THE EVER-CHANGING CLIMATE OF SOUTHERN AFRICA

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Climatic change has occurred ever since the atmosphere, as it is constituted today, formed thousands of millions of years ago. At least twice in the past southern Africa has been covered in great ice sheets. The most recent of these episodes lasted for more than 100 million years ending roughly 200 million years ago. It was during this time that the subcontinent's vast coal beds were deposited. Around 100 million years ago one of the hottest periods ever to occur in the earth's history laid its distinctive imprint on southern Africa. However, it is only in the last half million years or so that palaeorecords become sufficiently clear for a more continuous measure of climatic change to be evident.

Changes in the pre-historical period

Analysis of deep-sea sediment cores taken off the coast of Natal shows that in the last half million years at least six major cold phases (when higher latitudes in the southern hemisphere were glaciated) have occurred (numbered evenly in Fig 1a). At least seven major warm epochs have prevailed (odd-numbered peaks in Fig 1a).

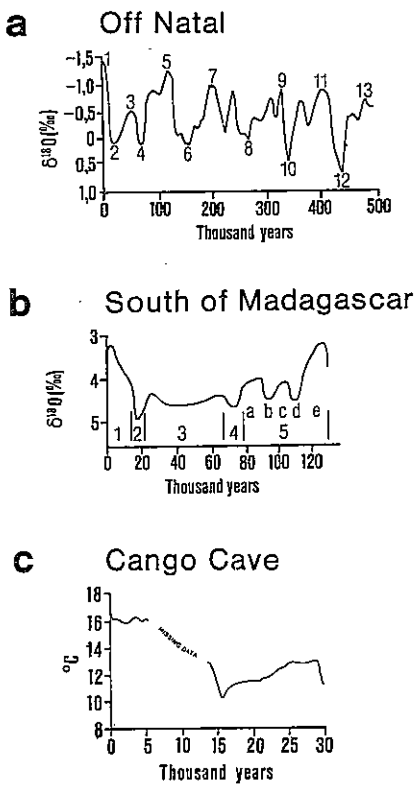

Fig 1. Oxygen isotope chronologies for (a) deep-sea core RC 17-69 off Natal (after Prell et al., 1979); (b) smoothed version of the benthic record core MD 73-025 south of Madagascar (after Shackelton, 1977); and (c) a Cango Cave spelcothem (after Talma and Vogel, 1986).

The coldest conditions occurred about 420 000 and about 16 000 years ago. The warmest period was experienced about 125 000 years ago when conditions were probably hotter than at present. From a more detailed record from a core taken to the south of Madagascar, it can be seen that irregular coolling occurred after this warm, so-called inter-glacial, period (Fig 1b). Temperatures dropped sharply as major ice sheets extended from the Antarctic and covered New Zealand and higher regions of South America. South Africa was not glaciated. Temperatures 16 000 years ago in the country were 5° to 6° C lower, on average, than those of today. Records from Cango Cave show the pattern of temperature change in the southern Cape (Fig 1c).

The period 17 000 to 15 000 BP (BP denotes years before present) appears to have been generally wetter over most of southern Africa (Fig 2). After 14 000 BP conditions became more variable. Nonetheless, for 2 000 years most regions of the subcontinent experienced above-average rainfall. Between 12 000 and 10 000 BP the whole of southern Africa underwent aridification before again becoming wetter after 9 000 BP. These generally wetter conditions appear to have prevailed for at least five millennia. Records from Cango Cave suggested that warm conditions were experienced around 3 500 BP following cooler times around 4 500 BP. After 3 000 BP abrupt cooling set in and temperatures reached a minimum at about 2 000 BP. This period of about a thousand years of somewhat cooler conditions was a phenomenon found all over the earth.

The Historical Period

To obtain some idea of what conditions were like over the last few centuries it is necessary to turn to the record of climatic change preserved in tree rings. During benign years rings are wider than those formed during adverse times. Tree ring series for *Podocarpus falcatus* (yellowwood) trees in the north-eastern Transvaal and Natal and *Widdringtonia cedarbergensis* (cedar) trees in the south-western Cape show that South Africa experienced the so-called Little Ice Age (Fig 3). In the summer rainfall region from at least the fourteenth century until the mid-seventeenth century clear below-normal tree growth conditions prevailed in response to the lower temperatures that prevailed in this period of world-wide cooling. The change from below-normal growth conditions in the north-east occurred at about 1570 and around sixty years later to the south-west as warming advanced southward from the tropics. Above-normal growth conditions prevailed for about a century during the seventeenth and early-eighteenth centuries, centred around 1630 in Natal and 1670 in the south-western Cape. A long period of widespread conditions conducive to vigorous tree growth occurred from the mid-eighteenth to early- to mid-nineteenth centuries.

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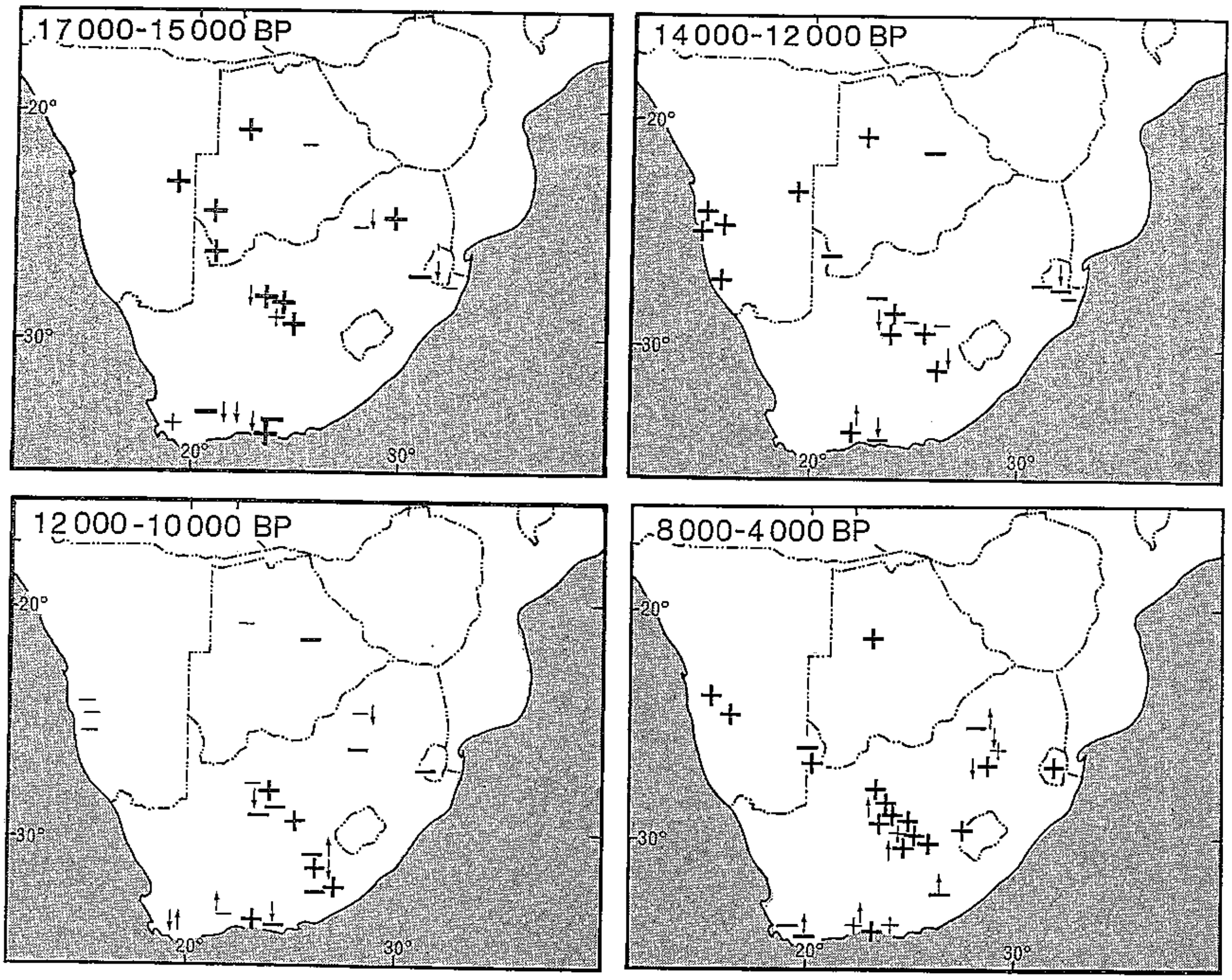

Fig 2. Moisture and temperature conditions in southern Africa (after Cockcroft et al., 1987). Heavy pluses and minuses indicate wetter and drier conditions; light pluses and minuses indicate wetter and drier trends, upward and downward arrows indicate warming and cooling.

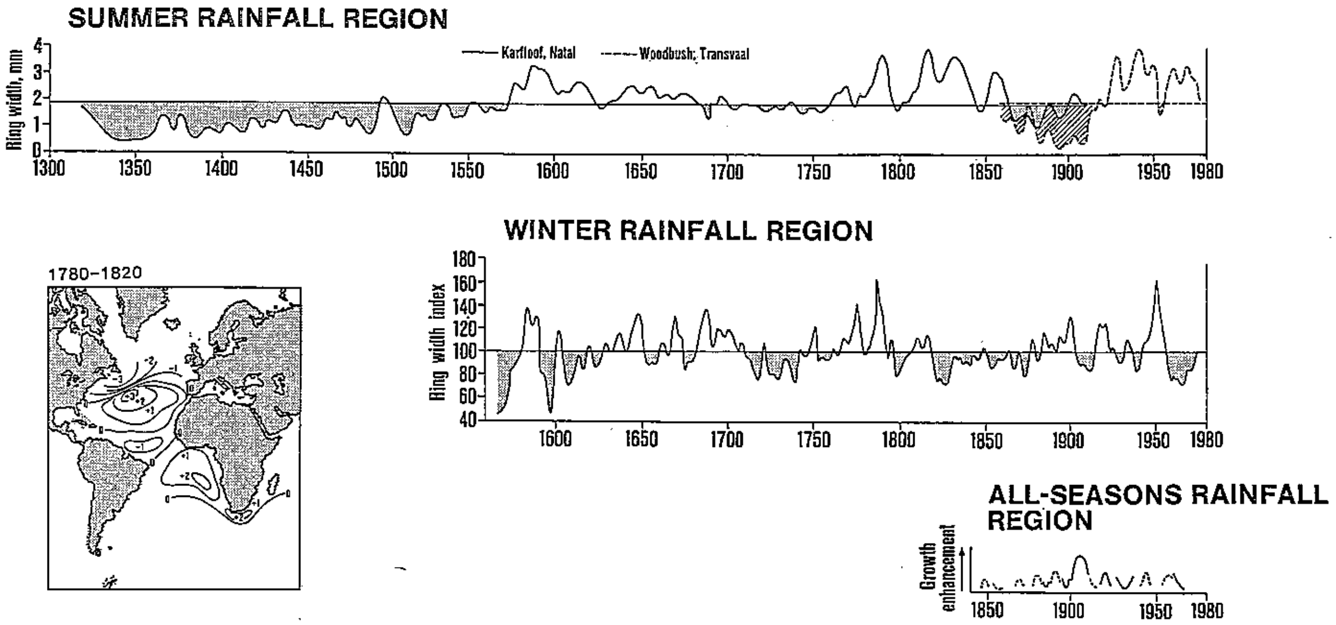

*Fig 3. Tree ring widths in **Podocarpus falcatus** in the summer rainfall region (after Hall, 1976 for a Karkloof, Natal, series and after Dyer, 1978 for a Woodbush, Transvaal series); in **Widdringtonia cedarbergensis** in the winter rainfall region (after Dunwiddle and LarMarche, 1980) and in **Podocarpus falcatus** in all-seasons rainfall region (after McNaughton and Tyson, 1979). Inset: January sea temperatures 1780 - 1820 as departures (°C) from the average values measured between 1887/99 and 1921/1938 (after Lamb, 1969).*

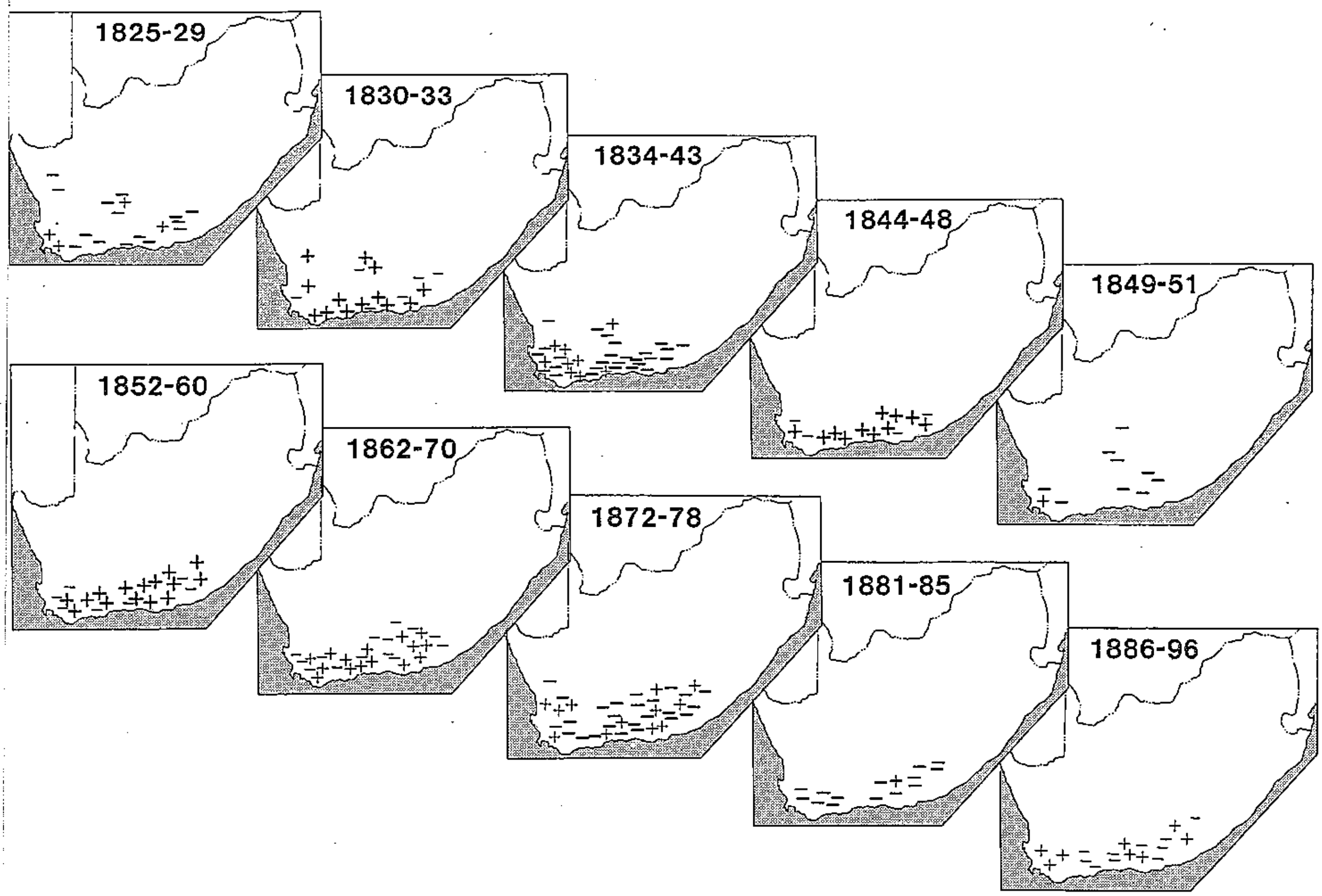

Fig 4. Precipitation anomaly maps for the nineteenth century as estimated from the analysis of historical documentation (after Vogel, 1987). Predominantly wetter (+) or drier (−) conditions are indicated by bold type. Normal type indicates an indeterminate situation as a whole.

Enhanced growth occurred in northern and eastern parts from 1760 to 1860 and in the south-west from 1760 to 1818. Such growth took place when sea surface temperatures were above normal all around the coast of southern Africa (Fig 3, *lower left*). At times clear regional differences are apparent in the tree ring series. An example is the extended period of retarded growth in northern and eastern parts of South Africa between 1860 and about 1915, which coincide with a period of above-normal growth conditions from 1874 to 1902 in the south-western Cape.

From about 1760 onwards the Natal tree ring series shows quasi-regular fluctuations with a peak at around 18 years in the spectrum. A similar peak is evident in the Cedarberg series and in rainfall records for the summer rainfall region of South Africa during the twentieth century.

Inferring climatic conditions from reports in travellers' journals, settlers' diaries, missionary records, Government Gazettes, early newspapers and other historical sources, allows the climate of the nineteenth century to be reconstructed for the Cape Province (Fig 4). The period 1825 to 1829 was characterised by a predominance of reports of droughts and desiccation, whereas between 1830 and 1833 flood and good-rain reports predominated. Other drought periods appear to have occurred 1834-1843, 1849-1851, 1872-1878 and 1881-1885. Wetter years were experienced between 1844 and 1848 and 1852 and 1860. At times no clear predominance of either wet or dry conditions could be identified, for example 1862-1870. A similar analysis for the rest of southern Africa would be most useful. However, such is the paucity of records that it is not possible to obtain anything meaningful. This is a pity since meteorological observations, though begun in the mid-nineteenth century at a few places, did not become widespread north of the Orange River until around the turn of the century.

The period of meteorological record

Since the turn of the century rainfall over most of the summer rainfall region has varied in a remarkably systematic way in response to an atmospheric forcing which apparently produced similar variations in some tree growth patterns going back over 300 years. If a spatial average is taken for 33 widely-distributed stations in the summer rainfall region, a clear oscillatory pattern is apparent in the rainfall series (Fig 5). If extreme variations are smoothed from the series, then it is clear that four extended spells of wet years, namely

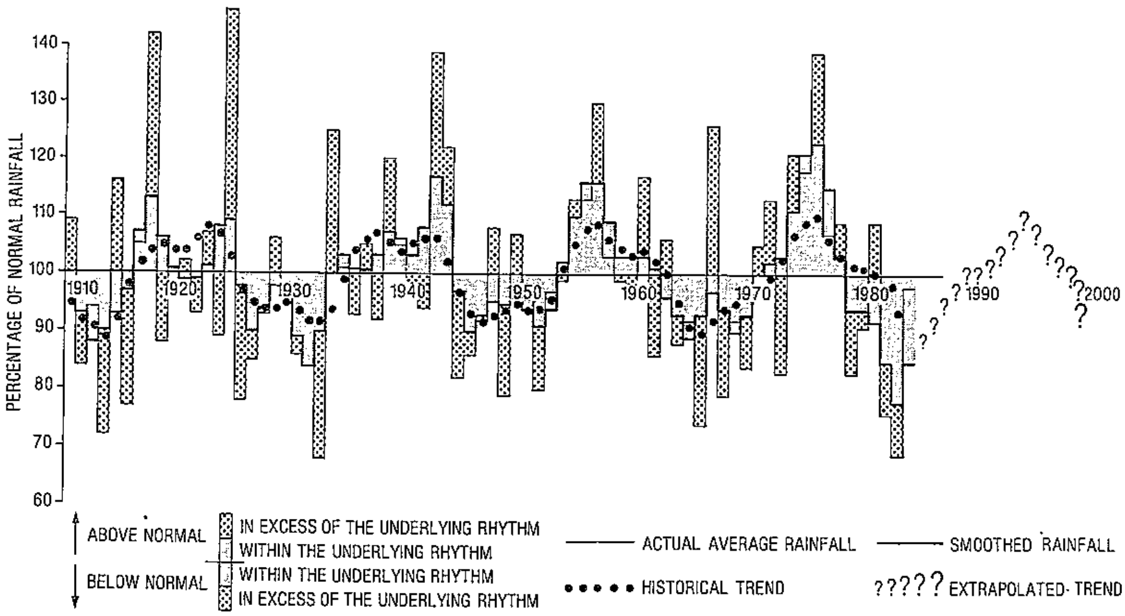

Fig 5. Spatially-averaged rainfall as a percentage of the normal for the summer rainfall region of South Africa as a whole. The October-September rainfall-year series is for 33 stations. Dates on the horizontal axis give the year in which the October rains began. Smoothing has been effected using a 5-term binomial filter. Extrapolation is based on the analysis of 1910/11 - 1983/84 data.

1916/17-1924/25, 1933/34-1943/44, 1953/54-1961/62 and 1971/72-1980/81, and five extended dry spells, namely 1905/06-1915/16, 1925/26-1932/33, 1944/45-1952/53, 1962/63-1970/71 and 1981/82 onwards have occurred in a quasi-periodic variation of about 18 years (Table 1). In such a variation, about nine years of an extended wet spell follow about nine years of an extended dry spell, and so on. Between 1905 and 1987 the highest space-mean rainfall in any one October to September rainfall year was recorded in 1924/25 (143 percent of normal); the lowest was in 1932/33 (66 percent of normal). In comparison, during the great drought of 1982/83 the space-mean rainfall was 68 percent of normal. The most persistently wet spell has been that of 1971/72-1980/81 with six consecutive years experiencing above-normal rainfall. The wettest year seldom coincides with the middle of a wet or dry spell and extreme years may often occur at the beginning of the spell in a sudden switch, for example in the 1916/17-1924/25 and 1933/34-1943/44 wet spells or the 1981/82 onwards dry spell. It also often happens that an extreme year of opposite sign may occur in a spell, for example, the extreme wet year of 1966/67 in the otherwise excessively dry year of the drought of the sixties. In general, two to three years of opposite sign may occur on average during any one wet or dry spell.

The spatial pattern of rainfall reversals this century is even more striking than the average series (Fig 6). It is clear from Figure 6 that the dry spells are more uniformally dry over the whole of southern Africa than the wet spells are wet. With each successive wet spell since the turn of the century the areal extent of the excess-rain areas has increased.

TABLE 1. Space mean deviation for wet and dry spells as a whole, wettest and driest years within wet and dry spells and the number of years during spells for which rainfall of the opposite sign occurred. October to September rainfall years have been used.

Spell	Period	Number of years	Space mean deviation (%)	Wettest or driest year	Max or min deviation (%)	Number of years with opposite sign
dry	1905/06 - 1915/16	10	−4,3	1913/14	−30,0	5
wet	1916/17 - 1924/25	9	+5,4	1924/25	−42,5	4
dry	1925/26 - 1932/33	8	−14,7	1932/33	−33,5	1
wet	1933/34 - 1943/44	11	+6,0	1942/43	+34,5	5
dry	1944/45 - 1952/53	9	−9,4	1949/50	−23,0	2
wet	1953/54 - 1961/62	9	+7,0	1956/57	+30,0	3
dry	1962/63 - 1970/71	9	−6,0	1965/66	−24,5	3
wet	1971/72 - 1980/81	10	−10,6	1975/76	+39,0	2
dry	1981/82 -	7 to date	–	1982/83	−32,0	–

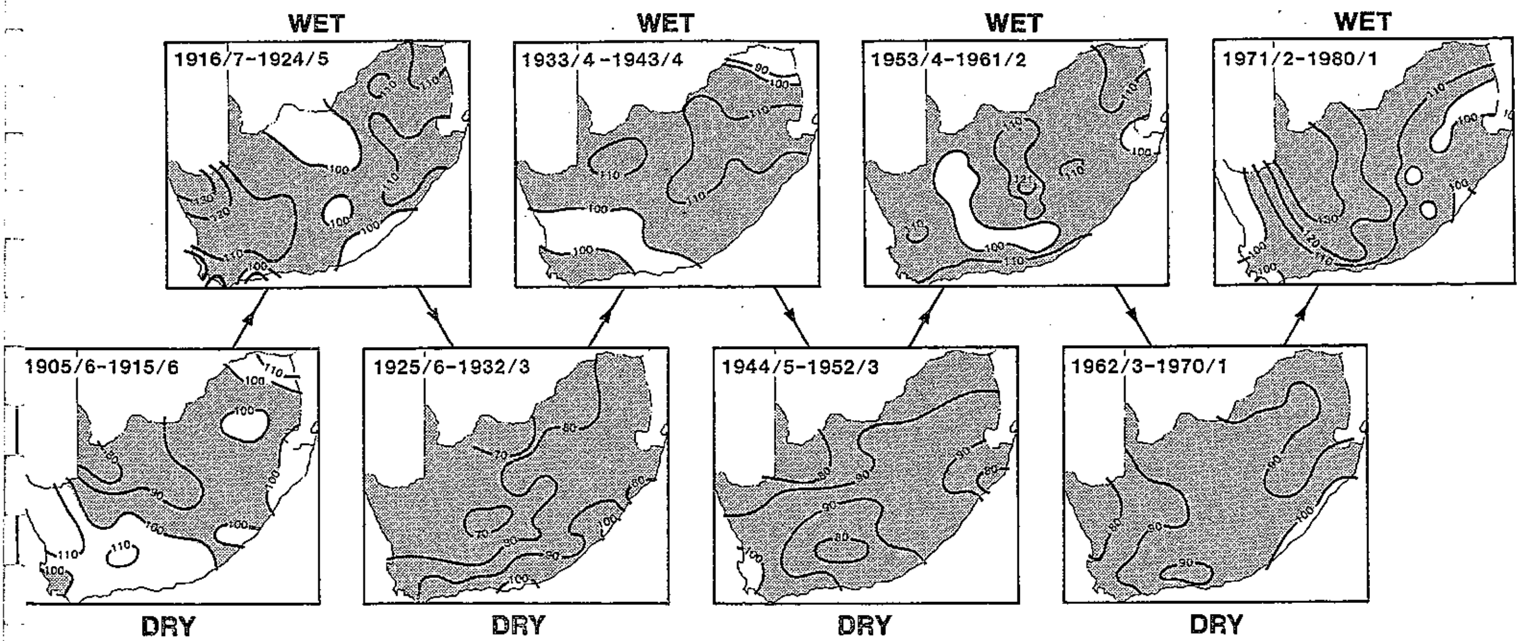

Fig 6. Percentage of mean rainfall for wet and dry spells based on analysis of October-September rainfall-year data for the period 1905/06 to 1983/84. No smoothing has been effected other than averaging individual station deviations over the duration of each spell. The analysis is based on data for 59 stations. Shaded areas indicate areas of above-normal rainfall in wet spells and below-normal in dry spells (after Tyson, 1986).

The future

It is possible to fit a mathematical curve to the series given in Figure 5 and extrapolate this into the future. This was done with data for 1910-1967 and the possibility of the wet spell in the seventies was suggested. The wet spell occurred. Using data for 1910-1972 suggested a generally drier run of years in the eighties. The dry spell materialized. Using 1910/11-1983/84 data suggests a possible wet spell in the nineties. When exactly a wet spell changes to a dry spell or vice versa the model does not predict accurately. Only time will tell if the droughts of the eighties have ended and whether the excessive rains of 1987/88 are simply an aberrance in a dry spell (like 1966/67) or whether the wet spell of the nineties (if it is to occur) has begun. A cautionary note is purposely added, since it is impossible to use the model to *predict* or *forecast,* since it is impossible to say whether the 18-year oscillation, on which it is based, will continue in future. There is some evidence of its presence for over 300 years, but only a fair certainty of its existence in the meteorological record during the twentieth century. There is also some evidence that its strength waxes and wanes and the certain knowledge that it may skip a beat from time to time, as happened at the beginning of this century. Also, it must be realised that the oscillation only accounts for up to 30 percent of the variance in southern African rainfall. It is thus strong enough to impart a clear rhythm on average conditions, but not strong enough to determine events in each particular year. Overlying the rhythm are other components (for example that exerted by El Nino) and a good deal of random variability. However, it may be said that, if the oscillation continues in the next few years as it has throughout this century, then a run of generally wetter-than-normal years may occur during the early and middle nineties.

Conclusion

Southern Africa is a semi-arid subcontinent. Its climate and rainfall has been highly variable for millennia and will continue to be so in future. It is a land of drought rather than a land of rainfall plenty. All future planning must be predicated on this assumption. The presently-observed rainfall oscillation, with its tendency to produce nine-year spells of generally wet and generally dry conditions in a quasi-cycle of about 18 years appears to be stable at present. There is no knowing how long it will last. If it does continue, then southern Africa may be looking to a number of years of plenty in the next decade. Not all places will experience them equally, or at all. On average things should be better than in the drought years of the eighties. The climatic prognosis for the next decade is pleasing rather than depressing.

Note:
A detailed treatment of this subject is given in 'Climatic Change and Variability in southern Africa' by P D Tyson, published by Oxford University Press, Cape Town in 1986.

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