WET AND DRY TROUGHS OVER SOUTHERN AFRICA DURING EARLY SUMMER

by

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ABSTRACT

The synoptic scale structure of troughs transiting southern Africa in October and November is examined. Cases are chosen on the basis of an upper trough being present over southern Africa, and a minimum horizontal and vertical temperature change.

Wet and dry troughs are differentiated by the extent and amount of interior rainfall produced. Once selected, a spatial and temporal framework was used on surface, upper-level synoptic maps and radiosonde sections. Individual and composite time-height and spatial sections are analysed for anomalies of temperature, geopotentials, kinematic, vorticity and divergence fields, dewpoint, dewpoint depression, mixing ratio, dry and total static energy and, equivalent potential temperature. European Centre for Medium Range Forecast (ECMWF) maps of vertical motion are analysed and ECMWF data were exclusively used in the wet and dry case study.

The essential features of wet troughs include: a large amplitude upper westerly wave with a diffluent and northward displaced sub-tropical jet stream, slow movement, westward tilted trough in the vertical and a negative - positive dipole where a high is located south of the low pressure system. In comparison dry troughs are characterised by a small amplitude upper wave, rapid movement, no tilted trough in the vertical, and a stationary high pressure system over the western interior. Radiosonde moisture variables, circulation anomalies and ECMWF fields of moisture flux give evidence in the wet cases of inflow from the north-east, in conjunction with a ridging anticyclone south of the continent. In dry cases the trajectory of flow is north-westerly and the supply of moisture is limited. In the ECMWF composite maps of vertical motion, lift is weak over the interior in dry cases consistent with a gentle slope in the divergence profile. For wet cases upward motions are intense and widespread over the interior consistent with a steep slope in the divergence profile, and compensated by descending motions over the adjacent oceans along 30° S band. Precipitation in wet events is a combination of dynamical forcing, prefrontal moisture and

unstable lower troposphere. In dry events, precursor moist inflow is limited, weak instability and, a gentle slope in the divergence/convergence fields are not conducive to sustain lift.

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PREFACE

South Africa by virtue of its geographical location lies beneath the mean southern hemisphere sub-tropical high pressure belt where subsidence and dry spells are the norm. Rainfall over South Africa is highly variable due to the influence of the Hadley and Ferrel cells and varied topography. In the October to December period the southward march of the sun causes tropical regions to penetrate the northern interior at a time when sub-tropical and temperate systems are still located over land.

Numerous studies have been concerned with the determination of circulation changes associated with South African temporal and spatial rainfall variations but most have tended to focus on the January - February period and a lack of understanding into the dynamics and circulation controls of October and November remains. Investigations to ascertain the nature of synoptic scale systems responsible for rainfall have been undertaken but few studies have focussed on troughs characterised by no-rain or on troughs that appear dynamically similar yet produce different precipitation results. Important differences in the circulation over South Africa in October and November during periods of above and below normal rainfall have been found in conjunction with temperate or tropical systems or both.

The intention in this dissertation is to contribute firstly, toward a better understanding of weather controls in October and November in wet and dry spells. Secondly, to discover synoptic and thermodynamic forcing mechanisms which are responsible for generating convective processes in wet events, in comparison to dry events.

The work may form a basis for future detailed studies on wet and dry periods in the October - November transitional season, and, the synoptic and thermal forcing mechanisms of wet and dry trough events. Spatial synoptic maps and temporal time-height profiles form the basis of data analyses in this research which is presented either on the event scale or as composites.

Specific aims of the work are:

1) to distinguish specific differences in the mean synoptic field at the surface and upper-level for wet and dry troughs with respect to the speed, latitude, wavelength and amplitude of the troughs which, would indicate along with the vorticity, kinematic and divergence fields the degree of synoptic forcing which is a vital determinant for vertical ascent and convection;

2) to discover the supply and availability of moisture and, its contribution or lack of toward instability, vertical motion and convective processes in wet and dry troughs;

3) to examine the thermodynamic structure of wet and dry troughs, to describe the essential differences in atmospheric stability which pertain to vertical movement and rainfall.

The thesis is divided into 6 chapters and diagrams are appended at the end of each chapter. In Chapter 1 the background literature pertaining to studies of rainfall variability over wet and dry spells is reviewed, whereafter the climatology characterising October and November is discussed. An issue of debate is the varying contribution of temperate and tropical systems. Researchers contributing toward the debate include Schulze (1965), Harrison (1984a, 1984b, 1986), Van Heerden et al (1988). A review of the literature pertaining to daily weather variability of rain and no-rain days follows the section on the mean October and November climatology and outlines the circulation and thermodynamic controls. Hypotheses pertaining to this study are outlined at the end of Chapter 1. The data and methodologies used in this dissertation are discussed in Chapter 2. The selection criteria used to identify troughs based on suggestions from Taljaard (1961) are outlined, whereafter the rainfall criteria to distinguish wet troughs from dry troughs are presented. Data used in this study are essentially synoptic surface and upper-level, radiosonde and ECMWF maps.

Analysis techniques and various moisture and thermodynamic computations on the data are discussed.

In Chapter 3, emphasis is placed on the degree of synoptic forcing and the prevailing upper/lower level divergence fields. The speed, latitude, amplitude and wavelength of the surface and upper-level synoptic charts as well as the kinematic, vorticity and divergence fields of wet and dry troughs are compared and their structural differences are noted. A table summarises major differences found between wet and dry troughs.

Much of the amount and distribution of rainfall depends on the availability of moisture and the degree of instability. Chapter 4 focuses on the supply and amount of moisture in wet and dry trough situations by considering; dewpoint, dewpoint depression, precipitable water and the mixing ratio. The thermodynamic structure with respect to the temperature structure, dry and total static energy, equivalent potential temperature and vertical movement is discussed.

In Chapter 5 one wet and one dry case study both from October 1986 are examined. Synoptic and thermodynamic features identified in these systems are compared with each other and, to the 6-case mean wet and dry composites. In Chapter 6 conclusions are summarised in point form, and implications to forecasting over South Africa are highlighted.

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CHAPTER 1

BACKGROUND

Rainfall Variability

Rainfall variability has become a focal point of attention in climatology over the past decade in South Africa. Work on South African rainfall variations has focussed on the temporal and spatial aspects of these variations (Tyson and Dyer 1975, Gillooly and Dyer 1979, Tyson 1980 and Lindesay 1984). Most attempts to relate rainfall variability to atmospheric circulation adjustments have considered circulation parameters within Southern Africa (Tyson 1981, Miron and Lindesay 1983, Tyson 1984, Taljaard 1986a, 1986b). Exceptions include the work of Dyer (1979), Harrison (1986) and Lindesay (1988) who have attempted to use teleconnections and have stressed the importance of southern hemisphere circulation influences on rainfall over Southern Africa.

The frequency of rainfall variations falls into two types: seasonal and event. Both the overall circulation changes between wet and dry periods (Triegaardt and Kits 1963, Hofmeyer and Gouws 1964, Louw 1983, Miron and Tyson 1984, Jury and Lyons 1992) and the circulations associated with specific rainfall events have been examined. The latter studies include case studies of synoptic situations producing excessive rainfall over multi-day periods (Triegaardt 1961, Hofmeyer and Gouws 1964, Taljaard 1985, Taljaard et al 1987, Lindesay and Jury 1991) or multi-week periods (King and Van Loon 1958, Taljaard 1981, Harrison 1986, Lindesay 1988, Matarira and Jury 1992). There are only a few equivalent investigations of the circulation during dry periods (King and Van Loon 1958, Shulze 1984, Matarira 1990a, Jury and Lyons 1992).

Prior to the establishment of widely recognised rainfall classification schemes of Harrison (1986) and Tyson (1986), it was difficult to determine the representativeness of the circulations revealed in the case studies. The manner in which observed circulation changes were reflected in various systems associated with rainfall or dry weather was problematical. Nor was it possible to ascertain contributions of the types of systems to the mean circulation, to the rainfall, or to circulation and rainfall variations over a given region. Inadequacies in delineating circulation adjustments associated with seasonal and event scale rainfall has led to considering hemispheric fluctuations of the general circulation to understand variations in South African climate parameters. Recognition of circulation differences over the subcontinent associated with wet and dry weather and the establishment of their links with the global circulation has provided the basis for efficient methods for the identification of rainfall predictors. These concepts are central to the study of wet and dry troughs which are analysed and compared to the broader temporal and spatial framework of the literature, on event, or seasonal scales.

Motivation

This study seeks to identify the synoptic circulation structure, the supply and availability of moisture and the degree of instability of wet and dry frontal systems with a view to better understand the circulation characteristics, the dynamics and the mechanisms of wet and dry troughs in October and November that either trigger or suppress precipitation. The recent work of Harrison (1986) has shed light on the various circulation characteristics of the early summer transitional season through introduction of the semi-annual cycle. The following section gives a brief overview of the issues concerning atmospheric circulation adjustments and rainfall related circulation changes over the subcontinent during October and November.

Research findings on seasonal (Schulze 1984, Harrison 1986, Lindesay 1988, Preston-Whyte and Tyson 1988) or event scale variability (Hofmeyer and Gouws 1964, Schulze 1986, Taljaard 1986b, Lindesay and Jury 1991) have tended to focus on the January - February period and a lack of knowledge and understanding into the dynamics and circulation controls during October and November remains.

The Climatology and Rainfall Variability Characterising October and November

Interest in the October - December period arose when significant differences were found between early and late summer circulation over the interior (Schulze 1965). In January - February clear flow changes between tropical wet and, non-tropical dry periods over South Africa gave an indication of the nature of weather systems present over the interior. In October and November flow changes between wet and dry spells are not clear and give no indication as to the nature of the weather systems. Circulation controls on rainfall over the interior are considered to be more temperate during October and November in contrast to tropical controls during January and February. Schulze (1965) and Van Heerden et al (1988) suggest that rainfall in November over the interior of South Africa may be associated with a temperate or cyclonic rainfall regime while rainfall in January may be associated with a tropical regime. But, according to Harrison (1986) 80% of the rainfall on rain days over the interior of South Africa in November is associated with tropical systems which are largely responsible for the annual wave in rainfall over the interior of the country.

In contrast Lyons (1991) suggests that the major source of convective variability over South Africa at any one time is associated with the equatorial penetration of a sub-tropical westerly wave. This equatorward penetration takes place through the tropical upper tropospheric trough which lies across the Mozambique channel. Sub-tropical wave kinetic energy moves north-west along the trough into equatorial Southern Africa. Westerly wave interaction with the upper trough is instrumental in strengthening the trough, developing a mid-level cool-cored cyclone within the trough, enhancing divergence aloft, and decreasing outgoing longwave radiation over equatorial South Africa. Lending support to the argument that interaction of transient sub-tropical and stationary tropical systems promotes convection, Harangozo and Harrison (1983) found that major cloud bands develop in the vicinity of upper air waves and are associated with cold fronts and westerly waves over the land. Taljaard (1990) believes that a large amplitude upper-level trough along with near-surface convergence is essential for the formation of the large north-west to south-east cloud band across Southern Africa. Garstang et al (1987) and

Kelbe (1988) have found that westerly perturbations exert a direct influence on the convective regime of north eastern regions, and in Zimbabwe (Hattle 1955). In the theoretical work of Webster (1982) and Kuhnel (1989) it is postulated that a high latitude response to an equatorial forcing can only be expected if sub-tropical westerly waves move over tropical disturbances. It appears thus, that a necessary condition for the north-west south-east cloud band formation and rainfall within the October - November period is the coupling between a tropical low and a large amplitude, northward penetrating westerly wave, (Webster 1982, Harangozo and Harrison 1983, Garstang et al 1987, Kelbe 1988, Kuhnel 1989, Lyons 1991 and Taljaard 1990).

An important component of the rainfall control are inter-seasonal circulation changes on the semi-annual cycle (Harrison 1986). The Inter Tropical Convergence Zone (ITCZ) lies further north in October and November than in January and February and is a minimum of outgoing long-wave radiation at 20° S on the semi-annual cycle. Compared to January and February, the region at 20° S is an energy sink in October and November (Harrison 1986). The persistent mean northerly flow in the lower atmosphere is consistent with the presence of a Ferrel cell over the centre of South Africa in October and November while during the high seasons the upper level flow reflects that of a Hadley cell (i.e. poleward). According to Harrison (1986) the meridional torroidal circulation switches between the Hadley and Ferrel cells according to the phase of the semi-annual cycle, assuming that the ageostrophic low-level circulation is a result of orographic effects induced by the elevated subcontinental plateau. Changes in the 200 hPa meridional circulation on the semi-annual cycle together with the semi-annual cycle of the temperature at that level appear to be related to shifts in the mean latitude of the sub-tropical jet stream. In general, the sub-tropical jet stream in November lies between 30° S and 40° S, with core winds between 20 - 30 m s^{-1} at a mean height of 200 hPa (Preston-Whyte and Tyson 1988). The dynamics of the upper-air sub-tropical jet has important influences on surface weather when associated with a large amplitude westerly trough, then the effects of both curvature of the streamlines, and diffluence will be significant. According to Harrison (1986) half-yearly oscillations in the zonal upper-tropospheric temperature at 30° S appear to be related to shifts in the mean latitude of the sub-tropical jet stream. Over Australia, where it is best developed and has been studied in detail (Harrison 1986), the mean latitude of the jet undergoes a 6-month oscillation with northerly extremes in May and November. Assuming the jet behaves similarly over South Africa, then according to Harrison (1986) it should be located in the mean to the north of Bloemfontein at 29° S and 26° E in November (with the possibility of cyclonic vorticity) and south of Bloemfontein in February. Maxima of the zonal flow are at a higher level in October and November when meridional flow is slightly equatorward and when the jet is to the north of Bloemfontein, than in January and February when it is poleward of Bloemfontein. The direct association between tropical convection and location of the jet stream wind maximum has been confirmed in the northern hemisphere (Riehl 1977a, 1977b). Thus, it is possible that during wet events in November the jet moves north to penetrate equatorial regions whilst during January and February the jet moves south when the ITCZ is displaced south over Southern Africa. Harrison (1986) suggests that frequent reversals in the meridional flow accompanying varying weather conditions over the interior of South Africa result in rapid fluctuations of the latitude of the sub-tropical jet.

Significant changes occur in the dynamics of the atmosphere over the central interior of South Africa during October and November (Harrison 1986). These include:

1. Meridional components modulated on the semi-annual cycle occur over the central parts of South Africa.

2. The circulation over the eastern parts of South Africa is cyclonic in October and November.

3. The 200 hPa meridional wind at Gough Island is opposite to that at Bloemfontein, suggesting that a standing wave across the Atlantic is displaced eastward and a Ferrel cell is dominant in flow across the central interior of South Africa.

Harrison (1986) suggests that with these shifts of the south Atlantic anticyclone (SAac) it is possible that there may be related changes in the structure of transient troughs over central Southern Africa such that the wavelength is a minimum when the amplitude is maximum. This suggests a stronger baroclinic structure in the atmosphere during October and November and a northward penetration of the surface trough into the tropics; an idea pursued by (Hattle 1955, Harrison 1986, Lindesay 1988, Preston-Whyte and Tyson 1988, Van Heerden et al 1988). Contrasting patterns of warm land and cool sea temperatures in spring enhance maximum low-level tropospheric meridional thickness gradients in October and November (Taljaard 1981, Van Heerden et al 1988).

The Climate and Structural Circulation Characteristics of Rain and Non-rain Days

South Africa (Figure 1-1) is located between the south Atlantic and south-west Indian oceans extending from 22° S in the north-east to 35° S. Most of the interior is above 1000 m and is separated from the narrow coastal plains by an escarpment which is particularly steep (2000 m rise in 100 km) in the south-east. The semi-permanent SAac flanks the subcontinent to the west and is situated further eastwards in October and November than in mid summer and winter. An upper air high pressure cell is present over the interior all year round (Harrison 1986, Tyson 1986). Budding of the SAac to the south of the subcontinent, leads to the regeneration of the south-west Indian anticyclone (SWIac) which is located west of its usual summer position in October and November. Generally, changes in position and intensity of the southern hemisphere sub-tropical high pressure belt and associated variations in mid-latitude cyclones have been viewed as one of the major controls on circulation and rainfall variations over Southern Africa (Harrison 1986, Tyson 1986). The intrusion of the SAac has major effects on South African weather on the event scale and is responsible for clear skies, warm weather and intense drying out of the atmosphere (Hofmeyer and Gouws 1964, Taljaard 1986b, Cressman and Helmick 1989, Matarira and Jury 1992).

During wet spells of a few days duration, a shallow north-west to south-east trough of low surface pressure lies over the interior (Triegaardt and Kits 1963, Hofmeyer and Gouws 1964, Taljaard 1961, 1981, Harrison 1986, Tyson 1986, Lyons 1991, Matarira 1990b). This quasi-barotropic trough is induced by forces "outside" the boundary of the country (D'Abreton 1991, Jury and Pathack 1992) and may be associated with increased frequency of tropical easterlies. The SWIac high pressure system is displaced further westward from its usual summer position in times of wet spells. Air flow associated with this pressure distribution is northerly to north-easterly over the interior. Changes in air flow between wetter and dryer periods accord well with the pressure variations, whereby increased near-surface northerly and north-easterly airflow over interior stations is associated with an intensified trough in the wet period. More westerly flow is typical of dry spells when pressure over the interior is higher and the circulation more anticyclonic (Taljaard 1986b). Decreasing pressure in the interior and rising pressure to the south are characteristic of wet periods (Taljaard 1985) whilst dry periods tend to show positive departures of geopotential height in the tropics and sub-tropics, and negative values in the west wind belt (Hofmeyer and Gouws 1964, Taljaard 1986b). The ridges of standing waves 1 and 3 may explain these mid-latitude pressure adjustments (Lindesay 1988, Preston-Whyte and Tyson 1988).

Cold fronts are a regular occurrence south of 25° S in the southern hemisphere. During summer months well defined fronts are seldom north of 30° S or 25° S whilst during winter the baroclinic troughs may penetrate to 20° S or even 15° S in some areas (Taljaard 1972). The passage of a summer cold front is characterised by a sharp drop in temperature, dewpoint and pressure, and the wind generally swings north-west to south-west as atmospheric stability declines. Cold fronts produce conditions favourable for the promotion of deep convection at the front, where low-level convergence in airflow with a marked southerly component is at a maximum. Some distance ahead of the front in airflow with a pronounced northerly component, divergence and subsidence are responsible for stable conditions. Frontal systems occur with weak statistical regularity every 5 - 6 days at all coastal stations (Preston-Whyte and Tyson

1988) with an estimated propagation speed on the order of 18 m s^{-1} found by Kelbe (1988) for 107 troughs. Van Loon (1967) found mid-latitude cyclone speeds to be slightly higher in winter than in summer due to increased zonal speed of the upper jet stream. Further, Van Loon (1967) found that cyclones in the 40° - 60° S zone in the south-west Indian ocean show maximum speeds > 20 m s^{-1} owing to wave 1 and enhancement of the thermal wind. According to Reeder and Smith 1885, Garratt (1988) and Hanstrum et al (1990a, 1990b), dry cold fronts (systems absent of mid-level cloud and convective instability) move at a mean trough speed of between 10 - 25 m s^{-1} near Australia compared to wet systems (complex system with prefrontal moisture) which move at an average speed of 10.5 m s^{-1}. According to the basic concept of Rossby the speed of the surface and upper-level trough is dependent on wavelength and amplitude. The shorter the wavelength, the faster the wave propagation. Further, above normal rainfall is related to westerly waves of large amplitude and wavelength which are able to sustain upper-level divergence on the front of the westerly wave (Preston-Whyte and Tyson 1988). The shape and the location of the cold front over South Africa at any particular time is perturbed by a "leader front", which is commonly referred to as the forward boundary of the sub-inversion layer of maritime tropical air which usually precedes the cold front (Taljaard 1972, Garrat 1988). It is also usual for the front to lag across the interior. An explanation for this phenomena is that the slope of the top of the moist layer is usually small and therefore it is displaced westwards over the high plateau (Taljaard 1972). Secondly, the thickness of the sub-inversion layer air increases southwards along a meridian so that the cool south Atlantic air spills over the western escarpment at an earlier stage in the south than in the north.

Within a westward tilted upper westerly wave opposite divergence fields in the low and upper-level flow exist, such that convergence is overlain by upper-level divergence and vice versa with direct effects on daily weather of South Africa. Enhancement of the upper air trough in wet events is largely encouraged by strong upper air divergence aloft overlying surface convergence on the rear of the surface wave (Keyser and Shapiro 1986). Should surface convergence not be accompanied by upper-level divergence, then no large scale uplift can occur. It is for this reason that surface conditions seemingly favourable for rainfall may not be accompanied by the anticipated weather, and it is generally believed that precipitation is related more to the position and forcing of the jet stream and upper-level dynamics than it is to the surface cold front (Taljaard 1985, Preston-Whyte and Tyson 1988). In a near-identical easterly wave surface circulation pattern on a rain day and on a no-rain day when the amounts of conditional instability and potential instability were similar Preston-Whyte and Tyson (1988) showed that upper-level divergence promoted uplift, while on the no-rain day an upper convergent ridge suppressed vertical motion. Much surface rainfall depends on; moisture fluxes, degree of instability, and the divergence field prevailing at any one time and place. On some occasions thermal instability in moist air may be adequate to produce rainfall, and upper-level divergence may not be strong enough to produce sufficient uplift in stable air to realise precipitation and only cloud will form. On other occasions all of the many features may act together to result in heavy rainfall. Thus the point stressed here, and supported by (Keyser and Shapiro 1986, Taljaard 1986b, Kuhnel 1989, Lyons 1991), is that the upper-level flow field and wave structure is an important determinant of rainfall in mobile wet and dry troughs over South Africa.

Exactly how these upper level frontal systems and baroclinic wave structure determine convective potential is not readily understood in the South African region and progress has been limited in describing and understanding the temporal evolution of structural changes of baroclinic waves through their life cycles. This slow rate of progress can be attributed primarily to restrictions in observational coverage, temporal resolution and accuracy of radiosonde data and the data in-filling process performed by satellites (Keyser and Shapiro 1986). A consequence of limited spatial coverage and temporal resolution is that upper-level frontal zones cannot be tracked continuously. Significant structural changes may occur in data sparse regions of South Africa, or between upper-air observing times. As a result observational documentations of initial development over South Africa, as well as details of the frontogenesis process, are fragmentary. Data limitations of the type mentioned above prevent establishing the degree to which a frontal system is advected in from the west relative to being generated locally, and the extent to which an upper-level and surface system merge. The significance of both surface and upper-level fronts stems from their relationship to the structure and evolution of mid-latitude baroclinic waves. According to Keyser and Shapiro (1986) although fronts occupy a fraction of the atmospheric volume which is affected by baroclinic waves, they contribute a substantial portion to the dynamical forcing involving vertical motions.

Despite temporal and spatial restrictions in observing baroclinic waves in Southern Africa, extensive studies by various authors such as (Triegaardt and Kraus 1957, Taljaard 1985, Triegaardt et al 1987, 1988) into the development of upper-level waves and cut-off lows has led to an understanding of the development of synoptic troughs. This development has been likened to a process named anticyclonic disruption by Sutcliffe (1953). It appears that large amplitude waves frequently disrupt by relative progression, either at the higher or lower latitude of the wave form, and that disruption, occurs more frequently at the higher latitude of the wave such that the ridge at the neck is strengthened and a cut-off low depression is formed. Cold and warm advection deepen the upper trough over the western interior and intensify the upper ridge to the south-west of the subcontinent. This results in the intensification of the high at sea level and the formation of a low pressure area at 850 hPa over the interior.

In the ensuing review of temperature, pressure and wind deviations from the South African climate mean, the literature is biased toward rain days and less is known about no-rain days.

The temperature structure over the interior of South Africa during wet events is expected to decrease at the surface with increasing rainfall (Harrison 1986, Lindesay 1988, Harangozo 1989). Increased cloud cover, reduced insolation and enhanced low-level northerly to north-easterly flow results in a precipitating air mass which is cooled by evaporation (Hofmeyer and Gouws 1964, Reed and Recker 1971, Miron and Lindesay 1983). In dry events observed increases in surface temperature may be ascribed to increases in insolation due to reduced cloud cover and also to changes in air temperature which is advected across the South African interior by subsident westerly winds. On rain days in October and November the vertical temperature structure is characterised by a 2-level temperature stratification with cooling in the lower troposphere below 600 hPa and warming above 500 hPa (Harangozo 1989), compared to the 3-level temperature structure of the mid-summer rain days where warming is restricted to between 500 hPa and 300 hPa with cooling above 300 hPa and below 500 hPa (Harangozo 1989, Lindesay and Jury 1991). This 3-level temperature structure is associated with tropical rain producing systems (Palmen and Newton 1969, Reed and Recker 1971, Riehl et al 1973, Chen and Hui 1989, Harangozo 1989, Lindesay and Jury 1991). Reduced pressures throughout the troposphere are characteristic over areas of above normal rainfall in South Africa during rain days in October and November (Triegaardt and Kits 1963, Hofmeyer and Gouws 1964), while raised pressures occur on rain days in the late summer months throughout the troposphere (Taljaard 1981, Miron and Tyson 1984, Taljaard 1987). It appears that mid-summer rain day conditions differ from early summer rain days in that decreased westerly wind shear favours convective rains in tropical regions. Further, a pressure increase in the middle and upper troposphere is associated with warm air outflow from storms, and lowered temperatures in the upper troposphere with a 3 layered temperature structure typical of summer conditions (Riehl 1977a, Harangozo 1989). The vertical structure of the troposphere on rain days in October and November is characterised by warming in the middle troposphere through latent heat release (Taljaard 1981), enhanced vertical wind shear, and strengthened westerlies above 700 hPa (Harangozo 1989). According to Harangozo (1989) convection determines the average thermodynamic structure on rain days in early summer.

The above results show that properties of vertical structures vary throughout rain and no-rain days in summer with significant differences occurring between early summer and late summer. However, temporal and spatial variations can be expected, since most thermodynamic studies have been conducted on specific synoptic circulation systems (Harrison 1986, Harangozo 1989, Lindesay and Jury 1991).

The bulk of the moisture source is from the north, mostly supplied from the Inter Tropical Convergence zone (ITCZ) a region of pronounced convective activity, which is fed by 3 major near-surface airstreams; the low-level recurved south Atlantic air that moves over the Congo basin, the north-east monsoon air of east Africa that moves south westward across the equator and thirdly the deep tropical easterlies from the Indian ocean. To the north of the ITCZ the climate is monsoonal. Arrival and persistence of air streams of northerly components provide the bulk of annual rainfall over Southern Africa on rain days (Torrance 1979, Harrison 1986, Lindesay 1988, Preston-Whyte and Tyson 1988). Contrary to popular belief that the ITCZ is responsible for South African rainfall, Taljaard (1990) suggested that the ITCZ is mistakenly identified as the Inter-ocean Convergence zone (IOCZ) which is formed from tropical moist air off the Indian ocean which travels west and converges over Namibia with dry air of Atlantic origin. The IOCZ is a trough at 700 hPa between the easterly trade wind current and humid air flowing in north-westerly winds across Zaire and northern Zambia. Jury and Pathack (1992) in their study of outgoing longwave radiation (OLR) have shown that a convective maximum (OLR minimum) lies along the 10° S across most of the subcontinent between 20 - 35° E. When the ITCZ comes far enough south, it is drawn into semi-permanent low pressure configurations over the interior (Taljaard 1986a, Lyons 1991). The intrusion of upper westerly waves into Zimbabwe result in interaction between extra-tropical cold fronts and tropical cloud masses to the north which provide moisture (Hattle 1955, Smith 1985, Matarira 1990b).

Hypotheses to be tested

Rainfall variations of wet and dry events within October and November are influenced by variations in both low latitude forcing (associated with tropical easterly flow) and mid-latitude transient dynamics (associated with a variety of both cyclonic and anticyclonic perturbations in the westerlies). Coupling of these tropical and temperate systems on rain days appears to be a combination of a large amplitude and sharply curving trough at upper-levels within which upper-level divergence is vital to sustain uplift. It is likely on no-rain days that a small amplitude trough which is dominated by zonal winds does not have similar upper-level divergence. From the literature it appears that moisture from a northerly source is a key factor for precipitation and the presence or lack of it is a major difference between wet and dry troughs. It appears that wet and dry circulation types identified on a seasonal scale (Harrison 1983, 1984a, 1986, Tyson 1986) are closely related to those operating on the event time scales such as those studied by (Triegaardt and Kits 1963).

Hypotheses on which this thesis is developed are as follows:

1. Wet and dry spell circulation characteristics spanning a few days will reflect certain circulation structures and dynamic similarities found in the long term circulation patterns associated with wet and dry seasons.

2. Secondly, it is postulated that distinct differences exist in the vertical structure of the troposphere between wet and dry events, and that these differences will be reflected in contrasting synoptic circulation features and/or distinct spatial and temporal properties of these features.

3. A third hypothesis is based on findings of Harrison (1986) that increased rainfall is associated with the poleward flow of tropical moist air. Thus, it is expected that wet (dry) frontal events during early summer are characterised by (a lack of) tropically induced precursor inflow of moist air and an unstable (stable) pre-frontal environment over the interior.

4. A fourth hypothesis based on findings of (Hofmeyer and Gouws 1964, Taljaard 1986b, Matarira 1990b) considers geopotential height anomalies at 700 hPa and 500 hPa. Geopotentials characterising wet events are expected to have negative anomalies over the tropics and sub-tropics and positive anomalies south of South Africa, with the reverse anomaly pattern occurring in the dry events.

5. It is expected that dry troughs in October and November will be characterised by a southward displaced trough axis, a short upper wavelength and amplitude, an east and northward displaced SAac, increased zonal as opposed to meridional flow over the interior of South Africa, and a lack of moist air. In comparison

wet troughs should be characterised by northward penetration of the trough axis, large upper wavelength and amplitude, increased meridional flow, and prefrontal flow of moist tropical air.

The above hypotheses will be tested by examining the synoptic setting and vertical structure of 6 wet and 6 dry troughs in the period October, November 1985-1989. The methodology employed in pursuance of these objectives is described below.

RAINFALL STATIONS

1	Robertson
2	Port Elizabeth
3	Touwsriver
4	Willowmoore
5	East London
6	Sutherland
7	Beaufort West
8	Graaf-Reinet
9	Cradock
10	Fraserburg
11	Queenstown
12	Calvinia
13	Grootfontein
14	De Aar
15	Van Wyksvlei
16	Springbok
17	Prieska
18	Fauresmith
19	Wepenaar
20	Shaleburn
21	Pofadder
22	Douglas
23	Bloemfontein
24	Upington
25	Postmasburg
26	Welkom
27	Newcastle
28	Keetmanshoop
29	Vanzylsvlei
30	Armoedsvlakte
31	Potchefstroom
32	Gemsbok Park
33	Tsabong
34	Carolina
35	Mmabatho
36	Pretoria
37	Oudestad
38	Gabarone
39	Thabazimbi
40	Hardap dam
41	Tsane
42	Ellisras
43	Pietersburg
44	Mahalapye
45	Louis Trichardt
46	Messina
47	Maun

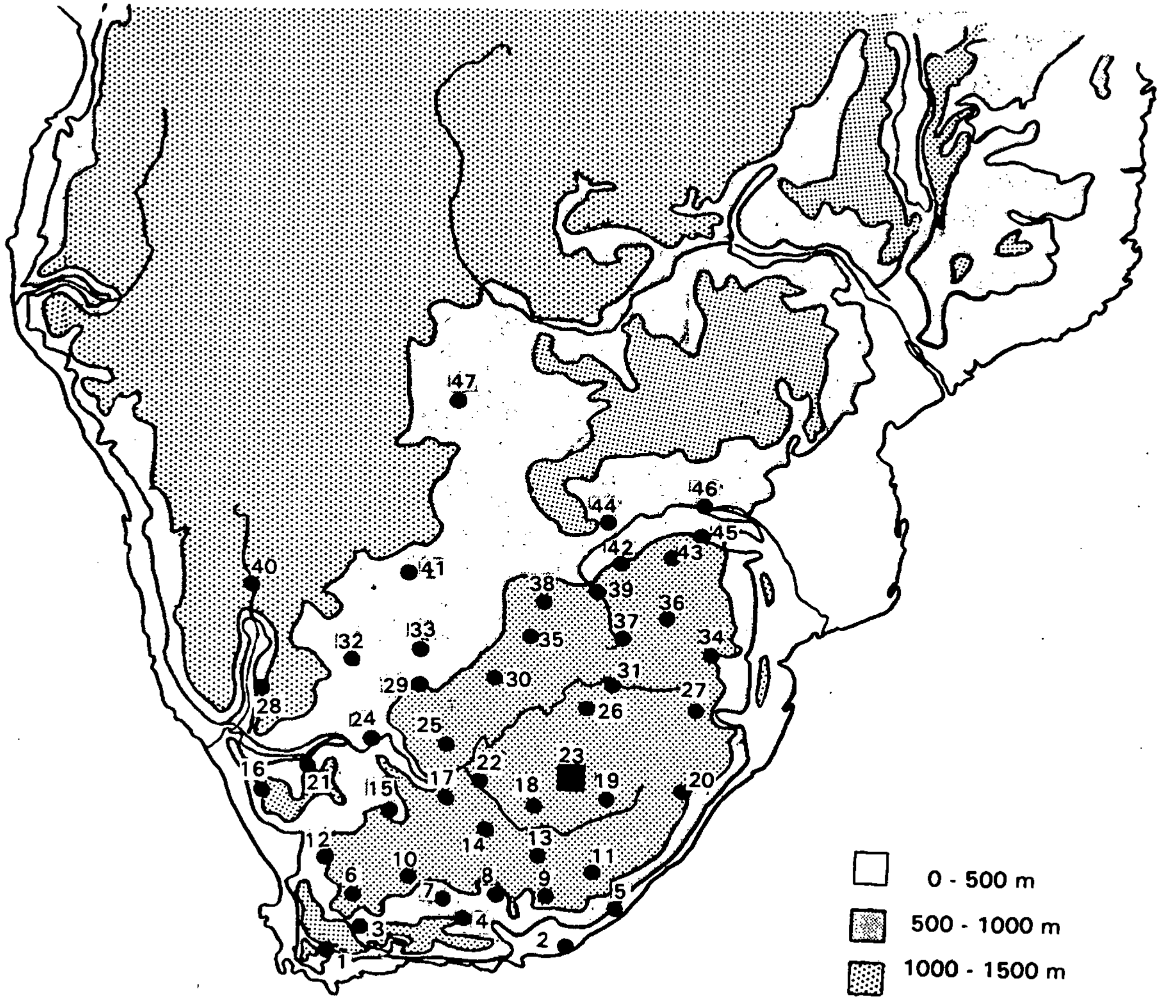


Figure 1-1 Topographic map of Southern Africa showing the spatial distribution of rainfall stations. Bloemfontein is represented by a square.

CHAPTER 2

DATA AND METHODOLOGY

Introduction

The data required to undertake this study of the structure and dynamics of wet and dry troughs during the early summer include surface and upper air synoptic charts and radiosonde data from all South African stations. Initially cases were chosen as objectively as possible according to certain criteria outlined by Taljaard (1961), briefly these include, a minimum horizontal temperature change and vertical extent of the frontal layer, such that the air masses bounding the frontal zone should be of a certain thickness. At first a variety of cases were chosen from October to December according to certain criteria outlined by Taljaard (1961) from the period 1985 - 1989. The study was restricted to the contemporary period of most accurate observational data products (i.e. ECMWF analyses). As a result, a full statistically representative sample is not necessarily achieved. Daily rainfall data from selected stations throughout Southern Africa were used to screen cases into those experiencing > 12 mm day^{-1} of rainfall and those with < 2 mm day^{-1} (Figure 2-1), 6 wet events and 6 dry events emerged and form the basis of this study;

Wet events	Dry events
9 - 12 November 1987	7 - 11 November 1988
13 - 17 November 1989	21 - 26 November 1989
26 - 29 October 1986	7 - 11 October 1989
3 - 6 November 1986	6 - 8 November 1985
6 - 10 November 1986	11 - 16 October 1986
8 - 12 October 1988	4 - 11 October 1989

The sources of data and the methods of analysis applied to the cases are detailed below.

Criteria for the selection of wet and dry troughs

Frontal events were selected from the months October to December from the years 1985 - 1989 on the following criteria based on Taljaard (1961):

1) A "cold front" (analysed in the South African Weather Bureau (SAWB) synoptic charts) transits across the country from west to east.

2) A significant variation in surface temperature (> 5°C), dewpoint (> 10°C), and a surface geopotential decrease of > 40 gpm is recorded over the region of Bloemfontein as the front passes eastwards.

3) The vertical depth of the frontal zone has to exceed 3 km, across which the temperature changes sharply in the horizontal direction by an average of 3° - 6°C.

4) The surface trough is associated with a well developed upper air trough, with an amplitude at 300 hPa > 6° latitude, and a 850 - 700 hPa thickness layer > 35 geopotential metres.

Wet and dry frontal events were distinguished from one another by the spatial distribution and quantity of rainfall from 47 selected stations (ref Figure 1-1). The rainfall maximum in wet events had to occur over a region bounded by 15 - 33° S and 18 30° E, with more than 80% of the rainfall stations experiencing > 10 mm. In dry events, rainfall exceeding 20 mm at any station prevented inclusion of the event. Only 12% of the stations had rain < 8 mm, most of this rainfall was recorded in the south western Cape. Pressure falls associated with the eastward passage for 6 wet cases is presented in Figure 2-2 for (a) the surface and (b) 500 hPa levels. The pressure tendency reaches a minimum at approximately 00h at the time of cold front passage over Bloemfontein. Thereafter the pressure tendency changes abruptly and follows a reverse sequence.

Owing to its regional centrality in South Africa, and the interaction of tropical and mid-latitude weather systems over the area, Bloemfontein is used as the focal station, around which, the timing of the frontal events have been determined. Figure 2-3 is a diagrammatic representation of the classification used to identify synoptic scale waves and relevant 12 h time stages. The westward tilt and lag of upper troughs is a typical characteristic south of 35° S in South Africa

(Preston-Whyte and Tyson 1988, Lindesay and Jury 1991). This westward tilt can be inferred in Figure 2-2 (b) where the pressure minimum at 500 hPa occurs 24 hours behind the surface frontal zone and peak rainfall.

Data

Rainfall data

Rainfall stations were chosen for their spatial coverage and reliability, determined by length of accurate records. The density of South African stations is lowest in the semi-arid north-west and central interior of South Africa and highest in the wetter east. For the purpose of this study rainfall stations below 1000 m and within 250 km of the Indian ocean and 100 km from the Atlantic ocean were eliminated to exclude coastal and orographic rain events.

Radiosonde data

Radiosonde data form the basis of the vertical temporal twelve hourly sequences in this study. Radiosonde data for October and November from 1985 - 1989 are obtained for the following stations; Bloemfontein, Pretoria, Pietersburg, Alexander Bay, Durban, Port Elizabeth and Upington. Midnight data from Harare, Zimbabwe were also utilised. All South African upper air stations were analysed except Cape Town whose location was considered too far south-west to indicate tropical interaction. Complete 5 year, October - November midday and midnight radiosonde data sets were available for Bloemfontein, Pretoria, Upington and Port Elizabeth. The Pietersburg upper air station was established in 1986, so data is not consistent for one case study, 6 - 9 November 1985. Further, equipment errors occurred at Alexander Bay and Durban for the case event of the 10 - 13 November 1987. Standard meteorological parameters were obtained from the radiosonde stations, these include temperature, dewpoint, geopotential height, wind speed and direction. Other meteorological variables, calculated from these standard parameters, include mixing ratio, dry and total static energy, dewpoint depression and equivalent potential temperature. Radiosonde data are presented either as a time-height composite spanning the length of the event from -48h to +36h or as individual north-south, west-east distance sections.

European Centre for Medium Range Weather Forecasts (ECMWF) data

The last ten years have seen rapid development in atmospheric modelling and numerical weather prediction for the whole globe. According to Hoskins et al (1989) these advances together with more sophisticated data integration methods have made it possible to increase horizontal and vertical resolution and hence make more accurate calculations of dynamical and physical meteorological processes in numerical model forecasts.

Today, the ECMWF model is the best known global model and is associated with high quality meteorological analyses, which are routinely produced and carefully monitored. ECMWF data exploit atmospheric observations from a number of sources including, radiosondes, satellite temperature and moisture soundings, satellite cloud track winds, surface observations from ships, oceanic buoys and land stations and aircraft reports Hoskins et al (1989). ECMWF manipulates these observations to enable as complete a description of atmospheric flow as possible. In this study 24 hourly ECMWF analyses were used in conjunction with radiosonde data, firstly to lend support to upper air observations, and secondly to supply detailed data on a 5° longitude and latitude gridded scale which includes the southern oceans from 0° - 50° E and 0° - 40° S. Complete ECMWF data sets for all the events were not available. Since inception, the ECMWF model has had major computational changes, with perhaps the biggest changes being made on the divergent winds and vertical velocity. The introduction in May 1985 of shallow convection, modified moistening in the parameterization of deep convection and reduced horizontal diffusion, effectively increased tropical troposphere temperatures. Satellite data since 1985 have partly filled the void left by the lack of conventional data.

ECMWF have invested considerable effort in improving analyses and forecast skills in the Southern Hemisphere over the last 10 years. Satellite data has had a positive impact on analyses and forecasts and has partly filled the void left by lack of empirical data (Hoskins et al 1989). Major analysis changes, since 1982 have strengthened the reliability of ECMWF. In 1982 the introduction of diabatic initialisation strengthened and improved the tropical divergent flow in ECMWF analyses and created a more realistic and intense Hadley and Walker circulation. A better boundary layer formulation has made new analyses realistic to the upward transport of moisture in the boundary layer, which gives rise to a larger latent heat flux from the ocean than the old model.

Methodology

Analysis techniques

Several analysis techniques have been incorporated into this study, including spatial synoptic assessment, individual distance sections and time-height analyses of standardised departures, time and distance composites, and various calculations including vorticity, static energy, mixing ratio, equivalent potential temperature, and surface and upper trough phase speeds. A brief description of the methods used is given below.

Composite analyses

The composite analysis technique has been used extensively in the field of climatology (Lamb 1978, Streten 1981, Tyson 1981, Rasmusson and Carpenter 1982, Hirst and Hastenrath 1983, Lindesay 1988 and Walker 1989). By using this method, ensembles can be derived from the time series data over Bloemfontein, yielding more valuable information on average changes than can be obtained by using individual cases. Compositing is particularly useful in showing trends which do not otherwise show due to the nature of daily weather variability. The technique offers the advantage of reducing the number of maps and figures to be assessed when developing relationships between variables.

To prepare the data for compositing to allow comparison of cases: wet vs dry or, case vs long term monthly mean, data were standardised according to a 20 year (1968 - 1987), 12 hourly, long-term mean.

The standardised departure refers to:

[actual value at a specific time (day or hour), place, level] - [long term mean at a specific time (month) place and level] ÷ [long term standard deviation].

Twenty year (1968 - 1987) means and standard deviations were available from the SAWB for temperature, dewpoint, geopotential height, zonal and meridional winds for all stations except Pietersburg and Harare. Only midday standard deviations were available which were used for the midnight variables, which according to Taljaard (1990) is acceptable above the surface of the South African plateau, which is approximately 850 hPa.

A mean and standard deviation were obtained for Pietersburg, Harare, equivalent potential temperature, mixing ratio, dewpoint depression and static energy by adding 6 wet midday (midnight) cases to 6 dry midday (midnight) cases, divided by the standard deviation obtained from the 6 wet midday (midnight) cases and 6 dry midday (midnight) cases, such that:

(actual wet midday (midnight) value) - (all wet and dry midday (midnight) cases) ÷ (all wet and dry standard deviation)

The resulting standard departure is either positive (above normal) or negative (below normal) in comparison to the long term mean. All composites in this study consist of 6 individual case studies, being either wet or dry events, which are added together. For dewpoint depression a negative departure means above normal moisture, while a positive departure means below normal moisture. Standardised departures (referred hereafter as departures) of > +0.8 or < -0.8 are considered significant in this study.

Spatial synoptic composites are formed by digitising wet/dry events using an *apriori* time frame, on a 5° latitude/longitude grid over the interior of South Africa and the surrounding oceans at 850 and 500 hPa levels. Spatial composites were prepared for 850 hPa and 500 hPa pressure, geopotential height and vorticity fields, and also for surface temperature and dewpoint sections.

Time section analyses

Time section analyses (ref Figure 2-3) are the most regularly used method of analysis in this study. Time sections are used in conjunction with 12 hour resolution radiosonde data to represent vertical sections through the troposphere. Radiosonde sections are presented either as mean 6 wet or 6 dry composites or as an individual wet or dry events. Stations such as Bloemfontein are presented for every meteorological parameter, (temperature, dewpoint, dewpoint depression, geopotential height, mixing ratio, U and V wind components, equivalent potential temperature and, dry and total static energy) while at other stations such as Port Elizabeth and Pretoria, composites are used to confirm and support important structural findings. Time section analyses for the remaining 5 individual wet and 5 dry events for the same meteorological parameters which do not appear in this study are presented in table form in Appendix A.

Distance Sections

North-south, east-west distance sections across South Africa were plotted for individual events at D-day (defined by maximum rainfall, and the location of the front over Bloemfontein) and for some meteorological parameters (equivalent potential temperature and static energy) at -12h to show the spatial structure and dynamics of the atmosphere at a time of maximum (minimum) rainfall in wet (dry) troughs. The north-south distance sections between 26° E and 31° E comprise 5 stations; Harare, Pietersburg, Pretoria, Bloemfontein and Port Elizabeth, while the east-west distance section between 28° S and 30° S comprises 4 stations; Alexander Bay, Upington, Bloemfontein and Durban. The large spatial distances between upper air stations smooths out mesoscale effects. North-south, east-west distance section analyses for the remaining 5 individual wet and 5 individual dry events are presented in table from in Appendix B.

Moisture and thermodynamic computations

Until 1986 the quality of the Southern Hemisphere ECMWF moisture calculations were questionable largely owing to vast data-sparse regions of the tropics and ocean areas, and an underestimation of the ECMWF model in computing divergent motion and vertical fluxes. Since 1985, considerable effort in quality control of observations, advanced satellite and computer techniques, and the introduction of shallow convection and a better boundary-layer formulation have lead to a more realistic upward transport of moisture from the boundary layer, enhancing the meridional circulation and giving rise to a large latent heat flux from the ocean and a more intense, deeper Hadley circulation (Bengtsson and Shukla 1988, Hoskins et al 1989). Moisture computations obtained from ECMWF data, used in this study are; water vapour flux and precipitable water which have been calculated over the South African domain by Landman (1991) and provide a large scale spatial overview of the moisture content of the atmosphere.

Mixing ratio

The amount of water contained in the atmosphere can be derived from temperature and dewpoint soundings of the upper air by means of radiosonde ascents and by estimation from satellite soundings. Mixing ratio Mr (g kg^{-1}) is the ratio of the mass of water vapour to the mass of dry air. Mixing ratio depends not only on the vapour pressure but also on the total pressure and is given by the following equation after Wallace and Hobbs (1977) and Pathack (1991); vapour pressure (e) $e = 6.11 * (e^{19.834 - \frac{(5417.753)}{TD}})$ then, the mixing ratio will be, $Mr = \frac{0.62197 * e}{p - e}$, where e (hPa), Td (K) dewpoint, p (hPa) at a specified standard level. The mixing ratio is important as it is often conservative; as air moves, the mixing ratio will only change if mixing with drier or wetter air, or if evaporation or condensation occurs. These variables vary diurnally. In this study mixing ratios are computed for the 700 hPa and

500 hPa levels, 12 hourly for all the radiosonde stations except Harare. Moisture above 500 hPa is limited.

Precipitable water

Precipitable water PW (mm), is a useful measure of the atmospheric integrated water content. The precipitable water of a column of air is usually defined as the depth of water that would be obtained if all the water vapour in the column, of unit cross-sectional area, were condensed on to a horizontal plane of unit area. Precipitable water in the layer between certain specified levels is expressed by; $PW = \frac{100\,T\,(p1 - p2)}{g}$ where, p1 - p2 is the pressure difference between 2 levels, T (K) is the mean temperature between layers and, g (m s^{-2}) is gravity. The addition of consecutive values of precipitable water for various layers from 850 - 300 hPa is done. In this study precipitable water is used in Chapter 4 as a wet and dry composite and in Chapter 5 for the analysis of a wet and dry case study.

Water vapour flux

Water vapour flux WvF (g cm^{-1} s^{-1}) is the advection of precipitable water by the horizontal wind. Since moisture is concentrated in the lower levels, the weighted vector average often reflects flow in the levels below 600 hPa. The total horizontal mean flux of water vapour WvF (g cm^{-1} s^{-1}) is obtained through vertical integration; $WvF = \frac{1}{g}\int_{p1}^{p2} q\,U\,dp$ where q (g kg^{-1}) is the specific humidity, g (m s^{-2}) gravity, p1 and p2 (hPa) refer to pressure levels from 850 - 300 hPa, and U (m s^{-1}) is the horizontal wind vector in the layer (dp).

Water vapour fluxes are presented on a 5° longitude/latitude spatial network on the ECMWF map in similar fashion to wind arrows, where the direction is in the conventional sense, each feather represents 100 g cm^{-1} s^{-1}.

Equivalent potential temperature (EPt)

Atmospheric temperature and moisture can be combined into EPt, usually represented as a vertical profile indicating suppressed or enhanced convection. The quantity EPt is the potential temperature of a parcel of air when its mixing ratio has been reduced to zero and all the latent heat turned into sensible heat (Betts 1974, Bolton 1980). When the air is compressed dry adiabatically to 1000 hPa the new higher temperature will be the EPt. Thermodynamic profiles in relation to precipitation for a summer season at Bethlehem approximately 180 km north-east of Bloemfontein have been developed by Steyn (1988) and are used as a guide in this study, since the profiles identify atmospheric conditions ranging from extreme dry to exceptionally moist. In general types associated with "above average" rainfall have their profiles east of the zero line in the positive region which indicates warm moist air (PW ≥ 25.0 mm) extending throughout the column and is an indication of tropical air over the interior. Profiles to the west of the zero line i.e. negative region are soundings from post-frontal weather systems, which are associated with cold dry subsident air with PW ≤ 9.0 mm. Holton (1979), Riehl (1979), Atkinson (1981) and Steyn (1988) have found that for radiosonde soundings taken in the tropics the profile of EPt has a mid-tropospheric minimum for almost all stations, while shallow or suppressed convection has a EPt minimum at low levels. The EPt is calculated from the vapour pressure and mixing ratio, thus $Tl = \frac{1}{\frac{1}{TD - 56}} + \frac{\ln \frac{T}{TD}}{800}$ Tl, temperature at saturation level, then substitute into the equation for EPt.

$$Ept = [T \frac{10}{p}^{3}\ {}^{0.2854\ (1 - 0.28 * 1000 * Mr)}] * e^{[(\frac{3.376}{Tl} - 0.00254) * Mr\ (1 + 0.81 * 1000)]}$$

Static energy

Standard pressure level values were used to calculate dry static energy (CPT + GZ) and moist static energy (CPT + GZ + LQ). Betts (1974) and Kelbe (1988) have shown that dry static energy is analogous to EPt if there is negligible dissipation by kinetic energy. If static energy is used, the implicit assumption is made that kinetic energy is all locally dissipated. While if equivalent potential temperatures are used, it is assumed that the maximum available kinetic energy is generated and none is locally dissipated. Since dry static energy is analogous to EPt, either one or other method will be discussed in the following chapters. In South Africa, Kelbe (1988) has successfully used dry and total static energy in an analysis of two extreme convective cases in the north eastern Transvaal. In this study dry and total static energy are used to illustrate marked changes in stability during wet and dry synoptic perturbations crossing South Africa. A breakdown of the components are; [CPT (1010 J kg^{-1} c^{-1}) specific heat at constant pressure * T (K) temperature] added to [GZ (m^2 s^{-2}) gravity * geopotential height], added to [L (2500.3 10^{-3} J kg^{-1}) * q (g kg^{-1})] specific humidity L, is the latent heat of condensation, which is the amount of heat required to convert a unit mass of material from the liquid to the vapour phase without a change of temperature, q is specific humidity.

The application of the methodology outlined above to study wet and dry troughs across Southern Africa, and the results obtained from these analyses forms the focus for the remainder for this study.

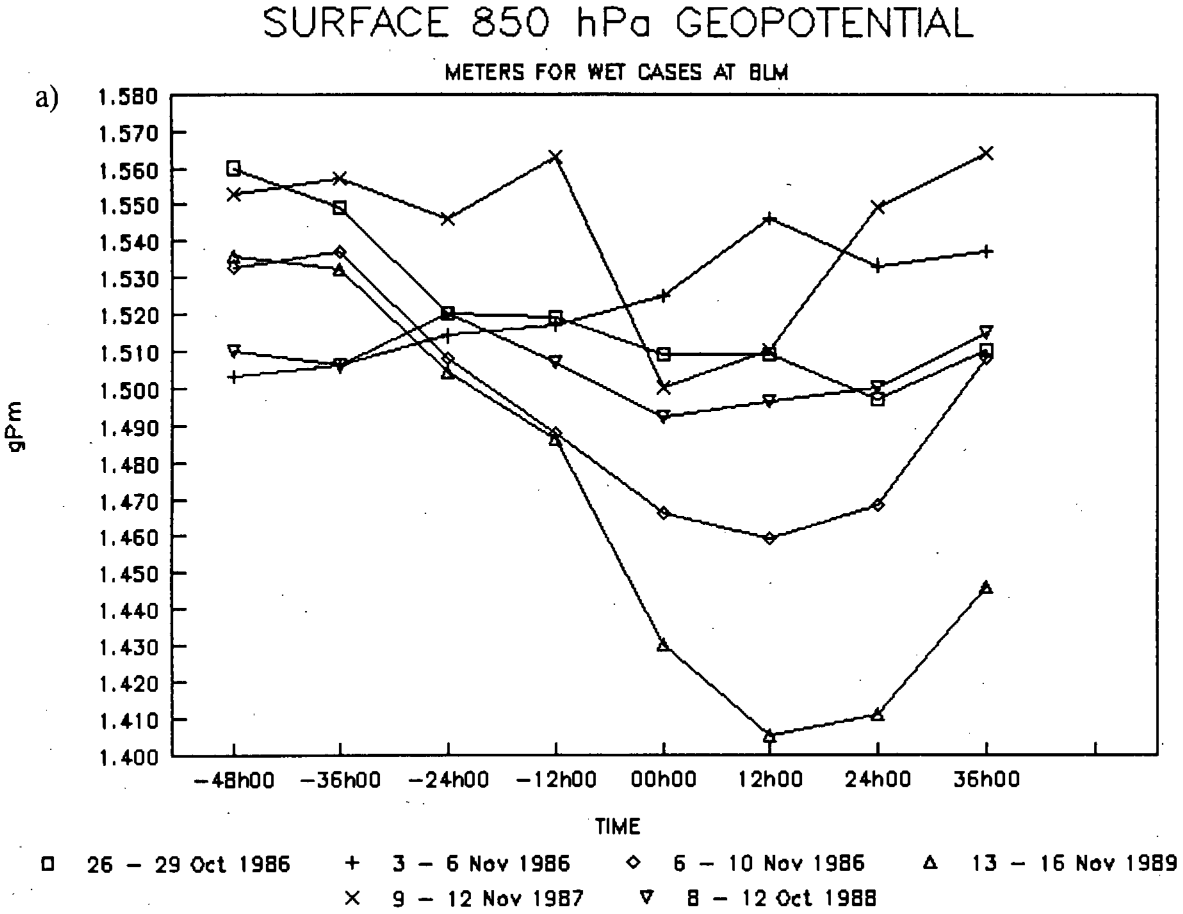
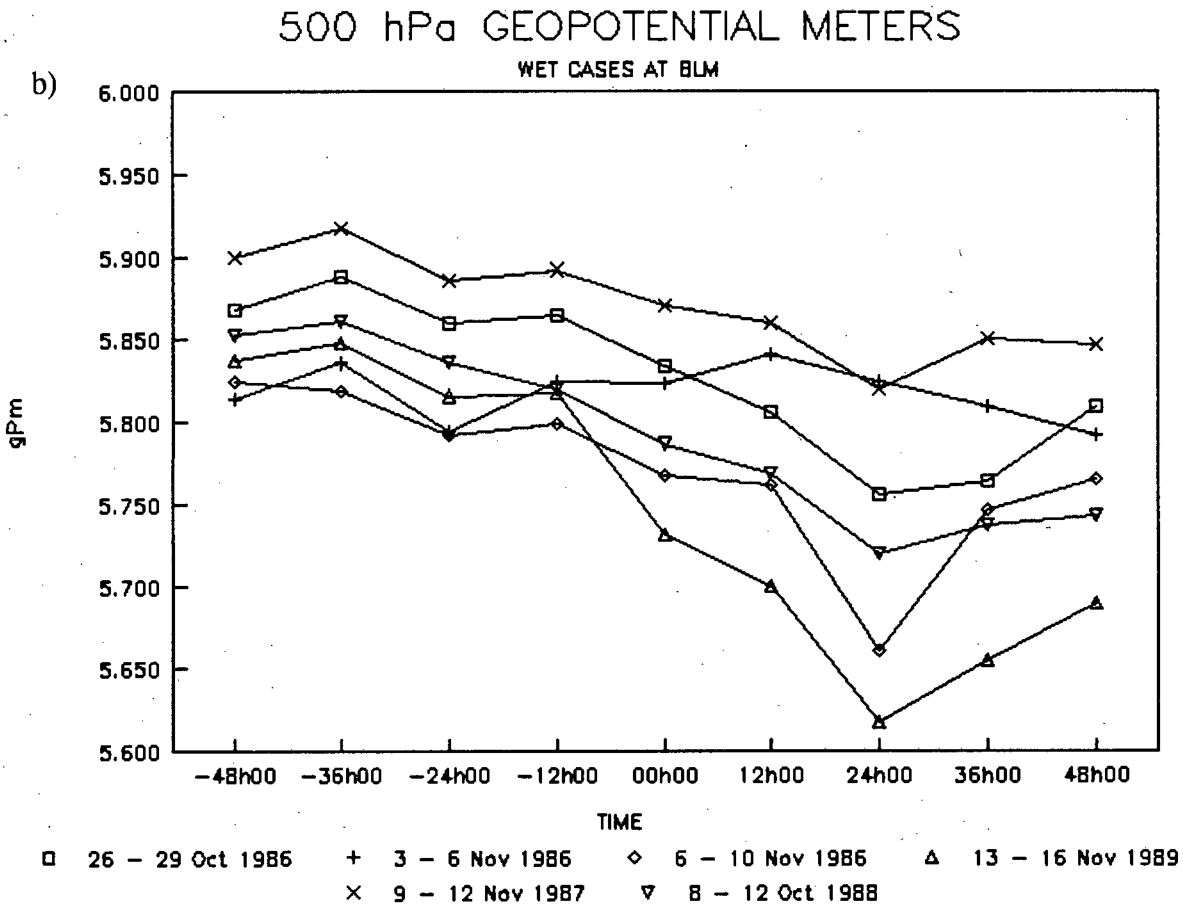


Figure 2-2 The eastward passage of 6 individual cold fronts across Bloemfontein from geopotential time-height sections for (a) surface (850 hPa) and (b) 500 hPa.



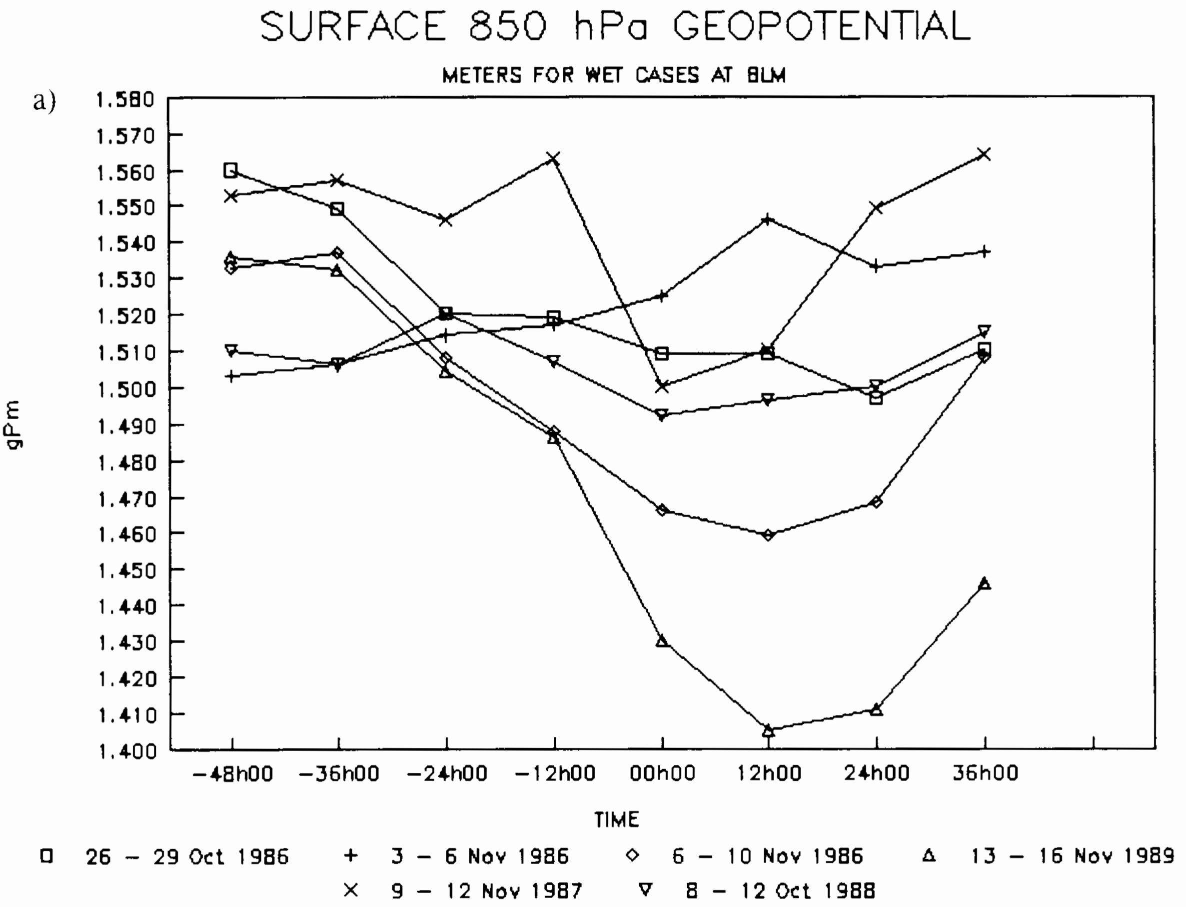
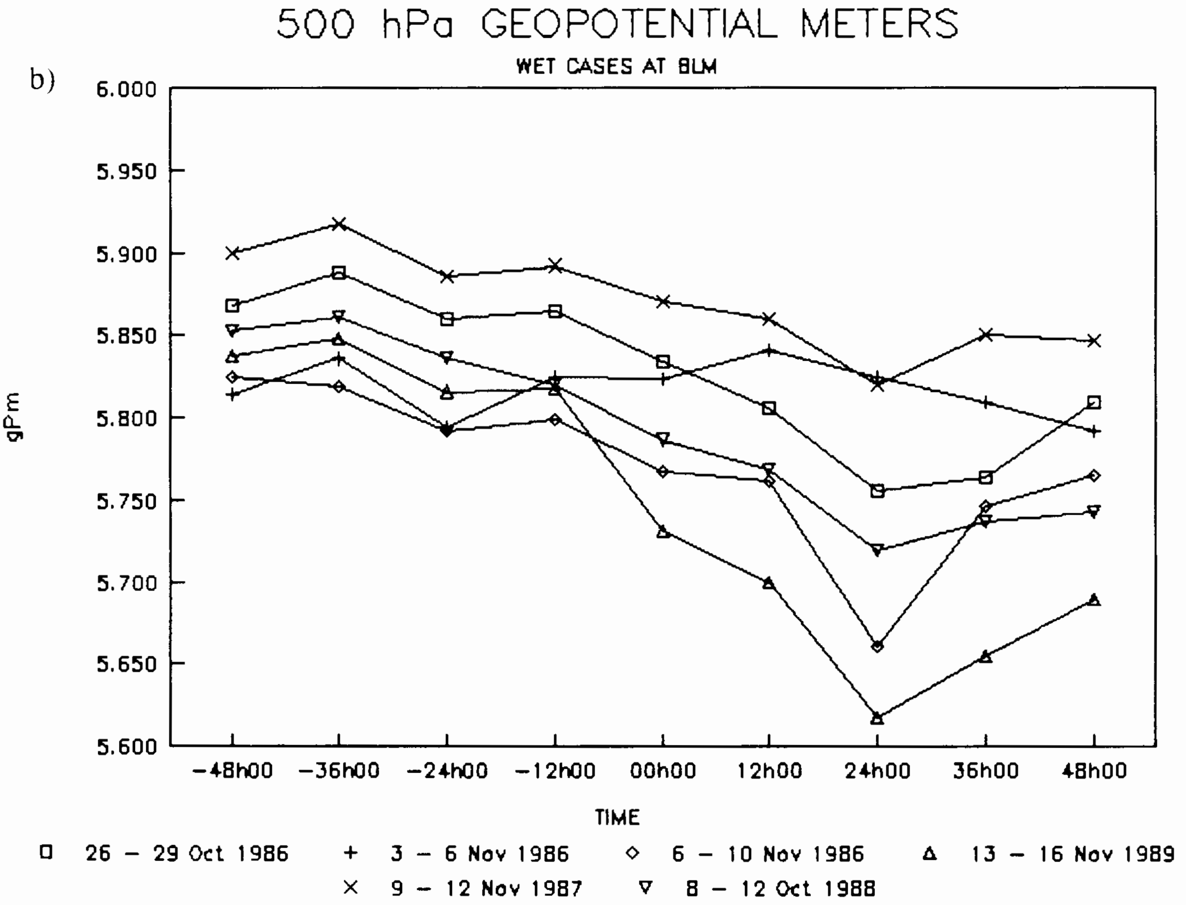


Figure 2-2 The eastward passage of 6 individual cold fronts across Bloemfontein from geopotential time-height sections for (a) surface (850 hPa) and (b) 500 hPa.



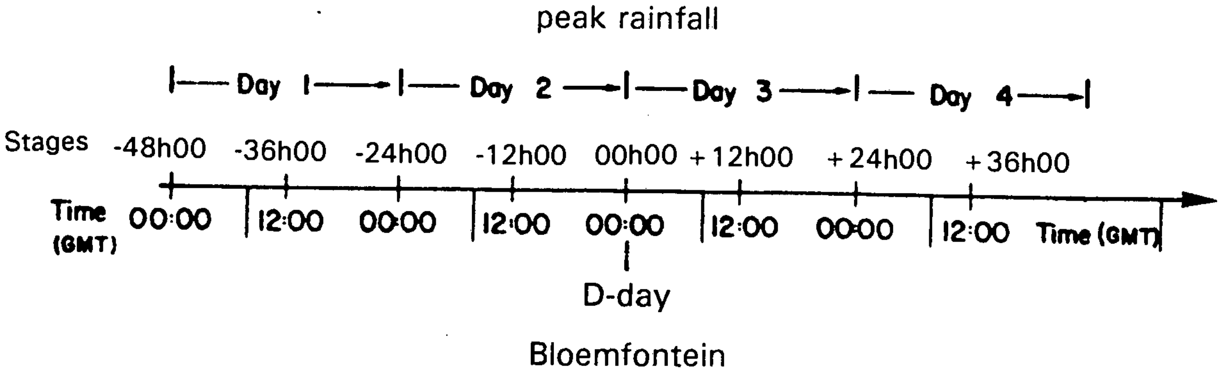


Figure 2-3 Diagrammatic representation of the time framework used to identify the synoptic scale waves and the relevant 12 hour time stages.

CHAPTER 3

MEAN CIRCULATION CHARACTERISTICS OF WET AND DRY TROUGHS

Introduction

This chapter focuses on the spatial coverage of wet and dry troughs across the interior of South Africa using SAWB synoptic charts with a 24 h resolution. Spatial composites of surface and upper-level synoptic charts form the bulk of this chapter, while radiosonde data of 12 hourly resolution is used to represent geopotential height and the kinematic structure to understand the changing life cycle of the eastward moving front. An effective means to describe mean weather conditions associated with wet and dry frontal events is by contrasting overall means from 6 similar wet cases and 6 similar dry cases using surface and upper-level synoptic data. Most results discussed in this chapter are presented as a wet or dry mean, wet or dry departure or wet-dry composite. Important aspects noted from the synoptic patterns, such as, the phase speed, pressure and latitude of the SAac, and details of the surface and upper air trough are investigated, as well as the kinematic, geopotential, vorticity and divergence fields that contribute toward a better knowledge of the mechanisms of synoptic forcing associated with wet and dry troughs.

Composite synoptic circulation patterns of wet and dry troughs

Pressure or geopotential height values on a 5° latitude/longitude grid over the South African domain were digitised from SAWB midday operational analyses at 1000 and 850 hPa pressure surfaces for 6 wet and 6 dry cases. These are presented in Figure 3-1 for (a) wet events and (b) dry events, and for the previous 24 hours, D-day and the following 24 hours. Composite surface pressure fields for wet and dry troughs (Figure 3-1 a, b) show the eastward movement of a trough-shaped low, followed by a ridge of high pressure and represent scenarios typical to those frontal events analysed by Kelbe (1988) and Preston-Whyte and Tyson (1988). Of particular interest in the mean wet synoptic composite is the presence of a deepening interior low pressure band that appears to move southward from -24h to reach a minimum of 1477 gpm over central South Africa on D-day. A band of low pressure (1493 gpm) occurs at -24h in the dry composite over the south western Cape, but north and eastward displacement of the SAac over the interior actively erodes the interior low by D-day. The SAac ridges over the west coast at 00h in dry events, while ridging to the south of the subcontinent occurs in wet events. By +24h in the wet event composites the faster moving ridging anticyclone is situated south of South Africa, while budding has only just commenced in dry events. The wet-dry (850 hPa) spatial temperature composite (Figure 3-2) for -24h, 00h and +24h show low temperature values throughout the wet sequences which is typical of increasing moisture and cloud suggested by the low over the interior. The temperature differences attain a maximum of 8°C at 00h and +24h at the time of maximum convection in the wet events. The centre of maximum difference moves eastward across the interior of South Africa with the passage of the cold front.

Figure 3-3 represents the mean (a) wet and (b) dry 500 hPa synoptic pressure map which shows the upper-level trough at D-day. In the wet events the upper-level trough with its well-defined amplitude and westward tilt is located over the western interior of South Africa. An interior geopotential height of 5840 gpm between 15 - 20° S is 40 gpm lower than the same pressure and latitude in the dry events and marks the upper-level trough. The upper-level trough in the dry events is centred over the southern part of South Africa, has more zonally aligned isobars and a centre of very low pressure in the westerly wind belt at 40° S, some 80 gpm lower than in the wet event. A very low standard deviation was noted between 35 ° - 45 ° S and 25 ° - 35 ° E which meant that low pressure centres were located at much the same latitude and longitude in the 6 dry events.

The difference between the wet and dry surface, (850 hPa) and 500 hPa troughs are presented in Figure 3-4 for D-day. Positive values dominate south of South Africa from 35° S to 40° S and probably represent fast ridging SAac in the wet events Negative values over the western interior and over the Atlantic characterise the presence of an interior trough and potential surface convergence. This pressure configuration of low values over the interior and high values south of South Africa represents a dipole structure and implies stronger meridional flow and weaker westerly flow for wet troughs. The surface north-south, negative-positive dipole between the ridging high and the interior low is apparent in Figure 3-4. A weak positive limb stretching up the east coast of the subcontinent suggests the SWIac is displaced more west in the wet events. This result is similar to those of Harrison (1986), Matarira (1990b) and Lindesay and Jury (1991), that a more westward displaced SWIac during rain days is associated with southward transport of moist tropical air. However, the role of the SWIac is small and bears no real significance in this study.

The 500 hPa wet-dry height difference (ref Figure 3-4) bears resemblance to the 850 hPa map where negative (positive) regions at 500 hPa overlay negative (positive) regions at 850 hPa implying that the wet events are characterised by a deep interior low and high pressure system to the south of South Africa. The most prominent feature of Figure 3-4 is the wave-like band of negative geopotentials over the southwest Indian ocean at 45° E (500 hPa) which stretches across South Africa and joins up to negative geopotentials over the west coast completing a north-west to south-east upper air trough. The negative-positive dipole at 25° E suggests that "splitting" of the subtropical jet stream occurs over the west coast of South Africa such that the southern limb of the jet stream flows southward and is associated with the fast ridging SAac, while the northern limb of the jet stream is displaced further north and may act to "spin up" interior lows.

The climatological structure of wet and dry troughs over South Africa during the early summer is presented in Table 3-1. Table 3-1, lists the speed, latitude, and the pressure of the SAac, the speed of the surface 850 hPa trough along 35° S over a period of -48h to +48h and, the speed, amplitude and wavelength of the upper air trough at 300 hPa for -24h and D-day. A discussion of these characteristics ensues.

South Atlantic anticyclone (SAac)

The length of time that it takes for the ridging SAac to move eastward along a certain latitude has important implications for South African weather depending on its speed it may either enhance "drying out" of the atmosphere or promote instability. Table 3-1 shows that the SAac for both wet and dry troughs moves eastward at a mean phase speed of 7.1 - 22 m s^{-1} in the latitudes 30° - 39.3° S with a central pressure of 1025 - 1030 hPa. In the wet events the SAac quickens from a speed of 8 m s^{-1} (-24h) to 22.6 m s^{-1} (D-day) when the ridge of the SAac is at its most elongated over the tip of Southern Africa. This is in contrast to the dry events where the speed of the trough moves slower (8 m s^{-1} to 15 m s^{-1}) from -24h to D-day. The quicker ridging speed of 23 m s^{-1} in the wet events between -24h and 00h suggests that the SAac is pushing rapidly behind the surface trough at the time of maximum rainfall, which suggests meridional flow as the low pressure system and the SAac promote low-level equatorward and upper-level poleward flux indicating that the air flow within these systems is similar to that of a Hadley cell. In comparison the mean SAac speeds during the course of the dry events appear sluggish and maximum speeds are only attained once the front has passed east of South Africa.

The central pressure of the ridging anticyclone is similar in both wet and dry scenarios. At D-day the mean pressure was 1029 hPa which is similar to pressures recorded by Taljaard (1972) for systems north of 50° S in the transitional seasons. A significant difference noted between the wet and dry troughs is the mean latitudinal position of the centre of the SAac during the frontal event. Prior to onset of the trough over Bloemfontein the SAac for the dry events is located between 30.3° - 36.4° S. The SAac intrudes into the interior in dry events indicative of active subsidence on the eastern limb of the SAac. In wet events, the SAac is located on average about 3° latitude further south between 34.6° - 39.3° S and the zone of subsidence remains south of the plateau..

Surface and upper-level trough

Midday surface SAWB synoptic weather maps are used to calculate the phase speed of surface wet and dry troughs at various stages. Mean wet and dry trough speeds were in the range 10 - 23 m s^{-1} similar to trough speeds recorded near Australia by Garrat (1988) and Hanstrum et al (1990a, 1990b). Table 3-1 shows that the dry troughs pass eastward between -24h and +24h at 19 m s^{-1}, about 7 m s^{-1} faster than the wet troughs which move at a speed of 12 m s^{-1} at the same time.

The phase speed of the upper-level trough, using the 300 hPa synoptic pressure maps, are calculated at -24h and D-day, the time of maximum rainfall in wet events. The average mean wavelength for the upper-level troughs at 300 hPa at D-day is 49.8° and 46.3° longitude for wet and dry troughs respectively, taken at 40° S. The difference of 3.5° longitude means wet cases have a upper westerly wave ≈ 255 km longer than their dry counterparts. Similarity of phase speeds is expected between the surface and upper-level troughs. The equation to estimate Rossby wave speed is given by $C = U - \beta\left(\frac{L}{2\Pi}\right)^2$ where U is the mean zonal wind speed here, averaged over 3 standard levels 700, 500 and 300 hPa. Beta (β) is the $\frac{df}{dy}$ term (the local change of the coriolis parameter with latitude), and L is the wavelength measured at 40° S. The mean upper trough phase speed at 00h is 8.57 m s^{-1} and 17.4 m s^{-1} for wet and dry troughs, respectively which is in accord with surface frontal speeds of 12 m s^{-1} and 19.5 m s^{-1}. Wet upper trough phase speed is theoretically 8.8 m s^{-1} slower than dry trough phase speed. The difference in the mean amplitude between wet and dry troughs at 300 hPa is of order 6° latitude with the wet trough showing a larger mean amplitude of 15.3° latitude, compared to the smaller amplitude of the dry upper troughs of 9° latitude. A large amplitude upper-level wave in wet events implies a decrease in the zonal flow and, more importantly, suggests a northward penetration of westerly waves into equatorial regions in wet events. The smaller amplitude and faster moving trough speed in the dry events suggest that no northward penetration of the trough axis occurs and, more zonally aligned isobars suggest only weak meridional flow. Significant differences are found in the evolution of fronts 24 hours prior to D-day. It was noted that on average the amplitude at 300 hPa increased from -24h to 00h for both wet and dry troughs over the interior of South Africa with the average wet(dry) trough amplitude increasing by 4.5°(0.8°) latitude. In the wet events the upper trough slowed from 11 m s^{-1} to 8.6 m s^{-1} while in the dry events the upper-level trough sped up from 12 m s^{-1} to 17.4 m s^{-1} between -24h and 00h. The dominant factor in the equation which determines the speed of the upper trough is the vertically integrated zonal wind. Dry trough events have a mean zonal windspeed of 24.3 m s^{-1} at 00h compared to the wet trough speed of 19.3 m s^{-1}. In both wet and dry events the zonal wind speed has increased by 3.5 m s^{-1} and 6.3 m s^{-1} from -24h to 00h respectively. In the dry trough cases a more zonal alignment of the isobars are the major cause for high zonal wind speeds.

A vertical time-height section of geopotential height across Bloemfontein from -48h to +36h is presented in Figure 3-5 for (a) wet and (b) dry troughs. The westward tilt of the upper-level trough at D-day is evident in the wet events where negative values below 700 hPa at -24h indicate the surface trough, while negative values from +24h above 300 hPa indicate the upper-level trough. The dry geopotential composite does not show the westward tilt of the upper-level trough instead weak negative departures (-0.3) occur throughout the composite which gain in intensity (-0.9) throughout the atmospheric column after 00h. In the wet events trough tilt implies baroclinicity and synoptic forcing whereby divergence fields of opposing sign in the low and upper-level flow are maintained and suggest a mature frontal system. The lack of westward tilt in the dry events shows that the prevailing divergence fields are weak or non-existent. The wet-dry geopotential composite (Figure 3-6) shows a similar structure to the wet geopotential composite in that departures of the wet events are large and positive prior to frontal passage and strongly negative from 00h. A region of strong positive geopotential height above 300 hPa at 00h and +12h is consistent with an upper-level anticyclone and upper air divergence in the wet events. The westward tilt of the upper-level trough, a characteristic of the wet events, is clearly evident in Figure 3-6.

Relative Vorticity

The indications of a large amplitude upper-level wave, a baroclinic frontal system and a diffluent and northward displaced jet stream in the wet events implies regions of cyclonic and anticyclonic vorticity which may be associated with convergence and divergence. Figure 3-7 represents the mean relative vorticity fields for (a) wet and (b) dry events at D-day at 500 hPa. In both wet and dry composites the relative vorticity fields are north-west to south-east aligned and anti-cyclonically biased over north-east Southern Africa which appears to be normal for both wet and dry spells as in Matarira and Jury (1992). The centre of maximum anticyclonic vorticity (positive) is located near 25° - 30° E and 25° S extending from ≈ 20° S to 28° S in both wet and dry events. In wet events, cyclonic vorticity extends across South Africa from west to east between 22° S and 35° S and is at a cyclonic maximum (-10 10^{-6} s^{-1}) at 20° E and 30° S over the south western interior. In dry events, cyclonic vorticity is located only over the south western tip of the continent in a north-west to south-east band, but a significant cyclonic vorticity area (-35 10^{-6} s^{-1}) is located far south of the country between 40° S and 25° E in a region characterised by a low 500 hPa geopotential field standard deviation indicating that dry event lows are maturing south of 40° S.

Convection at D-day appears to coincide with high cyclonic vorticity and low geopotential height in the wet spells, similarly to the wet 3 - 4 day spells of Matarira and Jury (1992). In mean wet events, cyclonic vorticity of value -5 10^{-6} s^{-1} occurs concurrently with a negative geopotential departure of -1.2 over Bloemfontein at 500 hPa. The converse occurs in dry events which are characterised by strong anticyclonic vorticity of +15 - +20 10^{-6} s^{-1} with a weak negative geopotential departure of -0.1. Little convection is therefore realised.

The amount of meridional shear or north-south gradient between regions of anticyclonic and cyclonic vorticity is far greater in the dry events (+20 to -35 10^{-6} s^{-1}) than the wet events (+10 to -10 10^{-6} s^{-1}). Dry events experience a north-west to south-east alignment of the gradient lines which is consistent with north-west winds. Wet events are characterised by a weaker north-west to south-east alignment, which is more conducive to northerly winds. The wet-dry vorticity pattern for 500 hPa (Figure 3-8) for D-day shows potentially intense cyclonic development over the centre of South Africa and strong anticyclonic flow south of the country in wet cases in contrast to dry cases. The negative - positive dipole stretching from 20° S to 45° S and centred over the interior at 25° E is the most noticeable difference between the wet and dry vorticity fields which implies strong rotation over the interior of South Africa.

Whether the upper-level westerly wave can sustain vertical lift through the prevailing divergence/convergence fields is considered below. Vertical uplift cannot develop through a deep layer if surface convergence is not overlain by upper-level divergence. Divergence profiles are graphically presented in Figure 3-9 for 3 time frames during the passage of a trough over Bloemfontein. Over Bloemfontein at -36h in wet events no convergence occurs, while at -12h some convergence occurs below 500 hPa. At +12h the profile shows maximum convergence at 700 hPa of $-1.3\ 10^{-5}\ s^{-1}$ which is overlain by upper-level divergence which reaches a maximum at 200 hPa of $+1.5\ 10^{-5}\ s^{-1}$. In comparison dry events at 00h show weak convergence of $-0.5\ 10^{-5}\ s^{-1}$ which is overlain by weak divergence of $+0.3\ 10^{-5}\ s^{-1}$. In wet events, precipitation at 00h occurs across Southern Africa implying that lift is sustained. Little to no rainfall in the dry events indicates that the slope of the divergence profile is not strong enough to produce sufficient lift, irrespective of instability to realise precipitation. Additional considerations include the availability of moisture and the degree of instability which will be the focus of Chapter 4.

The vertical movement (Pa hr^{-1}) of a column of air is calculated by the ECMWF model for each standard level from kinematic and mass conservation principles. For this study vertical movement from the ECMWF maps is derived from the 500 hPa and 700 hPa levels, the layer where maximum vertical ascent/descent is present. Vertical ascent for wet troughs at 00h of -330 to -702 Pa hr^{-1} over the interior of South Africa from 20° S to 35° S supports the findings that upper-level divergence at 200 hPa ($+1.5\ 10^{-5}\ s^{-1}$) is sufficiently strong to sustain lift over the interior of South Africa in wet events, while weak surface convergence overlain by weak upper-level divergence is supported by weak vertical ascent of -351 Pa hr^{-1} in dry events at 30° S and 28° E (ref. Figure 4-12).

Opposite divergence fields in the low and upper-level flow provide the synoptic setting for ascent or descent of air. However, lift and convection depend not only on divergence but also on availability of moisture and the degree of thermal instability. Whether vertical motion over the interior presented in Figure 4-12 produces convection or not will depend inherently upon these 3 factors. For this reason, vertical motion over the interior of South Africa and the southern oceans is again discussed in Chapter 4, once the availability of moisture and the degree of instability have been assessed.

Kinematic Structure

The time-height composite mean vector winds for Bloemfontein and Pretoria are presented in Figures 3-10 for (a) wet and (b) dry troughs respectively. North-easterly winds at Bloemfontein are clearly evident prior to the onset of the surface cold front from -48h to -24h throughout the troposphere in the wet events which suggests southward flow of moist air. At Bloemfontein south-easterly winds occur at the surface while predominantly strong northerly flow with a slight westerly component prevails from 700 hPa to 200 hPa, thereby dominating the middle troposphere circulation from 00h. Meridional departures from which wind vectors are calculated reveal a northerly (negative) flow of -1 to -2.1 from 00h to +12h in wet events compared to the weak < -1 northerly departure of dry events. This more northerly flow in wet events suggests an enhanced flow of moist air from northerly origins, which may be drawn southward on the east limb of the interior low and west limb of a westward displaced SWIac. An increase in the zonal flow and increased vertical wind shear is clearly evident in the dry composite where stronger westerly components dominate the flow.

Wind vector composites for Pretoria show similar results. North-easterly airflow dominates the troposphere prior to the cold front onset, followed by strong northerly flow with a slight westerly component in wet events. Convergent southerly flow dominates the troposphere in the dry composite prior to the onset of the front, followed by weak north-westerlies. At 850 hPa south-westerly winds occur at 00h in dry events with roughly the same magnitude as in wet events. Circulation around a north and eastward displaced SAac promote advection of cool, dry subsiding south-westerly flow in dry events. In wet events quicker and more southerly ridging SAac is responsible for south-easterly surface flow at Bloemfontein. The strong outflow of winds in the mid and upper troposphere in wet events at Pretoria and Bloemfontein and only in dry events at Bloemfontein, may be linked to outflow of air on the front of the large amplitude Rossby wave and the northward displaced sub-tropical jet as they pass over the interior. Thus the weak vertical wind structure over Pretoria during dry events from 00h may mean firstly, that the trough axis with its small amplitude has little influence at more sub-tropical latitudes, compared to its obvious influence on dry troughs at Bloemfontein. Secondly, the upper wind vectors close to D-day at Bloemfontein in dry events are weaker and indicate a lack of northward penetration of the sub-tropical jet stream.

Discussion and Summary

The surface and upper-level synoptic circulation features of wet and dry troughs over South Africa in October and November are summarised and presented schematically in Figure 3-11

Distinct differences are noted in the synoptic circulation features between wet and dry troughs over the interior of South Africa. At the surface, a deepening interior low pressure system of 1477 hPa at D-day, along with low surface temperatures marks the presence of an interior trough and near-surface convergence zone in wet events. The more southerly located SAac with a faster ridging speed highlights an undercutting action as the ridging SAac pushes beneath the surface trough. Circulation around the interior low and ridging SAac systems promotes meridional flow with low-level equatorward flow on the east limb of the high and mid-level poleward flow on the east limb of the interior low.

In dry events, northward and eastward intrusion of the SAac over the western subcontinent is one of the major causes for the dry troughs, which has been noted by Hofmeyer and Gouws (1964), Cressman and Helmick (1989) and Matarira and Jury (1992) in Zimbabwe for similar cases. Upper westerly winds over South Africa are rather dry since the associated air originates in anticyclones of the sub-tropical belt or actively subsides on the eastern flanks of these anticyclones as they move over the country. The northward and eastward displaced SAac over the interior actively erodes the interior low. The SAac appears to stagnate over the interior in dry events and is responsible for protracted periods of dry weather over summer rainfall areas.

A deep westward tilted trough is common in wet events. The westward tilt indicates a mature baroclinic frontal system which means that the divergence profile is steeply sloped, an idea supported by Garratt (1988), and Hanstrum et al (1990a, 1990b). The westward tilt of the upper-level trough in dry events is not clear and, the geopotential height structure suggests a more vertical alignment of the upper and surface trough, which implies that systems are moving toward a state of decay (Hanstrum et al 1990a). It was noted that dry troughs pass eastward

8.8 m s^{-1} faster than wet troughs, since the systems are governed by a shorter wavelength (3.5° longitude), a shorter amplitude (6.3° latitude) and a faster zonal wind speed of (5 m s^{-1}) at D-day. In the wet event an increase in the 300 hPa wave amplitude by 4.5° latitude and a slowing down of the phase speed by 3 m s^{-1} from -24h to 00h shows that the trough is maturing. In the dry events the converse occurs where the upper-level trough gains in speed by 5 m s^{-1} and only a small increase (0.8°) latitude occurs in the amplitude of the upper-level wave. It is worth noting that in wet events the surface high pressure system has a higher wave speed than the upper-level wave. This may imply an increase in baroclinicity, anticyclonic disruption and the formation of a cold pool whereas in dry events the wave speed remains more or less constant with height.

In dry events (ref Figure 3-11) at -24h and 00h indicates curvature is strongest south of South Africa (-35 10^{-6} s^{-1}) where low pressure systems are maturing in the westerly wind belt, a point supported by Hofmeyer and Gouws (1964), Tucker (1979) and Taljaard (1986b). Surface and upper-level geopotentials show below normal values over 40° S and 25° E, indicating more intense low pressure systems in the middle latitudes, which imply stronger than normal westerlies. Zonal flow is enhanced over the southern interior of South Africa in the dry events and consequently the sub-tropical low pressure systems decay. Negative pressure anomalies south of South Africa in the latitude belt 35° - 40° S are not uncommon in dry events and similar values have been observed in other studies of dry events, (Hofmeyer and Gouws 1964, Taljaard 1986b). A large meridional difference between the anticyclonic vorticity over the interior of South Africa and cyclonic vorticity to the south exists, and a north-west to south-east alignment of the vorticity lines is noted.

In wet events cyclonic vorticity at 500 hPa is at a maximum of -10 10^{-6} s^{-1} over the south-western interior of South Africa at 30° S and 20° E (a consequence of the westward tilted trough) with weak anticyclonic vorticity over the interior north of 25° S. The surface trough and weak north-south shear in the vorticity field (+20 10^{-6} s^{-1}) are more conducive to meridional flow in wet cases. The wet-dry relative vorticity field shows strong anticyclonic departures centred at 40° S (+40 10^{-6} s^{-1}) and, cyclonic rotation over the central interior (-20 10^{-6} s^{-1}). The north-south vorticity structure represents a negative - positive dipole in wet events and implies jet stream splitting.

The north-south vorticity pattern along with the negative - positive dipole structure evident in the surface and 500 hPa geopotential height wet-dry field constitute the most important difference noted between wet and dry troughs in this chapter. The strong north-westerly winds in the upper-troposphere from 00h at Pretoria and Bloemfontein in wet events at 200 hPa, wet-dry 500 hPa geopotential structure and, wet-dry vorticity field show that the jet stream is diffluent in wet events, and meanders northward into the sub-tropics (indicating cyclonic curvature through a trough which is displaced further northward than usual) and, southward in the mid-latitudes (indicating anticyclonic curvature) in the mid-latitudes. Upper-level divergence and lift in wet cases highlights synoptic forcing as a major ingredient. The weak synoptic forcing through the divergence fields in dry events is confirmed through weak vertical ascent on D-day.

Vector winds for wet events at Pretoria and Bloemfontein reveal light north-easterly winds prior to D-day throughout the troposphere. At 700 hPa (the level of greatest moisture potential) north-easterly winds dominate from -48h to -24h whereas in the dry events at the same time and level for both stations show south-easterly flow. From 00h the wet and dry composite for Bloemfontein show dominant north-westerly winds throughout the troposphere which is stronger and more northerly in wet events. At Pretoria wet events show a similar dominant north-westerly flow from D-day throughout the troposphere, while the dry wind vector composite shows almost non-existent north-westerly flow from 00h throughout the troposphere suggesting that no trough penetration has occurred. Upper-level winds occurring on the front of an eastward moving upper-level trough along with a northward displaced jet stream may be responsible for the late north-westerly burst at Pretoria and Bloemfontein in the upper troposphere in wet events. Since the outburst of north-westerly air occurs over Bloemfontein and Pretoria in wet events after the day of maximum rainfall, it is unlikely that any moisture is advected southwards within this flow. Rather the burst can be viewed as a "kinematic trigger" behind the convection. Emphasis is placed on the early stages prior to D-day where light north-easterly winds in wet events near to 700 hPa may be responsible for the advection of moisture into the interior of South Africa such that when an eastward moving trough along with its associated steep divergence profile promotes lift and convection.

The upper-level flow field is a vital determinant of rainfall. It appears that the more pronounced cyclonic curvature over the interior and anticyclonic curvature to the south of South Africa, along with upper-level divergence, the greater is the potential for rainfall. However, the prevailing kinematic fields alone are not sufficient to produce rainfall and much depends on moisture fluxes and instability.

The results of Chapter 3 are briefly summarised in Table 3-2 where the important differences between wet and dry troughs are noted.

Table 3-2 Summary of the synoptic circulation characteristics of wet and dry troughs.

SYNOPTIC STRUCTURE **Surface Trough**	WET		DRY	
- Speed of SAac (00h)	22.6 ms^{-1}	SAac pushes quickly behind surface trough	15.2 ms^{-1}	SAac stagnates over the west coast
- Latitude of SAac (00h)	37° S	no intrusion over int.	35° S	north and eastward displaced SAac erodes available moisture
- Pressure of SAac (00h)	1029 hPa		1029 hPa	
- Speed of surface trough				
- (-48h)	15.4 ms^{-1}	slowing down from -48h to 00h by 4.4 ms^{-1}	11.8 ms^{-1}	increasing from -48h to 00h by 3.5 ms^{-1}
- (-24h)	14.0 ms^{-1}		22.8 ms^{-1}	
- (00h)	11.0 ms^{-1}		15.3 ms^{-1}	
- Interior low pressure				
- (-24h)	1490 hPa	deepening int. low	1493 hPa	weakening int. low
- (00h)	1477 hPa		1500 hPa	
- Surface temperature				
- (-24h)	25° C		29° C	
- (00h)	22° C	cloud, no insolation	30° C	no cloud, insolation
- (+24h)	21° C		29° C	
- Circulation structure	dipole, negative-positive	low over the interior high south of SA, promotes meridional flow centred at 25° E	positive-negative	high over the int. and low at 40° S, promotes zonal flow

	WET		DRY	
VORTICITY FIELDS (00h) $(10^{-6}s^{-1})$				
- Cyclonic vorticity	0 - 10	region of cyclonic vorticity stretches across SA west to east from 22° - 35° S	0 - -35	region of cyclonic vorticity stretches southwards from tip of SA from 32 - 42° S
- Cyclonic vorticity max	-10	at 20° E and 30° S	-35	at 25° E and 40° S
- Shear (north-south)	+10 - -10 from 25 - 30° S	weak	+20 - -35 from 25 - 40° S	strong
- Alignment of gradient lines	NW - SE	conducive to northerly flow	WNW - SE	conducive to north westerly flow
DIVERGENCE PROFILES (00h) $(10^{-5}s^{-1})$				
- Slope (steep/gentle)	steep	steep slope implies strong vertical uplift	gentle	gentle slope indicates weak vertical uplift
- Max div/conv profile time	+12h00		00h00	
- Convergence at 700 hPa	-1.3	strong convergence over Bloemfontein	-0.5	weak convergence over Bloemfontein
- Divergence at 200 hPa	+1.5	strong divergence, enhanced by large amplitude wave and diffluent jet stream	+0.3	weak divergence, due to short amplitude wave and zonal flow.

Upper-level trough	WET		DRY	
- Wavelength at 300 hPa dx/dn				
- (-24h)	42° long	wave increases in length by 8° long from -24h to 00h	54° long	wave decreases in length by 8° long from -24h to 00h
- (00h)	50° long		46° long	
- Zonally integrated windspeed		waves propogate down-wind at speeds dependent on their wavelength and mean zonal windspeed		the shorter the wavelength the faster the propogation
- (24h)	15.8 ms^{-1}		18.1 ms^{-1}	
- (00h)	19.3 ms^{-1}		24.3 ms^{-1}	
		increase in wind speed by 3.5 ms^{-1}		increase in wind speed by 6.3 ms^{-1}
- Amplitude at 300 hPa dy/dn				
- (-24h)	10.8° lat	increase in latitude by 4.5° lat	8.2° lat	increase in latitude by 0.8° lat
- (00h)	15.3° lat		9° lat	
- Speed of the upper-level trough				
- (-24h)	11 ms^{-1}	slowing down from -24h to 00h by 2.4 ms^{-1}	12 ms^{-1}	speeding up from -24h to 00h by 5.4 ms^{-1}
- (00h)	8.6 ms^{-1}		17.4 ms^{-1}	
- Increase in trough amplitude prior D-day.	4.5° lat	maturation of frontal systems over interior at 28° S	0.8° lat	maturation of frontal systems south of 35° S
- 500 hPa geopotentials between 15 - 20° S	5840 gpm	low geopotentials imply upper-level trough	5880 gpm	high geopotentials imply anticyclonic conditions
- Baroclinicity	yes	westward tilted trough with height	no	vertical alignment of surface and upper level trough

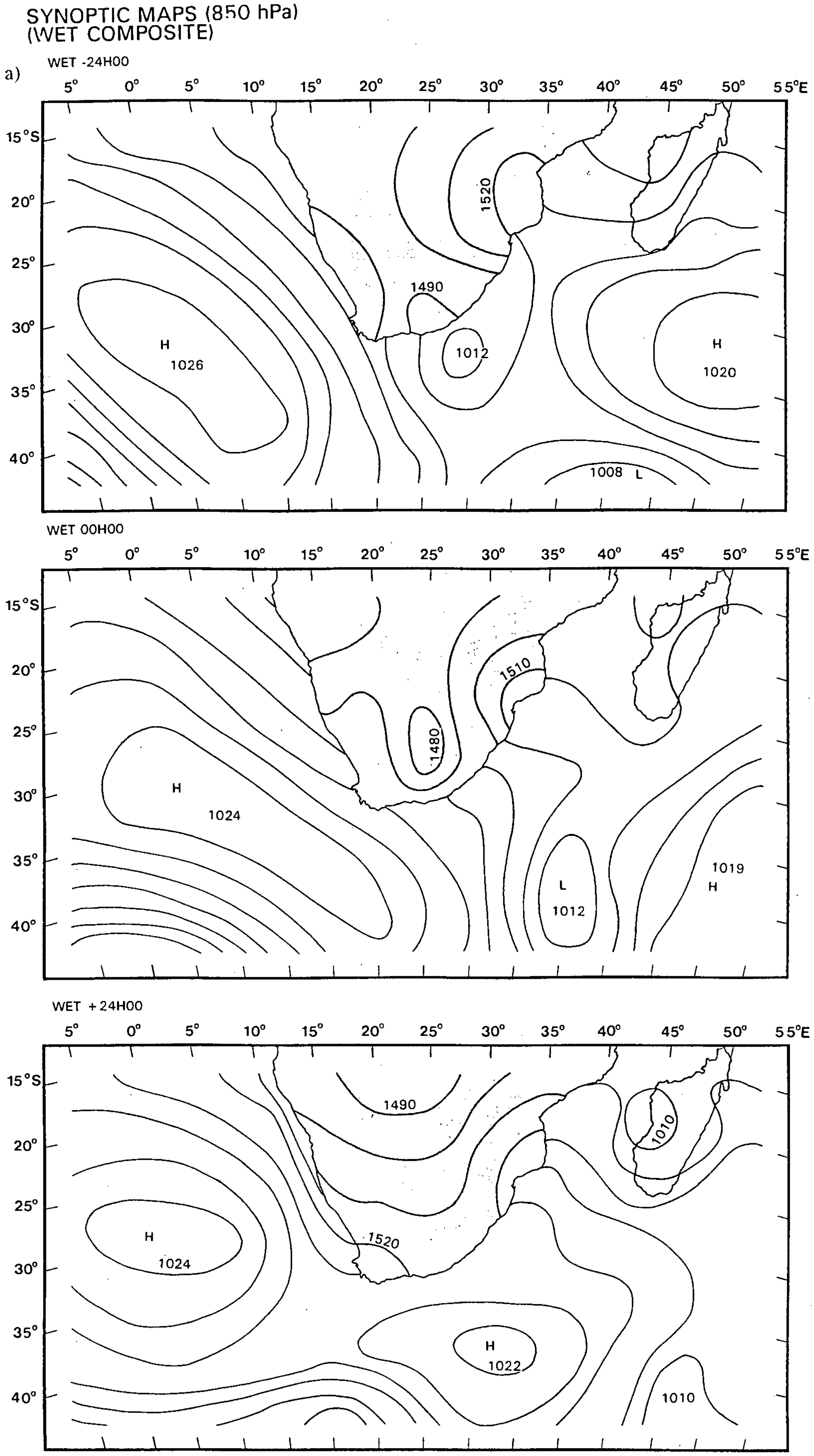
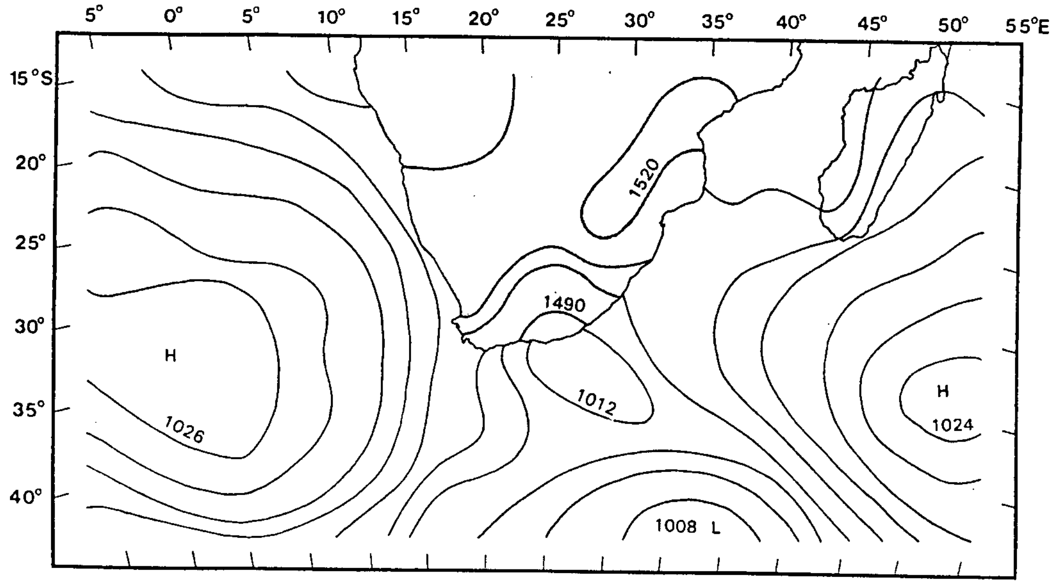


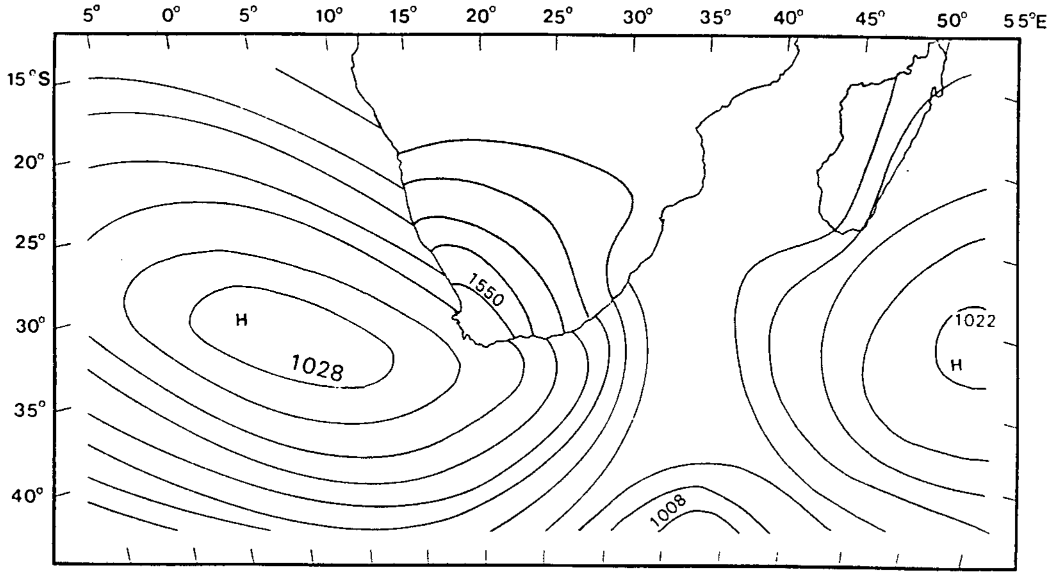
Figure 3-1 The mean surface (850 hPa) synoptic pressure maps contoured on a 5° latitude/longitude grid for -24h, 00h and +24h for (a) wet and (b) dry troughs, over Southern Africa and the southern oceans.

SYNOPTIC MAPS (850 hPa)
(DRY COMPOSITE)

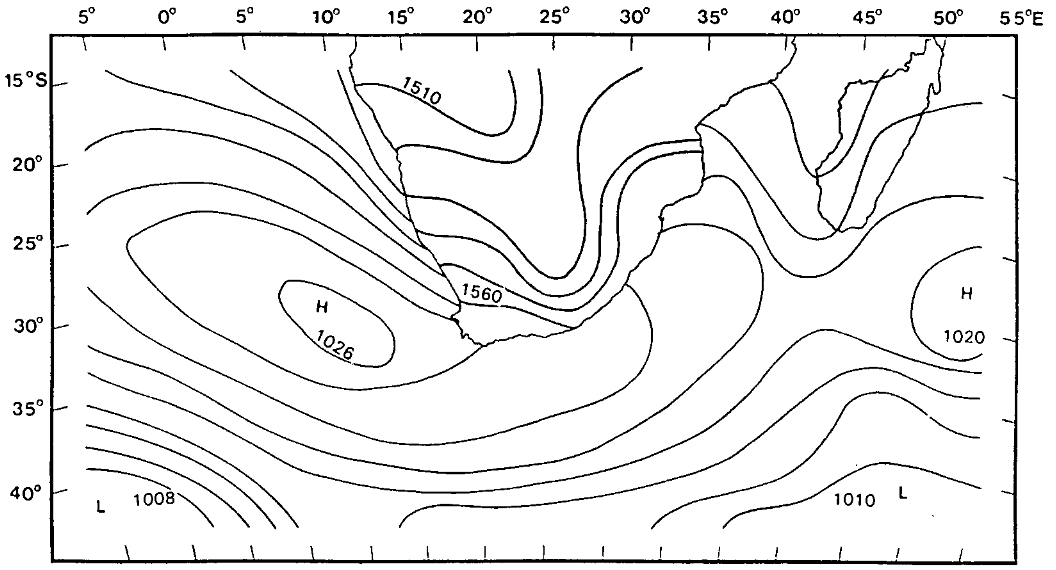
b) DRY -24H00



DRY 00H00



DRY +24H00



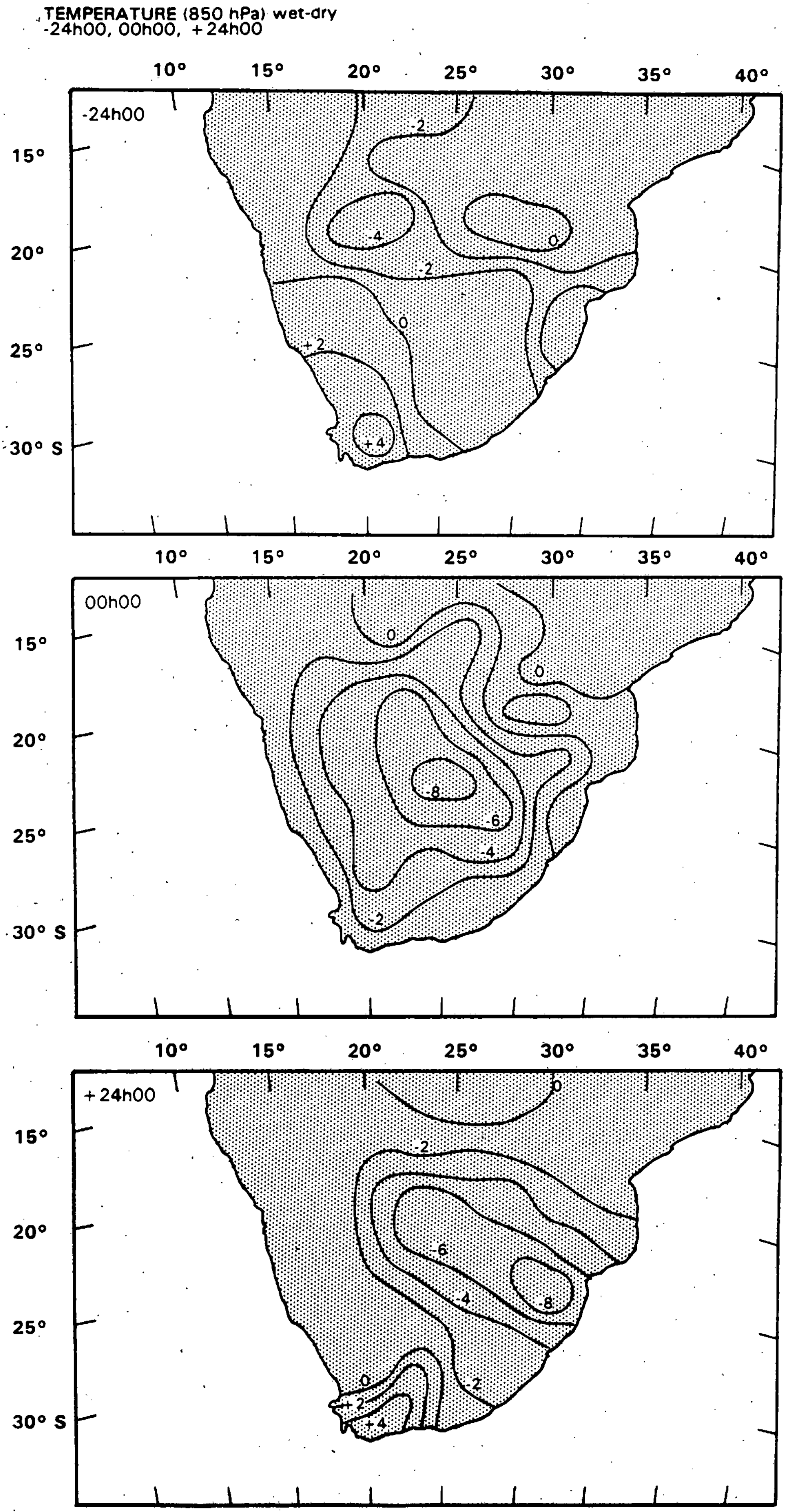


Figure 3-2 Spatial distribution of the surface (850 hPa) wet-dry temperature (° C) variations for -24h, 00h and +24h over Southern Africa.

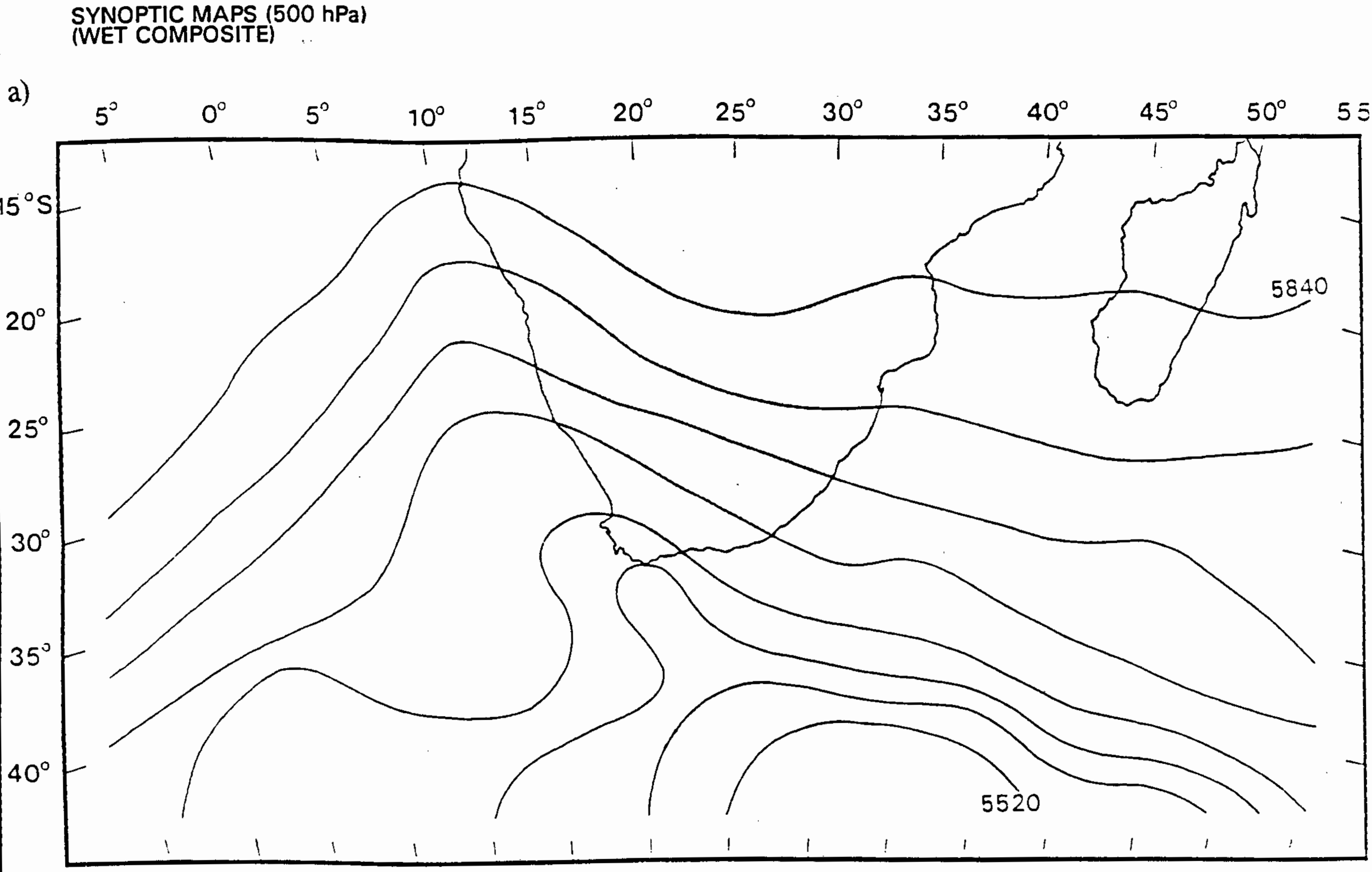
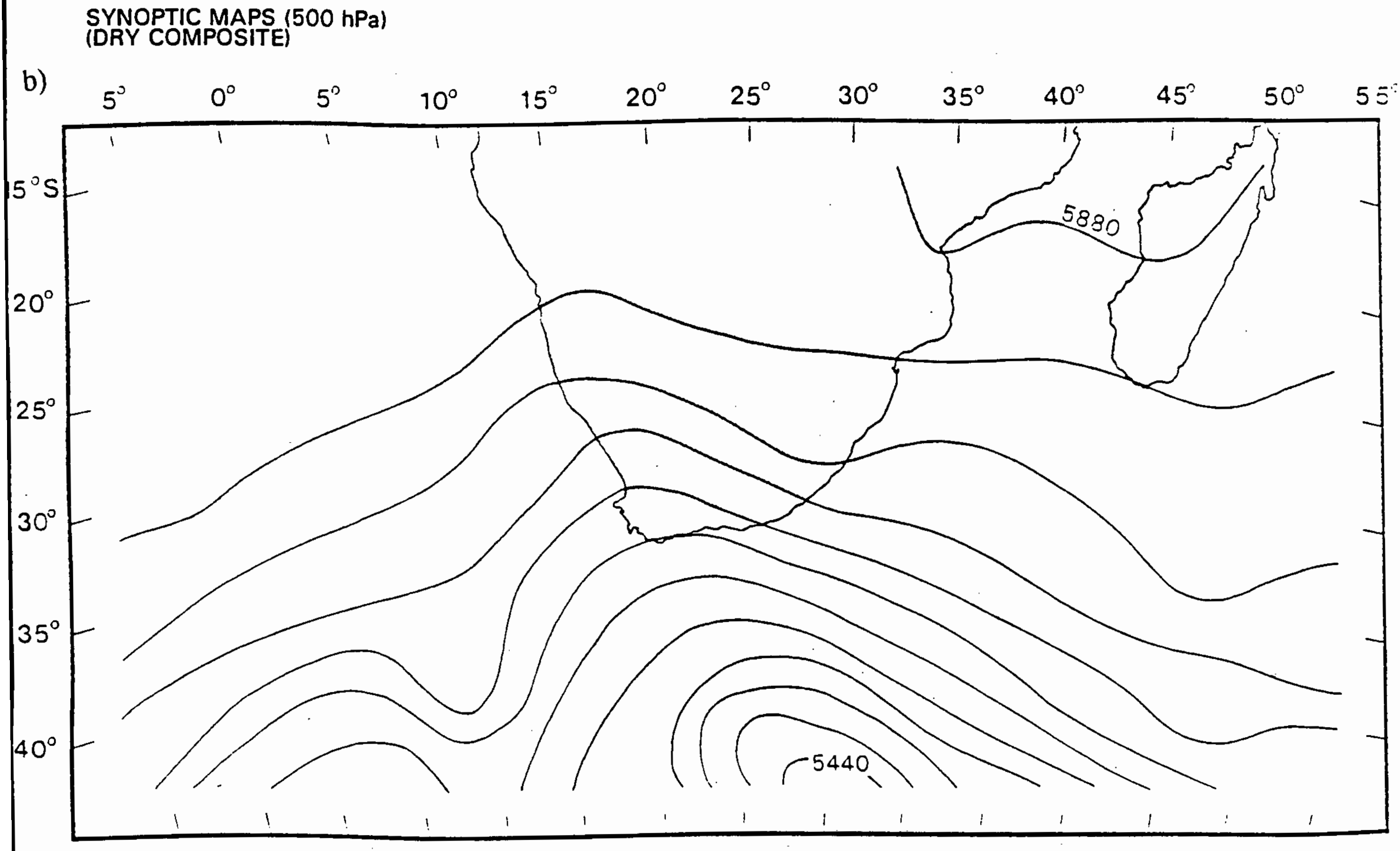


Figure 3-3 The mean upper-level (500 hPa) geopotential height maps contoured (40 gpm interval) on a 5° latitude/longitude grid for D-day for (a) wet and (b) dry troughs, over Southern Africa and the southern oceans.



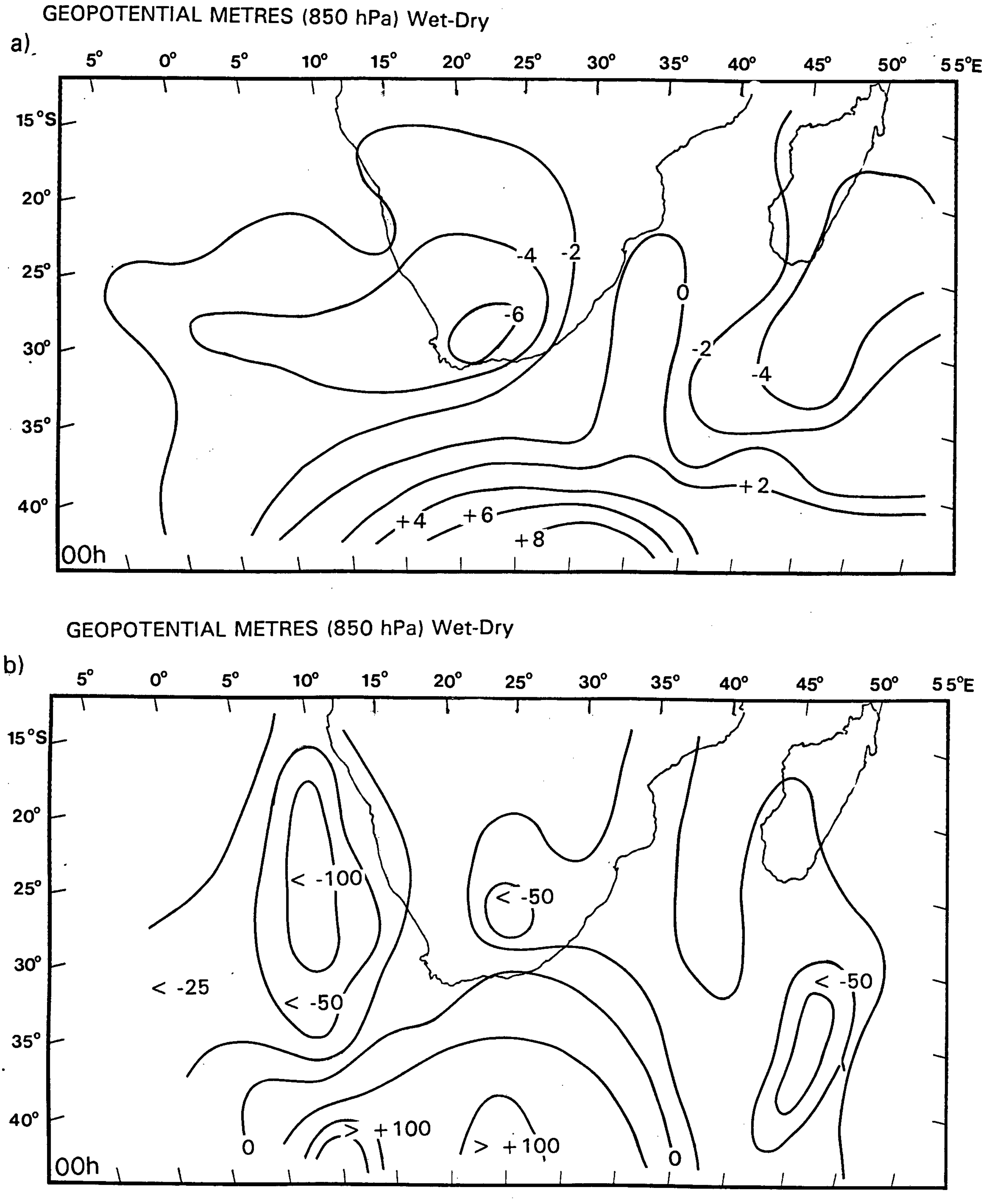


Figure 3-4 Surface (850 hPa) and 500 hPa wet-dry geopotential height variations for D-day over Southern Africa and the southern oceans.

Table 3-1 Individual and mean climatological characteristics determined from surface (850 hPa) and upper-level (500 and 300 hPa) synoptic charts from 6 wet and 6 dry troughs over Southern Africa. (dx/dn and dy/dn mean longitudinal and latitudinal distance (in degrees) respectively).

WET	SOUTH ATLANTIC ANTICYCLONE															WESTERLY WAVE								
DATES	SPEED OF SAAC (ms-1)					LATITUDE OF SAAC					PRESSURE OF SAAC (hPa)					SPEED OF SURFACE TROUGH (ms-1) AT 35? S (850 hPa)					SPEED OF UPPER TROUGH (ms-1) AT 00H (300 hPA)			
	-2	-1	0	1	2	-2	-1	0	1	2	-2	-1	0	1	2	-2	-1	0	1	2	dx/dn	dy/dn	U ms-1	C
9-12 NOV 1987	13.7	13.7	8.3	8.8	-	36.5	41.5	44	43.5	40	1032	1036	1034	1032	1028	19.8	8.3	13.2	-	-	49	12	17	9.0
13-17 NOV 1989	-11.0	8.8	39.0	15.9	-	32	38.5	37	46	36.5	1022	1026	1024	1026	1026	16.5	8.8	2.2	11.0	-	36	20	15	10.4
26-29 OCT 1986	-3.3	17.6	18.7	7.7	-	29	31	40	40	41	1024	1022	1028	1024	1026	22.0	28.6	11.0	15.4	-	51	13	19.3	6.28
3-6 NOV 1986	6.6	-1.1	30.8	11.0	-	36	31	32	35	40	1028	1028	1026	1024	1028	13.2	19.8	14.3	1.1	-	50	12	24.4	16
6-10 NOV 1986	15.4	1.1	7.7		-	33	29	28	33	-	1026	1026	1026	1030	_	18.7	3.3	15.4	14.3	-	55	18	18.6	7.15
8-12 OCT 1988	-5.5	5.5	30.8	-17.6	-	44	37	38	38	39	1032	1032	1034	1034	1030	2.2	15.4	11.0	12.1	-	58	17	21.9	2.6
MEAN	9.3	8.0	22.6	12.2	-	35.1	34.6	36.5	39.3	39.3	1027	1028	1029	1029	1028	15.4	14.0	11.0	10.7	-	49.8	15.3	19.3	8.57
STD DEVIATION	4.8	6.7	13.0	4.3	-	5.1	5	5.7	4.9	1.7	4.1	4.9	4.3	4.4	1.67	7.1	9.1	4.7	5.6	-	7.5	3.4	3.3	4.5
(means for -24h)																					42.2	10.8	15.8	11
																					7.1	3.1	4.0	3.1

DRY	SOUTH ATLANTIC ANTICYCLONE															WESTERLY WAVE								
	SPEED OF SAAC (ms-1)					LATITUDE OF SAAC					PRESSURE OF SAAC (hPa)					SPEED OF SURFACE TROUGH (ms-1) AT 35? S (850 hPa)					SPEED OF UPPER TROUGH (ms-1) AT 00H (300 hPA)			
	-2	-1	0	1	2	-2	-1	0	1	2	-2	-1	0	1	2	-2	-1	0	1	2	dx/dn	dy/dn	U ms-1	C
7-11 NOV 1988	7.7	1.1	4.4	-	-	30	35	35	37	-	1026	1030	1032	1032	-	7.7	25.3	17.1	-	-	45	10	21.7	13.21
21-26 NOV 1989	7.7	17.6	17.6	2.2	-	27	30	37	35	37	1024	1024	1024	1024	1024	11.0	37.4	6.6	16.5	-	40	7	22.5	21.6
7-11 OCT 1989	8.8	11.0	3.3	26.4	-	30	40	35	35	31	1026	1032	1032	1032	1028	-	35.2	15.0	7.7	-	60	12	26.2	15.57
6-8 NOV 1985	5.5	2.2	33.0	25.3	-	30	35	35	45	45	1022	1024	1026	1028	1036	-	22.3	15.6	10.6	-	42	8	23.6	16.87
11-16 OCT 1986	-12.6	6.1	2.2	30.8	-	34	33.5	36.5	31.5	36	1024	1028	1030	1034	1022	14.3	4.1	11.5	8.8	-	51	10	26.3	17.95
4-11 OCT 1989	0.0	13.2	30.8	24.2	-	31	32	29	34	33	1024	1028	1030	1034	1022	14.0	12.6	25.8	9.3	-	40	7	25.3	19.17
MEAN	7.1	8.5	15.2	21.8	-	30.3	34.3	35	36.3	36.4	1025	1028	1029	1030	1027	11.8	22.8	15.3	10.5	-	46.3	9	24.3	17.4
STD DEVIATION	4.1	6.5	14.0	11.2	-	2.3	3.4	2.8	4.6	5.3	1.6	3.2	3.5	3.6	5.4	3.1	12.0	6.4	3.4	-	7.8	2	1.9	2.9
(means for -24h)																					53.7	8.2	18.1	12.0
																					7.0	2.2	2.0	1.5

[-2, -1, 0, +1, +2 means -48h, -24h, 00h (D-day), +24h, +48h]

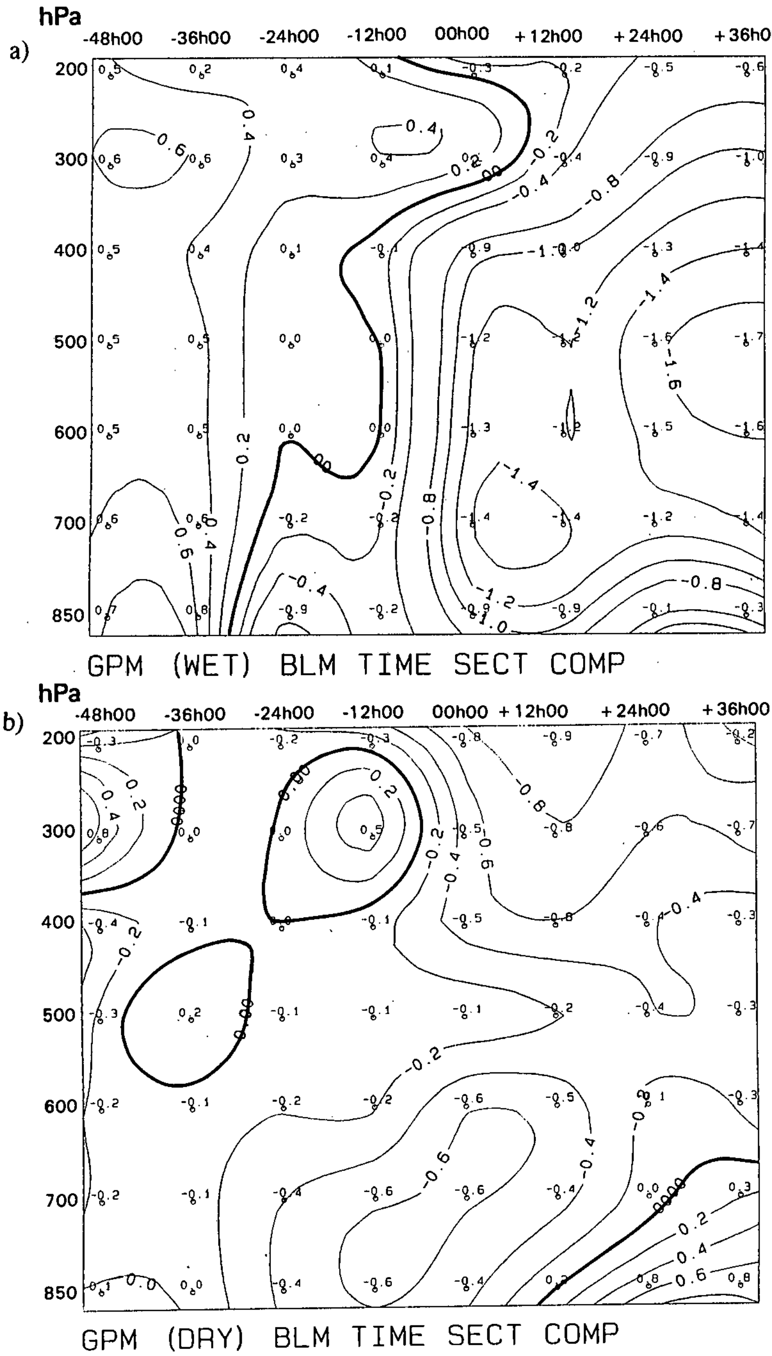


Figure 3-5 Time-height contours of geopotential height departures during the passage of the perturbation over Bloemfontein for (a) wet and (b) dry troughs from -48h to +36h.

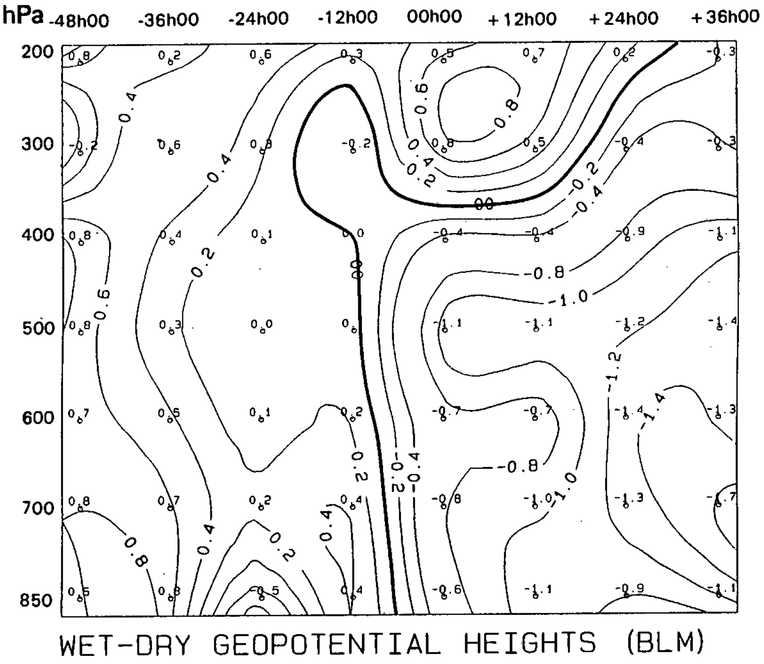


Figure 3-6 Time-height contours of wet-dry geopotential height departures during the passage of the perturbation over Bloemfontein.

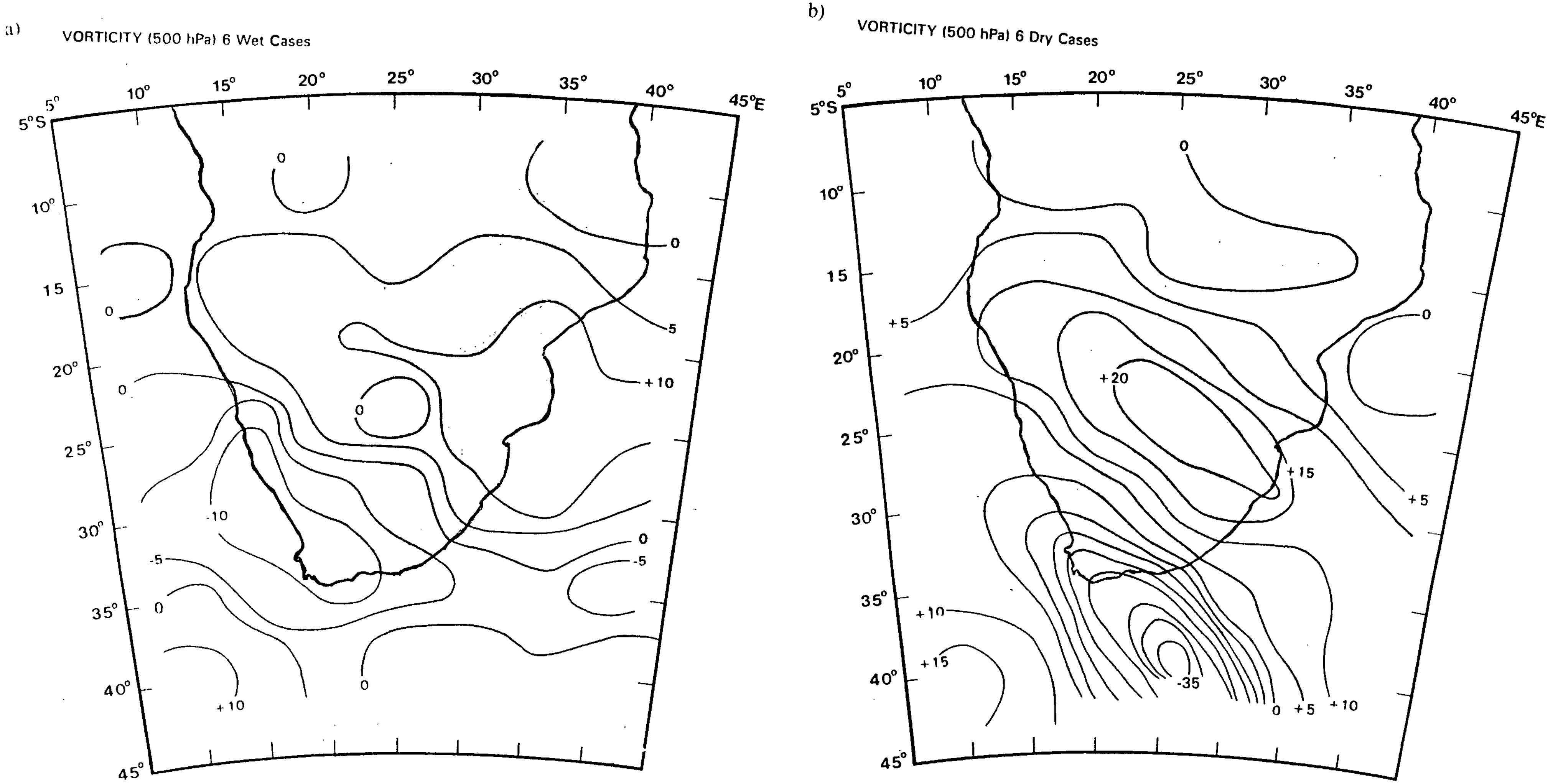


Figure 3-7 Relative vorticity ($10^{-6}s^{-1}$) fields at 500 hPa for (a) wet and (b) dry troughs over Southern Africa, (negative) positive means (cyclonic) anticyclonic vorticity.

VORTICITY (500 hPa) Wet-Dry

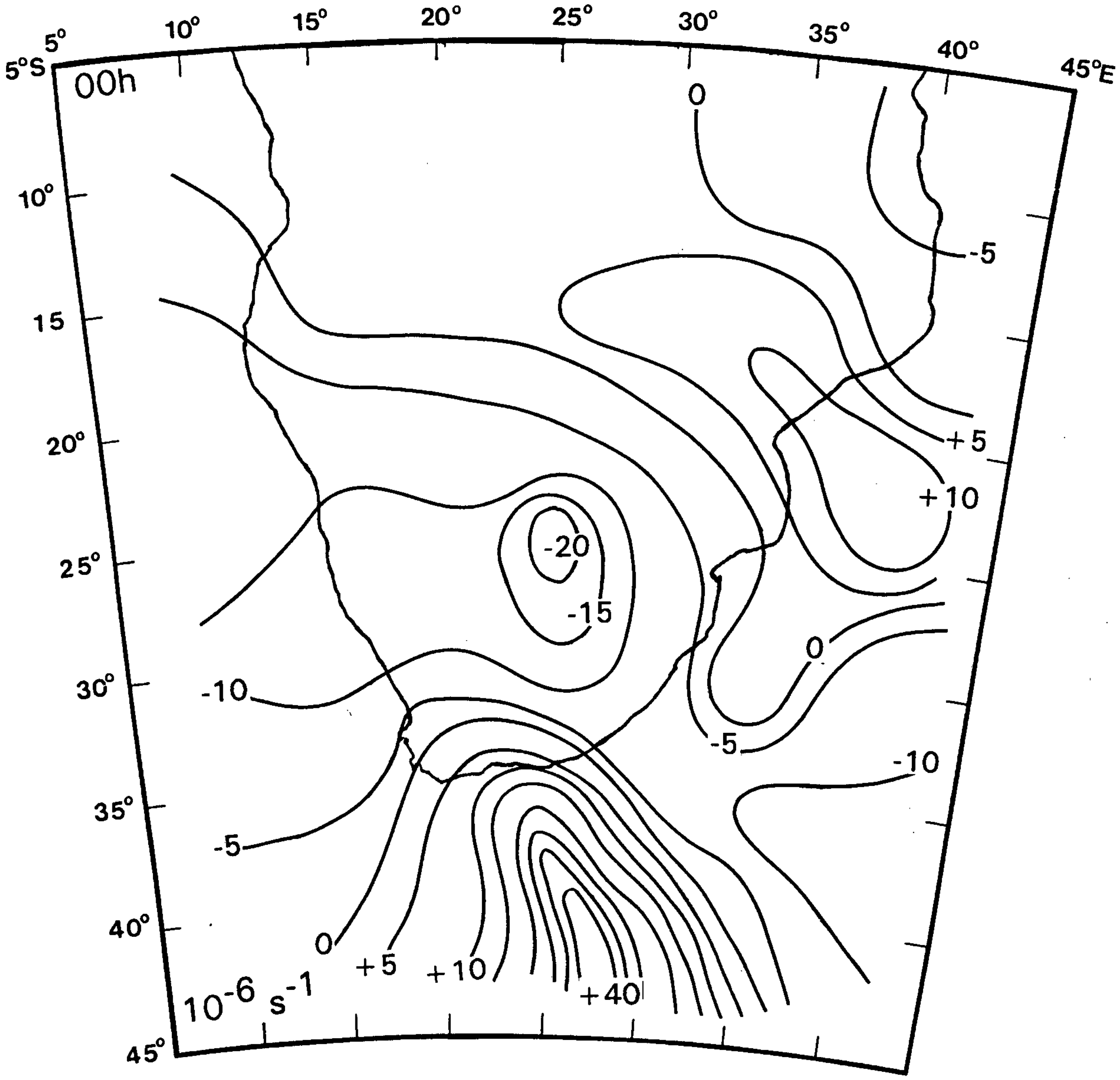


Figure 3-8 Upper-level (500 hPa) wet-dry relative vorticity field ($10^{-6}s^{-1}$) for D-day over Southern Africa..

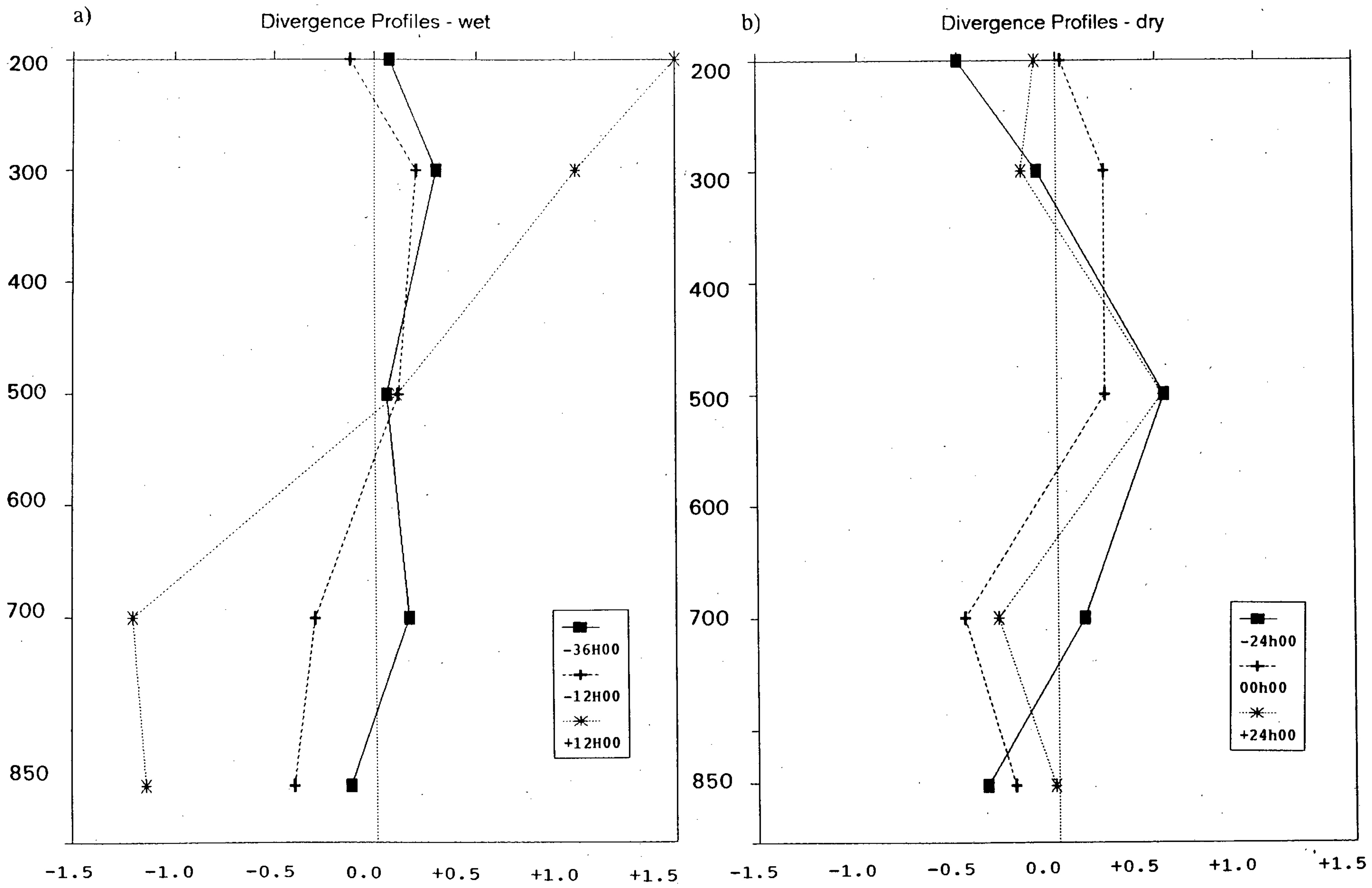


Figure 3-9 Divergence/convergence profiles ($10^{-5}s^{-1}$) for (a) wet and (b) dry troughs for 3 time periods; preceding, during and following the frontal event over Bloemfontein.

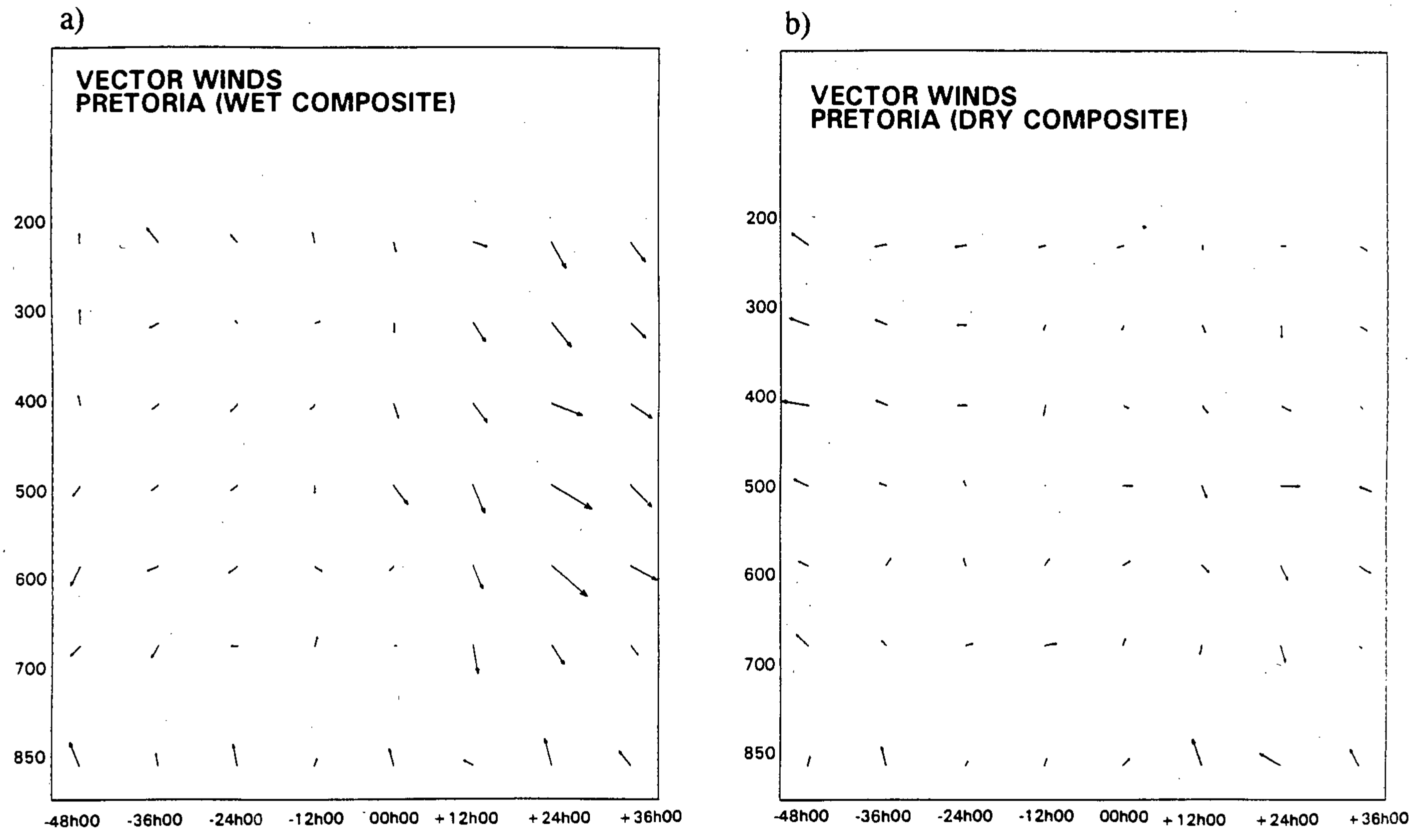
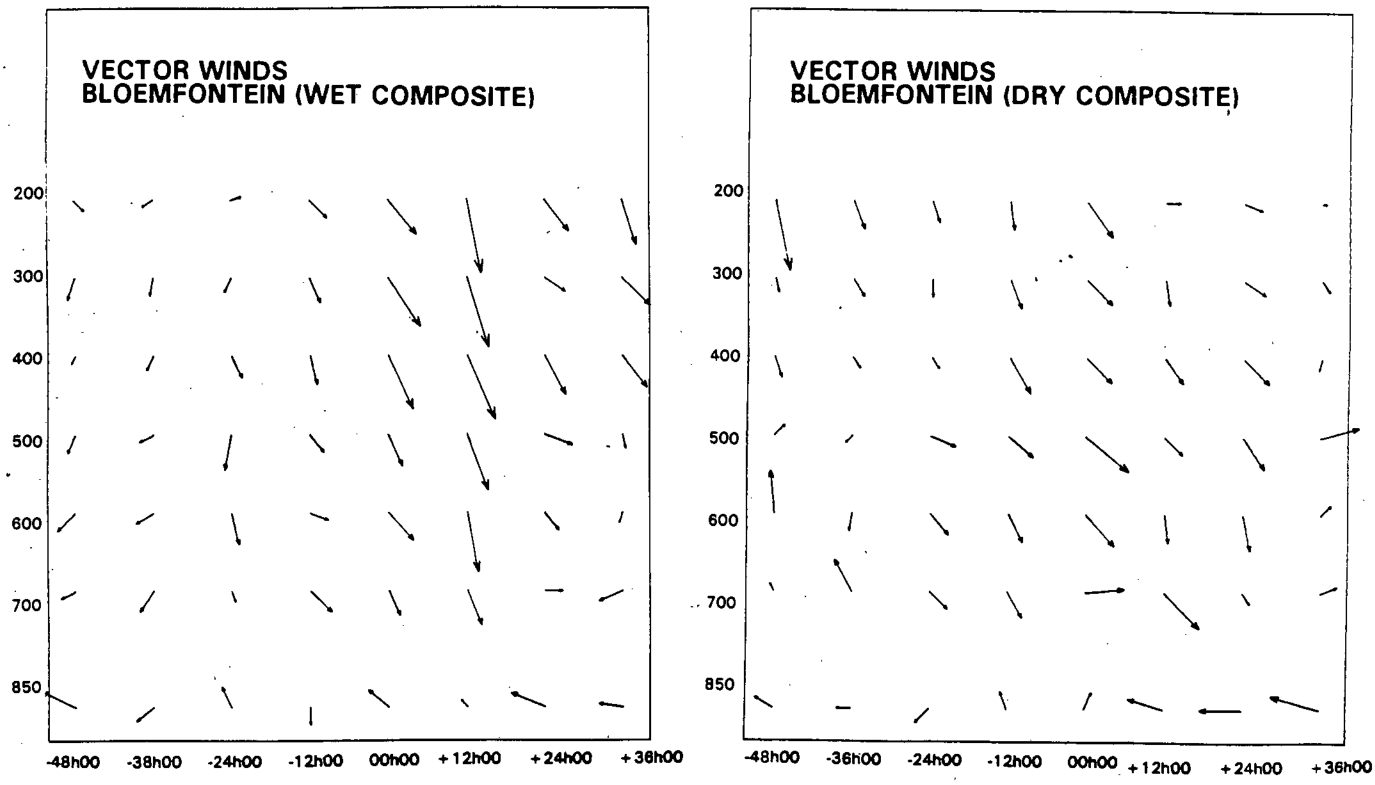


Figure 3-10 Time-height wind vectors (departures) during the passage of the perturbation for (a) wet and (b) dry troughs over Bloemfontein and Pretoria.



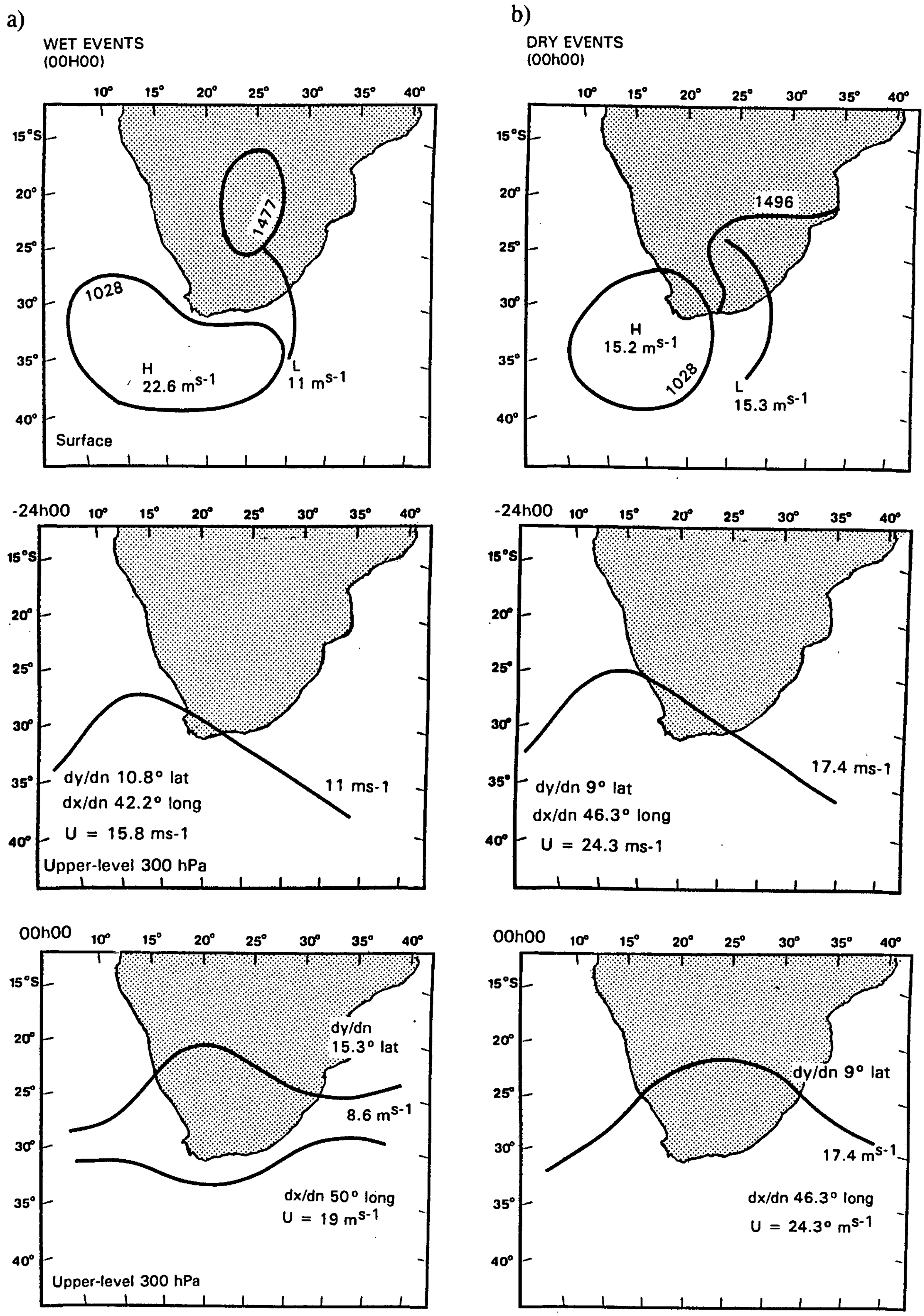


Figure 3-11 Summary of the surface and upper-level (300 hPa) synoptic circulation features for (a) wet and (b) dry troughs. At 00h the surface and (850 hPa) and 300 hPa levels are represented, while at -24h only the 300 hPa level is shown.

CHAPTER 4

THE AVAILABILITY AND SUPPLY OF MOISTURE AND THERMODYNAMIC INSTABILITY

A possible distinction between wet and dry events is the availability and supply of moisture and, the degree of instability. Chapter 3 indicated that a vital determinant for precipitation in both wet and dry troughs depends upon the structure and dynamics supporting vertical motion. However, unless there is a supply of moisture and some degree of thermal instability, the kinematic trigger will alone not be able to generate convection.

The intention of this chapter is to discover the supply and availability of moisture both in the pre-convective environment and at the time of trough passage and, secondly, the contribution of thermal instability

The aforementioned synoptic circulation characteristics suggest that the deep interior low acts as a "sink" to which moisture of a northerly source may be drawn. Secondly, wet events display an increase in amplitude and northward penetration of the sub-tropical trough into the equatorial regions suggesting a tropical-temperate interaction. Thirdly, circulation around a negative - positive dipole enhances the development of a Hadley cell and the poleward flow of moist air in mid-tropospheric levels. North-easterly flow at Pretoria and Bloemfontein advect moisture in wet events. In comparison to wet events an interior low does not develop in dry events as a dry subsiding air is responsible for its erosion. The small amplitude wave implies decreased meridional flow. Predominantly southerly flow at Pretoria and Bloemfontein are not conducive to the advection of moisture in the dry events.

The following section focuses on the temporal vertical structure and spatial distribution of water content in the atmosphere over the interior of South Africa from -48h to +36h.

The Supply and Availability of Moisture

Meteosat imagery for the wet event of the 13 - 17 November 1989 are presented in Figure 4-1 and show the southward flow of water vapour as a westerly wave passes across the interior of South Africa. The passage of the trough is clearly visible from -48h by the dry slot of air which marks the rear of the cold front. At -24h the cold front is situated just off the west coast and is beginning to take on a hook-shape characteristic of cold fronts. By the 15th, D-day the frontal event has developed and its influence on the southward flow of moisture from north of 15° S is evident. On the 16th the cloud band covers the entire eastern subcontinent as moisture is drawn from a tropical source. At the same time the dry slot of air marking the rear of the trough appears to fold in on itself as decay of the system begins. By the 17th the system has moved away from the subcontinent and the cloud band is decreasing.

Dewpoint and dewpoint depression

A spatial composite of surface dewpoint differences between wet and dry troughs over South Africa at 850 hPa for -24h, 00h and +24h is represented in Figure 4-2. High positive departures are evident throughout the sequence with maximum differences at 00h of 12°C over the central interior. A positive difference of 10°C and 8°C at -24h between 20° - 25° E and 15° - 25° S marks the presence of the interior low and the presence of moisture over the interior. The positive value at 22° E and 15° S of 6° - 8°C at -24h and 00h represent a surface low over Angola from which the interior trough appears to have its origin Taljaard (1990).

While, Figure 4-2 represents the spatial distribution of moisture at the surface, the dewpoint time-height composite of Figure 4-3 shows the advance of moisture and accompanying structural changes in the troposphere over Bloemfontein for (a) wet and (b) dry troughs. Above-normal dewpoint departures dominate the troposphere between -48h to +36h with maximum departures (> +1.0) occurring between -48h to -24h, below 700 hPa and above 500 hPa, and again at 00h the time of trough passage below 500 hPa. These high dewpoint values correspond firstly, with north-easterly flow at Pretoria and Bloemfontein, and secondly, with increased mid-tropospheric geopotential height and warmer temperatures which are associated with middle tropospheric latent heat release. Positive departures decrease appreciably from +36h in the wet events once the trough has passed Bloemfontein.

The dry dewpoint composite reveals appreciably lower values especially between -24h and +12h, a crucial time when moist airflow of northerly origin is expected but does not occur. At this time dry winds with a north-west and southerly component dominate the flow between -24h and +12h at Bloemfontein (ref Figure 3-10). Behind the surface cold front departures reach a minimum below 600 hPa at +12h the time of trough passage over Bloemfontein.

The wet-dry dewpoint variations are presented in Figure 4-4. Clear differences with a departure > +1.0 occur throughout the troposphere from -48h to -12h consistent with the presence of a prefrontal moist air stream in the wet events. Further, a distinct variation characterised by departures > +1.0 occurs below 500 hPa between 00h and +12h at the time of the passage of the trough.

Dewpoint depression is a parameter that effectively combines temperature and dewpoint and is a measure of saturation. Figure 4-5 represents the time-height composites of dewpoint depression for wet and dry troughs. The more negative the standard departure the closer the temperature and dewpoint lapse rates and the more moist the atmosphere. In wet events maximum saturation extends from 850 to 500 hPa at +12h with highest departures recorded at 700 hPa of -1.2 coinciding with convective activity. The converse holds for dry events where positive departures of +1.2 occur in the 850 to 700 hPa layer at +12h and from -24h to +12h at the surface.

The wet-dry dewpoint depression composite (Figure 4-6) shows a significantly large difference > -2.0 between 00h and +12h between wet and dry events This large difference marks the region of saturation between 400 hPa and 850 hPa in the wet events with respect to the dry events.

Dewpoint temperature is a good indicator of the moisture content of the atmosphere, which in this study has identified the presence of a prefrontal moist air stream in the wet events. Dewpoint depression on the other hand has indicated the location of saturation below 500 hPa and precipitation at 00h. Another measure of the amount of water vapour present in a certain quantity of air, is the mixing ratio which may be defined as the mass of water vapour to the mass of dry air.

Mixing ratio

The mixing ratio is graphically represented in Figure 4-7 for the 700 hPa and 500 hPa layers for (a) wet and (b) dry troughs for all upper air stations, excluding Harare, where 12 hourly data is not available. At all stations for the 700 hPa and 500 hPa levels the mean wet events exhibit greater mixing ratio values in comparison to the mean dry curves. The differences between wet curves and dry curves are far greater at 700 hPa than 500 hPa, since more moisture is available in lower levels. Diurnal variations are evident at all stations. A large prefrontal peak at 700 hPa and 500 hPa over Durban is evident in the wet trace. A similar peak at Durban relative to other stations was noted by Kelbe (1988), prior to the onset of the surface disturbance. Kelbe (1988) suggested that these prefrontal peaks are a consequence of diurnal variations. However, the proximity of Durban to the Indian Ocean may lead to an intense transfer of water vapour advected from the ocean onto the coastline from a rapidly ridging SAac and onshore flow from a displaced SWIac to the atmosphere. Mixing ratio maxima occur at Pretoria, Bloemfontein and Pietersburg between 00h and +12h at 700 hPa whilst Upington and Alexander Bay 480 km and 809 km further west experience this maxima at -24h, a consequence of the eastward moving system. Less variation is noted at 500 hPa as expected, since moisture is more prevalent in the lower levels. A systematic decline in moisture occurs in the post-trough stages at most stations.

The results from the time-height composites of dewpoint, dewpoint depression and mixing ratio confirm the presence of a prefrontal moist environment, saturation of the atmosphere at D-day and, the southward advection of moist tropical air into the interior of South Africa in the wet events. The mixing ratio maxima $> 6\ g\ kg^{-1}$ at Pretoria and Pietersburg and at westerly stations $> 5\ g\ kg^{-1}$ at Upington and $> 3\ g\ kg^{-1}$ at Alexander Bay, between 00h and +12h clearly indicates prefrontal moisture associated with the passage of the trough across the interior of South Africa in the wet events and, the intrusion of an equatorial air mass. In comparison the dry events are characterised by a lack of prefrontal moisture and little saturation of the atmosphere is occurring.

Thermodynamic Structure

Temperature structure

Temperature, pressure, density is related via equation of state ($P/\rho = RT$) and is the basic parameter in any thermodynamic equation. The time-height composite of temperature will be discussed below with static energy and equivalent potential temperature.

Temperature departures calculated from the long-term mean are presented in Figure 4-8 for (a) Pretoria and (b) Bloemfontein with respect to wet and dry troughs using a consistent time scale, where D-day represents the surface front overlying Bloemfontein. The temperature composite for wet and dry troughs at Bloemfontein shows negative departures below 600 hPa which in dry events extend into the upper atmosphere behind the cold front. The wet temperature structure is considerably more negative in the lower levels from 00h onwards. In the wet troughs above normal departures in the mid-troposphere overlay low-tropospheric negative values, while dry events experience strengthened negative departures in the mid-troposphere after 00h. It is possible that these greater positive values in the 500 - 400 hPa layer in wet events may be due to latent heat release generated within convective bands. The wet temperature composite for Pretoria is similar to the Bloemfontein composite, where positive anomalies dominate the mid-troposphere above 500 hPa, reaching a maximum positive departure of +1.2 at -12h at

300 hPa. Underlying this maximum positive departure, negative anomalies associated with the eastward passage of the front dominate the section below 700 hPa. Above 200 hPa negative departures dominate from -48h to 00h at Bloemfontein and from -48h to +36h at Pretoria owing to radiative cooling. In comparison the dry Pretoria structure shows weak positive departures in the mid-troposphere prior to the front followed by negative values throughout the troposphere. The temperature anomaly structure of the wet events for both Pretoria and Bloemfontein reveal a similar 3-level structure described by Harangozo (1989) for tropical systems with warming above 500 hPa and cooling below 600 hPa due to rainfall and above 200 hPa. Mid-tropospheric warming prior to onset of the front, together with increased geopotential height in the upper-troposphere, are consistent with latent heat release in the middle troposphere due to enhanced convective activity in wet events.

The time-height wet-dry temperature differences at Bloemfontein and Pretoria are presented in Figure 4-9. The 3-level temperature structure of wet events is clearly visible at Pretoria, between -12h and +12h, a negative departure difference of > -1.0 occurs below 600 hPa, a positive difference of > +1.0 occurs between 600 to 300 hPa and a negative difference above 100 hPa of > -1.0. A similar 3-level structure is evident in the wet-dry Bloemfontein composite, although anomalies between wet and dry events are not as large as in Pretoria. The important differences noted in the temperature structure indicate that tropical air is in circulation in wet events, and that warming in the 500 hPa to 300 hPa layer is due to latent heat release. The large anomalies occurring throughout the troposphere at Pretoria compared to Bloemfontein is an indication that the trough axis in the dry events have less northward penetration.

Dry and total static energy

Static energy is a measure of atmospheric stability which is often used to refer to convective potential. Temperature and moisture are inherent quantities of this measurement. Stability is generally defined as the condition of a body or system which responds to a disturbance by enhancement or suppression. The use of static energy in convective research has proved successful by Harrison (1986) and Kelbe (1988) in Southern Africa. Dry (CPT + GZ) static energy and total (CPT + GZ + LQ) static energy are used in this study to indicate changes of instability as troughs pass eastward.

Dry static energy composites for the 500 and 700 hPa levels are presented in Figure 4-10 for (a) wet and (b) dry troughs for Pretoria, Bloemfontein and Port Elizabeth. Pretoria and Bloemfontein show diurnal variations over and above the time filtered data at both 700 hPa and 500 hPa which is notably obvious in dry events over Bloemfontein at 700 hPa. The mean dry trough curve lies above the mean wet trough curve for the two interior stations at 700 hPa and is probably due to higher surface temperatures from lack of cloud and above normal geopotential height associated with anticyclonic conditions. The converse is true for the 500 hPa level, where the mean wet static energy curve lies above the mean dry event curve for Pretoria and to a lesser extent at Bloemfontein. In the case of Pretoria the greater wet static energy curves are associated with above normal temperatures and geopotential heights in the mid-troposphere and suggest the release of latent heat. Clear systematic changes of the eastward moving trough are seen at both the 700 hPa and 500 hPa levels throughout both wet and dry events, but are particularly clear at Port Elizabeth due to close proximity of the low system. At Port Elizabeth both the 700 hPa and 500 hPa level wet curves exhibit greater values than the dry curves. A possible reason for this occurrence in wet events may be the southward displaced and faster ridging SAac along with the associated mid-tropospheric temperature increase which would lead to high static energy values. The absolute minima of dry static energy for wet and dry troughs at 700 hPa over Pretoria is nearer +36h while the Port Elizabeth minimum occurs at 00h, this lack of accord shows that the trough over the interior is lagging its counterpart along the coast. Lagging of the surface trough over the interior is similar to results of Kelbe (1988) for two extreme convective cases which exhibit similar general features of westerly perturbations over north eastern regions of South Africa.

Moist static energy time-height composites are represented in Figure 4-11 for 3 stations in a north-south alignment, namely Pretoria, Bloemfontein and Port Elizabeth for (a) wet troughs and (b) dry troughs. Since the LQ term is the dominant term in the total static energy equation positive departures within the 850 - 600 hPa layer imply atmospheric instability while a low LQ would be responsible for negative departures implying stability. Low CPT and GZ values along with a high moisture content below 600 hPa (i.e. large positive departures) indicate atmospheric instability, while in the middle troposphere from 500 - 200 hPa where LQ values are low, one would expect in an unstable environment high temperature and geopotential departures associated with mid-troposphere warming and latent heat release (i.e. small positive departures). In an unstable atmospheric column, a typical total static energy curve would be characterised by large values close to the surface which decrease with height, such that a steep decrease of slope with height would be expected in the wet events. A decline with height of below-normal departures in dry events would indicate a more stable environment.

Moist static energy departures in wet events show large positive values at all three stations prior to onset of the cold front with the greatest positive departures occurring below 600 hPa (+0.8) at -24h. Negative values after 00h are evident at Pretoria, Bloemfontein and Port Elizabeth below 600 hPa typical of cold air advection behind the trough. Vertical gradients of total static energy in wet events at Pretoria decrease with height, with positive departures occurring below 600 hPa (+1.0) between -36h and -24h suggesting instability in the prefrontal moist air stream, followed by decreasing positive departures in the middle troposphere which are associated with mid-tropospheric warming and latent heat release. Similar vertical gradients of atmospheric instability occur at Bloemfontein and Port Elizabeth in wet events with high positive departures between 850 - 600 hPa whereafter departures decline with height from -48h to 00h. From 00h the vertical gradients appear to collapse, and negative departures dominate the lower troposphere below 600 hPa at all 3 stations suggesting a moisture decline. Negative departures above 600 hPa overlie these regions of low moisture at all 3 stations, but with greater values at Pretoria from 00h suggesting mid-tropospheric warming. Pretoria experiences the greatest instability < +1.0 from -24h. Possible reasons for this greater instability at Pretoria is more sub-tropical latitude along with northward penetration of the sub-tropical troughs into the tropical air mass.

The total static energy composites for dry events at Bloemfontein, Pretoria and Port Elizabeth (Figure 4.11 b) are significantly different to their wet counterparts. Weak negative values dominate the Pretoria trace with height, prior to 00h with weak positive values occurring below 600 hPa from 00h suggesting a stable environment. Gentle negative declining vertical gradients throughout the troposphere prior to 00h (from -1.1 at 850 hPa to -0.2 at 300 hPa) characterise dry events, while no clear vertical patterns exists for D-day. Total static energy across Bloemfontein shows weak instability in the middle troposphere before D-day, whereafter strong cold air advection occurs below 600 hPa and above 400 hPa indicating a move toward stability.

The Port Elizabeth wet and dry composites are most similar largely due to their close proximity to the trough axis, and the absence of moist tropical air at Port Elizabeth. The trough passage is clear on both wet and dry composites, where positive departures occur from -48h to -12h throughout the troposphere followed by negative values from -12h to +36h as the trough moves east. The dry composite for Port Elizabeth is weak with small vertical gradients, the departure at 700 hPa being +0.3 and at 300 hPa, +0.2.

The weak total static energy structure over Bloemfontein in the dry events along with this negative static energy structure over Pretoria prior to D-day suggests that lack of prefrontal moisture has a direct effect on the degree of air mass instability. The negative structure over Pretoria also means there is little tropical activity and less penetration of the westerly wave into sub-tropical regions.

Equivalent potential temperature

Equivalent potential temperature (EPt) is considered analogous to dry static energy if there is negligible dissipation by kinetic energy (Betts 1974, Bolton 1980). EPt is another way to combine temperature and relative humidity into one variable. In short, the vertical profile of EPt is indicative of suppressed or enhanced convection (Steyn 1988). Since the bulk of atmospheric moisture is concentrated close to the 700 hPa level, measures of EPt are conferred from traces below 500 hPa. Similarly to static energy the vertical gradient of EPt indicates tropospheric stability. Figure 4-12 shows vertical profiles of wet and dry EPt at Bloemfontein for -24h, 00h and +24h respectively. Inspection of wet and dry EPt profiles show that the thermodynamic characterisitcs of the air layers are in various stages of transition, the modification being due to mixing and vertical movement of air between the various layers with frontal passage. The dry EPt profiles show lower EPt values than wet profiles, typical of low rainfall and dry cold air. The EPt minimum occurs at a low altitude of 700-600 hPa at 00h indicating stability above this level. In the wet events the EPt profile at 00h indicates relatively warm and moist air extending throughout the column, usually an indication of maritime tropial air over the interior (Steyn 1988). The slope of the EPt profile in wet events (i.e. a reduction from 335K to 320K in the 850-600 hPa layer) hence instability (declining EPt) would enable surface convergence to be more readily translated to uplift.

An increase in the mixing ratio from D-day in the dry events was noticed at 700 hPa for Pretoria which shows a steady increase while Durban and Bloemfontein show a minimum at +12h (the expected time of the trough) followed by an increase until +36h. A characteristic of the dry events is a gradual increase toward moisture and instability which is realised approximately 24 hours after D-day with only little rainfall being recorded at or near +24h in the south western Cape. It appears that once the trough has moved from Bloemfontein some instability is generated in the troughs wake which is responsible for the scattered showers over the interior after +24h during dry events. Little to no convection occurs at the time that the tropical temperate connection is seen to occur as in the wet events. The lack of accord between the mixing ratio profiles, EPt profiles and divergence fields suggest that either the supply of moisture is too late or the synoptic forcing is not strong enough to sustain vertical lift.

The 00h profile in wet events is similar to the "above average" rainfall EPt trace of Steyn (1988), which has a precipitable water value of > 25 mm at Bethlehem (located north-east of Bloemfontein). A precipitable water composite of wet and dry events for -24h and 00h is presented in Figure 4-13 and represents the integrated water content of the atmosphere. Their is a significant increase from -24h to D-day in the wet events. At D-day precipitable water values have risen from an average of 16 mm to 23 mm over the interior of South Africa as moisture is transported southwards. In comparison the 20 mm and 15 mm contours in the dry events at D-day has retracted northwards by more than 5° latitude such that the average precipitable water value over the interior has decreased from -24h to 00h from 14 mm to < 12 mm.

Vertical movement

The effects of the combination of moisture into the interior, the instability that is generated through it and the synoptic forcing over South Africa at -24h and 00h is presented in Figure 4-14 for (a) wet troughs and b) dry troughs which represents vertical movement in Pa hr^{-1}. At -24h the surface cold front has not yet moved over Bloemfontein, yet the ridging anticyclone (ref Figure 3-1, a) located just south of the country is exhibiting large positive values (subsiding air > +300 Pa hr^{-1}). Vertical ascent (negative values > -300 Pa hr^{-1}) is greatest at 5° S over central Africa and at 25° S over northern Transvaal, Namibia and Botswana. The alignment and position of the circulation systems promotes meridional flow at -24h. The peak value of -798 Pa hr^{-1} representing vertical ascent over Namibia in wet events marks the edge of the IOCZ described by Taljaard (1990) where moist modified air from the Indian ocean moves across Zimbabwe arriving as a tropical air mass over the western interior. The northward penetrating upper westerly wave with its associated humid north-west winds across northern Botswana causes convergence and vertical ascent. A surface low over the western interior (ref Figure 3-1, a) enhances development of an interior trough and southward flow of moist air.

Approximately twenty four hours later at 00h the area of ascent has rapidly enlarged covering nearly the entire South African interior from 20° S to 35° S in the wet events. The region of maximum vertical ascent shifts south-eastwards across the interior as the upper-level trough and its associated divergence field on the front of the wave move across the interior. The region of vertical descent and is located south-east of the subcontinent and west of South Africa as ridging continues at +24h.

In comparison to the wet events, the dry events at -24h exhibit vertical ascent in a north-west, south-east band across South Africa with maximum ascent occurring south of Port Elizabeth at 35° S (-567 Pa hr^{-1}) and over Namibia at 25° S (-549 Pa hr^{-1}). Vertical ascent over Namibia in dry events suggests that moist tropical air is present at the northern boundary of South Africa advected in from the north-east coast by similar mechanism described for wet troughs. Weak ascent (-322 Pa hr^{-1}) in a south-easterly band across the interior at -24h marks the edge of a weak trough. At 00h the dry events are characterised by a large scale collapse of ascent over the interior, with only a small area of uplift existing over Bloemfontein at -24h (-351 Pa hr^{-1}). Divergence over Bloemfontein (ref Figure 3-9), shows weak low-level convergence and upper-level divergence. The band of maximum ascent marking the trough has broken away and the depression appears to mature in the main westerly belt at 40° S (-1323 Pa hr^{-1}), which according to Tucker (1979) is typical of intermediate seasons where maturation of mid-latitude depressions often occurs over the southeast Indian Ocean between latitudes 40° - 45° S. A well developed SAac (> +800 Pa hr^{-1}) at 15° E marks the region of maximum subsidence at -24h in dry events. However, the region of subsidence at 00h at 15 - 20° E indicates little eastward movement of the SAac suggesting stagnation over the south and west coast where a subsidence value of +261 Pa hr^{-1} at 20° S and 20° E occurs.

The most notable difference in Figure 4-14 between wet and dry troughs is the explosive tendency to large scale ascent over South Africa on D-day in wet events. This is a direct result of the brief period over which the tropical moisture interacts with the westerly wave. In the dry events a combination of weak synoptic forcing and little moisture is indicated in the vertical motion over South Africa.

Discussion and Summary

The supply and availability of tropical moist air into the interior of Southern Africa and the effect of moisture and temperature on the stability of the atmosphere in wet events with respect to dry events has been the focus of attention in Chapter 4. The synoptic structure of the atmosphere is conducive to sustain ascent of air in wet events, while weak and undefined divergence/convergence fields in dry events implies weak vertical motion. Whether uplift produces convective processes depends on the amount of moisture available and the temperature structure which has important consequences on atmospheric stability at any place and time. An important intention of this section has been to discover the availability and supply of moisture as a trough passes over the interior of South Africa.

The precipitable water vapour field shows a major difference between wet and dry troughs at D-day where an 8 mm anomaly occurs over the interior of South Africa. It appears from the results in Chapter 4 that a significant difference between wet and dry troughs is the presence of a prefrontal stream of moisture which is responsible for the high precipitable water value at D-day in wet events which is indicated in various moisture parameters. Firstly, the dewpoint time-height section over Bloemfontein clearly shows the presence of a moist prefrontal air stream throughout the troposphere between -48h and +24h in wet events. Secondly, low dry static energy curves for Pretoria and Bloemfontein in the wet events between -48h and 00h at 700 hPa imply low geopotential heights and temperatures which indicate the presence of a surface trough and cloud bands which have been generated within a moisture source. High mixing ratio values at northerly stations at 500 and 700 hPa between -48h and 00h indicate prefrontal moisture as do the precipitable water composites. Above normal static energy departures > +0.8 at 600 hPa at -24h at Pretoria and Bloemfontein imply instability in the prefrontal troposphere and surface convergence over South Africa. Above normal temperatures and geopotential departures in the middle and lower troposphere between -48h and 00h provide further evidence to the release of latent heat from a moist air stream which is described by Harrold (1973), Hastenrath and Heller (1977) and, Preston-Whyte and Tyson (1988) as a "conveyor belt" transporting westerly momentum heat and moisture poleward. The entrance region of the "conveyor belt" is over the east coast across the northern Transvaal and Zimbabwe (Taljaard 1990) where it is modified by surface warming and convection and, as it arrives over Botswana/Namibia. Vertical motion at -24h over Namibia indicates surface convergence of moisture to the east of the large amplitude sub-tropical troughs. A trough is formed between the east trade wind current and humid air flowing in from the north-west across Zaire and northern Zambia, and extends southwards into the interior of South Africa as it is drawn into an interior low.

The wet temperature structures for Bloemfontein and Pretoria reveal a 3-level structure with warming above 500 hPa and cooling below 600 hPa and above 200 hPa similar to that described by Harangozo (1989) for tropical systems and, by Harrison (1986). Mid-tropospheric warming implies latent heat release. The dry temperature structure shows prefrontal mid-tropospheric warming while negative departures dominate the troposphere after D-day. A 2-level temperature structure is evident at Bloemfontein in dry events from +12h where warming occurs above 500 hPa with cooling below. The 3-level temperature structure is clearly evident in wet-dry temperature structure especially at Pretoria where a positive difference of +1.5 between 400 and 300 hPa at +12h indicates the release of latent heat in wet events and a connection between the equatorial regions and temperate systems.

Above normal geopotential heights above 500 hPa prior to 00h together with a deep layer of above normal mid-tropospheric temperatures are consistent with upper-tropospheric outflow of air and latent heat release in the middle troposphere due to enhanced convective activity. While positive geopotential departures dominate the wet composite prior to the passage of the front negative values < -1.4 dominate the lower and middle troposphere over Bloemfontein from D-day. Similar negative geopotential heights throughout the troposphere at the time of the cold front have been found to occur with rainfall in regions with temperate westerly circulation (Palmen and Newton 1969, Harangozo 1989) and with above normal rainfall in South Africa (Hofmeyer and Gouws 1964, Taljaard 1981, Miron and Tyson 1984, Taljaard 1986b).

Atmospheric stability over the interior of South Africa was measured by dry and total static energy. The profile of static energy for mean dry troughs is greater than the mean wet curve for Pretoria, Bloemfontein and Port Elizabeth indicating higher temperatures from lack of clouds and above-normal geopotential heights associated with anticyclonic conditions. Total static energy which includes a term for latent heat release showed large positive departures at all 3 stations in wet events compared to dry events which were dominated by weak negative departures.

In the time-height section of total static energy the most unstable station is Pretoria from -24h. It is possible that the sub-tropical latitude of Pretoria, places the city under the influence of tropical circulation. However, it is more likely given the evidence of a large amplitude trough and northward displaced sub-tropical jet stream that the trough axis in wet events is displaced northward into sub-tropical regions. The idea of the northward penetration of a westerly wave into the sub-tropics which triggers convective processes is supported by Hattle (1955), Bhalotra (1973), Kumar (1978), Kelbe (1988), Lyons (1991) and Taljaard (1990). It is quite possible that in the wet events the northward penetrating waves produce instability, convergence and cyclonic rotation to stimulate the convection. Bhalotra (1973), Kumar (1978) and Lyons (1991) are in support of the idea that large amplitude waves which penetrate equatorial regions are able to produce convective activity when accompanied by some near-surface convergence (Taljaard 1990) and upper-level divergence.

The large amplitude wet troughs by the nature of cyclonic curvature over the interior and anticyclonic curvature in the mid-latitudes have pronounced regions of convergence and divergence. The presence of a warm tropical air stream which is drawn south into an interior low pressure system, prior to the frontal event, is an important stimulant which enhances atmospheric instability. Instability and moisture are prerequisites for convection, but they alone cannot produce rainfall. The large amplitude northward penetrating trough produces the energy to stimulate the vertical ascent of air. The divergence/convergence fields of Figure 3-9 and the vertical movement Figure 4-14 over South Africa provide sufficient evidence that the energy produced in the large amplitude wave in the way of upper-level divergence is the energy used to drive the unstable air mass. In dry events, the upper-level structure is in a state of decay as neither the surface inputs of moisture and thermal instability nor the upper-level synoptic circulation are strong enough to sustain vertical motion. In dry events vertical ascent over Namibia indicates that a supply of moisture is available at northerly latitudes, but the stagnant and eastward displaced SAac prevents this moisture from being driven southward by erosion of the moisture through dry subsiding air. The small amplitude trough in the dry events does not aid meridional flow, and the smaller amplitude of the troughs means greater zonal wind speeds and reduced residence times for convective conditions.

The results of Chapter 4 are briefly summarised in Table 4-1 where the important differences between wet and dry troughs are noted.

Table 4-1 Summary of the moisture and thermodynamic characteristics of wet and dry troughs.

MOISTURE AVAILABILITY AND THERMODYNAMICS	WET		DRY	
DEWPOINT				
- Surface dewpoint - (-24h) - (00h) - (+24h)	 13.8° C 22.4° C 12.5° C	cloud, moisture across South Africa	 5.2° C 4.0° C 6.2° C	no cloud, little moisture across South Africa
- Time-height dewpoint (departures) - -48h to +00h	> +1.0	high dewpoint departure warm temperatures and geopotentials, in the mid-troposphere indicate latent heat release	< +0.4	no moist air stream
- Time-height dewpoint depression (departures)	-1.2	maximum saturation from 850 - 500 hPa at +12h00	+1.2	no saturation from 850 - 500 hPa at +12h00
PRECIPITABLE WATER (mm)				
(at 25° S and 25° E) - (-24h) - (00h)	 24.3 mm 29.3 mm	increasing precip. water by 5 mm	 20.0 mm 11.0 mm	decreasing precip. water by 9 mm
MIXING RATIO (g kg^{-1})				
- 700 hPa level - -48h to 00h	high	wet events have greater mixing ratios at all stations	low	dry events have low mixing ratios at all stations

	WET		DRY	
- 500 hPa level - -48h to 00h	high		low	
THERMODYANMIC STRUCTURE (departures)				
- Temperature structure	3-level	warming above 500 hPa and cooling below 600 hPa and above 200 hPa.	2-level	warming above 700 hPa and cooling below
DRY STATIC ENERGY ($J\ g^{-1}$)				
- 700 hPa level - -48h to 00h (Pretoria and Bloemfontein)	low	low geopotentials and low temperatures due to interior low and cloud	high	high geopotentials and high temperatures due to anticyclonic conditions and no cloud
(Port Elizabeth)	high		low	
- 500 hPa level - -48h to 00h (Pretoria and Bloemfontein)	high	high geopotentials and temperatures in mid-troposphere suggest release of latent heat	low	low geopotentials and temperatures
(Port Elizabeth)	high	southward displaced fast ridging SAac and mid-tropospheric warming	low	characteristic of dry events is maturing low pressure systems in mid-latitudes

	WET		DRY	
TOTAL STATIC ENERGY (departures)				
- Time-height static energy (Pretoria, Bloemfontein and Port Elizabeth) - -48h to 00h	above-	instability in pre-frontal environment below 600 hPa especially at Pretoria	below-	weak negative departures dominate, the troposphere at all stations
EQUIVALENT POT TEMP (° K)				
- Vertical profile - -24h to 00h	+3.4	vertical difference between 850 - 700 hPa	0.2	weak vertical difference between 850 hPa - 700 hPa
- +24h to +36h		profile shfited into negative regions - implying stability		profile has become more unstable little rainfall +36h00
VERTICAL MOVEMENT (hPa hr^{-1})				
- Spatial coverage - (-24h) ascent	-798	5° S over central Africa and at 25° S, northern Tvl and Namibia	-567 -549	NW - SE band, max ascent at 35° S and Namibia at 25° S
descent	+606	fast ridging SAac at at 20° E and 35° S	+800	southwest coast of Africa
- (00h) ascent	-702	region of ascent has	-351	large scale collapse

descent	+510	enlarged from 20° S 35° S over entire South Africa ridging of SAac continues at 40° E and 40° S	+540	only small region at Bloemfontein, low matures at 40° S stagnation of SAac over the west coast at 15 -20° E

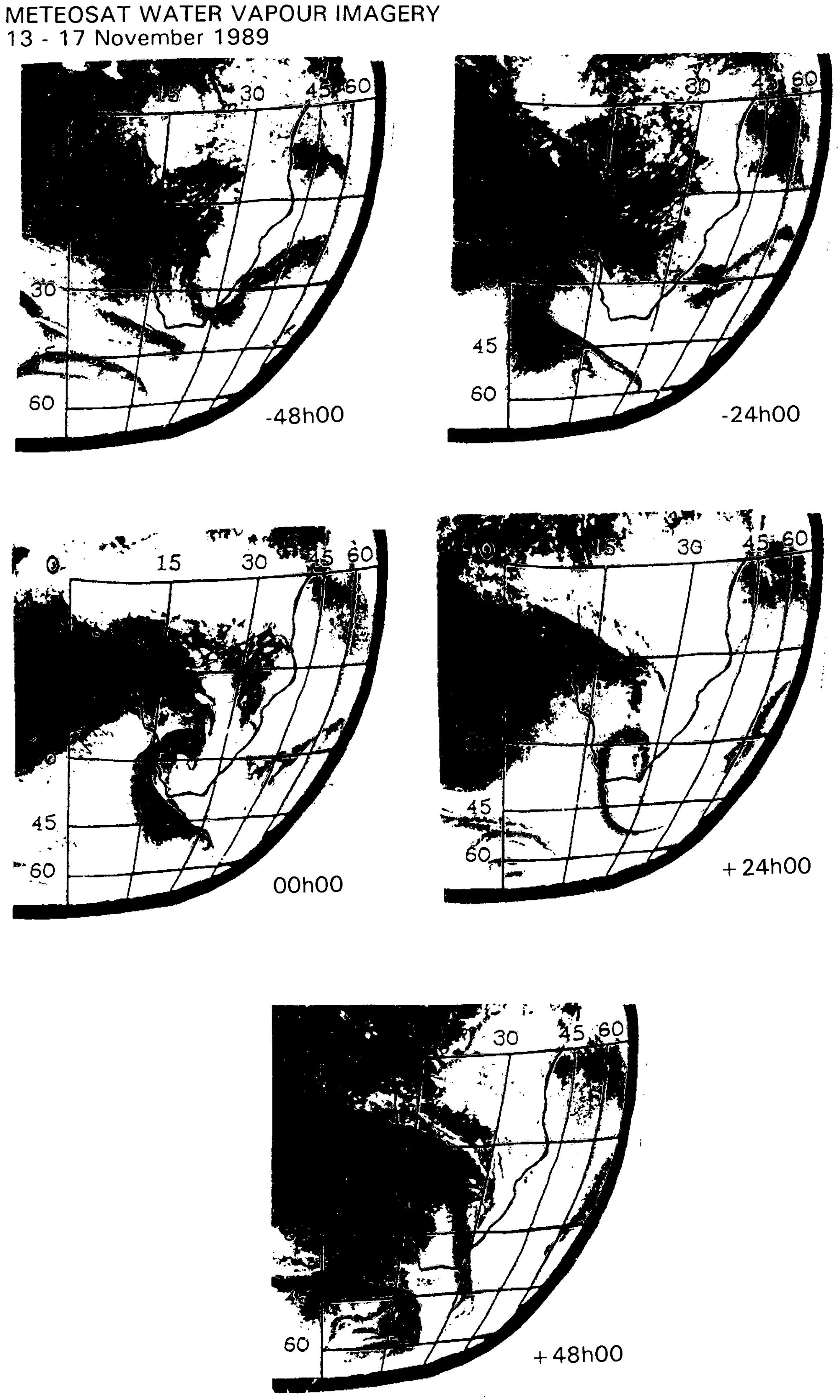


Figure 4-1 Meteosat satellite water vapour imagery for the wet event of the 13 - 17 November 1989

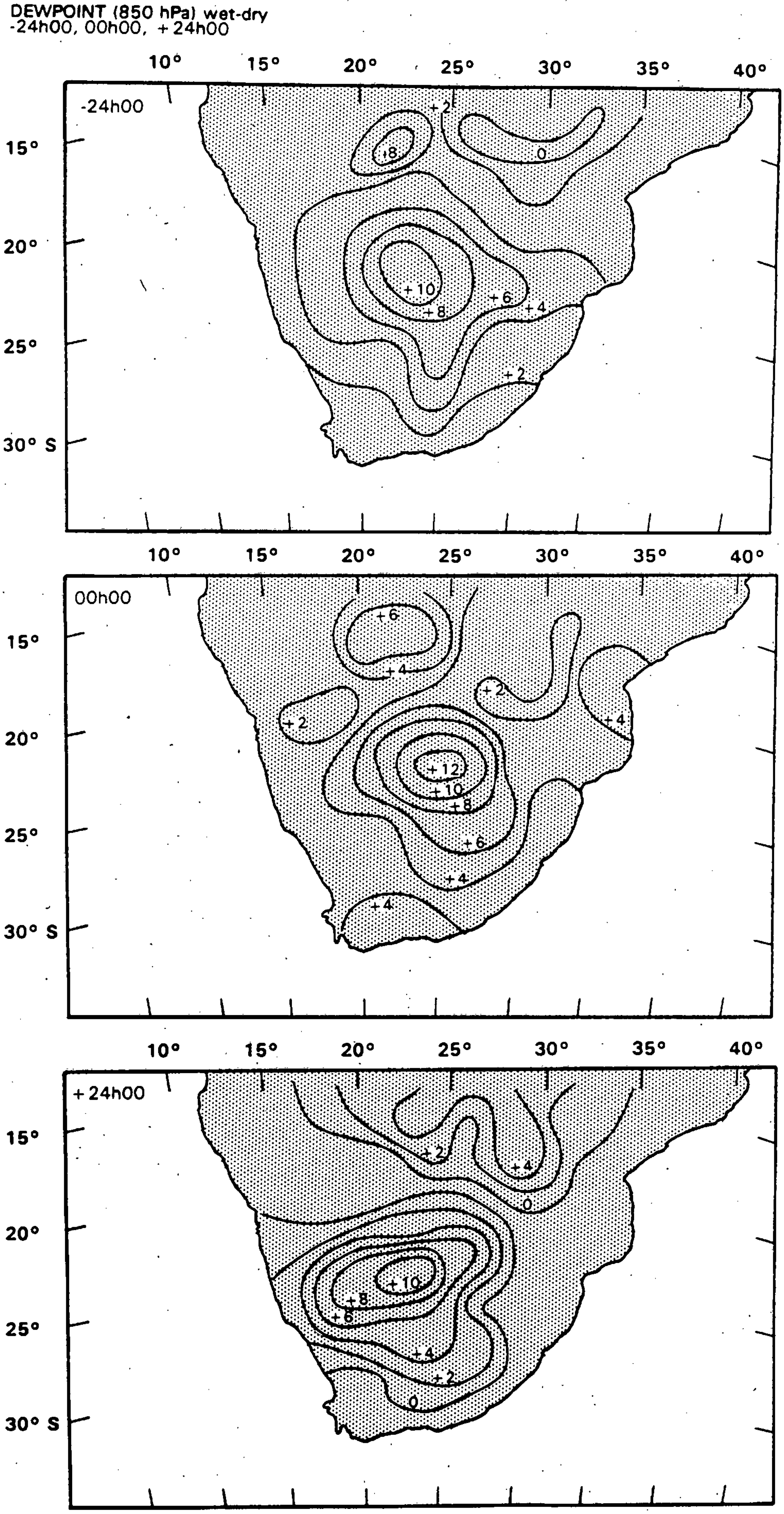


Figure 4-2 Spatial distribution of the (850 hPa) wet-dry dewpoint (° C) variations for -24h, 00h, and +24h, over South Africa.

a)

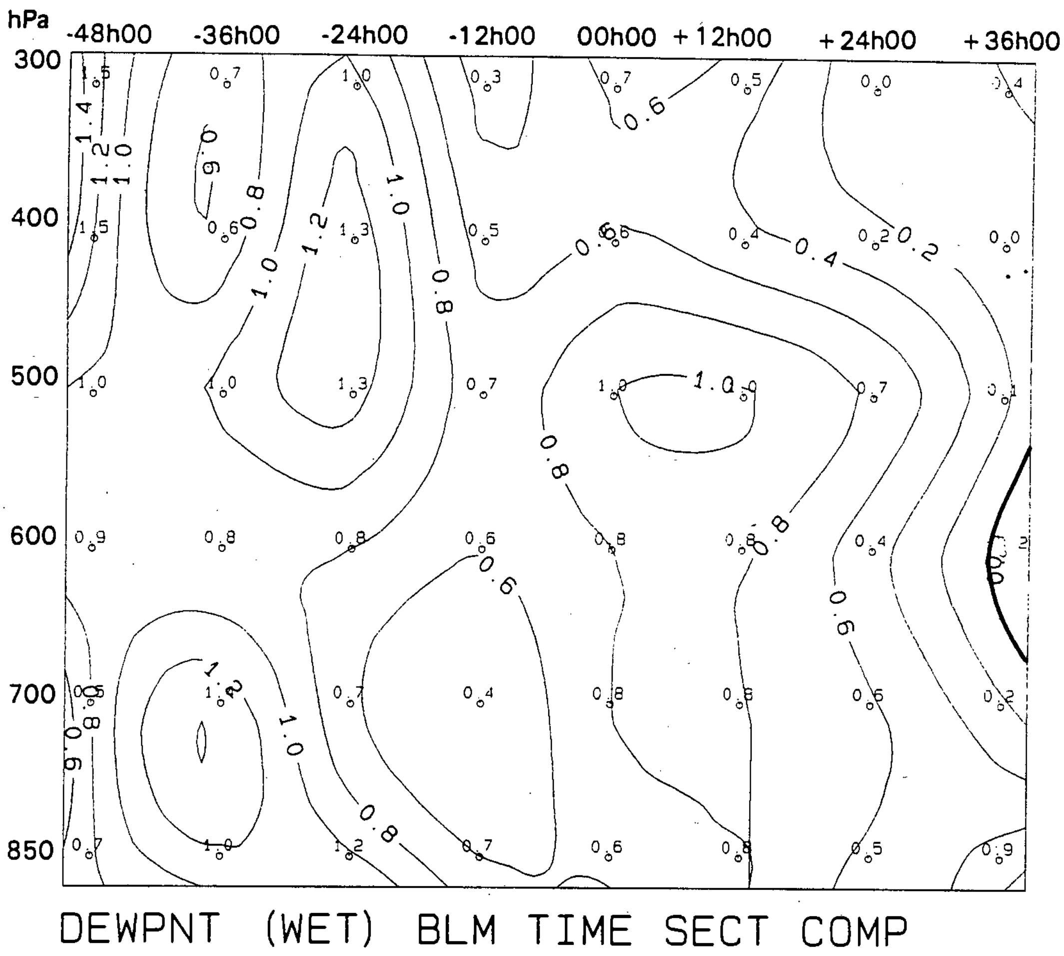


Figure 4-3 Time-height contours of dewpoint departures during the passage of the perturbation for (a) wet and b) dry troughs over Bloemfontein and Pretoria.

b)

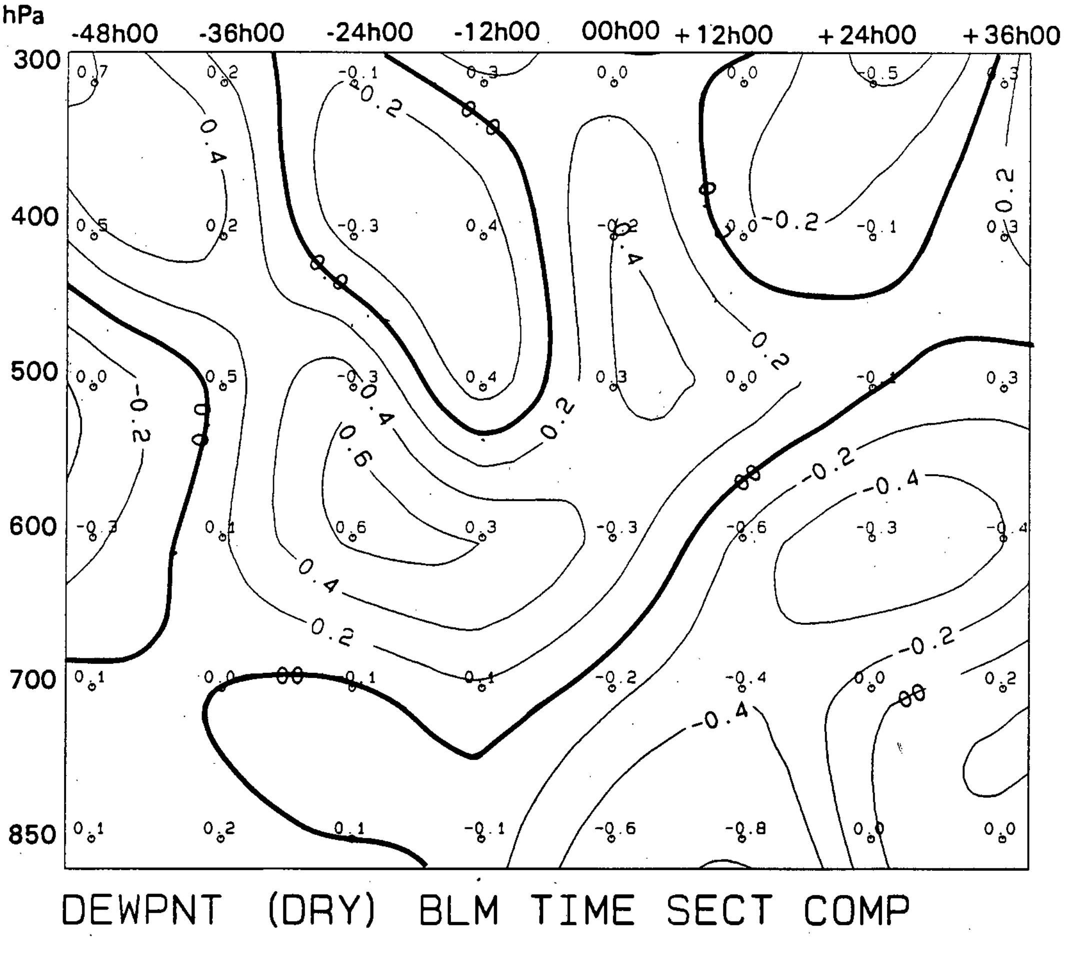
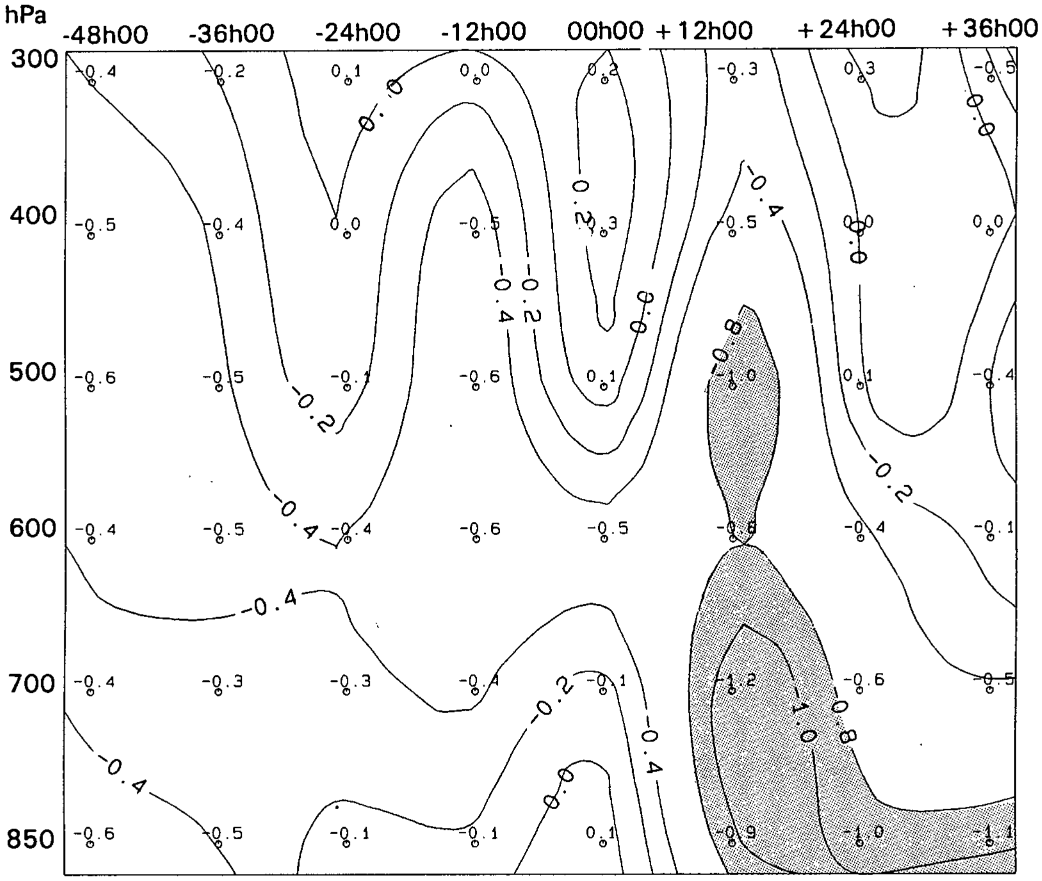


Figure 4-4 Time-height contours of wet-dry dewpoint variations during the passage of the perturbation over Bloemfontein. Positive regions with a departure > +1.0 are shaded.

Figure 4-6 Time-height contours of wet-dry dewpoint depression variations during the passage of the perturbation over Bloemfontein. Negative regions with a departure < -1.0 is shaded which represents saturation.

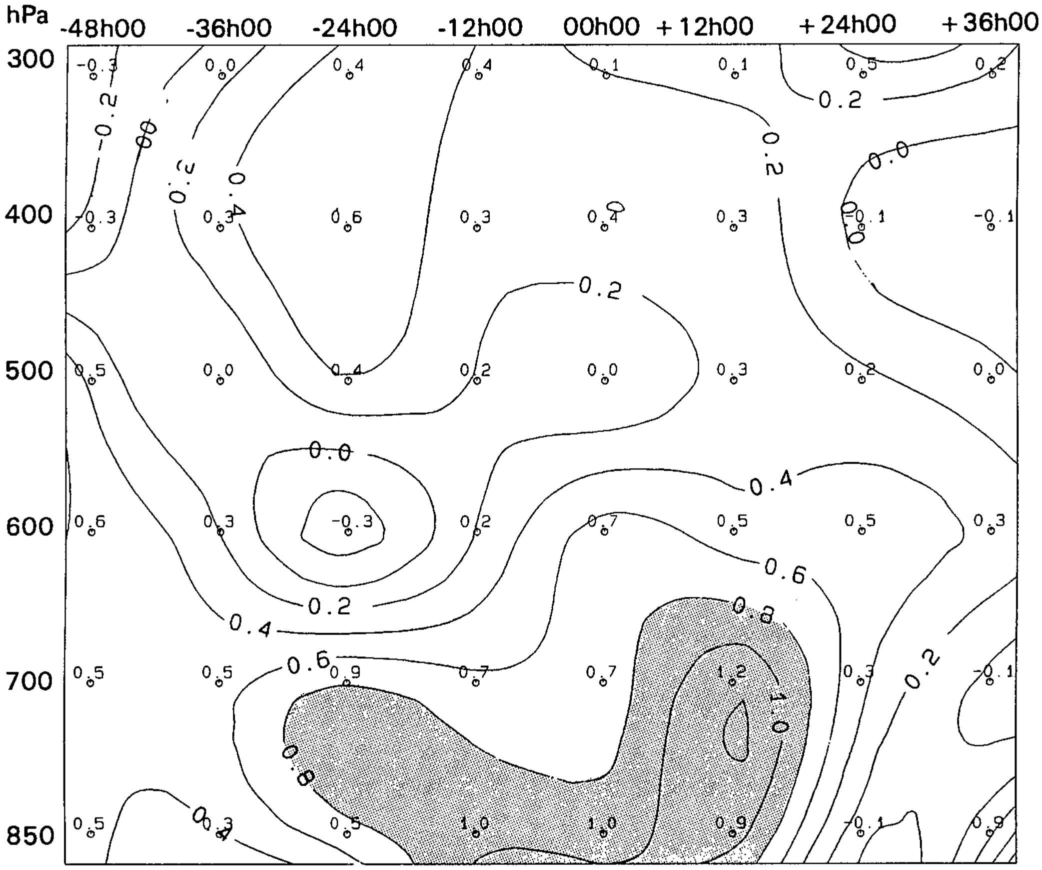
Figure 4-7 Temporal variations in mixing ratio (g kg^{-1}) during the passage of the perturbation for inland and coastal stations at 500 hPa and 700 hPa for wet and dry troughs.

a)



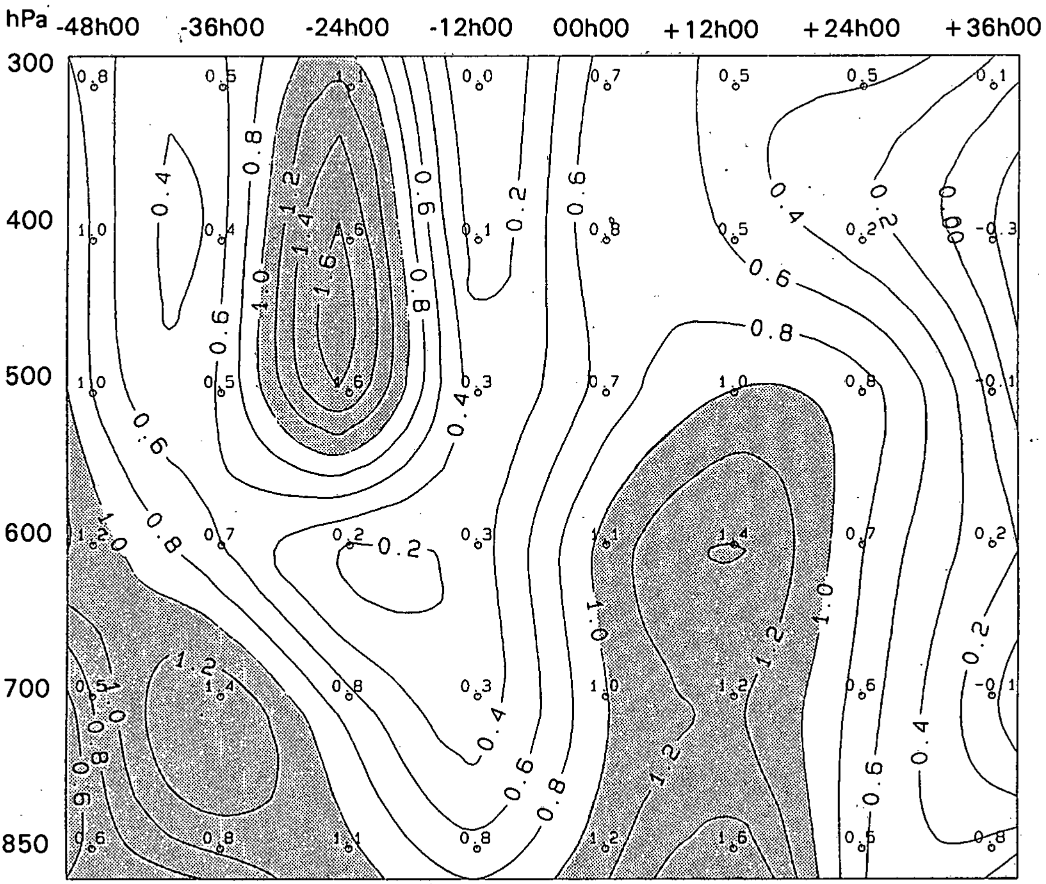
DEWDEPR (WET) BLM TIME SECT COMP

b)

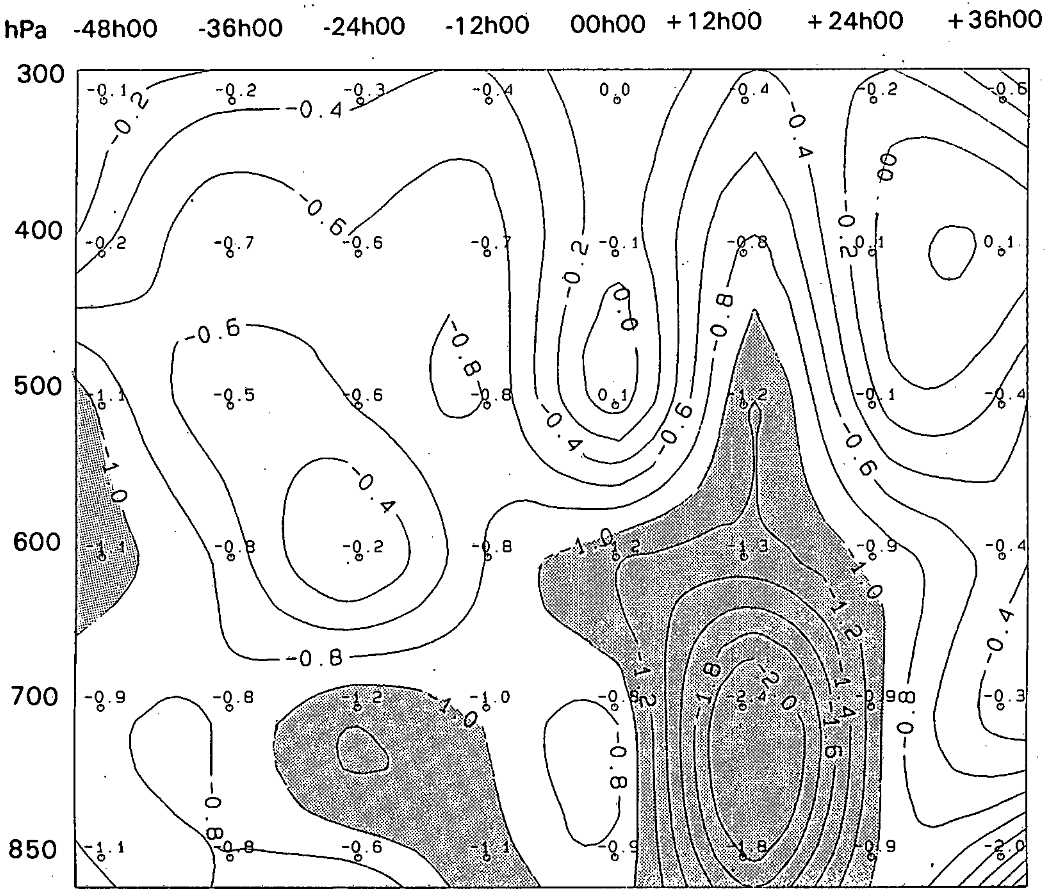


DEWDEPR (DRY) BLM TIME SECT COMP

Figure 4-5 Time-height contours of dewpoint depression departures over Bloemfontein during the passage of the perturbation for (a) wet and (b) dry troughs. Positive regions with a departure > +0.8 are shaded and represent no moisture in the dry events. Negative regions with a departure < -0.8 are shaded and represent saturation in the wet events.

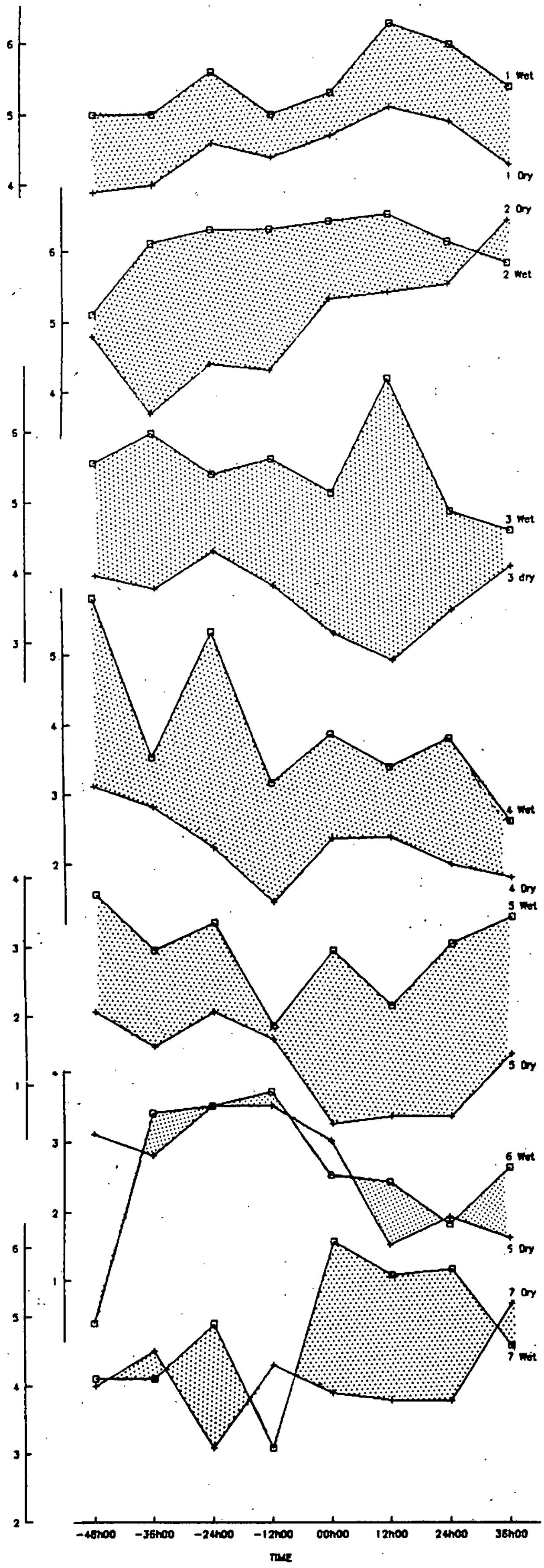


WET - DRY DEWPOINT (BLM)

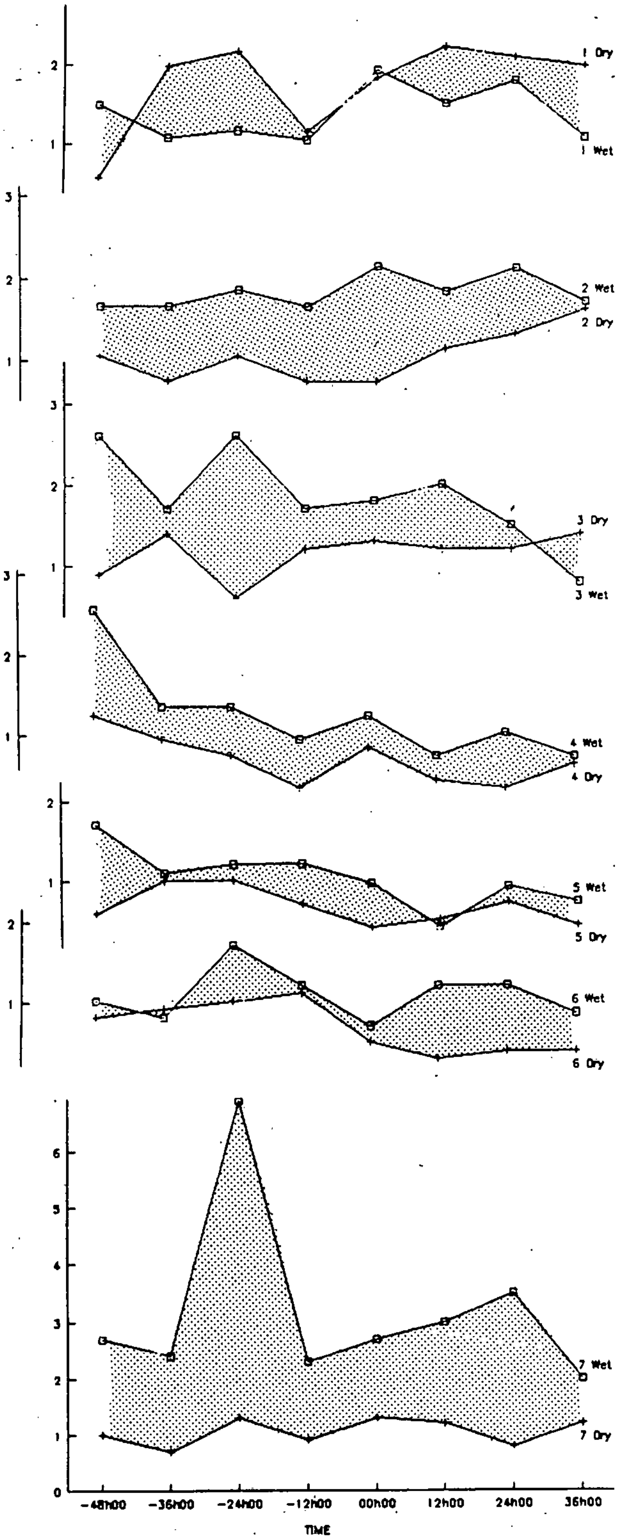


WET-DRY DEWPOINT DEPRESSION (BLM)

700 mb Mixing Ratio (g kg−1)



500 mb Mixing Ratio (g kg−1)



1 Pietersburg
2 Pretoria
3 Bloemfontein
4 Upington
5 Alexander Bay
6 Port Elizabeth
7 Durban

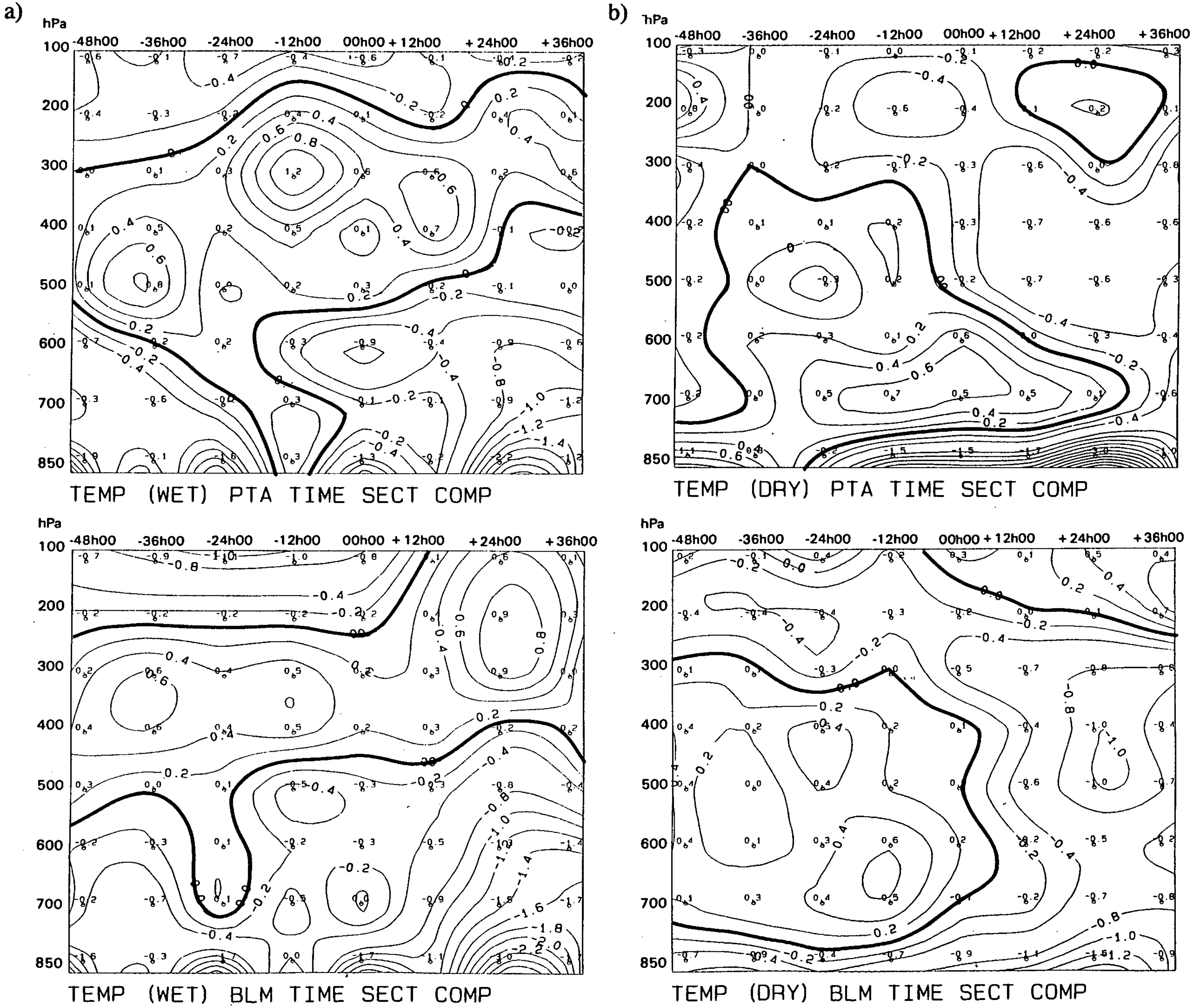
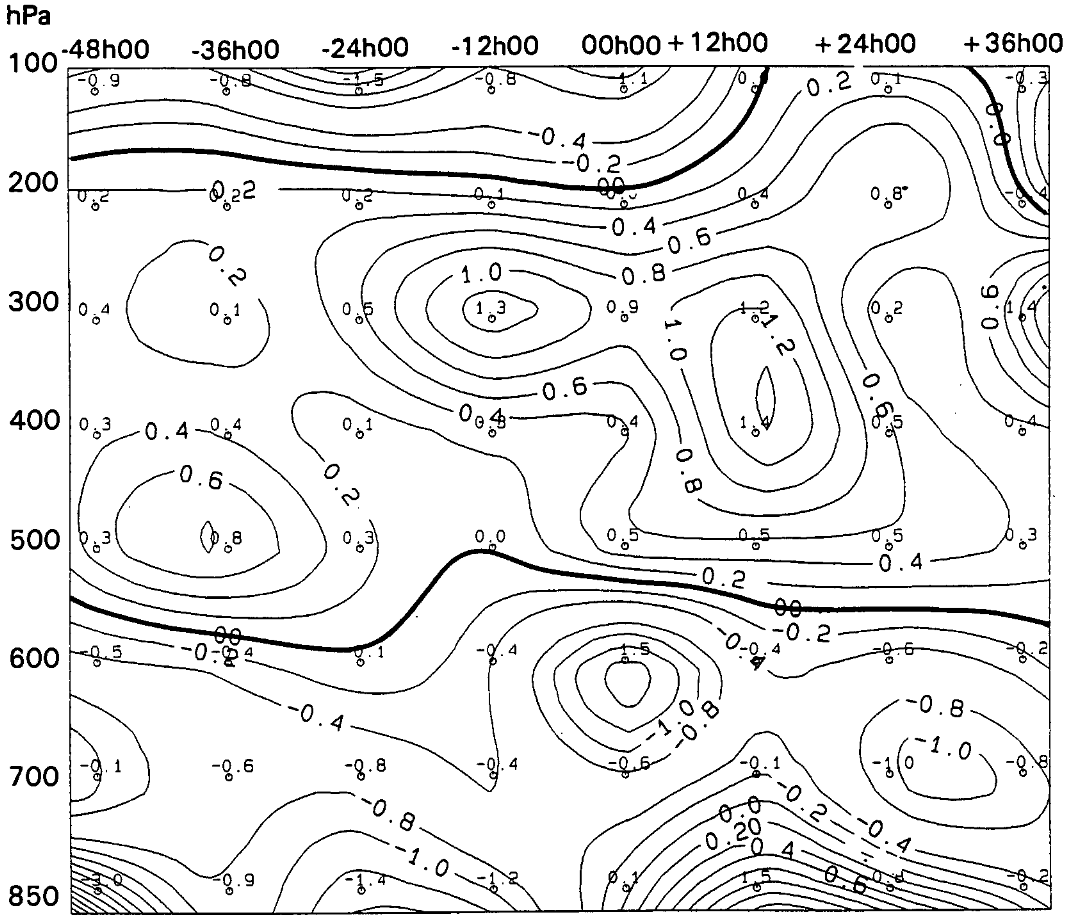
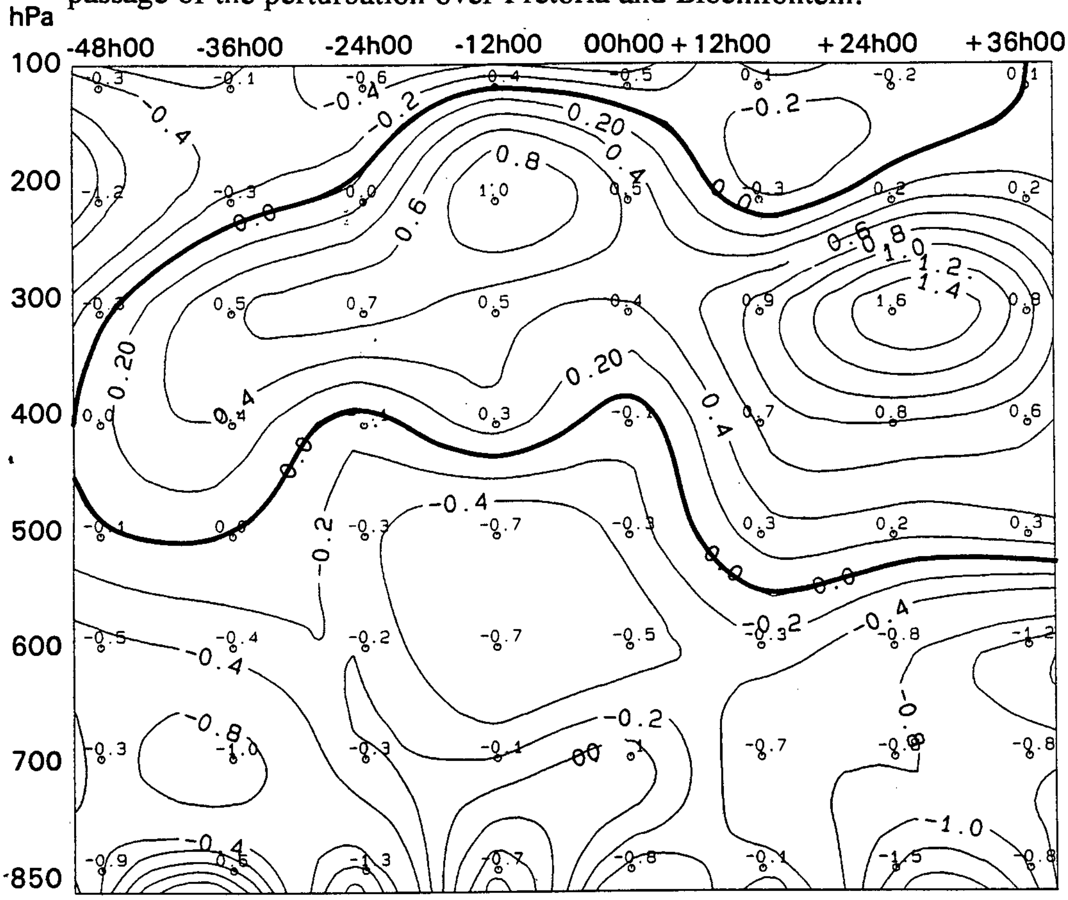


Figure 4-8 Time-height contours of temperature departures during the passage of the perturbation for (a) wet and (b) dry troughs for Pretoria and Bloemfontein.



PRETORIA WET-DRY TEMPERATURES

Figure 4-9 Time-height contours of wet-dry temperature variations during the passage of the perturbation over Pretoria and Bloemfontein.



BLOEMFONTEIN WET-DRY TEMPERATURES

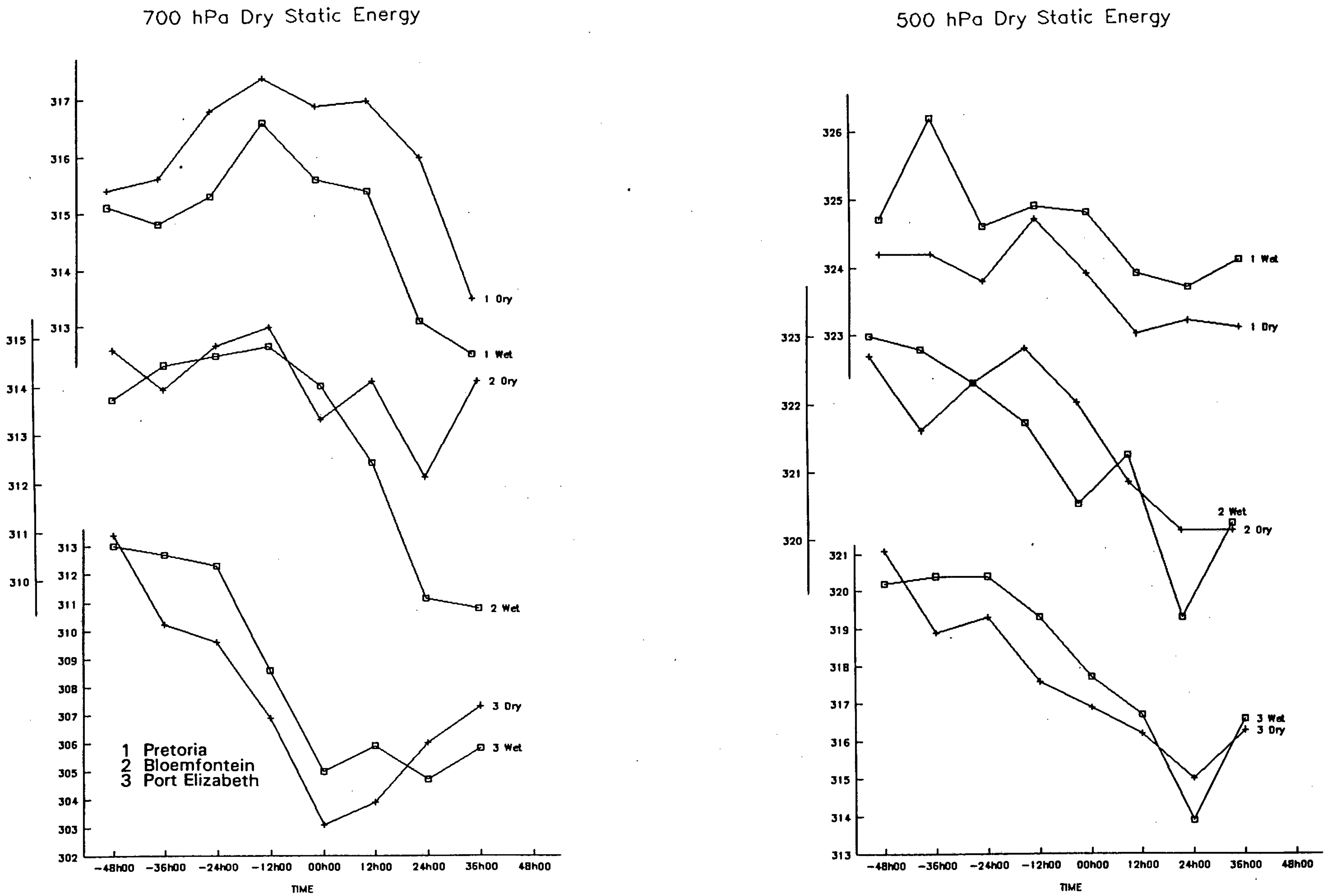
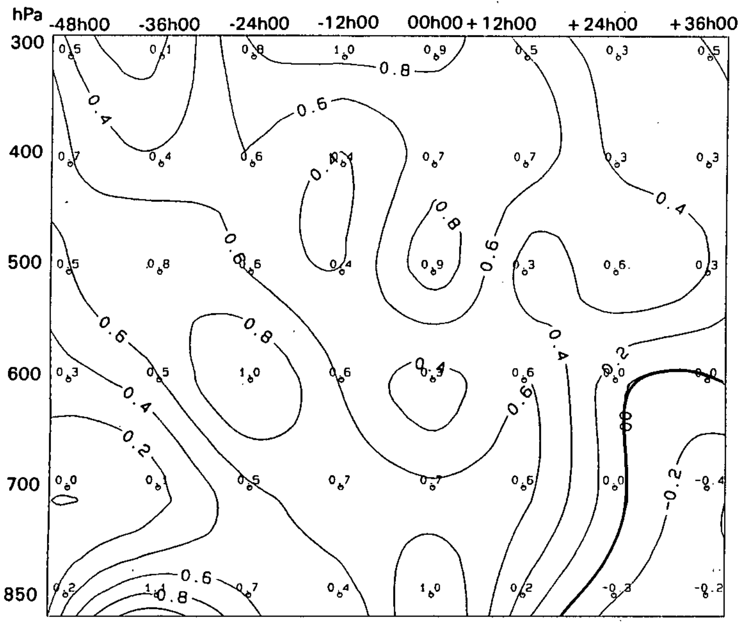
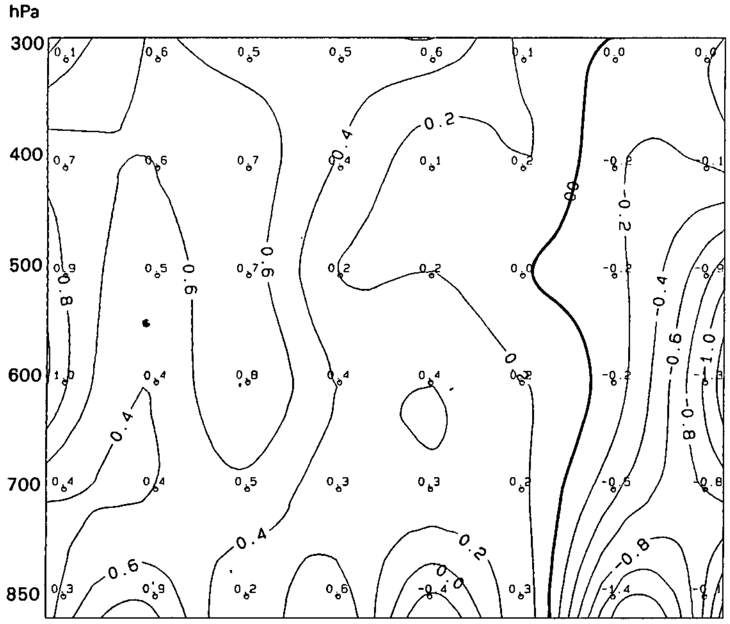


Figure 4-10 Dry static energy (CPT + GZ) (J g^{-1}) variations during the passage of the perturbation for Pretoria, Bloemfontein and Port Elizabeth for wet and dry troughs at 500 hPa and 700 hPa.

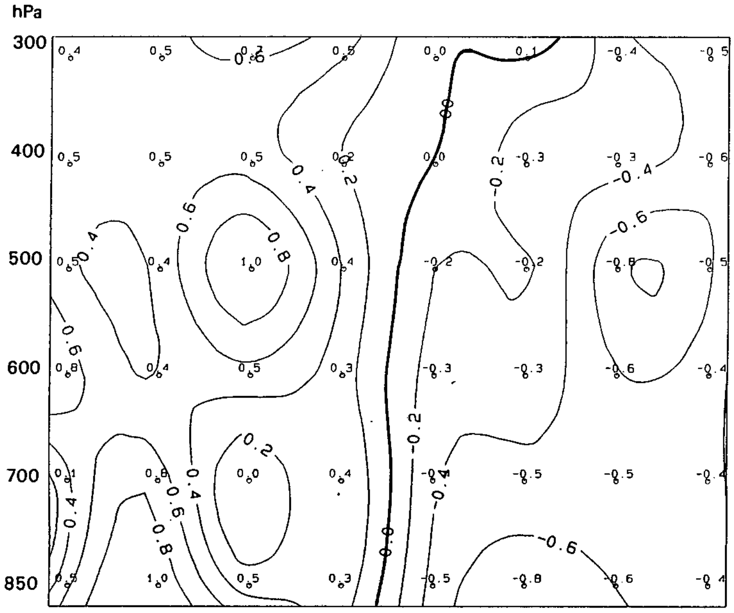
a)



PTA (WET) MOIST STATIC ENERGY



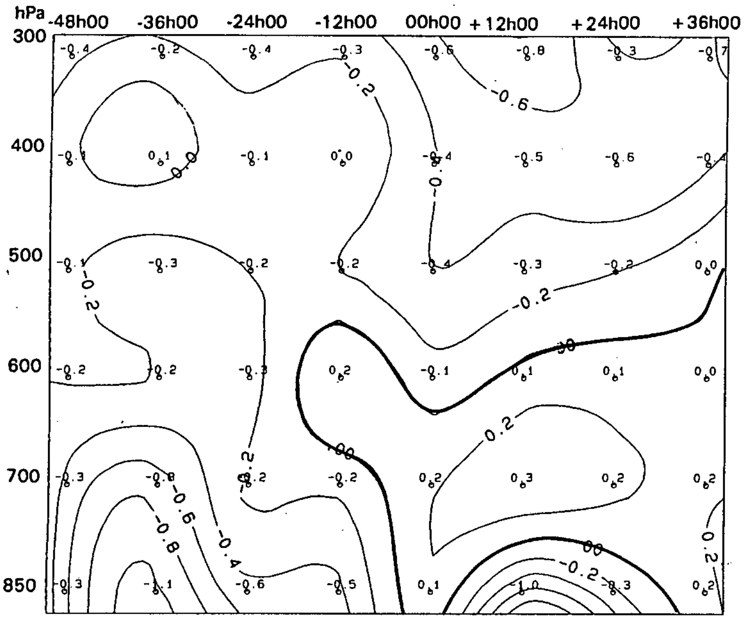
BLM (WET) MOIST STATIC ENERGY



PE (WET) MOIST STATIC ENERGY

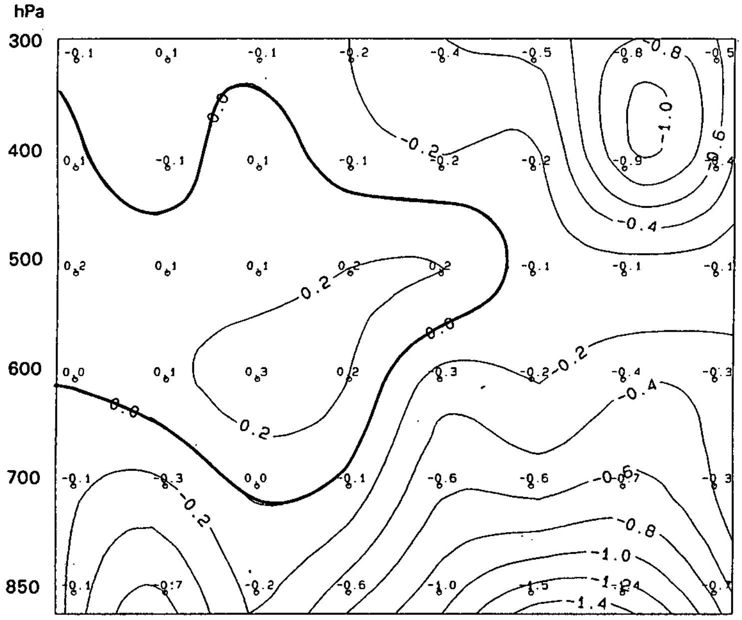
Figure 4-11 Time-height contours of total static energy advection (CPT + GZ + LQ) departures during the passage of the perturbation for Pretoria, Bloemfontein and Port Elizabeth for (a) wet and (b) dry troughs.

b)

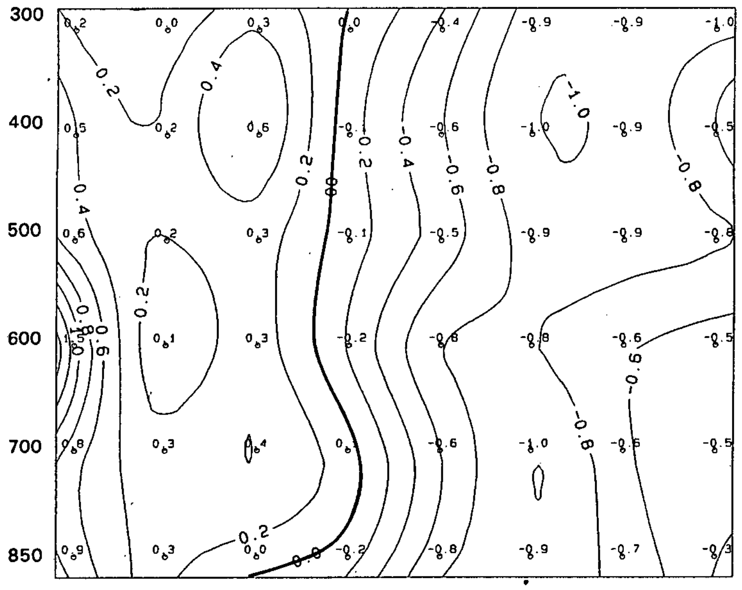


PTA (DRY) MOIST STATIC ENERGY

(ref Figure 4-11) caption
on previous page



BLM (DRY) MOIST STATIC ENERGY



PE (DRY) MOIST STATIC ENERGY

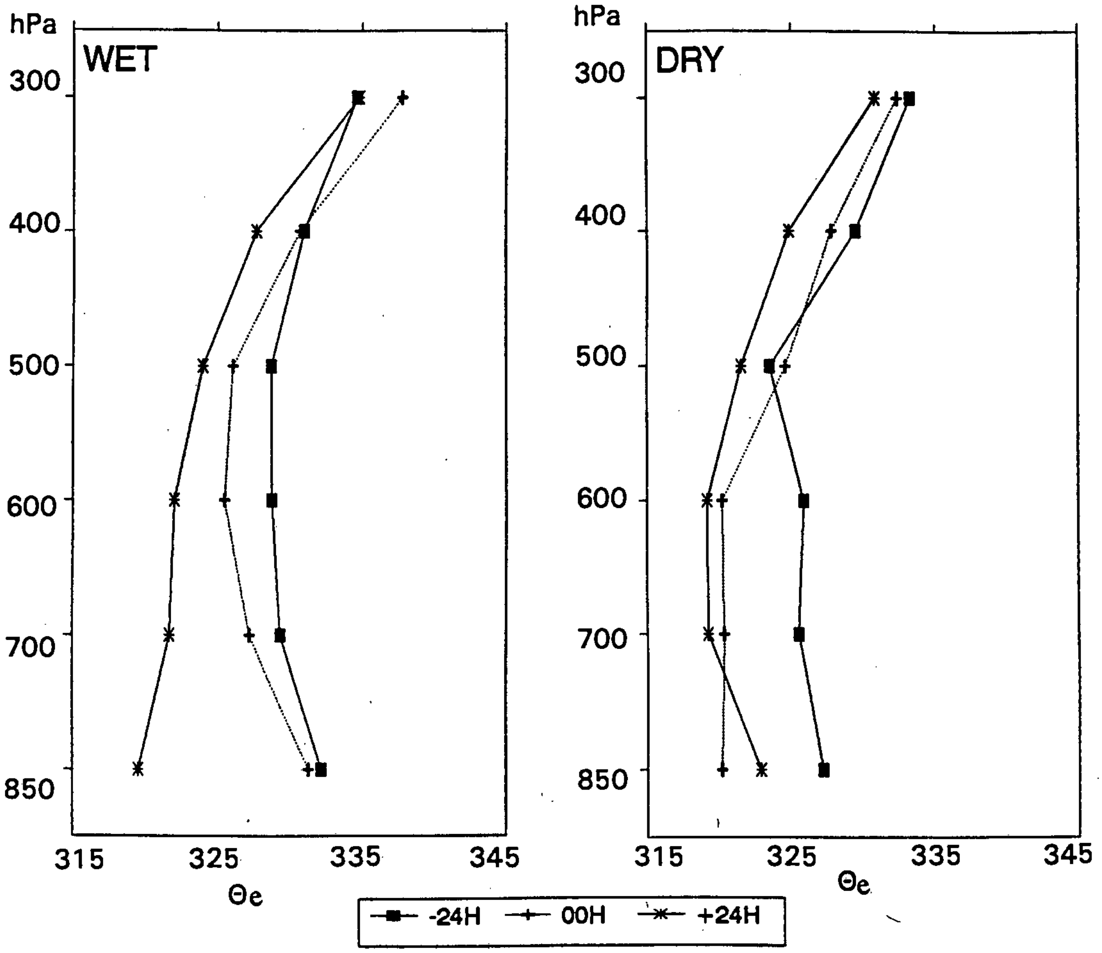


Figure 4-12 Vertical profiles of equivalent potential temperature for wet and dry troughs at 3 time periods; preceding, during and following the frontal event over Bloemfontein.

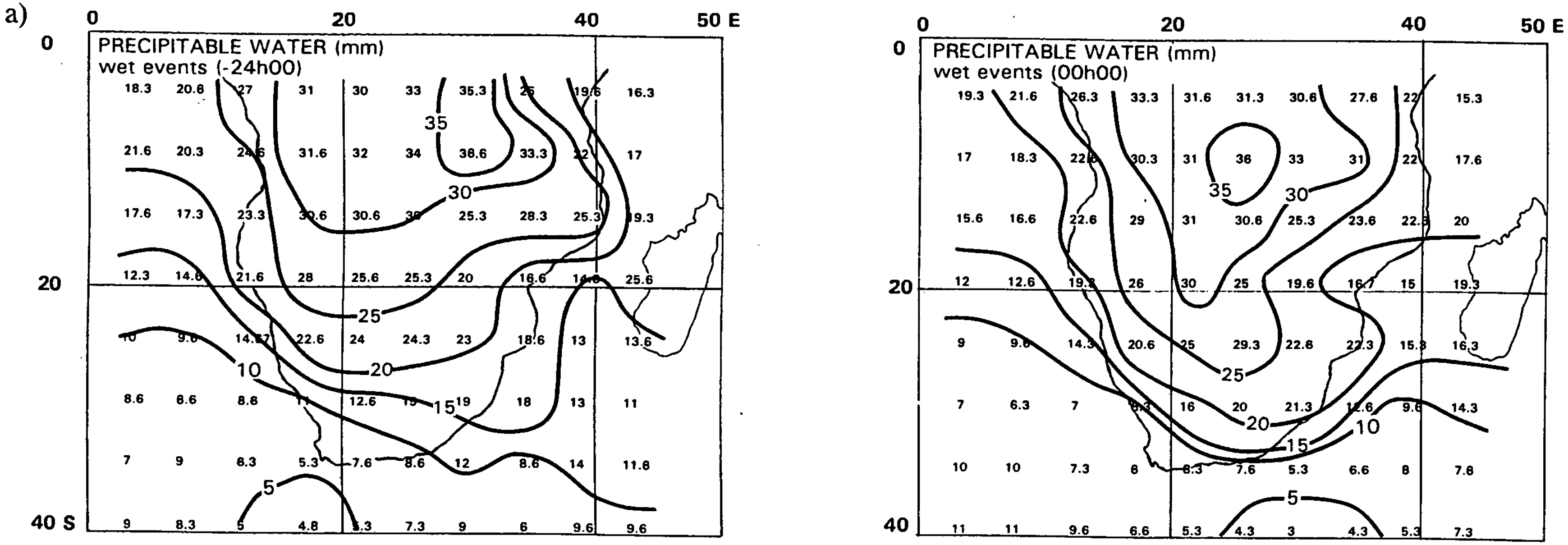
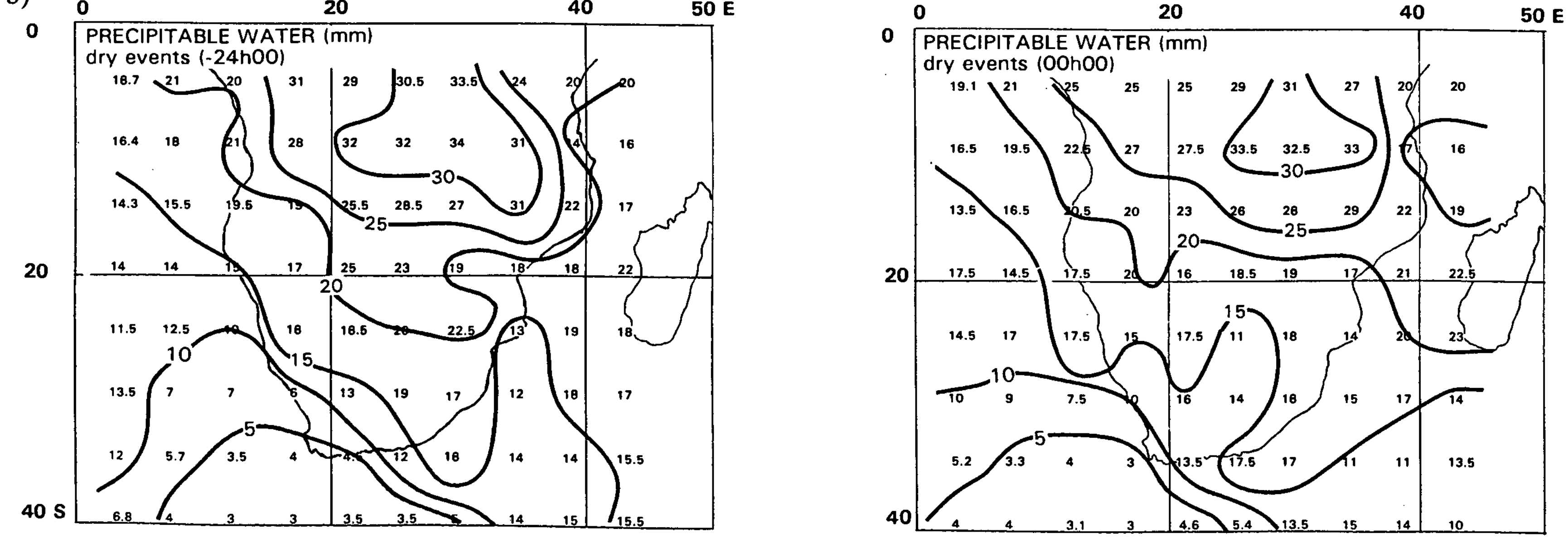


Figure 4-13 Precipitable water (mm) for (a) wet and (b) dry troughs for -24h and 00h.



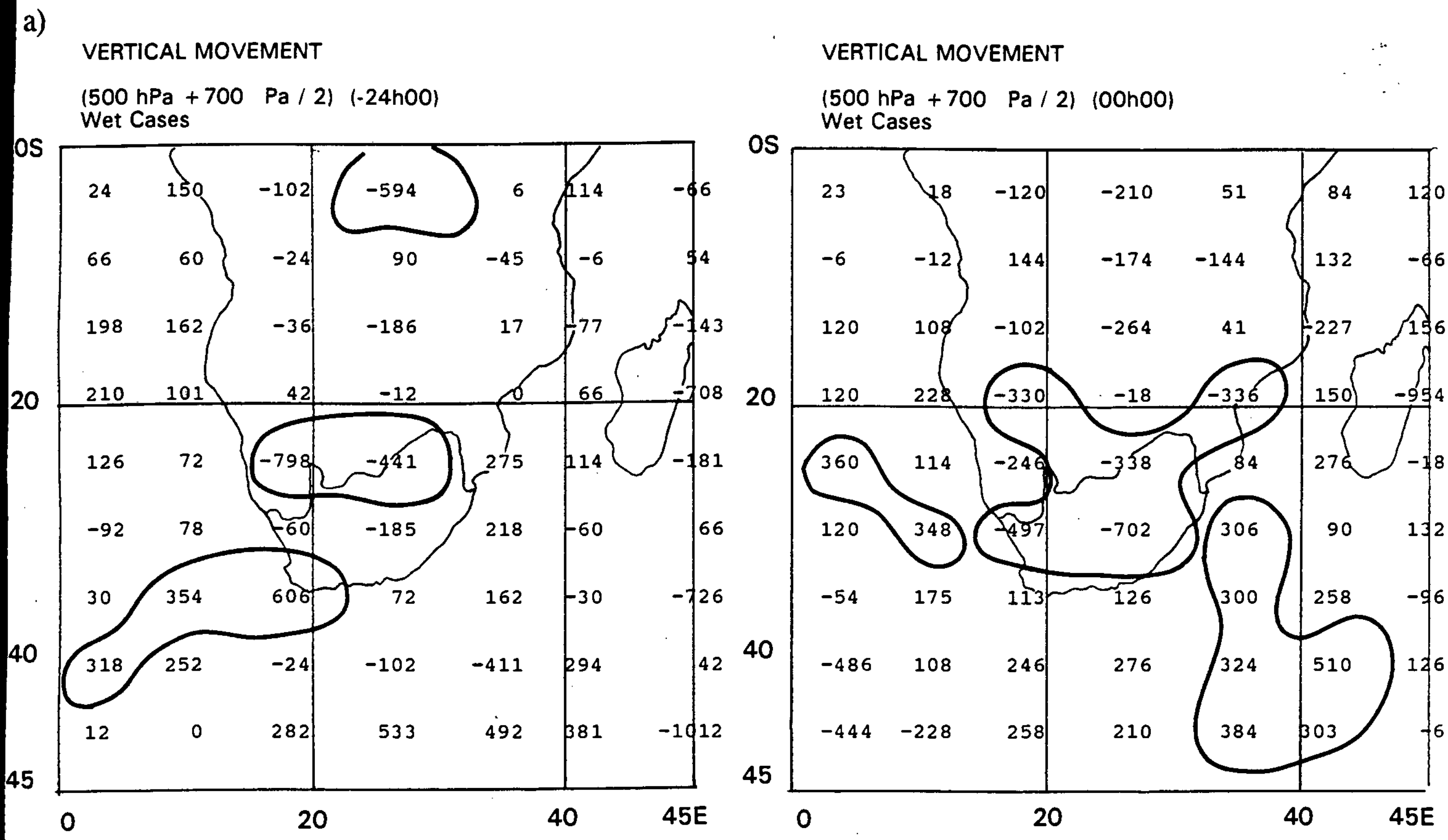
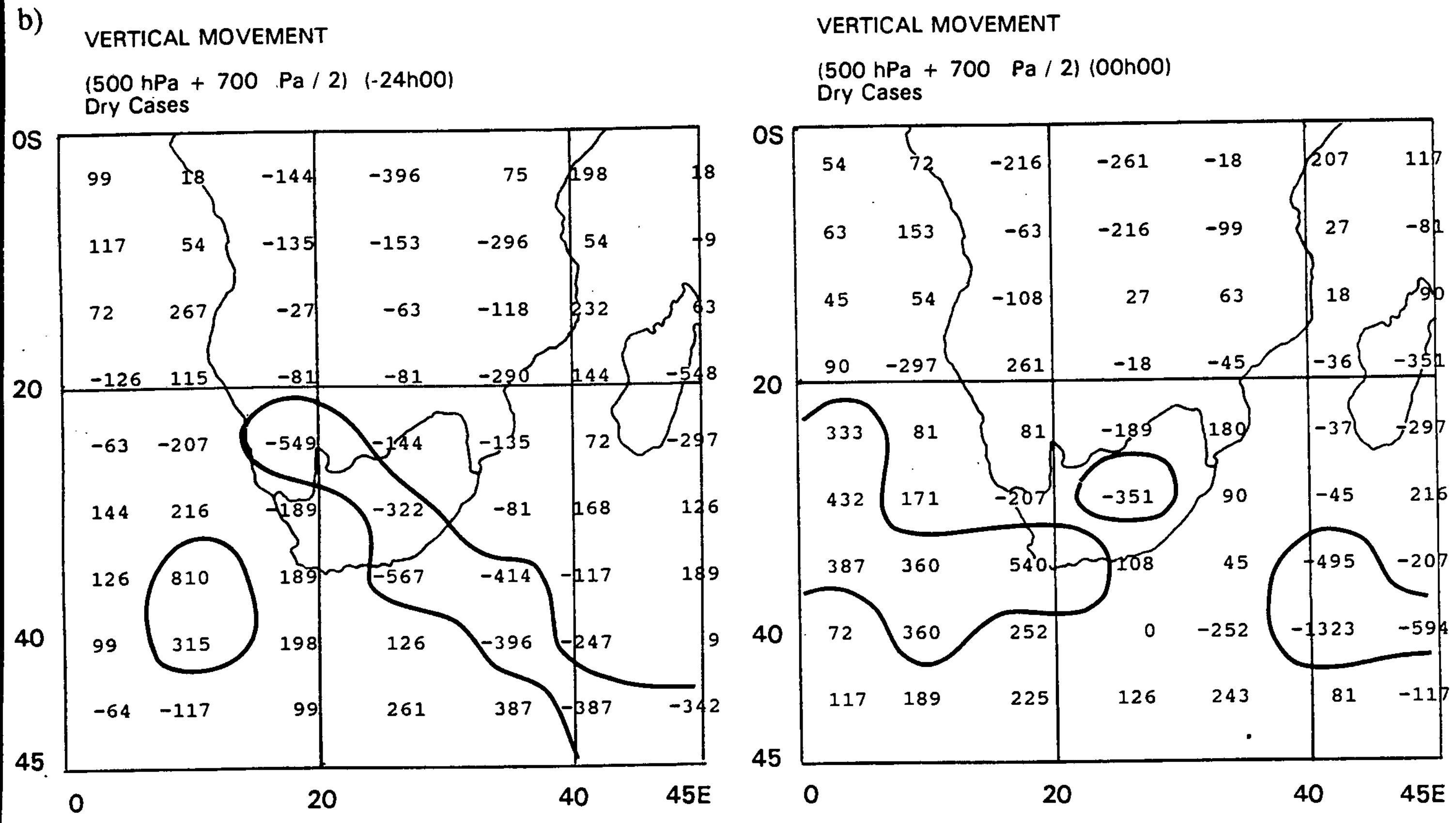


Figure 4-14 Vertical movement (Pa hr^{-1}) for -24h and 00h for (a) wet and (b) dry troughs. Regions of > +300 Pa hr^{-1} and < -300 Pa hr^{-1} are contoured.



CHAPTER 5

WET AND DRY CASE STUDY IN OCTOBER 1986

The month of October 1986 was characterised by fairly abundant rainfall over most of the country. Below normal falls were recorded over the Transvaal lowveld, northern Natal and south western Cape. The highest rainfall day over the interior occurred on the 28th over Pretoria and Bloemfontein, and was one of the highest rainfall figures recorded in the month of October in 70 years (Vallance 1986). Average monthly temperatures for the month were near normal, but sunshine hours were generally below average.

The weather preceding the dry event of 12 - 14 October 1986 was hot and clear with little precipitation. High temperatures over the interior were relieved by a depression south of the country on the 10th which advected cold air onto the south-eastern parts of the country. A cold front from the 10th to the 14th produced relatively low temperatures inland, with little rainfall recorded north of 30° S, whilst fairly good falls were recorded in the south western Cape coastal belt.

The weather leading up to the wet event of the 26 - 28 October 1986 was characterised by a couple of eastward moving cold fronts that deepened the pre-existent interior trough causing light rainfall. For two days prior to the 26th cloudy cool conditions prevailed over the eastern parts of the country. By the 27th a cold front was located over the southern parts of the country, while a low pressure area overlay the south east Transvaal. For the next 4 days until the end of the month a trough was present over the western interior and cool moist air was being fed into the trough. The upper air was favourable for convective development over much of the northern and central interior. Rainfall occurred in a north-west to south-east band across Southern Africa typical of a tropical-temperate connection.

The wet and dry event chosen for this case study are representative of early summer frontal passage. The events were chosen for their contrasting structural and dynamic differences and, the availability of data rather than for their abnormalities as single wet or dry events.

Wet Event: 26 - 30 October 1986

Synoptic Structure

The conditions at Bloemfontein represent those at other subcontinental stations and accurately depict the passage of the cold front across the subcontinent from 26 - 30 October 1986. Table 5-1 and Table 5-2 represent the various meteorological parameters for vertical time sections across Bloemfontein and, daily north-south, west-east distance sections across the interior on the 28th, the day of maximum rainfall.

The passage of the trough across South Africa is represented in the geopotential time-height section over Bloemfontein (Table 5-1) for the period 26 - 30 October 1986. Above normal departures occur throughout the troposphere in the prefrontal period. A sharp decline to below normal departures occurs from 00h below 500 hPa and marks the eastward passage of the trough. The westward tilt of the upper-level trough is evident at 00h since positive departures above 400 hPa overlie negative departures. As the upper wave moves eastward departures above 500 hPa become increasingly negative. The structure implies a fully developed frontal system whose upper-level trough to the west of the trough axis is being maintained by the opposite fields of surface and upper-level convergence and divergence fields (Figure 5-1).

Geopotential distance sections from north to south on the 28th between 26° E and 31° S include Harare, Pietersburg, Pretoria, Bloemfontein and Port Elizabeth (Table 5-2). Negative departures occur at all the stations below 600 hPa and to 300 hPa at Pretoria. Above the layer of negative values at 600 hPa, positive departures > +1.0 dominate the circulation on the 28th at all the stations. Positive geopotential departures above 300 hPa at northerly stations have been associated with wet periods (Lindesay and Jury 1991) which has been found in the mean wet composites on D-day. The west-east distance section includes 4 stations; Alexander Bay, Upington, Bloemfontein and Durban (Table 5-2). Departures at Upington are negative throughout the troposphere due to the eastward movement of the surface front followed by the westward tilted upper-level trough. At Bloemfontein and Durban positive values dominate the middle atmosphere above 500 hPa.

The surface trough shows a decline in phase speed between -12h and 00h from 28.6 m s^{-1} to 11 m s^{-1} (ref Table 3-1). At the same time the SAac shifts southward in latitude from 31° S to 40° S as it ridges quickly beneath the tip of Africa at a speed of 18 m s^{-1}, slightly below the mean for all 6 wet events. The fast ridging SAac encourages meridional flow through longitudinal alignment of an interior low pressure system, with the strong high located immediately south of the low at 25° E on the 28th. The amplitude of the 300 hPa wave is 13° latitude, and the trough speed is 6.3 m s^{-1}.

The 500 hPa spatial coverage of geopotential heights for the 26 - 28 October 1986 is presented in Figure 5-2. A decrease in geopotential height from 26 to 28 over the interior marks the eastward passage of the cold front across the country. An obvious feature from the geopotential structure is the "splitting" of geopotentials over the subcontinent on the 28th at 500 hPa which is clearly evident in the 300 hPa wind vectors (Figure 5-3). This "splitting" indicates that diffluence is occurring in the upper-level wave and jet stream. Northward penetration of the trough axis may be inferred from the north-south distance section on the 28th which shows a similar structure to the time-height geopotential height section through Bloemfontein at 00h where negative departures below 500 hPa are overlain by above normal departures at northerly stations. This structure was not evident at these stations on the 27th.

Diffluence of the upper westerly wave is usually associated with a sharply curving trough which has direct influence on the weather of South Africa. Diffluence of air motion at the upper-levels is responsible for generating upper-level divergence (ref Figure 5-1) which is vital to sustain vertical movement and surface convergence. The diffluent nature of the 300 hPa trough over the interior of South Africa, indicates the low-high dipole, of an intensifying surface low (1490 hPa) and a rapidly ridging SAac. The north-south alignment of the low and high pressure system promotes meridional flow and, the southward transport of moisture which enhances surface cyclogenesis. The splitting of the upper-level flow has a direct influence on trough slowing over South Africa.

Kinemâtic structure

The kinematic spatial structure over South Africa and the southern oceans is presented in Figure 5-3 for the 28 October 1986, (day of maximum rainfall) at 300 hPa. By considering the region between 15° - 30° E and 30° S, it is clear that the wind speed accelerates across South Africa from 15 m s^{-1} to 30 m s^{-1} in the wet events. Considering continuity, horizontal convergence at the surface is accompanied by vertical stretching, upward motion (approximately -1000 Pa hr^{-1}) and upper-level horizontal divergence (ref Figure 5-1). The kinematic vertical wind structure of the atmosphere in the South African region over the period 26 - 29 October 1986 is represented by zonal and meridional wind component anomalies through the troposphere for Pretoria and Bloemfontein in Table 5-1. At Pretoria east of the trough axis, predominantly easterly flow with a strong southerly component occurs throughout the troposphere, while D-day is characterised by an airflow from the north-east above 600 hPa whereafter north-westerly airflow with a southward component occurs at the surface. Predominantly northerly flow occurs at Bloemfontein and Pretoria in the wet events at 00h consistent with poleward flow generally associated with wet spells, (Hofmeyer and Gouws 1964, Harrison 1986). North-westerly flow from +12h at both stations throughout the upper troposphere is consistent with outflow on the front of the upper westerly wave. Prior to the location of the trough at 00h weak south-easterly winds are overlain by south-westerly winds at Bloemfontein. Closer to 00h the winds become north-easterly until 500 hPa then swing to northerly with a westerly component at 400 hPa and then back to north-easterly at 300 hPa. Southerly flow underlying the northerly flow at Pretoria and Bloemfontein is evidence for a Hadley cell which is typically characterised by near-surface equatorward flow and upper-level poleward flow. This feature is frequently linked to enhanced convection over the interior (Harrison 1986, Lindesay 1988). The north-south, distance section on the 28th shows essentially northerly flow with varying degrees of easterly and westerly direction at Harare, Pietersburg, Pretoria and Bloemfontein in the middle and upper troposphere, with southerly flow occurring at Port Elizabeth, Bloemfontein and Pietersburg near 850 hPa. The 4 stations in the west-east distance sections show north-easterly flow above 500 hPa with predominantly south-westerly flow below 500 hPa. The northerly flow overlying predominantly southerly flow at all stations except Durban, Pretoria and Port Elizabeth in the north-south, west-east distance sections provides sufficient evidence for the presence of Hadley forced convection.

Moisture availability over the period 26 - 28 October 1986

The interior of South Africa experiences sub-tropical air in circulation (Figure 5-4). Southward advection contributes to the north-south band of > 70% relative humidity at 700 hPa. A time-height section across Bloemfontein of dewpoint values (Table 5-1) clearly indicates the moist air in circulation. Dewpoint departures exceed > +1.0 throughout the profile but reach a maximum > +2.0 at the time of frontal passage above 500 hPa. The integrated precipitable water values for 26 to 28 October 1986 (Figure 5-5) show the spatial coverage of moist airflow (PW > 30 mm) south eastward across the interior of South Africa as it is drawn into the transient low pressure system. Water vapour flux vectors for the same period (Figure 5-6) show the flux of vapour across the interior of South Africa. On the 26th, westward fluxes (200 g cm^{-1} s^{-1}) predominate between 0° and 10° S, while southward fluxes (150 g cm^{-1} s^{-1}) occur over the western interior and eastward fluxes over the southern interior. The water vapour flux pattern remained essentially the same on the 27th but with a reduction in strength especially north of 10° S to < 50 g cm^{-1} s^{-1} and along the 20° E meridian where the southward flux reduced to 100 g cm^{-1} s^{-1}. On the 28th the system strengthened with easterly fluxes of 150 g cm^{-1} s^{-1} once again dominating flow between 0° and 8° S whilst a strong southward flow of moisture (300 g cm^{-1} s^{-1}) occurs across the interior of South Africa.

Thermodynamic structure and instability

The temperature structure clearly shows a 3 layered structure of cooling below 600 hPa of ≈ -1.0, a strong middle tropospheric warming of +2.2 between 300 - 600 hPa, and negative anomalies of -1,0 above 200 hPa. North-south and west-east sections of temperature and dewpoint show the thermodynamic structure of the atmosphere over 8 stations on the day of tropical-temperate interaction and maximum rainfall. The 3 layered temperature structure is clear at all stations in the north-south cross section. Below normal departures of < -1.0 occur below 700 hPa, mid-troposphere warming with a departure from > +0.8 - +2.2 occurs between 500 hPa and 300 hPa at Harare, Pietersburg, Pretoria and Bloemfontein which is overlain by negative values above 200 hPa of < -1.0. The 3-level temperature structure at northerly stations indicates tropical air in circulation on the 28th and is consistent with latent heat release in the middle troposphere due to enhanced convective activity.

Time-height sections of total static energy and EPt are presented in Table 5-1. Considering that they are both an indication of atmospheric stability only EPt will be discussed. The time-height EPt structure at Bloemfontein from 26th to 30th is haphazard with no clear profile emerging. Positive departures > +0.6 dominate the troposphere from -24h to 00h below 700 hPa, which indicates that a warm tongue of moisture extending into the frontal zone at the time of maximum rainfall is unstable. Within this same time span, positive departures ranging from 0 to +0.7 dominate the atmosphere between 600 hPa and 400 hPa which according to the 10 EPt stratification types over Bethlehem (Steyn 1988) means that warm moist air of tropical origin extends throughout the column. The vertical profiles of -24h, -12h and 00h are similar to Steyn (1988) type C stratification, which is associated with "above average" rainfall, usually occurs in mid-summer and is associated with a precipitable water value of 25,8 mm. The precipitable water value over Bloemfontein is > 25 mm (ref Figure 5-5) on the 28th. Positive departures occur in the middle troposphere of all stations in the north-south, west-east distance sections which indicates instability over the interior of South Africa.

Vertical movement on the 27 and the 28 October 1986 are presented in Figure 5-7. A region of intense vertical ascent -522 - -702 Pa hr^{-1} occurs between 15° E and 30° E in a north-east to south-west band between 20° and 30° S. Directly south of this vertical ascent, descent of +342 - +918 Pa hr^{-1} occurs between 10° E to 30° E, and centred over 38° S which represents the front edge of the fast ridging SAac. By the 28th the region of ascent at 25° E and 25° S has strengthened to -900 Pa hr^{-1} while descending motion within the ridging of the SAac continues at 40° E.

Table 5-1 Time-height sections of 26 - 30 October 1986 representing the various meteorological parameters over Bloemfontein

26 (00H00) - 30 (00H00) October 1986

28 October 1986 (00h00)

WET

Time sections (-48h00 to +36h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
100	-1.7	-1.3	-2.3	-1.3	-1.7	-1	-0.6	-0.8
200	-0.6	0	-0.2	0.2	-0.2	-0.1	1.3	1.6
300	0.4	1.1	0.3	1.6	0.5	1.9	5.2	0.7
400	0.6	0.8	0.7	0.3	0.8	2.2	0.4	1.3
500	0	0.6	0.3	0.7	0.5	1.6	0.1	0.4
600	0.2	0.8	0.8	0.2	0.4	0.2	-0.8	-1.2
700	0.2	0.7	1.3	0.9	1	-0.8	-0.8	-1.4
850	-1.1	1	-0.8	1.3	-1.3	-1.6	-2.6	-1.4

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	2.1	1	1.7	0.5	2	2	0.3	0.4
400	2.1	0.5	1.5	0.9	2.1	2.3	1	0.3
500	1.8	0.7	1.5	1.6	1.6	1.9	1.3	0.3
600	1.6	1.1	1.3	0.5	1	1.2	1.2	1.4
700	1.5	1.3	1	0.3	0.3	1.1	1.3	0.9
850	1.6	1.5	1.7	-0.5	0.9	1.5	0.8	1.3

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.9	1	0.9	0.9	0.9	0.9	0	0
300	0.9	0.9	0.7	0.7	0.6	0.6	-0.5	-0.5
400	0.9	1	0.7	0.7	0.1	0.1	-0.8	-0.8
500	1.1	1.1	0.7	0.7	-0.5	-0.5	-1.3	-1.3
600	1.1	1.1	0.5	0.5	-0.9	-0.9	-1.3	-1.4
700	1.1	1.1	0.4	0.4	-1.1	-1.1	-1.3	-1.3
850	0.7	0.7	-0.2	-0.2	-0.6	-0.5	-0.5	-0.5

Wind U component (Bloemfontein)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1.7	1.2	0.7	0.7	0.8	0.6	0.1	0.2
300	-0.4	1.2	0.6	1.2	0.4	-0.1	-0.7	1.7
400	0.3	0.4	0.8	0.2	0.4	0.4	0.6	1.4
500	0	-0.2	0.8	0.3	-0.8	0.4	0.4	0.7
600	-0.7	-0.6	1	0.7	-0.5	-0.2	-0.1	0.5
700	-0.5	0.2	0.8	0.4	-0.8	-1.4	0.9	0.7
850	-1.7	0.2	-0.7	0	-0.5	-0.9	-0.9	-0.7

Wind V component (Bloemfontein)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.4	-0.2	0.7	0.8	1.2	0.3	-0.4	0.7
300	-0.6	0.1	1.9	0.6	0.2	-0.6	-0.2	-0.2
400	0.3	0.4	0	0.8	0.2	-1.9	-0.3	0.2
500	0.7	0.6	0.3	0.3	0.2	-1.7	-0.1	1
600	0.8	0.6	1	0.8	0.1	-1.2	-0.8	1.6
700	0.3	0	0.7	0.6	-0.6	-1.2	3.1	1.5
850	1.1	0.6	1.1	0.8	-0.3	-1.1	-0.2	0.2

Wind U component (Pretoria)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.8	0.5	0.2	0.2	-0.1	0.8	0.8	1.3
300	0.4	-0.1	0.4	0.1	-0.5	0.2	0.7	1
400	-0.7	-0.8	-0.1	-0.2	-0.4	0.2	1	-0.2
500	-0.7	-0.7	-0.2	-0.2	-0.1	-0.1	1.2	1.2
600	-0.3	-0.5	-0.7	-0.3	-1.1	0.1	1.6	1.2
700	0.5	-0.3	-0.3	-0.2	0	0	0.3	0.9
850	-0.6	0.1	0.1	0.3	0.4	-0.6	-0.5	-0.4

Wind V component (Pretoria)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1.1	1.7	1.1	1.2	0.5	0.7	-0.7	0.7
300	0.8	0.3	1.5	1.1	-0.5	0.3	-0.6	1.3
400	0.2	0.9	0.1	0.6	-0.6	0.3	0	1
500	-0.1	0.5	0.9	0.5	-0.9	-1.1	-1	1.3
600	-0.1	1.1	1.4	0.4	0.8	-1.3	0	0.4
700	0.5	0.9	1.1	0.2	0.6	-2.5	-0.6	-0.1
850	0.5	0.2	1.2	0.4	1	0.2	0.7	0.1

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.9	-0.2	0.3	1.7	0	-1.9	0.1	-1.6
400	-0.6	-0.7	0.7	0.5	-0.7	-0.9	0	-0.9
500	-0.8	0	-0.4	-1.1	-0.8	-1.3	0.3	-0.9
600	-0.9	-0.3	-0.9	-1.2	-0.6	-1.3	0.6	0
700	-0.6	-0.3	-1.1	-0.9	-0.2	-1.8	0.6	0.2
850	-0.8	-0.6	-0.6	0.3	-0.7	-1.5	1.6	-0.1

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.1	0.4	0.2	0	0.5	1.8	1.2	0.9
400	0.3	0.4	0.3	0	0.4	1.8	-0.7	0.9
500	0.3	0.4	0.4	0.5	0.3	0.9	-0.1	0.4
600	0.3	0.5	0.5	0.3	0.4	0.3	-0.1	-0.2
700	0.4	0.7	1	0.8	0.9	-0.1	-0.1	-0.4
850	-0.8	1.1	-0.5	1.3	-0.9	-1.2	-2.1	-1

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.7	1.3	0.7	1.6	1	2	0.9	0.3
400	1.5	0.8	1.1	0.5	1.4	2.4	0	0.5
500	1.8	0.7	1.4	1.1	1.1	1.5	0.1	0.2
600	1.8	0.7	1.4	1.1	0.7	1.3	0.6	0.4
700	1.6	1.9	1.2	0.6	0.3	1	0.9	0.8

Table 5-2 North-south, west-east distance sections for 28 October 1986 representing the spatial variation of the various meteorological parameters

28 October 1986 (00H00)

WET

Location of the cold front over BLM

Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
100			-0.7	-1.8	-0.4
200	-2		-0.4	-0.2	0.6
300	0.9	2.1	1.6	1.9	1.6
400	0.5	2.1	1.6	2.2	0.7
500	1.1	1.5	0.8	-1.6	1.2
600	0.2	0	0.2	0.2	1.3
700	1	0	0.2	-0.8	0.1
850	1.1	-0.3	-0.2	-1.6	-1.4

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.7	-0.7	2.3	2	2
400	1.6	1.1	2.1	2.1	0.7
500	0.8	0.9	1.5	1.6	-0.3
600	1.4	1.2	1.1	1	-0.2
700	0.8	1.2	1	0.3	0.2
850	0.5	0.9	0.6	0.9	-0.6

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.6	1.2	-0.2	-0.5	0.9
300	0.5	0.9	-0.1	0.6	0.6
400	0.5	0.3	-0.3	0.9	0.4
500	0.1	0.4	-0.8	0.1	0.3
600	-0.4	-0.4	-1.1	-0.5	-0.1
700	-0.9	0	-1.2	-0.9	-0.4
850	-1.1	-0.6	-1.3	-1.1	0.5

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.4	0	0.8	0.3	0.9
300	0	0.4	-0.4	0.4	1
400	0.4	0.3	-0.4	0.4	0.3
500	0.8	1.2	0	-0.8	0.4
600	0.9	1.4	-1.1	-0.5	0.5
700	1	-3	0.1	-0.8	-0.3
850	0.1	-3	0.4	-0.5	-1.1

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.4	0	0.5	-0.3	0.4
300	-0.3	0.8	-0.4	-0.6	0.3
400	-1	0.2	-0.6	0.1	1.2
500	-0.7	-1.5	-0.9	0.2	1.5
600	-1.6	-3	0.4	0.2	1.6
700	-0.8	-2.9	-0.5	0.2	0.7
850	-0.3	3.4	-0.6	1.2	0.8

28 October 1986 (00H00)

WET

Location of the cold front over BLM

Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durba
100	-0.5	-1	-1.8	0
200	-0.5	0.8	-0.2	-0.2
300	0	1	1.9	1.4
400	-1.7	0.5	2.2	0.6
500	-0.8	0.2	-1.6	0.7
600	-0.6	-0.1	0.2	0.3
700	-1.5	-1	-0.8	-0.8
850	-0.4	-1.7	-1.6	-1.5

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durba
300	1.8	2.7	2	0.5
400	1.8	2.6	2.1	1.1
500	1.7	2.1	1.6	0.3
600	-1.8	-1.5	-1	0.1
700	1.8	0.5	0.3	0.7
850	1.6	0.5	0.9	0.4

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durba
200	-1.2	-0.8	-0.5	0.6
300	-1.3	-0.3	0.6	0.2
400	-0.8	0	0.9	0.5
500	-1.5	-0.7	0.1	-0.2
600	-1.3	-0.9	-0.5	-0.4
700	-1.3	-1.1	-0.9	-0.6
850	-1.2	-1.3	-1.1	-0.6

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durba
200	-1.5	-2.2	-0.3	0.9
300	-0.9	-0.4	-0.6	1
400	-0.7	-0.6	0.1	0.9
500	1.1	-0.9	0.2	0.7
600	0.3	-0.3	0.2	0.2
700	0.3	-0.1	1.2	-0.7
850	-1.4	1.4	1.2	1.5

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durba
200	-1.5	-2.2	-0.3	0.9
300	-0.9	-0.4	-0.6	1
400	-0.7	-0.6	0.1	0.9
500	1.1	-0.9	0.2	0.7
600	0.3	-0.3	0.2	0.2
700	0.3	-0.1	1.2	-0.7
850	-1.4	1.4	1.2	1.5

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.2	-0.2	0	1.6	-0.6
400	-1.1	-0.3	-0.3	-0.2	-1
500	-0.6	-0.8	-1.2	-0.6	-0.7
600	-1	-0.7	-0.9	-0.8	-0.4
700	-0.1	-0.5	-0.7	-0.7	1.1
850	0.8	0.7	0.8	0	-1.4

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durba
300	0.2	0.4	1.6	-0.7
400	0.3	1	-0.2	-1.2
500	1.3	0.7	-0.6	-1
600	0.7	-0.3	-0.8	0.6
700	-0.4	-1	-0.7	-0.8
850	-0.4	-1.2	0	-0.6

Equivalent Potential temp 27th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.2	2	1.6	1.8	1.6
400	1.2	0.6	0.2	0.4	1.1
500	0.2	1.3	0.4	0.7	1.1
600	1.8	0.6	0.7	0.6	0.5
700	0.5	0.5	1.1	1.2	-0.6
850	0.7	1.4	-0.2	1.4	-0.3

Equivalent Potential temp 27th

	Alex Bay	Uping	Blmfnt	Durba
300	1.7	2	1.8	0.9
400	1.6	1.1	0.4	1.8
500	1.2	0.9	0.7	1
600	0.8	0.8	0.6	0.9
700	0.7	0.9	1.2	0.7
850	1.1	0.8	1.4	0

Equivalent Potential temp 28th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.5	1.6	1.4	2	1.9
400	0.8	1.6	1.3	2	1
500	0.9	1.2	0.8	1	1.5
600	0.3	0.5	0.4	0.6	1.6
700	0.8	0.2	0.4	0.4	0.5
850	0.9	-0.2	-0.5	-0.9	-1.1

Equivalent Potential temp 27th

	Alex Bay	Uping	Blmfnt	Durba
300	0.8	0.9	2.1	1.6
400	-0.5	0.6	1.2	0.9
500	0.2	0.3	1	0.9
600	0.5	0.3	0.6	0.6
700	-0.3	-0.2	0.4	-0.3
850	0.2	-1.1	-0.8	-1.1

Total Static energy 27th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.2	2	1.5	1.6	1.4
400	1.2	0.7	0.7	0.5	1
500	-0.4	1	0.9	1.1	0.9
600	-0.4	2.1	0.6	1.1	0.4
700	0.8	2	2	0.7	-0.2
850	1.6	1.1	-0.2	0.1	0.4

Total Static energy 27th

	Alex Bay	Uping	Blmfnt	Durba
300	1.9	1.9	1.6	0.9
400	2.1	1.5	0.5	0.7
500	2	1.6	1.1	0.4
600	2.2	1.9	1.1	0.1
700	1.5	1	0.7	0.8
850	-0.1	-0.2	0.1	0.6

Total Static energy 28th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.4	1.7	1.4	1.9	1.8
400	2.2	1.1	1.7	2.4	0.9
500	1	0.9	1.7	1.5	1.2
600	1.5	0.9	1.5	1.3	0.6
700	1.3	2.1	1.4	1	-0.2
850	1.2	0.8	-0.3	0.5	-0.7

Total Static energy 28th

	Alex Bay	Uping	Blmfnt	Durba
300	0.7	0.9	1.9	1.7
400	-0.3	0.7	2.4	1.3
500	0.1	0.9	1.5	0.6
600	0.9	1.3	1.3	0.5
700	0.4	1	1	0.3
850	1.5	0.3	0.5	-1.2

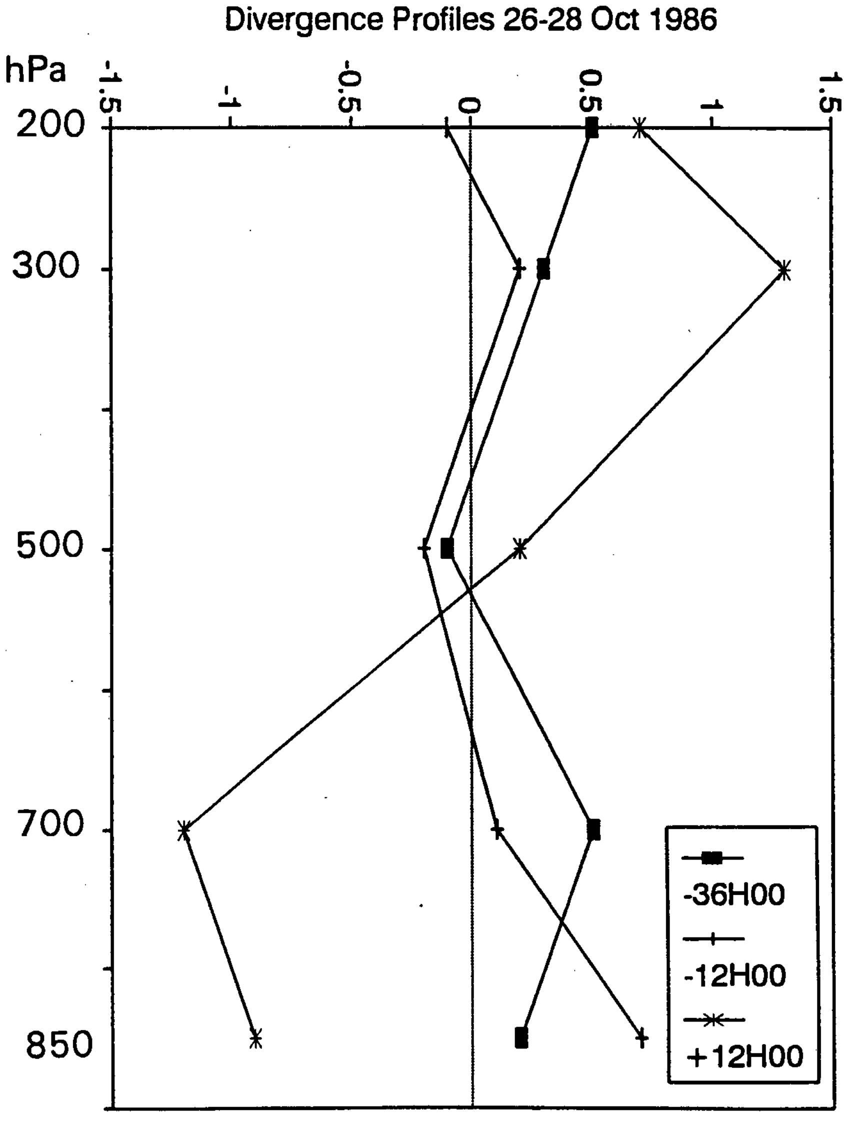


Figure 5-1 Divergence profiles ($10^{-5}s^{-1}$) for the wet case of 26 - 28 October 1986, for -24h, 00h and +24h.

GEOPOTENTIAL HEIGHTS (m) (500 hPa)
Wet 26 - 28 October 1986

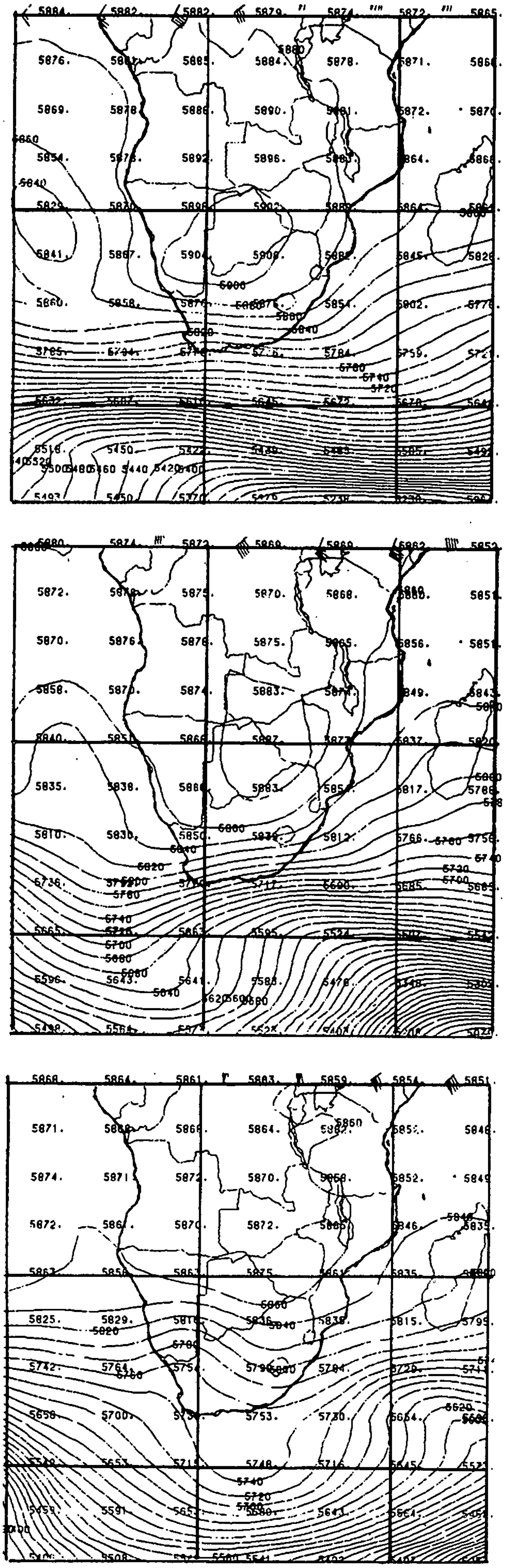


Figure 5-2 ECMWF (500 hPa) geopotential height for the wet event of 26 - 28 October 1986.

KINEMATIC FIELD (300 hPa)
28 October 1986

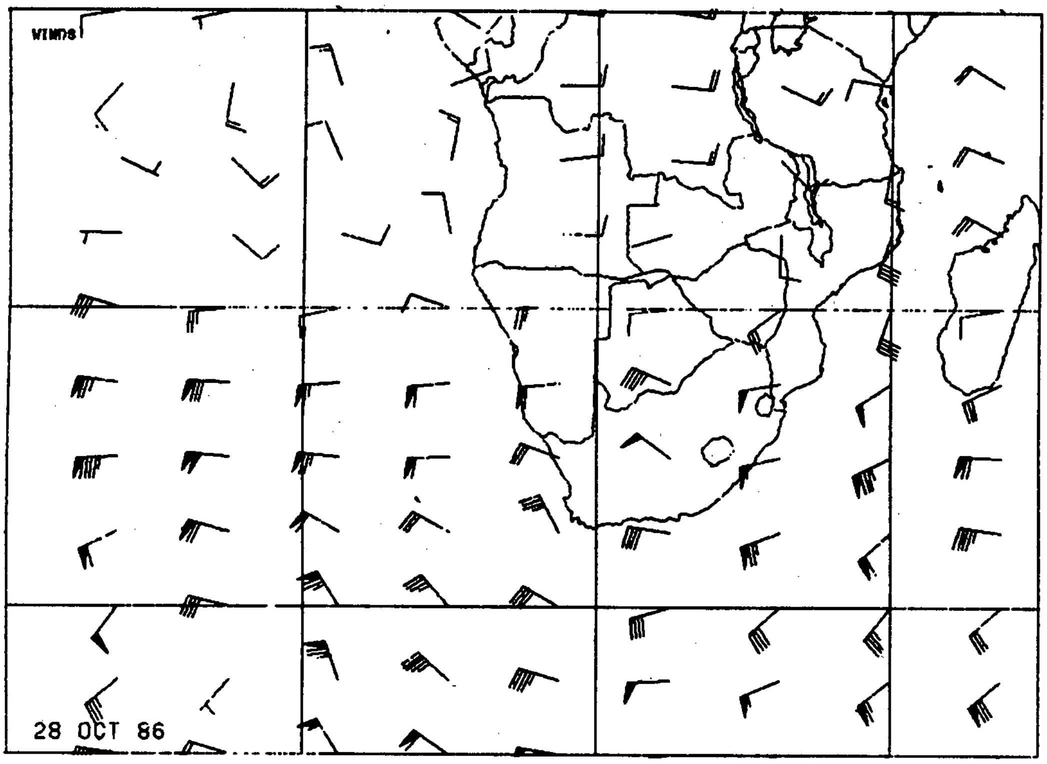


Figure 5-3 ECMWF (300 hPa) wind vectors (kts) for 28 October 1986, D-day.

KINEMATIC FIELD (300 hPa)
14 October 1986

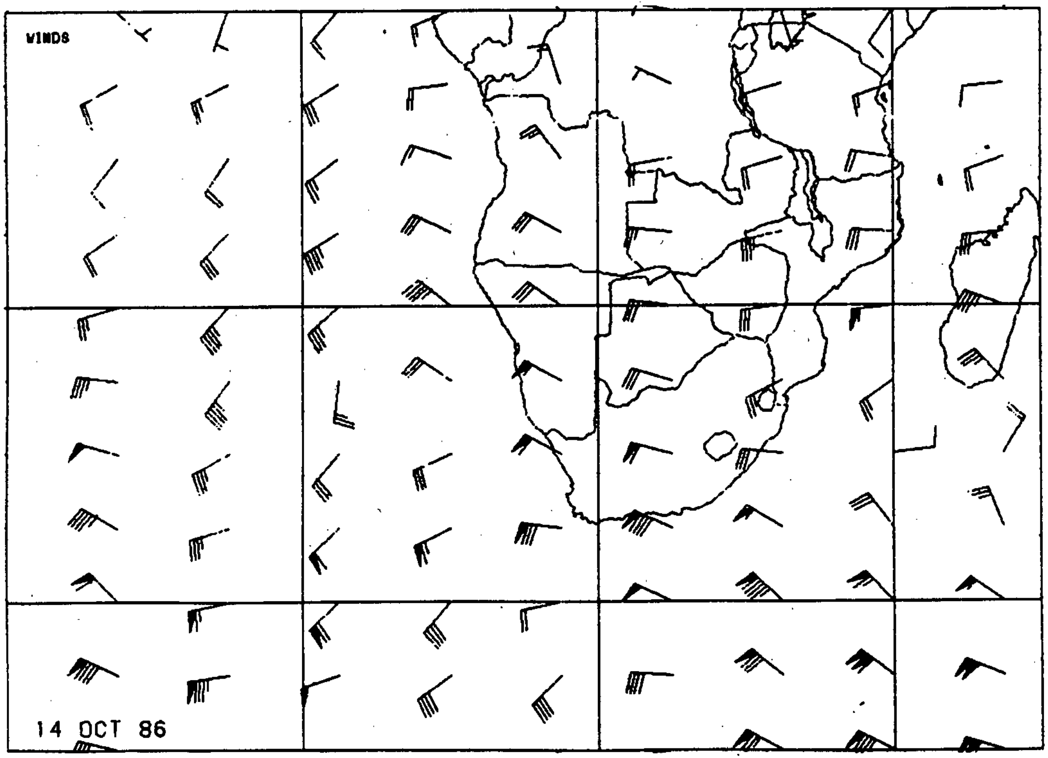


Figure 5-9 ECMWF (300 hPa) wind vectors (kts) for 14 October 1986, D-day.

RELATIVE HUMIDITY % (700 hPa)
26 - 28 October 1986

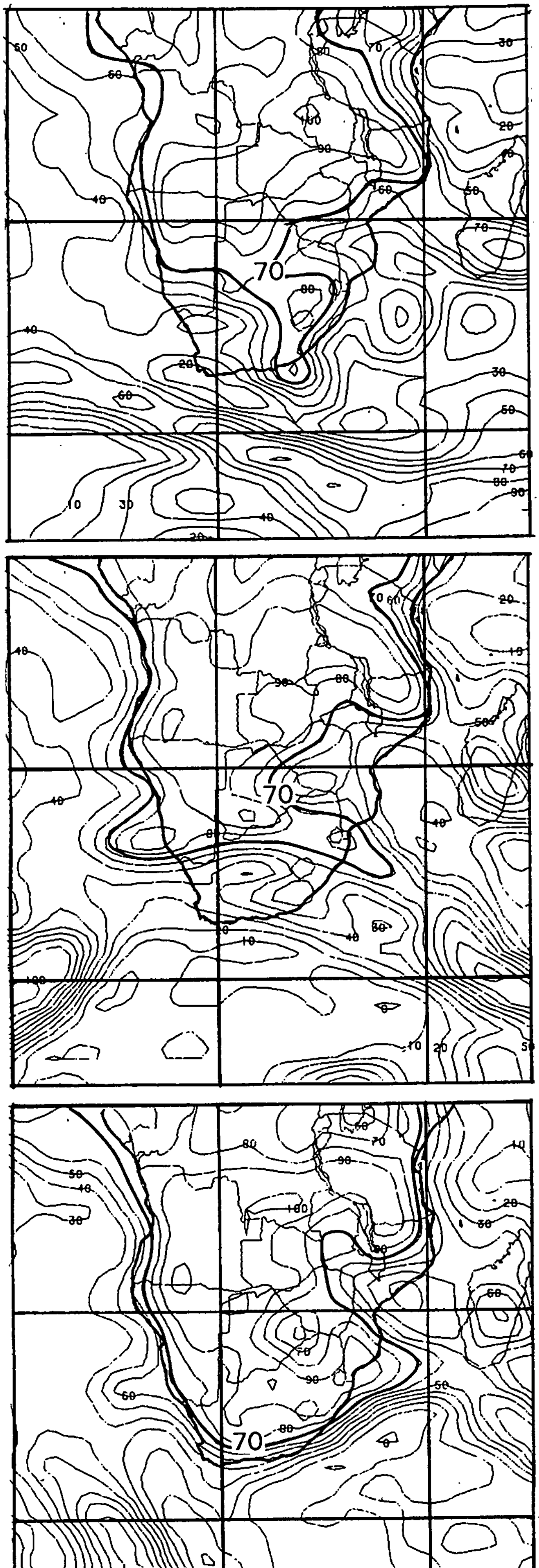
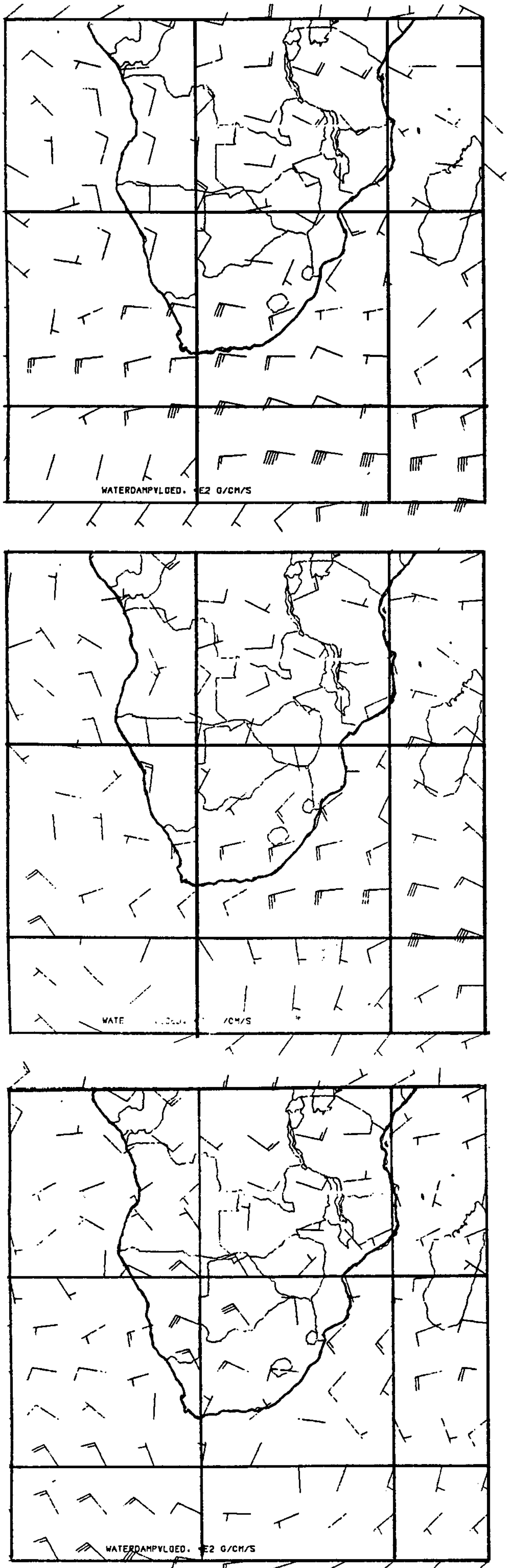


Figure 5-4 ECMWF (700 hPa) relative humidity (%) for the wet event of 26 - 28 October 1986

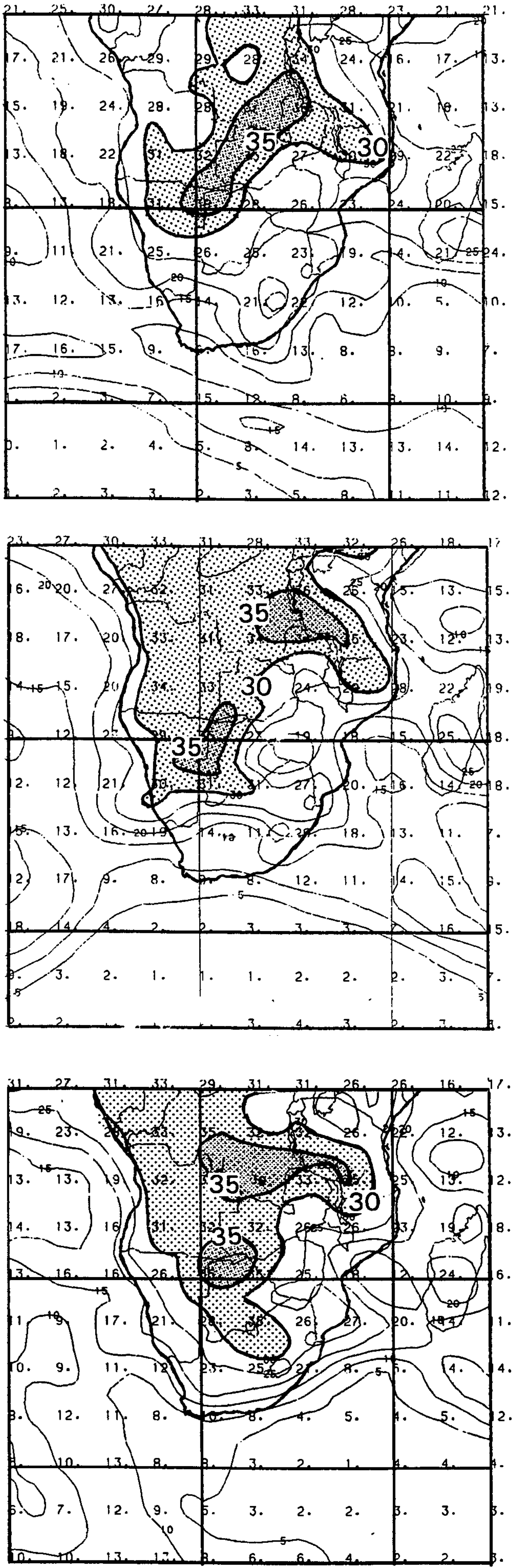
Figure 5-5 ECMWF precipitable water (mm) fields for the wet event of 26 - 28 October 1986.

Figure 5-6 ECMWF water vapour fluxes (g $cm^{-1}s^{-1}$) for the wet event of 26 - 28 October 1986.

WATER VAPOUR FLUX (g cm s^{-1})
Wet 26 - 28 October 1986



PRECIPITABLE WATER (mm)
Wet 26 - 28 October 1986



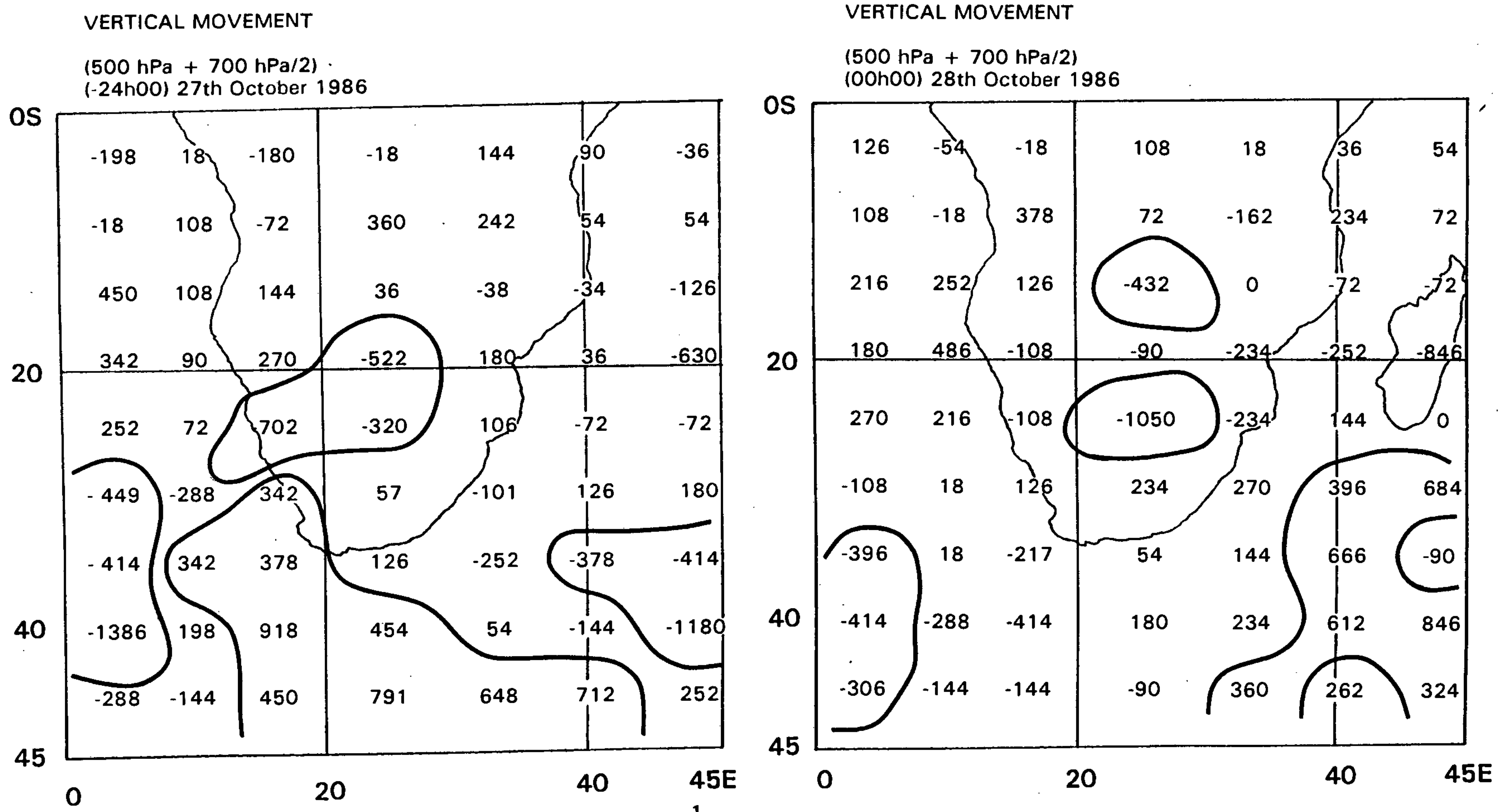


Figure 5-7 Vertical movement (Pa hr^{-1}) for -24h and 00h, the 27 and 28 October 1986. Regions of $> +300$ Pa hr^{-1} (descent) and < -300 Pa hr^{-1} (ascent) are contoured.

Dry Event: 12 - 16 October 1986

Synoptic Structure

The passage of a trough across South Africa over the period 12 - 16 October 1986 is represented in the time-height section of geopotential departures across Bloemfontein from -48h to +36h from 850 hPa to 200 hPa and is presented in Table 5-3.

Unlike the wet event of the 26 - 30 October 1986 where a distinct westward tilt of the upper trough occurs. Below normal departures dominate the troposphere at -12h and 00h in the dry events and indicate vertical alignment of the surface and upper-level trough. This "upright" structure implies that surface and upper-level divergence and convergence are incorrectly aligned and that vertical motion which is vital to maintain the upper-level trough is not sustained. The barotropic nature of this dry trough in a region which is generally characterised by baroclinicity suggests that the frontal event is in a state of decay between -12h and 00h and that little synoptic forcing is occurring. The fast phase speed of the upper-level trough at D-day of 18 m s^{-1} (ref Table 3-1) is a further indication that little interaction is possible.

The 500 hPa ECMWF geopotential heights for the 12 - 14 October 1986 (Figure 5-8) show the upper westerly wavelength of 51° longitude and amplitude of 10° latitude moving south-eastwards. The SAac moves slowly in comparison to both the mean speeds and to the wet event of the 26 - 28 October 1986. During the course of the dry event the SAac is located between 31.5° S to 36.5° S, 3° latitude further north than the wet event implying intrusion over the western interior. The north-south, west-east geopotential distance sections across the interior of the country are presented in Table 5-4 for the 14 October 1986. The below normal departures at all the stations throughout the troposphere infer that; firstly, all the radiosonde stations in the north-west, south-east sections are influenced by the frontal system, and secondly, the negative values above 500 hPa show that no westward tilt of the trough occurs.

Kinematic Structure

The spatial kinematic field over South Africa and the southern oceans is presented in Figure 5-9 for 14 October 1986 at 300 hPa (Figure 5-9 is appended to the same page as Figure 5-3). Unlike 28 October 1986 where the wind speed accelerates across South Africa at 30° S causing upper-level divergence and surface convergence to satisfy the continuity equation, the 14th is characterised by decelerating winds over 30° S from 30 m s^{-1} to 15 m s^{-1}. This deceleration indicates that horizontal divergence at the surface must be accompanied by vertical shrinking and convergence at the upper-level on D-day (Figure 5-10). The kinematic structure for the 12 - 14 October 1986 shows an unusual north-easterly flow prior to onset of the cold front over Bloemfontein, followed by strong north-westerly flow. The meridional wind departure across Bloemfontein from 00h to +36h shows southerly flow above 300 hPa, and strong northerly flow throughout the middle and lower atmosphere. This upper-level equatorward flow and low-level poleward flow suggests a Ferrel circulation with the major axis of surface convergence occurring south of South Africa with upper-level subsidence occurring over the interior of South Africa. Prefrontal south-easterly flow dominates the flow at Pretoria throughout the troposphere, which is followed by north-westerlies at 00h and +12h throughout the troposphere. North-westerly flow with a strong westerly component dominates the west-east cross section on the 14th while moist north-easterly flow above 500 hPa overrides dry westerly flow in the north-south cross section.

The reasons as to why the events are dry must depend upon the prefrontal moist inflow of air, the synoptic structure and prevailing divergence fields. Evidence from the barotropic nature of the frontal system suggests that the upper-level trough is in a state of decay, and the accelerating winds at 300 hPa suggest that upper-level convergence and subsidence are dominant on the 14th. The availability of moisture and the thermodynamic process will be discussed below.

Moisture availability over the period 12 - 16 October 1986.

The events leading up to the start of the dry event on the 12 October 1986 were responsible for the very low relative humidity (10%) present over the interior of South Africa (Figure 5-11). These were an eastward moving SAac on the 6th and a southward displaced trough from the 6th until the 10th. By the 13th the area bounded by the > 70% relative humidity contour had decreased from the west on the 12th and retracted northwards to north of 20° S. A small west-north-west to east-south-east band of > 70% lay along the front axis of the trough to the south of South Africa. Little difference in relative humidity is observed on the 14th, except for a slight increase over the interior to 20 - 30%. The complete lack of any southward flow of moisture on the 12th and 13th in this dry event appears to be due to an eastward moving high pressure system which actively erodes any available moisture. An indication of the lack of moisture in the troposphere is shown in the dewpoint time-height section from the 12 - 16 October 1986 (Table 5-3) where below normal dewpoint departures (> -1.0) occur both prior to D-day, and below 600 hPa between -12h and +12h from -0.3 to -1.2. The distance sections on the 14th show negative dewpoint values at all of the northerly stations below 600 hPa Harare (> -1.0), Pietersburg (-0.3) and Pretoria (-0.9).

The integrated precipitable water (mm) values for the 12th until the 14th are represented in Figure 5-12. A north-west to south-east band of very low precipitable water values < 10 mm dominate the interior from 16° - 30° S and from 20° - 25° E on the 12th. North of this dry zone values > 25 mm dominate the subcontinent to the north of 15° S. By the 13th values have risen over the interior from < 10 mm to 12 mm, but the main region of moisture > 25 mm has remained stationary, north of 15° S. Only on the 14th does a narrow tongue of moisture (> 30 mm) push south and the precipitable water values increase over the interior of South Africa to 18 mm in the central interior and 8 mm in the northern Cape.

The moisture fluxes are presented in Figure 5-13. Westward flow of moisture (150 g cm^{-1} s^{-1}) in tropical latitudes prevails from the 12th until the 14th and is responsible for bringing moist air into the interior north of 20° S. However, unlike 26 October 1986 in the wet event, the moisture is not advected southwards as a prefrontal moist flow 48 hours before D-day, instead the vector directions are haphazard on the 12th with little southward flow. An interior low pressure system over the interior is weakened so there is no pressure configuration to draw the moisture southward. Meridional advection occurs briefly on the 14th, aided by the west limb of an east coast high pressure system. Although the moisture fluxes appear to be in favour of precipitation, precipitable water values are 15 mm less than the wet event on the 28th and little rainfall occurs.

Thermodynamic structure and instability

The dry prefrontal environment from -48h to -24h can be seen in the high temperature, low dewpoint and high geopotential departures presented in Table 5-3 in the lower troposphere below 600 hPa. This warming, high geopotential departures and the well below normal dewpoint departures indicate the presence of an interior anticyclone and associated subsidence of dry air which actively erodes the moist air prior to D-day. The temperature structure for -24h to 00h shows that below normal values dominate the profile at +12h and +24h above 600 hPa which does not indicate latent heat release.

The time-height section for EPt is presented in Table 5-3, however no clear pattern of stability emerges. From -12h to +12h, departures are close to zero or negative compared to the wet event where positive departures in the vertical column occur from -12h to +12h. At the individual stations, north-south, west-east cross sections (Table 5-4) of EPt on the 14th show greater instability at lower levels than the Bloemfontein time sections (Table 5-3). Greater anomaly differences of +1.2 in the 700 - 850 hPa layer are recorded for the west-east cross section over South Africa, whilst negligible equivalent potential temperature gradients are found in the Harare - Port Elizabeth distance section.

The vertical velocity (Pa hr^{-1}) is presented in Figure 5-14 for 13 and 14 October 1986. On the 13th A west-east band of ascent > -300 Pa hr^{-1} occurs north of 10° S while a second west-east band occurs at 25° S stretching westwards into the Atlantic ocean. Strong descent occurs just west of South Africa. On the 14th vertical uplift at 20° E over the northern Cape is responsible for some rainfall in the south western Cape. The region of descent has shifted slightly eastwards.

Table 5-3 Time-height sections of 12 - 16 October 1986 representing the various meteorological parameters over Bloemfontein

12 (12H00) - 16 (12H00) October 1986
14 October (12h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
100	-0.6	-0.2	0.3	0.2	0.3	-0.1	-0.1	0
200	-1.4	-1	-1	-1	-0.8	-0.7	0.2	-0.6
300	-0.2	0.9	0.2	0.2	0.5	-0.8	-0.9	0.1
400	0.9	0.9	0.8	0	0.4	-0.6	-0.4	0.9
500	1.4	0.9	1.3	-0.6	-0.4	-0.7	-0.5	0
600	1.8	1.8	0.5	0.5	0.2	0	-1	0.5
700	1.4	1.2	1.7	1.6	-0.3	0.3	0.4	0.8
850	0.7	-1.3	1.3	-1.3	0.6	-1.9	0.3	-0.7

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.2	-0.8	-0.7	0.7	1.2	1.6	0.1	1.8
400	0.3	-0.1	-0.5	0	-0.2	0.7	1	1.5
500	0.4	-0.4	-1.2	1	1.1	1.3	1.4	1.6
600	-1.6	-1.1	0	0.4	-0.5	0.8	1	1.3
700	-0.7	0.2	0	-0.9	-0.3	0.3	0.5	1
850	0.1	-0.2	-1.2	-1.1	-1.2	-0.8	0.4	0.1

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.3	0.1	0.2	-0.5	-0.5	-0.9	-0.2	-0.5
300	0.6	0.5	0.4	3.4	-0.4	-0.8	-0.3	0.7
400	0.9	0	-0.3	-0.4	-0.1	0.1	0.5	0.2
500	0.9	-0.2	-0.5	-0.5	0	0.6	1	0.6
600	1.2	-0.3	-0.6	-0.8	-0.3	0.7	1.4	1
700	1.3	-0.2	-0.6	-0.8	-0.2	0.8	1.7	1.6
850	1.4	0.3	-0.3	-0.2	1	2.2	2.9	2.2

Wind U component (Bloemfontein)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.4	-0.2	0.1	-0.8	0.3	-1.5	0.1	-2.3
300	-1.3	-0.4	-0.7	-0.6	0.2	-1.2	0.4	0.5
400	-1.3	-0.5	-0.4	0.5	0.5	0.5	0.7	0.4
500	-1.4	-0.5	-0.5	1	1.9	1.2	0.3	0.9
600	-0.5	-0.6	-0.1	1.5	1.9	1.3	0.3	0.2
700	-1.1	-0.8	0.6	0.9	0.7	1.1	1.1	0.3
850	-0.5	-1.6	0.6	-0.7	0.8	-0.7	0.2	-0.7

Wind V component (Bloemfontein)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.3	-1.1	-0.6	-0.5	0.3	1.4	0.3	1.3
300	0.9	-1.1	-0.6	-0.2	-0.7	0.2	-1.3	
400	0.4	-0.4	-0.5	-1.5	-0.8	-1	-1.4	-1.3
500	0.2	-0.3	-0.4	-1.2	-0.9	-1	-1.6	-0.1
600	0.5	-0.8	-0.7	-0.9	-1.1	-1.5	-1.1	0.2
700	0.5	-0.3	-0.7	-0.9	0.3	-1.7	-0.6	-0.3
850	1	-0.2	-0.7	0.7	0.5	0.7	-0.2	0.7

Wind U component (Pretoria)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-1.3	-0.7	-1.2	-0.6	-0.7	0.5	0.4	1.3
300	-1.4	-1.3	-1	-0.6	-0.3	0.6	0	0.1
400	-1	-1	-1.4	-0.4	0	0.2	0	0.1
500	-1.2	-1.2	-0.6	0.2	0.5	-0.2	-0.2	-0.3
600	-0.8	-0.9	-0.8	0.5	0.6	0	-0.4	-0.7
700	-0.7	-0.6	-0.7	0.5	0.8	0.2	-0.5	-0.1
850	0.3	-0.3	0.2	0.6	0.5	-0.2	-0.1	0

Wind V component (Pretoria)

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1	0.5	0.4	0.3	-0.3	-0.3	-1.3	-1.6
300	1.1	0.9	0.7	-0.3	-0.1	-0.4	-1	-1
400	1.9	1.5	0.7	-0.6	-0.5	-0.9	-1.2	-1.1
500	1.6	1.2	1.3	0.1	-0.5	-0.9	-0.4	-1.2
600	1.5	0.8	1.3	0.9	0.5	-0.1	-1	-2.3
700	0.1	0.8	0.1	1.5	-0.5	-0.6	-1.7	-1
850	-0.6	0.5	-0.5	1	-1	0.1	-1.4	-0.7

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.2	0.9	1.1	0	-1.2	-0.8	-0.4	-0.7
400	0	0.7	0.9	0.4	0.3	-0.3	-1	-0.5
500	0.2	1.1	1.8	-0.6	-1	-0.9	-1.3	-1
600	2.5	2.1	0.4	0.1	0.9	-0.4	-1.1	-0.8
700	1.9	0.7	1.1	2.2	1	0.4	0.2	-0.3
850	0.8	1.1	2.3	2.1	1.8	1.3	0.3	1.2

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.6	-1.3	-0.2	-0.2	0.1	0.4	-1.4	0.2
400	0.5	-0.9	0.4	0.5	0	0.2	-0.7	0
500	0.7	-0.1	0.7	0.2	0	0.2	0	0.8
600	0.8	0.2	0.4	0.4	0.2	0.1	-0.2	0.7
700	1	0.4	1.2	0.7	0.1	-0.5	0.5	0.3
850	0.7	-1.5	1.3	-0.4	0.6	-1.8	0.5	-0.2

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.1	0.2	0.2	0.1	0.7	-0.6	-0.5	0.3
400	0.7	0.6	0.4	-0.1	0.3	-0.4	0	0.9
500	0.8	0.2	0.5	-0.4	0.5	-0.3	0.5	0.6
600	0.3	-0.1	0.3	-0.1	0	-0.1	0.5	0.7
700	0.1	0.1	0.6	-0.3	-0.2	-0.2	0.6	0.6

Table 5-4 North-south, west-east distance sections for 14 October 1986 representing the spatial variation of the various meteorological parameters

14 October 1986 (12h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
100			1.3	-0.1	-1.3
200	-0.9	0.5	-0.4	-0.8	0.8
300	0.5	1	0.3	0.5	-0.1
400	-1.6	-0.3	-0.6	0.4	-0.7
500	-0.9	0.2	-0.4	-0.4	-0.6
600	-0.7	0.3	0.2	0.2	-1.7
700	0.7	1	1.3	-0.3	-1.4
850	0.1	1	1.6	0.6	-1.3

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.4	-1.3	-1	0.7	1.6
400	0.1	-0.5	-0.4	0	0.9
500	0.7	-0.7	-0.3	1	0.4
600	-1.2	-0.1	0.1	0.4	1.4
700	-0.4	-0.3	-0.9	-0.9	1.2
850	-1	0.1	0.6	-1.1	0.8

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.7	0.2	-1	-0.5	-1
300	0.5	0.2	-0.9	-0.4	-1
400	-0.8	-0.1	-0.7	-0.6	-1.1
500	-0.1	0.6	-0.2	-0.6	-1.1
600	0.2	-0.1	0.1	-0.7	-1.1
700	0.4	0.2	0	-0.6	-0.8
850	-0.5	-1.1	-0.9	-0.6	0.1

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.5	-1.5	-0.9	-0.5	-1.7
300	1.2	-0.6	-0.7	-0.2	-1.2
400	0.2	0	-0.4	0.5	-0.9
500	-0.5	-0.8	0.1	1	0.4
600	-0.6	-0.8	0.5	1.5	1.3
700	-1.2	1.9	0.5	0.9	2.7
850	0.3	6.6	-0.3	-0.7	3.4

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.9	-0.2	0.3	-0.8	0.6
300	-0.3	0.4	-0.1	-0.6	-0.2
400	-0.4	2.2	-0.6	-1.5	-0.9
500	0.2	0.8	0.1	-1.2	-1.2
600	-0.1	1.4	0.9	-0.9	-2.1
700	-0.5	0.6	0.1	-0.9	-2.9
850	-1.3	-2.1	-0.9	0.7	3.9

14 October 1986 (12h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (12h00)

	Alex Bay	Uping	Blmfnt	Durban
100	-0.5	0.3	-0.1	-0.6
200	-1.5	-0.5	-0.8	-0.8
300	-1.1	0	0.5	0.8
400	-1.4	-0.4	0.4	-0.1
500	-1	-0.5	-0.4	-0.1
600	-0.4	0	0.2	0.6
700	-0.8	-0.5	-0.3	0.7
850	-2.1	-1.8	0.6	-0.3

Dewpoint (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.8	1.9	1.2	0.8
400	1	1.8	-0.2	0.1
500	0.7	1.2	1.1	0.7
600	-1	0.7	-0.5	0.4
700	-1.3	0.8	-0.3	0.3
850	0.4	0.1	-1.2	0.9

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.9	-0.7	-0.5	-0.1
300	-1.5	-0.5	-0.4	-0.1
400	-1.5	-0.6	-0.6	0
500	-1.4	-0.6	-0.6	-0.3
600	-1.3	-0.7	-0.7	-0.4
700	-1.3	-0.8	-0.6	-0.7
850	-0.3	-0.1	-0.6	-0.9

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.8	0.5	-0.5	-0.8
300	0.9	0.2	0.2	-0.2
400	-0.1	1.1	0.5	-0.1
500	0.1	0.8	1.9	0.4
600	-0.2	0.9	1.9	0.9
700	-0.3	1.7	0.7	-0.2
850	-1.5	0.3	0.8	0.5

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.5	-1.3	-0.8	-0.8
300	-0.8	-0.7	-0.7	-0.5
400	-0.3	-0.9	-0.8	-0.8
500	-0.2	-0.9	-0.9	-0.2
600	0.7	-0.8	-1.1	-0.4
700	0.2	-0.1	0.3	-0.2
850	0.9	0.8	0.5	0.7

Dewpoint depression

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0	0.6	0	-0.6
400	-1.7	-0.2	0.3	0.4	-0.5
500	-1.6	0	0.4	-0.6	-0.2
600	0.5	-0.2	0	0.1	-1.2
700	1.1	0.1	1.3	2.2	-0.9
850	1.1	0	0.1	2.1	-1.1

Dewpoint depression

	Alex Bay	Uping	Blmfnt	Durban
300	-0.3	-0.7	0	0.4
400	-1	1	0.4	0.4
500	-0.3	1	-0.6	1.1
600	1.5	1	0.1	-0.5
700	1.4	0.3	2.2	-0.1
850	0.9	-1	2.1	0.3

Equivalent Potential temp 13th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.3	-0.8	-0.7	0.3	1.4
400	-1.5	0.2	0.4	0.8	1.4
500	-1.4	0.4	0.6	0.8	0.7
600	-0.9	0.7	0.3	0.7	0.2
700	-1	0	0.4	1.5	0
850	-0.2	0.3	-0.3	1.3	-0.4

Equivalent Potential temp 13th

	Alex Bay	Uping	Blmfnt	Durban
300	1.1	0.7	0.3	0.3
400	1.1	0.6	0.8	1
500	0.7	0.9	0.9	1.3
600	0.7	0.7	0.7	1
700	0.1	0.7	1.5	0.7
850	-1	-0.2	1.3	0.1

Equivalent Potential temp 14th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.5	0.6	-0.1	0.5	0.2
400	-0.7	0	-0.4	0.4	-0.3
500	-0.8	0.3	0	0.3	-0.2
600	-1.5	0.7	0.3	0.6	-1.1
700	0.5	1.1	1.3	0.6	-0.9
850	0.1	0.8	-0.2	0.8	-1

Equivalent Potential temp 14th

	Alex Bay	Uping	Blmfnt	Durban
300	-0.2	0	-0.1	0.8
400	-0.2	0	-0.5	0.2
500	0	-0.2	-0.1	0.2
600	0.2	0.3	0.4	1.1
700	0.2	0.1	1.3	0.9
850	-1.1	-1.1	-0.2	0.1

Total Static energy 13th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.9	-0.9	-1.1	0.1	1.3
400	-0.7	-0.1	-0.1	0.4	1.3
500	-0.6	-0.2	0	0.5	0.7
600	0.3	-1	-1	0.3	0.3
700	-0.1	-0.6	-0.4	0.6	0.2
850	1.2	0.2	-0.4	-0.2	0.3

Total Static energy 13th

	Alex Bay	Uping	Blmfnt	Durban
300	1.3	0.7	0.1	-0.3
400	1.3	0.4	0.4	0.4
500	1.3	0.4	0.5	0.7
600	1.2	0	0.3	-0.5
700	1.1	-0.4	0.6	-0.2
850	-0.3	0	-0.2	0.4

Total Static energy 14th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.5	-0.4	-0.3	0.7	0.6
400	-0.6	-0.2	-0.6	0.3	0
500	0.1	-0.2	-0.5	0.5	0.3
600	-1.2	-0.2	0	0	0.5
700	-0.1	-0.3	-0.2	-0.2	0.1
850	-0.2	0.5	0	-0.6	-0.5

Total Static energy 14th

	Alex Bay	Uping	Blmfnt	Durban
300	0.1	0.3	0.7	0.8
400	0.1	0.4	0.3	0.1
500	0.2	0.2	0.5	0.3
600	-0.3	0.3	0.1	0.2
700	-0.6	0.3	-0.2	0.4
850	-1.3	-0.9	-0.6	0.9

GEOPOTENTIAL HEIGHTS (m) (500 hPa)
Dry 12 - 14 October 1986

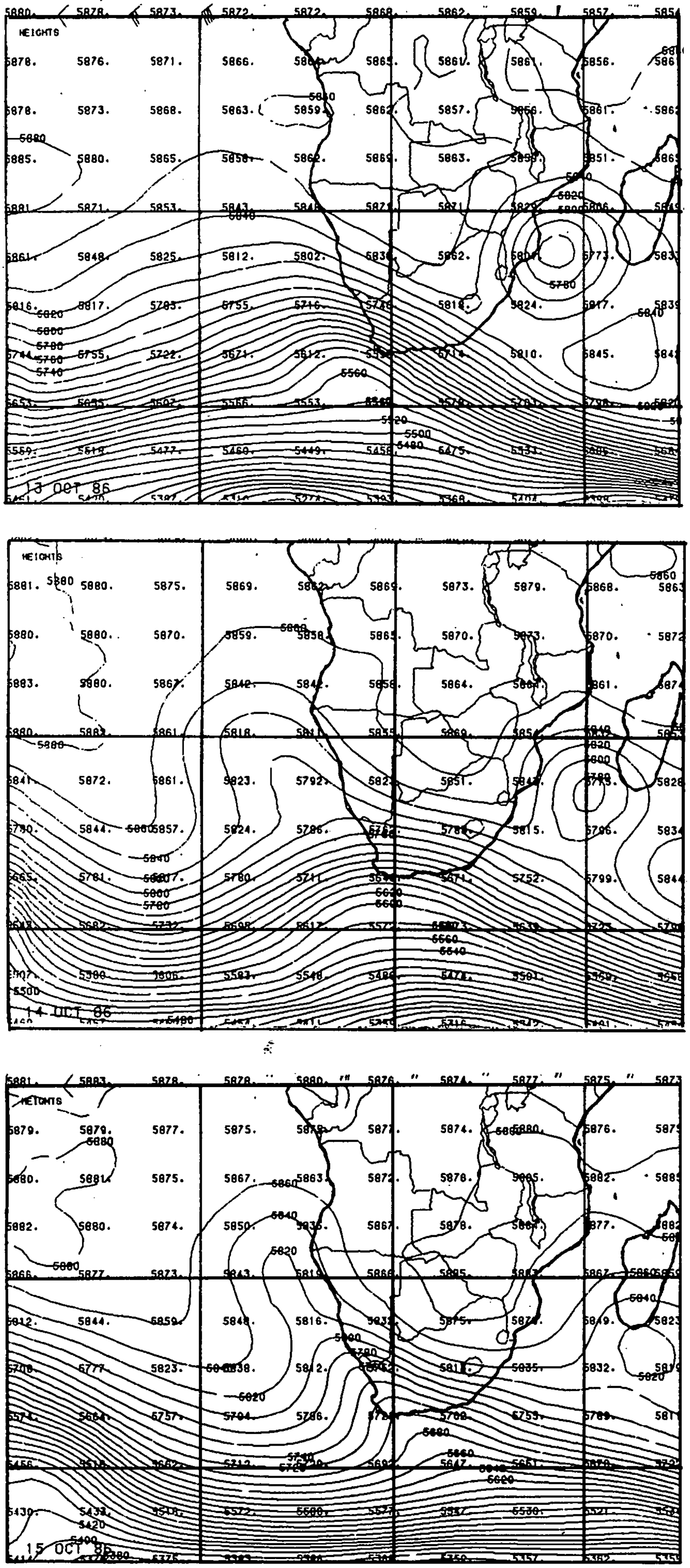


Figure 5-8 ECMWF (500 hPa) geopotential height for the dry event of 12 - 16 October 1986.

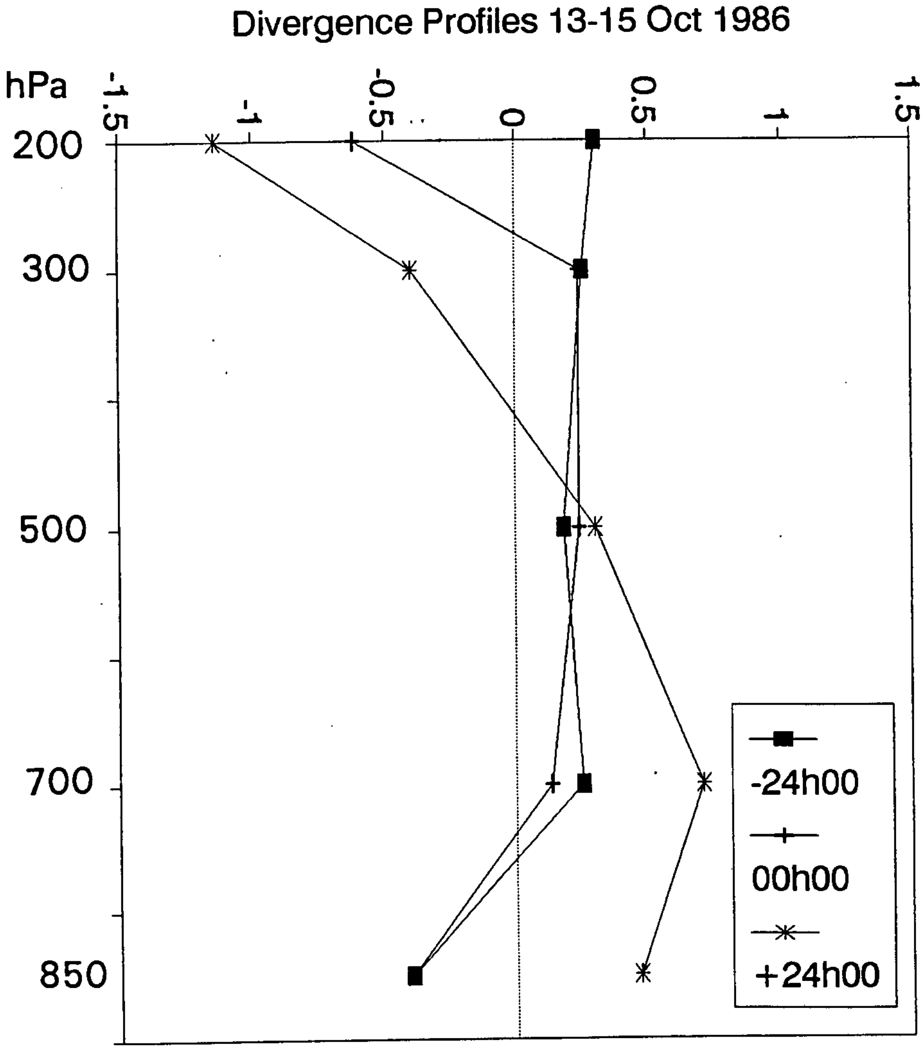


Figure 5-10 Divergence profiles ($10^{-5}s^{-1}$) for the dry event of 13 - 15 October 1986, for -24h, 00h and +24h.

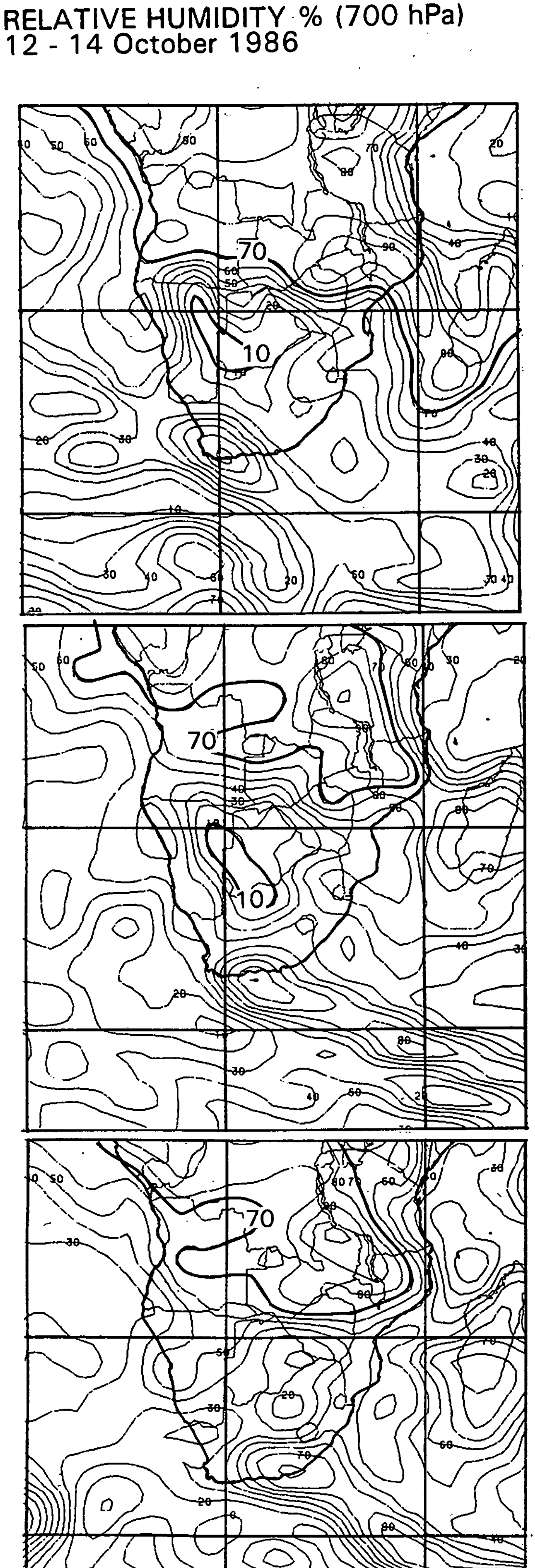
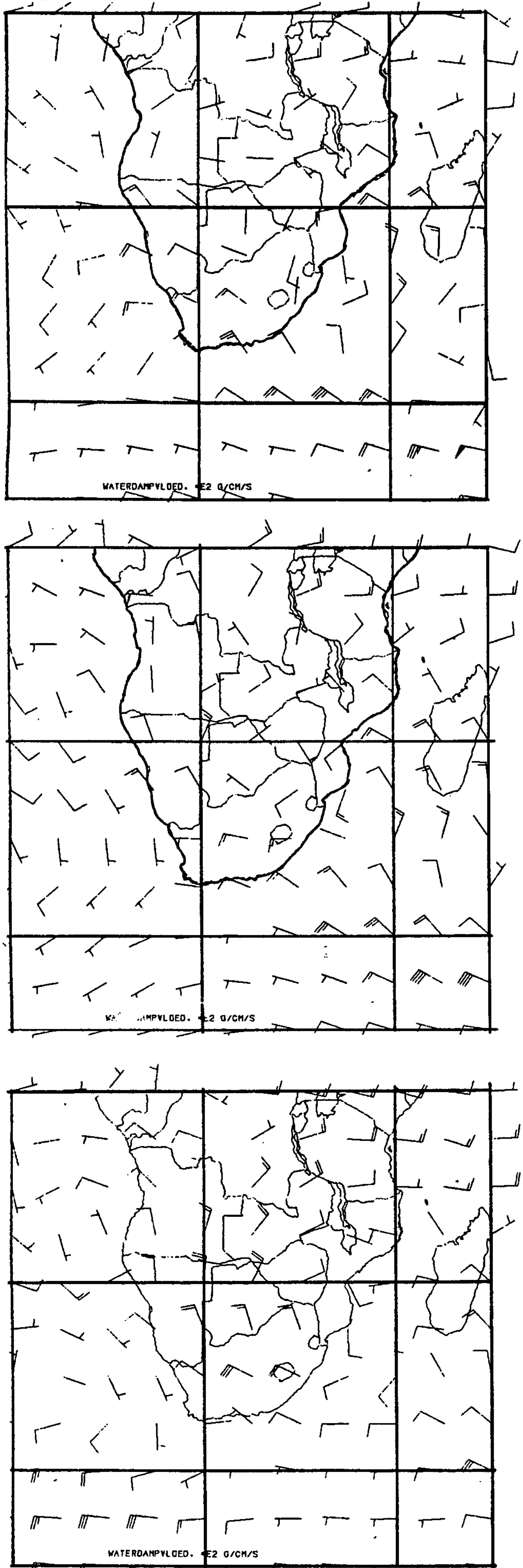


Figure 5-11 ECMWF (700 hPa) relative humidity (%) for the dry event of 12 - 14 October 1986.

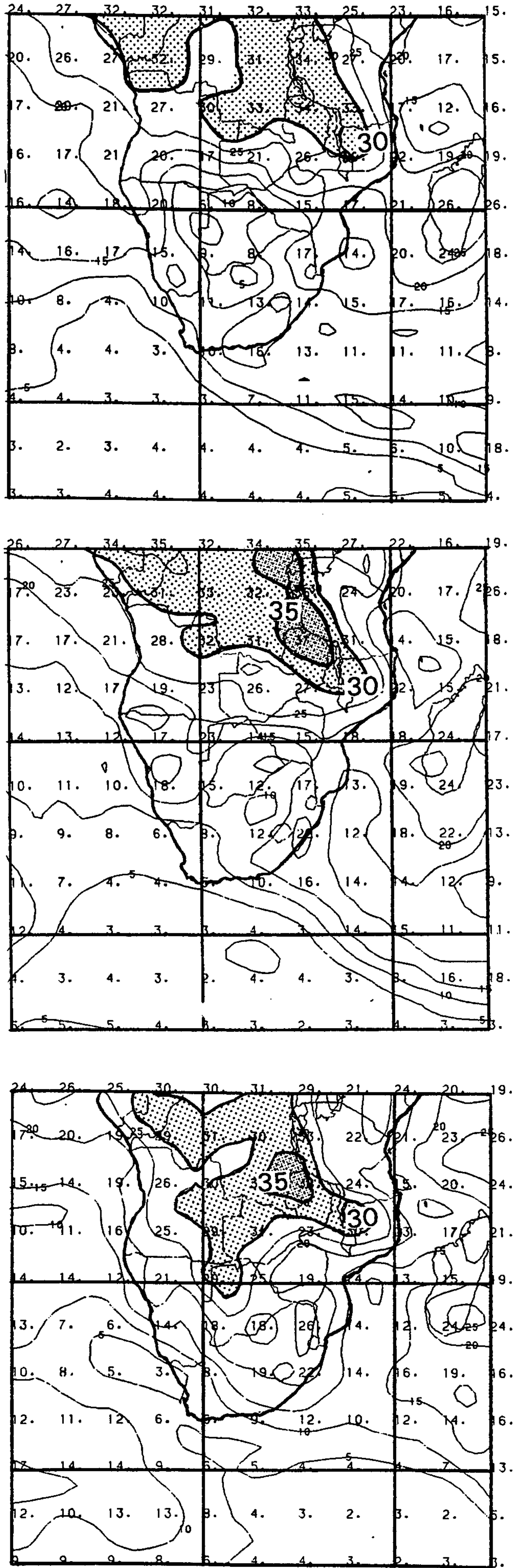
Figure 5-12 ECMWF precipitable water (mm) for the dry event of 12 - 14 October 1986.

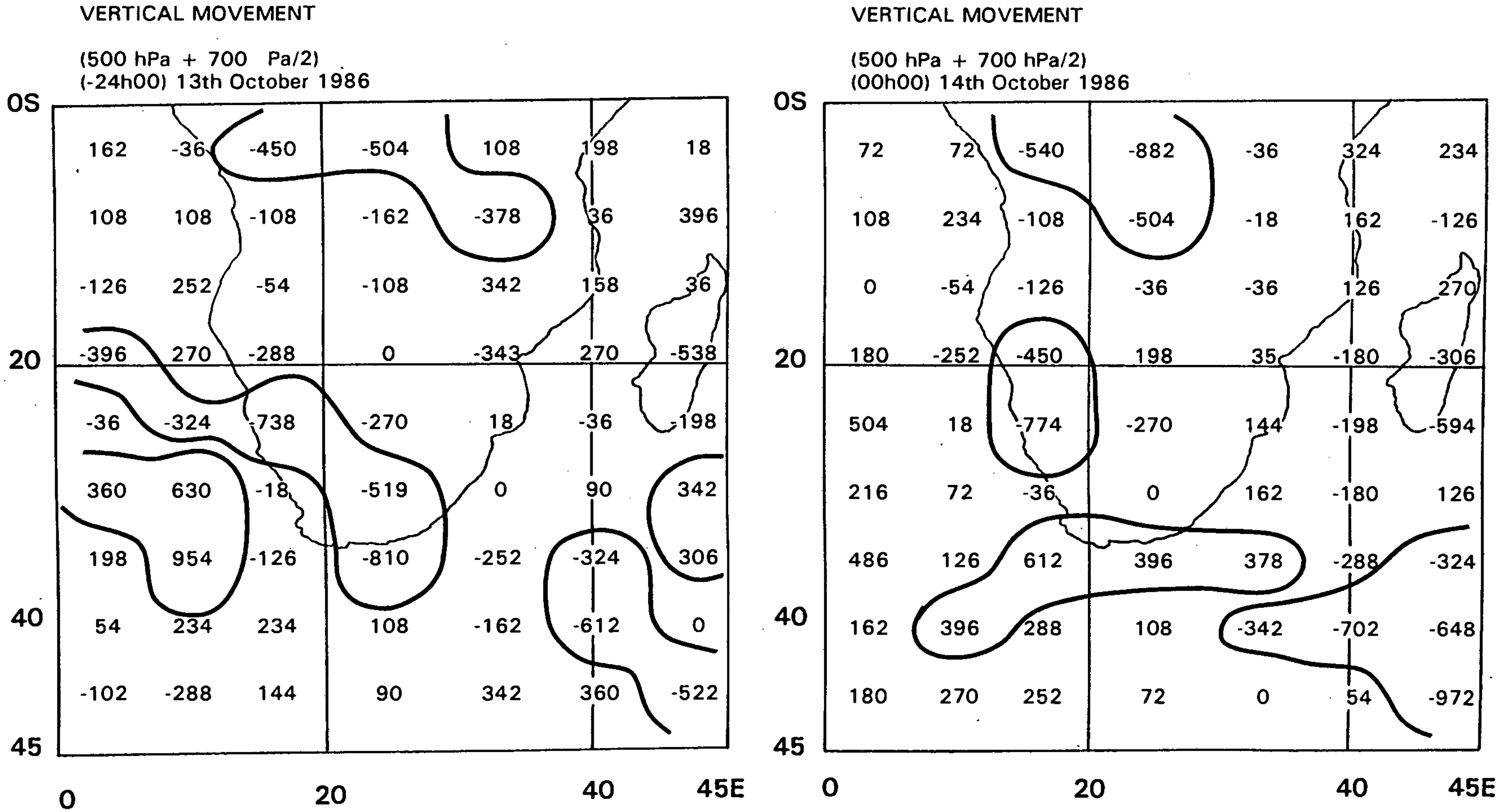
Figure 5-13 ECMWF water vapour flux (g $cm^{-1}s^{-1}$) for the dry event of 12 - 14 October 1986.

WATER VAPOUR FLUX (g cm s^{-1})
Dry 12 - 14 October 1986



PRECIPITABLE WATER (mm)
Dry 12 - 14 October 1986





VERTICAL MOVEMENT

(500 hPa + 700 Pa/2)
(-24h00) 13th October 1986

VERTICAL MOVEMENT

(500 hPa + 700 hPa/2)
(00h00) 14th October 1986

Figure 5-14 Vertical movement (Pa hr^{-1}) for -24h and 00h, 13 and 14 October 1986. Regions of > +300 Pa hr^{-1} (descent) and < -300 Pa hr^{-1} (ascent) are contoured.

Summary

On the SAWB *surface* synoptic charts the wet event of 26 - 30 October 1986 and the dry event of 12 - 16 October 1986 appear similar. An eastward moving cold front trails over Bloemfontein on the 28th and the 14th. A decrease in temperature and an increase in dewpoint occur during trough passage, atmospheric pressure drops and wind swings from north-west to south-west at western stations. Precipitation resulting from the passage of the troughs occurs on the 28th in a north-west to south-east band over the interior, while, scattered showers occur from the 14th in the Cape coastal plains.

Northerly flow in the dry event precursor environment increases precipitable water from < 10 mm to 18 mm. However, near-surface convergence is weak and is of a reduced amplitude and does not extend sufficiently equatorward to trigger convection. A lack of accord between moisture arrival, instability and synoptic forcing does not realise vertical uplift.

The small amplitude upper wave, the higher phase speed of 18 m s^{-1} and, the vertical alignment of the surface and upper-level trough indicate a weak upper-level trough in the dry case. The prevailing upper divergence and surface convergence field is not sufficient to realise sustained vertical movement given the weak instability in the precursor environment. The thermodynamic structure shows the dry prefrontal environment characterised by, high temperatures, low dewpoint departures and high geopotentials in the lower troposphere indicating anticyclonic conditions over the interior of South Africa. The northward displaced SAac is associated with dry subsiding air over the interior of South Africa. The meridional wind across Bloemfontein from 00h to +36h is southerly above 300 hPa, while northerly throughout the mid and lower troposphere. Upper-level equatorward flow and low-level poleward flow suggest a Ferrel cell anomaly, which has its major axis of surface convergence occurring south of South Africa with upper-level subsidence over the interior.

In the wet event the diffluent nature of the upper wave and the large amplitude sharp trough are responsible for the slow trough speed (6.3 m s^{-1}) on D-day. Cyclogenesis at the surface and upper-level is due to strong upper-level divergence a symptom of the northward displaced sharply curving large amplitude trough. The westward tilted trough over the period 26 - 30 October 1986 implies baroclinicity and a mature system. The 3-level temperature structure indicates the presence of tropical air over the interior and the development of a Hadley cell where meridional flow is being partly maintained by the negative - positive dipole circulation systems. The acceleration of winds at 300 hPa and the divergence/convergence on the 28th indicate that the precipitation trigger on the 28th is the link between strong upper-level divergence ahead of the trough axis to the negative - positive dipole over the interior.

CHAPTER 6

CONCLUSIONS

In this study of wet and dry troughs in October and November, three processes have been identified in the generation of convection. The amount of precipitation depends upon the northward penetration of a sub-tropical trough and the associated divergence field, the moisture fluxes and the degree of thermal instability at any one time and place. These components interact with one another such that if one is absent or weak significant precipitation may not be realised and only cloud may form.

Clear differences between wet and dry troughs with respect to these components have been found. Results from Chapter 3, and Chapter 4 emphasise the structure of the atmosphere and the interaction of the various meteorological processes which are responsible for triggering precipitation in wet events at D-day compared to dry events where one or more of the mechanisms is adverse to forcing.

There is evidence to indicate that a large amplitude westerly wave and a northward penetration is conducive to wet events. The diffluent nature of the sub-tropical jet in the upper troposphere and, the negative - positive dipole are peculiar patterns which trigger convection through enhanced upper divergence on the front of the wave and subsequent surface convergence. In comparison the small amplitude wave of the dry events is embedded in a zonal flow pattern, such that prevailing divergence is weak.

In Chapter 1 it was postulated that a tropically induced precursor inflow of moist air was a key factor in distinguishing wet and dry frontal events and for generating low-level atmospheric instability and convergence over the interior of South Africa near D-day. Perhaps the most obvious difference between the wet and dry troughs in this study is the presence of a prefrontal moist air stream and a high degree of instability in wet events, compared to a relative lack of moisture in dry events and a low degree of instability. Precipitable water in wet events is 8 mm higher. Precipitation in wet events is a combination of synoptic forcing which together with a prefrontal moisture source and unstable lower troposphere act jointly to initiate convective processes. The linkage between the dipole circulation and the divergence field on the front of the wave triggers convective processes on D-day. The main findings reached from this research are detailed below.

Circulation characteristics of wet and dry troughs

1 At D-day the SAac ridged to the south of the southern tip of South Africa, at 7.4 m s^{-1} faster in the wet events than the dry events. A negative - positive dipole is created at low levels which stimulates meridional flow.

2 The ridging SAac was located 3° latitude further south in the wet events than in the dry events. The northward and eastward intrusion of the SAac over the western subcontinent is the major cause of the short term dry spells, since upper westerly winds actively subside on the eastern flanks of these anticyclones.

3 In the wet events the interior low strengthens and reaches a minimum of 1477 hPa at the surface over central South Africa at D-day, little development occurs in the dry events.

4 The phase speed of the surface wet troughs is 7 m s^{-1} slower than the dry events, which in general tend to be shallower than their wet counterparts, seem to exhibit a more stable environment, appear to be less influenced by mesoscale effects.

5 Twenty four hours prior to D-day wet troughs are characterised by an upper-level wavelength of 42.2° longitude and an amplitude of 10.8° latitude. The 300 hPa speed at -24h is 11 m s^{-1} while the zonal wind speed is 15.8 m s^{-1}. Between -24h and 00h the wavelength in wet events increased by 7.6° longitude, the amplitude by 4.5° latitude and the trough speed decreased by 2.43 m s^{-1}.

This slowing down of the phase speed and the increasing amplitude of the wet events provides evidence to suggest that cyclonic development is being enhanced over the South African interior.

Twenty four hours prior to D-day the dry troughs are characterised by an upper-level wavelength of 53.7° longitude and an amplitude of 8.2° latitude. The 300 hPa speed at -24h is 12 m s^{-1} while the zonal wind speed is 18.1 m s^{-1}. Between -24h and 00h the wavelength decreased in size by 9° longitude, the amplitude increased slightly by 0.8° latitude, the wind speed increased by 6.2 m s^{-1}, and the 300 hPa speed increased by 5.3 m s^{-1}. The increasing wind and trough speed indicate zonal alignment of the isobars and strong westerly flow.

6 On D-day the wet events are characterised by a large amplitude Rossby wave of 15.3° latitude and a slow phase speed of 300 hPa of 8.5 m s^{-1}. In comparison, the dry events are characterised by an amplitude of 9° latitude and a phase speed of 17.4 m s^{-1}. The large amplitude wave and its associated strongly curving trough in the wet events is responsible for the slow trough speed and the enhancement of cyclogenesis as the prevailing divergence/convergence fields sustain vertical uplift over the interior of South Africa. In the dry events the small amplitude wave suggests zonal alignment of the isobars and an increased jet stream. Dry troughs have a zonal speed of 24.3 m s^{-1} compared to 19 m s^{-1} in the wet events.

7 The negative - dipole structure at 500 hPa at 25° E is characterised by a west-north-west to south-east trough, while strong positive values mark the SAac. The subtropical jet stream "splits" such that the southern limb flows poleward and the northern limb is displaced equatorward. "Splitting" of the upper-level flow causes diffluence and strong upper-level divergence in the wet events.

8 Geopotential height composites for wet events show a distinct westward tilt with height indicating a baroclinic environment and a mature system where opposing surface and upper-level divergence fields sustain the system. In the dry events vertical alignment of the upper-level and surface trough indicate a decaying system.

9 Above normal geopotential departures dominate the troposphere prior to D-day of ≈ +0.5, whereafter negative departures > -1.5 dominate the troposphere in the wet events. Negative geopotential height values from D-day throughout the troposphere are consistent with above normal rainfall in South Africa. The dry composite shows weak negative departures prior to D-day throughout the troposphere which gain in intensity (-0.9) from D-day.

10 Intense convection occurs with cyclonic vorticity over the interior and anticyclonic vorticity in the mid-latitudes and low geopotentials. In the wet events weak anticyclonic vorticity at 500 hPa of +5 10^{-6} s-1 occurs concurrently with a strong negative geopotential departure of -1.2. Dry events are characterised by the converse whereby strong anticyclonic vorticity of +20 10^{-6} s-1 occurs with weak geopotential departures of -0.1

11 Dry events experience a north-west to south-east alignment of the vorticity gradient lines with shear of the order of +20 to -35 10^{-6} s^{-1}. The wet events show a similar weak north-west to south-east alignment but with a shear of +10 to -10 10^{-6} s^{-1}, more conducive to meridional flow.

12 In wet events a 3-level temperature structure is evident for Pretoria and Bloemfontein with warming above 500 hPa and cooling below 600 hPa and above 200 hPa. Mid-tropospheric warming prior to onset of the front, together with increased geopotentials are consistent with upper tropospheric outflow of air and latent heat release. The dry events show prefrontal mid-tropospheric warming while negative departures dominate the troposphere after D-day. A 2-level temperature structure is evident at Bloemfontein from +12h where warming occurs above 500 hPa and cooling below.

13 North-east airflow dominates the troposphere prior to onset of the cold front at both Pretoria and Bloemfontein and is responsible for advecting moisture into the interior of South Africa in the wet events. South-easterly flow dominates the troposphere in the dry composite prior to onset of the trough.

14 Strong north-westerly flow above 500 hPa from D-day in the wet events at Pretoria and Bloemfontein may be linked to outflow of air on the front of the large amplitude Rossby wave and northward displaced jet stream. The weak

vertical wind structure at Pretoria throughout the troposphere during the dry events from 00h indicates that the trough has not penetrated into the subtropical latitudes.

15 Meridional wind in wet events are southerly at the surface and northerly at Bloemfontein and Pretoria. A torroidal circulation similar to a Hadley cell anomaly is suggested. In comparison, northerly flow at the surface which is overlain by southerly flow above 400 hPa suggests that the dry events are characterised by a Ferrel cell.

Characteristics of moisture behaviour in wet and dry troughs.

1 The prefrontal moist air stream in the wet events is characterised by above normal dewpoint values prior to D-day (> +1.0) throughout the troposphere. High dewpoint values between -24h and +12h correspond with increased mid-tropospheric geopotentials and warm temperatures associated with mid-troposphere latent heat release. The dry composites are characterised by low dewpoint departures (≈ 0.2) between -24h and +12h, a crucial time when moist tropical airflow is expected and does not arrive.

2 In the wet events precipitable water values increased from an average of 16 mm to 23 mm between -24h and 00h over the interior of South Africa. In the dry events precipitable water values decreased from an average of 14 mm at -24h to < 12 mm on D-day.

3 Saturation in the wet events extends from 850 - 500 hPa at +12h coinciding with convective activity. The converse holds for the dry events where positive departures of +1.2 occur in the 850 to 700 hPa layer from -24h to +12h.

4 High surface temperatures due to lack of cloud and anticyclonic conditions are responsible for high values of dry static energy in the dry events for Bloemfontein and Pretoria at 700 hPa. Low values for the wet events are due to clouds, low temperatures and low geopotentials.

At 500 hPa higher dry static energy values recorded for the mean wet troughs is associated with above normal temperatures and geopotential heights in the middle troposphere due to latent heat release.

5 In the wet events, at all stations for the 700 hPa and 500 hPa levels the mixing ratio values exhibit greater values than the dry events from -48h to +36h, with larger differences occurring at 700 hPa.

6 Moist static energy composites for Pretoria and Bloemfontein show greater atmospheric instability below 600 hPa in the wet events compared to the dry events. The curves for wet and dry troughs are most similar at Port Elizabeth owing to nearness of the station to the centre of the mid-latitude low.

In the time-height section of total static energy the most unstable station is Pretoria from -24h. The reason for this instability is, firstly, Pretoria's subtropical latitude which places the city under the influence of tropical circulation and, secondly, the northward penetration of the trough into tropical regions.

7 Vertical traces of EPt over Bloemfontein show atmospheric instability in the wet events up to D-day whereafter stability increases. The vertical profile on D-day in the wet events is similar to that found by Steyn (1988) for above average rainfall over Bethlehem. The profile shows mid-tropospheric warming. The dry EPt curve lies in the negative region meaning stability. From D-day the curve shows a gradual increase toward instability where scattered showers occur in the wake of the troughs.

8 The wet events show explosive convective tendencies at D-day over the interior as evident from measures of vertical movement, whilst the band of maximum vertical ascent in the dry events breaks away to mature in the main westerly belt at 40° S.

The findings from this research have presented adequate evidence to indicate that a large amplitude diffluent westerly wave and northward penetration is conducive to rain days in October and November. For operational analyses wet and dry troughs would be most easily identifiable through an analysis of the 500 hPa synoptic map as the surface front passes Cape Town. It is within this twenty four hours that an analysis of the surface and upper-level may decide whether a specific westerly wave is conducive to rainfall or not. The following flow chart outlines the sequence of events from -24h to D-day outlining identifiable circulation and dynamic characteristics which discriminate rain or no-rain situations.

A Forecasting Scenario

A sequence of events leading up to D-day.

	WET	DRY
Surface	temperature of 25°C and high dewpoint of 14°C over central SA some cloud	temperature of 29°C and low dewpoint of 5°C, hot, dry with little cloud
	southward displaced SAac at 37° S	north and eastward displaced SAac at 35° S
Upper-level	large amplitude wave	small amplitude wave
	westward tilt of upper level trough with height - maturity	vertical alignment of surface and upper-level trough - decay
	diffluent jet stream	no diffluence of jet stream
	northward branch of jet extends into the subtropics = cyclonic rotation	no northward penetration of westerly wave
	southward limb extends into the mid-latitudes = anticyclonic rotation	cyclonic curvature is strongest in the mid-latitudes
	the diffluent jet spins up the interior low and the SAac-	small amplitude wave governed by rapid zonal flow as low pressure systems mature at 40° S
	strong prevailing 200 hPa divergence fields	weak prevailing 200 hPa divergence fields
	wave increases in amplitude by approx 4° latitude	little change in amplitude

	slowing down of trough	speeding up of trough
	accelerating zonal winds across 30° S - upper-level divergence	deccelerating zonal winds across 30° S upper-level convergence
Moisture	north-easterly flow throughout troposphere over central interior	south-easterly or south-westerly flow throughout troposphere over central interior
	gradual drawing south of moisture into low pressure configuration	no southward flow of moisture
	instability is generated at lower levels	very little instability is generated at lower levels
	convection is triggered	convection is suppressed

A trained forecaster, could recognise this sequence of events and provide an improved forecast. Advanced comprehension of the dymanics of rain and no-rain days through better analyses and interpretation may allow continuous tracking and notification of significant structural changes, and would be an important contribution to the understanding and utilisation of the South African environment. Further work on causes of the abovementioned scenarios would be useful.

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APPENDIX A Time-height sections of meteorological variables as in Table 5-1 and 5-3 for the remaining 5 individual wet and dry events

13 (00H00) -17 (00H00) November 1989
15 November 1989 (00H00)
WET

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.9	-0.5	-0.3	0.4	-0.4	-1.2	-0.7	-1.5
400	-0.5	0.3	0	0.6	-0.3	-1.3	-0.3	-1.3
500	-0.2	-0.4	-0.3	0.4	-0.6	-2.5	-1.8	-1.3
600	-0.4	-0.2	-0.8	-0.2	0.2	-3.3	-2.2	-1.6
700	-0.2	-0.5	-0.1	-0.7	-0.9	-2.2	-2.3	-2.2
850	-2.1	-0.4	-2	-1.7	-1.3	-3.1	-2.3	-3.3

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.1	0.7	1	0.5	2	-0.4	-2.1	-0.8
400	1.5	1.1	1.6	0.5	2.1	-0.8	-1.5	-2.6
500	1.1	1	1.5	1.3	1.8	0	0	-0.4
600	1	0.9	0.8	1	1.4	-0.6	0.3	-0.2
700	0.9	1.1	0.5	0.6	1.5	1.1	0.3	0
850	0.6	0.9	0.9	0.7	1.1	0.3	0.6	0.9

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.1	-0.1	-0.3	-0.3	-2	-2	-2.7	-3
300	0.1	0.1	-0.2	-0.2	-2.3	-2.3	-3.1	-3.5
400	0.2	0.2	-0.3	-0.3	-2.7	-2.7	-3.7	-4.3
500	0.2	0.2	-0.5	-0.5	-2.5	-3.2	-4.2	-4.8
600	0.3	0.3	-0.7	-0.8	-3.4	-3.8	-4.4	-5
700	0.6	0.6	-1	-1	-4.5	-4.5	-4.1	-5
850	0.7	0.7	-1	-1	-4	-4	-2.5	-4

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-1.1	-1.1	-0.7	-0.8	0.4	-0.8	-0.9	-0.3
300	-1	-1	-0.8	-0.6	0	-0.6	1	0.2
400	-0.8	-0.9	-1.1	-1.1	-0.6	0.9	1.4	1.3
500	-0.7	-1.2	-0.9	-0.9	-0.5	0.2	0.6	0.1
600	-0.5	-1.7	-2	-0.9	-0.4	-0.5	-0.1	0.1
700	-0.4	-1.1	-1.8	0.1	0.2	0.2	0.7	-0.2
850	-2.9	0.2	-0.8	-0.2	0.3	0.3	0.4	0.3

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.2	0.4	0.6	0.7	-1.7	-3.8	-3.6	-3.6
300	-0.4	-0.4	0.4	0.1	-1.1	-3	-4	-3.4
400	0.2	-0.3	0	-0.3	-2	-2.6	-5.1	-3.4
500	0	1.1	-0.1	-0.5	-2	-2.6	-3.8	-2.1
600	1.5	0.7	0.1	-0.4	-2.2	-2.5	-2.9	-1.6
700	1.8	0.9	0.3	-0.1	-1.8	-2.3	-2.5	-1.9
850	-0.6	-0.4	-0.1	-0.8	1.7	-0.5	-0.6	-0.9

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.4	-0.9	-0.9	-0.5	1.8	0.5	-0.4	0.9
400	-0.9	-1.1	-1.2	-0.3	1.7	0.7	0.1	2.7
500	-0.9	-0.9	-1.2	-1.1	0.6	0.1	1.8	0.2
600	-0.6	-0.9	-1.2	-0.9	0	0.8	0.3	-0.2
700	-0.1	-0.8	-0.9	-0.1	-0.1	-0.9	-0.6	-0.5
850	-0.6	-0.4	-0.7	-0.2	0	-0.5	-0.5	-0.1

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.9	-0.4	-0.2	-0.2	0.7	-0.3	-1.2	-0.7
400	-0.4	0.4	0.1	0.7	0.7	-0.2	-1.2	-0.2
500	0.3	0.2	0.3	0.4	0.5	0.1	-0.6	-0.3
600	0.2	0.3	0.1	0.5	0.3	0.4	-0.9	-0.5
700	0.5	0.3	0.6	0.7	0.2	0	-0.9	-0.9
850	-1.1	0.3	-0.9	0.5	-0.7	-0.4	-1.9	-1.2

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.5	-0.2	-0.1	-0.1	0.3	-0.8	-1.7	-1.3
400	0.2	0.6	0.5	0.5	0.9	-0.8	-1.7	-1
500	0.5	0.4	0.7	0.7	1	-0.3	-1.1	-0.9
600	0.7	0.7	0.3	0.9	1.1	-0.4	-1.3	-1.2
700	0.4	0.9	0.1	0.6	0.7	0.5	-1.2	-1.2
850	-0.5	0.7	-0.2	0.6	0.1	-0.6	-1.2	-2

9 (00H00) - 13 (00H00) November 1987
11 November 1987 (00H00)
WET

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.1	0.7	0.8	0.8	0.3	0.3	0.2	0.7
400	1	1.1	0.7	1.1	0.8	0.8	0.4	0.5
500	1.3	0.9	0.5	0	-0.2	-0.8	0.2	0.6
600	0.2	0.4	0.4	0.2	-0.5	-0.8	-0.6	-0.8
700	-0.2	0.4	0.1	-0.1	0.2	-0.7	-1	-0.9
850	-0.4	0.4	-1.1	0.1	-2	-0.6	-2.8	-2

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	2.1	1.3	1.8	1.6	0.5	0.5	2	1.7
400	2.4	1.8	2	1.9	-0.6	0.4	2.1	-0.3
500	2	1.6	1.5	1.4	0.9	1.3	1.5	-0.3
600	1.5	1.4	1.1	0.3	0.8	0.7	1.1	0.7
700	1.6	1.5	1	0.7	0.9	0.7	1.5	1
850	0.9	1.1	1.4	0.5	1	1	0.9	1.2

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1.2	1.2	1.1	1.1	0.2	0.2	0.2	0.2
300	1.4	1.4	1.2	1.2	0.4	0.4	0.3	0.3
400	1.6	1.6	1.2	1.2	0.4	0.4	0.3	0.3
500	1.7	1.7	1.2	1.2	0.4	0.4	0.2	0.2
600	1.8	1.8	1.5	1.8	0.9	1.5	0.4	0.9
700	2	2	1.8	1.8	1.3	1.3	0.7	0.8
850	1.6	1.6	1.8	1.9	1.8	1.8	1.9	1.9

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.2	0.2	0.6	1.1	1.4	0.9	1.3	0.8
300	-0.4	-0.1	0.2	0.5	1	1	0	1.1
400	-0.5	-0.2	0.3	0.7	1	0.6	-0.4	-0.2
500	0	0.3	0.9	0.4	0.2	0.3	0	-0.1
600	0.4	0.6	1.5	0.8	-0.6	-1.1	-0.1	-0.1
700	0	-0.3	0	-1.1	-0.2	-0.8	0.7	-2.3
850	0.7	0.5	0.9	-0.6	-1.8	-0.2	-3.4	-2

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.7	0.5	-0.1	-0.1	-0.1	-0.3	0.2	-0.6
300	-0.1	-0.2	-0.6	-0.7	-0.5	-0.3	0.1	0
400	0.6	-0.5	-0.9	-0.8	-0.4	0.6	0.1	0
500	-0.6	-0.5	-0.9	0.5	1	0.3	0.7	0.2
600	-1.9	-0.7	-0.2	0.9	1.1	-0.4	-1.1	0.7
700	-0.4	-0.7	0.6	0.1	0.8	-0.9	-0.7	-0.2
850	1.2	-0.7	0.9	0.2	-0.9	-0.8	-0.2	-0.1

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1	-1.1	0.3	-1.3	-0.7	-0.3	0.8	-1.5
400	-0.8	-1.5	1	-1.7	-0.9	-0.1	1.1	0.5
500	-0.6	-1.1	-0.2	-1.2	-1	-1.3	1.5	0.7
600	-0.5	-1.2	-0.4	-0.1	-0.9	-0.8	0.7	-0.8
700	-0.5	-0.7	-0.3	-0.2	-0.8	-0.5	0.2	-0.8
850	0.1	-0.1	-0.1	0.2	-0.6	-0.6	-1.1	-1.6

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.1	0.9	1.2	1.2	0.6	0.6	0.4	1
400	1.1	1.2	0.9	1.2	1	1	0.6	0.6
500	0.9	0.7	0.6	0.3	0.3	0	0.4	0.6
600	0.5	0.5	0.5	0.4	0.2	0.1	0.1	0.1
700	0.5	0.9	0.7	0.6	0.8	0.2	0	0.1
850	0.4	1	-0.3	0.7	-0.9	0.2	-1.7	-1

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.1	1.2	1.4	1.4	0.6	0.6	0.7	1.1
400	2.1	1.8	1.6	1.8	0.6	0.7	1.3	0.3
500	2.1	1.4	1.2	0.9	0.4	0.4	1	0.3
600	1.8	1.6	0.9	0.3	0.5	0.3	0.8	0.3
700	1.3	1.8	0.7	0.1	0.7	0.4	0.7	0.6
850	0.8	1.5	1.2	0.6	0.2	0.8	-0.5	0.2

Table 5-4 North-south, west-east distance sections for 14 October 1986 representing the spatial variation of the various meteorological parameters

14 October 1986 (12h00)

DRY

Location of the cold front over BLM

Harare - Port Elizabeth distance section

Temp	(12h00)				
	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
100			1.3	-0.1	-1.3
200	-0.9	0.5	-0.4	-0.8	0.8
300	0.5	1	0.3	0.5	-0.1
400	-1.6	-0.3	-0.6	0.4	-0.7
500	-0.9	0.2	-0.4	-0.4	-0.6
600	-0.7	0.3	0.2	0.2	-1.7
700	0.7	1	1.3	-0.3	-1.4
850	0.1	1	1.6	0.6	-1.3

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.4	-1.3	-1	0.7	1.6
400	0.1	-0.5	-0.4	0	0.9
500	0.7	-0.7	-0.3	1	0.4
600	-1.2	-0.1	0.1	0.4	1.4
700	-0.4	-0.3	-0.9	-0.9	1.2
850	-1	0.1	0.6	-1.1	0.8

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.7	0.2	-1	-0.5	-1
300	0.5	0.2	-0.9	-0.4	-1
400	-0.8	-0.1	-0.7	-0.6	-1.1
500	-0.1	0.6	-0.2	-0.6	-1.1
600	0.2	-0.1	0.1	-0.7	-1.1
700	0.4	0.2	0	-0.6	-0.8
850	-0.5	-1.1	-0.9	-0.6	0.1

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.5	-1.5	-0.9	-0.5	-1.7
300	1.2	-0.6	-0.7	-0.2	-1.2
400	0.2	0	-0.4	0.5	-0.9
500	-0.5	-0.8	0.1	1	0.4
600	-0.6	-0.8	0.5	1.5	1.3
700	-1.2	1.9	0.5	0.9	2.7
850	0.3	6.6	-0.3	-0.7	3.4

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.9	-0.2	0.3	-0.8	0.6
300	-0.3	0.4	-0.1	-0.6	-0.2
400	-0.4	2.2	-0.6	-1.5	-0.9
500	0.2	0.8	0.1	-1.2	-1.2
600	-0.1	1.4	0.9	-0.9	-2.1
700	-0.5	0.6	0.1	-0.9	-2.9
850	-1.3	-2.1	-0.9	0.7	3.9

14 October 1986 (12h00)

DRY

Location of the cold front over BLM

Alexander Bay - Durban distance section

	Temp	(12h00)		
	Alex Bay	Uping	Blmfnt	Durban
100	-0.5	0.3	-0.1	-0.6
200	-1.5	-0.5	-0.8	-0.8
300	-1.1	0	0.5	0.8
400	-1.4	-0.4	0.4	-0.1
500	-1	-0.5	-0.4	-0.1
600	-0.4	0	0.2	0.6
700	-0.8	-0.5	-0.3	0.7
850	-2.1	-1.8	0.6	-0.3

	Dewpoint	(12h00)		
	Alex Bay	Uping	Blmfnt	Durban
300	0.8	1.9	1.2	0.8
400	1	1.8	-0.2	0.1
500	0.7	1.2	1.1	0.7
600	-1	0.7	-0.5	0.4
700	-1.3	0.8	-0.3	0.3
850	0.4	0.1	-1.2	0.9

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.9	-0.7	-0.5	-0.1
300	-1.5	-0.5	-0.4	-0.1
400	-1.5	-0.6	-0.6	0
500	-1.4	-0.6	-0.6	-0.3
600	-1.3	-0.7	-0.7	-0.4
700	-1.3	-0.8	-0.6	-0.7
850	-0.3	-0.1	-0.6	-0.9

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.8	0.5	-0.5	-0.8
300	0.9	0.2	0.2	-0.2
400	-0.1	1.1	0.5	-0.1
500	0.1	0.8	1.9	0.4
600	-0.2	0.9	1.9	0.9
700	-0.3	1.7	0.7	-0.2
850	-1.5	0.3	0.8	0.5

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.5	-1.3	-0.8	-0.8
300	-0.8	-0.7	-0.7	-0.5
400	-0.3	-0.9	-0.8	-0.8
500	-0.2	-0.9	-0.9	-0.2
600	0.7	-0.8	-1.1	-0.4
700	0.2	-0.1	0.3	-0.2
850	0.9	0.8	0.5	0.7

Dewpoint depression

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0	0.6	0	-0.6
400	-1.7	-0.2	0.3	0.4	-0.5
500	-1.6	0	0.4	-0.6	-0.2
600	0.5	-0.2	0	0.1	-1.2
700	1.1	0.1	1.3	2.2	-0.9
850	1.1	0	0.1	2.1	-1.1

Dewpoint depression

	Alex Bay	Uping	Blmfnt	Durban
300	-0.3	-0.7	0	0.4
400	-1	1	0.4	0.4
500	-0.3	1	-0.6	1.1
600	1.5	1	0.1	-0.5
700	1.4	0.3	2.2	-0.1
850	0.9	-1	2.1	0.3

Equivalent Potential temp 13th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.3	-0.8	-0.7	0.3	1.4
400	-1.5	0.2	0.4	0.8	1.4
500	-1.4	0.4	0.6	0.8	0.7
600	-0.9	0.7	0.3	0.7	0.2
700	-1	0	0.4	1.5	0
850	-0.2	0.3	-0.3	1.3	-0.4

Equivalent Potential temp 13th

	Alex Bay	Uping	Blmfnt	Durban
300	1.1	0.7	0.3	0.3
400	1.1	0.6	0.8	1
500	0.7	0.9	0.9	1.3
600	0.7	0.7	0.7	1
700	0.1	0.7	1.5	0.7
850	-1	-0.2	1.3	0.1

Equivalent Potential temp 14th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.5	0.6	-0.1	0.5	0.2
400	-0.7	0	-0.4	0.4	-0.3
500	-0.8	0.3	0	0.3	-0.2
600	-1.5	0.7	0.3	0.6	-1.1
700	0.5	1.1	1.3	0.6	-0.9
850	0.1	0.8	-0.2	0.8	-1

Equivalent Potential temp 14th

	Alex Bay	Uping	Blmfnt	Durban
300	-0.2	0	-0.1	0.8
400	-0.2	0	-0.5	0.2
500	0	-0.2	-0.1	0.2
600	0.2	0.3	0.4	1.1
700	0.2	0.1	1.3	0.9
850	-1.1	-1.1	-0.2	0.1

Total Static energy 13th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.9	-0.9	-1.1	0.1	1.3
400	-0.7	-0.1	-0.1	0.4	1.3
500	-0.6	-0.2	0	0.5	0.7
600	0.3	-1	-1	0.3	0.3
700	-0.1	-0.6	-0.4	0.6	0.2
850	1.2	0.2	-0.4	-0.2	0.3

Total Static energy 13th

	Alex Bay	Uping	Blmfnt	Durban
300	1.3	0.7	0.1	-0.3
400	1.3	0.4	0.4	0.4
500	1.3	0.4	0.5	0.7
600	1.2	0	0.3	-0.5
700	1.1	-0.4	0.6	-0.2
850	-0.3	0	-0.2	0.4

Total Static energy 14th

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.5	-0.4	-0.3	0.7	0.6
400	-0.6	-0.2	-0.6	0.3	0
500	0.1	-0.2	-0.5	0.5	0.3
600	-1.2	-0.2	0	0	0.5
700	-0.1	-0.3	-0.2	-0.2	0.1
850	-0.2	0.5	0	-0.6	-0.5

Total Static energy 14th

	Alex Bay	Uping	Blmfnt	Durban
300	0.1	0.3	0.7	0.8
400	0.1	0.4	0.3	0.1
500	0.2	0.2	0.5	0.3
600	-0.3	0.3	0.1	0.2
700	-0.6	0.3	-0.2	0.4
850	-1.3	-0.9	-0.6	0.9

6 (00H00) - 10 (00H00) November 1986
8 November 1986 (00H00)
WET

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.1	1.9	0.7	0.7	0.8	0.1	-0.2	0.3
400	1.4	1.2	0.4	0.6	-0.7	0	0.7	0.2
500	1	0.5	-0.1	0	-0.3	0.7	-0.5	0.4
600	-0.2	0.6	-0.3	0.3	-0.5	-0.3	-1.4	-1
700	-1.1	-1.3	-1	-0.7	-0.4	-0.5	-3.3	-2.3
850	-2.7	-2.7	-2.5	-1.4	-1.3	-2.2	-4.5	-2.4

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	2.5	0.4	0.1	0.2	-0.5	0.9	-1	0.1
400	2.5	0.2	0.5	0.6	-0.2	1.9	-1.2	0
500	2	1.4	1.5	-0.1	0.8	1.5	0.9	0.2
600	1.5	1.4	1.4	1.2	0.4	1.1	-0.1	-2
700	1.6	1	1.5	1.2	0.6	0.9	0.5	0.2
850	1.1	1.1	1.3	1.6	1	1	-0.8	0.1

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.6	0.6	0	0	-0.6	-0.6	-0.8	-0.8
300	0.4	0.3	-0.4	-0.4	-0.9	-0.9	-1.2	-1.2
400	-0.2	-0.2	-0.7	-0.7	-1.3	-1.3	-1.6	-1.6
500	-0.5	-0.5	-1	-1	-1.8	-2.1	-2.1	-1.3
600	-0.7	-0.7	-1.3	-1.3	-2.3	-2.3	-2.6	-2.6
700	-0.7	-0.7	-1.6	-1.6	-2.7	-2.7	-2.1	-2.1
850	0.9	0.9	-0.9	-0.9	-2	-2	-0.2	-0.2

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.4	-0.5	0.8	1	1.3	1.9	1.1	1
300	-0.5	-0.3	0.2	-0.3	2.5	1.2	1.5	0.8
400	-0.3	-0.3	0.2	0.3	1.8	1.2	1.7	1
500	-0.6	0	0	0.8	0.9	0	1.4	0.9
600	-0.9	-0.7	-0.4	0.7	1.7	1.4	0.4	0.7
700	0.3	-1	-0.1	2	-0.4	1.2	0.7	-1
850	-1.4	-2	-1.4	0.5	-0.8	-0.6	0.1	-0.8

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1.7	-1.8	-0.9	-0.8	-1.5	-2.9	-3.5	0.5
300	-1.3	-3.1	0	-1.2	-1.1	-2.6	-3.2	1.9
400	-2.2	-1.1	0	-0.6	-0.9	-2.4	-3.3	3.2
500	0.8	-2.8	-0.4	-1	-1.1	-2.6	-2.7	2.4
600	-0.5	-2	-0.6	-1.2	-0.1	-1.8	-2.1	2.4
700	-0.6	-0.1	-1	-0.9	-1.5	0.4	-0.4	3.5
850	-0.6	0.5	-0.6	-0.3	-0.7	0.6	0.2	1.5

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.6	0.8	0.9	0.4	1.3	-0.9	-0.6	-0.2
400	0.4	0.2	0.7	-0.4	1.2	-2.1	-0.9	0.1
500	-0.7	-1	1.2	0.3	1.3	-1.1	-1.1	0.1
600	-1.1	-1.1	-0.2	-1	0.3	-1	-1.4	2
700	-1.4	-1	-0.5	-0.9	-0.1	-0.6	-2.1	-0.7
850	-1.4	-1.9	-1.1	-1.6	1.6	-1.6	-2.9	-1

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.4	2.4	0.9	0.9	1.2	0.3	-0.1	0.5
400	1.5	1.3	0.5	0.7	-0.5	0.2	0.9	0.3
500	0.7	0.5	0.3	0.3	0.2	0.6	0.1	0.5
600	0.3	0.6	0.3	0.5	0.2	0.3	-0.1	0
700	-0.1	-0.3	0	0.2	0.4	0.3	-1.6	-0.9
850	-1.5	-1.5	-1.4	-0.5	-0.4	-1.2	-3.1	-1.3

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.6	1.9	0.7	0.6	0.7	0.1	-0.4	0.1
400	1.2	0.9	0.3	0.5	-0.7	0.6	0.2	-0.1
500	1.7	0.9	0.8	0	-0.3	1	-0.4	0.2
600	1.4	1.5	1.3	1.2	0	0.7	-0.7	-1.1
700	0.8	0.4	0.7	0.8	0	0.5	-1.5	-0.9
850	-0.3	-0.3	0.1	1	0.4	-0.3	-3	-1.2

8 (00H00) - 12 (00H00) October 1988
10 October 1988 (00h00)
WET

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.9	-0.2	0.2	0.2	-1.3	-0.7	0.5	-1.4
400	-0.1	0.5	0.7	0.4	-1	-1	-1.8	-1.7
500	0.1	-1.8	0.5	-3	-0.7	-3	-1.3	-1.6
600	0.5	-2.8	0.4	-2.3	-0.3	-4	-1	-2.6
700	1.8	-2.6	0.4	-3.4	0.1	-4	-1.8	-2.4
850	-0.1	1.3	-1.2	-0.3	-0.9	-0.4	-2.8	-0.9

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.9	-1	2	-0.9	0.6	0	-1.2	0.1
400	0.8	-0.5	2.2	-0.3	0.8	-0.8	-1.6	0.4
500	1	-0.6	1.8	-0.1	0.6	0.3	-0.9	0.2
600	1.1	0.6	1.5	0	0.7	1.1	-0.9	-1.4
700	0.6	0.7	1.4	0.6	1	1.3	-0.7	1.8
850	0.5	1.4	1.8	1.6	0.9	1.2	0.3	1

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.1	0.1	-0.2	-0.2	-0.9	-0.9	-1	-1
300	0.4	0.4	0	0	-1.3	-1.3	-1.9	-2
400	0.5	0.5	-0.1	-0.1	-1.3	-1.3	-2	-2
500	0.6	0.6	-0.2	-0.2	-1.2	-1.2	-1.8	-1.8
600	0.6	0.6	-0.2	-0.2	-1.2	-1.2	-1.4	-1.4
700	0.3	0.3	-0.4	-0.4	-1.3	-1.3	-1	-1
850	-0.7	-0.6	-0.6	-0.6	-1	-1	-0.4	-0.4

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.7	-0.1	-0.3	-0.2	0.2	0.8	0.5	0.8
300	-0.1	-0.3	-0.7	-0.4	0.3	0.9	0.8	1
400	-0.6	-0.6	-0.2	-0.3	0.6	0.8	0.5	0.4
500	-0.4	-0.9	-0.2	0.9	0.8	1.3	-0.7	0
600	-1.1	-0.4	0.5	0.3	1.2	0.9	0.8	-0.8
700	-0.7	0.4	0.7	0.7	0.2	1.3	-0.2	-1.4
850	0.5	0	1	-0.7	0.2	1.1	-1.5	-0.7

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-1.3	-1.5	-1.1	-1.7	-2.1	-2.3	-1.2	-1.5
300	-1.2	-1.3	-1.5	-2.4	-2.7	-2.4	-1.9	-1.7
400	-0.9	-1.2	-2.5	-2.4	-2.9	-1.8	-1.3	-1.5
500	-1.1	-1.3	-2.9	-1.2	-1.4	-1.7	-1.2	-1.6
600	-1.4	-1.6	-3.3	-1.1	-1.8	-2.2	-1.5	-0.7
700	-1.7	-2.1	-2.2	-1	-2.4	-0.9	0.4	-0.1
850								

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.1	0.4	0.1	0.5	0.9	-0.3	0.3	-0.2
400	-1.3	0.1	0	-0.1	1.4	0	-0.8	-1.3
500	-1.2	0.6	0.1	-0.2	1.2	-1.5	-0.9	-3
600	-1.1	-0.9	-0.2	-0.3	-1.3	-1.5	-0.9	-1
700	-0.5	-1.2	-0.5	-1.5	1.5	-3.2	-0.9	1.5
850	-0.3	0	-0.1	-1.1	0.9	-0.9	-0.9	-1

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.4	-0.6	-0.2	-0.1	-1.8	-1.1	0.2	-0.5
400	-0.4	0.1	0.3	0.1	-1.3	-1.3	-1.9	-2.2
500	0.2	-0.5	0.4	-1	-0.1	-2.4	-0.3	-2
600	0.4	-0.8	0.3	-0.6	0.1	-1.3	-0.1	-1.8
700	1.3	-1.1	0.5	-1.5	0.4	-2.1	-0.6	-3
850	0.1	1.3	-0.9	-0.1	-0.6	-0.2	-2.3	-0.6

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.3	-0.1	0.4	1.3	-0.9	-0.8	0	0.3
400	0.4	0.4	1.4	-0.5	-0.5	-0.9	-1.4	-2.8
500	0.6	-0.3	1.7	-0.5	-0.4	-1.6	-1.3	-4.1
600	1.1	-0.3	1.6	-0.6	0	-0.4	-1.2	-3.3
700	0.9	-0.2	1.5	0.2	0.7	-0.1	-1.3	-1.6
850	0.9	1.7	1.8	0.2	0.9	0.7	-0.6	-0.5

2 (00H00) - 6 (00H00) November 1986
5 November 1986 (00H00)
WET

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.2	0.3	0.2	0.1	-1.2	0.3	0.6	0.6
400	-0.2	-0.3	-0.1	0	-0.5	0.2	0.5	0.9
500	-0.4	0.2	-0.1	-0.8	-1.4	-0.4	-0.7	-0.2
600	-1.4	-0.6	0.2	0.3	-0.4	-0.5	-0.6	-0.6
700	-1.7	-1.1	0.1	0	-0.1	0	0.1	-0.6
850	-3	-1.3	-2.6	0.3	-2.7	-0.5	-2.2	-1.2

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.5	-0.3	-0.6	-0.3	-0.4	0	2.1	1
400	-0.2	-0.4	-0.1	-0.5	-0.6	-0.4	2.1	2.2
500	-1.8	0.6	-0.2	0.2	0.2	0.7	1.3	0.7
600	-1.5	-0.9	-1.5	0.3	0.4	1	0.6	0.2
700	-3	3	-1.2	-0.8	0.4	-0.9	0.6	0.6
850	-0.6	-0.1	-0.1	0.5	-1.1	-0.1	1	0.7

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0	-2.1	-0.1	-2.1	-0.7	-0.1	0.4	0.4
300	-0.1	-0.1	-0.3	-0.3	-0.1	-0.1	0.3	0.3
400	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	0.1	0.1
500	-0.2	-0.2	-0.1	-0.1	-0.4	-0.4	0	0
600	-0.3	-0.3	0	0	-0.2	-0.2	0.1	0.1
700	0	0	-0.1	-0.1	-0.2	-0.2	-0.5	0.4
850	1.2	1.2	-0.3	-0.3	0.2	0.1	1.2	1.2

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	1.5	-1.2	0.7	1	0.9	-0.8	2.1	-0.3
300	1.5	1.3	-0.1	1.4	1.5	1.3	1.2	1.6
400	1.2	0.5	1.5	1.2	1.2	1.4	-0.3	0.2
500	0.5	0.5	0.7	0.9	1.7	1.4	1.8	-0.9
600	-0.2	0.3	0.8	1.8	2.7	1.4	1.7	-0.7
700	-0.6	-0.1	0.9	1.5	2.5	1.7	0.4	0.3
850	-0.9	-1.2	-0.8	1	-0.8	-0.8	-0.8	-0.3

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.3	-0.3	1.1	-0.9	1.1	-1.8	-0.3	-1.7
300	0.9	-0.9	-0.3	-0.6	-0.9	-1.8	-1.8	-1.3
400	0.6	-0.7	-0.4	-1	-1.4	-2.5	-2.4	-2.2
500	1	0.3	-1.6	-1.2	-0.8	-1.1	0.2	0.8
600	0.3	0.1	-0.8	-1.2	-0.7	-1	0.1	-0.5
700	0	-0.7	-1.4	-2	-1.8	-1	-0.3	-0.6
850	0.6	0.3	0.6	-1.2	0.6	0.1	-0.6	-0.6

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.7	0.8	-0.8	0.6	-1.2	0.4	-0.9	-0.7
400	0.5	0.3	0.8	0.5	-1.6	0.5	0.2	-2
500	0.6	-0.3	0.3	-0.2	-1	-0.6	-1.5	-0.5
600	1.5	1	0	-0.1	-0.3	-1	-1.3	0.2
700	1	2.7	0.2	-0.3	0	-0.4	-0.9	-0.3
850	-0.3	-0.1	1.1	0.4	-1.2	0.3	-0.9	-0.7

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.1	0.6	0.4	0.2	-1.3	0.5	0.8	0.8
400	-0.1	-0.2	0	0.1	-0.3	0.3	0.5	1
500	0.2	0.4	0.3	0	-0.2	0.2	0.1	0.2
600	-0.2	0.1	0.4	0.4	0.2	0.2	0.1	0.1
700	-0.5	0	0.7	0.6	0.6	0.6	0.7	0.2
850	-1.8	-0.4	-1.5	0.9	-1.6	0.2	-1.2	-0.3

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.4	0.2	0.1	-0.6	0.4	1.1	0.8	1.6
400	-0.3	-0.1	-0.1	-0.4	0	1.6	1.6	1.1
500	-0.3	0	-0.1	-0.3	0.1	0.5	0.3	1.7
600	-1.6	-0.4	0.3	0.1	0.6	0.2	-0.3	1.4
700	-0.8	-0.7	0.7	0	0.9	0.3	0.3	0.8
850	-0.8	-1.5	0.6	-2.2	-0.3	-0.1	0	-0.2

3 (12h00) - 7 (12h00) October 1989
5 October 1989 (12h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300		0.7	1	0.6	0.2	-0.1	0.6	-0.2
400		0.6	0.5	0.4	0.8	0.3	0.4	-0.6
500		0.1	1.4	1.6	1.8	1	0.2	-1
600		-0.1	-0.5	1.4	1.5	0.1	0	-0.5
700		-1.4	-0.1	0.1	0.2	0.2	-0.2	0.4
850		-2.3	-0.8	-0.4	-0.5	-1.9	-0.4	-0.7

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.3	0.7	-0.6	0.2	0	0.1	-0.1	1.7
400	1.1	0.1	-0.2	0	0	-0.1	0	1.5
500	-0.4	0	-0.7	-0.5	-0.7	-0.7	-0.7	1.1
600	-0.7	-0.7	0	0	0.1	-1	-0.8	-0.4
700	-0.7	-2.1	-3.1	-0.2	-0.3	-0.9	-0.8	0.2
850	-0.4	-0.1	-1.2	-1.3	-1.8	-1.1	-0.9	-1.1

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-2.3	0.1	0.8	0.6	0.7	0.4	0.4	-0.5
300	3.5	-0.6	0.7	0.5	0.6	0.3	0.1	-0.6
400	-4	-0.8	0.6	0.6	0.7	0.5	0.2	-0.5
500	-4	-1	0.4	0.3	2.5	0.4	0.2	-0.3
600	3.4	-1.2	0.1	0.1	0.3	0.2	0.2	-0.1
700	-3.3	-1.3	-0.1	-0.1	0.4	0.2	0.4	-0.1
850	-1.5	-0.1	0.6	0	0.7	0.8	0.8	0

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.2	0.9	0	0.6	0.7	-0.1	-0.2	0.5
300	-0.4	-0.7	-0.3	0.7	0.3	-0.6	-1	-0.3
400	-0.9	-1.1	0	-1.2	0.5	0.3	-0.2	0.6
500	-1.9	-3	1.1	-1.2	0.1	0.4	-0.3	0.8
600	-2.1	-2.1	1	-0.9	-0.5	0.6	-0.3	0.2
700	-1.8	-4	1.5	-0.5	-0.8	1.8	-1	0.5
850	-0.3	-1.2	0.2	0.2	-1.2	-2.2	-2.5	-1.8

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.4	-1.5	-0.8	-1	-1.1	-0.2	0.2	0.6
300	-0.5	-0.7	-0.4	-1.2	0.9	0	0.4	0.5
400	-1.8	-0.3	-0.1	1	0.8	-0.7	0.5	-0.3
500	-1.2	0.2	0.5	1.8	1.5	-0.9	0.1	-0.4
600	0.1	-1.4	-1.1	1.9	2.6	-0.9	-0.1	-0.5
700	-0.2	0.7	0.3	1.3	1	-1.3	0.5	0
850	-0.5	0.3	-1.6	1.1	0.6	0.2	-0.6	0.1

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.5	0.2	1.4	0.4	0.3	0.4	0.5	-0.7
400	0.6	0.5	0.5	0.5	0.2	0.6	0	-0.9
500	0.7	0.5	1.4	1.4	1.4	1.4	1	-0.7
600	0.6	1.2	0.6	0.8	0.2	1.6	1.2	0.8
700	-1.6	2.7	4.3	0.8	1	1.8	1.5	0.5
850	1.7	0.1	1	3	1.7	1.6	1	2.5

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300		-0.5	0.7	-0.6	-0.2	-1.9	0.3	-1.9
400		0	0.4	-0.9	0.1	-0.8	-0.2	-1.1
500		0.6	0.8	-0.2	0.9	0	0.3	0.1
600		0.3	0.7	0	0.2	-0.1	0.2	-0.2
700		0.4	-0.6	0.5	-0.3	-0.1	-0.2	-0.4
850		-1.5	-0.6	-0.4	-0.3	-1.6	-0.2	-1.9

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300		0.4	0.8	0.5	0.4	0.1	0.7	-0.2
400		0.3	0.5	0.4	0.4	0.3	0.2	-0.2
500		-0.3	0.6	0.6	0.7	0.2	0.3	-0.5
600		-0.8	0.6	0.1	0.2	-0.7	-0.1	-0.9
700		-1.6	-0.9	-0.5	0	-0.8	-0.5	-0.2
850		-0.6	-1.3	-0.3	-1.3	-0.9	-1	-0.4

7 (12h00) - 11 (00h00) November 1988
9th Nov (12h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.5	0.3	-0.2	-0.4	-0.9	-1.7	-1	-1.7
400	0.5	0.6	1	-0.4	-0.7	-1.2	-1.2	-0.9
500	0.6	0	-0.1	0.6	0.3	-0.6	-0.4	-0.8
600	0.1	-0.4	0	0.6	0.8	0.3	0.4	-0.6
700	-0.1	-0.1	-0.6	-0.4	-2	0.1	-0.7	-0.9
850	-0.3	-1.9	-0.7	-1.8	-1.7	-3.3	-1.4	-1.2

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.5	1.9	0.5	-0.3	-1.5	-1.4	-0.8	-1.4
400	-0.1	2.1	0.6	0.4	-1.5	-0.9	-0.6	-1.3
500	-0.1	1.7	0.7	-0.1	-1.2	-0.5	-0.7	-0.6
600	0.4	1	1.5	-1	-1.8	-0.8	-1	-1
700	0.9	1.3	1.4	0.4	0.2	-2	-0.5	1.3
850	1.1	1.2	1.5	0.2	-0.5	0.1	0	0.5

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.5	0	-0.1	-0.3	-0.4	-0.8	-0.4	-0.6
300	0.8	0.1	-0.2	-0.6	-0.4	-0.4	-0.1	-0.4
400	0.9	0	-0.2	-0.4	-0.1	0.1	0.5	0.2
500	0.9	-0.2	-0.5	-0.4	0	0.6	1	0.6
600	1.1	-0.3	-0.6	-0.7	-0.3	0.7	1.4	1
700	1.3	-0.2	-0.6	-0.8	-0.2	0.8	1.8	1.6
850	1.4	0.3	-0.3	-0.2	1	2.2	2.9	2.2

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.2	0.9	0	0.6	0.7	-0.1	-0.2	0.5
300	-0.4	-0.7	-0.3	0.7	0.3	-0.6	-1	-0.3
400	-0.9	-1.1	0	-1.2	0.5	0.3	-0.2	0.6
500	-1.9	-3	1.1	-1.2	0.1	0.4	-0.3	0.8
600	-2.1	-2.1	1	-0.9	-0.5	0.6	-0.3	0.2
700	-1.8	-4	1.5	-0.5	-0.8	1.8	-1	0.5
850	-0.3	-1.2	0.2	0.2	-1.2	-2.2	-2.5	-1.8

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.4	-1.5	-0.8	-1	-1.1	-0.2	0.2	0.6
300	-0.5	-0.7	-0.4	-1.2	0.9	0	0.4	0.5
400	-1.8	-0.3	-0.1	1	0.8	-0.7	0.5	-0.3
500	-1.2	0.2	0.5	1.8	1.5	-0.9	0.1	-0.4
600	0.1	-1.4	-1.1	1.9	2.6	-0.9	-0.1	-0.5
700	-0.2	0.7	0.3	1.3	1	-1.3	0.5	0
850	-0.5	0.3	-1.6	1.1	0.6	0.2	-0.6	0.1

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.3	-0.7	-0.6	0.5	1.6	0.8	0.7	0.8
400	0.2	-1	-0.3	0	1.4	0.9	0.2	1.2
500	0.5	-1	-0.5	0.8	1.4	0.9	0.8	0.9
600	-0.2	-0.8	-1.4	1.5	2.2	1.2	1.3	1.1
700	-0.4	-0.8	-1	0	-0.6	2.5	0.7	-1.1
850	-0.5	-0.8	-1	0.3	0	-0.7	-0.25	0.4

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.8	0.5	-0.1	-0.3	-0.9	-1.8	-0.9	-1.8
400	0.6	0.7	1.1	-0.3	-0.6	-1	-1	-0.7
500	0.6	0.4	0.3	0.6	0.5	0.1	0.2	0
600	0.4	0.2	0.4	0.6	0.7	0.5	0.5	0.2
700	0.6	0.6	0.2	0.4	-0.7	0.7	0.2	0
850	0.4	-0.9	0.1	-0.8	-0.7	-2	-0.5	-0.3

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.9	0.5	0	-0.7	-0.8	0.2	-0.7	-0.4
400	0.5	0.7	0.9	-0.1	-0.7	0.2	-0.9	-0.5
500	0.4	0.9	0.3	0.5	0	0	-0.1	-0.2
600	0.3	0.9	1.5	-0.6	-0.2	-0.5	-0.1	-0.2
700	0.8	0	1.1	0	-0.7	-1	-0.6	0.5
850	1	0.2	1.2	-0.1	-1.2	-0.8	-0.6	-0.3

5 (00h00) - 9 (12h00) November 1985
7 Nov (12h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.4	0.4	0.6	0.3	0.1	-0.6	-1.1	-0.8
400	1	0.4	0.9	0.5	0.7	-0.7	-1.4	-0.3
500	1	-0.2	-0.1	-0.9	-0.5	-0.7	-0.6	0.9
600	1	0.6	0.6	0.6	0.9	-0.7	0	0.3
700	-0.1	0.7	0.9	1.2	1.3	0	-1.3	-1.6
850	-0.2	-2	0.7	-1.4	0.8	-0.4	-1	-3

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.9	-0.9	0.1	1.6	0.7	1.5	-0.8	1.1
400	-0.8	-0.2	-0.2	1.8	1.3	1.6	-0.3	1.7
500	-0.6	0.5	0.2	1	1.1	1	0.5	1.1
600	-0.5	-0.1	0	0.3	0.3	1	-0.5	-1
700	-0.3	-0.7	-1.2	-0.2	0.2	0.8	0.1	-1.1
850	-0.4	0.1	-0.6	0.5	0.3	-0.1	0.4	0.1

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.1	0.3	-0.4	-0.2	-1.2	-1.1	-0.9	-0.9
300	0.3	0.5	-0.3	0.2	-1.1	-1.7	-0.9	-1.4
400	0.2	0.4	-0.5	-0.3	-1.3	-1.6	-1	-1.5
500	0.34	0.4	-0.52	-0.34	-1.4	-1.7	-1.4	-1.7
600	0.33	0.5	-0.58	-0.4	-1.4	-1.8	-1.9	-1.8
700	0.1	0.3	-1.1	-1.7	-1.7	-1.9	-2.1	-1.8
850	0.2	-0.2	-1.6	-1.7	-1.6	-1.1	-0.8	-0.5

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.9	-1	-0.5	-0.2	1.5	0.1	0	-0.3
300	-0.9	-0.4	-0.2	0	1.6	0.8	1.1	0.3
400	-0.9	-0.7	-0.8	1	1	1	1.8	0.4
500	-0.3	-0.7	0	1.1	2.3	1.2	2.2	0.8
600	-0.6	-0.2	0.1	0.6	1.1	1.4	1.4	1
700	-0.5	0.4	-0.3	-0.4	1	2.5	1.2	1.4
850	0.6	-0.8	-0.3	-0.5	1.7	-1.4	1.1	-0.8

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.5	-0.7	-0.7	-0.9	-2.2	-1.1	0.8	1.3
300	0	-0.8	-0.5	-1.1	-1	-2.3	1.3	0
400	0	0.4	-1	-1.2	-1.2	-2.2	-0.8	-0.1
500	0.5	0	-1.3	-1.2	-4	-1.3	-1.3	0.1
600	1.4	0.2	-0.2	-1.8	-3.7	-2.5	-2	-0.1
700	0.9	5	-0.1	-1.6	-3	-2.3	-0.7	1.8
850	0.8	0.6	-0.5	2.1	0.2	-0.7	1.2	2.2

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.7	1	0.4	1.1	-0.6	-0.5	0.6	-0.7
400	1.2	1	0.5	0.7	-1.2	-0.8	-0.1	-0.9
500	1	1.1	0	0	-1	-0.7	-0.5	-0.6
600	0.9	0.3	0.3	0.6	0.1	0.1	0.6	-0.8
700	0.6	0.3	1.8	1.5	0.7	1.2	-0.1	-0.2
850	0.8	-0.1	1.5	0.2	0.8	0.3	-0.3	1.6

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.6	0.6	0.9	0.5	0.3	-0.6	-1.1	-0.7
400	1.1	0.5	1	0.7	0.8	-0.5	-1.2	-0.1
500	0.6	0.3	0.3	0	0.2	0.1	0.1	0.7
600	0.8	0.6	0.6	0.6	0.7	0.1	0.4	0.5
700	0.3	1.2	1.3	1.5	1.5	0.6	0.2	-0.6
850	0.5	-1	1.2	-0.5	1.4	0.3	-0.1	-1.8

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0.6	0.6	0.9	0.5	0.3	-0.6	-1.1	-0.7
400	1.1	0.5	1.1	0.7	0.8	-0.5	-1.2	-0.1
500	0.8	0.3	0.3	0	0.2	0.9	0.1	0.7
600	0.8	0.6	0.6	0.6	0.7	0.1	0.4	0.5
700	0.6	1.1	1.3	1.5	1.5	0.6	-0.2	-0.5
850	0.5	-1	1.2	-0.5	1.3	0.3	-0.1	-1.8

7 (00h00) - 11 (00h00) October 1989
9 October 1989 (00h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.2	-0.5	-1.4	0.1	-1.4	-0.9	-1.2	-1.3
400	-0.6	-0.7	-0.5	0.1	-0.8	-0.6	-2.3	-2.6
500	-1	-1.7	-0.6	0.5	-0.4	-1.1	-2.6	-2.2
600	-0.5	-1.2	-0.9	-0.5	-1.2	-1.4	-2.4	-2.2
700	0.4	-0.4	-0.7	-0.8	-1.2	-2.5	-3.9	-4
850	-0.7	0.8	-2	-0.1	-2.3	-1.2	-4.2	-2.4

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.7	-0.2	-0.8	0.8	0.7	-1.1	-2	-2
400	1.5	-0.7	-0.9	1.2	0.5	-1.2	-2.1	-2.1
500	1.1	1	-0.6	0.1	0.6	-1.9	-2	-1.9
600	-0.4	0.7	0.8	1.1	-0.4	-0.9	-1	-1.8
700	0.2	0.5	1.3	1	-0.6	-0.1	0.2	-0.1
850	-1.1	-0.3	0.9	0.9	-1.2	-1.1	-0.7	-0.2

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-0.5	-0.9	-1.4	-1	-2.1	-1.8	-2.3	-1.9
300	-0.6	-0.9	-1.3	-0.9	-0.2	-2	-2.7	-2.2
400	-0.5	-0.9	-1.2	-1.1	-2.2	-2.2	-2.7	-2
500	-0.3	-0.7	-1.3	-1.3	-2.5	-2.4	-2.5	-1.7
600	0	-0.4	-1.2	-1.5	-2.6	-2.4	-2.2	-1.3
700	-0.1	-0.2	-1.3	-1.6	-2.8	-2.3	-1.6	-0.5
850	0	-0.2	-0.9	-1.5	-2.3	-1.5	0.3	1.4

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	2	0.2	0.5	0.5	1	1.7	1.4	0.8
300	1.4	1.1	0.6	1.4	1.5	0.2	1.4	-0.5
400	-1.4	1.3	0.8	2	1.6	-0.1	0.9	-0.7
500	3.7	1.4	1.3	1.7	1	-0.8	0.2	-0.6
600	0.6	1.8	1	1.2	2.2	-1.5	0.3	-1.2
700	0.9	0.7	-0.2	-0.2	0.4	-1.3	-0.4	-1.2
850	-0.7	1.3	-1.4	0.2	-0.7	-1.3	-2.1	-1.6

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	-2.8	-0.7	-0.5	-1.4	-2	-0.4	-1.9	-0.6
300	-3	-1.1	0	-2	-2.1	-0.7	-2	0.5
400	-1.2	-1.5	0.1	-2.3	-2	0.8	-1.6	1
500	1.1	-1.8	-0.7	-2	-1.5	0.9	-1	1.4
600	0.4	-1.8	-0.7	-1.7	-2	0.6	-0.8	1.2
700	-0.4	-0.8	-0.9	-0.4	1.6	0.1	0	0.4
850	0.7	-0.7	-0.1	-0.2	0.7	-0.2	2	0.3

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.7	0.1	0.6	-0.9	-0.3	1.1	1.4	1.9
400	-0.9	0.6	1	-1.3	-0.1	1.1	1.5	1.4
500	-0.7	-1.1	1	0.3	-0.2	1.9	1.8	1.6
600	0.8	-0.8	-0.6	-1.1	0.7	0.9	1	1.8
700	0.5	-0.1	-1.2	-0.8	1	0	-0.8	-0.5
850	2.5	1.2	-0.7	-0.4	1.4	0.7	0.6	-0.7

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.9	-0.9	-1.7	-0.3	-2.6	-1.4	2.3	-1.8
400	-1	-0.4	-2.5	0.4	-2.6	-0.2	2.3	-0.7
500	0	-0.4	-0.8	0.4	-0.6	-0.2	1.9	-0.7
600	-0.2	-0.2	-0.7	0	-0.3	-0.3	0.5	-0.6
700	-0.3	0.1	-1.8	-0.2	-1.2	-0.5	-1.1	-1
850	-1.8	0.9	-3.4	0.1	-2.8	-0.8	-4.1	-1.9

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.7	-0.2	-1.1	0.2	-1.2	-0.9	-1.3	-1.3
400	-0.8	-0.4	-0.5	0.4	-0.8	-0.6	-1.9	-2
500	-0.3	0.2	-0.9	0.5	-0.6	-0.2	-2.3	-0.6
600	-0.8	0.2	-0.5	0.8	-1.3	-0.5	-1.9	-0.9
700	-0.6	0.5	0.4	0.9	-1.3	-0.8	-1.8	-1.4
850	-1.7	0	0.3	0.6	-1.3	-1.5	-1.9	-1.6

22 (00h00) - 26 (00h00) November 1989
24 November (00h00)
DRY

Time sections (-48h00 to +48h00), Bloemfontein

Temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.2	0.1	0	-0.3	0.3	-0.2	0	0.1
400	-0.1	-0.4	0.5	0	0.8	0.6	0	0.3
500	0	-0.3	0.4	-0.2	-0.2	-0.7	-0.6	-0.3
600	-0.2	0.4	0.4	0.6	0.5	0.5	0.6	0.7
700	0.6	0.5	1.1	1.1	1.3	1.1	1	1.1
850	-1.4	0.1	-1.2	0.9	-0.6	0.9	-1.9	0.9

Dewpoint

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	1.2	1.4	1	-1	-1	-0.5	0.7	0.5
400	1.2	-0.1	-0.5	-1.1	-1.5	-0.2	1.7	0.9
500	-0.2	0.5	-0.3	1	1	1	1.3	0.3
600	1.2	0.7	1.2	1.1	0.4	0.5	0.6	0.7
700	1	0.7	0.9	0.7	-0.3	-0.6	0.5	0.1
850	1	0.3	1.2	0.2	0.9	-1.5	0.9	0.8

Geopotential height

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.1	0.1	0.5	0.5	0.4	0.4	0.3	0.5
300	0.3	0.6	0.8	0.4	0.7	-0.4	0.5	-0.3
400	0.5	0.6	0.9	1.3	0.8	1.1	0.8	1.2
500	0.6	0.9	1	1.5	1	1.5	1.1	1.5
600	0.8	1.2	1.1	1.8	1.3	1.9	1.3	1.6
700	0.8	1.2	0.9	1.9	1.1	1.9	1.2	1.6
850	0.8	1.1	0.8	1.1	0.6	1.3	1.4	1

Wind U component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.4	0.4	0.7	0.1	0	0.3	0.2	0.1
300	-0.1	0.3	0.1	-0.3	0.2	0.6	0.5	-0.1
400	-0.4	0.3	0.5	0.2	0.1	0.5	0.7	0.3
500	1	0.4	0.8	1	1.1	0.6	0.8	0.7
600	0.8	0.4	1	1.3	0.7	1.1	0.5	1.3
700	1.6	0.3	1.7	1	2.7	0.5	-0.2	1
850	-2.2	0.9	-0.8	0.5	-0.8	0.3	-3.3	-2.5

Wind V component

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
200	0.1	-0.3	-0.6	-0.6	0.1	0.3	0.3	0.3
300	0.1	0	-0.7	0.1	-0.4	0	0.4	0.1
400	-0.2	-0.5	-0.7	-0.5	0.1	0.1	0.4	0.3
500	1.3	0.3	0.6	0.4	-0.1	0.1	-0.4	-0.1
600	0.7	-0.3	-0.6	-1	-0.5	-0.4	-0.7	0.3
700	0	-0.4	-1	-1.5	1.3	0	0.2	-0.1
850	-0.4	-1	0.6	-1.7	0.6	0.6	-1.9	-1.4

Dewpoint depression

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-0.4	-1.5	-0.4	1.2	1	-0.5	0	0.8
400	-0.5	0	0.9	1.2	1.8	0.4	-0.8	-0.9
500	0.6	-0.4	0.9	-0.8	-0.5	-1	-0.9	-0.2
600	-0.9	-0.4	-0.8	-0.9	0	-0.2	-0.1	-0.3
700	-0.2	0	0.1	0.2	1.4	1.4	0.5	0.8
850	-0.2	0.4	-0.3	0.9	0.5	2.3	-0.5	0.5

Equivalent Potential temperature

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	0	0.3	0.1	-0.2	0.5	0	0.2	0.3
400	0.1	0.6	0.7	1.2	0.9	-0.6	0.2	-1
500	0.3	0.2	0.5	0.3	0.3	0.1	0.1	0.2
600	0.3	0.5	0.5	0.6	0.6	0.6	0.6	0.6
700	1	1	1.4	1.4	1.6	1.4	1.4	1.4
850	-0.5	0.8	-0.3	1.4	0.2	1.4	-0.9	1.4

Total Static energy

	-48h00	-36h00	-24h00	-12h00	00h00	+12h00	+24h00	+36h00
300	-1.3	0.5	0	0	0.1	0.3	0.2	0.4
400	-0.5	-0.2	-0.2	0.1	-0.1	0.6	0.7	0.6
500	-0.3	0.2	-0.2	0.5	0.3	0.4	0.6	0.2
600	0.4	0.7	0.6	1.3	0	0.6	0.3	0.8
700	-0.1	0.9	0.4	1.2	-0.3	0.2	0.4	0.6
850	0.5	0.4	1	0.7	0.3	-0.5	0.5	1.3

11 November 1987 (00H00)
WET
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-1.5	-0.2	-0.5	0.3	0.8
300	0	1.1	0.6	0.3	0.1
400	1	1.9	0.1	0.8	-0.2
500	1.4	1.6	-0.1	-0.8	-0.6
600	1.1	-0.1	-0.3	-0.8	-0.9
700	0.3	-1.5	-2.1	-0.7	0.1
850	-0.8	-1.2	-1.6	-0.6	-1.3

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.3	-0.3	2	0.5	1.2
400	0.5	1.5	0.7	-0.6	0.3
500	1.2	1.3	1.3	0.9	-1.1
600	1.3	1	0.6	0.8	0.2
700	2.2	0.6	0.5	0.9	-1.1
850	1.1	0.3	1.4	1	0.3

Geopotential height (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.4	1	0.5	0.2	0
300	2.8	-0.1	0.6	0.4	0.1
400	1	0.9	0.4	0.4	0.2
500	0.8	1.3	0.2	0.4	0.4
600	0.5	0.6	0.3	0.9	0.7
700	0.2	1.4	0.9	1.3	1.1
850	0.8	1.8	0	1.8	1.8

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.4	-0.6	0.5	1.4	0.6
300	-0.4	-1.2	0.4	1	1.1
400	-0.1	-0.6	0.5	1	-1.4
500	-1	-0.6	0.9	0.2	0.1
600	0	-0.6	-1.5	-0.6	-0.4
700	-0.4	-0.5	-2	-0.2	-0.8
850	-2.7	-1.7	-0.5	-1.8	-1.2

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.7	0.1	0	-0.1	-0.2
300	0.3	-0.1	-0.4	-0.5	-0.1
400	-0.5	-0.1	0	-0.4	0.4
500	-0.2	0.2	0.5	1	0.3
600	2.1	0	1.6	1.1	0.1
700	0.7	0.2	0.5	0.8	-0.6
850	3.3	-0.2	-0.6	-0.9	-2.2

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.3	-0.1	-0.8	-0.7	-0.1
400	0.8	-0.4	-1.1	-0.8	-1.2
500	1.4	-0.6	-1.1	-1	-1.1
600	1.8	-0.6	-0.9	-0.9	-0.8
700	1.6	-0.4	-0.5	-0.8	-0.4
850	0.1	-0.4	0	-0.6	-1.5

Equivalent Potential Temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.2	-0.2	0.9	0.6	0.4
400	1	0.2	0.7	0.9	0.2
500	0.6	0.5	0.4	0	-0.2
600	1.2	0.2	-0.3	0.1	-0.3
700	0	-0.8	-0.7	0.2	0.5
850	-0.9	-0.4	-0.7	0.2	-0.9

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.3	0.6	1.1	0.6	0.5
400	0.5	0.8	1.3	0.7	0.1
500	-0.5	0.8	1.4	0.4	0.5
600	-1.2	0.9	0.3	0.3	0.4
700	0.7	0.6	0.3	0.4	-0.1
850	-0.3	0	0.6	0.8	-0.5

11 November 1987 (00H00)
WET
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.7	1.3	0.3	
300	1	0	0.3	
400	0.4	0.7	0.8	no
500	0	-0.2	-0.8	data
600	-1	-0.9	-0.8	
700	0.2	-0.5	-0.7	
850	0.6	0.3	-0.6	

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.6	0.9	0.5	
400	0.9	0.1	-0.6	no
500	-0.7	1.8	0.9	data
600	1.6	1.2	0.8	
700	1.6	1.3	0.9	
850	1.1	1.4	1	

Geopotential height (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.2	0.4	0.2	
300	0.1	0.4	0.4	
400	0.2	0.4	0.4	no
500	0.1	0.3	0.4	data
600	0.6	0.4	0.9	
700	0.7	0.7	1.3	
850	0.6	0.8	1.8	

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.2	0.9	1.4	
300	0.6	0	1	
400	1.2	0.3	1	no
500	1.2	0.1	0.2	data
600	0.4	-0.6	-0.6	
700	-0.5	-0.6	-0.2	
850	-0.5	0.4	-1.8	

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.7	-0.7	-0.1	
300	-0.8	-0.1	-0.5	
400	-0.7	-0.2	-0.4	no
500	-0.2	0.4	1	data
600	-0.8	0.2	1.1	
700	-1	0.1	0.8	
850	-1	-0.3	-0.9	

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.1	-0.2	-0.7	-0.9
400	0.2	0.3	-0.8	-1.1
500	-0.6	-0.8	-1	-1
600	-1	-0.6	-0.9	-1.1
700	-0.5	-1	-0.8	-1.1
850	1.2	-0.1	-0.6	-0.9

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.5	0.5	0.6	
400	0.9	1	0.9	no
500	0.6	0.3	0	data
600	0.1	0.2	0.1	
700	0.8	0.3	0.2	
850	1.1	1	0.2	

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.6	0.5	0.6	
400	1	0.8	0.7	no
500	0.3	0.6	0.4	data
600	1	1.1	0.3	
700	0.8	0.5	0.4	
850	1.3	1.3	0.8	

APPENDIX B North-south, west-east distance sections of meteorological variables as in Table 5-2 and 5-4 for the remaining 5 individual wet and dry events

15 November 1989 (00H00)
WET
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.4	1.2	-1.7	-1.5	-0.7
300	0.5	2.3	-0.2	-0.4	0.1
400	-0.7	-2.6	-0.2	-0.3	0.4
500	0.4	1.2	-0.3	-0.6	-0.1
600	-0.5	-1.5	0.5	0.2	-0.8
700	0.9	-0.5	-0.6	-0.9	-1.2
850	-0.8	0.6	-1.3	-1.3	-1

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.1	-1.6	-2.4	2	1.8
400	1.5	-0.1	-2.4	2.1	1.8
500	0.2	0.6	0.1	1.8	1.5
600	0.7	0.7	0.5	1.4	1.5
700	1.3	0	0.4	1.5	1.3
850	0.8	0.1	0.3	1.1	1.1

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-1.6	-0.1	-2	-2	-1.3
300	0.1	-2	-2.4	-2.3	-1.3
400	-2.2	-1.8	-2.9	-2.7	-1.7
500	-2.7	-1.9	-3.3	-3.2	-2.1
600	-3.1	-3.1	-3.9	-3.8	-2.3
700	-3.5	-2.8	-4.5	-4.5	-2.7
850	-3.4	-3		-4	-2.3

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.2	-0.8	-0.6	0.4	-1
300	0.4	-1.2	-1	0	-1.4
400	0.6	-0.8	-0.3	-0.6	-1.4
500	2.2	0.6	-0.3	-0.5	-0.9
600	1	0.4	-0.2	-0.4	-1
700	1.5	2.9	1.1	0.2	-0.5
850	0.2	-1.5	-0.3	0.3	-1.1

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-2.1	0.8	0.5	-1.7	0.8
300	0.7	0.6	0.4	-1.1	0.6
400	-0.8	0.2	0.1	-2	0.5
500	-0.2	-0.1	0	-2	0.2
600	-1.4	-0.8	0.3	-2.2	-0.1
700	-1	-1.4	-2.2	-1.8	-0.8
850	1.7	-1.1	-0.9	1.7	0.4

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.8	-0.5	-0.6	1.8	-0.2
400	-1.3	-0.7	2.4	1.7	-0.8
500	0	-0.7	1.3	0.6	-1.2
600	-0.5	-0.7	0.5	0	-1
700	-0.7	-0.4	-0.5	-0.1	-0.5
850	-1.1	-0.1	0.1	0	-0.1

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0	0.1	-0.3	0.5
400	-0.3	0.2	0.1	-0.2	0.2
500	0.1	2.3	0.1	0.1	0.4
600	-0.3	-1.1	0.4	0.4	-0.2
700	0.6	0	0.4	0	-0.7
850	-0.9	0.7	-0.6	-0.4	-0.7

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0.7	0.1	-0.8	0.2
400	1	0.6	0.3	-0.8	0.8
500	-0.3	0.4	-0.1	-0.3	1
600	0.1	0.6	0.1	-0.4	0.5
700	0.7	0.7	-0.6	0.5	0.2
850	-0.1	0.6	-0.2	-0.6	-0.5

15 November 1989 (00H00)
WET
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	2.8	2.9	-1.5	-0.7
300	-0.6	-1.8	-0.4	0.2
400	-4	-3.6	-0.3	1
500	-5.4	-4.2	-0.6	-0.7
600	-5.8	-4	0.2	-2
700	-6.1	-3.1	-0.9	0.5
850	-2.8	-2.6	-1.3	0.7

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.4	-1	2	0.9
400	0.1	0.7	2.1	0.3
500	1.1	0	1.8	1.2
600	0.7	-0.7	1.4	1.1
700	-0.1	1	1.5	0.9
850	0.9	1.2	1.1	0.9

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-4.2	-4.2	-2	-0.9
300	-5.8	-4.9	-2.3	-1
400	-6.3	-4.9	-2.7	-1.6
500	-5.9	-4.8	-3.2	-2
600	-5.2	-4.4	-3.8	-2.3
700	-4.3	-4.2	-4.5	-2.8
850	-2.7	-3.9	-4	-2.8

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.2	-0.6	0.4	-0.8
300	0.2	-0.1	0	-0.8
400	0.4	0.9	-0.6	-0.5
500	0.4	1.1	-0.5	-0.5
600	0.5	1.7	-0.4	-0.6
700	0.9	0.2	0.2	0.1
850	0.7	1.7	0.3	0.1

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1	-1.4	-1.7	0.1
300	-1.8	-2.6	-1.1	-0.4
400	-2.3	-2.9	-2	-0.7
500	-1.1	-3	-2	-1.3
600	0	-1.1	-2.2	-0.4
700	1	0.6	-1.8	-0.8
850	2.2	2.1	1.7	-2

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	1.2	0.7	1.8	-0.4
400	1.5	0.2	1.7	0.5
500	-0.9	-0.2	0.6	-0.7
600	0	-0.1	0	-0.9
700	-0.9	-0.6	-0.1	-0.6
850	-1.1	-1.5	0	-0.3

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.9	-1.2	-0.3	-0.2
400	-2.4	-2.4	-0.2	0.2
500	-3	-2.6	0.1	-0.3
600	-2.3	-2.1	0.4	-1.1
700	-2.8	-1.6	0	0.7
850	-1.5	-1.5	-0.4	0.9

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.6	-1.9	-0.8	-0.1
400	-2.7	-2.6	-0.8	0.2
500	-2.8	-2.7	-0.3	0.1
600	-2.2	-1.3	-0.4	0.2
700	-2	-0.6	0.5	1.1
850	-0.8	-0.9	-0.6	0.8

8 November 1986 (00H00)
WET
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.6	0.7	0.9	0.3	1.7
300	0.5	2.7	1.3	0.1	-0.9
400	0.2	2.7	0.7	0	-1.2
500	-1.1	0.4	0.3	0.7	-2
600	-1.2	0.6	1.1	-0.3	-2.4
700	0.6	0.4	-0.4	-0.5	-1.5
850	1.3	0.8	-0.6	-2.2	-1.5

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.8	-0.5	1.9	-0.5	1
400	-0.5	-0.2	1.6	-0.2	1
500	-0.1	1	0.4	-0.8	0.5
600	0.6	-1	0.9	-0.4	-1
700	0.4	-0.3	1.3	0.6	0.7
850	-1.1	0.3	1.3	1	0.3

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200		1.4		-0.6	-2.1
300	0.9	-0.5	0.4	-0.9	-2.4
400	2.2	0.1	-0.1	-1.3	-2.4
500	-1.2	0.1	-0.7	-1.8	-2.4
600	-1.2	-1	-1.5	-2.3	-2.2
700	-0.9	-0.9	-2	-2.7	-2.1
850	-1	-1.4	-2.5	-2	-1.2

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-1.3	0.8	0.8	1.3	0.6
300	-0.9	-1.2	-0.5	2.5	0.5
400	-1.1	0.9	0.1	1.8	1
500	0.2	2	1.2	0.9	0.1
600	1.1	1.2	0.6	-0.9	0.3
700	1	0.6	0.7	-0.4	-0.2
850	2.2	-0.7	-0.3	-0.8	-0.4

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.2	-1	-1.7	-2.9	-4.1
300	0.2	-1.5	-0.1	-2.6	-1.7
400	0.7	-2	-1	-2.4	-2.3
500	-0.7	-1.8	-2	-2.6	-0.7
600	-0.4	-2.3	-1.6	-1.8	-0.7
700	-1.6	-1.8	-1.1	0.4	0.4
850	0.1	-1.5	-0.7	0.6	1.5

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.5	-0.1	1.2	1.3	0.5
400	0.7	1	1.1	1.2	1.4
500	0.1	1.4	1.1	1.3	0.3
600	-0.5	-0.3	1.4	0.3	0.1
700	-0.1	-0.5	3.3	-0.1	0.9
850	-1.3	-0.8	1.6	1.6	0.3

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0.1	1.6	0.3	-0.6
400	0.4	0.4	1.6	0.3	-0.8
500	-0.9	0.1	0.7	0.6	-1.6
600	-0.9	0.8	0.8	0.3	-1.7
700	0.3	0.6	0.6	0.3	-1
850	0.9	0.8	-0.4	-1.2	-1.1

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.1	0.8	1.4	0.1	-1.1
400	-0.4	0.8	0.9	0.6	-1.1
500	-1.1	0.8	-0.2	0.9	-1.5
600	-0.3	0.8	0.8	0.6	-0.8
700	0.1	0.9	1.6	0.5	-0.3
850	-0.2	1.3	0.4	-0.3	-1

8 November 1986 (00H00)
WET
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.3	0.9	0.3	0.5
300	-0.5	1.3	0.1	1.6
400	-0.8	-1.3	0	0.2
500	-0.6	-1.5	0.7	-0.8
600	-5.4	-3.6	-0.3	-0.6
700	-6.6	-2.8	-0.5	-0.7
850	-3.6	-2.1	-2.2	-1

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.6	-0.1	-0.5	0.3
400	-1.1	0.4	-0.2	1.4
500	-0.9	0.2	-0.8	0.6
600	-0.5	-1.4	-0.4	-1.1
700	-0.7	0.9	0.6	0.6
850	0.8	0.9	1	1.2

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-3.3	-2.5	-0.6	-0.7
300	-3.4	-3.1	-0.9	-1.2
400	-3.9	-3.2	-1.3	-1.8
500	-4.4	-3.3	-1.8	-2.3
600	-4.6	-3.3	-2.3	-2.7
700	-3.6	-3	-2.7	-2.7
850	-0.6	-1.9	-2	-2

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.7	0.9	1.3	0.7
300	1.3	0.7	2.5	0
400	1.2	2.2	1.8	0.3
500	1.5	2.3	0.9	0.3
600	1.1	-0.7	-0.9	0
700	1.5	0.9	-0.4	0.3
850	-0.3	-0.5	-0.8	0.6

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.7	-1.3	-2.9	-1.4
300	-0.5	-1.4	-2.6	-1.5
400	0.2	-2.7	-2.4	-0.9
500	0.3	-0.6	-2.6	-1.1
600	0.4	-1.5	-1.8	-1.1
700	1	-0.8	0.4	0.1
850	3.1	1.7	0.6	0.9

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.7	0	1.3	-0.4
400	-0.2	-0.1	1.2	-0.6
500	-1	-0.1	1.3	-0.7
600	-0.7	1.6	0.3	-0.8
700	1.8	0.3	-0.1	-0.6
850	-0.3	-0.8	1.6	-0.4

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.8	-0.5	0.3	0.1
400	0	-0.7	0.3	-0.1
500	0.2	-0.7	0.6	0.5
600	-2.1	-1.8	0.3	-0.1
700	-3	-1.4	0.3	-0.1
850	-2.1	-1.1	-1.2	-0.4

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1	-1	0.1	0.2
400	-0.4	-0.9	0.6	0.1
500	-0.4	-1.3	0.9	0.6
600	-2	-1.7	0.6	0.5
700	-2	-1.7	0.5	0.7
850	-2	-0.7	-0.3	0.1

10 October 1988 (00H00)
WET
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	0.2	-0.3	-0.7	0
400	-1	0.6	0.3	-1	-1.4
500	1	-0.1	-0.5	-3	-1.9
600	2.6	0.4	0.6	-3	-2
700	2.3	1.4	0.4	-3.5	-1.6
850	2.2	1.1	1	-0.4	-0.6

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.1	-1.5	1.1	0.6	-0.8
400	0.9	0.2	0.9	0.8	0.2
500	0.2	1.5	1.2	0.6	-0.1
600	3	0.7	1	0.7	-1
700	0.1	0.5	0.7	1	0.7
850	-2	1.3	0.9	0.9	0.3

Geopotential height (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0	0	-1	-0.9	-1.1
300	0.9	-0.2	-1.2	-1.3	-1.6
400	0.9	0	-1.2	-1.3	-1.8
500	1	0.3	-1	-1.2	-1.7
600	0.3	0.2	-0.9	-1.2	-1.4
700	-1.1	0.1	0	-1.3	-1.1
850	-2.2	-1.1	-1	-1	-0.5

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.5	0.2	-0.2	0.8	-0.6
300	0.9	0.4	0.3	0.9	0
400	0.6	1.1	0.7	0.8	0.2
500	0.6	1.6	0.9	1.3	-0.8
600	1	1.2	0.7	0.9	-0.1
700	0.3	0.5	0.4	1.3	0.5
850	-1.6	-0.1	0	1.1	1

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.4	-0.5	-0.9	-2.3	-0.7
300	0.1	-0.4	-1.2	-2.4	-0.7
400	-0.8	-0.7	-1.6	-1.8	-0.6
500	-1.1	-0.8	-1.5	-1.7	0.2
600	1.1	-1.9	-0.6	-2.2	0.5
700	-1.3	-0.9	-1.9	-0.9	0.3
850	-2.7	-2.7	1	1.2	0.5

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.8	0	1.6	-0.9	-0.8
400	-0.1	-0.1	1.9	-1.2	-1.1
500	0.8	-0.4	-0.4	-1.2	-1
600	-0.4	-0.5	-0.6	-1.2	-0.8
700	2.2	-0.3	-0.6	-0.9	-0.5
850	0.1	1.2	1	0.9	0.3

Equivalent Potential Temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	-1	-0.8	-0.6	0.3
400	-0.3	-0.2	0.2	-0.6	-0.9
500	0.8	-0.5	-0.2	-1.4	-1.3
600	2.1	-0.2	0.6	-0.5	-1.3
700	1.9	0.9	0.6	-1.4	-1.1
850	1.7	1.4	-0.3	0	-0.2

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.3	-1.1	-0.9	-0.8	-0.2
400	0.4	-0.1	0	-0.9	-1.1
500	0.1	0.4	0.4	-1.6	-1.1
600	1.4	0.9	1	-0.4	-0.8
700	0	0.5	1.1	0	-0.3
850	-1	0.8	-0.3	0.7	-0.1

10 October 1988 (00H00)
WET
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.9	-0.5	-0.7	-0.1
400	-2	-1.4	-1	0.3
500	-1.9	-1.4	-3	0.3
600	-2.4	-1.6	-3	-1.2
700	-2.7	-1.5	-3.5	-0.3
850	-1.8	-1.7	-0.4	-0.3

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.5	-0.8	0.6	1.3
400	-0.8	0.8	0.8	1.2
500	-0.5	-0.1	0.6	1.3
600	0	-1.2	0.7	0.9
700	0.2	0.2	1	0.6
850	1	-0.1	0.9	0.7

Geopotential height (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.9	-1	-0.9	-0.5
300	-2.6	-1.6	-1.3	-0.7
400	2.4	-1.5	-1.3	-1
500	-2.2	-1.4	-1.2	-1.3
600	-1.9	-1.3	-1.2	-1.5
700	-1.4	-1.1	-1.3	-1.6
850	0.6	0	-1	-1.3

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.4	0.6	0.8	0.5
300	0.2	0.6	0.9	0.8
400	0.3	0.6	0.8	0.8
500	0.2	0.9	1.3	-0.1
600	0	0.5	0.9	2.1
700	-0.3	0.3	1.3	3.1
850	0.1	-0.4	1.1	0

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0	-0.2	-2.3	-1.9
300	-0.1	-0.5	-2.4	-2.4
400	-0.2	-0.5	-1.8	-2.3
500	0.1	-0.2	-1.7	-2.1
600	0.7	0.2	-2.2	-1.2
700	1	0.8	-0.9	-1.4
850	1	1.2	1.2	-0.8

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.9	0.9	-0.9	-0.5
400	0.2	0.1	-1.2	0
500	-0.5	0.6	-1.2	-0.8
600	0	1	-1.2	-1.1
700	1.2	-0.7	-0.9	-0.9
850	-1.1	-1	0.9	0

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.8	-0.4	-0.6	-0.1
400	-0.7	-0.9	-0.6	0.6
500	-0.6	-0.8	-1.4	0.6
600	-1	-0.7	-0.5	-0.6
700	-1.4	-0.6	-1.4	0.1
850	-1.1	-1.1	0	0.1

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.9	-0.8	-0.8	-0.3
400	-0.8	-1	-0.9	0.9
500	-0.9	-1	-1.6	1.4
600	-1.1	-1.1	-0.4	-0.2
700	-0.9	-1.2	0	0.3
850	0	-0.8	0.7	1

5 November 1986 (00H00)
WET
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.1	0.1	0.9	-0.1	0.6
300	0.5	1.8	0.8	0.3	0.2
400	1	1.3	0.1	0.2	-0.7
500	1.8	1.3	-1.3	-0.4	-0.9
600	1.1	0.5	0	-0.5	-1.5
700	0.3	1.2	0.4	0	-1.5
850	1.1	1.9	1.4	-0.5	-1.5

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.5	-1.9	0.1	-0.4	0.9
400	-0.9	-1.8	-0.9	-0.6	1.2
500	-1.2	2	-1.1	0.2	0.7
600	-1.5	2	0.3	-0.4	2.2
700	0.4	-1.2	-0.2	0.4	-2
850	-0.4	0.2	-0.1	-1.1	-0.2

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0	1.3	0.6	-0.1	-0.9
300	3.1	-0.2	0.4	-0.1	-1.2
400	0.9	0.7	0.2	-0.3	-1.3
500	0.6	1.2	0.3	-0.4	-1.3
600	0.3	0.7	0.6	-0.2	-1.7
700	0.2	1.2	0.6	-0.2	-0.9
850	0	0	0	0.1	0.4

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.8	0.2	0.9	0.9	0.3
300	-1	1.3	1.1	1.5	1.3
400	-1.4	1.9	0.8	1.5	1.7
500	-0.2	1.7	0.8	1.7	1.4
600	-0.2	0	0.6	2.7	1.5
700	0.7	1.1	0.7	2.5	1.1
850	0.1		-0.1	-0.8	1.5

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.5	-4	-0.8	-1.2	-0.9
300	-0.1	-2.4	0.2	-0.9	-1
400	-0.5	0	-0.8	-1.4	-0.8
500	-0.4	-2.4	-0.7	-0.8	-0.7
600	-1.4	-1	-0.4	-0.7	-0.7
700	0.4	1.4	0	-1.8	0.3
850	-0.3		-0.6	0.6	0.6

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.2	-0.6	-1.2	-0.9	-0.5
400	1.2	-0.8	-1.4	0.2	0.4
500	1.4	-0.8	-1.3	-1.5	-0.9
600	1.8	-0.7	-1.1	-1.3	1.3
700	-0.8	0.8	-0.3	-0.9	1.3
850	0.4	-0.8	-0.4	-0.9	1

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.2	0.1	1.6	0.9	0.2
400	1.2	0.3	1.2	1.1	0.4
500	0.9	1.2	1	0.3	0.8
600	1.8	0.7	0.2	0.1	0.8
700	-0.9	0.5	-0.5	0.3	-0.1
850	0.2	-0.4	-0.5	-0.3	-0.7

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.1	0.8	1.8	0.9	0.1
400	1.1	0.7	2	1.7	0.2
500	-0.3	0.6	2.1	0.3	0.2
600	-0.9	0.1	0.8	-0.3	0.1
700	-0.5	0.2	0.4	0.3	-0.9
850	-0.1	0.1	0.2	0	-0.5

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5 November 1986 (00H00)
WET
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.3	-0.2	-0.1	0.4
300	0.9	0.8	0.3	0.6
400	-1.8	-0.9	0.2	-0.2
500	-2.3	-0.7	-0.4	0.4
600	-2	-0.3	-0.5	0
700	-2.5	0.1	0	0.2
850	-1.5	-0.8	-0.5	-1.4

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.3	0.4	-0.4	-0.4
400	-0.5	-0.2	-0.6	-0.5
500	-0.2	0.1	0.2	-0.5
600	0.6	-0.9	-0.4	-0.6
700	-1.3	-0.6	0.4	0.3
850	0.8	0.6	-1.1	0.5

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1.8	-0.5	-0.1	0.1
300	-2.2	-0.7	-0.1	-0.1
400	-2.4	-1	-0.3	-0.2
500	-2.2	-1	-0.4	-0.3
600	-2	-0.9	-0.2	-0.3
700	-1.6	-1	-0.2	-0.4
850	-0.7	-0.8	0.1	0.4

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.8	1.2	0.9	0.5
300	2	1.9	1.5	0.3
400	1.8	2	1.5	0.9
500	1.6	1	1.7	0.5
600	2.3	1.6	2.7	0.7
700	0.9	2.5	2.5	0.1
850	0.4	-0.5	-0.8	0.7

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.9	-1.2	-1.2	-0.7
300	-2	-1.5	-0.9	-0.6
400	-1.6	-2	-1.4	-0.9
500	-1.4	-1.9	-0.8	-0.8
600	-1.5	-2.1	-0.7	-0.3
700	-0.7	-0.8	-1.8	-0.9
850	0.2	1.4	0.6	1.2

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.3	0.6	-0.9	-0.8
400	0.1	-1	0.2	-1.1
500	0.3	-1.3	-1.5	-0.9
600	-0.4	-0.7	-1.3	-0.9
700	-0.5	-0.8	-0.9	-0.9
850	0.5	-1.2	-0.9	-0.9

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.9	1.2	0.9	0
400	-0.7	0.9	1.1	-0.2
500	-0.9	0.1	0.3	0.2
600	-0.2	-0.8	0.1	-0.7
700	0	-0.7	0.3	-0.5
850	0.3	-0.6	-0.3	-0.6

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.6	1.1	0.9	0.2
400	-0.5	1.2	1.7	0.1
500	-0.1	1	0.3	0.3
600	0.1	0.2	-0.3	0
700	0.9	0.4	0.3	0.2
850	0.2	0.3	0	-0.2

5 October 1989 (12h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.4	-1.1	0	0.2	0.7
400	-1.1	0.6	1.2	0.4	1.2
500	-0.1	0.5	1.4	1.8	0.3
600	-1.1	1.2	1.7	0	-1.8
700	2	0.9	0.1	0.2	-2.3
850	1.1	0.8	0.8	-0.5	-1.2

Dewpoint (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.1	-0.8	-0.6	0.2	0.5
400	-1.7	-1.6	-0.5	0	0.4
500	-1.8	-1.6	-0.6	-0.5	0
600	-1.2	-1.3	-0.6	0	1
700	-4.3	-1.9	-2.1	-0.2	0.5
850	-2.6	0.8	-0.2	-1.3	0.3

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.1	0.8	0.2	0.7	-0.4
300	-1.4	1	0.4	0.6	-0.6
400	-1.1	1	0.7	0.7	-1
500	-0.1	1.7	0.7	2.5	-1.5
600	-1.1	1.1	0.9	0.3	-1.6
700	2	1.6	0.8	0.4	-1.1
850	1.1	0.6	0.5	0.7	0

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-1.4	-0.6	-0.6	0.1	3.2
300	-2	-0.2	-0.3	0.5	4.8
400	-1.3	-0.1	-0.9	0.9	3.9
500	-1.2	-0.4	-0.7	1.1	3.6
600	-2.2	0.5	0.1	0.8	2.4
700	-2.5	0.3	1.3	1.4	2.2
850	-0.1	0	-0.4	-0.7	1.4

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1	-0.2	0.1	-0.9	-1.9
300	0.3	0.2	-0.1	-0.6	-1.3
400	0.1	0.5	-0.3	-1.3	-1.2
500	0.1	0	-0.7	-1.6	-2.2
600	1.5	-0.4	0.2	-1.5	-2
700	2.5	-0.7	-0.9	-1	-2
850	-0.5	-1.2	-0.8	0.7	0

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.4	0.9	0.3	0.3	0.2
400	1.1	1	0.9	0.2	0.5
500	1.3	0.9	1.1	1.4	1.8
600	-0.1	1.1	1.1	0.2	1.5
700	3.2	2.4	0.3	1	-0.5
850	2	1.5	0.1	1.6	0.3

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1	-0.5	-0.7	-0.1	0.6
400	-0.7	-0.2	0.6	0.1	1.1
500	-0.1	0	0.8	0.9	0.4
600	-0.9	1.4	1.3	0.2	-1.7
700	1.9	0.9	0.2	0.4	-2.1
850	1.3	0.8	-0.1	-0.3	-1.1

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1	-0.8	-0.3	0.4	1
400	-0.7	0.3	0.5	0.4	1.3
500	-0.8	-0.2	0.1	0.7	0.4
600	-0.8	-0.5	-0.1	0.2	-1
700	-1.9	-1.8	0.1	0.1	-1.3
850	-0.4	-0.2	-0.7	-1.3	-1.3

5 October 1989 (12h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.9	0.3	0.2	0.1
400	-0.1	0.7	0.4	0.4
500	0.5	1.3	1.8	1.7
600	-0.3	0.2	0	-0.2
700	-1.2	-0.4	0.2	0.9
850	-2.3	-2.2	-0.5	1

Dewpoint (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.2	-0.4	0	-0.3
400	-0.1	-0.2	0	-0.4
500	-0.3	-1.3	-0.7	-0.8
600	-1.6	-1.1	-1.5	-1.7
700	-1.7	0.3	-0.3	-0.5
850	0.6	0.3	-0.5	-1.2

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.5	0.6	0.7	0.6
300	-0.3	0.6	0.6	0.6
400	-0.3	0.6	0.7	0.6
500	-0.2	0.4	2.5	0.4
600	-0.3	0.3	0.3	0.1
700	0.1	0.5	0.4	-0.3
850	2.6	1.7	0.7	-0.6

Wind U component (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	1.2	1.4	0.8	0.1
300	0.9	0.7	0.6	0.9
400	1.2	1.2	0.6	0.5
500	1.4	1.6	1	0.8
600	1	1.2	2.1	1.1
700	1.2	1.7	2.3	0.3
850	0	0.3	1.3	0.4

Wind V component (oohoo)

	Alex Bay	Uping	Blmfnt	Durban
200	-1	-0.3	-1.2	-1.6
300	-1.1	-0.8	-0.9	-0.6
400	-0.5	-0.7	-1.1	-1.2
500	0.1	-0.2	-0.7	-1.9
600	0.1	-0.1	-0.8	-0.4
700	0.9	0.4	-0.4	-1.1
850	1.6	-0.1	0.4	0.1

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.4	0.8	0.3	0.8
400	0.4	0.9	0.2	1.2
500	0.6	1.8	1.4	1.9
600	1.5	1.6	0.2	0.6
700	1.5	-0.4	1	1.5
850	-1.2	-1	1.6	2.8

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.6	-0.2	-0.1	-0.4
400	0.3	0.4	0.1	-0.2
500	0.8	0.8	0.9	1
600	-0.2	0.2	0.2	0.3
700	-0.5	-0.2	0.4	1.1
850	-1.8	-1.7	-0.3	1.2

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.1	0.3	0.4	0.1
400	0.6	0.5	0.4	0.4
500	0.7	0.3	0.7	1
600	-0.3	-0.3	0.2	-0.2
700	-0.7	-0.1	0.1	0
850	-1.1	-1	-1.3	0

9 November 1988 (12h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.3	-0.5	-1.6	-0.9	-0.8
400	-0.7	0.1	-2.3	-0.7	-0.6
500	-0.4	0.1	-0.3	0.3	0.1
600	0.1	-0.3	0.6	0.8	-0.2
700	0.6	-0.2	-0.4	-2	-1
850	0	-0.1	1.1	-1.7	-1.2

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.3	-0.2	-0.5	-1.5	-0.5
400	1.6	1	0	-1.5	-1
500	1.5	-0.3	-0.7	-1.2	-0.5
600	0.8	0.5	-1.3	-1.8	0.3
700	0.2	0.1	0.5	0.2	-2
850	1.3	-0.6	1.4	-0.5	0.1

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	2.4	-0.5	-0.5	-0.4	-0.3
400	0.7	0.7	-0.1	-0.1	-0.2
500	0.9	1.5	0.1	-0.1	-0.1
600	1.2	0.9	0.2	-0.3	0
700	1	1.3	0	-0.2	0.23
850	0.4	0.3	-0.2	1	1.5

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.6	0.6	1	0.6	0
300	-0.1	-0.1	0.9	0.7	0.5
400	-0.7	0.5	1	1	0.2
500	-0.5	1.5	0.7	1.8	0.1
600	-1.5	0.2	1.1	1.9	0.2
700	-0.6	0.5	1.2	1.3	0.6
850	0	1.1	-0.2	0.2	1.5

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.2	-0.9	-0.8	-1	-1.1
300	-0.8	-0.1	-0.3	-1.2	-2.1
400	0.7	-0.1	0.7	-1.2	-2.3
500	1.2	0.2	1.1	1.2	-2.1
600	0.5	0.2	0	-0.9	-2
700	0.5	0.1	-0.6	-0.5	-0.1
850	0.6	-2.2	-0.9	1.1	2.6

Dewpoint depression (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.2	-0.1	0.3	1.6	0.4
400	-1.3	-0.2	-0.3	1.3	1
500	-1.2	0.1	0.8	1.4	0.8
600	-0.5	-0.4	1.5	2.2	-0.1
700	0	-0.2	-0.2	-0.6	1.6
850	-1	0.8	-0.4	0	-0.7

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.2	-0.1	-0.7	-0.9	-0.5
400	-0.3	-0.2	-1	-0.6	-0.2
500	-0.4	-0.1	0.7	0.5	0.6
600	0.3	1.9	1.2	0.7	0.3
700	0.3	0.9	0.5	-0.7	-0.6
850	-0.2	1.3	-0.1	-0.7	-1.1

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.5	0.5	-0.7	-0.8	-0.4
400	1.5	0.4	-0.8	-0.7	-0.3
500	0.2	0.5	-0.2	0	0.1
600	0.7	0.9	-0.5	-0.2	0
700	0	0.9	0.7	-0.7	-1
850	0.6	0.9	1	-1.2	-1

9 November 1988 (12h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.5	-0.9	-0.9	1
400	-0.8	-1.3	-0.7	-1.4
500	-0.5	0.1	0.3	-0.7
600	-0.1	-0.3	0.8	-1.4
700	-0.3	-0.4	-2	-2.3
850	-1.5	-2.8	-1.7	-1.6

Dewpoint (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.1	1.2	-1.5	0.5
400	-1	0.9	-1.5	0.5
500	-0.8	0.1	-1.2	1.3
600	-0.4	-1.1	-1.8	1.1
700	-0.7	-0.9	0.2	0.7
850	0	0.9	-0.5	0

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.4	-0.7	-0.4	-1.3
400	0.1	-0.5	-0.1	-1.4
500	0.3	-0.4	-0.1	-1.3
600	0.6	-0.5	-0.3	-1.2
700	0.8	-0.4	-0.2	-0.7
850	2.7	0.7	1	0.8

Wind U component (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.1	0.2	0.7	0.5
300	-0.8	0.5	0.3	1
400	-0.8	1.5	0.5	2.1
500	-0.8	2.4	0.1	0.8
600	-0.5	1.5	-0.5	0.1
700	-1.5	2	-0.8	-0.7
850	-2.2	3.8	-1.2	0.5

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.3	-0.2	-1.1	-1.3
300	0.4	0.1	0.9	-2.1
400	0.6	0	0.8	-0.6
500	0.6	0.7	1.5	-2
600	1	0.9	2.6	-2.8
700	0.9	2.4	1.6	-0.9
850	0.4	1.3	0.6	3.2

Dewpoint depression (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	1.2	-0.9	1.6	0.3
400	1.2	-0.5	1.3	0
500	0.8	0.3	1.4	-1.2
600	0.5	1.3	2.2	-1.2
700	0.8	0.7	-0.6	-1.2
850	-0.1	-1.5	0	-0.8

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.9	-0.4	-0.9	-0.1
400	0	-0.6	-0.6	-0.8
500	0.2	0.7	0.5	-0.4
600	0.6	0.4	0.7	-0.6
700	0.5	0.3	-0.7	-1.3
850	-0.7	-1.6	-0.7	-0.9

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.6	-0.2	-0.8	0.1
400	0	-0.4	-0.7	-0.4
500	0	0.2	0	0.3
600	0.2	-0.6	-0.2	0.4
700	-0.2	-0.5	-0.7	0.2
850	-0.9	-0.9	-1.2	-0.5

7 November 1985 (12h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.8			-0.6	1.3
300	-1.3		-0.1	0.1	0
400	-0.7	no	0.2	0.7	-0.8
500	-1.1	data	-1.2	-0.5	-0.8
600	-1.5		0.9	0.9	-1.3
700	0.3		1	1.3	-1.4
850	0		1.6	0.8	-1.4

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.2		1.2	1.5	0.5
400	1.5	no	1.3	1.6	0.2
500	1.3	data	0.9	1	-0.6
600	1		0.6	1	-1
700	0.8		0.3	0.8	-0.7
850	0.3		-0.4	-0.1	0.4

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-1.8		-0.3	-0.2	-1.4
300	0.7		-0.2	-0.2	-1.6
400	-0.9	no	-0.3	-0.3	-1.7
500	-0.8	data	-0.1	-0.3	-1.8
600	-0.3		0	-0.4	-1.8
700	-0.2		-0.4	-1.1	-1.6
850	-0.6		1.4	-1.7	-0.7

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.1		-1.6	-0.2	0.6
300	0		-1.2	0	0.7
400	0.2	no	-1.1	1	0.8
500	0.5	data	-0.6	1.1	1.1
600	0.6		-0.7	0.6	-0.7
700	0.3		-0.3	-0.4	-0.4
850	-1.5		-0.4	-0.5	0.3

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	
200	0.1		-0.1	-0.9	-1.2
300	-1.1		-0.2	-1.1	-1.9
400	0	no	-1	-1.2	-1.4
500	-0.2	data	-0.5	-1.2	-1.6
600	0.1		0	-1.8	-0.6
700	-0.6		-1	-1.6	-2.5
850	-0.2		-0.8	2.1	1.4

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1.2		-0.9	-0.6	0.4
400	-1.2	no	-0.1	-1.2	-0.5
500	-1.2	data	-0.6	-1	0.8
600	-1		0.4	0.1	1.4
700	-0.4		0.3	0.7	-0.5
850	-0.4		0.1	0.8	-0.8

Equivalent Potential temperature (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0		0.3	0.3	0.3
400	-0.3	no	0.8	0.8	-0.4
500	-0.9	data	0.2	0.2	-0.4
600	-1.2		0.7	0.7	-0.7
700	0		1.5	1.5	-0.9
850	-0.2		1.4	1.3	-1.1

Total Static energy

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1		0.2	0.3	-0.1
400	0.9	no	0.3	0.9	-0.6
500	1.1	data	-0.2	0.4	-0.9
600	0.8		0.1	0.5	-1
700	0.2		1.2	0.7	-0.8
850	-0.1		0.4	0.7	-0.9

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7 November 1985 (12h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	1.4	1.4	-0.6	-0.2
300	0	0	0.1	0.2
400	-1.1	-0.4	0.7	0.9
500	-0.2	-0.3	-0.5	-0.4
600	-0.1	-1.4	0.9	1.3
700	-1.8	-0.3	1.3	0.3
850	-2.4	-1.7	0.8	0.2

Dewpoint (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.7	2	0.7	0.1
400	0.5	2	1.3	1.2
500	-0.7	1.9	1.1	1
600	-1.8	1.2	0.3	0.6
700	-2.1	0.8	0.2	0.5
850	-1.3	1	0.3	1.4

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-1	-1.1	-0.2	0.2
300	-1.6	-1.2	-0.2	0.2
400	-1.9	-1.3	-0.3	-0.1
500	-2.1	-1.5	-0.3	-0.2
600	-2.3	-1.4	-0.4	-0.4
700	-2.3	-1.5	-1.1	-0.8
850	-1.2	-1.4	-1.7	-0.8

Wind U component (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200				
300	1.4	0.6	1.6	-0.4
400	1.7	1.8	1	0
500	2.1	1.9	2.3	0.2
600	1.4	1.9	1.1	-0.1
700	0.3	1.4	1	0.7
850	-0.5	-0.5	1.7	-0.2

Wind V component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200				
300	-0.9	-1.1	-1	-1.5
400	-1.2	0	-1.2	-1.2
500	0.3	-1.4	-4	-0.7
600	-0.5	-2.5	-3.7	-1.2
700	0	-2	-3	-2.3
850	1	0.1	0.2	-0.2

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.8	-1.1	-0.6	0.2
400	-0.6	-1.1	-1.2	-0.7
500	0.8	-1.4	-1	-0.8
600	1.9	-0.9	0.1	-0.1
700	1.9	-0.7	0.7	-0.2
850	1	-1	0.8	-0.8

Equivalent Potential temperature (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	0.4	0.4	0.3	-0.1
400	-0.2	0.2	0.8	0.2
500	0.5	0.2	0.2	-0.2
600	0.6	-0.3	0.7	1.3
700	-0.3	0.4	1.5	0.6
850	-1.2	-0.7	1.4	0.5

Total Static energy

	Alex Bay	Uping	Blmfnt	Durban
300	0.2	0.4	0.3	0.1
400	-0.2	0.4	0.9	0.4
500	0	1.1	0.4	0.3
600	-0.3	0.2	0.5	0.7
700	-1	0.6	0.7	0.6
850	-1.9	-0.2	0.7	1.6

9 October 1989 (00h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.8	-0.3	0	1.3	0.9
300	-0.5	-0.8	-0.2	-0.9	-1.8
400	0	-0.9	0	-0.6	-2.4
500	-0.5	-1.1	-0.9	-1.1	-2.8
600	0.2	0.1	-0.9	-1.4	-2.9
700	1	-0.3	-0.3	-2.5	-2.6
850	1.1	1	-0.5	-1.2	-1.7

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-1	0.2	-0.9	0.7	-0.6
400	1.2	-1.8	-0.7	0.5	-0.5
500	0.3	-0.1	0.5	0.6	0.8
600	0.9	0.8	0	-0.4	0.9
700	0	0.4	0.9	-0.6	0.6
850	-0.6	0.4	0.7	-1.2	0.2

Geopotential height (12h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	-0.4	-1.9	-2.4	-1.8	-2.4
300	0.6	-0.9	-2.4	-2	-2.5
400	-0.4	-1.2	-2.6	-2.2	-2.4
500	-0.4	-0.4	-2.5	-2.4	-2.1
600	-0.4	-1.3	-2.4	-2.4	-1.7
700	-0.6	-1	-2.5	-2.3	-0.9
850	-1.1	-2.3	-2.4	-1.5	0.3

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.3	0	0	1	1.9
300	1	3	0.9	1.5	2.6
400	1.3	1.7	1.3	1.6	1.8
500	2.1	1.9	2.2	1	1
600	1	2.7	1.9	2.2	0.7
700	1.3	0.6	1.2	0.4	0.5
850	-0.7	1.7	-0.1	-0.7	0

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.5	-0.3	-1	-2	-1.1
300	0.2	-1.2	-0.9	-2.1	-1.7
400	0.3	-3.4	-1.4	-2	-1.4
500	-0.8	-2.9	-0.4	-1.5	-0.2
600	-1.3	-3.4	-0.8	-2	-0.3
700	-1.7	-1.8	-1.3	1.6	1.2
850	-0.9	-4	-0.7	0.7	2.7

Dewpoint depression (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	1.4	-0.6	-1.2	1.1	0.5
400	-0.9	-0.5	-0.6	1.1	0.2
500	-0.4	-0.3	-0.2	1.9	-0.2
600	-0.8	0	-0.3	1	-0.4
700	0.4	-0.4	-0.3	0	-1.1
850	1.3	0.6	2.6	0.7	-0.9

Equivalent Potential temperature (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.4	-0.5	-0.9	1.4	-2.1
400	0	-0.5	-0.4	-0.8	-2.4
500	-0.4	-0.8	-1	-0.2	-2.8
600	0	0.3	-0.8	-0.3	-2.7
700	1.1	0.2	-0.1	-1	-2.4
850	1.3	0.9	2.8	-0.8	-1.6

Total Static energy (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	-0.5	-0.7	-0.7	-0.9	-1.4
400	0.3	-0.1	-0.1	-0.6	-1.7
500	0	-0.4	-0.7	-0.2	-1.9
600	0.9	0	-0.7	-0.5	-1.5
700	0.5	1.1	0.3	-0.9	-1.4
850	0.6	1.3	1.6	-1.4	-1.2

9 October 1989 (00h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	1.1	1.3	1.3	-0.8
300	-2.1	-1.3	-0.9	0.1
400	-3	-1.3	-0.6	-0.3
500	-3.8	-1.9	-1.1	-1.2
600	-2.8	-2.2	-1.4	-2.8
700	-3.7	-4.1	-2.5	-1.7
850	-2.4	-2.5	-1.2	-1.5

Dewpoint (12h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.7	-2	-1.1	0.7
400	-1.9	-2.9	-1.2	0.2
500	-1.8	-2.6	-1.9	0.9
600	-1.5	-1.4	-0.9	0.7
700	-1.5	0.3	-0.1	0.7
850	0	0	-1.1	0.1

Geopotential height (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-2.9	-2.5	-1.8	-1.6
300	-3.3	-2.6	-2	-1.8
400	-3.2	-2.7	-2.2	-2.2
500	-2.8	-2.7	-2.4	-2.4
600	-2	-2.6	-2.4	-2.3
700	-1.1	-1.9	-2.3	-2.1
850	1.6	0	-1.5	-0.7

Wind U component (12h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.3	0.8	1	0.5
300	1.9	1.5	1.5	0.5
400	1.4	1.4	1.6	1.5
500	1.2	1.8	1	0.9
600	0.7	1.9	2.2	5.8
700	0.5	2	0.4	2
850	-0.2	1.6	-0.7	1.8

Wind V component (oohoo)

	Alex Bay	Uping	Blmfnt	Durban
200	0.1	-0.5	-2	-3.1
300	0.3	-0.5	-2.1	-2.1
400	0.4	-0.8	-2	-1.7
500	0.7	-0.8	-1.5	-4.5
600	1.8	-0.9	-2	-2.2
700	2.4	0.6	1.6	0.4
850	3.6	2.3	0.7	2.7

Dewpoint depression (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	1.9	1.6	1.1	-0.4
400	1.8	2.8	1.1	0.1
500	1.2	2.4	1.9	-1
600	0.8	1.4	1	-1
700	0.8	-1.4	0	-1.1
850	-0.6	-1	0.7	-0.7

Equivalent Potential temperature (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1.6	-1.7	1.4	-0.3
400	-2.1	-1.3	-0.8	-0.4
500	-2.6	-1.6	-0.2	-1
600	-2.2	-1.5	-0.3	-1.9
700	-2.2	-3.1	-1	-1.4
850	-1.7	-2	-0.8	-1

Total Static energy (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.9	-1.2	-0.9	-0.1
400	-1.4	-0.9	-0.6	-0.2
500	-1.8	-1.3	-0.2	-0.4
600	-1.7	-1.4	-0.5	-0.8
700	-1.8	-1.8	-0.9	-0.6
850	-2	-1.4	-1.4	-1

24 November 1988 (00h00)
DRY
Location of the cold front over BLM
Harare - Port Elizabeth distance section

Temp (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.4			-1.3	-1
300	0	-0.1	-0.2	-0.2	-0.5
400	0.6	0.3	-0.7	0.6	0
500	1.4	0.8	-1.5	-0.7	-0.2
600	0.5	0.2	0.5	0.5	-0.5
700	0.6	1.1	1.2	1.1	-1.5
850	1.8	1.4	1.6	0.9	-0.6

Dewpoint (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.1	-1.1	-4.1	-0.9	0.8
400	-0.5	-0.1	-1.3	-1.5	0.2
500	-1.1	-0.2	-1.1	1	0.8
600	-0.4	0.1	0.3	0.4	0.8
700	0.3	0.4	-0.5	-0.3	1.6
850	-0.9	0.6	-1.6	0.9	0.9

Geopotential height (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.3				
300	3	0	1	0.9	0
400	1.4	1.4	1.4	1.1	0.1
500	1.4	2.1	1.8	1.5	0.2
600	1.4	1.8	2.2	1.9	0.4
700	1.3	2.5	2.3	1.9	0.8
850	0.6	1.3	1	1.3	1.9

Wind U component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	1.2	0.3	-0.7	0	0.6
300	-0.2	-0.2	-0.7	0.2	0.4
400	-1.2	-0.6	0.1	0.1	0.3
500	-0.9	-0.6	-0.5	1.1	0.3
600	-2.6	-1.1	-0.7	0.7	0.3
700	0.2	-1.1	-0.5	2.7	-0.2
850	0	0.1	-0.3	-0.8	0.2

Wind V component (00h00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
200	0.3	0.1	0.8	0.1	-0.3
300	0.6	0.5	0.5	-0.4	-0.2
400	1.1	2	1.3	0.1	-0.4
500	1.8	0.3	0.7	-0.1	-0.4
600	1.8	3.1	-1.1	-0.5	-0.3
700	0.6	0.6	-0.1	1.3	-0.2
850	0.6	-0.5	-0.4	0.6	1.1

Dewpoint depression (00H00)

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0	0.9	-1.5	-0.5	-1.3
400	0.8	0.2	0.9	0.4	0.1
500	1.3	0.3	-0.4	-1	1.2
600	0.7	-0.4	-0.6	-0.2	1.1
700	-0.1	0.5	0.6	1.4	0.5
850	1.4	1.6	0.2	2.3	-0.8

Equivalent Potential temperature

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.9	-0.2	-0.2	-0.2	0.4
400	-0.3	-0.1	0.6	0.2	1.1
500	0.6	0	0	0.3	1.5
600	1.2	1.1	0.7	0.6	0.6
700	-0.3	0.6	1.2	1.4	1
850	1.1	0.9	-0.1	1.4	1.7

Total Static energy

	Harare	Pietbg	Pretoria	Blmfnt	Port Eliz
300	0.4	0.4	0.2	0.3	0
400	0.2	0.5	-0.2	0.6	0.3
500	-0.3	0.5	-0.3	0.4	-0.1
600	-0.8	0.7	1.1	0.6	-0.4
700	0.1	0.6	1.2	0.2	-1.2
850	-0.1	0.4	0.3	-0.5	0.5

24 November 1988 (00h00)
DRY
Location of the cold front over BLM
Alexander Bay - Durban distance section

Temp (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	-2	-1.8	-1.3	-1.6
300	0.6	0	-0.2	-0.4
400	0.2	0.4	0.6	0.8
500	0	0	-0.7	-0.6
600	0.2	0.5	0.5	-0.9
700	0	0.9	1.1	1.3
850	0	0.2	0.9	-0.6

Dewpoint (00h00)

	Alex Bay	Uping	Blmfnt	Durban
300	-1	-0.1	-0.9	-0.5
400	1.4	-1.1	-1.5	-1.3
500	-0.2	1	1	-0.2
600	-0.9	0.6	0.4	0.7
700	0.3	0.2	-0.3	0.5
850	-1	-0.9	0.9	-0.1

Geopotential height (00H00)

	Alex Bay	Uping	Blmfnt	Durban
200				
300	0.6	0.9	0.9	1
400	0.7	1	1.1	1
500	0.8	1.3	1.5	1.2
600	1	1.4	1.9	1.4
700	1.1	1.5	1.9	1.2
850	2.1	1.7	1.3	1.3

Wind U component (00h00)

	Alex Bay	Uping	Blmfnt	Durban
200	0.4	0.2	0	-0.4
300	0.6	0	0.2	-0.3
400	0.7	0.3	0.1	0.1
500	0.8	1.1	1.1	0.7
600	0.7	0.9	0.7	-0.2
700	1.5	1.2	2.7	-0.3
850	0.5	-0.5	-0.8	-1.9

Wind V component (oohoo)

	Alex Bay	Uping	Blmfnt	Durban
200	-0.5	-0.2	0.1	-0.1
300	-0.2	-0.2	-0.4	0.3
400	-0.4	0.3	0.1	0.8
500	0.1	-0.4	-0.1	1.4
600	-0.1	-0.6	-0.5	1.5
700	-0.4	0.4	1.3	0.9
850	1.2	1.7	0.6	-0.6

Dewpoint depression (00H00)

	Alex Bay	Uping	Blmfnt	Durban
300	-0.5	-0.1	-0.5	-0.9
400	-1.6	-0.2	0.4	0.3
500	1.5	0.1	-1	0.5
600	0.5	-0.6	-0.2	0.3
700	0.6	0.2	1.4	0.6
850	0.2	1.6	2.3	-0.3

Equivalent Potential temperature

	Alex Bay	Uping	Blmfnt	Durban
300	0.7	0.3	-0.2	-0.4
400	0.8	0.6	0.2	-0.3
500	0.7	0.4	0.3	-0.1
600	0.4	0.7	0.6	1
700	0.9	1.3	1.4	1.3
850	0.5	1.2	1.4	1.9

Total Static energy

	Alex Bay	Uping	Blmfnt	Durban
300	0.9	0.6	0.3	0
400	1.3	0.8	0.6	0.3
500	0.3	0.3	0.4	-0.1
600	0.3	1.2	0.6	0.3
700	0.1	0.5	0.2	0.7
850	0.4	-0.2	-0.5	0.1