

WEATHERSMART

NEWS Scientific meteorological and climatological
news from the South Africa Weather Service

MARCH 2023

Tropical Cyclone Freddy - one for the history books

The horrific impact of the January 2023 Northern Cape heat waves

Aircores: What are they and what makes them so special?

The Laingsburg Flooding of 2 to 3 November 2022

El Niño rainfall over South Africa

Variability in Long-Term Trends of Seasonal Rainfall in South Africa (1921 – 2022)



**South African
Weather Service**

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Welcome to yet another exciting edition of WeatherSMART News!. As usual, we have put together several interesting articles to share with weather enthusiasts, scientists, and the public alike.

One of the weather phenomena that had the public on tenterhooks in the last six months was the long path of Tropical Cyclone Freddy in February and March 2023. In this issue, we provide a clear record of what happened during that period which will be of value for future research about the behaviour of Tropical Cyclones. While South Africa was not affected as initially expected, the system eventually caused a lot of damage and loss of life in Mozambique and Malawi. Our hearts go out to our brothers and sisters in those countries.

We also dissect the effect of the severe heatwaves the country experienced during January 2023, claiming the lives of seven farm workers. While the meteorology behind heatwaves is an interesting subject, the loss of one life is one too many, and one hopes we will not see a recurrence of such a tragedy.

Elsewhere in the publication, we discuss “aircores” to shed light on new research in that area of our work. This research takes samples of the atmosphere, with a long 1/8 inch tube, at 32000 km aboveground level, to gather in situ measurements of gases such as Ozone, Carbon Dioxide, Methane, Carbon monoxide, Carbon-Fluoro-Carbons, Halo Carbon-Flouro-Carbons, Sulfur hexafluoride, water vapour, temperature, pressure and humidity. This research contributes to our understanding of climate change and the effects that some gases have on the depletion of the Ozone layer.

Meanwhile, the Cut-Off Low event that happened in the Western Cape from 2-3 November 2022 over Lainsburg was a reminder of the devastating floods that caused massive loss of lives and property in the same town in 1981, and as a meteorological service, we are glad that the damage and loss of lives this time around were not as severe. Read all about that too in this issue.

Further, after years of the El Nino Southern Oscillation (ENSO) cool phase domination, predictions are now for a moderate El Nino event that can be expected in the summer of 2023/24. The article on the El Nino rainfall over South Africa discusses the anomalies for historical El Niño events and shows the regional variation that can occur during warm ENSO phases, even though such events are usually associated with anomalously dry conditions over our region. The significance of this research once again emphasizes the fact that we still have lots to learn about the many variables that are at play during El Nino or La Nina events, and demonstrate that no event is exactly similar to another.

Lastly, long-term rainfall trends are becoming increasingly important to evaluate whether climate change has a significant impact on domestic rainfall patterns. However, indicators that can be identified from the statistical analysis of rainfall time series largely depends on the period of analysis. Long rainfall time series are most often characterised by wetter and drier periods and sometimes quasi-cyclical behaviour.

These features in the time series have the effect that, depending on the period analysed, different results will be obtained, which can range from strong negative to positive trends. Previous research in rainfall trends over South Africa illustrated this in that there is often not clear agreement over the trends observed in specific regions of the country. In this rainfall analysis work, a systematic range of trend evaluation periods up to 2022 were analysed, to determine whether there were recent trends in annual/seasonal rainfall totals that are at least 30 years long (i.e., over the period 1993 – 2022) and since when these trends were reflected in the historical rainfall by testing for statistical significance. For example, it is shown that in the South-Western Cape, the drying trend experienced in that region is evident over the period since the mid-1930s up to the present.

I hope you will find the content of this edition valuable and informative, and that it provides a small window into the type of work being undertaken by the South African Weather Service.

Enjoy,

Ishaam Abader
Chief Executive Officer

LONG-LIVED TROPICAL CYCLONE FREDDY– ONE FOR THE HISTORY BOOKS

Wayne Venter, Forecaster at Disaster Risk Reduction

The evaluation of long-term rainfall trends is becoming increasingly important to evaluate whether climate change has a significant impact on South African rainfall patterns. However, indicators that can be identified from the statistical analysis of rainfall time series largely depends on the period of analysis. Long rainfall time series are most often characterised by wetter and drier periods and sometimes quasi-cyclical behaviour. These features in the time series have the effect that, depending on the period analysed, different results will be obtained, which can range from strong negative to positive trends. Previous research in rainfall trends over South Africa illustrate this, in that there is often not clear agreement over the trends observed in specific regions of the country. In this rainfall analysis work, a systematic range of trend evaluation periods up to 2022 were analysed, to determine whether there are recent trends in annual/seasonal rainfall totals that are at least 30 years long (i.e. over the period 1993 – 2022) and since when these trends were reflected in the historical rainfall, by testing for statistical significance. For example, it is shown that in the South-Western Cape, the drying trend experienced in this region is evident over the period since the mid-1930s up to the present.

What was a zone of disturbed weather, quickly turned into one of the longest-lasting and longest tracked tropical systems in the southern Indian Ocean in recorded history. On 3 February 2023, a zone of unsettled weather developed within a monsoon trough near the Timor Sea in the Australian cyclone basin, roughly 900 km north-west of the town Broome in Australia. The Australian Bureau of Meteorology, a Tropical Cyclone Warning Center (TCWC) for the south-west Pacific and south-eastern Indian Oceans, formally gave the system the name *Freddy* on 6 February 2023 after the system rapidly intensified into a tropical cyclone during the morning.

Freddy remained at least a Category 1 Tropical Cyclone for its entire journey from 6 February until 21 February, when it made landfall along the central Madagascar coast. Up to this point, *Freddy* remained at intense tropical cyclone Category 3 status for the period 10 to 21 February, even reaching very intense tropical cyclone status (Category 5), with winds of up to 250 km/h, on 15 and 19 February 2023. On the evening of 21 February, *Freddy* slammed into the central coast of Madagascar as a high-end Category 1 tropical cyclone.

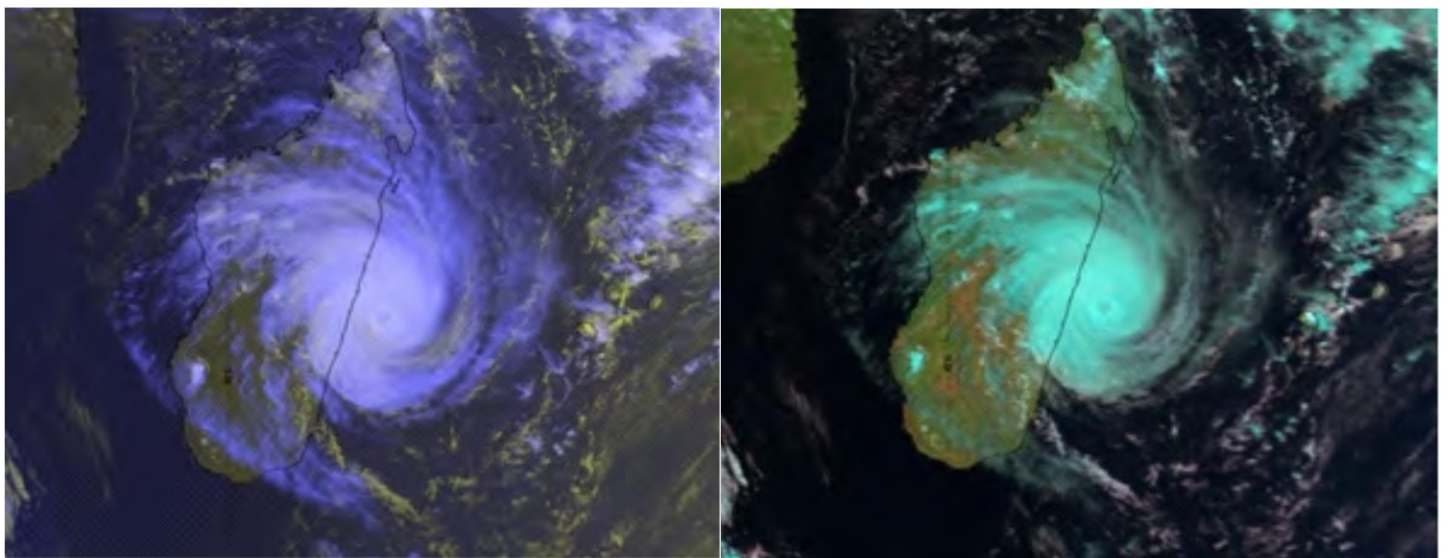


Figure 1: High resolution Visible (left) and Day Natural Colors (right) satellite images of tropical cyclone *Freddy* just before making landfall along the eastern Madagascar coast on Tuesday, 21 February 2023. (Source: Eumetsat)

Freddy immediately weakened overland due to the rugged terrain and became an overland depression, bringing widespread heavy rainfall and damaging winds near the core of the system. Unfortunately, eleven people lost their lives in Madagascar according to United Nations Office for the Coordination of Humanitarian Affairs (OCHA). According to a report released by OCHA, 226 000 people were affected by *Freddy* in Madagascar, with thousands of houses and classrooms destroyed by 1 March.

The system then continued in a west-south-westerly direction and re-emerged in the Mozambique channel in the afternoon of 22 February. By this time, a subtropical upper-air ridge was preventing *Freddy* from moving southwards and kept the system on track for landfall in Mozambique on Friday morning, 24 February, as a severe tropical storm between Vilanculos and Pomene.

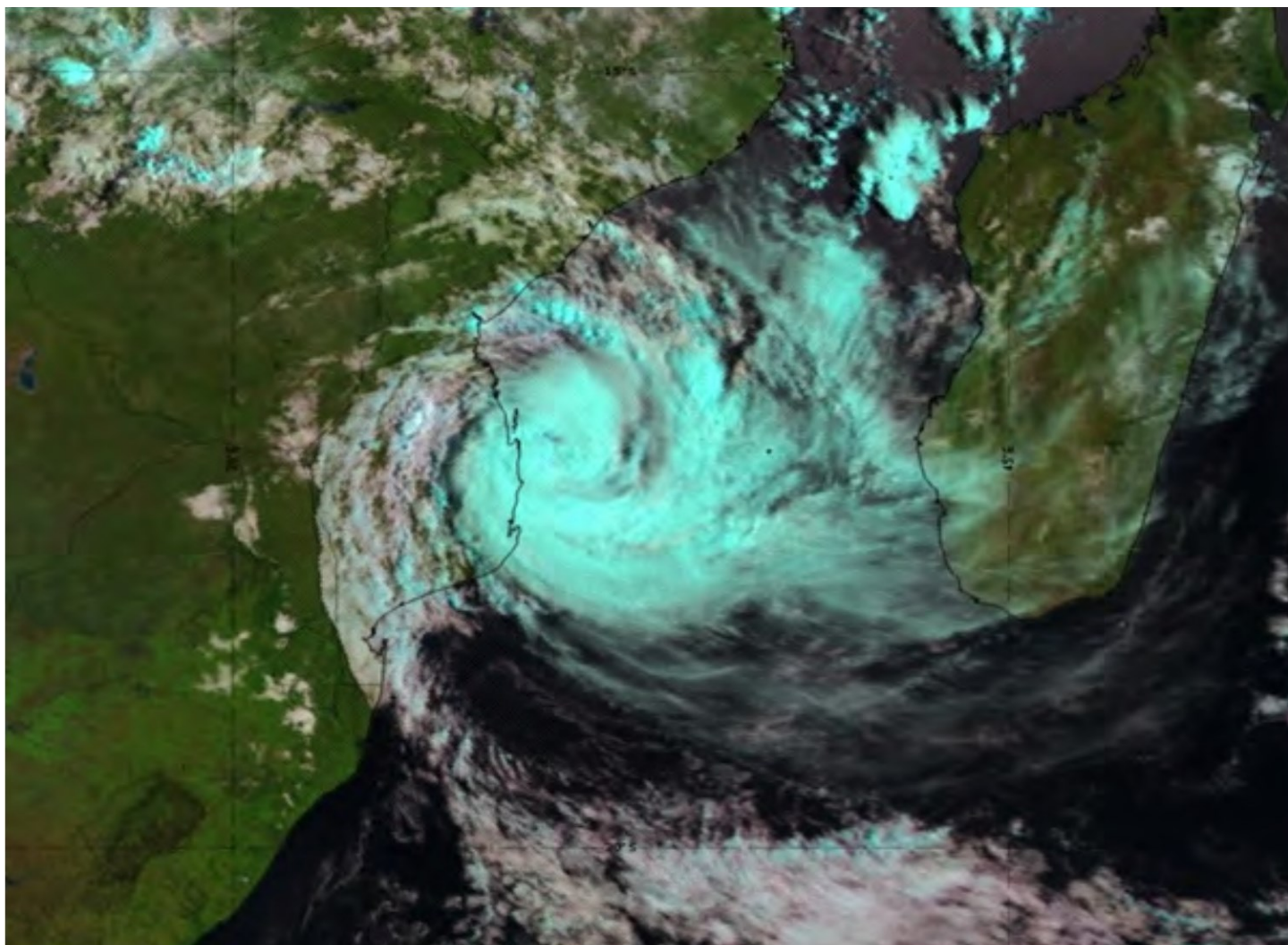


Figure 2: Day Natural Colors satellite image of severe tropical storm *Freddy* before making landfall between Vilanculos and Pomene along the Mozambican coast on Friday, 24 February 2023. (Source: Eumetsat)

Thereafter, *Freddy* once again became an overland depression and remained relatively stationary over southern Mozambique from 24 February until 1 March. It also briefly went into the extreme south-eastern parts of Zimbabwe on 27 February. During this time, 300 to 500 mm of accumulated rainfall was widely observed over southern Mozambique, with some observations near and in Vilanculos reporting accumulated rainfall in the order of 600 to 700 mm within a 6-day period. Unfortunately, surface observational data was limited.

By 28 February, 163 000 people were affected in Mozambique, with 27 000 houses destroyed or damaged and 658 km of road damaged by flooding according to OCHA. Unfortunately, ten people lost their lives in Mozambique because of *Freddy* bringing the total to 21 so far over the two countries.

The South African Weather Service issued several media releases with regards to this system from 21 February. Fortunately, it did not have any significant impact on South Africa, although rainy conditions were observed in the Lowveld and escarpment regions of Limpopo and Mpumalanga. To much of the relief of South Africans, *Freddy* was blocked by a strong subtropical ridge over South Africa, accompanied by several surface systems which prevented the low-pressure core from moving into the country.

Freddy is one of only two tropical cyclones that reached a track of this length since the beginning of the 21st Century. Tropical cyclone Eline of 2000 (called Leon in Australian Basin before it moved into the Indian Ocean waters), had a very similar path to *Freddy* and persisted for about 30 days before dying out.

Nevertheless, *Freddy* continued to remain in the Mozambique Channel from 3 March up to 10 March. The latest forecast from the WMO designated Regional Specialised Meteorological Centre (RSMC) located at La Reunion, suggests that *Freddy* will most likely have erratic movement but will not make landfall until at least the 10th of March.



Figure 3: *Freddy*'s predicted track on 8 March 2023 issued by La Reunion. *Freddy* was expected to make landfall over Mozambique for a second time (Source: MeteoFrance, La Reunion).

Freddy made landfall as a Category 1 tropical cyclone during Saturday evening (11 March) just north of Quelimane over Macuse (central Mozambique coast). It was *Freddy's* second landfall in Mozambique. Torrential rain, widespread flooding and damaging winds occurred across the central parts of Mozambique and the southern parts of Malawi from 11 to 14 March.



Figure 4: Damage around Quelimane in Mozambique due to *Freddy's* second landfall (Source: People's Weather, Facebook)



Figure 5: *Freddy's* predicted track on 13 March 2023 issued by La Reunion. (Source: MétéoFrance, La Reunion)

As of 13 March, *Freddy* technically broke the world record for the longest-lasting tropical cyclone with 36 days, which was held by Hurricane John (1994) with 31 days. This record is still being investigated by the World Meteorological Organization. Prof Randall Cervený at the World Meteorological Organization (WMO) says "At this time, it does appear to be a new record holder for 'longest-lasting' recorded tropical cyclone, but we are continuing to monitor the situation".

Freddy may have recorded the highest recorded accumulated cyclone energy (ACE) in history. Accumulated cyclone energy is a measure of the total amount of wind energy a cyclone uses over its lifetime. The previous record was held by hurricane Ioke in September 2006. This will still be investigated by the WMO. *Freddy* also had the most separate rapid intensifications in history with seven separate rapid intensifications recorded. The previous record was four. A rapid intensification is when a storm's wind increases by 56 km/h in 24 hours or less.

Extraordinary *Freddy* entered four African countries (Zimbabwe, Malawi, Mozambique and Madagascar), made landfall twice in Mozambique (24 February and on 11 March) and crossed the Mozambique Channel two times (22 February and 1 March).



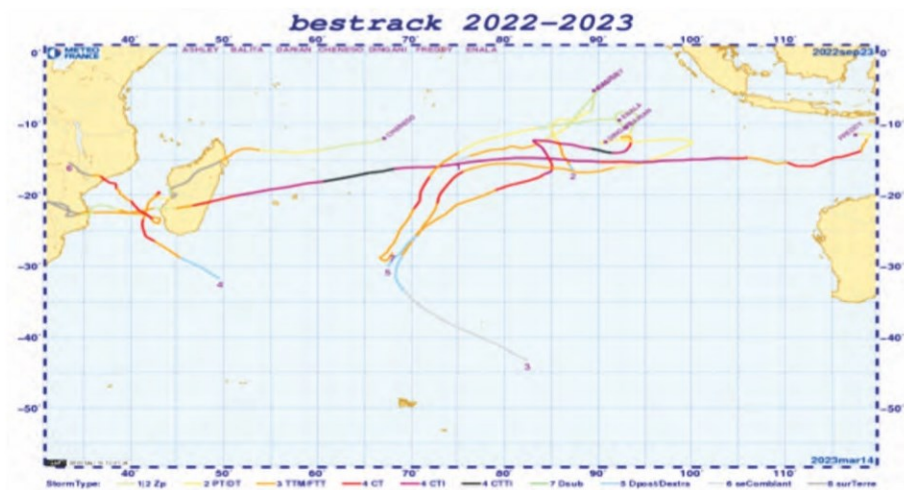


Figure 6: Freddy's observed track during its lifespan from 3 February until 14 March 2023 and the paths of the other tropical systems during the 2022/23 season (Source: MeteoFrance, La Reunion)



THE HORRIFIC IMPACT OF THE JANUARY 2023 NORTHERN CAPE HEAT A STUDY IN THE KAKAMAS REGION

Authors: Senior Forecaster - Ntshalle Stella Nake (Cape Town Weather Service)

Forecaster - Siyabonga Mpati (Bloemfontein Weather Office)

1. INTRODUCTION

Seven farmworkers lost their lives after a two-week-long heatwave left the Northern Cape sweltering in January 2023. The Department of Employment and Labour as well as the Northern Cape Department of Agriculture, Environmental Affairs, Rural Development, and Land Reform reported the unfortunate incidents to have occurred due to a suspected heat stroke on January 20, 2023. In his interview with News24, the owner of the farm, Verster, said, "The high temperatures were all the way to Springbok and right up to Upington, but the real issue was not water but load shedding, because without electricity we just can't pump water."

There is no set definition of a heatwave, but generally, a heatwave occurs when there are multiple days or weeks of higher-than-usual temperatures for an area during a specific time of year. The definition of a heatwave from the World Meteorological Organization (WMO) is when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5°C. The South African Weather Service (SAWS) considers a heatwave to exist when the daily maximum temperature for three consecutive days or more exceeds the average maximum temperature of the hottest month by 5 degrees Celsius (SAWS, 2022).

Effects of the heatwave

- **Heat stroke:** On extremely hot days, human bodies may not be able to keep cool enough through sweating alone, causing the core body temperature to rise. This can lead to headaches, dizziness, and even death.
- **Dehydration:** the loss of water from our bodies. It can cause tiredness and problems with breathing and heart rates.
- **Sunburn:** skin damage that can be painful and may increase the risk of developing skin cancer.
- **Air pollution:** "Scientists at USC found the excess risk of death on the hottest days with both high heat and extreme levels of air pollution was about three times higher than for either alone" (UNDRR, 2022).

2. DESCRIPTION OF STUDY AREA



The town of Kakamas is located in the Kai !Garib Municipality in the Northern Cape Province, South Africa. The town covers an area of 4055 square kilometers; it is surrounded by green vineyards, and is adjacent to the Orange River.

- It is approximately 78 km to the south-west of Upington and 36 km to the south-east of Augrabies Falls.
- The N14 and R359 are the primary roads in the area and are the main links to its neighboring towns.
- The climatic conditions are typical of a semi-desert or arid savannah. It experiences high temperatures, especially in the summer months, with average daily maximums of 35°C.
- Rainfall usually occurs during the late spring and summer months.

Figure 1: Kai !Garib Local Municipality-Northern Cape (Source: municipalities.co.za 2023)

3. METEOROLOGICAL ANALYSIS

3.1 Synoptic chart

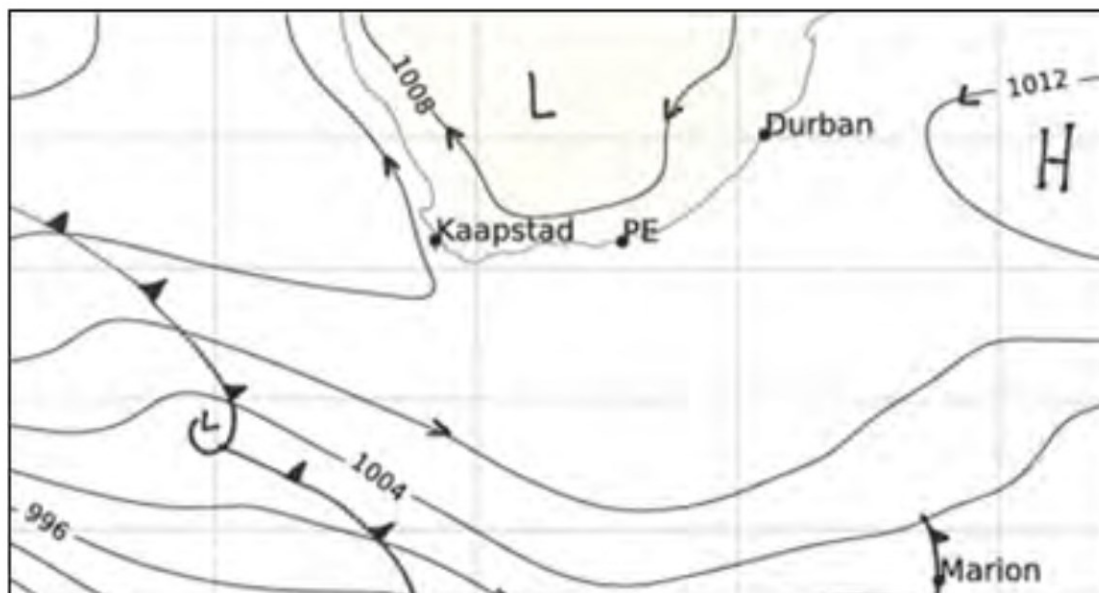
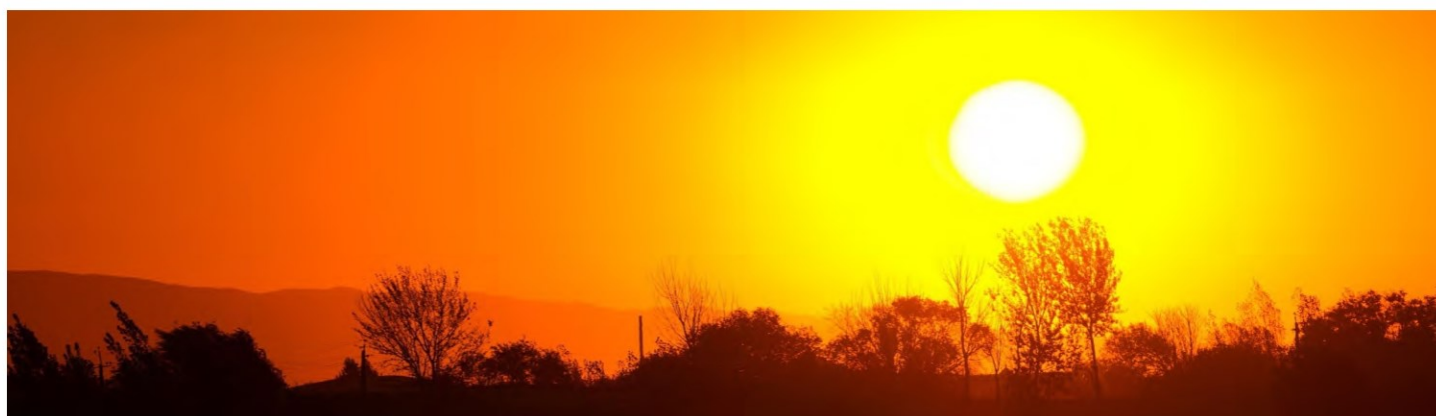


Figure 2: Synoptic chart for 2pm on 20 January 2023 (Source: SAWS, 2023)

The synoptic chart depicts a surface trough over the Central Interior, the Indian high pressure to the east, the South Atlantic high pressure to the west, and a cold front to the country's south-west. A surface trough is an elongated area of low pressure extending from the center of a region of low pressure. Air is moving around the surface trough in a clockwise direction, bringing a hot, dry tropical continental air mass to the study area. This pattern continued for most of the remaining days when heatwave conditions were observed in the area. According to Barclay (1992), there are two types of surface troughs, dry and wet surface troughs, which influence the weather patterns of South Africa during the summer months. These troughs are highly influenced by the positioning of the South Atlantic high-pressure system (Barclay, 1992).

A dry surface trough occurs when the South Atlantic high pressure is displaced north and eastward of 35° S as in Fig. 2 above. The South Atlantic high pressure erodes available surface moisture, reducing cloud cover and increasing insolation when it is located in this position (Barclay, 1992). Increases in insolation may be linked to increases in surface temperature. A wet surface trough on the other hand, develops when the South Atlantic high pressure extends its ridge to 37° S (Barclay, 1992). A dry trough signifies less or no precipitation, whereas a wet trough favours rainfall. The lack of rainfall in areas experiencing heatwaves affects the availability of soil moisture. According to Materia et al. (2022), the combination of soil moisture deficits and high summer temperatures exacerbates heat extremes such as heatwaves.



3.2 Satellite Imagery

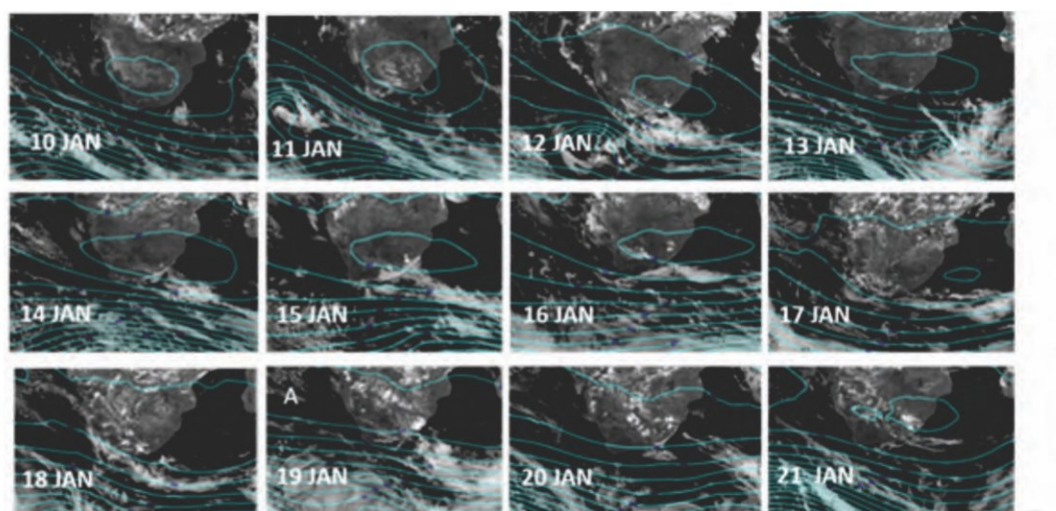


Figure 3: From left to right- the Infrared satellite images indicating 500 hPa geopotential heights from 10 Jan until 21 Jan 2023. Courtesy: EUMETRAIN, 2023

The combination of the satellite images and the upper-level geopotential heights (500 hPa) shown in figure 3 above indicates a stationary upper high-pressure system over the central interior that dominated the circulation from January 10 until January 21, 2023. This weather phenomenon is known to induce anticyclonic flow, resulting in subsidence and hot to very hot surface temperatures (Mbokodo, 2017). The satellite images indicate the presence of middle- and upper-level clouds around the periphery of the high-pressure area through the period. During hot days, the presence of these clouds acts as a cap, restricting surface heat radiation. This process results in high nighttime temperatures due to the trapped hot air at the surface that cannot escape and cool off.

3.3 Inspection of temperature data

The South African Weather Service does not have a weather station at Kakamas. The authors opted to use minimum and maximum temperatures for Augrabies Falls weather station since it is the nearest and has a similar climate and topography. The temperature dataset covers the period from January 1 to January 25, 2023. The threshold temperature for a heatwave over Augrabies Falls is 43°C. Table 1.1 below shows the temperatures that were observed.



Day	Minimum temperatures(°C)	Maximum Temperatures (°C)
1	24	44.1
2	n/a	44.2
3	25.9	42.6
4	19.2	37.9
5	15.8	32.4
6	17.5	35.1
7	18.9	38.4
8	18.2	41.9
9	20.1	44
10	22.8	45.8
11	25.9	45.5
12	28.4	45
13	21.8	46
14	24.1	46.9
15	24.9	47.3
16	26.1	45.3
17	28.5	45
18	26.4	45.8
19	24.9	43.2
20	24.7	44.6
21	26.5	37.1
22	22.4	41.9
23	22.3	43.1
24	20.4	34.9
25	15.9	39.2

Table 1.1: Minimum and Maximum temperatures at Augrabies Falls for the period 1-25 January 2023. (Courtesy: SAWS, 2023).

Based on the 43 degrees Celsius threshold, it can be clearly seen from Table 1.1 above that there were two episodes of heatwaves at Augrabies Falls within the dataset. The first episode lasted three days, beginning on the first and ending on the third. The second episode lasted twelve days, beginning on January 9 and ending on January 20, 2023. Studies have shown that the most serious health impacts of a heatwave are often linked with high nighttime temperatures, which are often the daily minimum (Sarofim et al., 2016). The minimum temperatures remained high, especially during the second event, with the highest recorded minimum of 28.5 degrees Celsius on the 17th.

4. Findings

- The Bloemfontein weather forecasters issued an advisory for the heatwave from the 11th until 15 January initially, which was extended on the 12th to include Monday, 16 January. An update to the heatwave advisory was issued on the 17th, extending the advisory to include January 18. The advisory was not extended for January 19 and 20 because maximum temperatures at Augrabies Falls were expected to fall below the heatwave threshold of 43 degrees Celsius.

5. Recommendations to assist operational forecasters in order to identify heatwaves

- The South African Weather Service has both provincial and national **heatwave threshold maps** available (Fig. 4). These maps will assist forecasters in identifying possible heatwave episodes.

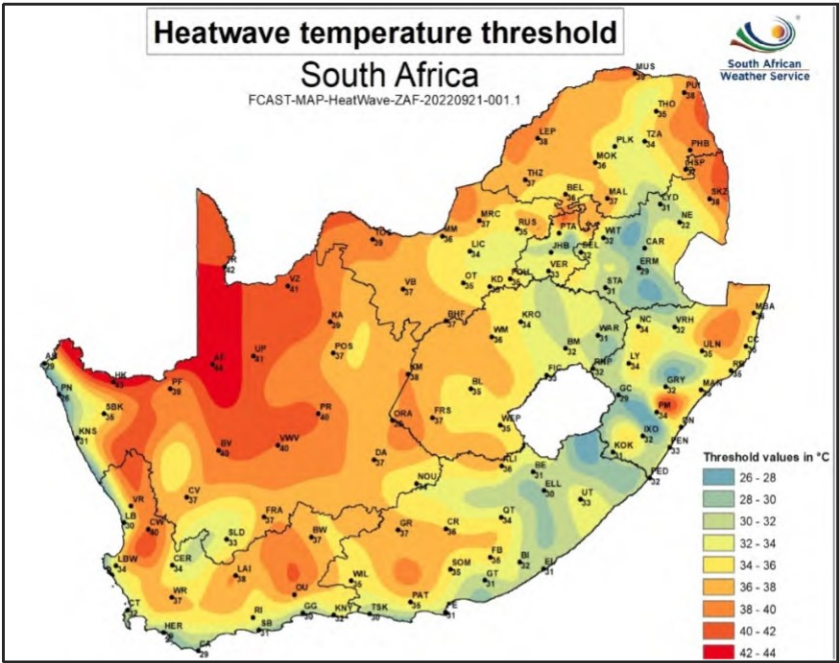


Figure 4: Heatwave temperature threshold map for South Africa (Courtesy: SAWS, 2023)

- The ECMWF's [Ensemble Prediction Systems \(EPS\) in figure 5 below](#) provide an opportunity for forecasters to gain local and regional perspectives of a possible heatwave event at a specific location far in advance.
- Understanding the needs of the user is critical to providing useful forecast uncertainty information. Forecasters can relay EPS-based information to decision-makers that can help them make public safety decisions.
- The 14-day SAWS in-house Ensemble Forecast Products (Fig. 6) can be used to determine the probability of a heatwave event over a wide area far in advance.

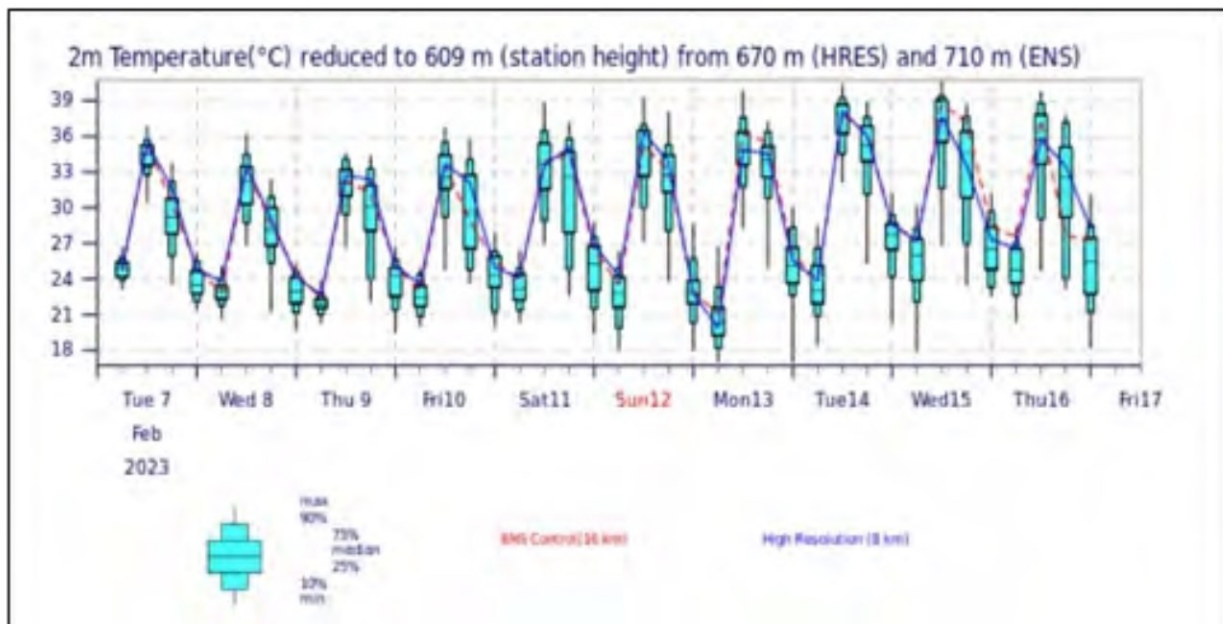


Figure 5: Example of Ensemble Prediction Systems (EPS) 10-day temperature output. (Source: ECMWF, 2023)

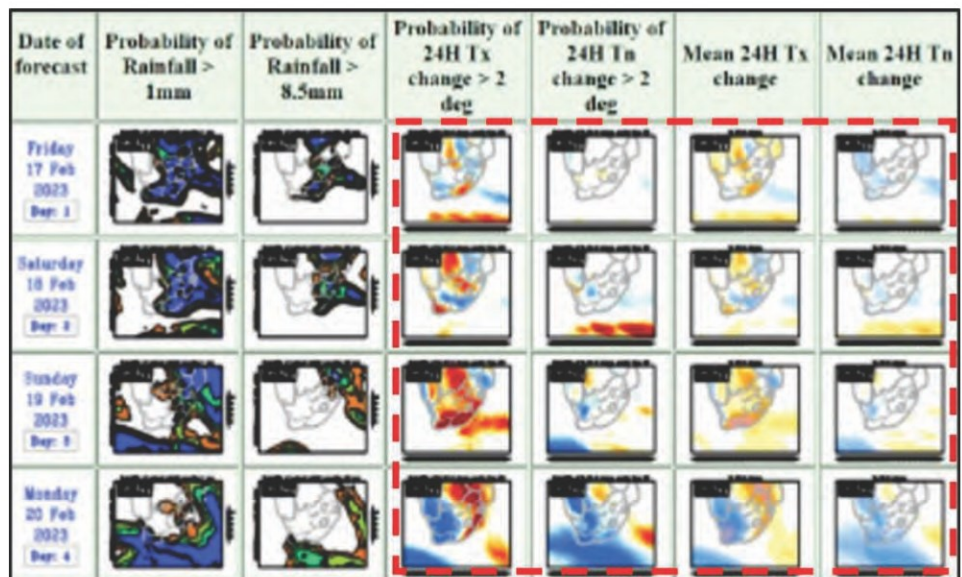


Figure 6: The Ensemble Forecast Products. Tx stands for maximum temperature, while Tn stands for minimum temperature (Courtesy: SAWS, 2023)

- The ensemble predictions:
 - Can provide estimates of probabilities as measure of forecast uncertainty ~ the forecaster would have a better judgment whether to follow the guidance or not.
 - Can provide probability of multiple events taking place concurrently ~ e.g., Tx changes over 24 hours versus Tn changes over 24 hours, as shown in Fig.6 above. Sarofim et al. (2016) have highlighted the dangers of minimum temperatures during heatwave events. This needs to be taken into consideration.
- The rainfall probability maps on the left can be used as an additional tool for identifying the onset of cooler conditions, which will imply a possible end to a heatwave event.

6. Conclusion

The incident that occurred in the town of Kakamas was tragic because lives were lost. Excessive heat and heatwaves are weather extremes that are projected to increase in frequency and intensity due to the effects of climate change and global warming. Although other factors contributed to the loss of lives at the farm, **it is imperative for SAWS to look at impact-based severe weather warnings for extreme temperatures such as heatwaves, excessive heat, and very cold conditions.** This can be done in consultation with the Department of Health, as they would be better informed about the rate of patients who get admitted during hot days.

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AIRCORES

WHAT ARE THEY AND WHAT MAKES THEM SO SPECIAL?

- by Markus Geldenhuys in cooperation with Hugh van Niekerk, Warren Joubert, Thumeka Mkololo, Casper Labuschagne, Pieter Labuschagne and Lynwill Martin

In March this year, three scientists from Forschungszentrum Juelich, Germany are visiting Beaufort-West, South Africa to do AirCores in collaboration with four scientists from the South African Weather Service (SAWS). With this observational campaign in mind, let us discuss the basics surrounding an AirCore.

We are sure that everyone has heard of scientists going to Antarctica to take ice cores. Now imagine an air core... Probably you still have no clue what this is... Don't worry, the first time we heard it, it also did not make any sense.

Let us start with something more familiar, an ice core, and draw some analogies between ice cores and AirCores. An ice core (Figure 1) is obtained by extracting a cylindrical core of ice from ice sheets or glaciers. These ice cores are then taken to a laboratory to be analysed for levels of carbon dioxide (CO_2) that are trapped as bubbles in the ice. Scientists expect that these glaciers were growing year by year, adding a new layer of ice every winter season. This means the top part of the ice core can now be said to be the “youngest” ice layer and the bottom part the “oldest” ice layer.



Figure 1: An ice core after it has been extracted from an ice sheet. (Source: Nasa, 2017)

An AirCore (visit <https://gml.noaa.gov/ccgg/aircore/> for a full scientific description) is slightly more intricate to obtain, but there are some similarities and differences to ice cores. One of the differences is that you can launch an AirCore anywhere in the world and not only where there are ice sheets (see Figure 2). Briefly described, an AirCore (Figure 3) is a very long 1/8 inch tubing attached to the bottom of a large balloon that ascends to about 32 000m above ground level. Here the balloon bursts and the instruments descend via a parachute. At 32 000m, the pressure is very low and almost all the air within the tube has escaped. As the instrument descends the air at 32 000 m it will fill into the tube first, followed by the air at 31 000 m, and so forth. Within this tube, minimal mixing takes place and the air from 32 000 m remains at one end of the tube (the top) and the boundary layer remains at the other end of the tube (the bottom). This basically provides an altitude profile of gas samples that can be analysed by a suitable instrument for whichever target gas species one is interested in.



Figure 2: An AirCore being launched at Beaufort West



Figure 3: An AirCore instrument in its protective polystyrene casing

As the parachute descends, a ground team will track it in real-time and needs to 'hunt' it down. Once the payload lands, the tubing needs to be blocked off to avoid the air sample within to escape. This filled tube is then taken to the lab to analyse the air samples taken from the top of the flight to the surface.

To come back to our ice core analogy, the cylindrical core of ice in the AirCore example is the tubing that contains the air samples. Like the ice core, the AirCore is divided into multiple layers. Each layer represents a different altitude, but also a different age. Looking at the chemical composition of the air samples we can thereby determine the “age of the air”. Age-of-air is defined as how much time has passed since the air sample was in contact with the surface of the earth (or the tropical tropopause as in some definitions). We expect to find air with a mean age between two to four years at the top of the balloon trajectory. The age-of-air is important in order to study stratospheric circulations such as the Brewer-Dobson circulation. Measurements like these can help to determine whether the circulation speeds up or slows down in a changing climate.

In combination with the AirCore, the research team will fly a CFH package (Figure 4) with more instruments to gather in-situ measurements of other gases. The chemical species that can be measured by both instruments include; Ozone (O_3), Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Carbon-Fluoro-Carbons (CFC-11, CFC-12), Halo Carbon-Flouro-Carbons (HCFC-22, Halon-1211, Halon-1301), Sulfur hexafluoride (SF_6), water vapour (H_2O), temperature, pressure and humidity.

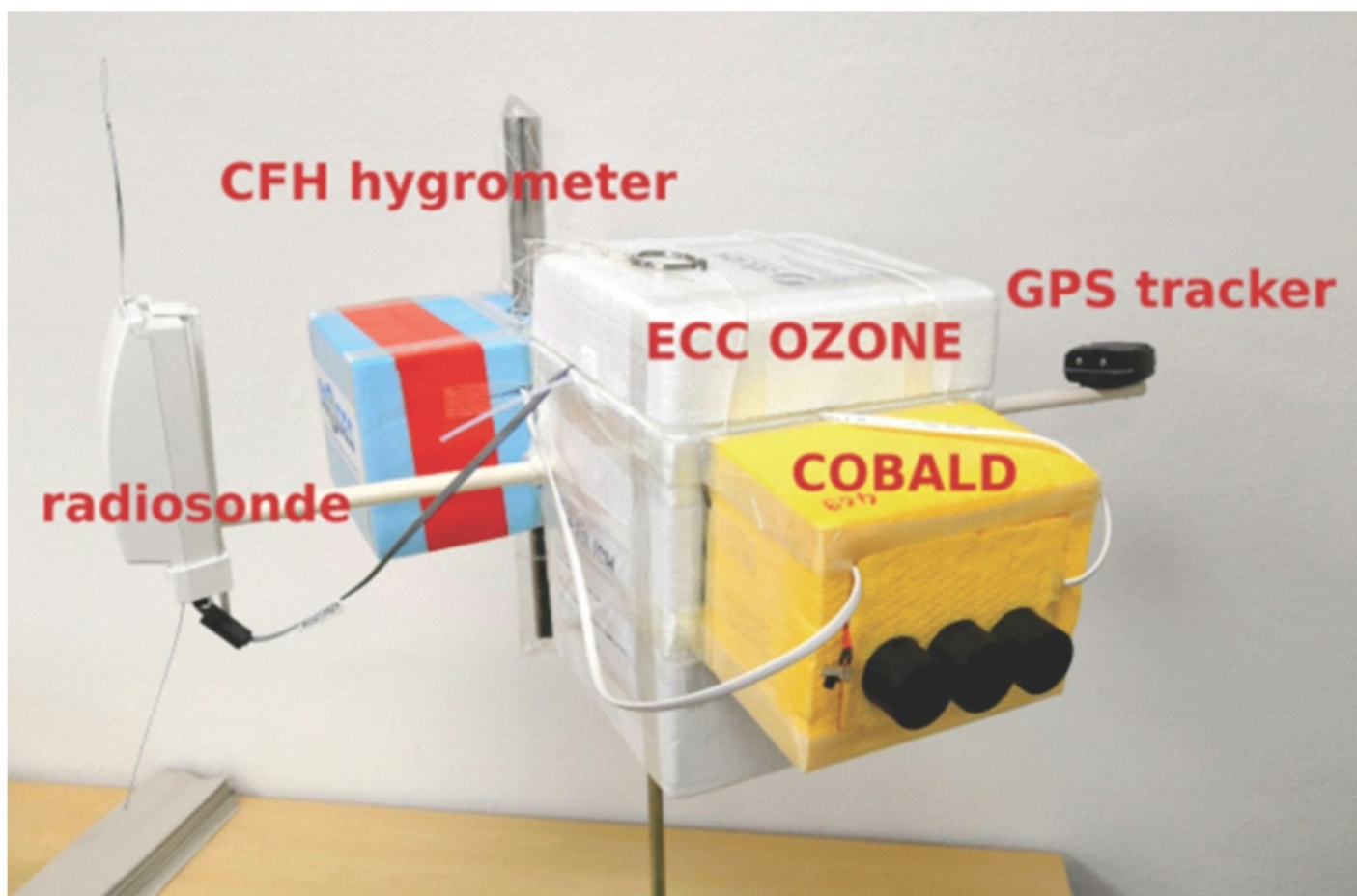


Figure 4: The CFH package can measure water vapour, ozone and standard radiosonde parameters

THE LAINGSBURG FLOODING OF 2 TO 3 NOVEMBER 2022

By: Kanyisa Makubalo

Edited by: Elani Heyneke

1. INTRODUCTION

The purpose of this article is to give a report on the flooding that occurred over Laingsburg, Western Cape, on 2 and 3 November 2022.

The 2022 flooding event over Laingsburg is not the first time that this semi-arid region experienced such extreme weather. The 1981 Laingsburg floods are still etched in the minds of the locals and caused shockwaves across the world when images surfaced with most of the town underneath mud and water, many missing and the death toll rising to 90. The weather system that contributed to this memorable event was a Cut-Off Low (COL), the same system that caused the 2022 flooding event. According to the Glossary of Meteorology, a COL is a cold low that initially starts as a trough in the upper atmosphere, becomes displaced out of the dominant westerly belt and gets positioned equatorward. COLs are usually associated with heavy rainfall leading to floods and flash flooding, severe thunderstorms (excessive lightning, large hail and or a large amount of small hail), strong winds and the occasional snow events.

2. BACKGROUND

The flood disaster that occurred in Laingsburg on 25 January 1981, was so immense that a Flood Museum was constructed to indicate the water level to which the river rose and for South Africans to never forget the sad tragedy. It is due to this fact that any COL associated with flooding in Laingsburg will always keep weather forecasters on guard. On that unfortunate day, heavy rainfall resulted in the Buffels river, which runs through Laingsburg, overflowing its banks at about 10h00 SAST. By 26 January 1981 08H00 SAST, the Touws River had accumulated 119,5 mm, the rainfall measured at Matjiesfontein was 138,1 mm and the Dwars-in-die-weg station measured 203 mm. The rainfall resulted in more than half of Laingsburg's houses and business premises being flooded, with about 90 people having lost their lives (Roberts and Alexander, 1982). The same area was affected by floods associated with a COL on 2 and 3 November 2022 - however, the rainfall amounts were significantly lower.

The Laingsburg municipality is situated in the eastern parts of the Central Karoo District of the Western Cape of South Africa. It is just north of the Anysberg and Towerkop Nature Reserves, with the N1 running through the town. The N1 is an important traffic route, because it connects Johannesburg and Cape Town and is used by the trucking industry to transport goods between the two mayor cities. North of it is Sutherland, while Beaufort-West lies towards the north-east.



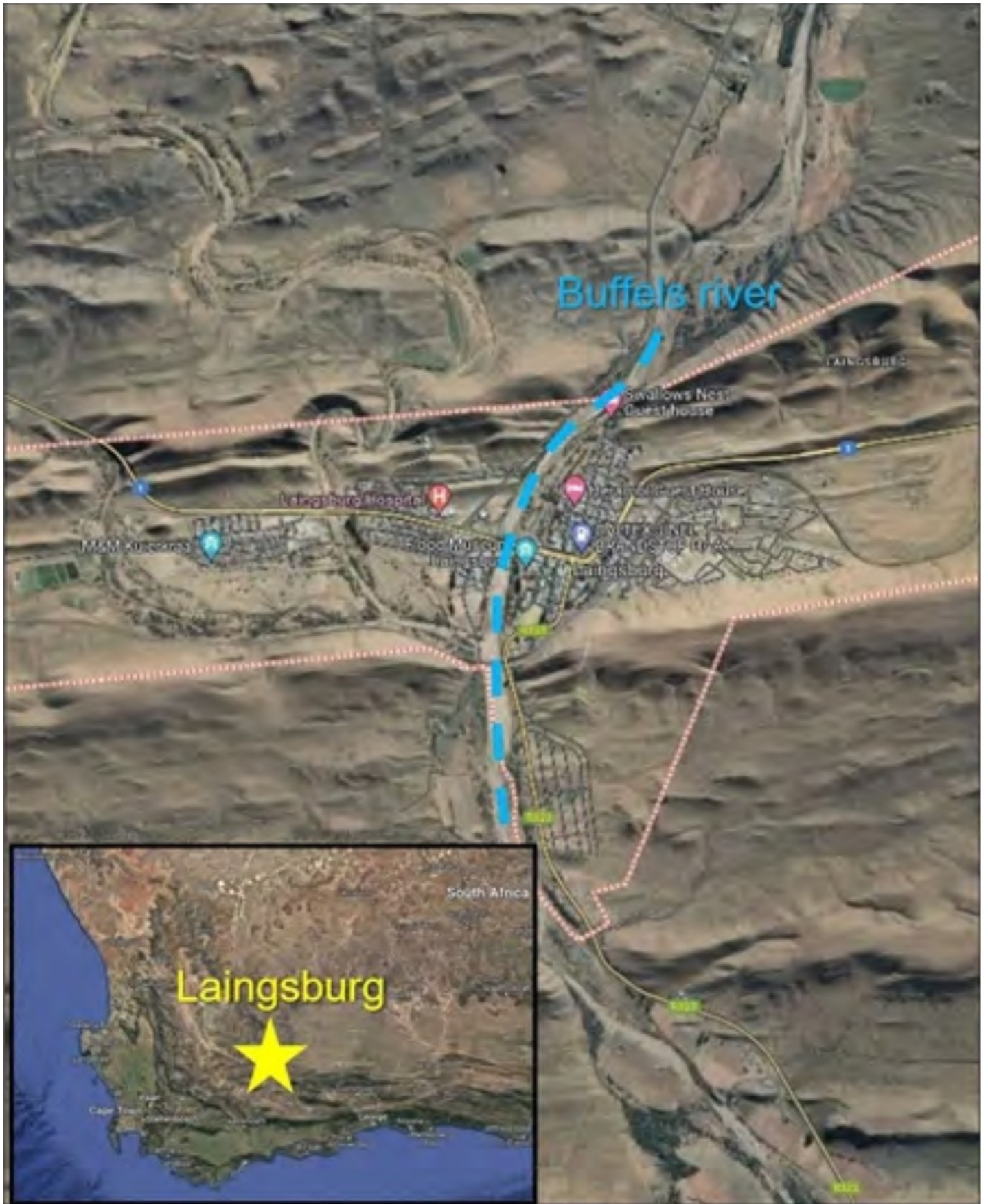


Figure 1: The location of Laingsburg (yellow star) with the Buffels river running through the town as highlighted as a dashed blue line (credit: Google Maps, 2023)

4. CUT-OFF LOW EVENT OVER WESTERN CAPE FROM 2-3 NOVEMBER 2022

A slow-moving COL in the upper levels of the atmosphere was situated over the south Atlantic Ocean just west of South Africa, with a surface trough over the central parts of the country extending to the south-western parts of the Western Cape. The combination of the systems resulted in an abundance of moisture in different levels of the atmosphere, exceptional instability just east of the surface trough axis and an impeccable amount of wind shear. These atmospheric ingredients together with decent surface convergence and the local topography, served as good triggers for severe thunderstorms to develop over the Sutherland area with a general southward movement of these storms. Due to this weather analysis, the weather forecasters determined that severe thunderstorms with heavy downpours are likely over the Laingsburg area on 2 November 2022.

Redevelopment was also possible the next day, contributing to a rain-on-rain scenario. Therefore, increasing the likelihood of worsening flood damage and flash flooding. Thus, it was agreed upon to send out a warning for the severe thunderstorms for 2 to 3 November 2022. A yellow level 2 for severe thunderstorms was issued, with the southern parts of Namakwa (Northern Cape) and eastern parts of the Western Cape as areas of interest, but only over the extreme southern parts of Namakwa and northern interior of the Western

Cape on 3 November 2022. The expected impacts included heavy downpours and flash flooding resulting in difficulty in driving conditions, strong and gusty winds as well as excessive lightning as seen figure 2.

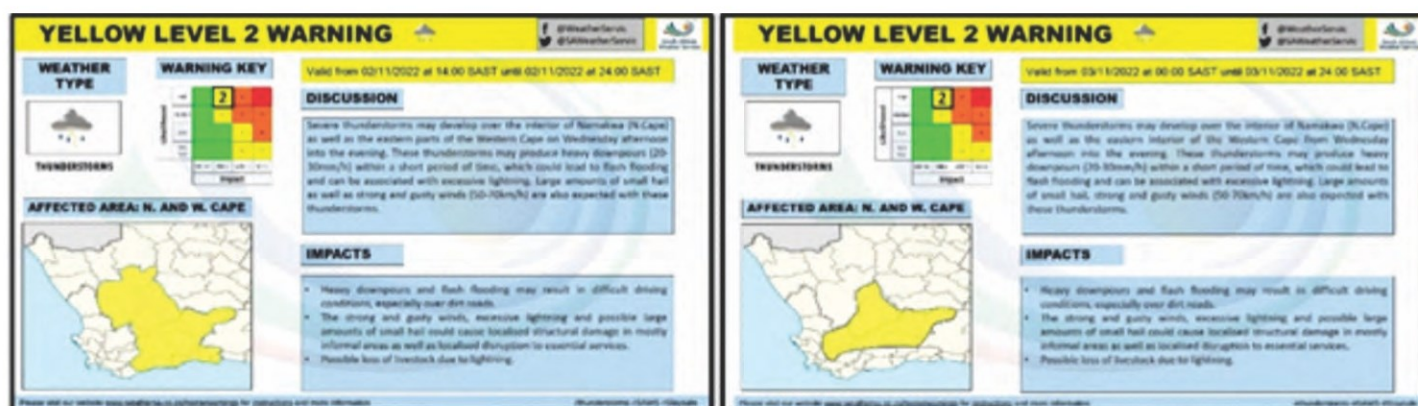


Figure 2: The Yellow Level 2 warning for Severe Thunderstorms social media images for the storms expected for 02-03 November 2022 (source: SAWS, 2022)

Satellite Imagery

The thunderstorms were following the classic scorpion's tail pattern with the tail of convection going across the Karoo Hoogland municipality, extreme northern parts of the Central Karoo, parts of the Cape Winelands into the West Coast and even Cape Metropole Districts on the morning of 2 November 2022 as seen in figure 3. Excessive lightning can be seen with the red, blue and green signals over the storms with the anvil of the storms covering the better part of the Western Cape.

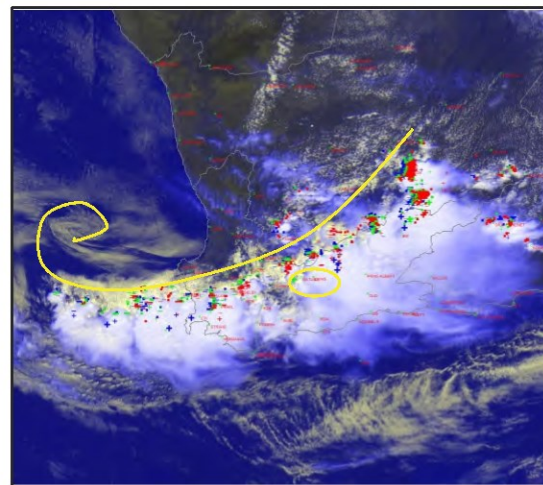
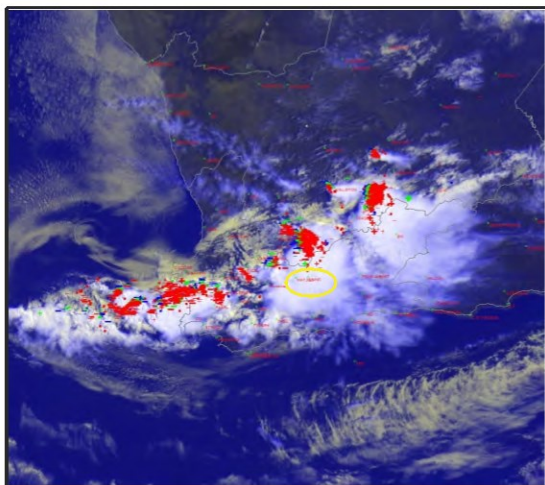


Figure 3: The HRV Cloud Enhance RGB valid for 2 November 2022 showing in detail the thunderstorms and the clouds associated with them. Laingsburg's relative location is circled in yellow with the scorpion's tail in the yellow line. (credit: EUMETSAT, 2023)

Laingsburg did not receive much thunderstorm activity on 2 November with very little rainfall measured and no reports of impacts. Although it was a different case for the next day, since the thunderstorms that redeveloped in the similar area affected Laingsburg. During the afternoon, moving thunderstorms with heavy downpours resulted in flash flooding. In addition, excessive lightning was also observed as seen on figure 4. This was the result of the slow-moving COL intensifying.

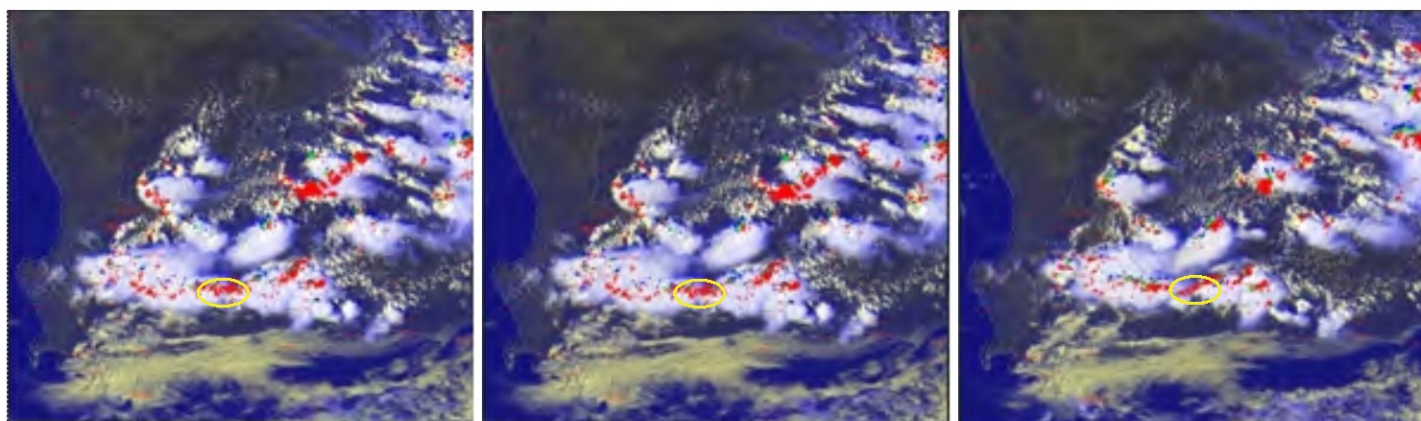


Figure 4: The HRV Cloud Enhance RGB valid for 3 November 2022 at 15:30, 16:00 and 16:30 SAST showing in detail the thunderstorms and the clouds associated with them. Laingsburg's relative location is circled in yellow. (credit: EUMETSAT, 2023)

Observed impacts

The positioning of a COL and the combination of other important factors as mentioned earlier, are likely to contribute to severe thunderstorms over the Laingsburg area and possibly lead to flash flooding as seen on 2 and 3 November 2022. This is due to the atmosphere being favourable for thunderstorms development and with a possibility of some of these becoming severe. The likelihood of flash flooding or flooding is exacerbated when the system is slow moving, since the downpours are relatively in the same area for an extended amount of time. This was the case for the system in question. Laingsburg received significant amounts of rainfall leading to flooding on the N1, which runs through the town and is a major road connecting Johannesburg and the City of Cape Town. The flow of traffic was disrupted with big trucks being stuck midway while others surged through. Screenshots of a video of flooding on the road running through Laingsburg on 3 November 2022 can be seen in figure 5, this was concerning, since the rain was still pouring.



Figure 5: Screenshots of the feedback from Lwandile Nokoyo, a disaster manager, as well as those of the video of the road through Laingsburg that was flooded on 3 November 2022 while the rain was still pouring.



Observed rainfall figures

Laingsburg recorded an accumulation of about 22.2 mm on 3 November 2022, which is a new 24-hour rainfall record. During this event, above-normal rainfall was also recorded, since the Long-Time Average (LTA) for November for Laingsburg is 12,9 mm. In addition, it was above April's average rainfall, which is usually the wettest month with an average of 16,1 mm as seen in figure 6.

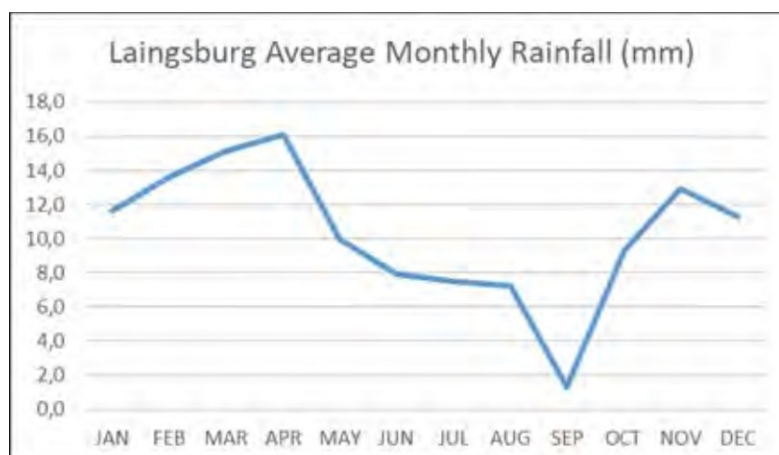


Figure 6: Line graph illustrating Laingsburg's average monthly rainfall from years 2000 to 2022 (source: SAWS, 2023)

Conclusions and recommendations

Lessons can be learnt through Cut-Off Lows and their effects in certain places. Many lessons were learnt through the 1981 Laingsburg floods event, studying concerning Cut-Off Low pressure systems still refer to that event to this day. The 2 to 3 November 2022 COL event that resulting in the flash floods in Laingsburg also offer many lessons. It revealed that it does not have to be an accumulation of hundreds of millimeters of rainfall that can flood areas of Laingsburg.

It does not have to be continuous rainfall for this area to flood, as it was the case in 1981, it took heavy downpours from severe thunderstorms in this 2022 case for the area to flood. One recommendation is that constant monitoring of COLs over the west coast be practiced through nowcasting tools such as satellite information, rainfall figures and others. The use of SARFFG to gauge how vulnerable the Karoo area is during the development of this system to prepare for warnings for disaster management is also advised. Lastly, a more in-depth study comparing COLs resulting in flash flooding in the Laingsburg area to those resulting in flooding from consistent rainfall is encouraged.

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EL NIÑO RAINFALL OVER SOUTH AFRICA

Christien Engelbrecht

1. INTRODUCTION

The El Niño Southern Oscillation (ENSO) is globally the dominant driver of interannual climate variability (e.g. Ropelewski and Halpert 1987). Over the southern African region, ENSO is considered to be the main driver of seasonal climate during austral summer, with El Niño (La Niña), the warm (cool) phase of ENSO associated with below-normal (above-normal) rainfall (e.g. Landman and Beraki 2012, Hoell et al. 2021). However, although El Niño events are typically associated with drier than normal conditions over South Africa, and La Niña events with wetter than normal conditions, it is not always the case (e.g. Blamey et al. 2018, Landman and Beraki 2012) as the relationship between ENSO and southern African climate variability is nonlinear (e.g. Fauchereau et al. 2009). Also, the strength of ENSO events is important, as strong El Niño events usually result in larger below-normal rainfall than weak to moderate El Niño events and with different rainfall anomaly patterns between strong vs weak to moderate El Niño events (Pomposi et al. 2018).

ENSO was in a cool phase the past three summer seasons, with the latest predictions indicating that a moderate El Niño event can be expected for the coming summer (2023/24). In this study, the rainfall anomalies for historical El Niño events are presented to show the regional variation that can occur during warm ENSO phases, even though such events are usually associated with anomalously dry conditions over the South African region.

Data and Methods

ENSO impacts South Africa during its summer season (e.g. Blamey et al. 2018, Landman et al. 2019), with seasonal predictability peaking during the mid-summer (December-January-February (DJF) period (Landman and Beraki 2012). DJF will therefore be a season for which rainfall anomalies during historical El Niño events will be presented in this study. Also, summer circulation characteristics over South Africa differs between the early (October-November-December (OND)) and the late (January-February-March (JFM)) summer periods, with the influence of tropical weather systems present during the late summer season. Rainfall anomalies for OND and JFM seasons during El Niño years will therefore also be presented.

The Climate Prediction Center Unified Gauge-Based Analysis of Daily Precipitation (CPC-Unified) (Chen et al. 2008) is used to derive the rainfall anomaly maps presented here. The data is available from 1979 onwards, has a resolution of 0.5 x 0.5 and is based on station observations. Rainfall totals for OND, DJF and JFM seasons are calculated if at least 80% of the days for each of the months that forms part of the particular 3-month season are present and converted to mm/day. Rainfall anomalies are calculated relative to the associated 1981-2010 (1981/1982-2010/2011 for DJF) seasonal rainfall climatology and expressed as a percentage of normal.

The Oceanic Niño Index (ONI) from the CPC is used to identify El Niño years (obtained from <https://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt>) for which rainfall anomalies for OND, DJF and JFM are calculated and presented. An El Niño event is defined as when the sea-surface temperature anomaly over the Niño3.4 region exceeds 0.5°C for 5 consecutive 3-month overlapping seasons.

Results

The strength of ENSO events can be classified as weak, moderate, strong or very strong according to the ONI value. For El Niño events, ONI values from 0.5-1 indicate a weak event, 1-1.5 a moderate event, 1.5-2 a strong event and larger than 2 a very strong event. The strength of La Niña events is determined similarly, but for negative ONI values. From 1979, the year from which the CPC dataset is available, 14 El Niño events occurred (Figure 1). The strength of each of these 14 events is shown in Table 1.

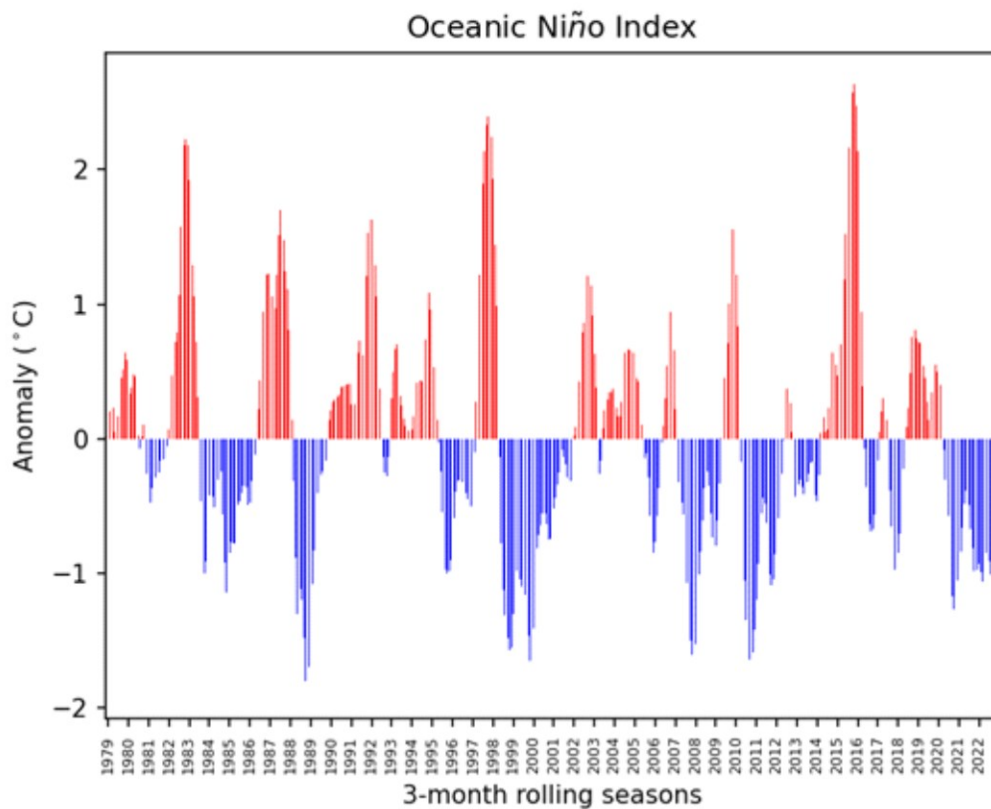


Figure 1: ONI for 3-month rolling seasons starting in DJF 1978-1979 to DJF 2022-2023.

Table 1: Strength of the 14 El Niño events that occurred since 1979

Strength of El Niño event	Summer season when the event occurred
Weak	1979-1980, 2004-2005, 2006-2007, 2014-2015, 2018-2019
Moderate	1986-1987, 1987-1988, 1994-1995, 2002-2003, 2009-2010
Strong	1991-1992
Very strong	1982-1983, 1997-1998, 2015-2016

Of these 14 El Niño events 5, 5, 1 and 3 events were weak, moderate, strong and very strong respectively (Table 1). The rainfall anomalies (expressed as the percentage of normal) for early summer (OND), mid-summer (DJF) and late summer (JFM) for these 14 El Niño events are shown in Figure 2. From Pomposi et al. (2018) it is known that for DJF seasons, strong El Niño events have on average different rainfall anomaly patterns compared to weak and moderate El Niño events. In the analysis presented here, the focus is on the regional variation of anomalous rainfall during El Niño events by means of comparing the El Niño events on an individual basis. From Figure 2, it can be seen that the warm ENSO phases that experienced above-normal rainfall over parts of South Africa that are prominent are the summers of 1979-1980, 1986-1987, 1987-1988 and 2009-2010. The weak El Niño event of 1979-1980 had above-normal rainfall over the northeastern parts of the country during the mid- and late summer. The two consecutive El Niño seasons of 1986-1987 and 1987-1988 as well as the 2009-2010 summer season experienced above-normal rainfall over relatively large parts of the summer rainfall region. The time within the summer season when the above-normal rainfall occurred for the 1986-1987, 1987-1988 and 2009-2010 El Niño seasons, vary from OND (1986-1987) to DJF and JFM (1987-1988 and 2009-2010). Also, the area where the above-normal rainfall occurred is not consistent. Whereas the areas of above-normal rainfall during the 1986-1987 and 1987-1988

seasons are more focussed on the northeastern to central parts of the country, the 2009-2010 summer season was mostly dry over the northeastern parts of the country with the western parts of the country that received above-normal rainfall.

The strong and very strong El Niño events were mostly dry over the larger part of the country. The exception occurred during the 1997-1998 summer season when areas over the central interior received above-normal rainfall. Of the other 3 strong to very strong El Niño events, the summer of 1982-1983 and 1991-1992 had the largest rainfall deficits during the mid- and late summer, whilst the early summer was exceptionally dry during the 2015-2016 summer season. The moderate El Niño seasons of 1994-1995 and 2002-2003 were dry over the larger part of the country, during the early, mid- and late summer, whilst the weak El Niño seasons of 2006-2007 and 2014-2015 were anomalously dry over large parts of the country during the mid- and late summer. This was also the case for the 2018-2019 weak El Niño event, but this event was also very dry during the early summer.

Discussion and conclusion

ENSO is a major driver of interannual rainfall variability over South Africa, with warm events associated with below-normal rainfall over South Africa. However, it does happen that some warm ENSO events experience above-normal rainfall over the country. The El Niño summer seasons that had above-normal rainfall over relatively large parts of the summer rainfall region were all of moderate strength, except for the 1979-1980 season when a weak El Niño event occurred. The strength of El Niño events is important, as strong to very strong El Niño events are mostly associated with widespread rainfall deficits. An exception occurred during the 1997-1998 El Niño event, when areas over the central interior had above-normal rainfall. It also happens that weak El Niño events are associated with widespread rainfall deficits, with the magnitude of the rainfall deficits comparable to that of strong El Niño events. As the relationship between ENSO and rainfall variability over South Africa is non-linear (Fauchereau et al. 2009) and complex (Pomposi et al. 2018), it is very important that seasonal forecast prediction systems are able to capture the cases where warm ENSO events do not result in anomalously dry conditions.

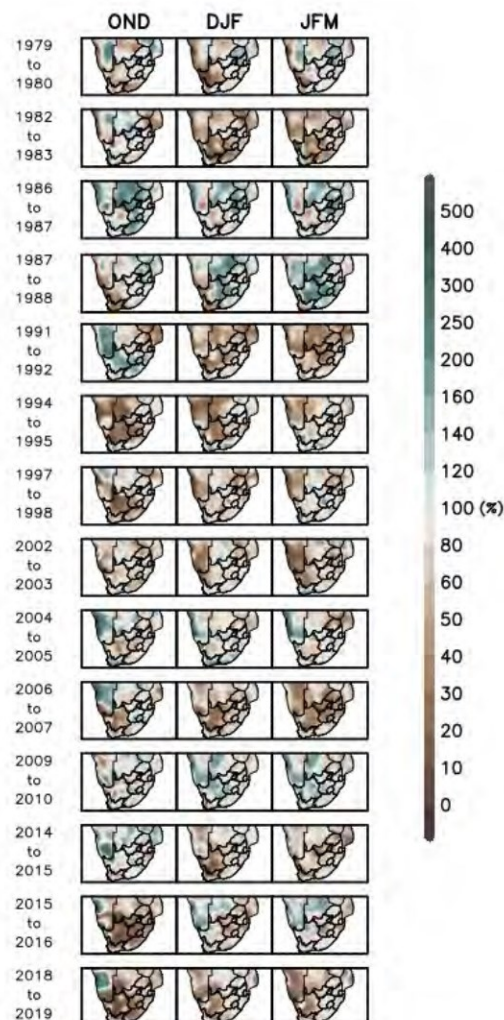


Figure 2: Rainfall anomalies expressed as a percentage of normal for the OND, DJF and JFM seasons during the 14 El Niño events from 1979 onwards

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VARIABILITY IN LONG-TERM TRENDS OF SEASONAL RAINFALL IN SOUTH AFRICA (1921 – 2022)

Andries Kruger, Department: Climate Service

1. INTRODUCTION

Climate change does not only have an effect on surface temperatures through a general long-term increase, but on other weather parameters as well. Of the most immediate significance is precipitation, of which changes in the features thereof have been observed by a large number of studies, global as well as regional. In terms of rainfall amounts, these changes have been largely positive (i.e. more rainfall). There is broad agreement that due to the warming of the atmosphere, the water holding capacity of the air will increase, with subsequent increase in rainfall generally.

However, climate projections show that, while most of the world is expected to experience increases in rainfall there are also regions that will undergo drying over the long-term. Long-term projections for South Africa indicate just that; where mainly the western, south-western and northern parts of the country is expected to become progressively drier. Figure 1 below has been extracted from the SAWS Climate Change Reference Atlas (<https://www.weathersa.co.za/home/climatechangeatlas>), which presents the annual total rainfall (mm per year) change projected for 2036-2065 (a) and 2066-2095 (b), relative to present (1976-2005), under conditions of the RCP 8.5 pathway (a business as usual greenhouse gas emission scenario). The latest IPCC Working Group I Report and Interactive Atlas, based on the most recent CMIP6 model projections, largely confirms the results in Figure 1, indicating significant drying over the western half of the country over the long-term (see <https://interactive-atlas.ipcc.ch/>).

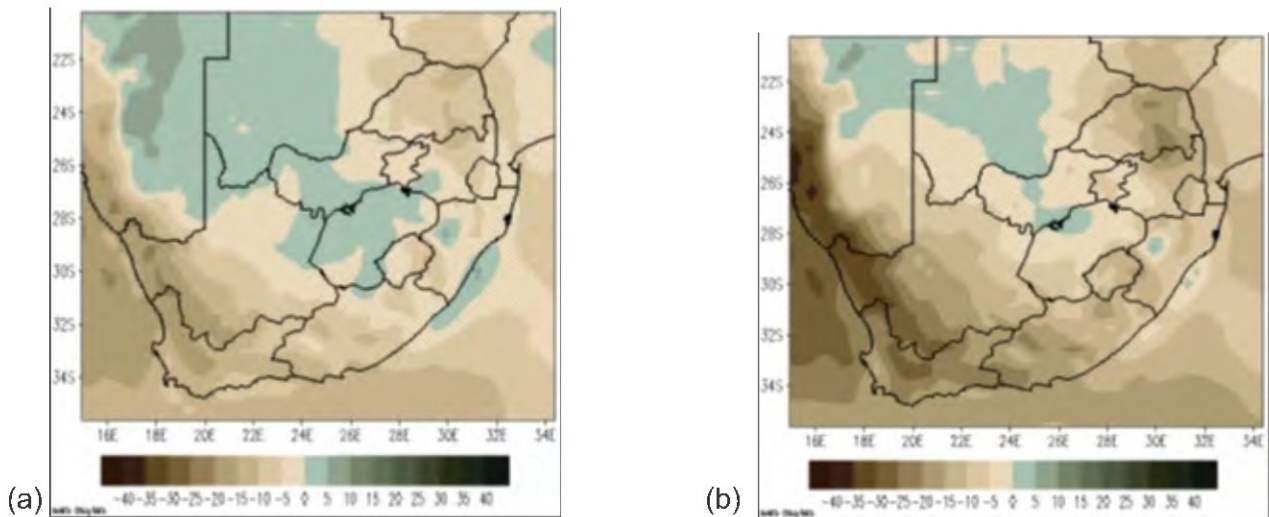


Figure 1: Annual total rainfall (%) change from the median projected for 2036-2065 (a) and 2066-2095 (b), relative to present (1976-2005), under conditions of the RCP 8.5 pathway (<https://www.weathersa.co.za/home/climatechangeatlas>).



The main question this article attempts to address is whether the changes in rainfall that are shown by climate projections over South Africa, above, are already evident in the historical rainfall record, and since when.

The evaluation of long-term rainfall trends largely depends on the period of analysis. Long rainfall time series are most often characterised by wetter and drier periods and sometimes quasi-cyclical behaviour. These features in the time series have the effect that, depending on the period analysed, different trend results will be obtained, which can range from strong negative to positive trends. In addition, it follows that the statistical significance of the trends will also be influenced by the selected analysis period. Previous research in rainfall trends over South Africa, illustrate this, in that there are often not broad agreement over the trends observed in specific regions of the country. While the different statistical methodologies applied can have an effect on the results (e.g. the choice of significance test e.g. parametric vs. non-parametric, and slope estimator e.g. linear vs. other assessment methods), it is most often the analysis period that is the main factor in the differences in results. An effective approach to address this challenge is to evaluate a systematic range of observation periods up to 2022, to determine whether there are recent trends in annual/seasonal rainfall totals and since which year/season those trends were sufficiently robust, by testing for statistical significance. These trends can then be compared against the projected long-term trends in rainfall in South Africa, to ascertain whether these scenarios are already evident in the historical record.

Data

There are a wide selection of data sets which can be utilised for long-term rainfall studies. These include global gridded data sets, e.g. GPCC, ERA 5 and others derived from observations, as well as the actual data from weather stations. A drawback of most of the former data sets are the fact that not all observed data are included in the assimilation of the gridded values. On the other hand, the utilisation of actual observed data over a large region, e.g. South Africa, can be complicated by the various lengths of observation periods, as well as the spatial variability in rainfall station density. In this study monthly district rainfall data, developed by the South African Weather Service, are used. The data consists of the monthly averages of all available rainfall stations reporting in a district in a particular month, for all months since 1921 up to the present. Figure 2 presents the delineation of the rainfall districts, which are deemed to be mostly homogeneous. While this statement can be argued against, for some districts at least, due to the complex topography of South Africa, the demarcation of the largely reflects the seasonal march of rain, main topographical influences, e.g. the escarpment, as well as the general decrease in rainfall from east to west.

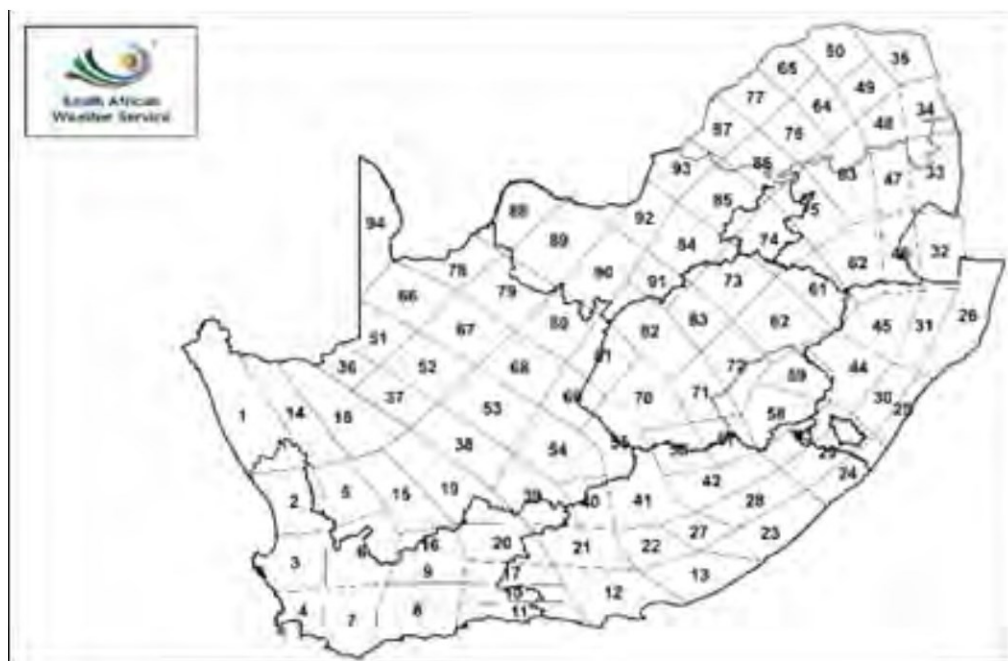


Figure 2: South African Weather Service homogeneous rainfall districts.

The monthly district rainfall totals were summed to annual (Jan to Dec) and seasonal (Jul to Jun) totals, depending on the season of maximum rainfall. Therefore annual totals were calculated for districts 1 to 4 and 5 to 7, while seasonal totals (centred on summer) were analysed for the remainder of the country.

Analysis approach

The analysis of rainfall trends is based on the linear least-squares regression. The significance of the resultant correlations factor, R , and therefore the trend, is tested with the Student's t -test at the 95% level of confidence.

The present climate is defined as the last 30-year period, 1993–2022, the shortest period over which specific climate parameters can be determined (e.g. average rainfall or trend thereof). While the official WMO climate normal period is defined as 1991–2020, the most recent 30-year period is used here to extract the most information from available data. The analysis of historical rainfall trends is approached in a systematic way:

- Firstly establish whether there is a significant trend in the annual/seasonal rainfall in the present climate, i.e. over the period 1993–2022.
- Establish whether there are other significant trends in the rainfall record over longer time periods, which does not necessarily reflect in the most recent 30 years (the present climate).
- Establish whether there are spatial coherencies in the trend results and compare with the future rainfall projections.

Results

The overwhelming majority of rainfall districts do not show any significant trends in rainfall over the last 30 years, with the exception of negative trends in districts 1, 4 and 5 (western and south-western Cape), district 17 (southern Karoo) and districts 27, 28 and 31 (central interiors of the Eastern Cape and northern KwaZulu-Natal), as presented in Figure 3. No significantly positive trends are evident over the recent historical past.

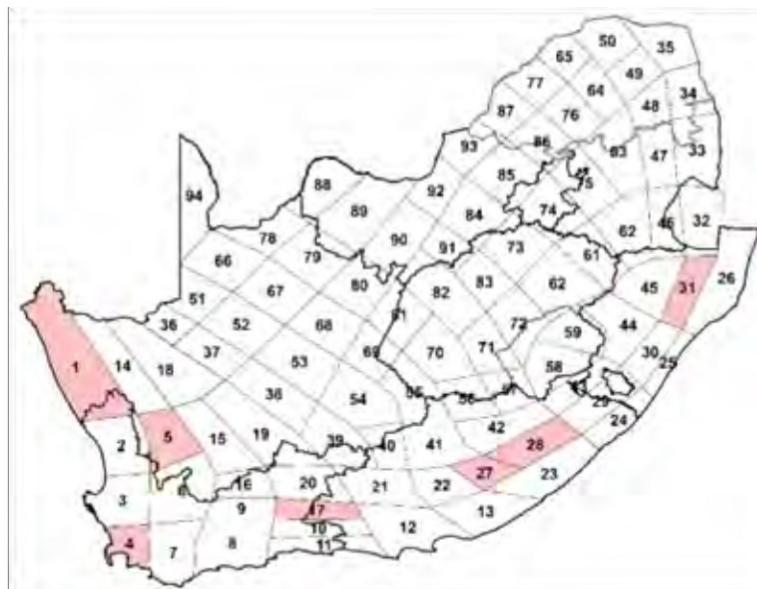


Figure 3: Rainfall districts with significantly negative seasonal rainfall trends over the period 1993–2022.

Regional results

(a) West Coast, south-western Cape and adjacent interiors

Apart from the recent drought in the south-western Cape, which was caused by persistently below-normal rainfall from 2015 to 2018, preliminary data indicates that 2022 was the driest on record. The correlation factor for district 4 is persistently negative from 1929 to the present, and significantly so since 1935, as indicated by the graph in Figure 4. If the black line, the correlation factor R , is between the two bands of positive and negative critical values the trend is not significant for the period from the year indicated on the x-axis up to 2022. However, where R is below the critical value (red dashed line) the trend is significantly negative over the period up to 2022, and above the upper critical value (blue dashed line), significantly positive.

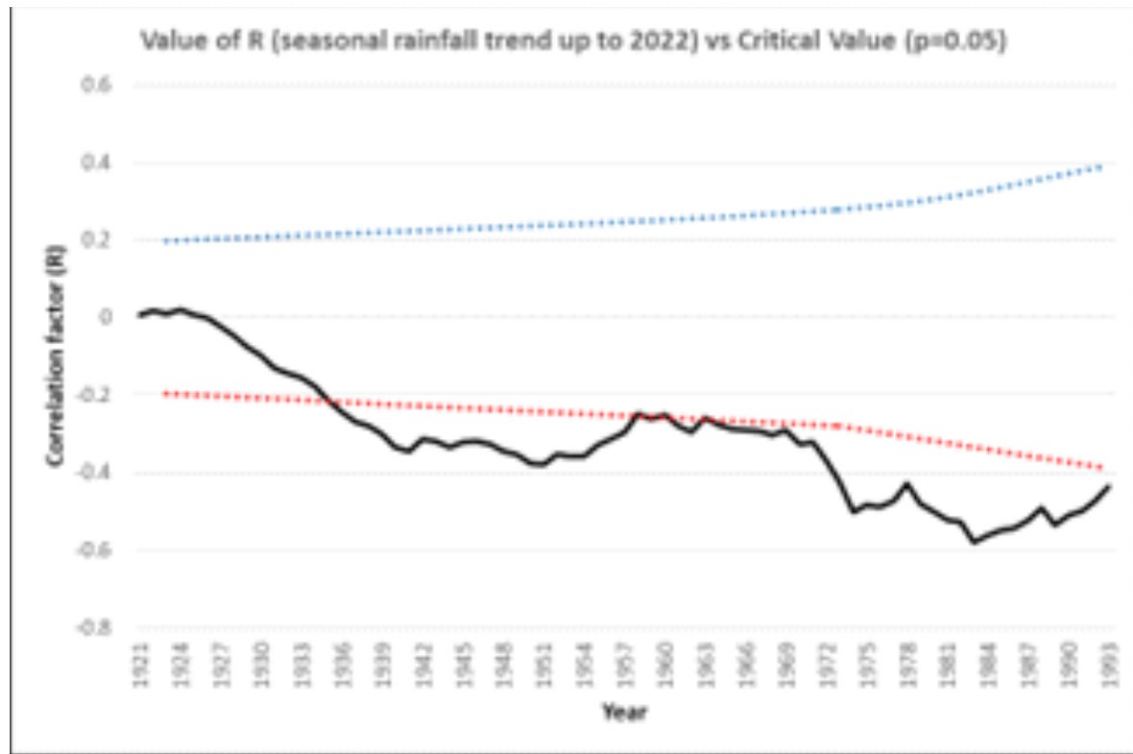


Figure 4: Value of the correlation factor (R) of the linear trend of annual rainfall of district 4 over the period from the year indicated on the x-axis up to 2022. The red dashed line indicate the critical negative values, and the blue dashed line significantly positive values of R.

Figures 5 (a and b) present the annual rainfall for district 4 over the periods 1935 – 2022 and 1993 – 2022 respectively. Over the former longer period the trend magnitude is about -14mm per decade and for the most recent -85 mm per decade, which could be an indication that the drying trend has strengthened over the course of the analysis period.

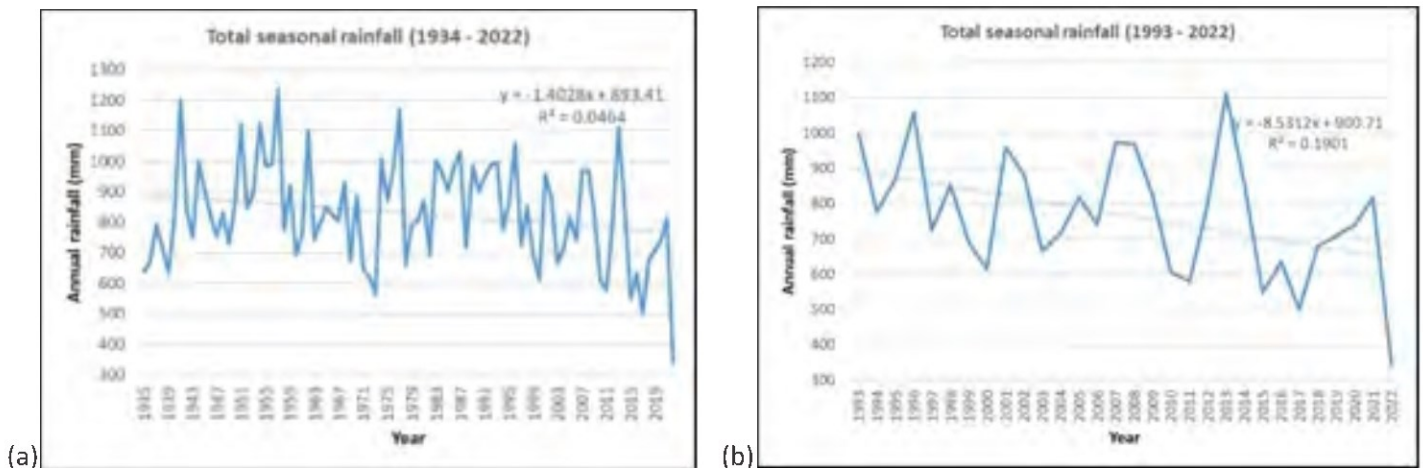


Figure 5: Annual rainfall totals for district 4 over the period (1935 – 2022) (a) and (1993 – 2022) (b).

As shown in Figure 3, several districts in the region show significantly negative trends over the recent past. However, further investigation reveals that the majority of districts in the region exhibit negative rainfall trends, depending on the period of analysis: Districts 1 and 3 show significantly negative trends for the period 1921 – 2022, district 4 since 1935, district 5 since 1972, district 17 since 1991 and district 18 since 1973. These districts are presented in Figure 6.

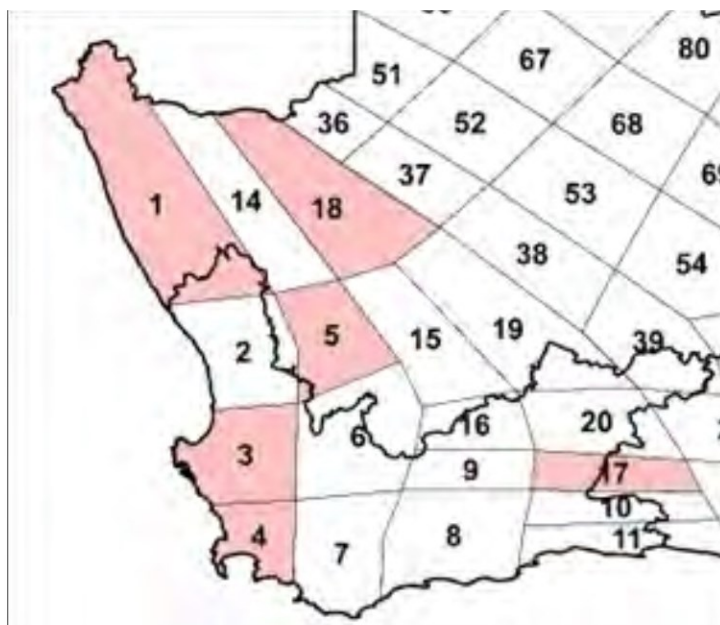


Figure 6: Rainfall districts in the western parts of South Africa with significantly negative seasonal rainfall trends over various time periods since 1921: Districts 1 and 3 (1921 – 2022), district 4 (1935 – 2022), district 5 (1972 – 2022), district 17 (1991 – 2022) and district 18 (1973 – 2022).

(b) Eastern Cape

In Figure 3 it is shown that district 27 and 29 in the central interior of the Eastern Cape have both experienced significantly negative trends in the recent past (1993 – 2022). However, additional districts in the province show significantly negative trends if calculated over other, longer, time periods ending in 2022. These are district 22 (1968 – 2022), district 27 (1958 – 2022), district 28 (1993 – 2022), district 56 (1973 – 2022) and district 57 (1970 – 2022), presented in Figure 7.



Figure 7: Rainfall districts in the Eastern Cape with significantly negative seasonal rainfall trends over various time periods since 1921: District 22 (1968 – 2022), district 27 (1958 – 2022), district 28 (1993 – 2022), district 56 (1973 – 2022) and district 57 (1970 – 2022).

(c) KwaZulu-Natal

As indicated, district 31 shows a recent significantly negative trend since 1993. However, the trend is also significant if calculated as far back as 1951, since when the R-values have been in significantly negative territory over a number of time periods, calculated up to 2022 (Figure 8).

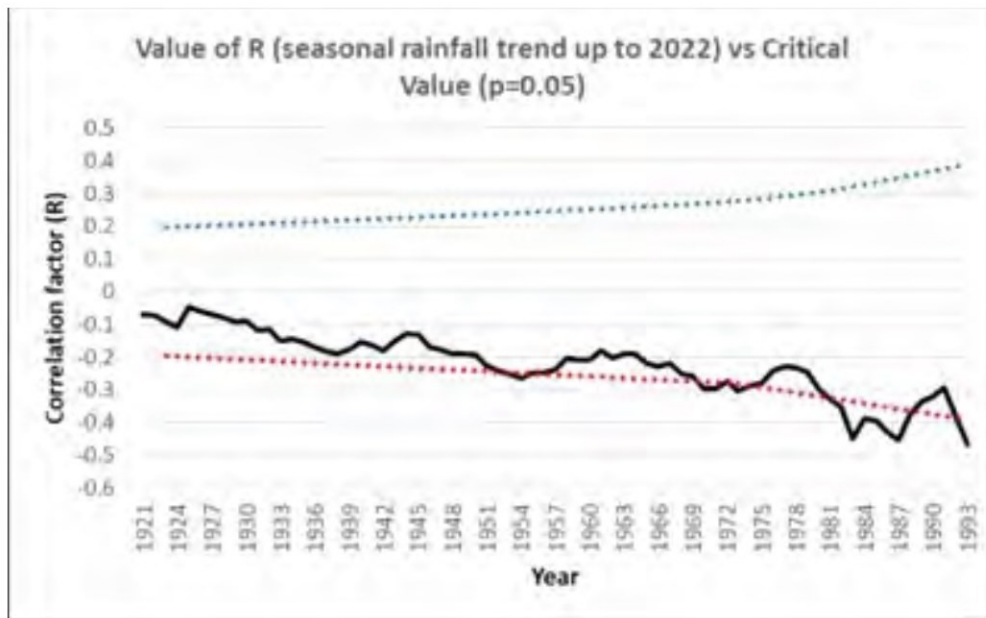


Figure 8: Value of the correlation factor (R) of the linear trend of annual rainfall of district 31 over the period from the year indicated on the x-axis up to 2022. The red dashed line indicate the critical negative values, and the blue dashed line significantly positive values of R.

Figure 10 (a) presents the seasonal rainfall totals for District 25 inclusive of the 2021/22 rainfall season and (b) excluding rainfall up to the 2020/21 season. It can be seen that the negative trend in Fig. 9(a) is weaker than in Fig. 9(b).

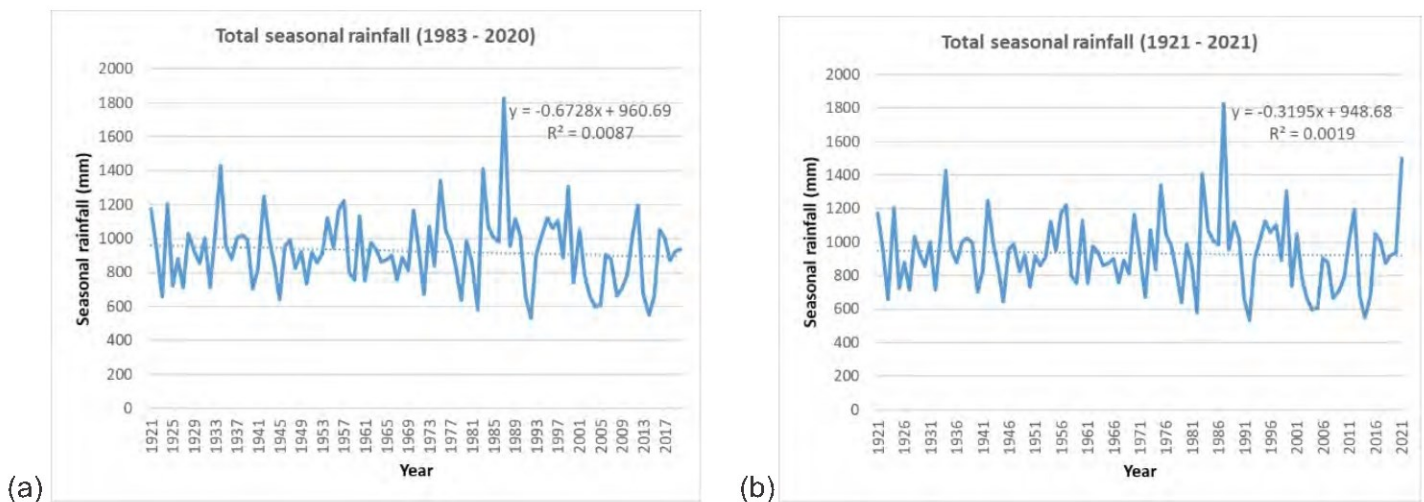


Figure 10: Seasonal rainfall for rainfall district 25 with linear trend for the period 1921/22 – 2021/22 (a) and 1921/22 – 2020/21 (b).

Further analysis shows that the district has a significant negative trend for the period 1983 – 2020, as shown by the statistically significant value of R in Figure 11(a). The seasonal rainfall trend for the period 1983 – 2020 is presented in Figure 11(b) and shows a decrease in seasonal rainfall of about 87 mm per decade over this period. This illustrates that a few exceptionally high rainfall events can have a significant effect on the long-term trend, even in regions which receives relatively high rainfall, such as the KwaZulu-Natal coast.

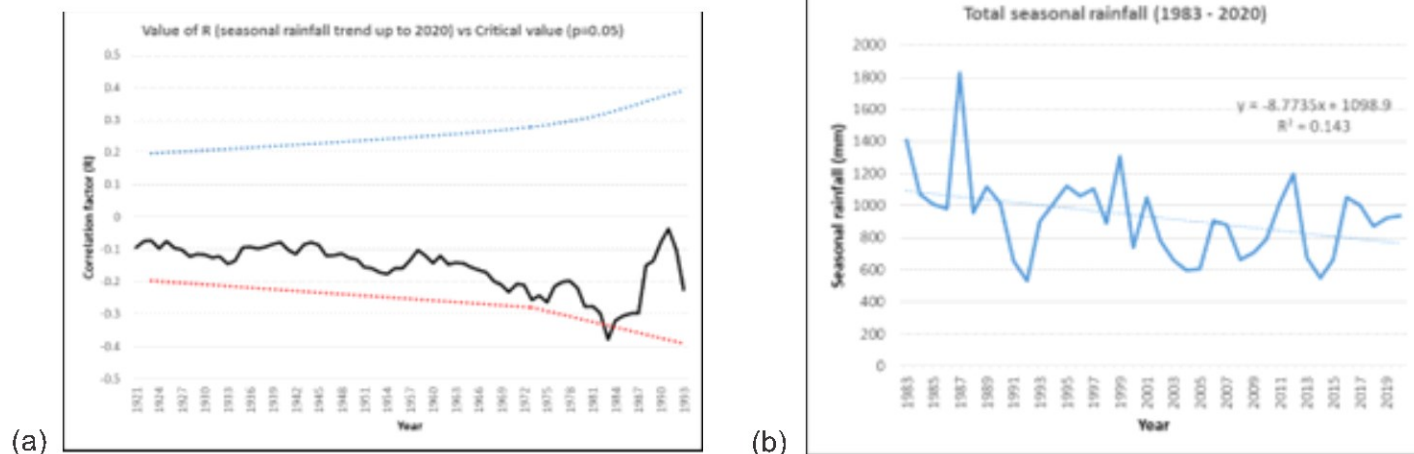


Figure 10: Seasonal rainfall for rainfall district 25 with linear trend for the period 1921/22 – 2021/22 (a) and 1921/22 – 2020/21 (b)

(d) Limpopo

A number of studies have shown that the northern part of South Africa, which mostly comprises Limpopo, experienced drying and is also expected to become drier in future. However, if the trends in seasonal rainfall is analysed over the last 30 years, no rainfall districts show significant drying. Nevertheless, district rainfall time series show significantly negative trends if analysed from further back in the past up to the present: Districts 64 and 65 (1921 – 2022) and district 86 (1966 – 2022). All these districts fall in the central and south-western parts of the province, as presented in Figure 12.

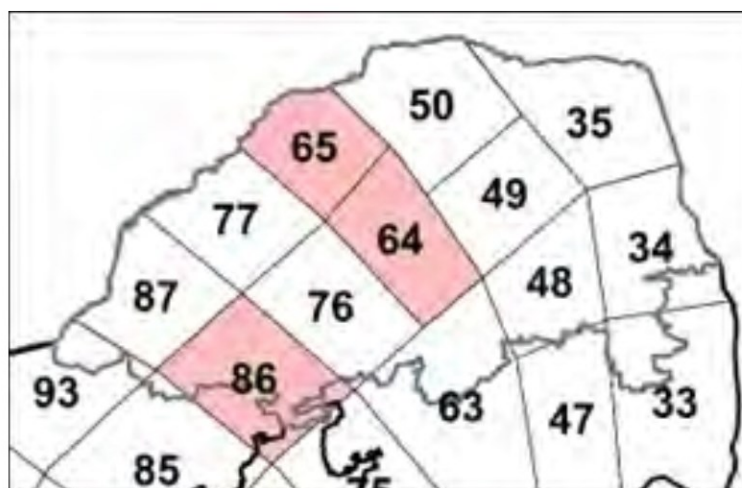


Figure 12: Rainfall districts in Limpopo with significantly negative seasonal rainfall trends over various time periods since 1921: Districts 64 and 65 (1921 – 2022) and district 86 (1966 – 2022).

National results

(a) Decreasing trends

Figure 13 presents a map of rainfall districts with significantly decreasing seasonal rainfall trends over any time periods of at least 30 years, ending in 2022. This largely summarises the regional results, with the addition of some districts in the western and far eastern interior, not discussed in the regional results. The results show that these districts are mostly situated along the western, southern, eastern and northern interiors, as well as some adjacent coastal areas.

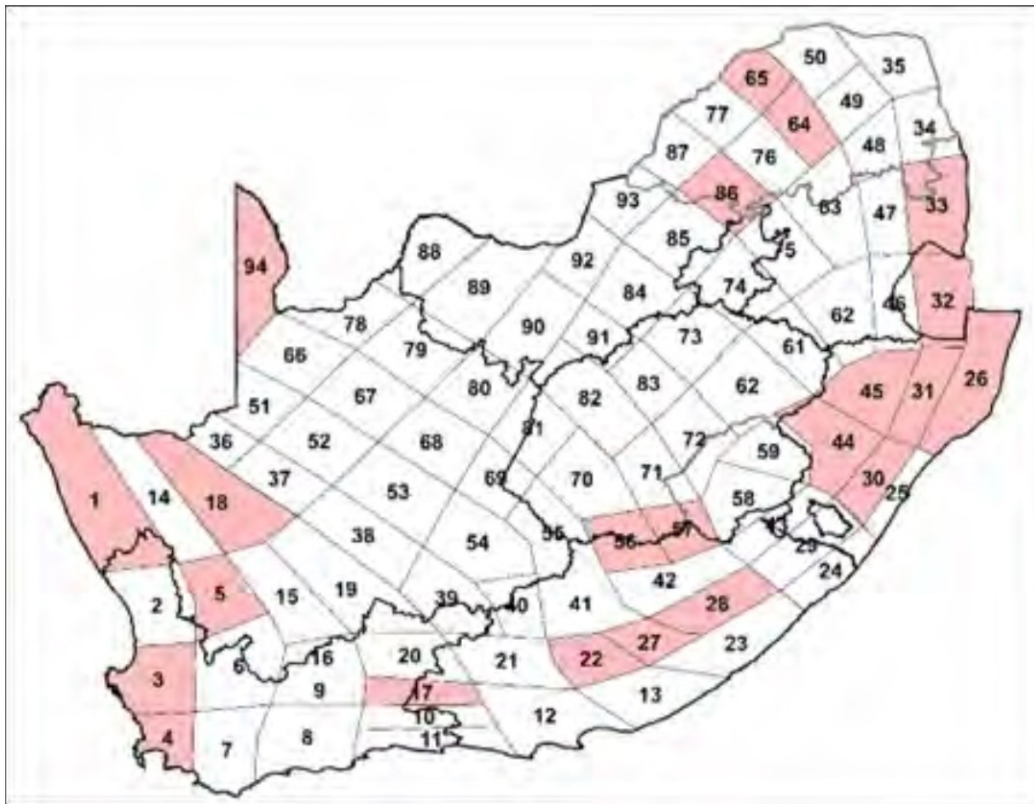


Figure 13: Rainfall districts in South Africa with significantly negative seasonal rainfall trends over various time periods since 1921, all ending in 2022.

(b) Increasing trends

There are a number of rainfall districts exhibiting significantly positive trends over various time periods of at least 30 years, ending in 2022. Fig. 14 presents these rainfall districts, which are mostly situated in the Southern Cape interior, Overberg region and north-western interior. It can be seen that some districts in the west are very close to those exhibiting significantly negative trends and district 17 show both significantly negative (1991 – 2022) and positive trends (1921 – 2022), depending on the analysis period.

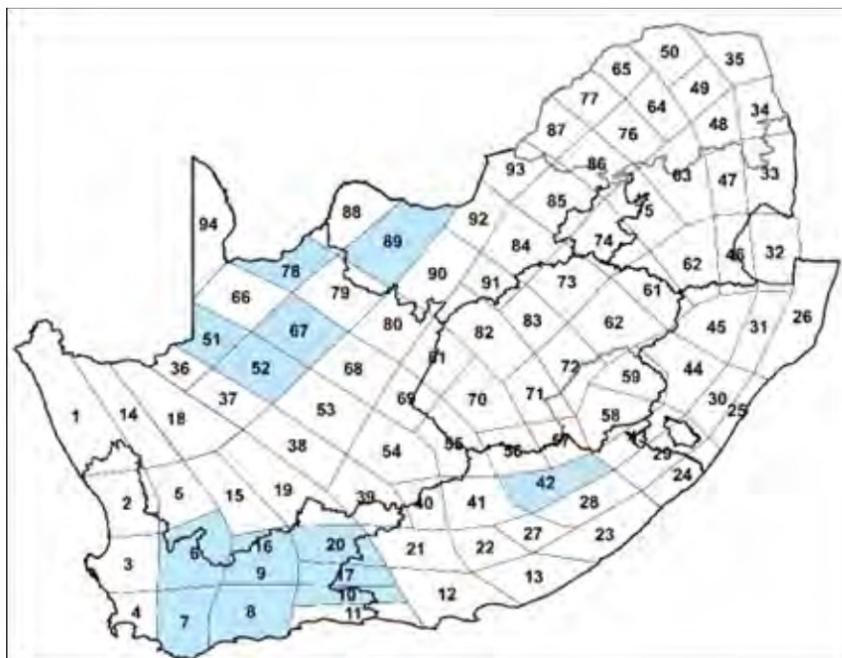


Figure 14: Rainfall districts in South Africa with significantly positive seasonal rainfall trends over various time periods since 1921, all ending in 2022.

All the districts highlighted in the south show significantly positive trends for the complete analysis period, i.e. 1921 – 2022. However, they do not show the same trends over the last 30 years. For example, district 7 in the Overberg has recorded its lowest annual rainfall total in 2022 and Fig. 15 shows that there is a general decrease in R as the analysis period is shortened to more recent periods.

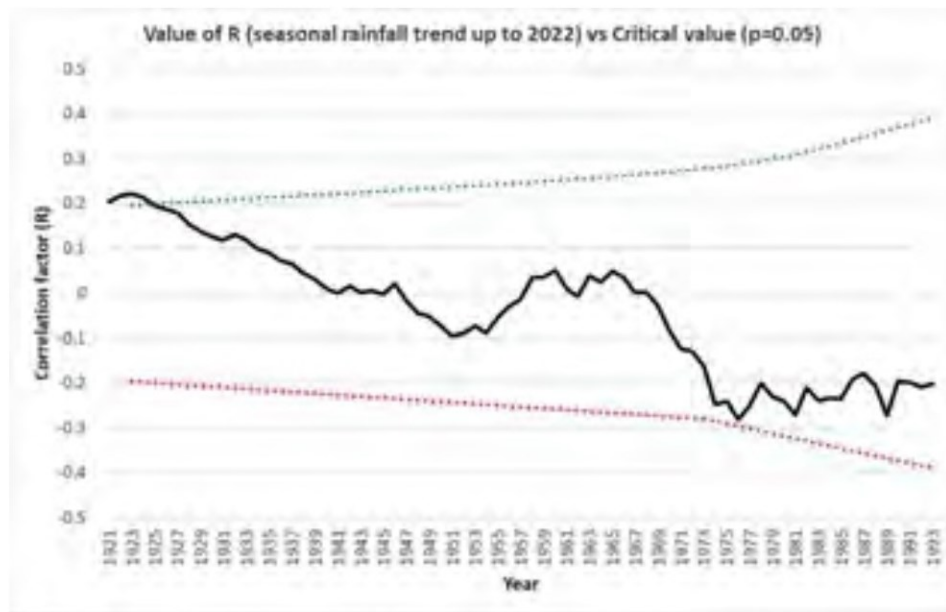


Figure 15: Value of the correlation factor (R) of the linear trend of annual rainfall of district 7 over the period from the year indicated on the x-axis up to 2022. The red dashed line indicate the critical negative values, and the blue dashed line significantly positive values of R.

In contrast with the southern regions, the districts in the north all have their significantly positive trends in since the early 1970s, indicating a more recent trend to a wetter climate.

Summary and conclusions

A systematic analysis of rainfall trends from 94 rainfall districts over the period 1921 – 2022 has been conducted. The majority of rainfall districts do not show any significant trends in rainfall over the last 30 years, with significantly negative trends limited to the extreme western, south-western, southern and eastern parts of South Africa.

Considering extended periods as far back as 1921, but ending in 2022, more widespread parts of the country exhibit significantly negative trends, but mostly in the above-mentioned regions, which excludes the central interior parts of the country.

The eastern half of the Western Cape exhibit significantly positive trends over the very long term since 1921, but exhibit signals indicating to a possible systematically drier climate in recent years. The north-western interior show significantly positive trends over more recent periods, since the early 1970s to the present.

The spatial distribution of the historical results (Figures 13 and 14) largely coincides with those of projections (see Fig. 1), except for the mentioned eastern half of the Western Cape.

The summary of the results lends confidence, in and largely corresponds, with the long-term rainfall projections, which points to a generally drier climate, with the exception of the central and north-western interior. Relatively large metropolitan areas and/or their main water sources, such as Cape Town, are situated in the drying regions. This calls for urgent adaptation measures, since the affected regions are undergoing substantial increases in population as well as urbanisation.

MEET THE AUTHORS

Dr Markus Geldenhuys is a forecaster in the Gqeberha (Port Elizabeth) weather office. He completed his MSc in Meteorology at the University of Pretoria where he studied low-level wind flow and turbulence in a mountainous environment. During his PhD in Physics at the Bergische Universität of Wuppertal and at Forschungszentrum Juelich in Germany he studied gravity waves in the troposphere and stratosphere. During his time in Germany he won the University award for the best PhD in the Mathematics and Physics department.

He has a particular interest in field work and experiments and has been conducting them from early on. He started working on fognets to collect water for isolated communities. In his masters he set-up an experiment using AWS's and radiosondes. For his PhD he worked with a remote sensing limb imager aboard a research aircraft. Here one of his key jobs was to plan a flight and direct the aircraft into gravity waves over Argentina and Antarctica.



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MS Kanyisa MAKUBALO

Ms Kanyisa Makubalo is a very energetic and curious forecaster that leans firmly on hard work to achieve most of her achievements and goals. She is a weather forecaster, holding an honours degree in Meteorology with a forecasting focus and special competency in public, marine and aviation forecasting. She is based at the Cape Town weather office where she plans on making her mark as one of the household names of the South African Weather Service.

Mr Siyabonga Mpati is a passionate meteorologist, with a particular interest in applying meteorology in farming. He has been a weather forecaster at the Bloemfontein weather office for over 3 years, and in his time as a forecaster has contributed to high quality research through his co-authorship (2nd author) in a journal paper: Ndarana, T., Mpati, S., Bopape, M., Engelbrecht, F. and Chikooro, H. (2021). The flow and moisture fluxes associated with ridging South Atlantic Ocean anticyclones during subtropical Southern African summer. International Journal of Climatology, 41, E1000-E1017, doi: 10.1002/joc.6745.

Also, he has co-authored another journal with Thando Ndarana, Tsholanang Rammopo, Donald Nkabinde, Mary Jane Bopape, Siyabonga Mpati, Patience Mulovhezi and Mthobisi Nxumalo. The dynamics and predictability of rainfall producing systems in the South African domain. WRC report no. 2829/1/21. ISBN 978-0-6392-0270-9. He graduated with an honours degree in Meteorology in 2018 from the University of Pretoria and did his forecasting training in 2019 with the the Regional Training Centre (RTC) in Pretoria. He is currently working on his Master's of Science (MSc) degree with the University of Pretoria, with the hope completing by the end of this year.



Mr Siyabonga MPATI

Dr Christien Engelbrecht started her career in July 1998 as a weather forecaster at what was then the South African Weather Bureau. She extended her weather forecast experience to tropical Africa, while forecasting for United Nations operations in Kinshasa during 2003. She returned to South Africa in 2004 to commence with a MSc (Meteorology) and graduated in 2007. Although she started her MSc research on a full-time basis, she joined the Institute for Soil, Climate and Water of the Agricultural Research Council in May 2006. As a researcher at the Agricultural Research Council, she obtained the PhD (Meteorology) degree at the University of Pretoria and graduated in April 2016.

At the ARC, she applied her skills in the analysis of climate model simulations towards an enhanced understanding of how various climate attributes may influence the agricultural sector in South Africa. This includes investigation of predictability attributes on agriculturally important timescales. In July 2019, Christien started to work in the Long-Range Prediction Group at the South African Weather Service, from where she will further contribute to produce climate forecasts to serve the various industries, but in particular the agricultural community of South Africa.



Dr Christien ENGELBRECHT



Ms Stella NAKE

Ms Stella Nake is a Senior Meteorologist based in the Cape Town Weather Office. She has worked for the South African Weather Service, specializing in weather forecasting since 2006. Her interests are related to mid-latitude weather systems, weather forecasting, disaster risk management, climate change adaptation, quality control, and operations management. She holds both a BSc degree in Meteorology and BSc Hons degree Meteorology from the University of Pretoria.

She is currently enrolled in an MSc in Disaster Management at the University of the Free State. Her research is based on the impacts of heat waves in the West Coast District municipality, South Africa.

Dr Andries Kruger is a Chief Scientist: Climate Data Analysis and Research in the Department: Climate Service of the South African Weather Service. His present and previous duties include the creation and writing of general climate publications, climate change and variability research with historical data as input, ad hoc scientific projects of which the numbers have increased substantially in recent years, climate data and information requests, where advanced statistical analyses are required, drought monitoring, and assisting in the quality control of climate data.

In 2001, Dr Kruger obtained a PhD (Civil Engineering) degree at the University of Stellenbosch on the research topic “Wind Climatology and Statistics of South Africa relevant to the Design of the Build Environment”. Before that, he obtained an MSc (Environmental and Geographical Science) degree at the University of Cape Town. He has published papers both locally and internationally, and authored a SAWS series of publications on the general climate of South Africa. He is widely recognised, both nationally and internationally, for his research, which involves advanced statistical analyses and interpretation of historical climate data.



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Mr Wayne Venter is a Forecaster at the Pretoria Head Office where he started in January 2016. He did his honours degree in Meteorology at the University of Pretoria and he has a particular interest in severe weather and the impacts thereof. He is an active supporter and contributor to SAWS' social media platforms.

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