(d) Areas characterised by relatively good air quality, i.e. ambient concentrations between the percentage of the standard/guideline constituted by background concentrations (pollutant-specific) and 50% of the relevant standard and/or guideline.

(e) Pristine environments, in which ambient concentrations are less than, or equal to the background concentrations of each pollutants as a percentage of the selected guidelines and/or standards.

For the purpose of the scoping procedure the latter three categories were grouped together as representing an 'acceptable' class of air quality. Projects which are to be constructed in environments classified within this average urban – pristine grouping will be allowed to "PROCEED" to the subsequent phase, the low concentrations of pollutants currently in the region rendering it unlikely that emissions from the proposed development will result in the exceedance of air quality guidelines. Proposed developments within environments classified as being at risk of non-compliance with relevant ambient air quality guidelines and/or standards, will be given a cautionary note but will be allowed to proceed should no "PROCEED WITH CAUTION" notes have been indicated in previous phases. Areas currently in non-compliance with relevant ambient air quality guidelines will be classified as unacceptable for the location of additional sources.

In instances where developments are proposed for a non-compliance area, it may be recommended that the user select an alternative site. Alternatively, it may be recommended that the user consider the possibility of "buying" an existing industry's "pollution rights". The purchasing of so called pollution rights, more commonly referred to as *emissions trading*, is widely practised in various European countries and within the United States. According to this option, a project proposer would need to persuade existing sources within the region to achieve sufficient additional emission reductions. The project proposers may even find it desirable to provide the capital for an existing source to reduce its emissions so as to achieve lower ambient air pollution concentrations.

8.2.3 Atmospheric Dispersion Potential

The dispersion potential model base serves to reconcile the macro- and meso-ventilation potentials of the proposed site and to categorize the ventilation potential in one of the following classes (Section 6.5.5):

(a) Good dispersion potential;

(b) Fairly good dispersion potential;

(c) Potential risk of poor dispersion, caution recommended; and

(d) Poor dispersion potential.

The manner in which such macro - and meso-ventilation potentials are reconciled for a particular source location is given in Table 6.2. Proposed developments which are to be located at sites included in the first or second categories are entitled to "PROCEED" to the next level. For proposed sites included in the third category (i.e. potential risk of poor dispersion), proposed developments are instructed to "PROCEED WITH CAUTION". All proposed projects within the final category are not allowed to proceed to the next level and the scoping procedure is terminated. In such instances it should be recommended that the project proposer consider various alternatives to the project proposal, such as the selection of an alternative site, and possible alterations to stack heights. Should such project changes not prove successful or feasible, it will be recommended that the proposed development be subject to a comprehensive air pollution impact assessment.

8.2.4 Sensitivity of Receiving Environment

In the proposed scoping procedure the sensitivity of the receiving environment was classified according to three classes, viz.: "sensitive", "potentially sensitive" and "non-sensitive" (Section 7.6). The air pollution scoping procedure is terminated for developments which are to be located within environments classified as being sensitive. It is recommended that such proposed developments be subject to comprehensive air pollution impact assessments. Developments within environments categorised as being potentially sensitive are allowed to "PROCEED WITH CAUTION" (should no previous cautionary note have been returned), whereas for "non-sensitive" environments, project proposals are allowed to "PROCEED".

8.2.5 Final Decision Making Phase

Following the completion of all phases, with a maximum of one "PROCEED WITH CAUTION" returned, the proposed development will be given the "GO AHEAD". It is expected that atmospheric emissions from such developments will have no significant impact on the receiving environment.

The implementation of the proposed air pollution scoping procedure outlined is beneficial even if the proposed project is not allowed to proceed without further assessments being undertaken. Information gained during the scoping procedure would serve to identify and assign priority to issues requiring further investigation, thus facilitating the tailoring of air pollution impact assessments and reducing the costs and durations of such assessments.

8.3 Conclusion

The methodological framework outlined in this section is designed to allow for scenario analysis. Opportunities are provided for the review of initial proposals and for the integration of alternatives to such proposals in instances where the impact of the proposals are found to be unacceptable. Such scenario analysis is fundamental to the integration of environmental planning into the project development process, rather than environmental impact assessments being viewed as an activity to be undertaken once the project plans have been finalised.

Due to the data constraints within which the proposed scoping procedure is to be implemented, it was necessary to include several subjective principles and procedures in the methodological framework. Such subjective stipulations include the decision to terminate the scoping procedure following the second "proceed with caution" note returned, and the manner in which atmospheric dispersion potentials and the sensitivity of receiving environments are classified. Each of these stipulations should be seen to be open to review and revision, particularly should improved information become available.

CHAPTER 9 - RECOMMENDATIONS AND CONCLUSIONS

9.1 Introduction

A real need exists for the successful incorporation of environmental considerations into planning and development strategies. The DEAT adopted the Integrated Environmental Management approach in the early 1990s, and recently rendered scoping and impact assessments mandatory for various activities. The implementation of IEM continues, however, to be undermined by the unavailability of comprehensive data bases and scientific procedures. Recent international and local shifts towards environmental management, based on the integrated pollution control (IPC) principle, have served to highlight this obstacle to the effective integration of environmental assessment into the planning process. Implicit in the IPC approach is a shift from an air pollution control approach based solely on source-based controls to an air quality management approach incorporating effects-based controls.

Air pollution investigations in South Africa are particularly affected by methodological and data constraints. The use of air pollution impact scoping or screening has been impeded by the absence of objective scoping criteria and a readily accessible dispersion climatology data base. A clear need exists for the development and implementation of a methodological framework able to facilitate the scoping studies which will undoubtedly form an essential component of IEM, IPC and the new EIA regulations. A conceptual methodological framework for air pollution impact scoping was developed in the current study. The utility and strengths, current limitations and possible future development of each component of this framework is discussed in the sections below.

9.2 Structure of Methodological Framework

The conceptual framework, designed to facilitate an assessment of whether proposed developments will impact significantly on the receiving environment, comprises five analytical phases:

- establishment of the type and extent of the proposed development's emissions;
- assessment of existing ambient air pollution concentrations at the proposed site;
- characterisation of the atmospheric dispersion potential of the site;
- analysis of the sensitivity of the receiving environment; and
- integration of conclusions reached in the initial four stages into a decision making process.

The application of the decision making framework ensures that *informed*, *transparent* and *reproducible* decisions are made with regard to the acceptability of the proposed development, or the need for further assessment.

The data bases, model bases and user interfaces for each of the five stages are outlined in the preceding chapters. The data bases were structured to provide the information required for the decision making. process, offsetting the need for extensive data collection and collation during the scoping procedure. Information on existing ambient air pollution concentration levels, macro- and meso-ventilation potentials, and the effects of criteria pollutants on various environmental components were included in the data base. The computation of industrial emission rates necessitates a detailed industrial data base containing various emissio . factors and information on industrial processes. The iron and steel industry was therefore selected for inclusion in the data base to demonstrate the utility of the framework. In the establishment of the data base, use was made of the best available data. In certain instances where data were unavailable or insufficient, particularly within the dispersion climatological field, an attempt was made to generate such data.

Model bases included in the scoping procedure were structured to fulfil the following functions: development of an emissions inventory for the proposed iron and steel plant, evaluation of existing ambient air pollutant concentrations, and the atmospheric dispersion potential at the proposed site, assessment of environmental sensitivity, and finally, evaluation of the acceptability of the proposed plant and the need for further more detailed investigations. The model bases draw on information, calculations and procedures contained in the data base, and on information provided by the user.

9.3 Acceptability of Predicted Emissions from Proposed Development

An industrial data base should include data required for the inventory of emissions, in addition to information on air pollution control techniques which may be implemented by the industry, An emission inventory represents the starting point for any assessment of a proposed development's impact on the environment. Information on abatement measures facilitates the review of design and control options which may be considered to reduce the potential emissions from a proposed process. Should the relevant information be readily available, the industrial data base may also include information needed to assess the cost and control efficiency of such control measures, in addition to calculating the percentage of additional control required to ensure compliance with emission limits.

An industrial data base thus provides the information necessary for *scenario analysis* within the project planning phase. Options which may be considered should emissions be predicted to exceed acceptable thresholds (emission limits) may include:

- alterations to the type or amount of raw materials to be used;
- changes in the process operations;
- implementation of additional or alternative abatement techniques; or
- a combination of all of the aformentioned changes.

Scenario analysis is designed to integrate environmental planning into the project development process. Environmental impact assessments should not be perceived as an activity to be undertaken once the project plans have been finalised.

Emission limits, promulgated by the Chief Air Pollution Control Officer (CAPCO), represent emission levels achievable through the application of *best practicable means*. It is not currently possible to include the DEAT's emission limits in the industrial data base since such limits are generally finalised following discussions between CAPCO and the project proposers as to what constitutes best practicable means. In the methodological framework, project proposals are classified based on comparisons between estimated emissions and the limits imposed by CAPCO (as input by the user). This classification provides a straightforward way of assessing the acceptability of emissions from the proposed plant, and integrating the results into the final decision making framework. In instances of non-compliance proposed developments would need to be altered or additional air pollution abatement techniques adopted. Alternatively, the existing emission limits may be renegotiated with CAPCO.

The utility of the iron and steel data and model base is not limited to applications within air pollution scoping studies, but may also be applied in air pollution impact assessments. Should it be recommended in the final decision making phase that further evaluation of the proposed industry's impact is needed, the emission inventory established would provide the necessary basis for a full-scale air pollution impact assessment.

9.4 Incremental Impacts on Ambient Air Quality

Existing ambient pollution concentrations at the proposed site need to be considered in order to assess the potential incremental effects of the proposed industry's emissions on the air quality of the region. Ambient air quality may either be assessed based on the compilation of an emissions inventory for existing sources and the modelling of dispersion from such sources to establish air quality levels, or on the basis of monitored levels of pollutants. In the current study, use was made of monitored levels of sulphur dioxide and particulates, measured at a large number of sites throughout South Africa. It is recommended that existing air pollutant concentrations at a proposed site be compared to ambient air quality guidelines and standards in order to asses the potential which exists for further emissions within the reg:

In the calculation of air quality indices, reference was made to the ambient air quality standards and goals of various countries and organisations, including the US, the EU and the WHO, in addition to local air quality guidelines. Although local guidelines represent the basis on which the acceptability of air quality is determined, the evaluation and inclusion of the air quality standards of other countries in the data base is recommended since:

- current guidelines may be revised in the near future;
- there is currently escalating public pressure for the implementation of stricter air quality standards;
- multinational corporations and bankers are increasingly placing pressure on local concerns to adhere to international standards; and
- the consideration of more stringent standards is in line with the *precautionary principle* outlined in the new environmental legislation recently promulgated in South Africa (DEAT, 1998a; 1998b).

The development of a single air quality index based on various air quality standards for application in air pollution scoping studies is problematic. Ambient air quality currently needs to be assessed on the basis of DEAT guidelines due to the legal implications of such guidelines. The development of a single air quality index, based solely on local guidelines would not, however, adequately reflect the acceptability of air quality in terms of human health and the natural and built environment. Three different indices (AQ-I, AQ-II, AQ-III) were, therefore, proposed for use in the scoping procedure:

- **AQI-I** reflects the relationship between monitored levels of pollutants and DEAT guidelines.
- **AQI-II** incorporates a combination of primary local and international guidelines and standards (i.e. standards are aimed primarily at the protection of human health).
- **AQI-III** defines air quality in terms of the relationship of measured levels of pollutants to secondary, more stringent air quality guidelines and standards designed to protect human welfare and the natural and built environment.

Ambient concentrations of TSP, SO_2 and PM10 monitored over various averaging periods (daily, annual) were used in the calculation of each of the three air quality indices, and the indices classified as follows:

Air Quality Class	Definition of Class	Ambient Concentrations as % of Standard or Guideline
1	non-compliance	≥ 100
2	risk of non-compliance	80 - 100
3	average (urban) air quality	50 - 80
4	relatively good air quality	BC – 50
5	pristine environment	≤ BC

BC represents the background concentration of each pollutant as a percentage of selected guideline or standard. The lowest air quality class estimated for all pollutants over all averaging periods, was taken to be indicative of the air quality of the station. This was done to provide a conservative estimate of the pollution levels present in the region. For the purpose of the scoping procedure, air quality classes 3, 4 and 5 were taken to represent 'acceptable' air quality. Proposed projects located in environments classified within this 'average urban – pristine' group are allowed to proceed to the subsequent phase. The low pollution concentrations at such sites render it unlikely that emissions from the proposed development will result in the exceedance of air quality guidelines.

Proposed developments within environments classified as being at risk of non-compliance with relevant ambient air quality guidelines and/or standards (air quality class 2), are given a cautionary note but are allowed to proceed, should no previous note of caution have been issued. Areas currently in non-compliance with relevant ambient air quality guidelines (class 1 sites) are categorised by the decision making framework as representing unsuitable sites for additional sources. In instances where developments are proposed for non-compliance areas, it is recommended that an alternative site be selected, or alternatively, that the project proposer consider the possibility of 'emissions trading' so that the overall pollution burden is not increased.

The current ambient air quality data base needs to be periodically updated so as to take into account changes in ambient pollutant concentrations. In the current scoping procedure, a proposed development is rejected should ambient concentrations of any of the pollutants taken into account, viz. TSP, PM10 and SO_2, be demonstrated to be in non-compliance with relevant air quality guidelines. The levels of such pollutants are thus perceived as being indicative of the general air quality of the area. The data base could in future be extended to include the evaluation of air quality based on ambient concentrations of additional pollutants, should such data become available.

9.5 Characterisation of Atmospheric Dispersion Potentials

An atmospheric dispersion climatology data base provides the cornerstone for effective air pollution scoping studies. No readily accessible dispersion climatology data base is available for the assessment of regional dispersion potentials within South Africa. In the current study a data and model base able to provide a realistic *qualitative* description of the air pollution dispersion potential of sites within South Africa, based on a limited number of input parameters, was developed. The dispersion climatology data base generated incorporates macro-scale ventilation potentials for all regions within South Africa, in addition to ventilation potentials for various meso-scale circulation scenarios.

9.5.1 Macro-scale Ventilation Potentials

The macro-ventilation characteristics of a region are a function of the meteorological properties, spatial and temporal trends, frequency of occurrence, persistence, sequence of occurrence of prevailing synoptic systems and weather disturbances. The frequency and sequence of occurrence, and persistence of synoptic systems have, to date, only been investigated on a *national* scale. Such information is inadequate to facilitate the estimation of the regional dispersion potentials required for the dispersion climatology data base.

A temporal air mass-based synoptic climatology was established in an attempt to provide the necessary information required for the calculation of regional ventilation potentials. The air mass-based synoptic climatology was generated, based on three years of upper air data for each of the nine rawisonde stations in South Africa, and the resulting synoptic classifications generalised for each region.

Results from the three year air mass-based synoptic climatology were used to provide a single index of the macro-scale ventilation potential of each region for winter and summer. Synoptic systems identified were classified as either stagnating, ventilating or neutral systems, based on the consideration of the vertically averaged wind speeds, mixing depths and precipitation potentials characterising such systems at each station. The macro-scale ventilation potential was defined as the ratio of the percentage stagnating days within an episode to the percentage of days on which ventilating systems predominated. An episode was defined as a period in which stagnating systems persisted for four or more days. Based on the estimated macro-ventilation potential, regions were classified according to three classes: (i) prone to poor dispersion, (ii) median dispersion potential; and (iii) good dispersion potential.

Although it was intended that the synoptic climatology be undertaken for all seasons, it was only possible to include winter and summertime synoptics. Despite the initial inclusion of autumn and spring months in the assessment, the analysis of these seasons was terminated since the use of upper air meteorological data recorded at twelve hourly intervals proved inadequate to reflect the rapid transition between circulation patterns characteristic of these periods with the analytical technique selected accurately. It is recommended that further techniques be evaluated to facilitate such analyses, so that the synoptic climatology established may be expanded to include all seasons. In the establishment of a synoptic climatology for autumn and spring (based on the available twelve hourly interval upper air data), the use of alternative input parameters may improve the results generated. Relative humidity could, for instance, be replaced by vapour pressure, and mixing heights could be computed for each twelve hour period and included as an input parameter.

For the purpose of the current study it was necessary to limit the period for which the air mass-based synoptic climatology was established to three years. The development of such synoptic climatologies abroad have frequently been based on up to 30 years of data. The nature and usefulness of the results produced indicates that it would be worthwhile to extend the climatology to include an additional number of years. The consideration of a longer period would facilitate an analysis of the inter-annual variations in dispersion potentials. The proposed extension of the synoptic climatology would, however, require careful review of the availability and accuracy of the upper air data required, and the availability of considerable computational capacity to facilitate the manipulation of the large meteorological data sets.

The air mass-based synoptic climatology, and the extension of this data base may provide valuable information for various areas of study. Temporal synoptic climatologies may be linked to large scale transportation patterns. In the US and UK, inter-annual variations in the frequency of occurrence and meteorological characteristics of the synoptic types identified as part of synoptic climatologies are examined to facilitate climate change studies.

Local studies are currently underway to assess the potential of fog as a source of potable water for rural communities in the eastern Drakensburg. The quantity of water which could be collected on a fog fence (per unit area) for each synoptic system, including ridging anticyclones, cold fronts and cut-off lows has been assessed. The development of a long-term synoptic climatology and the examination of inter-annual variations in the frequency of occurrence and meteorological characteristics of synoptic types could provide valuable information as to the ranges in the total water yield from this source.

9.5.2 Meso-scale Ventilation Potentials

Ventilation characteristics for various generic meso-scale circulation systems were included in the data base to demonstrate the manner in which such circulations may be incorporated into the assessment of the dispersion potential at a specific site. Due to the complexity of establishing such generic models, meso-scale systems related to *uneven terrain* were selected for inclusion in the data base. Such systems included the impact of hills and valleys on the low-level wind field and atmospheric stability regime.

Based on the nature of the proposed source (e.g. height of emission, location within the valley, proximity to hill), and the characteristics of the relief of the site (e.g. valley depth, hill slope and height), three meso-ventilation potential classes were defined: (i) poor dispersion potential (high probability of fumigation conditions), (ii) potential risk of poor dispersion (macro-ventilation potentials need to be considered), and (iii) no risk foreseen due to meso-scale circulations (macro-ventilation potentials need to be taken into account).

9.5.3 Reconciliation of Macro- and Meso-ventilation Potentials

It is unlikely that all potential sources will be excluded for an entire region which is prone to poor dispersion. It was therefore decided that macro-ventilation potentials should only serve to provide a cautionary note rather than a decisive recommendation as to whether or not a planned development be allowed to continue. Meso-ventilation potentials were thus given a greater weighting than were macro-ventilation potentials in the final classification of the overall dispersion potential of the site into one of four classes, viz.: (i) poor dispersion potential, (ii) potential risk of poor dispersion, caution recommended, (iii) fairly good dispersion potential, and (iv) good dispersion potential. It is proposed that the air pollution scoping procedure be terminated for proposed sites which are classified as being characterised by poor dispersion potentials. In such instances it should be recommended that the project proposed consider an alternative site, or that the proposed development be subject to a comprehensive air pollution impact assessment.

9.6 Sensitivity of Receiving Environments

Air pollution impact assessment studies need to include an appraisal of the associated environmental risk. Such risk assessments comprise identification of potentially sensitive environmental components in the vicinity of the site, and characterisation of the risk to such receptors posed by the estimated emissions. During the air pollution scoping phase it is not possible to undertake a dose-response analysis and exposure assessment needed to quantify risks. The identification of potential risks was, however, included in the scoping procedure. The integration of risk identification not only provides for a more comprehensive assessment of the impact of a proposed industry during the scoping phase, but also provides the basis for risk assessment studies should a more detailed air pollution impact assessment be required for such an industry.

In the proposed scoping procedure the sensitivity of the receiving environment was classified according to the following criteria: (i) whether or not the receiving environment is included in the 'list of environments' identified by the DEAT as necessitating a full-scale impact assessment, (ii) proximity of sensitive receptors to the proposed site, (iii) dispersion potential of the site, and (iv) extent of emissions anticipated. Receiving environments are classified into one of three classes, viz.: 'sensitive', 'potentially sensitive' and 'non-sensitive'. The air pollution scoping procedure is terminated for developments which are to be located within environments classified as being 'sensitive'. It is recommended that such proposed developments be subject to comprehensive air pollution impact assessments.

9.7 Strengths and Limitations of Proposed Decision Making Framework

The conceptual methodological framework comprises a holistic approach to air quality management, incorporating both source-based and effects-based controls. The acceptability of a proposed industry's emissions is determined on the basis of source-based controls; emission inventory results being compared with emission limits promulgated by CAPCO. The inclusion of an assessment of existing ambient air quality, based on local and international air quality standards, reflects the integration of an effects-based approach. The analysis of atmospheric dispersion potentials and sensitivity of receiving environments also forms an integral component of the effects-based approach.

The integration of assessments regarding types and extents of emissions, existing pollution concentrations, site-specific dispersion potentials, and environmental sensitivities into the decision-making process posed a significant challenge. In order to ensure the integration of all aspects in a transparent and consistent manner, it was necessary to establish a well documented scoping procedure. Such a procedure is not only important to ensure the transparency during the scoping phase, but may also provide the precedent for subsequent air pollution impact assessments.

The methodological framework incorporates several *subjective* principles and procedures. The more important of these include: the stipulation that the scoping procedure be terminated following the second cautionary note, classification of macro- and meso-ventilation potentials into classes and the manner in which such ventilation potentials are reconciled for a particular site, and the criteria used in used in the classification of receiving environments. Each of these stipulations may be subject to review and revision. The potential revision of various components within the methodological framework, particularly in instances where additional information becomes available, would serve to enhance the validity of the framework. Such revisions need to be well documented so as to ensure the continued transparency and reproducibility of the decision making process.

A fine line exists between attempting to store too much data in the data base required for air pollution scoping, and maintaining sufficient data to facilitate informed decision making. In the development of the current data base an attempt was made to incorporate only data essential to the decision making process. Should the data base be extended, all industrial, climatological, socio-economic data (etc.) incorporated should be shown to contribute significantly to the decision making process.

The implementation of the proposed air pollution scoping procedure outlined is beneficial even if the proposed project is not allowed to proceed without further assessments being undertaken. Information gained during the scoping procedure would serve to identify and assign priority to issues requiring further investigation, thus facilitating the tailoring of air pollution impact assessments and reducing the costs and durations of such assessments.

The conceptual decision-making framework for air pollution scoping studies proposed in the current study may play a much needed role in preparing common ground between project proposers, environmental authorities, and interested and affected parties. The transparent and consistent nature of decisions made within such a framework could enhance communication, promote the review of project options early on in the planning phase, and assist in the resolution of disputes with regarding the proposed process. Where no compromises are possible, or where the impact of the proposed development requires further study, the methodological framework not only provides useful baseline information, but also establishes the precedent for transparency and consistency in subsequent air pollution impact assessments.

APPENDIX A

INDUSTRIAL DATA BASE, MODEL BASE AND USER INTERFACE

The detailed industrial data base, model base and user interface compiled for the integrated iron and steel industry so as to demonstrate the utility of the conceptual framework is presented in Appendix A. This appendix is contained in electronic format on the accompanying computer disk.

APPENDIX B

Table B.1. Final air quality classes(a) assigned each of the sampling sites.

Sampling Site(b)	Air Quality Index			Sampling Site(b)	Air Quality Index		
	I	II	III		I	II	III
GAUTENG				**Johannesburg**			
Alberton				City Hall (C)	4	4	3
New Redruth (C)	3	3	2	Fordsburg (I)	4	2	1
Alrode (I)	2	2	1	**Kempton Park**			
Newmarket (I/R)	3	3	2	CBD (C)	4	4	4
Benoni				Fisonsnywerheid (I)	4	3	3
CBD (C)	4	4	4	**Sandton**			
Industrial area (I)	4	4	4	Marlboro (I)	4	4	3
Westdene (R)	4	4	4	Sandown (I/R)	4	4	4
Daveyton (R)	4	2	1	Rivonia (R)	4	4	4
Boksburg				**Meyerton**			
CBD (C)	4	3	3	CBD (C)	4	3	2
Cinderella (I)	4	4	3	Rothdene (C/R)	4	3	2
Boksburg North (I/R)	4	4	4	Kookrus (C/R)	4	4	4
Lilianton (R)	4	4	4	**Pretoria**			
Boksburg East (R)	4	2	2	CBD (C)	4	3	3
Reiger Park (R)	4	3	3	Visage Str (I)	4	2	2
Edenvale				Myburg Str (I/R)	4	4	4
Illiondale (R)	4	4	4	Arcadia (R)	4	4	4
CBD (C)	4	4	4	Scientia (R/I)	4	4	4
Sebenze (I)	4	4	4	**Randburg**			
Terrace Road (I/R)	4	4	3	Blairgowrie (R)	4	4	4
Germiston				Malans Hof (I/A161R)	4	4	4
CBD (C)	4	4	3	Randparkrif (R)	4	4	4
Wadeville (I)	4	4	3	**Roodepoort**			
Delville (I/R)	4	4	4	CBD (C)	4	4	4
Primrose (R)	4	4	4	Florida (R)	4	4	4
Tembisa (R)	4	4	3	Weltevredenpark (R)	4	4	4
Kathlehong (R)	4	2	2	Wilropark (R)	4	4	4
Bedfordview (R)	4	4	4	**Veereniging**			
Brakpan				Powerville (I)	4	2	2
CBD (C)	4	3	3	CBD (C)	3	3	3
Geluksdal (R)	3	3	3	Drieriviere (R)	4	4	4
Leachville (R)	4	4	4	Bedworthpark (R)	3	2	2

Table B.1. Final air quality indices for each of the sampling sites (continued).

Sampling Site(b)	Air Quality Index			Sampling Site(b)	Air Quality Index		
	I	II	III		I	II	III
GAUTENG				**MPUMALANGA**			
Springs				**Middleburg**			
CBD (C)	4	4	3	CBD (C)	4	4	3
New Era (I)	4	2	2	Weber Str (I)	4	4	4
Nuffield (I)	3	3	3	Fontein Str (R)	3	3	2
Bus Terminus (C)	4	3	3	**Nelspruit**			
Selection Park (R)	4	3	3	CBD (C)	4	4	4
Petersfield (R)	3	3	3	Industrial Area (I)	4	4	4
Vanderbijlpark				Lowveld High School (R)	4	4	4
CBD (C)	4	4	3	**Witbank**			
Municipal workshop (I)	4	4	3	CBD (C)	4	4	4
Municipal test ground (I/R)	4	2	2	Ferrobank (I)	4	3	3
Municipal licence office (I/R)	4	3	3	Extention 10 (R)	4	4	4
Municipal pool (R)	4	3	3	Tasbet Park (R)	4	4	4
Lekoa (Sebokeng) (RUR)	4	3	3	**NORTHERN PROVINCE**			
FREE STATE				**Pietersburg**			
Bethlehem				CBD (C)	4	4	4
CBD (C)	4	4	4	Annadale (I/R)	4	4	4
Workshop (I)	4	4	4	**NORTH WEST PROVINCE**			
Jordaine (R)	4	4	4	**Klerksdorp**			
Bohlokong (R)	4	4	4	CBD (C)	4	4	4
Bloemfontein				Jouberton (R)	4	4	4
CBD (C)	4	3	4	**Potchefstroom**			
Lang Str (I)	4	3	4	CBD (C)	4	2	2
Bayswater (R)	4	4	4	Gouws Str (R)	4	2	2
Mkuhlone Str (R)	3	2	2	Tlokwe (R)	3	2	2
Kroonstad				Dassie Rand (R)	5	4	4
Municipal workshop (C/I/R)	4	4	4	**KWAZULU NATAL**			
Voortrekker Hospital (I/R)	4	4	3	**Durban**			
Seisoville (R)	4	2	2	City Hall (C)	4	4	4
Welkom				Municipal Centre (C)	4	3	3
CBD (C)	4	4	4	Congella Fire Station (I)	4	3	3
Municipal workshop (I)	4	4	4	Southern Sewerage works (I)	2	1	1
Thabong (R)	4	2	2	South Bluff Reservoir (I/R)	3	3	3
Sasolburg				Wentworth Reservoir (I/R)	1	1	1
CBD (C)	4	4	3	Brighton Beach Reservoir (R)	2	2	2
Magasyn (I)	4	4	4	Durban North (R)	4	4	4
Grootfontein (R)	4	4	4	University (R)	4	4	4
Vaalpark (I)	4	3	3	Merebank (R/I)	3	3	2

Table B.1. Final air quality indices for each of the sampling sites (continued).

Sampling Site(b)	Air Quality Index		
	I	II	III
KWAZULU NATAL			
Durban			
Riverside (R/I)	4	3	2
Isipingo (R/I)	4	3	3
Chatsworth (R)	4	4	4
Bluff Army Base (R/I)	4	4	4
Amanzimtoti			
CBD (C)	4	4	3
Industrial Area (I)	4	4	3
Fire Station (R)	4	3	3
Estcourt			
Alfred Str (C)	4	3	3
Connor Str (C)	4	3	3
Newcastle			
Allen Str (C)	4	4	4
Edison Str (I)	4	4	4
Flame Cres. (I)	4	4	4
Drakensberg Commando (R)	4	4	4
Pinetown			
CBD (C)	4	4	4
Cowie's Hill (R)	4	4	4
Gillits Rd (I)	3	3	3
Pietermaritzburg			
CBD (C)	4	4	4
Mason's Mill (I)	4	3	3
Joliffe (I/R)	4	4	4
Old Beer Hall (I/R)	4	3	3
Northdale (R/I)	4	3	3
Chase Valley (R)	4	4	4
Richards Bay			
Alton (I)	4	4	4
Polaris (I)	4	4	4
Arboretum Ext 1 (R)	3	3	3
Meerensee (R)	4	4	4
Water works Arboretum (R)	3	3	2
Air Qual Lab (R)	4	4	4

Sampling Site(b)	Air Quality Index		
	I	II	III
EASTERN CAPE			
East London			
CBD (C)	4	4	4
Cambridge Clinic (R)	4	4	4
Port Elizabeth			
CBD (C)	4	3	3
Deal Party Estate (I)	4	4	3
Markman Township (I)	4	3	3
Perseverance (I)	4	4	4
Neave Township (I/R)	4	3	3
North End (I/R)	4	3	3
Sidewell (I/R)	4	2	2
Mount Croix (R)	5	4	4
Kwazakele (R)	4	4	4
WESTERN CAPE			
Cape Town			
Foreshore (C)	4	4	4
Drill Hall (C)	4	4	4
Epping Market (I)	4	4	4
Paarden Eiland (I)	3	3	3
Other			
Bellville South (R)	4	4	4
Edgemead (R/I)	4	4	4
Pinelands Nerine Cres. (R)	4	4	4
Parow (R)	4	4	4
Goodwood (R)	4	4	4
Elsies River (R)	4	4	4
Khayalitsha (R)	4	4	4

(a) The definition of the air quality classes are defined as follows: (1) non-compliance with guidelinesor standards; (2) risk of non-compliance; (3) average/urban air quality; (4) relatively good air quality; and (5) pristine environment.

(b) The nature of sampling sites are given by the following letters: C - Central urban areas; I - Industrial areas; R - Residential areas; and RUR - Rural areas.

Table B.2 Specific air quality classes(a) for each pollutant over each averaging perio   Letters A to G, which represent the pollutant and averaging period taken into account, are defined following the table. Classes generated for all three air quality indices (AQI) are given.

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
GAUTENG																						
Alberton																						
New Redruth (C)	4	4	3	3	3	3	4	4	4	4	3	3	3	3	4	3	4	4	3	3	2	2
Alrode (I)	4	4	3	3	2	2	4	2	3	3	3	3	2	2	4	2	3	3	3	3	1	1
Newmarket (I/R)	4	4	3	3	3	3	4	4	4	4	3	3	3	3	4	4	4	4	3	3	2	2
Benoni																						
CBD (C)	5	4				4	5	4	4	4				4	5	4	4	4				4
Industrial area (I)	4	4				4	4	4	4	4				4	4	4	4	4				4
Westdene (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Daveyton (R)	4	4				4	4	2	3	3				2	4	1	3	3				1
Boksburg																						
CBD (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3
Cinderella (I)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	3
Boksburg N (I/R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Lilianton (R)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Boksburg East (R)	4	4	4	4	4	4	4	2	2	3	4	4	4	2	4	2	2	3	4	4	4	2
Reiger Park (R)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Edenvale																						
Illiondale (R)	5	4	4	4	5	4	5	4	4	4	4	4	5	4	5	4	4	4	4	4	5	4
CBD (C)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Sebenze (I)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Terrace Road (I/R)	4	4				4	4	4	4	4				4	4	3	4	4				3
Germiston																						
CBD (C)	5	4				4	5	4	4	4				4	5	3	4	4				3
Wadeville (I)	4	4				4	4	4	4	4				4	4	3	4	4				3
Delville (I/R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Primrose (R)	5	4				4	5	4	4	4				4	5	4	4	4				4

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
Tembisa (R)	4	4				4	4	4	4	4				4	4	3	4	4				3
Kathlehong (R)	4	4				4	4	3	2	3				2	4	2	2	3				2
Bedfordview (R)	4	4				4	4	4	4	4				4	4	4	4	4				4
Brakpan																						
CBD (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Geluksdal (R)	4	4	3	4	4	3	4	3	3	4	3	4	4	3	4	3	3	4	3	4	4	3
Leachville (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Johannesburg																						
City Hall (C)	4	4				4	4	4	4	4				4	4	3	4	4				3
Fordsburg (I)	4	4				4	4	2	2	3				2	4	1	2	3				1
Kempton Park																						
CBD (C)	5	4				4	5	4	4	4				4	5	4	4	4				4
Fisonsnywerhd. (I)	4	4				4	4	4	3	4				3	5	4	3	4				3
Sandton																						
Marlboro (I)	4	4	5			4	4	4	4	4	5			4	4	3	4	4	5			3
Sandown (I/R)	4	4	5			4	4	4	4	4	5			4	4	4	4	4	5			4
Rivonia (R)	5	4	5			4	5	4	4	4	5			4	5	4	4	4	5			4
Meyerton																						
CBD (C)	4	4				4	4	3	3	3				3	4	2	3	3				2
Rothdene (C/R)	4	4				4	4	3	3	3				3	4	2	3	3				2
Kookrus (C/R)	4	5				4	4	5	4	5				4	4	5	4	5				4
Pretoria																						
CBD (C)	4	4	4	4	4	4	4	3	4	4	4	4	4	3	4	3	4	4	4	4	4	3
Visage Str (I)	4	4	4	4	4	4	4	2	3	3	4	4	4	2	4	2	3	3	4	4	4	2
Myburg Str (I/R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Arcadia (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Scientia (R/I)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Randburg																						
Blairgowrie (R)	4	4				4	4	4	4	4				4	4	4	4	4				4
Malans Hof (I.R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Rar[illegible]arkrif (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
R[illegible]oort																						

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
CBD (C)	4	4				4	4	4	4	4				4	4	4	4	4				4
Florida (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Weltevredenpk. (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Wilropark (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Springs																						
CBD (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
New Era (I)	4	4	4	4	4	4	4	3	2	4	4	4	4	2	4	3	2	4	4	4	3	2
Nuffield (I)	4	4	4	3	4	3	4	4	3	4	4	3	4	3	4	3	3	4	4	3	3	3
Bus Terminus (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Selection Park (R)	4	4				4	4	4	3	4				3	4	4	3	4				3
Petersfield (R)	4	4	3	4	4	3	4	4	3	4	3	4	4	3	4	4	3	4	3	4	3	3
Vanderbijlpark																						
CBD (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	3
Mun. workshop (I)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	3
Mun. test site (I/R)	4	4	4	4	4	4	4	3	2	4	4	4	4	2	4	3	2	4	4	4	4	2
Mun. office (I/R)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Municipal pool (R)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Lekoa (RUR)	4	4	4	4	4	4	4	3	3	3	4	4	4	3	4	3	3	3	4	4	4	3
Veereniging																						
Powerville (I)	4	4	4	4	4	4	4	2	2	3	4	4	4	2	4	2	2	3	4	4	4	2
CBD (C)	4	4	4	3	4	3	4	3	3	4	3	3	4	3	4	3	3	4	3	3	3	3
Drieriviere (R)	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Bedworthpark (R)	4	4	3	4	4	3	4	2	2	3	3	4	4	2	4	2	2	3	3	4	3	2
FREE STATE																						
Bethlehem																						
CBD (C)	5	4				4	5	4	4	4				4	5	4	4	4				4
Workshop (I)	5	4				4	5	4	4	4				4	5	4	4	4				4
Jordaine (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Bohlokong (R)	4	4				4	4	4	4	4				4	4	4	4	4				4
Bloemfontein																						
CBD (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	4
Lang Str (I)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	4

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	**B**	**E**	**F**	**G**	**AQ-I**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**AQI-II**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**AQI-III**
Bayswater (R)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4
Mkuhlone Str (R)	4	4	3	4	4	3	3	2	2	3	3	4	4	2	2	2	2	3	3	4	4	2
Kroonstad																						
Municipal workshop (C/I/R)	4	4				4	4	4	4	4				4	4	4	4	4				4
Voortrekker Hospital (I/R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	3
Seisoville (R)	4	4	4	4	4	4	4	3	2	3	4	4	4	2	4	2	2	3	4	4	4	2
Welkom																						
CBD (C)	4	4				4	4	4	4	4				4	4	4	4	4				4
Municipal workshop (I)	4	4				4	4	4	4	4				4	4	4	4	4				4
Thabong (R)	4	4				4	4	3	2	4				2	4	3	2	4				2
Sasolburg																						
CBD (C)	4	4				4	4	4	4	4				4	4	3	4	4				3
Magasyn (I)	4	4				4	4	4	4	4				4	5	4	4	4				4
Grootfontein (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Vaalpark (I)	4	4				4	4	3	4	4				3	4	3	4	4				3
MPUMALANGA																						
Middleburg																						
CBD (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Weber Str (I)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Fontein Str (R)	5	4	3	3	3	3	5	4	4	4	3	3	3	3	5	4	4	4	3	3	2	2
Nelspruit																						
CBD (C)	5	4				4	5	4	4	4				4	5	4	4	4				4
Industrial Area (I)	4	4				4	4	4	4	4				4	4	4	4	4				4
Lowveld High (R)	4	4				4	4	4	4	4				4	4	4	4	4				4
Witbank																						
CBD (C)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Ferrobank (I)	4	4	4	4	4	4	4	3	3	3	4	4	4	3	4	3	3	3	4	4	4	3
Extention 10 (R)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Tasbet Park (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
NORTHERN PROVINCE																						
Pietersburg																						
CBD (C)	5	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4
Annadale (I/R)	5	4	4	4	5	4	5	4	4	4	4	4	5	4	5	4	4	4	4	4	5	4
NORTH WEST PROVINCE																						
Klerksdorp																						
CBD (C)	5	4				4	5	4	4	4				4	5	4	4	4				4
Jouberton (R)	5	4				4	5	4	4	4				4	5	4	4	4				4
Potchefstroom																						
CBD (C)	4	4	4	4	4	4	4	4	2	4	4	4	4	2	3	4	2	4	4	4	4	2
Gouws Str (R)	4	4	4	4	4	4	3	4	2	4	4	4	4	2	2	4	2	4	4	4	4	2
Tlokwe (R)	3	4	4	4	4	3	3	3	2	3	4	4	4	2	2	2	2	3	4	4	4	2
Dassie Rand (R)	5	5				5	5	5	4	4				4	5	5	4	4				4
KWAZULU NATAL																						
Durban																						
City Hall (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Mun. Centre (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3
Congella Fire Station	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	3	3
Southern Sewerage works (I)	4	4	3	3	2	2	4	4	4	4	1	3	2	1	4	4	4	4	1	3	1	1
South Bluff Reservoir	4	4	3	3	4	3	4	4	4	4	4	3	4	3	4	4	4	4	4	3	4	3
Wentworth Reservoir	4	4	2	1	2	1	4	4	4	4	1	1	2	1	4	4	4	4	1	1	1	1
Brighton Beach Reservoir (R)	4	4	3	2	4	2	4	4	4	4	3	2	4	2	4	4	4	4	3	2	3	2
Durban North (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
University (R)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Merebank (R/I)	4	4	3	3	3	3	4	4	3	4	3	3	3	3	4	3	3	4	3	3	2	2
Riverside (R/I)	4	4	4	4	4	4	4	3	3	3	4	4	4	3	4	2	3	3	4	4	4	2
Isipingo (R/I)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Chatsworth (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
Bluff Army Base (R/I)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Amanzimtoti																						
CBD (C)	5	4	4	4	4	4	5	3	4	4	4	4	4	4	5	3	4	4	4	4	4	3
Industrial Area (I)	5	4	4	4	4	4	5	3	4	4	4	4	4	4	5	3	4	4	4	4	4	3
Fire Station (R)	5	4	4	4	4	4	5	3	4	3	4	4	4	3	5	3	4	3	4	4	4	3
Estcourt																						
Alfred Str (C)	4	4	4	4	4	4	4	3	4	4	4	4	4	3	4	3	4	4	4	4	4	3
Connor Str (C)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Newcastle																						
Allen Str (C)	5	5	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4
Edison Str (I)	5	5	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4
Flame Cres. (I)	5	5	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4
Drakensberg Commando (R)	5	5	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4
Pinetown																						
CBD (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Cowie's Hill (R)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4
Gillits Rd (I)	4	4	3	4	4	3	4	4	3	4	3	4	4	3	4	3	3	4	3	4	4	3
Pietermaritzburg																						
CBD (C)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Mason's Mill (I)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Joliffe (I/R)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Old Beer Hall (I/R)	4	4	4	4	4	4	4	3	3	3	4	4	4	3	4	3	3	3	4	4	4	3
Northdale (R/I)	4	4	4	4	4	4	4	3	3	4	4	4	4	3	4	3	3	4	4	4	4	3
Chase Valley (R)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4
Richards Bay																						
Alton (I)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Polaris (I)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Arboretum Ext 1 (R)	5	5	4	3	4	3	5	5	4	5	4	3	4	3	5	5	4	5	4	3	4	3
Meerensee (R)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Water works Arboretum M3 (R)	5	5	3	3	3	3	5	5	4	5	3	3	3	3	5	5	4	5	3	3	2	2

Sampling Site (b)	Specific Classes for Air Quality Index I(c)					Final Index	Specific Classes for Air Quality Index II(c)							Final Index	Specific Classes for Air Quality Index III(c)							Final Index
	A	B	E	F	G	AQ-I	A	B	C	D	E	F	G	AQI-II	A	B	C	D	E	F	G	AQI-III
Air Qual Lab (R)			4	4	4	4					4	4	4	4					4	4	4	4
EASTERN CAPE																						
East London																						
CBD (C)	5	5	4	5	5	4	5	5	4	4	4	5	5	4	5	5	4	4	4	5	5	4
Cambridge Clinic (R)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Port Elizabeth																						
CBD (C)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3
Deal Party Est. (I)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	3	4	4	4	4	5	3
Markman Township (I)	4	4				4	4	4	3	4				3	4	4	3	4				3
Perseverance (I)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4
Neave Township (I/R)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3
North End (I/R)	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4	4	3	4	4	4	4	3
Sidewell (I/R)	4	4				4	4	3	2	4				2	3	3	2	4				2
Mount Croix (R)	5	5				5	5	5	4	5				4	5	5	4	5				4
Kwazakele (R)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
WESTERN CAPE																						
Cape Town																						
Foreshore (C)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Drill Hall (C)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Epping Market (I)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Paarden Eiland (I)	4	4	3	3	3	3	4	4	4	4	3	3	3	3	4	4	4	4	3	3	3	3
Other																						
Bellville South (R)	5	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4
Edgemead (R/I)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Pinelands Nerine Cres. (R)	4	4	4	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4
Parow (R)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Goodwood (R)	5	5	4	4	4	4	5	5	4	4	4	4	4	4	5	5	4	4	4	4	4	4
Elsies River (R)	5	5	4	4	4	4	5	5	4	5	4	4	4	4	5	5	4	5	4	4	4	4
Khayalitsha (R)	4	4				4	4	4	4	4				4	4	4	4	4				4

(a) The definition of the air quality classes are defined as follows: (1) non-compliance with guidelines or standards; (2) risk of non-compliance; (3) average/urban air quality; (4) relatively good air quality; and (5) pristine environment.

(b) The nature of sampling sites are given by the following letters: C - Central urban areas; I - Industrial areas; R - Residential areas; and RUR - Rural areas.

(c) Definitions of pollutants and averaging period criteria used for calculation of specific air quality classes:

A. Highest measured TSP concentrations recorded for each month over 24-hour averaging period.
B. Annual average TSP concentrations.
C. Highest PM10 concentrations for each month over 24-hour averaging period (estimated from highest concentrations of TSP sampled).
D. Annual average PM10 concentrations (estimated from monitored annual average levels of TSP).
E. Highest measured SO_2 levels recorded for each month over 24-hour averaging periods.
F. Monthly average SO_2 levels sampled.
G. Annual average SO_2 levels sampled.

APPENDIX C

RESULTS OF A THREE YEAR AIR MASS-BASED SEASONAL (SUMMER AND WINTER) SYNOPTIC CLIMATOLOGY FOR SOUTH AFRICA

1. INTRODUCTION

The results of the three year air mass-based synoptic climatology established for each of the nine rawisonde stations for summer (December, January, February) and winter (June, July, August) seasons are presented in this Appendix. The percentage of winter and summer days for each station, for which sufficient data was available to enable statistical analysis and classification, is presented in Table C.1. Although the autumn and spring seasons were initially included in the assessment, the analysis of these periods was terminated since the use of upper air meteorological data recorded at twelve hour intervals proved inadequate to accurately reflect the rapid transition between circulation patterns characteristic of these periods with the technique selected.

The synoptic types identified as influencing each of the nine stations during summer and winter months are presented. The meteorological characteristics of synoptic types are discussed separately for coastal and inland stations due to the frequently distinctly different vertical profiles which characterise the atmosphere of coastal and inland regions under the influence of a particular synoptic type. The synoptic trends noted for each station are perceived to be representative of the region in which the station occurs, viz. Pietersburg, Irene, Bloemfontein, Bethlehem and Upington represent the Northern, Central, Southeastern, Eastern and Western Plateau respectively; whereas Cape Town, Springbok, Port Elizabeth and Durban represent the Southern, Western, Southeastern, and Eastern Coasts respectively.

Table C.1: Total number of days for which data were available for use in the establishment of the seasonal synoptic climatology.

STATION:	No. (PERCENTAGE) DAYS USED IN ANALYSIS	
	WINTER	SUMMER
Bethlehem	213 (77.2%)	192 (71.1%)
Bloemfontein	188 (68.1%)	179 (66.3%)
Cape Town	232 (84.1%)	218 (80.7%)
Durban	208 (75.4%)	180 (66.7%)
Irene	182 (66%)	206 (76.3%)
Pietermaritzburg	206 (74.6%)	198 (73.3%)
Port Elizabeth	245 (88.8%)	80 (29.6%)(a)
Springbok	174 (63%)	157 (58%)
Upington	197 (71.4%)	202 (74.8%)

a) Due the magnitude of missing data in December and January months, only February months were used in the analysis for PE.

Surface pressure and vertical profiles of temperature, humidity and zonal and meridional wind components are illustrated for each synoptic type at each station for both winter and summer (Figures C.1 - C.18). Tables indicating the frequency of occurrence and persistence (including the average and maximum number of days over which synoptic patterns exits) of each of the synoptic types are presented for each station (Tables C.5 - C.9, C12 - C15, C18 - C22, C25 - C28).

The impact of each synoptic type on the air pollution dispersion potential of individual regions was assessed based on the classification of synoptic types into three classes, viz. ventilating systems, stagnating systems and neutral systems. The classification of synoptic types was based on the mixing depth, the vertically averaged wind speed (VAWS) characteristic of the synoptic type and on the potential for precipitation to occur as a result of the synoptic type. All synoptic types associated with precipitation events were classified as ventilating systems. The remainder of the synoptic types were categorised according to their characteristic mixing depth and vertically averaged wind speed class, as outlined in Table C.2.

Table C.2: Criteria for the classification of non-precipitation synoptic types into stagnating (S), ventilating (V) and neutral (N) systems, according to vertically averaged wind speed (VAWS) and mixing depth.

	MIXING DEPTH (m)					
VAWS (m/s)	≤ 600	≤ 800	≤ 1 000	≤ 1 500	≤ 2 000	> 2 000
≤ 2	S	S	S	S	S	N
≤ 4	S	S	S	S	N	V
≤ 6	S	S	S	N	V	V
≤ 8	S	S	S	V	V	V
≤ 10	S	S	V	V	V	V
> 10	S	V	V	V	V	V

2. WINTER SYNOPTIC TYPES AFFECTING PLATEAU REGIONS

2.1 Wintertime Synoptic Types Identified for Plateau Stations

The synoptic types identified for each plateau station during the winter period are given in the sections below, and a synopsis provided in Table C.3. Cluster numbers indicated in Table C.3 were assigned on an arbitrary basis for each of the groupings of days for each station. Following the analysis of the meteorological characteristics of each of the clusters it was possible to classify the clusters as particular synoptic types. The results of the labelling of each of the clusters is presented in the table. In certain instances, two clusters identified for a particular station may both have been associated with the same synoptic type, e.g. clusters 3 and 4 defined for Upington are both representative of the passage of a cold front. Slight differences in the meteorological characteristics of these clusters are associated with variations in the location of the cold front.

2.1.1 Central Plateau (Irene)

1. Continental High Pressure Dominant over Interior
2. Eve of Frontal Depression
3. Miscellaneous Cluster (Associated with Continental HP)
4. Anticyclonic Bridge over Subcontinent
5. Westerly Wave Trough in Upper Atmosphere over Interior
6. Cold Frontal Passage
7. Day Following Passage of Cold Front
8. Ridging Anticyclones off Southeast or East Coast

2.1.2 Eastern Plateau (Bethlehem)

1. Continental High Pressure Dominant over the Interior
2. Ridging Anticyclone off South or Southeast Coast
3. Eve of Frontal Depression
4. Passage of Cold Front
5. Westerly Wave Trough in Upper Atmosphere over Interior
6. Day Following Passage of Cold Front
7. Miscellaneous Cluster (Associated with Continental HP)
8. Anticyclonic Bridge over Subcontinent

2.1.3 SouthEastern Plateau (Bloemfontein)

1. Continental HP Dominant over Interior
2. Ridging Anticyclone off the East Coast
3. Eve of Cold Frontal Passage
4. Passage of Cold Front
5. Day Following Cold Front Passage
6. Ridging Anticyclone off the Southeast Coast
7. Low Pressure over the West Coast
8. Surface Trough over the Western Interior

2.1.4 Western Plateau (Upington)

1. Continental HP Dominant over the Interior
2. Anticyclonic Bridge over Subcontinent
3. Cold Front Passage from the West
4: Cold Front Passage for the South
5. Eve of Cold Front Passage from West
6. Eve of Cold Front Passage from South
7. Ridging Anticylone off the Southeast Coast
8. Ridging Anticylone off the South Coast
9. Day Following Cold Front Passage
10. Surface Trough over the Western Interior
11. Low Pressure over the West Coast and Associated Upper Air Trough
12. Day Following Cold Frontal Passage and Eve of Subsequent Frontal Depression

2.1.5 Northern Plateau (Pietersburg)

1. Continental High Pressure Dominant over Interior
2. Eve of Frontal Depression
3. Ridging Anticyclone off the East Coast
4. Cold Frontal Passage
5. Westerly Wave Trough in Upper Air over the Interior
6. Ridging Anticyclone of the SouthEast Coast
7. Miscellaneous Cluster (Associated with Continental HP)
8. Anticyclonic Bridge over Subcontinent

2.1.6 Wintertime Synoptic Types Identified for All Plateau Stations

Table C.3: Synopsis of wintertime synoptic types for all plateau stations.

No.	SYNOPTIC TYPE	CLUSTER No(s)(a).				
		IR	BE	BL	UP	PT
1	Dominant HP over Interior	1	1	1	1	1
2	Miscellaneous Cluster Associated with Continental High Pressure	3	7			7
3	Anticyclonic Bridge over Subcontinent	4	8		2	8
4	Eve of Frontal Depression	2	3	3	5,6	2
5	Cold Front Passage	6	4	4	3,4	4
6	Day Following Passage of Cold Front	7	6	5	9	
7	Ridging Anticyclone off the South, SouthEast or East Coasts	8	2	2,6	7,8	3,6
8	Westerly Wave in the Upper Atmosphere over the Interior	5	5			5
9	Surface Trough over the Western Interior			8	10	
10	Low Pressure over the West Coast			7		
11	Low Pressure over the West Coast and Associated Upper Air Trough				11	
12	Day Following Cold Front Passage and Eve of Subsequent Cold Front				12	

a) IR = Irene, BE = Bethlehem, BL = Bloemfontein, UP = Upington and PT = Pietersburg.

2.2 Meteorological Characteristics of Wintertime Synoptic Types Affecting the Plateau

The meteorological characteristics, including surface pressure and vertical profiles of temperature, humidity and zonal and meridional wind components, discussed in this section are illustrated for each synoptic type at each station in Figure C.1 - C.5).

2.2.1 Dominant High Pressure over the Interior (Type 1)

Anticyclones situated over the subcontinent are associated with convergence in the upper levels of the troposphere, strong subsidence throughout the troposphere, and divergence in the near-surface wind field. Subsidence inversions, fine conditions with little or no rainfall, and light variable winds occur as a result of such widespread anticyclonic subsidence. For all stations this cluster is characterised by average to above average surface pressures, warm dry conditions and weak variable (but predominantly northwesterly) winds.

2.2.2 Miscellaneous Cluster Associated with Continental HP (Type 2)

This cluster, identified for both Irene and Pietersburg, is characterised by increases in surface pressure, low relative humidity, above average temperatures, and weak winds with a northerly wind component.

2.2.3 Anticyclonic Bridge over Subcontinent (Type 3)

A high pressure ridge may be established between the continental HP and an anticylone with its core to the east or southeast of the subcontinent. The establishment of a HP ridge over the subcontinent results in widespread subsidence, very high surface pressures (e.g. 6.2 hPa above the winter mean at Upington), generally warm and dry conditions and weak variable winds. The influence of the HP off the east coast may result in an easterly component in the wind field.

2.2.4 Eve of Frontal Depression (Type 4)

The onset of a frontal depression is heralded by a warm moisture surge with distinct increases in temperature (2 to 7 degrees celsius above winter mean) and often rather small increases in humidity. Surface pressure decreases (generally falling to 4.0 to 4.5 hPa below the seasonal average), and exceptionally strong northwesterly winds are experienced.

At Upington the eve of a cold front approaching from the west (cluster 5) is often distinguished from the eve of such a system approaching from the south (cluster 6) (Figure 4). Certain similarities in the meteorological conditions characterising days within both clusters are apparent, viz. low surface pressures (7.8 hPa and 4 hPa below the winter mean for clusters 5 and 6 respectively), warm conditions (3.5 to 5 degrees celsius above the seasonal mean) and strong winds. The wind direction and the moisture content of the air represents the only real difference between clusters 5 and 6. For cluster 5 the passage of a cold front from the west results in very strong northeasterly winds, whereas strong northwesterly winds occur on the eve of a frontal depression approaching from the south. Having circulated for a longer period over the interior, the northwesterly airflow occurring on days within cluster 6 is generally much drier than that of days within cluster 5. Cold fronts approaching the west coast, having been aligned NNW-SSE, generally change their orientation to NW-SE by the time they reach the eastern plateau. Consequently no distinction is made between such frontal systems for other stations in the interior.

2.2.5 Cold Frontal Passage (Type 5)

During winter months, the high pressure belt intensifies and moves northward and the upper level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. The winter weather of South Africa is, therefore, largely dominated by perturbations in the westerly circulation. Such perturbations take the form of a succession of cyclones and ridging anticyclones moving eastwards around the coast or across the country. The uplift resulting from the passage of frontal depressions proves a distinct shift from the widespread subsidence which dominates the winter months.

The passage of a cold front results in low surface pressures (4.5 to 6.4 hPa below the winter average), a sharp decrease in temperatures (2 to 7 degrees celsius below the seasonal mean, with the western and southeastern plateau frequently experiencing the greatest drop in temperatures), and very strong south-westerly winds below the 700 hPa level. Although relatively frequently affected by pre-frontal warming and the post-frontal passage of ridging anticyclones, cold fronts rarely pass over the northern plateau. When such systems do pass over the northern plateau they result in conditions which are generally drier and warmer than those conditions associated with the passage of cold fronts over other regions, particularly the western and southeastern plateau.

From the analysis of the vertical profiles of meteorological parameters, cold fronts seldom result in the dissipation of the lowest subsidence inversion located at about the 700 hPa level. The atmosphere above this level is therefore frequently decoupled from conditions in the lower atmosphere. For days within this synoptic typing, strong north-westerly winds predominated in the upper atmosphere (upper level winds being enhanced by the westerly jet), while a strong south-west to west-south-west wind component was observed below the 700 hPa level. Whereas very cold and humid conditions are observed in the lower atmosphere, average temperatures and predominantly dry conditions prevail above the 700 hPa level. In certain instances southwesterly winds prevail throughout the atmosphere, the winds become more westerly in the upper atmosphere with the southerly wind component weakening with altitude. The sharp discontinuities in the temperature and relative humidity profiles attest, however, to the persistence of the low level subsidence inversion despite the occurrence of west-south-westerly winds in the upper air.

The analysis of vertical trends in meteorological parameters at Upington revealed that the trends resulting from the passage of frontal depressions across the region were largely dependent on the angle of approaching cold fronts. The approach of cold front from a westerly direction (cluster 3) generally resulted in lower surface pressure and less cooling of the atmosphere compared with cold fronts approaching from the south (cluster 4) (Figure 4). For days within cluster 4 temperatures of 11 to 13 degrees celsius below the winter mean were observed. The passage of cold fronts originating to the south of the subcontinent impact, however, far less frequently on the western plateau. Notable differences were also evident in the wind field characterising clusters 3 and 4. For cluster 3 west-southwesterly winds predominated at and below the 900 hPa level, with west-northwesterly winds to northwesterly winds prevailing in the upper atmosphere. Days within cluster 4 were, however, characterised by exceptionally strong southwesterly winds through much of the atmosphere.

2.2.6 Day Following Passage of Cold Front (Type 6)

Days within this cluster generally refer to days following the passage of a strong frontal depression and occasionally the occurrence of a westerly trough over the interior. It should be noted that the coldest air temperatures and rising pressure occurs in the wake of the cold front and not at the time of minimum surface pressure as at coastal stations.

Surface pressure for days within this synoptic typing remains below the seasonal average despite having increased dramatically from previous days on which frontal systems moved over the region. For many stations this cluster is characterised by the lowest temperatures, particularly within the lower atmosphere at and below the 700 hPa level (6 to 7 degrees celsius below the winter mean). Very low relative humidities prevail in the upper atmosphere, with average to slightly above average relative humidities occurring near the surface. Very strong southwesterly winds prevail throughout the atmosphere except at the surface were localised winds may be apparent.

The effect of the passage of a frontal depression is not always proceeded by the impact of a ridging anticylone on the weather of Upington. In certain instances a RA may not follow the progression of the cold front, or the RA may be so weak that its effects are not felt that far inland. This cluster may also precede days on which the impact of RAs is evident (i.e. days within clusters 7 and 8).

2.2.7 Ridging Anticyclones off the South, Southeast and East Coasts (Type 7)

Ridging anticyclones follow the passage of the cold front, resulting in the influx of very cold moist air. During winter months strong RAs may impact fairly frequently on the weather of the plateau, particularly the western and southeastern regions. The RA to the south, southeast and east of the country results in very high surface pressures (approximately 4 to 8.5 hPa above the seasonal mean), with the location of the highest surface pressures depending on the proximity of the core of the RA to the region. The location of the core of the RA off the south coast, for example, results in the southeastern plateau experiencing the greatest increase in surface pressure.

The influx of cold marine air results in low temperatures, particularly in the lower atmosphere (4 degrees celsius below the winter mean) and sharp increases in the relative humidity below the 700 hPa level. Exceptionally low temperatures (9 to 12 degrees celsius below the seasonal mean) and strong west-southwesterly to southwesterly winds were observed for Upington on days on which the core of the RA was located to the south of the country.

The location of the RA determines the direction of the wind in the lower atmosphere. Ridging anticyclones located to the south of the country result in a strong southerly component in the airflow. A distinct easterly wind component becomes evident with the shift of the core of the RA to the southeast. As the RA moves to the east of the country northeasterly winds predominate in the lower atmosphere. Northwesterly winds may prevail in the atmosphere above the 700 hPa level despite the location of the RA. Alternatively southwesterly winds generated by the earlier passage of the cold front may continue to persist in the upper air.

It should be noted that days on which RAs occurred to the south, southeast and/or east were clustered together for the Irene and Bethlehem stations. For Pietersburg, the distinction was made during clustering, between RAs located to the southeast and east of the subcontinent, based on their characteristics wind field, i.e. southeasterly and northeasterly respectively.

2.2.8 Westerly Wave Trough in Upper Atmosphere over Interior (Type 8)

The location of a fairly strong upper trough over the interior favours the occurrence of rain over the eastern parts of the country. Low surface pressures (up to 6.3 hPa below the wintertime mean), high relative humidities and very strong northwesterly winds particularly in the upper air, characterised days within this synoptic type. Average to slightly above average temperatures in the lower atmosphere and cold conditions in the upper atmosphere were also observed for such days.

2.2.9 Surface Trough over the Western Interior (Type 9)

The location of a low pressure trough over the western interior results in low surface pressures and strong northwesterly winds at Upington which is located ahead of the wave in the region of divergence. The air is generally warm (3 degrees celsius above the seasonal average) and relatively dry having been over the land for a long period.

2.2.10 Low Pressure over West Coast (Type 10)

This synoptic type identified as influencing the atmosphere over the southeastern plateau is characterised by low surface pressure (4 hPa below the winter mean), warm moist conditions and high winds. Whereas northeasterly winds predominate below the 775 hPa level, northwesterly winds occur in the upper atmosphere.

2.2.11 Low Pressure over the West Coast and Associated Upper Air Trough (Type 11)

The low pressure over the west coast and the associated upper air tough result in cloudy, cool conditions with fairly general rain over the western, central and southern Cape. The proximity of the core of low pressure to Upington is evident in the low surface pressures (6.3 hPa below the winter mean) observed at the station. Average to below average temperatures, exceptionally moist conditions and strong northwesterly winds prevail.

2.2.12 Day Following Cold Frontal Passage and Eve of Subsequent Frontal Depression (Type 12)

This composite synoptic pattern was identified for the western plateau. The passage of an initial cold front results in low surface pressures (3.4 hPa below the winter mean) and low temperatures (4.5 degrees below average) being experienced for Upington. The occurrence of southwesterly winds which usually prevail to the rear of the front are, however, offset by the approach of a subsequent cold front which results in fairly strong northwesterly winds.

2.3 Implications of Synoptic Types for Atmospheric Dispersion Potential

The vertically averaged wind speed, mixing depth and precipitation potential of certain synoptic types vary between plateau stations. A particular synoptic type may therefore represent a ventilating system in one region, despite being labelled a stagnating or neutral system in another, as is evident in Table C.4.

Table C.4. Classification of Wintertime Synoptic Types for Plateau Stations into stagnating (S), ventilating (V) and neutral (N) systems according to vertical averages wind speeds (VAWS), mixing depths and precipitation potentials.

SYNOPTIC TYPE:	VAWS (m/s)	MIXING DEPTH (m)	PRECIPITATION POTENTIAL	CLASS
1	≤ 4.0	≤ 1 500	Low \ No	S
2	4.9 - 5.0	≤ 1 500	Low \ No	N (S)
3	≤ 2.0	≤ 1 500	Low \ No	S
4	8.3 - 14.3	≤ 1 500	High	V
5	4.8 - 13.2	≤ 1 500, > 1 500(a)	High	V
6	4.4 - 8.1	≤ 1 500, > 1 500(a)	Low \ No	V
7	2.4 - 2.7(b)	≤ 1 500(b)	Low \ No(b)	S(b)
	5.3 - 5.8(c)	≤ 1 500(c)	Low \ No(c)	N(c)
8	7.5 - 9.8	> 1 500	Low \ No	V
9	4.6(d)	≤ 1 500	High(d)	V(d)
	10.1(e)	≤ 1 500	Low \ No(e)	V(e)
10	15.5	≤ 1 000	High	V
11	15.3	≤ 1 500	High	V
12	6.0	≤ 1 500	High	V

a) The mixing depth varies between days within this synoptic type, although mixing depths of less than 1 500 m predominate, the mixing depth is extended intermittently when the passage of a frontal depression is able to displace or dissipate the low level subsidence inversion.
b) Occurs for Irene (cluster 8), Bethlehem (cluster 2) and Bloemfontein (cluster 2).
c) Occurs for Bloemfontein (cluster 7) and Upington (clusters 7 and 8).
d) Occurs for Bloemfontein (cluster 80).
e) Occurs for Upington (cluster 10).

2.4 Frequency of Occurrence and Persistence of Winter Synoptic Types

Table C.5: Frequency of Occurrence and Persistence of Wintertime Synoptic Types over the Central Plateau (Irene)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	28.5	1-2	3
2	8.3	1	1
3	15.5	1	1
4	33.4	3-4	5
5	5	1	2
6	2.1	1	1
7	3.8	1	1
8	3.4	1	2

It should be noted that HP systems (viz. clusters 1, 3 and 4) occurred 77.4 % of the time, whereas the remaining clusters comprising low pressure systems only occurred on 22.6 % of the days within the study period. These results appear therefore to support earlier studies which found that anticylones occurred with a maximum frequency of occurrence of approximately 79 percent in June and July (Preston-Whyte and Tyson, 1988).

Table C.6: Frequency of Occurrence and Persistence of Wintertime Synoptic Types over the Eastern Plateau (Bethlehem)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	76.6	2-5	8
2	11.1	2	3
3	2.4	1	2
4	3.2	1	1
5	2.6	1	1
6	1.6	1	1
7	1.6	1	1
8	0.9	2	2

Table C.7: Frequency of Occurrence and Persistence of Wintertime Synoptic Types over the SouthEastern Plateau (Bloemfontein)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	77.9	2-5	8
2	1.5	1-2	2
3	2.9	1	1
4	2.5	1	1
5	3.3	1	1
6	5.1	1	2
7	1.8	1	2
8	5.0	1-2	2

Table C.8: Frequency of Occurrence and Persistence of Winter Synoptic Types over the Western Plateau (Upington)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	71.3	2-6	8
2	2.3	2	2
3	2.2	1	1
4	0.4	1	1
5	0.4	1	1
6	5.5	1	2
7	7.8	1	2
8	0.7	1	1
9	5.4	1	1
10	2.0	1	2
11	2.0	1	1

Table C.9: Frequency of Occurrence and Persistence of Winter Synoptic Types over the Northern Plateau (Pietersburg)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	29.2	1-2	3
2	5.1	1	1
3	18.4	1-2	4
4	1.7	1	1
5	4.7	1	1
6	5.3	1-2	2
7	2.5	1	1
8	33.1	3-4	5

3. WINTER SYNOPTIC TYPES AFFECTING COASTAL REGIONS

3.1 Synoptic Types Identified for Coastal Stations

3.1.1 East Coast (Durban)

1. Continental HP Dominant over the Interior
2. Ridging Anticyclone off the South (SouthEast) Coast
3. Day Following Cold Front Passage and Core of Continental HP Located Behind the Front
4: Passage of Cold Front
5: Upper Air Trough over the Eastern Interior
6: Bergwinds Associated with Continental Anticyclonic Circulations
7: Bergwinds Associated with Pre-Frontal Divergence (Producing NW Winds)
8: Bergwinds Associated with Pre-Frontal Divergence (Producing SW Winds)
9: Pre-frontal Divergence (warming)
10: Coastal Low
11: Ridging Anticyclone to the East of the Country

3.1.2 SouthEast Coast (Port Elizabeth)

1. Continental HP Dominant over the Interior
2. Pre-frontal Divergence resulting in Bergwind Conditions
3. Pre-frontal Divergence
4. Bergwinds Associated with Continental HP
5. Passage of Cold Front
6. Ridging Anticyclone off the South Coast
7: Ridging Anticyclone off the East Coast
8. Ridging Anticyclone off the Southeast Coast
9. Coastal Low
10. Day Following Cold Frontal Passage and Eve of Subsequent Cold Frontal Passage
11. Day Following Cold Front Passage and Core of Continental HP Located Behind the Front
12. Anticyclonic Bridge between Ridging Anticyclone off SE or E Coast and HP over interior
13. Surface trough over western interior

3.1.3 South Coast (Cape Town)

1. Continental HP Dominant over the Interior
2. Bergwind Conditions Associated with a Continental High Pressure
3. Bergwind Conditions Associated with Anticyclonic Ridge over the West Coast
4. Ridging Anticyclone off Southwest Coast
5. Ridging Anticyclone off South Coast Following Passage of a Shallow Cold Front
6. Pre-frontal Divergence
7. Cold Front Passage from West
8. Cold, moist, WNW onshore airflow
9. Upper Air Low off South East Coast
10. Bergwinds Associated with an Anticyclonic Bridge over the Central Interior
11. Ridging Anticylone off the South Coast
12. Atlantic Ridging HP off the SouthEast or East Coasts
13. Coastal Low

3.1.4 West Coast (Springbok)

1. Continental HP Dominant over the Central Plateau
2. Cold Frontal Passage
3. Ridging Anticyclone off the West Coast
4. Ridging Anticyclone off the Southwest Coast
5. Cold HP over the West Coast
6. Upper Air Trough over the West Coast
7. Bergwind Conditions Associated with a Continental High Pressure
8. Warm HP located over Botswana
9. Bergwind Conditions Associated with Pre-Frontal Divergence
10. Bergwind Conditions Associated with Ridging Anticyclones off the East Coast

3.1.5 Wintertime Synoptic Types Identified for All Coastal Stations

Table C.10: Synopsis of wintertime synoptic types for all coastal stations.

No.	SYNOPTIC TYPE	CLUSTER No(s)(a).			
		DU	PE	CT	SP
1	Continental High Pressure Dominant	1	1	1	1
2	Bergwind Conditions Assoc. with Continental Anticyclonic Circulations	6	4	2	7
3	Bergwinds Due to Ridging Anticyclones off the East Coast				10
4	Bergwinds Associated with HP Ridges over the West Coast and Central Interior			3,10	
5	Bergwinds Assoc. with Pre-Frontal Divergence	7,8	2		9
6	Pre-Frontal Divergence	9	3	6	
7	Passage of Frontal Depressions	4	5	7	2
8	Ridging Anticyclones off the West Coast				3
9	Ridging Anticyclone off the SouthWest Coast			4	4
10	Ridging Anticyclone off the South Coast	2	6	5,11	
11	Ridging Anticyclone off the SouthEast Coast	2	8	12	
12	Ridging Anticyclone off the East Coast	11	7	12	
13	Cold, Moist West-NorthWesterly Onshore Airflow over the South Coast			8	
14	Coastal Lows	10	9	13	
15	Anticyclonic Ridges between Ridging Anticyclones and Continental HPs		12		
16	Cold HP over the West Coast				5
17	Warm HP located over Botswana				8
18	Upper Air Trough over the Eastern Interior	5			
19	Upper Air Trough over the West Coast				6
20	Upper Air Low off the SouthEast Coast			9	
21	Surface Trough over the Western Interior		13		
22	Day Following Cold Front Passage and Core of HP located behind Front	3	11		
23	Day Following Coal Front Passage and Eve of Subsequent Cold Front		10		

a) DU = Durban, PE = Port Elizabeth, CT = Cape Town, SP = Springbok.

3.2 Meteorological Characteristics of Winter Synoptic Types Affecting Coastal Regions

3.2.1 Continental High Pressure Dominant (Type 1)

The core of the HP may be situated in various places for this synoptic classification, including over the southwestern Cape, northeastern plateau, central interior, or the northwest (Botswana/Namibia). The core of the continental HP is, however, usually located over the northeastern parts of the country.

This synoptic type results in northwesterly (off-shore) airflow over the east and southeast coasts. Average to slightly above average surface pressure occurs. At Durban, during winter months which were characterised by a high frequency of occurrence of ridging high, this synoptic type was characterised by slightly below average surface pressures. Further characteristics of this synoptic type include average to slightly above average temperatures, dry conditions, and fairly weak, often variable but predominantly northwesterly winds. Below the 900 hPa level the occurrence of average to slightly moist air and northeasterly winds reflect the influence of the sea breeze. Northeasterly winds below 900 hPa are predominantly the result of sea breezes strengthened by the gradient wind component. Above the 900 hPa level northwesterly winds prevail with the westerly component becoming increasingly stronger with increasing altitude.

Over the West Coast this cluster frequently proceeds the passage of a frontal depression. With the shift of the cold front over the interior, a ridge appears over the north-western Cape Province. As the cold front moves further north skies over the west coast become practically clear due to the low-level anticyclonic circulation and fairly strong northwesterly (offshore) airflow is initiated. The wind may remain onshore over the west coast should frontal perturbations continue to persist to the south of the country.

For the South Coast days within this cluster are characterised by high surface pressures (3.4 hPa above the winter mean), and warm dry air with westerly airflow above the 900 hPa level. In the lower atmosphere generally cool, fairly dry conditions prevail and the airflow has an easterly component. The meridional component varies (S and N in lower atmosphere) to northerly in the middle atmosphere (900 hPa to 850 hPa) and southerly in upper atmosphere (700 hPa and 775 hPa). Winds are predominantly weak and variable.

3.2.2 Bergwind Conditions

Bergwinds are associated with the dynamic warming of subsiding air moving offshore with anticyclonic curvature, and form an important feature of coastal climates. Off-shore airflow can occur as a result of circulation associated with continental anticyclones, ridging anticyclones, or pre-frontal divergence. As the air descends over the escarpment it warms (according to the Dry Adiabatic Lapse Rate) and becomes warmer and drier. Such bergwinds could result in a very distinctive increase in temperature over a very short period, and are usually responsible for the highest maximum temperatures.

For the period of study almost all rapid rises in temperatures from day to day for all coastal stations was found to be as a result of bergwind warming (either from pre-frontal divergence or subsidence of air with anticyclonic curvature). Bergwinds most commonly occur in late winter and early spring and may blow for a few days or a few hours.

3.2.2.1 Bergwinds Associated with Continental HP Circulations (Type 2)

SouthEast and East Coasts
Over the east and southeast coast bergwinds usually occur as northwesterly winds. Such bergwinds result in average (Durban) to low (PE) surface pressures, very high temperatures throughout the atmosphere (3 to 7 degrees celsius and 5 to 9 degrees celsius above wintertime average for Durban and PE respectively), and exceptionally dry conditions (relative humidities of 30 to 40 % lower than the seasonal average). Bergwinds are normally associated with fairly high wind speeds (15 km per hour). Although bergwinds over the east coast were observed to be relatively weak, very strong northwesterly winds prevailed over the southeast coast.

South Coast
Bergwinds generally occur over the south coast when warm dry air is being circulated over the country (i.e. when anticyclonic circulation dominates) and when a low pressure system occurs along, or approaches the west or southwest coast. The steep pressure gradient between the intensive HP over the interior and the LP results in strong northwesterly airflow blowing the warm, dry air from the interior onshore to influence the south coast. This synoptic type is characterised by low surface pressures at Cape Town due to the proximity of the LP to the south coast. Despite the occurrence of the bergwinds, the atmosphere remains fairly stratified with a distinct change in the profiles of parameters at about the 1000 hPa level In the upper atmosphere very high temperatures (6.2 degrees higher than the winter time average representing the warmest CT wintertime cluster), low relative humidities (30 % below the winter average), and strong northwesterly winds prevail. At and below the 1000 hPa level, however, temperatures are lower (3 degrees above the winter mean), relative humidities are only 10 % below the seasonal mean, and fairly weak northwesterly winds occur.

West Coast
The occurrence of a continental HP over the interior and a low pressure system off the west coast result in the occurrence of bergwinds over the west coast.. Offshore (northeasterly) winds, high surface pressures (5.2 hPa above the winter mean) and exceptionally warm and dry conditions are characteristic of days within this synoptic category.

3.2.2.2 Bergwinds resulting from Ridging HPs off the East Coast (Type 3)

The location of Ridging Anticyclones off the east coast results in strong northeasterly (offshore) winds over the west coast. High surface pressures (3.2 hPa above winter mean), exceptionally high temperatures (9.8 degrees celsius above the winter average) and very dry conditions (relative humidities 30 % below average the seasonal mean) were observed to occur over the west coast for days on which such synoptic conditions occurred.

3.2.2.3 Bergwinds Associated with HP Ridges over the West Coast and Central Interior (Type 4)

Bergwinds over the south coast occasionally occur as a result of the establishment of an anticyclonic ridge between the core of the continental HP, located over the southwestern Cape coast, and the Atlantic Ridging HP which is located to the southwest of the country. In the upper atmosphere, above the 1000 hPa level, high temperatures (5 degrees above the winter average) above average relative humidities (10 to 18 % above the winter mean), and predominantly northwesterly winds predominate. In the lower atmosphere slightly warm, moist conditions occur and the airflow has a southwesterly component indicating the continued influence of the sea breeze system. High surface pressures (4.8 hPa above the winter time average) typically occur as a result of this synoptic type.

The establishment of a HP bridge between the continental HP, located over the central interior, and the Atlantic HP to the southwest of the country similarly results in bergwinds over the south coast. The continental HP dominates the airflow over Cape Town resulting in northeasterly (offshore) winds which result in bergwind conditions over Cape Town. Days within this cluster are characterised by high surface pressures (5.8 hPa above seasonal average), high temperatures, exceptionally low relative humidities (5 degrees C above and 50 % below the winter mean respectively) and northeasterly airflow in the upper atmosphere. The influence of the sea breeze system at the surface is evident in the slightly lower temperatures, higher relative humidities, and the presence of a westerly component in the airflow in the lower atmosphere.

The primary difference between bergwinds associated with HP ridges over the west coast and central interior is related to the nature of the wind field and the moisture content of the air over the south coast. The occurrence of ridges over the west coast results in southwesterly (onshore) winds and consequently above average relative humidities, whereas northeasterly (offshore) winds and consequently low relative humidities are typical of days characterised by HP ridges over the central interior.

3.2.2.4 Bergwinds Associated with Pre-Frontal Divergence (Type 5)

East Coast

Bergwinds are frequently associated with divergence either ahead of a low pressure trough over the eastern interior or ahead of a coastal low. Whereas the proximity of the low pressure system results in a decrease in the surface pressure, the resultant bergwinds produce very high temperatures (up to 7 degrees celsius above the winter mean), low relative humidities, and fairly strong northwesterly winds above the 900 hPa level. Weaker northeasterly winds, associated with the sea breeze, continue to prevail in the lower atmosphere.

In instances where the low pressure trough is located further east, the western (convergence) side of the wave is located over the east coast resulting in the occurrence of west-southwesterly bergwinds. Strong west-southwesterly winds occur above the 1000 hPa level, while southeasterlies dominate at the surface.

SouthEast Coast

The progression of cold fronts eastwards over the west coast give rise to strong bergwinds over the southern and southeastern coast. Strong northwesterly (offshore) winds occur ahead of the front due to the steep pressure gradient between the low pressure trough and the HP over the interior, resulting in very hot and dry conditions over the coastal regions. Bergwind conditions resulting from pre-frontal divergence are accompanied by very low surface pressure (approximately 7 hPa below the seasonal average), and very warm to hot (3 to 9 degrees celsius above seasonal average temperature) and very dry (30 degrees below seasonal average relative humidity) air. Strong northwesterly winds prevail, with an exceptionally prominent northerly component.

West and SouthWest Coast

As cold fronts approach the South African coast, frequently being orientated NW-SE, pressure along the southwest and south coasts decreases rapidly and the surface wind becomes north-westerly along the west and south-west coasts. As for the previous synoptic pattern, the offshore airflow over the west coast is very warm and dry having warmed adiabatically as it moved off the escarpment. The proximity of the cold fronts to the coast characteristic of this cluster results, however, in low surface pressures and stronger winds.

3.2.2.5 Comparison of Bergwind Conditions over the West Coast Associated with Various Synoptic Systems

Despite general similarities (viz. high temperatures and low relative humidities) which occur with the onset of bergwind conditions over the west coast, notable differences occur in the vertical profiles of meteorological parameters depending on the synoptic pattern generating such conditions. For bergwinds generated by the pressure gradient between a continental HP located over the interior and a weak low pressure system off the west coast, high temperatures and low relative humidities occur throughout a large section of the atmosphere indicating the dissipation of the characteristic subsidence inversions. Bergwinds conditions arising from pre-frontal divergence ahead of an approaching cold front seldomly, however, coincide with the dissipation of the low level subsidence inversion. High temperatures and low relative humidities are therefore confined to the lower atmosphere at and below the 850 hPa level. Pre-frontal divergence also differs from the continental HP and RA clusters in that it results in lower surface pressures and generally much greater wind speeds. The establishment of a RA off the east coast results in the highest temperatures and lowest relative humidities relative to the previous two synoptic patterns.

3.2.3 Pre-Frontal Divergence (Warming) (Type 6)

East Coast
All coastal lows produce warm, generally dry offshore airflow ahead of the system and cool onshore airflow behind it (southerly buster). Frontal depressions are similarly preceded by warm, dry conditions and upper air subsidence causing lowering of the inversion height. At Durban pre-frontal warming was observed to result in the lowering of the inversion layer, very low surface pressures (6 hPa lower than seasonal average), high temperatures throughout atmosphere (up to 5 degrees celsius above winter mean), low relative humidities and high energy northwesterly winds above the 900 hPa level. In the lower atmosphere (below 1000 hPa), the diurnal sea breeze circulation resulted in generally moister conditions and northeasterly airflow.

Southeast Coast
Pre-frontal divergence does not necessarily give rise to bergwind conditions over the southeastern coast. The angle at which the cold front approaches the coast and the location of the front determine whether the airflow occurs parallel to the coast or whether air moves over the escarpment. Cold fronts over the southern cape coast moving inland towards the northeast result in airflow being channelled along the coast rather than over the escarpment. This synoptic typing is therefore characterised by a strong westerly component, whereas pre-frontal divergence associated with bergwinds has a greater northerly wind component.

Pre-frontal divergence over the southeast coast is characterised by the lowest surface pressure (approximately 10 hPa below the wintertime mean) and warm dry air. Whereas southwesterly winds occur near the surface at 1000 hPa, northwesterly winds occur above 1000 hPa. Both upper and lower level winds have a notable westerly component. The strong pressure gradients between the approaching low pressure trough and the HP established over the interior results in very high wind speeds.

South Coast
The eastward movement of intensive cold fronts to the west of the country results in very strong northwesterly airflow over Cape Town. Days within this synoptic classification are characterised by the lowest surface pressures (8.2 hPa below the winter time mean), warm conditions (1 to 2.5 degrees C above average), average to below average relative humidities, and [illegible] northwesterly winds.

3.2.4 Passage of Frontal Depressions (Type 7)

Cold fronts occur most frequently in winter when the amplitude of westerly wave disturbances is greatest. Substantially deep cooling occurs as a result of westerly wave disturbances; the passage of cold fronts producing deep cooling to beyond the 700 hPa level. Whereas ahead of the cold front a northerly component dominates the airflow and subsidence and cloud free conditions occur, behind the cold front low level convergence takes place with a marked southerly component in the airflow. In the vicinity of the front there is a pronounced discontinuity in temperature and moisture, and a sharp shift from NE to SW winds. As the front passes over relative humidity increases and the temperature drops.

The nature of the weather along the cold front depends to a large degree on the structure of the warm air that is being displaced. Should dry stable air be displaced, the cold front will be accompanied only by broken clouds and no precipitation. The displacement of warm, humid air would most likely result in cumulonimbus clouds and frontal thunderstorms.

Cold fronts generally have steep gradients of between 1:50 and 1:150 and are lightly convex in shape. Due to its steep gradient and convex shape a large vertical section of the atmosphere could be affected simultaneously with the passage of the front. Due to their steep angle cold fronts also able to produce intense heavy showers of short duration and over a narrow area.

SouthEast and East Coasts
The passage of frontal depressions over the east coast results in below average surface pressure (2 to 3 hPa below the wintertime mean), a considerable drop in temperature throughout the airmass (up to 6 degrees C below the seasonal mean), moist conditions throughout the air mass, and the shift from northwesterly to southwesterly airflow.

Over the southeast coast this synoptic type is characterised by a fairly weak meridional component, and a very strong westerly zonal wind component. In the lower atmosphere (at and below the 900 hPa level) southwesterly airflow prevails, with northwesterly winds being recorded above 900 hPa. This wind profile may result from the angle of the cold fronts.

West Coast
With the approach of the cold front cloudiness increases and drizzle or light to moderate rain occurs on the west and southwest coasts on the windward slopes of the mountain ranges. Heavier rainfall is confined to the southwest coast south of about 32 degrees S and over the adjacent mountain ranges. The influx of maritime air behind the cold front over the western coastal belt results in temperature drops of several degrees (7 degrees celsius below the winter mean for Springbok). Strong winds with a prominent westerly component predominate (west-southwesterly winds) and very high relative humidities are observed (up to 45 % above the seasonal mean).

It should be noted that the passage of cold fronts across the west coast does not necessarily result in the dissipation of the low level inversion at approximately 650 metres. The presence of the subsidence inversion is often easily discernible due to the distinct differences in the moisture content and temperatures of the upper and lower atmosphere.

South Coast
The passage of a cold front from the west or southwest results in strong northwesterly rather than southerly airflow over Cape Town. Cold, cloudy conditions and rain follows the passage of the frontal depression. Gale force winds occur as a result of the steep pressure gradient. Low surface pressure (6.5 hPa below winter average), cold conditions throughout the airmass (2 to 6 degrees colder than average), high relative humidities, and gale force winds with a northwesterly component are characteristic of this cluster.

3.2.5 Ridging Anticyclones Following the Passage of Cold Fronts

Ridging Anticyclones follow the passage of frontal depressions, resulting in onshore airflow and widespread general rainfall over the eastern parts of SA. Such rainfall may occur as general rains or as scattered showers and thunderstorm activity. RAs give rise to extensive cloud cover along the eastern and southern coastal and adjacent inland areas. Although the passage of the cold front results in considerable cooling, the proceeding RA causes further cooling and increasing instability.

3.2.5.1 Ridging Anticyclone off the West Coast (Type 8)

As the cold front moves over the west coast the Atlantic HP remains located far to the west of the subcontinent and maintains its position while new cells bud off and move to the south and east of the subcontinent. The location of a ridging anticyclone off the west coast results in high surface pressures (3.4 hPa above the winter mean) and the circulation over the west coast of the cold and moist air which occurs behind the cold front. At Springbok temperatures and relative humidities of 6 degrees celsius below and 34 % above the winter mean are observed. Although the low level subsidence inversion (850 hPa) appears to have dissipated, the subsidence inversion at about the 700 hPa level is still apparent. At and below the 700 hPa level strong southeasterly winds and very cold and moist conditions prevailing, whereas above this layer weaker west-southwesterly winds, cool conditions and below average relative humidities occur.

3.2.5.2 Ridging Anticyclone off the SouthWest Coast (Type 9)

West Coast
Having shifted from their position off the west coast, ridging anticyclones located off the southwest coast of the country continue to affect the weather of the west coast. High surface pressures (3.2 hPa above the seasonal mean) and cold conditions (temperatures remain on average 6 degrees below the winter mean) continue to persist in the lower atmosphere. The relative humidity has decreased despite remaining 17 % above the seasonal mean, and the southeasterlies have extend to the 600 hPa level.

South Coast
For the south coast this synoptic classification refers to days during which the passage of a frontal depression resulted in atmosphere being affected to beyond the 700 hPa level. The cold fronts were followed by a HP Ridge bringing cold weather with scattered rain and showers over the southwestern, southern and southeastern cape. At Cape Town this synoptic type is characterised by high pressure at the surface (3 hPa above average), very low temperatures throughout the air mass (2.5 degrees to 7.8 degrees below average), and moist conditions (20 % higher than average relative humidities). Strong south-southwesterly winds predominate throughout the atmosphere, except at the surface where southeasterly winds occasionally occur.

3.2.5.3 Ridging Anticylone off the South Coast (Type 10)

South Coast
The location of a RA off the south coast dominates the airflow over the southern coast giving rise to southeasterly (onshore) winds and the influx of cool, moist air from the ocean to the south of the subcontinent. Exceptionally high surface pressures (8.5 hPa above the winter

mean) occur at Cape Town as a result of the HP ridge which develops between the continental HP located to the northeast of the country and the RA off the south coast. Cool conditions and southeasterly winds are characteristic of days within this cluster.

East Coast
Days within this synoptic type results in very high surface pressures (approximately 6 hPa above the wintertime mean), very low temperatures throughout the air mass (4 to 7 degrees celcius below the wintertime mean), high relative humidities, and very strong south-southwesterly winds throughout the air mass.

3.2.5.4 Ridging Anticyclone off the SouthEast Coast (Type 11)

The shift of RAs to the southeast of the country results the advection of cold, moist air over the northeastern coast. The circulation of the RA is reinforced by the anticyclonic circulation of the continental HP over the interior to produce offshore airflow over the western, southwestern and southern coast.

South Coast
Northeasterly (offshore) airflow is prevails along the southern Cape coast as warm, exceptionally dry air is transported over Cape Town. High surface pressures (8.2 hPa above winter mean), above average temperatures and low relative humidities (1.8 to 2.2 degrees C above and 20 to 40 % below the winter mean respectively). The relatively cooler and less dry conditions occur near the surface. Southeasterly winds indicative of the sea breeze system continue to prevail near the surface, while northeasterly airflow dominates throughout the rest of the atmosphere.

Southeast Coast
Port Elizabeth is characterised by very high surface pressure (4 to 6 hPa above seasonal mean), and very cold, moist conditions throughout the airmass (20 % to 30 % higher than the seasonal average relative humidity). The location of the RA core determines the exact nature of the onshore airflow. In instances where RAs are located to the south or southwest of the country very strong SW winds occur throughout the airmass. With the shift of the core of the RA is to the southeast of the country airflow with an easterly and a northerly component is initiated. Southwesterly and southeasterly winds occur in the lower atmosphere, whereas northeasterly and northwesterly winds occur above 900 hPa.

3.2.5.5 Ridging Anticyclones off the East Coast (Type 12)

The RA has moved further eastward and is located along the eastern coast. The advection of cold, moist air over the southern and eastern coast is replaced by the onshore flow of cold, moist air over the northeastern coast. The effect of such onshore airflow is felt along the northeastern coast and adjacent interior, sometimes as far inland as Pretoria.

West Coast
The location of RAs off the east coast result in continued strong northeasterly (offshore) winds, high surface pressures (3.2 hPa above winter mean), exceptionally high temperatures (9.8 degrees celsius above the winter average) and very dry conditions (relative humidities 30 % below average the seasonal mean). Such bergwind conditions were discussed in a previous section.

South Coast
In the clustering of PC scores for Cape Town no distinction is made between a RA located off the southeast coast and a RA located off the east coast since both systems give rise to very similar bergwind conditions and northeasterly airflow patterns.

SouthEast Coast
This airmass is characterised by the highest surface pressure (8 hPa above the wintertime mean). Although the airmass over PE is still cold throughout, it is still warmer than that occurring as a result of RAs located off the south or southeast coasts. The warming of the airmass is particularly evident with increasing altitude. The airmass is moist in its lower layer (at and below the 850 hPa level), but fairly dry in the upper layers above the 850 hPa level, becoming. increasingly dry with increasing altitude. Very strong NE airflow prevails due to the location of the RA core along the east coast.

East Coast
The development of an anticyclonic ridge between the continental HP and the RA off the east coast result in very high surface pressure (9 hPa above the winter mean). Although very low temperatures persist throughout the atmosphere (2 to 5 degrees lower than winter average), temperatures are generally warmer than for Cluster 2 days (4 to 7 degrees below winter mean). The upper layers of the atmosphere show the greatest increase in temperatures. Relative humidities have similarly decreased substantially, particularly in the upper atmosphere. The northeasterly winds which prevail below 925 hPa, and the persistence of low temperatures and humidities in the lower atmosphere reflects the continued advection of cool, moist air by the RA. The substantial increase in temperature and decrease in humidity, and predominance of northwesterly winds evident in the upper atmosphere illustrates the influx of warm dry continental air over the east coast.

3.2.6 Cold, Moist West-NorthWesterly Onshore Airflow over the South Coast (Type 13)

This miscellaneous cluster refers to all days (which do not fit into other appropriate clusters) during which cold moist air overlies Cape Town with onshore (WNW) airflow prevailing. The WNW airflow is associated with westerly disturbances and the Ridging HP which proceed such disturbances. This type of airmass occurs over Cape Town both behind and ahead of the passage of frontal depressions over Cape Town, and when no such depressions are present. Slightly below average surface pressure, cold and moist conditions (1 to 2.5 degrees C below and 10 to 25 % above the winter mean respectively), and strong WNW winds (the westerly wind component being exceptionally prominent) characterise this synoptic type.

3.2.7 Coastal Lows (Type 14)

Coastal lows originate along the west coast and follow the coastline towards the southeast coast resulting in the cyclonic curvature of the isobars. Confined to coastal areas, the effect of coastal lows seldom extend inland of the Cape mountains and over Natal no further inland than the Natal midlands.

The temperature and wind shifts characteristics associated with coastal lows resemble those of cold fronts and are may often be mistaken for such. The coastal low is heralded by the onset of the southerly buster (cool, onshore airflow behind coastal low) during which time the temperature drops rapidly and the pressure begins to rise. Although coastal lows frequently produce greater surface cooling than cold fronts, these systems are usually shallow (seldom deeper that 850 hPa or 1 500 m) and seldom produce any precipitation in excess of mist and drizzle. Cold fronts are, however, able to produce deep cooling to beyond 700 hPa. Coastal lows are usually decoupled from the wave usually present above the surface level. Should coastal lows become coupled with the wave they may develop into coastal depressions resulting in large scale rainfall.

The passage of coastal lows over coastal regions result in average to below average surface pressures, and the occurrence of cool, very moist conditions and fair to strong winds with a distinct southerly component at and below the 900 hPa level. The coastal low system is most frequently capped by the drier and warmer northwesterly airflow which arise from the dominant anticyclonic circulation.

For the southeast coast, for example, cold air with a southerly airflow component prevails in the lower atmosphere at and below the 900 hPa level, with southwesterlies occurring at 1000 hPa and southeasterlies at 900 hPa and 925 hPa levels. The air in the lower atmosphere is very moist throughout (15 % to 40 % higher than the wintertime mean relative humidity). In the upper atmosphere warm air with strong northwesterly airflow predominates.

At Cape Town coastal low systems are not associated with southerly airflow, very strong northwesterly winds prevailing throughout the atmosphere for such systems. The passage of coastal lows do, however, result in low surface pressures (2.3 hPa below the winter average), and cold, moist air in the lower atmosphere below the 900 hPa level whilst warm, dry conditions continue to predominate in the upper atmospher.

3.2.8 Anticyclonic Ridges between RAs and the Continental HP (Type 15)

Strong anticyclonic ridges occasionally develop between RAs and the continental HP. The location of the axis of the ridge determines the nature of the airflow over the subcontinent.

At Port Elizabeth the development of an anticyclonic bridge between RAs off the southeast or east coasts and the continental HP was found to follow cluster 7 (RA along east coast) during which time the influence of the RA along the east coast on the air over PE begins to diminish and the HP over the interior again exerts its influence on the southeast coast. High surface pressure (5 hPa above the wintertime mean) occurs despite the surface pressure having decreased from cluster 7. In the lower layers of the atmosphere, at and below the 900 hPa level, cold air with notheasterly airflow prevails. Above 900 hPa, warmer air with a strong northwesterly component occurs. The airmass is dry throughout (20 to 40 % below average RH), being particularly dry in the upper air above 925 hPa level.

At Cape Town the establishment of an anticyclonic bridge over the central interior was observed to give rise to bergwind conditions, as has already been discussed. In such instances the continental HP, located over the central interior, formed a bridge with the Atlantic HP to the southwest of the country. The continental HP dominates the airflow over the south coast resulting in northeasterly winds which result in bergwind conditions, and offshore flow over the station. Days within this cluster are characterised by high surface pressures (5.8 hPa above seasonal average), high temperatures, exceptionally low relative humidities (5 degrees C above and 50 % below the winter mean respectively) and northeasterly airflow in the upper atmosphere. The influence of the sea breeze system at the surface is evident in the slightly lower temperatures, higher relative humidities, and the presence of a westerly component in the airflow in the lower atmosphere.

The development of a ridge over the west coast, between the core of the continental HP over the southwest Cape coast and the Atlantic Ridging HP to the southwest of the country, similarly resulted in bergwind conditions over the south coast. The nature of the airflow and moisture content of the air over the south coast was, however, different from that associated with the ridge over the central interior. In the upper atmosphere, above the 1000 hPa level, high temperatures (5 degrees above the winter average) above average relative humidities (10 to 18 % above the winter mean), and predominantly northwesterly winds predominate. In the lower atmosphere slightly warm, moist conditions occur and the airflow has a southwesterly component indicating the continued influence of the sea breeze system. High surface pressures (4.8 hPa above the winter time average) typically occur on days within this cluster.

3.2.9 Cold HP over the West Coast (Type 16)

The impact of the RA located off the west coast (cluster 4) may be proceeded by the establishment of a cold cored HP over the west coast. The cold cored HP results in above average surface pressures and the circulation of cold (2 degrees below winter mean), dry air with a northeasterly component in the lower atmosphere. The low level subsidence inversion at about the 850 hPa level is again apparent representing a transitional layer between the lower atmosphere and the upper atmosphere in which the southwesterly winds initiated by the passage of the cold front continue to prevail. Average to slightly below average temperatures and fairly dry conditions are characteristic in the upper air.

3.2.10 Warm HP located over Botswana (Type 17)

The location of the HP core over Botswana results in onshore westerly flow over the western Cape Province despite the absence of a cold front. Considerable cloud occurs over the western and southern Cape Province, and orographically-induced rain may occur over the south-western Cape Province as a result of the fresh westerlies. Days within this cluster are characterised by above average surface pressures and temperatures (2.2 to 3.8 degrees celsius above the winter mean), average relative humidities and predominantly west-northwesterly (onshore) airflow. The occurrence of cool, moist conditions and a south-southeasterly wind component in the lower atmosphere below the 850 hPa level provides evidence of the persistence of the low level subsidence inversion under these conditions.

3.2.11 Upper Air Trough over the Eastern Interior (Type 18)

The occurrence of a low pressure trough in the upper air over the eastern interior affects the upper atmosphere above the 850 hPa level, with cool, moist air and very strong southwesterly flow capping the warm dry section in the middle atmosphere with its NW airflow and the warm moist NE airflow near the surface. This synoptic type is characterised by very low surface pressures (7 hPa below the wintertime mean). The wind direction gives a good indication of the origin of the air mass component. Northeasterly winds represents the sea breeze and gradient wind component below the 900 hPa level. Warm, dry continental air in the middle atmosphere originates in the interior and is transported by the northwesterly airflow characteristic of the dominant anticyclonic circulation over the subcontinent. The southwesterly winds in the upper atmosphere reflect the influence of the low pressure trough in the upper atmosphere.

3.2.12 Upper Air Trough over the West Coast (Type 19)

The establishment of a trough in the upper air over the west coast gives rise to below average surface pressures, strong west-northwesterly (offshore) airflow, high relative humidities (30% above the winter mean) and cool conditions at Springbok. The atmosphere remains, however, stratified with northeasterly winds, low relative humidities (20 % below the mean) and very warm conditions (5 degrees above the winter mean) prevailing below the 850 hPa level.

3.2.13 Upper Air Low off SouthEast Coast (Type 20)

In days within this cluster the passage of a cold front was observed to be proceeded by the establishment of a low pressure cell in the upper air off the southeast coast. At Cape Town the presence of the upper-air low resulted in cold and exceptionally moist conditions (3.8 degrees C below average temperatures and relative humidities of up to 70 % above average), and southeasterly airflow above the 900 hPa level. The effects of the cold frontal passage were still evident in the lower atmosphere with the predominance of cool, moist air with a southwesterly component.

3.2.14 Surface Trough over Western Interior (Type 21)

In certain instances an upper air trough over the western interior coincides with the occurrence of a continental high pressure over eastern parts and a RA off the east coast. A steep pressure gradient occurs between the west coast trough and the continental HP over the eastern parts facilitating the southward flow of air. The RA along the east coast advects cool moist air over the NE coast and adjacent inland areas. The upper air trough over the western interior results in the moist air moving southwards over the central and eastern regions. The air is warmed as a result of being over the continent. The west coast trough thus produces moist warm air to flow southwards affecting conditions over the southeastern coast.

At Port Elizabeth this synoptic typing is characterised by average surface pressures. Although the air is cool at the surface (2 degrees below the wintertime mean) it is warm throughout the rest of the atmosphere (2 degrees above average). The entire atmosphere is moist distinguishing this cluster from cluster 1 in which the HP over the interior results in the transport of warm but dry air over the southeastern coast. Northwesterly winds above the 900 hPa level predominate with a notable northerly component. Northeasterly winds occur below the 900 hPa level, indicative of the occurrence of the sea breeze.

3.2.15 Day Following Cold Front Passage and Core of Continental HP Located Behind the Front (Type 22)

Following the passage of a cold front an intense HP may become established behind the cold front altering to a degree the characteristics of expected weather following the passage of a frontal depression. The meteorological characteristics of this synoptic typing is very typical of the characteristics which occur on days following the passage of a frontal depression, except that higher than usual surface pressure occurs and temperatures may not be as low as would be expected. At Durban above average surface pressures (3 hPa higher than the wintertime mean), low temperatures throughout the air mass (up to 4 degrees celsius lower than the wintertime average), fairly moist air, and strong southwesterly winds characterise this synoptic type.

At Port Elizabeth the occurrence of such a synoptic situation resulted in exceptionally high surface pressure (7 hPa higher than seasonal mean) with cold conditions prevailing throughout the airmass (7 degrees celsius below the wintertime mean). The surface and upper levels (700 and 775 hPa levels) are dry, with very moist conditions occurring between these layers. The influence of the HP results in northwesterly airflow in the upper atmosphere, whereas southwesterly winds continue to occur at the 700 hPa level.

3.2.16 Day Following Cold Frontal Passage and Eve of Subsequent Cold Front (Type 23)

This synoptic type occurs when cold fronts occur both to the northeast and southwest of PE; the first cold front having just passed over and the other approaching the southeastern Cape coast. At PE this synoptic type is characterised by very low surface pressure (5 hPa below the wintertime mean) which is indicative of pre-frontal conditions, and very cold conditions throughout the airmass (4 to 6 degrees celsius below the wintertime mean temperature) which is characteristic of the passage of a cold front. Dry conditions occur at the surface and at the 700 hPa level, but above average RH prevails in the middle atmosphere. Whereas Northwesterly winds, with a notable westerly component, occur at the surface reflecting pre-frontal conditions), southwesterly airflow predominates in the upper reaches above the 700 hPa level.

3.3 Implications of Wintertime Synoptic Types at Coastal Stations for Atmospheric Dispersion Potential

The vertically averaged wind speed, mixing depth and precipitation potential of certain synoptic types vary from station to station for coastal stations. Springbok, in particular, is often characterised by unique characteristics for certain synoptic systems, which reflects the importance of the relative distance of this "coastal station" from the coast. A particular synoptic type may therefore represent a ventilating system in one region, despite being labelled a stagnating system in another, as is evident in Table C.11

Table C.11: Classification of Wintertime Synoptic Types for Coastal Stations into stagnating (S), ventilating (V) and neutral (N) systems according to vertical averages wind speeds (VAWS), mixing depths and precipitation potentials.

SYNOPTIC TYPE:	VAWS (m/s)	MIXING DEPTH (m)	PRECIPITATION POTENTIAL	CLASS
1	1.0 - 4.4	≤ 1 500(a) ≤ 800(b)	Low \ No	S
2	1.3 - 3.7	≤ 1 300(a) ≤ 800 (b)	Low \ No	S
3	8.3	≤ 1 500	Low \ No	V
4	0.2 - 0.7	≤ 800	Low \ No	S
5	1.2 - 3.3(c)	≤ 800(c)	Low \ No(c)	S(c)
	9.4(a)	≤ 1 300(a)	Low \ No(a)	V(a)
6	<4(c) 8.2(d)	≤ 800	Low \ No	S
7	6.1 - 13.7	≤ 1 500	High	V
8	5.2	1 500 - 2 000	Low \ No	N (V)
9	3.5 - 5.7	≤ 1 500	Medium	N (V)
10	7.0 - 9.6	≤ 1 500	High	V
11	1.3(d)	≤ 1 000(d)	Low \ No(d)	S(d)
	1.3 - 8.5(c)	≤ 1 500(c)	High(c)	V(c)
12	1.3 - 4.7(e)	≤ 1 000(e)	Low \ No(e)	S(e)
	3.7(f)	≤ 800(f)	High(f)	V(f)
13	4.2	≤ 1 000	High	V
14	3.1 - 9.0	≤ 1 500(e) ≤ 800(f)	High	V
15	5.2	≤ 800	Low \ No	S
16	7.1	≤ 1 500	Low \ No	V
17	2.5	≤ 1 500	Low \ No	S
18	4.5	≤ 1 000	Low \ No	S
19	5.8	≤ 1 500	Low \ No	N
20	13.5	≤ 1 500	High	V
21	5.9	≤ 1 000	Low \ No	S
22	7.6(f)	≤ 800(f)	High(f)	V(f)
	2.9(g)	≤ 800(g)	Low \ No(g)	S(g)
23	9.0	≤ 1 500	High	V

a) Occurs for Springbok (clusters 1, 7 and 9 for synoptic types 1, 2 and 5 respectively).
b) Occurs for Cape Town (clusters 1 and 2), Port Elizabeth (clusters 1 and 4) and Durban (clusters 1 and 6) (for synoptic types 1 and 2 respectively).
c) Occurs for Durban (clusters 7 and 8, 9, 2) and Port Elizabeth (clusters 2, 3 and 8) (for synoptic types 5, 6 and 11 respectively).
d) Occurs for Cape Town (clusters 6 and 12 for synoptic types 6 and 11 respectively).
e) Occurs for Port Elizabeth (cluster 7 and 9) and Cape Town (cluster 12and 13) for synoptic types 12 and 14 respectively.
f) Occurs for Durban (clusters 11, 10 and 3 for synoptic types 12, 14 and 22 respectively).
g) Occurs for Port Elizabeth (cluster 11 for synoptic type 22).

3.4 Frequency of Occurrence and Persistence of Winter Synoptic Types over Coastal Regions

Table C.12: Frequency of Occurrence and Persistence of Wintertime Synoptic Types over the East Coast (Durban)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	52.1	2-3	8
2	10.4	1-2	2
3	4	1	2
4	7.8	1	2
5	1	1	1
6	1.5	1-2	2
7	3.8	1-2	2
8	8.3	1	2
9	3.1	1	1
10	3.3	1	2
11	3.7	1	2
12	1(a)		

a) Percentage of days which could not be classified based on their meteorological characteristics and the use of daily SAWB weather charts.

Table C.13: Frequency of Occurrence and Persistence of Wintertime Synoptic Types over the Southeastern Coast (Port Elizabeth).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	42.1	2	6
2	6.7	1	2
3	4.9	1	1
4	3.7	2	2
5	3.7	1	1
6	20.6	2	4
7	4.3	1	2
8	4.3	1	1
9	2.4	1	2
10	4.3	1	1
11	0.6	1	1
12	1.2	1	1
13	1.2	1	1

From the analysis of the frequency of occurrence and persistence of wintertime synoptic types over the southeast coast it is evident that high pressure systems impact more frequently and prove more persistent than the transient low pressure systems (Table C.13). Continental HPs over the interior impact most frequently on the weather at PE, and the effects of such systems may persist for 6 days at a time. Ridging anticyclones located to the south of the subcontinent represent the second most frequently impacting synoptic type; the effects of this system on the weather of the southeast coast may persist for 4 consecutive days.

Synoptic types associated with the passage of low pressure systems (Clusters 2, 3, 5, 9, 10, and 11) occur less frequently and seldom impact on the weather of the southeast coast for longer than one day. This is particularly true of the types which represent the transitional phases in synoptic patterns, such as Clusters 10, 11 and 12.

Table C.14: Frequency of Occurrence and Persistence of Winter Synoptic Types over the West Coast (Springbok).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	59	2-5	6
2	25	1-2	2
3	3	1	1
4	5	1	1
5	12	1	2
6	8	1	2
7	14	1-3	3
8	8	2	3
9	7	1	1
10	2	2	2

Table C.15: Frequency of Occurrence and Persistence of Winter Synoptic Types over the South Coast (Cape Town).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	6.0	1-2	3
2	23.3	1-4	5
3	1.3	1	1
4	6.5	1-2	2
5	15.5	1-2	3
6	3.0	1	2
7	6.9	1	2
8	29.7	2-4	5
9	0.4	1	1
10	1.3	1	1
11	2.2	1	1
12	1.7	1	1
13	2.2	1	1

4. SUMMER SYNOPTIC TYPES AFFECTING PLATEAU REGIONS

4.1 Synoptic Types Identified for Plateau Stations

4.1.1 Central Plateau (Irene)

1. Surface Trough over the Central Interior and RA off NorthEast Coast
2. Surface Trough over SouthEastern Cape Province
3. Pre-Frontal Divergence (NorthWesterly Winds)
4. Pre-Frontal Divergence (SouthWesterly Winds)

5. Ridging Anticyclone off the East Coast
6. Ridging Anticyclone off the NorthEast Coast
7. Ridging Anticyclone off the East Coast and Upper Air Trough
8. Surface Trough over the East Coast and Interior
9. Ridging Anticyclone off the SouthEast Coast
10. Continental HP Dominant
11. Cold Front Passage from the South
12. Surface Trough over the SouthEast and Dominant Upper Air HP

4.1.2 Eastern Plateau (Bethlehem)

1. Ridging Anticyclone off the NorthEast Coast
2. Surface Trough over the SouthEast Cape Coast and Upper Air Low Pressure
3. Pre-Frontal Divergence (NorthWesterly Winds)
4. Ridging Anticyclone off the East Coast
5. Pre-Frontal Divergence (SouthWesterly Winds)
6. Cold Frontal Passage from the South
7. Ridging Anticyclone off the SouthEast Coast
8. Continental HP Dominant over Interior
9. Surface Trough over the SouthEast and Dominant Upper Air HP
10. Surface Trough over the SouthEast Cape Province
11. Surface Trough over the Central Interior and RA off NorthEast Coast

4.1.3 SouthEastern Plateau (Bloemfontein)

1. Ridging Anticyclone off the East Coast
2. Ridging Anticyclone off the NorthEast Coast
3. Surface Trough over the Central Interior
4. Cold Front Passage from West
5. Ridging Anticyclone off the South Coast
6. Ridging Anticyclone off the SouthEast Coast
7. Prefrontal Divergence (NorthWesterly Winds)
8. HP over NE and Trough over Botswana\Namibia
9. Continental HP Dominant10. HP Bridge over East Coast
11. Surface Trough over SouthEastern Cape Province

4.1.4 Western Plateau (Upington)

1. Surface Trough over the Western Interior
2. Cold Frontal Passage from the West
3. Ridging Anticyclone off the SouthWest Coast
4. Ridging Anticyclone off the East Coast
5. HP over the NorthEast and Surface Trough over Botswana\Namibia
6. Pre-Frontal Divergence (NorthWesterly Winds)
7. Ridging Anticyclone off the SouthEast Coast
8. Continental HP Dominant
9. Surface Trough over the SouthEastern Cape and Ridging Anticyclone off the SouthWest Coast
10. Surface Trough over the SouthEast and Dominant Upper Air HP
11. Ridging Anticyclone off the NorthEast Coast

12. Ridging Anticyclone off the NorthEast Coast, Surface Trough over the SouthEast Cape Province and a Well Developed Upper Air Low Pressure
13. Surface Trough over the SouthEast Coast

4.1.5 Northern Plateau (Pietersburg)

1. Ridging Anticyclone off the NorthEast Coast
2. Surface Trough over the Central Interior and RA off NorthEast Coast
3. Surface Trough over the SouthEast Cape and Ridging Anticyclone off the SouthWest Coast
4. Pre-Frontal Divergence (SouthWesterly Winds)
5. Ridging Anticyclone off the East Coast
6. Pre-Frontal Divergence (NorthWesterly Winds)
7. Surface Trough over the SouthEastern Cape Province
8. Surface Trough over the SouthEast and Dominant Upper Air HP
9. Ridging Anticyclone off the SouthEast Coast
10. Ridging Anticyclone off the SouthEast Coast and Tropical Cyclone over Madagascar
11. Cold Frontal Passage from the South
12. Continental HP Dominant

4.1.6 Synoptic Types Identified for All Plateau Stations

Table C.16: Synopsis of summertime synoptic types for all plateau stations.

No.	SYNOPTIC TYPE	CLUSTER No(s)(a).				
		IR	BE	BL	UP	PT
1	RA off SouthWest and/or South Coasts			5	3	
2	RA off the South East Coast	9	2,7	6	7	9,10
3	RA off the East Coast	5	4	1	4	5
4	RA off the NorthEast Coast	6	1	2	11	1
5	RA off the East Coast and Upper Air Trough	7				
6	RA off NE Coast, Surface Trough over SE Cape and Well Developed Upper Air Low Pressure System				12	
7	Cold Frontal Passage	11	6	4	2	11
8	Surface Trough over the Central Interior (and RA off the NE Coast)	1	11	3		2
9	Surface Trough over the SE Cape	2	10	11	9,13	3,7
10	Surface Trough over the SE Cape Province and Upper Air High Pressure	12	9		10	8
11	Surface Trough over the East Coast and Adjacent Interior	8				
12	Surface Trough over Western Interior				1	
13	Pre-Frontal Divergence	3,4	3,5	7	6	4,6
14	Dominant Continental High Pressure	10	8	9	8	12
15	Continental HP to the NorthEast and Surface Trough over Botswana and/or Namibia			8	5	
16	HP Bridge over the East Coast			10		

a) IR = Irene, BE = Bethlehem, BL = Bloemfontein, UP = Upington and PT = Pietersburg.

4.2 Meteorological Characteristics of Synoptic Types Affecting the Plateau

4.2.1 Ridging Anticyclones

4.2.1.1 Ridging Anticyclones off the SouthWest and South Coasts (Type 1)

The effects of RAs located off the southwest (and south) coast following the passage of frontal depressions over the south coast were noted at Upington and Bloemfontein stations. Average to above average relative humidities and very low temperatures (5 to 6 degrees C below the summer mean) were recorded. It should be noted that the effects of the RA were primarily felt below the 700 hPa level and 775 hPa level for Bloemfontein and Upington.

4.2.1.2 Ridging Anticyclone off the SouthEast Coast (Type 2)

With the shift of the RA to the southeast of the subcontinent, its effects were observed for all stations on the plateau. Low temperatures and southeasterly airflow occurred over all stations, with the highest surface pressures and lowest temperatures being experienced at Bloemfontein (4.7 hPa above and 3.8 degrees C below the summer mean respectively). Relative humidities of 10 to 30 % above the summer average were recorded for all stations with the exception of Upington where below average relative humidities were experienced due to the distance of this station from the southeast coast. High relative humidities were, however, observed to occur at Upington in instances where the location of the RA off the Southwest coast coincided with the occurrence of a tropical cyclone over Madagascar.

4.2.1.3 Ridging Anticyclone off the East Coast (Type 3)

The location of RAs off the east coast usually coincides with the occurrence of a surface trough over the western interior. Fairly strong pressure gradients are established between the two systems and northeasterly winds prevail over much of the country. The location of RAs off the east coast result in exceptionally low temperatures and high relative humidities at Pretoria (4.5 degrees C below and up to 55 % above the summer mean respectively). Low temperatures and high relative humidities, along with high surface pressures and strong northeasterly wind components are also evident at Pietersburg, Bloemfontein and Bethlehem. For Bloemfontein, days within this cluster are not, however, necessarily characterised by moist conditions; days on which weak northeasterly winds occur frequently coincided with below average relative humidities.

At Upington surface pressures are normally below average due to the proximity of this station to the surface trough over the western parts of the country, winds are generally north-northeasterly and temperatures are on average 2 to 3 degrees C above the summer mean. Relative humidities are, however, high at Upington (15 to 30 % above the seasonal mean) despite the distance from the moisture source.

4.2.1.4 Ridging Anticyclones off the NorthEast Coast (Type 4)

High surface pressures, low temperatures and high relative humidities persist over the northern, central and eastern plateau with the shift of the core of the RA to the northeast of the country. The northeasterly winds are, however, replaced by airflow with a distinct northwesterly component.

The effects of ridging HP systems located off the northeast coast are normally only experienced over the western plateau when such systems are accompanied by a surface trough over the southern Mozambique Channel. At Upington such synoptic conditions give rise to slightly below average surface pressures and cold, very moist conditions.

4.2.1.5 Ridging Anticyclone off the East Coast and Upper Air Trough (Type 5)

The effects of ridging anticyclones on the western, eastern, northern and central plateau is largely limited to the lower atmosphere at and/or below the 700 hPa level. Above the subsidence inversion cool to warm and generally drier air with a northwesterly component is often observed. In instances where the occurrence of a RA off the east coast was accompanied by a trough in the upper air strong southwesterly airflow, cold conditions and high relative humidities (4.5 degrees C below and 40 % above the summer mean) prevailed in the upper atmosphere.

4.2.1.6 Ridging Anticyclone off the NorthEast Coast, Surface Trough over the SouthEast Cape Province and Well Developed Upper Air Low Pressure (Type 6)

The western plateau is occasionally affected by a range of synoptic types which combine to produce unique meteorological profiles. During one instance, strong north-northwesterly winds, low temperatures and high relative humidities (5 degrees C below and 30 - 40 % above the summer mean respectively) were evident in the lower atmosphere as a result of the occurrence of a RA off the northeast coast and the establishment of a surface trough over the southeastern Cape. The upper atmosphere was, however, characterised by strong southeasterly airflow and cool rather than cold conditions as a result of the presence of a well developed low pressure in the upper atmosphere.

4.2.2 Cold Frontal Passage (Type 7)

Although occurring far less frequently than in winter months, the passage of frontal depressions over the plateau results in notable changes in the weather during summer months. Cold fronts aligned parallel with the west or southwest coasts generally affected the western and southern plateau regions with ver low surface pressures and temperatures, high relative humidities and strong west-northwest winds evident at Bloemfontein and Upington. The central and northern plateau were affected by strong cold fronts approaching from south of the subcontinent, with low surface pressures and temperatures, high relative humidities and distinct southwesterly airflow occurring. The effects of the passage of cold fronts were experienced most frequently at Bethlehem and Bloemfontein, while being rarely evident at Pietersburg and Pretoria.

4.2.3 Surface Troughs

Surface troughs occur fairly frequently across the subcontinent during summer months, stretching from PE to Windhoek. To the west of the trough axis the advance of cool maritime air in the southwesterly winds results in decreasing temperatures and increasing relative humidities, whereas to the east of the trough axis northwesterly winds circulate the warm dry continental air. The effect of the trough on the weather of the stations under study is therefore largely dependant on the location of the station in relation to the trough axis. The axis of the surface trough is most frequently located over the southeastern coast and adjacent interior, frequently shifting westwards over the central interior. Trough axes are seldom located over the western interior. Eastward shifts of trough axes are also fairly infrequent.

4.2.3.1 Surface Trough over the Central Interior (and Ridging Anticyclone off the NorthEast Coast) (Type 8)

The location of the trough axis over the central interior results in low surface pressures and strong northwesterly airflow over the eastern parts of the country. High temperatures and low relative humidities are observed over much of the plateau, including the northern region, due to the warm dry continental air being circulated.

In instances where the surface trough over the central interior coincides with the occurrence of a RA off the northeastern coast, generally higher surface pressures, lower temperatures and moister conditions are evident. The cool, moist maritime air being fed in by the RA over the subcontinent is circulated ahead of the trough axis in place of the warmer, drier continental air.

4.2.3.2 Surface Trough over the SouthEast Cape Province (Type 9)

The shift of the trough axis eastward results in much of the interior being exposed to the influx of cool, maritime air to the west of the axis; the cool conditions and southwesterly airflow being felt as far afield as Pietersburg. Days within this synoptic typing are characterised by low surface pressures and temperatures (0.9 to 4 hPa and 2 to 6 degrees C below the summer mean respectively), high relative humidities (5 to 25 % above the mean) and strong southwesterly winds. For days on which the surface trough is accompanied by a strong RA off the southwest coast generally higher surface pressures were noted for the western plateau.

The effects of troughs are frequently evident beyond the 700 hPa level indicating the absence of the low level subsidence inversion. In certain instances an upper level low pressure coincides with the surface trough, the effect of the upper air low evident in the occurrence of very strong southwesterly airflow, high humidities (30 % higher than the summer average) and low temperatures is the upper atmosphere above the 700 hPa level.

4.2.3.3 Surface Trough over the SouthEast Cape Province and Upper Air High Pressure (Type 10)

The coupling of a surface trough over the southeastern Cape and a HP in the upper air results in the occurrence of a heatwave over much of the interior. High surface pressures, exceptionally high temperatures and low relative humidities (up to 6.4 degrees C higher and 40 % lower than the seasonal average respectively) were observed to coincide with this synoptic type. Airflow is predominantly northwesterly for most stations, although northwesterly winds also occurred on occasion. In the upper atmosphere, above 700 hPa cooler and drier conditions generally prevailed.

4.2.3.4 Surface Trough over the East Coast and Adjacent Interior (Type 11)

The shift of trough axes eastward resulted in the replacement of the southwesterly winds with southeasterly airflow over much of the plateau. Surface pressures and temperatures remained low and above average relative humidities continued to prevail.

4.2.3.5 Surface Tough over the Western Interior (Type 12)

With the westward movement of the surface trough, previously located over the central interior, the effects of this system on the weather of the northern, central and southern plateau becomes negligible. Low surface pressure and relative humidities, high temperatures and strong northwesterly airflow continue, however, to occur over the western plateau.

4.2.4 Pre-Frontal Divergence (Type 13)

Pre-frontal divergence was observed to impact on the weather of the plateau stations even on occasions when the proceeding frontal system only affected the southern and southeastern coastal regions. Strong north-northwesterly to northwesterly winds, increased temperatures (2 to 5.8 degrees C above the seasonal mean) were observed to precede frontal depressions approaching from the west.

The location of a trough over the southeast of the country together with a cold front approaching the south coast resulted in strong southwesterly winds, low pressures and high temperatures over much of the plateau.

4.2.5 Patterns Associated with Strong Continental High Pressures

4.2.5.1 Continental HP Dominant (Type 14)

Unlike winter months during which the continental anticyclone dominates much of the weather over the interior, the continental HP plays a far less important role during the summer. In the absence of the stronger transient systems the effects of the continental anticyclone become evident with the occurrence of slightly above average surface pressures, warm, dry conditions and predominantly northwesterly winds.

4.2.5.2 Continental HP to the NorthEast and Surface Trough over Botswana and/or Namibia (Type 15)

Weak pressure gradients are set up between the continental HP located to the northeast of the country and the LP trough centred over Botswana and/or Namibia and northwesterly to north-northwesterly flows prevail over much of the subcontinent. The presence of the LP core to the north and the extension of the trough southwards across the western Cape results in low surface pressures over the western plateau while above average surface pressures are evident over the northern, central and eastern plateau. The circulation of warm dry continental air gives rise to low relative humidities and high temperatures for most days within this cluster.

4.2.5.3 HP Bridge over the East Coast (Type 16)

The development of a HP ridge between a RA located off the east coast and the continental HP located over the northwestern interior resulted in exceptionally high surface pressures, strong west-northwesterly winds and warm, moist conditions occurring at Bloemfontein.

4.3 Implications of Summer Synoptic Types occurring at Plateau Stations for Atmospheric Dispersion Potential

Table C.17: Classification of Summertime Synoptic Types for Plateau Stations into stagnating (S), ventilating (V) and neutral (N) systems according to vertical averages wind speeds (VAWS), mixing depths and precipitation potentials.

SYNOPTIC TYPE:	VAWS (m/s)	MIXING DEPTH (m)	PRECIPITATION POTENTIAL	CLASS
1	4.8(a)	≤ 1 500(a)	Low \ No(a)	N (S)(a)
	3.8(b)	≤ 1 500(b)	Low \ No(b)	S(b)
2	4.2(c) 7.3(d)	≤ 1 500(c) ≤ 2 000(d)	High	V(c)(d)
	3.1 - 3.5(e)	≤ 2 000(e)	Low \ No(e)	S(e)
3	2.1 - 9.8	≤ 1 500, ≤ 2000(f)	High	V
4	3.4(b)	≤ 1 500(b)	Low \ No(b)	S(b)
	2.8 - 4.7(f)	≤ 1 500(f)	High(f)	V(f)
5	4.7	≤ 1 500	High	V
6	6.1	≤ 1 500	High	V
7	3.9 - 11.3	≤ 2 000	High	V
8	4.0(a)	≤ 2 000(a)	Low \ No(a)	V(a)
	4.1 - 4.6(h)	≤ 2 000(h)	High(h)	V(h)
9	3.5 - 7.5(i)	≤ 2 000(i)	High(i)	V(i)
9	2.0 - 2.9(j)	≤ 1 500(j)	Low \ No(j)	S(j)
	6.0(b)	≤ 1 500(b)	Low \ No(b)	V(b)
10	3.5 - 5.7(k)	≤ 2 000(k)	High(k)	V(k)
	≤ 4.0(h)	≤ 1 500(h)	Low \ No(h)	S(h)
11	6.4	≤ 2 000	High	V
12	5.0	≤ 1 500	Low \ No	N
13	3.1 - 6.4(l)	≤ 1 500(l)	High(l)	V(l)
	3.7 - 3.8(k)	≤ 1 500(k)	Low \ No(k)	S(k)
	5.8 - 7.4(m)	≤ 1 500(m)	Low \ No(m)	V(m)
14	6.5(b)	≤ 1 500(b)	Low \ No(b)	V(b)
	0.9 - 3.3(n)	≤ 1 500(n)	Low \ No(n)	S(n)
15	3.2 - 5.2	≤ 1 500	High	V
16	3.4	≤ 1 500	Low \ No	S

a) Occurs for Bloemfontein (cluster 5 and 3 for synoptic types 1 and 8 respectively).
b) Occurs for Upington (cluster 3, 11, 9 and 8 for synoptic types 1, 4, 9 and 14 respectively).
c) Occurs for Pietersburg (cluster 10).
d) Occurs for Irene (cluster 9).
e) Occurs for Bethlehem (cluster 7), Bloemfontein (cluster 6), Upington (cluster 7) and Pietersburg (cluster 9).
f) The mixing depth varies for this synoptic type both between stations and between different days at a single station.
g) Occurs for Bloemfontein (cluster 2), Irene (cluster 6), Bethlehem (cluster 1) and Pietersburg (cluster 1).
h) Occurs for Irene (cluster 1 and 12) and Pietersburg (cluster 2 and 8) for synoptic types 8 and 10 respectively.
i) Occurs for Bethlehem (cluster 10) and Irene (cluster 2).

j) Oc urs for Upington (cluster 13), Pietersburg (cluster 3 and 7) and Bloemfontein (cluster 11).
k) Occurs for Bethlehem (cluster9 and 5) and Upington (cluster 10 and 6) for synoptic types 10 and 13 respectively.
l) Occurs for Bethlehem (cluster 3), Bloemfontein (cluster 7) and Pietersburg (cluster 6).
m) Occurs for Irene (cluster 3 and 4) and Pietersburg (cluster 4).
n) Occurs for Irene (cluster 10), Bethlehem (cluster8) and Bloemfontein (cluster 9).

4.4 Frequency of Occurrence and Persistence of Summer Synoptic Types over the Plateau

Table C.18: Frequency of Occurrence and Persistence of Summertime Synoptic Types over the Central Plateau (Irene).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	5.9	1	1
2	4.4	1-2	2
3	16.2	1-2	3
4	2.9	1	1
5	10.3	1-2	2
6	2.9	1	1
7	4.4	1-2	2
8	10.3	1-2	2
9	22.1	1-2	3
10	4.4	1	1
11	4.4	1-2	1
12	11.8	3	4

Table C.19: Frequency of Occurrence and Persistence of Summertime Synoptic Types over the Eastern Plateau (Bethlehem)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	12.7	1	2
2	3.6	2	3
3	7.3	1	2
4	21.8	1	2
5	10.9	1	1
6	9.2	1	1
7	7.3	1	1
8	3.6	1-2	2
9	12.8	3	4
10	7.2	2-3	3
11	3.6	1	1

Table C.20: Frequency of Occurrence and Persistence of Summertime Synoptic Types over the SouthEastern Plateau (Bloemfontein).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	22.6	1	2
2	15.1	1	2
3	16.9	2-3	3
4	5.7	1	1
5	9.4	1	2
6	1.9	1	1
7	5.7	1	2
8	7.5	2	2
9	5.7	1-2	2
10	3.8	2	2
11	5.7	2-3	3

Table C.21: Frequency of Occurrence and Persistence of Summer Synoptic Types over the Western Plateau (Upington)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	7.3	1	1
2	1.8	1	1
3	20	1-2	3
4	23.6	1-2	3
5	10.9	1	1
6	5.5	1	1
7	3.6	1	1
8	5.5	1-2	2
9	1.8	1	1
10	7.3	1-2	3
11	1.8	1	1
12	3.6	1-2	2
13	7.3	1-2	2

Table C.22: Frequency of Occurrence and Persistence of Summer Synoptic Types over the Northern Plateau (Pietersburg)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	7.3	1	1
2	6.4	1-2	2
3	7.3	1	2
4	10.9	1-2	2
5	39.9	2-3	6
6	5.5	1	2
7	3.6	1	1
8	5.5	2-3	3
9	5.5	1-2	2
10	1.8	1	1
11	1.8	1	1
12	4.5	1	2

5. SUMMER SYNOPTIC TYPES AFFECTING COASTAL REGIONS

5.1 Synoptic Types Identified for Coastal Stations

5.1.1 East Coast (Durban)

1. Bergwinds Associated with Pre-Frontal Divergence (NW Winds)
2. Passage of Cold Front
3. Ridging Anticyclone to the South (East) of the Country
4. Bergwinds Associated with Pre-Frontal Divergence (SW Winds)
5. Continental HP Dominant over the Interior
6. Ridging Anticyclone to the East of the Country
7. Day Following Cold Front Passage and Core of Continental HP Located Behind the Front
8. Surface Trough over the Central Interior or East Coast
9. Tropical Cyclone off East Coast

5.1.2 SouthEast Coast (Port Elizabeth)

1. Bergwinds Associated with the Continental HP
2. Coastal Low
3. Pre-frontal Divergence
4. Passage of Cold Front
5. Ridging Anticyclone off the East Coast
6. Continental HP Dominant over the Interior
7. Ridging Anticyclone to the South of the Country
8. Ridging Anticyclone to the Southeast of the Country

5.1.3 South Coast (Cape Town)

1. Surface Trough over the Central Interior
2. Cold Frontal Passage from South
3. Cold Frontal Passage from West
4. Ridging Anticyclone off the West Coast
5. Ridging Anticyclone off the SouthWest Coast
6. Ridging Anticyclone off the SouthEast Coast
7. Bergwind Conditions Associated with Ridging Anticyclone off the East Coast
8. HP over the Northeast and Surface Trough over Namibia/Botswana
9. Bergwind Conditions Associated with Ridging Anticyclones off the East Coast (and strong Low Pressure System over the SouthWest Coast)
10. Pre-Frontal Divergence (NorthWesterly Winds)
11. Continental HP Dominant

5.1.4 West Coast (Springbok)

1. Continental HP Dominant over Interior
2. Bergwind Conditions Associated with Pre-Frontal Divergence
3. Passage of Cold Front
4. Ridging Anticyclone to the South of the Country
5. Atlantic HP Ridge over West Coast
6. Ridging Anticyclone over SouthEast Coast
7. Bergwind Conditions Associated with a Ridging Anticyclone off the SE Coast

8. Surface Trough over the West Coast
9. Surface Trough over the SouthEast Coast
10. Bergwind Conditions Associated with a HP Bridge over the Central Plateau

5.1.5 Summertime Synoptic Types Identified for All Coastal Stations

Table C.23: Synopsis of summertime synoptic types for all coastal stations.

No.	SYNOPTIC TYPE	CLUSTER No(s)(a).			
		DU	PE	CT	SP
1	Continental HP Dominant over Interior	5	6	11	1
2	Bergwinds Assoc. with Continental HP and HP Bridges over the Central Plateau		1		10
3	Bergwinds Assoc. with Pre-frontal Divergence	1,4			2
4	Bergwinds Assoc. with RAs off SE or E Coast			7,9	7
5	Pre-Frontal Divergence		3	10	
6	Cold Frontal Passage	2	4	2,3	3
7	RA off the West Coast			4	
8	RA off the SouthWest Coast			5	
9	RA to the South of the Country	3	7		4
10	RA to the SouthEast of the Country		8	6	6
11	RA off the East Coast	6	5		
12	Ridging of Atlantic HP over the West Coast				5
13	Day Following Cold Front Passage and Core of Continental HP located behind the Front	7			
14	Coastal Low		2		
15	Surface Trough over Central Interior or East Coast	8		1	9
16	Surface Trough over the West Coast				8
17	Tropical Cyclone off the East Coast	9			
18	Continental HP over the NE and Surface Trough over Namibia/Botswana			8	

a) DU = Durban, PE = Port Elizabeth, CT = Cape Town, SP = Springbok

5.2 Meteorological Characteristics of Summer Synoptic Types Affecting Coastal Regions

5.2.1 Continental HP Dominant over the Interior (Type 1)

In the absence of the stronger, transient synoptic systems the effects of the continental HP are evident at coastal stations, viz. average to slightly above average surface pressures, average to above average temperatures, dry conditions and winds with a northerly wind component. At Cape Town and Port Elizabeth this synoptic type is usually characterised by weak northeasterly and northwesterly winds respectively. The sea breeze remains evident for both stations as southwesterly winds which continue to prevail at and below the 1 000 hPa level.

Exceptionally low relative humidities (up to 40 % lower than the seasonal mean) in the upper atmosphere have been recorded at Durban for days within this cluster, whilst at the surface and 1000 hPa level relative humidities are only slightly below average. Northeasterly (onshore) winds characterise the lower atmosphere, with the northerly wind component strengthening with increased altitude. The depth and strength of the northeasterly wind component in the lower atmosphere is dependent on the proximity of the Indian Ocean HP cell to the east coast. Airflow associated with the Indian Ocean HP strengthening the sea breeze airflow component.

The presence of a continental HP over the northeastern interior results in a northwesterly wind component being observed in the upper air over Springbok. The low level subsidence inversion, which is particularly prominent during summer months as a result of the proximity of the Atlantic HP, is clearly evident under this synoptic pattern. Warmer, moister conditions occur at and below the 900 hPa level and the wind field is dominated by southwesterly airflow.

5.2.2 Bergwind Conditions

5.2.2.1 Bergwinds Associated with Continental HP and HP Bridges over the Central Plateau (Type 2)

Over the east coast this synoptic type is characterised by above average surface pressure (2 hPa above the summertime average), exceptionally hot air (as high as 15 degrees celsius warmer that the summertime average temperature in the lower atmosphere), and dry conditions (20 % lower that the summertime mean relative humidity). The air near the surface has a higher relative humidity due to the occurrence of sea breezes. Northwesterly winds prevail throughout the airmass except at the surface where sea breezes occur as northeasterlies.

The establishment of an intense HP bridge between the continental HP and the Indian subtropical HP results in conditions over the west coast very similar to that of synoptic type 7 (RA off South-East Coast). Northwesterly (offshore) winds predominate over the west coast resulting in bergwinds conditions and the dissipation of the low level subsidence inversion. High temperatures (5 degrees C above the seasonal mean) and relatively moist conditions characterise days within this cluster. This synoptic type occurs predominantly during February due to the shift in the location of the Indian subtropical HP.

5.2.2.2 Bergwinds Associated with Pre-Frontal Divergence (Type 3)

East Coast

As in winter months, pre-frontal divergence over the east coast occurs either ahead of a low pressure trough over the eastern interior or ahead of a coastal low. The proximity of the low pressure system results in a decrease in the surface pressure (on average 8 hPa lower than the seasonal mean), whilst the bergwinds associated with divergence ahead of the system gives rise to very high temperatures (up to 8 degrees celsius above the summer mean), low relative humidities, and fairly strong northwesterly winds above the 900 hPa level. Moister and cooler conditions with northeasterly winds, associated with the sea breeze, occur in the lower atmosphere.

With the shift of the low pressure trough further eastwards the western (convergence) side of the wave is located over the east coast resulting in the occurrence of west-south-westerly bergwinds over Durban. Days within this synoptic type exhibit similar meteorological conditions to days on which bergwinds associated with northwesterly pre-frontal divergence occur, viz. high temperatures (up to 4 degrees celsius above the seasonal mean), and high relative humidities (up to 18 % higher than the seasonal average in the lower atmosphere).

The wind field is, however, characterised by strong south-westerly winds occurring throughout the atmosphere.

West Coast

For the west coast this synoptic type is essentially similar to the winter type (cluster 9) which comprises the warm moisture surge ahead of an approaching cold front. In the summer instances the northwesterly winds generated ahead of the approaching frontal depression generally destroyed the low level subsidence inversion resulting in mixing to at least the 775 hPa level. For days within this cluster the lower atmosphere is characterised by moist and very warm conditions, whereas above 775 hPa slightly moist and cool conditions prevail. Northwesterly winds prevailed throughout the atmosphere, and surface pressures continued to decrease as the front approached the station.

South Coast

Preceding the passage of a frontal depression, strong west-northwesterly to northwesterly winds, falling surface pressures (4 hPa below the mean) and warm (2 degrees C above the summer mean) dry conditions prevailed over the south coast.

5.2.2.3 Bergwind Conditions Associated with Ridging Anticyclones off the SouthEast or East Coast (Type 4)

The establishment of a ridging anticyclone off the southeast or east coasts provides ideal conditions for the development of bergwinds over the western, southwestern and southern Cape coasts. RAs off the east coast produce strong northwesterly winds over much of the western half of the subcontinent. At Springbok exceptionally warm (5 to 7 degrees C above the summer mean) and dry conditions prevail up to the 700 hPa level, above which warm (2 degrees C above the seasonal mean) and slightly moist conditions occur.

At Cape Town such RAs were observed to occur both independently (Cluster 7) and to coincide with strong low pressure systems located over the southwest Cape coast (Cluster 9). Whereas the RA resulted in average surface pressures and northeasterly airflow over the southern Cape coast, the presence of low pressure cells results in very low surface pressures (6.5 hPa below the seasonal mean) and much stronger northwesterly airflow. The offshore winds (northeasterly for cluster 7 and northwesterly for cluster 9) were at times only apparent above the 1000 hPa level along with hot dry conditions (4 degrees C above and 15 to 25 % below the summer mean respectively). In the lower atmosphere southwesterly winds and generally cooler, moister conditions signified the persistence of the sea breeze system. In certain instances, particularly when the RA off the east coast coincided with a low pressure system over the southwest coast, bergwinds were strong enough to displace the sea breeze near the surface.

5.2.3 Prefrontal Divergence (Type 5)

Due to the orientation of the southeast coast and the nature of the pre-frontal divergence over the coast, pre-frontal divergence seldom results in the occurrence of bergwind conditions at Port Elizabeth. Very low surface pressure (6 hPa below the summer mean), and warm and dry air with a west-north-westerly wind component attest to the occurrence of prefrontal divergence over the southeast coast.

5.2.4 Passage of Cold Fronts (Type 6)

East Coast

Although cold fronts occur most frequently during winter months, weaker frontal depressions occasionally occur during the summer time resulting in dramatic changes in the weather of the east coast. During the summer months under study the passage of frontal depressions over the east coast resulted in below average surface pressure (2 hPa below the summertime mean), very cold and moist conditions throughout the air mass (up to 6 degrees celsius lower and as much as 40 percent higher than the summer mean respectively). Strong southwesterly winds occurred throughout the airmass on days within this cluster.

Southeast Coast

As with the northeastward passage of cold fronts over the southeast coast during winter months, the occurrence of these systems during summer results in the predominance of moist air (up to 38% higher than the summertime mean RH), a strong southwesterly wind component and low surface pressures. Unlike winter months, however, the passage of frontal depressions during summer months is not characterised by such an extensive drop in temperature; temperatures of only 2 degrees celsius below the summertime mean being noted.

West Coast

The passage of cold fronts occur far less frequently during summer months as can be expected (7% frequency of occurrence compared to 25 % during winter months). As in winter months, the passage of cold fronts over the west coast results in the dissipation of the low level inversion and the predominance of cold moist air with a southwesterly component up to about the 700 hPa level at which the second subsidence inversion occurs. Above this inversion cool, dry conditions and northwesterly winds continue to occur.

South Coast

As at other coastal stations the passage of a frontal depression from the south results in low surface pressures (2.7 hPa below the summer mean), low temperatures and high relative humidities (2 to 8 degrees C below and 15 to 40 % above the seasonal mean respectively), and a strong southwesterly wind component. The approach of a cold front aligned parallel to the west coast similarly results in low surface pressures, sharp decreases in temperatures and increases in moisture. A distinct difference is, however, noted in the nature of the wind field. A northwesterly to west-northwesterly component is evident following the passage of a frontal depression from the west or southwest.

5.2.5 Ridging Anticyclones

As in winter, ridging anticyclones result in onshore airflow, cloudy conditions and general rainfall along the eastern and southern coastal and adjacent inland areas. Although the passage of the cold front results in considerable cooling, the proceeding RA causes further cooling and increasingly instability.

5.2.5.1 Ridging Anticyclone off the West Coast (Type 7)

The ridging of the Atlantic Subtropical HP over the west coast results in high surface pressures (3.4 hPa above summer average), decreasing temperatures and increasing humidities and a distinct west-northwesterly wind component. The occurrence of this synoptic type does not necessarily coincide with the passage of a frontal depression over the southern Cape coast.

5.2.5.2 Ridging Anticyclone off the SouthWest Coast (Type 8)

The passage of frontal depressions is usually proceeded by a RA located to the southwest of Cape Town. Days within this cluster are characterised by extremely high surface pressures (6.5 hPa above the seasonal average), exceptionally low temperatures (5 to 10 degrees C below the mean), high humidities, and strong southwesterly winds.

5.2.5.3 Ridging Anticyclone to the South of the Country (Type 9)

West Coast
The "budding off" of a cell from the Atlantic subtropical HP and the movement of the ridging HP to a position off the south coast results in strong cold, northeasterly airflow over the west coast in the lower atmosphere up until the 700 hPa level at Springbok. The lowest level subsidence inversion, destroyed by the passage of the frontal depression, remains absent. In the upper atmosphere cool, southwesterly winds prevail. Days within this cluster are characterised by high surface pressures and practically clear skies.

Southeast Coast
The very cold (5 to 7 degrees celsius below summertime mean temperature) and exceptionally humid (20 to 55 % above the summertime mean RH) air over the southeast coast, together with the predominance of strong southwesterly winds are characteristic of the occurrence of a RA to the south of the subcontinent. Above average surface pressures accompany these characteristics.

East Coast
For Durban no distinction is made between the conditions arising from the RA located to the south and southeast of the subcontinent. Both synoptic scenarios are characterised by high surface pressures (approximately 4 hPa above the summertime mean), very low temperatures throughout the air mass (up to 8 degrees celcius below the seasonal mean), high relative humidities (20 % higher than seasonal mean), and very strong northeasterly winds throughout the air mass over the east coast.

5.2.5.4 Ridging Anticyclone to Southeast of the Country (Type 10)

West Coast
High surface pressures (3.2 hPa above the summer mean), and the occurrence of high relative humidities and south-southeasterly winds in the lower atmosphere (below 700 hPa) characterise conditions at Springbok. Southwesterly winds continue to prevail in the upper air as a result of the passage of the cold front. The distinct discontinuity in the moisture content of the atmosphere illustrates the persistence of the subsidence inversion at the 700 hPa level.

South Coast
With the shift of the core of the RA to the east the southwesterly wind component is replaced by southeasterly airflow. At Cape Town temperatures begin rising and humidities falling despite remaining 4 degrees C below and 25 % above the seasonal average respectively. Surface pressures remain high over the south coast.

Southeast Coast
The shift of the RA to the southeast of the subcontinent gives rise to the influx of cold (4 degrees celsius below the summertime mean), very humid (up to 40 % higher than the seasonal average RH) air over the southeast coast. Due to eastward shift of the RA core

southeasterly winds prevail over the southeast coast. The proximity of the RA core to the coast also results in a sharp increase in the surface pressure.

5.2.5.5 Ridging Anticyclones to the East of the Country (Type 11)

Ridging anticyclones located off the east coast generally result in bergwind conditions over the western, southwestern and southern coastal regions as has been discussed in a previous section.

Southeast Coast
Surface pressure rises to 3 hPa above the summertime mean, and cool and very moist conditions (40 % above the seasonal mean) prevail along the southeast coast with the occurrence of a RA off the east coast. Although the airflow at the surface remains characterised by the southeasterly sea breeze, the strong north-northeasterly winds which occur above the surface reflect the impact of the RA on the circulation over the southeast coast. The RA is thus responsible for the influx of cool, moist maritime air.

East Coast
As RAs move further towards the east they form anticyclonic ridges with the continental high pressure. The airflow in the upper atmosphere over the east coast begins to be influence again by the continental northwesterly airflow pattern. Temperatures begin to rise, and relative humidities drop as the inflow of warm, dry continental air replaces the cold, moist onshore flow associated with the RA. Surface pressures increase substantially due to the HP bridge having been established and the cloudy weather in the east begins to clear.

The development of an anticyclonic ridge between the continental HP and the RA off the east coast result in very high surface pressure (8 hPa above the summer mean) and warm conditions (4 to 6 degrees celsius above the seasonal mean). Although fairly moist conditions (10 % above average) and strong northeasterly winds continue to characterise the lower atmosphere, warm and dry conditions with north-westerly winds occur in the upper atmosphere at and above the 850 hPa level.

5.2.6 Ridging of Atlantic HP over the West Coast (Type 12)

The location of the Atlantic subtropical HP nearly 5 degrees North of its mean position in January and the extension of a ridge towards the south coast resulting in fine but cooler weather over the south-west and west coasts. Southwesterly winds, which predominate throughout the atmosphere, facilitate the influx of cool maritime air from the west and south. Surface pressures remain high and cloudless conditions prevail due to the proximity of the HP and the associated subsidence. The coldest temperatures occur near the surface (2 to 4 degrees C below the summer mean), becoming cool at about the 775 hPa level, above which average to slightly warm conditions occur.

5.2.7 Day Following Cold Front Passage and Core of Continental HP Located Behind the Front (Type 13)

The meteorological characteristics of this synoptic type, observed to have occurred at Durban, typical of the characteristics which occur on days following the passage of a frontal depression, except that high surface pressure occurs and temperatures are not as low as expected. High surface pressures (6 hPa higher than the summertime mean), low temperatures throughout the air mass (4 to 9 degrees celsius lower than the seasonal average), very moist conditions, and high southwesterly winds throughout the atmosphere characterise the cluster.

5.2.8 Coastal Low (Type 14)

The passage of a coastal low is characterised by fairly average surface pressure. Moist conditions (20 % above summertime mean RH) and southwesterly winds prevail in the lower atmosphere over Port Elizabeth. The upper atmosphere, above the 1000 hPa level, is warmer, contains far less moisture, and is characterised by weak northwesterly winds, indicating the shallow nature of this low pressure system.

5.2.9 Surface Troughs

5.2.9.1 Surface Trough over the Central Interior or East Coast (Type 15)

For this synoptic type a well defined trough stretches from PE to Upington with a low pressure system present over Namibia and a westerly wave prominent over the south-eastern Cape coast. The semi-permanent HPs are present over the western Cape and Eastern Plateau. To the west of the trough (west coast) southwesterly (onshore) airflow occurs resulting in the influx of cool maritime air over the region. Cool (2 degrees below the summer mean) air with a distinct southwesterly component prevail throughout the atmosphere, and below average surface pressures are observed at Springbok.

The location of the surface trough over the central interior, stretching from PE to Windhoek, similarly results in onshore airflow and low surface pressures over the southern Cape coast. The south-southwesterly to southwesterly winds result in the influx of cool, very moist air (30 to 40 % higher than the seasonal mean relative humidity). Rainfall may occur on the seaward slopes of mountain ranges due to orographic uplift.

Widespread rainfall usually occurs over the eastern half of the country due to the location of a low pressure trough over the central interior or east coast. This synoptic type occurred primarily in December and February. Over the east coast days within this cluster were characterised by slightly below average surface pressure, cool conditions and southwesterly winds (west-south-westerly in the lower atmosphere). Above average relative humidities (20 to 28 % above the seasonal mean) and widespread rainfall was characteristic of this cluster.

5.2.9.2 Surface Trough over the West Coast (Type 16)

This cluster is characterised by a the establishment of a low pressure trough over the west coast and the location of the continental HP above the east coast. A pressure gradient is evident over the plateau resulting in strong NNW to NE winds over much of the country. The northeasterly winds which occur over much of the west coast result in the influx of moisture from the Indian Ocean. Warm, moist conditions prevail throughout the atmosphere as far inland as Springbok. The location of the trough results in low surface pressures (2 hPa below the summer mean) at Springbok.

5.2.10 Tropical Cyclone off the East Coast (Type 17)

The movement of tropical cyclones towards the east coast results in the occurrence of heavy rainfall and high winds. Such tropical cyclonic activity mainly occurs during late summer or autumn months, originating over the warm southern Indian Ocean where latent heat derived from condensed water vapour provides the energy needed to drive the system. As the tropical cyclone moves over land the supply of heat and moisture is cut off and the increased frictional drag of the land surface results in greater cross-isobaric motion and the system dissipates. During January 1990 tropical cyclonic activity off the east coast considerably affected the airmass over the east coast on two days. Very low surface pressures, high relative humidities, cold conditions and very strong northeasterly winds were observed.

5.2.11 Continental HP over the NorthEast and Surface Trough over Namibia/Botswana (Type 18)

A weak pressure gradient is established between the core of the tropical low pressure located over Botswana or Namibia with a trough extending southwards across the western Cape, and the centre of the continental HP located over the northeastern part of South Africa. Northwesterly to northeasterly winds prevail over the south coast; the offshore winds resulting in warm to hot and slightly moist conditions. Low surface pressures occur as a result of the location of the trough.

5.3 Implications of Summertime Synoptic Types at Coastal Stations for Atmospheric Dispersion Potential

The vertically averaged wind speed, mixing depth and precipitation potential of certain synoptic types vary from station to station for coastal stations. A particular synoptic type may therefore represent a ventilating system in one region, despite being labelled a stagnating or neutral system in another.

Table C.24: Classification of Summertime Synoptic Types for Coastal Stations into stagnating (S), ventilating (V) and neutral (N) systems according to vertical averages wind speeds (VAWS), mixing depths and precipitation potentials.

SYNOPTIC TYPE:	VAWS (m/s)	MIXING DEPTH (m)	PRECIPITATION POTENTIAL	CLASS
1	1.4 - 6.2	≤ 1 500(a) ≤ 800(b)	Low \ No	S
2	3.5 - 4.7	≤ 1 500	Low \ No	S
3	7.1(a) 3.0 - 10.6(c)	≤ 1 500(a) ≤ 100(c)	Low \ No	S
4	1.5 - 7.0(d)	≤ 100(d)	Low \ No(d)	S(d)
	5.6(a)	≤ 1 500(a)	Low \ No(a)	N(a)
5	6.0 - 7.4	≤ 100	Low \ No	S
6	3.7 - 12.6	≤ 2 000	High	V
7	5.1	≤ 800	High	V
8	4.4	≤ 800	No	S
9	5.9 - 13.8(e)	≤ 1 500(e)	High(e)	V(e)
	4.3(a)	≤ 1 500(a)	Low \ No(a)	S(a)
10	3.4(a) 9.5(d)	≤ 1 500(a) ≤100(d)	Low \ No(a)(d)	S(a)(d)
	3.7(f)	≤ 1 000(f)	High(f)	V(f)
11	8.3 - 9.6	≤ 1 000	High	V
12	4.5	≤ 1 500	Low \ No	N
13	8.9	≤ 800	High	V
14	2.8	≤ 100	High	V

SYNOPTIC TYPE:	VAWS (m/s)	MIXING DEPTH (m)	PRECIPITATION POTENTIAL	CLASS
15	5.7(a)	≤ 1 500(a)	Low \ No(a)	N(a)
	12.0(g)	≤ 100(g)	Low \ No(g)	S(g)
16	5.8	≤ 2 000	High	V
17	7.1	≤ 2 000	High	V
18	2.0	≤ 100	Low \ No	S

a) Occurs for Springbok (clusters 1, 2, 7, 4, 6 and 9 for synoptic types 1, 3, 4, 9, 10 and 15 respectively).
b) Occurs for Cape Town (cluster 11), Port Elizabeth (cluster 6) and Durban (cluster 5).
c) Occurs for Durban (clusters 1 and 4).
d) Occurs for Cape Town (clusters 7 and 9 for synoptic type 4; and cluster 6 for synoptic type 10).
e) Occurs for Durban (cluster 3) and Port Elizabeth (cluster 7).
f) Occurs for Port Elizabeth (cluster 8).
g) Occurs for Cape Town (cluster 1) and Durban (cluster 8).

5.4 Frequency of Occurrence and Persistence of Summer Synoptic Types over Coastal Regions

Table C.25: Frequency of Occurrence and Persistence of Summertime Synoptic Types over the East Coast (Durban)

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	8.1	1	2
2	9.4	1	1
3	6.7	1	2
4	6.0	1	1
5	53.7	2-3	5
6	5.4	1	2
7	0.7	1	1
8	7.4	1-2	2
9	2.6	2	2

Table C.26: Frequency of Occurrence and Persistence of Summertime Synoptic Types over the Southeastern Coast (Port Elizabeth).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE(%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	1.8	1-3	3
2	3.6	1	1
3	7.4	1	2
4	9.1	1	1
5	18.2	1	2
6	52.7	2-3	4
7	3.6	1	2
8	3.6	1	2

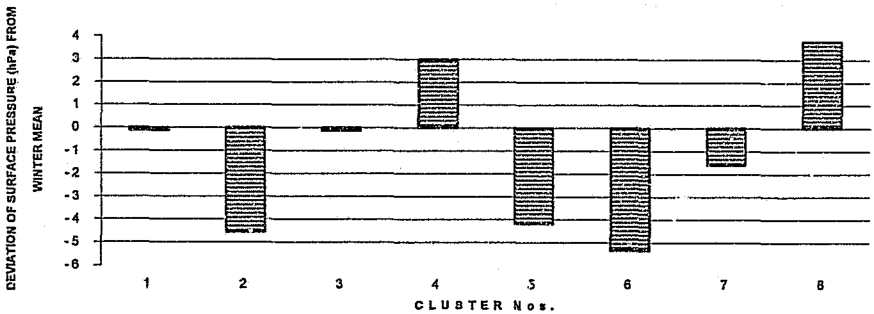
Table C.27: Frequency of Occurrence and Persistence of Summer Synoptic Types over the West Coast (Springbok).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	51.3	2-3	6
2	7.0	1-2	2
3	5.0	1	1
4	5.7	1	2
5	4.4	1	2
6	3.8	1	2
7	1.9	1	2
8	3.8	1	2
9	7.6	1	1
10	9.5	2-3	3

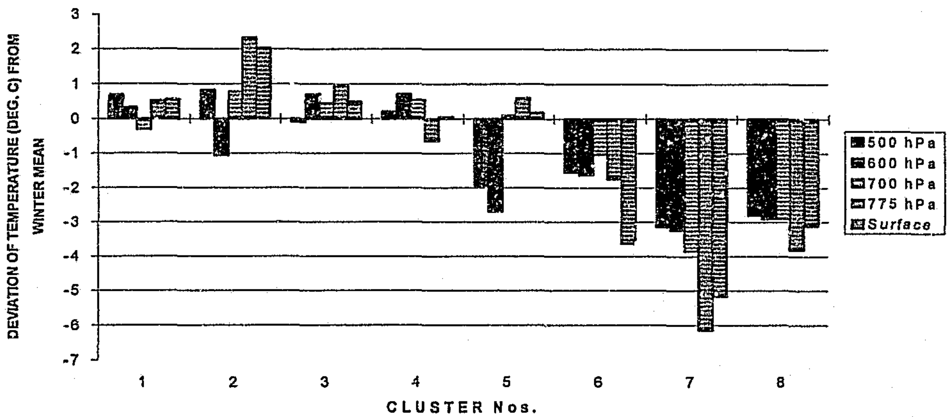
Table C.28: Frequency of Occurrence and Persistence of Summer Synoptic Types over the South Coast (Cape Town).

CLUSTER NUMBER	FREQUENCY OF OCCURRENCE (%)	PERSISTANCE - NO. OF DAYS	
		MEAN	MAXIMUM
1	5.6	1	2
2	3.7	1	1
3	14.8	1	1
4	11.1	1	2
5	12.9	1	1
6	18.5	1	1
7	11.1	1-2	2
8	1.9	1	2
9	14.8	1	1
10	1.9	1	2
11	3.7	1-2	3

C.1.(a)



C.1.(b)



C.1.(c)

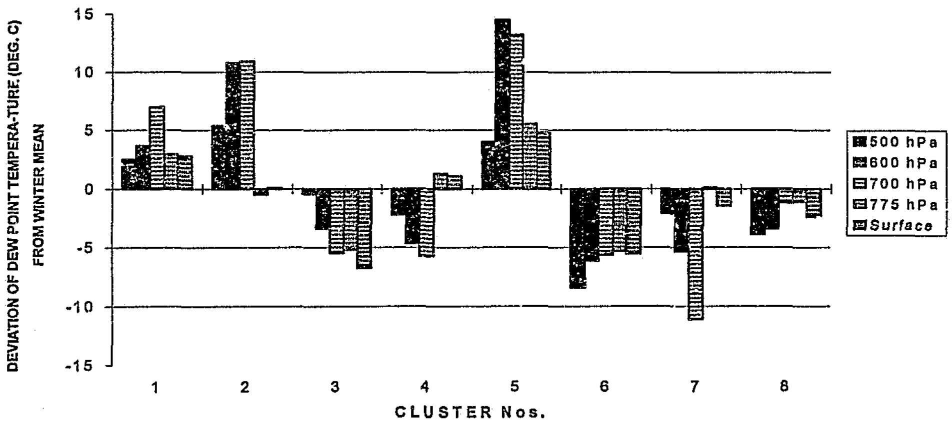
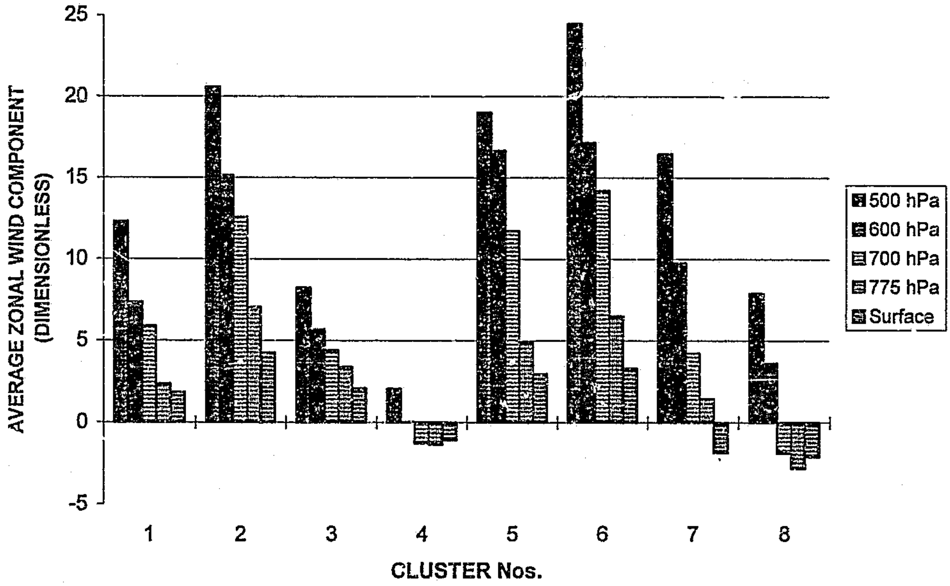


Figure C.1 (a) - (c): Meteorological characteristics of WINTER clusters for IRENE, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and dew point temperature (c).

C.1.(d)



C.1.(e)

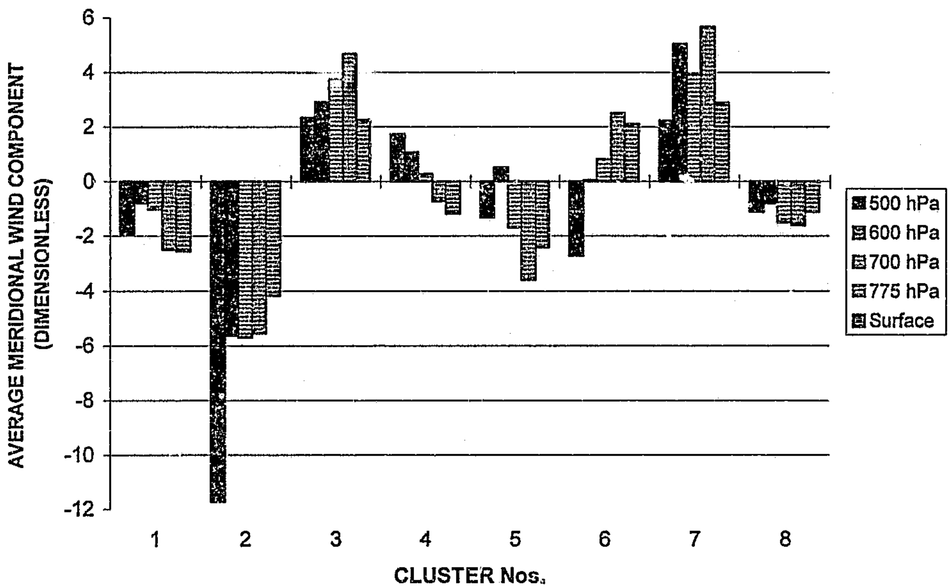
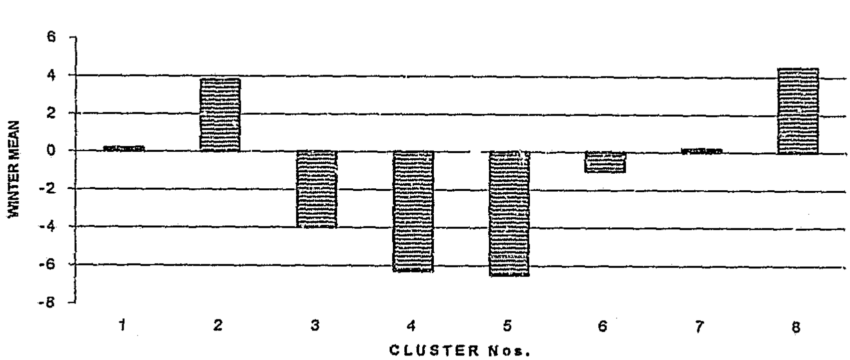
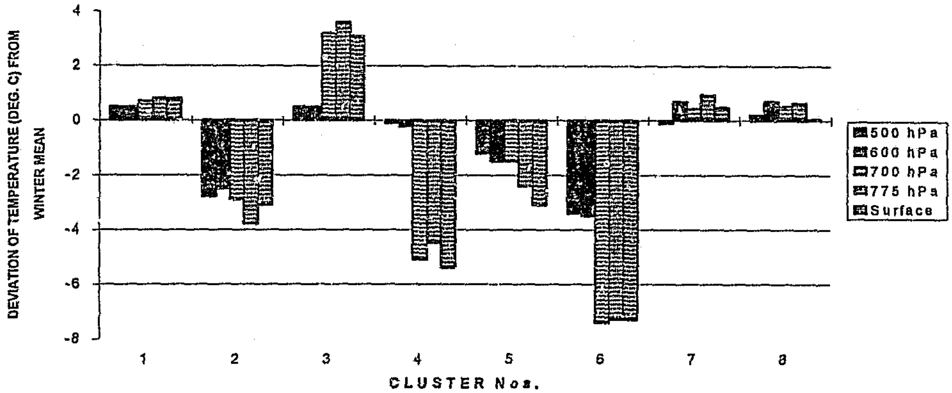


Figure C.1 (d) - (e): Meteorological characteristics of WINTER clusters for IRENE, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.2.(a)



C.2.(b)



C.2.(c)

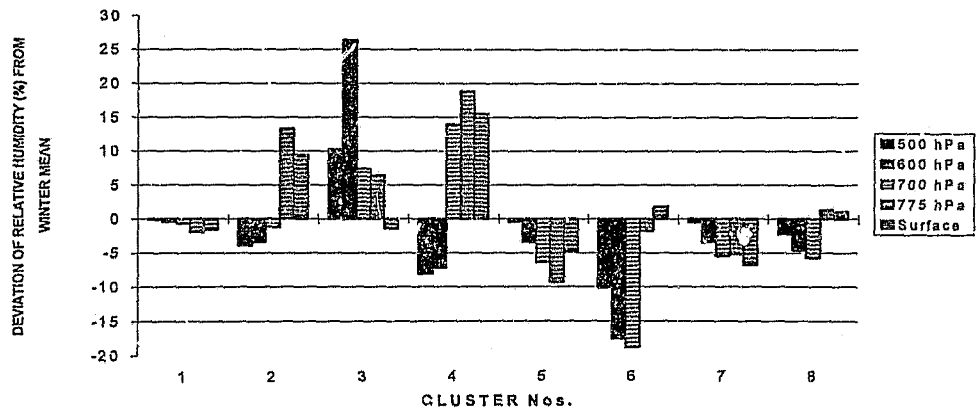
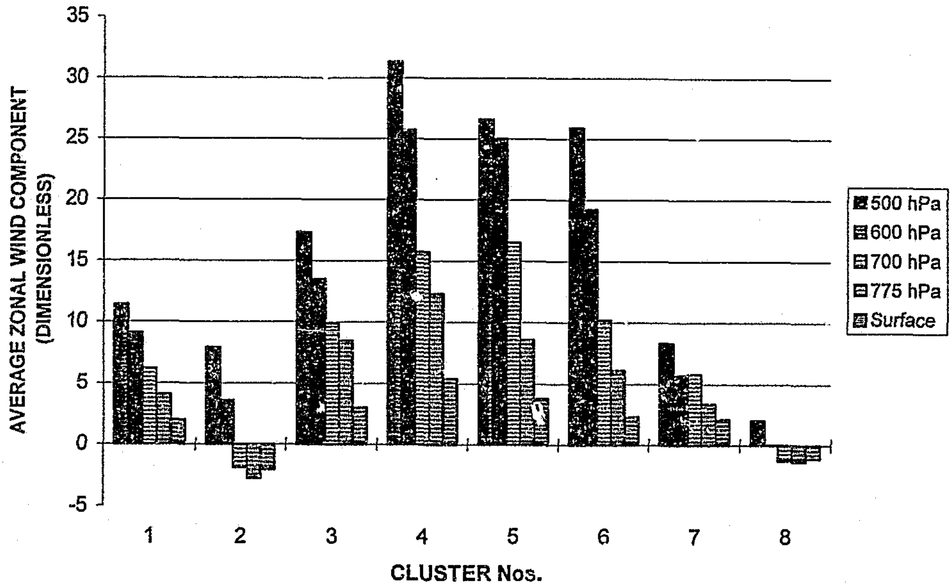


Figure C.2 (a) - (c): Meteorological characteristics of WINTER clusters for BETHLEHEM, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and dew point temperature (c).

C.2.(d)



C.2.(e)

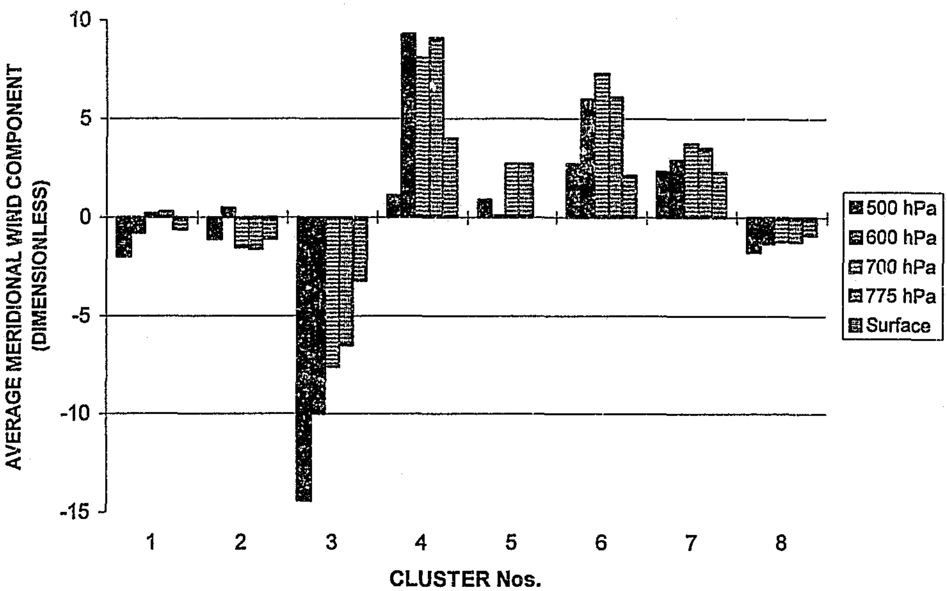
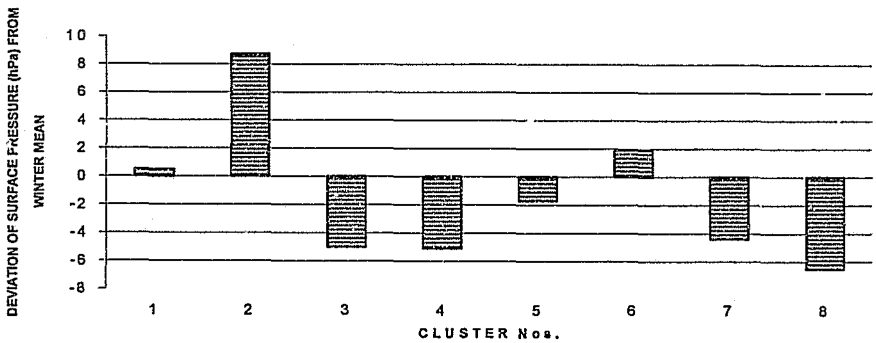
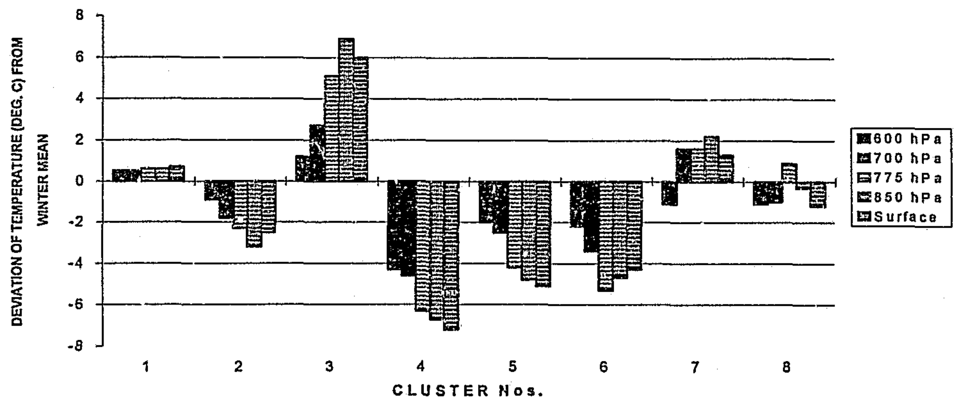


Figure C.2 (d) - (e): Meteorological characteristics of WINTER clusters for BETHLEHEM, including vertical profiles of deviations of average zonal (d) and meridional (e) wind components for each cluster.

C.3.(a)



C.3.(b)



C.3.(c)

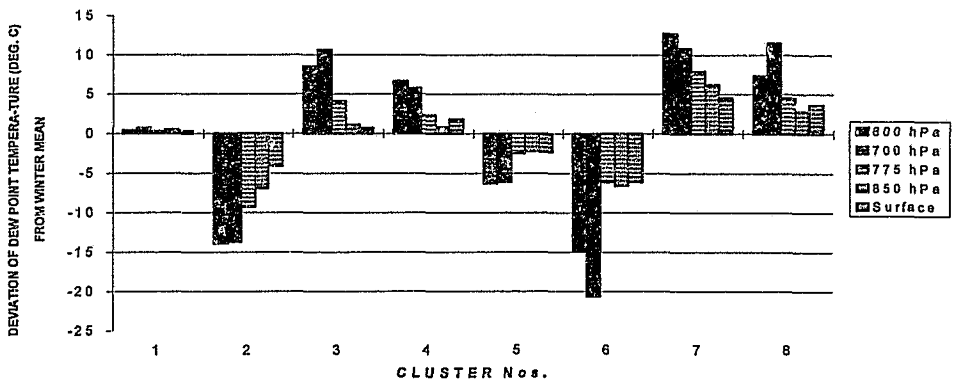
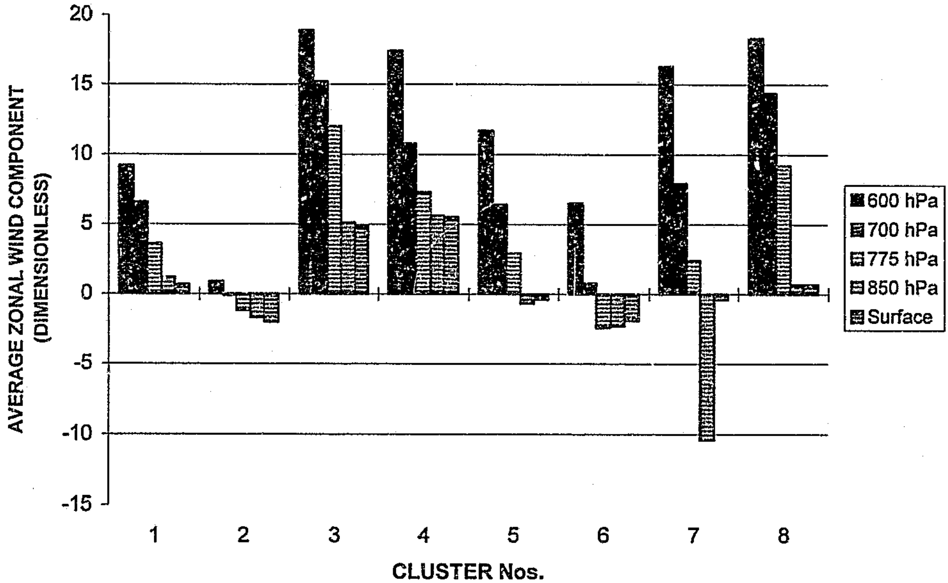


Figure C.3 (a) - (c): Meteorological characteristics of WINTER clusters for BLOEMFONTEIN, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and dew point temperature (c).

C.3.(d)



C.3.(e)

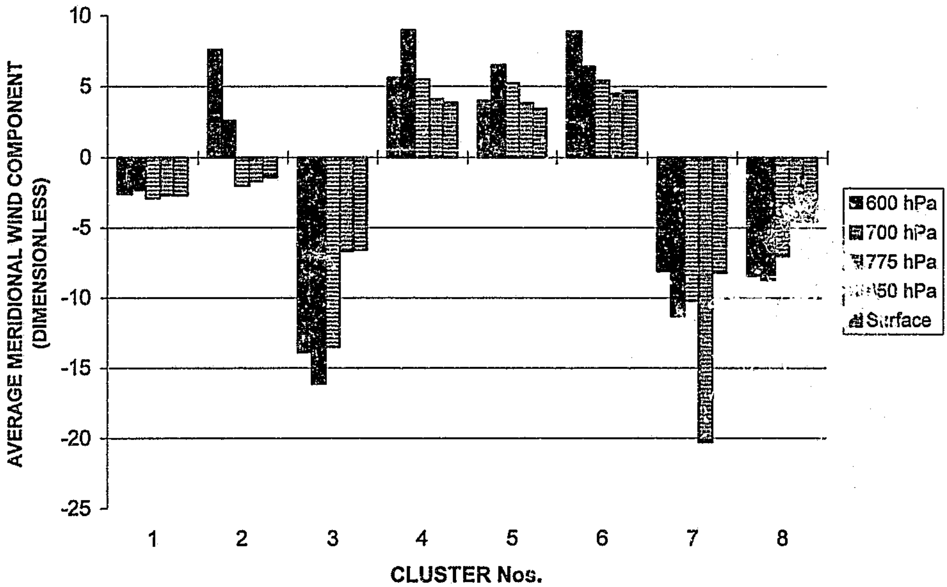
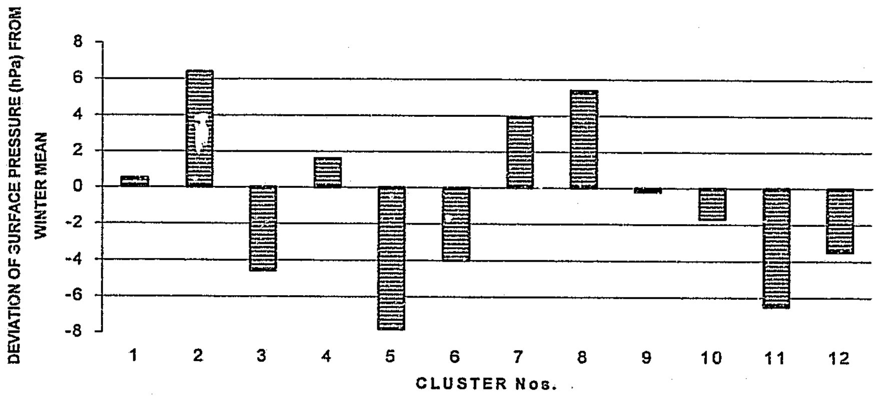
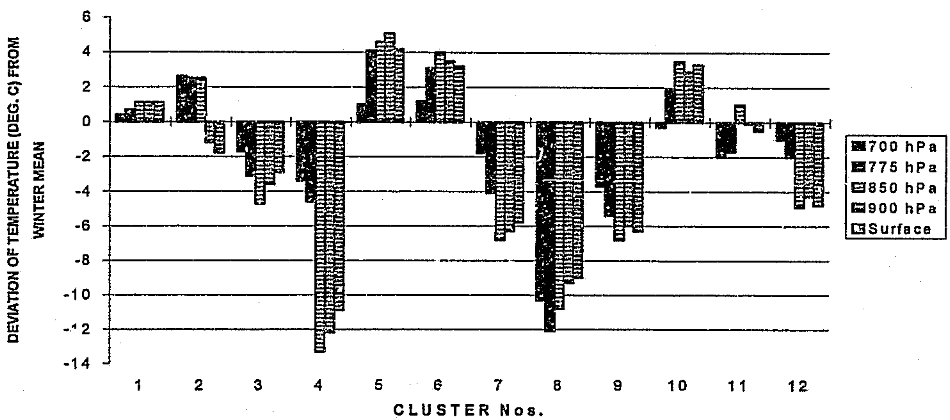


Figure C.3 (d) - (e): Meteorological characteristics of WINTER clusters for BLOEMFONTEIN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.4.(a)



C.4.(b)



C.4.(c)

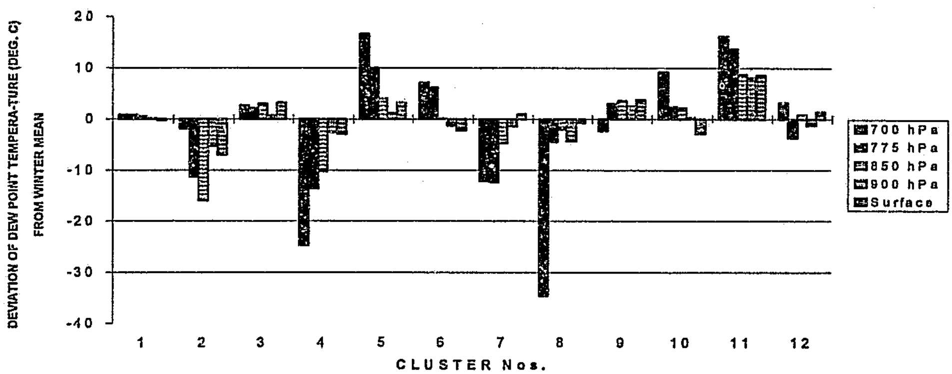
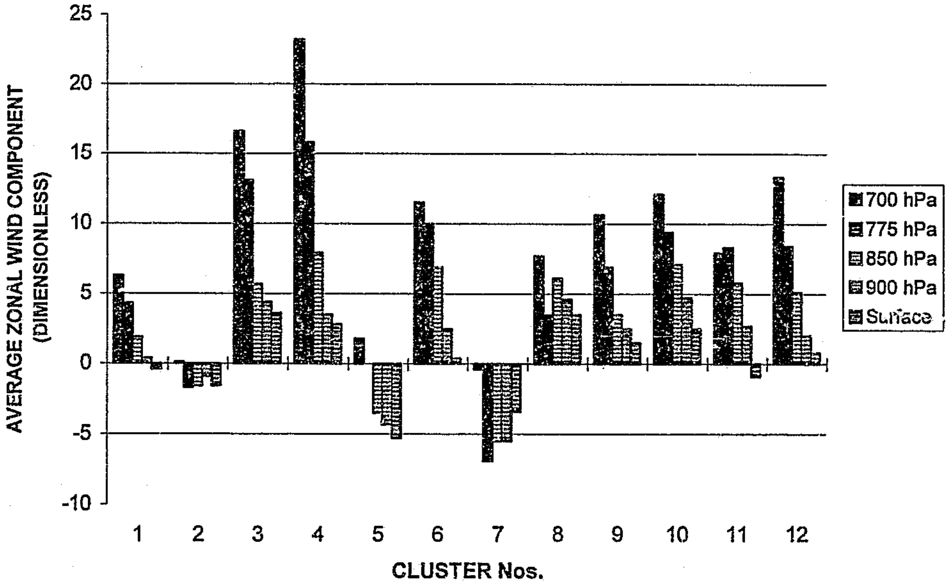


Figure C.4 (a) - (c): Meteorological characteristics of WINTER clusters . . . , including deviations of surface pressure (a), and vertical profiles of . . . of ambient temperature (b) and dew point temperature (c).

C.4.(d)



C.4.(e)

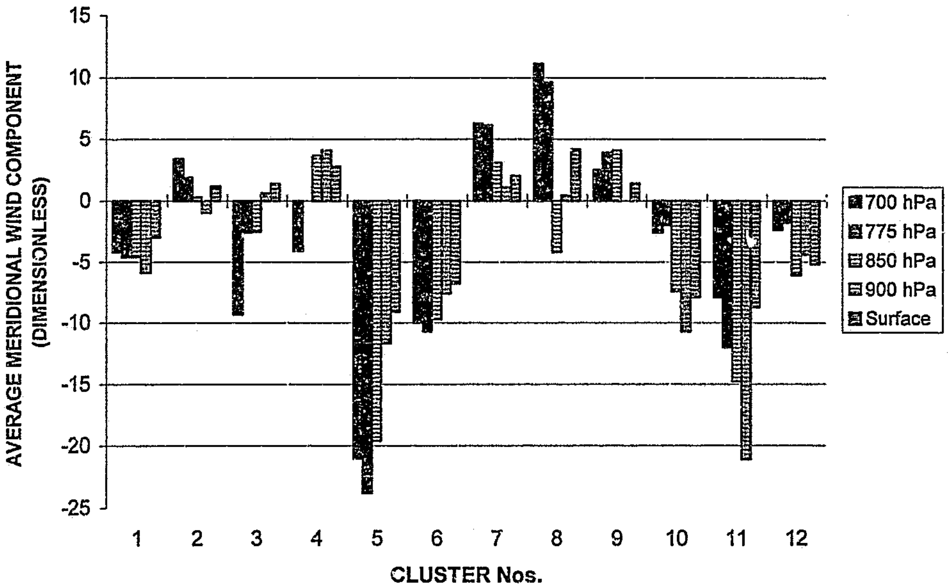
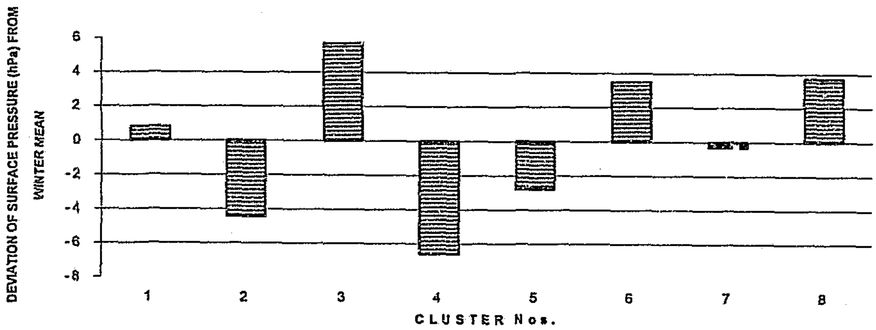
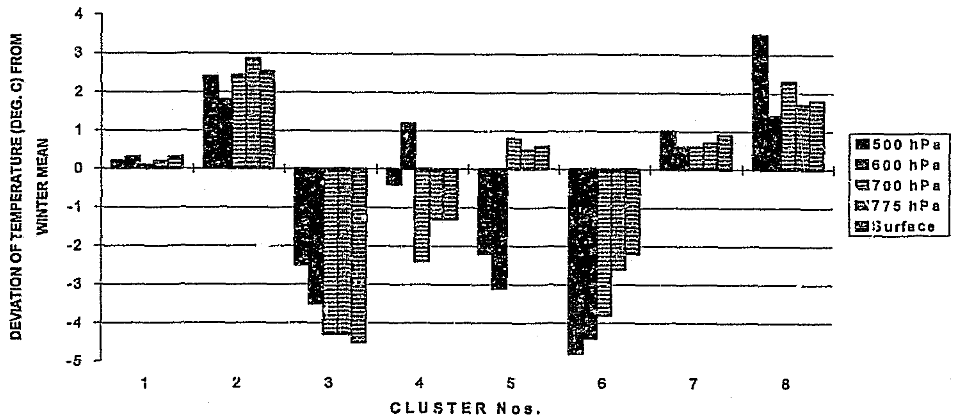


Figure C.4 (d) - (e): Meteorological characteristics of WINTER clusters for UPINGTON, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.5.(a)



C.5.(b)



C.5.(c)

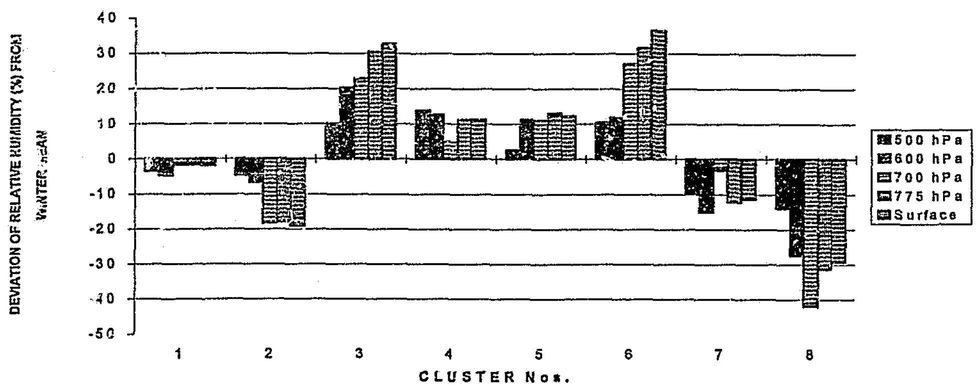
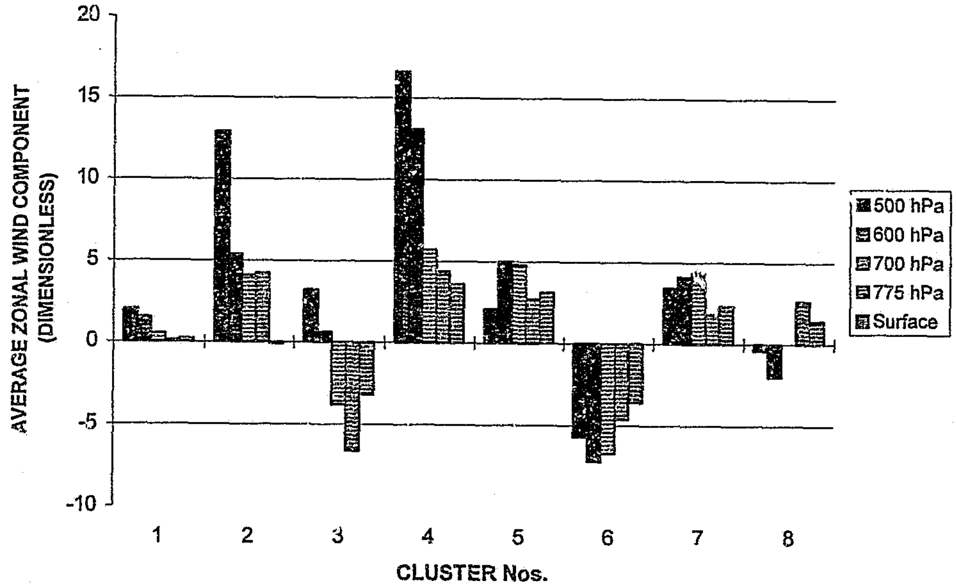


Figure C.5 (a) - (c): Meteorological characteristics of WINTER clusters for PIETERSBURG, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.5.(d)



C.5.(e)

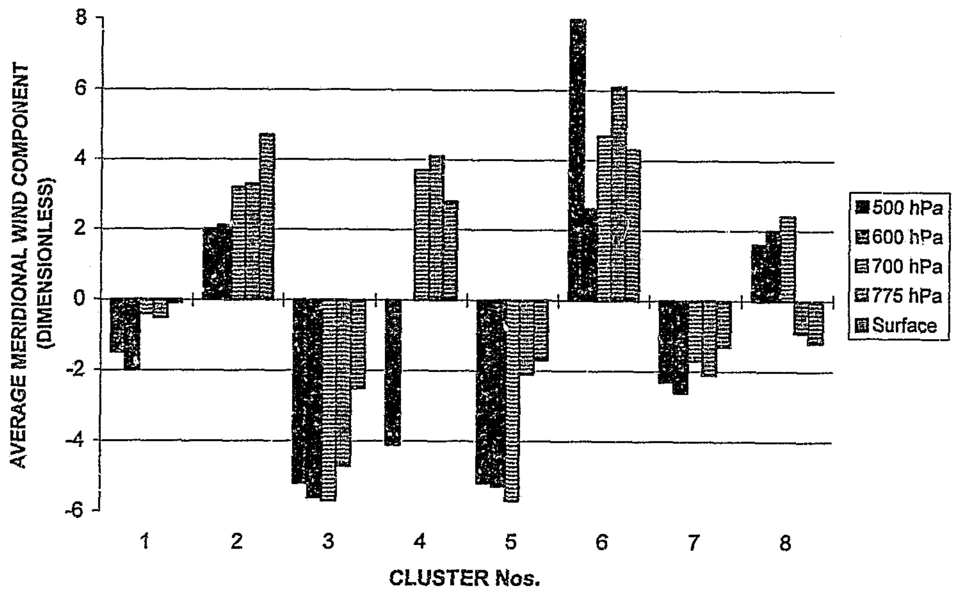


Figure C.5 (d) - (e): Meteorological characteristics of WINTER clusters for PIETERSBURG, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.6.(a)

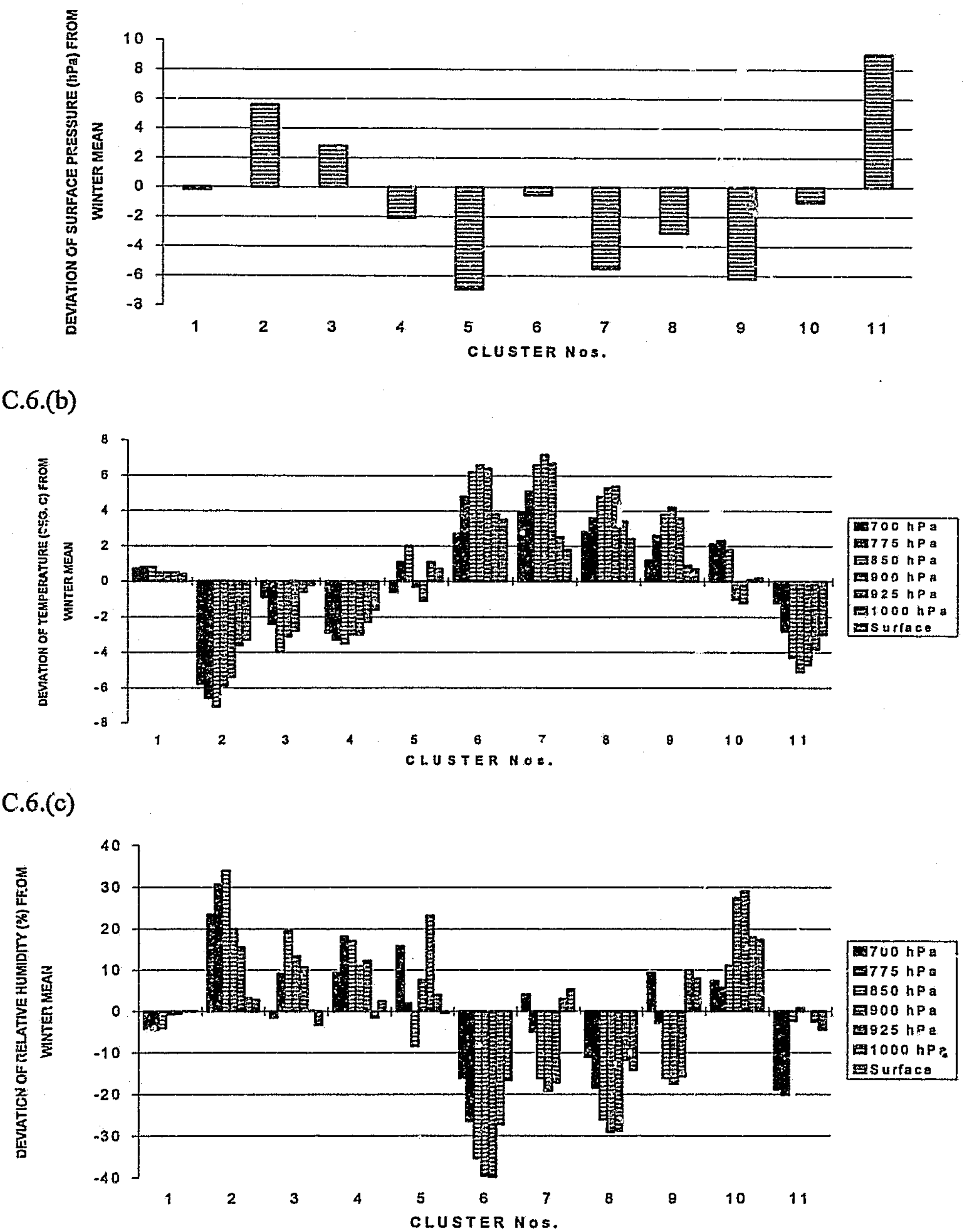
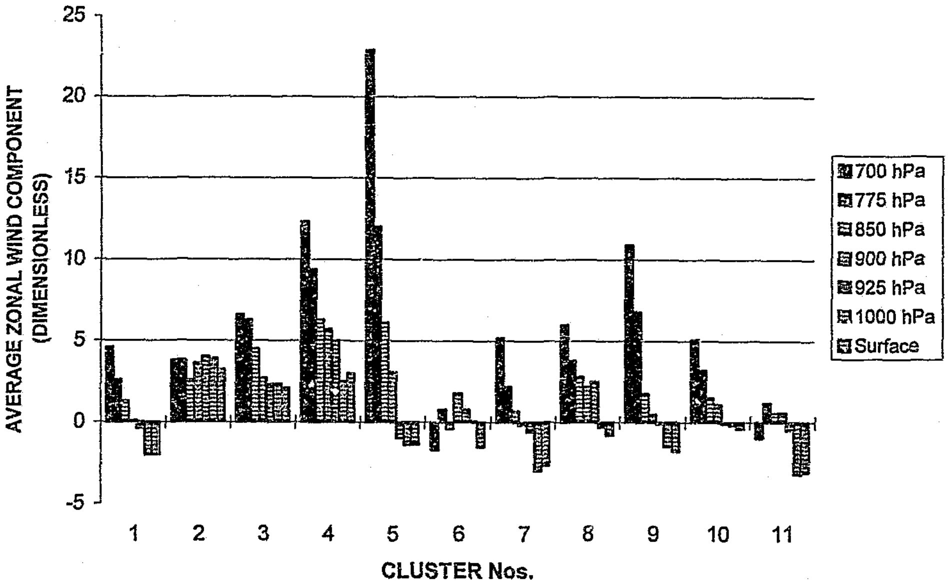


Figure C.6 (a) - (c): Meteorological characteristics of WINTER clusters for DURBAN, including deviations of surface pressure (a) and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.6.(d)



C.6.(e)

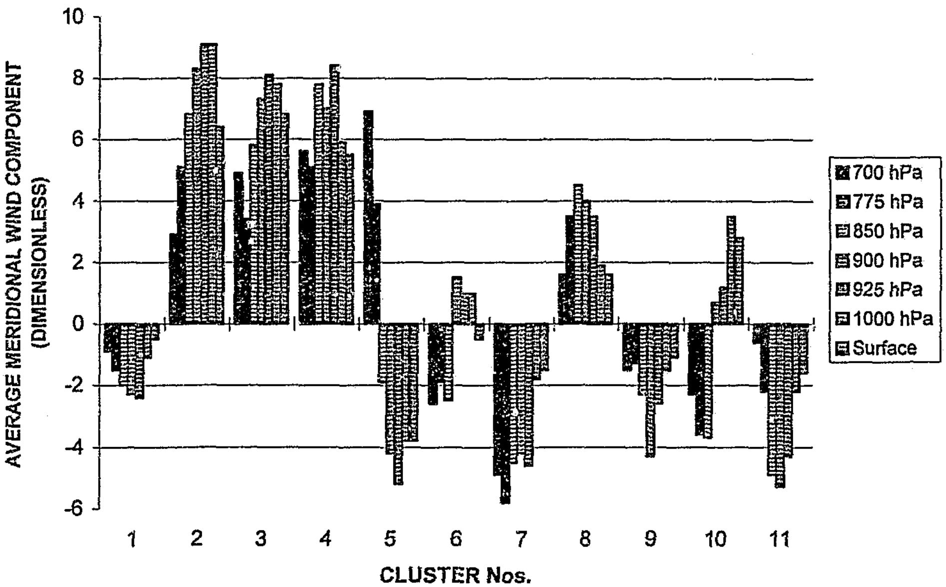
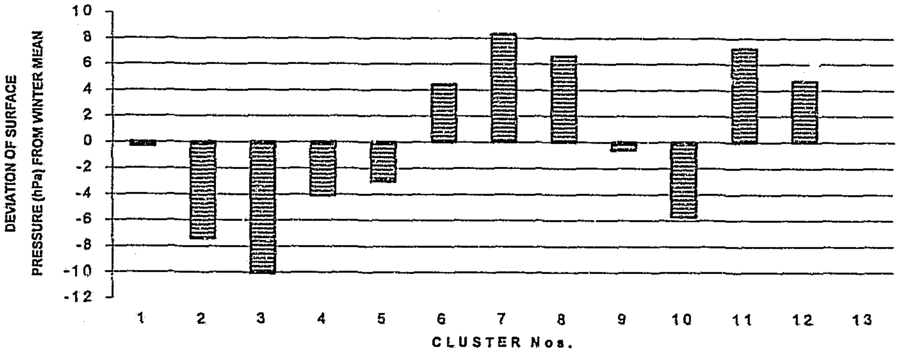
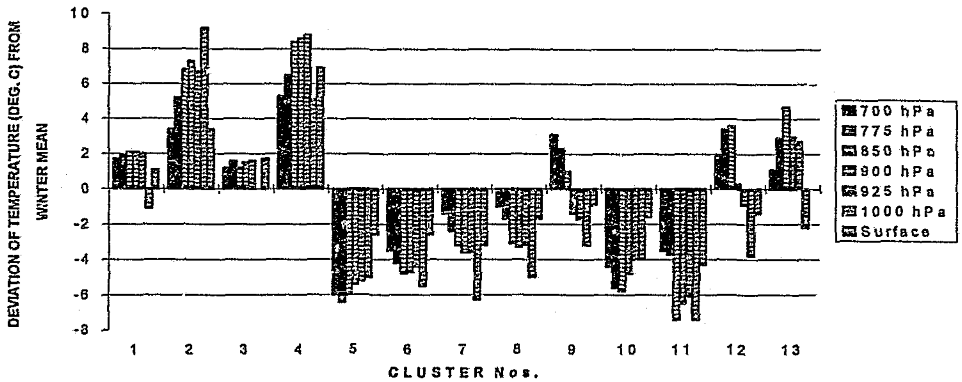


Figure C.6 (d) -(e): Meteorological characteristics of WINTER clusters for DURBAN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.7.(a)



C.7.(b)



C.7.(c)

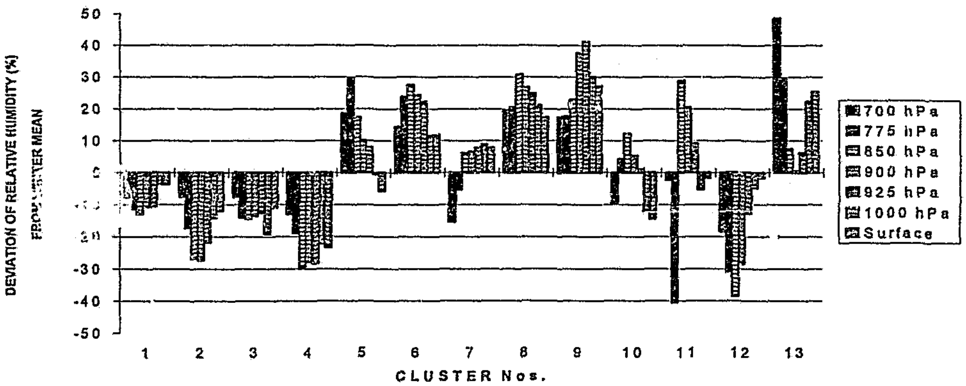
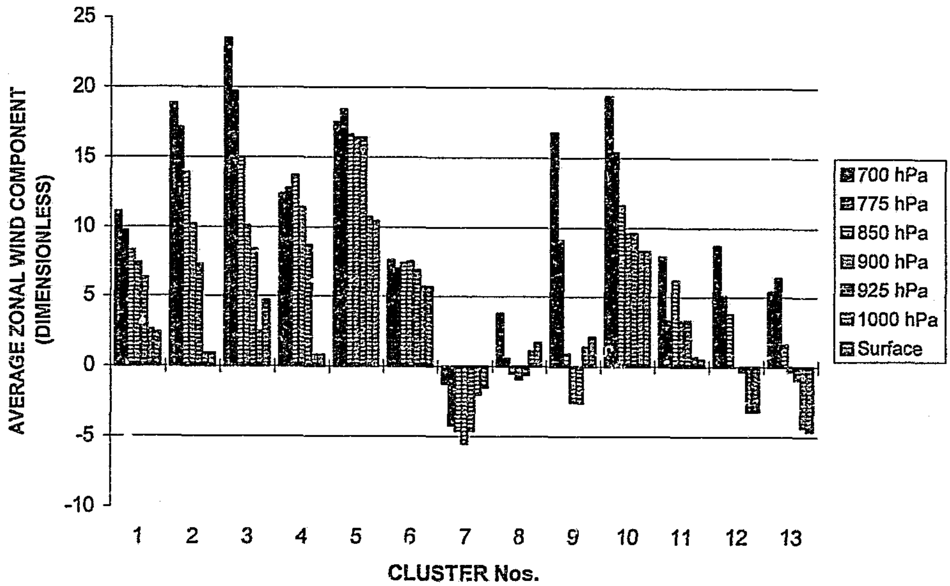


Figure C.7 (a) - (c): Meteorological characteristics of WINTER clusters for PORT ELIZABETH, including deviations of surface pressure (a) and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.7.(d)



C.7.(e)

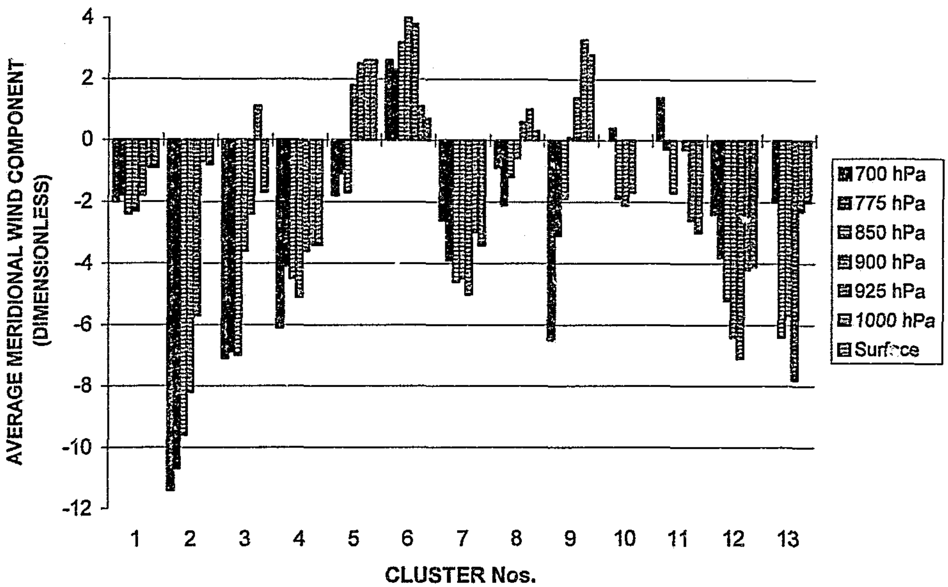
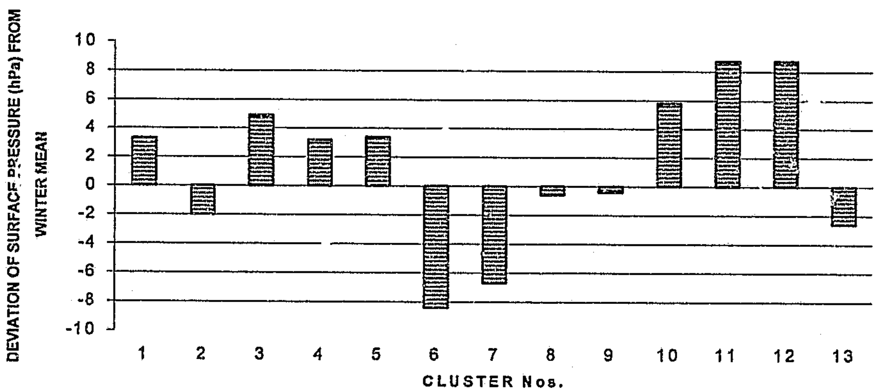
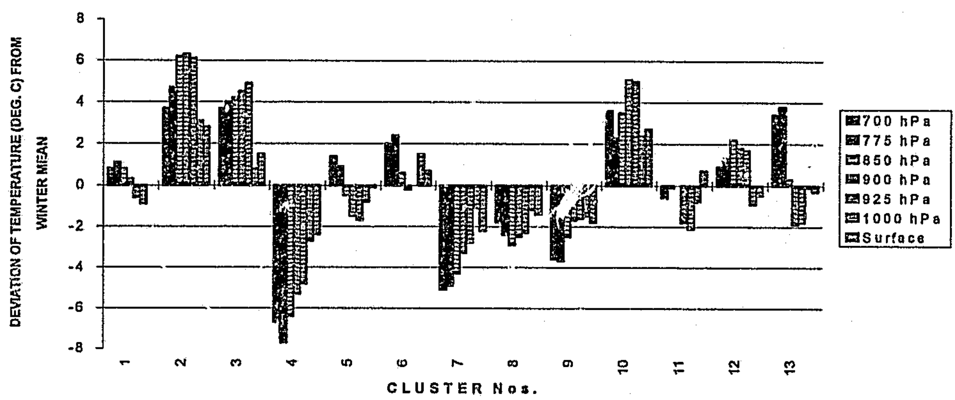


Figure C.7 (d) -(e): Meteorological characteristics of WINTER clusters for PORT ELIZABETH, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.8.(a)



C.8.(b)



C.8.(c)

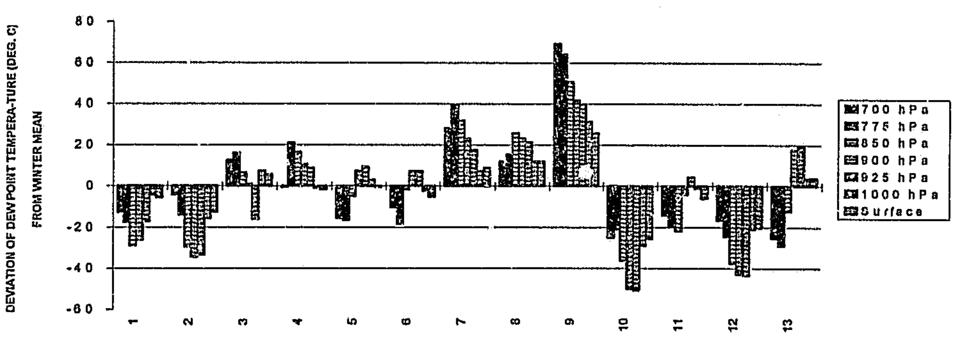
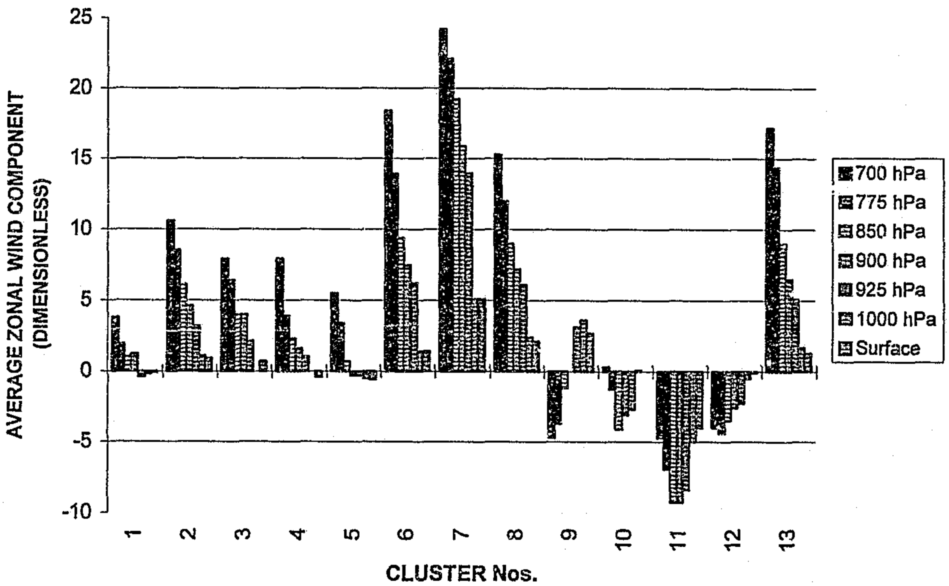


Figure C.8 (a) - (c): Meteorological characteristics of WINTER clusters for CAPE TOWN, including deviations of surface pressure (a) and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.8.(d)



C.8.(e)

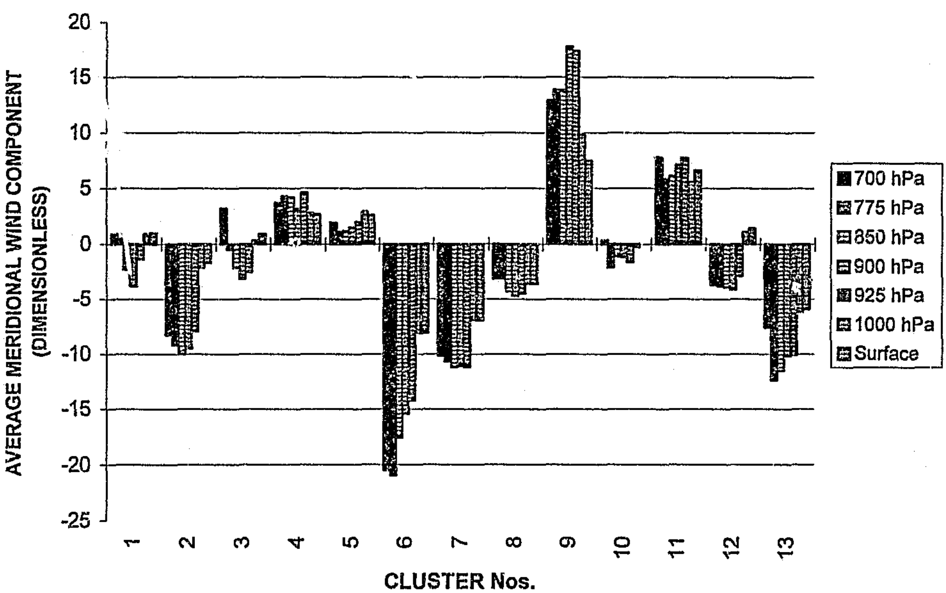
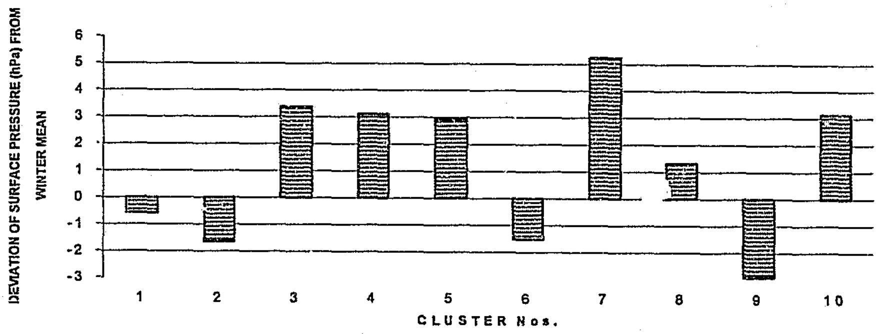
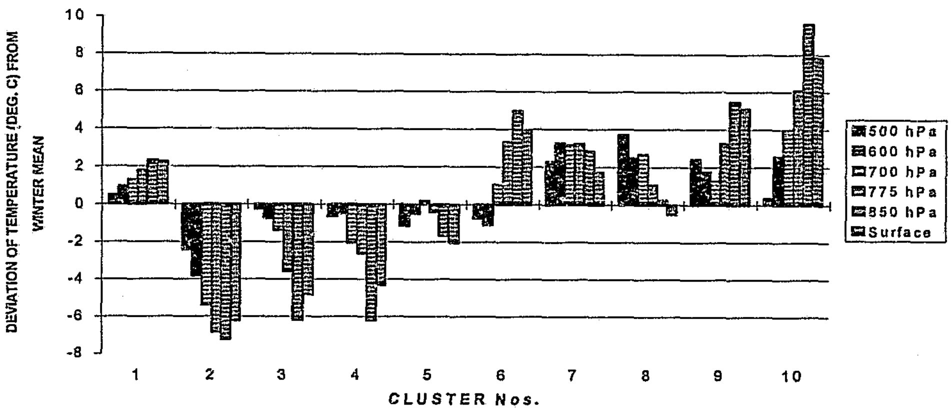


Figure C.8 (d) -(e): Meteorological characteristics of WINTER clusters for CAPE TOWN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.9.(a)



C.9.(b)



C.9.(c)

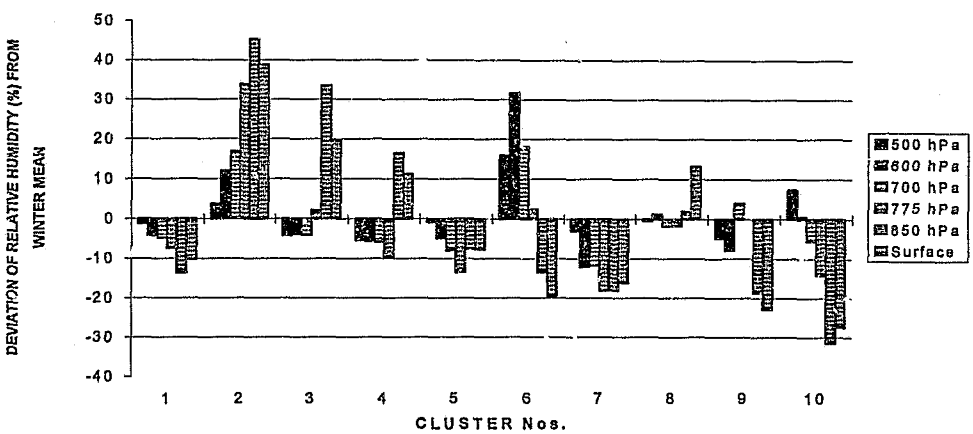
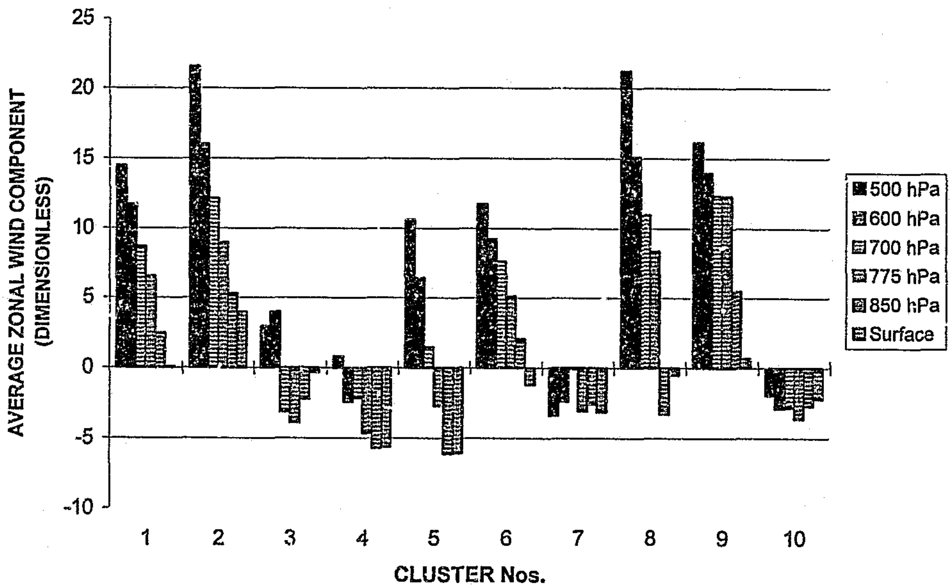


Figure C.9 (a) - (c): Meteorological characteristics of WINTER clusters for SPRINGBOK, including deviations of surface pressure (a) and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.9.(d)



C.9.(e)

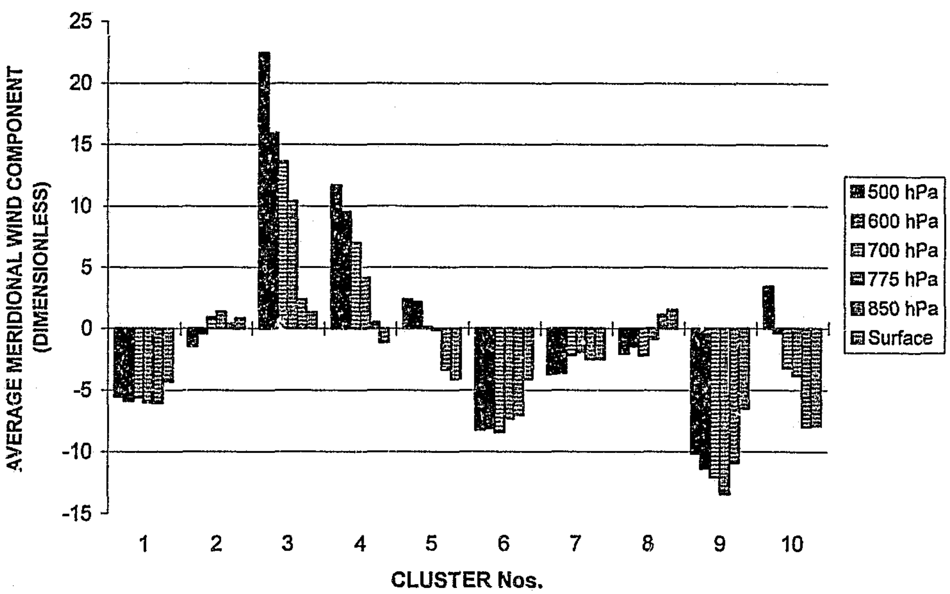
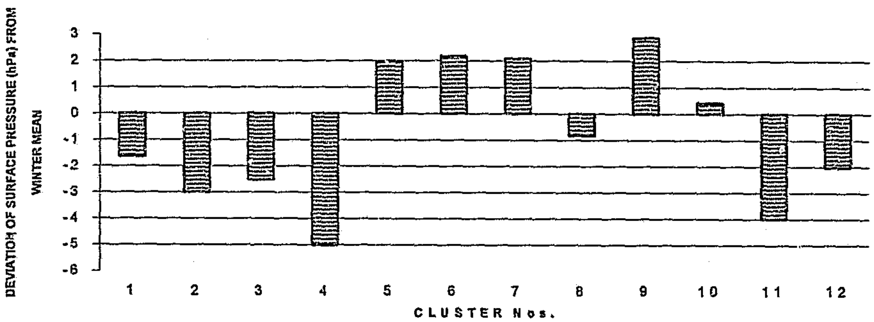
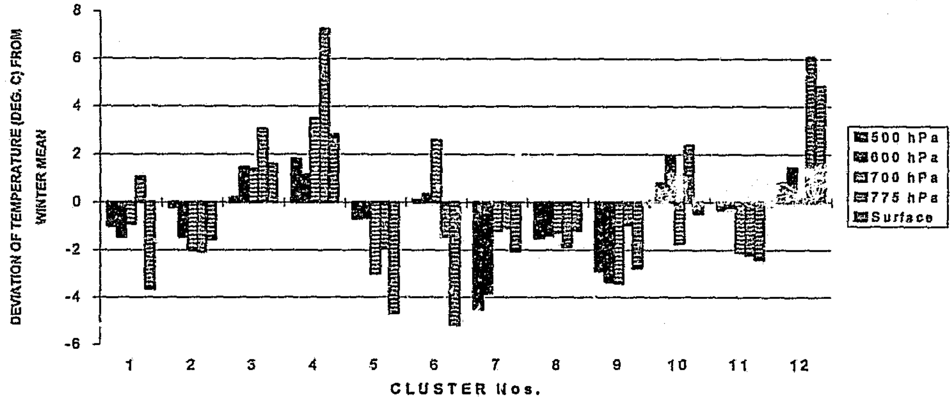


Figure C.9 (d) -(e): Meteorological characteristics of WINTER clusters for SPRINGBOK, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.10.(a)



C.10.(b)



C.10.(c)

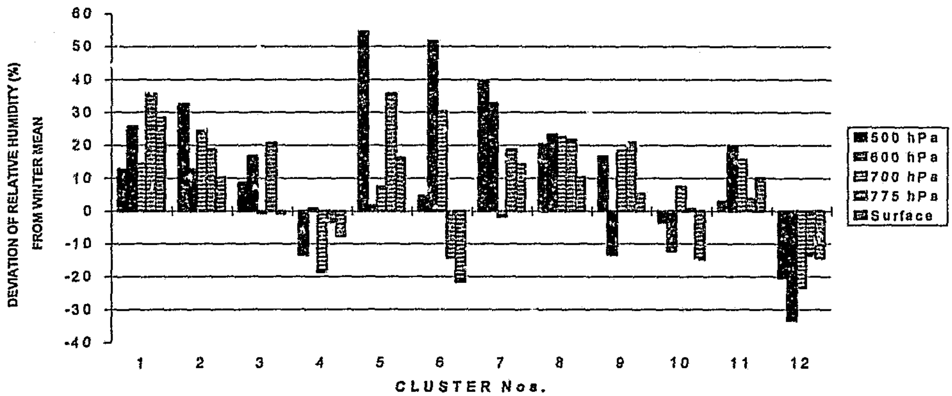
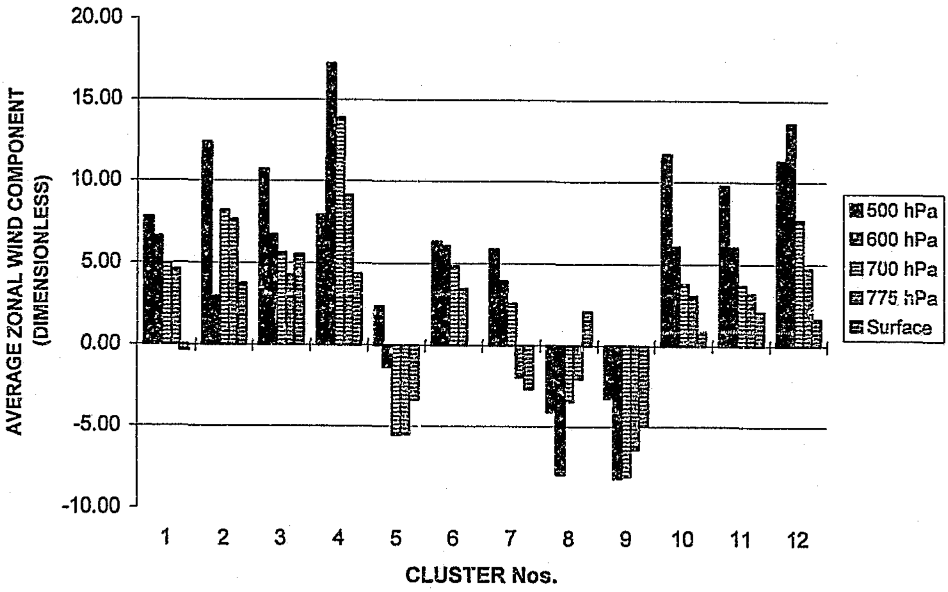


Figure C.10 (a) - (c): Meteorological characteristics of SUMMER clusters for IRENE, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.10.(d)



C.10.(e)

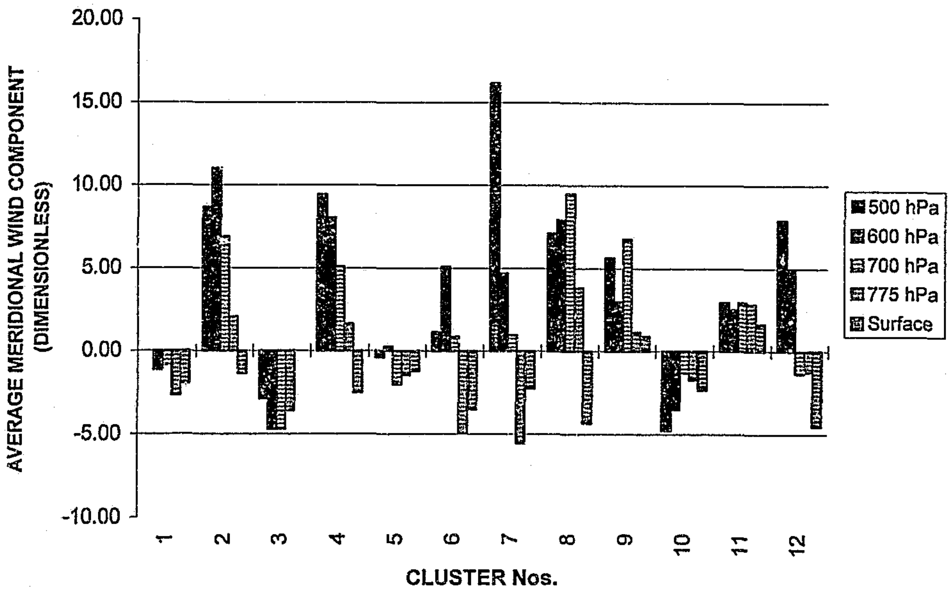
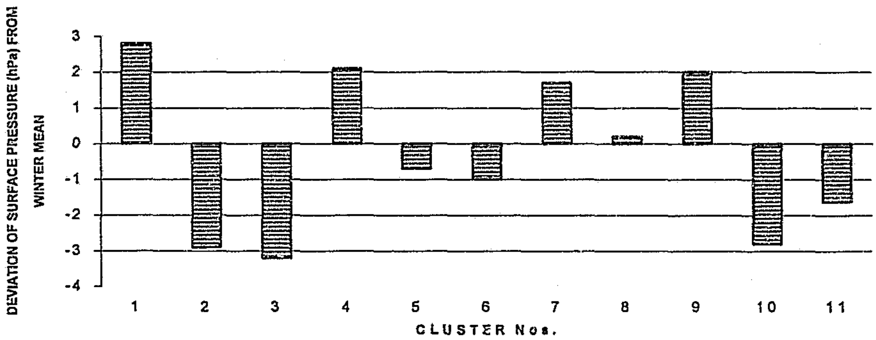
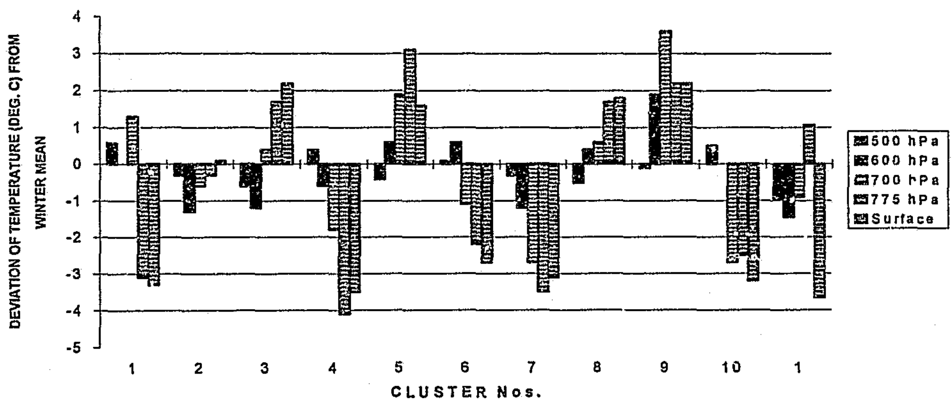


Figure C.10 (d) - (e): Meteorological characteristics of SUMMER clusters for IRENE, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.11.(a)



C.11.(b)



C.11.(c)

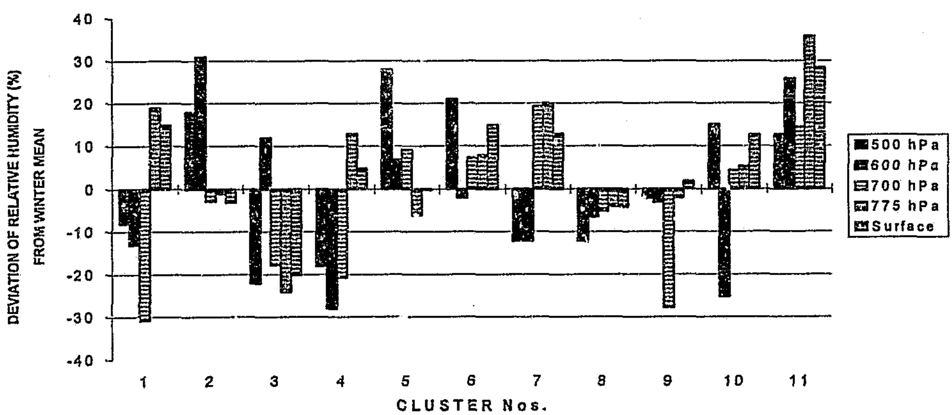
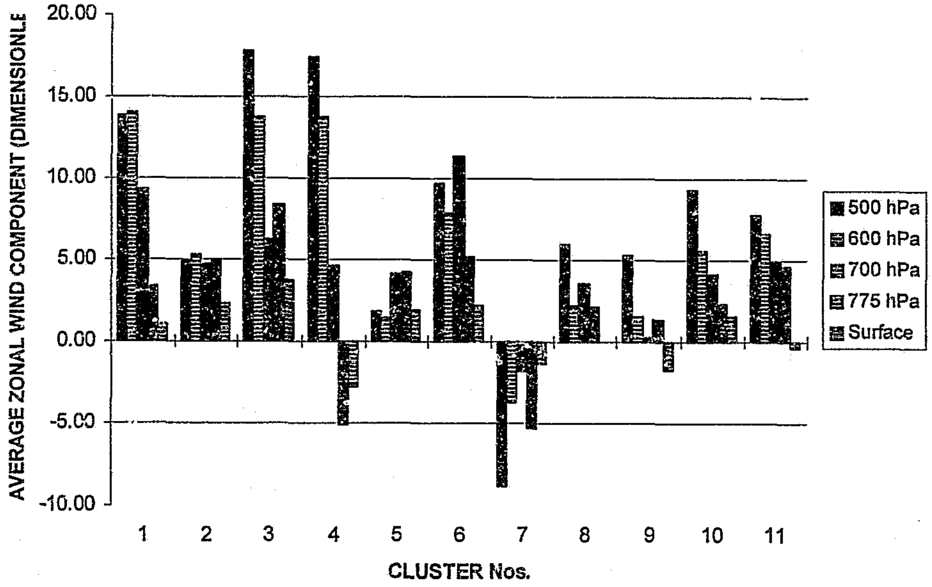


Figure C.11 (a) - (c): Meteorological characteristics of SUMMER clusters for BETHLEHEM, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.11.(d)



C.11.(e)

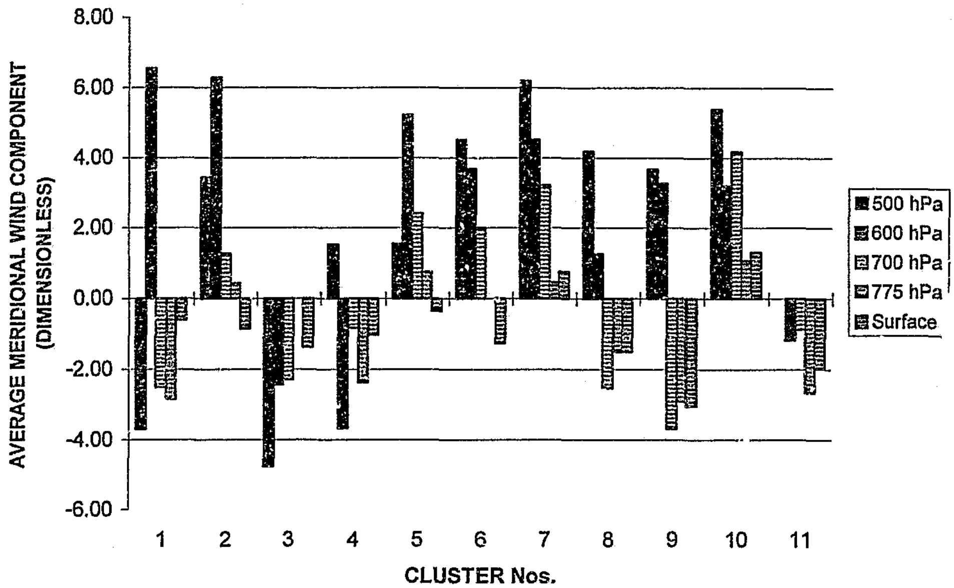
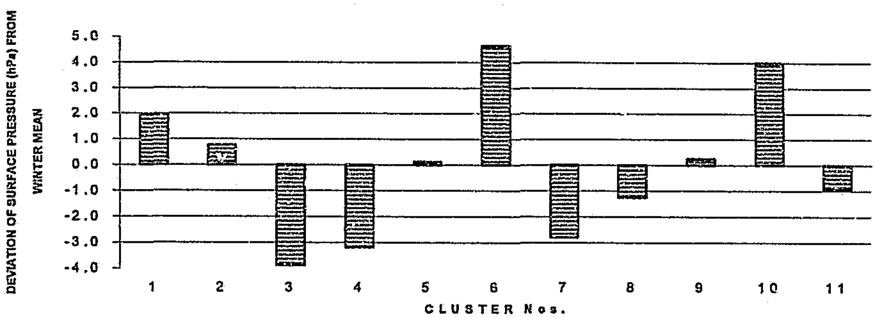
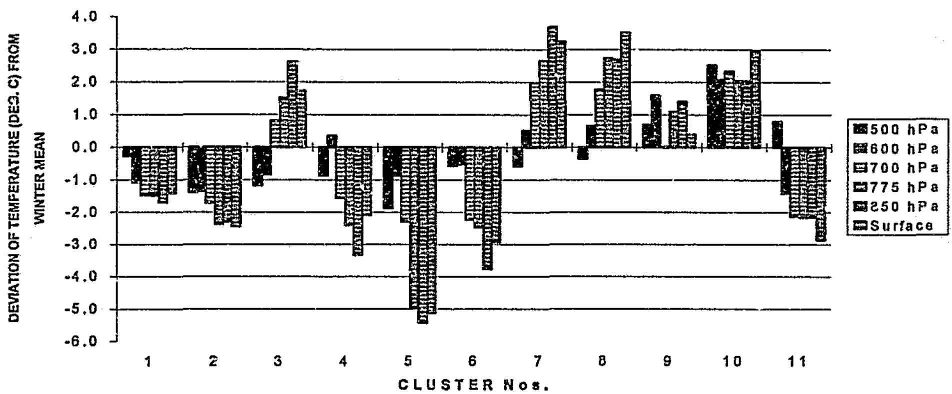


Figure C.11 (d) - (e): Meteorological characteristics of SUMMER clusters for BETHLEHEM, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.12.(a)



C.12.(b)



C.12(c)

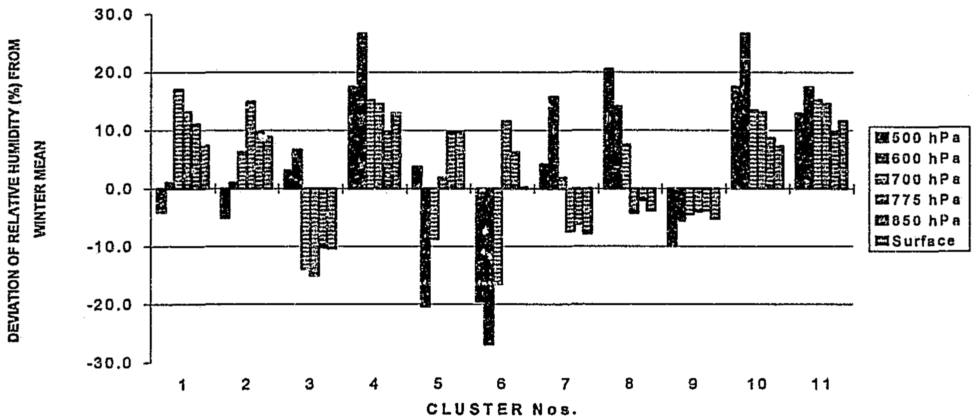
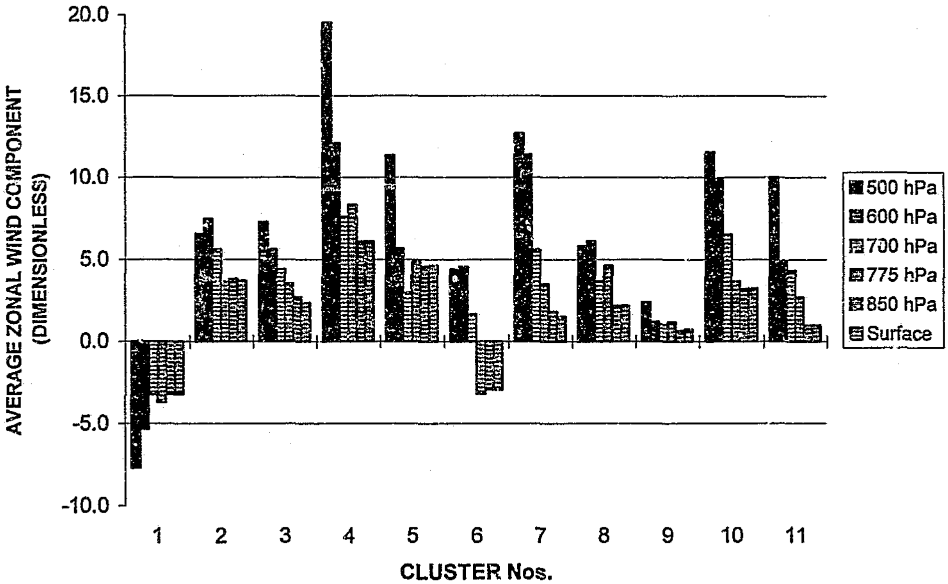


Figure C.12 (a) - (c): Meteorological characteristics of SUMMER clusters for BLOEMFONTEIN, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.12.(d)



C.12.(e)

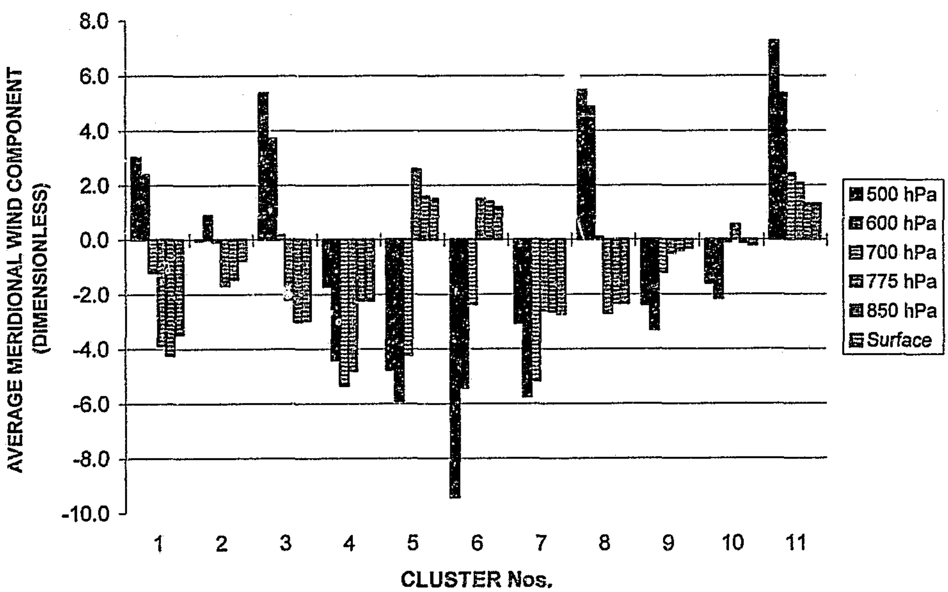
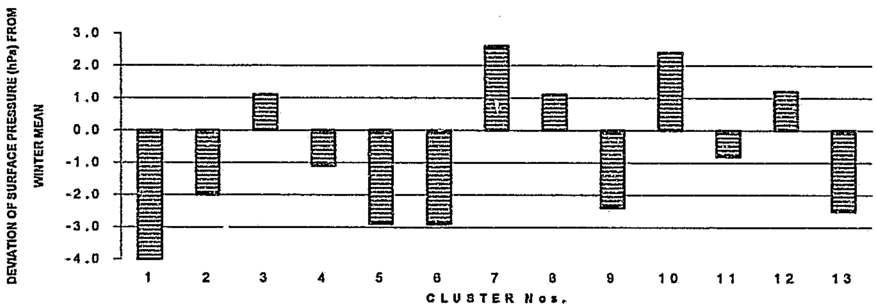
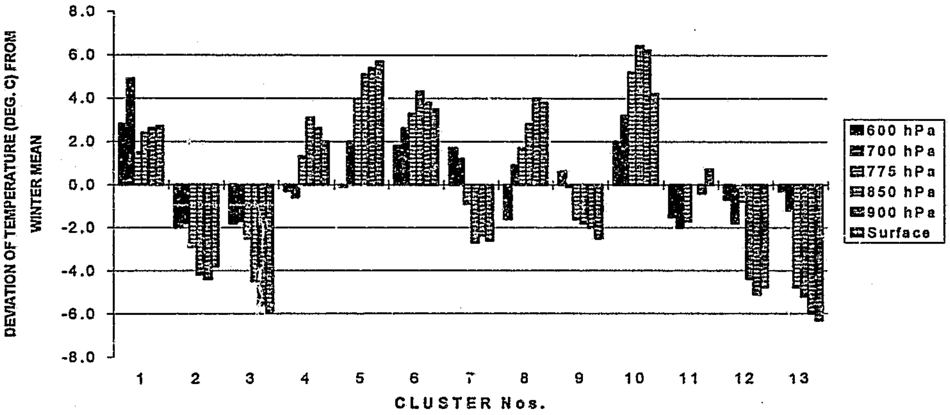


Figure C.12 (d) - (e): Meteorological characteristics of SUMMER clusters for BLOEMFONTEIN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.13.(a)



C.13.(b)



C.13.(c)

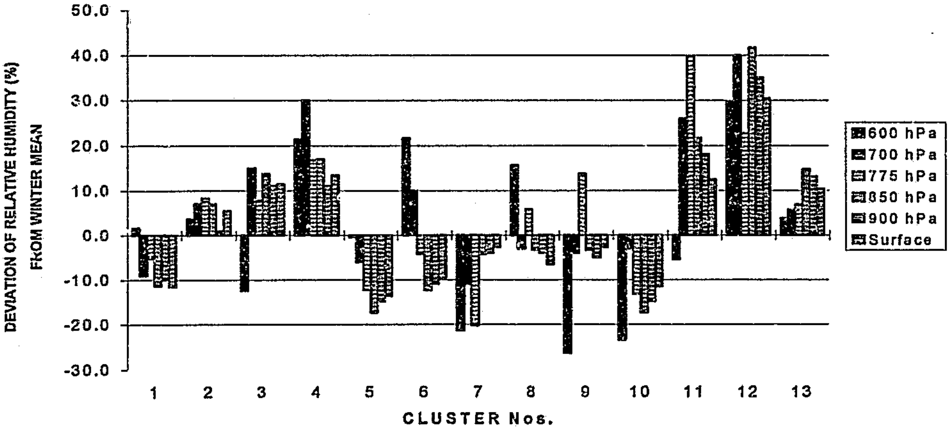
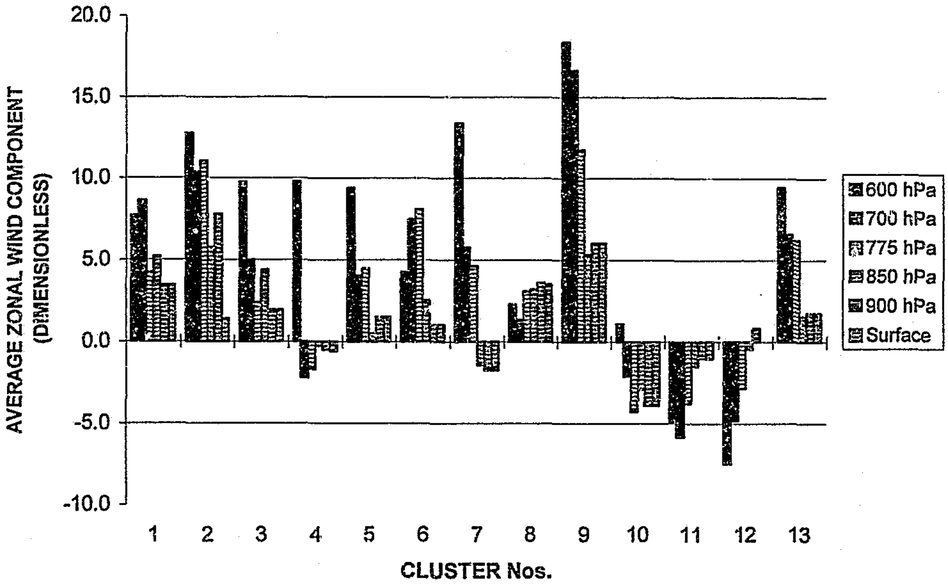


Figure C.13 (a) - (c): Meteorological characteristics of SUMMER clusters for UPINGTON, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.13.(d)



C.13.(e)

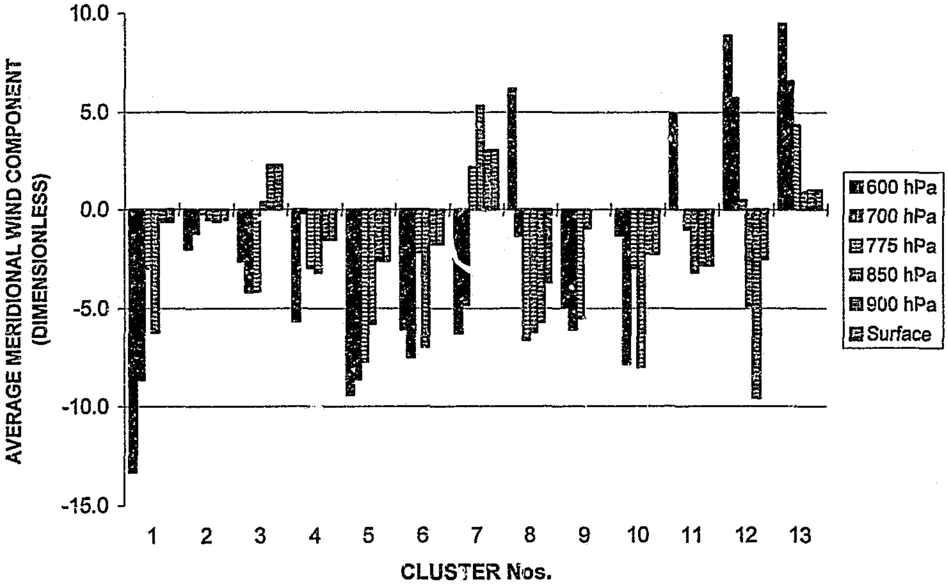
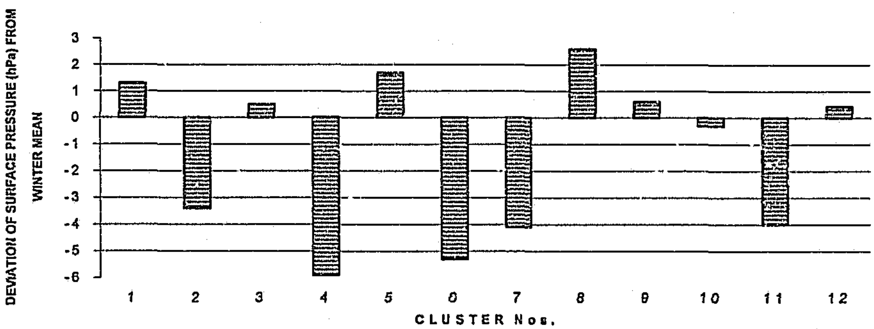
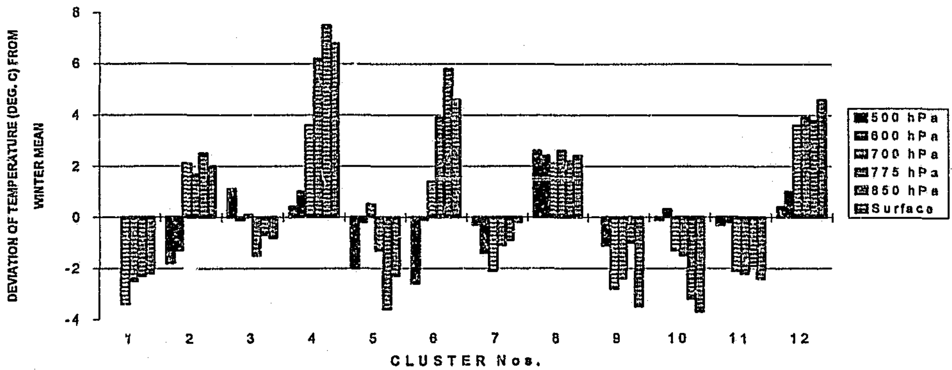


Figure C.13 (d) - (e): Meteorological characteristics of SUMMER clusters for UPINGTON, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.14.(a)



C.14.(b)



C.14.(c)

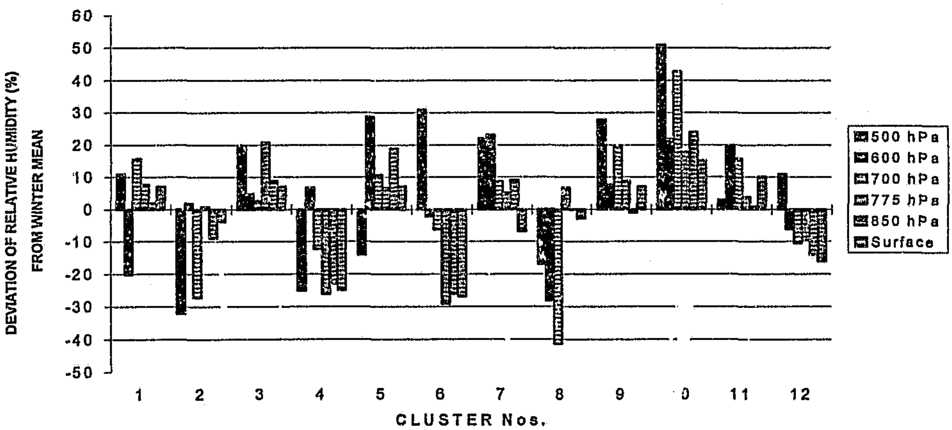
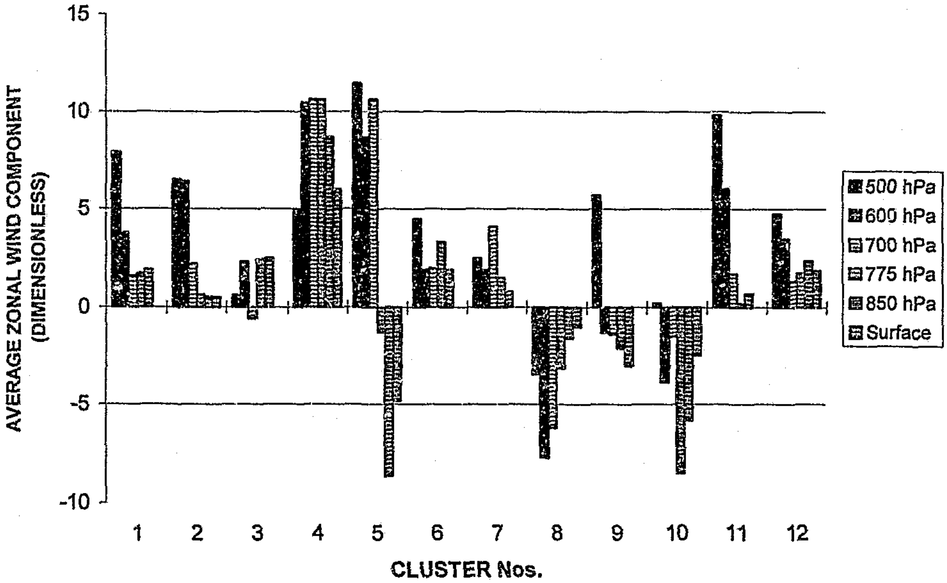


Figure C.14 (a) - (c): Meteorological characteristics of SUMMER clusters for PIETERSBURG, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c).

C.14.(d)



C.14.(e)

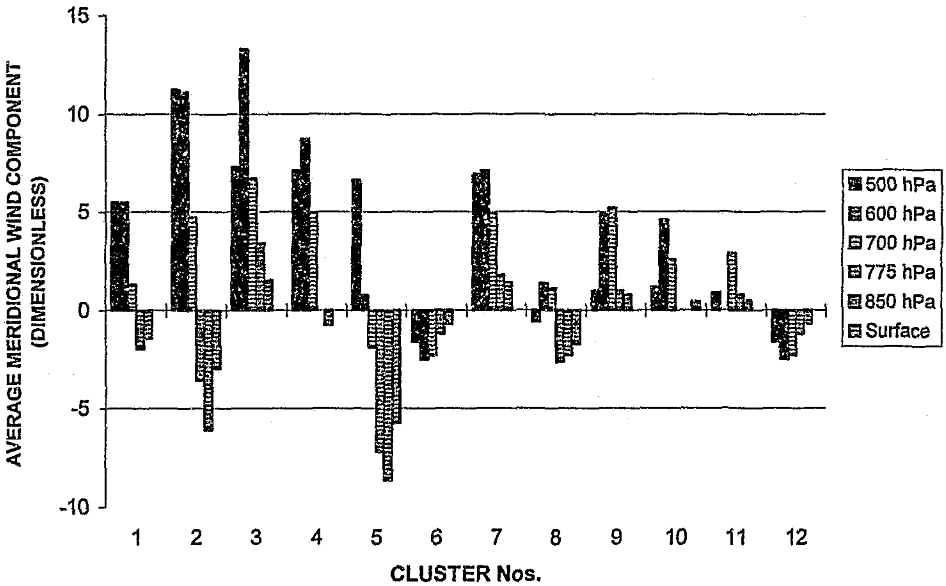
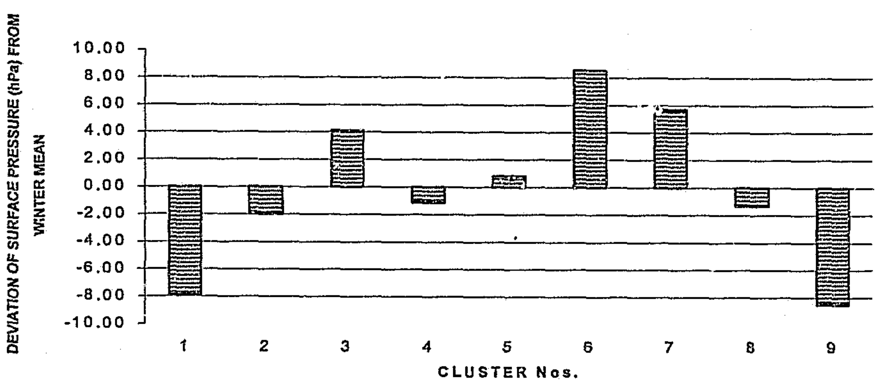
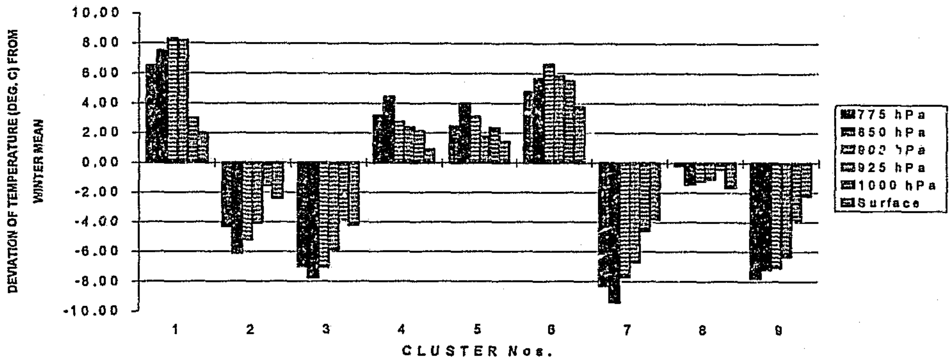


Figure C.14 (d) - (e): Meteorological characteristics of SUMMER clusters for PIETERSBURG, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

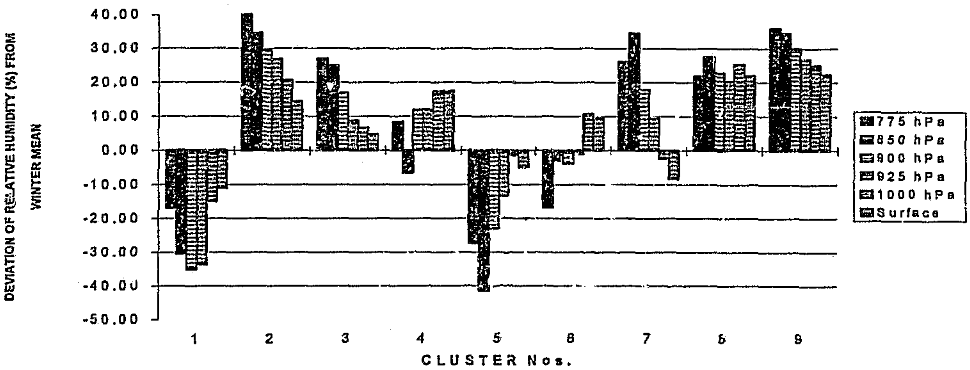
C.15.(a)



C.15.(b)

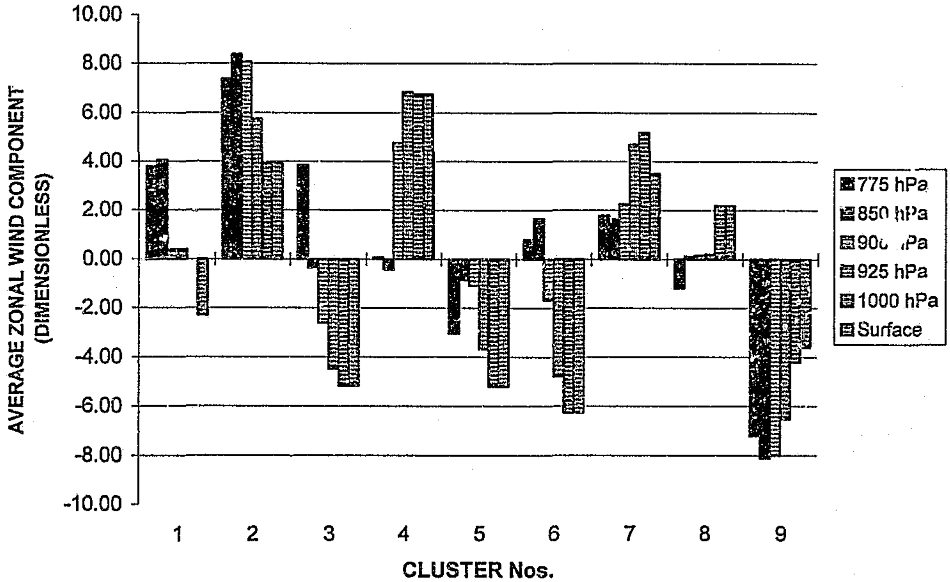


C.15.(c)



ᵂi. ·.'e C.15 (a) - (c): Meteorological characteristics of SUMMER clusters for DURBAN, .ncludin. ·leviations of surface pressure (a), and vertical profiles of deviations of ambie..t :. :perature (b) and relative humidity (c) from seasonal averages.

C.15.(d)



C.15.(e)

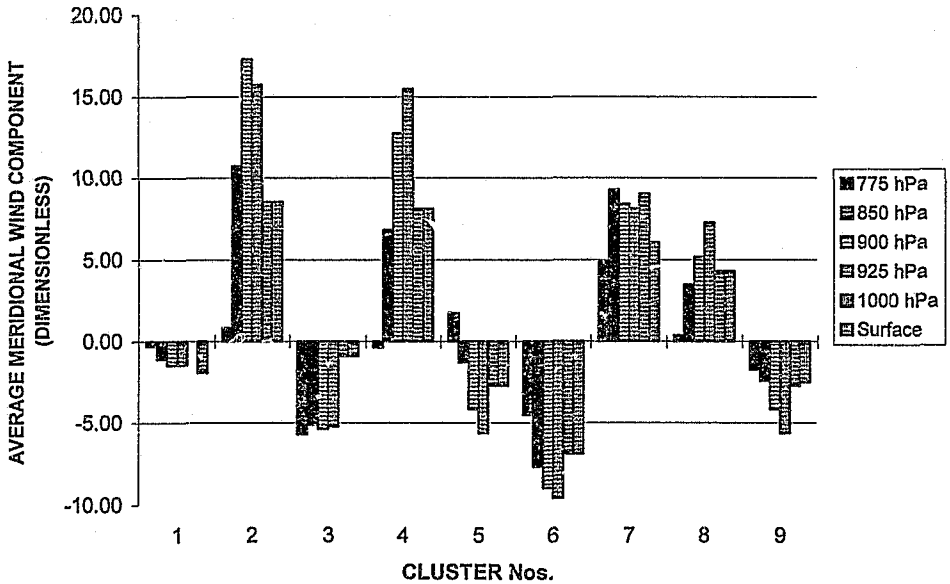
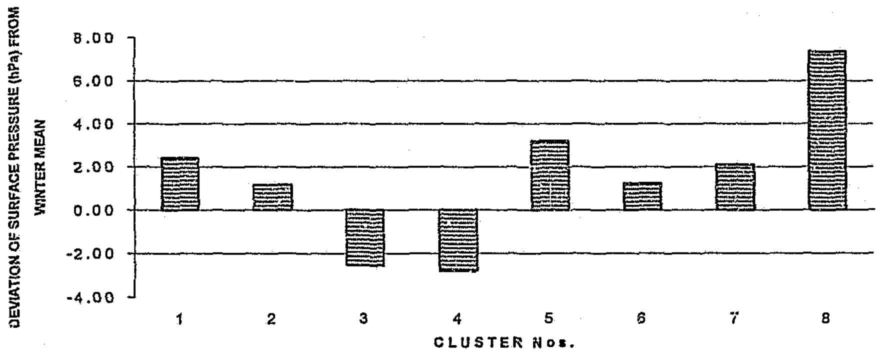
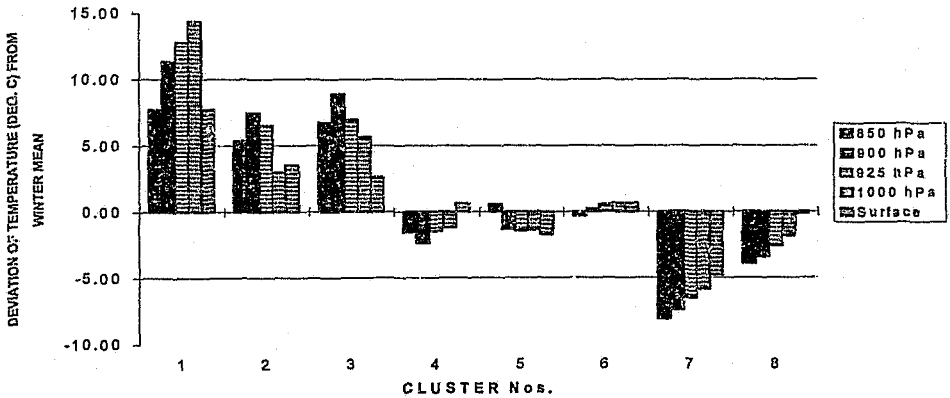


Figure C.15 (d) - (e): Meteorological characteristics of SUMMER clusters for DURBAN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.16.(a)



C.16.(b)



C.16.(c)

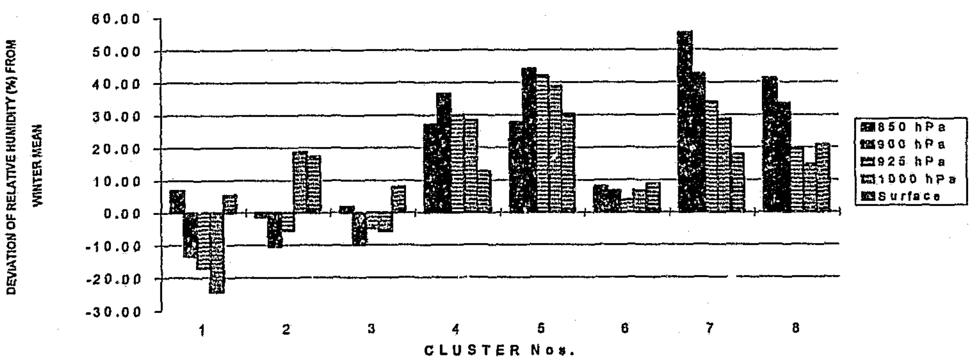
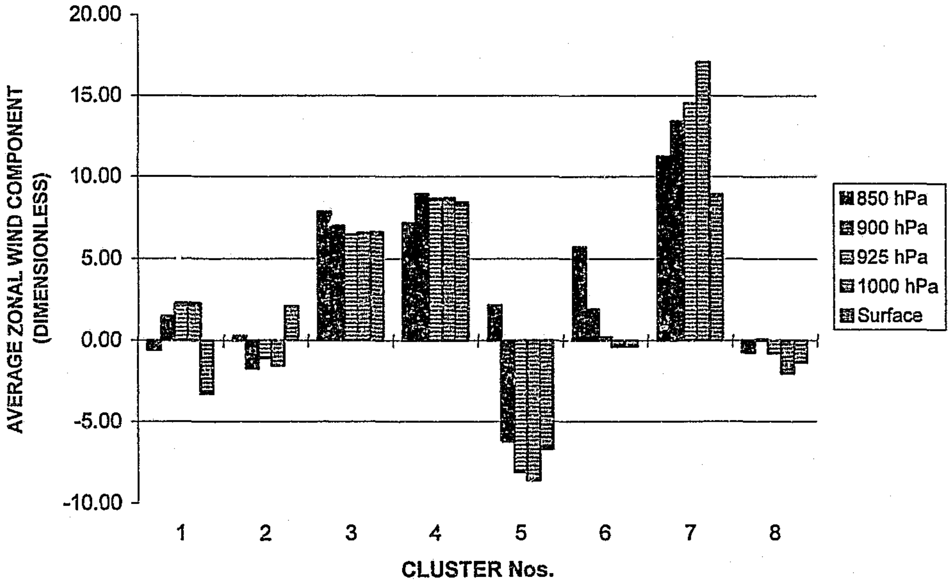


Figure C.16 (a) - (c): Meteorological characteristics of SUMMER clusters for PORT ELIZABETH, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.16.(d)



C.16.(e)

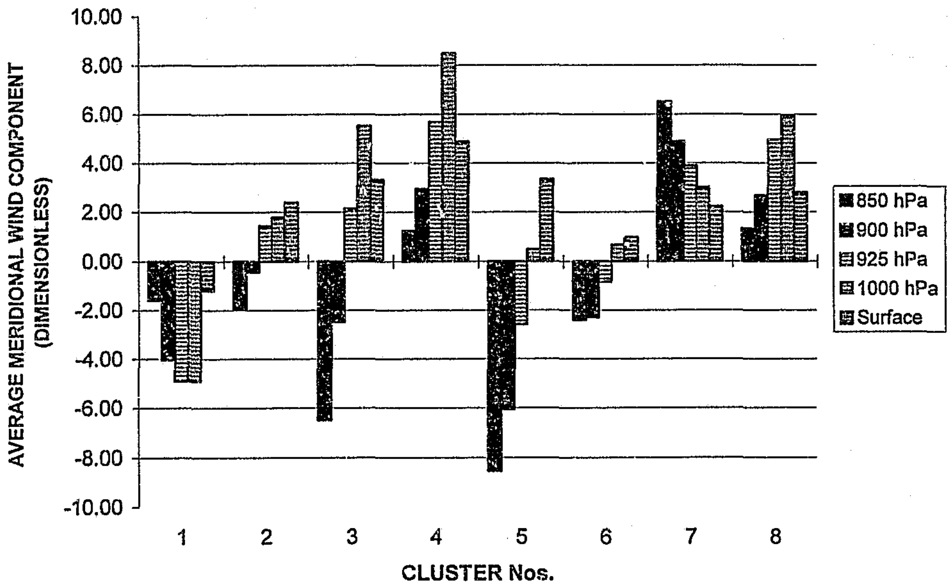
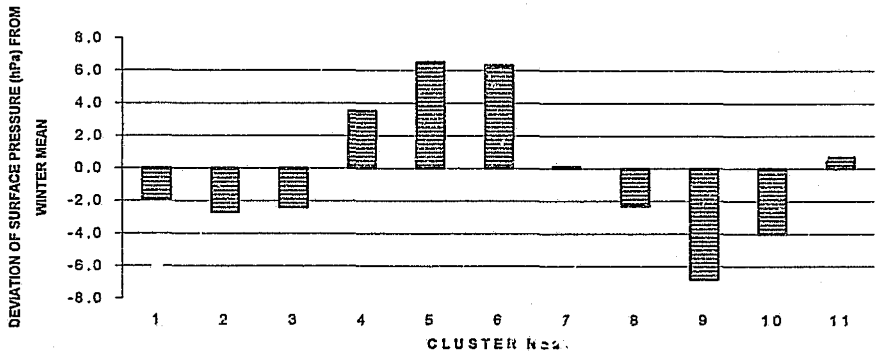
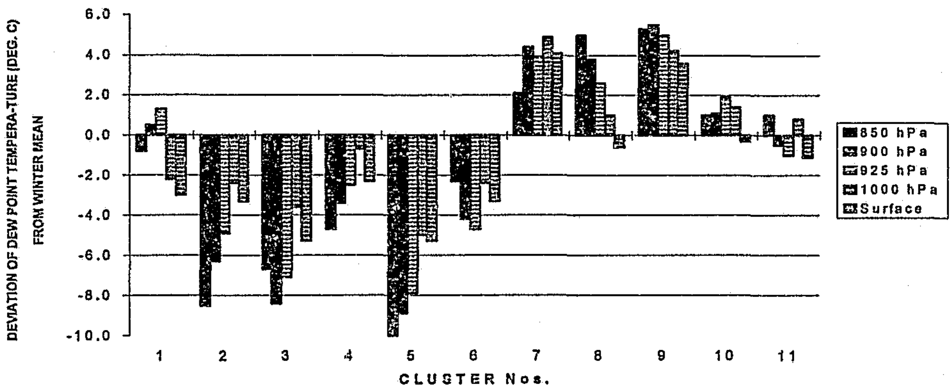


Figure C.16 (d) - (e): Meteorological characteristics of SUMMER clusters for PORT ELIZABETH, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.17.(a)



C.17.(b)



C.17.(c)

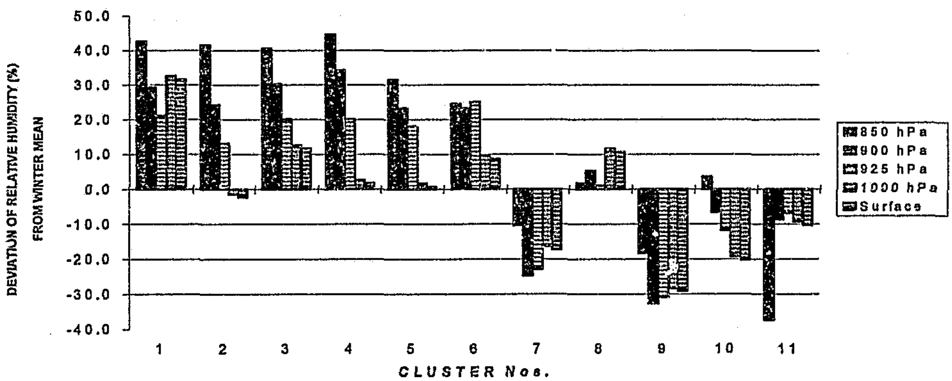
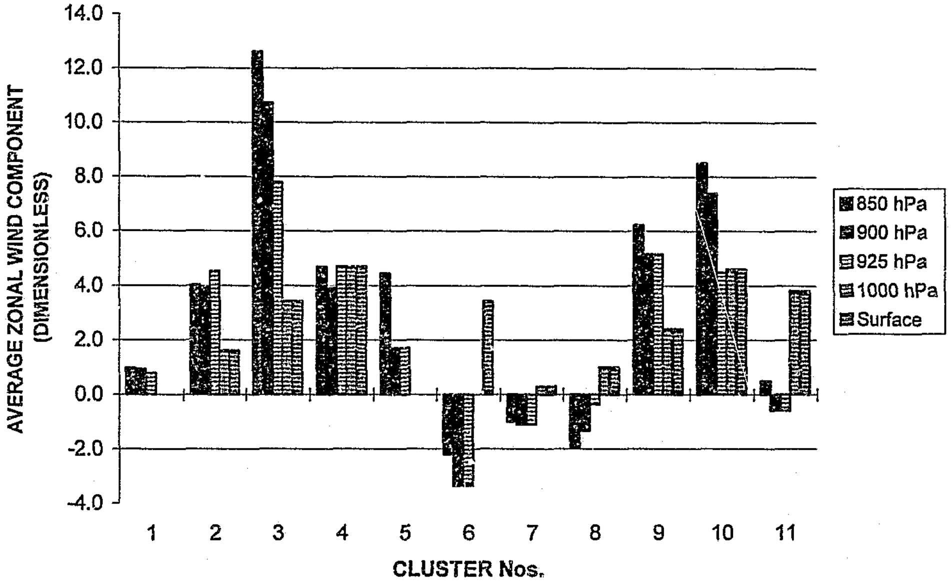


Figure C.17 (a) - (c): Meteorological characteristics of SUMMER clusters for CAPE TOWN, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and relative humidity (c) from seasonal averages.

C.17.(d)



C.17.(e)

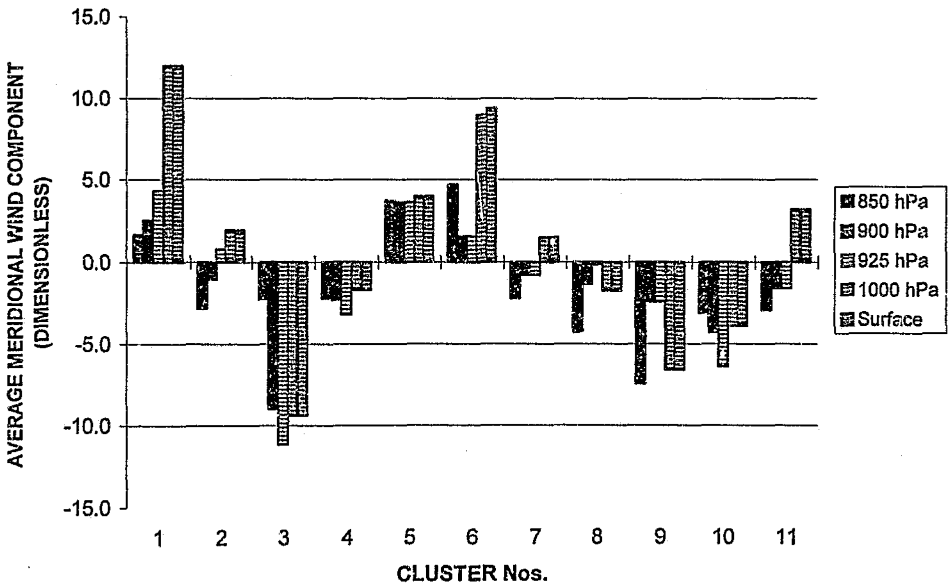
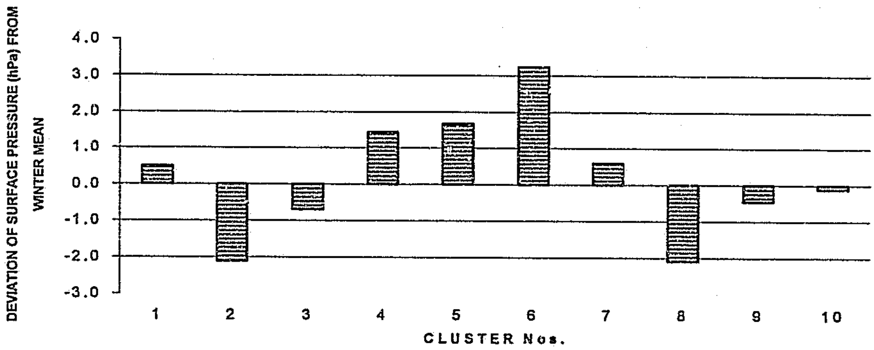
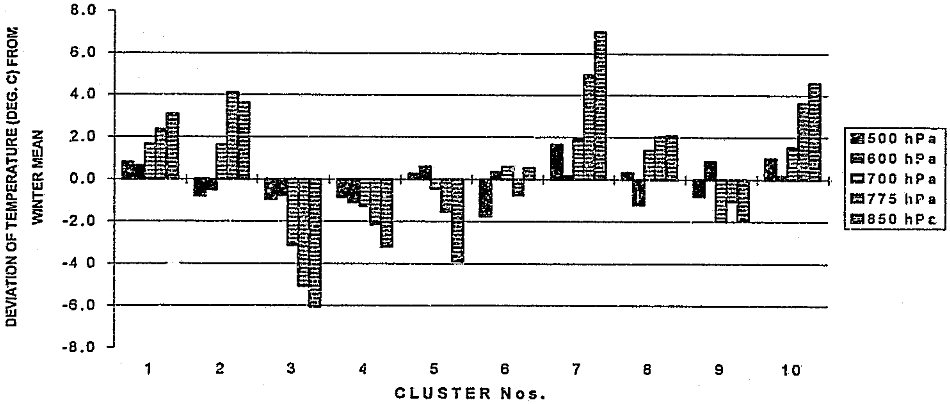


Figure C.17 (d) - (e): Meteorological characteristics of SUMMER clusters for CAPE TOWN, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

C.18.(a)



C.18.(b)



C.18.(c)

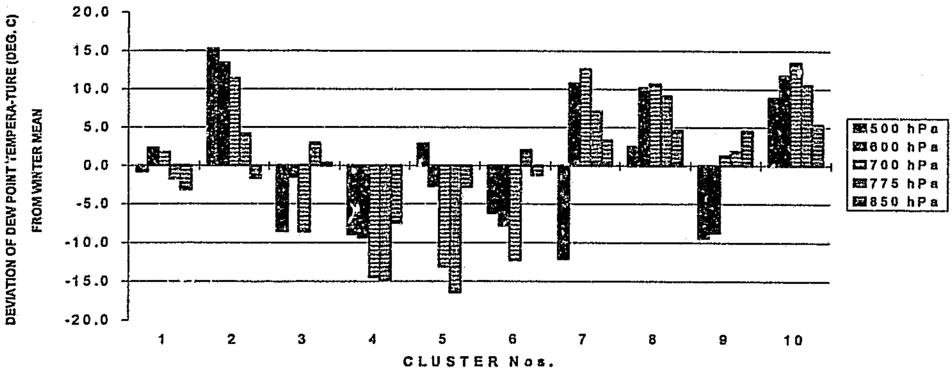
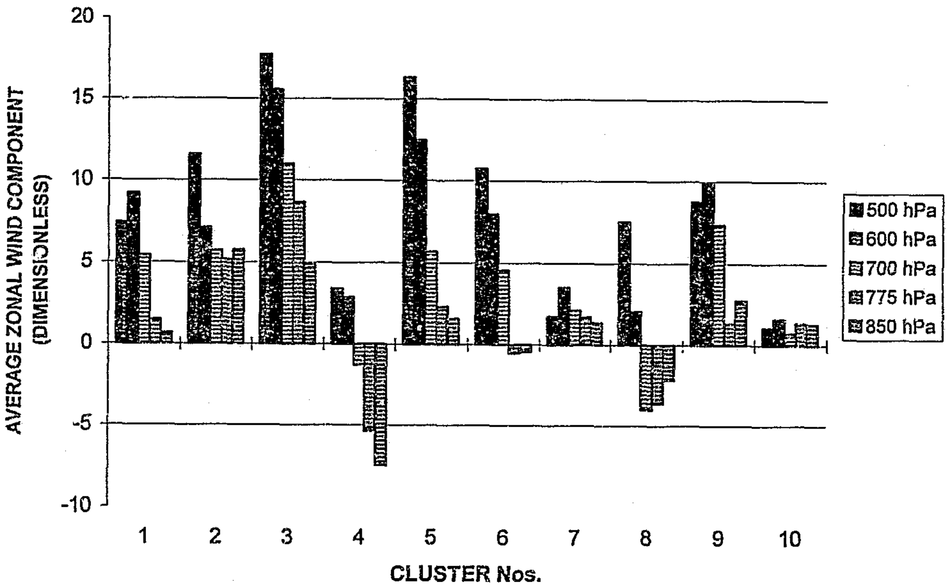


Figure C.18 (a) - (c): Meteorological characteristics of SUMMER clusters for SPRINGBOK, including deviations of surface pressure (a), and vertical profiles of deviations of ambient temperature (b) and dew point temperature (c) from seasonal averages.

C.18.(d)



C.18.(e)

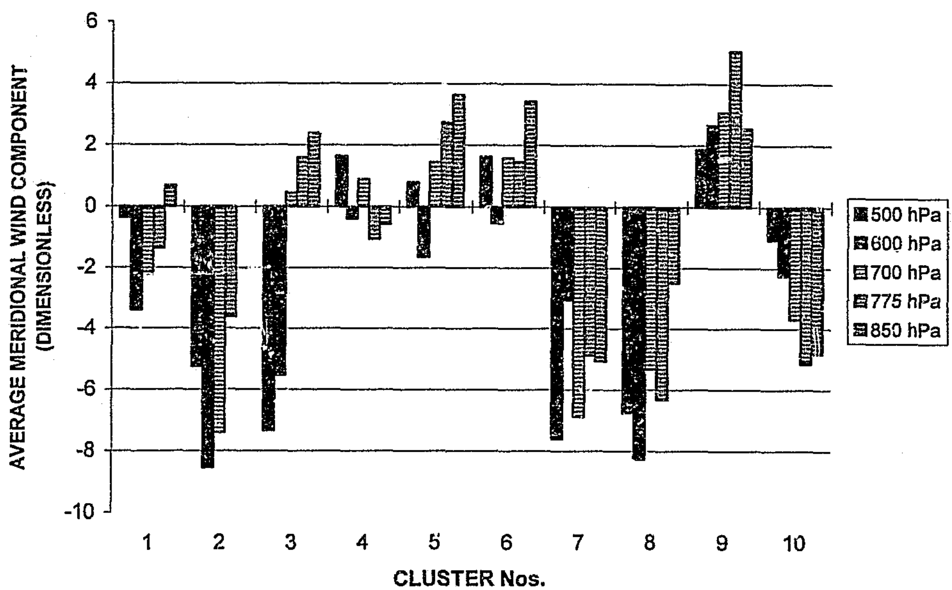


Figure C.18 (d) - (e): Meteorological characteristics of SUMMER clusters for SPRINGBOK, including vertical profiles of average zonal (d) and meridional (e) wind components for each cluster.

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