THE INFLUENCE OF ENSO AND QBO ON CYCLOGENESIS IN THE MOZAMBIQUE CHANNEL

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ABSTRACT

This study aims to investigate the influence of ENSO and QBO phenomena on cyclogenesis in the Mozambique Channel during the cyclonic seasons from 1979 to 2018. The study area is delimited by longitudes ranging from 35°E to 45°E, and latitudes ranging from 12°S to 24°S. In summary, although ENSO may have significant impacts on weather patterns globally, its effects on cyclogenesis in the Mozambique Channel can be modulated by a combination of local and regional factors specific to this area, such as submarine topography, wind shear, and sea surface temperature gradients. Conversely, the West phase of the QBO is much more conducive to cyclogenesis and cyclone intensification in our study area than the East phase of the QBO. However, its specific impact on cyclogenesis in the Mozambique Channel may be influenced by a complex combination of factors, including interactions with other climate variability modes and indirect effects on oceanic conditions.

Keyword : - *Cyclogenesis , Mozambique channel, Influence, ENSO and QBO.*

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1. INTRODUCTION

The Mozambique Channel, situated between the southeastern coast of Africa and the island of Madagascar, is known for its vulnerability to tropical cyclones during the cyclonic seasons. Understanding the factors influencing cyclogenesis in this region is crucial for effective disaster management and climate risk assessment. Two major climate phenomena, the El Niño-Southern Oscillation (ENSO) and the Quasi-Biennial Oscillation (QBO), have been recognized for their potential impact on global weather patterns. However, their specific influence on cyclogenesis in the Mozambique Channel remains a subject of research.

This study aims to investigate the influence of ENSO and QBO on cyclogenesis in the Mozambique Channel from 1979 to 2018. The study area is delimited by longitudes ranging from 35°E to 45°E and latitudes ranging from 12°S to 24°S. While ENSO is known to exert significant effects on global weather patterns, its impact on cyclogenesis in the Mozambique Channel may be modulated by local and regional factors.

Furthermore, the QBO, characterized by the alternating pattern of easterly and westerly winds in the equatorial stratosphere, has been identified as a potential driver of cyclogenesis [1]. However, the specific interactions between QBO phases and local environmental conditions in the Mozambique Channel require further investigation.

By examining the combined influence of ENSO and QBO on cyclogenesis in the Mozambique Channel, our work will be divided into three parts. The first part will focus on the materials and methodologies used, the second on the influence of QBO on cyclogenesis in our study area, and the third part on the influence of the ENSO phenomenon on cyclogenesis in the Mozambique Channel.

2. MATERIALS AND METHODOLOGY

2.1 DATABASE

- **Cyclone data**

The database is provided by IBTrACS (International Best Track Archive for Climate Stewardship) from NOAA. It is endorsed by the World Meteorological Organization's Tropical Cyclone Programme as an official resource for archiving and distributing "best track" data [2].

- **QBO indices at 50 mb**
- **ENSO oceanic indices**

2.2 STUDY AREA

2.2.1 Choice of Study Area

Chart 1 and 2 respectively depict the histogram of cyclone distribution by latitude and longitude during the cyclonic seasons from 1979 to 2018 in the Mozambique Channel. During this period, the IBTrACS database documented 58 storms or cyclones named in the South Indian Ocean by CMRS La Réunion. Figure 1 shows that the majority of cyclones formed between latitudes -12 °S and -24 °S, accounting for 48 out of the 58 recorded cyclones. Furthermore, Figure 2 illustrates that 83% of these cyclones originated between longitudes 35 °E and 45 °E, amounting to 49 out of the 58 cyclones.

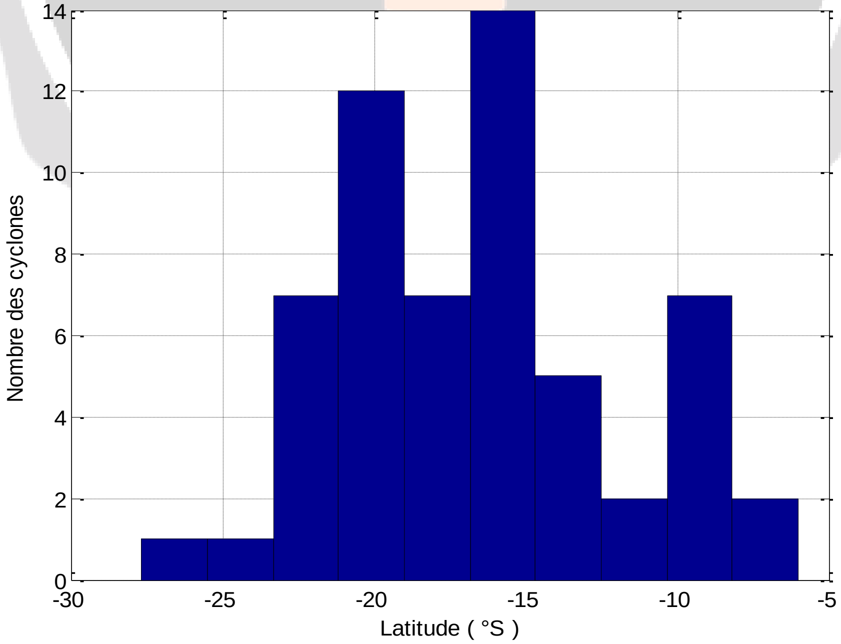

Chart-1 : Distribution of the number of cyclones by latitude during the cyclonic seasons from 1979 to 2018

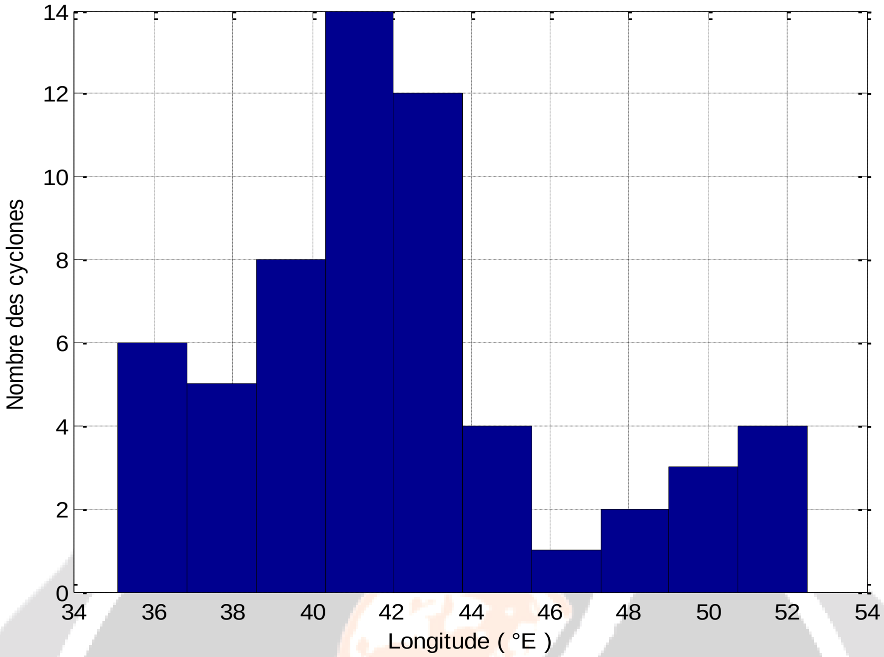

Chart-2 : Distribution of the number of cyclones by longitude during the cyclonic seasons from 1979 to 2018

2.2.2 Representation of the study area

Based on the distributions seen previously, we will focus our study on the area outlined in blue in Figure 1, bounded by longitudes ranging from 35 °E to 45 °E, and latitudes ranging from 12 °S to 24 °S.

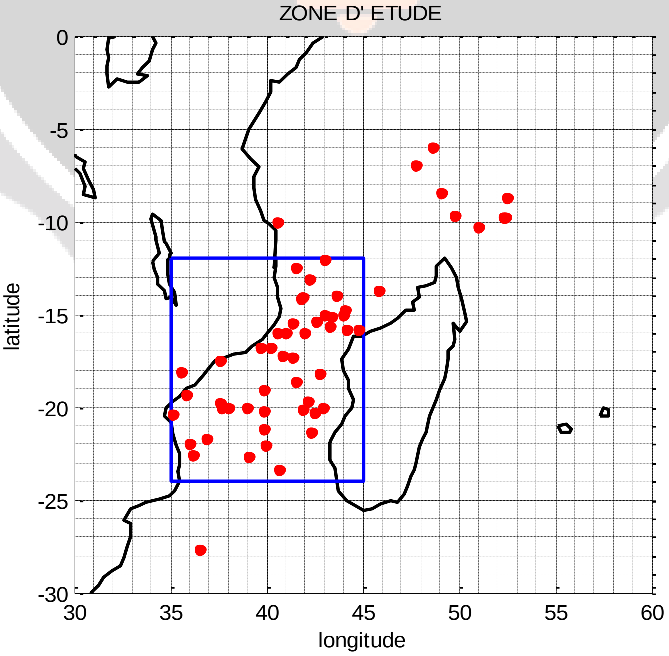

Fig-1 : Representation of the study area

2.3 MEAN [3]

We would like to emphasize that the mean is the most well-known measure of central tendency. This measure of central tendency is a value around which the data concentrate. It is obtained by dividing the sum of the values by the number of values.

$$\bar{x} = \frac{\sum n_i x_i}{\sum n_i} \qquad (1)$$

The climatological mean is written as follows :

$$\overline{x_{clim}} = \frac{\sum_{a=1}^{A} x_a}{A} \qquad (2)$$

Where *A* represents the number of years in the study period, and x_a is the observed quantity for each year.

3. RESULTS

3.1 Influence of QBO on cyclogenesis in the Mozambique Channel

3.1.1 Average of the QBO index for each cyclonic season from 1979 to 2018

Chart 3 represents the average of the QBO index for each cyclonic season. According to this figure, the cyclonic seasons 79/80, 81/82, 83/84, 84/85, 86/87, 89/90, 91/92, 94/95, 96/97, 98/99, 00/01, 01/02, 03/04, 05/06, 07/08, 12/13, and 14/15 correspond to the east phase of the QBO (negative QBO index). For the west phase of the QBO, it corresponds to cyclonic seasons where the QBO index is positive, such as the seasons 80/81, 82/83, 85/86, 87/88, 88/89, 90/91, 92/93, 93/94, 95/96, 97/98, 99/00, 02/03, 04/05, 06/07, 08/09, 09/10, 10/11, 11/12, 13/14, 15/16, 16/17, and 17/18.

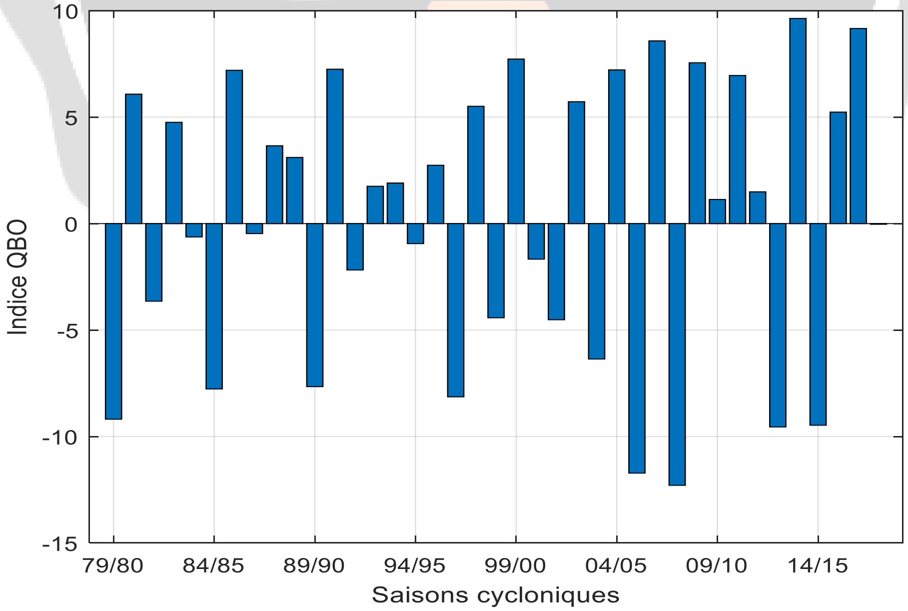

Chart -3: Average of the QBO index for each cyclonic season from 1979 to 2018

3.1.2 Influence of the QBO on cyclogenesis

Table 1 and chart 4 below provides information on the influence of the QBO on cyclogenesis during the cyclonic seasons from 1979 to 2018. Indeed, we note that there were 19 cyclogeneses during the East phase of the QBO and 28 cyclogeneses during the West phase of the QBO. This result confirms the findings obtained by Gray in 1984 during the study of the North Atlantic basin [4]. Thus, we can affirm that in the Mozambique Channel, the West phase of the QBO favors cyclone formation more than the East phase. During the West phase of the QBO, vertical wind shear is generally weaker, promoting more efficient development of cyclonic systems by reducing atmospheric constraints [5][6]. Additionally, atmospheric conditions can be more stable, creating a more favorable environment for cyclone formation.
We also observe that:

- During the East phase of the QBO: 7 of these cyclogeneses transformed into moderate tropical storms (filled green in the table), 9 into severe tropical storms (light green fill), 2 into tropical cyclones (orange fill), and 1 into a subtropical depression.
- During the West phase of the QBO: 13 of these cyclogeneses transformed into moderate tropical storms, 5 into tropical cyclones, 7 into severe tropical storms, 2 into intense tropical cyclones (yellow fill), and 1 into a very intense tropical cyclone.

Table 1: Influence of the QBO on cyclogenesis during the cyclonic seasons from 1979 to 2018.

Year	DJF	JFM	FMA	MAM	OND	NDJ	CYCLONE NAMES
1979	**7,38**	**8,84**	**6,03**	**5,86**	**-11,08**	**-10,58**	
1980	**-8,64**	**-8,84**	**-7,99**	**-6,65**	**8,18**	**8,41**	EDWIG
1981	**5,57**	**4,27**	**5,02**	**7,27**	**-0,62**	**-2,26**	
1982	**-2,86**	**-5,49**	**-5,32**	**-5,03**	**2,54**	**5,74**	20S_1982
1983	**5,68**	**5,15**	**4,71**	**7,31**	**1,96**	**0,15**	
1984	**-0,92**	**-1,57**	**-1,69**	**-0,04**	**-12,61**	**-9,98**	CABOTO, IMBOA
1985	**-8**	**-6,54**	**-4,73**	**0,68**	**8,03**	**6,58**	FELIKSA, ALIFREDY
1986	**5,78**	**6,14**	**8,33**	**8,87**	**1,73**	**-0,1**	BEROBIA, GISTA
1987	**0**	**-0,54**	**-1,95**	**-3,68**	**3,67**	**3,47**	
1988	**3,8**	**4,05**	**3,47**	**5,54**	**4,77**	**3,27**	
1989	**3,59**	**2,14**	**2,43**	**5,63**	**-8,02**	**-8,44**	CALASANJY, IANA
1990	**-7,65**	**-7,33**	**-7,25**	**-5,86**	**9,04**	**8,96**	HANTA
1991	**6,9**	**5,78**	**6,41**	**7,14**	**-0,98**	**-1,94**	CYNTHIA, DEBRA
1992	**-2,05**	**-1,82**	**-3,14**	**-3,67**	**-5,52**	**-1,33**	ELIZABETHA, C3_1992
1993	**3,62**	**4,46**	**4,64**	**7,58**	**3,75**	**2,86**	DESSILIA, GRACIA, IONIA
1994	**1,84**	**0,62**	**1,18**	**0,17**	**-9,1**	**-3,79**	
1995	**0,02**	**1,69**	**2,77**	**5,48**	**4,74**	**2,7**	FODAH, JOSTA
1996	**2,52**	**2,69**	**1,89**	**3,05**	**-11,88**	**-9,27**	
1997	**-8,51**	**-6,4**	**-6,38**	**-1,36**	**8,64**	**7,51**	LISETTE
1998	**5,13**	**4,07**	**3,85**	**4,68**	**-10,65**	**-7,32**	13S_1998, BELTANE
1999	**-4,04**	**-3,25**	**-0,64**	**2,85**	**7,66**	**7,97**	ALDA, 21S_1999
2000	**7,53**	**6,96**	**8,12**	**11,13**	**-0,5**	**-0,72**	
2001	**-1,88**	**-2,3**	**-2,31**	**-0,39**	**-11,39**	**-8,58**	DERA, CYPRIEN
2002	**-5,24**	**-2,92**	**0,52**	**6,05**	**8,03**	**5,98**	DELFINA
2003	**4,79**	**5,32**	**5,11**	**3,81**	**-9,78**	**-9,11**	JAPHET
2004	**-7**	**-4,89**	**-3,69**	**1,34**	**8,11**	**7,88**	ELITA

2005	6,23	6,15	7,47	6,51	-12,18	-12,42	FELAPI
2006	-13,22	-12,13	-10,18	-8,13	10,75	9,43	ANITA
2007	7,23	7,22	8,43	8,27	-12,52	-13,96	ELNUS
2008	-14,94	-12,65	-9,84	-6,67	6,91	7,73	FAME
2009	8,35	8,19	7,07	9,74	3,51	1,44	FANELE, IZILDA
2010	1,74	0,78	-0,34	-6,57	8,58	8,51	FAMI
2011	6	6,02	6,31	6,25	8,5	2,4	
2012	0,27	-0,56	-0,83	-0,32	-10,65	-11,7	CHANDA, FUNSO, IRINA
2013	-9,65	-8,66	-8,32	-5,71	9,74	9,95	HARUNA
2014	9,71	10	9,2	9,72	-5,24	-8,61	DELIWE, GUITO, HELLEN
2015	-9,95	-10,6	-11,21	-13,27	9,32	7,61	CHEDZA, FUNDI
2016	5,76	3,92	2,4	-1,83	7,11	8,7	
2017	9,66	9,9	9,8	10,72	1,26	0,29	DINEO
2018	-0,3	-1,1	-0,17	-1,17	-9,67	-5,32	
2019	0,8	0,8	0,8	0,7	0,5	0,5	

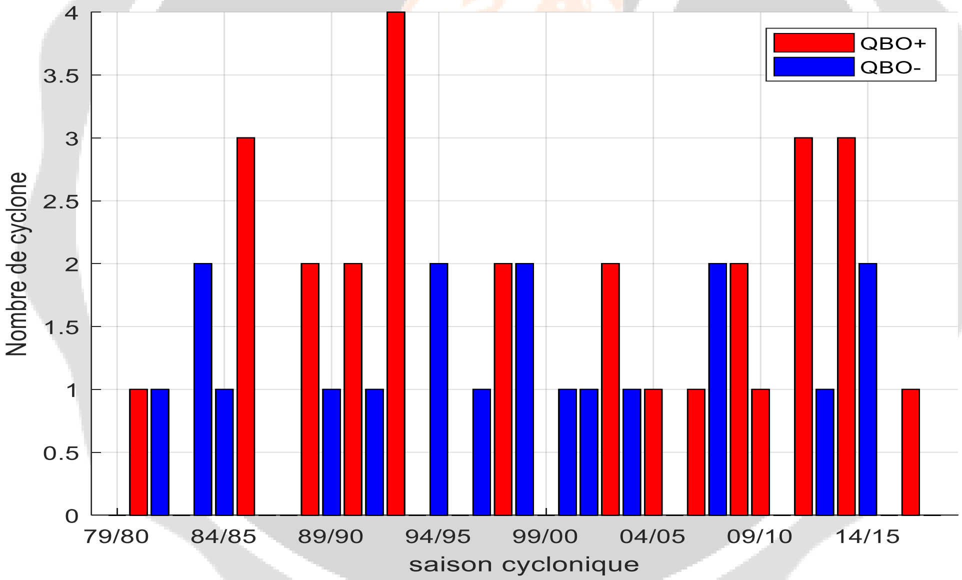

Chart-4 : The number of cyclones following the phases of QBO

3.2 Influence of the ENSO phenomenon on cyclogenesis in the Mozambique Channel

3.2.1 Average of the ONI index or each cyclonic season from 1979 to 2018

Chart 5 represents the average of the ENSO index for each cyclonic season. According to this figure, cyclonic seasons are divided into three different categories: El Niño, La Niña, and neutral. El Niño seasons correspond to seasons where the ONI average is greater than 0.5, such as the seasons 82/83, 86/87, 87/88, 91/92, 94/95, 97/98, 02/03, 04/05, 09/10, 14/15, and 15/16. For La Niña seasons, they correspond to seasons where the ONI average is less than -0.5, such as the seasons 83/84, 84/85, 88/89, 95/96, 98/99, 99/00, 00/01, 05/06, 07/08, 08/09, 10/11, 11/12, and 17/18. Finally, seasons with ONI averages between -0.5 and 0.5 are considered neutral.

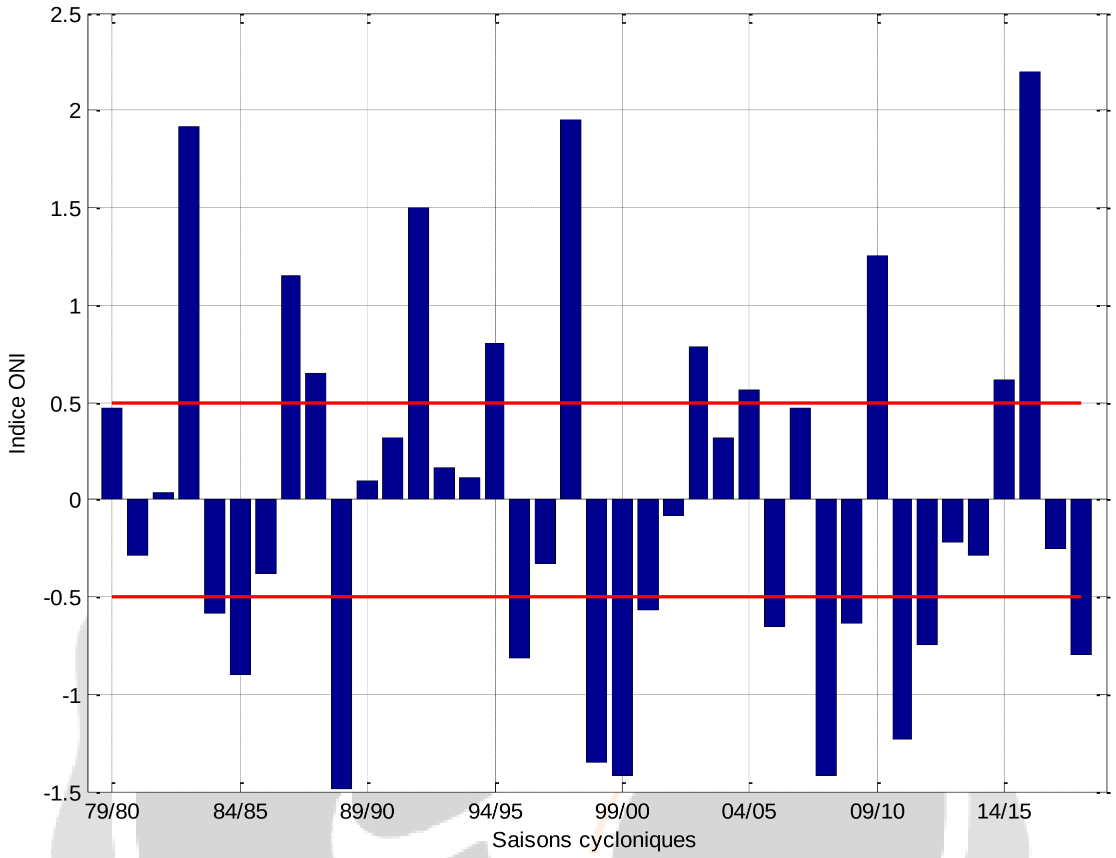

Chart -5: Average of the ENSO index for each cyclonic season from 1979 to 2018

3.2.2 Influence of the ENSO phenomenon on cyclogenesis

The table 2 and chart 6 below provides us with information on the influence of the ENSO phenomenon on cyclogenesis during the cyclonic seasons from 1979 to 2018. We note that there were 13 cyclogenesis events during the El Niño periods, 15 during La Niña periods, and 19 during neutral periods. We can say that the ENSO phenomena do not have much influence on cyclogenesis in the Mozambique Channel, unlike the Caribbean, which is influenced by La Niña [7], and in the western North Pacific basin by El Niño [8][9]. This could be due to the geographical position of the Mozambique Channel, which is too far from the Pacific region where ENSO occurs. It is also important to note that our study area is influenced by other modes of climatic variability, including the Southern Oscillation and the decadal oscillation of the Atlantic, which can have dominant effects on local meteorological ptterns or even counteract the potential effects of ENSO. Additionally, interactions between different atmospheric and oceanic anomalies in the Indian Ocean can neutralize the effects of ENSO.

We also observe that:

- During El Niño periods, 7 of these cyclogenesis events transformed into moderate tropical storms (green filling on the table), 5 into severe tropical storms (light green filling), and 1 into an intense tropical cyclone (yellow filling).

- During La Niña periods, 7 of these cyclogenesis events transformed into moderate tropical storms, 2 into tropical cyclones (orange filling), 5 into severe tropical storms, and 1 into an intense tropical cyclone.

- During neutral periods, 6 cyclogenesis events transformed into moderate tropical storms, 6 into severe tropical storms, 5 into tropical cyclones, 1 into a subtropical depression, and 1 into a very intense tropical cyclone.

Thus, we can say that cyclogenesis tends to occur during neutral periods, with a high probability of transforming into cyclones that are much stronger than during ENSO periods, such as the very intense tropical cyclone HELEN.

Table 2: ONI Index with the different cyclones that formed in the Mozambique Channel from 1979 to 2018.

YEAR	DJF	JFM	FMA	MAM	OND	NDJ	CYCLONE NAMES
1979	0	0,1	0,2	0,3	0,5	0,6	
1980	0,6	0,5	0,3	0,4	0,1	0	EDWIG
1981	-0,3	-0,5	-0,5	-0,4	-0,2	-0,1	
1982	0	0,1	0,2	0,5	2,2	2,2	20S_1982
1983	2,2	1,9	1,5	1,3	-1	-0,9	
1984	-0,6	-0,4	-0,3	-0,4	-0,9	-1,1	CABOTO, IMBOA
1985	-1	-0,8	-0,8	-0,8	-0,3	-0,4	FELIKSA, ALIFREDY
1986	-0,5	-0,5	-0,3	-0,2	1,1	1,2	BEROBIA, GISTA
1987	1,2	1,2	1,1	0,9	1,3	1,1	
1988	0,8	0,5	0,1	-0,3	-1,8	-1,8	
1989	-1,7	-1,4	-1,1	-0,8	-0,2	-0,1	CALASANJY, IANA
1990	0,1	0,2	0,3	0,3	0,4	0,4	HANTA
1991	0,4	0,3	0,2	0,3	1,2	1,5	CYNTHIA, DEBRA
1992	1,7	1,6	1,5	1,3	-0,3	-0,1	ELIZABETHA, C3_1992
1993	0,1	0,3	0,5	0,7	0	0,1	DESSILIA, GRACIA, IONIA
1994	0,1	0,1	0,2	0,3	1	1,1	
1995	1	0,7	0,5	0,3	-1	-1	FODAH, JOSTA
1996	-0,9	-0,8	-0,6	-0,4	-0,4	-0,5	
1997	-0,5	-0,4	-0,1	0,3	2,4	2,4	LISETTE
1998	2,2	1,9	1,4	1	-1,5	-1,6	13S_1998, BELTANE
1999	-1,5	-1,3	-1,1	-1	-1,5	-1,7	ALDA, 21S_1999
2000	-1,7	-1,4	-1,1	-0,8	-0,7	-0,7	
2001	-0,7	-0,5	-0,4	-0,3	-0,3	-0,3	DERA, CYPRIEN
2002	-0,1	0	0,1	0,2	1,3	1,1	DELFINA
2003	0,9	0,6	0,4	0	0,4	0,4	JAPHET
2004	0,4	0,3	0,2	0,2	0,7	0,7	ELITA
2005	0,6	0,6	0,4	0,4	-0,6	-0,8	FELAPI
2006	-0,8	-0,7	-0,5	-0,3	0,9	0,9	ANITA
2007	0,7	0,3	0	-0,2	-1,5	-1,6	ELNUS
2008	-1,6	-1,4	-1,2	-0,9	-0,6	-0,7	FAME
2009	-0,8	-0,7	-0,5	-0,2	1,3	1,6	FANELE, IZILDA
2010	1,5	1,3	0,9	0,4	-1,7	-1,6	FAMI
2011	-1,4	-1,1	-0,8	-0,6	-1,1	-1	

2012	**-0,8**	**-0,6**	**-0,5**	**-0,4**	**0**	**-0,2**	CHANDA, FUNSO, IRINA
2013	**-0,4**	**-0,3**	**-0,2**	**-0,2**	**-0,2**	**-0,3**	HARUNA
2014	**-0,4**	**-0,4**	**-0,2**	**0,1**	**0,6**	**0,7**	DELIWE, GUITO, HELLEN
2015	**0,6**	**0,6**	**0,6**	**0,8**	**2,5**	**2,6**	CHEDZA, FUNDI
2016	**2,5**	**2,2**	**1,7**	**1**	**-0,7**	**-0,6**	
2017	**-0,3**	**-0,1**	**0,1**	**0,3**	**-0,9**	**-1**	DINEO
2018	**-0,9**	**-0,8**	**-0,6**	**-0,4**	**0,9**	**0,8**	
2019	**0,8**	**0,8**	**0,8**	**0,7**	**0,5**	**0,5**	

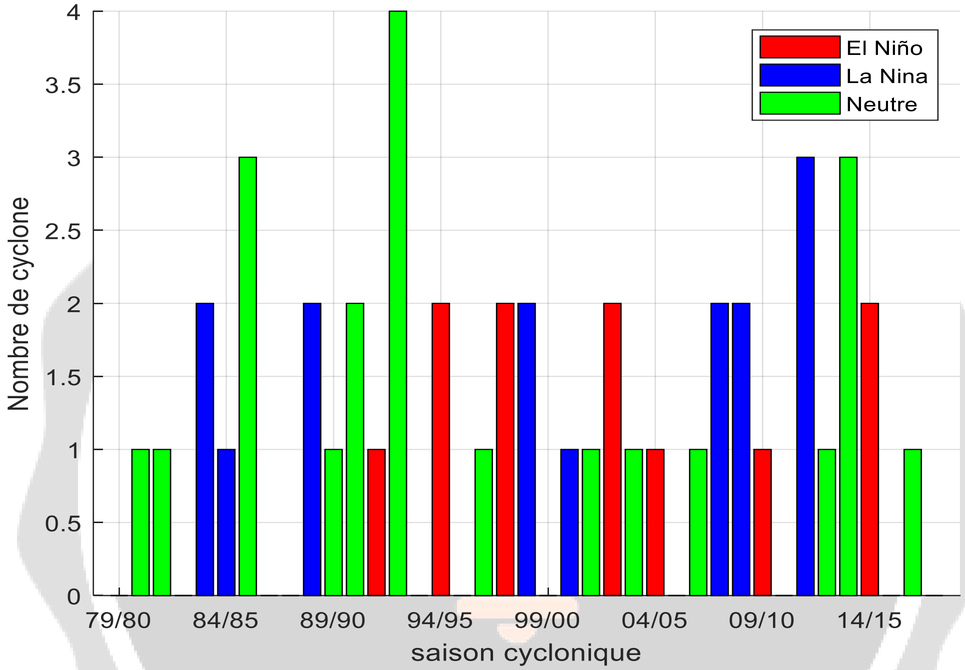

Chart-6 : The number of cyclones during El Niño, La Niña, and Neutral periods

4. CONCLUSION

In conclusion, this study has highlighted the importance of geographical location and climatic phenomena such as QBO and ENSO in cyclone genesis in the Mozambique Channel. The results have shown that the west phase of QBO favors cyclone formation in this region, while the impact of ENSO appears to be less significant compared to the Caribbean. Furthermore, the interaction between different climatic phenomena in the Indian Ocean can also moderate the effects of ENSO on cyclone genesis.

By examining data on El Niño, La Niña, and neutral periods, we have found that cyclone genesis tends to occur more frequently during neutral periods, with an increased probability of transforming into high-intensity cyclones. This underscores the importance of considering multiple climatic factors when assessing cyclone risks in the Mozambique Channel.

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