An analysis of Skukuza climate data

A.C. Kruger, L.B. Makamo and S. Shongwe

Data from the climate station at Skukuza, which has been open from 1912 to the present, are analysed. This exercise was done to provide the South African Regional Science Initiative (SAFARI-2000) experimental program with long-term climate statistics and trends. Climate parameters analysed are rainfall, temperature, humidity and sunshine. In the case of rainfall and temperature, the data was first tested for homogeneity and in only three out of 36 monthly cases, the data proved not to be homogeneous. No monthly rainfall trends proved to be significant (at the 5 % level), with five months indicating slightly negative trends and seven slightly positive. Only the monthly maximum temperature series for June proved to be non-homogeneous. The June maximum temperature trend and the February, March, May, July and December minimum temperature trends were significantly positive. The annual time series for minimum temperature were also significantly positive. The monthly results were reiterated by the seasonal results, with the winter maximum temperature trend and the autumn and summer minimum temperature trends significantly positive. Ten months showed negative temperature diurnal range trends with only March being significant. All long-term statistics of rainfall, temperature, humidity and sunshine were found to be typical of a savanna type climate in the southern hemisphere, although average monthly sunshine hours were somewhat less than the norm, due to frequent influx of moist air from the Mozambique Channel.

Key words: Skukuza, SAFARI-2000, climate, trends.

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Introduction

The South African Regional Science Initiative (SAFARI-2000) experimental program is developed for southern Africa to explore, study and address linkages between land-atmosphere processes and the relationship of biogenic, pyrogenic or anthropogenic emissions and the consequences of their deposition to the functioning of biogeophysical and biogeochemical systems (SAFARI-2000 Home Page). One of the SAFARI-2000 sites is about 13 km WSW of Skukuza in the Mpumalanga province. Many scientists are involved in the project or will use data forthcoming from it. However, climate data from the site itself only has a measuring period of about two years, from 2000 to 2001. The purpose of this paper is to provide an analysis of the data of the South African Weather Service climate station at Skukuza, entailing the calculations of long-term averages and trends, for the purpose of background data to interpret measurements at the flux measurement site.

General climate characteristics of the area

The climate station of Skukuza is situated at 24º59'S, 31º36'E at a height of 263 m above sea level. The area the station is situated in is generally known as the Lowveld and is

directly east of the eastern escarpment. According to the new climate regions developed by the South African Weather Service, loosely based on the vegetation regions of Low & Rebelo (1996) and the Köppen climate classification, Skukuza is situated in the Lowveld Bushveld region, which receives moderate summer precipitation (500–700 mm p.a.) with maximum rainfall in January. Warm to hot temperatures are usually experienced and no frost occurs. The humidity is usually fairly high and this makes summer days uncomfortable. Sunshine duration during summer is below average for this typical savanna climate, due to the influx of moist air from the coast and exacerbated by the proximity of the southern African escarpment close by towards the west. This type of climate lends itself to game, cattle and goat farming, subtropical fruit, vegetables and sugarcane through irrigation, and ecotourism.

Analysis of rainfall

To obtain a general idea of the rainfall climate of Skukuza, trends and long-term statistics are calculated. But before any analyses can be done, the data first have to be checked for overall quality, as inhomogeneities can influence the results significantly, especially in the case of trend calculations.

Homogeneity of rainfall data

To test for the homogeneity of Skukuza rainfall data, the non-parametric run test described by Thom (1966) was applied to monthly time series for January to December. This test is based on the number of runs (or groups of consecutive data points) above or below the median value of the time series. The results are shown in Table 1. In the second column the number of runs are shown which should ideally be about half of the total years used in the calculation (in this case about 80 years of data), to accept the time series as homogeneous. The third column shows the results when compared to the

lower and upper 10 % significance limits. Two of the months, March and May, showed possible inhomogeneities in their series, with much fewer than the ideal number of runs. This might indicate a possible trend or slippage in the mean. This is however not evident from the trend calculations, of which the results are shown in the following section. Thus, another possible explanation for the inhomogeneity results is that there might be relatively large clusters of consecutive months with rainfall above or below the median value, but not distributed in a way to cause a trend in the data. For March the largest clusters or runs with four or more consecutive values above or below the median are from 1912 to 1919 (below the median), 1929 to 1934 (above the median), 1943 to 1946 and 1962 to 1966 (below the median), 1967 to 1972 (above the median), and 1973 to 1976 and 1982 to 1986 (below the median). For May the runs are 1934 to 1937 (above the median), 1943 to 1946 (below the median), 1948 to 1951 (above the median), 1962 to 1965 and 1967 to 1970 (below the median), and 1979 to 1983 and 1990 to 1993 (above the median). Except for 1943 to 1946 and 1962 to 1965, none of the above periods are the same for both March and May, thus mostly excluding the probability of artificial biases introduced to the climate series, causing recorded values to be too high or low. Also, no mention is made in the metadata of

Table 1
Results of run test to determine homogeneity of monthly rainfall time series

Month	Number of runs	Result
Jan	49	Homogeneous
Feb	38	Homogeneous
Mar	34	Non-homogeneous
Apr	37	Homogeneous
May	34	Non-homogeneous
Jun	44	Homogeneous
Jul	39	Homogeneous
Aug	37	Homogeneous
Sep	36	Homogeneous
Oct	43	Homogeneous
Nov	38	Homogeneous
Dec	38	Homogeneous

Table 2
Monthly rainfall trends (mm p.a.) for the period 1912 to 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trend	−0.25	0.25	−0.13	0.13	−0.02	−0.03	−0.03	0.08	0.07	0.18	0.08	0.41

the station of changes in exposure during, just before or just after the mentioned periods, which lets one come to the conclusion that the above clusters are most possibly natural phenomena, a true reflection of the rainfall received at the station. No attempt was thus made to adjust data in the series before further analysis.

Trends in rainfall

Table 2 shows the analysis of linear trends in monthly rainfall time series for Skukuza for the period 1912 to 2001. The month with the highest trend is December with a very small positive value of 0.41 mm p.a. None of the trends calculated were significant at the 5% significance level. Trends were also calculated for seasonal rainfall, where summer is defined as the months from December to February, autumn from March to May, winter from June to August and spring from September to November. The results are shown in Table 3. Again, very small trends were detected, the highest being 1.4 mm p.a. for summer while none of the trends were significant. These results indicate that the long-term rainfall average for Skukuza has remained fairly constant over the past 90 years.

Long-term rainfall statistics

Figure 1 and Table 4 show long-term rainfall statistics for the period 1912 to 2001. Similar statistics is supplied by Scholes et al. (2001), but only for a shorter period, ending in 1999. The analyses reveal a typical summer rainfall climate in the southern hemisphere. From the absolute maximum and minimum monthly rainfall it is clear that the rainfall is highly variable, making the area prone to frequent droughts and floods.

Temperature

The same approach was followed with temperature analyses as in the case of rainfall. Firstly the data was checked for homogeneity, and after that long-term trends and statistics were calculated.

Homogeneity of temperature data

As with rainfall, the run test described by Thom (1966) was used to test monthly time series for homogeneity. The total number of years of data is 42 years (1960 to 2001).
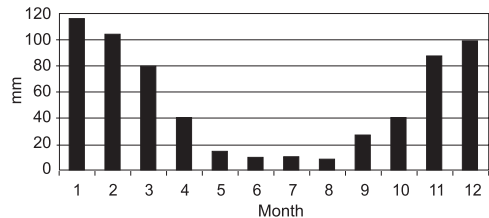
Table 3
Seasonal rainfall trends (mm p.a.) for the period 1912 to 2001

Season	Autumn	Winter	Spring	Summer
Trend	−0.07	0.07	1.1	1.4

Fig. 1. Average monthly rainfall (mm) for the period 1912 to 2001.

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Rainfall statistics (mm) for the period 1912 to 2001

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute Monthly Maximum	835	531	260	222	83	110	132	182	193	231	434	331
Absolute Monthly Minimum	8	0	4	0	0	0	0	0	0	0	0	1
Maximum daily rainfall	103.5	119.5	86.5	71.5	56.5	40.1	75.2	40.0	85.6	44.4	67.3	99.5
Average amount of rainy days (>= 0.1 mm)	9.8	9.6	8.8	5.7	3.0	2.1	1.8	2.3	3.3	7.0	10.6	9.8

According to the test, the ideal number of runs should be approximately 21 for a homogeneous data set. The results for the maximum and minimum temperatures are shown in Table 5. The third and last columns show the results of the test when compared to the lower and upper 10 % significance limits. Only the maximum temperature series for July showed possible inhomogeneities in its data series, indicating a high number of short runs in the series. This may in turn indicate a climatic vaccilation of the mean, or relatively short cycles in the series, although this was not verified by graphical analysis.

Trends in maximum and minimum temperature

Table 6 shows the trends of monthly average maximum and minimum temperatures. For the maximum temperature, only July showed

Table 5
Results of run test to determine homogeneity of maximum and minimum temperature time series

Month	Maximum temperature runs	Maximum temperature result	Minimum temperature runs	Minimum temperature result
Jan	23	Homogeneous	17	Homogeneous
Feb	19	Homogeneous	16	Homogeneous
Mar	21	Homogeneous	24	Homogeneous
Apr	24	Homogeneous	20	Homogeneous
May	23	Homogeneous	24	Homogeneous
Jun	26	Non-homogeneous	19	Homogeneous
Jul	19	Homogeneous	18	Homogeneous
Aug	23	Homogeneous	17	Homogeneous
Sep	22	Homogeneous	22	Homogeneous
Oct	25	Homogeneous	19	Homogeneous
Nov	23	Homogeneous	17	Homogeneous
Dec	23	Homogeneous	25	Homogeneous

Month	Maximum Temperature	Minimum Temperature
Jan	−0.020	0.007
Feb	−0.005	0.029*
Mar	−0.006	0.035*
Apr	0.026	0.021
May	0.010	0.034*
Jun	0.037*	0.011
Jul	0.008	0.041*
Aug	0.009	0.015
Sep	−0.002	0.026
Oct	−0.009	0.018
Nov	0.015	0.018
Dec	−0.001	0.019*
Average	0.005	0.024*

Season	Maximum Temperature	Minimum Temperature	Average Temperature
Autumn	0.010	0.030*	0.020
Winter	0.018*	0.029	0.024*
Spring	0.000	0.020	0.010
Summer	−0.009	0.018*	0.013

Trends in diurnal range of temperature

Table 8 shows the monthly trends in diurnal range of temperature. As can be expected, corresponding with the relative trends in maximum and minimum temperature, the trend is negative for most months, although only the trend for March is significant. For the seasonal trends of diurnal range, as shown in Table 9, all the results were negative. Autumn shows the highest negative trend of −0.023 ºC per year.

Long-term temperature statistics

Figure 2 and Table 10 show temperature statistics for the total period of record (1960 to 2001). Similar statistics is supplied by Scholes *et al.* (2001), but for the period until 1999. Summer temperatures are hot, while during the winter it is mostly warm and pleasant. Minimum temperatures rarely drop below freezing point during winter, but even at this time of the year maximum temperatures can reach levels in the mid-thirties.

a significant trend at the 5 % level. For the minimum temperature, five of the months showed significantly positive trends, as well as the annual average. These results are consistent with global trends where the minimum temperatures show higher positive trends than the maximum temperature (Easterling *et al.* 2000), causing the diurnal range in temperature to become progressively smaller. Table 7 shows the seasonal trends for maximum and minimum temperatures. The maximum temperature trend in winter, as well as the minimum temperature trend in autumn and summer, showed significantly positive trends.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trend	-0.027	-0.034	-0.041*	0.005	-0.025	0.027	-0.033	-0.007	-0.028	-0.027	-0.004	-0.020

Season	Autumn	Winter	Spring	Summer
Trend	−0.023	−0.010	−0.021	−0.017

which is usually the driest time of the day, ranges from a maximum of 54 % for February to a minimum of 38 % for June and August.

Humidity

Because of frequent influxes of moist air from the east, the humidity should be relatively high. This is reflected in Table 11. The average monthly humidity at 14:00 SAST,

Sunshine

Average sunshine data for 1960 to 2001 is shown in Table 12. One can see that, although daylight hours in summer is much longer than in winter, the sunshine hours show the opposite, indicating cloudier weather during summer. This region actually receives markedly less sunshine than the

Table 10
Long-term temperature statistics (°C) for the period 1960 to 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute minimum	11.3	10.0	7.6	5.6	0.8	−4.4	−3.8	−4.2	1.3	6.4	9.9	2.0
Absolute maximum	43.0	45.6	42.0	41.3	39.2	35.3	36.4	38.0	42.6	43.6	42.8	42.4

Table 11
Relative humidity (%) at 14:00 SAST for the period 1978 to 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	53	54	53	48	43	38	39	38	41	45	52	51
Lowest monthly	39	37	40	35	30	29	28	30	33	36	39	36
Highest monthly	66	77	67	57	64	57	58	60	57	56	84	62

Table 12
Monthly sunshine data (hours) for the period 1960 to 2001

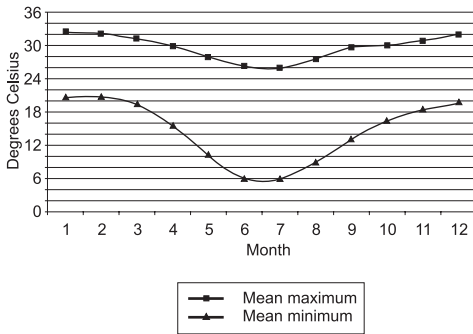| Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total average	7.3	7.3	7.2	7.5	8.0	8.1	8.1	8.1	7.5	6.7	6.2	7.0
Lowest average	4.8	5.2	4.4	5.4	6.4	6.7	6.4	5.8	5.5	5.0	4.2	4.8
Highest average	9.1	9.6	9.3	9.4	9.4	9.4	9.6	9.5	9.3	8.5	7.8	10.8

Fig. 2. Average monthly maximum and minimum temperature (°C) for the period 1960 to 2001.

norm for savanna regions, the reason being the frequent influx of moist air from the east, with its accompanying fog and cloud.

Discussion and conclusions

The motivation for this paper is to supply researchers, and other interested parties involved in the SAFARI-2000 project, sufficient long-term background data to serve as a baseline for comparison to future observations at the flux measurement site close by.

Meta data and homogeneity tests suggest that the data is generally of a high quality, suitable for trend analyses. The average rainfall (monthly and seasonal) stayed fairly constant during the previous century. How-

ever, there has been a marked increase in minimum temperature since the 1960s, especially during the summer and autumn months. This result corresponds to the average global trend (Easterling *et al*. 2000), and can also be considered a true reflection of temperature trends in the area, since no meaningful urbanisation or increased pollution has taken place since the starting point of the time series.

Long-term rainfall and temperature statistics indicate a highly variable climate, typical of the African savanna.

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