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About surface temperature and their shifts in the Free State Province, South Africa (1960–2013)

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ABSTRACT

The study analysed the temperature variability in the Free State Province, South Africa between 1960 and 2013. The three parameters considered were minimum temperature (Tmin), maximum temperature (Tmax) and diurnal temperature range (DTR) during the summer agricultural season spanning from October to March. Spatial interpolation of temperature characteristics was done using ArcMap V.10.2. Results show that the late summer subseason (January–March) generally experiences warmer temperatures than the early summer subseason (October–December). A significant shift towards warmer temperatures was detected for Tmax during the October–December subseason around 2003 and around 1983 for the January–March subseason for Tmin. The OND Tmax shift coincides with that in cloud cover, suggesting that the reduced cloud cover could have contributed to the Tmax shift. It is found that the significance of temperature change is stronger towards the north and northwestern regions of the province.

1. Introduction

There is overwhelming evidence of climate change in different places across the globe (Mahato, 2014; Manatsa & Reason, 2016; Seager & Vecchi, 2010). The impacts are most felt in Less Economically Developed Countries (LEDCs) compared to their Most Economically Developed Countries (MEDCs) counterparts given that they have weaker coping capabilities (IPCC, 2014). A noticeable increase in the frequency of extreme events ranging from drought to floods has been recorded. These extremes have been explained in terms of precipitation and temperature variability, both temporally and spatially, although it has not been spatially and temporally uniform (Ji, Wu, Huang, & Chassignet, 2014; Rigor, Colony, & Martin, 2000). In southern Africa, complications emanating from increased surface air temperatures (SAT) are emerging as serious threats, with impacts that are comparable to those resulting from deficits in rainfall (Manatsa, Matarira, Mushore, & Mudavanhu, 2015). Temperature plays a crucial role in the processes of climate change and climate variability because its variations can impact on the global hydrologic cycle and energy balance through thermal forcing (Caloiero, 2017). Southern Africa largely falls in a moisture constrained region (Kapangaziwiri, Hughes, & Wagener, 2012) and increasing temperatures are likely to worsen the problems associated with water scarcity already experienced in the region. This makes studying temperature variability imperative (Collins, 2011).

A study on the sensitivity of agricultural production to changes in South Africa's climate between 1970 and 2006 shows that the country is highly susceptible to climate change (Blignaut, Ueckermann, & Aronson, 2009). Free State Province is one of the main maize producing provinces in South Africa amongst North West and Mpumalanga Provinces. In total, they account for approximately 83% of total production (DAFF, 2014). The eastern part of the Free State Province, bordering Lesotho is punctuated by the Maluti-Drakensburg Mountains which form part of the main escarpment in southern Africa (Nel & Sumner, 2006). The impacts of climate change on mountain ecosystems extend to the hydrological, ecological, and societal systems (Beniston, 2005; Ji et al., 2014).

A number of studies have been done on the Free State Province using data from a few stations primarily due to the limited availability of observation data (Kruger & Shongwe, 2004). As such the results may not provide a good representation of the whole province, given the associated complexity of the terrain. This study therefore, provides an in-depth analysis of spatial and temporal variability of temperature at a much finer scale. The variables used in this analysis include minimum temperature (Tmin), maximum temperature (Tmax) and diurnal temperature range (DTR). We included DTR because it is independent of internal climate variation, making it a better signature of climate

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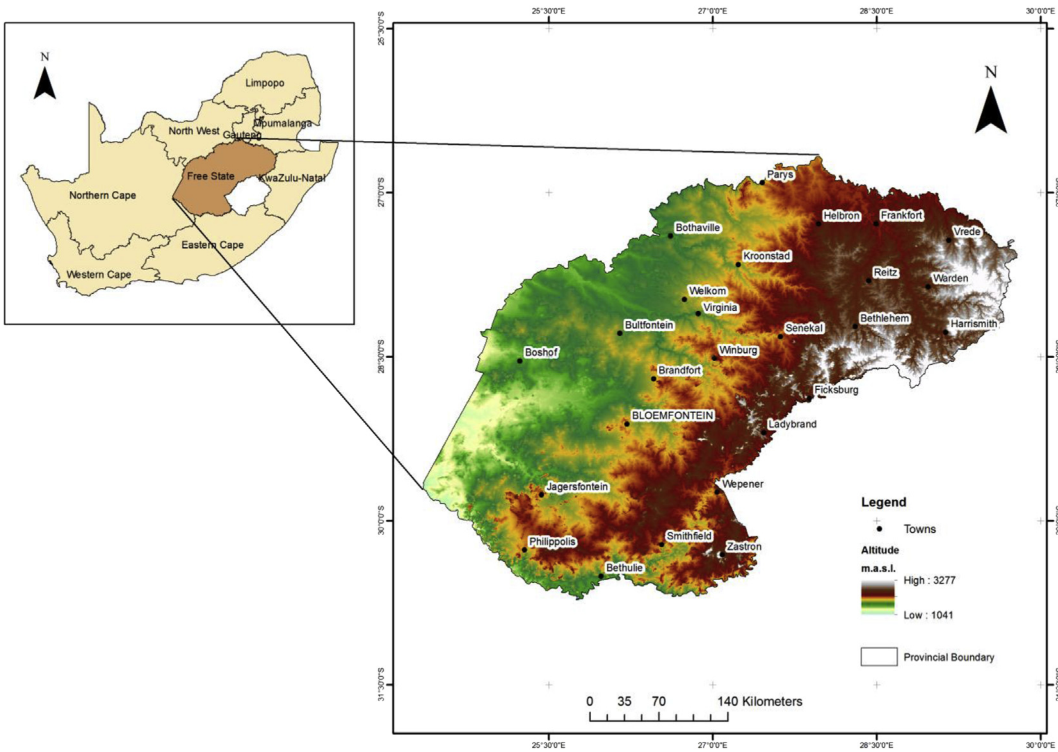

Fig. 1. Location of the Free State Province, South Africa and its elevation (metres above sea level).

change than the mean temperature (Manatsa et al., 2015). The objective was to identify the abrupt shifts in surface air temperatures, analyze the spatial variations of temperature and the trends in temperature time series in the Free State Province between 1960 and 2013.

2. Data and methods

2.1. Study area

This study focuses on the Free State Province of South Africa whose location is shown in Fig. 1. The province covers a total area of about 129,825 km^2 and lies between latitudes 26.6° S and 30.7° S and between longitudes 24.3° E and 29.8° E (Davis & Tavasci, 2006). The eastern Free State region is characterised by rugged terrain and is associated with livestock farming rather than crop production. Approximately 32,000 km^2 is under cultivation, while 87,000 km^2 is covered with natural veld and under grazing (DAFF, 2010). Agriculture in the province is mostly rain-fed with less than 10% of the arable land under irrigation (Moeletsi & Walker, 2012). This makes the agricultural output highly sensitive to temperature variability as soil moisture can highly be depleted by increased evapotranspiration.

The Free State Province experiences a continental climate characterised by warm to hot summers and cool to cold winters. The rainfall season (summer) spans from October to March, with the highest mean monthly rainfall received in January and February while winter spans from April to September (Rutherford & Westfall, 1986).

2.2. Data

We analysed the temperature variability within the agricultural summer season (October–March) between 1960 and 2013. Prior to 1960, data availability in southern Africa was limited (Jury, 2014). The 54 year period dataset is good enough for temporal and spatial analysis (Manatsa, Morioka, et al., 2015). Monthly land surface air temperature data was downloaded from Climate Explorer's Climate Research Unit (CRU) gridded data file at 0.5° × 0.5° spatial resolution. The data products are principally derived from observations in line with the World Meteorological Organisation guidelines and are freely available. CRU datasets have been validated and are widely used in climate research (El Kenawy & Mccabe, 2016; Ongoma, Chen, Gao, & Sagero, 2017). The temperature variables analysed include maximum temperature (Tmax), minimum temperature (Tmin) and diurnal temperature range (DTR). DTR is defined as the difference between the mean daily maximum temperature (Tmax) and minimum temperature (Tmin), at each grid point for each season (Braganza, Karoly, & Arblaster, 2004). We analysed the agricultural season in two parts, October to December (OND) and January to March (JFM) as the processes that control the summer season rainfall in the southern African subregion are different. Between October and December the subregion has a distinct extra-tropical nature with frequent cut-off lows while between January and March tropical circulation systems are more prevalent (D'Abreton & Lindesay, 1993; Manatsa & Reason, 2016). The general temperature characteristics of the two subseasons are presented in Table 1. The late season generally has higher average Tmax and Tmin than the early subseason, while the mean DTR is higher during the OND subseason than the JFM subseason. Tmax and DTR variance is greater for JFM than for OND (more than double) while Tmin variance is greater for OND than JFM. Higher variance means that the variable becomes less predictable, for example Tmax and DTR during the JFM subseason and Tmin during the OND subseason.

Table 1
Temperature characteristics for OND and JFM subseasons (1960–2013).

Subseason	N	Tmax		Tmin		DTR	
		Mean	Variance	Mean	Variance	Mean	Variance
OND	54	27.6	0.7	12.1	0.4	15.5	0.6
JFM	54	28.5	1.8	14.4	0.2	14.1	1.5

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