WEATHERSMART NEWS

Scientific meteorological and climatological news from the South Africa Weather Service

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South African Weather Service®

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South African Weather Service

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FOREWORD
Chief Executive Officer

Welcome to yet another exciting edition of WeatherSMART News.

It has been more than seven years since the first edition of this publication was issued. The enthusiasm, energy and zeal that the South African Weather Service (SAWS) had in compiling that first issue is the same passion that drove the compilation of all subsequent issues.

The (SAWS) continues to embody and personify its organisational vision of achieving an end-state where citizens are weathersmart and resilient and able to use the SAWS' information, products and services optimally.

This issue covers a wide spectrum of interesting and informative topics. We first take a retrospective view of the past six months, followed by research and case studies focused on the future.

The past six months have been riddled with adverse weather events such as the gustnado near Naval Hill on 30 May 2023, and the widespread snowfall over the Eastern Cape on 9-10 July 2023. The Western Cape was not spared as it encountered a Cut-Off Low system which wreaked havoc, followed by water and landspouts. Our neighbouring country, Namibia, experienced dust and sandstorms along their coast from 10-11 July 2023. These impacted not only marine and aviation forecasts, but also posed a threat to life and property as the blowing sand and dust led to significantly reduced visibility along southern Africa's coastal areas.

The SAWS prides itself in not only providing timely and accurate weather forecasts, but also conducting research to better understand and prepare for future weather events because the preparedness for weather events goes beyond the forecast and nowcast of the day. Insightful studies and research has been conducted on the extreme weather events of the past six months – these are certainly must reads!

As we shift gear from the past to the present and into the future, we take a look at the International Panel on Climate Change (IPCC) assessment report, which focuses on the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

We also focus on the state of heat waves in South Africa. Weather and climate extremes have adverse effects on the environment, biodiversity, economy, and society in general. They may hamper the attainment of Sustainable Development Goals (SDGs) and National Development Plan. Considering the current state of South Africa, any factors which impact on the SGDs and the NDP become areas of national importance.

I hope you find this edition valuable and informative. I further trust that you will enjoy reading it as much as we have enjoyed putting it together with the hope of creating a WeatherSMART nation.

Ishaam Abader

Chief Executive Officer

GUSTNADO NEAR NAVAL HILL NEAR BLOEMFONTEIN CITY: THE EVENT OF 30 MAY 2023

Puseletso Mofokeng, Michael Nethavhani, and Rejoyce Mohlamme

ABSTRACT

A wide range of factors such as hills, cliffs, mountains, the return period of extreme events in one location, climate change and building standards, amongst others, should be part of the preparation for the occurrence of extreme weather. Therefore, the preparedness for a variety of severe weather at multi-province scale or even at one localised zone (mesoscale) goes beyond the forecast and nowcast of the day.

This study attempts to reconstruct and ameliorate the impact of wind velocity profile of Tuesday, 30 May 2023, which led to the development of a gustnado. Consequently, this event led to uprooted trees, blown-off roofs, damaged property and disrupted municipal services to the south-east of Naval Hill in Bloemfontein in the Free State, South Africa.

1. BACKGROUND

The development of a cut-off low (COL) pressure on the last weekend of May 2023 posed a threat of a variety of extreme weather. Over and above daily forecasts and severe weather alerts, the South African Weather Service (SAWS) issued a media release on Friday, 26 May 2023.

The media release highlighted and heightened the potential bad weather from the last Sunday up to the last 3 days of May. The eminent events included disruptive rain over the Eastern Cape as well as storms that could be associated with hail and damaging winds over the central interior of South Africa.

The study excludes other weather reports but focus on calls, social media commentary and video footage which were received from the public and media. A team of surveyors was set up in a quest to establish the facts, following the question whether the wind impact resulted from a microburst or a tornado.

2. INTRODUCTION

The study of historical wind direction and high-speed over a specific site is essential for the prediction of the future wind speed value (Nof and Paldor, 1992; Cohen and Cangialosi, 2010; Nambandi, 2020). But beyond positional wind strength data, radial extent of such high-speed wind should also be considered (Knaff and Sampson, 2015).

Strong outflow wind is often found on the downstream of the convective storms (Terblanche et. al, 2000). Such occurrence is typical in regions with cross-band circulation and optimal shear instability, particularly in association with small-sized or narrow convective storms (Seltzer, 1984).

It is widely accepted among meteorologists that weather variables (pressure, temperatures, wind speed and direction, etc.) measured or estimated at 500 mb (i.e. about 5,5 km above mean sea level) have no influence of surface features like hills, cliffs, or mountains. But, according to Smith (1980), sensitivity of the wind flow could be reflected in infinite amplitudes (e.g., pressure perturbation) effects. Optimally increased moisture content often leads to instability of the flow (Seltzer, 1984). Sometimes, large amounts of vorticity advection at 500 mb generate strong rotating flows (Ndabambi, 2002).

Such flows occasionally interact with surface features (Davey, 1980). Outflow of the thunderstorm interacting with the bell-shaped mountain is usually deflected around it (Pan and Yang, 2022). Smith (1980), however, noted that the wind flow interacting with the broad mountain is often influenced by the Coriolis force.

Coriolis force is cyclonic in the southern hemisphere (Holton, 2004; Potts *et. al*, 2023). In interaction with broad significant landmark, fluids (e.g., convective storms) aligning with Coriolis force often moves to the left (Jury, 1984). But the wind flow could be channelled and compressed in a small-sized, concave-shaped surface feature (…)

Additional to compression, WMO (1978) illustrates that the suppression of wind flow in the lee (downslope) often becomes a trigger for high speed (damaging) wind. Complexities to the anticipation of well-approximated high-speed wind (e.g., gale force) should be considered. According to Evans (1992), such complexities include the size of the landmarks, depths of convective clouds and the speed of their respective gust fronts and gustnadoes.

A gustnado is defined as a small whirlwind which does not connect with any cloud base but forms as an eddy in outflow (gust fronts) of thunderstorms (NOAA, 2023). Therefore, a gustnado is not a tornado but stronger ones could cause damage, which could be rated in the scale of EF0 and EF1 phenomenon (Markwoski and Richardson, 2010).

3. DATA ACQUISITION AND METHODOLOGY

The forecast problem *du jour* (of the day) was determined for both Monday, 29 May 2023, and Tuesday, 30 May 2023 by using outputs of the Unified Model (UM) 4,4 km. A COL pressure system was found to be the dominant weather feature for these two days.

Associated instabilities, with the orientation of the trough axis, were used to determine the potential for extreme weather. The development, propagation, intensification, and decay of storms were monitored through the products generated from remote sensing tools, such as meteorological satellites and radar.

These tools were used alongside the in-situ station data as well as closed-circuit television (CCTV) footage. Moreover, a team of surveyors from the Bloemfontein Weather Office visited the site for public accounts (qualitative data) and the collection of photographic evidence to beef up the subsequent analysis.

4. RETROSPECTIVE ANALYSES

4.1 Numerical Prediction Model

The trough axis that was linked to the COL is compared for Monday, 29 May 2023, and Tuesday, 30 May 2023 (see Figure 1). As reflected in Figure 1a, throughout Monday, the COL was leaning backward with height (i.e. baroclinic) with the equatorward sector of the trough axis oriented to the west. Such a set-up most often causes comparatively less vorticity advection at 500 mb.

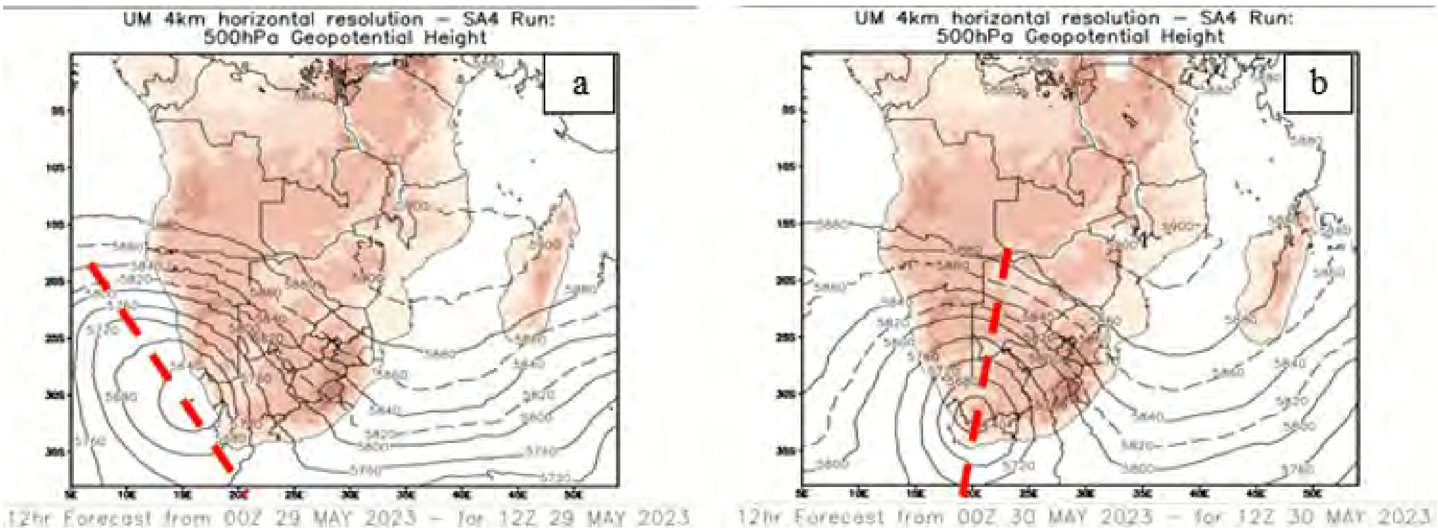

Figure 1: Comparison of trough axis (dashed red line) on 29 and 30 May 2023

However, on Tuesday, the trough axis shifted to a near north/south arrangement, as shown in Figure 1b. This shift in trough axis orientation, particularly when the north sector is oriented to the east, tends to generate a pronounced increase in 500 mb vorticity advection.

4.2 Satellite Image Analysis

Previous documentation argues that the north/south or north-east/south-west trough orientations have less baroclinicity (more towards barotropic arrangement). Such change is usually linked with convective cloud thinning and lesser potential showers, as shown in Figure 2, compared with a broader area of precipitation in earlier hours (not shown).

The satellite showed an organised thunderstorm cell at 15:45 SAST (Figure 2a) with estimated cloud-top temperatures (CTTs) of between -40 and -45°C to the south-west of Bultfontein (-28.50, 25.90). About 15 minutes later, at 16:00, the same storm moved for 74,76 km in Bloemfontein (-29.1, 26.25) and was slightly less organised, with warmer CTTs at between -39 and -44°C at 16:00 SAST. A steep drop in CTTs is often linked with stronger surface winds.

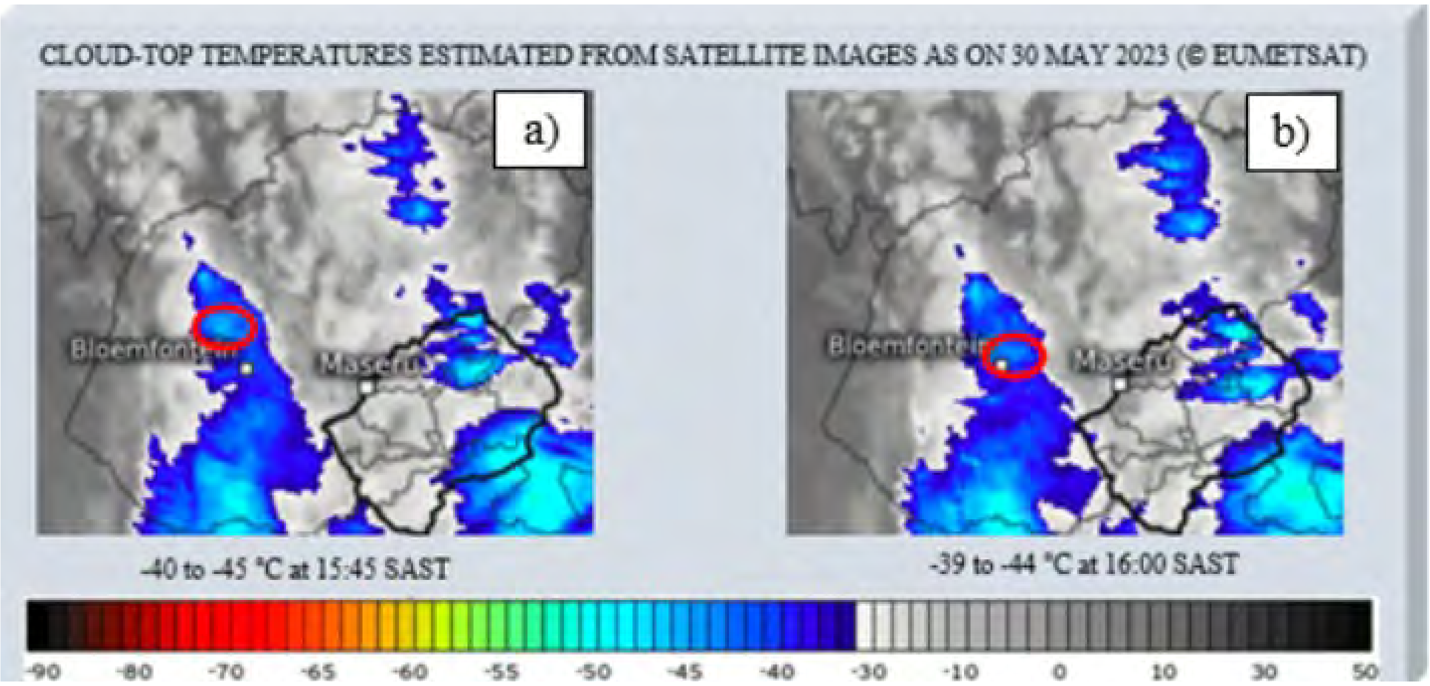

Figure 2: Cloud-band with colder temperatures on a) than 15 minutes later on b)

Rouault *et. al* (2001) argues that light to moderate showers are likely when cloud-top temperatures are in the region between -38 and -54°C. With such showers, discrete thunderstorm cells in a series could result in flooding when passing over a single flood-prone sub-region. Otherwise, heavy rain with flooding could be expected with cloud-top temperatures which are numerically less than -54°C (Rouault *et. al*, 2001).

4.3 Radar analyses

A squall-line (line of storms) developed on the far east of the Northern Cape in the early afternoon of Monday, 30 May 2023. This squall-line moved east-south-eastward across Bloemfontein city and the surrounding areas later that afternoon, as shown on the radar in Figure 3a below.

Deep convection is often found in summer. However, the event of the Monday afternoon in question showed non-alarming, modest convection (Figure 3b) which could mislead the operational forecaster to casual analysis and failure to issue mesoscale forecast.

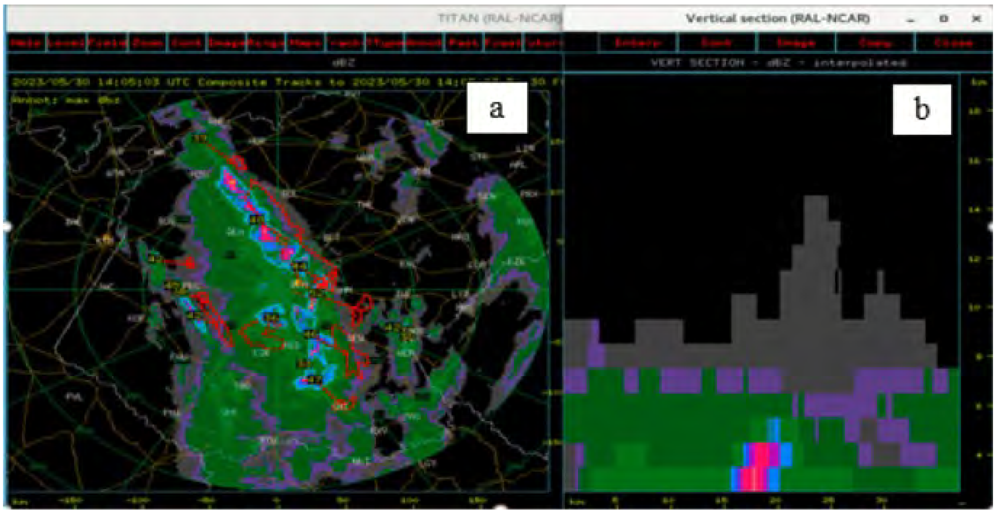

Figure 3: Radar imagery, reflectivity (DBZ) within the squall-line and cross section

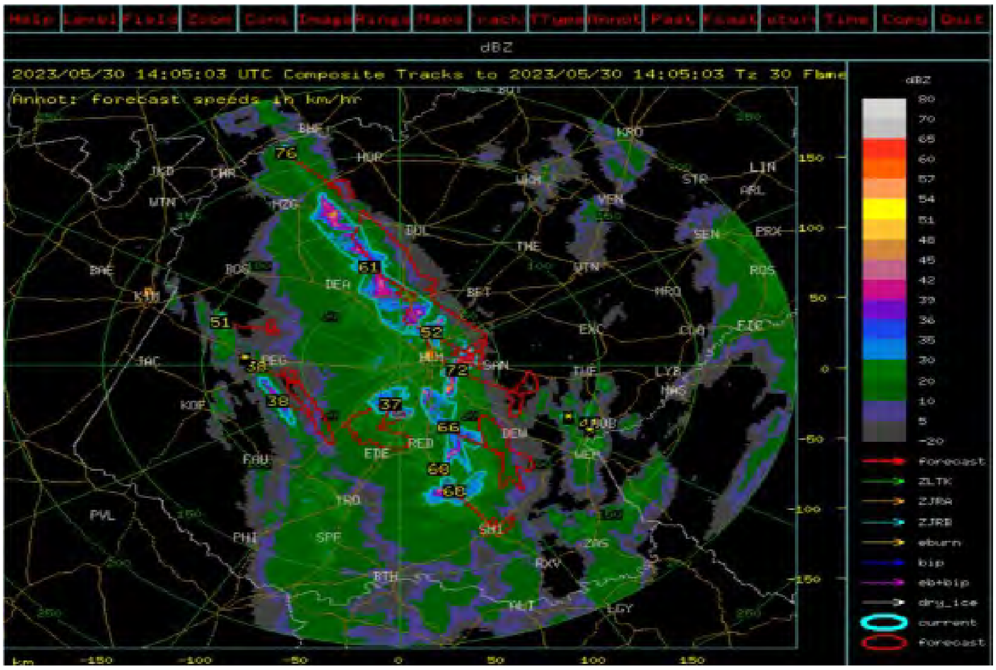

Figure 4: Radar imagery showing the storm speed

In a case study conducted by Feng and Hu (211), the near-surface wind speed of 27,5 $m.s^{-1}$ (99 km,h^{-1}) was recorded slightly ahead of a strong radar echo of 50 dBz. Such wind strength is potentially damaging and with vertical rotating movement it could be rated as an EF0 event.

A repeat finding by Liesker (2020) linked the strong thunderstorms with at least 50 dBz, travelling fast at a minimum of 50 km,h^{-1}. On 30 May 2023, the Bloemfontein radar displayed the highest cloud-tops near Bloemfontein at about 10 km above the ground, with an average reflectivity of 52 dBz and an estimated storm speed of 72 km,h^{-1}, as shown in Figure 4 above.

5. RESULTS

It is exceptionally complex to pinpoint the potential occurrence of localised events such as microbursts, tornadoes or even gustnadoes. A team of surveyors found that the damage started at Hilton, about 500 metre to the south-east of the Naval Hill, near Bloemfontein.

Figure 5 illustrates the damage to items and property in an almost linear fashion which was sustained for about 3 km to the south-east up to the East End in the industrial area.

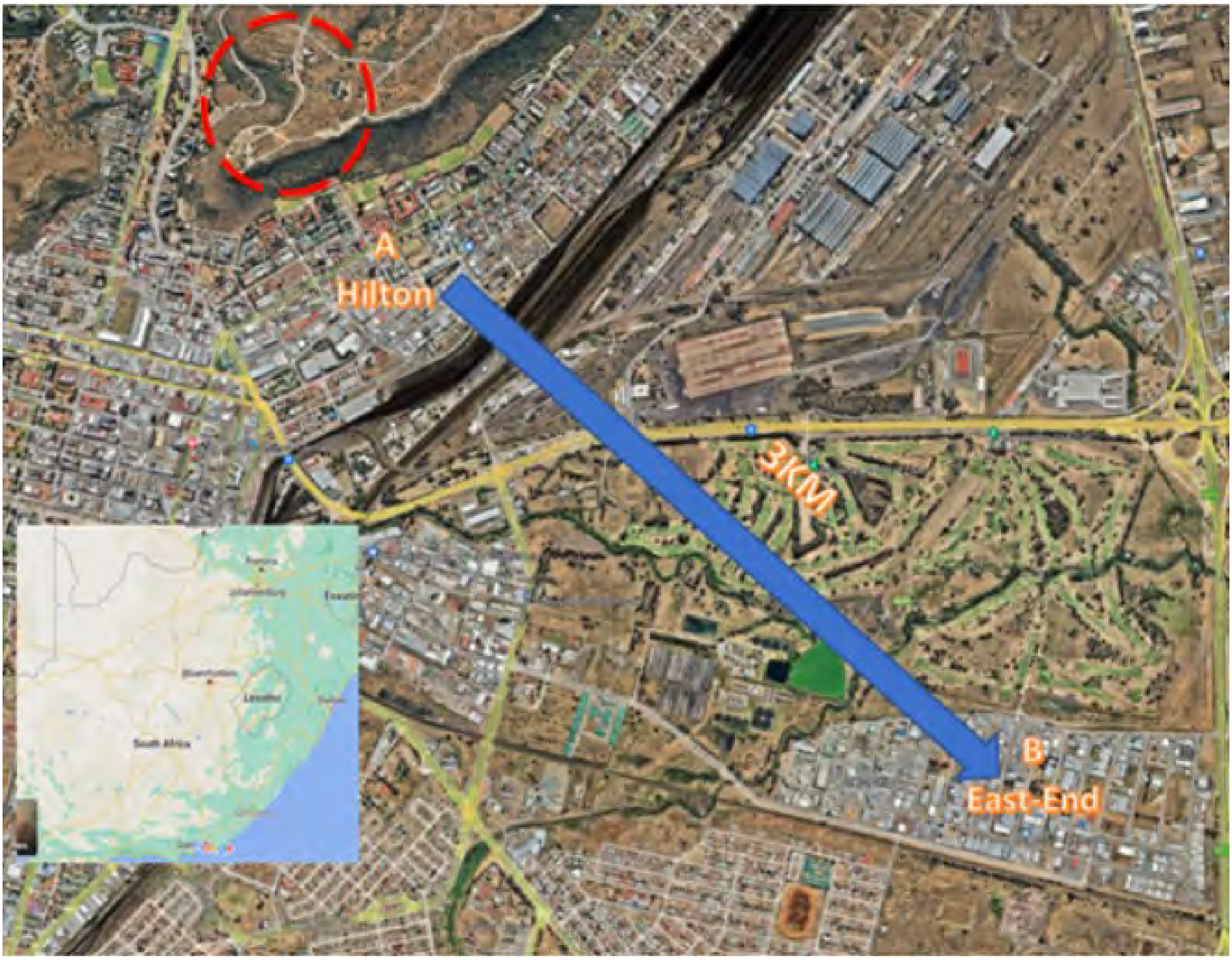

Figure 5: Areas which were impacted by the gustnado (Image source: Google earth map)

A large amount of vertical vorticity discussed in Sub-section 4.1, which occurred on Monday, and the theoretical resultant spiralling of the downdraft and the topography effect , stated in Section 2 should be combined. This combination, together with a v-shaped valley (concave-shape circled in red) on the south-eastern sector of Naval Hill most reasonably channelled, compressed, and exceptionally increased the wind speed from the thunderstorm.

Very strong and unequal wind speeds from either side of the valley most likely gained surface horizontal shear. This argument is supported by Dryden and Hill (1926) and (Alfahmi *et. al*, Ardhasena, 2019). Soon, a strong surface-generated spin was suppressed in the lee side as a rotating strong gust front, which led to the development of gustnado, as seen in the screenshots in Figure 6. Calm, wet surface conditions prevailed at 15:54:52 after the passage of individual thunderstorms cells in a squall-line, as Figure 6a shows.

Figure 6: Sudden change of wind signifying the arrival of gustnado

Figure 6b shows that approximately 18 seconds later, at 15:55:10, sudden gusty winds with rotating debris (gustnado) were seen and felt. Clearly the wind storms moved very fast and eyewitness accounts indicate that the surface water in the tarred street was also lifted.

As can be seen in Figures 7 and 8, the impacts of this gustnado included minimally twisted debris, and trees bent to the south-east.

Figure 7: Ground evidence from the media

Figure 8: Ground evidence in Hilton and East-End (Michael & Rejoyce)

Surveyors also noted the damage in the region of East End, marking the end of the gustnado. Affected by another thunderstorm cell of the squall-line at 16:30, the automatic weather station of the SAWS at Bram Fischer International Airport recorded comparatively less wind speed.

The north-westerly wind at the airport blew at 20 knots, gusting at 30 knots in a north-westerly direction. The airport is located about 7 km to the east of where gustnado moved.

6. CONCLUSION

Potential damaging winds, amongst other extreme weather impacts, which the SAWS had warned about on the last days of May 2023, could have resulted from a tornado, microburst or even a gustnado. Despite the accepted definitions of these phenomena, it is still currently impossible forecast either of the three phenomena as the forecasting problem for these events remains unresolved due to the lack of recorded observation.

Post-analysis of these events, however, offers some insights. In the case of 30 May 2023, the concave-shaped sector of Naval Hill with related storm analysis between 15:45 and 16:00, seems to have been the cause of the linearity of wind destruction between Hilton and East End in Bloemfontein. A combination of this analysis with the CCTV footage and accounts from the eyewitnesses lead to one conclusion: the windstorm at near Bloemfontein was a gustnado.

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WIDESPREAD SNOWFALLS OVER THE EASTERN CAPE ON 9-10 JULY 2023

Ayabonga Tshungwana

1. DEFINITIONS

hPa: - hectoPascal (pressure measurement).

GFS: - Global Forecasting System (Model).

UM: - Unified Model.

2. INTRODUCTION

An intense cold front with a steep upper-air trough was expected to make landfall over Western Cape on 8 July 2023, with strong winds over the interior of the Eastern Cape ahead of the front. These two systems moved over the Eastern Cape on 9 July 2023. Behind the cold front, a ridging-in high-pressure system of 1040 hPa was dominating, resulting in a significant drop in temperatures across the province.

Models indicated disruptive snow over high ground, with significant precipitation in places along the south coast and adjacent interior. The system was expected to move eastwards on 10 July 2023, causing very cold temperatures and disruptive snowfalls, which led to mountain passes to be closed due to an accumulation of snow. Some good amounts of precipitation fell over the Nelson Mandela Bay Metro, which brought hope of drought relief over the Metro.

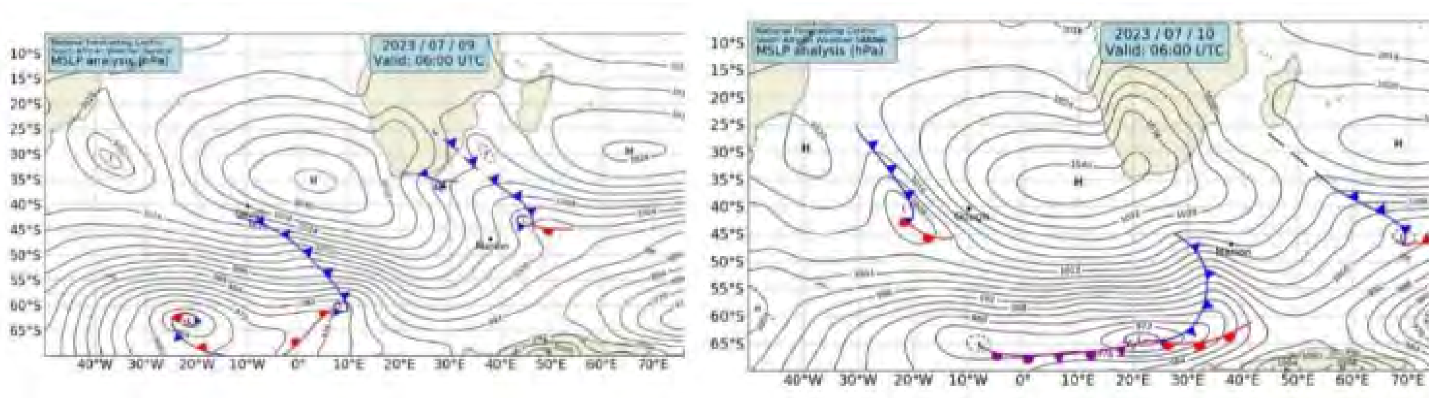


Figure 1: Synoptic charts showing the dominant surface weather systems on 9 and 10 July 2023

3. DISCUSSION

The model output (Unified Model) indicated a steep upper-air trough over western interior of the country on 9 July 2023 (Figure 2 top), which resulted in widespread rainfall across the province, and snowfalls over the high lying areas of the western half of the province. These conditions continued into the next day, 10 July 2023 (Figure 2 bottom), with good rainfall occurring in places along the south coast and the adjacent interior (Figures 4 and 5).

The cold front and strong ridging high-pressure system at the surface, supported by an upper-air trough, moved eastwards, and caused a significant drop in temperatures, thereby resulting in rainfall across the province and significant snowfalls over the high-lying areas of the eastern half of the province. The upper-air trough became a Cut-Off Low (COL) at 500hPa in the morning of 10 July 2023, enhancing snowfalls over the eastern parts of the province, with significant snowfalls as far as Cala in the southern parts of the Sakhisizwe Local Municipality.

Individual model parameters

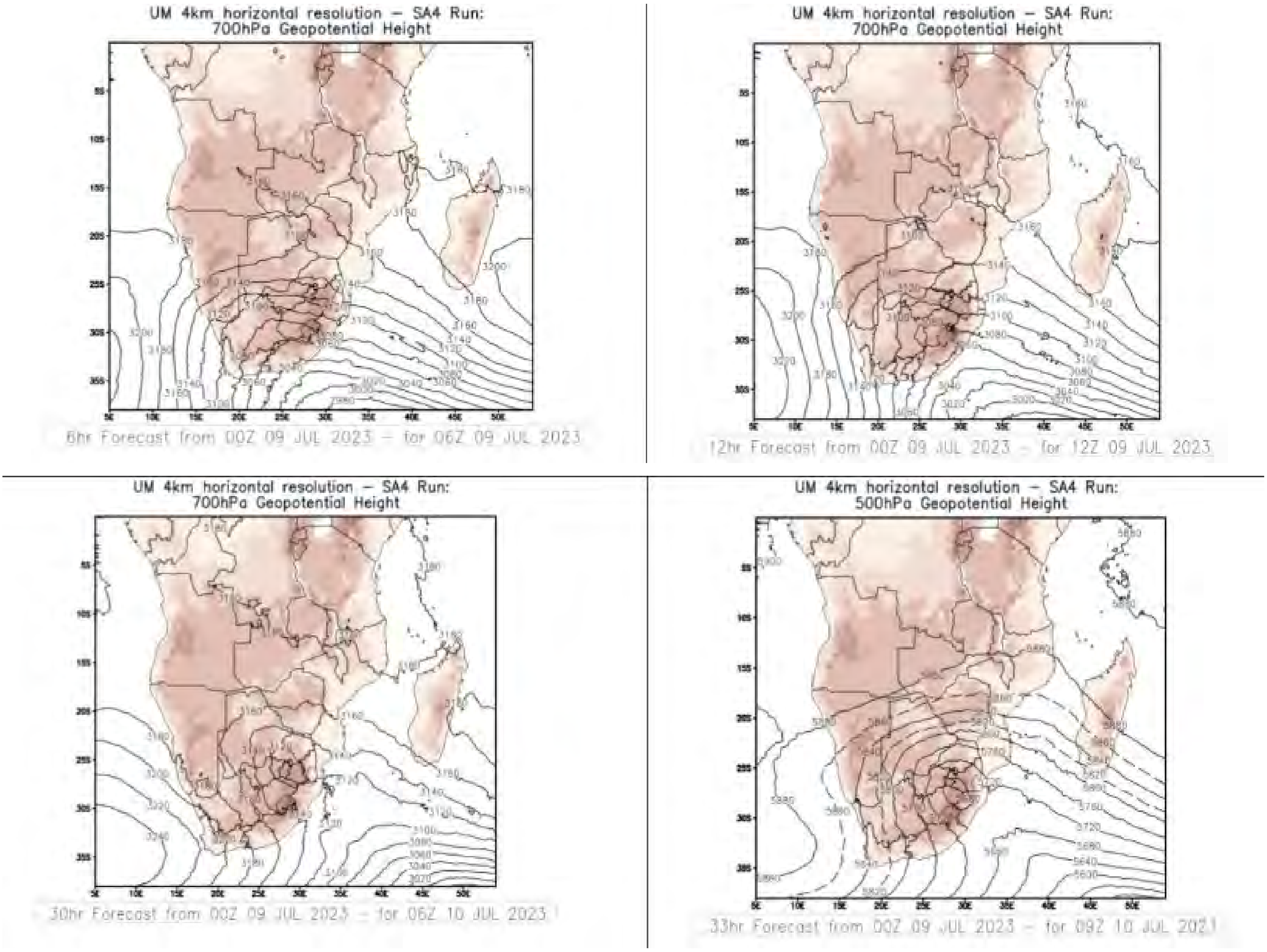


Figure 2: UM output showing geopotential height at 700 hPa on 9 and 10 July 2023, becoming a Cut-Off Low at 500hPa by 09h00

Rainfall

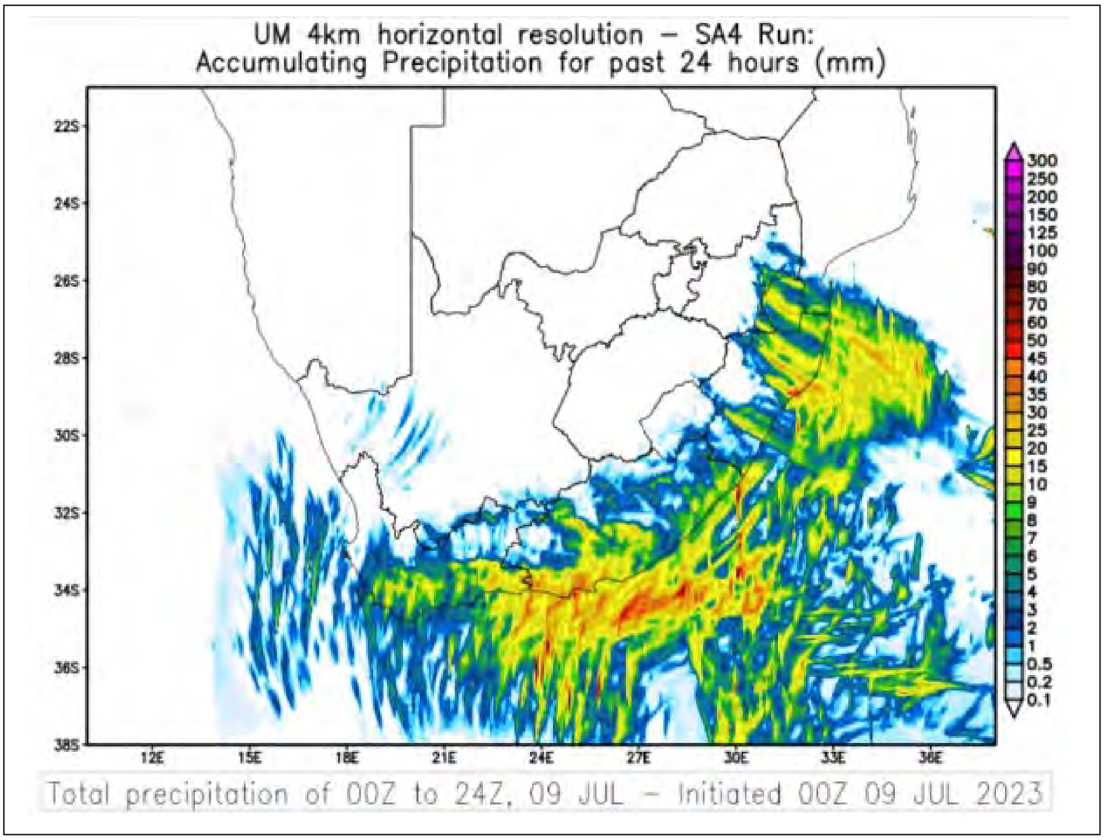


Figure 3: Model output showing 24-hour precipitation on 9 and 10 June 2023

This system produced precipitation across the province, with some great amounts that fell in places along south coast and adjacent interior. Some areas received above 50 mm of rain in 24 hours, with Woodridge receiving 96 mm in 24 hours.

These great figures of rainfall did not result in negative impacts over the province, but instead brought smiles to the people of Nelson Mandela Bay because of the great amounts that fell over the catchment areas. Figures 4 and 5 indicate rainfall figures across the Eastern Cape for this period.

Station Names		8	9	10	Total
Nelson Mandela Bay					
AWOS	Port Elizabeth Airport	NIL	6.4	28.6	3
ARS	3rd Ave Dip	NIL	7.4	45.4	5
ARS	Chetty	NIL	1.2	26.8	2
AWS	Coega	NIL	NIL	21.2	2
ARS	Flower Reserve	NIL	1.8	80.6	8
ARS	St Albans	NIL	3.6	55.0	5
AWS	Uitenhage	NIL	*	*	
MAN	Woodridge	NIL	2.0	96.0	9
Catchment					
AWS	Joubertina	NIL	0.4	33.0	3
ARS	Kareedouw	NIL	1.8	49.4	5
Man	Kareedouw	NIL	5.0	17.0	2
Man	Kouga Dam	NIL	1.5	22.0	2
AWS	Patensie	NIL	NIL	16.2	1

Figure 4: Amounts of rainfall over Nelson Mandela Bay and the catchment areas

	Other Towns				
AWS	Addo	NIL	NIL	19.0	19.0
AWS	Bisho/KWT	NIL	NIL	14.6	14.6
AWS	Cape St Francis	*	*	*	0.0
AWS	Cradock	NIL	NIL	NIL	0.0
AWS	East London	NIL	NIL	19.0	19.0
AWS	Fort Beaufort	NIL	NIL	3.4	3.4
AWS	George	NIL	3.3	21.5	24.8
AWS	Graaff Reinet	NIL	NIL	2.0	2.0
AWS	Grahamstown	NIL	NIL	16.0	16.0
AWS	Henry`s Flats	NIL	NIL	6.8	6.8
AWS	Joubertina	NIL	0.4	33.0	33.4
AWS	Mossel Bay	*	*	*	0.0
AWS	Mthatha	NIL	NIL	2.8	2.8
AWS	Plettenberg bay	NIL	4.2	26.4	30.6
AWS	Port Alfred	NIL	NIL	20.4	20.4
AWS	Queenstown	NIL	NIL	NIL	0.0

Figure 5: Amounts of rainfall over the Eastern Cape on 9 and 10 June 2023

Relative Humidity, Temperatures and Snowfall

The Unified Model has indicated widespread of snowfall over the Eastern Cape (Figure 8), which was valid for 9 and 10 June 2023. Models also indicated all the ingredients for possible disruptive snowfall over high-lying areas.

The day temperatures were expected to drop to 5 to 10 degrees across the province (Figure 9), with moisture from the surface to 700 hPa (Figure 6), a cold pool of -8 to -12 degrees at 700 hPa and -22 to -26 at 500hPa (Figure 7) and with precipitation expected across the province (Figure 3).

This was a good indication for significant snow to occur. The surface high-pressure system behind the cold front brought in cold air from the Atlantic Ocean, resulting in a significant drop of freezing levels across the province. Other models (such as the GFS) also captured the above ingredients very well. The following figures indicate the output of the Unified Model.

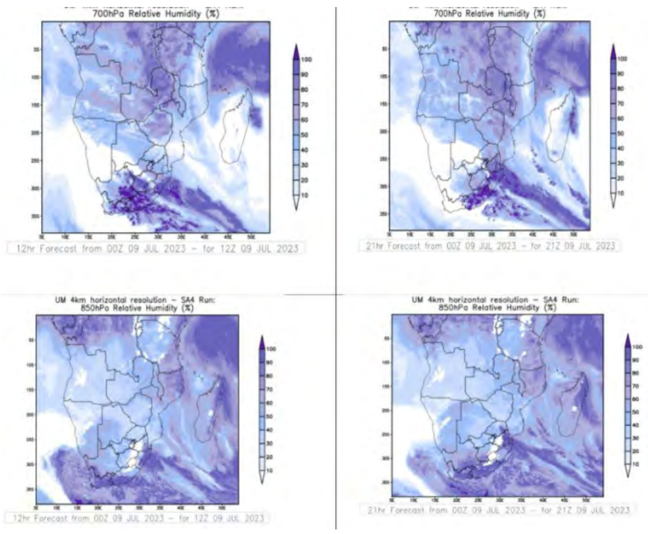


Figure 6: Relative humidity greater than 80% at 850 hpa to 700 hpa on 9 July 2023, drying from the west at 700 hPa on 10 July 2023

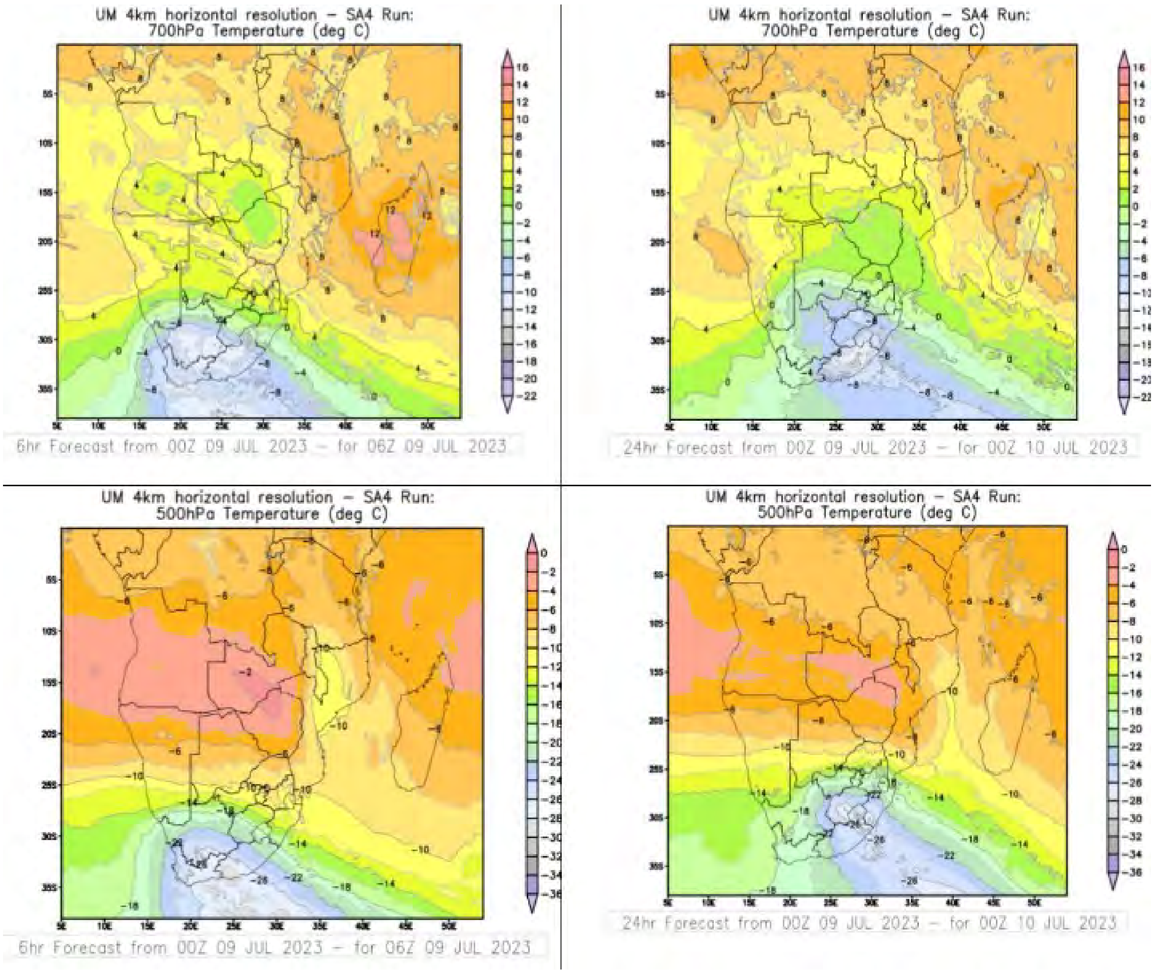


Figure 7: Temperature between -8 to -12 degrees at 700 hPa and -22 to -26 degrees at 500 hPa

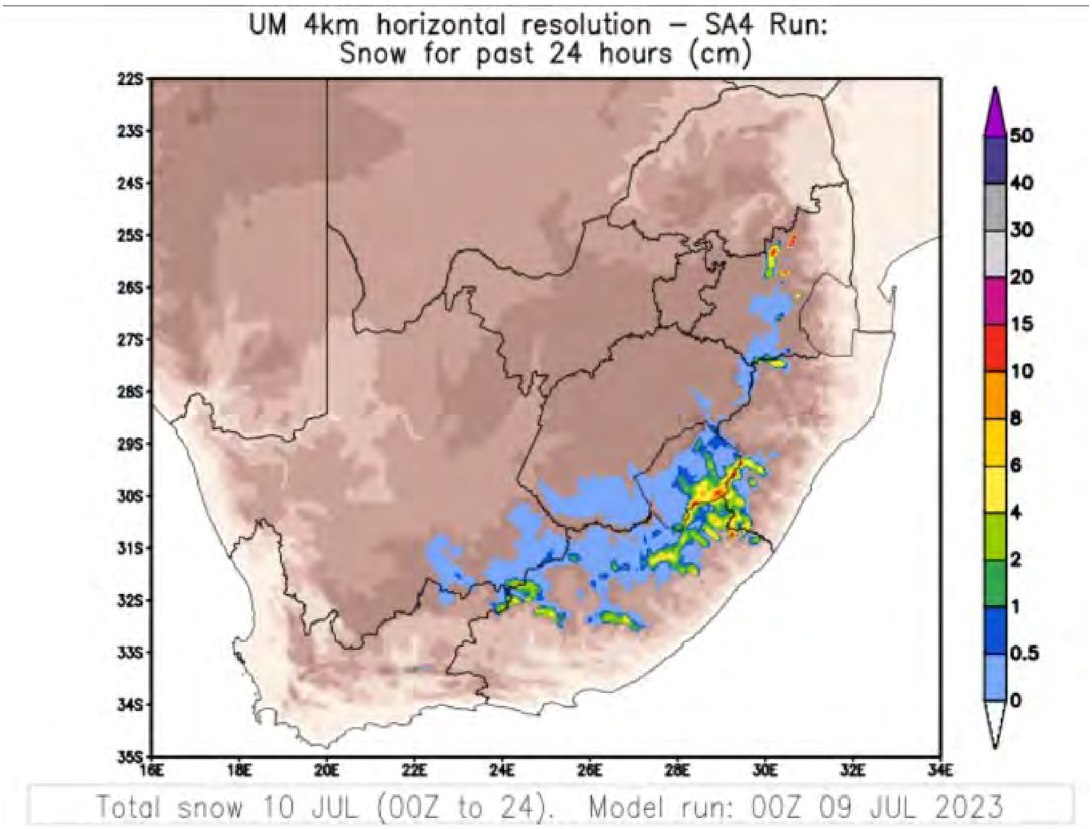


Figure 8: Possible widespread snow over Eastern Cape for 9 to 10 July 2023

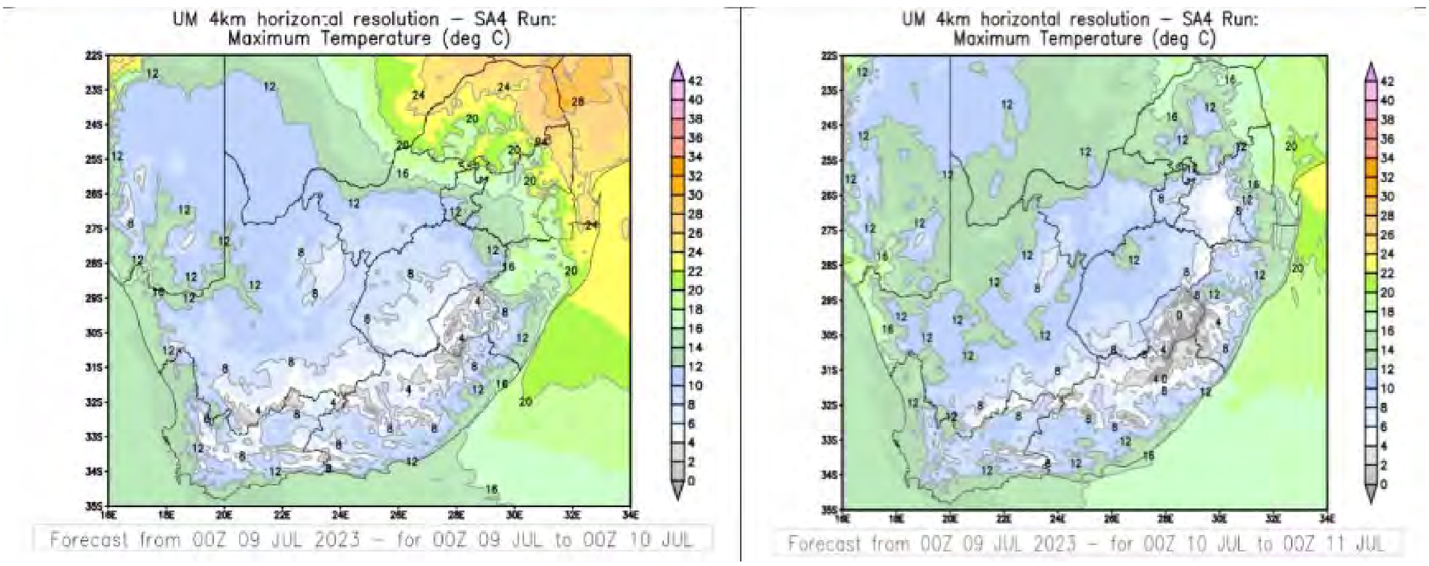


Figure 9: Unified Model indicating daytime temperatures for 9 to 10 July 2023

Table 1 below indicates the maximum temperatures in degrees Celsius that were observed on the 9 and 10 July 2023.

Table 1: Maximum temperatures observed on 9 and 10 July 2023 in degrees Celsius

Station	9 July 2023	10 July 2023
Buffelsfontein	4	4.8
Elliot	8	2.8
Barkly East	5	3.6

Warning issued

Due to the confidence of the models and the initiation season, an orange level 6 and yellow level 2 warning were issued for disruptive snow over the high-lying areas of the Eastern Cape. The warning was valid for 9 and 10 July 2023.

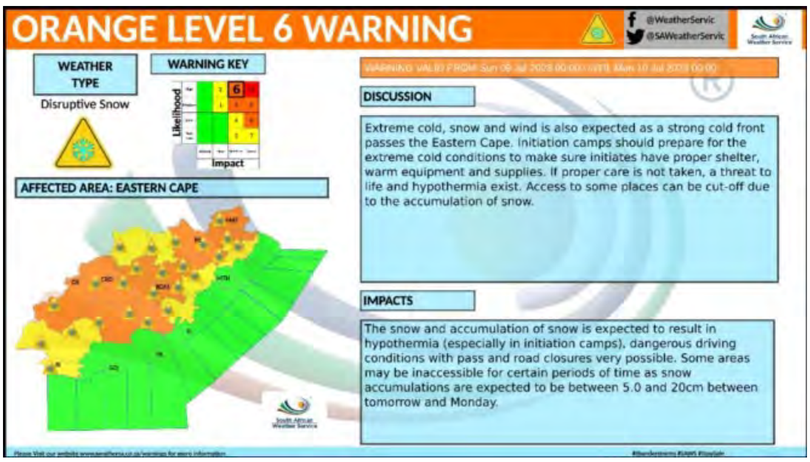


Figure 10: Impact table and area of and Orange level 6 and Yellow level 2 warning for disruptive snow

Impact observed

On 9 and 10 July 2023, snowfall occurred in all high-lying areas with some snow observed closer to houses. Significant snowfall occurred over the northern parts of the province, which led to the Barkly pass being closed due to snow accumulation.

Widespread incidents were reported in different areas of the province. Reported incidents included car accidents due to slippery roads. See Figure 11.

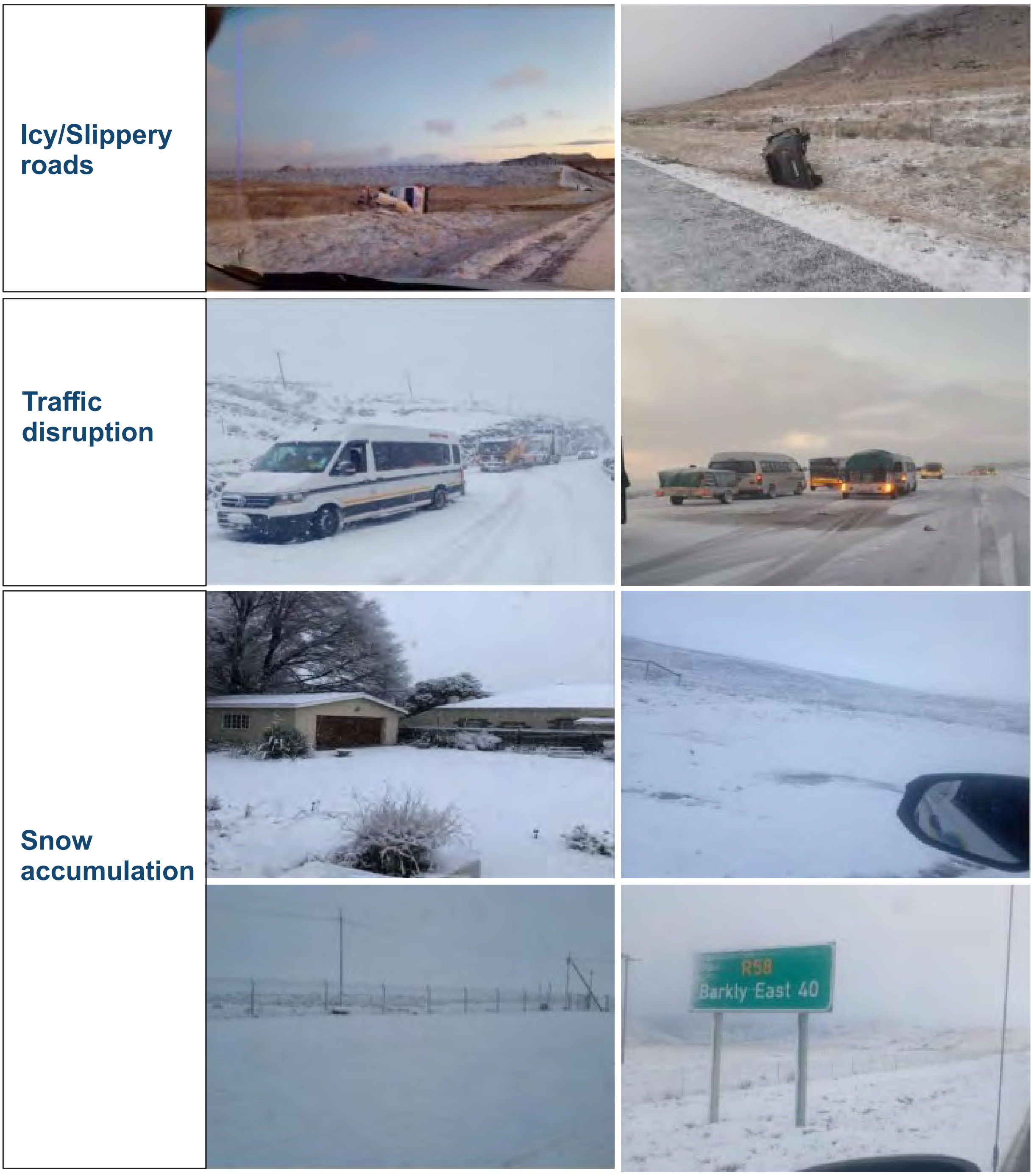


Figure 11: Reported incidents

4. CONCLUSION

Widespread snowfalls occurred over the northern and central high grounds, especially over Barkley East, Elliot and Graaff-Reinet, which led to the closure of the Barkley and Lootsberg passes. However, impacts also expanded to other areas such as the Cala area, which received snowfall in the town and surrounding villages. Snow accumulation led to delays of transport between Graaff-Reinet and Elliot because of slippery roads.

The Orange level 6 warning was a very good call because widespread snowfall did happen. This affected people because there were no movements due to the slippery conditions and the accumulation of snow – even a bus carrying a sick passenger was stuck.

The models picked up the system very well and well in advance, which gave good guidance to the forecasters.

5. RECOMMENDATIONS

More case studies are needed to build up the confidence in snow forecasting, especially seeing that significant snowfall events do not happen often. Comparing models helps with determining the area coverage and severity of the event. Applying sensitivity also helps to determine the appropriate level(s) for the impacts.

THE 5 MARCH 2023 CUT-OFF LOW SYSTEM YIELDS HAVOC OVER THE WESTERN CAPE

Kanyisa Makubalo

On 5 March 2023, there was an upper-air Cut-Off Low (COL) pressure system along the West Coast that was associated with a surface trough extending over the central interior, while over the Atlantic Ocean a surface high-pressure system dominated. The combination of these systems resulted in scattered to widespread showers and thundershowers over most parts of the Western and Eastern Cape throughout the day. Figure 1 shows the surface synoptic weather chart of the day.

The positioning of these synoptic systems was one of the factors resulting in the observed weather phenomena. Firstly, the COL was situated along the West Coast propagating to the south-east. It was cold-cored, with an area of divergence located over the western interior of South Africa, where a jet went through. A COL is a dynamic system and therefore inherently unstable.

Secondly, the surface trough over the central parts of the country, extending over the ocean, was to draw in warm and dry tropical air moving onto the western interior and therefore enhancing surface heating. Interestingly, the extension of the trough onto the ocean usually results in moisture being advected from the south into the south coast. Lastly, the Atlantic high-pressure system assisted with advecting cold polar air from the south into the south coast as well, as it started to ridge.

There was an expected undercutting effect as the cold air was moving towards the south coast and thereafter ascending the mountains (orographic lifting) and the surface heating over the western interior assisted in more air lifting and thereafter convection. The COL was a classic baroclinic system where it was associated with a strong ridging high pressure just south of it and a surface depression to the east of it (Taljaard, 1985; Singleton and Reason, 2007). This system was expected to result in severe windshear, a depth of moisture along the atmospheric column and some triggers being present leading to severe thunderstorms.

This was likely a subtropical type of COL, where the formation was from the subtropical jet extending equatorward. Another formation of a subtropical COL is where there is a split in a zonal polar jet to which a weak equatorward branch is caused (Price and Vaughan, 1992; Singleton and Reason, 2007). The latter form was not the one that was at play in this event.

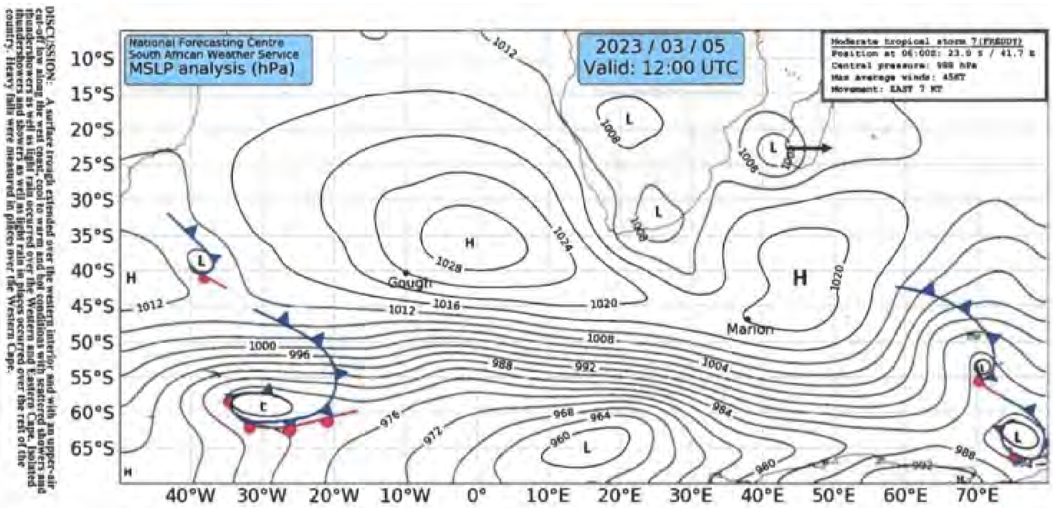


Figure 1: The 5 March 2023 synoptic chart (SAWS)

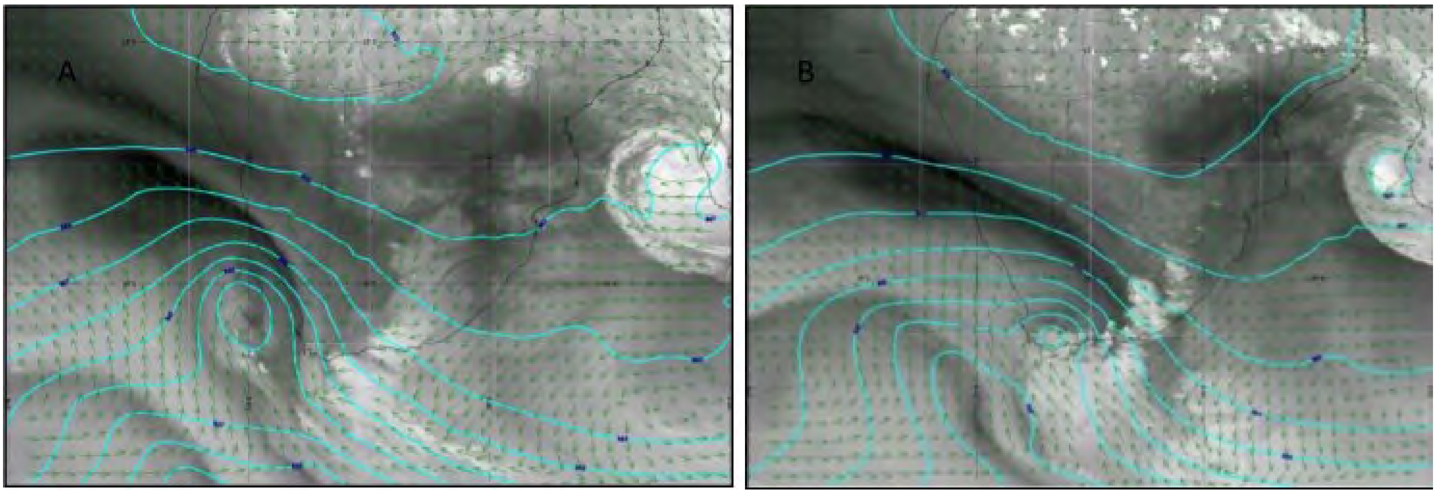


Figure 2a and 2b: MSG WV062 satellite with ECMWF 300 hPa geopotential heights and surface winds for 00z and 12z (Eumetrain, 2023)

In this case study, the weather systems' interaction and how the weather thereafter unfolded will be studied. Numerical weather models and observational data, which is inclusive of satellite images and rainfall records, will be examined. There will be an assessment of some of the products that were provided to disaster management and the public. Impacts that were observed and actions taken by disaster management according to their status report will be looked at.

THE ANALYSIS OF THE CUT-OFF LOW FORECAST (3-4 MARCH 2023)

On 3 March 2023, several models were already indicating the development of a COL west of the West Coast, including the South African Weather Service's tailor made Unified Model (SA4 UM) for 5 March 2023. The UM was indicating areas of deep moisture, instability and wind shear over the Western Cape, which were favourable for thunderstorm development.

The above-mentioned parameters were projected to be exceptional over the southern parts of the Western Cape, which could result in those thunderstorms being severe. Rain and showers were expected over much of the Western Cape and the southern parts of the Northern Cape, stretching all the way to the entire Eastern Cape as seen in the below image (Figure 3). Heavier downpours were also expected over the southern parts of the Western Cape. The south coast was projected to have accumulated rainfall of about 50 to 100 mm in 24 hours.

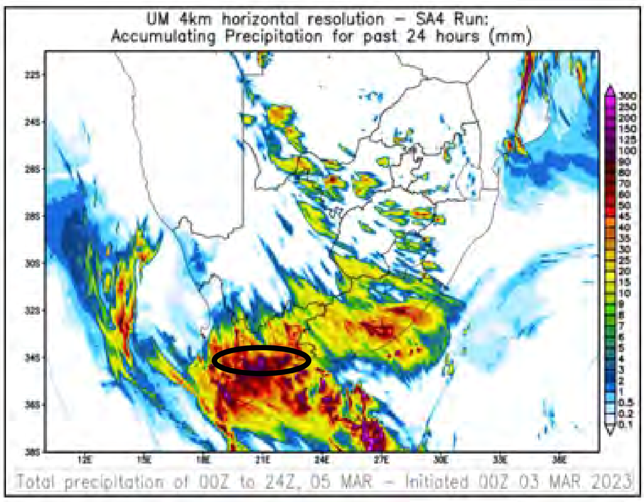


Figure 3: The Unified Model (UM SA4) 24-hour precipitation accumulation for 5 March 2023, 00Z 03 March 2023 run (SAWS)

With the combination of the forecasters' confidence and projections from different models, warnings were warranted. The Cape Town Weather Office issued two warnings for 5 March 2023 to Disaster Management of the Western Cape and Northern Cape through SMS, e-mail and WhatsApp.

These warnings were also sent to the various media houses and the public through the website and social media posts. A Yellow Level 4 warning for severe thunderstorms over the central interior of the Western Cape into the southern Cape Winelands was issued. This can be interpreted as a low likelihood of significant impacts that was anticipated for the areas at the given time.

An Orange Level 6 warning for severe thunderstorms over the southern Garden Route into the Overberg region was the second warning. This can be interpreted as a high likelihood of significant impacts over the mentioned area at the mentioned time. The following image, Figure 4, is the visual combination of the warnings.

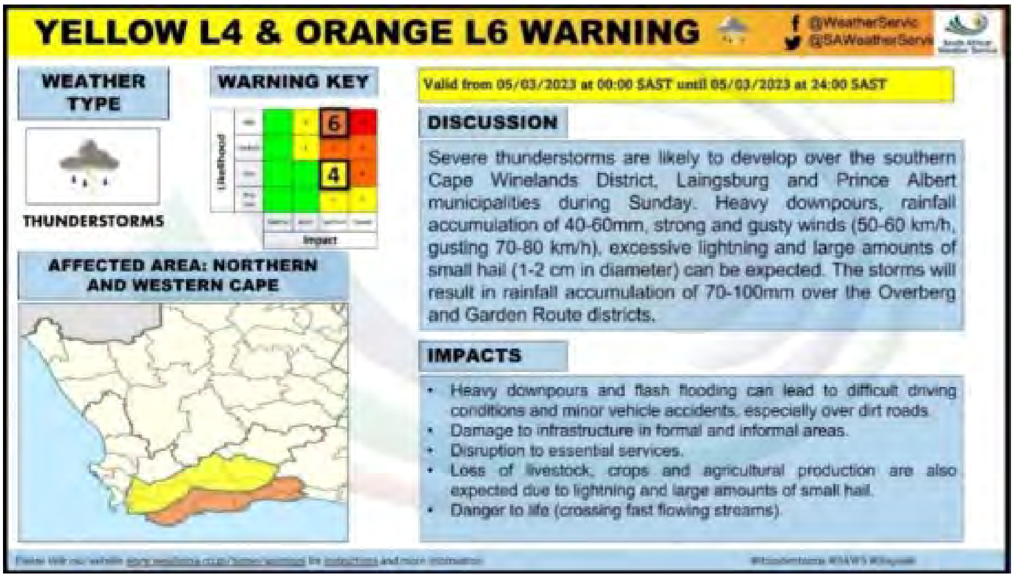
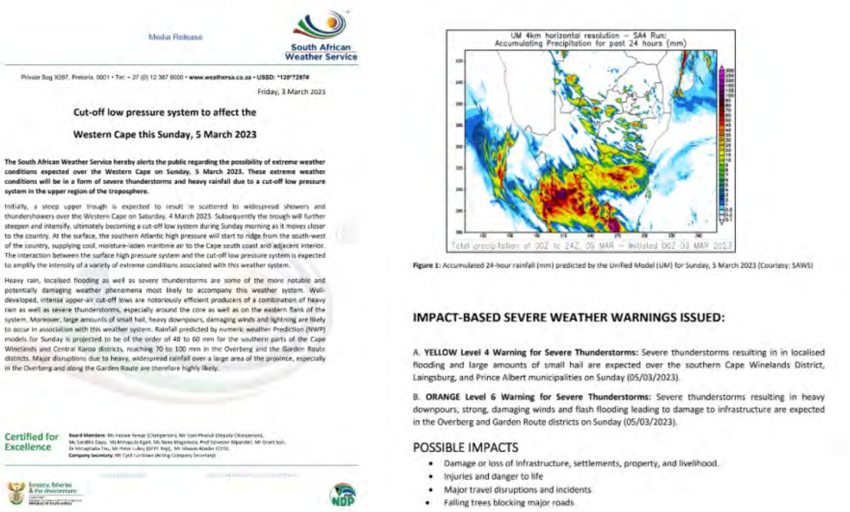


Figure 4: Western Cape Severe Thunderstorms warnings for 5 March 2023, issued on 3 March 2023 (SAWS)

Due to the expected significant changes in weather, a media release was published and sent to the media houses, the public and other relevant stakeholders. Its purpose was to alert the public and other stakeholders of the expected severe thunderstorms, rainfall accumulation, and possible impacts and allude to the warnings that had been sent out (Figures 5).


Media Release

South African Weather Service

Private Bag X097, Pretoria, 0001 • Tel: + 27 (0) 12 367 6000 • www.weathersa.co.za • USSD: *120*7297#

Friday, 3 March 2023

Cut-off low pressure system to affect the Western Cape this Sunday, 5 March 2023

The South African Weather Service hereby alerts the public regarding the possibility of extreme weather conditions expected over the Western Cape on Sunday, 5 March 2023. These extreme weather conditions will be in a form of severe thunderstorms and heavy rainfall due to a cut-off low pressure system in the upper region of the troposphere.

Initially, a steep upper trough is expected to result in scattered to widespread showers and thundershowers over the Western Cape on Saturday, 4 March 2023. Subsequently the trough will further steepen and intensify, ultimately becoming a cut-off low system during Sunday morning as it moves closer to the country. At the surface, the southern Atlantic high pressure will start to ridge from the south-west of the country, supplying cool, moisture-laden maritime air to the Cape south coast and adjacent interior. The interaction between the surface high pressure system and the cut-off low pressure system is expected to amplify the intensity of a variety of extreme conditions associated with this weather system.

Heavy rain, localised flooding as well as severe thunderstorms are some of the more notable and potentially damaging weather phenomena most likely to accompany this weather system. Well-developed, intense upper-air cut-off lows are notoriously efficient producers of a combination of heavy rain as well as severe thunderstorms, especially around the core as well as on the eastern flank of the system. Moreover, large amounts of small hail, heavy downpours, damaging winds and lightning are likely to occur in association with this weather system. Rainfall predicted by numeric weather Prediction (NWP) models for Sunday is projected to be of the order of 40 to 60 mm for the southern parts of the Cape Winelands and Central Karoo districts, reaching 70 to 100 mm in the Overberg and the Garden Route districts. Major disruptions due to heavy, widespread rainfall over a large area of the province, especially in the Overberg and along the Garden Route are therefore highly likely.

Certified for Excellence

Total precipitation of 00Z to 24Z 05 MAR – Initiated 00Z 03 MAR 2023

Figure 1: Accumulated 24-hour rainfall (mm) predicted by the Unified Model (UM) for Sunday, 5 March 2023 (Courtesy: SAWS)

IMPACT-BASED SEVERE WEATHER WARNINGS ISSUED:

A. **YELLOW Level 4 Warning for Severe Thunderstorms:** Severe thunderstorms resulting in in localised flooding and large amounts of small hail are expected over the southern Cape Winelands District, Laingsburg, and Prince Albert municipalities on Sunday (05/03/2023).

B. **ORANGE Level 6 Warning for Severe Thunderstorms:** Severe thunderstorms resulting in heavy downpours, strong, damaging winds and flash flooding leading to damage to infrastructure are expected in the Overberg and Garden Route districts on Sunday (05/03/2023).

POSSIBLE IMPACTS

- Damage or loss of infrastructure, settlements, property, and livelihood.
- Injuries and danger to life
- Major travel disruptions and incidents
- Falling trees blocking major roads

Figure 5: The media release indicating an expected COL on 5 March 2023, issued on 3 March 2023 (SAWS)

On 4 March 2023, there was a reassessment of the system and how it was expected to move, the duration and intensity of the system as well as the precipitation expected to come with it. Amongst the different models used, the UM SA4 indicated that there was a surface trough (dashed red line) over the central parts of the country extending to the south, with a localised low pressure over the central Eastern Cape (L) (Figure 6a).

This was expected to advect moisture onto the south coast (red arrows). Figure 6b shows the 500 hPa geopotential heights showing an extremely steep upper-air trough over the south-west of the Western Cape, extending from a COL down south. Moisture extended from the surface to the upper levels, including the mid-levels, as the 700 hPa relative humidity indicated in Figure 7a. The atmosphere over most parts of South Africa including the Cape provinces was quite unstable as the K-Index shows values of about 30-45 just over the Western Cape (Figure 7b), which is exceptional.

The European Centre for Medium-Range Weather Forecasts (ECMWF) model showed rainfall accumulation figures of about 10-30 mm over most parts of the Western Cape, reaching 50-200 mm over the central south coast and adjacent interior as seen in Figure 8a. All the while, the Global Forecast System (GFS) model showed generally a similar projection, with the difference being that it projected higher rain accumulations over the entire south coast, reaching 80-250 mm as seen in Figure 8b.

On the other hand, UM SA4 had been updated and showed somewhat similar 24-hour rainfall accumulations of about 10-30 mm for the larger part of the Western Cape and 50-90 mm over the central and extreme south-eastern Western Cape (Figure 9). On all the NWP models, it seemed that the west coast was to receive very little rainfall.

Another interesting feature was Tropical Cyclone (TC) Freddy over the Mozambique channel (cyan L).

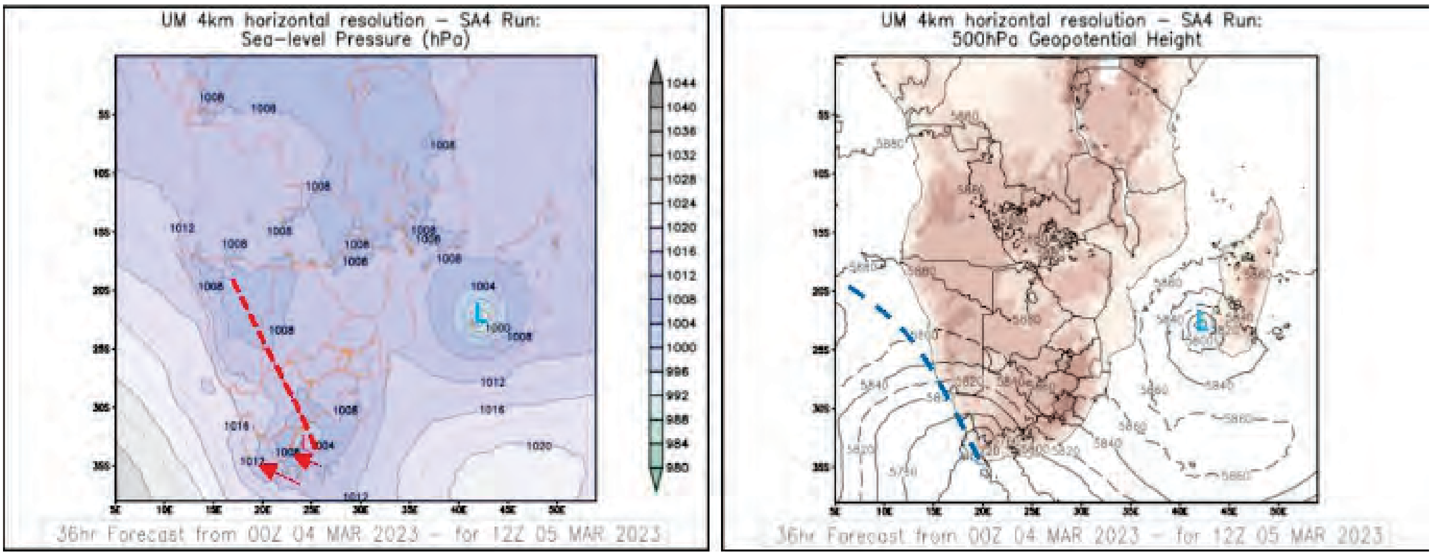
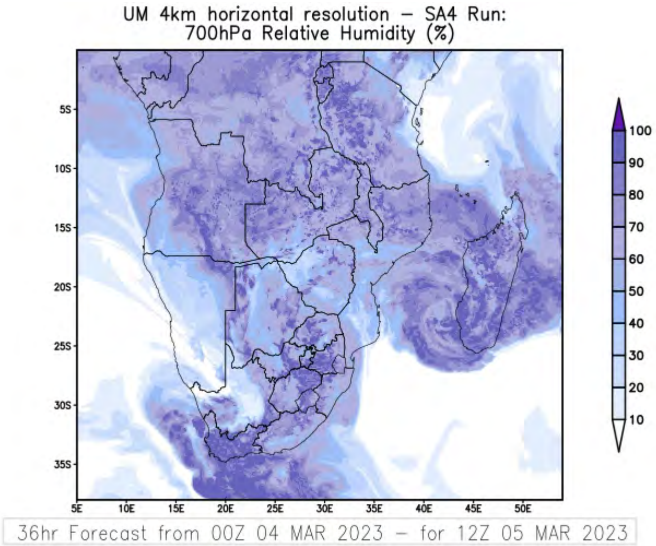


Figure 6a and 6b: UM SA4 sea level pressure showing weather systems expected at the surface level with surface trough (red dashed line) and UM SA4 500 hPa geopotential showing the upper air trough (blue line) heights for 12Z 5 March 2023, 00Z 4 March run. Tropical cyclone Freddy is indicated towards the right as the cyan “L” (SAWS)



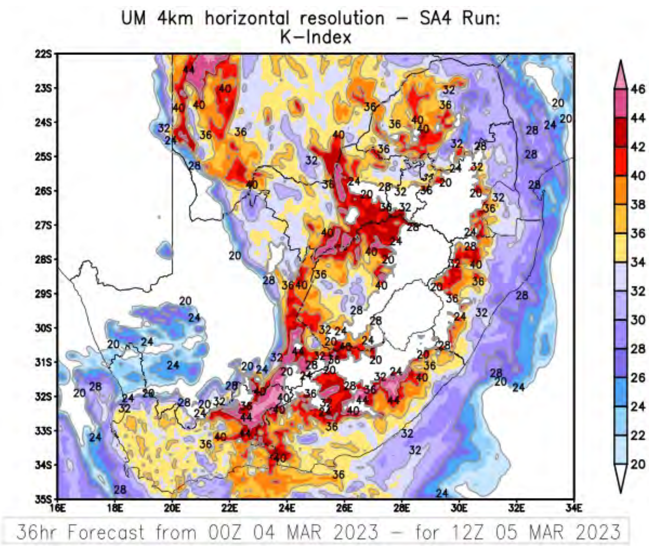


Figure 7a and 7b: UM SA4 700 hPa relative humidity and UM SA4 K-Index for 12Z 5 March 2023, 00Z 4 March run (SAWS)

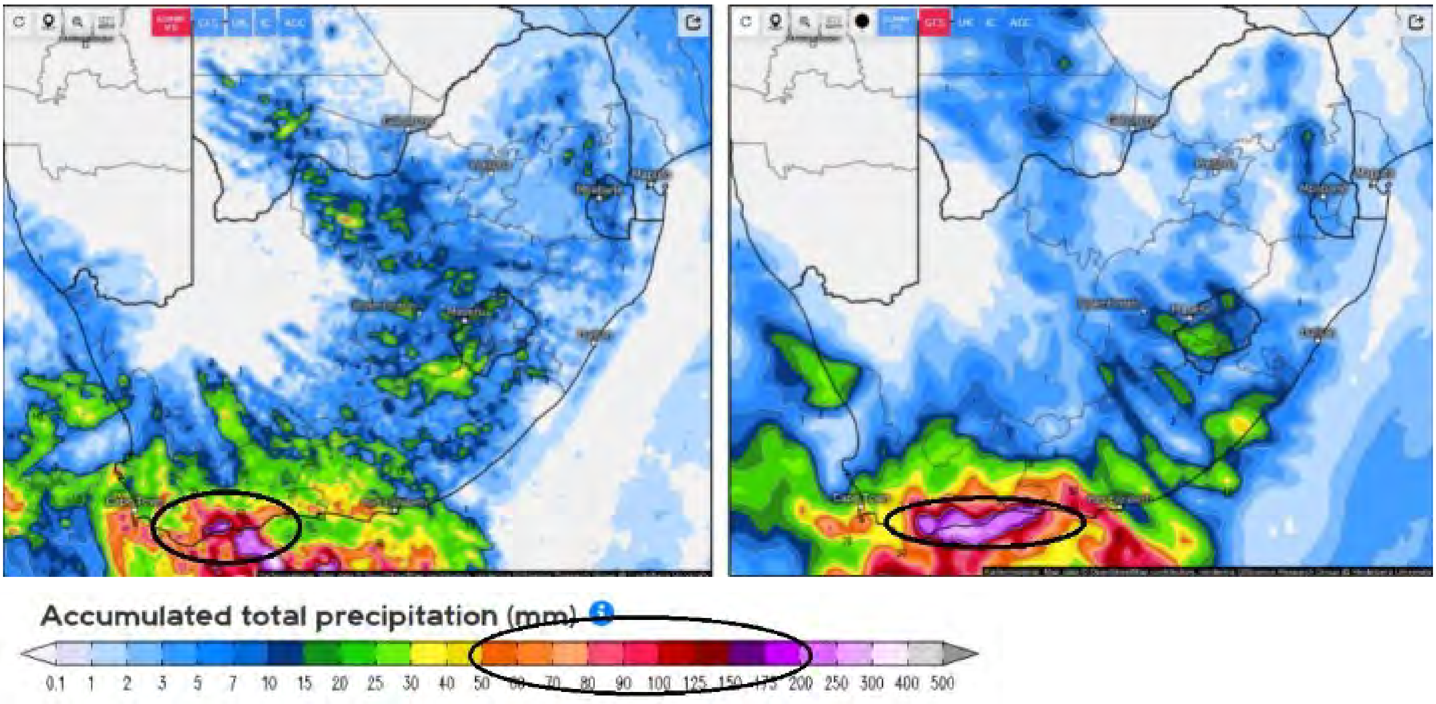


Figure 8a and 8b: ECMWF accumulated total precipitation and GFS accumulated total precipitation for 5 March 2023 (meteologix.com)

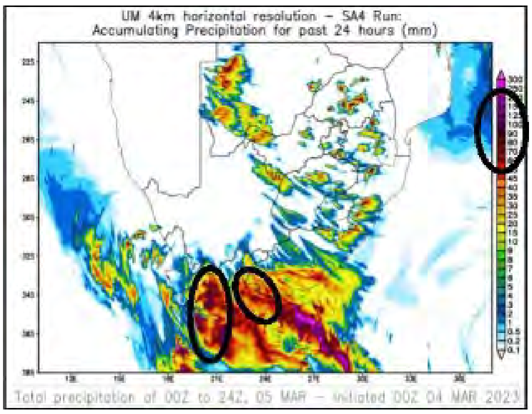


Figure 9: UM SA4 24-hour accumulated precipitation for 5 March 2023, 00Z 4 March run (SAWS)

The combination of these factors with a shorter lead time improved the forecasters' confidence to then adjust the warnings. There was a change in the area of intensity and some areas were also going to be added to the warnings, for example, the Cape Metropole. The warnings were updated to a yellow level 2 to include the Cape Metropole and northern Cape Winelands districts, while the orange level 6 warning was extended to the Little Karoo and the south-eastern parts of the Cape Winelands. Figure 10 indicates the image that was sent out to relevant stakeholders and the public as an update.

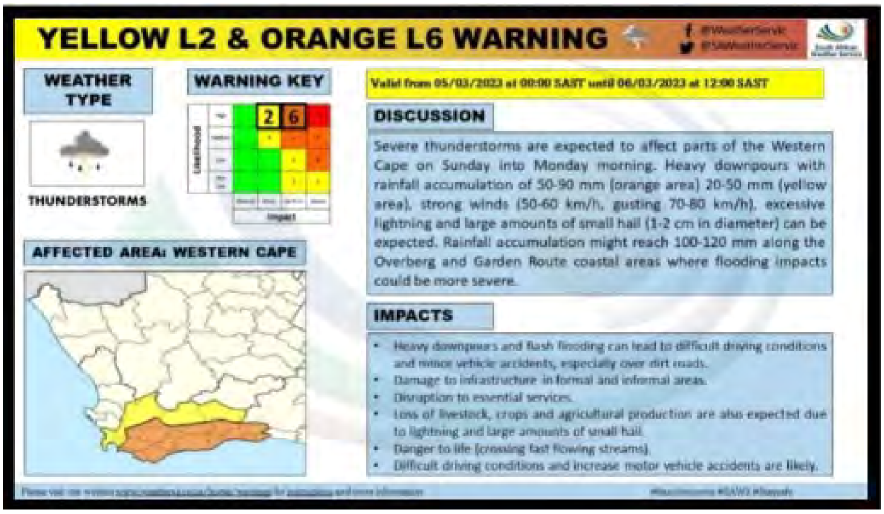


Figure 10: Western Cape severe thunderstorms warning for 5 March 2023, issued on 4 March 2023 (SAWS)

THE DAY OF THE EVENT (5 MARCH 2023)

Numerical Models

On the morning of the 5 March 2023, the models were further consulted to monitor the expected weather system. The UM SA4 projection of the pressure at mean sea level indicated that the surface trough would maintain its position over the central parts of the country, extending to the south with a localised low pressure over central Eastern Cape as seen on the previous day's model run.

The steep upper-air trough extending from the COL in the south was still projected in the similar area as the last run. In addition, the 700 hPa relative humidity illustrated a similar pattern as the runs to those of the day before. The area of instability was similar in a bigger picture, however, it seemed that the UM had toned down the instability, especially over the extreme south-west of the country.

The UM SA4 24-hour rainfall accumulations for areas of heavier downpours had been further refined and were still within the areas flagged from the previous run's projections. Oudtshoorn was one of the towns of concern as projections of up to 90 mm rainfall accumulation were seen. Figure 11 is the vertical cross section for Oudtshoorn for the day showing winds and moisture.

This plot indicates thunderstorms with cloud tops near 30 000 ft in the morning. Considering that the areas of concern were still the same as when the warnings were last updated, the warnings were not amended and therefore left as they were.

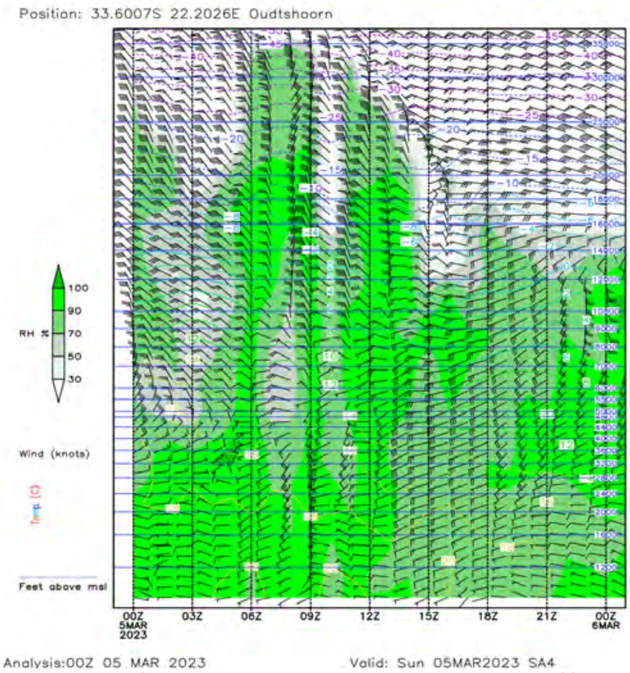


Figure 11: UM SA4 Oudtshoorn spotgraph for 5 March 2023, 00Z 5 March run (SAWS)

METEOROLOGICAL OBSERVATIONS

Satellite

The satellite imagery on 5 March 2023 was a spectacular sight as seen in Figures 12a and 12b. It can be observed that already by 08:00 SAST there were active thunderstorms over the Western Cape. Take note of the surface low pressure just west of the West Coast that can be identified by the curvature of the low clouds (Figure 12a).

At 14:00 SAST more intense thunderstorms had developed and were active over the Western Cape and Eastern Cape, resulting in heavy downpours and excessive lightning as seen in Figure 12b. The surface low pressure could still be observed with the faint low clouds just west of the Namibian coastline.

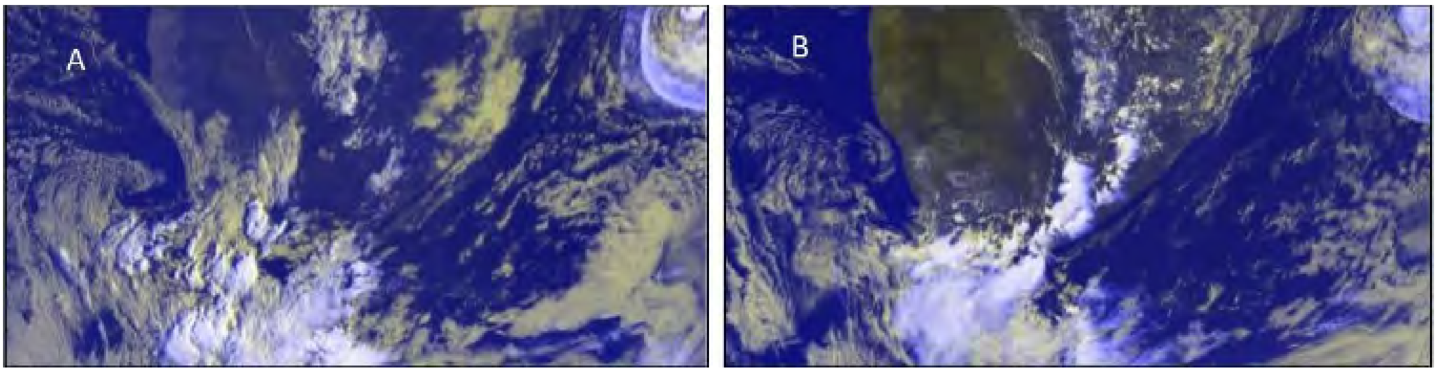


Figure 12a and 12b: High Resolution Visible (HRV) Cloud Enhance RGB for 5 March 2023 at 06Z and 12Z (SUMO, Eumetsat)

By the evening (20:00 SAST) some of the thunderstorms over the Western Cape had moved to the south, while others had dissipated. Low clouds with a possibility of foggy conditions along the west were being observed. There was also some remanence of mid-level clouds over the south-western parts of the country.

Rainfall records

A number of places over the Western Cape recorded noteworthy rainfall figures due to this system. The top three areas with the most rainfall in our available stations were Elgin Grabouw (84 mm), Still Bay (79,2 mm), and Stellenbosch (67,8 mm), respectively (Figure 13).

Other areas worth mentioning are Cape Town City and Kirstenbosch in the Cape Metropole recording 46,2 and 47,8 mm respectively, as well as Oudtshoorn, Riversdale and George in the Garden Route recording 51,6 mm, 56 mm, and 56,6 mm respectively. All models evaluated relatively well for rainfall accumulation in the south coast, however under-forecasted for the Stellenbosch area. This could be that the models could not factor in the influence of orographic lift, as areas around Stellenbosch measured below 20 mm. On the other hand, new daily rainfall records were broken on this case date with Still Bay breaking a 30 years' record (Figure 14).

Cape Metropole	Atlantis	7
	Robben Island	10
	Royal Yacht Club	33.6
	Molteno	46.2
	Observatory	27.6
	Cape Town International	20.3
	Cape Town Int AWS	34.2
	Kirstenbosch	47.8
	Slangkop	31.6
Cape Winelanc	Paarl	18.8
	Stellenbosch	67.8
	Worcester	19.6
	Ceres	8.8
	Wellington	12.8
Overberg	Hermanus	19.2
	Cape Agulhas	29
	Elgin Grabouw	84
	Struis Bay	34.6
	Tygerhoek	40.8
	Swellendam	28.6
Garden Route Dist	Oudtshoorn	51.6
	Ladismith	35.8
	Riversdale	56
	Stilbaai	79.2
	George	50
	George (Witfontein)	56.6

Figure 13: The recorded rainfall accumulations in mm for 5 March 2023 for the SAWS Western Cape working stations (SAWS)

Criteria	Old Value	Old Date	New Value	New Date	No. Years	Stations
Highest Daily Rain	30	2003/03/23	31.6	2023/03/05	28	CAPE TOWN SLANGKOP
Highest Daily Rain	43.8	2016/03/26	84	2023/03/05	8	GRABOUW
Highest Daily Rain	31	2014/03/26	33.6	2023/03/05	22	CAPE TOWN-ROYAL YACHT CLUB
Highest Daily Rain	28.6	2016/03/26	34.2	2023/03/05	22	CT-AWS
Highest Daily Rain	50.4	2012/03/15	63.8	2023/03/05	14	SWELLENDAM
Highest Daily Rain	62.8	2003/03/23	79.4	2023/03/05	30	STILBAAI

Figure 14: New rainfall records for areas in Western Cape working stations (SAWS)

IMPACTS OBSERVED

COLs resulting in severe thunderstorms are likely to result in devastating impacts. Damage could be because of strong, damaging winds, excessive lightning, heavy rainfall downpours, hail and sometimes tornadoes. Some of the impacts known to be associated with the above-mentioned phenomena are damage to settlements, infrastructure and roads, flash flooding, disruption of travel services and essential services, as well as loss of crops and livestock. Through the event at hand, a lot of the mentioned impacts were seen.

Social media platforms such as Facebook and WhatsApp played a big role as sources of information for the observed impacts. Figure 15 provides pictures and screenshots of videos received.

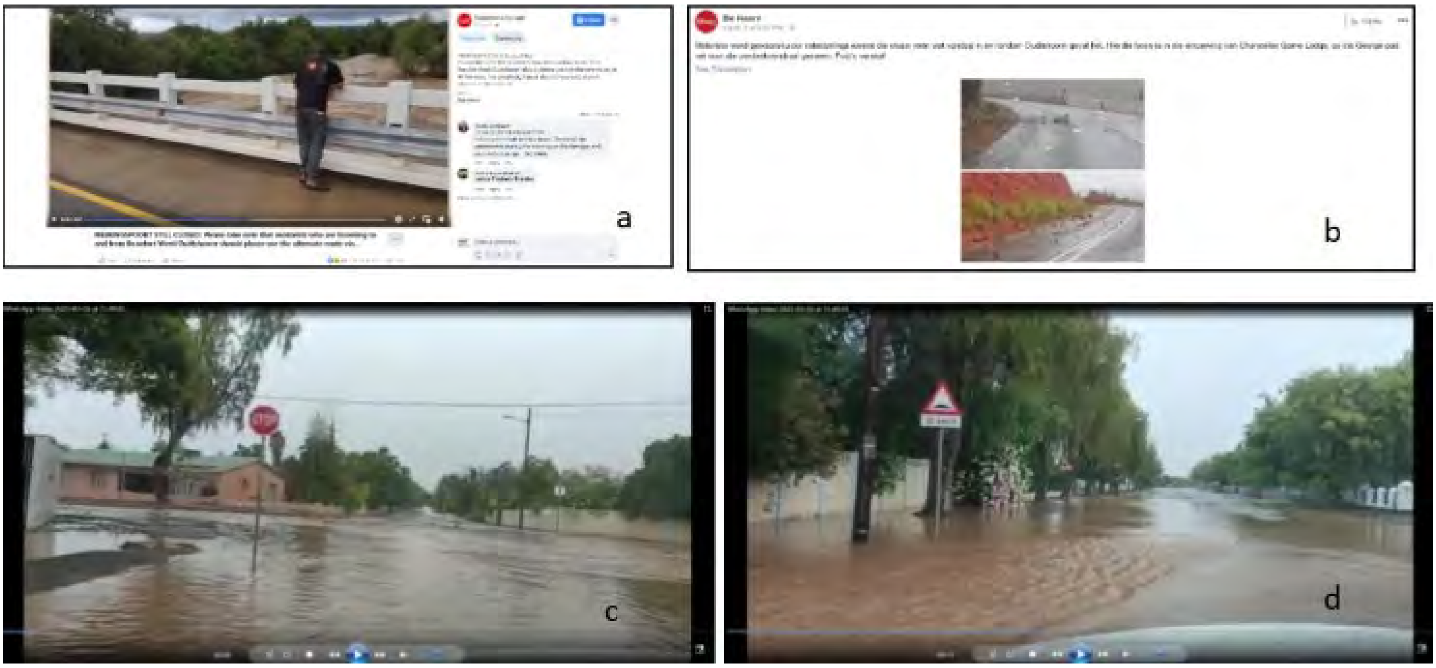


Figure 15: (a) The Meiringspoort river was full and closed while (b) there were rockfalls in a road in Oudtshoorn, (taken from Facebook), (c and d) video screenshots of a flooded Oudtshoorn road, shared by Kate Turner on WhatsApp.

SITUATION REPORT

Disaster Management provided the SAWS Western Cape Regional Office with a situation report for the 5 to 6 March 2023 severe weather incident. The status report indicated the impacts observed in the various municipalities as well as the progress of action by the disaster managers (16a, b and c). Figure 17 illustrates impacts reported and areas to which they occurred in.

b

General Updates

City of Cape Town

- An incident at Uitkyk informal settlement was reported.
- Assessments are underway.

Cape Winelands

Drakenstein:

- Minor flooding. Sandbags were issued.

West Coast

- No weather related incidents were reported.

Overberg

Swellendam:

- Provincial Road between Swellendam and Malgas was damaged.

c

Central Karoo

- No weather related incidents were reported.

Garden Route

Sporadic downpours of heavy rain have been experienced in the entire Garden Route District Municipal area. The areas mainly affected were the Hessequa, Central George and Northern Oudtshoorn/ Calitzdorp.

Bitou Local Municipality:

- No major infrastructure damages.
- No evacuations or displacements took place.
- All roads are still open.
- In the Kurland area, a few informal houses were reported to have roof damages due to strong winds.

Knysna Local Municipality:

- Several informal houses were affected by the flooding.
- No major problems were reported.
- All roads are still open.
- No evacuations or displacements took place.

George Local Municipality:

- A farm in the Kammanasie area was cut off due to flooding and water level have subsided.
- Infrastructure (roads and paving) damages were reported in Uniondale.
- Hail damages were reported to apple and pear orchards in the Langkloof area.
- No evacuations or displacements occurred.
- George Municipality is currently busy with assessments

Mossel Bay Local Municipality:

- All roads are open.
- No evacuations or displacements took place.

Hessequa Local Municipality:

- The OK Supermarket in Stilbaai experienced minor flooding.
- In Melkhoutfontein several houses were affected due to a small dam overflowing.
- Gravel roads in Riversdale as well as in rural areas were damaged by flooding. Garden Route District Municipal Roads, as well as the Hessequa Municipal teams are still assessing the damages.
- No evacuations or displacements occurred.

Kannaland Local Municipality:

- The Calitzdorp Hot Springs experienced minor flooding and had to be temporarily closed.
- All roads in the area are open.
- No evacuations or displacements occurred.

Oudtshoorn Local Municipality:

- Meiringspoort as well as Swartberg Passed were closed due to flooding, two trucks, two light motor vehicles were trapped in Meiringspoort. The light motor vehicles were able to turn around and exit the pass on the Klaarstroom side.
- A rockslide occurred approximately 10km from Oudtshoorn on the N12 causing the road to be temporarily closed, the rocks were cleared and the road was re-opened by the Provincial Roads Department.
- The low-water bridge giving access to Chandeliers Game Lodge was flooded.
- In the Dysselsdorp area several houses were affected due to flooding. Damages to roads infrastructure were reported.
- Oudtshoorn Municipality, provided with sandbags to mitigate the situation.
- Oudtshoorn experience power disruptions and several trees were blown over.
- No evacuations or displacements occured.

Meiringspoort as well as Swartberg Pass remains closed to traffic due to flooding.

Figures 16a, b, and c: The situation report provided by the Western Cape Disaster management

Impacts	Area
Flooding	Drakenstein, George, Hessequa, Kannaland, Oudtshoorn
Rockfalls	Oudtshoorn
Damage from strong winds	Kurland
Infrastructural damage	Swellendam, George, Hessequa, Oudtshoorn
Hail damage	George

Figure 17: Table of reported impacts over the Western Cape

CONCLUSION AND RECOMMENDATIONS

There was nothing particularly out of the ordinary about the weather system being studied in this paper. The dynamics of the system mostly followed the theory known about the system. However, the impacts of the severe thunderstorms that resulted still affected communities and services negatively.

As a result, this case study further emphasizes the importance of Impact-Based Forecasting (IBF), the monitoring of weather events and updating the warnings as circumstances change. The Oudtshoorn Municipality underwent the most significant impacts. Had the warning not been updated, this municipality would have remained in the minor impacts category, which would not have been enough warning for the impacts that were later experienced.

It is recommended that orographic lift be considered, especially over the Drakenstein and Stellenbosch areas, when such systems and circulation is expected. The weather system may result in higher rainfall amounts than reflected by model projections.

It is also recommended to use the SARFFG products when discussing warnings as they can inform the forecasters of the regions' soil moisture, flooding risk and other factors.

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WESTERN CAPE WATER - AND LANDSPOUTS 2022-2023

Elani Heyneke

The Western Cape, especially the south-western parts, is known for its Mediterranean climate. Summertime is dominated by the "Cape Doctor", with mainly warm and dry days, while winter is dominated by cold fronts and the occasional Cut-Off Low (COL) pressure associated with cold, wet, and windy conditions.

The term "thunderstorm" is not well known by Capetonians, since it is a rare phenomenon, even more so the term "tornado". However, in the last year (2022 to 2023), there have been numerous reports of "mini tornadoes" over the south-western parts of the country. The purpose of this article is to investigate these reports and to clarify the associated wind phenomena.

The South African Weather Service (SAWS) has conducted field assessments after each of these reports and has determined that the wind phenomena were either water- or landspouts and not tornadoes. Similar to a tornado, a landspout also rotates, is usually fast-moving and can be damaging. However, landspouts are much weaker and smaller in scale and form from the ground up, rather than from a cumulonimbus cloud (thunderstorm) to the ground.

For the SAWS to determine the type of wind phenomenon, various observational data are used. However, videos, photos and information from eyewitness accounts are vital during the final determination. The dominant weather system on each of the four case studies was predominantly cold fronts and one COL as seen in Figure 1. Referring to Table 1, the water- and landspouts were mainly observed during late afternoon, while the most recent landspouts (25 August 2023), that were observed near Cape Town, occurred in the morning.

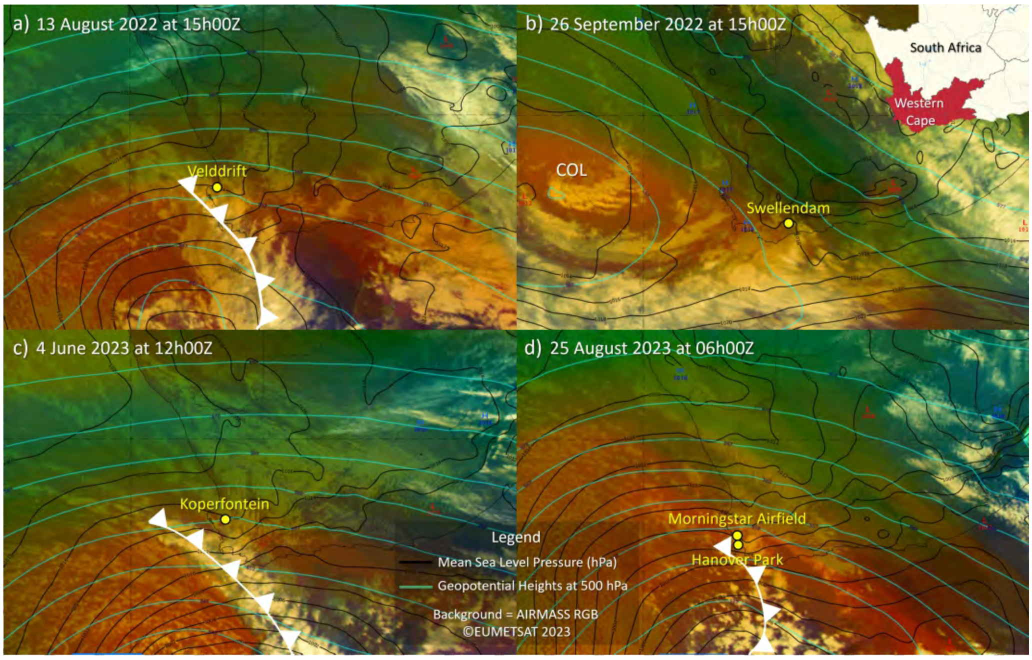

Figure 1: The dominant weather systems (mean sea level pressure and 500 hPa geopotential heights) on the four days when water- and landspouts were reported over the south-western parts of the Western Cape. a) Velddrift on 13 August 2022, b) Swellendam on 26 September 2022, c) Koperfontein on 4 June 2023 and d) Hanover Park and Morningstar Airfield on 25 August 2023 (©EUMETSAT 2023 and created by Elani Heyneke)

Table 1: Reported water- and landspouts over the south-western parts of the Western Cape from 2022 to 2023

Date	Time (SAST)	Location	EF-Rating	*Length (m)	*Width (m)	*Duration (min)	Dominant Weather System
13-Aug-22	16h00	Velddrift, West Coast	EF 1	565	20-26		Ahead of a cold front
26-Sep-22	15h30	Near Swellendam, Overberg	EF 1	1800	280	15	COL west of South Africa
4-Jun-23	16h30	Koperfontein, West Coast	EF 1			5	Ahead of a cold front
25-Aug-23	07h00	Hanover Park, City of Cape Town	EF 0				Cold front
25-Aug-23	10h00	Near Morningstar Airfield, West Coast	EF 1	4390		5	Cold front

*The length, width and duration are an estimation that was calculated on Google Maps and as reported by witnesses

The water- and landspouts that were reported during 2022 and 2023, and their associated damage, can be seen in Figure 2. Photos and videos during and after the event assist the SAWS to verify and confirm the type of wind phenomena and strength.

Although landspouts are not as severe as tornadoes, the SAWS urges the public to be as safe as possible and not to put oneself in harm's way. During a water-, landspout or tornado events, it is important to seek a secure and safe shelter. These events don't usually last longer than five minutes, but it does not mean that the danger is completely over.

Broken glass, exposed electrical wires and sharp edges from torn roofs can still cause harm to humans and animals. It is also essential to stay calm and to contact the local disaster manager and/or emergency services as soon as possible.

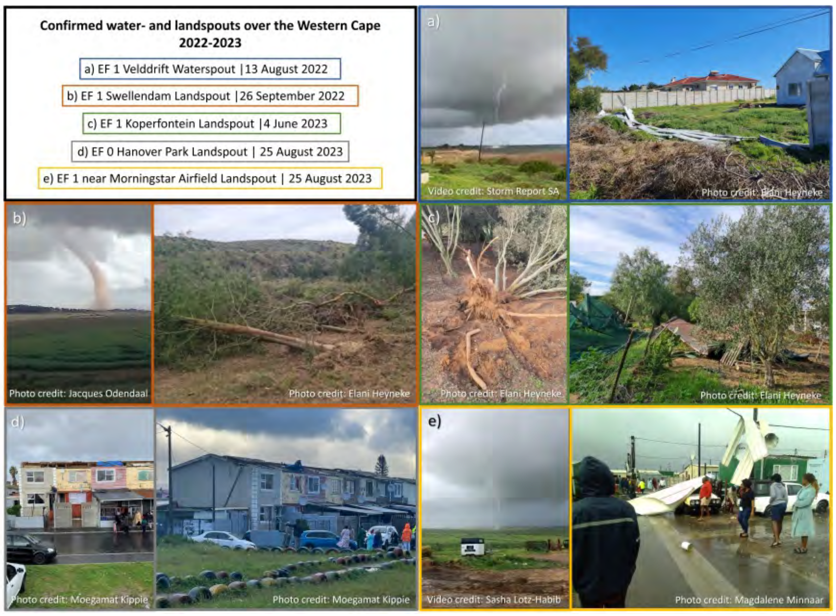

Figure 2: The five water- and landspouts that were reported and confirmed over the Western Cape during 2022 and 2023. a) EF 1 Velddrift Waterspout (13 August 2022); b) EF 1 Swellendam Landspout (26 September 2022); c) EF 1 Koperfontein Landspout (4 June 2023); d) EF 0 Hanover Park Landspout (25 August 2023) and e) EF 1 near Morningstar Airfield Landspout (25 August 2023)

The Enhanced-Fujita (EF) rating scale is used to determine the strength of water- and landspouts as well as tornadoes. The EF-rating (strength) takes the damage severity to structures and trees into consideration and ranges from EF 0 to EF 5. The EF-rating scale can also be used to determine the estimated wind speed of the wind phenomenon.

Even though it is extremely difficult to forecast these wind phenomena, the information and assistance from the public and disaster management after such an event are crucial in understanding what factors play a role in their development. This information, coupled with the increasing accuracy of weather forecasts, will hopefully assist in predicting these events with greater lead times.

For detailed information on the above case studies, please visit the SAWS website.
www.weathersa.co.za

1. EF 1 Velddrift Waterspout | 13 August 2022
2. EF 1 Swellendam Landspout | 26 September 2022
3. EF 1 Koperfontein Landspout | 4 June 2023
4. EF 0 Hanover Park Landspout | 25 August 2023
5. EF 1 near Morningstar Airfield Landspout | 25 August 2023

DUST AND SANDSTORM ALONG THE NAMIBIAN COAST FROM 10 - 11 JULY 2023, AND ITS INFLUENCE ON MARINE AND AVIATION FORECASTS

Samukelisiwe Thwala - Meteorologist | Disaster Risk Reduction (DRR)

INTRODUCTION

The central and eastern parts of Namibia receive most of their rainfall (about 90%) during the summer-autumn season. Subsequently, between June and September Namibia receives minimal rainfall and less than 10 percent of its annual rainfall occurs during the winter season. Therefore, it can be divided into primarily two seasons, namely a cool and dry winter, and a hot and rainy summer. Considering that Namibia is a semi-arid and sandy country which usually experiences hot and dry climatic conditions in winter and bare soil, the presence of strong winds over the interior enhances the chance of dust and sand particles suspended in the lower atmosphere and transported in the direction where the wind is blowing to.

The aim of this case study is to determine the effect of berg wind conditions on the development of blowing dust and sand along the coastal areas of Namibia.

BACKGROUND

Anti-cyclonic weather systems such as the South Atlantic High Pressure (SAH) play a vital and crucial role in the winter climate of southern Africa. These semi-permanent subtropical high pressure systems cover about 40 percent of the earth and are usually located at approximately 30 degrees in the northern and southern hemispheres.

Berg winds are most common over elevated areas such as mountains or plateaus. These hot and dry winds are transported over the eastern and central interior of Namibia, westwards towards the coast. As berg-winds descend towards the coast, the mean sea level pressures are expected to drop to form surface low pressure troughs. The berg winds can result in sand and dust particles being suspended in the atmosphere and transported towards the direction the wind is blowing to.

Forecasting dust and sandstorms is important because they can result in serious social and health impacts and can also affect visibility, a crucial factor in the aviation and marine industries. However, forecasting for this dust and sand storms can be challenging because it requires a skilled forecaster to take into the consideration the historic weather conditions such as recent rainfall events, the soil moisture of the area of interest as well as, in this case, the vegetation cover. With the climatic knowledge of the area, forecasters understand that Namibia barely receives rainfall in winter, therefore, with the rainfall sparsity, vast amounts of bare land and strong winds, blowing dust and sand is most likely to occur.

On 10 and 11 July 2023, post a cold front event, a high pressure system with a central pressure of 1040 hPa was situated west of the South Africa, with its ridge extending over the southern parts of southern Africa (See Figure 1). This set-up resulted in an exceptional strong and tight pressure gradient over the western interior of southern Africa, which generated strong winds. Subsequently, considering that most parts of Namibia are arid and semi-dessert, vast areas of the land cover are bare and therefore dust and sand particles were lifted and blown westwards because of the strong, warm and dry winds from the interior.

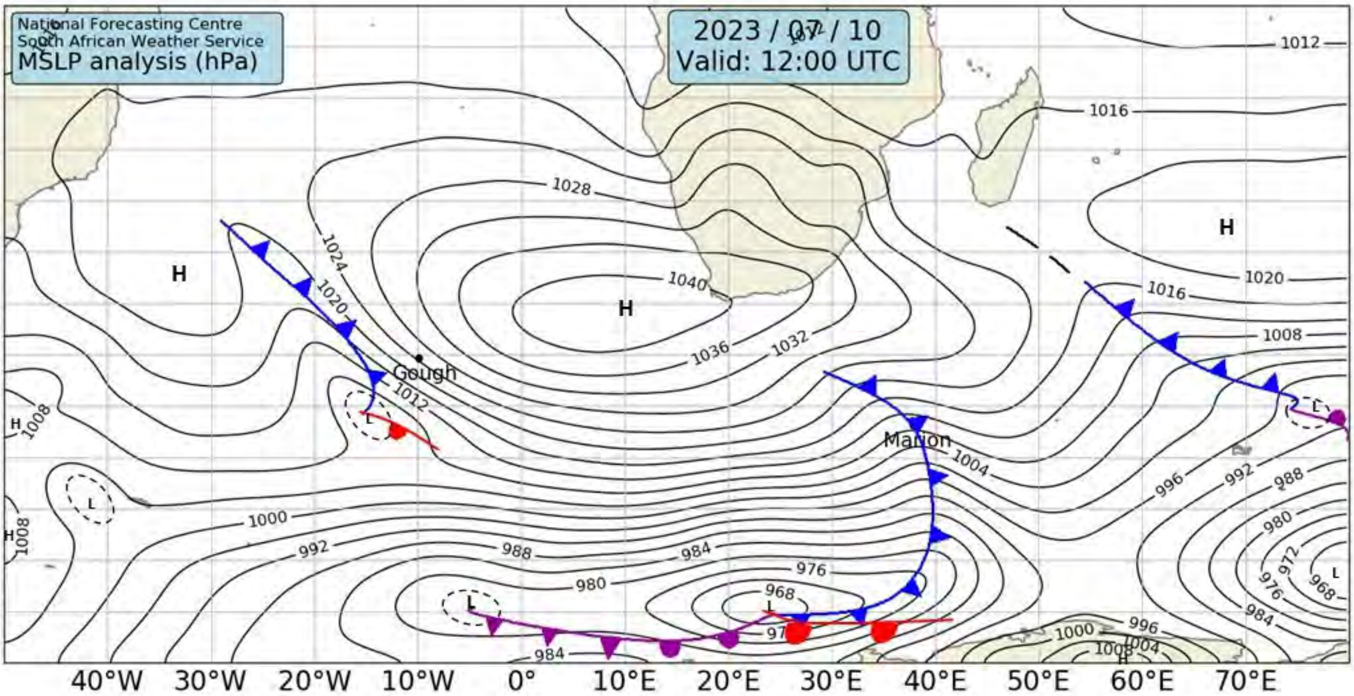

Figure 1: Synoptic chart observed at 12Z (UTC) on 10 July 2023 depicting a strong ridging high pressure system (1040 hPa) over South Africa, with a surface trough in the western parts of Namibia. (Source: SAWS 2022)

The distance between Upington and Windhoek is approximately 775 km (as the crow flies), and Upington is the closest station that has an upper-air ascent, therefore, for this case, we shall use Upington's upper-air sounding data. The Upington upper-air ascent at 00Z on 11 July 2023 (see Figure 2) , observed that the atmosphere was fairly dry from the surface into the upper levels.

Strong winds of about 20 knots (40 km/h) were observed already from midnight. However, as using surface observations, the winds over Windhoek were slightly stronger than the winds observed at Upington.

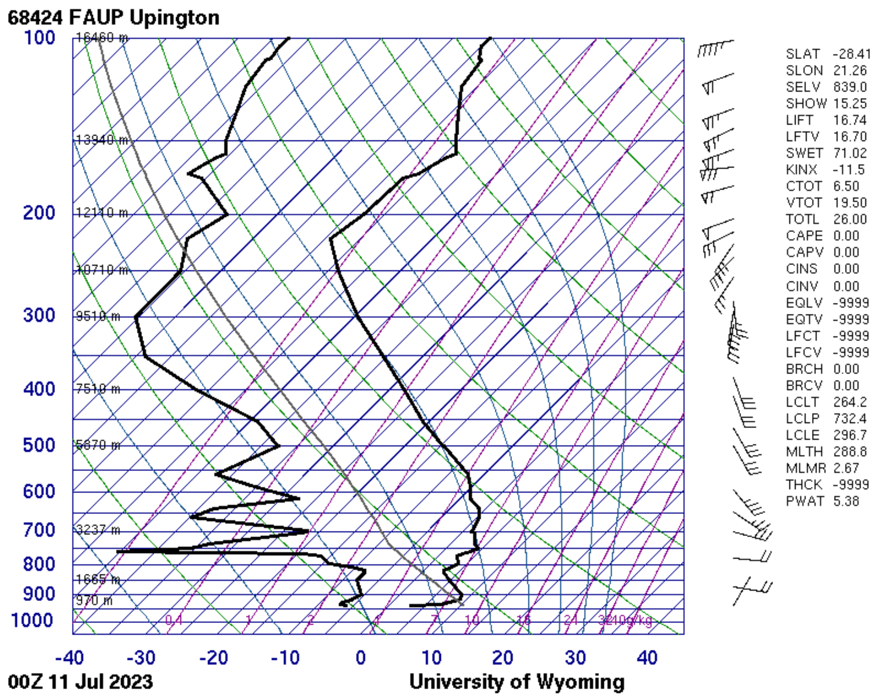

Figure 2: Upington skew t graph observed at 00Z on 11 July 2023 depicting a dry vertical profile of the atmosphere with strong winds. (Source: University of Wyoming 2022)

FORECASTING PRODUCTS

Strong winds observed over the Windhoek Airport (see Figure 3) at 12 UTC were ranging between 25 km/h to 32 km/h, with maximum winds of 75 km/h. Windhoek METARs also reported strong north-easterly winds over a prolonged period with a dry atmosphere, as the dew point depression measured was very huge. These conditions were conducive for the development of blowing sand and dust off the coast of Namibia.

Date: 2023-07-11 - **Time:** 08:00 **(Packtime: 2023-07-11 08:11)**

FYWW 110800Z 09016G34KT CAVOK 07/M13 Q1033=

Date: 2023-07-11 - **Time:** 10:00 **(Packtime: 2023-07-11 10:11)**

FYWW 111000Z 08015G29KT CAVOK 11/M11 Q1033=

Date: 2023-07-11 - **Time:** 11:00 **(Packtime: 2023-07-11 11:11)**

FYWW 111100Z 08017G31KT CAVOK 12/M10 Q1032=

Date: 2023-07-11 - **Time:** 12:00 **(Packtime: 2023-07-11 12:11)**

FYWW 111200Z 08016G34KT CAVOK 14/M11 Q1030=

Date: 2023-07-11 - **Time:** 13:00 **(Packtime: 2023-07-11 13:11)**

FYWW 111300Z 08013G25KT CAVOK 15/M10 Q1029=

Date: 2023-07-11 - **Time:** 14:00 **(Packtime: 2023-07-11 14:11)**

FYWW 111400Z 08012G25KT CAVOK 16/M10 Q1029=

Figure 1: METARs for the Windhoek airport observed between 08 and 14UTC

Satellite imagery (Figure 4 a and b) depicts the blowing sand and dust particles off the coast of Namibia propagating westwards in the direction the wind is blowing to.

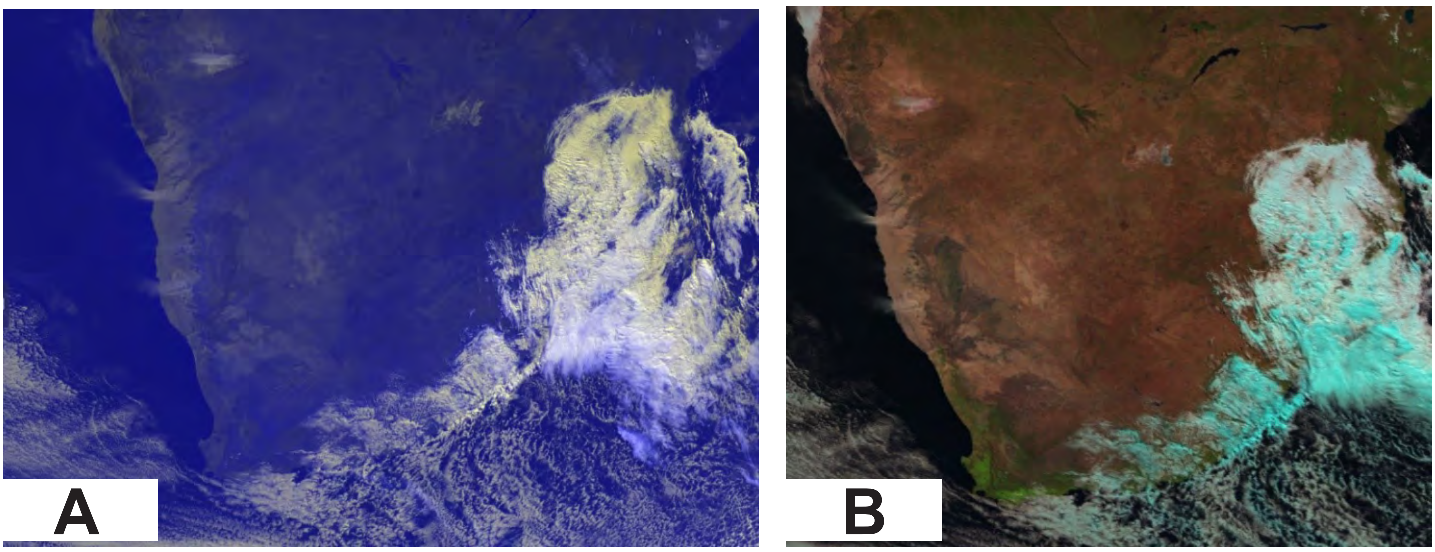

Figure 4: High resolution (a) as well as the Day Natural Colour (b) satellite imagery showing the wind blowing from the interior of Namibia towards the west (Source Eumetsat 2023)

As mentioned, sand and dust storms are hazardous weather conditions that can cause harm to the marine and aviation industry. The blowing sand and dust that developed on 10 and 11 July lead to significantly reduced visibility along the coastal areas, therefore this had to be forecasted and included in the warning component of the forecasting products and be considered as a warning for the marine and aviation industry (See Figure 6).

For the marine users out at sea, a weather forecast for coastal waters up to 50 nautical miles off-shore (approximately 92,6km) was issued and disseminated at 08 UTC and at 13 UTC. These forecast products included a reduced visibility (see Figure 5) forecast and warning for this particular coastline.

CUNENE RIVER TO WALVIS BAY:
WIND : SE to E 10 to 20, becoming NE to E 15 to 25 towards mid-period, reaching 30 to 35 in the second half of the period.
VIS : Good, but very poor in blowing sand and dust at times.
SEA STATE: 2.0 to 3.0m, S to SW swell.

WALVIS BAY TO ORANGE RIVER:
WIND: E to SE 15 to 25, becoming NE 15 to 25 north of Elizabeth Bay towards mid-period.
VIS: Good, but very poor in blowing sand and dust at times.
SEA STATE: 2.0 to 3.0m, S to SW swell.

Figure 5: Coastal forecast issued on the 10 July 2023 at 10 UTC forecasting possibility of blowing dust and sand along the coast of Namibia. (Source SAWS 2023)

ALERTS:
=======
WARNING:
----
1. Very poor visibility in blowing sand and dust is expected between Walvis Bay and Orange River.

2. Moderate visibility in showers and rain is expected in places along over the Mozambique Channel.

3. A Gale force NE to E wind of 35 is expected between Cunene River and Walvis Bay in the second half of the period.

4. Very rough seas with wave heights between 4.5 to 5.0m are expected over the south and central of the Mozambique Channel.

Figure 6: Coastal alerts that included a reduction in visibility warning due to the blowing sand and dust from the interior to the coast. (Source SAWS,2023)

As previously mentioned, the aviation industry can be badly affected by sand and dust storms. Any Visual Flight Rule (VFR) aircraft that operates under these conditions is faced with a great hazard and is advised by aviation forecasters not to operate. The visibility can be reduced to below 5000 m which may cause the aircraft to crash, leading to possible injuries and fatalities.

The Aviation Weather Centre is responsible for issuing significant weather charts that cover the southern and central parts of southern Africa, and on 11June 2023, sandstorms were forecasted for the coast of Namibia (see Figure 7). An AIRMET, which is an inflight weather advisory, was issued by the South African Weather Service (SAWS) which warned of this phenomenon.

The Namibian Meteorological Service issued a Terminal Aerodrome Forecast (see Figure 8) which forecasted the strong winds as well as sandstorms (Figure 9).

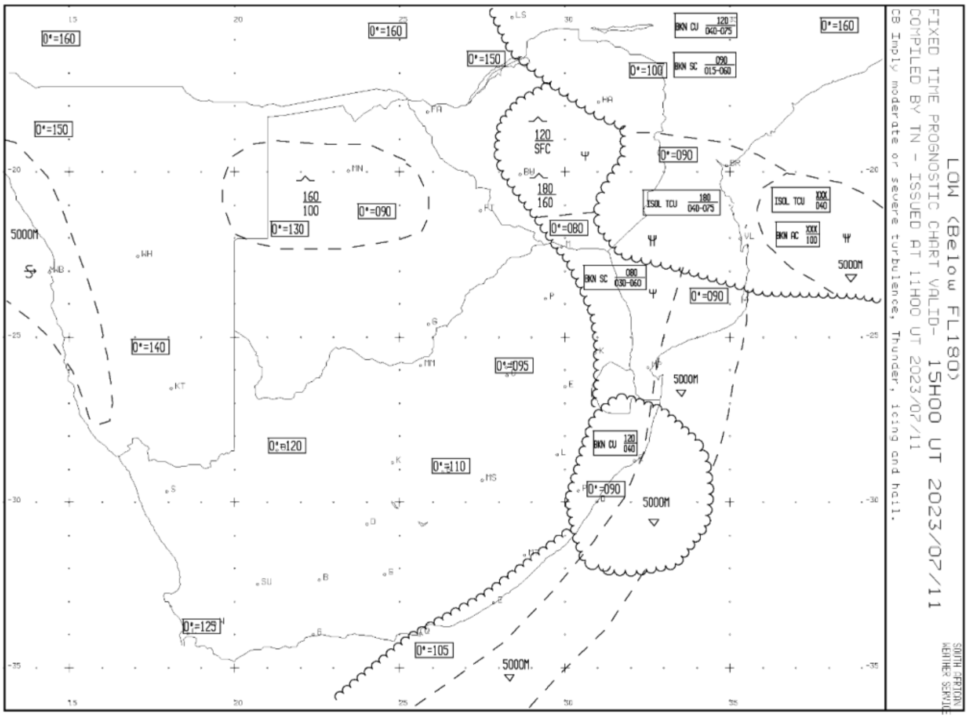

Figure 7: Significant weather chart showing the forecasted sandstorms along the coast of Namibia. (Source SAWS, 2023)

S2401 E02650 - S2333 E02930 FL240/300=
Airmet FAJA (Johannesburg) FIR
FAJA AIRMET C02 VALID 111000/111400 FAOR- FAJA JOHANNESBURG FIR SFC VIS 0500M DU
FCST WI S2730 E01500 - S2730 E01616 - S2803 E01635 - S2823 E01502 - S2820 E01500=

Figure 8: AIRMET for the blowing dust storm expected over Namibia expected between 10 and 14 UTC. (Source SAWS, 2023)

Namibia
TAF FYWH 111000Z 1112/1212 10013G24KT CAVOK BECMG 1119/1121 08010KT=
TAF FYKT 111000Z 1112/1212 08019KT CAVOK BECMG 1119/1121 06008KT=
TAF FYWB 111000Z 1112/1212 11026KT 5000 +SS NSC BECMG 1113/1115 05010KT CAVOK=
TAF FYGF 111100Z 1112/1121 09015KT CAVOK=
TAF FYLZ 111100Z 1112/1121 07017G34KT 1000 +SS NSC BECMG 1115/1117 13012KT CAVOK=
TAF FYRU 111100Z 1112/1121 11012G22KT CAVOK=

Figure 9: Terminal Aerodrome Forecast issued by the Namibian Meteorological Service, depicting the strong winds over Windhoek and sandstorms over Walvis Bay. (Source SAWS, 2023)

CONCLUSION

Sandstorms as well as dust storms have a negative impact on the social, economic, and agricultural sector. With the aid of early warnings of this weather phenomenon, we can reduce economic losses, and save lives (WMO, 2023).

The South African Weather Service as well as the Namibian Meteorological Service successfully forecasted the dust storms and issued severe weather alerts to warn and conscientise the public, marine stakeholders, the aviation industry as well as other stakeholders of the possible hazardous weather.

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HEAT WAVES IN SOUTH AFRICA: CURRENT AND NEAR FUTURE CLIMATES

Innocent Mbokodo

1. INTRODUCTION

Weather and climate extremes have adverse effects on the environment, biodiversity, economy, and society in general. They may hamper the attainment of sustainable development goals and national development plans. Climate change is increasing the frequency and intensity of some extreme events, including heat waves and heavy rainfall events (Shongwe et al. 2011).

Vulnerability to these extreme weather and climate events is highly variable across the globe, depending on exposure, socio-economic status, and other factors, with the poorest likely to be most adversely impacted by them. Climate extremes such as floods, droughts, and heat waves have become a topical issue because they have triggered the majority of natural disasters over the past few decades. This study focusses on heat waves in the current climate and their future projections.

Characteristics of heat waves are expected to change due to global warming. Heat waves can have negative impacts, ranging from agricultural yields to human health problems. The occurrence of heat waves may lead to illnesses, particularly in children and the elderly (Vandentorren et al 2003), which may result in an increase in mortality rates. Heat waves can impact on water supply through increased evaporation rates, and can also damage crops and vegetation in general.

They also may minimize crop production since environmental factors such as temperature and soil moisture are determinant factors of yields (Waggoner 1983). Furthermore, heat waves can also affect the economy of a region through extensive usage of air conditioners as a mitigation strategy to heat stress. Several studies have focused on longer lasting heat waves (e.g., Kunkel), with limited research done on short-lived heat waves. Short-lived heat waves can induce wildfires that can damage property, because they usually occur during droughts, due to enhanced subsidence and coinciding with dry vegetation.

2. DATA AND METHODS

Daily maximum and minimum temperatures were obtained from the South African Weather Service (SAWS) for the period from 1981 to 2020 as our current climate. The data are recorded at a uniform time at all stations as per the World Meteorological Organization (WMO) standards. This study selected 24 stations of different altitudes that have at least 95% data available during the study period. Selected stations are well distributed across South Africa so that all thermal regions (Clusters) are well represented (Figure 1).

This study furthermore adopted the SAWS definition that a heat wave occurs “when for at least three consecutive days the maximum temperature of a certain region is five degrees Celsius higher than the mean maximum for the hottest month for a particular station”.

We used 2040-2069 as our near future climate and the Conformal Cubic Atmospheric Model (CCAM) was used to simulate heat waves with surface forcing from six different Global Climate Models (i.e., ACCESS, CCSM4, CNRM, GFDL, MPI, NorESM1M) forced in return by two different emission scenarios, namely Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and RCP8.5). RCP 4.5 represents a modest-high mitigation future, whilst RCP 8.5 represents a low mitigation future. The December-January-February (DJF) season was considered as it experiences most heat waves.

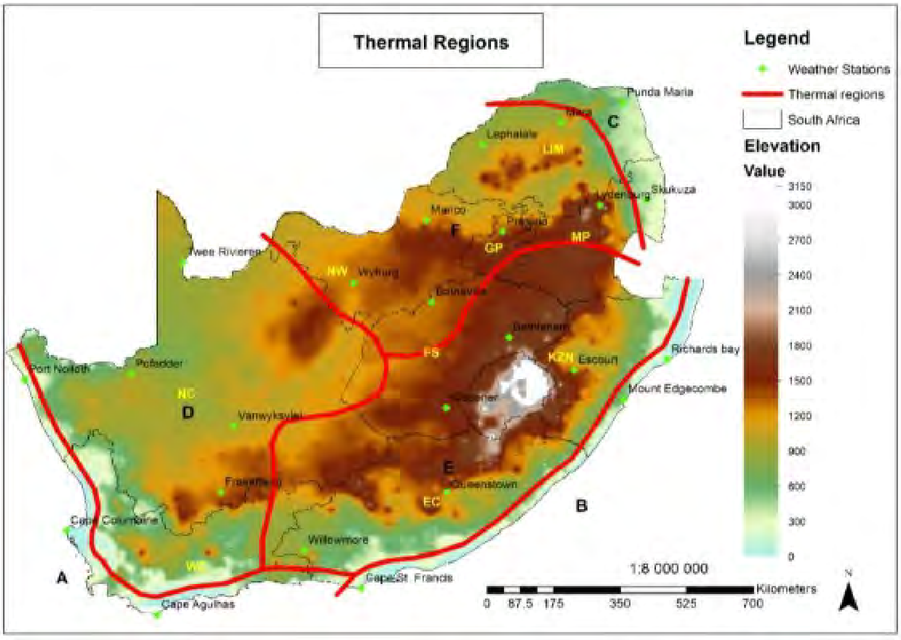

Figure 1: Topographical map of South Africa showing thermal regions and SAWS point station names (in black) with at least 95% data availability from 1981 to 2020 (after Kruger and Shongwe 2004). The abbreviations in yellow represent provincial names: Western Cape (WC), Northern Cape (NC), Eastern Cape (EC), Free State (FS), KwaZulu-Natal (KZN), North West (NW), Gauteng (GP), Mpumalanga (MP), and Limpopo (LIM)

3. RESULTS

3.1 . Heat wave variability in the current climate: 1981-2020

Over most thermal regions of South Africa, heat waves are most common during the austral summer (Figure 2). However, the western coast (thermal region A) proves to be an exception and recorded most of its heat waves during the austral winter months (Table 1).

This can be linked to the establishment of a semi-permanent high-pressure system over land during winter, which persistently drives warm inland air down the escarpment during this season and results in berg winds around the region that warms adiabatically. Berg winds are foehn types of wind that occur along the coast of South Africa when continental air descends a steep escarpment toward the coast, usually in the presence of a coastal low.

The winter season over South Africa is also the rainy season along the west and south coasts, due to the passage of cold fronts from the South Atlantic. Coastal lows often precede cold fronts, resulting in berg winds, high temperatures, or heat waves, which may lead to wild forest fires.

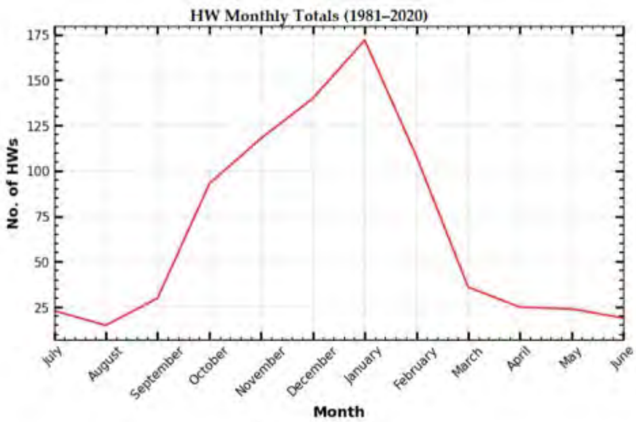

Figure 2: Monthly totals of heat wave frequency (red line) over South Africa from 1981 to 2020 from the 24 selected stations. The peak in January is clearly discernible.

Table 1 presents the monthly heat wave frequency of the selected stations, while Table 2 presents the monthly average duration. It is observed that heat waves are a common feature of the climate of South Africa, with almost half of the selected stations experiencing an average of at least one heat wave event per season over the 40-year period.

Stations experiencing high total heat wave frequency are those that are more equatorward, such as Port Nolloth (29.23 °S, 16.87 °E) and Punda Maria (22.68 °S, 31.02 °E), which have 104 and 79 events, respectively. Thermal region F bordering Botswana in the north also recorded a high total number of heat waves (325) and these events lasted for more than four days.

Not many heat wave occurrences are observed on the south-western coast, and the few that occur tend to last for an average of three days. No significant heat wave activity was observed on the south-east coast. The Mount Edgecombe station in the thermal region B on the south-east coast did not record any heat wave events during the 40-year study period. This can be attributed to the regular cooling effect of the adjacent oceans as well as temperature changes along the coast due to perturbations from traveling weather systems such as cold fronts and ridging highs.

3.2 Heat waves in near future climate: 2040-2069

Heat wave events are projected to be significantly higher during the 2040 – 2069 period than during the present-day climate. Some regions, such as the Free State and the Highveld of KwaZulu-Natal, that were simulated as not experiencing heat waves in winter during present-day climate are beginning to experience few events over the 30-year with a dramatic increase. Over 20 events are projected to occur over those areas during winter.

Table 1: The monthly heat wave frequency from 1981–2020 from the 24 selected stations

Thermal region (Cluster)	Station Name	1981 - 2020 heatwave frequency											
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
A	Cape Agulhas	0	0	0	0	0	0	0	0	0	0	0	0
	Cape Columbine	0	0	2	1	1	3	4	2	2	7	1	0
	Port Nolloth	22	14	6	4	1	0	0	1	5	16	18	17
B	Cape St. Francis	1	0	0	0	0	0	1	0	1	0	5	2
	Mount Edgecombe	0	0	0	0	0	0	0	0	0	0	0	0
	Richards bay	0	0	0	0	1	0	2	3	1	1	0	0
C	Punda Maria	0	1	1	13	16	21	10	4	3	0	0	0
	Skukuza	0	0	6	8	6	13	8	3	6	0	0	0
D	Fraserburg	0	0	0	0	0	2	9	13	0	0	0	0
	Pofadder	0	0	0	0	1	0	6	0	0	0	0	0
	Twee Rivieren	0	0	0	0	3	7	8	2	0	0	0	0
	Vanwyksvlei	0	0	0	0	0	1	7	1	0	0	0	0
	Bethlehem	0	0	0	1	4	6	7	4	0	0	0	0
	Willowmore	0	0	0	3	4	6	13	11	2	0	0	0
E	Escourt	0	0	5	7	12	9	13	3	0	1	0	0
	Queenstown	0	0	0	3	3	4	6	10	4	0	0	0
	Wepener	0	0	0	0	0	2	9	1	1	0	0	0
F	Bothaville	0	0	0	6	8	13	14	9	1	0	0	0
	Lephalale	0	0	2	6	10	9	6	7	3	0	0	0
	Lydenburg	0	0	2	3	3	0	0	0	0	0	0	0
	Mara	0	0	6	17	13	12	9	6	4	0	0	0
	Marico	0	0	0	9	18	12	19	14	2	0	0	0
	Pretoria	0	0	0	8	10	5	7	6	1	0	0	0
	Vryburg	0	0	0	4	4	15	14	8	0	0	0	0

Table 2: The monthly heat wave average duration from 1981–2020 from the 24 selected stations

Thermal region (Cluster)	Station Name	1981 - 2020 heat wave Average duration (days)											
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
A	Cape Agulhas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Cape Columbine	0.0	0.0	3.5	4.0	3.0	3.0	4.0	3.3	3.5	3.9	3.0	0.0
	Port Nolloth	4.1	3.4	3.3	3.0	3.0	0.0	0.0	3.0	3.6	3.6	3.4	3.6
B	Cape St. Francis	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	3.0	3.0	3.0	3.0
	Mount Edgecombe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Richards bay	0.0	0.0	0.0	0.0	3.0	0.0	3.0	4.0	6.0	4.0	0.0	0.0
C	Punda Maria	0.0	3.0	3.0	3.4	3.8	3.4	3.2	3.8	3.0	0.0	0.0	0.0
	Skukuza	0.0	0.0	3.3	3.6	3.9	3.3	3.4	4.0	3.3	0.0	0.0	0.0
D	Fraserburg	0.0	0.0	0.0	0.0	0.0	3.0	3.4	3.0	0.0	0.0	0.0	0.0
	Pofadder	0.0	0.0	0.0	0.0	3.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
	Twee Rivieren	0.0	0.0	0.0	0.0	3.3	3.3	4.6	3.0	0.0	0.0	0.0	0.0
	Vanwyksvlei	0.0	0.0	0.0	0.0	0.0	3.0	3.3	3.0	0.0	0.0	0.0	0.0
	Bethlehem	0.0	0.0	0.0	4.0	5.0	4.5	3.3	3.5	0.0	0.0	0.0	0.0
	Willowmore	0.0	0.0	0.0	3.5	3.0	3.3	3.6	3.5	3.0	0.0	0.0	0.0
E	Escourt	0.0	0.0	3.0	3.3	4.1	3.6	3.7	3.0	0.0	3.0	0.0	0.0
	Queenstown	0.0	0.0	0.0	3.0	3.3	3.3	3.9	4.2	3.0	0.0	0.0	0.0
	Wepener	0.0	0.0	0.0	0.0	0.0	6.0	4.1	3.0	3.0	0.0	0.0	0.0
F	Bothaville	0.0	0.0	0.0	4.3	3.7	4.3	4.8	3.9	3.0	0.0	0.0	0.0
	Lephalale	0.0	0.0	3.0	4.0	4.3	3.4	4.7	4.1	4.0	0.0	0.0	0.0
	Lydenburg	0.0	0.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mara	0.0	0.0	3.3	3.4	3.6	3.7	3.8	3.0	3.3	0.0	0.0	0.0
	Marico	0.0	0.0	0.0	4.9	4.3	3.9	4.4	4.4	3.0	0.0	0.0	0.0
	Pretoria	0.0	0.0	0.0	5.8	4.6	6.0	4.2	5.9	4.0	0.0	0.0	0.0
	Vryburg	0.0	0.0	0.0	6.0	4.0	4.4	4.7	3.5	0.0	0.0	0.0	0.0

Dramatic increases in December - January - February (DJF) heat wave frequency are expected during the 2040-2069 period (Figure 3c-d) when compared to the present climate, particularly along the south and eastern coasts.

These regions are expected to experience up to 100 events during summer over the 30-year period, which averages to slightly over three events per summer season per year. However, it must be noted that these heat waves will last for less than a week along the coasts but the number of days per event are expected to increase inland. An increase in the number of heat waves is also observed to a greater extent over the Karoo during both summer and autumn.

The simulations also indicate that for the 2040-2069 period, heat waves will last the longest, between 9 and 10 days, over this region in summer. This may be associated with the dry conditions over the Karoo, as the region experiences little or no rainfall throughout the year.

Drier regions heat up quickly because the heating that reaches the surfaces does not start by evaporating water on the surface, which can also result in cooling by latent heat absorption. There is a continual pattern of heat waves becoming more intense simulated over most parts of the eastern half of South Africa. These increases are strong in late summer and early winter over the northern parts of the country, where daily maximum temperatures are the highest.

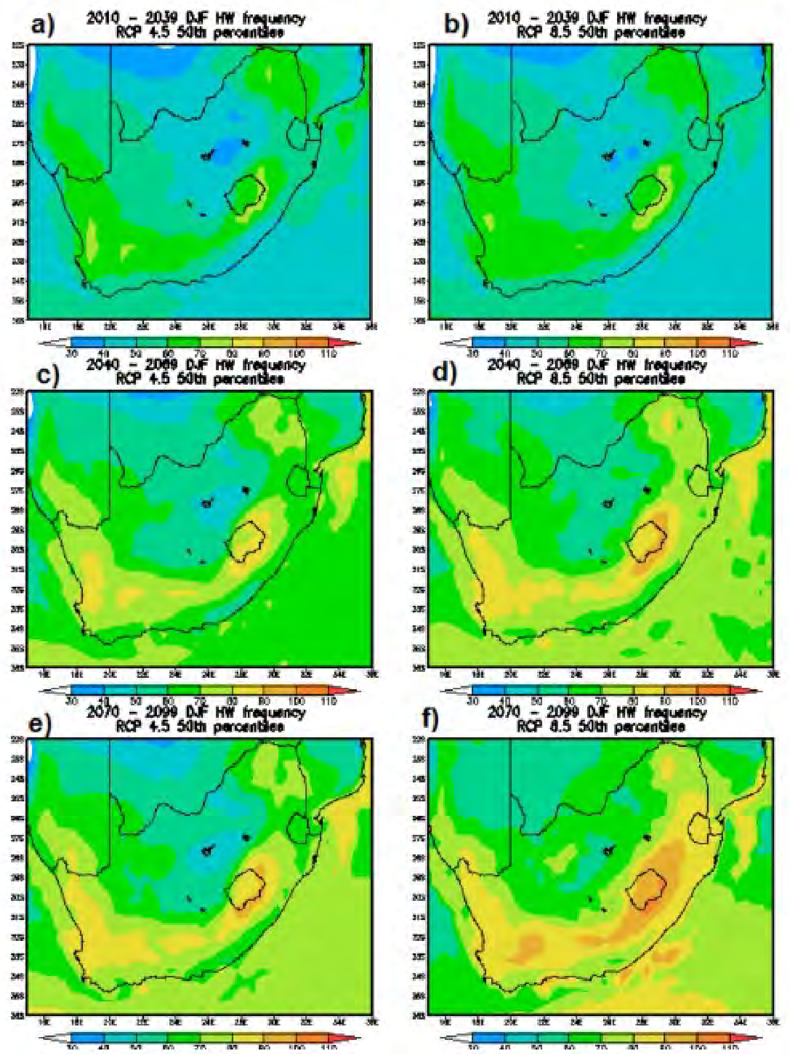

Figure 3: Simulations of DJF heat wave frequency 50th percentile for a) 2010-2039 RCP 4.5, b) 2010-2039 RCP 8.5, c) 2040-2069 RCP 4.5, d) 2040-2069 RCP 8.5, e) 2070-2099 RCP 4.5 and f) 2070-2099 RCP 8

3. CONCLUSIONS AND SUMMARY

There is consensus that the average global temperature is increasing due to increased greenhouse gas concentrations. This study has found that heat waves are unusual in some parts of the country in the present-day climate, but are expected to occur more frequently in the future warmer climate when using both RCP 4.5 and RCP 8.5 emission scenarios.

It is also indicated that heat waves are expected to last longer, particularly over the interior, and become more intense. Heat wave occurrences are mainly due to the persistence of a middle-level high-pressure system, which is often located over Botswana and Namibia and commonly referred to as the Botswana High. This Botswana High typically strengthens at its most southward position during summer, a season where most heat waves occur in South Africa.

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THE IPCC AR6 WGI REPORT: EXCERPTS WITH A SPECIFIC FOCUS ON AFRICA AND SOUTHERN AFRICA IN PARTICULAR

Andries Kruger

The International Panel on Climate Change (IPCC) prepares comprehensive Assessment Reports about the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

It also produces Special Reports on topics agreed to by its member governments, as well as Methodology Reports that provide guidelines for the preparation of greenhouse gas inventories. The IPCC is working on the Sixth Assessment Report which consists of three Working Group contributions and a Synthesis Report. The Working Group I (WG I) contribution was finalized in August 2021 and the WG II reports in 2022 (https://www.ipcc.ch/).

These reports collectively provide the most authoritative guidance to policymakers regarding adaptation to and mitigation of climate change. This summary intends to synthesize the main findings of the WGI report with a focus on the significance of the inferences at the continental, regional (Southern Africa) and/or national level.

The Working Group I contribution to the Sixth Assessment Report addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science (https://www.ipcc.ch/report/ar6/wg1/). The following headline statements summarise the main conclusions of the WG I report (https://www.ipcc.ch/report/ar6/wg1/resources/spm-headline-statements/):

THE CURRENT STATE OF THE CLIMATE

- It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.
- The scale of recent changes across the climate system as a whole – and the present state of many aspects of the climate system – are unprecedented over many centuries to many thousands of years.
- Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since Ar5.
- Improved knowledge of climate processes, paleoclimate evidence and the response of the climate system to increasing radiative forcing gives a best estimate of equilibrium climate sensitivity of 3°C, with a narrower range compared to Ar5.

POSSIBLE CLIMATE FUTURES

- Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1,5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide (CO_2) and other greenhouse gas emissions occur in the coming decades.

- Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, heavy precipitation, and, in some regions, agricultural and ecological droughts; an increase in the proportion of intense tropical cyclones; and reductions in Arctic sea ice, snow cover and permafrost.

- Continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events.

- Under scenarios with increasing CO_2 emissions, the ocean and land carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere.

- Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.

CLIMATE INFORMATION FOR RISK ASSESSMENT AND REGIONAL ADAPTION

- Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes.

- With further global warming, every region is projected to increasingly experience concurrent and multiple changes in climatic impact-drivers. Changes in several climatic impact-drivers would be more widespread at 2°C compared to 1,5°C global warming and even more widespread and/or pronounced for higher warming levels.

- Low-likelihood outcomes, such as ice-sheet collapse, abrupt ocean circulation changes, some compound extreme events, and warming substantially larger than the assessed very likely range of future warming, cannot be ruled out and are part of risk assessment..

LIMITING FUTURE CLIMATE CHANGE

- From a physical science perspective, limiting human-induced global warming to a specific level requires limiting cumulative CO_2 emissions, reaching at least net zero CO_2 emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH4 emissions would also limit the warming effect resulting from declining aerosol pollution and would improve air quality.

- Scenarios with very low or low greenhouse gas (GHG) emissions (SSP1-1.9 and SSP1-2.6) lead within years to discernible effects on greenhouse gas and aerosol concentrations and air quality, relative to high and very high GHG emissions scenarios (SSP3-7.0 or SSP5-8.5). Under these contrasting scenarios, discernible differences in trends of global surface temperature would begin to emerge from natural variability within around 20 years, and over longer time periods for many other climatic impact-drivers (high confidence).

IMPACT ON AND ADAPTATION ROUTES FOR AFRICA MAINLY SUB-SAHARAN AFRICA

The following significant aspects of the physical science basis for climate change associated to Africa, and sub-Saharan Africa in particular, have been extracted from the Technical Summary, highlighting the most important issues relevant to South Africa

(https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf):

- Warming over land drives an increase in atmospheric evaporative demand and in the severity of drought events (high confidence). Greater warming over land than over the ocean alters atmospheric circulation patterns and reduces continental near-surface relative humidity, which contributes to regional drying (high confidence). A very likely decrease in relative humidity has occurred over much of the global land area since 2000. Projected increases in evapotranspiration due to growing atmospheric water demand will decrease soil moisture over South Africa, amongst other regions (high confidence).

- South-western and southern Africa are amongst the regions in the world that show significant increases in hot events, heavy precipitation events and agricultural and ecological droughts.

- For Cape Town, South Africa, despite consistency among global model future projections, there is medium confidence in a projected future drier climate due to the lack of consistency in links between increasing greenhouse gases, changes in a key mode of variability (the Southern Annular Mode) and drought in Cape Town among different observation periods and in model simulations.

- For the sub-Saharan region as a whole, global warming levels of 2,0°C to 2,4°C, are projected to cause significant increase in the mean air temperature, including extreme heat events; decreases in cold spells and frost where applicable; general decreases in precipitation but increases in floods and heavy precipitation events; increases in agricultural and ecological drought; increases in sea level, marine heat waves and ocean and lake acidity and increases of atmospheric CO_2 at the surface. These projection concur with recent historical trend evidence.

    - Wet and dry: Mean precipitation changes have been observed over Africa, but the historical trends are not spatially coherent (high confidence). North Eastern Africa, East Southern Africa and Central Africa have experienced a decline in rainfall since about 1980 and parts of West Africa an increase (high confidence). Increases in the frequency and/or the intensity of heavy rainfall have been observed in East and West Southern Africa, and the eastern Mediterranean region (medium confidence).

      Increasing trends in river flood occurrence can be identified beyond 1980 in East and West Southern Africa (medium confidence) and Western Africa (high confidence). However, Northern Africa and West Southern Africa are likely to have a reduction in precipitation. Over West Africa, rainfall is projected to decrease in the western Sahel sub-region and increase along the Guinea Coast sub-region (medium confidence). Rainfall is projected to increase over Eastern Africa (medium confidence).

      Precipitation declines and aridity trends in Western Africa, Central Africa, Southern Africa and the Mediterranean co-occur with trends towards increased agricultural and ecological droughts in the same regions (medium confidence). Trends towards increased hydrological droughts have been observed in the Mediterranean (high confidence) and Western Africa (medium confidence). These trends correspond with projected regional increases in aridity and fire weather conditions (high confidence).

- Wind: Mean wind, extreme winds and the wind energy potential in North Africa and the Mediterranean are projected to decrease across all scenarios (high confidence). Over Western Africa and Southern Africa, a future significant increase in wind speed and wind energy potential is projected (medium confidence). There is a projected decrease in the frequency of tropical cyclones making landfall over Madagascar, East Southern Africa and East Africa (medium confidence).

- Coastal and oceanic: Relative sea level has increased at a higher rate than GMSL around Africa over the last 3 decades. The present day 1-in-100-year extreme total water level (ETWL) is between 0,1 m and 1,2 m around Africa, with values around 1 m or above along the East and West Southern and Central Eastern Africa coasts. Satellite-derived shoreline retreat rates up to 1 m yr–1 have been observed around the continent from 1984 to 2015, except in South Eastern Africa, which has experienced a shoreline progradation (growth) rate of 0,1 m yr–1 over the same period.

In addition to the above it is of interest to look into warming and the projected warming at the 1,5°C and 2,0°C increase scenarios in South Africa: There is sufficient evidence that South Africa has warmed at a rate comparable to the rate of warming globally. There is also evidence that the rate of warming has recently accelerated. The last decade was on average the warmest since instrumental records began. It is expected that surface temperatures over South Africa will further increase, probably at a faster rate than the global average. Some areas have already reached the global target of a cap of 1,5°C warming, compared to pre-industrial times.

In conjunction with the warming, hot extremes have increased and cold extremes decreased over most of South Africa. The prevalence of drought in the north and south of the country has increased. However, although there are signals of drying in the mentioned regions, there is evidence of increases in precipitation extremes.

It is yet to ascertain whether the climate has become more variable in general, and therefore, whether the frequencies of extremes have increased. In addition to the above, temporal large-scale changes to the atmosphere will be modulated by the natural drivers and internal variability of the climate. These effects will either amplify the impact of anthropogenic climate change or have a moderating effect, and should be considered in risk assessments and adaptation.

In the sub-continent, the changes will be more severe at a 2°C compared to 1,5°C global warming. For example, under the Representative Concentration Pathway 8,5, a 2°C warming will cause more intense warming over the sub-continent than the global mean. Specifically, areas in the south-western region of the subcontinent, covering South Africa and parts of Namibia and Botswana are projected to experience the largest increase in temperature, which are greater than the global mean warming, particularly during the September–October–November season (Maúre et al 2018).

Also, “under 2,0 °C GWL, a larger fraction of land is projected to face robust decreases between 0,2 and 0,4 mm day−1 (around 10%–20% of the climatological values) over most of the central subcontinent and parts of western South Africa and northern Mozambique”(Maúre et al 2018).

CONCLUSION

We intend to compile similar articles on the IPCC WGII: Impacts, Adaptation and Vulnerability and the WG III: Mitigation of Climate Change reports, to summarise the detailed contents to the reader in a concise manner, focusing on the suggested measures to be taken to adapt to and mitigate against climate change from an African perspective.

Additional reference:

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Elani Heyneke is a senior forecaster at the Cape Town weather office; however, she started her career at the Bloemfontein Weather Office in 2017. She always had a keen interest in weather and has been cloud watching from an early age - trying her best to predict the arrival time of the afternoon thunderstorms. Her passion is predicting severe weather events, with a focus on agrometeorology.

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