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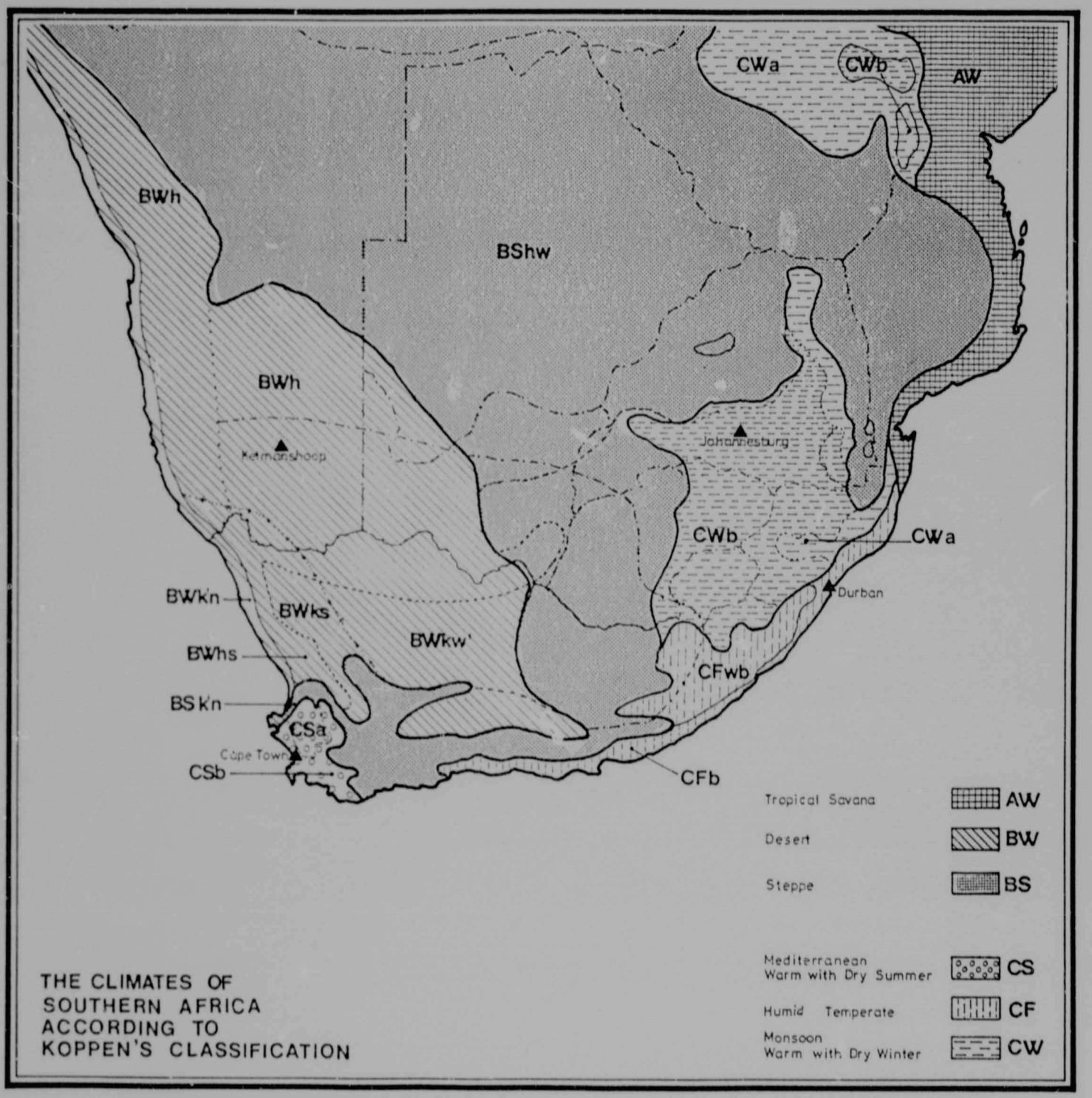
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# Passive solar systems for domestic architecture in Southern Africa

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THE CLIMATES OF
SOUTHERN AFRICA
ACCORDING TO
KOPPEN'S CLASSIFICATION

References

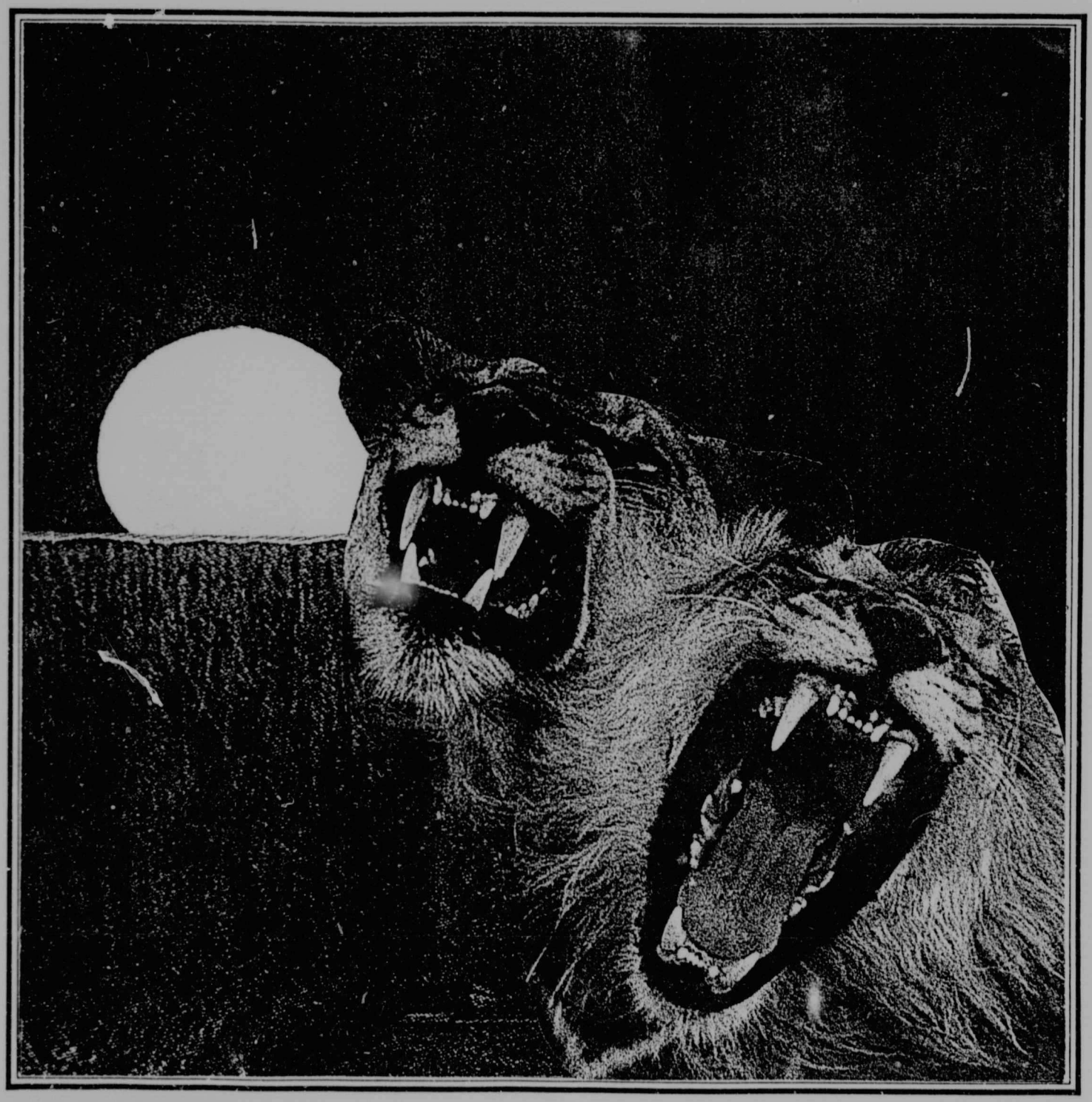
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# Southern Africa

# Climate



The climates of Southern Africa are strongly influenced by the position of the subcontinent in relation to the pressure and wind systems of the Southern Hemisphere.

From the equator to about 20° S. isohyets of mean annual rainfall have a general east-west trend; the rainfall increases towards the equator, and the maximum falls at the time of the equinoxes.

Changes in the distribution of rainfall take place in response to the movement of the inter-tropical convergence zone and associated belts of disturbance.

South of 20°S, however, the isohyets assume a nearly north-south alignment, such that the 400mm isohyet (25.4mm) almost bisects Southern Africa, dividing it into a wetter eastern section and a drier western section.

This meridonal distribution of rainfall reflects the replacement of the latitudinally operating convergence zone by the subtropical high- pressure centres, and further south the disturbed westerly air-streams, as the main controls of weather and climate.

The east-west contrast in climate is accentuated by the warm, southwardflowing Mozambique and Agulhas Currents in the east and the cool, northward-flowing Benguela Current in the west.

An exception to the prevailing aridity of the Namib Desert of the west coast is to be found in the limited area of Mediterranean climate of the South-Western Cape.

Winter, with its succession of eastward-moving cyclonic disturbances, is the wet season in this region.

The altitude and configuration of the inland plateau, which forms the greater part of Southern Africa, likewise exert strong influences on rainfall and temperature, while the varied topography of the marginal lands around the plateau edge is responsible for a variety of local winds and climates.

Circulation Patterns

Most of Africa south of about 20°S. is dominated by the subtropical anti-cyclones. Over the oceans the high-pressure cells are conspicuous.

The South Atlantic anticyclone is centred well off the Namib coast and produces south-westerly on-shore winds that blow over the cold ocean current.

Coupled with strong and persistent

subsidence, the air is highly stable, and frequent low cloud and fog (called "cacimbo" in Angola) may occur in association with fine drizzle during the morning.

By contrast, the position of the South Indian anticyclone off Durban fluctuates more than its Atlantic counterpart.Thus the cell withdraws in summer and advances toward the coast in winter.

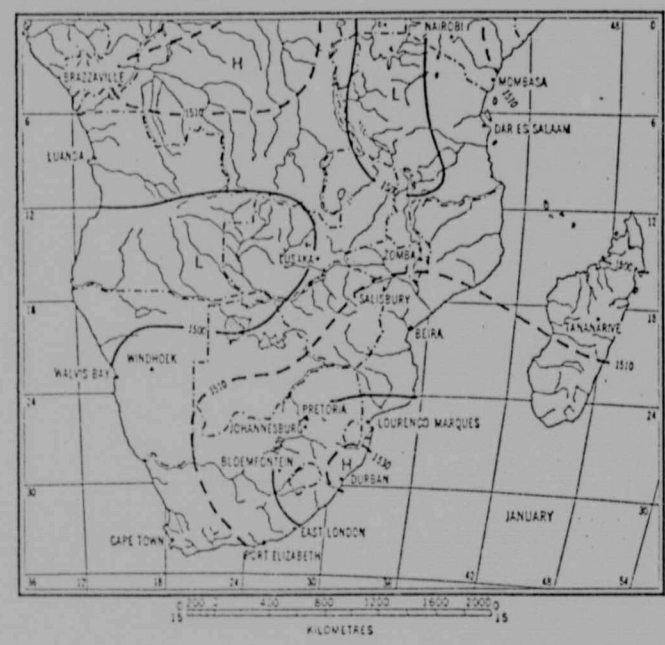
South of the anticyclones is the zone of the "westerlies", in which mid-latitude frontal depressions form and travel eastwards, carrying their normal sequence of weather with them.

Over Southern Africa the pressure and circulation patterns are not as simple.

An anticyclonic circulation is the predominant feature over the land, and apart from a weakening and southward movement of the system through a few degrees of latitude in summer, the essential features of the circulation in winter and summer are not greatly different.

Yet the seasonal contrasts of climate are marked.

Winter circulation is typified by conditions obtaining in July.



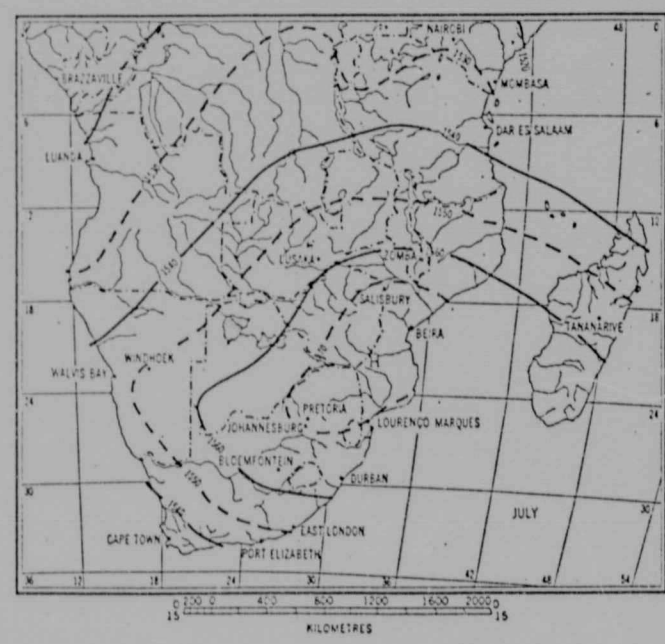




Fig.46: Contours (in meters) of the surface for Jan. and Jul.

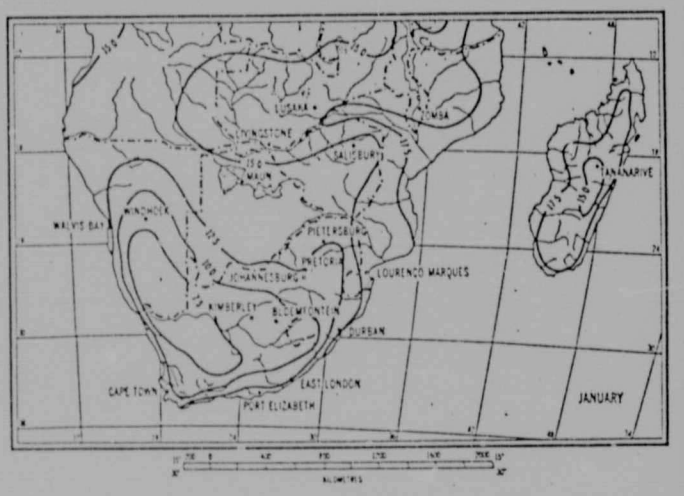
The anticyclonic centre is situated over the Easten Transvaal.

Prevailing winds at the surface are light and, apart from a marked and regular diurnal variation due to changes in the horizontal gradient of temperature in the air close to the plateau surface, the directions are those that would be expected from an anticyclone situated in the position shown in Fig.46, i.e. westerly and north-westerly over the Republic of South Africa and easterly over Mozambique, Zimbabwe, Zambia and Angola.

The air is subsiding gently, especially in the easterly stream; atmospheric moisture near the surface of the plateau is low, Fig.47; days are usually cloudless and warm, but the nights cool rapidly as the ground loses heat by radiation through the dry atmosphere.

The climatic importance of the dry, slowly subsiding, easterly stream of air over Southern Africa at this time can be seen from the distribution of rainfall in July: dry weather extends from Madagascar, where the only appreciable rainfall is on the exposed slopes of the eastern escarpment, across Mozambique and Zimbabwe to Namibia and Angola.

Resulting from the subsidence of air in the winter anticyclone, atmospheric stability is pronounced, and a strong temperature inversion frequently occurs over coastal and adjacent areas as far inland as the Escarpment.



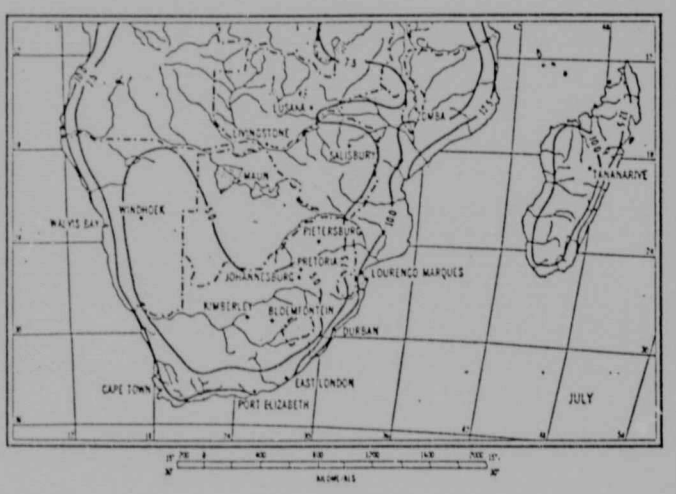




Fig.47: Atmospheric moisture (gm/kgm) for Jan. and July.

During the day the base of this inversion occurs at a height of about 1 km above the ground at about 30°S. and slopes upwards to a height of 2 km in Mozambique.

Thus the base of the inversion (and associated stable discontinuity) is usually below the level of the plateau.

Consequently, upward and westward transport of moisture by the easterly airstream on the northern periphery of the anticyclone is inhibited, and plateau areas experience dry winters.

The driest winter weather in Southern Africa occurs between the northern side of the anticyclone and the parallel of about 10°S.

Southwards from Zimbabwe to the Cape Province the proportion of rainfall increases as the "westerlies" are approached.

The winter circulation of the South-Western Cape is associated with disturbances in the circumpolar westerly winds, taking the form of a succession of eastern-moving cyclones (depressions) and anti-cyclones.

Originating in areas of cyclogenesis far to the south and west of Southern Africa, these disturbances first bring rain to the south-western and later to the south and south-eastern coasts and may even extend far inland.

Fronts are associated with the depressions: warm fronts are diffuse, difficult to recognise and almost impossible to follow: cold fronts are more usual, sharper and more easily recognized.

Following the passage of a cold front, winds back from north-west to west and south-west, pressure starts rising, temperatures fall and instability showers and storms may occur.

Most winter rain in the South-Western Cape, however, occurs in association with north-westerly pre-frontal winds.

Deep cyclonic disturbances followed by an advancing anticyclone from the South Atlantic sometimes cause outbursts of subpolar air on the plateau, so producing cold snaps in winter.

Snow on the Cape mountains and along the Escarpment, particularly in Natal, is common; and intensely cold, windy weather may reach as far north as Zimbabwe.

Over coastal areas a coastal lowpressure

system (sometimes called a leader front) frequently precedes the true passage of a cold front.

Coastal lows are associated with a shallow circulation note extending far inland or to the level of the interior plateau.

The pressure drop and wind direction changes rapidly from north-west to south-west with the passage of the system.

With the change in direction, wind speeds and turbulence increase sharply, and low cloud and light precipitation (drizzle or mist) are common.

The onset of westerly or southwesterly winds and the simultaneous deepening of the maritime air in advance of a cold front are characteristic of the southern and eastern coasts of South Africa.

Durban may experience four to five such occurrences per month, with a minimum in February and a maximum in August.

The temperature discontinuity produced by the coastal low may often be sharper than that of the following cold front.

North-westerly gradient winds on the east coast are normally associated with pre-frontal subsidence of air, with highly stable conditions and positive temperatures.

Berg winds

A berg wind is an extremely hot and dry wind blowing seawards from the interior.

In some respects berg winds are similar to the chinook and the föhn of North America and Central Europe respectively.

The weather they produce is enervating and conducive to feelings of depression and irritation in people so disposed.

Berg winds may occur in the transition zone between anticyclonic and cyclonic circulations that develops with the approach of a depression.

Under such conditions divergence and subsidence of air are pronounced, and these hot, dry and highly turbulent winds may be most unpleasant.

Berg winds give rise to the curious anomaly that coastal areas of Southern Africa frequently experience their highest temperatures during the winter season.

Likewise, highest absolute temperatures for these localities have usually been

recorded during berg winds, e.g. the maximum of 42°C at Durban, where on one occasion a temperature of 36°C was recorded at midnight.

Berg winds occur mainly from April to September and are most frequent on the west coast, where they occur approximately fifty times a year.

Although the frequency of occurrence decreases toward the east coast, the characteristics and effects of these winds are no less noticeable.

The onset of the wind is normally associated with an increase of temperature that frequently exceeds 10°C.

The cessation of the wind, however, can be even more marked, especially when termination occurs with the passing of a cold front.

Rapid decreases of temperature, exceeding 15°C, are not uncommon under such conditions.

Local winds

A feature of the winter circulation that needs mentioning is the occurrence of well-developed local winds in the deep valleys of the marginal areas between the Escarpment and the sea.

Most marked in Natal, these winds are to be observed on almost every clear day.

During the day air movements are up the valleys, and above ridge level a deep, integrated drift of air takes place toward the Drakensberg as a characteristic southeasterly breeze.

During cold winter nights the direction of movement is reversed and local down-valley winds are to be experienced in most, if not all, valleys.

Above the ridges a cool north-westerly wind a few thousand feet deep blows from the Drakensberg toward the sea and can be distinguished from its general circulation counterpart of the same direction by the negative temperature departures it produces.

Summer circulation patterns show a slight weakening and southward movement of the anticyclone centred over the Eastern Transvaal, as shown in the contours of the 850-mb surface for January, Fig.59.

Development of weak and shallow troughs of low pressure at the surface of the plateau permit the influx of humid air from the Indian Ocean to the east and from the damp African lowlands to the

north.

The heat low near the surface weakens rapidly with height, so that the circulation at about 2 km is anti-cyclonic.

More important than the lowered pressure near the surface, however, is the fact that the subsidence inversion, present in winter over so much of eastern South Africa and which restrains the free vertical flux of moisture, is to be found above the level of the plateau, if present at all.

Thus inland transport of moist air takes place freely over the plateau eastwards and southwards around the anti-cyclone at 2 km, and in summer the moisture content of the air rises to 12-14 grams of water vapour per kilogram of dry air. Fig.50

North of about 20° S. the zone of converging air, in which the rains of tropical Africa occur, has moved south. Fig.48, shows the principal air-streams involved in the convergence - the Atlantic air entering Africa at about 12°S., the Monsoon Current flowing across the equator from the north-east and the tropical maritime air from the Indian Ocean originating in the south-east trade winds over Mozambique.

Vertical transport of air takes place freely in this situation of convergent winds.

Rains are convectional and the analogy with a mid-latitude frontal system must not be pushed too far.

The essential condition seems to be slow vertical motion, associated with convergence in the wind field and maintained throughout a layer of moist air deep enough for the latent instability of the air mass to be realised.

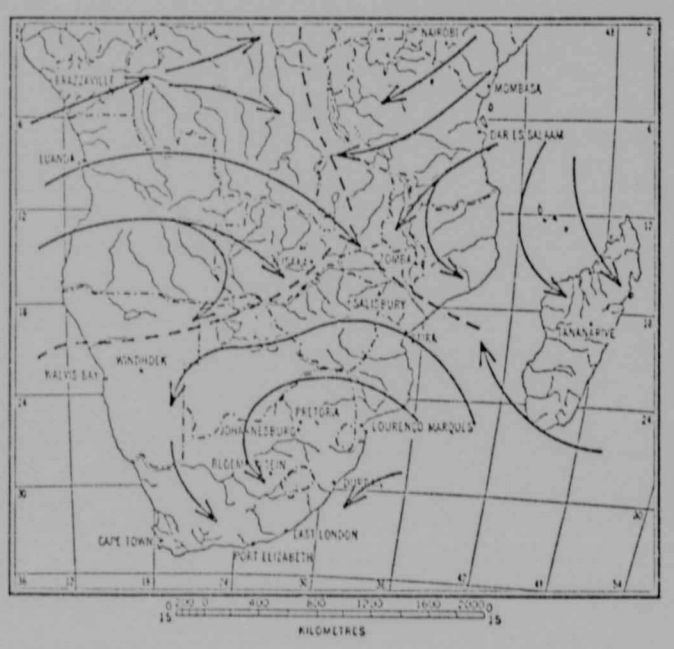



Fig.48: Converging air-streams in summer

Rains are usually heavy, occasionally violent and accompanied by hail.

Sometimes, though rarely, rain continues throughout the day.

Usually a clear diurnal pattern occurs, with most of the rain falling in the late afternoon and in the evening.

Characteristic of the summer plateau weather of South Africa is the occurrence of thunderstorms, which form the main source of rainfall.

Storms occur most frequently, not as isolated thermal convection cells, but as organised line thunderstorms, almost always advancing from the south- west and apparently against the surface wind of a northerly component.

Thus the storms form in two opposing currents: a warm and humid surface current and a cool, subsiding south-westerly current at a height of about 4 km.

Warming of the surface air by thermal convection probably initiates the instability, while convergence of the surface air over the subsiding south-westerly air realises the instability and leads to heavy precipitation of rain and often hail.

Strong down draughts in the storm cells act to invigorate the storms by providing wedges of cool air, over which the warm, unstable air may rise in a process analogous to frontal convection.

At the same time the down draughts give rise to the characteristic storm collar of a line squall and high wind speeds of variable direction and considerable turbulence are usually experienced.

As the winter circulation of the South-Western Cape is distinctive, so is the circulation in the summer months, the dry and windy season.

South and south-east winds prevail for about 60% of the time, with force and direction being modified to some extent by the alignment of the mountains.

At times the anti-cyclonic Cape south-easters are notoriously strong and gusty, and in the vicinity of Cape Town may blow with gale force for two or three days at a time.

These winds are not usually associated with bad weather, but with typical fair-weather clouds capping the mountains, as in the case of the 'table-cloth' on Table Mountain.

Occasionally a 'black' southeaster may

bring some rain to the south-western and southern coast (while the normal cloud cap on the mountain is associated only with the wind).

The popular belief that a south-easter in the Cape brings rain to the Highveld is to some extent true, for the same anti-cyclonic circulation that produces the Cape wind may produce widespread advection of moist air over eastern South Africa and in so doing may produce rain.

Local mountain and valley winds are widespread in Natal during summer, with the former being very much weaker than in winter and often non-existent, while the latter are much stronger.

Convergence of the south-easterly valley wind along the Escarpment zone of the Drakensberg undoubtedly contributes to the frequent summer occurrence of thunderstorms in this area.

Along the coasts " sea-breezes " blow more strongly for a longer daily period than in winter.

Regular sea-breezes are an important feature of the climate of the entire coastal region, but are especially marked along the Natal and Namib coasts.

On the west coast the sea-breeze is much stronger than on the east coast, owing to the absence of vegetation and the strong land/sea temperature gradients that are present as a result of the juxtaposition of cold sea and hot desert.

On both coasts the sea-breezes back during the day, so that during the afternoon they blow at a small angle to the coast and in close adjustment to the direction of the gradient wind.

Thus at Maputo, the breeze is southeast, at Durban north-east and at Walvis Bay south-west.

During winter the mean circulation pattern is a good representation of the daily synoptic situation, in which anti-cyclones dominate the plateau areas, with few interruptions by rain- bearing disturbances.

Types of Weather

Though much study remains to be done, it is possible to make a tentative classification of weather types affecting Southern Africa.

The typical fair-weather type conforms closely to the mean anticyclonic circulation.

During midsummer (November-February)

anti-cyclonic synoptic situations will prevail with about 17% frequency, in contrast to the 77% frequency for midwinter (June-August).

The high winter maximums of anti-cyclonic activity explains the bright, cloudless, hazy days and cold nights of plateau areas so typical of this season.

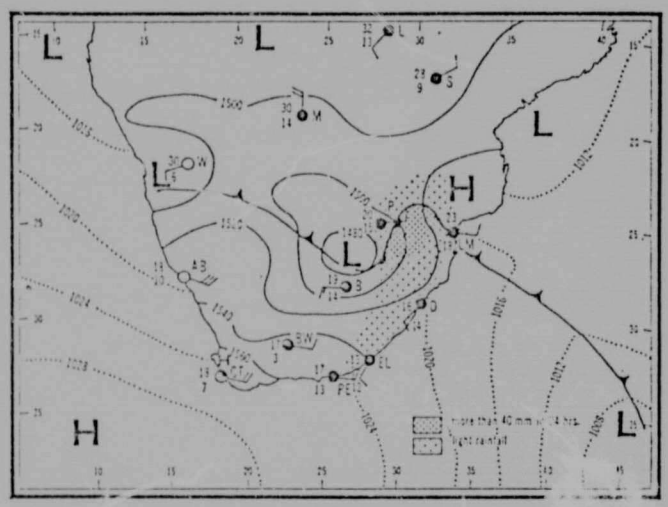
Most warm spells occur with synoptic situations similar to those outlined for the occurrences of berg winds, i.e. situations characterised by a weakening anti-cyclonic circulation, associated with the approach of a cyclonic disturbance from the south-west.

Weather is essentially of a pre-frontal nature, and unpleasantly hot conditions occur most frequently during August to October, especially in coastal and adjacent inland areas below the Escarpment.

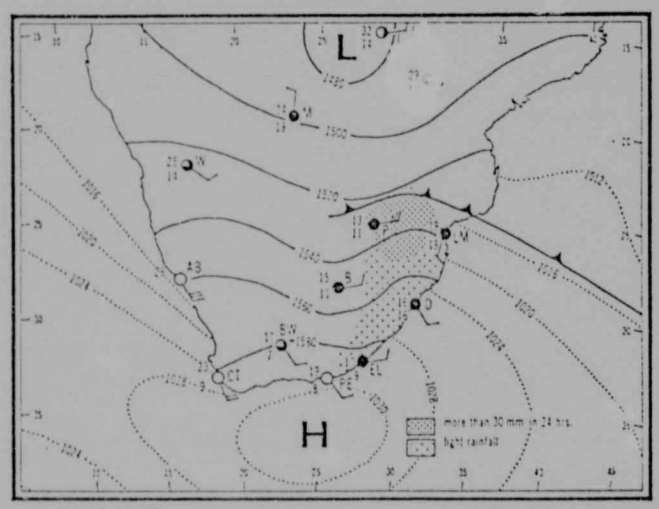
The cold-spell weather type occurs with the passage of a deep cyclonic disturbance and a pronounced cold front over Southern Africa.

This in turn is followed by the strong advection of cold and unstable sub-polar air from the south-west.

Cold snaps occur most frequently in winter, with maximum activity in August.




(a) 25.10.67




(b) 18.11.67

Fig.49 a), b): Isobars at mean sea level (broken lines) and contours (in meters) of the 850 mb surface (solid lines).

With the stagnation or slow movement of a

depression over Southern Africa (a so-called cut-off low) a situation such as is illustrated in Fig.49 a), exists.

With this type of situation it is common to find that as the depression and cold front move north-east warm, humid air is drawn increasingly into the low from the Indian Ocean.

Along the discontinuity between tropical and subpolar maritime air, as well as within the two air masses, widespread rainfall can occur over a period of up to a few days.

Along mountain ranges and the Escarpment rain may be particularly heavy. Occurring in all seasons, this type of weather reaches its maximum during January-April with about an 18% frequency.

Most floods in South Africa occur in association with cut-off lows, just as droughts occur with prolonged anti-cyclonic activity.

Prolonged rainy and cloudy spells on the plateau are also frequently associated with advection of unstable maritime air from the east.

Occasioned by an anti-cyclone off the southeastern coast, steady convergence within the air mass itself (and accentuated by orographic influences) causes realisation of the instability. As a result widespread rains may occur, mainly in summer.

An example of such an occurrence is given in Fig.49 b).

With a southerly extension of the low-latitude trough of low pressure and the consequent advection of tropical continental and maritime air from the north, the synoptic situation is often favourable for widespread shower activity.

The precise situation conducive to thunderstorm and shower activity is, however, almost impossible to define, as storms occur with a variety of situations, frequently including the fair-weather anticyclonic type.

Between November and February situations conducive to storm formation occur with about a 26% frequency on the plateau.

## CLIMATIC ELEMENTS

### Radiation and Sunshine

Total radiation from the sun and space is at a maximum over the western interior and at a minimum over the east coast.

The opposite happens in the case of diffuse radiation.

Clear skies and dry air in the west permit maximum transmission of energy, whereas in the east the higher moisture content of the air and more frequent cloud cover give rise to greater attentuation of direct solar energy and greater diffuse radiation from the sky and clouds.

Considering annual radiation over Durban, one finds that 53% of the radiation received at the outer limit of the earth's atmosphere penetrates to the ground, and of this 38% is in the form of diffuse radiation.

At Keetmanshoop, on the other hand, 73% is received at the ground, of which on 17% is diffuse radiation.

Pretoria, with an annual average radiation receipt of 473 cals/sq cm/day (61% of energy received at the top of the atmosphere), receives 138 cals/sq cm/day in the form of diffuse radiation and falls between the extremes given above.

Apart from latitudinal movements of the sun, variations in circulation and weather patterns cause marked seasonal variations in the receipt of radiation.

Long hours of sunshine, possibly more than any other factor, are responsible for considering South Africa's climate, particularly that of the plateau areas, to be one of the finest in the world.

Duration of mean and annual sunshine is given in Fig.63.

Maximum sunshine is recorded in the dry western interior, as at Beaufort West and Kimberley, where 78% of the possible maximum is recorded.

Further to the north-east Pretoria receives 74% and Pietersburg 69%.

Coastal areas of South Africa receive the lowest percentages of the possible yearly maximum: Cape Town 67%, Port Elizabeth 67%, Durban 54%.

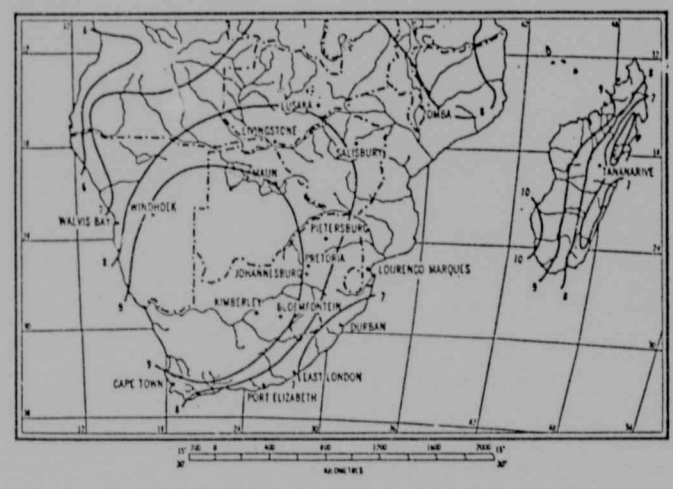



Fig.50: Mean annual sunshine (hours/day)

By comparison with the figures quoted above, Washington receives 57%, San Francisco 65%, London 33%, Rome 53% and Sydney 49% of possible sunshine.

Sunshine variability generally increases from west to east.
Cloud cover varies from less than two-tenths over Bushmanland and Namaqualand to more than six-tenths over the eastern plateau margins in January.

In July it is less than three-tenths almost everywhere excepting the South-Western Cape and the coastal fringe, extending to Natal.

Precipit

Precipitation is undoubtedly the most important climatic element in Southern Africa, as large areas are sufficiently arid to be incapable of supporting human settlement and agriculture.

Less than one-third of the country receives enough rain for reliable agriculture without irrigation, and the high intensity of precipitation and long duration of sunshine make it less effective than it would be in a region of more temperate climate.

Evaporation losses are high and vary from more than 404 cm a year in the western interior and southern South-West Africa to less than 152 cm in parts of Natal in the mist belt between altitudes of 457 and 1,524 metres.

Throughout Southern Africa water is considered an important natural resource and as such is carefully conserved.

Mean annual precipitation is given in Fig.51.

Two important features of the annual distribution are at once apparent: the first is the east-west decrease in rainfall south of 20°S., the second is the strong control exerted by relief.

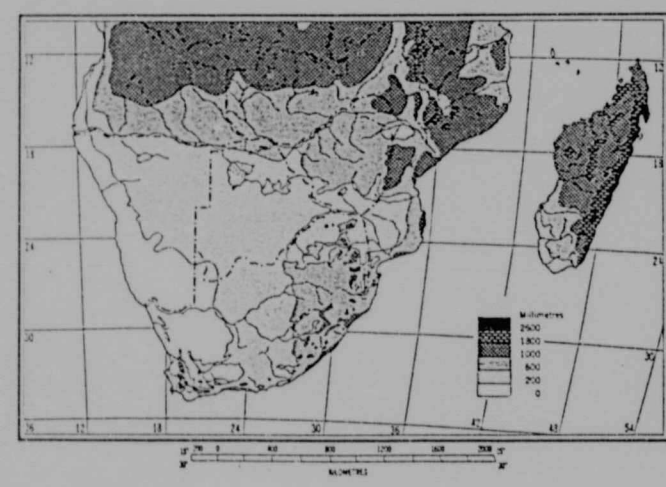


Fig.51

As an instance of the east-west decrease the following annual rainfall figures can be quoted: Durban 1,008 mm, Bloemfontein

564 mm, Kimberley 414 mm, Upington 156 mm, Alex-ander Bay 41 mm.

The cause of the decrease in rainfall westwards over continental Southern Africa is not easy to state in simple terms.

The explanation cannot be sought from the south-east trade winds, as these do not ordinarily occur south of Mozambique and are normally shallow circulations not penetrating far inland.

On-shore south-easterly winds occur along the littoral of Natal only when induced by off-shore disturbances, while the frequent south-east winds of inland Natal are almost entirely local and a fair-weather phenomenon.

Westward flow of moisture from the Indian Ocean around the northern periphery of the continental anticyclone in a layer about 1 km deep in summer is significant in influencing precipitation over the eastern half of the continent.

In addition, temperatures in the upper air are lower (promoting atmospheric instability) than over the central plateau and west coast, where subsiding air increases atmospheric stability.

In the first 5 km above the surface to the east the atmosphere is relatively damp, has a fair lapse rate and slow upward motion.

In contrast, the drier air over the western plateau has a low lapse rate and tends to be descending.

For the realisation of potential instability these differences between the east and west of the plateau are important enough to account for the main differences in rainfall.

At the same time the weakened anti-cyclonic control in summer is sufficient to allow frequent interruption by perturbations and their maritime air, mainly from the westerly air-stream of middle latitudes as well as from tropical latitudes, though to a lesser extent.

Abnormally wet summers are associated with negative departures of pressure, stronger cyclonic activity in the westerlies and further southward penetration of the equatorial trough than is usual.

On the other hand, dry summers occur with positive pressure anomalies and increased anti-cyclonic activity.

Rainfall exceeding 1,400 mm occurs only in the highlands of Malawi and

Mozambique, and along the Transvaal and Natal Drakensberg and the north-south trending Cape mountains.

All the areas of highest rainfall coincide with prominent ground elevations, and local variations between low- and high-lying ground may be pronounced.

For instance, Broederstroom (altitude 1,549 metres) in the Eastern Transvaal Drakensberg, receives a yearly rainfall of 2,088 mm, while Tzaneen (774 metres), at the foot of the Escarpment, receives 906 mm.

Similarly, Bergville in Natal receives 749 mm, while 34 km away, in the foothills of the Drakensberg at Cathedral Peak, 1,262 mm is received.

In the Cape, Cape Town receives 627 mm, the top of Table Mountain 1,780 mm, while in the Jonkershoek Mountains at Stellenbosch the mean annual rainfall is 3,200 mm.

In the same way as mountains have a positive effect on rainfall, so the deep valleys and lowlands have a negative effect.

In the lowlands of the Limpopo valley, separating the plateau of Zimbabwe and the Transvaal, rainfall decreases in places to less than 300 mm and, as in the case of the Zambezi valley, the dry semi-desert extends to almost the east coast.

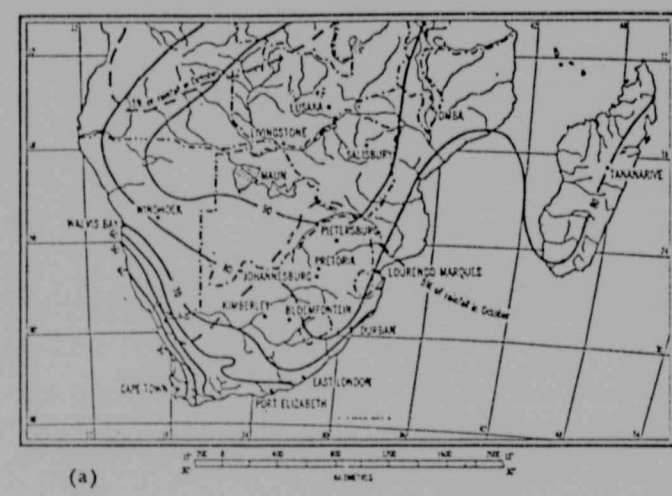



Fig.52 a) Summer rainfall b) Seasonal rainfall

All the major river valleys of the eas-

rainfall results from instability showers and thunderstorms.

In the South-Western Cape and south coast areas rainfall is of lower intensity but longer duration, owing to its origin in perturbations and disturbances in the "westerlies".

Maximum thunderstorm activity takes place along the Natal Drakensberg, Fig.53, while vast areas of the plateau experience more than 70 thunder days in a year. Since thunder activity is confined almost entirely to the period October-March, it can be expected on about 40% or more of days in summer on the plateau.

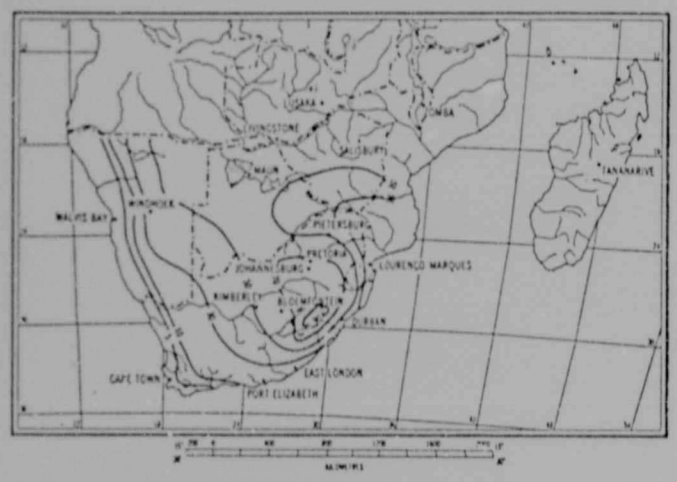



Fig.53.

Storms are least frequent along the west coast and in the South-Western Cape, where the frequency of occurrence is less than five days a year.

Generally greatest intensities of rainfall occur in the storms of the Highveld and Escarpment zones, where rainfall exceeding 10 mm an hour occurs in more than 7% of all storms.

Intensities of 254 mm in 1 hour have been recorded on a few occasions in various parts of the country, while the greatest storm intensity so far recorded in a South African storm is 610 mm in 24 hours at Eshowe on 5 May 1940.

Unlike the annual variation of rainfall and thunderstorms, hailstorms occur most frequently in late spring, usually November, when lapse rates are steep and temperatures high.

Over the Highveld the average number of hailstorms per year is about 5.

In Lesotho the figure rises to 8 per year.

Hail shows a strong diurnal variation and seldom occurs except between midday and 10 pm., with maximum occurrence between 5 and 6 p.m.

Snow occurs mainly on the mountain ranges of the Cape and those of Lesotho and

Natal. In the first case about 5 falls a year can be expected; in the latter cases about 8.

Temperature

Air temperature in Southern Africa depends to a great extent on the altitude and configuration of the land.

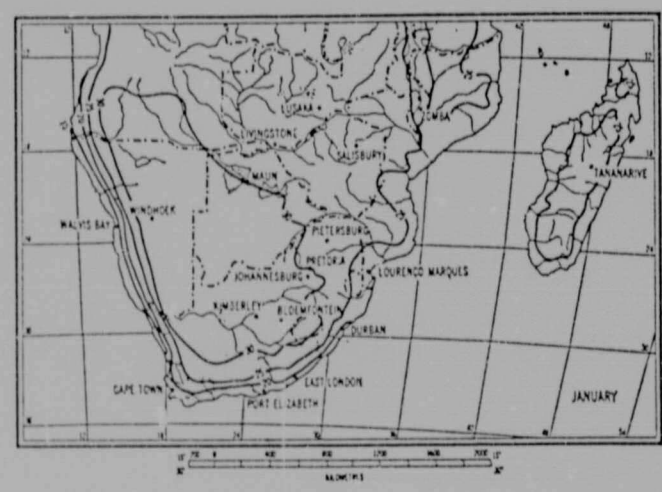
In a region that extends through more than 20 degrees of latitude, that varies from sea-level to a plateau at 1,524 metres and to mountains exceeding 3,048 metres in height, the range of temperature conditions is great indeed.

Mean annual temperature varies between 23,3°C at Goodhouse in the western Orange River valley to about 38°C in parts of the Zambezi valley and to 11,5°C at Mokhotlong in Lesotho.

The temperature of the surrounding seas and the nature of the ocean currents may also greatly affect temperatures along the coast.

Thus at 29° S. the mean annual temperature on the west coast is 15°C, while on the east coast it is about 21°C.

Generalised isotherms of mean surface temperature tend to follow the contours of the ground, and lowest temperatures occur along the Escarpment zone, from Sutherland in the South-Western Cape to north of Belfast in the Transvaal and on into the highlands of Zimbabwe and Malawi.



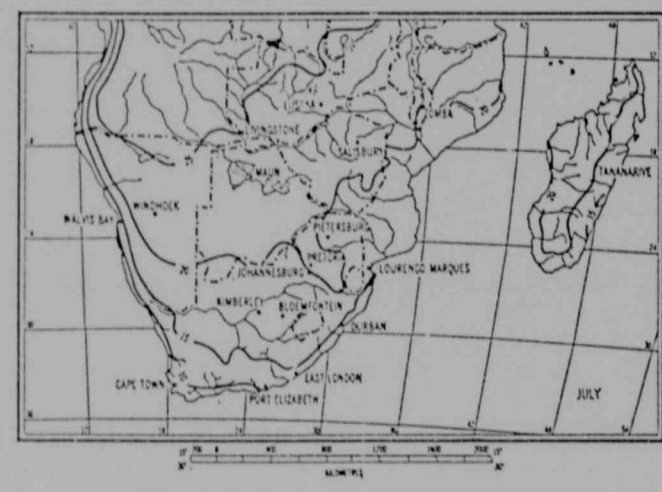




Fig.54: Mean daily maximum temp. in °C

Highest temperatures are experienced in the Kalahari and in the lowlands of the

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