

Tropical cyclone meteorological extreme events and their large impacts in Mozambique during the period 1926 to 2021

Eventos meteorológicos extremos de tipo ciclone tropical e seus grandes impactos em Moçambique, no período de 1926 a 2021

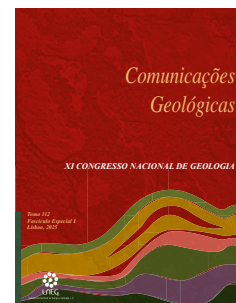
H. V. Nganhane^{1,2*}, A. O. Tavares², P. P. Santos³, A. Fernández-Sánchez⁴

DOI: <https://doi.org/10.34637/8v2y-0q77>

Recebido em 15/07/2023 / Aceite em 26/02/2024

Publicado online em abril de 2025

© 2025 LNEG – Laboratório Nacional de Energia e Geologia IP



Artigo original
Original article

Abstract: The monitoring and prediction of tropical cyclones in Mozambique rely on short databases that sometimes lead to inadequate interpretations due to the lack of precision in equipment and limited human resources. Misinterpretations are also related to the notoriously unstable climatic conditions in the oceanic domain, especially in the Mozambique Channel region, particularly in recent years. It is essential to have a better understanding of the history of these events, as Mozambique has been frequently devastated by tropical cyclones. In this paper, we present our contribution to reconstructing the historical record of these events, their human and material impacts on Mozambican territory from 1926 to 2021. In this interval, 33 tropical cyclones were highly destructive, causing severe human, material and environmental impacts. The research has shown that extreme meteorological events of the tropical cyclone type cause greater human, material and infrastructure damage, mainly because of their duration after landfall and because they are associated with heavy rainfall after energy dissipation.

Keywords: Tropical cyclones, Mozambique, database, risk management

Resumo: A monitorização e previsão dos ciclones tropicais em Moçambique baseiam-se em bases de dados curtas que, por vezes, conduzem a interpretações deficientes devido à falta de precisão dos equipamentos e de recursos humanos. As interpretações erróneas estão também relacionadas com as condições climáticas reconhecidamente instáveis no domínio oceânico e principalmente na região do canal de Moçambique, sobretudo nos últimos anos. É necessário conhecer melhor a história destes eventos, uma vez que Moçambique tem sido frequentemente devastado por ciclones tropicais. Neste trabalho procurou-se construir o histórico destas ocorrências, os seus impactos humanos e materiais no território moçambicano, no período de 1926 a 2021. Neste intervalo, 33 ciclones tropicais foram bastante devastadores e tiveram graves impactos humanos, materiais e ambientais. A pesquisa mostrou que os inventos extremos meteorológicos de tipo ciclone tropical causam maior danos humanos, materiais e nas infraestruturas, principalmente pela sua duração no conteúdo depois do landfall e por estarem associados a grandes precipitações de chuvas depois da dissipação energética.

Palavras-chave: Ciclones tropicais, Moçambique, base de dados, gestão de risco

⁴Department of Geography, Complutense University of Madrid, Calle Profesor Aranguren s/n. 28040, Madrid, Spain

* Corresponding author / Autor correspondente: nganhanehelio@gmail.com

1. Introduction

Most coastal regions in the world have seen an increase in extreme hydro-meteorological energy processes, along with an increase of communities' exposure and vulnerability (Garrote *et al.*, 2018). Mozambique is no exception, with the additional of having an extensive coastline of 2770 kilometres and 60% of the population living in the coastal districts (Maputo, Gaza, Inhambane, Sofala, Zambézia, Nampula and Cabo Delgado provinces), exposed to extreme coastal events associated with high-energy processes that often generate disasters.

While the majority of tropical cyclones generated in the Mozambique Channel during the cyclone season make landfall in Mozambican territory, research predominantly focuses on Madagascar as the most vulnerable country. Existing research delves into the trajectories and the economic and social impacts of these cyclones, with minimal attention to Mozambique (Matyas and Silva, 2013; Matyas, 2014). Tropical cyclones, floods and droughts are the most significant hydrometeorological processes affecting Mozambique, with significant human and economic damage for the period 2017 to 2021. Tropical cyclones are characterized by three hazardous processes – winds, rain, and waves – that can result in material damage and loss of life (Garrison, 2009).

In Mozambique, despite the material damage and loss of life caused by tropical cyclones due to the powerful impact of strong winds, the primary challenge arises from floods triggered by the substantial rainfall they induce. Even after the cyclone centers have dissipated, intense precipitation persists, frequently exceeding 2.5 centimeters per hour (Mavume *et al.*, 2010, 2021). This excessive precipitation overwhelms both natural and artificial water drainage systems. The presented research was conducted with the aim of reconstructing the historical record of tropical cyclones that have made landfall in Mozambique and, consequently, understanding their impacts in order to contribute to more efficient spatial planning, as well as to address the impacts' social and economic driving forces, aiming the reduction in disaster risk.

The earliest available data pertains to the impact of the tropical

¹ Faculty of Exact and Technological Science, Púnguè University, Chimoio City, Manica Province, Mozambique.

² Department of Earth Sciences, Faculty of Sciences and Technology, Centre for Social Studies, University of Coimbra, Rua Silvío Lima, Univ. Coimbra - Pólo II, 3030-790 Coimbra, Portugal.

³ Centre for Geographical Studies, Institute of Geography and Spatial Planning (IGOT), Associated Laboratory TERRA, University of Lisbon, Lisbon, Portugal.

cyclone in 1926. Despite the absence of wind intensity information for this event in the Meteo-France or NOAA databases, our research designated this year as the initial point for historical reconstruction. It was also possible to find damage and impacts from the severe tropical system of 1936 in our database, but it was not possible to obtain its trajectory from the NOAA-IBTRACS databases (Knapp *et al.*, 2018).

2. Meteorological setting

Mozambique has a territory of 801,000 km² of continental surface that is more susceptible to extreme hydroclimatic events such as droughts, floods and tropical cyclones, with a tendency to increase due to climate change (Araneda-Cabrera *et al.*, 2021; Mavume *et al.*, 2021). It has two annual seasons: the rainy season (November to March, with an average of 80% rainfall) and the dry season (May to September, with an average of 20% rainfall). In La Niña years, rainfall is even higher than normal. The average annual temperature in Mozambique ranges from 23 °C to 25 °C, which varies greatly according to the topography. However, the coastal regions in the centre and north are the warmest (Cabrera *et al.*, 2021, 2022).

The tropical cyclones in Mozambique emerge in the South West Indian Ocean (SWIO) within the central sector of basin VI (Figura 1), occurring between the months of October and April (Lin *et al.*, 2013; Malan *et al.*, 2013; Mavume *et al.*, 2009), with the highest magnitudes detected between January and March. Each year, an average of 10 to 12 tropical systems forms in the SWIO region (Leroux *et al.*, 2018; Manhique *et al.*, 2021; Mavume *et al.*, 2009), but not all of them reach the continental part of Mozambique.

The occurrence of cyclonic activity in ocean basin VI is contingent upon broader environmental conditions that undergo shifts due to diverse oscillatory atmospheric-ocean phenomena (Bie, 2022; Mavume *et al.*, 2009, 2010). Examples of such phenomena include El Niño, impacting climate internal variability and exerting a primary influence on cyclonic activity genesis to the east of the 75° meridian, and La Niña, associated with a higher concentration of genesis occurrences to the west of the same meridian (Ho *et al.*, 2006; Mavume *et al.*, 2021). Monitoring and early warning of cyclone activity for Mozambique is coordinated by Meteo-France (RSMC La Réunion), which is responsible for the basin VI committee, providing information to the Mozambique National Meteorological Institute (INAM), as shown in the division of Tropical Cyclone basins in figure 1.

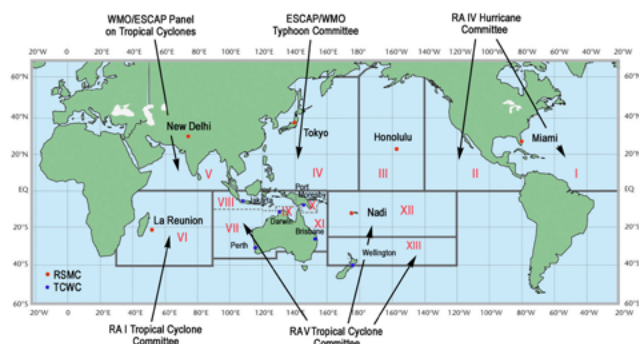


Figure 1. Regional division of tropical cyclone bodies by monitoring committees, source: NHC.NOAA (2023).

Figura 1. Divisão dos comités de monitorização dos ciclones tropicais, fonte: NHC. NOAA (2023).

3. Material and methods

The Meteo-france LR-RSMC(LRSMC,2023) database, in conjunction with the NOAA database, was employed via the IBTRACS project (Knapp *et al.*, 2018) as detailed in the article by Knapp *et al.* (2018). This utilization aimed to assess trajectories, landfall dates, duration on the mainland, and wind speeds. The methodology involved the use of satellite data, as illustrated with the example of Tropical Cyclone Eloisa in 2021.

In linking tropical cyclones to human and social impacts, we utilized a database exclusive to Mozambique. This database is currently under construction, employing hemerographic data and drawing inspiration from the methodologies outlined by Du *et al.* (2015), Jiménez *et al.* (2012), Santos *et al.* (2014) and Zêzere *et al.* (2014) and applied to different contexts and processes. All the methodological steps used to carry out this work are summarised in figure 2.

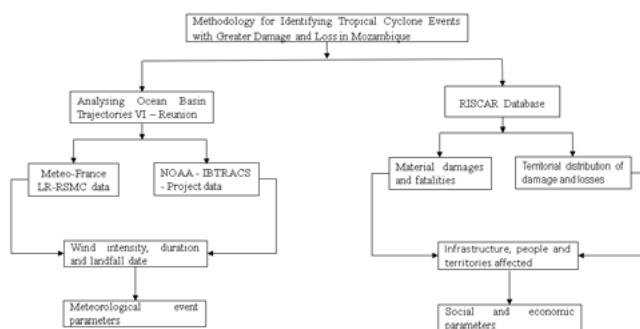


Figure 2. Methodological flowchart used to carry out the research.

Figura 2. Fluxograma metodológico utilizado para a realização da investigação.

4. Results and Discussion

Hereafter, we present a synthesis of the main impacts and characteristics of the Tropical Cyclones that have caused the greatest human losses and material damages on the country’s social and economic systems, from 1926 to 2021. The disasters associated with TC in Mozambique are historical, although not all are well-documented and reported. These processes are the second cause of loss of life compared to other natural hydro-meteorological processes in the last 15 years (Baez *et al.*, 2020; Manuel *et al.*, 2021).

4.1. Impact of tropical cyclones on Mozambique

From 1926 to 2021, the consulted sources allowed to identify 61 TCs that hit Mozambique with considerable impacts. Of these, 34 were of greater magnitude and had greater impacts (Figura 3). Since 1992, onwards there has been a greater frequency of tropical cyclones with more devastating characteristics. The most catastrophic in this series were the cyclones of 1999/2000 (CT Eline and CT Hudah), 2002/03 (CT Japhet), 2007/08 (CT Jokwe), 2011/12 (CT Dando), 2016/17 (CT Dineo) and, recently, in 2018/19 (CT Idai and Kenneth) and 2020/21 (CT Eloise).

TC Eline and TC Hudah caused 750 fatalities in southern and central Mozambique, accounting infrastructure losses estimated at 2.3 billion US dollars (Chang-Seng and Jury, 2010). In 2017, TC Dineo affected the province of Inhambane and part of Sofala, destroying 33.712 homes and 72 health centres, affecting 550.959 people. Very recently, TC Idai and Kenneth caused the fatality of 745 persons and infrastructure losses estimated at 2.1 billion US dollars (Devi, 2019; Emerton *et al.*, 2020).

Several researchers have pointed out that the meteorological effects

of increased atmospheric instability associated with warming ocean waters, conducting to an increase in the frequency and magnitude of extreme cyclones (Adams and Heidarzadeh, 2023). The latest tropical cyclones (TC) in Mozambique confirm this trend, both in terms of the number of tropical cyclones that have made landfall in Mozambique with some impact and the most destructive ones (Figura 3).

The provinces with the highest number of tropical cyclones and, consequently, most affected throughout this period were the provinces of Sofala, Inhambane and Zambézia. The center of the country has the highest number of occurrences and is the most affected region, according to Figure 4.

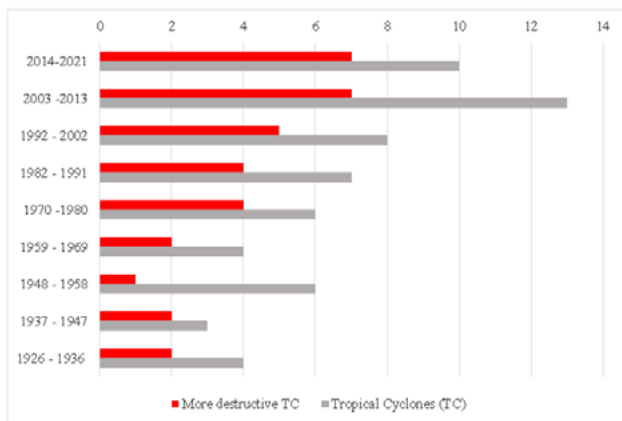


Figure 3. Evolution of tropical cyclones that have affected Mozambique: 1926 – 2021.
 Figura 3. Evolução dos ciclones tropicais que afetaram Moçambique: 1926 – 2021.

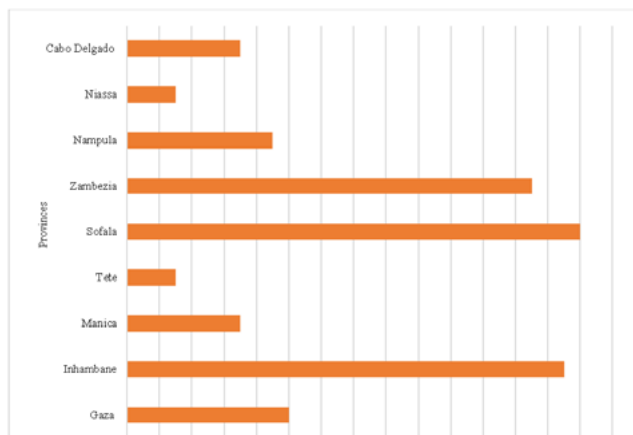


Figure 4. Distribution of events by province, sequenced from the north (Cabo Delgado) to the south (Maputo) of Mozambique.
 Figura 4. Distribuição dos eventos por província, sequenciados do norte (Cabo Delgado) para o sul (Maputo) de Moçambique.

In summary, in the 1926-2021 period, tropical cyclones in Mozambique caused 2.222 human fatalities, destroyed 1.051.581 homes, 1.379 hospital centres, 10.100 schools and contributed to a series of other damages to agriculture and the environment.

4.2. Characteristics of tropical cyclones versus damage and impacts

In order to understand the impacts and damage depending on the characteristics of the physical atmospheric processes of tropical

cyclones, we analysed the intensity of the wind speed, the day of the system’s landfall and its duration on the continent. This was motivated by the fact that, in theory, the destructive effects of tropical cyclones come from the natural forcing characteristics, as the wind, rainfall, windshear and the duration of the cyclonic system on the continent (Garrison, 2009).

Among the 33 destructive tropical systems analysed, it was noted that the magnitude of the wind speed alone is strongly explicative of the level of fatalities. As evidenced in Figure 5, TC Nadia (1994), TC Eline (2000), TC Hudah (2000) and TC Idai (2019) are not the only ones with the highest wind speeds, as the ones that caused the most human losses and material damages. The most intense, from a wind speed criterion, were TC Bonita with 250 km/h in 1996, TC Hallen with 241 km/h in 2014, as shown in Figure 5 and Table 1.

Two prevalent features were observed in the cyclones with the greatest destructive impact, likely linked to the extent of their severity. The first is the coincidence of the time of landfall with the time the system reaches its maximum speed, as was the case with TC Idai (2019) and TC Eline (2000). The second is the duration of the landfall, as after the system dissipates it still causes torrential rain, causing urban and river flooding. There are evidently additional non-physical or meteorological factors influencing the extent of severity in the impacts and damage resulting from tropical cyclones during the analyzed period, like the housing infrastructure, deficiencies in emergency management, and the absence of sanitation facilities in temporary shelters.

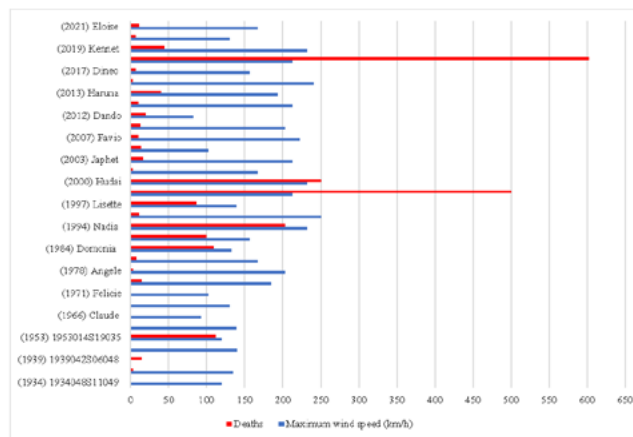


Figure 5. Maximum wind speed intensity (Km/h) of Tropical cyclones and fatalities.
 Figura 5. Intensidade máxima da velocidade do vento (Km/h) dos ciclones tropicais e fatalidades.

The disasters associated with TC in Mozambique are historical, although not all are well-documented and reported. These processes are the second cause of loss of life compared to other natural hydro-meteorological processes in the last 15 years (Baez *et al.*, 2020; Manuel *et al.*, 2021).

The increase in the devastating impact of tropical cyclones hitting Mozambican territory is also implicitly associated with social and demographic causes. Between 1960 and 2021 the resident population increased from 7.18 to 32.08 million inhabitants (INE, 2021). This demographic increase intensifies construction in hazardous locations, aggravated by the use of precarious materials. Several authors who analyze the sociology of risk explain that the increase in impacts is not always proportional to the physical parameters of the hazard, but rather to social and anthropogenic factors (Mattedi, 2017; Mendes, 2015).

Table 1. Data from most destructive tropical cyclones in Mozambique.

Tabela 1. Dados dos ciclones tropicais mais destrutivos em Moçambique.

Year	Name of Tropical Cyclone	IVV (km/h)	Day of IVV	Duration (dias)	Day of landfall	Fatalities	Number of affected residences	Health centres	Number of affected schools
1934	1934048S11049 (Identificador)	120	18.02	3	20.02	unspecified	unspecified	unspecified	unspecified
1934	1934048S1158 (Identificador)	135	20.03	2	18.03	4	unspecified	unspecified	unspecified
1939	1939042S06048 (ID)			3	15.02	15	unspecified	unspecified	unspecified
1944	1944016S12043 (ID)	140	17.01	3	17.01	indefinido	unspecified	unspecified	unspecified
1953	1953014S19035	120	20.01	1	15.01	112	unspecified	unspecified	unspecified
1962	Daisy	139	20.01	1	23.01	indefinido	unspecified	unspecified	unspecified
1966	Claude	93	26.12	2	3.01	indefinido	unspecified	unspecified	unspecified
1968	Flossie	130	10.01	1	12.01	indefinido	unspecified	unspecified	unspecified
1971	Felicie	102	26.01	1	27.01	indefinido	unspecified	unspecified	unspecified
1976	Danae (Terry)	185	20.01	2	27.01	15	unspecified	unspecified	unspecified
1978	Angele	204	24.12	3	18.12	4	unspecified	unspecified	unspecified
1981	Benedicte	167	23.12	1	24.12	8	unspecified	unspecified	unspecified
1984	DOMONIA	133	26.01	2	28.01	109	3200	4	90
1988	Filao	157	1.03	2	1.03	100	36349	unspecified	unspecified
1994	Nadia	232	22.03	4	24.03	204	146839	unspecified	unspecified
1996	Bonita	250	9.01	3	13.01	11	400	4	200
1997	Lisette	139	1.03	3	25.02/02.03	87	17000	1	5
2000	Eline	213	22.02	2	22.02	500	300000	90	unspecified
2000	Hudai	232	1.03	2	8.03	250	90000	85	unspecified
2001	Dera	167	12.03	1	6.03	3	345	unspecified	unspecified
2003	Japhet	213	1.03	3	2.03	17	25000	7	500
2003	Delfina	102	31.03	5	31.03	14	4570	unspecified	6
2007	Favio	222	21.02	2	22.02	10	32157	918	264
2008	Jokwe	204	8.03	1	8.03	13	40339	15	944
2012	Dando	83	16.01	2	16.01	20	2403	12	466
2012	Funso	213	24.01	1	1.02	10	4104	8	309
2013	Haruna	194	21.02	2	16.02	40	5230	5	2202
2014	Hellen	241	30.03	1	22.03	3	1929	unspecified	unspecified
2017	Dineo	157	15.02	2	15.02	7	33712	72	1692
2019	IDAI	213	11.03	7	4.03/15.03	603	239000	45	3100
2019	Kennet	232	25.04	3	25.04	45	40106	16	90
2021	Chalane	130	30.12	2	30.12	7	2595	11	82
2021	Eloise	167	23.01	1	23.01	11	26303	86	150

5. Conclusions

Simultaneously to an increase in exposure, it is important to emphasise the finding that the frequency of tropical systems have also increased significantly, combining in more severe damage and impacts reported in the database.

The fact that when landfall coincides with maximum wind speed intensity, the severity of the damage increases, is something that needs to be assimilated and mastered by the entities that monitor tropical cyclonic systems and better communicated to the communities.

Tropical cyclones affect the whole of Mozambique, causing human and material damages, but the centre of the country has the greatest exposure, vulnerability and consequently the highest risk of these extreme weather events, particularly the provinces of Sofala and Zambézia.

Risk management actions need to be strengthened, together with local committees, in order to reduce human and material losses through collective efforts with communities.

Acknowledgments

The authors would like to acknowledge the Humact -Erasmus+ KA2 project for the opportunity to collect data during the project activities and for the exchange of experience between various stakeholders (government and NGOs) and students involved in climate change and displacement from Mozambique, Portugal, Cape Verde and Greece. For their rich contributions and corrections, the authors would also like to acknowledge Filipa Naughton, Luís Vitor Duarte and an anonymous referee.

References

- Adams, K., Heidarzadeh, M., 2023. Extratropical cyclone damage to the seawall in Dawlish, UK: eyewitness accounts, sea level analysis and numerical modelling. *Natural Hazards*, **116**: 637-662.
- Afonso, R. S., Marques, J. M., Ferrara, M., 1998. A Evolução Geológica de Moçambique. Lisboa: *Instituto de Investigação Científica Tropical*.
- Alexander, D. David E., 2016. How to write an emergency plan. Dunedin Academic Press.
- Baez, J. E., Caruso, G., Niu, C., 2020. Extreme Weather and Poverty Risk: Evidence from Multiple Shocks in Mozambique. *Economics of Disasters and Climate Change*, **4**(1): 103-127.
- Bié, A., 2022. Ciclones tropicais no Sudoeste do Oceano Índico: Representação em reanálises atmosféricas e experimentos de sensibilidade com modelo regional acoplado. *Instituto de Astronomia, Geofísica e Ciências Atmosféricas*.
- Cabrera, A. R., Bermúdez, M., Puertas, J., 2021. Revealing the spatio-temporal characteristics of drought in Mozambique and their relationship with large-scale climate variability. *Journal of Hydrology: Regional Studies*, **38**: 1-16.
- Cabrera, A. R., Bermúdez, M., Puertas, J., Penas, V., 2022. Comparación de índices de sequía univariados y multivariados basados en datos satelitales para la monitorización de sequías hidrológicas en el ARA Sur, Mozambique. *Ingeniería Del Agua*, **26**(3): 217-229.
- Chang-Seng, D. S., Jury, M. R., 2010. Tropical cyclones in the SW Indian Ocean. Part 2: Structure and impacts at the event scale. *Meteorology and Atmospheric Physics*, **106**(3-4): 163-178.
- Devi, S., 2019. Cyclone Idai: 1 month later, devastation persists. World Report. *The Lancet* **393**: 1585.
- Du, S., Gu, H., Wen, J., Chen, K., Van Rompaey, A., 2015. Detecting flood variations in shanghai over 1949-2009 with Mann-Kendall tests and a newspaper-based database. *Water*, **7**(5): 1808-1824.
- Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Tittley, H., Magnusson, L., Pappenberger, F., Klingaman, N., Stephens, E., 2020. Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, **50**(10181): 1-30.
- Garrison, T., 2009. Essentials of Oceanography. Brooks/Cole.
- Garrote, J., Díaz-Álvarez, A., Nganhane, H. V., Garzón Heydt, G., 2018. The severe 2013-14 winter storms in the historical evolution of Cantabrian (Northern Spain) beach-dune systems. *Geosciences*, **8**(49): 1-16.
- Ho, C.-H., Kim, J.-H., Jeong, J.-H., Kim, H.-S., Chen, D., Ho, C., Kim, J.-H., Jeong, J.-H., Kim, H.-S., Chen, D., 2006. Variation of tropical cyclone activity in the South Indian Ocean: El Niño-Southern Oscillation and Madden-Julian Oscillation effects. *Journal of Geophysical Research: Atmospheres*, **111**(22101): 1-9.
- INE., 2021. Perfil de Indicadores Sócio-demográficos da Província de Sofala - 2021. www.ine.gov.mz
- Jiménez, J. A., Sancho-García, A., Bosom, E., Valdemoro, H. I., Guillén, J., 2012. Storm-induced damages along the Catalan coast (NW Mediterranean) during the period 1958-2008. *Geomorphology*, **15**(143-144): 24-33.
- Knapp, K. R., Diamond H. J., Kossin J. P., Kruk, M. C., Schreck, C. J., 2018. International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4. NOAA National Centers for Environmental Information, 10.
- Leroux, M. D., Meister, J., Mekies, D., Dorla, A. L., Caroff, P., 2018. A climatology of southwest Indian Ocean tropical systems: Their number, tracks, impacts, sizes, empirical maximum potential intensity, and intensity changes. *Journal of Applied Meteorology and Climatology*, **57**(4): 1021-1041.
- Leipper, D. F., Volgenau, D., 1972. Hurricane heat potential of the Gulf of Mexico. *J. Phys. Oceanogr.*, **2**(3): 218-224.
- Lin, I. I., Goni, G. J., Knaff, J. A., Forbes, C., Ali, M. M., 2013. Ocean heat content for tropical cyclone intensity forecasting and its impact on storm surge. *Natural Hazards*, **66**: 1481-1500.
- Mattedi, M., 2017. Dilemas e perspectivas da abordagem sociológica dos desastres naturais. *Tempo Social*, **29**: 261-285.
- Malan, N., Reason, C. J. C., Loveday, B. R., 2013. Variability in tropical cyclone heat potential over the Southwest Indian Ocean. *Journal of Geophysical Research: Oceans*, **118**(12): 6734-6746.
- Manhique, A. J., Guirruogo, I. A., Nhantumbo, B. J., Mavume, A. F., 2021. Seasonal to interannual variability of vertical wind shear and its relationship with tropical cyclogenesis in the mozambique channel. *Atmosphere*, **12**(6): 1-15.
- Manuel, L., Chiziane, O., Mandhlate, G., Hartley, F., Tostão, E., 2021. Impact of climate change on the agriculture sector and household welfare in Mozambique: an analysis based on a dynamic computable general equilibrium model. *Climatic Change*, **167**(1-2): 1-18.
- Matyas, C. J., 2014. Tropical cyclone formation and motion in the Mozambique Channel. *International Journal of Climatology*, **35**(3): 375-390.
- Matyas, C. J., Silva, J. A., 2013. Extreme weather and economic well-being in rural Mozambique. *Natural Hazards*, **66**(1): 31-49.
- Mavume, A. F., Banze, B. E., Macie, O. A., Queface, A. J., 2021. Analysis of climate change projections for Mozambique under the representative concentration pathways. *Atmosphere*, **12**(5): 588.
- Mavume, A. F., Rydberg, L., Rouault, M., Lutjeharms, J. R., 2009. Climatology and landfall of tropical cyclones in the south-west Indian Ocean. *Western Indian Ocean Journal of Marine Science*, **8**(1): 15-36.
- Mendes, J. M., 2015. Sociologia do risco: uma breve introdução e algumas lições. *Imprensa da Universidade de Coimbra/Coimbra University Pres.*
- Meteo France, 2023. Centre des Cyclones Tropicaux de La Reunion – RSMC La Reunion Archives. http://www.meteo.fr/temps/domtom/La_Reunion/webcmrs9.0/anglais/index.html
- Santos, P. P. dos, Tavares, A. O., Zêzere, J. L., 2014. Risk analysis for local management from hydro-geomorphologic disaster databases. *Environmental Science & Policy*, **40**: 85-100.
- Tavares, A. O., 2018. Modelos de Gestão dos Riscos e as Políticas Públicas. In: Lourenço, L., Amaro, A. (Eds.), *Riscos e Crises da Teoria a Plena Manifestação*. Imprensa da Universidade de Coimbra, 179 - 205.
- Wehn, U., Rusca, M., Evers, J., Lanfranchi, V., 2015. Participation in flood risk management and the potential of citizen observatories: A governance analysis. *Environmental Science and Policy*, **48**: 225-236.
- Zêzere, J. L., Pereira, S., Tavares, A. O., Bateira, C., Trigo, R. M., Quaresma, I., Santos, P. P., Santos, M., Verde, J., 2014. DISASTER: a GIS database on hydro-geomorphologic disasters in Portugal. *Natural Hazards*, **72**: 503-532.