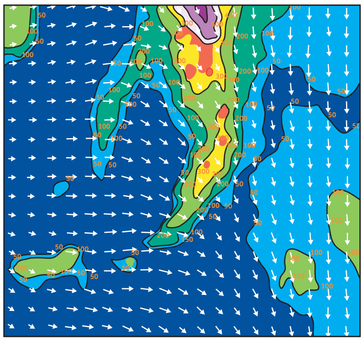
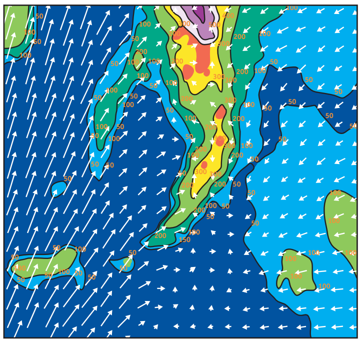
Evaluation of Air Pollution Model TAPM (version 2) for Adelaide





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Evaluation of The Air Pollution Model TAPM (Version 2) for Adelaide

Case Study (17–31 December 2002)

November 2004

Environment Protection Authority
South Australia

Evaluation of The Air Pollution Model TAPM (Version 2) for Adelaide: Case Study (17-31 December 2002)

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ISBN 1 876562 74 9

November 2004

Printed on recycled paper

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SUMMARY

This report summarises the results of a statistical evaluation of a three-dimensional prognostic model, called The Air Pollution Model, or TAPM (Version 2), for a well-defined, high ground-level ozone period, 17–31 December 2002, in Adelaide, South Australia. The emission inventory used in the TAPM evaluation is based on 1998–99 emission estimates for Adelaide.

The results indicate that TAPM predicted the meteorological and ozone pollution situation reasonably well for the simulation period. The model captured the extreme values (i.e. highs and lows) in the ambient temperature at Kent Town (an inland station) better than at Adelaide Airport (near the shoreline). This suggests that modelling data from stations near shorelines can have problems because of significant local effects, such as sea-breezes, that render the grid resolution inadequate for accurate simulation.

Overall TAPM satisfactorily reproduced the broad scale meteorological features but some aspects of local meso-scale features such as sea-breezes and north-easterly flows (gully winds) were not fully captured. A more comprehensive evaluation should be undertaken on local meso-scale winds.

The model captured the general features of surface ozone variation at both Elizabeth and Gawler air monitoring stations without any adjustment to the emission inventory. The maximum ozone concentration at Elizabeth was overestimated by 4.3 ppb and at Gawler by 1.83 ppb, but the overall performance at both stations was very good, with an index of agreement of greater than 0.7.

This limited quantitative assessment indicates that there is some room for improvement in the agreement between the monitoring data and the modelling output. However, the results are encouraging. The next stage of this study will be to evaluate a number of emission control strategies using this simulation as the base case scenario.

1 INTRODUCTION

Air quality modelling provides a link between measured air quality and emission estimates. It can thus be used to improve an air monitoring program and emission inventories in an airshed. Modelling allows air quality to be assessed in locations where no monitoring is/can be undertaken because of cost or logistics associated with monitor siting. Furthermore, it is nearly impossible to monitor at every point of interest and for the ever-increasing variety of air pollutants. Modelling helps fill in the gaps and serves as a tool for visualising the spatial extent and distribution of air pollution. It helps decision makers locate areas of concern where an air quality management plan is essential. However, local effects can vary from region to region and can affect model performance, even in a relatively homogenous environment. Thus an air quality dispersion model must be evaluated in a region before it is used as a decision-making tool in that region.

The South Australian Environment Protection Authority (EPA) began a project in June 2003 to apply the CSIRO's The Air Pollution Model, Version 2 (TAPM) framework, with meteorological and photochemistry/transport inputs, to an area of South Australia centred on the city of Adelaide. TAPM is a three-dimensional meteorology and air pollution dispersion model. In Phase I of the project, which is reported here, TAPM was applied retrospectively to a period chosen from the existing ambient air quality network within the study region, with the goal of establishing its usefulness as an air quality planning tool in Adelaide.

We approached this task through a step-wise model performance evaluation, using two meteorological and two air quality monitoring sites during a well-defined high surface ozone (O_3) pollution episode period in Adelaide. The O_3 mixing ratio did not exceed the one hour National Environment Protection Measure (NEPM) air quality criterion of 0.10 ppm at either of the two air quality sites but the maximum concentration approached 71% of the hourly NEPM criterion during this period. This report describes the results of our evaluation.

1.1 Adelaide region

Adelaide (with a population of approximately 1.03 million people) is the capital of South Australia. The Adelaide plains are bounded on the east (138° 35′ E) and south (34° 55′ S) by the Mount Lofty Ranges (called the Adelaide Hills in their central portion) and by the north–south coastline of Gulf St Vincent on the west. Figure 1 shows the map of South Australia with locations of the Adelaide meteorological and O_3 monitoring sites used in this study. Details of the physical characteristics of the regions can be found in *Ambient Air Quality Monitoring Plan for South Australia* (EPA 2001).

Meso-scale weather features in the Adelaide region are a consequence of the overall geographical situation of the coast, a relatively narrow coastal plain and then the ranges, which extend southwards to the tip of Fleurieu Peninsula and well to the north of Adelaide. The height of the ranges, reaching 700 m at Mount Lofty, and their orientation strongly influence winds on the Adelaide plains, particularly in north-west or south-east synoptic wind situations.

Adelaide has a moderate Mediterranean climate, with long, warm to hot summers and short, mild winters. Its average rainfall is approximately 553 mm (www.bom.gov.au).

Significant point pollution sources are either south of the residential suburbs, or in the north-western sector of the metropolitan area close to or on the Lefevre Peninsula (Figure 1) and its port facilities. In the north-west, there are cement works, a soda ash plant and glass works, and three gas-fired power stations with electrical capacity in excess of 1600 MW. Mitsubishi foundry is located south of Adelaide adjacent to the coast.

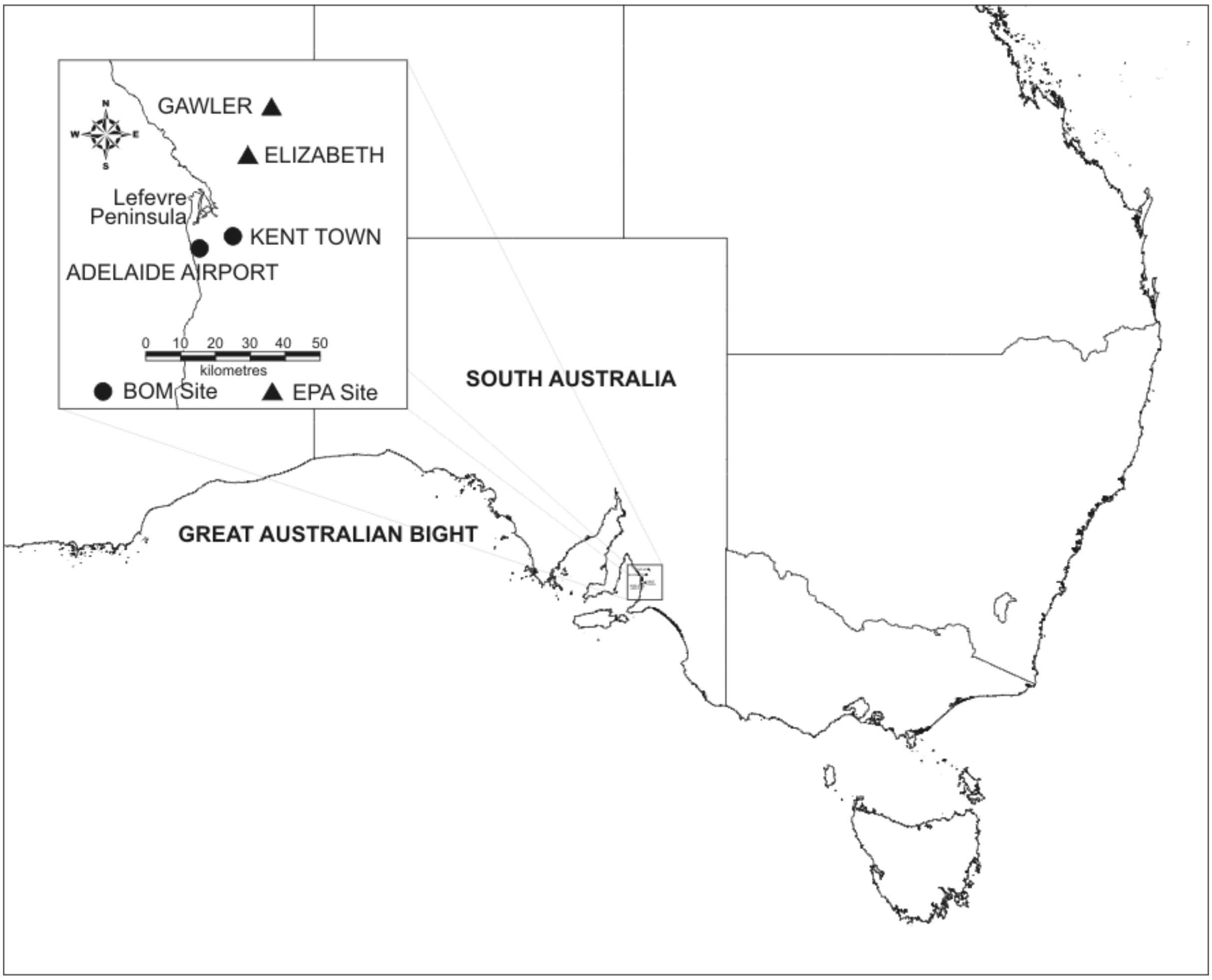

Figure 1. Map of South Australia showing salient coastal features and locations.
BOM = Bureau of Meteorology

1.2 Local summer wind patterns in the Adelaide region

Adelaide's siting along Gulf St Vincent brings sea breezes as a frequent feature, mainly over the summer months. These west to southwest winds develop during the day at variance with the synoptic flow and become more southerly during the day, before returning to the synoptic flow late afternoon or evening.

The strength of sea breezes can differ. Some sea breeze fronts push well inland while some stay along the coastal margin.

Downslope winds, known locally as 'gully winds', are a feature overnight and early morning in south-east to easterly synoptic wind flows, and under low wind conditions predominantly in summer.

Another feature is a low level northerly jet ahead of approaching frontal systems, when fresh to strong northerly winds are focused between the ranges and the approaching front. Gully winds create a light north-east 'drainage' flow across the Adelaide plains under light synoptic gradients, with good nocturnal (night-time) cooling.

1.3 Synoptic situation for 17–31 December 2002

The 14-day assessment period 17–31 December 2002 began with a high-pressure system centred in the western Tasman Sea, extending a weak ridge south of Western Australia into the Indian Ocean. A heat low in northern Western Australia extended a trough in a south-east direction to near Adelaide.

During 18 and 19 December a front to the south of the Great Australian Bight extended a trough through Adelaide as the Tasman high-pressure system moved further eastwards. A new high-pressure centre became established south of the bight during 20 December, weakening with the passage of another trough later on 21 December but returning during 22 December, with strong pressure rises during this period. The high remained the dominant feature of Adelaide weather for several days, moving only slowly eastwards into the Tasman Sea by 27 December, ahead of a low-pressure centre developing in the west of the bight. The low developed to be the dominant synoptic feature in the area on 29 and 30 December.

The synoptic situation during the period produced a predominately south-easterly airstream, with some north-easterly to north-westerly winds ahead of the passage of troughs, and south-westerly winds after the passage of troughs, in the last few days of the assessment period.

1.4 Ozone pollution situation for 17–31 December 2002

The goal for O_3, which is measured at five sites over Adelaide, is to keep hourly-averaged concentrations below 0.10 parts per million (ppm; or 100 parts per billion (ppb)[1]) and four-hourly-averaged concentrations below 0.08 ppm (80 ppb). These figures have not been exceeded at any site in Adelaide since 1986.

The EPA started monitoring for O_3 at Elizabeth and Gawler in January 2002. The Elizabeth monitoring station is located in a school in a residential suburban area about 1 km away from arterial roads and was established to track photochemical species north of Adelaide.

The Gawler (southern end of the Barossa Region) monitoring site was proposed in the 2001 air monitoring plan for South Australia (EPA 2001) as a useful position to ascertain any impact from the Adelaide urban plume, which contains principally photochemical oxidants (Physick et al. 1995). The results to date indicate low values of O_3.

In 2002, one-hour averaged concentrations at Elizabeth were in the range 0–0.072 ppm and did not exceed the NEPM criterion (Table 1). There were no exceedences of the NEPM

[1] 1 ppm = 1000 ppb

criterion at Gawler (Table 2), where the range was 0–0.056 ppm. The average over the year was 0.014 ppm at Elizabeth and 0.021 ppm at Gawler; neither exceeded the one-year NEPM criterion (0.03 ppm).

Table 1. 03 statistics at Elizabeth (2002)

Standard	No. of exceedences of standard	Maximum concentration (ppm)	90th percentile (ppm)	99th percentile (ppm)
1-hour NEPM criterion for O_3 (0.10 ppm)	0	0.072	0.031	0.042
4-hour NEPM criterion for O_3 (0.08 ppm)	0	0.057	0.030	0.038

Table 2. O_3 statistics at Gawler (2002)

Standard	No. of exceedences of standard	Maximum concentration (ppm)	90th percentile (ppm)	99th percentile (ppm)
1-hour NEPM criterion for O_3 (0.10 ppm)	0	0.056	0.030	0.040
4-hour NEPM criterion for O_3 (0.08 ppm)	0	0.050	0.030	0.038

Figure 2 shows the time series of O_3 data at Gawler and Elizabeth monitoring sites during 17–31 December 2002.

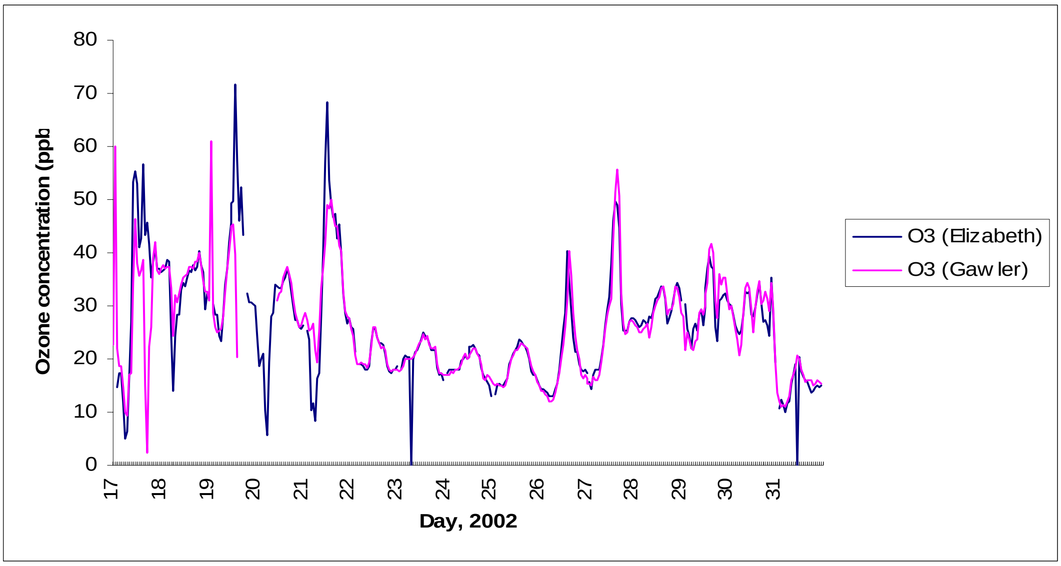

Figure 2. Time series of hourly O_3 data at Gawler and Elizabeth monitoring sites (17–31 December 2002)

It is apparent that, in spite of the differences in the station locations, the time series of O_3 has the same qualitative features. O_3 levels at Elizabeth tend to be lower than those at Gawler, especially at early morning hours. This is expected, since the Elizabeth monitoring site is characterised by high concentrations of freshly emitted nitric oxide (NO), which reacts quickly with any ambient O_3 in the reaction:

$$NO + O_3 \Rightarrow NO_2 + O_2.$$

The highest concentration of 71.1 ppb of O_3 occurred at the Elizabeth station at 1400 CST on Thursday 19 December 2002. The Gawler site does not exhibit any predominant increase in O_3 concentration at this time and corresponding concentration at this site is 40 ppb.

2 METHODOLOGY

2.1 Software

The modelling was carried out using TAPM software (version 2), a three-dimensional meteorology and air pollution dispersion model developed by CSIRO Atmospheric Research (Hurley 2002). It is built around the incompressible, non-hydrostatic equations of motion for atmospheric flow over complex topography. The lack of any approximations in the dynamic equations means that the model can theoretically be applied to simulate motion of any scale. TAPM is more complex than Gaussian models, such as AUSPLUME, in that the fundamental fluid dynamics and scalar transport equations are solved to model meteorology and pollutant concentration. The version of TAPM used in this study employs the GRS photochemistry option described by Hurley (2002).

2.2 Model setup and input data

The simulation was initiated at 0100 CST on 17 December 2002[2] and ran for 359 hours until 2200 CST December 31. The model was configured with three nested grids: the 50×50 points in the horizontal in grid spacings of 10 km, 3 km and 1 km. The 20 vertical levels had variable thicknesses at heights above the ground of 10 m, 50 m, 100 m, 150 m, 200 m, 300 m, 400 m, 500 m, 750 m, 1000 m, 1250 m, 1500 m, 2000 m, 2500 m, and 3000–8000 m in 1000 m intervals. The terrain data used was obtained from Geoscience Australia at nine-second grid spacing (approximately 0.3 km). The synoptic analysis data used in this model is based on six-hourly analysis fields of wind, temperature and specific humidity at a grid spacing of 1.0° from the Bureau of Meteorology Global Analyses and Prediction system, which accounts for the larger-scale synoptic variability. Other input data sets include Rand's global sea surface temperatures from NCAR, and soil and vegetation classification data from CSIRO Wildlife and Ecology.

The model calculates the concentration of a certain pollutant in the ambient air, based on a known amount of pollution (i.e. emission estimates) being emitted by industry, traffic and heating sources. This modelling evaluation exercise used Adelaide aggregate air emissions of 1998–99 (Ciuk 2002), which provide data for the following categories:

- line sources: emissions along roads and railways, recreational boating and shipping and commercial boating
- area sources: emissions arising over a large area, such as from domestic heating, architectural surface coatings, cutback bitumen, domestic and commercial solvents, domestic gas fuel, dry cleaning, lawn mowing and solid fuel burning
- sub-threshold sources: sub-threshold fuel combustion and sub-threshold industrial solvents.

Conventional preparation of emission inventories for air quality modelling is typically an extended and time consuming process using computer routines to reformat, quality check, chemically speciate, and temporally and spatially allocate data. The 1998–99 emission

[2] Actual modelling runs were conducted from 0100 CST of 15 December 2002. This first two-day period was required to adjust the internal dynamics of the model.

inventory for Adelaide was processed by CSIRO for a study assessing the impact of the Torrens Island power station upgrade on regional photochemical smog levels (Physick et al. 2003). Emissions files prepared by CSIRO for this study have been used in the current Adelaide region evaluation of TAPM for consistency. CSIRO separated vehicle emissions into petrol, diesel and LPG emissions (at 25°C), applied a summer diurnal profile to these emissions, generated a commercial/domestic and surface industrial file, and prepared a biogenics file (M Cope, CSIRO Melbourne, pers comm 2004).

The model was run with default model options and a deep soil moisture content of 0.09 (dry) for the simulation period. The background ozone level and the 'R_{smog}' reactivity parameter[3] were set at 20 ppb and 0.7 ppb respectively. Physick et al. (2003) suggested that a background ozone level of 20 ppb and an R_{smog} reactivity parameter of 0.7 were reasonably accurate for Adelaide data.

All applications were performed on a desktop workstation with 512 megabytes of memory. TAPM simulation required 20 minutes CPU time for every hour of simulated time. Modelled predictions (time resolution of one hour) were extracted at the nearest grid point to the Adelaide Airport, Kent Town, Elizabeth and Gawler monitoring stations on the innermost grid (1000 m) at the lowest model level (10 m above the ground) for winds, at screen-level for temperature and ozone.

One set of observed data is from the Bureau of Meteorology central wind anemometer at Adelaide Airport, about 7 km west-south-west of Adelaide GPO and 2 km from the coast. The other observation set is from the Bureau's SA Regional Office at Kent Town, 2 km east-north-east of the GPO.

2.3 Statistical measures for model evaluation

The accuracy of the base case model prediction was quantitatively assessed using statistical measures such as those suggested by Willmott (1981; 1982) and Pielke (1984). The principal statistical measures used for TAPM evaluation are:

- observed and modelled means and standard deviations of wind (U,V components, the west–east and south–north components respectively) and temperature and ozone concentration data
- root-mean-squared differences (RMSD) between modelled and observed data (measures the variance between observed and estimated values), as well as the systematic and unsystematic (RMSDu) components of the RMSD; a small value of RMSDu can be interpreted as an estimate of the precision of the model (Willmott 1985)
- the index-of-agreement (IOA) based on departures from the mean observed value; a value of IOA=1 indicates perfect agreement, and IOA=0 indicates absolutely no agreement
- the correlation, r, a normalised measure of how well the two series of data (observed and modelled) co-vary; a value of 1 or –1 implies observed and modelled are linearly dependent.

[3] R_{smog} = VOC concentration multiplied by an activity coefficient for smog production

The formulae for these measures can be found in the CSIRO Technical Paper No. 57 (Hurley 2002), which provides a brief summary of some verification studies for TAPM Version 2.

An additional statistical measure used to evaluate ozone time series is the robust highest concentration (RHC; Cox and Tikvart 1990) which is based on the mean of the top 10 pollutant concentrations. The RHC is preferred to the actual peak value because it mitigates the undesirable influence of unusual events while still representing the magnitude of maximum concentration (unlike percentiles or averages over the top-percentiles) (Hurley 2002).

3 RESULTS AND DISCUSSION

3.1 Meteorological evaluation

Meteorology plays a key role in the transport of secondary pollutants and their precursors. It is a critical driving factor for determining impact of emissions on air quality in an airshed and a model needs to be able to get this right if we are to have confidence in air quality predictions. A detailed analysis of the meteorological forecasts is presented in the following sections.

3.1.1 Adelaide Airport

The predicted hourly temperature is plotted against observed temperature for Adelaide Airport (AAP) for the period 17–31 December 2002 in Figure 3. The modelled temperature time series is in good agreement with observations at this station and the model generally appears to capture the overall trend (with troughs and crests). However, it does not quite get the extreme values. The other statistics for this site (Table 3) show the predicted temperature average was very accurate, only out by 0.1°C. Standard deviation of the temperature is 5.8°C for the observation and 7.8°C for the prediction. The RMSD of the modelled temperatures was 4.4°C; RMSDu made up most of this deviation, contributing 4.32°C. The IOA of 0.9 indicates very good model performance at this site.

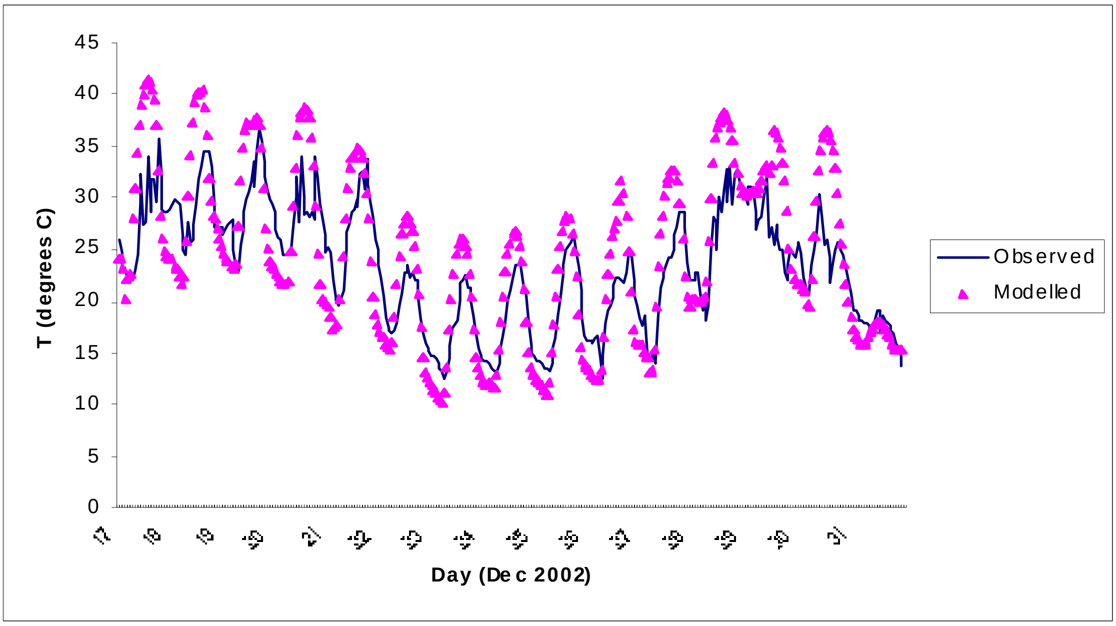

Figure 3. Predicted hourly temperature vs observed temperature for Adelaide Airport (17–31 December 2002)

Table 3. Temperature time series statistics (17–31 December 2002)

Station	n	T_o °C	T_m °C	STD_o °C	STD_m °C	RMSD °C	$RMSD_s$ °C	$RMSD_u$ °C	IOA	r
AAP	359	23.40	23.50	5.80	7.80	4.40	0.75	4.32	0.90	0.83
KT	359	24.60	23.50	6.90	7.80	3.91	1.12	3.75	0.93	0.88

T = time-averaged temperature; STD = standard deviation; o = observed values; m = modelled values; AAP = Adelaide Airport; KT = Kent Town meteorological monitoring site

The modelled time series of wind speed and direction are quite similar to the observed series at Adelaide Airport, although there are intervals where the errors are large (Figures 4, 5 and 6). The observed wind direction shows predominately south-east to south-west winds, as is expected from the wind climatology for the area (Figure 4). The south-east winds are reflective of the synoptic winds around high-pressure systems south of Adelaide, as seen through much of the assessment period. The model similarly displayed generally south-easterly winds in this time but there were fewer south-westerly winds predicted, in particular during the period of December 17 to 22 (Figure 5). During the period 21–26 December 2002 wind directions generally stayed within the east to south sector. At the Adelaide Airport site TAPM predicted the magnitude and frequency of the wind direction fluctuations very well.

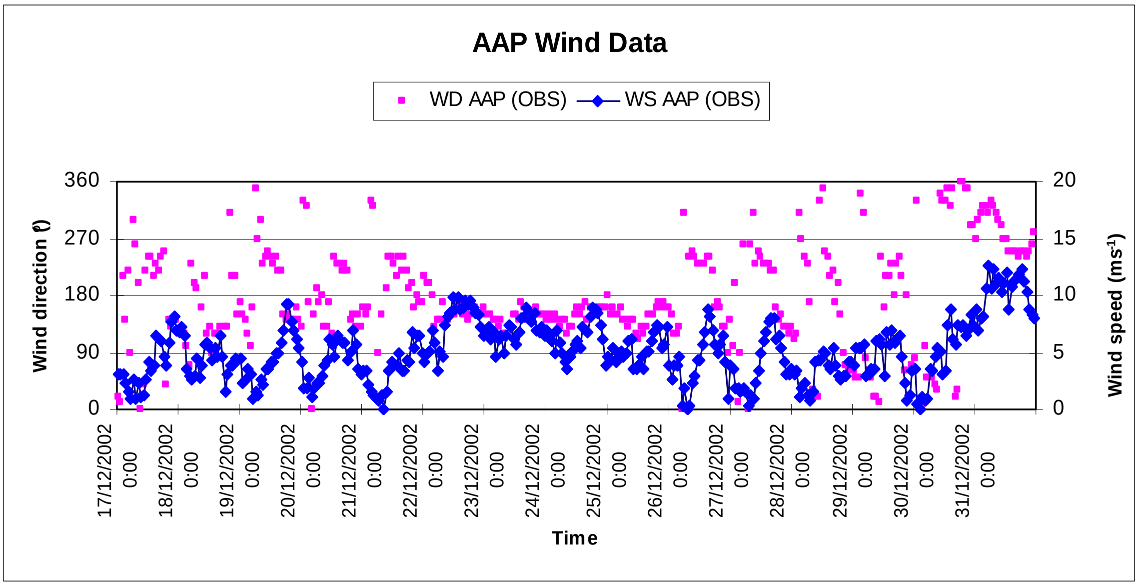

Figure 4. Observed hourly winds at Adelaide Airport (17–31 December 2002) WD = wind direction; WS = wind speed

In the later period, from 28 December, the winds shifted through the east to become north-east to north-west, before turning south-west then south-east and going north-east again overnight. This pattern saw a number of troughs moving through the area associated with various low centres in the Great Australian Bight. A front moved through the area on 30 December, as one of the low centres deepened.

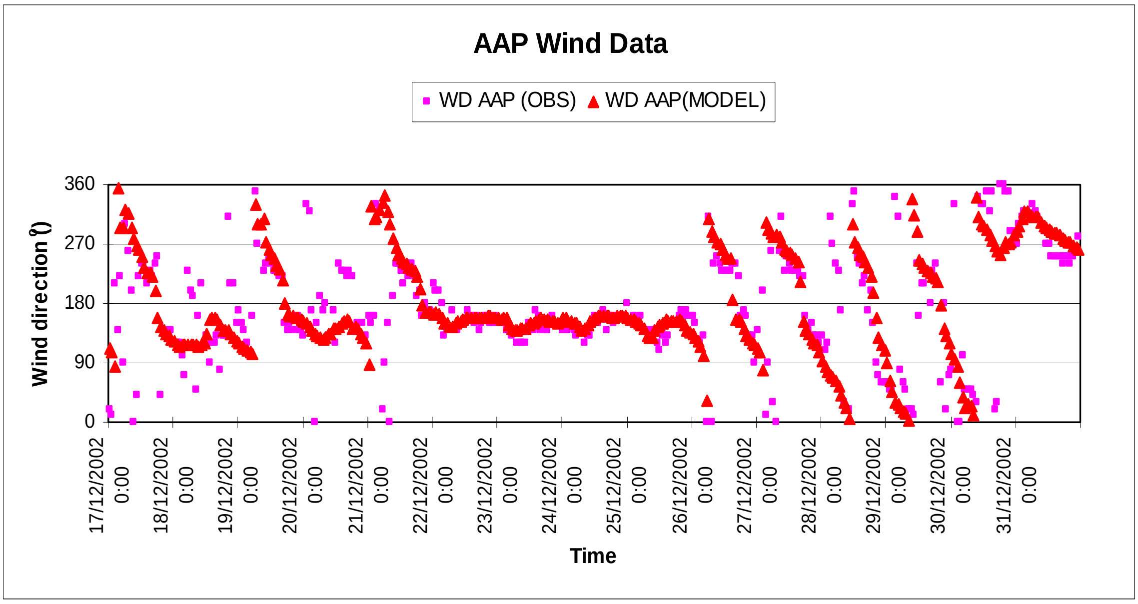

Figure 5. Observed and modelled hourly winds at Adelaide Airport (17–31 December 2002) WD = wind direction

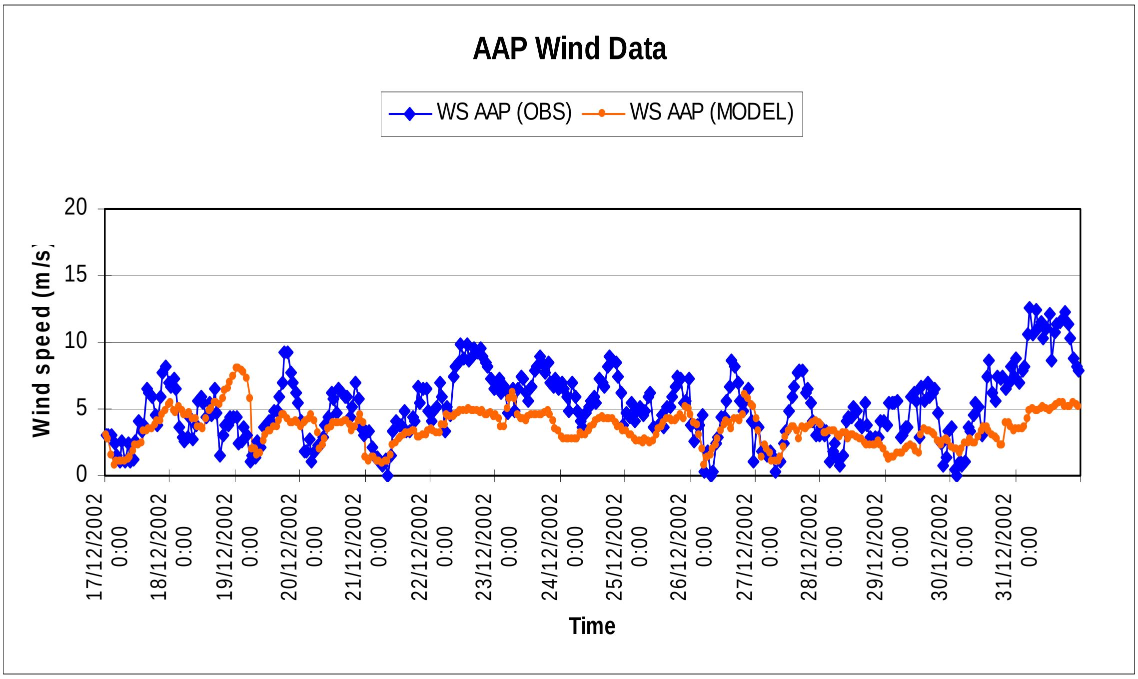

Figure 6. Observed and modelled hourly winds at Adelaide Airport (17–31 December 2002) WS = wind speed

Following the passage of the front and related troughs, the winds moved through the west to establish as fresh south-west winds on 31 December. In this period, the model similarly shifted the wind through the north then west, becoming fresh south-west winds by the end of 31 December.

The modelled wind speed for the study period is for the most part slightly lower than that observed at Adelaide Airport (Figure 6).

As sea-breezes are a major meso-scale feature over the region in December, they were given special attention in the comparison. Sea breeze onset and frequency varies across the airshed, with coastal locations experiencing earlier and more frequent sea-breeze events. Table 4 compares the time of onset and end of sea-breeze events at Adelaide Airport and Kent Town and how the TAPM modelled these events.

Table 4. Sea-breeze onset and cessation times in LDST 24-hr clock (December 2002)

Date	Adelaide Airport		Average TAPM		Kent Town		Average TAPM	
	onset	end	onset	end	onset	end	onset	end
17	1100	1800	1000	1700	1100	1800	1000	1700
19	1000	1700	1200	1600	1100	1600	1200	1600
20	1300	1800			1300	1800		
21	900	2000	1100	1800	1000	1900	1200	1900
26	900	1700			1200	1900		
27	1000	1700			1300	1900	1400	1800
28	1200	1800	1300	1900	1500	1800	1600	2000
29	1100	1900	1200	1800	1300	2100	1400	2100

Eight sea-breeze events are seen at Adelaide Airport. The criterion used for onset was the wind moving into the south-west quadrant during the day at variance with the synoptic winds. The end criterion was the wind moving into the south-east quadrant during the afternoon or evening (winds on 31 December satisfied these criteria but were excluded after examination of the synoptic situation).

Five of the eight observed sea-breeze events were produced by TAPM at Adelaide Airport and six at Kent Town, but usually with later onset times and earlier end times (Table 4).

On one of the five TAPM sea-breeze days (19 December) the model showed a quite late onset sea-breeze only lasting for four hours (see Table 4), which did not represent the observed winds of that day. No sea-breezes were observed nor modelled during 22–25 December in the moderate to fresh south-east winds present at that time at both Adelaide Airport and Kent Town.

The observed standard deviation of wind speed was nearly twice that of the model (Table 5), reflecting the model's inability to correctly estimate the strength of the sea-breeze. Average RMSD errors and its components are reasonably small, and the average IOA of 0.73 indicates that the predicted winds are acceptable. The IOA is a measure of how well predicted variations about the observed mean are represented; a value greater than 0.5 considered to be good, as judged by several other published prognostic modelling studies (Hurley et al. 2002).

Table 5. Wind time series statistics at Adelaide Airport (17–31 December 2002)

Para -meter	n	AVG_o m/s	AVG_m m/s	STD_o m/s	STD_m m/s	RMSD m/s	$RMSD_s$ m/s	$RMSD_u$ m/s	IOA	r
WS_{10}	359	5.1	3.5	2.6	1.3	2.75	2.50	1.15	0.58	0.50
U_{10}	359	-0.2	-0.6	3.9	2.6	2.74	2.01	1.86	0.81	0.71
V_{10}	359	2.2	1.6	3.6	2.1	2.56	2.15	1.39	0.80	0.75

WS_{10} = wind speed at 10 m above ground; U_{10} = west–east time-averaged wind component; V_{10} = south–north time-averaged wind component; STD = standard deviation; o = observed values; m = modelled values

3.1.2 Kent Town

The predicted temperature–time series is in good agreement with the observed values at Kent Town (KT) station (Figure 7). Table 3 lists the temperature statistics at this site; the average modelled temperature was 23.5°C instead of the observed 24.6°C. The modelled standard deviation was 7.80°C, which is acceptably close to the observed 6.9°C. The RMSD error of the simulation was small at 3.91°C, with a systematic component of 1.12°C and unsystematic component of 3.75°C. The IOA of 0.93 and a correlation of 0.88 shows that the model does a better job of estimating the highs and lows (i.e. extreme values) at Kent Town than it did at Adelaide Airport.

Comparison of the modelled wind directions with observations at Kent Town revealed TAPM predicted the sea-breeze directions to have slightly more westerly components, but generally there was good agreement with observations in the arrival times (Figures 8, 9 and 10). During the period 21–26 December 2002 wind directions generally stayed within the east to south sector. At the inland Kent Town site the TAPM predictions were in advance of the observations by several hours and the magnitude of the predicted fluctuations was slightly larger. In terms of wind speeds (Figure 10) an overall impression is that at the coast, TAPM underestimates the speeds but inland there are some large overestimates of peak heights and offsets in the times of occurrence of changes, e.g. 0300 CST on 23 December 2002. Eight sea-breezes were observed at Kent Town (Table 4). Six were produced by TAPM, with onset and end times, and speeds, being more in agreement with observations than was the case with Adelaide Airport.

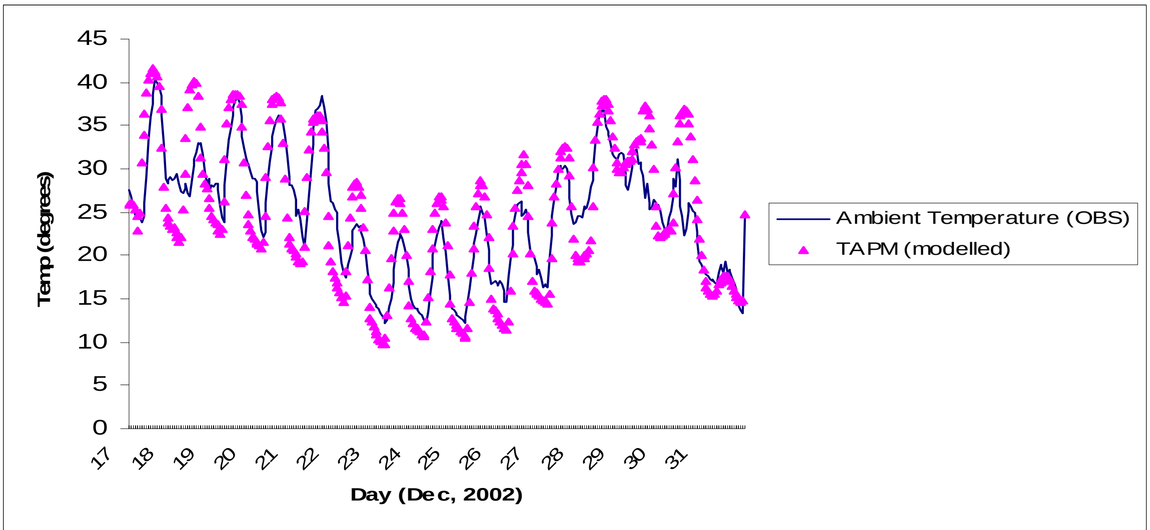

Figure 7. Predicted hourly temperature vs observed temperature for Kent Town (17–31 December 2002)

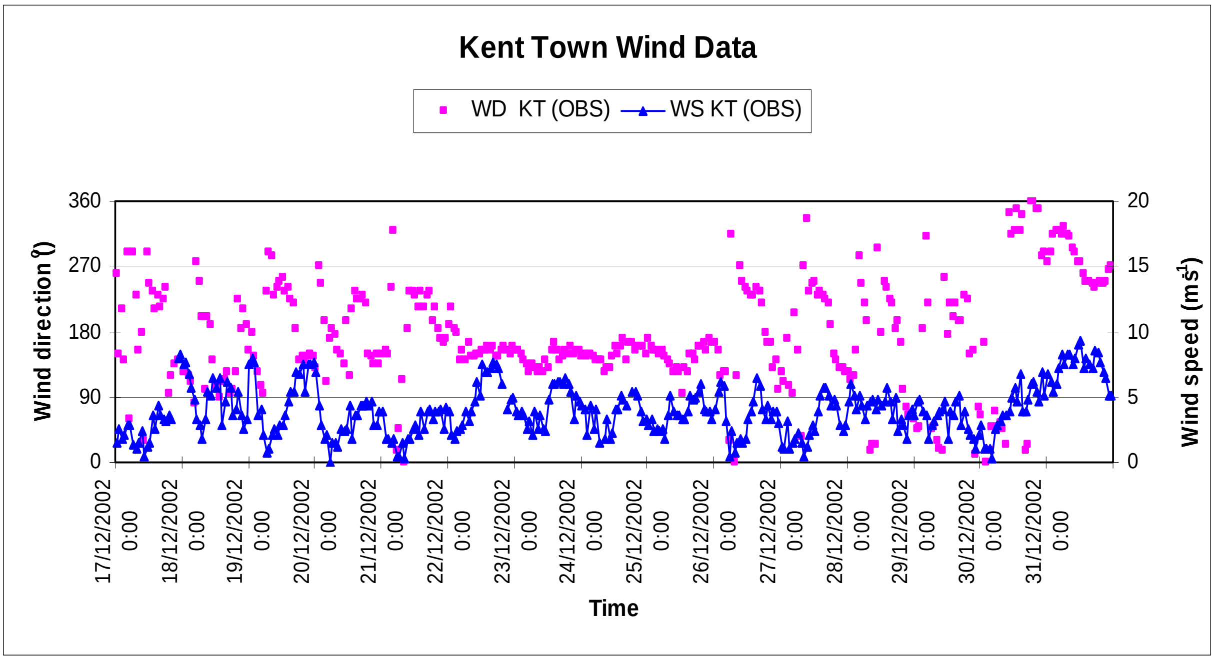

Figure 8. Observed hourly winds at Kent Town (17–31 December 2002) WD = wind direction; WS = wind speed

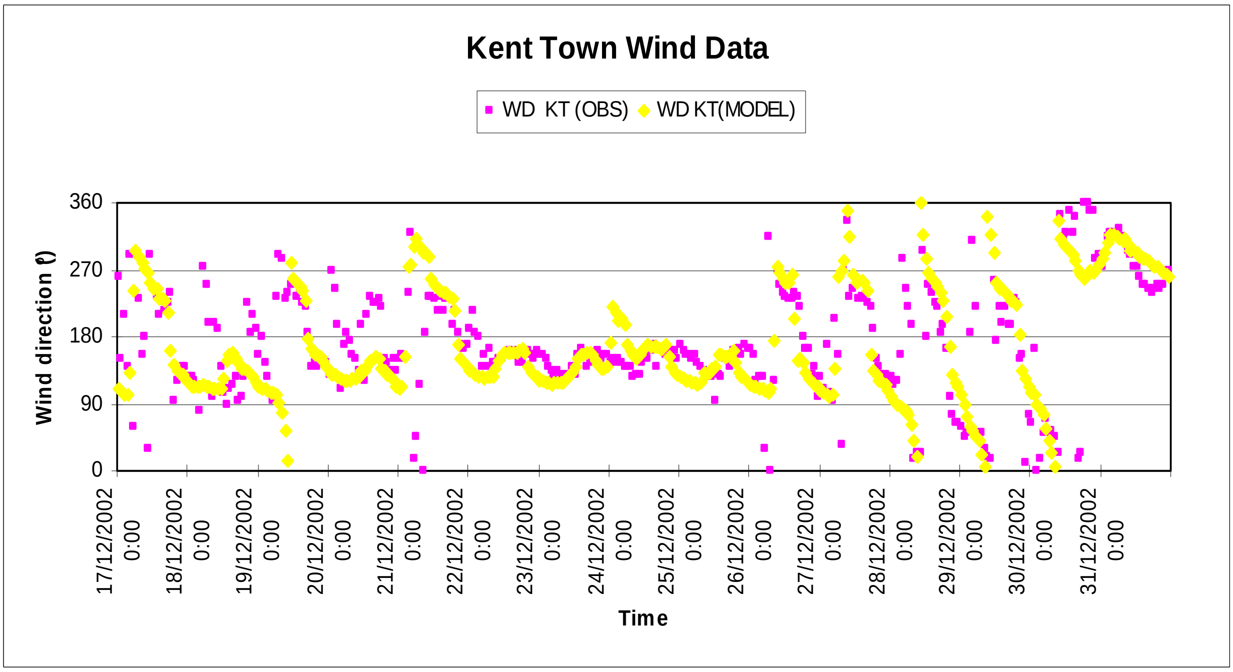

Figure 9. Observed and modelled hourly winds at Kent Town (17–31 December 2002) WD = wind direction

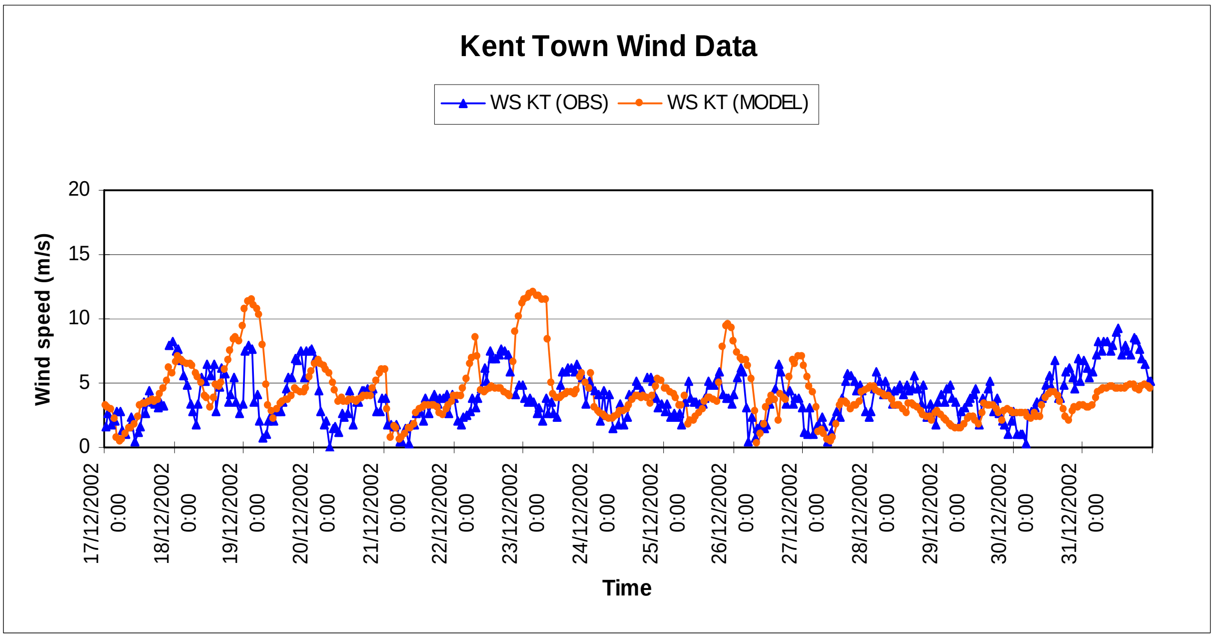

Figure 10. Observed and modelled hourly winds at Kent Town (17–31 December 2002) WS = wind speed

Table 6 shows other statistics for this site. The average standard deviations of the wind vectors are 2.9 m/s for the observations and 2.8 m/s for the prediction. The average RMSD of the wind vector components was 2.64 m/s. The unsystematic component, $RMSD_u$ contributed 2.21 m/s of this deviation. The average index of agreement is 0.78, indicating good model performance at this site.

Table 6. Wind time series statistics at Kent Town (17–31 December 2002)

Parameter	n	AVG_o m/s	AVG_m m/s	STD_o m/s	STD_m m/s	RMSD m/s	$RMSD_s$ m/s	$RMSD_u$ m/s	IOA	r
WS_{10}	356	4.0	4.2	1.9	2.3	2.62	1.40	2.21	0.50	0.23
U_{10}	356	-0.2	-1.6	3.0	3.6	3.34	1.61	2.43	0.73	0.60
V_{10}	356	1.8	1.8	2.7	2.1	1.95	1.26	1.49	0.82	0.75

WS_{10} = wind speed at 10 m above ground; U_{10} = west–east time-averaged wind component; V_{10} = south–north time-averaged wind component; STD = standard deviation; o = observed values; m = modelled values

3.2 Photochemical evaluation

Figure 11 depicts the time series of observed and predicted O_3 concentration at the Elizabeth site. In general, the model captured the day-to-day variation in overall O_3 concentration. On 90% of the simulation days, the TAPM modelled peak O_3 agrees to within 10 ppb of the observations. The highest concentration predicted by the model, on Friday 27 December 2002 at 1500 CST, was 61 ppb.

While the model predicted the O_3 peaks and the day-to-day variation at Elizabeth, it did not capture the extremely low values. It is possible (assuming that the observed measurements are accurate) that the rate of surface deposition of O_3 was underestimated.

The modelled average O_3 concentration over the study period varied by only 2.3 ppb from the observed value, and the predicted standard deviation was similar to the observed value of 10.6 ppb (Table 7). The overall performance of the simulation at this station was very good, with an IOA of 0.82. The high precision of the model is indicated by the small value of $RMSD_u$—less than 8 ppb at Elizabeth—suggesting that the model results vary almost linearly with the observations.

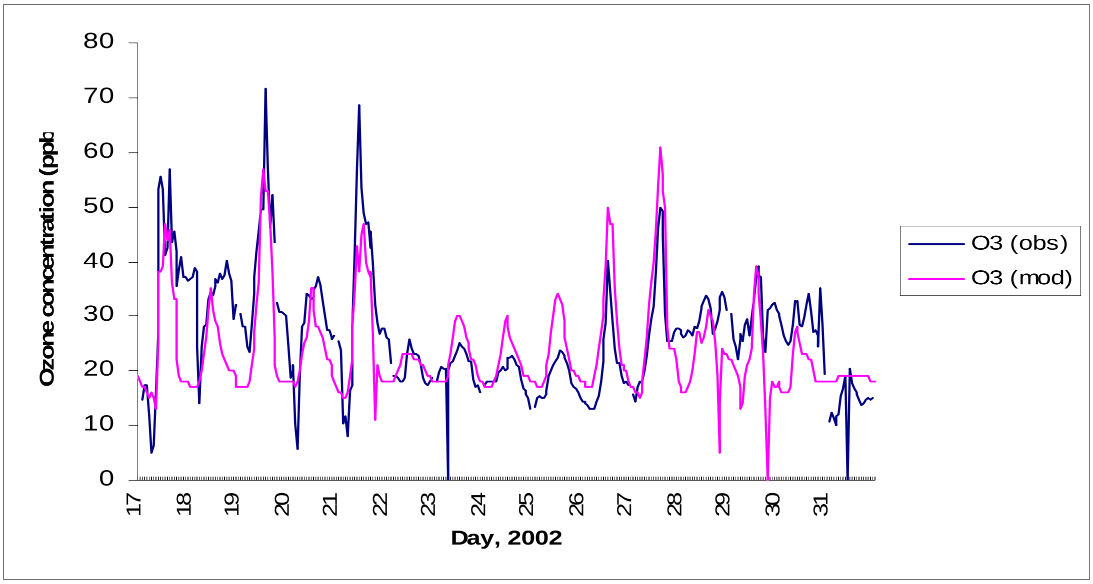

Figure 11. Observed and modelled hourly O_3 at Elizabeth (17–31 December 2002)

Table 7. O_3 time series statistics (17–31 December 2002)

Station	n	AVG_o ppb	AVG_m ppb	STD_o ppb	STD_m ppb	RMSD ppb	$RMSD_s$ ppb	$RMSD_u$ ppb	IOA	r
Elizabeth	359	26.4	24.1	10.6	10.7	8.70	3.99	7.73	0.82	0.70
Gawler	342	25.9	23.8	9.3	8.6	9.32	5.49	7.52	0.71	0.49

o = observed value; m = modelled value; STD = standard deviation

Modelled and observed statistics for O_3 at Elizabeth are shown in Figure 12. The model overestimated the maximum by 4.3 ppb and the 99.9th percentile concentrations by 2.65 ppb. Given the small dataset for simulation, the model's overall performance for O_3 is very good at this site.

Figure 13 depicts the time series of observed and predicted O_3 concentration at Gawler site. In general, the model satisfactorily captured the day-to-day variation in overall O_3 concentration. However, peak values were overestimated on some days. The highest concentration predicted by the model of 63 ppb occurred on Friday 27 December 2002 at 1700 CST.

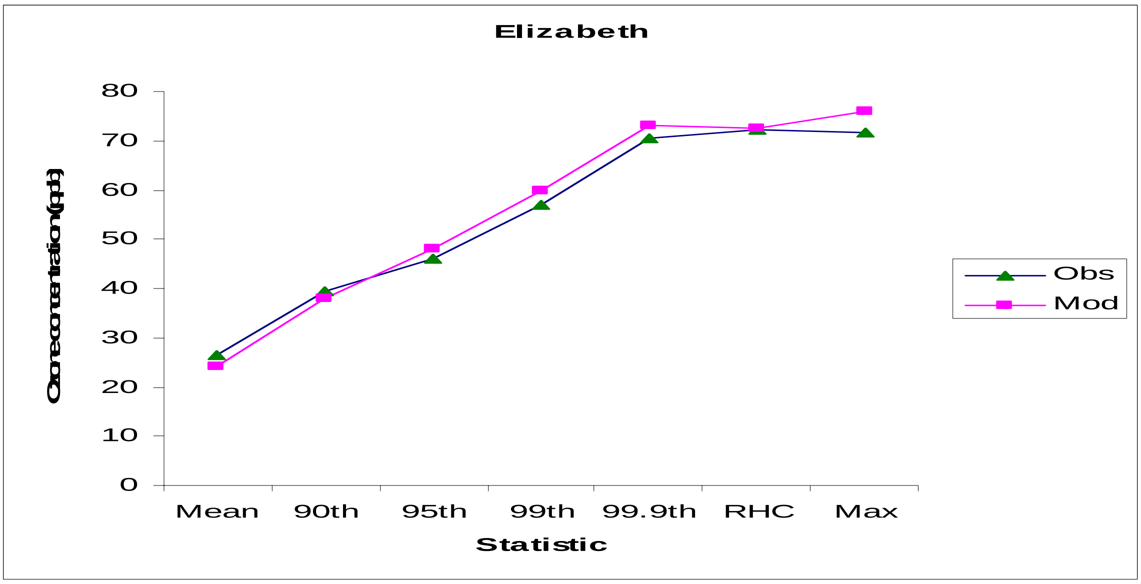

Figure 12. Observed and modelled O_3 statistics at Elizabeth (17–31 December 2002)

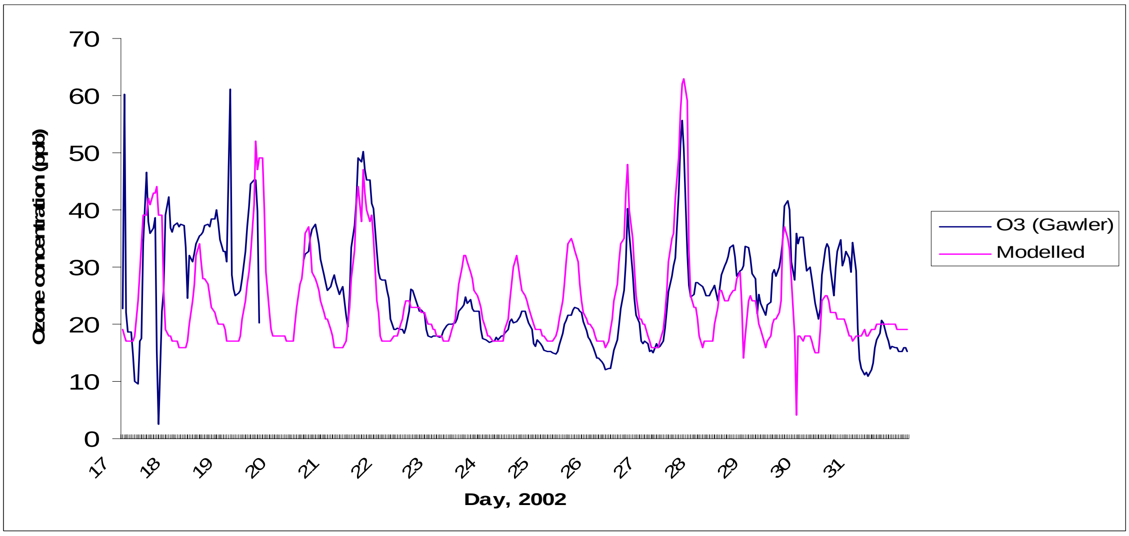

Figure 13. Time series of hourly observed and predicted O_3 concentration at Gawler (17–31 December 2002)

The performance statistics for O_3 prediction at Gawler (Table 7) show that the modelled average O_3 concentration over the study period was lower by 2.1 ppb, and the predicted standard deviation was out by 0.7 ppb. The overall performance of the simulation at this station was good with an IOA of 0.71.

Modelled and observed statistics for O_3 at Gawler are shown in Figure 14. The middle-range of concentrations, 24–42 ppb, were simulated well by the model, but it overestimated the RHC by 1.12 ppb and the maximum value by 1.83 ppb.

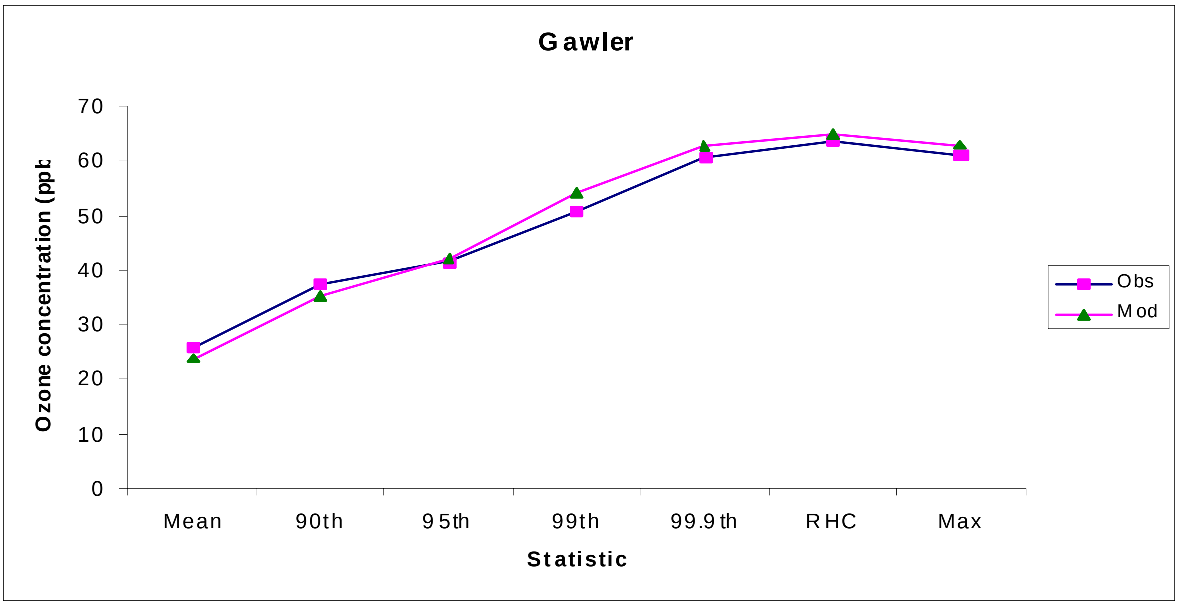

Figure 14. Observed and modelled O_3 statistics at Gawler (17–31 December 2002)

4 CONCLUSION

The detailed quantitative assessment shows that The Air Pollution Model (TAPM) predicted the meteorological and ozone pollution situation with reasonable accuracy for 17–31 December 2002.

TAPM proved good at modelling temperatures for both coastal (Adelaide Airport) and inland (Kent Town) stations. The predicted temperature average was very accurate and only out by 0.1°C at Adelaide Airport. The IOA of 0.93 and a correlation of 0.88 at Kent Town shows that the model did better at estimating the highs and lows (i.e. extreme values) at Kent Town than at Adelaide Airport. This suggests that stations near shorelines can have problems, because of significant local effects, where the current grid resolution becomes inadequate for accurate simulation.

The limited dataset presented does not allow overall model performance to be thoroughly assessed for important meso-scale features such as gully winds and upstream air mass blocking. The present analysis also provides only a limited analysis of sea-breeze events, since they were only light to moderate during the case study period. Thus the model's representation of strong sea-breeze events has not been evaluated.

From the limited assessment possible, it would appear that the TAPM model reproduces broad scale meteorological features well (recognising that some readjustments are made on a daily basis). Overall, TAPM predicted wind direction changes reasonably well. Wind speeds were slightly underestimated on the coast and the peaks were overestimated inland. Some aspects of local meso-scale features, i.e. sea-breezes and north-easterly flow (gully winds), were not fully captured. Sea-breezes play an important role in air pollution events in coastal situations and so need to be well represented in modelling pollution levels. Meso-scale winds and in particular boundary layer stability should be more comprehensively evaluated to better capture local features that impact on air quality and pollution distribution. In particular, TAPM could be run in the mode where observations are also included in the model input and other model options such as soil moisture variations should be investigated.

The ozone forecasts at both stations were very good according to the IOA. The model captured the general features of ozone variation, without any adjustment to the emission inventory. While the maximum ozone concentration at Elizabeth is overestimated by about 4.3 ppb, the overall performance of the simulation at this station was very good, with an IOA of 0.82. The high precision of the model is indicated by the small value of $RMSD_u$, which was less than 8 ppb at Elizabeth. At Gawler, middle range O_3 concentrations, 24–42 ppb, are simulated well by the model, but it overestimates the RHC by 1.12 ppb and maximum value by 1.83 ppb.

Although it is clear that there is room for improvement, the results are very encouraging. The next stage of this study will be to evaluate a number of emission control strategies using this simulation as the base case scenario. The emission inventory for South Australia has very recently been updated and it may be reasonable to do a comparative simulation with the 2002–03 emission estimates.

5 ACKNOWLEDGEMENTS

This study has been completed in collaboration with the Australian Government Bureau of Meteorology in Adelaide, with special thanks to Beth Curran, John Nairn and Darren Ray for providing free access to data archives, technical assistance in the analysis of synoptic charts and surface meteorological data. The Bureau's synoptic conclusions were derived from a comparison of 10 km grid resolution NWP output against meteorological station data.

Data for ground-level ozone was obtained from the EPA's air monitoring network.

The EPA would like to thank Dr Peter Hurley (CSIRO), Dr Jorg Hacker (Airborne Research Australia), Mr. G.H. Clark (ANSTO, NSW) and Dr David Shooter (University of Auckland, New Zealand) for their useful comments on the report.

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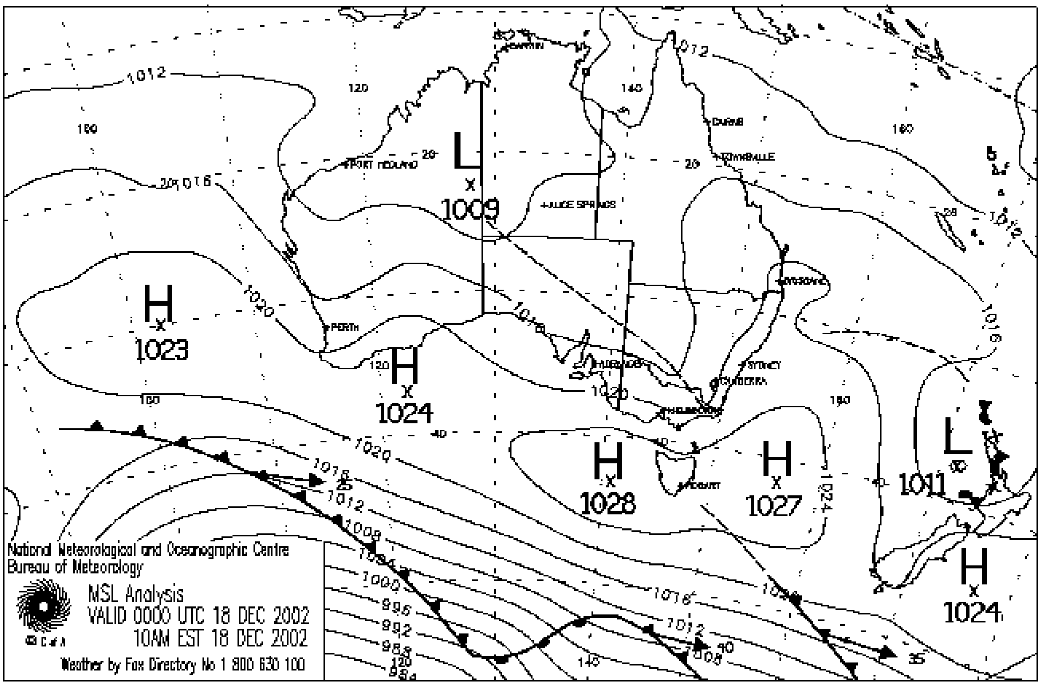
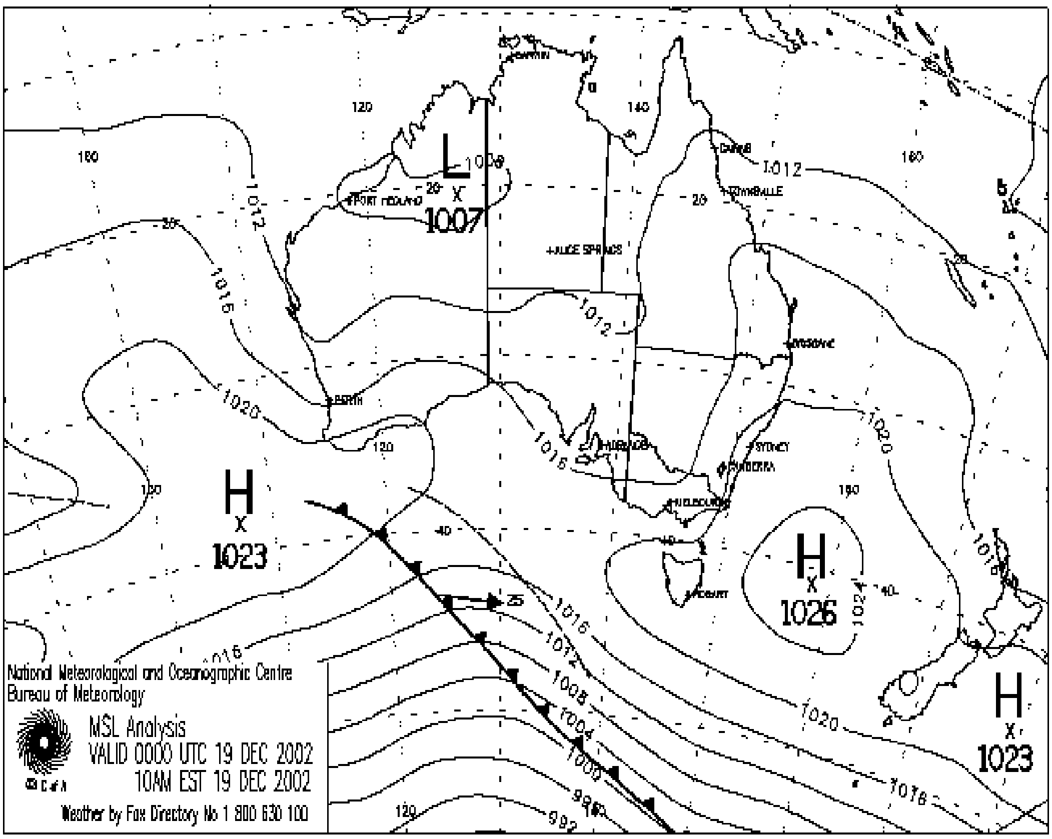
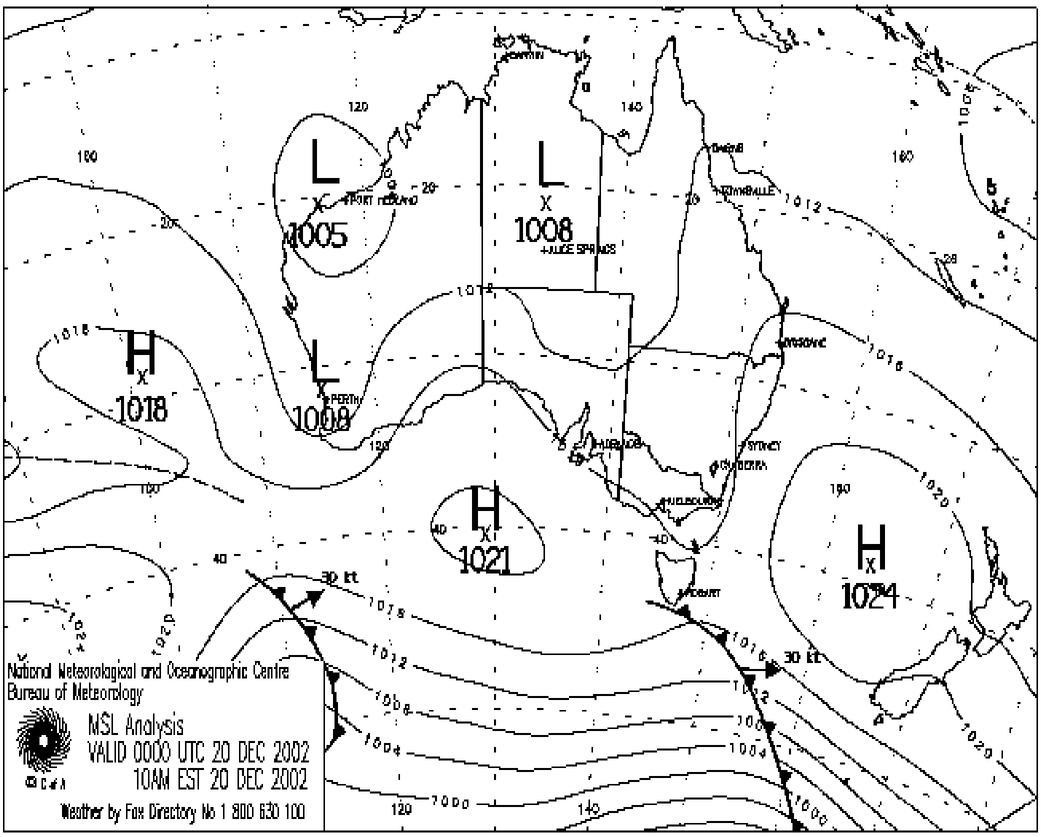
APPENDIX SYNOPTIC CHARTS FOR 18–31 DECEMBER 2002



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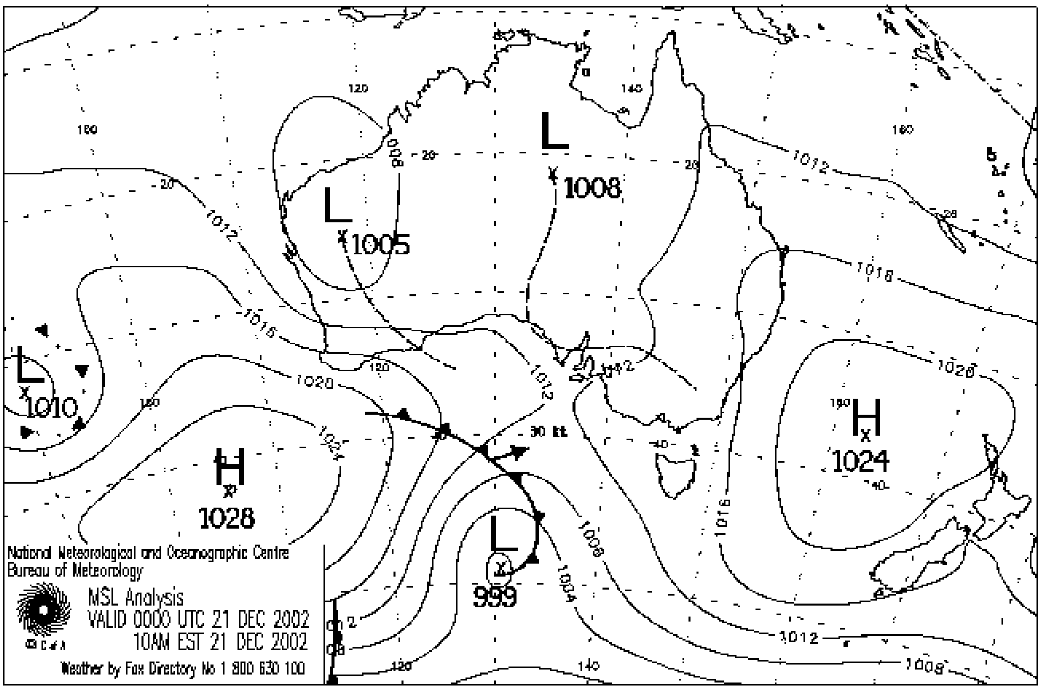
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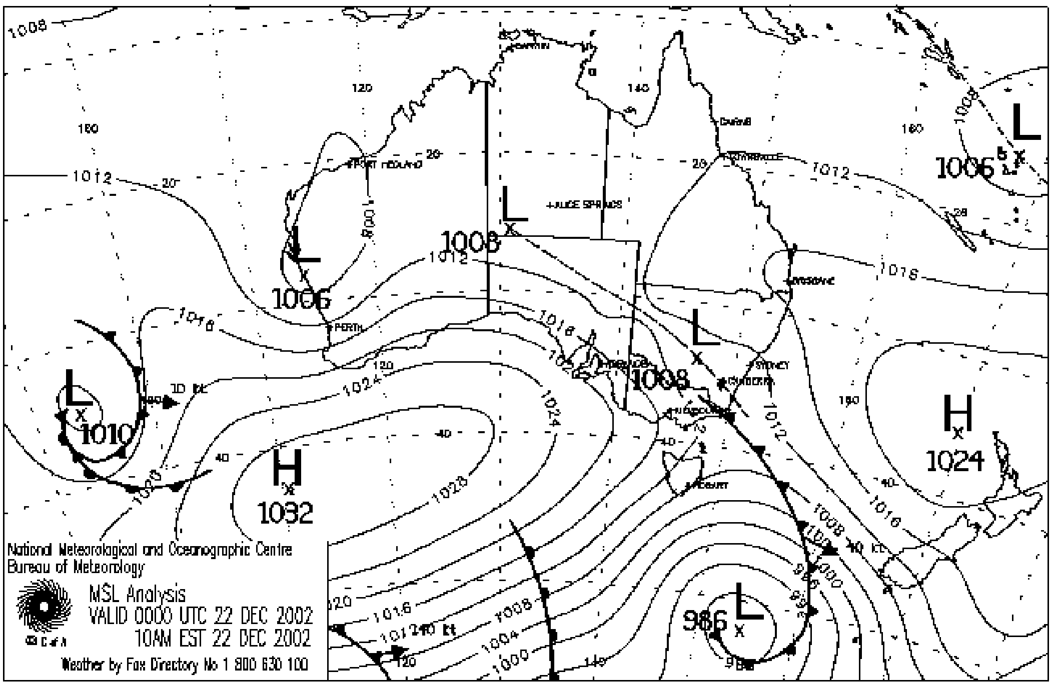
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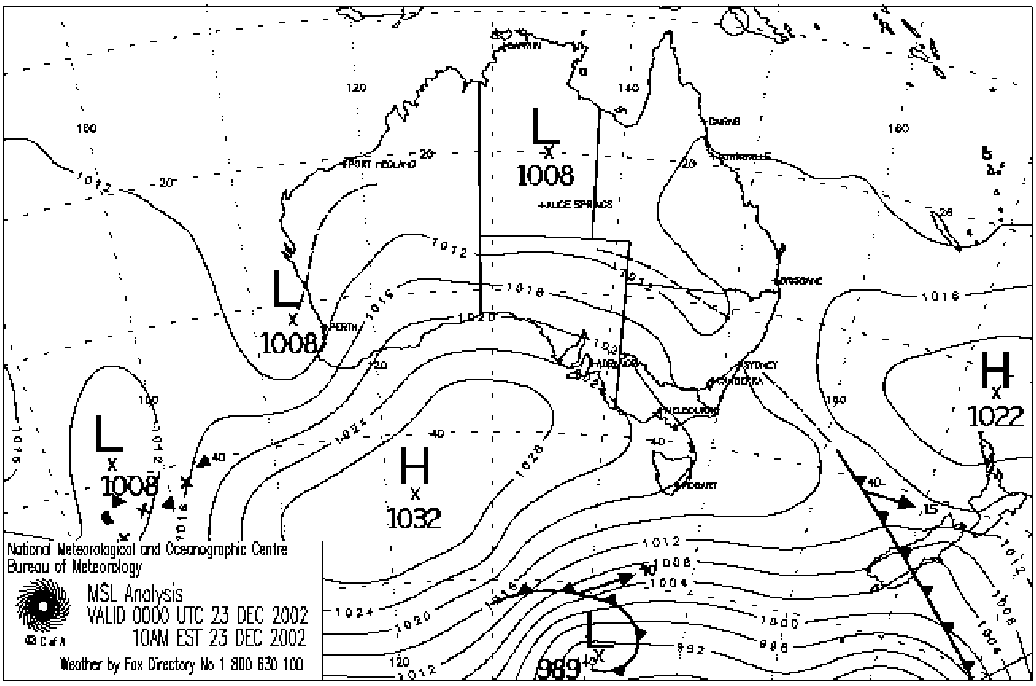
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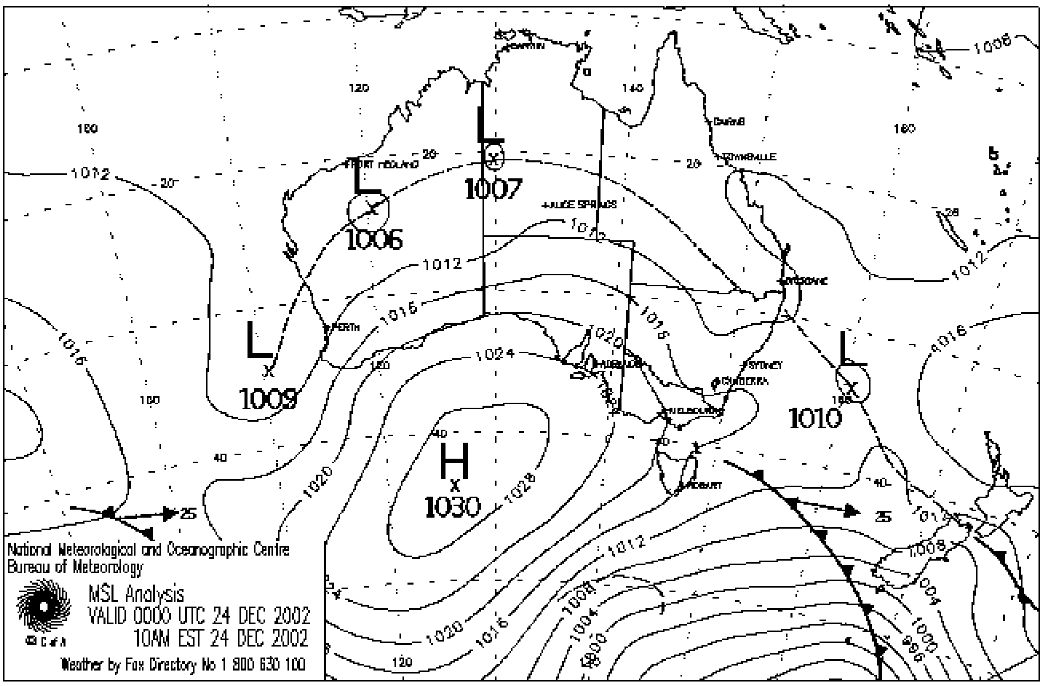
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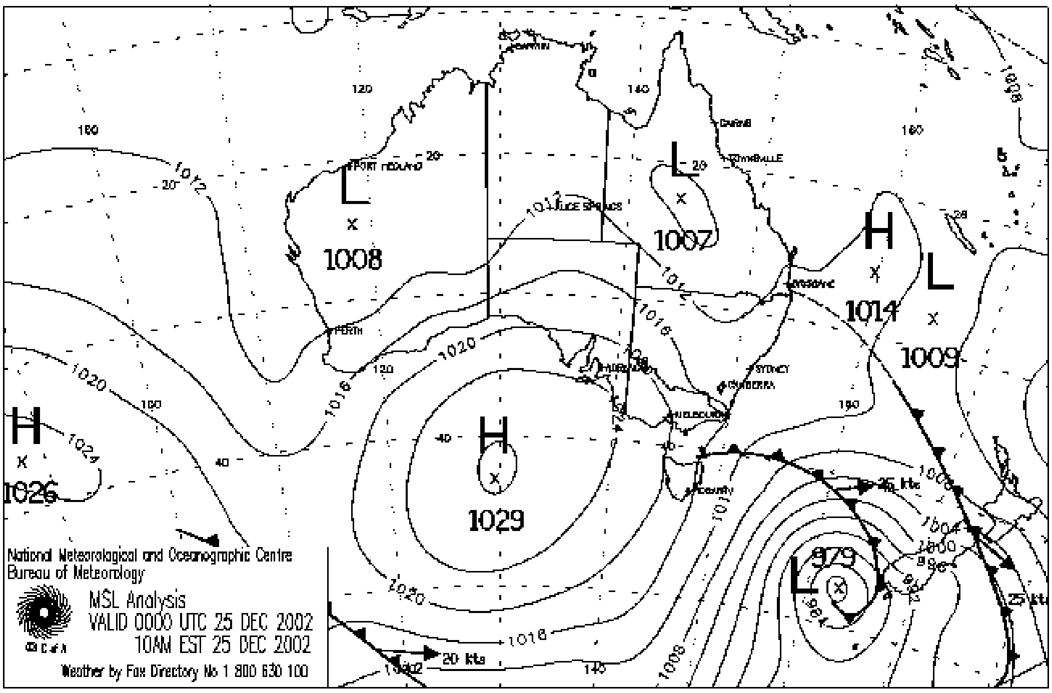
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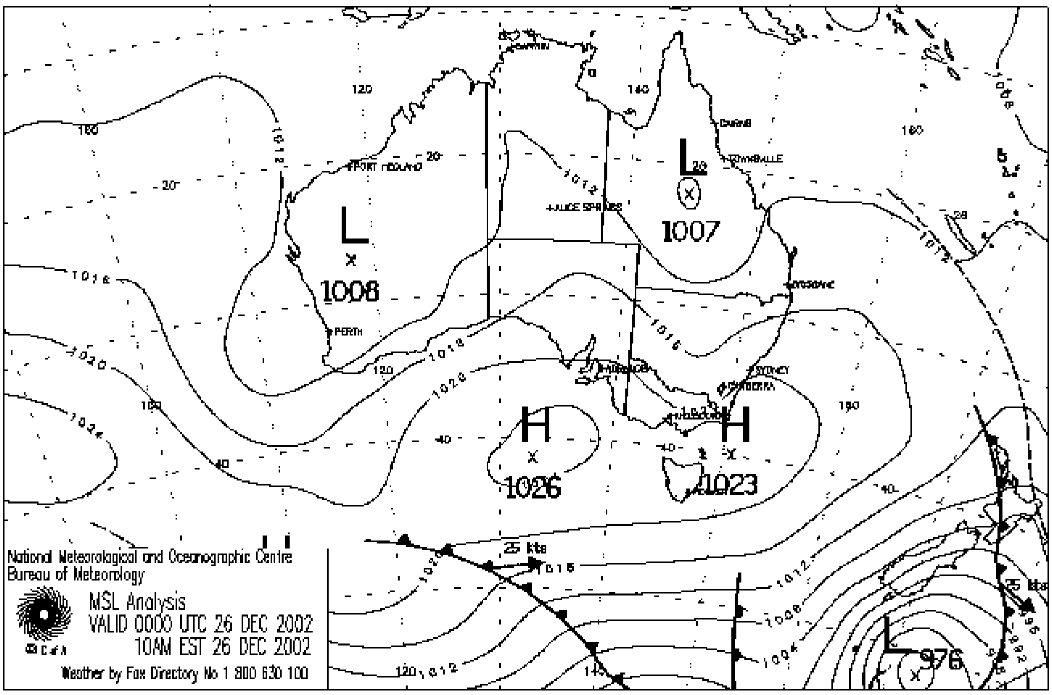
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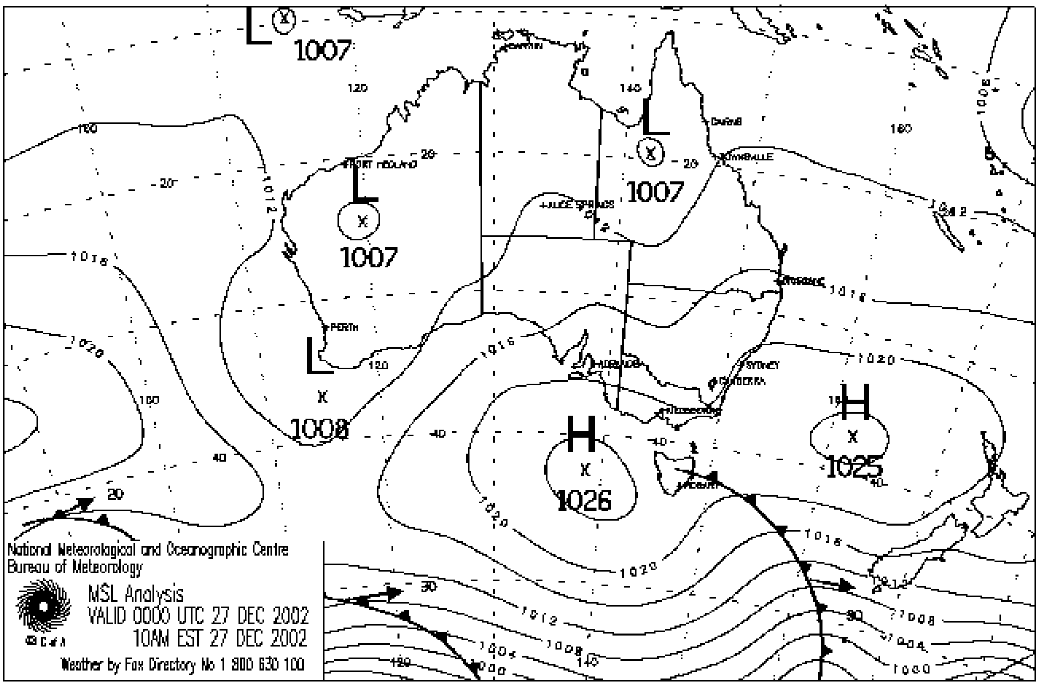
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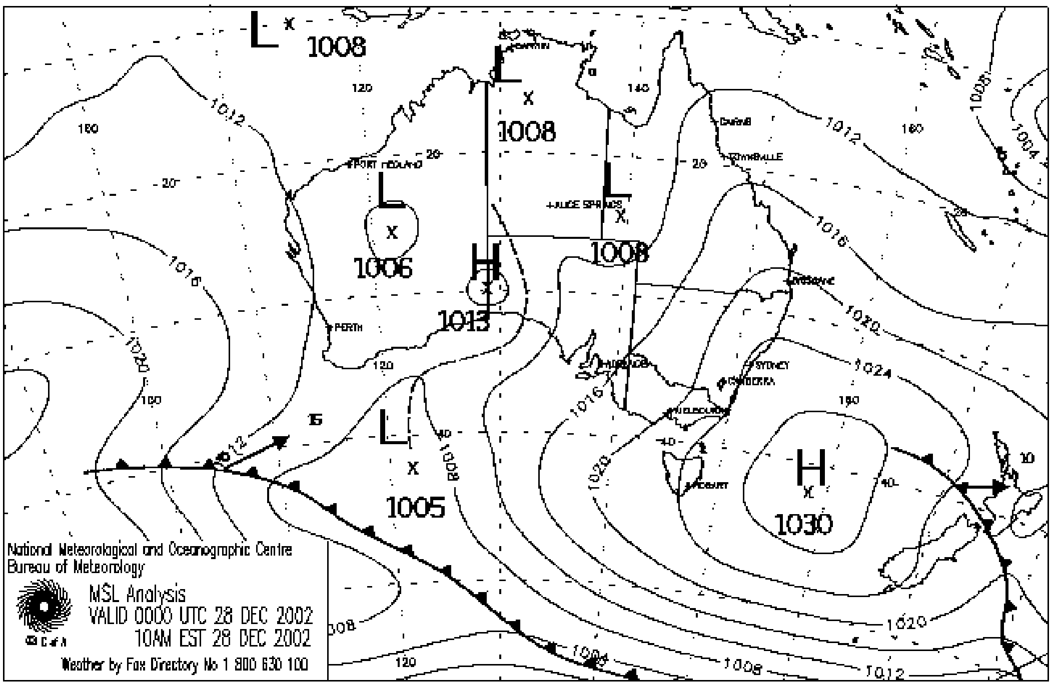
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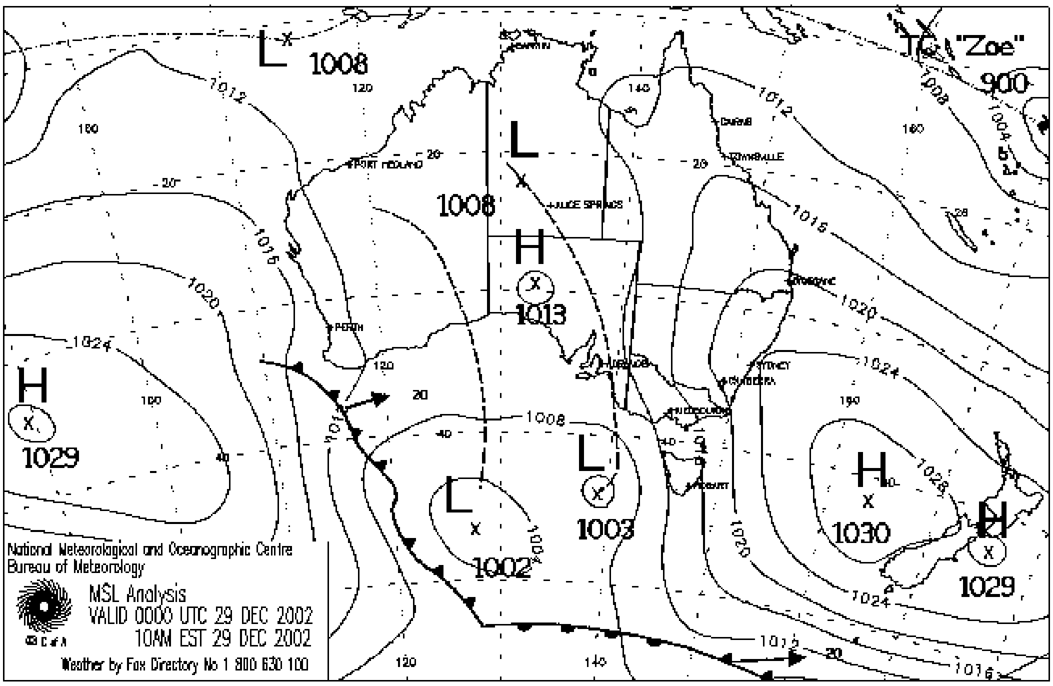
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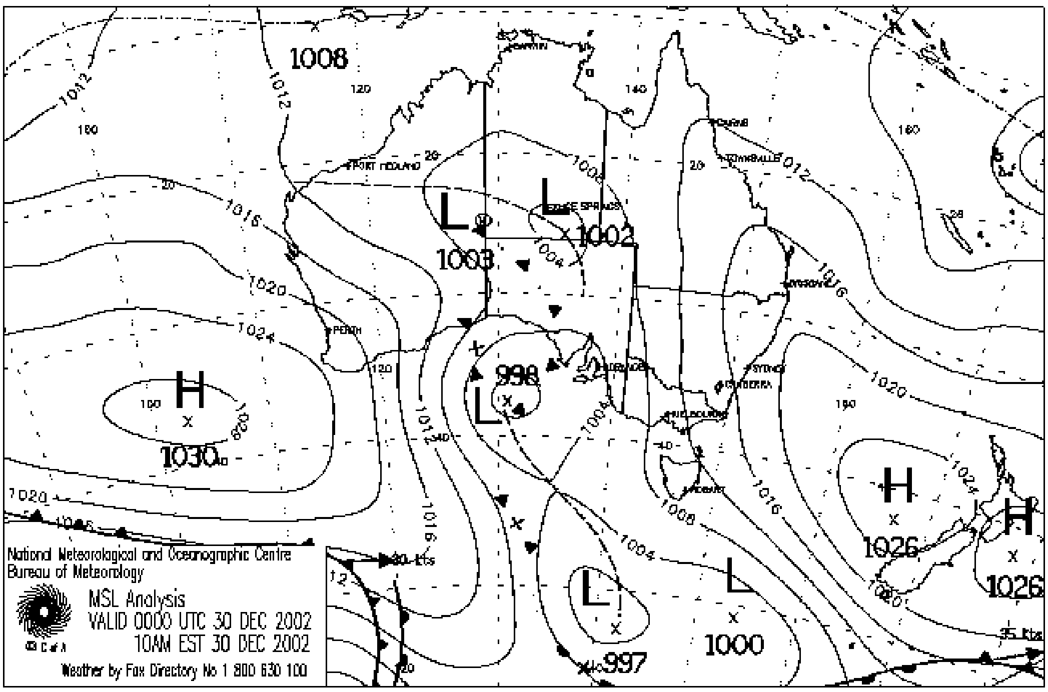
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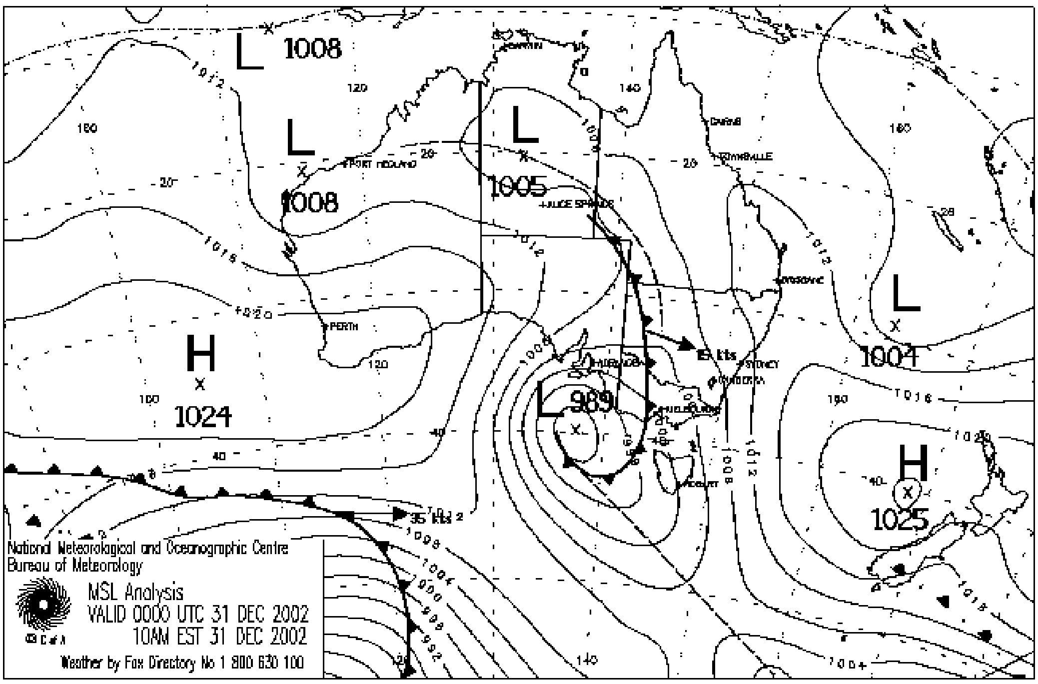
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