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Change in the Number of Tropical Cyclone Landfall and Approach over Mozambique from 1980 to 2020

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Abstract

In this study, the variability of tropical cyclone (TC) landfall and approach over Mozambique as well as the environmental factors influencing were investigated. The frequencies of tropical cyclone landfall and approach as well as environmental factors were compared between the two periods (1980 to 1999 and 2000 to 2020). This study found that, according to International Best Track Archive for Climate Stewardship (IBTrACS) tropical cyclone data, the number of tropical cyclones making landfall over Mozambique increased by about 66% in the second period (2000-2020), compared to 34% in the first period (1980-1999). While the number of tropical cyclone approaches reduced from 59% in the first period to 41% in the second period. An assessment of the environmental conditions showed that warmer sea surface temperature (SST) and low vertical wind shear (VWS) were favorable to more TC genesis and, consequently, an increase in landfalls and a reduction in TC confined to the approach.

Keywords

Mozambique, Tropical Cyclone Landfall, Tropical Cyclone Approach, Environmental Conditions

1. Introduction

When comparing weather-related risks, tropical cyclones are among the most devastating natural disaster due to the heavy winds and torrential rainfall it brings causing floods resulting in increasing human mortality, huge damages in infrastructure and severe environmental damages (Ibanez et al., 2019; Lee et al., 2020; Peduzzi et al., 2012).

The terminology for classification of tropical cyclones varies from basin to basin. In the Southwest Indian Ocean basin, is called tropical disturbance when its wind speed does not exceed 27 knots, tropical depression when the wind speed is in range between 28 - 33 knots, moderate tropical storm when wind speed is between 34 - 47 knots, severe tropical storm when wind speed is between 48 - 63 knots, tropical cyclone when wind speed range between 64 - 89 knots, intense tropical cyclone when wind speed is between 90 - 115 knots and very intense tropical cyclone when the wind speed near center is estimated to exceed 115 knots (Leroux et al., 2018). In the present study, "tropical cyclone" refers to all categories. The Southwest Indian Ocean basin is the most active basin in the Southern Hemisphere and experiences between 3 to 12 cyclone geneses on climatological average per season (Charrua et al., 2021). The main regions for tropical cyclone formation in Southwest Indian Ocean are Mozambique channel and east Madagascar (Jury & Matyas, 2022; Mavume et al., 2010). Tropical cyclone that form in these areas can attain winds that can reach 67 m/s (Emerton et al., 2020) and are associated with heavy winds and torrential rainfall, causing a disastrous impact in southeastern African countries such as Mozambique and Madagascar. Mozambique is located in the eastern coast of Africa between the latitude 10˚ - 27˚S and has approximately 2700 km of coastline extension (Hoguane, 2007) along the most active cyclonic basin in the southern hemisphere (Charrua et al., 2021; Vitart et al., 2003) Approximately 55% of the country is vulnerable to climate change (Das, 2009) and about 60% of Mozambique population live along the coast and are vulnerable to cyclical tropical storms (MICOA, 2021). Mozambique vulnerability to extreme weather events ranks (10^{th}) tenth globally and (3^{rd}) third in Africa. Mozambique is ranked 160 out of 178 nations in the ND-Gain Index, which rates nations based on how vulnerable they are to climate change (Lundgren & Strandh, 2022). The same score reveals that Mozambique is the 35^{th} most susceptible and the 24^{th} least prepared nation (Lundgren & Strandh, 2022). Currently, Mozambique experiences a lot of negative effects from climate change, as this Southern African country is frequently hit by extreme weather and adverse climate events (Charrua et al., 2021). Tropical cyclones developing in the Southwest Indian Ocean can make multiple landfalls in Mozambique in a single season (Mavume et al., 2010). Rural Mozambique is dotted with farming villages that rely solely on agriculture (Kruger, 2016). Their income is negatively impacted by drought, but heavy rainfall brought by tropical cyclones has caused significant damage and losses of lives when it produces flooding rainfall (Matyas & VanSchoick, 2021).

Over the past several decades, one of the most difficult topics in meteorology has been the understanding of tropical cyclone genesis, development, and associated characteristic features (Deo et al., 2011). A deep understanding of how the behavior of tropical cyclones may change, such as frequency and intensity, has scientific and socio-economic value. The question of whether the number of tropical cyclones is increasing has received a lot of attention in light of global warming.

Understanding the environment in which tropical storms and cyclones occur is essential for making predictions about them (Kaplan & DeMaria, 2003; McBride & Zehr, 1981). Numerous attempts have been made to examine tropical cyclone risk characteristics like tropical cyclone intensity, size, and track, but when discussing tropical cyclone severity, wind-related terms like maximum wind speed (Vmax) are typically referred (Nordhaus, 2010). Klotzbach et al. (2020) emphasized that the minimum sea level pressure, a different intensity metric, has a stronger correlation with damage and mortality than Vmax. According to Hsiang and Narita (2012), tropical cyclone intensity, size, and track are significant factors in predicting the number of damages. Nam et al. (2018) claim that even a slight deviation in the route of less than 250 km can be a significant factor in determining the severity of tropical cyclone effects.

Since the impacts of extreme weather brought on by tropical cyclones are closely related to the rainfall, winds, and storm surge associated with tropical cyclones that make landfall in Mozambique, the overall trend of the frequency of tropical cyclone landfall has been of great concern and significance for the disaster management agencies and policymakers in Mozambique.

Improved comprehension of variations in TC activity has been the focus in various studies and have pointed out increasing pattern of TC-induced damages over the past several decades (Mendelsohn et al., 2012; Peduzzi et al., 2012).

Fewer studies have been carried out to investigate tropical cyclone landfall over Mozambique. Vitart et al. (2003) used observational data and model integrations to study landfall over Mozambique. They used a cyclone record from Elms and Neumann (1993), zonal wind from the National Centers for Environmental Prediction (NCEP) reanalysis, and sea surface temperature (Kalnay et al., 1996) to investigate predictors and potential physical mechanisms responsible for landfall and concluded that a coupled Global Circulation Model with high horizontal resolution is capable of predicting tropical cyclone landfall.

Landman et al. (2005) evaluated the capacity of a regional model to reproduce landfall regions and tracks of the tropical cyclones. According to the findings, the regional model can reproduce cyclone-like vortex tracks across Madagascar and into the Mozambique Channel. Mavume et al. (2010) studied the occurrence, frequency and tropical cyclone landfall in the Southwest Indian Ocean, west of the longitude 100˚E during the period from 1952 to 2007 and used tropical cyclone merged data from LR-RSMC (La Reunion - Regional Specialized Meteorological Center) and JTWC (Joint Typhoon Warning Center) to ensure maximum coverage. The results indicated a decrease in the number of tropical cyclone landfalls during the previous period of 1953-1979, and that there was no apparent change in tropical cyclone landfall during the more recent period of 1980-2007. However, there have been changes in tropical cyclone track patterns compared to earlier decades, which may be related to large-scale atmospheric changes.

Most of these studies focus on the tropical cyclone landfall variation and almost none focus on the approach tropical cyclone. This current study investigates whether the tropical cyclone making landfall or approach Mozambique have changed since 1980 to 2020 in terms of number and environmental conditions associated. The environmental conditions include sea surface temperature (SST), relative humidity (RH) at 600 hPa, relative vorticity (RV) at 850 hPa and winds at different level.

2. Data and Method

The TC data was supplied from the IBTrACS, which creates an integrated dataset by combining the best track data for tropical cyclones from various forecasting organizations (Finney et al., 2020). The data were examined for the time period from 1980-2020 which is after the satellite era where data are unquestionably more consistent and reliable. This was done to avoid issues with data heterogeneity for earlier records that were compiled from ship logs, coastal records, and a sparse distribution of aerial reconnaissance data rather than satellite imagery used from 1970 onward (Fitchett & Grab, 2014; Mavume et al., 2010). Names of tropical cyclones, location (latitude and longitude) and maximum sustained wind speed were included in the data, which were measured every six hours. In this study, we focus on the Mozambique tropical cyclone season (November to April). The TC frequency in this study is calculated over the Southwest Indian Ocean (10˚ - 40˚S, 30˚ - 110˚E). The first position of TC recorded by IBTrACS is considered as the TC genesis location. To define the TC landfall the present study, rely on the method employed by Mavume et al. (2010) which considered landfall when the TC eyewall crosses directly over a coastline line of a country. The tropical cyclone approach is considered when the eyewall skirted or is close to the country's coastal line within less than 100 km without making landfall.

The study also employed the environmental conditions obtained from the ERA 5 fifth generation monthly data reanalysis from European Center for Medium-Range Weather Forecast (ECMWF) that included the following variables: sea surface temperature, relative humidity, relative vorticity, and winds at different levels. The data consisted of the latitude and longitude grids of 0.25˚ × 0.25˚.

When tropical cyclones are over the ocean, the environmental factors are calculated to determine how the favorable conditions for tropical storm development have evolved over the past 41 years. In order to better understand the influence of environmental factors and change in number of tropical cyclones, the period of study is divided in 2, the first period spans from 1980-1999 and the second from 2000-2020.

The environmental factor such as VWS was determined by calculating the difference between the two winds at 200 hPa and 850 hPa, by using the Equation (1) from (Choi et al., 2016):

$$\mathrm{VWS} = \sqrt{\left(\mathrm{U}_{200} - \mathrm{U}_{850}\right)^2 + \left(\mathrm{V}_{200} - \mathrm{V}_{850}\right)^2} \quad (1)$$

where U and V are zonal and meridional winds respectively, and 200 and 800 refers to 200 hPa and 850 hPa levels.

3. Results

3.1. Mozambique Tropical Cyclone Landfall and Approach Frequency Changes

The current study focuses on the total number of Southwest Indian Ocean tropical cyclones that made landfall or approached over Mozambique throughout each season (from November to April). Figure 1 shows the time series for the Southwest Indian Ocean tropical cyclone landfall number. We divide the years 1980 to 2020 into two periods, with turning points in 1980 to 1999 (first period) and 2000 to 2020 (second period), respectively.

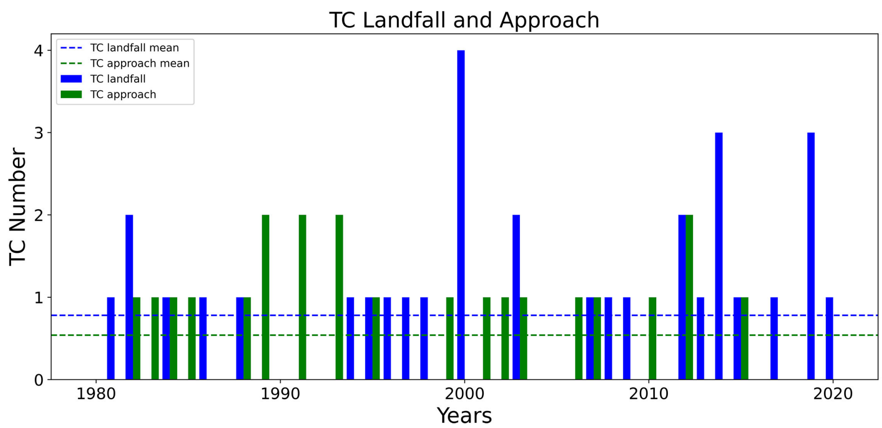


Figure 1. Temporal series of tropical cyclone frequency during Landfall (blue bars) and approach (green bars) over Mozambique from 1980-2020 in November-April season.

Landfall

The interannual variation frequency of Mozambique tropical cyclone landfall shows that in the first period, from 1980 to 1999, has a decreased landfalling activity, with more than one storm making landfall in 1982. From 1989 through 1993, there were five years in a row with no recorded cyclone activity landfall. Mozambique landfalling tropical cyclone frequency has increased since the 2000s. As a result, a tendency of landfalling tropical cyclone frequency was slightly enhanced, however statistically it was not significant as the Mann-Kendall test (*not illustrated*) showed no trend with the p-value = 0.88, although according to some studies, this test only gives the significance and direction of the trend, but not the trend itself (Mavume et al., 2010). During the second period the high tropical cyclone landfall activity was verified in the year of 2000 with 4 TC landfall, followed by 2014 and 2019 with 3 TC landfall respectively. The total frequency landfall during the second period (21 TCs) was 1.9 times greater than in the first period (11 TCs).

The annual variation of Mozambique tropical cyclone approach shows high tropical cyclone approach activity with more than 1 cyclone in the years of 1989, 1991 and 1993 in the first period. The long period with no recorded tropical cyclone approach activity was verified from 1996 to 1998, three consecutive years. The second period shows a relatively low tropical cyclone approach activity compared to the first period with only the year of 2012 with maximum number approach activity with 2 tropical cyclones. The reduction in the number of tropical cyclone approaches was not statistically significant has Man-Kendall test (*not illustrated*) showed p-value = 0.16. Five years with no recorded tropical cyclone approach were verified from 2015 to 2020. The total frequency of tropical cyclone approaches during the first period (13 TCs) was 1.4 times greater than in the second period (9 TCs).

The monthly tropical cyclone landfall and approach over Mozambique for the entire period and the two periods was analyzed. During the period from 1980 to 2020 (**Figure 2(a)**), the pick of tropical cyclone landfall was in January and February accounting for approximately 63% followed by March with 19%. There's a slight preponderance of tropical cyclone landfall activity in April, November and December. These findings are in accordance with Mavume et al. (2010) which found a high tropical cyclone activity in the months of January and February during the tropical cyclone season (November-April) in the Southwest Indian Ocean from 1980-2007.

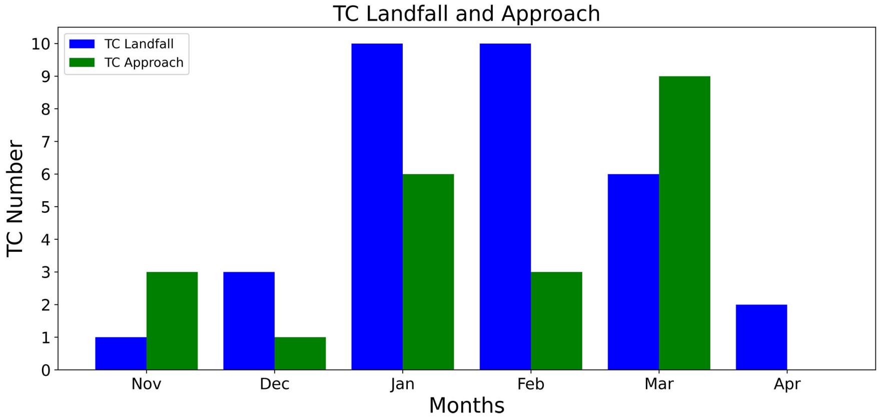
The total number of tropical cyclones approaches for the entire period showed that the maximum number of tropical cyclone approaches was verified in March with approximately 40% followed by January with more than 25%. There is smooth difference in tropical cyclone approach in November and February compared to December.

Comparing the tropical cyclone landfalling between the two periods, during the first period (**Figure 2(b)**) the landfalling was concentrated in January which accounted for approximately 46% of total landfalling cyclones during the first period followed by February with 27% and the other months with equal frequency number and no landfalls were recorded in April. On the other hand, in the second period (**Figure 2(c)**) a shift in the pick and more equitable distribution is verified with more landfalling in February accounting for 34%, January and March with 24% each and December and April with 9% each and no tropical cyclone made landfall in November. This shows a decrease in landfalling of tropical cyclones in January and November but an increase in December, February, March and April from the first to the second period.

The difference in the frequency occurrence of tropical cyclone approach between the two periods showed that in the first period the maximum number of approaches was in March with 46% followed by January and February with 23% each and November with 8% and no approach was verified in December. For the second period the maximum approach was verified in January and March with approximately 34% each followed by November with 22% and December with 10%.

Table 1 presents the interdecadal variation of both tropical cyclone landfall and approach. During the first 20 years 11 out of 32 tropical cyclones made landfall accounting for approximately 34% of tropical cyclone frequency. An increase in the frequency of tropical cyclone landfall was verified in last 21 years where 21 out of 32 made landfall accounting 66%.

The cyclone approach showed a reduction where 13 out of 22 tropical cyclone approached Mozambique accounting for approximately 59%. A reduction was verified during the last 21 years where the frequency of approaching tropical cyclone accounted for 41%.



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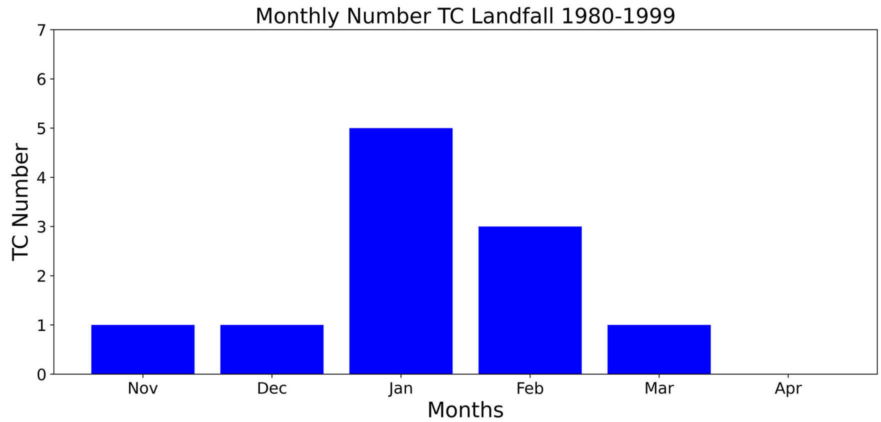

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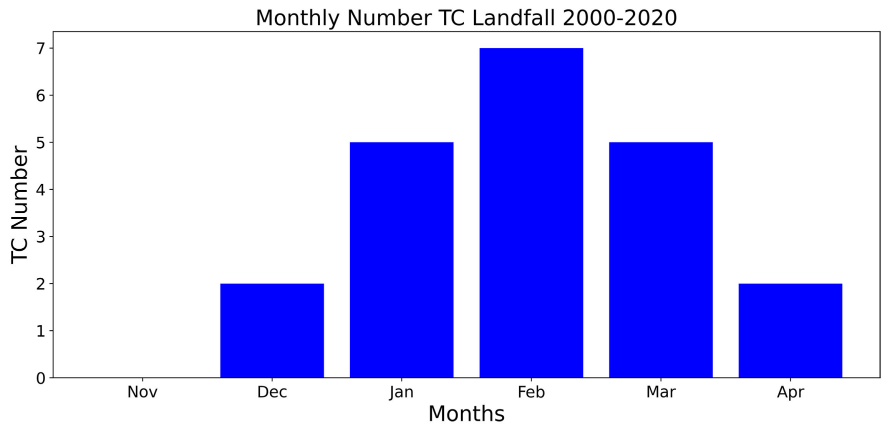

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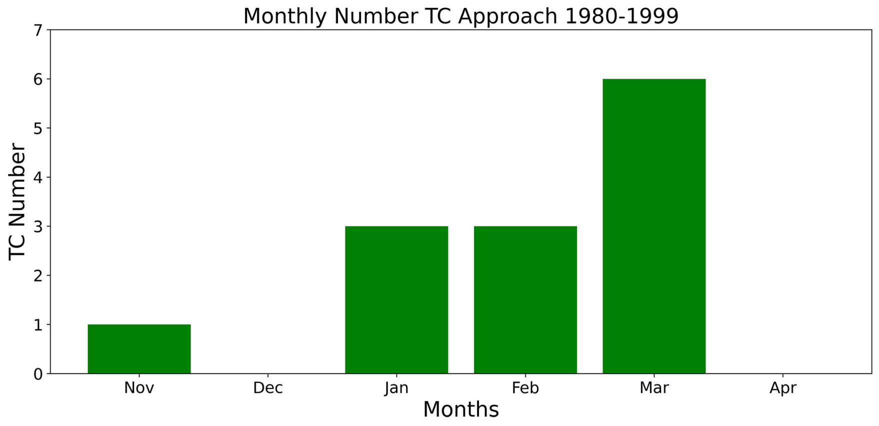

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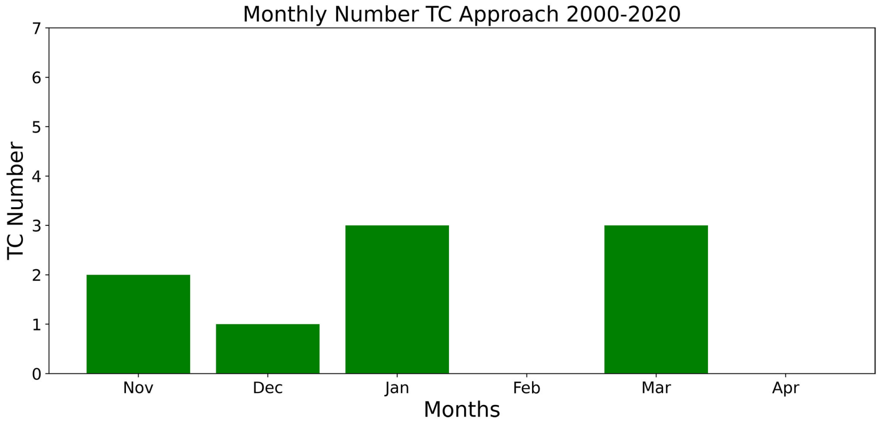


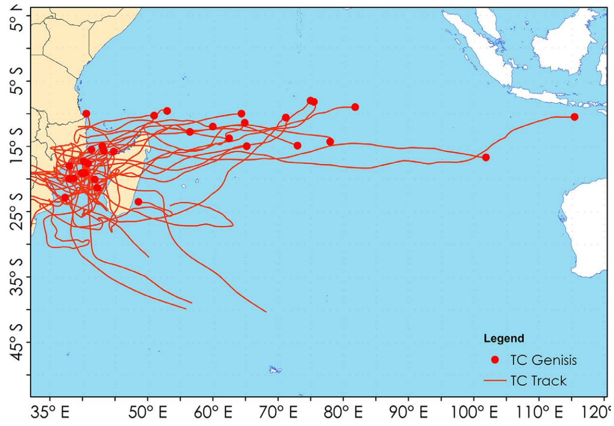
(e)

Figure 2. Monthly frequency of Mozambique tropical cyclone during the season (November-April). (a) landfall and approach for the entire period 1980-2020, (b) landfall for the first period 1980-1999 (c) landfall for the second period 2000-2020, (d) approach for the first period 1980-1999 and (e) approach for the second period 2000-2020. Blue bars denote landfall cyclones and green approach cyclones.

Table 1. Interdecadal changes for landfall and approaching tropical cyclone frequency over Mozambique during their frequent season.

Landfall			
Interdecadal	Length	N˚ of TC	TC frequency (%)
1980-1999	20 yrs	11	34
2000-2020	21 yrs	21	66
Approach			
Interdecadal	Length	N˚ of TC	TC frequency (%)
1980-1999	20 yrs	13	59
2000-2020	21 yrs	9	41

According to climatological genesis and track of tropical cyclone landfall (Figure 3(a)), most of the tropical cyclone that made landfall had its genesis in the eastern part of Madagascar accounting for 53% of the tropical cyclone formation and 47% was generated into the Mozambique channel. The landfall track density (**Figure 3(c)**) illustrates that the track density is mainly concentrated between 15˚and 25˚S with the highest density around 11 days·yr^{-1}. The climatological genesis of tropical cyclone approach showed that approximately 32% were formed in the eastern part of Madagascar and 68% in the Mozambique channel. The preferred path (**Figure 3(d)**) for approach tropical cyclone the track density is concentrated between 15˚ and 20˚S also with highest density around 11 days·yr^{-1}.



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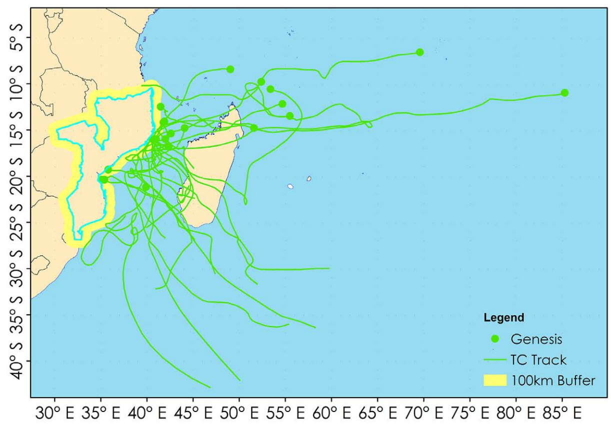

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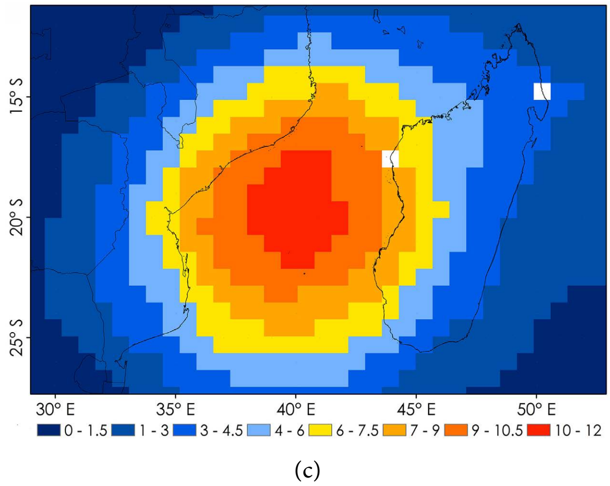

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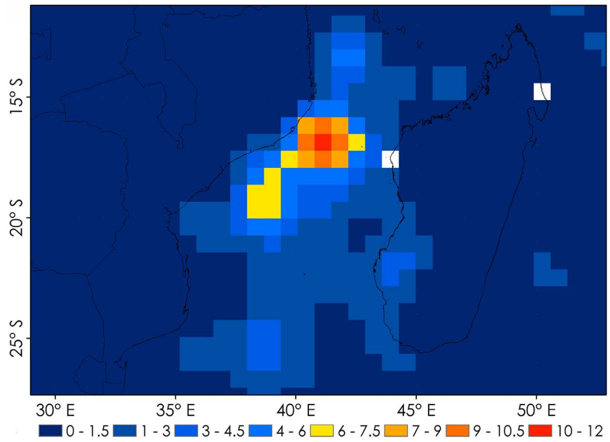


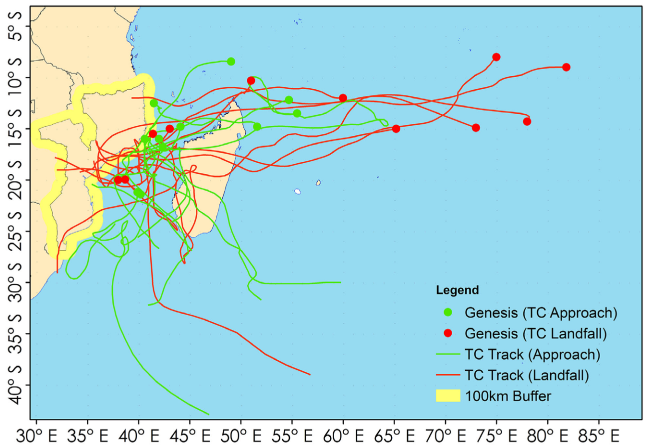
(d)

Figure 3. Mozambique climatological tropical cyclone genesis and track for (a) landfall and (b) approach. Tropical cyclone track density (days·yr^{-1}) for (c) landfall and (d) approach.

Figure 4 shows the track and spatial distribution of the difference in tropical cyclones occurrence frequency that made landfall and approach over Mozambique between the two different periods. Increase in the occurrence of tropical cyclone landfall is noticeable in the second period indicating that many cyclones made landfall over the coast of Mozambique comparing to the first period.

The genesis location for land-falling cyclones is strongly displaced toward the west of 80˚E in accordance with Leroux et al. (2018), which found that the tropical cyclones are uniformly distributed from 35˚E to 95˚E. According to the same figure, very few tropical cyclones had its genesis east of longitude 80˚E made landfall apart from the 2 tropical system (Eline and Hudah) in 2000 that were formed between 110˚E and 120˚E and crossed all the Southern India Ocean and Madagascar till make landfall over Mozambique. The strong cyclone genesis is observed from latitude 10˚S to 17˚S in the open Southwest Indian Ocean east of Madagascar and in the Mozambique channel the activity shifts 5˚S southward and the tropical cyclone occurs frequently between the latitude 15˚S to 25˚S. Moreover, 14 out of 32 landfalls, almost 44% of the tropical systems that made landfall in Mozambique had its cyclone geneses into Mozambique channel. For the first period (Figure 4(a)) most of tropical cyclones that made landfall over Mozambique had its genesis east of Madagascar. For the second period (Figure 4(b)) there's a balance between the cyclone geneses for the landfalling tropical cyclones, half of the tropical cyclones had its cyclone genesis into the Mozambique channel and the other were formed east of Madagascar. The preferred location for landfalling cyclones in the first period was in the center and northern part but in the second period beside landfalling in the central and northern part, the landfall activity was also felt in the southern part making entire Mozambique vulnerable to tropical cyclone landfall.

Most of the tropical cyclones that approached the Mozambique coastal line had its cyclogenesis within the Mozambique Channel, where 13 out of 22 tropical approached Mozambique coast accounted for approximately 59% and the other tropical cyclones formed east of Madagascar. The tropical cyclone genesis that approaches Mozambique are frequently formed between the latitude 10˚S - 17˚S and the first period (**Figure 4(a)**) had more tropical cyclone geneses in the Mozambique channel compared to the second period (**Figure 4(b)**). Approximately 70% of the tropical cyclone approach in the first period were formed within Mozambique channel and the other 30% had its cyclone genesis in the eastern part of Madagascar. The same situation is verified in the second period where the cyclone geneses is high in the Mozambique channel compared to the eastern part of Madagascar. The track of tropical cyclone approach over Mozambique also shows that the preferred location for approach in the first period was in all regions, different in from the second period where most of the approaches were verified in the northern and central part of Mozambique.



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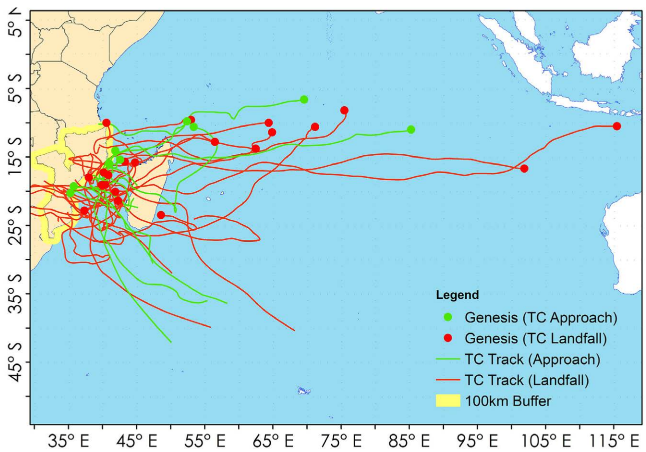
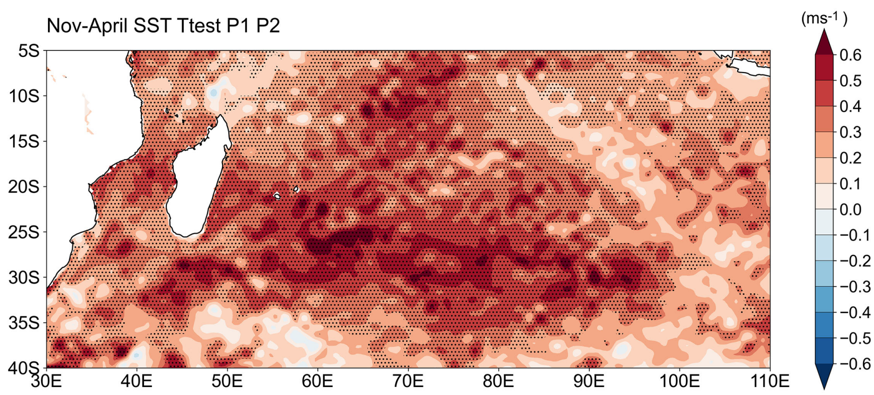


(b)

Figure 4. Mozambique-landfall and approach tropical cyclone for (a) the first period (1980-1999) and (b) for the second period (2000-2020). The red dots denote each tropical cyclone's landfall genesis location and red lines indicates its track. The green dots denote each tropical cyclone approach genesis location and green lines indicates its track.

3.2. Changes in Environmental Conditions

Figure 5(a) shows that there a significant positive SST differences between the two periods in the Southwest Indian Ocean, with enhanced SST in the eastern part (50˚ - 100˚E, 5˚ - 40˚S) of Madagascar and into the central and southern part (35˚ - 45˚E, 15˚ - 27˚S) of Mozambique channel. An increase relative vorticity can be found in the northern part (50˚ - 70˚E, 5˚ - 10˚S) of the Southwest Indian Ocean. Figure 5(c) also shows that the relative vorticity is negative significant in the northeastern part of Madagascar and in the northern part of the Southwest Indian Ocean as well as into Mozambique channel. The central and southern part of Southwest Indian Ocean exhibit slight positive significance. The vertical wind shear Figure 5(d) exhibits a negative significance into Mozambique channel and in the north and eastern part of Madagascar and the far edge central part of Southwest Indian Ocean suggesting that the vertical wind shear was low during the second period comparing to the first period, a positive significance of vertical wind shear is present in the southern part (30˚ - 110˚E, 30˚ - 40˚S) of Southwest Indian Ocean. From the environmental conditions illustrated in Figure 5 we can suggest that the enhanced SST, reduced relative vorticity and vertical wind shear into Mozambique channel and northeastern part of Madagascar were conductive to tropical cyclone formation during the second period compared to the first period and being these areas the core regions for tropical cyclone formation and intensification.



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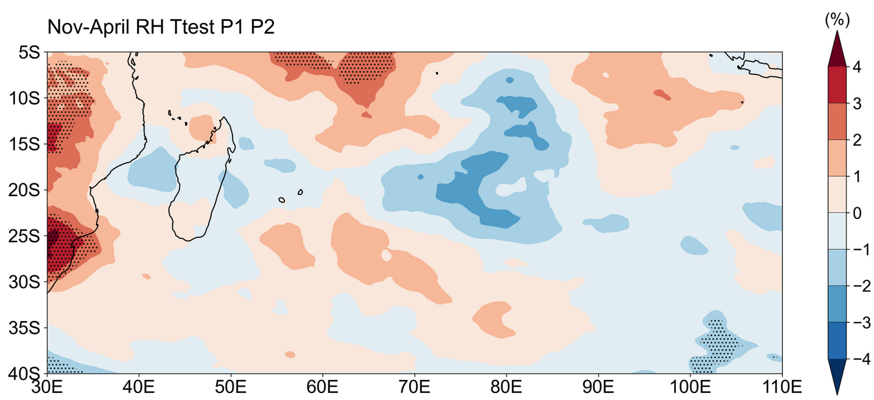

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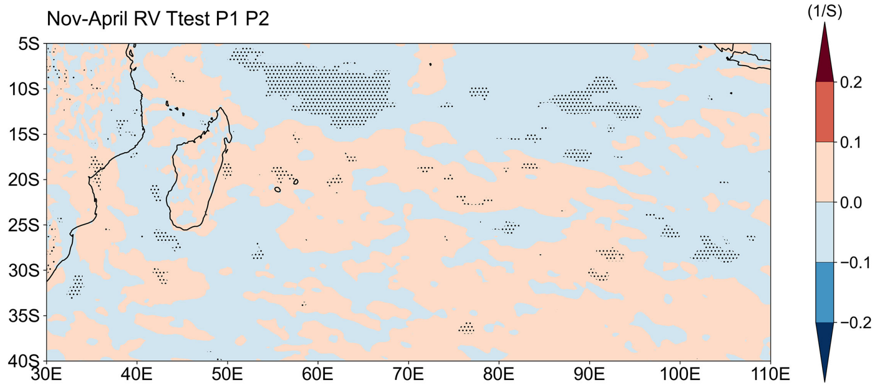

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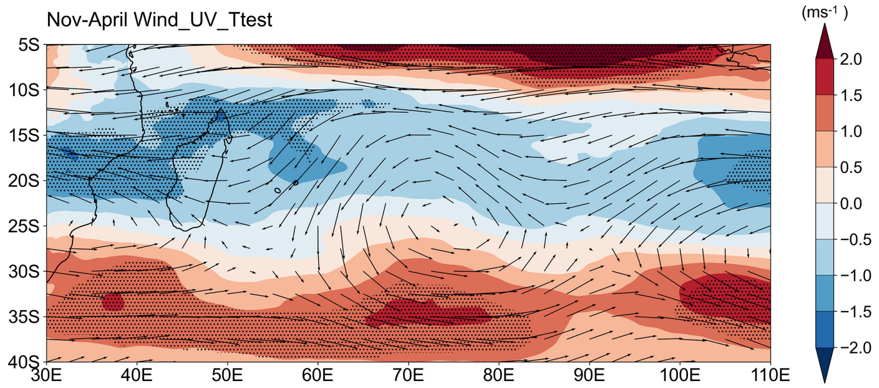
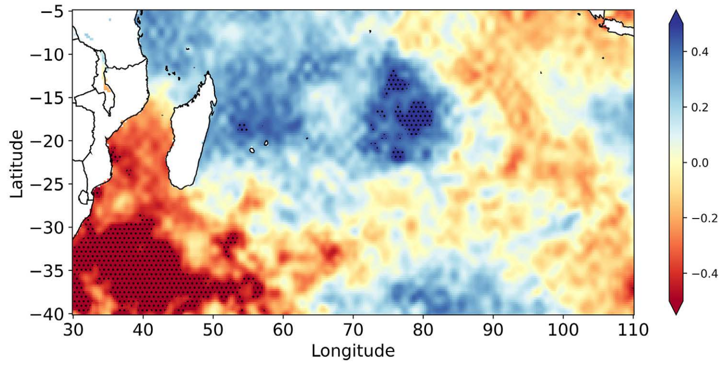


(d)

Figure 5. Difference between first and second period of (a) SST, (b) relative humidity at 600 hPa, (c) relative vorticity at 850 hPa, (d) 200 - 850 hPa Vertical wind shear. for the tropical cyclone season (November-April), dots indicate differences which are statistically significant at 95% confidence level.

The correlation of Mozambique TC landfall frequency throughout the cyclone season (November-April) with environmental factors over the southwest Indian ocean during the two periods was calculated **Figure 6**. A significant positive correlation is exhibited for SST (**Figure 6(a)**, **Figure 6(b)**) during the first period in the northeastern part (50˚ - 85˚E, 10˚ - 20˚S) of Madagascar, also a strong negative correlation is exhibited in the central and southern part of Mozambique channel. The negative correlation is exhibited in the central to southern part of Southwest Indian Ocean during the second period. The relative humidity (**Figure 6(c)**, **Figure 6(d)**) exhibited an enhanced positive significance into Mozambique channel but more pronounced in the second period covering all extension of Mozambique channel. the relative vorticity (**Figure 6(e)**, **Figure 6(f)**) exhibits a negative relationship between Mozambique tropical cyclone landfall into Mozambique channel and northeastern part of Madagascar, being this negative relationship more noticeable in the second period compared to the first. The vertical wind shear (**Figure 6(g)**, **Figure 6(h)**) illustrates decreased values into Mozambique channel and east of Madagascar during the second period although these changes were not significant. These changes in environmental conditions play a role in TC formation and increase in number of TC landfall over Mozambique.



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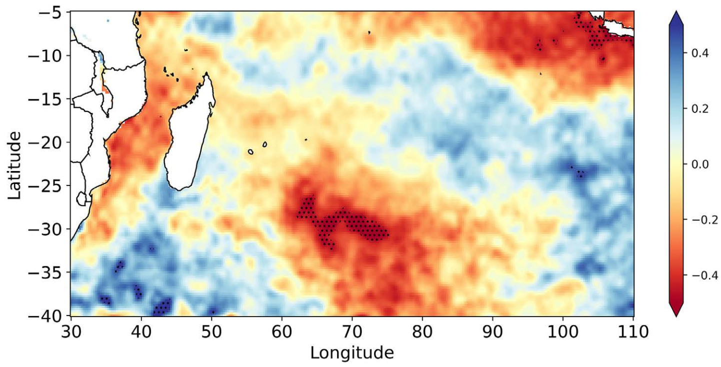

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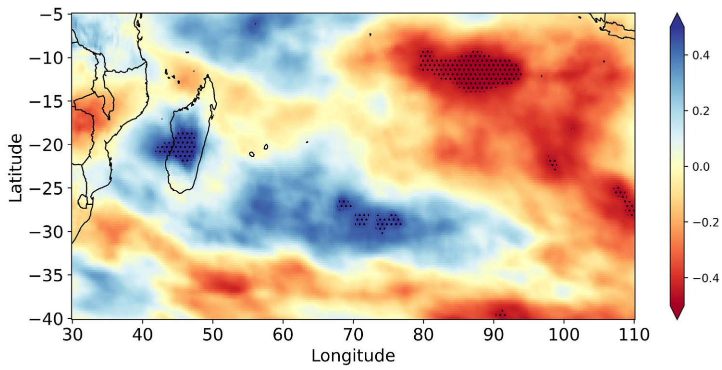

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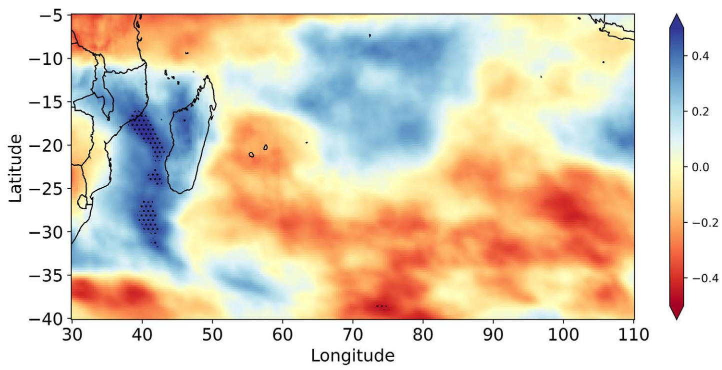
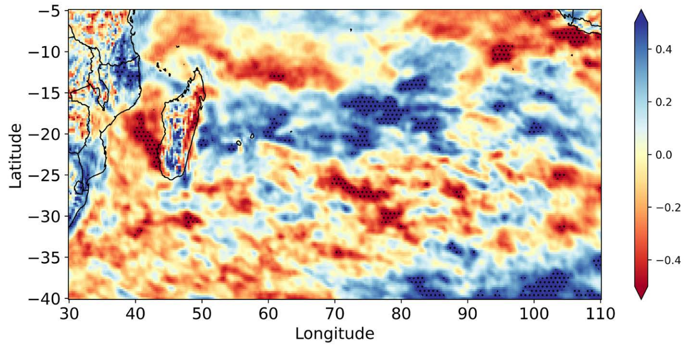
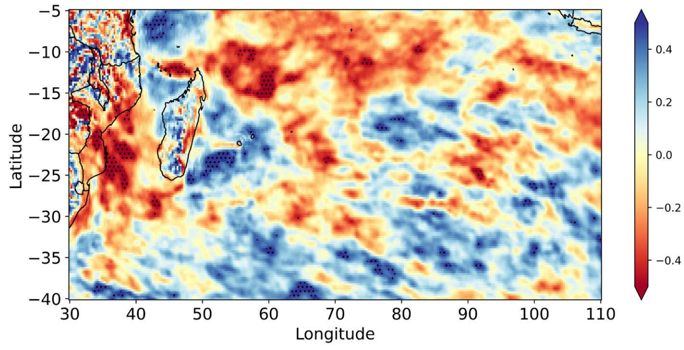


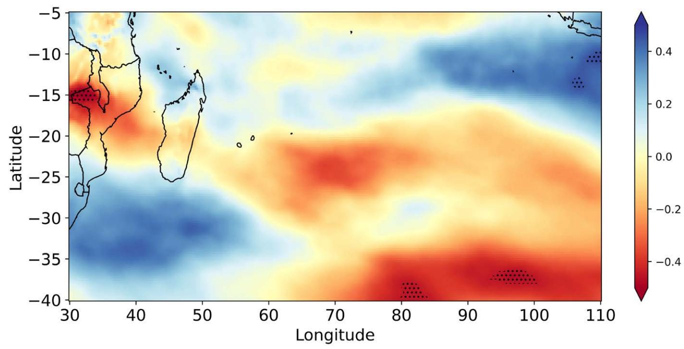
(d)



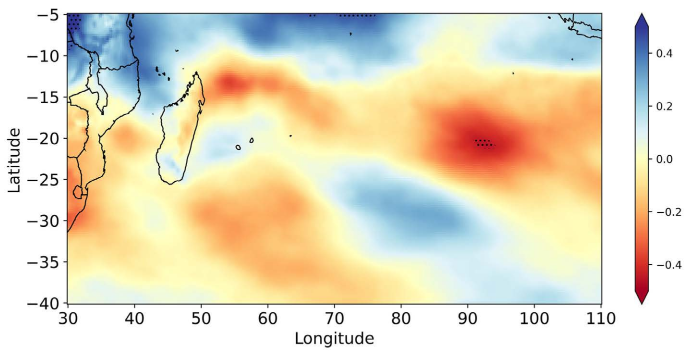
(e)



(f)



(g)



(h)

Figure 6. Correlation between TCs landfall and environmental conditions for the first and second period (a, b) Sea surface temperature, (c, d) relative humidity 600 hPa, (e, f) relative vorticity at 850 hPa and (g, h) 200 - 850 hPa vertical wind shear for the tropical cyclone season (November-April). Dots indicate 95% confidence level.

4. Discussion

This study has a propose to understand whether there's a change in the number of tropical cyclones that made landfall or approached Mozambique over the last 41 years from 1980 to 2020 based on best track tropical cyclone and reanalysis data. The frequency of tropical cyclone landfall over Mozambique showed an overall increase in the number where 11 out of 32 tropical cyclone landfalls made landfall during the first period and 21 in the second period. The landfall activity during the first period was mainly verified from November to March with high activity in January and February, a shift was verified during the second period where the landfall activity was verified from December to April with high landfall activity in January and March. The tropical cyclone landfall genesis increased in number within Mozambique channel was from 4 to 9 and the eastern part of Madagascar was from 7 to 10 from the first to the second period. Similar increase patterns in the number of tropical cyclones were registered in many parts of the world (Choi et al., 2016; Shan & Yu, 2021; Wang & Wang, 2023; Yamaguchi & Maeda, 2020). The total frequency landfall during the second period was 1.9 times greater than in the first period.

The Mozambique tropical cyclone landfall increase in the number is suggested to be due to the fact that the ocean was warmer especially in the Mozambique channel during the second period compared to the first, and this goes in agreement with Leroux et al. (2018) which underlined that higher sea surface temperatures in the Mozambique channel and the monsoon trough's farther-poleward position, which gives rise to the majority of South-west Indian Ocean storms, are factors that contribute to tropical cyclone development and intensification.

The vertical wind shear which is crucial for the cyclone formation and intensification (Choi et al., 2016; Manhique et al., 2021) exhibited low values in the north and central region of Mozambique channel and east of Madagascar and associated with the easterly winds from southwest Indian ocean, created a necessary ventilation condition for the propagation of the tropical cyclones generated in those areas. Nolan and McGauley (2014) studied from the period 1969-2008 the relationship between vertical wind shear and tropical cyclone genesis events in the latitudes 20˚S and 20˚N, concluded that values of vertical wind shear that ranges from 1.25 - 5 m/s are more favorable to tropical cyclone formation, despite other studies suggesting values that ranges between 5 - 10 m/s (Bracken & Bosart, 2000). Some other studies suggest that there's a value of vertical wind shear in which above that the tropical cyclone may not form. Zehr (1992) determined the threshold value from 12.5 m/s and above for North Pacific in which is almost impossible for the formation of tropical cyclone.

The tropical cyclone approach over Mozambique verified a reduction in number, and the approach TC frequency in the first period was 1.4 times greater than in the second period. This reduction of tropical cyclone approach is suggested to mainly influenced by the favorable environmental conditions that contributed for the increase in the tropical cyclone landfall activity over Mozambique, this is, more tropical cyclone that approached Mozambique ended up making landfall leading to few tropical cyclones confined within less than 100 km from the Mozambique coast.

5. Conclusion

The present study investigated whether the tropical cyclones landfall and approach over Mozambique from 1980 to 2020 has changed in terms of number and the environmental condition associated with the changes. The study shows that based on the best track tropical cyclone data, the TC's making landfall over Mozambique has increased over the last 41 years, from 1980 to 2020 and the TC's confined to approach has decreased. Analyzing the environmental factor between the first period (1980-1999) and second period (2000-2020) we realized that the SST difference was enhanced in second period, leading to warmer SST and the VWS showed low values in second period comparing to the first period. These condition of warmer SST and low VWS played a core role in TC formation and increase in the number of TC that made landfall over Mozambique during the second period. The authors suggest further research to be conducted in the future to address this issue and relate to the climate change and believe it is unclear whether the changes in the environmental condition between the first period and the second period are due to global warming.

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Data Availability

The data for support the findings in this study are open source, particularly tropical cyclones and the environmental conditions can be accessed from the following links:

https://www.ncei.noaa.gov/data/international-best-track-archive-for-climate-stewardship-ibtracs/v04r01/access/csv/

ERA5 monthly averaged data on pressure levels from 1940 to present (copernicus.eu)

https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure-levels-monthly-means?tab=form

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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