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Research Article

Analysis of the 16-20 February 2025 Damaging Heavy Rainfall in Botswana

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Abstract: Heavy rainfall that occurred from 16-20 February 2025 over most of Botswana caused, for example, flash flooding, fatalities, and widespread displacement, with the most severe impacts in the Gaborone-Mochudi region in the southeastern parts of the country. The drivers of this event are poorly understood; hence, this study analyses the rainfall characteristics using CHIRPS and station data. It also analyses related atmospheric circulation anomalies using ERA5 reanalysis. Results show that the event produced rainfall anomalies that exceeded two standard deviations, making it one of the three most intense events in the 1981-2025 period. ENSO had a limited role in driving the event because it showed weak correlations with rainfall and La Niña conditions were weak. The event was mainly driven by a weakened Botswana High, an intensified Angola Low, enhanced mid-level uplift, and increased moisture transport from adjacent tropical South East Atlantic and South West Indian Oceans. These findings show that it is not only ENSO forcing that triggers extreme rainfall events in the region, but complex interactions between regional circulation systems and oceanic moisture sources can also play a major role. There is therefore a need to design or upgrade infrastructure for higher rainfall extremes. There is also a need for early warning systems to incorporate regional circulation systems to improve forecasting skill.

Keywords: Angola Low, Botswana High, ENSO, Heavy Rainfall

Introduction

Extreme rainfall events (Moses et al., 2023a; Mokone, 2025) and severe drought (Blamey et al., 2018; Moses et al., 2023b; 2024) are common in southern Africa, including Botswana, and have profound effects on life and property. For example, floods that occurred in southeastern Africa in 2024 were induced by tropical cyclone Chido (Jiang et al., 2026), and those that occurred in 2025 were induced by tropical cyclones Jude and Dikeledi (Joshua et al., 2025), resulting in loss of life and property. Due to climate change, the intensity and frequency of extreme rainfall events in the region are increasing (IPCC, 2013; 2014; 2021; Hambira et al., 2024); hence, there is a need to better understand them.

Recently, the Ministry of Child Welfare and Basic Education in Botswana temporarily closed schools from 20-24 February 2025 due to heavy rainfall that occurred between 16-20 February 2025 (Xinhua, 2025). The heavy rainfall caused flash flooding over most parts of the country, which cut off some roads, killed nine people and displaced over five thousand (UNICEF, 2025; World Weather Attribution, 2025; Xinhua, 2025). The situation was worse in southeastern Botswana, particularly in Gaborone, Mochudi and their surrounding areas (described in Section 2.1). World Weather Attribution (2025) noted that a combination of extreme rainfall and rapid urbanisation increased the flood risk. Weak La Niña conditions prevailed mainly between December 2024 and February 2025 in the tropical Pacific (NASA Earth Observatory, 2025). But weak La Niña conditions may be less impactful compared to La Niña conditions, which often bring above-average rainfall to southern Africa (Hart et al., 2010; 2018; Blamey et al., 2018; Thoithi et al., 2026). There is a need, therefore, to better understand circulation anomaly patterns that may have contributed to the heavy rainfall event.

It is worth noting that although the heavy rainfall damaged some infrastructure, it made an important contribution to the water levels in Botswana's dams, including the Gaborone dam (BOPA, 2025). In 2025, water levels in this dam reached a peak level of 105% on 21 February, which resulted from rainfall accumulation from the preceding days. Previous

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studies also noted that extreme rainfall events can make a significant contribution to water resources (Moses et al., 2023a).

In Botswana and most parts of southern Africa, seasonal rains are highly variable and mainly occur between October and March or April. Most of the rainfall in the region is caused by tropical-extratropical cloud bands (Harrison, 1984; Hart et al., 2010; Macron et al., 2014; De Kock et al., 2022). Moisture at an early stage of the development of these cloud bands is supplied by the Angola Low (Hart et al., 2010; Munday and Washington, 2017; Crétat et al., 2019). Main sources of this moisture include the western tropical Indian Ocean, tropical South East Atlantic Ocean, and the South West Indian Ocean (Reason et al., 2006; Lyon and Mason, 2007; Blamey et al., 2018; Thoithi et al., 2026). The Botswana High, a mid-tropospheric circulation system whose weakening typically enhances rainfall and its strengthening suppresses rainfall (Driver and Reason, 2017; Reason, 2019), is also important in the region.

The region's high rainfall variability is contributed to by factors that include anomalies in Sea Surface Temperatures (SST), commonly expressed through regional climate modes including the Benguela Niño (Rouault et al., 2003; Hansingo and Reason, 2009) and the subtropical South Indian Ocean Dipole (Reason, 2001; Behera and Yamagata, 2001; Hoell et al., 2017), as well as the El Niño-Southern Oscillation (ENSO) in the tropical Pacific Ocean (Lindesay, 1988; Blamey et al., 2018; Moses et al., 2025). Wetter summers tend to occur over some parts of southern Africa during positive SIOD events, whereas during negative SIOD events, it is the opposite (Hansingo and Reason, 2009; Moses et al., 2022). Benguela Niños have been linked with above-normal rainfall, especially in Namibia and Angola (Reason et al., 2006; Reason and Smart, 2015). The main climate mode that causes interannual climate variability in southern Africa is ENSO (Lindesay, 1988; Reason et al., 2006; Maoyi and Abiodun, 2024). These authors found that in most cases, rainfall is suppressed during El Niño events whilst during La Niña events, it is enhanced.

This study analyses the 16- 20 February 2025 heavy rainfall event which occurred over most parts of Botswana. Although this event caused flash flooding, fatalities, widespread displacement, infrastructure damage and school closures (Xinhua, 2025; UNICEF, 2025; World Weather Attribution, 2025), it has not yet received adequate attention. Therefore, this study provides a novel analysis of this extreme event, focusing mainly on circulation anomaly patterns associated with it. Attention is also paid to the Gaborone and Mochudi areas in southeastern Botswana, which experienced the worst flooding impact. The findings of this study are vital for improved resource management.

Materials and Methods

Study Area

While Botswana is the study area, attention was also paid to southeastern parts of the country, particularly Gaborone (the country's capital city), Mochudi, and their surrounding areas, termed the Gaborone-Mochudi-box (Fig. 1). Areas within this box were hardest hit by the flooding caused by the 16- 20 February 2025 heavy rainfall event.

Datasets

In the study area, there is a poor ground-based rain gauge network; hence, the Climate Hazards Infrared Precipitation with Station dataset (CHIRPS) version 2 (Funk et al., 2015) was used for rainfall analysis over the period 1981-2025. CHIRPS, explicitly built by interpolating satellite imagery with robust in-situ station data, spans from 1981 to near-present. This dataset's temporal (daily) and spatial (0.05°) resolutions are high. Previous studies in the region (Du Plessis and Kibii, 2021; Moses et al., 2022) have successfully used CHIRPS data. Available rain gauge data from the Botswana Department of Meteorological Services were also used. CHIRPS data was preferred over other datasets like NASA's Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (IMERG) products (Huffman et al., 2020), which are only available from 2000 and have an inferior spatial resolution of 0.1°.

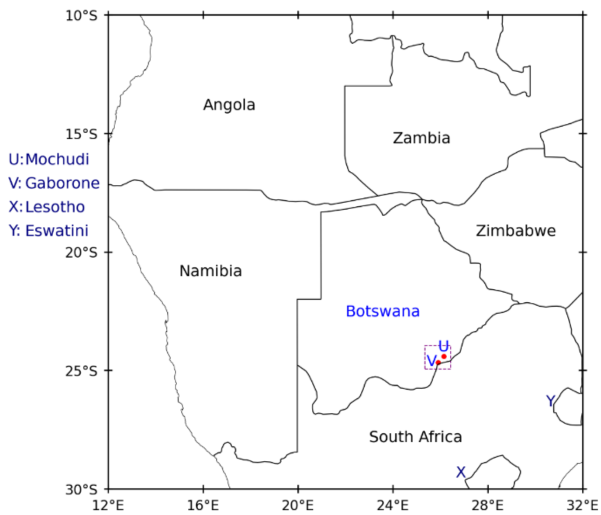

Fig. 1: Map of Botswana in southern Africa. The box over southeastern Botswana contains Gaborone and Mochudi (denoted by "V" and "U", respectively), and their surrounding areas, referred to as the "Gaborone-Mochudi-box" in the text. Areas within this box were hardest hit by flooding on 16-20 February 2025

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Vertical velocity, horizontal wind fields, specific humidity, and geopotential heights at 850 hPa and 500 hPa from ERA5 reanalysis with a spatial resolution of 0.25° (Hersbach et al., 2020) were used to examine circulation anomaly patterns linked to the 16-20 February 2025 heavy rainfall event. It is worth noting that the horizontal ERA5 resolution might be inadequate to explicitly resolve mesoscale systems (e.g., local convection). Therefore, to evaluate the results obtained using this dataset, NCEP/DOE2 reanalysis (Kanamitsu et al., 2002) was utilised. This dataset, with a 2.5° spatial resolution, produced results comparable to those from ERA5 data, hence are not shown.

Other datasets that were used in the analysis of circulation anomaly patterns were the outgoing longwave radiation (Liebmann and Smith, 1996) and the NOAA Optimum Interpolated SST (OISST) version 2. The latter was also used to compute the Benguela Niño index (Moses et al., 2022) and the SIOD index (Reason, 2001; Behera and Yamagata, 2001; Hoell et al., 2017). To analyse ENSO events, the Oceanic Niño Index (ONI) was utilised. This ONI is one of the main indices for monitoring such events.

Methods

CHIRPS data were validated using rain-gauge data obtained from the Botswana Department of Meteorological Services. The validation included visual comparison of the datasets and quantitative metrics, specifically the bias and Root-Mean-Square-Error (RMSE). Previous authors (Jamal et al., 2023) have also used these metrics successfully. It is worth noting that while NASA's Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (Huffman et al., 2020) products provide global precipitation data, practical constraints impact their use for high-precision hydrology, climate, and event-based studies.

Circulation anomaly patterns analysed included the Angola Low, Botswana High, vertical velocity (omega), SST spatial patterns, moisture flux convergence (a scalar quantity), and moisture flux (a vector quantity). Anomalies were computed by subtracting the 16-20 February climatology (1991-2020) of a particular field from the mean for 16-20 February 2025 of that field. Anomaly patterns for the Angola Low, with its core over the region 16°-20°S, 18°-22°E (Florenchie et al., 2004; Munday and Washington, 2017), were assessed by plotting 850 hPa geopotential height anomalies. Negative (positive) anomalies over the core region of this Low indicate that it is stronger (weaker) than normal. Similarly, anomaly patterns in the Botswana High, with its core over the region 19°-23°S, 16°-21°E (Driver and Reason, 2017; Reason, 2019), were analysed by plotting anomalies of the 500 hPa geopotential height. Negative anomalies over the core region of this High indicate that it is weaker than normal, whereas positive anomalies indicate that it is stronger than normal. SST spatial anomalies were plotted to analyse SST anomaly patterns in the oceans adjacent to southern Africa and in the tropical Pacific Ocean. To analyse omega anomaly patterns, 500 hPa omega anomalies were plotted. Positive and negative anomalies of this field indicate downward and upward motions, respectively.

Moisture Flux Convergence (MFC) was computed as Moisture Flux Divergence (MFD) times negative one, as in Moses et al. (2023b). While both MFC and MFD are scalar quantities, the former is directly related to rainfall, hence was plotted because it is easier to interpret (Moses et al., 2023b; 2025). For moisture transport vectors that are converging, the MFC is positive, whereas for those that are diverging, the MFC is negative. Positive MFC is favourable for uplift and rainfall. Moisture flux (a vector quantity) was computed as in Moses et al. (2023b). Anomalies of the moisture flux are vital for tracking the abnormal movement of moisture from the oceans surrounding southern Africa, hence were analysed.

Historical correlations of some of the main climate modes (SIOD, Benguela Niño, ENSO) were computed to quantify relative contributions of each of them to the heavy rainfall event in the Gaborone-Mochudi box (Fig. 1). To do this, the Pearson correlation coefficient was applied using a 95% confidence level. For ENSO correlations, the Oceanic Niño Index, determined as the 3-month running average of NOAA Extended Reconstruction SSTs Version 5 (ERSSTv5) anomalies (with respect to the 1991-2020 baseline) in the Niño 3.4 region (5°S-5°N, 120°W-170°W) (Ashok et al., 2007), was employed. For the event to be classified as an El Niño, those anomalies should be at least + 0.5°C for not less than six months in a row, whereas in the La Niña case, the anomalies should be less than or equal to -0.5°C for at least six months in a row (Webb and Magi, 2022). The Benguela Niño index was calculated by averaging SST anomalies over the area 10°S-20°S and 8°E-14°E. This area is the core region of the Benguela Niño events (Rouault et al., 2003). The SIOD index was calculated as the normalised difference between SST anomalies averaged over the western (37°S-27°S, 55°E-65°E) and eastern (28°S-18°S, 90°E-100°E) poles of the subtropical South Indian Ocean (Behera and Yamagata, 2001; Reason, 2001; Hoell et al., 2017).

Results and Discussion

Combined results and discussion are presented in this section. The focus is on the temporal and spatial rainfall distribution and related circulation anomaly patterns.

Rainfall Spatial and Temporal Distribution

Fig. 2 shows the temporal and spatial distribution of CHIRPS daily rainfall versus station data of at least 50 mm/day over Botswana, for 16-21 February 2025 (6-day

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period). Station data equal to or greater than this threshold are plotted because the study focuses on heavy rainfall that occurred on these dates. This threshold is used by the Botswana Department of Meteorological Services to define heavy rainfall in the country (Moses, 2016). It can be seen from Fig. 2 that although CHIRPS tends to underestimate rainfall, it is generally consistent with station data in terms of rainfall spatial distribution over the country, including the areas worst hit by flooding, i.e., the Gaborone-Mochudi-box (Fig. 1). Over the Gaborone-Mochudi-box, the bias is -3 mm/day, consistent with Fig. 2, which shows that CHIRPS slightly underestimates rainfall. The small root mean square error value of 4 mm/day also shows consistency between CHIRPS and station data. Previous authors (Du Plessis and Kibii, 2021; Moses et al., 2022) similarly found consistency between CHIRPS and station data. It is worth noting that CHIRPS also shows extensive spatial coverage of rainfall of 50 mm/day or more over Botswana's neighbouring countries, particularly Zimbabwe and South Africa on 18-19 February 2025 (Fig. 2c-d). It was beyond the scope of this study to validate CHIRPS data with station data over Botswana's neighbouring countries.

Overall, Fig. 2 shows that heavy rainfall occurred over Botswana from 16-20 February 2025, making this period the focal point of this study. Rainfall that occurred just before (1-15 February) and after (21-28 February) the 16-20 February 2025 period was not heavy (not shown); hence, it was not of interest to analyse further.

Fig. 3a shows climatology of 5-day average rainfall for 16-20 February 1991-2020. In this climatology, the Gaborone-Mochudi-box (Fig. 1) receives mainly 4-8 mm/day, with patches of 8-12 mm/day in certain areas. The country records the highest values of 16-20 mm/day over the extreme northeastern part and the lowest values of 4-8 mm/day over the southwestern part. Previous authors found similar rainfall distribution over the country for the months October to December during the period 1982 to 2015 (Moses et al., 2022), and for the months January to April during the period 1981 to 2021 (Moses et al., 2023a). Fig. 3b plots anomalies of the 5-day average rainfall for 16-20 February 2025 relative to the 1991-2020 climatology. Except for the extreme southwestern part, strongly positive anomalies of rainfall occurred largely across Botswana, including the Gaborone-Mochudi box, consistent with the heavy rainfall which caused flash flooding, infrastructure damage, fatalities and school closures.

Fig. 3c shows a time series of standardised anomalies of 5-day average rainfall for 16-20 February, from 1981 to 2025, averaged over the Gaborone-Mochudi-box. Rainfall anomalies were two standard deviations above average in 2025, consistent with Fig. 3b. Over the 1981-2025 period, the 2025 rainfall anomaly ranked third.

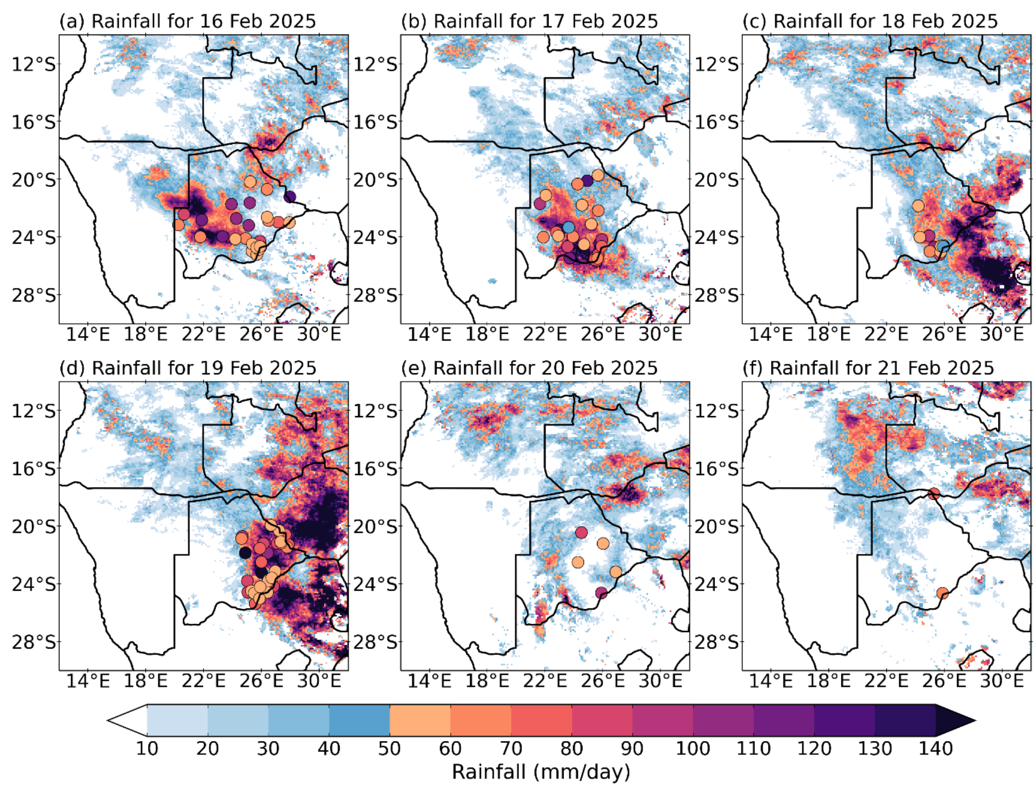

Fig. 2: Daily CHIRPS rainfall (shaded) and daily rain gauge data (circles) of at least 50 mm/day, for 16-21 February 2025 (a-f)

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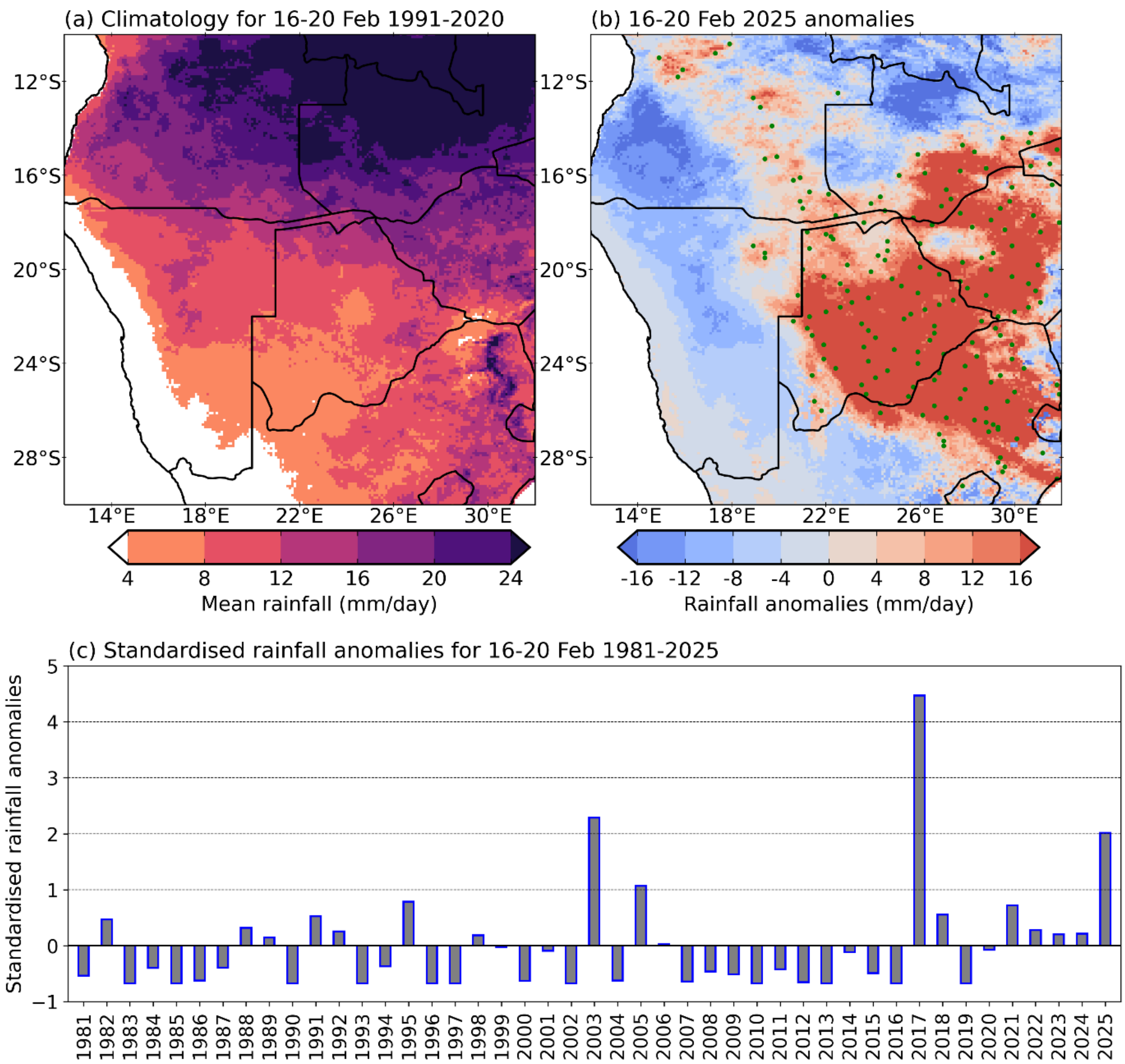

Fig. 3: Five-day (16- 20 February) rainfall: (a) Climatology (1991–2020). (b) 2025 anomalies relative to the climatology in (a). Stippling denotes 95% bootstrap confidence level. (c) Standardised anomalies calculated over the Gaborone-Mochudi-box shown in Fig. 1

The largest and second largest anomalies occurred in 2017 (4.5 standard deviations) and 2003 (2.3 standard deviations), respectively. Previous authors found similar results for the year 2017 over the Okavango Delta region in Botswana (Moses et al., 2023a). This area experienced significantly wetter-than-average conditions (2.5 standard deviations) over the months of January-April, which resulted in substantial damage. While the 2003 and 2017 rainfall anomalies were larger than those for February 2025, the latter caused greater impact because the rain fell heavily within shorter periods (thirty minutes) on each day it occurred rather than being spread over the whole day.

It can be seen from Fig. 3c that the intensity and frequency of heavy rainfall events are increasing over time, consistent with previous studies (IPCC, 2013; 2021; Moses et al., 2023a). Such an increase is associated with climate change. This calls for investment in climate-resilient infrastructure, which is a challenge in developing countries like Botswana due to the high financial costs (Infrastructure for a Climate-Resilient Future (OECD), 2024).

Fig. 4a shows a time series of the ENSO index for February, from 1982 to 2025. The ENSO index was -0.4°C in February 2025, indicating that La Niña conditions were weak, consistent with NASA Earth Observatory (2025). Historical correlation between the rainfall anomalies (Fig. 3c) and the ENSO index (Fig. 4a) was also weak (0.01).

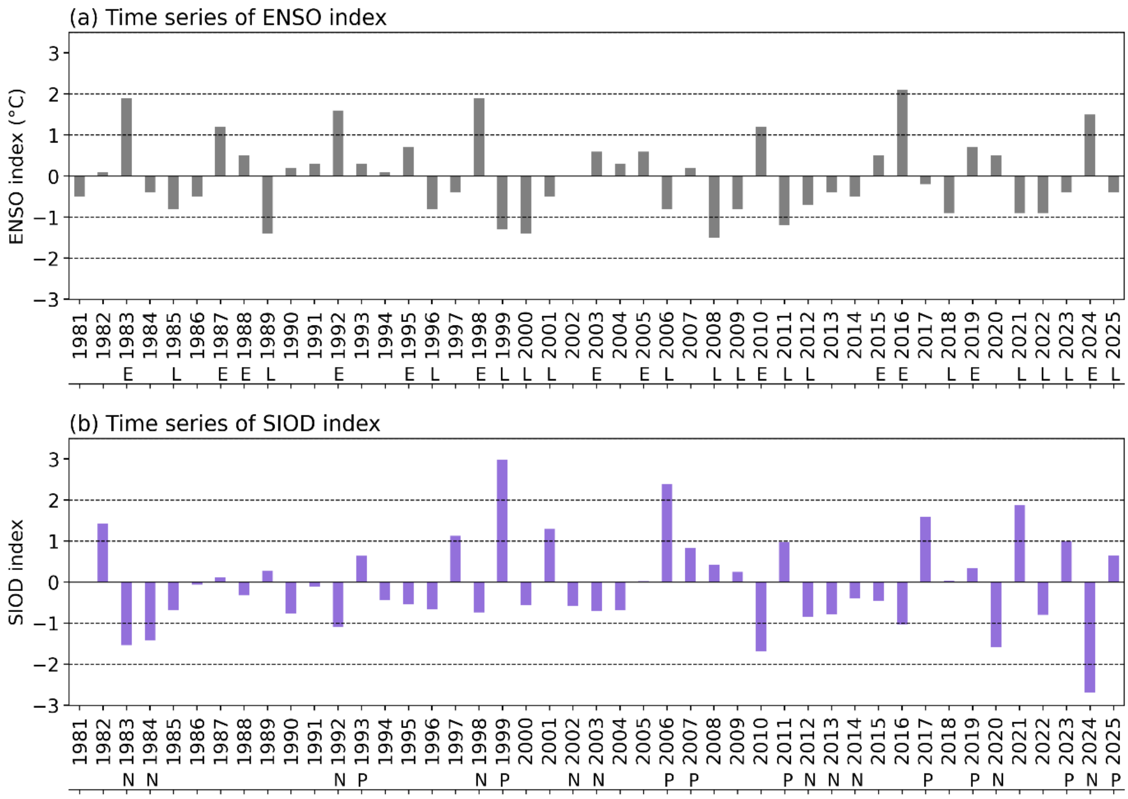

Fig. 4: February time series: (a) ENSO (L and E denote La Niña and El Niño, respectively) index and (b) SIOD (N and P denote Negative and Positive, respectively) index

The February 2025 weak La Niña conditions coincided with a positive SIOD index (0.65), as can be seen from Fig. 4b, which could have contributed to the heavy rainfall. This finding corroborates with previous authors (Hoell et al., 2017; Moses et al., 2022) who found co-occurrence of a positive SIOD index and La Niña to be linked to wetter-than-average conditions in the southern Africa region. However, the historical correlation between the SIOD index (Fig. 4b) and the rainfall anomalies (Fig. 3c) was weak (0.25). Unlike February 2025, February 2024 experienced a combination of El Niño conditions (ENSO index = 1.5°C) (Fig. 4a) and a negative SIOD (-2.7) (Fig. 4b), which led to a drought (Moses et al., 2025). A combination of positive ENSO index and negative SIOD index has also been previously associated with drier summers in southern Africa (Hoell et al., 2017; Moses et al., 2022).

Fig. 5 plots the Benguela Niño index time series for February from 1982 to 2025. In February 2025, the index was positive (0.79°C), which likely contributed to the heavy rainfall mentioned above, consistent with previous authors who found that Benguela Niños tend to be linked to above-average rainfall in the region, especially in Namibia and Angola (Hansingo and Reason, 2009; McPhaden et al., 2024). However, the historical correlation between the Benguela Niño index (Fig. 5) and the rainfall anomalies (Fig. 3c) was weak (0.12).

Circulation Anomaly Patterns

Circulation anomaly patterns associated with the heavy rainfall mentioned above are now considered. Fig. 6a plots anomalies of the 5-day average of 500 hPa geopotential height for 16-20 February 2025 relative to climatology (1991-2020). The strongest negative anomalies over the southern African landmass lie over the southwestern Botswana/southeastern Namibia border, which is where the core of the Botswana High lies. This high-pressure system is linked with subsidence in southern Africa (Reason, 2016; 2019; Maoyi and Abiodun, 2024). When this weather system is weaker than normal, as in Fig. 6a, subsidence is weaker, allowing convection to develop, hence favouring the heavy rainfall. Fig. 6b is similar to Fig. 6a but shows 500 hPa omega anomalies. Strongly negative anomalies lie over most parts of Botswana, including the Gaborone-Mochudi box (Fig. 1), stretching into South Africa and Eswatini. This indicates that the atmosphere experienced stronger-than-normal ascent, with moist air rising and cooling, forming clouds, consistent with the heavy rainfall. Past regional studies also found stronger-than-normal ascent to cause wet conditions (Cook et al., 2004; Rapolaki et al., 2019).

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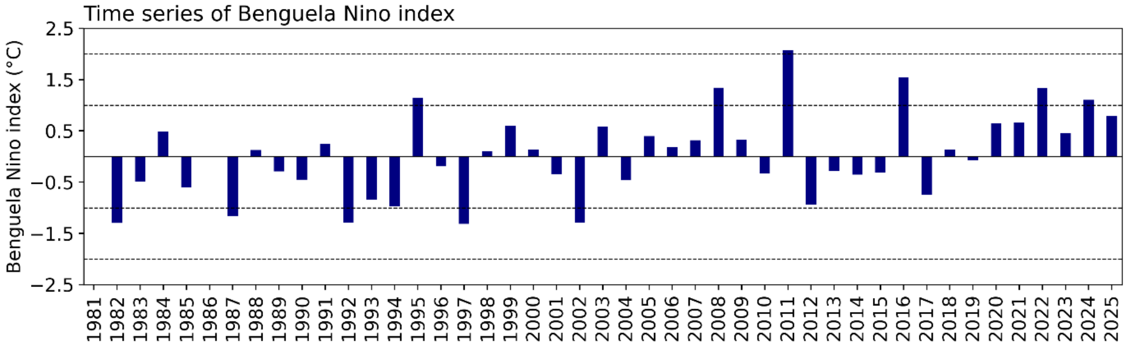

Fig. 5: February time series of the Benguela Niño index

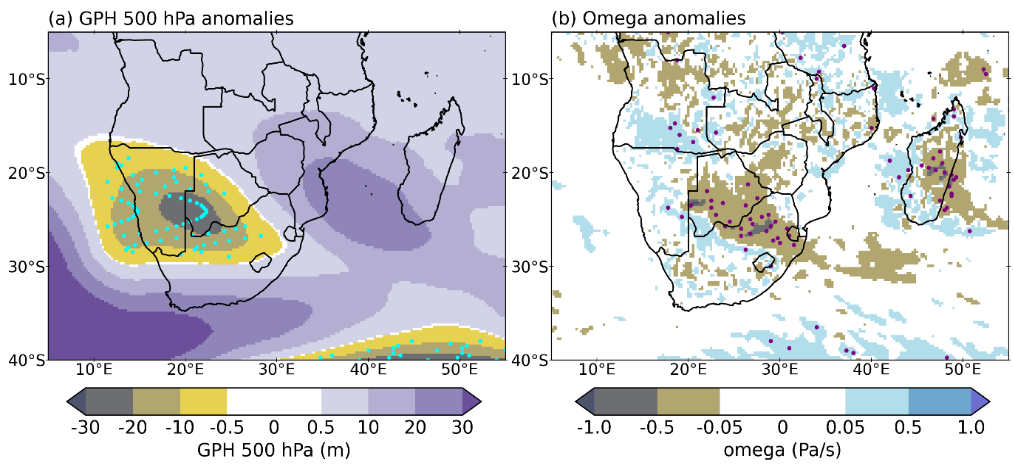

Fig. 6: (a) 5-day average 500 hPa geopotential height (GPH) anomalies for 16-20 February 2025 with respect to 1991-2020 climatology. (b) As in (a) but for 500 hPa omega. Stippling denotes 95% bootstrap confidence level

Fig. 7a shows anomalies of the 5-day average of outgoing longwave radiation for 16-20 February 2025. Lowest negative anomalies lie over most of Botswana stretching into northeastern South Africa, in a northwest/southeast direction, which is characteristic of tropical-extratropical cloud bands (Harrison, 1984; Hart et al., 2010; 2018; Macron et al., 2014). These anomalies mean below-normal radiation escaped to space, which produced deep convection and resulted in the heavy rainfall. Fig. 7b shows anomalies of the 5-day average of 850 hPa geopotential height. Lowest negative values are displayed midway along the Botswana/Namibia border. Northern Namibia stretching into southern Angola, which is the core region of the Angola Low (Reason et al., 2006; Monerie et al., 2024), also shows negative anomalies. These anomalies indicate that this Low was stronger than normal, hence drew more moisture from adjacent oceans into southern Africa (Lyon and Mason, 2007; Blamey et al., 2018), which favoured the heavy rainfall.

The shading in Fig. 7c shows anomalies of the 5-day average of moisture flux convergence at 850 hPa. The anomalies are strongly positive over most parts of Botswana, including the Gaborone-Mochudi-box, indicating a net accumulation of atmospheric moisture in the region, which favoured the heavy rainfall. Past studies also found such anomalies to cause wetter conditions in the region (Cook et al., 2004; Rapolaki et al., 2019). Moisture flux convergence anomalies are also strongly positive over southwestern Zambia/southern Angola/northern Namibia, central and northeastern South Africa, stretching eastwards to south of Madagascar.

Fig. 7c also shows moisture flux anomalies (vectors). There is anticyclonic flow over the Mozambique Channel, which means the Mozambique Channel Trough (Barimalala et al., 2018, 2020; Chongue and Nishii, 2024) was weaker than normal. Based on these studies, this caused more moisture to be advected from the South West Indian Ocean into the southern African landmass, including most parts of Botswana, hence the heavy rainfall. Northwesterly moisture flux anomalies over the tropical South East Atlantic Ocean helped advect moisture (Cook et al., 2004; Rapolaki et al., 2020) to countries like Angola, Namibia and Botswana, which also resulted in the heavy rainfall.

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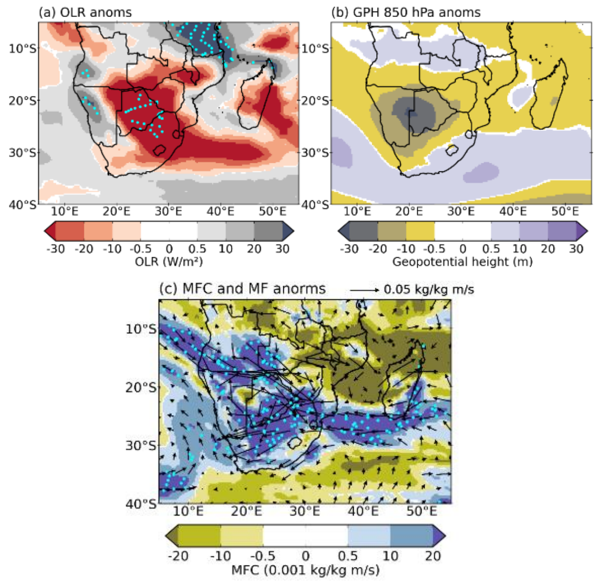

Fig. 7: Anomalies (anoms) (relative to 1991-2020) of the 5-day (16-20 February 2025) average of: (a) Outgoing Longwave Radiation (OLR), (b) 850 hPa moisture flux (MF; vectors in kg/kg m/s) and moisture flux convergence (MFC; shading), (c) 850 hPa geopotential height (GPH). Stippling denotes 95% bootstrap confidence level

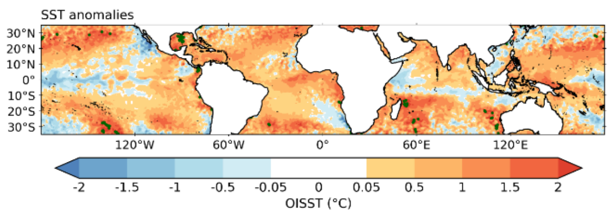

Fig. 8: Anomalies of the 5-day (16-20 February 2025) average of Optimum Interpolation SST (OISST) relative to 1991-2020 climatology. Stippling indicates 95% bootstrap confidence level

Fig. 8 plots anomalies of the 5-day average of SST for 16-20 February 2025. The anomalies are negative in the central equatorial Pacific Ocean, but positive in the western and eastern parts of this basin, in what appears to be a La Niña Modoki-like pattern (Preethi et al., 2015; Moses et al., 2022). However, the anomalies are generally weak, as also indicated in the NASA Earth Observatory (2025). As already mentioned, La Niña conditions are less impactful when they are weak (Hart et al., 2010; 2018; Blamey et al., 2018). In the South West Indian Ocean stretching to the western Australian border (Fig. 8), SST anomalies were generally positive. Such anomalies increase evaporation, which increases the flux of moisture from the ocean to the atmosphere, causing deep convection and heavy rainfall, as also previously found in the region (Behera and Yamagata, 2001; Reason, 2001; Hoell et al., 2017; World Weather Attribution, 2025). Fig. 8 also generally shows anomalous positive SST in the core region of the Benguela Niño (Rouault et al., 2003; McPhaden et al., 2024), consistent with the positive Benguela Niño index in 2025 (Fig. 5) and the heavy rainfall.

Conclusion

The heavy rainfall event that occurred in Botswana from 16-20 February 2025, which caused flash flooding, infrastructure damage, and loss of life, with the greatest impacts concentrated in Gaborone, Mochudi, and their surrounding areas, termed the Gaborone-Mochudi-box (Fig. 1), has been analysed in this study.

The study found that the event was not primarily driven by La Niña (Reason et al., 2006; Dieppois et al., 2015; Hart et al., 2018), which was weak.

It was mainly driven by a combination of regional ocean-atmosphere interactions and circulation anomalies. Moisture availability appears to have been enhanced by a positive SIOD and Benguela Niño (Hansingo and Reason, 2009; Moses et al., 2022).

A weaker than average Botswana High (Reason, 2019; Maoyi and Abiodun, 2024), a stronger than average Angola Low (Munday and Washington, 2017; Crétat et al., 2019), enhanced uplift at mid-levels (Blamey et al., 2018; Rapolaki et al., 2019), and strong moisture flux convergence (Ratnam et al., 2015; Moses et al., 2022, 2023a) produced favourable conditions for deep convection. There was enhanced moisture advection from the tropical South East Atlantic and the South West Indian Oceans (Cook et al., 2004; Barimalala et al., 2018; 2020; Rapolaki et al., 2020), which further amplified rainfall.

So, while ENSO is the major climate mode that causes interannual climate variability in southern Africa, extreme rainfall can also arise from interactions between atmospheric circulation and oceanic variability (Reason et al., 2006; Lyon and Mason, 2007; Maoyi and Abiodun, 2024). These findings are crucial for resource management. For example, there is a need to design or upgrade infrastructure for higher rainfall extremes. There is also a need for early warning systems to incorporate regional circulation features, including the Botswana High, to improve weather and seasonal forecasting.

Although this study is limited by its short analysis period in the sense that the results may not be generalisable to other scenarios, it is crucial because it improves scientific understanding of extreme rainfall events in the region. In addition, although the study is limited by its dependence on reanalysis data such as

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ERA5 reanalysis (0.25º resolution) for the analysis of circulation anomaly patterns, which may not be fine enough for representing complex terrain effects, Botswana is generally a flat country; hence complex terrain effects are not a major issue.

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Ethics

The author has written and proofread the manuscript and approves and gives the assurance that no part of this original research article is being considered for publication in whole or in part elsewhere.

Conflict of Interests

The author does not have any financial-related interests to disclose.

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