A CLIMATOLOGY OF THE COASTAL LOW IN THE SW CAPE

BY

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ABSTRACT

The Coastal Low is a shallow cyclonic mesoscale weather 'disturbance' which migrates around the southern African subcontinent on a fairly regular basis. It is generated and maintained by the synoptic scale circulations. The movement and surface characteristics have been well documented by a number of authors but few detailed studies have been undertaken on its vertical structure in southern Africa. In addition to this, most of the previous work has been of a meteorological nature. This study has concentrated on a more climatic approach in its investigation of the vertical and surface features of the Coastal Low as it migrates through the South Western (SW) Cape.

The SW Cape is a 'transition region' for the migration of the Coastal Low; situated between the west and south coasts with a distinct local climate due to the complex topography of the region. This fact tends to alter the characteristic features of the Coastal Low system but appears not to prevent the Coastal Low from migrating through the region. The Coastal Low is regarded as being an internal trapped Kelvin wave and corrected surface pressure values best indicate its migration characteristics. However upper air analysis indicates that temperature values (between 950-900mb) at the level of the inversion, produce one of the best signatures of the Coastal Low's passage. This is related to the strong subsidence from above the 850mb level in the pre-Low period. This strong divergence dynamically compresses the lower layers into low level wind speed maxima on either side of the centre of the system. The Coastal Low appears to have a very complex structure, and two results from this study in the SW Cape bear particular mention. Firstly the offshore flow at the escarpment level is weakly defined. Secondly also, the longshore spatial extent of the Coastal Low system has been estimated to have an 'inner' diameter of 150-200km and an 'outer' diameter of aproximately 1000km.

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CHAPTER 1

INTRODUCTION

INTRODUCTION

Southern Africa's weather and climate, is dominated by the subtropical anticyclonic and westerly frontal systems of the Southern Atlantic and Indian Oceans. The topography of the subcontinent with its interior plateau, bordering mountain ranges and narrow coastal plain, aids in the development of mesoscale coastal weather systems. One such disturbance is the Coastal Low - a low pressure feature which migrates around the southern African coastline. The interaction between the larger scale synoptic systems and the mesoscale Coastal Low produces a variety of inclement weather conditions. These include, hot and dry berg winds preceding the system and a drop in temperature with the influx of low level cloud once the centre has passed. Many of these features have been studied and reported under a broad spectrum of "weather" occurrences, in most coastal regions of the world. However, the occurrence of the Coastal Low is comparatively rare, being restricted mainly to five coastlines in the world (Figure 1). The southern African system appears to be the most well defined and integrated of these.

'COASTAL LOWS' : A WORLD REVIEW

The Coastal Low as a mesoscale coastal circulation disturbance is not unique to southern African coastal areas (except in name). In western Australia, Troup (1956) referred to such phenomena as "Meridional" fronts. In southern Australia it is called a "Cool Change" (Berson et al., 1957,1959; Smith et al., 1972; Wilson & Stern, 1985; Garratt et al., 1985; Ryan & Wilson, 1985) and in South Eastern Australia as the "Southerly Buster" (Hunt, 1894; Gentilli, 1962). In Chile these disturbances cause high

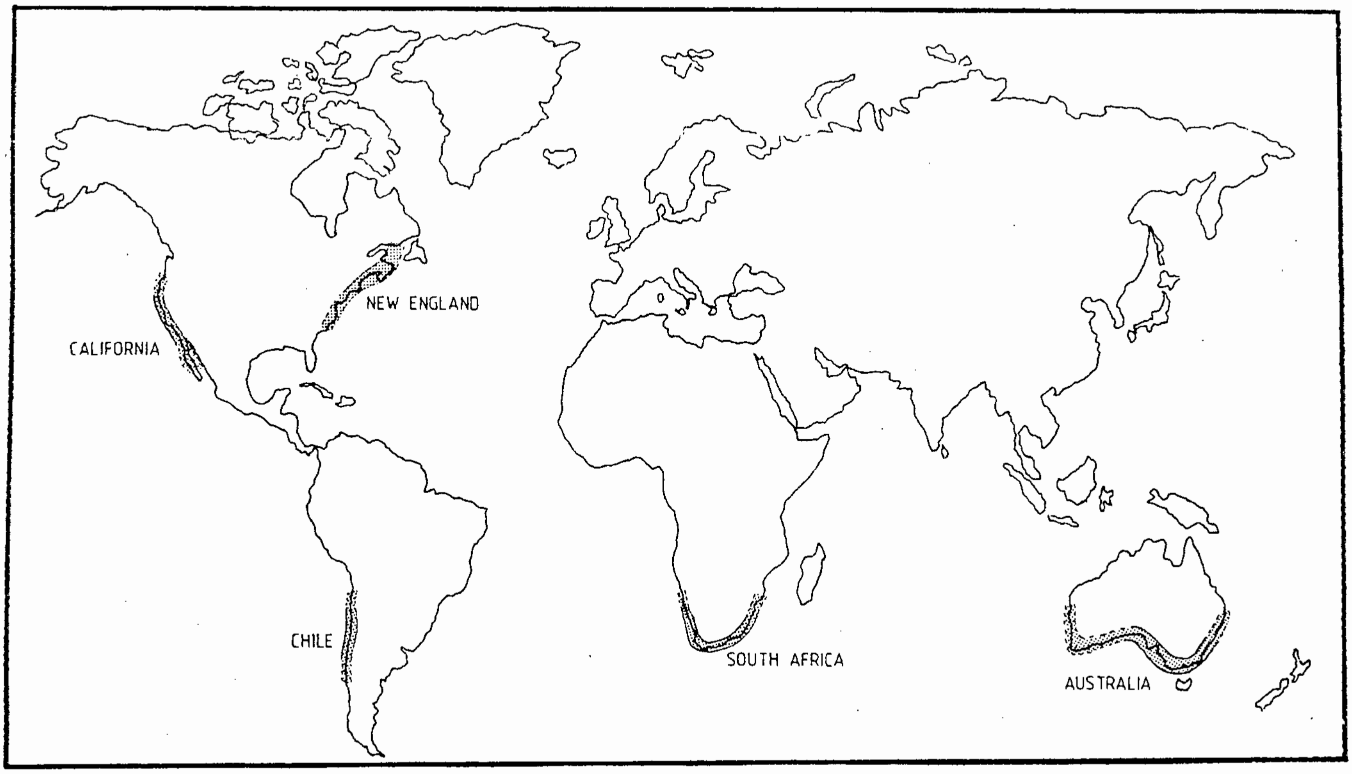

Figure 1. Location of mesoscale systems similar to the southern African Coastal Low.

pollution potentials and have been referred to as "Coastal Lows" (Rutland, 1981,1983). Mesoscale disturbances also occur along both coastlines of North America. On the East Coast, these disturbances have been described as "coastal frontogenesis and cyclogenesis" (Bosart et al., 1972; Bosart, 1975,1980; Maccarthy & Young, 1978; Marks & Austin, 1979; Ballentine, 1979; Gedzelman & Donn, 1979) with the emphasis of research on the frontal characteristics. On the West Coast, focus of research has been on coastal marine fog which is related to these mesoscale disturbances (Palmer, 1917; Leipper, 1948; Noonkester, 1979).

The various studies show that these mesoscale disturbances differ in their nature and in their characteristics in the different regions of the world, thereby making direct comparison difficult. In addition, an obvious difference exists between Northern and Southern Hemispheric disturbances, due to the 'sense of rotation' in each hemisphere and thus in their subsequent cyclogenesis. Despite the variations of the mesoscale systems a number of features similar to those of the southern African Coastal Low are found.

One of the most noticeable features of these coastal disturbances, is the subsiding warm offshore flow, found in the pre-Low period. Rutland (1983) showed that this occurred below 2000m, with the subsidence being maintained through the night into the early morning hours. This warm offshore flow is referred to as the Santa Anna on the Californian coastline (Noonkester, 1979), and is similar in nature to the Berg wind found in southern Africa. According to Rutland (1983) maximum heating at the 900mb level accompanied by severe pollution episodes occurred during the pre-Low period.

The centre of the system is marked by a surface pressure minimum and varying intensities of cyclogenesis, a feature which appears to be common to all regions. However Bosart (1975) has discussed the coastal front (boundary between offshore and onshore flow), which tends to occur 12 hours in advance of the passage of the Coastal Low pressure in the New England region of NE America. This front, often demarcated the boundary between frozen and non-frozen precipitation. Information extrapolated from Noonkester's study on coastal marine fog showed that a minimum wind speed (of <4m/s) occurs at the pressure minimum and lasts for approximately 5-6 hours. The combination of this calm period and a pre-Low wind maximum (of >8m/s) at a height of 300-500m suggest strong similarities to the Coastal Low in the SW Cape.

In the post-Low period, an inflow of cool moist air, referred to as the "Cool Change" by Berson et al. (1957, 1959) and the "Southerly Buster" by Hunt (1894) and Gentilli (1962) is one of the most commonly discussed features. The gust 'front' talked about by Gentille is very similar to that experienced along the east coast of southern Africa.

COASTAL LOWS: SOUTHERN AFRICA

Lombard et al. (1941) described the Coastal Low as a low pressure region with a closed circulation occurring on, or just off the coast, its formation being linked to the continental equatorial trough when it extended to the coast. This was said to result in warm subsiding air from the plateau displacing the cooler coastal air and giving rise to a "thermal low" on the coast. The low pressure was described as being associated with a number of weather features such as offshore berg winds, subsidence, low inversions, high temperatures and the backing of shallow longshore south east winds (for a west coast system) to easterly and finally north westerly winds. They went on to suggest that if the north west wind gradients are relatively slack, then the post-Low period could be accompanied by shallow nocturnal radiation fog or low Stratus cloud and possibly drizzle. It was suggested that the movement of the Coastal Low is restricted by the diurnal circulation and also by the behaviour and speed of the "Southerly Low". The Coastal Low was also seen to be seasonal in that it occurs more frequently in summer along the west coast and in winter along the south coast.

Van Lingen (1944) further discussed the Coastal Low as a wave or "subtropical front" which separated the continental air from the advancing maritime air behind it. She proposed that the low pressure itself, was generated by the off-plateau winds which caused a "scouring effect" in the lee of the mountains. The travelling speed of the systems was related to the rate of backing of the offshore flow and hence to the speed of the retreating overland High and the advancing "Sub-Antartic" depression from the west.

Taljaard et al. (1961) and Taljaard (1972) subsequently referred to a "sub-tropical front" and a "leader front", as being the forward boundary of the sub-inversion layer of cool moist air which precedes a cold front. The "leader front" was not perceived to be a true front but rather to be a surface discontinuity which could often be sharper and more intense than that found at the real front. These included sudden changes in wind direction, temperature drops of up to 15^{o}C and appearance of low cloud. The pressure minimum found at the "leader front" was seen by Taljaard to be a lee trough formed by an offshore flow in the lowest 2 or 3km.

A study of the movements of pressure minima over southern Africa by Preston-Whyte and Tyson (1973) showed a 6-day periodicity along the South African coastline. This was equated with the periodicity of the travelling westerly disturbances. The authors stated that they were unsure as to what extent the Coastal Low amplified this pressure oscillation. Preston-Whyte (1975) further discussed the bio-climatic consequences of Coastal Lows on local populations in coastal Natal. Restricted ventilation in the pre-Low period, due to the lowering of the subsidence inversion, resulted in increased pollution potentials. The high temperatures in some episodes were also shown to result in acute heat stress, particularly in urban environments.

In the late 1970's and early 1980's attention was given to the more theoretical aspects of the generation and modelling of the Coastal Low. Gill (1977), in a significant study, interpreted the Coastal Low of South Africa as an atmospheric coastally trapped internal Kelvin wave. The forcing function of these disturbances appeared to be the velocity component of the large scale synoptic flow, normal to the coastline. An associated strong low level inversion prevented the escape of 'energy' upwards while the escarpment acted as a horizontal boundary. The model showed that due to effects of nonlinearity (for eg. large-amplitude disturbances such as the changes in inversion heights), Low's are more prominent than High's. Nguyen and Gill (1981) later showed that in the linear case, the generation of Coastal Lows is not more predominant than the generation of

Coastal Highs. Gill's model however gave a rough estimate of the Rossby deformation, as being in the order of 300km with a longwave speed of 20m/s. With a speed of 6-8m/s (21-30km/h), a Coastal Low could travel between 480-720km per day. Due to nonlinear effects, the average speed of the system was shown to increase to some critical point along the coastline. The minimum inversion height was found to coincide with the low at the surface. However due to phase differences in the lower atmosphere, the orientation of the low pressure vortex above the inversion was such that it did not occur until some time later. The example of Durban was cited where the lowest height of the 800mb surface occurred on the day after the lowest surface pressure.

Bannon(1980) went on to show that using a 2-layer equatorial beta-plane model, a relationship could be shown to exist between the Coastal Low and a similar cell located over the interior plateau (Lombard et al., 1941; van Ligen, 1944). This "companion" Low is most intense near the coast and decays with distance inland. It was also found to move in conjunction with the Coastal Low. Below the plateau, low-level synoptic divergence was found to generate the Coastal Low, while upper-level convergence aided in the formation of the low over the interior. This prompted Banon to conclude that the Coastal Low and its "companion" Low over the interior may be interpreted as forced internal double Kelvin waves. Another point raised by Banon was the effect of the synoptic forcing function. Synoptic anticyclones, are found to be responsible for the generation of Coastal Lows along the west coast and are thus associated with large scale subsidence. This subsidence aids in the lowering and the strengthening of the coastal and plateau inversions. Synoptic cyclones would have the opposite influence. A weaker inversion would be less effective in containing the Coastal Low vertically. Westerly cyclones would therefore produce a weaker response than the anticyclonic circulation of the South Atlantic ocean.

The effect of the topography on weather systems over southern Africa was modelled by De Wet (1979) using a 5-layer, primitive equation, fine grid model. In a case study of a Coastal Low on the west coast, the model showed very little horizontal wind inflow into the lower layers, thereby indicating massive upper air divergence. This divergence resulted in a substantial heating effect below 750mb. The model showed a temperature difference between the topography case and the no-topography case of about 9°C at 900mb.

By the early 1980's an overall understanding of the characteristics and behavioural properties of the Coastal Low was still lacking. This lead to a Coastal Low workshop which was held in March 1984 under the auspices of the South African Society for Atmospheric Sciences (SASAS). A summary of the papers presented at the workshop follows.

Coastal Low Workshop:

de Wet: showed that by using a numerical simulation model, the effects of topography were found to have a significant impact in the short term forecasting (24-36 hours) of Coastal Lows.

Walker: Discussed the relative frequency of Coastal Lows and found them to be more frequent in February and October on the west coast with a mean frequency of 10 days. Migration speeds of the systems were calculated to be between 4-10m/s (15-35km/h). The system's effect on local wind regimes was found to be much reduced at Olifantsbos (southern tip of peninsula) than further north on the west coast at Hondeklip Bay (north of Langebaanweg - Figure 2).

Hunter: Showed that a 4,4 day periodicity was found between Coastal Low systems on the east coast (Durban). He stated that in general on the south coast, the Coastal Low systems travelled about 10-16 hours ahead of the westerly frontal systems.

Shillington: Studied micro-pressure oscillations (linked to Cut-Off/Coastal Lows) and calculated that the systems moved along the south coast at speeds between 17-54m/s. Low pressure systems were also shown to be related to long period edge wave activity in the sea.

Estie: Offered a basic definition of the "Coastal Low" as a unique low pressure system (below the elevation of the plateau - 1,5km in height or 850mb level) which develops along the coast. He discussed a number of features which related to the formation and movement of Coastal Lows along the southern African coastline and drew an important distinction between Coastal Lows and Cut Off Lows. These were the absences of vertical shear and upper air inversions in the Cut Off Low systems.

Jury: Considered several case studies in the SW Cape, using vertical and horizontal data sets. He concluded that some Coastal Lows were shown to "pulse" while others deteriorated when approaching the Peninsula from the west coast and were then seen to "jump" to the east of Mossel Bay (Figure 2). He also suggested that winter Coastal Lows were more energetic and unpredictable than summer systems.

Kamstra: Used vertical soundings (up to 250m) over the sea to investigate the passage of the Coastal Low. He concluded that Coastal Lows were highly asymmetrical in both the vertical and horizontal scales.

Diab: Considered the effects of Coastal Lows on the availability of wind power for the east coast (Richards Bay -north of Durban) and for the west coast (Koeberg). It was concluded that the east coast systems in the pre-Low and post-Low regimes contributed up to 70% of the total wind power, while on the west coast this was only about 50%.

Nelson & Glyn-Thomas: Investigated the changing of flow direction in ocean currents in the SW Cape and found this phenomenon to occur typically every 3-10 days. It was often associated with low atmospheric pressure events.

Sciocatti: Showed that fog formation (up to 15-20 nautical miles off the coast) on both the west and south coasts was found to be a common occurrence in the post-Low periods of Coastal Lows.

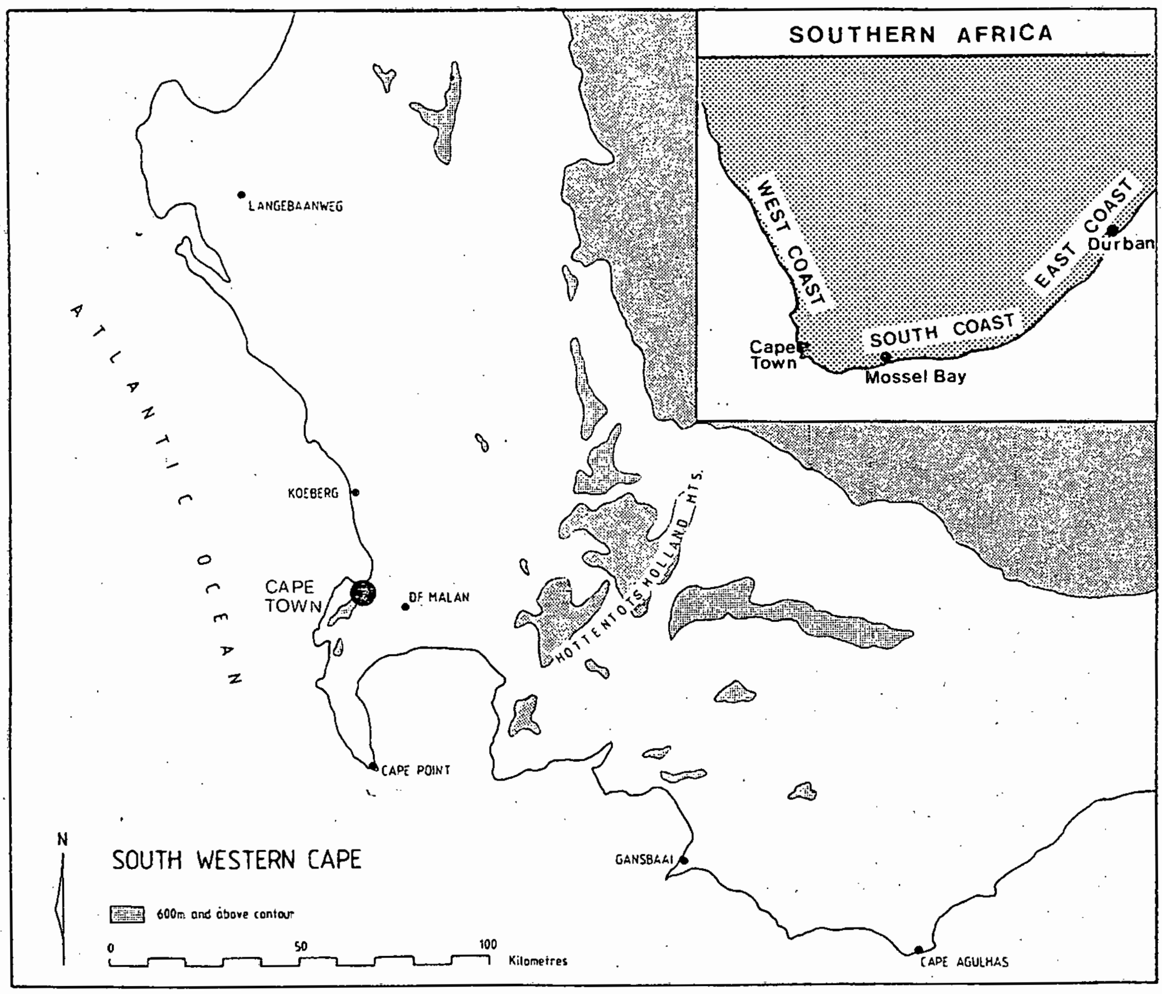

Figure 2. Location of study region in the SW Cape with the inset showing the names and positions of the various coastal margins used in this study.

The workshop produced a proceedings booklet containing the various papers and also a chapter identifying the current knowledge of Coastal Lows in southern Africa. Furthermore, the participants listed areas in which further research of the phenomena ought to be addressed. One such telling statement being.. "..there is a distinct lack of all forms of data needed to establish the nature of the Coastal Low".

DEFINING THE "COASTAL LOW"

Before proceeding with the details of this study, attention must be given to a clear identification of a Coastal Low. While the workshop tended to offer a fairly broad definition of the phenomena, it was finally agreed to accept the following description used by forecasters at the South African Weather Bureau.

> "A Coastal Low is a small area of relatively lower pressure which appears in the lower levels of the atmosphere (below 700mb) along the coast. It is associated with subsidence off the interior escarpment. The accompanying inversion and wind shear in the lower levels strengthen the recognition of the Coastal Low for the forecaster, but the essential features of the Coastal Low are the pressure minimum and the shallowness of the system."

The workshop appended two further notes to the definition. The first was, that the definition excluded any low pressure system situated on the coast which would be supported by an upper air trough or Cut-Off Low in the vertical alignment. Secondly, that the Coastal Low would not form as a discrete circulation system if there were no topography along the southern African coastline.

SUMMARY OF THE GENERATION MECHANISM OF COASTAL LOWS

The Coastal Low appears to be generated and maintained by the large scale synoptic systems. The forcing function being the offshore flow of these synoptic circulations (Gill, 1977). The offshore flow (often referred to as berg winds) results in falling pressures along the coast due to lower air densities (adiabatically heated subsiding air) and a "lee" effect (where conservation of potential vorticity pertains) (Taljaard et al., 1961). The Coastal Low is vertically contained by a subsiding upper air inversion and horizontally by the coastal escarpment (Figure 3). The mesoscale disturbances result in large amplitude disturbances (eg. inversion heights). It therefore follows that non-linear effects favour the formation of coastal "lows" as against coastal "highs" (Gill, 1977). Gill further commented upon the similarity of the Coastal Low system to the coastally trapped internal Kelvin wave. The Coastal Low is thus strongly dissipative and its horizontal speed along the coastline and its offshore extent are entirely controlled by the synoptic scale forcing functions.

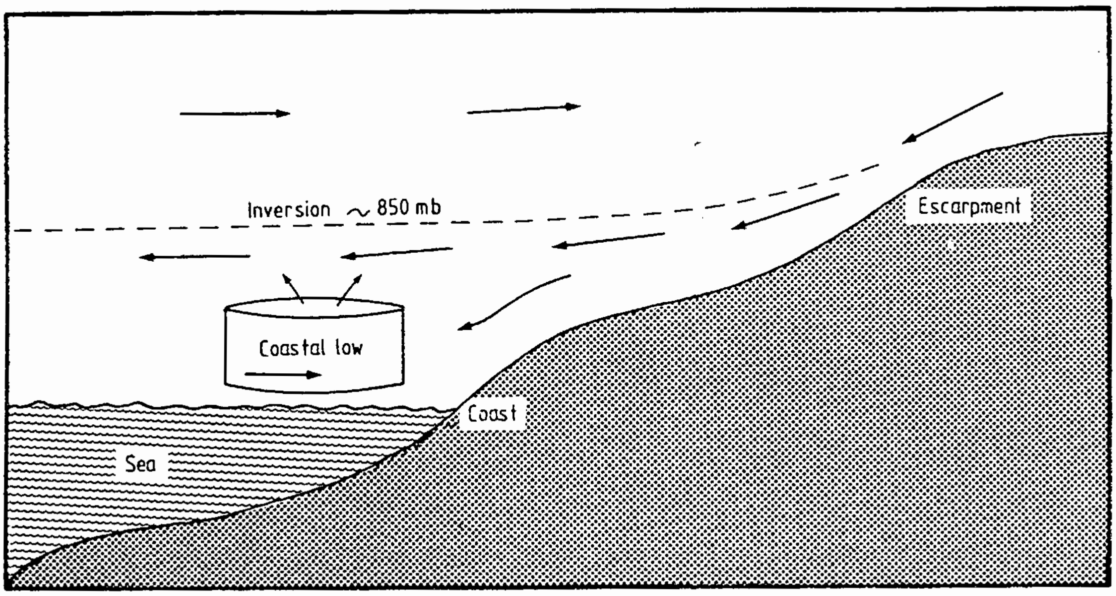

Figure 3 Coastal Low Mechanism (after the Coastal Low Workshop 1984).

CLASSIFICATION OF COASTAL LOWS

Two distinct synoptic conditions have been identified to be responsible for the generation of Coastal Lows along the southern African coastline. In the first situation a high pressure cell ridges south of the country, resulting in offshore flow over the west coast. This is generally considered to be a summer phenomenon, and has been referred to as a "Summer Coastal Low" ("class 1" Coastal Low

Workshop) (Figure 4a). The second situation, is more characteristic of the winter circulation where the offshore flow takes place over the south coast ahead of the westerly frontal depressions, . This has been referred to as a "Winter Coastal Low" ("class 3" Coastal Low Workshop) (Figure 4c). It is further considered that the second situation can evolve naturally from the first, resulting in a Low moving down the west coast, through the SW Cape to the south coast. This situation has been referred to as the "Travelling Coastal Low" ("class 2" Coastal Low Workshop) and is depicted in Figure 4b.

THE APPROACH AND AIMS OF THIS STUDY

The incidence of Coastal Lows over the SW Cape during the period November 1984 through to October 1985 was considered. During this 12-month period 28 mesoscale disturbances were identified. According to the definition suggested by the Coastal Low Workshop, 13 of these systems could unambiguously be classified as Coastal Lows. Analysis was in fact restricted to these 13 case studies (details of which are given in Appendix 1).

While analysis of each case study provided an insight into the nature and behaviour of the individual systems within their synoptic settings, it failed to provide an overall viewpoint of the Coastal Low in a climatological sense. This was achieved by use of an Eulerian viewpoint which effectively considers the Coastal Low systems moving over a particular point or vertical line in space. By analysing each system relative to some common identifying feature (eg. the lowest surface pressure reached), each Coastal Low sequence could be considered as a similar time series in space. Then by summating all 13 of these time series (each aligned relative to their minimum pressure), it was possible to calculate a set of average data points through time and space, thereby depicting a 'mean' Coastal Low.

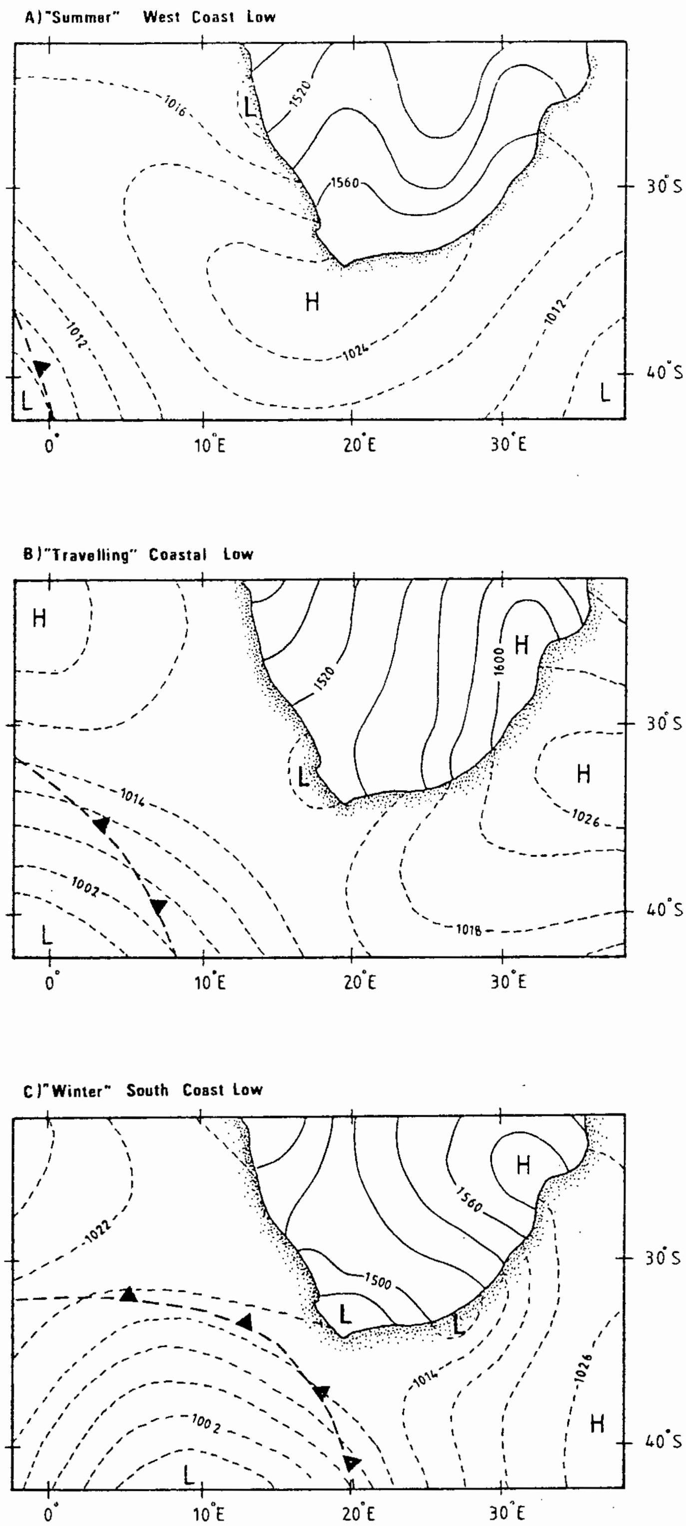

Figure 4(a,b,c) The seasonal (synoptic) classification used by the Coastal Low Workshop (1984).

The overall aim of this study was to identify the mean characteristic changes in meteorological conditions of the Coastal Lows in its migration through the SW Cape, ie. to document the climatology of Coastal Lows.

A new approach has been adopted for the presentation of this thesis; The body of the text is made up of four chapters in the form of written papers ready for journal submission. The climatology of the Coastal Low has been investigated using four different sampling techniques and methods and thus each is reported in a separate chapter (paper) [1]

Chapter 2

The structure of Coastal Lows as sampled by
Radiosonde soundings in the SW Cape.

Analysis of the mean larger scale synoptic conditions (through the 1000 to 700mb layer) using Radiosonde soundings from DF Malan airport. The following parameters were considered in the analysis; pressure, dry bulb temperature dew point temperature, wind speed and direction, the presence and strength of inversions and the amount of clouds prevailing during the passage of a Coastal Low.

1. The data used for each chapter is given in the appropriate Appendix, ie. Chapter's 2 data can be found in Appendix 2.

Chapter 3

The wind structure of Coastal Lows in the SW Cape as penetrated by Doppler Acoustic Radar.

A detailed investigation of the lower 1000m of the boundary layer focusing in particular on the mean wind structure as observed from a Doppler Acoustic Radar (Sodar) situated at a site in Milnerton (12km north west of DF Malan).

Chapter 4

Surface characteristics and spatial behaviour of the Coastal Low in the SW Cape.

A mesoscale surface analysis of the mean Coastal Low wave as it passes over the SW Cape using a network of six surface stations.

Chapter 5

A mesoscale analysis of a Coastal Low: 19 to 22 January 1985.

A case study of a typical Coastal Low passage through the SW Cape. The episode chosen was 19 to 22 January 1985 and both radiosonde and Sodar data were employed in the analysis as well as data obtained from the surface stations.

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CHAPTER 2

THE STRUCTURE OF COASTAL LOWS AS SAMPLED BY RADIOSONDE SOUNDINGS IN THE SW CAPE

A climatology of Coastal Lows in the SW Cape, as provided by Radiosonde soundings at DF Malan shows that in the pre-Low period, upper air subsidence is a significant feature in the Coastal Low system. However, offshore flow appears to be weakly defined. The Coastal Low passage is most clearly identified in the free atmosphere by a maximum temperature signature between the 950-900mb levels. Pressure variations are greatest near the surface and show a 12 to 24 hour phase lag between the surface and the layer above the upper air inversion (greater than 850mb).

THE STRUCTURE OF COASTAL LOWS AS SAMPLED BY RADIOSONDE SOUNDINGS IN THE SW CAPE

Mesoscale migratory low pressure systems are a common feature along the coastal areas of southern Africa. Known generally as 'Coastal Lows', they appear to form on either the west or south coasts (depending on the synoptic conditions) and to migrate eastward to dissipate finally off the coastal margin north of Durban (see location map, Figure 1). The migration and associated weather characteristics of these phenomena are well known and have been discussed by a number of authors (Lombard et al, 1941; van Ligen, 1944; Taljaard, 1961, 1972; Preston-Whyte, 1975; Coastal Low Workshop, 1984). The modelling and dynamics have been addressed by several authors, amongst whom are Gill, 1977; De Wet, 1979; Banon, 1980; Nguyen & Gill, 1981. Very little however has been written about the vertical structure of Coastal Lows. It is the aim of this paper to examine the vertical structure and associated features as sampled by radiosonde soundings in the South Western (SW) Cape area.

BACKGROUND

The Coastal Low was described by Gill (1977) as a coastally trapped atmospheric Kelvin wave. Associated with this 'wave' is an area of relatively low surface pressure (a leeward trough, Taljaard et al., 1961) and a cyclonic circulation which is generated and maintained by the offshore component of the synoptic flow. Weather conditions often associated with the pre-Low period include warmer temperatures (berg winds) and a high pollution potential related to upper air subsidence and the lowering of the inversion level. This is followed by the backing of winds, the influx of cool moist air and the occurrence of substantial cloud cover. However, a significant feature of the system is its relative shallowness, occurring below the 700mb level; and, has a distinctive surface pressure minimum (Coastal Low Workshop, 1984). Pressure therefore, could be used as a primary identification feature of such systems.

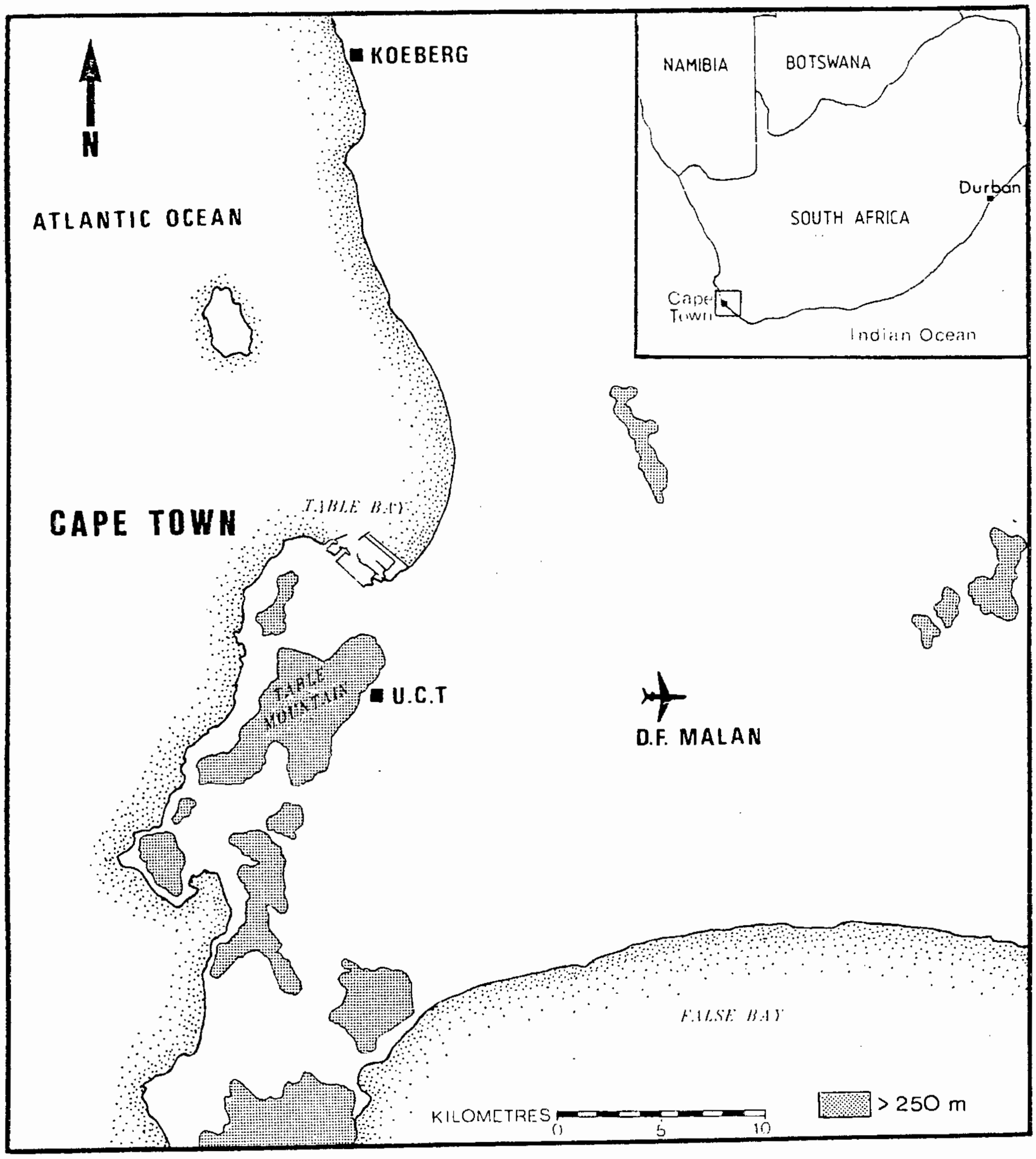

Figure 1. Location of the study region.

METHODOLOGY

The 12 month period from November 1984 to October 1985 was used as the sample period. Surface and 700mb synoptic charts were examined to identify possible Coastal Low occurrences. The 700mb level was used to distinguish between 'Cut-Off Low' and 'Coastal Low' systems, with pressure minimums for Coastal Lows not being discernable by this level. Three stations with hourly pressure values, namely D.F. Malan, Koeberg and the University of Cape Town (UCT) were used to cross-check the upper air signature as identified by the radiosonde soundings. In order to obtain a clear identification of each Coastal Low episode, the 24 hour period preceding the surface pressure minimum had to register a pressure drop of not less than 4mb. This ensured that the normal diurnal pressure fluctuation was not mistaken for a Coastal Low passage and also that the systems being examined were sufficiently 'mature'. A sequence period of 60 hours was used for each Coastal Low episode; 36 hours before the pressure minimum (-36H) and 24 hours after (+24H). A total of 28 non-frontal systems were identified of which 13 were classified as 'classic' Coastal Lows. For each of these thirteen '60-hour' sequences, the dry bulb temperatures (T), dew point temperatures (Td), pressure-height levels (mb) and wind speeds and directions were sampled at each of the standard pressure levels (1000, 925, 900, 850, 775, 700mb). In addition air mass quality, cloud conditions and inversions were investigated.

In order to show the characteristics of the Coastal Low specifically, it was decided to consider the system as an 'atmospheric disturbance' about a mean. In order to calculate such a mean (actually a series of means), the monthly means for each of the 01h00(AM) and 13h00(PM) radiosonde soundings (for P, T, Td, etc) were 'averaged' to annual mean values, thus giving an AM and PM annual mean value (Table 1). These were then compared in order to determine possible diurnal correction factors. The only significant difference in AM and PM values occurred in the temperature parameter at the 1000mb level where the difference was 4,7°C. It was decided in this case, to use the annual mean AM and PM values where necessary; for the remainder, (H, Td and T at other levels) a single annual mean was used (see column headed 'annual mean' Table 1).

TABLE 1. Annual means for the 01h30 and 13h30 Radiosonde soundings at DF Malan for the period November 1984 to October 1985.

PRESSURE LEVEL (mb)	PARAMETER	TIME 01h30 (AM)	13h30 (PM)	DIFFERENCE BETWEEN AM & PM	ANNUAL MEAN	COMPARISON TALJAARD (1981)
1000	Height H (gpm)	139	146	7	143	
	Temperature T (C)	14,5	19,3	4,7	*	
	Temperature Td (C)	10,9	10,7	0,2	10,8	
925	H	799	809	10	804	
	T	14,2	14,6	0,4	13,8	
	Td	5,2	4,5	0,7	4,9	
900	H	1030	1041	11	1035	
	T	13,4	13,6	0,2	13,5	
	Td	2,4	1,8	0,6	2,1	
850	H	1509	1520	11	1514	1520
	T	11,5	11,5	0	11,5	10,8
	Td	-3,0	-1,9	1,1	-2,5	
775	H	2276	2286	10	2281	
	T	8,0	8,2	0,2	8,1	
	Td	-11,0	-11,5	0,5	-11,3	
700	H	3108	3119	11	3113	3120
	T	3,5	3,7	0,2	3,6	3,8
	Td	-17,6	-17,4	0,2	-17,6	

For each 12 hour interval during the 60 hour period of the Coastal Low sequence (-36H to +24H) the annual mean value for each parameter was subtracted from the actual reported values, giving an absolute difference at each time interval. For the 13 cases the differences were then finally summated and averaged to give a mean time-height sequence of values (i.e. differences about the mean - Table 2).

TABLE 2. Difference about an annual mean (from Table 1), of pressure levels (H) and temperatures (T & Td) for the passage of Coastal Lows through the SW Cape.

PRESSURE LEVEL (mb)	PARAMETER	TIME (HOURS) -36	-24	-12	0	+12	+24
1000	Height H (gpm)	38,3	12,8	-20,3	-47,5	-35,0	-21,0
	Temperature T (C)	-1,8	0,3	2,5	3,7	0	-1,7
	Temperature Td (C)	-2,0	-1,4	-1,0	-0,2	1,6	0,3
925	H	31,9	16,2	-11,5	-36,7	-32,6	-26,0
	T	-0,9	2,5	6,4	6,8	0,4	-3,2
	Td	-1,3	-3,8	-3,2	-3,1	0	2,2
900	H	31,7	17,7	-7,4	-32,6	-34,1	-28,5
	T	-1,3	2,9	5,5	5,8	0	-3,7
	Td	-2,0	-4,8	-2,5	-1,8	0,5	3,6
850	H	31,5	22,2	1,1	-22,0	-34,1	-34,5
	T	-0,2	2,9	5,6	5,0	0,3	-2,3
	Td	-6,0	-5,7	-6,2	-2,7	0,1	1,9
775	H	31,1	29,2	14,5	-10,5	-31,5	-36,9
	T	0,6	2,5	4,1	3,9	0,5	-1,5
	Td	-7,9	-6,2	-4,1	-1,8	2,0	0,6
700	H	34,0	34,3	22,3	-0,8	-30,3	-40,9
	T	1,6	2,5	2,5	2,7	1,2	-0,4
	Td	-7,1	-5,2	-5,5	1,5	1,1	-3,8

In summary, the following analysis was based on the 'averages' calculated from 13 case studies which were in turn obtained from absolute differences about the annual mean. Each of these parameters will now be discussed in greater detail.

DISCUSSION

(a) Pressure:

By graphically plotting the variation of pressure at the standard levels of the Coastal Low sequence (Table 2), it is obvious that pressure variation (-36H to 0H) is greatest near the surface [+38,3-(-47,5]=85,8gpm at 1000mb and [34,0-(-0,8]=35gpm at the 700mb level for the same time period (Figure 2). From the slope of the contour lines it is clear that a phase lag exists between the occurrence of the pressure minimum at the 1000mb surface and at progressively higher levels. This lag is about 12 to 24 hours between the 1000 and 700mb levels, a result similarly noted by Gill (1977) where a phase lag of approximately 24 hours between the surface and the 800mb level for a Durban location was found. One other notable observation evident from the plotted data is that in the post-Low period the continued

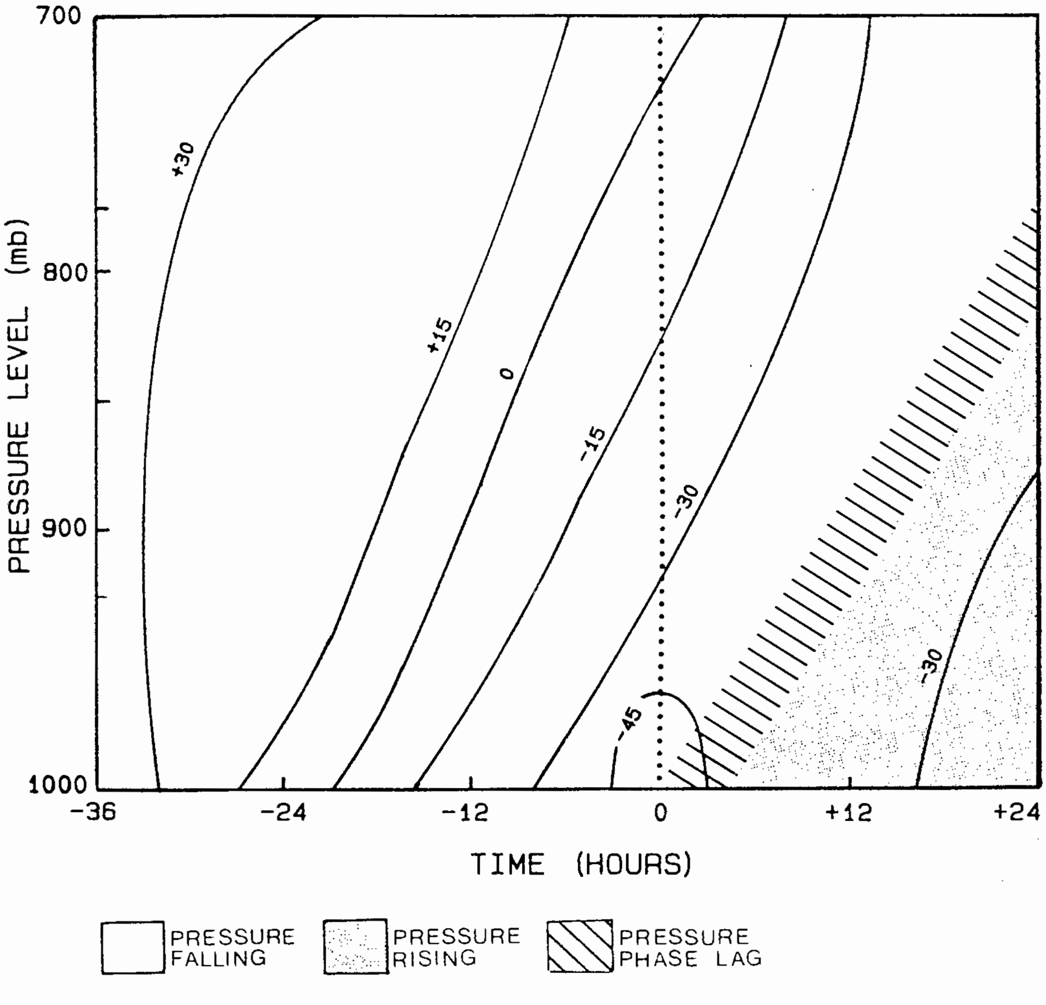

Figure 2. Variation about the annual mean for the standard pressure levels (gpm) from 36 hours (-36H) preceding the Coastal Low pressure minimum (at DF Malan) to 24 hours (+24H) after the minimum. (The Coastal Low passage is from left to right in this and all subsequent diagrams).

falling pressure tendency in the lower layers (below 900mb) changes and starts to rise while it is still falling in the layers above 900mb.

(b) Temperature:

One of the most notable features about the passage of a Coastal Low is its effect on temperature. By plotting and contouring the temperature variation shown in Table 2 (Figure 3), it is clear that the greatest temperature variations are not found at the surface but in the 950 to 900mb layer. Furthermore, the heating due to subsidence is significant up to the 775mb level, as the centre of the Coastal Low passes over the sampling point (DFM). De Wet

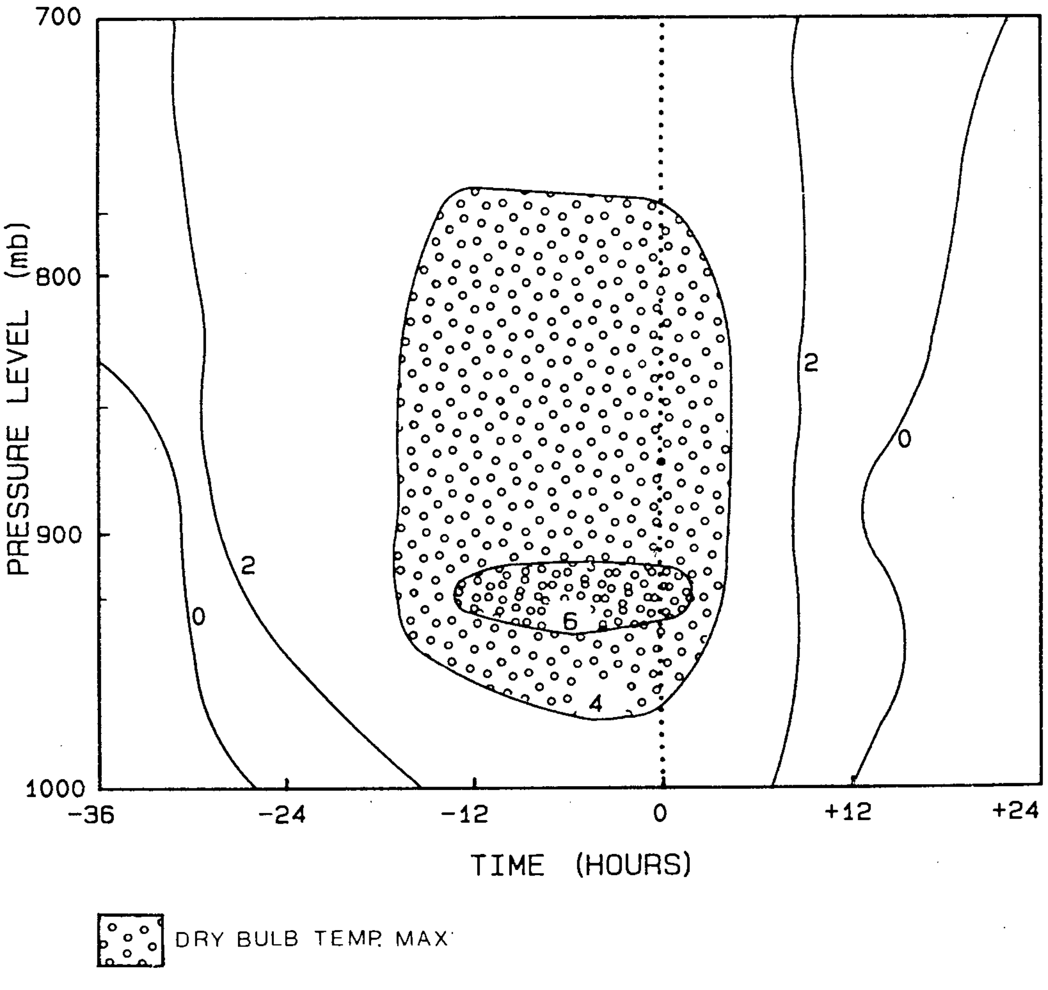

Figure 3. Variation about the annual mean for the dry bulb temperature (T oC) from -36H to +24H.

(1979) has also observed similar significant heating to the 750mb level along the west coast. The vertical orientation of the isotherms in Figure 3 further suggest that in the passage of a Coastal Low, subsidence and convergence appear to be significant features of the dynamics of the system.

(c) Moisture Content:

Dew point temperature reflects the moisture content of the air. Plotting this variable in a similar pattern to that of temperature, shows that in the pre-Low period (-36H to -12H) relatively dry air appears to subside at levels above 850mb (Figure 4). From -12H to +24H there is a gradual increase in

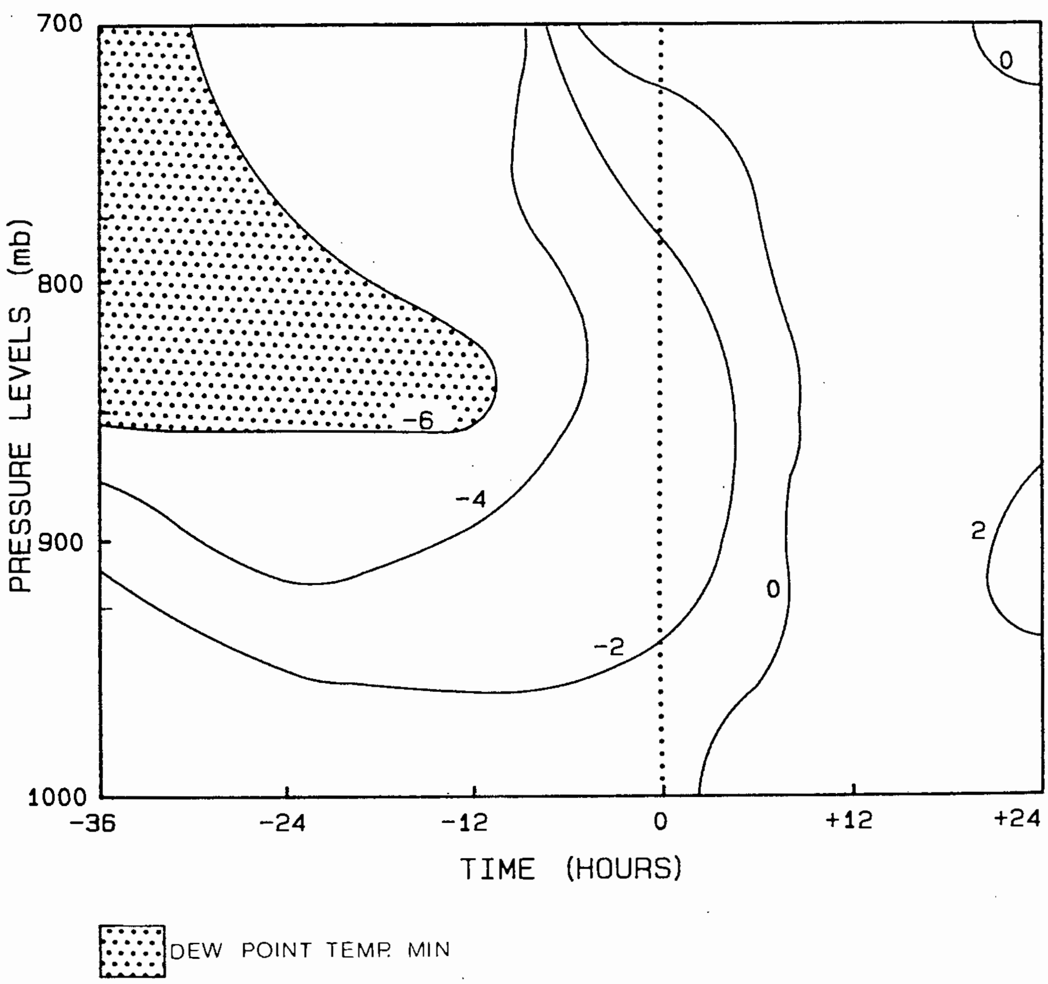

Figure 4. Variation about the annual mean for the dew point temperature (Td OC) from −36H to +24H.

moisture through the whole vertical layer. However there appears to be very little change in moisture at the surface during the Coastal Low sequence.

(d) Air Mass Characteristics:

A depiction of dew point depression (T-Td in Figure 5) shows from the points of inflection, that there is a gradual drop in height through time, which suggests a subsidence of somewhat drier air from above the 775mb level. The time series further shows a gradual lowering of the values (T-Td) between the -24H and +24H soundings.

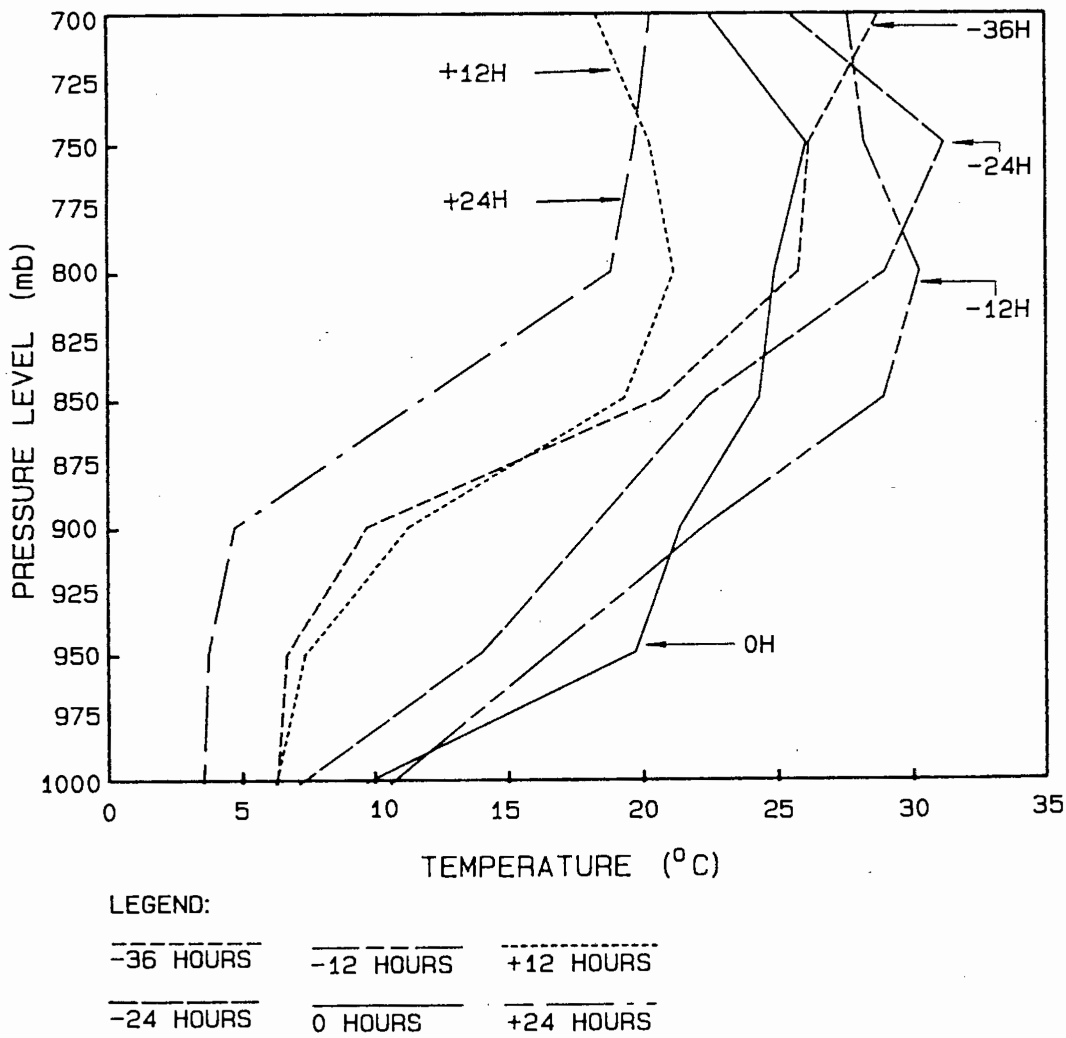

Figure 5. A time-height series of 12 hour intervals for the dew point depression (T-Td °C), from -36H to +24H.

(e) Clouds:

Clouds were classified simply by their presence and quantity (as a percentage) during the Coastal Low sequence. Their variations during the Coastal Low passage are shown in Figure 6. Few clouds were observed in the pre-Low period for all the cases studied. Following the pressure minimum, low cloud (in the form of fog, stratus or strato-cumulus) increased significantly. The occurrence of high and middle level clouds varied between 0 and 20% during the entire Coastal Low sequence.

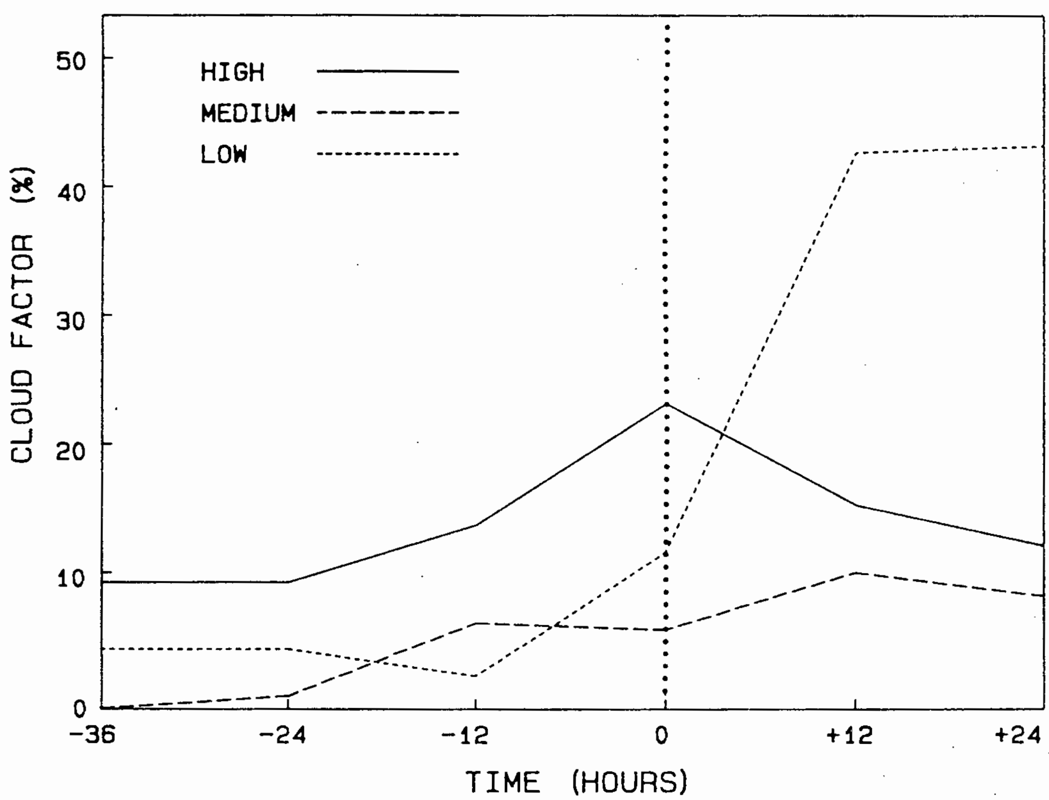

Figure 6. Cloud cover as reported at DF Malan during the passage of a series of Coastal Lows. The cloud factor is expressed as a percentage, and is calculated by multiplying the percentage of cloud occurrences during the 13 case studies and the actual reported cloud cover.

(f) Inversions:

The model proposed by Gill (1977) suggested that a capping inversion at or slightly below the escarpment height (850mb), was one of the prerequisites for the maintenance of the Coastal Low. Estie (1984) has emphasized this fact by suggesting that unless the upper air subsidence inversion is found below this level, the system should not be classified as a Coastal Low. However this study has found that the upper air inversions were often weakly defined with approximately 40% having a strength of less than $1^{o}C$. A number of authors have mentioned the characteristic lowering of the upper air subsidence inversion in the pre-Low period and the rising of the inversion in the post-Low period. This was also found to be the the case in this study (Table 3). The mean minimum inversion height of 955mb(450m) (a figure confirmed by Diab 1984), was found to correspond with the centre of the Low. Both the depth (approximately 30mb) and the strength (2-$3^{o}C$) of the upper air inversion remain remarkably consistent throughout the passage of the Coastal Low. Preston-Whyte et al. (1977) have reported similar results of mean depth (30-40mb) and mean strength ($1,4$-$3,3^{o}C$) for non-surface inversions (upper air subsidence inversions) over Cape Town. However it was also found that the upper air subsidence inversions often amalgamated with the surface based nocturnal radiation inversion in the pre-Low period, as mentioned previously by Diab (1977), Jury (1984) and Kamstra (1984). The mean strength ($9^{o}C$) and the depth (60mb) of the surface based radiation inversion were both considerably larger than the upper air subsidence inversion, a feature in agreement with the inversion studies of Tyson et al. (1976) and Preston-Whyte et al. (1977).

(g) Wind Speed and Direction:

Wind direction and speed varied considerably over the cases analysed and also during the actual passage of the individual systems. Since DF Malan was the sampling site,

TABLE 3. The mean upper air subsidence inversions are described for the pre-Low, centre and post-Low periods, while the surface based nocturnal radiation inversions are described for the whole period (-36H to +24H). This is due to the smaller sample size.

	UPPER AIR SUBSIDENCE INVERSION			SURFACE BASED NOCTURNAL RADIATION INVERSION
Parameter	Pre-Low (-36H to -24H)	Centre (-12H to 0H)	Post-Low (+12H to +24H)	Mean
Mean base height (mb)(m)	905 (950m)	955 (450m)	905 (950m)	
Standard deviation of height (mb)	60	60	47	
Mean strength (C)	3,0	2,2	2,5	9,3
Standard deviation of strength (C)	2,2	1,9	2,2	3,3
Mean depth (mb)	32	30	32	61
Standard deviation of depth (mb)	21	15	17	17
No. of cases	23	23	20	12

the complex topography and the coastline orientations cannot be excluded as factors influencing these values. Analysis of the wind fields was attempted by considering pre-Low (-36H and -24H), centre (-12H and 0H) and post-Low (+12H and +24H) average soundings. Wind roses were drawn for the significant levels reported for the three time periods (Figure 7). Visually it appears that in the pre-Low period, winds below 850mb were predominantly southerly and became more variable above this height. The offshore flow in this period appears to be much weaker than expected. This may be either a peculiarity of the location of DF Malan as mentioned above, or the offshore flow as a forcing function may not be as significant in the pre-Low dynamics as previously thought. In the central part of the Coastal Low, winds are weak and variable at the lowest levels (below the inversion), increasing in speed and becoming significantly north westerly in direction in the upper levels. Post-Low wind speeds appear to increase slightly in strength with a larger deviation in direction between northerly to westerly.

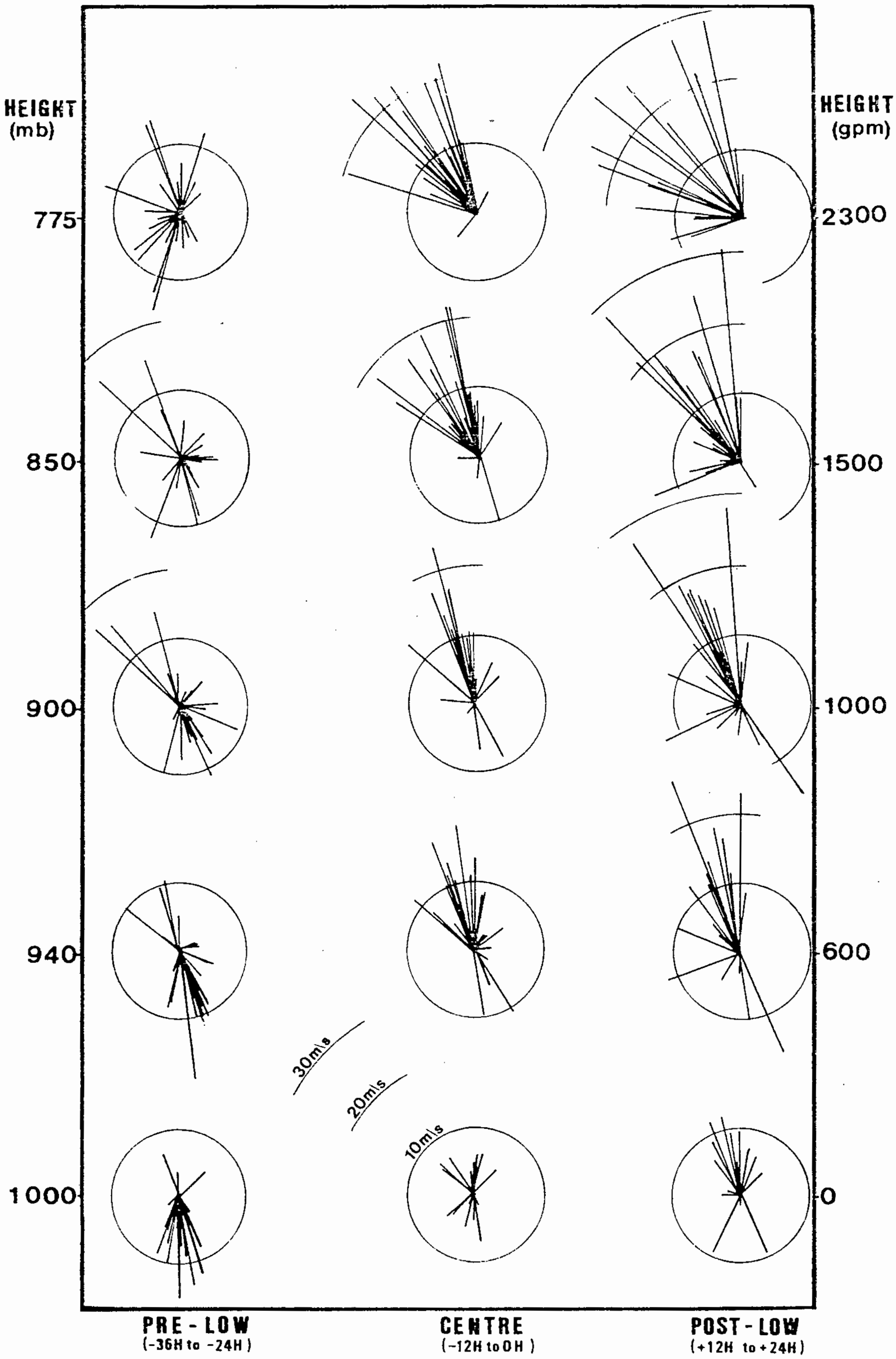

Figure 7. A time–height series of windroses for DF Malan at selected heights during the passage of the 13 Coastal Lows. The pre–Low period is represented by the period −36H to +24H; the centre, −12H to 0H and the post–Low by the period +12H to +24H.

SUMMARY AND CONCLUSIONS

An attempt has been made to show by use of an 'average' Eularian time-height depiction, the characteristics of the passage of a Coastal Low past DF Malan, Cape Town. An analysis and summation of 13 'classic' Coastal Lows provided the data for the study. While providing new information about the structure of the Coastal Low, the study has also confirmed the findings of previous researchers. This study has shown that for the SW Cape (Figure 8):

1) There appears to be a substantial subsidence of dry continental air from above 850mb level, 36 to 24 hours preceding the pressure minimum.

2) The offshore flow at the escarpment level (850mb) is surprisingly weak in the pre-Low period. This is possibly due to the location of DF Malan in the SW Cape, or due to the fact that the offshore flow as a forcing function is not as significant in the pre-Low dynamics as previously thought.

3) Winds below the upper air inversion tend to be southerly, very variable near the inversion, and westerly to northerly above the inversion in the pre-Low period.

4) The upper air subsidence inversion has a mean strength of 2-3^{o}C and drops about 50mb(500m) in height to about 955mb (450m mean minimum height) during the centre of the Coastal Low.

5) Upper air subsidence inversions are often found to amalgamate with the nocturnal surface radiation inversion in the pre-Low and centre of the Coastal Low system.

6) The greatest temperature variation during the passage of a Coastal Low does not occur at ground level, but at a

height of between 950-900mb, more or less coinciding with the top of the mean height of the inversion layer.

7) Due to a phase lag of 12-24 hours between the surface (1000mb) and the atmosphere above the inversion (850-700mb), a rising of surface pressures below the 900mb level takes place, while pressures continue to fall above the 900mb level in the post-Low period.

8) A decrease in temperature (T) and a gradual rise in dew point temperature (Td) occurs in the whole boundary layer (1000-700mb) in the post-Low period. These appear to be associated with the influx of cool moist north-westerly winds and the occurrence of low cloud.

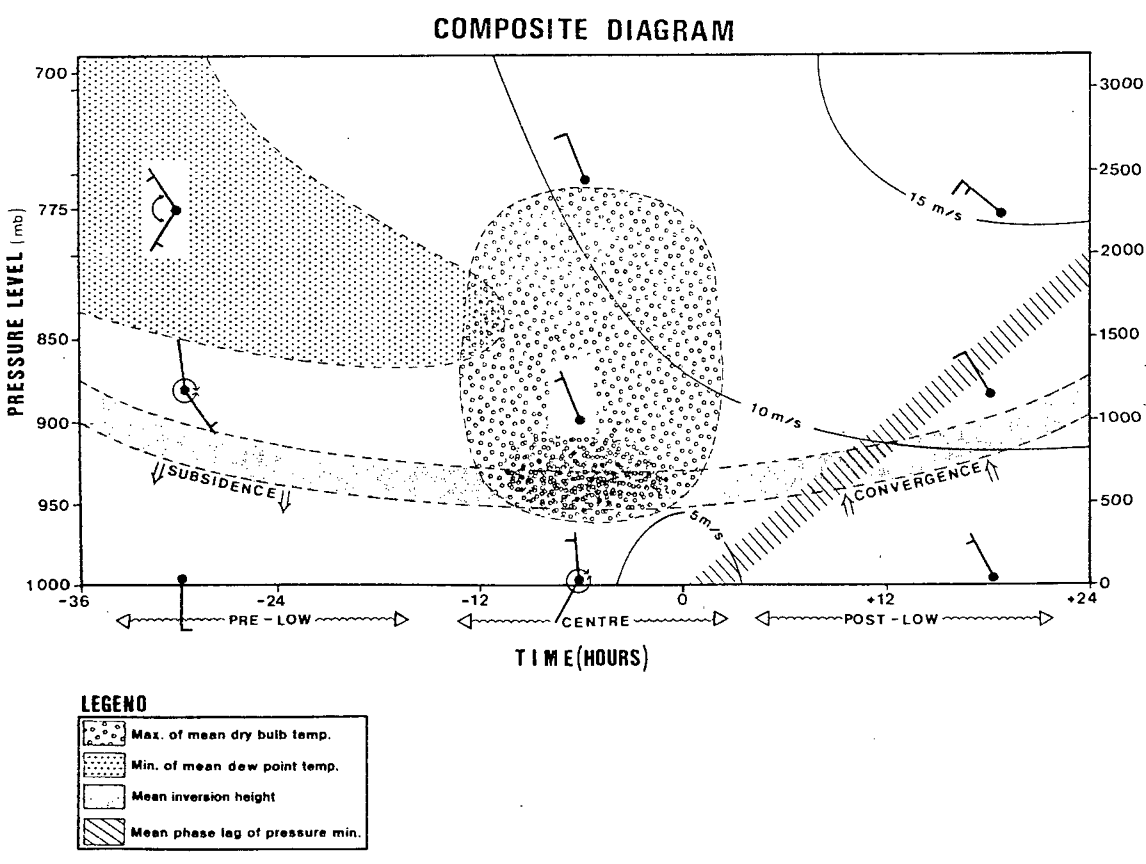

Figure 8. A summary diagram showing the major features of a typical Coastal Low sequence for the SW Cape.

The variation or 'disturbance' caused by the passage of a Coastal Low has been shown to impose a distinctive signature on the atmospheric conditions in the lower boundary layer. This signature can be further explained by showing the range of the mean values for each parameter in the -36H to +24H period (Figure 9). The Coastal Low 'pulse' is clearly shown below 900mb in the pressure-height variation (a). The maximum variation in heating is shown to occur near the top of the mean inversion height (950-900mb) (b). The characteristic drying of the upper atmosphere (above 850mb) is depicted by dew point temperature (Td) ranges (c). The maximum change in air mass characteristics (from warm, dry to cool moist conditions) occurs in the 925-850mb layer (d).

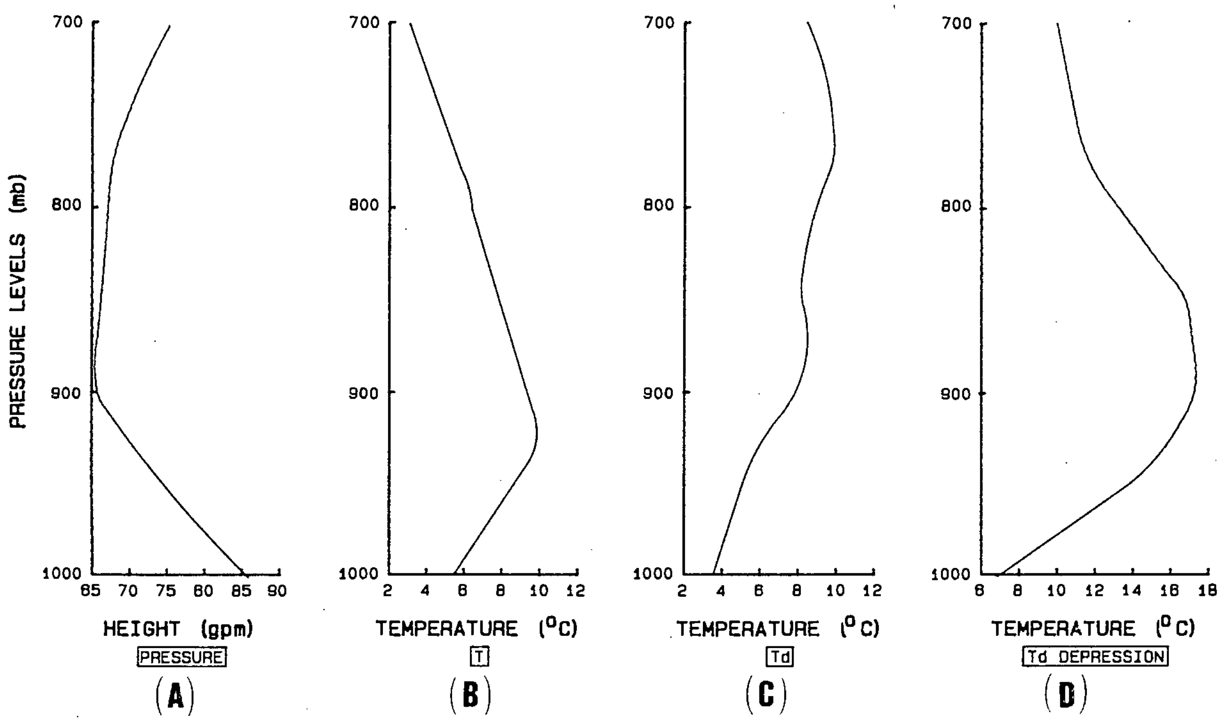

Figure 9. The variation of the mean values in the period –36H to +24H for each of the following parameters; (a) pressure level heights, (b) dry bulb temperature (T), (c) dew point temperature (Td) and (d) dew point depression temperature (T–Td).

It must be emphasised that during the 12 month period this study identified 13 'classical' Coastal Low episodes. The remaining non-frontal pressure minimum systems sometimes showed remarkably similar characteristics to that of the Coastal Lows. The reason they were not classified as such, was that according to the definition decided upon at the Coastal Low Workshop (1984), the vertical extent of the pressure minimum ought not to exceed 700mb. This study suggests that a ceiling of 850mb and not 700mb may be more applicable, confirming the level originally reported by Estie (1984). 'Coastal Lows' with pressure minima found above 850mb at the centre of the system, would therefore be regarded as another class, or as an 'extended Coastal Low'.

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CHAPTER 3

THE WIND STRUCTURE OF COASTAL LOWS IN THE SW CAPE AS PENETRATED BY DOPPLER ACOUSTIC RADAR.

A mean wind structure through the lower 1000m was calculated from the passage of 7 Coastal Low episodes. Results indicate that backing of the wind during the passage of the Coastal Low is most clearly defined in the 200-600m layer. The offshore flow in the vicinity of the upper air inversion is weak while maximum subsidence is maintained below this level. The core of the Low is identified by low horizontal and vertical wind speeds and high variability of wind direction. On either side of the core and below the inversion level is a region of higher wind speeds. The longshore spatial extent of the Coastal Low system was estimated as an 'inner' core of 150km and an 'outer' diameter of about 1000km.

THE WIND STRUCTURE OF COASTAL LOWS IN THE SW CAPE AS PENETRATED BY DOPPLER ACOUSTIC RADAR.

Doppler acoustic radars (Sodars) have been used since the mid 1970's for the routine monitoring of boundary layer atmospheric winds. Conventional anemometers and radiosonde systems cannot provide the sampling depth and sensitivity and hence the detail of wind structure which the Sodar systems provide. Sodars have been employed in the analysis of many mesoscale weather systems (Gaynor, 1982) for example coastal marine fog studies (Noonkester, 1979), land and sea breeze studies (Rao et al., 1981; Raghu Kumar et al., 1985), complex terrain studies (Dickerson,1980; Eberhard, 1980) and in turbulence studies (Kaimal, 1973; Gaynor, 1977). Since the early 1980's Sodars have also been used extensively in site surveys and in the routine monitoring of the lower boundary layer at nuclear and fossil fuel power stations (Netterville, 1981; Clark, 1982) and at various airports around the world. The Remtech Doppler Acoustic Radar system used in this study was situated in Milnerton, 12kms to the north of Cape Town (Figure 1) during the period November 1984 to October 1985. During this period, seven Coastal Low sequences were sampled in detail. Categorization and identification of these Coastal Lows followed the guidelines suggested by the Coastal Low Workshop (1984) and Heydenrych (Chapter 2). Hourly pressure values from DF Malan (DFM), Koeberg and the University of Cape Town (UCT) as well as radiosonde data from DF Malan were used as part of this identification of the Coastal Low pulse. It is the aim of this paper to examine the vertical structure of Coastal Lows, with regard to their wind patterns, as the systems appear over the South Western (SW) Cape.

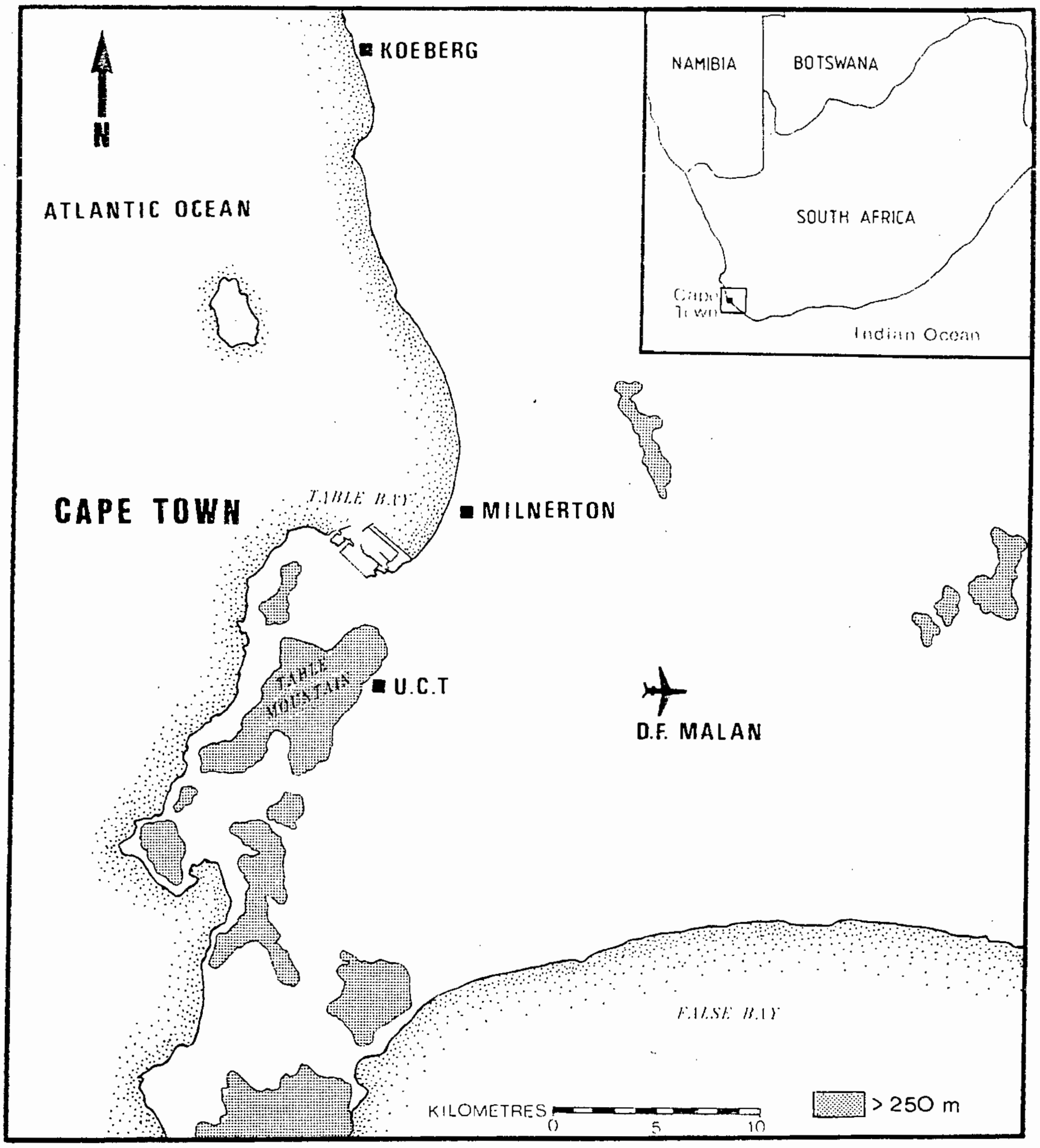

Figure 1. Location of study area

COASTAL LOWS

Coastal Lows are mesoscale features which migrate around the southern African coastline. The Coastal Low systems are generated and maintained by the offshore component of the synoptic flow; and, which Gill (1977) has likened their behaviour to coastally trapped atmospheric Kelvin waves. They have limited vertical extent and have an area of relatively low surface pressure (a leeward trough - Taljaard et al., 1961). They are also associated with a cyclonic circulation system. Considerable variations in local weather conditions can be experienced with the passage of a Coastal Low. These include warmer temperatures, high pollution potentials and a lowering of the inversion levels. Significant features of the system are its relative shallowness, occurring below the 700mb level, and a distinctive surface pressure minimum (Coastal Low Workshop 1984). Once the pressure minimum has passed there is a sharp backing of low level winds, an influx of cool moist air and low level cloud. Figure 2 summarizes the main features of the Coastal Low as it occurs in the SW Cape (Heydenrych, Chapter 2).

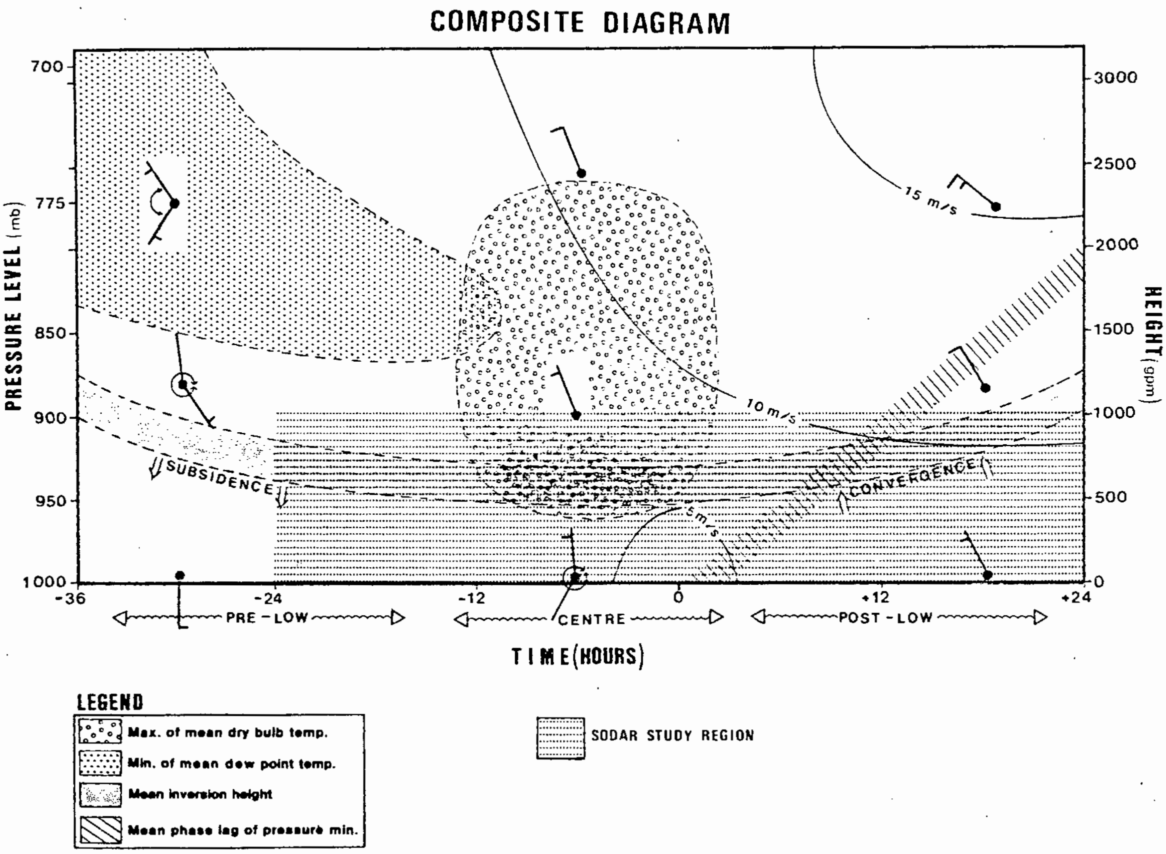

Figure 2. A summary diagram showing the major features of a typical Coastal Low sequence for the SW Cape as identified from Radiosonde soundings. (after Heydenrych, Chapter 2).

REMTECH DOPPLER SYSTEM

The Remtech Sodar used in this study was a 1600 Hz system, fitted with A01 antennae which operated to a maximum height of 1000m. The Sodar provided information on six parameters ;

Horizontal wind speed (V), direction (θ), standard deviation of direction (σ_θ), vertical wind speed (W), standard deviation of vertical wind speed (σ_W) and echo intensity. Values of these parameters were available every 50m through the vertical sounding height. The data were logged onto cassette tape in 15 minute 'averaged' samples. These were later combined into an hourly value with a minimum of at least two 15 minute values being accepted for the hourly mean.

DATA ANALYSIS

The Coastal Low can be considered as a cyclonic mesoscale disturbance which would infer that a core or centre is present within the system. In a previous publication (Heydenrych, Chapter 2),the minimum geopotential height of the 1000mb layer was used to identify this centre. However in the present study it was possible to identify the centre of the Coastal Low from the hourly wind parameters because of the greater resolution obtained from Sodar measurement. In the 12 month study period, November 1984 to October 1985, seven complete Coastal Low sequences were covered by the Sodar profiles (out of a total of 13 cases)(Heydenrych, Chapter 2).

During the progression of the Coastal Low it is possible to distinguish an area where wind speeds decrease and wind directions fluctuate more than in the pre-Low and post-Low periods. In quantitative terms, these were horizontal wind speeds of less than 4m/s, vertical wind speeds of 0cm/s and sigma values greater than 20^{o} in the horizontal.

With these criteria, it was possible to use the 'core' of the system as a time reference point for each Coastal Low sequence. By overlaying each of the seven time-height sequences, using the core as a reference point, an 'average' Coastal Low model could be constructed by summating and averaging all of the wind parameters obtained from the

Sodar. A wind climatology of a typical Coastal Low was thus obtained.

(a) Horizontal Winds:

Wind vectors for a 48-hour period through the Coastal Low are shown in Figure 3. By categorizing the wind directions into the four major quadrants, a cross sectional behaviour pattern becomes apparent. In the pre-Low period, winds are generally southerly up to about 500m, above that they back to easterly and diminish in speed. In the central core region, wind speeds are 'calm' (V < 4m/s) with a general northerly component. The winds back further to a westerly direction with increasing speed in the post-Low period. It can also be seen from Figure 3 that above about 300m a

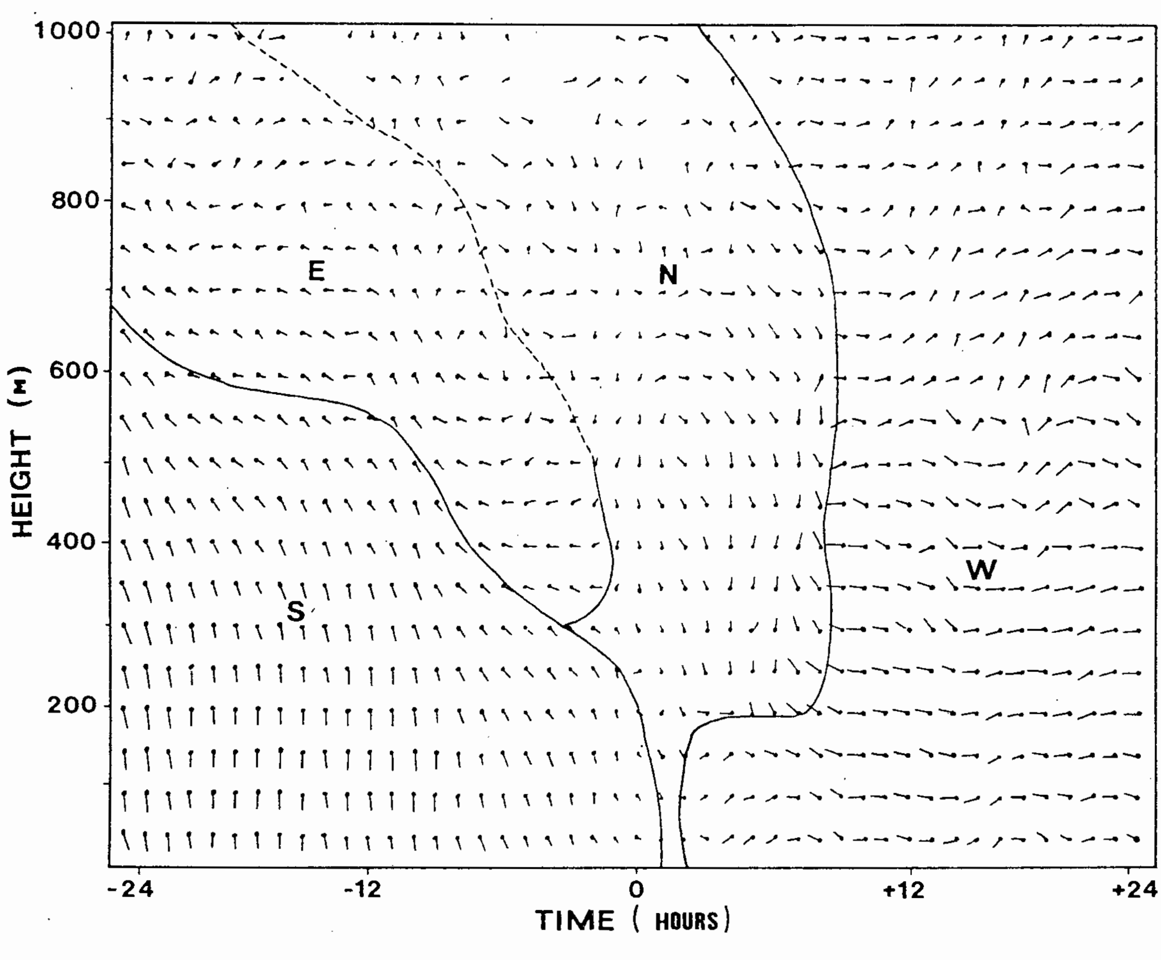

Figure 3. A time-height series of the horizontal wind vectors from -24H to +24H. (The Coastal Low passage is from left to right in this and all subsequent diagrams).

clearer pattern is evident, with wind directions systematically backing from easterly through northerly to westerly during the passage of a Coastal Low. This signature is less clear in the near surface layer (below 200m) where the change from the pre-Low southerly to post-Low north-westerly appears much more variable.

A depiction of isotachs (Figure 4) shows the occurrence of low level (below 500m) wind maxima (>8m/s) on either side of the calm core. Preston-Whyte (1975) and Jury (1984) have previously discussed a low level wind maximum, although Preston-Whyte only found this in the post-Low period on the Natal Coast. Above 500m (inversion), wind speeds are generally low, (less than 4m/s).

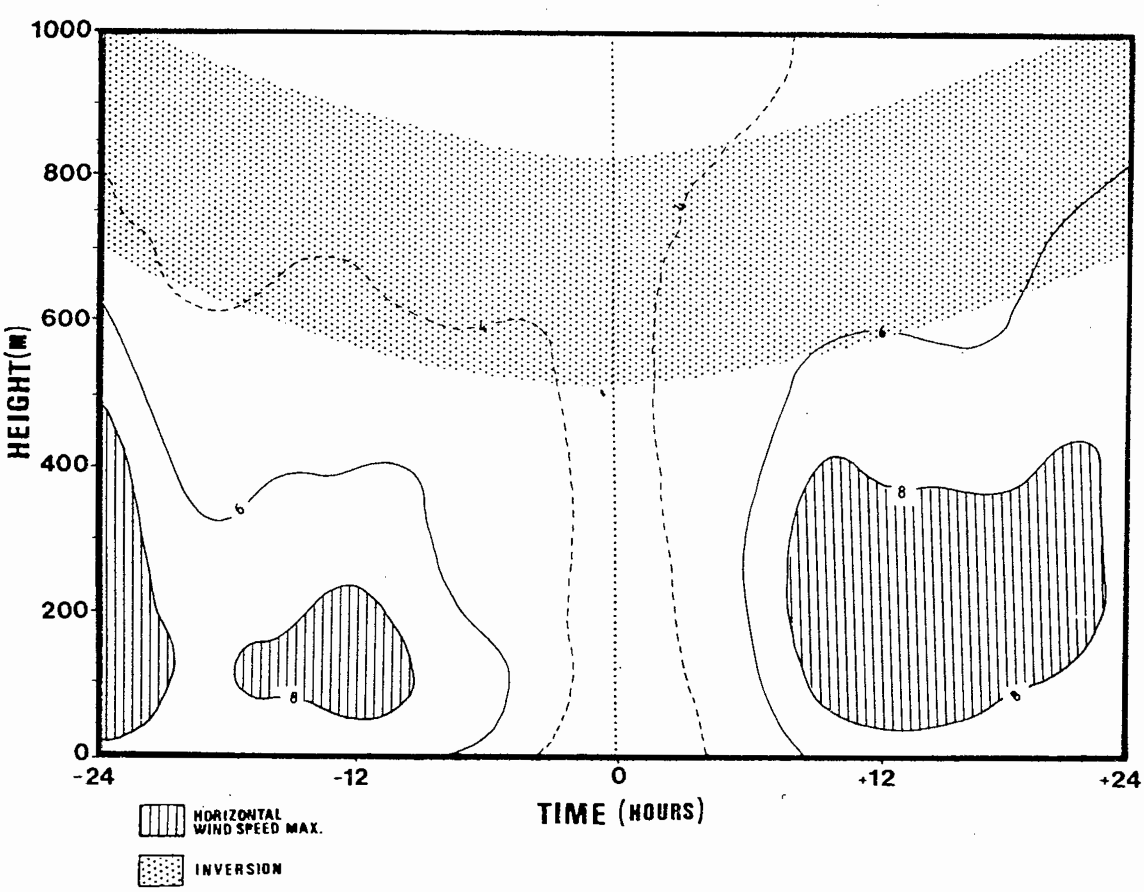

Figure 4. A time-height series of the Horizontal wind speed (m/s) from -24H to +24H.

By showing the standard deviation of the horizontal wind direction component (σ_θ), a relatively clear pattern of behaviour is also seen (Figure 5). Below the inversion level and on either side of the core, (σ_θ) values of less than 10^{o} are found, suggesting relatively steady wind directions. In the core area the values are greater than 20^{o}, reflecting a significant backing of the winds taking place in this region. Above the inversion, an even greater variability in direction is apparent because of the light wind speeds.

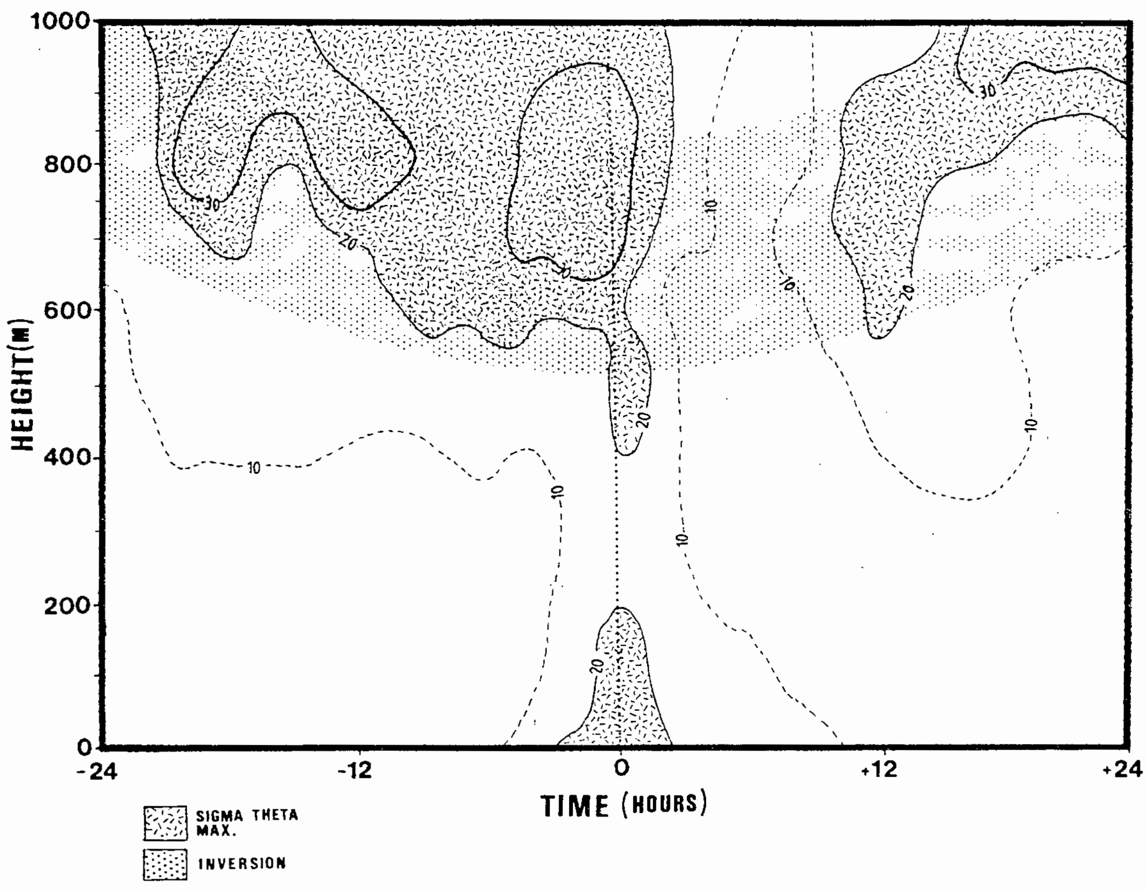

Figure 5. A time-height series of the standard deviation of the horizontal wind direction (^{o}) from -24H to +24H.

(b) Vertical Winds:

A plot of the vertical wind component (W) (Figure 6) shows significant subsidence in the pre-Low period with velocities in excess of 40cm/s. The maximum subsidence values appear to be more closely associated with the southerly winds (ie below 500m) than with the easterly offshore flow (Figure 7). This suggests that maximum downward momentum appears to be maintained beneath the offshore flow and below the subsidence inversion level. Subsidence in the easterly flow is of the order of 20cm/s, with horizontal wind speeds of 4m/s. In the central part of the system, or core (0H), where northerly horizontal winds predominate, no significant vertical winds are to be found. The post-Low period is characterised by weak convergence which varies between 0-20cm/s.

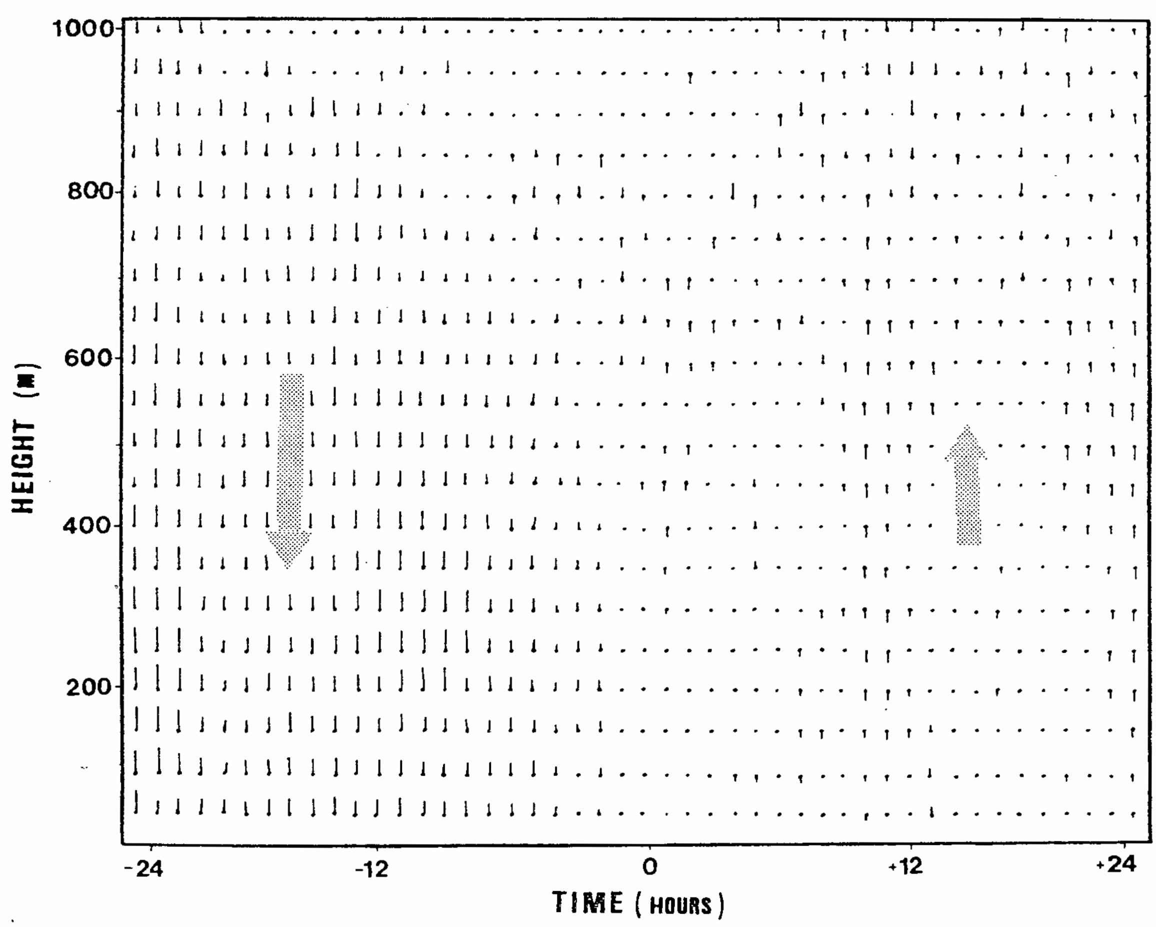

Figure 6. A time-height series of the vertical wind velocity (cm/s) from -24H to +24H.

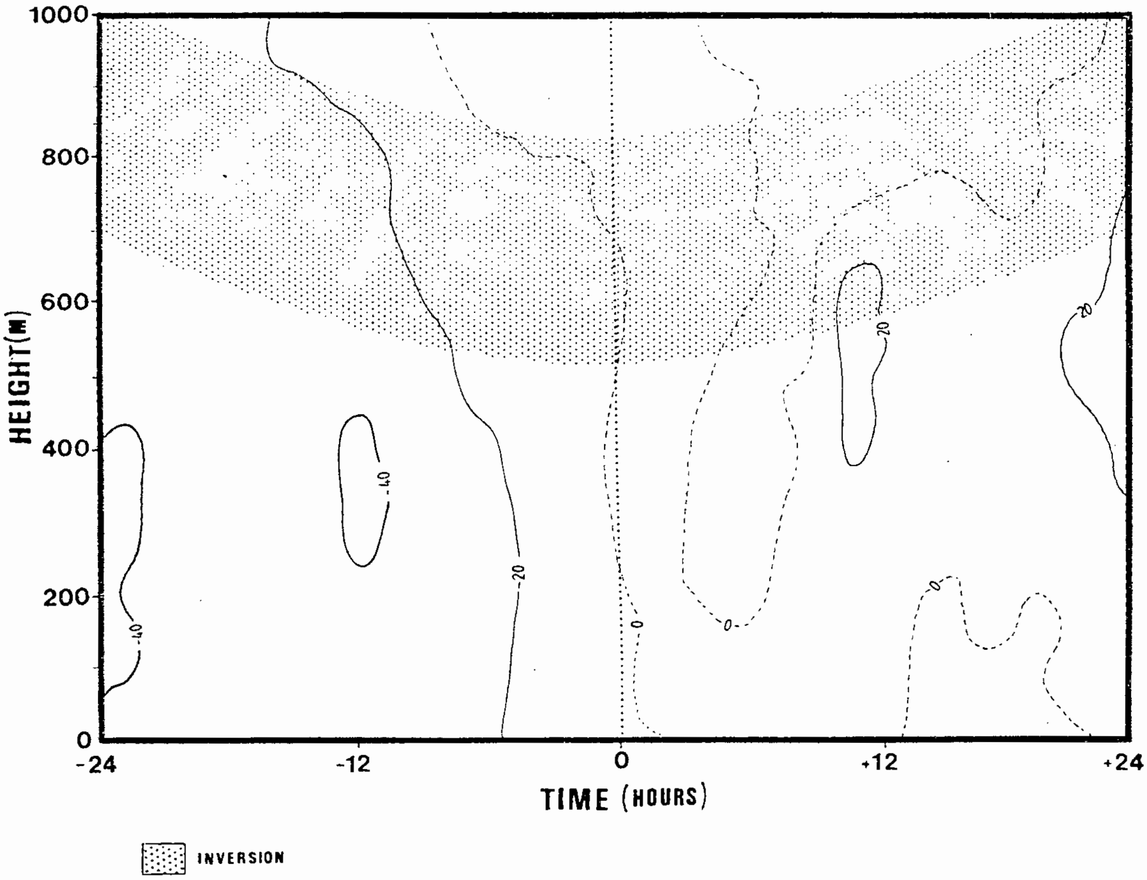

Figure 7. A time–height series of the vertical wind speed (cm/s) from –24H to +24H. Negative values indicate subsidence and positive values, convergence.

A consideration of the standard deviation of the vertical wind speed (σ_W) shows the greatest values (greater than 30cm/s) in the pre-Low and post-Low periods (Figure 8). In the core region slightly lower values are more apparent. The vertical alignment of these contours suggest that a pre-Low and post-Low pulsing (also mentioned by Jury, 1984) occurs in the vertical wind velocities, associated with the horizontal wind speed maxima.

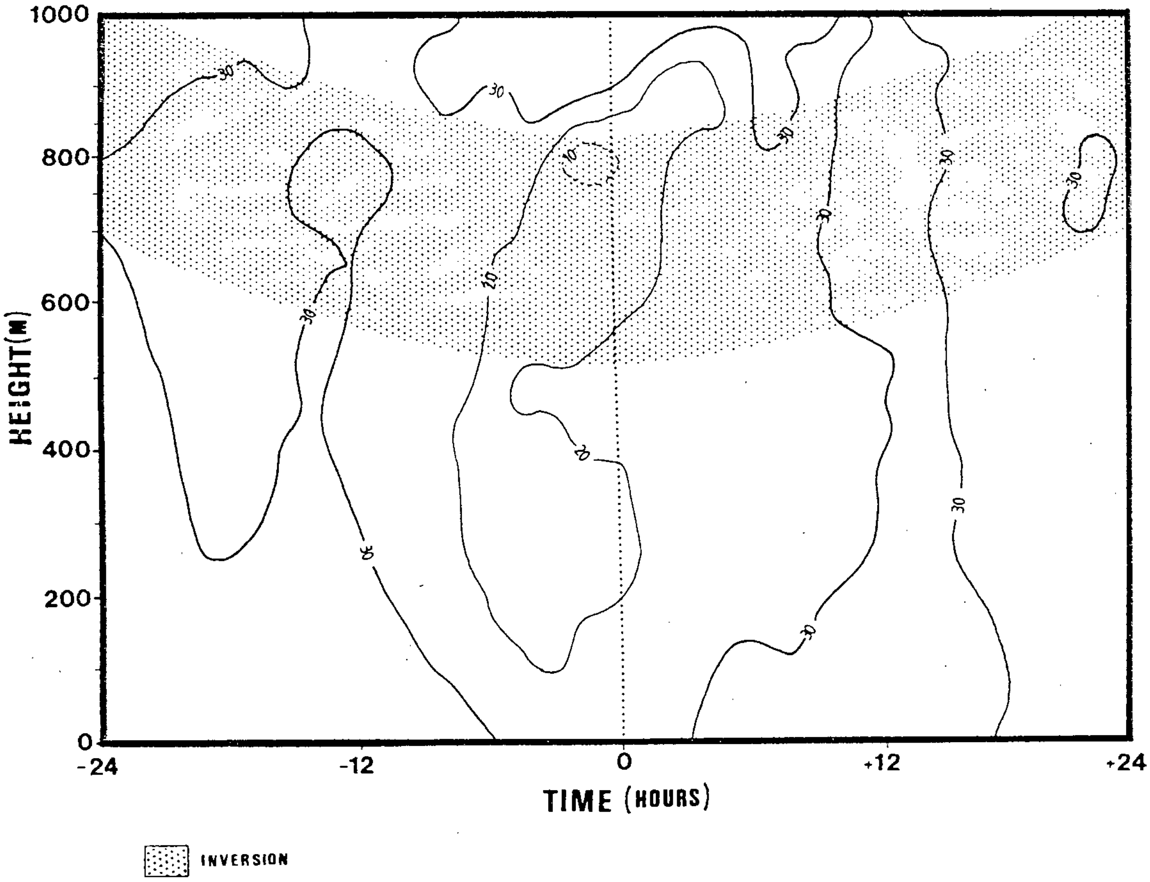

Figure 8. A time–height series of the standard deviation of the vertical wind speed (cm/s) from –24H to +24H.

The positive association between high horizontal wind speeds (V) and the high standard deviation of vertical wind speeds (σ_W) together with a negative correlation to the standard deviation of the horizontal direction (σ_θ) has been shown to occur - similarly noted by Jury (1986). The present data set has however not been normalised for these correlations. This aspect may need to be addressed in the future.

(c) Spatial Characteristics:

By timing the passage of the systems past the Sodar, an estimation of the longshore spatial structure of the Coastal Low can be obtained. Migration speeds of Coastal Low systems along the South African coastline have been quoted in the order of 6,3m/s (Preston-Whyte and Tyson, 1973); 8m/s (Gill, 1977); 4,3 - 9,6m/s (Walker, 1984). As speeds of migration along the coastline can vary considerably for individual systems (Gill, 1977; Walker, 1984; Estie, 1984), a mean value of 7m/s (25km/h) for the SW Cape was assumed in this study. The temporal passage of the Coastal Low system is perhaps best shown from a time-height depiction of horizontal wind speeds in Figure (4). The inner diameter or core (where winds V < 4m/s), appears to take about 6 hours to pass an observational point. This gives the diameter of the core to be about 150km. It is also suggested here that an 'outer diameter' of the system can be estimated. This would correspond to the outer edges of the low level wind speed maxima (V > 8m/s). This time difference is about 40 hours which in turn gives an estimated diameter of about 1000km.

SUMMARY AND CONCLUSIONS

The wind structure of the Coastal Low through the lower 1000m of the boundary layer has been considered in this paper. Data obtained from a Doppler Acoustic Radar were used to produce an 'average' Coastal Low model as it appears from an Eulerian view point in the SW Cape. The study has shown that during the passage of a Coastal Low over an observation point :

1) A systematic backing of the wind from southerly through easterly to northerly and westerly is clearly evident in the 200-600m layer.

2) Winds in the lower 200m of the system appear to fluctuate more in this backing process than in the layer above, and a less obvious pattern is noticeable.

3) The expected offshore easterly flow associated with the cyclonic circulation system of the Coastal Low appears to

occur near the inversion level but is weak in strength (V <4m/s). The maximum vertical wind speeds (W >40cm/s) are maintained below this offshore flow.

4) Horizontal wind speed maxima (V >8m/s) occur in the pre-Low and post-Low periods below the inversion level. Associated with these wind speed maxima are regions of little fluctuation in the horizontal wind direction (σ_θ <10^0) and high variations in vertical wind speed (σ_W >30cm/s).

5) Above the inversion level (above 500m) wind speeds are light (V <4m/s) and variable (σ_θ >30^0).

6) The core of the system is identified below the inversion level (500m) by low wind speeds (V <4m/s), no vertical wind speed (W =0) and large changes in wind direction (σ_θ >20^0).

7) By using an average migration speed for Coastal Lows along the South African coastline of 7m/s (25km/h), the longshore spatial size of the system could be calculated to be:

a) 150km for the inner core diameter where wind speeds are less than 4m/s.

b) 1000km for the 'outer diameter' of the system marked by the low level wind speed maxima (V >8m/s) on either side of the inner core.

By way of a summary depiction, Figure 9 illustrates the major features as identified in this study. The greater resolution obtainable by Doppler Acoustic Radars has provided an insight into the physical structure of the wind regime within a Coastal Low system. It has also confirmed some of the findings of other authors who have reported on the occurrence of Coastal Lows in southern Africa.

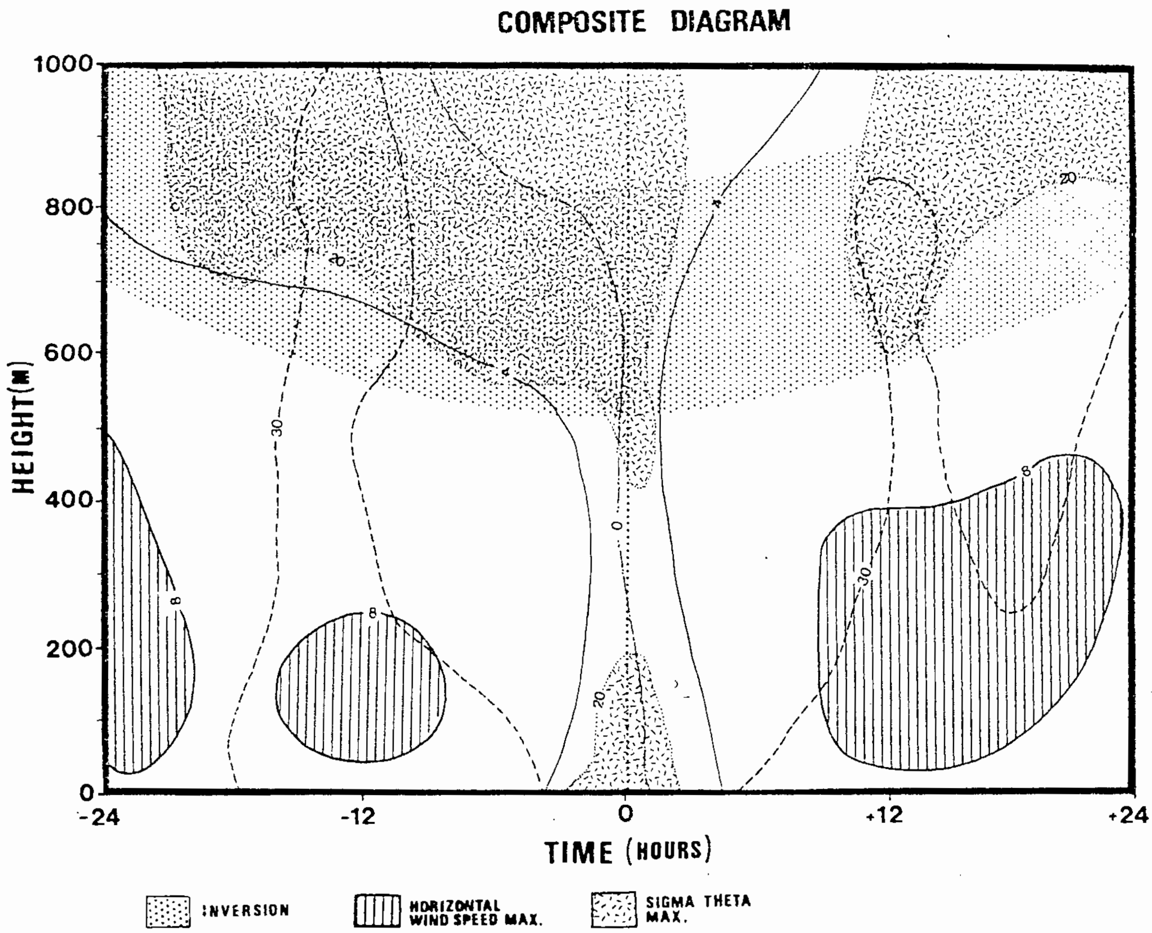

Figure 9. A summary diagram of the wind structure of a typical Coastal Low in the SW Cape as shown by a Doppler Acoustic Radar.

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CHAPTER 4

SURFACE CHARACTERISTICS AND SPATIAL BEHAVIOUR OF THE COASTAL LOW IN THE SW CAPE.

The migration of the Coastal Low through the SW Cape is shown by use of corrected surface pressures. The mean pressure minimum associated with the Coastal Low, was found to be relatively consistent during the systems migration through the region. Pressure tendencies however, indicated that non linear effects were present within the system. Generally little or no abrupt changes in dry bulb and dew point temperatures occured during the passage of the Coastal Low. The backing of the wind appeared to be both gradual and variable between stations with the wind speed increasing dramatically towards the Peninsula due to local topographic effects.

SURFACE CHARACTERISTICS AND SPATIAL BEHAVIOUR OF THE COASTAL LOW IN THE SW CAPE.

The South Western (SW) Cape is a transition region, where the Coastal Low changes from a west coast to a south coast system. The behaviour of the system through this region was addressed at the Coastal Low workshop (1984) where Walker, Jury, Kamstra and Diab respectively commented on their observations of pressure, temperature and wind fields. At the same workshop Nelson & Glyn-Thomas and Sciocatti discussed oceanographic aspects and the occurrence of fog with Coastal Low systems. This paper follows two previous papers (Heydenrych, Chapters 2 and 3) which addressed the vertical structure of the system. Focus is now given to the surface and spatial behaviour of these systems as they pass over the SW Cape.

BACKGROUND

The Coastal Low was described by Gill (1977) as an atmospheric coastally trapped Kelvin wave, the Coastal Low being both generated and maintained by the offshore component of the synoptic flow. Associated with this wave is an area of relatively low surface pressure (a leeward trough - Taljaard et al., 1961), as well as warm temperatures, low humidities, light and variable winds which back from the south east to the north west as the system passes. Another common feature is the high pollution potential associated with the lowering of the inversion level as the Low approaches. However, the essential feature of this system is its relative shallowness, occurring notably below the 700mb level, together with a distinct pressure minimum (Coastal Low Workshop, 1984).

THE STUDY

Heydenrych (1987, Chapter 2 & 3) has investigated the upper air characteristics of Coastal Lows by using a Eulerian perspective and by summating and averaging the individual vertical observations of a series of Coastal Low events. Thirteen such sequences were included in a 12 month period - November 1984 to October 1985. The same data set has been used for this study where the focus is now upon the surface characteristics of the Coastal Low system. Figure 1 shows the spatial domain covered by this study and the location of the 6 surface stations. Observations were at 6-hourly

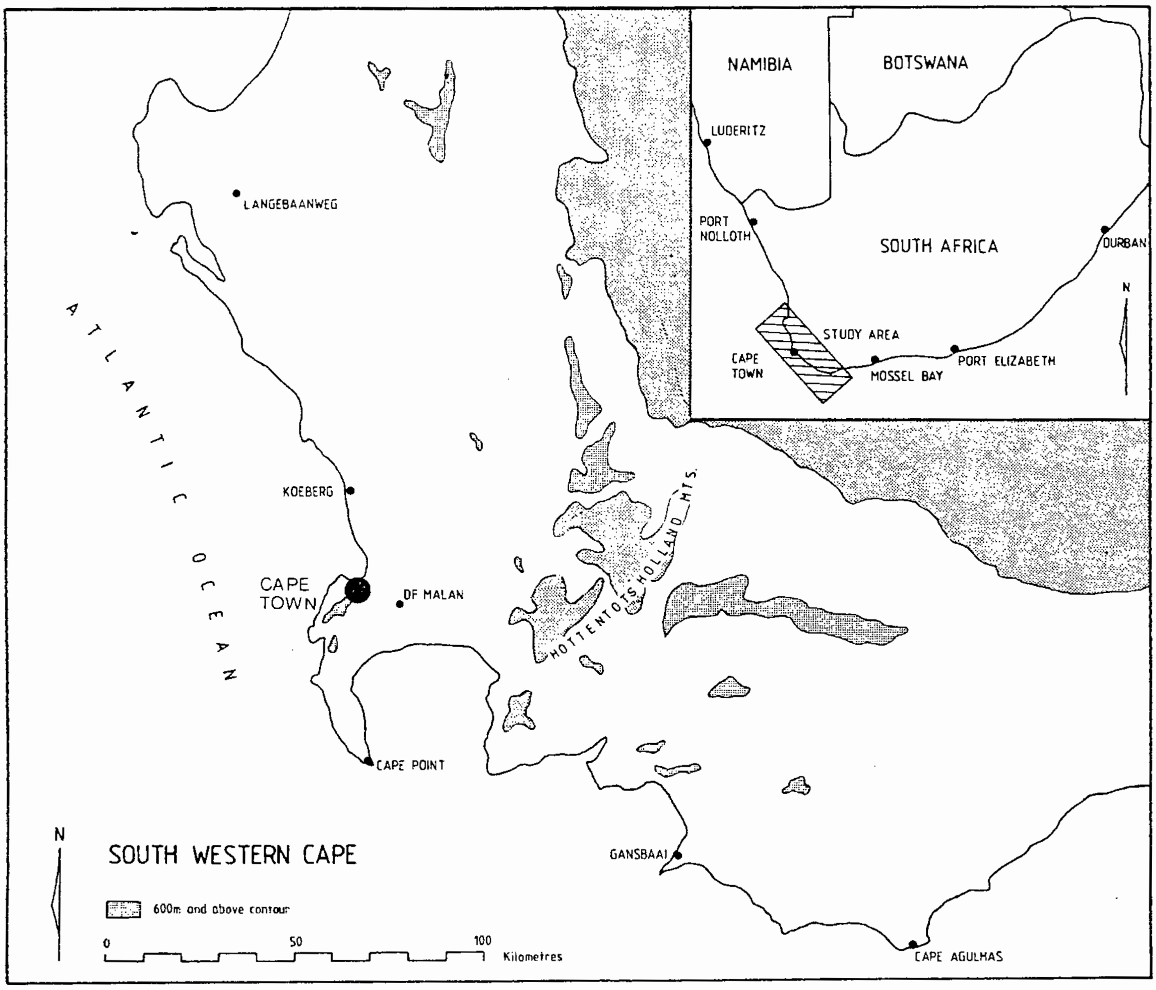

Figure 1. Location of the 6 surface stations used in the study region.

intervals and included pressure, wind speed and direction and temperature. The following analysis uses a similar approach to the previous articles (Heydenrych, Chapters 2 & 3) by obtaining 'averages' or 'means' of the 13 case studies for each of the six stations. The reference point of the temporal framework (OH - Zero hour) is defined as that time the pressure minimum was detected at DF Malan.

It has been suggested by Jury (1984) that the Coastal Low pulse deteriorates north of Cape Town and reforms east of George in its migration from the west to the south coasts. In this study atmospheric pressure is used as the primary feature in detecting the passage of the Coastal Low wave through the SW Cape.

DISCUSSION

(a) Pressure:

In order to use atmospheric pressure as the primary recognition feature of the Coastal Low wave, corrections for diurnal atmospheric fluctuations (van Ligen, 1944; Walker, 1984) and altitude variations had to be made. Since no hourly diurnal correction factors existed for the SW Cape, this was computed for a 10 year period (1976-1985) for DF Malan. The results are shown in Figure 2 where the actual wave is described for each of the four seasons, summer (Dec-Feb), autumn (Mar-May), winter (Jun-Aug) and spring (Sep-Nov). Corrections for the variation in altitude between the stations was done by applying the pressure height equation (values confirmed by Observers Handbook 1975, pg 219) with all the station pressures thereby being reduced to mean sea level. A further correction factor had to be applied in order to normalize the values obtained at the various stations. This arose because of possible variations in the calibration of instruments at the different stations and also because atmospheric moisture content is not a variable in the pressure-height equation.

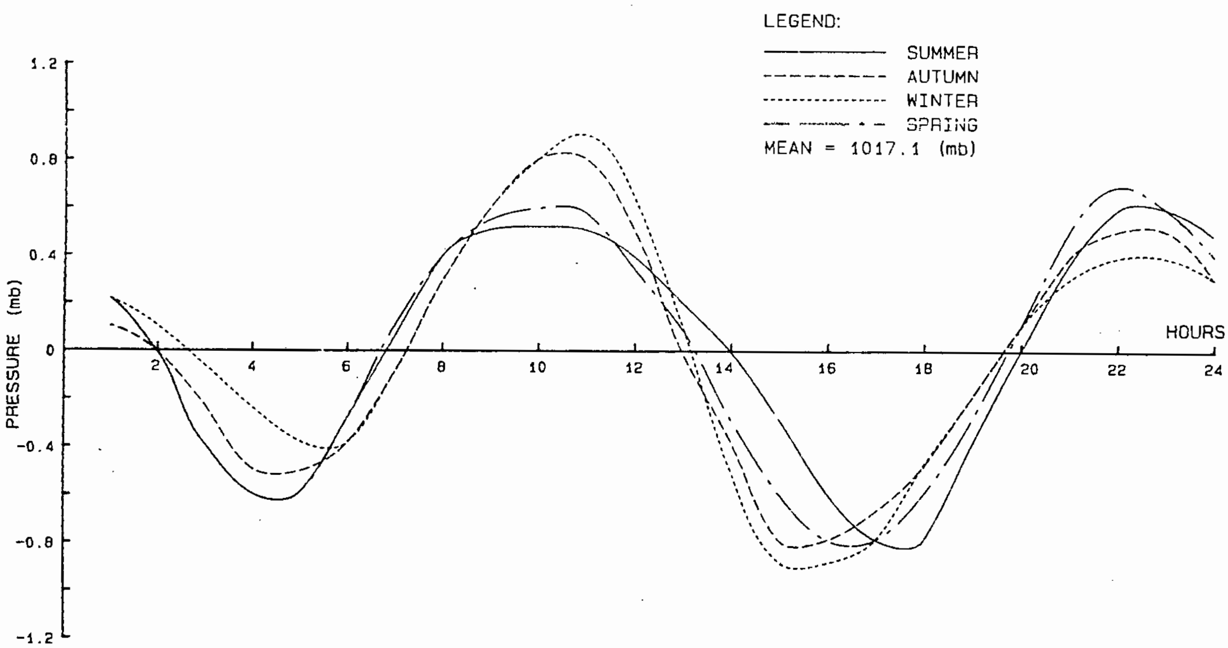

Figure 2. The 24 hour cycle of pressure variations for DF Malan station for a 10 year period (1976–1985). The four seasons are represented as summer (Dec–Feb), autumn (Mar–May), winter (Jun–Aug) and spring (Sep–Nov).

A contemporaneous 60 hour period (at 6 hourly intervals) was considered for each of the 6 stations: 30 hours (-30H) before the pressure minimum at DF Malan and 30 hours (+30H) after. An average pressure pattern for the 13 cases was then computed for each station, these are shown in Figure 3. It is clear from these graphs that the pressure minimum (bold line) of the wave system is maintained in its migration across the SW Cape. The maximum variation between the station's minimum pressures (eg. Gansbaai and DF Malan), varied by no more than 1,5mb.

It is noticeable from the graph and particularly from Table 1 that in the pre-Low period, pressure-drops tend to become greater as the system migrates to the south coast (eg. 5,9mb at Langebaanweg and 9,9mb at Cape Agulhas). Nelson & Glyn-Thomas (1984) have mentioned a typical depression of 8mb associated with Coastal Lows on the west coast. In the post-Low period, pressure rises are not only numerically smaller for all the stations, but also appear to rise less for the south coast staions than the west coast ones (2,2mb for Cape Agulhas and 4,1 at Langebaanweg). This would seem to suggest one or both of two possibilities; either the influence of the trailing frontal system is more marked on the 'south' coast stations of the study region, or the Coastal Low undergoes a change in its physical and possibly its spatial characteristics when migrating through the SW Cape (Nelson & Glyn-Thomas, 1984). Also shown in

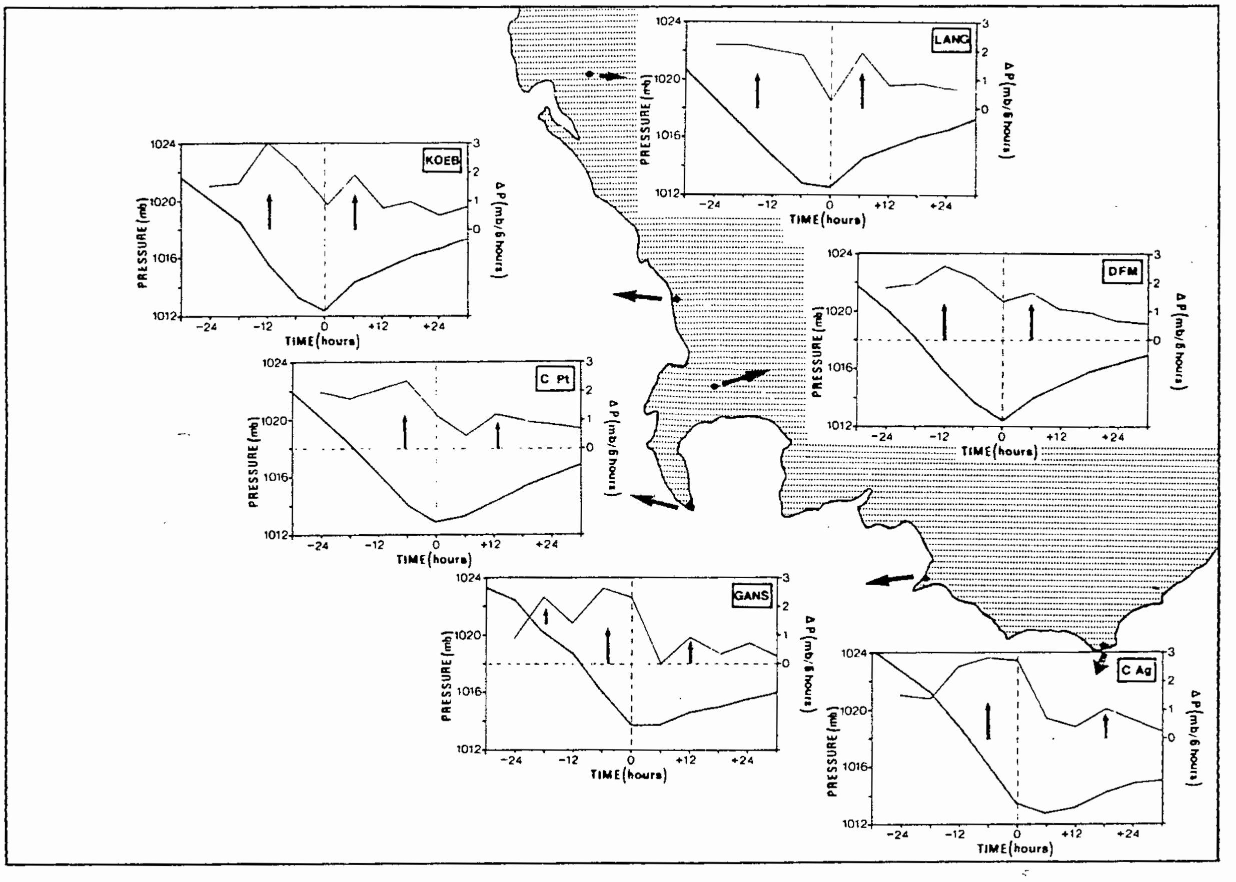

Figure 3. The mean 6 hourly surface pressure values for 6 stations in the SW Cape during the passage of a Coastal Low. The corrected mean sea level pressures for each station are represented by the thicker lines and the 6 hourly pressure tendencies by the thinner lines. (The Coastal Low passage is from left to right in each diagram).

Figure 3 are the 6 hourly pressure tendencies for each station (thin line). All the stations show a characteristic maximum (represented by a peak) on either side of the centre of the pressure minimum. This maximum pressure tendency is found in general to be greater in the pre-Low period for the SW Cape. The maximum pressure tendency indicates a region of relatively stronger pressure discontinuity within the mesoscale system, and is often associated with strong gust fronts. This observation has been made in the non-linear model of Gill (1977), and in studies by Preston-Whyte (1975), Jury (1984) and Heydenrych (Chapter 3). The actual centre of the Low is however characterised by relatively weak pressure gradients and hence low wind speeds.

TABLE 1. The 24 hour pressure (mb) variations about the pressure minimum for the pre and post-Low periods for the 6 stations.

STATION	PRE-LOW PRESSURE VARIATION (MB) (-24H TO 0H)	POST-LOW PRESSURE VARIATION (MB) (0H TO +24H)
LANGEBAANWEG (LANG)	5,9	4,1
KOEBERG (KOEB)	7,7	4,2
DF MALAN (DFM)	7,8	4,1
CAPE POINT (C Pt)	7,1	3,2
GANSBAAI (GANS)	8,6	1,9
CAPE AGULHAS (C Ag)	9,9	2,2

By plotting surface pressure maps of 12 hourly intervals, the migration of the low pressure minimum through the region can be seen (Figure 4). The centre is estimated to have a diameter of 150-200km - a value similar to that calculated by Heydenrych (Chapter 3) and slightly less than a theoretical value (300km) suggested by Gill (1977).

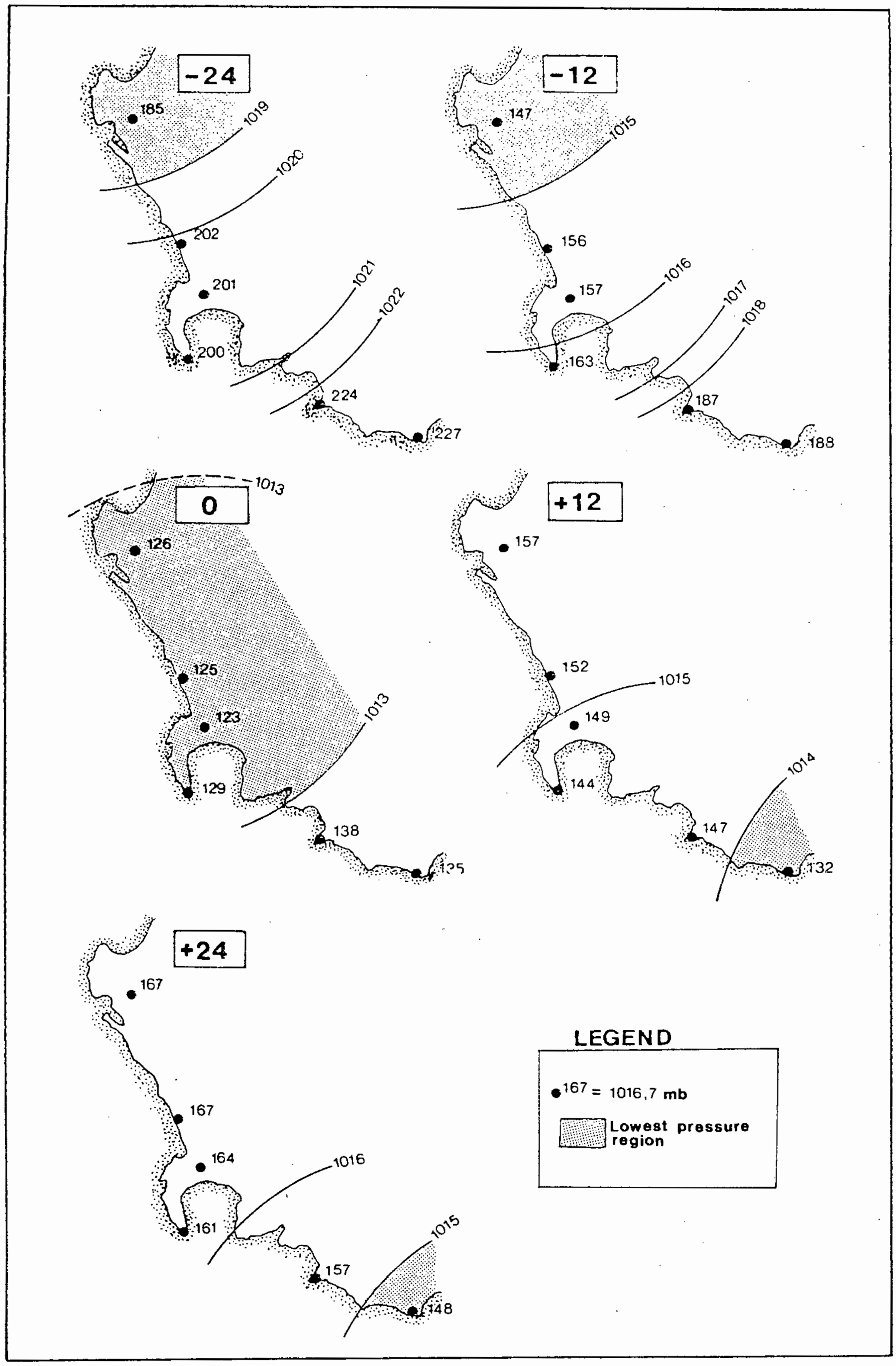

Figure 4. The mean 12 hourly isobaric maps for the Coastal Low movement through the SW Cape. The contour interval is 1mb, with the shaded area at each time interval representing the regions of lowest pressures.

(b) Temperature:

It has long been recognised (Van Rooy, 1936; Taljaard, 1940,1961,1972; Jackson, 1941,1947; Tyson, 1964,1965), that during the pre-Low period (6-30 hours before the pressure minimum) warm, dry offshore winds (berg winds) often prevail which are associated with 'pre-frontal' subsidence. Temperature discontinuities of up to 15°C have been recorded with the passage of Coastal Lows (Taljaard, 1961; Tyson, 1964). In this study the temperature parameter was not used as an indicator of the propagation of the coastal wave (c/f Jury, 1984). This was largely because the diurnal temperature variations between all six stations were not uniform and therefore no easy correction factor could be applied. In addition, the mean range in surface temperature for DF Malan and Koeberg (Table 2a) was only 4°C. However, during the same period, the temperature range increased substantially in the vertical to the 925mb level and thereafter decreased to approximate surface values again by the 700mb level (Table 2b).

TABLE 2a. The mean surface temperatures (°C) for DF Malan (1m) and Koeberg (10m; 75–10m) from –24H to +24H. The standard deviation for each time interval of the 13 cases is also given.

TIME (H)	DF MALAN		KOEBERG (10m,75m)		
	MEAN T	s	MEAN T(10m)	s	DT (75-10m)
-24	17,4	6,5	17,7	5,2	+0,7
-18	17,6	6,1	18,4	6,1	+1,1
-12	18,2	7,5	19,8	5,9	+1,5
-6	18,8	5,2	20,1	4,5	+1,7
0	20,2	5,5	18,4	3,9	+1,2
+6	17,7	4,6	17,5	4,5	+0,2
+12	17,9	3,9	16,4	3,3	-0,2
+18	16,2	2,5	15,3	2,1	-0,4
+24	16,7	3,1	15,9	2,2	-0,7
RANGE OF T	4,0		4,2		

TABLE 2b. The mean surface and upper air temperature ranges (^{O}C) for DF Malan from -24H to +24H. (after Heydenrych, Chapter 2)

SURFACE	1000MB	925MB	900MB	850MB	775MB	700MB
4,0	5,4	10,0	9,5	7,9	5,6	3,1

The pre-Low subsidence of the Coastal Low system, associated with hot dry berg winds, has often been reported (Jackson, 1947; Schulze, 1960; Tyson, 1964; Preston-Whyte, 1975) to be responsible for some of the highest temperatures in a season. To test this hypothesis the Koeberg station data was used since it provided both daily means and daily maximums. These daily means and maximums were listed for the full year covering the 13 Coastal Low episodes. The daily temperatures (mean and maximum) for all the months were then ranked from 1 to 30 or 31 depending on the number of days in the month. The temperature ranking for the Coastal Low episodes were then extracted and listed (Table 3). It is clear from the tabulations that it cannot be held that Coastal Lows are consistently responsible for the highest temperatures in the SW Cape. However during September 1985, it will be noted that the three highest temperatures were associated with Coastal Low episodes. The remaining maximum temperature occurrences resulted from other synoptic features such as Cut Off Lows, stagnating Highs or "extended" Coastal Lows (Heydenrych Chapter 2).

TABLE 3. Daily Mean and Maximum temperatures for Koeberg. (Lowest rankings correspond to highest temperatures, while highest rankings correspond to lowest temperatures).

COASTAL LOW DATES	DAILY MEAN: DAILY MEAN	DAILY MEAN: RANK (MONTH)	DAILY MAXIMUM: DAILY MAX	DAILY MAXIMUM: RANK (MONTH)
30/11/84	25,1	1	29,1	1
11/12	18,3	9	22,1	8
16/12	20,3	3	26,3	3
01/01/85	18,7	19	28,5	3
21/01	20,3	9	29,7	1
26/05	17,3	4	25,0	3
06/08	13,8	13	15,1	19
17/08	21,8	1	31,4	1
21/08	13,4	15	16,2	13
08/09	18,6	2	25,3	3
17/09	18,7	1	27,1	1
21/09	17,9	3	27,0	2
27/10	19,3	3	24,8	5

(c) Moisture Content:

In this study and according to the observations of Jury (1984) no significant surface moisture fronts could be identified. Only a gradual increase of moisture content occurs with the passage of the Coastal Low. These observations are supported by Heydenrych (Chapter 2) where it was shown that the low level layer (<925mb) does not show any sharp difference in moisture content during the passage of the Coastal Low. This feature is most likely related to the gradual and variable horizontal wind shear in this near surface layer.

(d) Wind Fields:

The wind regime in the SW Cape during the passage of a Coastal Low is marked by two distinct features. Firstly the complex nature of the topography results in substantial variations in the surface wind direction and speed between stations during similar mesoscale weather conditions. Secondly the horizontal wind shear associated with the passage of the Coastal Low is found to be very gradual (Estie, 1984; Jury, 1984; Heydenrych, Chapter 2) and not nearly so defined in the lowest 200m as it is above this level (Heydenrych Chapter 3). As a consequence of these features, the wind direction was classified into two broad sectors. A pre-Low south east (SE) sector (45^{o}-224^{o}) and a post-Low north west (NW) sector (225^{o}-44^{o}). [Diab (1984) used a similar categorisation in a wind energy study for Koeberg and Durban]. By making graphs of the mean wind directions (expressed in the form of percentages), the change in wind direction about the zero hour (OH) is clearly apparent at all the stations (Figure 5). This indicates that horizontal wind shear, although variable, is maintained during the Coastal Low's migration around the SW Cape. Also evident in Figure 5 is the occurrence of a larger percentage of calms during the Coastal Low's passage for the more inland sites of DF Malan and Langebaanweg. This would suggest that a high pollution potential is a very real possibility at locations away from the coastal margin. This is due to the fact that the vertical mixing layer is substantially reduced by the subsidence of the upper air inversion during this period (c\f Preston-Whyte, 1975).

The mean wind speeds at the different locations through the SW Cape vary considerably during the passage of Coastal Lows (Figure 6). As Coastal Lows migrate down the west coast towards DF Malan, the mean wind speeds vary between 2-6m/s for the whole period. Diab (1984) has shown similar results for Koeberg, with a mean wind speed of 4,2m/s in the pre-Low period and 7,2m/s in the post-Low period. Wind speeds change

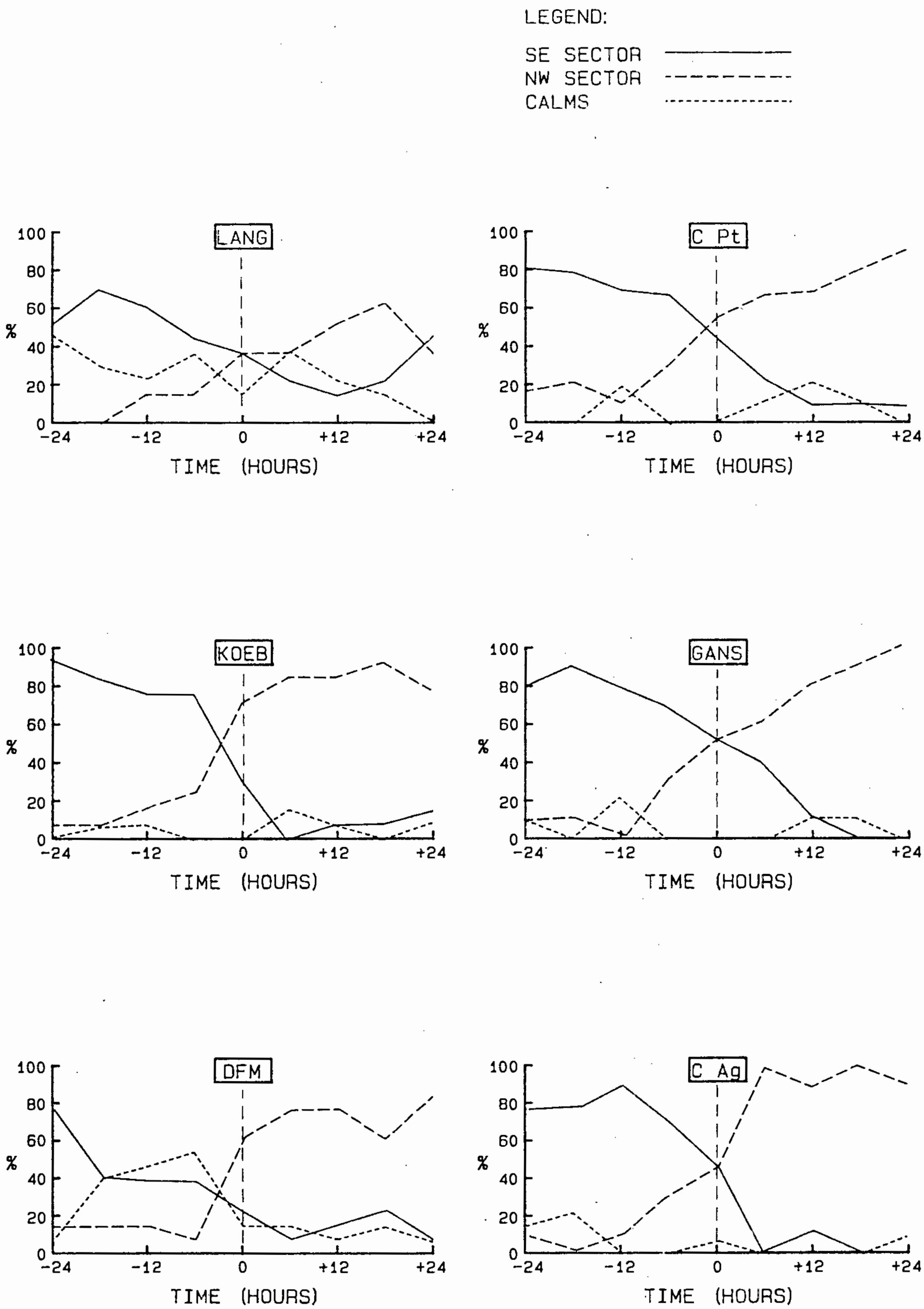

Figure 5. The mean surface wind direction (expressed as a percentage) for the 6 stations during the passage of the Coastal Low system. The pre-Low, SE sector is between 45-224° and the post-Low, NW sector is between 225-44° (measured clockwise).

dramatically as the systems migrate through the SW Cape. The mean wind speed increases substantially between DF Malan and Cape Point and Gansbaai respectively. A further difference is also shown between the two stations of Cape Point and Gansbaai. At Cape Point, the south easterly winds tend to swamp the pre-Low mesoscale wind regime while at Gansbaai the post-Low north westerly winds are enhanced due to a leeward jet effect from the Hottentot Holland Mountains. By the time the system has reached Cape Agulhas the wind regime has started to normalize back to the typical structure of a Coastal Low. As the pressure minima have been shown to remain fairly consistent through the SW Cape, the wind speed variations between stations are attributed to the variation in topography.

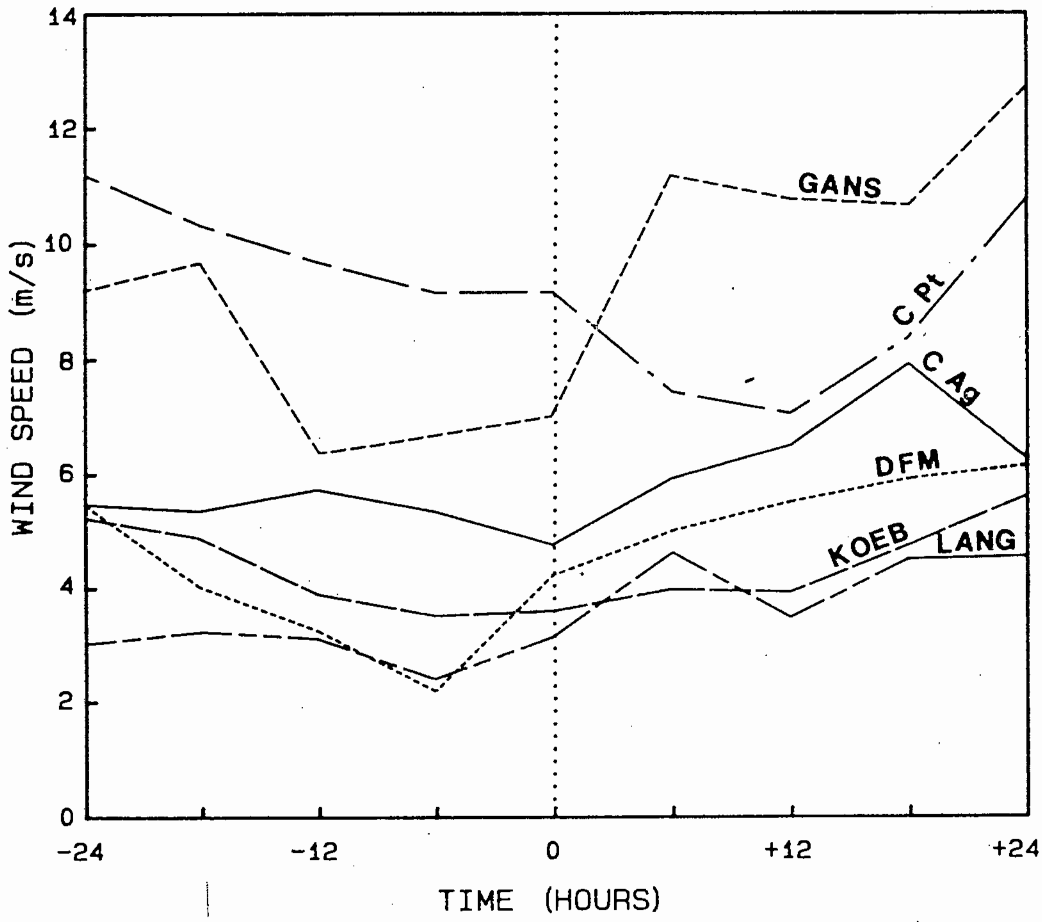

Figure 6. The mean wind speeds (m/s) for the 6 stations during the passage of the Coastal Low system.

SUMMARY AND CONCLUSIONS

This paper has considered the surface characteristics and in particular the pressure and wind fields during the passage of a summated series of Coastal Lows through the SW Cape. This study has shown that :

1) By using corrected atmospheric pressure as the primary recognition feature, the Coastal Low was identified and shown to migrate down the west coast through the SW Cape and on to the south coast. There was no sign of "jumping" between the west and south coasts or any significant deterioration of pressure values.

2) The pressure minimum was found to be relatively consistent between stations (with a variation of less than 1,5mb) as the Coastal Low passes through the SW Cape.

3) The pressure tendencies were found to be greatest (-1,5 to -3,0mb per 6 hours) in the pre-Low period for all the stations in the SW Cape.

4) Mean surface temperature ranges of about $4^{\circ}C$ were found for both DF Malan and Koeberg between -24H and +24H. The surface range being substantially less than that of the free atmosphere above.

5) No abrupt changes in near surface moisture conditions were seen to occur during the passage of the Coastal Low in the SW Cape.

6) The surface wind change was found to be gradual and very variable between stations. However, there was a consitent general backing of the wind from the SE sector to the NW sector at the zero hour (0H) for all the stations in the SW Cape.

7) The wind speeds were seen to vary considerably in magnitude through the region. A substantial increase in wind speed between DF Malan and Cape Agulhas was noted, due to local topographic effects.

The findings of this paper apply in particular to the Coastal Low as it appears over the SW Cape. It is likely that some of the observed values would be different if the system was sampled further up or along the coast. The surface characteristics discussed here are nevertheless entirely consistent with the theoretical findings of Gill (1977) and in general support the many observations and findings of other authors in their analyses of the Coastal Low along the southern African coastline.

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CHAPTER 5

A MESOSCALE ANALYSIS OF A COASTAL LOW THROUGH THE SW CAPE : 19 TO 22 JANUARY 1985.

A case study analysis of a Coastal Low system through the SW Cape using both upper air (Radiosonde and Sodar soundings) and surface recordings confirms that the Coastal Low has a highly complex structure. Its influence on local weather appears dependent upon the actual synoptic scale circulation pattern and the effect of the local coastal topography.

A MESOSCALE ANALYSIS OF A COASTAL LOW THROUGH THE SW CAPE : 19 TO 22 JANUARY 1985.

Coastal Lows are well known mesoscale phenomena occurring along the southern African coastline. Many of the associated weather features (eg berg winds) are recognised and talked about by the general public. Scientific investigation of the surface and upper air features of these coastal systems have been undertaken over many years (Lombard et al., 1941; van Ligen, 1944; Preston-Whyte, 1975; Estie, 1984; Jury, 1984; Heydenrych, Chapters 2,3,4). This paper considers a particular episode of a Coastal Low over the South Western (SW) Cape (from 19 to 22 January 1985) and presents a detailed meso-analysis of the system through space and time. Figure 1 shows the study area and the stations used in the data capture.

BACKGROUND

Gill (1977) first described the Coastal Low as an atmospheric, coastally trapped Kelvin wave. The Coastal Low is generated and maintained by the offshore component of the synoptic scale circulation. This offshore flow from the high plateau (approximately 1500m) to the coastal plain, results in the formation of a leeward trough and an area of relatively low surface pressure (Taljaard et al 1961). Associated weather conditions in the pre-Low period of the Coastal Low include lowering of the upper air inversion, hot dry offshore winds (known as berg winds), high temperatures, low humidities and as the centre approaches, light variable winds . The post-Low period is accompanied by cooler, moister conditions, sometimes associated with fog and/or more blustery winds and thunderstorms. The essential features however are the relative shallowness of the system, occurring below the 700mb level, and a distinct surface pressure minimum (Coastal Low Workshop 1984).

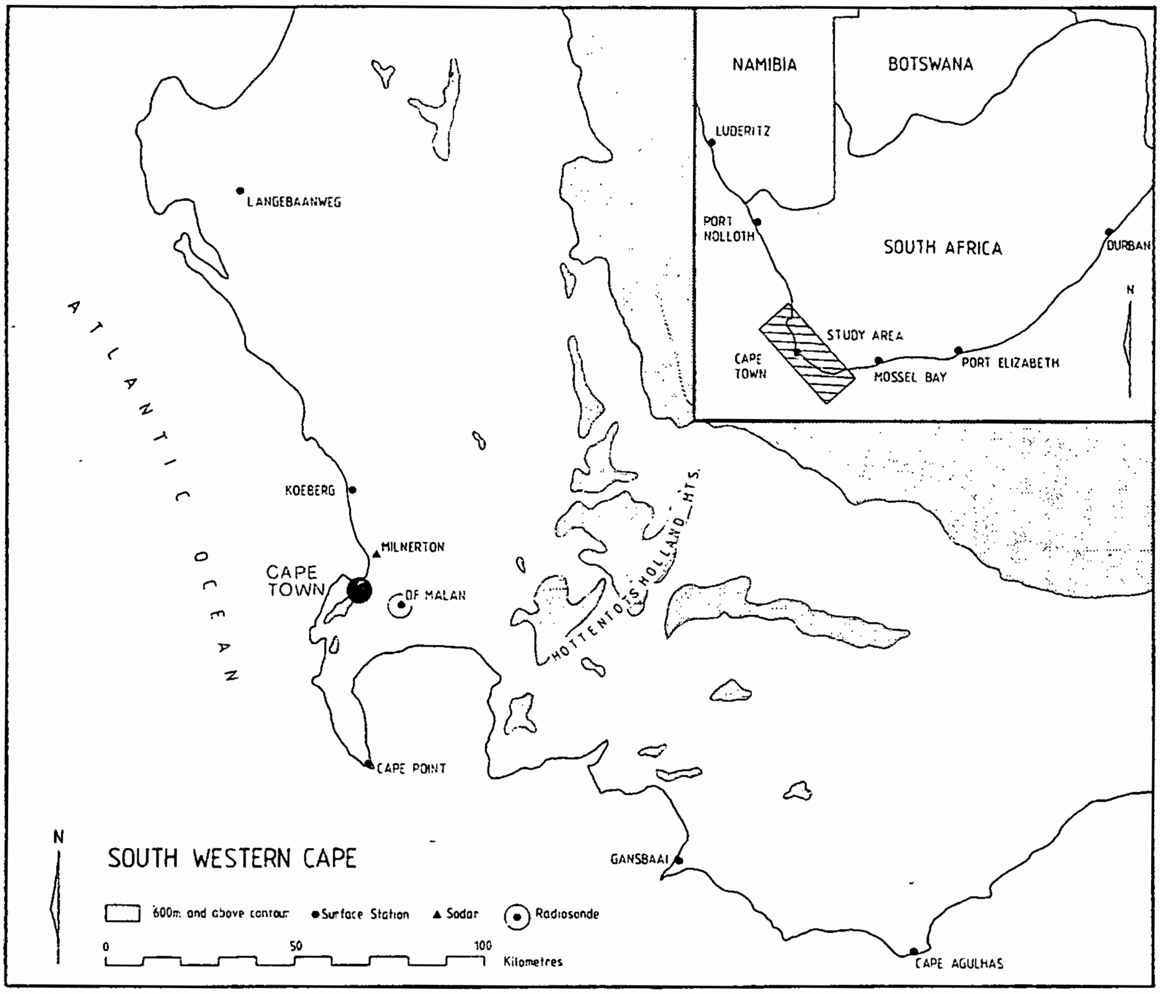

Figure 1. Study area showing the 6 stations and the type of data obtained from them.

THE STUDY

This 'case study' forms part of a series of investigations by Heydenrych (Chapter 2,3,4) and the reader is referred to the above papers for a more detailed description of the methodologies used in this paper. This study represents a typical sequence of the migration of a Coastal Low through the SW Cape. The 19 to 22 January 1985 episode was investigated firstly from a synoptic overview, and then through a consideration of the upper air features (i.e. below 700mb). Finally a detailed surface analysis of the Coastal Low pulse was undertaken as it rounded the SW Cape.

SYNOPTIC CONDITIONS

Figure 2 shows the positions and progressions of the Coastal Low, the South Atlantic High pressure cell, the 850mb pressure surface (over the southern African subcontinent) and the trailing frontal system during the period 19 to 22 January 1985. Each component of the synoptic circulation is represented in its approximate position at 14H00 (SAST) for the 4 days (19,20,21,22 January 1985).

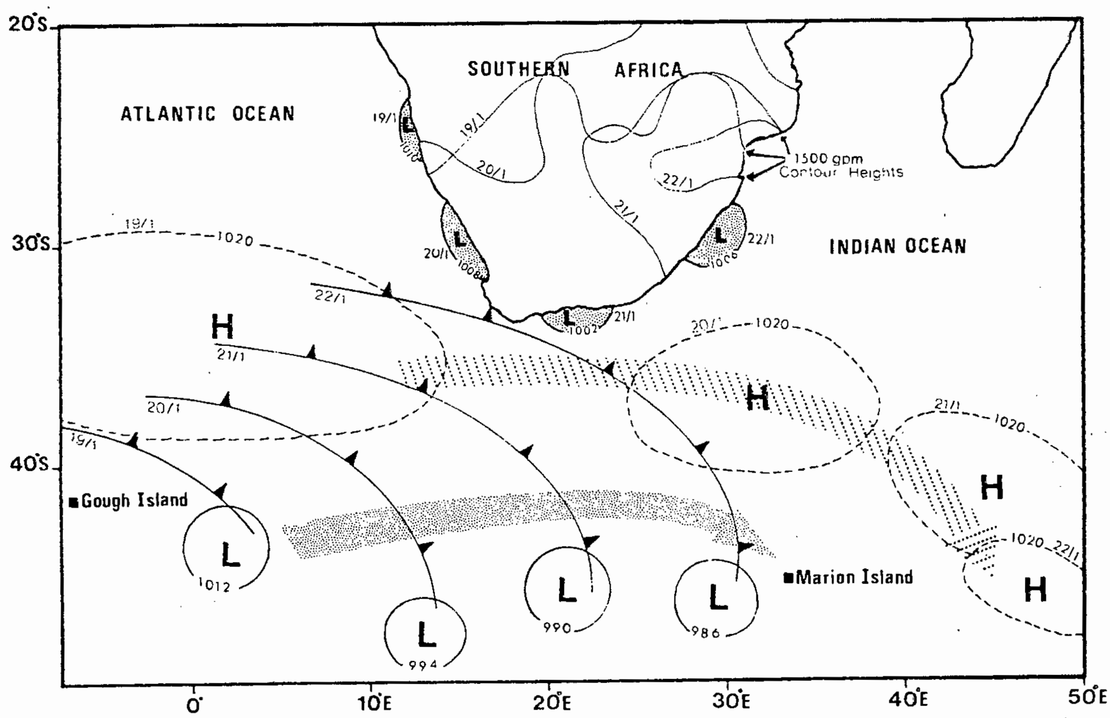

Figure 2. The synoptic conditions at 14H00 SAST from 19 to 22 January 1985.

The Coastal Low first appeared off the coast of Namibia (25^{o}S) with a pressure minimum of approximately 1010mb. The intensification of the pressure wave in its eastward movement can be seen by the pressure minimum of 1002mb at

Mossel Bay. Some distance up the east coast the atmospheric pressure wave reversed in pressure tendency and started to rise - as indicated by the pressure minimum of 1006mb at Durban. On the west coast, temperatures were generally higher and cloud cover was less than along the south and east coasts. This is more probably due to the stronger subsidence (in the pre-Low period) associated with the Anticyclonic high pressure cell than the westerly cyclone. This feature has been previously noted and discussed by De Wet (1979) and Banon (1980).

The Coastal Low travelled a distance of roughly 2300-2400km in a period of 72 hours. The speed of the system appears not to have been consistent, showing a gradual increase in speed as the system migrated eastwards (Table 1). Gill (1977) and Estie (1984) have also commented upon the non linear speeds of the Coastal Low in its migration around the southern African coastline.

TABLE 1. Speed of the Coastal Low system along the southern African coastline. (calculated from Figure 2, Chapter 5)

COASTLINE	WEST	SOUTH WEST	SOUTH EAST	MEAN
Distance travelled in 24 hours (km)	600	800	1000	800
Average Speed (km/h)	25	33	40	33

UPPER AIR ANALYSIS

The Radiosonde system, situated at DF Malan provided the larger scale, background detail (<700mb or 3000m) at a temporal resolution of 12 hours. A doppler acoustic radar (Sodar) located at Milnerton, gave a more detailed picture of the lower boundary layer wind structure (<1000m) with a temporal resolution of 1 hour.

(a) Radiosonde analysis: DF Malan

A chronological history of the Coastal Low system is shown in Figure 3. A summary of the relevant features is given in Table 2 where dry bulb temperature (T), dew point temperature (Td), height of the base of the inversion and a depiction of mean wind speeds and directions are tabulated.

TABLE 2. Summary of the upper air meteorological conditions at DF Malan from the 19 to 22 January 1985 (–36H to +24H).

TIME	PRESSURE	TEMPERATURE(T)	TEMPERATURE(Td)	INVERSION	WIND	CLOUDS
-36H	Surface values falling faster than 700mb	Above 850mb at maximum	Falling for whole layer(1000-700mb)	905mb - 2C Above 900 isothermal	S-E below 775mb W above 775mb	Sc (1/8)
-24H	Falling whole layer(1000-700mb)	Rising below 850mb Above 850mb constant	850-700mb -minimum Below 850mb falling	970mb - 4C	S-E below 850mb W above 850mb	none
-12H	Falling whole layer(1000-700mb)	Rising below 850mb Above 850mb constant	950-850mb -minimum	970-930mb isothermal	S below 900mb W-NW above 900mb	none
0H	Surface - minimum Falling above 900mb	Maximum below 775mb	Increase to 775mb	Surface- 890mb 11C	NNE-NW whole layer	none
+12H	Surface rising Upper air falling	Drop 6-10C in 1000-775mb layer	Moist below 900mb	900mb - 1C	NW-W whole layer	St (1/8)
+24H	Rising below 900mb Falling above 900mb	Droping for whole layer (1000-700mb)	Constant for most the layer	895mb - 3C	S-SW below 900mb SW-NW above 850mb	Ci (1/8) Sc (6/8)

In order to show the specific effects that the passage of the Coastal Low had on the lower boundary layer, the system was considered as an 'atmospheric disturbance' about a mean. The mean was calculated from the monthly averages during the 12 month study period to produce an annual mean. The temporal variations of parameters (pressure height, dry bulb temperature and dew point temperature) were thus described about their annual means for all the standard levels (1000, 925, 900, 850, 775 and 700mb) during the passage of this particular Coastal Low.

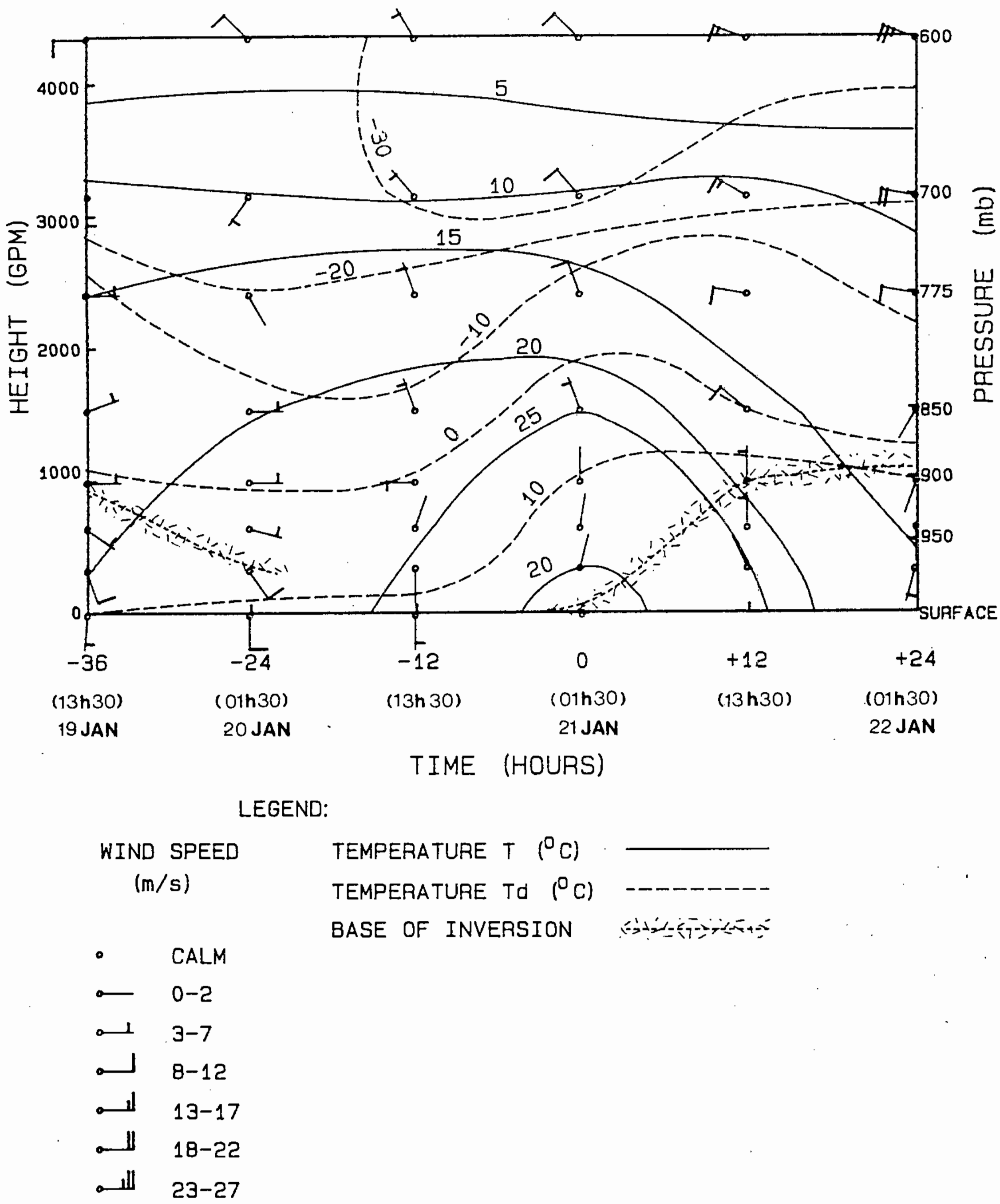

Figure 3. A time-height series of the Coastal Low from -36H to +24H (19 to 22 January 1985). The zero hour (0H) sounding is at 01H30 on the 21 January 1985. (The passage of the Coastal Low is from left to right in this and subsequent diagrams).

Pressure:

By plotting the variation of pressure at each of the standard levels, one can see that the slope of the contours indicate a phase lag of 24-36 hours between the near surface layers (<900mb) and the upper levels (>800mb) (Figure 4). This would suggest that the trailing frontal system lags behind the Coastal Low by roughly the same period. This phase lag is confirmed by the evidence shown in Figure 2 and by the findings of Gill (1977) and Heydenrych (Chapter 2). Another salient feature of the plotted data is the shallowness of the system which occurs below the 900mb level (as shown by the -75m contour). The post-Low period shows a general merging of the pressures of the Coastal Low system with those of the trailing frontal system below the 850mb level.

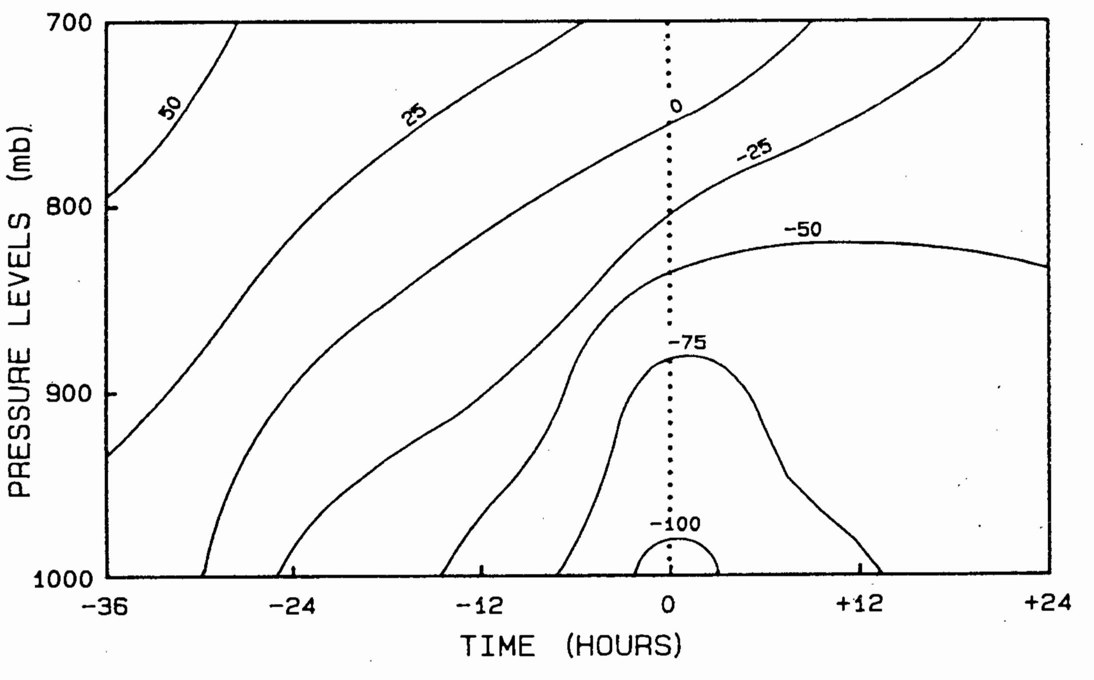

Figure 4. Variation about the annual mean for the standard pressure levels (gpm) from −36H to +24H.

Temperature:

Often the most predominant feature of the Coastal Low is the above normal temperatures associated with the pre-Low period of the system. The maximum variation (between -36H to OH) of the dry bulb temperature (10°C) occurs at the 900mb level (Figure 5). However the variation of heating at the surface is only 4-6°C, approximately 50% of that at the 900mb level. This difference between the surface temperatures and the 900mb level temperatures, has previously been noted by Heydenrych (Chapter 2). The horizontal temperature variation also suggests a vertically aligned 'front' or discontinuity in both the pre-Low (-24H) and post-Low (+12H) periods.

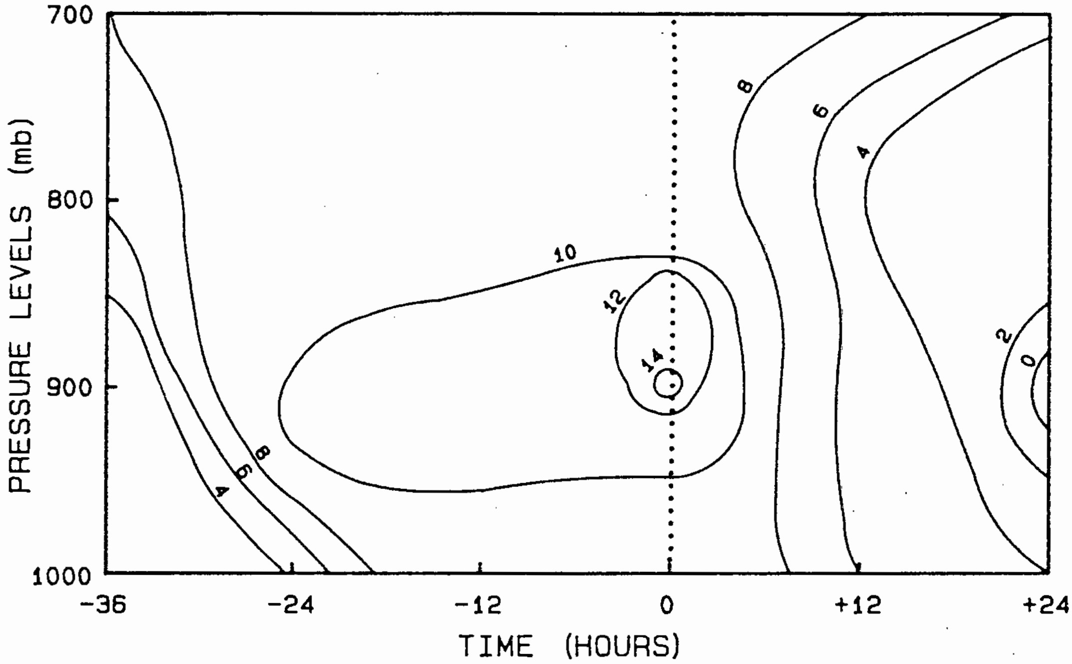

Figure 5. Variation about the annual mean for dry bulb temperature (T °C) from -36H to +24H.

Moisture Content:

Dew point temperature (Td) reflects the moisture content of the air. The change from drier to moister conditions occurs between -12H and OH (Figure 6), and is associated with the influx of northerly to north westerly winds. As with the dry bulb temperature, the vertical alignment of the isotherms is again shown between 950 and 800mb (500-2000m). The near surface moisture change (below 950mb) is very gradual, a feature previously discussed by Estie (1984), Jury (1984) and Heydenrych (Chapter 2).

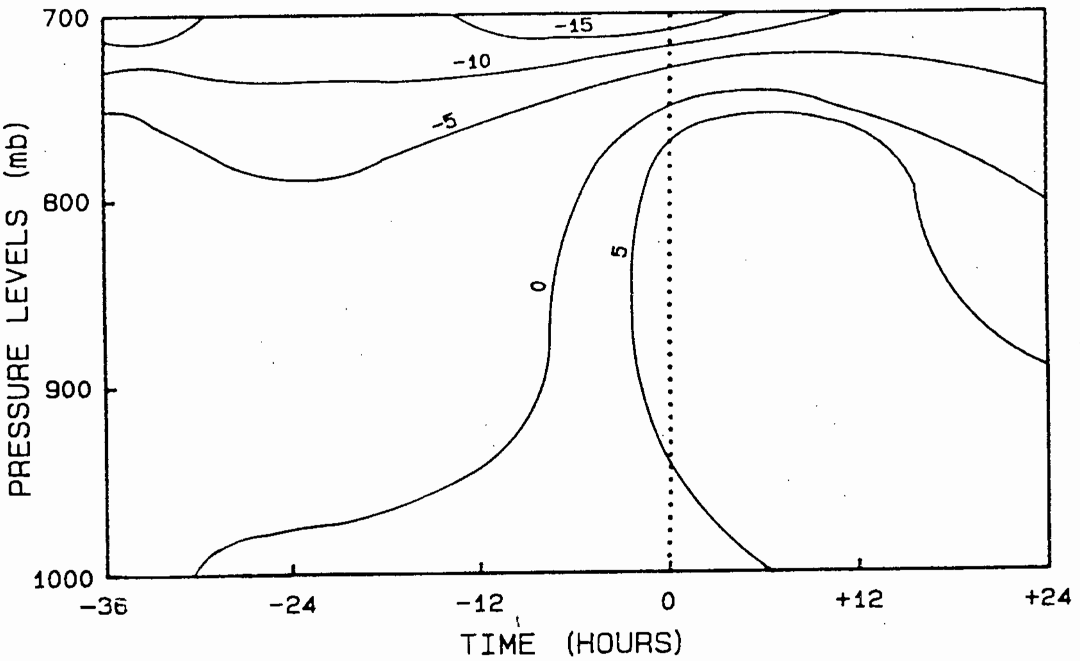

Figure 6. Variation about the annual mean for dew point temperature (Td °C) from -36H to +24H.

Inversions:

The Coastal Low shows a weakly defined upper air inversion (<2°C) at -36H in the 900mb region (Figure 7). Above this level, a near isothermal lapse rate (to the 800mb level) and also a marked depression in the dew point temperature, indicate a region of dry subsided continental air. By -24H the upper air inversion can be seen to have strengthened (4°C) while the base has descended to 970mb. No inversion is present at -12H but the whole layer is characterised by an increase in dew point depression values. This indicates that a general drying of the atmosphere was still taking place (Table 3). At 0H a well defined surface based nocturnal radiation inversion (11°C in strength and 1200m in depth) can be seen to have formed, while through the whole layer an increase in moisture is apparent (lower dew point depression values). The post-Low period shows an increase in moisture levels below the upper air inversions (900mb), while above this level the air continues to remain fairly dry.

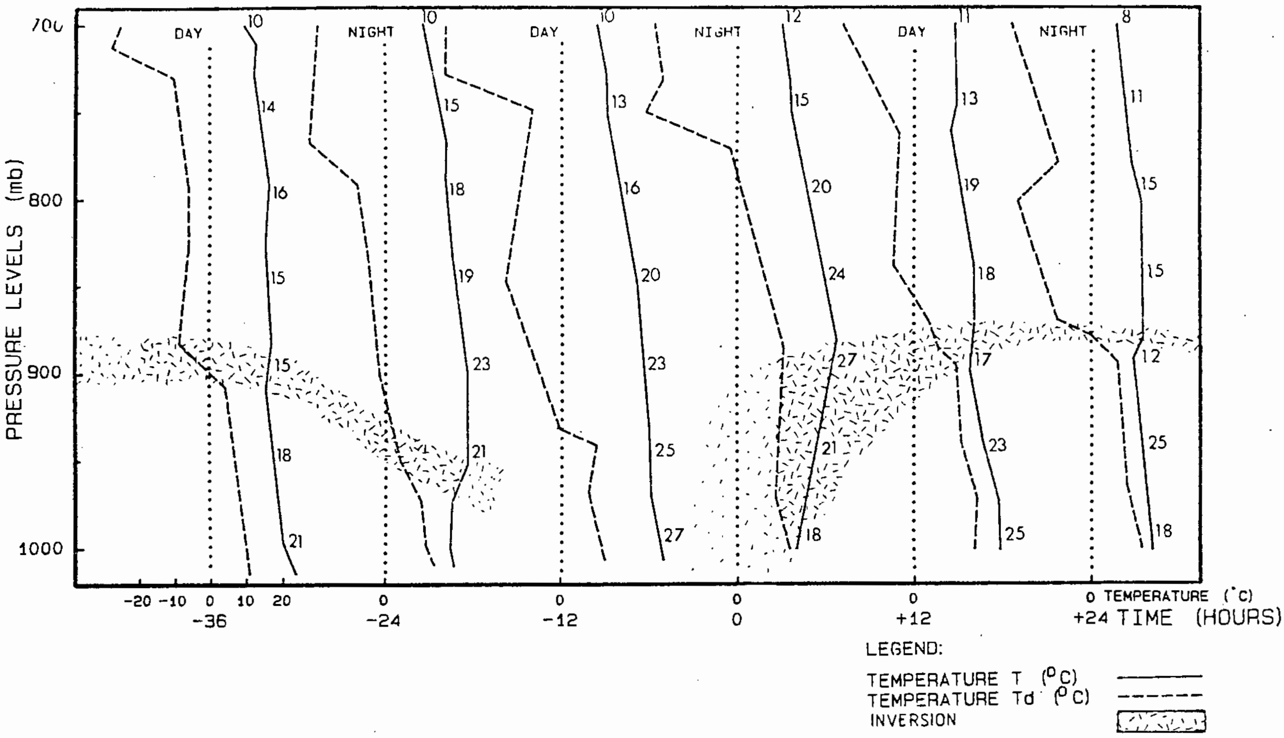

Figure 7. A time-height series of temperature (T °C) and dew point temperature (Td °C) from -36H to +24H. The actual temperature values and the base of the inversion level are also shown .

TABLE 3. The dew point depression (T-Td) from -36H to +24H at selected levels.

	TIME (HOURS)					
LEVEL (MB)	-36H	-24H	-12H	0H	+12H	+24H
1000	11	6	21	2	.7	2
950	11	19	16	10	5	5
900	15	25	29	12	4	3
850	22	24	35	17	22	28
800	22	25	29	18	19	35
750	23	36	25	41	19	32
700	35	30	43	36	31	28

(b) Sodar analysis: Milnerton

A Remtech Doppler Acoustic Radar (Sodar) was situated at Milnerton 12km north west of DF Malan (Figure 1). The Sodar provided averaged hourly wind data at 50m intervals vertically up to a maximum height of 1000m. The following parameters were sampled : Horizontal wind speed (V) and direction (θ), sigma theta (σ_θ), vertical wind speed (W) and sigma W (σ_W). The identification and methodology used in this paper are similar to that used by Heydenrych (Chapter 3). The centre (OH) of the Coastal Low was identified at 06H00 on the 21 January 1985.

Horizontal Winds:

The depiction of the Coastal Low is best done by plotting the horizontal wind vectors in the form of a time sequence (Figure 8). A 60-hour time-height series of the hourly values of the horizontal wind speed and direction is shown for the period 19 to 22 January 1985.

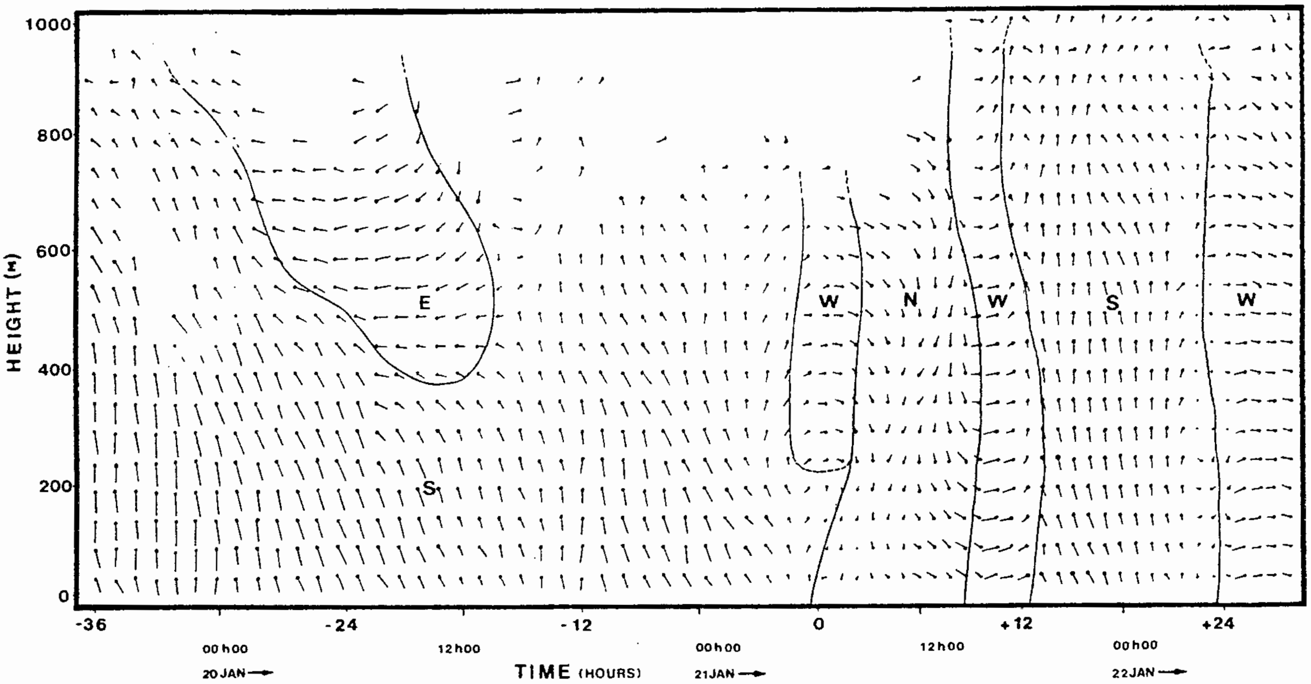

Figure 8. A time-height series of hourly horizontal wind vectors form -36H to +24H.

At -30H a strong southerly component (>12m/s) was blowing in the layer below 400m. By -24H this low level wind had backed to easterly above 500m. This easterly pulse gradually subsided by -18H to between 400-800m. Subsequently, between -12H and -6H the easterly core was replaced by a northerly wind (above 500m) while below this level the southerly expanded to approximately 600m, with another increase in wind speed (below 400m). From -6H the wind veered (rather than backed) through westerly to northerly by 0H. It was only in the post-Low period that the wind started backing to westerly (by +6H) and to southerly by (+12H). The wind finally veered back to westerly after +24H, signalling the arrival of the prefrontal winds of the trailing westerly cyclone. The veering of the wind at 0H is contrary to the theoretical description of the Coastal Low (Coastal Low Workshop, 1984) and it would seem to suggest that the actual core or vortex of the Coastal Low can be overwhelmed by the synoptic meteorology. Heydenrych (Chapter 3) has shown the more characteristic backing from south through east to north for a 'mean' Coastal Low in the SW Cape. It has been pointed out that no two episodes are exactly the same or show all the typical features of an "ideal" Coastal Low (van Ligen, 1944; Estie, 1984; and Jury, 1984). Hence the abnormal veering behaviour of the wind profile at 0H does not necessarily put into question, the recognised general behaviour of a typical Coastal Low. Another feature shown in Figure 8 is the abrupt change in wind direction through the whole boundary layer, particularly in the centre and post-Low periods. This pulsing or non-linear jump (Preston Whyte, 1975; Gill, 1977; Jury, 1984; Heydenrych, Chapter 3) is a common feature of the Coastal Low, and is usually more pronounced on the south and east coasts than it is on the west coast.

A depiction of the isotachs (Figure 9) for the same time sequence shows the occurrence of a wind speed minimum (<4m/s) at the centre (0H). This was seen to last approximately 6 hours, (in accordance with an earlier finding of Heydenrych Chapter 3). On either side of this 'calm' centre, are wind speed maxima (>8m/s) which exist below 400m in the pre-Low period and below 600m in the post-Low period. These two cores of higher wind speeds have been suggested by Heydenrych (Chapter 3) as possibly indicating the outer edges of the Coastal Low system. Figure 9 shows that the system took approximately 32 hours to pass the Sodar. Therefore with the average speed of the system in the SW Cape being calculated at 33km/h (from Table 1), the outer diameter was calculated to be approximately 1050km. Thus the core of the Low (<4m/s) which extended over a period of approximately 6 hours, thus had an inner diameter of roughly 200km.

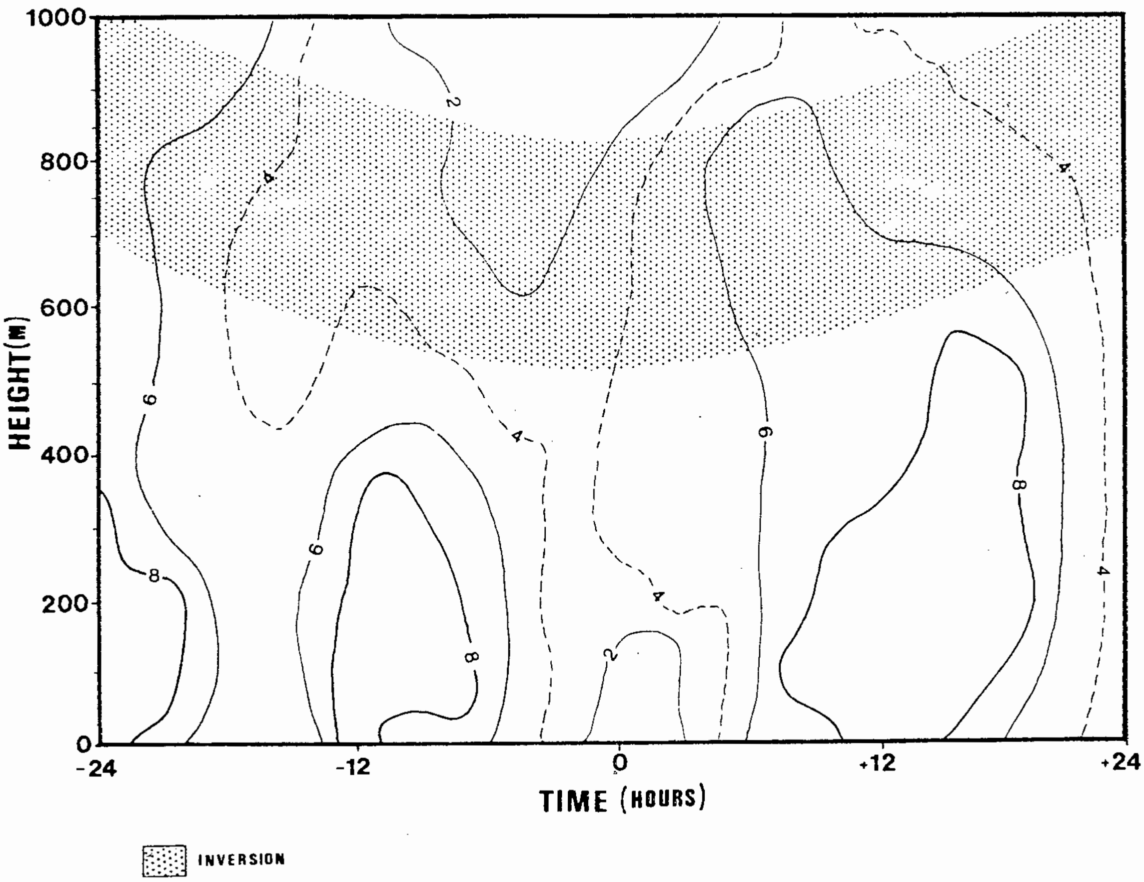

Figure 9. The horizontal wind speed (m/s) from -24H to +24H.

The variation of the horizontal wind direction (Figure 10), as described by sigma theta (σ_θ), indicates several characteristics. The central region (around 0H and wind speeds of <4m/s), is found to have a highly variable component of the horizontal wind direction in the lower 200m (i.e. high σ_{θ} values). Then above the low level wind speed maxima (>8m/s), there is another region of lighter and more variable winds which can be seen, where high sigma theta values also exist for most of the period. By contrast low sigma theta values, are found in the low level wind speed maxima (below 500m), on either side of the centre.

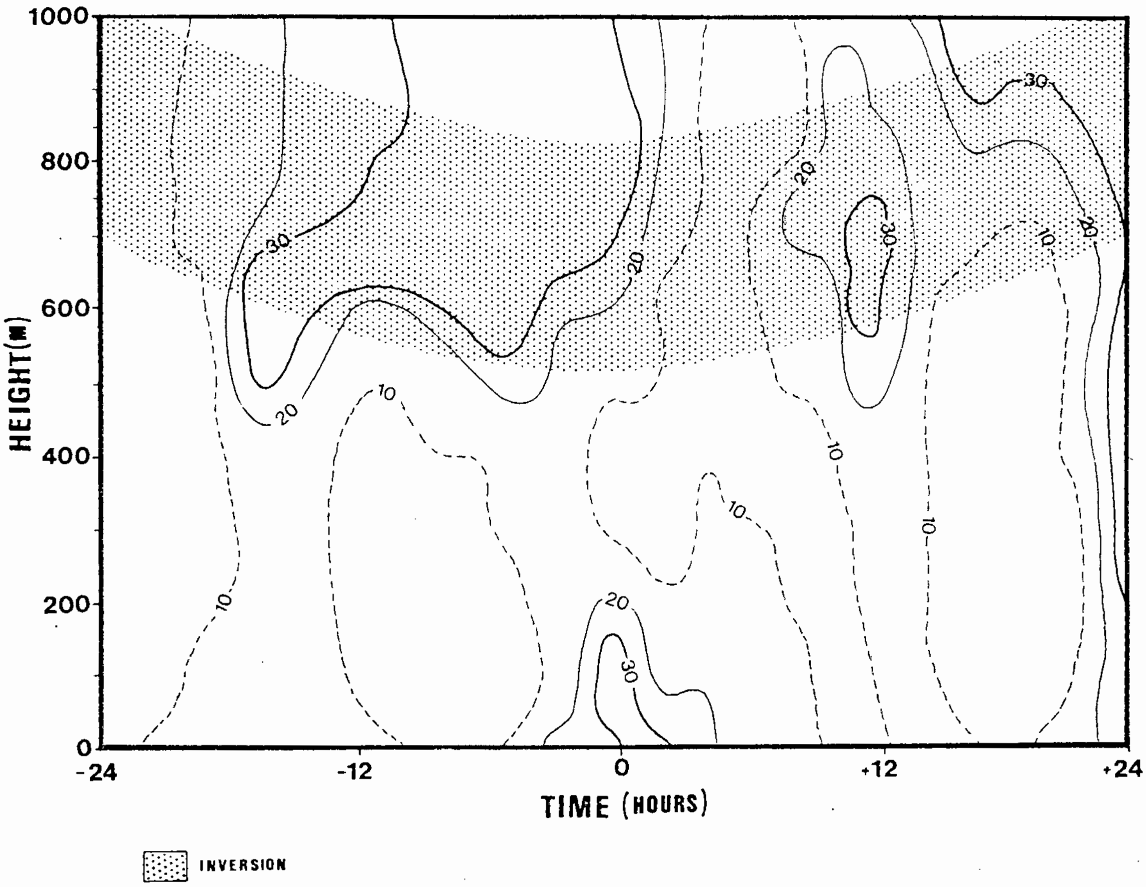

Figure 10. The standard deviation of the horizontal wind direction component (^{O}) from -24H to +24H.

Vertical Winds:

The zero contour of the vertical wind speed component, is found in the central region (0H). Strong divergence (>40cm/s) exists in the pre-Low period and much weaker convergence (<20cm/s) in the post-Low period (Figure 11). The high variability of the vertical wind speed component (σ_W) is closely aligned to the region of high horizontal wind speeds (Figure 12).

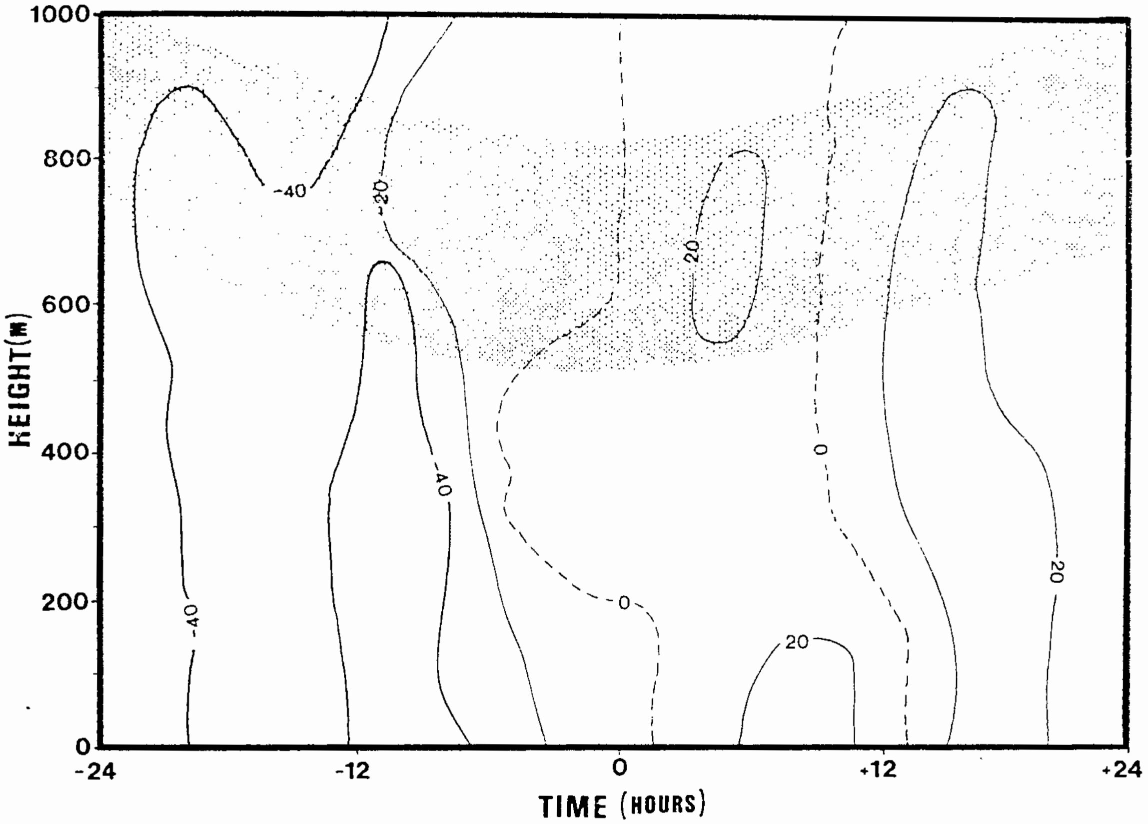

Figure 11. The vertical wind speed (cm/s) from -24H to +24H.

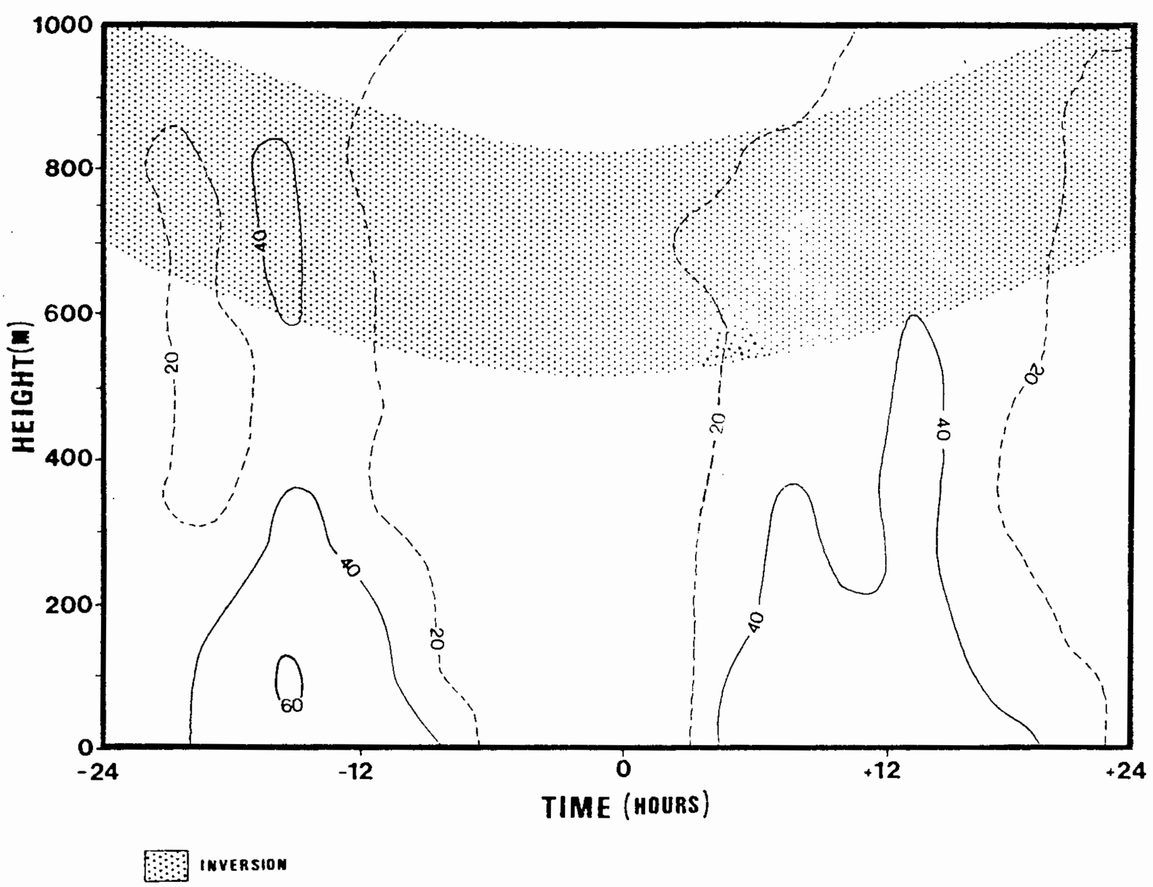

Figure 12. The standard deviation of the vertical wind speed component (cm/s) from -24H to +24H.

SURFACE CHARACTERISTICS

It has been shown that the Coastal Low migrates through the SW Cape without any significant variation in the pressure minimum (Heydenrych Chapter 4). In this study a similar methodology and distribution of monitoring stations were used to those in the previous studies (Figure 1). The movement of the Coastal Low in the SW Cape was monitored primarily by atmospheric pressure.

Pressure :

Surface pressure over a 60-hour period (at 6 hourly intervals) for the 6 stations was first corrected for diurnal pressure and altitude variations. A further correction to the station pressure had to be made because of moisture and calibration variations between stations (the pressure height equation assumes a constant moisture level). This was accomplished by a simple normalisation of the pressure values. The pressure values are therefore expressed relative to a mean sea level value. The reference point (depicted as 0H on all the diagrams) is the time at which the lowest pressure was experienced as the Coastal Low passed through DF Malan.

Figure 13 shows the observed isobaric plot by means of a time sequence for each station. The pressure minima clearly pass over the SW Cape, starting from -6H at Langebaanweg through to Cape Agulhas by +6H. The value of the minimum pressure between Langebaanweg and Cape Point appears to remain fairly constant (1006,5-1007,7mb). After Cape Point there appears to be a weakening of the pulse (an increase to 1009,7mb) at Gansbaai and a slight strengthening thereafter towards Cape Agulhas (1008,4mb).

Also shown in Figure 13, are the 6 hourly pressure tendencies. They are all characterised by sharp peaks (emphasised by the arrows) on either side of the pressure minimum region. These peaks indicate regions of sharp pressure changes or pulses and suggest that pressure changes are not uniform with the passage of the Coastal Low but that they occur rather in 'waves' or 'fronts'. This non-linear change or jump has already been discussed by a number of authors for the South African Coastal Low (Taljaard et al., 1961; Tyson, 1964; Taljaard, 1972; Preston-Whyte, 1975; Gill, 1977; Jury, 1984 and Heydenrych, Chapter 4) and in the Australian 'cool change'(Berson et al., 1957,1959; Garratt, 1985).

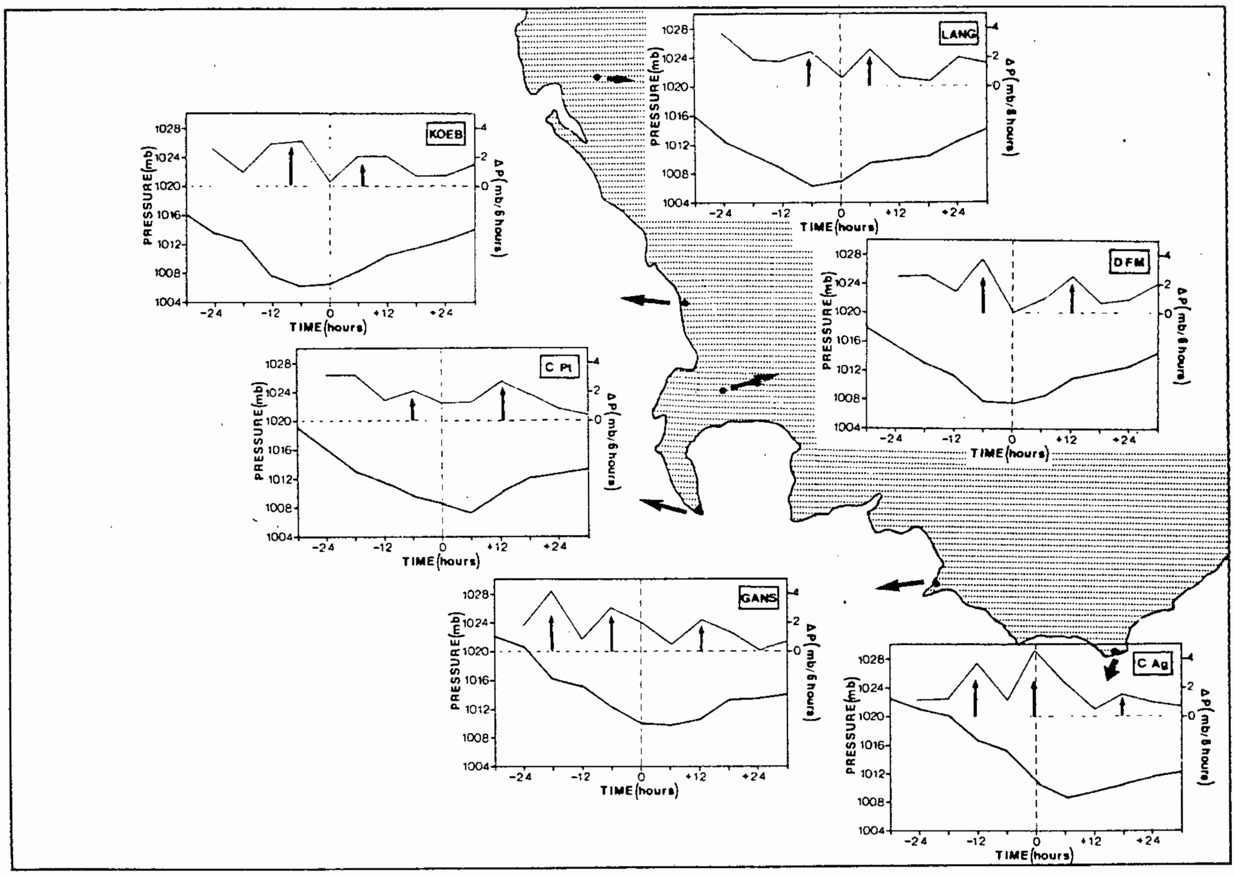

Figure 13. The corrected surface pressure (mb) for the 6 stations from -36H to +24H. The centre (0H) was identified at 04H00 21 January 1985 (the time that the Coastal Low pressure minimum passed through DF Malan). For each station the bottom line represents the absolute pressure (reduced to the M.S.L) with the top line representing the 6 hourly pressure tendencies.

The speed of the system can be calculated through the identification of the movement of the pressure minimum around the coastline. Using corrected hourly pressure data from Langebaanweg and DF Malan, the Coastal Low was shown to travel south towards the Peninsula with a velocity of approximately 27km/h. This would support earlier calculations of the average speed of the system from the synoptic charts (Table 1).

Temperature:

Apart from a general warming in the pre-Low and a cooling in the post-Low period, the 60 hour sequence did not reveal anything significant regarding the spatial pattern of the temperature. However the west coast stations in the pre-Low period did indicate a greater variation and higher temperatures than the south coast stations (Table 4).

TABLE 4. Summary of the main temperature features (^{O}C) for the 6 stations from -36H to +24H.

	WEST COAST				SOUTH COAST	
PARAMETER	LANG	KOEB	DFM	CPt	GANS	CAg
Maximum	32,8	29,6	26,3	21,4	-	23,6
Minimum	15,6	16,8	15,6	16,0	-	17,0
Mean	21,5	20,6	20,8	18,1	-	20,4
Std. deviation of mean	5,6	4,3	3,6	1,7	-	2,0

An analysis of hourly temperature variation for DF Malan and Koeberg show that the diurnal cycle completely swamps the signature of the Coastal Low on the surface (Figure 14).

Wind Fields:

By depicting the wind flow in a spatial-time series (Figure 15) it is possible to show the effect the Coastal Low has on local wind circulation patterns. In general the pre-Low period is characterised by a large increase in the wind speed gradients towards Cape Point and Gansbaai. The wind direction is essentially parallel to the coastline with

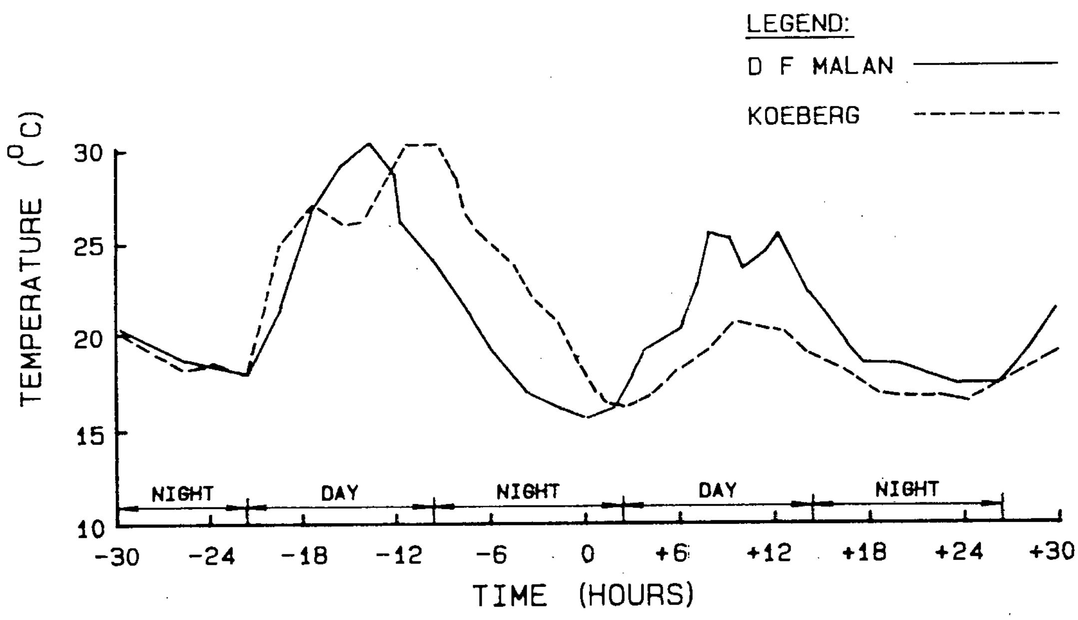

Figure 14. The hourly temperature at DF Malan and Koeberg from -30H to +30H.

little or no sign of offshore flow. This is to be expected, given the fact that the Sodar showed the offshore component (easterly through to northerly) to be confined to above 400m for this Coastal Low sequence. From -6H to 0H the wind was light and variable (except for Cape Point), with no predominant wind flow direction. By +6H the Low was situated over the southern part of the study region, while the north-west wind was established over most of the SW Cape, except for Cape Agulhas where the wind was still easterly. From +12H the wind backed through to south-west to south sector for most of the region. It was only at +30H that the wind veered back to the west - north-west with the arrival of the weak frontal system.

The summary of the wind regime for this 60 hour case study shows a marked increase in mean and maximum wind gradients towards Cape Point (Table 5). This increase is a local peculiarity of the wind circulation in the SW Cape, due to the complex topography of the region (see Figure 1).

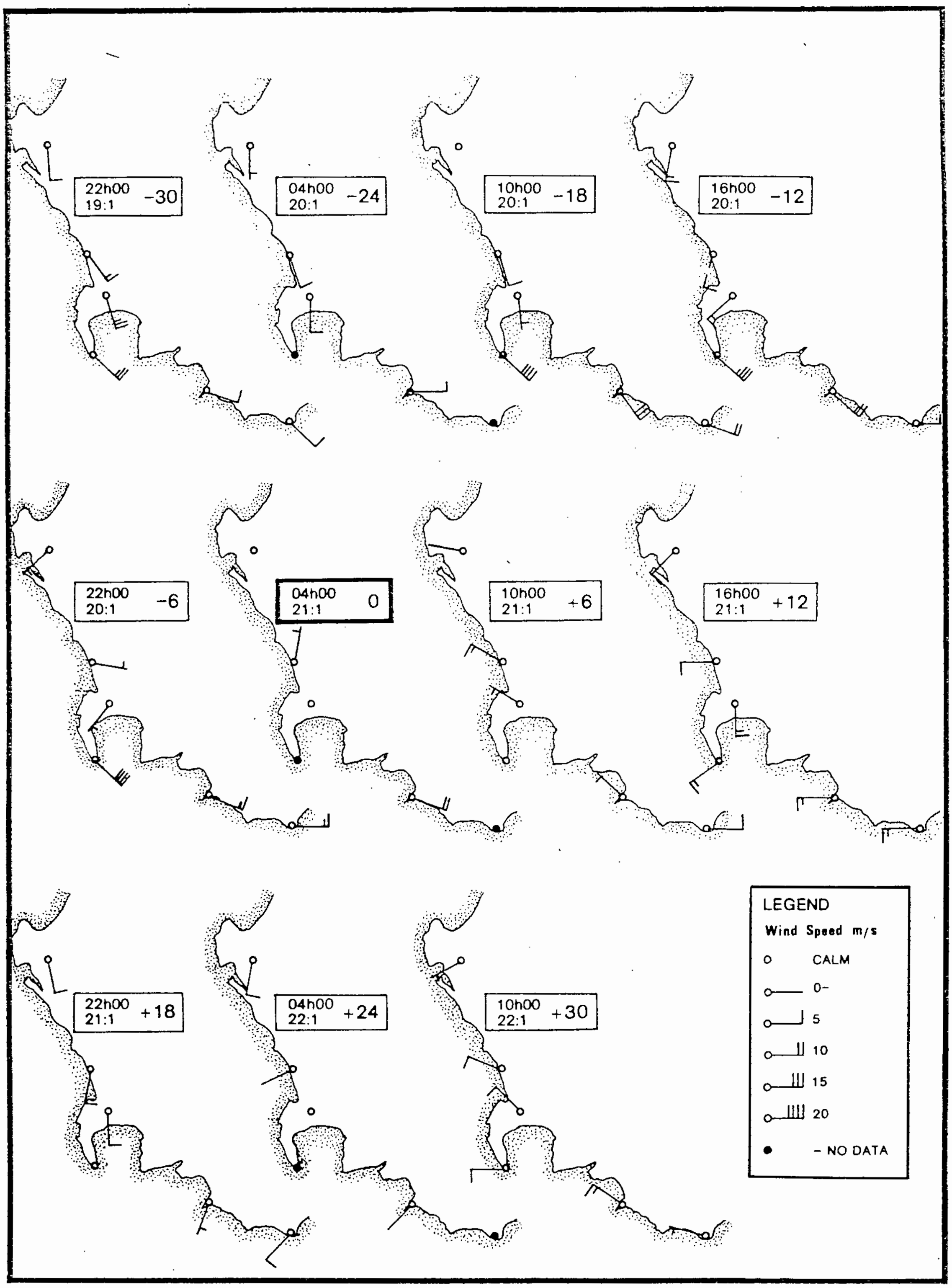

Figure 15. A spatial time series of the wind regime for the 6 stations from -30H to +30H. Note that the 0H is emphasised to show the time interval when the centre of the Low is situated over the central SW Cape.

TABLE 5. Summary of the wind speed (m/s) features for the 6 stations from -30H to +30H.

	WEST COAST				SOUTH COAST	
PARAMETER	LANG	KOEB	DFM	CPt	GANS	CAg
Maximum	6	7	12	20	14	9
Minimum	0	1	0	0	2	2
Mean	3,0	4,1	4,3	10,3	7,5	6,0
Std. deviation of mean	2,7	1,9	3,5	8,1	4,1	2,2

SUMMARY AND CONCLUSIONS

This paper has considered the upper air and surface characteristics of a Coastal Low episode through the SW Cape. The significant features of the Coastal Low system which passed over DF Malan on the 21 January 1985 are summarized below :

Upper Air:

-The offshore wind component was found to prevail 36 to 24 hours before the pressure minimum, between 400-2500m. This offshore wind tended to subside at about the same rate as did the upper air subsidence inversion.

-Winds below the inversion were typically alongshore for both the Milnerton (Sodar) and DF Malan (Radiosonde) sites.

-A low level horizontal wind speed maximum (>8m/s), in the layer below 400m, was found to exist 12 hours before the pressure minimum.

-The base of the upper air inversion dropped from 905mb (950m) with a $2^{o}C$ strength at -36H, to 970mb (300m) with a $4^{o}C$ strength by -24H. There was no inversion at -12H (according to the 13H30 Radiosonde sounding from DF Malan).

-The maximum variation of temperature ($10^{o}C$) between -36H and 0H was found at the 900mb level. Surface temperature variations were found to be considerably less ($4-6^{o}C$).

-The vertical alignment of the isotherms suggests that a 'front' like discontinuity exists in both the pre-Low (-24H to -12H) and post-Low (+12H) periods.

-No moisture front was discernible, but with the onset of north to north-westerly winds a gradual transition of dry continental air to more moist oceanic air occurred between -12H and 0H.

-The centre of the Low was marked by a veering of the low level winds (Sodar), by low horizontal and vertical wind speeds and by large sigma theta values.

-A strong nocturnal surface based inversion was present at 0H with a depth of 1200m and a strength of $11^{o}C$.

-A pressure minimum was clearly distinguishable to the 900mb level, above which it merged with the trailing frontal system.

-A phase lag of 24-36 hours between the surface and upper level layers of the pressure minimum indicated the period which the trailing frontal system lagged behind the Coastal Low system.

-The post-Low period was characterised by falling temperatures, unchanging moisture conditions and a backing of the wind from north-westerly to southerly.

-Near surface pressures started to rise, while above 900mb, pressures continued to fall in the post-Low period.

-Winds started to back to westerly from +24H onwards, thereby signalling the arrival and influence of the trailing frontal system.

-The low level wind speed core (>8m/s) on either side of the centre could possibly indicate the outer diameter of the Coastal Low system. The longshore diameter of this was about 1000km. An inner diameter of 200km was calculated for the core of low wind speeds (<4m/s).

Surface Features:

-Surface pressure variations at all 6 stations showed that the Coastal Low wave passed through the SW Cape. The pulse appeared to diminish slightly in strength (2mb) in the Gansbaai region between Cape Point and Cape Agulhas.

-The pressure change in the pre-Low and post-Low periods was not uniform and showed periods of pulses or 'pressure fronts' at all the stations throughout the study area.

-The migration speed of the system through the SW Cape , as determined by the minimum pressure pulse, was of the order of 25-30km/h.

-Uncorrected temperature values indicated only an expected pre-Low warming and post-Low cooling. Temperatures in the pre-Low period on the west coast were however higher than those on the south coast.

-The wind direction was essentially alongshore (southerly on the west coast and easterly on the south coast) in the pre-Low period. Wind gradients weakened as the Low passed and backed from north-westerly to southerly in the post-Low period. The arrival of the major frontal system was also marked by a veering of the winds to a westerly to north-westerly direction.

-Wind gradients increased substantially towards Cape Point in the pre-Low period which indicated, amongst other factors, the considerable influence which the complex topography has on the Coastal Low structure.

The episode between the 19 to 22 January 1985 showed a typical sequence of a Coastal Low through the SW Cape. Its upper air features conform to the mean characteristics noted by Heydenrych (Chapter 2). While the surface patterns showed a distinct pressure pulse passing through the SW Cape, the temperature and wind fields showed a more complex pattern as the system passed through the area.

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CHAPTER 6

THESIS

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

This thesis has addressed various aspects of the Coastal Low in the SW Cape. The methodology has been mainly climatological in nature where a 'mean' Coastal Low sequence was conceived, based on data obtained from 13 sampled episodes. One such episode was studied in detail and has been presented as a case study of a Coastal Low passage over the SW Cape. By use of data obtained from Radiosonde, Doppler Acoustic Radar and from a series of surface weather stations, the dynamics and behaviour of Coastal Lows has been investigated. The results of each technique employed have been written up as a different Chapter (paper). The overall conclusions reached in this thesis can be diagrammatized in the form of a composite summary diagram (Figure 6.1). The conclusions reached in these studies can be summarized as follows:

1) Large scale divergence of dry continental air from above the 850mb level occurs in the pre-Low period (-36H to -12H) during the passage of the system.

2) This divergence results in the subsidence of the upper air inversion (of 2-3^{o}C strength) from the 900mb (1000m) level to a mean minimum of 955mb (450m). The upper air inversions were often found to merge with the nocturnal surface based radiation inversions.

3) The greatest variation in temperature during the passage of a Coastal Low does not occur at ground level but at a height of between 950-900mb. This coincides with the top of the mean height of the inversion layer. Maximum heating occurs in the centre of the system (-12H to 0H) and is discernible up to the 775mb level.

4) The variation in pressure (at each of the standard levels) during the passage of the Coastal Low decreases with

height (i.e. the amplitude or intensity of the pressure wave decreases). Furthermore, a phase lag of 12 - 24 hours was found to occur between the surface layer and the layer above the inversion (>850mb). In the post-Low period this resulted in surface pressures beginning to rise while they were still falling in the layers above above 850mb.

5) Offshore flow at the escarpment level (850mb) was found to be surprisingly weak in the pre-Low period of the Coastal Low passage. This may be due to the location of DF Malan within the topography of the SW Cape, or that the offshore flow as a forcing function may not be as significant in the pre-Low dynamics as previously thought. Notwithstanding this, winds below the inversion are dynamically compressed into a longshore low level wind maxima on either side of the Coastal Low centre. The centre of the system is marked by weak horizontal and vertical wind speeds and high sigma theta values. In the immediate surface layer the backing of the winds as the centre passes is often not clearly discernible. However this backing is quite clear in the 200-600m layer.

6) By assuming an average horizontal speed for the system of 7m/s (25km/h), the mean longshore spatial diameter of the system was calculated: The inner core (wind speeds <4m/s) had a diameter of 150-200km while the outer core (wind speeds >8m/s) extended for about 1000km .

7) By correcting surface pressures, it was evident that the pulse of the Coastal Low showed a steady migration through the peninsular of the SW Cape. The wind field regime showed a general backing as the system passed, but appeared to be considerably influenced by the local topography of the area. Temperatures (T or Td) were not found to be suitable parameters with which to monitor this 'wave' migration through the SW Cape.

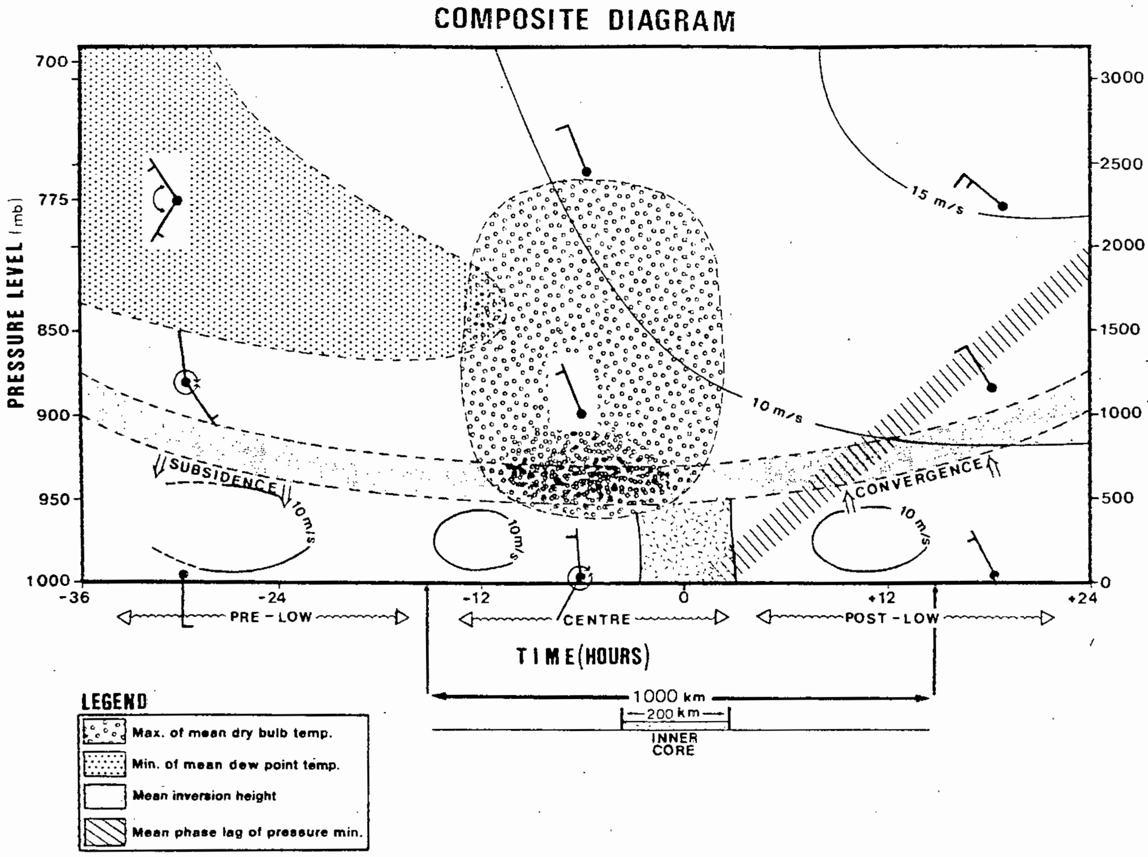

Figure 6.1 A composite diagram of the Coastal Low system as monitored in the SW Cape.

While producing new insights into the dynamics and behavioural characteristics of Coastal Lows in the SW Cape in particular, and along the South African coastline in general, this thesis has confirmed many of the observations and findings of other researchers. A number of problems were also identified. The findings in this thesis have led to a suggestion that the definition of a Coastal Low be altered to include a more stringent vertical identifying parameter. This would limit the vertical development of a 'classic' Coastal Low to under 850mb level. It is suggested that systems penetrating beyond this height, be given a qualifying description by being called 'extended Coastal Lows'.

Sodar penetration was limited to below 1000m. Future research into Coastal Lows would have to address the critical heights from 1000m to at least the 2000m level with resolution approaching that obtained from the Sodar. This area would provide an insight into the generation mechanism and in particular the relationship of the offshore wind component in the overall cyclogenesis of the Coastal Low system.

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APPENDIX 1

LIST OF 27 NON-FRONTAL PRESSURE MINIMUMS: NOV84-OCT85

1984

1) 6/7 Nov
2) 30 Nov/1 Dec (*)
3) 11 Dec (*)
4) 16 Dec (*)
5) 30/31 Dec

1985

6) 2 Jan (*)
7) 5 Jan
8) 10 Jan
9) 21 Jan (*)
10) 25 Jan
11) 31 Jan
12) 10 Feb
13) 9 Mar
14) 28 Mar
15) 11 Apr
16) 15 May
17) 26 May (*)
18) 2 Jun
19) 25 Jun
20) 5 Aug (*)
21) 16 Aug (*)
22) 21 Aug (*)
23) 28 Aug
24) 8 Sep (*)
25) 17 Sep (*)
26) 21 Sep (*)
27) 10/11 Oct
28) 27 Oct (*)

Note:

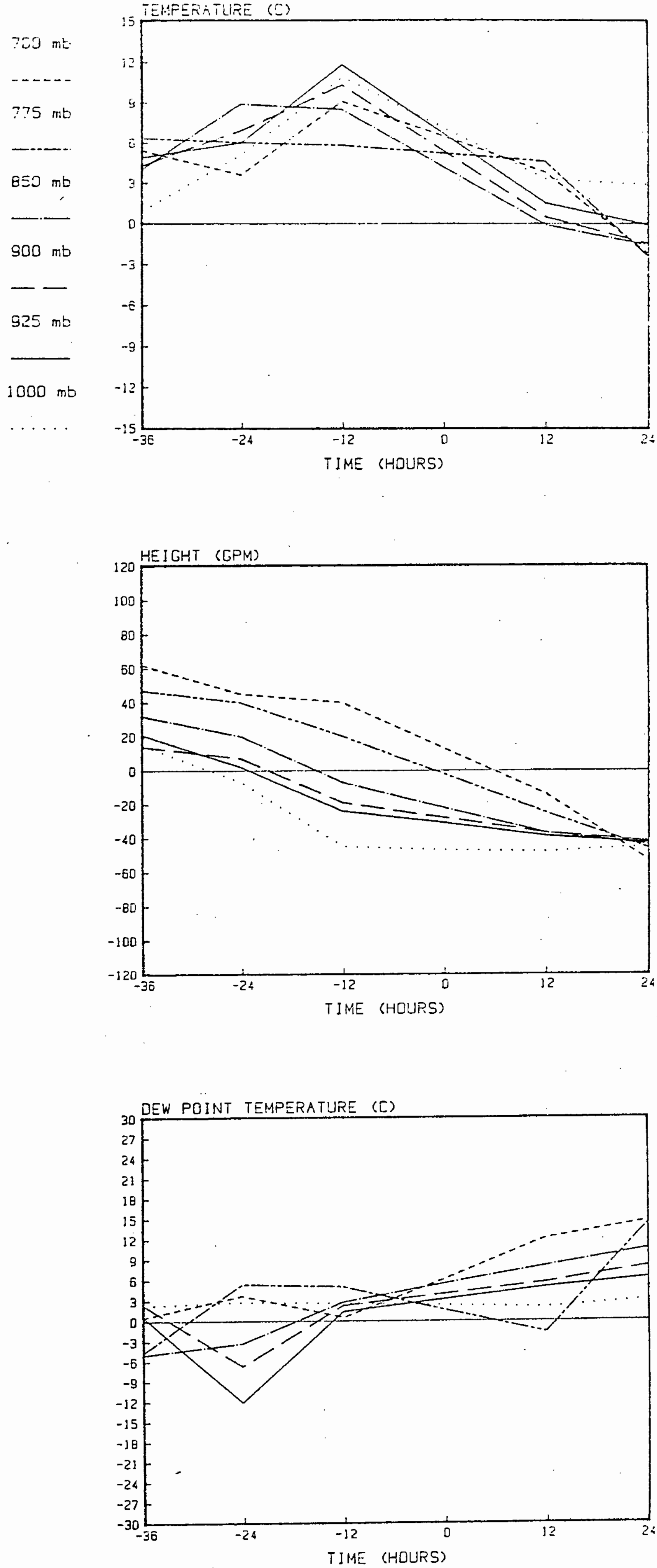
1) A pressure change of greater than 4mb in the 24 hours preceeding the pressure minimum was used to identify a low pressure system.

2) The cases marked with a (*) indicate the low pressure systems identified in this thesis as 'classic' Coastal Lows.

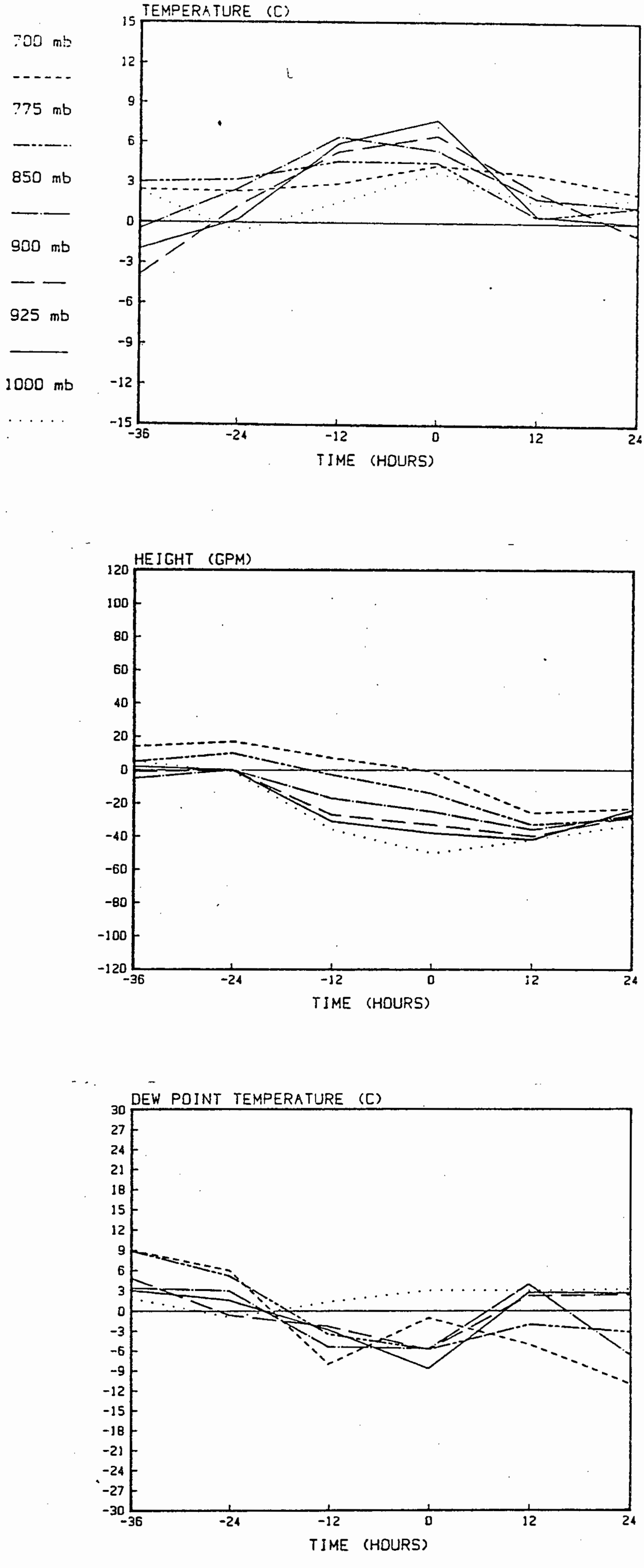
APPENDIX 2

2.1: 13 Coastal Lows as identified from Radiosonde data at DF Malan between November 1984 to October 1985. The paramters, pressure, dry bulb and dew point temperatures are described as deviations about their annual means for the standerd pressure levels 1000, 925, 900, 850, 775 and 700mb. The Coastal Low movement is from left to right in each of the 60 hour sequences.

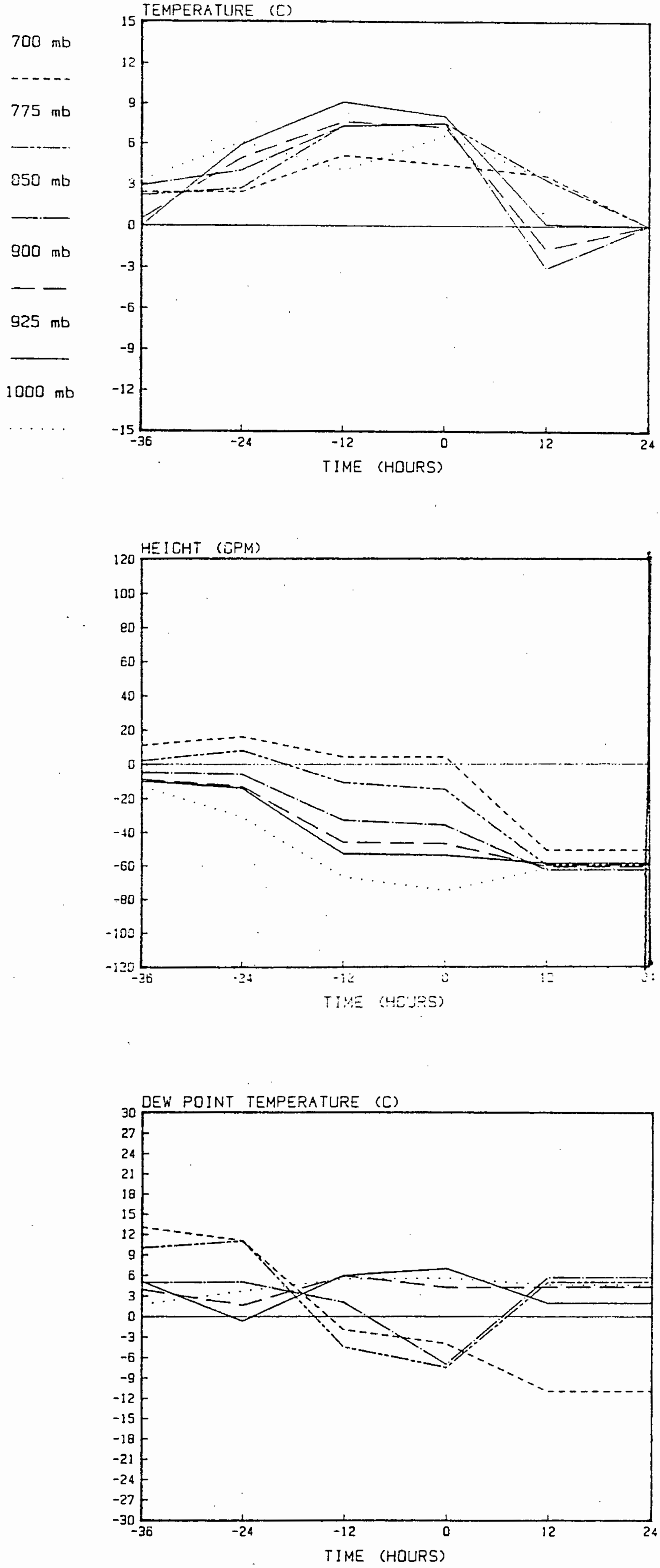
COASTAL LOW - 30 NOVEMBER 1984



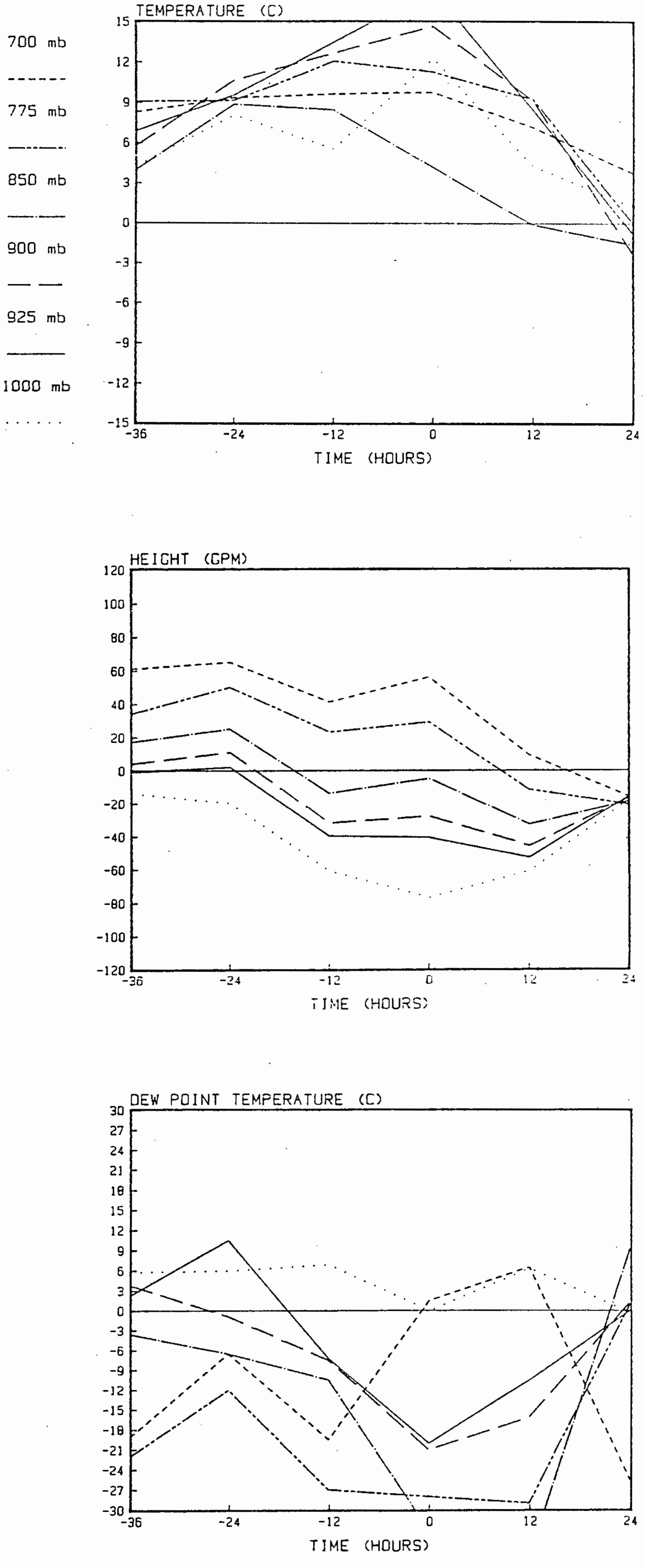
COASTAL LOW - 11 DECEMBER 1984



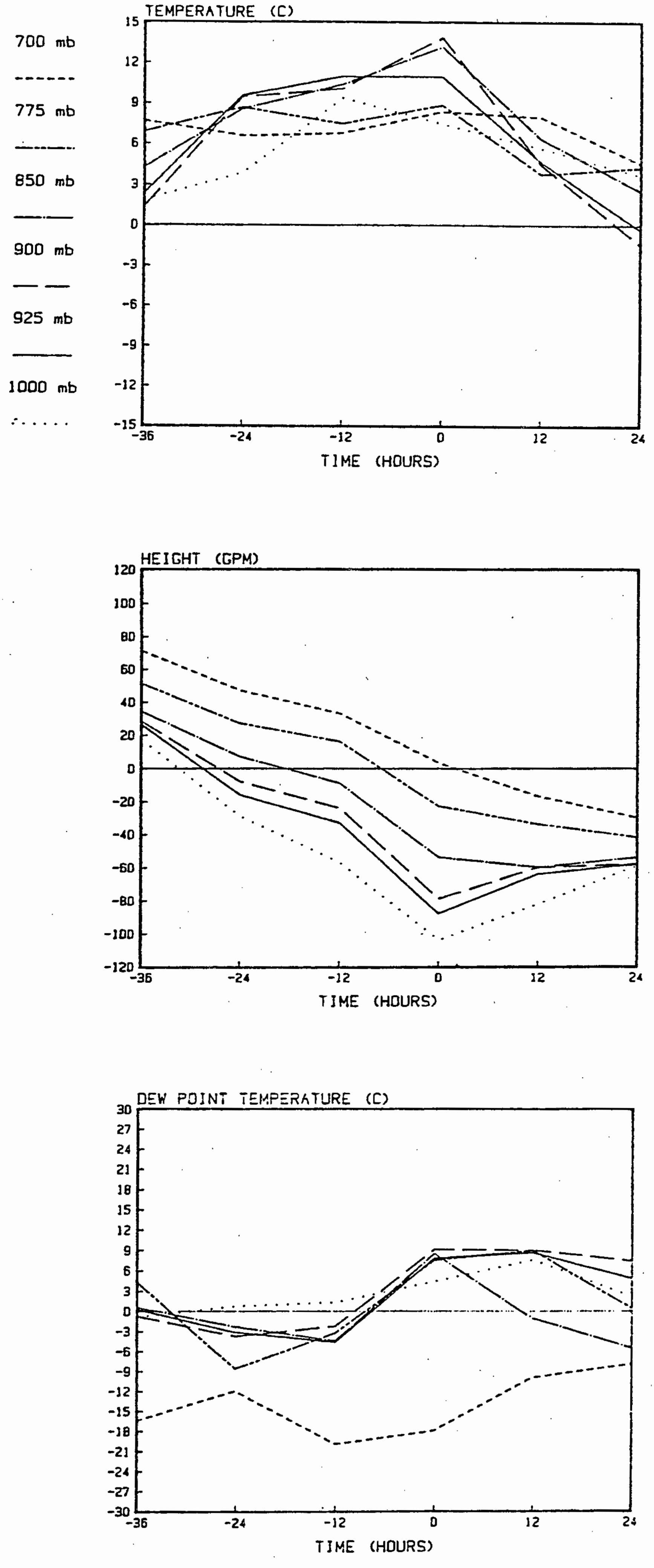
COASTAL LOW - 16 DECEMBER 1984



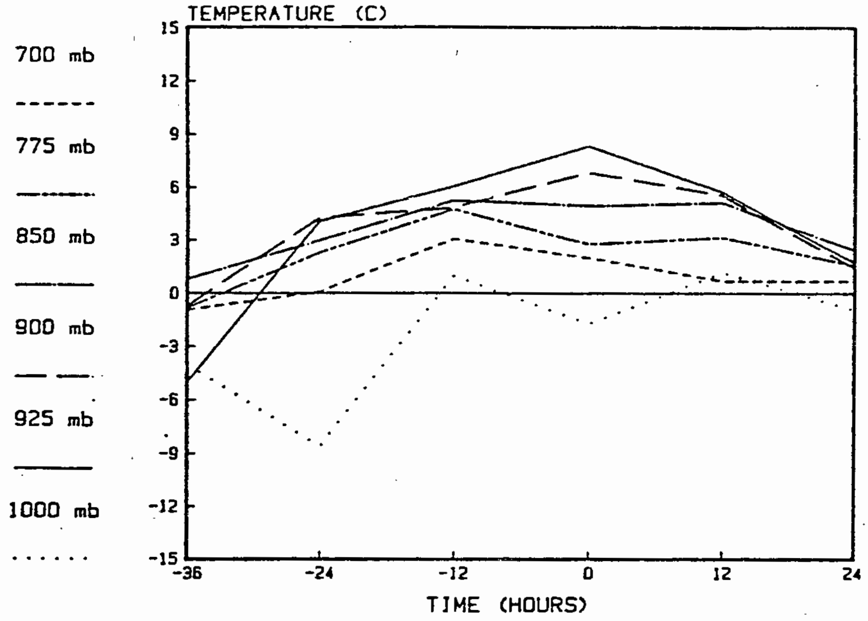
COASTAL LOW - 2 JANUARY 1985

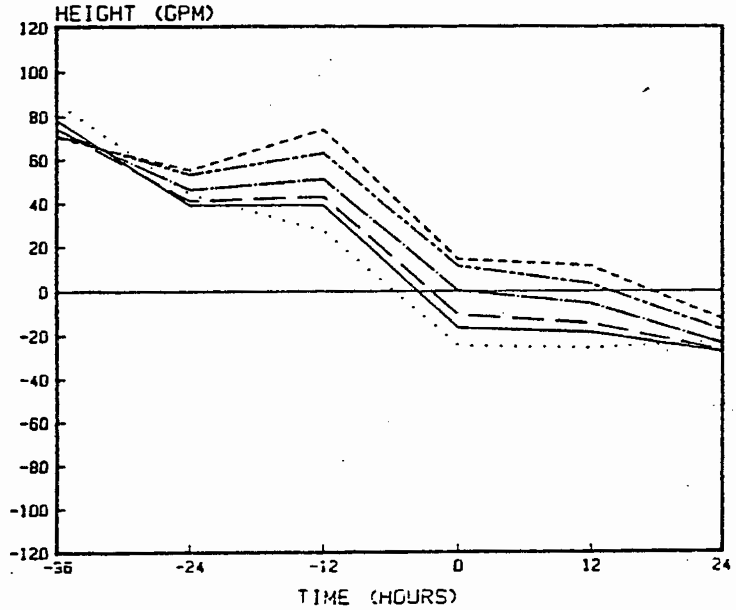


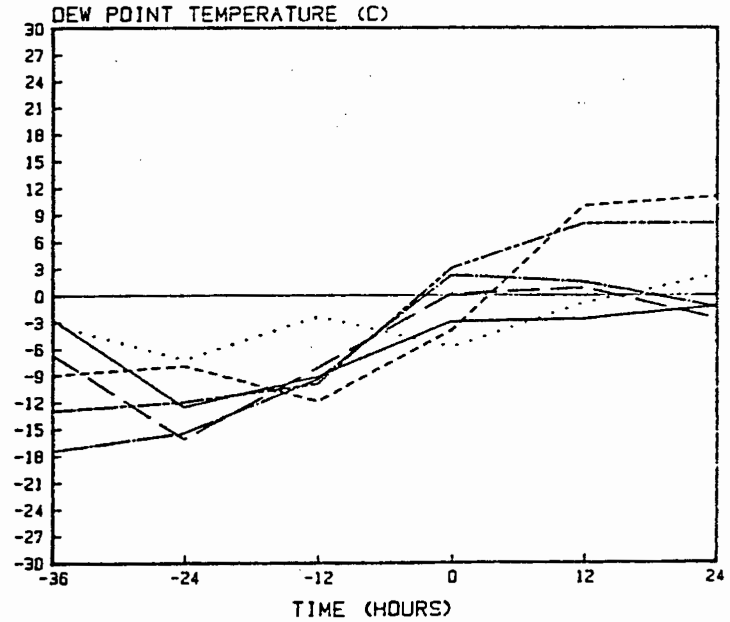
COASTAL LOW - 20 JANUARY 1985



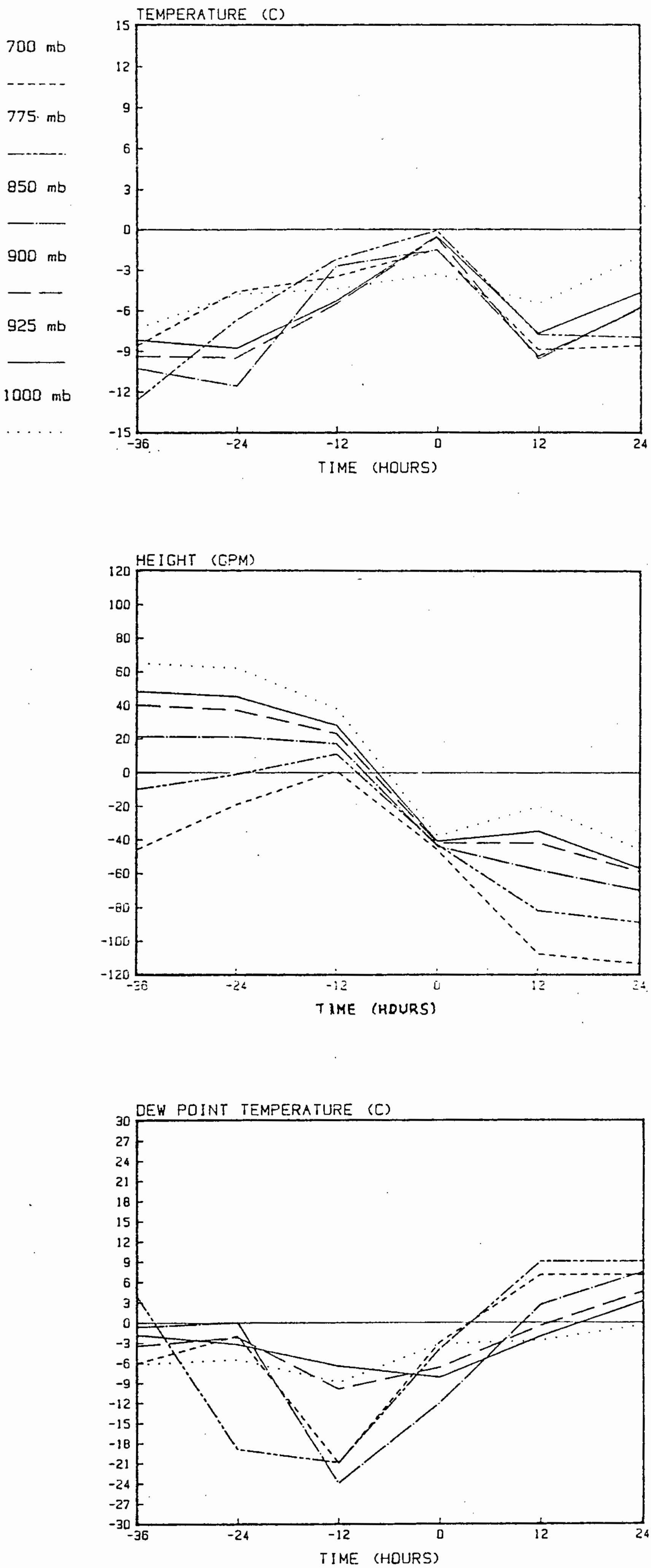
COASTAL LOW - 26 MAY 1985



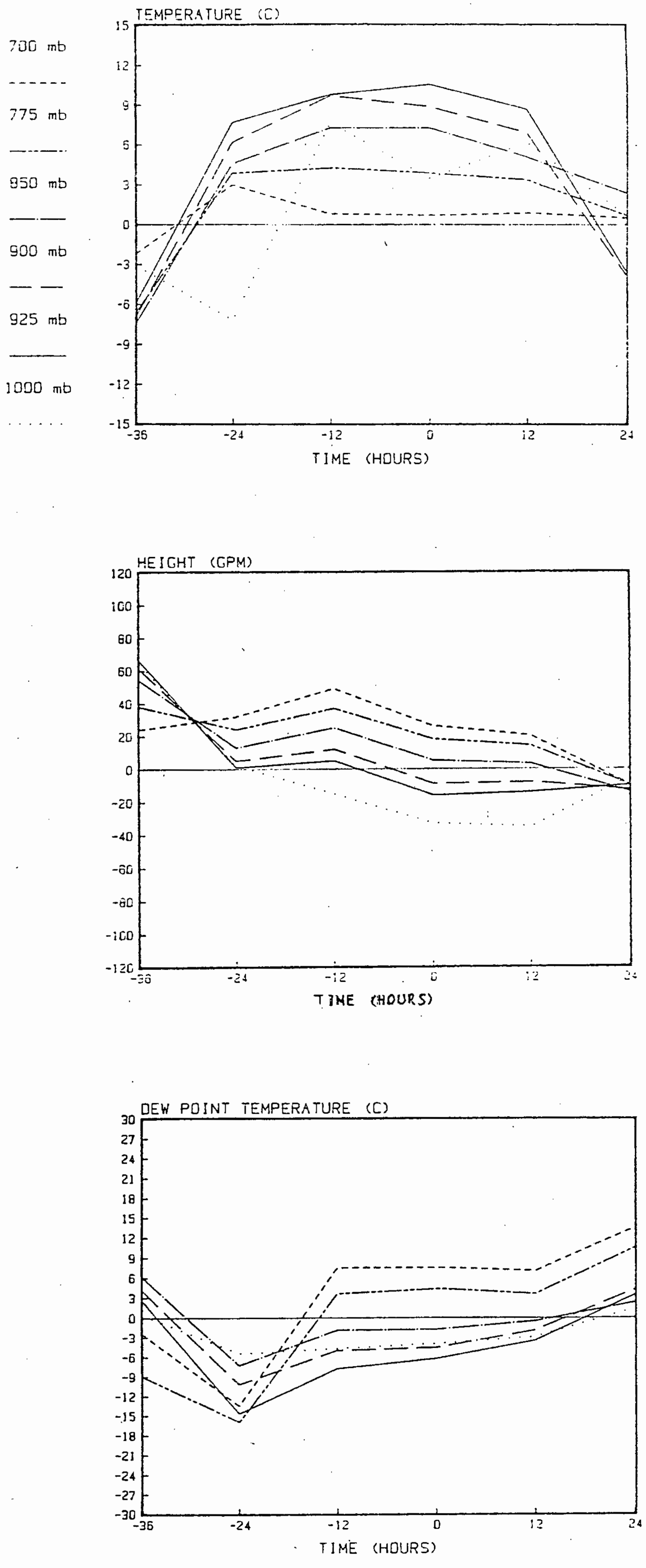




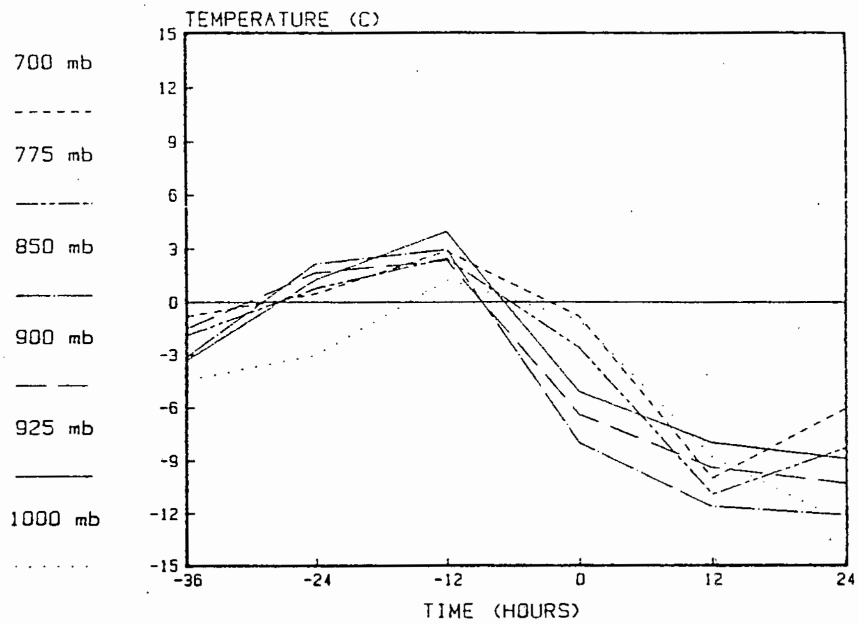
COASTAL LOW - 5 AUGUST 1985

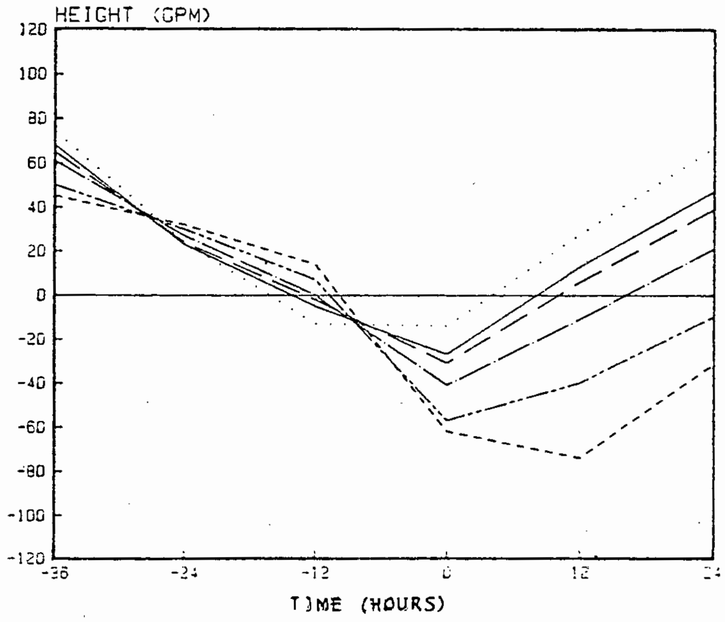


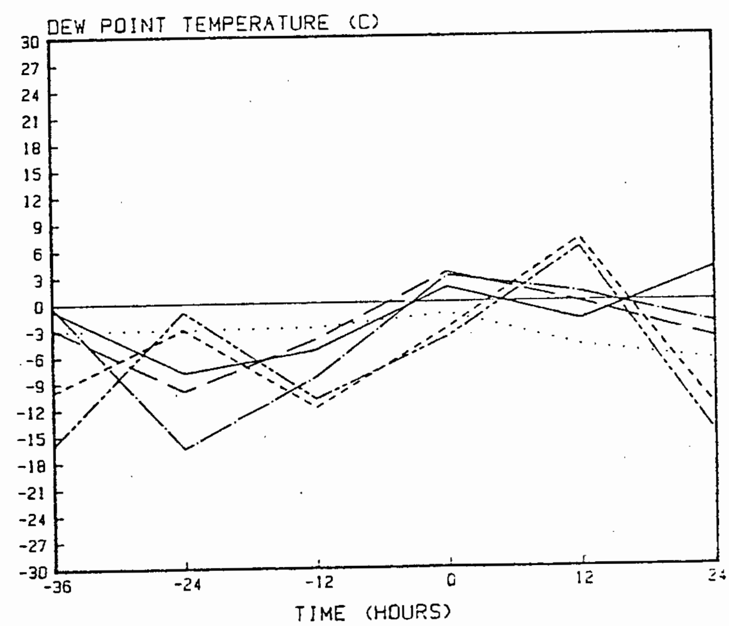
COASTAL LOW - 16 AUGUST 1985



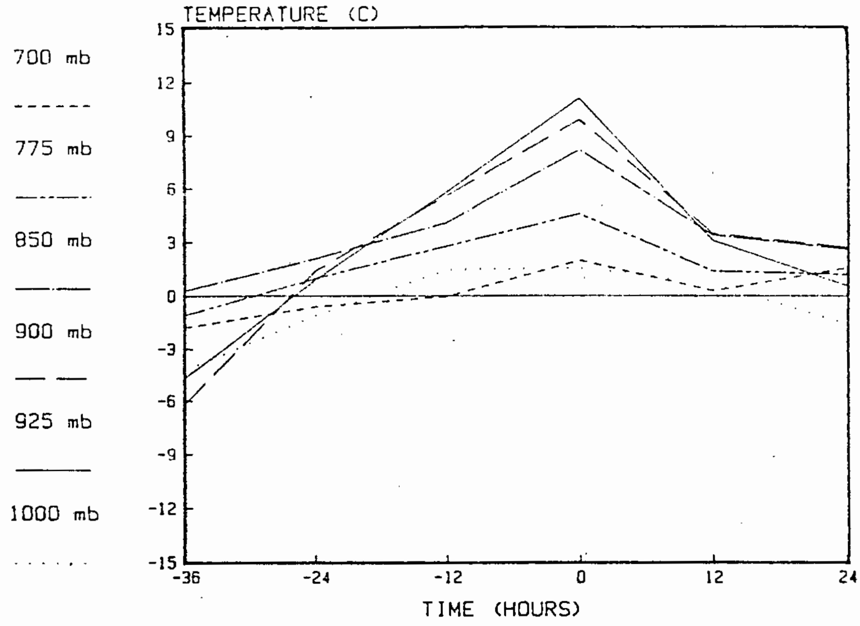
COASTAL LOW - 21 AUGUST 1985

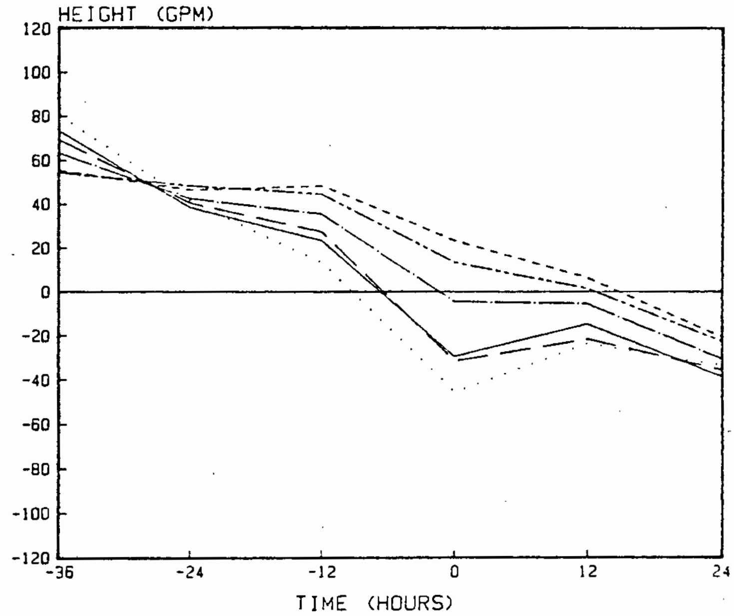


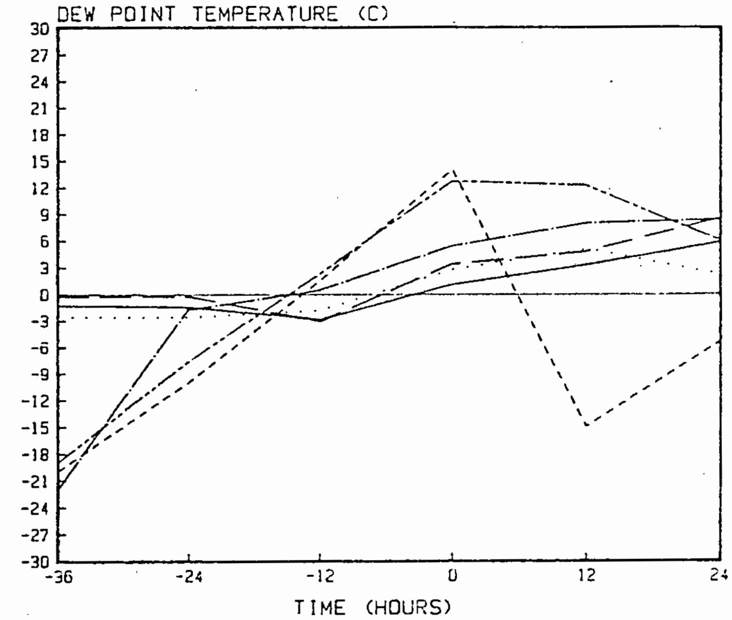




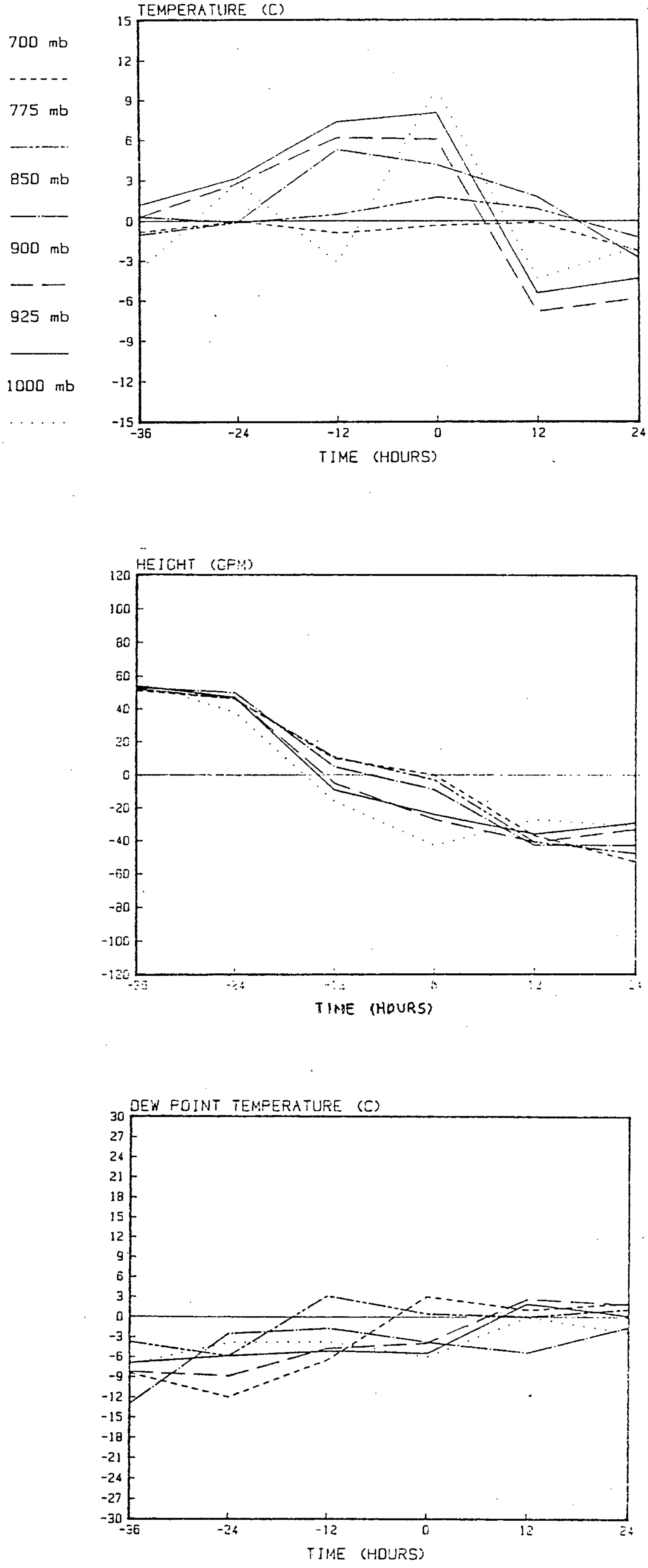
COASTAL LOW - 8 SEPTEMBER 1985



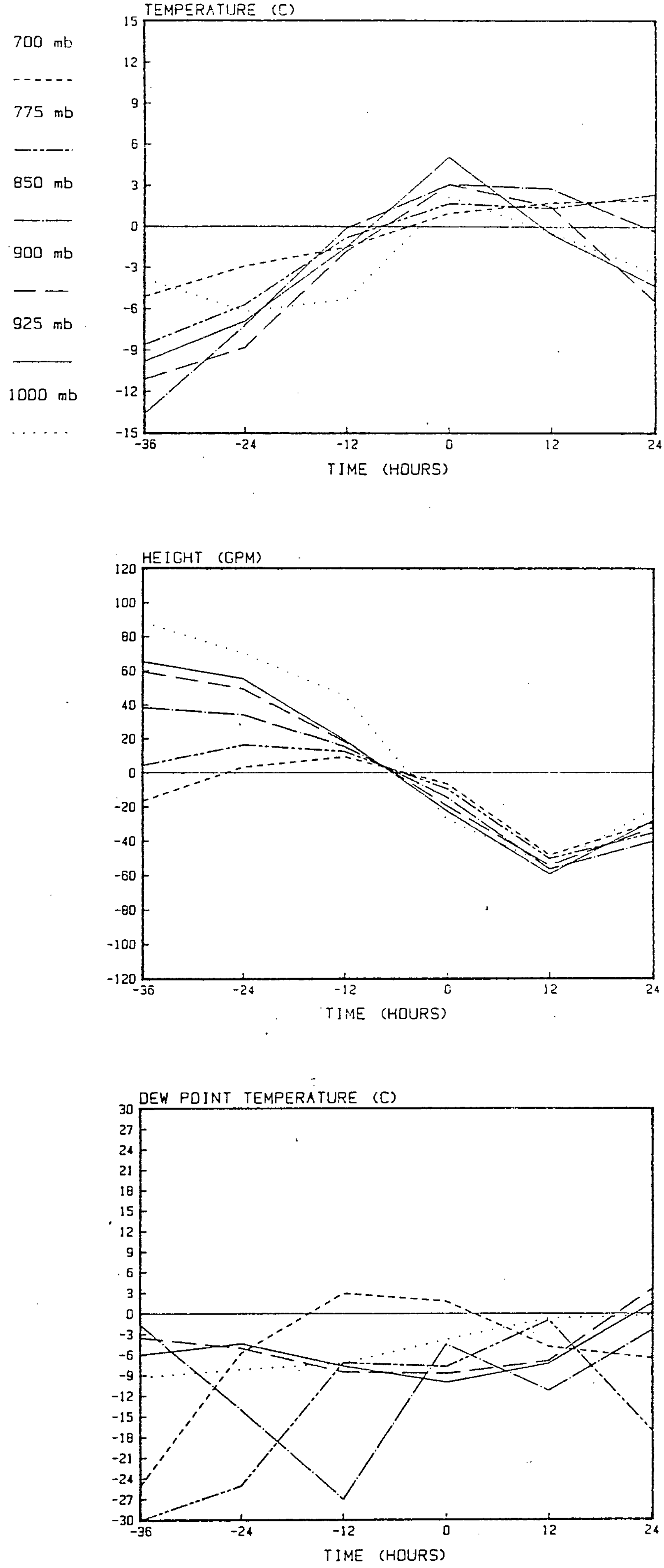




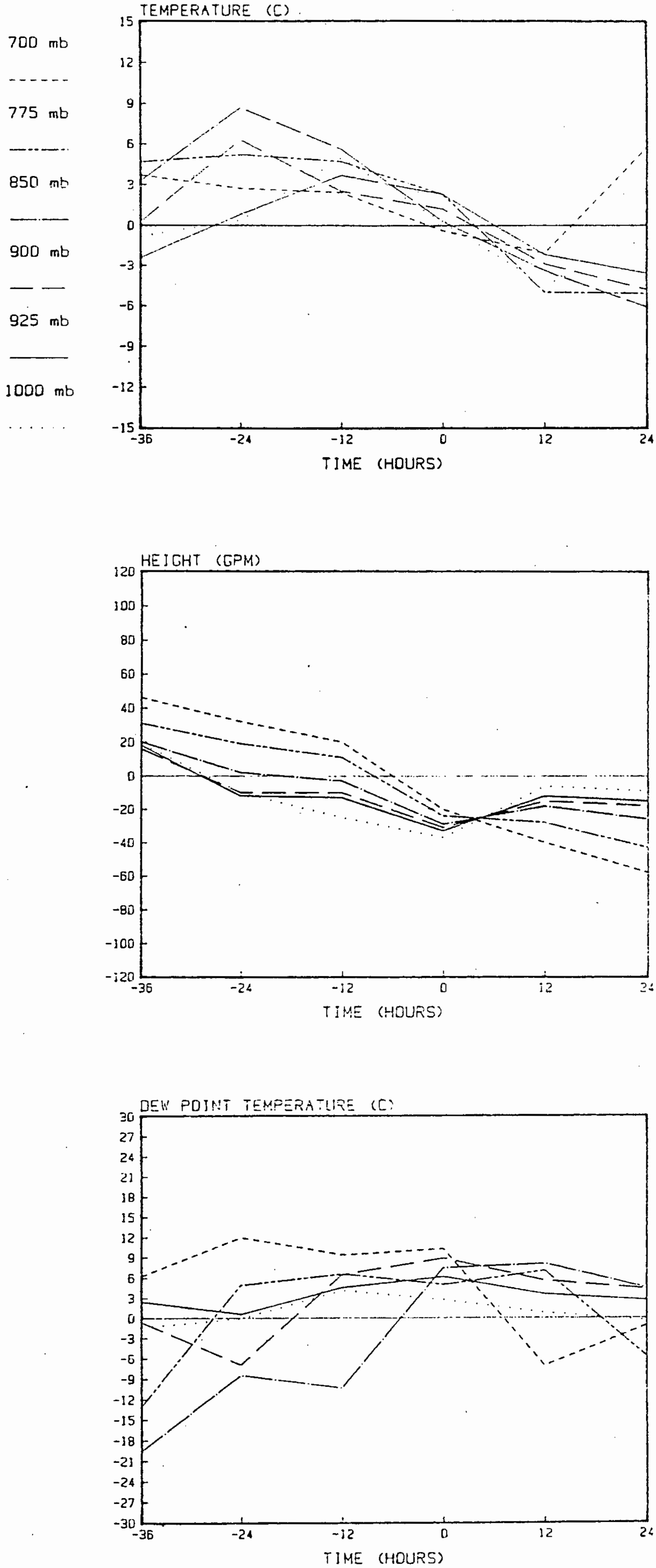
COASTAL LOW - 17 SEPTEMBER 1985



COASTAL LOW - 21 SEPTEMBER 1985



COASTAL LOW - 27 OCTOBER 1985

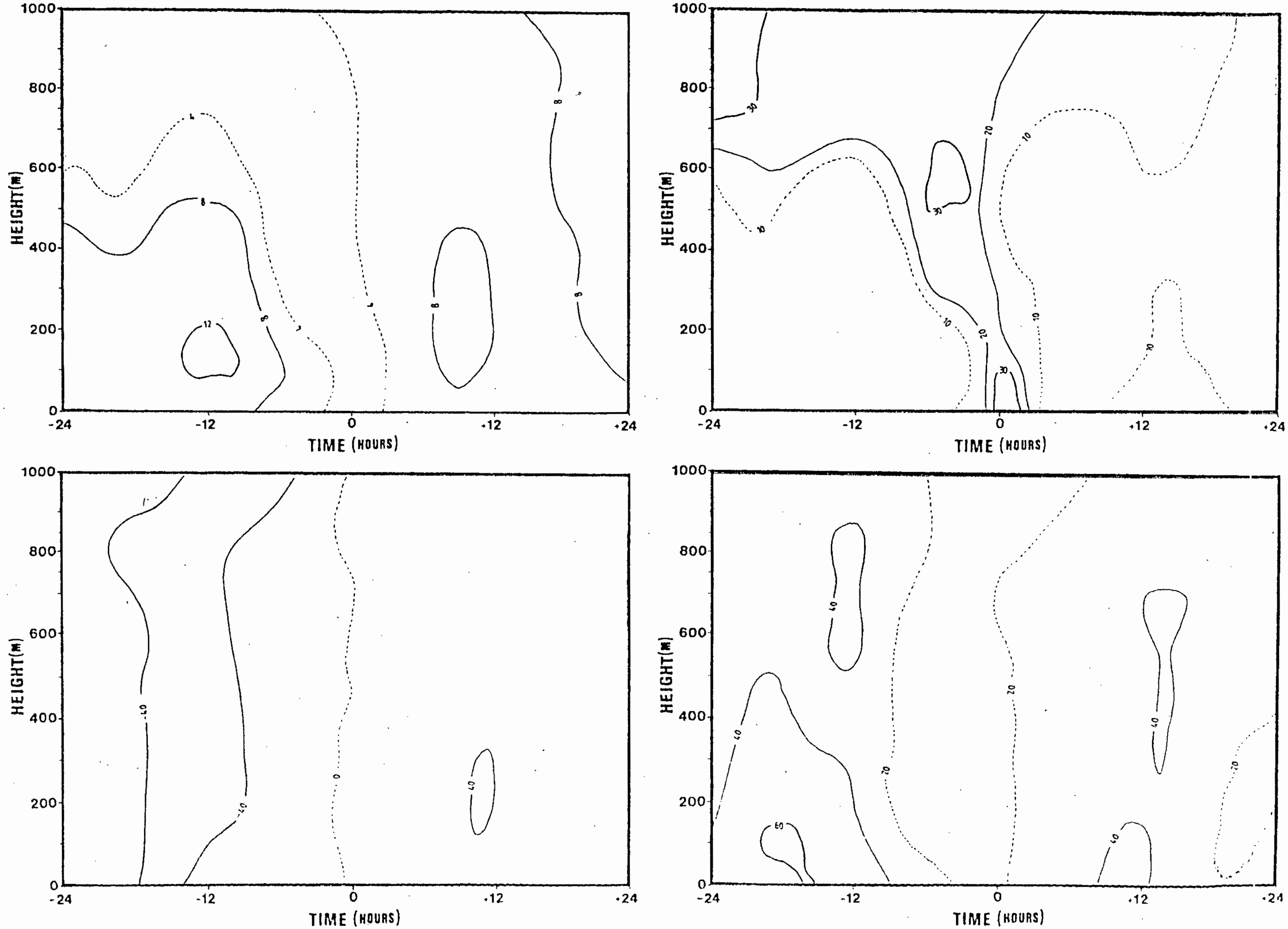


2.2: List of the type and quantity of cloud cover reported at DF Malan during the 13 Coastal Low episodes. H refers to high cloud, M to medium cloud and L to low cloud. The notation e.g. Ci2 - describes Cirus cloud of 2/8 cover.

DATE	TIME (HOURS) -36H			-24H			-12H			0H			+12H			+24H		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
30 Nov									St1									St6
11 Dec													Ci2		St2		Ac1	Sc2
16 Dec	Ci2			Ci2			Ci2	Ac2		Cs2			Cs4	Ac2	St4	Cs4		
2 Jan						Sc1	Ci1	Ac4	Sc1	Ci2			Ci2	Ac3	St3	-	-	St7
21 Jan															St1	Ci1		Sc6
26 May										Ci1		St1	Ci1		St1		Ac1	
5 Aug												St2	-	-	Sc7	-	-	Sc7
16 Aug	Ci1		Sc1															
21 Aug	Ci3		Cu1	Ci1			Ci1			Ci1		St6	-	-	Fc8			St3
8 Sep			Sc1				Ci4			Ci5			Ci1	Ac1	St1	-	-	St8
17 Sep				Ci1			Ci1			Ci1	Ac1		-	-	Sc8			Sc4
21 Sep	Ci1		Sc1	Ci1		Sc1	Ci1			Cs6			Ci4	Ac1	Sc1	-	-	Sc7
27 Oct	Ci2		Sc1	Ci3	Ac2	Sc1	Cs5	Ac2	Sc1	Cs4	Ac2	St1	-	-	St6	Ci6	Ac5	

APPENDIX 3

3.1 The six Coastal Low episodes used to obtain the mean Coastal Low in Chapter 3, (the seventh case study has already been shown in Chapter 5). For each episode the following is represented :a) horizontal wind speed (m/s), b) standard deviation of horizontal wind direction $\sigma_{\theta}(^{o})$, c) vertical wind speed W(cm/s) and d) standard deviation of the vertical wind speed σ_{W}(cm/s).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TIME (HOURS)
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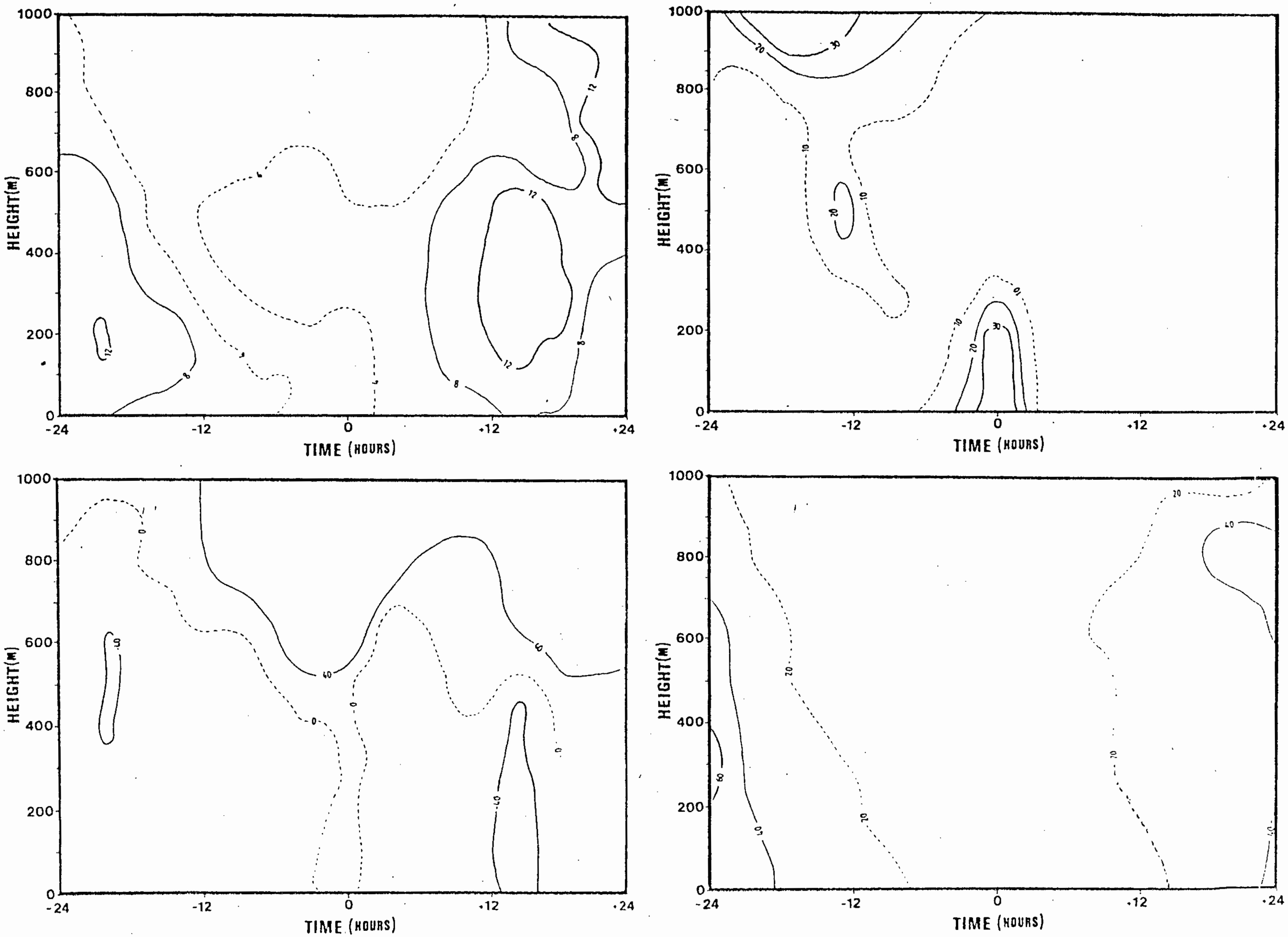
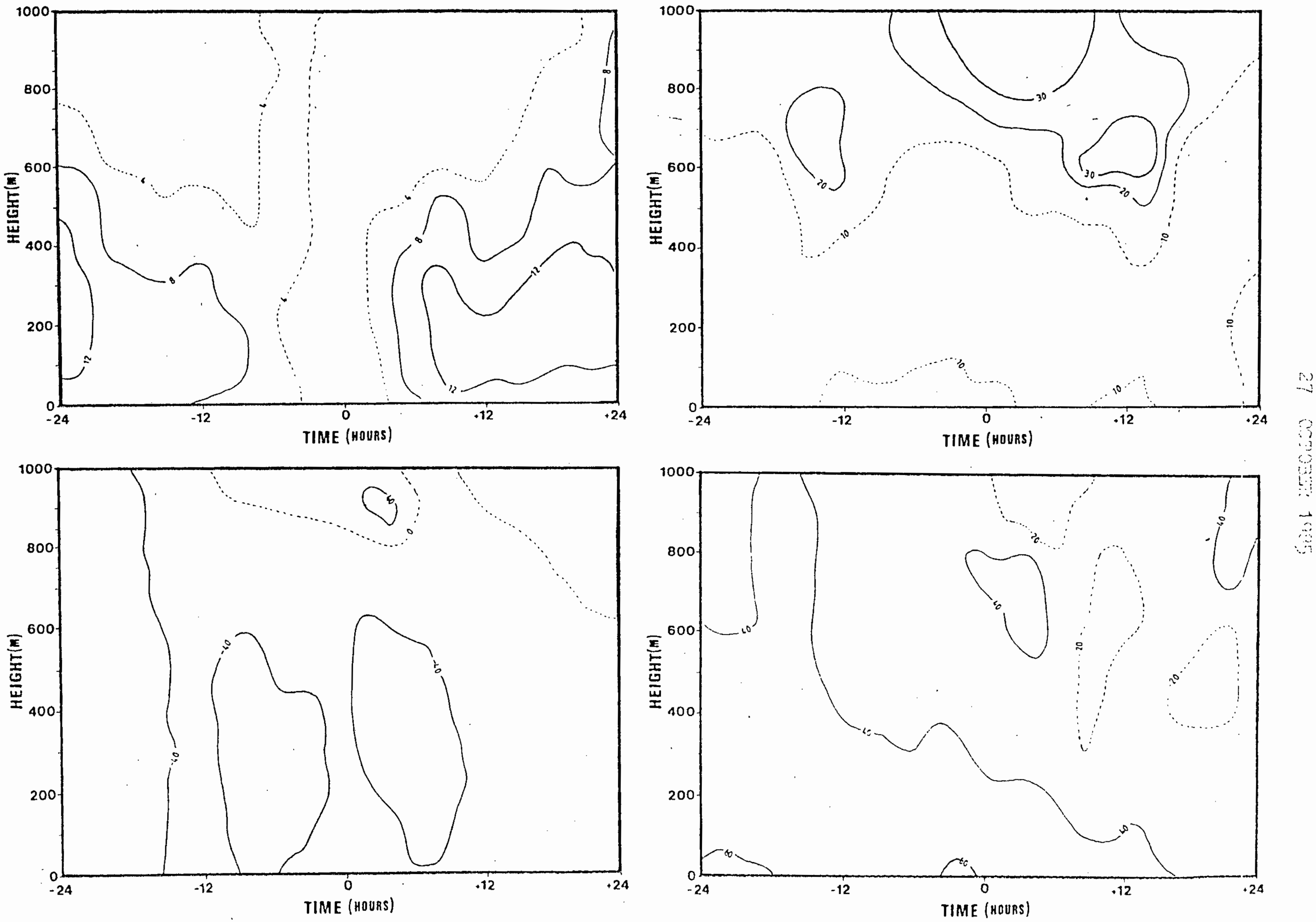
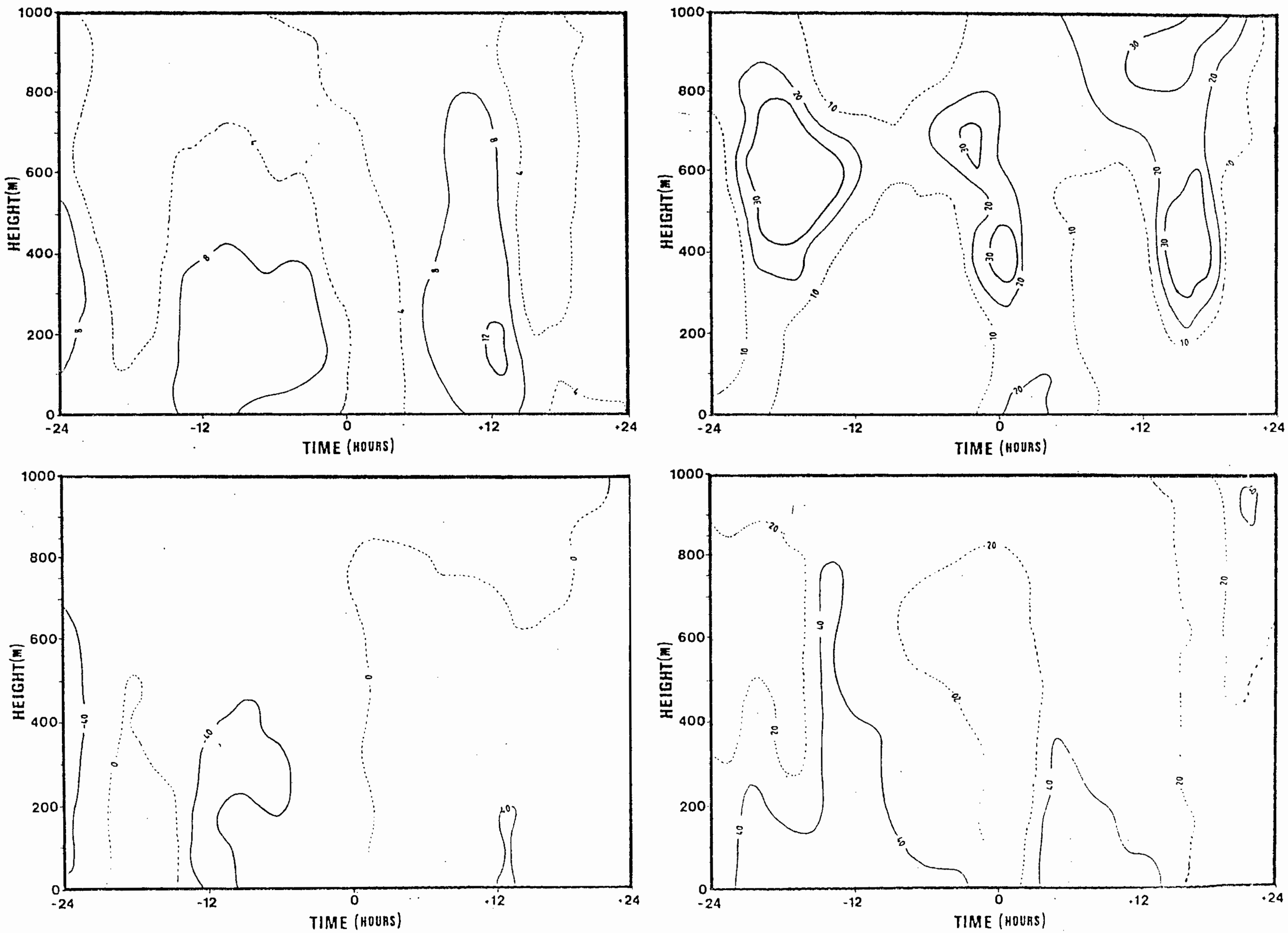
600
400
200
0
-24
-12
0
+12
+24

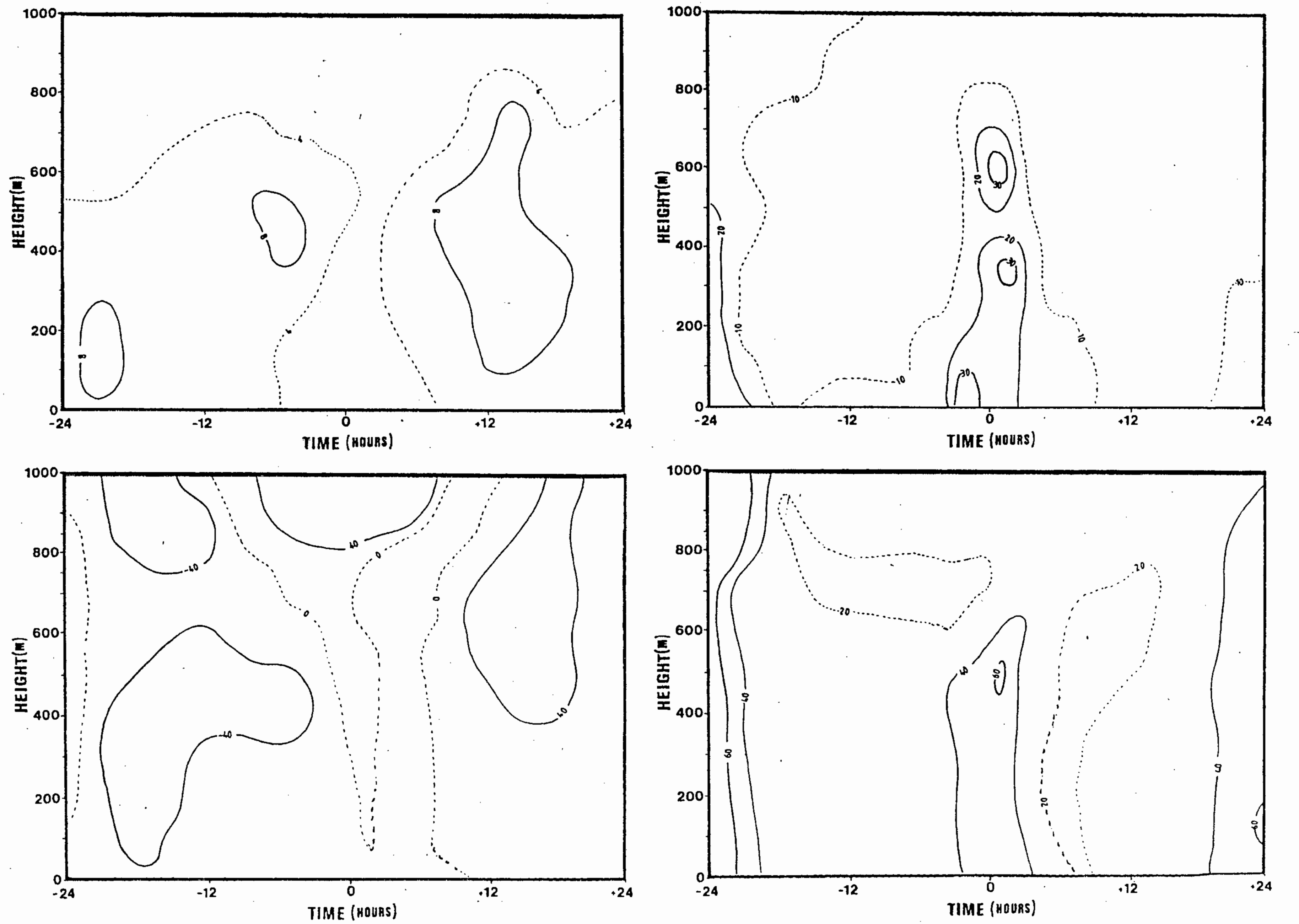

1000
800
600
400
200
0
HEIGHT(M)
-24
-12
0
+12
+24
TIME (HOURS)
12
8
4
20
30
10
40
0
60



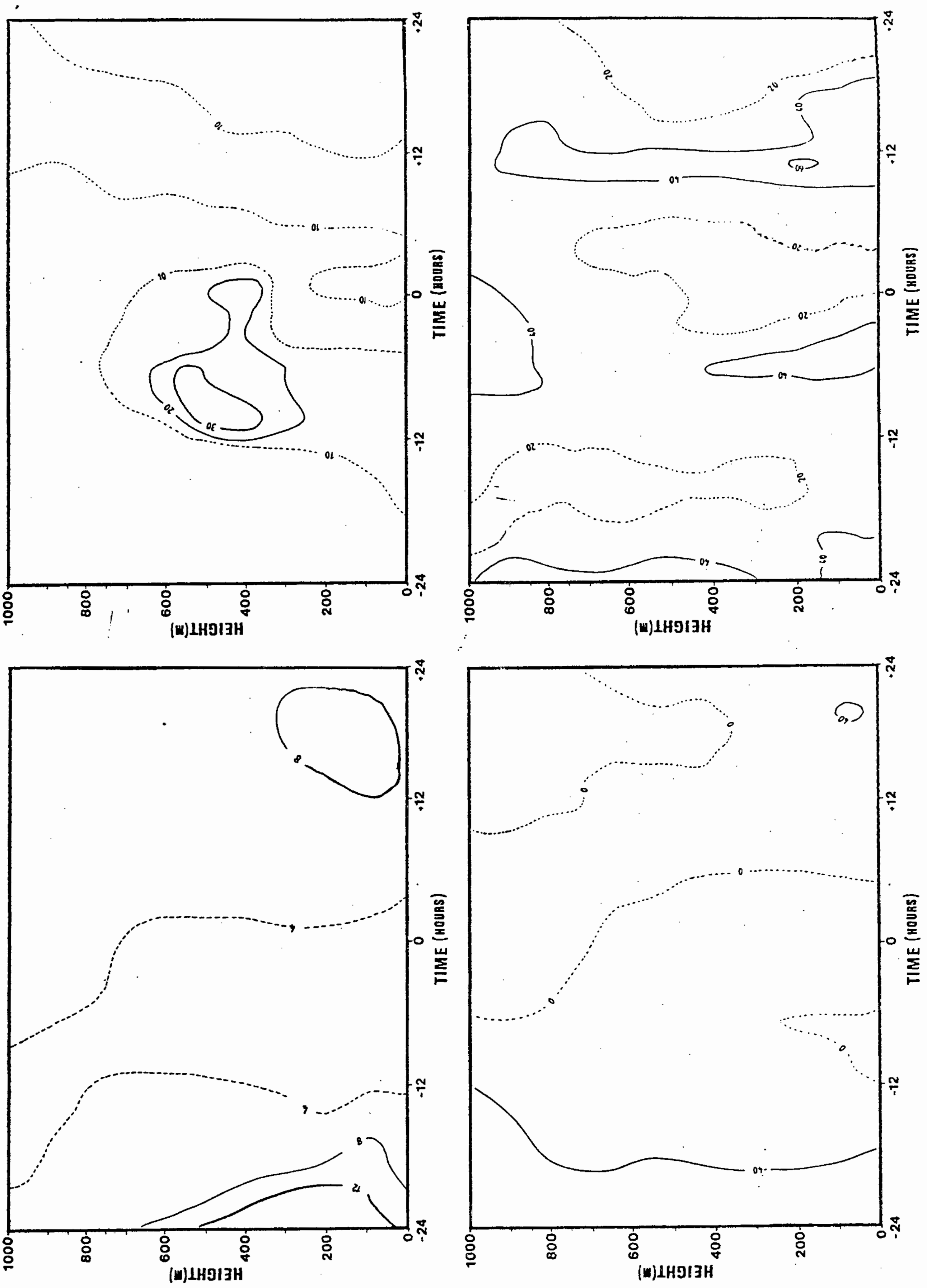
27 OCTOBER 1985



16 DECEMBER 1984


HEIGHT(M)
TIME (HOURS)
1000
800
600
400
200
0
-24
-12
0
+12
+24

30 NOVEMBER 1984



APPENDIX 4

4.1 The 24 hour cycle of pressure variations for DF Malan station for a 10 year period (1976-1985). The four seasons are represented as summer (Dec-Feb), autumn (Mar-May), winter (Jun-Aug) and spring (Sep-Nov). The mean pressure for the 10 year period was 1017.1mb.

HOURS	SUMMER (D-J-F)	AUTUMN (M-A-M)	WINTER (J-J-A)	SPRING (S-O-N)
1	+0,2	+0,1	+0,2	+0,2
2	0	0	+0,1	0
3	-0,4	-0,2	-0,1	-0,4
4	-0,6	-0,5	-0,2	-0,6
5	-0,6	-0,5	-0,4	-0,6
6	-0,3	-0,4	-0,4	-0,3
7	0	-0,1	-0,1	+0,1
8	+0,4	+0,3	+0,3	+0,4
9	+0,5	+0,6	+0,6	+0,5
10	+0,5	+0,8	+0,8	+0,6
11	+0,5	+0,8	+0,9	+0,6
12	+0,4	+0,5	+0,6	+0,3
13	+0,2	0	+0,1	+0,1
14	0	-0,4	-0,5	-0,3
15	-0,3	-0,8	-0,9	-0,6
16	-0,6	-0,8	-0,9	-0,8
17	-0,8	-0,7	-0,8	-0,8
18	-0,8	-0,5	-0,5	-0,6
19	-0,4	-0,2	-0,2	-0,3
20	0	+0,1	+0,1	+0,1
21	+0,3	+0,4	+0,3	+0,5
22	+0,6	+0,5	+0,4	+0,7
23	+0,6	+0,5	+0,4	+0,6
24	+0,5	+0,3	+0,3	+0,4

4.2 The mean 6 hourly surface pressure values for 6 stations in the SW Cape during the passage of a Coastal Low. The pressure (P) represents the corrected pressure + 1000mb. The zero hour (OH) represents the hour that the minimum pressure pulse of the Coastal Low systems passed through DF Malan.

	TIME (HOURS)										
	-30H	-24H	-18H	-12H	-6H	0H	+6H	+12H	+18H	+24H	+30H
Station					LANGEBAANWEG						
Pressure P (mb)	20,7	18,5	16,7	14,7	12,9	12,6	14,5	15,3	16,0	16,7	17,3
Std dev. P	4,4	4,4	3,6	3,4	3,2	2,6	2,5	2,5	3,0	4,1	4,3
Station					KOEBERG						
Pressure P	21,7	20,2	18,6	15,6	13,4	12,5	14,4	15,2	16,2	16,7	17,5
Std dev. P	4,8	5,5	5,5	4,7	4,0	3,4	3,1	2,5	3,2	3,9	4,8
Station					DF MALAN						
Pressure P	21,9	20,1	18,2	15,7	13,6	12,3	13,9	14,9	15,8	16,4	16,9
Std dev. P	4,0	4,1	3,8	3,3	3,1	2,6	2,3	1,9	2,7	3,9	4,5
Station					CAPE POINT						
Pressure P	21,9	20,0	18,3	16,3	14,0	12,9	13,3	14,5	15,3	16,1	16,8
Std dev. P	3,7	3,5	3,5	3,3	3,0	2,9	2,4	2,2	3,1	4,2	5,2
Station					GANSBAAI						
Pressure P	23,3	22,4	20,1	18,7	16,1	13,8	13,8	14,7	15,0	15,7	16,0
Std dev. P	3,4	3,2	2,7	2,6	2,4	2,1	2,0	1,7	3,0	3,6	
Station					CAPE AGULHAS						
Pressure P	24,2	22,7	21,3	18,8	16,1	13,5	12,8	13,2	14,2	14,8	15,0
Std dev. P	4,5	4,0	3,0	3,0	2,8	3,2	2,8	2,3	3,2	4,0	5,1

4.3 The mean surface wind speed (m/s) and direction (°) (expressed as a percentage) for the 6 stations during the passage of the Coastal Low systems. The SE sector is between 45-224° and the NW sector is between 225-44° (measured clockwise). The zero hour (0H) again represents the hour that the minimum pressure pulse of the Coastal Low systems passed through DF Malan.

PARAMETER	TIME (HOURS)								
	-24H	-18H	-12H	-6H	0H	+6H	+12H	+18H	+24H
Station				LANGEBAANWEG					
Wind speed (m/s)	3,0	3,2	3,1	2,4	3,1	4,6	3,4	4,5	4,5
Wind dir'n: NW (%)	0	0	15	15	38	54	54	62	38
SE (%)	54	69	62	46	38	23	15	23	46
Calm (%)	46	31	23	38	15	38	23	15	0
Station				KOEBERG (10M)					
Wind speed	5,2	4,9	3,9	3,5	3,6	4,0	3,9	4,8	5,6
Wind dir'n: NW	8	8	15	23	69	85	84	92	77
SE	92	84	77	77	31	0	8	8	15
Calm	0	8	8	0	0	15	8	0	8
Station				DF MALAN					
Wind speed	5,4	4,0	3,2	2,2	4,2	5,0	5,5	5,9	6,1
Wind dir'n: NW	15	15	15	8	62	77	77	62	85
SE	77	38	38	38	23	8	15	23	8
Calm	8	38	46	54	15	15	8	15	8
Station				CAPE POINT					
Wind speed	11,2	10,3	9,7	9,1	9,1	7,4	7,0	8,3	10.7
Wind dir'n: NW	18	22	10	33	55	67	70	78	91
SE	82	78	70	67	45	22	10	11	9
Calm	0	0	20	0	0	11	20	11	0
Station				GANSBAAI					
Wind speed	9,2	9,6	6,3	6,7	7,0	11,0	10,7	10,6	12,7
Wind dir'n: NW	10	10	0	30	50	60	80	90	100
SE	80	90	80	70	50	40	10	0	0
Calm	10	0	20	0	0	0	10	10	0
Station				CAPE AGULHAS					
Wind speed	5,4	5,4	5,7	5,3	4,5	5,9	6,5	7,9	6,2
Wind dir'n: NW	8	0	10	29	46	100	88	100	92
SE	77	78	80	71	46	0	12	0	0
Calm	15	22	10	0	8	0	0	0	8