THE MODIFICATION OF GRADIENT WINDS BY DISSECTED TOPOGRAPHY IN THE VICINITY OF THE JONKERSHOEK VALLEY.

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1993

TABLE OF CONTENTS

	PAGE
LIST OF FIGURES	I
LIST OF TABLES	II
ACKNOWLEDGEMENTS	III
ABSTRACT	IV
1. INTRODUCTION	1
1.1. THE AIM OF THE STUDY	1
1.2. STUDY AREA	1
1.3. LIMITATIONS IN MOUNTAIN WEATHER AND CLIMATE STUDIES	4
2. CONCEPTUAL BASES	5
2.1. MOUNTAIN AND VALLEY WINDS	5
2.1.1. THE MECHANISM OF MOUNTAIN AND VALLEY WINDS	5
2.1.2. ONSET AND CESSATION TIMES OF MOUNTAIN AND VALLEY WINDS	7
2.1.3. VELOCITY FLUCTUATIONS AND DEPTH OF MOUNTAIN AND VALLEY WINDS	9
2.1.4. THE SEASONAL AND MONTH-BY-MONTH OCCURRENCE OF MOUNATIN AND VALLEY WINDS	11
2.1.5. THE ANTI-VALLEY AND ANTI-MOUNTAIN WINDS	12
2.1.6. THE RELATIONSHIP BETWEEN THE SYNOPTIC FIELD AND THE MOUNTAIN AND VALLEY WINDS	13

TABLE OF CONTENTS

	PAGE
LIST OF FIGURES	I
LIST OF TABLES	II
ACKNOWLEDGEMENTS	III
ABSTRACT	IV
1. INTRODUCTION	1
1.1. THE AIM OF THE STUDY	1
1.2. STUDY AREA	1
1.3. LIMITATIONS IN MOUNTAIN WEATHER AND CLIMATE STUDIES	4
2. CONCEPTUAL BASES	5
2.1. MOUNTAIN AND VALLEY WINDS	5
2.1.1. THE MECHANISM OF MOUNTAIN AND VALLEY WINDS	5
2.1.2. ONSET AND CESSATION TIMES OF MOUNTAIN AND VALLEY WINDS	7
2.1.3. VELOCITY FLUCTUATIONS AND DEPTH OF MOUNTAIN AND VALLEY WINDS	9
2.1.4. THE SEASONAL AND MONTH-BY-MONTH OCCURRENCE OF MOUNATIN AND VALLEY WINDS	11
2.1.5. THE ANTI-VALLEY AND ANTI-MOUNTAIN WINDS	12
2.1.6. THE RELATIONSHIP BETWEEN THE SYNOPTIC FIELD AND THE MOUNTAIN AND VALLEY WINDS	13

2.1.7. SYNOPTIC WEATHER PHASES OVER THE SOUTH-WESTERN CAPE 14

3. METHODOLOGY 18

3.1. DATA STANDARDISATION PROCEDURE 18

3.2. DATA MANIPULATION 19

3.3. CASE STUDIES 20

3.4. PILOT BALLOON DATA 21

3.5. RADIOSONDE DATA 23

3.6. ONSET AND CESSATION TIMES OF WIND REGIMES 23

3.7. WIND DIRECTION FREQUENCIES 23

3.8. PIBAL DATA 24

4. THE CLIMATOLOGY OF THE JONKERSHOEK VALLEY BOTTOM 25

4.1. SUMMER 25

4.2. WINTER 28

4.3. WIND REVERSALS AT THE VALLEY BOTTOM 30

5. CASE STUDIES OF WINDS AT THE JONKERSHOEK VALLEY 33

5.1. MOUNTAIN AND VALLEY WINDS 33

5.2. NORTHWESTERLY WINDS 35

5.3. DEEP SOUTHEASTERLY WINDS 37

5.4. SHALLOW SOUTHEASTERLY WINDS 39

6. SPATIAL VARIABILITY OF WIND DIRECTIONS AND VELOCITIES 42

6.1. VALLEY WINDS AT SWARTBOSKLOOF: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS 42

6.2. MOUNTAIN WINDS AT SWARTBOSKLOOF: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS 47

6.3. SOUTH-EASTERLY WINDS AT SWARTBOSKLOOF: WIND DIRECTION FRQUENCIES AND VELOCITIES AT OTHER STATIONS 55

6.4. NORTH-WESTERLIES AT SWARTBOSKLOOF: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS 60

7. ONSET AND CESSATION TIMES OF THE VARIOUS WIND REGIMES AT SWARTBOSKLOOF BY SEASON 65

7.1 MOUNTAIN AND VALLEY WINDS AT SWARTBOSKLOOF 65

7.2 GRADIENT NORTHWESTERLY WINDS 70

7.3 GRADIENT SOUTH-EASTERLY WINDS 71

8. VERTICAL PROFILES OF WINDS AT JONKERSHOEK 72

9 SUMMARY AND CONCLUSIONS 104

9.1 THE CLIMATOLOGY OF JONKERSHOEK 104

9.2 THE RESPONSE OF THE VALLEY BOTTOM ATMOSPHERE TO VARYING SYNOPTIC FIELDS 105

APPENDICES

LIST OF FIGURES

	PAGE
1.1. STUDY AREA MAP	2
2.1 LOCAL BAROCLINIC ZONES	6
2.2 SCHEMATIC MAP SHOWING THE FOUR SYNOPTIC PHASES	15
5.1 BEHAVIUOR OF WINDS AT SBK, VP AND D.F. MALAN (26/11/84)	34
5.2 BEHAVIOUR OF WINDS AT SBK, VP AND D.F. MALAN	36
5.3 BEHAVIUOR OF WINDS AT SBK, VP AND D.F. MALAN	38
5.4 BEHAVIOUR OF WINDS AT SBK, VP AND D.F. MALAN	39
6.1 (A-D) WIND DIRECTION FREQUENCIES AT VP WITH VALLEY WINDS AT SBK	43
6.1 (E-H) WIND DIRECTION FREQUENCIES AT D.F. MALAN WITH VALLEY WINDS AT SBK	45
6.2 (A-D) WIND DIRECTION FREQUENCIES AT VP WITH MOUNTAIN WINDS AT SBK	48
6.2 (E-H) WIND DIRECTION FREQUENCIES AT D.F. MALAN WITH MOUNTAIN WINDS AT SBK	50
6.1 (i-l) TIME-SPEED SECTIONS TO SHOW THE DIURNAL WIND SPEED VARIABILITY AT SBK	51-54
6.3 (A-D) WIND DIRECTION FREQUENCIES AT VP WITH	

GRADIENT SE WINDS AT SBK 56

6.3 (E-H) WIND DIRECTION FREQUENCIES AT D.F. MALAN WITH GRADIENT SE WINDS AT SBK 58

6.4 (A-D) WIND DIRECTION FREQUENCIES AT VP WITH GRADIENT NW WINDS AT SBK 61

6.4 (E-H) WIND DIRECTION FREQUENCIES AT D.F. MALAN WITH GRADIENT NW AT SBK 62

7.1-7.3 ONSET AND CESSATION TIMES FOR VARIOUS WIND REGIMES 66-68

8.1 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (21/07/90) 74

8.1 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (21/07/90) 74

8.1 (c) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (22/07/90) 77

8.1 (d) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (22/07/90) 77

8.2 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (27/07/90) 81

8.2 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (27/07/90) 81

8.2 (c) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (28/07/90) 82

8.2 (d) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (28/07/90) 82

8.3 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS

IN THE VALLEY (12/08/90) 87

8.3 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (12/08/90) 87

8.3 (c) TIME-HEIGHT SECTION TO SHOW LOCAL WINDS IN THE VALLEY (13/08/90) 88

8.3 (d) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (13/08/90) 88

8.4 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (28/01/92) 91

8.4 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (28/01/92) 91

8.4 (c) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (29/01/92) 92

8.4 (d) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (29/01/92) 92

8.5 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (30/01/92) 95

8.5 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (30/01/92) 95

8.5 (c) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (31/01/92) 96

8.5 (d) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (31/01/90) 96

8.6 (a) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS IN THE VALLEY (07/03/92) 99

8.6 (b) TIME-HEIGHT SECTIONS OF HOURLY ALONG-VALLEY COMPONENTS (07/03/92) 99

8.6 (c) TIME-HEIGHT SECTIONS TO SHOW LOCAL WINDS
IN THE VALLEY (08/03/92) 100
8.6 (d) TIME-HEIGHT SECTIONS OF HOURLY
ALONG-VALLEY COMPONENTS (08/03/92) 100

LIST OF TABLES

PAGE

1. NUMBER OF HOURS WITH MISSING DATA 19
2. SEASONAL CONTRIBUTIONS AND STRENGTHS OF VARIOUS WIND REGIMES AT JONKERSHOEK 26
3. THE OCCURRENCE OF WIND REVERSALS AT JONKERSHOEK 31

AKNOWLEDGEMENTS

The author would like to thank the following people for their contributions in the completion of this project:

Mr Washington, R., (formerly with the department of Environmental and Geographical Science, UCT), without whose patient supervision this research would not have been completed. Mrs Butcher, S (Geographic Information Systems, UCT) and Mr Winters, K. (ENGEO, UCT) for their assistance with computing. The management and staff at the Jonkershoek Forest Research Station for supplying valuable station data and for allowing onsite observations at Jonkershoek. The staff at the D.F. Malan airport weather office for allowing access into their weather records. Dr Hewitson, B.(ENGEO, UCT) for supplying some valuable comments. Special thanks go to my wife Nguta, F and daughter Nguta, N for their patience and understanding throughout the duration of this project. My parents Mr and Mrs Ngeleza for their unwavering support.

Eric B. Ngeleza Jr

December, 1993.

ABSTRACT

The pilot balloon runs and synoptic charts show that mountain and valley winds at the Jonkershoek valley correspond with the west to east ridging of anticyclones over the South Western Cape. Saddles between the South Atlantic and South Indian anticyclones are particularly conducive to the development of well established local wind circulations at Jonkershoek. Gradient winds during the occurrence of saddles are shown to be light and variable. Deep gradient southeasterlies undergo an acceleration to the lee of the ridges resulting in strong airflow at the Jonkershoek valley bottom. The topography at Jonkershoek is shown not have any meaningful modifying effect on the gradient northwesterlies.

CHAPTER ONE
INTRODUCTION

1.1 THE AIM OF THE STUDY

In this study, three main aims are recognised. The first aim is to establish the climatology of the Jonkershoek valley bottom. This will indicate first, whether the classification of the dominant flow regimes over the South Western Cape by Diab and Garstang (1984) and Jury (1987) applies at Jonkershoek. Secondly, an understanding of the Jonkershoek climatology will improve our judgement regarding fire management at Jonkershoek.

The second aim is to establish the influence of dissected topography to varying synoptic circulations. This includes an investigation of the vertical temperature stratification with varying synoptic fields. This would allow for a prediction of the valley bottom flow field.
Thirdly, the interseasonal variations in flow regimes in the vicinity of the valley will be investigated. Seasons in this report are based on the classification used by Lindsay and Harrison (1986) viz. October-December (early summer), January-March (late summer), April-June (early winter) and July-September(late winter).

1.2. STUDY AREA

Figure 1.1 is a map of the Jonkershoek valley which was used as a study area for the purpose of this research. This valley is situated about 10 km to the east of Stellenbosch in the South Western Cape. The selection of this site was based on a number of reasons, three of which are that:
(i) the Jonkershoek valley is one of the few valleys in the South Western Cape with long periods of climatic data available.

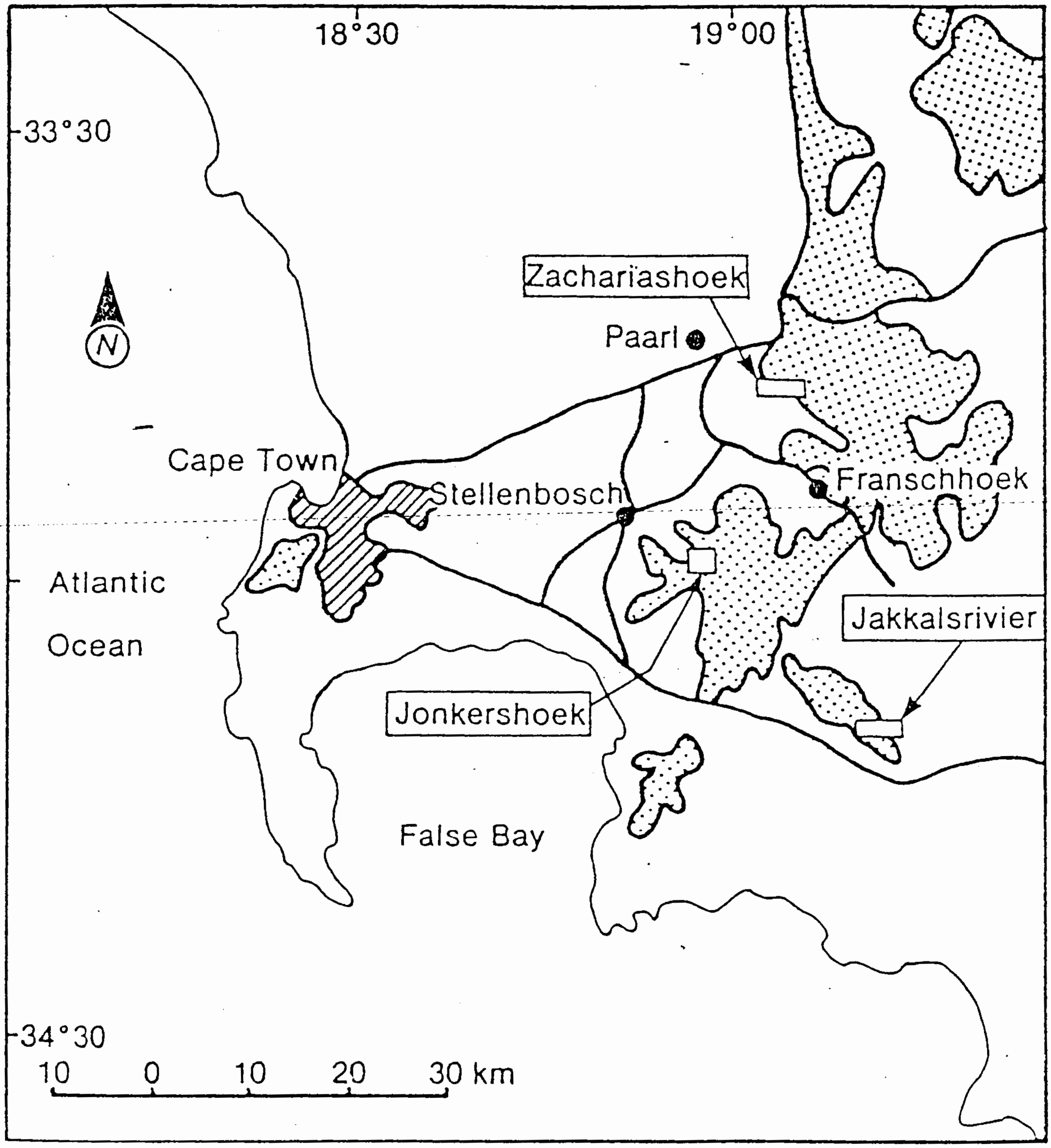


Fig 1.1 Location of the Jonkershoek Forest Research Centre. Dotted shading represents land at elevations above 600m and hatched shading shows developed urban areas of Cape Town (After Jonkershoek Forestry Research Centre, Pamphlet 384).

(ii) Climatic data for Victoria Peak, whose altitude is approximately 1400m above sea level was collected via an automatic weather station until 1986 (the station was removed in 1986). At its altitude, it is the author's belief that with proper verification, data from Victoria Peak provides a fair measure of gradient wind velocities and directions relevant to this study (the duration and persistence of winds, from the different directional categories, coupled with the synoptic pressure field from synoptic charts were used to verify whether winds at Victoria Peak were synoptic or local scale, (see chapter three).

(iii) The lower station at Jonkershoek (Swartboskloof) which is at an altitude of 305 m above sea level has a central situation,commanding a good view of both the head and the mouth of the valley. Such a site is suitable for the observation of local wind systems.

(iv) The site at Swartboskloof is virtually free of any small scale obstructions (e.g. tall trees close by or small hills or ridge) that would have localized, microscale effects on the winds at the surface.

These stations are manned by the CSIR which is responsible for the management of the Jonkershoek State Forest. The monitoring of the weather stations at Jonkershoek, data collection and archiving is performed by the staff of the Forest Research Centre which is situated at Jonkershoek.

From head to mouth the valley trends around 303^{o} (from true north) and therefore can be regarded as being south-east in orientation. The head of the valley is closed at the south-eastern end by the Dwarsberg. The Dwarsberg mountain as well as the flanking ridges of the valley are all at heights greater than 1000m. Peaks of the northern flanking ridge reach a height of around 1500m and those of the south flanking ridge around 1200-1300m. Victoria Peak is one of the east flanking ridges and as stated above, is at a height of 1400m above sea level. The height difference between Swartboskloof and Victoria Peak is therefore about 1001m.

1.3 LIMITATIONS IN MOUNTAIN WEATHER AND CLIMATE STUDIES

Barry (1981) identified the following limitations to mountain weather and climate studies.

(a) Many mountain areas are remote from major centres of human activity and tend to be neglected by scientists. The problem is compounded by the difficulty of physical access. The section of the Hottentots Holland mountains in the vicinity of the Jonkershoek valley is unique in that a state forest had been established within the valley. Physical access is therefore not a problem.

(b) The nature of the mountain terrain sets up such a variety of local weather conditions that any station is likely to be representative of only a limited range of sites. The above point means that some of the results from this study cannot be infered for another site without verification.

The layout of this report is as follows. Chapter two is a review of relevant literature. The methods used in gathering and analizing data for this study are presented in chapter three. In chapter four, the climatology of the Jonkershoek valley is investigated. This is followed in chapter five by the presentation of cases during which the flow regimes relevant to the study prevailed in the vicinity of Jonkershoek. Chapter six investigates the spatial variability of wind directions and velocities during the prevalence of the different flow regimes at the valley bottom. Onset and cessation times for local winds and gradient winds are investigated in chapter seven. This is followed in chapter eight by the presentation of pilot balloon results. This report ends in chapter nine with a summary and conclusions.

CHAPTER TWO

CONCEPTUAL BASES

In this chapter, literature on thermo-topographic circulations is reviewed. More emphasis is placed on studies conducted within the Republic of South Africa and Namibia. International contributions are included in so far as they enhance and/or dispute the validity of local findings.

The following order is adopted in this review. Firstly, literature on local scale mountain and valley winds is presented. This is then followed by a presentation of the synoptic phases that dominate the flow over the South Western Cape.

2.1 MOUNTAIN AND VALLEY WINDS

According to Tyson (1968b), nocturnal down-valley flow is defined as a mountain wind and its return current as the anti-mountain wind. The daytime up-valley flow is referred to as the valley wind.

2.1.1 THE MECHANISM OF MOUNTAIN AND VALLEY WINDS

The mountain and valley winds develop as a consequence of differences in the energy balance regime on slopes and in the free air adjacent to them. The differential heating or cooling of the air closer to the slopes and free air results in the development of baroclinic fields on slopes (Tyson, 1988). During the day-time, absorption of radiation by the sloping terrain results in the warming of the air near the surface thus becoming warmer than air in the free atmosphere at the same height (Atkinson, 1981; Barry, 1981).

The opposite occurs at night where radiative cooling near the surface occurs under calm conditions (Tyson, 1968b; Tyson and Preston-Whyte, 1972; Barry, 1981). This results in the air near the surface being cooler than the air in the free atmosphere at the same height. As a result, isobars and isotherms are deformed (Fig 2.1). Solenoidal circulations are initiated within the baroclinic zone upto a depth H (Tyson,1988).

According to Preston-Whyte and Tyson (1988), the circulation in each cell has a counteracting effect on its neighbours, except in the outer layer of cells. This results in the initiation of a low level up-slope anabatic flow of air up warmed slopes by day. A compensating return flow occurs at the top of the baroclinic layer to complete the closed circulation (Barry, 1981;Tyson, 1988).

By night, radiational cooling of the slopes and the reversal of the baroclinicity produces down slope katabatic flow and

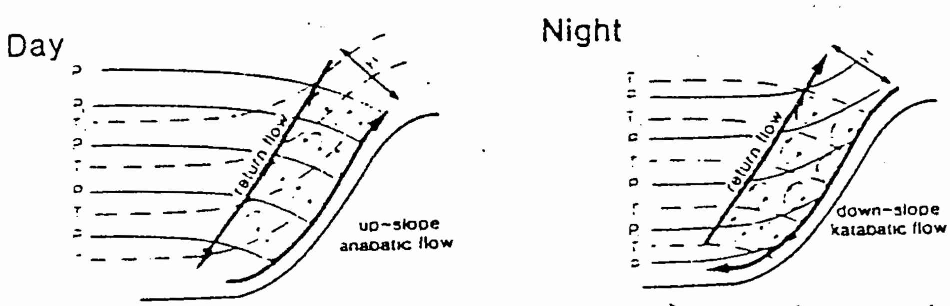


Fig. 2.1. Local baroclinic zones and solenoidal circulations producing anabatic and katabatic winds and their return flows (After Tyson, 1988).

its return flow (Tyson, 1988). Temperature differences of only a fraction are sufficient to initiate this mechanism (Atkinson,1981).

The movement of air up and down the valley is caused by the axial temperature gradients which exist between the mouth and the head of the valley. According to Tyson (1988), strong axial temperature gradients develop between the valley mouth and head in the late morning due to variations in surface heating. This gradient results in the movement of air up-valley. The opposite occurs at night.

According to the U.S. Atomic Energy Commission (1968), airflow within valley is relatively undisturbed by night. By day however, the turbulence induced by the heated land surface can be expected to stir the air within the valley and cause mixing within the free flow above the ridges. This turbulence constitutes a general disruptive mechanism and hinders the development of any sensitively balanced circulation pattern. Therefore although day-time valley patterns exist, they are no so common or so marked as down-valley flow.

The occurrence of mountain and valley winds has been extensively studied in the Republic of South Africa and Namibia e.g. (Tyson, 1966, 1967, 1968b; Tyson and Seely, 1979; Tyson, 1988). Mountain and valley winds were related to the dispersion of atmospheric pollutants, e.g. (Sturman, 1987 and Tyson et al., 1988). Numerous other studies of valley atmospheres have been conducted internationally, e.g. (Schmaus, 1929; Sceata, 1934; Ekhart, 1936).

2.1.2 ONSET AND CESSATION TIMES OF MOUNTAIN AND VALLEY WINDS

In their study of mountain and valley winds in the central Namib, Tyson and Seely (1979) found that in Gobabeb, a cool mountain wind was initiated around 21h00 and prevailed until at least 09h00 the following morning. The period

09h00-12h00 was found to be that of transition during which general winds (particularly Bergwinds) are most likely to be strong and unmodified by local conditions. By noon the local thermal pressure gradients between the open Kuiseb valley and the narrow middle and upper valley were found to have been reversed with the prevalence of a valley wind.Month-by-month changes in the behaviour of local wind systems were observed in the study under review. Down-valley movement of air was found to be initiated between 18h00 and 21h00 from March to August. Cessation takes place between 06h00 and 09h00 from June to August, in other winter months, a little earlier.

At Giant's Castle in the Natal Drakensberg, Tyson (1968) observed a regular dissipation of the mountain wind from 06h00 onwards. Up-valley flow was initiated shortly before 07h00 above the height of the flanking ridges below which the mountain wind continued to blow. The up-valley movement of the entire air mass within the valley was observed by 08h30 (when both slopes were receiving direct solar radiation). In valleys around Pietermaritzburg, the onset of mountain winds were found to occur soon after sunset and blew for 14 hours before reversing to up-valley winds (Tyson, 1968). The down-valley flow was found not to cease by night unless interrupted by external influences.

Doran et al. (1990) reported from Rattlesnake mountains in Eastern Washington (USA) that mountain winds are initiated between 18h00 and 19h00 and reversed around 10h00 the following morning.

In view of the above findings on onset and cessation times, it is important that the extent to which local circulations at Jonkershoek correspond to what happens in other valleys be established.

cessation in some cases. Prantle (1942) advanced a mean mountain profile. His profile represents the mean mountain wind as a dampened oscillation about U=0. This profile was found to be well described by the mountain wind in Pietermaritzburg (Tyson, 1968a). Tyson (1968b) described the velocity fluctuations (surges) for mountain winds in Pietermaritzburg. The up-valley wind was found to reach its maximum depth at the time of maximum radiational exchange during the early afternoon. The maximum intensity was observed in the mid-afternoon followed by a rapid decay after sunset.

In another study of velocity fluctuations in the mountain wind which was conducted in valleys around Pietermaritzburg by Tyson between 1961 and 1965, it was found that the onset of the mountain winds occurs as a localized front of cold air moving down-valley at speeds upto 6.5 m/s (Tyson, 1968). After the initial surge of about 3 hours, the wind was found to weaken throughout the night.

The Atomic Energy Commission (1968) reported that mountain winds usually extend to ridge level. Working in the eastern Transvaal Highveld, Tyson et al. (1988) reported that as a rule of thumb, valley and mountain winds extend to the ridges in which they occur.

The onset of an avalanche in the Bavarian Alps was described by Schmaus (1926) and Sceatta (1935). Wilkins (1955) studied the same phenomenon in the United States. Surges in the mountain wind were predicted by Fleagle (1950). Egger (1983) found that in Dischma Valley in France, valley winds extend throughout the valley atmosphere. All released balloons were found to move up the valley with horizontal velocities of the order of 2-4 m/s. Topographically induced wind systems were also studied by Doran et al. (1990) on the slopes of Rattlesnake Mountains in eastern Washington. Up-valley wind velocities were found to be between 1 m/s and 3 m/s at 15h46 pm. Mountain winds were found to be strongest (6-7 m/s) at about 75 m level.

2.1.4 THE SEASONAL AND MONTH-BY-MONTH OCCURRENCE OF MOUNTAIN AND VALLEY WINDS

In the central Namib, Tyson and Seely (1979) found that the diurnal cycle of local winds was most apparent in winter in Rooibank and Gobabeb. In this study, it was established that an inverse correlation existed between the monthly frequencies of the occurrence of valley and mountain winds at Gobabeb.

Mountain winds were found to be an autumn-winter-spring phenomenon, with a maximum occurrence in July and decrease to near zero between October and February. By contrast, valley winds were found to occur throughout the year, but most markedly in summer, and with a maximum in January. In summer, mountain winds were found to be weak. In January, this wind regime was found to be absent.

The maximum frequency of occurrence of mountain winds was found to occur between 21h00 and 00h00 in March, getting later as winter progresses. From March to November the Gobabeb valley winds only occur by day. During December, January and February, the valley wind may blow strongly until midnight except during the late afternoon of interruption by the seabreeze. The post sunset persistence of the valley wind in summer was also reported in a study conducted in Natal by Tyson and Preston-Whyte (1972). Ian et al. (1990) reported from Wright valley on the Antarctic continent that the highest frequency of valley winds occurs during the summer months.

2.1.5 THE ANTI-VALLEY AND ANTI-MOUNTAIN WIND

The return current to the mountain wind is known as the anti-mountain wind (Tyson, 1968b). The anti-valley wind is also defined here as the return current to the valley wind.

According to Tyson (1968b), the anti-mountain wind is easily recognized as a current of air moving between the mountain and the down-valley gradient winds.

The anti-mountain wind may be difficult to distinguish (Atkinson,1981). Tyson (1968b) found that at Giant's Castle, the developing mountain wind undercuts the decaying valley winds resulting in the merging of the anti-mountain wind and the valley wind. This can maintain the continuity of the up-valley flow at ridge level for long periods. The direction of the anti-mountain wind was also found to be influenced by the direction of the mountain below and if a weak gradient wind exists, the flow can be strikingly similar and sinuous, but of opposite direction to that of the mountain wind over distances of a few kilometres. The variation of velocity with height was found to be similar to that of the mountain wind, though opposite in sign. Return currents to mountain and valley winds were also found to develop by Tyson et al. (1988) unless prevented from doing so by the strength of the synoptically induced winds.

2.1.6 THE RELATIONSHIP BETWEEN THE SNOPTIC FIELD AND THE MOUNTAIN AND VALLEY WINDS

A review of literature on the relations between the synoptic field and local valley circulations will assist in the intepretation of the results of this study, i.e. the manner in which dissected topography modifies synoptic scale circulations.

This relationship between local thermo–topographic winds and the synoptic field was reported in a number of studies eg : (Ekhart, 1936, 1948; Tyson,1968; U.S. Atomic Energy Commission, 1968; Tyson and Preston–Whyte, 1972) .

Stable atmospheric conditions and the fine weather associated with anticyclonic circulations are conducive to the development of well defined local air circulations eg: (U.S. Atomic Energy Commission, 1968; Tyson and Preston–Whyte, 1972; Posnik, 1990). Barry (1981), and Ekhart (1936, 1948) reported that in light pressure gradients with clear skies, the valley and slope atmosphere may be decoupled from the surrounding atmosphere, whereas in strong airflow and cloudy conditions the only distinctive features tend to be those associated with mechanical sheltering effects.

According to Mahrt and Larsen (1990) with very stable atmospheric conditions, the resultant winds are generally directed down slope by night regardless of the direction of the overlying wind, suggesting control by the down slope buoyancy forces. Accoding to this report, when the ambient wind is directed up the slope and the stability is moderate, the surface valley winds are significantly retarded compared to a case with weak stability. This was found to imply that the slope buoyancy forces and associated pressure gradient field at the surface act to retard the upslope flow.

Jury (1987) reported from aircraft observations of meteorological conditions along Africa's West Coast between 30^{o}-35^{o} that under restricted flow resulting from an anticyclonic ridging over the continent, variable topographic friction and thermal contrasts would create perturbations in mesoscale windfield. Doran and Horst (1986) reported a surface flow sensitive to the ambient winds, often with destruction imminent when ambient winds exceed 3-4 m/s. Tyson et al. (1988) also reported that the in the absence of strong synoptically induced winds, valley circulations tend to be upslope in the early morning and down slope around sunset.
According to Neff and King (1988), opposing winds delay the onset of drainage winds. Tyson (1968) found that strong gradient winds exert a controlling influence on the vertical development of mountain winds. He found that if the valley is deep and the gradient wind is blowing obliquely across the valley, the mountain wind is depressed to ridge level.

2.1.7 SYNOPTIC WEATHER PHASES OVER THE SOUTH-WESTERN CAPE

as stated in the introduction, the Jonkershoek valley is located in the South Western cape. It is therefore affected by the synoptic circulations that dominate the region. That the mesoscale circulation over the South-Western Cape is related to the larger scale forcing through a sequential weather cycle was reported by Jury and Guastella (1987). They found that such a cycle evolves over time scales of 4-16 days. The cycle is controlled by the eastern movement of midlatitude weather systems. Jury (1980) and Diab and Garstang (1984) independently found four discrete phases in the synoptic weather/gradient wind cycle near Cape Town. Jury's classification (1987) is used in the following paragraphs to describe the four phases.

The south westerly wind phase follows the passage of a cold front. The phase is characterized by cold air advection associated with the leading edge of a ridging anticyclone (fig. 2.2 a). This phase is typically accompanied by rising pressures, limited diurnal variations and divergent wind streamlines. The large scale flow is forced to separate as it reaches the continent, westerlies continue to blow along the south coast, while over the Benguela-facing coast, southerly flow commences. Subsequently, this regime is followed by a continued ridging of the high-pressure cell and a strengthening of the gradient winds.

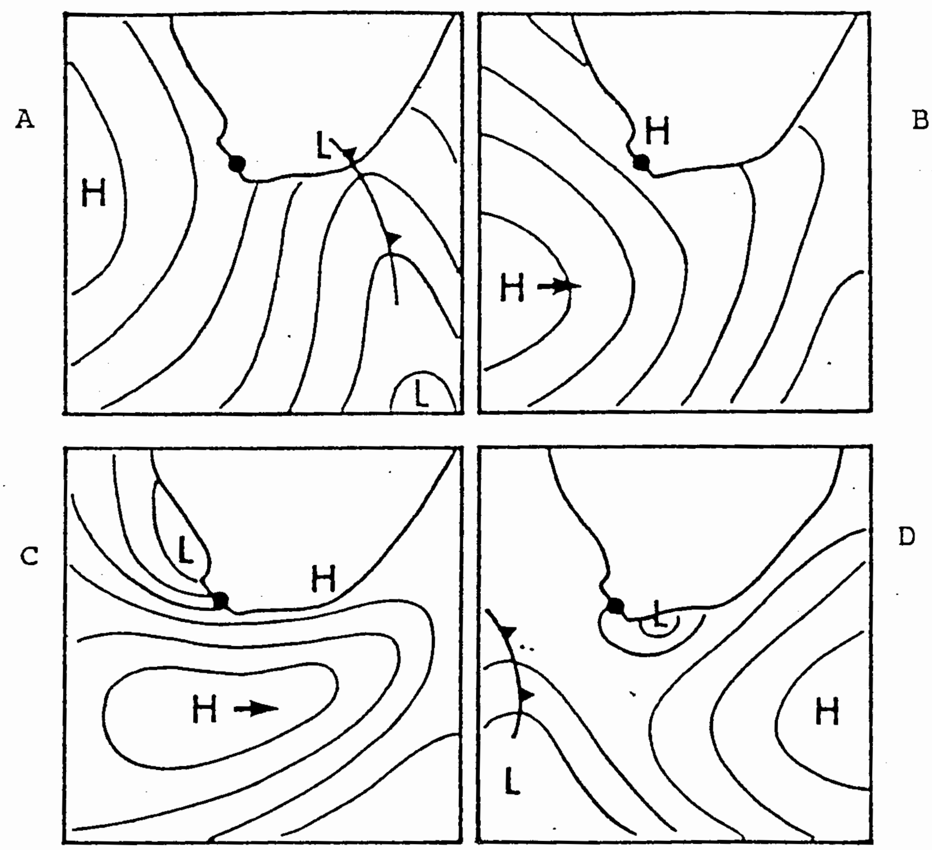


Fig 2.2 A schematic map showing the four main phases of the synoptic weather cycle which affect coastal winds and meteorological conditions along the southwestern tip of Africa: SW, top left; deep SE, top right; shallow SE, bottom left; NW, bottom right.

The deep southeasterly wind phase which follows the southwesterly wind phase is produced by the joining of the eastward moving high pressure cell with the semi-permanent South Indian high (fig 2.2 b). This serves to increase the central pressure and the area of influence of the high pressure cell, so that it affects the entire west coast of Africa from 30°S to 35°S. As the transient high pressure cell moves eastward, it impinges onto the continental plateau and resident summertime thermal low (Newton, 1972). This serves to increase the pressure gradient through the density field. When the transient high slips around the southern tip of the continent and separates from the permanent cell, a subsidence inversion limits the flow depth, leading to the occurrence of the shallow southeasterly phase. This field (the shallow southeasterly phase) precedes the passage of a coastally trapped low (Gill, 1977). The phase occurs under the waning influence of the transient high-pressure cell (fig.2.2 c). It is associated with warm advection, a low-level inversion and sharp land/sea temperature contrasts. Topographic and thermal circulations become enhanced during this phase, this is suggested by the vertical constriction of flow depth and the appearance of a thermal low in the Berg River Valley.

The last phase (the northwesterly wind phase) heralds the approach of the next cold front and follows the passage of a coastally trapped low (fig. 2.2 d). It is characterized by a sudden influx of cool moist air below a decaying inversion. This northwesterly sea breeze phase may be either a post-coastal low (fair weather) or prefrontal (scattered showers), depending on the strength and latitude of the approaching westerly Rossby wave. Under prefrontal conditions, more typical during winter, seabreezes and mesoscale gradients become swamped by onshore winds and rain showers.

According to Jury (1987), these synoptic phases develop chronologically as outlined in figure 2.2, embedded within the larger seasonal adjustments of the subtropical/midlatitude wind belts. In summer, southeasterly wind regimes dominate, while in winter the westerlies shift equatorward and the southwesterly and northwesterly regimes prevail (Nelson and Hutchings, 1983). The southeasterlies are associated with coastal upwelling and sharp air mass contrasts due to a capping warm inversion layer. In contrast, the westerly winds increase in speed aloft, mix the waters over the continental shelf and advect cool, moist air landward, thus limiting the development of thermal gradients.

CHAPTER THREE

METHODOLOGY

This chapter presents the methods used in data collection and analysis.

3.1 DATA STANDARDISATION PROCEDURE

Data from Swartboskloof and Victoria Peak had to be translated to meteorological standard units before any analysis could be performed. The wind velocities at Jonkershoek for the years 1984-1986 were recorded using a data logger which decodes in volts per minute. For standardisation, velocity data was converted to metres per second using the conversion term:

$$0.10613*X+0.2902$$

Where X is the number of volts as recorded by the data logger. Wind velocity data for D.F. Malan airport was recieved in meteorological standard units (metres per second) so no conversions were necessary.

Hourly wind direction data for 1984-1986 for Swartboskloof and Victoria Peak stations was received from the Forestry Research Centre recorded in degrees from north. To facilitate analysis, wind directions were classified into eight directional categories with one being the northerly winds and twelve the northwesterlies eg. Winds from the north-northeasterly quadrant and those from the east-northeasterly quadrant were considered to be northeasterlies. The same was applied with winds from the other quadrants. Directions from D.F. Malan airport for the corresponding years were also decomposed into eight categories.

Following the above procedures, 1984 was selected as a suitable study period as it is the most complete of the whole three year period. This is inspite of the absence of VP data for the whole of January. Table 1 indicates the number of hours with missing data by month for 1984.

In percentages, missing data for Swartboskloof accounted for about 3.4% of the total 1984 data. A total of 13% of the 1984 data for Victoria Peak was missing. There was 100% data availability from D.F. Malan airport.

3.2 DATA MANIPULATION

For the section on the climatology of the valley bottom, data for Swartboskloof was utilised. Seasonal percentage contributions of the different wind regimes for 1984 were determined by doing a count of the number of hours during which winds from a particular quadrant persisted at SBK on a particular season. The total was then converted into a percentage.

TABLE 1 Number of hours with missing data for 1994

MONTH	SWARTBOSKLOOF	VICTORIA PEAK
JANUARY	NONE	ALL
FEBRUARY	25	NONE
MARCH	30	178
APRIL	8	NONE
MAY	36	16
JUNE	24	52
JULY	76	26
AUGUST	18	NONE
SEPTEMBER	NONE	17
OCTOBER	43	107
NOVEMBER	16	NONE
DECEMBER	21	NONE
TOTAL	297	1140

The same was done in determining the month-by-month contributions.

Up-valley winds at Jonkershoek are northwesterly and down-valley winds are southeasterly. In order to make a distinction between the local valley winds and the gradient northwesterlies (or mountain winds and the gradient southeasterlies), the durations of winds from a northwesterly/southeasterly quadrant was considered to be a suitable guide. A duration of more than 24 hours was considered to be indicative of gradient winds. Local winds were identified by their relatively short duration. The strengths of the winds was used to supplement the above method. The winds in the vicinity of the valley were decomposed into their u and v components.

3.3. CASE STUDIES

The selection of cases for the purpose of investigating the characteristics of the various wind regimes was based upon the observation of the nature of the synoptic fields. Synoptic charts for 1984 were obtained from D.F. Malan. The characterizations by both Jury (1980) and Diab and Garstang (1984) were used as the bases for the classification of cases (see section 2.1.7). The resulting classifications were varified by scrutinizing the directions for Victoria Peak and Swartboskloof. Cases which did not conform to the expected directions were discarded and new cases identified.

A total of about twelve cases for each wind regime were retrieved, of which one, considered to be most representative of each regime, was selected for use in this report.

3.4 PILOT BALLOON DATA

The single theodolite method was adopted for the purpose of this research. Wind directions, velocities and heights were determined from pilot balloon ascents made approximately at hourly intervals. Recording commenced around 06h00 and stopped around 20h00. This provided data on both nocturnal and daytime regimes and their switchovers.

The height of the balloon depends on the reliability of the assumed rate of ascent of the balloon (Tyson, 1969). Weights are attached to a hydrogen filled balloon until the balloon equilibrates, i.e. neither ascend nor descend. With the removal of the weights, the equilibrium is destroyed and a lift is imparted to the balloon. According to Tyson (1969), the rate of balloon ascent is expressed by the equation:

$$V=83{,}34\ L^{1/2}/(L+W)^{1/3}$$

Where V denotes the rate of ascent in m/s, W is the weight of the balloon in grams; L is the free lift in grams and the constant 83,34 taken for balloons with a diameter less than 229 cm.

Balloons were set to ascend at a rate of approximately 120m per minute. The balloon position in terms of the elevation and azimuth were made at minute intervals. The elevation reading on the theodolite gives the angular height of the balloon above the ground. Since the height of the balloon is known from the rate of ascent, the application of trigonometrical ratios fixes the balloon position at each reading. Both the direction and speed may be obtained from the balloon trajectory, the latter calculated from the balloon displacement per time (Tyson, 1969). This was achieved by plotting the course of the balloon on a sheet of tracing paper using a suitable scale and reading off its speed and direction. The azimuth denotes the direction of the balloon from the observer in the horizontal plane and is measured in degrees from true north.

There are both advantages and disadvantages associated with the single theodolite tracking technique. The advantages are that the establishment of balloon stations is fairly easy and that manpower is reduced. It is possible for one researcher to observe the ascent as well as taking readings of a pilot balloon ascent.

The disadvantages of this method are that results are subject to errors caused by departures from the computed rate of ascent of the balloon (Tyson, 1969). Convectional currents give the balloon a greater ascensional velocity than that assumed. Diffusion of the gas through the balloon will decrease its rate of ascent. Radiational heating during the day and cooling at night increases or decreases the balloon ascent respectively.

The accuracy of the single theodolite method has been examined by Arnold (1948) and Ayers (1958) who compared this method to double theodolite measurements which served as a standard (Tyson,1969). Generally an error in height of between 10 and 15 percent and a mean speed error of 1 m/s was identified.

In the South Western Cape, the atmosphere is almost always absolutely stable. This makes constant height assumptions reasonable.

At night, balloons were tracked by attaching pre-weighed styrofoam cups with lit candles placed inside the ascending balloon. The advantages of this method are the constant intensity of light emitted as well as the possibility that the increase in buoyancy credited to the balloon by the wasting candle would help counteract the loss by radiational cooling.

3.5 RADIOSONDE DATA

Lapse rates of temperature were obtained from the D.F. Malan radiosonde data. The radiosonde records velocities, direction and air temperature as well as dew point temperature aloft at various pressure levels. Since the temperature at various pressure levels is known, it is possible to calculate the depth of a layer and thereby ascertain its height above the surface using the standard relationship:

$$Dz=29.27\,\overline{T}\,(\log_e p_o-\log_e p)$$

Where Dz is the thickness of the layer in metres between pressure levels p_o (lower level) and p (higher level) and $\overline{T}$ is the mean temperature in Kelvin between the levels p_o and p.

3.6 ONSET AND CESSATION TIMES OF WIND REGIMES

The determination of onset and cessation times for the various wind regimes was performed using data from Swartboskloof (SBK). The number of cases during which a particular wind regime was initiated or terminated at a particular time was determined by doing a simple count. The resultant values computed by season were used as indicators of onset and cessation times.

3.7 WIND DIRECTION FREQUENCIES

Wind direction frequencies presented in chapter six of this report were also determined by conducting counts of hours during which winds from a certain quadrant persisted.

3.8 PIBAL DATA

Data from the pilot balloon runs were plotted into height vs time graphs. These graphs depict the heights of the different flow regimes. Wind velocity data from pilot balloon runs is also depicted in time vs height sections of wind velocities. Time vs. height graphs are also used in this report to depict wind direction frequency data.

CHAPTER FOUR

THE CLIMATOLOGY OF THE JONKERSHOEK VALLEY BOTTOM

This chapter seeks to address the first aim of this report by investigating the dominant flow regimes at the Jonkershoek valley bottom during 1984. The seasons are used as the basic temporal units. The seasons are divided into early summer (October-December), late summer (January-March), early winter (April-June)and late winter (July-September), see section 1.1. Percentages in this section refer to the number of cases during which a particular regime occurred.

4.1 SUMMER

In early summer season (October-December) of 1984, the circulation at the valley bottom was dominated by the southeasterlies. Their contribution to the seasonal circulation amounted to 73.4% (Table 2). The separation between the deep and shallow southeasterlies was not performed due to the size of the data. Southeasterlies blew at a seasonally averaged velocity of 12.9 m/s. An absolute maximum of 55 m/s was recorded. The contributions of October and November to the occurrence of this wind regime in early summer were almost equal. December had the least southeasterlies of the season.

The contribution of the northwesterlies to the seasonal flow amounted to 25.7%. The wind velocities during the prevalence of this wind regime were lower than during the occurrence of the southeasterlies. The seasonally averaged wind velocity for this regime was 6.4 m/s. An absolute maximum of 25 m/s was recorded. The contributions made by the northeasterly bergwinds and the southwesterlies were of little significance during this season.

TABLE 2 Seasonal contributions and strengths of the various wind regimes at Jonkershoek

ON	CATEGORY	AVG. SPD	MAX.SPD	MIN.SPD	TOT.CONTR(%)	MONTHLY CONTR.(%)
SUMMER MAR	NE	5.2	24	1	4.4	J-59.2 F-22.1 M-26.6
Y WINTER JUNE		4.9	17	1	11.3	A-31.8 M-28.6 J-39.6
WINTER SEPT		4.5	24	1	10	J-45.6 A-31.2 S-22.3
Y SUMMER DEC		3.8	19	1	3.6	O-19.4 N-11.6 D-69.0
SUMMER AR	SE	18.6	59	1	68.6	J-31.7 F-37.3 M-27.3
WINTER UNE		5.1	38	1	45.2	A-39.7 M-17.6 J-43.1
WINTER EPT		7	50	1	35.7	J-20.7 A-48.8 S-30.8
SUMMER EC		12.9	55	1	73.4	O-34.1 N-36.4 D-29.6
SUMMER AR	SW	7.9	20	1	5.1	J-49.1 F-42.2 M-8.70
WINTER UNE		3.8	15	1	4.5	A-29.1 M-54.0 J-16.9
WINTER EPT		5.1	28	1	11.2	J-59.9 A-33.4 S-13.4
SUMMER EC		22.8	16	1	6.9	O-20.4 N-55.9 D-24.6
SUMMER AR	NW	6.2	20	1	23	J-11.1 F-34.6 M-54.4
WINTER AR		7.1	43	1	26.9	A-20.8 M-23.4 J-50.2
WINTER PT		7.2	27	1	29.1	J-12.1 A-35.2 S-52.7
SUMMER C		6.4	25	1	25.7	O-28.4 N-29.9 D-41.7

In late summer (January-March) the circulation at Jonkershoek was again dominated by the southeasterlies. Southeasterlies contributed 68% to the total circulation of this season. This contribution is less than that observed in early summer. The southeasterlies of this season were stronger than those of early summer. The seasonally averaged wind velocity for this season was 18.6 m/s with an absolute maximum of 59 m/s. Both the average velocities and the absolute maximum were higher than those for the other categories of winds. Most southeasterlies during this season occurred in February (37.3%). This contribution did not depart significantly from that of January (31.7%). There was a decrease in the percentage contribution towards early winter, March contributed 27.3% to the total southeasterlies of this season (see table 2).

The next significant contribution to the 1984 late summer circulation was made by the northwesterlies. This is similar to early summer. The percentage contribution of this category during this season varied only slightly from that of early summer. The same can be said about the strength of this category. The northwesterlies blew for 23% of the time during this season at a seasonally averaged velocity of 6.2 m/s. An absolute maximum of 20 m/s was observed. The greatest contribution to this category occurred in March (54%). The changing ratio of southeasterly and northwesterly winds demonstrates the transitioning from the summer to winter regimes. As was the case in early summer, the northeasterlies and the southwesterlies did not make significant contributions to the circulation of this season.

It can be concluded that the southeasterly wind regime is the strongest regime within the Jonkershoek valley during summer months. This could be caused by the steep pressure gradient that developes between the offshore highs and the heat low which locates over the Berg river valley during this season.

4.2 WINTER

During the early winter season (April-June) of 1984, the circulation at the valley bottom was again dominated by southeasterly winds. The contribution of this category to this season's circulation was much less than it was during the summer season and the winds were weaker. During this season, the southeasterlies blew for 45% of the time. The seasonally averaged southeasterly wind velocity was 5.1 m/s. An absolute maximum of 38 m/s was observed. Most southeasterlies during this season occurred in June.

The northwesterlies again displayed little variation in terms of contribution and velocity between summer and winter. Their contribution to the total circulation of this season amounted to 26.9% with an average velocity of 7.1 m/s. The absolute maximum for this season was higher than those of the two summer seasons. This was 43 m/s during this season. Most northwesterlies occurred in June.

The contributions of the northeasterlies increased during this season to 11.3%. The seasonally averaged velocity was 4.9 m/s. The contribution of the southwesterlies was again of little significants.

As in all other seasons of 1984, the southeasterly wind category dominated during the late winter season (July-September) at the Jonkershoek valley bottom. The contribution of this category during this season was the least of all other seasons (35.7%),see table 2. Late winter's southeasterlies were stronger than those of early winter but weaker than those of summer. This season's average velocity was 7 m/s, with an absolute maximum of 50 m/s. Most southeasterlies in this season occurred in August.

The northwesterlies contributed 29.1% during this season. This is higher than the contributions of this regime in all other seasons. In winter, the westerlies shift equatorward resulting in the prevalence of the northwesterly winds over the South Western Cape. This season's average velocity for the northwesterlies was 7.2 m/s with an absolute maximum of 27 m/s.

There was little variation in the percentage contribution of the northeasterlies between early and late winter. In late winter, the northeasterlies contributed 10% to the total circulation at a seasonally averaged velocity of 4.5 m/s. The absolute maximum was 24 m/s. According to Tyson (1988), northeasterly berg winds along the coasts of South Africa have a peak occurrence in late winter and early spring. The largest contribution of this category during this season occurred in July.

This is the only season during which the southwesterlies had a double digit contribution to the valley bottom circulation (11.2%) as against contributions of below 5% during the other seasons. The contribution of the southwesterlies during this season is slightly higher than the contribution made by the berg winds. The seasonally averaged velocity for the southwesterlies was 5.1 m/s with an absolute maximum of 28 m/s.

In summary, the southeasterly wind category dominated the flow at Jonkershoek in all seasons of 1984 with strongest winds occurring during the late summer season. This suggests that fires occurring during this season at the Jonkershoek valley would be the most difficult to control. The southeasterlies at the valley bottom were stronger in summer than in winter. Strongest southeasterlies occurred in late summer. The next dominant category of winds were the northwesterlies. This category showed little inter-seasonal variability in frequency and strength. The northeasterlies blew at velocities below 6 m/s in all seasons of1984. Their contribution to the circulation during the summer months remained below 5%. An increase in their contribution occurred in winter. The southwesterly wind category was the least significant at Jonkershoek in 1984.

The above observations suggest that Jury and Diab's synoptic classes for the South Western Cape can be applied to the Jonkershoek valley atmosphere keeping in mind that the southwesterly regime is of little significance throughout the year.

4.3 WIND REVERSALS AT THE VALLEY BOTTOM

This section investigates the occurrence of wind reversals at the Jonkershoek valley bottom using seasonal data from Swartboskloof. Reversals are defined here as cases with variable winds, with winds frequently making 180° turns from hour to hour. No established flow was identified during these cases. This investigation is important for fire management. Pollution dispersion is known to be poor during the occurrence of variable winds.

Table 3 includes average velocities during the occurrence of reversals by season, seasonal percentage contributions to the total annual occurrence of reversals and month to month contributions per season.

The early summer season experienced more reversals than during any other season of 1984 with a contribution to the annual occurrence of 45.6%. This season's reversals were the strongest of all seasons. The seasonally averaged velocity was 6.3 m/s. Most reversals occurred between October and November.

Late summer (FM) and early winter (AMJ) had an almost equal contribution of reversals. Late summer contributed 20% whilst early winter contributed 19.8%. The average wind velocities were 3.7 m/s and 3 m/s for late summer and early winter respectively. Of the two late summer months, March had the highest contribution (Table 3). In early winter, April contributed the most.

The occurrence of reversals was least in late winter (JAS) with a contribution of only 14.6%. The strength of reversals during this season had an average of 3.6 m/s. A total of 95.4% of this season's reversals occurred in September.

TABLE 3 The occurrence of wind reversals at the Jonkershoek Valley by season.

SEASON	AVG. SPEED	ANNUAL % CONTR.	MONTHLY EARLY
SUMMER	6.3	45.6	O=7.2
			N=46.1
			D=46.7
LATE SUMMER	3.7	20	F=44.4
			M=55.6
EARLY WINTER	3	19.8	A=52.4
			M=36.5
			J=11.1
LATE WINTER	3.6	14.6	J=0
			A=4.6
			S=95.4

The peak occurrence of wind reversals coupled with highest wind reversal speeds during the early summer season imply that fire management would be difficult during this season. It was noted in section 4.2 that the late summer season would provide difficulties in terms of fire management due to the occurrence of strongest southeasterlies during that season. The above observations considered together suggest that the summer season as a whole should be seen as a fire danger season at the Jonkershoek valley.

CHAPTER FIVE

CASE STUDIES OF WINDS AT THE JONKERSHOEK VALLEY

The second aim of this project which is to establish the influence of dissected topography on synoptic circulations is partly achieved in this chapter by investigating the behaviour of winds at the Jonkershoek valley bottom with varying synoptic fields. A selection of cases representing different wind categories are presented. Data from Victoria Peak (1400 m ASL),Swartboskloof (300 m ASL) and D.F.Malan Airport are analysed. For cases during which synoptic scale circulations prevailed within the valley, Jury and Guastella's classification is followed (see section 2.1.7)

5.1 MOUNTAIN AND VALLEY WINDS

On the 26/11/84, the South Western Cape was under the influence of an anticyclone (Appendix A) which is associated with subsiding air which warms on decent, increasing atmospheric stability (Tyson and Prestn-Whyte, 1988). Mountain and valley winds occurred at Swartboskloof (SBK), see figure 5.1. Valley winds developed at SBK at 06h00 and persisted till 17h00. They blew for a total of 12 hours. A mountain wind was established at 18h00 and blew till 05h00 in the morning, also blowing for a total of 12 hours.

The valley bottom local winds were overlain at Victoria Peak (VP) by a southeasterly gradient flow. A clear decoupling of the valley atmosphere from that aloft was evident during this case. Wind directions at the airport were also southeasterly throughout this case. No local wind circulation was established at the airport. Figure 5.1 indicates that the wind velocities recorded at SBK during this case remained below 5 m/s. Calm conditions prevailed at SBK between 02h00 and 07h00. Tyson et al. (1988)

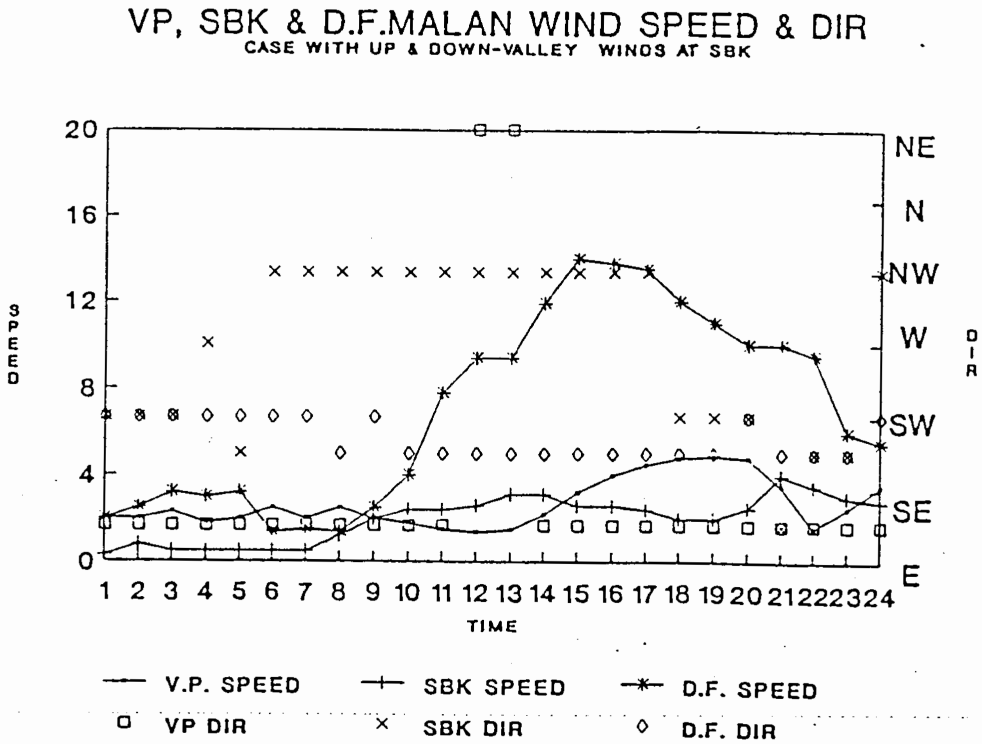


Fig. 5.1 A chart showing the behaviour of winds at Swartboskloof, Victoria Peak and D.F. Malan on the 26/11/84. Wind speeds along the left vertical exis are in m/s. Directions are displayed on the vertical exis to the right of the chart. Time along the horizontal exis is in hours.

reported that by night the stability of the lower atmosphere causes wind speeds to diminish near the ground. The tendency for mountain winds to stabilise several hours following sunset was reported by Doran et al. (1990) and Ye et al. (1990). The maximum mountain wind velocity was recorded at 21h00, four hours after onset. Tyson (1968) reported an onset surge of the mountain winds in the Bushman's Valley in the Natal Drakensberg. Day time valley winds accelerated gradually after onset to a peak of 3 m/s between 13h00 and 14h00. The valley winds are known to have a midday peak in velocity. This occurs at a time of maximum surface heating and instability (Tyson et al., 1988). According to Egger (1983), low pressure exists at the valley's upper end and relatively high pressure occurs at the entrance during the day. This pressure gradient would be strongest during the time of maximum surface heating.

Mountain and valley winds during this case corresponded with summit (VP) wind velocities which were below 6 m/s. The southeasterly winds which occurred at the airport were stronger than the valley bottom thermo-topographic winds. Airport winds accelerated from velocities lower than 4 m/s between 01h00 and 08h00 to a maximum of 14 m/s at 15h00. Day time velocities at the airport were higher than those recorded at the two other stations. These differences between the airport and valley circulations suggest that at the valley, topographic sheltering and thermal contrasts produced conditions which were suitable for the development of local circulations.

5.2 NORTHWESTERLY WINDS

On the 03/12/84, a cold front was approaching the South Western Cape (Appendix A). A mountain wind at the Jonkershoek valley was terminated with the arrival of the cold front at 06h00. Between 06h00 and midnight, wind directions at the valley bottom were northwesterly (Fig. 5.2.). Directions at the summit station (VP) also had a pronounced northerly component throughout the 24 hour period. According to Preston-Whyte and Tyson (1988), airflow ahead of cold fronts has a pronounced northerly component. Before the arrival of the front, calm conditions prevailed at the airport. By 09h00, north-westerly pre-frontal flow occurred at the airport.

The valley bottom circulation was also calm prior to the arrival of the front. These calm conditions were overlain at the summit by westerly winds whose velocity did not exceed 6 m/s. With the arrival of the cold front, summit northwesterlies strengthened to velocities higher than 6 m/s. This strengthening of the gradient winds was

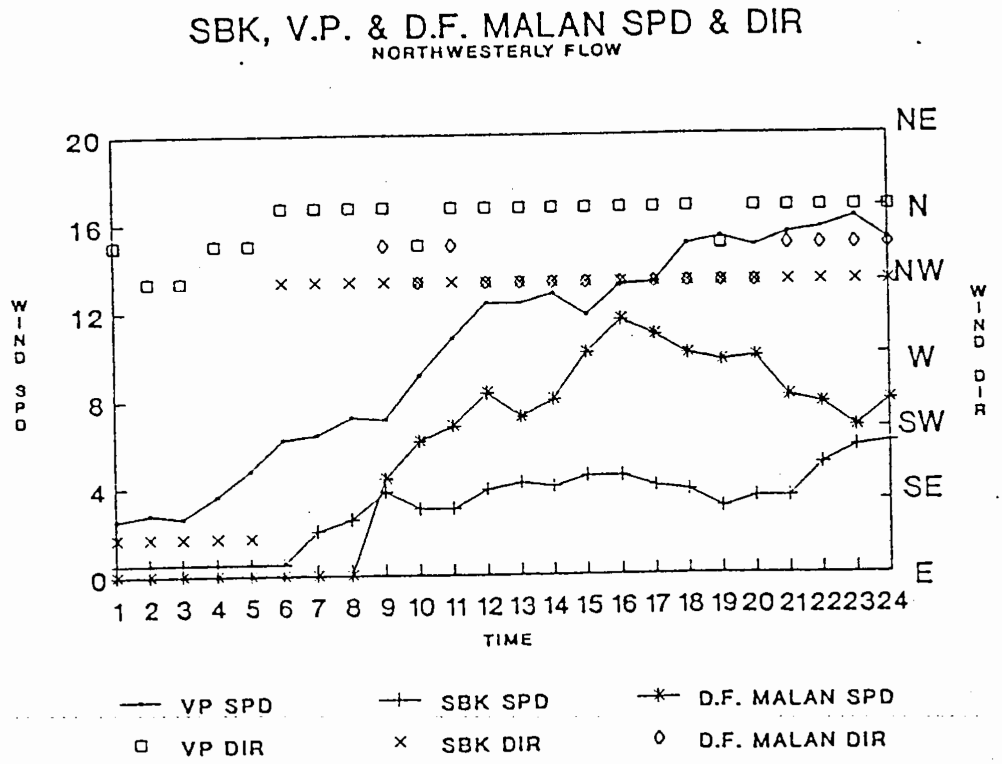


Fig 5.2 A chart showing the behaviour of winds at Swartboskloof, Victoria Peak and D.F. Malan on the 03/12/84. Wind speeds along the left vertical axis are in m/s. Directions are displayed on the vertical axis to the right of the chart. Time along the horizontal axis is in hours.

accompanied by the destruction of the valley bottom local circulation. This tendency for local winds to be destroyed under strong ambient winds was reported by Ekhart (1936, 1948). Working in the Dichma Valley in France, Horst and Doran (1986) found that winds of less than 5 m/s generally did not prevent or interfere with the development of drainage flow. With the arrival of the gradient northwesterlies at SBK at 06h00, velocities increased gradually to about 4 m/s between 09h00 and 21h00. More acceleration occurred after 21h00 to velocities of 7 m/s by 24h00. This nocturnal acceleration could have been induced by the reduction of thermally induced turbulence. At the summit, acceleration was maintained throughout this case. A maximum velocity of 16 m/s was recorded at the summit station at 23h00. Strong vertical shear occurred in the vicinity of the valley.

The calm conditions at the airport were terminated at 09h00 by a sudden jump in velocity to 4 m/s. The northwesterlies which occurred at the airport were much stronger than those which occurred at the valley bottom. Wind velocities at the airport increased to a peak of 11 m/s at 16h00. The difference in wind velocities between D.F. Malan (11 m/s) and the valley bottom (4 m/s) indicates that winds within valleys experience more frictional drag due to the nature of topography than those that blow on flat terrain such as that of D.F. Malan.

5.3 DEEP SOUTHEASTERLY WINDS

On the 18/02/84, an anticyclone was ridging to the south of Cape Town (Appendix A). Wind directions at the valley bottom and at the summit were southeasterly throughout this case with little variability. Southerly winds blew at the airport for the whole 24 hour period (Fig. 5.3). This scenario is indicative of a deep southeasterly event. The depth of flow within a deep southeasterly event exceeds 1 Km in depth and is able to flow over the isolated peaks of the Cape Peninsula (Jury, 1987). There was coupling between the valley atmosphere and the upper atmosphere during this case.

Wind velocities at SBK and at VP were above 5 m/s for the duration of this case. Wind velocities were higher at the valley bottom (SBK) than they were at the summit (VP), (see figure 5.3)

Jury (1987) also stated that in the lee of mountains, winds are forced down slope, resulting in sudden warming due to compression. This would have presumably resulted in the leeward acceleration of winds on the 18th and would explain the higher wind velocities at the valley bottom. Winds at both the valley bottom and the summit accelerated throughout the day with maxima (10.2 m/s for SBK and 9.5 for VP) occurring at 19h00 at both stations.

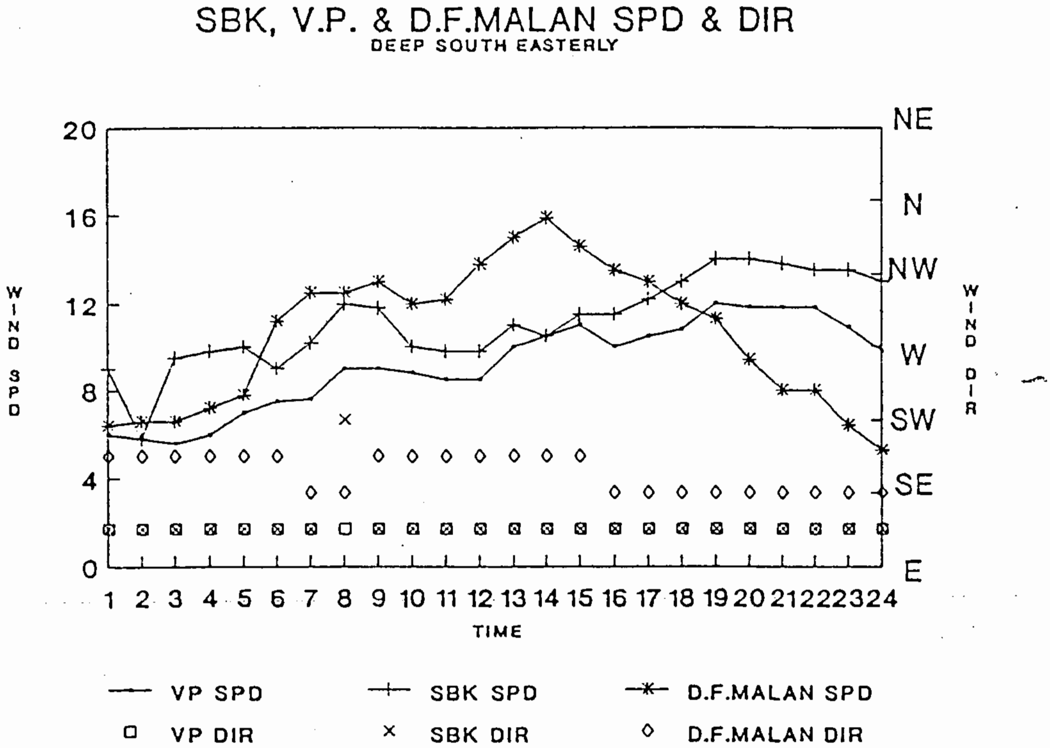


Fig 5.3 A chart showing the behaviour of winds at Swartboskloof, Victoria Peak and D.F. Malan on the 13/02/84. Wind speeds along the left vertical axis are in m/s. Directions are displayed on the vertical axis to the right of the chart. Time along the horizontal axis is in hours.

At the airport, winds accelerated to a maximum of 12 m/s at 14h00. Wind velocities at the airport were generally higher than velocities at the Jonkershoek valley bottom during the day (06h00-17h00). Nocturnal velocities at the airport were lower than those recorded at the valley.

5.4 SHALLOW SOUTHEASTERLY WINDS

On the 12/11/84, an anticyclone ridged to the south of Cape Town (Appendix A). Wind directions at the valley bottom were southeasterly for the rest of this case (Fig. 5.4).

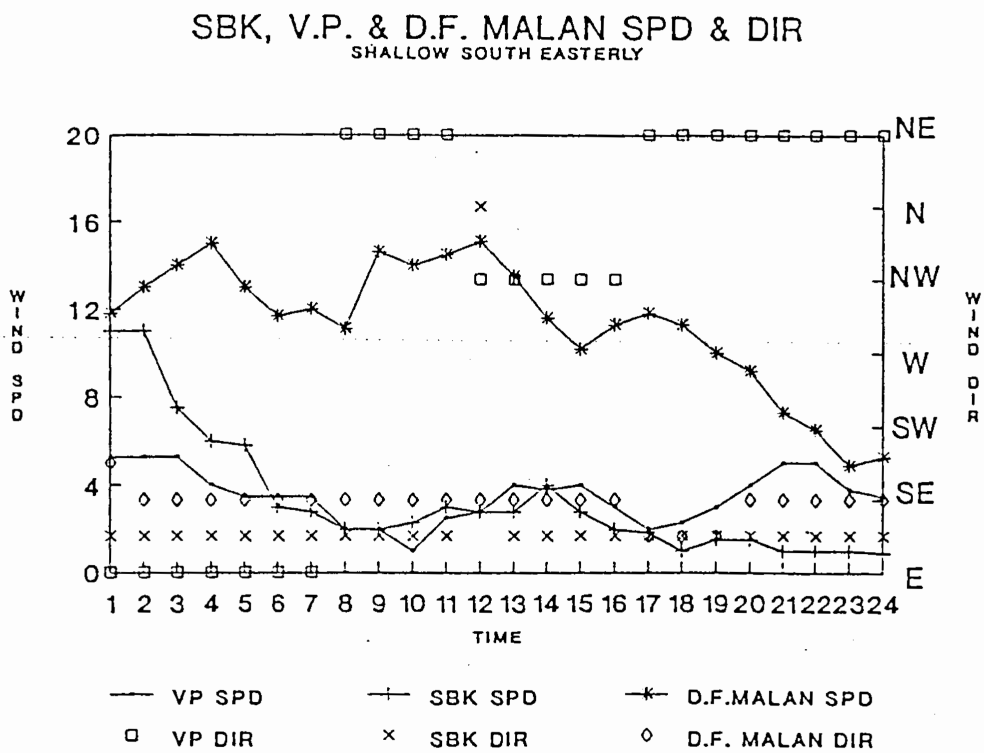


Fig 5.4 A chart showing the behaviour of winds at Swartboskloof, Victoria Peak and D.F. Malan on the 12/11/84. Wind speeds along the left vertical axis are in m/s. Directions are displayed on the vertical axis to the right of the chart. Time along the horizontal axis is in hours.

These were overlain at the summit by winds from a more easterly quadrant between 01h00 and 07h00. Northeasterly winds occurred at the summit between 08h00 and 11h00 and again between 17h00 and midnight. Between 12h00 and 16h00, northwesterly winds were recorded at the summit.

This case seems to indicate the occurrence of deep southeasterlies between 01h00 and 07h00, followed by a shallowing of flow as the anticyclone presumably continued to ridge eastwards over the study area. As the transient high continued to ridge eastward, northeasterly warm advection was initiated. This warm air advection was found to be responsible for the development of a strong elevated temperature inversion which could have limited the southeasterly flow depth in the vicinity of the valley (Jury and Barclay, 1992). At the airport, southeasterly winds occurred throughout this case.

Between 01h00 and 05h00, the southeasterlies at the valley bottom were stronger than those which occurred at the summit (Fig. 5.4). This nocturnal acceleration of the down slope flow was presumably caused by the nature of the valley bottom pressure gradient, with higher pressures expected at the valley's end and relatively lower pressures expected at the exit. This pressure gradient might have aided the southeasterly downslope flow.

The day time retardation of flow at the valley bottom might have been caused by the opposing nature of the valley bottom pressure gradients with higher pressures expected at the exit and relatively low pressures expected at the valley's upper end (Egger, 1983). More research into the influences of the valley bottom pressure gradient on wind velocities at Jonkershoek would be required before any conclusive statement can be made.

Between 18h00 and 24h00, velocity shear occurred in the vertical dimension. Wind velocities were higher at the summit than they were at the valley bottom. Wind velocity shear also occurred in the horizontal plane with stronger southeasterlies recorded at the airport than at the valley bottom during this case. A maximum velocity of 15.6 m/s was recorded at the airport at 12h00. The dissected topography in the vicinity of the valley could have weakened the strength of the southeasterly. The mechanism by which this was achieved was not investigated in this study. Velocities at the valley bottom weakened to below 6 m/s by midnight. This observation further proves that wind flow is altered when it encounters steep topography and shear is generated both vertically and horizontally.

CHAPTER SIX

SPATIAL VARIABILITY OF WIND DIRECTIONS AND VELOCITIES

This chapter investigates the spatial variability of winds during four dominant flow regimes as observed at Jonkershoek. Horizontal and altitudinal variabilities in wind directions were obtained by analyzing wind direction frequency data for both Victoria Peak (vertical) and D.F Malan airport (horizontal) which coincided with each of the four dominant wind regimes at the valley in 1984. Variabilities in wind velocities both horizontally and with altitude were obtained by comparing wind velocities at Swartboskloof with those which occurred at the airport (horizontal) and at the summit (vertical) for the same period. The results of this analysis will indicate to some extent, the response of winds at the Jonkershoek valley to varying mesoscale conditions. The sampling that follows is based on seasons as the basic temporal units.

6.1 VALLEY WINDS AT SWARTBOSKLOOF (SBK): WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS

Summit (Victoria Peak) and airport wind direction frequencies which coincided with valley winds at the valley bottom are presented in figures 6.1(a-d) and 6.1 (e-h) respectively for the four seasons of 1984. Valley winds at Jonkershoek were overlain by winds having a westerly component at the summit in all seasons (Fig 6.1 a-d). The westerly winds at the summit were part of the mid-latitude westerlies which are a dominant part of the general circulation (Tyson, 1988). The frequencies of westerlies at the summit reached a peak after 12h00 midday, particularly in late summer (JFM) and early winter (AMJ). This mid-day peak in the frequency of westerlies at the summit station suggests that valley winds on some occasions deepen to heights beyond 1500m. During early summer (OND) and early

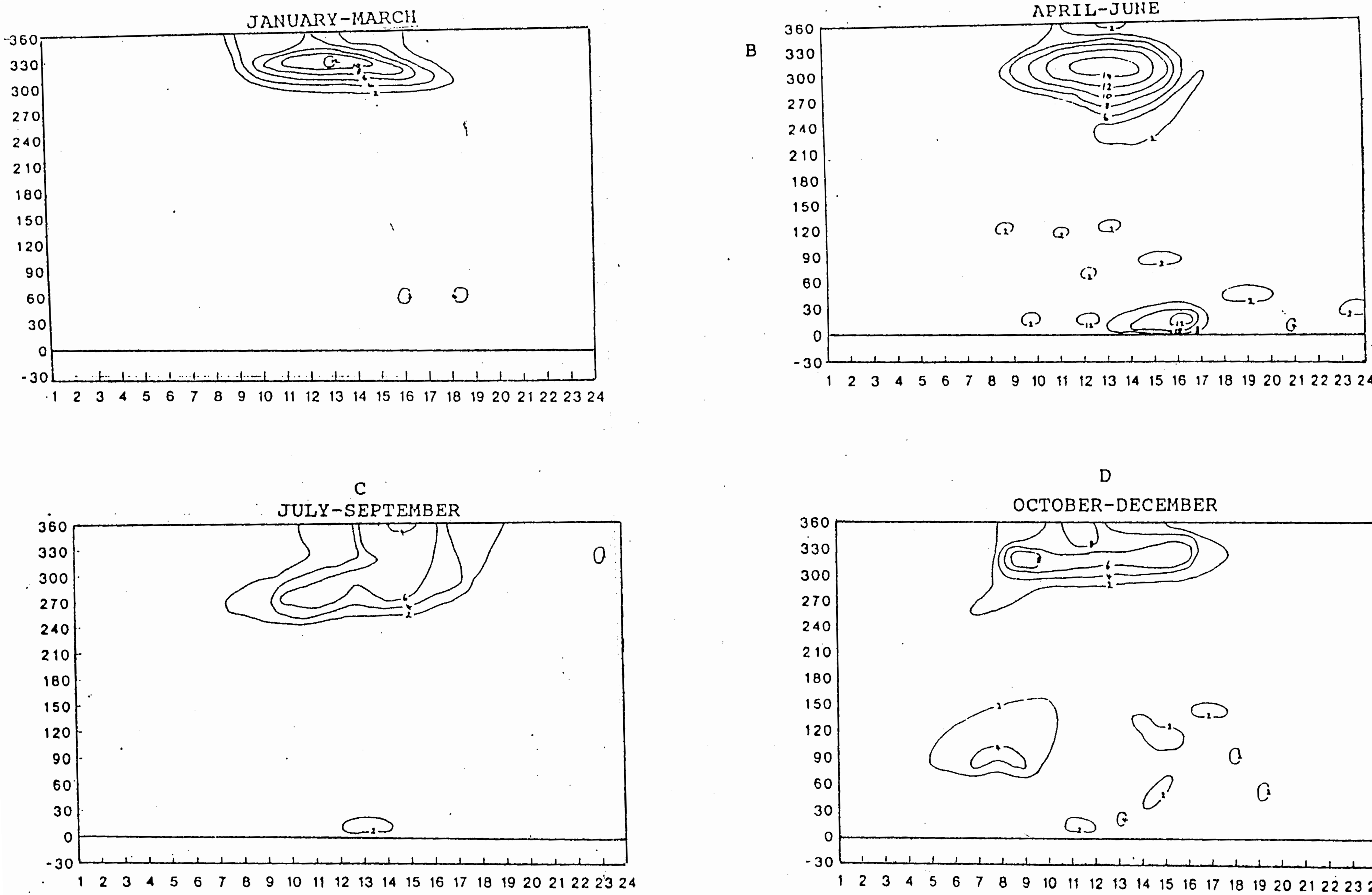


Fig 6.1 (a-d) Wind direction frequencies at Victoria Peak with valley winds at Swartboskloof by season.

winter (AMJ) in figure 6.1 b and d, some valley wind cases were overlain by northeasterly berg winds. The frequency of berg winds with valley winds at the valley bottom was higher in early winter than in early summer. According to Tyson 91988), berg winds along South African coastal regions are common in late winter and early summer.

Some early summer (OND) valley wind cases were overlain by southeasterly winds at the summit (Fig 6.1d). This presumably indicates that valley winds also develop under ridging anticyclonic conditions. Anticyclonic conditions promote atmospheric stability which is conducive to the establishment of thermo-topographic flows in valley 9Tyson et al., 1988).
That valley winds were found to develop under different synoptic fields suggests that the nature of the synoptic field alone cannot be used to predict valley bottom circulations. At the airport, westerly winds reach the surface during some valley wind cases at Jonkershoek (Fig 6.1 e-h). Southwesterly winds also dominate the airport circulation in all seasons. The frequency of southwesterly at the airport was higher during the summer months than it was during winter months. Peak occurrence of southwesterlies at airport was observed during the time of maximum solar heating (13h00-15h00). Calm conditions at the airport were also found to coincide with valley winds at Jonkershoek.

Wind velocities for the valley bottom (SBK), the summit (VP) and the airport (D.F. Malan) are investigated using velocity time series for the four seasons of 1984 9Fig 6.1I-6.11). Valley winds at the valley bottom accelerate gradually following their initiation to afternoon peaks. Strongest valley winds at SBK were recorded around 15h00 for the late winter and early summer seasons (Fog 6.1I, 6.1k and 6.11). In early winter (AMJ), the peak occurred at 12h00,

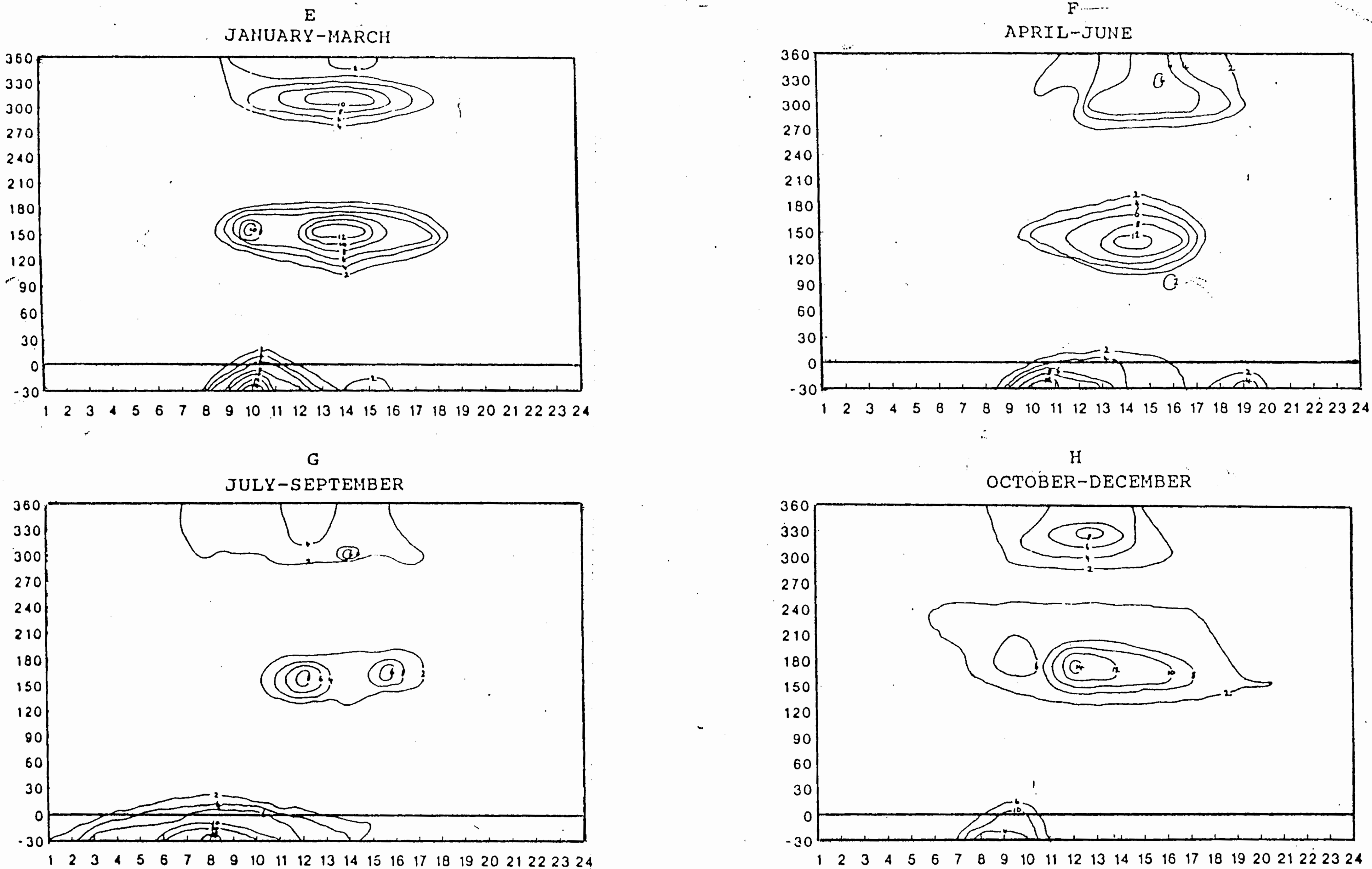


Fig 6.1 (e-h) Wind direction frequencies for D.F. Malan airport with valley winds at Swartboskloof. Time along the x axis. Units reflect the number of cases. Values below

about three hours earlier than in other seasons. This tendency for winds at the surface to display midday peaks was also reported by Tyson et al. (1988). Egger (1983) found that in the Dischma valley in France, low pressure existed at the valley's upper end and relatively high pressure at the exit during the day. The strength of such a pressure gradient would be strongest at midday. Strongest valley winds at Jonkershoek occurred during the summer season (JFM and OND, fig 6.1I and 6.11). In summer, the seasonally averaged valley wind velocities were of the order of 10 m/s. In early winter (AMJ), the strongest valley winds recorded were 9.8 m/s and those for late winter (JAS) were 9 m/s.

The strongest valley winds in summer might have been as a result of stronger surface heating during that season. This strong surface heating could have resulted in steeper valley pressure gradients than in winter.

With the exception of early winter, daytime velocities at the summit were lower than the valley winds which they overlay. This was the case particularly after 10h00 (Fig 6.1I and 6.1k). cases with weaker ambient winds do not prevent the development of thermo-topographic flows (Barry, 1981; Doran and Horst, 1986; Tyson et al., 1988). Winds at the summit were not influenced by the underlying topography. The summit winds were weaker in summer than in winter. During the summer season, summit velocities remained below 4 m/s whereas in winter, they blew at velocities the order of 6 m/s. The zonal westerly winds are known to strengthen in winter (Tyson, 1988). The velocity of ambient winds appear to be a reliable tool for the prediction of valley bottom circulations in that ambient winds whose strength was below 6 m/s did not prevent the establishment of local valley bottom circulations.

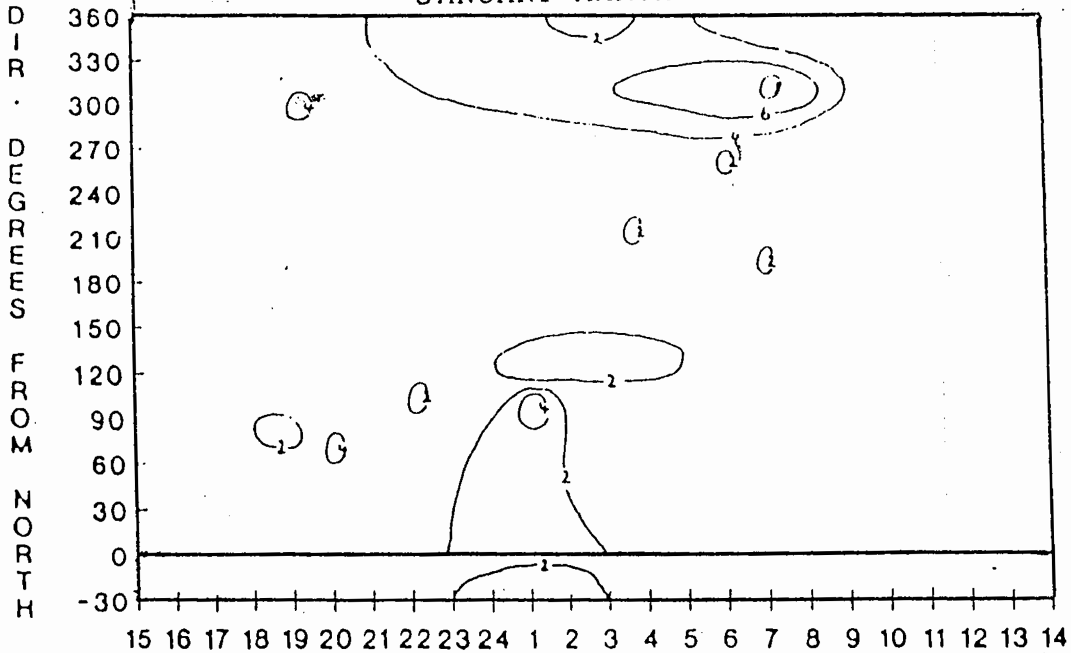
The airport experienced winds which were weaker than those which occurred both at Jonkershoek and at the summit. This is an expression of the importance of the daytime pressure gradient within valley atmospheres. Peak airport velocities occurred in the afternoon probably due to stronger surface heating. Winds at the airport were stronger during the summer months (JFM and OND) than they were during the winter months (April-September). Maximum day-time velocities in summer at the airport were 6 m/s and 8 m/s for early and late summer respectively. In winter, maximum day-time velocities were 5 m/s. The summer peaks are also a reflection of the importance of solar heating in determining wind velocities.

6.2. MOUNTAIN WINDS AT SWARTBOSKLOOF: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS

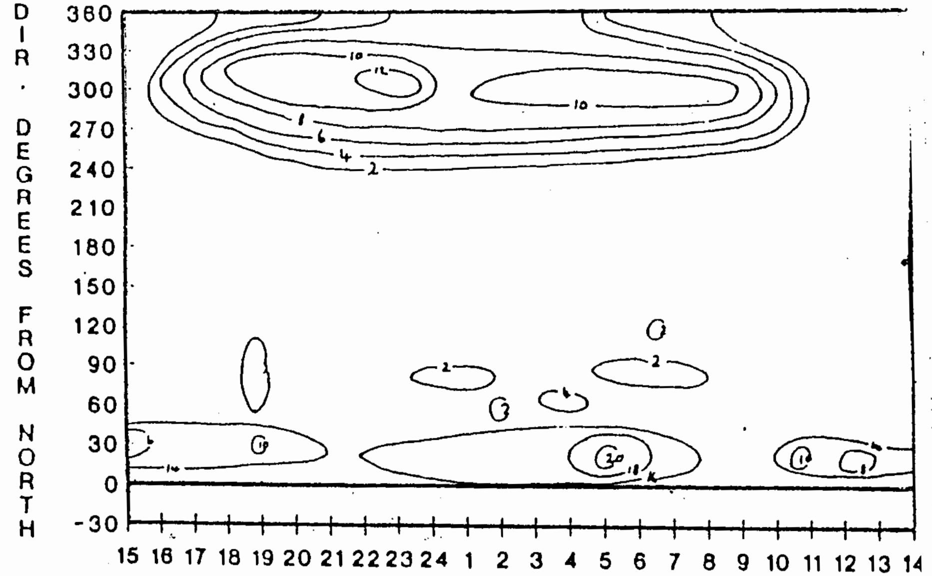
Mountain winds at the valley bottom were overlain in all seasons by circumpolar westerlies above the summit (Fig. 6.2 a-d). This scenario is similar to that which was observed for valley winds. Some cases of mountain winds were overlain by southeasterlies, an indication of the west to east movement of anticyclones over the study area. As is the case with valley winds, the synoptic field alone is a poor predictor of the occurrence of mountain winds.

Southeasterlies at the summit were as in the case with valley winds, most common in early summer (OND, fig 6.2.d). Summit southeasterlies with mountain winds at the valley bottom were absent in late winter, this again was observed to have been the case with day-time valley winds. Northeasterlies occurred at the summit during some cases of valley bottom mountain winds, this was particularly true for early winter (AMJ) in figure 6.2 (b). Few cases of summit northeasterlies overlay mountain winds in late winter.

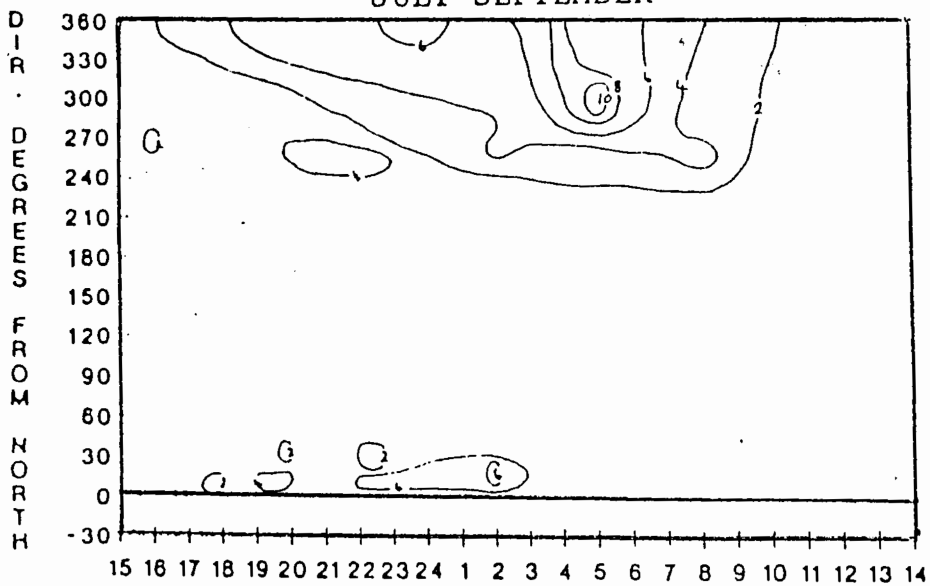
JANUARY-MARCH



B
APRIL-JUNE



C
JULY-SEPTEMBER



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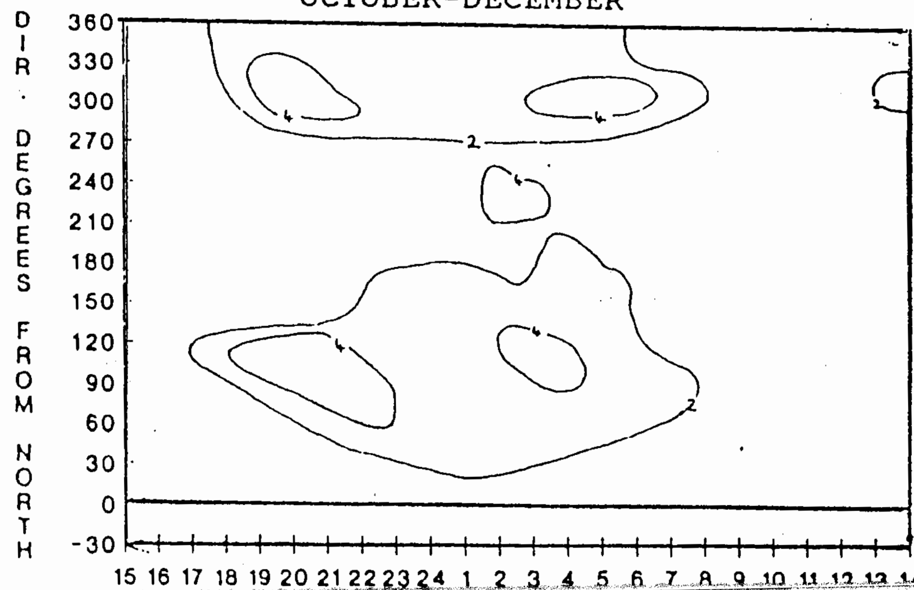
OCTOBER-DECEMBER



Conditions at the airport during the persistence of nocturnal mountain winds at the valley bottom differed slightly from those which were observed during the day (Fig 6.2 e-h). Although winds with a westerly component occurred at the airport, their frequency was much lower than during the occurrence of day-time valley winds at Jonkershoek. This would seem to indicate that during cases with thermo-topographic circulations at the valley, either circumpolar westerlies are prevented from reaching the surface at night or that when westerlies are prevented from reaching the surface, thermo-topographic circulations may occur. The opposite occurs during the day. Southwesterlies occurred throughout the year at the airport with the occurrence of mountain winds at the valley. This regime was less common in late summer. Northeasterly berg winds also occurred at the airport. As was the case with valley winds at the valley, bergwinds during the persistence of mountain winds at the valley bottom were most common in early winter at the airport (Fig 6.2 f). Some mountain winds at Jonkershoek coincided with calm conditions at the airport. These calms were most frequent in early winter.

Mountain winds at Jonkershoek were below 4 m/s in all seasons of 1984 (Fig 6.1i-6.1l). Interseasonal variabilities and those that occur from hour to hour in mountain wind velocities did not occur. The tendency for mountain winds to blow at steady velocities was reported by Ye et al., (1990) in their study of the impact of atmospheric thermal stability on the characteristics of nocturnal down slope flow. Mountain winds at SBK were weaker than the valley winds in all seasons.

Summer time (JFM and OND) mountain winds were overlain by weak summit winds. Velocities at the summit were of the order of 4 m/s. No vertical velocity shear was apparent during this season. Summit winds strengthened to about 6 m/s in winter (April-September). Surges in nocturnal summit

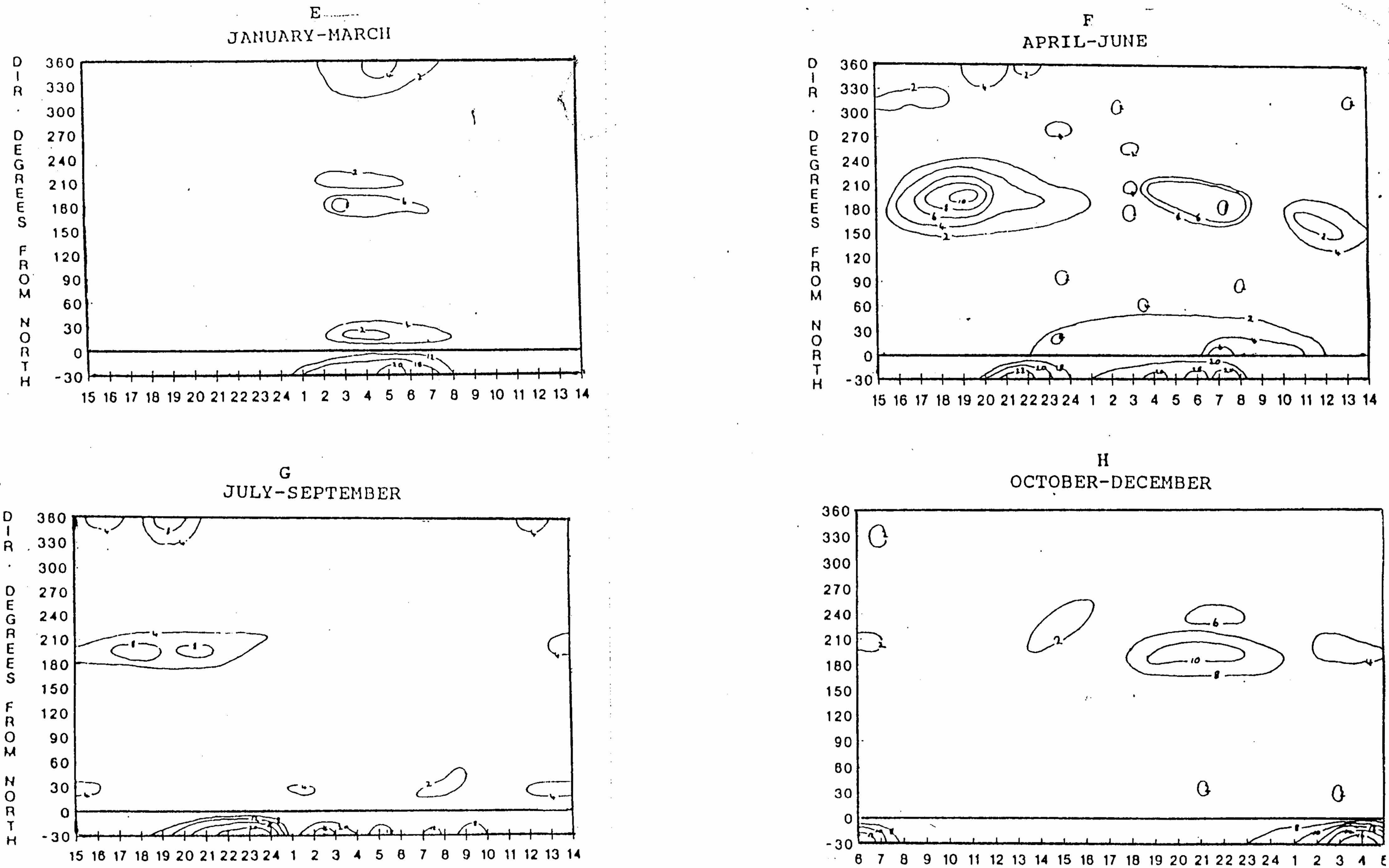


Fig 6.2 (e-h) Wind direction frequencies at D.F. Malan airport with ... Swartboskloof. Time along the x axis in

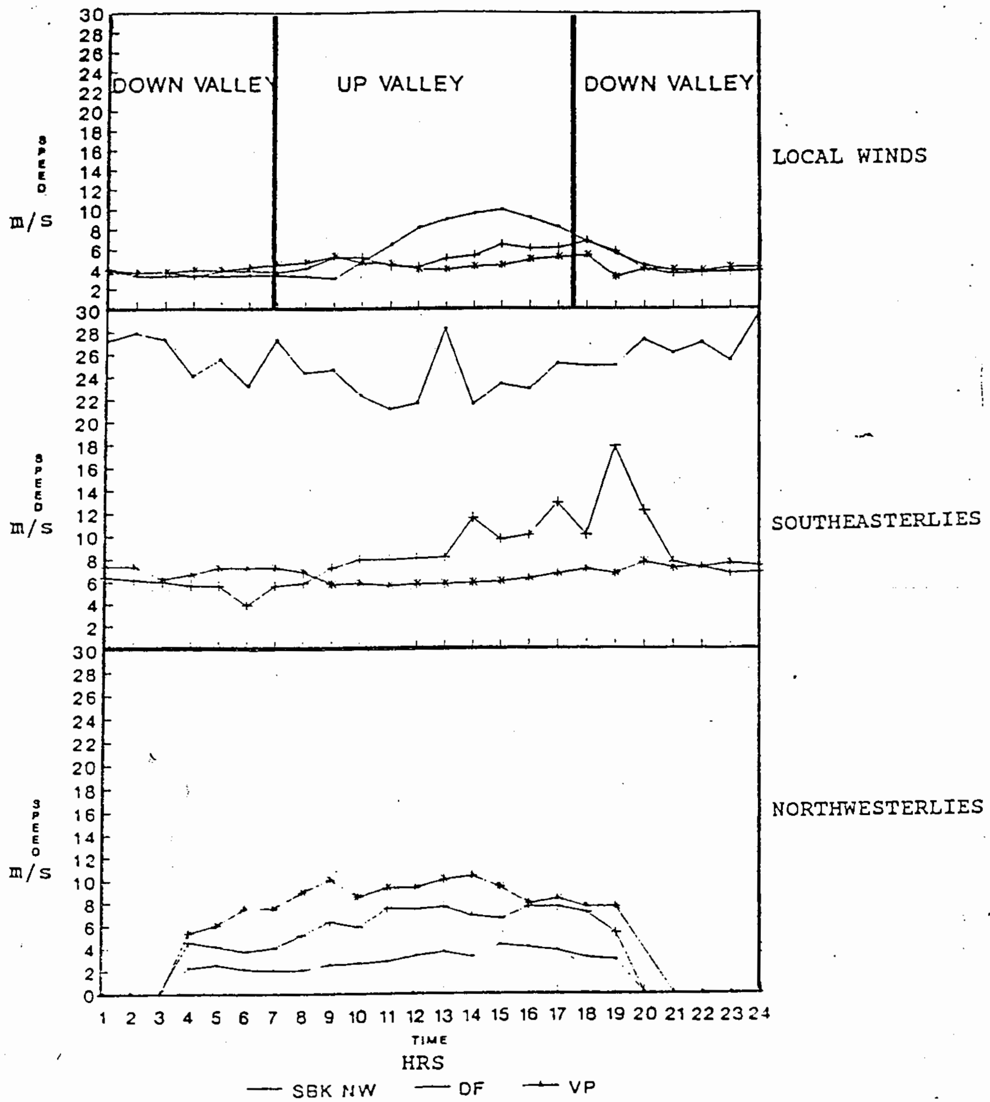


Fig 6.1 (i) Time-speed sections to show the diurnal wind speed variability at Swartboskloof between January and March.

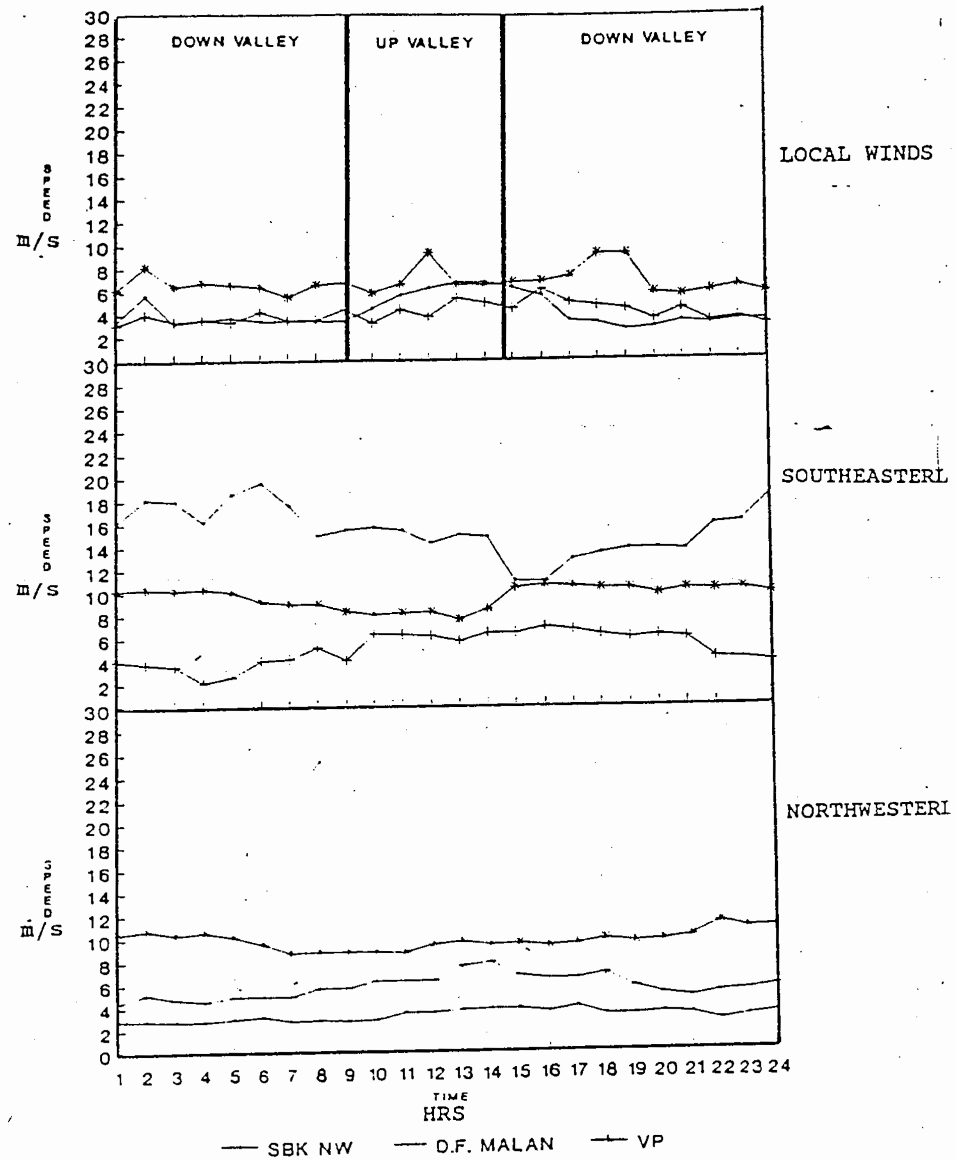


Fig 6.1 (j) Time-speed sections to show the diurnal wind speed variability at Swartboskloof between April and June.

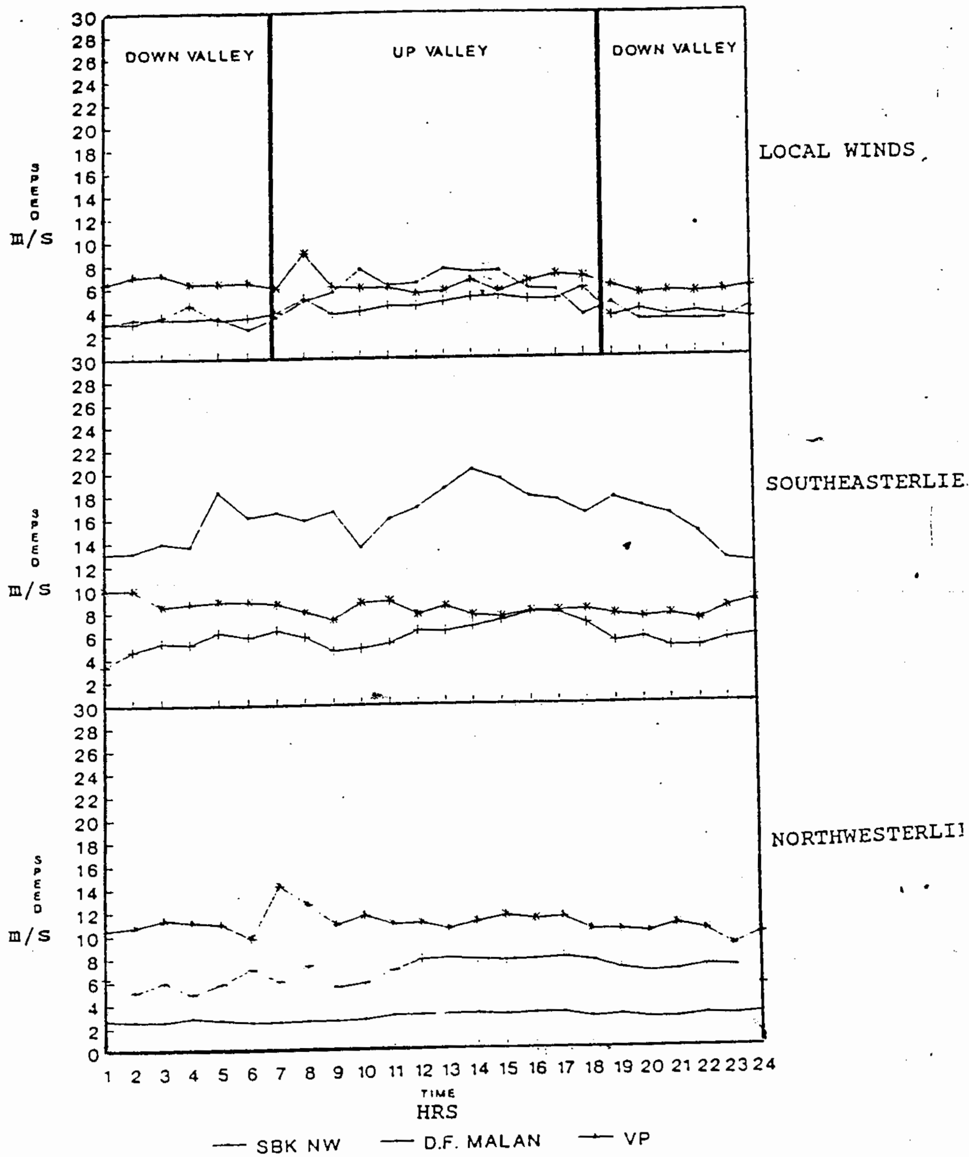


Fig 6.1 (k) Time-speed sections to show the diurnal wind speed variability at Swartboskloof between July and September.

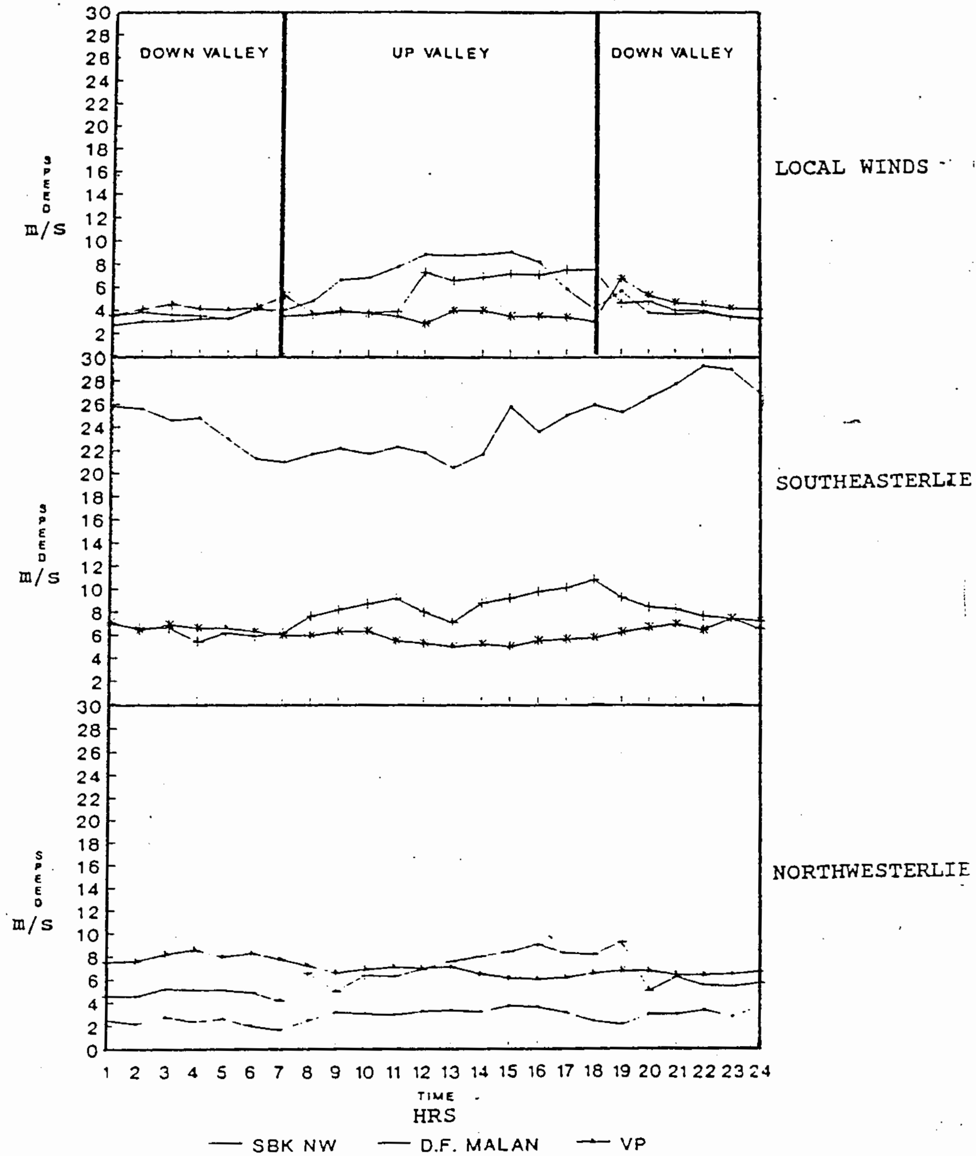


Fig 6.1 (l) Time-speed sections to show the diurnal wind speed variability at Swartboskloof between October and December.

winds occurred in early winter (AMJ, fig 6.1j) with a seasonally averaged maximum of 10 m/s between 18h00 and 19h00. A surge at the summit also occurred in early summer (OND, fig 6.11). The seasonally averaged maximum velocity of this surge was 7 m/s and was recorded at 19h00. Velocities at the airport equalled the velocity of the mountain winds which occurred at the valley.

6.3 SOUTH-EASTERLY WINDS AT SBK: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS

Wind direction frequencies for the summit and the airport which coincided with south-easterly winds at the valley bottom are investigated (Fig 6.3. a-d). Southeasterlies at the valley bottom were overlain by winds from the same quadrant at the summit in all seasons. This indicates that deep southeasterlies in the vicinity of the valley are a year round feature. Jury (1987) found that under the deep southeasterly wind regime over the South Western Cape, the depth of flow exceeded 1 Km and was able to flow over isolated peaks of the Cape Peninsula.

In the lee, these winds were found to be forced down slope. Southeasterlies at the summit were less frequent in winter (April-September). High frequencies of southeasterlies occurred in summer (JFM and OND). In summer over the South Western Cape, the southeasterly wind regime dominates (Jury, 1987). The frequency of this wind regime at the summit peaked after 12h00 midday. This might be caused by the strengthening of the thermal low over the berg river valley at mid-day. Further research into this area would be required to verify this. Low frequencies were recorded in the early morning (05h00-08h00).

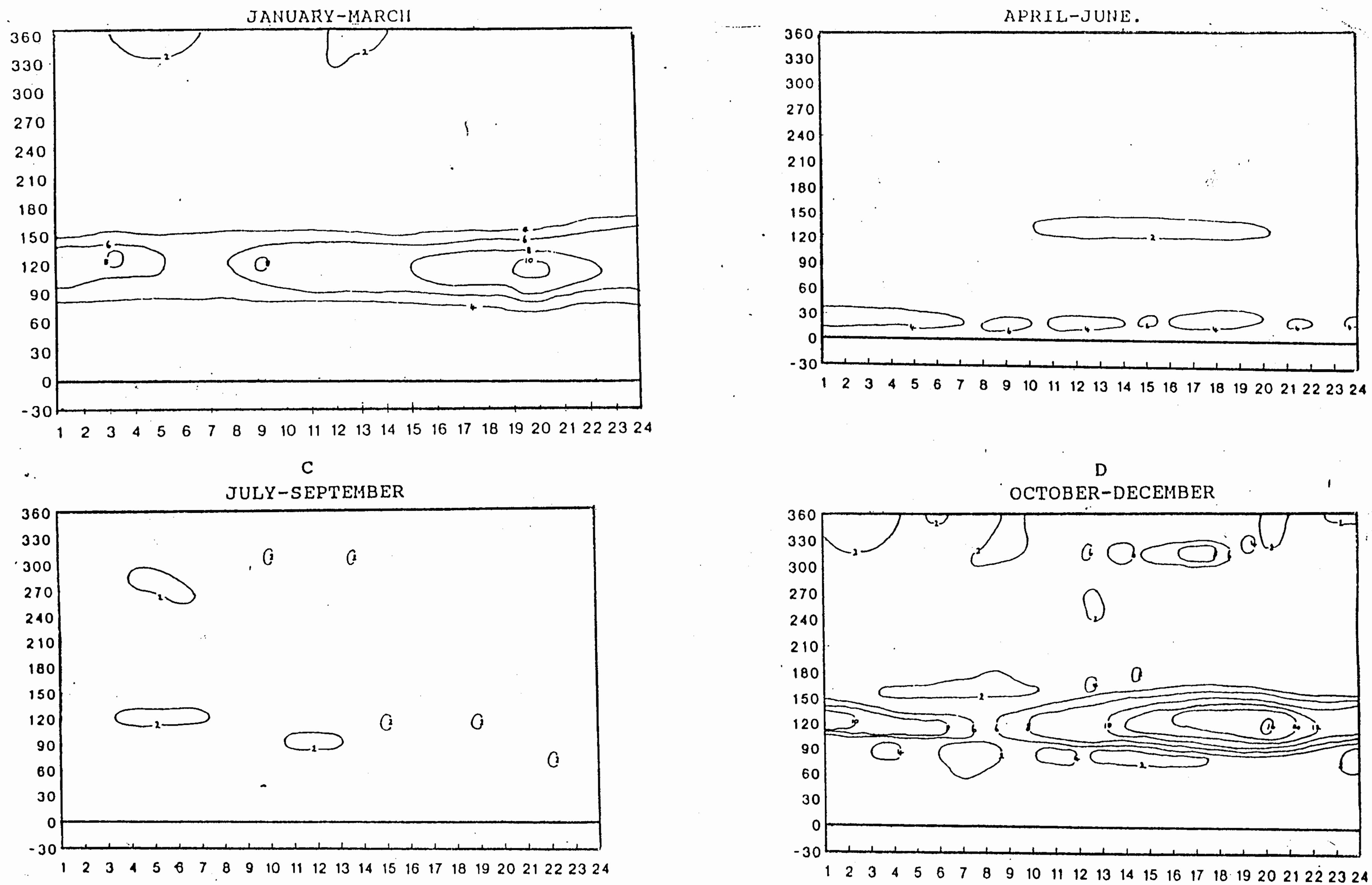


Fig 6.3 (a-d) Wind direction frequencies at Victoria Peak with gradient southeasterlies at Swartboskloof. Time along the x axis in hours.

Shallow southeasterlies also occurred at SBK. This is indicated by the occurrence of northeasterlies at the summit during some cases with southeasterlies at the valley bottom. This was particularly true for the early summer of 1984 (Fig 6.3d). Shallow southeasterlies occur during cases when an anticyclone ridges from west to east over the study area. This ridging is coincident with a progressive descent of a warm atmospheric layer (Jury, 1987).

Shallow southeasterlies in the vicinity of the valley were most frequent in early summer. This wind regime was absent in early winter (Fig 6.3b). In early winter (Fig 6.3b), northeasterly berg winds overlay some cases of valley bottom southeasterlies. These may have enhanced the decoupling of the valley atmosphere from that aloft. Southeasterly, southerly and southwesterly winds occurred at the airport during all four seasons. The highest frequencies of these winds occurred in summer (Fig 6.3 a and d). This is the season during which the west to east ridging of anticyclones is at a peak. The occurrence of southerly and southwesterly winds at the airport during the prevalence of the southeasterly wind regime over the Cape plain (on which the airport is located) was attributed by Jury (1987) to cyclonic vorticity in the southeasterlies, forced by the obstruction of the southeasterlies by the Cape Hangklip ridge to the east of the airport. The ridge was found to deflect air streams seaward. Calm conditions occurred at the airport during some southeasterly wind cases. Anticyclonic circulations are known to promote calm and settled conditions near the surface (Taljaard, 1955).

Southeasterly wind velocities were much higher than those recorded during cases with local thermo-topographic circulations at the valley at all three stations (Fig 6.1I-6.11). Winds at the valley bottom were stronger in all

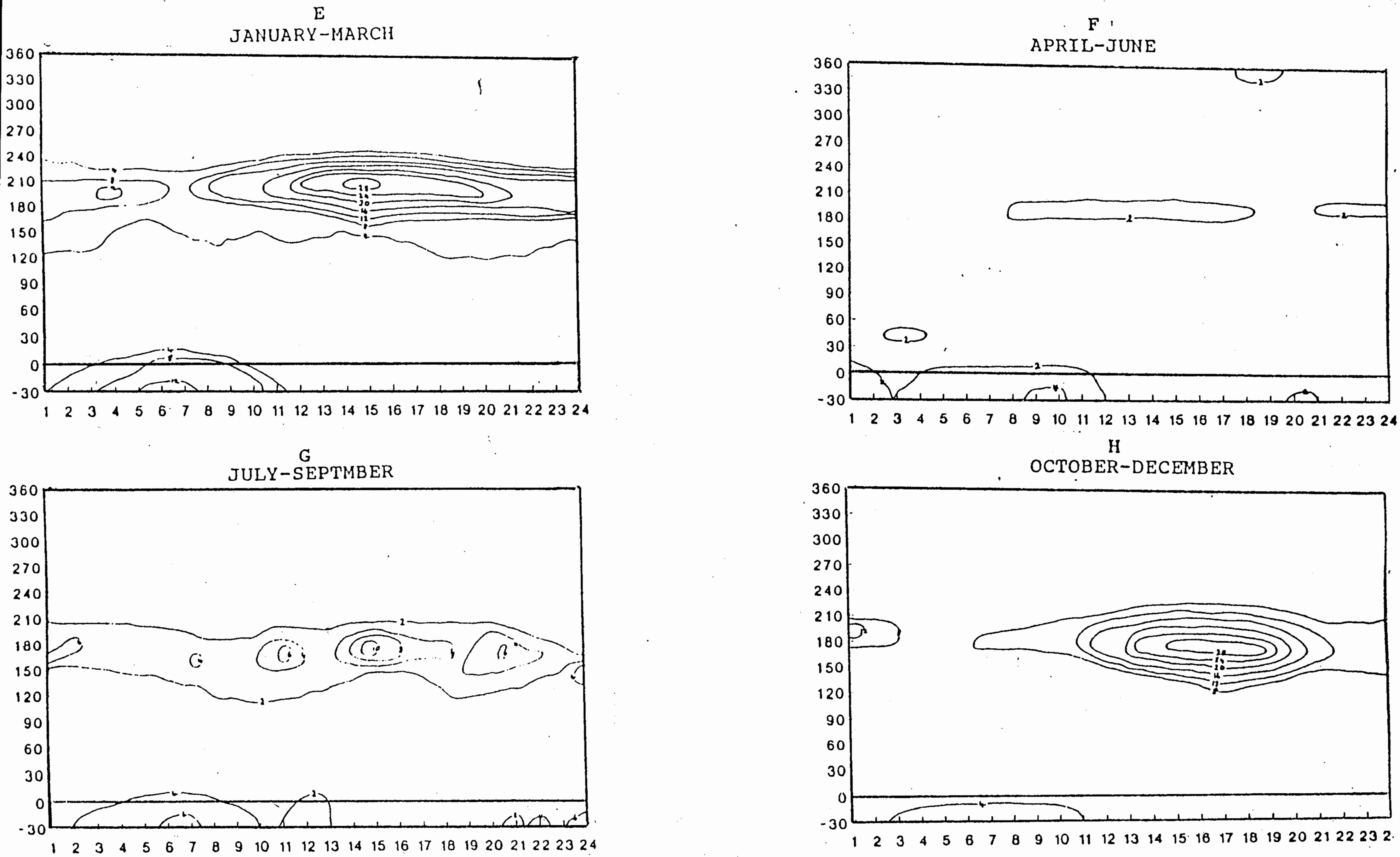


Fig 6.3 (e-h) Wind direction frequencies at D.F. Malan airport with [illegible] at Swartboskloof. Time along the

seasons than those which occurred either at the summit or at the airport. This down slope acceleration of southeasterlies was presumably a result of the heating of the down slope flow due to compression (Jury, 1987).

Down slope velocities as recorded at SBK were generally above 12 m/s in all seasons of 1984. The maximum seasonally averaged southeasterly down slope winds occurred in summer with velocities higher than 20 m/s (Fig 6.1i and 6.1l). Atkinson (1981) reported gust strengths in down slope winds in Boulder, at the foot of the Rocky Mountains. This tendency for down slope flow to reach gust strengths may also be attributed to the deformation of the isobars across ridges with a ridge of high pressure on the windward side and a trough of low pressure to the lee (Brinkmann in Atkinson, 1981).

Down slope winds tended to accelerate towards night-time and decelerate during the day. This was particularly the case in summer with velocities reaching 28 m/s at night. These high wind velocities of above 10 m/s prevented any establishment of local up and down valley flow. This nocturnal strengthening of the southeasterlies within the valley atmosphere can be attributed to the nature of the pressure gradient within the valley atmosphere at night (see section 6.1).

In contrast to conditions at the valley bottom, southeasterly seasonally averaged wind velocities at the summit peaked in winter (Fig 6.1j and 6.1k). Summit velocities in winter were above 10 m/s. In summer, velocities at the summit were about 6 m/s. Little temporal variation occurred in summit southeasterlies. Winds at the airport accelerated to velocities greater than those recorded at the summit in summer during the day (Fig 6.1i and 6.1j). Maximum summer velocities at the airport occurred between

18h00 and 19h00. This summer maximum can be attributed to a local pressure gradient which was found to exist between the offshore high and an interior thermal low located on the 1500m South African plateau (Jury, 1987). The early evening peak in summer might be due to a partial seabreeze response to the heating of the land (Jury, 1987). Winter time winds at the airport were weaker than those recorded at the summit.

6.4 NORTH-WESTERLIES AT SBK: WIND DIRECTION FREQUENCIES AND VELOCITIES AT OTHER STATIONS

Northwesterly winds were deep in the vicinity of the valley in 1984. Winds with a northerly component were present in all seasons both at the summit and at the airport (Fig 6.4 a-h). At the summit, the late summer season was found to have had the lowest frequency of north-westerly winds (Fig 6.4 a). This is in accordance with the southward shift of the circumpolar westerly wind belt during this season (Tyson, 1988).

The occurrence of summit northwesterlies showed little variation in the remaining seasons of 1984. Peak summit northwesterly frequencies occurred just after 12h00 midday in all seasons except in late summer. This might indicate that during some cases, surface valley winds couple with the north-westerly gradient winds to a depth beyond 1500m.

The afternoon peaks in frequencies also appeared at the airport. Northwesterly frequencies at the airport showed similarities with those observed at the summit station with the exception that in both the early and late summer seasons, a break in the occurrence of this regime occurred at the airport during a 24 hour period. No break was observed at the summit.

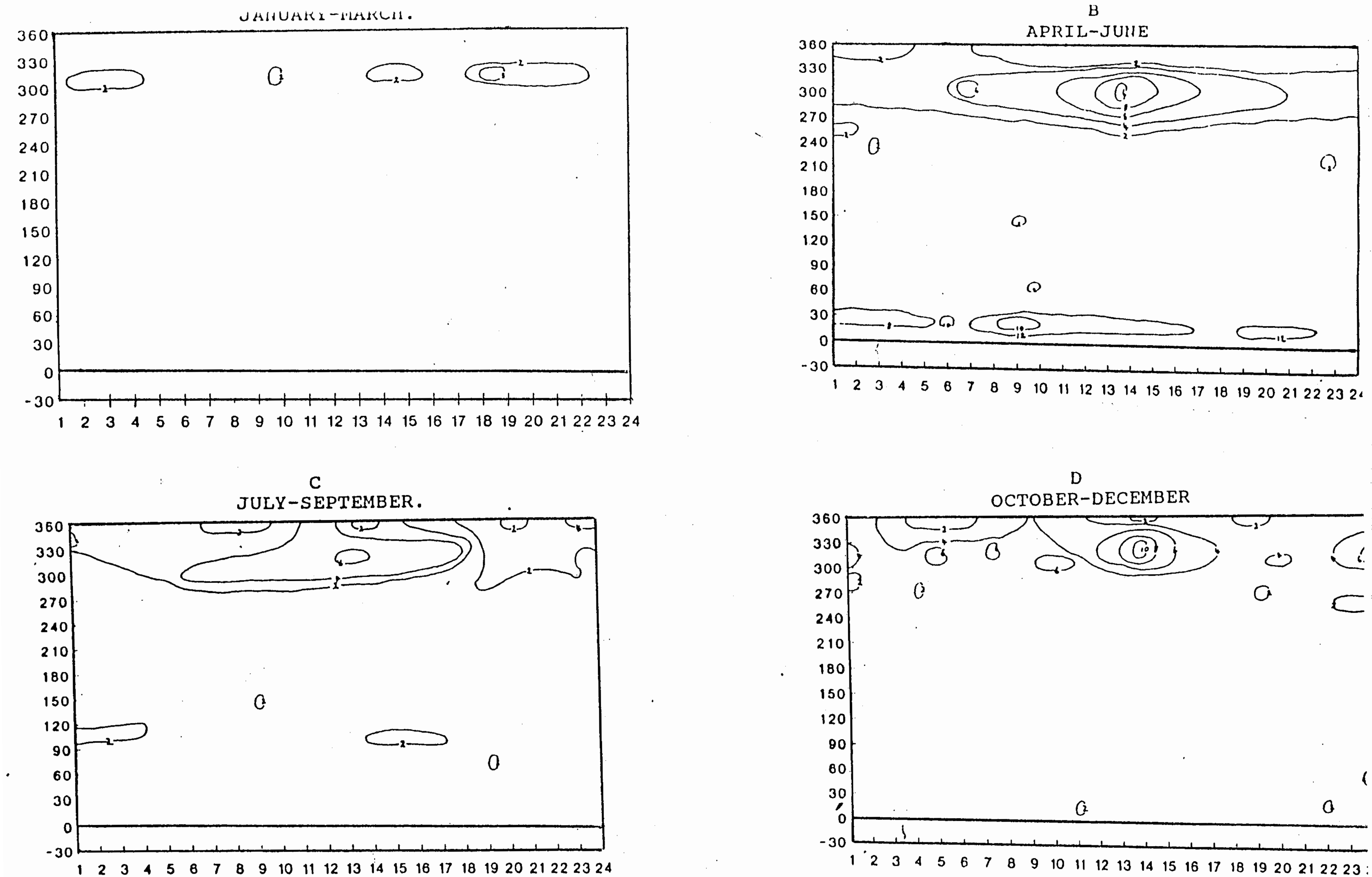


Fig 6.4 (a-d) Wind direction frequencies at Victoria Peak with gradient northwesterlies at Swartboskloof. Time along the x axis in hours. Units reflect the number of cases. Values below 0 ...

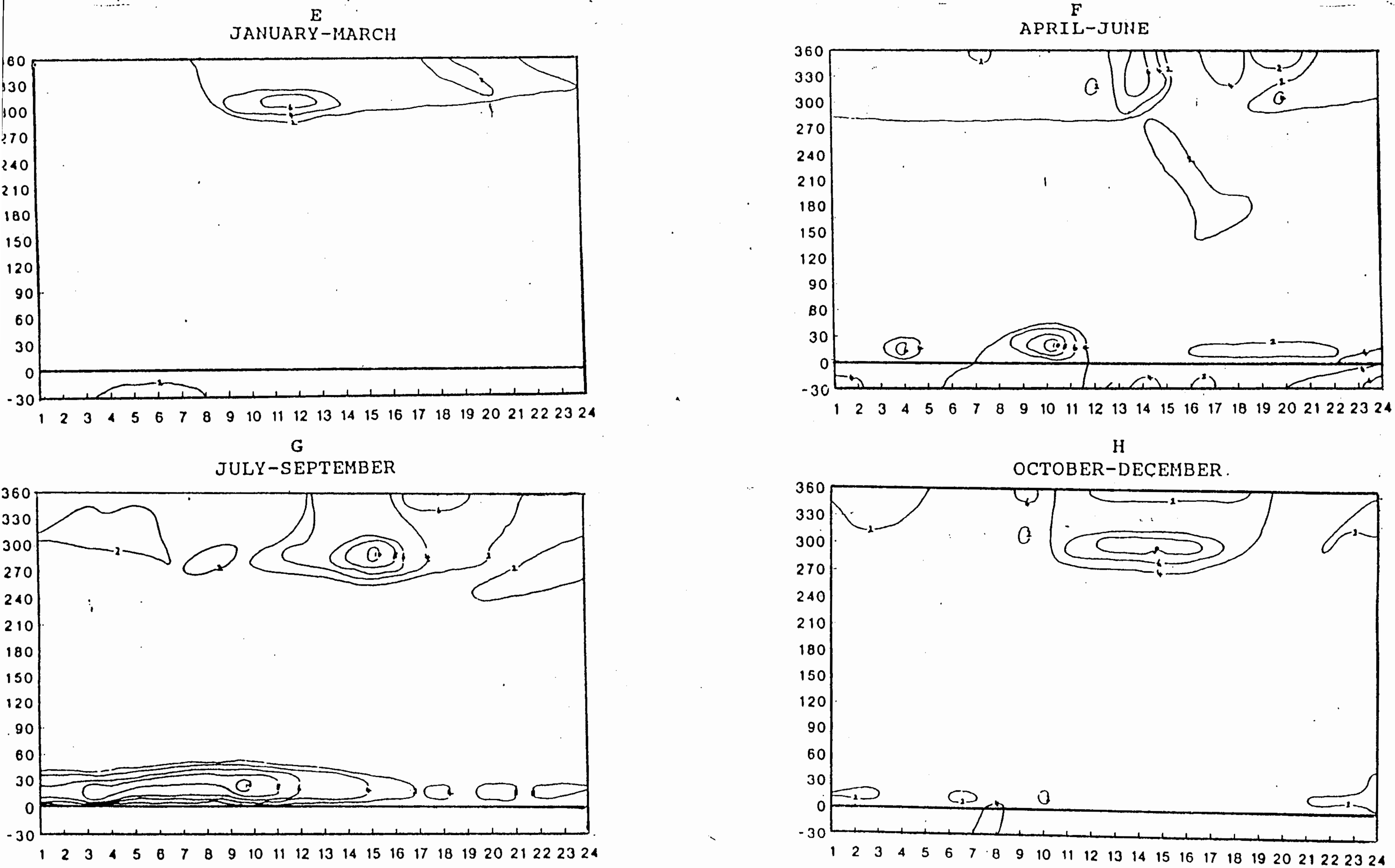


Fig 6.4 (e-h) Wind direction frequencies at D.F. Malan airport with gradient northwesterlies at Swartboskloof. Time along the x axis in hours. Units reflect the number of cases. Values below 0 are calms.

From these observations, it can be concluded that under the northwesterly wind regime, spatial variability in the mesoscale wind field is lowest over the South Western Cape. This synoptic regime therefore allows for easier predictions of conditions within the valley atmosphere. Wind velocities for all three stations during the persistence of northwesterly winds at the Jonkershoek valley are presented in figures 6.1i-6.1l. The northwesterly seasonally averaged wind velocities at the valley bottom remained below 4 m/s during all four seasons of 1984. The trend for valley bottom northwesterly wind velocities was flat with no apparent fluctuations throughout the 24 hour periods and for all seasons.

There was evidence of vertical shear in the westerly winds in the vicinity of the valley. Northwesterly wind velocities at the summit were generally above 6 m/s in all seasons. This observation seems to further validate the conclusion that an ambient wind velocity of 6 m/s is the upper limit for the occurrence of local valley circulations (see section 6.1). The summit westerlies were generally of the same magnitude in all seasons (about 10 m/s) with little hourly fluctuations. An exception to this occurred in early summer (OND) when the strength of this regime at the summit was reduced to about 8 m/s.

Summit westerlies were also stronger than those experienced at the airport. In early summer though, airport velocities exceeded those recorded at the summit between 13h00 and 19h00. Velocities at the airport were also stronger than the valley bottom westerlies. Airport westerlies were of the order of 6 m/s in all seasons. These also did not go through any majorhourly fluctuations.

It is evident from this presentation that during the persistence of a northwesterly wind regime, shear is generated both vertically and horizontally with the valley bottom experiencing the weakest westerlies.

CHAPTER SEVEN

ONSET AND CESSATION TIMES OF THE VARIOUS WIND REGIMES AT SWARTBOSKLOOF BY SEASON

In this chapter, onset and cessation times of local valley and mountain winds are investigated. This investigation also includes the onset and cessation times of gradient southeasterlies and northwesterlies. Seasons are again used in this chapter as the basic temporal units.

For the purpose of this investigation, seasonal time frequency sections of onset and cessation for the various regimes at the valley bottom are presented using data from Swartboskloof (figures 7.1-7.3). Frequencies in this analysis indicate the number of days during which a particular wind regime was initiated or terminated at a particular time of day.

7.1 MOUNTAIN WINDS AND VALLEY WINDS AT SWARTBOSKLOOF

Figures 7.1 (a) and (b) show the seasonal frequencies of onset and cessation times for both the mountain and valley winds at SBK in 1984. The onset of mountain winds at the Jonkershoek valley occurred at 18h00 in late summer (JFM) and early winter (AMJ). Early summer mountain winds also displayed a preference for 20h00 for their onset. There were more days with onset times of 18h00 in early winter than in early summer. Tyson and Seely (1979) found that in the Kuiseb Valley in the Central Namib, mountain winds were initiated between 18h00 and 21h00 from March to August. The early initiation in early winter could have been caused by the early cooling of the slopes at Jonkershoek during that season.

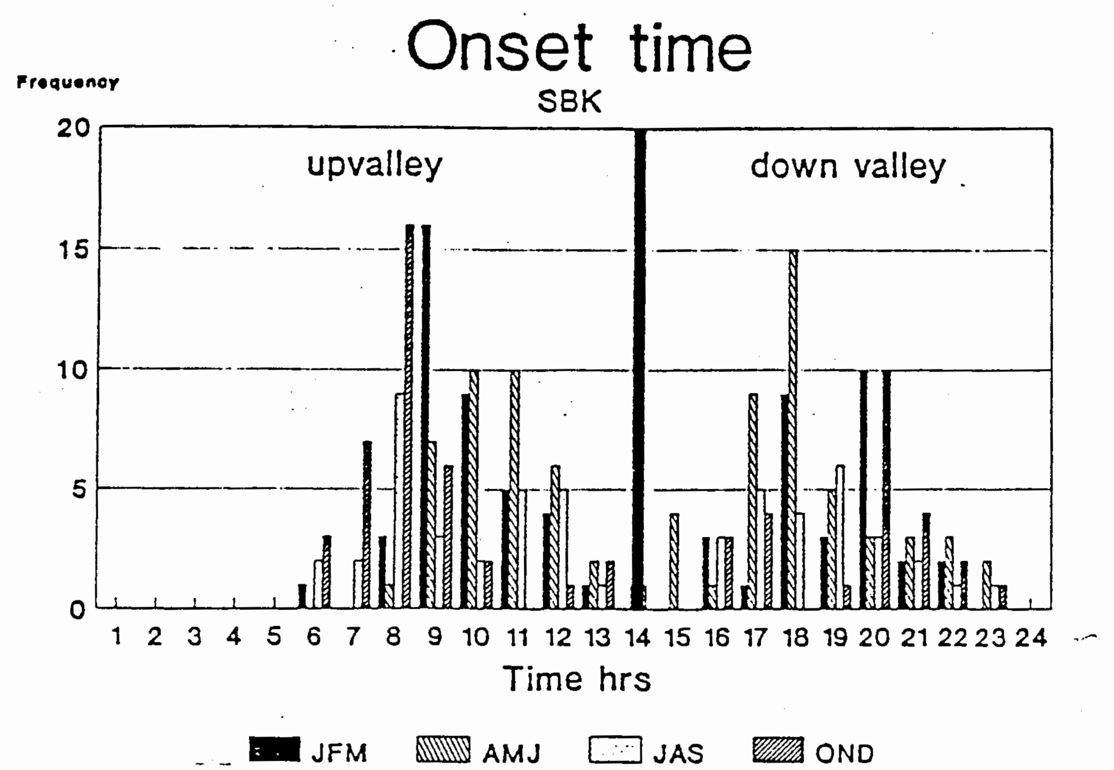


Fig. 7.1 (a) Onset times for valley and mountain winds at Swartboskloof by season.

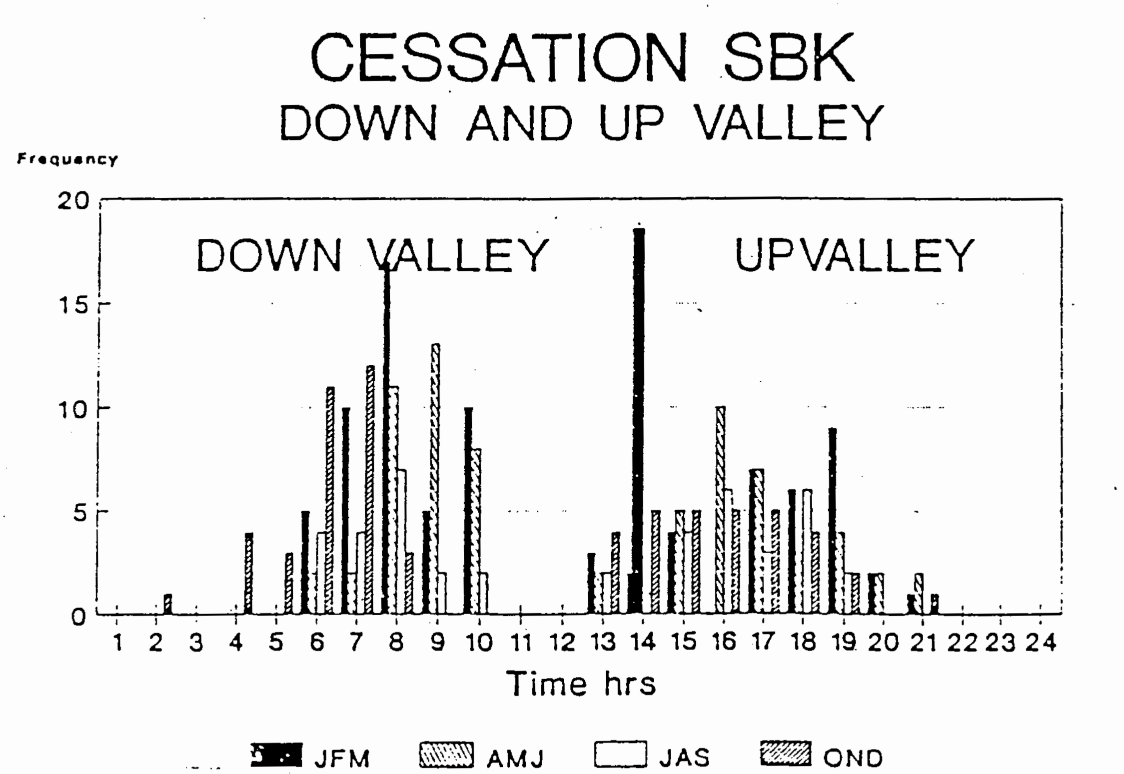


Fig. 7.1 (b) Cessation times for valley and mountain winds at Swartboskloof by season.

1984

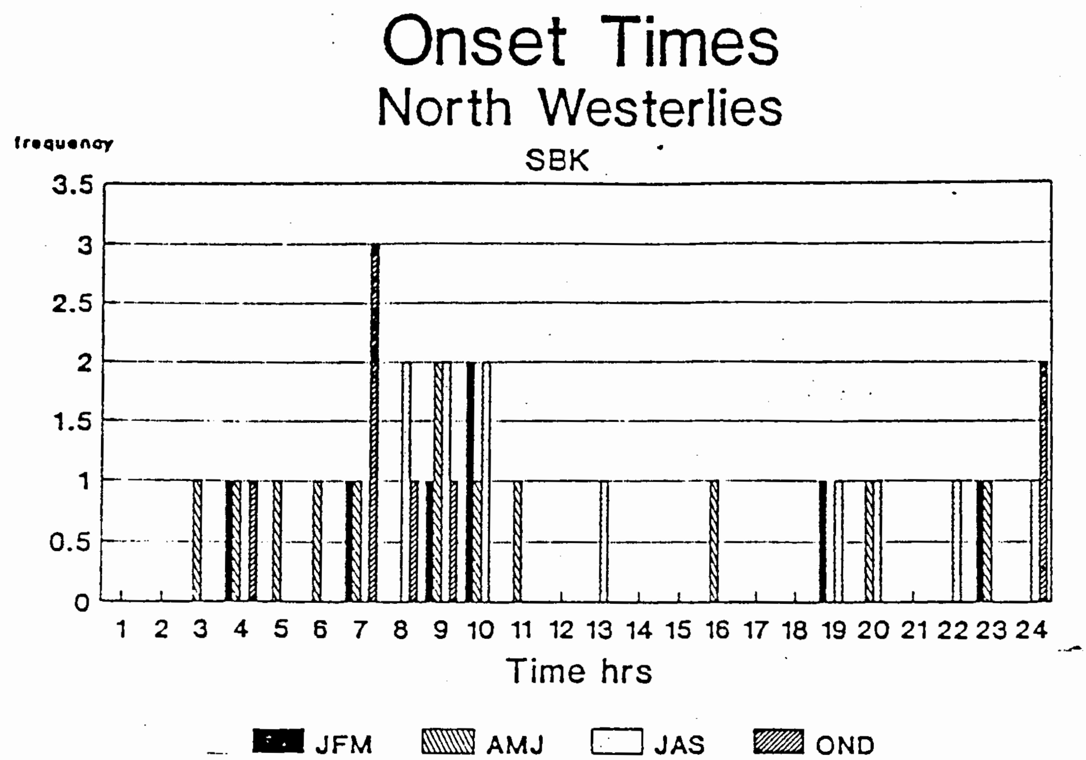


Fig. 7.2 (a) Onset times for gradient northwesterlies for Swartboskloof by season

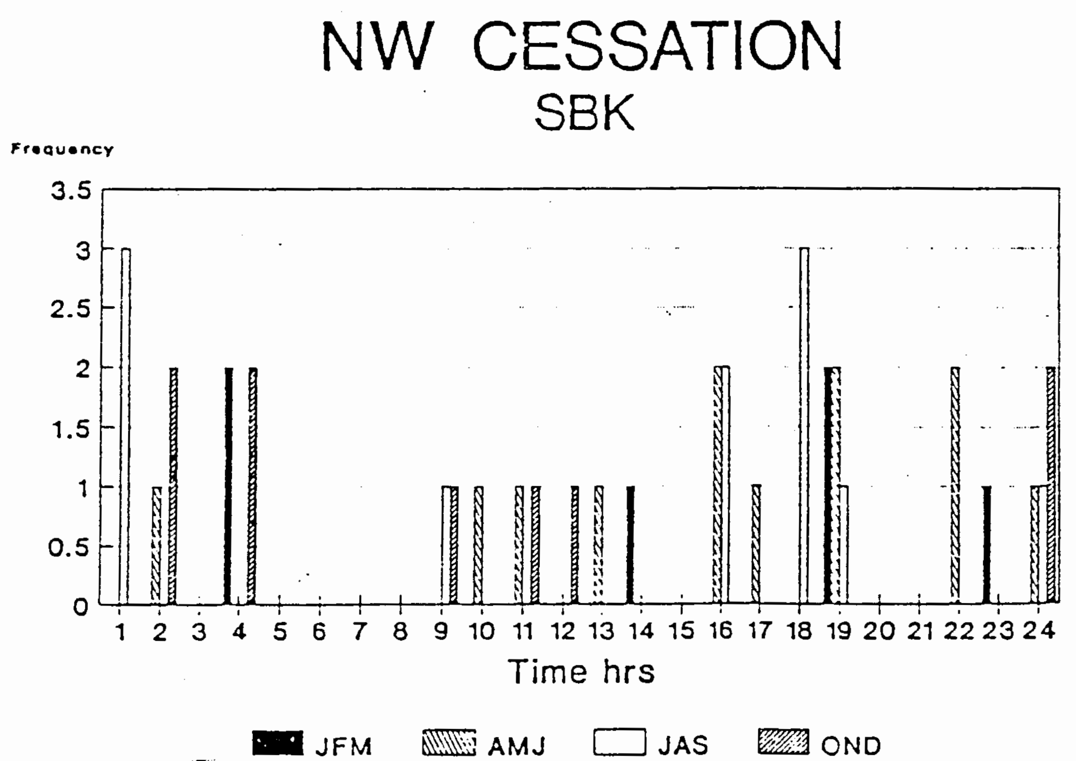


Fig. 7.2 (b) Cessation times for gradient northwesterlies for Swartboskloof by season.

1984

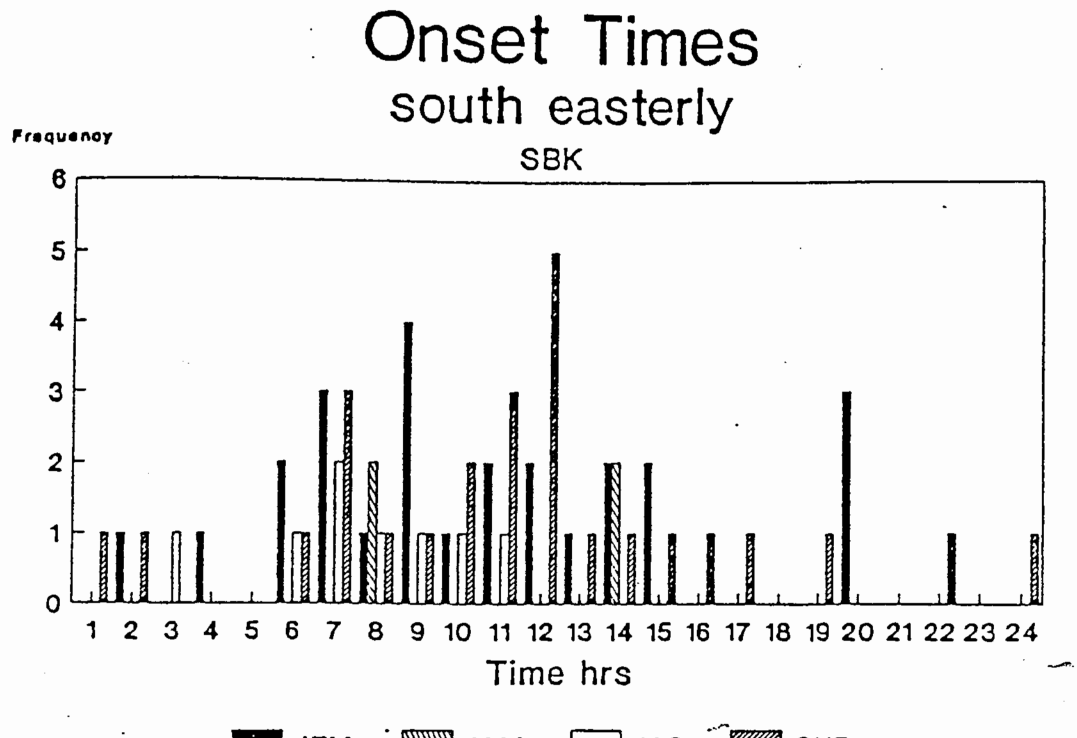


Fig. 7.3 (a) Onset times for gradient southeasterlies for Swartboskloof by season

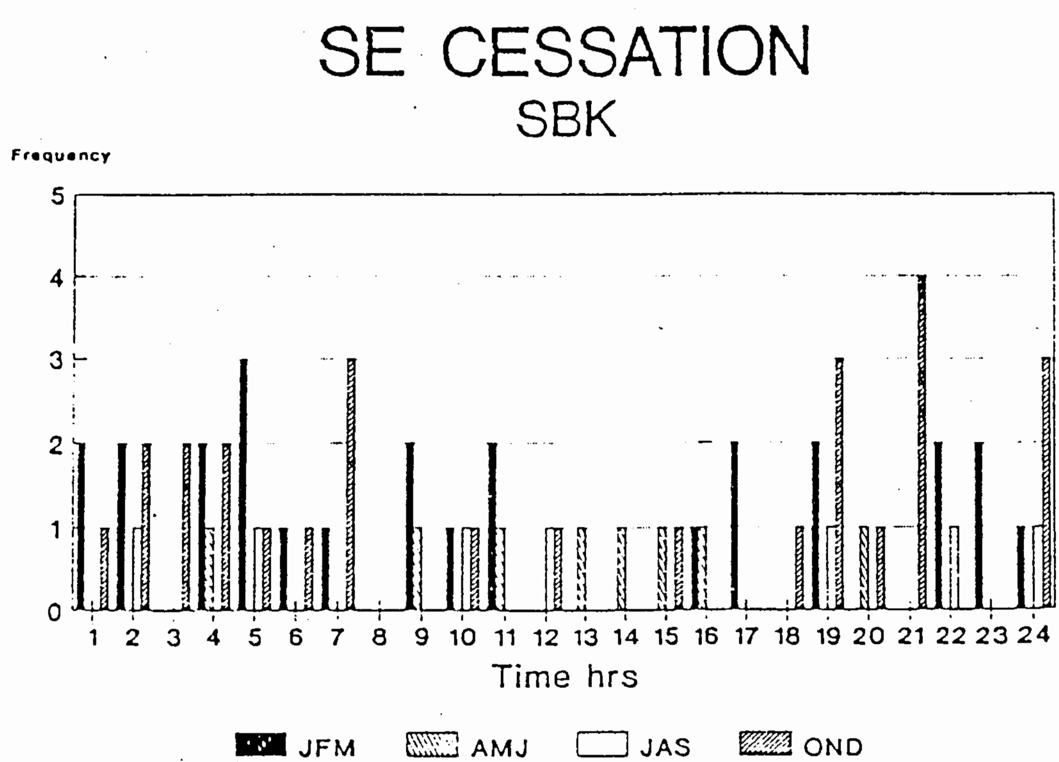


Fig. 7.3 (b) Cessation times for gradient southeasterlies for Swartboskloof by season.

1984

Early winter mountain winds blew until 09h00 the following morning, blowing for a total of 16 hours (Fig 7.1 b). In late summer, cessation was concentrated at 08h00. Some late summer cases ceased at 10h00. Mountain winds in late summer blew for a total of between 15 hours and 17 hours. Onset in early summer for the mountain winds at Jonkershoek was latest of all seasons.This occurred at 20h00. Cessation during this season was earliest of all seasons i.e between 06h00 and 07h00. The duration of the early summer mountain winds was thus between 11 hours and 12 hours. This duration was the shortest of all seasons.

The duration of the mountain winds in late winter (JAS) was 14 hours. Onset during this season occurred at 19h00, an hour later than both in early winter and late summer and an hour earlier than in early summer. Cessation in late winter occurred at 08h00 (Fig 7.1 b)

From the above investigation, it is evident that mountain winds blew for more hours in early winter and late summer than during the other seasons. It is possible that the greatest contribution to early initiation and late cessation times for late summer occurred towards the end of that season. This was not investigated in this study. Mountain winds at Jonkershoek in 1984 were initiated between 18h00 and 20h00. Cessation occurred between 06h00 and 10h00.

The duration of valley winds at Jonkershoek in 1984 was shortest in early winter (AMJ). The duration of this system during this season was between 6 to 7 hours. Onset in early winter was latest of all seasons in 1984. This occurred between 10h00 and 11h00. Cessation during this season was earliest, having occurred at 16h00 (Fig 7.1 a and b).

Valley winds in late winter (JAS) and early summer (OND) were initiated at 08h00. The longest blowing valley winds persisted for 11 hours in both seasons. Cessation occurred between 16h00 and 18h00 in late winter (a duration of between 9 hours and 11 hours), whereas in early summer, cessation occurred between 14h00 and 18h00 (a duration of between 7 hours and 11 hours).

In late summer, onset occurred at 09h00, an hour later than in both late winter and early summer and an hour earlier than in early winter. Valley winds persisted until 19h00 during this season, this is later than during the other seasons of 1984 (Fig 7.1 b). The duration of this regime at Jonkershoek during this season was 11 hours. Valley winds were therefore initiated between 08h00 and 11h00 with cessation occurring between 14h00 and 19h00. The longest blowing valley winds persisted for 11 hours.

7.3 GRADIENT NORTHWESTERLY WINDS

The onset and cessation times for northwesterly gradient winds at Jonkerhoek were also investigated (Fig 7.2 a). It appears from this figure that in most occasions, gradient north-westerly flow reached the valley bottom between 07h00 and 10h00. These onset times interestingly coincided with onset times for valley winds. This observation seems to suggest that a relationship exists between the occurrence of northwesterly gradient winds at the surface at Jonkershoek and the occurrence of valley winds. Indepth research into this area of the valley atmosphere would be required in order to verify or dispute this assumption.

The cessation of gradient northwesterlies at the surface at Jonkershoek displayed a late afternoon to nocturnal preference (Fig 7.2 b). Cessation during cases with northwesterlies occurred between 16h00 and 04h00. There were few cases which ceased between 05h00 and 15h00. Again this observation is not supported by previous research.

7.4 GRADIENT SOUTH-EASTERLY WINDS

Most gradient southeasterlies in the vicinity of the valley reached the surface between 06h00 and 15h00. This was particularly true for the summer season (JFM and OND). In early summer, some cases reached the surface at 20h00.

Only during few cases did this wind regime reach the surface at night (Fig 7.3 a). Surface cessation of this regime was concentrated at night. Figure 7.3 (b) shows that most gradient southeasterlies at the valley bottom ceased between 19h00 and 07h00. This observation is again particularly true for the summer season. In winter, no major preferences for surface onset and cessation were apparent.

CHAPTER EIGHT

VERTICAL PROFILES OF WINDS AT JONKERSHOEK

To get a picture of the vertical wind velocities and directions at Jonkershoek during cases which correspond with the synoptic phases relevant to this project, vertical wind velocity and direction profiles were made using pilot balloons. The results of the runs are presented in this chapter.

Runs were conducted during six late summer days of 1992, from the 28/01/92-31/01/92 and from the 07/03/92-08/03/92. Winter runs were conducted in 1990. They also covered a total of six days i.e 21/07/90-22/07/90 and again on the 27/07/90-28/07/90. The last runs were made on the 12/08/90-13/08/90.

Winter tracks were conducted at hourly intervals between 08h00 and 20h00. Late summer tracks covered the hours 06h00-20h00 also at hourly intervals.

The pilot balloon (PIBAL) results are accompanied by synoptic charts that reflect the nature of the synoptic field during respective runs. These are included in appendix B. The results are presented in sequences of two days in order to both make presentation easier and to allow for the expression of continuity between the phases. The results from the 1990 winter runs are presented and discussed first, these are followed by those conducted in 1992. Each presentation ends with a summary of what are considered to be the most important observations from each run.

8.1. THE SEQUENCE OF THE 21st AND 22nd OF JULY, 1990.

From the time-height section in figure 8.1 (a), it is evident that a mountain wind had prevailed at the valley overnight. The mountain wind was terminated by the onset of a valley wind at the surface at 10h30 on the 21/07/90. The mountain wind had weakened to 1 m/s prior to reversal (Fig. 8.1 b). At initiation, the depth of the valley wind was 150m. The valley wind deepened to 300m by 12h00. The maximum valley wind depth of 400m occurred just before dissipation at 17h30. The dissipation of the valley wind was initiated at the surface whilst at 200m, the valley wind continued to blow for another 30 minutes. With the exception of the pre-reversal surge of 4 m/s, which occurred at 300m at 16h30, the valley wind of the 21st remained below 2 m/s through its eight hour duration. The occurrence of the afternoon surge in the valley wind of this case is in agreement with the observation from secondary data (section 6.1) that late winter valley wind velocities peak around 15h00 within the Jonkershoek valley atmosphere. Tyson and Preston-Whyte found that in the Umsinduzi valley in Natal, the height of occurrence of maximum velocities in the valley wind was between 250-300m.

Between 12h00 and 15h30, the valley wind of the 21st was overlain by an anti-valley wind whose depth was approximately equal to that of the valley wind. The depth of the anti-valley wind was reduced about a half an hour before the dissipation of the valley wind. Tyson (1988) found that a return current to the valley wind develops unless prevented from doing so by the strength of the gradient wind. A mountain wind terminated the valley wind circulation of the 21st. This system was first experienced at the surface and gradually deepened to a depth of 500m by 20h00. This evening mountain wind was not overlain by an

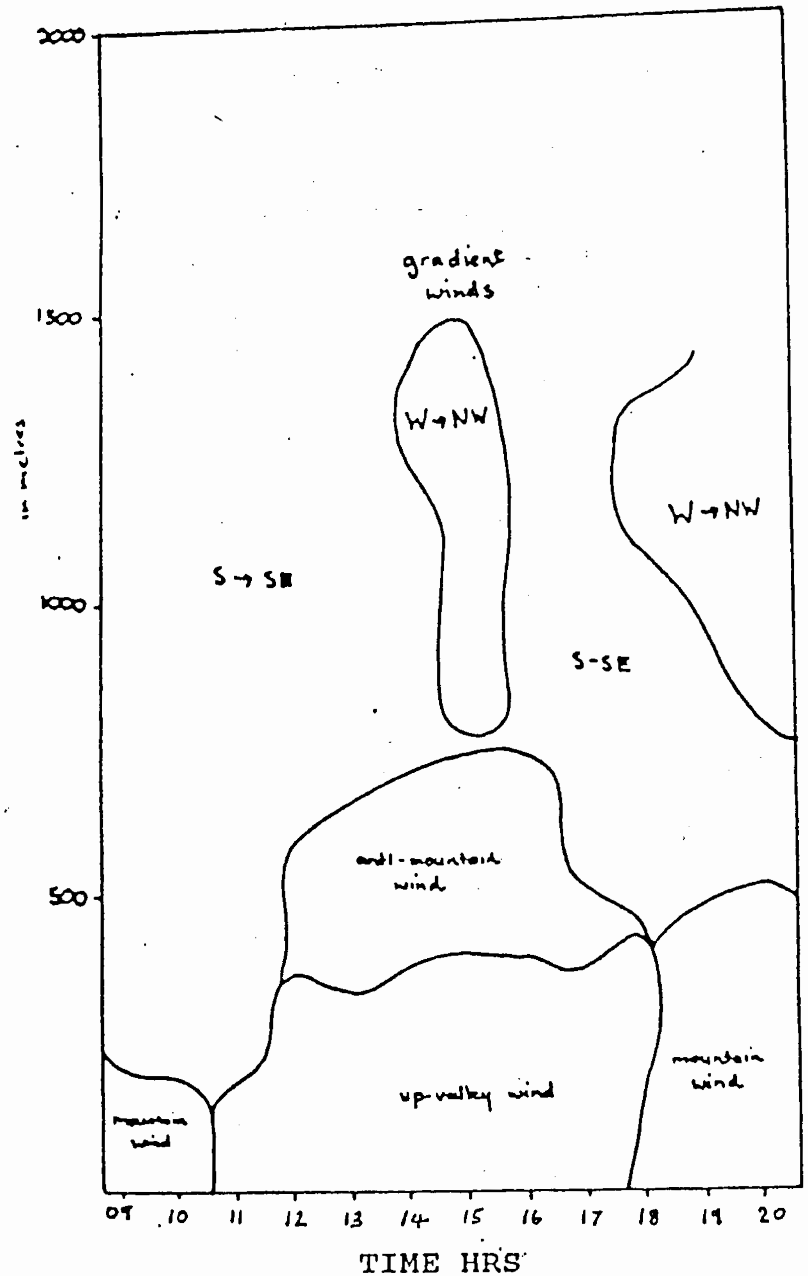


Fig 8.1 (a) Time-height sections to show local winds in the valley for the 21st of July.

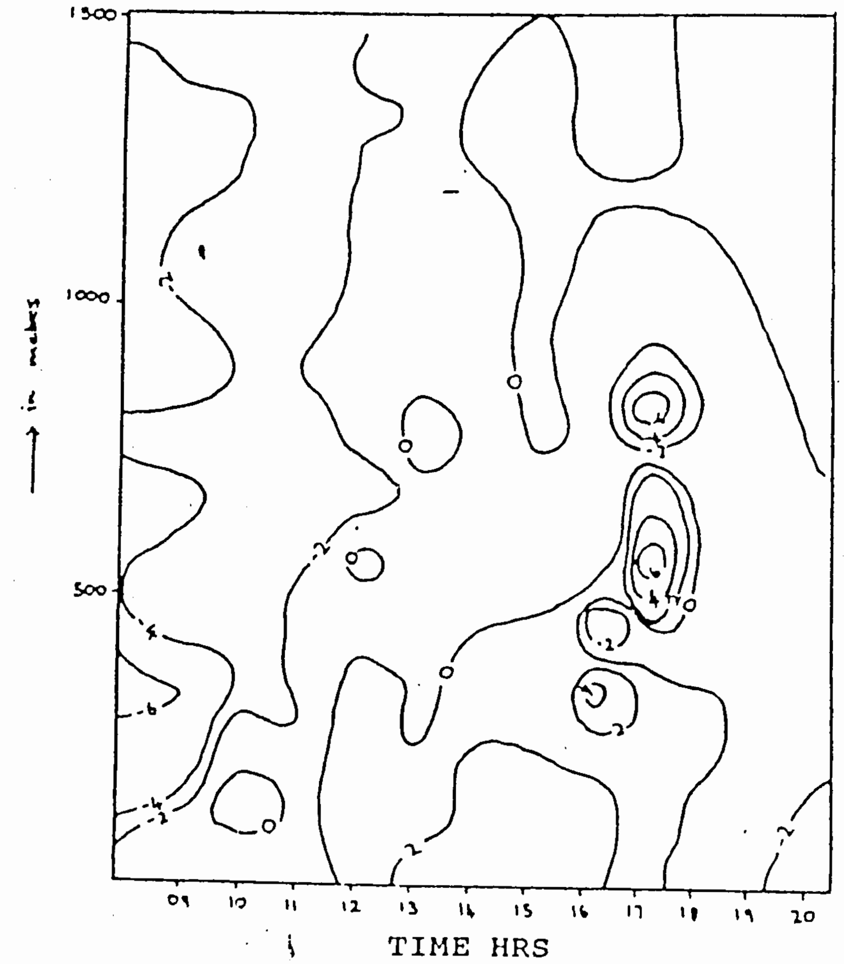


Fig 8.1 (b) Time-height sections of hourly along-valley components for the 21st of July. Isotachs in m/s.

anti-mountain wind. The velocity of this mountain wind was about 2 m/s.

An examination of the synoptic charts for the 21st of July 1990 (Appendix B) shows that a transient high pressure cell had moved around the southern tip of the sub-continent and by mid-day, had separated from the South Atlantic high pressure cell and continued to move eastwards. Lapse rates of temperature for this case in Appendix C for 00h00 show that a subsidence inversion existed between 900m-1300m. The strength of this inversion was 3^{o}C.

The thermo-topographic circulations of this case were overlain by weak gradient southeasterlies which were associated with the ridging anticyclone. Southeasterlies extended beyond ridge level throughout this case. A low level jet whose core was at 800m appeared within the gradient southeasterlies at 17h00. The velocity at the core of this jet was 6 m/s. The weak elevated temperature inversion that existed during this case did not decouple the valley atmosphere from that above. The association of the ridging anticyclone with the development of thermo-topographic circulations within valleys was identified by Jury (1987) for the west coast of Africa.

A tongue of west-northwesterly winds appeared between 14h00 and 16h00 and extended from 750m to ridge level. This tongue may have been related to the deepened valley winds to beyond ridge level during this case which probably indicates that the inversion had lifted and weakened during the day. This deepening was linked to the peak in the frequency of northwesterly winds at the summit station after 12h00 mid-day in (see section 6.1).

It can be concluded that the atmosphere on the 21st was stable as a result of the transient high pressure cell ridging eastward over the South Western Cape. The southeasterly winds during this case were deep and conform to the characterization of deep southeasterlies as proposed by Jury (1980) and Diab and Garstang (1984). The weak gradient southeasterly did not prevent the establishment of local circulations. The valley wind reached its maximum depth and velocity in the afternoon during the time of maximum surface heating. This is in agreement with secondary data observations (see section 6.1). The mountain wind which was terminated in the morning of the 21st was reduced in depth prior to its reversal to up-valley. This mountain wind had reached its maximum depth of 500m at 20h00, a few hours following onset.

The mountain wind of the 21st was terminated at 11h15 on the 22nd of July of 1990 (fig. 8.1 c). There is evidence from this figure that the depth of the mountain wind of the 21st and 22nd had reduced by night. At 08h00 on the 22nd, the mountain wind depth was 350m. This is in contrast to the depth of 500m which had occurred at 20h00 on the 21st. At its cessation at 11h15, this mountain wind had undergone a further depth reduction to 300m. As was the case with the mountain wind which was terminated during the morning of the 21st, the cessation of this mountain wind occurred simultaneously throughout its depth. There was no fluctuation in the velocity of this mountain wind (Fig 8.1 d). This was also observed in section 6.2.

A valley wind terminated the mountain wind of the 21st and 22nd. At initiation, the depth of this system was 250m. The valley wind deepened to 400m by 12h00. This midday occurrence of maximum depth within the valley wind was also observed during the valley wind of the 21st. This behaviour of the valley winds at Jonkershoek is in contrast to the observation made by Tyson (1968) at Giant's Castle in the Natal Drakensberg. He found that valley winds there were initiated above the heights of the ridges. This difference suggests that within the Jonkershoek valley, the surface

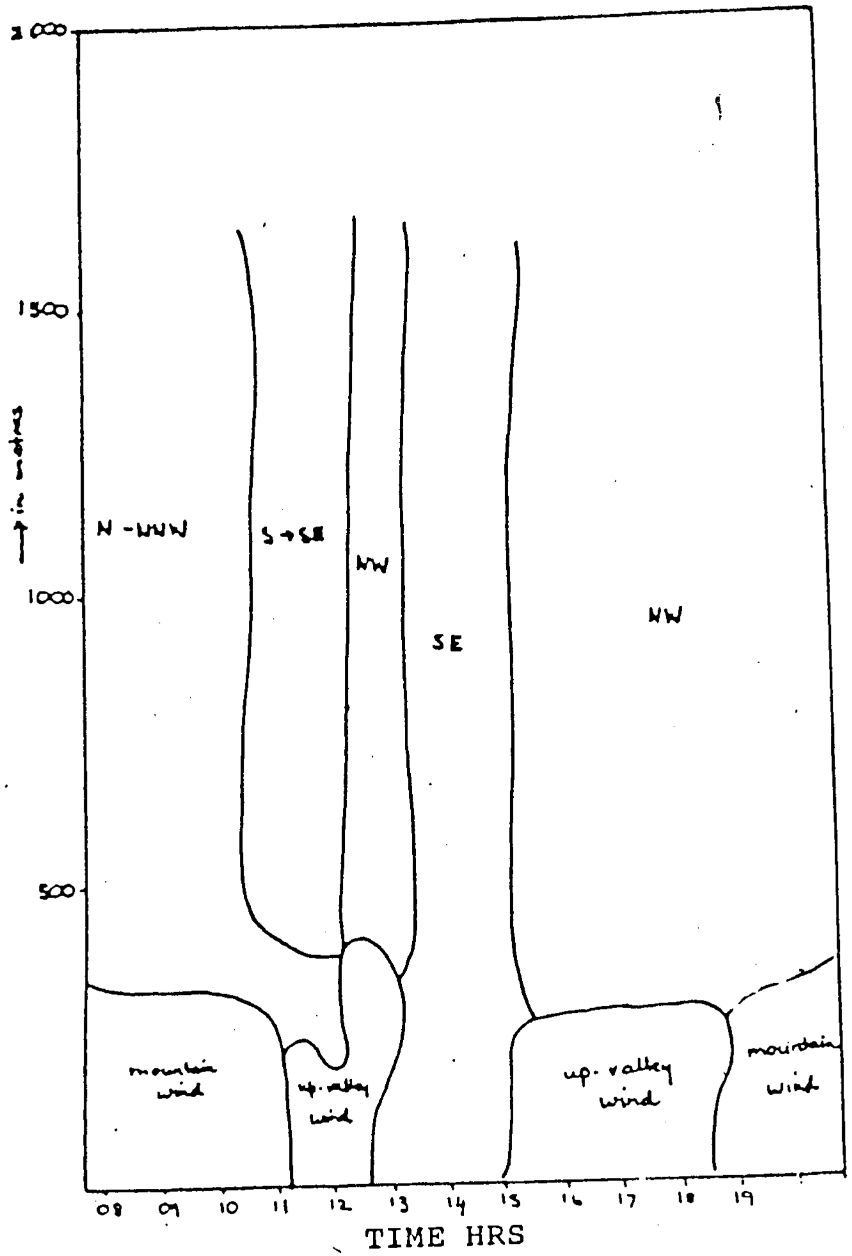


Fig 8.1 (c) Time-height sections to show local winds in the valley for the 22nd of July.

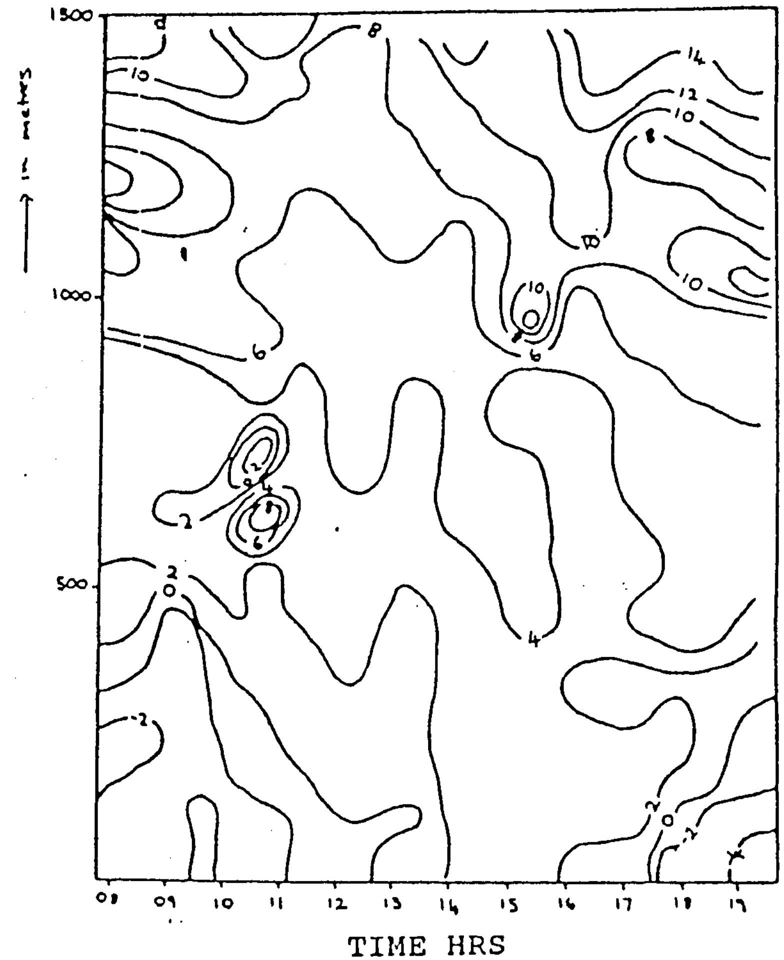


Fig 8.1 (d) Time-height sections of hourly along-valley components for the 22nd of July. Isotachs in m/s.

processes which include the reversal of the pressure distribution between the valley's exit and its upper end (section 6.1) are also important in the initiation of valley winds.

The velocity of the valley wind of the 22nd remained below 2 m/s. The local circulations of the 22nd were interrupted by the arrival of a weak gradient south-easterly at the surface between 12h30 and 15h00. Valley winds resumed at 15h00 and persisted until 18h30. The depth of this system was reduced to 300m after 15h00 probably due to the stronger overlying gradient northwesterly winds. As was the case with the valley wind of the 21st, the cessation of this valley wind occurred earlier at the surface than at 200m level. This system was terminated at the surface by the initiation of a mountain wind at 18h30. This does not deviate significantly from the observation of onset times of 19h00 (see section 7.1). Between 200-300m, the valley wind continued to blow for about 30 minutes before its final cessation at 19h00. The velocity of the valley wind remained below 2 m/s. The mountain wind which terminated the valley wind of the 22nd increased in depth from 300m at initiation to 400m by 21h00. There was evidence of a gradual acceleration of this system from 2 m/s at initiation to 4 m/s by21h00.

An examination of the synoptic field in Appendix B indicates that on 22/07/90, the South Western Cape was under the influence of a saddle between the South Atlantic and the South Indian high pressure cells. Such a saddle was also identified by Juhnke and Fuggle (1987). They observed that such a saddle is associated with warm and settled conditions. This saddle could have been responsible for the considerable variability in velocities and directions which occurred above the local valley circulations on the 22nd (Fig. 8.1 c). This variability was reported by Washington (1990) as characteristic of stable anticyclonic conditions.

The radiosonde results for the 22nd in Appendix C indicate that at 00h00, a radiational surface inversion had occurred to a depth of 400m. The inversion was much weaker at noon ($2^{o}C$). This weakening could have allowed the gradient southeasterlies to reach the surface between 12h30 and 15h00 (Fig. 8.1 c).

Appendix B also shows that a cold front was approaching from the southwest. This system was pushed to the south of the sub-continent by the resident South Atlantic Anticyclone. The northwesterly gradient flow which appeared above the valley wind at 15h00 and persisted throughout the remaining hours of observation could have been related to this frontal system. Gradient winds strengthened with the onset of northwesterly

winds at 15h00. There were indications of velocity shear in the vertical plane (Fig. 8.1 d). These observations suggest that the occurrence of inversions whose strength is above $3^{o}C$ below ridge level is important for the initiation of local valley circulations.

In conclusion, this case was representative of a shallow southeasterly event. The deepening of the valley wind at mid-day which occurred on the 22nd was also observed on the 21st. The occurrence of the mountain wind which terminated the valley wind first at the surface was also common between the mountain winds of the 21st and 22nd. Common also was the deepening of the mountain wind after its onset, followed by its shallowing prior to reversal the following morning. The evening mountain wind of the 22nd differed from that of the 21st in that it strengthened after its onset.

8.2 THE SEQUENCE OF THE 27th AND 28th OF JULY 1990

The mountain wind of the 27th of July was much deeper than those discussed in section 8.1. The depth of the mountain wind during this case was 850m at 08h00 (Fig 8.2 a). This mountain wind was overlain by a return current of the anti-mountain wind which extended to ridge level i.e 850-1200m. The pre-reversal reduction in the depth of this system was observed during this case. This reduction in depth was accompanied by a surge of 4 m/s which was initiated about 2 hours before its reversal to up-valley at the surface (Fig. 8.2 b). The reversal of the mountain wind which occurred at 13h00 occurred almost simultaneously throughout the depth of this system.

The valley wind that was established at 13h00 on the 27th reached a maximum depth of 500m about an hour before its reversal to down-valley (Fig. 8.2 a). The velocity of the valley wind remained below 2 m/s. The mountain wind which terminated the valley wind at 18h30 had a depth of 600m at 19h00. The depth of this system underwent a reduction towards midnight. The velocity of this mountain wind remained below 2 m/s.

Appendix B indicates that on the 27th of July, following the passage of a cold front, an anticyclone ridged eastwards over the South Western Cape. This is characteristic of the onset of a deep southeasterly phase (Jury, 1987). A subsidence inversion descended from 1800m at 00h00 to 1100m by 12h00 (Appendix C). On the morning of the 27th, gradient southeasterlies were confined to above ridge level by the high elevated temperature inversion. These gradient southeasterlies were weak and thus unable to disrupt the valley circulations. The association of well established thermo-topographic circulations with light winds was made by Barry (1981) and Ekhart (1936, 1948).

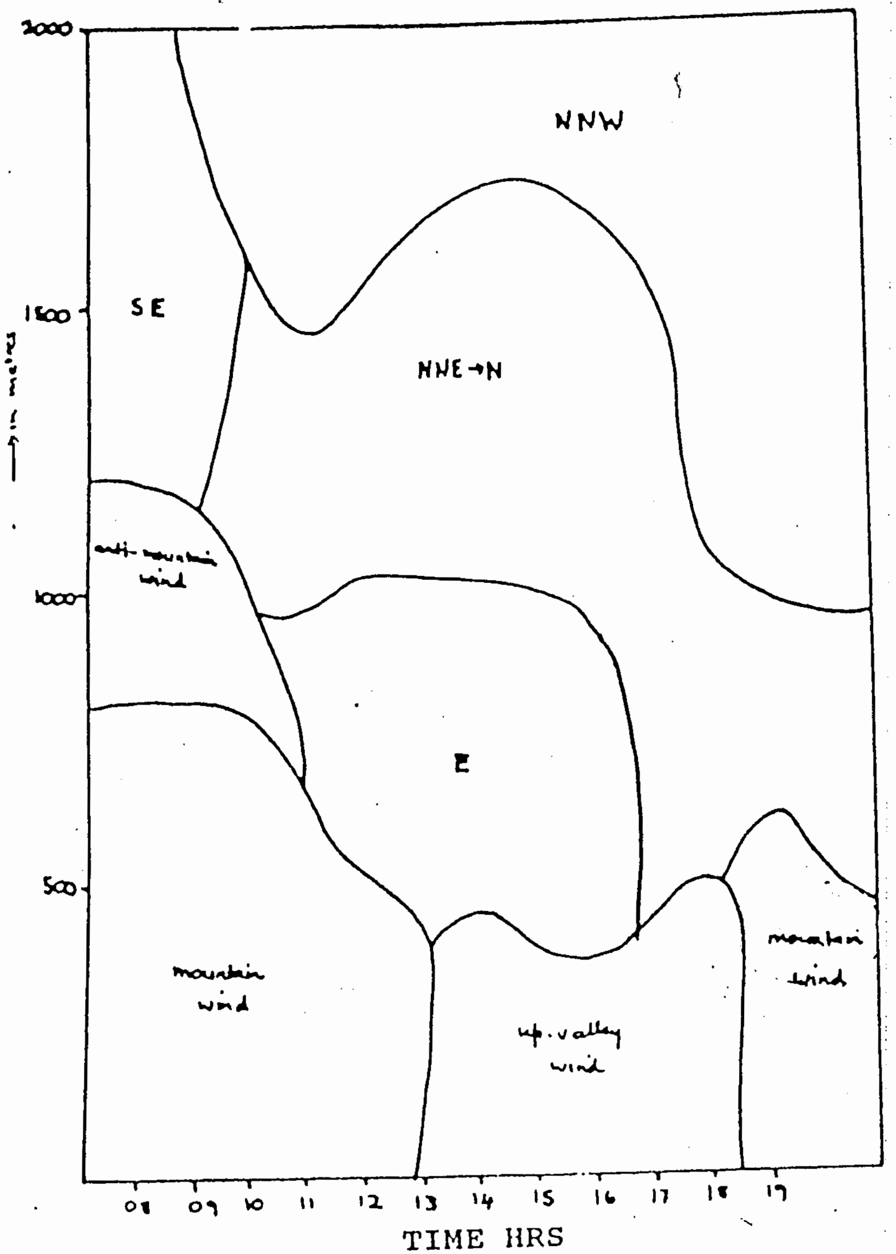


Fig 8.2 (a) Time-height sections to show local winds in the valley for the 27th of July.

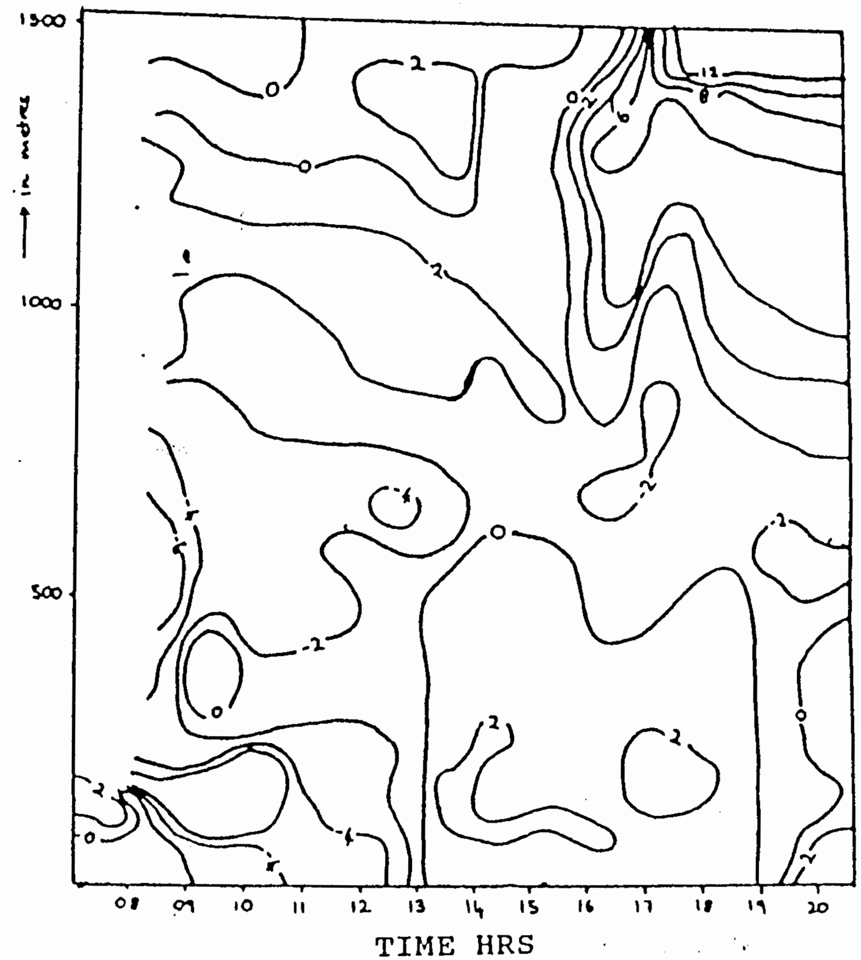


Fig 8.2 (b) Time-height sections of hourly along-valley components for the 27th of July. Isotachs in m/s.

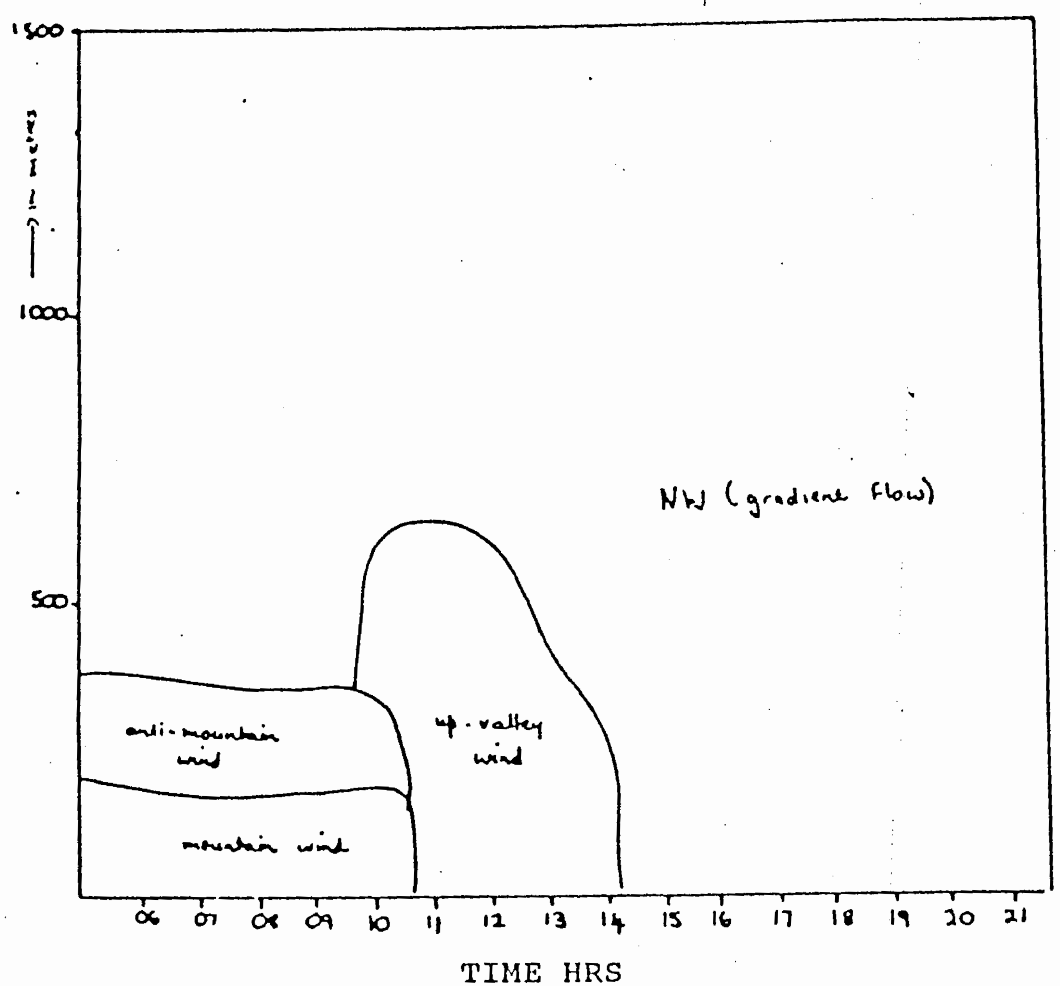


Fig 8.2 (c) Time-height sections to show local winds in the valley for the 28th of July.

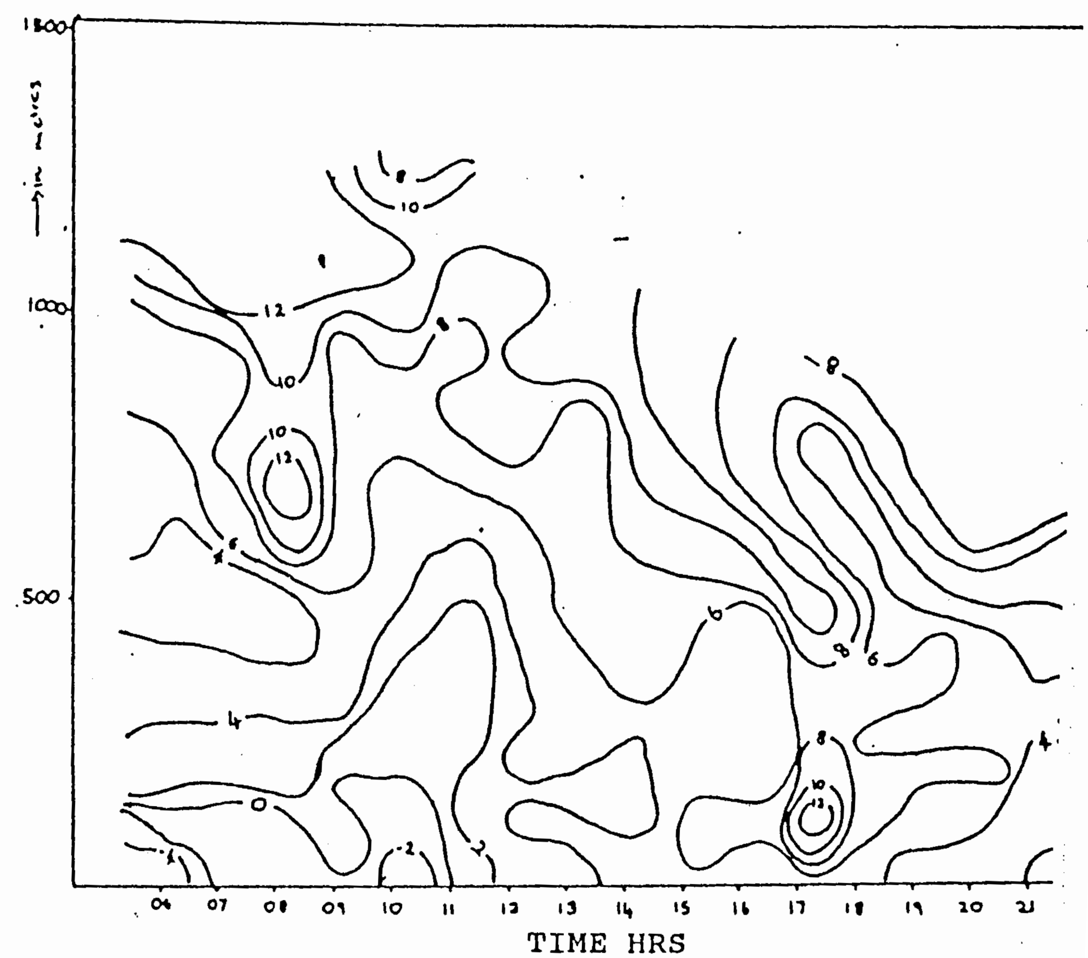


Fig 8.2 (d) Time-height sections of hourly along-vall components for the 28th of July. Isotachs in m/s

With the lowering of the inversion, the local circulations within the valley were restricted to depths of between 500 and 600m. The return current of the mountain wind was terminated at 11h00, two hours before the termination of the mountain wind at the surface. This could have been caused by the restriction of flow depth by the descending inversion layer.

As the anticyclone continued to ridge eastward over the study area, northeasterly warm air advection occurred above the valley circulations from 10h00 onwards (Fig. 8.2 a). The circumpolar westerlies descended from 1700m at 15h00 to 1000m at 18h00. Vertical velocity shear occurred within the westerlies (Fig.8.2 b).

It is noted that the mountain wind which was terminated on the morning of the 27th also underwent a pre-reversal reduction in depth. This depth reduction was accompanied by a pre-reversal surge of 4 m/s which was initiated two hours before the final reversal of this system. As was the case with other valley winds, the valley wind of the 27th reached a maximum depth after mid-day. The velocity of this system was also below 2m/s.

The mountain wind which terminated the valley wind of the 27th differed from those already presented in that its depth was reduced soon after its initiation. Its velocity also remained below 2 m/s. The gradient southeasterlies which overlay the valley circulations were weak and were confined to above ridge level. Warm advection accompanied the continued ridging of the anticyclone and overlay the valley bottom circulations.

The mountain wind of the 27th continued to blow until 10h30 on the 28th. The flow depth had been reduced to 250m by 06h00 and the system was overlain by an anti-mountain wind of the same depth (Fig 8.2 c). Wind velocities dropped from 4 m/s at 06h30 to 2 m/s just before reversal to up-valley (Fig 8.2 d). The overlying anti-mountain wind had the same velocity as the mountain wind. As in the cases already presented, cessation of this system on the 28th occurred simultaneously throughout the depth of this system.

The valley wind of the 28th differed from those already presented in that it was initiated between 400m and 650m about an hour prior to its initiation at the surface (Fig 8.2 c). The valley wind of the 28th reached a depth of 700m between 09h30 and 12h00. This was deeper than those presented in the sections above. After 12h00, the depth of this system was reduced so that at termination at 14h10, the depth of the valley wind was only 250m. The velocity within the valley wind was below 4 m/s (Fig 8.2 d). This differed from the valley winds already discussed in that their velocities was found to be below 2 m/s. This observation seems to suggest that a positive correlation exists between the depth of valley winds and their velocities. This valley wind was terminated by northwesterly gradient winds which persisted for the remainder of the observation time. The local valley bottom circulations were overlain by gradient northwesterly winds whose velocity immediately above the local circulations was 4 m/s. The strength of this gradient wind increased with height.

Appendix B shows that on the 28th, the transient high pressure cell had merged with the South Indian Anticyclone. A cold front reached the sub-continent by late afternoon-early evening. The radiosonde results of the 28th show that temperature lapse rates were positive (an inversion) from the surface up to 600m at 00h00. An elevated inversion occurred between 800 m and 1150 m (Appendix C). This surface based inversion allowed for the establishment of local circulations within the valley atmosphere. The surface inversion had collapsed by 12h00, this was accompanied by the gradual lowering of the elevated temperature inversion which by then occurred between 500m and 1200m.

It is expected that the elevated temperature inversion collapsed with the arrival of the cold front after 12h00. This could have resulted in the surface occurrence of gradient north-westerly winds after 14h00. Futhermore, wind velocities after the arrival of the front exceeded the lower ambient velocity limit (6 m/s) required for the establishment of local thermo-topographic circulations at the valley bottom (see section 6.2). Velocities of 12 m/s occurred at 100m levels at 17h00 after the arrival of the front (Fig. 8.2 d).

To conclude, it is noted that the mountain wind of the morning of the 28th was overlain by an anti-mountain wind of the same depth as the mountain wind. This mountain wind underwent a pre-reversal weakening from 4 m/s to 2 m/s. The system was terminated simultaneously throughout its depth. The valley wind of the 28th was initiated above the surface, this differs from those already presented and is in agreement with Tyson's obseravtions (see section 8.1). In addition, the valley wind on the 28th was deeper and stronger than those already presented. The north-westerly gradient wind which overlay the valley circulations had a velocity of 4 m/s above the valley bottom circulations. The termination of the valley bottom local circulations was accompanied by the strengthening of winds at the surface to velocities in excess of 6 m/s. A surface inversion accompanied the circulation of the 28th. Finally, the circulation on the 28th conforms to the characterization by Jury (1987) of a shallow southeasterly event. This event was terminated by a strengthening of the overlying northwesterly gradient winds.

8.3 THE SEQUENCE OF THE 12th AND 13th OF AUGUST, 1990

The 12th of August was characterized by the occurrence of southeasterlies throughout the valley atmosphere (Fig 8.3 a). Velocities of up to 20 m/s were recorded at Swartboskloof during this event (Fig 8.3 b)

Mountain winds appeared at 18h30 and gradually deepened towards midnight. This cessation of the southeasterlies at the surface towards the night was noted in section 7.4. The velocity of the mountain wind was of the order of 8 m/s at the surface. The flow in the vicinity of the valley was comprised of three layers between 18h00 and 20h00. Gradient southeasterlies whose velocity was 4 m/s above the mountain wind continued to blow between 250m and 600m after 18h00. These were overlain above 600m by northeasterlies of the order of 2 m/s (Fig 8.3 a).

Appendix B shows that on the 12th, a transient high was moving around the southern tip of the sub-continent. This high had a central pressure of 1040 hPa and might explain the exceptional strength of this case's mountain winds
(8 m/s). A weak surface based inversion whose strength was 1^{o}C occurred at 00h00 overlain between 1200m and ridge level by a subsidence inversion. The strength of the southeasterlies allowed them to reach the surface at Jonkershoek in spite of the existence of these inversions. It is probable that the subsidence inversion was gradually lowered, this accompanied by the weakening of the southeasterlies could have allowed the mountain wind to develop in the evening. This case conforms with Jury's characterization of deep southeasterlies.

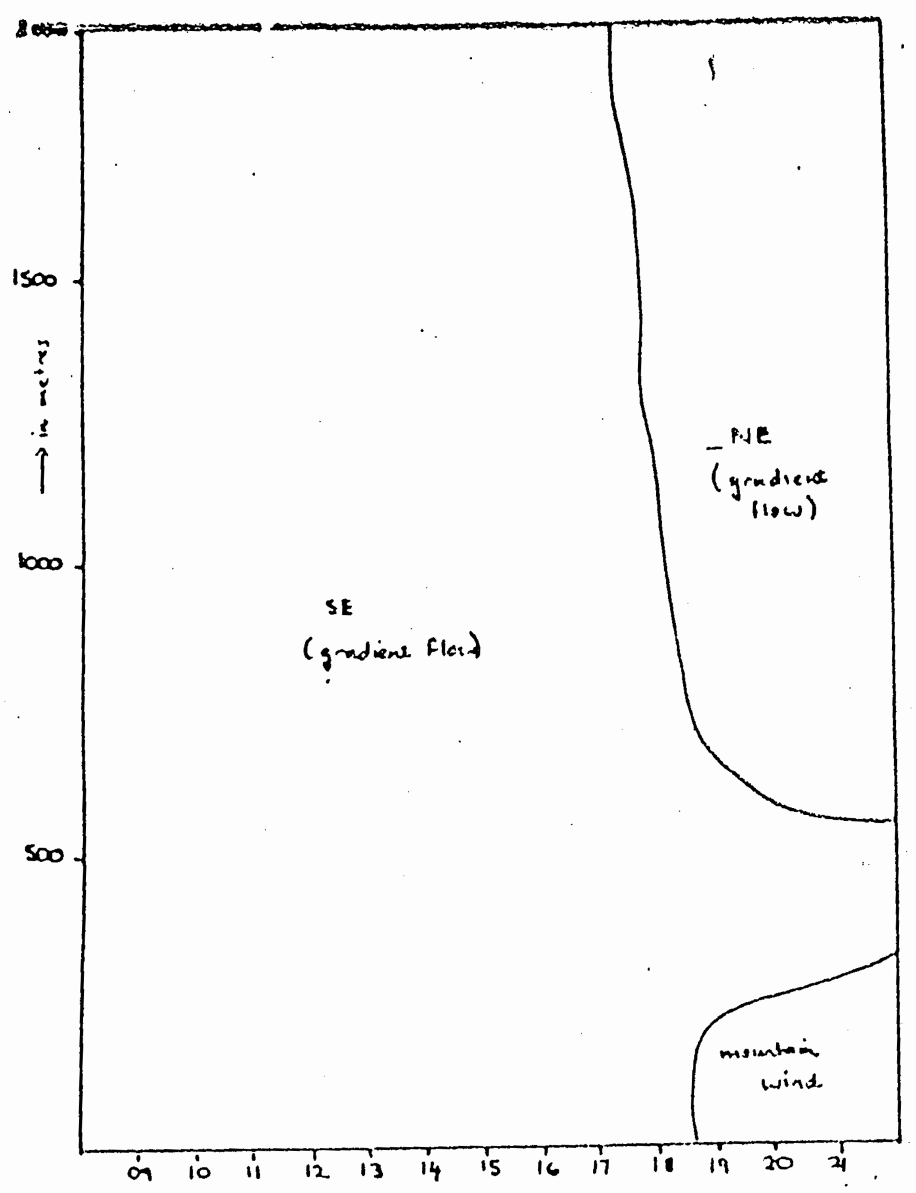


Fig 8.3 (a) Time-height sections to show local winds in the valley for the 12th of August.

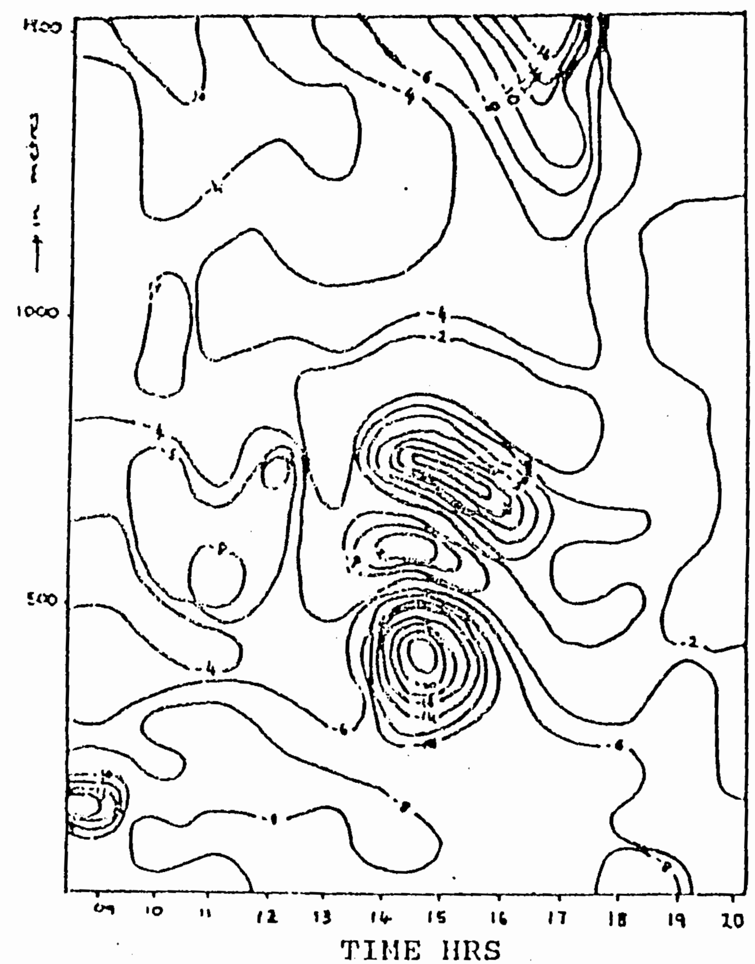


Fig 8.3 (b) Time-height sections of hourly along-valley components for the 12th of August. Isotachs in m/s.

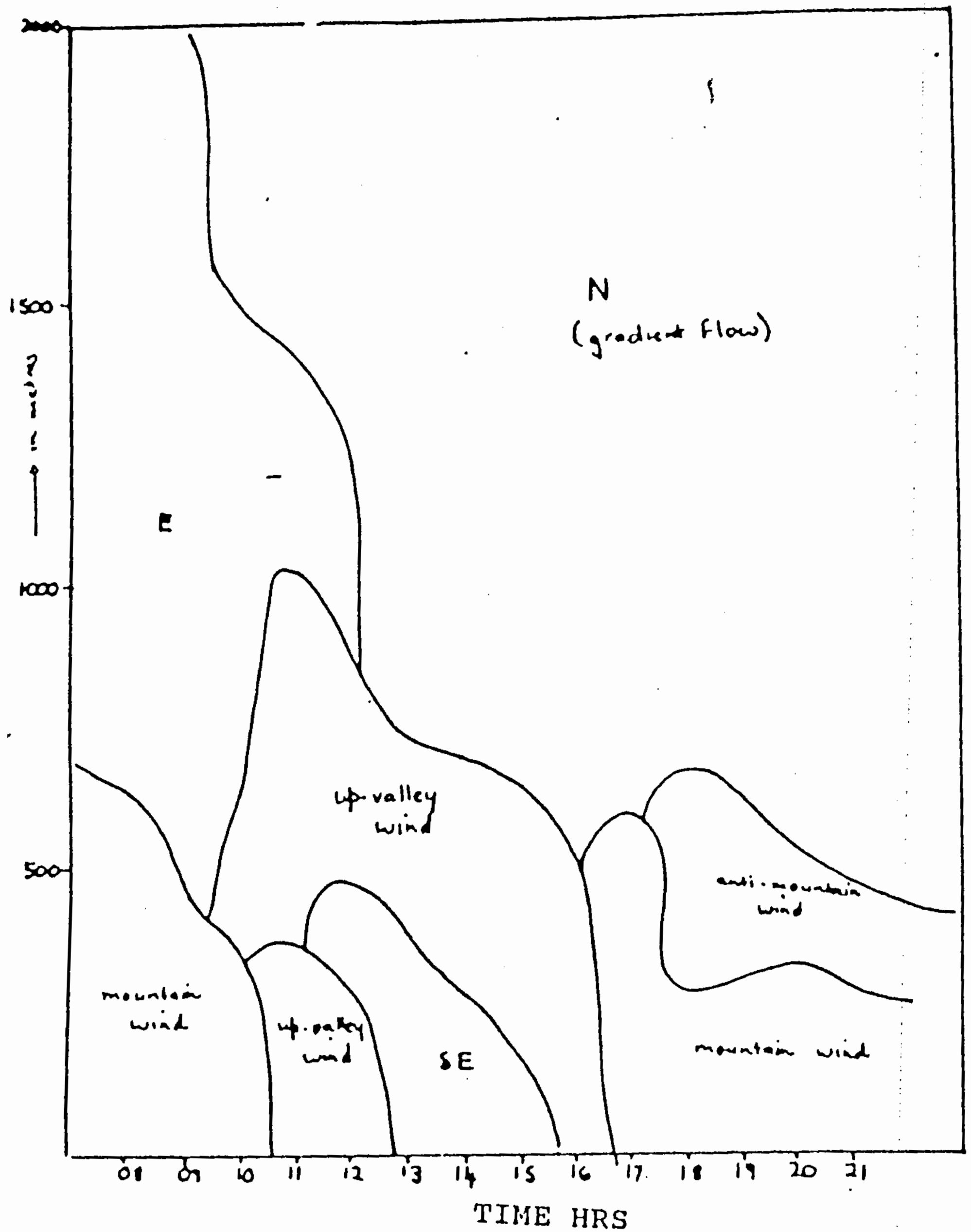


Fig 8.3 (c) Time-height sections to show local winds in the valley for the 13th of August.

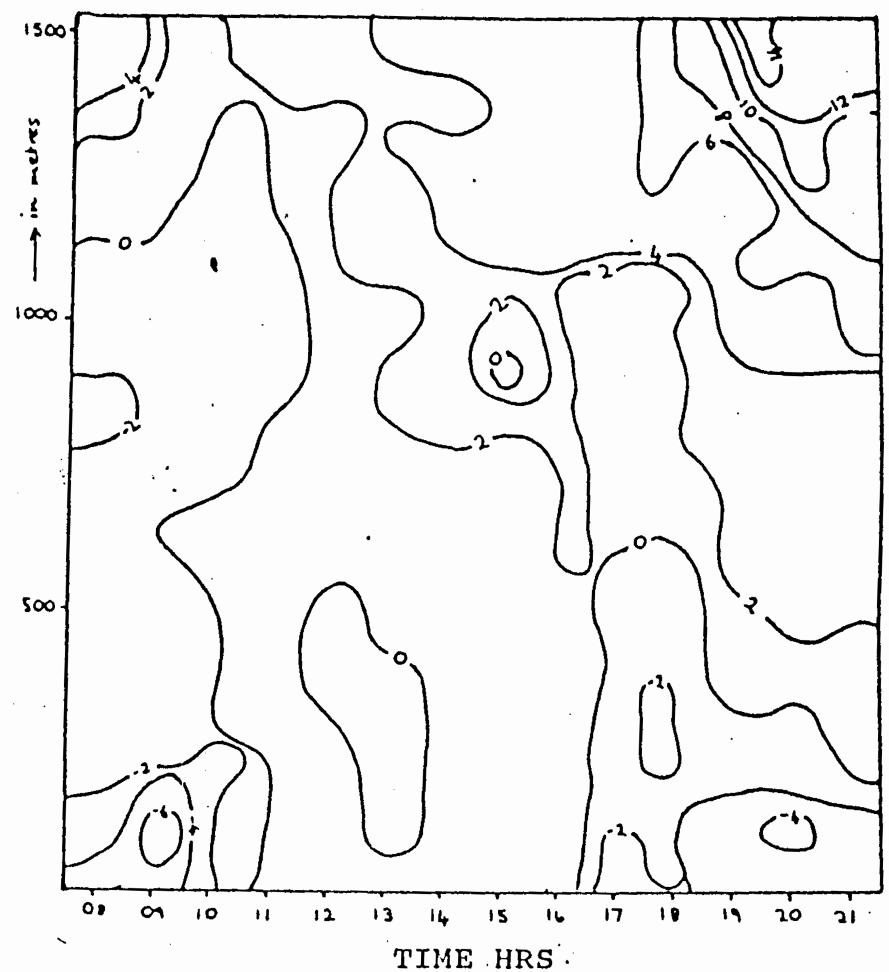


Fig 8.3 (d) Time-height sections of hourly along-valley components for the 13th of August. Isotachs in m/s.

The circulation on the 13th differed altogether from that of the 12th. The mountain wind which was established on the 12th was terminated at 10h30 on the 13th (Fig 8.3 c). A pre-reversal reduction in the depth of the mountain wind occurred. A pre-reversal surge of 6 m/s also occurred within the mountain wind of the 13th (Fig 8.3 d).

The valley wind that terminated the mountain wind reached a height of 1000m at 11h00. This system was first experienced at 400m about an hour before its occurrence at the surface. The valley wind of the 13th was weak and was interrupted by the occurrence a southeasterly wind between 13h00 and 15h45. The mountain wind which terminated the valley wind of the 13th first occurred at 500m level at 16h00. This mountain wind reached the surface at 16h45. The flow depth of the mountain wind increased rapidly after initiation to 600m at 17h00. This was subsequently reduced to 350m from 18h00 onwards.

The mountain wind of the evening of the 13th was overlain by an anti-mountain wind after 17h30 (Fig 8.3 c). The mountain wind reached a velocity of 4 m/s at 20h00. This occurred at 100m level.

The valley bottom circulations were overlain by a gradient southeasterly between 07h00 and 12h00. The velocity of this system was of the order of 2 m/s. Gradient winds backed to northerly after 12h00 with acceleration occurring after 17h00.

Appendix B shows that a coastal low was approaching the South Western Cape on the 13th. This explains the shifts in the gradient wind directions from easterly to northerly. A strong surface based inversion ($6^{o}C$) permitted the establishment of local circulations (Appendix C). This phase can be categorized as a shallow south-easterly phase.

Observations which can be made from the circulation on the 13th are the pre-reversal reduction in the depth of the mountain wind which was initiated on the 12th. The pre-reversal surge in this mountain wind reached a velocity of 6 m/s. The valley wind which followed was quiet deep, reaching a height of 1000m at 11h00. The valley wind was first experienced at 400 m about an hour before it reached the surface. The mountain wind which terminated the valley wind of the 13th was also first experienced at 500 m level about 45 minutes before its occurrence at the surface. The mountain wind increased its flow depth after initiation with maximum depth occurring at 17h00. The easterlies which overlay the valley bottom local flow between 07h00 and 12h00 were very weak, with velocities of the order of 2 m/s and hence could not disrupt the local circulation.

8.4 THE SEQUENCE OF THE 28th AND 29th OF JANUARY, 1992

From the time height section of winds in figure 8.4 (a) that covers the hours 06h00-20h00, it can be seen that the Jonkershoek circulation was characterized by the occurrence of southeasterlies. This wind regime shallowed from 1300m at 09h00 to 800m at 13h00. The system deepened again to 1200m at 17h00. The velocity of the southeasterlies was of the order of 8 m/s (Fig 8.4 b). A low level jet occurred at 200m level at 19h00. The core of the jet had a velocity of 18 m/s. The southeasterlies within the valley were overlain by light and variable winds.

Appendix B shows that the circulation over the South Western Cape was anticyclonic on the 28th. This resulted in the occurrence of deep southeasterlies as observed within the valley atmosphere. Radiosonde results show that at 01h29, two elevated temperature inversion layers had occurred. The

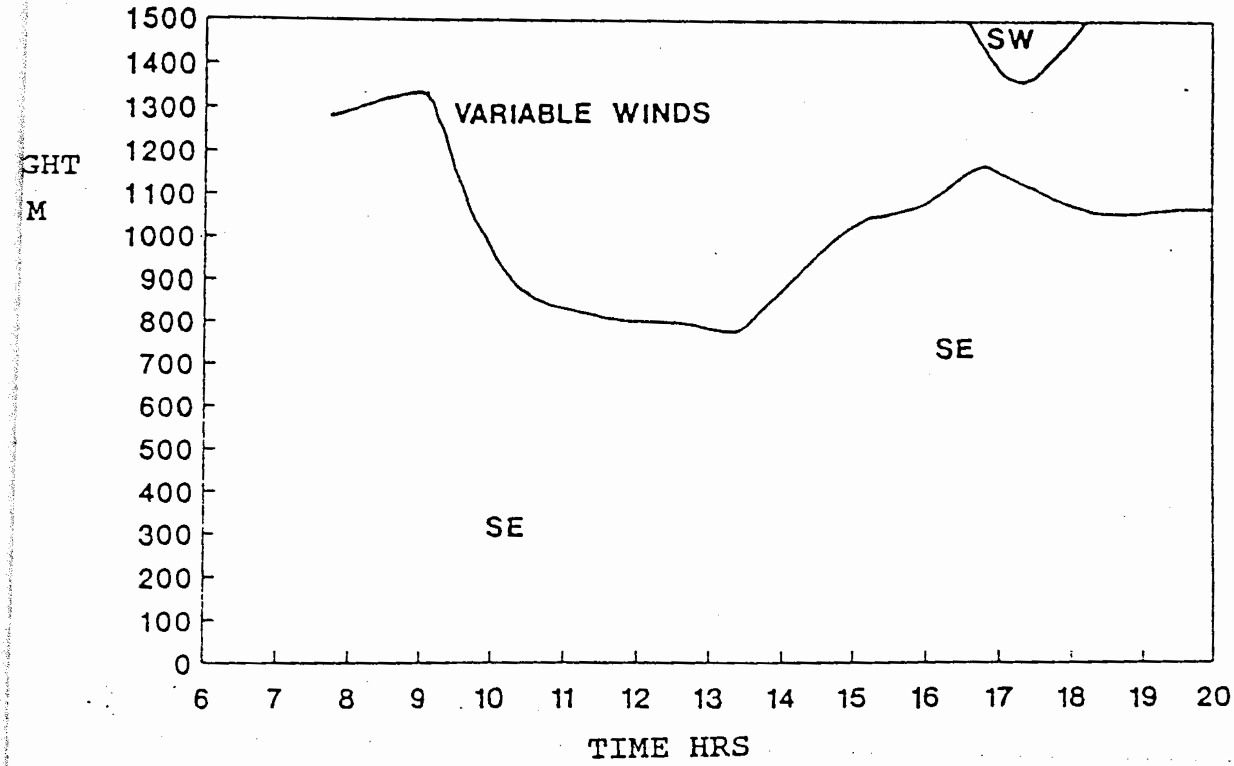


Fig 8.4 (a) Time-height sections to show local winds in the valley for the 28th of January.

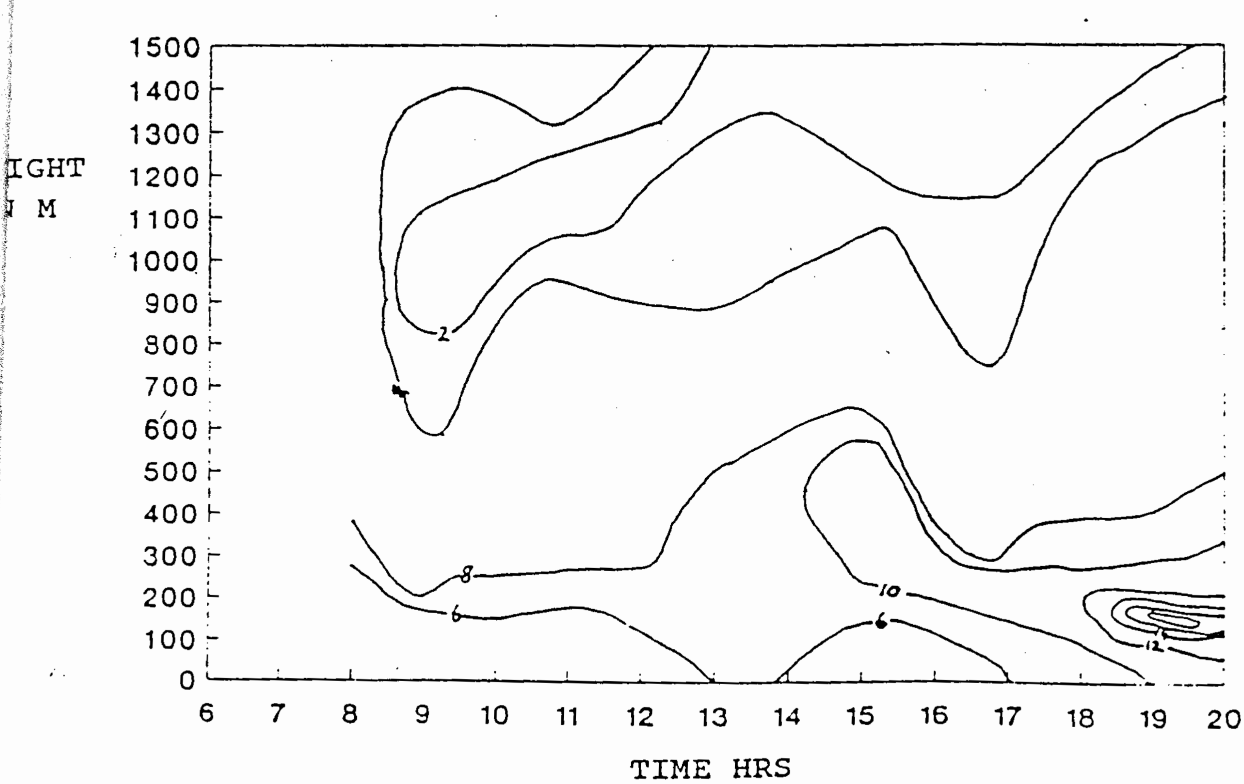


Fig 8.4 (b) Time-height sections of hourly along-valley components for the 28th of January. Isotachs in m/s.

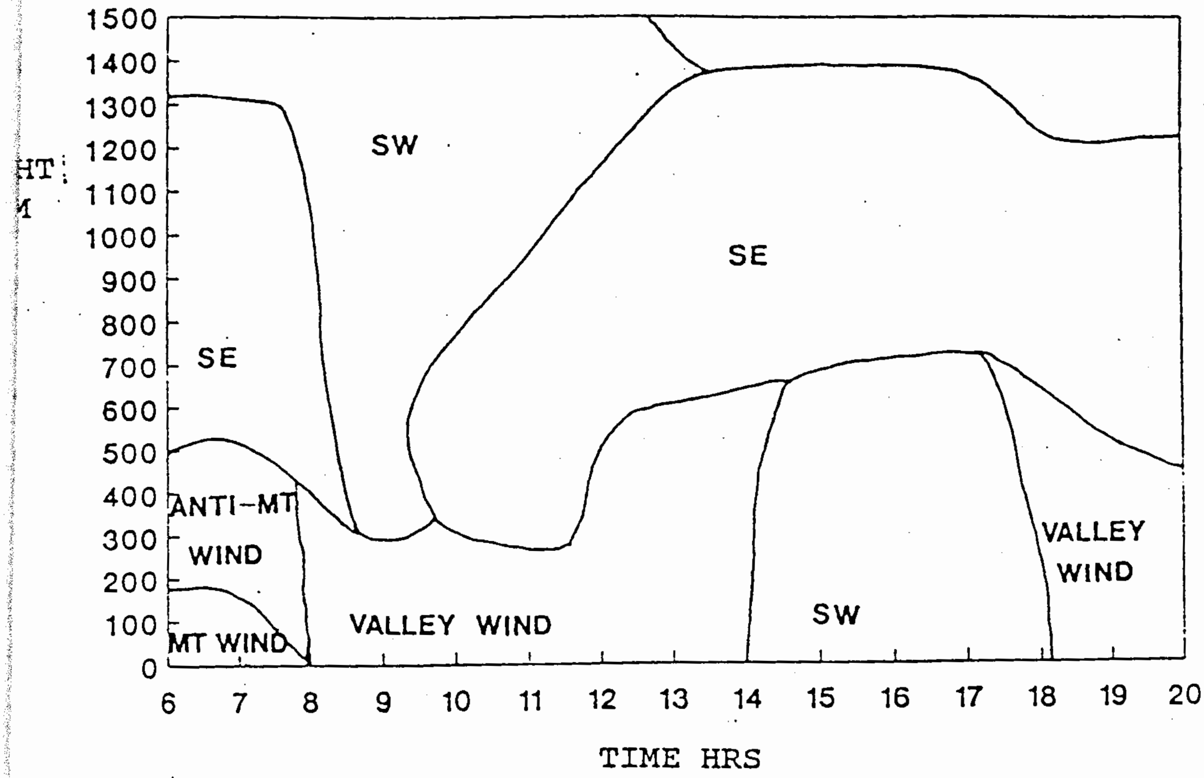


Fig 8.4 (c) Time-height sections to show local winds in the valley for the 29th of January.

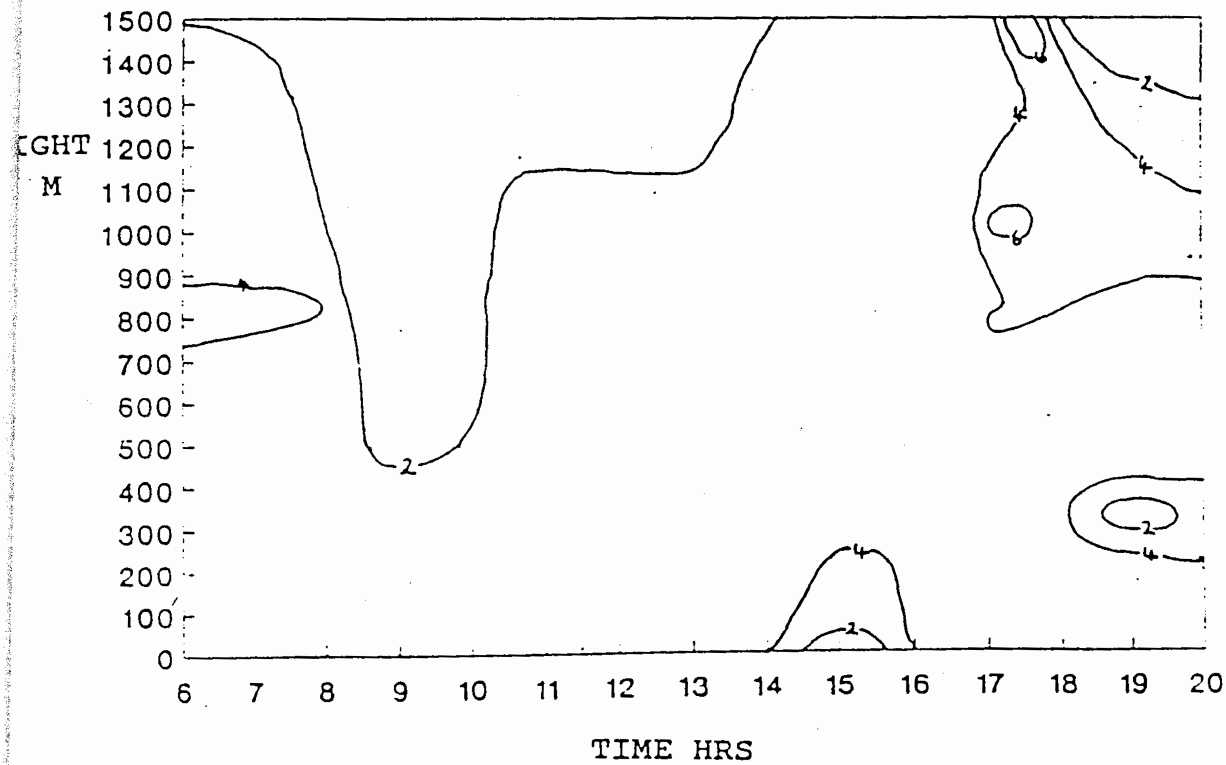


Fig 8.4 (d) Time-height sections of hourly along-valley components for the 29th of January. Isotachs in m/s.

lowermost layer was between 500m and 750m and had a strength of $4^{o}C$. The second layer occurred between 1100m and 1250m, with a strength of $4^{o}C$. By 12h38, only one inversion layer was identified between 1000m and 1400m. The strength of this layer was $2^{o}C$.

The shallowing of the south-easterly flow depth between 09h00 and 14h00 could be an indication that this elevated inversion layer had descended. This could have limited the depth of flow within the south-easterly wind regime. The deepening of flow after 14h00 could have been caused by the lifting of the inversion due to strong surface heating. During the night of the 28th, a mountain wind was established at the Jonkershoek valley. This local wind system persisted until 08h00 on the 29th (Fig 8.4 c). Secondary data observations in section 7.1 indicate that mountain winds in late summer at the and variable winds Jonkerhoek valley are terminated at about 08h00. There was a pre-reversal reduction in the depth of this mountain wind which was overlain by an anti-mountain wind of the same strength between 200m and 500m. A valley wind was initiated at 08h00. This system deepened from 300m at 08h00 to 680m prior to its interruption by a southwesterly cross-valley flow at 14h00. The strength of the valley wind was also of the order of 2 m/s (Fig 8.4 d). The velocity of the cross-valley circulation which lasted for three and a half hours was 4 m/s. The valley wind reappeared first at 750m level at 17h30. This system reached the surface only at 18h00 and continued to blow for the remainder of the observation period (Fig 8.4a).

The local valley circulations of the 29th were overlain by gradient southeasterlies whose velocity did not exceed 6 m/s (Fig 8.4 d). A tongue of south-westerly winds overlay the valley wind between 08h30 and 10h00.

The synoptic field during the 29th did not differ from that of the 28th (Appendix B). An elevated temperature inversion occurred at 03h40 on the 29th between 1100m and 1250m. The inversion descended to between 600m and 1100m by 13h30. This descent in the elevated inversion resulted in the restriction of the flow depth between 06h00 and 12h00.

The reduction in the depth of the mountain wind was again identified during this case. The velocities of both the valley and mountain winds were as in the other cases of the order of 2m/s. The tendency for the valley wind to deepen towards mid-day was again apparent on the 29th. What is unique for this case is the occurrence of a southwesterly cross-valley flow interrupting the valley flow. This could have been caused by a differential heating of the slopes. The south-easterly gradient flow which overlay the valley bottom circulation was less than 6 m/s.

8.5 THE SEQUENCE OF THE 30th AND 31st OF JANUARY, 1992

The circulation on the 30th was characterized by the
occurrence of southeasterlies at Jonkershoek. This system was deep and persisted upto ridge level. The southeasterlies deepened to 1600m at 16h00. Between 16h00 and 20h00, the system depth gradually decreased so that by 20h00, the depth of this regime was only 700m (Fig 8.5 a). A low level jet appeared within the southeasterlies at 11h00. The core of the jet was at 400m with a velocity of 16 m/s (Fig 8.5 b). A shallow southwesterly cross-valley flow whose depth was 100m occurred between 12h30 and 20h00. The velocity of the cross-valley flow which seems to charecterize the mid-day valley bottom circulationin summer was 6 m/s.

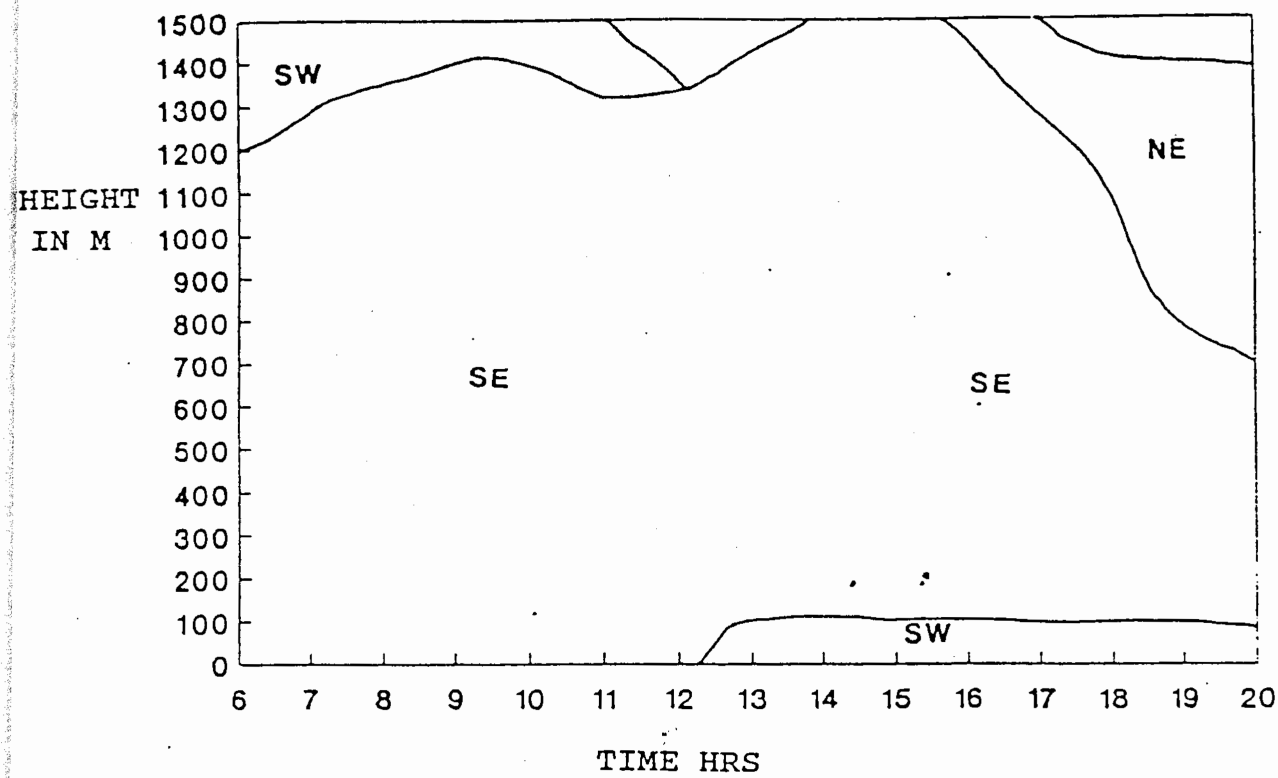


Fig 8.5 (a) Time-height sections to show local winds in the valley for the 30th of January.

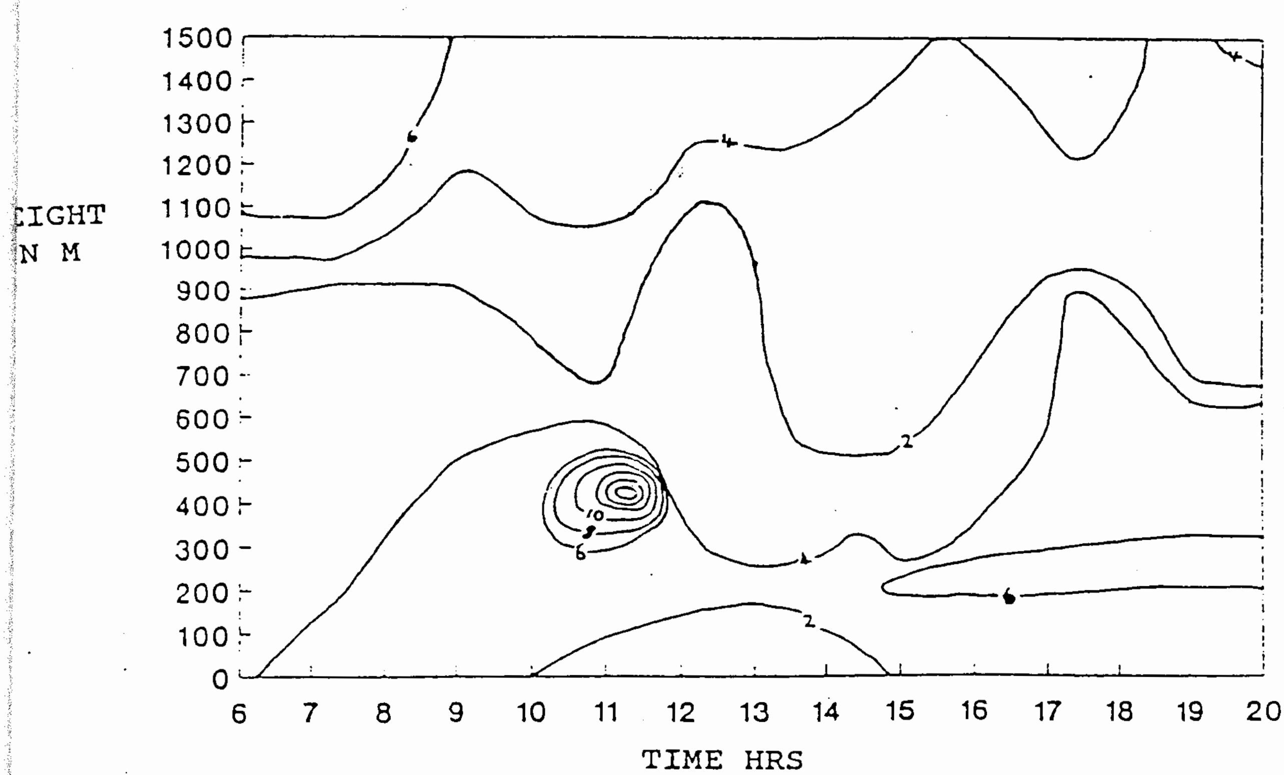


Fig 8.5 (b) Time-height sections of hourly along-valley components for the 20th of January. Isotachs in m/s.

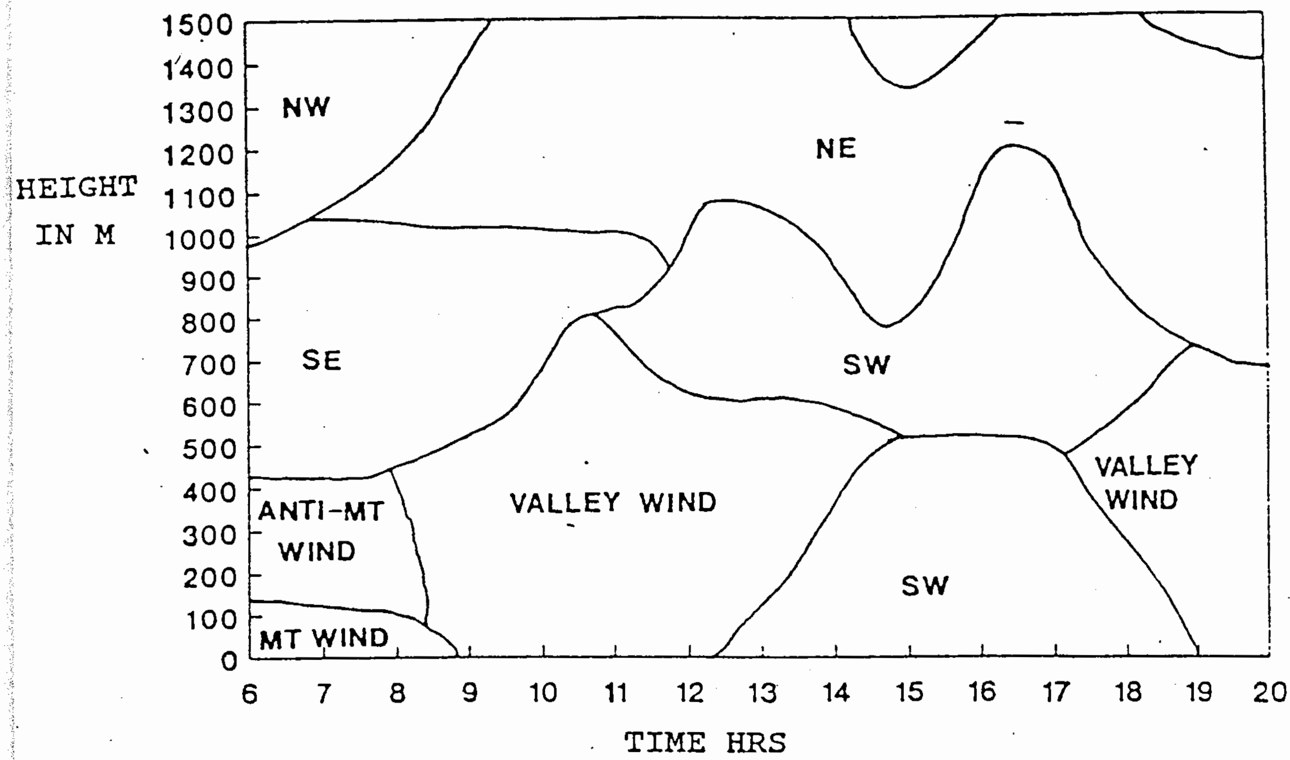


Fig 3.5 (c) Time-height sections to show winds in the valley for the 31st of January.

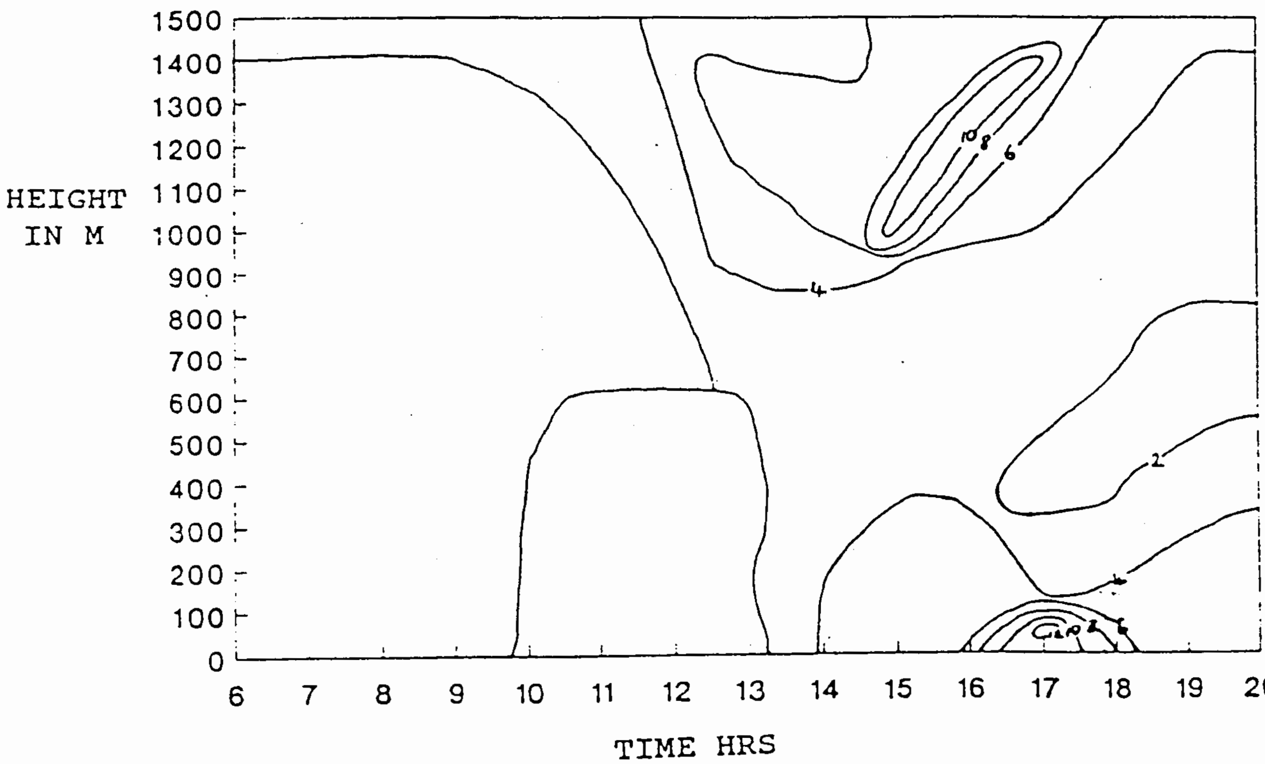


Fig 3.5 (d) Time-height sections of hourly along-valley components for the 31st of January. Isotachs in m/s.

The southeasterlies were overlain by gradient southwesterlies until 12h00. Northeasterly warm air advection overlay the valley bottom southeasterlies after 12h00. From Appendix B, it can be seen that the South Western Cape was under the influence of a ridging high pressure cell. This was responsible for the persistence of southeasterlies at Jonkershoek. Appendix C shows that an elevated temperature inversion occurred between 1100m and 1250m at 01h40. The inversion lifted to between 1600m and 1800m by 21h30. This lifting allowed for the deepening of the southeasterly flow between 14h00 and 16h00.

It is of interest to note the occurrence of a cross-valley circulation under the persistence of weak southeasterlies within the valley.

On the 31st, local circulations were established at Jonkershoek (Fig 8.5 c). A 125m deep mountain wind reversed to up-valley at 08h50. The velocity of the mountain wind was 2 m/s (Fig 8.5 d). The anti-mountain wind which overlay the mountain wind of the 31st was deeper than the mountain wind. It occurred between 125m and 420m. The velocity of this opposing current was of the same magnitude as that of the mountain wind.

The valley wind which terminated the mountain wind was first experienced between 50m and 500m at 08h00. By 08h30, the system had reached the surface. The valley wind deepened gradually to a depth of 850m at 11h30. The strength of this system was below 2m/s. A cross-valley flow interrupted the valley wind of the 31st between 12h30 and 19h00. The velocity of the cross-valley flow reached 12 m/s at the surface at 17h00. This was the time at which the cross-valley flow reached its maximum flow depth of 550m. The valley flow was resumed first at 500m level at 16h30. This occurred at the surface only at 16h30. This valley circulation blew for the remainder of the observation period.

The local valley circulations of the 31st were overlain by southeasterlies until 12h00. Southwesterlies followed and blew till 19h00. These were followed by a northeasterly warm air advection which persisted upto ridge level.

It can be seen from Appendix B that on the 31st, the South Western Cape was under a saddle between the South Atlantic and the South Indian Anticyclones. This would explain the variability of winds above the local circulations. The inversion layers between 1100m-1300m and 1600m-1750m lifted to 1250m-1750m (Appendix C).

The depth reduction of the mountain wind prior to reversal was again apparent on the 31st, so was the deepening of the valley wind circulation at mid-day. The velocities of the local circulations were again below 2 m/s. The valley wind first appearance above the surface was again observed. The cross-valley circulation which was not observed during any of the late winter cases occurred on the 31st. What seems to be a summer phenomenon at the Jonkershoek valley is the persistence of valley winds past 20h00. Valley winds were found to have the longest duration during this season at Jonkershoek (see section 7.1)

8.6 THE SEQUENCE OF THE 7th AND 8th OF MARCH, 1992

The 7th of March was characterized by the occurrence of mountain winds at the Jonkershoek valley bottom. This regime was terminated at 10h00 (Fig 8.6 a). The depth of this mountain wind was 400m. The mountain wind of the 7th underwent a reduction in depth to 200m prior to its final

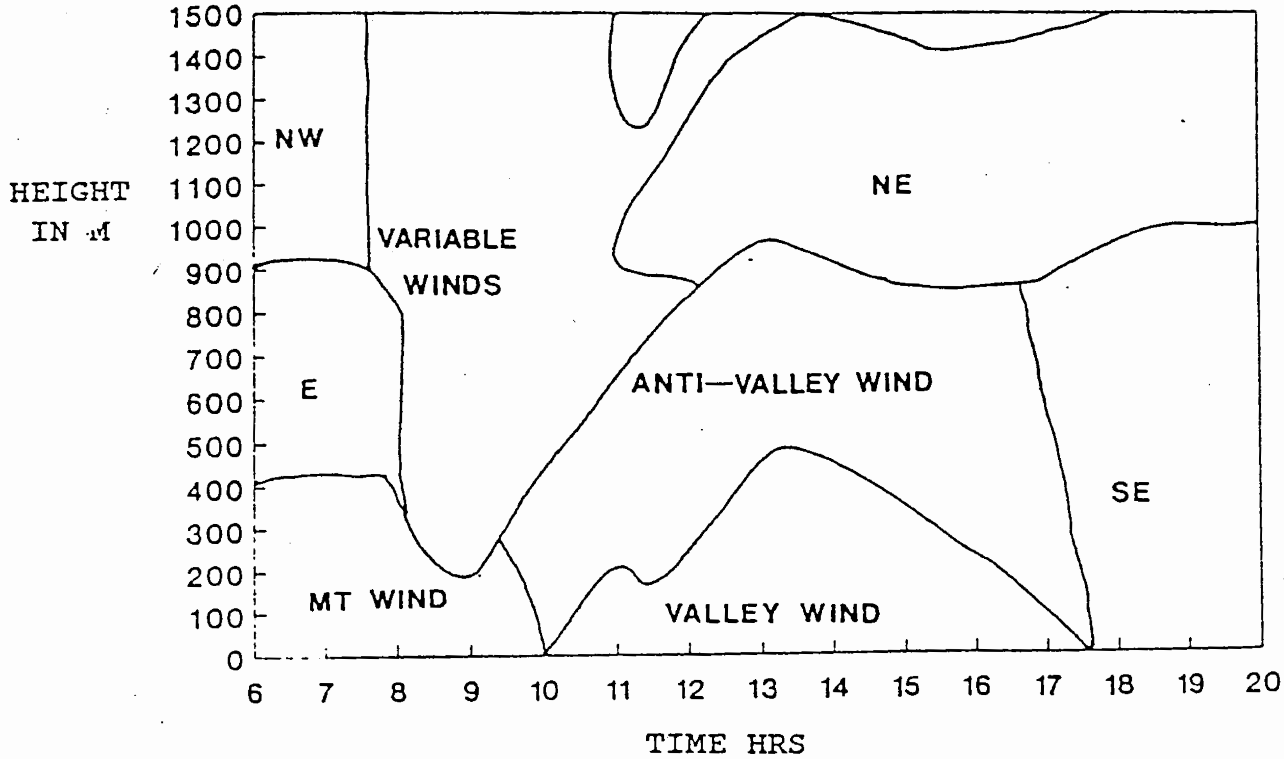


Fig 8.6 (a) Time-height sections to show winds in the valley for the 7th of March.

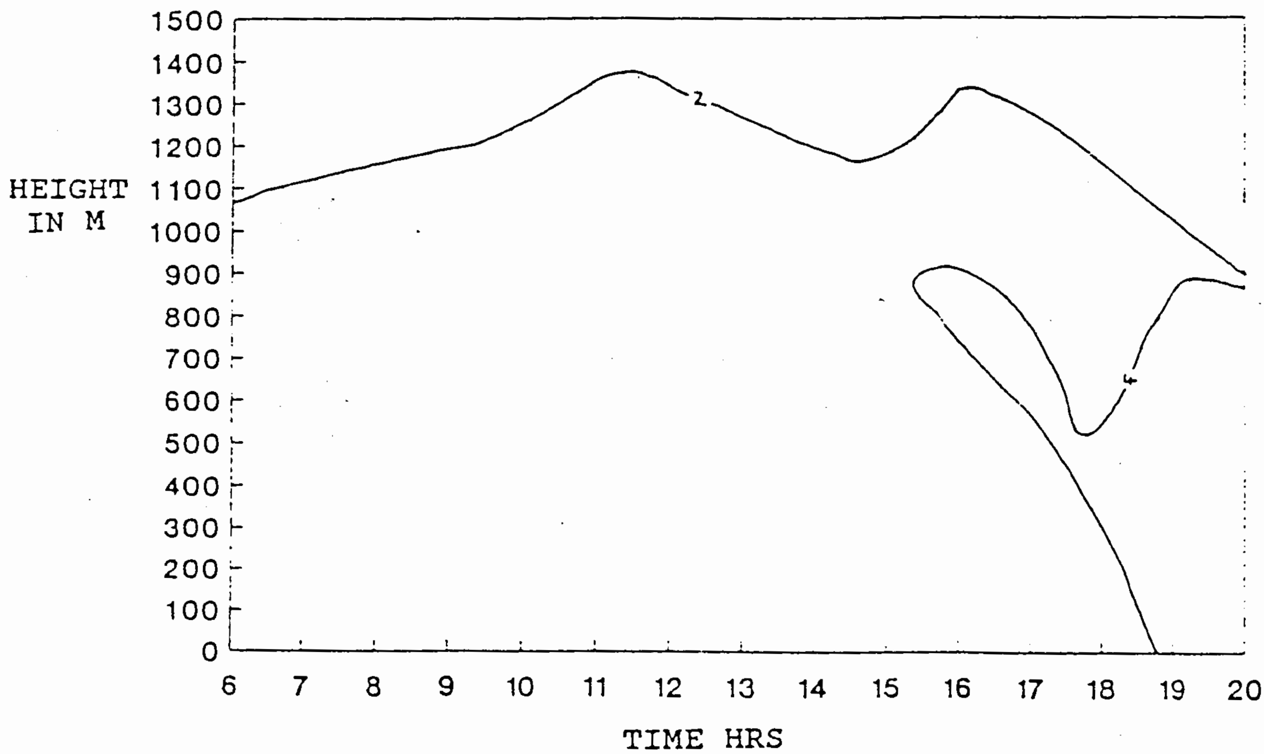


Fig 8.6 (b) Time-height sections of hourly along-valley components for the 7th of March. Isotachs in m/s.

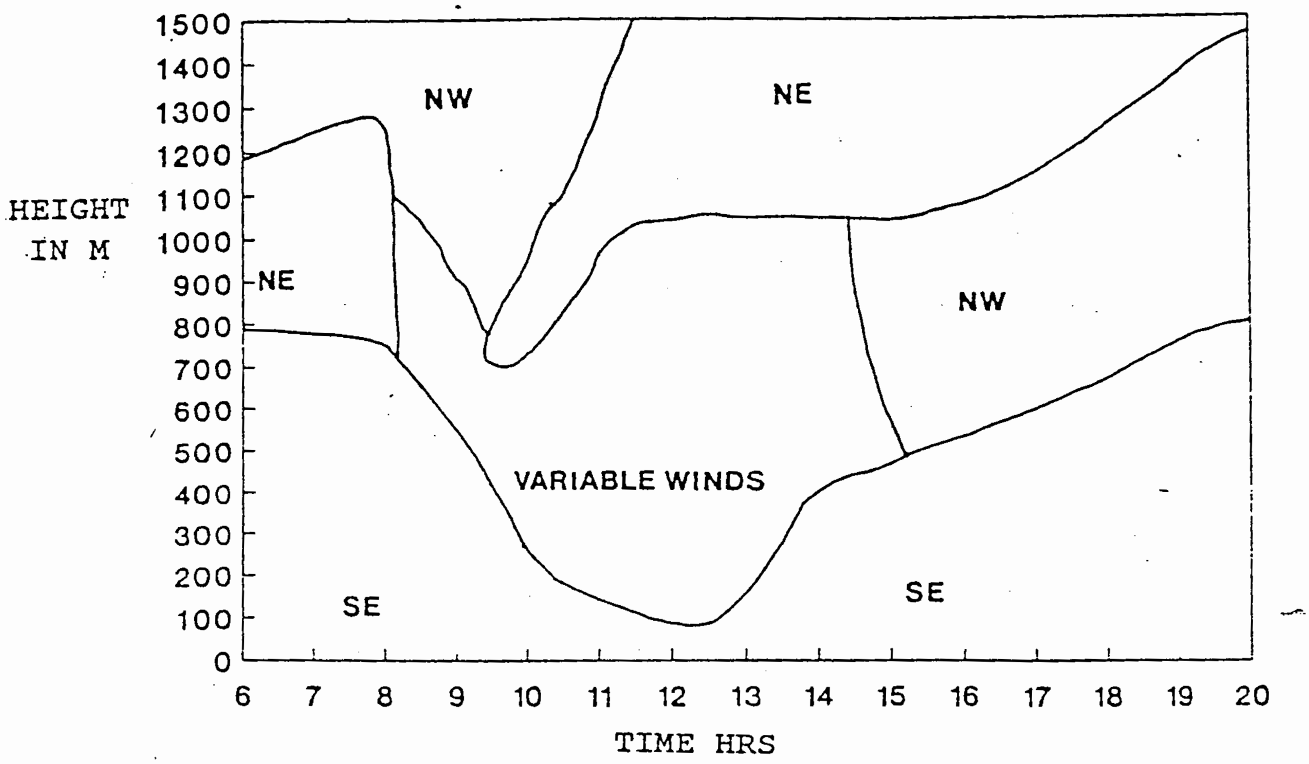


Fig 8.6 (c) Time-height sections to show winds in the valley for the 8th of March.

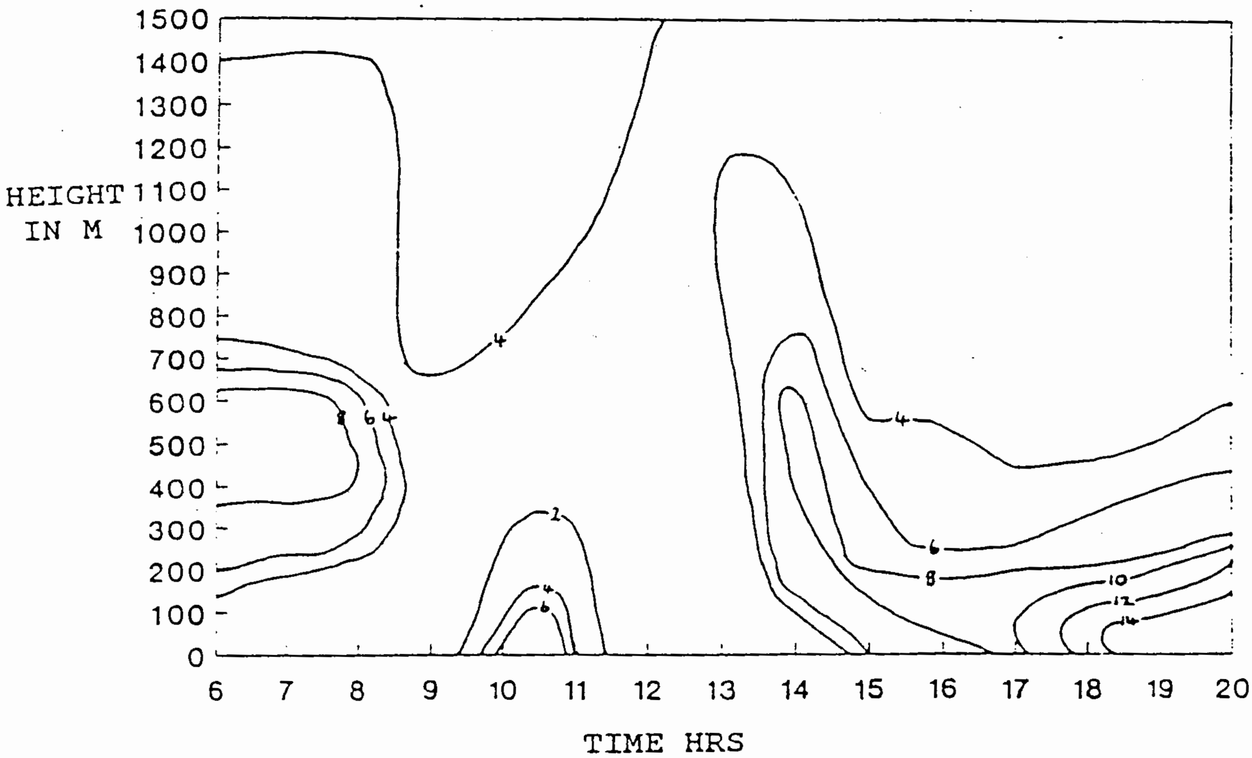


Fig 8.6 (d) Time-height sections of hourly along-valley components for the 8th of March. Isotachs in m/s.

cessation. The velocity of the mountain was of the order of 2 m/s (Fig 8.6 b).
The valley wind which terminated the mountain wind during this case was first experienced at the surface. This regime subsequently deepened to a maximum depth of 500m at 13h00. The valley wind of this case was overlain by a return current of the anti-valley wind. This return current reached a depth of 1000m. The velocities of both the valley wind and the anti-valley wind were of the order of 2 m/s. The cessation of the valley flow occurred first above 100m.

The valley flow of the 7th was terminated by the arrival of gradient southeasterly winds at the surface at 18h00. A low level jet whose core velocity was 12 m/s occurred at 50m level at 19h30.

The valley bottom local circulation was overlain by easterly winds between 06h00 and 08h30 (Fig 8.6a). Easterlies persisted upto a height of 900m. Above the easterlies, gradient northwesterlies prevailed to above ridge level. Variable winds interrupted this three layered flow between 08h30 and 12h00. From 12h00 onwards, light north-easterly warm air advection occurred upto ridge level. Northwesterly winds persisted above ridge level.

Appendix B shows that on this case, the South Western Cape was under the influence of a saddle between the South Atlantic and the South Indian high pressure cells. Juehnke and Fuggle (1979) associated such a saddle with warm and settled conditions. The saddle permitted the establishment of local valley circulations within the valley. It can be seen from Appendix C that the height of the elevated temperature inversion was low at 01h02 (between 350m and 600m). This inversion was strong ($6^{o}C$). The inversion layer lifted to between 600m and 750m by 12h32. This lifting was accompanied by a reduction in inversion strength to $4^{o}C$. This reduction in the strength of the inversion could have continued by day so that by 18h00, the gradient southeasterlies were able to reach the valley bottom.

This event conforms to Jury's (1987) characterization of shallow southeasterlies. The pre-reversal reduction in the depth of the mountain wind was again evident during the above case. So was the deepening of the valley wind to a mid-day maximum depth. The velocities of the local winds also remained below 2 m/s. The occurrence of a low level jet within the southeasterly winds was again observed. No mid-day cross-valley southwesterly circulation during this case, a probable indication that this flow only occurs during the warmer months of the summer season.

The valley bottom gradient southeasterlies which were established on the 7th continued to blow on the 8th (Fig 8.6 c). The velocity of this system was above 4 m/s (Fig 8.6 d). A low level jet appeared within the southeasterlies of the 8th at 18h15. The core of this jet was located at 100m and the core velocity was 14 m/s. The southeasterlies were reduced in depth between 08h00 and 12h30. At 12h30, the depth of this system was 100m from 800m between 06h00 and 08h00.

The southeasterlies were overlain by northeasterlies between 06h00 and 08h00. The velocity of the northeasterlies was between 2 m/s and 4 m/s. Between 08h00 and 15h00, the valley bottom southeasterlies were overlain by light and variable winds. A tongue of northeasterlies appeared above the variable winds between 10h00 and 15h00. These northeasterlies overlay the southeasterlies till 20h00.

According to Appendix B, a high pressure centre was ridging to the south of the subcontinent on the 8th. The vertical temperature structure on this case was almost isothermal between 350m and 750m at 13h03. This case was again representative of shallow southeasterlies with the occurrence of a low level jet.

CHAPTER NINE

SUMMARY AND CONCLUSIONS

9.1 THE CLIMATOLOGY OF JONKERSHOEK

The four phases identified by Jury(1980) and Garstang and Diab (1984) occur in the vicinity of the Jonkershoek valley. The most predominant wind regime is the southeasterly regime. This wind regime dominates the Jonkershoek circulation in all seasons of the year. Southeasterlies at Jonkershoek have a peak in occurrence in early summer (October-December). Southeasterlies are least frequent in late winter (July-September). Although no clear differentiation was made between the deep and shallow southeasterlies in this study, a close scrutiny of wind direction frequency data seems to suggest that early summer is also the season during which shallow southeasterlies have a peak in occurrence.

In addition to being the most dominant wind regime at Jonkershoek, southeasterlies are also accompanied by the strongest wind velocities at the valley bottom. Southeasterly winds occasionally blow at velocities above 20 m/s. The season with strongest southeasterlies at the valley bottom is the late summer season (January-March). This suggests that fires occurring during this season within the Jonkershoek valley are likely to be most difficult to control. In 1984, the seasonal average for this season was 18.6 m/s. Southeasterlies are weakest in early winter. The 1984 seasonal average for early winter (April-June) was 5.1 m/s.

The next important regime at Jonkershoek is the northwesterly wind regime. The frequency and strength of this wind regime has little interseasonal variations in the vicinity of the Jonkershoek valley. The velocities of this regime averaged around 7 m/s in 1984.

The northeasterly bergwinds display a peak in occurrence in winter. They only contributed 11.3% to the total early winter circulation in 1984. The velocities of the bergwinds are generally below 5 m/s. Although the southwesterly wind regime occurs in the vicinity of the valley, its contribution to the valley bottom circulation is negligible.

9.2 THE RESPONSE OF THE VALLEY BOTTOM ATMOSPHERE TO VARYING SYNOPTIC FIELDS.

9.2.1 LOCAL VALLEY BOTTOM CIRCULATIONS

The development of local valley circulations at Jonkershoek cannot be predicted by looking at the nature of the synoptic phase alone. A conclusion that is drawn from observations made during this study is that ambient wind velocities together with inversion strengths are the two most reliable predictive tools of valley bottom circulations. It must be noted that these local wind sysytems occur under varying synoptic regimes. It is therefore suggested here that the synoptic field alone cannot be used as a reliable predictive tool for valley bottom circulations. The ambient wind velocities and strengths of elevated temperature inversions have a more controllong influence upon the valley bottom circulations. Ambient wind velocities weaker than 6 m/s and elevated temperature inversions (whose heights are below ridge level) whose strength is stronger than 3^{o}C are required for the development of valley bottom local wind systems. Ambient winds stronger than 6 m/s occurring with inversions weaker than 3^{o}C were found to prevent the development of local valley bottom circulations.

The development of local valley bottom circulations at Jonkershoek is encouraged by the persistence of anticyclonic conditions over the south western Cape. Saddles are particularly conducive to the development of well established valley bottom circulations in the form of nocturnal mountain and daytime valley circulations. The depths of these local wind systems is dependent upon the heights of the accompanying elevated temperature inversions. Elevated temperature inversions occur mostly at heights that are below ridge level. This decouples the valley atmosphere from that aloft.
The elevated temperature inversions in the vicinity of the Jonkershoek valley have a tendency of descending by day. This limits the daytime flow depth of the valley bottom circulations to a few hundred metres by midday. The strength of the southeasterly winds which normally overly the valley bottom mountain and valley winds was found to be below 6 m/s just above the valley circulations. The gradient winds which overly the valley bottom local circulations are predominantly from the westerly quadrant. The occurrence of southeasterlies at the summit station is normally accompanied by the backing of the winds to northeasterly as the day proceeds.

9.2.2 THE CHARACTERISTIC OF MOUNTAIN AND VALLEY WINDS AT JONKERSHOEK.

Nocturnal mountain winds occur at Jonkershoek in both summer and winter. Mountain winds at Jonkershoek are initiated mostly between 18h00 and 20h00. The mountain wind of this valley is terminated earlier in summer than in winter. Summer cessation occurs between 08h00 and 09h00. In winter, this occurs between 10h00 and 13h00.

After onset, the mountain winds deepen gradually to depths of around 400m. This occurs between 17h00 and 21h00 at Jonkershoek. The velocity of this system is of the order of 2 m/s. Mountain wind velocities stabilise during the nocturnal period.

Occasionally, pre-reversal surges in the mountain wind of Jonkershoek occur. This was observed for the mountain wind of the 27th of July, 1990. Surges occur about an hour before final cessation.

Mountain winds undergo a reduction in their flow depth about an hour or two prior to reversal. Mountain winds at Jonkershoek can reach a height of 800m. The mountain wind of the morning of the 27th of July in 1990 was 850m deep. Anti-mountain winds occasionally overly the mountain winds of Jonkershoek. These usually are of the same depth and magnitude as the mountain winds that they overly. The height of the elevated temperature inversion is a significant determinant of the depth of the anti-mountain winds. When they occur, anti-mountain winds are terminated an hour before the final cessation of the mountain wind by the lowering of the inversion depths.

The valley winds at Jonkershoek are initiated between 08h00 and 09h00 in summer. In winter, initiation is later. It occurs between 10h00 and 13h00. The cessation of this system occurs mostly at 18h30 in winter. In summer, this system occasionally blows past 20h00. All valley winds deepen after onset. The time of maximum depth occurs at midday, during the time of maximum solar heating. Although valley winds are of the order of 2 m/s, seasonal averages display that they generally accelerate by day to reach maximum velocities around midday. Strongest valley winds in the vicinity of Jonkershoek occur in summer. There are cases during which the onset of valley winds at Jonkershoek occurs first above the surface, at heights of about 400m.

Occasionally, valley winds are overlain by a return current of the anti-valley wind. This is usually of the same depth and magnitude as the valley wind. Valley winds of Jonkershoek occasionally reach depths of 1000m. This occurred on the 13th of August of 1990.

In summer, it is not infrequent for valley winds to be interrupted by southwesterly cross-valley winds whose magnitude is usually more than that of the valley winds. Cross-valley flows can reach 12 m/s. This wind system is a summer phenomenon at the Jonkershoek valley and does not appear during winter months.

9.2.3 THE MODIFICATION OF GRADIENT SOUTHEASTERLIES AND NORTHWESTERLIES.

Deep gradient southeasterlies occur in the vicinity of the Jonkershoek valley. These are associated with inversion layers which occur either above or slightly below ridge level. Gradient southeasterlies are able to fill the valley during such cases. Gradient southeasterlies at Jonkershoek are characterized by leeward acceleration. Valley bottom southeasterlies are stronger than those occurring both at the summit or at the airport. In addition to the general leeward acceleration of this regime which can reach velocities of above 20 m/s at Swartboskloof, the southeasterlies display a general tendency towards nocturnal strengthening. This is related to the develoment of higher pressures at the valley's head and relatively lower pressures at the exit by night.

Another characteristic feature of the Jonkershoek southeasterlies is the occurrence within the valley atmosphere of low level jets. The cores of these jets range in height from 100m to 400m. The core velocities range from 14 m/s to 18 m/s. Low level jets are daytime to early evening features of this wind regime within the valley. The depth of the southeasterlies at Jonkershoek is responsive to the heights of the elevated inversions. Most gradient southeasterlies were found to reach the valley bottom between 06h00 and 15h00 particularly in summer. Surface cessation was concentrated between 19h00 and 07h00.

The Jonkershoek valley does not have much effect on the gradient northwesterlies. This wind regime occurs under an advancing cold front. Local thermo-topographic circulations do not develop during the prevalence of this wind regime particularly because the ambient wind velocities within this regime are usually stronger than 6 m/s in the vicinity of Jonkershoek.

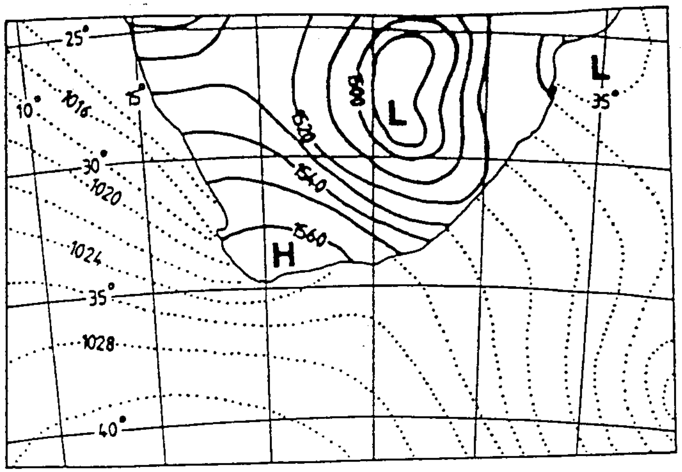
The northwesterlies in the vicinity of Jonkershoek are deep. Both the summit and the valley bottom stations reported winds from the westerly quadrant during all identified cases. The frequencies of this regime is lowest in late summer.

Strong vertical wind velocity shear occurs under the persistence of this regime. Northwesterlies at the summit are stronger than those recorded at both the valley bottom and the airport. Summit northwesterlies are generally above 6 m/s in velocity. Those at the valley bottom can be as weak as 2 m/s. There is a tendency for northwesterlies to be weaker at the valley bottom than at the airport. This suggests that winds at the valley bottom experience more frictional drag than elsewhere over the Western Cape. The velocity trend for the valley bottom during the persistence of this regime is flat, with no apparent fluctuations.

In conclusion, it might be stated that the results from this study provide evidence of the ability of dissected topography to modify the general winds. This feature of valleys allows for the establishment of circulation systems within them.

APPENDIX A

SYNOPTIC CHARTS FOR CHAPTER FIVE



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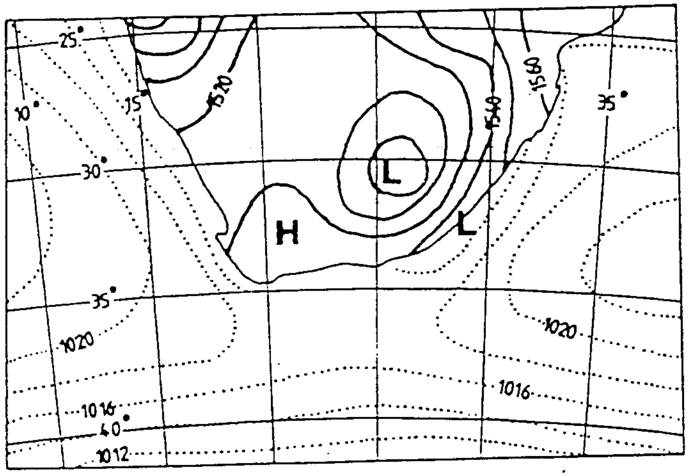

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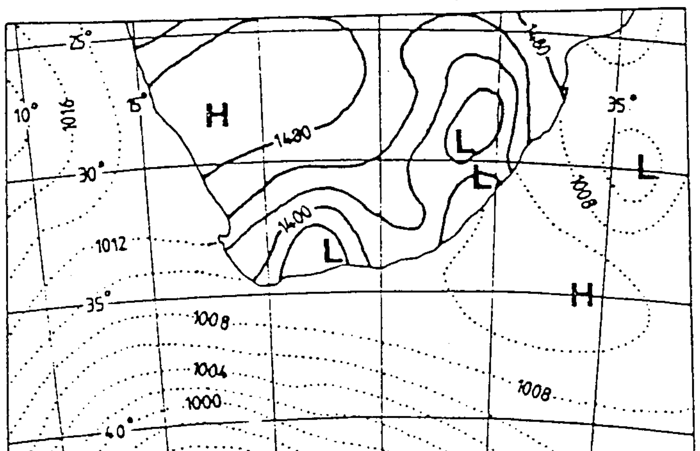

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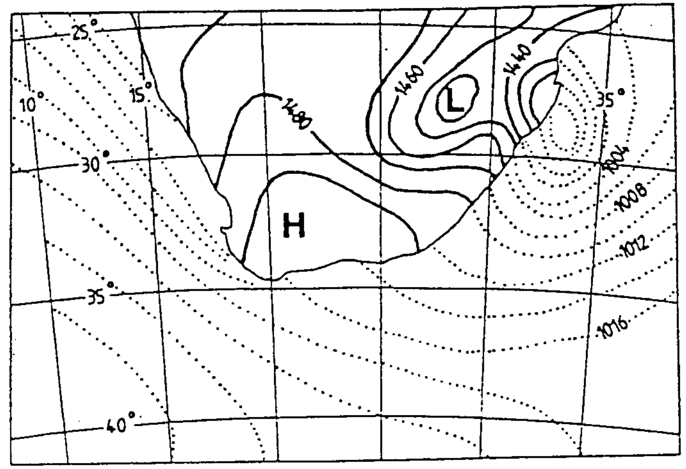
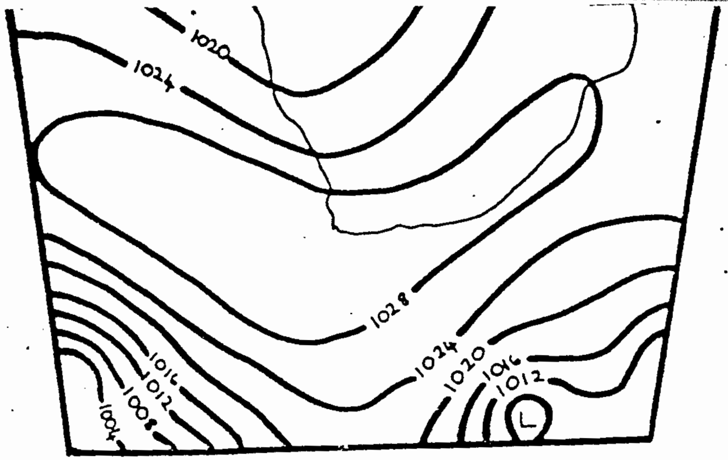


APPENDIX B

SYNOPTIC CHARTS FOR CHAPTER EIGHT

21/07/90



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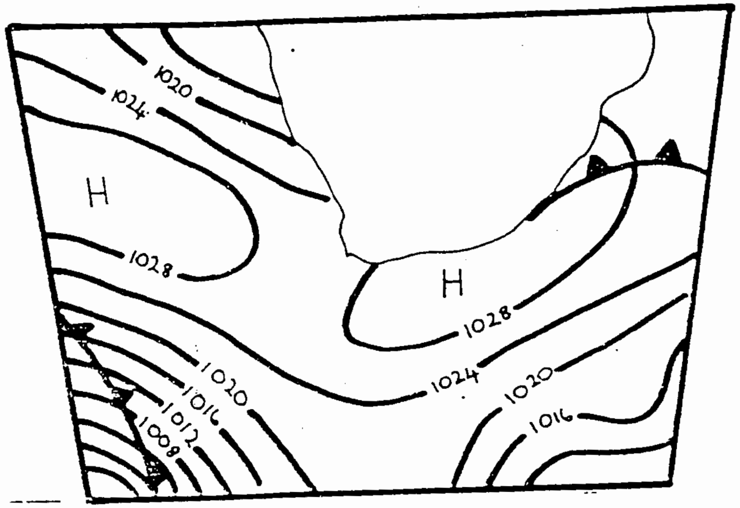

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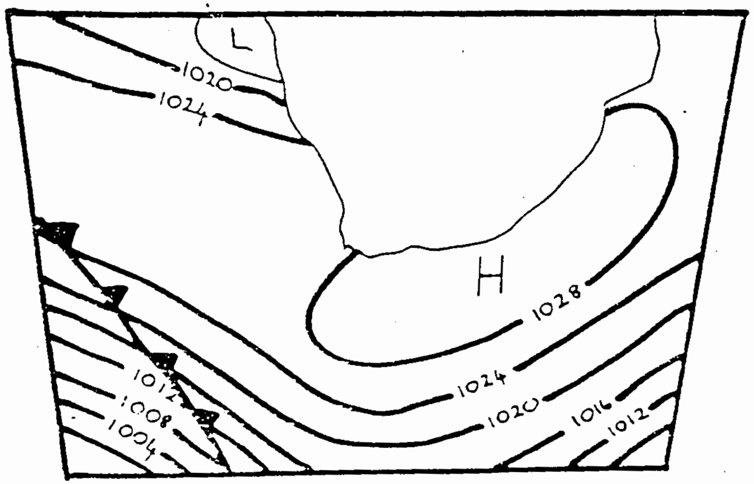

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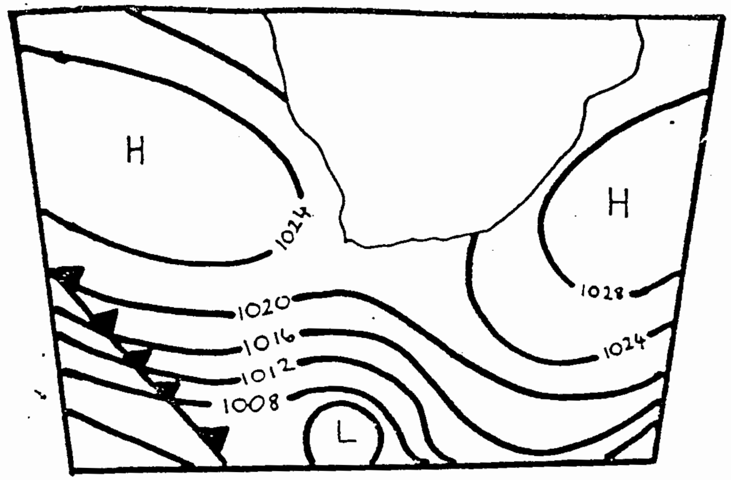

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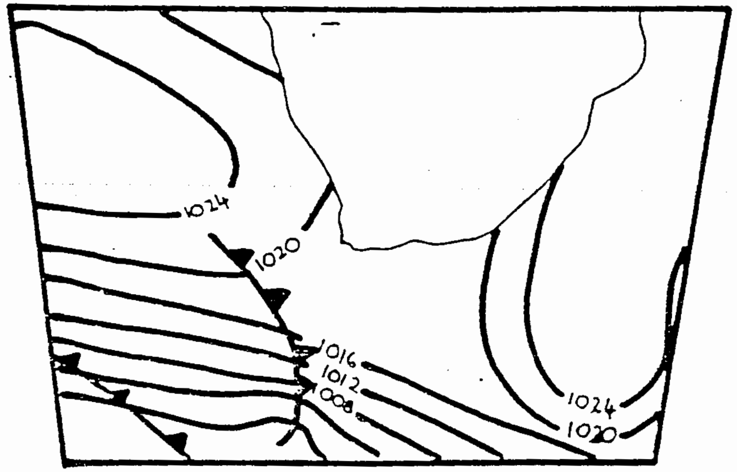

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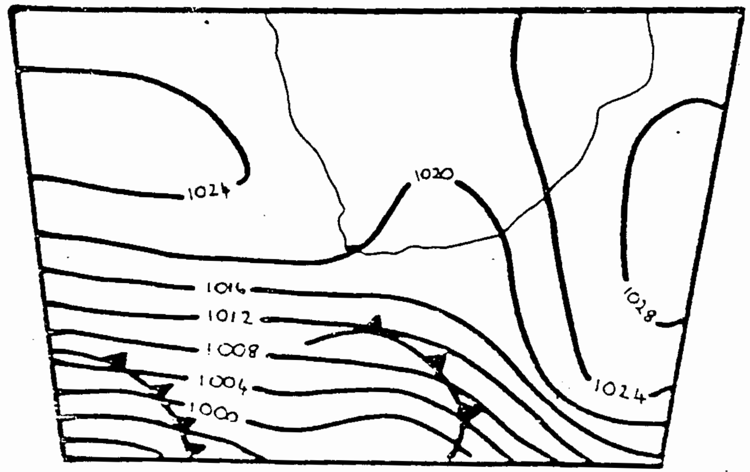

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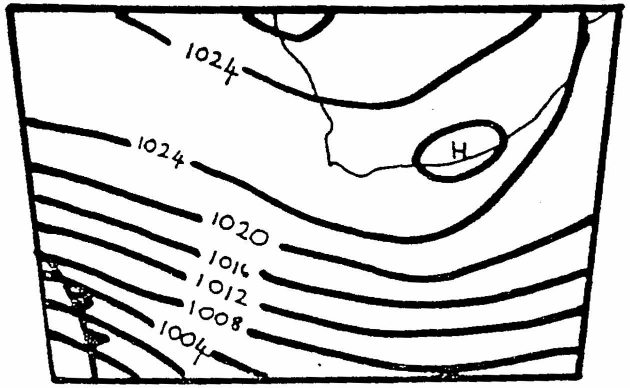

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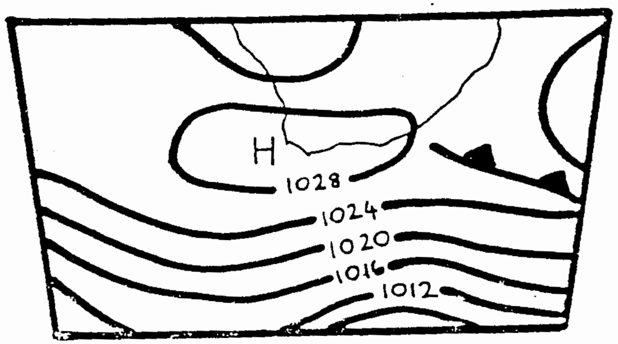

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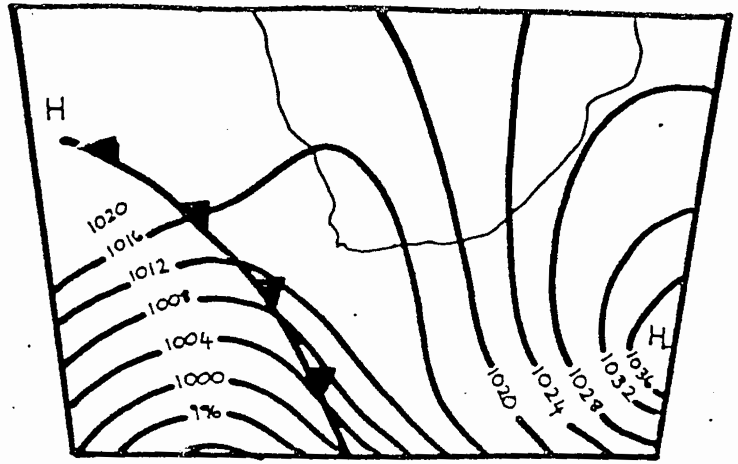

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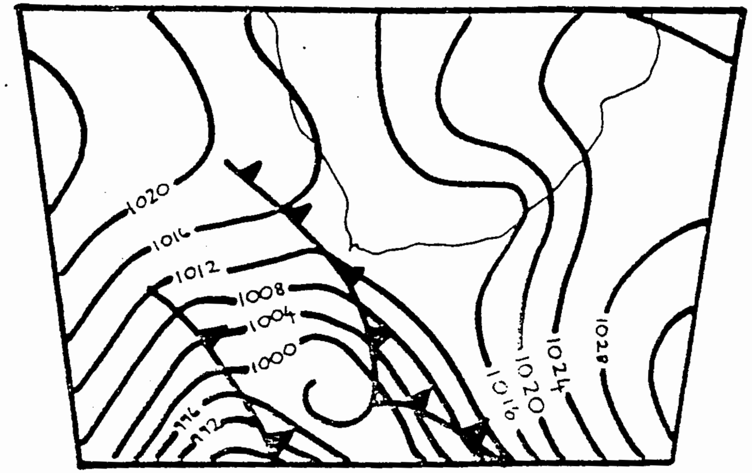

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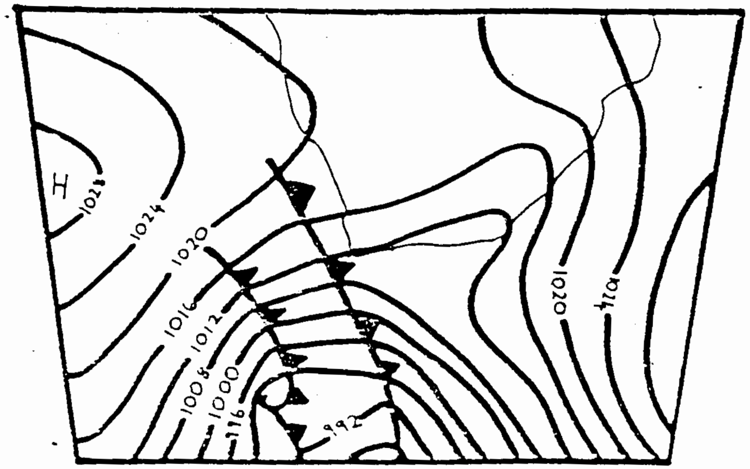

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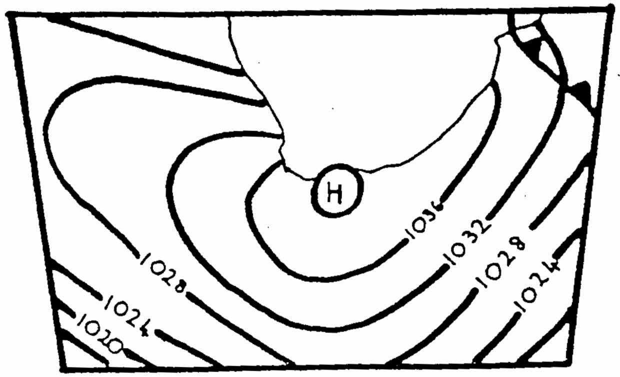
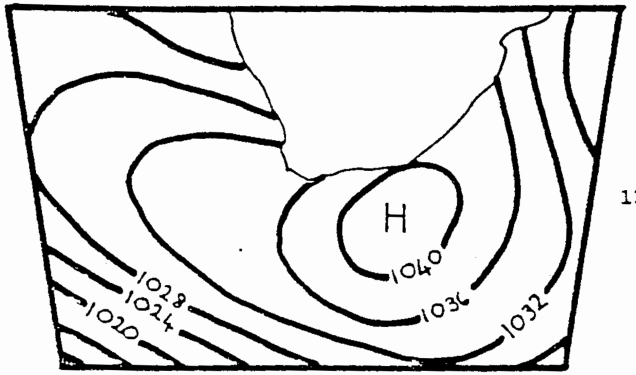


06H00



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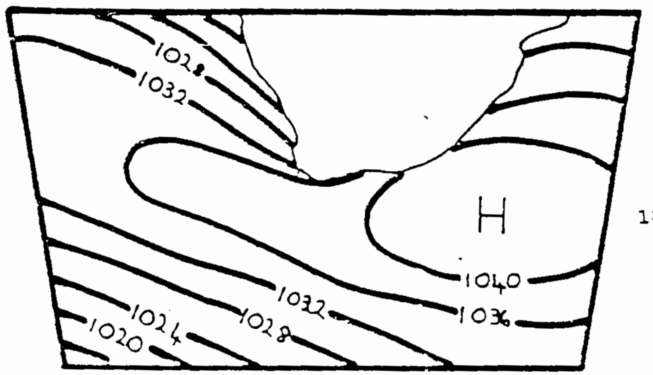
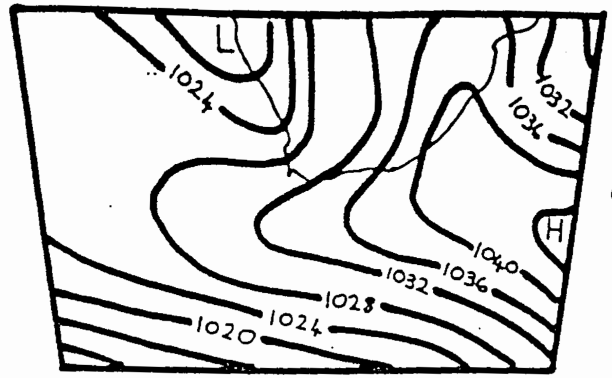


18H00

13/08/90



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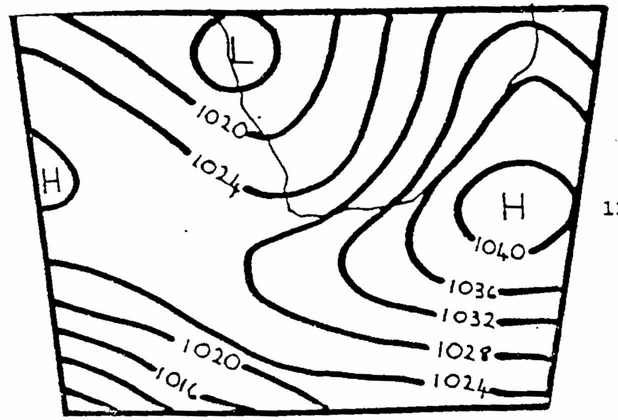

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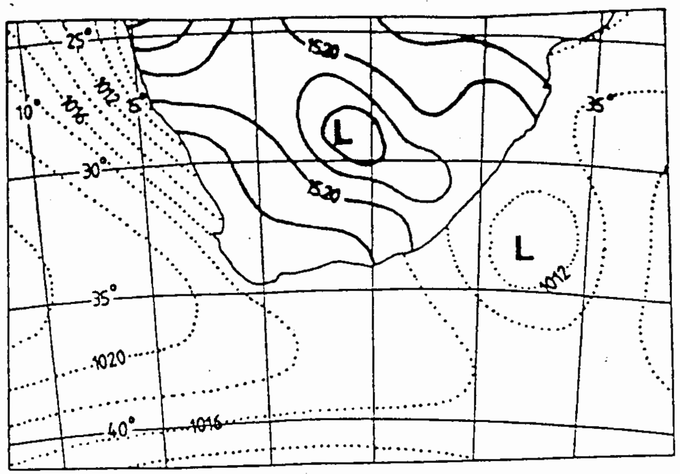
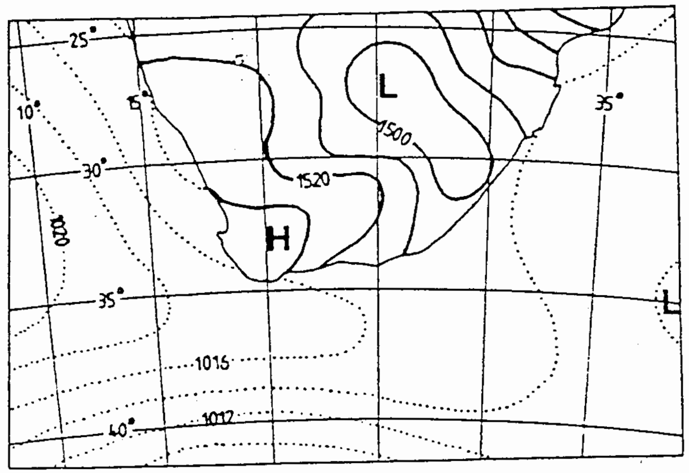
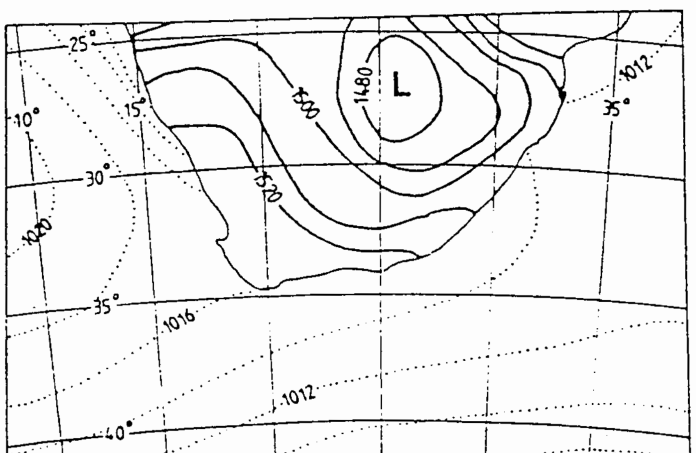


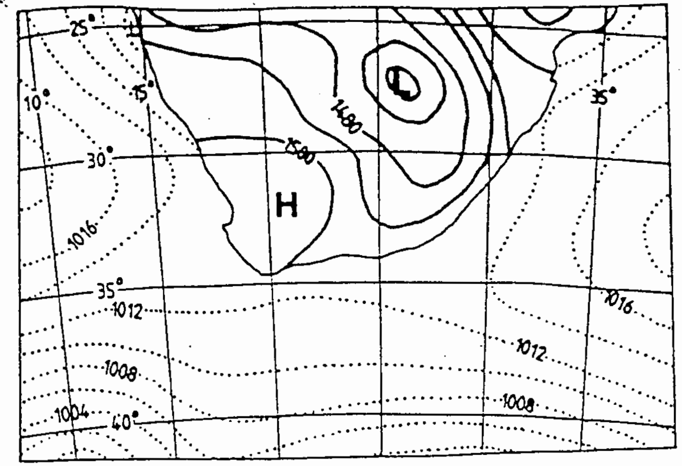
28/01/92



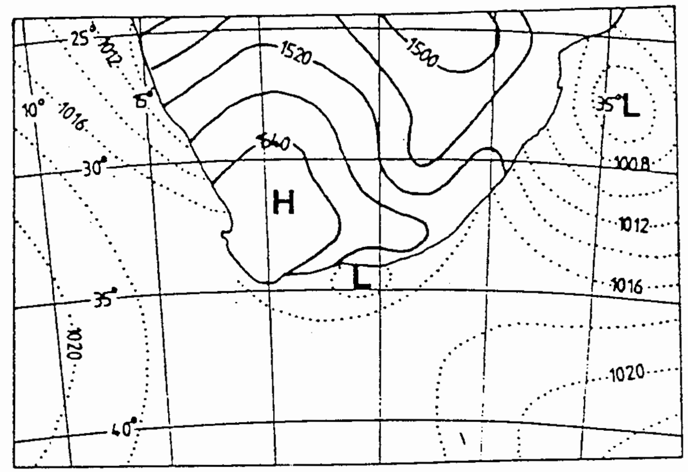
29/01/92



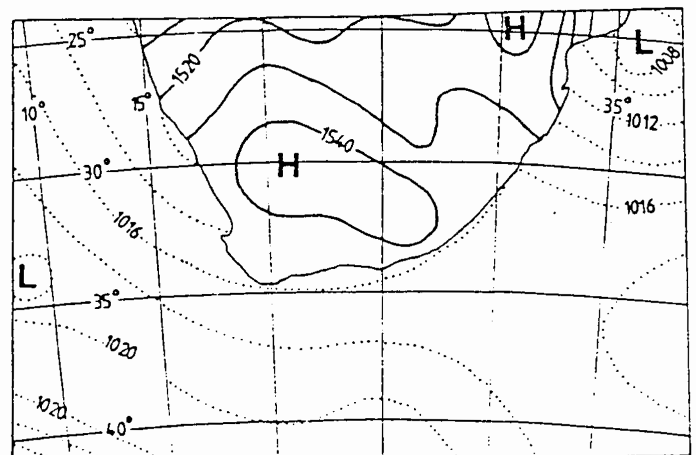
30/01/92



31/01/92



07/03/92

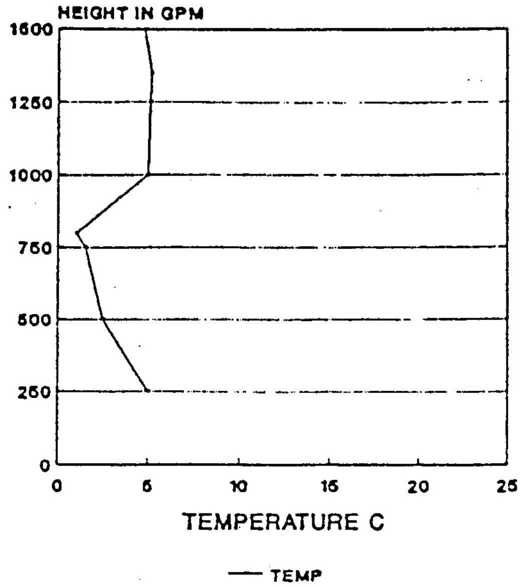


08/03/92

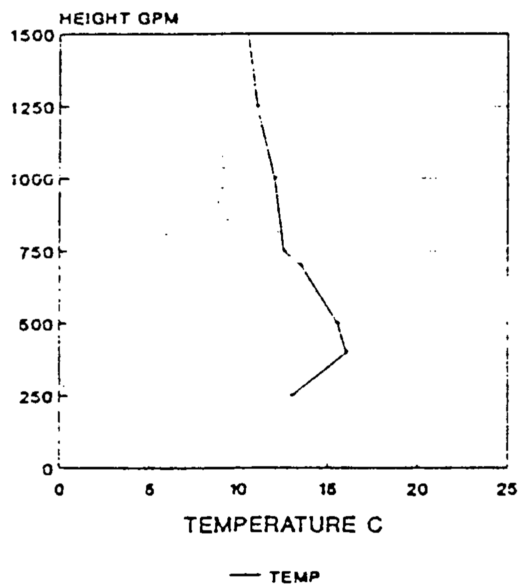
APPENDIX C

VERTICAL TEMPERATURE PROFILES FOR CHAPTER EIGHT

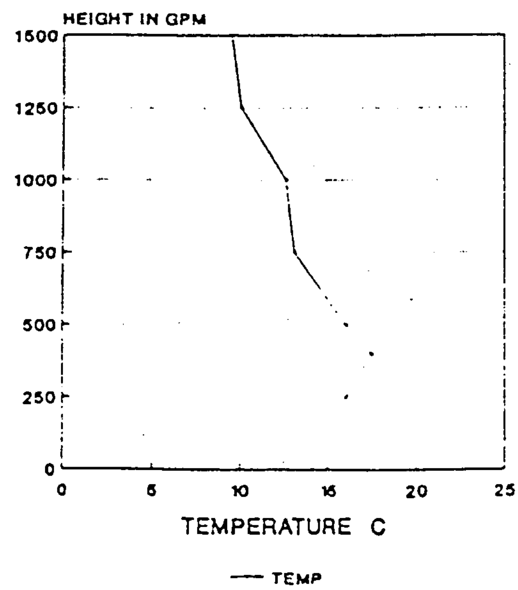
21/07/90
00h00



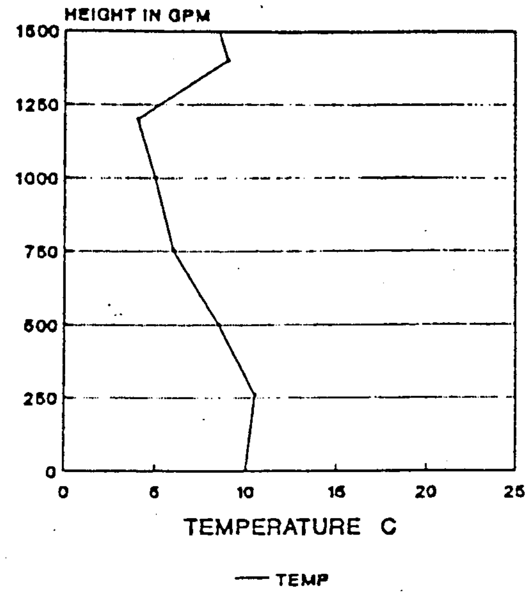
22/07/90
00H00



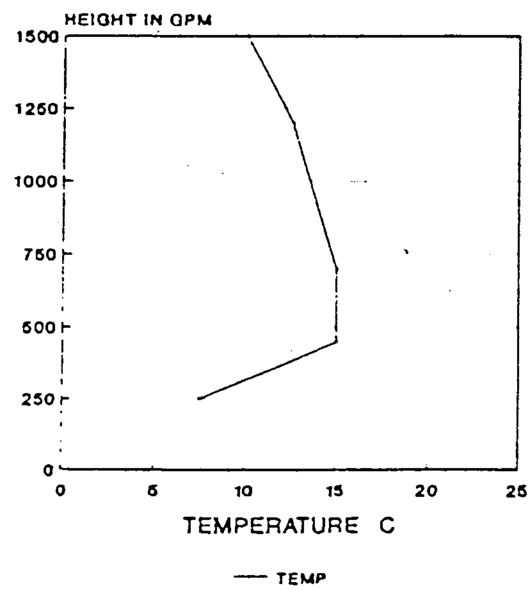
22/07/90
12H00



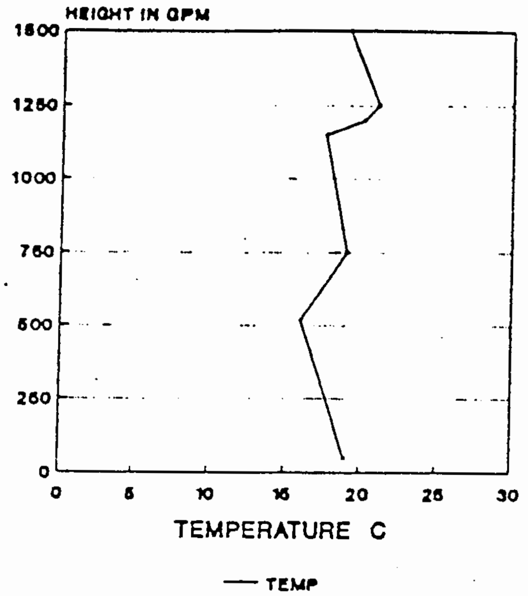
12/08/90
00H00



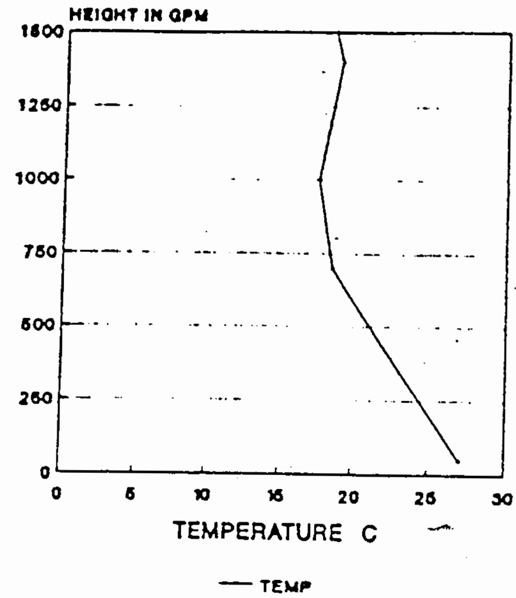
13/08/90
00H00



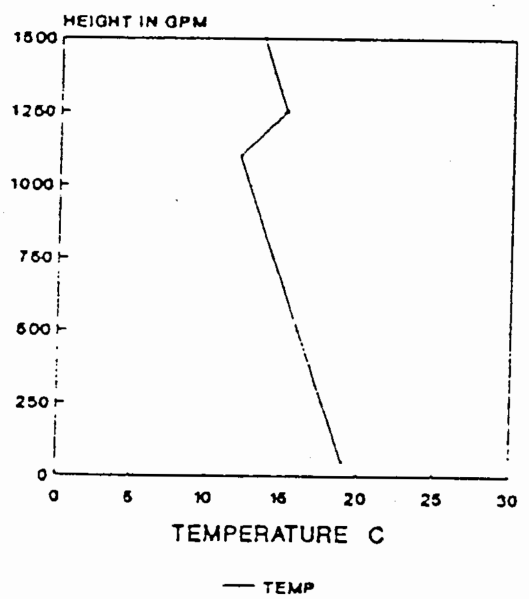
28/01/92
01:29



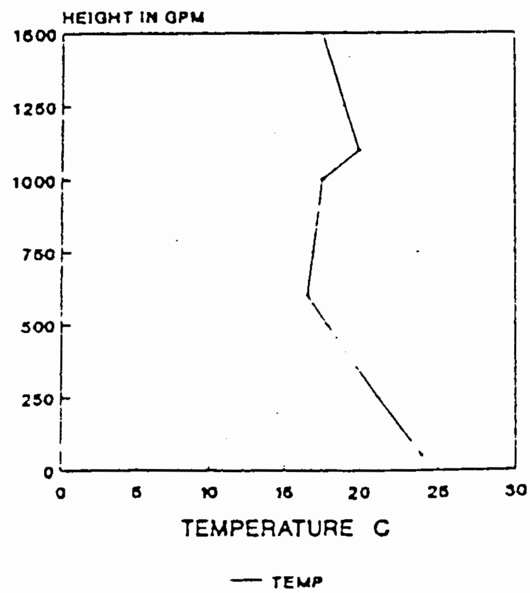
28/01/92
12:38



29/01/92
03:40



29/01/92
12:31



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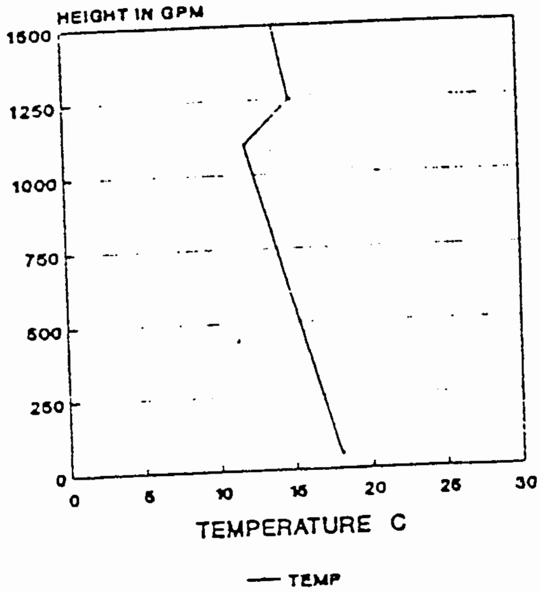

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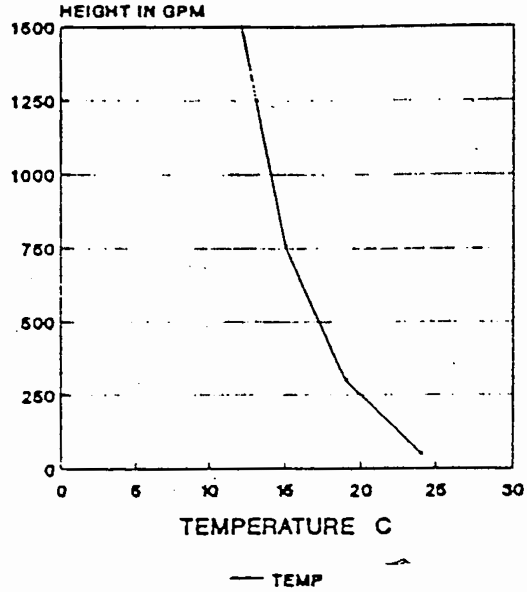

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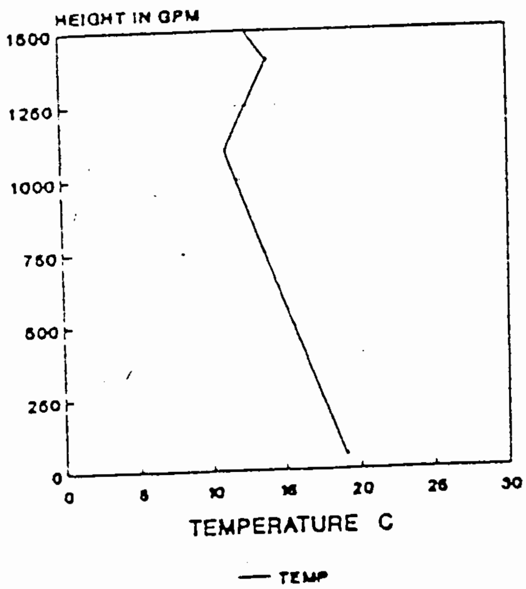

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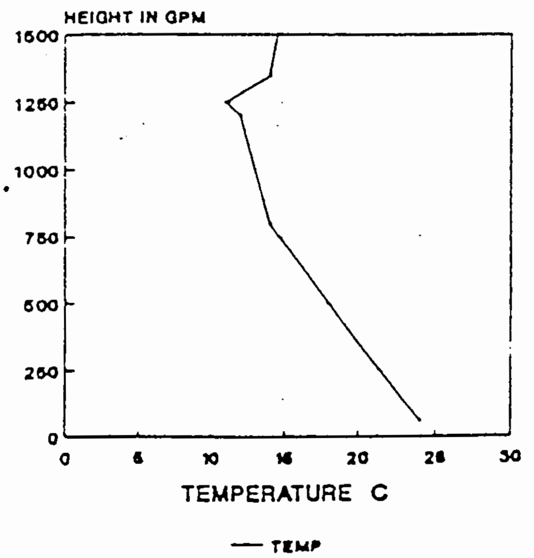
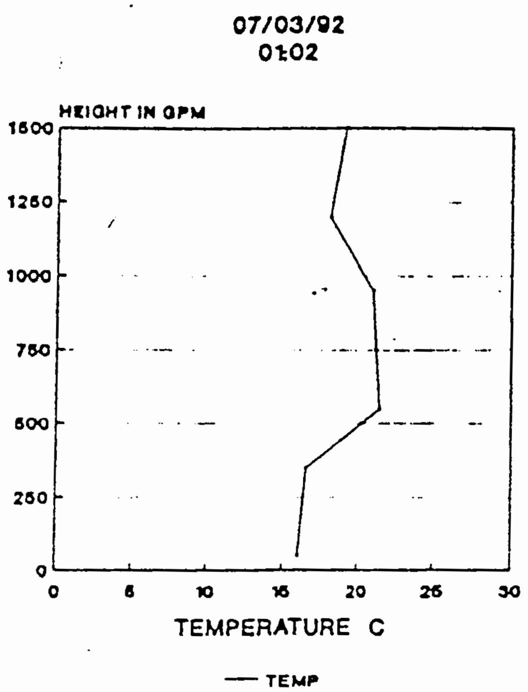
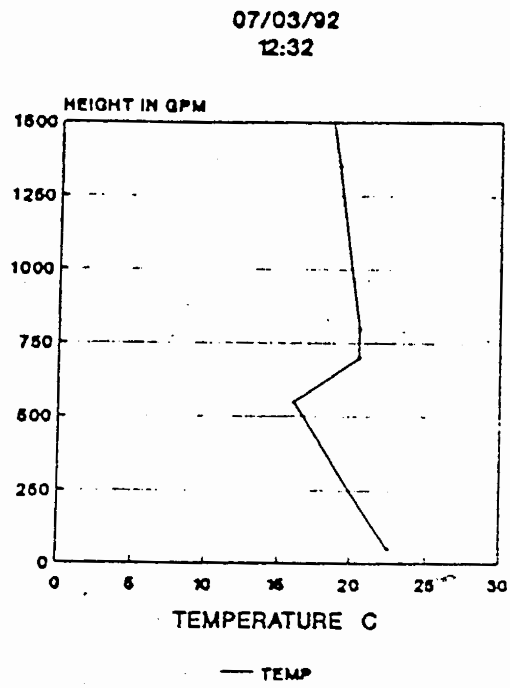



07/03/92
01:02
HEIGHT IN GPM
1500
1250
1000
750
500
250
0
0 5 10 15 20 25 30
TEMPERATURE C
TEMP


07/03/92
12:32
HEIGHT IN GPM
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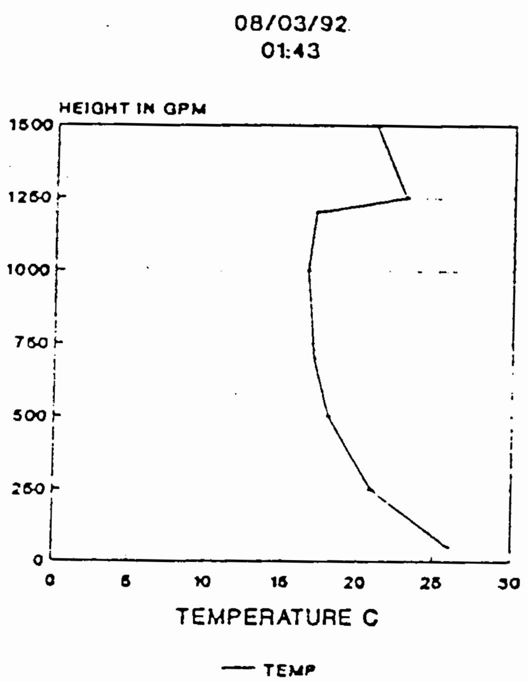
1250
1000
750
500
250
0
0 5 10 15 20 25 30
TEMPERATURE C
TEMP


08/03/92
01:43
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1250
1000
750
500
250
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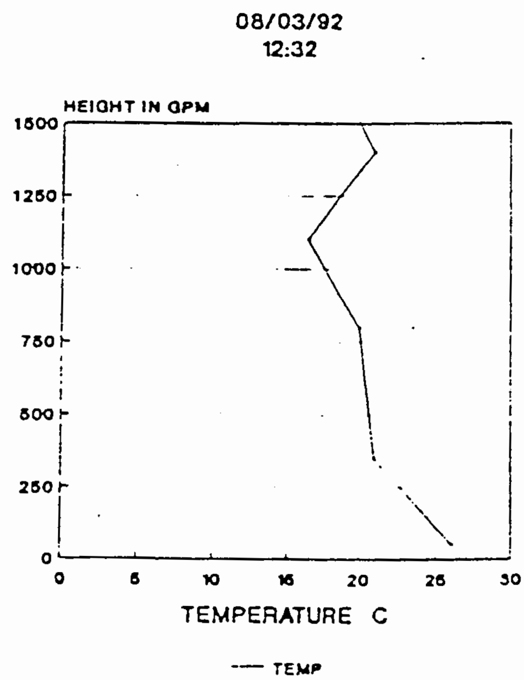
TEMPERATURE C
TEMP


08/03/92
12:32
HEIGHT IN GPM
1500
1250
1000
750
500
250
0
0 5 10 15 20 25 30
TEMPERATURE C
TEMP

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