Trends in Extreme Climate Indices in South Africa 2023

Document Reference: WCS-CLS-WMO_EXTREME_CLIMATE_INDICES_2023.001
Document Type: Project Report
Version: 1

Document Control

Version and Amendment Schedule

Version No.	Version Date	Authors	Description of Amendments
1	31 March 2024	AC Kruger, S Mbatha	Document created

Executive Summary

- The South African Weather Service (SAWS) provides updates of Annual Extreme Climate Indices on a yearly basis.
- The indices provide a general impression of the trend in weather and climate extremes in South Africa, with the latest index values included in the report for comparative purposes.
- A set of 27 core indices were developed By the WMO to track extremes in surface temperature and precipitation known as the ETCCDI Extreme Climate Indices. However, not all of the indices are relevant to the South African climate. In this regard a subset of 10 surface temperature and 11 precipitation indices were selected for reporting purposes. In addition to the core indices, the WMO has developed additional sector-specific indices, and collectively these are known as the Climpact Indices
- The data sets analysed consist of a set of 27 homogenised temperature time series for the period 1931 – 2022 and 70 rainfall time series for 1921 - 2022.
- In the case of rainfall data the analysis does not necessarily include the data up to 2023. There are several reasons for that, e.g. significant periods of non-measurement from manual stations due to Covid-19 related restrictions and closing of stations shortly thereafter. However, the long-term trends of the stations with recent missing data are deemed to be still valid or representative due to the long period over which the trend values were calculated.
- The trends in the indices are calculated with the Climpact software (https://github.com/ARCCSS-extremes/climpact/tree/master). This software was developed under the auspices of the WMO and in effect replaces the previous RClimDex software that was developed to calculate trends of the core indices. It should be noted that the Climpact software is stricter with regards to the estimation of trends vs. data availability, with the effect that for eight stations which could be used to determine trends in temperature indices with RClimDex, it is no longer possible. This reduced the number of temperature stations to 19. Considering this, follow up reports will utilise a larger number of stations but with a shorter analysis period, probably restricted to only the last 30 years.
- It should be noted that the trends shown in the analysis of the long period data do not necessarily coincide with more recent trends. As an example there is a general tendency over recent decades of drying in the west and south-west of South Africa, but over the last century these trends are not evident. However, it should also be acknowledged that analyses over longer periods should be regarded as more robust than over relatively shorter periods.
- Overall the results show evidence of a climate that has become more extreme with regards to shorter term precipitation events as well as maximum temperatures. In contrast, cold extremes have become less prevalent.

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1. Introduction

The World Meteorological Organization (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 (Donat et al., 2013). The South African Weather Service (SAWS) has previously used these indices to analyse historical trends in rainfall and temperature extremes in South Africa, contributing to the Donat et al. (2013) study, as well as subsequent updates (Kruger and Nxumalo, 2016; 2017). The results were also included in the South African Third National Communication on Climate Change, which provided a general overview of the historical trends in the climate, including climate extremes. As awareness in the indices grew, due to increased awareness of climate change and the need to quantify the changes, it was decided that the WMO ETCCDI indices be updated on an annual basis. Since the implementation of this report, the WMO developed additional indices and accompanying software Climpact, which expanded the indices to include more sector-relevant indices (Dunn et al., 2024). This report utilizes Climpact.

2. Data

The Kruger and Nxumalo (2016, 2017) papers provide the information on the data that are utilised for the index updates. For surface temperature the data of 26 homogenised temperature series are used, but since Climpact is stricter in terms of trend determination vs. data availability, the temperature stations were reduced to 19 in this report. The table below provide the details of these stations and the subsequent map of the positions of the stations. From the map it can be seen that the stations can be deemed to be adequately distributed across the spatial domain of South Africa, with the number of stations exceeding the minimum required to provide an adequate impression of climate trends over the country.

Table 1. Basis set of stations used for the surface temperature extreme index analysis (from Kruger and Nxumalo, 2016) (Note: Not all stations in the list are used in this report due to unavailability of more recent data, and stricter Climpact availability criteria).

Station	No. of time series	No. of inhomogeneities		Approx. latitude (°)	Approx. longitude (°)	Approx. height (m)	Start year (after which 90% years available)
		Tx	Tn				
Cape Agulhas	1	2	0	−34.83	20.02	8	1931
Cape Point	1	0	0	−34.35	18.50	208–227	1931
Cape St. Blaize	4	4	3	−34.18	22.15	60–76	1931
Cape Town International	5	0	6	−33.98	18.60	42–46	1939
Jonkershoek	2	3	2	−33.97	18.93	244–350	1936
Port Elizabeth	2	1	1	−33.98	25.60	59–60	1937
Langgewens	1	1	2	−33.28	18.70	175	1931
Cape Columbine	1	6	0	−32.83	17.85	63	1936
Beaufort West	7	2	3	−32.35	22.60	857–902	1939
Calvinia	2	0	0	−31.48	19.77	975–980	1941
Vanwyksvlei	2	4	2	−30.35	21.82	962	1939
Emerald Dale	1	3	3	−29.93	29.95	1189	1931
Cedara	1	0	3	−29.53	30.28	1076	1931
Mount Edgecombe	1	4	0	−29.70	31.05	91	1931
Glen College	2	1	0	−28.95	26.33	1304	1932
Upington	4	0	0	−28.45	21.25	793–841	1943
Cape St. Lucia	4	4	2	−28.50	32.40	3–107	1947
Vryburg	1	0	0	−26.95	24.63	1234	1931
Zuurbekom	2	1	0	−26.30	27.80	1578	1931
Johannesburg International	4	4	4	−26.13	28.23	1676–1695	1946
Buffelspoort	1	1	4	−25.75	27.48	1230	1938
Pretoria PUR	1	0	0	−25.73	28.17	1286	1937
Pretoria	4	2	2	−25.73	28.18	1300–1330	1939
Pretoria University Experimental Farm	2	4	5	−25.75	28.27	1372	1931
Bela Bela	1	1	4	−24.90	28.33	1143	1937
Polokwane	5	0	0	−23.87	29.45	1230–1311	1939
Musina	2	3	1	−22.27	29.90	525	1933

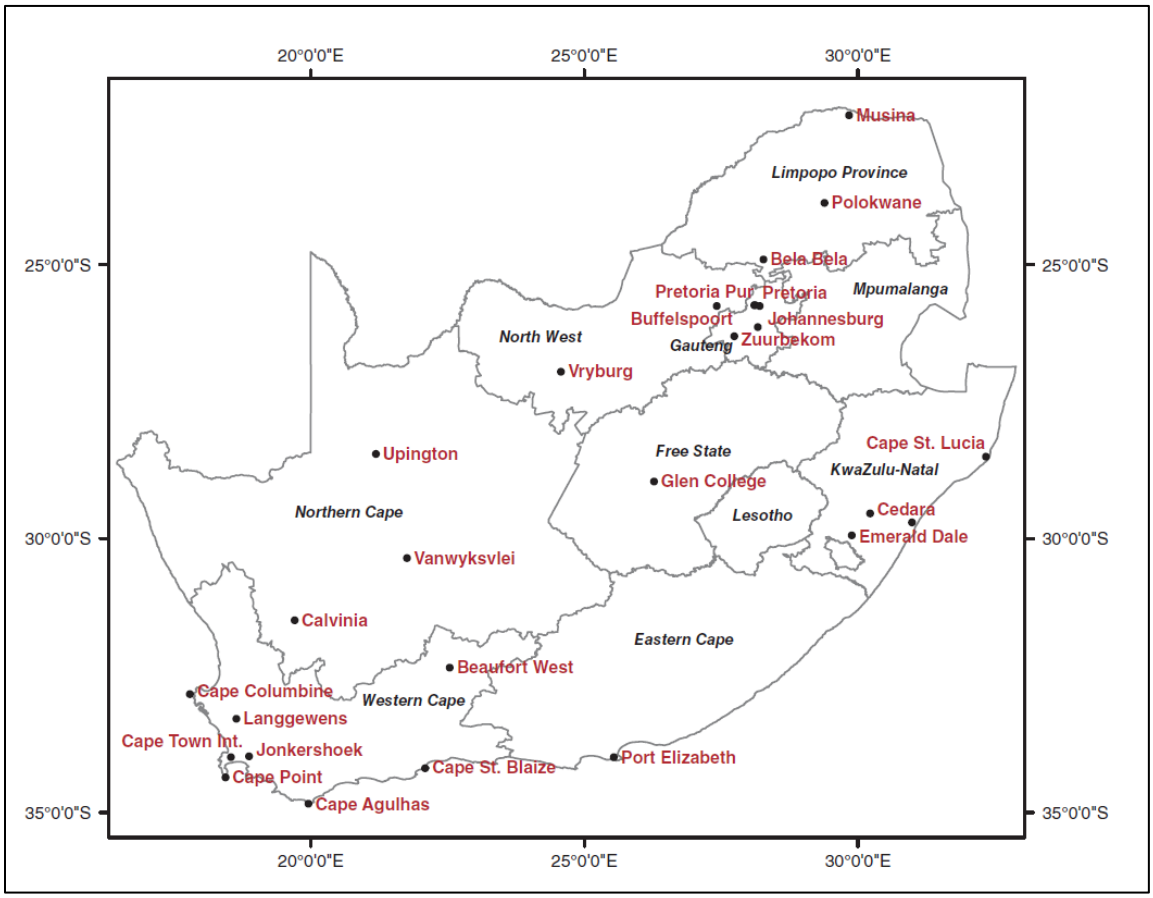

Figure 1. Positions of basis set of stations used for the surface temperature extreme index analysis (Kruger and Nxumalo, 2016).

For the precipitation indices the approach in the station selection was based on the initiative to cover the rainfall climate as much as possible. Therefore the rainfall district areas were used to select the stations with the longest and most complete record per homogeneous rainfall area/district. Eventually it was possible to select a total of 70 stations out of a total of 94 districts which are still in operation and have near-complete data since at least 1921. Figure 2 below show the spatial distribution of the stations superimposed on the 94 homogeneous rainfall districts of South Africa. However, since the Kruger and Nxumalo (2017) analysis some stations closed and alternative stations were subsequently selected for analysis.

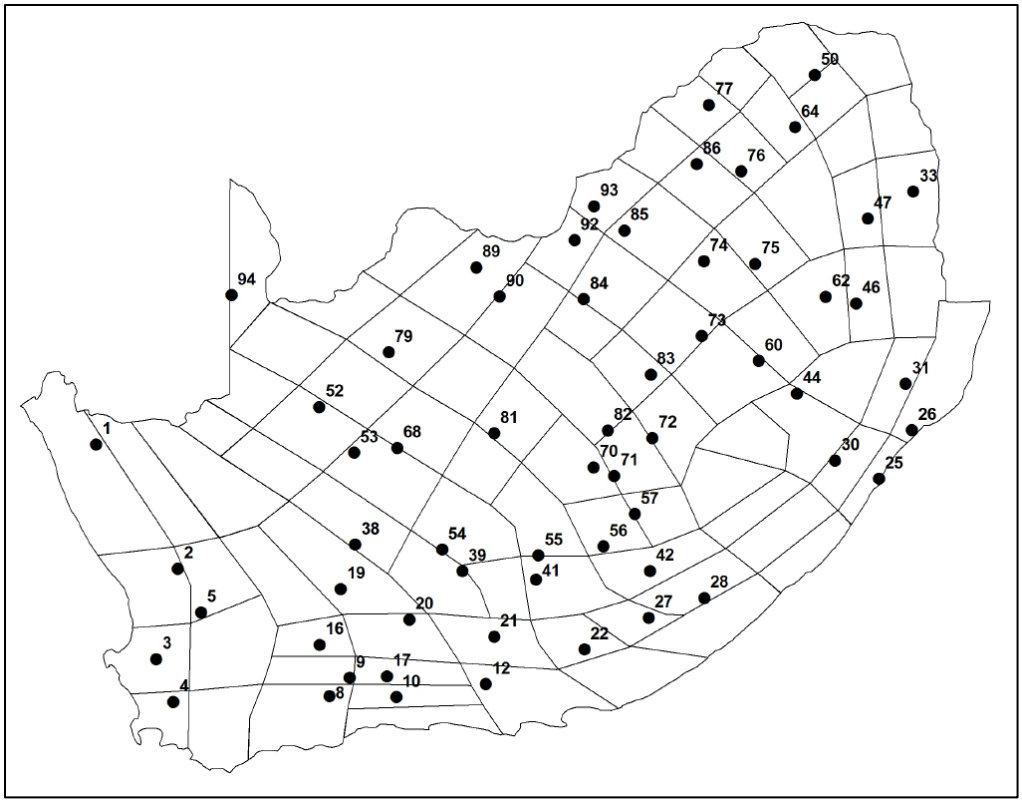

Figure 2. Locations of rainfall stations used in the trend analysis of individual stations, with rainfall districts represented. Rainfall district borders are superimposed (Kruger and Nxumalo, 2017)

Table 2. Basis set of stations used for the rainfall extreme index analysis (from Kruger and Nxumalo, 2016) (Note: Not all stations in the list are used in this report due to unavailability of more recent data).

Rainfall district	Number	Name	Lat.	Lon.
1	0244405 5	STEINKOPF	-29.27	17.74
2	0133202 2	NIEUWOUDTVILLE SAPD	-31.37	19.12
3	0062444 7	PIKETBERG-SAPD	-32.91	18.75
4	0022038 8	VRUGBAAR	-33.63	19.04
5	0086007 4	REENEN	-32.11	19.51
6	0045184 2	DWARS IN DIE WEG	-33.07	20.62
7	0003020 4	CAPE AGULHAS	-34.83	20.02
8	0027302 1	CALITZDORP - POL	-33.53	21.69
9	0048043 2	PRINCE ALBERT - TNK	-33.22	22.03
10	0029542 X	ROOIRIVIER	-33.55	22.82
11	0032507 4	KAREEDOUW - POL	-33.95	24.29
12	0052590 5	STEYTLERVILLE - MAG	-33.33	24.34
13	0057048A9	GRAHAMSTOWN - TNK	-33.32	26.49
16	0068010 3	MERWEVILLE - POL	-32.66	21.52
17	0049372 3	RONDAWEL	-33.20	22.66
19	0113673 X	SAAIFONTEIN	-31.72	21.88
20	0092386 9	BLOUBOSKUIL	-32.44	22.71
21	0073871 1	KENDREW ESTATES	-32.52	24.48
22	0076884 3	ALBERTVALE-FRM	-32.74	26.01
25	0241072 9	MOUNT EDGECOMBE	-29.71	31.05

26	0272121 2	GINGINDHLOVU	-29.03	31.57
27	0101192 X	EXWELL PARK	-32.21	27.10
30	0239482 0	CEDARA	-29.54	30.27
31	0337431 5	SURPRISE STORE	-28.18	31.25
33	0596179 3	SKUKUZA	-24.99	31.59
38	0166238A6	CARNARVON - POL	-30.97	22.13
39	0142805 X	RICHMOND C/K - TNK	-31.42	23.94
40	0096101 0	ROODEBLOEM	-32.18	24.57
41	0121518 3	HOFMEYR - MUN	-31.65	25.80
42	0149204 3	DORDRECHT CLARKS SIDING	-31.41	27.12
44	0334174 6	MOORSIDE	-28.40	29.61
45	0372852 9	HLOBANE	-27.7	30.98
46	0444203 6	TAFELKOPPIES	-26.88	30.62
47	0555567 2	ALKMAAR	-25.45	30.82
49	0679164 3	LETABA DISTRICT	-23.73	30.1
50	0722721 3	HANGLIP	-23.02	29.92
52	0284008 4	THORNLEA	-28.63	21.52
53	0253174 2	MARYDALE - POL	-29.41	22.11
54	0142153 5	LEKKERVLEI	-31.05	23.60
55	0145399 0	GRAPEVALE	-31.15	25.23
56	0174312 0	HUGHENDEN	-30.69	26.19
57	0177552 5	FUNNYSTONE	-30.70	27.82
60	0368831 1	WARDEN SKOOLSTRAAT	-27.85	28.96
61	0369505 9	VERKYKERSKOP	-27.91	29.27
62	0443451 9	BLAAUWKOP	26.50	30.27
63	0517430 6	MACHADODORP	-25.67	30.25
64	0678144 2	KALKFONTEIN	-23.90	29.58
68	0254589 8	NIEKERKSHOOP - POL	-29.33	22.84
69	0227127 X	HOPETOWN	-29.62	24.08
70	0230073 5	SLANGFONTEIN	-29.72	25.55
71	0262479 9	THE CLIFF	-29.49	26.76
72	0263373 6	WATERLAND	-29.22	27.22
73	0437660 7	VREDEFORT	-27.01	27.36
74	0513382 2	IRENE	-25.87	28.22
75	0477762 5	WITBANK STREHLA	-26.21	28.91
76	0590307 7	NYLSVLEY	-24.65	28.67
77	0675182 9	VILLA NORA-POL	-23.53	28.13
79	0356285 4	HOPKINS	-27.71	22.70
80	0359808 X	BOETSAP	-27.97	24.45
81	0257845 5	EUREKA	-29.08	24.48
82	0261722 8	MASELSPOORT DAM	-29.03	26.41
83	0329215 5	VENTERSBURG - MAG	-28.09	27.14
84	0434888 3	OTTOSDAL - POL	-26.81	26.00
85	0510308 6	SWARTRUGGENS - POL	-25.65	26.69
86	0588721 5	RANKINS PASS-POL	-24.53	27.91
89	0468318 4	VRYBURG PALMYRA	-26.27	24.18
90	0432136 3	VRYBURG WELGELEVEN	-26.76	24.58
92	0508649 3	SLURRY	-25.81	25.85
93	0546314 1	TUSCANY	-25.24	26.18
94	0423044 6	RIETFONTEIN SAPS	-26.74	20.03

3. Methodology

Climpact is a software package developed under the auspices of the WMO that provides for the calculation of core indices of temperature and rainfall extremes for the detection of changes in the climate, as well as a wide range of additional sector-relevant indices (Dunn et al., 2024). Of these indices 14 surface temperature and 12 precipitation indices were selected which can be considered to be the most relevant to the South African climate. The base period, from which the percentiles for the relevant indices were calculated, was defined as 1991–2020, which can be considered to be the present general norm for similar trend studies. The statistical significance of the Sen's slope (trend) of the indices was evaluated by the Mann-Kendall test at the 5% level. The details of the temperature indices are presented in Table 3 and the rainfall indices in Table 4.

Table 3. List of relevant Climpact indices utilized in the assessment of surface temperature trends. The relevant sectors are indicated as H (Health), AFS (Agriculture and Food Security) and WRH (Water Resources and Hydrology)

Short name	Long name	Definition	Plain language description	Units	Sector(s)
FD	Frost Days	Number of days when TN < 0 °C	Days when minimum temperature is below 0°C	days	H, AFS
TNlt2	TN below 2°C	Number of days when TN < 2 °C	Days when minimum temperature is below 2°C	days	AFS
TXx	Max TX	Warmest daily TX	Hottest day	°C	AFS
TNn	Min TN	Coldest daily TN	Coldest night	°C	AFS
WSDI	Warm spell duration indicator	Annual number of days contributing to events where 6 or more consecutive days experience TX > 90th percentile	Number of days contributing to a warm period (where the period has to be at least 6 days long)	days	H, AFS, WRH
CSDI	Cold spell duration indicator	Annual number of days contributing to events where 6 or more consecutive days experience TN < 10th percentile	Number of days contributing to a cold period (where the period has to be at least 6 days long)	days	H, AFS
TXgt50p	Fraction of days with temperatures above the median	Percentage of days where TX > 50th percentile	Fraction of days with above-median temperature	%	H, AFS, WRH
TXge30	TX of at least 30°C	Number of days when TX >= 30 °C	Days when maximum temperature is at least 30°C	days	H, AFS
TXdTNd	User-defined consecutive number of hot days and nights	Annual count of d consecutive days where both TX > 95th percentile and TN > 95th percentile, where 10 >= d >= 2	Total consecutive hot days and hot nights (where consecutive periods are user-specified)	events	H, AFS, WRH
TNx	Max TN	Warmest daily TN	Hottest night	°C	All
TXn	Min TX	Coldest daily TX	Coldest day	°C	All
TX10p	Amount of cool days	Percentage of days when TX < 10th percentile	Fraction of days with cool day time temperatures	%	All
TX90p	Amount of hot days	Percentage of days when TX > 90th percentile	Fraction of days with hot day time temperatures	%	All
TN10p	Amount of cold nights	Percentage of days when TN < 10th percentile	Fraction of days with cold night time temperatures	%	All
TN90p	Amount of warm nights	Percentage of days when TN > 90th percentile	Fraction of days with warm night time temperatures	%	All

Table 4. List of relevant Climpact indices utilized in the assessment of precipitation trends. The relevant sectors are indicated as H (Health), AFS (Agriculture and Food Security) and WRH (Water Resources and Hydrology)

Short name	Long name	Definition	Plain language description	Units	Sector(s)
CDD	Consecutive Dry Days	Maximum number of consecutive dry days (when PR < 1.0 mm)	Longest dry spell	days	H, AFS, WRH
R10mm	Number of heavy rain days	Number of days when PR >= 10 mm	Days when rainfall is at least 10mm	days	All
R20mm	Number of very heavy rain days	Number of days when PR >= 20 mm	Days when rainfall is at least 20mm	days	AFS, WRH
PRCPTOT	Annual total wet-day PR	Sum of daily PR >= 1.0 mm	Total wet-day rainfall	mm	AFS, WRH
R95pTOT	Contribution from very wet days	100*r95p / PRCPTOT	Fraction of total wet-day rainfall that comes from very wet days	%	AFS, WRH
R99pTOT	Contribution from extremely wet days	100*r99p / PRCPTOT	Fraction of total wet-day rainfall that comes from extremely wet days	%	AFS, WRH
SPI	Standardised Precipitation Index	Measure of "drought" using the Standardised Precipitation Index on time scales of 3, 6 and 12 months. See McKee et al. (1993) and the WMO SPI User guide (World Meteorological Organization, 2012) for details.	A drought measure specified as a precipitation deficit	unitless	H, AFS, WRH
CWD	Consecutive Wet Days	Maximum annual number of consecutive wet days (when PR >= 1.0 mm)	The longest wet spell	days	All
SDII	Daily PR intensity	Annual total PR divided by the number of wet days (when total PR >= 1.0 mm)	Average daily wet-day rainfall intensity	mm/day	All
R95p	Total annual PR from heavy rain days	Annual sum of daily PR > 95th percentile	Amount of rainfall from very wet days	mm	All
R99p	Total annual PR from very heavy rain days	Annual sum of daily PR > 99th percentile	Amount of rainfall from extremely wet days	mm	All
Rx1day	Max 1-day PR	Maximum 1-day PR total	Maximum amount of rain that falls in one day	mm	All
Rx5day	Max 5-day PR	Maximum 5-day PR total	Maximum amount of rain that falls in five consecutive days	mm	All

4. Tables of results

4.1 Temperature

Table 5 presents the decadal trend and statistical significance thereof for the temperature indices (see Table 3) for most of the weather stations listed in Table 1 in alphabetical order. It should be noted here that due to data constraints and the methodology in the calculation of WSDI and CSDI the results were very limited.

Table 5. Selected WMO Climpact surface temperature index trends and values for the selected stations. Statistical significance at the 5% level is indicated with "*"

Station	Lat	Lon	fd	tnlt2	txx	tnn	tnx	txn	wsdi	csdi	txgt50p	tx10p	tx90p	tn10p	tn90p	txge30
Cape Agulhas	-34.83	20.02	0.0	0.0	0.1	0.2*	0.1*	0.1*	0.0	0.0	1.6*	-0.7*	0.5*	-2.1*	1.0*	0.0
Cape Point	-34.35	18.50	NA	NA	0.4*	NA	NA	0.2*	0.0	NA	4.0*	-2.8*	0.7*	NA	NA	0.4*
Cape St. Blaize	-34.18	22.15	0.0	0.0	0.2*	0.2	0.1	0.1*	0.0	0.0	0.9*	-0.6*	0.4*	-1.0	0.6	0.5*
Cape Town Int.	-33.98	18.60	0.0	-1.3*	0.1	0.3*	0.3*	0.1	0.0	0.0	2.4*	-1.5*	0.6*	-2.9*	1.4*	2.0*
Port Elizabeth	-33.98	25.60	-0.0	-1.4*	0.3*	0.5*	0.3*	0.1*	0.0	0.0	2.3*	-1.0*	0.5*	-3.7*	1.3*	0.6*
Langgewens	-33.28	18.70	0.0	-0.2*	0.3*	0.2*	0.2*	0.2*	0.0	0.0	2.1*	-1.5*	0.7*	-1.9*	0.5	3.8*
Cape Columbine	-32.83	17.85	0.0	0.0	0.2*	0.1*	0.1*	0.3*	0.0	0.0	3.8*	-3.7*	0.4*	-0.3	0.2*	0.2*
Calvinia	-31.48	19.77	0.9*	0.9	0.2*	0.0	0.0	0.0	0.0	0.0	1.1*	-0.4*	0.8*	0.0	0.1	2.7*
Vanwyksvlei	-30.35	21.82	-1.1*	-1.7*	0.2*	0.1*	0.0	0.2*	0.0	0.0	1.7*	-0.8*	1.0*	-0.7*	0.3*	3.1*
Cedara	-29.53	30.28	-1.7*	-2.4*	0.0	0.2*	0.1*	-0.0	0.0	0.0	1.0*	-0.1	0.6*	-1.8*	0.8*	1.5*
Mount Edgecombe	-29.70	31.05	0.0	0.0	0.4*	0.3*	0.2*	0.2*	0.0	-1.7	3.7*	-1.7*	0.7*	-3.3*	1.2*	4.1*
Glen College	-28.95	26.33	-1.1	-1.7*	0.0	0.1	0.0	0.2*	0.0	0.0	1.3*	-0.4*	0.6*	-0.6	0.3	3.1*
Upington	-28.45	21.25	-0.8	-1.1*	0.3*	0.2*	-0.0	0.2*	0.0	0.0	3.1*	-1.2*	1.6*	-0.9*	0.3	5.4*
Johannesburg	-26.13	28.23	-1.9*	-3.8*	0.0	0.3*	0.4*	-0.0	0.0	-1.2	0.1	-0.0	0.2	-2.7*	1.7*	0.3
Bela Bela	-24.90	28.33	-0.8*	-1.6*	0.0	0.2*	0.0	0.0	0.0	0.0	1.3*	-0.7*	0.4	-1.2	0.7*	2.5*
Polokwane	-23.87	29.45	-0.2*	-1.8*	0.2*	0.2*	0.1	0.0	0.0	-1.4*	2.1*	-0.6*	1.0*	-2.2	1.2*	4.0*
Cape St Francis	-34.20	24.83	0.0	0.0	0.0	0.2*	0.2*	0.0	0.0	0.0	0.0	-0.1*	-0.3*	-1.9*	0.9*	0.0
East London	-33.03	27.83	0.0	0.0	0.0	-0.1	-0.1*	-0.0	0.0	0.0	0.5	-0.3	0.1	0.6*	-1.3*	0.2
George	-34.00	22.38	0.0	0.0	0.1	-0.2*	-0.2*	0.2*	0.0	0.0	1.9*	-1.3*	0.6*	1.1*	-1.9*	0.8*

4.2 Rainfall

Table 6 presents the decadal trend and statistical significance thereof for the rainfall indices (see Table 4) for the weather stations listed in Table 2 in alphabetical order.

Table 6. Selected WMO Climpact extreme rainfall index trends and values for the selected stations. Statistical significance at the 5% level is indicated with "*"

Station Name	Lat	Lon	cdd	cwd	r10mm	r20mm	r30mm	rx1day	rx5day	prcptot	sdii	r95p	spi12
ALBERTVALE-FRM	-32.74	26.01	0.3	0.0	0.6*	0.2*	0.0	-0.1	-0.4	7.1*	0.1*	2.3	0.10*
ALKMAAR	-25.45	30.82	-0.3*	0.0	0.0	0.0	0.0	0.2	0.3	3.5	-0.3	-1.5	0.00*
BLAAUWKOP	26.5	30.27	0.3*	0.0	0.2	0.0	0.0	-0.4	0.8	-3.6	0.2*	0.0	-0.03
BLOUBOSKUIL	-32.44	22.71	-1.7	0.0	0.4*	0.0	0.0	0.5	1.3	8.2*	0.1	0.0	0.12*
BOETSAP	-27.97	24.45	2.4	0.0	0.0	0.0	0.0	0.0	0.2	-2.9	0.2*	0.0	-0.02*
CAPE AGULHAS	-34.83	20.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.04
CARNARVON - POL	-30.97	22.13	-0.5	0.0	0.0	0.0	0.0	-0.2	0.1	-3.2	0.0	0.0	-0.03*
CEDARA	-29.54	30.27	0.0	0.0	-0.4	-0.1	0.0	-0.4	-0.9	-9.2	0.0	-4.1	-0.07*
DORDRECHT CLARKS SIDING	-31.41	27.12	-2.3*	0.1*	0.3	0.0	0.0	-0.5	0.1	9.2	-0.3*	0.3	0.05*
DWARS IN DIE WEG	-33.07	20.62	-0.3	0.0	0.0	0.0	0.0	-0.1	0.6	0.1	0.0	0.0	0.01
EUREKA	-29.08	24.48	1.2	0.0	0.4*	0.0	0.0	0.8	1.3	6.8	0.1	0.3	0.06*
EXWELL PARK	-32.21	27.1	-1.0	0.0	0.0	0.0	0.0	0.2	0.3	0.7	0.0	0.6	-0.00
FUNNYSTONE	-30.7	27.82	0.0	0.0	0.4	0.3	0.0	0.6	0.8	11.2	0.1	1.3	0.06*
GINGINDHLOVU	-29.03	31.57	0.0	0.0	0.3	0.1	0.0	1.8	3.9	5.8	0.2*	7.1	0.02
GRAHAMSTOWN - TNK	-33.32	26.49	1.3	0.0	0.0	0.0	0.0	-0.8	-2.7	-8.7	0.1	-1.3	-0.05*
GRAPEVALE	-31.15	25.23	-1.2	0.0	0.7*	0.2*	0.0	0.8	1.3	12.4*	0.2*	2.3	0.11*
HANGLIP	-23.02	29.92	1.5	-0.2*	-0.4	0.0	0.0	0.0	-0.4	-13.3	0.1	0.0	-0.05*
HLOBANE	-27.7	30.98	-0.3	0.0	0.6*	0.7*	0.6*	4.8*	6.0*	24.7*	0.7*	20.2*	0.15*
HOFMEYR - MUN	-31.65	25.8	2.1	0.0	0.6*	0.2*	0.0	1.0	2.1*	12.5*	0.1	1.3	0.13*
HOPETOWN	-29.62	24.08	-0.2	0.0	0.2	0.0	0.0	0.5	1.5	3.5	0.2*	0.0	0.05*
HOPKINS	-27.71	22.7	3.7	0.0	0.0	0.0	0.0	0.7	0.1	0.4	0.4*	0.0	-0.00
HUGHENDEN	-30.69	26.19	1.8	0.0	0.4*	0.3*	0.1*	1.2*	2.5*	12.9*	0.2*	6.6*	0.10*
IRENE	-25.87	28.22	0.0	0.0	0.3	0.1	0.0	0.7	2.4*	8.6	0.2*	3.5	0.05*
KALKFONTEIN	-23.9	29.58	5.0*	0.0	0.0	0.2	0.0	0.0	1.0	-1.2	0.2	0.0	-0.01
KAREEDOUW - POL	-33.95	24.29	0.4	0.0	-0.4	-0.5*	-0.1	0.5	-1.5	-20.2*	0.1	-0.6	-0.10*
KENDREW ESTATES	-32.52	24.48	0.7	0.0	0.2	0.1*	0.0	0.0	0.0	4.8	0.1	0.6	0.05*
LEKKERVLEI	-31.05	23.6	-2.3	0.0	0.2	0.0	0.0	0.8*	1.2	6.1	0.0	0.0	0.07*
LETABA DISTRICT	-23.73	30.1	-1.7*	-0.4*	-1.0*	-0.5*	-0.3	0.5	-3.7	-31.7*	-0.1	-3.4	-0.07*
MACHADODORP	-25.67	30.25	1.3	-0.3*	0.2	0.2	0.0	0.2	0.2	-3.9	0.5*	2.9	-0.06*
MARYDALE - POL	-29.41	22.11	-1.5	0.0	0.2	0.0	0.0	0.3	0.9	3.3	0.1	0.0	0.02*
MASELSPOORT DAM	-29.03	26.41	1.5	0.0	0.4	0.4*	0.2*	0.8	0.8	7.8	0.3*	5.0*	0.03*
MERWEVILLE - POL	-32.66	21.52	-4.2*	0.0	0	0.0	0.0	0.7	1.0	1.1	0.1	0.0	0.02
MOORSIDE	-28.4	29.61	-1.1	0.0	-0.4*	0.0	0.0	0.4	0.4	-4.2	-0.1	1.8	-0.03*
MOUNT EDGECOMBE	-29.71	31.05	1.0*	0.0	-0.1	0.0	0.0	0.6	-0.2	1.7	0.1	2.5	0.01
NIEKERKSHOOP - POL	-29.33	22.84	-0.8	0.0	0.2	0.0	0.0	0.5	1.1	3.8	0.2	0.0	0.04*
NIEUWOUDTVILLE SAPD	-31.37	19.12	-3.1*	0.0	0.0	0.0	0.0	0.2	0.5	1.1	-0.2*	0.0	0.01

NYLSVLEY	-24.65	28.67	3.5*	-0.1*	0.0	0.0	0.0	0.9	1.3	0.0	0.3*	5.1	-0.00
OTTOSDAL - POL	-26.81	26	0.7	0.0	0.0	0.3*	0.2*	1.4	1.8	5.7	0.2	6.2	0.02
PIKETBERG-SAPD	-32.91	18.75	-0.3	0.0	0.2	0.0	0.0	-0.2	0.6	0.7	0.1	-0.6	-0.03*
PRINCE ALBERT - TNK	-33.22	22.03	0.0	0.0	0.3*	0.2*	0.0	0.9*	1.4*	4.1	0.4*	0.0	0.04*
RANKINS PASS-POL	-24.53	27.91	4.8*	-0.2*	-0.4*	0.0	0.0	1.0	1.2	-13.6*	0.5*	0.0	-0.07*
REENEN	-32.11	19.51	-5.2*	0.0	0.0	0.0	0.0	0.7*	0.8	2.9	-0.1	0.0	0.05*
RICHMOND C/K - TNK	-31.42	23.94	0.0	0.0	0.0	0.0	0.0	0.3	0.1	1.4	0.1	0.2	0.01*
RIETFONTEIN SAPS	-26.74	20.03	0.5	0.0	0.4*	0.0	0.0	0.2	1.5	4.1	0.4*	0.0	0.06*
RONDAWEL	-33.2	22.66	-5.7*	0.0	0.4*	0.0	0.0	0.5	0.6	9.1*	0.0	0.0	0.17*
ROODEBLOEM	-32.18	24.57	-0.9	0.0	0.4*	0.2*	0.0	0.9*	1.4*	13.2*	0.1	1.8	0.17*
ROOIRIVIER	-33.55	22.82	-0.7	0.0	0.3*	0.0	0.0	-0.4	0.2	4.3	0.1	0.0	0.04*
SAAIFONTEIN	-31.72	21.88	-4.8*	0.0	0.4*	0.0	0.0	0.5	0.5	11.3*	-0.1	0.0	0.15*
SKUKUZA	-24.99	31.59	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-0.00
SLANGFONTEIN	-29.72	25.55	-1.6	0.0	0.3	0.2*	0.0	-0.2	1.2	11.0*	-0.3*	0.8	0.07*
SLURRY	-25.81	25.85	2.8	0.0	0.0	0.0	0.0	0.2	1.2	1.1	0.3*	3.6	-0.09*
STEINKOPF	-29.27	17.74	-1.4	0.0	0.0	0.0	0.0	-0.2	-0.4	-0.8	-0.1	0.0	-0.01
STEYTLERVILLE - MAG	-33.33	24.34	0.0	0.0	0.2	0.0	0.0	0.5	0.3	4.9	0.0	0.7	0.06*
SURPRISE STORE	-28.18	31.25	-0.4	0.0	-0.8*	-0.6*	-0.1	-0.2	0.8	-19.4*	-0.4*	-4.0	-0.07*
SWARTRUGGENS - POL	-25.65	26.69	3.1	-0.1*	0.0	0.3*	0.1	2.3*	2.1	2.3	0.5*	1.8	-0.03*
TAFELKOPPIES	-26.88	30.62	-2.0*	0.0	0.0	0.0	0.0	1.2	2.6*	11.9	-0.2*	10.0*	0.06*
THE CLIFF	-29.49	26.76	3.1*	0.0	0.3	0.3*	0.2*	0.8	0.2	2.7	0.5*	1.3	0.03*
THORNLEA	-28.63	21.52	1.6	0.0	0.0	0.0	0.0	0.5	0.6	-0.5	0.4*	0.0	-0.00
TUSCANY	-25.24	26.18	0.2	0.0	0.0	0.0	0.0	0.0	1.2	1.2	-0.2	0.0	0.01
VENTERSBURG - MAG	-28.09	27.14	2.2	0.0	-0.2	0.0	0.0	0.4	0.5	-7.1	0.2	.0.0	-0.05*
VERKYKERSKOP	-27.91	29.27	-0.6	0.0	-0.7*	-0.3*	-0.2*	-1.2*	-1.7	-27.7*	-0.1	-9.4*	-0.20*
VILLA NORA-POL	-23.53	28.13	1.1	0.0	-0.2	0.0	-0.3*	-1.5	-2.0	-10.7*	-0.3	-5.7	-0.11*
VREDEFORT	-27.01	27.36	0.5	0.0	-0.2	-0.2	0.0	-0.5	-1.8	-9.2	-0.1	0.0	-0.04*
VRUGBAAR	-33.63	19.04	0.6	0.0	0.0	0.3*	0.0	0.4	0.4	3.3	0.1*	1.9	0.01
VRYBURG PALMYRA	-26.27	24.18	1.6	0.0	0.6*	0.3*	0.2*	1.6*	2.6*	9.0	0.6*	1.9	0.05*
VRYBURG WELGELEVEN	-26.76	24.58	1.9	0.0	0.0	0.0	0.0	0.1	0.9	-0.1	-0.1	0.0	-0.01*
WARDEN SKOOLSTRAAT	-27.85	28.96	2.1	0.0	0.2	0.2	0.3*	1.3	1.3	6.0	0.6*	5.8*	-0.01*
WATERLAND	-29.22	27.22	1.7	0.0	0.3	0.3*	0.2*	0.3	0.4	5.1	0.3*	4.4	0.03*
WITBANK STREHLA	-26.21	28.91	2.8*	0.0	0.5*	0.3	0.1	0.3	1.8	8.6	0.3*	2.6	0.04*

5. Maps of Extreme Index Trends

5.1 Temperature

Figures 3 to 11 present the surface temperature extreme index trends for the stations of which the trend details are provided in Tables 4. *Note that due to the stricter requirements for trend estimation in Climpact, the trend maps for CSDI and WSDI are for the previous calculation with RClimDex up to 2022.*

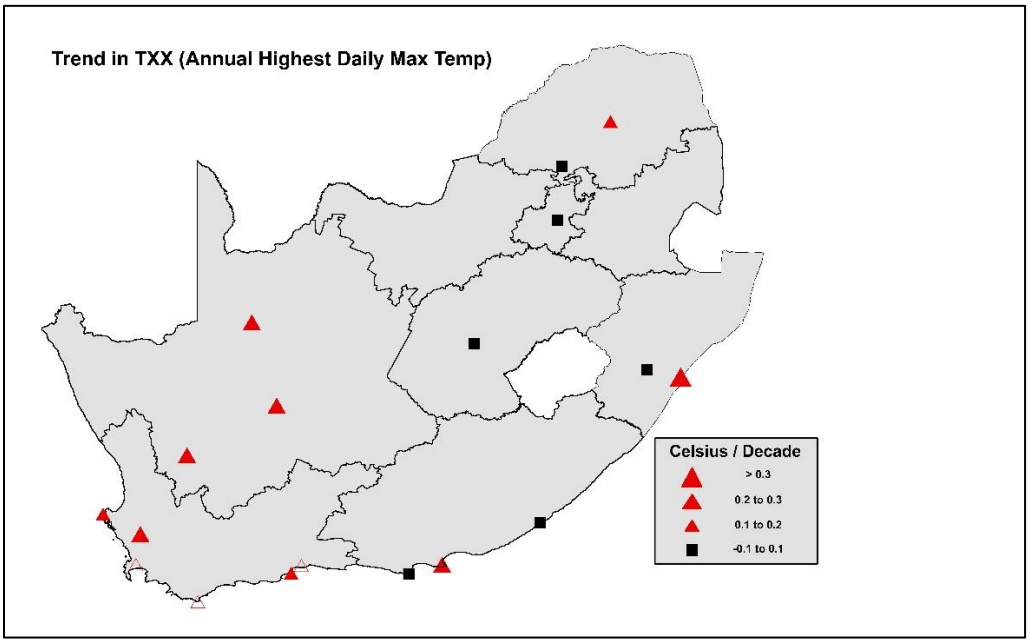

Figure 3. Trends in annual extreme temperatures: TXX in ◦C per decade – 1931-2023 (red triangles denote significant trends at the 5% level).

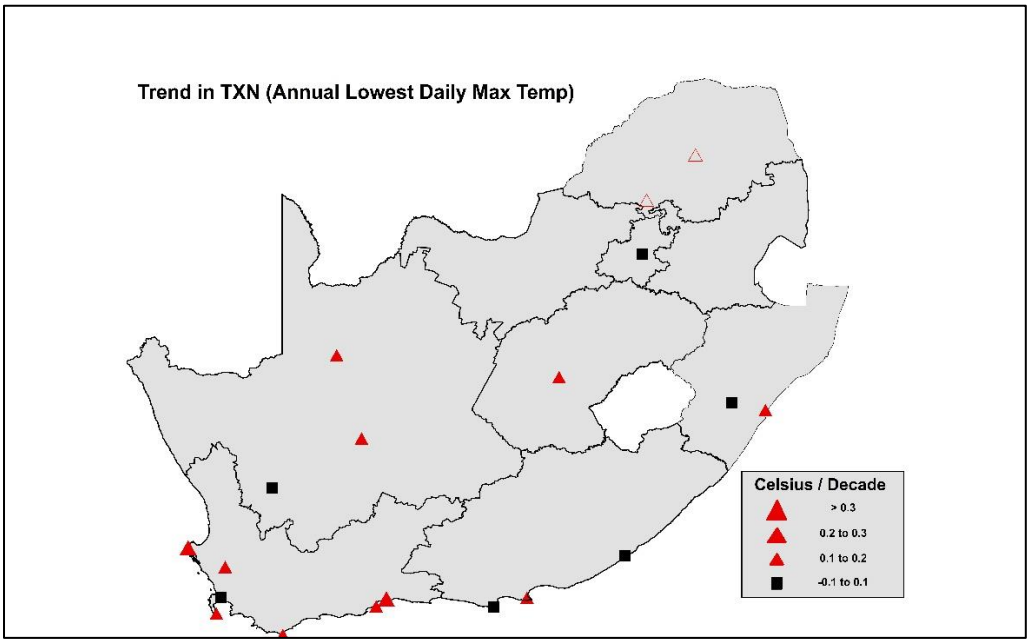

Figure 4. Trends in annual extreme temperatures: TXn in ◦C per decade – 1931-2023 (red triangles denote significant trends at the 5% level).

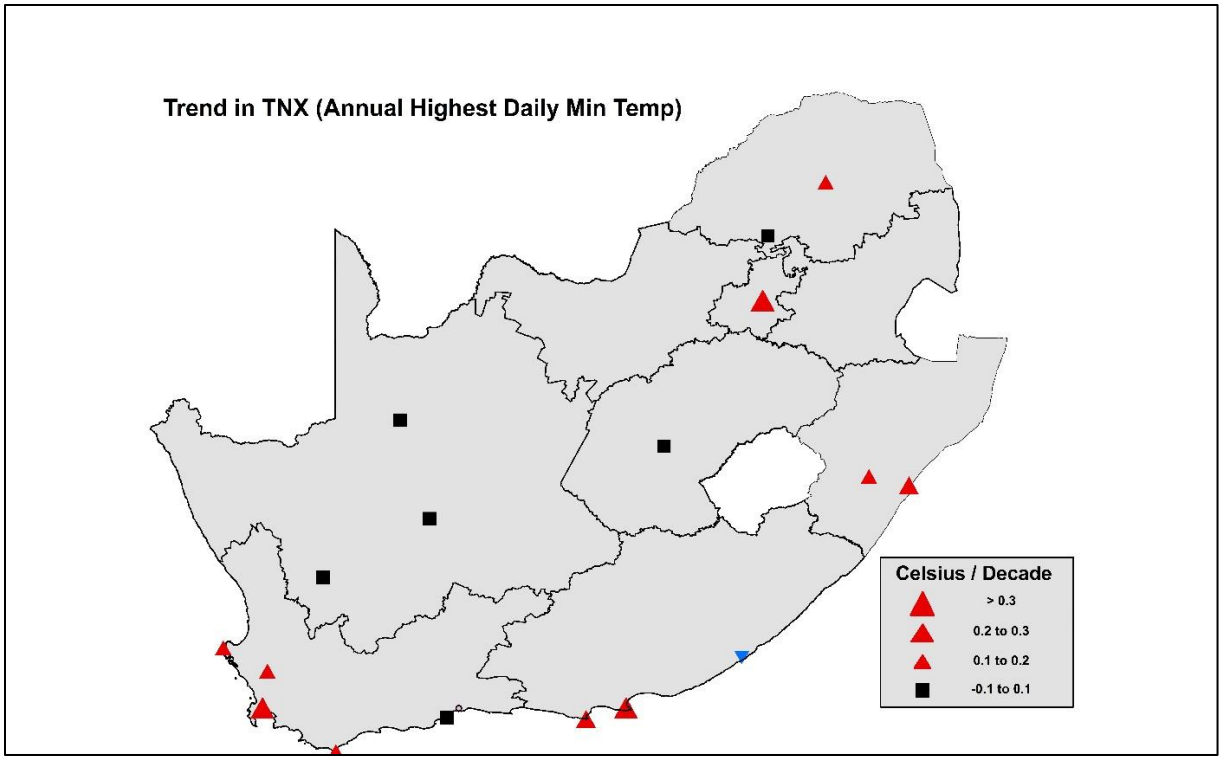

Figure 5. Trends in annual extreme temperatures: TNX in ◦C per decade – 1931-2023 (red/blue triangles denote significant trends at the 5% level).

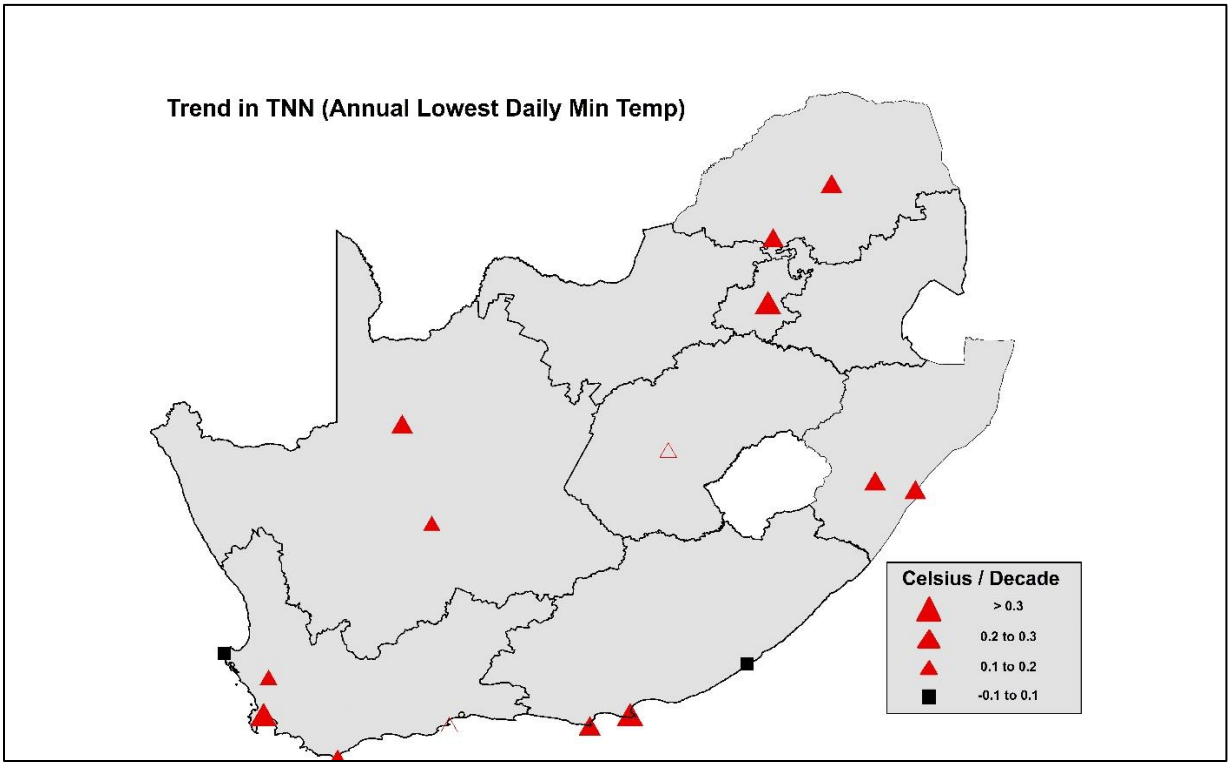

Figure 6. Trends in annual extreme temperatures: TNn in ◦C per decade – 1931-2023 (red/blue triangles denote significant trends at the 5% level).

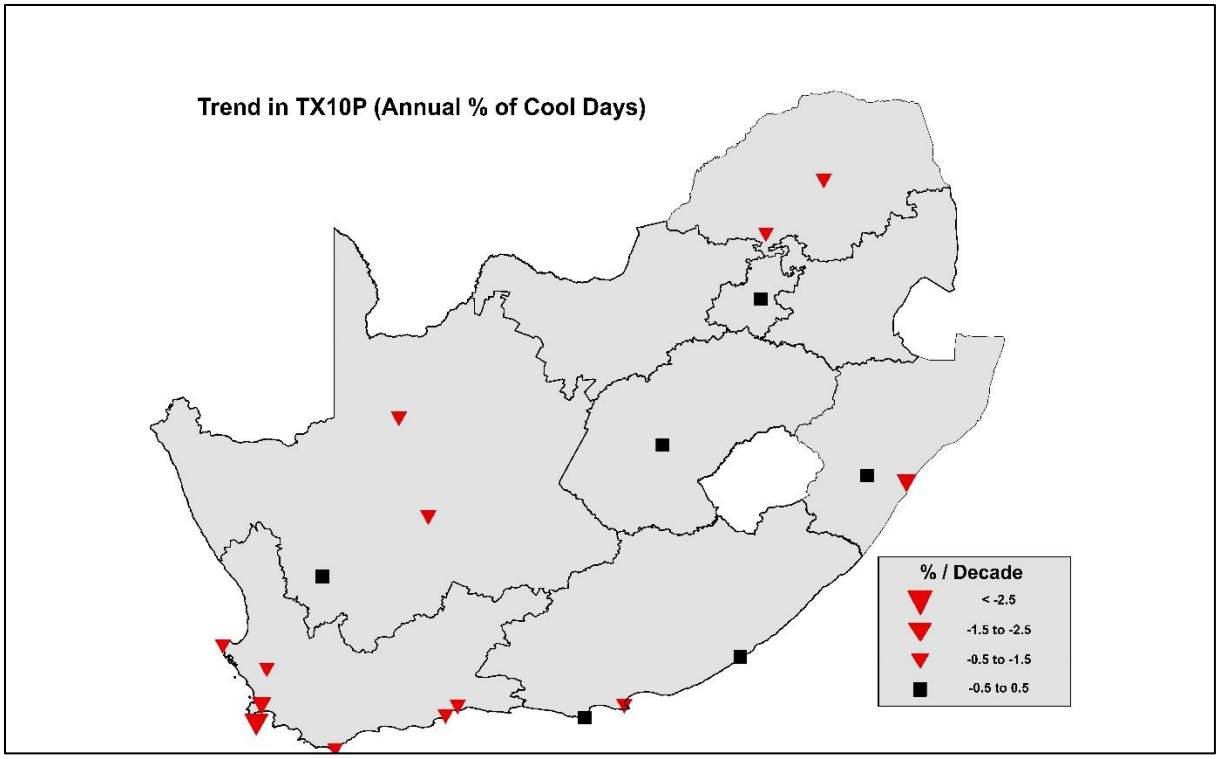

Figure 7. Trends in cool days: TX10P for the period 1931–2023 in % days per decade (red triangles denote significant trends at the 5%level).

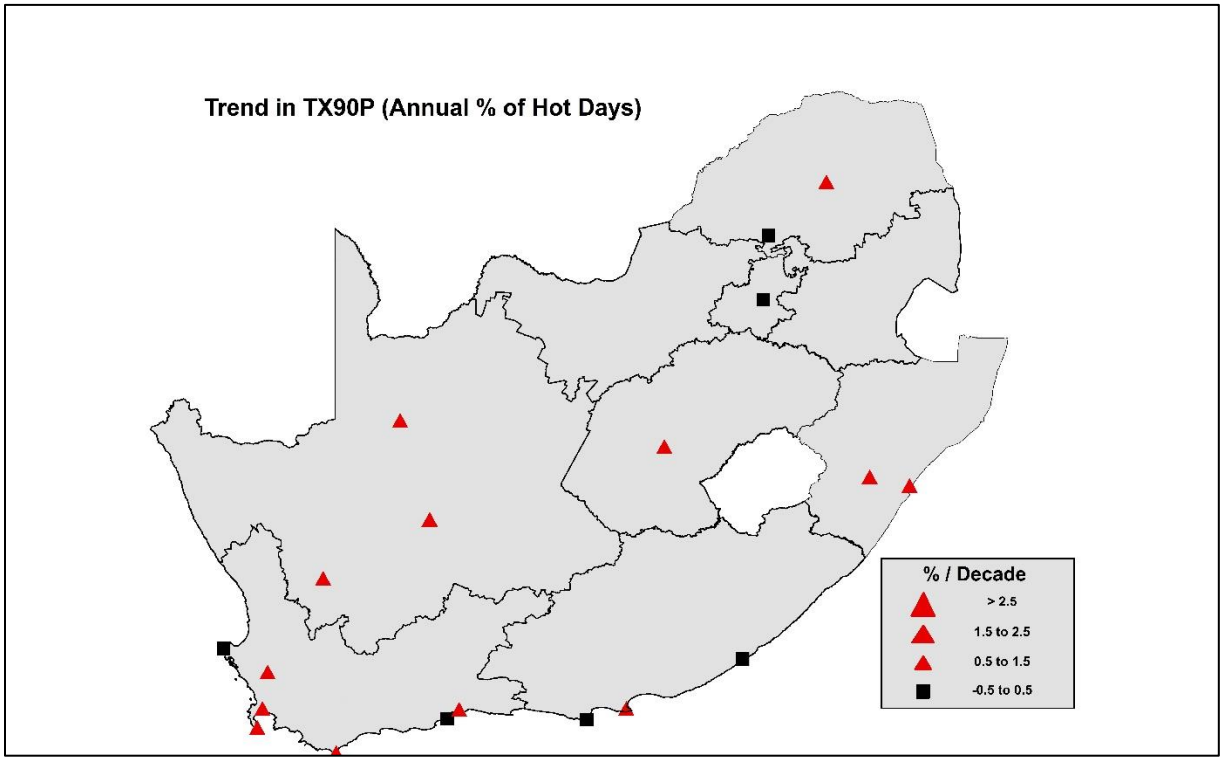

Figure 8. Trends in hot days: TX90P for the period 1931–2023 in % days per decade (red triangles denote significant trends at the 5%level).

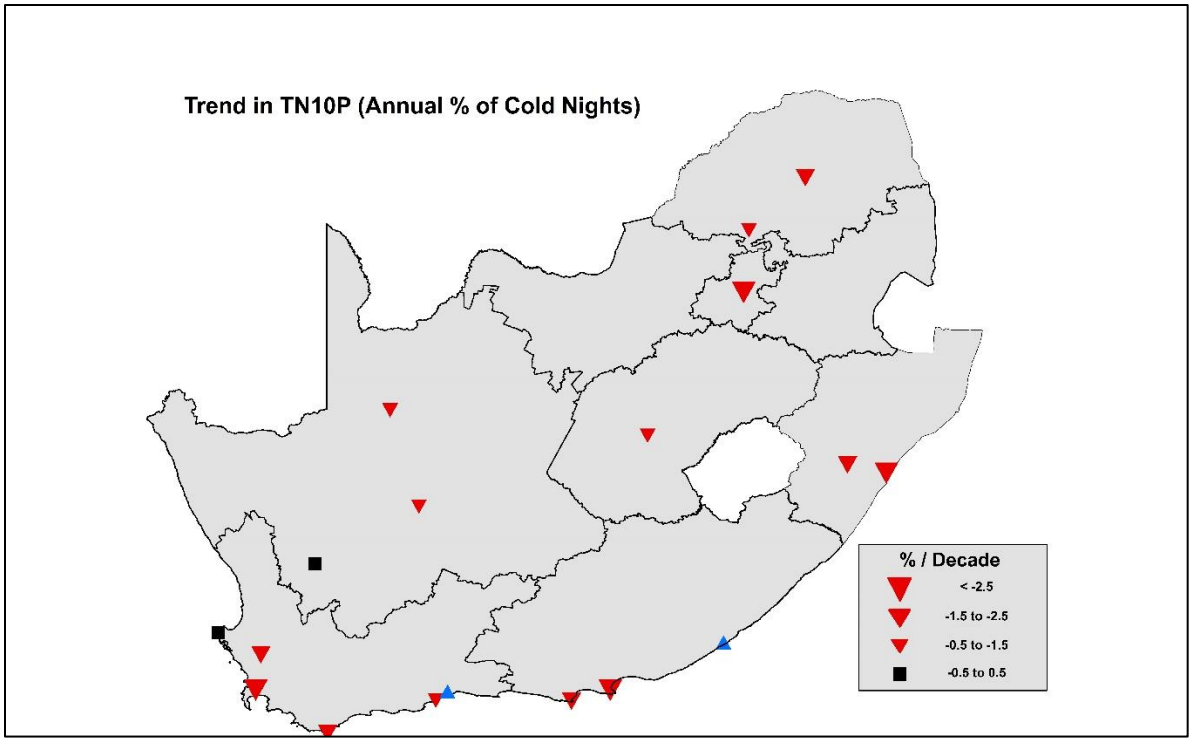

Figure 9. Trends in cold nights: TN10P for the period 1931–2023 in % days per decade (filled triangles denote significant trends at the 5% level).

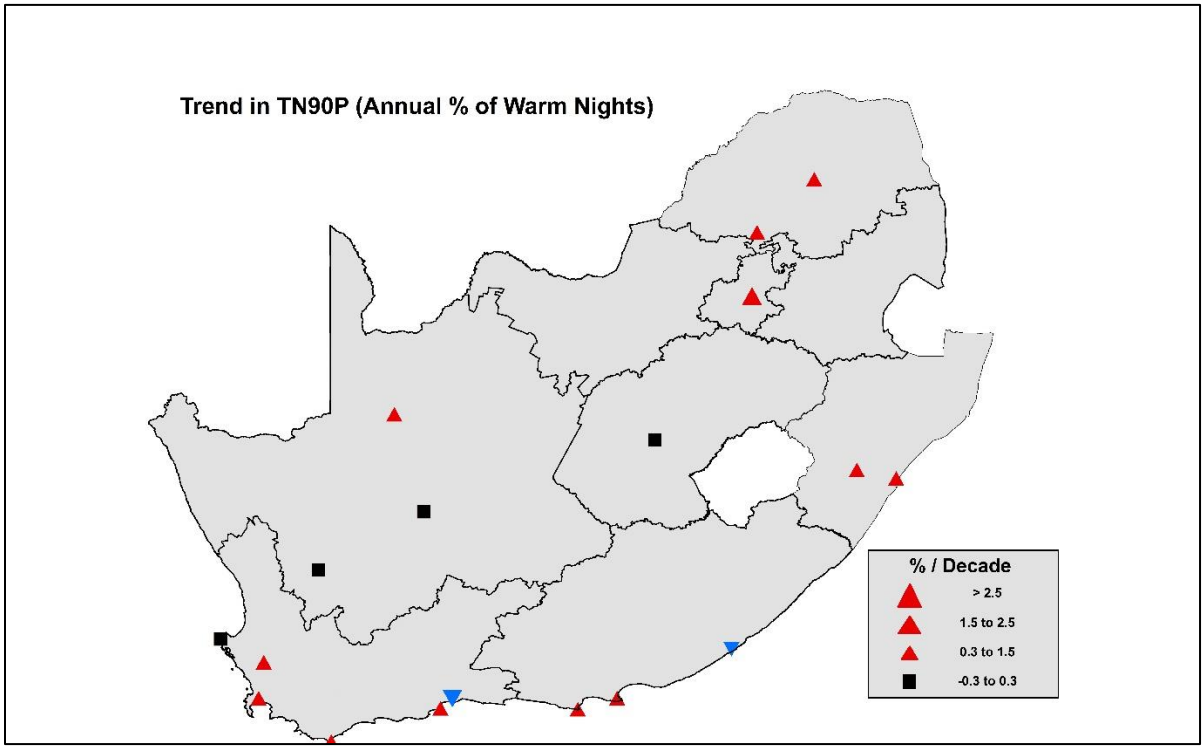

Figure 10. Trends in warm nights: TN90P for the period 1931–2023 in % days per decade (filled triangles denote significant trends at the 5% level).

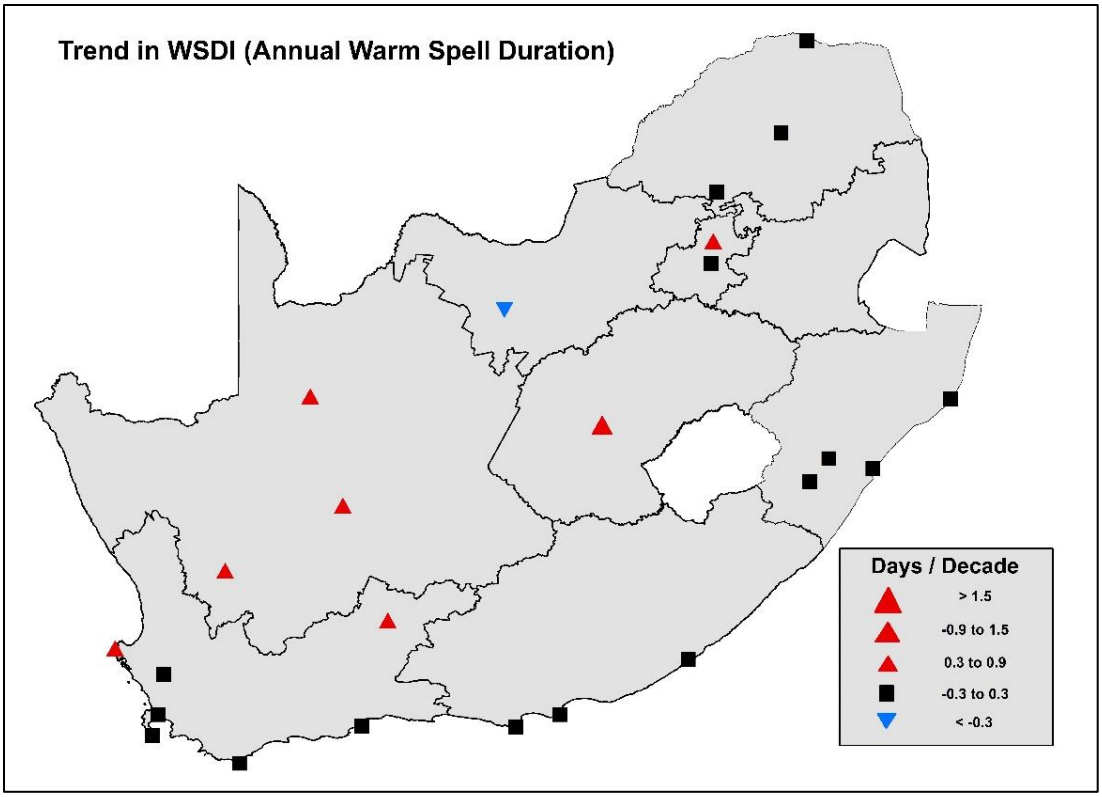

Figure 11. Trends in warm spells durations in days per decade: WSDI over the period 1931 – 2022 (filled triangles denote significant trends at the 5% level).

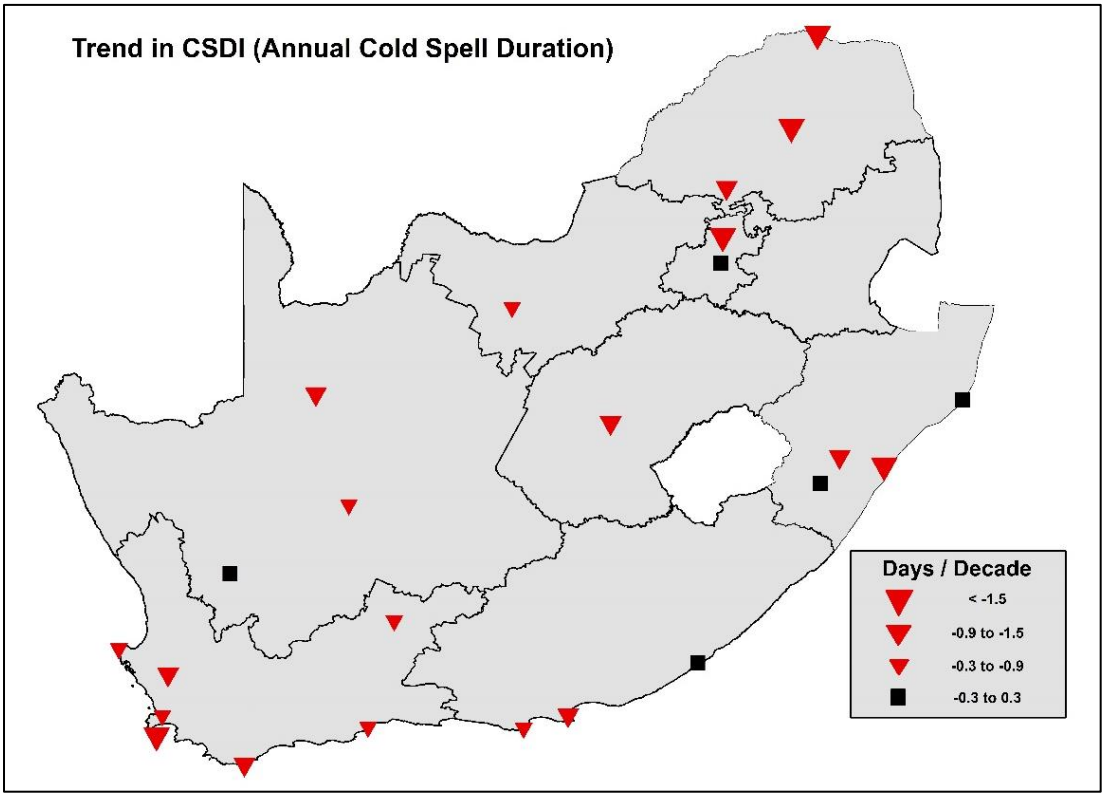

Figure 12. Trends in cold spells durations in days per decade: CSDI over the period 1931 – 2022 (filled triangles denote significant trends at the 5% level).

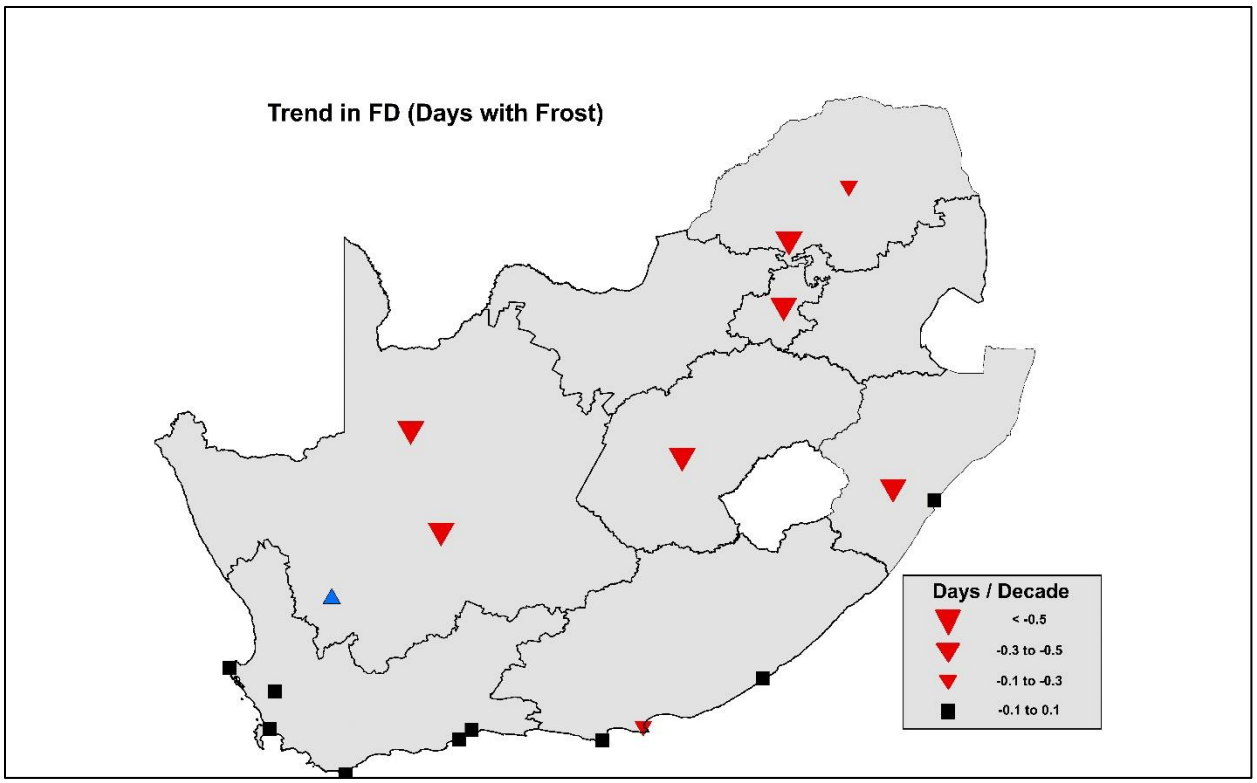

Figure 13. Trends in frost days in days per decade: FD over the period 1931 – 2023 (filled triangles denote significant trends at the 5% level).

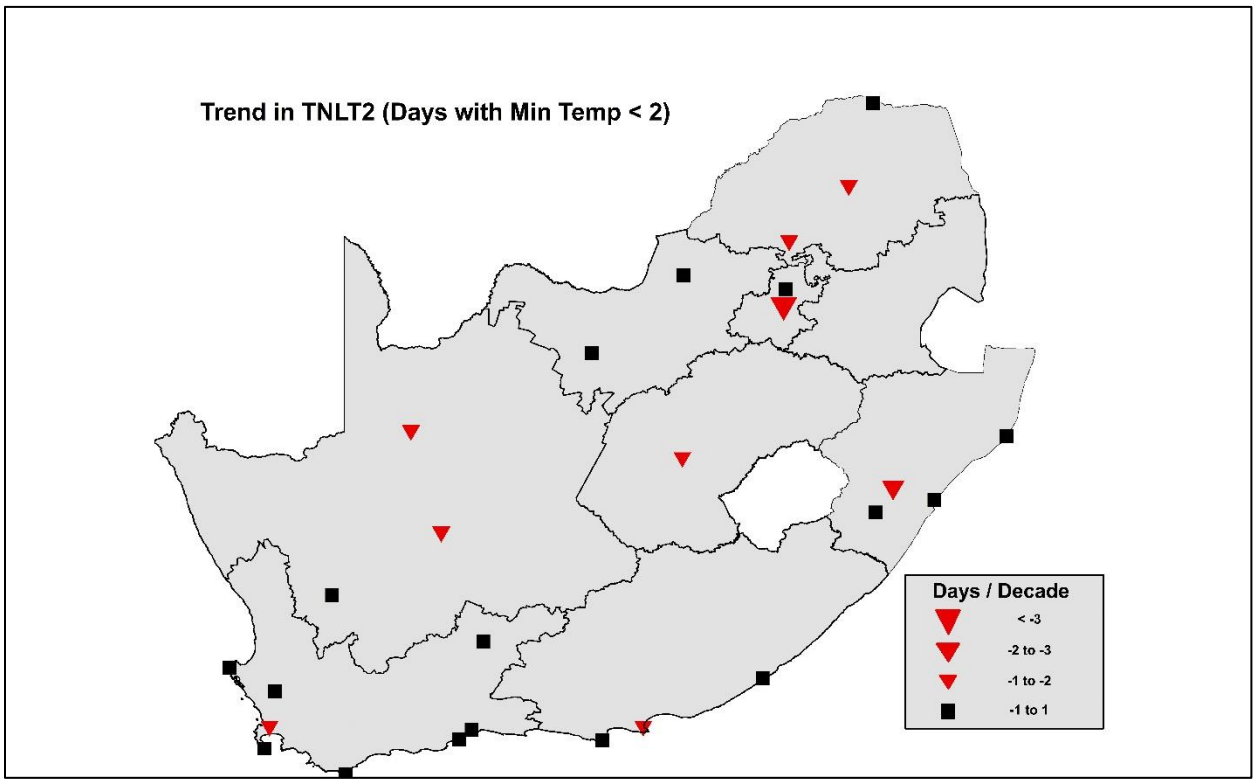

Figure 14. Trends in likely frost days (TN < 2) in days per decade: TNLT2 over the period 1931 – 2023 (filled triangles denote significant trends at the 5% level).

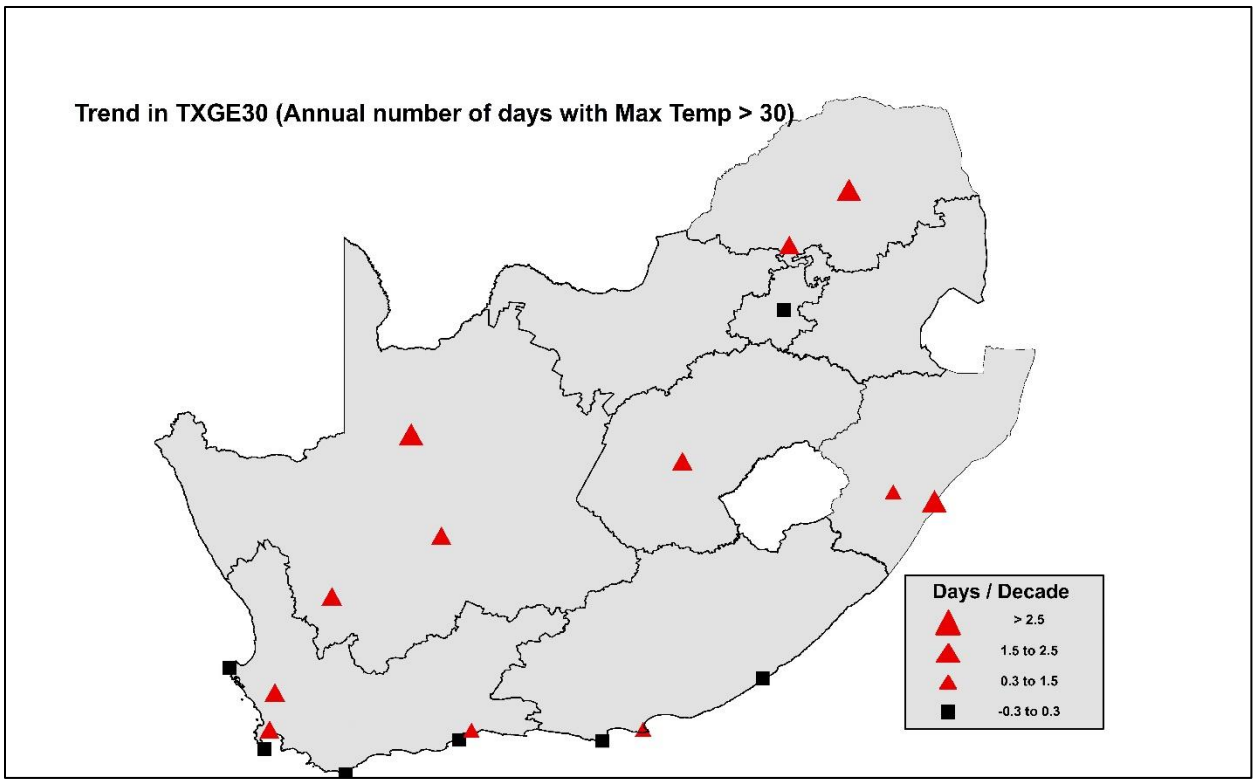

Figure 15. Trends in days with TX > 30 in days per decade: TXGE30 over the period 1931 – 2023 (filled triangles denote significant trends at the 5% level).

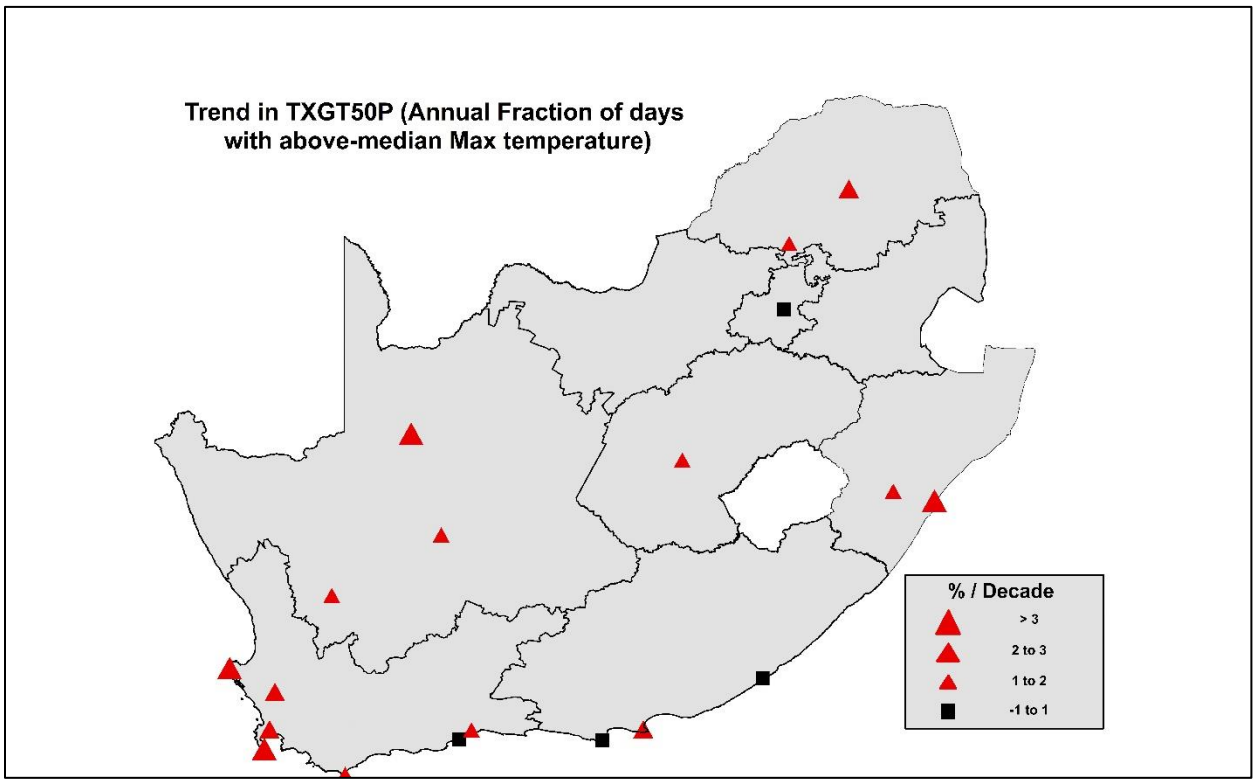

Figure 16. Trends in annual fraction of days with above median TX per decade: TXGT50P over the period 1931 – 2023 (filled triangles denote significant trends at the 5% level).

5.2 Rainfall

Figures 17 to 28 present the rainfall extreme index trends for the stations of which the trend details are provided in Table 6.

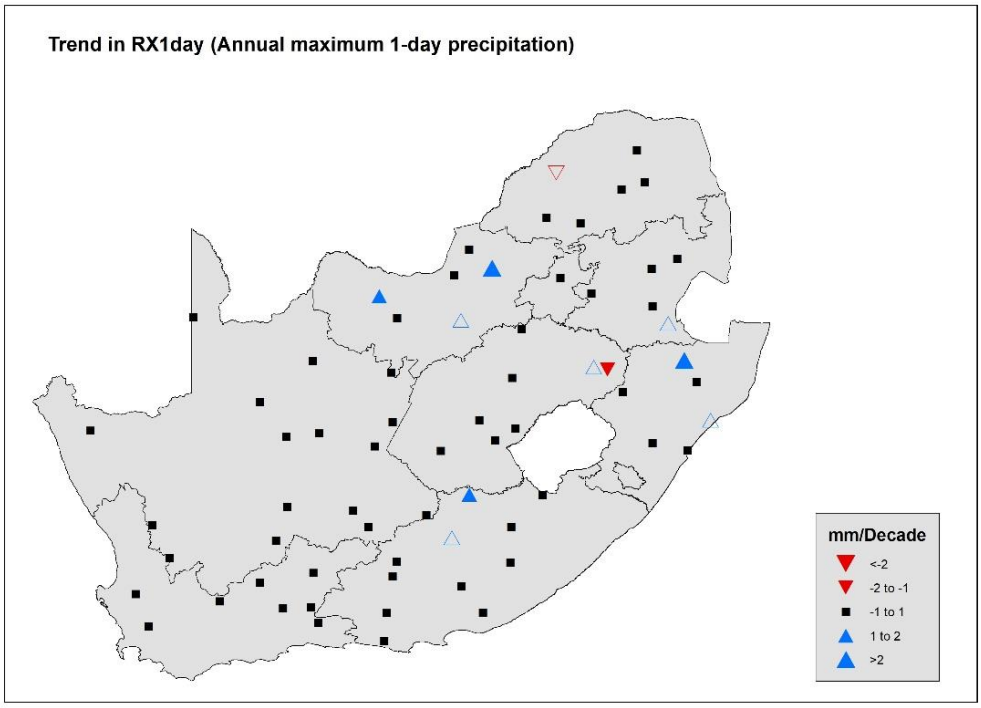

Figure 17. Trends in rx1day, the annual maximum 1-day precipitation, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

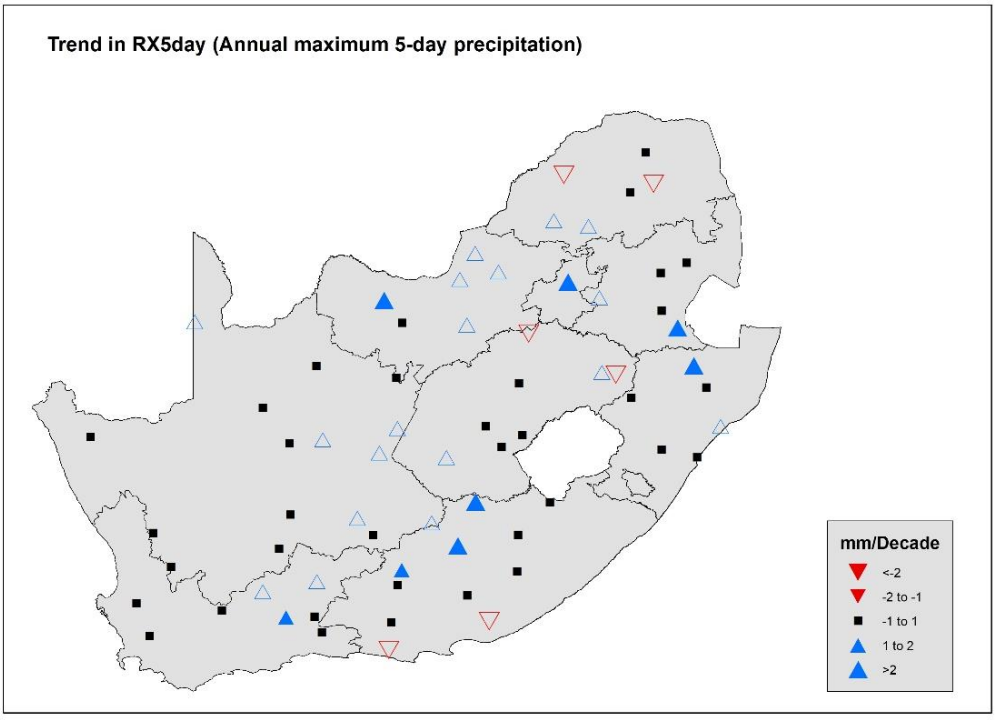

Figure 18. Trends in rx5day, the annual maximum 5-day precipitation, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

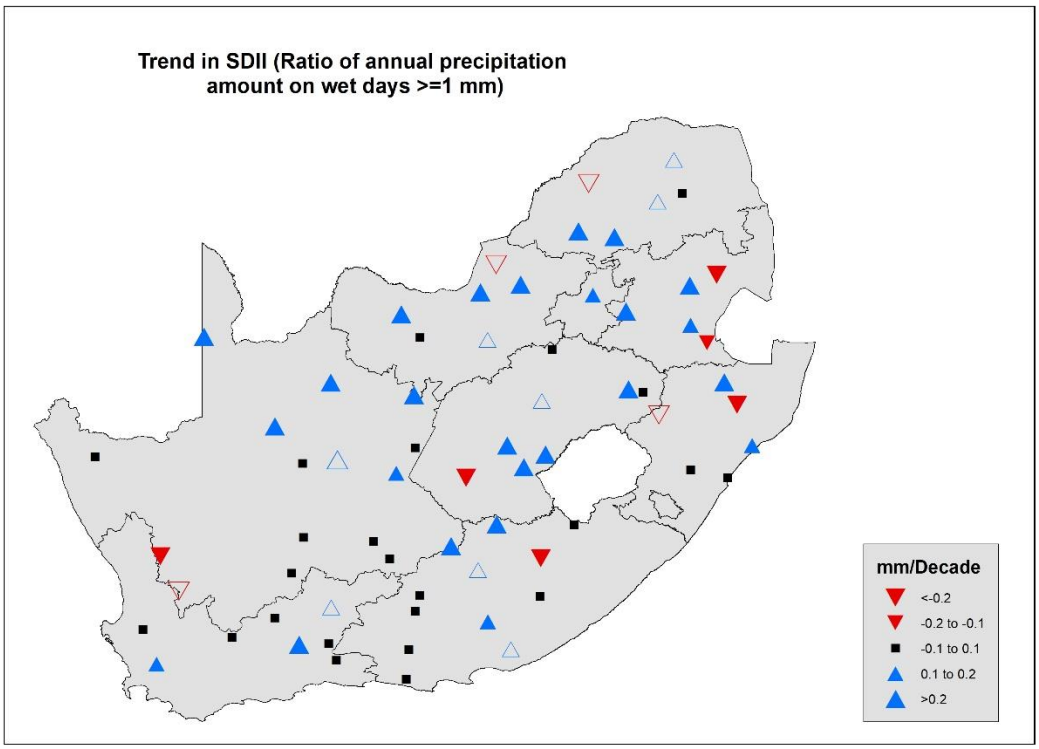

Figure 19. Trends in SDII, the simple daily intensity index, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

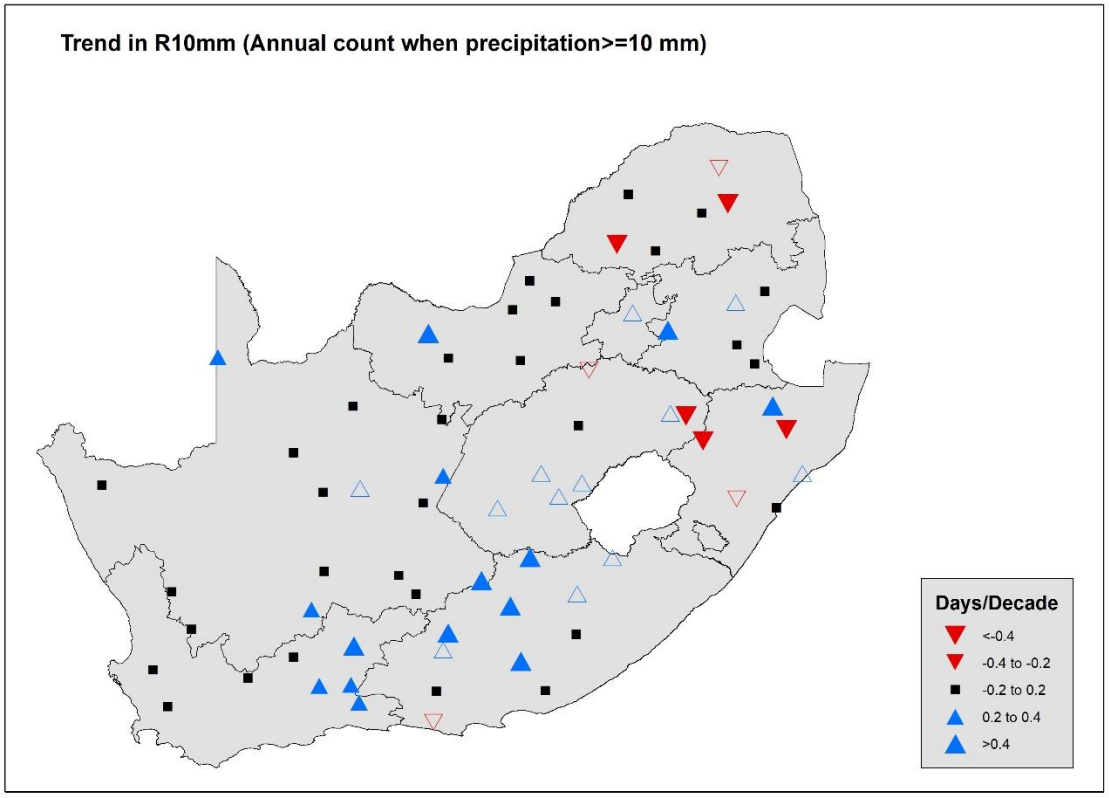

Figure 20. Trends in r10mm, the annual number of days with precipitation > 10mm, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

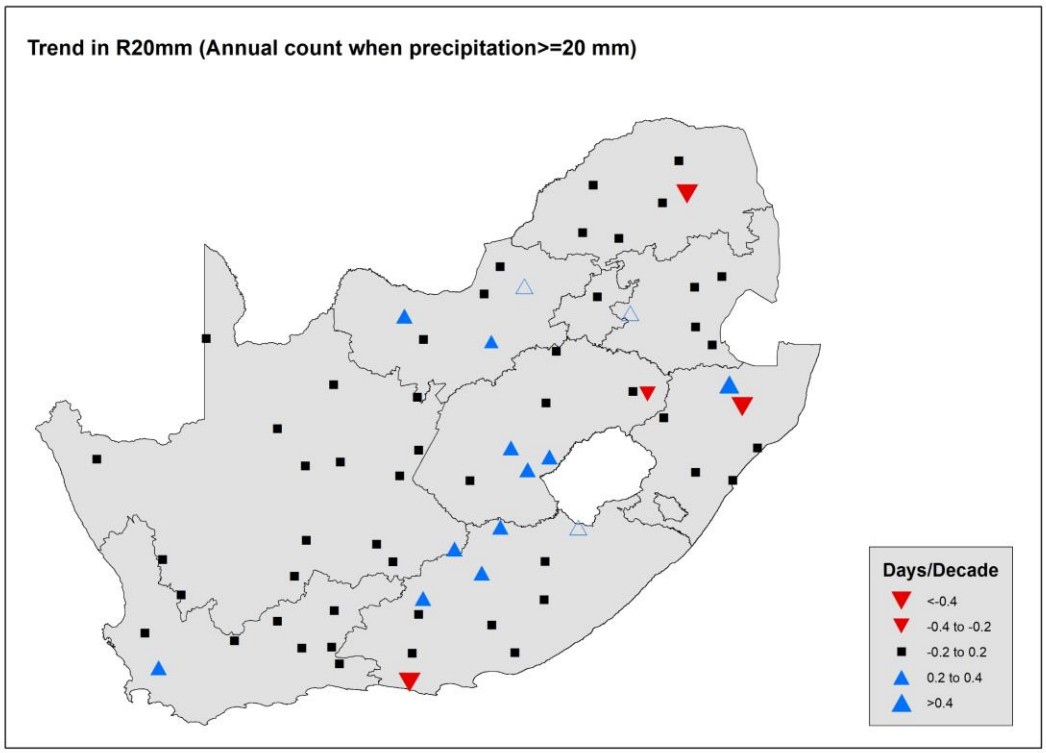

Figure 21. Trends in r20mm, the annual number of days with precipitation > 20mm, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

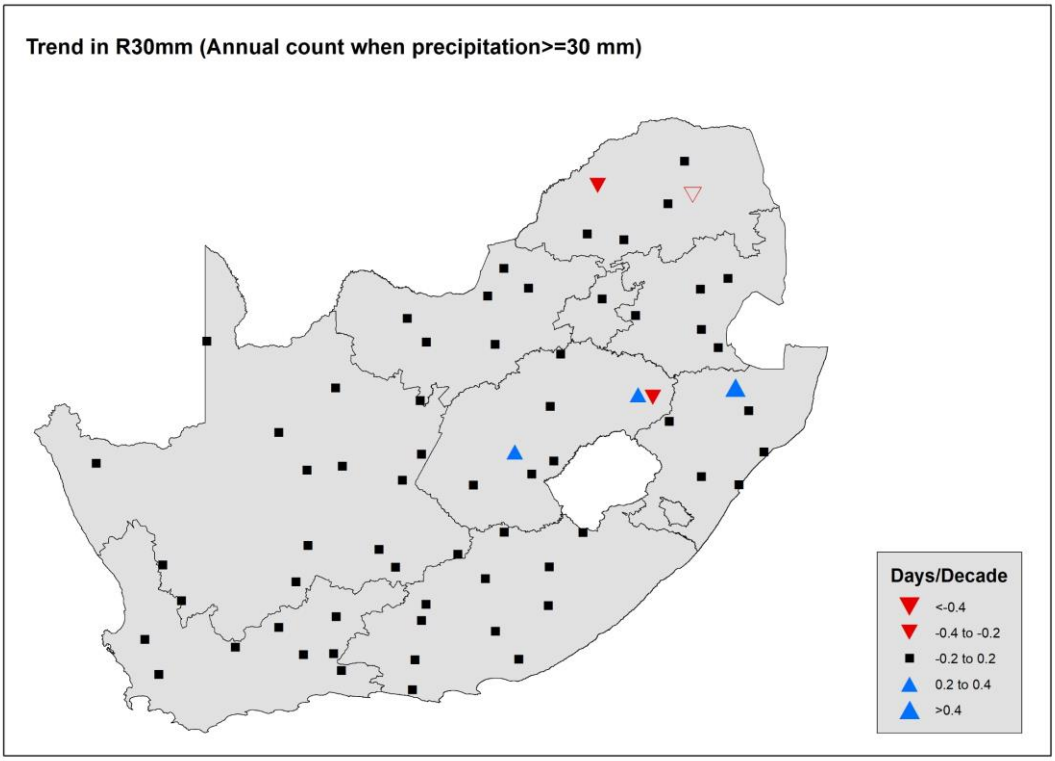

Figure 22. Trends in r30mm, the annual number of days with precipitation > 25mm, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

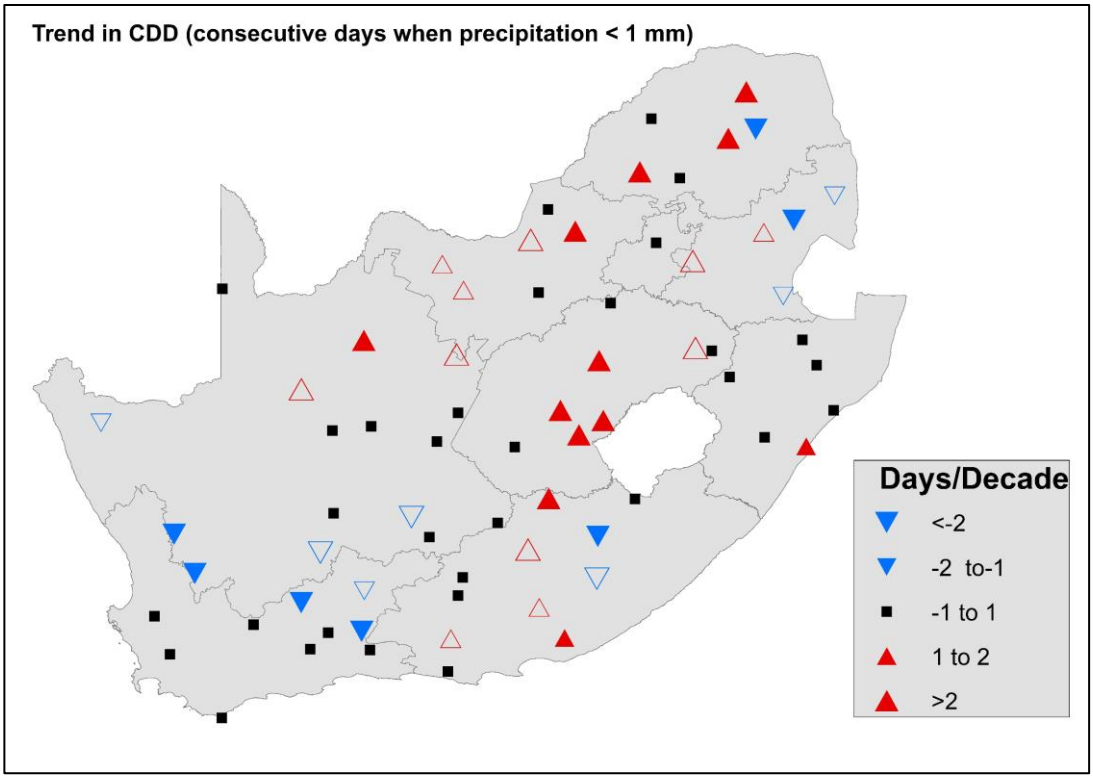

Figure 23. Trends in CDD, the annual maximum number of consecutive dry days, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

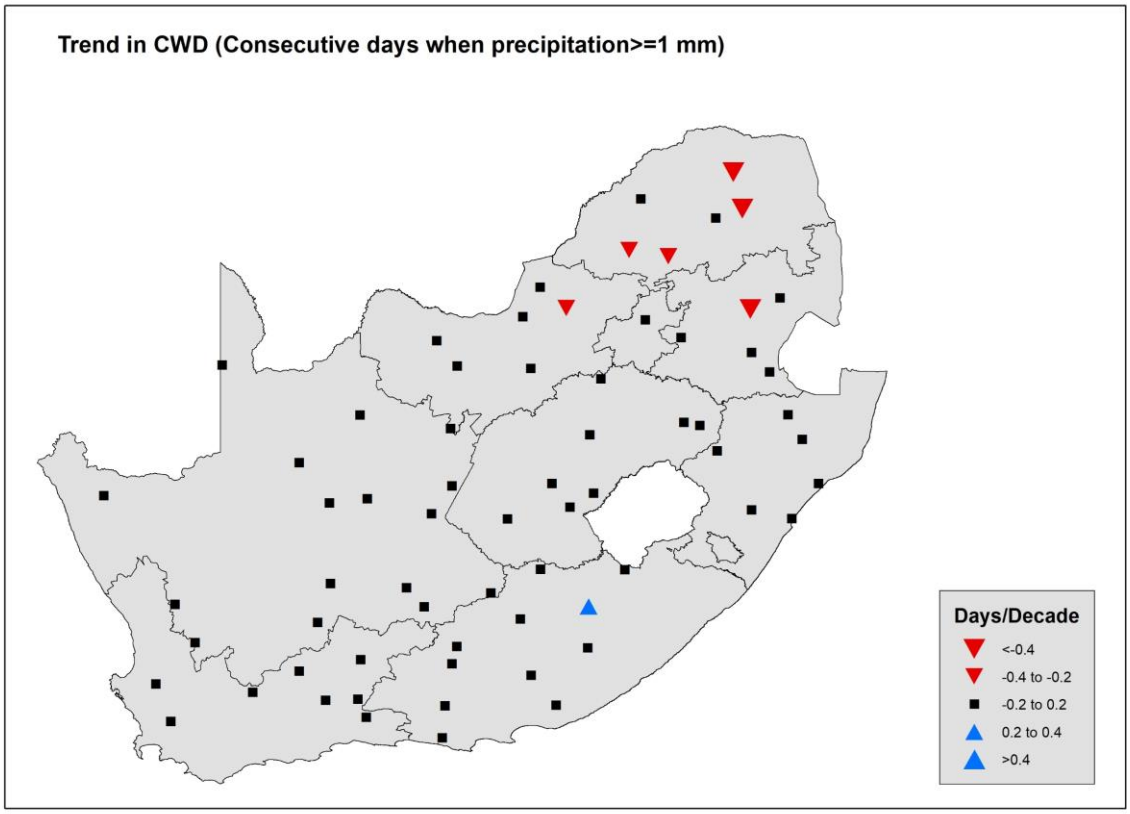

Figure 24. Trends in CWD, the annual maximum number of consecutive wet days, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

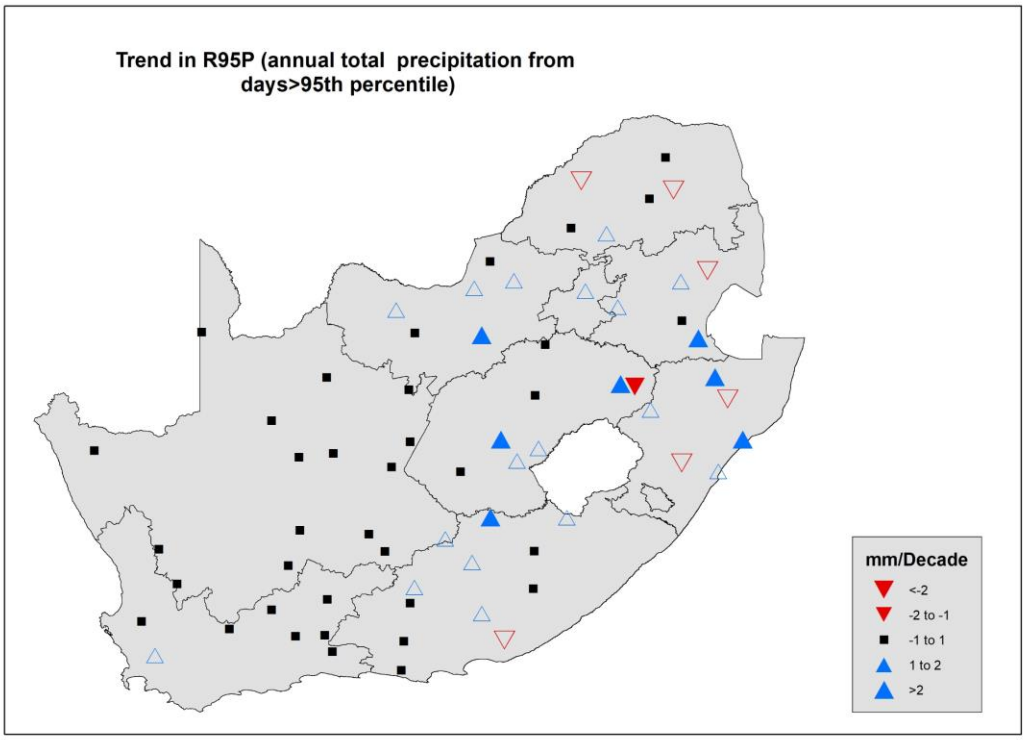

Figure 25. Trends in r95p, the annual precipitation from daily precipitation > 95th percentile (base period: 1991 – 2020), for the period 1921–2022. Shaded symbols indicate statistical significance at the 5% level.

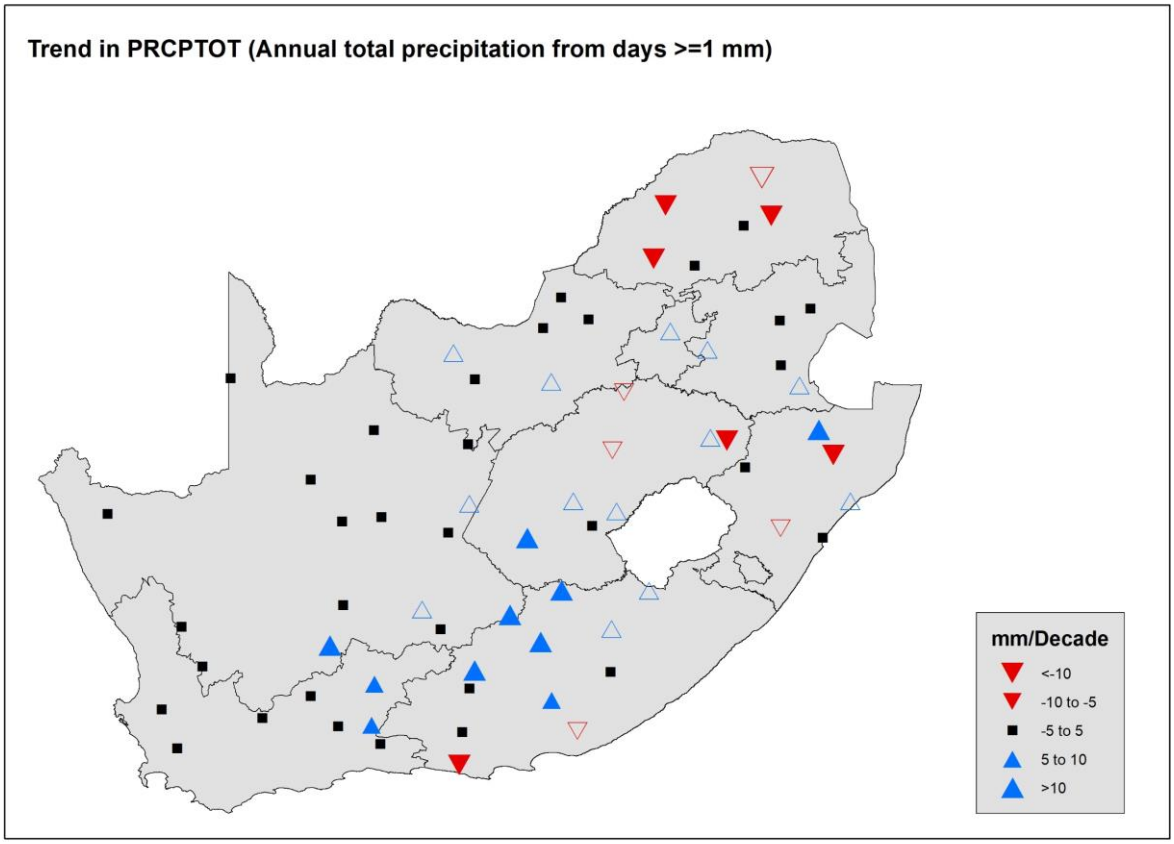

Figure 26. Trends in prcptot, the annual precipitation from daily precipitation >= 1mm, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

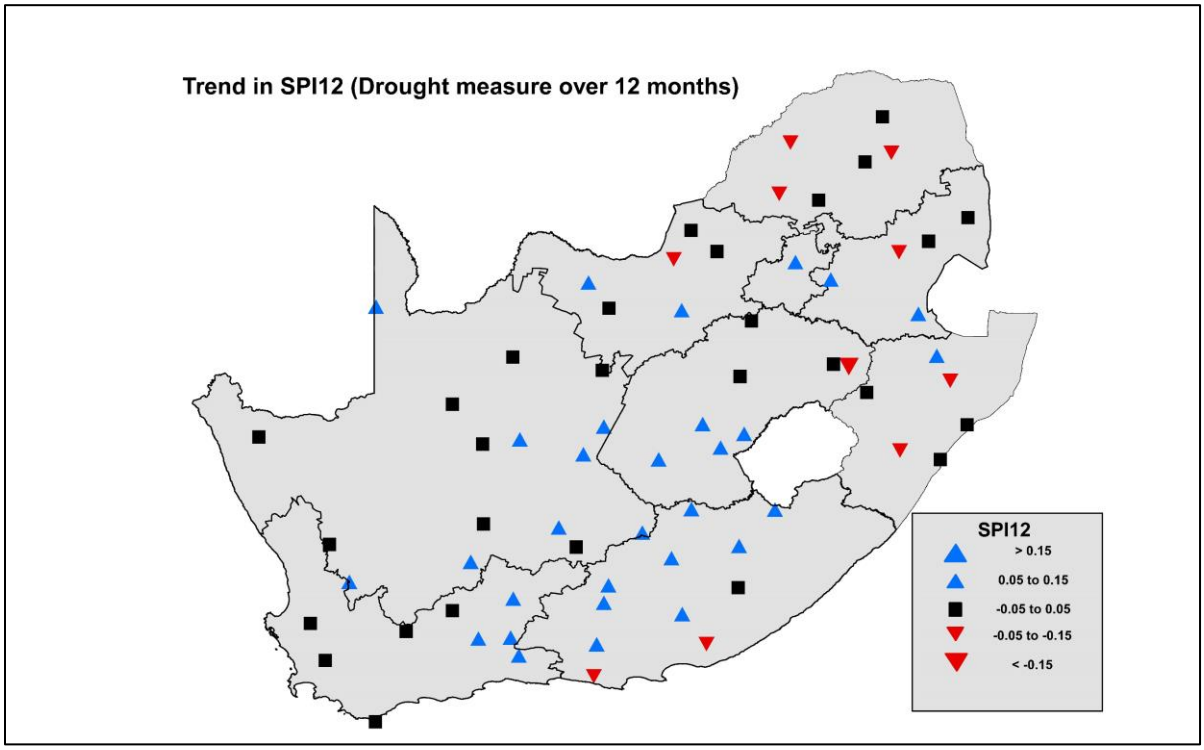

Figure 27. Trends in SPI12, the Standardised Precipitation Index over 12 months, for the period 1921–2023. Shaded symbols indicate statistical significance at the 5% level.

Notes on the precipitation trends: Due to the long observational period of more than a century, the trends shown in the analysis do not necessarily reflect the most recent trends observed over the last number of decades. One example is the long term trends in prcptot and SPI12. It has been shown in recent studies that there is evidence of negative rainfall trends in the western and especially south-western parts of South Africa. These recent trends are not reflected in Figures 26 and 27.

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