

CONCLUSIONS

The Drakensberg is a World Heritage site and has been declared a Trans-Frontier National Park on the border between KwaZulu-Natal and eastern Lesotho. This area receives above average rainfall for South Africa and has increasingly become a valuable source of surface water for the densely populated Gauteng province through two inter-basin transfer schemes that operate in the Drakensberg region. Notwithstanding the hydrological importance, geomorphologically, the area has also generated debate in the field of climatic and palaeoclimatic interpretation based on landforms. This thesis addresses the lack of contemporary climatic data and presents findings on rainfall and surface-temperature attributes and how these affects geomorphological processes.

The first Chapter in Section 1 of this thesis (Nel and Sumner, 2006) analysed records on annual rainfall totals and intra- and inter-annual rainfall variability trends from 1970 to 2000 in the KwaZulu-Natal Drakensberg foothills and thus extends aspects of the earlier assessments by Tyson *et al.* (1976) and Schulze (1979) as well as presenting new findings on the effects of latitude on rainfall variability. Mean annual rainfall on the eastern side of the Drakensberg escarpment is affected by altitude, and this correlates well with findings from earlier work undertaken on the western side of the escarpment (Sene *et al.*, 1998). Also, more consideration should be given to the eastward distance from escarpment when assessing rainfall totals and this Chapter found that altitude is not necessarily the only important factor influencing rainfall in the mountains. In the KwaZulu-Natal Drakensberg, latitude plays no significant role in influencing rainfall totals, but was found to influence inter- and intra-annual rainfall variability. Rainfall variability increases from the southern Drakensberg to the north where important water transfer schemes operate. The spatial trend could be related to increased winter frontal activity in the south or greater thunderstorm variability in the north, but this study calls for further research into the climatic causes of rainfall variability in the Drakensberg.

Chapter 2 of Section 1 (Nel, submitted) analysed historical rainfall records from 11 stations and the study shows no increase or decrease in mean annual rainfall during the last half of the 20th century in the Drakensberg, but that the annual rainfall does show cyclic variation of between 15 and 20 years. This compares well with previous findings (Tyson *et al.*, 1975; Tyson *et al.*, 1976) who propose that the Drakensberg falls into the area that has a quasi 20-year rainfall oscillation. In this region, although no change in annual rainfall can be seen, an increase in the variability of the distribution of monthly rainfall indicates an increase in the seasonality of monthly rainfall in the Drakensberg. Trend analysis of the four different rainfall seasons shows a statistically significant decrease in rainfall during autumn and this rainfall trend could affect the late crop-growing season in this area. The El Niño/Southern Oscillation influences summer rainfall variability with a strong statistically significant correlation existing between summer rainfall in the Drakensberg and the contemporaneous Southern Oscillation Index. This correlation implies that an increase in the frequency and intensity of ENSO should negatively affect rainfall in the Drakensberg. There also exists a statistically significant correlation between summer rainfall and the SOI for preceding periods. The lagged correlation between summer rainfall in the Drakensberg and SOI could be used as an indicator for seasonal forecasting.

Section 2 presents and discusses new rainfall and temperature data collected in the Drakensberg, which includes a number of unique studies for the region. This section presents contemporary measured rainfall as well as observations on rainfall totals generated from individual rainfall events. The thesis discusses storm erosivity characteristics of individual storms as well as the rainfall intensity, kinetic energies, rainfall frequency and erosivity of storm events. Analyses of extreme erosive events in the Drakensberg with regards to the within-storm distribution of rainfall and kinetic energy attributes are also presented. Surface-climate attributes from an exposed site in the Drakensberg foothills and on the Drakensberg escarpment edge are discussed and the effects these attributes have on geomorphological processes observed. Findings from some of the data, notably rock and air

temperatures, are placed in a regional context in the Appendix where a climatic-zonal approach to temperatures relevant in mechanical rock weathering is questioned.

Several key findings on the contemporary climatic environments and its implications on the geomorphology of this region can be made from the assessments in Section 2:

- Rainfall totals at the escarpment have previously been overestimated. Even though wind catch deficiency may exist to some extent and the rainfall measured in this thesis is probably slightly below long-term rainfall averages for the sites, earlier estimates for total annual rainfall between 1800 mm and 2000 mm at the escarpment appears to be an over-estimation. Many authors cited MAP exceeding 1000 mm per annum when extrapolating from current values for palaeoclimate above the escarpment zone (Boelhouwers, 1988; Grab, 1994; 1996). Authors in favour of the presence of ground ice during the Last Glacial Maximum (Grab, 2002) prefer to cite high values for MAP (>1500 mm per annum) that support snow accumulation during this period. This thesis found dryer contemporary conditions that probably would favour periglaciation at high altitude during the LGM.
- The number of rain days and rainfall events increases with altitude, but daily rainfall and mean rainfall from individual rainfall events is less on the escarpment than in the foothills. This challenges the assumption of an increase in rainfall with altitude in the Drakensberg above the escarpment zone (above 2200 m a.s.l.). Clear altitudinal differences also exists with regards to the amount of rainfall generated by events of 10 mm or more, with the escarpment stations receiving less rainfall from high rainfall events than the stations in the foothills. On the escarpment a lower contribution to the overall rainfall totals from rain days with single rainfall events was measured than at the low altitude stations.

- Individual erosive storm events at all altitudes in the Drakensberg has the potential to detach soil, but at high altitude a lower percentage of rain falls as erosive storms, and the cumulative kinetic energy produced as well as total erosivity of rainfall is less on the escarpment than in the foothills. The high altitude stations recorded lower maximum five-minute rainfall intensities as well as fewer high intensity events than the stations at lower altitude, but mean kinetic energy produced during individual storms are similar throughout the area. Analysis of the monthly distribution of erosive events show that the differences in cumulative kinetic energy and cumulative erosivity can be explained by the lack of erosive events during early and late summer at the escarpment, and significant erosive rains during this period at lower altitudes in the foothills.
- Extreme rainfall events in the KwaZulu-Natal Drakensberg generate most of their rainfall, as well as peak rainfall intensity, within the first half of the storm duration. This could possibly decrease peak runoff rates, soil loss and overall erosivity from storms events in the region. However, rainfall is generated at varied intensities, implying more soil loss and different characteristics of wash material than if the storms exhibit constant intensity. These factors make it difficult to assess total erosivity from rainfall in the Drakensberg.
- Rock temperature and rainfall frequency records at a site in the Drakensberg foothills show an environment conducive to thermal fatigue and wetting and drying with potential for frost action. Rainfall patterns imply numerous rock wetting and drying cycles in summer. At the site, air, rock and soil temperatures differ considerably with respect to absolute temperature and daily ranges on a diurnal basis. Mean rock daily ranges, as conducive to possible thermal fatigue, are found to be similar in the summer and winter periods. Darker coloured basalt attains higher maximum and marginally lower minimum temperatures than the lighter sandstone and both rock

types maintain relatively high rock temperatures in winter (exceeding 25°C) thus chemical weathering is probably only restricted by a lack of moisture during this dry period. Findings also highlight the importance of directly monitoring rock temperature when attempting to discern the rock-weathering environment rather than attempting to extrapolate from general climate data.

- Mean air temperature measured on the escarpment edge falls within the range previously estimated for the area, but is somewhat higher than the MAAT postulated by other authors for the plateau peaks immediately behind the escarpment.

Comparing across the escarpment, no difference exist with regards to mean air and soil temperatures although temperature range differences appear related to the soil characteristics and vegetation cover. No long-duration, or seasonal freeze was found for the soil surface and in general the soil temperatures are higher than that of air and thus air temperature cannot be realistically used as a surrogate to study soil frost. When comparing temperature data with those at slightly higher (Sumner, 2003) and lower altitudes (Sumner and Nel, 2006) it appears that air temperature decreases more rapidly with altitude than soil does. A strong decline in soil temperatures may exist behind the escarpment onto the highest peaks but more field data are required to verify this.

Rainfall measured in this thesis indicates that an increase in altitude increases the number of rain days and the number of rainfall events measured. However, daily rainfall, maximum five-minute rainfall intensities, high intensity events, the amount of rainfall generated by erosive events, the percentage of rain that falls as erosive storms, the cumulative kinetic energy produced and total erosivity of rainfall is less on the escarpment than in the foothills.

Temperature findings support the current classification of the Drakensberg-Lesotho summit area as being marginal periglacial. Data collected in this thesis suggest that soil frost could

be enhanced under a declining grass cover but the effect of amelioration of global temperatures and changes in land use on frost action and land degradation still require further exploration. In addition, palaeoenvironmental extrapolation based on inflated current rainfall values, such as used in support of former glaciation, requires re-consideration. Distance from the escarpment needs to be considered when rainfall is assessed and the persistence of rainfall variability trends of the 20th century into the new millennium and its effect on the region should be monitored. The erosion models used in the Drakensberg needs to be revisited and the structure of erosive rain should be incorporated when soil loss for the region is modelled and further research into determining the effect within-storm rainfall characteristics has on runoff and soil detachment can be undertaken. Detailed rock temperature recordings are needed in weathering studies in this region, and using air temperatures, as a surrogate for rock temperatures, should be avoided. Differences in air and soil temperature measured in this thesis also highlights the problem associated with measuring soil temperatures, and that air temperatures cannot be used to realistically attain soil thermal conditions.

The papers presented in this thesis have been through accepted reviewing procedures and have been published in peer reviewed journals. However, the study area is characterised by few data relating to climatic records. Furthermore, given that findings presented are largely based on a four year monitoring period and from spatially discontinuous data, discussions should be treated with the necessary prudence.

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