholars have identified some conditions which are essentially associated with their formation. The formation of tropical cyclones depends upon fulfilment of the following requirements.

(i) Continuous Supply of Large Amount of Warm and Moist Air: It is a well observed fact that tropical cyclones originate only over large tropical ocean surface where temperature is 270C or above. The cold ocean currents lower the surface temperatures below this desired level on the eastern sides of the tropical oceans. Therefore, tropical cyclones originate in the western side of tropical oceans. As this condition is not fulfilled in the South Atlantic Ocean they fail to grow. It is noteworthy that this high temperature condition should prevail not just on surface but upto a depth of 60-70 metres deep from sea surface. Otherwise, convection process beneath cyclone will drag cooler water to surface and heat supply which is essential for cyclone will break. The power of a tropical cyclone depends on latent heat of condensation and thus, indirectly on supply of warm and moist air. Therefore, tropical cyclones are most frequent over warmer tropical oceans and especially during warmer parts of the year.

(ii) Strong Coriolis Force: Although the temperature conditions are favourable at equator but tropical cyclones are absent. This is due to absence of coriolis force at equator which is a prerequisite for circulatory motion of air towards a low pressure centre, anticlockwise in northern hemisphere and clockwise in southern hemisphere. It is only at 50 latitudes that the minimum required level of coriolis force for deflection of winds prevails. Therefore, tropical cyclones are mostly concentrated in the belt of 50 to 300 latitudes. Though the coriolis force increases from equator (zero) to pole but the number of tropical cyclones does not follow this trend because the surface temperature of the oceans starts decreasing. Therefore, the tropical cyclones originate and develop most frequently between 100 and 200 latitudes. Greater coriolis force is still more in the areas of increasing latitudes but the decline in the sea surface temperature does not allow the tropical cyclone to develop. It is also clear that factors do not operate in isolation rather together they determine origin and development of tropical cyclones.

(iii) Upper LevelAir Divergence: The upper troposphere (8 to 15 km) just above the surface disturbance must have well developed divergence or anticyclonic circulation to pump out the ascending air currents and to maintain continuous supply from below. This sustains convergence at surface and lifting mechanism in the cyclone which are its lifeline.

(iv) Minimal Vertical Wind Shear: Wind shear represents the differences between wind speeds at different altitudes. The ideal condition for tropical cyclone formation is of minimal vertical wind shear between lower and upper troposphere. In case, different wind directions and speeds operate vertically over an area, the latent heat carried aloft would be swept away and a circulatory core ascending area i.e. cyclone will fail to develop. For instance, in summer season over large parts of South Asia including India, cyclone formation is least active in July and August when surface monsoon winds and upper air easterly jet streams prevail simultaneously. Likewise the subtropical jet streams limit the extent of tropical cyclones towards temperate areas.

(v) Existence of Mild Tropical Disturbances: As mentioned in the types of tropical cyclones that the weak tropical disturbances such as easterly waves may occasionally develop into a large tropical cyclone. This happens when abundant warm and moist air results into the formation of intense column of latent heat induced instability. In addition to mild tropical disturbances, tropical cyclones develop around small atmospheric vortices in the ITCZ.

1.4 STRUCTURE OF TROPICAL CYCLONE

From the discussion so far, it is clear that tropical cyclones are circulatory motion towards low pressure centres. Winds circulation in a cyclone is anticlockwise in northern hemisphere and clockwise in southern hemisphere. Structure of a typical tropical cyclone of hurricane level shows six distinct regions. These six regions from core to periphery are – (i) the eye of the cyclone, (ii) the eye wall, (iii) the spiral bands, (iv) the annular zone, (v) the outer convective band, and finally (vi) the trade winds cumulus. The most important structural characteristic of tropical cyclone is the central part known as the eye of the cyclone. It is small central area of calm winds, clear skies and elliptical to circular shape. The eye wall is basically wall of vertical clouds i.e. cumulonimbus clouds. The eye wall region has the strongest winds and heaviest precipitation (Figure 3). The spiral shaped bands in satellite images give galaxy type appearance to cyclones (Figure 4). These rotating bands are associated with heavy precipitation, thunder and lightning. In the outer region of cyclone, subsidence tendency results into the formation of the annular zone. Here cloudiness is less extensive and high temperature and low humidity conditions prevail. This zone is surrounded by the outer convective band. Trade wind cumulus clouds constitute the outermost fringe of cyclone around which normal atmospheric conditions prevail.

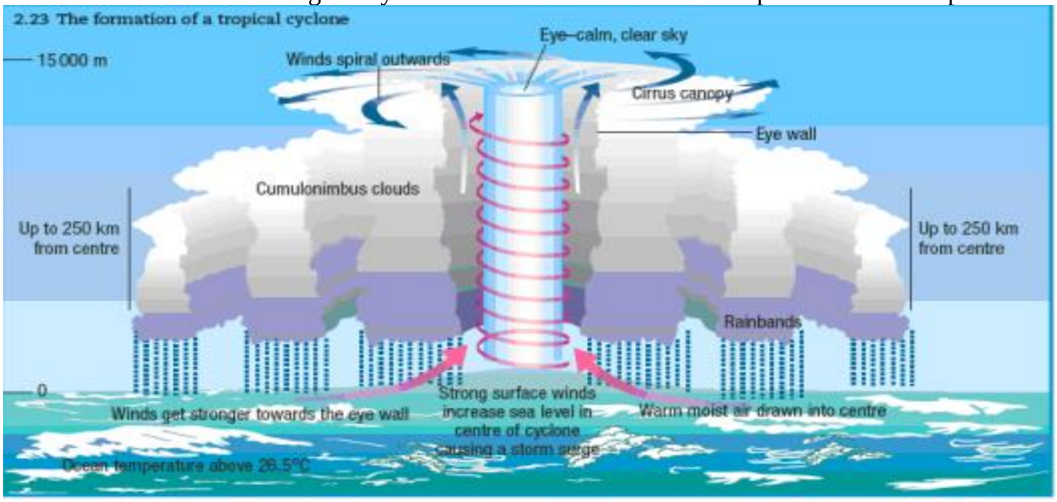

Figure 3: Structure of Tropical Cyclone

Figure 4: Spiral Bands of Clouds and Eye of Cyclone

1.5 DISTRIBUTION OF TROPICAL CYCLONES

Tropical cyclones are confined to tropical areas. The origin and development frequency of tropical cyclones in the latitudinal range of 30 -100 is about 22 per cent, in 100 -200 about 65 per cent and beyond this, it isabout 13 per cent(Figure 5). At equator and near equator they are absent due to absence of coriolis force and occurrence frequency is at peak in the central parts of tropics, and it again decreases due to absence of warm water surface with 270C temperature. The six major source regions of tropical cyclones are:

(i) North Atlantic (western tropical part): Mainly over Caribbean sea and Gulf of Mexico and maximum frequency is during August to October.

(ii) Indian Ocean: Bay of Bengal and Arabian Sea, with two maxima one in May and another in October-November.

(iii) South Indian Ocean:The area extending from Madagascar and Reunion islands upto 900 E longitude and Timor sea in north-western Australia and mainly during January to March.

(iv) North Pacific Ocean (eastern tropical part): Over western coastal areas of Mexico and Central America upto California coast and maximum occurrence is during August to October.

(v) North Pacific Ocean (western tropical part):This region has maximum occurrence of cyclones in the world with maximum frequency in August and September and includes mainly, Philippines, China sea and areas around Japan.

(vi) South Pacific Ocean (western tropical part): east coast of Australia, in and around Samoa and Fiji Islands and around the Coral Sea region and majority occur during.

II- LITERATURE REVIEW

Crespo *et. al* [**2023**], assessed the performance of the Regional Climate Model version 4 (RegCM4) in simulating the climatology of the cyclones near the west coast of South America. The synoptic evolution and seasonality of these systems were thoroughly investigated. The analyses were based on four simulations from the CORDEX-CORE Southern America (SA) domain, at 0.25° of horizontal resolution: one had driven by ERA-Interim and three driven by different GCMs. The reference dataset was represented by ERA5. [12].

Kotsias *et. al* [**2023**], An objective cyclone detection and tracking analysis was performed for the Mediterranean region with the use of 6-hourly (00, 06, 12, and 18 UTC) 1° × 1° mean sea-level pressure data obtained from the ERA5 database for the period 1950–2018. At first, the main cyclogenesis and high-density areas of cyclones were identified. Next, principal component analysis and cluster analysis were performed, classifying the detected cyclone trajectories into 12 clusters. In the following step, the application of the above methodology, this time on the intra-annual variations of the 12 cyclone clusters' frequencies leads to the objective definition of four seasons, which generally correspond to the conventional ones, but they present differences in their limits and duration [13].

Wang *et. al* [**2023**],a two-dimensional objective cyclone identification method based on outermost closed isolines was used to obtain the EC-related datasets, and the summertime ECs in East Asia were classified by the relationship between ECs of different intensities and the corresponding precipitation. [14].

Bourdin *et. al* [**2022**],compares four trackers with very different formulations in detail. Author's assessed their performances by tracking tropical cyclones in the ERA5 reanalysis and by compared the outcome to the IBTrACS observations database. [15].

Chand *et. al* [**2022**],Assessed the role of anthropogenic warming from temporally homogeneous historical data in the presence of large natural variability was difficult and has caused conflicting conclusions on detection and attribution of tropical cyclone (TC) trends. Here, used a reconstructed long-term proxy of annual TC numbers together with high-resolution climate model experiments, Author's showed robust declining trends in the annual number of TCs at global and regional scales during the twentieth century. The Twentieth Century Reanalysis (20CR) dataset was used for reconstruction because, compared with other re-analyses, it assimilated only sea-level pressure fields rather than utilize all available observations in the troposphere, making it less sensitive to temporal inhomogeneities in the observations [16].

Stegner *et. al* [**2021**], proposed a strong cyclone-anticyclone asymmetry of the eddy detection on the altimetry products AVISO/CMEMS in the Mediterranean Sea. Large-scale cyclones having a characteristic radius larger than the local deformation radius were much less reliable than large-scale anticyclones. Author's estimated that less than 60% of these cyclones detected on gridded altimetry product are reliable, while more than 85% of mesoscale anticyclones were reliable. Besides, both the barycenter and the size of these mesoscale anticyclones were relatively accurate. This asymmetry comes from the difference of stability between cyclonic and anticyclonic eddies. Large mesoscale cyclones often split into smaller sub-mesoscale structures having a rapid dynamical evolution. The numerical model CROCO-MED60v40 showed that this complex dynamic was too fast and too small to be accurately captured by the gridded altimetry products. The spatio-temporal interpolation smoothes out this sub-mesoscale dynamics and tends to generate an excessive number of unrealistic mesoscale cyclones in comparison with the reference field [17].

YANG *et. al* [**2020**], The differences in the detected center position and vertical tilt were generally small during the course of rapid intensification and eyewall replacement. All four methods lead to similar small-scale track oscillations that rotate cyclonically around the mean track. While the MVC and PVC lead to a relatively smooth rotation, abrupt changes exist in the track oscillation of the MTC; the track oscillation of the PCC contained amplified embedded rotations that were associated with the PV mixing in the eye region. The tracks of the MVC and PVC relative to the lowerlevel center (vertical tilt) were generally smooth, while the relative tracks of the MTC and PCC contain abrupt changes. The MVC also leads to the strongest symmetric structure in the tangential wind, PV, and radial PV gradient in the eyewall region. This study suggests that the MVC should be selected in the study of inner-core processes [18].

Wang *et. al* [**2020]** multilevel structural features of the images was exploited. Furthermore, a two-step scheme for locating the TC center was proposed, which contains the object detection for TCs with deep learning and the comprehensive decision for TC centers. In the object detection, considering the statistical scale distribution of TCs, the global and local features extracted by the network were combined to form the fusion feature maps through the up-sampling and concatenation [19].

III-CONCLUSION

In this paper, research work of various authors regarding tropical cyclone has been depicted. Centre detection in tropical images has become an essential topic to analyze frequency and energy in a cyclone. By evaluating such parameters of cyclone lives of people living near coastal area can be saved by alarming them become cyclone reaches to coastal area. Further we are going to propose a technique using an optimization algorithm to predict center of tropical cyclone.

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