WEATHERSMART

NEWS

Scientific meteorological and climatological news from the South African Weather Service

FEBRUARY 2020

- Predicting malaria cases...
- New annual climate updates
- Assessment of global horizontal irradiance in SA
- Analysis of a mid-winter cape storm
- Anvil and turbulence
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- Repositioning for the fourth industrial revolution...

South African Weather Service

WEATHERSMART NEWS

Scientific meteorological and climatological news from the South African Weather Service

Impact-Based Severe Weather Warning System

WHAT IS IMPACT-BASED FORECASTING?

Severe weather is a regular occurrence across South Africa which often negatively affects humans. Due to the vast distribution of vulnerabilities across the country, the same weather hazard can result in different impacts in two areas, depending on the specific vulnerability of the area.

Impact-Based warnings combine the level of impact the hazardous weather conditions expected with the level of likelihood of those impacts taking place

Moving from :	To :
What the weather will be: (Meteorological thresholds) - 50mm in 24 hours - 35 knot winds	What the weather will do: (Impact Warnings) - Roads flooded - Communities cut off

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FOREWORD AND EDITORIAL COMMENT

– by the Acting Chief Executive Officer

Welcome to the WeatherSMART news edition of February 2020. As we have entered a new decade, weather and climate science keeps on evolving and research allows us to obtain new insights.

As part of the strategy of the South African Weather Service, relevant research is done to enhance our body of knowledge, which is used in our efforts to combat the impact of climate change, hazardous and severe weather and environmental threats.

This edition covers the scientific weather news relating to malaria research in Nkomasi, South Africa; new annual climate updates; and an assessment of global horizontal irradiance in South Africa.

The importance of weather and health cannot be overemphasised, and the research on predicting malaria cases using remotely sensed variables is indeed ground breaking. We are now able to get a much clearer picture on possible weather-related health threats.

The article on new climate updates and additions reflects on what to expect from end March 2020 on the website of the South African Weather Service. Several additions to our information will be added to these updated publications.

This edition also reflects on the South African Weather Service radiometric network consisting of 13 stations collects data which enable quantification of the potential contribution of the solar energy resource, improvement and validation of satellites as well as the development and verification of empirical models. Quality control assessment of data was conducted and our data were classified as good data.

This edition also contains an in-depth discussion of the 21 June 2019 mid-winter storm – which could have caught the public off guard due to other matters requiring their attention. Anvil and turbulence, their complexities and possible dangers are discussed and an important awareness raising article addresses what needs to be done when thunderstorms occur. This article is especially important in light of the dangers of lightning associated with thunderstorms.

As the fourth industrial revolution era is upon us, the way forward for organisations to adapt to this new era is shortly addressed.

The South African Weather Service produces a wealth of useful information which can be used by weather and climate-sensitive industries as well as the general public. Our information is only useful when it is acted upon, and the aim of this newsletter is to provide relevant information to all interested citizens, scientists and weather enthusiasts.

Dr Jonas Mphepya

Acting Chief Executive Officer

PREDICTING MALARIA CASES USING REMOTELY SENSED ENVIRONMENTAL VARIABLES IN NKOMAZI, SOUTH AFRICA (EXTRACT)

– by Abiodun Morakinyo Adeola, Joel Ondego Botai, Christina M. Botai

Extract from the full article which was published in Geospatial Journal, 2019.

Abstract

There has been a conspicuous increase in malaria cases since 2016/2017 over the three malaria-endemic provinces of South Africa. This increase has been linked to climatic and environmental factors. In the absence of adequate traditional environmental/climatic data covering ideal spatial and temporal extent for a reliable warning system, remotely sensed data are useful for the investigation of the relationship with, and the prediction of, malaria cases. Monthly environmental variables such as the normalised difference vegetation index (NDVI), the enhanced vegetation index (EVI), the normalised difference water index (NDWI), the land surface temperature for night (LSTN) and day (LSTD), and rainfall were derived and evaluated using seasonal auto-regressive integrated moving average (SARIMA) models with different lag periods. Predictions were made for the last 56 months of the time series and were compared to the observed malaria cases from January 2013 to August 2017. All these factors were found to be statistically significant in predicting malaria transmission at a 2-months lag period except for LSTD which impact the number of malaria cases negatively. Rainfall showed the highest association at the two-month lag time (r=0.74; P<0.001), followed by EVI (r=0.69; P<0.001), NDVI (r=0.65; P<0.001), NDWI (r=0.63; P<0.001) and LSTN (r=0.60; P<0.001). SARIMA without environmental variables had an adjusted R^2 of 0.41, while SARIMA with total monthly rainfall, EVI, NDVI, NDWI and LSTN were able to explain about 65% of the variation in malaria cases. The prediction indicated a general increase in malaria cases, predicting about 711 against 648 observed malaria cases. The development of a predictive early warning system is imperative for effective malaria control, prevention of outbreaks and its subsequent elimination in the region.

Key words: *Malaria; Environmental; Climatic; Remote sensing; SARIMA; Prediction.*

INTRODUCTION

Malaria is a major public health problem in the north-eastern part of South Africa, where it affects about 5 million of the population. The endemic regions are in the provinces of Mpumalanga, Limpopo, and KwaZulu-Natal (South Africa National Department of Health, 2011) and have recently witnessed a surge in malaria morbidity and mortality (STATS SA, 2017). The disease is markedly seasonal, with varying intensity of transmission due to environmental and climatic factors such as rainfall, temperature, elevation, and humidity favouring the development of the vector and parasite (Ngomane and de Jager, 2012). The transmission is highest during the wet summer months (September to May), and peak transmission occurs in January/February (Ngomane and de Jager, 2012). The Plasmodium falciparum parasite accounts for about 95% of the total malaria infections in South Africa and the mosquito Anopheles arabiensis is the major local vector (Govere et al., 2007).

Rainfall has both a direct and indirect relationship with its incidence by creating suitable breeding habitats for the vector. However, excessive rainfall can also have a negative impact on the mosquitoes by washing away the larvae (Teklehaimanot et al., 2004). Temperature impacts survival of both mosquito and parasite. Larval development takes about 47 days at 16°C, while parasite development ceases at temperatures of <15°C and the organism dies at temperatures >40°C (Weiss et al., 2014). Vegetation provides a resting habitat for adult Anopheles and also serves as an indicator of the availability of moisture (Machault et al., 2011; Sarfraz et al., 2014). Elevation is associated with the flight range of the vector as the proportion of moving mosquitoes declines exponentially with distance and height from the breeding habitat (Thomas et al., 2013).

Environmental as well as climatic variables derived from Earth-observing satellites, for instance: land surface temperature (LST), the enhanced vegetation index (EVI), the normalised difference vegetation index (NDVI), the normalised difference water index (NDWI) and rainfall estimates have been used to identify mosquito breeding habitats (Julie et al., 2010), to predict outbreaks (Hay et al., 1998; Adimi et al., 2010) and for the development of malaria EWSs (Ceccato et al., 2005; Midekisa et al., 2012). These studies have led to a significant contribution to malaria control in various regions; however a large percentage of malaria studies in South Africa are based on the use of conventional climate data (Kleinschmidt et al., 2001; Craig et al., 2004; Silal et al., 2014) rather than RS despite its great potential. Hence, this study aims at determining the relationships between malaria cases and remotely sensed climatic and environmental variables; and to develop a modeling framework for predicting malaria cases based on remotely sensed variables.

MATERIALS AND METHODS

Study area

Nkomazi Municipality is located in the North-eastern part of South Africa, and lies between latitudes 25°19'0"S and 26°00'0"S and longitudes 31°15'0"E and 32°01'0"E. The municipality is bordered to the east by Mozambique and in the south by Eswatini and the Kruger National Park to the north. The area covers a total area of 3255, 67 km2, representing 4.1% and 23% of the total land area of Mpumalanga Province and Ehlanzeni District, respectively (Figure 1). The municipality had a total population of 277 864 in 1996 that has increased to 410 907 in 2016 (STATS SA, 2016). It enjoys sub-tropical weather conditions, with temperatures ranging between 2°C and 43°C, with an average of 22.6°C, and an annual average rainfall of 680 mm. Nkomazi Municipality varies in elevation from about 120 to about 1 250 m. The western part is densely vegetated with undulating hills and deeply incised valleys. The area is drained by two major rivers, namely the Komati River to the east, with its main tributary, the Lomati River to the west.

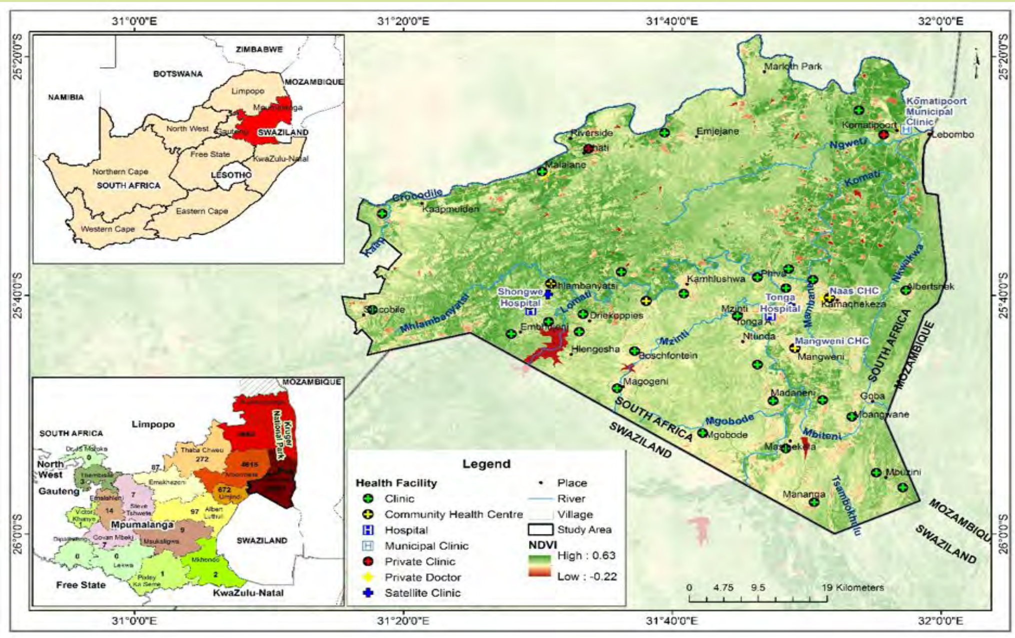

Figure 1: Maps of the study area in South Africa. Left top: South African provincial map showing Mpumalanga Province in red; left bottom: Mpumalanga Province showing the malaria case distribution from January 1997 to August 2017; right: Nkomazi Municipality showing the villages, health facilities and major rivers with the Normalized Difference Vegetation Index (NDVI) overlay

Data collection

Both malaria and environmental data used in this study span a period of approximately 18 years (from 2000 to August 2017). Daily malaria data, including both passive and active data, were acquired by the malaria control programme of the Department of Health, Mpumalanga. Vegetation indices consisting of NDVI, EVI, and water index NDWI were extracted from a 16-day composite of Moderate-resolution Imaging Spectroradiometer (MODIS) MOD13Q1 on board of both Terra and Aqua satellites system (NASA, 2017). The indices, providing regular spatial and temporal assessments of vegetation conditions, were computed from atmospherically corrected bi-directional surface reflectance masked for water, clouds, heavy aerosols, and cloud shadows (NASA, 2017). The day-time (LSTD) and night-time (LSTN) values were derived from an 8-day composite of the MODIS MOD11A2 thermal sensor on board the NASA-Terra satellite system (NASA, 2017). The procedure for downloading and processing data is fully described by Busetto and Ranghetti (2016). Monthly rainfall estimates were derived from the tropical rainfall measuring mission (TRMM)-3B43.

Data analysis

All data processing, statistical analyses and modeling were performed in R (R Core Team, 2016). Malaria cases and environmental data were aggregated to monthly data. Pearson's correlation was used to statistically determine the association between monthly malaria cases and environmental variables and at different lags at 0 to 3 months lagged periods. The seasonal auto-regressive integrated moving average (SARIMA) model without exogenous variables and with exogenous variables was employed as the baseline predictive model (Box and Jenkins, 2008). The SARIMA model provides a robust set of tools for performing time series analysis, parameter estimation and forecasting. SARIMA is particularly appropriate in situations when the time series data exhibit seasonality periodic fluctuations. The lag periods were used to assess the associations between malaria cases and the environmental variables from 0 to 3 months using cross-correlation analysis (a time lag was defined as the time duration between malaria incidence and environmental observation).

The adequacy of each model was diagnosed by plotting the residuals of the ACF and PACF using Ljung_Box Q statistics (Ljung et al., 1978). Out-of-sample predictions of the models (SARIMA with environmental variables; SARIMAX) for the last 56 months of the time series were made and compared with the observed malaria data (January 2013 to August 2017). The performance measures of prediction were assessed by computing the Root Mean Squared Error (RMSE), which gives an indication of how the predicted values differ from the observed values.

RESULTS

During the study period, a total of 25,897 malaria cases were recorded in Nkomazi Municipality. This number of cases accounts for 32.3% of the total malaria cases in Mpumalanga Province (80,058 malaria cases - see inset map in Figure 1). Within this period, a total of 37,054 (46.3%) malaria cases were locally transmitted, 43,004 (53.6%) imported and 62 (0.08%) untraceable. Mozambique was the highest contributing source of imported malaria (41,550) accounting for 96.6% of the total figure. In Nkomazi Municipality, 24,684 (95.3%) of the cases were detected by passive surveillance and 1213 (4.7%) by active. Gender-wise, males accounted for 13,601 (52.5%) and females for 12,296 (47.5%) of the cases. Age was categorized into 3 major groups of 0-14, 15-64 and ≥65 representing the young, those working and the elderly, respectively. Malaria infection was more common in the economically active group - 16,459 (63.6%), while those belonging to the young amounted to 8,956 (34.6%) and those in the old-age group were only 482 (1.9%). Figure 2(a) indicates that there is monthly variation in the cases of malaria in Nkomazi, with incidence rising from September and dropping after May, while Figure 2(b) shows the annual locally notified malaria cases in Nkomazi Municipality from January 2000 to December 2016.

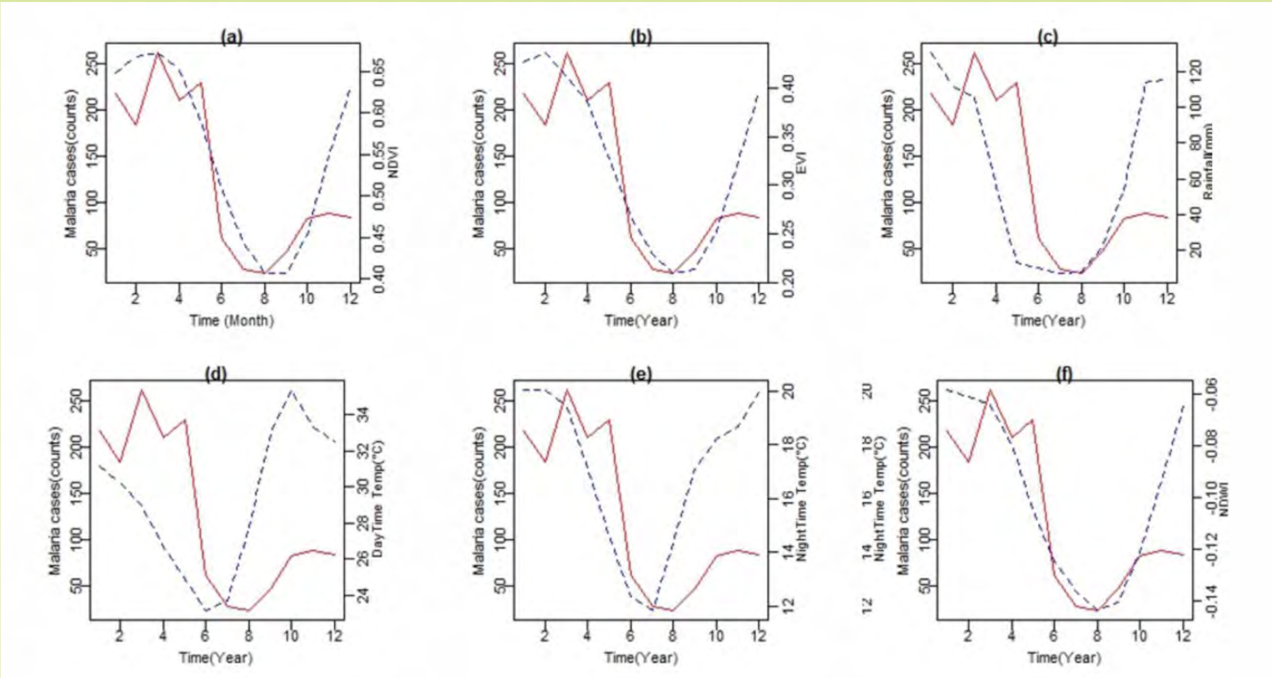

***Figure 2:** The plot of total monthly time series of malaria cases in relation to environmental variables. Red line, malaria case count; Blue line, the various environmental variables as follows: (a) NDVI; (b) EVI; (c) rainfall; (d) day-time land surface temperature; (e) night-time land surface temperature; (f) NDWI*

The result of the Pearson's correlation indicated that there was a statistically significant association between the monthly environmental variables and the malaria case time series (Figure 3). The highest correlation between the number of malaria cases and an environ-mental variable was shown by rainfall (r=0.36; P<0.001), followed by NDVI and EVI (r=0.28; P<0.001), and NDWI (r=0.17; P=0.014). There was no statistically significant relationship between the temperatures and malaria case count (r=-0.094; P=0.179 and r=0.056; P=0.423 for LSTD and LSTN, respectively). At the two-month lag time, rainfall showed the highest association (r=0.74; P<0.001), followed by EVI (r=0.69; P<0.001), NDVI (r=0.65; P<0.001), NDWI (r=0.63; P<0.001) and LSTN (r=0.60; P<0.001). When different combinations of the environmental variables with the number of malaria cases were performed, total monthly rainfall, monthly mean EVI, NDWI and LSTN, at a two-month lagged effect, were found to be the most significant climatic variables for malaria transmission in Nkomazi Municipality having an adjusted coefficient of determination (R^2=0.64; P<0.001).

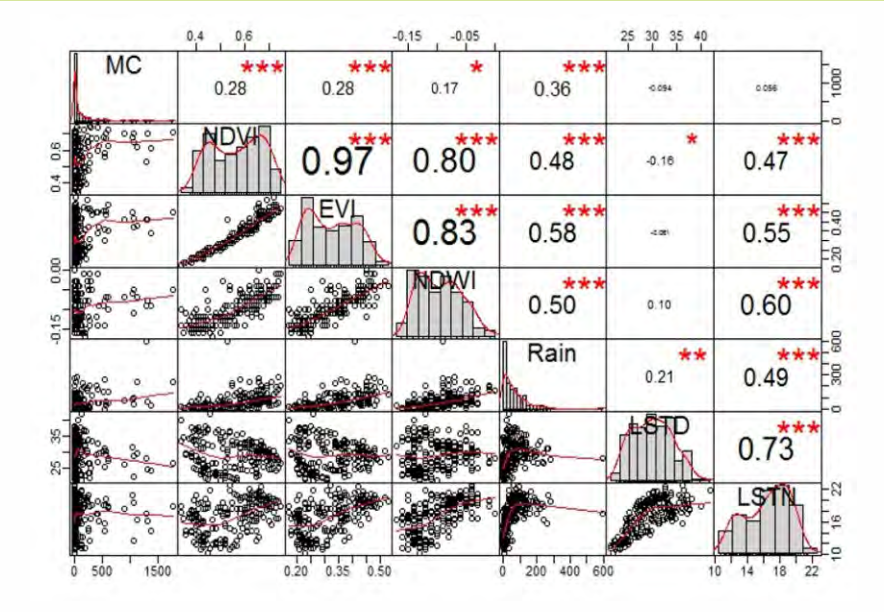

__Figure 3:__ Spearman's correlation analysis between the number of monthly malaria case counts. MC, malaria cases

The result further indicates that the predicted number of malaria cases were relatively close to the number of cases observed, which indicates that the model provides an acceptable fit to predict the number of malaria cases within the study area. The prediction indicated a general increase of malaria which is a deviation from the downward trends witnessed in the observed data after the major peak in the year 2000 although with few peaks in 2004, 2006, 2011 and 2014. In general, the SARIMA model over-predicted malaria cases in the study area. The model predicted a total number of 711 malaria cases as against 648 observed in the study area.

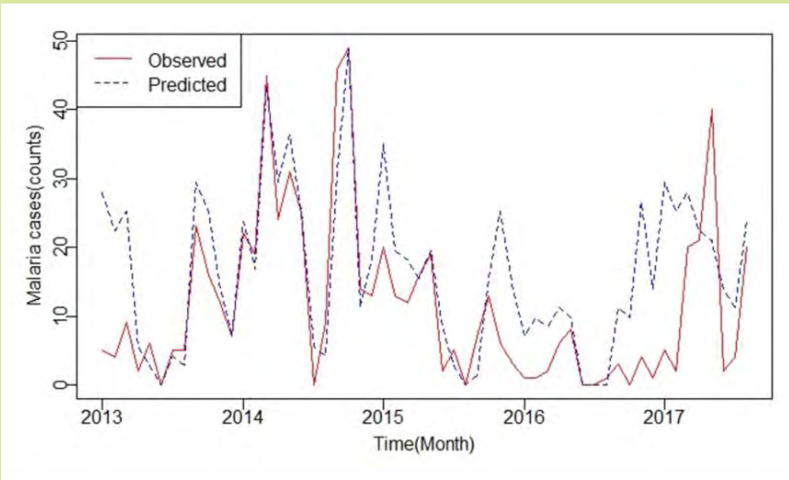

Figure 4:
lot of Actual (observed) and predicted (fit) malaria cases in Nkomazi Municipality January 2013-August 2017

DISCUSSION

The spatial and temporal distribution of malaria transmission is largely determined by climatic and environmental variables (Weiss et al., 2014; Ferrão et al., 2017). These determinants range from the provision of suitable thresholds for the survival of both the parasites and vectors, to the provision suitable breeding habitats and to the availability of host (human or animals). For this study, the SARIMA model was developed and shown to be specifically useful for epidemiological studies that exhibit seasonal patterns. The SARIMA model in the (2,1,1)(2,0,1)12 form that was developed in this study aims to provide a prediction tool to predict the expected number of malaria cases based on historically observed data with and without environmental variables. The latter (rainfall, NDVI, EVI, NDWI and LSTN at the 2-month lag time) were found to be significantly associated with the number of malaria cases in Nkomazi Municipality. These environ-mental variables were lagged by one to three months, considering the accumulation of rainfall which has an influence on the availability of soil moisture and indirectly on vegetation greenness and water availability in ponds. This, in turn, influences the occurrence of the Anopheles vector which takes about two weeks to complete its life cycle, with an additional two weeks for the incubation of parasites in the human host.

In general, this study found that the spatial and temporal patterns of malaria cases in the Nkomazi Municipality is associated with satellite-derived environmental factors. The developed SARIMA model improved the adjusted R2 from 0.41 to 0.64 after the inclusion of the environmental variables, i.e. the SARIMAX model with monthly total rainfall, EVI, NDWI and LSTN were able to explain about 64% of the variation. This implies that 64% of the total variation in the number of malaria cases can be explained by the linear relationship between the environmental variables and malaria. The other 36% of the total variation might be explained by other factors such as a high number of imported malaria cases and social factors like population mobility, housing type, sanitation, control measures, public health systems, etc. which were not considered in this present study. From the result, it can be deduced that malaria is expected to appear between 9-10 weeks following adequate rainfall of about 20-120 mm, at an average temperature between 17-20°C, NDVI of 0.40-0.65 or EVI of 0.28-0.45 and NDWI values of -0.12 to -0.06. The prediction indicated a general increase in malaria cases with a distinct seasonal pattern and significant peaks in February to April. This is as a result of about 2 to 3 months lag effect of environmental variables, particularly rainfall, which starts in September/October. Although, the model under-predicted malaria cases in 2014 which recorded a high malaria incidence, the model was able to depict monthly variation and distinct seasonal pattern. The under-prediction might be attributed to the influence of non-climatic external factors which could have triggered the increase. The over-prediction of the model could be due to the non-inclusion of the malaria control strategies which could have been reinforced after the notice of the sudden rise in the number of malaria cases.

CONCLUSIONS

As South Africa progresses in efforts to eliminate malaria in three endemic provinces by 2023, an effective and operational EWS as proposed by the World Health Organization becomes imperative. Hence, a SARIMA model regressed with the external variables such monthly total rainfall, EVI, NDWI and LSTN is ideal for estimating the number of malaria cases. This study indicates that total rainfall is the most significant predictor of malaria cases in the study area. The lagged time of 1 to 3 months between the environmental variables and malaria can be used to develop a malaria EWS for municipalities commonly ravaged by high malaria transmission. The performance of the model has the potential for improvement by the inclusion of factors like population movement, migration, elevation, data on indoor residual spraying and proximity to health.

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NEW ANNUAL CLIMATE UPDATES

– by Andries Kruger, Musa Mkhwanazi, Sandile Ngwenya and Sifiso Mbatha

As the effects of climate change are increasingly experien-ced by different economic sectors and the public at large, interest has grown significantly in how the recent climate and significant weather events compare to the long-term averages, as well as trends that can be detected through the analysis of long-term climate data.

The South African Weather Service is the custodian of the vast majority of historical climate data in the country. This data, managed by the Climate Services department, goes back to the late 19th century and a significant fraction of the data is updated on an almost real-time basis. The department is tasked with the provision of data and data-related products and has on an annual basis contributed to the World Meteorological Organization (WMO) Annual State of the Climate report and the Global State of the Climate special edition of the Bulletin of the American Meteorological Society journal. This work will now be expanded and from 2020 includes a national Annual State of the Climate report as well as the new "Trends in Extreme Climate Indices in South Africa" publication, both of which will be updated and released every year by the end of March and available through the website of the South African Weather Service.

Annual State of the Climate

The South African Weather Service intends to revise and update the Annual Climate Summary into an Annual State of the Climate report. The Annual State of the Climate Report is expected to then provide the basis for the South African Weather Service contributions to the annual updates of the South African climate to the WMO Global State of the Climate report and the Bulletin of the American Meteorological Society special edition on the Global State of the Climate. The current Annual Climate Summary is available on the website at http://www.weathersa.co.za/home/annualclimatesummary. The revised content will mainly consist of the following (new content in red):

Summary

- Summary of the most significant aspects of the climate in the past year
- A summary of the most severe weather events in a map format

Annual Temperature Statistics

- Summary
- Trend graph of temperature anomalies for 26 selected stations since 1951
- Temperature summary for selected weather stations categorised according to province (with accompanying map showing positions of stations).

  The statistics include:

  - Maximum temperature table
    - Average temperature for the year
    - Temperature Normal (1981 – 2010)
    - Average temperature rank (highest since 1981)
    - Highest Annual average temperature (since 1981)
    - Lowest Annual average (since 1981)
    - Highest daily temperature for the year
    - Highest daily (since 1981)
    - Lowest daily temperature for the year
    - Lowest daily temperature (since 1981)
  - Minimum temperature (following the same format as the above)

Annual Rainfall Statistics

- Summary
- Map of rainfall anomaly for the year (% of normal)
- Provincial rainfall graphs of the percentage of normal since 1900. The calculation method can be revised to make the district rainfall statistics the basis of the mean total provincial rainfall per year.
- Rainfall summary for selected weather stations categorised according to province. The statistics include:
  - Table, which provide the following statistics (with accompanying map showing positions of stations):
    - Total for the year

- Normal for the period (1961 – 90) (in contrast with 1981 – 2010) for temperature
- Highest annual total (1961 – 90)
- Lowest annual total (since 1961)
- Highest daily rainfall in the past year
- Highest daily total (since 1961)
- Number of rainy days (>= 1 mm)
- Highest number of rainy days (>= 1 mm) (since 1961)
- Average number of rainy days (1961 – 90)

- Indications of drought: A short summary of the Standardised Precipitation Index and maps of the 12- and 24-month SPI maps.

Annual Course of the Climate on a Monthly Basis

- Introduction and Summary
- Monthly maps of the following
  - Maximum temperature deviations from the 1981-2010 normal
  - Minimum temperature deviations from the 1981-2010 normal
  - Standardized Precipitation Index (SPI), indicating dry areas
  - Lightning-stroke density in number of strokes per square kilometre

Discussion of climate in the main centres

The weather and climate statistics over the previous year in Cape Town, Port Elizabeth, Bloemfontein, Durban and Johannesburg are provided in tabular format.

The revised content includes the recalculation of provincial rainfall, which will now be based on the mean rainfall in rainfall districts that falls mostly in a particular province, a section that focuses on the annual weather and climate in the larger populated centres in South Africa, a more comprehensive summary of significant weather and climate events and a map indicating the percentage of normal rainfall of the year.

Due to the complexity of the South African rainfall a review was done of the current calculation of provincial rainfall statistics, which will now be based on average rainfall calculated on a monthly basis for the 94 homogeneous rainfall districts developed by the then South African Weather Bureau. These districts were developed to represent areas that are very similar in rainfall climate.

Figure 1 presents the provinces according to near-, above- or below-normal rainfall received in 2018, and Figure 2 is an example of the Northern Cape provincial rainfall percentage of normal statistics for the 1921 – 2018 period.

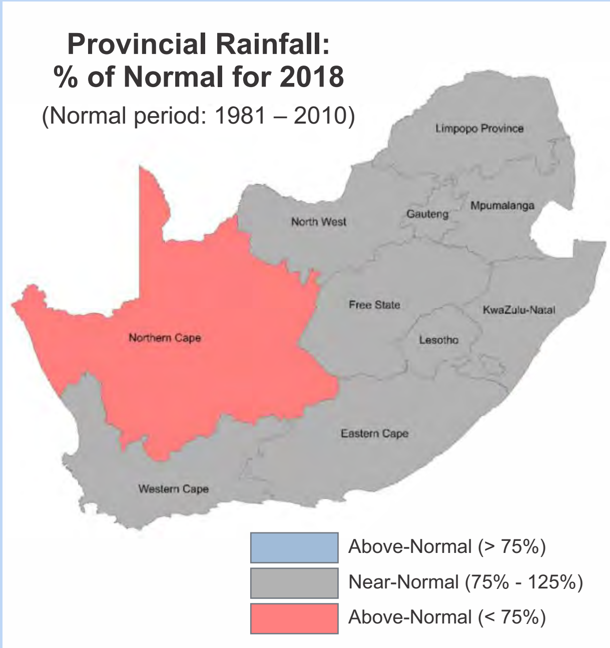

***Figure 1:** Near-, above- or below-normal rainfall received in 2018 according to provincial rainfall statistics*

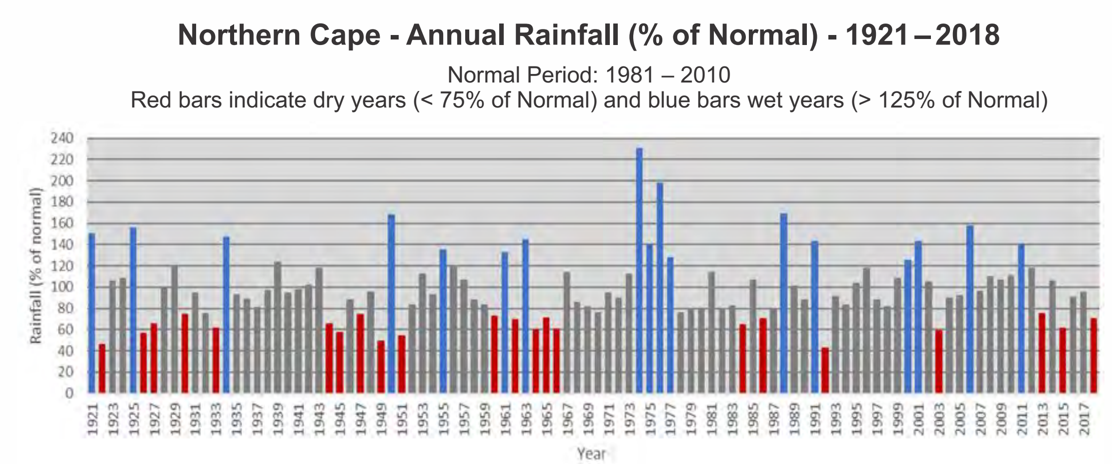

***Figure 2:** Northern Cape annual percentage of normal rainfall statistics for the period 1921 – 2018*

In addition to the revision of the provincial rainfall statistics, a short discussion of the climate in the main centres of the country will be included. In this regard, the weather and climate statistics over the previous year in Cape Town, Port Elizabeth, Bloemfontein, Durban and Johannesburg and Pretoria will be provided in tabular format. There is already an extensive list of stations provided in the Annual Climate Summary and therefore this section will only highlight the main centres. The information will comprise the following:

- Average temperature and % of 1981 – 2010 average
- Total rainfall and deviation from 1981 – 2010 average
- Total sunshine and deviation from 1981 – 2010 average

Tables 1 to 3 present the temperature, rainfall and sun-shine statistics for the six main centres in South Africa for 2018. The specific weather stations used are given in the footnotes.

Table 1: 2018 total rainfall climate in the six main centres

City	Rainfall (mm)	% of 1981 – 2010 average	Comments
Johannesburg[a]	520	69	Below-normal
Cape Town[b]	422	78	Near-normal
Pretoria[c]	522	76	Near-normal
Durban[d]	866	85	Near-normal
Port Elizabeth[e]	416	72	Below-normal
Bloemfontein[f]	426	75	Near-normal

OR Tambo International Airport[a], Cape Town International Airport[b], Pretoria UNISA[c], King Shaka International Airport[d], Port Elizabeth Airport[e], Bram Fischer International Airport[f]

Table 2: 2018 average surface temperature in the six main centres

City	Temperature (°C)		Departure from 1981 – 2010 average		Ranking (since 1981)	
	Max	Min	Max	Min	Max	Min
Johannesburg[a]	23,2	11,1	+0,9	+1,0	4	7
Cape Town[b]	23,1	12,2	+0,4	+0,8	4	9
Pretoria[c]	25,4	10,8	-0,4	-0,7	16	23
Durban[d]	25,7	17,3	+0,3	+0,8	7	7
Port Elizabeth[e]	23,1	12,5	+0,5	-1,0	6	33
Bloemfontein[f]	25,7	7,2	+0,8	-0,2	8	22

OR Tambo International Airport[a], Cape Town International Airport[b], Pretoria Burgerspark[c], King Shaka International Airport[d], Port Elizabeth Airport[e], Bram Fischer International Airport[f]

Table 3: 2018 sunshine in the six main centres

Sunshine (average hours per day)	Departure from 1981 – 2010 (average hours per day)
8,4	+0,2
8,5	+0,0
8,4	+0,2
6,8	+0,2
7,8	+0,2
8,8	-0,1

OR Tambo International Airport[a], Cape Town International Airport[b], Irene[c], King Shaka International Airport[d], Port Elizabeth Airport[e], Bram Fischer International Airport[f]

Trends in Extreme Climate Indices in South Africa

The WMO Expert Team on Climate Change Detection and Indices (ETCCDI) has developed a set of 27 core indices which is used globally to detect trends in relevant climate extremes. The South African Weather Service has previously used these indices to analyse historical trends in rainfall and temperature extremes in South Africa, and published the findings through peer-reviewed papers. In addition, the organisation also contributes to global studies, which assess the long-term trends in climate extremes. The trend analyses are also included in the South African National Communications on Climate Change. As interest in the indices grew, it was decided that the WMO ETCCDI indices be updated on an annual basis.

For surface temperature the data of 26 homogenised temperature series are used with station names and positions presented in Figure 3. For the precipitation indices it was possible to select a total of 71 long-term stations out of a total of 94 homogeneous rainfall districts which are operational, presented in Figure 4. For surface temperature trends are calculated mostly from 1931 and for rainfall since 1921 or shortly thereafter.

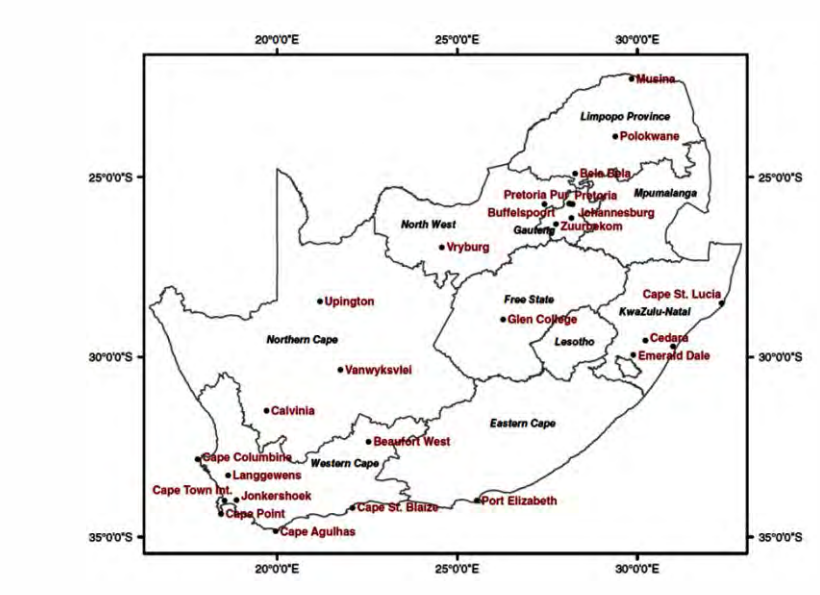

Figure 3: *Positions of basis set of stations used for the surface temperature extreme index analysis*

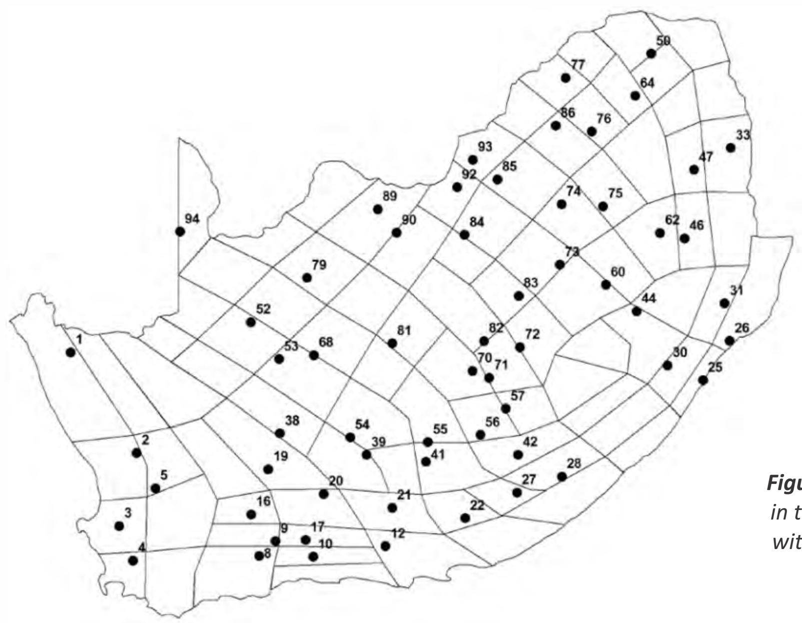

Figure 4: *Locations of rainfall stations used in the trend analysis of individual stations, with rainfall districts represented. Rainfall district borders are superimposed*

Of the 27 WMO ETCCDI core indices 10 surface temperature and 11 precipitation indices were selected, which are considered relevant to the South African climate. The data sets of the stations are updated on an annual basis and the index values recalculated. The base period, from which the percentiles for the relevant indices were calculated, was defined as 1981–2010, which is considered the present general norm for similar trend studies. The statistical significance of the trends is also provided. The details of the temperature indices are presented in Table 4 and the rainfall indices in Table 5.

Table 4: List of relevant ETCCDI indices utilized in the assessment of surface temperature trends

Index	Description	Units
TX9OP	Percentage of days when TX > 90th percentile	%
TX1OP	Percentage of days when TX < 10th percentile	%
TXx	Annual maximum value of TX	°C
TXn	Annual minimum value of TX	°C
WSDI	Annual number of days with at least 6 consecutive days when TX > 90th percentile	days
TNx	Annual maximum value of TN	°C
TNn	Annual minimum value of TN	°C
TN9OP	Percentage of days when TN > 90th percentile	%
TN1OP	Percentage of days when TN < 10th percentile	%
CSDI	Annual number of days with at least 6 consecutive days when TN < 10th percentile	days

Table 5: List of relevant ETCCDI indices utilized in the assessment of precipitation trends

Index	Description	Units
prcptot	Annual total precipitation in wet days, i.e., days with precipitation ≥1mm	mm
05p	Annual total precipitation from daily precipitation > 95th percentile	mm
r99p	Annual total precipitation from daily precipitation > 99th percentile	mm
rx1day	Annual maximum 1-day precipitation	mm
r10mm	Annual count of days when precipitation ≥ 10mm	days
r20mm	Annual count of days when precipitation ≥ 20mm	days
r25mm	Annual count of days when precipitation ≥ 25mm	days
SDII	Simple Daily Intensity Index, annual mean of daily precipitation intensity	mm
CWD	Annual maximum length of wet spell, maximum number of consecutive days with precipitation ≥ 1mm	days
CDD	Annual maximum length of dry spell, maximum number of consecutive days with precipitation < 1mm	days

For each station the start year, end year, trend (slope), p-value (a value below 0.05 means the trend is significant at the 95% level of confidence) and the last annual value will be published. Table 6 presents the surface temperature index trends and values for Beaufort West and Table 7 the rainfall index trends and values for Cedara, both analysed up to 2018.

Table 6: WMO ETCCDI surface temperature index trends and values for Beaufort West (1931 – 2018). P-values below 0.05 indicate the trend to be significant at the 5% level

Indices	Start Year	End Year	Slope	P_Value	2018 value
txx	1931	2018	0.032	0	42
txn	1931	2018	0.015	0.045	7.6
tnx	1931	2018	-0.004	0.627	25.2
tnn	1931	2018	0.031	0	0.6
tx10p	1931	2018	-0.069	0	5.48
tx90p	1931	2018	0.158	0	21.37
tn10p	1931	2018	-0.175	0	3.84
tn90p	1931	2018	0.145	0	21.12
wsdi	1931	2018	0.104	0	14
csdi	1931	2018	-0.004	0.698	0

Table 7: WMO ETCCDI rainfall index trends and values for CEDARA (1921 – 2018). P-values below 0.05 indicate the trend to be significant at the 5% level.

Indices	Start Year	End Year	Slope	P_Value	2018 value
rx1day	1921	2018	0.105	0.461	54.2
rx5day	1921	2018	0.082	0.705	74.0
sdii	1921	2018	0	0.995	8.1
r10mm	1921	2018	-0.043	0.048	25
r20mm	1921	2018	-0.019	0.122	7
R25mm	1921	2018	-0.016	0.131	4
cdd	1921	2018	-0.02	0.76	59
cwd	1921	2018	-0.007	0.294	5
r95p	1921	2018	-0.249	0.594	87.6
r99p	1921	2018	-0.086	0.804	54.2
prcptot	1921	2018	-1.07	0.093	743.8

In addition to the above tables for each weather station, the report will also include maps for every index, which present the trend magnitudes of all stations together. As examples, Figure 5 presents the trends in hot days, i.e. the TX90P index for the period 1931 – 2018 and Figure 6 the trends in the number of days with rainfall higher than 10mm over the period 1921 – 2018.

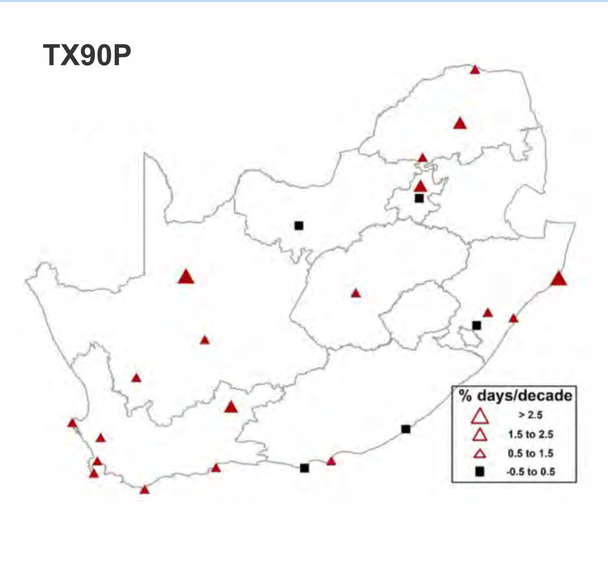

Figure 5: Trends in hot days: TX90P for the period 1931–2015 in % days per decade (filled triangles denote significant trends at the 5% level)

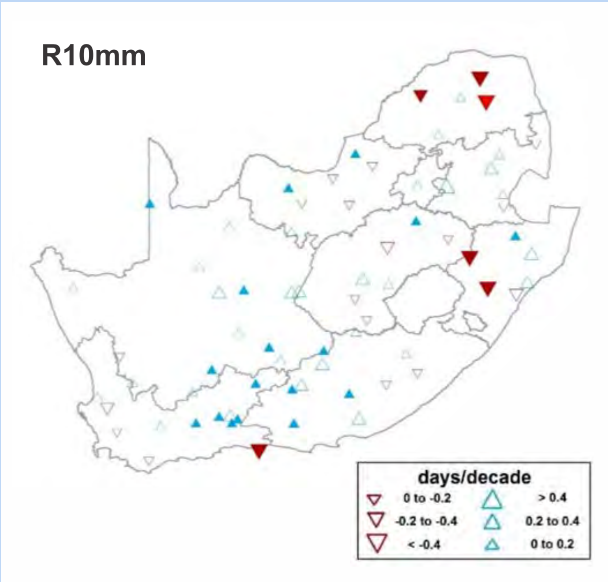

Figure 6: Trends in r10mm, the annual number of days with precipitation > 10mm, for the period 1921–2018. Shaded symbols indicate statistical significance at the 5% level

It is envisaged that the routine annual updates of the state of the South African climate, and the additional publication on climate extremes, will enable the South African Weather Service to provide a timely source of information about the state of the climate and climate change and variability in South Africa. Please visit the website of the South African Weather Service at www.weathersa.co.za after March 2020 for these new climate publications.

ASSESSMENT OF GLOBAL HORIZONTAL IRRADIANCE IN SOUTH AFRICA

– by Brighton Mabasa, Henerica Tazvinga, Nosipho Zwane, Joel Botai and Lucky Ntsangwane

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Abstract

The South African Weather Service (SAWS) manages a radiometric network of 13 stations located in six climatic zones of South Africa since 2013. The data collected from the network enable quantification of the potential contribution of the solar energy resource, improvement and validation of satellites as well as the development and verification of empirical models. Quality control (QC) assessment of SAWS data was conducted using pro-cedures outlined by the Baseline Surface Radiation Network (BSRN). For all the stations, on average 98.25% of the global solar radiation (GHI) data were classified as good quality data. The annual average daily GHI ranged from 186 W/m² to 265 W/m² with consistently higher values in the arid interior climatic zone and lower values in the subtropical coastal climatic zone. Validation of results showed that Satellite Application Facility on Climate Monitoring (CM SAF) data were closer to the observation data with an overall mean absolute deviation (MAD) of 11.81 W/m² and National Aeronautics and Space Administration (NASA), Surface Meteorology and Solar Energy (SSE) had an overall MAD of 19.59 W/m². The solar resource's monthly, seasonal and annual characteristics analysed for different stations provide information that has a strong influence on the technical and economic evaluation of solar energy technologies. Validated satellite data sets are important in providing additional long term data sets for areas and times with no in-situ solar radiation observations.

Key words: *Incident radiative flux; Radiometric network; Solar energy resource; Baseline Solar Radiation Network; Global Horizontal Irradiance; Satellite, Validation.*

1. INTRODUCTION AND THEORY

1.1 Global Horizontal Irradiance (GHI)

Solar radiation is the electromagnetic radiation emitted by the sun [1]. GHI is the electromagnetic radiation that reaches the earth's surface after passing through the atmosphere and it is the sum of direct normal irradiance (DNI) which is the incident radiative flux on the surface without interacting with the atmosphere and diffuse irradiance (DIF) which is as a result of the scattering of radiation by the atmospheric constituents [2]. GHI covers the spectral range between 250 and 3000 nm [3]. At SAWS, GHI is measured with an unshaded secondary standard Kipp & Zonen pyranometer (CMP11) with a hemispherical view that is mounted horizontally. The irradiance values are measured in W/m2 and calculated by dividing voltage by the sensors' calibration factor. The pyranometers are mounted on a Kipp & Zonen SOLYS 2 sun-tracker which is mounted on a cage housing the data logger, batteries and some electronic devices, raising the solar radiation sensors to a standard height of 2 meters above sea level as shown in Figure 1.

Figure 1: *Configuration of a radiometric station with an unshaded pyranometer at the centre*

1.2 Significance of GHI measurement

Solar radiation measurement is important because solar radiation resource data is the foundation of information for the development of solar energy technologies [4]. Accurate knowledge of the strength of the sun is important for the technical and economic evaluation of solar energy technologies, therefore, obtaining true solar measurements is important in assessing the available solar resource at a particular location [5]. Reliable solar measurements are also important in the development of empirical models to predict and forecast the availability of solar energy at other locations [6]. Satellite derived data is also critical for better understanding wider coverage of solar radiation and can also be validated using high quality ground data [7]. According to [8] the main aim of solar radiation measurement is to provide investment grade bankable radiation data to the solar industry. It is important to provide reliable and accurate data sets and their related characteristics, that is information for different locations and temporal resolutions (i.e. hourly, daily, monthly, seasonal and annual statistics). This paper contributes towards the provision of reliable solar radiation data to the energy industry, project developers, decision makers in the financing institutions, policy makers and also to the scientific community.

1.3 Data acquisition, station maintenance and sensor calibration

Global Solar Radiation (GHI) data from 13 radiometric stations located in six climatological regions of South Africa as shown in Table 1 were acquired using a Campbell Scientific CR1000 data logger. The sampling rate was 5 seconds and the mean, maximum, minimum and standard deviation values were recorded every minute. Solar radiation sensors were connected on the differential inputs of the CR1000 to minimise measurement offsets.

Table 1: South African Weather Service radiometric station locations (latitude, longitude, altitude, data coverage and climatic zone)

Station	Latitude	Longitude	Altitude (m)	Data coverage	Climatic Zone
Prieska	-29.68	22.71	989	2013-09 to 2015-08	Arid Interior
Upington	-28.48	2132	848	2014-02 to 2019-03	Arid Interior
De Aar	-30.67	2199	1284	2014-02 to 2019-03	Cold Interior
Irene	-25.91	28.21	1524	2014-02 to 2019-03	Temperature Interior
Nelspruit	-2539	31.1	870	2014-02 to 2019-03	Hot Interior
Mahikeng	-25.81	25.54	1289	2014-08 to 2019-03	Temperature Interior
Mthatha	-31.55	28.67	744	2014-08 to 2019-03	Subtropical Coastal
Bethlehem	-2825	28.33	1688	2015-01 to 2019-03	Cold Interior
Cape Point	-3435	18.48	86	2015-02 to 2019-03	Temperature Coastal
George	-34.01	22.38	192	2015-01 to 2019-03	Temperature Coastal
Durban	-29.61	31.11	91	2015-03 to 2019-03	Subtropical Coastal
Polokwane	-23.86	29.45	1233	2015-03 to 2019-02	Temperature Interior
Thohoyandou	-23.08	30.38	619	2015-03 to 2017-10	Hot Interior

Maintenance, inspection and cleaning activities at these stations are conducted on a bi-weekly basis. These involve the dusting of the sensor dome using a soft lint-free cloth and distilled water to remove any deposits on the domes and optical windows, and checking of the spirit levels in the pyranometers (i.e. must be level horizontally), all the cables and any damages. Desiccants are also replaced within 6 months. Cleaning and inspection times are recorded and kept as metadata.

A radiometer measures radiant energy, however, its sensitivity reduces with time necessitating periodic calibration of the instrument [9]. Frequent sensor calibration remains the best practice to ensure that high quality data are collected and is the standard operating procedure in radiation monitoring networks [10]. For this work, all operational field pyranometers were calibrated by the manufacturer and they are traceable to the World Radiometric Reference (WRR) based on International Pyrheliometer Comparison (IPC) factors. This means that SAWS measurements meet the international criteria for accurate and scientifically valid radiometric data.

2. DATA AND ANALYSIS METHOD

GHI data at one minute intervals collected during the periods shown in Table 1 from 13 solar radiometric stations were subjected to quality check procedures based on Meteorological Organisation (WMO)'s BSRN QC standards [11,12,13]. Only the data that passed the first two quality check tests were used in the study [14,15,16].

After quality checks, the minute values were averaged to 15 minutes and then 4 slots of 15 minute averages were averaged to get hourly mean using the methodology used in our previous study [17]. Hourly mean values were then averaged to get daily mean values and monthly mean values were calculated from daily mean values and from monthly mean values annual average values were calculated.

Daily CM SAF Surface incoming shortwave radiation (SIS) data from Meteosat Second Generation (MSG) with a spatial resolution of 0.05° x 0.05°, covering a period from 1983 to 2019 were also used in the study [18]. Daily insolation data from (NASA), (SSE) with a spatial resolution of 1° x 1° [19], covering a period from 2013 to 2019 were also used in the study.

CMSAF SIS and NASA SSE daily mean data sets were validated using mean daily GHI per month from each station (i.e. measured data) and then the overall aggregated means were calculated from the monthly MAD for each station. Monthly averages per year were calculated from quality checked observation data, aggregated monthly means and standard deviations were calculated from monthly means. Aggregated seasonal and annual means were also calculated from monthly means. The coefficient of determination (r^2), a measure used in statistical analysis to assesses how well a model explains and predicts future outcomes was used in the analyses of the different data sets. This measure gives an indication of the level of the variability in the data set and is used as a guideline to measure the accuracy of a model or specific data set. Another statistical metric used was the mean absolute deviation, which is the average distance between data points and the mean and gives an idea of the variability in a data set (i.e. high variability indicates the data are spread out while low variability indicates that the data are clustered together).

Table 2: Summarises the BSRN QC results as percentages of the data associated with a code per station

Station/Code	0	5	8	10	16	32	40	0+16 +32
Prieska	96.12	3.59	0.00	0.00	0.02	0.26	0.00	96.40
Upington	96.74	1.64	0.04	0.01	0.07	1.49	0.00	98.30
De Aar	97.66	1.38	0.00	0.00	0.60	0.36	0.00	98.61
Irene	97.07	0.03	0.07	0.88	1.23	0.41	0.10	98.71
Nelspruit	92.22	0.67	0.10	0.71	0.23	6.00	0.05	98.45
Mahikeng	92.87	0.59	0.07	0.84	1.56	3.93	0.13	98.36
Mthatha	94.13	0.55	0.14	0.72	0.44	3.91	0.05	98.48
Bethlehem	91.08	4.36	0.01	0.00	0.27	4.26	0.02	95.61
Cape Point	79.61	1.61	0.37	0.00	1.82	16.55	0.03	97.98
George	99.21	0.00	0.00	0.00	0.23	0.54	0.02	99.98
Durban	94.26	0.01	0.00	0.00	1.14	4.58	0.00	99.97
Polokwane	92.54	0.98	0.03	0.12	0.96	5.27	0.08	98.77
Thohoyandou	91.05	2.27	0.00	0.00	5.31	1.26	0.00	97.62
Overall	93.43	1.36	0.06	0.25	1.07	3.76	0.04	98.25

3. RESULTS AND DISCUSSIONS

3.1 BSRN QC results

The BSRN QC approach [11,12,13] was applied to check the quality of minute GHI data and suspected values were discarded before conducting any analysis. The results were as shown in Table 2 and these show that the overall percentage was good indicating that the data were of good quality with an average of 98.25 %. All 13 stations had more that 95 % and less than 5 % erroneous data, missing data (i.e. data coded 5) and data that failed comparison tests (i.e. when GHI parameters were compared to other radiation parameters and coded 16 and 32) dominated the percentage of bad data with 1.36 %, 1.07 % and 3.76 %.

3.2 Validation results

Daily GHI values were compared to their corresponding values from CMSAF SIS and NASA SSE and the results are shown in Table 3. As shown in Table 3, CMSAF data showed a very good relationship when compared with the observation data with an overall MAD of 11.81 W/m² and r^2 of 0.943. NASA SSE showed an overall MAD of 19.59 W/m² and r^2 of 0.870. All the stations met the optimal accuracy target of 15 W/m² [20] when compared to CMSAF SIS data set.

Table 3: Summaries the validation results between SAWS GHI observations, CMSAF SIS and NASA SSE.

Station	OBS	CMSAF	NASA	CMSAF(MAD)	NASA(MAD)	CMSAF(R2)	NASA(R2)
Upington	265.64	259.08	256.53	12.62	15.14	0.948	0.922
PriesKa	253.80	253.41	250.96	9.96	13.26	0.970	0.941
De Aar	253.00	249.90	246.21	11.49	16.75	0.958	0.915
Irene	231.28	237.13	234.59	12.38	18.20	0.904	0.850
Nelspruit	205.05	212.62	210.69	11.90	19.66	0.945	0.867
Mahikeng	248.24	248.22	239.81	13.28	16.54	0.917	0.880
Idthatha	192.01	196.99	198.77	10.60	18.20	0.963	0.899
Bethlehem	235.00	235.84	227.38	9.97	18.51	0.955	0.886
Cape Point	218.00	220.43	236.27	12.36	25.37	0.936	0.781
George	195.26	200.61	208.32	10.58	30.18	0.971	0.772
Durban	186.08	191.48	192.78	10.40	19.54	0.950	0.873
Polokwane	232.23	235.15	227.67	11.09	20.00	0.931	0.836
Thohoyanclou	207.93	221.93	218.37	16.92	23.26	0.915	0.847

Using CMSAF SIS data sets, climatological trends can also be determined. In this paper, a case study of Polokwane GHI data sets from 1983 to 2018 were analysed. The results were as shown in Figure 2 and reveal that the GHI quantities fluctuate, and the trend line shows general decrease over the time. From Figure 2, the long term average from 1983 to 2018 was 231.6 W/m² and this value falls within the annual average that was calculated using observation data 232.23 W/m² +SD (i.e. 232.23 ± 9.63 W/m²).

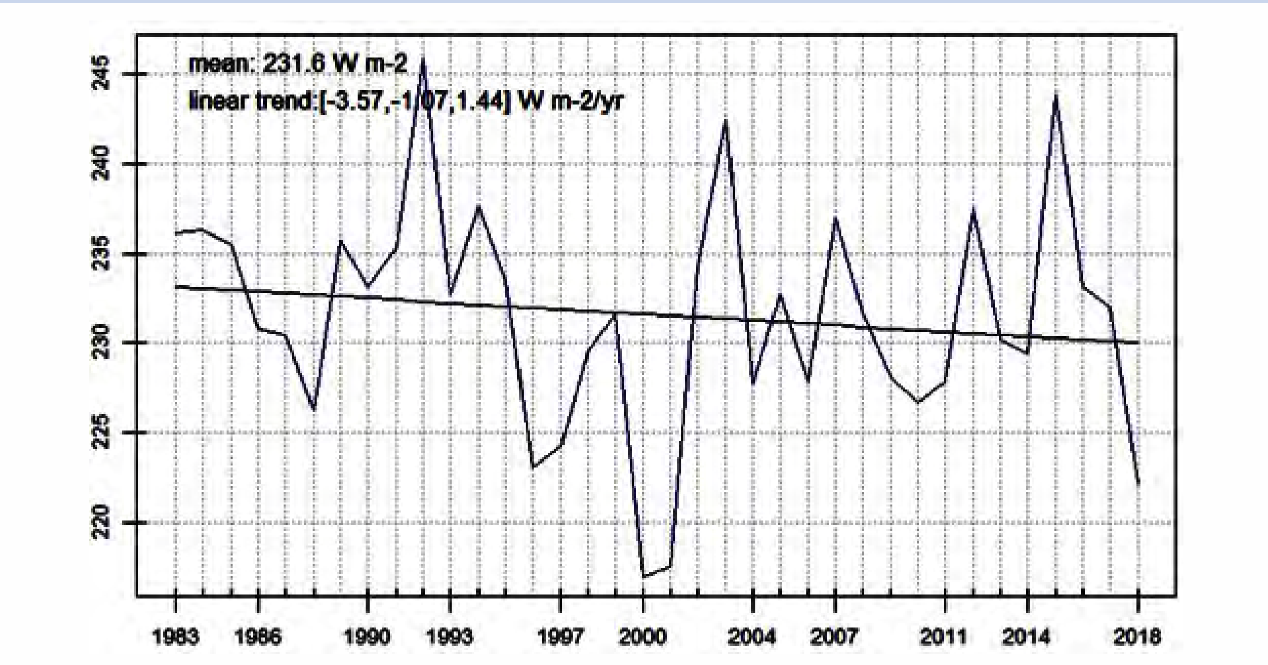

***Figure 2:** Polokwane GHI annual climatology and trends from 1983 to 2018 using CMSAF SIS satellite data*

The CMSAF SIS gridded data set can also be used to get a full map of the country showing daily mean, monthly mean, seasonal mean and annual mean values represented by different colours. In this paper, the mean monthly GHI values for January 2017 for South Africa was represented as shown in Figure 3. In January 2017, Thohoyandou received lowest amount of SIS ranging from 235-245 W/m² and Upington received the highest amount of SIS ranging from 340-350 W/m². These values were in agreement with the long term monthly average observation for January with Upington having the highest of 343.99±SD and Thohoyandou 243.72±SD.

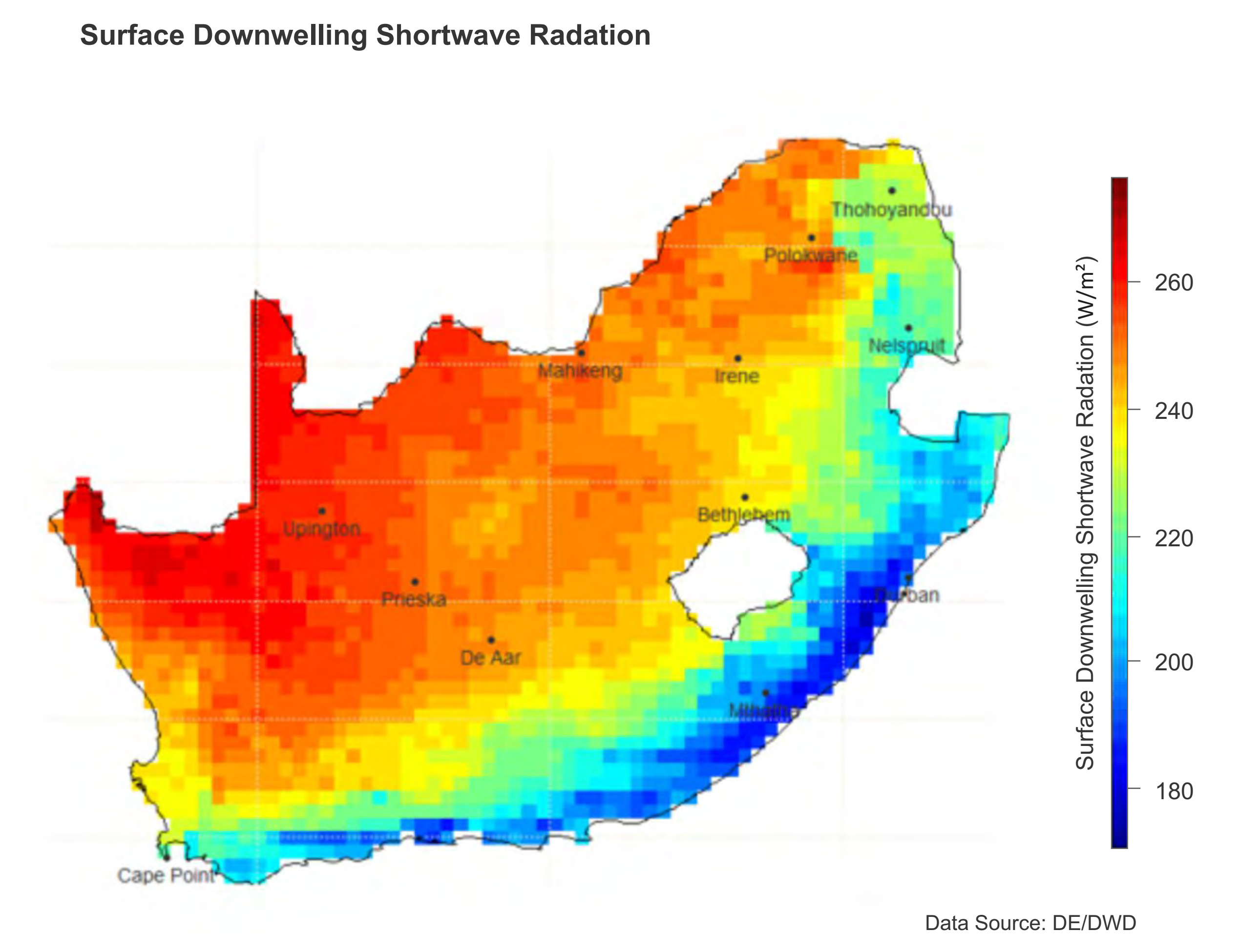

Figure 3: *CMSAF SIS gridded data set used to plot January 2017 monthly mean for a whole South Africa*

Aggregated monthly means and their standard deviations (SD) were calculated using monthly means calculated from minute quality checked GHI values and the results are as shown in Table 4 and Table 5. The highest GHI value of 370.18 W/m² was recorded in Upington in December while Cape Point recorded the lowest GHI of 98.51 W/m² in June. Of all the stations, Upington had the highest annual GHI of 265.63 W/m² while Durban had the lowest annual value of 186 W/m². The annual SD ranged from 8.72 W/m² to 15.12 W/m². Cape Point had the lowest annual variability while Irene had the highest annual variability. It was observed that that the variability was generally higher in summer when the values of GHI were high and lower in winter when the GHI values were low.

Table 4: Aggregated monthly mean (Mean) and standard deviations (SD) from January to December

Station	Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
PRI	Mean	330.89	342.45	268.61	211.46	170.09	145.88	157.79	180.65	248.09	311.85	336.79	341.03	253.80
	SD	12.73	13.46	8.67	4.90	11.02	11.40	10.93	4.24	10.31	1.61	7.16	17.50	9.49
UPN	Mean	343.99	319.04	282.39	219.03	182.30	160.24	169.53	209.71	253.27	319.93	358.05	370.18	265.63
	SD	21.92	18.42	4.94	5.24	3.40	9.78	6.31	14.80	6.27	8.06	12.93	17.04	10.76
DAA	Mean	331.60	313.81	271.24	200.95	163.28	144.26	155.06	193.97	243.96	305.04	345.56	367.27	253.00
	SD	14.34	17.38	8.49	9.17	6.50	10.76	7.29	12.23	9.79	5.40	18.10	10.45	10.83
IRN	Mean	278.01	251.27	238.86	195.39	174.10	166.15	175.20	212.23	244.62	277.30	281.15	281.12	231.28
	SD	18.31	24.33	19.75	15.78	11.57	6.38	6.74	14.34	12.86	15.95	17.47	18.00	15.12
NEL	Mean	252.74	222.79	225.20	184.24	170.63	160.09	160.99	190.46	206.09	218.85	224.22	244.28	205.05
	SD	13.38	10.23	5.05	22.24	19.23	6.67	3.33	16.23	17.04	15.92	19.97	12.62	14.31
MAH	Mean	296.66	253.00	260.73	204.79	184.53	172.49	181.62	214.47	258.26	297.40	322.55	320.59	248.24
	SD	28.75	24.44	11.09	10.85	1.86	7.27	6.01	10.09	4.48	8.71	7.41	7.64	10.72
MTH	Mean	250.65	227.11	191.90	166.71	140.73	129.22	137.33	161.13	193.30	224.75	241.35	251.20	192.95
	SD	16.58	20.59	27.41	7.84	9.01	7.43	14.36	6.94	16.02	2.45	8.2	20.89	13.14
BTH	Mean	303.50	279.10	222.94	189.07	169.39	156.46	161.75	200.67	240.43	282.99	313.56	300.05	235.00
	SD	24.81	18.19	22.17	14.44	11.68	6.78	9.38	13.84	16.54	11.59	0.00	12.79	13.52
CPT	Mean	313.72	301.64	234.13	180.52	123.59	98.51	112.50	150.65	191.72	259.69	314.08	335.25	218.00
	SD	10.75	9.17	7.47	8.16	11.98	2.24	4.03	19.03	10.35	11.10	9.80	13.60	8.72
GEO	Mean	271.09	249.70	200.39	159.82	121.95	101.80	112.54	143.22	184.67	234.77	266.34	296.79	195.26
	SD	7.69	9.85	10.23	6.29	8.29	0.85	12.80	10.18	7.76	10.43	14.23	14.69	9.44
DBN	Mean	256.54	234.81	201.53	165.18	140.59	128.03	127.95	157.33	166.96	201.57	218.59	233.94	186.08
	SD	24.38	23.42	11.51	7.98	3.78	5.26	7.68	13.63	12.10	16.57	25.61	11.96	13.66
PLK	Mean	281.77	228.62	245.84	194.80	184.65	173.36	179.90	208.49	242.61	278.77	285.58	282.79	232.23
	SD	20.30	3.13	2.01	4.15	8.37	4.83	3.94	7.20	14.86	15.19	12.47	19.10	9.63
THO	Mean	243.72	217.37	218.84	178.15	172.25	155.11	161.29	204.99	207.25	229.89	240.77	285.60	207.93
	SD	9.91	18.43	14.50	5.67	13.25	7.55	11.03	19.50	1.92	7.60	25.29	19.97	12.88

Aggregated seasonal averages and annual averages were also calculated with their corresponding CMSAF SIS values and the results are shown in Figures 4 -7. From the results, stations in arid, cold and temperature interior climato-logical regions had consistently higher GHI values with annual values of more than 230 W/m² while stations in hot interior, subtropical coastal and temperature coastal climatological regions had consistently lower GHI values with annual values of less than 220 W/m².

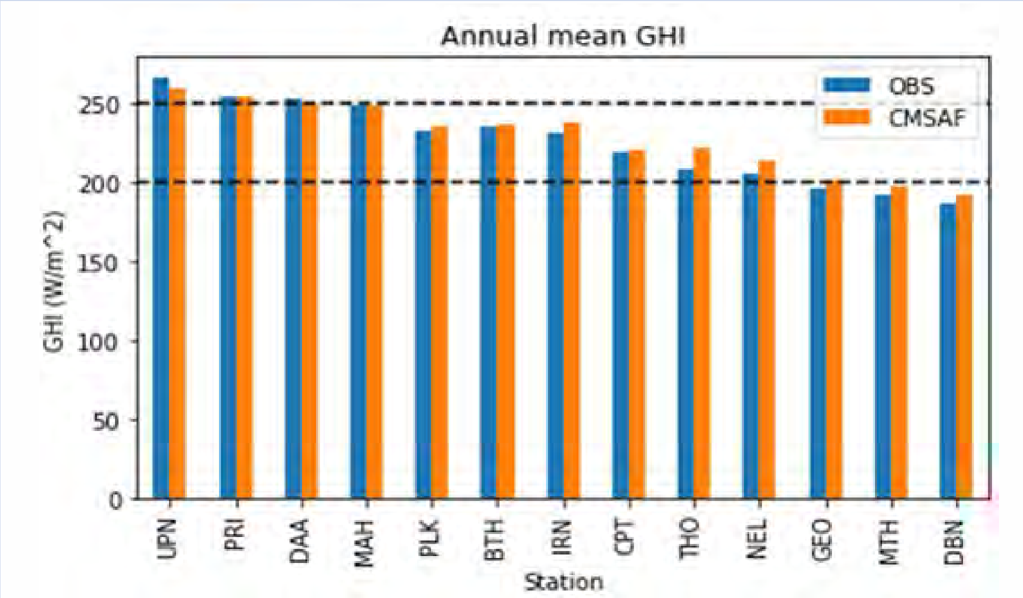

Figure 3: *Aggregated annual mean GHI for all SAWS radiometric stations*

The annual mean GHI ranged from slighted greater than 250 W/m² to slightly less than 200 W/m², most of the stations had GHI values between 200 W/m² and 250 W/m².

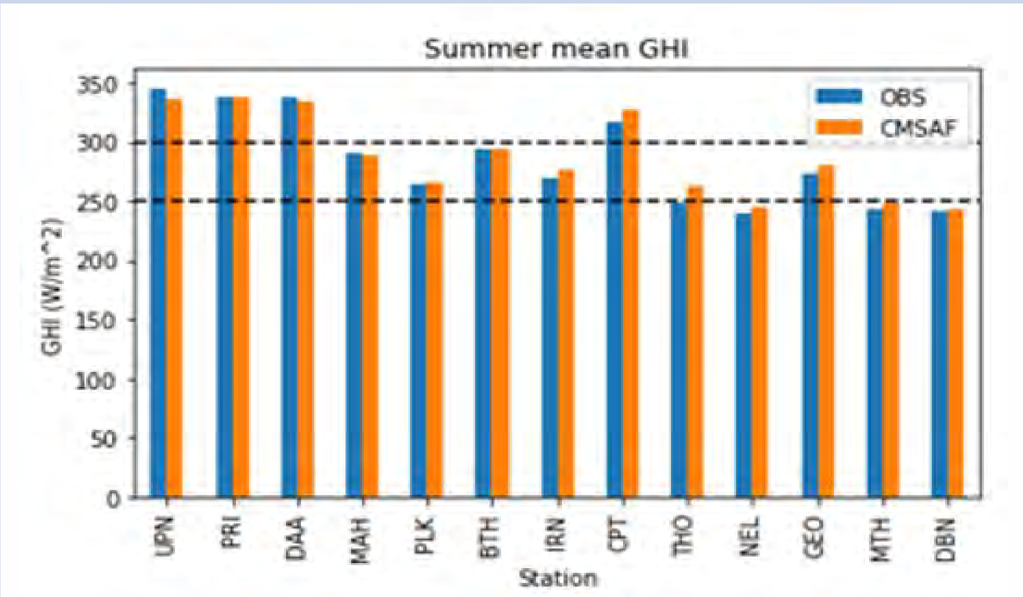

Figure 4: *Aggregated summer (December, January and February) mean GHI for all SAWS radiometric stations*

Upington, De Aar, Prieska and Cape Point received more than 300 W/m² GHI while Nelspruit, Durban and Mthatha stations receives less than 250 W/m² in summer.

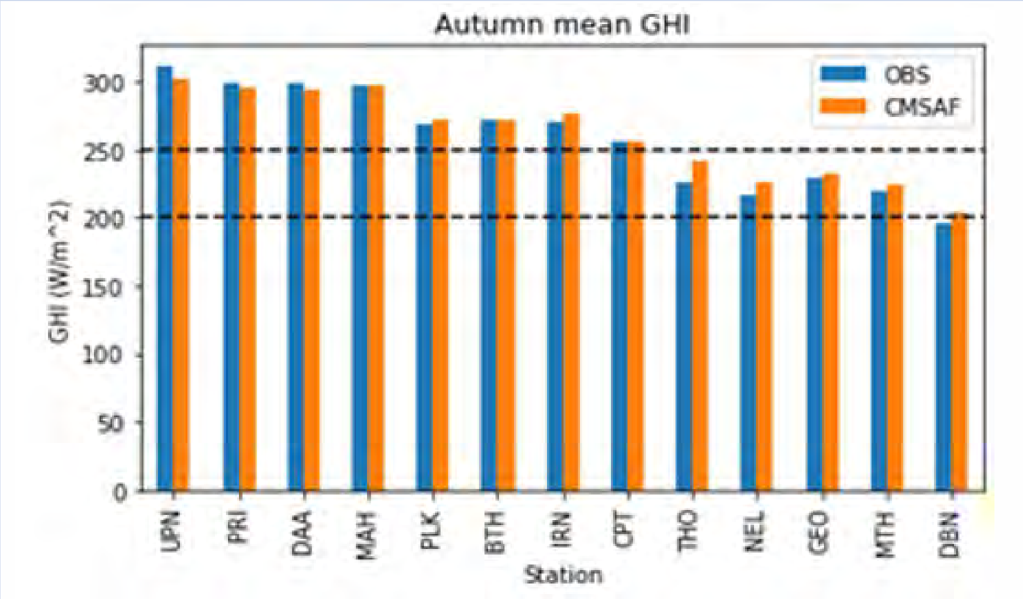

Figure 5: *Aggregated autumn (March, April and May) mean GHI for all SAWS radiometric stations*

In autumn all the stations except Durban received more than 200 W/m².

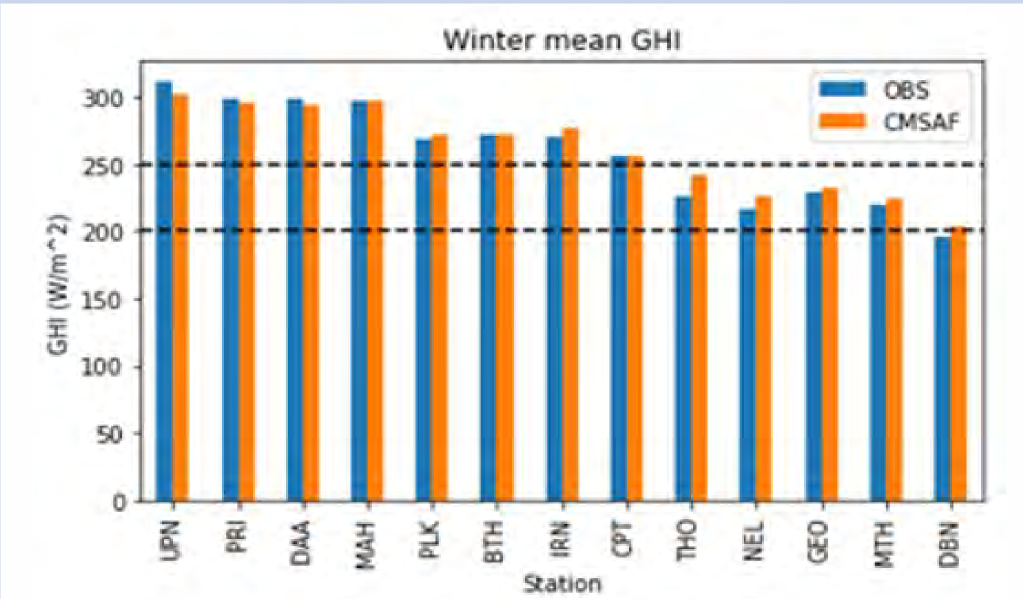

Figure 6: *Aggregated winter (June, July and August) mean GHI for all SAWS radiometric stationsradiometric stations*

In winter all the stations except Durban received more than 200 W/m².

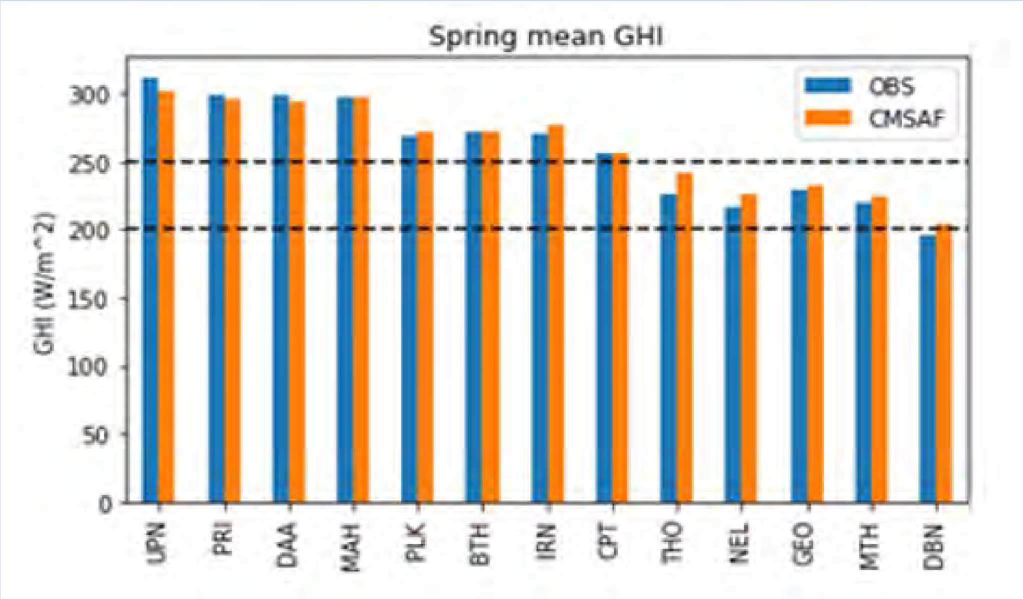

Figure 7: *Aggregated spring (September, October, November) mean GHI for all SAWS radiometric stations*

In spring all the stations except Durban received more than 200 W/m². GHI amounts decreased from Northwest of the country to Southeast, with inland stations having slightly higher GHI values than coastal stations this can be because of lower elevation, high humidity and cloudiness conditions on the coastal sites.

5. CONCLUSION

The GHI data quality recorded at SAWS was found to be of good quality with less than 5 % of data being erroneous based on the BSRN quality check test. This indicates that the data are reliable for use in solar resource assessment. CMSAF SIS data showed a very good relationship with observed data compared to NASA SSE data and it also met the optimal accuracy target of 15 W/m². The validation process confirmed that these data can be used with confidence for different renewable energy applications. The mean monthly, seasonal and annual values can be useful in providing solar radiation information that can be used to make decisions regarding the location and selection of solar energy technologies. The radiation amounts were higher in summer than in winter as expected for locations in the Southern hemisphere. According to [21] detection of climatological variation requires at least decadal monitoring of solar radiation and testing the accuracy of understanding of the climate system and the anthropogenic process requires half of a century of observations; to achieve this SAWS continue to focus on minimizing data loss and regular calibration of the radiometric network for long term measurement of reliable, high quality solar radiation data sets.

Acknowledgements

We want to acknowledge Department of Science and Technology (DST) who helped with the funding of the installation of the SAWS SOLYS radiometric network. SAWS staff from regional offices for the continuous efforts in helping with station inspection, cleaning and maintenance and the National Research Foundation (NRF) of South Africa. Dr. Amelie Driemel, Director of the World Radiation Monitoring Center who helped us with some answers related to the BSRN toolbox software operation and Mr. Louis van Hemert from the South African Weather Service who helped with the FORTRAN code to convert data from station-to-archive format.

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ANALYSIS OF A MID-WINTER CAPE STORM – 21 JUNE 2019

– by Kate Turner and Stella Nake

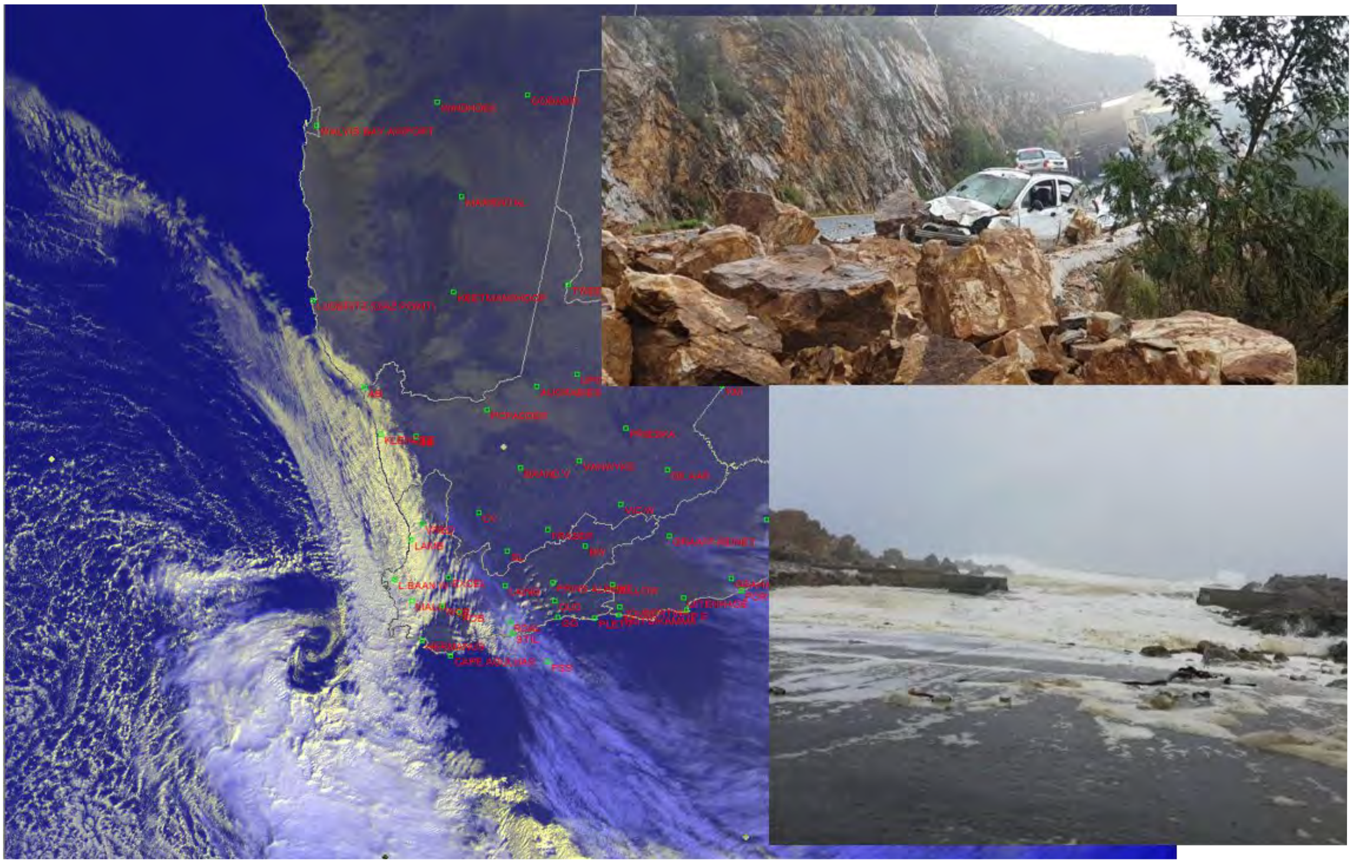

Figure 1: *Satellite image of the severe cold front at 1300UTC on 21 June 2019 along with damage photos – rock falls in the Franschhoek pass and storm surge at Kleinmond (Courtesy EUMETSAT 2019)*

Extreme weather is often associated with several simultaneous processes which contribute to damage across broad areas. Amongst other things, these processes can include high winds, heavy rainfall, (flash) flooding, extreme wave heights and storm surge. This was the case with the intense cold front system that passed over the south-western parts of South Africa on the 21-22 June 2019 (Figure 1).

Early in the week, the forecasters identified and monitored the cold front as it developed. Subsequently alerts were issued on Wednesday, 19 July 2019, to different stakeholders including the Provincial Disaster Management and the public, cautioning them about the potential severe weather conditions expected on Friday, 21 July 2019. In addition, a media release was issued and shared on the social media pages of the South African Weather Service. Impact-Based warnings detailing the severity of expected high winds, high seas, heavy rain, localised flooding and storm surge were issued and disseminated to the Provincial Disaster Management Western Cape (PDMC). Furthermore, the office contacted the Director at PDMC telephonically, emphasising the severity of the impacts.

A few days prior to this event, weather conditions across the Western Cape were relatively pleasant, with light winds and mild to warm temperatures. These conditions persisted into the first half of Friday, 21 June. Added to these predominantly

BACKGROUND

An intense cold front associated with a cut-off low moved over the Western Cape during the late afternoon of 21 June 2019. What made this cold front so unique and intense was the central position of the low pressure passing uncommonly close to the South African coast. This is by no means abnormal, but it is uncommon. This resulted in extreme wind conditions ahead of the cold front over the Western, Northern and Eastern Cape as well as off the south-west coast and later south coast. Heavy downpours were expected with the passage of the front during the afternoon and into the next morning, which led to flooding and flash flooding in areas.

Also associated with this front were high sea conditions and possible storm surge. Significant wave heights between 6 - 9 m were expected along the Western Cape south-west coast during the night of the 21st into the morning of the 22nd and spreading along the south coast. Furthermore, the strong winds "pushing" water further up onto the beachfronts, were likely to result in storm surge.

As it was a "mid-winter" storm occurring on the winter solstice, spring tides enhanced the high wave conditions along the coast. Spring tide means that the high tides are higher than normal. Therefore, the period of high tides was particularly perilous.

INDIVIDUAL STORM PARAMETERS

Wind Strength and barometric pressure

Very strong winds were expected across the Western Cape and southern parts of the Northern Cape during the afternoon ahead of the cold front with anticipated speeds of 40 – 65 km/h and wind gusts of 65 - 80 km/h were also expeced. Stronger winds reaching gale force (70 - 90 km/h) were expected in places over the Western Cape Karoo areas, Breede Valley as well as the Cape Peninsula. Off the south-west coast, wind spreeds of 65 – 90 km/h and gust of 85 – 100 km/h were expected (Figure 2).

Although slightly delayed in timing, these winds did materialise, and at times even exceeded 100 km/h gusts along the coastal areas (Figure 4). At the Cape Town International Airport, the average wind speeds reached 57 km/h and peak gust recorded at 96.8 km/h. The highest recorded wind gust of 124 km/h was at Cape Point of 124 km/h. These strong wind gusts coincided with the rapid drop in pressure (Figure 3), signaling the close proximity of the center of the low as it moved eastwards. Over the interior, although the average winds were not as strong and somewhat inconsequential where average winds were only between 20 - 50 km/h, it was the gusts that were the noteworthy factor and would cause the most damage. The gusts generally reached between 40 – 80 km/h with Worcester peaking at 107 km/h through the night.

High wind speeds contributed to major property and infrastructure damage, not mainly confined to the most vulnerable informal sectors but widespread across cities. Several areas were affected by the wind, where homes were left without power and some residents had to be evacuated because of an unstable building. Between Grabouw and Villiersdorp on the R321, cars were left stranded due to a sandstorm that piled significant amounts of sand on the road.

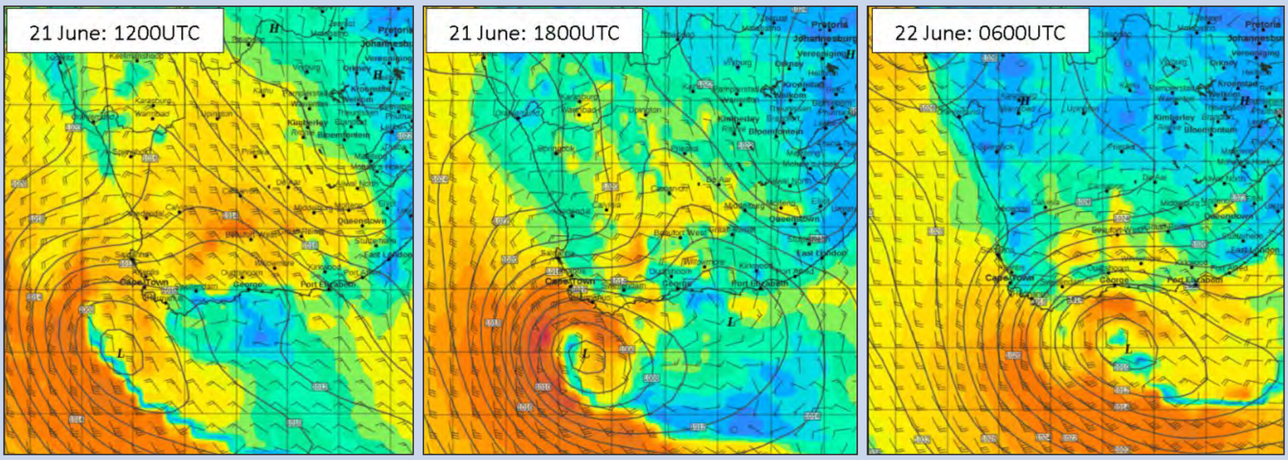

Figure 2: *GFS model data of average wind speeds for 12UTC, 18UTC on the 21 June and 06UTC on the 22 June (Courtesy NOAA 2019).*

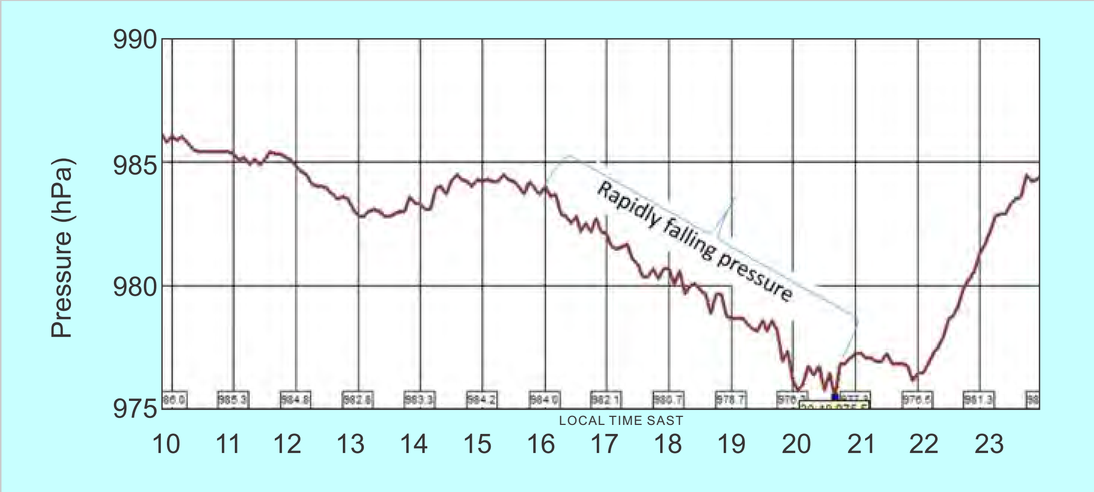

Figure 3: *Pressure graph showing station level pressure (hPa) at Cape Point.*
Note the steep pressure fall between 18h00 and 21h00 SAST (Courtesy SAWS 2019)

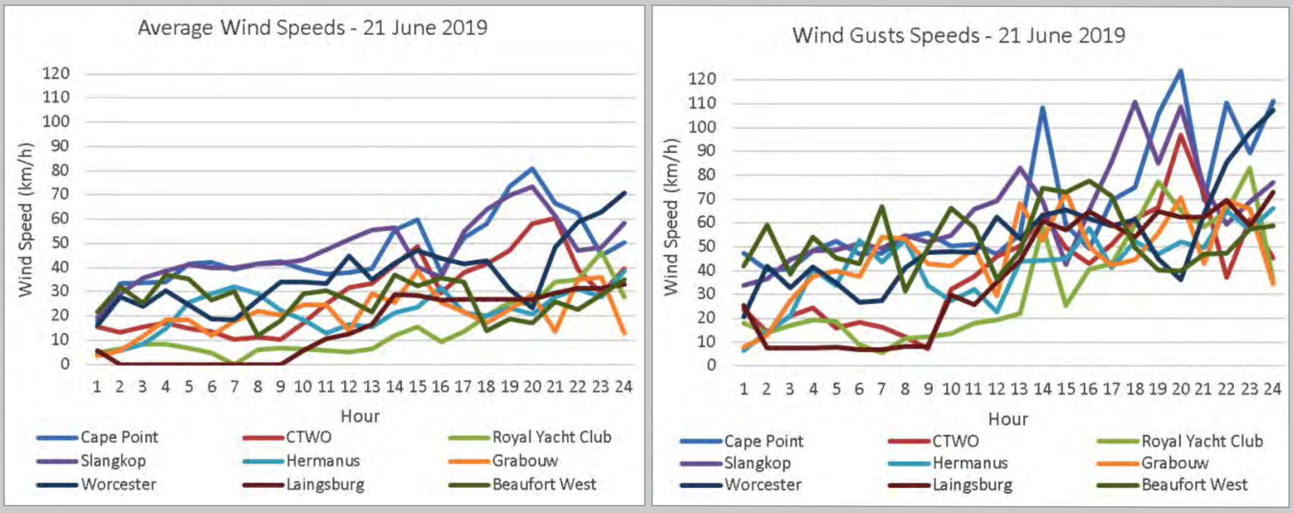

Figure 4: *Average wind speeds and gusts for selected areas on 21 June 2019 (Courtesy SAWS 2019)*

Rainfall and Flooding

Intermitent rain, with heavy downpours at times, was expected predominantly over the western parts of the Western and Northern Cape from the afternoon of 21 June (Figure 5). Rain and showers spread along the south coast and adjacent interior overnight Friday into the early hours of Saturday morning. However, very little rainfall was expected for the eastern parts of the Western Cape, where accumulations where expected to be between 5 – 15 mm.

There was an alert issued for heavy rain, leading to localised flooding for areas in the Cape Metropole, Cape Winelands and the Overberg from 21 -22 June 2019. Kirstenbosch recorded rainfall of 56.6 mm, Grabouw recorded 28.6 mm, Ceres recorded 45 mm, while Stellenbosch recorded 76.4 mm, which was the highest for the day.

According to the reports from Disaster Management, there were isolated areas where flooding and mudslides occurred. A car was severely damaged on the Franschhoek pass due to rockfalls, subsequently the pass was closed for a number of days thereafter.

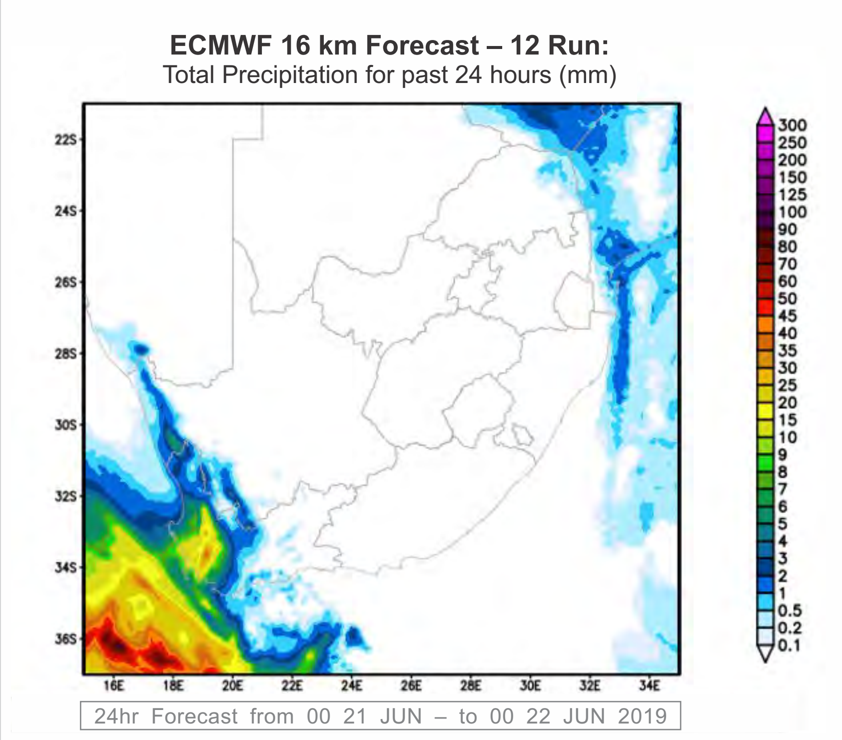

Figure 5:
Model projected accumulated rainfall for 21 June 2019 (courtesy ECMWF 2019)

Table 1: Selected areas accumulated rainfall on 21 and 22 June 2019 (SAWS 2019)

Rainfall	21	22	Total
Stellenbosch	61.6	14.8	76.4
Kirstenbosch	50.8	5.8	56.6
Ceres	44.6	X	44.6
Molteno	32.2	9.8	42
Moreesburg (Langewens)	30.6	1	31.6
Elgin Grabouw	19.4	9.2	28.6
Wellington	19.4	2.4	21.8
Observatory	17.4	3.4	20.8
Malmesbury	19	1	20

Wave Heights and Storm Surge

The intense cold front was also expected to generate significant wave heights of between 6 – 9 m. These wave heights stretched between Cape Columbine and Cape Agulhas on the evening of the 21st, spreading to Plettenberg Bay the following morning, abating from the afternoon (Figure 6). As the low moved further eastwards, the winds changed from a north-westerly direction to south-westerly early on Saturday, coinciding with the timing of the high wave heights. These strong onshore winds were aiding in pushing water further up the beachfront, and could likely to result in storm surge. Storm surge is defined as the abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide.

Over and above the high wave heights and strong onshore winds, the “mid-winter” storm occurred on the winter solstice, subsequently resulting in spring tides. It is thus around the time of high tide where conditions would be particularly hazardous. High tides occurred around 18h00 on Friday and 06h00/18h00 on Saturday.

As swell directions along the south-west coast were predominantly westerly on the Friday evening, coastal damage was more likely to have occurred along the west coast and Atlantic seaboard. These swell directions changed to a southerly component early on Saturday, putting areas such as False Bay and the south coast at risk for coastal damage and inundation. No reports of damage or coastal impacts were received other than coastal inundation at Kleinmond on the Saturday morning.

Off the coast, sea conditions for small and medium vessels would be adverse throughout Friday and Saturday for areas between Cape Columbine and Plettenberg Bay.

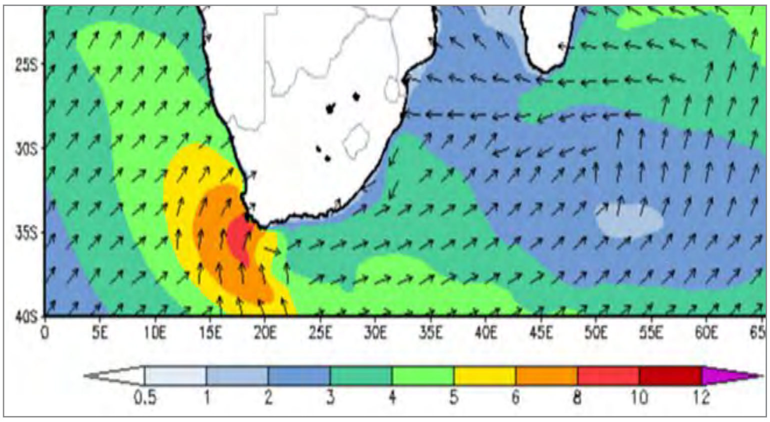

***Figure 6:** Wave heights (in meter) and direction for Saturday 02h00 SAST, 22 June 2019. (Courtesy passageweather.com)*

IMPACT WARNINGS

A number of Impact Based Severe Weather Warnings were issued for 21 and 22 June 2019.

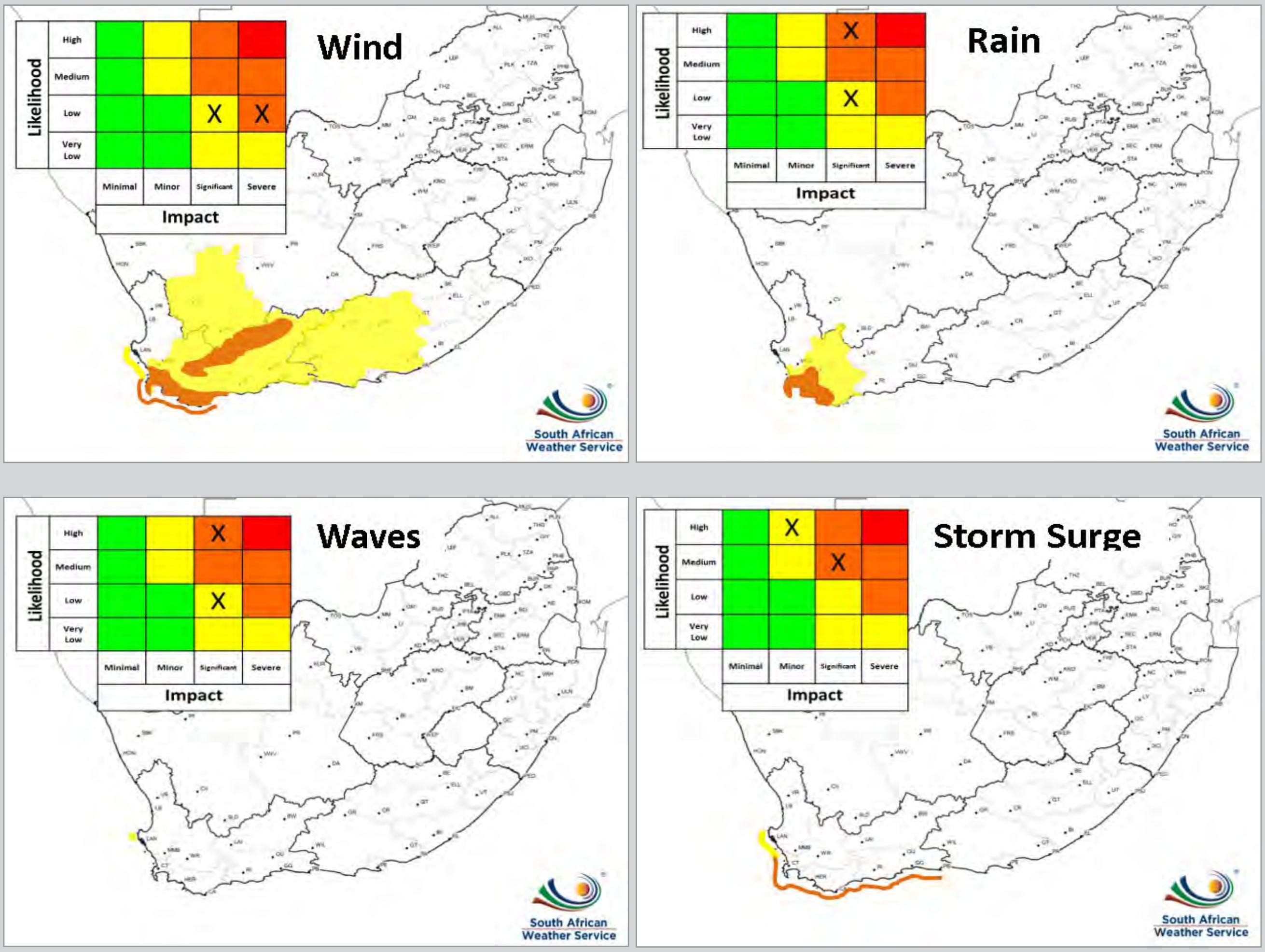

***Figure 7:** Impact-based forecasts issued for 21 and 22 June 2019*

IMPACTS

Impacts that were reported from disaster management and various social media platforms included:

- Roofs blown and partially blown off (mainly informal) – City of Cape Town, West Coast
- Several fallen trees
- Tree blown over on Garcia Pass R323 between Rivers-dale and Ladismith. Road temporarily closed
- Franschhoek Pass closed due to rock falls
- Sandstorm on R321 between Grabouw and Villiersdorp left cars stranded and closure of the road
- Electricity outages from fallen trees
  - City of Cape Town (Ravensmead, Claremont, Constantia, Plumbstead, Bergvliet, Kenilworth, Newlands, Pinelands, Mowbray, Portlands, Big Bay, Melkbosstrand, Athlone, Kensington, Silverton, Thornton, Meadowridge, Hazendal, Bonteheuwel, Belgravia, Bellville, Boston, Durbanville, Tamboerskloof, Woodstock, Maitland, Parow, Crawford, Grassy Park, Mitchells Plain, Mfuleni, Rylands and Heideveld)
  - Greyton
- Damage to settlements
  - West Coast (Swartland) - Chatsworth – Silverton Informal Settlement: 25 structures damaged due to flooding
    - 100 people displaced
  - Stellenbosch - Azania Informal Settlement: 40-50 structures affected due to flooding and strong winds
  - Overberg - Grabouw and Greyton: 45 Informal structures affected by flooding and strong winds. 3 Formal structures damaged by fallen trees
  - Vallhalla Park – 5 dwellings destroyed by strong winds

CONCLUSIONS

The intense cold front did result in severe weather over the Western and Northern Cape, where the wind caused widespread damage. The models predicted extreme conditions associated with the passage of this intense cold front well in advance and forecasters were able to issue alerts on time. Although the expected conditions did occur and the models predominantly captured the system well, the conditions were over-estimated to a certain extent. Along with this, the timing was slightly out, particularly relating to the winds which occurred later than projected by the models.

Although some damage could have been avoided (e.g. by parking cars in a garage, tightening loose objects around the yard, cancelling night travelling along the coastal routes, etc.) much of the damage could not be prevented.

While forecasting models indicate general areas where adverse weather is likely to occur, it remains a challenge for forecasters to pinpoint the areas likely to be affected and the severity of the impacts. The dynamic vulnera-bilities across the province and susceptibility must be taken into account in determining the likelihood of various impacts occurring. This calls for a back and forth flow of information between the South African Weather Service and Disaster Management. This two-way relationship is vital in assessing impact likelihood and issuing the impact-based warnings. The value of highly accurate warnings is always a priority for forecasters. However, in order for this to be achieved, strong partnerships need to be established. Collaboration with other departments such as engineering and maritime operations will also enhance the accuracy and effectiveness of the warnings.

Based on the feedback from the PDMC, forecasters will be in a better position to disseminate tailored impact-based weather warnings. Knowledge of vulnerable areas increases understanding of what weather conditions lead to the various impact categories (Minor, Significant and Severe). These tailored warnings in turn better equips disaster managers to plan and mitigate the severe weather.

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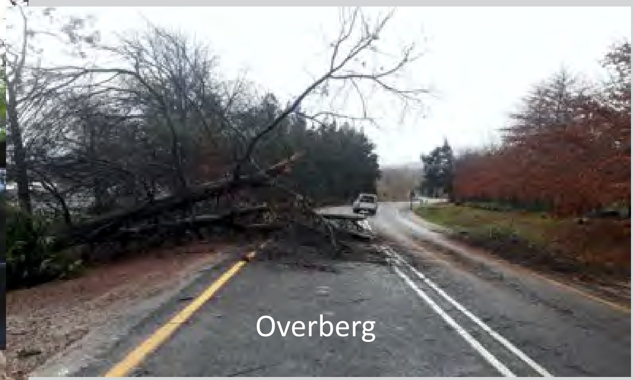
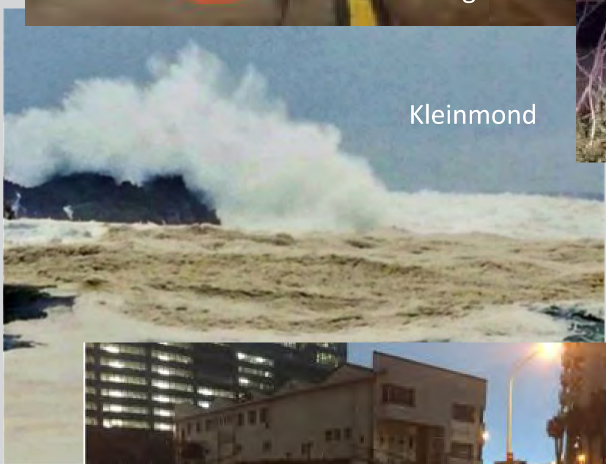
Greyton


Overberg

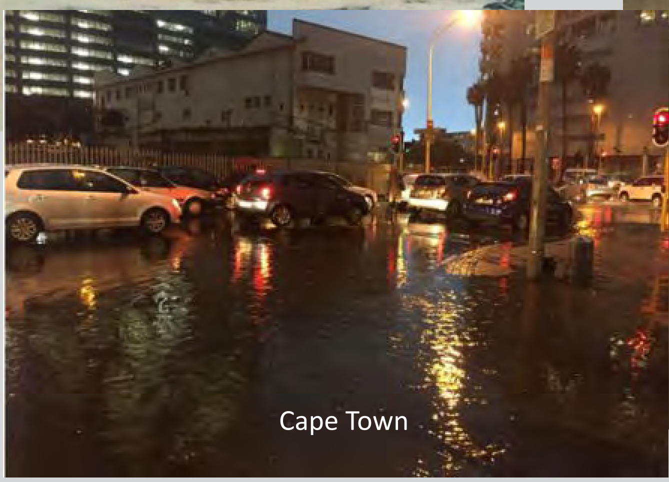

Plane pushed away from yellow line from strong winds


Franschhoek Pass


Thornton


Kleinmond


R321 between Grabouw and Villiersdop - Sandstorm


Cape Town

ANVIL AND TURBULENCE

– by Tumi Phatudi, Oscar Shiviti and Xolile Jele

The world connects through aviation as one of the most valued modes of transport. Aviation operations require accurate and timely weather forecasts for both safety and economic reasons.

One of the weather-related issues in aviation is turbulence. The presence of turbulence in the atmosphere is hazardous and dangerous and can cause stress and injuries to both passengers and crew members as well as structural damage to aircraft. It is very important to understand the development, onset, and type of turbulence and thus forecasting techniques need to improve so that the impact of turbulence can be reduced.

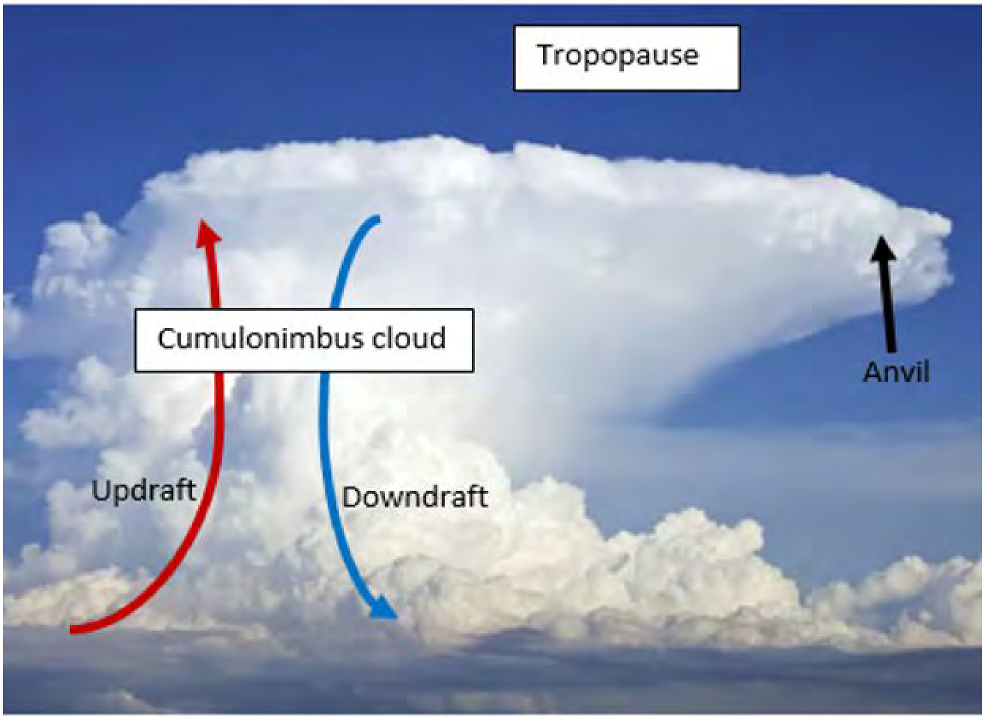


Figure 1: *A mature Cumulonimbus cloud with an anvil*

Turbulence is still a scientific problem due to its mathematical complexity. Turbulence is defined as an irregular motion of air in the atmosphere. When an aircraft flies through this disturbed air, it experiences bumpiness and instability. There are four types of turbulence, namely Mechanical, Orographic, Clear air turbulence, and Convective turbulence.

Convective turbulence occurs within cumulonimbus cloud (thunderstorm cloud) and can easily be avoided using remote sensing techniques. However, despite its characteristics, the spatial distribution is poorly understood more especially outside the cloud in clear skies. A mature thunderstorm will develop an anvil which forms in the upper parts of the thunderstorms.

Anvils gets their shape when the rising air (updraft) in the thunderstorm reaches the tropopause (Figure 1). It expands and spreads sideways as air bounces against the tropopause because air in the stratosphere is cooler than the rising warm air in the anvilAnvils determine the directional movement of the cloud. Within the anvil there are vertical/horizontal upper level winds producing turbulence. This turbulence can extend more than 50km horizontally away from the anvil in clear skies.

A recent study conducted by Trier S.B. and Sharmanan R.D. (2018) from National Centre for Atmospheric Research in Boulder, Colorado, concluded that the outer portions of anvils are usually thin and always appear relatively innocent (though they are prone to turbulence).

Anvil appears thin and smooth on a satellite image while cumulonimbus cloud is clumpy, bright and thick (Figure 2). The South African Weather Service (SAWS) has relatively diverse weather stations that are mostly automatic with no human observers in most areas. Therefore, the theory of the anvil and turbulence cannot yet be confirmed in South Africa without numerous observations and studies.

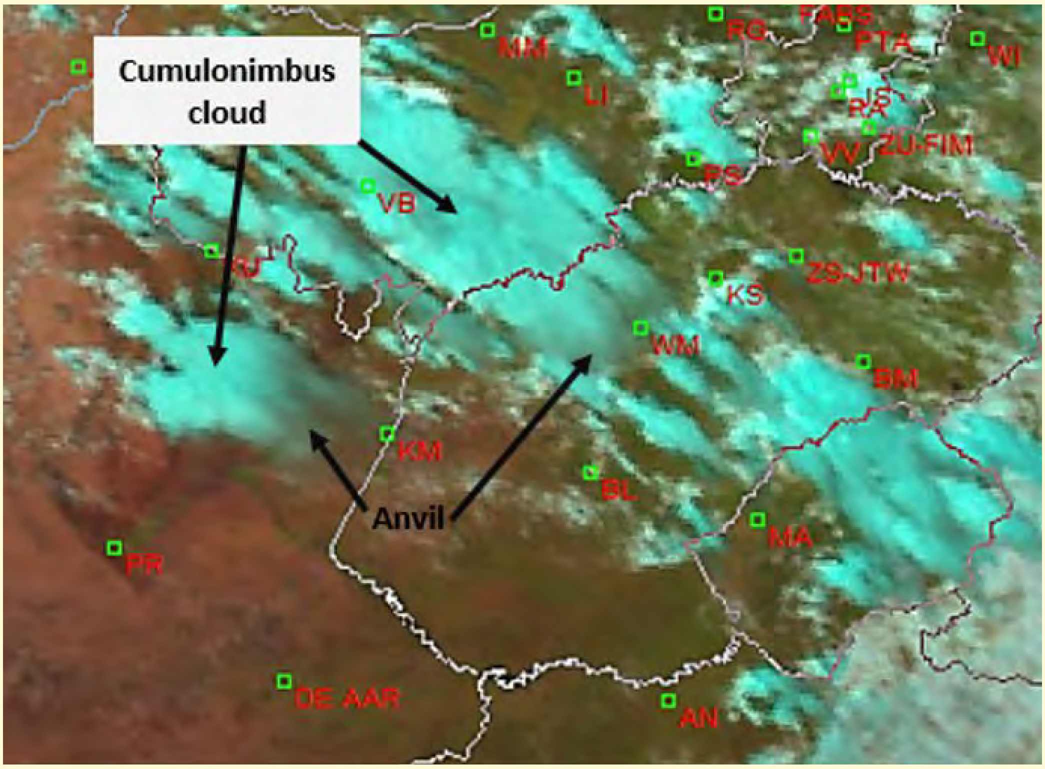


Figure 2: *Day Natural Colours (RGB) satellite image showing cumulonimbus cloud and anvil*

Figure 3 below indicates turbulence intensity inside and outside the thunderstorm cloud. The study also showed that about 50 km away from the anvil, light to moderate turbulence can be experienced by light aircrafts. There was an accident in early 2020 in the Free State, South Africa where a micro-aircraft crashed kilometers away from the anvil.

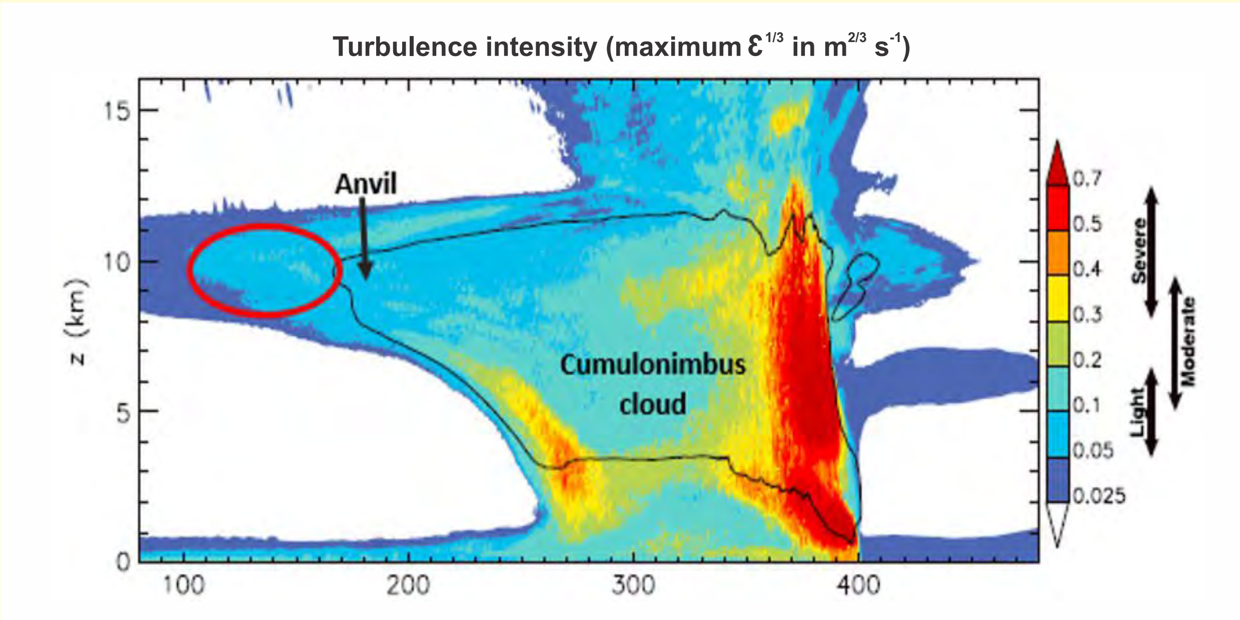


Figure 3: *Turbulence intensity about 50 km away from the anvil*

WHAT TO DO WHEN THUNDERSTORMS ARE ALL AROUND YOU

– by Elani Heyneke

In recent months, South Africa has experienced a lot of severe thunder-storms that produced heavy rainfall, leading to flash and localised flooding, large and large amounts of small hail and even damaging winds in the form of gust fronts or tornadoes. However, this is not uncommon, seeing that the eastern and central parts of South Africa are situated in the summer rainfall region, where most of the precipitation occurs in the form of afternoon thunderstorms as seen from the number of lightning strokes that occurred over South Africa in January 2020 (Figure 1).

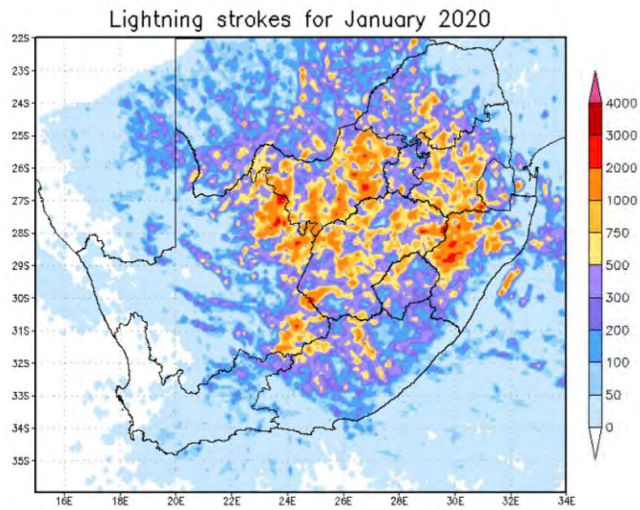


Figure 1: Map of the lightning strokes that occurred during January 2020 over South Africa (SAWS)

Figure 2: The difference between normal and severe thunderstorms (SAWS)

When comparing normal thunderstorms to those that are severe, referring to Figure 2, there are a number of common occurrences, but the most significant one is lightning.

Lightning is an electric discharge in the form of energy that is associated with cumulonimbus clouds. It can either be from one cloud to another cloud or cloud-to-air or the most common types - within the clouds (intracloud) or from the cloud to the ground (cloud-to-ground). Because light travels faster than the sound one will first see the lightning and then hear the thunder (the air rapidly expanding) afterward. Most of the energy within lightning is transferred as heat, which is one of the reasons why it is so dangerous. It can set a dry veldt alight, burn electronics and the most frightening of all, when it strikes a person, it can cause severe injury or even death.

The question remains: What should you do when thunder-storms are all around you? The first thing to remember is: **"When thunder roars, go indoors"**. The safest place to be is in the middle of a secure building away from metal, water and plugged in electronics. The second safest place to be is within a car (should there be no other option) because the lightning travels around the surface of the vehicle to the ground. It is best to pull the car to the side of the road, turn off the engine, and put your hands in your lap and do not touch any metal or your cellular phone when it is plugged in. Should lightning strike a vehicle, damage is highly likely (burned electronics, popped airbags and or melted tires) due to the immense heat generated by lightning. Should you find yourself in an open field and there is no shelter around you should find the lowest point as quickly as possible and then do the lightning crouch as seen in Figure 3.

Figure 3:
What to do: Thunderstorms – where is it safe?

As seen in figure 4, when looking for shelter the following places should be avoided at all costs: hilltops or the highest point in an open field; isolated sheds; under a tree; close to telephone and power lines as well as unprotected gazebo's and picnic shelters.

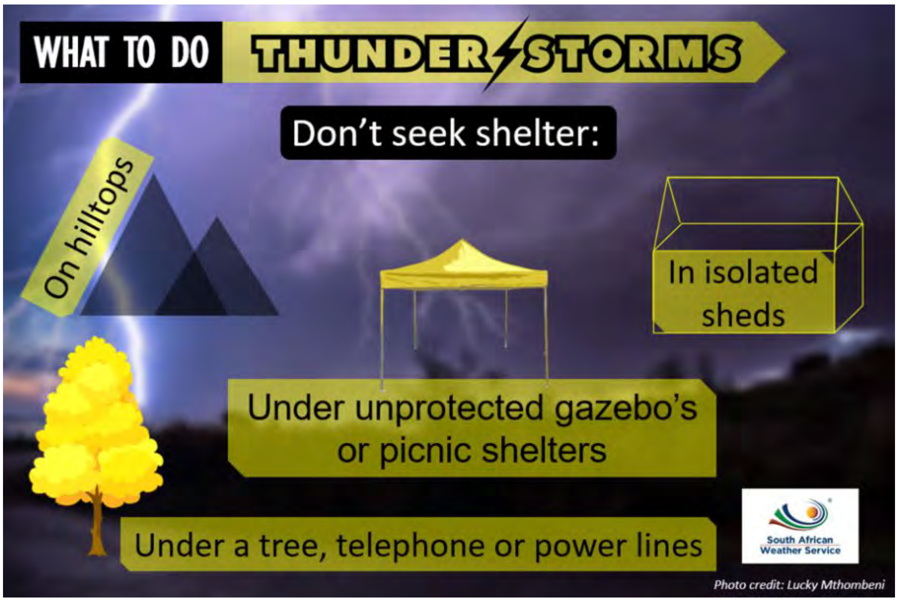


Figure 4:
What to do: Thunderstorms – where it is not safe

Be #WeatherSMART and always keep an eye on the weather forecast before going out or attending an outside event so that you can prepare yourself should there be thunder-storms. You can visit the website of the South African Weather Service, www.weathersa.co.za or download the WeatherSMART app for Apple Smartphones: https://apps.apple.com/za/app/weathersmart/id1045032640; for Android Smartphones: https://play.google.com/store/apps/details?id=za.co.afrigis.saws.droid.activity&gl=ZA) or call the nearest forecasting office, especially if you are hosting a big event during the summer.

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Infographics created by Elani Heyneke, SAWS, article edits by Tonie Rossouw; lightning map provided by Morné Gijben

REPOSITIONING FOR THE FOURTH INDUSTRIAL REVOLUTION (4IR) ERA

– by Alex Malapane, Manager: Research Projects and Strategic Partnership

In recent years, the global spheres have been abuzz with the Fourth Industrial Revolution (4IR). The 4IR narrative, tools, and applications continue to evolve in diverse contexts and circumstances offering huge potential to transform and realign our economies and societies. But what does this mean for organisations? The truth is that the 4IR has arrived and organisations need to keep pace if they want to maintain public trust. We are in the 4IR era, the age of intelligence and information where everything is rapidly becoming smart, connected and personalised. Are we taking advantage of this opportunity to remain smart and relevant while remaining appealing to the public? There is a need for organisations to re-evaluate their business processes, systems, and procedures to fully realise and benefit from the technological advancement brought by the 4IR. However, despite its promises, the 4IR also arouses worries, especially for its impact on employment as it is viewed as disruptive. There is an increasing realisation that the 4IR could also exacerbate problems for people and the planet. What should organisations do to remain relevant? Smart strategies should first be in place, redefining and aligning to smartly doing business. This will present an opportunity to re-evaluate policies, processes and enhance optimisation while realigning to the 4IR.

The speed and measure of the changes coming about by the 4IR are not to be ignored as they have the potential to render organisations obsolete. Careful planning and transition into the digital age are a primary requirement for all organisations that aspire to remain relevant. On the other hand, there are a variety of challenges stemming from the 4IR to overcome. The benefits of the 4IR have obstacles that must be harnessed, directed and overcome, such as cybersecurity and ethical dilemmas. Technology and advancements should assist organisations to drive transformation across the offerings in the value chain. I believe that these endeavours if implemented will create ripple effects on societies, institutions, and economies. They will transform the ways in which we live, work, and interact with one another. Understanding these new technologies and their disruption potential is critical.

These being said, what are the benefits of launching into the 4IR? Many people are using social media platforms to connect, learn and change information. This presents an opportunity for organisations to think of social media and its utilising and take advantage of this benefit of reaching stakeholders and users online. Another benefit is the access to digital platforms of marketing, sales of digital products such as data, data access, and offerings that are information driven. This allows consumers to be more and more involved in the production and distribution chains. The main effect of this revolution on the business environment is the impact it will have on consumer expectations, products and solutions quality, the move toward collaborative innovation, and innovations in organisational forms. Organisations should invest in their technical infrastructure and data analysing capabilities. All businesses, profit making or not, must be making a move to be smart, connected organisations or they will soon fall behind the competition.

As professionals, we need to embrace change and realise that what our jobs as they exist today might be dramatically different in the not too distant future. Our education and training systems need to adapt to better prepare people for the flexibility and critical thinking skills they will need in the future workplace.

MEET THE AUTHORS

Dr Abiodun Adeola

Dr. Abiodun Adeola is a Lead Scientist: Climate Change and Variability in Research & Development Department of the South African Weather Service (SAWS). Dr. Abiodun obtained his PhD in Geoinformatics in 2016 at the University of Pretoria (UP), he graduated with a MSc degree in Geographic Information System in 2010 and BSc degree in Geography in 2007 both at the University of Ibadan (UI), Nigeria. He is actively involved in capacity building through support and supervision of postgraduate students.

He is appointed as an extraordinary Lecturer in the School of Health Systems and Public Health, University of Pretoria. He previously worked as a Part-time lecturer in Department of Geography, Geoinformatics and Meteorology, UP (2012-2016). He is a registered Professional GIS Practitioner with the South African Geomatics Council, a member of the American Association of Geographers, and a member of African Association of Remote Sensing of the Environment. Till date, he has published more than 25 Scientific papers in accredited journals and presented more than 15 talks at local and international conferences.

Dr Christina Botai

Dr. Christina Botai is a Senior Scientist in Hydrometeorology applications at the South African Weather Service. She has a PhD in meteorology from the University of Pretoria, MSc. in Astrophysics and Space Science from North West University (Potch Campus), BSc. (Hons) in Astrophysics and Space Science from UCT and BSc from the University of Venda for Science and Technology. Dr Christina has more than 10 years of experience as a researcher specialising in satellite and hydrometeorology applications.

She has authored and co-authored more than 10 peer reviewed journal publications and has presented at various national and international workshops and conferences. Dr Christina is leading the Hydrometeorology applications research group at SAWS, which is responsible for developing applications research products and services that address the impacts of weather and climate on water resources management in South Africa. Dr Christina Botai is currently affiliated with Tshwane University of Technology, offering guest lectures and also supervises BSc. (Hons) students at the University of Pretoria.

Ms Elani Heyneke

Elani Heyneke started working at the Bloemfontein Weather Office in January 2017. Her passion is severe weather, especially severe thunderstorms in which she is planning to do her Masters Degree. She likes a challenge and will find an innovative way of solving it.

“Imagine a world where everyone strives for excellence."

Ms Xolile Jele

Ms Xolile Jele is an aviation weather forecaster based at O.R Tambo International Airport. She holds a BSc Natural Sciences degree and BSc (hons) Meteorology from the University of Pretoria.

Dr Andries Kruger

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

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

Dr Joel Botai

Dr. Joel Ondego Botai, PhD (Meteorology), MSc (Astrophysics), MSc (Space Engineering), BSc Hons (Eds.), Chief Scientist, Applications research, South African Weather Service, is a chief scientist at the South African Weather Service leading a team of scientists undertaking research and developing weather and climate products and services in support of strategic sectors of the economy including water resources, agriculture, health, energy and socio-economic research applications.

Dr. Botai was awarded PhD (Meteorology) by University of Pretoria in 2011, MSc (Astrophysics) by Rhodes University in 2006, MSc (Space Eng.) by Chalmers University, (Sweden) in 2005 and BSc (Hons) by Moi University (Kenya) in 1998. Dr. Botai has a multi-disciplinary academic background with a vast experience in cross-cutting research areas including earth and atmosphere sciences. Dr. Botai is also currently an extra-ordinary staff member of the University of Pretoria, an honorary research fellow at the school of Agriculture earth and environmental sciences, University of KwaZulu-Natal and an Adjunct Professor, Department of Information Technology, Central University of Free State. Dr Botai has been actively involved in capacity building especially supervision of MSc and PhD students. His current research interests include data science, advanced numerical and computational techniques as well the development of early warning systems. Lastly, Dr. Botai is a fervent Jazz and country music listener.

Mr Brighton Mabasa

Mr. Brighton Mabasa is a research scientist in Applications (Renewable Energy Applications and scientific consulting) at South African Weather Service (SAWS). Brighton's duties in the group includes SAWS Solar Radiometric Network monitoring and maintenance, data archiving, data quality control using Baseline Solar Radiation Network (BSRN)standards , satellite data validation, product development, observation data preparation for model verification, solar radiation and biometeorology station installation and calibration using ISO standards, writing peer reviewed articles and writing Standard Operating Procedures (SOPs) for operational activities.

Brighton Mabasa is registering for MSc in Atmospheric Physics at UNISA, research outputs will support an advanced operation of the SAWS solar radiometric network.

Mr Alex Malapane

Alex Malapane is a Manager: Research Projects and Strategic Partnerships at South African Weather Service (SAWS). He is the current General Conference Chair for the Fourth Industrial Revolution [4IR] Indaba Convention. He holds a Bachelor of Earth Sciences in Mine Surveying, a B-Tech in Project Management, a Postgraduate Diploma in Management and a Master of Business Administration (MBA). Alex is an author of four books with his latest been "Tracking the Future: The Fourth Industrial Revolution", a book set to be published and launched in April 2020.

Mr Sifiso Mbatha

Mr Sifiso Mbatha is a Climate Service Scientist: Climate Data. He joined SAWS as an intern in 2015 and was employed in July 2016 under the sameunit. He completed his BSC degree in Physics and Geography in 2013 and further obtained his Climatology Honors in 2014 from the University of Zululand. Sifiso is currently enrolled with the University of Venda for his Master's degree, modelling the variability of convective activity over East Rand South Africa.

Mr Musa Mkhwanazi

Mr. Musa Mkhwanazi is a Senior Scientist: Climate Information: Climate Services of the South African Weather Service.
His responsibilities includes providing Public Goods services to clients and to generate climate information related products for the website which includes historical rainfall maps, drought monitoring desk, etc.

Ms Stella Nake

Ms Stella Nake was born in a village approximately 100km outside of Pretoria, called Ratjiepan. The indigenous weather knowledge from the community fascinated her so much, and she undoubtedly picked up an interest in weather forecasting at a very early age. She can remember as a young girl, sitting under a tree watching the clouds as they move over ahead of a thunderstorm; and she asked herself: “who was pushing the clouds and where did lightning come from?”

When she was in Grade 12, a group of students from the Department of Geography, Geophysics and Meteorology of the University of Pretoria visited their school as part of their school outreach programme. They showed the learners weather observing instruments and explained to them what weather forecasting was all about. She got inspired and a year later after matric enrolled at theUniversity of Pretoria as a Meteorology student! After completing her Honours Degree in Meteorology in 2006, she joined SAWS as a Weather Forecaster based at Cape Town Weather Office until the present.

Mr Sandile Ngwenya

Mr Sandile Ngwenya is a Scientist in Climate Services: Climate Data Research and Analysis. He joined the South African Weather Service in 2017. He holds a BSc degree in Geography and Hydrology and a BSc Honors degree in Climatology from University of Zululand; He recently obtained an MSc degree in Environmental Sciences from University of Venda.

Ms Tumi Phatudi

Ms Phatudi is a Forecaster in the Aviation Weather Centre at OR Tambo International Airport. She studied BSc in Physics and Agrometeorology and BSc. Honours in Agrometeorology at the University of the Free State, Bloemfontein. She started working in Bloemfontein office in 2016 where she became an active supporter and contributor of SAWS social media.

Mr Lucky Ntsangwane

Mr. Lucky Ntsangwane is a Senior Manager Research and Development at the South African Weather Service.

Mr Oscar Shiviti

Mr Hetisani Oscar Shiviti is a forecaster at the Aviation Weather Center (AWC) at OR Tambo International Airport. He completed both the BSc degree and BSc honours degree in Meteorology at the University of Pretoria. He also further completed the forecasting training provided by the South African Weather Service (SAWS) for a full year. Since his employment he has been a willing participant on SAWS outreach initiatives to educate the public on weather related issues."

Dr Henerica Tazvinga

Dr. Henerica Tazvinga is a lead scientist for Energy at the South African Weather Service (SAWS). She has a PhD (Engineering) from University of Pretoria and Msc in Renewable Energy. Henerica has wide experience in renewable energy systems, energy efficiency and engineering acquired over 25 years having worked as a lecture, researcher and engineer in educational, technological and industrial institutions.

Prior to joining SAWS, she worked for organisations such as CSIR as a Hybrid Power Plant Specialist and the University of Pretoria's Energy efficiency and demand side Management Hub & Centre of New Energy Systems as a senior Management and Verification engineer. She also worked as a lecture at Polytechnics and Universities where she taught in Production, Mechanotrics and Fuels and energy Engineering Departments.

Her research interests are in energy optimization and management of micro-grid systems, and meteorology for energy sector. She has participated in many local and international energy projects. Further to this, Dr. Henerica Tazvinga received the National Research Foundation Scare Skills Award in 2014 and UK Newton Fund Award in collaborations with the University of Strathclyde in 2016 (Electric vehicle study).

She is a member of organisations such as the Southern African Research & Innovation Management Association (SARIMA); Southern African Solar Thermal Training (SOLTRAIN); International Solar Energy Society, Global Women's Network for the Energy Transition (GWNET)and institute of Electrical and Electronics Engineers (IEEE). Dr.Tazvinga has published many articles on hybrid energy systems and is a reviewer of many high impact energy journals including Applied Energy , Solar Energy, IEEE Access and IET Generation, Transmission & Distribution ; Energy Policy, International Journal of Electrical Power and Energy Systems, Energy Strategy Reviews as well as the Journal in Southern Africa (JESA) .She is a National Research Foundation rated researcher. Dr. Henerica also serves as an Evaluator and Assessor for the National Research Foundation Engineering Panel and has served on several international local technical advisory, organising and review for committees for conferences. She also supervises students and has served as an external examiner for several local universities.

Ms Kate Turner

Ms Kate Turner a senior forecaster at the Cape Town regional office and have been working here since November 2012. I completed BSc and BSc Hon Meteorology through the University of Pretoria in 2011. Thereafter continued to complete the Post Graduate certificate in Weather Forecasting in 2012. This was the first year that this course was available which required a separate research honours instead of directly specialising in Forecasting in honours level.

Ms Nosipho Zwane

Ms Nosipho Zwane is a research scientist in Applications (Renewable Energy Applications and scientific consulting) at South African Weather Service (SAWS). Ms Nosipho Zwane is a research scientist at SAWS since 2014. She started specializing in climate change and later moved to research applications weather/climate and energy. In 2019 she obtained her MSc Meteorology at the university of Pretoria. Her key research interest include variable renewable resources under changing climate and how renewable resources can be utilised in South Africa in order to meet the energy demands.

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