

THE INTEGRATIVE NATURE OF THE SYNOPTIC WEATHER MAP
IN RELATION TO ADOLESCENT COGNITIVE STRUCTURES
AND THE TEACHING OF SENIOR SECONDARY
METEOROLOGY-CLIMATOLOGY



by

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A B S T R A C T

A poorly consolidated concept base creates considerable difficulty amongst adolescents when it comes to the higher order task of analyzing complex, abstract and scientific weather phenomena as they appear on synoptic charts. The nature of the difficulties which they experience tends to encourage them to resort to the rote memorisation of concepts rather than understanding them. Kuhn (1962) avers that concepts, not enquiry methods, are at the core of rational thought. A well taught concept becomes a well developed mental construct which encourages understanding.

It is the author's firm belief that in order for pupils to come to a thorough understanding of senior secondary meteorology-climatology and the synoptic chart, teaching of basic concepts should be graded and sequential.

This thesis attempts to show the difficulties inherent in synoptic climatology. It relates these difficulties to adolescent cognitive development. Within this framework, the syllabus and past examinations of the Cape Education Department, and textbooks are examined.

Teachers' views and pupils' understanding are gauged through the analyses of questionnaires and worksheets respectively. Conclusions are drawn and the problems which teachers and pupils encounter are addressed.

P R E F A C E

Mapwork skills are fundamental to geographical activity. My pupils over the past seven years have found difficulty with concepts relating to topographical maps. The inability to visualize the three-dimensional equivalents of the two-dimensional representation of reality appears to be a general problem. This concurs with the findings of Burton (1986). I have found that the problem is exacerbated when the same skills are required of pupils with respect to synoptic charts. The reasons for this may be many. Meteorology is scientific, its concepts are abstract and complex and its dynamic nature makes the study of a specific situation difficult. Synoptic climatology thus becomes an intangible reality with which children experience difficulty.

Weather charts contain a myriad of complex ideas which are intangible. Unlike the static portrayal of landform on topographic maps, surface synoptic charts are momentary depictions of dynamic and ever-changing air masses. Meteorologists can often only make sense of the weather on synoptic charts when they are analyzed in conjunction with charts for a given time sequence and their corresponding upper air maps. The synoptic chart is an integrated representation of many imperceptible ideas.

Pupils do not come to a full understanding or appreciation of these complexities and interrelationships unless they acquire an understanding of those basic phenomena and concepts which appear in some form on the weather chart. My hypothesis is that the analysis and interpretation of synoptic charts is dependent upon the acquisition of a sound concept base, and furthermore, that the skills involved in meteorology-climatology are of such a high order that less able pupils are at a distinct disadvantage. To overcome these problems deliberate classroom strategies are needed.

It is my concern that pupils resort too quickly to rote memorisation of fact and have seldom come to a mature understanding of meteorological and climatological concepts. This may be a consequence of several factors, one of which may be the teaching strategy.

Miller (1953) states that weather science concepts need to be given their due consideration to facilitate a description of the atmospheric environment. The device which comes closest to this aim is the synoptic chart. Miller (1953, p 100) states that with time the "mental processes involved may become subconscious but they are never subjective or unscientific". In Ausubelian learning theory meaningful forgetting amounts to the spontaneous obliteration of irrelevant detail. A well taught concept, however, is well integrated and promotes understanding.

What is presented in the following chapters is an attempt to make the challenging task of teaching climatology easier for teachers, stimulating for higher grade geographers and manageable for standard grade pupils. Much of what follows is drawn from my classroom experiences over the past seven years.

A C K N O W L E D G E M E N T S

I wish to record by sincere gratitude to Dr E.A.G. Clark (Rhodes University Education Department, Grahamstown) for his support and encouragement, his interest in my research and for willingly devoting many hours beyond the call of duty to the task of assisting me.

Bev, my wife, has spent many hours at the typewriter. For her infinite patience, readiness to make last minute amendments, proof-reading and for being a wife and mother all at the same time, I am immensely grateful.

Without the Cape Education Department's permission to allow me to do research in East London schools this study could not have been undertaken. My thanks go, too, to the teachers who volunteered their time and classes for the completion of worksheets and questionnaires and their five hundred and thirty-three charges who willingly completed the worksheet. I am indebted also to the headmasters of the five participating East London schools without whose consent the research could not have been conducted.

Last, but not least, I record my appreciation of the financial assistance granted by the Human Sciences Research Council. The opinions expressed in the text are solely mine and do not reflect the views of the Human Sciences Research Council.

For Bev, who has taught me so much about patience and perseverance, and Lauren, whose first three months have been more academic than she would ever imagine!

Also for Dr Cecil Keen, who instilled in me a love for Meteorology.

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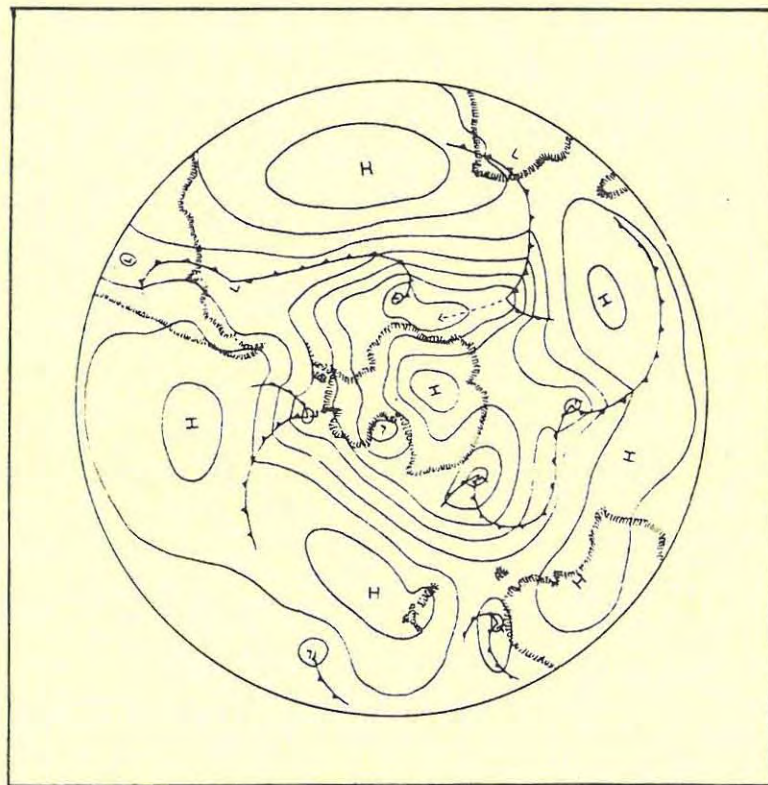
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CHAPTER 1

AN OVERVIEW OF THE SYNOPTIC CLIMATOLOGY OF SOUTH AFRICA
AND THOSE PHENOMENA RELEVANT TO THE STUDY AND DEEPER
UNDERSTANDING OF SYNOPTIC CHARTS AT THE
SENIOR SECONDARY LEVEL



Circumpolar synoptic chart for 4 September 1958 (during the International Geophysical Year, when additional and special weather observations were made). The following features can be clearly seen: subtropical cells of high pressure; inter-cell-cum-polar fronts, with wave depressions; a (slightly off-centre) polar high

AN OVERVIEW OF THE SYNOPTIC CLIMATOLOGY OF SOUTH AFRICA
AND THOSE PHENOMENA RELEVANT TO THE STUDY AND DEEPER
UNDERSTANDING OF SYNOPTIC CHARTS AT THE
SENIOR SECONDARY LEVEL

For the purposes of this chapter, the author has consulted the works of Tyson, Jackson and Taljaard, each an expert in the field of South African weather and climate. The work of these writers is more recent and detailed than the general and dated accounts of Wellington and Cole. The literature on South African weather and climate is dominated by many articles on specific topics rather than overviews of South African weather in general. The work of Hurry and van Heerden is a recent, concise resumé of South African weather and this work has proved to be a useful diagrammatic resource. Hattle (1972) provides an extremely valuable and readable exposition of the climate of the southern hemisphere. This account places the African subcontinental weather in a global perspective and clearly contrasts the homogeneity of land surface patterns in the southern hemisphere with the heterogeneity of those in the northern hemisphere. This contrast leads Hattle to suggest that the synoptic conditions prevailing in the southern hemisphere are more general than those in the northern hemisphere. The most recent and comprehensive account of the weather and climate of Southern Africa, however, is that by Tyson (1986). It is this text that has served as the basic meteorological literature source. Where works by the authors mentioned in this paragraph have been used, the articles are specifically referenced.

To the meteorologist the distinction between weather and climate is an obvious one. To the layman, however, the distinction is not as clear. The short term fluctuations and disturbances in the state of the atmosphere are termed "weather". The trend or pattern which weather phenomena establish over extended time periods, through their repeated occurrence, is termed "climate".

This chapter sets out to show the short term weather features as a functional part of the South African climatic context. It is often these short term weather features which characterise mesoclimates, and it is often with these mesoclimates that regions become associated.

The organisation of the chapter is such that the macroscale setting forms the introduction, followed by an investigation of the mesoscale features by region. A short account of the distinctive local or "anomalous" features of the sub-

continental weather is then presented, followed by a presentation of synoptic charts and their accompanying satellite images typical of

- o summer rain
- o summer drought
- o calm, clear winter nights associated with frost
- o winter cold fronts over the south western Cape.

Finally schematic classifications of southern African weather types and cloud patterns, based on circulation patterns at the surface and at 500 hPa, are presented.

1. MACROSCALE SETTING

The physical characteristics of the South African subcontinent, its location in relation to the pressure and wind systems of the southern hemisphere and the nature of the oceans surrounding the continent are the primary factors which affect the weather and climate of South Africa.

1.1 Physical

The topographical variability of the coastal belt characteristic of the perimeter of the country accounts for local climates and winds. The coastal belt rises via the escarpment to a saucer-like plateau which extends across the country at an altitude of approximately 1500 m. The altitude of the west coast terrain is slight in comparison with the east coast Drakensberg.

1.2 Pressure systems

The latitudinal displacement of the Intertropical Convergence Zone (ITCZ) and its replacement by subtropical high pressure systems, and the westerlies further south carrying cyclonic disturbances and their characteristic weather, may be considered the two main synoptic controls.

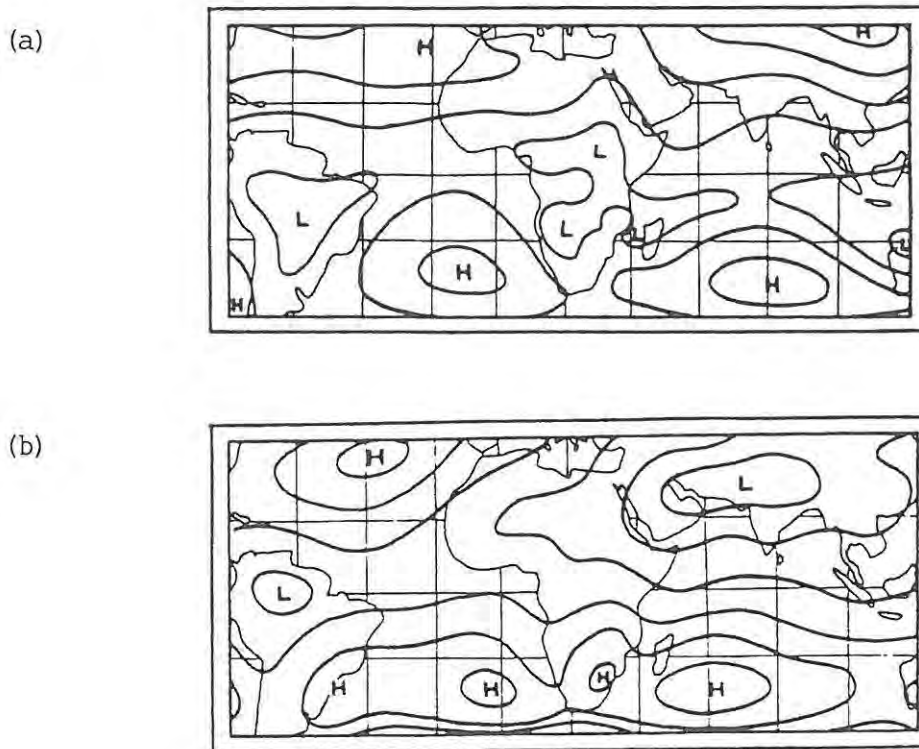


Fig. 1 Mean pressure patterns over Africa in the context of the southern hemisphere

(a) December to February

(b) June to August

(after Hattle, 1972)

1.3 Circulation patterns

The circulation patterns are associated with the pressure systems. The South Atlantic anticyclone is situated west of the Namib and South African west coast. The winds deriving from this system are south-westerly on-shore winds which traverse the cold Benguela current. Subsidence in this system is strong and stable conditions prevail, producing the dry climate of the west coast. Low stratus cloud and fog are characteristic of the west coast. Mean circulation patterns are shown in Figure 2.

The South Indian anticyclone fluctuates seasonally, moving toward and away from the east coast in winter and summer respectively. The sea level component of this system gives rise to east and north-easterly winds over the subcontinent. The shift of the South Indian anticyclone to the west during winter exerts a profound effect on the weather and climate of the northern and eastern parts of South Africa. The annual variation in position of the South Indian and South Atlantic anticyclones is illustrated in Figure 3.

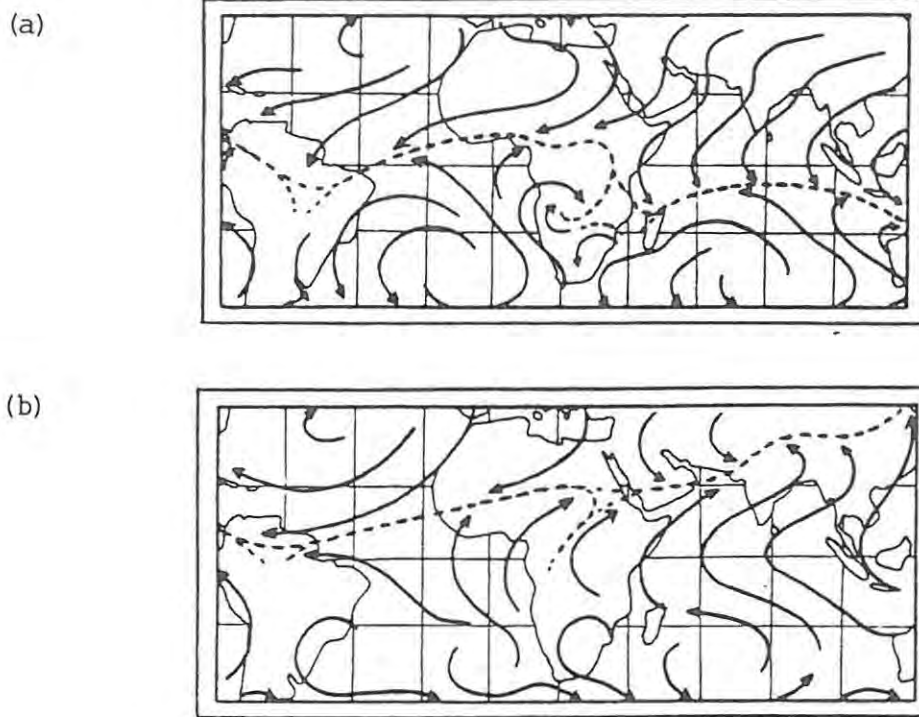


Fig. 2 Mean circulation patterns and the ITCZ over Africa
 (a) December to February
 (b) June to August
 (after Hattle, 1972)

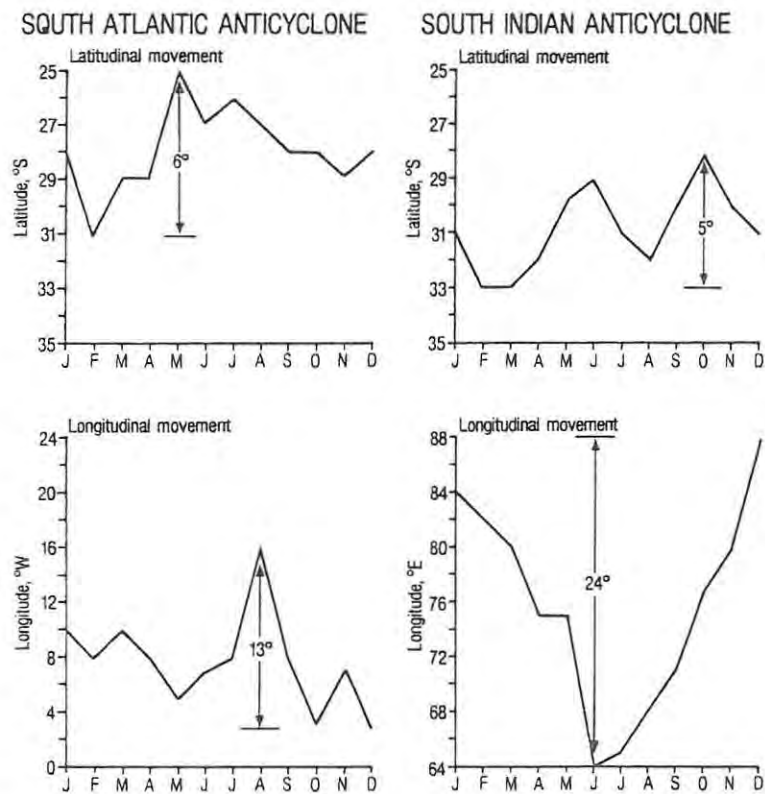


Fig. 3 Annual variation in the positions of the South Indian and South Atlantic anticyclones
 (as reproduced in Tyson, 1986)

Between latitudes 40° and 60°S , the westerlies, characterised by their zones of cyclogenesis, transport cyclonic disturbances eastwards. Their influence over the south-west and southern Cape coast is strongest during winter, when winds become north-westerly as the front approaches, changing to south-westerly as the front passes.

The greater thermal capacity of the land surface accounts for less simple pressure distributions and circulation patterns. An anticyclonic circulation predominates throughout the year over the plateau, subject only to a latitudinal shift between seasons. The anticyclonic system weakens and moves south during summer, the opposite being the case in winter. During July, the high pressure system is situated over the Eastern Transvaal, and these systems are typical of the winter period. Summer conditions are typical of those found in January. At the level of the plateau a weak thermal low pressure system develops, but weakens with height so that at two kilometres the circulation is again anticyclonic. The weak surface low permits an influx of moisture-laden maritime air from the east and from the wet tropical lowlands to the north. The vertical structure of the anticyclone, which is discussed later, accounts for the characteristic weather of the highveld.

1.4 Nature of the oceans

The potential for evaporation of the oceans flanking the subcontinent is a function of their temperatures. The water vapour content of the east coast air mass is greater by virtue of the warm Mozambique current flowing southward, eventually merging with the Agulhas current along the Cape south coast. The cold Benguela current, likewise retaining the thermal properties of its source region, flows northwards up the South African west coast. The moisture content of the west coast air is thus comparatively less.

Atmospheric Instability

Instability, as it relates to atmospheric moisture and temperature relationships, is the essential mechanism accounting for the weather of the troposphere. Sufficiently vertically displaced air results in the condensation of its water vapour content. Latent heat is released into the atmosphere. The lapse rate will then change from an initial dry adiabatic rate to a wet adiabatic rate. The wet adiabatic rate will intersect the prevailing (environmental)

Lapse rate and instability is realised.

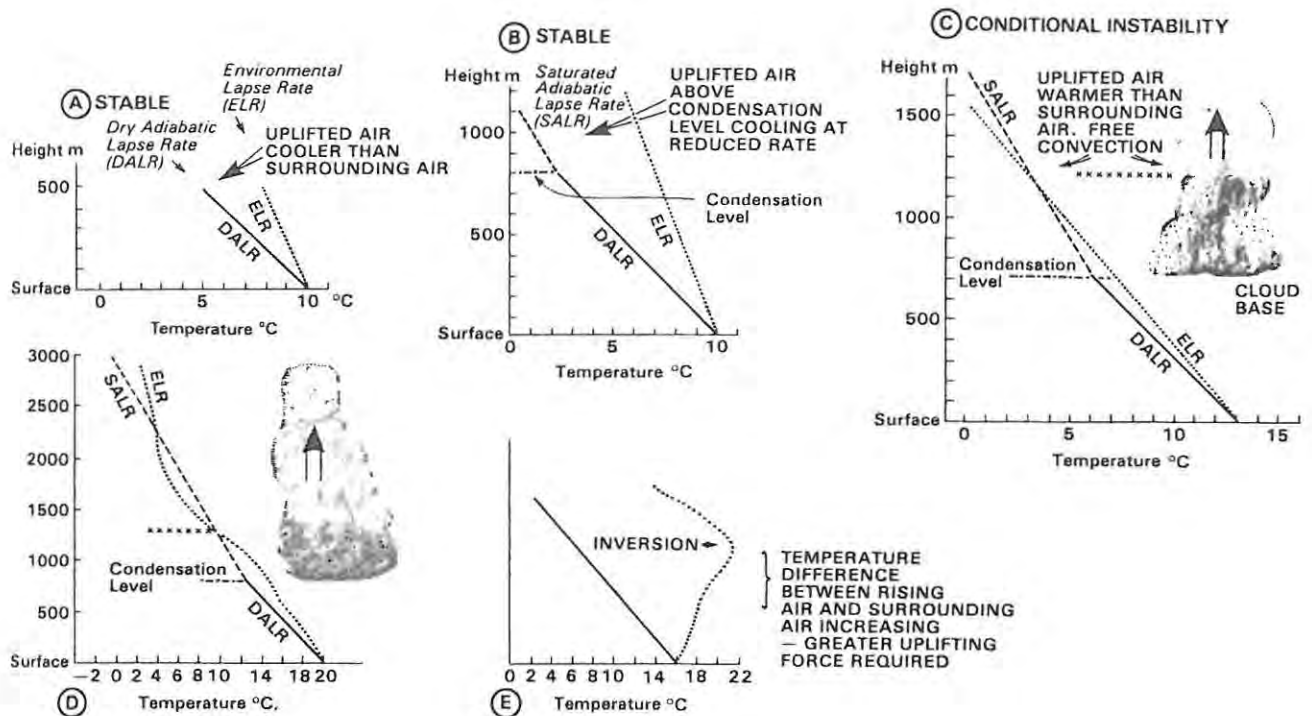


Fig. 4 Lapse rates, stability and instability (after Hilton, 1985)

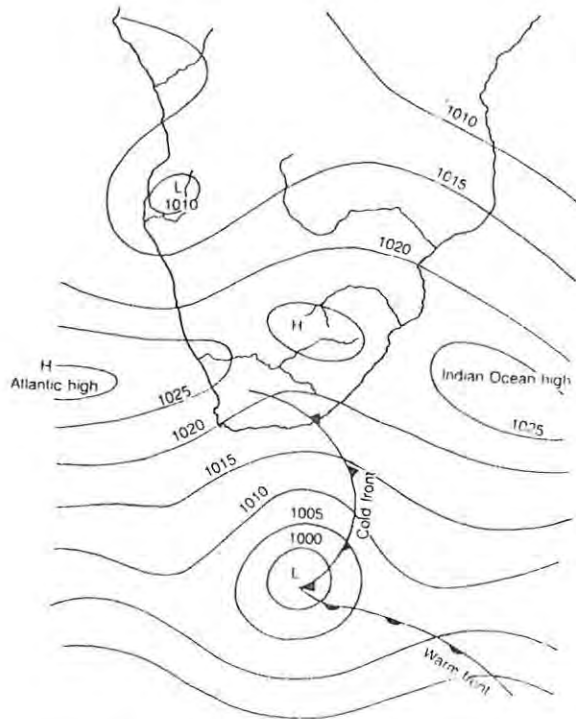
The instability of the atmosphere thus depends on

- o a sufficient moisture content, and
- o a mechanical lifting strong enough to overcome low level stabilities.

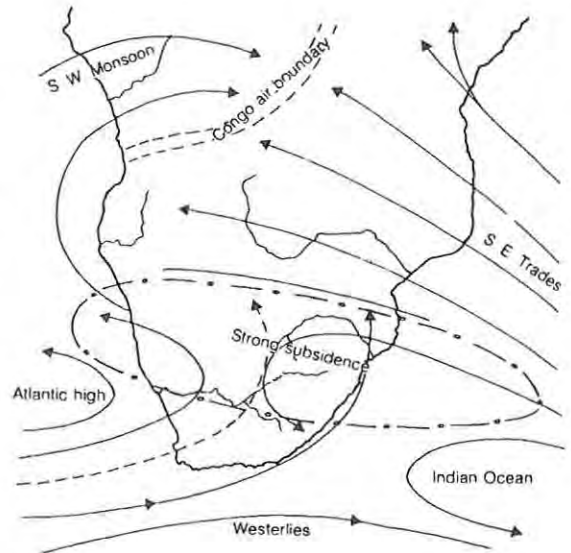
In the South African situation these requirements are fulfilled as follows. The moisture made available to the atmosphere by the evaporation, particularly over the Indian Ocean and the damp central African lowlands, constitutes a dynamic link in the hydrologic cycle as it operates over the subcontinent.

The macroscale picture presents two major regions where instabilities prevail so as to characterise the regions. This occurs on the Transvaal Highveld and in the south-west and southern Cape coast, during summer and winter respectively.

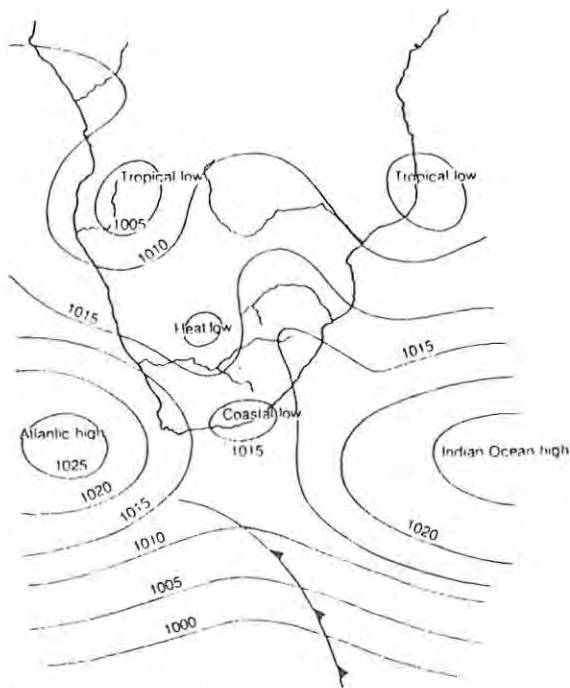
Over the Eastern Transvaal west of the escarpment, the convergence of air masses aids the development of instability line thunderstorms.



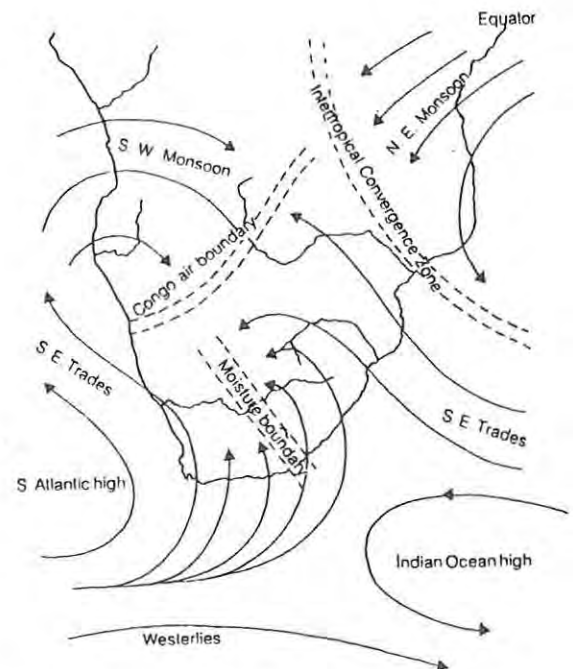
Basic elements in the pattern of pressure distribution for winter



Basic movement of air masses over Southern Africa in winter



Basic elements in the pattern of pressure distribution for mid-summer



Basic movement of air masses over Southern Africa in summer

Fig. 5 Pressure patterns and air mass movement.
Note Congo air boundary is equivalent to Zaire air boundary
(after Hurry and van Heerden, 1986)

East of the escarpment, orographic uplift (under the control of a temperature inversion) allows instability to be realised. Refer to page 13.

In the south-west and southern Cape, frontal uplifting in cyclonic systems, coupled with orographic uplift, induces instability and the associated winter weather.

2. MESOSCALE FEATURES

2.1 Highveld Thunderstorms

The main source of rainfall in South Africa is the thunderstorm, especially on the plateau (Tyson, 1964). The average number of days per annum on which thunder occurs is at its maximum over the Transvaal and along the Natal coast.

The Highveld thunderstorm is principally a summer phenomenon by virtue of the South Indian anticyclone feeding moist maritime air into the continent, beneath an elevated inversion. The available moisture is greater during the summer months.

The vertical structure of pressure systems over the Highveld is crucial to the understanding of the development of the thunderstorms, bearing in mind the need of moisture and a vertical wind shear for their inception (Newton, 1963, Ludlam, 1961, 1963). Figure 6 shows a section through a storm line adapted from Taljaard.

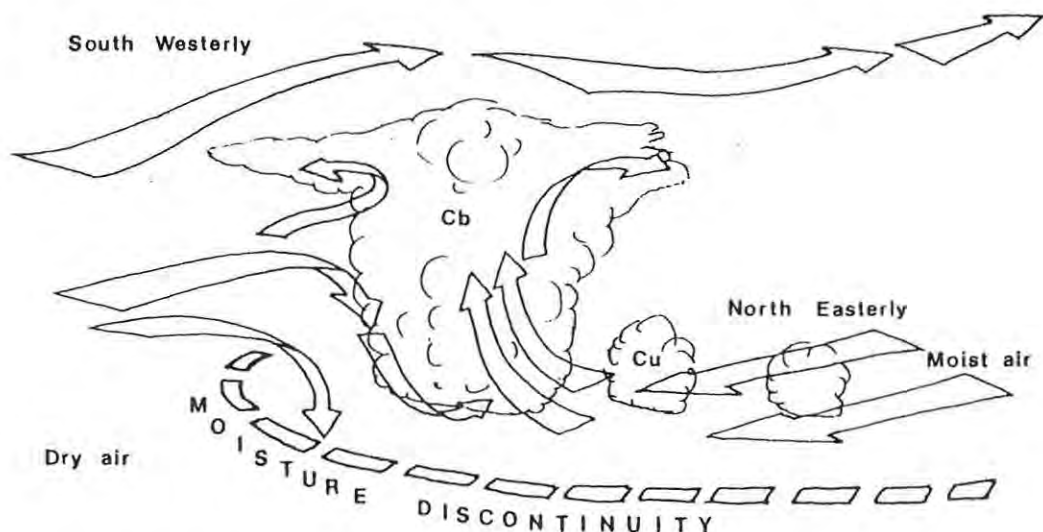
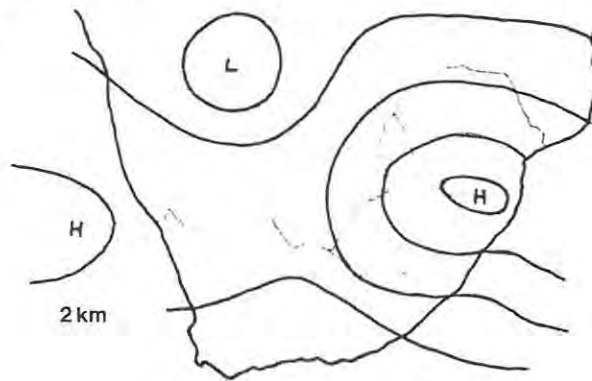


Fig. 6 The development of cumulonimbus thundercloud as a consequence of vertical wind shear (adapted from Taljaard, 1958)

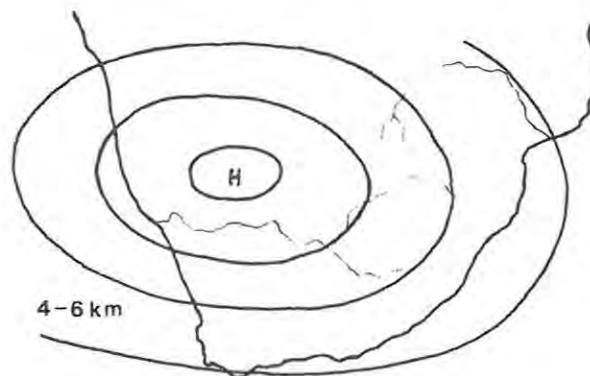
In summer a surface low pressure develops due to continental heating, producing convective low level turbulence which gives the initial impetus for uplift and instability. The low weakens with height, however, so that at two kilometres an anticyclonic circulation again prevails. This anticyclonic circulation is a feature of both the summer and winter atmosphere, the only difference being their seasonal strength and position. The anticyclone is stronger in winter. The axis of the anticyclone tilts sharply west north-west so that between four to six kilometres aloft the anticyclone is situated over South West Africa. (See Figure 7)

The Eastern Transvaal anticyclone drives the surface north-easterlies, and the superior anticyclone over South West Africa drives the south-westerly and south-easterly circulation aloft. The diminishing effects of friction with increasing altitude makes for strong wind velocities in the upper atmosphere. The exchange of momentum between the opposing current creates an imbalance which results in the formation of extended belts of thunderstorms near the leading edge of the maritime air (Talljaard, 1958). The moisture discontinuity is aligned NW-SE and advances north-eastwards, against the surface current, bringing showers to a large part of the Highveld.

Fig. 7 (a)

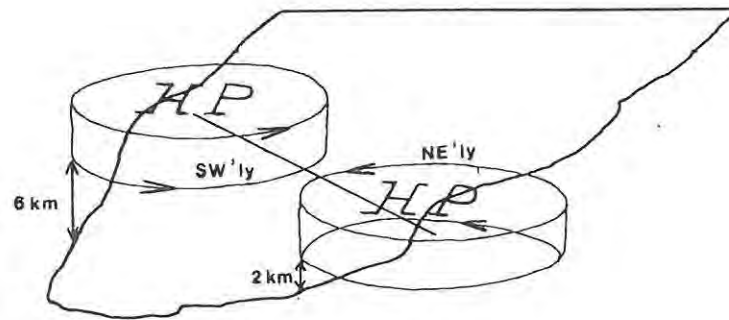


Comparison of surface and upper air pressure distribution in January. Note that in this example the upper air high pressure is displaced to the west and overlies the surface low



(after Hurry and van Heerden, 1986)

(b)



The three dimensional character of the perennial anticyclone over South Africa

2.2 Natal Thunderstorms

Natal experiences thunderstorms of similar origin. Preston-Whyte (1971) recognises peculiarities in the local situation and proposes modifications on Taljaard's work which does not account for local diurnal meso-scale features of the atmosphere and/or the low level westerly advection around the Lesotho massif.

The establishment of a surface low over the southern Orange Free State produces westerly winds (recorded at Bloemfontein) blowing toward the Lesotho massif. At Kokstad the winds are south-westerly. This may be explained in terms of the advection of the low level westerly air stream around the Lesotho massif, or to the presence of a coastal low inducing a cyclonic landward influx of low maritime air. The continental anticyclone further north is not explanatory of the north-easterly air stream since the isobaric patterns, as they occur, would engender an offshore component. The north-easterly winds are onshore - and it is thus suggested that these are sea breezes. The convergence of these three air streams is sufficient for the development of an instability line. These atmospheric circulations are illustrated in Figure 8.

The recognition of the crucial need for vertical wind shear for instability line development, by experts in the field of thunderstorms is also satisfied in the case of the Natal thunderstorm. The low level north-easterly winds are shown to back to north-westerly with height, with a change from velocities of ten knots to thirty to fifty knots respectively. (See Figure 9)

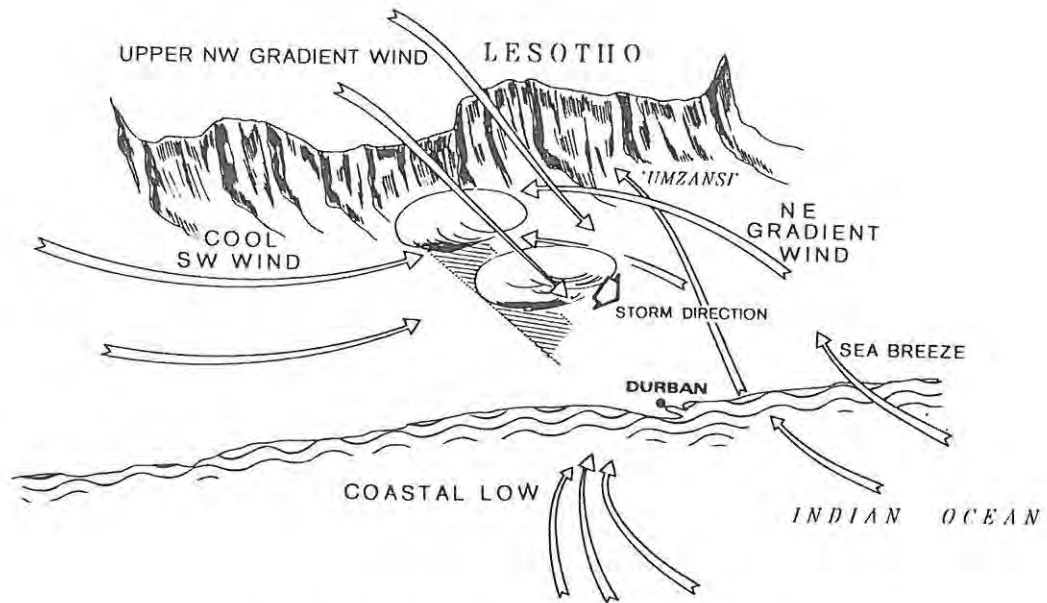


Fig. 8 Schematic diagram of atmospheric circulations associated with instability line formation in Natal
(after Preston-Whyte, 1971)

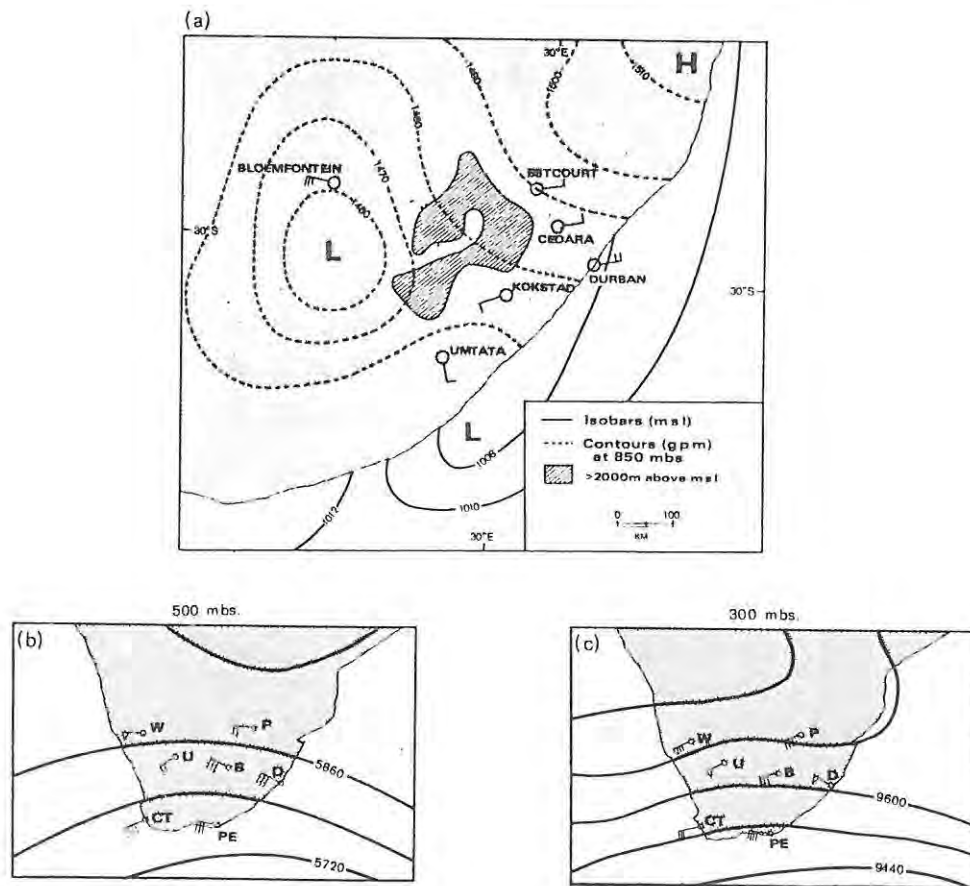


Fig. 9 Composite diagram showing for 9 January 1968, (a) surface, (b) 500 mb and (c) 300 mb pressure charts

As discussed earlier, the availability of moisture for the development of the thunderstorms is crucial. This moisture is largely available during summer and is advected inland beneath the inversion which is, on average, found above the plateau in summer as a result of a weakened anticyclonic circulation.

The Role of the Temperature Inversion in Thunderstorm Development

Taljaard (1958) recognises a high frequency of temperature inversions which separate moist surface air masses from subsided air over and above Southern Africa. These inversions are stronger in winter than in summer. The South African east coast serves as an example in explaining the seasonal effects of the stable discontinuity. (See Figure 10)

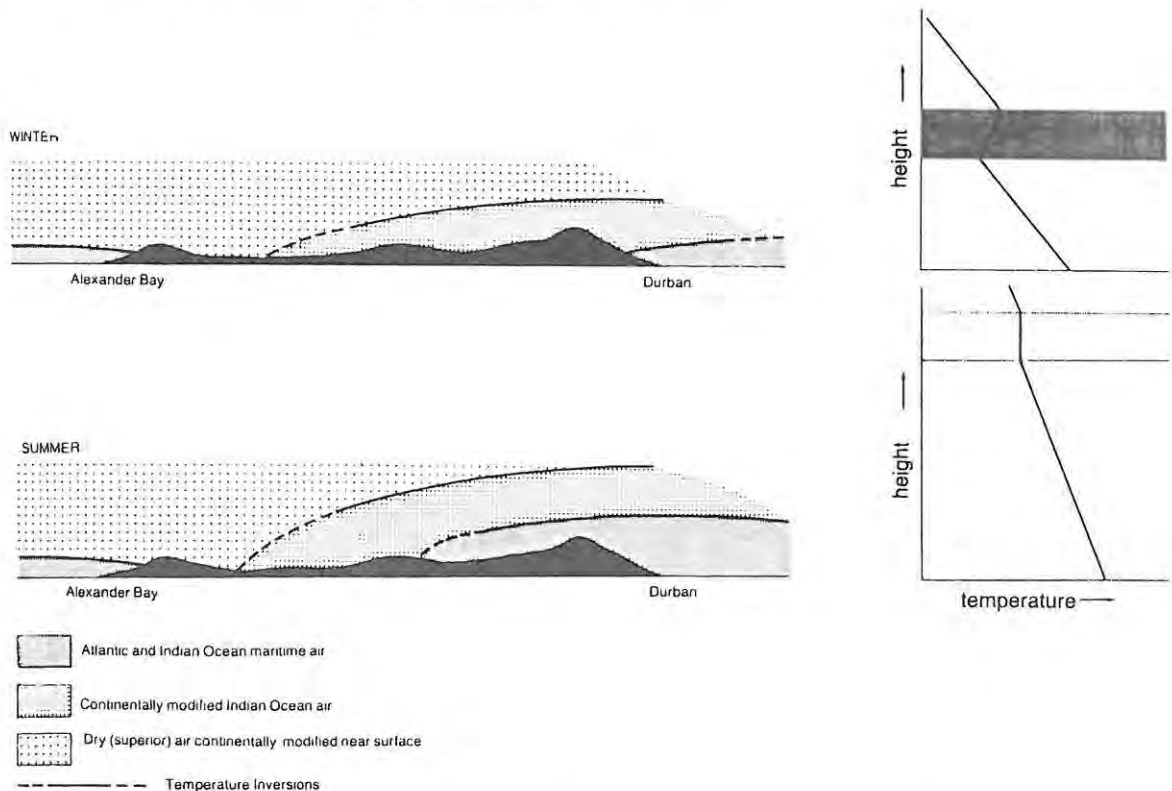


Fig. 10 Cross-section through the atmosphere (and corresponding temperature profiles) extending from west of Alexander Bay to east of Durban. The section shows the seasonal variation in the depth and location of maritime air, continentally modified maritime air and dry upper air

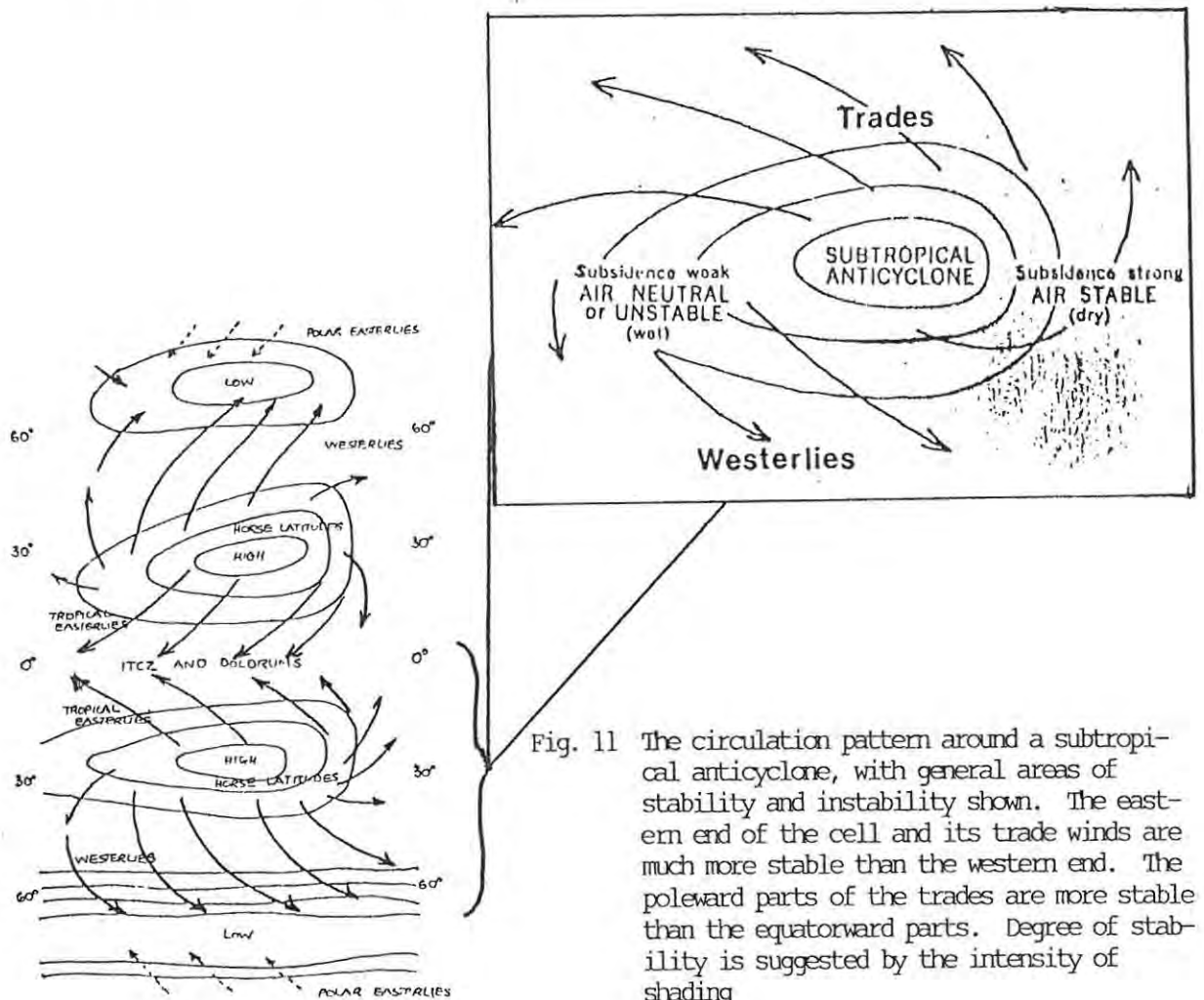
In summer the height and intensity of the stable discontinuity fluctuates, but is found above the level of the escarpment, and the due easterly winds of the summer circulation transport the moisture to the interior, where it is precipitated in the thunderstorms described earlier.

In winter the stable discontinuity south of the tropic is below the escarpment, because of the intensified high pressure system. Winds are now due south-easterly. (The change in the mean direction of the wind between seasons is attributable to the meridional displacement of the South Indian anticyclone.) The strong winter subsidence from the anticyclonic circulation produces clear skies and fine winter weather over the plateau.

2.3 Namib and South African west coast

The weather conditions in the western section of the country are remarkably different.

The South Atlantic anticyclone centred off South West Africa is the primary cause of the dry weather in the western sector. The eastern limb remains fairly stationary along the coast and subsidence is strong and persistent. (See Figure 11)



Subsidence and associated adiabatic warming effectively reduce the precipitable water content of the west coast air mass. The ineffective height of the west coast topography eliminates any consequential orographic influences.

2.4 South Western Cape

An exception to the arid western sector is the South Western Cape.

The latitudinal shifting ITCZ brings the south west Cape under the influence of the cyclones embedded in the westerlies during winter. The precipitation is a combination of cyclonic and orographic rainfall. The eastward travelling cyclones distribute their moisture along the south and south-east coasts during winter. With a southward shift of the ITCZ in summer, the cyclones skirt the tip of the subcontinent. The south coast between Gansbaai and Alexandria is a transition zone where rainfall is not seasonal, but perennial.

3. DISTINCTIVE AND ANOMALOUS FEATURES

3.1 Land/sea breezes

Jackson (1954) has devoted a paper to the sea breezes in South Africa. This land/sea breeze circulation is most marked on the west coast where the temperature differential is significant because of the contrast between mid-latitude continental heating and cold Benguela water.

The east coast sea breeze is not as strongly developed. The determinants of the land/sea breeze on South African coasts are summarised in Figure 12.

Of interest is the dependence of the sea breeze on the prevailing gradient winds on the east coast and the constant south-westerly sea breeze on the west coast. This is attributable to the southward displacement of the ITCZ being extensive down the east coast such that sea breezes between Maputo and Durban blow south-easterly and north-easterly respectively in summer at least. The effect of the land breeze on rain on the Natal coast has been studied by Preston-Whyte (1970) who discovered that land breezes are coincident with light rain at night.

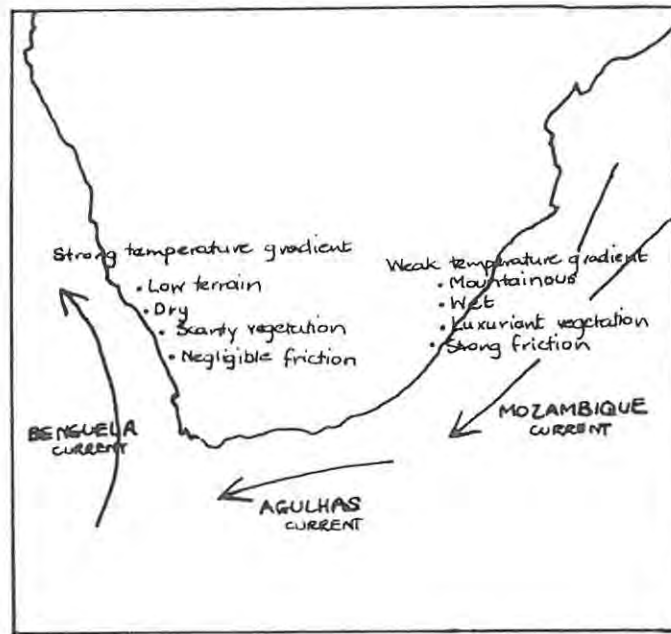


Fig. 12 Factors determining land, sea breeze development along the South African coastline

3.2 Coastal lows

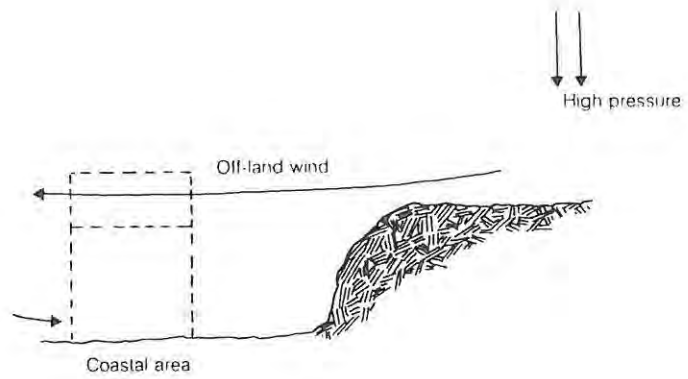
These owe their origin to the generation of cyclonic vorticity with coastward movement of air off the high interior plateau, with large-scale flow having a substantial velocity component normal to the coastline (Tyson, 1986). The development of the coastal low is a result of the topographic configuration of the plateau, escarpment and coastal littoral (de Wet, 1979). The sequence of diagrams in Figure 13 illustrates the development and coastal migration of a coastal low.

3.3 Berg Winds

The berg winds originate in the interior and blow toward the coast and are experienced along the entire coastline from west to east. They are warmed adiabatically on descending from the plateau and reach the coastal locations as dry, hot winds. Their development is in association with the cyclonic westerly depressions and coastal lows.

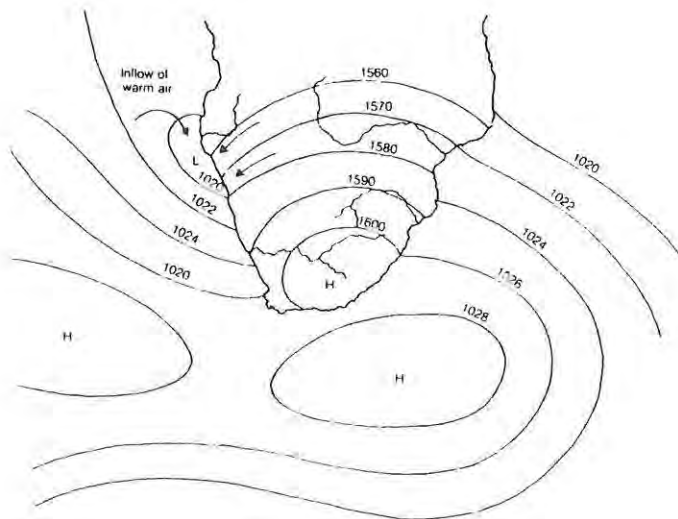
(a)

The origin of coastal lows



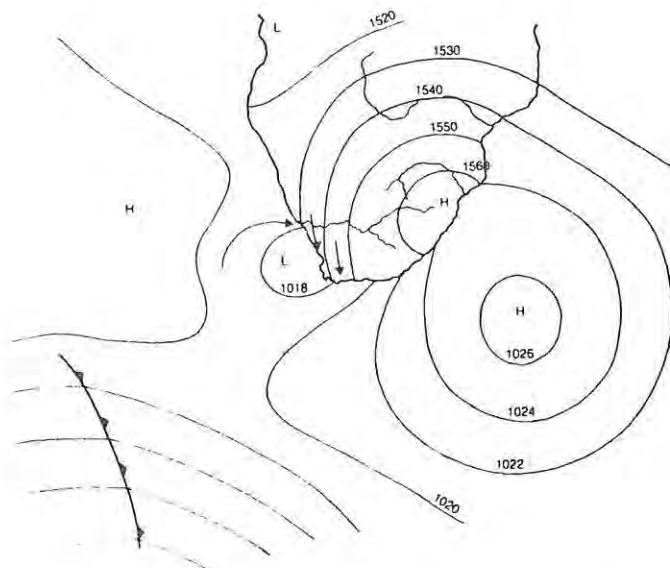
(b)

Development of a coastal low off the west coast



(c)

Two days after the formation of a coastal low



(after Hurry and van Heerden, 1986)

Fig. 13 Coastal low developmental stages

The anomaly of the highest temperature, often as high as 25°C to 30°C, occurring at the coast during winter is accounted for by berg wind conditions. The berg wind occurs most frequently along the west coast.

3.4 Cut-off lows

Cut-off lows originate as troughs in the upper westerlies and deepen into closed circulations extending downward to the surface and are often fed by cold air advected from far south. They develop ahead of tardy low pressure systems and tend to stagnate over the continent. They may be blocked by an established South Indian anticyclone over the Indian Ocean. This inhibits their continued eastward movement. The low is associated with strong convergence and vertical motion in its deepening stage. The dissipation of the low is dependent on another eastward moving cyclone, which attracts the cyclone over the continent into its eastward passage, or simply by the low raining itself out over the plateau. The floods which occur in South Africa are often associated with these cut-off lows. (See Figure 14).

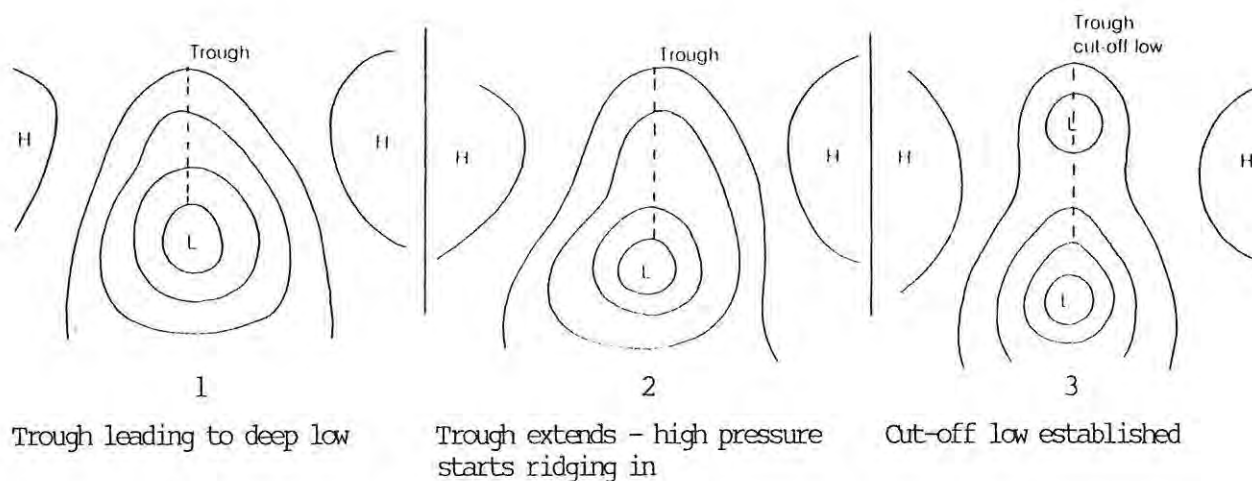


Fig. 14 The formation of a cut-off low

(after Hurry and van Heerden, 1986)

3.5 Polar outbreak

The warm, fine winter weather of the Highveld is temporarily interrupted on occasions when cold polar outbreaks bring with them frigid temperatures as they move out of the westerlies across the country. This equatorward surge of cold polar air is, in effect, a mechanism of the

general circulation which helps to maintain the earth's heat balance and is associated with westerly disturbances with large amplitude. This occurrence is also referred to as a cold snap.

3.6 Meagre winter rainfall in the South West Cape

A negative departure in the rainfall over the south west Cape during winter is a consequence of the South Indian anticyclone being far to the west of its normal position, and this results in the blocking of cyclones from the Atlantic.

3.7 Summer circulation anomalies

An abnormally wet summer over the eastern parts is related to negative departures of pressure, stronger cyclonic activity in the westerlies and a deeper continental trough. Unusually dry summers show positive pressure departures over the continent and to the east. The South Indian anticyclone is located well to the west and north of its usual position.

Sustained wet conditions over the plateau may also be associated with the advection of moist maritime air from the east.

3.8 Autumn rainfall maximum over the western regions

Taljaard (1986) attributes the autumn rainfall maximum over the western regions to a weak heat low centred over the central interior, which is linked by a trough across the northern Cape and Botswana to a tropical low north of Botswana. The centre of the trough shifts in an east-west direction along the southern branch of the ITCZ in the region of the Zaire air boundary. A weak ridge is observed over the northern Cape. The change to a single high pressure cell takes place by March, resulting in a northerly flow of moist air from the tropics over the western parts of Southern Africa at a time when the air masses over Zimbabwe, Zambia, northern Botswana and Namibia are still moist. The influx of moist air is largely responsible for the autumn rainfall maximum over the western regions.

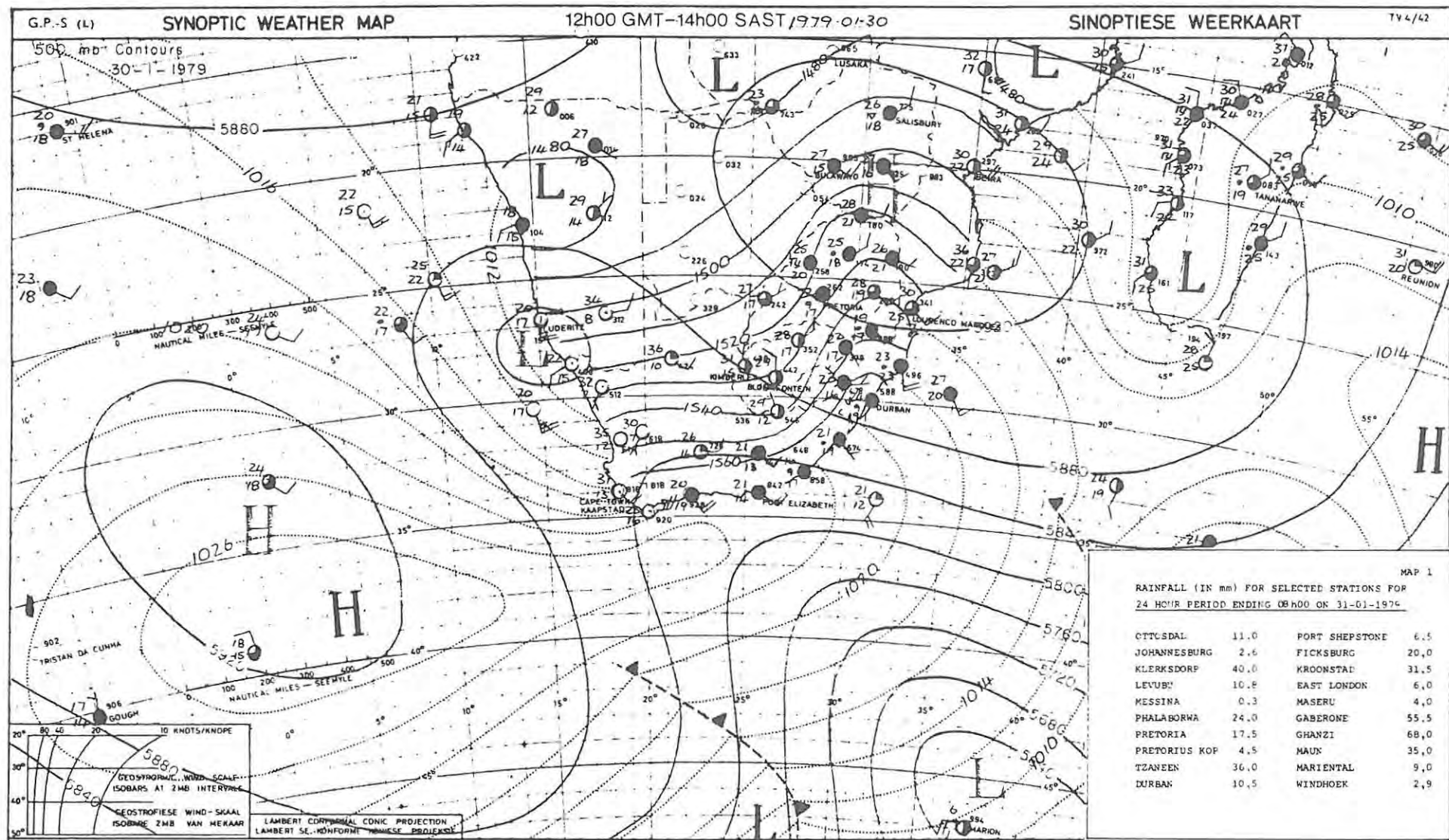
3.9 Typical South African weather synopses (after Hurry and van Heerden, 1986)

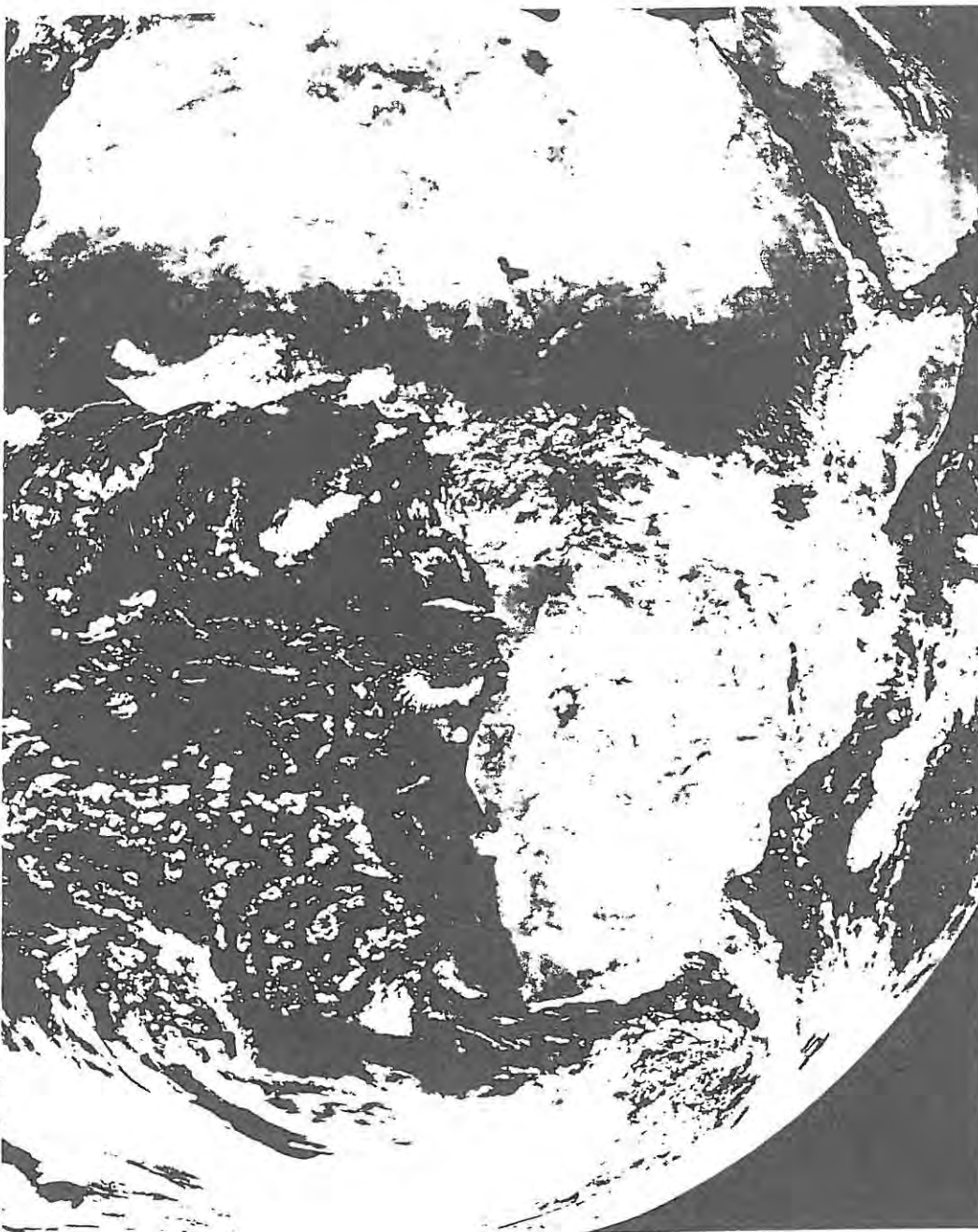
Four typical South African weather synopses, as presented and commented on by Hurry and van Heerden (1986), follow. These typical weather synopses viz.

- o general rain in summer
- o drought in summer
- o a typical winter situation
(calm, clear conditions with frost during the night)
- o cold front over the south-western Cape

are the basic weather charts applicable to Senior Secondary weather chart studies. (See Figures 15 to 18).

Fig. 15 Synoptic chart typical of general rain in summer





1. Surface map

The Atlantic high is ridging eastwards south of the country. (Meteorologists will say that the high is "pushing in".) Note that the air circulating anti-clockwise around this high has had a long sea track by the time it arrives over the south and south-eastern coastal regions, and is therefore both moist and cool. At the 850-mb level a low is situated over South-West Africa/Namibia and a trough extends from this low south-eastwards to the south-east coast. The maritime air crossing the Natal coast has reached the Transvaal Highveld and is recurving southwards. If temperatures are considered one sees that Pretoria (262) is already in the cool air, while stations at Bloemfontein, Kimberley and points further west still have warm air. At Upington (424) it is quite hot at 36 °C. Over Zimbabwe as well as the Northern Transvaal it is overcast but the temperatures show that these areas are still under the influence of moist tropical air.

2. 500-mb Map

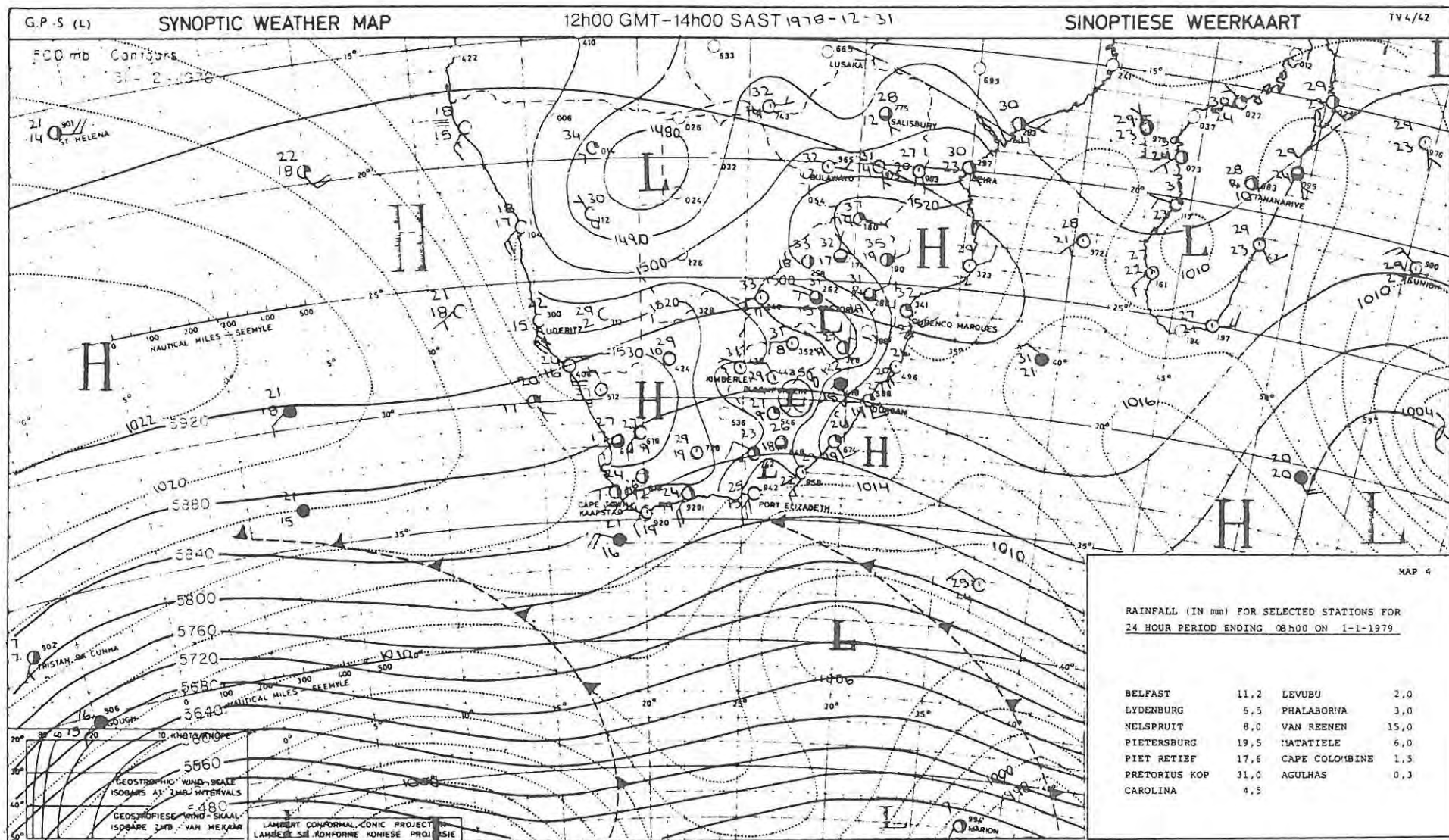
A trough lies from Marion Island (994) northwards to Alexander Bay (406) where a cut-off low is situated. East of this trough we have vertical motion which, together with the influx of moist air, is responsible for the fairly general rains over the eastern parts of the country.

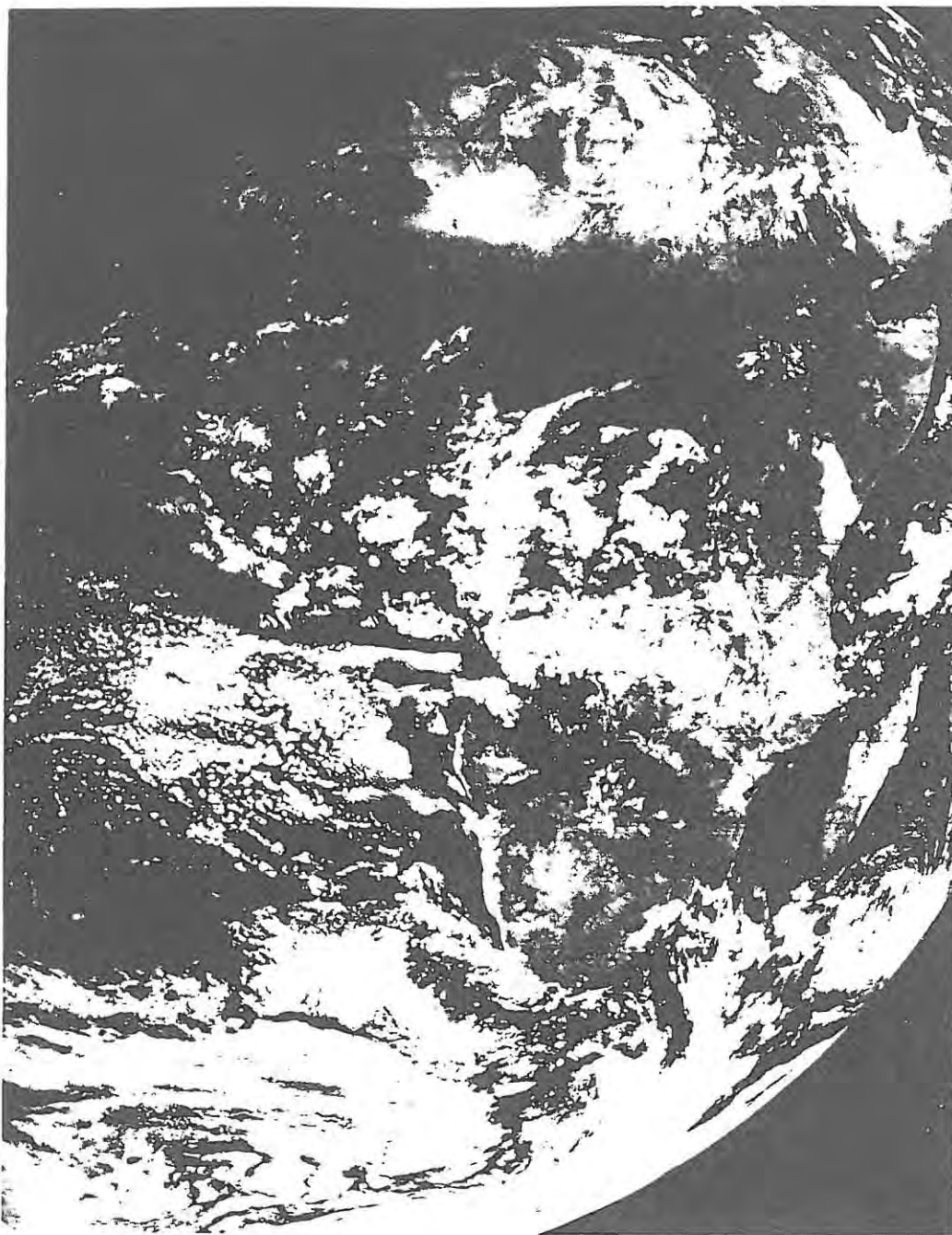
3. METEOSAT photograph

Although the quality of this photo is not good, one can see that the cloud cover is complete south and east of the main escarpment. These clouds are normally layer cloud such as stratocumulus and nimbostratus. Most of the subcontinent is cloudy because moist, tropical air covers most parts of central Africa.

4. General

The synoptic situation here has a lot in common with the flood situation (Black South-easter) described later. The intensity of the upper air disturbance, however, is considerably less and the moisture content of surface not as high as in the case of the Black South-easter.





1. Surface map

The Atlantic high pressure system is ridging eastwards over the country, bringing dry subsiding air with it. Both cold fronts south of the country are much further north than is normal for summer and the whole map is reminiscent of a winter situation. Along the south-eastern coasts a weak cell of high pressure is pushing some moisture over Natal and Eastern Transvaal. With the tropical low over north-west Botswana and some moisture over the eastern parts, a few air mass thundershowers are developing, e. g. at Nelspruit (288).

2. 500-mb Map

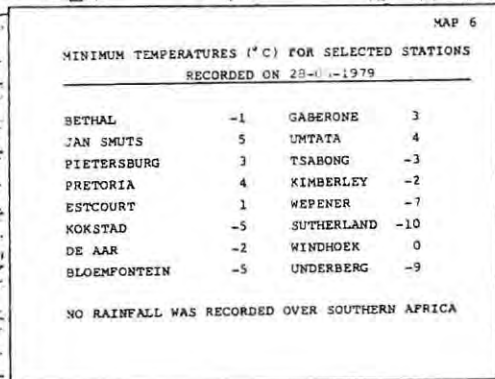
A strong upper air high lies over most of the country and will have a strong dampening effect on thundershower development. The reason for this is that an upper air high is generally an area of slowly subsiding air.

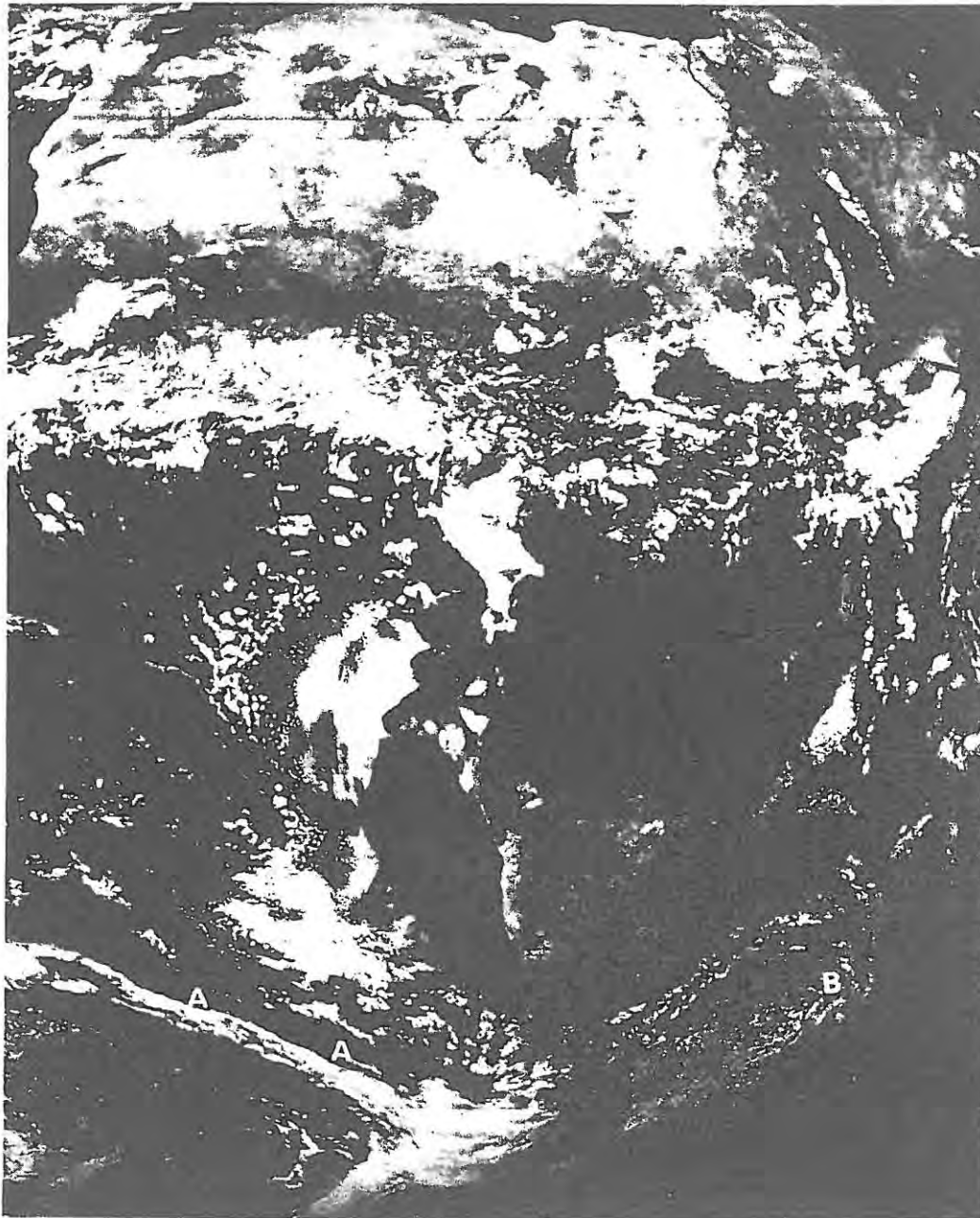
3. METEOSAT photograph

Clear conditions caused mainly by the upper air high. Note the small patch of cloud over Natal, south of the Drakensberg, where moisture is moving inland under the influence of the weak high south of Durban (588).

4. General

Except for the eastern parts, note the high temperatures over the rest of the country and good showers restricted mainly to the eastern and northern Transvaal.





1. Surface map

High pressure dominates the region at the 850-mb surface. The Atlantic high is weak and extends a ridge eastwards across the region to the Indian Ocean. The Indian Ocean high has been replaced by a trough extending northwards from the deep low east of Marion Island (994) (not visible in this synoptic map).

Over the interior gradients are weak and there is little or no surface wind. The skies are clear and conditions are ideal for frost formation during the night.

Dew-points are very low over the interior. This is largely because of subsidence.

The cold fronts are as yet far from the region, although strong gradients exist south of the continent. This explains the presence of westerly winds over the southern parts of the region.

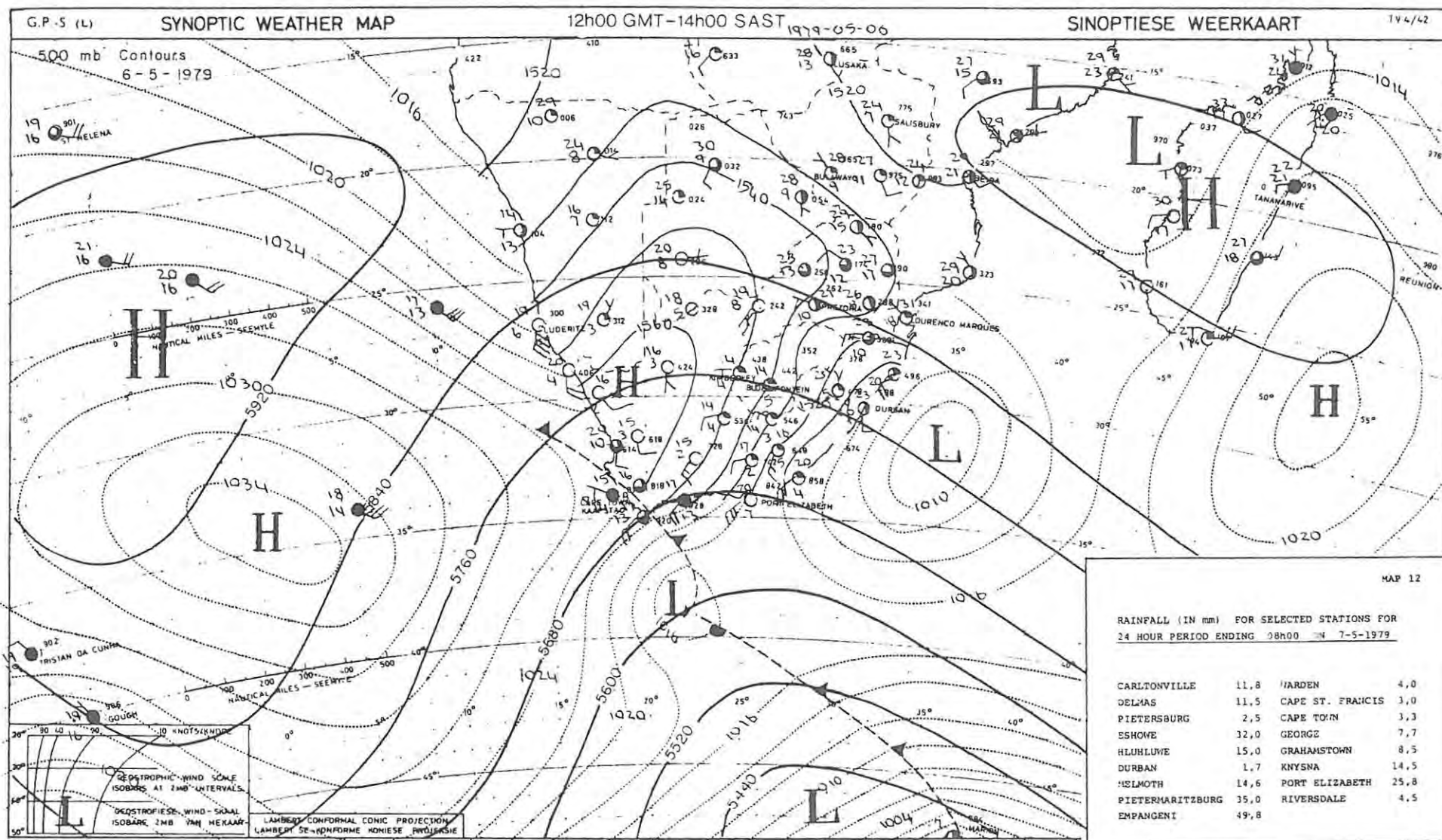
2. 500-mb Map

As with the surface map, a strong high is centred over the central interior. This high is an area of subsidence. As air subsides it warms. This warming contributes further to the dry nature of the air over the land.

3. METEOSAT photograph

Both the cold fronts seen on the surface map can be identified on the photograph as extensive areas of cloud (A & B).

The clear skies over the land are due to the subsidence mentioned above. Because of a strong off- and flow of air there is no cloud off the west coast for a distance of several hundred kilometres.





1. Surface map

A cold front lies over the south-western Cape Province. The Atlantic high is strong (above 1 034 mb) and is ridging in over the interior from the west, forcing the front rapidly eastwards.

Note the presence of a weak low (about 1 010 mb) east of the country (near Durban). This low is much deeper than a normal coastal low and is the remains of a low pressure system that has left South Africa and moved eastwards. Together with the upper trough this system will cause some rain over the eastern parts. (See the rainfall figures.)

2. 500-mb Map

A trough lies from Marion Island (994) north-westwards to the southern coast of South-West Africa/Namibia. Note the strong ridge just east of Gough Island (906). These systems are the westward-leaning parts of the surface pattern. The presence of the trough will make showers possible over the eastern regions.

3. METEOSAT photograph

The cloud associated with the cold front is clearly visible just south of the country. Note how the broken clouds, which are cumulus clouds, spiral inwards to the approximate position of the surface low. Over the south-western coast we have larger clouds, mainly nimbostratus and stratocumulus.

4. General

Dry air is in circulation over most of the interior, hence the cloudless conditions. An examination of the dew-point temperatures in the cloudless areas will confirm this fact.

By way of summarising this chapter Tyson's (1986) schematic classification of South African weather types based on circulation patterns at the surface and at 500 hPa is presented, (Figure 19), accompanied by a brief description of each weather type.

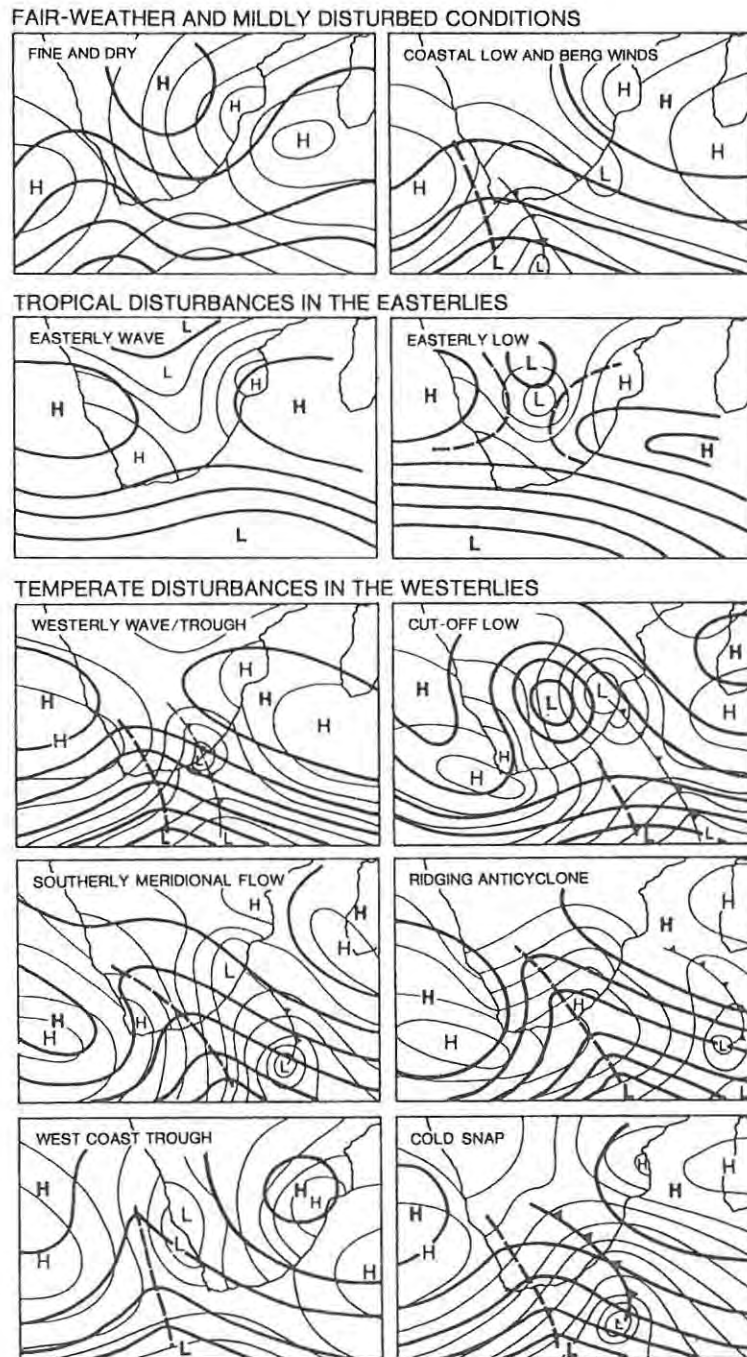
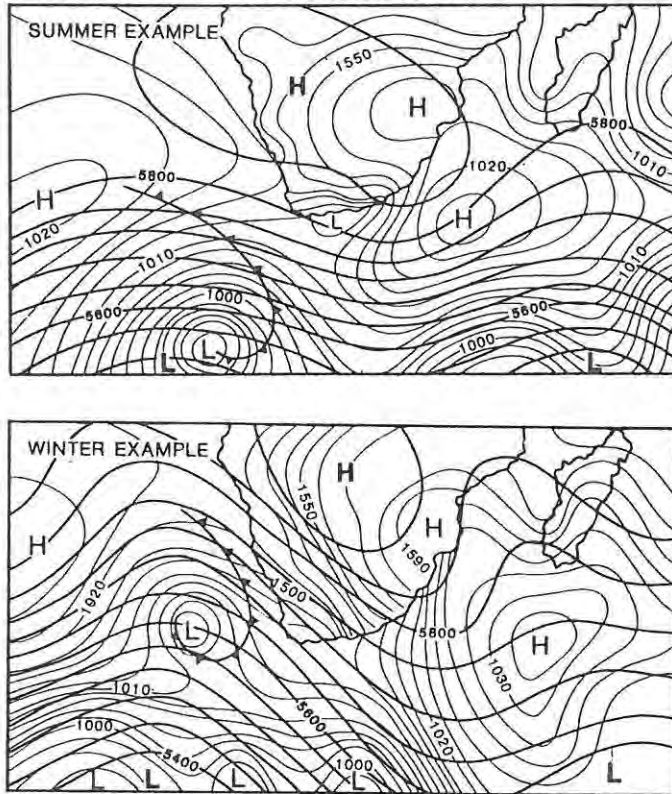


Fig. 19 A schematic classification of southern Africa weather types based on circulation patterns at the surface (light lines) and at 500 mb (heavy lines) (after Tyson, 1986)

WEATHER CLASSIFICATION AND ASSOCIATED METEOROLOGICAL PHENOMENA

(a) Fair weather and mildly disturbed conditions

FAIR-WEATHER CONTINENTAL HIGH



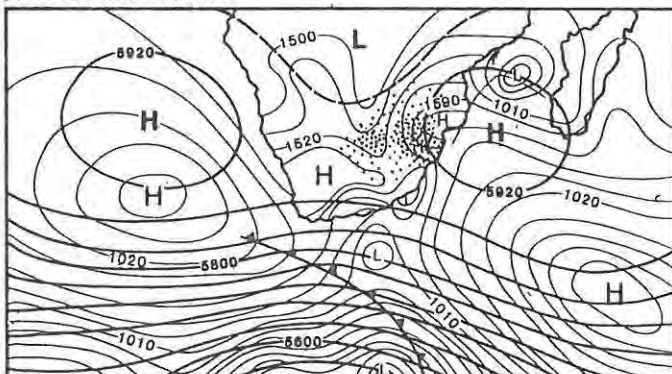
An example of a fair-weather continental high pressure type prevailing on 10 April 1981 (top) and 2 August 1984 (bottom) [Light lines show isobars at mean sea level (mb) over the oceans and contours of the mb surface (gpm) over the land; heavy lines show contours of the 500 mb surface (gpm) for all remaining diagrams]

- Anticyclones over the subcontinent
- Divergence in the near surface wind field
- Strong subsidence
- Occurrence of inversions
- Fine, clear conditions
- Coastal low development
- Berg wind development

(b) Tropical disturbances in the Easterlies

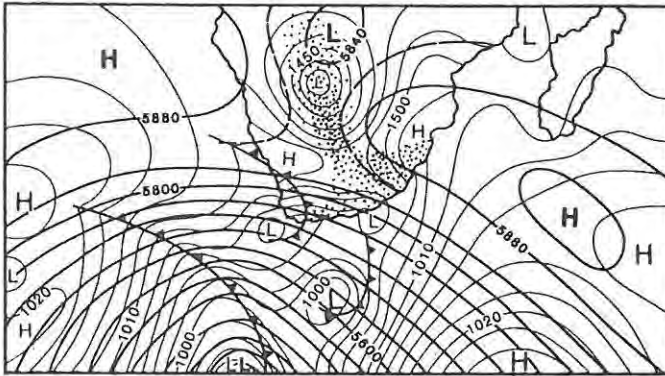
No detailed study of the dynamics of African easterly waves and lows has been undertaken (Tyson, 1986)

EASTERLY WAVE



An example of an easterly wave situation on 16 January 1983

EASTERLY LOW

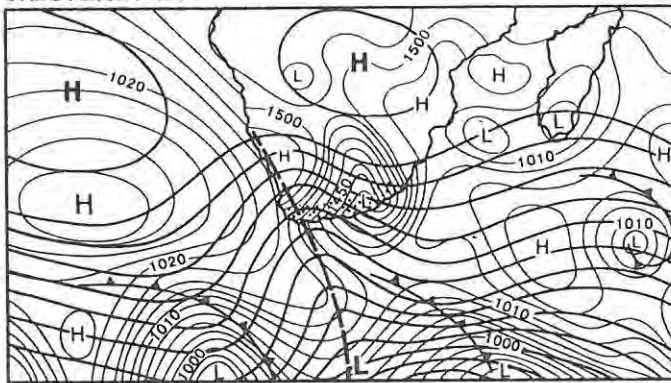


An easterly low type on
28 February 1974
In the remaining diagrams
areas receiving precipitation
are stippled

- ITCZ and warm easterly winds between the ITCZ and the subtropical high pressure belt (Taljaard, 1985)
- Copious rainfall occurs when convergence is strongest to the east of the trough and is associated with northerly winds
- A surface trough of an easterly wave is associated with a moisture discontinuity separating moist air to the north-east and drier air to the south-west. Thunderstorms tend to develop in squall lines in a convergence zone two hundred to three hundred kilometres eastward of the moisture discontinuity and advance north-eastward whilst being steered by the air flow at 500 hPa.
- Tropical disturbances are influenced by northward penetrating mid-latitude disturbances and vice versa.

(c) Temperate disturbances in the westerlies

WESTERLY LOW

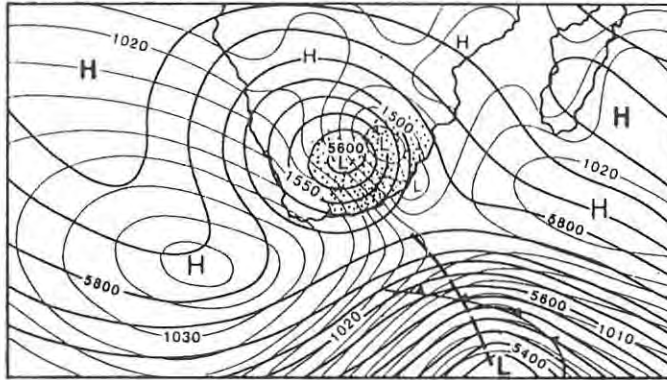


An example of a westerly low
type on 7 November 1981

In westerly waves

- coincident surface convergence and upper air divergence provide ideal conditions for sustained uplift of air.
- the low pressure system may be deep and associated with heavy rain.
- the effects of westerly waves are seldom experienced as far north as the tropics, but westerly waves may indirectly induce squall line precipitation in the interior.

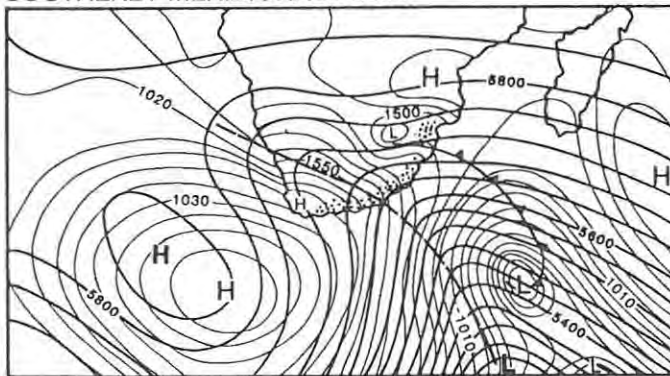
CUT-OFF LOW



A cut-off low type on
27 August 1970

Cut-off lows are associated with strong convergence and vertical motion during the deepening stage and are responsible for severe flooding. It is an intense form of westerly trough.

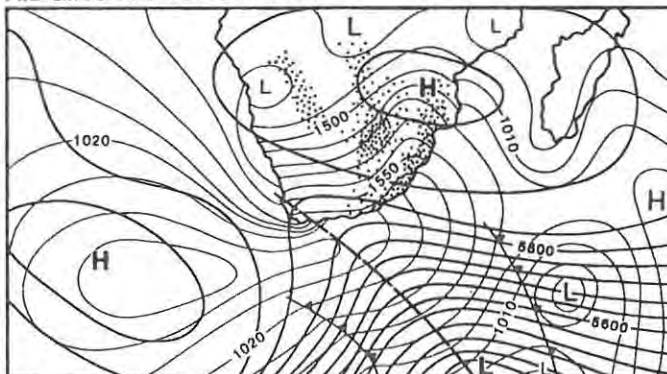
SOUTHERLY MERIDIONAL FLOW



An example of a southerly
meridional flow type on
17 August 1981

Southerly meridional flow produces coastal rainfall because of sustained uplift. Rainfall may penetrate to the Lowveld.

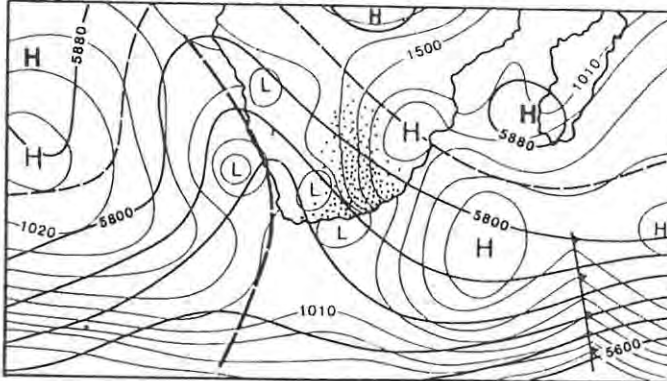
RIDGING ANTICYCLONE



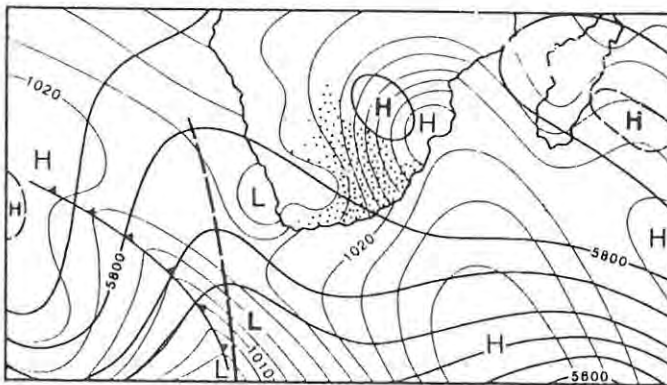
A ridging anticyclone type on
30 January 1979

A ridging anticyclone may produce widespread general rainfall over the eastern parts of Southern Africa when associated with a westerly wave at 500 hPa.

WEST COAST TROUGH



Examples of the west coast trough type (top) strongly developed on 19 November 1962 and (bottom) less so on 28 March 1963



West coast troughs, in conjunction with an upper tropospheric westerly wave to the west of the continent, are conducive to widespread rains in the western parts of the country.

Cold fronts occur in winter when the amplitude of westerly disturbances is greatest.

(d) Other rain-producing systems

Storms

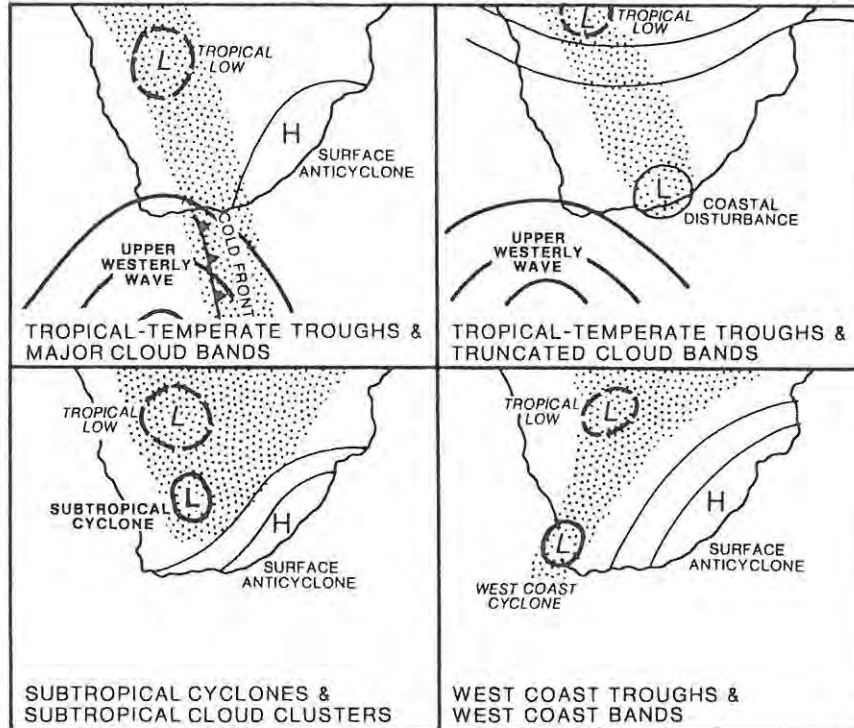
No single mechanism is responsible for storm formation and usually synoptic and mesoscale forcing and local convective cycles combine to generate them.

Tropical cyclones

These form over the Indian Ocean in summer and although occasionally moving onto the coast, seldom cross over the escarpment. They are severe atmospheric disturbances and can wreak havoc when they travel inland eg. cyclones Domoina and Imboa in 1983 and 1984.

To conclude the chapter, Figure 20, an illustrated generalized classification (after Harrison, 1986) of circulation types and their attendant cloud systems is included. The schematic classifications which conclude this chapter are regarded as useful resources for the teacher of Senior Secondary climatology.

SYSTEMS LINKED TO TROPICAL CIRCULATIONS



SYSTEMS WITHIN THE WESTERLY CIRCULATION

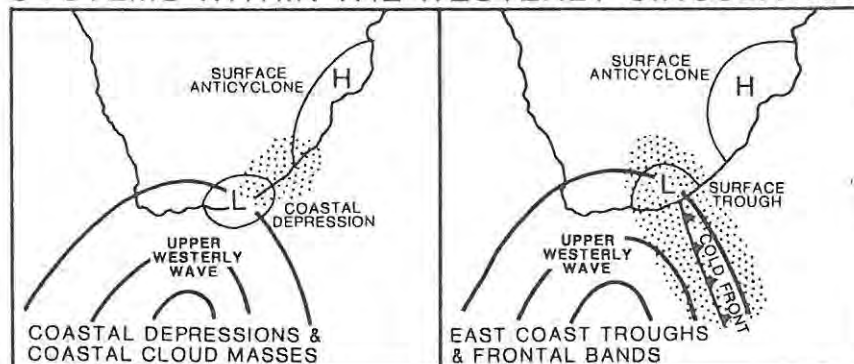


Fig. 20 Generalized classification of circulation types and their attendant cloud systems (after Harrison, 1986). Lower-level circulation is shown by light lines; upper level by heavy lines. Cloud cover is shown by stippling.

It is important to note that the classifications are based on single-type examples; various circulation types tend to occur simultaneously in practice (Figure 21), creating complex composite situations (Tyson, 1986). It is, however, beneficial to understand these single-type examples in order to progress toward a fuller understanding of any given composite synoptic situation.

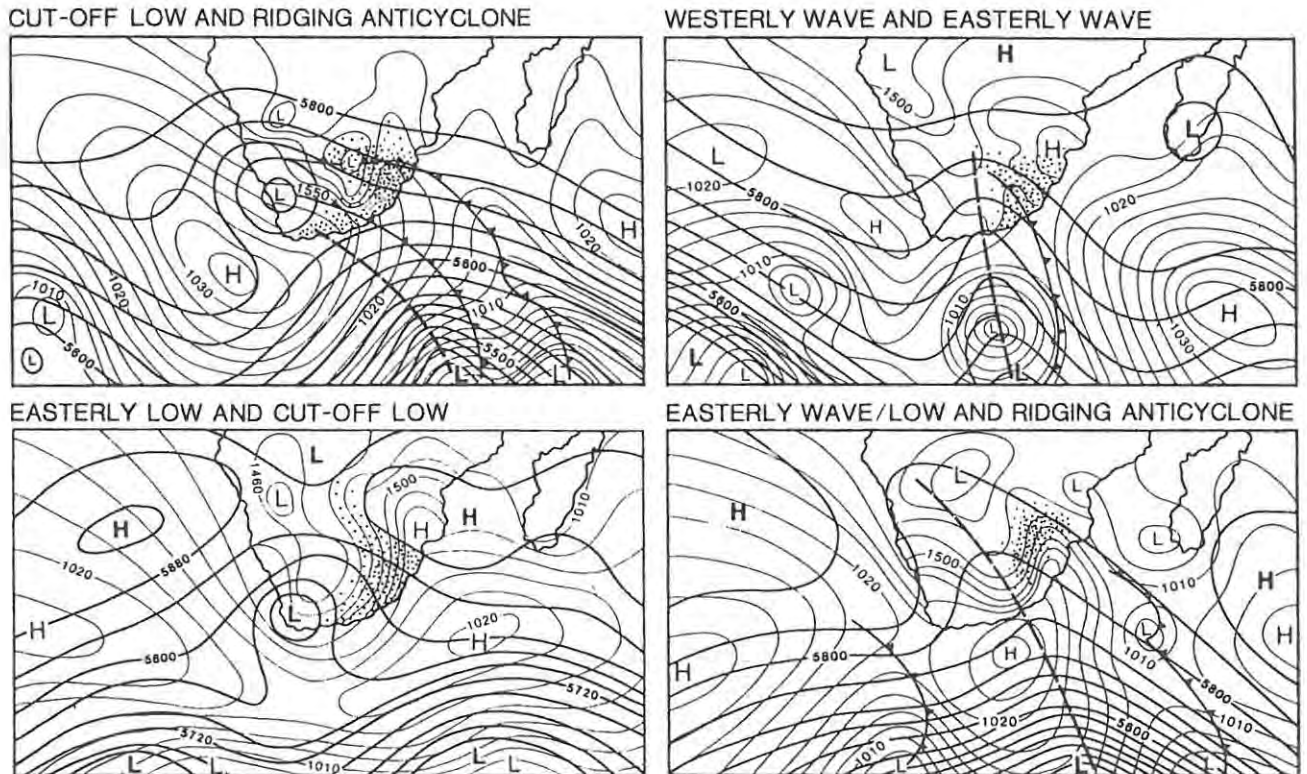
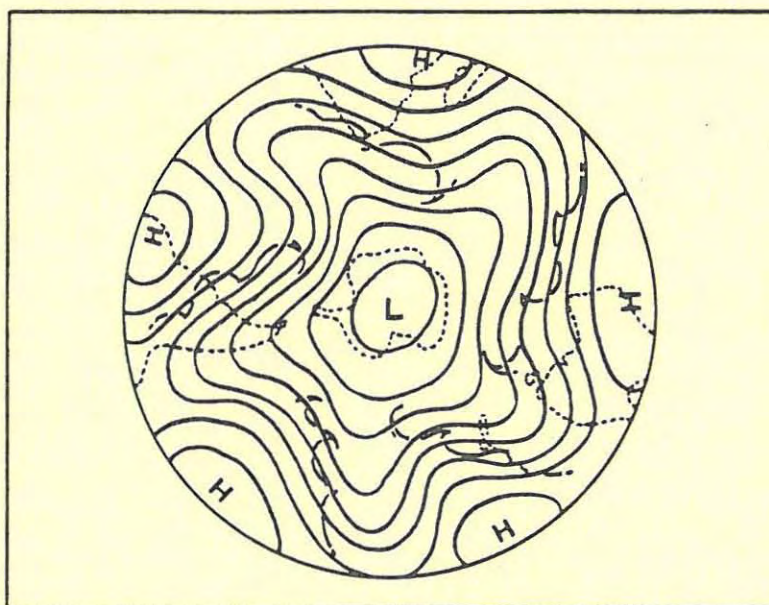


Fig. 21 Composite circulation types on 9 September 1981 (upper left), on 23 April 1983 (upper right), on 9 December 1978 (lower left) and 7 January 1980 (lower right). Light lines show isobars at mean sea level (mb) over the oceans and contours of the 850 mb surface (gpm) over the land; heavy lines show contours of the 500 mb surface (gpm). Areas receiving precipitation are stippled.

South African weather is clearly diverse along its littoral, ranging from desert on the west coast to the Mediterranean south western Cape, to the sub-tropical south and east coasts. The local variations are largely determined by the nature of the topography, the oceans and synoptic controls. Dry climates are extensive in the interior, due largely to the prevalence of the anticyclonic circulation throughout the year.

CHAPTER 2

AN ALTERNATIVE TO THE CONVENTIONAL VIEW OF
SOUTHERN HEMISPHERE CYCLOGENESIS

Upper westerly waves integral to cyclogenesis

AN ALTERNATIVE TO THE CONVENTIONAL VIEW OF SOUTHERN HEMISPHERE CYCLOGENESIS

From a review of the literature, there appears to be no recent, detailed account of southern hemisphere cyclogenesis appropriate for the classroom.

Since 1920 the theory of cyclogenesis developed by Norwegian meteorologists under the leadership of J. Bjerknes has been largely accepted. This states that the low pressure systems or depressions common to the westerlies originate as waves on semi-permanent fronts (in the west of oceans) which separate tropical air usually deriving from high levels in subtropical anti-cyclones, from polar air. Both air masses are usually moving east at different speeds, but in some cases the polar air is moving westward. This is how Kendrew (1957) describes the origin and development of the mid-latitude cyclone. Reference is made to North America in the text and the context is clearly that of the northern hemisphere. Hurry and van Heerden (1986) present the wind direction as westerly on both sides of the incipient wave front for the southern hemisphere. (See Figure 22)

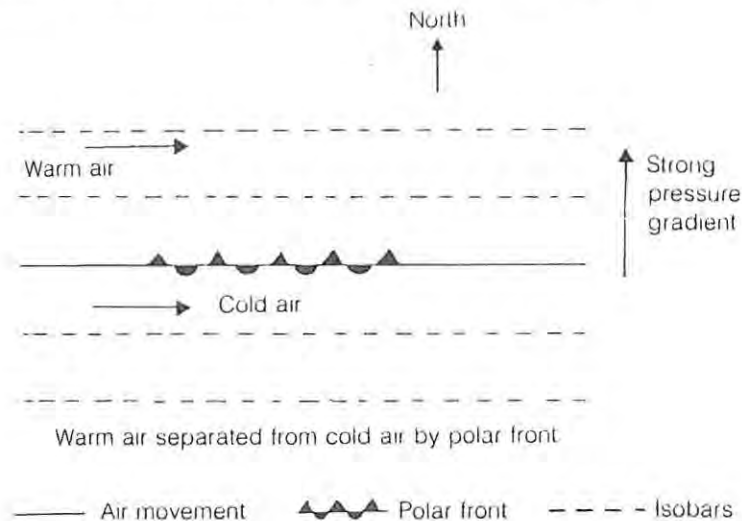


Fig. 22 The incipient wave front (after Hurry and van Heerden, 1986)

This is contrary to the general presentation of air flow in most current texts where it is presented as being opposite in direction. This is illustrated in Figure 23.

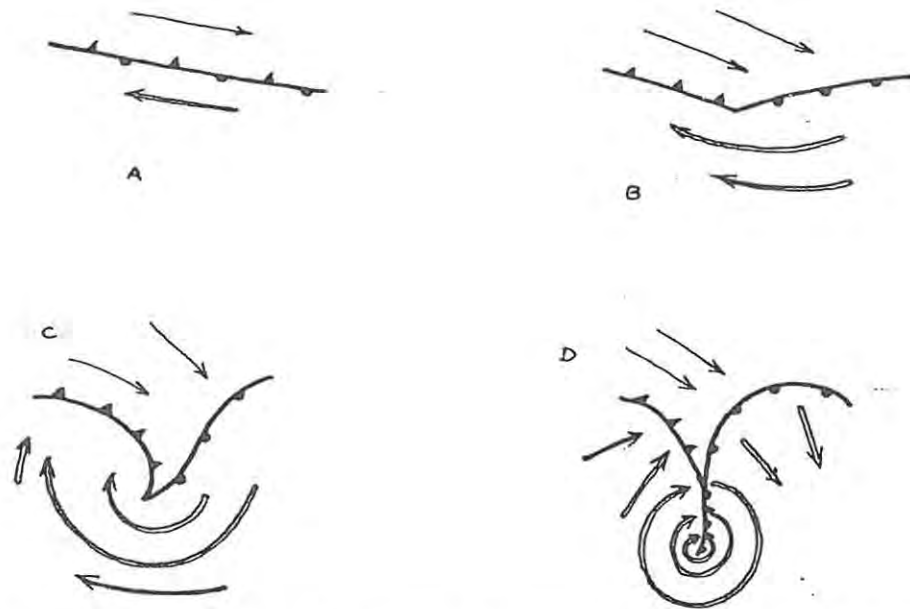


Fig. 23 Mid-latitude cyclone formation showing the incipient wave on a front separating oppositely moving air masses

From the Kendrew account it emerges that the depressions have their origin at extremely high latitudes, either entirely within the belt of polar easterlies or at the front between it and the westerlies - a latitude remote from the subtropical high pressure belts. Generalized world mid-latitude cyclone paths are illustrated in Figure 24.

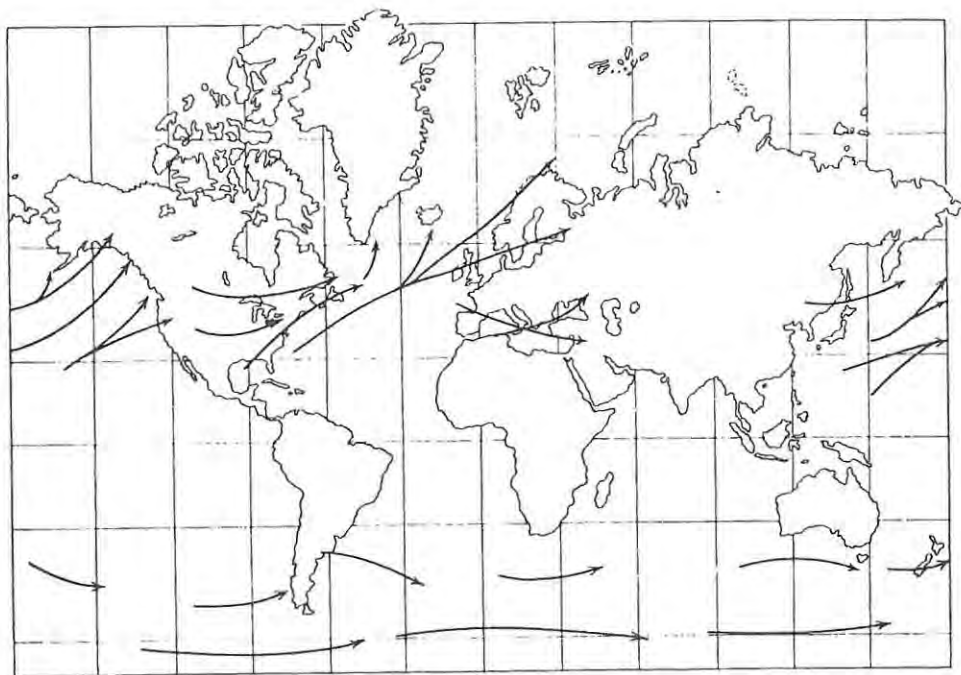


Fig. 24 Generalized world mid-latitude cyclone paths (after Donn, 1975)

Hattle (1972) regards the "polar" front as a misnomer since at the time that the theory was devised only polar and equatorial air masses were envisaged. It was long afterwards that the tropical air mass was recognised as being adjacent to the polar air mass, and that an air mass of higher latitude viz. the Arctic/Antarctic air mass, was in fact colder than polar air. According to Hattle (1972), therefore, "polar" air does not originate at the poles.

Hattle (1972, p78) is also of the opinion that "...frontal waves which give rise to warm sector depressions of temperate latitudes, do not originate on a polar front encircling the hemisphere in the vicinity of latitude 60° . On the contrary, many of them develop in subtropical regions, that is, on the other side of the westerly wind belt."

"It is a great pity that the empirical foundations of meteorology were established in the northern hemisphere, where the irregular distribution of continents and oceans tends to produce highly complex weather patterns and sequences. It would have been much simpler to formulate meteorological rules south of the equator, where there are vast stretches of sea and a more or less even spacing of land masses around the pole. The resulting theories could subsequently have been modified to fit the more complicated northern hemisphere systems, instead of the other way round."

Hattle (1972, p2)

The author has, in the course of his reading, selected various aspects which relate particularly to cyclogenesis and presents these ideas in the context of the southern hemisphere as a substitute for what would seem to be an incomplete account in textbooks. Details from accounts by Kendrew (1957), Riehl (1965), Hattle (1972), Barry and Chorley (1976), Tyson (1986) and Hurry and van Heerden (1986) are used in this presentation.

SOUTHERN HEMISPHERE CYCLOGENESIS

If the inception of the mid-latitude disturbance is within the westerlies as intimated - and more specifically at its northern extremity - the influence of the subtropical high pressure cells must be considered. The juxtaposition of the two subtropical highs is illustrated in Figure 25.

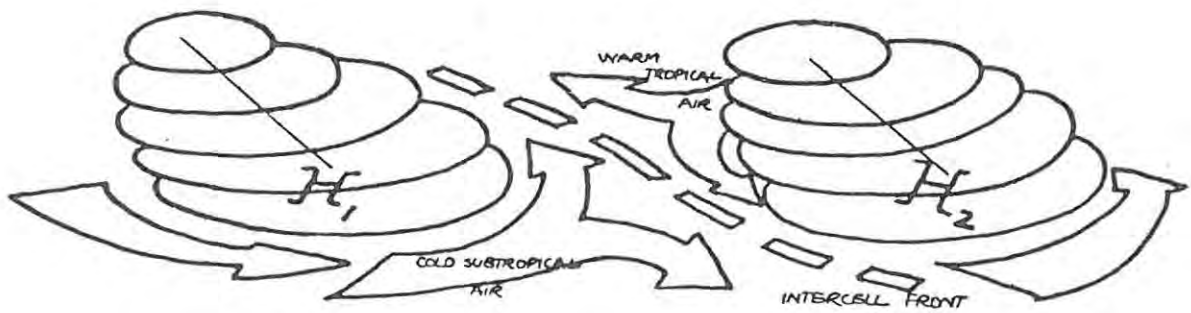


Fig. 25 The cyclones in the westerlies are associated with what is called an intercell front. The middle latitude high pressure "belt" is not continuous around the globe and the circulation around these cells (in the southern hemisphere) is such that it favours the development of intercell fronts (after Hattle, 1972)

By virtue of the fact that these cells are in the southern hemisphere, the circulation around them is anticlockwise. The air flow generated from both systems will converge as depicted in the diagram along a front, referred to by Hattle (1972) as an intercell front. A front develops here as a result of the different air masses adjacent to one another. The north-easterly air flow around the eastern anticyclone brings to the frontal position warm tropical air as opposed to cool south-westerly temperate air brought by the western anticyclone. Figure 26 places this development in the context of the south Atlantic subcontinents and southern oceans.

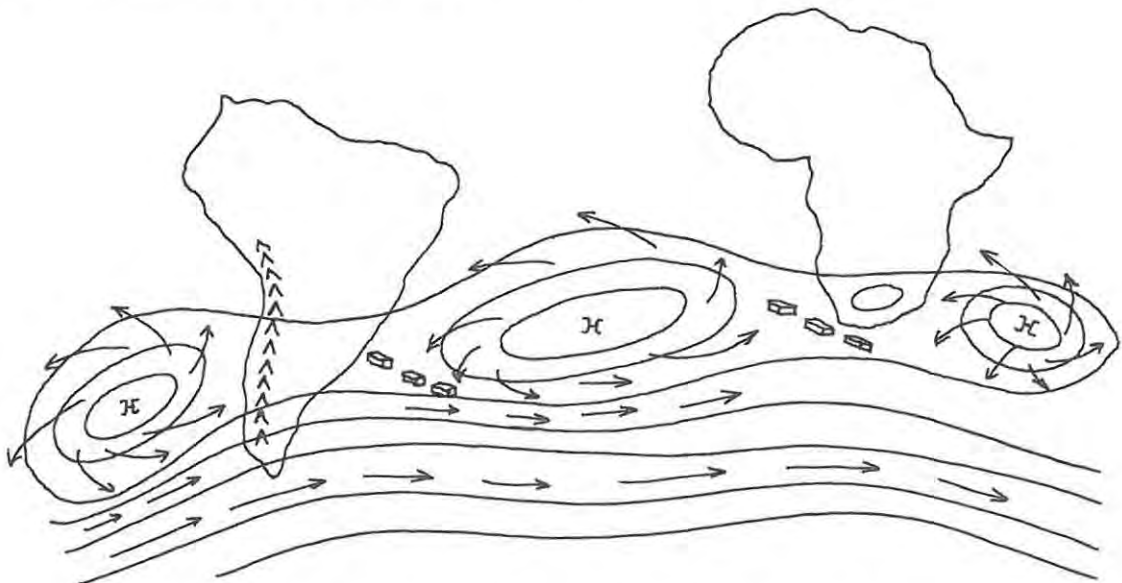


Fig. 26 A schematic illustration to show the development of intercell fronts in the context of the South Atlantic subcontinents and oceans

Since the isobaric patterns in the southern hemisphere are more idealized because of the expanse of ocean, the patterns of cyclogenesis are more consistent, greatly facilitating the understanding of their development.

FACTORS FAVOURING SOUTHERN HEMISPHERE MID-LATITUDE CYCLOGENESIS

1. The rotor effect of winds in the lee of mountains

"The protrusion of large mountain ranges into the atmosphere affects large scale climate in several ways, even in regions remote from the mountains." Riehl (1965, p214)

In mountainous regions the heat source for the atmosphere is raised above the surrounding plains and ocean areas. Probably the strongest impact on the general circulation comes from mountain ranges (especially the Andes in the southern hemisphere) that extend perpendicularly to the westerly flow in the upper air, over thousands of kilometres. Because of this very great length, the major portion of the westerly air current cannot go round this range; it must cross it. Air columns shrink vertically as they approach the mountains in order to get across; on the lee side they expand vertically. On the windward side the contracting columns must expand horizontally or diverge; the reverse happens on the leeward side. The absolute vorticity of the columns decreases when they diverge horizontally and increases when they converge horizontally. A broad westerly current will, therefore, move along a wavy path. The wave is forced by the mountains.

When the wave pattern is established the south-west flow east of the mountains will act to draw cold outbreaks northward. Once initiated the wave motion should continue downstream of South America. It is therefore true that a single large mountain range would indeed influence climate around a very large portion of the latitude belt in which it is situated.

The rotor effect of winds blowing eastward across the Andes caused by a change in depth of the atmosphere in the lee of the Andes is seen as a contributing factor to the development of the mid-latitude cyclone which influences Southern Africa. (See Figure 27).

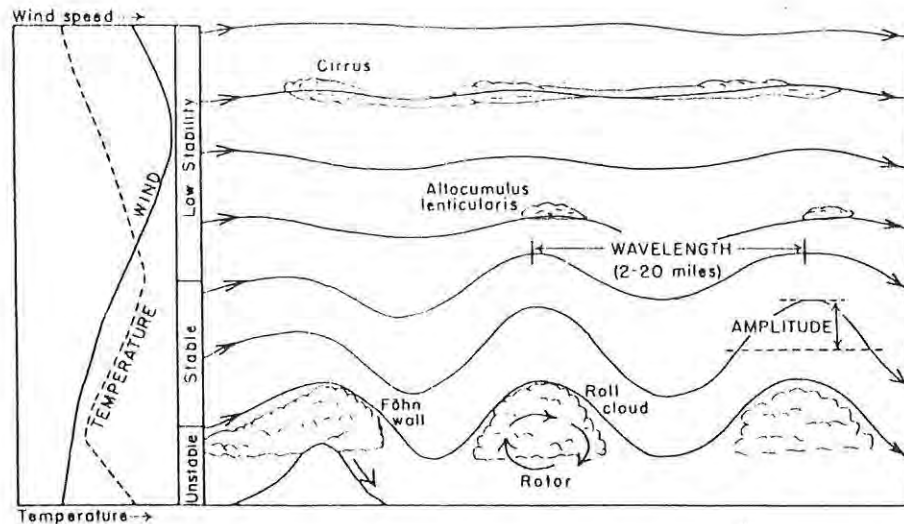


Fig. 27 Lee waves and rotors are produced by air flow across a long mountain range. The first wave crest usually forms less than one wavelength downwind of the ridge. There is a strong surface wind down the lee slope. Wave characteristics are determined by the wind speed and temperature relationships, shown schematically on the left of the diagram. The existence of an upper stable layer is particularly important (after Wallington, 1960; as reproduced in Barry and Chorley, 1976)

2. Evaporation zone in the western Atlantic Ocean

The Brazilian ocean current washing the east coast of South America and originating in the equatorial region, is a potential water vapour source in terms of its higher temperatures. The lee of the Andes coincides with this zone of potential evaporation and latent heat energy source.

3. The intercell front

The col that exists between the anticyclones off the west and east coasts of South America (see Figure 26) serves to bring into contact with one another air masses of different properties. The west coast anticyclone drives the westerly winds in its southern extremity and perpetuates this westerly zonal flow east of the South American subcontinent. The South Atlantic anticyclone east of South America advects warmer equatorial air from its northern extremity in an anticlockwise motion around its western ridge, creating a NW-SE orientated front. The temperature difference between these two opposing air streams further encourages the development of the front. The NW-SE orientation of the front could be a part explanation for the fact that warm fronts associated with westerly depressions seldom affect subcontinental weather.

4. Confluent air flow

"Divergence (or convergence), vertical motion and vorticity hold the key to a proper understanding of modern meteorological studies of wind and pressure systems on a synoptic and global scale."

Barry and Chorley (1976, p137)

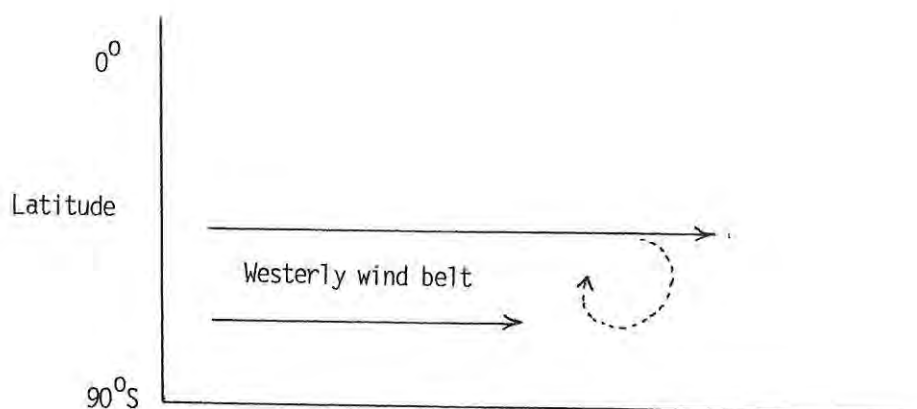


Fig. 28 Vectors representing windspeed and direction of air flow at different latitudes, to show the resultant clockwise cyclonic vorticity - a step toward understanding the exchange of air masses between latitudes

Confluence causes an increase in the velocity of the air particles, but no mass accumulation, and may reinforce mass convergence. Furthermore, this horizontal inflow at the surface has to be compensated by vertical motion, and consequently cyclonic vorticity (angular velocity of particles in a fluid system) may result from cyclonic curvature of the streamlines from cyclonic shear (stronger wind on the left side of the current, viewed in the southern hemisphere).

This appears to be what takes place at the intercell front described in point three above. The horizontal confluence of the north-easterly and westerly air streams results in convergence along the front and the subsequent vertical compensation of the ascending air creates a localised low pressure zone along the surface front. The cyclonic vorticity related to this low pressure is encouraged by the cyclonic shear which comes about as a result of the comparatively stronger wind velocities of the more equatorward air. More simply, parallel winds at different speeds generate cyclonic vorticity. (See Figure 28).

5. The upper air westerlies

Kendrew (1957) claims that a serious weakness in the wave theory of the birth of depressions is the failure to explain adequately the very low atmospheric pressure which develops. The low pressure seems to imply a removal of enormous masses of air by a process of great magnitude. There is a conviction here that air is drawn aloft creating extremely low surface pressure.

In a variety of modern meteorological and climatological texts the function of the jet stream in cyclogenesis is given considerable import. Barry and Chorley (1976, p208) state that "the superimposition of a region of upper air divergence over a frontal zone is the prime motivating force of cyclogenesis." The long or Rossby waves in the middle and upper troposphere are particularly important in this respect (Figure 29). This may explain the weakness identified by Kendrew (1957).

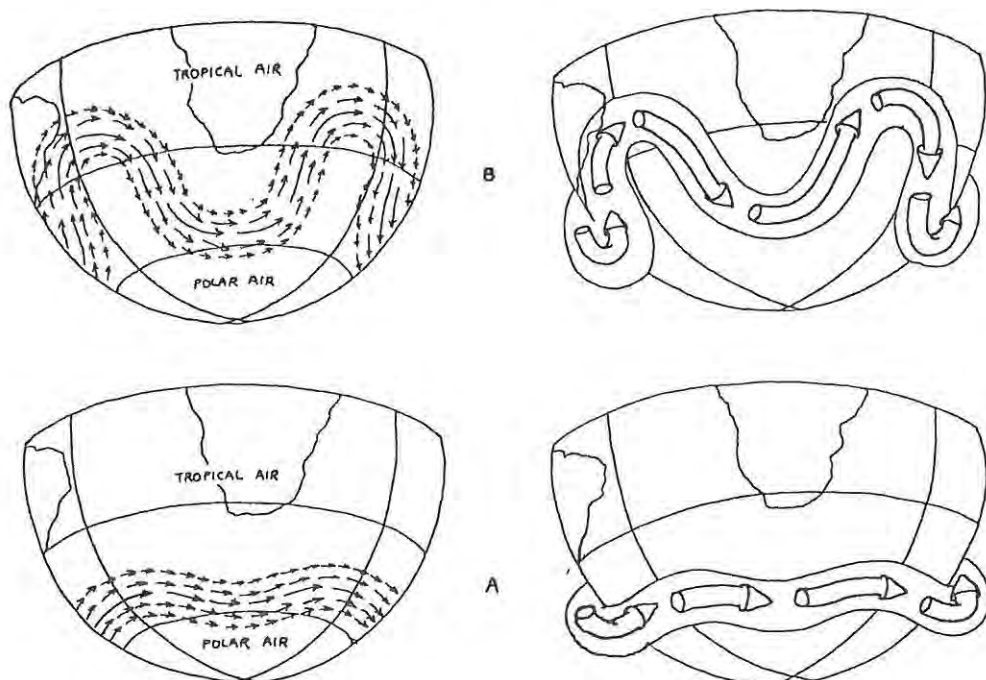


Fig. 29 To illustrate the jet stream and long (Rossby) waves in the upper and middle troposphere. In stage A the jet (embedded) in the long Rossby waves is positioned well to the south (southern hemisphere), waves are weak and weather is relatively quiet. In stage B the jet has developed large oscillations in the form of waves. These waves carry polar air into middle and high latitudes; such are stormy periods in the earth's weather

It is appropriate to clarify at this point the term "Rossby wave", which is often used synonymously with "jet stream". A Rossby wave is an undulation in the upper westerlies. These waves comprise concentrated relatively narrow bands of strong winds called jet streams, often reaching windspeeds of 160 to 240 kilometres per hour. (See Figure 30).

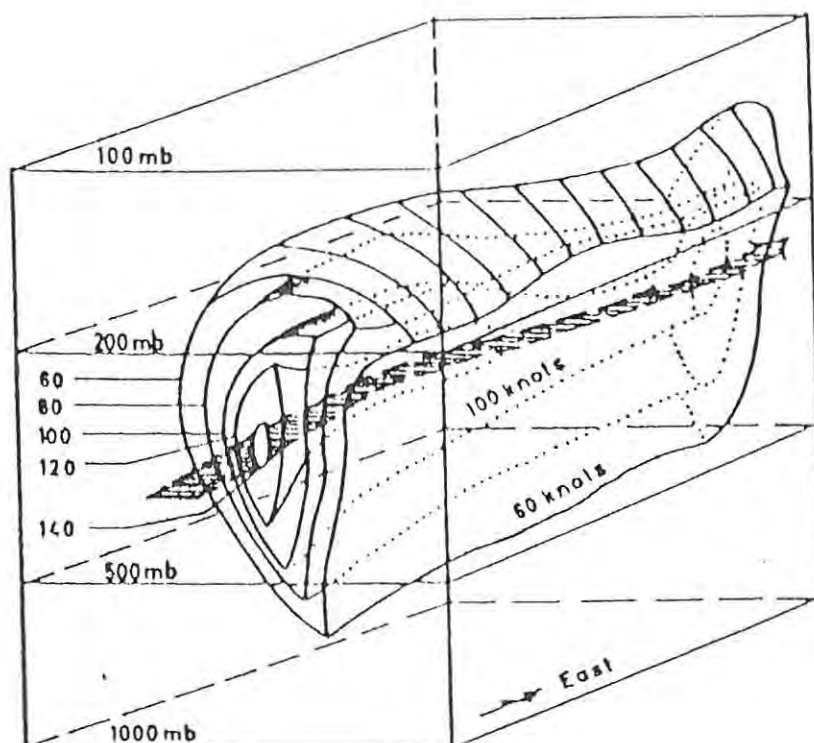


Fig. 30 A three-dimensional representation of a jet stream
(after Giles, 1977)

The average direction of the jet is from west to east. Jet streams occur at the height of the tropopause at the "polar" front and in the subtropics (illustrated in Figures 31, 32 and 33). They are often continuous around the globe and contain a number of waves (Figure 29).

The sinuosity of the stream is a result of the rotation of the earth and the latitudinal variation of the Coriolis parameter.

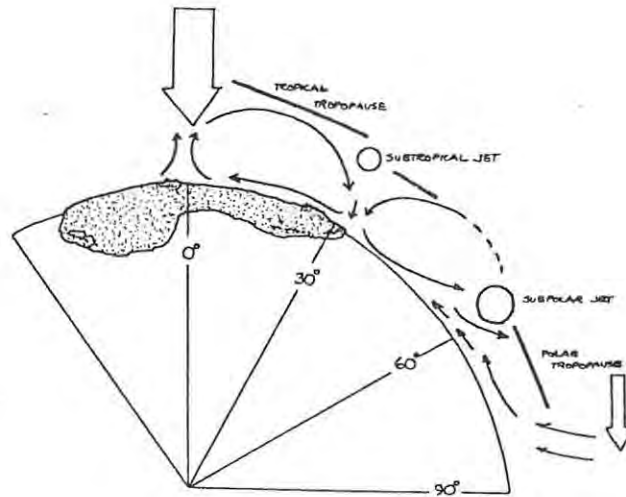


Fig. 31 The general circulation of the atmosphere showing the position of the subtropical and subpolar jets, for the southern hemisphere. The broad arrow above the equator signifies large amounts of insolation. The narrow arrow in the polar region is the depleted solar beam being received at the pole

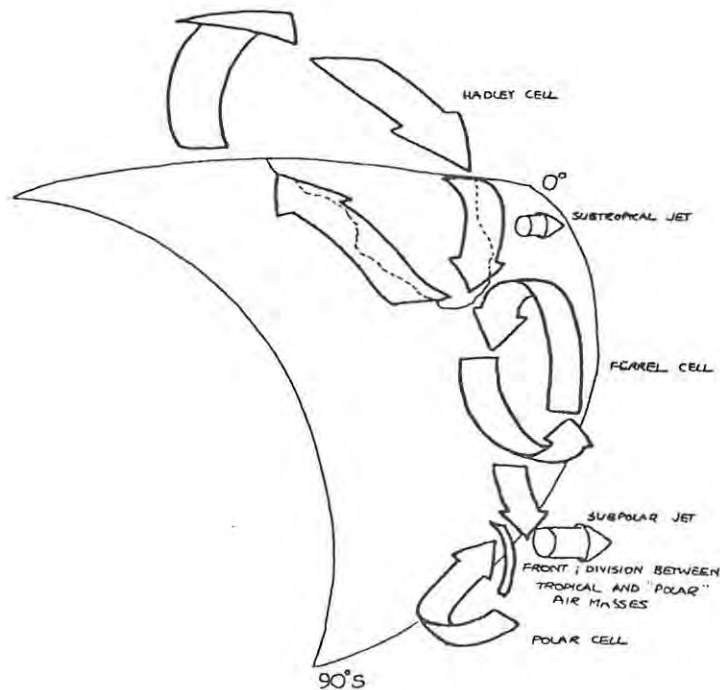


Fig. 32 A three-dimensional schematic illustration of the general circulation showing the position of the subtropical and subpolar jets

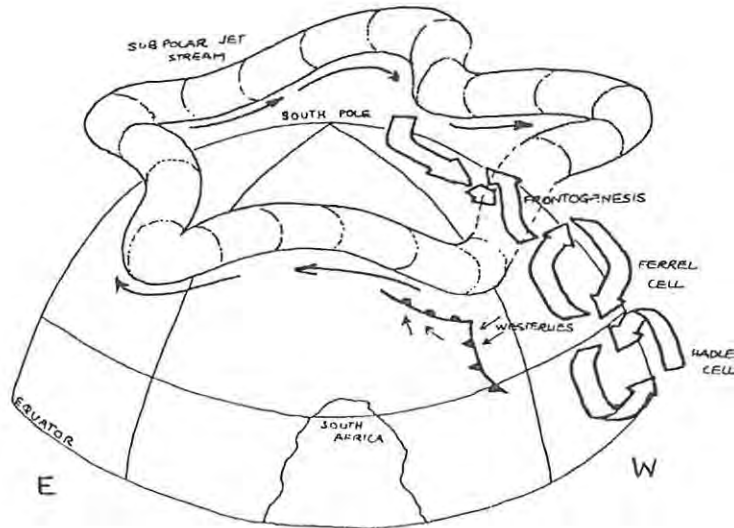


Fig. 33 Inverted globe... to depict the association between the subpolar jet stream and the low level convergence between tropical and subtropical air, the zone of frontogenesis

The vertical component of absolute vorticity consists of

(i) relative vorticity ζ

(ii) the latitudinal value of the Coriolis parameter $f = 2 \Omega \sin \phi$.

Barry and Chorley (1976) state that for large scale motion this absolute vorticity tends to be conserved i.e. $\frac{d(f + \zeta)}{dt} = 0$. The symbol $\frac{d}{dt}$ is the rate of change with respect to the motion and hence if air moves poleward (f increasing) the cyclonic vorticity tends to decrease. The curvature thus becomes anticyclonic and the current returns toward lower latitudes. If the air moves equatorward of its original latitude f tends to decrease, requiring ζ to increase, and the resulting cyclonic curvature again deflects the current polewards. In this way large scale flow tends to oscillate in a wave pattern. (See Figure 34).

Barry and Chorley (1976) further make the point that the latitudinal circumference limits the circumpolar westerly flow to between three and six major Rossby waves, and these affect the formation and movement of surface depressions.

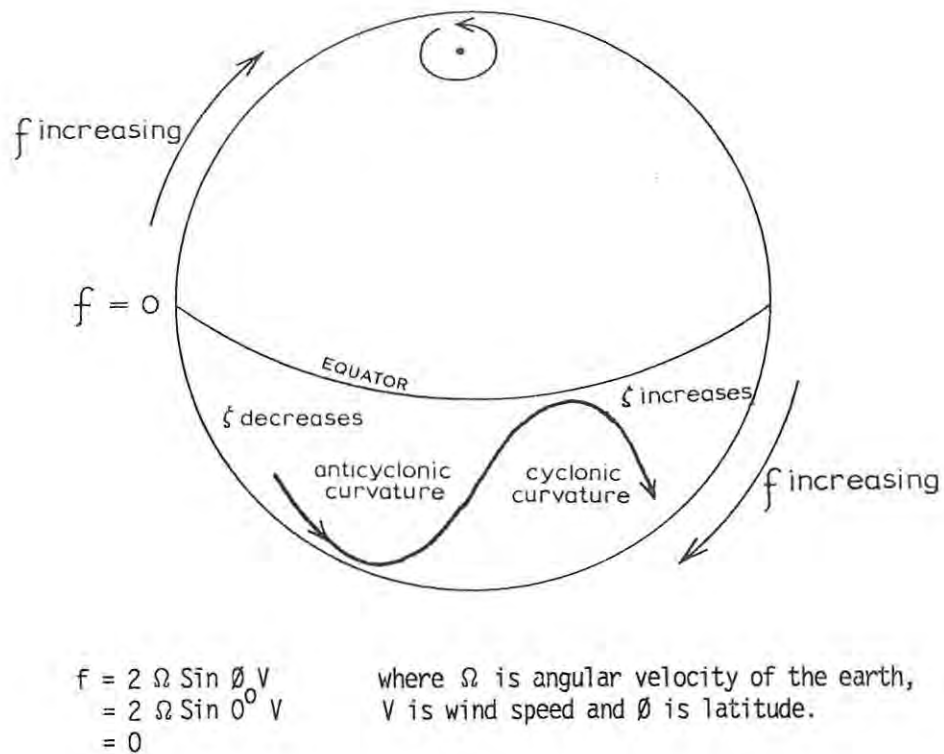


Fig. 34 A schematic illustration of the mechanism of long-wave development in the tropospheric westerlies for the southern hemisphere (adapted from Barry and Chorley, 1976)

The vertical relationship between the jet stream and front is illustrated in Figure 35. The actual relationship between the two phenomena may depart from the idealized representation in the schematic model, but the jet is often located to the rear of the cold front.

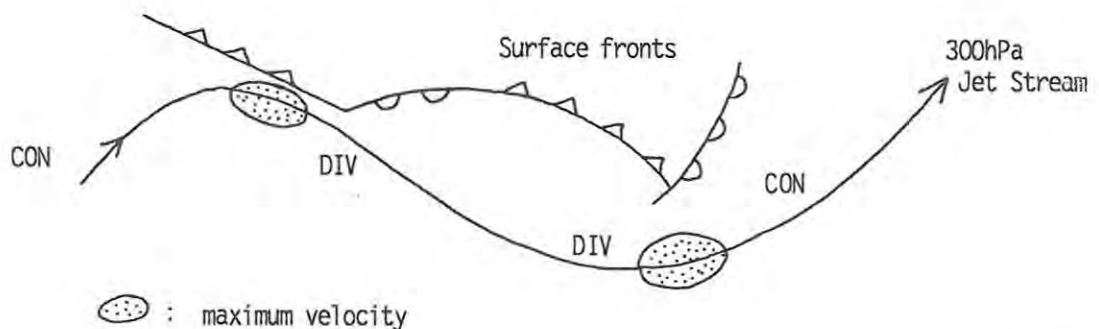


Fig. 35 A model of the jet stream and surface fronts, showing cores of upper tropospheric divergence and convergence and the jet stream cores with respect to the southern hemisphere (adapted from Barry and Chorley, 1976)

In short, mid-latitude cyclogenesis can be explained in terms of

- (i) the rotor effect of winds in the lee of the Andes generating surface low pressure;
- (ii) the evaporation zone in the lee of the Andes over the warm Brazilian current in the south Atlantic;
- (iii) the extension of the upper westerly wave containing the jet stream to latitude 45°S , coinciding with the zones in (i) and (ii);
- (iv) the configuration and location of the subtropical high pressure cells so as to promote intercell frontal development; and
- (v) confluent air flow between the northern extremity of the westerlies and the tropical easterlies so as to generate cyclonic vorticity.

In the light of the above, Figure 36 illustrates an alternative sequence of stages for the growth and ultimate dissipation of the southern hemisphere mid-latitude cyclone.

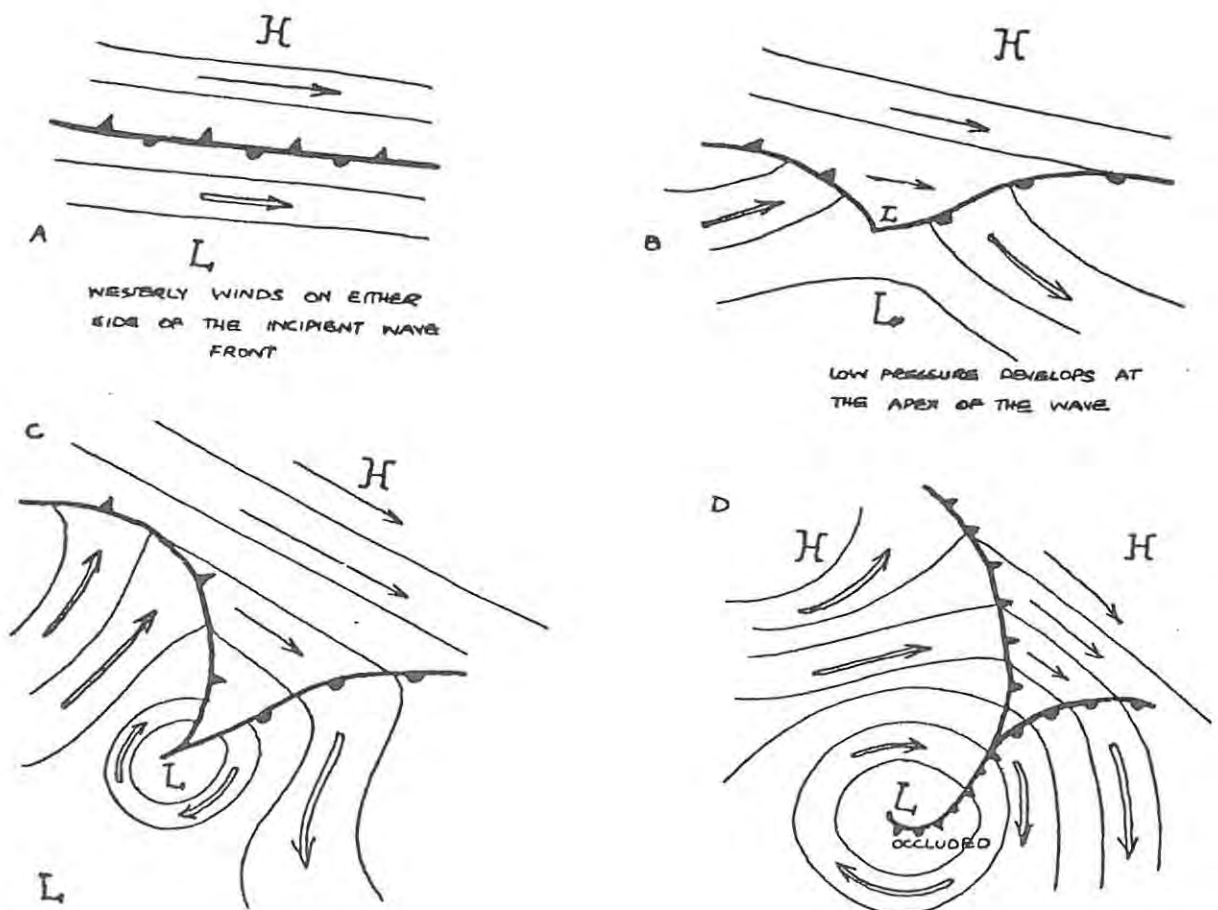
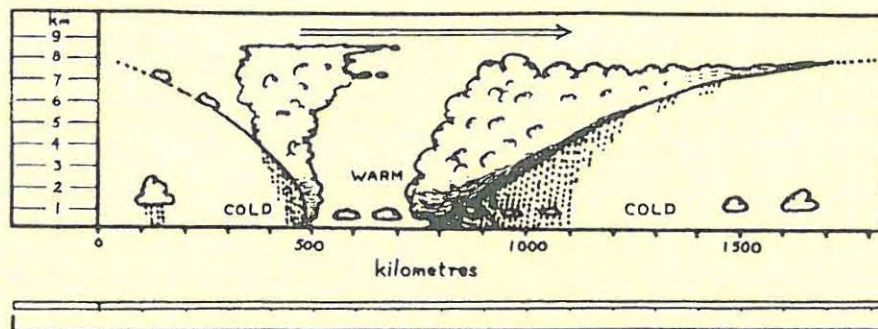


Fig. 36 The inception and development of the mid-latitude cyclone within the westerlies (adapted from Hattle, 1972)

CHAPTER 3

COGNITIVE DEVELOPMENT AMONG ADOLESCENTS AND ITS
RELATION TO THE LEARNING OF SCIENTIFIC CONCEPTS
PECULIAR TO THE UNDERSTANDING OF
SYNOPTIC CHARTS



Cross-section through a depression, with moist air in the warm sector. The vertical scale is greatly exaggerated; if the diagram were drawn to scale it would have to fit into the panel at the bottom of the figure. This is a difficult cognitive task!

COGNITIVE DEVELOPMENT AMONGST ADOLESCENTS AND ITS RELATION TO THE LEARNING OF SCIENTIFIC CONCEPTS PECULIAR TO THE UNDERSTANDING OF SYNOPTIC CHARTS

The author presents in this section the underlying ideas of the psychology of adolescent understanding, focusing particularly on those scientific concepts pertinent to synoptic chart interpretation. The introductory section is based on the Piagetian theory of cognitive development, whereafter the problem is addressed in terms of the Ausubelian Assimilation theory of learning. The implications of both theories for synoptic chart teaching are presented, and finally, a concept matrix for senior secondary meteorology-climatology is designed. This matrix is the author's attempt at a graded sequential teaching strategy which is hoped will promote amongst pupils a sound ability to analyze and interpret synoptic charts.

Definitions of terminology applicable to this chapter are listed below.

DEFINITIONS

Concept: The way in which the mind structures particular experiences such that these experiences become classified and evoke a similar response. In other words, reality is simplified by concentrating on the essential attributes of certain experiences. Concept acquisition, and concept growth, therefore, are intimately linked to a development of language and a person's experience of the world.

Classes of Concepts:

Overt: Those which are observable and concrete eg. rain, snow, hail and cloud, without an awareness of causal relationships.

Overt concepts may furthermore occur on two levels.

- Level 1 o Simple descriptive concepts eg. wind. Such a concept usually acquires meaning through experience at the earliest stage.
- Level 2 o More difficult descriptive concepts, graded as such because of their scale or location eg. katabatic wind, sea-breeze.
- o More difficult concepts, graded because of their pre-requisite understanding of two or three other concepts eg. cloud.
- o Very complex descriptive concepts requiring the understanding of a large number of related concepts eg. hail.

Covert: o Those ideas which are unobservable and discrete, but nevertheless measurable eg. temperature, pressure and humidity.
These ideas are experienced before they acquire conceptual meaning.

Definitional: o Those ideas which are descriptive of relationships between ideas eg. relative humidity.

- o Simple defined relationships between two variables eg. knot.
- o More complex defined relationships in which more variables are related eg. geostrophic flow, isohypses (geopotential metre isolines).

Organizational: o Those denoting a complex of inter-related concepts pertaining to one aspect of a subject eg. climatology, meteorology.

It is noted at this stage that a vast number of ideas in the climatology/ meteorology syllabus contain complex covert and definitional concepts.

It is imperative for a teacher, therefore, to distinguish between the various classes of concept. Such an awareness is essential for the graded preparation of teaching content. There is an inherent grading from the overt to organizational class of concept as outlined above. In view of this, it is feasible to posit that a lower order concept must be mastered before a higher order concept will be accommodated. Graves (1977) claims a need for a cognitive hierarchy within a discipline. There is a similar need for a cognitive hierarchy of concepts pertaining to the meteorology and climatology aspects of the syllabus and for those concepts related to the synoptic weather chart.

Before embarking on a developmental cognitive matrix for the climatology, meteorology and gestaltic interpretation of the synoptic chart, one needs to seek a framework within which such a task can be undertaken.

Essential to such a task is the

- o understanding of children's/adolescents' mental or intellectual development, especially from the beginning of the secondary education phase;
- o understanding of the properties of maps and how children/adolescents relate to these attempts at the simplification of complex physical realities.

THE PIAGETIAN THEORY OF INTELLECTUAL DEVELOPMENT

Phillips (1975) clearly makes the claim that when Piaget began his investigations among children he was concerned primarily with how cognitions develop, not with developing cognitions. It would appear, therefore, that his work was not solely intended to have educational implications, but that his work has since come to have vast implications for teaching practice is indisputable. Piaget has discovered much about children, about their thought processes and intellectual development, and it would be remiss of any educationalist to ignore his contributions to the art of teaching. Boardman (1983) claims that Piaget has provided the only comprehensive theory of spatial

concept development which can be directly applied to the study of maps. It is this that justifies the use of Piagetian theory in this study.

It is the Piagetian viewpoint that cognitive development commences at birth, and from that point on a child moves progressively through different stages of thought, each characterised by its distinctive way of thinking and increased language sophistication.

Each of the four stages of development comprises a gradual development from a preparatory to an achievement phase.

The following stages constitute the developmental sequence:

Stage 1: Sensorimotor	(0 - 2 years)
Stage 2: Preoperational	
o Preconceptual period	(2 - 4 years)
o Intuitive period	(4 - 7 years)
Stage 3: Concrete Operational	(7 - 12 years)
Stage 4: Formal Operational	(12 - 15 years)

It is important to note that all the given age ranges are approximations. Among children in any range one can usually find manifestations of more than one stage or period. Of crucial importance is that in every child the sequence of development is the same.

The Sensorimotor Stage

This stage is characterised by the child's egocentricity. He operates only from and within his own perspective. He familiarizes himself with objects through the senses of touch and vision and perceives himself as an object of his own environment.

The Pre-operational Stage

Pre-conceptual period

This period of the pre-operational stage is characterised by communication through language, albeit yet inadequate to convey what the child wishes to express. The use of words is inconsistent and indicative of the fact that true concepts cannot yet be formed. Objects are represented symbolically via writing, drawing and playing activities whilst the thought processes are still immature and egocentric.

Intuitive period

At this particular time simple concepts are formed and are stimulus-dependent and related to the immediate environment. A child tends to be able to cope with only one relationship at a time. Terms such as "big" and "small" are absolute and have meaning only in terms of his own experiences.

The Concrete Operational Stage

This stage coincides with the development of the first signs of true logical thought. The description of the stage as "concrete" refers to objects in a physical sense rather than a hypothetical sense. The term "operation" itself is fundamental to Piaget's theory of intellectual development and is descriptive of the process whereby the mind absorbs all the facts presented to it, digests them and organises them into a structure. It is in the concrete operational stage that thought is first internalised or that things are consciously worked out.

Two key ideas in the process of logical thought are those of conservation and reversibility. Since it is during this stage that the first logical thought processes occur, it is appropriate that they are defined. Conservation is the awareness that a given volume or mass remains the same irrespective of the shape or size of its container. In terms of this study the idea of conservation may be extended to the idea of the conservation of area on a map, for example. Further applications of these ideas are detailed under the section "Implications of Piagetian Psychology for Teaching Synoptic Charts".

Reversibility is the ability to cope with the idea that a return to the original state produces the same amount, be it mass, volume or area. The extension of this idea is again inevitable when one relates it to map interpretation.

It is also during this stage that children become aware that certain concepts include others. They begin to understand reference systems, for example co-ordinate axes, which incorporates the ability to locate places in terms of longitude and latitude, and become familiar with orders of magnitude.

The Formal Operational Stage

This stage is marked by the ability to distance oneself from one's environment and to take an objective look at reality. A child's thought process becomes less egocentric in that he is not wholly dependent on his personal experiences. This, in turn, allows him to manipulate ideas which are not physically present and this equips him with the tools of reason, argument and conjecture, and hence the ability to make inferences and deductions from given premises. The formal thinker is able to employ the skills of analysis and discernment in attempts to make judgements about truth and falsity. The processes of thought can produce a variety of solutions and propositions about data. In essence, the child can engage in hypothetico-deductive thinking - hypotheses can be posited, tested and then accepted or refuted. The formal thinker can think systematically. He considers each variable individually and can make inferences about its isolated or combined effect.

Some never attain formal operational thought levels. The time of transition from the concrete to formal operational stages also varies widely from individual to individual and it is important for teachers to detect it, which, for a secondary school teacher, may not be as simple as it sounds since within a class the stages at which pupils operate may be many and varied.

To conclude this section, Table 1 summarises the Piagetian developmental stages.

TABLE 1 SUMMARY OF PRAGETIAN DEVELOPMENTAL STAGES

IMPLICATIONS OF PIAGETIAN PSYCHOLOGY FOR TEACHING SYNOPTIC CHARTS

It has long been the author's concern that children, by virtue of a complexity of factors, seldom seem to come to a mature understanding of meteorological and climatological concepts. There appears to be a tendency toward rote memorisation of fact rather than a developed and progressive understanding of fundamental concepts. A sad consequence of this is that progress toward formal propositional thought is hindered because intellectual development is impeded as a result of a lack of sequential integration of structures. This concurs with Rushdoony's (1968) claim that children's errors or misconceptions were more a lack of systematic teaching than an inability to read maps.

From experience this would seem to be the case in many current curriculum subjects but, in the author's experience, the problem is exaggerated in meteorology/climatology as a consequence firstly of the very scientific nature of the subject, secondly its high degree of abstraction, and thirdly the need to be able to unravel this detailed symbolic scientific abstraction on synoptic charts.

The Piagetian ideas of Conservation, Reversibility and Centration have particular bearing on synoptic chart analysis and interpretation.

Conservation and Reversibility

Conservation and reversibility relate to the understanding of scale. A child will conserve when confronting a 1:1 map, on which reality is represented exactly as it is, albeit by means of symbols. In essence, on a 1:1 map, detail is conserved. The point being made is that as the scale reduces, detail must inevitably be lost and for an adolescent to accommodate the loss of detail due to scale reduction, the concept of conservation needs to have been mentally assimilated.

A small scale map, for example the synoptic chart scale of 1:20 000 000, must indicate to a child that what he observes can only be an approximation of reality as a result of the inevitable loss of detail. Once again if the basic process of reversibility is not assimilated cognitively, the extension of the principle would be unsuccessful. An issue which may compound this problem is that the map is crowded with a myriad of meteorological data.

Centration

Centration relates to the skill of forecasting.

To be able to make weather forecasts from a synoptic chart at the most rudimentary level, one needs to appreciate the parts of the whole - and then make formulations from a gestaltic viewpoint.

The immature formal thinker will fixate on the detail of the micro-features of the chart, a tendency referred to by Piaget as centration, and lose sight of its significance as part of the macro-features of the weather chart.

On the other hand, it appears that for those groups who have chronologically attained formal operational thought the converse is true. The macro-view dominates the micro-features and there is a resulting inability to synthesize sufficiently to make well-reasoned formulations or forecasts. These pupils operate under a distance decay principle. Recently taught or revised ideas are familiar to them, a fixation in this regard occurs and delays and/or inhibits progress toward deductive analysis - a phenomenon known by psychologists as retroactive inhibition.

Since it is a well documented fact that only some attain the formal operational stage of thought and that immature formal thinkers have a tendency toward centration whilst chronologically mature formal thinkers may tend to allow the macro-features to dominate their thought processes, it is understandable that some teachers claim that one of the problems they face in the teaching of the chart is to train pupils to forecast from synoptic charts. It was indeed the admission of some teachers that for them forecasting was the most difficult aspect of the chart.

The systematic, analytic and integrative nature of hypothetico-deductive thought would seem to be an essential mental skill required for the sound and successful interpretation of synoptic charts. The author claims this since to make sufficiently sound and well-reasoned judgements based on a synthesis of map information, a child will need to analyse the micro-scale map phenomena and integrate them.

THE PROPERTIES OF MAPS IN RELATION TO SYNOPTIC CHART ANALYSIS

From a review of the literature, not much research has been done on synoptic charts per se, but the extensive investigations on maps and mapwork involving children have produced findings which may be extrapolated to the synoptic chart.

Boardman (1983) makes the point that Piaget has provided the only comprehensive theory of spatial development which can be directly applied to the study of maps, and Boardman (1976) himself points out that perceptual ability and the development of spatial concepts are crucial to the meaningful study of maps and photographs.

Two strong and inter-related ideas which emerge from these claims are those of perception and spatial conception.

1. Perception can be defined as the ability to observe and identify details in a given situation and to match the observations with existing mental structures. Incorporated in this ability is a sense of intuition, which may well develop with experience. In the context of map interpretation, perception is that ability to observe a situation and to select detail appropriate to the task in hand.
2. Conceptualisation is a mental process of ordering information into structures. Lower order concepts may later become inextricably embedded in higher order concepts. This important mental process serves to enable us to produce succinct explanations, so that communication becomes more efficient with increasing semantic sophistication. When geographers speak of spatial conceptualisation they refer to one's personal mental frame of reference within which the relationships between objects can be structured. Space is simply an idea in the mind. It is subjective and relative and varies from person to person in accordance with one's intellectual progress.

The ideas outlined above are integral to the ability to interpret maps and photographs. In terms of this study, the failure to acquire these cognitive abilities exacerbates the problem of understanding synoptic charts. An additional difficulty is that synoptic charts are crowded with information.

For many learners the most important quality which they look for in a map is clarity. A map containing too much information is liable to be misread and will, therefore, not serve its primary function. With this in mind and the fact that maps are scaled representations of reality for the purpose of efficiently communicating information, the synoptic chart must surely rate as anathema for pre-formal thinkers.

A further problem in this regard presents itself if one compares the very nature of topographic maps and synoptic charts. The former represents a constant land surface whereas the latter are only representations of surface weather phenomena at a given moment in time and for them to have meaning they need to be interpreted in consultation with a sequence of pre- and post-condition maps, with an added appreciation for the meteorological processes in the vertical.

In an attempt to alleviate the burden which many high-schoolers bear, teachers need to understand how children's minds only gradually accommodate the map properties of location, scale, direction and symbolism - the fundamental elements of graphicacy.

Graphicacy is a term that was first used by Balchin and Coleman (1965) and is defined by Balchin (1972) as the communication of spatial information (through maps and other forms of illustration) that cannot be adequately conveyed by verbal or numerical means.

For the geographer, graphicacy is only one of the major communication modes which will aid the student in the understanding and interpretation of maps. The skills of numeracy, oracy and literacy are equally important and Boardman (1983) avers that children's graphicacy skills are largely dependent on their competence in these three.

It is, however, the skill of graphicacy which has a strong bearing on the study of synoptic charts and it is therefore examined further at this point. The skill of graphicacy is regarded as an essential skill not only for geography, but for other curriculum subjects as well. This is so much so that the Geographical Association (1981) made a strong plea for the inclusion of the tuition of graphicacy per se in geography.

The fundamental elements of graphicacy are:

1. Direction
2. Location
3. Symbolism
4. Scale

1. Direction

From the verbal mode of communicating direction viz. NE, SSW and so on, children need to progress to the point where direction can be communicated in terms of bearing or degrees.

2. Location

Location of sites by way of the co-ordinates of longitude and latitude stems from being familiar with, and proficient at, co-ordinate axes as reference systems.

3. Symbolism

The skill of graphicacy also entails being able to associate a symbol with the real phenomenon or concept which it represents, once the symbol has been perceived. In the context of synoptic charts, the perception and correct association demands the retention of information, since for examination purposes the key is ordinarily absent on charts. Symbols on synoptic charts present their own unique problems in that they are generally devoid of colour (not as in physical maps), saturated with information, and never a constant picture of reality because of the ever-changing nature of the air masses.

4. Scale

The property of scale is probably the most difficult for pupils to master. It is linked to the development of spatial conceptualisation. Piaget (et al) in Boardman (1983) has shown that this progression passes through three stages:

- o Topological space
- o Projective space
- o Euclidean space

4.1 A topological idea of space is the most rudimentary and concerns the ability to understand simple connections between parts of a whole in terms of the proximity of the objects in question. A child may represent space in a picture devoid of scale and accuracy. Topological maps are symbolic and characteristic of the child's initial conception of space.

- 4.2 A projective understanding of space equips the child with an ability to translate plan drawings into three dimensions. Soon after this, children acquire an appreciation of the relativity of spatial perspectives, which involves the mental co-ordination of perspectives from a variety of vantage points.

The evolvement from an understanding of topological to projective space is normally completed by the late concrete operational stage, and it must be inferred that the average child should have attained this level of spatial conceptualisation by the time he enters high school. It is accepted that pupils should cope with translating plan maps into three-dimensional mental pictures. It has been evident in the author's teaching of synoptic charts over the past six years that this is not so. One needs to question, therefore, whether our teaching is sufficiently graded to facilitate a sequential integration of concepts for the purpose of bringing about progress toward formal operational thought.

By the time a child has the skill of projective spatial conceptualisation, he should be able to convert a two-dimensional contour representation into its three-dimensional equivalent. Boardman (1983, p23) avers that "topographic maps showing relief are more difficult to understand because of the complex array of features which they contain". Satterley (1964) also showed that secondary school pupils have an inability to visualize the solid reality from contours on maps.

These assertions are particularly relevant to synoptic charts, where the added dimension of an invisible atmospheric mass is portrayed symbolically. With topological maps there exists a potential for a sequential progression from map feature to the observation of the real thing and a concomitant association between reality and portrayed reality. When working with synoptic weather charts, this association is, however, infinitely more complex - and in many instances - incomprehensible, owing to the virtual absence of an atmospheric mass to observe.

- 4.3 The ability to understand space in Euclidean terms very often only develops after the onset of formal operational thought, and involves the structuring of relationships between objects in geometrical terms. It would appear that this level of spatial conceptualisation is not an absolute necessity for handling the ideas peculiar to the synoptic chart.

Scale is, therefore, strongly associated with space - both in the horizontal and the vertical - in that it allows children to associate spatial map relations with the real distances involved with some accuracy.

Synoptic charts are small scale maps where a substantial reality is confined to a small area, resulting in an enormous amount of detail and more need for generalisation. Micro-scale phenomena are embedded in macro-scale phenomena and it is interesting to note that Sandford (1970,1972) found that large scale maps needed to be mastered before small scale maps. Where this has not occurred, a 1:20 000 000 synoptic chart is sure to create mental disequilibrium.

The synoptic chart is a scaled representation of an unobservable, intangible reality abounding in complex symbolism and a myriad higher order concepts which remain a mystery to the untrained mind.

To place in perspective the interrelatedness of cognitive development and map reading skills, the author presents a comparative table of graphicacy skills associated with topographic maps, with which pupils are usually more familiar, and their equivalent synoptic chart skill. Such a summary provides teachers with a chronological sequence of tasks valuable in setting assignments. (See Table 2)

ADAPTING THE GRAPHICACY SKILLS APPLICABLE TO TOPOGRAPHIC MAPS FOR THE SYNOPTIC CHART

Boardman (1983) lists the graphicacy skills pupils should have acquired by certain age ranges and offers the following justification for doing so:

"The ages at which children should be able to achieve various skills of graphicacy cannot be specified precisely because of their different rates of intellectual development. Nevertheless the experience of teachers in the classroom, together with research evidence and the requirements of public examinations, does make it possible to suggest tentatively the approximate ages by which children of average ability should normally be capable of acquiring various skills of graphicacy...Some pupils will master the various skills at earlier ages than those suggested here; slow learners will not attain them until much later." (Boardman 1983, p167)

From Boardman's comprehensive listing of graphicacy skills expected to be mastered within certain age ranges the author has selected those which he deems appropriate for synoptic chart work and has adapted them accordingly. The author has chosen to classify the age ranges eleven to thirteen, thirteen to sixteen and sixteen to nineteen as being associated with Basic, Intermediate and Advanced graphicacy skills respectively.

Table 2

AGE AND ORDER OF SKILL	GRAPHICACY SKILLS ASSOCIATED WITH TOPOGRAPHIC MAPS	EXAMPLES OF HOW THE GRAPHICACY SKILL CAN BE EXTRAPOLATED TO SYNOPTIC CHARTS
11 - 13 Basic	1. Give 6 figure grid reference	Give co-ordinates of weather station model, low pressure centre etc.
	2. Measure curved distances	Determine the extent of fronts using the ratio scale 1:20 000 000
	3. Describe a route	Describe the movement of a cyclone by consulting a sequence of charts
	4. Identify and draw conventional symbols	Identify warm/cold fronts; draw weather station models given particular data
	5. Read heights on contours and estimate heights between contours	Read and infer pressures by inspecting isobars, and determine pressure difference between isobars
	6. Draw a cross-section of map contours	Draw a cross-section through a cyclone
	7. Calculate vertical exaggeration	Appreciate the vertical exaggeration of profiles
	8. Calculate gradient of a slope	Calculate the pressure fall over a given distance
	9. Calculate area	Calculate the areal extent of a tropical cyclone
	10. Identify simple topographic features	Identify basic pressure patterns eg. ridge, col, trough, tongue
	11. Annotate a landscape map from a photograph	Annotate a satellite image from a synoptic chart
	12. Describe a landscape using combined evidence of map and photograph	Describe prevailing weather at a given place using satellite image and synoptic chart
13 - 16 Intermediate	13. Generalize about the height of an area	Generalize about the intensity of prevailing pressure systems
	14. Identify overall relief divisions	Identify zones of high and low pressure, cyclones and anti-cyclones

16 - 19 Advanced	15. Describe the shapes of slopes	Recognize and describe steep and gentle pressure gradients
	16. Describe the nature and pattern of rivers in a drainage basin	Describe air flow patterns around pressure systems
	17. Correlate features on the photo with those on the map	Correlate features on the satellite image with those on the synoptic chart
	18. Use the combined evidence on map and photo to make inferences about human activity	Use the combined evidence on synoptic chart and satellite image to make inferences about anticipated weather
	19. Construct a landscape model from a map and show selected features on it	Convert two-dimensional pressure patterns to their three-dimensional equivalents
	20. Identify relief patterns and suggest origins	Identify pressure patterns and describe/suggest origins
	21. Identify drainage patterns and suggest reasons for them	Identify air flow patterns and suggest reasons for them, eg. geostrophic flow, gradient flow, sea breezes contrary to prevailing pressure flow
	22. Designate stream order	Infer stage of maturity of atmospheric weather phenomena
	23. Read geology maps and relate rock strata to relief and drainage	Read rainfall maps and relate weather phenomena to climatic regions/Read temperature maps and relate to latitude, altitude, continentality or prevailing weather phenomena

A COMPARISON OF GRAPHICACY SKILLS APPLICABLE TO
TOPOGRAPHIC MAPS AND SYNOPTIC CHARTS

COMMENTARY ON THE EXTRAPOLATION OF SKILLS

It would seem that there cannot be a one-to-one correlation between the graphicacy skills required for topographic map interpretation and synoptic charts. This shift is illustrated in Figure 37. This appears particularly true for the Basic and Intermediate skills. The author advocates that basic synoptic chart skills should be established in the twelve to fourteen year age range so as to consolidate basic meteorological and climatological principles. If this strategy proves successful the time required to develop intermediate skills will be reduced to only two years viz. fifteen and sixteen year olds or standards eight and nine. The advanced skills pertaining to synoptic charts appear to be comfortably handled in the sixteen to nineteen age range, but the author is inclined to think that the consolidation of advanced synoptic graphicacy skills may only occur during the period of tertiary education.

The justification for these assumptions may be found throughout the chapter, especially where the author alludes to the difficulties of a psychological nature peculiar to the synoptic chart. The concepts underlying an analysis of the synoptic chart, when compared to those relating to topographic map analysis, are clearly more numerous and of higher order. They are generally covert and definitional concepts requiring more mental abstractions.

A comparative resumé of problems peculiar to topographic maps and synoptic charts (Table 3) concludes this section.

AVE AGE	STD	ORDER OF TOPOGRAPHIC MAP GRAPHICACY SKILLS	ORDER OF SYNOPTIC MAP GRAPHICACY SKILLS	PIAGETIAN DEVELOPMENTAL STAGE
6	A			PRE-OPERATIONAL
7	B			
8	1			
9	2			
10	3			CONCRETE-OPERATIONAL
11	4			
12	5	Basic	Basic	
13	6			
14	7			FORMAL
15	8	Intermediate	Intermediate	
16	9			
17	10	Advanced	Advanced	

Fig. 37 A comparison between topographic map and synoptic chart graphicacy skills in relation to the Piagetian developmental stages

Table 3

TOPOGRAPHIC MAP	SYNOPTIC CHART
1. Mapped observable, tangible reality	1. Mapped unobservable, intangible reality
2. 1:50 000 scale retains fair detail 1 cm represents 0,5 km	2. 1:20 000 000 loss of detail requires greater perception. 1 cm represents 200 km
3. Concept of contours can be conveyed/ taught through the medium of physical models eg. Plasticine model of hill can be immersed in a water tank. Contour lines can be successively inscribed on the model.	3. Contours are of two kinds: (i) Geopotential metre isolines: heights of 850 hPa over the plateau, and (ii) Isobars: hPa pressure reduced to sea level. The derivation of the contour concept (isolines) can only be conveyed/taught through inter- polation exercises, and consolidated in the formal operational period.
4. Reasonable amount of clarity and handleable information.	4. Abundance of information and therefore diminished clarity.
5. Representation of a constant land surface configuration. Interpreta- tion aided by consulting an aerial photograph.	5. A representation of a momentary condi- tion of the atmosphere - each represen- tation different from the other, meaning that a sound interpretation is dependent on the consultation of a sequence of maps - and satellite images.
6. Spatial conceptualisation can take place within an established frame of reference.	6. Spatial conceptualisation becomes an intricate and sophisticated mental process.
7. Representation of a static situation.	7. Representation of a dynamic situation.
8. Interpretation of fixed phenomena.	8. Interpretation of dynamic phenomena re- lative to a fixed position eg. forecasting.

COMPARATIVE RESUMÉ OF PROBLEMS PECULIAR TO
TOPOGRAPHIC MAPS AND SYNOPTIC CHARTS

LEARNING - THE INHERENT PROBLEM

Essentially the problem at hand has to do with how the pupil learns; a process involving the mental operations of acquiring concepts, principles, theories and skills.

According to Piagetian theory, learning involves assimilating experience into one's conceptual framework and accommodating one's conceptual framework to new experiences. If new classroom experiences do not unduly disturb the conceptual framework of the child then there is an equilibrium in the mental system. If new experiences prove difficult to assimilate within the existing conceptual framework, then disequilibrium sets in and the process of equilibration can only occur when the pupil changes his conceptual framework to accommodate the new experience through the mastering of appropriate activities and/or problems.

In theory, the crux of the Piagetian idea of learning amounts to the successful meeting of challenges and hence and accrued intellectual growth. The author questions whether pupils are faced with challenges appropriate enough for them to be intrinsically motivating. "Appropriate" here requires qualification. Challenges need not, and must preferably not, be such that children feel beaten by them. Where this happens it becomes the teacher's responsibility to re-establish interest by means of a clue rather than a cue, for the latter has the effect of diminishing pupil self-thought. An appropriate challenge is one that accommodates a pupil's stage of intellectual development.

A lack of lower order concept development in addition to the introduction of higher order concepts at any given stage of development creates a mental disequilibrium which is seldom, if ever, resolved. This amounts to an inappropriate challenge which is demotivating and thus destructive to the learning process.

If learning (and thereby is implied teaching) is the problem at the centre of the acquisition of climatic and meteorological concepts, then Ausubel's Assimilation theory of learning serves as a valid frame of reference.

AUSUBEL'S ASSIMILATION THEORY OF LEARNING

The most important factor in Ausubel's learning theory is what the learner already knows.

Key concepts of Ausubelian learning theory

Meaningful learning:

This amounts to the conscious effort by a learner to relate new knowledge in a way relevant to existing concepts. This is in contrast to rote learning where new knowledge is incorporated verbatim into one's cognitive structure. Ausubel maintains that there is no dichotomy between rote and meaningful learning, but rather that they exist on a continuum; insofar as rote concept acquisition is almost a prerequisite for meaningful learning.

Subsumption:

New knowledge interacts with existing, meaningful, relevant concepts and is assimilated into these concepts, the result being that the original concept and newly accrued knowledge are transformed into a progressively more meaningful concept. What Ausubel calls subsumption is equivalent to Piagetian assimilation, but the two differ in that the former is seen as cognitive development as a result of the continuous differentiation and integration of relevant concepts in the existing cognitive structure and as a stage-by-stage development in the latter.

The implication of this distinction is that according to Ausubel, older children can operate in abstract terms more successfully than younger children as a consequence of their higher overall level of differentiation and integration of more elaborate concepts. It furthermore implies that to operate with mental abstractions is not a function of age, but rather a function of the degree of sophistication of a child's cognitive structures or repertoire.

Obliterative subsumption:

Meaningfully learned material is associated with a longer mental retention than rote learned material, but this does not mean that meaningfully acquired material cannot be forgotten. Obliterative subsumption is the mind's ability to meaningfully forget residual detail, but retain the original concept with the advantage that it can still be useful in learning new things and expanding one's cognitive structures.

Progressive Differentiation:

One never "acquires" new concepts. Rather, any given concept is in the process of being differentiated. In this regard concepts are dynamic in that they are continually being modified and linked with existing concepts to the end that an elaborate relevant cognitive framework is developed. This progress is surely a function of the stimulus provided for children – in other words, it has a strong bearing on teaching methodology.

Superordinate Learning:

When concepts are introduced which have an "umbrella" relationship to existing concepts superordinate learning takes place. Superordinate learning, therefore, also strengthens progressive differentiation of cognitive structures, since subordinate concepts now acquire new integrative meaning.

Integrative Reconciliation:

This occurs wherever superordinate learning occurs since concepts that were initially seen as independent of others or in conflict, are integrated into higher order concept meanings.

Integrative reconciliation may also occur when the pupil recognizes that several terms represent the same concept, or that one label may represent two distinct concepts.

Advance Organizer:

Advance organizers facilitate new learning only when the material to be learned is meaningful. When material is completely novel and no relevant concepts exist in the learner's cognitive structure meaningful learning cannot take place; for example when the essential graphicacy skills of synoptic charts have not been acquired the application and synthesis of information is difficult.

IMPLICATIONS OF AUSUBELIAN LEARNING THEORY FOR TEACHING SYNOPTIC CHARTS

Piagetian terminology is often used in Ausubelian exposition, pointing to the fact that Piaget's contribution pervades educational thought. However, the most marked distinction between Piagetian developmental psychology and Ausubelian learning theory is that the former attempts to describe those mental abilities which children on the average exhibit at various stages, whilst the latter pertains to the teaching methodology and learning processes relevant to science based education.

From an Ausubelian viewpoint, significant educational achievements are those which result in the acquisition and differentiation of basic scientific concepts. The thrust of Ausubelian learning theory lies in its recognition of the importance of the rote learning of fundamental scientific concepts - a factor of significant relevance for this study by virtue of the very scientific nature of climatic and meteorological concepts.

Novak (1978) claims with conviction that reception teaching methods can be effective in developing highly functional conceptual frameworks amongst learners at all levels. Rote learning, which Novak claims is merely the lower extreme of a continuum of which meaningful learning is the higher bound, is equivalent to the reception-discovery teaching continuum.

Novak (1978) refers to the fact that Kuhn(1962) and Toulmin (1972) lucidly point out that concepts, not enquiry methods, are at the core of rational human thought. There appears, therefore, to be a sound argument for the rote learning of climatic and meteorological concepts, so that a sound knowledge base may be established.

Given Ausubel's view of cognitive learning, one must accept that the rate of cognitive development may also be a function of the method of tuition and

the degree of stimulation afforded the individual. This implies that younger pupils can engage in formal operational thought if given the appropriate cognitive preparation.

Cognitive development may, therefore, be manifested in an expanding sophistication and elaboration of specific concepts. Such a viewpoint may further be seen as supportive of the idea that different individuals exhibit varying degrees of specific cognitive skills; for example, one individual may show particular strength at verbal rather than non-verbal cognitive tasks.

The challenge for educators is to present well designed educational experiences for their charges. Novak (1978) states that most public school and university instruction is far from direct and explicit in the extent to which and the manner by which concepts are made evident to students. In a similar vein, Graves (1977) feels that some geographers recognize the principle of adiabatic cooling, for example, but seldom provide a detailed explanation of the physical processes which result in this cooling. Graves (1977) further argues that geographers have traditionally given relatively weak explanations of some relationships and strong explanations of others and that no rational basis exists for such distinctions. Graves thus exhorts geographers to be thorough in their teaching of all relationships in the same way that Ausubel encourages the development of advance organizers for the learning process.

The exhortation is valid, but one needs to question its practicality. Teacher training is often specific and directly related to the interests of the prospective teacher; and this moreso in the case of geography which, by nature, is so multi-disciplinary.

Stevens (1972) in his assessment of senior secondary physical geography claims that the teaching of the subject is characteristically non-scientific, with an emphasis on description and simplified explanation. He feels that the general weakness of school physical geography is that it consists of little more than the acquisition of interesting "facts" and simplified explanations about natural phenomena.

These assertions are equally and specifically applicable to the meteorology and climatology components of senior secondary geography teaching. Stevens (1972) also recognises that in climatological studies there has been a shift

in emphasis from the cataloguing of data to the explanation of data. From Chapter 1 it is clear that adolescent tasks involving synoptic chart analysis and interpretation require pupil comprehension of ideas and an ability to apply a volume of integrated knowledge in a synthetic manner. It is inevitable that explanation is a desirable teaching activity. Stevens (1972) summarises the point well when he claims that meteorology is fundamental and not extraneous.

Weather of all types involves concepts from thermodynamic physics eg. condensation, evaporation and precipitation. Where teachers are faced with inexperience in these areas, inter-curricular co-operation may aid the development of a wider scientific concept base.

A part solution to the problem is that teachers undergo in-service training in the specific fields which were either not catered for or pursued in their own tertiary education careers, with the intention of expanding and ramifying the concept base in the hope that pupils will be equipped to enter into formal operational thought, not only at the Piagetian stage of formal operations, but as early as circumstances warrant it or the child's innate ability enables him to do so.

This would appear to be the need when one examines the senior secondary climatology syllabus. The meteorological and climatological concepts which pervade the entire syllabus have strong scientific foundations, and a plethora of abstractions which need to be mastered. The intricately interwoven and difficult concepts pertinent to weather science, if they are to be mastered, need to be taught with care and practised patiently.

It is to this end that a concept matrix spanning the climatology of standards eight, nine and ten has been designed and presented in Figure 38.

SENIOR SECONDARY METEOROLOGY-CLIMATOLOGY CONCEPT MATRIX

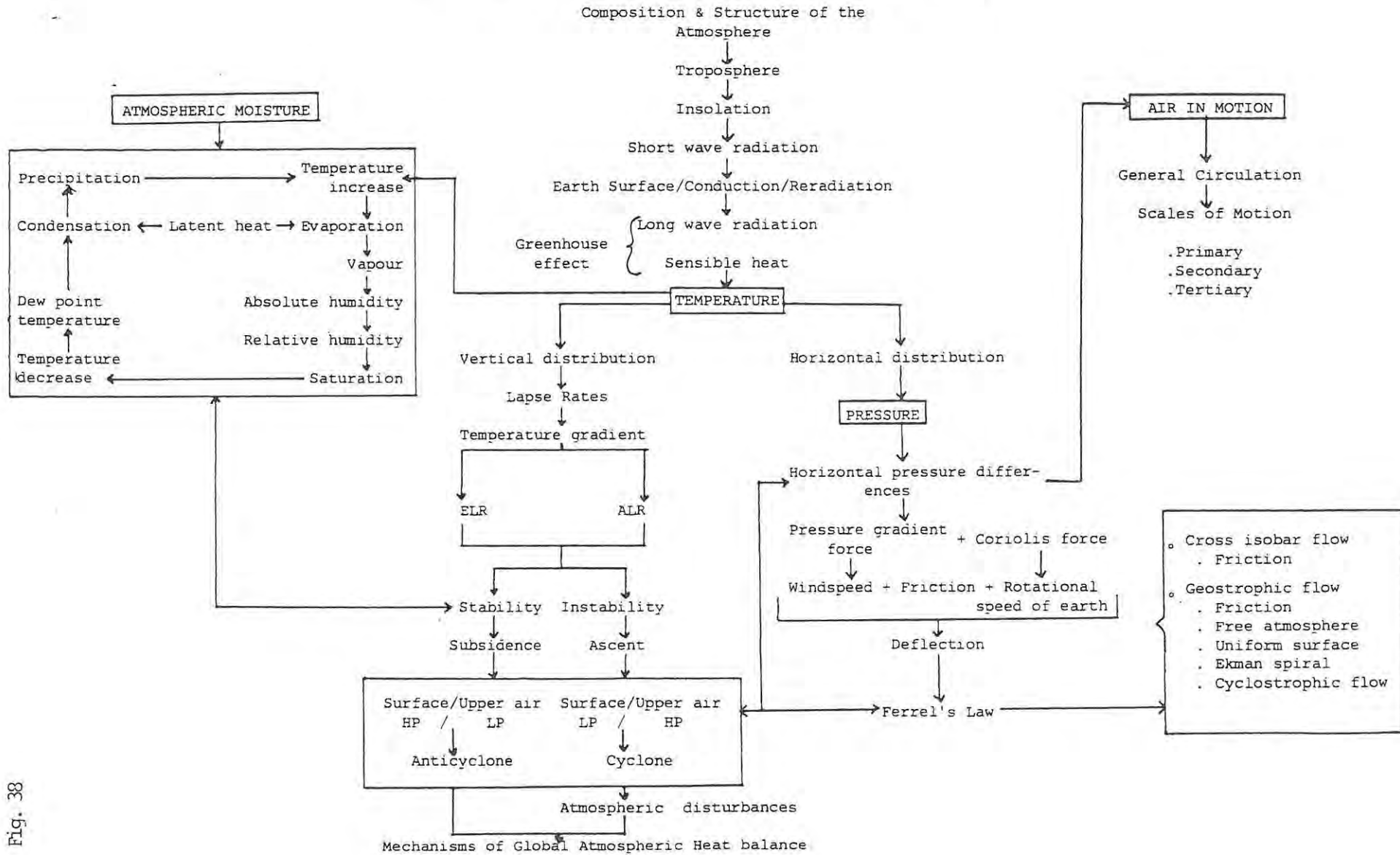


Fig. 38

COMMENTARY ON THE METEOROLOGICAL CONCEPT MATRIX

The author has relied on his own classroom experience rather than on specific reference works for this section.

Temperature

The central concept of meteorological study is the climatic element of temperature in that it is responsible for the development of pressure differences and consequently the dynamics of air in motion. Temperature is also integral to the concept of atmospheric moisture because the air's capacity for holding moisture is temperature dependent.

For many a school-goer the concept of temperature remains an experiential phenomenon and the understanding of its origin is seldom grasped. In order for the concept to acquire cognitive meaning the development of ideas outlined in the concept matrix is seen as desirable by the author.

The most important atmospheric layer in terms of the earth's weather and climate is the troposphere, and it is this layer that should be focused upon when dealing with the composition and structure of the atmosphere. The impact of solar energy on the troposphere is fundamental to the heating of the atmosphere. There is a need for a distinction between the short wave nature of insolation as opposed to the long wave terrestrial reradiation and the process of conduction which links the two. It is the longwave terrestrial radiation which we experience as varying degrees of heat and hence temperature. The response of the longwave radiation to the moisture and carbon dioxide content of the troposphere accounts for the relative permanence of tropospheric heat. Clouds inhibit the loss of terrestrial reradiation and thereby act as insulators. These processes are summarised in the "Greenhouse Effect" and are important to the understanding of frost formation.

The Significance of Vertical Temperature Distribution

The change in temperature with altitude is termed a lapse rate. The distinction here between environmental (normal) and adiabatic lapse rates and their behaviour relative to one another is important for the understanding of stability and instability of an atmospheric mass. The former is associated with subsidence as opposed to the association of ascending air with the latter. The introduction of the subsidence and ascent of air and the implied relation

to pressure is indicative of the inevitable interrelatedness of meteorological concepts. Systems of ascending and descending air are associated with the cyclones and anticyclones respectively and with the tri-cellular general circulation patterns. It is at this point that the idea of lows replacing highs aloft and vice versa is of significance in the teaching strategy.

The manifestation of surface cyclonic lows is synonymous with atmospheric disturbances and these in conjunction with the moving anticyclones are responsible for alternating "bad" and "good" weather, and ultimately these mechanisms are in part responsible for the global atmospheric heat balance. The vertical temperature distributions, therefore, have a bearing on the development of weather at one scale and the zonal and meridional flow of the tri-cellular arrangement at another scale by virtue of their connection with pressure.

The Significance of the Horizontal Temperature Distribution

Differences in temperature result in the pressure differences in the horizontal (and concomitant compensations in the vertical) and a direct consequence of this unequal distribution of pressure is wind.

The concept of wind brings with it the concepts of pressure gradient force and Coriolis force. These two concepts are of particular relevance to the understanding of zonal air flow between the planetary pressure belts, and leading on from this, the cyclonic and anticyclonic circulation of air. Ferrel's Law summarises the differences in the direction of air flow in the hemispheres.

Where winds are sufficiently strong by virtue of the pressure gradient and/or diminished friction, there tends to be a balance between the pressure gradient force and Coriolis Effect, and the resulting wind tends to blow parallel to the isobars and, as such, is termed geostrophic.

Geostrophic winds are common in the free atmosphere, that is the atmosphere between 500 and 1000 metres aloft. However, where certain ideal conditions prevail at the surface such as in high velocity cyclonic vortices eg. tornadoes, hurricanes, winds tend to blow parallel to the isobars and are termed cyclostrophic. Where winds blow across uniform homogeneous surfaces such as the expansive South Atlantic they tend to blow geostrophically.

Cross-isobar flow is a surface phenomenon and a function of increased friction, reduced windspeed and, hence, reduced Coriolis Effect since from the definition of the Coriolis parameter

$$C = 2 \Omega \sin \phi V$$

where Ω is the angular velocity of the earth (a constant),
 $\sin \phi$ is the sine of the latitude and V is the velocity of the wind,

the Coriolis Effect is directly proportional to the wind velocity. The Coriolis Effect may also be explained in terms of the varying rotational speeds at different latitudes.

Surface wind is affected by friction and with increasing altitude, and diminishing friction, there are direction and speed changes in the wind. This is illustrated by the Ekman spiral in Figure 39.

The effect of the unequal distribution of pressure, both in the horizontal and vertical, is that it sets air in motion, and since we are dealing with a non-stationary earth, the Coriolis force serves to deflect the wind from its expected path of motion.

The behaviour of wind is summarised in Ferrel's Law which states that if one stands with one's back to the wind in the southern hemisphere the deflection will be to the left of the wind's path of motion, and vice versa in the northern hemisphere.

Once an understanding of the forces responsible for and operating on winds have been grasped, the author feels that an automatic progression would be to the description of the general circulation where Ferrel's Law can be applied. It is also seen as desirable to emphasize scales of motion at this stage so that pupils accommodate the orders of magnitude associated with the primary, secondary and tertiary circulations. It is hoped that this approach will strengthen the pupil's global perspective.

The Significance of Atmospheric Moisture

Knowledge of the fundamental properties of water is vital for the understanding of weather processes. It is important for pupils to know that the energy stored and released in the atmosphere is intimately linked with the phase changes of water, and that it is this energy that originally derived from the sun, that drives the earth's weather systems.

The heating of a water surface agitates the surface molecules through increased kinetic movement. The energy used in this evaporation process effectively is taken into the atmosphere as the water vaporizes. This leads to the understanding that the amount of vapour present in the atmosphere is related to the temperature of the atmosphere, and hence that relative humidity is the ratio between the vapour present in the air and the greatest amount of vapour which the air can hold at that temperature. Where this ratio amounts to one, the air is termed saturated.

With the above in mind, it may be easier to appreciate that the vapour capacity will be reduced if there is a decrease in temperature or a further addition of vapour to the air, producing condensation. The concept of dew point temperature is then assimilated. The energy stored in the vapour phase is released when condensation occurs and this serves to trigger further atmospheric instability, providing, for example, the energy responsible for making cumulonimbus clouds tower to heights often in excess of twelve kilometres. The precipitation realized from such instabilities returns water to its source and completes the hydrologic cycle.

The concept matrix may serve several functions. It can firstly provide a schema or frame of reference for teachers. Secondly, it may place in perspective the interrelatedness of the various atmospheric components of weather science and thirdly, it may serve as a diagnostic aid for teachers in that it may help one assess where pupil difficulties lie.

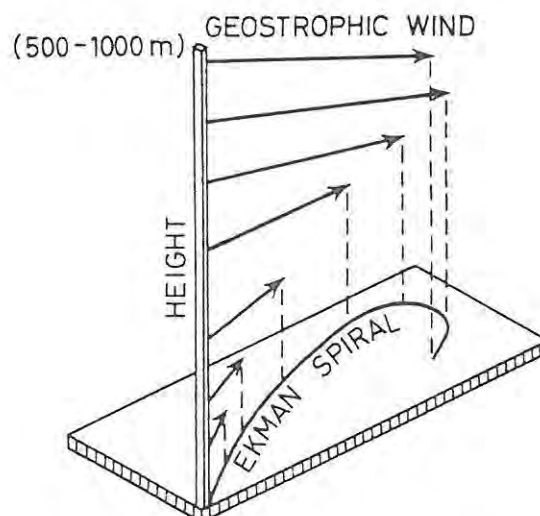


Fig. 39 The Ekman Spiral (after Barry and Chorley, 1976)

CHAPTER 4

A CRITIQUE OF THE SENIOR SECONDARY CLIMATOLOGY SYLLABUS (1985);
TRENDS IN THE MATRICULATION EXAMINATION QUESTIONS OF THE
CAPE EDUCATION DEPARTMENT AND AN EVALUATION OF
CURRENT TEXTBOOK CONTENT

SENIOR SECONDARY CLIMATOLOGY/METEOROLOGY SYLLABUS (1985)

<u>Standard eight</u>	<u>Standard nine</u>	<u>Standard ten</u>
The Atmosphere	Atmospheric Pressure	Mid-latitude and Tropical cyclones
o Composition and Structure	o Definition, measurement, and representation	on a global scale
Temperature	[SG study only relationship between pressure and wind]	o Growth, decay and associated weather
o Heating of the atmosphere	Geostrophic flow	o Consequences
o Factors influencing horizontal temperature gradient	General Circulation	[SG study only general description of tropical cyclone]
o Vertical temperature gradient	o Primary	Weather and climatic explanations
Atmospheric Moisture	o Secondary	o Regional scale
o Relationship between temperature and moisture	o Tertiary	o Travelling disturbances and anticyclonic circulations and their effect on weather patterns in Southern Africa
o Absolute and Relative humidity	Weather Processes	o Line thunderstorms and their effect on the weather pattern of South Africa
o Dewpoint temperature	o Causes of uplift	o Local Scale
o Simple cloud classification	o Lapse rates	o Valley and City climates
o Precipitation	o Thermal stability and instability	
	Thunderstorms and tornadoes on a global scale	
	o Growth, decay and associated weather	
	o Consequences	
	[SG study general description only]	
	Climatic significance of oceans	
	o Moisture source	
	o Role in climate control	

CRITIQUE OF THE 1985 SENIOR SECONDARY CLIMATOLOGY SYLLABUS

General

Point 3.1.3 (c) on page 5 of the Cape Education Department's syllabus for Senior Secondary Geography states that "several components of the syllabus could be taught as subsystems such as those associated with weather, drainage and urban subsystems". In the light of this recommended teaching guideline, and in terms of classroom experience, the author is in favour of such a systems approach to the teaching of the meteorological and climatological aspects of the syllabus only insofar as it serves to lay a foundation for the eventual integration of weather science (content) with other syllabus components.

A description of the content of and amendments to the new Senior Secondary Climatology syllabus is contained in Table 4.

By way of introduction to the standards eight and nine climatology work, the syllabus suggests the use of synoptic weather charts, satellite images, graphical representation and quantitative techniques "where appropriate". The suggestion is commendable, but the author is of the opinion that such vague intimation as "where appropriate" is insufficient in a document from which guidance and direction is sought. In addition to the same suggestion being incorporated into the standard ten syllabus, a vital point is made viz. that, quote, "Relevant concepts learnt in standards eight and nine should be applied".

The implications of these syllabus recommendations are two-fold:

- (a) They stress the fundamental importance of the weather chart in climatology studies, and, although not specifically stated, the chart must therefore form an integral part of the work undertaken in standards eight, nine and ten.

From the recommendations one must assume that it is hoped that pupils will associate the teaching of climatic elements with the chart. It is, however, anomalous to find, in this regard, that teachers spend very little time on synoptic weather charts in standard eight, slightly more time in standard nine and the most time in standard ten, as gleaned from interviews with teachers.

- (b) There should be a developmental approach to the synoptic chart. The

Table 4

SENIOR SECONDARY CLIMATOLOGY/METEOROLOGY SYLLABUS (1985)

<u>Standard eight</u>	<u>Standard nine</u>	<u>Standard ten</u>
The Atmosphere	Atmospheric Pressure	Mid-latitude and Tropical cyclones
o Composition and Structure	o Definition, measurement, and representation	on a global scale
Temperature	[SG study only relationship between pressure and wind]	o Growth, decay and associated weather
o Heating of the atmosphere	Geostrophic flow	o Consequences
o Factors influencing horizontal temperature gradient	General Circulation	[SG study only general description of tropical cyclone]
o Vertical temperature gradient	o Primary	Weather and climatic explanations
Atmospheric Moisture	o Secondary	o Regional scale
o Relationship between temperature and moisture	o Tertiary	. Travelling disturbances and anticyclonic circulations and their effect on weather patterns in Southern Africa
o Absolute and Relative humidity	Weather Processes	. Line thunderstorms and their effect on the weather pattern of South Africa
o Dewpoint temperature	o Causes of uplift	o Local Scale
o Simple cloud classification	o Lapse rates	. Valley and City climates
o Precipitation	o Thermal stability and instability	
	Thunderstorms and tornadoes on a global scale	
	o Growth, decay and associated weather	
	o Consequences	
	[SG study general description only]	
	Climatic significance of oceans	
	o Moisture source	
	o Role in climate control	

Changes to the syllabus are minimal and amount to the following:

1. Standard ten standard grade candidates now study only the general description of the tropical cyclone.
2. Standard ten higher and standard grade candidates study line thunderstorms specifically. The study of the thunderstorm in general has been relegated to standard nine.
3. More emphasis is placed on the use of satellite photographs in conjunction with synoptic charts.
4. Standard nine candidates study the influence of oceans on weather in more detail.
5. Particular emphasis is placed on the need for concepts learned in standards eight and nine to be applied in standard ten.

foundation concepts studied in standards eight and nine should be taught in conjunction with the chart so that by standard ten climatic concepts can be applied in synoptic chart analysis and interpretation. For the past six years the application of standard eight and nine concepts has not been examined to any significant extent in climatology/meteorology questions based on synoptic charts; a trend one would not expect in terms of syllabus specifications.

By inspecting Table 4 it is evident that the standard eight core syllabus concerns the teaching of the climatic elements viz. temperature, atmospheric moisture and precipitation forms. It is the author's contention that atmospheric pressure should also form part of the standard eight core syllabus. If the syllabus were arranged in such a fashion, a sound knowledge of the basic climatic elements will have been acquired by the end of standard eight, and hopefully pupils will then be prepared for the work of the proceeding years.

The core syllabus for standard nine will then seek to equip pupils with the general principles of vertical and horizontal atmospheric motion. In essence, therefore, the distinction between the standards eight and nine core syllabi would be the static study of the elements in the former and an introduction of the dynamic dimensions of the atmospheric medium in the latter.

The standard ten core syllabus concerns the weather systems affecting South African climate at large and the general global characteristics of these systems. It is characterised by a need for the general integration and application of previously acquired concepts. In the light of this, it is understandable that the majority of past Senior Certificate climatology examination questions have been based on the South African synoptic weather chart. The relegation of the general study of thunderstorms to the standard nine year (where it fits in well with vertical weather processes and atmospheric instability) is a welcomed amendment in the author's opinion. The introduction of the "line thunderstorm" to the standard ten syllabus is also a commendable amendment in that the topic is specifically related to South Africa and thus relevant to synoptic chart analysis.

In general, therefore, the current syllabus is appropriately designed in terms of the introduction of static concepts at standard eight level, pro-

gressing toward the dynamics of atmospheric motion in standard nine and culminating with an interpretive approach at standard ten level. The major incongruity in the author's opinion is the inclusion of the teaching of the "pressure" concept in standard nine rather than standard eight. Furthermore, the current syllabus design caters for a developmental approach to climatology and, therefore, also to the weather chart. It is, however, this approach which is vaguely defined in the syllabus and possibly therefore the factor responsible for few teachers, at standard eight level especially, teaching climatology in conjunction with the chart.

The concept matrix developed in Chapter 3 is compatible with the syllabus design. The matrix sets out a procedural sequence essentially in order to facilitate the ordered teaching of concepts. It is the author's preference not to approach the work inductively or deductively, but rather for teachers to adopt an eclectic approach. This entails teaching in the manner most appropriate for a given ability range or set of circumstances. On the standard grade, for example, it may be necessary to teach basic concepts, for example weather elements and their representation, before applying them to the chart. This inductive approach may facilitate deductive analysis which is then founded on a strong factual knowledge base. However, higher grade candidates, in the author's opinion, may respond favourably to a deductive approach, whereby the overall general climatology (average weather patterns) is taught before investigating the specific mechanisms responsible for South African regional weather regimes.

There appears, therefore, to be a valid underlying rationale behind the syllabus design with the exception of the placement of the "pressure" concept which, in the author's opinion, is easily rectifiable by the teacher.

MORE SPECIFIC OBSERVATIONS RELATING TO THE SYNOPTIC WEATHER CHART IN TERMS OF THE SYLLABUS

At no one stage are pupils specifically required to study the synoptic chart as a communicative device. In the preamble to each standard's climatology syllabus, it is, however, only recommended that use be made inter alia of the synoptic weather chart and satellite images.

In an instance where a teacher consults and works according to the syllabus, as is normally expected, energies are spent on teaching the content of

the syllabus, and it was gleaned from interviews with teachers, and pupil worksheet responses, that rarely are synoptic weather charts used in the recommended sense. For example, standard eight candidates performed particularly poorly on synoptic chart related questions on the pupil worksheet (see Chapter 5) whilst teachers, by their own admission, spend little time on the chart in standard eight. There appears to be a concentrated endeavour to teach the synoptic chart in standard ten, rather than an equal distribution of attention given it from standard eight to standard ten.

A further justification for synoptic charts being included per se as a topic of study in the syllabus has to do with time. Where a topic is specified, it is apportioned teaching time. It is the author's experience that where this is not so, the topic's relevance diminishes in favour of those topics which are clearly examinable.

Further, for any pupil still in the process of acquiring and mastering intermediate graphicacy skills, the synoptic weather map and satellite photograph are extremely difficult instruments to make rational sense of by virtue of their graphicacy problems outlined earlier, especially when the charts are presented as fait accompli.

Station models are also treated as integral to climatological studies in some textbooks; for example, Senior Geography Std 10 (1987) and Active Geography Std 9 (1986) handle the subject well. In these two texts the station model is handled in conjunction with synoptic chart interpretation. The author's approach to the teaching of the synoptic chart is presented in Chapter 6. Where emphasis and clarity on whether they should be taught per se is lacking in syllabi, they somehow become relegated to inconsequential status and seldom, therefore, do pupils acquire the skills pertinent to synoptic weather chart analysis and interpretation.

It is, therefore, recommended that the synoptic chart be treated as a teaching topic so as to acquaint and familiarize pupils with the complexities of the chart. Nowhere in the prescribed syllabus, for example, is it necessary to study the weather station model - that symbol which provides the fundamental data for the compilation of the chart.

Further points of concern have to do with the standard grade syllabus requirements. It is understandable that "absolute and relative humidity"

are omitted from the standard eight syllabus since the concept does not have any fundamental bearing on any subsequent content. The concept of "vertical temperature gradient" is, however, incongruously omitted. A standard nine pupil on the standard grade may not need the concept of "temperature inversion", but suddenly the standard ten requirement is that the effect of anticyclonic circulations on Southern African weather be understood - the phenomenon responsible for the seasonal character of the Highveld climate - and an understanding of these dynamic influencing factors is rooted in an understanding of temperature inversions, which is inextricably linked with the concept of vertical temperature gradients.

The point can be taken further. In standard nine the standard grade candidate is not required to study the concepts of "stability" and "instability". These concepts are so fundamental to anticyclonic and cyclonic circulations respectively that the omission, even only of the "stability" concept from the standard grade, is incomprehensible.

Similar criticism can be brought against the cursory dealing of the thunderstorm, when the effects of the line thunderstorm on South African weather is again a requirement in standard ten.

The requirements of the standard ten standard grade climatology syllabus presume known concepts which standard grade candidates are not required to have mastered prior to their matriculation year. This does not conform to sound educational methodology, and constitutes for pupils a hindrance when confronting a final examination.

The criticisms brought forward here further testify to the fact that hierarchically lower order concepts are not sufficiently taught or taught at all, and this, in Piagetian terms does not augur well for learning - it is unfortunately educationally unsound and demotivating.

One hopes that cognizance will be taken of the preamble to the 1985 syllabus, which includes the principles on which the syllabus is based and valuable teaching guidelines.

If our aim is to educate, the syllabus should serve purely as a guide to our procedure. Ideally where relevant content is omitted it is the teacher's responsibility to teach what is required known and this can only be achieved

if we have a global view of the entire syllabus – the concept matrix in Chapter 3 will hopefully facilitate such an awareness and approach. However, not all teachers responsible for teaching geography may have sufficient experience or qualifications to perceive unmentioned requirements. In such cases more specific guidance is necessary, especially in terms of content required known for the matriculation examination.

In conclusion, the syllabus design and content is appropriate except for the fact that

- (a) it does not require the teaching of synoptic charts as a specific topic, but nevertheless ultimately requires pupils to understand the graphicacy of charts for interpretational analysis. The synoptic chart effectively synthesises the elements of South African weather and climate;
- (b) the "pressure" concept would ideally be more appropriate at the standard eight, rather than standard nine level; and
- (c) the presumed knowledge at standard ten standard grade level is incompatible with previously acquired concepts.

REVIEW OF TEXTBOOKS AND MORE SPECIFICALLY THEIR TREATMENT OF SOUTH AFRICAN WEATHER, CLIMATE AND THE SYNOPTIC CHART

At this point in time, when the Cape Education Department schools are in the throes of accommodating modifications to the geography syllabi, the development of new textbooks has been an important issue. The position is such that although the modified syllabus was introduced in 1985 at standard eight level, the effects of any new approaches will only be gleaned from the results of the impending Cape Provincial Matriculation examinations. There is thus no past record to analyze and, in the same way, the new issue range of textbooks, when under scrutiny, bear similar problems for their critics. It is difficult to evaluate an innovation without an existing frame of reference; the frame of reference in this instance being experience.

At the time of writing, no standard ten text had yet been extensively used in the classroom as a result of the fact that they had not yet been published. This delay in publication precipitated several meetings of senior geography staff in the Border region. Their task was to interpret the modified syllabi and present to their colleagues their varying interpretations based on their own knowledge, research and expertise. The exercise was invaluable. It showed innovation, creativity and a freedom which was inherently educational. The dependence upon each other's experience of classroom teaching and personal talents propelled us from the isolated confines of our classrooms to a gathering of a professional standard where ideas ranging from technical facts to creative genius were deployed.

This provokes an assessment of the value of textbooks. There is little doubt that the current crop of matriculant geographers will have benefitted from the absence of an acceptable text. Their knowledge of any modified or new area of the syllabus will certainly be broader than the knowledge of those who follow them. The freedom to invent creatively without the restrictions imposed by the availability of a textbook bears the stamp of sound education. If teaching is textbook-bound, teachers run the risk of creating slaves to the textbook, who merely regurgitate factual content, rather than independent, rational thinking geographers. The shared ingenuity and experience of professional people very often produces self-motivating educational innovations worthy of being taught in any classroom.

The author has, therefore, resorted to establishing what he would consider reasonable criteria for the evaluation of textbooks and in this sense the

exercise is largely a subjective one. Furthermore, the criteria have been applied only to the climatology-meteorology sections of the textbooks.

Four series of textbooks viz. (i) Our New World
(ii) New Window on the World
(iii) Senior Geography
(iv) Active Geography have been evaluated on the criteria listed in Table 5. Each book in the series has been rated per criterion on a scale ranging from 1 to 5, where the following meanings were assigned to each score:

- 1: Criterion not met
- 2: Criterion incompletely met
- 3: Criterion met in general
- 4: Criterion soundly achieved
- 5: Criterion excellently met.

Of the eight schools in the East London area, five responded to the request to participate in this study. The textbooks currently in use in these five schools are tabulated below.

SCHOOL	STD 8	STD 9	STD 10
A	<u>New Window on the World</u>	<u>New Window on the World</u>	<u>Senior Geography</u>
B	<u>New Window on the World</u>	<u>New Window on the World</u>	<u>Senior Geography</u>
C	<u>New Window on the World</u>	<u>Senior Geography</u>	<u>Senior Geography</u>
D	<u>New Window on the World</u>	<u>Senior Geography</u>	<u>Senior Geography</u>
		<u>New Window on the World</u>	<u>Our New World</u>
E	<u>New Window on the World</u>	<u>Our New World</u>	<u>Senior Geography</u>
		<u>New Window on the World</u>	

Note: Departmental regulation does not permit the identification of schools A to E.

In addition to the use of the above series of textbooks two schools found Hurry and van Heerden (1986) particularly useful in teaching the synoptic chart.

Hurry and van Heerden (1986) is a concise resumé of climatic and meteorological information related to the interpretation of synoptic weather charts. A large part of the book is devoted to the discussion of selected synoptic maps (and their accompanying Meteosat images) of typical South African weather days. The succinct nature of the text makes it an ideal handbook for teachers and pupils involved with Senior Secondary climatology. Very often the content exceeds syllabus requirements, but that serves as enrichment and/or as clarification for an otherwise ill-defined or poorly elaborated concept. In this sense the book can only be of benefit to those who use it and it may even serve to whet the appetite of prospective meteorologists. Its use as a resource in the classroom is, therefore, highly recommended, and

Table 5
CRITERIA USED IN THE EVALUATION OF TEXTBOOKS

1. Text

- 1.1 Reading fluency/Intelligibility
- 1.2 Appropriateness of language use
- 1.3 Concept clarification
- 1.4 Variety of print styles (Colour)
- 1.5 Enrichment (per se)
- 1.6 Systematic presentation (chronology)

2. Illustrations

- 2.1 Quality (Clarity)
- 2.2 Relevance (Appropriateness)
- 2.3 Realistic (True to life)
- 2.4 Content (Amount)
- 2.5 Dimensional
- 2.6 Graphical data representation

3. General

- 3.1 Attractive (Pupil appeal)
- 3.2 Teacher resource
- 3.3 Pupil resource
- 3.4 Consolidation exercises
- 3.5 Syllabus compatibility
- 3.6 Integrative with satellite photograph
- 3.7 Differentiation
- 3.8 Reference to synoptic weather chart

particularly, as a handbook for teachers. It is interesting to note Nightingale's (1985) assertion that some of the textbooks in current use are slightly adapted notes of university lecturers.

DEFINITION OF CRITERIA USED IN THE EVALUATION OF METEOROLOGY/CLIMATOLOGY TEXTS (CHAPTERS)

Before an investigation of the salient features emerging from the evaluation can be undertaken, the criteria used warrant definition.

The following criteria were used in the evaluation of the written text:

The intelligibility of the text refers to its reading fluency. Is the work easy to read and understandable particularly by the pupils? The appropriateness of language use refers to the use of meteorological-climatological vocabulary. The clarification of concepts is self-explanatory, but nevertheless important, since "concept dropping" impedes comprehension. Enrichment, per se, was investigated and to fulfil this criterion, textbooks needed to devote specific page-space to it rather than integrate it into the text. The latter tendency may often break the fluidity of presentation. A text's systematic presentation of information deals with the chronological sequence and development of concepts as deemed desirable by this study, whilst a variety of print styles and use of colour as a visual stimulus could serve to encourage frequent use of the textbook or reinforce the retention of material.

Illustrations are undoubtedly a means of expounding a concept, especially when the concept is covert as is the case with meteorological ideas. In such an event, a diagram should be clear and of high quality, appropriate (rather than irrelevant to the discussion) and as accurate as possible in terms of its representation of reality. Geography lends itself to diagrammatic communication, and more so climatology, where the conceptualisation of intangible realities needs to be facilitated. In this respect a greater abundance of relevant graphic/pictographic information, the better. It has often been the case in the past that illustrative material pertinent to this section of the syllabus has been two-dimensional and in the author's experience this has led to faulty and inaccurate perceptions of phenomena. The two-dimensional nature of diagrams thankfully seems to be becoming a thing of the past!

In general, the following criteria were seen to be valuable for textbook assessment. Their overall attractiveness and appeal to pupils, as well as their resource value for both teacher and pupil, would increase their worth. Consolidation exercises need to be meaningful and the chapter should largely, but not necessarily entirely, be compatible with the syllabus. Chapters should also clearly differentiate work prescribed for the higher and standard grades to be in keeping with the Education Department's philosophy of differentiated education. The syllabus, furthermore, recommends that all climatology teaching be integrated with synoptic chart and satellite image interpretation to fulfil the practical aspect of their section of the syllabus - and this, justifiably, is a worthy criterion.

Each series of texts has been evaluated and the results are recorded in Table 6 at the end of this section. Rating scores appear in Appendix 1.

SALIENT FEATURES OF THE EVALUATION

What emerges is that it is indeed difficult to satisfy everyone's needs in providing an ideal textbook coverage of senior climatology.

The old syllabus series, Our New World (1981) scores particularly low on the majority of criteria, whereas the new series evaluated show marked improvements all round. The new syllabus textbook for this series is expected to be published early in 1988. Where one criterion was well fulfilled in one series, it was not in another, and vice versa. It is thus reasonable to recommend that where a class only has access to one series their teachers make use of a combination of the best textbook and other resources for a thorough treatment of the topic.

TEXTBOOK QUALITY IN TERMS OF TEXT

In the area of the written text each of the series New Window on the World, Senior Geography and Active Geography was generally very good. Particular mention should be made of the reading fluency of Active Geography and its approach to clarifying each concept used (either in the text or in a glossary). This was the case though only for the standard eight textbook. The author found this helpful particularly in that pupils would not lose comprehension when encountering undefined concepts. The trend, however, diminishes with each standard and the series resorts to "concept dropping" again at the standard ten level - at exactly that point when one would have hoped the

trend would be maintained. In the area of enrichment only the New Window on the World series contained a reasonable amount of enrichment material clearly indicated. There was a notable absence of enrichment material in the other series.

TEXTBOOK QUALITY IN TERMS OF ILLUSTRATIVE MATERIAL

The improvement in illustration quality in the new textbook range is most heartening, except in the Active Geography series where the illustrations were very much average on most criteria. Other than the New Window on the World series the general tendency was still to produce two-dimensional representations of three-dimensional phenomena. The improvement on the old series is, however, gratifying.

TEXTBOOK QUALITY IN TERMS OF GENERAL CRITERIA

In general there is a dearth of consolidation exercises in each series of textbooks except for the New Window on the World series where this aspect is particularly well handled. The consolidation exercises contain a large variety of ordered questions stimulating enough to be enjoyed by mixed ability classes.

It is a specific and important syllabus recommendation that climatology teaching be integrated with synoptic chart and satellite photograph interpretation. Despite this recommendation, and taking account of the obvious value of this exercise, each of the series does not treat the matter as comprehensively as desired, except the New Window on the World series where the idea is handled well at the standard ten level only. It is desirable to introduce the synoptic chart to pupils as early as their first acquaintance with matters climatological in their standard six year and thereafter progressively make the chart more integral to the teaching of climatology.

Most texts refrain from referring to the synoptic weather chart in the earlier basic concept stages.

It appears that rival authors/educators and publishers do not collaborate in the compilation of textbooks for the classroom, since in this way a comprehensive single text could be produced. However, this is not the way a free-market economy operates, and, as teachers, therefore, we need to widen

our resource base so as to produce effective teaching material.

CONCEPT (CONTENT) SPECIFIC AREAS OF WEAK DEFINITION

On the whole the textbooks examined follow the syllabus outlines fairly rigidly. It often, in fact, appears that textbooks were written with the syllabus as a guide. Tertiary level texts, like Tyson (1986), Donn (1975) and Stringer (1972) are advanced meteorological commentaries which do not address the specific concepts required known by secondary school pupils and they therefore serve as useful source books for teachers only. The following concepts, although not specifically detailed in the syllabus, are integral to South African meteorology and therefore deserve attention.

1. Coastal lows

Seldom, if ever, is any mention made of the factors contributing to the formation of coastal lows. Since a coastal low is very often a contributing system to the formation of the berg wind, a lack of understanding of this phenomenon inhibits closure of this concept in psychological terms. Furthermore, an absence of concept closure here may be responsible for pupils confusing coastal lows with westerly depressions, since the latter may be responsible for berg winds in association with the continental anticyclone. Absent or poor definitions, therefore, may ultimately result in weak concept links which in turn contribute to a weak gestaltic concept map or framework, leading to poor understanding and thus a cause for resorting to rote memorization of concepts.

2. The tilt and three dimensional nature of anticyclonic systems

The tilt of the anticyclonic systems associated with South African weather in particular is not clearly explained - quite possibly as a result of the behaviour of pressure systems in the vertical not receiving adequate attention. A more sophisticated clarification of this phenomenon is valuable, if not essential, for the understanding of line thunderstorms and the changing direction of air flow within a given system from a fixed surface reference point. Refer to Figure 40.

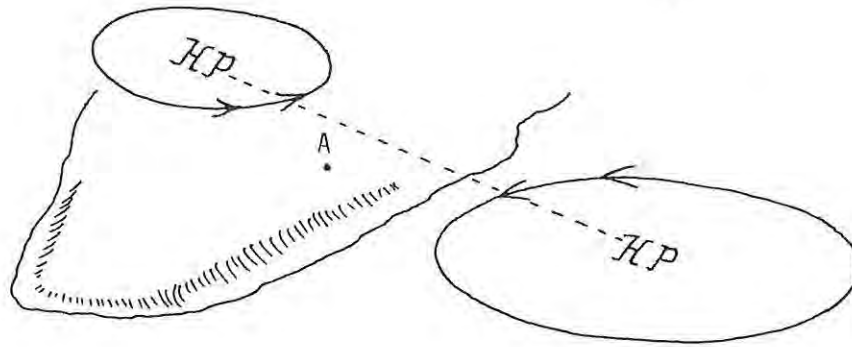


Fig. 40 Change in direction of air flow within a single anticyclonic system with respect to a fixed point of observation

NOTE: The tilt of this anticyclonic system is linked to the concept of thermal winds; a concept beyond the scope of school meteorology.

The observation from point A, for example, produces westerly to south-westerly flow aloft to the west of A, but easterly to north-easterly surface flow to the east; both patterns of circulation originating from the same system.

3. Stability and Instability

The concepts of stability and instability relating to air mass are seldom portrayed in terms of the normal and adiabatic lapse rates relative to one another. The author has found that when the concept is taught by means of the lapse rates on altitude and temperature axes, one can visually compare the ambient air temperature with temperature of the ascending air pocket at a given altitude and hence deduce whether the ascending air is stable or unstable. When working on the altitude-temperature axes, the only hidden variable is the density-temperature relationship. This method of teaching stability/instability may also enhance the skill of graphicacy.

In the diagram which follows, for example, the ascending air at fifty metres (i.e. that air rising according to the dry adiabatic lapse rate) is cooler than the surrounding air (and hence more dense) and will, therefore, tend to subside to its original level and as such produce stability in the lower layers.

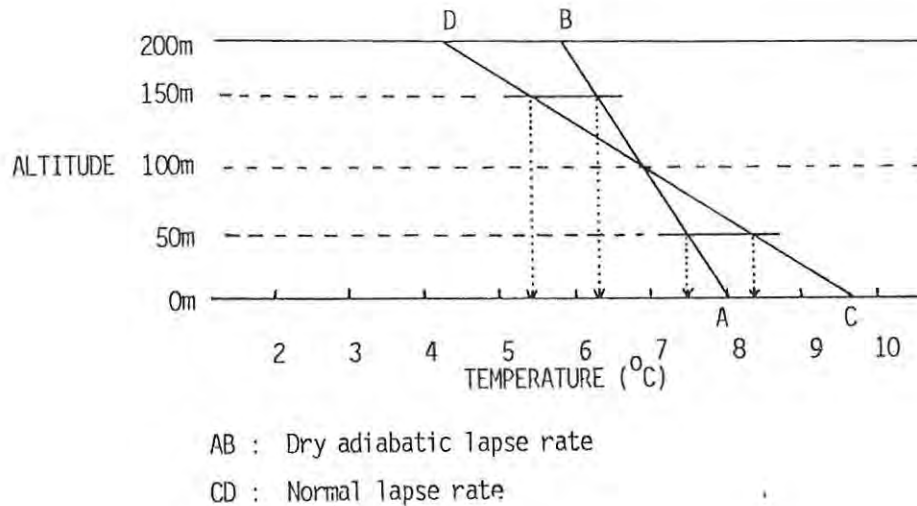


Fig. 41 Stability and instability explained in terms of temperature-altitude axes

Should the air parcel, however, be forced to rise beyond the hundred metre level, it is unstable at one hundred and fifty metres and its continued ascent will largely depend on the amount of latent heat of condensation as a result of the moisture content of the atmosphere. (At one hundred and fifty metres the rising air is warmer than the surrounding air, therefore less dense and will continue to rise until it is in temperature equilibrium with the surrounding air.)

4. Windshifts at the passing of fronts

The author has found that the textbooks' treatment of the concepts of backing and veering is often without due clarity. If the idea were illustrated it may be more readily understood by pupils. The foremost difficulty appears to be the failure to accommodate the vorticity motion of the passing system with respect to a fixed point of observation. Figure 42 illustrates the author's approach to the problem.

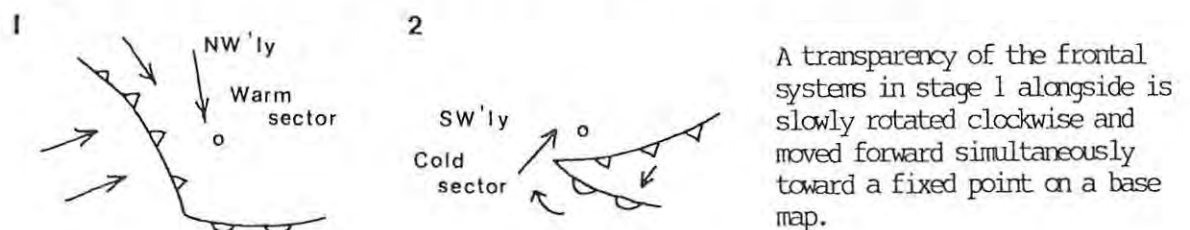


Fig. 42 Windshift with respect to a fixed point of observation at the passing of fronts

5. Cyclogenesis

Current textbooks deal with the inception of the mid-latitude cyclone in a manner that does little justice to the syllabus requirement that the growth, decay, associated weather and consequences be given attention and that the topic be studied on a global scale. It is, therefore, of little wonder that the inception and life cycle of the mid-latitude cyclone is the subject of scant examination at senior secondary level. The irony of the matter is that these cyclones are fundamental weather systems affecting the subcontinent.

The concept of cyclogenesis in the southern hemisphere is unique in that there is a greater abundance of homogeneous ocean surface as opposed to the heterogeneity of land surface type in the northern hemisphere. The latter factor creates anomalies in the cyclogenesis process and these peculiarities of northern hemisphere cyclogenesis patterns have been transferred to the southern hemisphere. The author avers, therefore, that there is confusion and lack of clarity regarding southern hemisphere mid-latitude cyclogenesis in current school texts.

The description which still pervades most current school texts, with accompanying illustrations of mid-latitude cyclone development as shown in Figure 23, presents the air flow on either side of the incipient wave front as opposite in direction and the most common explanation for the generation of the depression is that "the stationary state of the frontal surface is disturbed to produce waves" Swanevelder et al (1987, p55). Generally, the initiating disturbance is attributed to an "acceleration of air movement in one of the two air masses", for reasons of the shape of a coastline, mountain range or the contrast between land and sea temperatures.

It is the author's opinion that explanations of such a simplistic nature are vague, inaccurate and incomprehensible. If, for example, in an extreme case of the higher latitude air mass accelerating, for whatever reason, in opposition to the air mass adjacent to it, the shearing effect will produce a general westerly motion of the depression - a phenomenon quite unique and contrary to observed reality.

Steyn et al (1987, p38) states: "There are various theories concerning the development of cyclones, the frontal depression theory being at present the most acceptable. According to this theory, low pressure areas or depressions originate as a result of the interaction between two contrasting air masses - the one tropical, the other polar."

Barnard and Nel (1981) confirm that the travelling cyclones develop off the east coast of South America, which is at latitude 45°S approximately, but resorts to describing the inception of the low pressure westerly cells at the front between the westerlies and polar easterlies.

Earle et al (1987), in contrast to the above, introduces the influence of the upper air Rossby waves and thereby jet stream influences, especially when an apex extends equatorward and deepens. This text also mentions that those mid-latitude cyclones affecting South African weather have their origin in association with the upper air trough which is situated over the western south Atlantic Ocean, east of South America. Earle et al (1987) is therefore more accurate and relevant to the South African situation.

Extensive comment on this aspect of South African weather and climate is included in Chapter 2 where an alternative to the conventional view of mid-latitude cyclogenesis is proposed. The meteorological sophistication of the exposition is not intended for secondary school tuition. It is presented as an alternative to what is viewed at present as an insubstantial account of mid-latitude cyclogenesis. The detail is presented as substantiation of the author's conviction and as a resumé for teachers.

The meteorological detail of this section brings one to question the inclusion of southern hemisphere cyclogenesis in the senior secondary climatology syllabus. The author avers, however, that the cyclogenesis concept, if presented in a manner which summarises accurately the real situation, is preferable to the presentation of insufficient and/or unsubstantiated facts. The omission of mid-latitude cyclogenesis from the senior secondary syllabus is not seen as desirable since weather systems so produced are integral to an understanding of South African weather and climate. The introduction of the cyclogenesis concept at matric level is regarded as essential and a more sophisticated treatment of the topic may be pursued at tertiary levels.

The concept of mid-latitude cyclogenesis exemplifies the difficulties of teaching advanced and abstract concepts and models to school pupils.

There are, therefore, several different approaches to the subject in current textbooks. The author's proposal of an alternative approach to southern hemisphere cyclogenesis forms the focus of Chapter 2. A simplified version of this account is envisaged for the classroom.

Where South African geography textbooks are authored largely by tertiary educationalists, overseas equivalents, for example in Britain, are produced by teachers of the respective levels. If South African teachers could collaborate with tertiary educationalists with regard to geography textbooks, the problems relating to their appropriateness for the classroom as outlined in this section could be eliminated.

Table 6

COMPARISON OF TEXTBOOK SCORES ON EVALUATION CRITERIA

TEXTBOOK SERIES		Our New World (Old syllabus)	New Window on the World	Senior Geography	Active Geography
CRITERIA	STD	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1. Text					
<u>Intelligibility</u>	8	* * *	* * * * *	* * * * *	* * * * *
	9	* *	* * * * *	* * * * *	* * * * *
	10	* *	* * * * *	* * * * *	* * * * *
Appropriateness of language	8	* * *	* * * * *	* * * * *	* * * * *
	9	* * *	* * * * *	* * * * *	* * * * *
	10	* *	* * * * *	* * * * *	* * * *
Concept Clarification	8	* * *	* * * *	* * * *	* * * * *
	9	* *	* * * *	* * * *	* * * * *
	10	* *	* *	* * * *	* * *
Variety of Print Styles	8	* *	* * * * *	* * * *	* * * * *
	9	* *	* * * * *	* * * *	* * * * *
	10	* *	* * * * *	* * * *	* * * * *
Enrichment	8	* *	* * * *	* *	*
	9	* * *	* * * * *	* * *	* *
	10	* * *	* * * * *	* *	* *
Systematic Presentation	8	* * * * *	* * * * *	* * * * *	* * * * *
	9	* * * * *	* * * * *	* * * * *	* * * * *
	10	* * * * *	* * * * *	* * * * *	* * * * *
2. Illustrations					
<u>Quality</u>	8	* * * * *	* * * * *	* * * *	* * * * *
	9	* * * * *	* * * * *	* * * *	* * * * *
	10	* * * * *	* * * * *	* * * *	* * *
Relevance	8	* * * * *	* * * * *	* * * * *	* * * * *
	9	* * * * *	* * * * *	* * * * *	* * * * *
	10	* * * * *	* * * * *	* * * * *	* * * *
Realistic	8	* * * * *	* * * * *	* * * * *	* * * * *
	9	* * *	* * * *	* * * * *	* * * * *
	10	* * * *	* * * * *	* * * * *	* * *
Content	8	* * * * *	* * * * *	* * * *	* * * *
	9	* * * * *	* * * * *	* * * * *	* * * * *
	10	* * * * *	* * * * *	* * * * *	* * *
Dimensional	8	*	* * * *	* * *	* *
	9	*	* * * * *	* * * *	* * * *
	10	* *	* * * * *	* * * *	* *

Graphical data representation	8	* * * *	* * * *	* * * * *	* *
	9	* * *	* * * *	* * * * *	* * * *
	10	* * *	* * * *	* * *	* * *
3. General					
Pupil Appeal	8	* *	* * * * *	* * *	* * * *
	9	* *	* * * * *	* * * *	* * * *
	10	* *	* * * * *	* * * *	* * *
Teacher Resource	8	* * * *	* * * *	* * *	* *
	9	* * * * *	* * * *	* * *	* *
	10	* * * * *	* * * *	* * *	* *
Pupil Resource	8	* * *	* * * *	* * * *	* * * *
	9	* *	* * * * *	* * * *	* * *
	10	* *	* * * * *	* * * *	* * *
Consolidation exercises	8	* * *	* * * *	* * *	* * * *
	9	* *	* * * * *	* * *	* *
	10	* *	* * * * *	* * *	*
Syllabus compatibility	8	* * * * *	* * * * *	* * * * *	* * * *
	9	* * *	* * * * *	* * * * *	* * * *
	10	* * *	* * * * *	* * * * *	* * * *
Integrative with satellite photographs	8	*	* * *	* * * *	*
	9	*	* * *	* * *	*
	10	*	* * * * *	* * *	*
Differentiation	8	* *	* * *	* * * * *	* *
	9	* *	* * * * *	* * * * *	* *
	10	* * *	* * * *	* * * * *	* *
Reference to Synoptic Weather Chart	8	*	* * *	* * * *	* *
	9	*	* * * * *	* *	* * * *
	10	* *	* * * * *	* * * *	* * * *

TRENDS IN THE CAPE EDUCATION DEPARTMENT'S EXAMINATION QUESTIONS
ON THE SYNOPTIC WEATHER CHART AND SATELLITE PHOTOGRAPH
FOR THE YEARS 1981 TO 1986

In order to ensure a balanced examination paper in terms of the cognitive skills deemed appropriate for all developmental levels, Bloom's taxonomy of educational objectives for the cognitive and affective domains serves as a useful frame of reference.

A taxonomic blank was used to record the total number of marks awarded to each of the taxonomic categories with respect to questions on the synoptic weather chart and satellite photograph for the past six years. Each question was assessed in order to establish the kind of cognitive objective it sought to examine. There is a degree of subjectivity entering into such an exercise since it has depended on individual interpretation. The overall outcome of such an exercise has produced an accurate average trend. The taxonomic grid forms Table 7 and reveals the raw score data and this may be compared with the examination questions and taxonomic categories assigned to them as found in Table 8 at the end of this section for convenient referencing.

The format of the Senior Certificate geography examination warrants comment before an analysis of the trend over the past six years is undertaken. The examination paper comprises seven questions (sometimes eight on the standard grade) of which candidates must attempt four. The format of the paper is as follows:

- Section A: Physical Geography (comprising two questions)
- Section B: Settlement Geography (comprising two questions)
- Section C: Regional Geography (comprising three or four questions)

Candidates must answer one question from each section and a fourth from a section of their own choice.

The analysis in this study concerns only Section A. Prior to 1984 each of the two questions in Section A contained a balance of climatology and geomorphology content. Since 1984, however, Section A has devoted an entire question of eighty/sixty marks to climatology and another entirely separate question of the same value to geomorphology. The latter practice makes it possible for pupils to eliminate either climatology or geomorphology from their study programme. If this trend continues it will encourage so-called "spotting" and may further lead to either climatology or geomorphology being omitted from the teaching programme especially where teachers

have certain preferences and/or where time and pressure become factors in the teaching programme. One questions, therefore, whether the current structure of Section A is conducive to sound examining. Such practice will reduce the content validity of the examination since it will not sample the syllabus adequately. Section A will not achieve what it should normally set out to achieve i.e. to test whether pupils have a grasp of both climatology and geomorphology. In essence the content will not match the learning and general objectives of the syllabus.

The range of skills identified by Bloom's taxonomy is as appropriate to the analysis of the physical section of the examination per se, as it would be to the analysis of an entire examination paper, since the physical geography questions can cover the full range of educational objectives.

The following general points emerge from the analysis:

Figure 43 shows the average percentage (for the past six years) of a physical geography question devoted to the synoptic weather map and/or satellite photograph. On average, a higher grade physical geography question has 64,1% of the total marks awarded to synoptic map and/or satellite photograph analysis, whilst the apportionment on the standard grade is 53,3%. These percentages are significantly high and indicative of the import given to this topic by the examiners of the Cape Education Department.

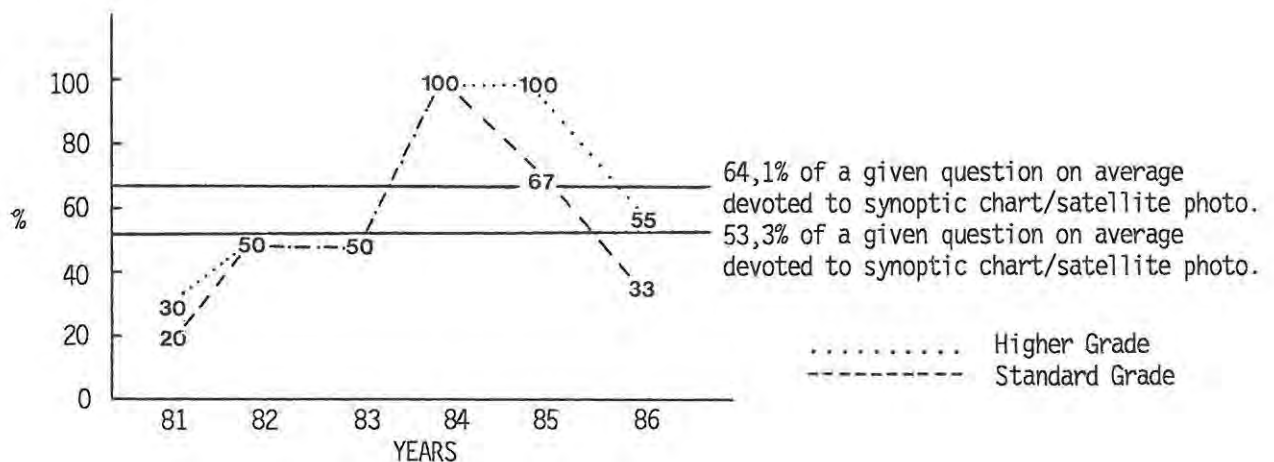


Fig. 43 Percentage of Physical Geography question devoted to synoptic chart and satellite photograph

Synoptic charts have not been omitted from Cape Senior Certificate geography examinations in the past six years. In three of the six years synoptic charts have been examined in conjunction with their corresponding satellite photographs. This procedure is in keeping with the syllabus recommendation that synoptic charts and satellite photographs be integrated wherever possible in the teaching of Senior Secondary climatology. It is, however, surprising that if the chart, per se, forms such a fundamental topic of the examination, that the chart is not taught specifically as a communicative device. It is the author's argument that if this were the case the scope, and hence validity, of the examination questions would increase and be more compatible with the syllabus requirement that each successive year should build on the concepts of previous years.

COMPARISON BETWEEN HIGHER AND STANDARD GRADE LOWER ORDER SKILLS EXAMINED

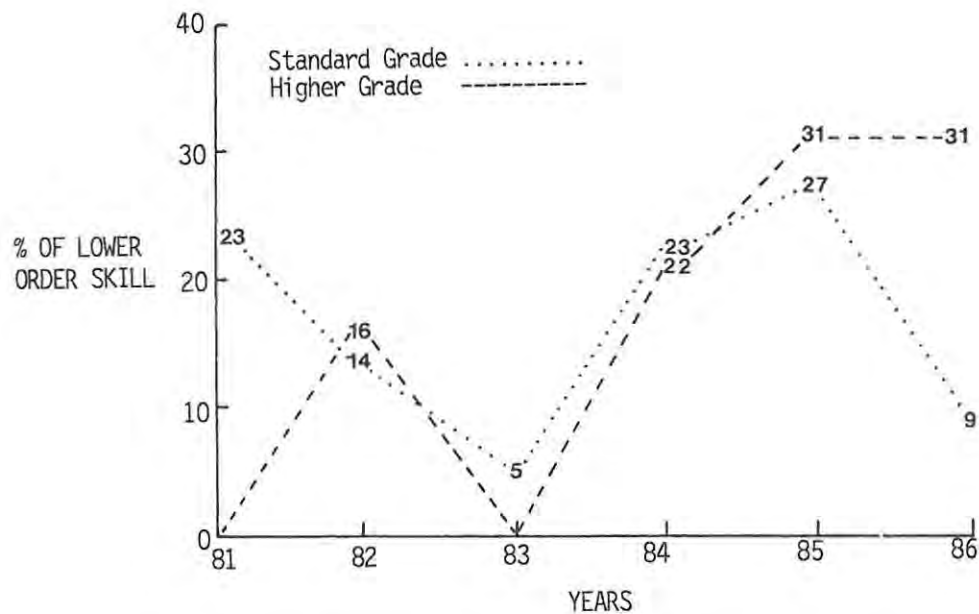


Fig. 44 Comparison between higher and standard grade lower order skills examined

For the content in question, Figure 44 shows a disturbing discrepancy over the past three years. It is anomalous that higher grade candidates be afforded a greater percentage of lower order questions on a section of work which they find particularly less demanding cognitively. The converse is also true.

COMPARISON BETWEEN HIGHER AND STANDARD GRADE HIGHER ORDER SKILLS EXAMINED

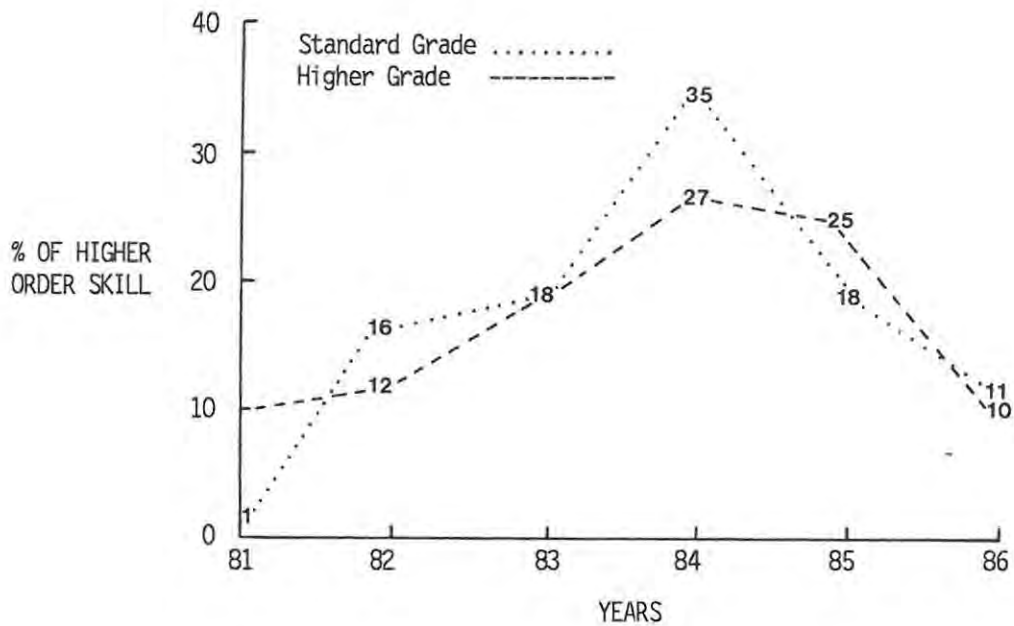


Fig. 45 Comparison between higher and standard grade higher order skills examined

A similarly disturbing pattern emerges from Figure 45. By definition, the standard grade is designed for pupils who do not necessarily possess academic strength and therefore will not cope with higher order or complex-ability skills. It is, therefore, once again an anomaly to find that for the past six years, standard grade candidates have matched the higher grade candidates in terms of the percentage of complex-ability objectives examined on the synoptic chart and satellite photograph and their related content. The discrepancy in 1984 in this regard is particularly noteworthy. Nightingale (1985) makes the point that current syllabi do not take sufficient cognizance of the intellectual development and abilities of children, particularly the less able, non-academic child. It appears that standard grade examiners have been guilty of such practice.

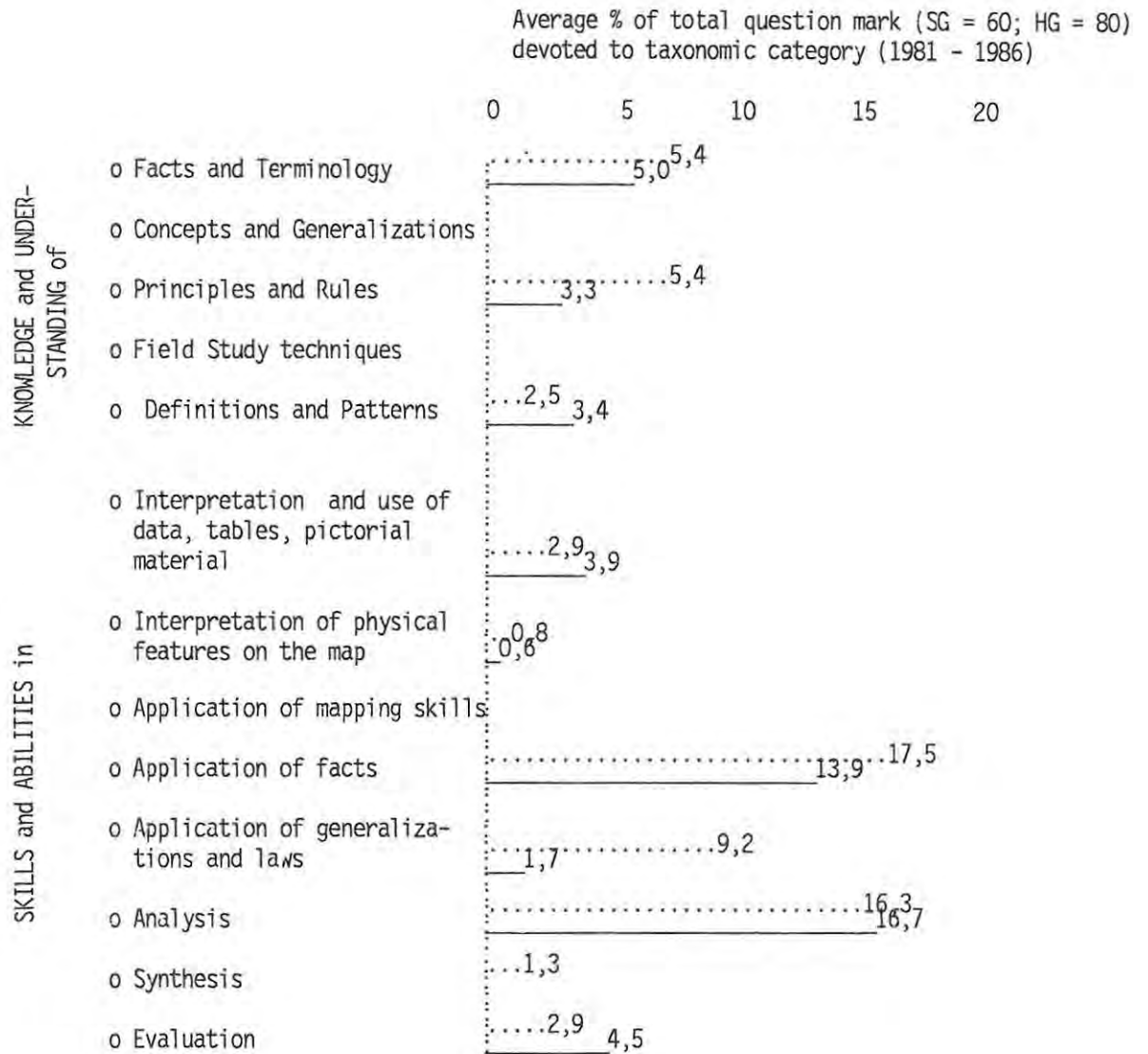


Fig. 46 Average percentage of total question mark devoted to various of Bloom's taxonomic categories
Standard Grade —————
Higher Grade

AVERAGE PERCENTAGE OF TOTAL MARKS AWARDED FOR SYNOPTIC CHART AND SATELLITE PHOTOGRAPH QUESTIONS DEVOTED TO SPECIFIC TAXONOMIC CATEGORIES FOR 1981 TO 1986

Figure 46 clearly shows that on the average over the past six years that standard grade candidates have been required to perform complex ability skills under examination conditions to a greater degree than higher grade candidates. From Figure 46 it is clear that this is so for the following taxonomic educational objectives:

- (a) the interpretation and use of data, tables and pictorial material,
- (b) analysis skills, and
- (c) evaluation skills.

Standard grade candidates had, furthermore, to apply facts to new situations in 13,9% of questions whilst higher grade candidates had to do the same in 17,5% of questions; a small percentage margin in terms of an expected dichotomy between higher and standard grade examination content. Quite ironically, also, for the lower order skills, higher grade candidates had the benefit of a greater percentage of questions devoted to the knowledge and comprehension of facts and terminology, and principles and rules.

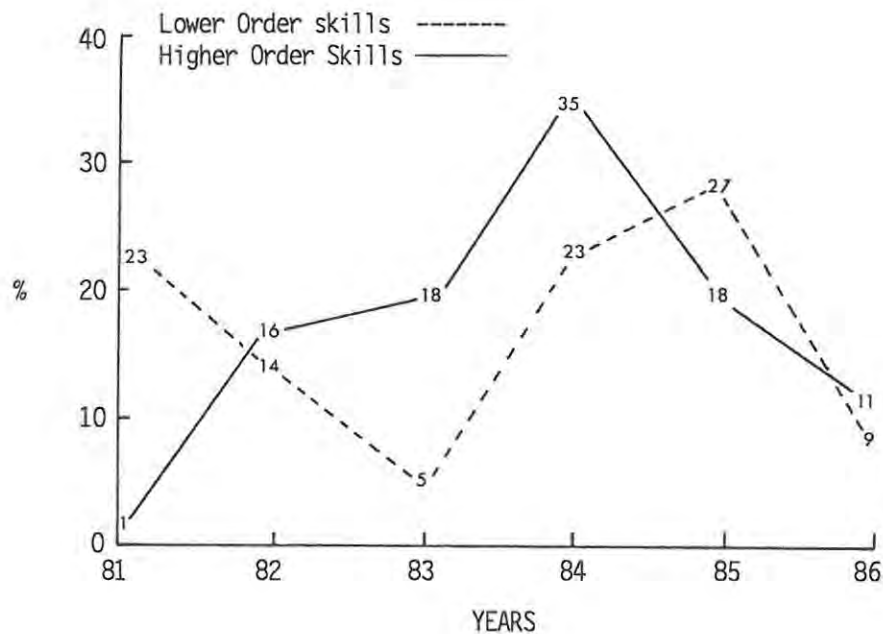


Fig. 47 Comparison of lower and higher order skills examined on the standard grade

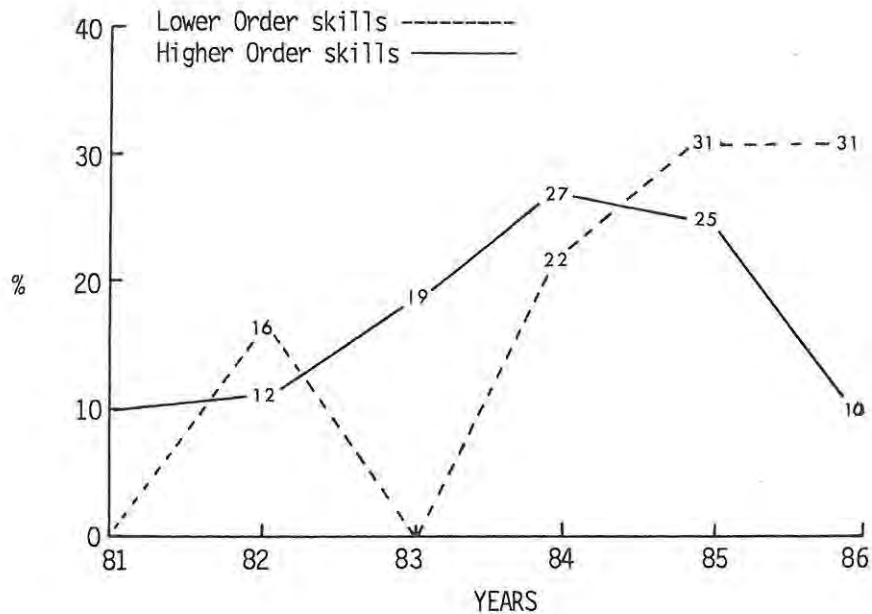


Fig. 48 Comparison of lower and higher order skills examined on the higher grade

In Figures 47 and 48, lower order skills show an erratic pattern in standard grade questions, but a marked increase in higher grade questions. Higher order skills show a steady decline on both higher and standard grade papers. This does not augur well for the development of the subject.

These findings concur with those of Earle (1974) that an analysis of a selection of recent matriculation geography examination papers showed that the aim of most of them was confined largely to the evaluation of the ability to recall pieces of information and the understanding at face value only of those pieces.

Earle (1974) makes a further valid point. He claims that one of the reasons for unsatisfactory examination papers is that while the tester may recognize that geography is moving in new directions at high school level, he does not know how to evaluate the more complex educational objectives which are involved. The author supports this contention. To confirm such suppositions one would, however, need to analyze, by item analysis, the performance of senior certificate candidates on the final examinations

for the questions relevant to this study as well as scrutinize the marking memorandum. This information is, however, unavailable from the Cape Education Department.

By comparing the higher and standard grade examination questions for the topic under consideration, and the examination paper as a whole for that matter, it emerges that there is a strong overlap between the content of the two grades; the only obvious difference being a more simplified language on the standard grade and an occasional attempt at aiding standard grade pupils by systematising questions into subsections which ultimately produce that same content as required on the higher grade. This does not guarantee that the standard grade candidate has the academic expedience to cope with higher order examination objectives.

Nicol (1979) claims that teachers are insufficiently clear about what they should be assessing at different levels. This would also be a valid criticism of the standard grade examination of Cape Senior Secondary Climatology. When one compares the calibre of questions on the higher and standard grades with respect to synoptic charts, it is evident that there is very little divergence between the grades. Table 8 provides a chronological record of the Cape Education Department's examination questions for the years 1981 to 1986 and the marks allocated to them. Each question is further classified according to Bloom's taxonomic categories. This is in keeping with the Earle (1974) assertion that examiners do not know how to evaluate the complex-ability objectives. This is especially true with respect to the standard grade. There is obvious error in the fact that complex-ability objectives examined on the higher grade are expected to be known by standard grade candidates. It would seem that the similarity of content in higher and standard grade questions, therefore, has greater benefit for examiners than for pupils. If anything, this is unsound educational practice and sufficient to expect poor examination performance by standard grade candidates. One must, therefore, assume that the similarity of content between higher and standard grade examination questions is coincidence and not intentional practice.

A more deliberate analysis of questions of the Cape Education Department's examinations for the years 1981 to 1986 will serve to throw light on the above criticisms. The author deals with abridged versions of examination questions relating to weather and weather charts. The section is structured

in such a way that objective, average difficulty and higher order questions have been selected and differentiated as such on the basis of Bloom's taxonomy. Each batch of questions is then analyzed in general.

1. OBJECTIVE TYPE QUESTIONS

Questions of an objective-recall nature or simple observation would be seen as sufficiently easy to score marks on, on both the standard and higher grades. Such questions are of the following type:

- (a) Name the pressure system situated over the interior of South Africa.
- (b) Name the season applicable to a given weather chart (when the date is given).
- (c) Draw a symbol representing an occluded front.
- (d) Identify the stage of a temperate cyclone.
- (e) Draw a cross-section through a temperate cyclone in its mature stage.
- (f) Describe and explain berg wind conditions prevailing at a certain place.
- (g) Supply reasons from the chart to support the fact that a tropical cyclone is in its dissipating stage.
- (h) What is the significance of the name, for example, "Barbara", given to a tropical cyclone?
- (i) What is meant by the "eye" of a cyclone?
- (j) Compare a temperate and tropical cyclone in terms of their latitude of origin and central pressure.
- (k) Name the anticyclone off the west coast of Africa and state the pressure belt it forms part of.

For both grades questions (a) to (e) should present little, if any, problem. However, it is the author's opinion that questions (d) to (k), whilst comfortably answerable on the higher grade, are too demanding on the standard grade. The difficulty may not lie in the content for the latter candidates but certainly in the use of sophisticated vocabulary. Words such as "significance" and "dissipating" seldom appear to be part of a standard grade candidate's repertoire. Two points emerge here. What is deemed a lower order type question on the higher grade is not necessarily lower order questioning on the standard grade, and the phraseology of questions should be appropriate to the academic level of the examinees.

2. AVERAGE DIFFICULTY QUESTIONS

Examples of questions of average difficulty could be of the following type:

- (a) Interpret the weather station model at a given location (and infer the pressure at the station by inspecting the isobars).
- (b) How do tropical and mid-latitude (temperate) cyclones compare in terms of which of the two
 - (i) have the strongest winds?
 - (ii) strike the east coast of continents?
 - (iii) have the largest diameter?
- (c) Insert a cold front, warm front and sectors of a depression by inspecting cloud cover on the satellite photograph.
- (d) Explain by means of a diagram how one could be drawn outside by the passing of cyclone "eyes" and then be caught by hurricane winds from the opposite direction.
- (e) Explain the wind direction at a given place in terms of the geostrophic wind model.

Standard grade candidates should cope with questions (a) and (b). Questions (c) and (d) are answerable on both grade levels, but are considered a far greater test on the standard grade by virtue of the fact that the question requires the extrapolation of information to an unfamiliar situation. Question (e) is purely higher grade in terms of syllabus stipulation, but nevertheless regarded as being of average difficulty owing to the need to apply learned information to a new situation.

3. HIGHER ORDER QUESTIONS

Questions of a higher order deemed difficult by the author are as follows:

- (a) Determine the direction of wind once a cold front has passed a given point of observation.
- (b) Forecast the changes in weather in the wake of a cold front.
- (c) Describe the weather conditions prevailing ahead of a warm front.
- (d) Describe and account for the changes in temperature, dew point temperature, precipitation and cloud cover that a station will experience in the next twenty-four hours.
- (e) Explain how the inversion layer lifts and allows the influx of moist air into the interior.
- (f) Explain the reasons for the strongest winds in the south-west quadrant of a tropical cyclone (having first identified the quadrant in question).

- (g) Explain why tropical cyclones Domoina and Imboa caused flood damage rather than gale damage.
- (h) Given a temperate cyclone at a certain stage of development, deduce its ensuing stage and concomitant weather changes.
- (i) Suggest reasons by inspecting a southern hemisphere map as to why a system of linked depressions is regarded as a family.
- (j) Describe how the air circulation over the interior affected the temperatures and humidity of towns along the west coast.
- (k) Explain the difference in the unit of pressure measurement over land and sea.

Questions (a) to (k) are common to both standard and higher grade papers. Their level of difficulty for the standard grade candidate is obvious, but comment on specific questions is desirable. Each of questions (a) to (k) require a candidate to have considerable conceptual depth and language ability in order to produce a coherent, meaningful answer, and this only after the candidate has made deductions from the map and/or satellite photograph.

Questions (a) and (b), for example, require a candidate to perceive movement of a weather system relative to a fixed point of observation and to bear in mind the clockwise cyclonicity of advection - no mean feat for a genuine standard grade candidate.

Question (c) can only be answered by recalling a cross-sectional diagram through a depression and then analyzing the precipitation, cloud types and air mass temperatures in the zone in question.

Question (d) requires a candidate not only to describe, but to account for the changes in various climatic elements associated with passing frontal systems. For a successful response the candidate will need to remember the relationship between atmospheric temperature and moisture - concepts last dealt with in standard eight - and unless these were understood, the information desired of the question cannot be accounted for. This is clearly a higher grade question.

Question (e)'s answer is dependent on the knowledge of stability and instability related to pressure systems. The latter concepts are not required known by standard grade candidates and, yet, are examined.

Question (f), although learnable, embodies the concepts of directional and rotational velocities of the system - a difficult idea to convey to a less able candidate.

Question (g) requires insight into the fact that tropical cyclones affecting the east coast of South Africa usually have impeded velocities due to friction and because they have already approached their dissipating stage - once again not easy for a standard grade candidate to deduce.

It is one thing to understand the concept of occlusion, but another to recognize that it is the next stage of a temperate cyclone in its mature stage. To ask, furthermore, a standard grade candidate to describe the concomitant weather changes as in Question (h) is unreasonable.

To deduce that a linked system of depressions is a family as in Question (i) requires the candidate to observe their continuity and their distribution within the belt of westerlies. The former point is alluded to in textbooks and the latter fact is not mentioned in any text with which the author is familiar.

Question (j) demands an understanding of adiabatic processes, and particularly the converse of the process ordinarily taught. From the author's research in schools it was quite evident that most candidates could not explain that by compression air upon descent heats up adiabatically, rendering temperatures warm and the wind dry.

Question (k) seeks an understanding of purpose. The old system of constructing continuous isobars for land and ocean surfaces led to the misconception that South Africa's climate was monsoonal. The current practice of using geopotential metre isolines (isohypses) for the interior and isobars for ocean surface has eliminated the fallacy and makes day to day weather forecasting more practical. It is the author's experience that standard grade candidates (and higher grade candidates) find the concept of drawing isolines for the height of the 850 hPa pressure surface difficult to comprehend, and yet the question is deemed suitable for standard grade candidates.

Several points emerge from this analysis. Firstly it must be borne in mind by the reader that the questions recorded in this section are abridged versions of the original questions and that each one pertains to a synoptic

chart and/or satellite photograph, implying that observation and deduction are usually essential before the candidate can commit his answer to paper. This means that there is a basic assumption that most pupils have mastered the skills of graphicacy - certainly a misconception in the author's experience. Secondly, what amounts to an average cognitive demand in terms of examination questions for the higher grade candidate can satisfactorily be regarded as higher order tasks for the standard grade candidate. This means that the vast number of marks apportioned to what the author regards as difficult questions on the standard grade is automatically lost by these candidates. Thirdly, where questions would ordinarily be seen as comparatively easy for higher grade candidates, the phraseology and sophisticated vocabulary of the question can be an unnecessary hindrance to a candidate producing an obvious answer correctly. The same applies to the standard grade. Finally, there appears to be little difference between higher and standard grade examination content and order of questioning.

ANALYSIS OF MARKS ALLOCATED TO VARIOUS QUESTIONS IN TERMS OF BLOOM'S TAXONOMY

YEARS GRADE	1981		1982		1983		1984		1985		1986		HG & SG	TOTAL NUMBER OF MARKS		% OF TOTAL MARK	
	HG	SG	HG	SG	HG	SG	HG	SG	HG	SG	HG	SG		HG	SG	480 HG	360 SG
TYPE OF OBJECTIVE																	
1. KNOWLEDGE AND UNDERSTANDING OF																	
A. Facts, terminology		10		4			4		10	4	12		44	26	18	5,4	5,0
B. Concepts, Generalizations																	
C. Principles, rules			8			2	4	2	6	4	8	4	38	26	12	5,4	3,3
D. Field Study Techniques																	
E. Definitions and Patterns			2	2			6	8	4	4			26	12	14	2,5	3,9
TOTAL KNOWLEDGE OBJECTIVES		10	10	6		2	14	10	20	12	20	4	108	64	44	13,3	12,2
2. SKILLS AND ABILITIES IN																	
A. Interpretation and use of data, tables, pictorial material							12	10	2	4			28	14	14	2,9	3,9
B. Interpretation of physical and cultural features in the field		2	4										6	4	2	0,8	0,6
C. Application of Facts	24			10	26	14	10	12	24	10		4	134	84	50	17,5	13,9
D. Application of mapping skills																	
E. Application of generalizations and laws			14				8		6		16	6	50	44	6	9,2	1,7
F. Analysis			12	14	14	14	16	12	28	14	8	6	138	78	60	16,3	16,7
G. Synthesis							6						6	6		1,3	
H. Evaluation							14	16					30	14	16	2,9	4,4
TOTAL COMPLEX-ABILITY OBJECTIVES	24	2	30	24	40	28	66	52	60	28	24	16	392	244	148	50,8	41,1
3. AFFECTIVE OBJECTIVES																	
TOTAL FOR SYNOPTIC CHART AND SATELLITE PHOTO QUESTIONS	24/80	12/60	40/80	30/60	40/80	30/60	80/80	60/60	80/80	40/60	44/80	20/60	500	308	192	64	53

Table 8

EXAMINATION QUESTIONS OF THE CAPE EDUCATION DEPARTMENT
AND THEIR RELEVANT MAPS (1981 - 1986)

<u>Year</u>	<u>Examination question and marks awarded</u>	<u>Nature of question in terms of Bloom's taxonomy</u>
1981	Synoptic chart 14h00 1980-08-17	
	<p>HG: Study the accompanying synoptic weather chart and describe and explain the changes in air temperature, air pressure, winds and rainfall that East London would probably have experienced in the next twenty-four hours.</p> <p style="text-align: right;">[24/80]</p>	<p>o Application of knowledge of weather associated with pre- and post cold front conditions</p> <p>o Analysis of map data</p>
	<p>SG: Study the accompanying synoptic weather chart and answer the following:</p> <p>(i) Name the pressure system situated over the interior of South Africa (2)</p> <p>(ii) During which season is this system best developed? (2)</p> <p>(iii) Complete: In the next 24 hours the general direction of air movement in the Eastern Cape will change from north-west to (2)</p> <p>(iv) Describe the air pressure and wind conditions which were experienced at 25°S 10°E at 14h00 on 1980-08-17 (6)</p> <p style="text-align: right;">[12/60]</p>	<p>o Factual recall</p> <p>o Principle</p> <p>o Interpretation/map analysis</p> <p>o Application of facts</p>
1982	Synoptic chart and satellite photograph 1979-03-19	
	<p>HG: Study the accompanying meteorological satellite photograph and the corresponding synoptic weather map of conditions of 1979-03-19. Use the sketch map given and indicate the under-mentioned phenomena by making use of the symbols indicated:</p> <p>(a) (i) the approximate position of the ITCZ (solid line and letters ITCZ) (2)</p> <p>(ii) the active cold front to the south west of Cape Town (using conventional sign for cold front) (2)</p> <p>(iii) the sector of the depression south west of Cape Town which is characterised by cumulus clouds, south-westerly winds and showers (boundaries of the sector and letters CU) (4)</p> <p>(iv) the low pressure centre of this depression (L) (2)</p> <p>(v) the low pressure trough over the interior of South Africa (LPT) (2)</p> <p>(b) Study the synoptic weather map given (1977-02-27)</p> <p>(i) Name the type of depression which dominates the weather over the Mozambique Channel (2)</p> <p>(ii) Explain in one sentence what the meaning of the name of this depression entails (2)</p> <p>(iii) Which quadrant of this depression will experience the strongest winds? (2)</p> <p>(iv) Explain in one or two sentences why the winds in the quadrant in b(iii) are the strongest 2X2= (4)</p>	<p>o Interpretation of physical features on maps, pictorial material, application of facts</p> <p>o Knowledge of pattern</p> <p>o Knowledge of principle</p> <p>o Knowledge of principle</p> <p>o Understanding of rules</p>

- (v) Name two proofs from the map which indicate that this depression is already in the dissipating stage 2X2=(4)
 - (vi) Explain the wind direction at A (South east of Malagasy) in terms of the geostrophic wind model 7X2=(14) [40/80]
- o Interpretation of map patterns
 - o Application of generalizations and laws

SG: Study the accompanying meteorological satellite photograph and corresponding synoptic weather chart which represent conditions on 1979-03-19

- (a) (i) Describe and explain the changes in air pressure and in the direction and velocity of the wind which will probably be experienced at X (on the map) during the following 24 hours (8)
 - o Interpretation of physical map representation
 - o Application of facts associated with fronts
- (ii) Indicate the following on the simplified copy of the satellite photograph making use of the symbols in brackets:
 - o an active cold front to the south west of Cape Town (the conventional symbol for cold fronts)
 - o the cold sector of a depression to the south west of Cape Town (the outline and letters CS)
 - o the direction in which this depression will continue (an arrow)
 - o a trough of low pressure over the interior of South Africa (a dotted line and letter T) (8)
- (b) Study the synoptic weather chart (1977-02-27)
 - (i) Name the type of cyclone which dominates weather over the Mozambique Channel (2)
 - o Knowledge of terminology
 - (ii) Select the correct word from the possibilities in brackets:
The (north-eastern/south-eastern/south-western/north-western) quadrant of this cyclone will experience the strongest winds (2)
 - o Knowledge of pattern of movement
 - (iii) State one fact from this map that proves that this cyclone is in its dissipating stage (2)
 - o Application of facts
 - (iv) Name the high pressure cell situated over the interior of South Africa (2)
 - o Knowledge of terminology
 - (v) Describe the prevailing weather conditions in Pretoria as indicated on the synoptic chart (6) [30/60]
 - o Analysis and interpretation

1983 HG: The following questions refer to the satellite photograph and corresponding synoptic weather chart of conditions on 1978-04-22

- (i) Describe and explain the Berg wind conditions as experienced in the western coastal regions at X (10)
 - o Application of facts
- (ii) During the next 48 hours the ship at Y will experience the weather conditions of two successive fronts. Describe and explain the cloud and precipitational changes which the ship will probably experience during this period (16)
 - o Application of facts
- (iii) Clearly indicate on the copy provided by making use of the symbols as indicated:
 - o the centre of the south-westernmost depression on this map (L)
 - o the various fronts associated with the depression (the conventional signs for fronts)
 - o Interpretation and application

- o the warm and cold sectors of this depression (indicate the boundaries of the sectors and state whether they are warm or cold)
- o the wind direction in the warm sector of this depression (draw several arrows) (14)

[40/80]

SG: The following questions refer to the satellite photograph and the corresponding synoptic weather map of conditions on 1978-04-22

- (i) Describe the weather conditions experienced by the ship at Y at 14h00 SAST on 1978-04-22 (6)
 - o Analysis and interpretation
 - o Application of facts
- (ii) A warm front will reach the ship at Y within the next few hours. Describe and account for the changes in temperature, dew point temperature, precipitation and clouds that the ship will most probably experience during this period 7X2=(14)
- (iii) Draw the symbol that is used on a synoptic weather map such as this to depict an occluded front (2)
 - o Knowledge of symbols
- (iv) On the copy provided clearly indicate the following by making use of the symbols as indicated:
 - o the centre of the most westerly depression on this map (L)
 - o the warm and cold fronts of this depression (the conventional symbols for fronts)
 - o the wind circulation of this depression (draw a number of arrows) (8)

[30/60]

1984 HG: Refer to the accompanying synoptic weather chart

- (a) Briefly explain the large extent of cloud and precipitation conditions over the eastern interior of South Africa on the basis of the air pressure and weather patterns 4X2=(8)
 - o Application of facts
- (b) Briefly explain the significance of the name of the tropical cyclone indicated on this map (2)
 - o Knowledge of definition
- (c) Name any two indications from the map that this cyclone has already reached the dissipating stage (4)
 - o Application of facts

Sections (d) to (h) refer to the accompanying cyclone warning poster of the American weather bureau.

- (d) Explain the precautions recommended in 1, 2, 3 6X2=(12)
 - o Interpretation of data
- (e) What is meant by the "eye" of the cyclone mentioned in 4? (2)
 - o Knowledge of terminology
- (f) Explain with the aid of a sketch, how one could be drawn outside by the passing of the eye of the cyclone and then be caught by hurricane winds from the opposite direction 3X2=(6)
 - o Synthesis of generalization and laws
- (g) Describe and explain the problems facing the authorities after a specific area has been devastated by a tropical cyclone 7X2=(14)
 - o Understanding of consequences/Evaluation
- (h) Early in 1984 extensive flood damage was caused in Natal, Swaziland and Mozambique by cyclones Imboa and Domoina. Briefly explain why these cyclones, as do all cyclones in this area, caused mainly flood damage and why there was relatively little gale damage 2X2=(4)
 - o Understanding of principles

Sections (i) to (l) refer to the Tiros weather satellite photograph

- (i) Indicate the following features on the satellite photograph with the aid of the symbols in brackets:
 - o the ITCZ (solid line and letters ITCZ) (2) o Interpretation and application of facts
 - o the centre of a temperate depression (cyclone) in the northern hemisphere (an L at the centre) (2)
 - o the cold front and the occluded front of a temperate depression over the South Atlantic Ocean (conventional symbols for fronts) (4)
 - o the cold and warm sectors (shaded lightly and with the letters CS and WS) of the depression in the above question (4)
 - o the main wind direction in each of these two sectors mentioned above (each with an arrow) (4)
 - (j) Briefly explain how the situation of the ITCZ on this photograph can indicate which season was being experienced at the time in the southern hemisphere (2) o Application of laws
 - (k) Briefly explain where over Africa the so-called c-zone of the ITCZ will be situated on this photograph. Justify your answer (4) o Application of generalizations
 - (l) Describe the cloud and precipitation conditions that would probably be experienced in this c-zone of the ITCZ (4) o Knowledge of patterns
- [80/80]

SG: (a) The following questions refer to the synoptic weather map

- (i) Describe the weather conditions which the ship experienced on 1975-12-16 at 14h00 SAST (6) o Analysis and interpretation
 - (ii) Briefly explain what the name of the tropical cyclone which is indicated on the map, means (2) o Knowledge of rule
 - (iii) What evidence is there on the map which indicates that this tropical cyclone is in its dissipating stage? (2) o Application of fact
 - (iv) Name the pressure features which are marked B and C respectively on this map (4) o Knowledge of patterns
- (b) The following questions refer to the notice by the weather bureau of the United States concerning a tropical cyclone threat
- (i) Explain the measures recommended by 1, 2, 3 (10) o Interpretation of data
 - (ii) What is meant by the "eye" of the cyclone as referred to in 4? (2) o Knowledge of terminology
 - (iii) Describe the weather conditions which would probably be experienced in this "eye" (4) o Knowledge of definition
 - (iv) Name any FOUR problems which the authorities will encounter after a certain area has been devastated by a tropical cyclone 4X2=(8) o Understanding of consequences/Evaluation
 - (v) Briefly compare tropical cyclones and mid-latitude depressions with regard to the latitudes where they occur, the direction in which they move and the wind speed associated with each (6) o Analysis
- (c) The following refers to Tiros weather satellite photograph
- (i) Indicate the following on the satellite photograph provided using the symbols in brackets:
 - o the centre of a mid-latitude depression over the south Atlantic Ocean (L at centre) o Interpretation and application of facts

- o the cold front of this mid-latitude depression (conventional symbol for fronts)
 - o the cold sector of this mid-latitude depression (shaded lightly and letters CS)
 - o the main direction of the wind in this cold sector (with an arrow) (8)
 - (ii) Describe the pressure, cloud and precipitation conditions which are usually experienced in the cold sector of a mid-latitude depression 4X2=(8)
[60/60]
 - o Application of knowledge
- 1985 HG: (a) The following sections (i) - (v) refer to the tropical cyclones depicted on the synoptic weather map and corresponding satellite photograph (1984-02-19)
- (i) Supply two indications from the synoptic weather map which may prove that cyclone Imboa had already reached its dissipating stage in this case (4)
 - o Application of rule, fact, pattern
 - (ii) Briefly explain why cyclones such as Imboa are more noted for flood damage in South Africa than for gale damage 3X2=(6)
 - o Understanding of principles
 - (iii) Explain how the air circulation of Imboa and the warm ocean current along our east coast can combine to cause heavy precipitation over northern Natal 3X2=(6)
 - o Application of facts, principles
 - (iv) Supply two indications which prove that cyclone Jaja is younger than Imboa (4)
 - o Interpretation of map and application of fact
 - (v) Which quadrant of Jaja is the most intensively developed? Briefly explain this phenomenon 3X2=(6)
 - o Interpretation of map and application of fact
- (b) The following sections (i) - (iv) refer to the synoptic weather map and the corresponding satellite photograph (1984-10-16)
- (i) Indicate on the given map the following features using the symbols given
 - o a cold front and an occluded front (conventional symbols for fronts)
 - o the cold sector of a temperate depression (its boundaries and letters CS)
 - o the general direction of airflow in this sector (with a few arrows)
 - o the centre of the western coastal depression (a small x in the centre) 5X2=(10)
 - (ii) Explain in detail how the air circulation around the western coastal depression leads to berg winds to its south and foggy weather to its north. Also describe the weather conditions to which this leads 6X2=(12)
 - o Application of principles
 - (iii) Explain how the inversion layer above the interior plateau has apparently changed, enabling the moisture to penetrate the interior 3X2=(6)
 - o Understanding and application of principles
 - (iv) The weather maps of 1984-02-19 and 1984-10-16 show two different types of cyclone which influence the weather of the eastern coast. In one sentence respectively state how these two types of cyclone would compare regarding
 - o the latitudes where they originate 2X2=(4)
 - o the air pressure at their centres 2X2=(4)
 - o Understanding of facts
- (c) The following sections (i) - (iv) refer to the synoptic conditions in the southern hemisphere on 1961-07-03 at 14h00 SAST
- (i) Name two indications from the figure which prove that the three temperate depressions 1,2,3 are part of the
 - o Knowledge of definition

- same family of depressions (4)
- (ii) Name the high pressure cell at 4 and state which high pressure belt it forms part of (2) o Knowledge of terminology
- (iii) In which stage of development can the temperate cyclone at 1 be considered to be? (2) o Understanding of pattern; interpretation of data
- (iv) Which will be the next developmental stage for this depression at 1? Which changes will then set in? (8) o Application of knowledge
[80/80]

- SG: (a) (i) Supply one indication from the synoptic weather map (1984-02-19) which indicates that the cyclone Imboa had already reached its formative stages (2) o Knowledge of pattern
- (ii) Supply one indication from the map or photograph that indicates that Jaja is younger than Imboa (2) o Application of facts
- (iii) Which quadrant of Jaja is most intensively developed? (2) o Application of facts
- (b) Sections (i) to (iii) below refer to the synoptic weather map (1984-10-16) and the accompanying satellite photograph
- (i) Indicate the following features on the copy provided using the symbols in brackets
- o a cold front (conventional symbol)
 - o a cold sector of a temperate depression (boundaries and letters CS)
 - o the general direction of air circulation in this cold sector (a few arrows)
 - o the centre of the west coast depression (small x at centre)
 - o a region where this west coast depression causes Berg winds (several B's in the area concerned)
 - o a region where the west coast depression causes mist (several M's in the region concerned) (14)
- (ii) Behind the cold front along the east coast moist air is flowing onshore. Briefly explain how the inversion layer above the plateau has probably changed so that the moist air can penetrate the interior (4) o Understanding of principle
- (iii) The weather maps of 1984-02-19 and 1984-10-16 illustrate two different types of depressions which influence the weather of the east coast. Name the two types of depressions and state which one experiences the strongest winds
- normally strikes the east coasts of continents
 - has the largest diameter 3X2=(6)
- (c) Sections (i) to (iii) refer to the synoptic conditions on 1961-07-03 in the southern hemisphere at 14h00 SAST
- (i) Suggest a reason for concluding from the figure that the three temperate cyclones 1,2,3 form part of a family (2) o Knowledge of definition
- (ii) As for HG (4) o Knowledge of terminology
- (iii) As for HG (4) o Understanding of pattern; interpretation of data

[40/60]

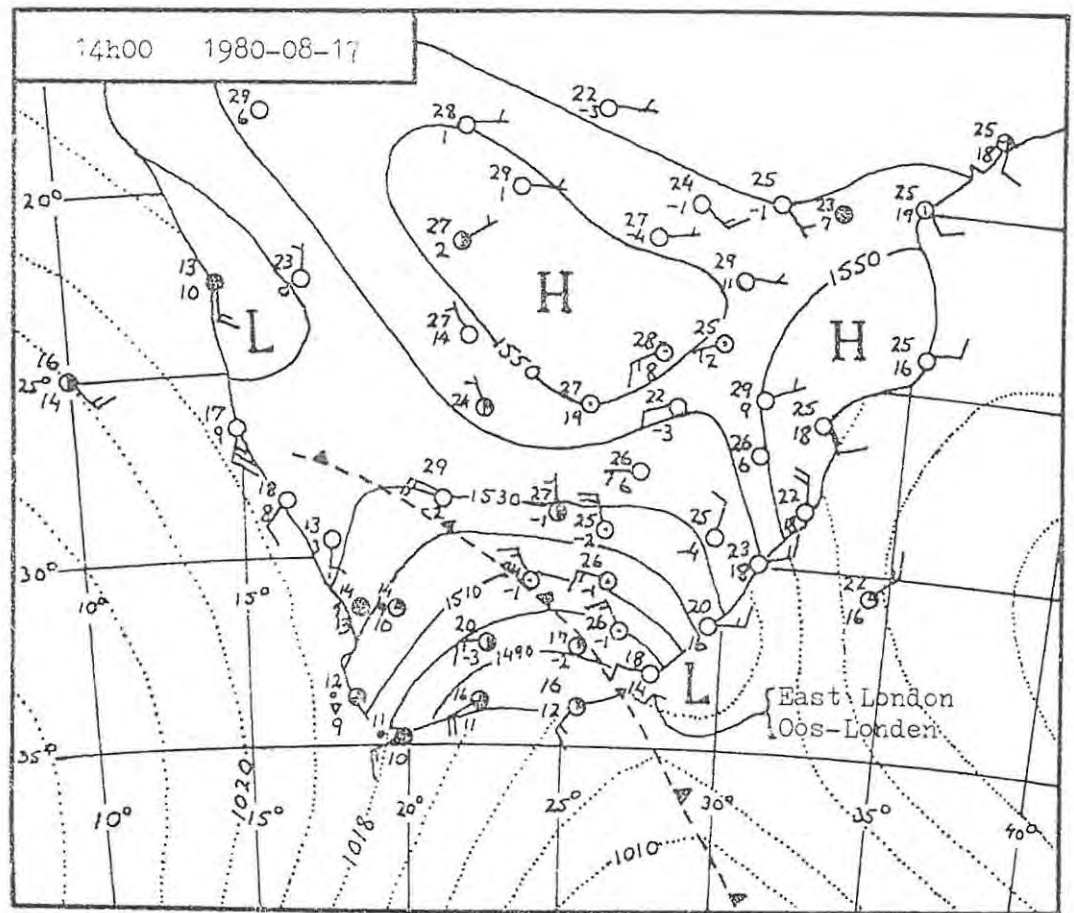
- 1986 HG: (a) Sections (i) to (iv) refer to air circulation and weather patterns on the simplified synoptic weather map of the

Republic of South Africa 1986-02-05

- (i) Name the season represented and list evidence on the map to substantiate your answer 4X2=(8) o Deduction/Analysis
 - (ii) Briefly explain and describe how isobaric readings are recorded on the map 4X2=(8) o Knowledge of procedures (rules)
 - (iii) Describe and explain how the air circulation in the interior of the RSA will affect the temperature, precipitation and cloud conditions at the stations marked AB and MP (16) o Application of generalizations
 - (iv) Draw a cross section along the line AB through the atmospheric pressure cell situated south west of Cape Town. Clearly indicate and label
 - o the fronts
 - o the air masses (and the relative temperature of each)
 - o air circulation in the cell
 - o cloud types
 - o precipitation types
 - o general movement of entire cell 12X1=(12)
- (b) Tropical cyclones (16) o Analysis and interpretation of data, graphics
- (c) Thunderstorms (6) o Interpretation of data, graphics and knowledge application
- (d) Valley fog (10) o Understanding of principles

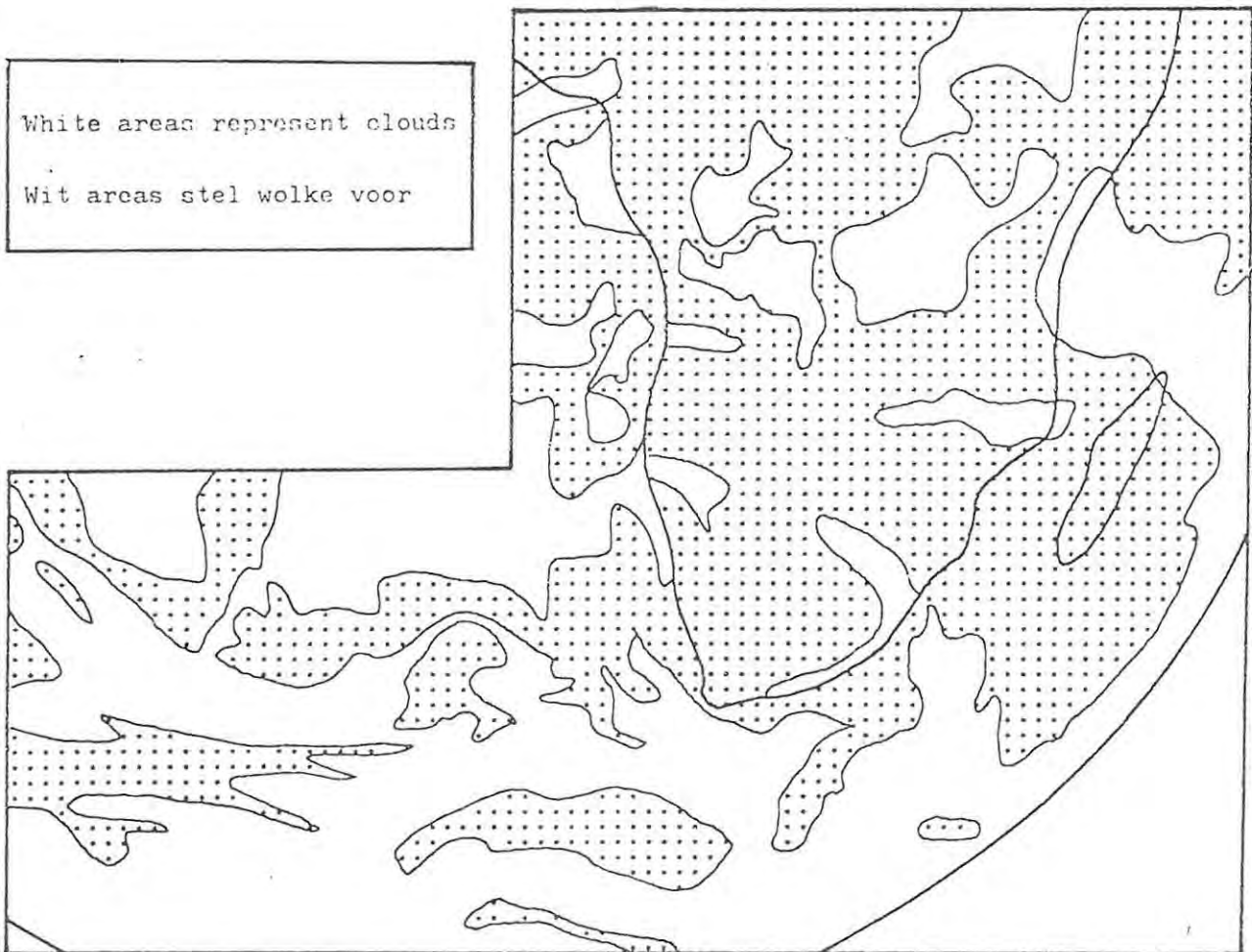
SG: (a) Refer to the weather map dated 1986-02-05

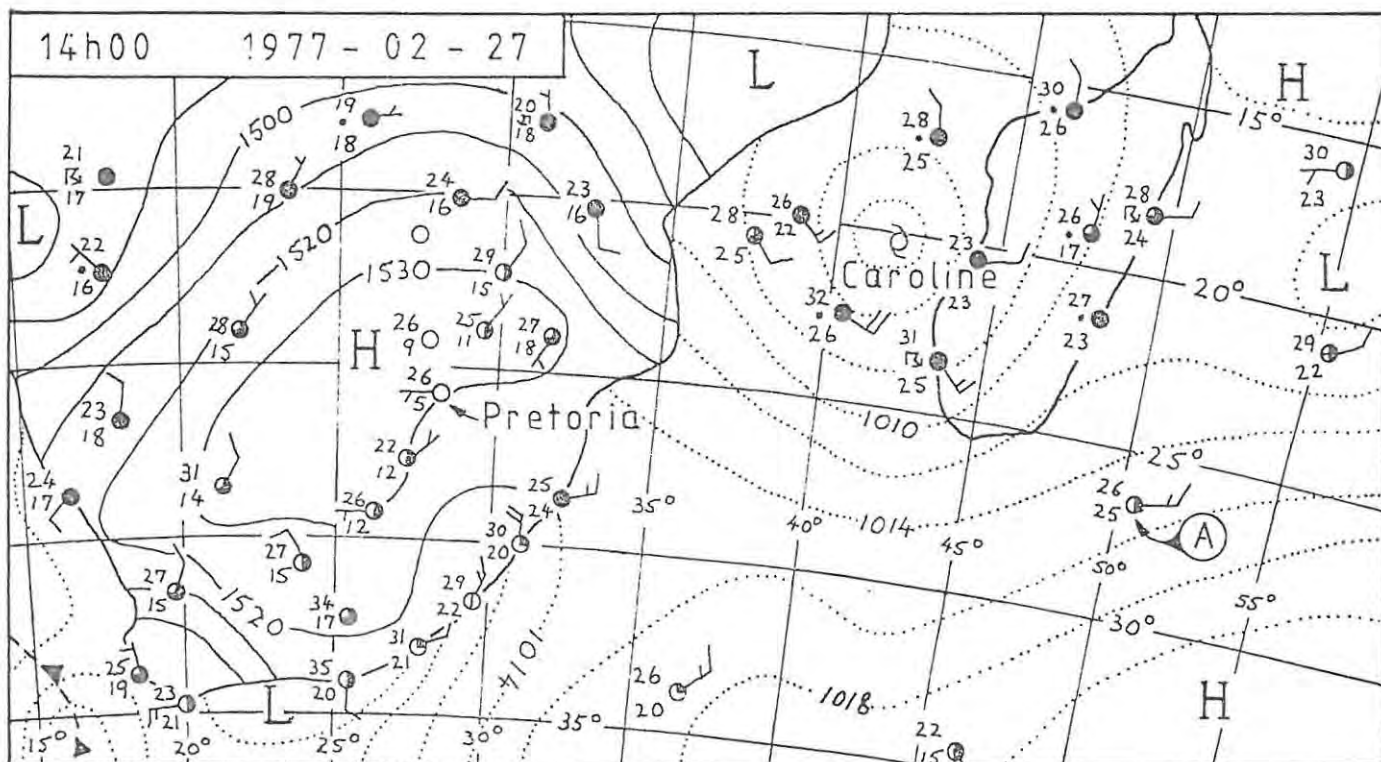
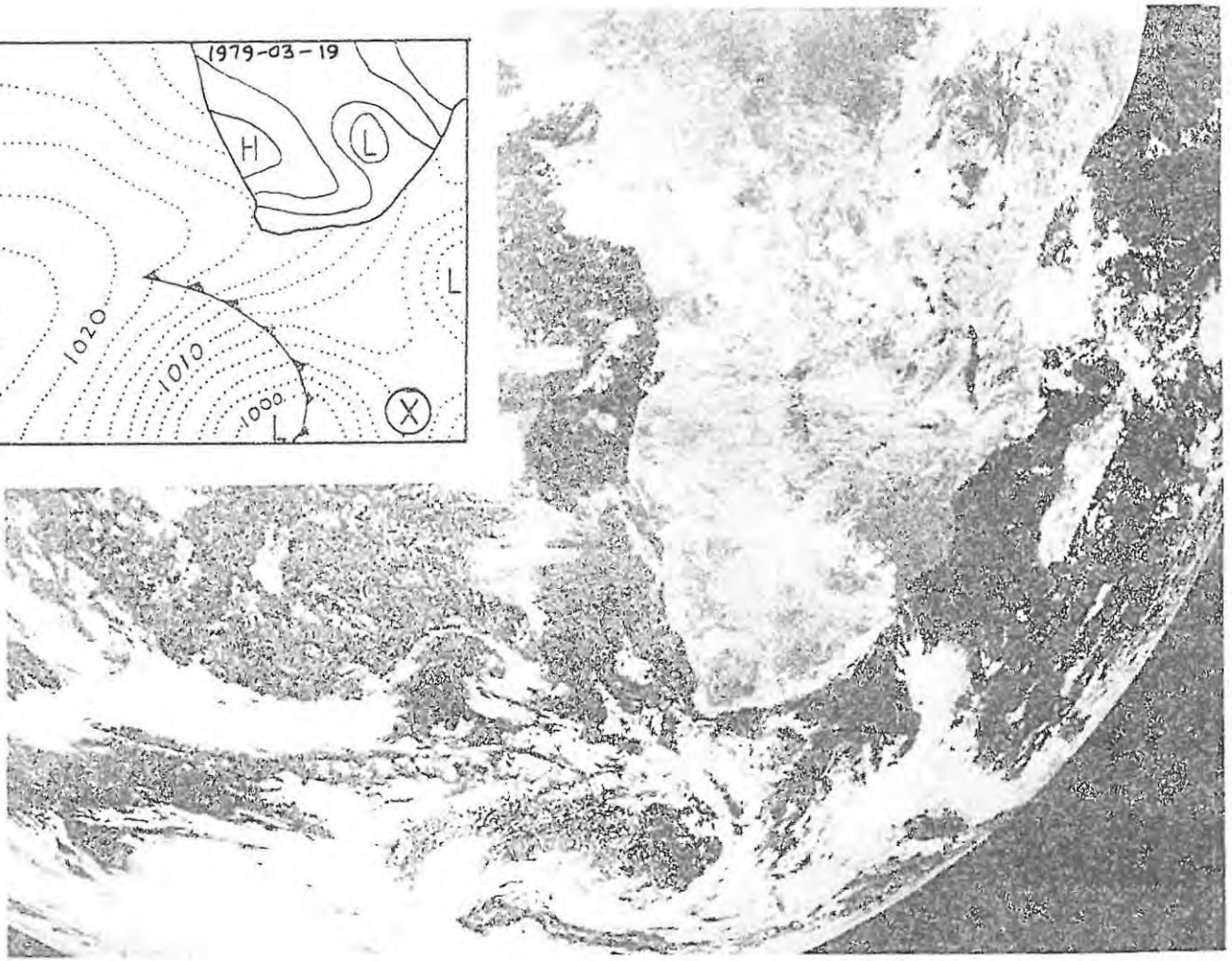
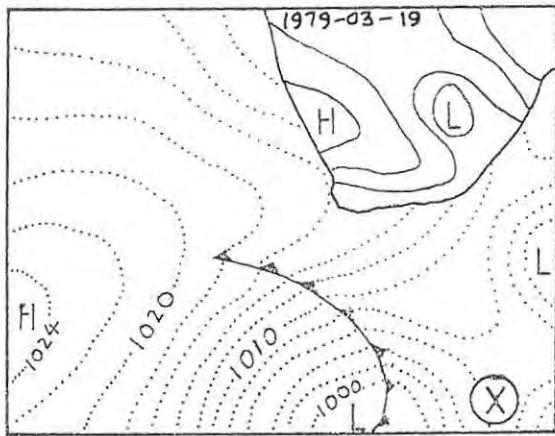
- (i) Name the season when this map was completed and give two reasons for your answer 3X2=(6)
 - (ii) Briefly describe and explain how isobaric values are represented on land and sea surfaces on this map 2X2=(4)
 - (iii) Draw a cross-section AB of the atmospheric low pressure cell situated south west of Cape Town. Clearly name and indicate the following phenomena:
 - o the type of front and its probable gradient
 - o two air masses (and the relative temperature of each)
 - o the direction of air flow within the cell
 - o one cloud type in front of the cell (6)
 - (iv) Briefly describe how the air circulation over the interior of the RSA affected the temperatures and the humidity of towns situated along the west coast 2X2=(4)
- (b) Tropical cyclones (20) o Analysis and interpretation of data, graphics
- (c) Thunderstorms (6) o Interpretation of data
- (d) Fog (14) o Knowledge application/recall

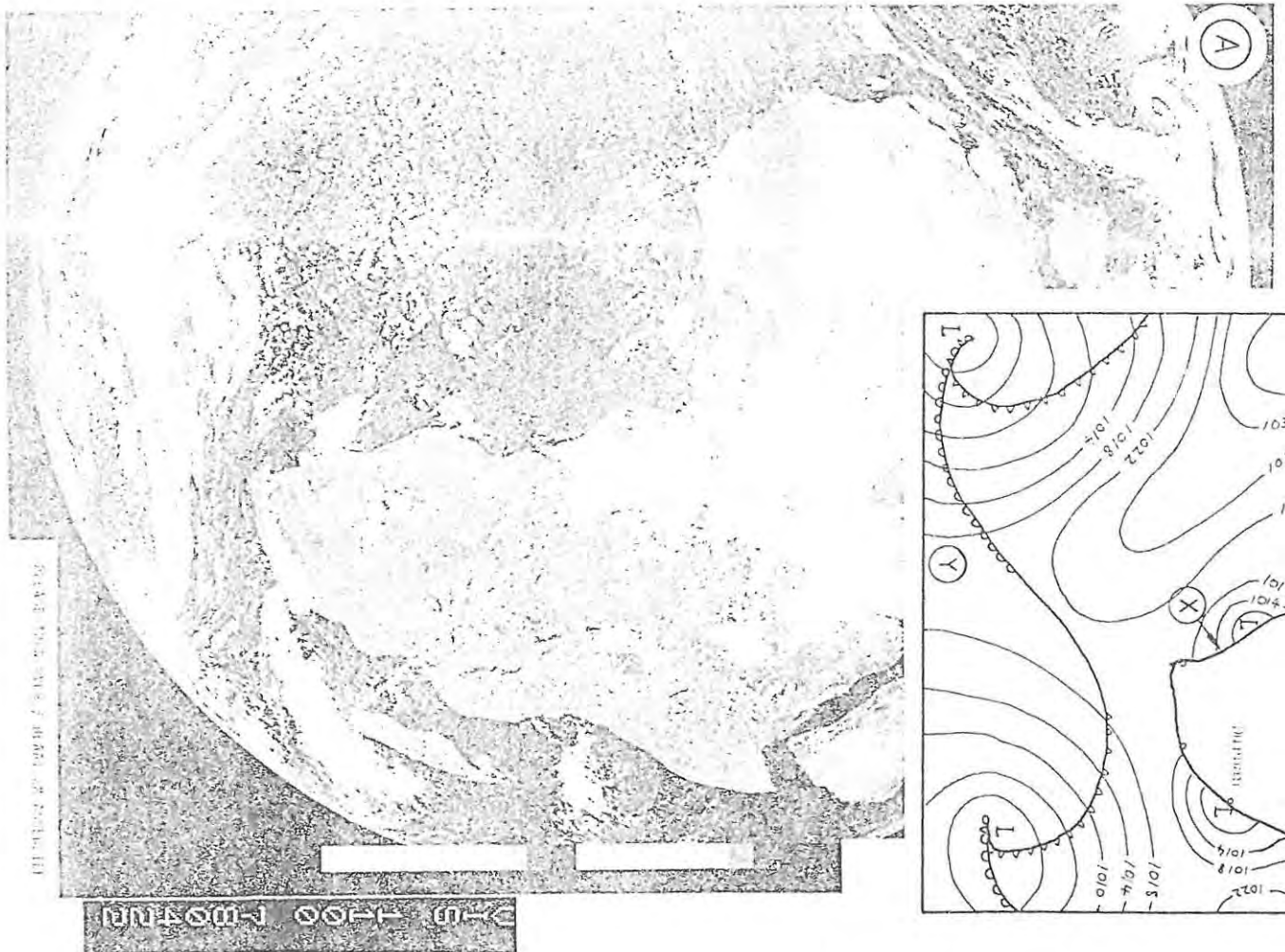
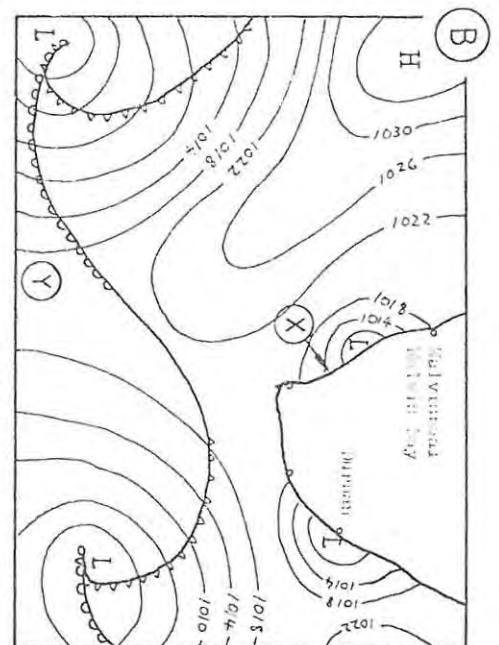
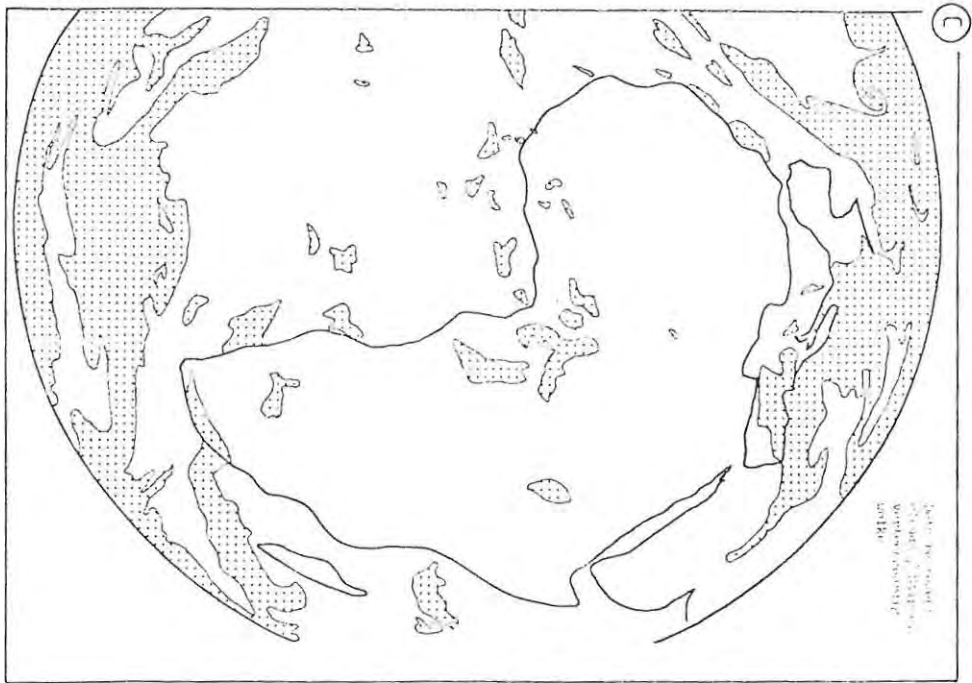


White areas represent clouds

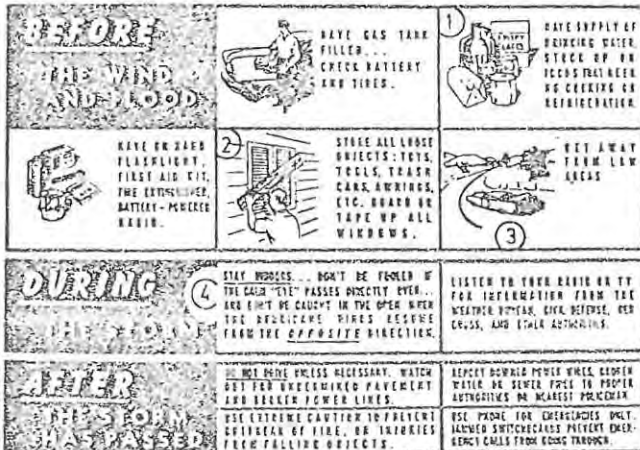
Wit areas stel wolke voor







KEEP YOUR RADIO OR TV ON...AND
LISTEN TO LATEST WEATHER BUREAU ADVICE
TO SAVE YOUR LIFE AND POSSESSIONS



YOUR ABILITY TO MEET EMERGENCIES
WILL INSPIRE AND HELP OTHERS

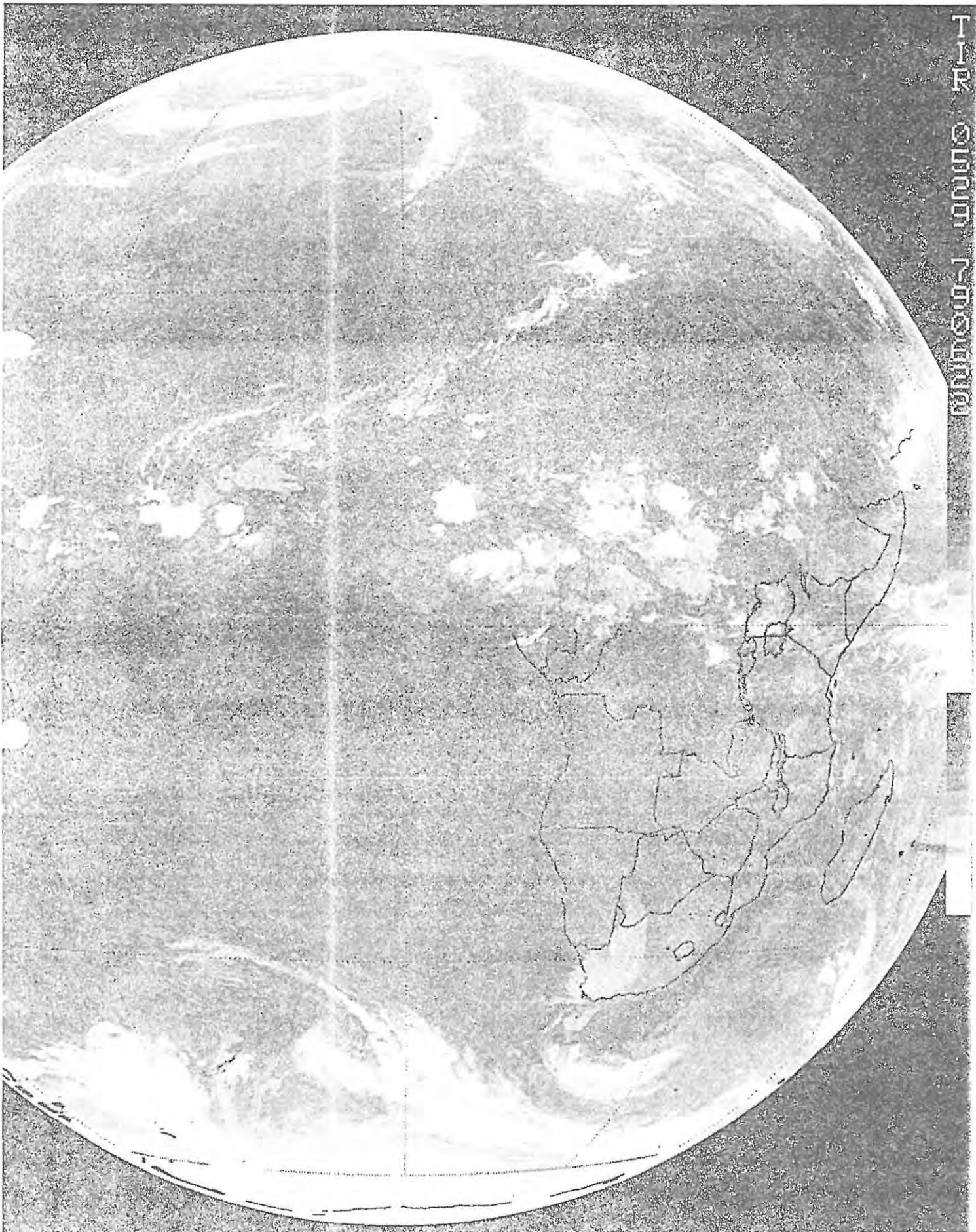
U.S. DEPARTMENT OF COMMERCE - WEAVER BUREAU

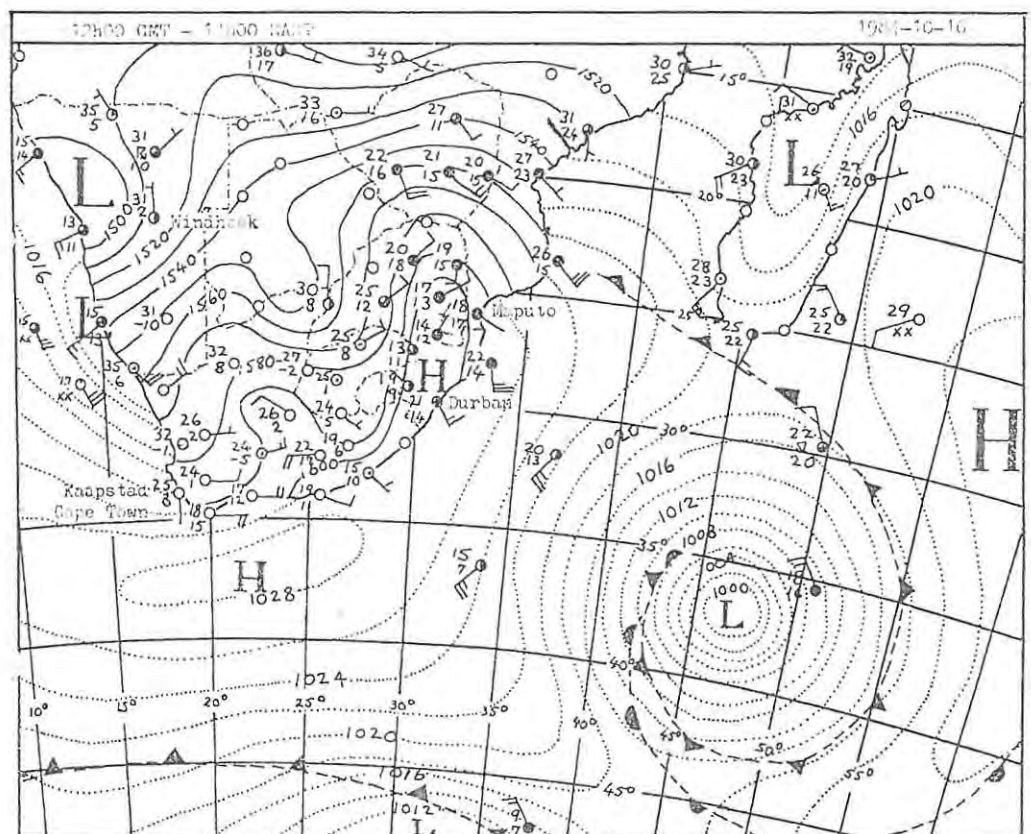
HOI JOU RADIO OF TV AAN ... EN LUISTER NA DIE JONGSTE ADVIES VAN DIE WEERSURO
OM JOU LEWE EN EITENDOM TE BEVEILIG

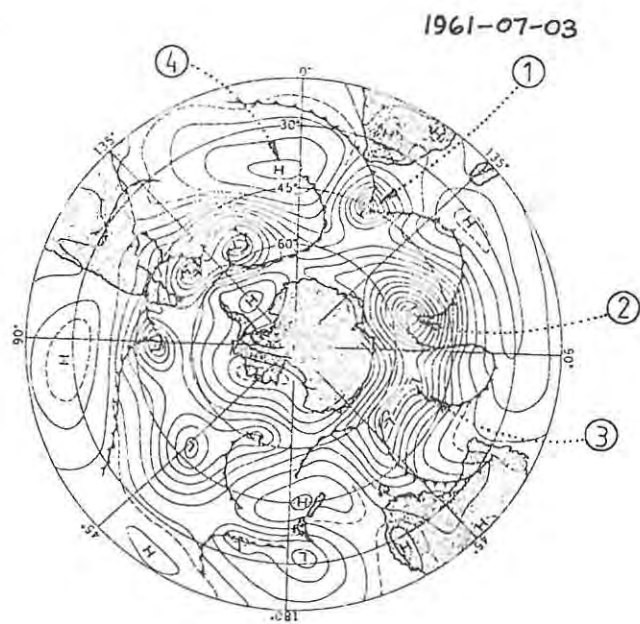
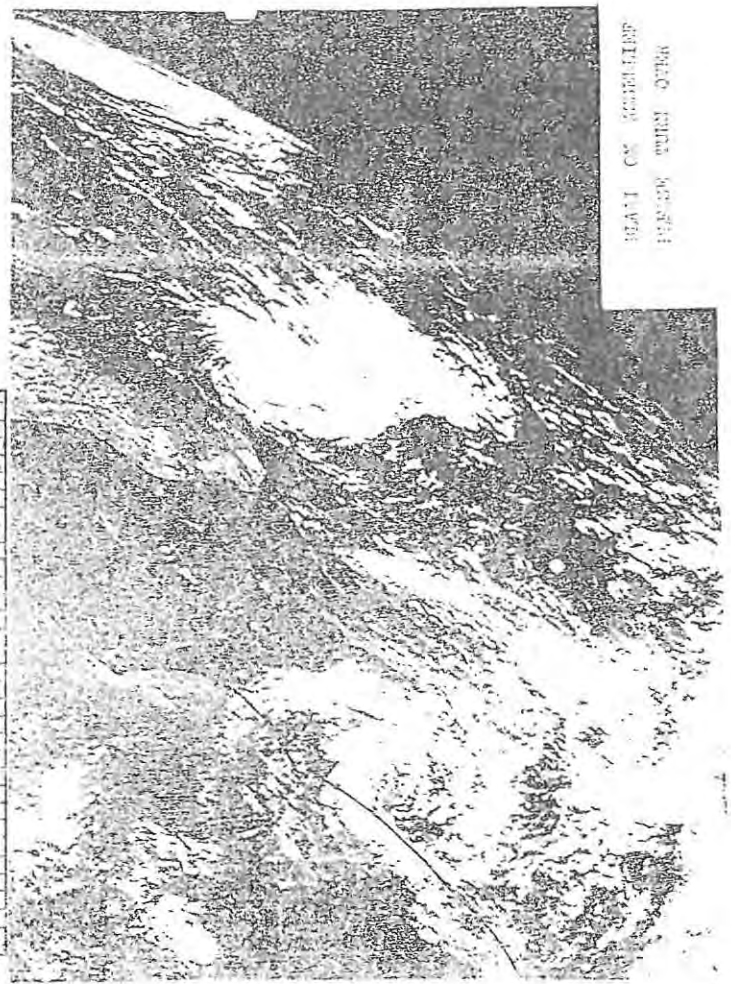
<p><u>VOOR</u></p> <p>DIE WIND</p> <p>EN VLOED</p>	<p>Kaak tena vol ...</p> <p>Gaan battery en</p> <p>bande na.</p>	<p>①</p> <p>Kom n drinkwatervoorraad op.</p> <p>Vergader voedsel wat nie</p> <p>hoef gekook of gevaries te</p> <p>word nie.</p>
<p>Hou n flitselig, noodhulpetel,</p> <p>transkluseer en battery-radio</p> <p>tyderhand.</p>	<p>Wra alle los voorwerpe weg</p> <p>speelgoed, gereedskap,</p> <p>vullistieke, skonekmas, ens.</p> <p>Spyker of plak alle vensters</p> <p>toe. ②</p>	<p>③</p> <p>Verlaat alle</p> <p>laagliggende gebiede.</p>
<p><u>TYDENS</u></p> <p>DIE STORM</p>	<p>Bly binneshuise ... Moenie op</p> <p>die bos geleë word wanneer</p> <p>die kalm "oog" regoor jou</p> <p>beweeg nie.... en skoenie</p> <p>buite betrap word wanneer</p> <p>die orkaanwinde verniet die</p> <p>teensorgestelde rigting</p> <p>hervat die. ④</p>	<p>Luister na jou radio of TV</p> <p>vir inligting van die</p> <p>weerbuur, burgerlike</p> <p>beskerming, die rookruis of</p> <p>ander owerhede.</p>
<p><u>NA</u></p> <p>DIE STORM</p>	<p>Moenie op die pad gaan nie,</p> <p>teny dit noodsaaklik is.</p> <p>Passop vir spydragjies wat</p> <p>weggekalve is en vir</p> <p>gebreekte kraglyne.</p>	<p>Rapporteer gebreekte krag-</p> <p>lyne, watertyppe of rioolyppe</p> <p>aan die betrokke owerhede of</p> <p>aan die naaste polisieaan.</p>
	<p>Wees uiters versigtig om te</p> <p>verhoed dat brande uitbreek</p> <p>of om beserings s.g.v.</p> <p>vallende voorwerpe te</p> <p>voorkom.</p>	<p>Gebruik die telefoon</p> <p>slegs vir</p> <p>noodgevälle.</p>

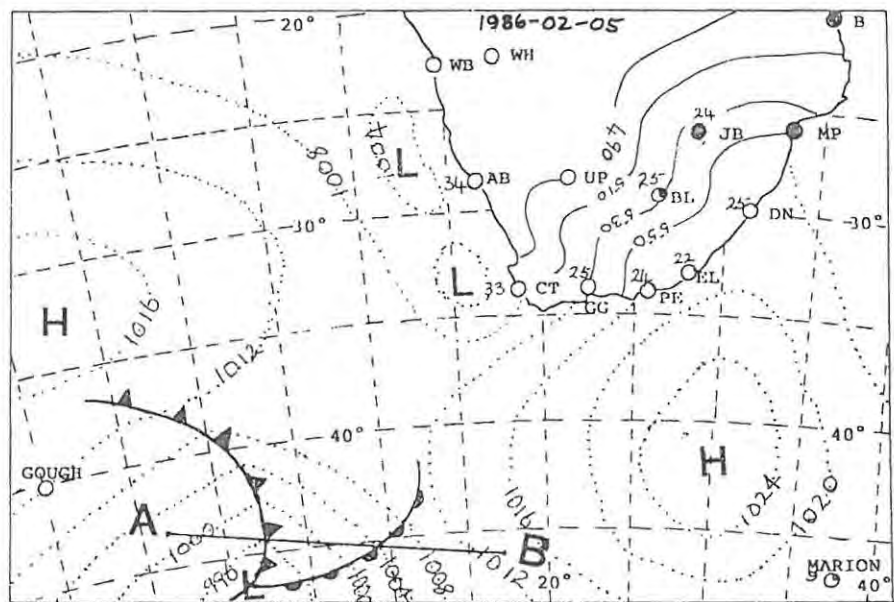
U VERPOEG OM NOODGEVALLE TE HANTEER SAL
ANDERE INSPIREER EN HELP

V.S. DEPARTEMENT VAN HANDEL • WEEERBURO



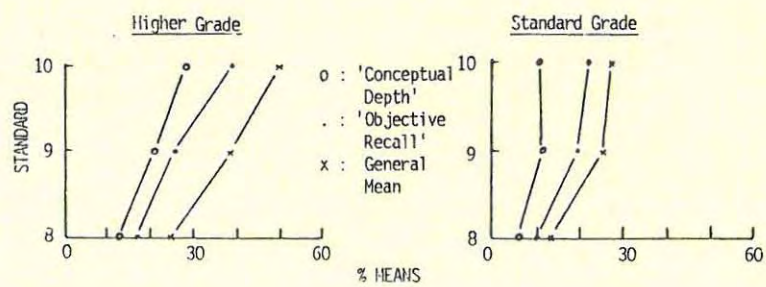
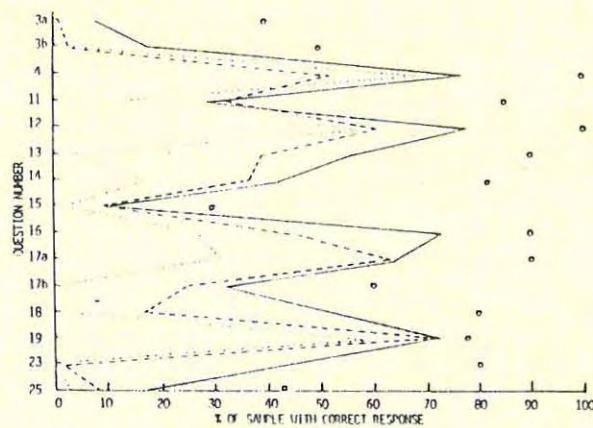
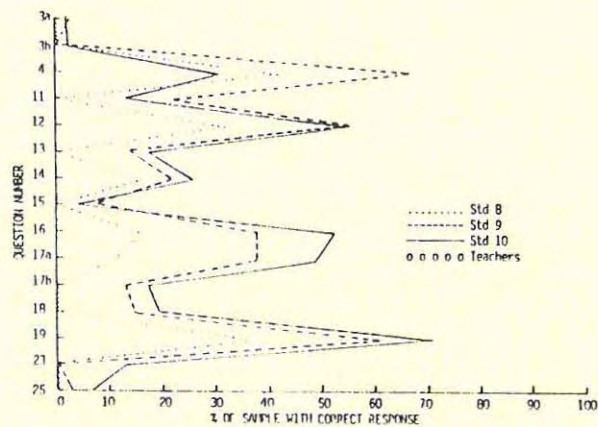






CHAPTER 5

AN ANALYSIS OF THE RESEARCH INTO CURRENT CLASSROOM PRACTICE
WITH REGARD TO METEOROLOGY-CLIMATOLOGY AND THE
SYNOPTIC CHART



AN ANALYSIS OF THE RESEARCH INTO CURRENT CLASSROOM PRACTICE
WITH REGARD TO METEOROLOGY AND THE SYNOPTIC CHART

The organisation of Chapter 5 is such that, firstly, teachers' viewpoints are presented and analyzed on the basis of group interviews conducted with them. This is followed by a presentation and analysis of data derived from a pupil worksheet administered to five hundred and thirty-three East London school pupils. The data provides evidence of pupil understanding of meteorological and climatological concepts relevant to the senior secondary climatology syllabus of the Cape Education Department.

To investigate current classroom practice and pupil understanding in the area of synoptic chart teaching, the author devised a pupil worksheet and a teacher questionnaire in the hope that the findings from these two sources could be compared. The response from teachers, however, was poorer than anticipated and, although comparison of the findings is not always possible, certain trends have emerged and these are analyzed at a later stage.

The research instruments contained in Appendix 2 are

- (a) Teacher interview questionnaire
- (b) Examples of interview responses from teachers
- (c) Guidelines for administering pupil worksheet
- (d) Pupil worksheet (questions)
- (e) Marking memorandum for pupil worksheet
- (f) Examples of completed pupil worksheets

Permission granted by the Cape Education Department enabled the author to gain the support of five out of eight East London schools approached for their co-operation. It is Cape Education Department ruling that participating schools are not named; therefore reference in the text is made to schools A, B, C, D and E.

Of the twenty-one teachers requested to complete the interview questionnaire, only thirteen responded.

Pupil worksheets were administered to a standard eight, nine and ten class in each of schools A to E by their respective teachers. The details of the sample population are recorded in Table 9.

Table 9

DETAILS OF THE RESEARCH SAMPLE

<u>School</u>	<u>Standard</u>					
	8		9		10	
	SG	HG	SG	HG	SG	HG
A	15	10	17	14	13	10
B	2	36	6	22	14	32
C	0	16	4	26	17	9
D	2	20	19	68	12	41
E	<u>0</u>	<u>35</u>	<u>15</u>	<u>23</u>	<u>22</u>	<u>13</u>
	19	117	61	153	78	105

A total of three hundred and seventy-five higher grade candidates and one hundred and fifty-eight standard grade candidates participated in the research.

Administering the Teacher Interview Questionnaire

Interviews conducted with several teachers initially established the fact that teachers felt insecure in a one-to-one interview situation. The reasons for this insecurity were possibly the teachers' unfamiliarity with the subject content, lack of personal teaching experience and inability to make constructive, meaningful suggestions on the spur of the moment in an interview situation. In view of this response to the initial interviews and discussions the author resorted to a group interview procedure.

Those teachers of a given geography department volunteering to participate in the research assembled in a group and were briefed by the author as to the specific expectations of each question on the interview questionnaire. Teachers responded favourably to this procedure which further meant that the final responses were consistent in terms of the uniformity gained in the interpretation of the questions.

Ten of the thirteen teachers volunteered to complete the pupil worksheet under test conditions.

ANALYSIS OF THE TEACHER INTERVIEW QUESTIONNAIRE

Specific teaching strategy for climatology/meteorology

Ten teachers had a specific teaching strategy, but could not elaborate further.

Three had no specific strategy. Seven teachers used the same method consistently from year to year whilst five stated that modifications were made annually on the basis of difficulties experienced and their own personal development in the subject area through the reading of journal articles or attending teacher centre meetings.

Strategies found useful for synoptic chart teaching

No teachers reported the use of specific classroom aids. However, the most valuable suggestion was the use of a five-day series of television weather reports typical of a season. The teacher concerned made the point that this exercise was done only once the entire chart had been taught and it, therefore, served as a consolidation exercise.

No unusual strategies were offered, and teachers reported to make use of the following methods:

1. Teacher exposition with the use of the overhead projector and/or blackboard enabled summaries to be made.
2. Teacher exposition was sometimes supplemented with teacher questioning classes and obtaining individual pupil responses.
3. Some teachers found questioning relating to problem solving a useful method of encouraging pupil participation.
4. In addition to the above strategies, teachers found group work and subsequent feedback useful.
5. Worksheets and assignments were presented for pupils to do without prior exposition and a general post-task discussion ensued. An alternative to this approach was to teach the topic first and then to use a worksheet as a consolidation exercise.

Lesson hours per annum spent on synoptic chart teaching

The average amount of time per class spent on the synoptic chart was 7,6 hours per annum. One teacher commented that such a statistic was difficult to assess since the synoptic chart was integrated into climatology and regional studies of South Africa.

Textbooks or visual aids regarded as useful by teachers

The climatology of Southern Africa made available by BP (Southern Africa) in the form of a mural and the overhead projector series produced by the same company were regarded as particularly useful.

Four teachers cited Hurry and van Heerden (1986) as being a useful class-room resource.

Concepts relating to the climatology syllabus and synoptic chart which teachers find pupils regard as difficult to understand

Six teachers found the following three ideas to be the most exacting for pupils to understand:

- o the three-dimensional portrayal of atmospheric phenomena, particularly pressure systems
- o the isohypse concept i.e. the height of the 850 hPa pressure surface above sea level measured in geopotential metres
- o geostrophic flow

Recommendations for the teaching of these concepts appear in the final chapter.

The following ideas were cited once only as being difficult for pupils to understand:

- o geostrophic windspeed measurement
- o jet stream
- o adiabatic lapse rates
- o stability and instability
- o global (general) circulation
- o relative humidity
- o frost formation
- o convergence and divergence
- o occlusion
- o inception of the mid-latitude cyclone
- o upper air movement
- o the interpretation of unseen data (weather forecasting)

Problems which teachers themselves encounter in the teaching of the chart

The most common problem amongst the teachers interviewed is the isohypse concept. Further problems which teachers encountered are listed below:

General:

- o Frustration with pupils not grasping synoptic chart concepts
- o Teachers find pupil background knowledge lacking
- o Abstract concepts are difficult to teach and, therefore, difficult for pupils to grasp

Specific Problems:

- o Getting pupils to understand that the chart is only for a precise time of day
- o The distinction between the tropical and mid-latitude cyclone
- o The general aversion to climatology which girls appear to exhibit
- o Insufficient time in standard ten to cover climatology in the amount of detail desirable for a sound understanding of the synoptic chart

Methodology related problems:

- o Teaching pupils how to extract information from the chart
- o Trying to make the content real, meaningful and exciting
- o Portraying atmospheric phenomena three-dimensionally

There is consensus amongst the teachers interviewed that climatology is a section favoured by higher grade candidates who display insight, whilst standard grade candidates show little interest or ability to accommodate the abstract nature of the subject. In general, girls do not show interest in climatology, according to teachers of girls.

Items evoking YES/NO responses

Responses to these items are presented in Table 10.

REFLECTIONS ON THE ANALYSIS OF THE TEACHER INTERVIEW QUESTIONNAIRES

The approaches to the teaching of climatology, and more specifically the synoptic chart, lacked variety. Teachers generally gave the impression that the textbook was the most important source of reference and that the teaching methodology largely depended on textbook presentation. One teacher was in the process of structuring a booklet of notes for the senior secondary climatology course. The booklet contained selected information from various texts.

From a review of the literature on the topic there is clearly a dearth of South African teacher contributions on approaches to the classroom teaching of the subject, unlike the British publication, Teaching Geography, in which teachers provide their colleagues with new ideas stemming from classroom experimentation.

The synoptic chart is not used as a consolidation exercise, the manner which the author sees it as being most beneficial. The fact that twelve of the thirteen teachers interviewed spent on the average 7,6 hours per annum on the

Table 10

<u>Question number</u>	<u>Précised question</u>	<u>% of teachers responding affirmatively to question</u>	<u>% of teachers responding negatively to question</u>
1	Use of specific and consistent meteorology or climatology teaching strategy	77%	23%
4	Revision of climatic concepts prior to teaching the synoptic chart	85%	15%
5	Synoptic chart used to revise South African weather	100%	0%
6	Synoptic chart taught according to textbook presentation	15%	85%
8	Past matric examination papers used as a guide to teaching	100%	0%
12	Climatic and meteorological concepts of standard eight and nine are essential to a thorough grasp of the chart	100%	0%
13	In-service training requested	92%	8%

TEACHERS' RESPONSES TO INTERVIEW QUESTIONS
REQUIRING YES/NO ANSWERS

teaching of the chart is indicative of the fact that the chart is taught with a narrow focus on preparing pupils to answer examination questions, a finding further supported by the fact that all teachers interviewed used the matriculation examination questions as a guide to their teaching of the chart.

A noteworthy coincidence is that the isohypse concept was regarded by teachers as the most difficult concept for pupils to understand, and the most difficult concept for teachers to teach. The former difficulty may be explained by the latter.

The inherent difficulties in the teaching and understanding of meteorology-climatology were clearly defined by teachers to be as a result of the abstract and scientific nature of meteorology - a field which teachers themselves were not necessarily trained in, and which pupils find difficult to understand.

The problems which pupils and teachers experience have been addressed in terms of the development of a graded concept matrix, developed by the author in Chapter 3. The sequential development of concepts may be a part solution to the current problem. Further ideas for the classroom are presented in the final chapter.

Three of the thirteen teachers claimed that girls found the scientific nature of climatology difficult and uninteresting. The author thus requested pupils to identify their sex on the pupil worksheet responses. The statistical analysis is dealt with later in the chapter.

DESIGN OF PUPIL WORKSHEET ON SOUTH AFRICAN WEATHER, CLIMATE AND THE SYNOPTIC CHART

A worksheet comprising twenty-five questions (Appendix 2) was administered to five hundred and thirty-three pupils as detailed in Table 9. The worksheet was designed in such a way that it contained approximately equal proportions of concepts pertinent to standards eight, nine and ten. The rationale behind such a strategy was to see whether pupils retained the earlier concepts and used them effectively in explanatory type answers. The average results were, therefore, expected to improve from standard eight to standard ten.

The worksheet was constructed so that fifty percent of questions were of the 'objective recall type', while the other fifty percent were designed to test 'conceptual depth', which is defined as the effective retention and under-

standing of necessary conceptual detail relevant to the answering of explanatory type questions.

Marks were awarded for the use of relevant concepts. The allocation of marks appears in the marking memorandum in Appendix 2.

Three scores were arrived at. A maximum of twenty marks was allocated to 'objective recall' type responses and a maximum of fifty marks to 'conceptual depth' questions. A general score for the performance on the worksheet as a whole was given out of a maximum of thirty marks. In the last mentioned marking category any correct response on a 'conceptual depth' question scored a single mark, irrespective of its sophistication, and this was added to the 'objective recall' score.

The rationale behind the three marking categories was to compare 'conceptual depth' and 'objective recall' information retained by pupils, the third category simply gave an indication of how much the pupil knew generally about the worksheet topics.

ANALYSIS OF PUPIL PERFORMANCE ON THE WORKSHEET

The pupil worksheet and a comprehensive rationale behind it and the bearing of the required knowledge on applied synoptic chart interpretation are located here rather than in an appendix to facilitate referencing. See pages 152 to 155.

Item Analysis

The data shows that pupils exhibit a sound knowledge

- (i) of a relationship between atmospheric temperature and moisture
- (ii) that the predominant climatic element on synoptic charts is pressure
- (iii) of the circulation patterns of cyclones and anticyclones
- (iv) that isobars show pressure distribution over the oceans
- (v) that mid-latitude cyclones can be responsible for wet Cape Mediterranean winters
- (vi) that station models indicate regional cloud cover.

It is possible that these concepts are easily grasped by pupils or that they are emphasized by teachers.

Figures 49 to 52 show the percentage of the sample group who produced the correct answer for given questions. The expected profile pattern in terms

Fig. 49

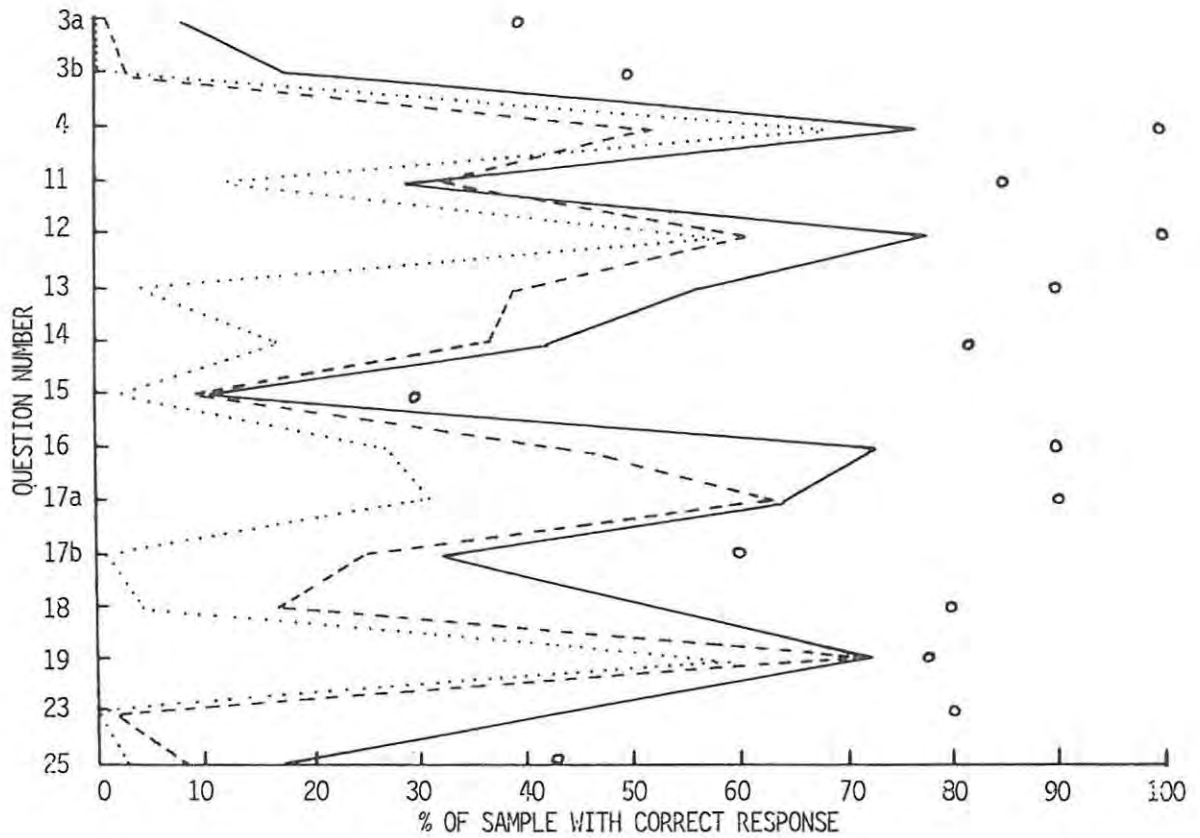
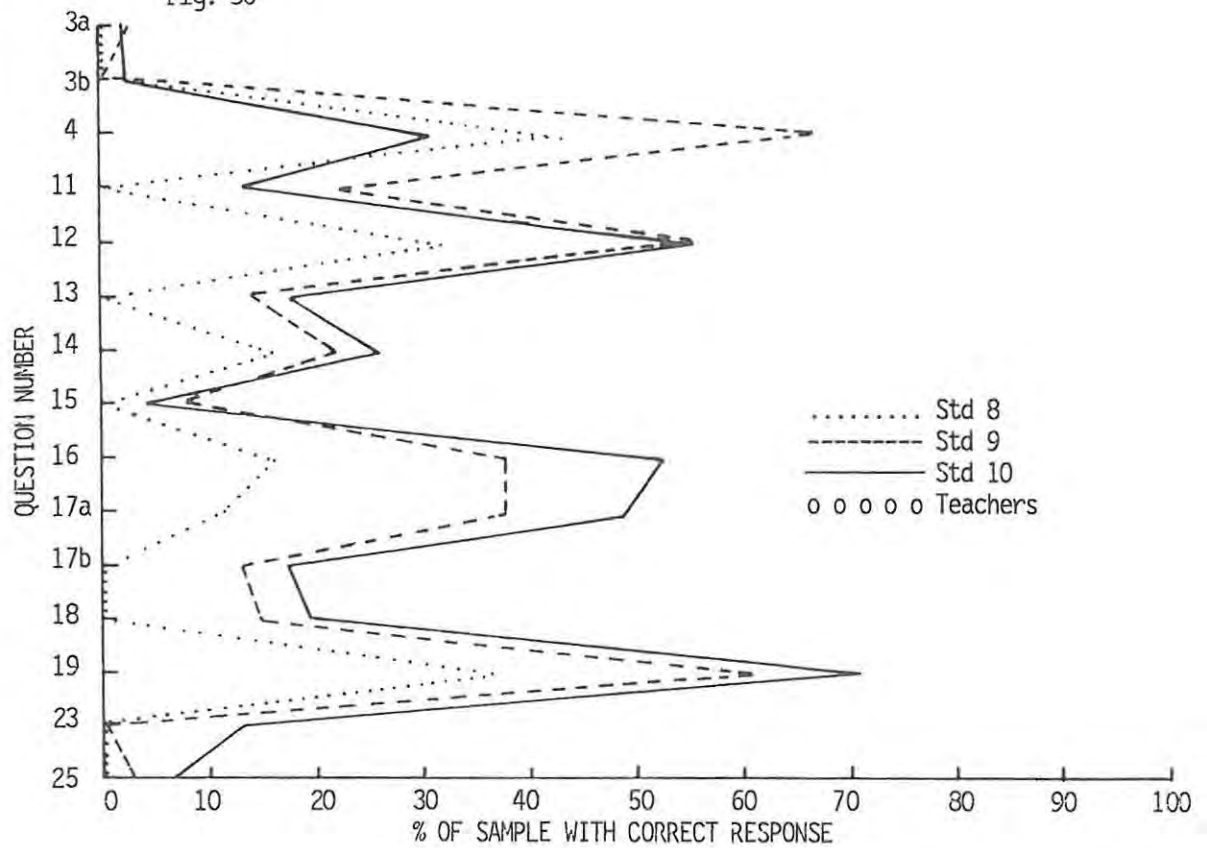


Fig. 50



Item analysis profiles for objective type questions for the higher grade (Fig. 49) and standard grade (Fig. 50)

of the design of the worksheet is for the percentage of correct answers to increase from standard eight to ten. Where profiles intersect each other this deviation from the expected pattern needs to be explained. General observations are made above; a discussion of anomalies follows.

Item analysis of objective type questions - higher grade (Figure 49)

Question eleven (difference between normal and adiabatic lapse rates) produces a discrepancy in that standard tens score lower than standard nines. The concept of lapse rates is syllabus-specific to standard eight and standard nine and the unexpected poor performance by standard tens may be ascribed to retroactive inhibition, a phenomenon described by psychologists as the interference of recently learned material on earlier learned material. This discrepancy is viewed as significant since a knowledge of the lapse rates has a strong bearing on the understanding of atmospheric stability and instability.

Question fifteen, which deals with the interpretation of pressure digits on station models, poses difficulty for all three standards. This question was designed to test knowledge of detail beyond the syllabus and, therefore, the question would only have been answered by pupils who were specifically taught the method of deducing the station pressure from the conventional three digit code.

Question seventeen (b) confirms that too few pupils are aware that the isohypse is the device for representing pressure over the subcontinent.

The poor performances by standards eight and nine on question twenty-three may be explained in terms of the temperature inversion over the escarpment being syllabus-specific to standard ten.

The analysis of pupil performance of the worksheet reveals that pupils generally understand those ideas which are visually represented. The areas of general difficulty seem to be concerned with abstract and/or statistical ideas - a trend which also emerges in the chapter on the psychology of adolescent understanding.

In Figure 49 it is also evident that teacher responses to questions three(a) and (b), fifteen, seventeen (b) and twenty-five were below the mean for teacher

performance on the worksheet, meaning in effect that

- o global heat transfer mechanisms
- o interpretation of three digit pressure code on station models
- o geopotential metre isolines
- o atmospheric systems in three dimensions

are those ideas which the teachers participating in the research needed clarification on.

Item analysis of objective type questions - standard grade (Figure 50)

Deviations from the expected pattern in Figure 50 occur on questions four, eleven and fifteen.

Question four is a typical higher grade question in that it demands a knowledge of the relationship between temperature and potential vapour content at that temperature and the application of this principle. It is expected, therefore, that a standard grade performance mean for this type of question be low, bearing in mind the problem being compounded by the effects of retro-active inhibition. The comparatively better performance by standard eights may be explained in terms of the syllabus-specific nature of the question.

Questions eleven (difference between normal and environmental lapse rates) and fifteen (interpretation of pressure digits on station models) may be explained in the same terms as those applicable to question four.

Comparison between higher and standard grade performance on objective type questions

If it is assumed that lower ability pupils opt for geography on the standard grade then the generally lower scores, with particular reference to the standard ten standard grade profile, is indicative of such pupils experiencing more difficulty with the abstract scientific nature of climatology - a point worth noting by the classroom teacher.

The worksheet is regarded by the author to contain a good balance of questions, tending to cater to the higher grade ability pupil in order that the discrepancies as already outlined should clearly emerge. More importantly, the standard of the worksheet compares favourably with the level of questions currently appearing in Cape Education Department matriculation examinations on both the higher and standard grade.

Comparison of figures 49 and 50 would also suggest that higher grade candidates retain ideas, perhaps because they grasp them more fully, and hence develop 'conceptual depth' whilst the same cannot be said of standard grade pupils. This phenomenon may be accounted for by factors already mentioned above, in addition to the fact that the volume of work characteristic of the standard ten syllabus constitutes a further burden, especially for less able pupils.

Item analysis of 'conceptual depth' questions - higher grade (Figure 51)

The most noteworthy discrepancy occurs on questions six and seven where standard tens show a particularly poor understanding of the behaviour of pressure and temperature with increasing altitude. This is a significant finding since it confirms that pupils do not perceive easily the nature of pressure systems in the vertical plane. This negatively affects their understanding of the upper air trough which is often orientated NW-SE across the country and responsible for rain and thundershowers in the central and north-eastern interior.

The convergence of scores on questions two (explanation of cold Highveld winters) and twenty (explanation of the occurrence of Highveld frost in winter) would seem to indicate a recurrence of content between standard eight and ten.

Teacher response to questions six (the nature of the vertical distribution of pressure), twenty (as in previous paragraph) and twenty-two (explanation of dry south-western Cape summers) are also below the teacher mean for the worksheet. This may explain the generally poor pupil understanding of the behavior of pressure with respect to the vertical in terms of question six. The effects of the semi-permanent continental anticyclone (which strengthens in winter) on frost formation seems also to be poorly understood by the sample of teachers who undertook to complete the worksheet.

The low scores on both the higher and standard grade for question twenty-two may be explained in terms of an insufficient use of interrelated concepts in explaining the berg wind mechanism, and secondly, the fact that the memorandum may have been designed too rigidly and the expected answer may therefore have been too sophisticated to produce a better mean performance for the question.

Fig. 51

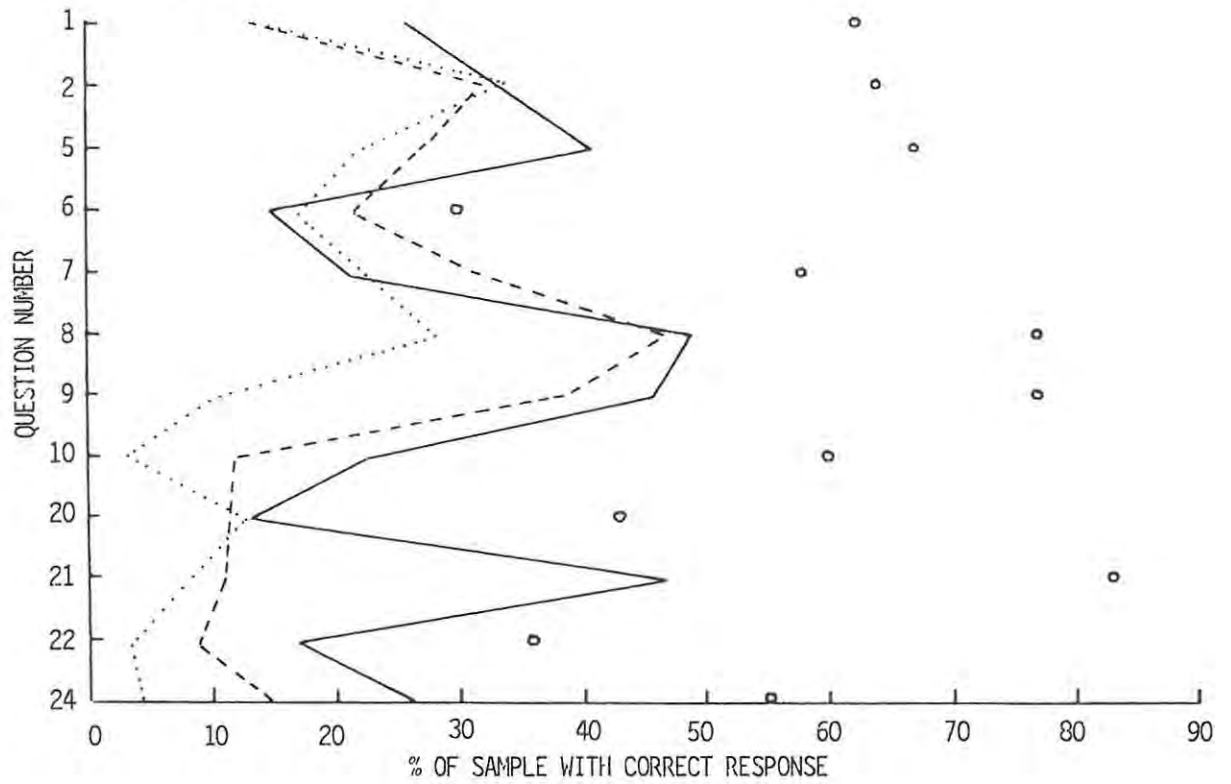
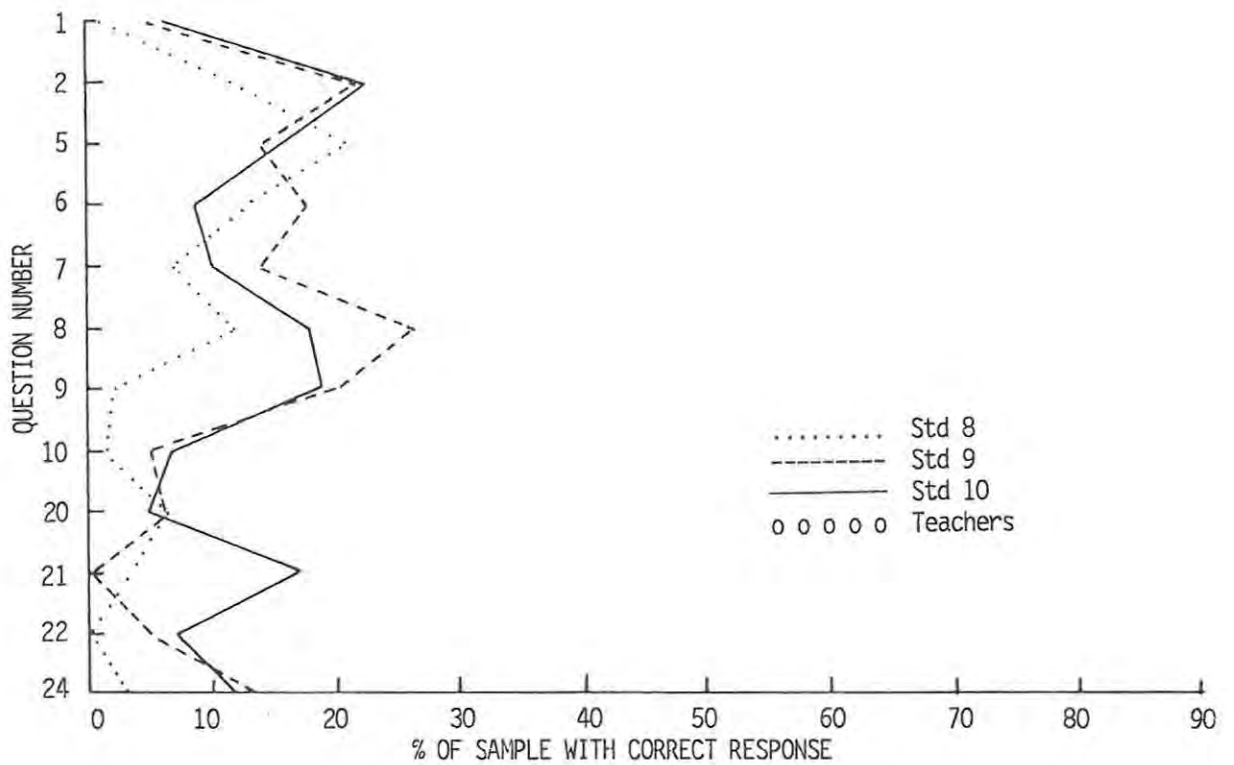


Fig. 52



Item analysis profiles for 'conceptual depth' questions for the higher grade (Fig. 51) and standard grade (Fig. 52)

Item analysis of 'conceptual depth' questions - standard grade (Figure 52)

Standard ten performance on questions five to nine, and questions twenty and twenty-four are characterised by intersecting profiles. Since the research sample population is drawn randomly from five schools, each with independent teaching methods, one can infer that standard grade pupils do not have sufficient 'conceptual depth' to do justice to these questions which are essentially higher order questions.

In questions eight (the origin of wind) and nine (the influence of the Coriolis effect on wind) the standard nine performance exceeds that of standard ten, presumably due to the syllabus-specific concepts of the origin and deflection of wind.

Standard ten standard grade pupils show clearly by their performance on question twenty (explanation of Highveld frost in winter) that those factors responsible for Highveld frost formation were not adequately, if at all, established at standard eight level.

Standard ten performance on question twenty-four (explanation of the nature of berg winds) is also indicative of a poor knowledge of the berg wind mechanism, but even a poorer ability to explain the cause of the phenomenon - a phenomenon clearly tied up with the adiabatic processes operating on descending air parcels.

The skills of being able to integrate, synthesise and apply knowledge at this abstract level are clearly not within the ability range of standard grade pupils.

Comparison between higher and standard grade performances on 'conceptual depth' questions

An immediately obvious anomaly is the attenuated range of scores for the standard grade, meaning that for this set of questions, correct responses were obtained from 9,7% of the pupils. On the higher grade 20,4% of pupils produced correct responses.

By normal standards and in terms of a normal distribution a correct response from fifty percent of pupils would have been satisfactory. The overall depressed percentages may be attributed to the standard of questions and the fact that pupils did not prepare for the worksheet as they might have for an examination.

School

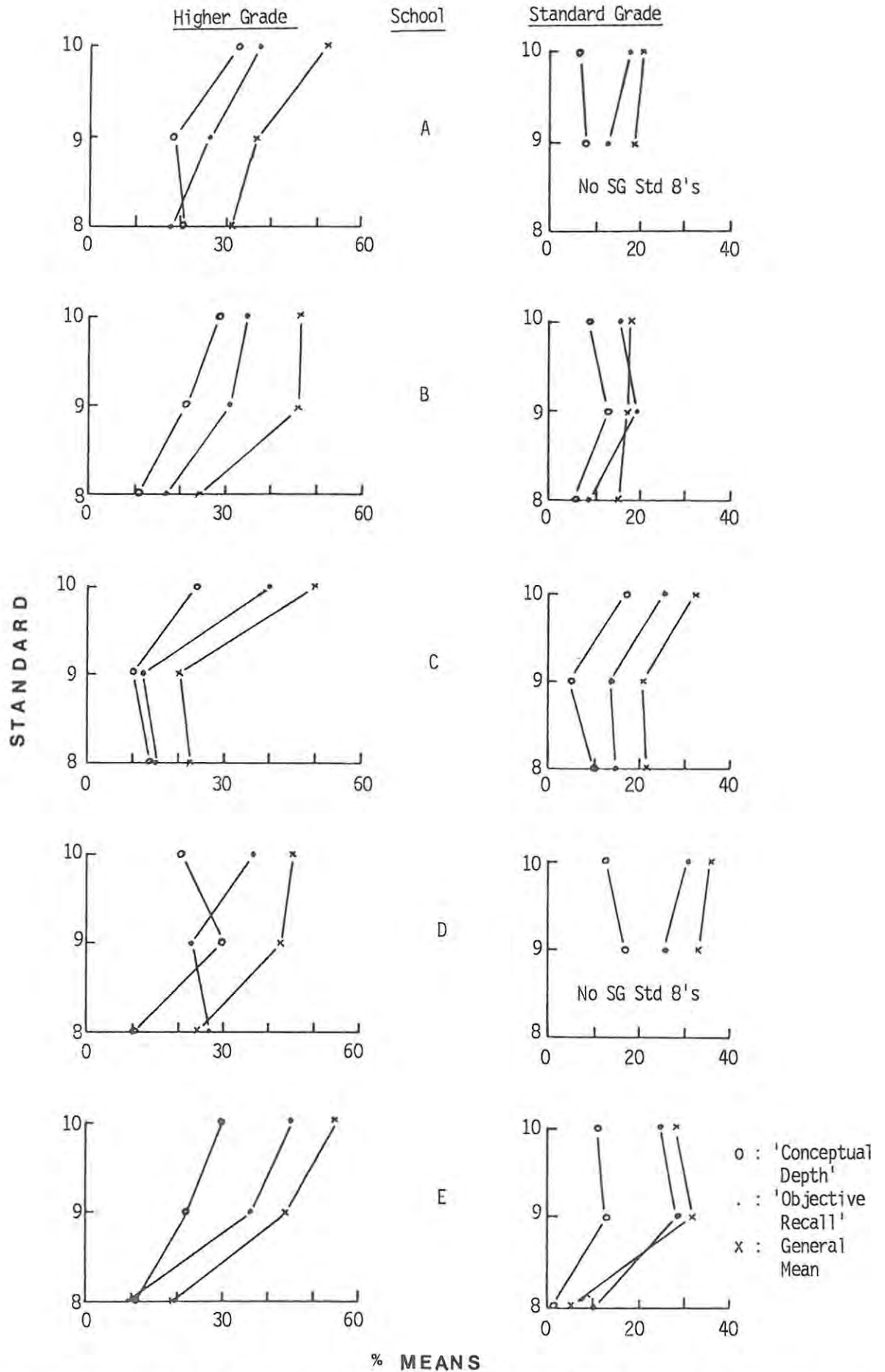


Fig. 53 Comparison of 'conceptual depth', 'objective recall' and general performance means for five East London schools

Comparison of 'conceptual depth', 'objective recall' and general performance means for schools A to E (Figure 53)

The purpose of the general score was to obtain a realistic indication of the general ability of pupils on the worksheet (given that no preparation time was allowed). Answers supplied were an indication of the knowledge and understanding which pupils had retained.

With reference to the figure, it is evident that standard grade pupils (using the standard ten group as a representative sample) achieved a general performance mean of 28,4% while higher grade pupils achieved a mean of 50,2%. These results are realistic in terms of the restraint that no prior learning was permitted.

It is significant that, without exception, the 'conceptual depth' score for each of the five schools on both grades is the lowest, meaning that understanding proved more difficult than recall questions.

Comparing the performances of standards eight, nine and ten on the standard grade, the trend is inconsistent from eight to nine. There appears, with the exception of one school, that 'conceptual depth' diminishes in standard ten. On the higher grade, however, the trend from standard nine to ten is for 'conceptual depth' performance to increase, with the exception of one school. This highlights the fact that meteorology-climatology at standard ten level is considerably more difficult for standard grade pupils.

These observations are borne out by the graphs illustrating the means for all three marking categories on the higher and standard grade for each standard. (Figure 54).

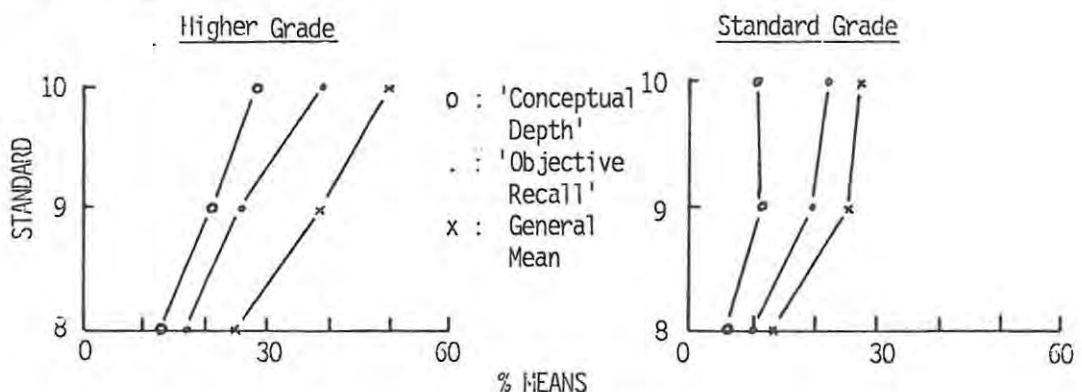


Fig. 54 Means for the three marking categories on the higher and standard grades for each standard

The means for each standard and grade on each category are summarized in Table 11.

Std.	Means in %		General score
	'Objective recall' score	'Conceptual Depth' score	
8SG	11,12	5,75	13,92
HG	16,67	13,04	24,89
9SG	20,11	11,72	26,15
HG	25,67	20,56	38,71
10SG	23,42	11,68	28,35
HG	39,02	27,58	50,15

Table 11

MEANS FOR EACH STANDARD AND GRADE ON THREE MARKING CATEGORIES

The statistical data tabulated below further confirms the above findings.

	'Objective recall' responses		'Conceptual Depth' responses	
	SG	HG	SG	HG
Mean	22,79	40,95	11,46	28,37
Standard deviation	12,21	13,90	8,24	13,03
Coefficient of variation	53,58	33,94	71,90	45,93
Standard error of mean	1,39	1,36	0,81	1,28

Table 12

MEANS, STANDARD DEVIATIONS, COEFFICIENTS OF VARIATION AND
STANDARD ERRORS OF THE MEAN FOR 'CONCEPTUAL DEPTH' AND
'OBJECTIVE RECALL' RESPONSES FOR THE RESEARCH SAMPLE

Comparison between male and female performance on worksheet (See Appendix 3)

Macfarlane-Smith (1964) observed that spatial ability develops more quickly in boys than in girls. In view of the spatial conceptual nature of meteorology-climatology this assertion could be related to boys' and girls' performances on the pupil worksheet. An investigation into a difference between male and female performance was further prompted by teachers who, when interviewed, claimed that boys showed greater interest and a better innate ability in climatology than girls.

The standard ten group was the most homogenous sample for testing the significance of such a claim by virtue of their having covered the content of the syllabus and thus they were not disadvantaged by any question on the worksheet. Subjects were randomly drawn from five schools.

A representative sample is a sample drawn in such a way that its resemblance to the population is guaranteed (Minium, 1970). A statistical weakness is that the sample may have been too small and thus insufficiently representative to confirm any significant differences between boys' and girls' performances on the worksheet. Minium (1970) states that a moderate departure from homogeneity of variance will probably have little effect when each sample consists of twenty or more observations. On the standard grade the sample comprised eighteen boys and fourteen girls.

It was decided, however, to test whether sex of the subjects played any significant role in the answering of the worksheet on both the higher and standard grades. The results derived from Student's t test for independent samples are tabulated below.

	<u>Higher Grade</u>	<u>Standard Grade</u>
$t_{\text{calculated}}$	0,466	1,442
t_{critical}	2,021	2,042
Probability level	0,05	0,05
Degrees of freedom	38	30
N_{males}	20	18
N_{females}	20	14

Table 13

SUMMARY OF STATISTICAL DATA FOR THE INVESTIGATION OF SEX ON
PUPIL WORKSHEET PERFORMANCE (STUDENT'S t TEST)

At the five percent level of significance, the null hypothesis is accepted for both higher and standard grade male and female means. Sex can, therefore, be regarded as having no significant effect on the worksheet performance.

Correlation between 'objective recall' and 'conceptual depth' scores for pupil performance on worksheet (See Appendix 4)

The rationale behind such a statistical analysis was to investigate whether there was any relationship between 'objective recall' and 'conceptual depth' for the higher and standard grades.

A Pearson product moment correlation was applied to the data and the following results derived:

	<u>Higher Grade</u>	<u>Standard grade</u>
Pearson's r	0,53	0,47
t	6,25	4,63
df	103	76
N	104	77

Table 14

SUMMARY OF STATISTICAL DATA FOR CALCULATING PEARSON'S r FOR THE
RELATIONSHIP BETWEEN 'OBJECTIVE RECALL' AND 'CONCEPTUAL DEPTH' RESPONSES

On the higher grade $r = 0,53$ is significantly different from $r = 0$ with greater than 99,9% confidence. There is a significant correlation between 'objective recall' and 'conceptual depth'.

On the standard grade $r = 0,47$ is significantly different from $r = 0$ with greater than 99,9% confidence.

There is, therefore, a moderate positive correlation between 'objective recall' and 'conceptual depth' for both the higher and standard grade performances, the inference being that the establishment of solid concept bases will augment the performance on 'conceptual depth' questions, and presumably a sounder concept base will produce a higher positive correlation between the two variables.

From another viewpoint, however, there need not be a high correlation between 'conceptual depth' and 'objective recall' if they are regarded as different mental abilities. In terms of the nature of the problem, however, the author avers that a comprehensive factual foundation reflected in the ability to perform well on 'objective recall' questions will promote a better performance on 'conceptual depth' questions where higher level abilities are tested - this being the case in terms of the design of the pupil worksheet.

Limitations of the research

Insufficient funding did not permit the author to increase the sample population by including schools beyond the East London area. A larger sample may have confirmed more convincingly that difficulties exist in the area of climatology for both pupils and teachers.

Schools have to remain anonymous in the research and, therefore, the findings become generalisations rather than specific to schools where problems are more severe than others.

The participation of more teachers may have been beneficial in that more classroom experience may have contributed to the practical value of this research.

The pupil worksheet, according to some teachers, may have been too sophisticatedly worded and therefore may have disadvantaged certain pupils.

Finally, the time made available by the Cape Education Department for research in the schools was limited to half an hour and, therefore, the selected number of questions made it difficult to test adequately the desired range of content.

SUMMARY OF FINDINGS

Several obvious findings emerge strongly.

1. Standard grade candidates perform particularly poorly on 'conceptual depth' questions for reasons already enumerated.
2. Conceptual bases are not strongly developed so that explanatory answers are ultimately not produced satisfactorily.
3. Where teacher 'conceptual depth' responses are poor, pupil responses are similarly weak for the behaviour of pressure and temperature with increasing altitude, the fundamental reasons for Highveld frost in winter and the explanation for dry Western Cape summers.
4. Poor teacher 'objective recall' responses match strongly with poor pupil responses for an understanding of the mechanisms of global heat balance, the isohypse concept and the perception of pressure systems in three dimensions.
5. 'Conceptual depth' responses on both the higher and standard grades did not produce sound and correct enough responses from a satisfactory number of pupils.
6. Understanding proved more difficult than recall type questions.
7. There is a general increase in 'conceptual depth' from standard eight to ten on the higher grade.
8. The pattern for 'conceptual depth' on the standard grade is inconsistent, highlighting the difficulties which less able pupils experience in this area.
9. Although teachers felt that girls did not perform well at climatology, a statistical t test conducted on the standard ten boys and girls showed

that the means for boys and girls were not significantly different.

10. A Pearson product moment correlation coefficient was calculated for the relationship between 'objective recall' and 'conceptual depth' responses for the higher and standard grade standard ten group, which is the most representative sample group. There is a moderate positive correlation between 'objective recall' and 'conceptual depth' responses, showing a dependence of one upon the other for both higher and standard grade groups.

Poor grounding in fundamental meteorological-climatological concepts makes a fait accompli approach to the synoptic chart difficult and meaningless for pupils.

PUPIL WORKSHEET ON SOUTH AFRICAN WEATHER,

CLIMATE AND THE SYNOPTIC CHART

Please answer the following questions as fully as you can. If you cannot answer a question move onto the next one immediately. You only have 30 minutes for the worksheet. Your answers will be used to help with research and will not count for marks. Your co-operation is much appreciated.

1. If the sun's rays are vertically overhead at noon each day, why are the hottest temperatures only recorded 2 hours later?
2. If the atmosphere were motionless, with no wind at night and there was no cloud cover would you expect the temperature to be warm or cold? Can you explain your answer with respect to winter conditions?
3. What atmospheric weather phenomenon is responsible for the transfer of
 - (a) heat poleward?
 - (b) cold equatorward?
4. Would the atmosphere at a place at the equator or at the poles be able to retain a greater vapour content?
5. If at a given time the temperature of the atmosphere is 15°C and the temperature at which condensation will occur is $-1,0^{\circ}\text{C}$, what can be said about the moisture content of the air?
6. Does atmospheric pressure always decrease with increasing altitude? Substantiate your answer.
7. Does temperature always decrease with increasing altitude? Substantiate your answer.
8. Can you explain how wind originates? Please do so.
9. Why is it that wind will never follow a direct path between two places?
10. Why would you regard the air in a high pressure system to be more stable than the air in a low pressure system?
11. Briefly state the fundamental difference between a normal (environmental) lapse rate and an adiabatic lapse rate.
12. Which of the climatic elements: temperature, wind, moisture, pressure, is the most visual feature on a synoptic chart?
13. What two operating forces are in equilibrium in a geostrophic wind?
14. Would one be able to locate geostrophic wind flow on a synoptic chart? Explain.
15. If the pressure digits associated with a weather station model are 023, what is the prevailing pressure at the station?
16. Is the circulation around a northern hemisphere anticyclone clockwise or anti-clockwise? Explain.

17. What name is given to the isolines on a synoptic chart over
 - (a) the ocean?
 - (b) the continent?
18. What weather systems are responsible for wet Cape Mediterranean winters?
19. What symbols on synoptic charts can be used to ascertain regional cloud cover?
20. Why is it that the Transvaal is highly susceptible to frost during the winter months?
21. Why is it that Highveld winters are dry?
22. Why is it that Western Cape summers are dry?
23. What atmospheric upper air feature inhibits the flow of warm, moist maritime air into the Transvaal interior during winter?
24. Why are South African Berg winds hot and dry?
25. Make a simple sketch of what you imagine a South Atlantic anticyclone to look like.

RATIONALE BEHIND PUPIL WORKSHEET QUESTIONS AND THE BEARING OF THE REQUIRED KNOWLEDGE ON A
SOUND, SOPHISTICATED, APPLIED INTERPRETATION OF THE SYNOPTIC WEATHER CHART

Indented paragraphs contain information on the value of the required knowledge for the interpretation of synoptic charts.

Each question has been asked in order for the author to ascertain pupil understanding ...

1. that shortwave radiation (solar) is converted to longwave terrestrial radiation before being transmitted back into the atmosphere, and that this contributes to a time lag diurnally.
The South African weather chart commonly used in the classroom is compiled at 14h00 SAST. This being the hottest time of the day, the pressure differentials are theoretically maximal and, therefore, sea-breeze circulations are likely to be most developed.
2. of the Greenhouse effect, and that a loss of terrestrial radiation into the outer atmosphere contributes to falling temperatures.
An absence of cloud cover, indicated by a region's sum total of weather stations showing open circles, permits a loss of heat to the outer atmosphere. This is important in deducing whether frost is likely or not.
3. that the atmospheric system is one which strives toward equilibrium, in that there are these mechanisms which seek to balance the heat budget thereby redistributing the surplus heat energy of the equatorial regions.
This is significant because South Africa is located in a latitudinal zone of influence of these two weather phenomena i.e. the tropical cyclone from the north and the mid-latitude cyclone from the south.
4. the relationship between atmospheric temperature and moisture, and more specifically the capacity of warm air to hold more vapour than cold air, and upon condensation that the former would realize a greater moisture release.
Evaporation off the Indian Ocean is carried aloft in the comparatively warmer air above the warm ocean, and condenses aloft, giving rise to a substantial precipitation along the eastern escarpment. The air over the Benguela is similarly not a source of precipitation along the western escarpment.
5. that the closer the dewpoint temperature is to the dry-bulb temperature, the greater is the relative humidity of the atmosphere and therefore the greater the chance of precipitation should temperatures fall.
For each weather station model on a synoptic chart the dry-bulb and dewpoint temperatures are recorded. Precipitation can, therefore, be forecast for a given station in the light of expected conditions; for example, the approach of a cold front.
6. that for a given surface low pressure the pressure increases with altitude in accordance with the terminology i.e. if the surface pressure is low, the pressure aloft is presumably higher. The converse is true for a surface high pressure.
The configuration of surface isobars and geopotential metre isolines are simple surface components of vertically extending pressure systems, and hence the idea of upper air troughs, ridges of high pressure and tongues of low pressure. Without this knowledge pressure systems are erroneously regarded as two-dimensional features.

7. that temperature can increase with altitude. In such a case, an inversion lapse rate exists.

The dry Highveld winters are a function of the inversion lapse rate created by the subsiding air from the continental anticyclone. The subsiding air accounts for increasing pressure in the lower reaches of the system approximately two kilometres aloft. The increased pressure raises the temperature of the air at this level. Now with ascent, air cools until this level is reached, whereupon its temperature increases. Furthermore, during winter the continental high pressure system is closer to the surface than in summer in response to the lower temperatures of the winter, and therefore is found at a level below the height of the escarpment. The inversion, by virtue of its higher temperatures relative to the atmosphere below it, will therefore inhibit any further upward movement of rising air. Consequently the warm, moist air advected from the east by the South Indian anticyclone, cannot rise over the escarpment and penetrate the interior, thus rendering the Highveld dry in winter.

8. that wind results from the atmosphere balancing the surplus air accumulating in a high pressure with the deficit occurring in a low pressure system.

The observation of high and low pressure systems juxtaposed on charts then enables pupils to deduce that there is air movement from one to the other. It further establishes that synoptic charts do not portray a static, but a dynamic medium.

9. that the Coriolis effect always operates on moving objects as a result of a rotating earth.

Pupils may therefore accommodate more easily the circular motion of air flow around pressure systems. A corollary of this is the difference in the direction of circulation in the two hemispheres as a result of deflection to the left of the path of motion in the southern hemisphere and to the right in the northern hemisphere. Furthermore, if it has been established that air flow is generated from high to low pressure, it can further be deduced that air has the tendency to flow "out of" high pressures and "into" low pressures. This initiates the concepts of divergence and convergence respectively. This also serves to eliminate the misconception that the latter two terms are associated with planar phenomena.

10. that air in high pressure systems is subsiding and that in a low pressure system is ascending

Subsiding air heats adiabatically as the pressure in the lower layers increases, creating an inversion and therefore inhibiting the upward movement of any buoyant air from below. The heat of the inversion is further sufficient to evaporate any moisture in the form of cloud cover which may have formed as a result of condensation in a warm, moist rising air parcel. This knowledge facilitates an understanding of the clear skies characteristic of the Highveld in winter. Similarly the weakened continental high pressure system of the summer months permits thermally induced surface air to be more unstable, carried aloft and eventually generate thunderstorm activity. A further application of this knowledge relates to the air flow from the continental high pressure descending over the escarpment onto the coastal belt. As it descends it is subject to adiabatic heating, evaporates any moisture present and reaches the coast as a hot, dry berg wind.

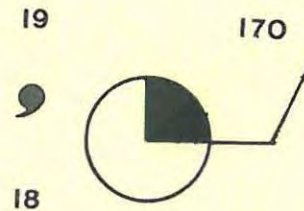
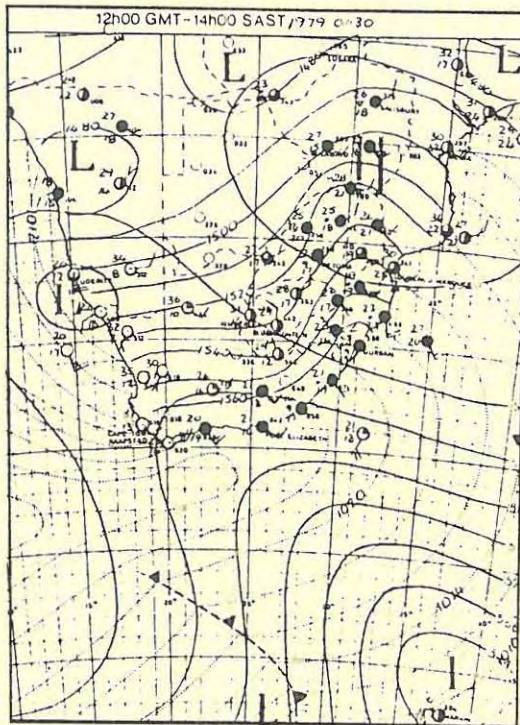
11. that normal lapse rates are concerned with stationary air or simply the distribution of temperature with altitude, whilst adiabatic lapse rates are concerned with the change in temperature in a moving air parcel.

The correct application of the term "adiabatic" as used in question ten is required. It is furthermore fundamental to the understanding of stability and instability.

12. that the configuration of lines on the map are pressure lines.
This is an application of theory to practical interpretation.
13. that pressure gradient force and Coriolis force are in balance in geostrophic flow.
This is an application of theory to practical interpretation.
14. that near surface flow over the oceans can be geostrophic.
This is an application of theory to practical interpretation.
15. of how to interpret a weather station model and whether the pupil knows how to translate the pressure code.
This enables one to determine the pressure around the station.
16. of Coriolis effect and Ferrel's Law.
A pressure system not labelled on a synoptic chart can then still be identified as high or low.
17. that different units of measurement are used to record pressure over land and sea, viz. isobars and geopotential metre isolines.
This enables pupils to understand the discontinuity of isolines at the coast.
18. that the northward migration of the sun draws the westerly wind belt north and brings the western Cape under the influence of mid-latitude cyclones.
Inspecting the data again reveals the latitude at which the sun's vertical rays may be, and hence also the thermal equator and the subtropical high pressure belt.
19. of the spread of station models signifying general cloud cover.
Observation of general cloud cover and a thorough description of prevailing conditions is encouraged.
20. that the clear, still night air during winter allows terrestrial radiation and the surface layers cool considerably. The further dryness of the winter air provides ideal conditions for frost formation.
The strengthened high pressure system of winter has sufficient subsidence to create atmospheric conditions for frost formation. This may be deduced by looking at the date of the map, inspecting the station model for cloud cover, the dry bulb and dewpoint temperatures for the relative humidity of the air, and the prevailing windspeeds for the calmness factor.
21. of the effect of the lowered inversion level.
The date of the map, inspection of the pressure system and weather station models enables the interpretation to be made.
22. that the subtropical high pressure belt is too far south for mid-latitude cyclones to have any effect on the western Cape weather.
The date is an indication as is the latitudinal position of the westerly wind belt.
23. of the inversion layer.
This shows the prevailing weather of the Transvaal.
24. of the nature of subsiding air.
As for question ten.
25. of the three-dimensional nature of pressure systems.
The conversion of the two-dimensional map representation to its three-dimensional equivalent is required.

CHAPTER 6

CONCLUSIONS AND RECOMMENDED TEACHING STRATEGIES FOR
SENIOR SECONDARY METEOROLOGY-CLIMATOLOGY AND ITS
RELATION TO SYNOPTIC CHARTS



Miller (1953) states that all the intricately interwoven weather science concepts must be given equal consideration in a description of the (atmospheric) environment. He claims that the device that comes nearest to this desirable aim is the 'synoptic chart' that shows at any moment of time the totality of weather. Such a map is a synthesis; its understanding demands analysis. Success at synoptic chart interpretation is born out of trial-and-error experience. Miller (1953) avers that with time the mental processes involved may become subconscious, but they are never subjective or unscientific.

CONCLUSIONS AND RECOMMENDED GENERAL TEACHING STRATEGIES FOR SENIOR SECONDARY CLIMATOLOGY AND THE SYNOPTIC WEATHER CHART

The Nature of the Problem

There is undoubtedly a problem with regard to the teaching of the complex, abstract nature of senior secondary meteorology-climatology. A thorough knowledge of meteorological concepts is required for a sound understanding and interpretation of synoptic charts. The subject is one which favours more able pupils. For less able pupils, generally those on the standard grade, the complexities of meteorology-climatology and its synthesised content on synoptic charts presents severe difficulty. The problem may be alleviated by the graded, sequential teaching of meteorological concepts.

The research has been concerned with the integrative nature of the synoptic chart in relation to adolescent cognitive structures and the teaching of senior secondary meteorology-climatology. The following points emerge from the analyses of the previous chapters.

Concluding Remarks

Chapter 1 reveals the highly complex nature of the science of weather and climate and underlines the need for a fundamental understanding of basic meteorological and climatological concepts before advanced work can confidently be undertaken. Chapter 2 introduces an alternative to the conventional view of southern hemisphere cyclogenesis in response to the incompatibility between syllabus requirements and textbook presentation of the topic.

Chapter 3 investigates the cognitive development of adolescents and relates this to the intricacies of map analysis. A comparison is made between the topographical map and the synoptic chart. It is concluded that the skills pertinent to synoptic chart interpretation are of higher cognitive order. This is because of the abstract, scientific and dynamic nature of the synoptic chart. Graves (1977) claims that all geographical concepts and relationships deserve equal attention, irrespective of their level of difficulty. Stevens (1972) further claims that teachers of physical geography often resort to description rather than explanation. Kuhn (1962) and Toulmin (1972) point out that concepts are at the core of human rational thought. Novak (1978) advocates, particularly regarding scientific concepts, reception teaching methods. Learning of this nature is propounded in Ausubelian learning theory.

It is the author's conviction that if the synoptic chart is to be regarded as a means of consolidating senior secondary climatology, then the views of the above authors must be noted. Fundamental concepts need to be taught and developed in a graded sequential fashion. It is to this end that the author devised the concept matrix in Chapter 3. Tables 2 and 3 are comparative resumé's of this section.

According to the Piagetian developmental stages some never attain formal operational thought levels. This is significant since teachers of geography should be aware of the difficulties which less able pupils may experience in learning complex meteorological concepts, and should build this awareness into their teaching strategies.

Chapter 4 examines in depth the content of the senior secondary climatology syllabus (1985) of the Cape Education Department and relates it firstly to current textbook content and presentation, and secondly, to the content of the Cape Education Department's examination of the topic for the years 1981 to 1986. The specifications and recommendations of the syllabus are sound, other than for the placement of the pressure concept in standard nine rather than standard eight; the omission of concepts, eg. vertical temperature gradient, needed at standard ten standard grade level, from standard nine and the omission of the station model and synoptic chart as specific teaching topics. Textbooks have shown considerable improvement, but err marginally in failing to present detailed enough accounts of coastal lows; the tilt and three-dimensional nature of anticyclonic systems; stability and instability; wind-shifts at the passing of fronts and southern hemisphere cyclogenesis. Alternative ideas are proposed by the author in Chapter 4, except in the case of cyclogenesis to which Chapter 2 is devoted. All these ideas are fundamental to a sound understanding of synoptic charts. An analysis of final examination papers shows that there has been too little differentiation between higher and standard grade, with the result that standard grade candidates are expected to perform considerably more higher order skills than is necessary or appropriate, whilst, on occasions, the order of questioning on the higher grade seems too low.

The data deriving from the administration of a worksheet on 'South African weather, climate and the synoptic chart' to five hundred and thirty-three pupils in East London schools is analyzed in Chapter 5 on the basis of item analysis profiles. The difficulty which pupils experience with meteorologi-

cal concepts is reflected in poor means (Table 11) on each of the marking categories: 'objective recall', 'conceptual depth' and 'general performance'. A Pearson product moment correlation coefficient, $r = 0,47$, shows a moderate positive correlation between 'conceptual depth' and 'objective recall' for the standard ten group. In terms of the design of the worksheet, one would have hoped for a higher positive correlation. It is concluded that the graded teaching of concepts, as outlined in Chapter 3, may assist in achieving the retention of ideas and, ultimately facilitate understanding.

The worksheet highlights specific problems which teachers find pupils experience difficulty with, viz. the three-dimensional portrayal of atmospheric phenomena; the isohypse concept and geostrophic flow. Teachers who volunteered to complete the worksheet prove to have difficulty with these concepts as well. Generally pupils fared better on questions where answers could be visualized than on questions which demanded a synthesis of abstract concepts. When comparing the 'objective recall', 'conceptual depth' and 'general performance' means for each of the five schools, there is a trend for 'conceptual depth' to diminish for standard grade candidates from standard eight to ten. On the higher grade the 'conceptual depth' performance increases. This means that standard grade candidates do not develop and/or sustain concept bases or have difficulty in accommodating a considerable volume of abstract information. In general standard grade candidates experience difficulty with climatology. The means which are most indicative of the problem are those of the standard ten standard grade group; ('Conceptual depth' = 11,68%; 'Objective recall' = 23,42%; General performance = 28,35%) and higher grade standard ten group ('Conceptual depth' = 27,58%; 'Objective recall' = 39,02%; 'General performance' = 50,15%).

A solution to the problem would appear to be a redefinition of syllabus content on the standard grade. This could not be achieved in the short term and the author, therefore, makes recommendations for the classroom.

The remainder of the chapter is organised such that

1. some ideas clearly emerging as problems in the classroom research are given attention;
2. the author's approach to the teaching of the station model is outlined; and
3. a variety of classroom activities are presented.

PROBLEMS ARISING OUT OF CLASSROOM RESEARCH

The three most important problems encountered by pupils are the portrayal of weather phenomena in three dimensions, the isohypse concept and geostrophic flow.

The Portrayal of Weather Phenomena in Three-dimensions

The problem here arises out of the absence of relevant diagrams in textbooks. It is noted, however, that the new series of textbooks rectify this and a series of three-dimensional diagrams appear in Hurry and van Heerden (1986) which will be of value in the classroom. A selection of such diagrams from a variety of texts, and as devised by the author, is found in Appendix 5 and in the body of the work.

Some interesting classroom ideas are produced in Teaching Geography. For the sake of brevity two such ideas are presented in diagrammatic form in Figure 55. Notably, both are for the northern hemisphere. However, the problem of hemisphere (and air flow etc.) is easily corrected if the northern hemisphere diagram is copied onto a transparency and inverted and then laterally reversed on the overhead projector. It is true that theory informs, but practice convinces. The use of models, as in Figure 55, is indeed useful.

The Isohypse Concept

One of the most difficult concepts for pupils to come to terms with, as confirmed by the research data in Chapter 5, is the isohypse. These are lines of equal height above sea level of the 850 hPa pressure surface over the continent. When drawn, they exhibit the same properties as sea level isobars. Justification for their use lies in the fact that there is a large discrepancy of approximately 1500 m between sea level and the average height of the South African plateau, and that the 850 hPa pressure surface is on the average at an altitude corresponding with the average height of the plateau.

The author's attempt at illustrating the isohypse concept is contained in Figure 56. Each vertical line in the figure is equivalent to the height of the 850 hPa pressure surface above sea level. Stations A, B, C and D record the height of this surface at 1540 m whilst stations E, F, G and H record the 850 hPa surface at 1530 m. By interpolation the places recording the same height are joined. The solid "ellipses" in the figure represent iso-

Fig. 55 (a)

A simple card model adapted for the southern hemisphere to facilitate the understanding of a depression

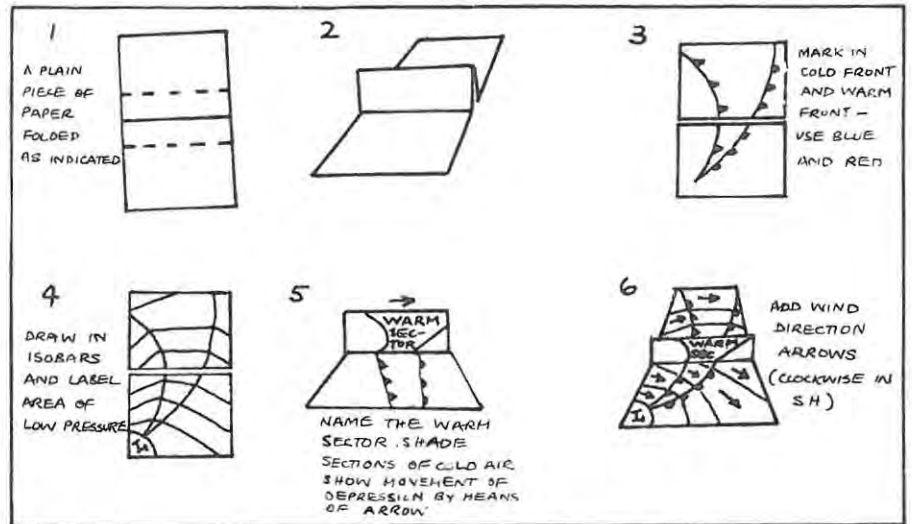
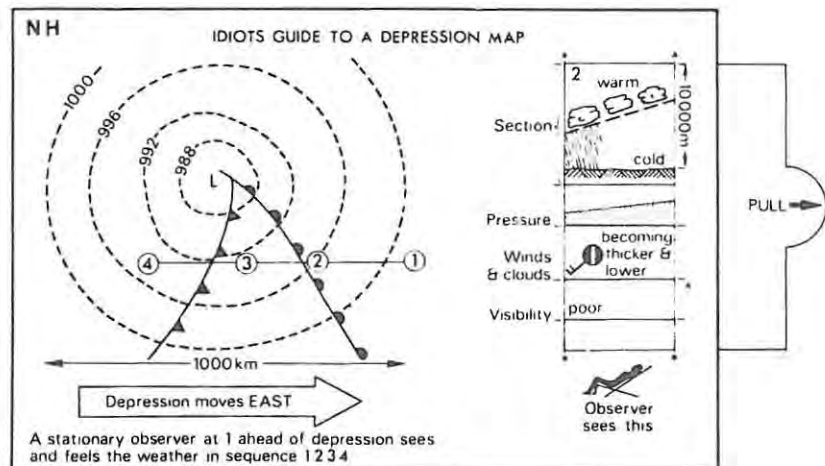
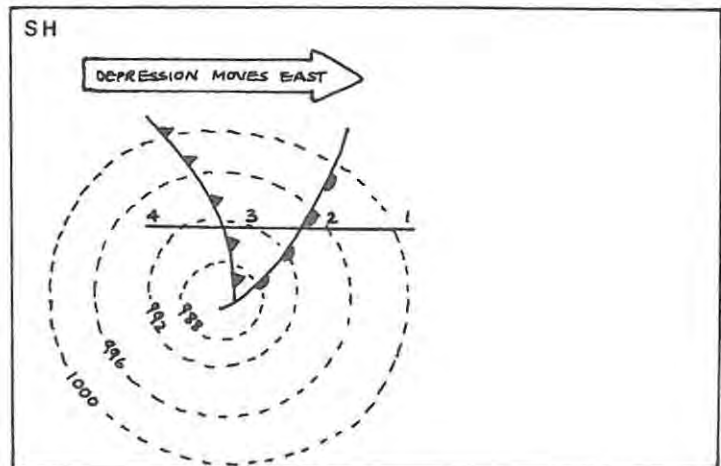


Fig. 55 (b)

Good white card, approximately 25×15 cm, and the use of colour help the presentation. The right end of the sliding card should be clearly labelled START. The eastward movement of the entire depression was considerably reinforced by marking fronts and isobars on tracing paper and drawing this across a wall map. The amount of detail included can be adjusted to the needs of the occasion: pressure might be shown in mb, or as here, simply by a bar of varying width, the other symptoms being altered accordingly.



The southern hemisphere equivalent of northern hemisphere model above



hypsies, also called geopotential metre isolines or equal pressure surface lines. The horizontal axis represents the breadth of the subcontinent from west to east coast. The isohypse model may be used as an overhead projector overlay on a three-dimensional subcontinent.

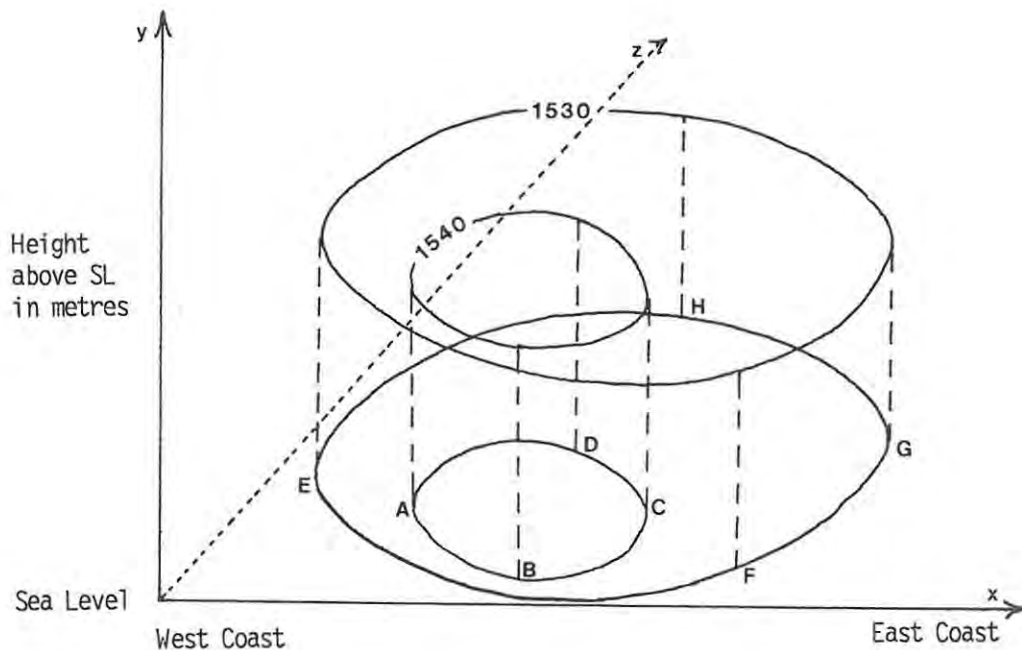


Fig. 56 A model for illustrating the isohypse concept. Axes x and z form the horizontal plane; y indicates the vertical plane

The research data shows that higher grade candidates cope with a meteorology-climatology syllabus far better than the standard grade candidates. The order of difficulty of the last mentioned concept is obvious and yet an explanation of it has ironically been asked of standard grade candidates in final examinations.

Geostrophic Windflow

An idealised condition of winds blowing parallel to the isobars is a rare phenomenon. However, there is a need to show the balance between the Coriolis force and the pressure gradient force. This is effectively illustrated in textbooks, but the author advocates the use of the Ekman spiral (see Figure 39) in conjunction with the explanation above. The Ekman spiral illustrates the effects of diminishing friction on changing velocities and wind

direction. Where vectors form part of a pupil's mathematics knowledge, the concept becomes easier to grasp.

Explanation of the Pressure Concept

Pressure, being an intangible element, is often a difficult concept to convey to pupils. The normal experiment of turning a water filled tumbler covered by a sheet of paper upside down usually convinces pupils that air exerts pressure in all directions. However, the idea that the unit of measurement of pressure is the millibar (mb) or hectopascal (hPa) remains an anathema to many pupils. The author has found that the explanation of the derivation of the unit in mathematical terms usually convinces higher grade pupils.

Derivation of the unit of measurement for pressure

It is the author's experience that a common enquiry, amongst higher grade candidates particularly, has to do with what a millibar/hectopascal really is. The explanation below appears to satisfy their curiosity and, once detailed, the concept is more readily assimilated into the cognitive framework. Even though the detail may soon be lost, a subconscious understanding of the concept permits confident use of the terminology.

Pressure is force exerted by the atmosphere per unit area of surface. In meteorology, the most commonly used units of pressure are hectopascals. The height of the mercury (Hg) column in millimetres is also reported, but these are not really units of pressure because "millimetres of mercury" are not the correct dimensions for force per unit area. When it is said that pressure is 760 mm of mercury, it means that the pressure is sufficient to support a column of mercury 760 mm high. The conversion is as follows:

$$1 \text{ cm Hg} = 13,33 \text{ hPa}$$

Pressure is defined thus:

$$\begin{aligned} \text{Pressure} &= \frac{\text{FORCE}}{\text{AREA}} \\ &= \frac{\text{mass} \times \text{acceleration}}{\text{area}} \\ &= \frac{\text{grams} \times \text{cm} \text{ sec}^{-2}}{\text{cm}^2} \\ &= \frac{\text{dynes}}{\text{cm}^2} \quad \text{and} \quad \frac{1000 \text{ dynes}}{\text{cm}^2} = 1 \text{ hPa (mb)} \end{aligned}$$

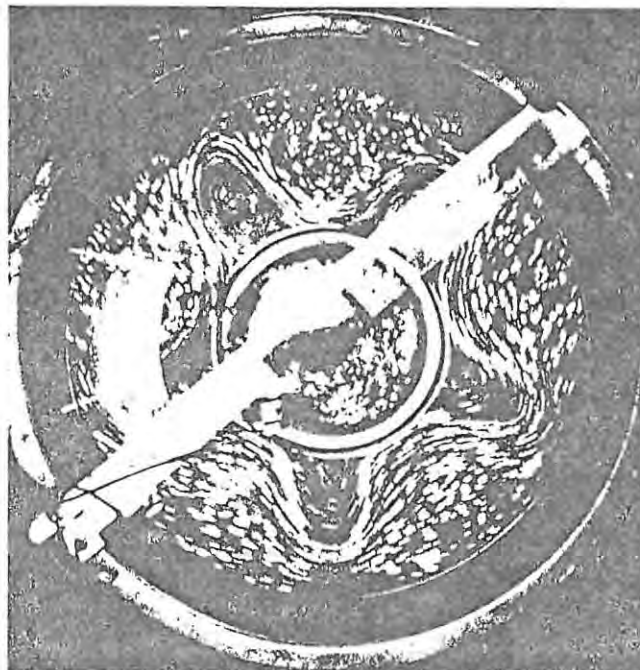
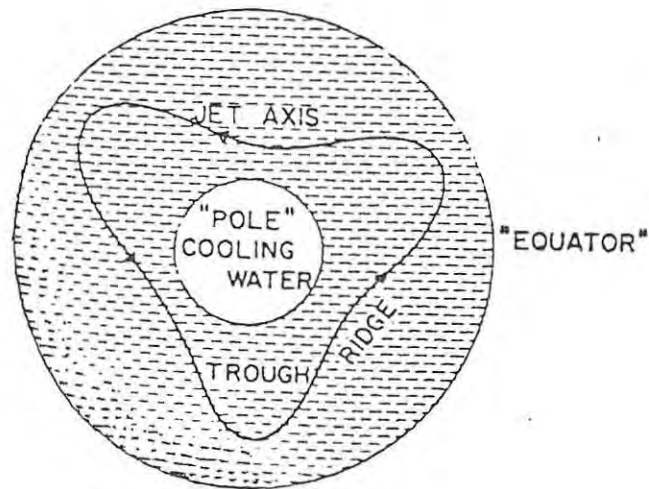
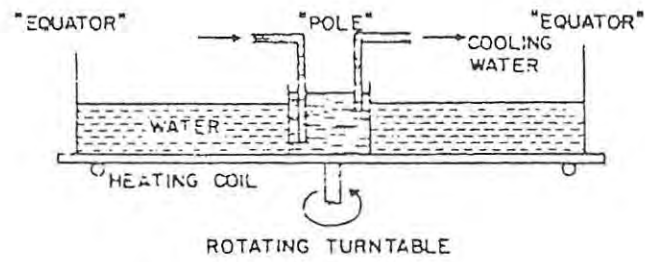


Fig. 57 Dishpan model of the development of waves at an appropriate temperature gradient and rotation rate. The perimeter of the pan is warm, equivalent to the equator and the centre is cool, equivalent to the poles - a model for the laboratory simulation of the jet stream. The contribution of vorticity and angular momentum to jet stream formation needs to be emphasised (sketches after Fairbridge, 1967; photograph after Donn, 1975)

Teachers have also reported that the following are difficult to teach:

Jet Stream Simulation

The sequence of diagrams in Figure 57 illustrates how the jet axis of the upper westerlies may be simulated in the classroom. This procedure may aid the child to accommodate this highly complex concept.

Forecasting from Surface Weather Maps

Teachers indicated in the interviews that one of the most difficult aspects of weather map teaching was forecasting. Donn (1975, pp 369 - 373) provides a useful set of rules for the weather forecaster which may be employed by the teacher and pupil. These rules form Appendix 6.

STATION MODEL APPROACH TO SYNOPTIC CHART TEACHING

The author proposes the teaching of the weather elements in the order outlined in the senior secondary meteorology-climatology concept matrix (Figure 38). Each element as it is taught is related to the synoptic chart. However, the teaching of the chart per se, as a communicative device, should commence with the station model.

To appreciate the gestalt of the synoptic chart, one needs to understand the parts that contribute to the whole. These parts amount to the weather station model. By international convention weather station models depict the following climatic elements: prevailing pressure; pressure change (which is a clue to the movement of pressure systems); precipitation forms; dry bulb temperature; dew point temperature; visibility; wind direction; cloud type and amount.

The Weather Station Model

Figure 58 illustrates a comprehensive weather station model depicting all the elements that can be recorded for any given station.

It is, however, practice not to depict all the elements for South African synoptic weather stations for the sake of simplicity. The typical format is illustrated in Figure 59.

Fig. 58

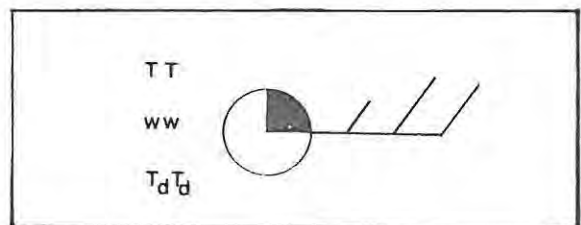
Basic station model for plotting weather data. The key and example are tabulated in the internationally-agreed sequence for teletype messages. These data would be preceded by an identifying station number, date and time (after Barry and Chorley, 1976)

Basic station model for plotting weather data			
MODEL enlarged	KEY	EXAMPLE	
TT	N Total cloud (oktas) ¹	7	
dd	Wind direction (tens of degrees)	32	
ff	Wind speed (knots)	20	
VV	vv Visibility (code)	66	
ww	ww Present weather (coded symbol)	80	
ppp	W Past weather (coded symbol)	9	
Td Td	PPP Sea-level pressure (mb) ²	105	
Nh/h	TT Temperature (°C)	20	
	Nh Low cloud (oktas)	4	
	CL Low cloud type (coded symbol)	2	
	h Height of CL (code)	3	
	CM Medium cloud type (coded symbol)	5	
	CH High cloud type (coded symbol)	2	
	Td Td Dew-point temperature (°C)	14	
	a Barograph trace (coded symbol)	3	
	PP 3-hour pressure change (mb) ³	04	

¹ okta = eighth
² Pressure in tens, units and tenths, mb, omitting initial 9 or 10, i.e. 105 = 1010.5
³ Pressure change in units and tenths, mb

Fig. 59

Basic station model typically found on South African weather charts



The fundamental elements of wind direction, wind speed, cloud cover, dry and dew point temperature, prevailing pressure and present weather (where applicable) are all ascertainable from the given station models as follows:

(a) Wind direction

Bearing in mind that winds are named in terms of the direction from which they blow into the station, this information is obtained by relating the orientation of the shaft to the compass points.

(b) Windspeed

The number of barbs at the end of the shaft indicates the windspeed, one barb being equivalent to ten knots (approximately 5 ms^{-1}). Where the windspeed is only five knots, a half-barb is positioned slightly down from the end of the shaft furthest from the station. This enables the reader to distinguish between a full and half-barb. A fifty knot wind

is represented by a wedge at the end of the shaft.

(c) Cloud cover

This is illustrated by means of shading the circle representing the weather station, and conventionally is given in eighths. It is noted that the key on South African weather charts reduces the fraction.

(d) Dry bulb temperature

This is recorded in a position north-west of the station model by two digits read literally in degrees centigrade.

(e) Dew point temperature

This is recorded in a position south-west of the station model by two digits read literally in degrees centigrade.

(f) Prevailing pressure

This is recorded conventionally in a position north-east of the station model by three digits in tenths of millibars, but are absent from South African synoptic charts. Where the conventional method is employed, a nine or ten needs to be prefixed to the given digits to arrive at the correct pressure. A cut-off reading of 960 mb (or hPa) is assumed eg.
 006 is equivalent to 1000,6 hPa
 060 is equivalent to 1006,0 hPa
 599 is equivalent to 1059,9 hPa and not 959,9 hPa since this reading is below 960 hPa.
 600 is equivalent to 960,0 hPa.

(g) Prevailing weather

A symbol appearing due west of the station model represents the weather being experienced at the time of observation, that is at 14h00 SAST. These symbols appear infrequently on the average and their occurrence is region specific for reasons outlined later.

Seven out of fifteen possible information items ordinarily appear on synoptic chart weather station models.

Each of the elements recorded on synoptic chart weather station models is associated with a host of symbols as shown in Appendix 7. However, for a satisfactory interpretation of weather charts, their keys contain as much information as is necessary to commit to memory. This small percentage of symbolic information committed to memory is essential as the key, usually, is absent from the chart for examination purposes.

IMPLICATIONS OF WEATHER STATION DATA FOR THE ANALYSIS OF SYNOPTIC CHARTS

(a) Wind Direction

The wind direction associated with a station model generally indicates the circulation of the pressure system in which it is located. Where anomalies arise, i.e. flow contrary to the expected airflow, explanations are sought in terms of the station's context. One such an anomalous flow pattern is associated with the local sea breeze effect, especially where the configuration of the isobars is such that a weak synoptic pressure gradient prevails. This implies calm general wind conditions, allowing a local sea breeze to be generated as a result of the relative difference in pressure between land and water bodies.

Another airflow anomaly could result along the Natal coast where local anabatic winds, generated in the valleys of the Drakensberg foothills and at right angles to the coast, are contrary to the expected off-shore advection generated by the continental anticyclone. The strength of the anabatic flow may be compounded because of the strengthened temperature differential at the time of observation (time of maximum temperature) and a strengthened sea breeze may develop.

Coastal stations often record sea breezes blowing obliquely rather than at right angles to the coastline. Along the Natal littoral, for example, stations record wind directions as north north-easterly, rather than an expected easterly or north-easterly flow, in accordance with an on-shore advection from the South Indian anticyclone. This phenomenon can be associated with the day time anabatic flow, but the path of the wind has been subject of Coriolis effect - and the stronger the wind, the greater the degree of deviation of deflection.

The flow of air parallel to the isobars over the ocean, discernible by inspecting the station model, is indicative of geostrophic flow, a phenome-

non which obtains predominantly over the oceans. The airflow over the continent is more inclined to blow obliquely to the isobars because of the effects of friction.

(b) Windspeeds

Strong winds prevail in association with strong pressure gradients. Knowledge of the association of calm conditions with anticyclonic flow and strong winds with cyclonic flow, particularly toward the centre of the vortex, enhances deductive analysis. High velocity winds (gales) are also common around the vortices of tropical cyclones, a phenomenon not common to South African synoptic charts because of the fact that the tropical cyclones, which traverse the Mozambique Channel and skirt the northern Natal littoral, are often in the dissipating stage.

(c) Cloud Cover

Without the aid of a satellite image, one can ascertain, at first glance, by inspecting the station models, the general cloud cover for a given region. In this regard there are two patterns which may commonly occur. The north-east coast and/or east coast and their interiors may exhibit general cloud cover, and a similar extent of cloudiness may occur over the south-western Cape and extend later to the southern and eastern Cape coastal regions.

The cloud development is most likely to be associated with the advection of warm, moist air over the Drakensberg and/or around the Lesotho massif by virtue of the ascended inversion layer during summer. These conditions could also be linked with line thunderstorms along a NW-SE orientated line of discontinuity between the moist eastern sector and dry western sector. The limit of the cloudy region may well coincide with the moisture discontinuity.

The general cloud cover over the east coast and eastern interior may be the consequence of a deep cut-off low, stationed over the continent, being fed from the south by moist air of South Atlantic anticyclonic origin. Such conditions may persist for days at a time and are responsible for the heavy rains and associated floods, such as those experienced in Natal in late September 1987. The prolonged effects of these systems may be attributed to the blocking effect of a South Indian anticyclone in-

hibiting the continued eastward passage of the South Atlantic anticyclone.

The general cloudiness, as indicated by station model shading, of the south-western Cape, southern and eastern Cape coast is most commonly the result of the eastward passage of a mid-latitude cyclone during winter and its associated frontal cloud bands.

Heavy cloud confined to the south-western Cape and Peninsula, particularly during summer, may be associated with the "Cape Doctor" or black southeaster which brings with it moist air (and sometimes light rain) either from the far south or south-east, depending on the position of the eastward moving anticyclone.

It is often the case that the Transvaal and the interior are cloudy, but that coastal stations under the influence of the same system are cloudless. The absence of cloud may be attributed to the effects of adiabatic heating and the consequent warming of air as it descends the eastern escarpment and evaporates its moisture content in the process. Such are berg wind conditions along the eastern Cape and/or Natal coast - a phenomenon common in winter owing to a steepened pressure gradient as a consequence of a strengthened continental anticyclone and passing mid-latitude cyclone. Berg wind conditions often spread from west to east coast as the mid-latitude cyclone approaches from the west and moves eastward, causing a pendulum movement of the pressure-gradient axis from west to east. The same coastal weather phenomena may be born of a coastal low migrating along the escarpment edge from west to east coast, as it is manoeuvred eastward by a South Atlantic anticyclone ridging in south of the country.

There is often an absence of general cloud over the central interior during winter and this is associated with the low humidity resulting from adiabatic heating in anticyclonic subsidence.

The western sector, or that region west of the 500 mm isohyet, is generally cloudless by virtue of strong anticyclonic subsidence over the west coast (coupled with the cold and upwelling west coast waters being a meagre source of evaporation because of its temperature). This renders the west coast a desert region.

(d) Dry bulb temperature

The dry bulb temperatures, recording the actual temperatures experienced at a station, may vary by as much as ten to fifteen degrees Celsius on either side of a cold front, thereby indicating the cold and warm sectors of the mid-latitude depression.

(e) Dew point temperature, with dry bulb temperature

In conjunction, however, the dry bulb and dew point temperatures are an index of the precipitation potential. The greater the divergence between the temperatures, the more the dry bulb temperature needs to fall before condensation can occur.

(f) Pressure

It is current practice for the Weather Bureau to record pressure in hectopascals instead of millibars. The most valuable skill with regard to pressure at the station is being able to determine the pressure relative to the surrounding isobars, and to recognize that pressures decrease toward low pressure centres whilst they increase toward high pressure centres. Pupils should be able to estimate pressure readings of stations by taking the isobar interval into consideration.

(g) Prevailing weather

The infrequent recording of prevailing weather is a function of the temperate climate of the country. There appear to be only two areas where the prevailing weather is recorded.

Thunderstorms are frequently indicated over the Highveld in summer, especially since the map is a recording of 14h00 SAST observations; the time of maximum temperature, and hence the time when convective turbulence will promote instability and the development of cumulonimbus thunderclouds through the release of the latent heat of condensation.

Rain, drizzle or showers are sometimes indicated on stations associated with cold fronts and are more common over the southern ocean, where the fronts are most developed, or at coastal stations at the tip of the subcontinent.

The absence of the mist symbol along the western littoral is again a function of the time of observation, since by this stage the mist will have lifted under the influence of terrestrial radiation.

The afore-going analysis and exposition serves to show that the concepts desirable for sound and rewarding synoptic chart interpretation are rooted in the fundamental meteorology-climatology syllabi of standards eight and nine, and if teachers are going to give import to the wise syllabus recommendation that concepts learned in standards eight and nine should be applied in the analysis of the weather chart in standard ten, then a functional strategy needs to be devised - a strategy which is incorporated in the concept matrix referred to earlier in the chapter.

If such an approach is adopted the implication for examiners is that the integration and use of previously acquired concepts, as specified in the syllabus, should be considered when examination questions on synoptic charts are set. The author is inclined to believe that the recommendations of this thesis will not be initiated in the classroom until such time as the examination questions reflect what the author avers is a desirable level of integrated concept reconciliation.

By the above intimation the author does not advocate that pupils maintain a detailed knowledge of all concepts, but that they rather operate under Ausubelian obliterative subsumption, as outlined in Chapter 3. This meaningful forgetting of detail is not acquired by tuition, but occurs spontaneously.

SPECIFIC SYNOPTIC CHART EXERCISES

Interpolation exercises using weather station data

As an elementary exercise in getting to understand the content of the chart, the author advocates that Miller's (1953) idea of the piecemeal analysis by pupils of station models by interpolation and drawing isolines for dew point, wind direction and force, pressure and pressure change, as depicted in Figure 60 is invaluable. Such an exercise becomes more meaningful when completed for the country as a whole.

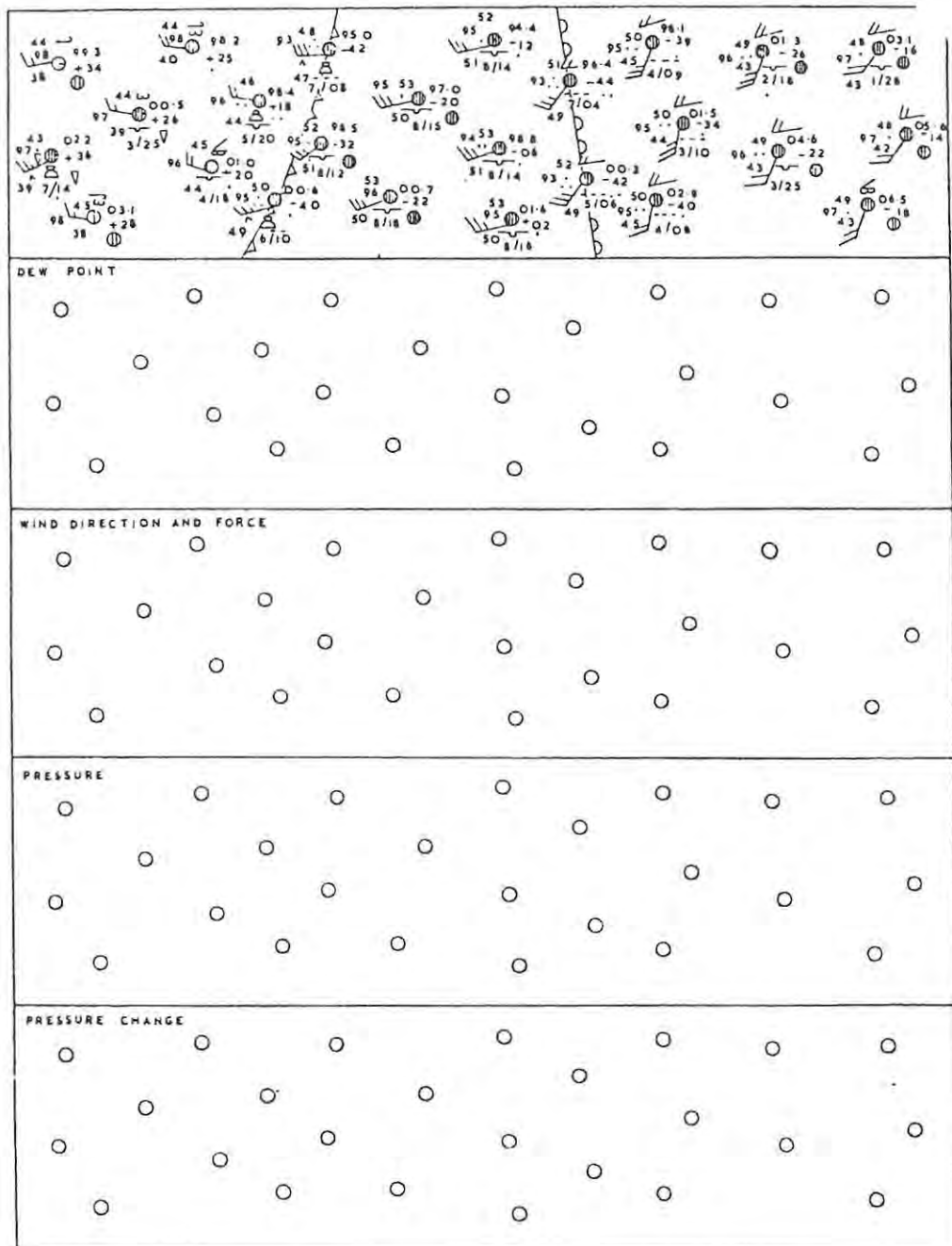
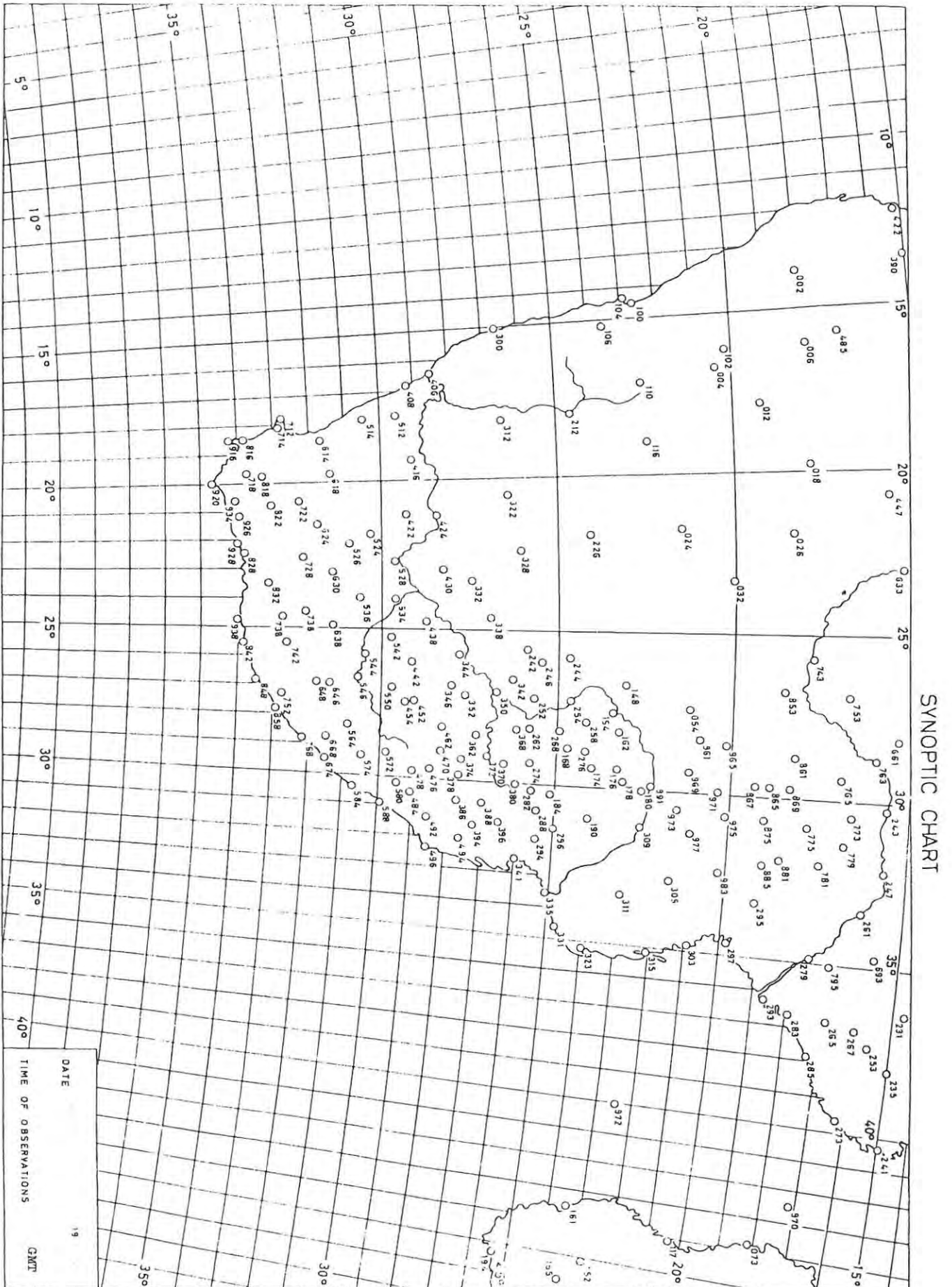


Fig. 60 Basic grid for interpolation exercises involving weather station data
(after Miller, 1953)

Fig. 61 Synoptic chart blank



To this end, teachers can compile a chart of station models complete with data (but devoid of isolines), by consulting the Weather Bureau daily weather bulletin and transferring data for the relevant stations to the synoptic chart blank as illustrated in Figure 61. It then remains for pupils to do the interpolation exercise and produce the prevailing patterns. The author believes that by doing this pupils will

1. understand the concept of isolines (and that such lines can be drawn for each of the climatic elements);
2. appreciate the process of interpolation and understand how the chart is compiled (even though such a tedious task may be computerised. Such learning may even be computer assisted).
3. through repeated exercises, particularly of the pressure and temperature elements, gain an understanding of the relationship between the two. By superimposing isotherms on isobars the pressure-temperature relationship will be strengthened and ultimately fronts can be inserted on the maps to signify air mass discontinuities;
4. by comparison of the various isolines for the same set of data be able to make associations between elements. For example, isotachs of high velocity will become associated with steep pressure gradients (represented by crowded isobars); and
5. observe and compare the nature of horizontal pressure gradients, per one hundred kilometres, for example.

Analysis of station model statistical data and the use of the psychrometric chart

It is a useful exercise for pupils to compare the difference between a ship report station in the Atlantic ocean, a coastal station and Windhoek, all on approximately the same latitude. Comparative differences can then be associated with the available moisture source for each station.

For example, on 19 July 1970 the following data were recorded; where T is dry bulb temperature and T_d is dew point.

	<u>Ship report</u>	<u>Walvis Bay (coastal)</u>	<u>Windhoek (inland)</u>
T	16	14	24
T_d	12	11	-14
$T - T_d$	4	3	38
Cloud cover	$\frac{4}{8}$	0	0

It becomes clear from such an exercise that the precipitation potential is greater near moisture sources, and that the greater the divergence between the dry and dew point temperatures, the drier the air.

As a classroom exercise based on the above, and as reinforcement of standard eight concepts, the table can be extended by use of a psychrometric chart as depicted in Figure 62.

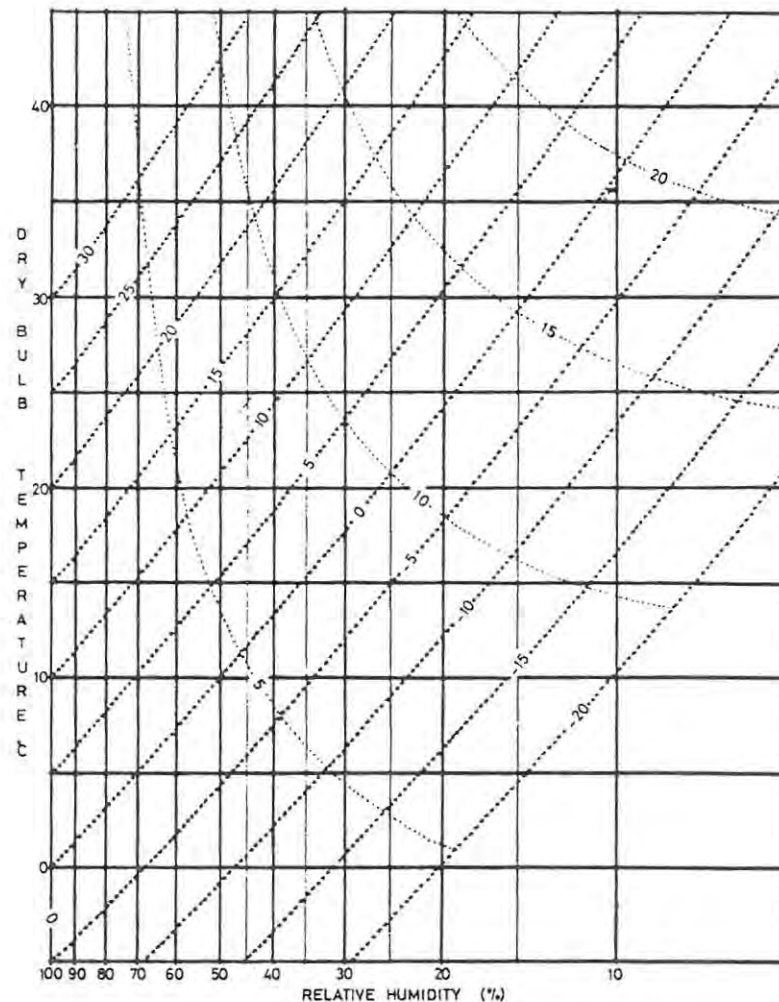


Fig. 62 A skeleton version of a psychrometric chart appropriate for classroom use.
(as found in Hattle, 1972)

The dry bulb temperature of a station is found along the left hand vertical axis. This line is followed horizontally until it meets the appropriate dew point temperature line (a line sloping upward to the right). From the point

where they intersect a perpendicular is dropped to the horizontal axis where the relative humidity of the station is read. For the case in question, the relative humidity over the ocean is approximately 80%, 82% at Walvis Bay and 5% at Windhoek.

The advantages of such an exercise are numerous. Firstly, it encourages the skill of graphicacy; secondly, it relates dry bulb and dew point temperatures and relative humidity (i.e. the "wetness" of the air) visually, and thirdly, it integrates the work of different standards, thereby strengthening the general meteorological concept base, and hence promoting a sound ability to apply knowledge.

Advanced synoptic chart exercises for higher grade pupils

1. Applications of the geostrophic wind scale

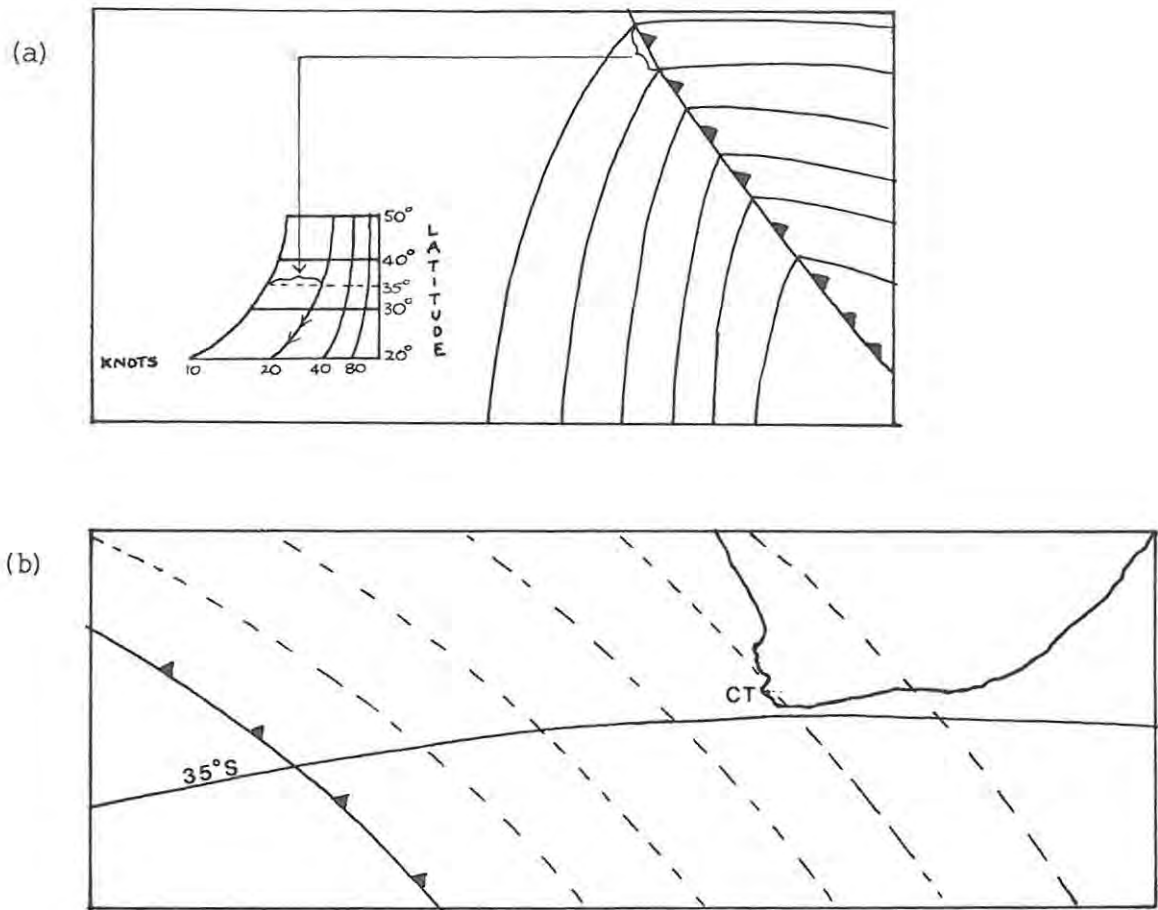
The geostrophic wind scale on synoptic charts is of inestimable value in the understanding of the rate of movement of fronts, and in determining the geostrophic windspeeds over uniform surfaces.

Rate of movement of fronts:

For the former exercise a replica needs to be made of the geostrophic wind scale. It is then placed along the front with the end on one isobar and the value where it crosses the next isobar is determined. This does not give the wind velocity, since the scale is not placed at right angles to the isobars. This produces the rate of movement of the front at right angles to its length. The procedure is illustrated in Figure 63.

If the reading is 20 knots, for example, this amounts to approximately 10 metres per second, producing a rate of movement of 36 kilometres per hour. In the context of the given map, it is then calculated that the cold front may reach the south-western Cape after approximately 30 hours. The calculation is dependent on the scale of the chart viz. 1:20 000 000.

It is clear that a linear distance of 1 cm on the chart represents 200 km. (given that the scale is most accurate at 40°S). In 6 hours, therefore, the front will have advanced $36 \times 6 = 216$ km. The anticipated positions of the front parallel to the existing front are drawn 1 cm apart. Each 1 cm parallel spacing represents 6 hours and, therefore, simply by counting the number of anticipated frontal positions it is determined that the south-western Cape will experience the front about 30 hours later.



(a) Application of the geostrophic scale to the frontal position, and
(b) the anticipated frontal positions

Fig. 63 Application of the geostrophic scale to determine the rate of movement of fronts

These calculations are approximations by virtue of the peculiarities of scale, assuming all things equal at the time of calculation. The accuracy is not the issue here. The value of the exercise lies in the development of concepts such as rate of movement and scale application - and ultimately the valuable skill of numeracy.

The same exercise may be performed with regard to warm fronts. However, since the movement of warm fronts is tardier than cold fronts (it is established in the theory that cold air advecting behind the cold front is more aggressive than the warm air in the rear of the warm front and consequently advances more quickly), the speed of movement is regarded as approximately 0,75 that of the geostrophic value (Miller, 1953).

By comparative study of the rate of movement of cold and warm fronts, it

can furthermore be established (or reinforced, depending on teaching strategy) that the cold front will catch up with and under-ride the warm front and hence the initiation of the concept of occlusion.

2. Determining the geostrophic windspeed

To determine the geostrophic windspeed at any given set of co-ordinates, pupils proceed as follows. The perpendicular distance between the isobars is measured and this measurement is transferred to the correct latitude on the geostrophic wind scale. The windspeed (in knots) is read off at the top of the scale by following a line parallel to the curved isobars. The procedure is illustrated in Figure 64.

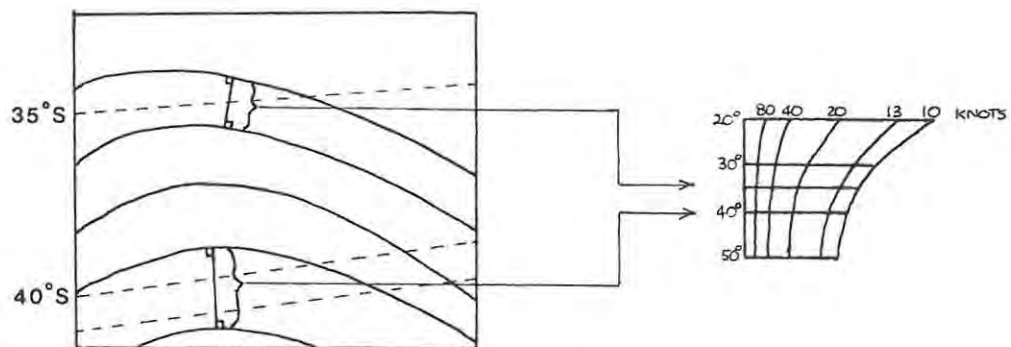


Fig. 64 Determining the geostrophic windspeed using the geostrophic scale

Such an exercise may assist pupils to establish for themselves the relationship between isobar spacing and windspeeds.

An almost inevitable question from pupils is the reason for winds being parallel to the isobars over the ocean, yet oblique to the isobars at the coast or inland. An explanation in terms of the Ekman spiral (Figure 39) is often useful.

Ideas for higher grade candidates based on the isohypse concept

For the higher grade candidate the concept can be reinforced through an application of the hypsometric equation – the equation linking pressure and height. The example considered here assumes a dry atmosphere, since atmospheric moisture will affect the density of the air column under consideration and modifications to the formula will need to be made in this case.

(Hattle, 1972, p127)

Hypsometric Equation

$$h_2 - h_1 = 67,4 T (\log p_1 - \log p_2)$$

where h_2 is the upper height in metres,

h_1 is the lower height in metres,

T is the mean virtual temperature of the air column in degrees Kelvin
(i.e. add 273° to the centigrade reading. The Kelvin scale runs from
0 to infinity. On this scale the melting point of ice is $273,16^{\circ}\text{K}$
and the boiling point of water is $376,16^{\circ}\text{K}$.)

p_1 is the pressure at the lower level in hPa

p_2 is the pressure at the upper level in hPa.

If it is required to convert the isohypse reading of an inland station to its sea level equivalent, Figure 65 illustrates the procedure.

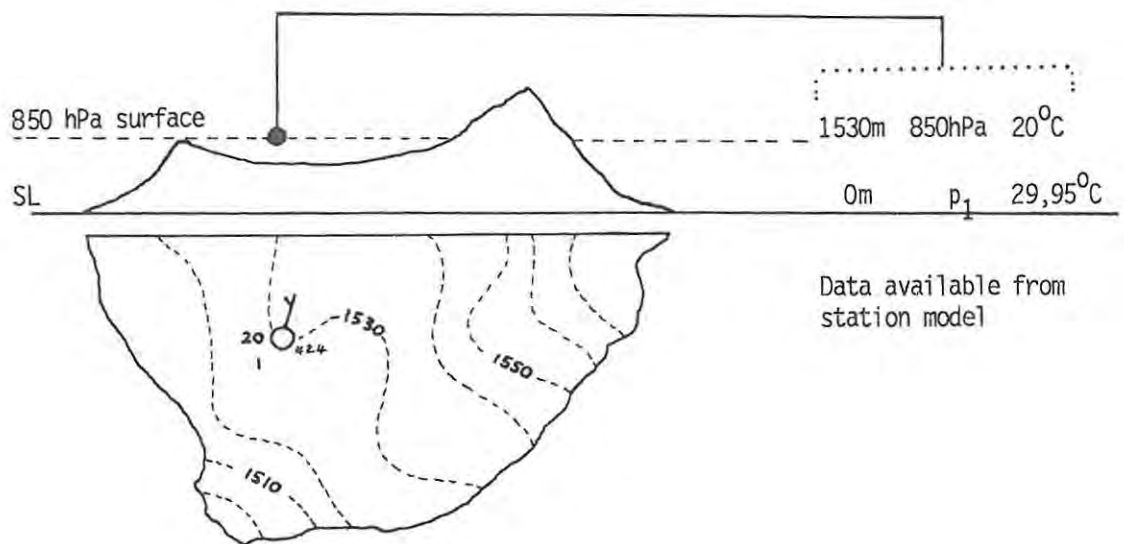


Fig. 65 Converting an inland pressure reading to its sea level equivalent

The data available from station 424 is as follows:

- i. the pressure is 850 hPa
- ii. the dry bulb temperature is 20°C
- iii. the height of the pressure surface is 1530 m above sea level.

$$h_2 - h_1 = 67,4 T (\log p_1 - \log p_2)$$

We have $h_2 = 1530$ m

$$h_1 = 0 \text{ m}$$

$p_2 = 850$ hPa, but need to determine T_1 before p_1 can be calculated.

If the temperature at 1530 m is 20°C , and we legitimately assume a dry and stationary atmosphere (relative humidity is less than 30%; determined from psychrometric tables) and thus the environmental lapse rate of $0,65^{\circ}\text{C}$ per 100 m, the equivalent sea level temperature of the station will be $9,945^{\circ}\text{C}$ warmer i.e. $29,945^{\circ}\text{C}$. If T is the mean temperature of the air column in degrees Kelvin, $T = 24,9725 + 273^{\circ}$

$$= 297,9725$$

Hence, $h_2 - h_1 = 67,4 T (\log p_1 - \log p_2)$

implies $1530 - 0 = 67,4 (297,9725) (\log p_1 - \log 850)$

therefore $67,4 (297,9725) (\log p_1 - \log 850) = 1530$

therefore $\log p_1 = \frac{1530}{67,4(297,9725)} + \log 850$

$$= 3,0056014$$

$$p_1 = 1012,9813$$

$$1013,0 \text{ hPa}$$

A pressure of 1013,0 hpa is a reasonable answer considering the station's location in a context of a high pressure system, and the derived answer being compatible with the average sea level pressure of 1013,2 hPa. If an adiabatic lapse rate is assumed, considering the descending air of the anti-cyclone, an answer of 1007,0 hPa is arrived at.

The mathematical manipulation of the hypsometric equation is within the scope of the higher grade mathematics syllabus in that calculators are at the pupils' disposal, and that logarithms are taught.

An argument may be that not all pupils doing higher grade geography do higher grade mathematics. There are, however, many who fall into this category and even if the exercise is not undertaken by pupils, it should be within the teachers' scope. This level of mathematics is done by A level candidates in Britain, but they have more hours per week for the subject.

The value of such a problem is that it allows pupils to make meaningful associations between the similarity of isohypses and isobars. Grappling with the underlying concepts such as the conversion of a plateau temperature to its sea level equivalent through the use of the dry adiabatic lapse rate (or normal lapse rate), strengthens the lower order overt concepts and deepens the definitional and organizational concept levels. Such is the fibre of true learning. This approach is in keeping with Ausubelian progressive differentiation and integrative reconciliation as discussed in Chapter 3.

TEACHING IDEAS ON THE INTEGRATIVE NATURE OF THE SYNOPTIC CHART

The use of daily newspaper weather synoptic charts to gain an appreciation of weather sequences

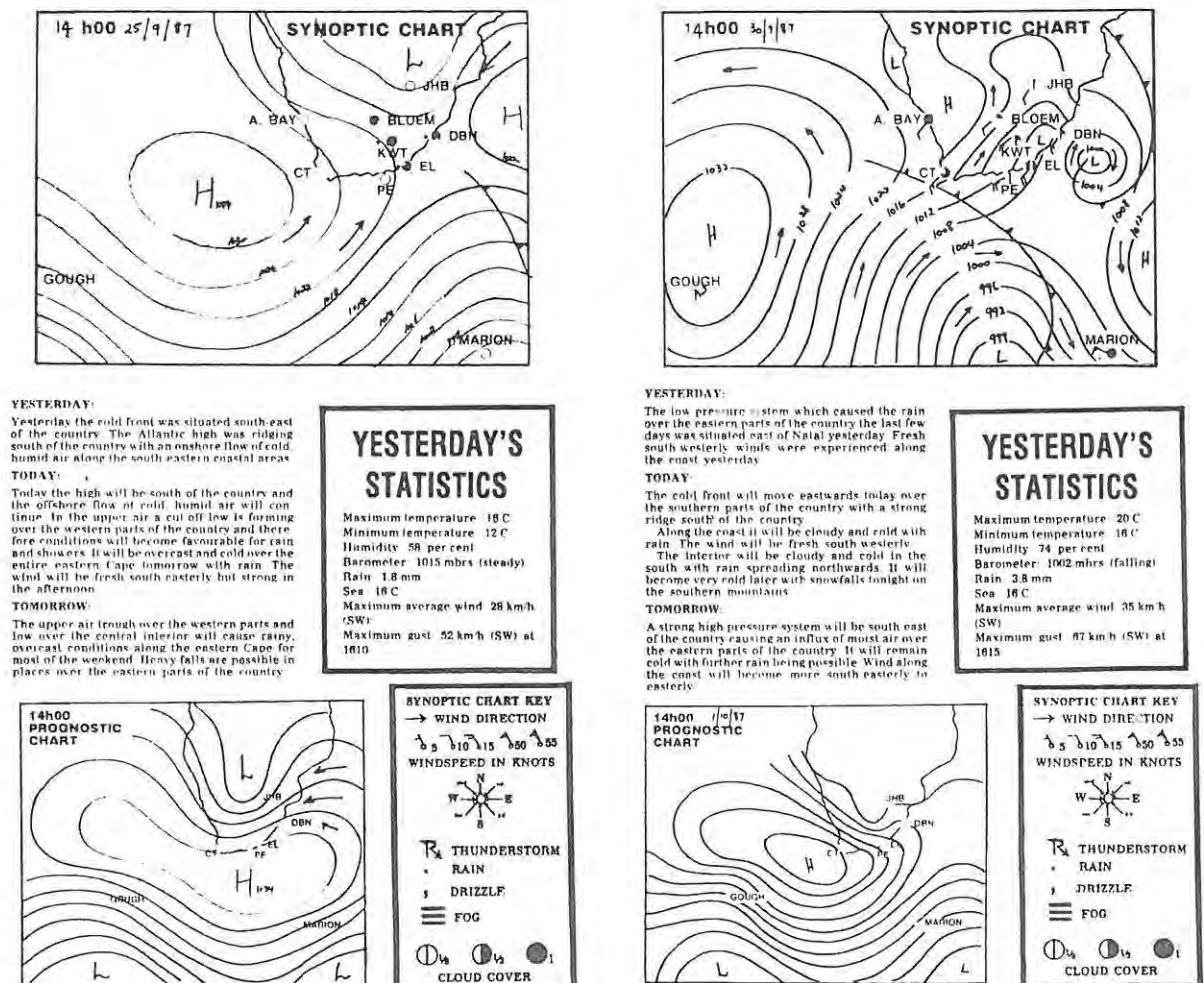


Fig. 66 Daily Dispatch synoptic charts

The advantage of daily weather charts (see Figure 66) as they appear in local newspapers, is that they are simplified, containing the predominant pressure systems in terms of the surface isobaric patterns. An added advantage is the inclusion of a prognostic chart which enables pupils to see the anticipated weather and thereby gain a feel for the motion of the atmosphere and its weather systems. In such a way the sequence of pattern may be reinforced.

The description of "yesterday's, today's and tomorrow's" weather also serves to equip pupils with the appropriate vocabulary typically used in forecasting. A three-day sequence may be presented, for example, with comprehensive reports. The charts only for the immediately ensuing three-day sequence can then be presented and pupils may then test their skills at forecasting - and their answers may eventually be compared with the actual conditions which prevailed for a given sequence.

This kind of exercise allows pupils to become aware of the weather conditions prevailing in their locality and explain the conditions in terms of the synoptic systems. They also are encouraged to view local weather in terms of a national weather perspective - and may eventually learn to observe and ascribe the prevailing weather to certain synoptic conditions, theoretically without consulting the relevant chart. Such an approach furthermore adds a dimension of excitement for pupils, especially when their forecasts are accurate.

The weather report published daily by the Daily Dispatch, East London, includes the weather statistics for the previous day. This data may be used by pupils and a graphical time series analysis may be compiled - and then compared with the synoptic conditions for East London. The information provided in this exercise allows pupils to explore the relationships between the elements.

A case study of a weather disaster using newspaper weather charts

The sequence of charts for the last seven days of September 1987, as in Figure 67, serves to show the synoptic developments and accompanying floods which ravaged Natal.

September 23 marks the initial stages of the development of a deep cut-off low to the south-east of the country. By 25 September the low is established

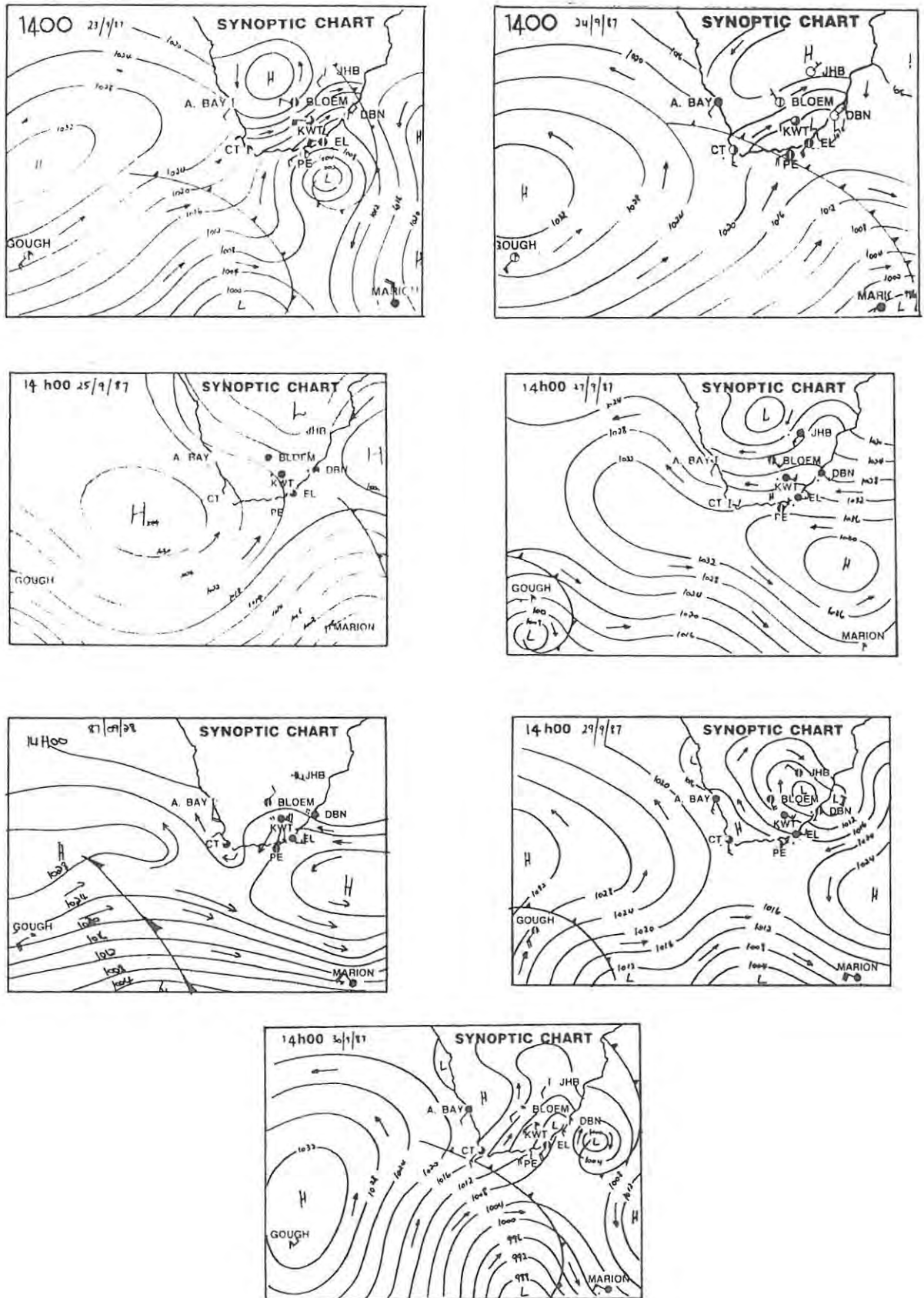


Fig. 67 A synoptic chart case study of the Natal flood disaster in September, 1987

over the continent and is effectively being blocked by the South Indian anticyclone to its east. On 27 September the South Indian anticyclone continues to feed moist maritime air from the far south, causing widespread rainfall over the eastern parts as instability conditions are promoted by the cut-off low over the continent. It is interesting to note the off-shore west coast advection causing warm clear conditions as the air descends over the western escarpment. By 29 September the cut-off low is driven partly off the continent under the influence of a strong South Atlantic anticyclone as it ridges in south of the country. The cut-off low remained semi-stationary over the continent for the best part of four days, sustaining heavy rainfall over Natal, before eventually entering the Mozambique Channel by 30 September. The rainfall over this period was exacerbated by frontal rain from the south-west.

Such a weather sequence is rare. The observation of the conditions provides documentation of South Africa's worst weather phenomenon to date in terms of loss of life and environmental damage.

Synoptic chart worksheets as consolidation exercises

By way of recommendation, and as a conclusion to this chapter, the author provides three synoptic chart worksheets; the contents of which are based on the suggestions mentioned earlier.

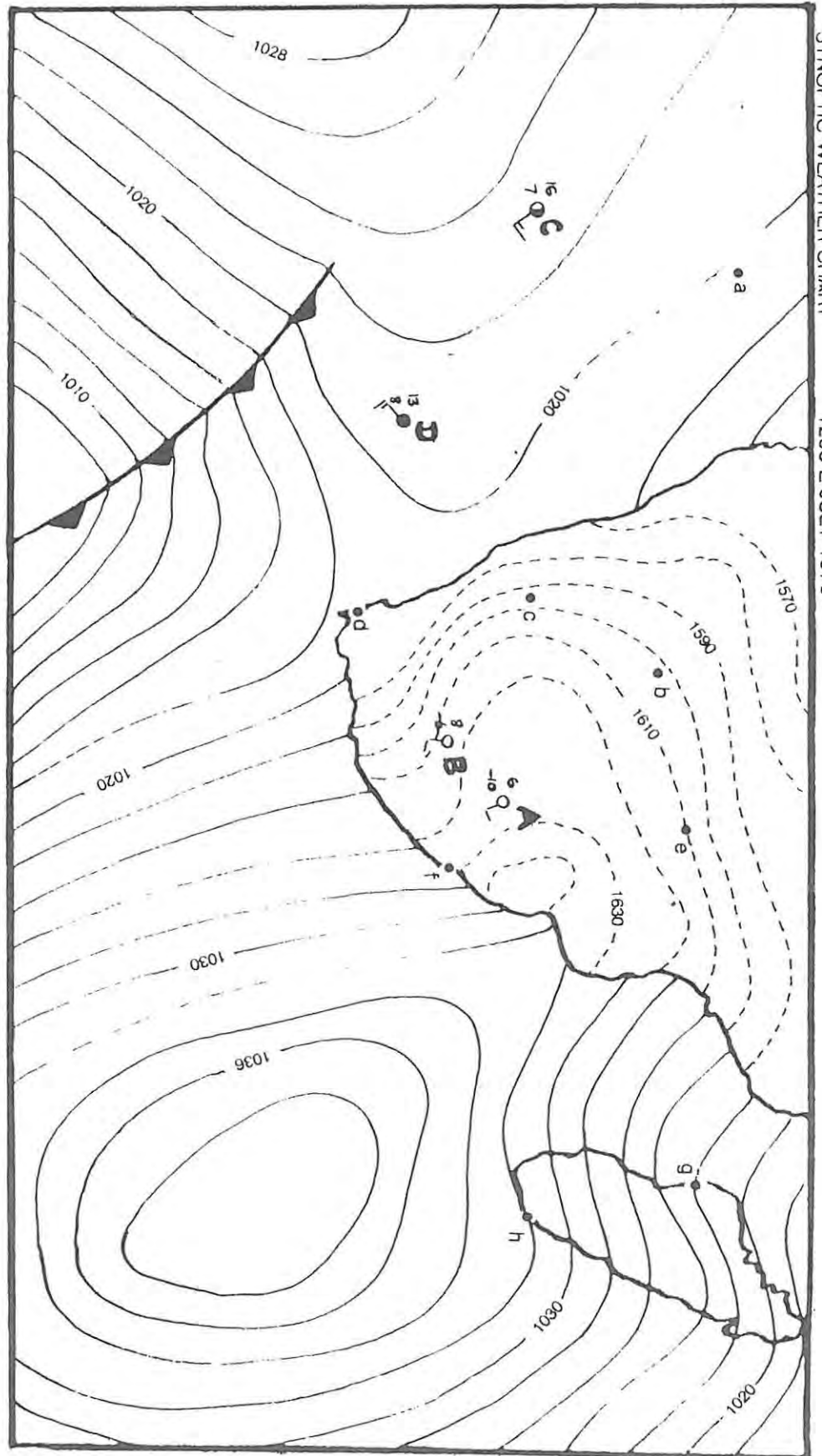
Worksheet 1 contains questions of an objective nature largely, requiring pupils to recognize basic synoptic systems. Application of knowledge is based on the fundamental concepts learned in the climatology of standard eight. It should be noted that the chart being used is simplified considerably so as to eliminate extraneous information initially so that Piagetian centration is promoted. The content of worksheet 1 should be within the ability range of standard eight pupils.

Worksheet 2 is designed on the basis of standard nine syllabus content and goes beyond the syllabus to the extent that pupils are required to explore the concept of geostrophic windspeed by using the geostrophic wind equation and the geostrophic wind scale. It furthermore serves to extend the geostrophic model to its practical level in terms of its application to synoptic charts. The chart itself is not simplified anymore, but detailed; the version issued by the Weather Bureau.

SYNOPTIC CHART (WORKSHEET 1)

Refer to synoptic weather chart dated 1200z July 1970

1. Weather station C in the south Atlantic shows a dry bulb temperature of 16°C and a dew point temperature of 7°C . How was this information obtained?
2. Label clearly on the map supplied:
 - (i) South Atlantic anticyclone
 - (ii) South Indian anticyclone
 - (iii) a trough
 - (iv) a ridge (wedge)
 - (v) the cold front
3. Place H and L in appropriate places to show the high and low pressures respectively.
4.
 - (i) What is the central pressure of the South Indian anticyclone?
 - (ii) What is the central pressure of the westerly depression as shown on the chart?
5. Insert on the map the general wind direction around the
 - (i) cyclone
 - (ii) anticyclone and
 - (iii) over the continent.
6. State the direction of the prevailing wind at
 - (i) a
 - (ii) b
 - (iii) c
 - (iv) d
7. Shade the area that will experience Berg wind conditions. Describe the conditions necessary for Berg wind development.
8. Tabulate the dry bulb and dew point temperatures for the stations marked A, B, C, D. Comment, with reasons, and explain the marked differences between land and sea stations.
9. How do you account for
 - (i) the cloud cover at C and D, and
 - (ii) the clear skies at A and B?
10. State the surface winter weather phenomenon that could prevail at A, and the conditions which would favour its formation.
11. Calculate the approximate length of the cold front (in kilometres) if the scale of the map is 1:20 000 000.
12. Indicate (by marking on the map) the place where
 - (i) the pressure gradient is weakest
 - (ii) the pressure gradient is strongest
 What will the effect of these gradients be on the winds at (i) and (ii)?



SYNOPTIC CHART (WORKSHEET 2)

Refer to the synoptic chart dated 19-07-70

1. Identify and label the South Atlantic and South Indian anticyclones, the coastal low and the westerly depression.
2. What is the central pressure of the westerly depression?
3. Account for the isobars over land being represented by solid lines and the isobars over the ocean by dotted lines.
4. Locate the following weather stations:
 A. $22\frac{1}{2}^{\circ}\text{S}, 9^{\circ}\text{E}$ B. $34^{\circ}\text{S}, 11^{\circ}\text{E}$
 (i) Are these permanent weather stations? If not, what are they?
 (ii) What is the wind direction and speed at each station?
 (iii) Explain the differences observed in 4(ii).
5. Interpret fully the weather station model for Gough Island.
6. Why is the north east coast of Malagasy completely overcast?
7. (i) Calculate the geostrophic wind speed at $35^{\circ}\text{S}, 10^{\circ}\text{E}$, using the following formula

Geostrophic Wind Equation

$$V_g = - \frac{1}{\rho} \frac{dp}{dr} \frac{1}{2 \Omega \sin \phi}$$

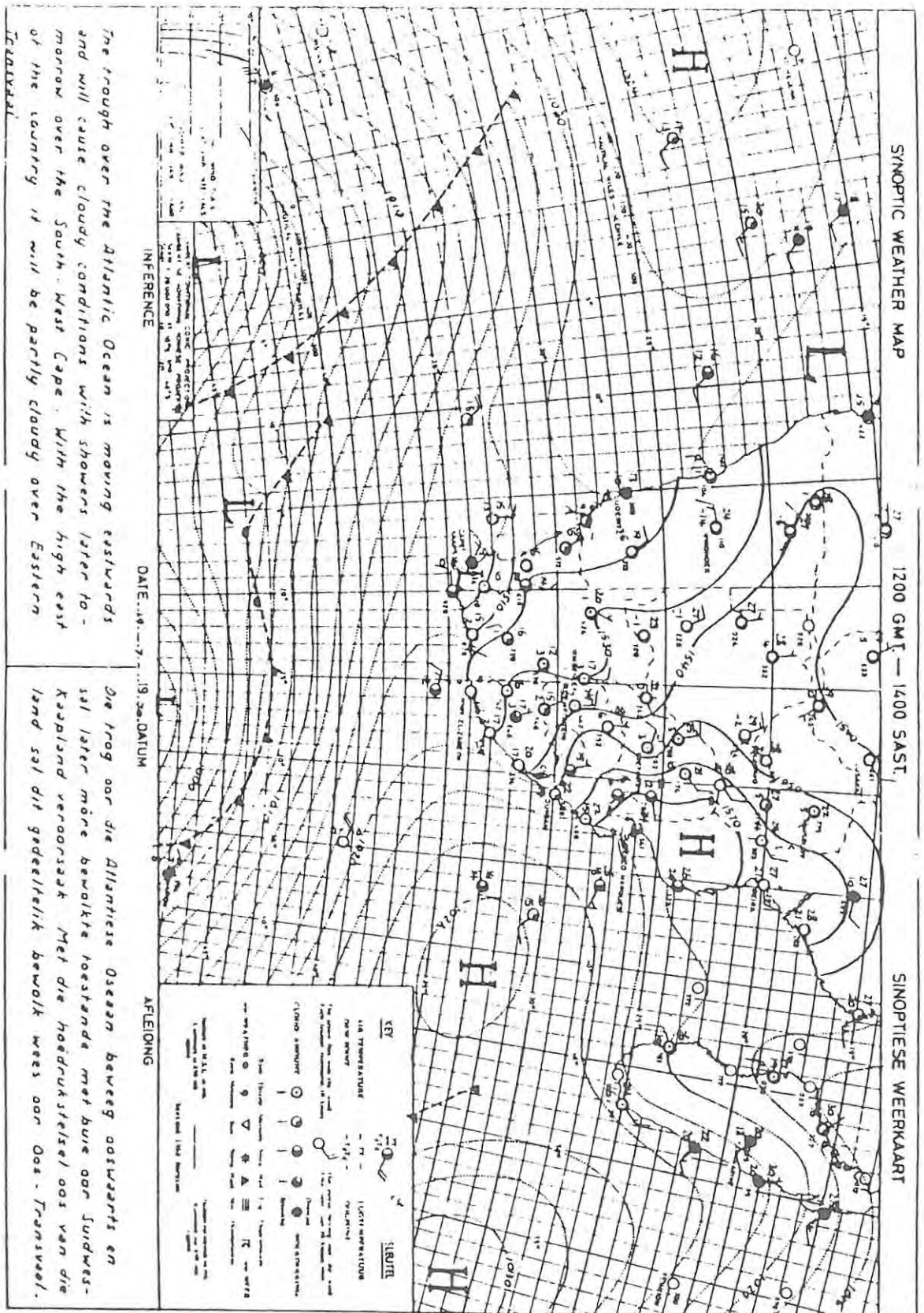
$$\rho = \text{density of air} = 1,2 \times 10^{-3}$$

$$dp = 2\text{mb} \times 10^3 \text{ (dynes conversion)}$$

$$dr = \text{distance between isobars} \times \text{scale } 20\,000\,000$$

$$\Omega = \text{angular velocity of earth } 7,29 \times 10^{-5}$$

- (ii) Now find the wind speed using the geostrophic wind scale.
- (iii) Calculate the geostrophic wind speed at $31^{\circ}\text{S } 36^{\circ}\text{E}$. (Formula)
- (iv) Find the wind speed of the same place using the wind scale.
 How do you explain the difference between the two locations?



SYNOPTIC CHART AND SOUTH AFRICAN WEATHER (WORKSHEET 3)

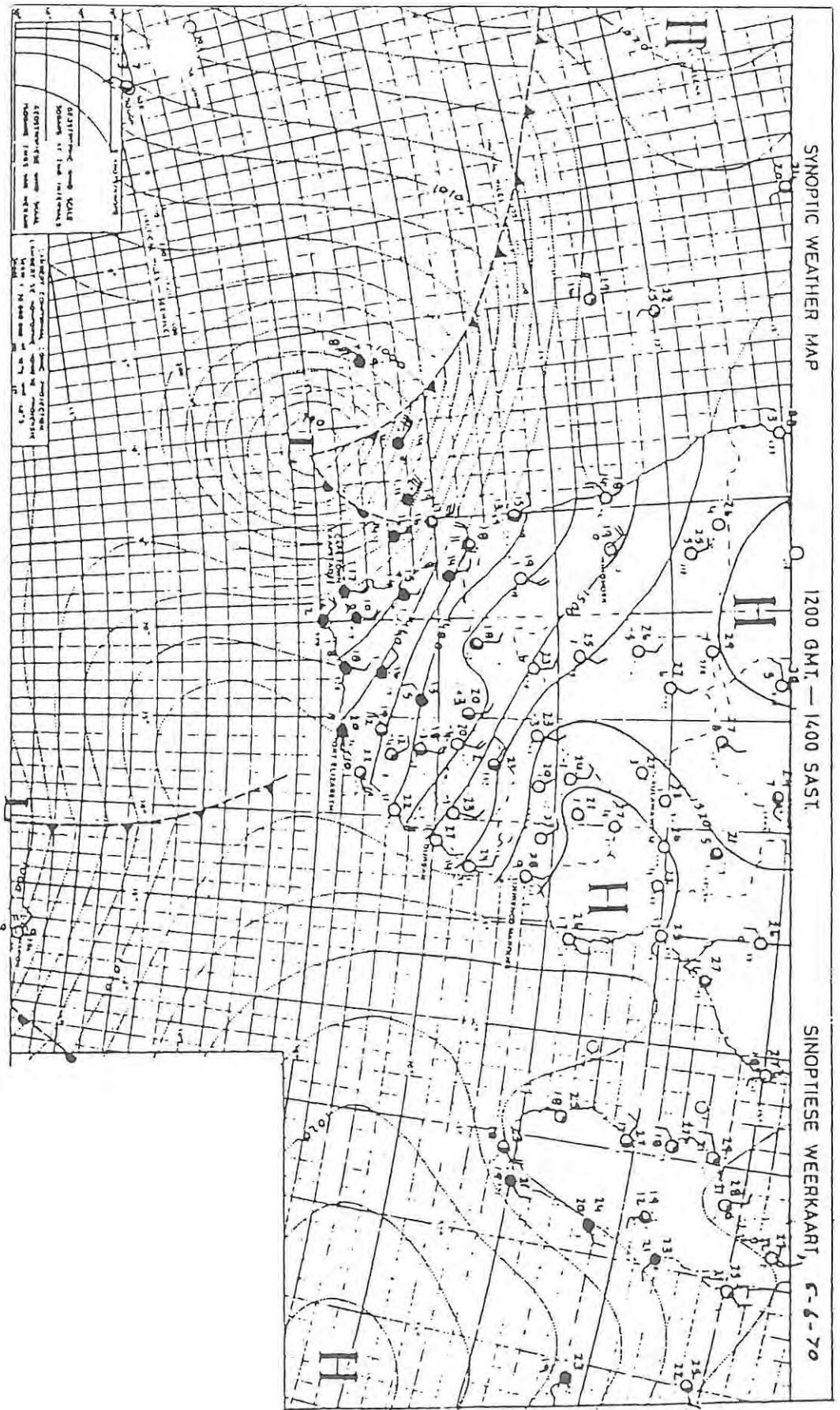
Refer to the synoptic chart dated 1970-C6-C5

1. Name each of the synoptic systems appearing on the map.
2. Tabulate and compare the dry bulb and dew point temperatures at Windhoek and the coastal station west of Windhoek. Explain the difference.
3. Explain the occurrence of clear skies over the eastern and central interior.
4. In which stage of its life cycle is the system located west of Cape Town?
5. Give a fully labelled sketch of the cross section through the system in question four along the line between Cape Town and 30°S , 5°E .
6. Give a detailed forecast of Cape Town's weather for the next twenty-four hours.
7. Name and describe the microclimatological surface weather phenomenon likely to be found on the Highveld. Also describe the conditions necessary for its formation.
8. The air flow along the west coast of Malagasy appears to be contrary to the general circulation. Suggest reasons for this.
9. Name the solid lines over the continent. Why is this unit of measurement used instead of isobars?
10. (i) Explain the type of wind being experienced along the coast between Maputo and just north of Port Elizabeth.
(ii) Why are these winds blowing north-easterly parallel to the coast?

Refer to the synoptic chart dated 1975-12-16

1. Describe the origin of the low pressure over the subcontinent.
2. (i) Explain the overcast conditions being experienced over the eastern half of the country.
(ii) How can one say for sure that precipitation has occurred?
(iii) State the type and nature of precipitation that has prevailed.
3. Explain the clear skies, being experienced over the south-western Cape.
4. Determine the geostrophic windspeed at A. (In the middle of this symbol and not at the station indicated).
5. How was meteorological data obtained for the station situated at approximately 29°S , 12°E ?
6. State how the cold front to the south of Cape Town will affect the weather over the continent.
7. Compare the latitudinal position of the high pressure belt on this map with the same on the other synoptic chart. Explain the difference.
8. (i) What type of weather phenomenon occurs to the extreme north east of the chart? What is the significance of the name "Barbara"?
(ii) Explain the conditions necessary for these phenomena to form.
(iii) State reasons, from the map, which confirm that this phenomenon is in its dissipating stage.

9. Explain the wind direction at the station 20°S , 5°E in terms of the geostrophic wind model.
10. There are four islands to the west, south-west and south-east of Cape Town. Highlight these islands in blue and make sure you know their names and location.
11. Confirm the windspeed at the station approximately 44°S , 32°E as being 25 knots. How did you go about it?
12. At which latitude is the ITCZ approximately on this day? Explain your answer. Sketch in the position in red.
13.
 - (i) The "coastal low" hugging the west coast moves around the tip of Africa and up the east coast. Why?
 - (ii) How did this low originate?
 - (iii) These coastal lows, inter alia, are instrumental in the development of Berg wind conditions along the coast in winter. Explain how this occurs.
14.
 - (i) The station at 20°S , 23°E is experiencing a particular weather phenomenon. What type?
 - (ii) Explain the development of this phenomenon by referring to conditions evident of the map.



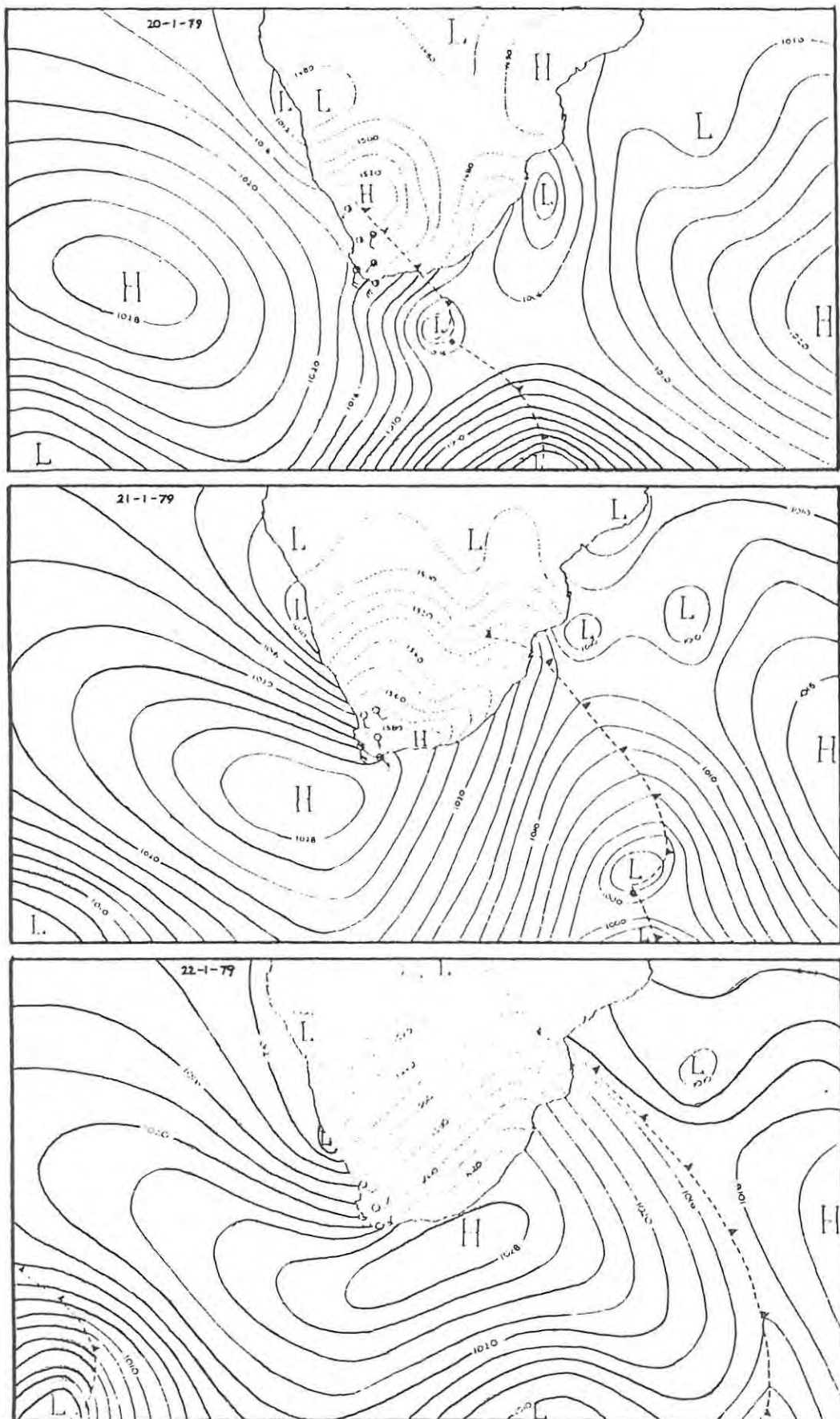


Fig. 68 A sequence of synoptic charts for 20 - 22 January 1979

Worksheet 3 is an attempt to integrate the meteorology/climatology of the senior secondary syllabus as far as it pertains to the synoptic chart. The author regards the standard of questioning presented on this worksheet to be that which pupils should find stimulating by virtue of the sequentially graded teaching approach from the standard eight year. The worksheet is also of such a nature that it compares a typical summer and winter weather day. The questions also encourage the pupil to observe South African weather conditions in the context of the southern Atlantic oceans and the subcontinent.

The answers as envisaged by the author are contained in Appendix 8.

Further worksheets may be designed by teachers by consulting the recommendations in the section on the adaption of Boardman's (1983) graphicacy skills for the synoptic chart in Chapter 3.

A further type of exercise may be formulated using a sequence of charts as in Figure 68. Pupils may then work in groups, answering questions of the following type:

- (i) Explain the latitudinal position of the high pressure belt.
- (ii) Describe and explain the changes in weather experienced by Capetonians over the period 20 to 22 January 1979.
- (iii) Describe the general direction of movement of the westerly depression over the three day period.
- (iv) Estimate the rate of movement of the cold front.

Report-backs and discussions are valuable consolidation exercises.

A simulation game

Simulation games promote general class interest and although they may appear time consuming, pupil involvement encourages learning.

Weather forecasting for Britain - The Depression Game:

A game of this nature can be adapted for the South African situation, but as it stands satisfies the syllabus requirement that mid-latitude cyclones should be studied on a global scale. The grids and keys for the game form Appendix 9.

The passage of a depression across the British Isles is usually from west to east, but the tracks it follows vary enormously; moreover no two depressions

are exactly the same.

The aims of this game are:

- (i) to make the variability of the British weather more real.
- (ii) to provide an understanding of the influences on British weather.
- (iii) to build on climatology as a real means of understanding changes in weather.

Notes:

Your depression is divided into 9 inner areas, numbered 1 to 9, and 3 outer or marginal zones X, Y and Z. The weather conditions in each of these areas or zones are given in the weather keys.

eg, The weather in area 8, for example, is drizzle and long clear spells, air temperature is 14⁰C, stratus and some cumulus cloud covering half the sky, pressure remaining steady and wind blowing about 10 knots from the SSW.

How the game works: (working in groups)

- (a) Write your name and the name of the 'station' (shaded area) you are forecasting for.
- (b) Place the depression over the base map starting with the C squares covering each other.
- (c) Write down the actual weather conditions being experienced at your 'station' on the table provided.
- (d) Forecast the weather for the next 2 hours (fill in on the table). You may move the depression temporarily to help you see how conditions may change.
- (e) The movement of the depression is determined by 2 dice. Move your depression in the direction determined by the total scored by the dice.
- (f) Fill in the actual conditions experienced by your 'station' and mark your forecast correct (✓) or incorrect (X) in the right hand column of your table.
- (g) Draw an arrow on the base map to show the direction of movement of the depression; using the C square as a reference.
- (h) Repeat the process for the next round.
- (i) Now forecast all the remaining eight rounds before finding out the actual weather for the full time period.
- (j) Check the accuracy of your forecasts as the depression moves and draw in arrows to track the movement of the depression.
- (k) When all ten rounds have been completed, count the number of ticks and add a zero to find out your percentage success.

Table 15 presents, by way of conclusion, the author's contributions to classroom activities as a result of his experience and survey of the relevant literature.

Table 15

1. Classification of the isohypse concept using a three-dimensional model
2. Three-dimensional diagrams to portray atmospheric phenomena
3. Northern hemisphere depressions or three-dimensional phenomena which often occur in texts may be converted to their southern hemisphere equivalent by inverting a transparency and laterally reversing it on the overhead projector.
4. Geostrophic flow may be explained in terms of the conventional model in conjunction with the vector concept and the Ekman spiral
5. Explanation of pressure is aided by the use of a water-filled tumbler covered with a sheet of paper and gently inverted
6. Explanation of the unit of pressure is facilitated by a mathematical approach
7. The piecemeal analysis of station models by interpolating isolines for the respective weather elements
8. The description of station model data independently of the synoptic chart
9. Deductions about prevailing weather using the statistical data on station models
10. Higher grade candidates may be stimulated by investigating the properties of the hypsometric equation to verify the isohypse concept
11. The geostrophic wind scale can be used by higher grade candidates to
 - (a) determine the geostrophic windspeed at specified latitudes, and
 - (b) determine the rate of movement of fronts
12. Newspaper synoptic charts may be used to develop a time series analysis
13. Accumulated newspaper weather charts may be used for the study of a weather disaster, for example, the Natal floods of September 1987
14. Worksheets as individual or group exercises
 - (a) Various fundamental knowledge may be applied by inserting items on skeleton charts
 - (b) A sequence of charts may be investigated as a theme to ascertain the general direction of movement of weather systems
15. Simulation games are useful activities for pupil involvement and a means of discrete learning
16. Jet streams may be simulated by using science laboratory equipment
17. Reference to everyday examples like condensation of vapour on an ice-filled glass and the excessive heating of a closed car on a hot day being analogous to the Greenhouse effect, facilitate concept accommodation
18. Placing of the concept matrix in Chapter 3 at the pupils' disposal will allow them to see climatology within a general and interrelated framework
19. Donn (1975) provides useful rules relating to the interpretation of surface weather maps

SUMMARY OF CLASSROOM TEACHING IDEAS

It has long been the author's concern that children, by virtue of a complexity of factors, seldom seem to come to a mature understanding of meteorological and climatological concepts. There appears to be a tendency toward rote memorisation of fact rather than a developed and progressive understanding of fundamental concepts. A sad consequence of this is that progress toward formal propositional thought is hindered because intellectual development is impeded as a result of a lack of sequential integration of structures. This adversely affects their ability to understand and interpret synoptic charts. It is hoped that the above will go a small way toward aiding teachers with their teaching and pupils with their understanding of the complexities of meteorology-climatology and weather chart analysis.

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A P P E N D I C E S

TEXT BOOK RATINGS ON SELECTED CRITERIA

- CRITERIA -	SERIES: STD.:	OUR NEW WORLD (1981) (Old Syllabus)			NEW WINDOW ON THE WORLD (1987)			SENIOR GEOGRAPHY (1987)			ACTIVE GEOGRAPHY (1986)		
		8	9	10	8	9	10	8	9	10	8	9	10
1. Text													
1.1 Reading fluency/Intelligibility		3	2	2	5	5	5	5	5	5	5*	5	5
1.2 Appropriateness of language use		3	3	2	5	5	5	5	5	5	5	5	4
1.3 Concept clarification		3	2	2	4	4	2	4	4	4	5	5	3
1.4 Variety of print styles (colour)		2	2	2	5	5	5	4	4	4	5	5	5
1.5 Enrichment (per se)		2	3	3	4	5	5	2	3	2	1	2	2
1.6 Systematic presentation (chronology)		5	5	5	5	5	5	5	5	5	5	5	5
2. Illustrations													
2.1 Quality (clarity)		4	4	4	5	5	5	4	4	4	5	5	3
2.2 Relevance (appropriateness)		4	4	5	5	5	5	5	5	5	5	5	4
2.3 Realistic (True to life)		4	3	4	5	4	5	5	5	5	5	5	3
2.4 Content (amount)		5	5	5	5	5	5	4	5	5	4	5	3
2.5 Dimensional		1	1	2	4	5	5	3	4	4	2	4	2
2.6 Graphical data representation		4	3	3	4	4	4	5	5	3	2	4	3
3. General													
3.1 Attractive (pupil appeal)		2	2	2	5	5	5	3	4	4	4	4	3
3.2 Teacher resource		4	5	5	4	4	4	3	3	3	2	2	2
3.3 Pupil resource		3	2	2	4	5	5	4	4	4	4	3	3
3.4 Consolidation exercises		3	2	2	4	5	5	3	3	3	4	2	1
3.5 Syllabus compatibility		5	3	3	5	5	5	5	5	5	4	4	4
3.6 Integrative with satellite photograph		1	1	1	3	3	5	4	3	3	1	1	1
3.7 Differentiation		2	2	3	3	5	4	5	5	5	2	2	2
3.8 Reference to Synoptic weather cht.		1	1	2	3	5	5	4	2	4	2	4	4

Meanings assigned to scores :

1. Criterion not met
2. Criterion incompletely met
3. Criterion met in general
4. Criterion soundly achieved
5. Criterion excellently met

A P P E N D I X 2

RESEARCH INSTRUMENTS

- (a) Teacher interview questionnaire
- (b) Examples of interview responses from teachers
- (c) Guidelines for administering pupil worksheet
- (d) Pupil worksheet on South African weather, climate and the synoptic chart
- (e) Marking memorandum for pupil worksheet
- (f) Example of completed pupil worksheet

INTERVIEW WITH TEACHERS OF SENIOR SECONDARY CLIMATOLOGY

The information obtained in this interview will be used in the compilation of my M.Ed thesis entitled

THE INTEGRATIVE NATURE OF THE SYNOPTIC WEATHER MAP
IN RELATION TO ADOLESCENT COGNITIVE STRUCTURES
AND THE TEACHING OF SENIOR SECONDARY
METEOROLOGY-CLIMATOLOGY

and will be treated as strictly confidential. I trust that the questions will not be seen as threatening to you or your school. Your co-operation is very much appreciated.

QUESTIONS

1. Do you have a specific teaching strategy when teaching meteorology/climatology? Is it consistent from year to year?
2. Have you found any one particular strategy for teaching the synoptic weather chart especially valuable?
3. How much time (lesson hours) do you spend on the synoptic chart?
4. Do you find you need to revise basic climatological concepts with a class before tackling the synoptic weather chart?
5. Do you use the synoptic chart to revise South African weather or do you treat the chart as an independent component of the syllabus?
6. Do you teach synoptic charts according to the textbook layout or independently of it?
7. Have you found any particular textbooks or overhead projector aids useful?
8. Have you used past Std 10 examination papers to guide your teaching of the Senior Secondary Geography syllabus?
9. Are there particular concepts on or relating to the chart that pupils find difficult to understand? Please elaborate. Is there any other climatic or meteorological concept with which pupils experience difficulty?
10. What particular difficulties do you experience in the teaching of the chart?
11. How do your pupils respond to the teaching of climatology relative to the other areas of the syllabus? Do HG and SG pupils respond differently?
12. Do you regard the climatic and meteorological concepts required known by the end of Std 8 and 9 as essential to a thorough grasp of the synoptic chart?
13. Would you like to be trained particularly in the teaching of Senior Secondary climatology at, for example, a workshop?

Your co-operation is sincerely appreciated.

Thank you.

P.P. VAN JAARSVELD

TEACHER RESPONSES TO QUESTIONNAIRE

1. ☒ YES NO YES ☒ NO
2. No.....
.....
3. Six..... hrs. ($\leq 2.1 + 10 = 6 \text{ hrs}$)
4. ☒ YES NO
5. ☒ YES NO
6. YES ☒ NO
7. ☒ YES NO If YES, which? Swan-felders new Std 10 textbk...
8. ☒ YES NO
9. 3D idea of mid-latitude cyclone & 3D idea of H.Ps...
the global air circulation system.
.....
.....
10. None really, possibly frustration with inability of some
pupils to fully grasp the synoptic chart concepts.....
11. Bright HG pupils love climatology. The weak pupils
particularly weak HG pupils really struggle with the
question as it isn't clear if it is HG pupils.....
12. ☒ YES NO
13. ☒ YES NO most definitely & can highly recommend you as
the ideal person for the job!
14. GENERAL

TEACHER RESPONSES TO QUESTIONNAIRE (Responses ticked)

1. ☒ YES NO ☒ YES NO
2. Using profiles along with plan views.....
Using sequences over a few days.....
3. 5 hrs. p.a.
4. ☒ YES NO
5. ☒ YES NO
6. YES NO
7. ☒ YES NO If YES, which? 1. Murray
8. ☒ YES NO Audio-visual transparencies
9. Nothing in particular.....
Sometimes find the same for every height.....
contours indicating SLOs and level features than
isobars over the land, difficult to understand.
10. Nothing in particular.....
11. Tend to find it more work, sometimes more
difficult than other sections - more so with
SLO pupils.
12. ☒ YES NO
13. YES NO
14. GENERAL

- * 3-dimensional models would facilitate the drawing of synoptic charts.
- * TV weather reports can be used very effectively as a supplement based on observation over a week.
- * Constant reference is made to weather patterns experienced on certain days eg onset of Bay winds, cold fronts, thunderstorms. Pupils are encouraged to use powers of perception and relate theory to reality outside.

DATA RECORDING SHEET

TEACHER RESPONSES TO QUESTIONNAIRE

underline textbook.
talk + chalk

1. ☒ YES ☐ NO ☒ YES ☐ NO
2. ~~Talk and chalk~~ standard grade - underline textbook then actually giving them the notes important points.....
3. ... 4-5 hrs. 1 week
4. ☒ YES ☐ NO
5. ☒ YES ☐ NO
6. ☒ YES ☐ NO
7. ☒ YES ☐ NO If YES, which? ..Hurry + VanHeerden.. / Strahler.....
8. ☒ YES ☒ NO notes yet but will in next few weeks before finals.
9. Pressure to standard anterior pressure. Hainichig → concept of pressure
→ humid air lighter.....
.....
.....
10. geopotential meter lies → difference over land and sea.
→ lies not joining etc.....
11. Prefer human generally although some have high interest
using TV weather forecasts etc.....
.....
12. ☒ YES ☐ NO
13. ☒ YES ☐ NO
14. GENERAL

GUIDELINES FOR ADMINISTERING PUPIL WORKSHEET

1. The pupil must indicate at the top right hand of the first page
 - (a) his/her grade
 - (b) his/her standard
 - (c) his/her sex

The pupil's name is NOT REQUIRED. The school must also remain anonymous on the returned script.

2. Please do not assist the pupil with any question.
3. Although only 30 minutes have been allocated for the test, an extra 5 to 10 minutes may be allowed, if needed, and if this meets with your approval.
4. Pupils should attempt ALL of the questions, irrespective of whether or not a section has been taught. If the answer to a question is not known at all, a hyphen is sufficient to indicate this. The pupil's standard (i.e. 8, 9 or 10) will be taken into account when the answers are analysed.
5. Answers may be recorded on foolscap where the paper provided is insufficient.
6. The worksheet must be answered under strict test/examination conditions. This is necessary to ensure an accurate reflection of each pupil's understanding of the concepts.
7. The completed worksheets may be returned to me, unmarked, by post at the following address:

P.P. van Jaarsveld
 97 Kennington Road
 Woodleigh
 East London
 5241

OR I am willing to collect them from the secretary if such an arrangement meets with the secretary's approval.

8. If you wish to indicate that a class has not been taught certain sections of the syllabus, please feel free to write a covering note on the respective class. This is not compulsory.
9. Please collect worksheets (questions) and return them to me with the completed scripts.

Your co-operation is much appreciated.

PUPIL WORKSHEET ON SOUTH AFRICAN WEATHER,
CLIMATE AND THE SYNOPTIC CHART

Please answer the following questions as fully as you can. If you cannot answer a question move onto the next one immediately. You only have 30 minutes for the worksheet. Your answers will be used to help with research and will not count for marks. Your co-operation is much appreciated.

1. If the sun's rays are vertically overhead at noon each day, why are the hottest temperatures recorded only 2 hours later?
2. If the atmosphere were motionless, with no wind at night, and there was no cloud cover would you expect the temperature to be warm or cold? Can you explain your answer with respect to winter conditions?
3. What atmospheric weather phenomenon is responsible for the transfer of
 - (a) heat poleward?
 - (b) cold equatorward?
4. Would the atmosphere at a place at the equator or at the poles be able to retain a greater vapour content?
5. If at a given time the temperature of the atmosphere is 15°C and the temperature at which condensation will occur is $-1,0^{\circ}\text{C}$, what can be said about the moisture content of the air?
6. Does atmospheric pressure always decrease with increasing altitude? Substantiate your answer.
7. Does temperature always decrease with increasing altitude? Substantiate your answer.
8. Can you explain how wind originates? Please do so.
9. Why is it that wind will never follow a direct path between two places?
10. Why would you regard the air in a high pressure system to be more stable than the air in a low pressure system?
11. Briefly state the fundamental difference between a normal (environmental) lapse rate and an adiabatic lapse rate.
12. Which of the climatic elements: temperature, wind, moisture, pressure, is the most visual feature on a synoptic chart?
13. What two operating forces are in equilibrium in a geostrophic wind?
14. Would one be able to locate geostrophic wind flow on a synoptic chart? Explain.
15. If the pressure digits associated with a weather station model are 023, what is the prevailing pressure at the station?
16. Is the circulation around a northern hemisphere anticyclone clockwise or anti-clockwise? Explain.

17. What name is given to the isolines on a synoptic chart over
 - (a) the ocean?
 - (b) the continent?
18. What weather systems are responsible for wet Cape Mediterranean winters?
19. What symbols on synoptic charts can be used to ascertain regional cloud cover?
20. Why is it that the Transvaal is highly susceptible to frost during the winter months?
21. Why is it that Highveld winters are dry?
22. Why is it that Western Cape summers are dry?
23. What atmospheric upper air feature inhibits the flow of warm, moist maritime air into the Transvaal interior during winter?
24. Why are South African Berg winds hot and dry?
25. Make a simple sketch of what you imagine a South Atlantic anticyclone to look like.

MEMORANDUM FOR PUPIL WORKSHEET ON SOUTH AFRICAN WEATHER,
CLIMATE AND THE SYNOPTIC CHART
"Concept Depth"

1. There is a temperature lag between the time of maximum insolation and maximum temperature as a result of the time taken for the shortwave insolation to be converted to longwave terrestrial radiation and be conducted as sensible heat into the atmosphere. (4)
2. During winter the atmosphere is cold and with the given conditions the Greenhouse effect is minimized. Terrestrial radiation is permitted to escape into the outer atmosphere since there is no cloud cover to reflect it back into the troposphere. The continuous loss of heat in this way causes the surface temperature to fall quickly and by the same process of conduction the lower layers of air are also cooled...The surface temperatures would, therefore, be cold. (5)
5. The difference between the dry bulb and dew point temperatures is indicative of the moisture content of the air. The greater the difference the drier the air, since the atmosphere will have to cool considerably before condensation will take place. (3)
6. No. A surface low may be replaced with a high pressure aloft. (2)
7. No. Temperature inversions occur at the surface as a result of nocturnal terrestrial radiation and aloft as a result of anticyclonic subsidence. (5)
8. Wind is the movement of air as a result of the equilibrium sought between adjacent (in the horizontal and vertical) high and low pressure systems as it moves from high to low. (3)
9. Wind, since it is moving from high to low pressure zones, is subjected to the Coriolis effect as a result of the earth's rotation. All moving objects are subjected to the same deflective force, to the right of the path of motion in the northern hemisphere and to the left in the southern hemisphere. (3)
10. High pressure systems are subsiding air systems. Subsidence creates pressure on the lower layers of air and thereby also increasing the temperature adiabatically. An increased temperature creates an inversion and serves to evaporate any moisture that may be condensed out as a result of vertical ascent from below. When upward air mobility and consequent cloud formation is inhibited, the atmosphere is classified stable. (4)
20. Skies are clear because of the predominant anticyclone. It is cold because of the altitude and season (absence of cloud cover). It is calm because of anticyclonic subsidence and dry because of the temperature inversion inhibiting the influx of moisture from the east (or simply stable system aloft). (7)
21. The temperature inversion created by the subsidence from the semi-permanent anticyclone is strongest in winter and is intersected by the Drakensberg escarpment, thereby inhibiting the advection of warm, moist air from the east thus rendering the atmosphere over the Transvaal absent of moisture. (3)

22. Western Cape summers are dry as a result of the southward migration of the thermal equator and consequent latitudinal shift of the wind and pressure belts to the south. The mid-latitude cyclone bearing westerlies are therefore too far south for their influence to be felt over the south-western Cape. (5)
24. As air descends from the plateau in its course of movement between the continental high and a coastal low (or eastward moving mid-latitude cyclone) it is warmed adiabatically by compression. Its moisture content is evaporated and reaches the coast as a hot, dry wind. (6)

"Objective Recall"

3. (a) Tropical cyclone
(b) Mid-latitude cyclone
4. Equator
11. A normal lapse rate is concerned with stationary air, i.e. the distribution of temperature with height, whilst an adiabatic lapse rate concerns the changing temperature of a moving air parcel.
12. Pressure
13. Pressure gradient force = Coriolis force
14. Yes. Geostrophic winds blow parallel to the isobars and this will occur where friction is least i.e. over the oceans.
15. 1002,3 mb/hPa
16. Clockwise
17. (a) isobars
(b) geopotential metre lines
18. Mid-latitude cyclones
19. Weather station models
23. Temperature inversion resulting from the subsidence of the semi-permanent anticyclone over the subcontinent.
25. A spiral air column with air descending in an anticlockwise manner.
- 1 Direction of air flow
 - 2 West north-westerly tilt
 - 3 Three dimensional



PUPIL ANSWER SHEET FOR WORKSHEET ON SOUTH AFRICAN WEATHER, CLIMATE
AND THE SYNOPTIC CHART

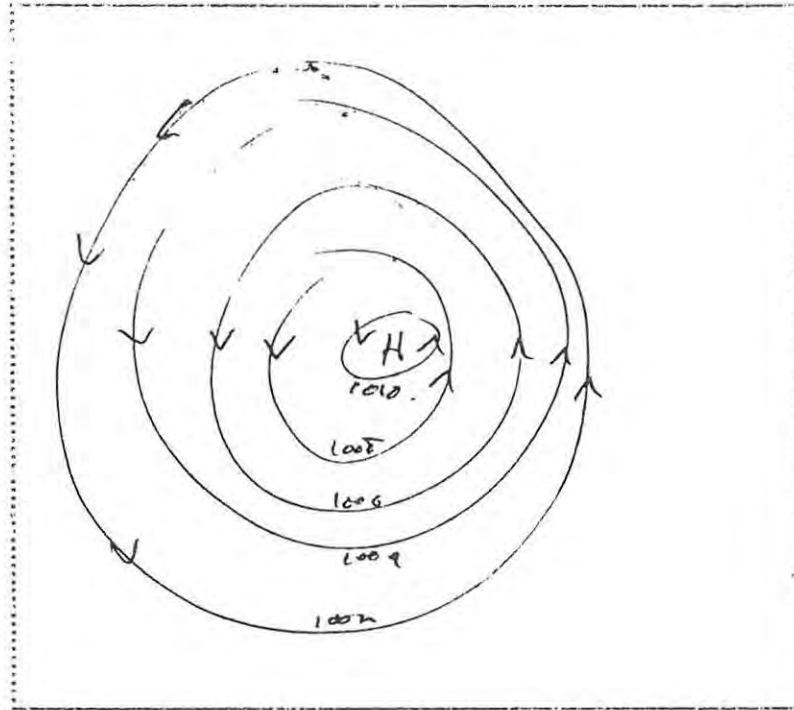
1. It takes time for the radiation to warm up the
toughest layers of earth while in turn warm up
the atmosphere above and lead to higher temperatures.
2. It would be cold because there would be no
cloud cover to initiate a greenhouse effect (as the
clouds absorb heat in re-radiation from the ground).
Thus in winter the H.P. situation results in
no cloud formation and this in turn results
in cold, dry conditions.
3. (a) tropical easterlies
(b) jet stream
4. the equator
5. It may be said that the moisture content of the
air is very little i.e. extremely dry air.
This is because of the large difference in day
and night temperatures.
6. ~~No~~ Yes the lighter gases always carry on rising with
the ~~reach a height of~~
7. No certain layers have inversions i.e.
an increase in temp with altitude.

3. ... Wind ... moving ... from ... a ... difference ... of ... pressure ...
 i.e. air will move from a H.P. area to a L.P. area
 ... along a pressure gradient ... This air is called wind.
9. ... The ... Coriolis effect, ... relief, ... latitude ... variations,
 ... gravity ... etc. will ... all ... affect ... the ... path, speed
 ... and ... direction ... of ... wind ... Relief ... for ... example ...
 ... will ... cause ... air ... to ... rise ... and ... sink ... as ... more ... and ...
 ... topographical ... obstacles ...
10. ... Air ... in ... a ... H.P. ... is ... descending ... air ... and ... no ... clouds,
 ... thunderstorms ... etc. ... will ... form ... No ... air ... disturbances
 ... will ... cause ... or ... be ... caused by ... instability ...
 ...
 ... In ... a ... L.P. ... cell ... air ... is ... constantly ... rising ... and ...
 ... condensation ... is ... occurring ... Thunderstorms, ... cyclones ...
 ... and ... even ... tornadoes ... may ... form ... as ... a ... result ...
11. ... The ... normal ... lapse ... rate ... is ... the ... rate ... at ... which ... air ... cools ...
 ... in ... still ... air ... while ... the ... adiabatic ... lapse ... rate ... is ...
 ... the ... pressure ... rate ... at ... which ... air ... cools ... down ... for ... (convection)
12. ... pressure ...
13. ... pressure / gravity ...
14. ... Yes, ... one ... would ... need ... to ... take ... a ... reading ...
 ... and ... compare ... it ... to ... the ... geostrophic ... wind ... scale ...
15. ... 1002, 3 mbars ...

15. ...clockwise because in the N. hemisphere anything is opposite to the
respect to wind flow
17. (a) ...isobars.....
(b) ...geopotential values.....
18. ...Atlantic Cyclones.....
19. ...Cy, Cs, As, Ns, C, Ac.....
20. ...The high level is under the influence of the Katabatic
H.P. cell. The clear, cold nights are the high altitude of
the plateau make for ideal frost conditions. The dry
air can lead to black frost. Some times.....
21. ...No rain occurs because the H.P. cell covers
the inversion layer to be below the level of the
escarpment thus cutting off any flow of moisture. 4
warm so air precipitation is thus nearly
impossible.....
22. ...In summer the W. Cape is under the influence of
the H.P. cell. (S. Atlantic cell) which for the
some years on a vertical above leads to
limited precipitation. 0
23. ...The inversion layer.....

24. When the air blows down the escarpment it...
 moves up at the dry adiabatic lapse rate and...
 becomes drier... water per 100 ft drop the winds are...
 dry because the air has ascended on the escarpment...
 and the air is thus hot and dry...

25.



A P P E N D I X 3

SUMMARY DATA AND CALCULATION OF STUDENT'S t FOR THE COMPARISON
BETWEEN MALE AND FEMALE MEANS ON PUPIL WORKSHEET PERFORMANCE

[x = male, y = female]

Higher Grade

$$\begin{aligned}\Sigma x &= 296 \\ \bar{x} &= 14,8 \\ \Sigma y &= 275 \\ \bar{y} &= 13,75 \\ \Sigma d_x^2 &= 864,8 \\ \Sigma dy^2 &= 1063,75\end{aligned}$$

Standard Grade

$$\begin{aligned}\Sigma x &= 126 \\ \bar{x} &= 7 \\ \Sigma y &= 68 \\ \bar{y} &= 4,86 \\ \Sigma d_x^2 &= 332 \\ \Sigma dy^2 &= 187,7144\end{aligned}$$

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{(\Sigma d_x^2 + \Sigma d_y^2)}{(N_x + N_y - 2)} \cdot \left[\frac{1}{N_x} + \frac{1}{N_y} \right]}}$$

$$\begin{aligned}t &= \frac{1,05}{2,2528053} \\ &= 0,4660855 \\ N_x &= 20 \\ N_y &= 20 \\ df &= 38 \\ t_{\text{critical}} &= 2,021 \\ p &= 0,05\end{aligned}$$

$$\begin{aligned}t &= \frac{2,14}{1,4831889} \\ &= 1,4428371 \\ N_x &= 18 \\ N_y &= 14 \\ df &= 30 \\ t_{\text{critical}} &= 2,042 \\ p &= 0,05\end{aligned}$$

A P P E N D I X 4

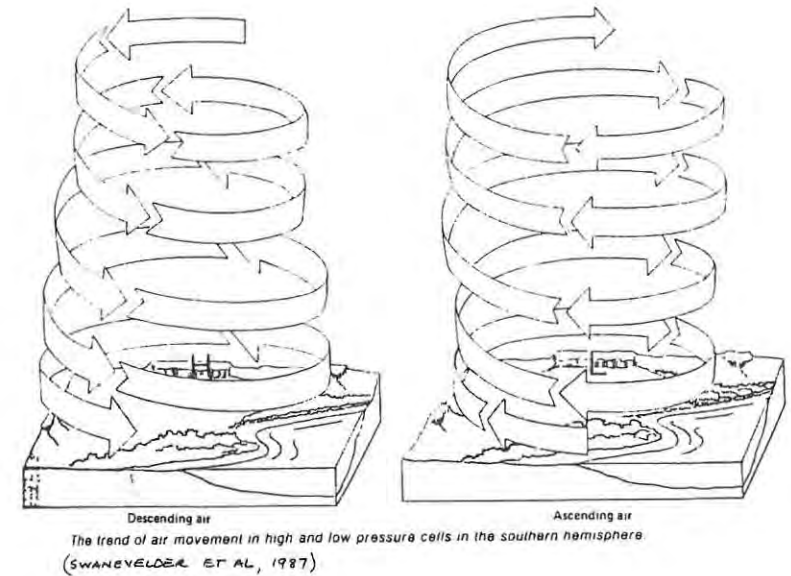
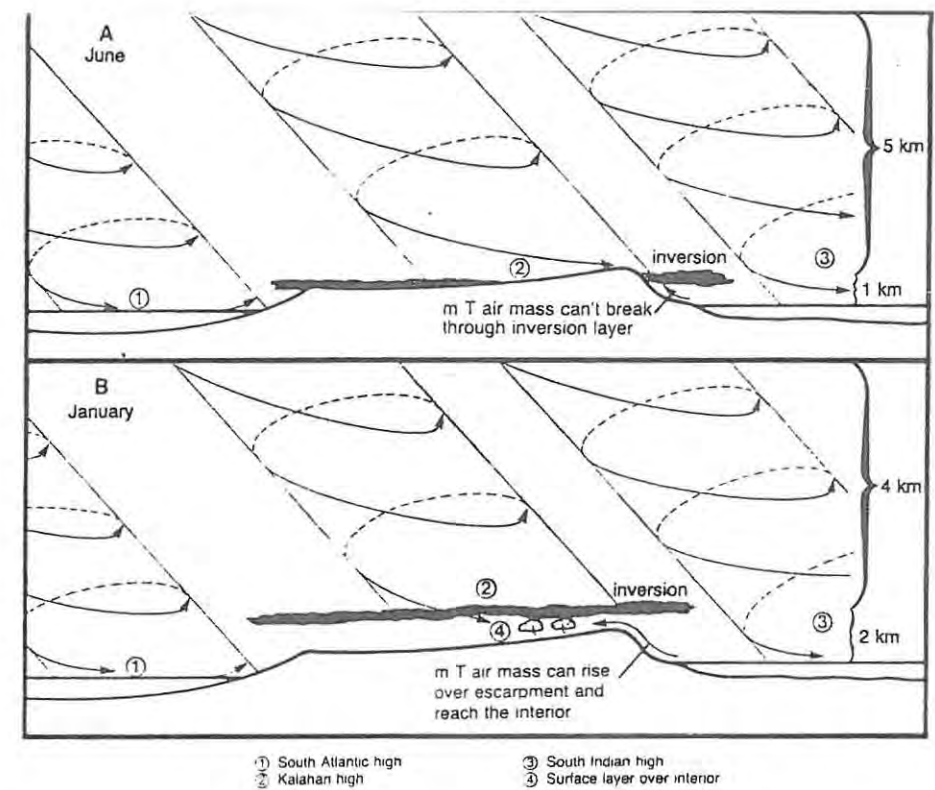
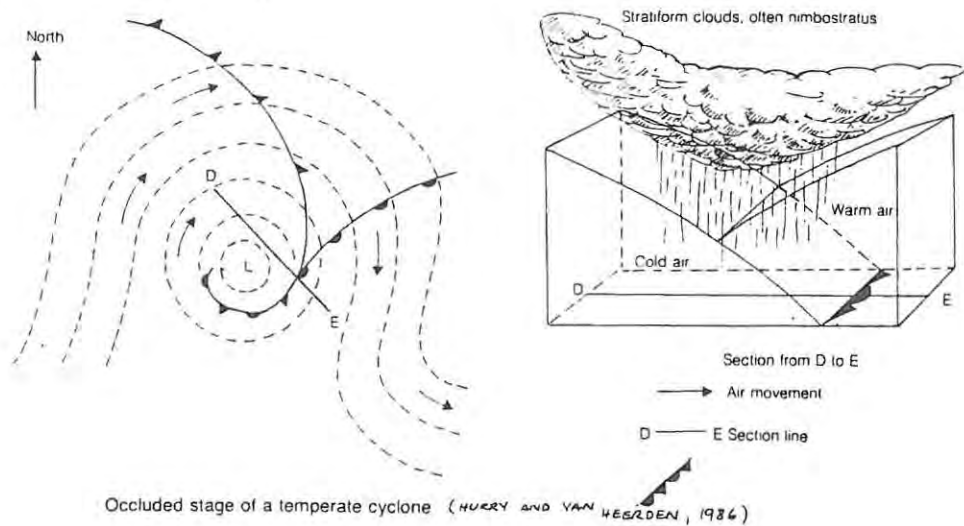
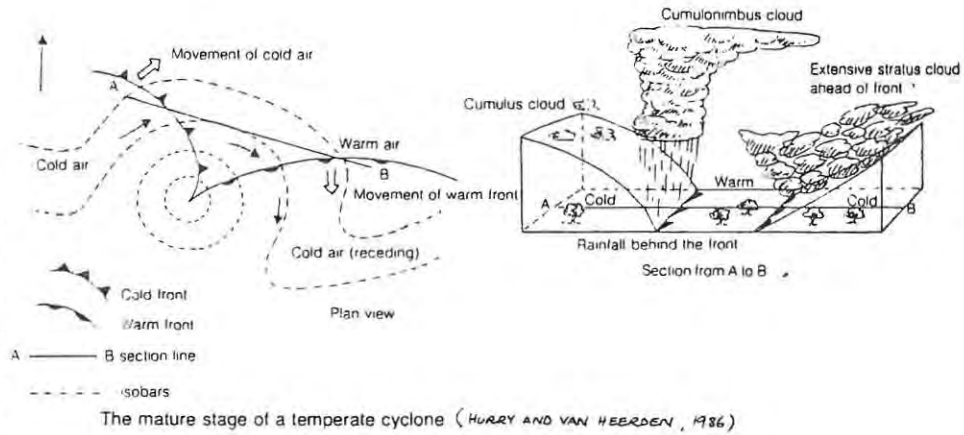
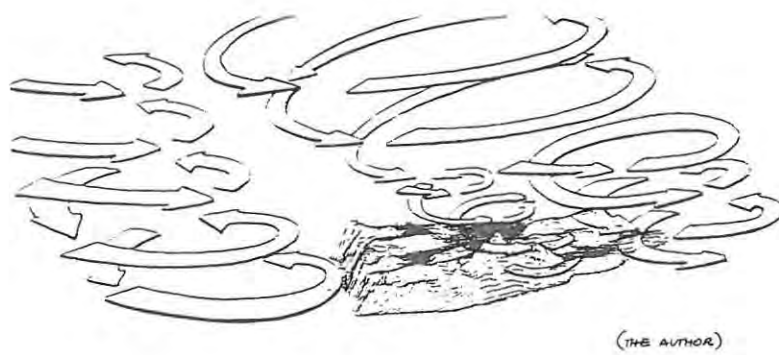
SUMMARY DATA AND CALCULATION OF PEARSON'S r FOR A CORRELATION
BETWEEN 'OBJECTIVE RECALL' AND 'CONCEPTUAL DEPTH' SCORES

	<u>Higher Grade</u>	<u>Standard Grade</u>
Σx	425	183,5
Σy	295,9	88,4
Σx^2	1937,25	517,99
Σy^2	1017,81	154,6
Σxy	1038	241,52

$$r = \frac{\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{N}}{\sqrt{\left[\Sigma x^2 - \frac{(\Sigma x)^2}{N}\right]\left[\Sigma y^2 - \frac{(\Sigma y)^2}{N}\right]}}$$

$$t = \frac{r \sqrt{N - 2}}{\sqrt{1 - r^2}}$$

r	0,526074	0,4712898
t	6,2474655	4,6276533
df	103	76
p	0,01	0,01



FORECASTING FROM SURFACE WEATHER MAPS. Recall that weather patterns move generally eastward in the middle latitudes. However, a particular weather system may move either north or south of a due-east line. Also, conditions within the system may change as it moves. As a general procedure, forecasting involves an estimation of (1) the movement and changes in highs, lows, and other pressure configurations; (2) the movement and changes of fronts and associated frontal weather conditions; and (3) the changes in air-mass characteristics shown on the previous map.

Although modern forecasting requires the careful analysis of the upper-level wind field which guides the synoptic features seen on surface-level maps, it is with these latter that we are concerned here. Remember that the forecasting process requires a thorough examination of previous weather maps, as well as of the current one. From this examination, an attempt is made to project these conditions into the future and determine the probable appearance of succeeding weather maps, thereby showing the weather conditions 12 to 36 hours later. Thus, forecasting is the estimation of future weather conditions from a study of past and present conditions. The forecast must therefore be in logical conformance with these conditions. Based on the long history of observations and synoptic weather studies of the National Weather Service, a number of useful general rules have been developed for use with surface weather maps. It should be realized, however, that each situation must be interpreted within the weather pattern at the time and that actual professional forecasting is based more on upper tropospheric than on surface patterns.

FORECASTING RULES RELATED TO LOWS.

1. An occluded low will move very slowly or remain almost stationary until it dissipates.
2. In general, lows tend to follow the record of previous days, that is, their historical sequence; they will also tend to move toward regions of greatest rainfall during the last 24 hours.
3. Secondary depressions tend to move in the direction of the wind circulation around the primary low, moving faster in winter than in summer.
4. Lows moving southeastward (northeastward in the Southern Hemisphere) usually increase in intensity on recurving to the northward (southward in Southern Hemisphere), but their movements will be slow while recurving.
5. Lows with isobars closely crowded on the west and northwest (west and southwest in the Southern Hemisphere) generally move slowly to the east or southeast (east or northeast in the Southern Hemisphere).
6. Rainfall and strong winds will continue for a longer period than usual in western and northern sections of the low (western and southern sections in the Southern Hemisphere).
7. A young low usually moves in the direction of the isobars in the warm sector.
8. Until a low occludes, its rate of movement increases.
9. After a low has occluded, its speed decreases until the maximum deepening of its center occurs.

FORECASTING RULES RELATED TO HIGHS.

1. Ridges of high pressure between lows tend to move in the same direction and with the same speed as the lows.
2. Highs that separate a series of lows tend to move southward (northward in the Southern Hemisphere).
3. In general, highs move with the same speed and in the same direction as the frontal cyclone (low).
4. Small (closed) highs usually move faster than large ones.
5. Warm highs tend to move slowly or become stationary.

FORECASTING RULES APPLICABLE TO PRESSURE CENTERS.

1. When the warm sector narrows, the disturbance deepens until occlusion takes place.
2. When fresh cold air intrudes in a filling depression, it will start to deepen again.
3. In winter a low will usually deepen when passing over the ocean from land; in summer, deepening usually takes place as the low passes from ocean to land.
4. A fully occluded depression rarely deepens, but it may fill up slowly or persist for several days.
5. Old depressions may fill up rapidly when new deepening lows move into their circulation.
6. Large depressions, when completely occluded, move very slowly and sometimes on an irregular course.
7. Depressions tend to move around large, warm, well-established highs in the direction of the airflow around the boundaries of the highs.

FORECASTING RULES APPLICABLE TO FRONTS.

1. Fronts tend to dissipate (frontolysis) in anticyclonic regions.
2. When cold air lies to the left of the general airflow, the sharpness of the front increases.
3. Fronts with warmer air in the cold air mass to the northward (southward in the Southern Hemisphere) are short-lived.
4. A fast-moving cold front soon dissipates; warm fronts usually move more slowly than cold fronts.
5. When the pressure increases slowly after passage of a cold front, continued poor weather is indicated; a rapid rise in pressure and drop in temperature following a cold-front passage indicate clearing weather.
6. A nonfrontal depression tends to move in the same direction as the strongest winds circulating around it, that is, in the direction of the isobars where they are nearest together.
7. The more a secondary depression deepens, the more it approaches the center of the primary depression. Eventually it will absorb the old primary and become the primary depression itself.

FORECASTING RULES RELATING TO WEATHER ALONG FRONTS.

1. Frontal precipitation normally will be more intensive the sharper the frontal convergence of winds as indicated by the angle of isobars and the resultant shift of the wind.
2. The prefrontal rainfall zone on a warm front will be narrow if the axis of the high-pressure ridge ahead is relatively near the warm front.
3. An extended area of prefrontal precipitation occurs when there is a strong pressure gradient within the warm sector and no marked ridge of high pressure ahead.
4. In subtropical latitudes, weather activity of cold fronts is more pronounced than that of warm fronts; in polar latitudes, the greater weather activity accompanies warm fronts and occlusions of the warm-front types.
5. A slow-moving cold front normally has a broader zone of precipitation than a rapidly moving cold front. In this connection, there may not be a continuous zone of precipitation along a rapidly moving cold front but some prefrontal showers and squalls instead.
6. A continuous precipitation zone may be expected along and behind a slowly moving cold front but no squalls and showers.

FORECASTING FROM LOCAL INDICATIONS. It is only in recent years that the mariner has had the aid of radio bulletins to provide synopses and forecasts of weather conditions at sea. As a result many, if not most, mariners have developed a so-called "weather sense." Actually, they are simply drawing conclusions after noting certain observational conditions with their results during a period of years at sea. We have now studied the scientific basis for many of these conclusions.

1. When the dew is on the grass,
Rain will not come to pass.
2. A morning fog that obscures the sun's ray
Indicates the coming of a clear day.
3. Mackerel sky, twelve hours dry.
4. A veering wind means weather fair,
A backing wind, foul weather's near.
5. Rainbow at night, sailor's delight,
Rainbow at morning, sailor take warning.

Proverbs 1 and 2, of course, refer to conditions that require clear nights, and hence some time lapse is necessary for any bad weather that may follow. Proverb 3 refers to cirrocumulus which is often associated with the outer fringe of the stratus cloud deck preceding the warm front. As a rule, precipitation will not fall for another 12 hours, until the front draws much closer. The fourth proverb may often, but not necessarily, be true. The reader can explain this one for himself. The fifth is slightly more involved. Rainbows are common features of showers or thundershowers and are always seen in the opposite part of the sky from the sun. A rainbow at night, with the sun setting in the west, must be in the eastern sky, indicating that the storm has already passed. A rainbow in the morning must, in the same way, exist in the western sky, thereby heralding the approach of the storm.

Numerous other weather adages and examples of local forecasting could be cited. On the whole, however, such forecasting simply requires that the observer explain and interpret to himself the conditions he may see, drawing on his knowledge for this purpose.

COMPREHENSIVE CHART OF SYMBOLS USED ON SYNOPTIC CHARTS

C ₁ Clouds of type C	C ₂ Clouds of type C	C ₃ Clouds of type C	W Past Weather	N Total amount of clouds	B Barometric characteristics
0 No Sc, St, Cu, or Cb clouds	0 No As, Al, or Nl clouds	0 No Ci, Cs, or Cs	0 Clear or few clouds	0 No clouds	0 Rising then falling. Now higher than 3 hours ago
1 Cu with little vertical development and insignificantly flattened	1 Thin As (altocumulus) layer	1 Filaments of Ci scattered and not increasing	1 Partial cloudy layer (clouds in variable sky)	1 Less than one tenth or one fourth	1 Rising, then steady, or rising, then rising more slowly. Now higher or lower than 3 hours ago
2 Cu of considerable development generally towering, with or without other Cu or Sc below at same level	2 Thick As, or Nl	2 Dense Ci in patches or limited sheets only, not increasing	2 Cloudy (broken or overcast)	2 Two or three tenths	2 Rising steadily, or unsteady. Now higher than 3 hours ago
3 Cb with tops reaching cloud layer, but distinctly not predominant and unchanged with or without Cu, Sc, or St	3 Thin Al, cloud elements not changing much and at a single level	3 Ci, often small, shaped, formed, from an associated with Cu	3 Squally or stormy, or drizzling or blowing rain	3 Four tenths	3 Falling or steady, then rising, then rising more slowly. Now higher than 3 hours ago
4 St formed by spreading out of Cu. Cu often present also	4 Thin Al in patches, cloud elements and/or scattering of more than one level	4 Ci, often small, gradually increasing and usually thickening as it approaches	4 Fog, or smoke, or thick dust haze	4 Five tenths	4 Steady. Same as 3 hours ago
5 St not formed by spreading out of Cu	5 Thin Al in bands or in a few gradually spreading patches and usually thickening as it approaches	5 Ci, and Cu, often in converging bands or Ci above the center, but never not reaching 45° altitude	5 Drizzle	5 Six tenths	5 Falling, then rising. Same as 3 hours ago
6 St or Sc both but not Sc of bad weather	6 Al formed by the spreading out of Cu	6 Ci and Cu, often in converging bands, or Ci above the center, but never not reaching 45° altitude	6 Rain	6 Seven or eight tenths	6 Falling, then steady, or falling, then falling more slowly. Now lower than 3 hours ago
7 Sc and/or Sc of bad weather	7 Dense layered Al as a thick layer of Al, or some or different levels	7 Ci covering the entire sky	7 Snow, or rain and snow mixed, or ice pellets (sleet)	7 Nine tenths or more (but with openings)	7 Falling steadily, or unsteady. Now lower than 3 hours ago
8 Cu and Sc both formed by spreading out of Cu with bases at different levels	8 Al in the form of Cu, topped with Al, or with heights	8 Ci increasing and not spreading into the Cu and Cu may be present	8 Thunderstorm with or without precipitation	8 Completely overcast	8 Steady or rising then falling or falling then falling more slowly. Now lower than 3 hours ago
9 Cu having a clearly defined vertical top when level topped with or without Cu, Sc, or St	9 Al of a cloud the upper part of dense, Cu and Cu may be present	9 Ci being the most common cloud present	9 Thunderstorm with or without precipitation	9 The obscured	9 The obscured

† The symbol is not plotted for "low" when "00" is reported. When "01, 02, or 03" is reported for "low" the symbol is plotted on the station circle. Symbols are not plotted for "h" when "3 or 8" is reported.

Symbols used on the station model.

00	01	02	03	04	05	06	07	08	09
Cloud development: Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	State of ice on the ground: generally unchanged during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour	Clouds generally not observed or NOT observed in becoming visible during past hour
10	11	12	13	14	15	16	17	18	19
Light fog	Light fog	Light fog	Light fog	Light fog	Light fog	Light fog	Light fog	Light fog	Light fog
20	21	22	23	24	25	26	27	28	29
Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain	Shallow (NOT freezing) rain
30	31	32	33	34	35	36	37	38	39
Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain	Slight or moderate rain
40	41	42	43	44	45	46	47	48	49
Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation	Fog or drizzle at time of obs. but NOT at time of observation
50	51	52	53	54	55	56	57	58	59
Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle	Intermittent drizzle
60	61	62	63	64	65	66	67	68	69
Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)
70	71	72	73	74	75	76	77	78	79
Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)	Intermittent rain (NOT freezing)
80	81	82	83	84	85	86	87	88	89
Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers	Slight snow showers
90	91	92	93	94	95	96	97	98	99
Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow	Moderate or heavy snow

† Refers to "hail" only. †† Refers to "soft hail," "small hail," and "hail."

Symbols used on the station model (continued).

A P P E N D I X 8

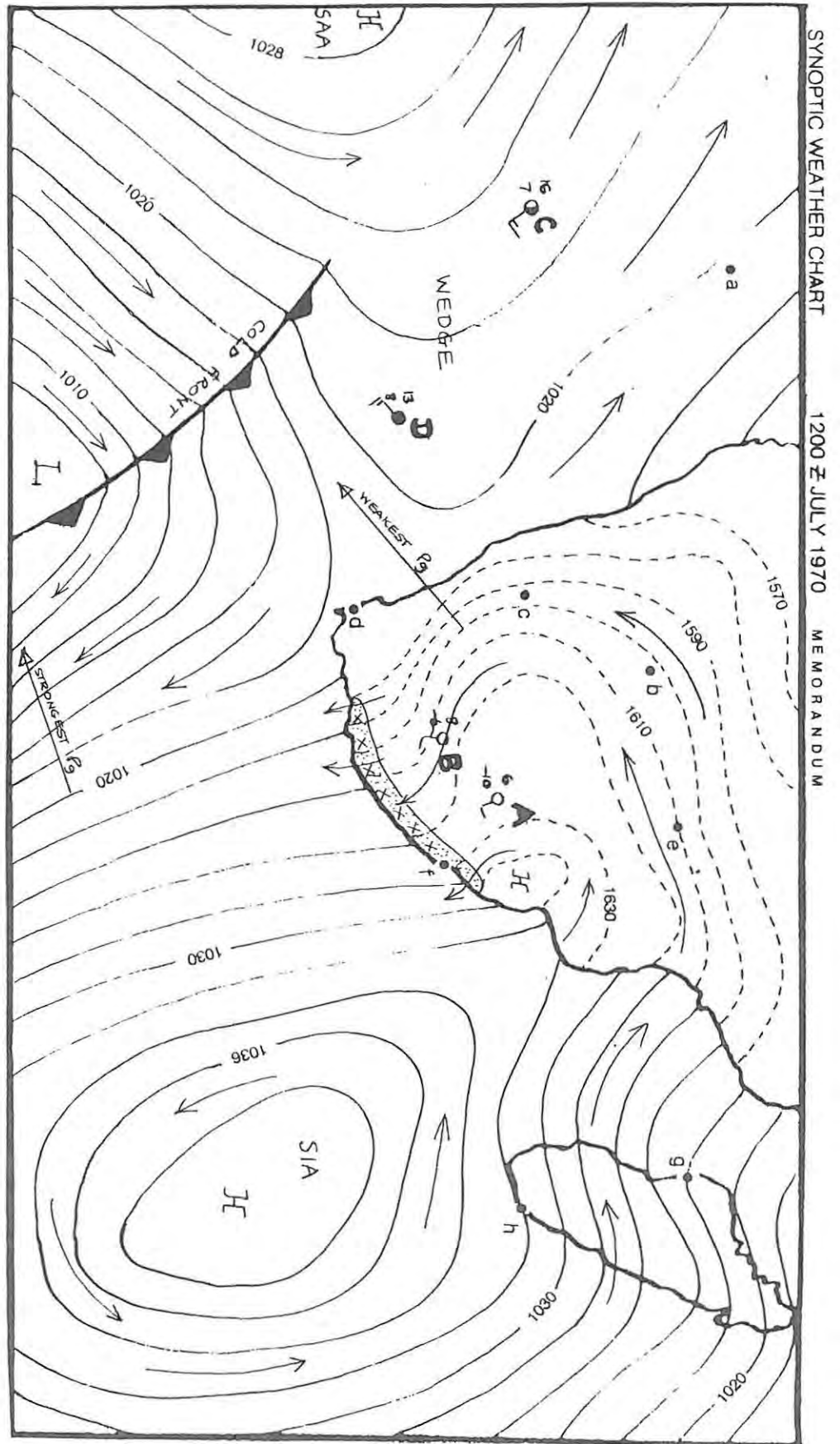
MEMORANDA FOR SYNOPTIC CHART WORKSHEETS 1, 2 AND 3

ANSWERS (WORKSHEET 1)

1. Ship report
2. See labelled chart
3. See labelled chart
4. (i) 1038 hPa
(ii) 1008 hPa
5. See labelled chart
Ferrel's Law
6. (i) south easterly
(ii) north easterly
(iii) northerly
(iv) variable (if any)
7. See labelled chart

8. <u>Temperature</u>	<u>Land stations</u>		:	<u>Sea stations</u>	
	A	B		C	D
<u>Dry bulb</u>	6	8	:	16	13
<u>Dew point</u>	-10	-6	:	7	8
<u>T - Td</u>	16	14	:	9	5

9. The difference between dry bulb and dewpoint temperatures is greatest over the land where the moisture content is less.
9. (i) C and D are associated with the cloud band ahead of the cold front.
(ii) A and B have clear skies because of the effects of anticyclonic subsidence.
10. Frost: Cold temperatures; calm atmosphere; clear skies; dry air and ground (winter)
11. Approximately 1600 km
12. See labelled map
Steepness of pressure gradient is directly proportional to windspeed.



ANSWERS - WORKSHEET 2

1. See map
2. 996 mb
3. Geopotential metres
4. (i) No
 (ii) Weather station reports by ships
 (iii) Northerly station: South-easterly at 10 knots
Southerly station: North-westerly at 20 knots
 (iv) Northerly station conditions associated with air flow anticyclonically around South Atlantic anticyclone. Wind speed only 5 msec^{-1} because isobars spaced wide apart (comparatively)

Southerly station conditions associated with air flow cyclonically around westerly depression. Isobar spacing accounts for considerably stronger winds.
5. Winds blowing south-westerly at 30 knots . Conditions overcast. Dry bulb temperature is 4°C ; dew point temperature 2°C .
6. Mountainous east coast induces southeasterly winds generated by anticyclone (Indian) to rise. Warm ocean - moisture content high.
7. (i) $19,93 \text{ msec}^{-1}$
 (ii) approximately 17 msec^{-1}
 (iii) $10,09 \text{ msec}^{-1}$
 (iv) 8 msec^{-1}
 Isobar spacing; HP, LP

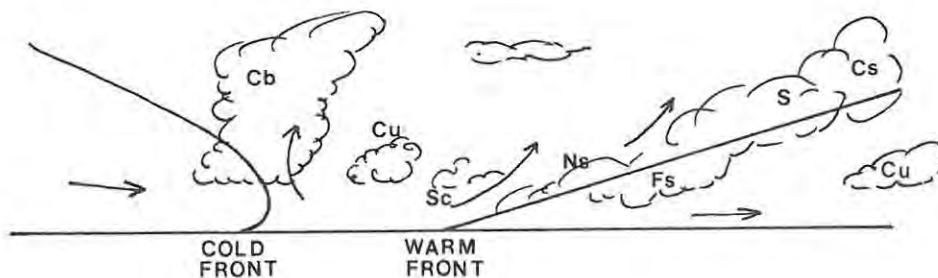
ANSWERS - WORKSHEET 3

1. South Indian anticyclone, South Atlantic anticyclone, Mid-latitude cyclone, Continental high pressure system (strong because of winter)

	Windhoek	Coastal Station
Dry bulb	19	18
Dew point	0	14

Windhoek's dry bulb temperature is warmer because it is further from the moderating influence of the cold Benguela current. The dew point temperature is the temperature at which condensation will take place, hence it is dependent on the moisture content of the atmosphere. Windhoek's dew point temperature is 0°C which means that temperature (dry bulb) must fall 19°C before condensation will occur. It emphasises the dryness of the continental air. The coastal station shows a dry bulb - dew point difference of only 4°C , because of its coastal location.

3. The area is dominated by the high pressure system over the land. The air is thus subsiding. Subsidence results in air heating adiabatically and therefore tends to evaporate any moisture in the air and suppress the formation of clouds.
4. Mature stage
- 5.



6. Simply describe in the order of occurrence each of the climatic elements as the fronts pass over Cape Town. Mention must be made of cloud type; precipitation; humidity; pressure; windshifts; temperatures (all obtainable from the chart)
7. Frost; dew. Since temperatures in the interior are very low eg. -1° ; -3°C mention can be made of Black frost and Hoar frost.
Conditions: Cold, dry ground; windless; cloudless
 T_d 0°C : Dew forms
 T_d 0°C : Hoar frost forms
 T 0°C and T_d not reached: Black frost forms

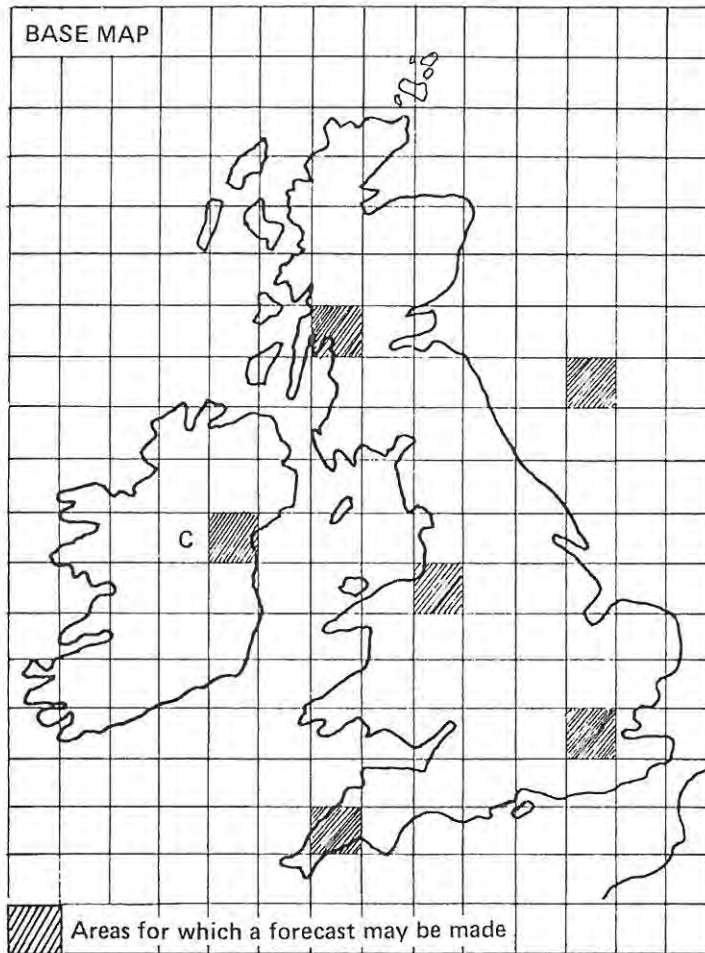
The presence of the high pressure system causes cloudless skies; subsiding air; usually gentle winds (see weather station models for confirmation). Temperatures are cold, therefore all conditions are satisfied.

8. The general circulation is anticlockwise around the South Indian anticyclone. Winds are therefore expected to be northerly and north-easterly longshore, if at all (see isobar spacing). They are, however, onshore 10 knots. Since this is 14h00, the sea breeze is probably beginning to peak as a result of onshore flow between a relative low pressure on the island and high pressure offshore.
 9. Geopotential metre lines: contours of the pressure at 850 mb; the height which corresponds with the height of the plateau. This is a more accurate pressure indication than reducing pressures to sea level.
 10. (i) Berg winds from the interior, dropping off the plateau, are warmed adiabatically.
(ii) Conform to the north-easterly surface flow of the South Indian anticyclone.
1. Southward extension of the ITCZ combined with local thermally induced surface low.
 2. (i) It is summer (1970-12-16). The continental high pressure system has weakened and hence has lifted, lifting as well the temperature inversion. The South Indian anticyclone can, therefore, feed in warm, moist air off the Indian Ocean over the Drakensberg and around the Lesotho massif. Upon reaching the continent the air is lifted orographically and condensation occurs forming thick cloud cover which in places has given rise to drizzle.
(ii) ☉ = symbol for drizzle
(iii) Light, intermittent drizzle. It is effective since it allows infiltration. It is important to agriculture.
 3. Cape Town is under the influence of the South Atlantic anticyclone. South-easterly winds of 10 to 15 knots prevail. Also the South Indian anticyclone airflow is subsiding, therefore there is no cloud cover.
 4. Approximately 25 knots
 5. Ship report
 6. Not dramatically, if at all. The South Atlantic anticyclone ridging in behind the front will push the cold front toward the south-east.
 7. The high pressure belt on the 1970-06-05 chart has moved northward in response to the migration of the sun's rays. The westerly wind belt has also moved northward so that the mid-latitude cyclones of this belt affect the weather of the subcontinent. On the 1975-12-16 chart the high pressure belt is further south for similar reasons.
 8. (i) Tropical cyclone; second cyclone of the season.
(ii) Tropical oceans; temperatures of approximately 27°C; spawned here because of high rate of evaporation in summer; have origins in easterly wave.
(iii) Central pressure is 1006 mb which is relatively high therefore the tendency is to be increasing; windspeeds decreasing; fairly far south already; areal expanse decreasing.
 9. A pressure gradient exists between the South Atlantic anticyclone and the thermal low pressure over the land. The expected airflow, therefore, under stationary global conditions is perpendicular to the isobars. However, because the earth is rotating, any moving body will experience a deflectional effect called the Coriolis effect. The effect is given by Ferrel's Law (Buys Ballot law) which is to the left of the path of motion with one's back to the wind in the southern hemisphere. The movement is, therefore, toward the north-west, causing a south-easterly geostrophic flow obtained when the Coriolis force equals the pressure gradient force causing a wind parallel to the isobars. The geostrophic nature is enhanced because of the uniformity of the sea surface which reduces friction.

10. See map
11. Approximately 30 knots; used the geostrophic wind scale.
12. Approximately $23\frac{1}{2}^{\circ}\text{S}$; very close to the summer solstice on 22 December, when the sun's rays are overhead this latitude.
13. (i) It moves in response to the eastward movement of the South Atlantic anticyclone in its wake.
 (ii) Winds blowing offshore from the escarpment lifting air off the ocean as it passes over the coast.
 (iii) During the winter months the high pressure system over the subcontinent is well developed. The westerlies are further north than at any other time and consequently a pressure gradient is set up as the mid-latitude cyclones move eastward. A pressure gradient can also be set up between the high pressure system and a coastal low. The airflow is thus offshore at the coast. These winds drop from the plateau onto the coastal plain, are warmed adiabatically on descending and the increased temperatures evaporate any moisture. They therefore reach coastal locations as hot, dry, oppressive winds.
14. (i) Thunderstorm
 (ii) Convictional thunderstorm. The trigger mechanism is solar heating. The dry bulb temperatures are approximately 30°C . The dew point temperatures are 18°C therefore the air is moist. This is obtained from the feeding in of warm, moist air by the South Indian anticyclone.

A P P E N D I X 9

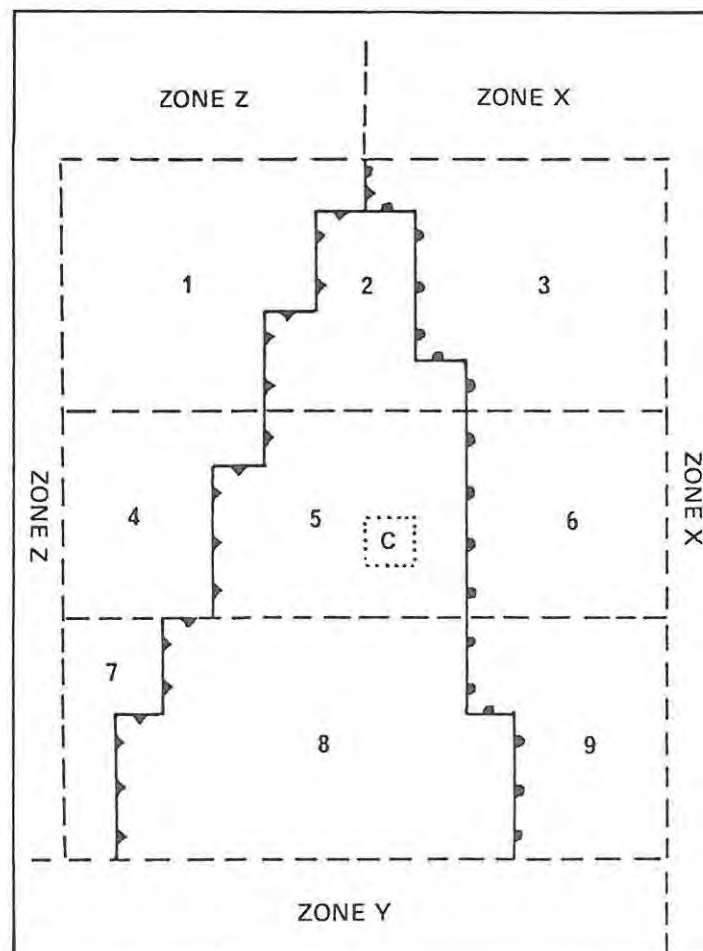
GRIDS AND KEYS FOR 'THE DEPRESSION GAME'



12	11	6	
	10	5 7 and 8	2
3	4	9	

The centre box (10) coincides with the 'C square' on the depression model.

Movement matrix for the depression model



Depression model

WEATHER KEYS

HEAVY then CLEAR	HEAVY	DRIZZLE and RAIN
VERY HEAVY	DRIZZLE SHORT CLEAR SPELLS	VERY HEAVY
HEAVY	DRIZZLE LONG CLEAR SPELLS	HEAVY

RAINFALL

8	12	7
10	13	9
11	14	10









TEMPERATURE °C

CUMULUS 4	some NIMBO- STRATUS 6	STRATUS and ALTO- STRATUS 7
CUMULO- NIMBUS 8	STRATUS 3	NIMBO- STRATUS and STRATUS 8
NIMBO- STRATUS 7	STRATUS and some CUMULUS 4	NIMBO- STRATUS 8

CLOUD TYPE and COVER (1/8)

RISING then STEADY	STEADY for SHORT TIME	FALLING SLOWLY
RISING FAST	STEADY	FALLING FAST
RISING	STEADY for LONG TIME	FALLING

PRESSURE

	CALM	
		
		

WIND DIRECTION
and STRENGTH

Weather in Marginal Zones

X Infrequent drizzle, 8 °C,
cirrus cloud 2/8 cover,
pressure falling slightly, SSE
wind, 5 knots.

Y Clear, 16 °C scattered stratus
cloud 4/8 cover, pressure
steady, SW wind, 5 knots.

Z Showers, 9 °C, fair weather
cumulus 3/8 cover, pressure
steady, NNE, 5 knots.

The information is boxed for easy reference.
Wind information is shown by arrows flying
with the wind; half a barb represents 5 knots.
Area 6 has southerly winds blowing at about
15 knots.

Weather keys for depression model

RECORD SHEET

AREA		FORECAST					ACTUAL WEATHER					Right or Wrong?
START	Senior Forecaster											
2hrs												
4												
6												
8												
10												
12												
14												
16												
18												
20												
	Rainfall	°C	Cloud type and cover ($\frac{1}{8}$)	Pressure	Wind direction & strength	Rainfall	°C	Cloud type and cover ($\frac{1}{8}$)	Pressure	Wind direction & strength		