final report

FEEDLOT

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Cattle heat load forecasting service - summer 2006-2007

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Abstract

A weather forecasting system was developed to assist in warning operators of cattle feedlots of impending adverse weather conditions that could lead to excessive heat loads (and potential mortality) for feedlot cattle. This forecasting system covered several locations in the proximity of feedlots where Bureau of Meteorology (BoM) automatic weather stations (AWS) are located.

The forecasts were made over the period 1 December 2006 to 31 March 2007 at 17 sites throughout Queensland, New South Wales, South Australia, Western Australia and Victoria. Forecasts were made of wind speed, temperature and dew point, these being the input parameters necessary to calculate the Heat Load Index (HLI) and ultimately the Accumulated Heat Load Unit (AHLU).

Forecasts for all 17 sites were posted daily onto a website (www.katestone.com.au/mla) for easy access to all feedlot operators.

There was good agreement between the forecast and observed temperature and dew point. The relative humidity was calculated from these parameters. Solar radiation was calculated analytically using the date, time of day and latitude of the site. The wind speed forecasting performance, however, was relatively poor.

Heat stress is divided into four risk categories: low, medium, high and extreme. The risk categories span AHLU values of 0 to greater than 100. The low risk category ranges from 0 to 20 AHLU, the higher risk categories extend over 30 and 50 AHLU. It is more important to predict the risk category well than the actual AHLU. The forecasting system's performance at predicting the risk category has been found to be good. It is much more difficult to predict individual AHLU values and, consequently, the forecasting system did not perform as well in this regard.

Executive summary

Introduction

One of the issues that needs to be addressed in managing feedlots is the possibility of cattle deaths due to heat stress brought on by adverse weather conditions. One tool for managing heat stress is to forecast stress inducing conditions for a prescribed future period. In the summer of 2001-02, Katestone Environmental developed a forecasting system for MLA to predict a cattle heat stress index out to 6 days ahead for four sites in Queensland and New South Wales. Meteorological data were obtained on a daily basis from the on-site meteorological stations and the nearest Bureau of Meteorology automatic weather station (AWS). The Temperature Humidity Index (THI, an indicator of heat stress) was calculated from these data and made available to feedlot operators.

The forecasting study was expanded over the summer of 2002-03 to incorporate a Heat Load Index (HLI) developed specifically for feedlot cattle and to extend the coverage to 14 sites across eastern Australia. The service was expanded for the 2003-04 summer period with the addition of Katanning (Western Australia), again in 2004-05 to include Charlton in Victoria and also to incorporate a revised HLI algorithm and the Accumulated Heat Load Unit (AHLU). In 2005, the service was again expanded to include the site at Cessnock, NSW. The present study (2006-07) includes the following 17 sites:

- Queensland – Amberley, Emerald, Miles, Oakey, Roma, Warwick;
- New South Wales – Albury, Armidale, Cessnock, Griffith, Hay, Moree, Tamworth, Yanco;
- South Australia – Clare;
- Western Australia – Katanning; and
- Victoria – Charlton.

Key issues

The key issues in implementing a viable feedlot weather forecasting system include:

(a) Identification of primary and derived meteorological parameters that indicate excessive heat load in cattle.

(b) Selection of methodology for predicting primary and derived parameters at AWS locations for a suitable time horizon.

(c) Development of a forecasting software system for predicting feedlot conditions.

(d) Making the forecasting results available to all feedlot operators on a daily basis.

At the outset, the following constraints were identified:

- Bureau of Meteorology AWS sites are not generally in close proximity to feedlots and this limits the utility of forecasts made from these sites. Most AWS sites are situated near significant populations or industrial regions and as such only 17 sites were identified to be in close proximity to feedlot operations.
- The Bureau of Meteorology's weather forecast model data (LAPS and GASP), necessary to conduct a forecast, is only stored by the Bureau of Meteorology when requested. Therefore the models created for the recently added sites (viz. Cessnock and Charlton) were based on a small amount of historical LAPS/GASP data, which can affect model performance.
- It was found that the most effective technology for making the forecasts available to feedlot operators was through the World Wide Web. The advantages are that the data

can be presented in a way which is easily interpreted and is readily accessible by all feedlots.

Selected methodology

The following methodology was adopted following discussions between MLA and Katestone Environmental on the most viable options:

- Utilise fully the information from the nearest AWS maintained by the BoM.
- Calculate the key parameters at a fine time resolution out to 6 days ahead.
- Transfer forecasts to a web site on a daily basis.
- Software system to include automatic model retraining as more data become available.

The forecasts were based on the models generated during the previous study conducted by Katestone Environmental for MLA. See Appendix A for a description of the models.

Forecast performance

The main factors that affect the HLI (and AHLU) are temperature, relative humidity (obtained from the dew point) and wind speed. There was good agreement between the forecast temperature and dew point and the observed quantities, however, the wind speed forecasting performance was relatively poor.

In terms of forecasting the heat stress category, it should be noted that the categories are broad – the low risk category ranges from 0 to 20 AHLUs, the higher risk categories extend over 30 and 50 AHLUs. Therefore, although agreement between the forecast and observed AHLU values might be poor, these would fall into the same heat stress category, giving better performance in predicting the category in contrast to forecasting individual AHLU values.

Recommendations

If a future forecasting system is to include more sites, we would recommend ample warning of the sites of interest so we can request that the Bureau of Meteorology store the LAPS/GASP information for these regions. Having a larger database of information from which to conduct the forecasts would improve forecast performance in the initial months.

As heat stress management in cattle is an ongoing area of research, future projects should include up to date methods for calculating heat stress parameters on cattle and reporting these on a regular basis.

Contents

1 Introduction

One of the issues facing feedlot managers is the possibility of cattle death in feedlots due to heat stress caused by adverse weather conditions. One tool in the overall management strategy is the ability to forecast stress inducing conditions for a prescribed future period. In the summer of 2001-02, Katestone Environmental undertook a feasibility study for MLA (FLOT.313) for forecasting excessive heat load in cattle. This forecasting system utilised data from four feedlots that operated on-site meteorological stations and was based on the calculation of the Temperature Humidity Index (THI), previously developed as an indicator of human comfort, derived from available forecast meteorological variables (temperature and dewpoint). Forecasts were conducted for on-site meteorological stations and for the nearest Bureau of Meteorology AWS. These forecasts were then compared with observations and it was confirmed that suitable forecasts could be generated from the AWS stations for the feedlot sites.

Recent studies on cattle heat stress (Gaughan et al., 2002) indicate that the HLI was a better indicator of cattle heat stress than the originally used THI. These studies also found that the number of hours that the HLI was above a threshold (89) was also a good indicator of accumulated heat load in cattle. The studies also found that if the HLI fell below 77 for a number of hours then the cattle would be able to recover somewhat from the heat stress.

Further studies (see MLA report FLOT.327) have indicated that the Accumulated Heat Load Unit (AHLU), a parameter obtained by accumulating the number of hours the HLI exceeds a certain threshold, is indicative of the heat stress in feedlot cattle. Also, it was found that the threshold depended on genus, environmental factors (wind speed, temperature etc) and pen factors (availability of shade, cooled drinking water etc).

This forecasting system has been expanded each summer since 2001-02 and now includes seventeen sites around Australia with forecasts being conducted every day over the summer period. For the 2006/2007 summer period, the service provided heat stress forecasts for the period 1 December 2006 to 31 March 2007 for the following sites:

- Queensland – Amberley, Emerald, Miles, Oakey, Roma, Warwick;
- New South Wales – Albury, Armidale, Cessnock, Griffith, Hay, Moree, Tamworth, Yanco;
- South Australia – Clare;
- Western Australia – Katanning; and
- Victoria –Charlton.

2 Study definition and objectives

MLA requested a forecasting system to assist in identifying potential cattle heat stress events. The objectives of the study were to:

- Provide forecasts out to 6 days ahead for predicted daily maximum and minimum HLI, AHLU for various upper HLI thresholds and forecast rainfall. These forecasts were to be made for the period 1 December 2006 to 31 March 2007.
- Allow the forecasts to be accessible on a daily basis by each of the feedlot operators.
- Retrain the models regularly to improve the forecasts.
- Examine the accuracy of the forecasts.

3 Short-term forecasting of excessive heat load

3.1 Key forecasting parameters

Short-term forecasting of dry bulb temperature, dewpoint temperature and wind speed are performed on a routine basis by the Bureau of Meteorology (BoM). These are the parameters from which many heat stress indices can be derived. It is also highly desirable to include rainfall and solar radiation parameters in any heat load forecasting scheme but there is currently less skill in producing such forecasts.

Regional rainfall forecasts are available from the Bureau of Meteorology which have been included in the daily forecasts. Solar radiation was calculated analytically using the date, time of day and latitude of the site. The solar radiation value does not account for cloud cover and therefore will overestimate solar radiation for cloudy days. The dependence of the HLI on solar radiation used here is relatively minor and as such the resulting overestimation is not considered significant.

The above variables were used to calculate the HLI and AHLU for each site on a half-hourly basis.

3.2 Forecasting methodologies for fine spatial resolution

Most available forecast models give a regional forecast for areas up to usually 25 x 25 km. The forecasting system adopted for this project gives a forecast for the location of interest. This can be more beneficial in incorporating local influences on the meteorology such as terrain.

The forecast models for each site for the meteorological variables were produced using the same methodology as previous forecasting detailed in “FLOT. 313 – Development and trial operation of a weather forecasting service for excessive heat load events for the Australian feedlot industry”. In these models, both the wind speed and wind direction are forecast for all sites except Griffith and Hay. For these sites it was necessary to model wind speed alone (as a scalar quantity) due to the large spatial separation between the feedlot and the upper-level input forecast region.

3.3 Bureau of Meteorology services

LAPS and GASP data were provided by the Bureau of Meteorology for each of the forecasting sites along with the AWS data on a daily basis. Details of this information can be found in the previous forecasting report (Katestone Scientific, 2002). The LAPS and GASP, along with the AWS data, were downloaded, on a daily basis from a web site specially arranged by the Bureau of Meteorology.

3.4 Parameters for characterising Heat Stress

Three parameters for characterising heat stress in feedlot cattle are the HLI, the AHLU and the panting score. The HLI and AHLU are indirect measures of heat stress, being derived from the prevailing meteorological conditions. The panting score is a direct measure, being derived from the breathing rate of cattle.

3.4.1 Heat Load Index (HLI)

The HLI is obtained from the half-hourly average meteorological parameters. These include wind speed, relative humidity and, through an intermediate parameter – the Black Globe Temperature (BGT) - temperature and solar radiation.

The HLI can be thought of as a rate of heat input into a system. Consequently, even though a high HLI value may potentially be highly detrimental, it will have little effect if it is of short duration. A more sensible measure of heat stress is obtained by integrating the HLI to obtain the AHLU, which will be discussed in the following section.

If any calculation yielded a HLI value less than 50, this value was set to 50.

3.4.2 Accumulated Heat Load Unit (AHLU)

The AHLU is obtained by integrating or, in the case of discrete data, accumulating the product of HLI and time interval (in hours) between HLI estimates. The AHLU can be thought of as the level of heat stress existing in a system. A high HLI for a short time interval will have the same impact as a low HLI over a long time interval. Conversely, a high HLI for long periods of time will result in high (and detrimental) values of AHLU.

The Thermo-Neutral zone is defined as a range of HLI values wherein no heat stress is accumulated by cattle. The lower boundary of the Thermo-Neutral zone is set at a HLI value of 77 – recovery occurs when the HLI falls below this value. The upper boundary (upper HLI threshold) of the Thermo-Neutral zone depends on the genus, physical condition and the pen environment of the cattle in question.

Different genotypes react differently to HLI. For example, healthy Bos Taurus would exhibit the symptoms of heat stress at an earlier stage than a healthy Bos Indicus exposed to identical conditions. In other words, Bos Taurus will reach a given AHLU level more quickly than Bos Indicus. To incorporate this into the AHLU calculation and still maintain a consistent correspondence between AHLU and cattle heat stress, an upper HLI threshold below which the AHLU does not accumulate is obtained in terms of genotype, pen conditions and animal state. For discussion and details of how this upper threshold is calculated, the reader is referred to “FLOT. 327 – Development of a Heat Load Risk Assessment Process for the Australian feedlot industry”.

Thus there are two HLI thresholds that must be considered when calculating the AHLU. An upper threshold determined from the report cited above and a lower threshold set at 77. If the HLI value exceeds the upper threshold, the AHLU is incremented by the product of the interval between HLI values and the difference between the HLI and the upper threshold. If the HLI value is less than the lower threshold, the AHLU is decremented by one half of the product of the interval and the difference between the lower HLI threshold and the actual HLI value. The factor of one half is included to allow for the slower recovery rates.

For example, suppose that the current AHLU value is 42 and the upper HLI threshold for a particular cattle type is 90. If the observed HLI were 94, then the excess would be +2 ((94–90)*0.5; the 0.5 representing the half hour interval between observations) and this excess would be added to the current AHLU value giving a new AHLU value of 44. If, instead, the observed HLI value were 65, the nominal excess would be –6 ((65–77)*0.5; 77 being the lower threshold, 0.5 being the half hour interval between observations). Since the excess is negative, it is halved as the recovery rate is slower, thus final excess is now –3, giving a new AHLU value of 39. For HLI values between 77 and 90, the Thermo-Neutral zone, the excess would be zero.

Evidently, the upper HLI threshold can take a large number of values depending on the characteristics of the animal and its environment, resulting in a corresponding large number of AHLU values. To avoid the situation where excessive amounts of data are generated and analysed, it was decided to determine AHLU values for discrete upper HLI threshold values of 80, 83, 86, 89, 92 and 95.

3.4.3 Panting Score

A direct measure of heat stress is the panting score. This is obtained by measuring the breathing rates of cattle in the feedlot. The relationship between AHLU and panting score is summarised in the following table:

AHLU	**Heat stress category**	**Cattle indications**
0-20	Low risk	No stress or panting score 1
20-50	Medium risk	Panting score 1-2
50-100	High risk	Panting score 2-4
Over 100	Extreme risk	Panting score 4

3.4.3.1 Relative Humidity Calculation

The relative humidity (RelHum in %) used in the calculation of HLI was calculated from the temperature (Temp in ºC) and dew point temperature (DewPt in ºC) using the following equation:

$$RelHum = 100 * \left(\frac{1.8*DewPt - 0.18*Temp + 201.8}{1.62*Temp + 201.8} \right)^8$$

Equation 1. Relative humidity calculated from temperature and dew point

3.4.3.2 Solar Radiation Calculation

Solar radiation (SolRad in W/m^2) is not recorded at any of the Bureau of Meteorology AWS sites. The following equations were used to calculate solar radiation for each hour for each day based on the location of the sun throughout the day and year (Oke, 1987). The equation assumes no reduction in radiation due to cloud cover resulting in a conservative estimate of the HLI.

$$localHr = \frac{15\pi}{180}(12 - t)$$

$$declination = \frac{-23.5\pi}{180}\cos\left(\frac{2\pi(day + 10)}{365}\right)$$

$$elevation = \sin^{-1}\left(\sin(lat)\sin(declination) + \cos(lat)\cos(declination)\cos(localHr)\right)$$

$$SolRad = 1050\sin(elevation) - 65$$

Equation 2. Solar radiation equation

where

t is the time of the day in hours
day is the Julian day of the year
lat is the latitude of the site.

3.4.3.3 Heat Load Index Calculation

To calculate the HLI for each data record, the following equations were used:

$$
\begin{aligned}
& BGT = 1.33*Temp - 2.65*\sqrt{Temp} + 3.21*\log(SolRad + 1) + 3.5 \\
& if \;\; BGT < 25 \\
& HLI = 1.3*BGT + 0.28*RelHum - WSpeed + 10.66 \\
& else \\
& HLI = 1.55*BGT + 0.38*RelHum - 0.5*WSpeed + \exp(2.4 - WSpeed) + 8.62
\end{aligned}
$$

Equation 3. Heat Load Index equations

where

Wspeed (wind speed) is measured in m/s.
Temp (temperature) is measured in °C.
RelHum (relative humidity) is expressed as a %.
SolRad (solar radiation) is measured in W/m²
BGT (Black Globe Temperature) stated in ºC.

3.4.3.4 Accumulated Heat Load Unit Calculation

The AHLU was calculated using the following algorithm:

$$
\begin{aligned}
& if \;\; HLI < 77 \\
& excess = HLI - 77 \\
& else\ if \;\; HLI > upper\_threshold \\
& excess = HLI - upper\_threshold \\
& else \\
& excess = 0 \\
& \\
& if \;\; excess < 0 \\
& excess = excess / 2 \qquad \text{// halve it for slower recovery rate} \\
& \\
& excess = excess * time\_interval \\
& AHLU_{new} = AHLU_{old} + excess
\end{aligned}
$$

Equation 4. Algorithm for accumulating AHLU

where

HLI is the Heat Load Index.
AHLU is the Accumulated Heat Load Unit.
upper_threshold is the HLI value where AHLU starts to accumulate
time_interval is the interval between HLI estimates (0.5 hours)

3.5 Service delivery mechanisms

For this project, forecasts were automatically generated every morning (06:00 hrs), checked by Katestone Environmental staff and transferred to the web site www.katestone.com.au/mla.

4 Overall methodology

The prototype system was based on the models developed in our previous forecasting system developed for the MLA. It consists of the following steps:

a) Obtain upper-level forecast data from numerical weather prediction models via a special web site maintained by the Bureau of Meteorology.

b) Collect concurrent information from an automatic weather station close to the site of interest.

c) Once a sufficient training set of information is collected, use proprietary Katestone software to develop statistical models that relate the surface measurement to a subset of the upper-level variables.

d) Use these models and the most recent data to provide the necessary forecasts.

5 Accuracy of forecasting system

5.1 Statistical measures for forecast accuracy

Three coefficients were used to determine the performance of the HLI forecasting system: the Pearson Correlation Coefficient, Index Of Agreement (IOA) and the Root Mean Square Error (RMSE).

The Pearson Correlation Coefficient is a measure of the strength of the linear relationship between the predicted and observed measurements (defined in Equation 5). The closer this value is to unity the stronger the relationship. The Index Of Agreement (IOA) is defined in Equation 7 and gives an index from 0-1 (1 representing strong agreement). The Root Mean Square Error (RMSE) defined in Equation 6 is an indication of the absolute error. The smaller the RMSE (i.e. the closer the value is to zero) the better the forecast. Note that the RMSE does not indicate whether the forecasts are predominantly higher or lower than the observed values – ie whether the method over or under predicts – it only reports on the difference between the observed and predicted values.

The equations for calculating the coefficients are:

$$r = \frac{N\left(\sum_{i=1}^{N} O_i P_i\right) - \left(\sum_{i=1}^{N} O_i\right)\left(\sum_{i=1}^{N} P_i\right)}{\sqrt{\left[N\left(\sum_{i=1}^{N} O_i^2\right) - \left(\sum_{i=1}^{N} O_i\right)^2\right]\left[N\left(\sum_{i=1}^{N} P_i^2\right) - \left(\sum_{i=1}^{N} P_i\right)^2\right]}}$$

Equation 5. Pearson Correlation Coefficient

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(P_i - O_i\right)^2}$$

Equation 6. Root Mean Square Error

$$IOA = 1 - \frac{\sum_{i=1}^{N}\left(P_i - O_i\right)^2}{\sum_{i=1}^{N}\left(\left|P_i - O_{mean}\right| + \left|O_i - O_{mean}\right|\right)^2}$$

Equation 7. Index of Agreement

5.2 Forecasting results

The reliability of the AHLU forecasts hinges on the accuracy of the HLI forecasts which ultimately rely on the accuracy of the BoM forecasts. Since any AHLU value also relies on the past behaviour of the HLI (through the accumulation process) any inaccuracies in past HLI predictions will have an impact on the most recent AHLU value. However, in the case of low AHLU values, any extreme behaviour is curtailed by not permitting its value to become negative.

One further issue that the reader should be aware of is that there is a discontinuity imposed on the data in the form of the various cut-off values or thresholds, viz. the Thermo-Neutral zone boundaries. The HLI is also limited to a value of 50 should calculations yield a value lower than 50. AHLU values are not permitted to take on negative values. Consequently, any statistical analyses should not be applied indiscriminately and any results arising from such analyses should be interpreted with this in mind.

By way of example, assume that the observed HLI and the one day ahead forecast HLI are being compared. There will be instances when both of these values will be 50, even though calculations would indicate otherwise. This situation indicates perfect correlation between observed and predicted values. There will also be instances when only one of these parameters will be 50. This will result in a number of (say) observed HLI values paired with predicted values which are set to 50 resulting in statistics which may not be representative of the true situation.

The situation is further complicated since two separate equations are used to calculate the HLI value, depending on whether the Black Globe Temperature (BGT) is less than or greater than or equal to 25.

Finally, the quantity of data available for analysis is rather large. There are 17 sites and for each of these sites there are 3 pairs of HLI data sets that can be considered: the observed HLI with each of the one, three and six day ahead forecasts. Also, for each of these sites there are 3 pairs of AHLU data sets and each of these is further subdivided into 6 HLI threshold categories, resulting in excess of 300 pairs of data sets for each of these parameters.

In order to keep this report at a reasonable length, discussion will be restricted to the general behaviour of the relevant parameters. Detailed summaries are presented in appendices. Any behaviour that warrants further investigation will be discussed in greater detail.

5.2.1 HLI behaviour

The HLI was calculated according to Equation 3 using half-hourly predictions of wind speed, temperature and relative humidity. If the calculated HLI value fell below 50, it was set to 50. Cloud information and solar radiation were not available, hence solar radiation was calculated using Equation 2. This represents the maximum radiation for the time of year, time of day and latitude of the site. Whilst this will tend to overestimate the actual solar radiation, it has only a minor effect on the predicted HLI because of the logarithmic dependence of HLI on solar radiation. To illustrate this, a factor of 10 change in solar radiation (say from 1000 W/m^2 to 100 W/m^2 or cloudless to very cloudy) will cause a decrease in HLI value of either 4.16 to 4.96, the exact value depending on whether the BGT was below or above 25 respectively.

Appendix B contains a table of statistical and line of best fit parameters describing the accuracy of the forecasting process. The model performed very well with correlation coefficients ranging, on average, from 88% for the one day ahead forecasts to 78% for the six day ahead forecasts. The other statistical measures showed similar behaviour. The bias indicated that the one and three day ahead forecasts tended to over-predict the HLI whereas the six day ahead forecasts showed an even mix of over and under predictions. Overall, the forecasting performance is very good, with the tendency for the forecast accuracy to decrease as the forecast horizon increases, as would be expected. The remainder of this section will focus on specific aspects of HLI behaviour

The Figure 1 is a scatter plot of the one day ahead forecasts of HLI plotted against observed HLI (half-hourly data) for Emerald. There are several features in this graph which merit some comment.

Firstly, there is a sharp cutoff in the data due to the lower limit of 50. Secondly, the remaining data are scattered about a straight line of unit slope. Perfect forecasts would have resulted in all the points lying exactly on the line. The scatter about the line results from errors in forecasting and increases as the errors in the forecasts increase. This is typical of plots depicting observed versus forecast variables. Note also that the data form two distinct groups or clusters – one centred about a HLI value of about 55 and the other centred on a HLI value of about 88, representing night time and daytime observations/forecasts respectively. Thirdly, there are some data points – the outliers - which are located a substantial distance from the line. Possible explanations for the existence of these are that the forecast technique failed due to exceptional processing conditions (eg an algorithm failed to converge) or missing or erroneous input data or these result from using two different expressions for calculating the HLI, ie whether the BGT is above or below 25.

Figures 2 and 3 illustrate the variability that can be expected in the data. Figure 2 is the three day ahead and Figure 3 is the six day ahead forecasts plotted against observed HLI (half-hourly data) for Emerald.

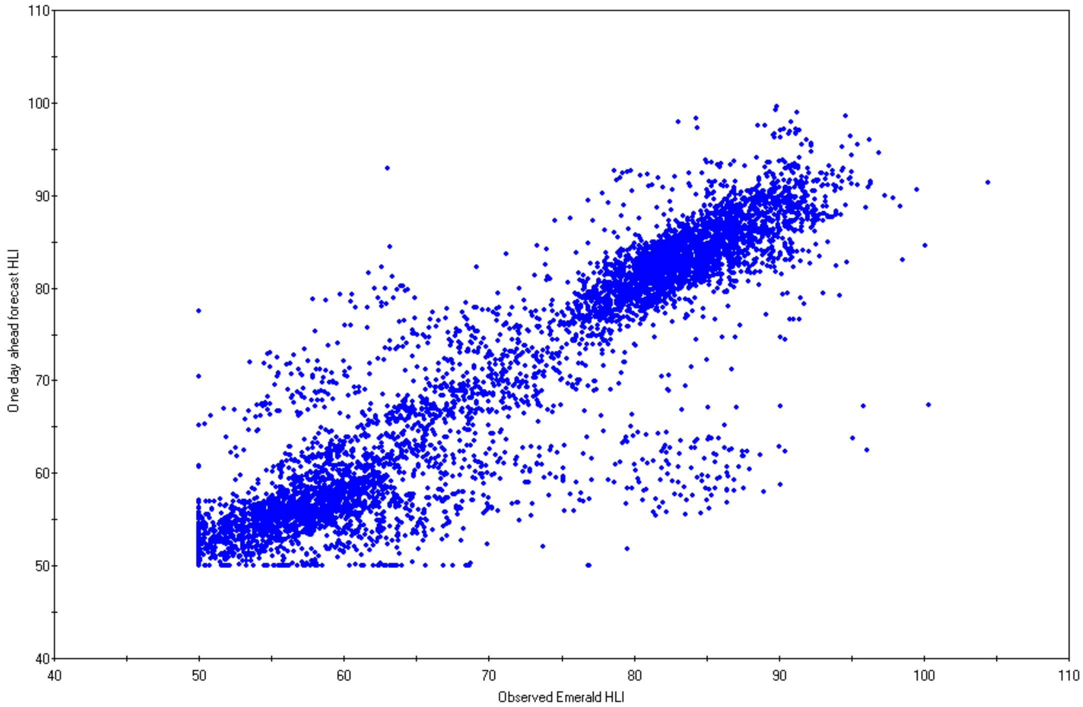

Figure 1: One day ahead forecast versus observed HLI for Emerald

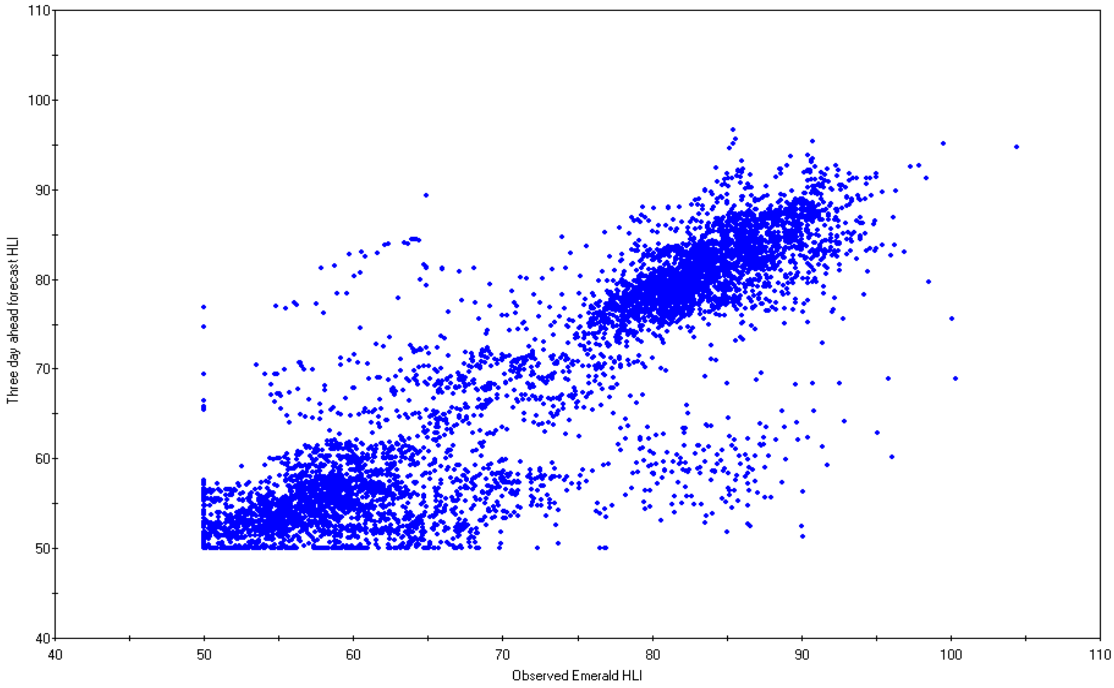

Figure 2: Three day ahead forecast versus observed HLI for Emerald

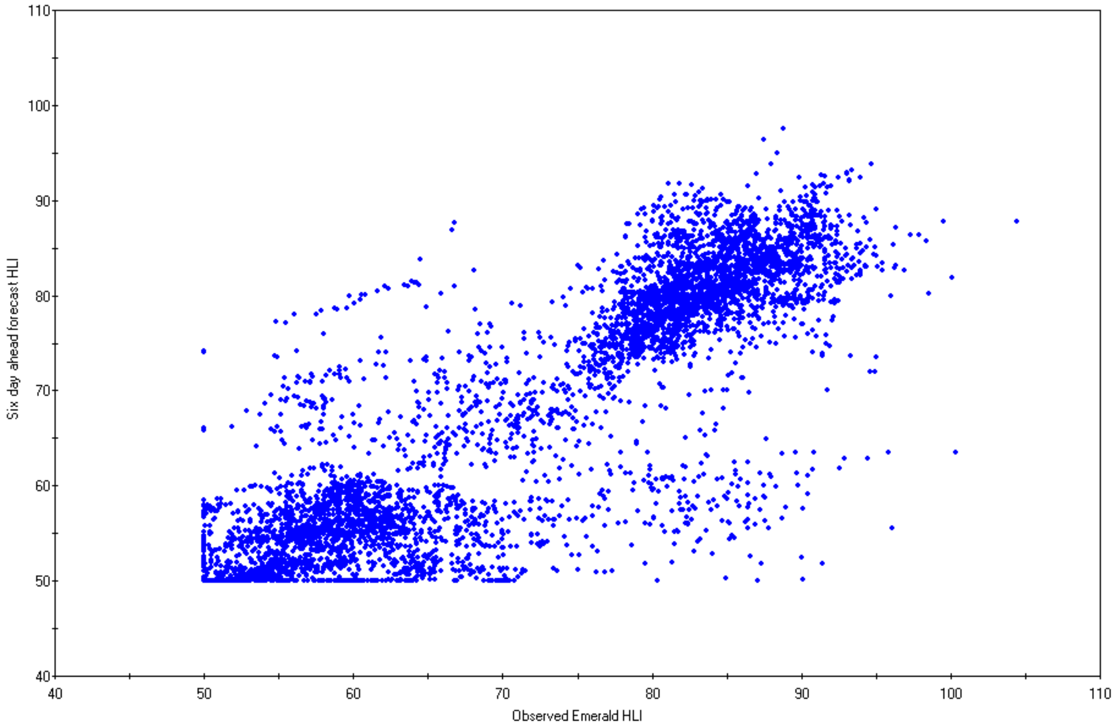

Figure 3: Six day ahead forecast versus observed HLI for Emerald

Note that the features discussed above are still present; also the correlation deteriorates noticeably for the six day ahead forecasts. This is to be expected as it is more difficult to forecast accurately weather six days ahead than one day ahead.

5.2.2 AHLU behaviour

In order to keep the volume of information presented in this report to a manageable level, analyses of AHLU will be restricted to those corresponding to an upper HLI threshold of 86. Also, as the daily maximum AHLU value is the parameter of concern, preliminary analyses will concentrate on this variable. Appendix C contains contingency tables for individual sites for one, three and six day ahead forecasts for AHLU categories using Thermo-Neutral zone upper limits (upper HLI thresholds) of 86, 89, 92 and 95. It should be stressed that the algorithm for calculating the AHLU from the HLI includes extremely non-linear effects. Consequently, even though the forecasting performance for the HLI is good, the forecasting performance for the AHLU will not be related to the HLI forecast performance. The situation is further complicated because the HLI is truncated at a value of 50. Whilst this will not influence the HLI statistics significantly, it will affect the calculated AHLU value.

Table 1 contains a summary of average forecast performance of the daily maximum AHLU for all sites for the four upper HLI thresholds and three forecast periods. The first row which is labelled "Error" represents the error in the forecasts in terms of risk categories. An error of zero indicates that the correct risk category was forecast. An error of +1 represents a forecast risk category that was one category higher than the observed category (eg forecast a medium and observed a low; forecast extreme and observed a high). Similarly an error of -2 represents a forecast risk category that was two categories lower than the observed category (eg forecast a low and observed a high; forecast medium and observed an extreme). All entries in the table are percentages. Detailed site tables can be found in Appendix C, Tables C6 to C9.

Inspection of Table 1 reveals that the correct risk category (error = 0) was forecast 90% of the time or better. Also, the performance tends to improve as the upper HLI threshold is increased, with correct category predicted for 99.9% of the time for an upper HLI threshold of 95. This can be explained as follows. The higher thresholds represent cattle that are less susceptible to heat stress. For this situation, both the forecast and observed AHLU values tend to be increasingly in the low risk category with negligible instances of AHLU values occurring in the medium or higher categories.

There are no obvious dependencies between error and forecast horizons and attempts to infer any dependencies should be tempered by the fact that the equations used to calculate the AHLU values are discontinuous and will introduce anomalous behaviour.

Results for each individual site can be found in Tables C6 to C9, Appendix C. Inspection of these tables reveals that the performance at Emerald and Roma is consistently poorer to the remaining sites. Time series of daily maximum AHLU values (one day ahead forecasts, upper HLI threshold of 86) for Emerald, Roma and Amberley (for comparison) are shown in Figures 4, 5 and 6 respectively. Traces labeled AHLU_86_FC1 represent forecast values and traces labeled AHLU_86_Obs represent observed quantities. Horizontal lines at 20, 50 and 100 are the risk category boundaries.

The main contribution to the poor performance at Roma occurs during the second half of January 2007 when the observed AHLU values were significantly greater than the observed values. Further investigation revealed that during this period, the observed relative humidity was 100% from 1500 hrs, on the 19 January to 0830 hrs, 22 January. This resulted in excessive HLI values with no overnight recovery and consequently high overnight AHLU values which continued to increase the following day. A similar sequence of events occurred at Emerald, however the relative humidity was not as consistently high as Roma, consequently the discrepancies between observed and forecast AHLU values were not as great.

In summary, the performance in forecasting the correct risk category is generally quite good, with the correct risk category being forecast in excess of 90% of the time.

Error	-3	-2	-1	0	+1	+2	+3
Upper HLI threshold = 86							
One day	0.19	0.49	1.65	92.37	4.47	0.68	0.15
Three day	0.34	0.54	2.24	92.85	3.06	0.78	0.19
Six day	0.54	0.78	2.58	93.68	2.19	0.24	0.00
Upper HLI threshold = 89							
One day	0.15	0.34	0.68	97.42	1.22	0.19	0.00
Three day	0.19	0.24	0.97	97.42	1.02	0.15	0.00
Six day	0.29	0.29	1.07	97.96	0.39	0.00	0.00
Upper HLI threshold = 92							
One day	0.24	0.15	0.29	98.98	0.34	0.00	0.00
Three day	0.24	0.19	0.24	99.32	0.00	0.00	0.00
Six day	0.24	0.19	0.24	99.32	0.00	0.00	0.00
Upper HLI threshold = 95							
One day	0.15	0.05	0.24	99.47	0.10	0.00	0.00
Three day	0.15	0.05	0.24	99.56	0.00	0.00	0.00
Six day	0.15	0.05	0.24	99.56	0.00	0.00	0.00

Table 1: Table of risk category forecast error averaged over all sites combined (daily maximum AHLU values)

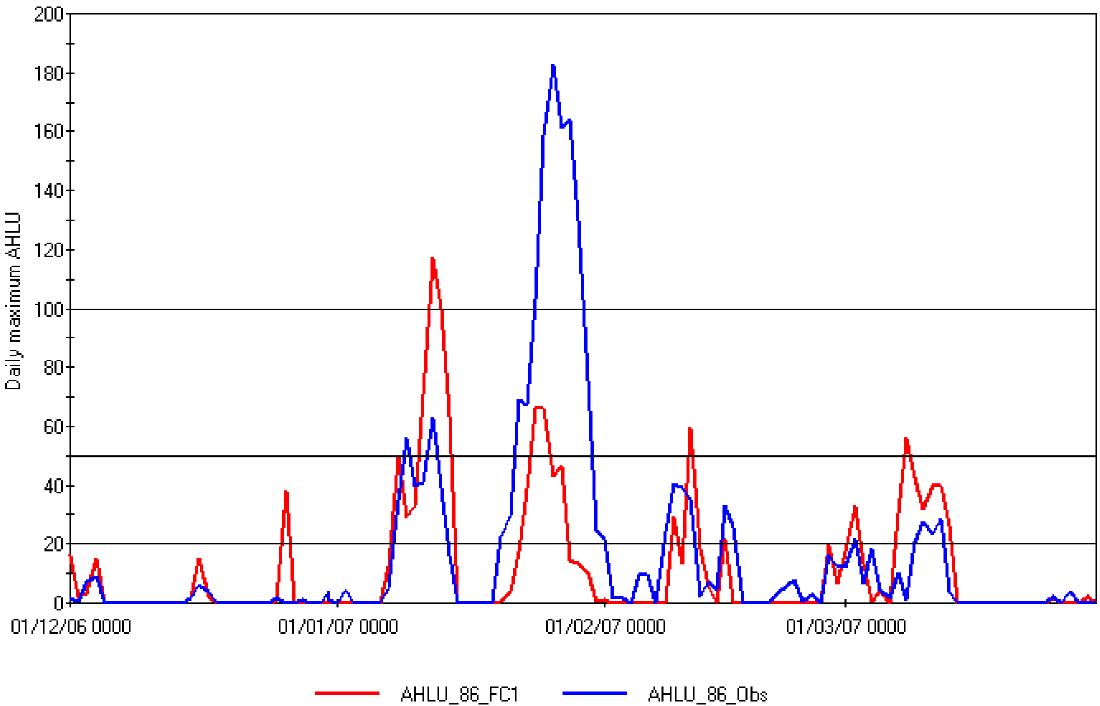

Figure 4: Time series of one day ahead forecast and observed AHLU (daily maximum values) for Emerald using a HLI value of 86 for the Thermo-Neutral zone upper limit

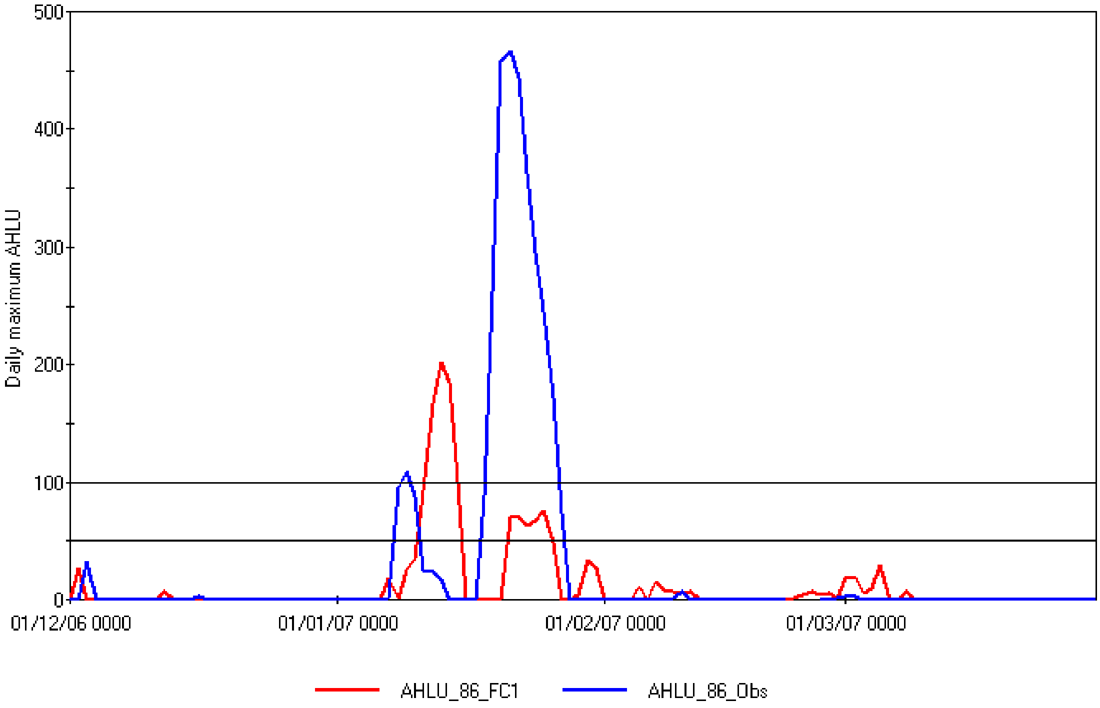

Figure 5: Time series of one day ahead forecast and observed AHLU (daily maximum values) for Roma using a HLI value of 86 for the Thermo-Neutral zone upper limit

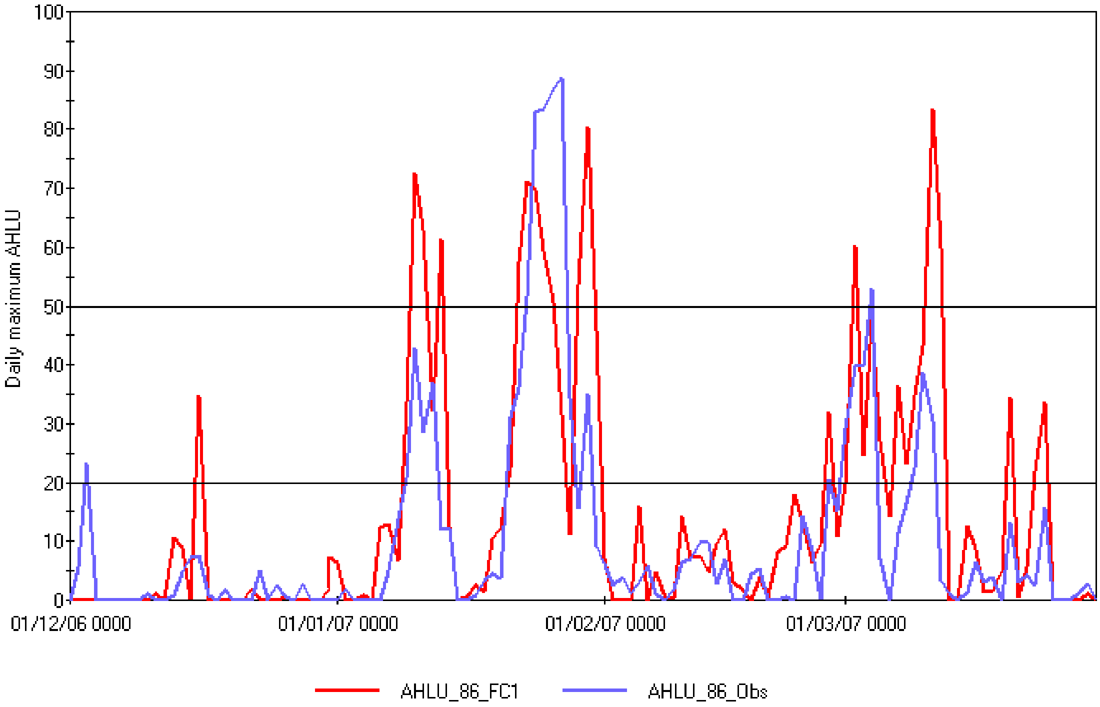

Figure 6: Time series of one day ahead forecast and observed AHLU (daily maximum values) for Amberley using a HLI value of 86 for the Thermo-Neutral zone upper limit

6 Forecasting performance for meteorological variables

The meteorological parameters used in this project are derived from BoM forecasts and BoM observations at weather stations. These data are used to train propriety models to produce site specific forecasts. Clearly the accuracy of any forecast is dependent on the accuracy of the input data – in this case, BoM forecasts.

Figures 7, 8 and 9 show scatter plots of one day ahead forecasts plotted against observed temperature, relative humidity and wind speed for Emerald. There results are typical of forecasts obtained for the other sites. The least squares regression line is also included in the figures. The quantisation of the observed wind speed is due to the BoM providing wind speed observations in km/hr quantised to 0.5 km/hr. It is evident that the gross behaviour is modelled reasonably well (except for the wind speed), however, it is not clear to what degree the discrepancies can be attributed to errors in the supplied BoM forecasts. It is envisaged that a substantial effort would be required to resolve this issue.

Statistics for all sites for one, three and six day ahead forecasts are included in Appendix D.

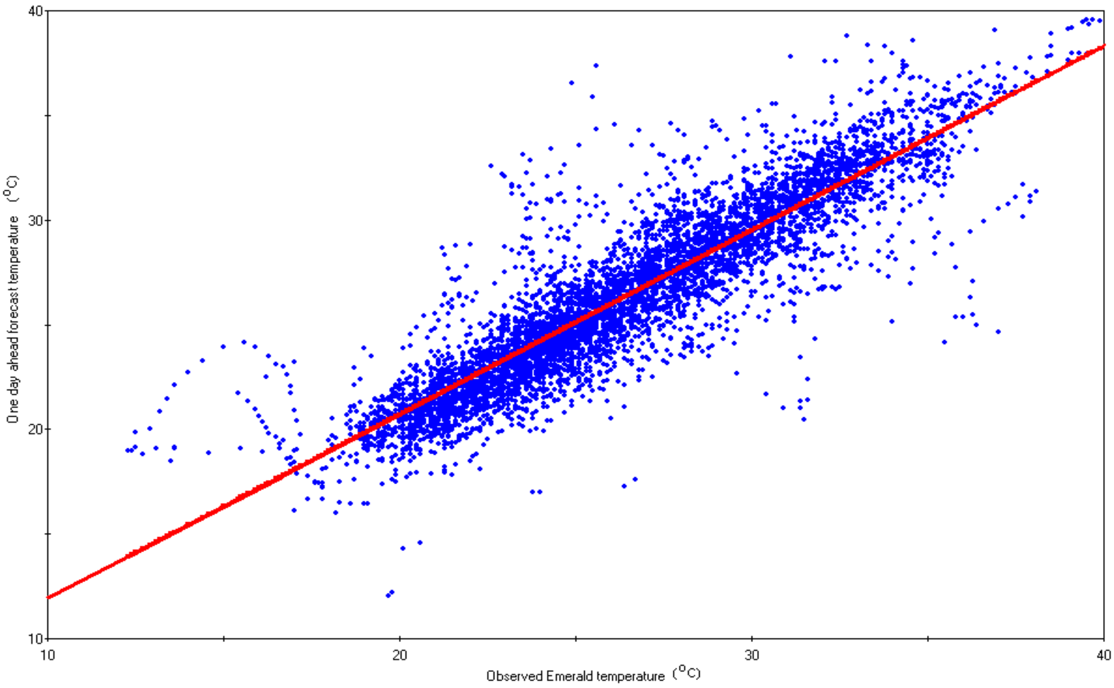

Figure 7: Scatter plot of one day ahead forecast of temperature plotted against observed temperature for Emerald

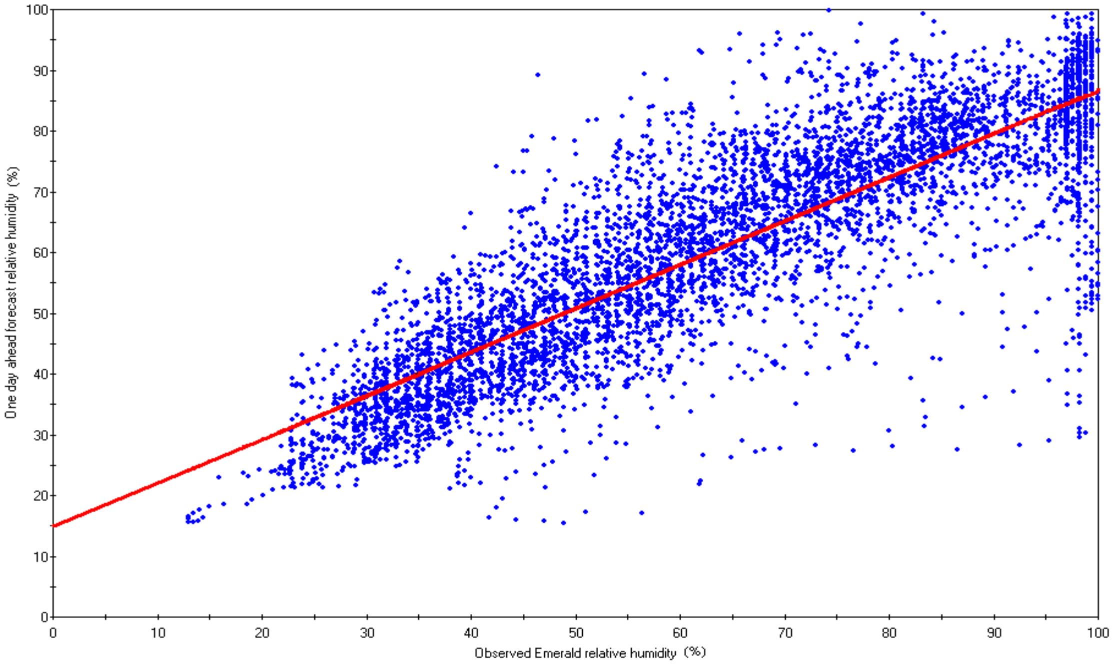

Figure 8: Scatter plot of one day ahead forecast of relative humidity plotted against observed relative humidity for Emerald

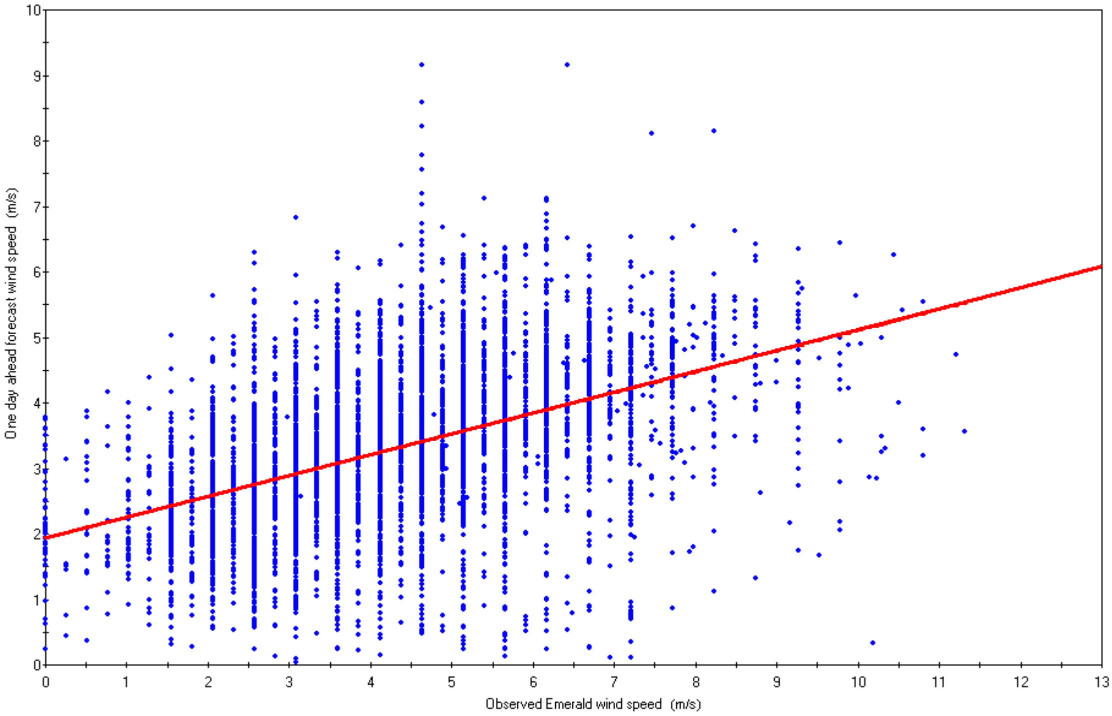

Figure 9: Scatter plot of one day ahead forecast of wind speed plotted against observed wind speed for Emerald

7 Service delivery and utility

Forecasts of the following parameters were checked by the Katestone Environmental staff and posted to the web site www.katestone.com.au/mla on a daily basis:

- Tables of previous six days' AHLU values obtained using HLI thresholds of 80, 83, …95;
- Tables of previous six days' minimum and maximum daily HLI value;
- Tables of previous six days' rainfall;
- Tables of six day forecasts of the above parameters; and
- Graphs of six day forecasts of HLI and AHLU for HLI thresholds of 80, 83, … 95.

These forecasts were transferred to the web site on a daily basis for access by all feedlot operators. The previous six days' forecasts were also made available should the feedlot operators need to check an earlier forecast.

The implementation of the forecast model is very flexible. Any future need for forecasting at these same locations will require only a basic retraining of the models with more recent data. The addition of new sites would require correspondence with the Bureau of Meteorology in order to make the additional data available. Katestone Environmental would then need to extend the existing models to incorporate the new sites.

8 Recommendations for future work

It is recommended that earlier advice is necessary on the need for any new forecasting sites to ensure an ample amount of concurrent upper-level and AWS data are available to train the models. This will improve the initial forecast accuracy of the models. Also, the project would benefit from investigations into alternative methods for calculating the AHLU.

No allowance has currently been made for the difference between feedlot conditions and conditions at the AWS site, or for factors such as shading. These factors could readily be included when the results of other studies are available.

As heat stress management in cattle is an ongoing area of research, future projects should include up to date methods for calculating heat stress in cattle and reporting these on a regular basis. Also, since cattle can adapt to heat stress to a limited extent, (Leonard et al (2001), calculation of parameters relating to the state of cattle as a result of previous heat stress should also be investigated and incorporated into the modelling.

9 Conclusions

A system for forecasting the HLI (which now incorporates wind speed) and the AHLU has been developed and implemented over the extended summer period 1 December 2006 to 31 March 2007. Modelling of the various input parameters was performed on a half hourly basis for each of the feedlot sites using the Bureau of Meteorology LAPS and GASP forecasts. The parameters generated were the temperature, wind speed and dew point. The solar radiation was calculated analytically from the date, time of day and latitude of the site.

Two factors were found to contribute to the poor AHLU forecasts these were the performance in forecasting the HLI and the method for determining the AHLU, with the method for calculating the AHLU being the major factor.

Finally, although the forecast AHLU values were generally higher than the values obtained from observations, the performance in predicting the risk categories is good and is more relevant as far as feedlot operations are concerned than predicting the actual AHLU values.

10 References

EA Systems (2004), “FLOT.327 – Development of a Heat Load Risk Assessment Process for the Australian feedlot industry”.

Gaughan J, Goopy J and Spark J (2002), “Excessive Heat Load Index for Feedlot Cattle”, University of Queensland.

Katestone Scientific (2002), “FLOT.313 – Development and trial operation of a weather forecasting service for excessive heat load events for the Australian feedlot industry.”

Leonard MJ, Spiers DE and GL Hahn, “Adaptation of feedlot cattle to repeated sinusoidal heat challenge”, Livestock Environment VI – Proceedings of the Sixth International Symposium Galt House Hotel Louisville, Kentucky, May 21-23, 2001, Published by The Society for engineering in agriculture, food and biological systems.

Oke TR (1987), “Boundary Layer Climates”, Second Edition, Routledge.

11 Appendices

11.1 Appendix A - Description of Model

11.1.1 A1 Preliminary considerations

The first step in producing site-specific weather forecasts takes advantage of detailed information made readily available from well-proven numerical models in association with determined correlations of local weather variables with such numerical forecasts. The direct predictions from the traditional numerical modelling may be very useful for some variables under normal conditions but are unlikely to properly predict the detailed diurnal variations of key parameters required for constructing heat comfort indices.

Some type of expert system is needed to improve such forecasts. This could involve, for example, the use of more detailed or a wide variety of numerical models to give greater confidence in predictions or alternatively the use of a trained meteorologist to be able to estimate the likely differences between feedlot conditions and those forecast by the numerical model.

An automated approach would utilise the available database of concurrent site measurements and upper-level forecasts to determine statistically significant correlations. These correlations are then assumed to hold over forthcoming events and are used with numerical forecasts to predict feedlot conditions over the next 48-144 hours. The predicted time history of individual meteorological variables can then be combined in various ways to give a time history of a selected thermal comfort index. These index values can be screened against critical thresholds determined from field studies in order to give suitable alarms for various types of likely animal reactions.

This “downscaling” methodology (i.e. relying on a correlation procedure to produce site-specific values from a regional model prediction of atmospheric profiles) has been shown by experience elsewhere to require at least a period of 1-3 months of training data before adequate results are obtained and thereafter a regular retraining over a one year period to produce optimal results. The correlations themselves are only as good as the database upon which they are based.

For general predictions, a short database may suffice as relatively simple relationships are likely to be useful for normal conditions. Extreme conditions are less frequently encountered and may not be present in a short-term database. Given that there is considerable variability between years in general weather conditions (and even more so for extreme events), there is no guarantee that the recent past is a good guide to the forecasting of a series of adverse days, as required in heatwave analysis. The accuracy of the downscaling methodology in heatwave conditions is reliant on the ability of numerical models to accurately predict fluctuations in parameters outside the ranges for which they have been optimised and hence is expected to be limited.

11.1.2 A2 Available data

Over the past 30 years, many field and theoretical studies have demonstrated the sensitivity of near-surface meteorological conditions to changes in local and regional terrain characteristics. Temperatures are very sensitive to terrain elevation, distance from the nearest coastline and vegetation cover. Relative humidity is sensitive to the presence of vegetation cover, local water bodies or the coastline. Wind speed is strongly influenced by the presence of trees, hills or valleys, inland location and the aerodynamic roughness of land within 1 km of the weather station.

In contrast, numerical weather prediction models (regional forecast models) use relatively coarse terrain and land-use information and are very unlikely to capture the influences of the surface characteristics within 1-3 km of the site. On the other hand, on-site measurements will show directly the influences of the local environment by the presence of strong diurnal patterns in wind and, to a lesser extent, temperature variables. On-site weather information is often very important, especially if the nearest Bureau of Meteorology (BoM) automatic weather station is over 15-20 km away or if the feedlot environment is unusual compared to that of the region (say within 25 km).

There are several Australian agencies (hereafter referred to as “service providers”) that routinely run numerical models that could be suitable for either direct forecasts or in conjunction with an expert system using local meteorological information (that is, the prediction of parameter values at a given point from values predicted over a broader scale). These include:

The BoM operates the Global Analysis and Prediction Scheme (GASP) and Limited Area Prediction System (LAPS) models on a regular basis for their Australia-wide weather prediction service. The LAPS model covers an area of Australasia, South East Asia and much of the Indian and Pacific Oceans at various resolutions. The finest resolution (5 km) is only currently used in research work or for the use of the internal BoM consulting arm. The 25 km resolution forms the basis of most publicly-available forecasts.

The information available from these forecasts that is most applicable to the current project includes surface level (screen height) temperature, dew point, sensible and latent heat fluxes, total heat flux and a set of upper-level temperature, dew point and wind components.

By special arrangements, these forecasts can be provided for any given grid point on a three-hourly basis out to a prediction horizon of 48 hours. They do not generally take account of local weather station data from the nearest BoM AWS site. The numerical forecasts from the model are not edited or screened for reliability and are from one model run.

The GASP model provides a similar set of temperature and wind variables at a coarser resolution of 75 km on a twelve-hourly basis to a time horizon of 6 days. No local data assimilation is included at this scale.

The numerical model results can be made available relatively cheaply on a dedicated web site. Various energy companies have used such information over the past 4 years (using the Katestone downscaling software) as a basis for demand prediction and trading activities. The service has proved to be very reliable with only very infrequent excursions in some parameters. The BoM model accuracy is reported in various BoM publications.

The CSIRO runs a different type of numerical model on a regular basis for a current trial service for agricultural and energy users. The model is run at a resolution of 5 km or better to a time horizon of 8 days. The predicted variables include rainfall and cloud cover, as well as the standard temperature, wind and moisture variables.

The University of New South Wales provides a commercial prediction system to a time horizon of 7-10 days at spatial resolution to 1 km. Their approach is claimed to be a more refined model than the operational models used by the BoM and can include site-specific data assimilation. The support services and reliability are less clear as they depend on staff availability but several publications have been produced showing the very satisfactory performance in extreme events (e.g. bushfires, air quality and sailing forecasts).

11.1.3 A3 Description of model

The system that was implemented was strongly based on a pre-existing and proven scheme developed by Katestone Scientific for use in energy forecasting. It consists of the following steps:

- Obtain upper-level forecast data from numerical weather prediction models via a special web-site provided by the BoM.
- Collect concurrent information from an automatic weather station close to the site of interest.
- Once a sufficient training set of information is collected, use proprietary Katestone software to develop statistical models that relate the surface measurement to a subset of the upper-level variables.
- Use these models and the most recent data to provide the necessary forecasts.

The process is illustrated in Figure A1.

Past experience has shown that an accounting of natural diurnal and seasonal cycles together with a partitioning of the data into half-hourly time steps allows relatively simple linear regression techniques to be used, rather than more complex hybrid statistical/neural network schemes often used.

The robustness of this approach was demonstrated by the error statistics Table A obtained for a period of one year for various parameters and the location of Sydney and Brisbane. For example, there is a pleasing performance for temperature and windspeed, with only minor seasonal variations and the expected slow decrease in accuracy with an increasing prediction horizon.

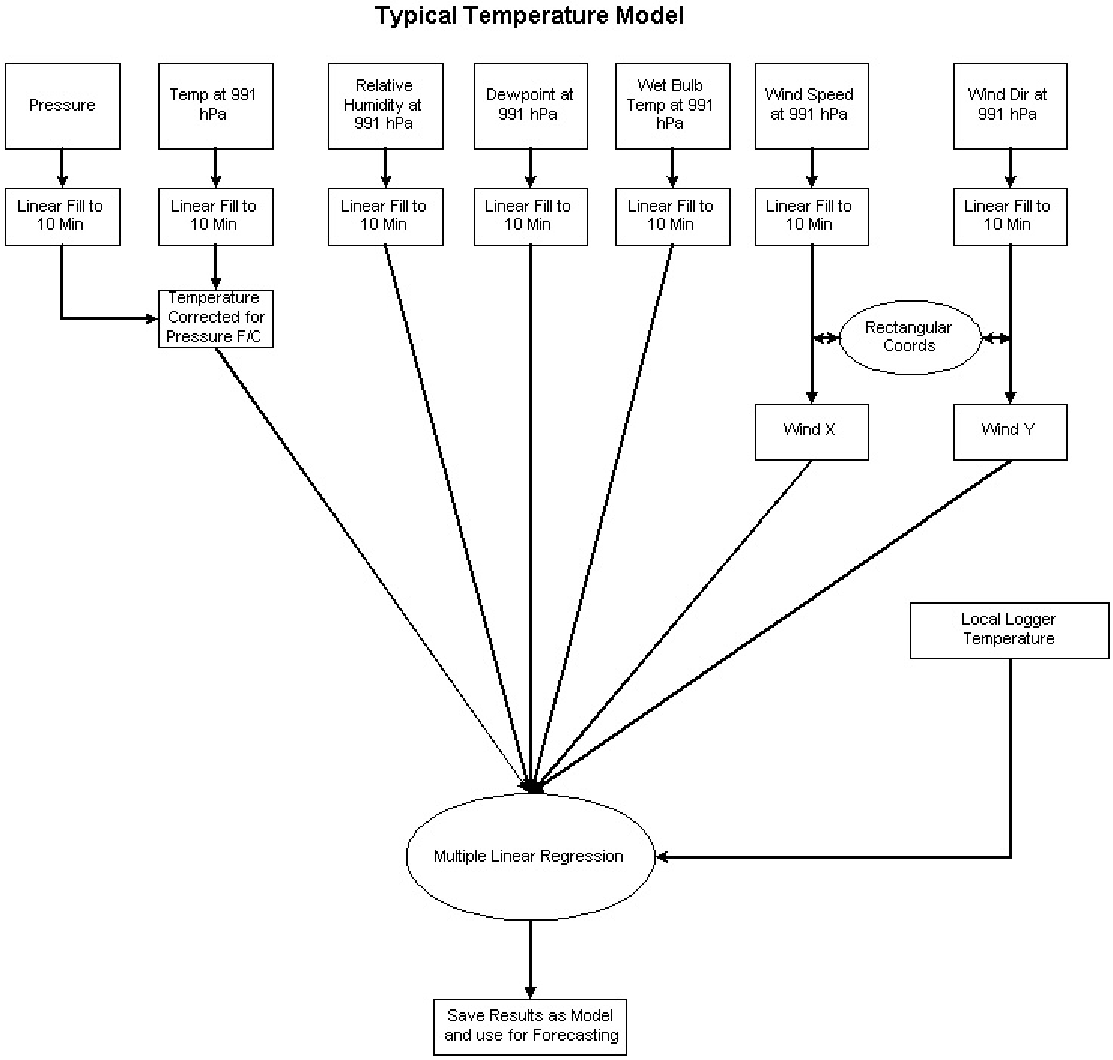

Figure A1: Example of process of using LAPS/GASP data (e.g. 991 hpa parameters) in downscaling to give a surface temperature forecast

Table A1: Mean Absolute Error for Sydney and Brisbane forecasts

Variable	Season	Forecast horizon		
		1 - 2 days	3 - 4 days	5 - 6 days
Sydney Temp (°C)	Summer	1.44	1.78	2.15
	Autumn	1.26	1.72	1.88
	Winter	1.27	1.52	1.71
	Spring	1.37	1.61	2.23
Sydney Wind Speed (m/s)	Summer	1.62	1.84	1.95
	Autumn	1.54	1.56	1.60
	Winter	1.44	1.74	1.68
	Spring	1.86	2.03	2.09

11.2 Appendix B

11.2.1 Overall behaviour of the HLI

The performance of the forecasting model was characterised using (a) a line of best fit, (Slope and Intercept) (b) the Pearson Correlation Coefficient, (c) the Root Mean Square Error (RMSE), (d) the Index of Agreement (IOA) and (e) the Bias. The Bias is obtained by summing the difference between the predicted and observed quantities and dividing by the number of samples. Although it is not, strictly speaking, a statistical measure, it does give an indication whether the model is under predicting (negative bias) or over predicting (positive bias).

Table B1 lists the above parameters for the one, three and six day ahead forecasts. The parameters include the three statistical measures, the bias and the slope and intercept of the line of best fit of the forecast vs observed quantities. The column labelled “Count” reports how many data points were processed to produce the associated statistical measures. All data points where either of the observed or forecast HLI was equal to 50 were omitted.

Features worth noting are:

- The overall performance is very good. Correlation coefficients range from about 90% for the one day ahead forecasts to about 70%-80% for the six day ahead forecasts.
- All statistics show the same behaviour – forecasting performance slightly decreases as the forecast horizon increases.
- The Bias indicates that the model, in general, over predicts the HLI for one and three day ahead forecasts and over predicts about half of the six day ahead forecasts.

Cessnock, the last site to be added to the forecasting service and, consequently, with little data for purposes of training the model, performed surprisingly well.

Table B1: HLI statistics for the period 1 December 2006 to 30 March 2007

Site	Slope	Intercept	Pearson	RMSE	IOA	Bias	Count
	One day ahead forecasts						
Albury	0.96	5.03	0.87	6.18	0.92	2.32	3918
Amberley	0.98	2.26	0.94	4.93	0.97	0.89	5548
Armidale	0.95	4.90	0.86	5.76	0.92	1.85	3408
Cessnock	0.98	3.04	0.91	5.92	0.95	1.83	5135
Charlton	0.97	4.36	0.90	5.16	0.93	2.42	3423
Clare	0.89	8.42	0.82	5.90	0.90	0.92	3143
Emerald	0.93	4.20	0.91	5.61	0.95	-0.91	5563
Griffith	0.91	6.51	0.88	4.66	0.94	0.35	3669
Hay	0.87	9.77	0.85	5.42	0.92	0.76	3322
Katanning	0.81	12.22	0.82	4.94	0.91	-0.22	2764
Miles	0.96	3.05	0.90	5.63	0.95	-0.13	5178
Moree	1.01	1.37	0.87	6.38	0.92	1.92	4322
Oakey	0.97	2.71	0.93	4.56	0.96	0.35	4343
Roma	0.84	11.72	0.82	7.20	0.90	0.33	4745
Tamworth	1.00	1.35	0.91	5.34	0.95	1.27	4213
Warwick	1.01	0.36	0.94	4.71	0.96	1.10	4971
Yanco	0.91	7.27	0.87	5.09	0.93	0.90	3836
	Three day ahead forecasts						
Albury	0.93	7.45	0.82	7.07	0.89	2.49	3845
Amberley	0.91	4.97	0.90	5.98	0.95	-1.54	5507

Site	Slope	Intercept	Pearson	RMSE	IOA	Bias	Count
Armidale	0.89	10.48	0.82	7.03	0.88	3.16	3437
Cessnock	0.92	8.68	0.88	6.96	0.92	3.36	5154
Charlton	0.93	6.94	0.82	6.74	0.89	2.39	3364
Clare	0.98	4.13	0.83	6.75	0.89	2.87	3206
Emerald	0.90	4.00	0.88	7.11	0.92	-3.50	5485
Griffith	0.83	11.82	0.82	5.59	0.90	0.17	3598
Hay	0.77	16.99	0.80	6.14	0.89	0.92	3266
Katanning	0.80	14.19	0.80	5.28	0.89	0.84	2734
Miles	0.91	6.45	0.88	6.30	0.94	0.00	5197
Moree	0.92	7.79	0.85	6.56	0.91	2.25	4355
Oakey	0.92	4.64	0.91	5.13	0.95	-0.64	4430
Roma	0.83	11.52	0.80	7.45	0.89	-0.67	4609
Tamworth	0.94	6.51	0.87	6.39	0.92	2.27	4155
Warwick	0.99	1.52	0.92	5.08	0.96	0.68	5023
Yanco	0.84	12.51	0.81	6.26	0.89	1.26	3796
	Six day ahead forecasts						
Albury	0.87	10.34	0.75	7.60	0.86	0.93	3348
Amberley	0.86	7.98	0.85	7.59	0.91	-2.17	4818
Armidale	0.81	15.93	0.74	8.14	0.84	3.48	3200
Cessnock	0.92	8.85	0.87	7.35	0.91	3.20	4678
Charlton	0.75	18.76	0.67	8.14	0.81	1.19	2882
Clare	0.81	14.49	0.68	8.22	0.82	1.32	2807
Emerald	0.88	5.37	0.86	7.71	0.91	-3.69	4904
Griffith	0.76	16.38	0.74	6.51	0.86	-1.05	3083
Hay	0.67	23.04	0.69	7.39	0.83	-0.05	2843
Katanning	0.74	18.44	0.72	6.50	0.85	1.50	2580
Miles	0.90	7.35	0.85	6.82	0.92	-0.08	4659
Moree	0.87	11.56	0.81	7.08	0.89	2.50	3889
Oakey	0.90	6.08	0.87	5.92	0.93	-0.73	3930
Roma	0.83	11.61	0.81	7.24	0.90	-0.92	4155
Tamworth	0.89	10.38	0.82	7.35	0.89	2.54	3693
Warwick	0.97	2.73	0.89	6.20	0.94	0.78	4473
Yanco	0.75	17.70	0.72	7.07	0.84	-0.14	3271

11.3 Appendix C

11.3.1 Overall behaviour of the AHLU

The performance of the forecasting model is presented as a collection of contingency tables contained in Tables C1 through to C4 for one, three and six day ahead forecasts for the four risk categories. Table C1 is for HLI cutoff of 86, C2 corresponds to 89 etc. In the contingency tables, the horizontal represents the observed and the vertical represents the forecast AHLU category. The AHLU categories are defined in the following table:

Table C1: Table of AHLU values for the four categories

AHLU	Heat stress category
0-20	Low risk
20-50	Medium risk
50-100	High risk
Over 100	Extreme risk

Tables C6 through to C9 present an alternative to the contingengy tables. Again, the results are presented for the three forecast periods and the four HLI cutoff values. The row at the top of each table containing the entries -3, -2 …2, 3 represent the forecast error, that is, “-3” indicates that the model predicted a category three below the observed category – eg predicted an low risk event and an extreme risk event was observed. A “0” indicates no error – that is the correct heat stress category was predicted. At the other extreme, a “3” indicates that the model predicted an extreme event and a low risk event was recorded.

All entries in the tables are percentages.

Inspection of the contents of the tables indicates that the performance of the forecasting model in predicting the AHLU categories is generally quite good.

Finally, since only one datum per day is available for the daily maximum, any statistics obtained from such data sets may not reveal trends that would otherwise be evident were a larger quantity of data available.

Table C2: Contingency tables of forecast vs observed daily maximum AHLU using an upper HLI threshold of 86

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Albury												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	1.7	0	0	0	3.3	0	0	0	0	0	0	0
Medium	4.1	0	0	0	3.3	0	0	0	1.7	0	0	0
Low	93.4	0.8	0	0	92.6	0.8	0	0	97.5	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Amberley												
Extreme	0	0	0	0	0	0	0.8	0	0	0	0	0
High	2.5	5	3.3	0	0	0.8	1.7	0	0.8	0	0	0
Medium	6.6	5.8	1.7	0	0.8	5.8	2.5	0	3.3	2.5	1.7	0
Low	72.7	2.5	0	0	81	6.6	0	0	77.7	10.7	3.3	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Armidale												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Cessnock												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0.8	0.8	0	0	0.8	0	0	0
Medium	5.8	0.8	0	0	8.3	0	0	0	5.8	0.8	0	0
Low	91.7	1.7	0	0	88.4	1.7	0	0	90.9	1.7	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Charlton												
Extreme	0	0	0	0	3.3	0	0	0	0	0	0	0
High	0	0	0	0	0.8	0	0	0	0.8	0	0	0
Medium	3.3	0	0	0	0.8	0	0	0	3.3	0	0	0
Low	96.7	0	0	0	95	0	0	0	95.9	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Clare												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	1.7	0	0	0	0.8	0	0	0
Medium	1.7	0	0	0	4.1	0	0	0	1.7	0	0	0
Low	98.3	0	0	0	94.2	0	0	0	97.5	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Emerald												
Extreme	0	0.8	0.8	0	0	0	0	0	0	0	0	0
High	1.7	1.7	0	1.7	0	0	0	1.7	0	0	0	0
Medium	2.5	7.4	1.7	1.7	0.8	1.7	0.8	1.7	2.5	1.7	0.8	1.7
Low	71.1	5.8	1.7	1.7	74.4	14	3.3	1.7	72.7	14	3.3	3.3
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Griffith												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	0.8	0	0	0	0	0	0	0
Low	98.3	0	0	0	99.2	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Hay												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	0	0	0	0	0	0	0	0
Low	97.5	0.8	0	0	99.2	0.8	0	0	99.2	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Katanning												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Miles												
Extreme	0	0	0	0	0	0.8	0	0	0	0	0	0
High	0	2.5	2.5	0	0.8	0.8	1.7	0	0	0	0	0
Medium	5.8	0.8	0	0	6.6	0.8	0.8	0	5.8	0.8	2.5	0
Low	86	1.7	0.8	0	84.3	2.5	0.8	0	86	4.1	0.8	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Moree												
Ext	0	0	0	0	0	0	0	0	0	0	0	0
High	0.8	0	0	0	0	0	0	0	0.8	0	0	0
Med	14	0	0	0	7.4	0	0	0	1.7	0	0	0
Low	85.1	0	0	0	92.6	0	0	0	97.5	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Oakey												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0.8	0	0	0	0	0	0	0
Medium	2.5	0	0	0	0.8	0	0	0	0	0	0	0
Low	97.5	0	0	0	98.3	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Roma												
Extreme	2.5	0.8	0	0	0	0	0	0	0	0	0	0
High	0	0.8	0	4.2	0.8	0	0	2.5	0	0	0	0
Medium	3.4	0	0.8	1.7	3.4	1.7	0.8	0.8	1.7	0	0.8	1.7
Low	80.5	0.8	2.5	1.7	82.2	0.8	2.5	4.2	84.7	2.5	2.5	5.9
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Tamworth												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	4.1	0	0	0	2.5	0.8	0	0	3.3	0	0	0
Low	94.2	1.7	0	0	95.9	0.8	0	0	95	1.7	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Warwick												
Ext	0	0	0	0	0	0	0	0	0	0	0	0
Extreme	1.7	0	0	0	3.3	0.8	0	0	0	0	0	0
Medium	7.4	0	0	0	5	0.8	0	0	5.8	0.8	0	0
Low	89.3	1.7	0	0	90.1	0	0	0	92.6	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Yanco												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	1.7	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0	0	3.3	0	0	0	0.8	0	0	0
Low	96.7	0.8	0	0	95.9	0.8	0	0	98.3	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Table C3: Contingency tables of forecast vs observed daily maximum AHLU using an upper HLI threshold of 89

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Albury												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	2.5	0	0	0	0	0	0	0
Low	98.3	0	0	0	97.5	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Amberley												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0.8	0	0	0	0	0	0	0	0	0	0	0
Medium	5.8	3.3	0	0	0.8	2.5	0	0	0.8	0	0	0
Low	86.8	3.3	0	0	92.6	4.1	0	0	92.6	6.6	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Armidale												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Cesnock												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	2.5	0	0	0	1.7	0	0	0
Low	99.2	0.8	0	0	96.7	0.8	0	0	97.5	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Charlton												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	1.7	0	0	0	0	0	0	0
Medium	0.8	0	0	0	1.7	0	0	0	1.7	0	0	0
Low	99.2	0	0	0	96.7	0	0	0	98.3	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Clare												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	3.3	0	0	0	0	0	0	0
Low	100	0	0	0	96.7	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Emerald												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0.8	0	0	0	0	0	0	0	0	0	0
Medium	3.3	1.7	0.8	0	0.8	0	1.7	0	0.8	0	0	0
Low	89.3	3.3	0.8	0	91.7	5.8	0	0	91.7	5.8	1.7	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Griffith												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	**One day ahead forecasts**				**Three day ahead forecasts**				**Six day ahead forecasts**			
Hay												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Katanning												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Miles												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0.8	0.8	0	0	0	0	0	0
Medium	2.5	2.5	0	0	1.7	0.8	0	0	0	0	0	0
Low	94.2	0.8	0	0	94.2	1.7	0	0	96.7	3.3	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Moree												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	0	0	0	0	0.8	0	0	0
Low	98.3	0	0	0	100	0	0	0	99.2	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Oakey												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0	0	0.8	0	0	0	0	0	0	0
Low	99.2	0	0	0	99.2	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Roma												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	2.5	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0.8	2.5	0	0	0.8	1.7	0	0	0	0
Low	86.4	1.7	2.5	2.5	89.8	1.7	2.5	3.4	89.8	1.7	3.4	5.1
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Tamworth												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Warwick												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	2.5	0	0	0	0.8	0	0	0
Low	98.3	0	0	0	97.5	0	0	0	99.2	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Yanco												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0	0	0	0	0	0	0	0	0	0
Low	99.2	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Table C4: Contingency tables of forecast vs observed daily maximum AHLU using an upper HLI threshold of 92

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Albury												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Amberley												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0	0	0	0	0	0	0	0	0	0
Low	95.9	3.3	0	0	96.7	3.3	0	0	96.7	3.3	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Armidale												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0

Site	**One day ahead forecasts**				**Three day ahead forecasts**				**Six day ahead forecasts**			
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Cessnock												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Charlton												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Clare												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Emerald												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	2.5	0	0	0	0	0	0	0	0	0	0	0
Low	96.7	0.8	0	0	99.2	0.8	0	0	99.2	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Griffith												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Hay												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Katanning												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Miles												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0.8	0	0	0	0	0	0	0	0	0	0	0
Low	99.2	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Moree												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Oakey												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Roma												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0.8	0	0	0	0	0	0	0	0	0
Low	90.7	0	2.5	4.2	92.4	0	3.4	4.2	92.4	0	3.4	4.2
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Tamworth												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Site	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Warwick												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Yanco												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Table C5: Contingency tables of forecast vs observed daily maximum AHLU using an upper HLI threshold of 95

	One day ahead forecasts				Three day ahead forecasts				Six day ahead forecasts			
Albury												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Amberley												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	99.2	0.8	0	0	99.2	0.8	0	0	99.2	0.8	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Armidale												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Cesnock												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

	One day ahead forecasts				**Three day ahead forecasts**				**Six day ahead forecasts**			
Charlton												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Clare												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Emerald												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Griffith												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Hay												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Katanning												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Miles												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

	One day ahead forecasts				**Three day ahead forecasts**				**Six day ahead forecasts**			
Moree												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Oakey												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Roma												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	1.7	0	0	0	0	0	0	0	0	0	0	0
Low	91.5	3.4	0.8	2.5	93.2	3.4	0.8	2.5	93.2	3.4	0.8	2.5
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Tamworth												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Warwick												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext
Yanco												
Extreme	0	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	0	0	0	0	0	0
Medium	0	0	0	0	0	0	0	0	0	0	0	0
Low	100	0	0	0	100	0	0	0	100	0	0	0
	Low	Med	High	Ext	Low	Med	High	Ext	Low	Med	High	Ext

Table C6: Model forecast performance for a HLI cutoff of 86

	One day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.83	93.39	4.13	1.65	0.00
Amberley	0.00	0.00	4.13	81.82	11.57	2.48	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	1.65	92.56	5.79	0.00	0.00
Charlton	0.00	0.00	0.00	96.69	3.31	0.00	0.00
Clare	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Emerald	1.65	3.31	9.09	78.51	4.96	2.48	0.00
Griffith	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Hay	0.00	0.00	0.83	97.52	1.65	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.83	1.65	89.26	8.26	0.00	0.00
Moree	0.00	0.00	0.00	85.12	14.05	0.83	0.00
Oakey	0.00	0.00	0.00	97.52	2.48	0.00	0.00
Roma	1.65	4.13	5.79	80.99	4.13	0.83	2.48
Tamworth	0.00	0.00	1.65	94.21	4.13	0.00	0.00
Warwick	0.00	0.00	1.65	89.26	7.44	1.65	0.00
Yanco	0.00	0.00	0.83	96.69	0.83	1.65	0.00
	Three day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.83	92.56	3.31	3.31	0.00
Amberley	0.00	0.00	9.09	88.43	2.48	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	1.65	88.43	9.09	0.83	0.00
Charlton	0.00	0.00	0.00	95.04	0.83	0.83	3.31
Clare	0.00	0.00	0.00	94.21	4.13	1.65	0.00
Emerald	1.65	4.96	16.53	76.03	0.83	0.00	0.00
Griffith	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Hay	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.83	3.31	86.78	7.44	1.65	0.00
Moree	0.00	0.00	0.00	92.56	7.44	0.00	0.00
Oakey	0.00	0.00	0.00	98.35	0.83	0.83	0.00
Roma	4.13	3.31	4.13	84.30	3.31	0.83	0.00
Tamworth	0.00	0.00	0.83	96.69	2.48	0.00	0.00
Warwick	0.00	0.00	0.00	90.91	5.79	3.31	0.00
Yanco	0.00	0.00	0.83	95.87	3.31	0.00	0.00

	Six day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.83	97.52	1.65	0.00	0.00
Amberley	0.00	3.31	12.40	80.17	3.31	0.83	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	1.65	91.74	5.79	0.83	0.00
Charlton	0.00	0.00	0.00	95.87	3.31	0.83	0.00
Clare	0.00	0.00	0.00	97.52	1.65	0.83	0.00
Emerald	3.31	4.96	14.88	74.38	2.48	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.83	6.61	86.78	5.79	0.00	0.00
Moree	0.00	0.00	0.00	97.52	1.65	0.83	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	5.79	4.13	3.31	85.12	1.65	0.00	0.00
Tamworth	0.00	0.00	1.65	95.04	3.31	0.00	0.00
Warwick	0.00	0.00	0.83	93.39	5.79	0.00	0.00
Yanco	0.00	0.00	0.83	98.35	0.83	0.00	0.00

Table C7: Model forecast performance for a HLI cutoff of 89

	One day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Amberley	0.00	0.00	3.31	90.08	5.79	0.83	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.83	4.13	90.91	4.13	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.83	96.69	2.48	0.00	0.00
Moree	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Oakey	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Roma	2.48	4.96	2.48	86.78	0.83	2.48	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Yanco	0.00	0.00	0.00	99.17	0.83	0.00	0.00
	Three day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	97.52	2.48	0.00	0.00
Amberley	0.00	0.00	4.13	95.04	0.83	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.83	96.69	2.48	0.00	0.00
Charlton	0.00	0.00	0.00	96.69	1.65	1.65	0.00
Clare	0.00	0.00	0.00	96.69	3.31	0.00	0.00
Emerald	0.00	0.00	7.44	91.74	0.83	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	1.65	95.04	2.48	0.83	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Roma	3.31	4.13	2.48	90.08	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	97.52	2.48	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Six day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	6.61	92.56	0.83	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.83	97.52	1.65	0.00	0.00
Charlton	0.00	0.00	0.00	98.35	1.65	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	1.65	5.79	91.74	0.83	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	3.31	96.69	0.00	0.00	0.00
Moree	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	4.96	3.31	1.65	90.08	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Table C8: Model forecast performance for a HLI cutoff of 92

	One day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	3.31	95.87	0.83	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.83	96.69	2.48	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	99.17	0.83	0.00	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	4.13	2.48	0.83	90.91	1.65	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Three day ahead forecasts						
	-3	-2	-1	0	1	2	3

Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	3.31	96.69	0.00	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	4.13	3.31	0.00	92.56	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Six day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	3.31	96.69	0.00	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	4.13	3.31	0.00	92.56	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Table C9: Model forecast performance for a HLI cutoff of 95

	One day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	2.48	0.83	3.31	91.74	1.65	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Three day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	2.48	0.83	3.31	93.39	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	Six day ahead forecasts						
	-3	-2	-1	0	1	2	3
Albury	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Amberley	0.00	0.00	0.83	99.17	0.00	0.00	0.00
Armidale	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Cessnock	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Charlton	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Clare	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Emerald	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Griffith	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Hay	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Katanning	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Miles	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Moree	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Oakey	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Roma	2.48	0.83	3.31	93.39	0.00	0.00	0.00
Tamworth	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Warwick	0.00	0.00	0.00	100.00	0.00	0.00	0.00
Yanco	0.00	0.00	0.00	100.00	0.00	0.00	0.00

11.4 Appendix D

11.4.1 Summary of statistics for meteorological parameters

Tables D1, D2 and D3 present statistics for one, three and six day ahead forecasts of temperature, relative humidity and wind speed respectively. The explanation of these statistics can be found in Appendix B. The trends portrayed by these statistics are similar to the trends followed by the HLI.

Table D1: Temperature statistics for the period 1 December 2006 to 30 March 2007

One day ahead forecasts							
Site	Slope	Intercept	Pearson	RMSE	IOA	Bias	Count
Albury	0.92	1.60	0.93	2.36	0.96	-0.24	5806
Amberley	0.92	1.20	0.92	1.93	0.95	-0.61	5806
Armidale	0.87	2.26	0.92	1.90	0.96	0.01	5805
Cesnock	0.80	4.20	0.87	2.69	0.93	-0.24	5780
Charlton	1.01	-0.31	0.95	2.24	0.98	0.01	5806
Clare	0.93	1.02	0.92	2.81	0.96	-0.48	5808
Emerald	0.88	3.12	0.90	1.95	0.95	-0.08	5808
Griffith	0.97	0.62	0.95	2.10	0.97	-0.14	5705
Hay	0.93	1.64	0.93	2.51	0.97	0.02	5530
Katanning	0.83	3.32	0.89	2.97	0.94	-0.15	5474
Miles	0.89	2.24	0.90	2.29	0.95	-0.52	5808
Moree	0.87	3.01	0.89	2.47	0.94	-0.37	5808
Oakey	0.93	1.11	0.94	1.87	0.96	-0.62	5806
Roma	0.87	3.20	0.89	2.34	0.94	-0.39	5570
Tamworth	0.91	1.91	0.92	2.24	0.96	-0.22	5808
Warwick	0.90	1.73	0.93	1.94	0.96	-0.55	5775
Yanco	0.98	0.32	0.96	1.82	0.98	-0.09	5806
Three day ahead forecasts							
Albury	0.90	1.93	0.89	3.10	0.94	-0.56	5806
Amberley	0.86	1.58	0.89	2.68	0.91	-1.66	5806
Armidale	0.86	4.17	0.89	2.76	0.92	1.62	5805
Cesnock	0.84	4.15	0.86	2.89	0.92	0.65	5780
Charlton	0.96	0.77	0.92	2.86	0.96	-0.16	5806
Clare	0.87	2.48	0.90	3.03	0.95	-0.23	5808
Emerald	0.75	5.41	0.85	2.64	0.90	-1.19	5808
Griffith	0.92	1.68	0.90	2.93	0.95	-0.32	5705
Hay	0.88	3.14	0.89	3.12	0.94	0.07	5530
Katanning	0.81	3.58	0.89	2.97	0.94	-0.19	5474
Miles	0.84	4.13	0.87	2.48	0.93	0.13	5808
Moree	0.87	3.93	0.88	2.61	0.94	0.50	5808
Oakey	0.88	2.48	0.90	2.19	0.95	-0.43	5806
Roma	0.81	4.21	0.85	2.75	0.92	-0.71	5570
Tamworth	0.91	3.46	0.89	2.86	0.93	1.22	5808
Warwick	0.87	2.41	0.91	2.16	0.95	-0.36	5775
Yanco	0.93	1.80	0.91	2.60	0.96	0.01	5806
Six day ahead forecasts							
Albury	0.84	2.60	0.85	3.64	0.91	-1.10	5183
Amberley	0.84	1.70	0.83	3.30	0.86	-2.05	5182
Armidale	0.79	5.69	0.82	3.42	0.87	1.85	5182
Cesnock	0.76	6.16	0.78	3.54	0.88	0.81	5159
Charlton	0.88	1.98	0.84	4.19	0.91	-0.64	5183

Clare	0.79	3.82	0.79	4.56	0.89	-0.61	5184
Emerald	0.73	5.94	0.79	3.02	0.87	-1.15	5184
Griffith	0.84	3.37	0.83	3.87	0.91	-0.70	5092
Hay	0.81	4.52	0.82	4.06	0.91	-0.28	4921
Katanning	0.79	4.54	0.85	3.57	0.92	0.24	4895
Miles	0.83	4.48	0.83	2.95	0.91	0.04	5184
Moree	0.82	5.29	0.85	3.00	0.91	0.71	5184
Oakey	0.84	3.35	0.84	2.87	0.91	-0.40	5184
Roma	0.76	5.59	0.79	3.33	0.88	-0.86	4985
Tamworth	0.86	4.78	0.85	3.37	0.90	1.36	5184
Warwick	0.85	3.09	0.86	2.76	0.93	-0.31	5154
Yanco	0.85	3.48	0.84	3.51	0.92	-0.30	5183

Table D2: Relative humidity statistics for the period 1 December 2006 to 30 March 2007

One day ahead forecasts							
Site	Slope	Intercept	Pearson	RMSE	IOA	Bias	Count
Albury	0.76	14.96	0.85	11.93	0.90	4.54	5806
Amberley	0.80	15.87	0.88	9.20	0.93	2.19	5806
Armidale	0.75	17.89	0.85	11.41	0.92	-0.17	5805
Cesnock	0.72	21.01	0.83	11.97	0.90	2.63	5780
Charlton	0.86	10.90	0.88	12.02	0.93	4.76	5806
Clare	0.77	13.80	0.82	15.29	0.90	2.45	5808
Emerald	0.72	14.84	0.85	12.14	0.91	-3.04	5808
Griffith	0.89	8.42	0.85	11.66	0.91	4.40	5705
Hay	0.77	12.26	0.81	12.88	0.89	3.53	5363
Katanning	0.79	13.70	0.86	12.05	0.92	2.31	5474
Miles	0.71	17.38	0.84	11.47	0.91	1.88	5808
Moree	0.64	19.68	0.75	13.58	0.85	3.22	5808
Oakey	0.83	13.36	0.90	9.16	0.94	2.80	5806
Roma	0.60	21.59	0.67	16.82	0.82	1.64	5570
Tamworth	0.76	14.53	0.86	10.62	0.92	2.00	5808
Warwick	0.81	15.65	0.92	9.08	0.95	3.30	5775
Yanco	0.91	6.86	0.85	11.80	0.92	3.13	5806
Three day ahead forecasts							
Albury	0.59	21.92	0.76	14.30	0.84	4.62	5806
Amberley	0.70	21.36	0.83	10.52	0.90	0.73	5806
Armidale	0.70	16.33	0.82	13.59	0.88	-5.59	5805
Cesnock	0.77	17.93	0.81	12.79	0.89	3.16	5780
Charlton	0.75	15.41	0.84	12.92	0.90	4.11	5806
Clare	0.60	23.36	0.81	15.76	0.87	3.32	5808
Emerald	0.61	20.75	0.79	14.40	0.86	-4.30	5808
Griffith	0.68	15.11	0.81	11.60	0.89	2.92	5705
Hay	0.60	17.12	0.77	13.14	0.86	2.12	5363
Katanning	0.76	17.29	0.85	12.91	0.91	4.22	5474
Miles	0.68	14.63	0.81	12.45	0.89	-2.44	5808
Moree	0.64	16.19	0.76	13.02	0.86	-0.29	5808
Oakey	0.83	9.78	0.87	10.11	0.93	-0.73	5806
Roma	0.49	24.78	0.64	16.81	0.79	-0.90	5570
Tamworth	0.69	12.61	0.81	12.48	0.89	-3.46	5808
Warwick	0.82	13.16	0.89	9.77	0.94	1.22	5775
Yanco	0.67	13.62	0.82	11.78	0.89	0.50	5806
Six day ahead forecasts							

Albury	0.59	22.06	0.71	15.41	0.82	4.50	5180
Amberley	0.64	25.17	0.75	12.58	0.86	1.02	5182
Armidale	0.65	19.28	0.76	15.56	0.85	-5.87	5182
Cesnock	0.73	20.56	0.76	14.35	0.86	2.80	5159
Charlton	0.65	18.42	0.74	16.09	0.85	2.58	5183
Clare	0.51	25.93	0.69	19.04	0.81	1.94	5184
Emerald	0.57	21.87	0.72	16.61	0.82	-5.80	5184
Griffith	0.56	18.08	0.68	14.76	0.81	1.54	5092
Hay	0.54	19.02	0.68	15.30	0.81	1.52	4781
Katanning	0.77	16.49	0.85	13.02	0.91	3.68	4895
Miles	0.63	17.58	0.72	15.05	0.84	-2.38	5184
Moree	0.62	17.05	0.72	14.20	0.84	-0.25	5184
Oakey	0.78	12.29	0.80	12.82	0.89	-1.54	5184
Roma	0.42	28.54	0.53	19.44	0.72	-0.52	4985
Tamworth	0.65	14.89	0.75	14.40	0.85	-3.33	5184
Warwick	0.79	14.72	0.84	11.51	0.92	0.75	5154
Yanco	0.54	16.96	0.67	15.59	0.81	-1.40	5180

Table D3: Wind speed statistics for the period 1 December 2006 to 30 March 2007

One day ahead forecasts							
Site	Slope	Intercept	Pearson	RMSE	IOA	Bias	Count
Albury	0.21	0.73	0.51	2.66	0.56	-1.76	5806
Amberley	0.46	0.21	0.77	2.38	0.70	-1.72	5808
Armidale	0.50	0.92	0.52	2.25	0.65	-1.38	5805
Cesnock	0.28	0.80	0.47	2.46	0.58	-1.67	5780
Charlton	0.48	1.14	0.66	1.92	0.73	-1.09	5806
Clare	0.39	1.03	0.52	1.83	0.65	-1.06	5808
Emerald	0.32	1.95	0.48	1.87	0.62	-0.97	5808
Griffith	0.39	2.86	0.60	1.75	0.73	-0.04	5705
Hay	0.41	2.13	0.56	1.64	0.73	-0.21	5532
Katanning	0.34	3.60	0.55	1.91	0.70	0.09	5474
Miles	0.29	1.19	0.57	1.46	0.63	-0.85	5808
Moree	0.20	1.72	0.33	3.02	0.51	-2.11	5808
Oakey	0.52	1.67	0.64	1.88	0.75	-0.85	5808
Roma	0.33	1.52	0.44	2.18	0.60	-1.40	5610
Tamworth	0.38	0.97	0.58	2.26	0.65	-1.42	5808
Warwick	0.31	1.05	0.65	1.82	0.65	-1.02	5775
Yanco	0.45	1.40	0.67	2.11	0.72	-1.19	5806
Three day ahead forecasts							
Albury	0.19	0.63	0.53	2.77	0.54	-1.92	5806
Amberley	0.48	0.16	0.75	2.37	0.72	-1.68	5808
Armidale	0.38	1.60	0.42	2.25	0.61	-1.23	5805
Cesnock	0.29	0.72	0.51	2.44	0.58	-1.71	5780
Charlton	0.35	1.43	0.55	2.22	0.64	-1.34	5806
Clare	0.27	1.34	0.43	1.95	0.58	-1.18	5808
Emerald	0.27	1.91	0.41	2.08	0.58	-1.22	5808
Griffith	0.25	3.25	0.43	2.03	0.61	-0.32	5705
Hay	0.32	2.20	0.46	1.84	0.65	-0.47	5532
Katanning	0.20	4.35	0.41	2.07	0.57	0.11	5474
Miles	0.22	1.10	0.47	1.69	0.57	-1.12	5808
Moree	0.22	1.76	0.36	2.88	0.53	-1.95	5808
Oakey	0.37	1.98	0.50	2.33	0.64	-1.32	5808

Roma	0.26	1.39	0.41	2.47	0.55	-1.82	5610
Tamworth	0.22	1.49	0.42	2.50	0.55	-1.54	5808
Warwick	0.24	1.05	0.52	2.05	0.59	-1.21	5775
Yanco	0.29	1.59	0.50	2.66	0.59	-1.72	5806
Six day ahead forecasts							
Albury	0.16	0.73	0.46	2.81	0.52	-1.91	5183
Amberley	0.44	0.20	0.73	2.50	0.69	-1.77	5184
Armidale	0.20	2.27	0.22	2.61	0.51	-1.37	5182
Cesnock	0.24	0.85	0.43	2.54	0.56	-1.73	5159
Charlton	0.24	1.85	0.38	2.46	0.56	-1.40	5183
Clare	0.20	1.64	0.31	2.06	0.54	-1.14	5184
Emerald	0.22	1.95	0.35	2.19	0.54	-1.35	5184
Griffith	0.24	3.26	0.38	2.13	0.60	-0.35	5092
Hay	0.26	2.52	0.32	2.05	0.59	-0.39	4923
Katanning	0.15	4.68	0.26	2.36	0.52	0.22	4895
Miles	0.17	1.21	0.34	1.77	0.53	-1.16	5184
Moree	0.17	2.04	0.26	2.96	0.50	-1.92	5184
Oakey	0.22	2.53	0.31	2.71	0.54	-1.54	5184
Roma	0.25	1.49	0.36	2.49	0.53	-1.81	5022
Tamworth	0.11	1.83	0.21	2.72	0.48	-1.58	5184
Warwick	0.19	1.08	0.43	2.21	0.55	-1.34	5151
Yanco	0.20	2.03	0.34	2.83	0.53	-1.70	5183