A SYSTEM FOR PREDICTING BURNING WEATHER
IN THE SOUTH-WESTERN CAPE
MOUNTAIN CATCHMENT AREAS

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ABSTRACT

This study addresses the problem of predicting suitable burning weather for the south-western Cape Province by means of synoptic analysis. Weather which is suitable for veld burning is defined in terms of maximum hourly windspeed (< 16 km/hr), maximum daily temperature (18° - 28°C) and minimum daily humidity (15 - 45%). Synoptic conditions which are associated with favourable burning weather are outlined.

Burning weather in the study area was found to be associated with weak anticyclonic air flow. The pressure configuration which gives rise to the required anticyclonic flow consists of a high pressure cell over the eastern part of the subcontinent, a trough of low pressure along the north-western interior and the location of the climatological high pressure system of the South Atlantic Ocean to the south-west of the subcontinent.

A model five-day sequence of pressure charts was developed for use as an analogue consultation system for predicting burning weather. During a test application of the model five-day sequence it could be shown that the system is useful for alerting catchment managers three days in advance, when to expect weather suitable for controlled burning.

to Irene

"Fire is a good servant
but a bad master"

(Lightfoot, C.J. in Cohen, M., 1973)

"But to have done instead of not doing
this is not vanity
To have, with decency, knocked
That a Blunt should open
To have gathered from the air a live tradition
or from a fine old eye the unconquered flame
This is not vanity.
Here error is all in the not done,
all in the diffidence that faltered."

(Pound, E., 1917: Homage to Sextus Propertius, V,2)

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CHAPTER 1

INTRODUCTION

The literature on fynbos vegetation (figure 1) abounds with discussions on the necessity of fire for fynbos management. Frequency, season, and to a lesser extent the intensity of fire in fynbos have been well documented (Jordaan, 1949; Bands, 1977; Bond, 1980; Kruger, 1977, 1979 and 1982; Van Wilgen, 1981a; Kruger and Bigalke, 1984; Van Wilgen, Le Maitre and Kruger 1985; and many others). Nevertheless, little information exists on the weather patterns and atmospheric conditions which are ideal for prescribed burning. From the literature it is clear that meteorological understanding has lagged behind ecological and biological knowledge with regard to fire in the fynbos ecosystem. Furthermore, it would appear that past investigations into fire weather have been centred around fire hazard conditions and have not addressed conditions suitable for controlled veld burning (King, 1957; Vowinckel, 1958; Wicht and De Villiers, 1963; Le Roux, 1969; Van Wilgen and Burgan, 1984).

1.1 Need to predict burning weather

Knowledge about burning weather on its own is of little practical value to the veld manager who needs to plan a prescribed burn some time in advance. In addition to the recommended season during which prescribed burns should be applied the veld manager needs to know, preferably one to two days in advance, when suitable burning weather can actually be expected. The present study addresses the problem of predicting suitable burning weather for the south-western Cape Province by means of synoptic analysis.

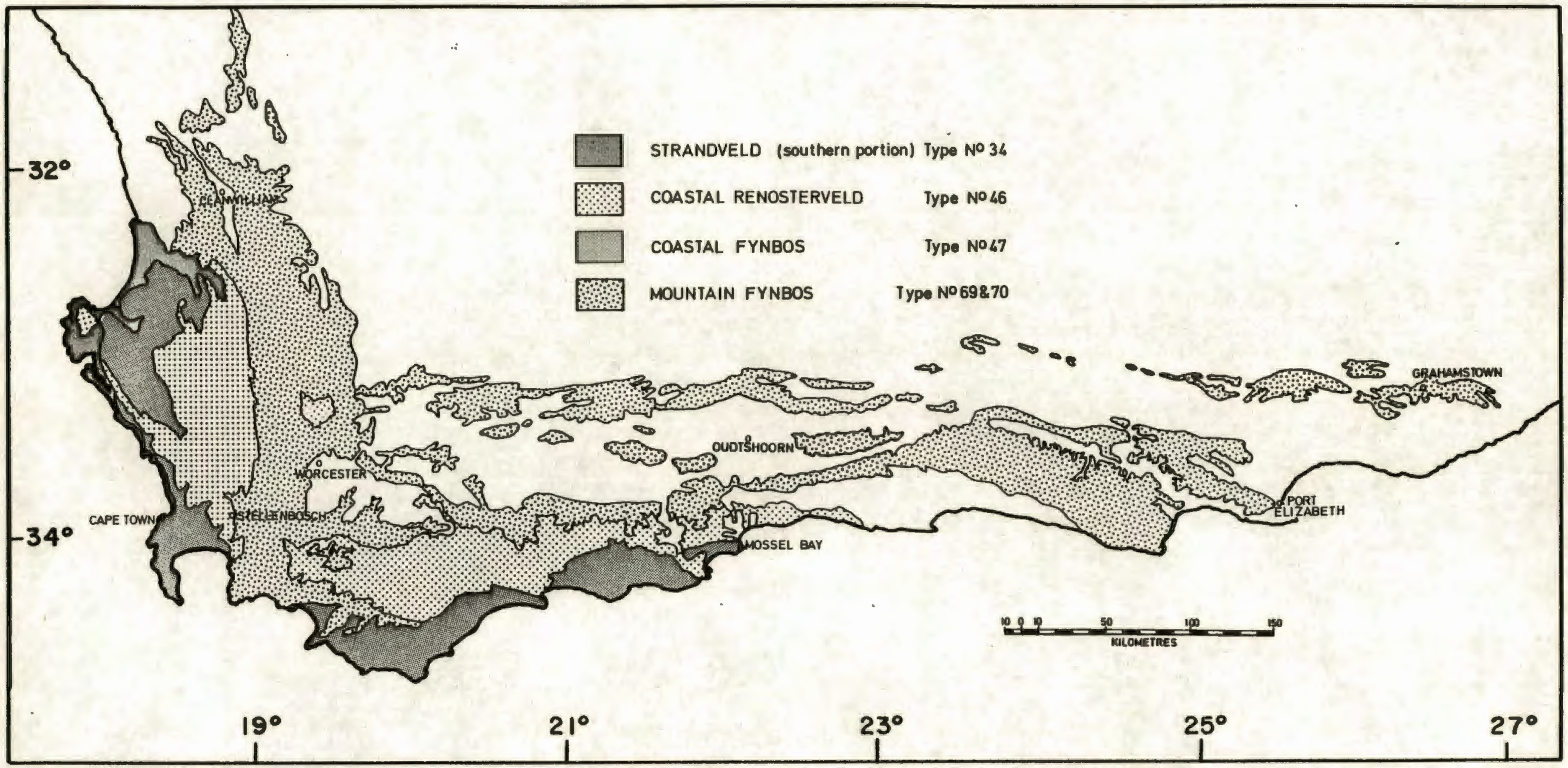

FIGURE 1 : Map of the fynbos biome (after Acocks, 1975)

1.2 Aim of study

At present the fynbos manager in the south-western Cape relies mainly on his intuitive feeling (implicit decision) when or when not to burn, based on the experience gained during earlier burning operations. In the absence of guidelines on how to select suitable and safe burning days, many suitable burning days are "lost" on the one hand, due to overcautiousness. On the other hand a planned burn often has to be cancelled due to an unexpected change in weather.

It has been noted that in practice decisions in ecological management are often based on qualitative data and an individual's accumulated experience (Starfield, 1983). The problem with such decision-making is that the links between the data and the final decision are usually implicit. It is the aim of this study to investigate the possibility of making the links between the data (climatic parameters) and the decision (to execute a burning operation) explicit. The intention is to develop a simple knowledge-based consultation system which can be used by the veld manager to guide his choice of days for prescribed burning in the ecologically desirable season.

1.3 Approach

The fynbos vegetation in the mountains of the Cape is largely managed by foresters who have only an elementary understanding of weather systems. As this study seeks to meet the needs of the forestry fraternity, an approach had to be adopted by which information about weather systems is easily communicated.

Weather charts (synoptic maps) are known for their capability to communicate information about pressure patterns and air masses. It has therefore been decided to adopt the analogue method in this study for predicting burning weather, based on the principle that sequences of weather events tend to follow a similar course if the initial conditions are almost identical.

A sequence of pressure maps associated with ideal burning weather will be established. This sequence could serve as a preliminary model against which real time weather maps should be matched in order to select days suitable for veld burning in the south-western Cape Province.

CHAPTER 2

MANAGEMENT OF FYNBOS IN MOUNTAIN CATCHMENT AREAS

2.1 Introduction

Mountain catchment areas are specific areas in the landscape of Southern Africa characterised by high runoff regimes. It has been noted that mountain catchment areas make up 12% of the land area (figure 2), but account for 53% of the country's runoff (Van der Zel, 1980).

The management of mountain catchment areas, both on private and State land, is entrusted to the Forestry Branch of the Department of Environment Affairs. Catchment areas are managed primarily with the object of providing the maximum volume of water of the highest possible quality on a sustainable basis. On State land secondary management objectives include the promotion of nature conservation and outdoor recreation, while on private land, agriculture (mainly in the form of extensive grazing) and judicious flower harvesting may rate as secondary management objectives, provided that such land-use is not in conflict with the primary aim of water conservation.

The catchment areas of the south-western Cape (figure 2) are predominantly covered by mountain fynbos (Acocks's (1975) Veld Types 69 and 70), one of the four major botanical subdivisions of the fynbos biome (figure 1). Most references cited in the present study are based on studies undertaken in catchment areas of the south-western Cape mainly covered by mountain

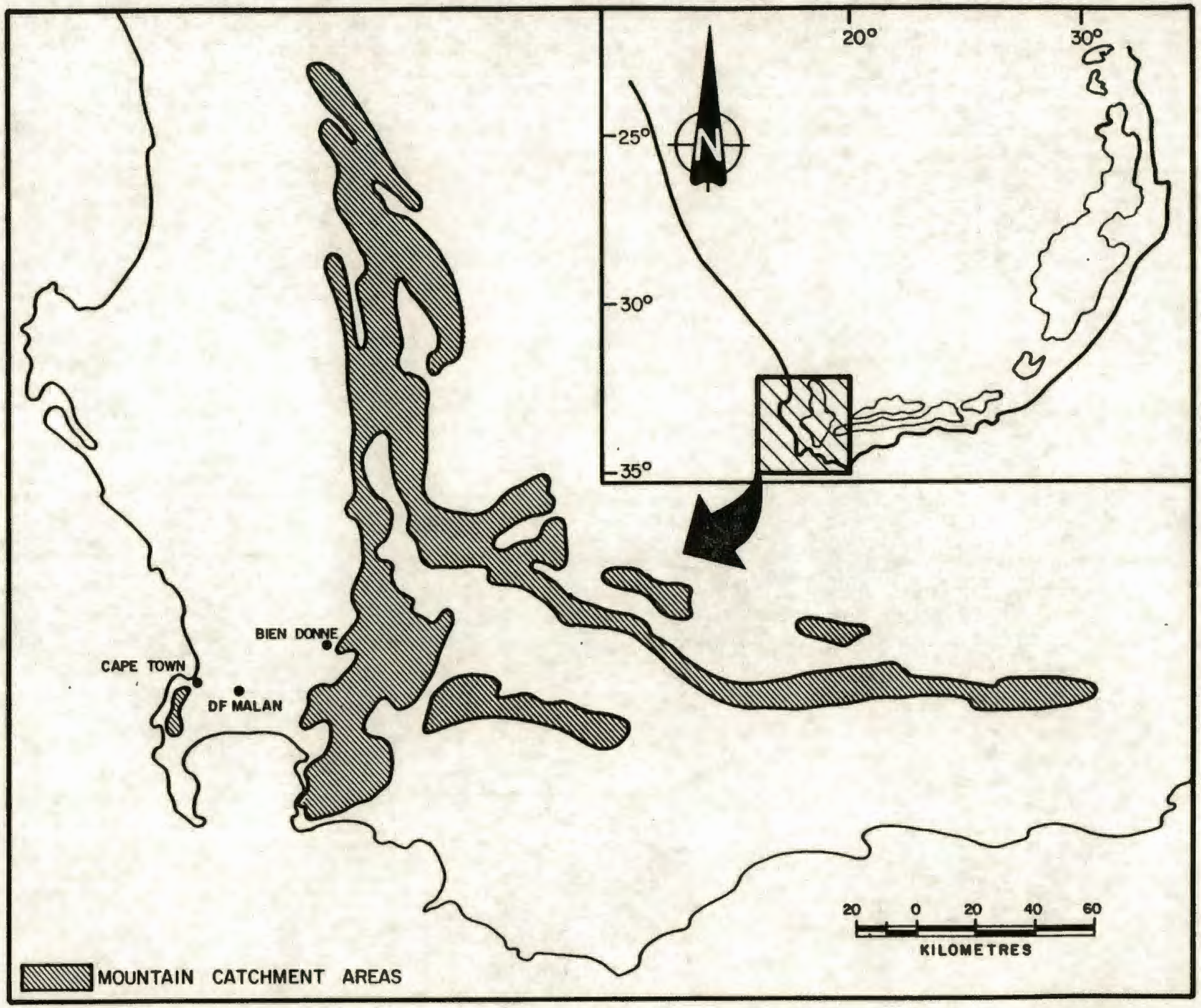

FIGURE 2: Map of the distribution of mountain catchment areas

fynbos. For the purpose of this study mountain fynbos will therefore generally be referred to simply as fynbos.

Fynbos is adapted to fire and falls under the category of fire climax vegetation communities. These communities are dependent on regular burns for their survival. The evolutionary development of many of the fynbos species complies with the community behavioural response to fire (Edwards, 1984).

2.2 Policy of controlled burning

The use of fire is generally acknowledged as an important tool in the management of mountain catchment areas. For the fynbos mountain catchment areas a policy of controlled burning is followed by the Forestry Branch in order to:

(i) rejuvenate the vegetation

(ii) reduce the fuel loads and so prevent or at least diminish the chances for the occurrence of severe wild fires (after Van Wilgen, 1984b).

2.2.1 Veld rejuvenation

Veld rejuvenation is not only essential for the maintenance of plant species diversity but also enhances water recovery (Wicht, 1971; Van der Zel and Kruger, 1975). With the exception of possibly only a few species (Kruger, 1982) all fynbos species mature and produce sufficient seed to ensure their survival within 15 years of burning, and most do so within ten years (Kruger, 1977). Most species utilize only a portion of the post-fire development cycle and will reappear in the same

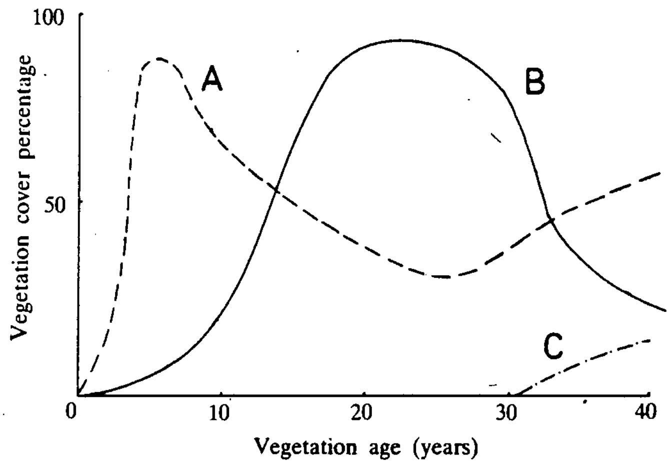

FIGURE 3: A speculative relationship between post-fire age of vegetation and its percentage cover. The lines represent graminoid and herbaceous plants (A), large seed-reproducing shrubs (B), and trees (C) (after Van Wilgen, 1981a).

stage of development in subsequent cycles (figure 3).

In order to augment runoff, relatively frequent burning is advisable since increasing amounts of water are lost through evapotranspiration as the canopy density increases through the post-fire successional cycle (Wicht, 1971; Van der Zel and Kruger, 1975). Erosion rates in the mountains of the Western Cape remain low even after fire (Bands, 1977) and nutrient release resulting from prescribed burning seems to be limited to the first rains after burning (Van Wyk, 1982; Van Wilgen and Le Maitre, 1981).

2.2.2 Fuel load reduction

In the past, devastating wildfires have largely resulted from an earlier policy of complete protection from fire resulting in veld ages of up to 35 or 40 years. With the present policy of prescribed burning on a 12 - 15 year rotation (Department of Forestry, 1970, now Department of Environment Affairs), a large mosaic of different veld ages will be created and maintained. Stands of older vegetation are alternated with areas which have been burnt more recently to prevent an excessive accumulation of dead material (fuel) over large tracts of land.

The mean age of the vegetation is reduced from about 18 years to 6 or 7 years. An average veld age of approximately 6 to 7 years allows for a high sustainable water yield as well as maximum plant species diversity (Van der Zel and Kruger, 1975).

2.3 Management problems

Mediterranean ecosystems, of which the fynbos ecosystem forms part, are characterised by wet winters and dry summers. Throughout this paper the four seasons are those as defined by the South African Weather Bureau (1957), namely

summer: December, January and February
autumn: March, April and May
winter: June, July and August
spring: September, October and November

In the Western Cape a controversy exists as to the season in which prescribed burns should be applied. There is general agreement amongst researchers that summer and autumn are the ecologically optimum seasons for burning fynbos. The most desirable season for applying prescribed burns is late-summer to mid-autumn (Jordaan, 1949; Kruger, 1982; Van Wilgen, 1984a). Strong appeals are made that management burns other than for fire-breaks should be discouraged between the end of autumn and spring (Kruger, 1982; Van Wilgen and Richardson, 1985).

The manager of fynbos mountain catchment areas, however, is faced with the problem of burning in the ecologically correct season which is also a time of great fire hazard (figure 4). Due to the abundance of areas with very old veld ages resulting from the previous policy of complete protection from fire and hence the danger of devastating "run-away" fires, burning was permissible at "safer" times during the implementation of the 1970 controlled burning policy. Late autumn to early winter and early spring were considered as "safer" times largely because of calmer and wetter weather. With burning operations in the south-western Cape already in the second rotation of the fire regime the desired shift to burn during earlier times of the year is hardly materialising (figure 5).

Management problems with respect to burning operations in the south-western Cape are caused by inherently conflicting goals. The conflict is between burning with the aim of nature conservation (rejuvenation of the veld) on the one hand and fire control (fuel load reduction) on the other.

Burning with the intention of fuel load reduction is theoretically not bound to any particular season of the year and could take place whenever weather conditions are suitable. The same, however, does not apply to burning which is intended to rejuvenate the veld for ecological (conservation) reasons. The annual growth pattern of fynbos limits the application of a controlled burn to an ecologically desirable season which happens to be late summer to mid-autumn, according to present ecological understanding of the ecosystem. During late summer and early autumn most

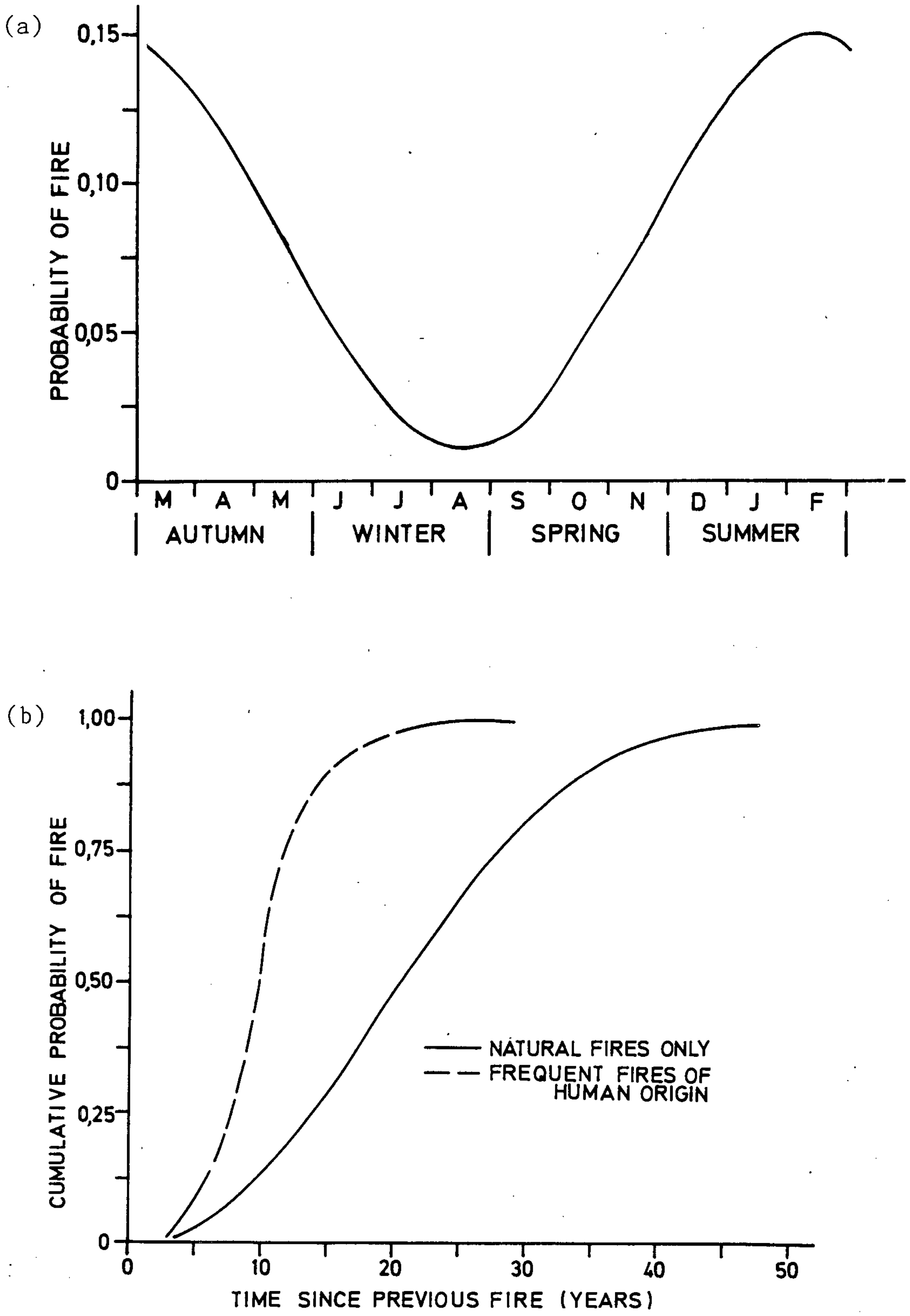

FIGURE 4: Hypothetical fire frequencies

(a) Hypothetical seasonal fire frequency for fynbos in the western Cape.

(b) Hypothetical fire frequencies, expressed as cumulative probabilities of occurrence over any given area, as a function of time since previous fire (the burning rotation). Solid line represents a probability function for an area where fires of human origin are at a minimum, and broken line that for an area with many fires of human origin (after Kruger, 1979).

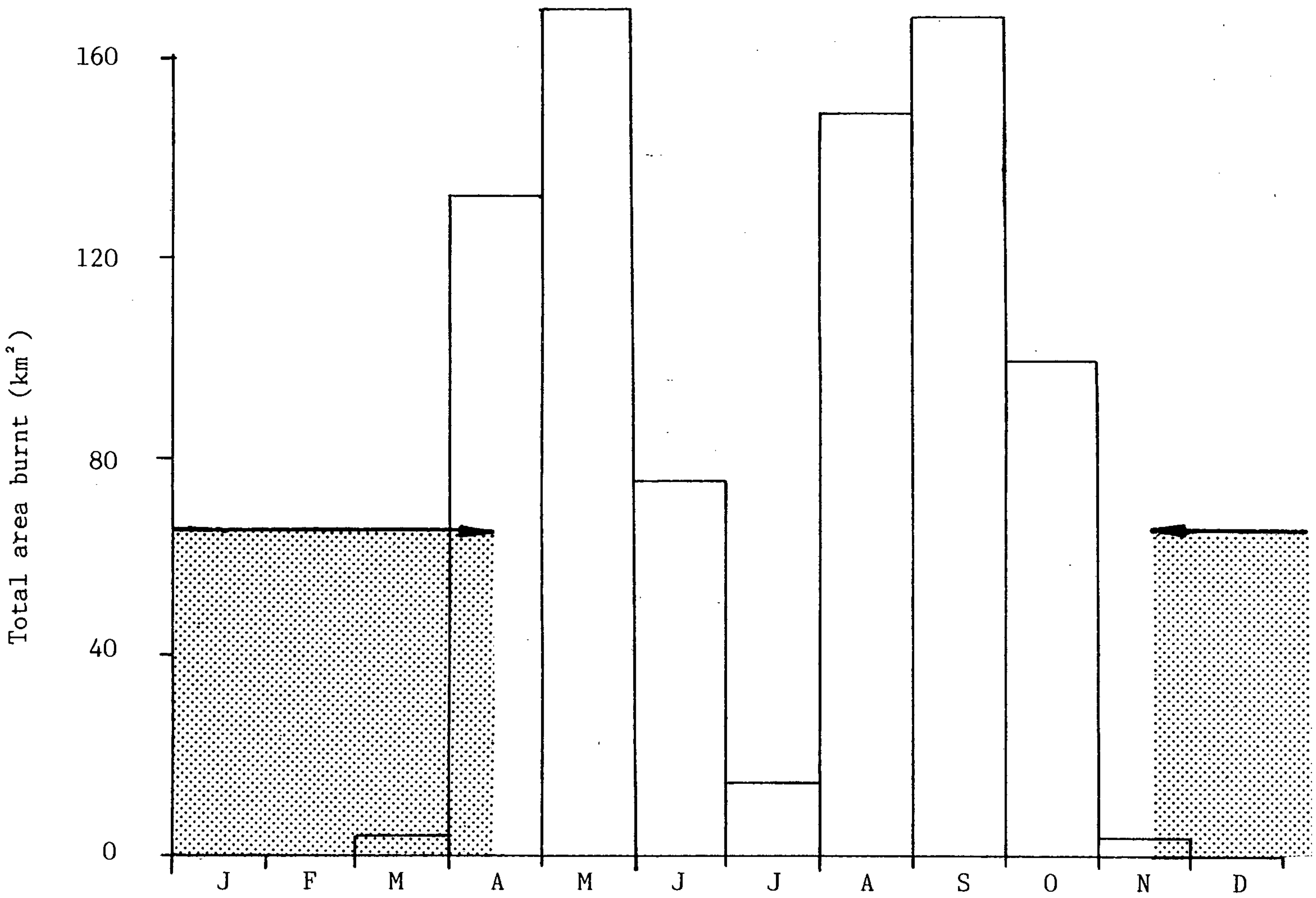

FIGURE 5 : Seasonal distribution of the area burnt in burning operations in the western inland zone, 1978 - 1983, (shaded area indicates desirable burning season) (after Van Wilgen and Richardson, 1985)

species have produced seed and are dormant awaiting the first signs of the approaching winter to begin their annual growth cycle. Late autumn, which more than often heralds the first significant winter rains, is generally accepted as the start of the renewed growing season.

Deviations from the desirable burning regime may degrade the fynbos ecosystem which is already increasingly threatened by agricultural and urban development, especially in the lower lying environs. The effects of winter burns on certain fynbos species have been studied by Jordaan (1949, 1965). He demonstrated how a winter burn severely reduced certain Proteaceae. In a related study similar results have been reported (Bond 1980). Bond found that protea seedling densities and the ratio of seedlings to adults were more than 10 times higher in autumn than in spring burns.

The effects of an artificially changed community structure of fynbos on the hydrological regime of the Western Cape mountain catchment areas are yet to be explained.

The present general pattern of the seasonal distribution of burns in the south-western Cape is shown in figure 5. It is evident that the situation is ecologically unacceptable. The reason for this particular pattern is reflected in the catchment managers experience derived from the legacy of burning in winter or spring. The meteorological circumstances which are most influential in the manager's decision-making will be described below.

2.4 Climatological evidence for present burning pattern

Southerly to south-easterly winds occur predominantly during summer in the south-western Cape (figures 6 and 7) resulting from the close proximity of the South Atlantic high pressure system over the ocean just off the south-west coast of the country.

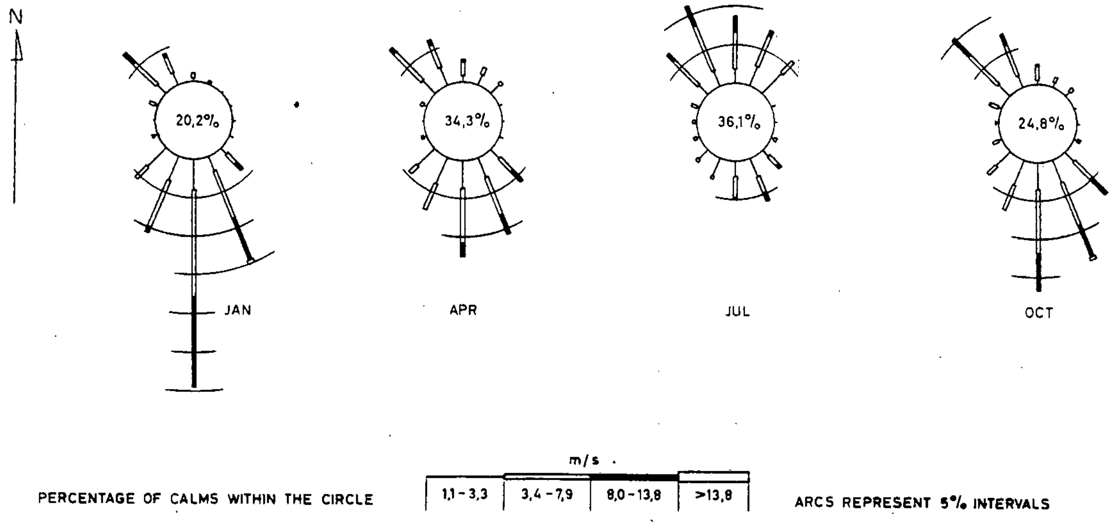

FIGURE 6: Windroses for Cape Town, D.F. Malan Airport (after South African Weather Bureau, 1975)

These winds may blow for several successive days and are usually strong and gusty (Jackson and Tyson, 1971; Schulze, 1980). The annual march and the diurnal variation of windspeed for Cape Town are illustrated in figures 8 and 9 respectively.

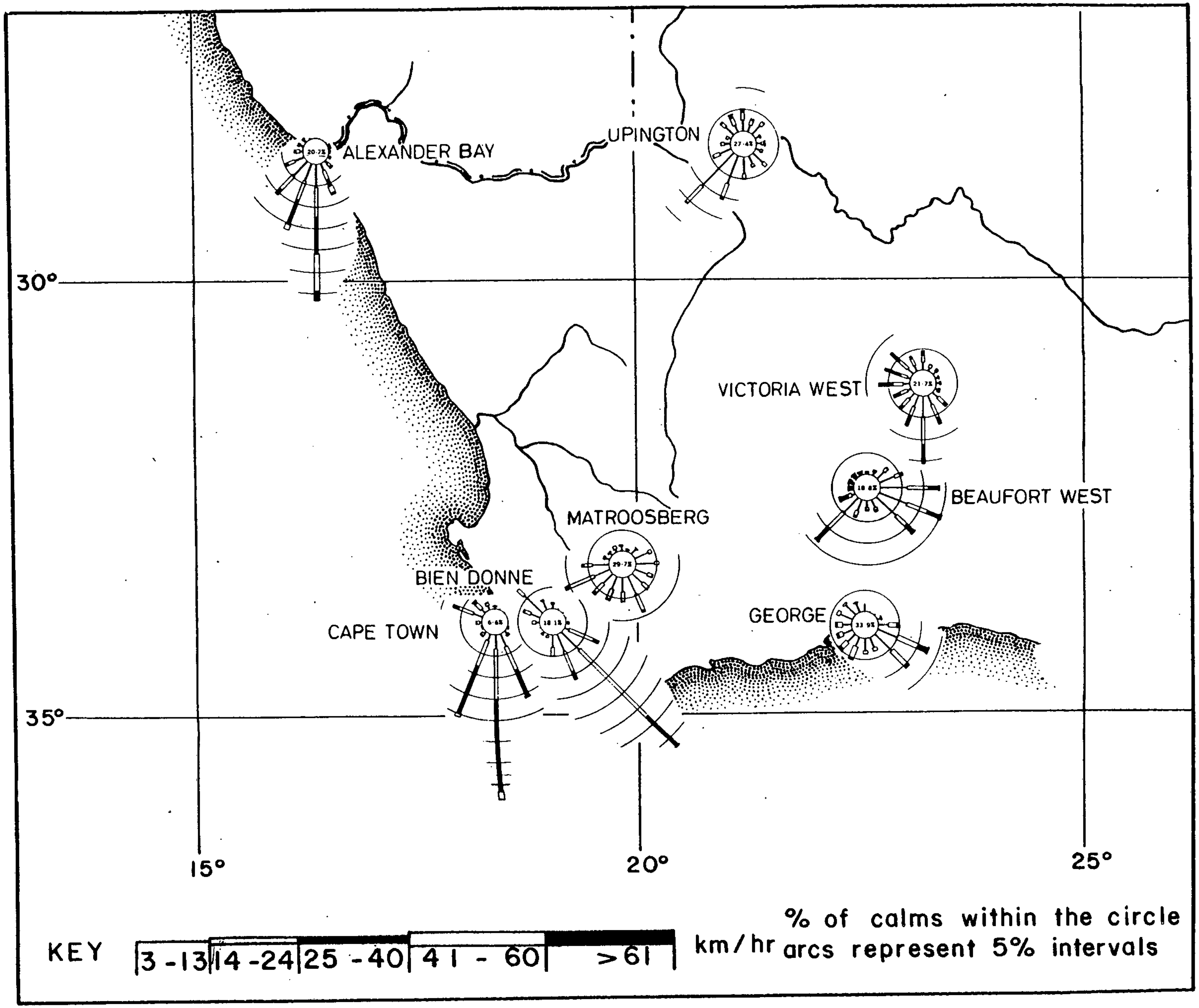

FIGURE 7: January windroses for first order weather stations in the western half of the Cape Province (after Schulze, 1980)

The persistent nature and desiccating effect of the south-easterlies together with high temperatures have made summer the most dreaded fire hazard season of the Western Cape. This resulted in the present prohibition of all prescribed burns during that time of the year.

Times of great fire hazard may also occur during Berg Wind situations. Berg Winds are hot and dry winds which occur mainly from April to September. Over the south-western Cape these winds blow from an easterly to northerly direction and herald the transition from an anticylonic to a cyclonic circulation. Such conditions are associated with pronounced subsidence giving rise to unseasonally hot and dry weather, which on its own may be ideal for burning operations. It is only when Berg Wind conditions are associated with higher windspeeds lasting for several days that fire hazard levels are assumed.

From the discussion it is evident that both kinds of fire hazard conditions are associated with strong anticyclonic circulations. It may also be true that ideal burning weather is also associated with anticyclonic air flow, though this may be of a different kind and certainly of a far lesser intensity. It would appear, however, that there is a fine dividing line between burning weather and fire hazard weather. The dividing line possibly depends on the position and intensity of the high pressure systems.

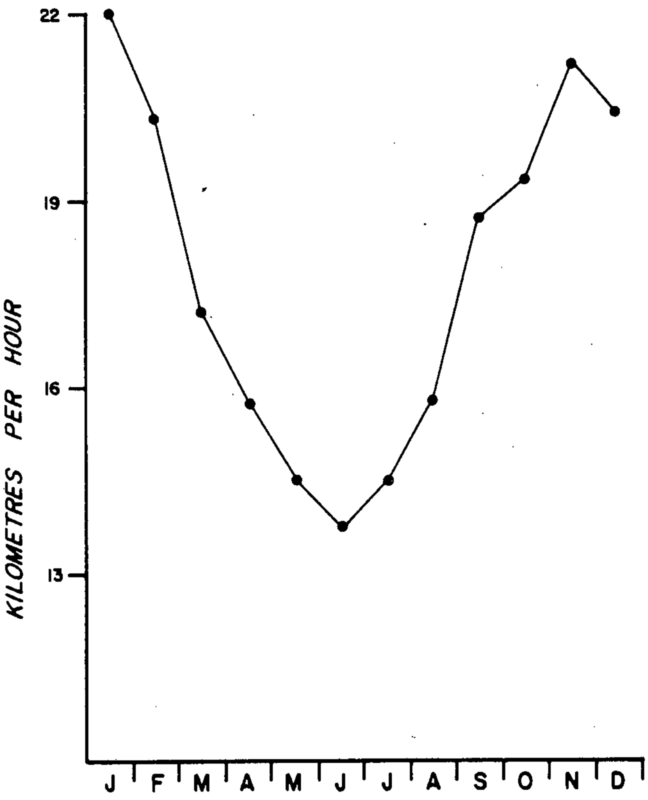

FIGURE 8: Annual march of windspeed for Cape Town (after Schulze, 1980).

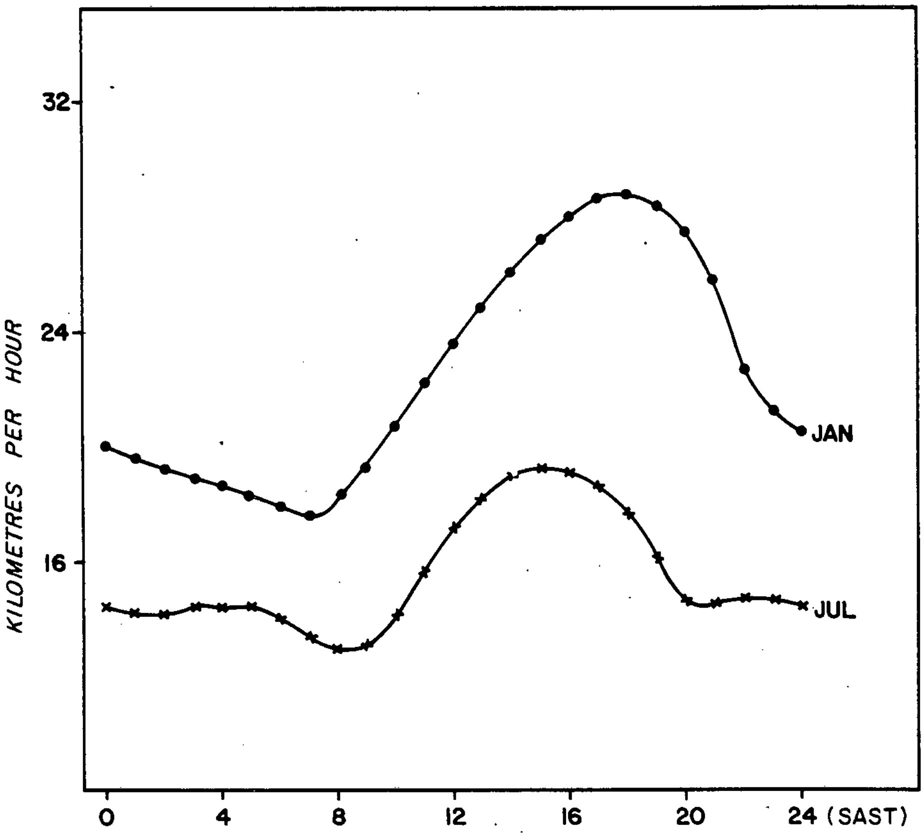

FIGURE 9: Diurnal variation of windspeed for Cape Town (after Schulze, 1980).

Figures 10 and 11 show the annual march of temperature and relative humidity for Cape Town respectively. It is clearly noticeable how the dry and warm to hot summer conditions differ from the cold and wet winters. The relatively low relative humidity during June may be explained in terms of Berg Wind occurrence. It may not be far fetched to argue that June is the month with the highest frequency of Berg Wind conditions although this notion could not be substantiated in the literature.

It has been noted that fires can occur whenever conditions are warm and dry, notwithstanding the season of the year (Kruger, 1979; Van Wilgen, 1981b). It is only when fire weather is associated with moderate to high windspeed and temperatures of 30°C and higher that real fire hazard conditions result. As a rule of thumb it would therefore be too hot and windy, or too cold and wet to burn in summer and winter respectively. The warm and dry conditions during winter are invariably associated with Berg Wind weather, whether intense or not, and are therefore avoided.

From these observations it is understandable that catchment managers select the inbetween season (autumn and spring) to carry out their burning operations, hoping to find enough suitable weather to complete their programme. This situation is reflected in figure 5. Although autumn is on average a calmer season than spring (figures 6 and 12) burning still takes place mainly in spring. The reason may be twofold.

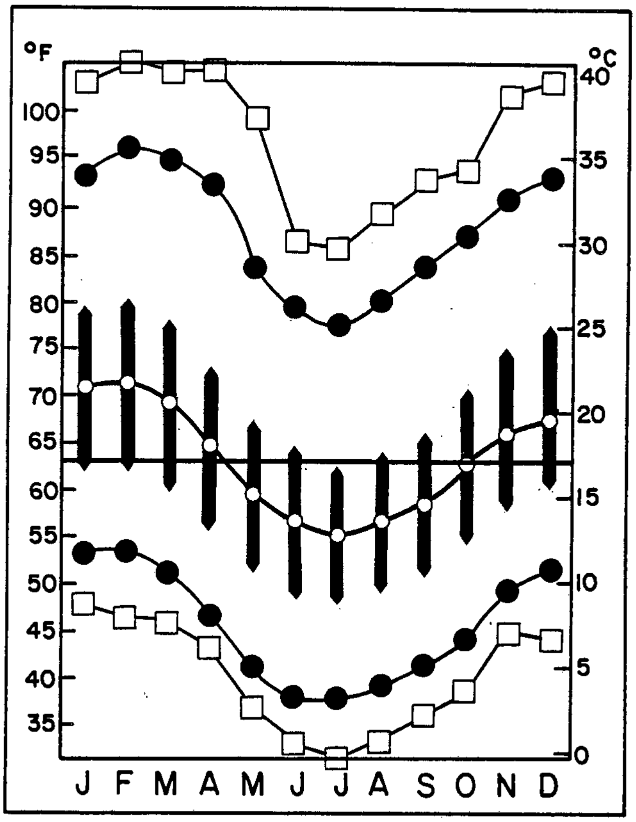

FIGURE 10: Annual march of temperature for Cape Town (Vertical bars give daily range of temperature; full circle lines give mean monthly maxima and minima; boxed lines give absolute monthly maxima and minima; mean annual temperature indicated by a horizontal line) (after Schulze, 1980)

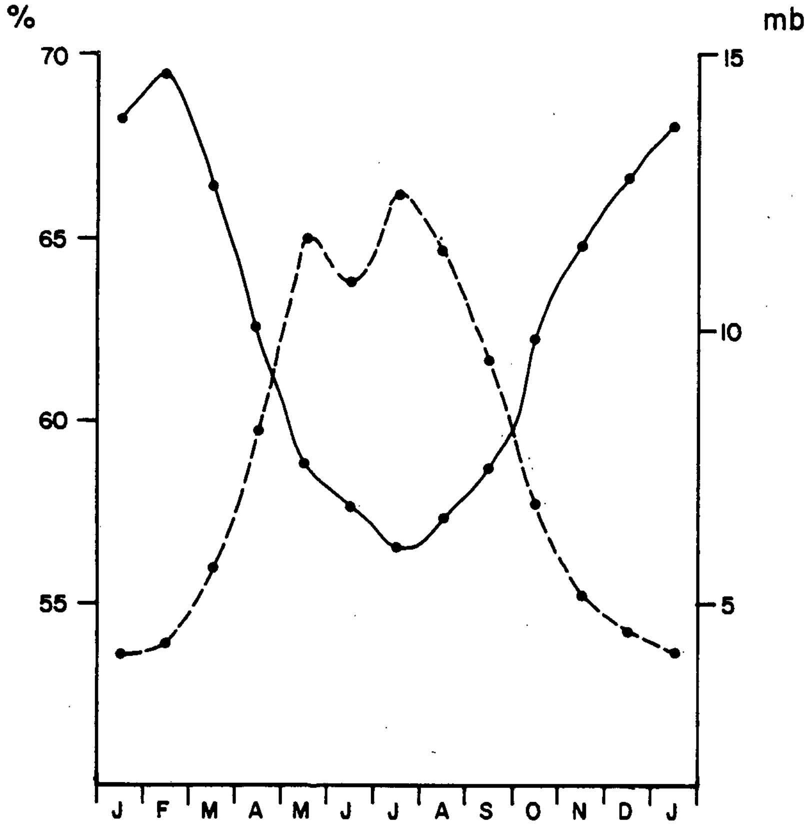

FIGURE 11: Annual march of relative humidity (•--•--•) and saturation deficit at 14h00 (•—•—•) for Cape Town (after Schulze, 1980)

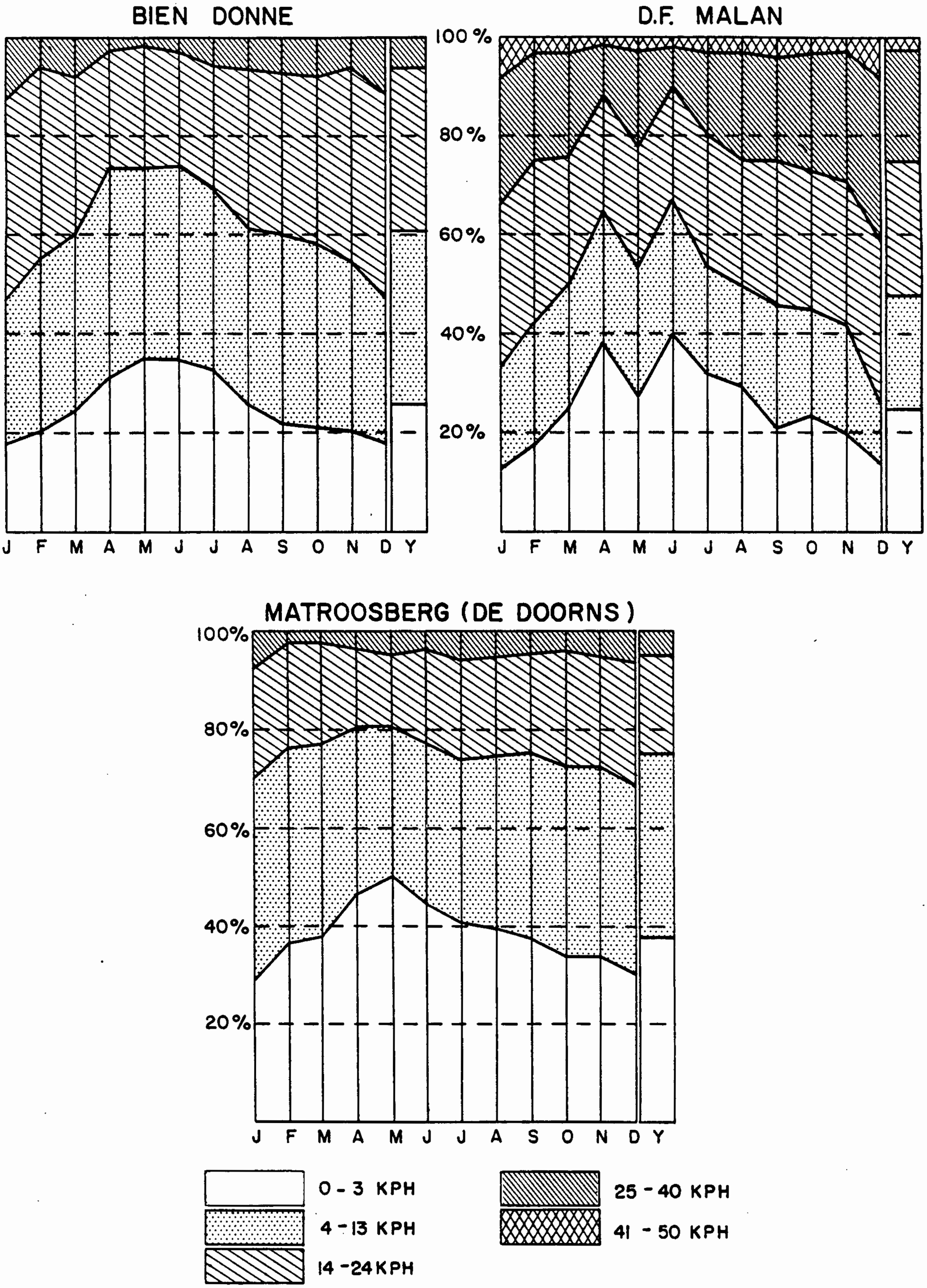

FIGURE 12: Percentage frequency of windspeed within given limits (after Schulze, 1980)

During spring cooler and more humid conditions are experienced which is seen as relatively safe compared to the still warmer and drier autumn. It may also be that pressure on the manager to complete his annual burning programme leads him on to take greater risks.

A possible solution to the problem of burning in autumn rather than in spring may be found in the actual occurrence and predictability of suitable burning days in the late-summer to mid-autumn period. If burning days are properly defined and guidelines drafted as to the selection and prediction of these suitable burning days from an otherwise potentially hazardous climatic environment, then there is little excuse why concerted efforts should not be undertaken to burn in the desirable season. The three major aims of catchment management, i.e. water conservation, nature conservation and fuel load reduction, will be satisfied simultaneously if burning takes place in the late-summer to mid-autumn season.

CHAPTER 3

FIRE WEATHER AND SYNOPTIC STUDIES

3.1 Natural fires and fire climates

Fynbos communities can accumulate remarkable quantities of fuel for fire, depending largely on post-fire successional age. Fuel quantities of between 40 and 400 kg/km^2 have been recorded by Kruger (1977) and Van Wilgen (1982). A regrowth of four years is usually necessary to sustain a spreading fire (Martin, 1966; Kruger, 1977) but the vegetation must be somewhat older to burn readily under average summer conditions.

Mature fynbos will burn under fine and warm conditions regardless of the season (Kruger, 1979; Van Wilgen, 1981b). In figure 13 it can be seen that wild fires occur in all seasons yet show an increased frequency between January and March.

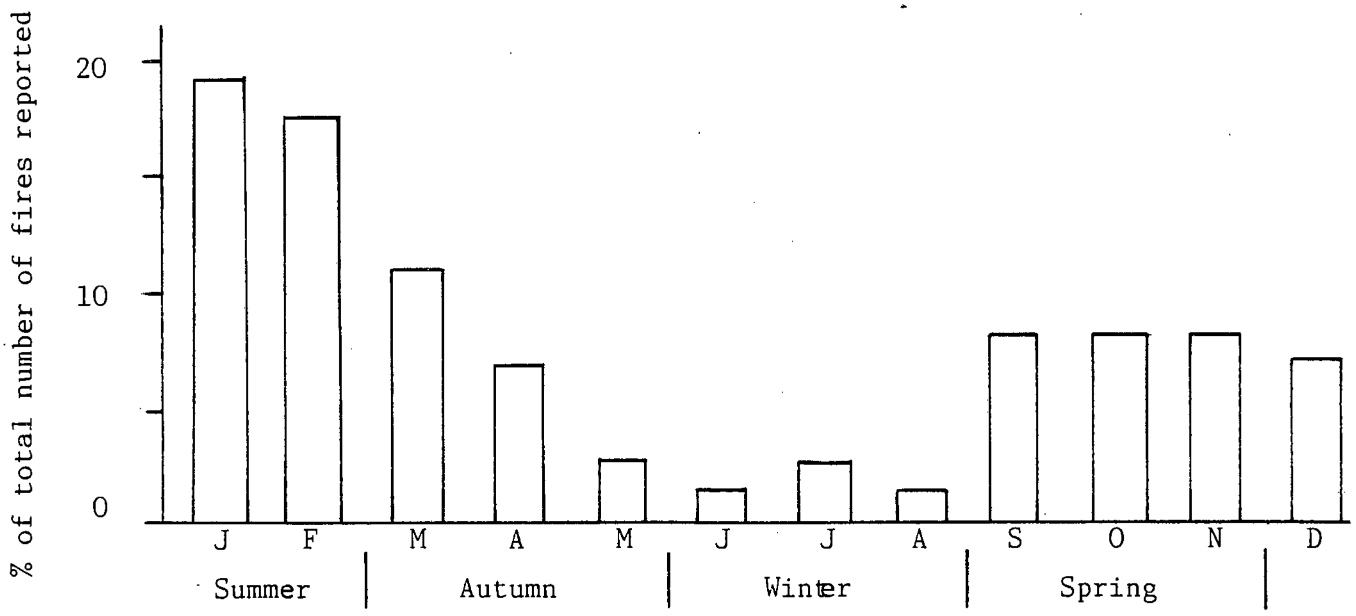

FIGURE 13: Seasonal incidence of fynbos fires on State forest land in the western Cape during 1966/67 to 1975/76. (Data courtesy of P.J. le Roux, Department of Environment Affairs).

In a study on fires and associated weather factors van Wilgen (1981b) found remarkable differences in weather conditions between different categories of burns (Table 1). Weather conditions characteristic of wild fires are persistent windy conditions, coupled with high temperatures and low mean daily relative humidities. Van Wilgen also found that except for the extreme south-eastern areas of the study area, where wild fires were found to be associated with south-westerly to north-westerly winds, most wild fires in the western Cape were associated with winds of a southerly or south-easterly direction.

TABLE 1: Comparison of weather conditions in four categories of burn (after Van Wilgen, 1981b)

Parameter	All wild fires	Large wild fires	Pre-scribed burns	Fire-break burns
Mean wind speed (km/hr)	38,9	46,7	14,8	15,0
Mean minimum temperature (°C)	15,7	16,2	9,7	10,9
Mean maximum temperature (°C)	30,9	37,0	22,4	22,3
Mean relative humidity (%)	48,3	37,2	69,7	69,4
Mean minimum relative humidity (%)	32,9	17,8	33,5	35,6
Number of observations	16	4	31	69

The results of a study on the frequency of veld fires in the Groot Swartberg mountain catchment area of the southern Cape (Horne, 1981) showed that fires were mainly associated with south-westerly and north-westerly winds (figure 14). These findings imply that care should be taken during fire weather prediction along the common boundary of the two regions. The results of the present study should therefore not be applied to fynbos regions in other parts of the Cape Province.

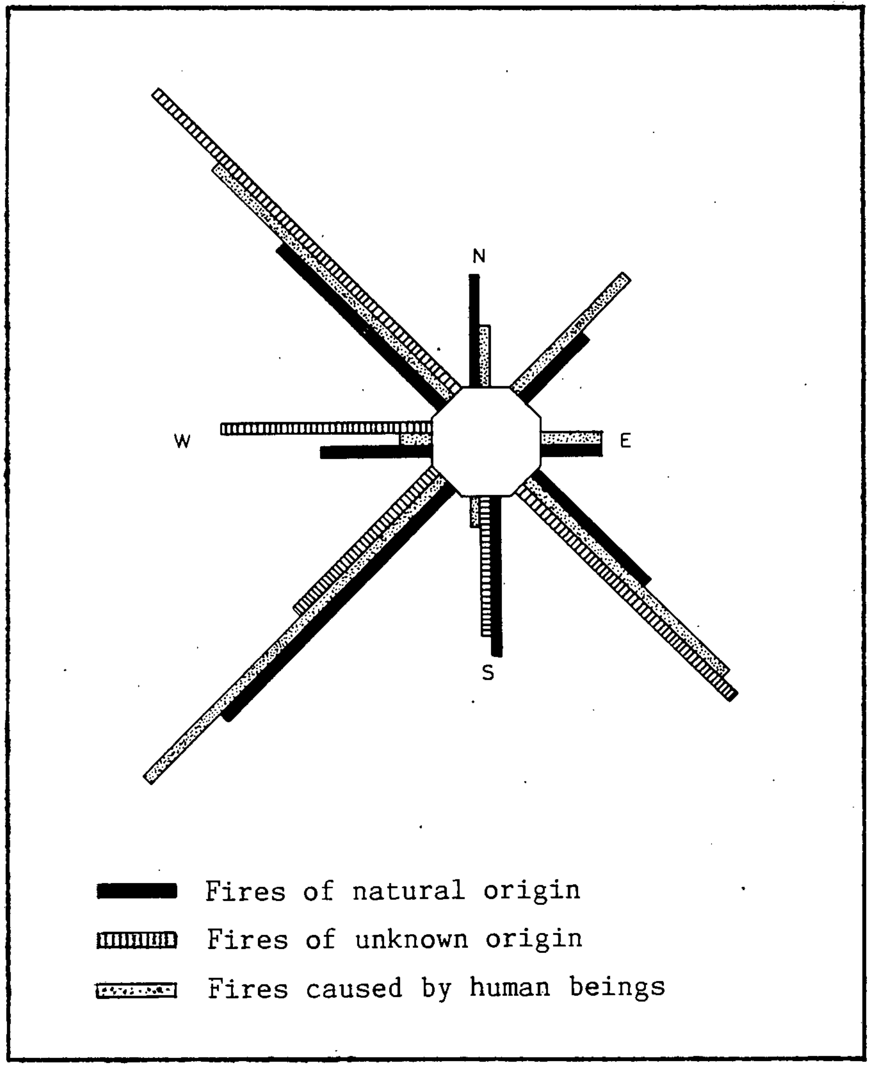

FIGURE 14: Frequencies of fires of natural, man-made and unknown origins, classified by wind direction recorded during each fire, Groot Swartberg mountain catchment area, 1951 to 1977 (after Horne, 1981).

Van Wilgen (1984a) has attempted to establish fire climates for the western and southern Cape Province based on daily weather observations of relative humidity, temperature, rain and sunshine (figure 15c). The energy release component of the United States fire danger rating system was calculated from the weather records of 40 weather stations in the fynbos biome, which was then used to delineate and define areas with similar climatic conditions in terms of potential fire risk (figures 15a & 15b). Van Wilgen found that fuel moisture may be explained in terms of weather conditions and that fuel moisture provides the important link between weather and fire behaviour. By addressing the problem of potential fire risk his study provides a useful basis for fire weather forecasting, wild fire control and the planning of prescribed burns. Van Wilgen's "western inland zone" corresponds with the boundaries of the present study area.

3.2 Weather conditions suitable for controlled burning

Conditions currently favoured by field managers for burning operations have recently been investigated most rigorously by Van Wilgen and Richardson (1985). They found that most burning operations took place when the maximum daily air temperature was between 20° and 28°C and the mean daily windspeed between 4 and 12 km/hr. There was however a wide range of minimum relative humidity during burns. The ranges of preferred and acceptable conditions for prescribed burns which they used for defining suitable burning days are given in Table 2. Van Wilgen and Richardson used two sets of prescriptions; one included a restriction on days since last

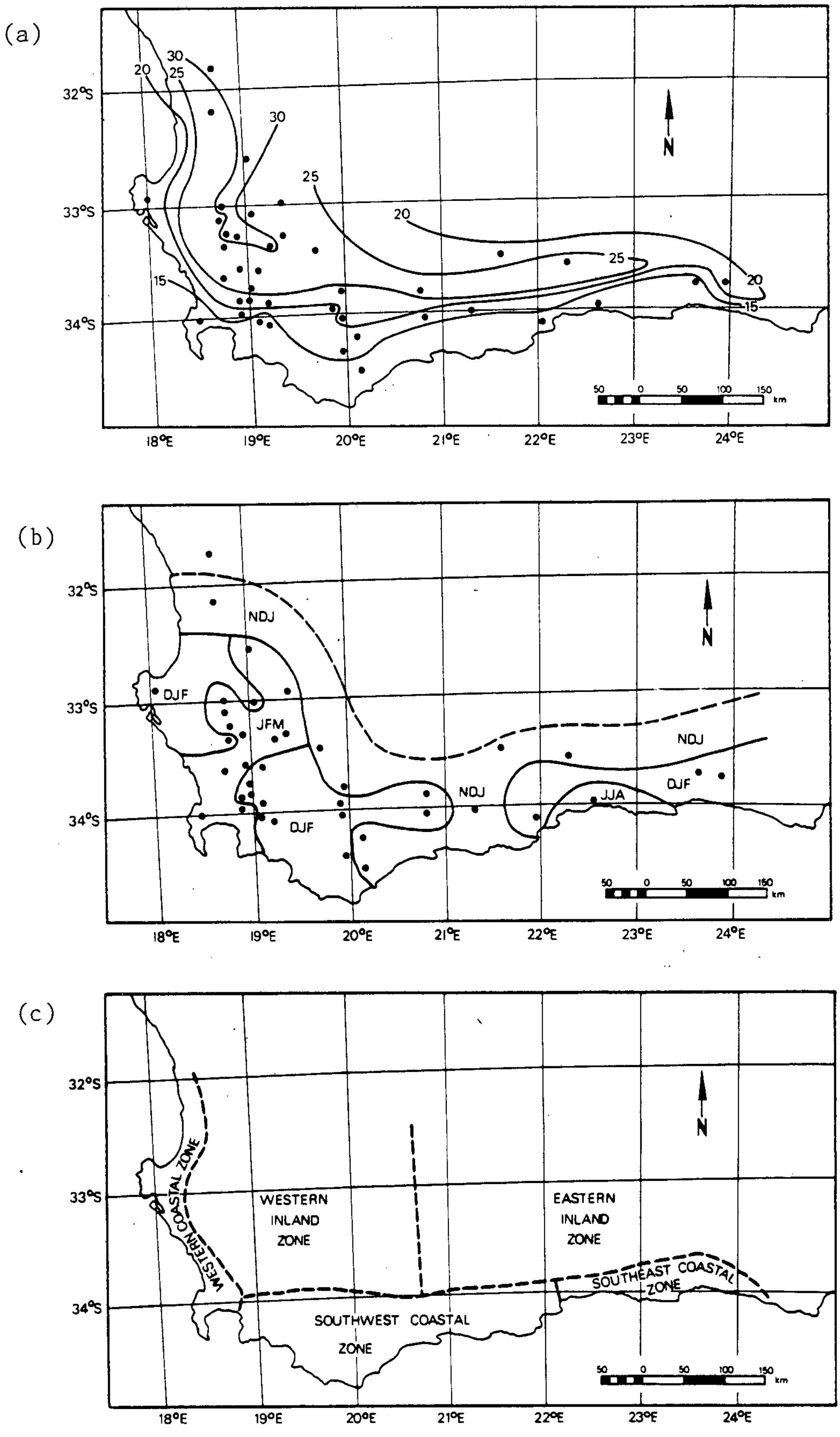

FIGURE 15: Fire climates for the western and southern Cape Province

(a) Isolines of mean energy release component during the fire season
(b) Distribution of fire season classes (the three-month period of highest mean energy release component)
(c) Fire climate zones based on fire potential during the fire season

Dots indicate the position of weather stations (after Van Wilgen, 1984a)

TABLE 2: Ranges of preferable and acceptable burning conditions (from Van Wilgen and Richardson, 1985)

Parameter	First range Preferable	 Acceptable
Wind speed (km/hr)	2 - 12	0 - 14
Maximum temperature (°C)	20 - 28	18 - 28
Minimum relative humidity (%)	20 - 40	15 - 45
Days since last rain	3 - 6	2 - 8
Parameter	**Second range Preferable**	** Acceptable**
Wind speed (km/hr)	4 - 6	0 - 8
Maximum temperature (°C)	20 - 26	18 - 28
Minimum relative humidity	33 - 40	25 - 45

rain, while a second set excluded rain but put more stringent requirements on the remaining three parameters. The effect of days since last rain may be negligible since the moisture content of the fuel adjusts rapidly to the characteristics of the ambient air (Kruger, 1979; Kruger and Bigalke, 1984). It has been noted that fuel moisture may be explained by weather conditions.

Van Wilgen and Richardson (1985) suggest that wind is probably the single most important factor in determining fuel moisture and hence fire behaviour. It should be noted that they used the mean daily windspeed to arrive at their prescriptions. Diurnal fluctuations in windspeed in the study area are usually pronounced (figure 9). It may therefore be true to state that the mean hourly windspeed may have been considerably more at times than specified in the prescription of the mean daily windspeed.

The specifications of burning weather which have been established by Van Wilgen and Richardson above will be employed to define ideal burning weather for the present investigation. The weather system which is associated with ideal burning weather and the synoptic developments during the previous two to three days which may result in the occurrence of burning weather will be used to determine the predictability of burning weather. A short synopsis of some previous studies on weather patterns is given below.

3.3 Weather patterns of South Africa

In view of the frequent occurrence of droughts over the sub-continent it is understandable that synoptic studies in South Africa have been centred around rainfall events. An early start in weather type classification was done by Vowinckel (1955) (appendix 1). The characteristics of South African thunderstorms, together with the synoptic charts for the days on which they occurred (appendix 2), were reviewed by Davison (1977). He found that information provided by the daily synoptic chart could not adequately account for why isolated storms occur on certain days and squall-line or multi-cell storms on other days. A synoptic systems classification scheme based on the occurrence of cloud cover was developed by Erasmus (1980) who focussed attention on the influence which large-scale systems (secondary atmospheric circulations) have on convective events (appendix 3).

A method whereby weather could be related to weather maps (synoptic charts) has been developed by Lund (1963). The purpose of his experiment was to select a small number of winter maps of the north-eastern United States such that each map would represent an unmistakable different sea-level pressure pattern which reappears much more frequent than would be expected by chance. His study was designed to explore the possibility of applying simple linear correlation methods to the problem of identifying recurring map-pattern configurations.

Although no two weather maps look exactly alike, similar weather maps could be grouped into sets (appendix 4). By describing and defining the main features of all the days combined in a set, one is able to reach conclusions about the weather of another day when the map looks similar.

A consideration of several methods of procedure resulted in the conclusion that Lund's method of classification could lead to a better understanding of the realtionship between South Africa's weather and South Africa's weather maps (Longley, 1976). Longley's study was restricted to the variables of temperature and precipitation. Having established a map pattern classification he went on to investigate which circulation pattern was associated with rainfall and where. The study proved to be successful in identifying the pressure systems that could produce rain over different parts of Southern Africa.

In appendix 5 some of his pattern days are shown which represent summer maps for the south-western Cape which are associated with rain. The months November - February were taken by Longley to represent the summer conditions. The boundaries of the present study area approximate those given to Zone M of figure 1 in appendix 5.

It is evident that synoptic studies have made a contribution to the understanding of weather and weather patterns in South Africa. Nevertheless, no attempt has as yet been made to describe synoptic patterns which are associated either with fire hazard conditions or with conditions suitable for veld burning in the south-western Cape.

In this study an attempt will be made to use synoptic analysis for the prediction of burning weather. The procedure by which weather patterns are to be used to identify burning weather in the south-western Cape are outlined in the next chapter.

The possibility of predicting burning weather in the south-western Cape from one to two days in advance will put the fynbos manager more at ease in his difficult task of burning in the ecologically desirable season, which is unfortunately also a hazardous season with regard to veld fires.

CHAPTER 4

DEVELOPMENT OF METHOD AND RESULTS

4.1 Data

Climatological records of hourly windspeed, maximum daily temperature and minimum daily relative humidity were obtained for three agricultural weather stations, Bien Donne, Elgin and De Doorns (figure 16). The stations were carefully selected in order to be representative of a large portion of mountain catchment land in the south-western Cape.

The short record of climatological data for mountainous areas and the presently still limited number of parameters per station for which data is collected on a regular basis, restricted the number of stations for which data could be analysed in this study. Each of the three stations selected had a reliable, quality controlled record of data for at least five years (1981-1985) which is stored on magnetic tape at the Agrometeorological Section of the Soil and Irrigation Research Institute, Elsenburg, Cape Province.

(Note: After analysis had been completed it was found that windspeed was recorded at different heights above ground. Elgin and De Doorns record windspeeds at 10 m. The wind data which was analysed for Bien Donne, however, was recorded at 2 m. It was then found out that Bien Donne has another anemometer which records windspeed at 14 m. The data for 10 selected ideal burning days was subsequently checked and it was found that no real differences in windspeed existed when recordings taken at 2 m and 14 m were compared. Out of the 10 selected days, all having hourly windspeeds of < 16 km/hr at 2 m, only 1 day (20/4/1982) reported windspeeds of > 16 km/hr between 22h00 and 24h00 at 14 m. Mean daily windspeed for 20/4/1982 was 5.8 km/hr at 2 m and 6.8 km/hr at 14 m. The analysis was therefore left as it is.)

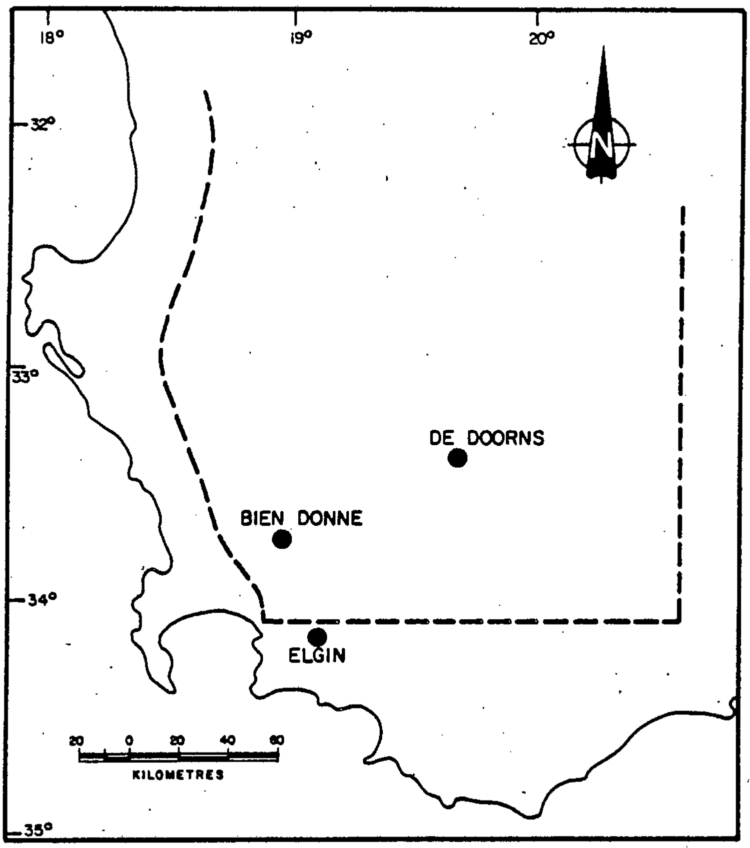

FIGURE 16: Location of weather stations for which data was analysed. (--- Boundary of western inland zone, Van Wilgen, 1984a).

TABLE 3: Salient features of the three weather stations used in this study

Station	Co-ordinates	Altitude (m)
Bien Donne	33°50'S 18°59'E	138
De Doorns	33°28'S 19°40'E	457
Elgin	34°08'S 19°02'E	305

4.2 PROCEDURE

4.2.1 Selection of ideal burning days

The specifications laid down by Van Wilgen and Richardson (table 2) were used with slight modifications to define and select ideal burning days. The upper limit of 14 km/hr for windspeed was relaxed slightly to 16 km/hr in view of the fact that Van Wilgen and Richardson used mean daily windspeed whereas hourly windspeed is used in the present analysis.

The pronounced diurnal variations of windspeed in the study area have been mentioned earlier (figure 9). Hourly windspeed values can at times therefore be expected to be considerably higher than the mean daily windspeed of 14 km/hr. The South African Weather Bureau also regards 16 km/hr as the upper limit for their category of light wind (gentle breeze - on the Beaufort description (Smithsonian meteorological tables, List, 1968)).

It was decided to drop the rainfall restriction which Van Wilgen and Richardson used in their study as fuel moisture adjusts rapidly to ambient weather conditions. A dry and sunny day following a rain event, usually a light shower during summer and autumn, will dry out the fuel sufficiently for it to catch fire.

For the purpose of this study an ideal burning day is defined as a day during the months of February, March and April during which the following conditions prevail:

(i) hourly windspeed of less than or equal to 16 km/hr for all hours of the day
(ii) maximum daily temperature between 18° and 28°C
(iii) minimum daily relative humidity between 15 and 45%.

The Statistical Analysis Systems (SAS) programming language was used on an IBM computer to process the windspeed data of the three stations. Programmes were written to select days on which the windspeed specification was met (see appendix 6).

Initially all days on which hourly windspeed never exceeded 16 km/hr were identified for each of the three weather stations. The days, on which the windspeed qualification occurred simultaneously at the three stations, were subsequently manually scrutinised to impose temperature (18° - 28°C) and humidity (15 - 45%) specifications. Only those days which qualified in terms of all three specifications for the three stations simultaneously were regarded as ideal burning days and used for further analysis.

4.2.2 Selection of synoptic maps

Having established the dates of the ideal burning days it was possible to obtain the corresponding 14h00 SAST surface synoptic chart of each day (Daily Weather Bulletin, South African Weather Bureau). Five-day sequences were compiled for each of the ideal burning days by incorporating the synoptic charts of the previous three days and the following day.

Surface air pressure values were then obtained from each synoptic chart for 54 regularly spaced gridpoints. The gridpoints at 5° intervals for the area 20° - 45° South and 0° - 40° East were used. Time averaged pressure values were subsequently calculated for each gridpoint from the 10 charts representing a particular day in the five-day sequence. The result was a mean pressure chart for each day in the five-day sequence.

The boundaries of the pressure charts outlined above coincide with the boundaries of the weather map which is published daily in a local newspaper called "The Argus". This newspaper has a wide distribution throughout the western Cape and will reach most of the foresters concerned on the day it is published.

4.3 Presentation of results

4.3.1 Summary tables of burning days

The number of days for February, March and April which meet the windspeed specification are listed in table 4. A total number of 75 days for the period 1981 to 1984 gives an average of 19 days per year for the specified season.

TABLE 4: Days with an hourly windspeed of less than 16 km/hr common to the stations of Bien Donne, Elgin and De Doorns.

Month	Year 81	82	83	84	Total	Mean
February	nil	3	nil	1	4	1,00
March	5	5	5	5	20	5,00
April	10	10	14	17	51	12,75
Total	15	18	19	23	75	
Mean	5,00	6,00	6,33	7,66		

In tables 5a & b the figures for the months January to June are given for critical windspeeds of 16 and 19 km/hr respectively.

TABLE 5: Summary of suitable burning days common to the stations of Bien Donne, Elgin and De Doorns according to the windspeed specification only:
(a) hourly windspeed less than 16 km/hr
(b) hourly windspeed less than 19 km/hr

(a)

Month	Year 81	82	83	84	Total	Mean
January	1	2	1	2	6	1,50
February	nil	3	nil	1	4	1,00
March	5	5	5	5	20	5,00
April	10	10	14	17	51	12,75
May	11	13	15	13	52	13,00
June	10	12	11	10	43	10,75
Total	37	45	46	48	176	
Mean	6,16	7,50	7,67	8,00		

(b)

Month	Year 81	82	83	84	Total	Mean
January	2	7	2	4	15	3,75
February	1	4	4	2	11	2,75
March	8	10	9	12	39	9,75
April	14	16	17	21	68	17,00
May	18	18	19	15	70	17,50
June	13	15	14	12	54	13,50
Total	56	70	65	66	257	
Mean	9,33	11,67	10,83	11,00		

Clearly the number of days with light wind increase towards the end of autumn, peaking in April and May with February showing the lowest figure. It is interesting to note that the incremental increases between table 5a and 5b are largest for the first three months. This is understandable when seen in relation to the observation that autumn and winter are the calmest seasons of the year (figure 6 and 12). One would therefore expect a proportionally larger increase in calmer days with increasingly relaxed windspeed limits for summer than for the otherwise already calmer seasons of autumn and winter.

The number of days for the specified months which meet the windspeed specification, as well as the temperature and humidity specifications respectively, are listed in Tables 6a and b. For both cases the month of April shows a distinctly higher figure than the other two months. It may also be observed that February is too hot, when compared to March and April, a finding which is in agreement with figure 10.

In Tables 7a and b the figures for the first six months of the year are given for comparison. The trend in the occurrence of burning days discernible in Table 5 is also clearly evident in Table 7, with April and May once again showing the highest scores. While May scores highest according to the windspeed and temperature specifications, April has the highest score for the combination of the windspeed and humidity specifications.

TABLE 6: Summary of suitable burning days for the specified season common to the stations of Bien Donne, Elgin and De Doorns according to the windspeed specification, and
(a) temerature specification
(b) humidity specification

(a)

Month	Year 81	82	83	84	Total	Mean
February	nil	nil	nil	nil	nil	nil
March	3	2	1	1	7	1,75
April	5	6	6	6	23	5,75
Total	8	8	7	7	30	
Mean	2,67	2,67	2,33	2,33		

(b)

Month	Year 81	82	83	84	Total	Mean
February	nil	2	nil	1	3	0,75
March	3	3	2	2	10	2,50
April	5	6	7	6	24	6,00
Total	8	11	9	9	37	
Mean	2,67	3,67	3,00	3,00		

The number of ideal burning days which occurred during the specified season for the years 1981 to 1984 are listed in Tables 8a and b. April once again shows the highest figures when compared to February and March. It should be noted that the weak response for the year 1984 is mainly a result of the Elgin record which showed consistently low figures for temperature on the one hand and consistently high humidities on the other hand. This may tentatively be explained in terms of increased cloudiness in the Elgin area during 1984, possibly related to orographic cloud.

TABLE 7: Summary of suitable burning days for the first six months of the year common to the stations of Bien Donne, Elgin and De Doorns according to the windspeed specification, and
(a) temperature specification
(b) humidity specification

(a)

Month	Year 81	82	83	84	Total	Mean
January	1	1	1	1	4	1,00
February	nil	nil	nil	nil	nil	nil
March	3	2	1	1	7	1,75
April	5	6	6	6	23	5,75
May	8	9	8	7	32	8,00
June	4	5	3	8	20	5,00
Total	21	23	19	23	86	
Mean	3,50	3,83	3,17	3,83		

(b)

Month	Year 81	82	83	84	Total	Mean
January	1	1	nil	nil	2	0,50
February	nil	2	nil	1	3	0,75
March	3	3	2	2	10	2,50
April	5	6	7	6	24	6,00
May	6	5	7	2	20	5,00
June	4	6	3	3	16	4,00
Total	19	23	19	14	75	
Mean	3,17	3,83	3,17	2,33		

TABLE 8: Summary of ideal burning days for the specified season common to the stations of Bien Donne, Elgin and De Doorns:
(a) hourly windspeed less than 16 km/hr
(b) hourly windspeed less than 19 km/hr

(a)

	Year					
Month	81	82	83	84	Total	Mean
February March April	nil 2 2	nil nil 4	nil 1 1	nil nil nil	nil 3 7	nil 0,75 1,75
Total Mean	4 1,33	4 1,33	2 0,67	nil nil	10	

(b)

	Year					
Month	81	82	83	84	Total	Mean
February March April	nil 2 2	nil nil 4	1 2 2	nil nil nil	1 4 8	0,25 1,00 2,00
Total Mean	4 1,33	4 1,33	5 1,67	nil nil	13	

TABLE 9: Summary of ideal burning days for the first six months of the year common to the stations of Bien Donne, Elgin and De Doorns:
(a) hourly windspeed less than 16 km/hr
(b) hourly windspeed less than 19 km/hr

(a)

Month	Year 81	82	83	84	Total	Mean
January	1	1	nil	nil	2	0,50
February	nil	nil	nil	nil	nil	nil
March	2	nil	1	nil	3	0,75
April	2	4	1	nil	7	1,75
May	5	3	5	1	14	3,50
June	2	5	3	3	13	3,25
Total	12	13	10	4	39	
Mean	2,00	2,17	1,67	0,67		

(b)

Month	Year 81	82	83	84	Total	Mean
January	1	2	nil	nil	3	0,75
February	nil	nil	1	nil	1	0,25
March	2	nil	2	nil	4	1,00
April	2	4	2	nil	8	2,00
May	6	4	5	2	17	4,25
June	2	5	3	5	15	3,75
Total	13	15	13	7	48	
Mean	2,17	2,50	2,17	1,17		

The occurrence of ideal burning days during the first six months of the year are given in Tables 9a and b for comparison. Higher figures are consistently associated with May, while February has an all-round low score. The effect of the 1984 record for Elgin still remains remarkable.

Table 10 lists the weather data for each of the ten ideal burning days shown in table 8a.

4.3.2 Description of pressure charts

The fifty (5 x 10) synoptic charts from which the five mean pressure charts were compiled are attached in appendix 7. Appendix 8 contains the mean gridpoint pressure values for each day of the five-day sequence.

The pressure charts of the five-day sequence, which were drawn by computer (courtesy of the South African Weather Bureau, Pretoria), are shown in figures 17a to 17e. The charts of days 1 to 3 are the "forecast charts". Day 4 is the target day on which burning should take place and day 5 represents the chart for the day after the burn.

TABLE 10: Weather data for the 10 ideal burning days

Date	Mean daily windspeed (km/hr)			Maximum daily temperature (°C)			Minimum daily humidity (% Rel. hum.)		
	Bien Donne	Elgin	De Doorns	Bien Donne	Elgin	De Doorns	Bien Donne	Elgin	De Doorns
27.3.1981	8,6	5,3	8,2	25,9	23,0	23,3	30,0	44,0	25,0
29.3.1981	11,8	4,3	7,1	28,0	24,8	26,0	32,0	41,0	20,0
9.4.1981	7,5	3,9	8,6	26,2	22,7	25,2	24,0	41,0	17,0
30.4.1981	4,5	2,5	5,6	25,7	22,5	24,2	27,0	35,0	23,0
13.4.1982	4,7	2,2	5,8	25,5	22,8	25,5	31,0	41,0	23,0
14.4.1982	4,7	1,6	8,4	25,4	22,0	24,0	38,0	38,0	30,0
20.4.1982	5,8	3,0	6,3	22,4	20,2	20,2	33,0	40,0	26,0
25.4.1982	4,2	5,5	8,0	27,2	25,9	25,0	38,0	44,0	32,0
19.3.1983	5,2	3,4	8,1	21,8	19,5	22,6	37,0	42,0	32,0
24.4.1983	5,9	3,2	9,0	27,8	25,5	26,7	22,0	29,0	29,0

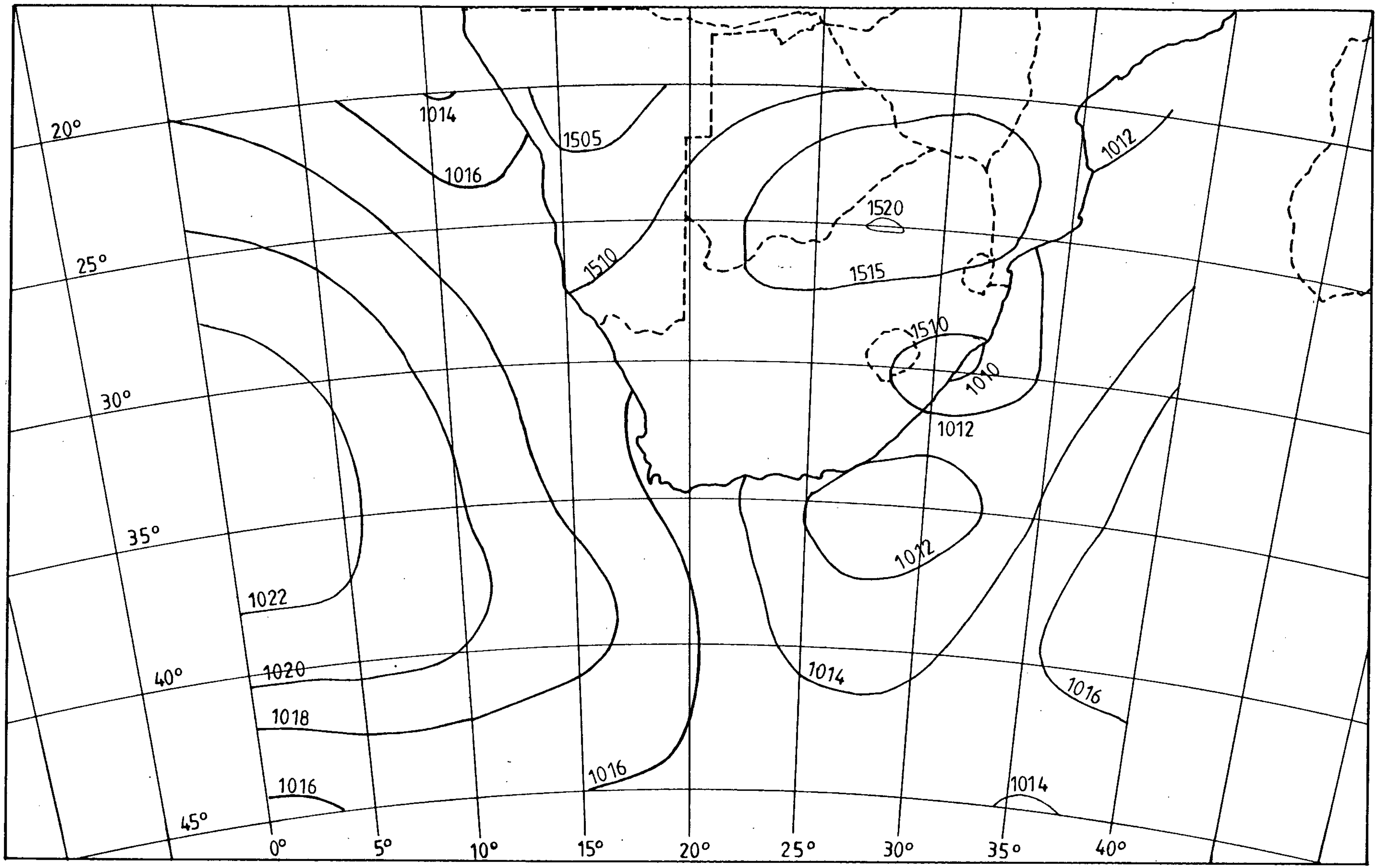

FIGURE 17 : Pressure charts for selecting burning days (sealevel in mb at 2mb intervals; Land - 850mb contours (gpm) at 5m intervals)

(a) DAY 1 - three days before burning day

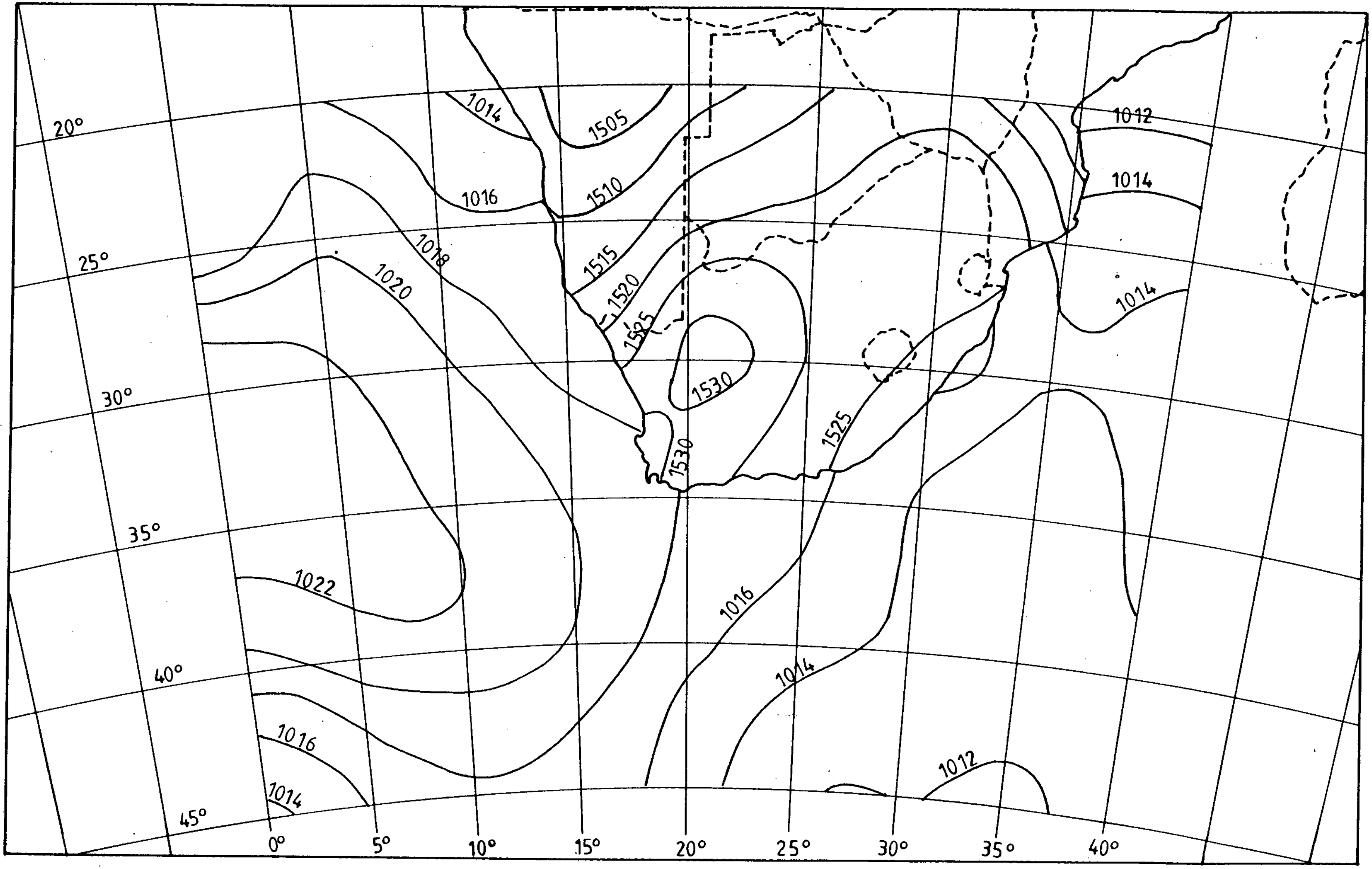

FIGURE 17 (cont.) : (b) DAY 2 - two days before burning day

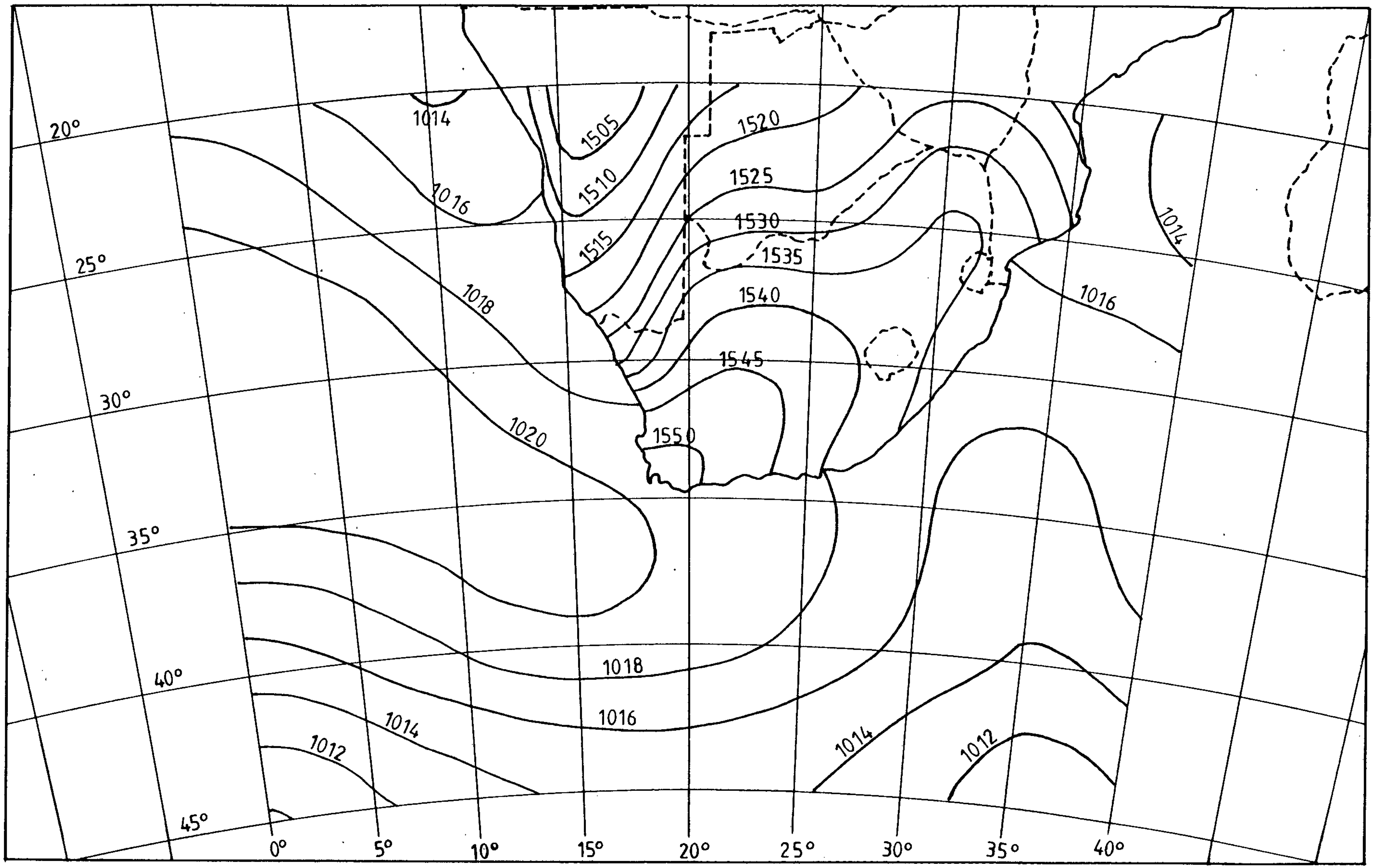

FIGURE 17 (cont.) : (c) DAY 3 - one day before burning day

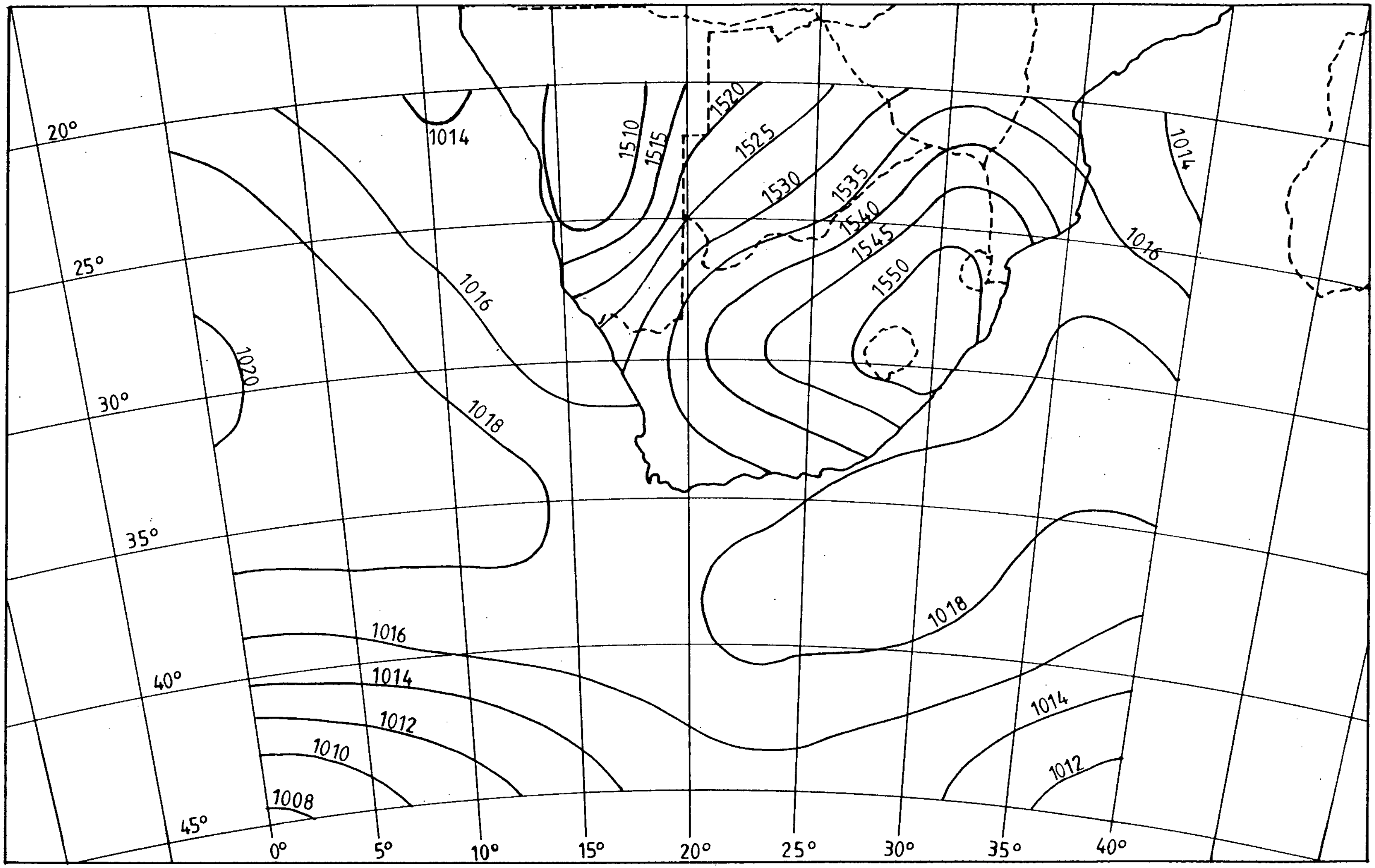

FIGURE 17 (cont.) : (d) DAY 4 - burning day

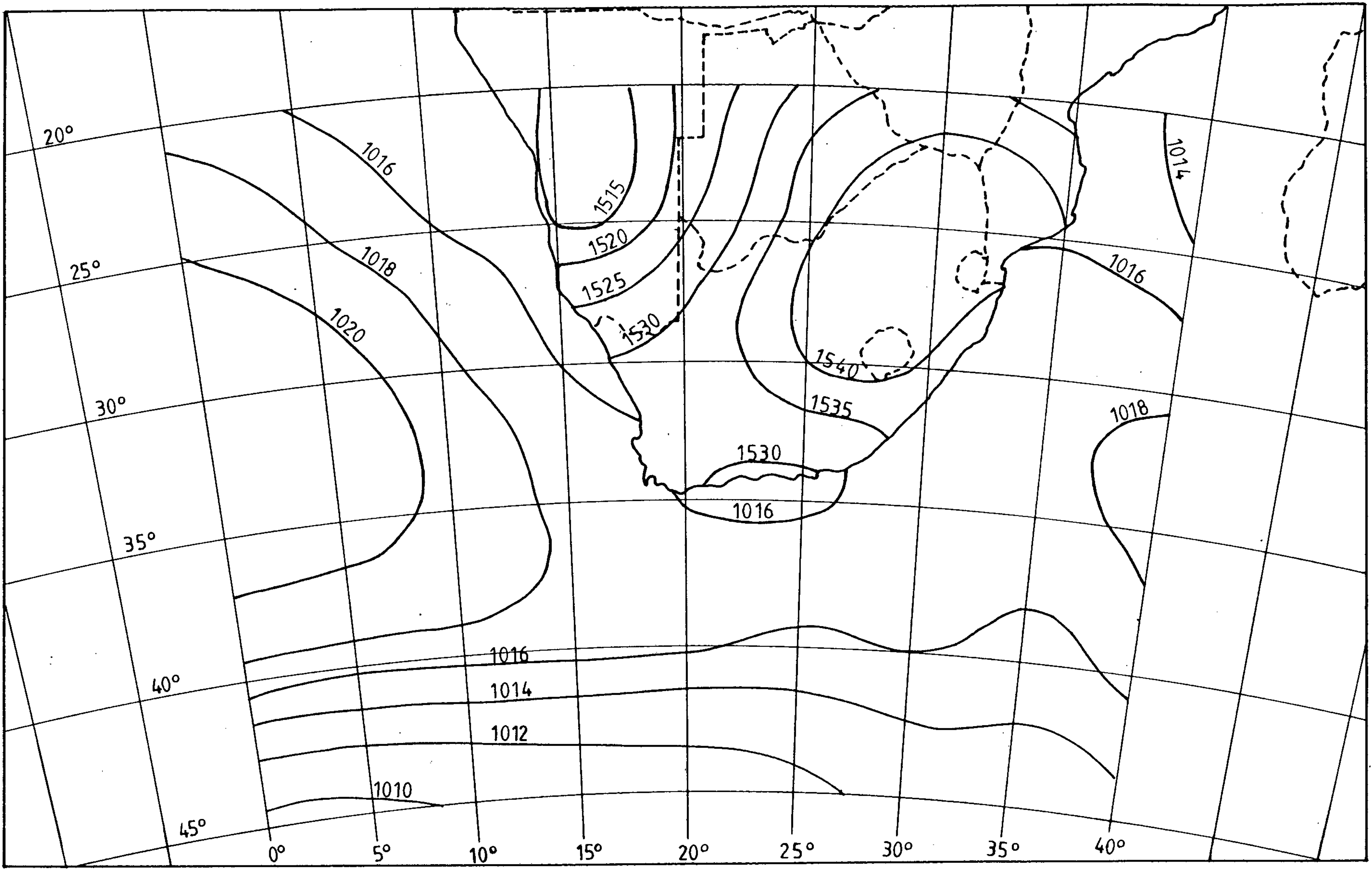

FIGURE 17 (cont.) : (e) DAY 5 - one day after burning day

It should be noted that the pressure patterns on each chart of the five-day sequence reflect a mean from 10 synoptic maps. As is the case with all mean pressure maps extremes become less pronounced, resulting in decreased gradients between high and low pressure areas. It is therefore fundamentally important to look for similarities in pressure patterns when using the charts and not to compare actual pressure values.

Day 1 (figure 17a)

A westerly trough is clearly discernible along the southern parts of the subcontinent with a mid-latitudinal cyclone centre just off the south-eastern Cape coast linked to a cyclone further south. This situation is invariably associated with the passing of a cold front across the subcontinent from west to east.

An unmistakable high pressure system is located south-west of the subcontinent with its centre roughly between Gough Island and Cape Town.

The meridional alignment of the isobars along the eastern part of the high pressure system indicates advection of polar air equatorwards in the wake of the frontal disturbance.

The isobars in the bottom righthand corner of the chart seem to indicate the presence of another cell of high pressure over the Indian Ocean to the far south-east of the subcontinent.

A strong pressure gradient exists along latitude 35°S.

Day 2 (figure 17b)

The frontal disturbance has swept across the subcontinent discernible from the westerly trough along the east coast of the subcontinent. Its northerly location is remarkable for this time of the year.

The high pressure cell over the South Atlantic Ocean is starting to ridge in behind the depression in an easterly direction. Cold air advection from south to north continues to occur across the subcontinent, especially the eastern parts.

A fairly strong pressure gradient can still be noticed along latitude 35°S.

Day 3 (figure 17c)

The south-easterly shift of the westerly trough indicates that the frontal disturbance is receding eastwards across the South Indian Ocean.

The South Atlantic high is now surging strongly around the subcontinent.

A clear reduction in the pressure gradient along latitude 35°S is noticeable.

Day 4 (target day) (figure 17d)

A well established high pressure cell (budded high) is now situated along the south-eastern seaboard extending a ridge over the north-eastern interior of the subcontinent.

The South Atlantic high has moved back into position between Gough Island and Cape Town.

The position of these two high pressure systems gives rise to a "saddle" in the alignment of the isobars along the south-west coast of the subcontinent.

Only a weak pressure gradient exists along latitude 35°S. Near the centre of the "saddle" the north-south pressure gradient appears to be weak as well.

Day 5 (figure 17e)

The "saddle" is disappearing with the development of another westerly trough south of the subcontinent, signalling the approach of a renewed frontal disturbance.

The high pressure cell along the south-eastern seaboard has moved further away in an easterly direction.

A clear strengthening of the pressure gradient along latitude 35°S is noticeable.

A high pressure cell is located over the north-eastern interior in contrast to an easterly trough along the north-western seaboard.

CHAPTER 5

APPLICATION AND DISCUSSION

5.1 Application of the five-day sequence

The model five-day sequence was applied to the 14h00 SAST surface synoptic maps of February, March and April 1985, compiled and stored at the D.F. Malan Airport weather office, Cape Town, in order to test its ability to select burning days. An analogue procedure was used to compare the synoptic maps to the model pressure charts of the five-day sequence. When a map was encountered which matched day 1 of the model it was retained. The synoptic map of the following day was then compared to day 2 of the model. This process was continued until a sequence was found where the synoptic maps of five consecutive days resembled those of the model sequence. The procedure was repeated until all synoptic maps had been examined.

A total of seven sequences were found to match with the model five-day sequence during February, March and April 1985. The synoptic maps which form part of the seven sequences are presented in appendix 9.

Having identified sets of synoptic sequences by using the model sequence of pressure patterns without reference to windspeed, temperature or humidity, it was necessary to establish the actual suitability for controlled burning of the predicted days. Data for hourly windspeed, maximum daily temperature and minimum daily relative humidity for Bien Donne, Elgin and De Doorns for the seven predicted burning days is presented in appendices 10, 11, 12 respectively. The weather of each of the seven days is outlined below with an indication of how suitable each day would have been as a burning day.

10 February 1985

Hourly windspeed was nearly within the specification for all 3 stations. Bien Donne reported hourly windspeeds of between 25, (29)* and 18 km/hr for the first six hours of the day. A short-lived peak of 19 km/hr at 19h00 was reported from De Doorns.

All 3 stations reported temperatures that slightly exceeded the specification, with the highest figure being from Bien Donne, 31,1°C.

All stations were within the humidity specification.

This day can be regarded as an acceptable burning day as the relatively high humidities compensate for the somewhat higher temperatures (Elgin and De Doorns). The situation at Bien Donne is marginal.

20 February 1985

At Bien Donne only 9 (5) hours were found to be within the windspeed specification. For the remaining hours windspeeds of

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* Figures in brackets show windspeed values at 14 m.

between 18 and 23 (up to 27) km/hr were recorded. Otherwise only De Doorns reported at 22h00 a windspeed higher than the specification. All stations reported temperatures above the specification with the highest figure being 32°C at Bien Donne.

All stations were within the humidity specification.

This day can be regarded as an acceptable burning day for Elgin and De Doorns but is unacceptable for Bien Donne.

6 March 1985

Only 3 (10) hours for Bien Donne and 1 hour for De Doorns exceeded the windspeed specification slightly.

With 28,9°C only Bien Donne exceeded the temperature specification.

De Doorns reported a humidity value of 14% which is 1% lower than the acceptable minimum specification.

Due to the limited violations of the specifications this day could be regarded as a good burning day for all three stations.

10 March 1985

All hourly windspeed values were within the specification.

Maximum daily temperature exceeded the specification by more than 5°C for all three stations.

The humidity specification was met by all stations.

If it were not for the allround high temperatures this day would have been an ideal burning day. It could, however, still be regarded as an acceptable burning day. Because of the very low windspeeds a run-away fire would have been virtually impossible.

20 March 1985

All hourly windspeed values were within the specification.

All temperature values were within the specification.

Elgin reported a humidity value of 51% which was 6% higher than the maximum specification.

This day could be regarded as an ideal burning day for all stations.

25 March 1985

Only Bien Donne reported windspeeds of more than 16 km/hr but not more than 19 (20) km/hr during four (five) hours in the early morning.

Bien Donne (29°C) and De Doorns (28,5°C) reported temperatures slightly higher than the specification.

Elgin reported a humidity value of 51%.

Due to the limited violations of the specifications this day could be regarded as a good burning day for all the stations.

26 April 1985

All hourly windspeed values were within the specification.

Bien Donne reported a temperature of 28,5°C, only 0,5°C above the specification.

The humidity recordings were all within the specification.

This day could be regarded as an ideal burning day for all stations.

TABLE 11: Summary of the suitability of burning days predicted in using the five-day model sequence

Date	Suitability for burning
20 March 1985	ideal burning day
26 April 1985	ideal burning day
6 March 1985	good burning day
25 March 1985	good burning day
10 February 1985	acceptable burning day
10 March 1985	acceptable burning day
20 February 1985	unacceptable burning day

More than half of the number of days which have been identified as possible burning days during the test run of the five-day sequence could be regarded as good burning days (table 11). Only one out of seven possible burning days could be regarded as unacceptable for the study region as a whole, but may have been quite acceptable for individual stations.

5.2 Discussion

5.2.1 Past burns

The number of prescribed burns which were undertaken in the study area between 1978 and 1983 is outlined in table 12. From the table it is evident that no forest station had to undertake more than an average of three burns per year during the period of record. The highest average number of burns per year per station is close to 2,5 burns.

It is evident that some stations have a far greater burning load than others and would therefore require an average of about 3 ideal burning days per year to complete their burning schedule. Furthermore, it is clear that in some years more burns were executed than in others, a finding which is most likely to be related to the annual variation of suitable burning weather over the study region.

TABLE 12: Summary of prescribed burns which were executed in the study region between 1978 and 1983 (Departmental records)

Forest Station	Year 78	79	80	81	82	83	Total	Mean
Hawequas	3	4	1	5	2	3	18	3,00
La Motte	1	3	2	2	3	1	12	2,00
Nuweberg	4	3	3	nil	nil	3	13	2,17
Kluitjieskraal	nil	nil	5	6	6	nil	17	2,83
Grabouw	2	nil	1	1	nil	4	8	1,33
Lebanon	3	nil	1	2	2	nil	8	1,33
Jonkershoek	2	2	1	1	nil	1	7	1,17
Total	15	12	14	17	13	12	83	
Mean	2,14	1,71	2,00	2,43	1,86	1,71		

5.2.2 Occurrence of burning weather during the study period

The number of ideal burning days which occurred during the recommended burning season between 1981 to 1984 are shown in figure 8a. A total of 10 ideal burning days over 4 years gives a mean value of 2,5 ideal burning days per year for the study region as a whole. This result is compatible with the observations of the previous section and the results of the model test.

Furthermore, it would appear that a considerable increase in burning days could result from a more realistic application of the burning weather specifications, e.g. where higher humidities could compensate for higher temperatures and vice versa. Besides a category of ideal burning weather, categories of good and acceptable burning weather could be established, based on the magnitude (within limits) of the violations of the preferred specifications. It is suggested that the above-mentioned refinements of the proposed consultation system could be based on practical experiences obtained during an application of the system.

The negative effect which the weather of the Elgin station had on the occurrence of ideal burning days for the region as a whole during 1984 has been mentioned earlier. Therefore there is little doubt that individual stations may have experienced considerably more days of ideal burning weather than the region as a whole. Although it may be suggested that synoptic scale burning weather should be equally suitable for all stations within a given region, local variations may still be considerable. This is particularly true for mountainous regions which one is faced with in the present study.

5.2.3 Burning weather meteorology

Burning weather over the south-western Cape Province is evidently associated with weak anticyclonic air flow (figure 17d). The flow is steered around the western part of the high pressure cell which is centred over the eastern part of the subcontinent. As the flow continues in a westerly to southerly direction across the subcontinent it becomes increasingly continental in nature, hence dry and warm. Entrainment of moist tropical air from the north is unlikely to occur further south than latitude 25°S.

Horizontal divergence over the study area is clearly noticeable in figures 17d and e. In the north the north-easterly air flow is deflected cyclonically around the west coast easterly trough. In the south of the subcontinent it continues on its anticyclonic trajectory in a southerly to south-easterly direction. This situation is invariably associated with calm, subsiding and stable air over the study area.

Due to the weak off-shore winds, discernible by the widely spaced 850 mb contours, the development of deep coastal lows or strong Berg Winds is unlikely. Most of the ideal burning days which were used to develop the model five-day sequence showed a change of wind direction through 180° between day and night. It is therefore suggested that during ideal burning conditions mountain and valley winds have a greater influence on wind direction than the gradient wind which will be very light.

It is interesting to note that the pressure configuration of the ideal burning day contains elements of both the summer and winter circulation over the subcontinent. This is not unusual for the late summer to mid-autumn season. The west coast easterly trough is certainly a feature of the summer circulation while the high pressure cell over the eastern part of the country is usually indicative of winter conditions.

5.2.4 Summary of synoptic events of the model five-day sequence

The outstanding features of the surface circulation which are associated with the five-day sequence are:

(i) the passage of a mid-latitudinal frontal disturbance,

(ii) the eastward surge of the high pressure system over the South Atlantic Ocean, and

(iii) the juxtaposition of a high pressure system over the eastern parts of the country and an easterly trough along the north-west coast.

The strong influence of a cold front over the subcontinent for the first two days of the sequence is slowly but increasingly replaced by the ridging process of the South Atlantic high pressure system. On the fourth day (target day) a cell of high pressure has separated from the South Atlantic high and is situated along the east coast, with a ridge over the eastern parts of the country. A distinct "saddle" linking the two high pressure cells is noticeable over the south-west and south coast. The "saddle", which appears to be the key to burning weather over the study region, ceases to exist on the 5th day with the eastward movement of the budded high and the approach of a new frontal disturbance from the west.

Common terms have been used to summarise the sequence of synoptic events which are associated with the model five-day sequence. The eastward movement of the budded high pressure cell is basically the manifestation of a short-wave travelling disturbance (cold front) and its associated anticyclone.

With the continued surge of the high pressure system around the subcontinent the air flow over the southern parts of the country changes from south-west to south-east, eventually becoming light easterly to north-easterly over the study region. This will bring about the necessary clearing of the rainy weather and hence drying of the vegetation (fuel). This, together with the weather which prevails on the 4th day of the sequence sets conditions suitable for execution of a prescribed burn. When these conditions prevail the veld manager can be reasonably sure that the burn will not get out of control because of sudden unexpected changes in the weather.

CHAPTER 6

CONCLUSION

This study was conducted in order to investigate the predictability of suitable burning weather for the south-western Cape Province. The aim of the study was to develop a simple knowledge-based system which can be used by the catchment manager to guide his choice of days for prescribed burning in the ecologically desirable season. It was decided to adopt a synoptic analogue method to develop and apply the consultation system which is referred to as the model five-day sequence. This approach has the practical advantage of being helpful to a user who has only a rudimentary knowledge of weather analysis.

The system which has been developed consists of a five-day sequence of mean surface pressure charts according to which day 4 is the day on which controlled burns should be executed. The weather conditions of this burning day are likely to facilitate safe and efficient veld burning. During a test application it was demonstrated that the consultation system proved useful in alerting the catchment manager three days in advance when to expect suitable burning weather.

The value of the present system could be amplified by using it in conjunction with the ECMWF (European centre for medium range weather forecasting) numerical forecast technique which has recently been adopted by the South African Weather Bureau. This forecast technique provides a five-day forecast for the surface and 500 mb circulations.

By comparing the predicted pressure pattern by the ECMWF System with those of the model five-day sequence it would be possible to compare the entire sequence in advance. When the pressure patterns match, the actual synoptic maps could be compared with the forecast maps and the charts of the model sequence to improve confidence in the selection of a burning day. The ECMWF computer generated maps are presently only obtainable from the weather office in Pretoria but they will be available at the D.F. Malan Airport weather office in Cape Town possibly as early as 1986.

In conclusion it can be stated that this study achieved its aim of describing and predicting weather conditions suitable for prescribed burning of fynbos vegetation in the south-western Cape Province. The model sequence of pressure charts developed in the study provides a tool for the catchment manager that will give him greater confidence when selecting days on which to execute controlled burns in a potentially hazardous fire season.

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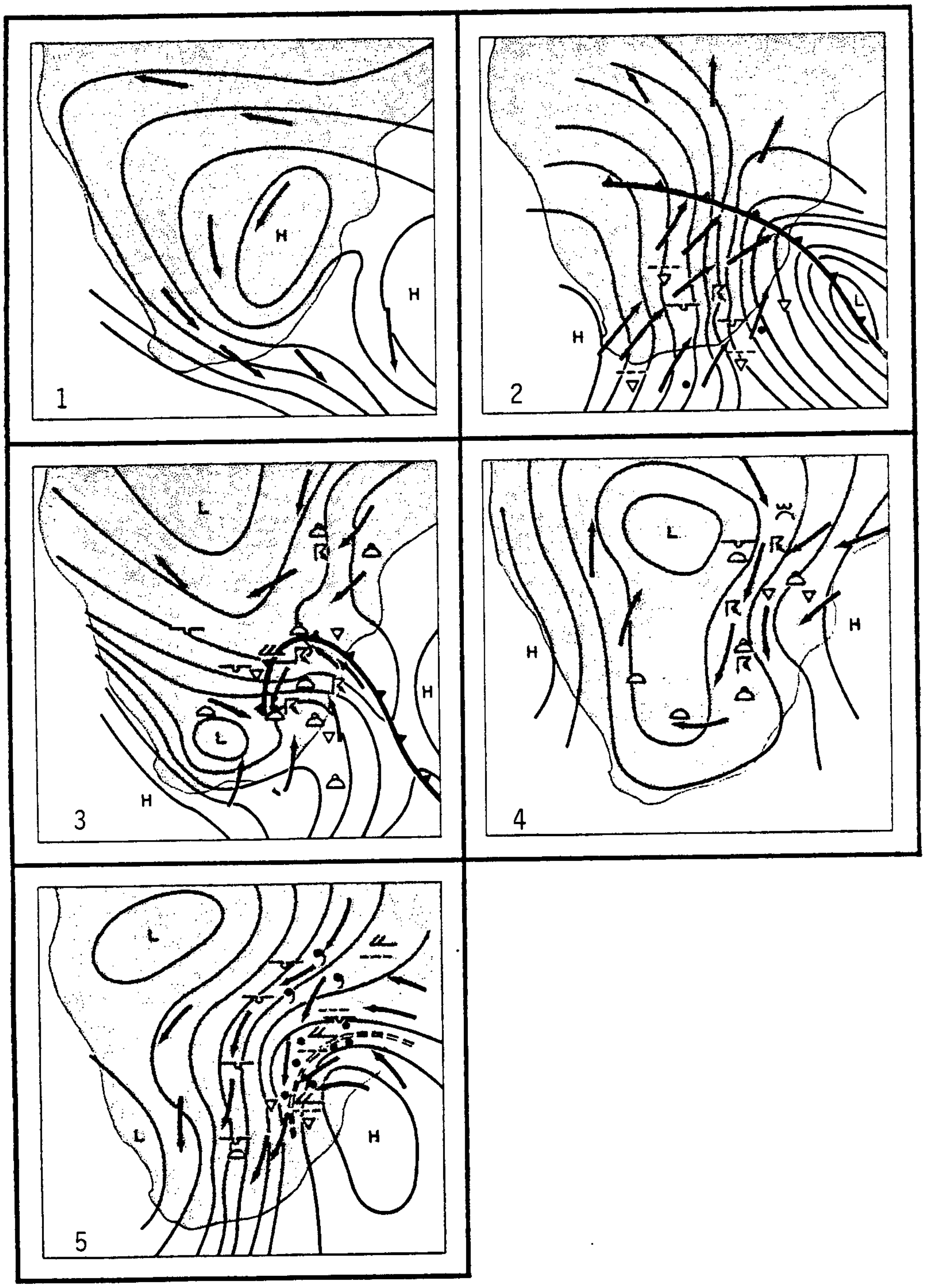
APPENDIX 1

Five important weather types of South Africa (1 = fair-weather type; 2 = cold-air type; 3 = monsoon type; 4 = equatorial type; 5 = bad-weather type (after Vorwinckel, 1955))



APPENDIX 2

Summary of South African thunderstorm structures and synoptic charts

Storm	Type	Regeneration	Cell Movement	Wind Direction	Wind Speeds	Direction of Storm Travel	Position of Core	Precipitation	Synoptic Chart
14 January 1975 Kelbe (1975)	Single Cell	On Left Flank (Continuous)	Echo Tops from Left to Right	Westerly (Upper)	Light	—	—	—	
29 November 1972 Carte and Mader (1977) storm 1	Single Cell	Left Flank at first Right Flank	Echo Tops and W.E.R.'s From Right to Left	Northerly (Lower) West South West (Upper)	20 km/h(800 mb) 60 km/h(300 mb)	To Right of Upper Winds	Rear of Storm	Hail from Core and Rain	
storm 2	Single Cell	—	—	Ditto	Ditto	—	—	—	
storm 4	Single Cell	Left Flank and Right Flank occassionally	No movement but crescent shaped core	Ditto	Ditto	To Right of Upper Winds	Rear of Storm	Hail and Rain	
13 November 1961 Tyson (1964)	Squall Line	—	—	North Easterly (Lower) South Westerly (Upper)	—	—	—	Rain	
15 January 1964 Carte (1964)	Squall Line	On Left Flank (Discrete)	From Left to Right	North Easterly (Lower) South Westerly (Upper)	20 km/h (Lower)	To Left of Upper Winds	—	Hail and Rain	
9 January 1968 Preston-Whyte (1971)	Squall Line	On Left Flank	—	Onshore Easterly (Lower) North Westerly (Upper)	—	—	—	—	
14 November 1975 Held and vanden Berg (1977)	Squall Line	To Left of existing cells some times between and ahead of them	From Left to Right along the squall line i.e. with the 500 mb winds	Westerly (Lower) North Westerly (Upper)	30 km/h (Lower) 120 km/h (200 mb)	60 degrees to Left of 500 mb winds	Near Leading Edge of Storm	Hail from Core	
12 December 1975 Mather (1976)	Squall Line	On Right Flank	—	—	—	—	—	Hail on Right Flank	
15 November 1971 Carte (1971)	Multi Cell	On Left Flank (Discrete)	—	Westerly (Lower) North Westerly (Upper)	— 65 km/h (Upper)	To Left of Upper Winds	—	--	

APPENDIX 3

A synoptic systems classification scheme

TYPE 1 - TROPICAL INFLUENCES

Situation 1A.

a) Synoptic Chart

i) surface trough across central parts of country, connected in north to tropical low;

ii) confluence set up by inland component of coastal low advancing towards high cell.

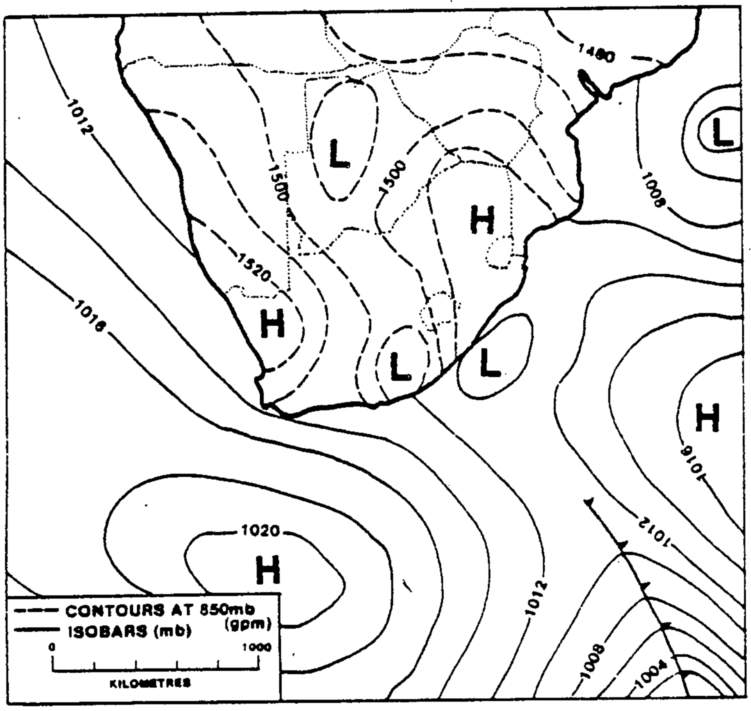
b) Satellite Imagery

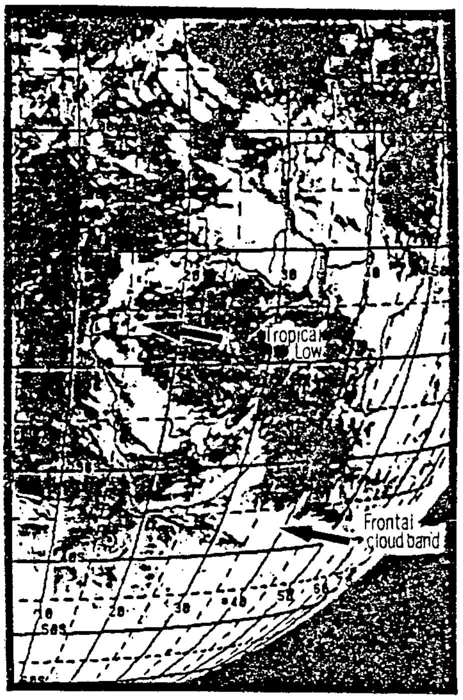
i) active tropical convection connected to clouds in north-east Orange Free State;

ii) cloud configuration indicates southward flow of tropical air from tropical low;

iii) cumulus cloud development is most prominent in the confluence region.

(Note on diagrams: All are taken from Erasmus (1980). Synoptic analyses are adapted from 1200 GMT Weather Bureau analyses. METEOSAT infra-red photographs are either 1200 or 1700 GMT and intercepted at the Hartbeeshoek tracking station.)





APPENDIX 3 (cont.)

Situation 1B.

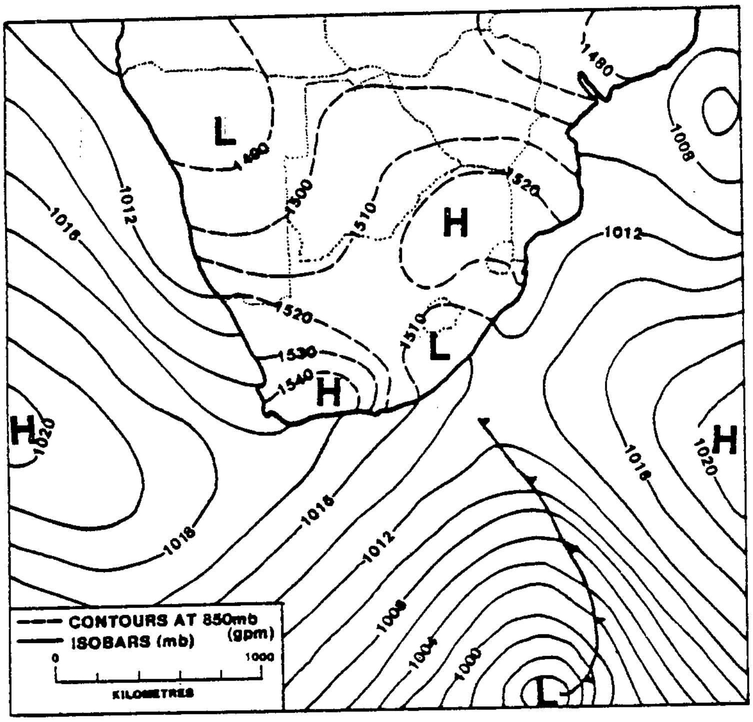
a) Synoptic Chart

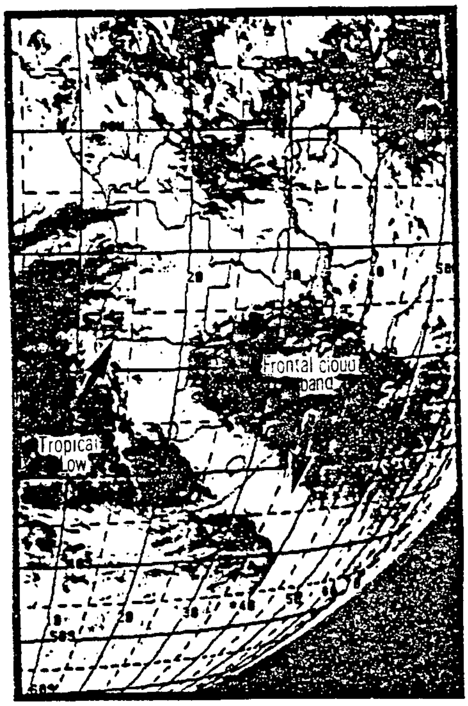
i) surface trough across central parts of country, connected in north to tropical low;

ii) little or no surface confluence apparent.

b) Satellite Imagery

i) a well-defined continuous cloud band connecting tropical and temperate latitudes, the southern sections being of a frontal nature.





APPENDIX 3 (cont.)

TYPE 2 - TEMPERATE INFLUENCES

Situation 2A.

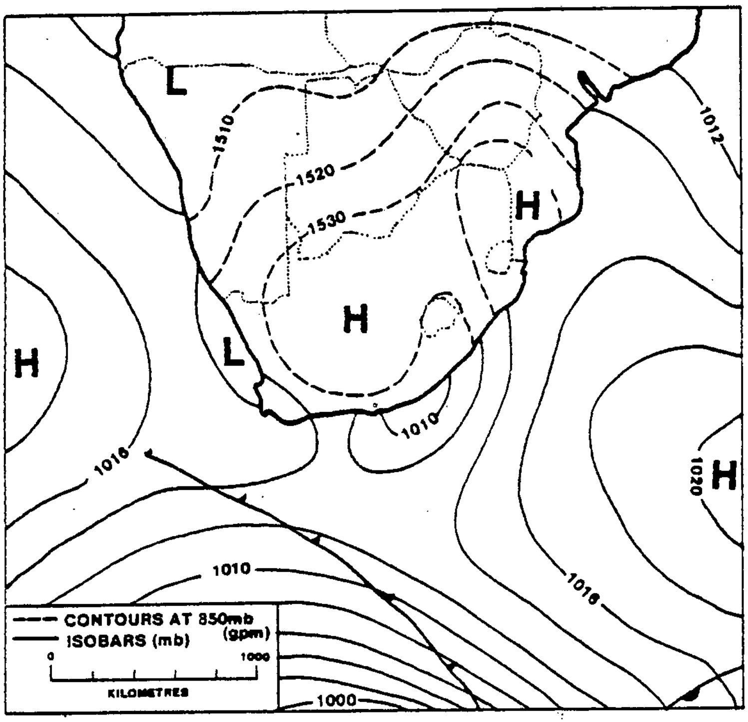
a) Synoptic Chart

i) confluence set up by inland component of coastal low advancing towards high cell.

b) Satellite Imagery

i) frontal cloud band south of the sub-continent;

ii) cumulus cloud development in the confluence region.



APPENDIX 3 (cont.)

Situation 2B.

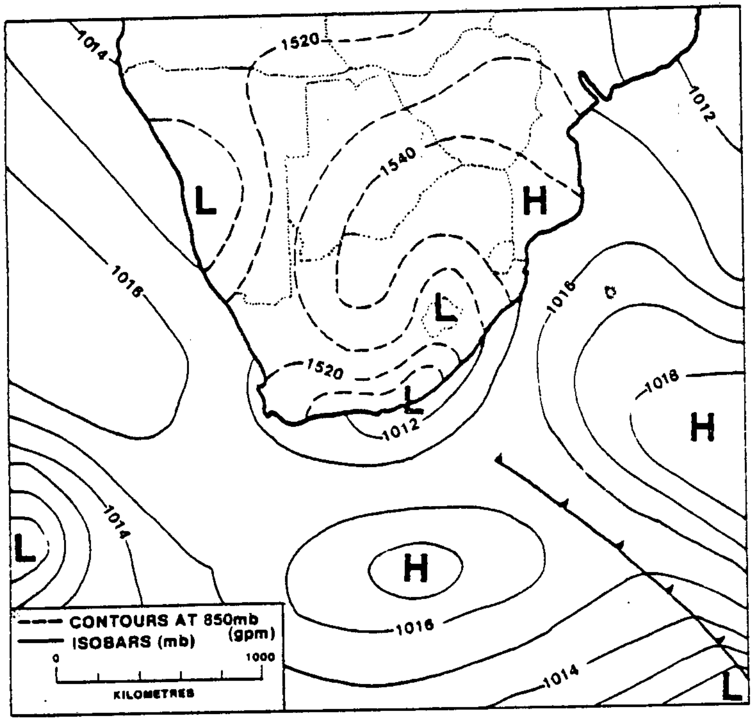
a) Synoptic Chart

i) confluence set up by overland trough directly associated with cold front advancing on high cell.

b) Satellite Imagery

i) cloud over north-east Orange Free State directly connected to frontal cloud band;

ii) tropical convection may be present but is not connected to frontal band.



APPENDIX 3 (cont.)

TYPE 3 - LOCAL INFLUENCES

Situation 3.

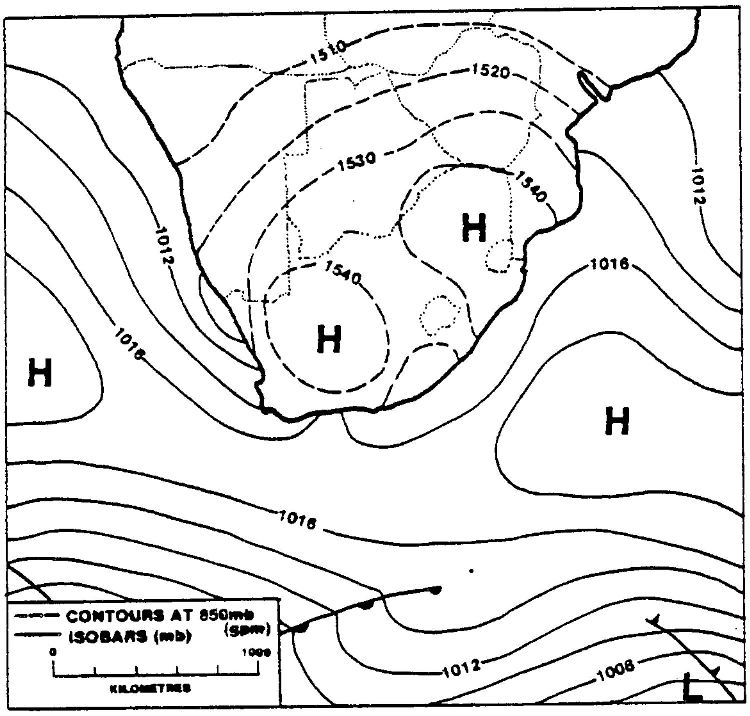
a) Synoptic Chart

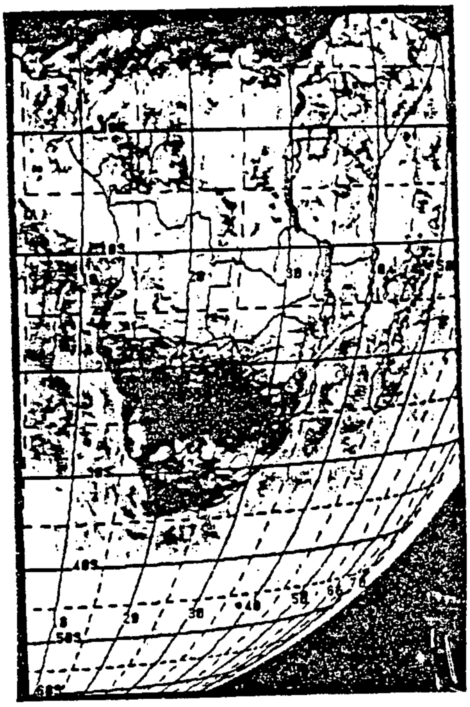
- i) heat low over central interior;
- ii) light and variable surface winds;
- iii) no significant troughs.

b) Satellite Imagery

- i) nearly cloudless region in vicinity of heat low;
- ii) no front or subtropical cloud band over the sub-continent.

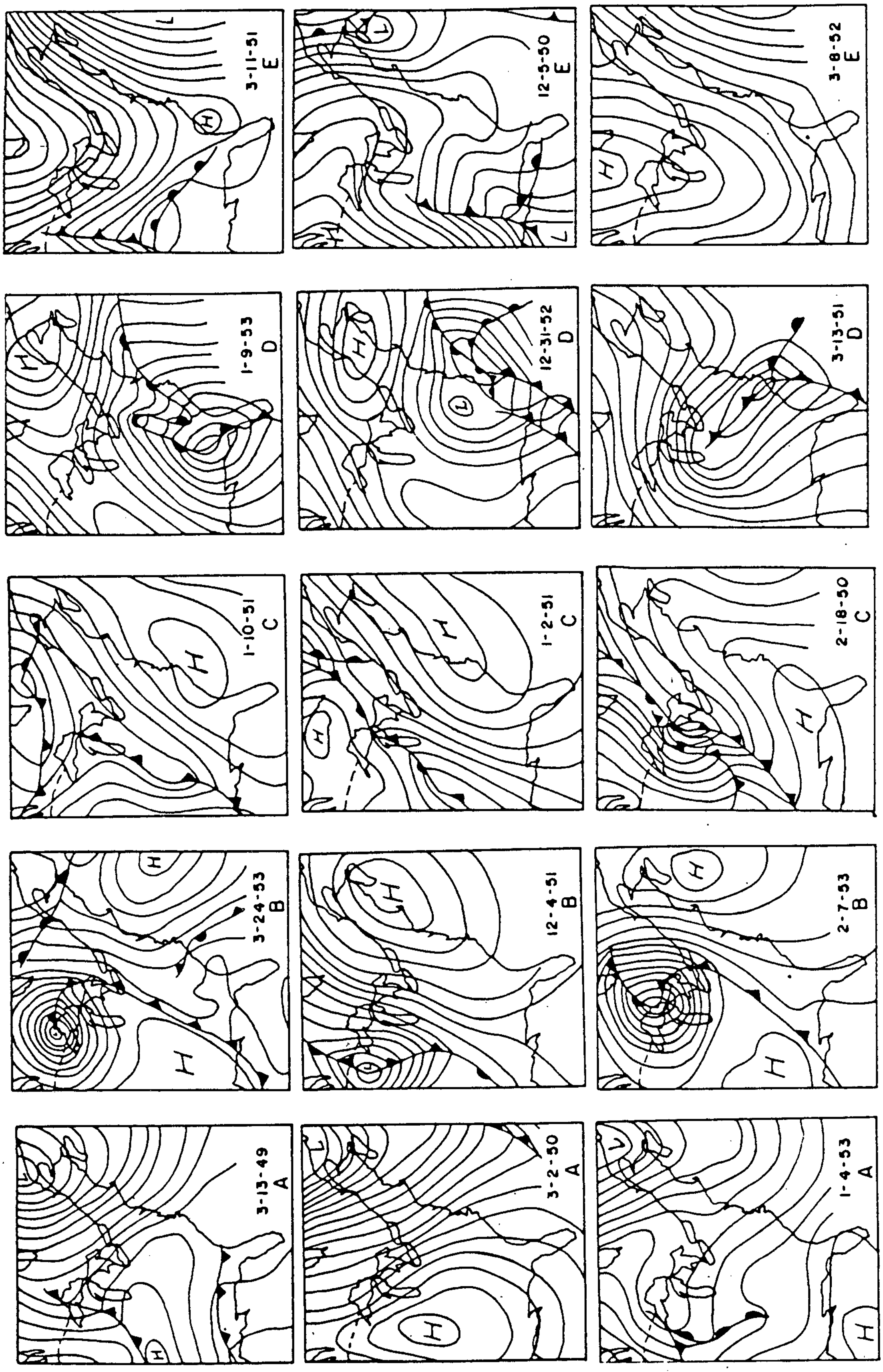
(Note that only light rains were associated with this situation.)



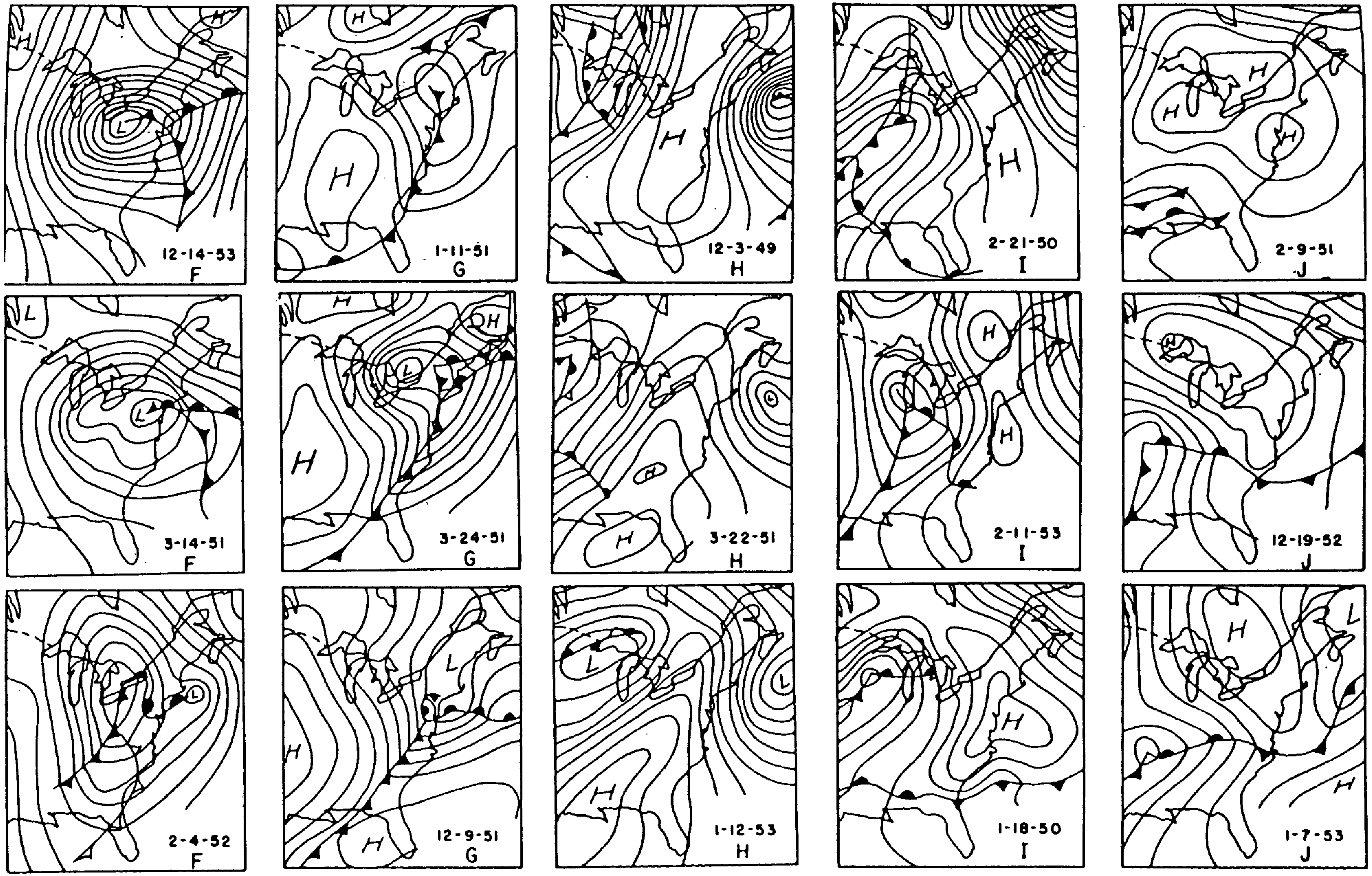


APPENDIX 4

Three examples of each of ten map types (after Lund, 1963)



APPENDIX 4 (cont.)



APPENDIX 5

Examples of weather maps for some pattern days (after Longley, 1976)

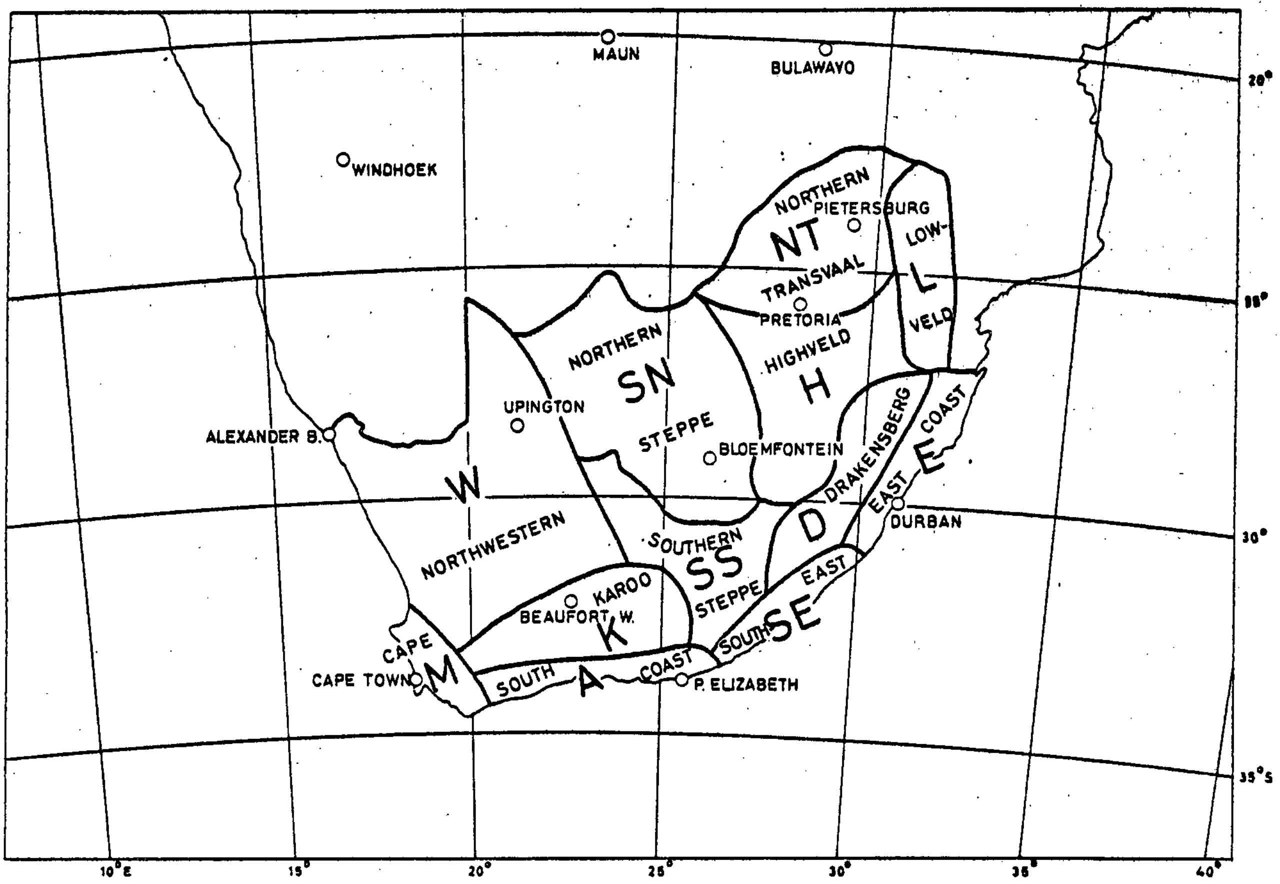
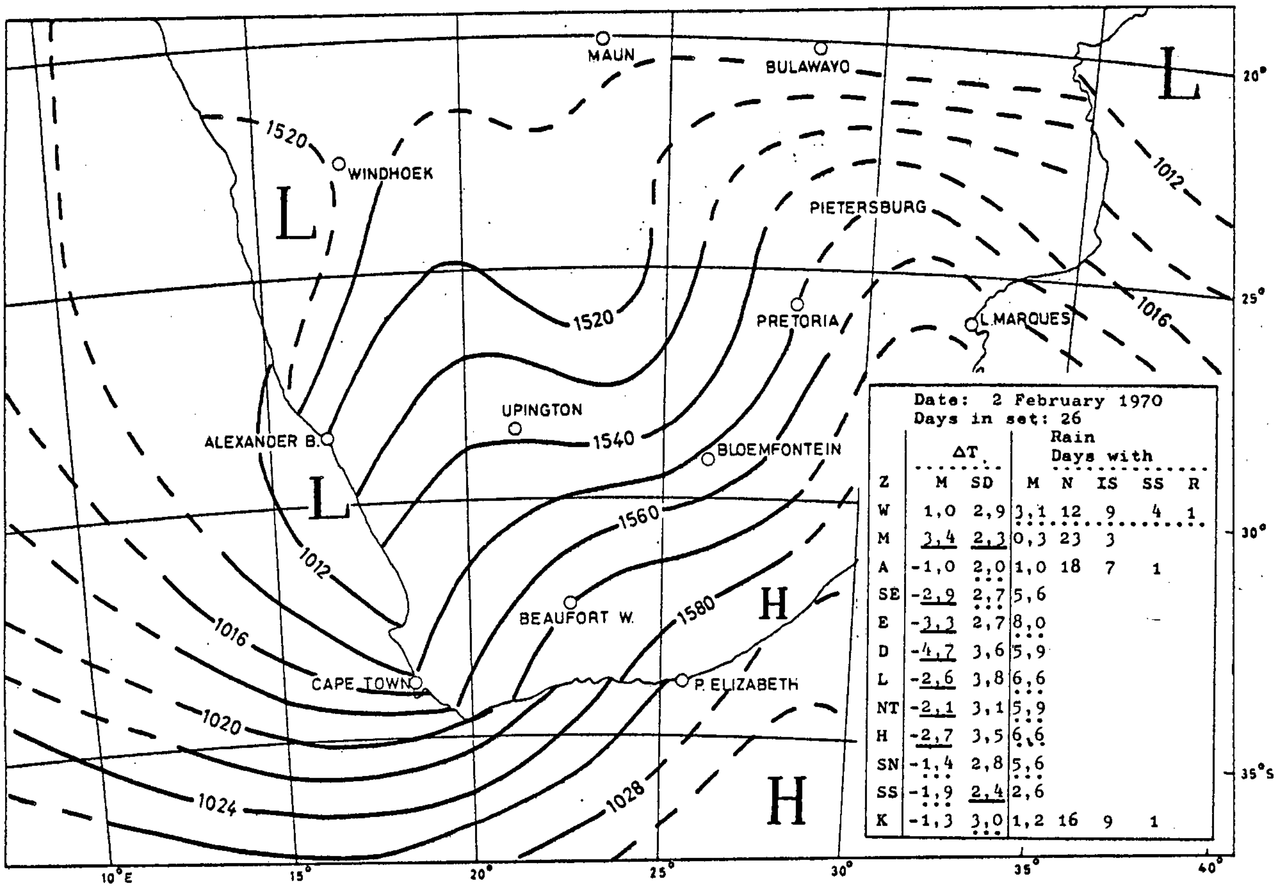


FIGURE 1: Climatic zones of South Africa (after Monthly Weather Report, South African Weather Bureau)

APPENDIX 5 (cont.)



Date: 2 February 1970
Days in set: 26

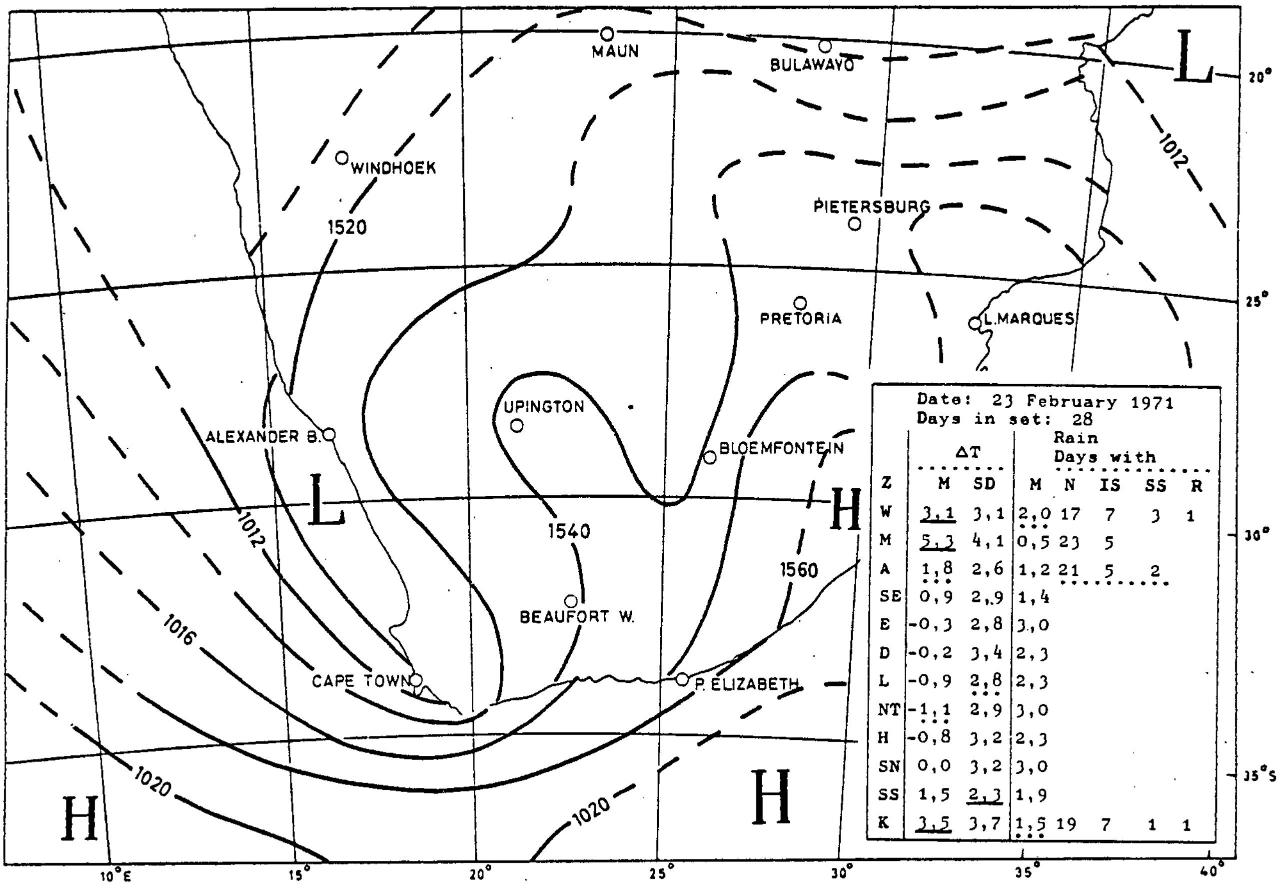
	ΔT		Rain Days with				
Z	M	SD	M	N	IS	SS	R
W	1,0	2,9	3,1	12	9	4	1
M	3,4	2,3	0,3	23	3		
A	-1,0	2,0	1,0	18	7	1	
SE	-2,9	2,7	5,6				
E	-3,3	2,7	8,0				
D	-4,7	3,6	5,9				
L	-2,6	3,8	6,6				
NT	-2,1	3,1	5,9				
H	-2,7	3,5	6,6				
SN	-1,4	2,8	5,6				
SS	-1,9	2,4	2,6				
K	-1,3	3,0	1,2	16	9	1	

FIGURE 2: Weather map for pattern day 2 February 1970

NOTES

The following notes relate to figures 2, 3 and 4 of appendix 5. Column 1 lists the climatic zones as given in figure 1. In columns 2 and 3, ΔT refers to the departure of the maximum temperature from the normal, with M giving the mean for the set, and SD the standard deviation. Columns 4 to 8 refer to the numbers of stations with significant rain (rain over 1,9mm). Column 4 gives the mean for the set. When the mean is 10 per cent or more above the normal for the zone and the season, it is underlined. Columns 5 to 8 give the number of days of the set when no station reported rain (N), days when 1 to 6 stations reported rain (IS), days when 7 to 13 stations reported rain (SS), and days when 14 to 20 stations reported rain (Except column 4, a dotted line below a value or set of values indicates that the value is significantly different from the normal at the 0,05 level. A solid line indicates a difference from normal significance at the 0,01 level.

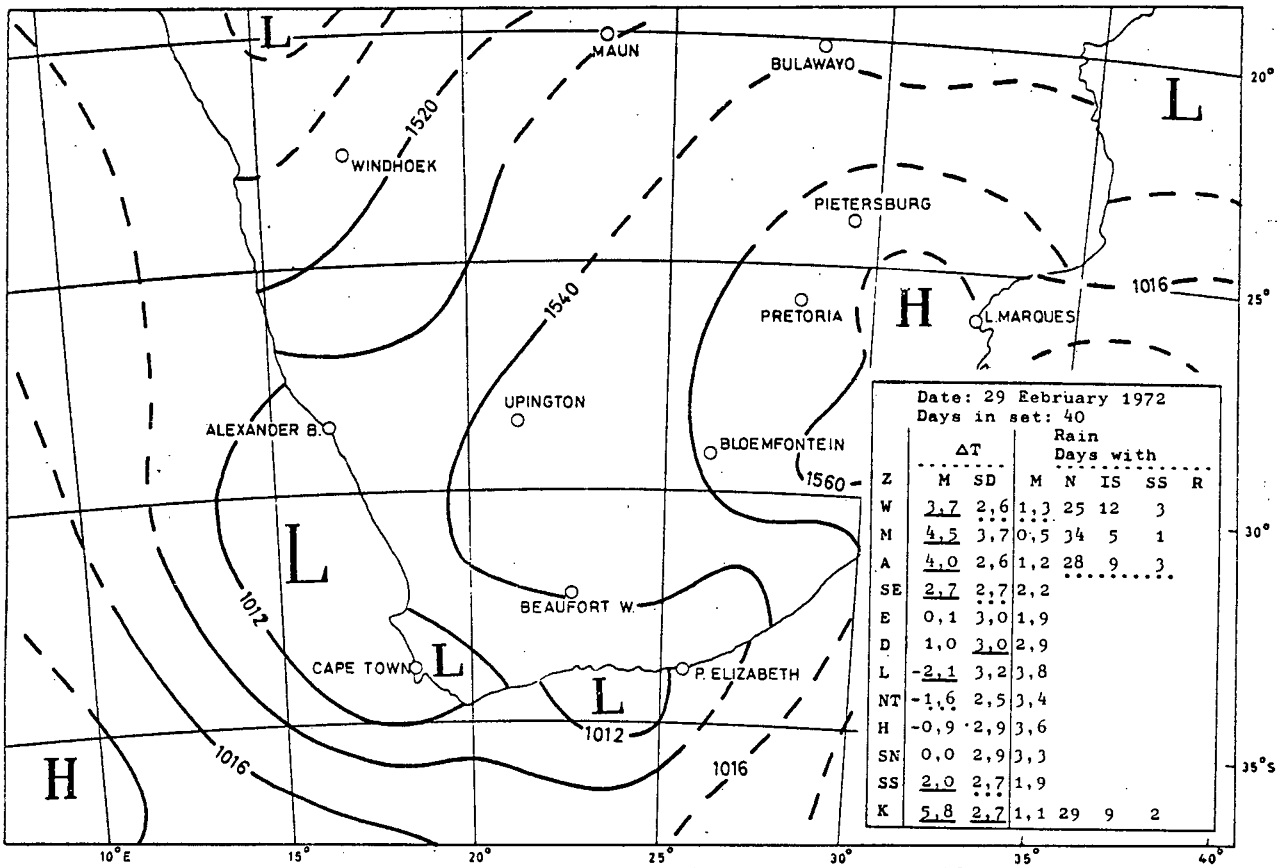
APPENDIX 5 (cont.)



Date: 23 February 1971
Days in set: 28

Z	ΔT		Rain	Days with			
	M	SD	M	N	IS	SS	R
W	3,1	3,1	2,0	17	7	3	1
M	5,3	4,1	0,5	23	5		
A	1,8	2,6	1,2	21	5	2	
SE	0,9	2,9	1,4				
E	-0,3	2,8	3,0				
D	-0,2	3,4	2,3				
L	-0,9	2,8	2,3				
NT	-1,1	2,9	3,0				
H	-0,8	3,2	2,3				
SN	0,0	3,2	3,0				
SS	1,5	2,3	1,9				
K	3,5	3,7	1,5	19	7	1	1

FIGURE 3: Weather map for pattern day 23 February 1971



Date: 29 Eebruary 1972
Days in set: 40

Z	ΔT		Rain	Days with			
	M	SD	M	N	IS	SS	R
W	3,7	2,6	1,3	25	12	3	
M	4,5	3,7	0,5	34	5	1	
A	4,0	2,6	1,2	28	9	3	
SE	2,7	2,7	2,2				
E	0,1	3,0	1,9				
D	1,0	3,0	2,9				
L	-2,1	3,2	3,8				
NT	-1,6	2,5	3,4				
H	-0,9	2,9	3,6				
SN	0,0	2,9	3,3				
SS	2,0	2,7	1,9				
K	5,8	2,7	1,1	29	9	2	

FIGURE 4: Weather map for pattern day 29 February 1972

APPENDIX 6

SAS programme used to process windspeed data

(The wind data was transferred from a computer tape to a SAS file. The short programme which was written to read the data in already screened the data to exclude all values above a specified limit. SAS files GOODAY1 and GOODAY2 contain hourly windspeed values of 16km/hr and 19km/hr respectively for several stations with varying periods of record).

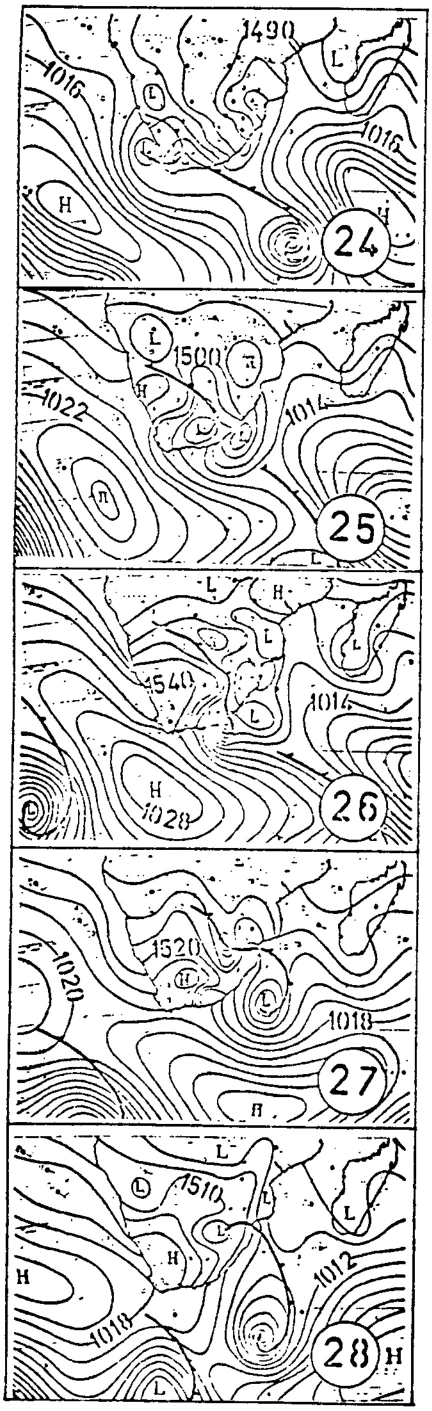
```
DATA WIND; SET STORE. GOODAY1;
  IF W-DIR=1 AND W-SPD=1 THEN DELETE;
     * UNRELIABLE DATA WAS INDICATED BY  1;
     * W-DIR STANDS FOR WIND DIRECTION;
     * W-SPD STANDS FOR WINDSPEED;
  IF STATION=200 OR STATION=17 OR STATION=16;
  IF MONTH GE 1 AND MONTH LE 6;

PROC SORT; BY STATION YEAR MONTH DAY HOUR;

PROC FORMAT;
  VALUE STATION 200=BIEN DONNE 16= DE DOORNS 17=ELGIN;

PROC FORMAT;
  VALUE WD 36=N 02=NNE 05=NE 07=ENE 09=E 11=ESE 14=SE
          16=SSE 18=S 20=SSW 23=SW 25=WSW 27=W 29=WNW
          32=NW 34=NNW;

PROC MEANS N NOPRINT;
 BY STATION YEAR MONTH DAY;
 VAR HOUR;
OUTPUT OUT=DAYGOOD N=SLOWIND;
    * SLOWIND : STANDS FOR THE NUMBER OF HOURS;
    * PER DAY WITH WINDSPEEDS LT 16KM/HR;

DATA DAYGOOD1; SET DAYGOOD;
 DO I=1 TO 24;
 STATION=STATION; YEAR=YEAR; MONTH=MONTH; DAY=DAY;
 SLOWIND=SLOWIND; HOUR=I:OUTPUT;
 END;

PROC SORT; BY STATION YEAR MONTH DAY HOUR;

DATA GOODDAY; MERGE WIND DAYGOOD1;
 BY STATION YEAR MONTH DAY HOUR;
 IF SLOWIND=24;
```

APPENDIX 6 (cont.)

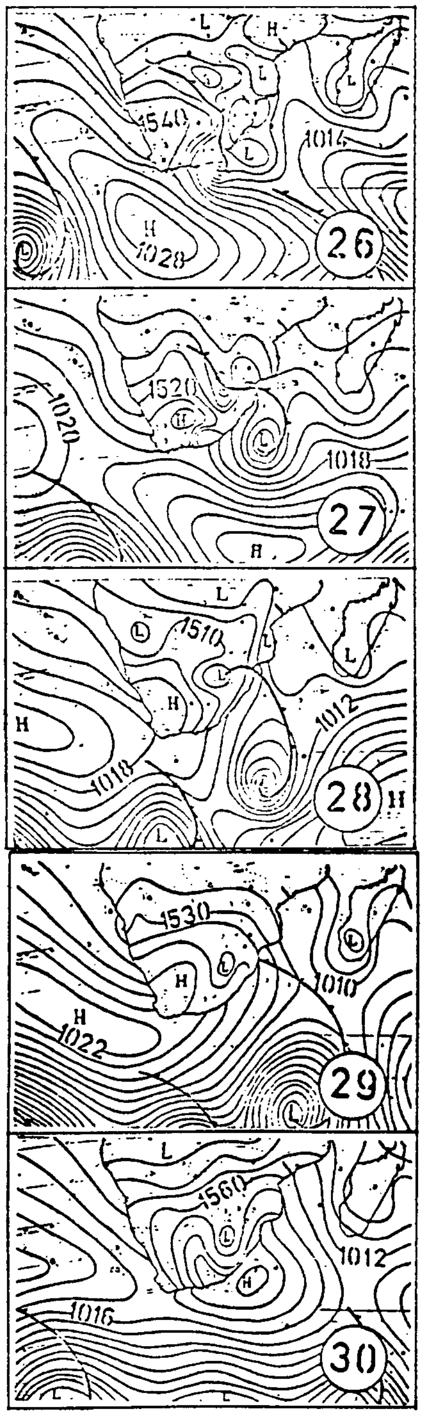
```
    * CALCULATION OF SUITABLE BURNING DATES;
    * COMMON TO THE THREE STATIONS OF;
    * DE DOORNS, ELGIN AND BIEN DONNE;
    * UNRELIABLE DATA REMOVED;

DATA GOODDAY; SET GOODDAY;
 IF HOUR=1;

PROC SORT; BY YEAR MONTH DAY STATION;

PROC MEANS N NOPRINT;
 VAR STATION;
 BY YEAR MONTH DAY;
 OUTPUT OUT=GOODDATE N=NRSTNS;
    * NRSTNS : STANDS FOR NUMBER OF STATIONS;

DATA GOODDATE; SET GOODDATE;
 BY YEAR MONTH DAY;
 IF NRSTNS=3;
 DATE=DAY;

PROC SORT; BY YEAR MONTH DATE;

DATA DATEGOOD; SET GOODDATE;
 BY YEAR MONTH DATE;
 IF FIRST.DATE THEN OUTPUT;

PROC TRANSPOSE;
 VAR DATE;
 BY YEAR MONTH;

PROC PRINT: BY YEAR;
 ID MONTH;

TITLE1 SUITABLE BURNING DATES COMMON TO;
TITLE2 BIEN DONNE, ELGIN AND DE DOORNS;
TITLE3 ( WINDSPEED SPECIFICATION MET );
//
```

Ten five-day synoptic sequences associated with ideal burning weather between 1981 and 1984 (copied from Newsletters, South African Weather Bureau)

24 - 28/3/1981

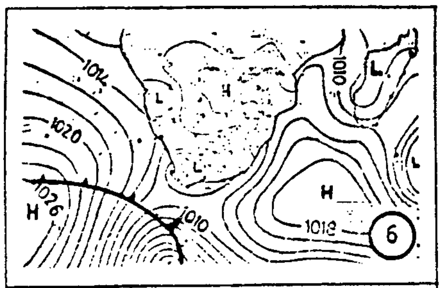


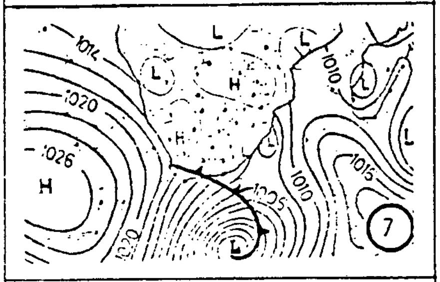
26 - 30/3/1981

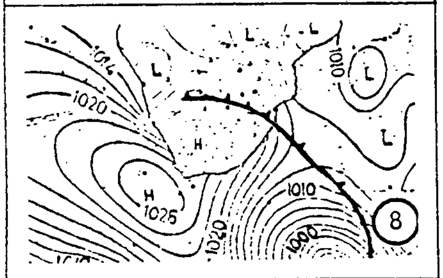


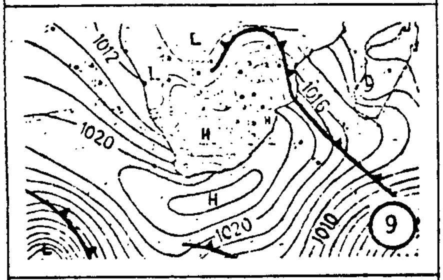
APPENDIX 7 (cont.)

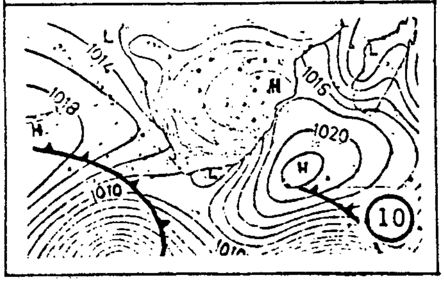
6 - 10/4/1981



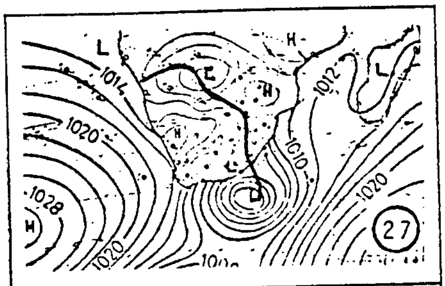


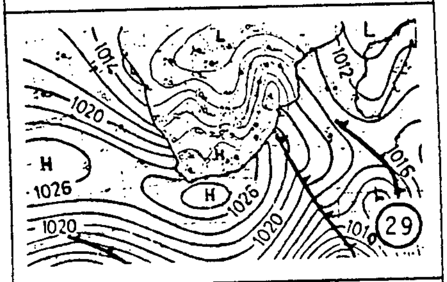


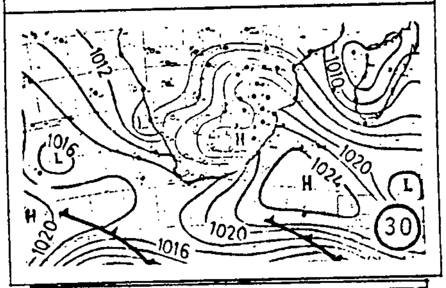


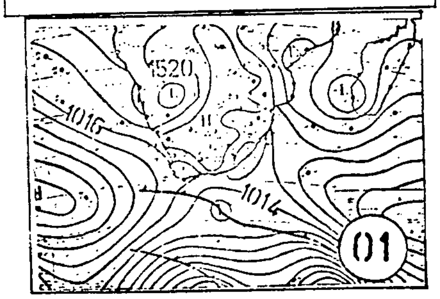


27/4 - 1/5/1981



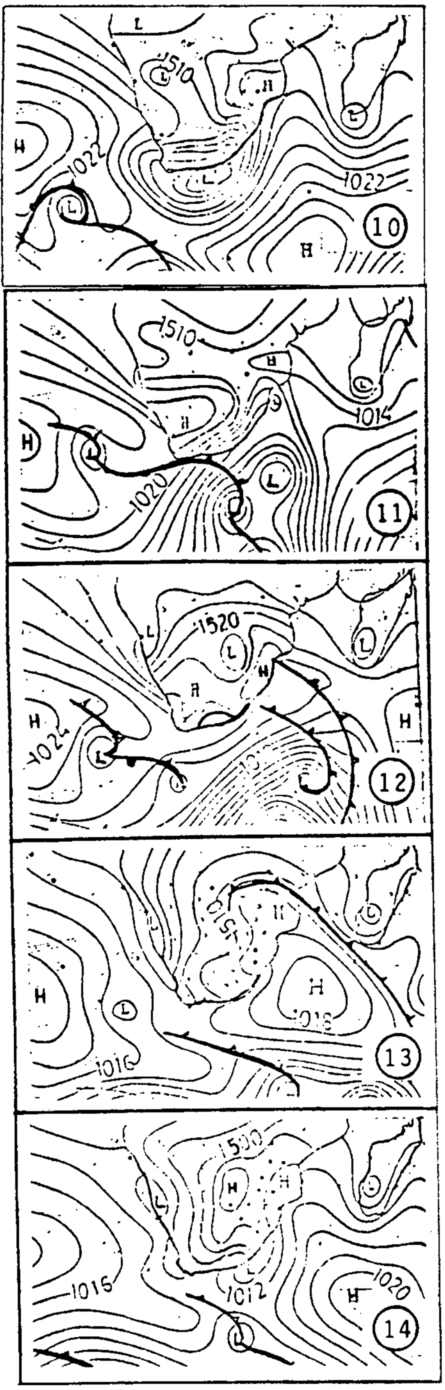




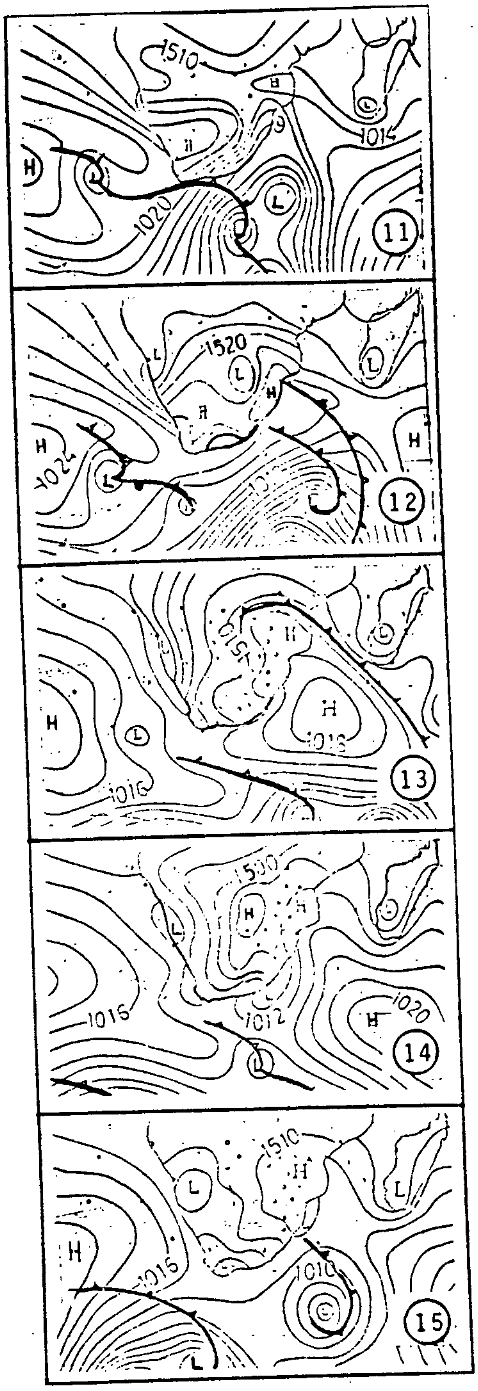


APPENDIX 7 (cont.)

10 - 14/4/1982

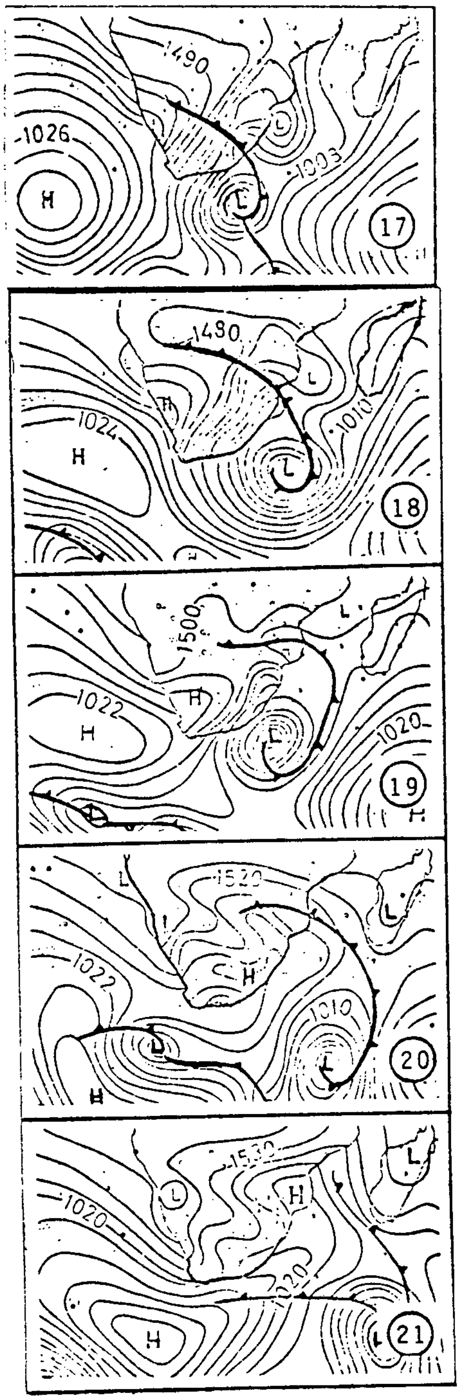


11 - 15/4/1982

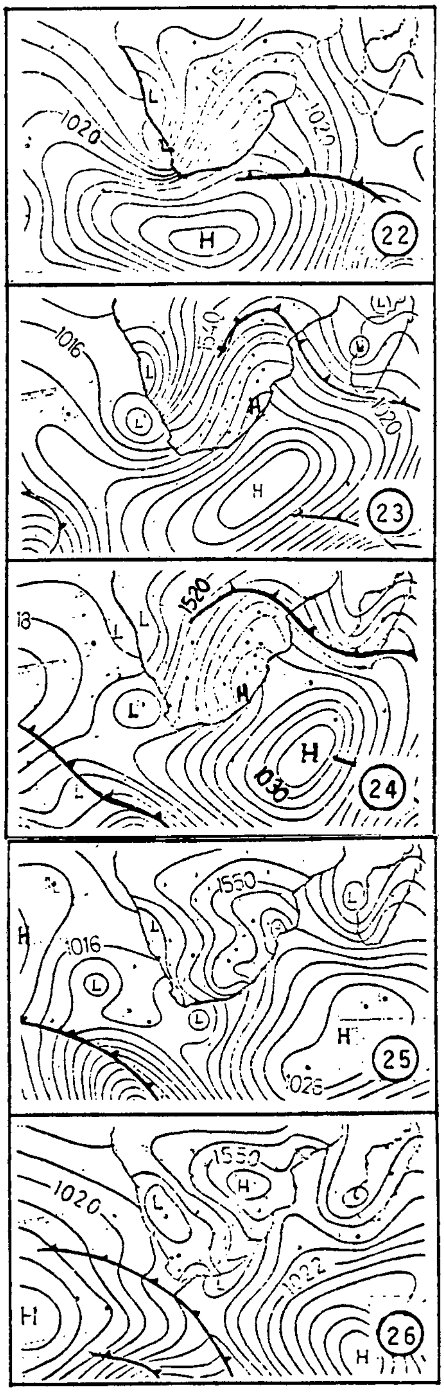


APPENDIX 7 (cont.)

17 - 21/4/1982

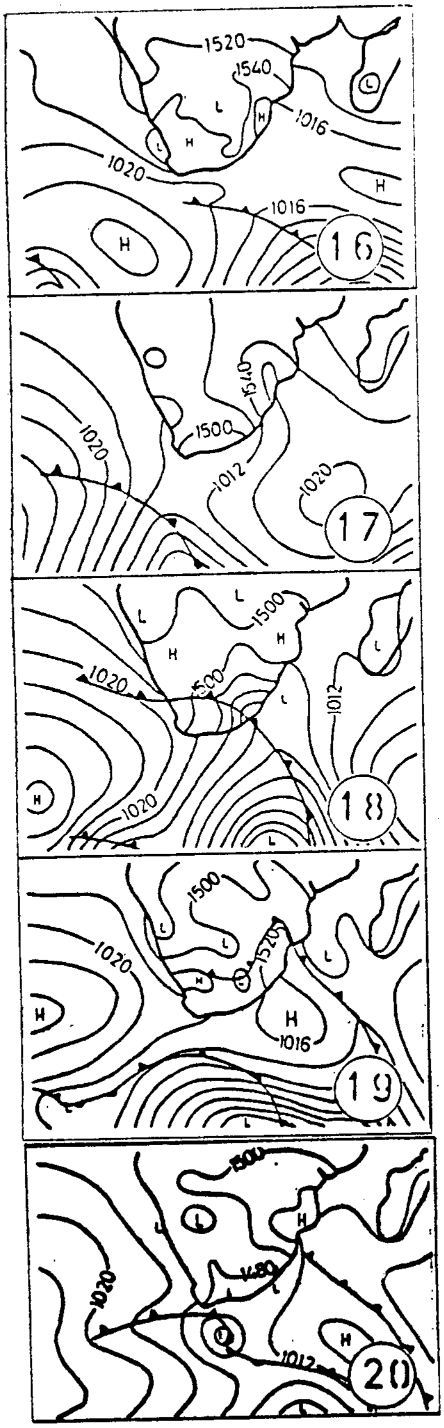


22 - 26/4/1982

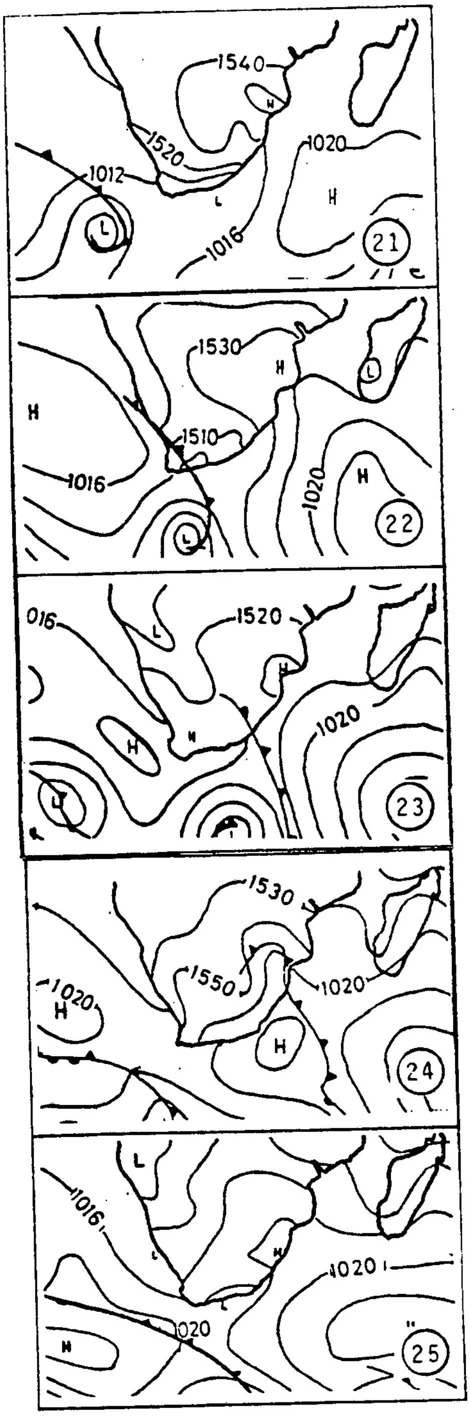


APPENDIX 7 (cont.)

16 - 20/3/1983



21 - 25/4/1983



APPENDIX 8

Time averaged pressure values of the gridpoints on the pressure charts in the five-day sequence.

DAY 1

SEALEVEL

LATLONG	PRESSURE (in mb)
2000	1018.0
2005	1016.5
2010	1013.8
2040	1011.4
2500	1020.5
2505	1019.5
2510	1017.0
2535	1012.6
2540	1013.3
3000	1023.1
3005	1021.7
3010	1019.3
3015	1016.3
3035	1013.5
3040	1016.3
3500	1023.5
3505	1022.3
3510	1020.2
3515	1017.4
3520	1015.2
3525	1011.9
3530	1010.7
3535	1014.1
3540	1017.5
4000	1020.4
4005	1020.9
4010	1019.9
4015	1018.8
4020	1016.3
4025	1013.3
4030	1013.6
4035	1015.7
4040	1017.2
4500	1015.5
4505	1016.3
4510	1016.7
4515	1016.0
4520	1015.9
4525	1015.8
4530	1015.0
4535	1013.9
4540	1014.4

LAND (850mb SURFACE)

LATLONG	HEIGHT (in gpm)
2015	1502.3
2020	1506.1
2025	1509.0
2030	1512.9
2035	1513.5
2515	1507.4
2520	1512.3
2525	1519.2
2530	1519.4
3020	1514.7
3025	1511.9
3030	1508.6

(LATLONG gives the co-ordinates of the gridpoints with the first two and last two digits indicating latitude and longitude respectively)

APPENDIX 8 (cont.)

DAY 2

SEALEVEL

LATLONG	PRESSURE (in mb)
2000	1018.1
2005	1016.3
2010	1014.3
2040	1011.4
2500	1021.1
2505	1019.6
2510	1016.6
2535	1013.3
2540	1013.3
3000	1023.7
3005	1022.3
3010	1020.1
3015	1017.2
3035	1014.1
3040	1015.9
3500	1023.3
3505	1022.7
3510	1021.7
3515	1019.8
3520	1017.9
3525	1016.3
3530	1013.7
3535	1012.3
3540	1014.9
4000	1019.3
4005	1021.1
4010	1021.5
4015	1019.8
4020	1016.6
4025	1015.0
4030	1013.4
4035	1013.6
4040	1013.5
4500	1013.6
4505	1016.3
4510	1017.7
4515	1017.1
4520	1014.8
4525	1012.3
4530	1012.1
4535	1011.5
4540	1013.2

LAND (850mb SURFACE)

LATLONG	HEIGHT (in gpm)
2015	1501.7
2020	1506.4
2025	1514.1
2030	1516.9
2035	1503.5
2515	1509.9
2520	1519.1
2525	1520.9
2530	1525.4
3020	1531.7
3025	1524.8
3030	1518.4

(LATLONG gives the co-ordinates of the gridpoints with the first two and last two digits indicating latitude and longitude respectively)

APPENDIX 8 (cont.)

DAY 3

SEALEVEL

LATLONG	PRESSURE (in mb)
2000	1017.8
2005	1016.3
2010	1013.7
2040	1011.6
2500	1020.6
2505	1019.2
2510	1016.5
2535	1015.0
2540	1013.9
3000	1021.7
3005	1021.5
3010	1019.8
3015	1016.9
3035	1016.6
3040	1016.8
3500	1019.7
3505	1020.3
3510	1020.7
3515	1020.5
3520	1019.3
3525	1018.5
3530	1016.1
3535	1015.0
3540	1017.4
4000	1014.5
4005	1016.1
4010	1018.5
4015	1019.4
4020	1018.8
4025	1017.5
4030	1015.5
4035	1013.7
4040	1014.9
4500	1009.7
4505	1011.7
4510	1013.2
4515	1014.3
4520	1014.6
4525	1014.1
4530	1012.7
4535	1010.8
4540	1011.4

LAND (850mb SURFACE)

LATLONG	HEIGHT (in gpm)
2015	1501.7
2020	1511.6
2025	1517.9
2030	1524.5
2035	1516.5
2515	1510.1
2520	1526.3
2525	1527.1
2530	1536.5
3020	1542.0
3025	1543.0
3030	1534.2

(LATLONG gives the co-ordinates of the gridpoints with the first two and last two digits indicating latitude and longitude respectively)

APPENDIX 8 (cont.)

DAY 4

SEALEVEL

LATLONG	PRESSURE (in mb)
2000	1017.5
2005	1015.7
2010	1013.6
2040	1012.0
2500	1019.5
2505	1017.8
2510	1015.2
2535	1016.6
2540	1014.7
3000	1020.2
3005	1019.3
3010	1017.4
3015	1014.6
3035	1018.6
3040	1018.2
3500	1018.7
3505	1018.9
3510	1018.6
3515	1018.2
3520	1017.1
3525	1018.0
3530	1018.7
3535	1018.0
3540	1017.9
4000	1014.5
4005	1015.3
4010	1016.2
4015	1017.1
4020	1018.4
4025	1018.2
4030	1017.9
4035	1016.5
4040	1014.5
4500	1007.5
4505	1009.2
4510	1011.0
4515	1013.2
4520	1015.1
4525	1015.4
4530	1014.6
4535	1012.4
4540	1010.9

LAND (850mb SURFACE)

LATLONG	HEIGHT (in gpm)
2015	1508.3
2020	1515.1
2025	1524.0
2030	1532.8
2035	1523.5
2515	1508.3
2520	1524.8
2525	1533.2
2530	1548.8
3020	1538.9
3025	1547.9
3030	1553.6

(LATLONG gives the co-ordinates of the gridpoints with the first two and last two digits indicating latitude and longitude respectively)

APPENDIX 8 (cont.)

DAY 5

SEALEVEL

LATLONG	PRESSURE (in mb)
2000	1017.3
2005	1015.3
2010	1014.2
2040	1012.6
2500	1020.1
2505	1018.4
2510	1016.0
2535	1015.9
2540	1014.2
3000	1021.7
3005	1020.9
3010	1018.5
3015	1015.6
3035	1017.4
3040	1017.7
3500	1021.3
3505	1020.9
3510	1019.4
3515	1017.4
3520	1015.9
3525	1015.8
3530	1016.6
3535	1017.2
3540	1018.6
4000	1017.0
4005	1017.1
4010	1017.2
4015	1016.7
4020	1016.2
4025	1015.8
4030	1016.1
4035	1015.1
4040	1016.6
4500	1009.5
4505	1009.7
4510	1010.2
4515	1010.5
4520	1010.8
4525	1011.5
4530	1012.8
4535	1012.9
4540	1013.3

LAND (850mb SURFACE)

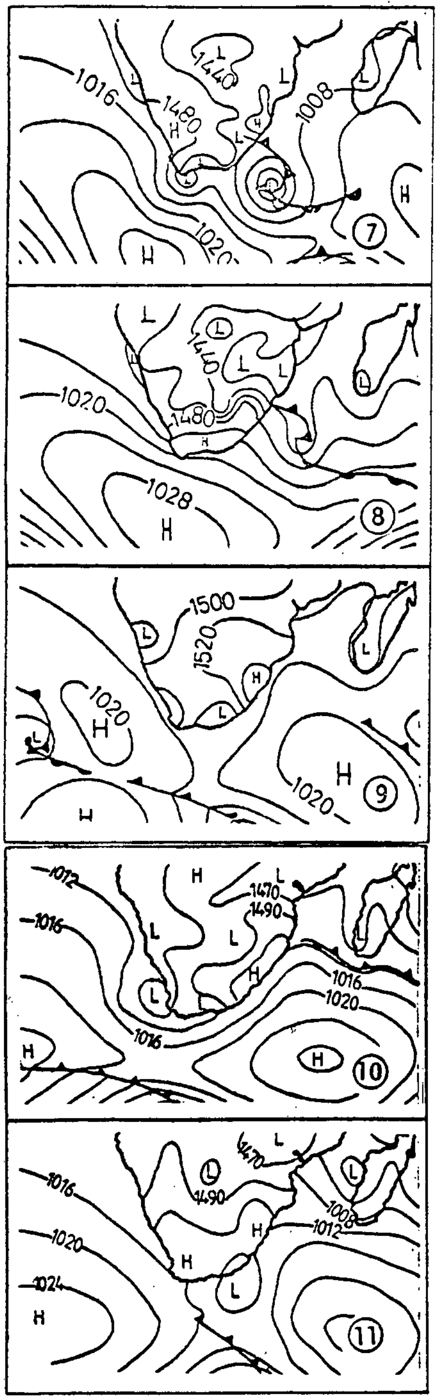
LATLONG	HEIGHT (in gpm)
2015	1513.3
2020	1520.7
2025	1531.9
2030	1536.2
2035	1531.7
2515	1514.3
2520	1523.6
2525	1538.5
2530	1544.6
3020	1532.1
3025	1540.8
3030	1539.4

(LATLONG gives the co-ordinates of the gridpoints with the first two and last two digits indicating latitude and longitude respectively)

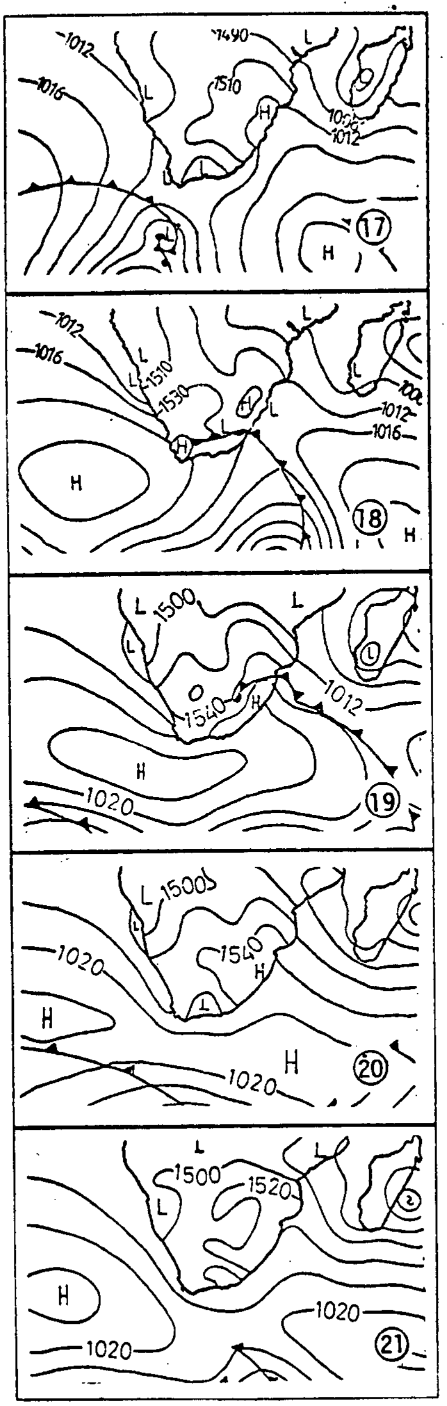
APPENDIX 9

Five-day synoptic sequences associated with potential burning days identified by means of the model sequence (copied from Newsletters, South African Weather Bureau)

7 - 11/2/1985

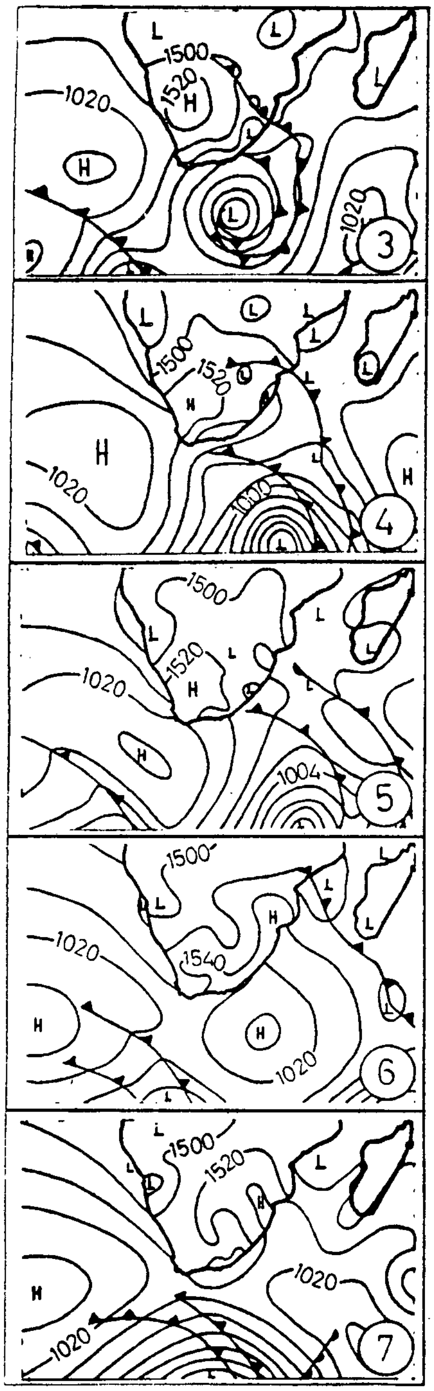


17 - 21/2/1985

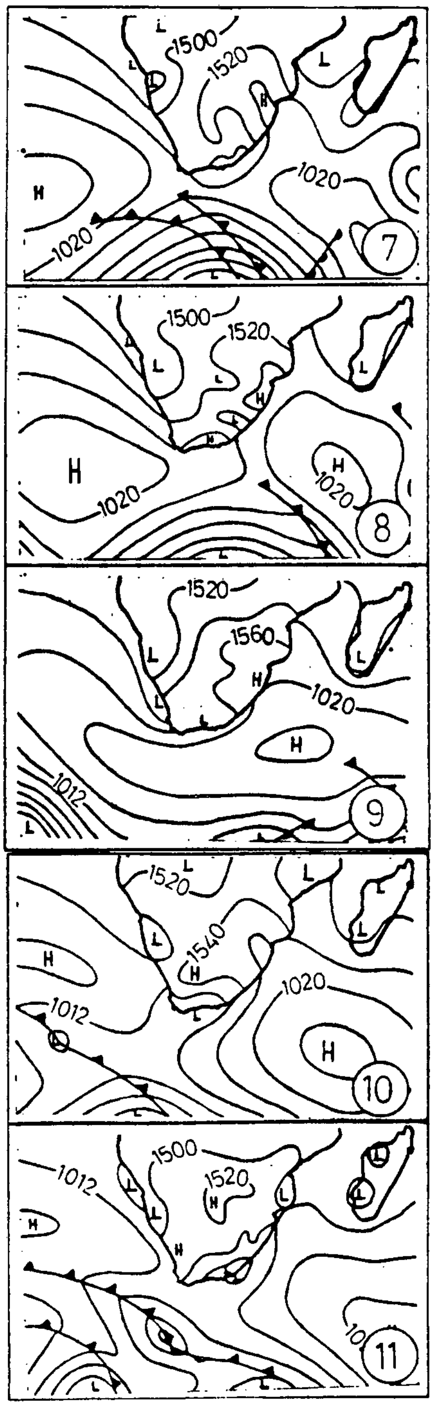


APPENDIX 9 (cont.)

3 - 7/3/1985

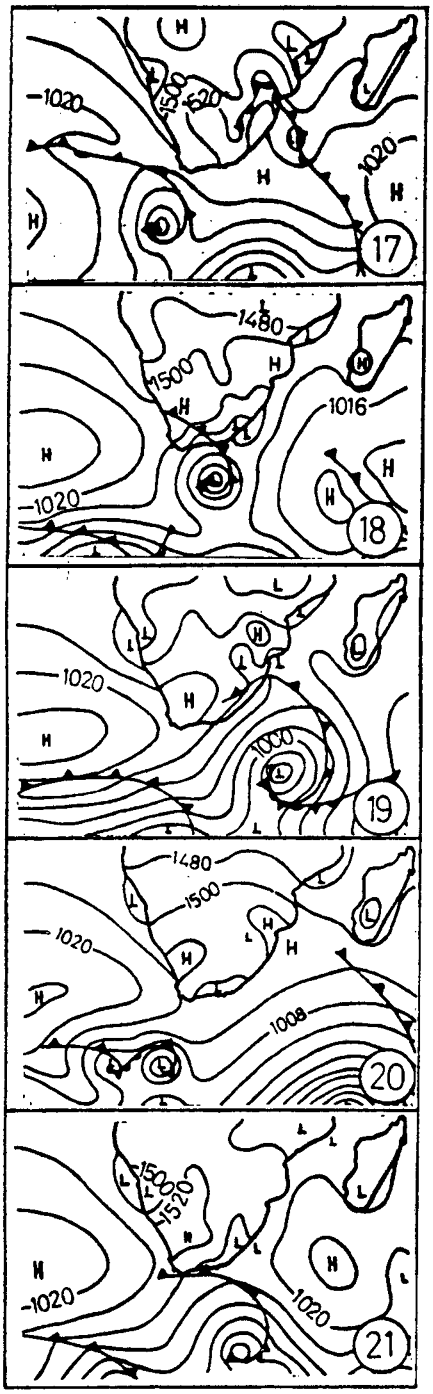


7 - 11/3/1985

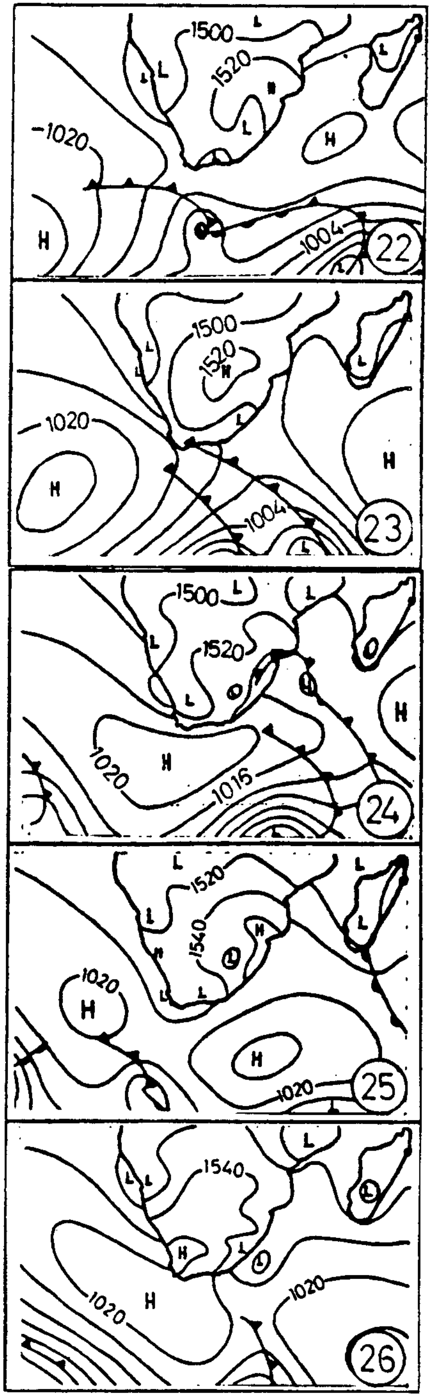


APPENDIX 9 (cont.)

17 - 21/3/1985

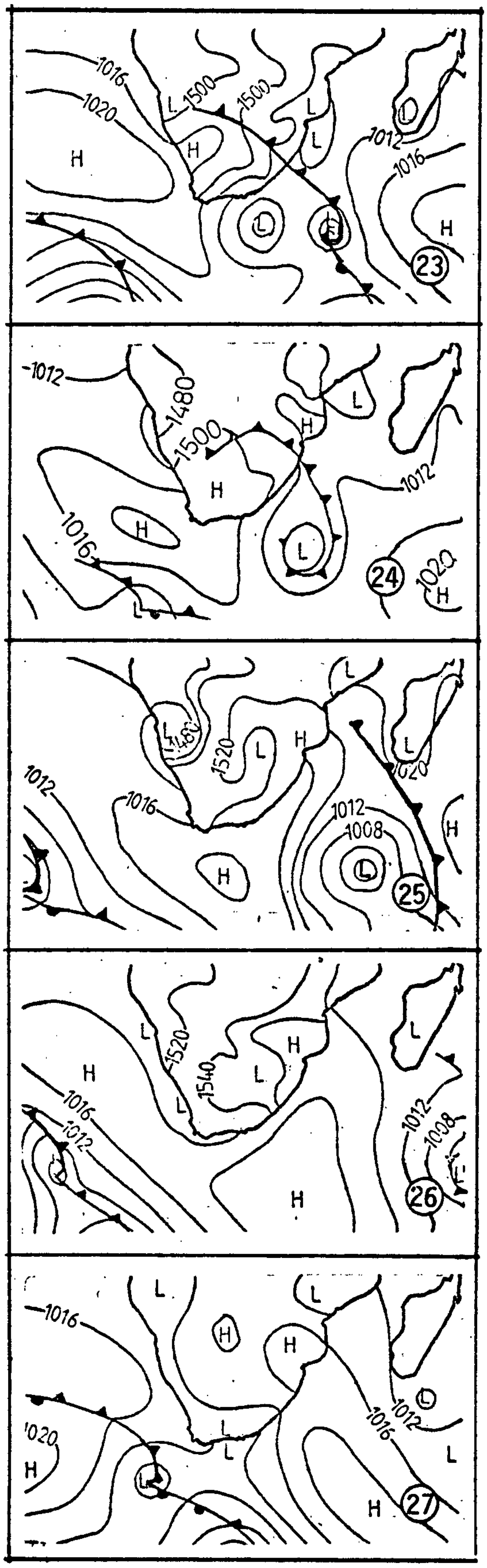


22 - 26/3/1985



APPENDIX 9 (cont.)

23 - 27/4/1985



APPENDIX 10

Hourly windspeed values (in km/hr) for the burning days identified by means of the model sequence.

10 FEBRUARY 1985

HOUR	STATION			
	BIEN DONNE		ELGIN	DE DOORNS
	(2m)	(14m)	(10m)	(10m)
1	24	29	6	5
2	25	25	6	5
3	21	22	6	7
4	22	23	6	7
5	20	20	8	5
6	18	18	7	12
7	15	14	5	13
8	14	12	6	11
9	12	9	9	11
10	12	11	6	12
11	11	7	7	13
12	5	0	7	14
13	9	7	6	11
14	12	8	6	7
15	11	9	9	9
16	13	11	16	11
17	11	9	16	8
18	13	9	14	9
19	9	4	11	19
20	8	0	7	7
21	0	0	0	7
22	6	0	0	8
23	5	0	0	7
24	0	0	0	7

APPENDIX 10 (cont.)

20 FEBRUARY 1985	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	23	25	11	6
2	20	25	10	6
3	21	23	10	8
4	19	20	5	11
5	16	19	6	9
6	15	16	6	9
7	18	18	7	8
8	19	21	11	7
9	19	23	13	9
10	20	23	15	6
11	13	17	11	6
12	12	12	7	6
13	12	12	6	7
14	13	13	8	10
15	14	15	13	12
16	15	18	14	13
17	16	19	14	14
18	22	25	12	14
19	21	15	9	11
20	21	26	10	10
21	20	23	9	16
22	22	27	5	20
23	22	26	0	5
24	19	23	0	5

APPENDIX 10 (cont.)

6 MARCH 1985

	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	19	21	8	16
2	17	21	9	16
3	13	16	10	18
4	13	18	7	15
5	13	18	7	15
6	15	-	5	12
7	15	-	5	9
8	15	-	6	8
9	16	19	7	15
10	10	11	8	15
11	9	8	6	12
12	6	0	10	8
13	5	0	7	7
14	7	5	7	6
15	8	8	6	6
16	6	5	8	9
17	10	12	9	12
18	9	10	9	11
19	9	10	7	10
20	14	17	5	6
21	15	21	0	5
22	18	21	5	0
23	15	21	5	0
24	16	20	5	5

Note: - indicates a missing value

APPENDIX 10 (cont.)

10 MARCH 1985

	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	0	0	0	8
2	0	0	0	13
3	5	0	0	10
4	0	0	0	8
5	0	0	0	7
6	7	-	0	8
7	0	0	0	7
8	5	0	0	6
9	5	0	5	0
10	5	0	0	6
11	5	0	5	7
12	5	0	6	7
13	7	6	6	6
14	9	7	12	7
15	10	10	12	6
16	11	10	11	7
17	11	9	10	10
18	8	8	11	13
19	5	0	5	10
20	5	0	0	9
21	6	0	0	7
22	0	0	0	5
23	8	7	0	8
24	8	0	0	7

Note : - indicates a missing value

APPENDIX 10 (cont.)

20 MARCH 1985

	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	6	-	0	7
2	5	-	0	8
3	0	-	0	7
4	0	-	0	6
5	0	-	0	7
6	0	-	0	8
7	0	-	0	6
8	5	-	0	5
9	6	0	0	0
10	7	-	0	0
11	6	-	6	5
12	0	-	6	6
13	7	-	6	7
14	8	-	8	7
15	9	-	7	10
16	8	-	9	12
17	8	-	7	12
18	6	-	8	11
19	5	-	7	7
20	7	-	0	9
21	0	-	0	6
22	0	0	0	6
23	0	0	0	7
24	0	0	0	7

Note : - indicates a missing value

APPENDIX 10 (cont.)

25 MARCH 1985

	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	19	20	6	0
2	19	20	5	6
3	15	17	5	7
4	19	18	0	8
5	14	16	0	7
6	14	16	5	0
7	18	17	6	0
8	9	6	0	7
9	14	-	5	9
10	11	-	8	11
11	7	-	7	11
12	5	-	6	6
13	9	-	7	6
14	11	9	6	7
15	9	-	6	6
16	10	7	9	13
17	8	5	10	11
18	6	4	5	13
19	5	0	0	15
20	5	0	0	10
21	0	0	0	7
22	0	0	0	8
23	0	0	0	10
24	5	0	0	9

Note : - indicates a missing value

APPENDIX 10 (cont.)

26 APRIL 1985

	STATION			
HOUR	BIEN DONNE		ELGIN	DE DOORNS
1	6	7	0	5
2	8	8	0	9
3	7	6	0	8
4	5	0	0	6
5	6	0	0	9
6	0	0	0	6
7	0	0	0	8
8	5	0	0	7
9	5	0	0	7
10	5	0	0	5
11	0	0	0	5
12	0	0	0	5
13	0	0	0	0
14	6	0	6	5
15	7	5	10	5
16	6	0	10	6
17	0	0	7	7
18	0	0	6	5
19	0	0	0	8
20	0	0	0	10
21	5	5	0	10
22	0	0	0	9
23	0	0	0	10
24	0	0	0	9

APPENDIX 11

Maximum daily temperature (°C) for the burning days identified by means of the model sequence.

DAY	STATION		
	BIEN DONNE	ELGIN	DE DOORNS
FEBRUARY 1985			
10	31.1	28.1	29.3
20	32.0	28.6	29.9
MARCH 1985			
6	28.9	25.4	27.9
10	33.3	33.1	34.4
20	23.6	21.8	24.3
25	29.0	25.7	28.5
APRIL 1985			
26	28.5	25.6	28.0

APPENDIX 12

Minimum daily relative humidity (%) for the burning days identified by means of the model sequence.

DAY	STATION		
	BIEN DONNE	ELGIN	DE DOORNS
FEBRUARY 1985			
10	29	44	34
20	25	44	25
MARCH 1985			
6	22	38	14
10	27	34	16
20	33	51	28
25	24	51	21
APRIL 1985			
26	20	39	15