

# BMRC

**Bureau of  
Meteorology  
Research  
Centre**

---

## **BMRC Research Report No. 47**

**THE DEVELOPMENT OF A GENERALISED UNIX VERSION OF THE  
VICTORIAN REGIONAL OFFICE'S OPERATIONAL ANALOGUE  
STATISTICS MODEL**

**R.R. Dahni<sup>1</sup> and H. Stern<sup>2</sup>**

**JANUARY 1995**

---

**BMRC  
GPO Box 1289K  
Melbourne  
Victoria  
Australia 3001**

<sup>1</sup>Bureau of Meteorology Research Centre (BMRC)

<sup>2</sup>Victorian Regional Office (VRO)

## CONTENTS

	PAGE
ABSTRACT	1
1. INTRODUCTION	2
2. BACKGROUND	3
3. ANALOGUE STATISTICS MODEL	4
3.1 Analogue Retrieval	4
3.1.1 Synoptic data base	4
3.1.2 Similarity parameter	6
3.1.3 Selection window	7
3.2 Local Weather Data Retrieval	7
3.2.1 Local weather data base	7
3.3 Wind Guidance	7
3.3.1 Wind direction	9
3.3.2 Wind speed	10
3.3.3 Worded wind	11
3.4 Weather Guidance	12
3.4.1 Weather probabilities	12
3.4.2 Weather phenomena	13
3.4.3 Worded weather	15
3.5 Regression Analysis	15
3.5.1 Regression analysis data base	15
3.6 Specification of Parameters	19
3.7 Fire Weather Temperatures	19
3.8 Output	19
4. PARALLEL TRIAL	20
5. OPERATIONAL IMPLEMENTATION	21
6. CONCLUSIONS	32
ACKNOWLEDGMENTS	33
REFERENCES	33

**THE DEVELOPMENT OF A GENERALISED UNIX VERSION  
OF THE VICTORIAN REGIONAL OFFICE'S  
OPERATIONAL ANALOGUE STATISTICS MODEL**

R.R. Dahni<sup>1</sup> and H. Stern<sup>2</sup>

<sup>1</sup>Bureau of Meteorology Research Centre, Melbourne, Australia

<sup>2</sup>Victorian Regional Office, Bureau of Meteorology, Melbourne, Australia

**ABSTRACT**

The analogue statistics (AS) approach to the generation of weather forecast guidance has been under research at the Australian Bureau of Meteorology for over 20 years. With this approach, analogues to a current or forecast synoptic situation are retrieved and the forecast guidance is derived via statistical analyses of the local weather data associated with the analogues.

A pilot (non-operational) AS model was developed during the 1970s. It was later adapted and modified for operational application and, in 1982, became available for the provision of real-time guidance in the Regional Forecasting Centre (RFC) of the Victorian Regional Office (VRO). A module to extend its application to fire weather was operationally implemented during 1985.

Recently, a generalised (because of its potential for national implementation) UNIX version was developed as a joint effort between the Bureau of Meteorology Research Centre and the VRO. This version was trialled in the RFC of the VRO and operationally implemented during April 1994. The report describes that development, documents its main features, compares its performance with the previous version and suggests areas of future work. The comparison shows that the level of skill at predicting temperature and rainfall is preserved in the UNIX version.

## 1. INTRODUCTION.

Analogues have been used by meteorologists involved in day-to-day forecasting for many years (Gedzelman, 1994). Wagoner (1973) noted that "a large portion of the forecaster's subjective prognosis is nothing more than an analog procedure. He simply searches his mind for situations similar to the one presently confronting him. These are then converted into a modified forecast by mentally determining the average outcome of all the situations".

Advances in computer technology and physical understanding have enabled the development of complex numerical models of the atmosphere which provide expected weather patterns on the synoptic scale. These are then employed as guidance by weather forecasters who, using their experience and memory, interpret local weather conditions from these synoptic scale prognoses. However, computers can now analyse the predicted weather patterns and generate a worded weather forecast by simulating the experience of a human forecaster. This has led to the development of computer-based statistical models to interpret numerical model output in terms of weather. A range of statistical techniques are available to interpret local weather from the large-scale flow and produce weather forecast guidance in a worded form.

Many meteorological services, including the Australian Bureau of Meteorology, have implemented forecast guidance systems based on model output statistics (MOS), first referred to by Klein (1970) as the "imperfect prog" approach. MOS involves the derivation of regression equations with predictors including variables output by a numerical weather prediction (NWP) model. A weakness of MOS is that frequent changes to the NWP model necessitates re-derivation of the prediction equations on small samples of new data. Also, the user is "locked in" to guidance based on the output of a particular NWP model. Notwithstanding the fact the MOS is widely used, these weaknesses may be ameliorated by employing the "perfect prog" (PP) approach (Klein, 1970). PP prediction equations are developed on large samples of historical data and the user has the freedom to adjust the NWP model output.

Forecast guidance systems are constrained if they do not account for non-linear effects (similar initial states leading to a range of outcomes). Often a set of linear prediction equations have been used, derived by regression techniques, to interpret the output of the NWP model in terms of local weather. In Australia, non-linear effects have been addressed by the development of a forecast guidance system that retrieves synoptic analogues to initial data or the output of NWP models (the analogue statistics system). To arrive at a prediction, the system statistically interprets either the NWP model output or the initial data in terms of future local weather. The Australian system, described in this report, represents the first comprehensive, operational, PP system of weather forecast guidance that is based on synoptic stratification via analogue retrieval.

The operational application of the various methods of forecast guidance require significant computing power. Hence, programs have been implemented worldwide that introduced automation into weather forecasting operations - for example, the major automation program of the United States National Weather Service, "Automation of Field Operations and Services" program (Klein, 1978); and the Automated Regional Operations System (AROS) (Barclay and Butt, 1988) program in Australia.

## 2. BACKGROUND.

During the 1970s, a pilot (non-operational) analogue statistics (AS) model and an associated comprehensive system of forecast terminology was developed by Stern (1980, 1985). The pilot AS model, which was developed for Melbourne, for the month of October, retrieved analogues to the current or forecast synoptic situation and the forecast guidance was derived via statistical analyses of the local weather data associated with the analogues. It employed the forecast terminology to provide the worded component of the forecast guidance enabling the computer generated guidance to be translated into an unambiguous worded forecast. Trials of the pilot model (Stern, 1980, 1985; Stern and Dahni, 1981, 1982) during the Springs of 1979-81 demonstrated that, for temperature prediction, the model displayed superior skill to the officially issued forecasts.

The practical use of the AS model was in the operational environment of the Bureau Of Meteorology Regional Forecasting Centres (RFCs) to provide real-time weather forecast guidance to the forecasters. The pilot AS model was adapted and modified to meet the operational requirements of the RFC of the Victorian Regional Office (VRO), as part of the overall implementation of AROS (Dahni et al, 1984; de la Lande, 1985). The operational version was implemented on a TANDEM mini-computer in March 1982 and provided real-time weather forecast guidance for Melbourne, Mildura, East Sale, Mt Gambier and Wagga during all months of the year.

The operational AS model was subjected to a number of trials using data from the years 1980, 1985 and 1986 (Dahni et al, 1984; Dahni, 1988) in a simulated operational environment to evaluate its performance and assess its skill in comparison to that of the official forecasts and several other guidance techniques (for the 1980 trial only), namely the pilot AS model and the MOS system (Woodcock, 1984). They were conducted in a simulated real-time manner, the operating conditions being fixed and almost identical to those presently used in running the operational model. Although Woodcock (1984) reported that the October 1980 pilot AS model and MOS forecasts "had similar accuracy", Bureau of Meteorology (1990) reported that the operational AS model forecasts were "considered superior" to the corresponding MOS guidance (Mills and Tapp, 1984).

During the mid 1980s a system of mesoscale forecast guidance designed specifically for the prediction of regional centre maximum temperatures was developed (Stern et al, 1987). This system employed synoptically stratified relationships between maximum temperature at each of the regional centres and five major centres (Melbourne, Mildura, East Sale, Mt Gambier and Wagga). Based on this work, a "Fire Weather Temperatures" module, which also included minimum and dewpoint temperature, was added to the operational AS model, although the relationships were stratified monthly (de la Lande, 1985; Dahni, 1988).

The initial development of the AS model largely took place at the VRO endorsing Clarke's (1978) philosophy that an "Australian counterpart (to MOS)...will perhaps best be done at the regional level to meet regional problems". The 1990s have seen the development of a generalised UNIX version of the AS model, a joint effort between the Bureau of Meteorology Research Centre and the VRO. The purpose of this report is to record the progress to date that has been achieved with the development of the generalised UNIX version of the VRO's operational AS model, including documenting its main features, comparing the relative performances of the TANDEM and UNIX versions, describing its operational implementation and suggesting areas of future work. This latest version can be applied in the UNIX based, Australian Integrated Forecast System (Love, 1994).

### 3. ANALOGUE STATISTICS MODEL.

A detailed description of the generalised UNIX version of the Victorian Regional Office's operational analogue statistics (AS) model, including the methods of analogue and local weather data retrieval, the derivation of the wind and weather guidance and the statistical analyses is presented.

#### 3.1 Analogue Retrieval.

The means by which the operational AS model retrieves analogous synoptic situations (analogues) to the current or forecast synoptic situation is now presented. Included are a description of the synoptic data base, the method of calculation of the similarity parameter (a measure of the difference between two synoptic situations) and the selection window.

##### 3.1.1 Synoptic data base.

The synoptic data base is obtained from grid point data extracted from synoptic scale analyses. Since 1970, the 00UTC (Coordinated Universal Time) and 12UTC Australian region grid point analyses have been archived on an extensive 39x24 rectangular grid (see Figure 1) by the Bureau of Meteorology (Seaman et al, 1977). The analogues are retrieved using the 00UTC grid point data.

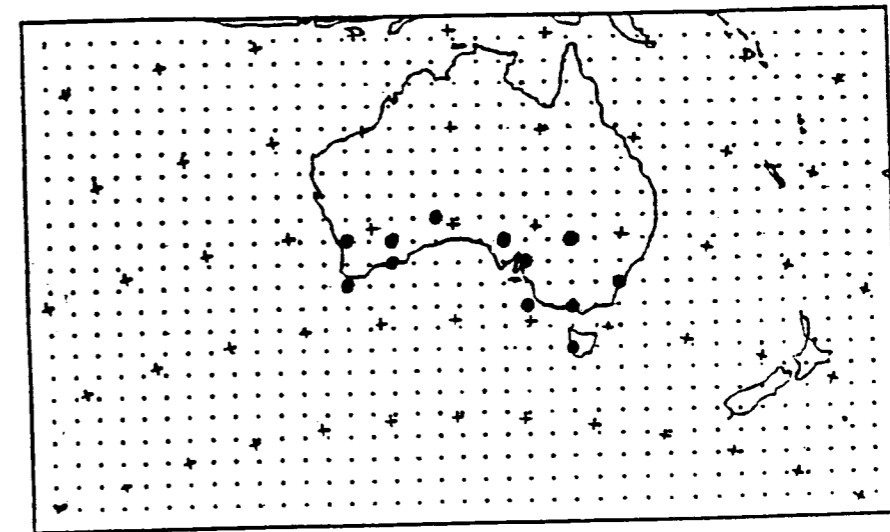
The synoptic data base of the previous version of the model, on the AROS TANDEM mini-computer, only covered the period 1970-84 inclusive. With the development of the UNIX version, this data base was extended to, and included, 1992 due to the importance of having as large as possible a data base available to select the best analogues. The synoptic data base of the operational model now covers the situations leading up to almost every day of the year over the period 1970-92 inclusive, using the 00UTC data extracted from the Australian region grid point analyses.

Each synoptic situation is described in terms of the surface flow during the preceding 24 hours. The surface flow is defined by data from a set of twelve grid points. A number of grid point sets are currently available. The first set, denoted as the original (pilot model) grid (see Figure 1(a)), are those grid points located near Perth, Albany, Esperance, Forrest, Kalgoorlie, Adelaide, Mt Gambier, Woomera, Cobar, Nowra, Laverton and Hobart. The second set, denoted as the Melbourne grid (see Figure 1(b)), are those grid points which form a 12-point rectangular grid covering southeastern Australia centred near Melbourne. It was considered that data from these grid points would describe most synoptic features relevant to Melbourne's (and Victoria's) weather. The third set, denoted as the Sydney grid (see Figure 1(c)) can be used to retrieve analogues relevant to Sydney's (and New South Wales') weather.

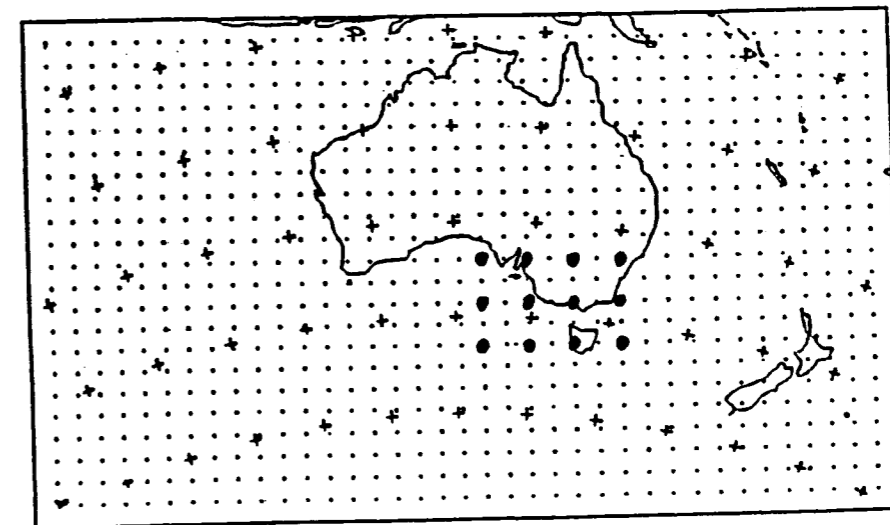
The data types used to describe the surface flow during the preceding 24 hours are the 09EST (Eastern Standard Time) Mean Sea Level (MSL) pressure and the change in MSL pressure during the 24 hour period ended 09EST (on the day of the situation), at each grid point. These data form the synoptic data base. The time 00UTC is a nominal time for the synoptic scale analyses (or prognoses) and is equivalent to 09EST. MSL pressure was selected as a major parameter because of its good correlation with weather elements.

Other grid point sets (including additional data types) can be readily made available in the generalised version.

(a)



(b)



(c)

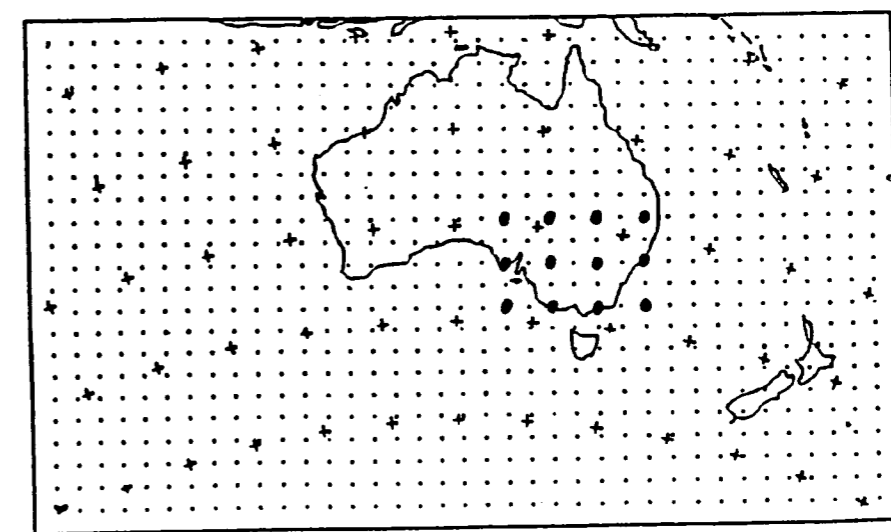


Figure 1 Original (pilot model) (a), Melbourne (b) and Sydney (c) grids.

### 3.1.2 Similarity parameter.

The basis for analogue selection is the "similarity" parameter, chosen because it employs a means to weight the influences of different data types. This parameter provides a measure of the difference between two synoptic situations defined in terms of the following data types:

1. Departure of the 09EST MSL pressure at each grid point from the mean of the 12 pressure values (or, alternatively, from the mean of a subset of the 12 pressure values); and
2. Change in the MSL pressure, during the 24 hour period ended 09EST (on the day of the situation), at each grid point.

The rationale behind its design was to develop a score that represents the sum of the root mean square differences between the data types used to specify the synoptic situations. The similarity parameter is defined as follows:

To compare synoptic situation  $j$  with synoptic situation  $k$ , let  $D_{uj}$  and  $D_{uk}$  refer to data type  $t$ , associated with grid point  $u$ , from situation  $j$  and  $k$ , respectively;

$W_t$  refers to the weight given to data type  $t$ ;

$W_u$  refers to the weight given to grid point  $u$ ; and

$S_t$  refers to the standard deviation about the mean of data type  $t$ .

The value of the similarity parameter comparing the two synoptic situations is given by:

$$R_{jk} = 100 \sum_{t=1}^{t=2} W_t S_t^{-1} \left[ \sum_{u=1}^{u=12} W_u (D_{uj} - D_{uk})^2 \right]^{1/2}$$

where  $\sum_{t=1}^{t=2} W_t = 1$  and  $\sum_{u=1}^{u=12} W_u = 12$

The factor 100 is a convenient scaling factor.

Let  $M_t$  refer to the mean of items of data type  $t$  associated with  $N$  synoptic situations where

$$M_t = (12N)^{-1} \sum_{v=1}^{v=N} \sum_{u=1}^{u=12} W_u D_{uv}$$

then  $S_t$  are given by:

$$S_t = [(12N)^{-1} \sum_{v=1}^{v=N} \sum_{u=1}^{u=12} W_u D_{uv}]^{1/2} \text{ or}$$

$$S_t = [(12N-1)^{-1} \sum_{v=1}^{v=N} \sum_{u=1}^{u=12} W_u D_{uv}^2 - (12N)^{-1} (\sum_{v=1}^{v=N} \sum_{u=1}^{u=12} W_u D_{uv})^2]^{1/2}$$

The role that  $S_t$  (standard deviation) plays is in normalising the data types relative to each other. Not all the synoptic situations in the data base need to be considered for analogue selection, so that  $S_t$  could not be predetermined and preset as a constant. The  $S_t$  are determined each time the operational model is run.

The operational model retrieves the most analogous synoptic situation to the current or forecast synoptic situation, according to the criteria of selection (see section 3.6) and the weightings used (which must be specified beforehand), by comparing the current or forecast synoptic situation with each of the synoptic situations (or subset of) in the synoptic data base in turn. The similarity parameter  $R$  is calculated for each comparison and the "best" analogue is regarded as that one associated with the smallest value of  $R$ . Similarly, the "second best" analogue is regarded as that one associated with the second smallest value of  $R$ . The process is repeated until the required number of analogues, that is, the number specified beforehand, has been retrieved.

In addition to the similarity parameter, the S1 skill score (Teweles and Wobus, 1954) and correlation coefficient are calculated for each analogue. An option exists where the selection of analogues can be based on the S1 skill score instead of the similarity parameter. No other data types were used at this stage of development of the operational model, but they can be readily defined with the expansion of the synoptic data base.

### 3.1.3 Selection window.

In order that the data most relevant to the forecast problem is included, the synoptic data base need not be stratified on a calendar month basis. The data base can be stratified according to an  $N \pm X$  day window about the date ( $N$ ) for which the forecast guidance is required, where  $X$  is usually set at 15. For example, if the forecast guidance is required for 1 October, the analogues are selected from the period 16 September to 16 October inclusive from all the years in the data base.

## 3.2 Local Weather Data Retrieval.

The operational model extracts the local weather data associated with the analogues (for the current, previous and next days of the analogues) for a number of stations in and near Victoria (Melbourne, Mildura, East Sale, Mt Gambier and Wagga). In the generalised version, if the Sydney grid were used for analogue retrieval, local weather data could be extracted for a number of stations in and near New South Wales (Sydney, Wagga, Coffs Harbour, Cobar and Mildura). These data can be used in statistical analyses to produce forecast guidance for numerous meteorological elements for each of the above stations.

### 3.2.1 Local weather data base.

The local weather data has been extracted from the climatological archives of the Bureau of Meteorology, quality controlled and designed to be easily maintained and available for general use. The data currently available in the operational model now covers almost every day of the year over the period 1970-92 inclusive, for Melbourne, Mildura, East Sale, Mt Gambier and Wagga. A description of the local weather data, divided into surface and radiosonde observations, is given in Tables 1 and 2, respectively. Not all of the local weather data are used, at present, in the operational model but have been included in the data base for any future enhancements and expansion of the weather forecast guidance produced by the model.

The maximum and minimum temperatures cover the preceding 24 hour period to 9 am. The frost observed and the maximum wind gust direction and speed cover the 24 hour period, midnight to midnight. The definition of the present and past weather codes in terms of the weather observations are given by Bureau of Meteorology (1977). The radiosonde observations are available only for Melbourne, Mt Gambier and Wagga.

Local weather data sets for other stations can be readily made available with the generalised version.

## 3.3 Wind Guidance.

The forecast wind guidance consists of both the wind speed and direction and a worded description. The means by which the operational model determines the forecast wind guidance in a quantitative and qualitative form is now presented.

Date (yymmdd)	6 pm low cloud 1 type code (0-9)
9 am dry-bulb temperature (tenths °C)	9 pm low cloud 1 type code (0-9)
Noon dry-bulb temperature (tenths °C)	Midnight low cloud 2 amount (octas)
3 pm dry-bulb temperature (tenths °C)	3 am low cloud 2 amount (octas)
9 am dewpoint temperature (°C)	6 am low cloud 2 amount (octas)
Noon dewpoint temperature (°C)	9 am low cloud 2 amount (octas)
3 pm dewpoint temperature (°C)	Noon low cloud 2 amount (octas)
Maximum temperature (tenths °C)	3 pm low cloud 2 amount (octas)
Minimum temperature (tenths °C)	6 pm low cloud 2 amount (octas)
Frost observed (1=yes, 0=no)	9 pm low cloud 2 amount (octas)
Midnight present weather code (00-99)	Midnight low cloud 2 type code (0-9)
Midnight past weather code (00-99)	3 am low cloud 2 type code (0-9)
3 am present weather code (00-99)	6 am low cloud 2 type code (0-9)
3 am past weather code (00-99)	9 am low cloud 2 type code (0-9)
6 am present weather code (00-99)	Noon low cloud 2 type code (0-9)
6 am past weather code (00-99)	3 pm low cloud 2 type code (0-9)
9 am present weather code (00-99)	6 pm low cloud 2 type code (0-9)
9 am past weather code (00-99)	9 pm low cloud 2 type code (0-9)
Noon present weather code (00-99)	Midnight low cloud amount (octas)
Noon past weather code (00-99)	3 am low cloud amount (octas)
3 pm present weather code (00-99)	6 am low cloud amount (octas)
3 pm past weather code (00-99)	9 am low cloud amount (octas)
6 pm present weather code (00-99)	Noon low cloud amount (octas)
6 pm past weather code (00-99)	3 pm low cloud amount (octas)
9 pm present weather code (00-99)	6 pm low cloud amount (octas)
9 pm past weather code (00-99)	9 pm low cloud amount (octas)
Midnight wind direction (16 compass points)	Midnight middle cloud amount (octas)
3 am wind direction (16 compass points)	3 am middle cloud amount (octas)
6 am wind direction (16 compass points)	6 am middle cloud amount (octas)
9 am wind direction (16 compass points)	9 am middle cloud amount (octas)
Noon wind direction (16 compass points)	Noon middle cloud amount (octas)
3 pm wind direction (16 compass points)	3 pm middle cloud amount (octas)
6 pm wind direction (16 compass points)	6 pm middle cloud amount (octas)
9 pm wind direction (16 compass points)	9 pm middle cloud amount (octas)
Midnight wind speed (knots)	Midnight middle cloud type code (0-9)
3 am wind speed (knots)	3 am middle cloud type code (0-9)
6 am wind speed (knots)	6 am middle cloud type code (0-9)
9 am wind speed (knots)	9 am middle cloud type code (0-9)
Noon wind speed (knots)	Noon middle cloud type code (0-9)
3 pm wind speed (knots)	3 pm middle cloud type code (0-9)
6 pm wind speed (knots)	6 pm middle cloud type code (0-9)
9 pm wind speed (knots)	9 pm middle cloud type code (0-9)
Maximum wind gust direction (16 compass points)	Midnight high cloud amount (octas)
Maximum wind gust speed (knots)	3 am high cloud amount (octas)
Midnight total cloud amount (octas)	6 am high cloud amount (octas)
3 am total cloud amount (octas)	9 am high cloud amount (octas)
6 am total cloud amount (octas)	Noon high cloud amount (octas)
9 am total cloud amount (octas)	3 pm high cloud amount (octas)
Noon total cloud amount (octas)	6 pm high cloud amount (octas)
3 pm total cloud amount (octas)	9 pm high cloud amount (octas)
6 pm total cloud amount (octas)	Midnight high cloud type code (0-9)
9 pm total cloud amount (octas)	3 am high cloud type code (0-9)
Midnight low cloud 1 amount (octas)	6 am high cloud type code (0-9)
3 am low cloud 1 amount (octas)	9 am high cloud type code (0-9)
6 am low cloud 1 amount (octas)	Noon high cloud type code (0-9)
9 am low cloud 1 amount (octas)	3 pm high cloud type code (0-9)
Noon low cloud 1 amount (octas)	6 pm high cloud type code (0-9)
3 pm low cloud 1 amount (octas)	9 pm high cloud type code (0-9)
6 pm low cloud 1 amount (octas)	9 pm-midnight rainfall (tenths mm)
9 pm low cloud 1 amount (octas)	Midnight-3 am rainfall (tenths mm)
Midnight low cloud 1 type code (0-9)	3 am-6 am rainfall (tenths mm)
3 am low cloud 1 type code (0-9)	6 am-9 am rainfall (tenths mm)
6 am low cloud 1 type code (0-9)	9 am-noon rainfall (tenths mm)
9 am low cloud 1 type code (0-9)	Noon-3 pm rainfall (tenths mm)
Noon low cloud 1 type code (0-9)	3 pm-6 pm rainfall (tenths mm)
3 pm low cloud 1 type code (0-9)	6 pm-9 pm rainfall (tenths mm)

Table 1 Description of the local weather data surface observations.

DESCRIPTION
Date (yymmdd)
9 am Surface pressure (hPa)
9 am Surface dry-bulb temperature (tenths °C)
9 am Surface mixing ratio (dg/kg)
9 am 900 hPa dry-bulb temperature (tenths °C)
9 am 900 hPa mixing ratio (dg/kg)
9 am 850 hPa dry-bulb temperature (tenths °C)
9 am 850 hPa mixing ratio (dg/kg)
9 am 800 hPa dry-bulb temperature (tenths °C)
9 am 800 hPa mixing ratio (dg/kg)
9 am 700 hPa dry-bulb temperature (tenths °C)
9 am 700 hPa mixing ratio (dg/kg)
9 am 600 hPa dry-bulb temperature (tenths °C)
9 am 600 hPa mixing ratio (dg/kg)
9 am 500 hPa dry-bulb temperature (tenths °C)
9 am 500 hPa mixing ratio (dg/kg)
9 am 400 hPa dry-bulb temperature (tenths °C)
9 am 400 hPa mixing ratio (dg/kg)

Table 2 Description of the local weather data radiosonde observations.

### 3.3.1 Wind direction.

A frequency analysis is made of the wind direction observations associated with the analogues to determine the forecast wind direction.

A score is determined for each of the wind directions using the 16 compass points (NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW and N) and "CALM/VARIABLE" by calculating the difference (in compass points) between the analogue wind directions and each of these wind directions, and using Table 3 to determine the score. The forecast wind direction becomes the wind direction with the highest score, or in the event of two or more wind directions of equal highest score, the wind direction of the highest order of priority (see Table 4).

DIFFERENCE (compass points)	SCORE
0	3
1	2
2	1
≥3	0

Table 3 Score attributed to difference (in compass points) in wind directions.

The forecast wind direction is determined for each of the four time periods (early morning, late morning, afternoon and evening) and combined to determine the forecast morning and afternoon wind directions.

A similar frequency analysis is made of the maximum wind gust direction observations associated with the analogues to determine the forecast maximum wind gust direction.

ORDER	WIND DIRECTION
1	NORTHERLY
2	WESTERLY
3	EASTERLY
4	SOUTHERLY
5	NORTHWESTERLY
6	NORTHEASTERLY
7	SOUTHWESTERLY
8	SOUTHEASTERLY
9	NORTH TO NORTHWESTERLY
10	NORTH TO NORTHEASTERLY
11	WEST TO NORTHWESTERLY
12	EAST TO NORTHEASTERLY
13	WEST TO SOUTHWESTERLY
14	EAST TO SOUTHWESTERLY
15	SOUTH TO SOUTHWESTERLY
16	SOUTH TO SOUTHEASTERLY
17	CALM/VARIABLE

**Table 4** Order of priority of the wind directions.

An option exists where the wind and maximum wind gust direction observations associated with the analogues may be weighted by their similarity parameter before determining the forecast wind and maximum wind gust directions. The weighting is defined as follows:

let N be the number of analogues selected and  $R_i$  the value of the similarity parameter for analogue i, then the weighting for analogue i is given by:

$$W_i = \frac{R_N}{(R_i + 1)}$$

The above weighting scheme enables the better analogues (those with a smaller similarity parameter) to exert a greater influence on the weather forecast guidance produced by the operational model by taking into account the quality (similarity to the current or forecast synoptic situation) of the analogues themselves.

### 3.3.2 Wind speed.

The forecast morning and afternoon wind speeds (in knots) are determined by averaging the analogue wind speeds during the early and late mornings, and afternoon and evening, respectively.

The forecast maximum wind gust speed (in knots) is determined by averaging the analogue maximum wind gust speeds.

An option exists where the wind and maximum wind gust speed observations associated with the analogues may also be weighted by their similarity parameter before determining the forecast wind and maximum wind gust speeds, using the same weighting scheme defined earlier (see section 3.3.1).

### 3.3.3 Worded wind.

The worded wind descriptions are obtained from an analysis of the quantitative forecast wind speed and direction. By utilising a vocabulary of the appropriate words and phrases the worded wind descriptions are constructed each time the operational model is run. The operational model determines the worded wind guidance as follows:

- (a) the forecast morning and afternoon wind directions are used to determine the worded forecast morning <AMD> and afternoon <PMD> wind directions, by referring to Table 5.

WIND DIRECTION	WORDED WIND DIRECTION
1	NORTH TO NORTHEASTERLY
2	NORTHEASTERLY
3	EAST TO NORTHEASTERLY
4	EASTERLY
5	EAST TO SOUTHEASTERLY
6	SOUTHEASTERLY
7	SOUTH TO SOUTHEASTERLY
8	SOUTHERLY
9	SOUTH TO SOUTHWESTERLY
10	SOUTHWESTERLY
11	WEST TO SOUTHWESTERLY
12	WESTERLY
13	WEST TO NORTHWESTERLY
14	NORTHWESTERLY
15	NORTH TO NORTHWESTERLY
16	NORTHERLY
99	AND VARIABLE

**Table 5** Worded wind direction descriptions.

- (b) the forecast morning and afternoon wind speeds are used to determine the worded forecast morning <AMS> and afternoon <PMS> wind speeds, by referring to Table 6.

WIND SPEED (KNOTS)	WORDED WIND SPEED
0 - 6	LIGHT
7 - 10	LIGHT TO MODERATE
11 - 16	MODERATE
17 - 21	FRESH
22 - 33	STRONG
> 33	GALEFORCE

**Table 6** Worded wind speed descriptions.

- (c) the mean of the forecast morning and afternoon wind speeds (APMS) is determined.
- (d) if the forecast morning and afternoon wind directions are two or fewer compass points apart or both are "CALM/VARIABLE", then a worded combined wind direction for the day <CD> is determined as the mean of the two wind directions.
- (e) if the day is one for which a combined wind direction has been determined, a worded combined wind speed for the day <CS> is determined by application of the following set of conditions:
1. If <AMS> = <PMS> then <CS> = <AMS>.
  2. If one of <AMS> and <PMS> is "LIGHT" the other being "LIGHT TO MODERATE", then;
    - if APMS ≥ 6.5 knots, then <CS> = "LIGHT TO MODERATE",
    - else <CS> = "LIGHT".

3. If one of <AMS> and <PMS> is "MODERATE", the other being "LIGHT TO MODERATE", then;  
if APMS  $\geq$  10.5 knots, then  
<CS> = "MODERATE",  
else <CS> = "LIGHT TO MODERATE".
4. If one of <AMS> and <PMS> is "MODERATE", the other being "FRESH", then  
<CS> = "MODERATE TO FRESH".
5. If one of <AMS> and <PMS> is "FRESH", the other being "STRONG", then  
<CS> = "FRESH TO STRONG".
6. If one of <AMS> and <PMS> is "STRONG", the other being "GALEFORCE", then  
<CS> = "STRONG TO GALEFORCE".

If none of the above conditions are satisfied, then the day is not one of a combined wind speed.

(f) The following rules are then applied in order to obtain the worded forecast wind <WIND>:

1. If the day is one of a combined wind direction but not one of a combined wind speed, and <AMS> describes a lighter speed range than <PMS>, then;  
if <AMS> = "MODERATE" and <PMS> = "STRONG" or "GALEFORCE", then  
<WIND> = "<AMS> <CD> WINDS STRENGTHENING", or  
if <AMS> = "LIGHT TO MODERATE" and <PMS> = "FRESH", then  
<WIND> = "<AMS> <CD> WINDS FRESHENING",  
else <WIND> = "<AMS> <CD> WINDS INCREASING TO <PMS>".
2. If the day is one of a combined wind direction but not one of a combined wind speed, and <AMS> describes a stronger speed range than <PMS>, then;  
if <AMS> = "STRONG" or "GALEFORCE" and <PMS> = "MODERATE", then  
<WIND> = "<AMS> <CD> WINDS MODERATING",  
else <WIND> = "<AMS> <CD> WINDS DECREASING TO <PMS>".
3. If the day is one of a combined wind direction and combined wind speed, then  
<WIND> = "<CS> <CD> WINDS".
4. If the day is not one of a combined wind direction, then;  
if <AMD> = "AND VARIABLE", then  
<WIND> = "LIGHT AND VARIABLE WINDS BECOMING <PMS> <PMD>", or  
if <PMD> = "AND VARIABLE", then  
<WIND> = "<AMS> <AMD> WINDS BECOMING LIGHT AND VARIABLE",  
else <WIND> = "<AMS> <AMD> WINDS TURNING <PMS> <PMD>".  
If <AMS> = <PMS>, the second reference to wind speed given above is excluded.

### 3.4 Weather Guidance.

The means by which the operational model determines the forecast weather guidance in a quantitative and qualitative form are now presented. The determination of the forecast weather guidance in a quantitative form (probability estimates) and its conversion into a qualitative (worded) form are sophisticated features of the operational model.

#### 3.4.1 Weather probabilities.

A frequency analysis is made of the weather observations associated with the analogues to determine the weather probabilities using the following two (broad and specific) classifications of weather phenomena:

- A. precipitation, thunderstorms and fog; and
- B. thunderstorms, snow, sleet, rain, showers, drizzle, isolated thunderstorms, fog and local fogs.

The definition of these two classifications of weather phenomena in terms of the weather observations using the past and present weather codes and the low cloud type are given in Tables 7 and 8, respectively.

The probabilities of each of the above weather phenomena are determined during the early morning, late morning, afternoon and evening. Additionally, the probability of precipitation (POP), during the late morning or afternoon is also determined.

PHENOMENA	PRESENT OR PAST WEATHER CODE
PRECIPITATION	15-16, 20-27, 29, 50-99
THUNDERSTORMS	13, 17, 29, 91-99 or low cloud type 9
FOG	11-12, 28, 40-49

**Table 7** Classification A - Definition of precipitation, thunderstorms and fog.

PHENOMENA	PRESENT OR PAST WEATHER CODE
THUNDERSTORMS	17, 19, 29, 91-99
SNOW	22, 26, 70-79, 85, 86
SLEET	23, 68-69, 83-84
RAIN	21, 24, 58-67
SHOWERS	15-16, 25, 27, 29, 80-82, 87-90
DRIZZLE	20, 50-57
ISOLATED THUNDERSTORMS	13 or low cloud type 9
FOG	12, 28, 42-49
LOCAL FOGS	11, 40-41

**Table 8** Classification B - Definition of thunderstorms, snow, sleet, rain, showers, drizzle, isolated thunderstorms, fog and local fogs.

An option exists where the weather observations associated with the analogues may be weighted by their similarity parameter before determining the probabilities of the weather phenomena, using the same weighting scheme defined earlier (see section 3.3.1).

#### 3.4.2 Weather phenomena.

The forecast weather phenomena during the early morning, late morning, afternoon and evening are determined by applying the following conditions in each time period:

1. If the probability of thunderstorms using classification A  $\geq$  threshold value (arbitrarily chosen as 50%), thunderstorms are to be forecast. The type of thunderstorms to be forecast is determined from the probabilities of thunderstorms and isolated thunderstorms using classification B. The type associated with the higher probability (or in the event of equal probabilities, the earlier type) is forecast.
2. If the probability of precipitation using classification A  $\geq$  threshold value (arbitrarily chosen as 50%), precipitation is to be forecast. The type of precipitation to be forecast is determined from the probabilities of thunderstorms (if thunderstorms or isolated thunderstorms have not already been forecast), snow, sleet, rain, showers and drizzle using classification B. The type associated with the higher probability (or in the event of equal probabilities, the earlier type) is forecast.
3. If the probability of fog using classification A  $\geq$  threshold value (arbitrarily chosen as 50%), fog is to be forecast. The type of fog to be forecast is determined from the probabilities of fog and local fogs using classification B. The type associated with the higher probability (or in the event of equal probabilities, the earlier type) is forecast.

The mean cloud amount (over the analogues) is used to determine the forecast weather, if no significant weather phenomena (precipitation, thunderstorms or fog) are forecast, by referring to Table 9.

WEATHER	CLOUD AMOUNT (OCTAS)
FINE AND SUNNY	< 2.0
FINE AND MAINLY SUNNY	≥ 2.0, < 3.5
FINE ALTHOUGH PARTLY CLOUDY	> 3.5, ≤ 6.0
FINE ALTHOUGH MAINLY CLOUDY	> 6.0, ≤ 7.0
CLOUDY BUT WITHOUT PRECIPITATION	> 7.0

**Table 9** Worded weather descriptions from cloud amount.

The mean rainfall (over the analogues) is regarded as the forecast rainfall, and is used to modify (if necessary) the forecast precipitation type but not its occurrence (or non-occurrence). This sometimes leads to an anomaly (a non-zero forecast rainfall and a worded weather forecast not including a precipitation type). If the forecast precipitation type is one of snow, sleet, rain or showers, and the forecast rainfall ≤ 0.5 mm, then the forecast precipitation type becomes, little snow, little sleet, little rain and few showers, respectively. If the forecast precipitation type is drizzle, and the forecast rainfall ≤ 0.2 mm, then the forecast precipitation type becomes little drizzle.

The forecast weather during the morning and later are determined by combining (taking the weather phenomena of higher priority by referring to Table 10) the forecast weather during the early and late mornings, and afternoon and evening, respectively.

NUMBER	WEATHER PHENOMENA
1	THUNDERSTORMS
2	SNOW
3	SLEET
4	RAIN
5	SHOWERS
6	DRIZZLE
7	ISOLATED THUNDERSTORMS
8	FOG
9	LOCAL FOGS
10	LITTLE SNOW
11	LITTLE SLEET
12	LITTLE RAIN
13	FEW SHOWERS
14	LITTLE DRIZZLE
15	FINE AND SUNNY
16	FINE AND MAINLY SUNNY
17	FINE ALTHOUGH PARTLY CLOUDY
18	FINE ALTHOUGH MAINLY CLOUDY
19	CLOUDY BUT WITHOUT PRECIPITATION
20	FINE AND BECOMING CLOUDY
21	FINE AND BECOMING SUNNY

**Table 10** Order of priority of weather phenomena.

### 3.4.3 Worded weather.

The worded weather descriptions are obtained from the weather probabilities, and give a consistent, representative description. By utilising a vocabulary of the appropriate words and phrases the worded weather descriptions are constructed each time the operational model is run. The operational model determines the worded weather guidance as follows:

- let <FPM> denote the worded forecast precipitation during the morning, and <FPL> denote the worded forecast precipitation later.  
If no precipitation phenomena is forecast during the morning or later, <FPM> or <FPL> become the forecast weather determined from the forecast cloud amount (see Table 9).  
If <FPM> = <FPL> then the worded forecast precipitation becomes <FPM>.  
Otherwise, Table 11 is used to determine the worded forecast precipitation.  
If a worded forecast precipitation cannot be determined using Table 11, it becomes: "<FPM> DURING THE MORNING. <FPL> LATER".
- let <FTM> denote the worded forecast thunderstorms during the morning, and <FTL> denote the worded forecast thunderstorms later.  
If <FTM> = <FTL> then the worded forecast thunderstorms becomes <FTM>.  
Otherwise, Table 11 is used to determine the worded forecast thunderstorms.
- let <FFM> denote the worded forecast fog during the morning and <FFL> denote the worded forecast fog later.  
If <FFM> = <FFL> then the worded forecast fog becomes <FFM>.  
Otherwise, Table 11 is used to determine the worded forecast fog.
- the worded forecast weather is determined by combining the worded forecast precipitation, thunderstorms and fog.

### 3.5 Regression Analysis.

The operational model can determine regression estimates of the maximum, minimum and dewpoint temperatures, in addition to rainfall and fog probability. These variables are just a small sample of potential predictands from the regression analysis data base. If no predictors are specified, the mean value is used as the estimate.

An option exists where the data associated with the analogues may be weighted by their similarity parameter before determining the regression estimates, using the same weighting scheme defined earlier (see section 3.3.1).

#### 3.5.1 Regression analysis data base.

The local weather data base consists of observed data extracted from the climatological archives of the Bureau of Meteorology. Many other useful prediction parameters can be derived from these data (e.g. dewpoint depression and thickness) to enlarge the number of data types available for regression analysis.

These other data types are derived each time the model is run, without significantly increasing the run-time. The observed and derived data together form the regression analysis data base, data types available for regression analysis.

The data types that can be used in the regression analysis, as predictands or predictors, are presented in Table 12. Only a small subset of these data types are used, at present, in the operational model.

FORECAST WEATHER DURING THE MORNING	FORECAST WEATHER LATER	FORECAST WEATHER
THUNDERSTORMS	ISOLATED THUNDERSTORMS	THUNDERSTORMS EASING
ISOLATED THUNDERSTORMS	THUNDERSTORMS	THUNDERSTORMS INCREASING
SNOW	LITTLE SNOW	SNOW EASING
LITTLE SNOW	SNOW	SNOW INCREASING
SLEET	LITTLE SLEET	SLEET EASING
LITTLE SLEET	SLEET	SLEET INCREASING
RAIN	LITTLE RAIN	RAIN EASING
LITTLE RAIN	RAIN	RAIN INCREASING
SHOWERS	FEW SHOWERS	SHOWERS EASING
FEW SHOWERS	SHOWERS	SHOWERS INCREASING
DRIZZLE	LITTLE DRIZZLE	DRIZZLE EASING
LITTLE DRIZZLE	DRIZZLE	DRIZZLE EASING
FOG	LOCAL FOGS	FOG EASING
LOCAL FOGS	FOG	FOG INCREASING
FINE AND SUNNY	FINE AND MAINLY SUNNY	FINE AND MAINLY SUNNY
FINE AND MAINLY SUNNY	FINE AND SUNNY	
FINE ALTHOUGH PARTLY CLOUDY	FINE AND SUNNY	FINE ALTHOUGH PARTLY CLOUDY
	FINE AND MAINLY SUNNY	
	FINE ALTHOUGH MAINLY CLOUDY	
	CLOUDY BUT WITHOUT PRECIPITATION	
FINE ALTHOUGH MAINLY CLOUDY	FINE AND SUNNY	FINE AND BECOMING SUNNY
	FINE AND MAINLY SUNNY	
CLOUDY BUT WITHOUT PRECIPITATION	FINE AND SUNNY	
	FINE AND MAINLY SUNNY	FINE AND BECOMING CLOUDY
FINE AND SUNNY	FINE ALTHOUGH MAINLY CLOUDY	
	CLOUDY BUT WITHOUT PRECIPITATION	
FINE AND MAINLY SUNNY	FINE ALTHOUGH MAINLY CLOUDY	
	CLOUDY BUT WITHOUT PRECIPITATION	
FINE ALTHOUGH MAINLY CLOUDY	CLOUDY BUT WITHOUT PRECIPITATION	FINE ALTHOUGH MAINLY CLOUDY
CLOUDY BUT WITHOUT PRECIPITATION	FINE ALTHOUGH MAINLY CLOUDY	

Table 11 Worded forecast weather from the forecast weather during the morning and later.

DATA TYPE	DESCRIPTION
1	9 am dry-bulb temperature (°C)
2	Noon dry-bulb temperature (°C)
3	3 pm dry-bulb temperature (°C)
4	9 am dewpoint temperature (°C)
5	Noon dewpoint temperature (°C)
6	3 pm dewpoint temperature (°C)
7	Maximum temperature (°C)
8	Minimum temperature (°C)
9	9 am surface pressure (hPa)
10	9 am surface dry-bulb temperature (°C)
11	9 am surface mixing ratio (g/kg)
12	9 am 900 hPa dry-bulb temperature (°C)
13	9 am 900 hPa mixing ratio (g/kg)
14	9 am 850 hPa dry-bulb temperature (°C)
15	9 am 850 hPa mixing ratio (g/kg)
16	9 am 800 hPa dry-bulb temperature (°C)
17	9 am 800 hPa mixing ratio (g/kg)
18	9 am 700 hPa dry-bulb temperature (°C)
19	9 am 700 hPa mixing ratio (g/kg)
20	9 am 600 hPa dry-bulb temperature (°C)
21	9 am 600 hPa mixing ratio (g/kg)
22	9 am 500 hPa dry-bulb temperature (°C)
23	9 am 500 hPa mixing ratio (g/kg)
24	9 am 400 hPa dry-bulb temperature (°C)
25	9 am 400 hPa mixing ratio (g/kg)
26	9 am 1000-700 hPa thickness (dam)
27	9 am 1000-500 hPa thickness (dam)
28	Probability of precipitation during the early morning (%)
29	Probability of precipitation during the late morning (%)
30	Probability of precipitation during the afternoon (%)
31	Probability of precipitation during the evening (%)
32	Probability of precipitation during the morning (%)
33	Probability of precipitation later (%)
34	Probability of precipitation during the forecast period (%)
35	Probability of thunderstorms during the early morning (%)
36	Probability of thunderstorms during the late morning (%)
37	Probability of thunderstorms during the afternoon (%)
38	Probability of thunderstorms during the evening (%)
39	Probability of thunderstorms during the morning (%)
40	Probability of thunderstorms later (%)
41	Probability of thunderstorms during the forecast period (%)
42	Probability of fog during the early morning (%)
43	Probability of fog during the late morning (%)
44	Probability of fog during the afternoon (%)
45	Probability of fog during the evening (%)
46	Probability of fog during the morning (%)
47	Probability of fog later (%)
48	Probability of fog during the forecast period (%)
49	Cloud amount during the early morning (octas)
50	Cloud amount during the late morning (octas)
51	Cloud amount during the afternoon (octas)
52	Cloud amount during the evening (octas)
53	Cloud amount during the morning (octas)
54	Cloud amount later (octas)
55	Cloud amount during the forecast period (octas)
56	Mean of midnight and 3 am total cloud amount (octas)
57	Mean of 6 am and 9 am total cloud amount (octas)
58	Mean of noon and 3 pm total cloud amount (octas)
59	Mean of 6 pm and 9 pm total cloud amount (octas)
60	Mean of midnight, 3 am, 6 am and 9 am total cloud amount (octas)
61	Mean of noon, 3 pm, 6 pm and 9 pm total cloud amount (octas)
62	Mean of midnight, 3 am, 6 am, 9 am, noon, 3 pm, 6 pm and 9 pm total cloud amount (octas)
63	Mean of midnight and 3 am total low cloud amount (octas)
64	Mean of 6 am and 9 am total low cloud amount (octas)

see next page ...

65	Mean of noon and 3 pm total low cloud amount (octas)
66	Mean of 6 pm and 9 pm total low cloud amount (octas)
67	Mean of midnight, 3 am, 6 am and 9 am total low cloud amount (octas)
68	Mean of noon, 3 pm, 6 pm and 9 pm total low cloud amount (octas)
69	Mean of midnight, 3 am, 6 am, 9 am, noon, 3 pm, 6 pm and 9 pm total low cloud amount (octas)
70	Mean of midnight and 3 am total middle cloud amount (octas)
71	Mean of 6 am and 9 am total middle cloud amount (octas)
72	Mean of noon and 3 pm total middle cloud amount (octas)
73	Mean of 6 pm and 9 pm total middle cloud amount (octas)
74	Mean of midnight, 3 am, 6 am and 9 am total middle cloud amount (octas)
75	Mean of noon, 3 pm, 6 pm and 9 pm total middle cloud amount (octas)
76	Mean of midnight, 3 am, 6 am, 9 am, noon, 3 pm, 6 pm and 9 pm total middle cloud amount (octas)
77	Probability of low cloud type 9 during the early morning (%)
78	Probability of low cloud type 9 during the late morning (%)
79	Probability of low cloud type 9 during the afternoon (%)
80	Probability of low cloud type 9 during the evening (%)
81	Probability of low cloud type 9 during the morning (%)
82	Probability of low cloud type 9 later (%)
83	Probability of low cloud type 9 during the forecast period (%)
84	Rainfall during the early morning (mm)
85	Rainfall during the late morning (mm)
86	Rainfall during the afternoon (mm)
87	Rainfall during the evening (mm)
88	Rainfall during the morning (mm)
89	Rainfall later (mm)
90	Rainfall during the forecast period (mm)
91	9 am dewpoint depression (°C)
92	Noon dewpoint depression (°C)
93	3 pm dewpoint depression (°C)
94	Mean of 9 am and noon dewpoint depression (°C)
95	Mean of 9 am and 3 pm dewpoint depression (°C)
96	Mean of noon and 3 pm dewpoint depression (°C)
97	Mean of 9 am, noon and 3 pm dewpoint depression (°C)
98	9 am surface dewpoint temperature (°C)
99	9 am surface dewpoint depression (°C)
100	9 am 900 hPa dewpoint temperature (°C)
101	9 am 900 hPa dewpoint depression (°C)
102	9 am 850 hPa dewpoint temperature (°C)
103	9 am 850 hPa dewpoint depression (°C)
104	9 am 800 hPa dewpoint temperature (°C)
105	9 am 800 hPa dewpoint depression (°C)
106	9 am 700 hPa dewpoint temperature (°C)
107	9 am 700 hPa dewpoint depression (°C)
108	9 am 600 hPa dewpoint temperature (°C)
109	9 am 600 hPa dewpoint depression (°C)
110	9 am 500 hPa dewpoint temperature (°C)
111	9 am 500 hPa dewpoint depression (°C)
112	9 am 400 hPa dewpoint temperature (°C)
113	9 am 400 hPa dewpoint depression (°C)
114	Estimate of mean of midnight and 3 am high cloud amount (octas)
115	Estimate of mean of 6 am and 9 am high cloud amount (octas)
116	Estimate of mean of noon and 3 pm high cloud amount (octas)
117	Estimate of mean of 6 pm and 9 pm high cloud amount (octas)
118	Estimate of mean of midnight, 3 am, 6 am and 9 am high cloud amount (octas)
119	Estimate of mean of noon, 3 pm, 6 pm and 9 pm high cloud amount (octas)
120	Estimate of mean of midnight, 9 am, noon, 3 pm, 6 pm and 9 pm high cloud amount (octas)
121	U component of morning's wind (knots)
122	V component of morning's wind (knots)
123	Magnitude of morning's wind (knots)
124	U component of afternoon's wind (knots)
125	V component of afternoon's wind (knots)
126	Magnitude of afternoon's wind (knots)
127	Not used
128	Not used
129	Not used
130	Not used
131	Data type 1 (previous day)
.	.
.	.
260	Data type 130 (previous day)

Table 12 Data available for regression analysis.

### 3.6 Specification of Parameters.

The following parameters need to be specified beforehand for analogue and local weather data retrieval, determination of the wind and weather guidance, and the regression analysis:

- grid name;
- grid point (station) names;
- initial data or prognosis;
- grid point weights for analysis and/or prognosis data;
- grid point weights for calculation of mean MSL pressure;
- data type weights;
- similarity parameter or S1 skill score;
- beginning and end year of analogue search;
- flag indicating window selection;
- lower and upper limits of selection window;
- forecast station names;
- flag indicating radiosonde station;
- flags indicating weighted wind and weather observations;
- threshold probabilities of precipitation, thunderstorms and fog;
- number of maximum, minimum and dewpoint temperature, rainfall and fog probability predictors and their data types; and
- flag indicating weighted regression analysis.

### 3.7 Fire Weather Temperatures.

The fire weather temperatures module of the operational model uses the forecast temperature guidance generated for all the five forecast stations (Melbourne, Mildura, East Sale, Mt Gambier and Wagga) and a series of previously developed monthly regression equations to produce forecast maximum, minimum and dewpoint temperature guidance for each of the following regional centres; Penola, Bombala, Albury, Deniliquin, Swan Hill, Nhill, Horsham, Stawell, Bendigo, Shepparton, Beechworth, Bonegilla, Omeo, Mt Buffalo, Mt Hotham, Nowa Nowa, Orbost, Yallourn, Olsens Bridge, Latrobe Valley Airport, Noojee, Melbourne Airport, Geelong, Mangalore, Ballarat, Hamilton, Warrnambool and Weeaprounah.

The statistical technique used is multiple linear regression to derive an equation of the form:

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5$$

where Y is an estimate of the predictand (maximum, minimum or dewpoint temperature at a particular regional centre),  $X_i$  are the five predictors (Melbourne, Mildura, East Sale, Mt Gambier and Wagga maximum, minimum or dewpoint temperature) and  $B_i$  are the regression constant and the five regression coefficients derived from the development data sample (climatological data archives of the Bureau of Meteorology).

The forecast temperature guidance is not available for a particular regional centre and temperature if there were insufficient observations to derive the regression equation or the percentage of variance explained by the regression equation was less than 20% (arbitrarily chosen after perusal of the regression equation results).

### 3.8 Output.

Output from the operational model after analogue retrieval are the number of analogues retrieved and their dates, similarity parameters, S1 skill scores and correlation coefficients (for example, see section 5).

For each of the forecast stations, output from the operational model after local weather data retrieval are a subset of local weather data associated with the analogues. After determination of the wind and weather guidance, output are the worded description of the next day's wind and the maximum wind gust, the forecast probabilities of precipitation, thunderstorms and fog during the early morning, late morning, afternoon and evening, and the worded description of the next day's weather. After the regression analysis, output are the forecast maximum, minimum and dewpoint temperatures, rainfall and fog probability (for example, see section 5).

For each of the regional centres, output from the operational model are the forecast maximum, minimum and dewpoint temperatures (for example, see section 5).

#### 4. PARALLEL TRIAL.

The development of the generalised UNIX version of the Victorian Regional Office's (VROs) operational analogue statistics (AS) model was a joint effort between the Bureau of Meteorology Research Centre (BMRC) and the VRO. It was introduced into the VRO during August 1993 with the intention to provide more timely and accurate real-time weather forecast guidance in the Regional Forecasting Centre (RFC) of the VRO. The forecasters in the RFC of the VRO gained familiarity with this updated version (new data entry interface and updated data base) through "telnet" access to a BMRC workstation.

A parallel trial of the TANDEM and UNIX versions of the AS model was conducted by the forecasters in the RFC of the VRO during the following three months (Spring 1993). Apart from providing them with additional familiarity with the UNIX version, it enabled an assessment to be made of the impact of the enlarged data base and consistency of the output from both the TANDEM and UNIX versions. This was necessary prior to operational implementation, in particular, to reveal any errors introduced with the UNIX version.

The input data used in the parallel trial were extracted and entered into the AS model by the forecasters in the RFC of the VRO, using the NWP "model of choice" and the same set of operating conditions for the TANDEM and UNIX versions. The results of this trial do not represent a verification of the model, rather a comparison of the relative performances of the TANDEM and UNIX versions. The performance of the forecast temperature and rainfall guidance is measured in terms of the root mean square error (RMSE), in addition to the number of major errors ( $\geq 6^\circ\text{C}$ ) for temperature only. In addition, the statistical significance of the difference between the two sets of forecast guidance is tested using a 2-tail t-test (Yamane, 1973). The 2-tail test was chosen as the changes to the AS model would not be anticipated to lead to a significant improvement in performance.

The RMSEs and number of major errors (in brackets) for temperature only of the Melbourne forecast maximum, minimum and dewpoint temperature and rainfall guidance produced by the UNIX version of the AS model over the three Spring months in 1993 are presented in Table 13. Also presented in Table 13, in italics, are the differences (UNIX - TANDEM) in the RMSEs and number of major errors (in brackets) for temperature only. Application of the 2-tail t-test suggests no significant differences between the RMSEs of the temperature and rainfall guidance for Melbourne produced by the TANDEM and UNIX versions.

MELBOURNE 1993	TEMPERATURE ( $^\circ\text{C}$ )			RAINFALL (ranges)
	Maximum	Minimum	Dewpoint	
September	2.35 (0) <i>+0.05 (0)</i>	1.82 (0) <i>-0.05 (0)</i>	2.71 (2) <i>+0.00 (+1)</i>	1.45 <i>+0.05</i>
October	1.99 (0) <i>+0.05 (0)</i>	1.64 (0) <i>+0.04 (0)</i>	2.86 (1) <i>+0.21 (0)</i>	1.18 <i>+0.00</i>
November	4.40 (4) <i>+0.20 (0)</i>	1.20 (0) <i>-0.12 (0)</i>	3.19 (4) <i>+0.29 (+2)</i>	1.15 <i>-0.02</i>
Spring	3.13 (4) <i>+0.11 (0)</i>	1.57 (0) <i>-0.04 (0)</i>	2.94 (7) <i>+0.18 (+3)</i>	1.27 <i>+0.02</i>

**Table 13** RMSEs and number of major errors (in brackets) for temperature only of the Melbourne forecast maximum, minimum and dewpoint temperature and rainfall guidance produced by the UNIX version of the operational AS model over Spring 1993. In italics, differences (UNIX - TANDEM) in the RMSEs and number of major errors of the two versions.

The impact of the enlarged data base can be represented by the percentage of analogues selected from the additional years (1985-92 inclusive) in the synoptic data base. During the Spring 1993 trial an average of 8 analogues were selected from the additional years. This indicates that 33% of the analogues selected were from these latter years, which is consistent with the increase in the length (from 15 to 23 years) of the synoptic data base.

An error in the TANDEM version of the AS model was revealed during the familiarisation period and evident during the trial. The handling of missing data in the regression analysis was incorrect in that the mean was used as the regression estimate in these cases (instead of eliminating the day with missing data prior to deriving the regression equation). This situation occurred 7 times during the trial, in particular, 4 times for Melbourne, and would be expected to have had a small negative influence on the accuracy of the forecast guidance. This error was subsequently corrected in the UNIX version.

After completion of the parallel trial during the Spring of 1993 and the assessment of the results of this trial, the generalised UNIX version of the VRO's operational AS model was now ready for operational implementation.

#### 5. OPERATIONAL IMPLEMENTATION.

The UNIX version of the operational analogue statistics (AS) model was implemented operationally in the Regional Forecasting Centre (RFC) of the Victorian Regional Office (VRO) during April 1994 on its Silicon Graphics workstation. The weather forecast guidance is now available to the forecaster immediately upon completion of the data extraction and entry (compared to waiting several minutes with the TANDEM version).

An example of the weather forecast guidance produced by the operational AS model in the RFC of the VRO on 3 October 1994 for the next day is presented. The operating conditions of the AS model have been fixed when run in the operational environment. The parameters (see section 3.6) used in the operational model can be summarised as follows:

- (a) Original (pilot model) grid;
- (b) See Table 14;
- (c) Prognosis;
- (d) See Table 14;
- (e) See Table 14;
- (f) 0.75 and 0.25 (data type weights);
- (g) Similarity parameter;
- (h) 1970-93 inclusive (analogue search);
- (i) True (window selection);
- (j) ±15 days;
- (k) See Table 15;
- (l) See Table 15;
- (m) True (weighted wind and weather observations);
- (n) 50% (threshold probabilities);
- (o) See Table 15; and
- (p) True (weighted regression analysis).

(b) Grid point (station) name	Grid point weight	
	(d)	(e)
Perth	0	0
Albany	0	0
Esperance	0	0
Forrest	2	0
Kalgoorlie	0	0
Adelaide	2	0
Mt Gambier	2	0
Woomera	0	0
Cobar	0	0
Nowra	2	0
Laverton	2	12
Hobart	2	0

Table 14 Parameters (b), (d) and (e).

In order to access the operational model the forecaster enters the following command on the workstation "vicgamma" after the "%" prompt:

gasm <cr> where <cr> means press the RETURN key

(k) Forecast station name		Melbourne	Mildura	East Sale	Mt Gambier	Wagga
(l) Radiosonde station		True	False		True	
(o) P r e d i c t o r s	Dewpoint temperature	850 hPa temperature [14]	Dewpoint temperature (previous day) [136]			
	Maximum temperature		Dewpoint temperature (previous day) [136] Maximum temperature (previous day) [137]			
	Minimum temperature					
	Fog probability					
	Rainfall	Nil				

Table 15 Parameters (k), (l) and (o). The numbers in square brackets refer to the data type number (see Table 12).

and the following display and prompt will appear:

ANALOGUE STATISTICS MODEL  
ANALOGUES (PART 1) ? (Y/N) : Y

The ANALOGUES (PART 1) option prompts the forecaster for both analysis and prognosis MSL pressure data for 6 stations (grid points). After data entry is completed a maximum of 25 analogues are selected from the data base which covers the period 1970-92 inclusive.

If "N" is entered as the answer to the above prompt this part of the operational model will be skipped, not updating the list of analogues selected from the previous run. When "Y" is entered as the answer to the above prompt (<cr> default) the following prompt will appear:

Enter date (dd/mm/yy, T or Y) : T

Normally "T" (today's date) will be entered as the answer to the above prompt (<cr> default). The forecast date (tomorrow's date) is calculated by adding one day to today's date. Any date (in the form dd/mm/yy) or "Y" (yesterday's date) can also be entered as the answer to the above prompt to enable the selection of analogues using historical input data.

After a valid date (for example, 3/10/94) has been entered as the answer to the above prompt, the analysis and prognosis MSL pressure data previously entered will be displayed and the following prompt will appear:

Forecast Date : 4/10/94

PERTH	0.0	0.0
ALBANY	0.0	0.0
ESPERANCE	0.0	0.0
FORREST	1015.5	1014.0
KALGOORLIE	0.0	0.0
ADELAIDE	1006.1	1010.0
MT GAMBIER	1003.6	1006.0
WOOMERA	0.0	0.0
COBAR	0.0	0.0
NOWRA	1005.7	1008.0
LAVERTON	998.8	1006.0
HOBART	1004.3	994.0

Correct date ? (Y/N) : Y

If "N" is entered as the answer to the above prompt then the forecaster will be prompted again to re-enter the date. When "Y" is entered as the answer to the above prompt (<cr> default) the following display and prompt will appear:

Update ANALOGUE data

1 - Analysis (MSL Pressure)  
2 - Prognosis (MSL Pressure)  
E - Exit

Enter choice (1-2 or E) : 1

If "1" (or "2") is entered as the answer to the above prompt, each non-zero analysis (or prognosis) MSL pressure will be displayed, in turn, for updating by entering the new value to the right of the ":" prompt (for example, the current 09EST MSL pressures extracted from the 00UTC MSL analysis (3/10/94) (see Figure 2(a)) and the forecast 09EST MSL pressures extracted from the 00UTC MSL prognosis (4/10/94) (see Figure 2(b))). If <cr> is entered the pressure value will remain unchanged. The grid points (stations) used for analogue retrieval can neither be added to or deleted when the model is run operationally. A display similar to the following will appear:

Forecast Date : 4/10/94

	Analysis (MSL pressure)
	Old                      New
FORREST	1015.5 : 1009.8
ADELAIDE	1006.1 : 1011.6
MT GAMBIER	1003.6 : 1008.7
NOWRA	1005.7 : 1008.9
LAVERTON	998.8 : 1009.2
HOBART	1004.3 : 996.6

After the last pressure value has been entered the updated analogue data will then be displayed and the following prompt will appear again:

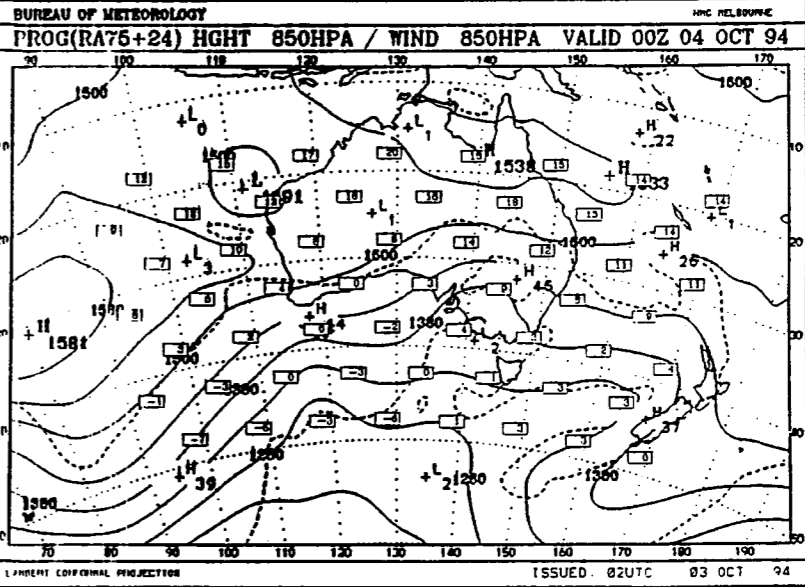
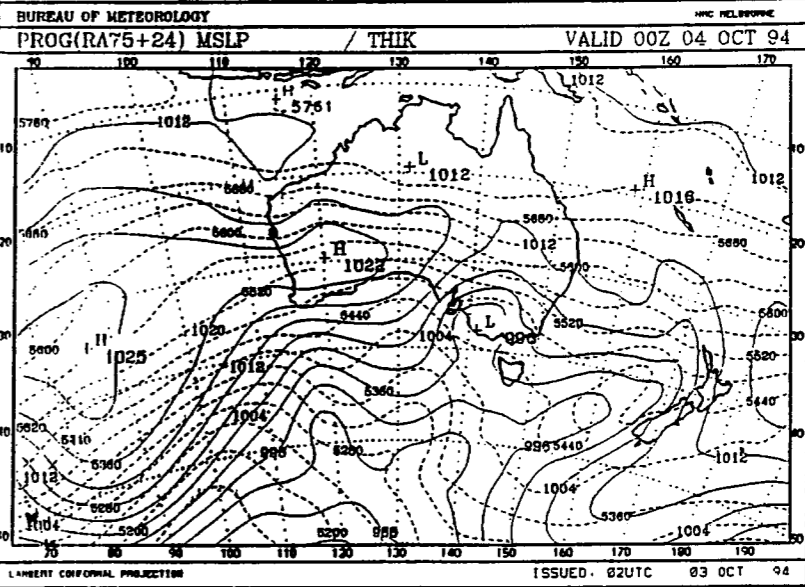
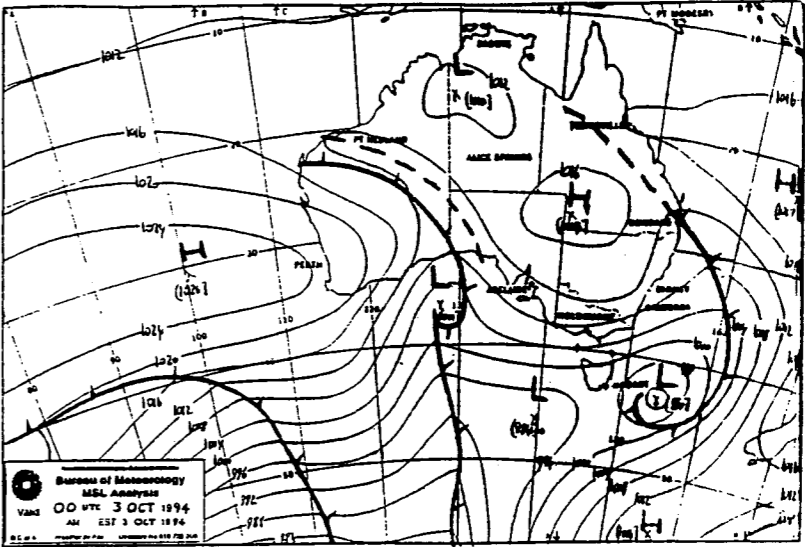


Figure 2 (a) 00UTC MSL analysis (3/10/94); (b) 00UTC MSL prognosis (4/10/94); and (c) 00UTC 850 hPa prognosis (4/10/94).

Forecast Date : 4/10/94

PERTH	0.0	0.0
ALBANY	0.0	0.0
ESPERANCE	0.0	0.0
FORREST	1009.8	1020.0
KALGOORLIE	0.0	0.0
ADELAIDE	1011.6	1002.0
MT GAMBIER	1008.7	996.0
WOOMERA	0.0	0.0
COBAR	0.0	.0
NOWRA	1008.9	1006.0
LAVERTON	1009.2	999.0
HOBART	996.6	1000.0

Update ANALOGUE data

- 1 - Analysis (MSL Pressure)
- 2 - Prognosis (MSL Pressure)
- E - Exit

Enter choice (1-2 or E) : E

When "E" is entered as the answer to the above prompt (<cr> default), the following prompt will appear:

Data OK ? (Y/N) : Y

If "N" is entered as the answer to the above prompt the analogue data will be re-displayed for updating. When "Y" is entered as the answer to the above prompt (<cr> default) the input analysis and prognosis data and a list of the analogues retrieved (and their similarity parameter, S1 skill score and correlation coefficient) will be displayed. A display and prompt similar to the following will appear:

INPUT ANALYSIS/PROGNOSIS DATA		
Station	Analysis MSL pressure	Prognosis MSL pressure
PERTH	0.0	0.0
ALBANY	0.0	0.0
ESPERANCE	0.0	0.0
FORREST	1009.8	1020.0
KALGOORLIE	0.0	0.0
ADELAIDE	1011.6	1002.0
MT GAMBIER	1008.7	996.0
WOOMERA	0.0	0.0
COBAR	0.0	0.0
NOWRA	1008.9	1006.0
LAVERTON	1009.2	999.0
HOBART	996.6	1000.0

THE NUMBER OF ANALOGUES SELECTED WAS 25  
WITH THE FOLLOWING DATE, SIMILARITY PARAMETER,  
S1 SKILL SCORE AND CORRELATION COEFFICIENT:

891012	171	29	0.43
921004	190	51	0.35
901019	204	29	0.37
701019	229	64	0.58
751011	233	38	0.68
721010	234	22	0.49
871016	235	17	0.41
790928	240	71	0.06
921017	246	58	0.27
850925	249	28	0.48
841003	266	50	0.44
711001	274	44	0.46
840921	279	92	0.55
790929	282	71	0.08
780922	282	55	0.14
901005	283	75	0.43
801006	285	100	0.28
870929	285	72	0.57
861018	296	41	0.31
740923	300	83	0.51
711015	301	36	0.54
890922	301	66	0.58
791010	303	47	0.75
910920	305	55	0.57
861006	310	63	0.32

WEATHER (PART 2) ? (Y/N) : Y

The WEATHER (PART 2) option prompts the forecaster for station data from a maximum of 5 stations. After data entry is completed a series of regression equations which the model has developed using data associated with the analogues selected in PART 1 are solved, and together with further statistical analyses of these data, weather forecast guidance is produced.

If "N" is entered as the answer to the above prompt this part of the operational model will be skipped, not updating the station data entered from the previous run. When "Y" is entered as the answer to the above prompt (<cr> default), the station data previously entered will be displayed and the following prompt appear:

Forecast Date : 4/10/94

MELBOURNE	Current Dewpoint	1
MELBOURNE	Current Maximum	19
MELBOURNE	Forecast 850 hpa Temperature	0
EAST SALE	Current Dewpoint	8
EAST SALE	Current Maximum	16
MILDURA	Current Dewpoint	4
MILDURA	Current Maximum	20
MT GAMBIER	Current Dewpoint	6
MT GAMBIER	Current Maximum	16
WAGGA	Current Dewpoint	3
WAGGA	Current Maximum	19

Update STATION data

- 1 - Current Dewpoint
- 2 - Current Maximum
- 3 - Forecast 850 hpa temperature
- E - Exit

Enter choice (1-3 or E) : 1

If "1" is entered as the answer to the above prompt, each current dewpoint will be displayed, in turn, for updating by entering the new value to the right of the ":" prompt (for example, the 3 pm dewpoint temperature extracted from the local weather observations). If <cr> is entered the dewpoint value will remain unchanged.

If "2" (or "3") is entered as the answer to the above prompt, each current maximum (or forecast 850 hPa temperature) will be displayed, in turn, for updating in the same manner as before (for example, the maximum temperature extracted from the local weather observations and the forecast 850 hPa temperature extracted from the 00UTC 850 hPa prognosis (4/10/94) (see Figure 2(c))). A display similar to the following will appear:

Forecast Date : 4/10/94

	Current Dewpoint	
	Old	New
MELBOURNE	1	: 2
EAST SALE	8	: 4
MILDURA	4	:
MT GAMBIER	6	: 9
WAGGA	3	: 4

If weather forecast guidance is not required for any station the value "-99" should be entered for its station data. After the last station data value has been entered the updated station data will then be displayed and the following prompt will appear again:

Forecast Date : 4/10/94

MELBOURNE	Current Dewpoint	2
MELBOURNE	Current Maximum	19
MELBOURNE	Forecast 850 hpa Temperature	4
EAST SALE	Current Dewpoint	4
EAST SALE	Current Maximum	18
MILDURA	Current Dewpoint	4
MILDURA	Current Maximum	20
MT GAMBIER	Current Dewpoint	9
MT GAMBIER	Current Maximum	15
WAGGA	Current Dewpoint	4
WAGGA	Current Maximum	18

Update STATION data

- 1 - Current Dewpoint
- 2 - Current Maximum
- 3 - Forecast 850 hpa temperature
- E - Exit

Enter choice (1-3 or E) : E

When "E" is entered as the answer to the above prompt (<cr> default), the following prompt will appear:

Data OK ? (Y/N) : Y

If "N" is entered as the answer to the above prompt the station data will be re-displayed for updating. When "Y" is entered as the answer to the above prompt (<cr> default) then the input station data and the weather forecast guidance for the first forecast station will be displayed. A display and prompt similar to the following will appear:

INPUT STATION DATA			
Station	Max	Dewpt	850hPa Prog Temp
MELB	19.	2.	4.
SALE	18.	4.	0.
MILD	20.	4.	0.
MTGA	15.	9.	0.
WAGG	18.	4.	0.

DATA AND FORECAST FOR MELBOURNE

DATA ASSOCIATED WITH ANALOGUES:											PREVIOUS DAY	
NO.	DATE	MAX	MIN	RAIN	DPT	T850	THK7	THK5	T500	MAX	DPT	
1	891012	18.8	11.0	2.4	7	-99.0	-99	-99	-99.0	18.4	8	
2	921004	15.9	14.5	28.0	13	6.8	293	553	-17.4	22.6	7	
3	901019	15.1	10.9	7.4	10	3.1	289	546	-21.7	23.9	9	
4	701019	18.3	10.7	10.3	15	8.6	293	550	-17.8	21.8	1	
5	751011	17.5	12.2	6.6	7	7.4	293	551	-21.0	22.6	11	
6	721010	22.9	10.4	3.9	1	4.7	292	-99	-99.0	17.4	8	
7	871016	19.4	13.2	11.6	4	-99.0	-99	-99	-99.0	24.1	10	
8	790928	18.4	15.4	12.0	14	10.0	295	556	-17.8	20.1	15	
9	921017	17.8	13.0	18.4	14	7.9	293	555	-16.7	16.9	13	
10	850925	19.7	13.1	2.0	7	4.2	289	543	-24.9	25.1	10	
11	841003	18.7	16.3	23.0	13	7.5	293	554	-16.0	24.0	8	
12	711001	21.6	12.1	20.6	8	8.1	293	550	-19.7	15.8	11	
13	840921	13.2	8.6	10.6	6	0.3	285	538	-26.4	12.6	10	
14	790929	15.8	10.0	4.0	7	2.6	287	540	-25.5	18.4	14	
15	780922	16.9	11.5	0.0	9	5.2	290	548	-21.1	19.6	8	
16	901005	24.0	14.0	4.9	11	7.0	293	551	-15.4	19.8	11	
17	801006	17.4	14.3	14.4	15	7.1	293	554	-14.6	22.0	8	
18	870929	20.2	13.0	13.8	4	4.7	290	548	-19.8	25.9	9	
19	861018	20.8	14.7	1.4	13	9.8	295	557	-16.0	23.5	9	
20	740923	12.0	9.3	8.2	7	-0.2	285	536	-27.5	14.8	5	
21	711015	16.8	11.7	10.1	5	4.0	289	545	-21.5	27.0	12	
22	890922	17.2	12.6	8.8	11	-99.0	-99	-99	-99.0	20.0	5	
23	791010	17.7	11.9	13.0	8	5.2	291	549	-19.5	17.0	13	
24	910920	14.5	4.5	3.2	5	0.5	285	536	-25.2	14.0	3	
25	861006	18.3	12.2	3.0	12	5.5	291	552	-18.2	19.6	7	

FORECAST GUIDANCE ON 4/10/94 FOR MELBOURNE

PROBABILITY OF	EARLY MORNING	LATE MORNING	AFTERNOON	EVENING
PRECIPITATION	67	92	96	68
THUNDERSTORMS	4	3	14	0
FOG	0	0	0	0

WEATHER:  
RAIN DURING THE MORNING. SHOWERS LATER.

WIND:  
LIGHT NORTHERLY WINDS TURNING LIGHT TO MODERATE WESTERLY.  
MAX WIND GUST: WEST TO SOUTHWESTERLY AT 30 KNOTS

MIN: 9.9 MAX: 16.4 DPT: 9.6  
RAIN: 9.7 FOG PROBABILITY: 0.0 POP: 89

\*\*\* HIT RETURN TO CONTINUE \*\*\*

When <cr> is entered the next station's weather forecast guidance (see Figure 3) will be displayed. After the last station's guidance (see Figure 3) is displayed the following prompt will appear:

Enter new values for STATION DATA ? (Y/N) : N

If "Y" is entered as the answer to the above prompt the station data will be re-displayed for updating and production of new weather forecast guidance. When "N" is entered as the answer to the above prompt (<cr> default) the following prompt will appear:

FIRE WEATHER TEMPERATURES ? (Y/N) : Y

The FIRE WEATHER TEMPERATURES option uses the forecast data generated for ALL of the five stations in PART 2 and a series of previously derived regression equations to produce forecast maximum, minimum and dewpoint temperature guidance for each of the "Fire Weather" forecast stations.

If "N" is entered as the answer to the above prompt then this part of the operational model will be skipped. When "Y" is entered as the answer to the above prompt (<cr> default) then the forecast maximum, minimum and dewpoint temperature guidance from PART 2 for all the five stations will be displayed. A display and prompt similar to the following will appear:

\*\*\*\*\*

VICTORIAN COUNTRY TOWNS FORECAST GUIDANCE

FORECAST for: 4/10/94

Input FORECAST TEMPERATURES were:-

	Min	Max	Dpt
Melbourne	: 9.9 C	16.4 C	9.6 C
Mildura	: 9.9 C	18.6 C	6.2 C
East Sale	: 6.2 C	19.3 C	4.8 C
Mt Gambier	: 7.3 C	13.8 C	8.3 C
Wagga Wagga	: 8.1 C	17.9 C	6.2 C

\*\*\*\*\*

\*\*\* HIT RETURN TO CONTINUE \*\*\*

After <cr> is entered the forecast temperature guidance for some of the "Fire Weather" stations will be displayed. A row of asterisks indicates that the forecast temperature guidance is not available for that station and temperature. A display and prompt similar to the following will appear:

DATA AND FORECAST FOR EAST SALE													
DATA ASSOCIATED WITH ANALOGUES:													
NO.	DATE	MAX	MIN	RAIN	DPT	T850	THK7	THK5	T500	PREVIOUS DAY	MAX	DPT	
1	891012	20.4	8.2	1.4	10-99.0	-99	-99	-99.0	-99	17.6	11		
2	921004	19.7	9.3	6.1	15-99.0	-99	-99	-99.0	-99	18.2	10		
3	901019	16.1	12.8	7.6	12-99.0	-99	-99	-99.0	-99	26.5	13		
4	701019	21.1	4.6	0.8	0-99.0	-99	-99	-99.0	-99	17.0	0		
5	751011	18.0	10.2	7.8	12-99.0	-99	-99	-99.0	-99	22.7	14		
6	721010	23.4	8.3	2.0	9-99.0	-99	-99	-99.0	-99	20.3	9		
7	871016	22.3	11.4	20.0	4-99.0	-99	-99	-99.0	-99	25.9	19		
8	790928	21.3	12.0	3.0	14-99.0	-99	-99	-99.0	-99	22.1	15		
9	921017	15.7	12.6	6.0	14-99.0	-99	-99	-99.0	-99	20.5	14		
10	850925	19.8	11.6	5.6	11-99.0	-99	-99	-99.0	-99	23.7	13		
11	841003	21.7	12.1	1.4	14-99.0	-99	-99	-99.0	-99	21.6	9		
12	711001	18.2	10.1	17.1	13-99.0	-99	-99	-99.0	-99	14.0	12		
13	840921	16.1	9.8	9.6	9-99.0	-99	-99	-99.0	-99	17.7	12		
14	790929	18.6	7.5	4.0	11-99.0	-99	-99	-99.0	-99	21.3	14		
15	780922	16.3	7.7	0.0	10-99.0	-99	-99	-99.0	-99	15.0	8		
16	901005	21.9	7.6	10.6	13-99.0	-99	-99	-99.0	-99	19.8	12		
17	801006	17.8	11.9	4.2	14-99.0	-99	-99	-99.0	-99	16.9	10		
18	870929	20.0	11.9	4.0	-99-99.0	-99	-99	-99.0	-99	26.9	-99		
19	861018	22.4	5.0	0.8	7-99.0	-99	-99	-99.0	-99	20.4	10		
20	740923	15.0	8.0	3.4	7-99.0	-99	-99	-99.0	-99	14.5	6		
21	711015	18.0	8.7	5.9	9-99.0	-99	-99	-99.0	-99	30.5	11		
22	890922	17.4	6.6	6.2	12-99.0	-99	-99	-99.0	-99	16.9	10		
23	791010	21.1	8.6	4.2	11-99.0	-99	-99	-99.0	-99	22.7	12		
24	910920	14.8	3.4	4.4	1-99.0	-99	-99	-99.0	-99	13.0	5		
25	861006	17.1	5.7	2.6	13-99.0	-99	-99	-99.0	-99	17.7	9		

FORECAST GUIDANCE ON 4/10/94 FOR EAST SALE

PROBABILITY OF	EARLY MORNING	LATE MORNING	AFTERNOON	EVENING
PRECIPITATION	52	69	85	73
THUNDERSTORMS	13	0	29	9
FOG	36	23	0	0

WEATHER:  
RAIN DURING THE MORNING. SHOWERS LATER.

WIND:  
LIGHT AND VARIABLE WINDS BECOMING LIGHT TO MODERATE WESTERLY.

MAX WIND GUST: WESTERLY AT 32 KNOTS

MIN: 6.2 MAX: 19.3 DPT: 4.8  
RAIN: 5.5 FOG PROBABILITY: 38.8 POP: 73

DATA AND FORECAST FOR MILDURA													
DATA ASSOCIATED WITH ANALOGUES:													
NO.	DATE	MAX	MIN	RAIN	DPT	T850	THK7	THK5	T500	PREVIOUS DAY	MAX	DPT	
1	891012	21.6	13.8	0.0	-1-99.0	-99	-99	-99.0	-99	25.2	4		
2	921004	19.6	13.8	17.6	11-99.0	-99	-99	-99.0	-99	25.1	4		
3	901019	18.6	13.7	0.8	2-99.0	-99	-99	-99.0	-99	30.7	1		
4	701019	21.6	13.2	1.7	12-99.0	-99	-99	-99.0	-99	24.8	3		
5	751011	17.8	14.3	5.2	0-99.0	-99	-99	-99.0	-99	21.3	9		
6	721010	22.5	11.0	0.3	8-99.0	-99	-99	-99.0	-99	25.9	7		
7	871016	17.9	9.3	3.0	10-99.0	-99	-99	-99.0	-99	22.3	17		
8	790928	20.0	11.5	8.8	2-99.0	-99	-99	-99.0	-99	19.0	16		
9	921017	24.1	15.0	4.6	14-99.0	-99	-99	-99.0	-99	22.3	13		
10	850925	19.1	11.0	1.4	10-99.0	-99	-99	-99.0	-99	27.5	-3		
11	841003	17.7	14.6	9.4	11-99.0	-99	-99	-99.0	-99	28.8	-1		
12	711001	22.9	11.7	0.0	5-99.0	-99	-99	-99.0	-99	24.7	7		
13	840921	16.2	6.2	0.0	-1-99.0	-99	-99	-99.0	-99	16.1	5		
14	790929	18.6	9.9	4.6	8-99.0	-99	-99	-99.0	-99	20.0	2		
15	780922	17.9	9.2	6.6	7-99.0	-99	-99	-99.0	-99	16.8	8		
16	901005	23.6	16.0	0.0	5-99.0	-99	-99	-99.0	-99	26.2	2		
17	801006	20.8	15.4	9.8	15-99.0	-99	-99	-99.0	-99	31.2	2		
18	870929	18.9	10.5	2.8	5-99.0	-99	-99	-99.0	-99	30.7	9		
19	861018	21.5	14.5	7.2	3-99.0	-99	-99	-99.0	-99	28.3	-3		
20	740923	11.8	6.0	1.8	7-99.0	-99	-99	-99.0	-99	15.2	3		
21	711015	19.6	14.9	0.3	-1-99.0	-99	-99	-99.0	-99	25.7	-1		
22	890922	22.3	12.4	0.0	7-99.0	-99	-99	-99.0	-99	25.0	3		
23	791010	17.2	12.1	4.6	5-99.0	-99	-99	-99.0	-99	22.1	12		
24	910920	19.5	2.4	0.2	1-99.0	-99	-99	-99.0	-99	15.2	4		
25	861006	21.2	12.3	5.0	12-99.0	-99	-99	-99.0	-99	24.2	1		

FORECAST GUIDANCE ON 4/10/94 FOR MILDURA

PROBABILITY OF	EARLY MORNING	LATE MORNING	AFTERNOON	EVENING
PRECIPITATION	63	59	58	16
THUNDERSTORMS	9	0	9	4
FOG	0	0	0	0

WEATHER:  
RAIN DURING THE MORNING. FEW SHOWERS LATER.

WIND:  
MODERATE WEST TO NORTHWESTERLY WINDS.

MAX WIND GUST: WESTERLY AT 33 KNOTS

MIN: 9.9 MAX: 18.6 DPT: 6.2  
RAIN: 3.8 FOG PROBABILITY: 0.0 POP: 65

DATA AND FORECAST FOR MT GAMBIER													
DATA ASSOCIATED WITH ANALOGUES:													
NO.	DATE	MAX	MIN	RAIN	DPT	T850	THK7	THK5	T500	PREVIOUS DAY	MAX	DPT	
1	891012	14.5	9.6	13.6	6-99.0	-99	-99	-99.0	-99	17.3	8		
2	921004	16.1	13.1	2.9	12 4.0	290	548	-20.9	20.0	20.0	8		
3	901019	12.0	6.9	5.4	7-99.0	-99	-99	-99.0	-99	18.3	10		
4	701019	13.2	3.9	0.3	5 6.1	291	549	-20.1	17.9	7			
5	751011	14.5	10.6	9.8	4 2.8	-99	-99	-99.0	16.6	11			
6	721010	15.2	9.5	5.5	11 1.6	286	540	-24.4	17.1	10			
7	871016	12.1	9.5	32.2	10-99.0	-99	-99	-99.0	21.0	13			
8	790928	14.2	12.4	24.6	10 4.5	290	548	-19.3	15.4	14			
9	921017	13.5	10.1	16.8	11 4.5	291	549	-19.6	18.2	10			
10	850925	16.4	11.2	2.0	11 4.9	290	546	-22.6	21.1	9			
11	841003	13.7	12.0	26.8	12 4.8	290	549	-20.2	20.5	8			
12	711001	14.7	11.2	10.5	11 5.0	291	-99	-99.0	15.6	11			
13	840921	13.9	3.5	3.4	3 -2.0	282	533	-25.3	12.8	6			
14	790929	16.2	4.0	3.0	7 2.2	288	542	-24.6	14.2	10			
15	780922	17.9	7.5	1.4	11 3.9	289	547	-21.0	17.2	9			
16	901005	14.2	10.3	4.2	9-99.0	-99	-99	-99.0	20.7	11			
17	801006	12.5	9.2	10.4	10 1.4	287	544	-20.9	15.2	14			
18	870929	15.7	9.5	3.8	11 2.1	287	542	-24.4	21.0	12			
19	861018	17.9	13.0	5.2	5 5.9	291	549	-18.9	25.3	7			
20	740923	13.0	3.9	4.8	6 -0.7	284	-99	-99.0	13.7	8			
21	711015	13.9	6.9	6.6	7 -0.6	285	533	-30.3	17.6	8			
22	890922	14.7	10.2	1.1	6-99.0	-99	-99	-99.0	21.0	10			
23	791010	13.5	9.9	14.4	6 0.3	285	537	-27.7	16.1	6			
24	910920	12.4	3.6	9.9	5 1.4	286	542	-22.9	11.7	3			
25	861006	15.9	11.6	5.4	12 5.7	291	551	-18.0	19.9	7			

FORECAST GUIDANCE ON 4/10/94 FOR MT GAMBIER

PROBABILITY OF	EARLY MORNING	LATE MORNING	AFTERNOON	EVENING
PRECIPITATION	85	96	96	92
THUNDERSTORMS	6	9	7	0
FOG	8	4	0	4

WEATHER:  
RAIN DURING THE MORNING. SHOWERS LATER.

WIND:  
LIGHT TO MODERATE WESTERLY WINDS.

MAX WIND GUST: WEST TO SOUTHWESTERLY AT 32 KNOTS

MIN: 7.3 MAX: 13.8 DPT: 8.3  
RAIN: 9.0 FOG PROBABILITY: 11.9 POP: 96

DATA AND FORECAST FOR WAGGA													
DATA ASSOCIATED WITH ANALOGUES:											PREVIOUS DAY		
NO.	DATE	MAX	MIN	RAIN	DPT	T850	THK7	THK5	T500	MAX	DPT		
1	891012	24.3	6.7	0.0	0-99.0	-99	-99	-99.0	-99	18.9	8		
2	921004	17.4	13.4	10.1	12 10.1	294	556	-15.0	20.9	10			
3	901019	16.7	14.7	20.0	9-99.0	-99	-99	-99.0	-99	25.6	6		
4	701019	27.8	10.0	9.9	13 13.3	298	559	-16.7	25.3	12			
5	751011	16.3	7.3	21.2	13 7.9	283	553	-17.4	21.7	15			
6	721010	22.6	12.9	0.0	5 14.3	299	564	-14.0	22.7	7			
7	871016	20.9	15.5	2.2	2-99.0	-99	-99	-99.0	-99	23.4	9		
8	790928	15.3	12.4	2.0	14 9.7	29	-99	-99.0	-99	23.4	9		
9	790929	16.7	14.7	20.0	9-99.0	-99	-99	-99.0	-99	25.6	6		
10	850925	17.7	12.6	1.0	9-99.0	-99	-99	-99.0	-99	23.5	11		
11	841003	16.0	14.6	24.8	13 8.8	295	558	-13.2	22.4	8			
12	711001	25.7	12.1	0.0	7 14.2	298	559	-16.7	25.3	12			
13	790928	15.3	12.4	2.0	14 9.7	29	-99	-99.0	-99	23.4	9		
14	790929	16.7	14.7	9.9	5 14.3	288	549	-99.0	-99	23.4	9		
15	780922	16.1	9.6	6.0	10 11.8	293	554	-18.2	21.7	10			
16	801005	17.7	8.0	0.0	10 9.7	29	-99	-99.0	-99	23.4	9		
17	870929	18.8	14.6	6.8	12 9.0	295	556	-15.8	21.7	11			
18	861018	20.5	9.0	7.0	15 12.1	296	558	-15.2	21.8	6			
19	740923	15.7	-0.4	2.0	24 6.6	293	553	-17.4	21.7	15			
20	890922	-0.5	7.4	0.0	3 11.7	296	-99	-99.0	-99	26.1	13		
21	790922	15.3	7.4	0.0	5 12.9	-99	-99	-99.0	-99	19.1	7		
22	791010	19.2	15.8	8.0	13 10.0	296	559	-16.2	21.7	15			
23	910920	13.5	2.3	7.0	13 1.7	283	538	-21.8	8.8	3			
24	890922	-0.5	7.4	0.0	14 4.5	291	551	-16.6	20.0	9			

## 6. CONCLUSIONS.

The main aim of this report has been to document the development of a generalised UNIX version of the Victorian Regional Office's (VRO) operational analogue statistics (AS) model. The AS model retrieves analogues to a current or forecast synoptic situation and the forecast guidance, in both quantitative and worded forms, are derived via statistical analyses of the local weather data associated with the analogues.

The AS model has been run operationally in the VRO since 1982. Since development of the generalised UNIX version, it has been run interactively by forecasters on a Silicon Graphics workstation. This recent development has been successful in that the time taken to run the model is shortened considerably while testing reveals the UNIX version's accuracy at predicting temperature and rainfall to be not significantly different from that of the TANDEM version.

An "ensemble" forecasting technique is currently employed in the Regional Forecasting Centre (RFC) of the VRO. Choices are made, from the suite of available numerical weather prediction (NWP) models, about the most likely evolution of the atmosphere and the forecast products are prepared manually. The operational AS model has become an integral part of the short term forecasting process. Development and extension of the AS model will facilitate automation in the preparation of these products. It is therefore suggested that further development of the AS model be undertaken in the following areas:

- . extension to other RFCs (national implementation);
- . extension (including addition of other grids, stations and relevant data types) of the synoptic (surface and upper air) and local weather data bases;
- . implementation of pilot model's concept to interactively vary operating conditions, and adoption as a standard, the improved, composite (fixed) operating conditions of Dahni (1988);
- . selection of analogues based on the synoptic situations of the past 2 or 3 days to try to take into account further the evolution of the current synoptic situation;
- . expansion of statistical analyses (including vectorial analyses of wind observations, variability analyses of weather elements, probability estimates of individual weather phenomena and codes, and stepwise screening of potential predictors);
- . expansion (including wind direction and speed) of guidance for fire weather stations;
- . prediction of specific weather elements out to 4 days in advance;
- . addition of an aviation module (generation of hourly weather guidance at an airport location);
- . verification of the UNIX version's weather forecast guidance in comparison with the official forecasts including a diagnosis of sources of error in the guidance (poor prognoses, analogues or diagnosed weather);
- . automation of data entry (accessing output of a variety of NWP models and observations from the real-time database);
- . initialisation of a forecast data base (for automatic verification and generation of "first guess" forecasts); and
- . addition of a graphical user interface and graphical display of analogues and forecast guidance (synoptic maps, scatter plots and weather meteors).

The operational application of the AS approach will continue to improve the standard of weather forecasting services provided by the Bureau of Meteorology.

## ACKNOWLEDGMENTS.

The authors thank forecasters of the RFC of the VRO for their assistance in running the trial, in particular, R. Ackroyd, R. Houghton, A. Kemp and W. Schereck. The authors also are grateful to the VRO RFC Supervisor, N. Fitt, for his support with the project and also the other reviewers, N. Davidson and P. Stewart. The help and advice of P. Gigliotti and J. Kelly is also appreciated.

## REFERENCES.

- Barclay, P.A., and Butt, I.C. 1988. Automation of regional forecasting centres in Australia. Preprints of the fourth international conference in interactive information and processing systems for meteorology, oceanography, and hydrology, Anaheim, Calif., 1-5 February 1988, Amer. Met. Soc., 21-24.
- Bureau of Meteorology. 1977. Recording and encoding weather observations. Bur. Met., Australia.
- Bureau of Meteorology. 1990. VRO 1989/1990 Fire Weather Report (internal Bureau of Meteorology document).
- Clarke, R.H. 1978. The future of weather forecasting in Australia. A lecture delivered at the Bureau of Meteorology, Melbourne, on 3 November, 1977. Australia Numerical Meteorology Research Centre, Melbourne, Australia. 44pp.
- Dahni, R.R. 1988. The development of an operational analogue statistics model to produce weather forecast guidance. Ph.D. Thesis, Department of Meteorology, University of Melbourne, Australia.
- Dahni, R.R., de la Lande, J., and Stern, H. 1984. Testing of an operational forecast guidance system. Aust. Met. Mag., 32, 105-106.
- De la Lande, J.D. 1985. Fire weather forecast preparation using AROS. Proceedings of the Fire Weather conference, 1985, Adelaide, Bur. Met., Australia.
- Gedzelman, S.D. 1994. Chaos rules. Weatherwise, Aug/Sep 1994, 21-26.
- Klein, W.H. 1970. The forecast research program of the Techniques Development Laboratory. Bull. Am. Met. Soc., 51, 133-142.
- Klein, W.H. 1978. The AFOS program of the U.S. National Weather Service ECMWF Seminars 1978 "The interpretation and use of large-scale numerical forecast products". 273-302.

- Love, G. 1994. An Australian Integrated Forecast System. International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography and Hydrology. Jan 23-28, 1994. Nashville, Tennessee. American Meteorological Society.
- Mills, G.A., and Tapp, R.G. 1984. The Australian operational MOS forecast system. Tech. Rep. 56, Bur. Met., Australia. 50pp.
- Seaman, R.S., Falconer, R.L., and Brown, J. 1977. Application of a variational blending technique to numerical analysis in the Australian region. Aust. Met. Mag., 25, 3-23.
- Stern, H. 1980. A system for automated forecasting guidance. Aust. Met. Mag., 28, 141-154.
- Stern, H. 1985. The development of a system of automated forecasting guidance using analogue retrieval techniques. M.Sc. Thesis, University of Melbourne, August 1980. Met. Study 35, Bur. Met., Australia. 182pp.
- Stern, H., and Dahni, R.R. 1981. Further testing of Stern's (1980) system for automated forecasting guidance. Aust. Met. Mag., 29, 69-70.
- Stern, H., and Dahni, R.R. 1982. An automated system for forecasting guidance. Abstracts of the fourth conference on Science Technology, Melbourne, August 1982 (ANZAAS-AIST).
- Stern, H., de la Lande, J., Dahni, R.R., Jasper, J.D., and Wilson, K. 1987. Meso-scale forecast guidance at the Victorian Regional Office. Operational Forecasting. Papers from the Senior Forecasters Conference June 1985. Training Note 2, Bur. Met., Australia. 175-179.
- Teweles Jr., S., and Wobus, H.B. 1954. Verification of prognostic charts. Bull. Am. met. Soc., 35, 455-463.
- Wagoner, R.A. 1973. A technique for using historical analogs to forecast the central pressure of tropical cyclones in the western North Pacific Ocean and South China Sea. M.S. Thesis, Department of Meteorology, Texas A & M University, College Station, Texas. 65pp.
- Woodcock, F. 1984. Australian experimental model output statistics forecasts of daily maximum and minimum temperature. Mon. Weath. Rev., 112, 2112-2121.
- Yamane, T. 1973. Statistics. An introductory analysis. (3rd Edn.). Harper and Row: New York. 664-666.