

Munmorah Power Station Rehabilitation Project
Assessment of elevated sulfur dioxide predictions

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For AURECON Australia Pty Ltd

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SUMMARY

As part of the assessment for the Munmorah Power Station Rehabilitation project, potential air quality impacts were predicted using CSIRO's air pollution model, TAPM, Version 3 (CSIRO, 2005). The modelling was undertaken according to the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DECC 2005).

Over the 8,784 hours in the modelled year (2004), on one hour (12:00, 31st March, 2004) the highest predicted sulfur dioxide concentration in the modelled domain exceeded the relevant assessment criterion of 570µg/m³ at sensitive receptors (residential area).

On a second occasion (11:00, 28th January, 2004) the highest predicted sulfur dioxide concentration in the modelled domain exceeded the relevant assessment criterion in an area of non-sensitive receptors.

In applying the *Approved Methods*, the Department of Environment Climate Change and Water (DECCW) has indicated a readiness to consider alternatives to the "default" requirement that the highest prediction (the 100th percentile) at sensitive receptors is below the assessment criterion, subject to the proponent demonstrating acceptable health and environmental outcomes.

A recent CSIRO report (Lilley et al 2007a) assessed the performance of the three air quality models approved for use in the *Approved Methods*. Amongst other things the report found that

"..the 100th percentile concentration is not appropriate for assessing the potential impacts from tall stacks under the diverse range of conditions examined in this project, due to potential over estimation at the very top end of the frequency distribution. This is due to uncertainty in several critical meteorological parameters in the lower atmosphere which are either predicted or derived from measurements at ground level."

Malfroy Environmental Strategies Pty Ltd was engaged by AURECON Australia Pty Ltd, on behalf of Delta Electricity, to prepare a report which examines the likelihood of the two elevated predictions occurring. In arriving at the conclusions presented below the following tasks were undertaken:

- Extraction of data from the TAPM output files for the 2 days in question, with particular reference to critical meteorological parameters;
- Review of the 2007 model evaluation assessment:
 - Critical parameters;
 - Examination of 100th percentile predictions;
 - Examination of "case-study" days of elevated predictions;
- Obtain relevant observational data from the Bureau of Meteorology (BoM) and Delta Electricity for the 2 days in question;
- Develop an understanding of the nature of the days in question from an air pollution dispersion perspective, with particular reference to critical meteorological parameters.

Conclusions arising from the review of the two event days are:

- Under a "worst-case" emission scenario, TAPM predicted two, hourly-average events for the year 2004 in which the assessment criterion for sulfur dioxide was exceeded.
- A detailed review of the meteorology on the two event days found that TAPM performed well in predicting the gross atmospheric boundary layer conditions.

- While the predicted boundary layer conditions are physically possible, the TAPM predictions for the critical boundary layer parameters are likely to have resulted in plume dispersion being underestimated and hence maximum concentrations being over-estimated on the two days.
- Relatively small, realistic changes to the predicted critical boundary layer parameters, based on the observational data for the days in question, could result in maximum concentrations less than the assessment criterion.
- The examination of the boundary layer meteorology on the days in question supports the earlier CSIRO conclusion that the predicted 100th percentile concentration is not appropriate for assessing the potential impacts from tall stacks under the diverse range of conditions occurring in the Central Coast region.
- Even if the highest concentration predicted by TAPM was correct, the probability of it occurring is estimated to be in the order of 1 in 350,000 (hours) or once in about 40 years.

1. INTRODUCTION and SCOPE

As part of the assessment for the Munmorah Power Station Rehabilitation project, potential air quality impacts were predicted using CSIRO's air pollution model, TAPM, Version 3 (CSIRO, 2005). The modelling was undertaken according to the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* (DECC 2005).

Over the 8,784 hours in the modelled year (2004), on one hour (12:00, 31st March, 2004) the highest predicted sulfur dioxide (SO₂) ground level concentration (glc) in the modelled domain exceeded the relevant assessment criterion of 570µg/m³ at sensitive receptors.

On a second occasion (11:00, 28th January, 2004) the highest predicted SO₂ glc in the modelled domain exceeded the relevant assessment criterion in an area of non-sensitive receptors.

In applying the *Approved Methods*, the Department of Environment Climate Change and Water (DECCW) has indicated a readiness to consider alternatives to the "default" requirement that the highest prediction (the 100th percentile) at sensitive receptors is below the assessment criterion, subject to the proponent demonstrating acceptable health and environmental outcomes.

A recent CSIRO report¹ (Lilley et al 2007a) assessed the performance of the three air quality models approved for use in the *Approved Methods*. Amongst other things the report found that

"...the 100th percentile concentration is not appropriate for assessing the potential impacts from tall stacks under the diverse range of conditions examined in this project, due to potential over estimation at the very top end of the frequency distribution. This is due to uncertainty in several critical meteorological parameters in the lower atmosphere which are either predicted or derived from measurements at ground level."

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- Review of the 2007 model evaluation assessment:
 - Critical parameters;
 - Examination of 100th percentile predictions;
 - Examination of "case-study" days of elevated predictions;
- Obtain relevant observational data from the Bureau of Meteorology (BoM) and Delta Electricity for the 2 days in question;
- Develop an understanding of the nature of the days in question from an air pollution dispersion perspective, with particular reference to critical meteorological parameters.

¹ A copy of this report was provided to, and discussed with DECCW. A paper arising from this work was presented at the IUAPPA World Congress in Brisbane, 2007 (Lilley et al 2007b)

2. MODEL INFORMATION

The Munmorah Power Station Rehabilitation air quality assessment (Aurecon, 2009) was undertaken using TAPM Version 3 (CSIRO, 2005).

A nested grid of 30km-10km-3km-1km was used for the meteorological modelling with the pollution concentration estimates having double the spatial resolution (15km-5km-1.5km-0.5km).

Emissions from Munmorah were conservatively modelled with the power station operating at full-load throughout the year, burning coal with maximum sulfur content of 0.7%. The probability of these two situations occurring at the same time as “worst-case” meteorological conditions is considered in Section 6.

Emissions from the 2 other large SO₂ sources in the region (Vales Point Power Station and Eraring Power Station) were included in the cumulative assessment by adopting the *Approved Methods* “Level 2” assessment methodology, in which contemporaneous hourly average monitoring data for the modelled year are added to the predicted concentrations for each hour of the year.

The “background” air quality data was factored up by 14% to account for the approved, but yet to be constructed, increase in output from Eraring Power Station.

The modelling was undertaken for the year 2004, a year in which Munmorah Power Station was non-operational for much of the time, so minimising the likelihood of “double counting”. 2004 was demonstrated to be a representative year, in terms of meteorology and emissions from Vales Point and Eraring Power Stations.

Further detail of the assessment can be obtained from the assessment report (Aurecon, 2009).

3. SUMMARY OF MODEL RESULTS

Presented below as Figure 1 is Figure 6.1 from the assessment report. For each hour of the year the figure includes the domain-wide highest predicted cumulative ground level concentration. It can be seen that for 2 hours in the year the cumulative predictions were higher than the assessment criterion of 570 µg/m³.

- 28th January, 2004 at 1100 hours occurring in an area of non-sensitive receptors immediately to the south of the power station. The predicted highest cumulative concentration was 584 µg/m³, (Munmorah contribution 549 µg/m³ and background contribution 35 µg/m³);
- 31st March, 2004 at 12:00 hours occurring at sensitive receptors to the north-north-east of the power station (Figure C1b of the assessment report). The predicted highest cumulative concentration was 738 µg/m³, (Munmorah contribution 683 µg/m³ and background concentration 55 µg/m³).

Figure 1 combined with Figure 6.2 from the assessment report (presented here as Figure 2) demonstrate the highly “skewed” nature of the predicted SO₂ concentrations, both across the domain and at individual sensitive receptor sites. That is, the occurrence of predictions approaching the air quality criterion is extremely infrequent with the vast majority of predictions well below levels of concern for the conservative emission scenario assessed.

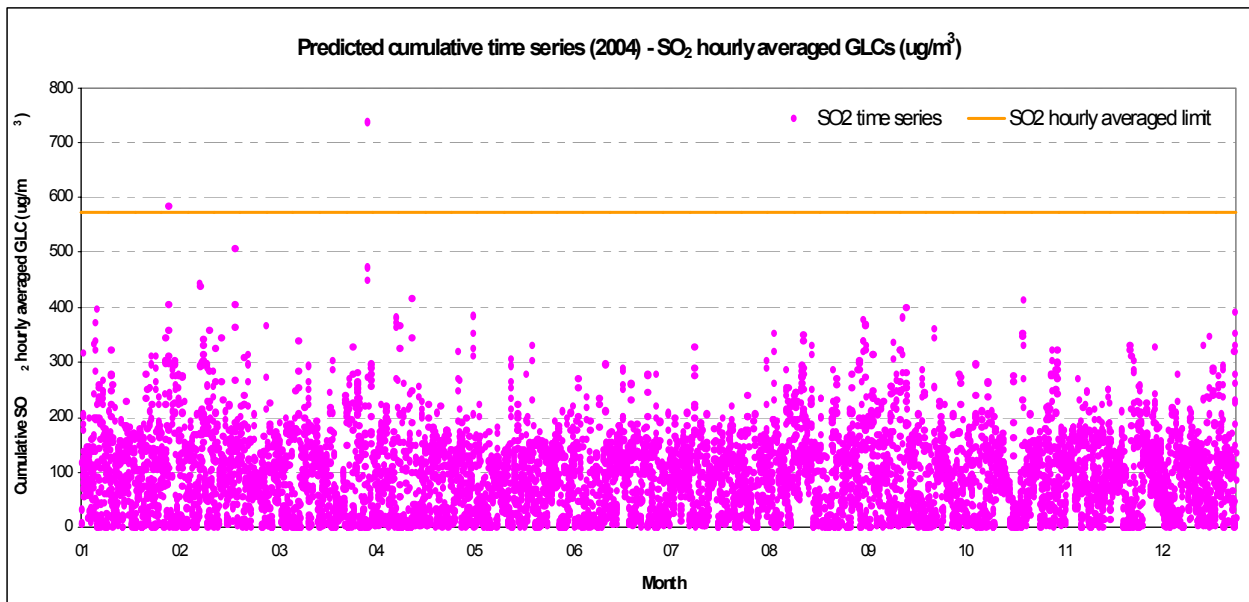


Figure 1: Time series for 2004 of the domain-wide maximum predicted SO₂ hourly averaged ground level concentrations (µg/m³). (Figure 6.1 in the Assessment Report).

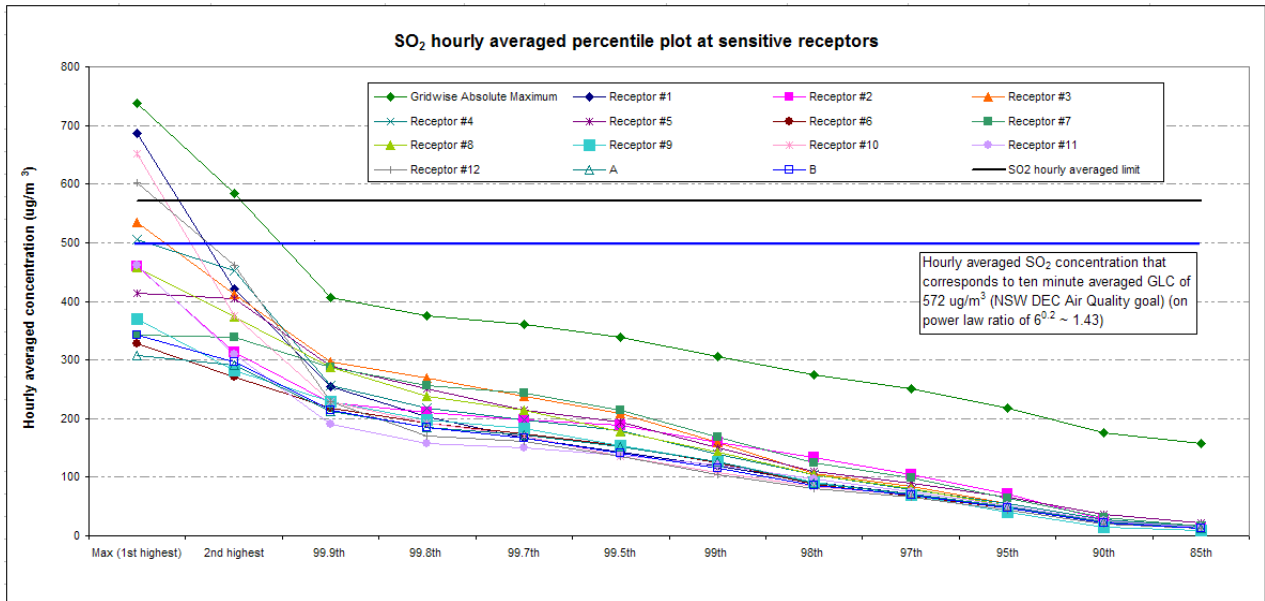


Figure 2: Percentile plot of hourly averaged SO₂ concentrations (µg/m³) at each sensitive receptor. Note: the grid wise absolute maximum exceedance occurs in a non-sensitive land use south of Receptor 1. (Figure 6.2 in the Assessment Report).

4. CRITICAL METEOROLOGICAL (BOUNDARY LAYER) PARAMETERS

A recent CSIRO report (Lilley et al 2007) found that TAPM was generally well suited to model dispersion from tall stacks in the Central Coast region which experiences complex meteorology due to the coastal / lake location and varied terrain. This is consistent with the findings from a number of other studies reported on by Lilley et al. Notwithstanding these generally good results, it has also been reported that TAPM (and other models approved for regulatory use) has the potential to over-estimate concentrations at the very top end of the frequency distribution. For example, Hibberd et al (2003) found that TAPM modelled concentrations at each of four monitoring locations well when comparing the third highest modelled concentration with the maximum observed concentration in each of three years modelled. That is, when the top 2 predictions were discarded.

Lilley et al found that TAPM consistently over-estimated the very highest concentrations at particular monitoring sites in both the Central Coast and Western Coalfields regions of NSW and concluded that in regions of complex meteorology and / or terrain, the 99.9th percentile prediction (9th highest) may be a more appropriate indicator of maximum concentrations to be expected.

From an examination of a number of case study days, Lilley et al concluded that the potential to over-estimate at the top of the frequency distribution is likely to be due to “*..uncertainty in several critical meteorological parameters in the lower atmosphere which are either predicted or derived from measurements at ground level.*”

From information presented in Lilley et al, the critical meteorological factors can be summarised as:

- Very light wind speeds through the boundary layer up to plume height (generally less than 1.5 m/s);
- Little directional wind shear through the boundary layer;
- Limitation on mixing height in the boundary layer (generally less than ~800m); and
- Convection in the boundary layer capable of bringing the plume to ground.

These factors operate in concert to determine the likelihood of emissions from a tall stack being mixed to the ground in high concentrations. As noted above, the values for these parameters are not input to the model from measurements but rather are estimated or derived from other values. It is therefore possible that the model’s meteorological module’s prediction(s) for one or more of these critical parameters can lead to plume behaviour which, while theoretically possible, results in predictions which are not observed in the “real world”.

In the following section, actual conditions in the boundary layer on the 2 days of predicted elevated concentrations in the Munmorah assessment are compared with TAPM predicted meteorology, in order to assess the likelihood of the predicted elevated concentrations occurring in reality.

5. METEOROLOGICAL CONDITIONS

Synoptic (large-scale) conditions drive the meteorology of the boundary layer². TAPM uses specific synoptic scale meteorological and other more general data on things like vegetation cover, to predict a number of the critical boundary parameters relevant to plume dispersion. This section looks at the synoptic conditions and the observed and predicted meteorological conditions prevailing on the 2 days.

² The boundary layer is that part of the atmosphere directly above the surface; its height varies both temporally and spatially, reaching a maximum height up to about 2,000m.

5.1 28th January, 2004

Synoptic conditions

Figure 3 shows the synoptic weather charts for 1000 and 1600 hours on the 28th January, 2004. The charts show eastern Australia was dominated by surface low pressure systems and upper level troughs, conditions which are likely to result in unstable, complex weather conditions.

Sunshine and cloud data from the nearest BoM sites, Williamtown and Mascot³, indicate that the morning of the 28th January had cloud coverage of 4/8 – 7/8 up until about 0900 hours. After this time there was about 1/8 cloud coverage.

BoM wind and temperature profiles for this day are examined in the next section.

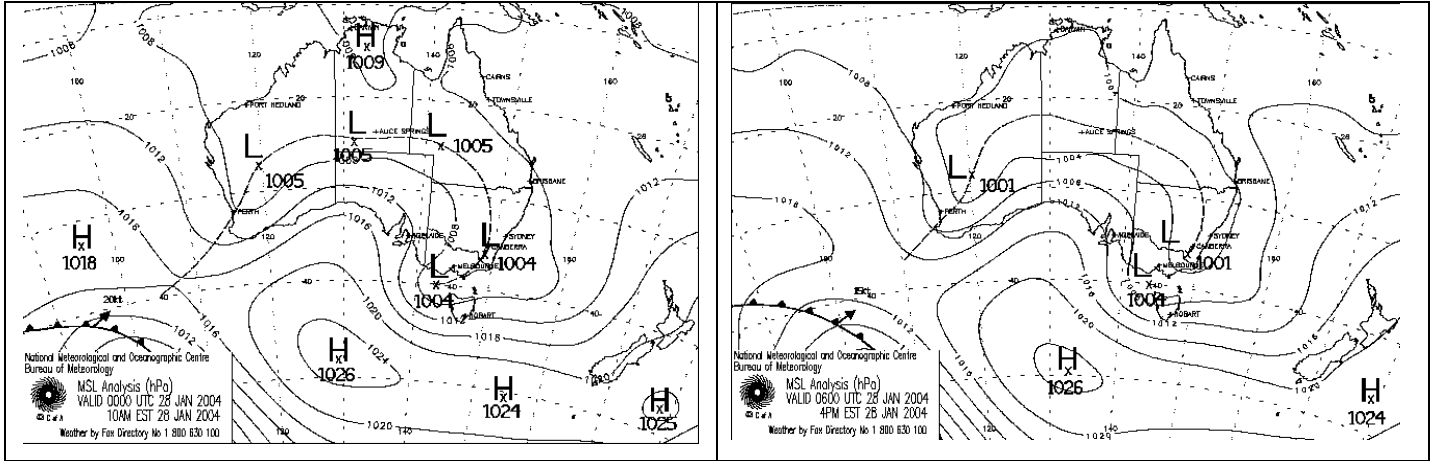


Figure 3: Synoptic charts for the 28th January, 2004 at 1000 and 1600 hours.

Boundary layer parameters

Observational data

Boundary layer data for the 28th January are available from the BoM Williamtown and Mascot sites (wind and temperature profile data through the lower atmosphere) and from Delta Electricity surface sites in the Central Coast region.

Wind (0500, 0900 and 1400 hours) and temperature (0500 and 1400 hours) profiles from Mascot and are shown in Figure 4.

Wind (0600 and 1500 hours) and temperature (0600 and 1500 hours) from Williamtown are shown in Figure 5.

³ Williamtown is approximately 60 km to the north of Munmorah and Mascot is about 90 km to the south of Munmorah.

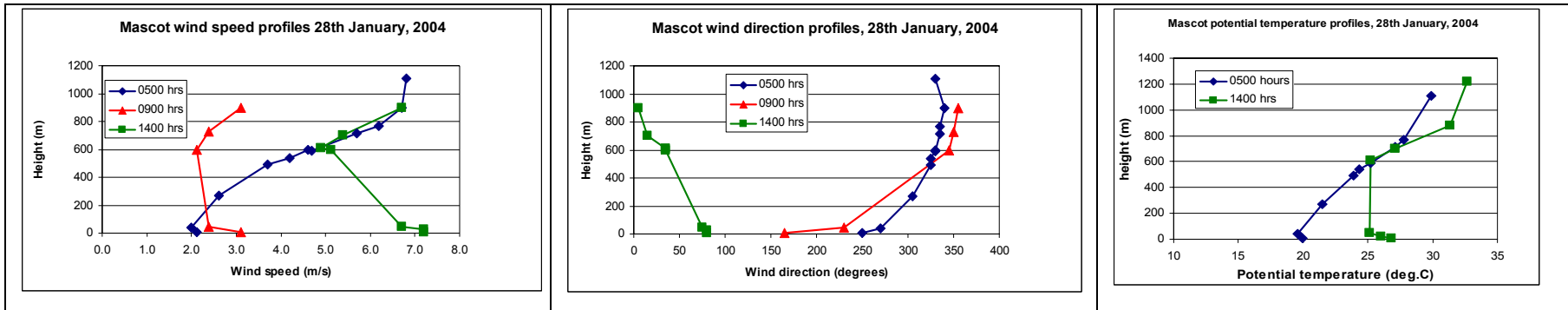


Figure 4: Wind speed, wind direction and potential temperature profiles from Mascot, 28th January, 2004.

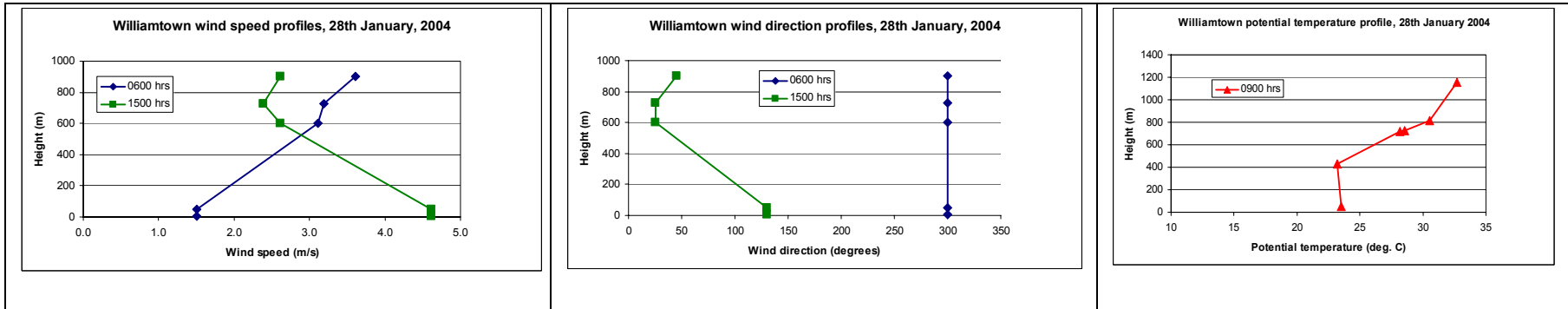


Figure 5: Wind speed, wind direction and potential temperature profiles from Williamtown t, 28th January, 2004

Wind directions were north-westerly above the surface in the morning, with speeds of about 2 – 5 m/s. The Mascot 0500 potential temperature profile showed a stable atmosphere from the surface to 1,200 m.

In the afternoon, wind speeds near the surface increased significantly, decreasing with height through the boundary layer. Wind directions in the lower atmosphere became north-easterly to south-easterly, indicative of the development of a sea-breeze. Above about 400m the atmosphere remained stable.

Data from the surface anemometers in the region indicated very light and variable direction winds in the morning followed by the arrival of what appears to be a sea breeze mid to late morning. Wind speeds increased to 3-4 /m/s from the east, south-east with the arrival of the sea breeze.

Delta Electricity operates a weather station at Munmorah Power Station which was out of service on the 28th January. Temperature data from the nearby Wyee monitoring station recorded a maximum temperature of 26.9°C at 1100 hours.

TAPM predictions

Data were extracted from the TAPM output files to illustrate the model's predictions for boundary layer parameters on the 28th January. Boundary layer profiles for 0900 hours and 1100 hours (the hour of highest glcs) are shown in Figures 6 and 7 respectively.

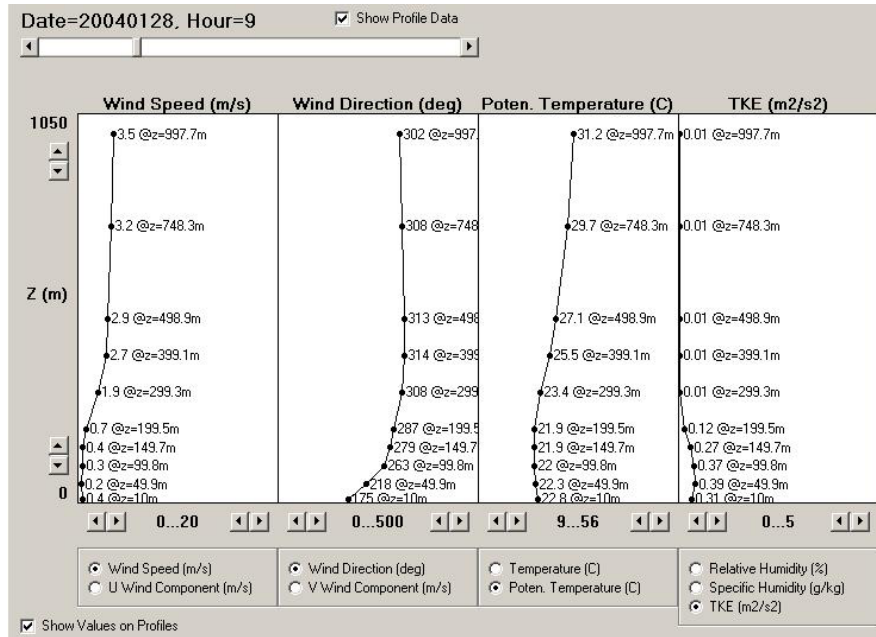


Figure 6: TAPM predictions of wind speed, wind direction, potential temperature and turbulence (TKE) at 0900 hours on the 28th January, 2004.

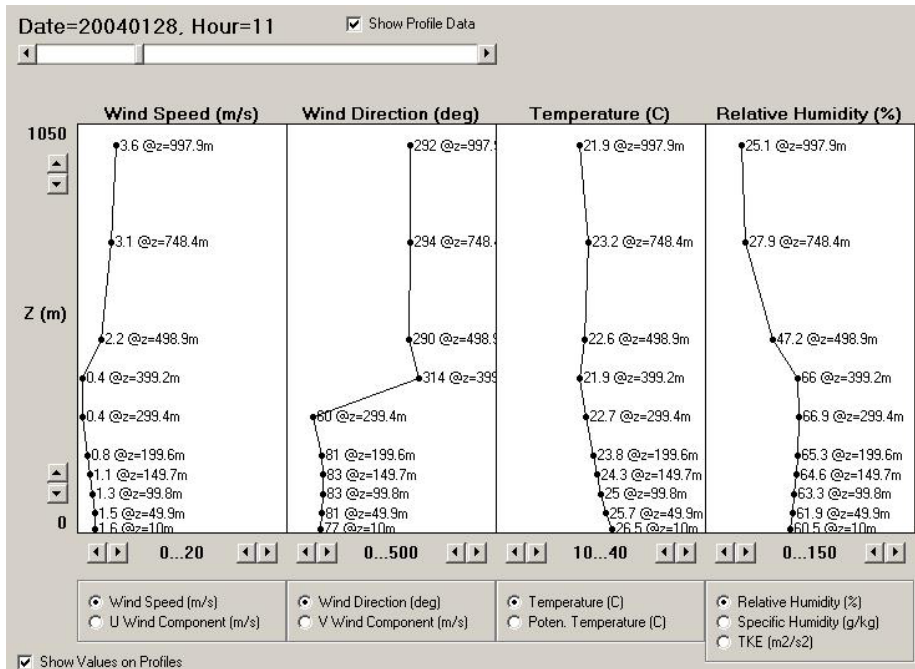


Figure 7: TAPM predictions of wind speed, wind direction, temperature and relative humidity at 1100 hours on the 28th January, 2004.

The figures at 0900 hours show that the lower atmosphere is stable (as indicated by the potential temperature profile) with light (1 -3 m/s) wind speeds in the lower atmosphere from the south-west to north-west

At 1100 hours, the hour in which elevated SO₂ concentrations were recorded, winds below about 350 m are very light (less than 1 m/s) and from the east. The elevated relative humidity in this layer supports the view that it is a sea breeze. A subsequent profile indicates turbulence mixing in this layer with stable air above.

At 1100 hours, TAPM predicted mixing heights of about 300 m in the region and the effect of this is reflected in Figure 8 which, at the time of maximum predicted concentrations, shows TAPM predicted that the Munmorah plume was mostly contained below 300 m.

TAPM predicted net radiation values up to 732 W Wm⁻² on this day and convective velocity (W star) of up to 1.3 m/s.

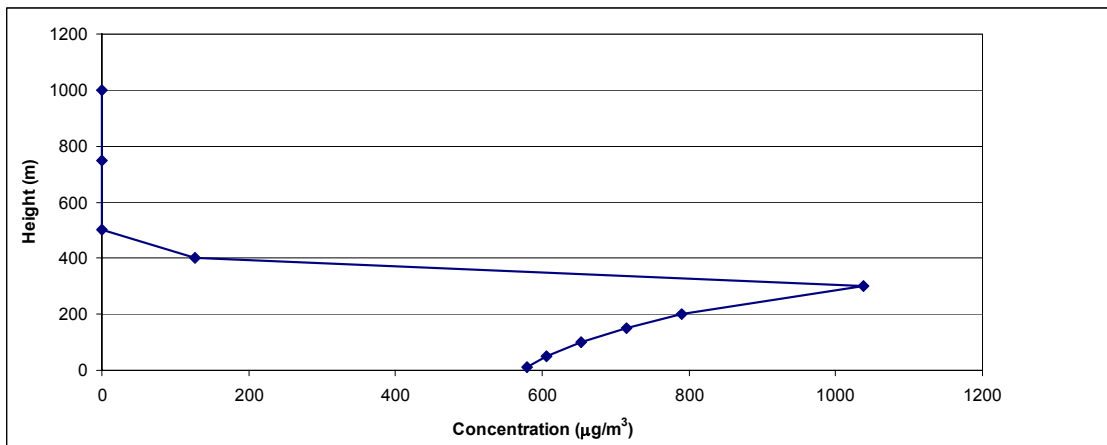


Figure 8: Modelled concentration profile on the 28th January 2004

Summary

TAPM performed very well in predicting the gross features of the boundary layer meteorology on the 28th January, 2004, including the early morning wind and stability conditions followed by the arrival of the sea breeze and limited mixing in the boundary layer. Some of this good agreement, particularly for near-surface winds, may be explained by the use of data from local anemometers to “nudge” the results.

However, at the time of maximum glcs, it is considered that TAPM may have under-estimated the (very light) wind speeds in the boundary layer. BoM profiles for the relevant hour (1100) are not available, but it is instructive to note that wind speeds recorded at Wyee and Lake Munmorah School at this time (2.5 and 3.3 m/s, respectively) are greater than predicted by TAPM (from Figure 7, < 2 m/s at the surface decreasing to < 1 m/s at height). The potential significance of these small differences in (light) wind speeds will be commented on in Section 6.

Also of note, is that TAPM predicted very little direction shear (change in direction with height) through the sea breeze (Figure 7) at 1100 hours. Again, BoM profile data at the same time are not available but Figures 3 and 4 show considerable directional shear with height through the sea breeze measured at Williamtown and Mascot a couple of hours later in the day. The TAPM output for 1500 hours (Figure 9) continues to show very little wind shear through the sea breeze. The potential significance of these differences in wind direction shear will be commented on in Section 6.

Finally, the containment of the plume below 300 m at the time of maximum predicted gles is also likely to play a “critical” part in the predicted high gles, and will be commented on in Section 6.

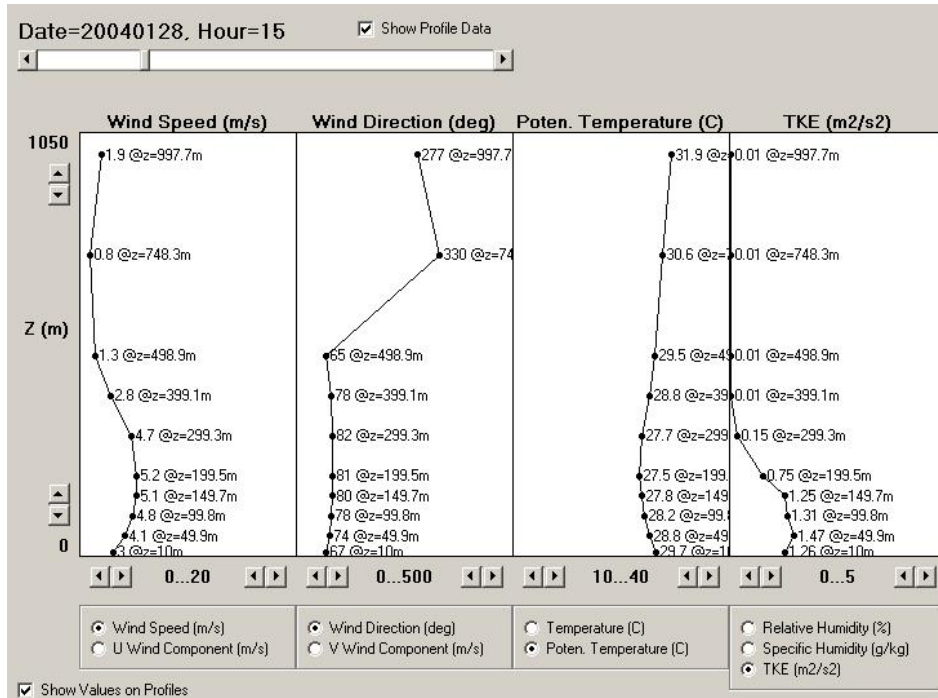


Figure 9: TAPM predictions of wind speed, wind direction, potential temperature and turbulence (TKE) at 1500 hours on the 28th January, 2004

5.2 31st March, 2004

Synoptic conditions

Figure 10 shows the synoptic charts for 1000 and 1600 hours on the 31st March, 2004. The charts show the passage of a weak front along the central eastern coast during the morning, with an upper trough to the north, with a further front to the south-west; between the 2 fronts pressure gradients are very “slack”, indicative of light, variable winds in the lower atmosphere.

Sunshine and cloud data from Williamtown and Mascot indicate that the 31st March was generally free of cloud.

BoM wind and temperature profiles for this day are examined in the next section.

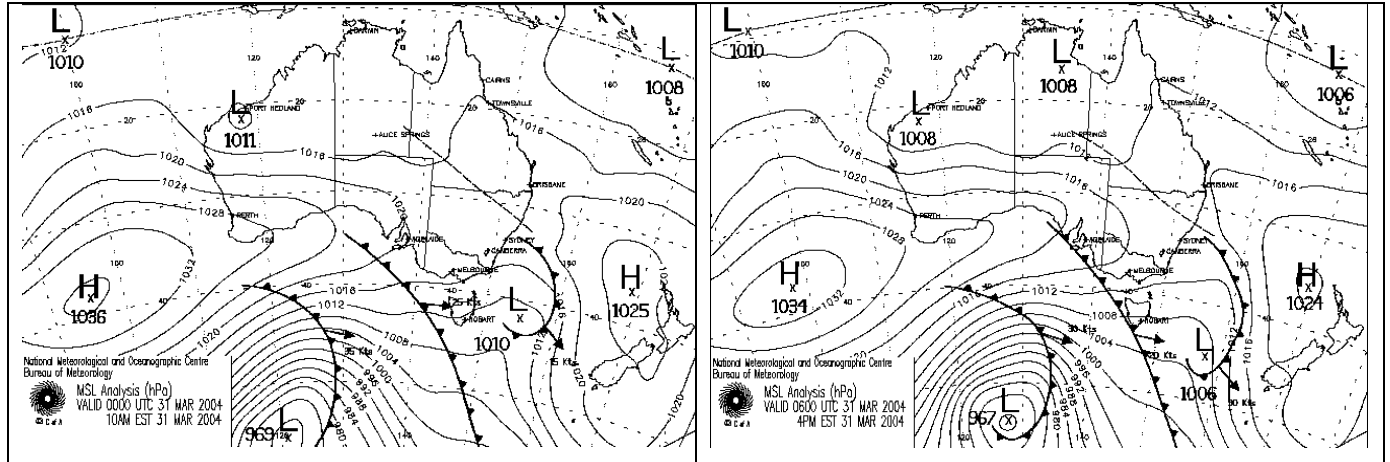


Figure 10: Synoptic charts for the 31st March, 2004 at 1000 and 1600 hours.

Boundary layer parameters

Observational data

Boundary layer data for the 31st March are available from the BoM Williamtown and Mascot sites (wind and temperature profile data through the lower atmosphere) and from Delta Electricity surface sites in the Central Coast region.

Wind (0300, 0600, 0900 and 1500 hours) and temperature (0600 and 1500 hours) profiles from Mascot and are shown in Figure 11.

Wind (0300, 0900 and 1500 hours) and temperature (0900 hours) from Williamtown are shown in Figure 12.

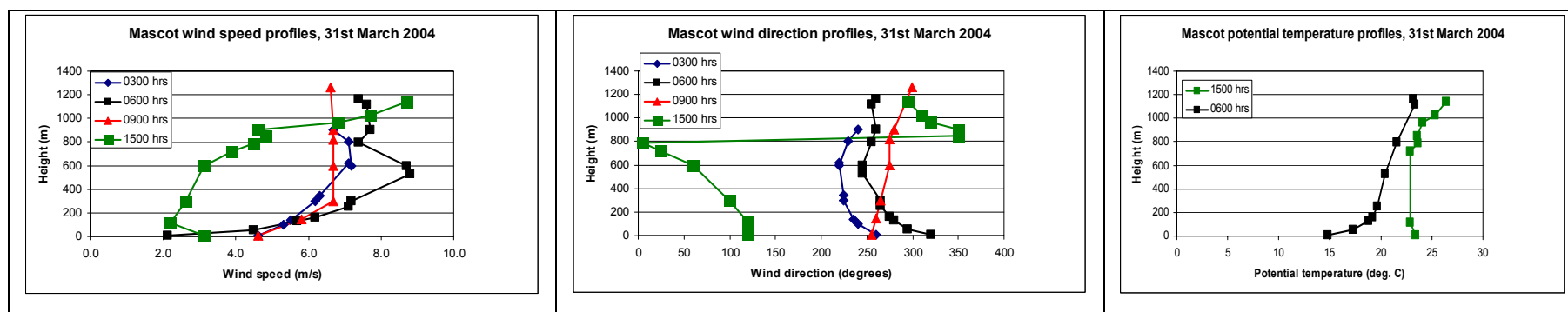


Figure 11: Wind speed, wind direction and potential temperature profiles from Mascot, 31st March, 2004.

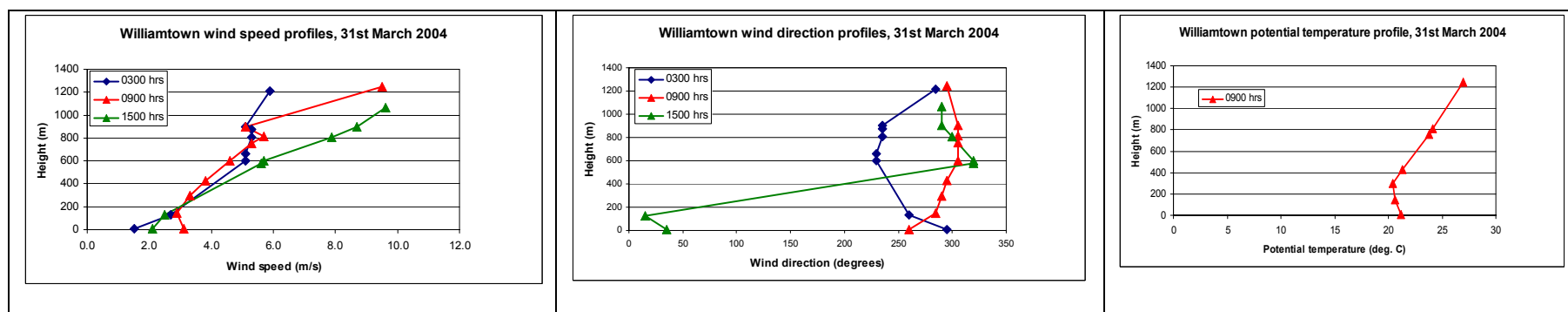


Figure 12: Wind speed, wind direction and potential temperature profiles from Williamtown, 31st March, 2004

Wind directions were south-westerly to north-westerly above the surface in the morning, with speeds exceeding 6 m/s. The Mascot 0600 potential temperature profile showed a stable lower atmosphere. The Williamtown 0900 temperature profile shows a mixed layer of about 300 m, probably the result of morning surface heating, with stable conditions above.

In the afternoon (1500 hours) winds below about 800 m (Mascot) and 600 m (Williamtown) show considerable wind shear indicative of the development of a sea-breeze with speeds 2 – 5 m/ through this layer. Above about 600m the atmosphere remained stable.

Data from the surface anemometers in the region indicated very light winds in the morning followed by the arrival of what appears to be a sea breeze around 1100 hours. Wind speeds increased to 2 - 3 m/s from the north- east to east with the arrival of the sea breeze.

Munmorah climatic station recorded a maximum temperature of 26.8°C at 1200 hours which is up to 4 degrees lower than daily maxima recoded on other days in the period mid-March to mid-April and maximum net radiation of 450 Wm⁻² at 1100 hours. The maximum net radiation value during the year was 690 Wm⁻² and in the period mid-March to mid-April, 540 Wm⁻².

TAPM predictions

Data were extracted from the TAPM output files to illustrate the model’s predictions for boundary layer parameters on the 31st March. Boundary layer profiles for 0900 hours and 1200 hours (the hour of highest glcs) are shown in Figures 13 and 14 respectively.

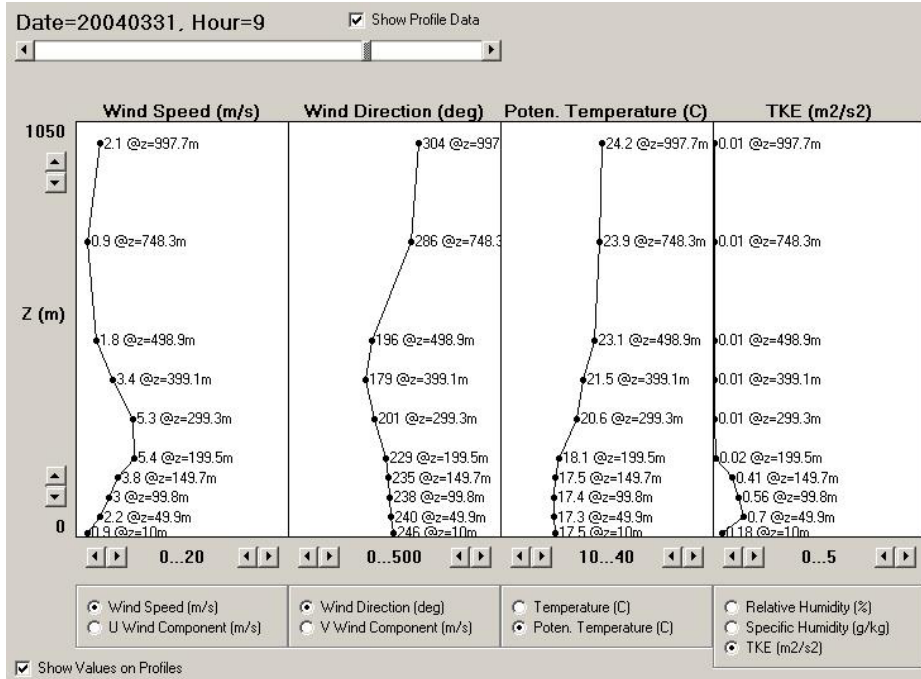


Figure 13: TAPM predictions of wind speed, wind direction, potential temperature and turbulence (TKE) at 0900 hours on the 31st March, 2004

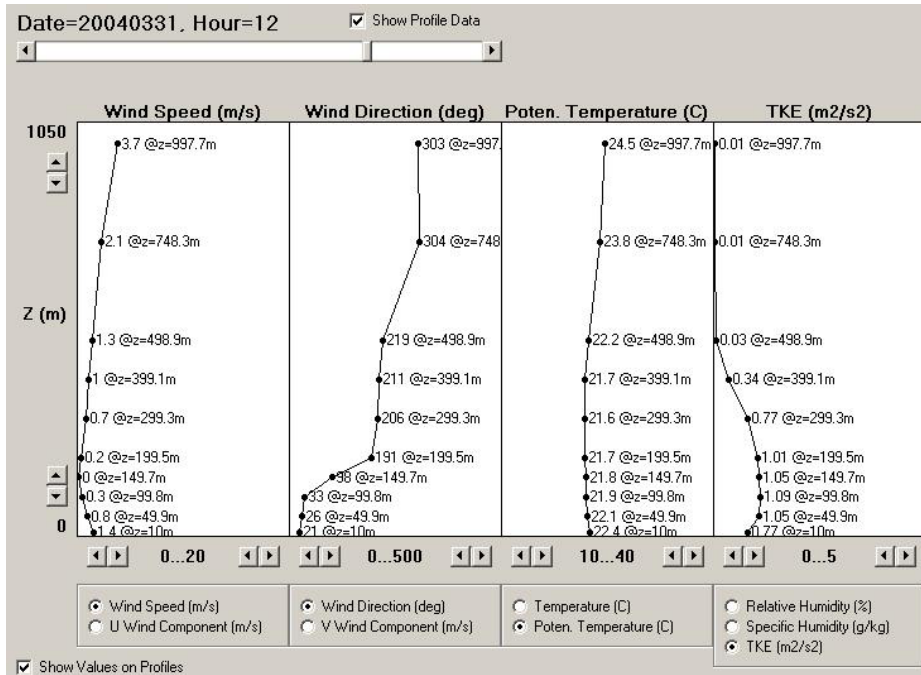


Figure 14: TAPM predictions of wind speed, wind direction, potential temperature and turbulence (TKE) at 1200 hours on the 31st March, 2004

The figures at 0900 hours show that the lower atmosphere is generally stable (as indicated by the potential temperature profile) with wind speeds up to 5.4 m/s and with a profile that appears to indicate a drainage or katabatic flow.

At 1200 hours, the hour in which the maximum SO₂ concentrations were recorded, winds below about 500 m are very light (around 1 m/s and less). Below about 200 m winds are from the north-east, indicating the arrival of a shallow sea breeze. The TKE profile indicates a convectively mixed layer of about 300 - 400m with stable air above.

At 1200 hours, TAPM predicted mixing heights of about 340 m in the region and the effect of this is reflected in Figure 15 which, at the time of maximum predicted concentrations, shows TAPM predicted that the Munmorah plume was mostly contained below 400 m.

TAPM predicted net radiation values up to 572 W Wm⁻² on this day and convective velocity (W star) of up to 1.3 m/s.

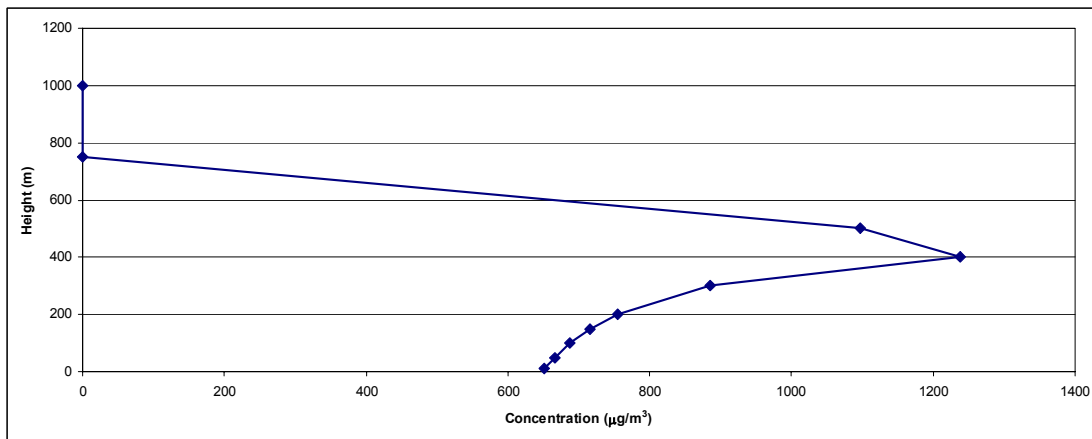


Figure 15: Modelled concentration profile on the 31st March, 2004

Summary

With respect to the gross features of the boundary layer, the conditions on the 31st March, 2004 are similar to those on the 28th January, 2004 and, as was the case with the 28th January, TAPM performed very well in predicting these gross features of the boundary layer meteorology on the 31st March, 2004, including the early morning wind and stability conditions followed by the arrival of the sea breeze and limited mixing in the boundary layer. Again, some of this good agreement may be explained by the use of data from local anemometers to “nudge” the results.

However, as was the case with the 28th March, at the time of maximum glcs, it is considered that TAPM may have under-estimated the (very light) wind speeds in the boundary layer. BoM profiles for the relevant hour (1200) are not available, but it is instructive to note that wind speeds recorded at Wyee and Lake Munmorah School at this time (2.5 and 2.7 m/s, respectively) are greater than predicted by TAPM, which indicated wind speed of less than < 1.5 m/s at the surface (Figure 14). At heights of between 100 and 200m, TAPM predicted wind speeds as low as 0.2, 0.3 and 0 m/s (i.e. “calm”). (Figure 14). Again, this will be commented on in Section 6.

As was the case with the sea breeze on the 28th March, TAPM predicted very little direction shear (change in direction with height) through the sea breeze. BoM profile data at 1500 hours (Figures 11 and 12) show considerable directional shear with height through the sea breeze measured at Williamtown and Mascot whereas the TAPM output for 1500 hours (Figure 16) shows very little wind shear through the sea breeze.

Finally, the containment of the plume below 400 m at the time of maximum predicted glcs is also likely to be play a “critical” part in the predicted high glcs, and will be commented on in Section 6.

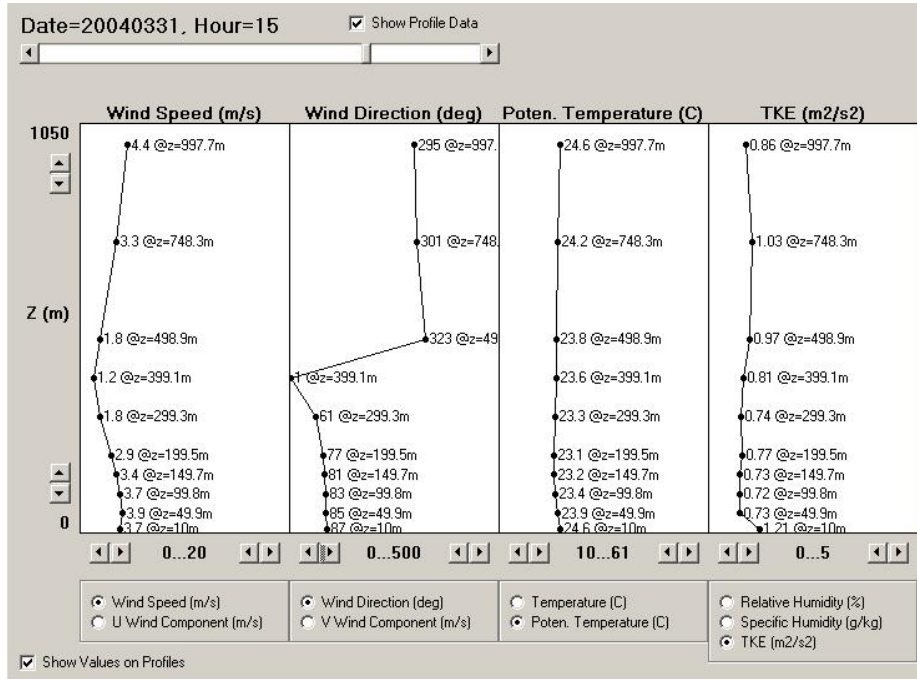


Figure 16: TAPM predictions of wind speed, wind direction, potential temperature and turbulence (TKE) at 1500 hours on the 31st March, 2004

6. DISCUSSION

The assessment undertaken for this report has indicated that TAPM has performed well in predicting the gross features of the boundary layer on 2 days on which high SO₂ concentrations were predicted to occur. On both days the lower atmosphere was stable in the early morning and it appears that the predicted high concentrations occurred in association with the development of a shallow sea breeze and very light winds, low mixing heights and little directional shear. Convection was strong enough to bring the plumes to the ground in high concentrations. (On both days, “elevated” concentrations occurred in the hours preceding and following the maximum predicted glcs. but at levels below the assessment criterion.)

From the earlier discussion in Section 4, it is apparent that conditions in the boundary layer on both days satisfy the “critical” boundary layer conditions considered to be associated with the occurrence of elevated glcs from tall stack emissions, namely:

- Very light wind speeds through the boundary layer up to plume height (generally less than 1.5 m/s);
- Little directional wind shear through the boundary layer;
- Limitation on mixing height in the boundary layer (generally less than ~800m); and
- Convection in the boundary layer capable of bring the plume to ground.

However, it should be noted that the parameters are called “critical”, in part, because small changes in one or more of these parameters can bring about a significant change in the predicted glcs. In the points

below, TAPM's predictions for the critical boundary layer parameters on the 2 event days are considered in relation to plume dispersion and hence predicted maximum glcs.

First, it was shown that TAPM may have under-predicted wind speeds in the boundary layer at the times of maximum predicted glcs. On the 31st March, TAPM (implausibly, perhaps for an hourly average) predicted hourly average wind speeds of 0 m/s (i.e. "calm") and 0.2 m/s between 150 – 200m above the surface at the time of maximum predicted glcs. On the 28th, wind speeds well above the surface in the sea breeze were predicted to be less than 1 m/s. Other things being equal, predicted glcs are proportional to the wind speed in the boundary layer. At the very light wind speeds being considered in these cases, an under-prediction of as little as 0.5 m/s, for example, could result in glcs being over-predicted by 50%.

Secondly, it was shown that TAPM predicted very little wind shear through the sea breezes at the times of maximum predicted glcs. In comparison, BoM data for Mascot and Williamtown showed considerable directional shear through the sea breezes on these 2 days. The effect of directional shear with height is to mix, or spread, the plume horizontally in the atmosphere prior to it mixing to the ground and hence resulting in lower glcs compared with the situation where there is little shear, other things remaining equal.

Thirdly, on both days TAPM predicted that the Munmorah plume was contained in a shallow layer near the surface (< 400m). The significance of low mixing heights on plume dispersion was illustrated in Figures 8 and 15, showing the plume to be constrained in the height in the lower atmosphere through which it can be mixed. It is not possible to test the accuracy of these predictions here, but it is noted that the temperature profile from Williamtown at 0900 hours on the 31st March, showed what appeared to be a developing mixed layer of about 300 m. It is, therefore, not implausible to suggest that with 3 hours of additional surface heating between 0900 and 1200 hours, the mixed layer would have reached a height well in excess of that predicted by TAPM. It is also noted that in a previous assessment of elevated SO₂ events in the Central Coast region (Lilley et al 2007) mixing heights in the order of 600 – 800m were reported, albeit on different days and in relation to other emission sources.

Fourthly, solar radiation drives convection in the boundary layer and TAPM's calculated value of the convective velocity scale, W_{star} , is in large part determined by the solar radiation input. The Munmorah climatic station does not record solar radiation but does record net radiation⁴, a useful surrogate for solar radiation. On the 2 days in question, it appears that TAPM's value for the maximum radiation recorded on the day was in excess of values actually measured. No measurements are available for Munmorah climatic station on the 28th January, but TAPM's maximum net radiation value of 732 Wm⁻² was higher than the maximum value of 690 Wm⁻² recorded at Munmorah climatic station in all other hours of the year. On the 31st March, TAPM's maximum net radiation value of 572 W Wm⁻² was 27% higher than the net radiation recorded at Munmorah climatic station (450 Wm⁻²). It is therefore possible that TAPM's prediction of the strength of convection in the boundary layer was over-estimated, contributing to higher glcs than might otherwise have been predicted.

The overall conclusion from the 4 points discussed above is that while TAPM performed well in predicting the gross boundary layer conditions on the days in question, and that while the predicted conditions are physically possible, the TAPM predictions for the critical boundary layer parameters are likely to have resulted in plume dispersion being under-estimated and hence maximum concentrations being over-estimated.

⁴ Net radiation is the difference between downward and upward radiation (both shortwave and longwave).

It is further considered that relatively small, realistic changes to the predicted critical boundary layer parameters, based on the observational data for the days in question, could result in maximum concentrations less than the assessment criterion.

Finally, it is worth noting that the predicted occurrence of these “critical” meteorological factors operating in concert is infrequent. For the assessment year, there was one hour out of 8,784 hours during which the critical meteorological parameters resulted in predicted glcs exceeding the assessment criterion at a sensitive receptor. Added to this is the conservative nature of the air quality modelling undertaken for the assessment in which it was assumed that Munmorah Power Station was operating at full load and with 0.7% sulfur coal for all hours of the year. In reality, Munmorah is unlikely to operate at full-load for more than 50% of the hours in a year (and this may well be a significant over-estimate). Further, indicative data indicate that coal with a sulfur content as high as (the modelled) 0.7% will be burnt for perhaps 5% of the time and that for the significant majority of the time coal sulfur levels will be *well* below 0.7% and closer to levels traditionally supplied to the power station. Combining these pieces of information suggests that the probability of the highest predicted glc occurring (irrespective of the veracity of that prediction) is in the order of 1 in 350,000 (hours)⁵.

⁵ Probability ~ 1/8784 x 1/2 x 1/20

7. CONCLUSIONS

- Under a “worst-case” emission scenario, TAPM predicted two, hourly-average events for the year 2004 in which the assessment criterion for sulfur dioxide was exceeded.
- A detailed review of the meteorology on the two event days found that TAPM performed well in predicting the gross atmospheric boundary layer conditions.
- While the predicted boundary layer conditions are physically possible, the TAPM predictions for the critical boundary layer parameters are likely to have resulted in plume dispersion being underestimated and hence maximum concentrations being over-estimated on the two days.
- Relatively small, realistic changes to the predicted critical boundary layer parameters, based on the observational data for the days in question, could result in maximum concentrations less than the assessment criterion.
- The examination of the boundary layer meteorology on the days in question supports the earlier CSIRO conclusion that the predicted 100th percentile concentration is not appropriate for assessing the potential impacts from tall stacks under the diverse range of conditions occurring in the Central Coast region.
- Even if the highest concentration predicted by TAPM was correct, the probability of it occurring is estimated to be in the order of 1 in 350,000 (hours) or once in about 40 years.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

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