Weather in the Tallong Region

by

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1 Introduction

Meteorological data from the Tallong region are expected to be influenced by local geographic features such as proximity to the coast, hills and valleys. It is the purpose of this report to draw together historic data from a number of sources, some of which date back to the late 1900's; these data mostly relate to rainfall observations. Log books from these times indicate the influence of extreme weather events on the day-to-day lifestyles of the residents and will be discussed briefly. More modern computer-based digital data acquisition systems allow detailed analyses of short time scale observations. These are important for such processes as noise propagation and atmospheric dispersion of industrial emissions like dust and air pollutants. As such this report could also be used as a resource for any future planned industrial expansion in the region.

1.1 Data sources

The majority of data have been provided by a network of rainfall observers in the region. The observations are dependent on the exposures and types of the rain gauges, which maybe highly variable. This report will attempt to extract information on the systematic variability of rainfall across the region independent of the rain gauge idiosyncrasies. The digital computer-based data are available from three stations in the region, two in the South Marulan area operated by Boral Limited and a private station in the Tallong area. Data collected from these stations are virtually based on the original factory calibrations, some of which may have drifted with time. As such these data will be indicative rather than scientifically rigorous, although comparisons with other in-situ data measurements will be discussed. Inter-comparisons between simultaneous readings will also indicate geographic influences on the data.

1.2 Geographic Locations Data Types and Collection Periods

The station descriptors and geographic locations are seen in Table 1 and plotted on Google Earth in Figure 1; the negative Latitudes indicate they are in the Southern Hemisphere. These co-ordinates were used for plotting the locations in Google Earth and are in the vicinity of the property dwellings. The exact location of the historic Bureau of Meteorology (BOM) station in Tallong Village was presumed to be near the Old Post Office which is located in Memorial Drive. The UTM co-ordinates in Table 1 are within UTM Zone 56. Also included in Table 1 are the durations of the observation periods and the data types. The daily rainfall observations are typically taken at 0900 LST (Local Standard Time).
The digital data available from Peppertree Quarry and Boral Cement in South Marulan and Clark in Tallong are taken every 15 minutes at Eastern Standard Time (EST) which varies from LST during periods of Daylight Saving. The types of digital

data available are also noted in Table 1. The wind direction standard deviation σ_θ gives a measure of the wind direction fluctuations during the averaging period and is important as an indicator of the atmospheric stability. The (incoming) solar radiation is a measure of the intensity of sunshine during the daylight period.

The Tallong region is at the southern end of the Southern Highlands of NSW. From the viewpoint of geological and geographic features of the region, the Black residence on Caoura Road is about 63 km inland and west from the coastline which runs approximately NNE to SSW at that point. The region is a “gently undulating surface with some hills, ridges and small higher plateau remnants” (Tallong 2010) punctuated by deep gorges with the Shoalhaven River gorge most prominent at only 100m above MSL in our area compared to the plateau being above 600 m. To the east of our region lies the coastal plain and the escarpment which is likely to exert some influence on our observed weather patterns.

2 Rainfall

The largest databases in this study are the daily, 24 hour rainfall observations. Monthly and annual totals will be compared between various stations over the full data collection period as well as on a more restricted, but uniform, time-scale across a smaller network of stations in order to investigate the geographic variations. The statistics presented require some explanation. The average values are simply determined by summing the total number of observations and dividing by that number. The median values indicate that in 50% of the years on record the monthly or yearly rainfall total was lower than this value. The decile 1 and 9 values indicate that in 10% and 90% respectively of the years on record the monthly or yearly rainfall total was lower than these values.

In Table 2 the rainfall statistics are presented over all months for the years 2006-2013 and for a restricted number of stations. There are remarkably similar monthly average (61 to 67 mm) and median (41 to 50 mm) values at all stations in the central area of Tallong with the exception of those at the Botticchio residence which are higher (average = 72.8 mm, median = 55.8 mm). The values further north (at the Clark residence) and west (at the Montgomery residence) are lower. The extreme monthly values observed in June 2007 indicate a different trend with the highest on the plateau region (308 mm at Woods) closely followed at the Black residence down Caoura Road (305.2 mm). With this statistic Montgomery (290.1 mm) shows the third highest value and Leese the lowest (254.5 mm).

The annual rainfall totals have also been assessed for the eight years between 2006 and 2013. There is a consistent decrease in the mean values from Black to Darda to Kettle to Clark. However, there are higher values at both Leese (802.6 mm) and

Botticchio (873.0 mm) compared to those at a similar latitude (e.g. Kettle 738.1 mm). The lowest annual average is again observed at Montgomery (717.3 mm). The highest annual total was observed at Woods (1097 mm) during this analysis period. In summary, these analyses tend to indicate that there is a decreasing trend in the rainfall away from the coast but that there might some very local geographic features in Tallong which are also important influences.

If this type of analysis is now extended to the full datasets at all the observation stations other interesting trends emerge (Table 3). There are some very long datasets in excess of 40 years observed at the Charles, BOM-Caoura Road, Montgomery and BOM-Tallong Village sites. These show that the extreme events occurred well outside the 2006-2013 analysis period above. For example, the maximum monthly observation at Charles was 595.6 mm in May, 1943 with the highest annual value 2028.2 mm in 1950. The four stations furthest to the east in the network (Wingello, BOM_Caoura_Rd and Charles) all have the highest and similar monthly mean values (77.4 to 79.6 mm), much higher than the other stations (58.1 to 64.7 mm); Onslow is an exception, possibly due to the shorter record (1991-2009) than at the other easterly stations. The mean annual values (929.3 to 965.2 mm) at these east stations are also significantly higher compared to the more inland stations (688.6 to 863.2 mm).

2.1 Annual variations

From all years of observations, there is a detailed analysis of the variations of rainfall through the year in Table 4. The mean monthly rainfall data plotted in Figure 2 highlight the months when maximum rainfall is observed. February has the highest observations at all stations except the Tallong Village – BOM (the high Wingello values are only over 3 years, 2011 to 2013); the observations at this station span the period from 1895 to 1936 while those at all other stations are more current. It might be speculated that the low February values and indeed the small variations across all months at this station are due to climate change but further detailed and wider analyses would be required. A second lower peak in the rainfall is observed in June with the driest months being April-May and July-September. Some stations have a third minor peak in the November-December. The highest monthly rainfall observations and the years of those observations are noted at the bottom of Table 4.In the larger datasets observed at Charles/Onslow most of the highest values are earlier than the observation periods of other stations i.e. before 1999.

2.2 Rainfall rates

The automatic weather stations have the ability to measure rainfall over short periods like 15 minutes to 1 hour. Such rainfall rates can be important when discussing wash-out of air pollutants as well as having implications for land erosion which may be important for agriculture and mining activities. Data available for analysis from the Clark, Peppertree Quarry and Boral South Marulan stations have been integrated to common 1 hour rainfall rates for direct inter-comparisons. The frequencies of occurrence of the rainfall rates (mm/hr) are analysed in Table 5. They indicate lighter rain may be experienced in the hilly Tallong area compared to the open plains in the South Marulan region. The high rainfall rates above 6 mm/hr, typical of thunderstorms observed in the region, are analysed in more detail in Table 6. They show that when looking at the full datasets, the average, median and decile statistics confirm the higher rainfall rates in the South Marulan area. However the heaviest falls can be localised as thunder clouds tend to be smaller and meander through the region with the result that Mulwaree Drive has the highest rate of 35 mm/hr.

The localised nature of these high rainfall cases can be seen in a couple of examples where simultaneous measurements are made (Table 7). In the first case on December 23, 2012 the storm cell must have been centred more over South Marulan where the highest values (about 24 mm/hr) were observed. In Mulwaree Drive Tallong the rate was only 7.2 mm/hr. In the second example on February 24, 2013, the opposite was the case with Mulwaree Drive experiencing an extremely high rainfall rate(35 mm/hr) compared to South Marulan where one station experienced no rainfall.

2.3 Special high rainfall events

Some of the high rainfall events observed over the last few years are now discussed in order to further study the geographic influences on local rainfall (Table 8). The stations are listed roughly in a line inland from the coast with Onslow closest and Boral-Cement furthest inland. On February 3, 2012 there was a suggestion of a band of highest values on a north-east line through Wingello-Woods-Kettle-Montgomery but not reaching South Marulan. By contrast on March 1, 2012 there was a wide range of rain totals across all stations with values from 7.3 to 73.5 mm. Lowest values were observed at the Woods and Darda stations with highest values at Wingello, Botticchio, Montgomery and Boral Cement stations. A week later on March 8 , 2012 the highest values (56-64 mm) were observed at the north-east stations of Botticchio, Wingello and Woods and lowest at Montgomery (12.8 mm).

In 2013 very heavy rain was observed across the region between February 23 and 25. It was patchy on February 23 but on February 24 highest 24 hour rainfall totals were above 90 mm at nearly all stations except Clark (70 mm) which has hills rising to the east of the station and maybe a blocking/shadow effect. The combined Feb. 23 and 24 data indicated highest values were observed at Montgomery (134 mm) and Wingello and Black (124 mm). On Feb. 25 Wingello recorded 55 mm with Clark and Botticchio near 43 mm whereas Montgomery and the South Marulan stations were lowest, below 17 mm. On June 25 and 26 there was extremely heavy rainfall across the region which resulted in local flooding. Black recorded 142 mm and Wingello 120 mm on June 25 with most other stations between 100 and 112.5 mm except Clark (94 mm) and Montgomery (98 mm). Wingello (108 mm) was highest on

June 26 with the lowest values generally across the more south-westerly stations (41 mm).

On March 25, 2014 there was another heavy rainfall event with the north-easterly stations of Wingello (90 mm) and Woods (85 mm) recording the highest values. The values at Winslow (52 mm) and nearby Black (36 mm) are significantly lower than the more northerly stations. Elsewhere Clark (62 mm) was lowest with the values across the Shoalhaven river gorge from Montgomery (76.5 mm) lower in South Marulan by 7 to 10 mm. This suggests a rainfall event that had its origins more in the north-east direction.

The last heavy rainfall events to be reported here occurred in August 2014. From August 17 to 19 the highest rainfall totals were observed at the more easterly stations of Woods (129mm) and Black (125.6mm). The total at the Botticchio station (124mm) was high compared to that at Darda (102.8mm) more to the SSE suggesting a local topographic influence there. As you progress further SW across the Shoalhaven valley the figures in South Marulan are reduced by 9 to 13 mm compared that of Montgomery (107mm) on the Tallong side of the valley. Similar observations applied to the rainfall event on August 26 and 27 except that Black (62.6mm) was lower when compared to Woods (92mm) on the plains between Wingello and Tallong and Botticchio (85mm).

Overall, there appears to be some influence of the regional topography on the high rainfall events with the more easterly and north-easterly stations experiencing higher extreme daily totals. However, the local terrain of hills and valleys also seems to cause variations in the more westerly stations. In particular, the Clark station appears to be in a rain shadow area and the stations further west over the Shoalhaven valley in South Marulan generally lower than those nearby in Tallong. It would require a more detailed analysis of synoptic weather maps to further refine the conclusions in terms of the influence of wind directions, etc.

2.4 Special observations from the historic records at the Charles property, 1639 Caoura Road, Tallong

Log books of observations were available from the Bill Charles property at 1639 Caoura Road from 1919 until 1968. These revealed some interesting anecdotal observations some of which will be mentioned here. In 1922 there were periods of extreme weather. In March there was a period of 8 weeks of drought and this was followed later in the year by another period of 6 weeks of drought in November. In between times there was very heavy rainfall recorded in July with 330 mm over “two nights and one day”. In May 1925 254 mm of rain were recorded in one 24 hour period. After a very dry November in 1926 it was recorded that “The Great Bushfire” came through on December 10. On September 4, 1931 there was a record snowfall, 15 cm deep. Snow was also experienced in August and September in 1941 and 1942. May 1943 was the wettest month on record with 595.6 mm with very heavy rain “continuing for a fortnight” through the middle of the month. Luckily this was followed by two very dry months when totals less than 14 mm were recorded in both.

Unusually for that time of the year, in June 1957 following two dry months it was recorded that there was a “severe drought with bushfires”. Snow seemed to be observed much more frequently than in recent times with an observation that “Bundanoon was white” in September 1958 and 15 cm deep snow recorded locally in June 1959. Again snow was recorded in July and August of 1964 when the “tank top froze”. The “BIG” Chatsbury fire devastated the region on March 6, 1965. The annotated comments finished in August 1968 when Mr Charles handed the rainfall readings over to another person.

3 Winds

The automatic weather stations which take readings every 15 minutes (every 1 hour at Boral-Cement) allow detailed analysis of the variations of winds across the region. Superimposed on the influence of large scale weather systems which traverse southern Australia there are regional effects of the nearby coastline and local terrain which will be discussed below. It is also possible to study both the diurnal and seasonal wind variations at the three stations. The amount of data available is very large and these can be made available to interested parties while here a much briefer summary will be attempted.

3.1 Seasonal and diurnal variations

The datasets available from the Clark (Tallong), Peppertree and Boral Cement stations (South Marulan) cover different periods of recording times (Table 9). Those at the Southern Marulan stations have winds measured at 10 metres above ground level whereas the Clark station has the sensors only at 2 metres. As a consequence there will be a difference in the measured wind speeds with higher values experienced at the higher altitudes and more calms expected at Clark in Tallong.

There will be an initial seasonal inter-comparison between stations with all times combined for the full datasets. In Figure 3 the summer wind rose indicates a peak of light winds from the SE sectors with a secondary peak of stronger winds from the W. This contrasts with the South Marulan stations (Peppertree Quarry Figure 4; Boral Cement Figure 5) where E to ESE (Peppertree) and E to ENE (Boral Cement) predominate. These winds with an easterly component are likely to have maritime origins some of which are sea breezes which will be analysed in more detail later. There is also a secondary peak of stronger winds from the WSW to NNW sectors which most likely correspond to the hot summer winds from inland Australia.

In autumn there is strong peak in winds from the W in (Clark) Tallong which is also reflected to a degree at Peppertree Quarry where the W to NW sectors predominate.

The autumn winds at Boral Cement are stronger and more evenly distributed with peaks in a sector between WSW and NNW and another in the ENE and E sectors. The frequency of calm conditions has peaked in autumn at Clark (29%), Peppertree (9%) and Boral Cement (9%). In winter 45% of winds in Tallong occur from the W to WNW sectors and this is also experienced at Peppertree (46%). The longer dataset at Boral Cement indicates the peaks in the distribution are turned more to the WSW to W sectors.

The spring winds in Tallong again show a clear predominance from the W sector (24%) with a smaller secondary peak from the SE (11%). At Peppertree Quarry the W to NW sectors predominate with 45% of all winds. There is again a more even distribution of winds across the WSW to NNW sectors at Boral Cement.

In order to determine whether these differences reflect regional topographic variations, simultaneous winds and other meteorological measurements are compared for all three stations. Both Clark (C) and Peppertree (P) have 15 minute observations but Boral Cement (BC) has a 1 hour averaging period. Peppertree also has a 1 hour averaged dataset so this is compared with Boral Cement. The comparisons between the South Marulan stations are shown in Table 10; in this table S.D. means standard deviation and the differences are (Boral Cement - Peppertree). The two stations were side-by-side before February 22, 2012 so any subsequent differences due to the location change need to be considered in that context. There are two types of analyses: the Absolute Differences gives an indication of the size of the difference between the station, independent of which station is larger while the Actual differences take account of one station or the other being larger.

When side-by-side the P and BC have similar temperature, wind speed and rainfall measurements whereas the wind directions and standard deviation of wind direction (σ_θ indicates direction gustiness) have greatest differences and spread (S.D.) of differences. However at separate locations these differences are larger which reflects a definite local topographic influence. The wind directions at BC are slightly (1.18°) more towards the north than P (a 6.14° variation from side-by-side) on average but the distribution of wind direction differences is much larger at the different locations (28.39°) compared to when side-by-side (13.33°). In addition the wind speeds at BC are higher on average by 2.3 ms^{-1} than at P and σ_θ values higher on average by 4.25° indicating increased surface roughness and near ground turbulence at P.

The wind directions at Clark are only recorded to the 16 compass points (i.e. N, NNE, etc) whereas at P they can be anywhere within one of those sectors (i.e. for N between 347.75° and 12.25°). There are also no σ_θ data available at the Clark station. The major difference between these sites is in the wind speeds which are always higher at P than C where the lower instrument (2m vs 10m) also records a significantly higher number of calm conditions. On average the wind directions are similar at the two sites (-1.12°) but there is a significant spread of the distribution (47.2°) around this average. These differences only reinforce the seasonal wind rose analyses shown in Figures 3 to 5.

There is an example of the diurnal variation of winds from the Clark-Tallong station in Figure 6. The main feature is the large occurrence of calm conditions at 2m during the night hours, up to nearly 40% at this station. As the analyses above have shown this is much greater than at the South Marulan stations where a maximum of 12.7% calms were observed at 10m between 0300 and 0600 EST at the Boral Cement station. During all hours of the day there is a peak of stronger winds from the W direction Tallong. Secondary peaks from the NNE to NE and SE to SSE sectors are also observed from 2100 through the night to 0600 EST. W winds predominate between 0900 and 1500 EST when there is a change to the SE and later the more easterly sectors. It is suggested these winds are associated with the arrival of a sea breeze. Sea breeze observations in the Tallong region will now be discussed in more detail.

3.2 Coastal breezes

After looking at wind direction and dew point temperature traces over many months it became obvious that coastal breezes were observed to arrive with a definite pattern in the traces; it has been pointed out that winds from the coast may be sea breezes or they may be associated with a southerly change that backs towards the east as it travels inland to end up from a sea breeze type of direction i.e. NE to SSE (Miskelly 2014). In Figure 7 (Miskelly 2011) there are two examples of coastal breeze arrival on consecutive days in September, 2014 at the Mittagong and Tallong weather stations. On Sept. 14 the wind direction changes abruptly from the W ( = west wind direction) to SE (Tallong) and ENE (Mittagong) at 1815 EST simultaneously at both stations accompanied by a sudden increase in the dew point temperature (indicative of the moisture content in the atmosphere) and decrease in the temperature. On Sept .15 the coastal breeze is seen to arrive at Mittagong at 1515 EST and 1645 EST at Tallong. Criteria had to be developed to be able to detect the coastal breeze arrival automatically in a FORTRAN computer program for analysis of the long term dataset. Three were investigated:

If the wind direction changed to between NE and SSE (“coastal breeze sector”) between 1200 and 2400 EST and there was:

1. C1 - a relative humidity (RH) increase of >15%.
2. C2 - a dew point (DP) increase of >3°C.
3. C3 - a dew point (DP) increase of >4°C.

Wind direction, relative humidity, temperature and dew point data were then output from 45 minutes before the wind direction change until 3 hours afterwards and all data plotted in an Excel spreadsheet for closer inspection to see if they had the same type of traces as in Figure 7. Of the 96 cases identified by the different criteria between 12/12/2011 and 11/06/14 closer inspection of the traces revealed “no coastal breeze” occurrence on 17 occasions (i.e. 18%). Of these, there were 9 cases meeting C1 only and not C2 and C3. If all three criteria are met independently then only about 50% of coastal breeze traces are detected but of these there were less than 8% false cases. If both C1 and C2 are combined (i.e. increases RH >15% **and** DP >3°C) 57% of coastal breezes are detected and the false detection rate falls to 4%.

Coastal breezes are predominantly late spring, early autumn phenomena but the arrival times in Tallong are quite variable (Figure 8). With more intense solar radiation heating in summer it might be expected that stronger coastal breezes would develop and penetrate inland earlier. This trend is not obvious in Figure 8. In Figure 9 a histogram of all coastal breeze arrival times independent of season reveals a peak in the distribution between 1500 and 1600 EST. However, coastal breezes are also observed to arrive later in the evening with about 10% of cases being after 2000 EST.

The distribution of wind direction changes after passage of coastal breezes is seen in Figure 10. Here a negative change indicates anti-clockwise turning of the wind say from a sector south through west to north into the “coastal breeze sector”. Almost 81% of cases have winds turning anticlockwise. There were 25% of all cases when the coastal breeze signature was observed with winds starting in the “coastal breeze sector”. In 98.7% of all cases examined temperatures fall with an average decrease of 5.2°C (Figure 11). The distributions of relative humidity and dew point temperature changes on the passage of the coastal breezes are seen Figure 12 with average changes of 28% and 5°C respectively. Thus coastal breezes can have a modifying effect on the climate in Tallong, albeit smaller than in communities closer to the coast. It has been reported that “sea breezes” arrive more frequently and earlier (e.g. 2pm or even late morning) at 1095 Caoura Road, sometimes up to 2 hours before reaching Tallong Village (Black 2104). To differentiate between sea breezes and southerly change type of coastal breezes would require more detailed analyses which may be followed up in the future.

4 Atmospheric Pressures

Atmospheric pressures show both seasonal and diurnal variations in response to synoptic and local scale conditions. Detailed statistics are presented in Table 11 with the average pressures plotted in Figure 13. The high pressure systems migrate north during the winter months and hence the highest pressures observed in Tallong are in the months of June and July. By contrast the lowest atmospheric pressures are observed during December and January when the high pressure systems are centred more to the south of the Australian continent. During the day the highest pressures are observed in the morning typically between 0600 and 1200 EST. Lowest atmospheric pressures during the afternoon coincide with the maximum temperatures of the day, maximum convection and upward movement of the air.

5 Atmospheric Temperatures

Dry bulb temperatures are recorded every 15 minutes on the automatic weather stations in the Tallong region. At Tallong the sensor is in an un-aspirated white radiation screen at 1.2m. Similar screens are used on the Peppertree Quarry tower with sensors at 2 and 10m while at the Boral South Marulan station the sensor is at 1.2m. The Peppertree Quarry temperature data allow study of the temperature inversion and atmospheric stabilities in the surface layer which is discussed in the next chapter. The temperature data from all stations will now be compared.

The full statistics from Tallong are shown in Table 12 and the average dry bulb temperatures are plotted in Figure 14. The average maximum temperatures are highest in December and lowest in June, although the extreme minimum of temperature was observed in July. In terms of minimum temperatures, similar lowest averages and extreme values are observed in July and August.

In Figure 15 there is a comparison of average temperatures across the region for typical summer (January) and winter (July) months. In January the early morning and late evening temperatures are lowest in Tallong and highest at the Peppertree Quarry. Daytime temperatures are highest at the Peppertree Quarry and about 1°C lower at the Boral South Marulan site. In July the early morning temperatures are again lower at Tallong by about 1.3°C but this trend is reversed in mid-afternoon when Tallong records higher temperatures. The Boral South Marulan and Peppertree Quarry stations have similar temperatures during all hours in July. In terms of minimum temperatures, it has been reported that frosts are less severe at and summer maximum temperatures milder at 1095 Caoura Road than in the Tallong Village probably due to the coastal influence (Black 2014).

5.1 Minimum Temperatures in August 2014

During the early part of August, 2014 the Southern Highlands and Southern Tablelands experienced unusually cold nights and clear days under the influence of a very stable High pressure system located over southern Australia (Figure 16). Under these conditions on August 12, 2014 the lowest minimum temperatures for 15 years were observed at Goulburn airport (Table 13). Over 15 days there was only one morning when the minimum temperature was above 0 °C at Goulburn and two days at Tallong (Figure 17). It is apparent that Goulburn has the lowest minimum temperatures during this period but Tallong is generally lowest in the Tallong/South Marulan region. By comparison with Table 12, summarised over the period December 2011 to June 2014, the extreme minimum in Tallong has been lowered to -6.2°C on August 3, 2014.

5.2 Temperature Inversions at Peppertree Quarry

One indicator of the stability of the lower atmosphere can be measured using temperature sensors at two altitudes above the ground. At Peppertree Quarry there are sensors at 2 and 10m. During the daytime temperatures generally decrease with increasing height in the lower atmosphere. This situation is known as an unstable or neutral atmosphere. At night, temperatures typically increase above the ground in a phenomenon referred to as a “temperature inversion” or stable atmosphere. Temperature inversions can lead to anomalous propagation of noise from ground level sources to more distant receptors (O'Connor 2006) due to the bending of sound waves as they move higher into a stable atmosphere. This may be important for noise propagation from night-time industrial operations as well as road and railway transport movements (e.g. freeway traffic) and their impacts on quiet rural communities (Black 2014).

In Table 14 there is a summary of the temperature difference data as a function of time of day and months in the year. As expected the daytime temperature differences are more unstable (negative) in the summer months with the overnight stable/temperature inversions being stronger and persisting later in the winter months. The relationship of the stable conditions to wind direction indicates about 48% of all cases occur with winds from the W to NW sectors (Table 15). This confirms the observations in Figure 4 for the spring, winter and autumn wind roses when most stable conditions are observed.

6 Atmospheric stabilities

Another measure of the atmospheric stability has been developed by Pasquill (1961) to describe the dispersion of airborne pollutants in the lower atmosphere. The Pasquill scheme has been extended to now have categories A (unstable) through neutral (D) to the most stable (G). Over the years, definition of these categories has been investigated extensively using different meteorological measurements. Apart from temperature difference measurements discussed above, a scheme with wide applications has been extended (by Mitchell and Timbre 1979) and applied in USEPA (2000). This uses wind speed (u), wind direction standard deviation (σ_θ) [gustiness] and time of day and is the scheme used here. It should be noted that this scheme has also been recommended in the NSW Industrial noise policy (NSW 2000).

The Pasquill categories were determined directly from the 15 minute average u and σ_θ data using USEPA (2000) and not from the hourly averaged categories measured at Peppertree Quarry. In Table 16 the categories separated by Night and Day indicate a majority of the neutral, D category or good atmospheric dispersion and sound propagation conditions. At night there are only 13% of the most stable F and G categories which indicate poor dispersion, potential anomalous noise propagation/temperature inversion conditions. When these categories are compared to the prevailing wind directions (Table 17) it is apparent that there is a majority of the stable categories (E to G) associated with winds from the W to NNW sectors. This confirms what was found in analysis of temperature inversions in Table 15.

7 Solar Radiation

Incoming solar radiation is monitored at the Peppertree Quarry site. The monthly average values are plotted by time of day in Figure 18 and tabulated in Table 18. The typical annual cycle is observed with maximum values occurring in the summer months (November to January) and minimum values in the winter months (June and July). Data are also available on the standard deviation (σ) of hourly values around the mean values (mean) which might give an indication of the presence of clouds. The ratios of σ to mean values are plotted in Figure 19 as a function of month and time of day. Near sunrise and sunset the mean values are low and these ratios are higher. However, if the values between say 0900 and 1500 EST are considered this indicates that February and June are the cloudiest months. August and October the clearer months have the lowest ratios. Its is interesting that the peak months of cloudiness corresponds to the peak months of rainfall plotted in Figure 2. November shows variablity during the day with peaks of cloudiness at 1000 and 1500 EST.

8 Additional Meteorological Data

Apart from the tables, graphs and figures contained in this report there are much more extensive analyses available if people are interested. With data recorded every 15minutes it is possible to break down analyses by time of day, month of the year and season for many more of the meteorological parameters shown in Table 1. Data from the Boral South Marulan and Peppertree Quarry sites would require special permissions to be given but that from Clark can be made available in digital form.

9 References

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11 Tables and Figures

Figure 1: Observer stations in the Tallong region using Google Earth

Figure 2**:** Mean monthly rainfall over all years of observations

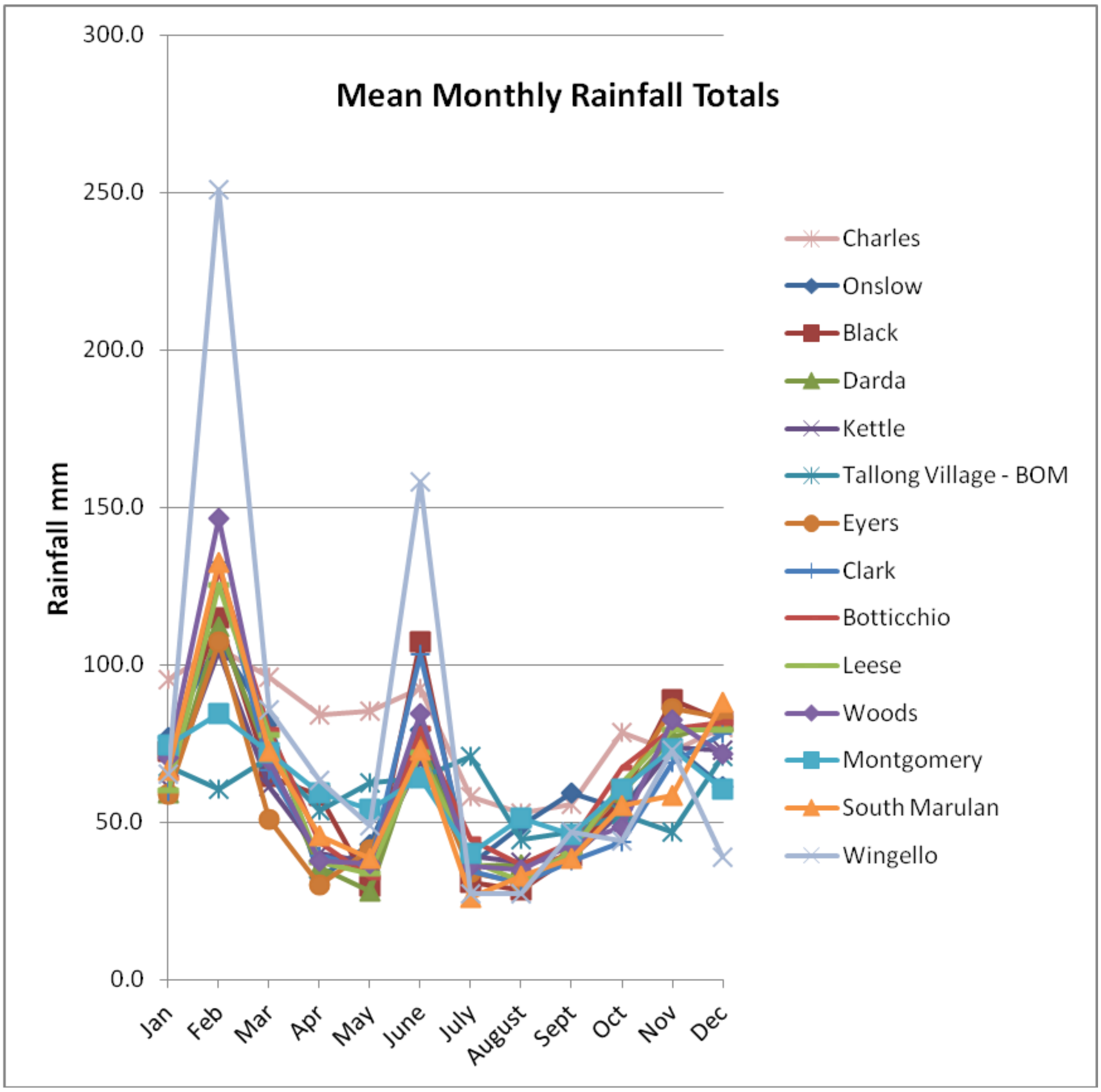
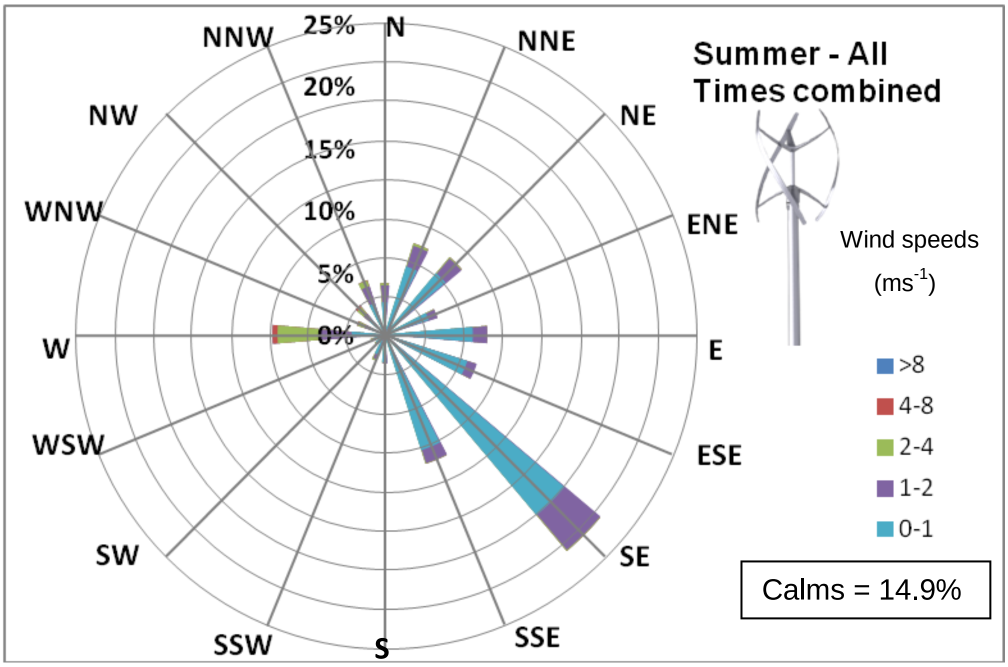


Figure 3: Wind roses from the Clark station 12-12-2011 to 11-6-2014



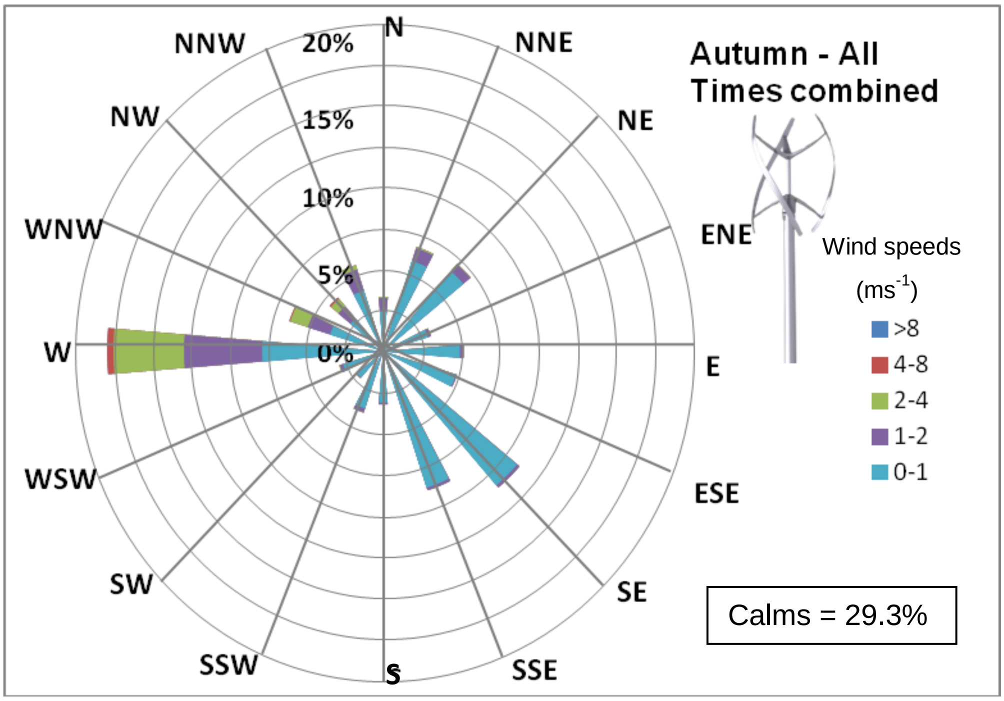
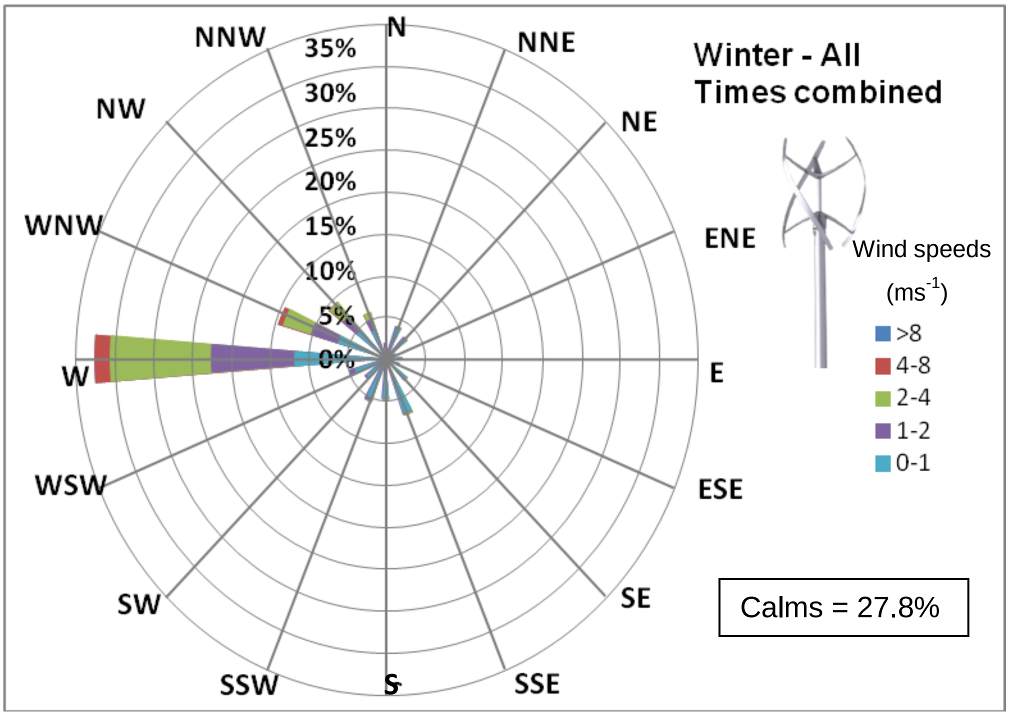


Figure 3 contd.: Wind roses from the Clark station 12-12-2011 to 11-6-2014



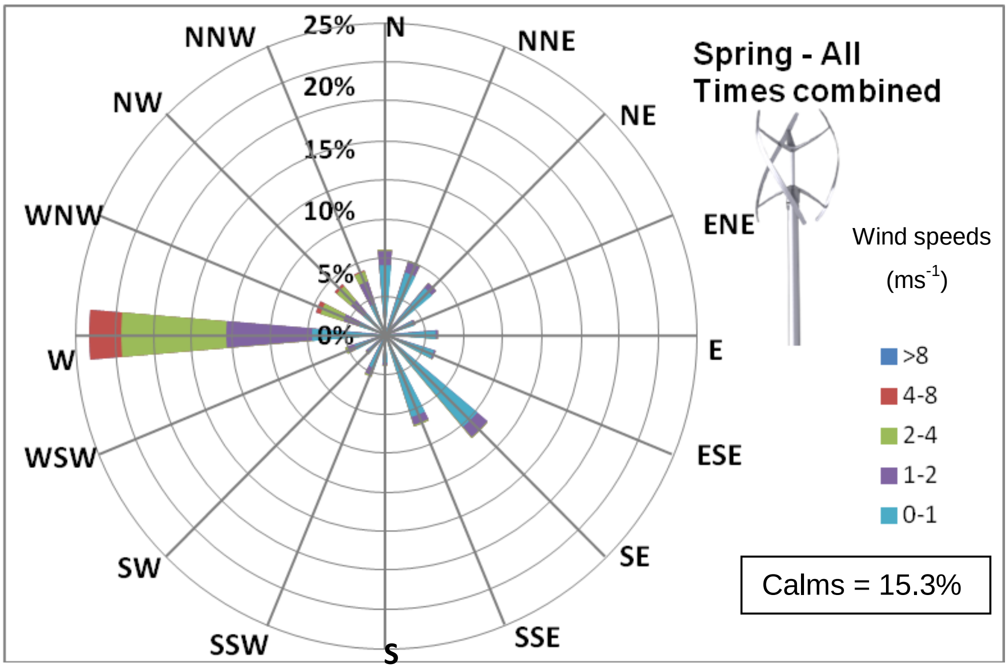
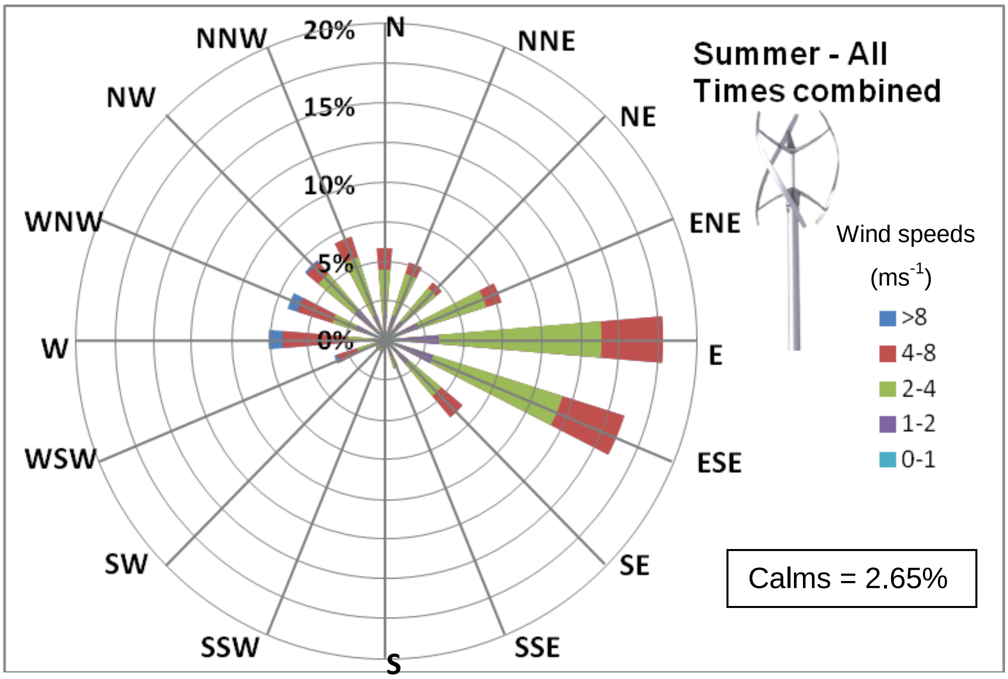


Figure 4: Wind roses from the Peppertree Quarry station 23-2-2012 to 11-6-2014



Wind speeds

(ms^{-1})

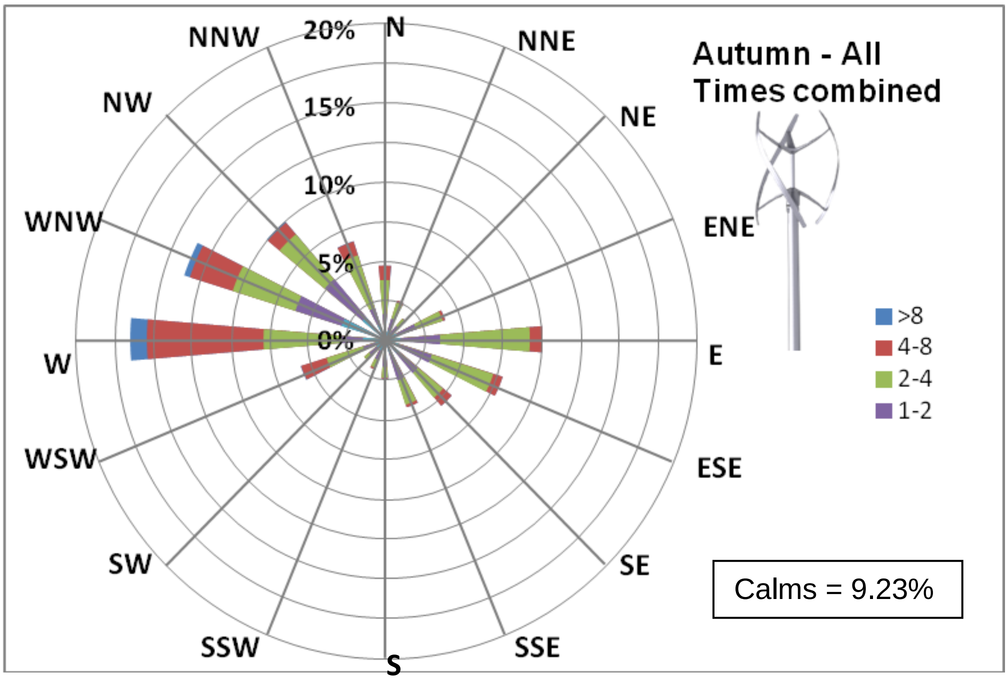
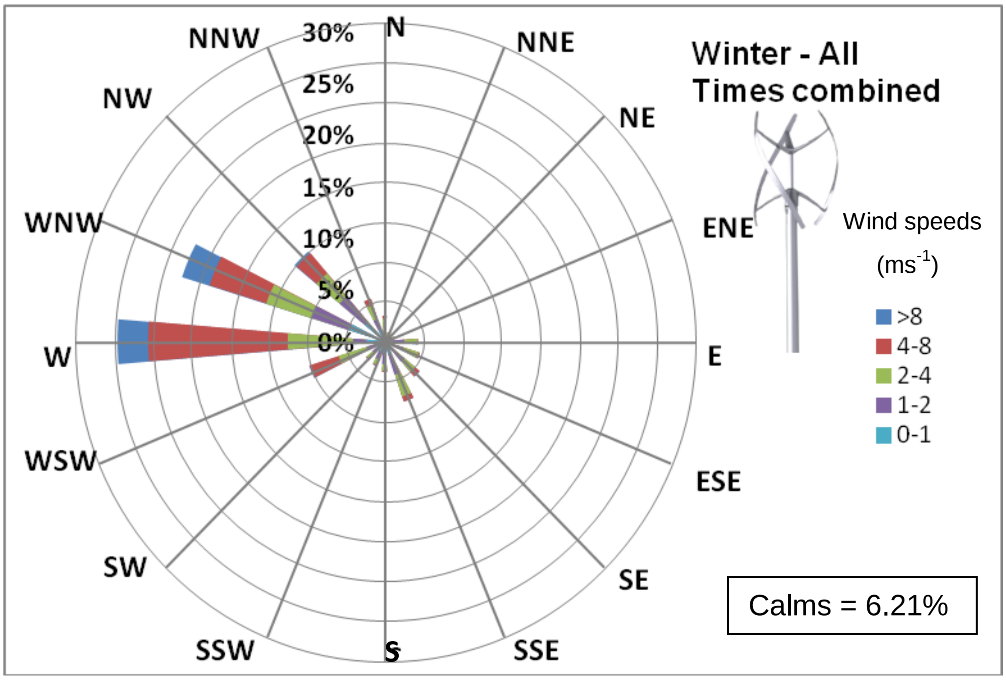


Figure 4 contd.: Wind roses from the Peppertree Quarry station 23-2-2012 to 11-6-2014



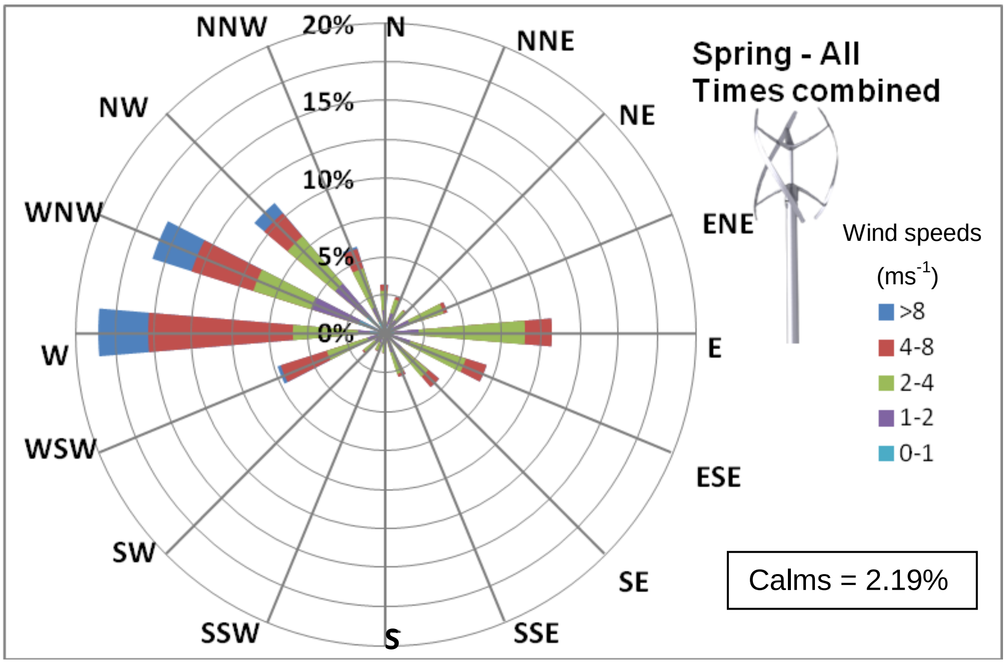
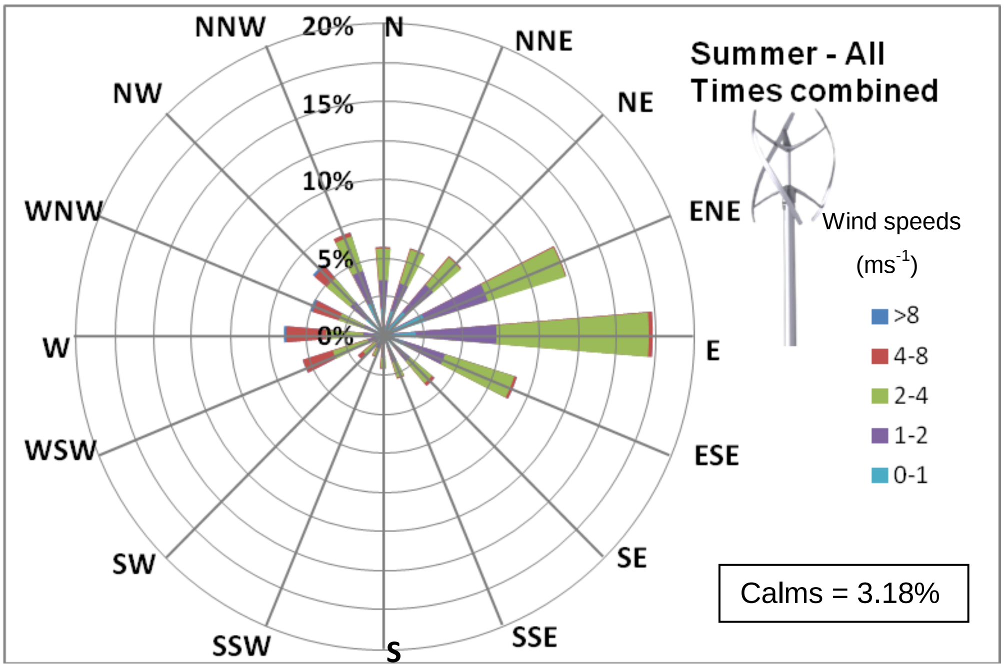


Figure 5: Wind roses from the Boral Cement station 1-1-2008 to 11-6-2014



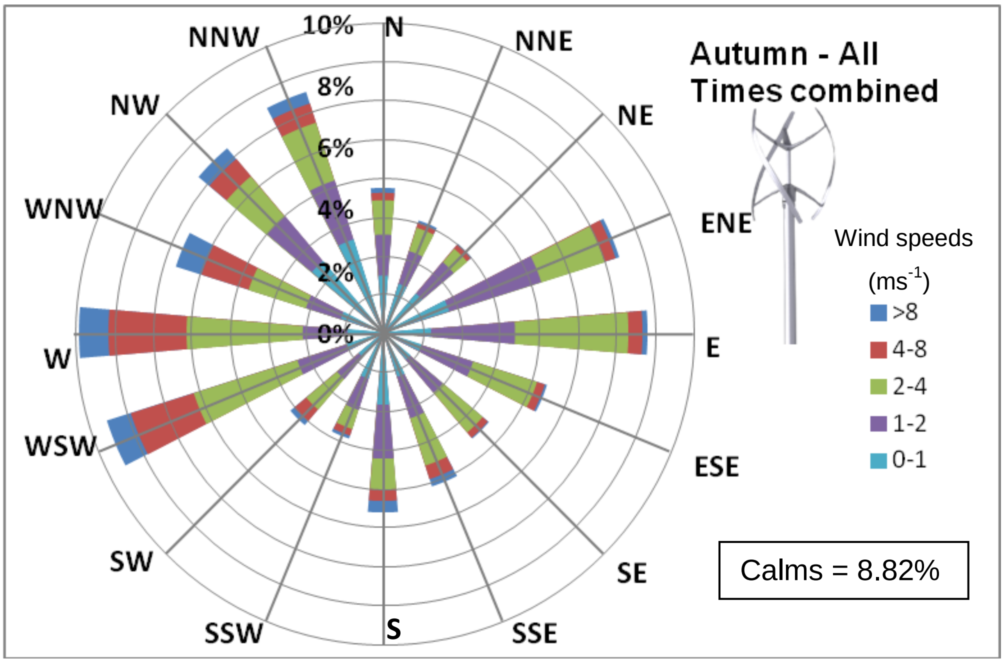
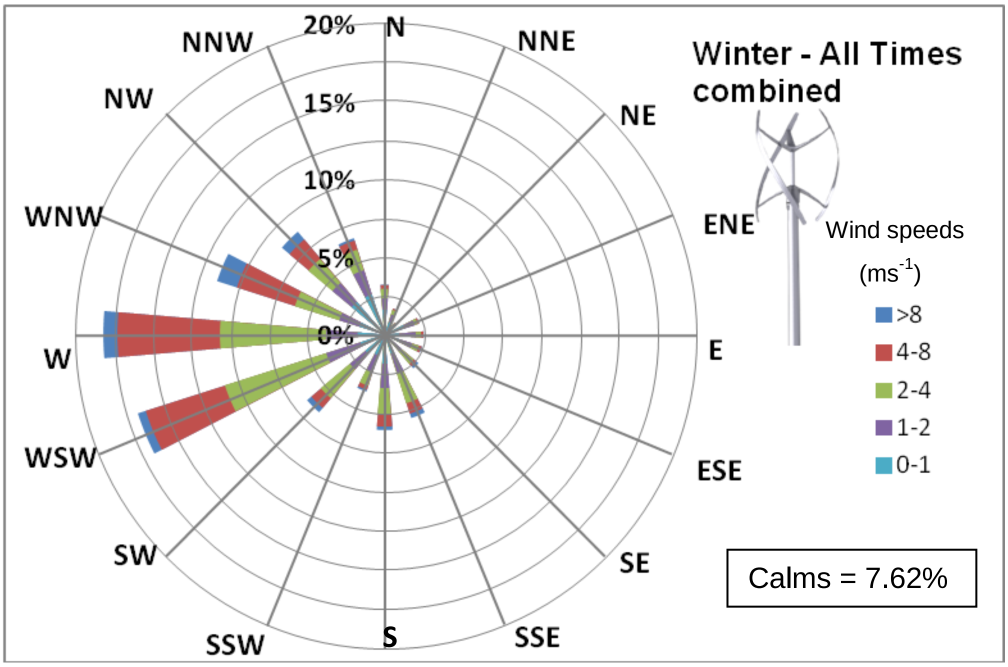


Figure 5 contd.: Wind roses from the Boral Cement station 1-1-2008 to 11-6-2014



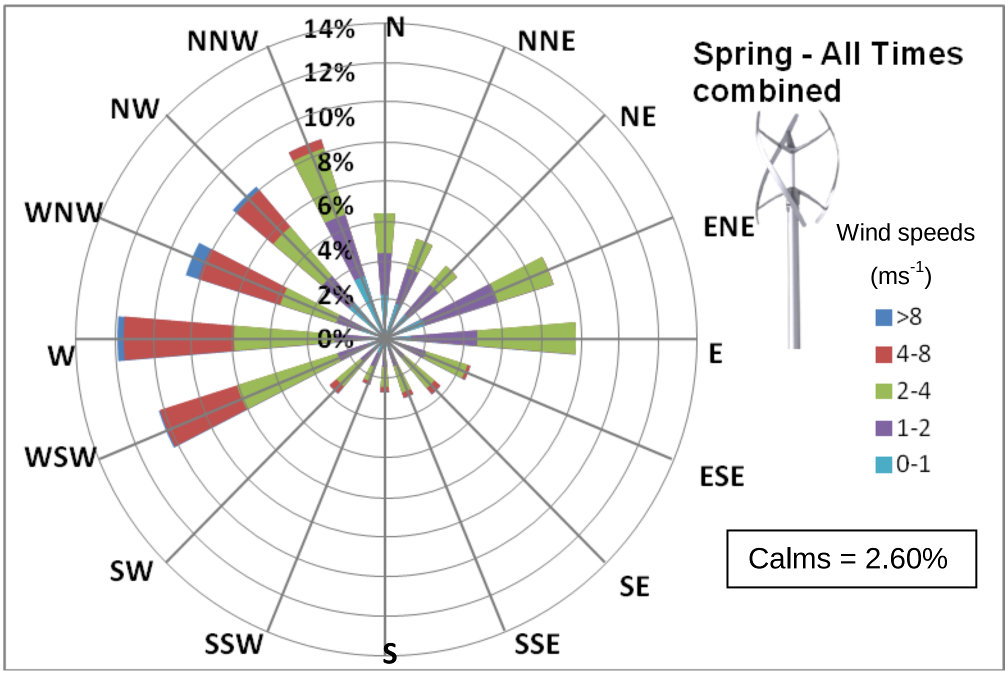
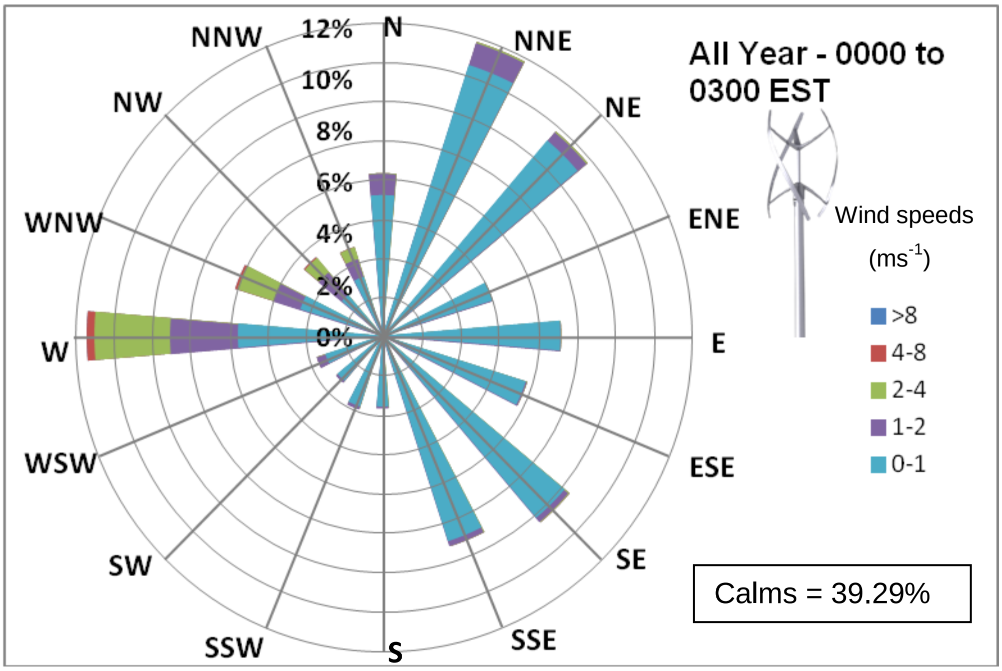


Figure 6: Wind roses from the Clark station 12-12-2011 to 11-6-2014



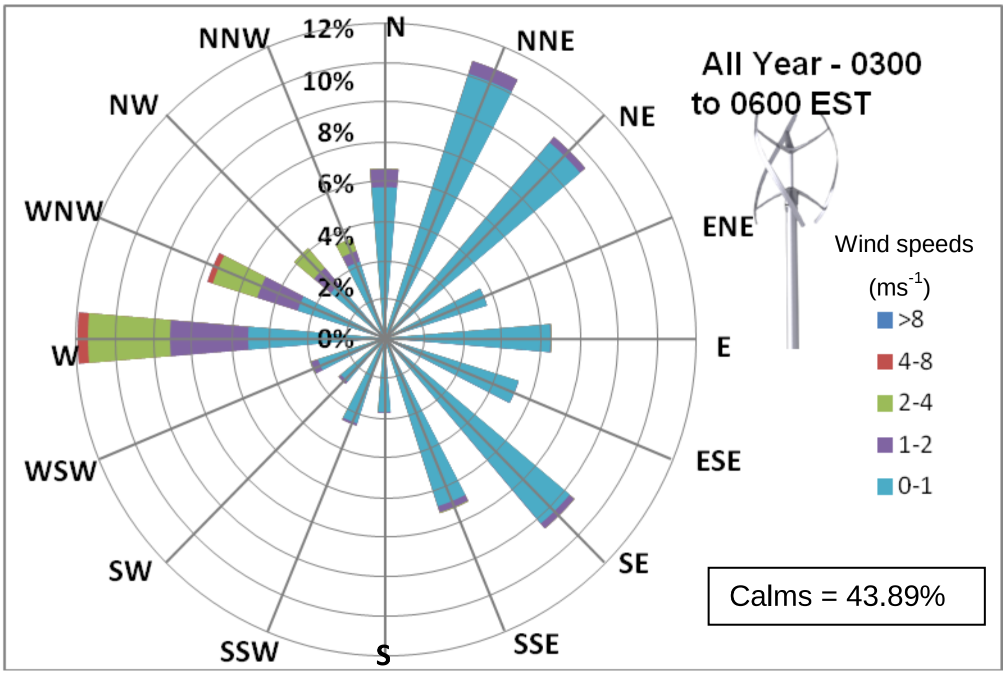
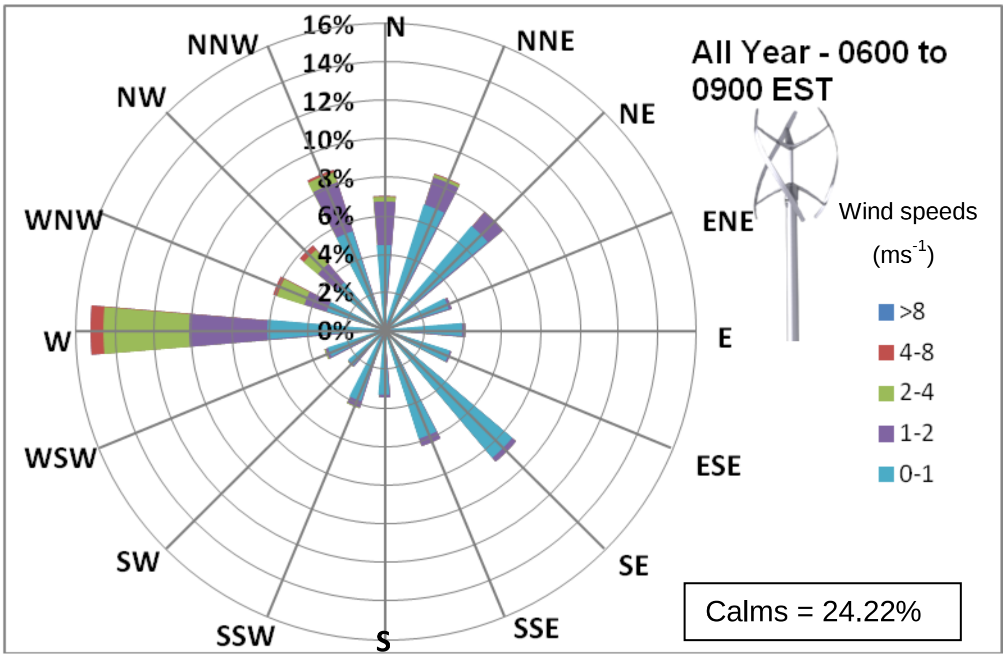


Figure 6 contd.: Wind roses from the Clark station 12-12-2011 to 11-6-2014



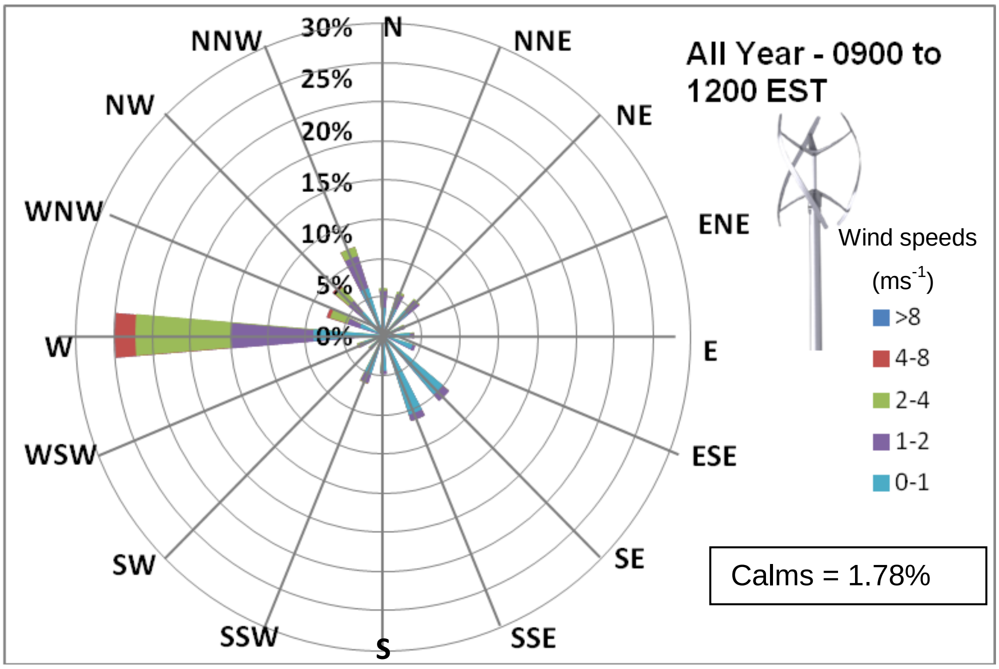
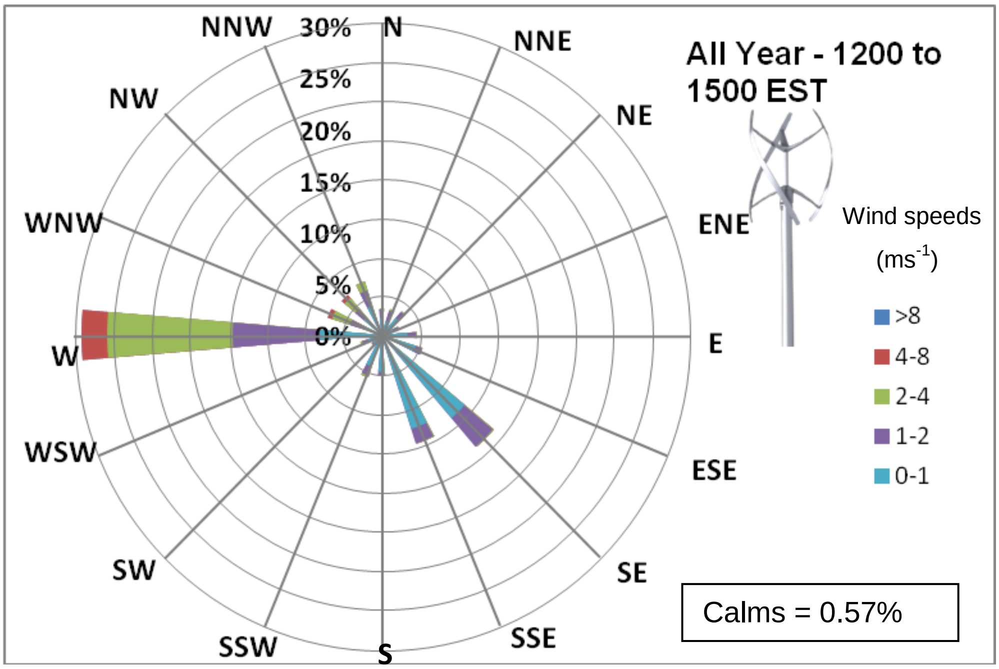


Figure 6 contd.: Wind roses from the Clark station 12-12-2011 to 11-6-2014



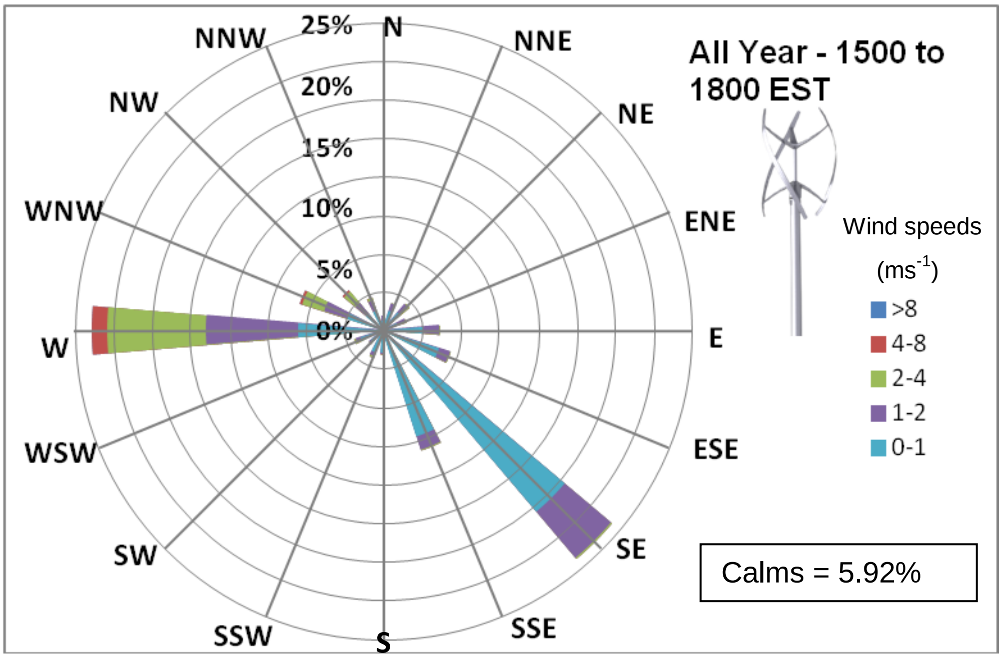
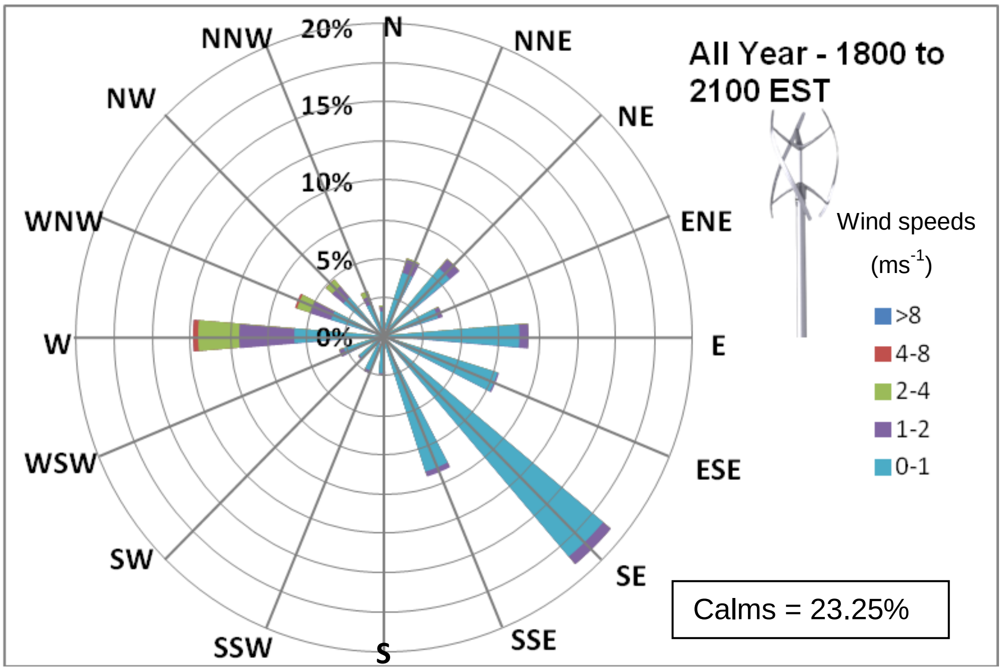


Figure 6 contd.: Wind roses from the Clark station 12-12-2011 to 11-6-2014


All Year - 1800 to 2100 EST
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
20%
15%
10%
5%
0%
Wind speeds (ms-1)
>8
4-8
2-4
1-2
0-1
Calms = 23.25%

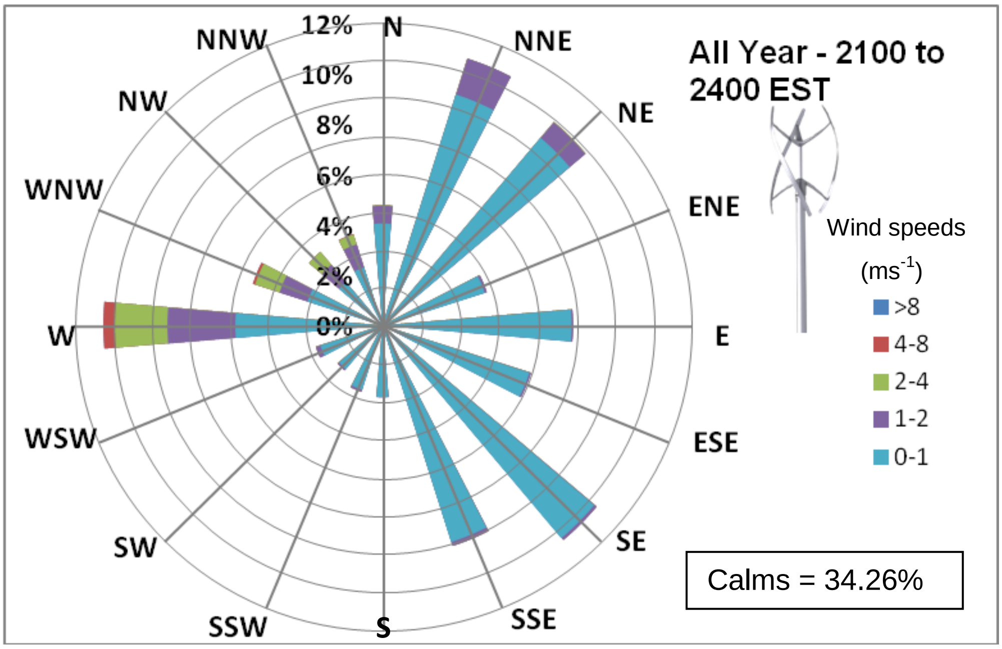

All Year - 2100 to 2400 EST
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
12%
10%
8%
6%
4%
2%
0%
Wind speeds (ms-1)
>8
4-8
2-4
1-2
0-1
Calms = 34.26%

Figure 7: Example of coastal breeze arrival at the Clark-Tallong and Miskelly-Mittagong weather stations

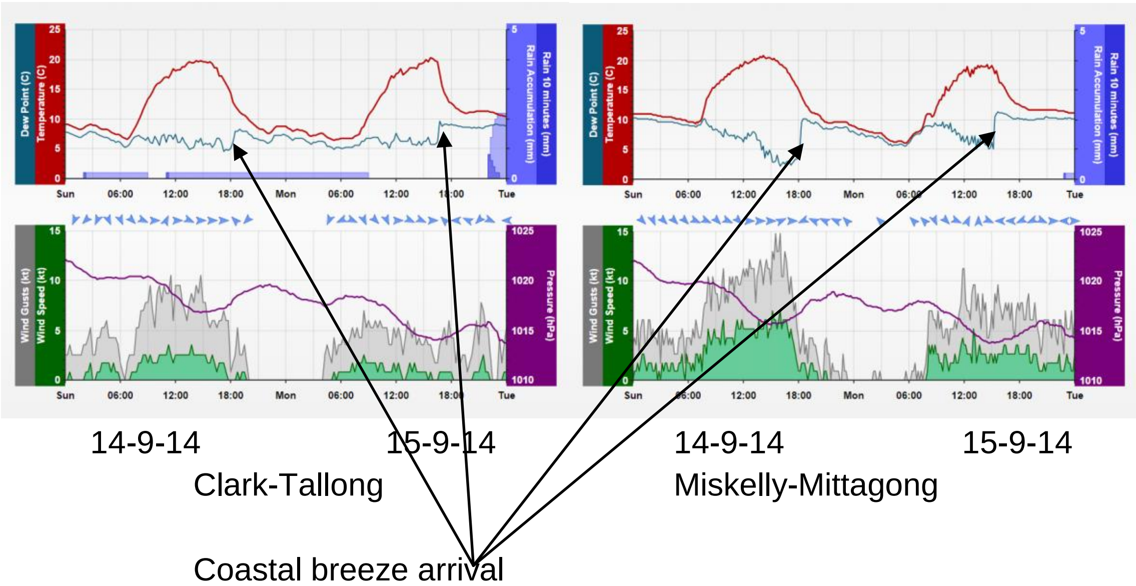


Figure 8: Coastal breeze arrival times versus month of the year

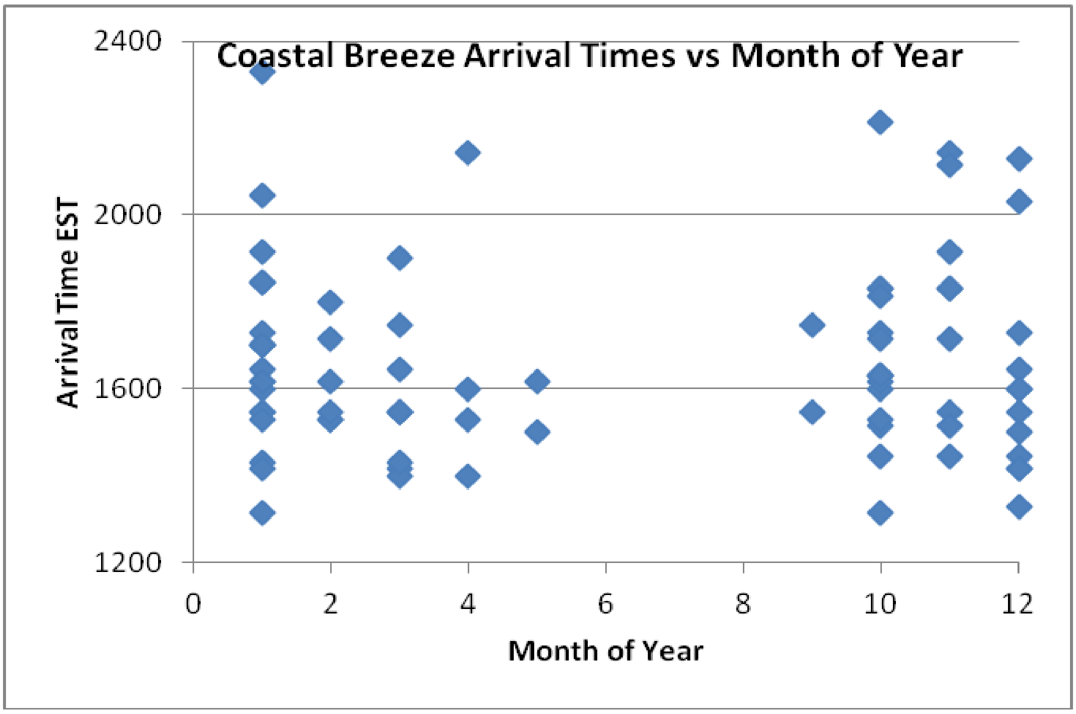


Figure 9: Distribution of coastal breeze arrival times in Tallong

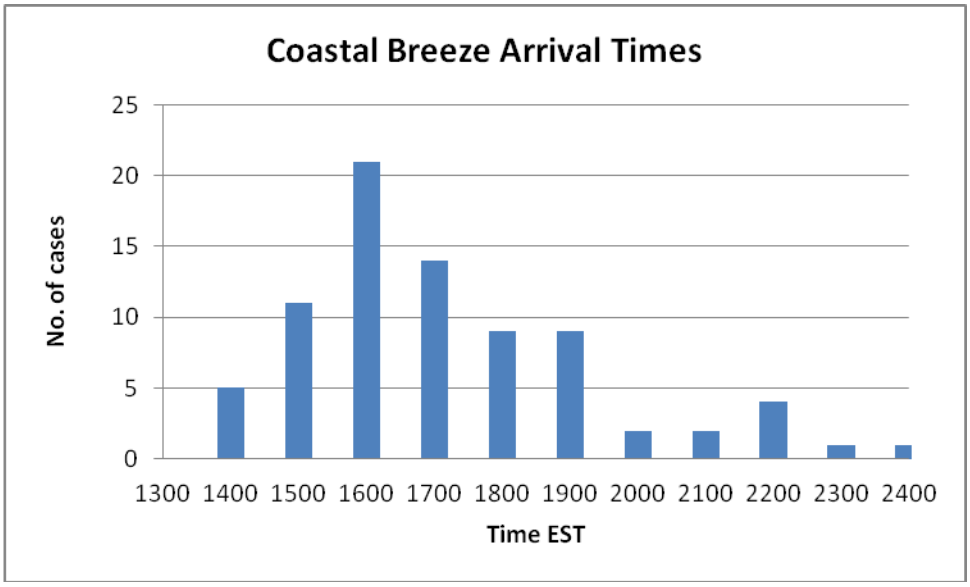


Figure 10: Wind direction changes after passage of the coastal breezes

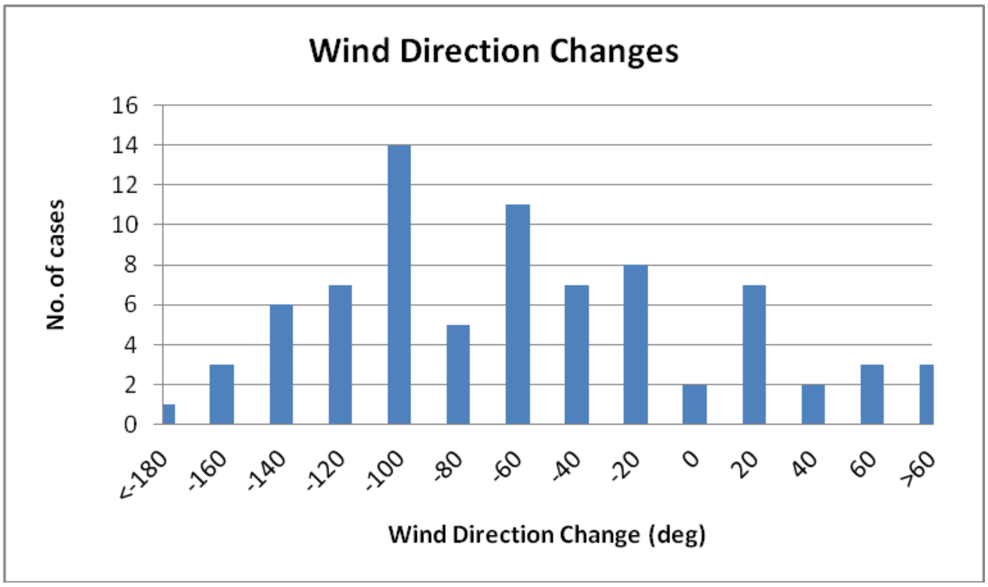


Figure 11: Temperature changes after passage of the coastal breezes

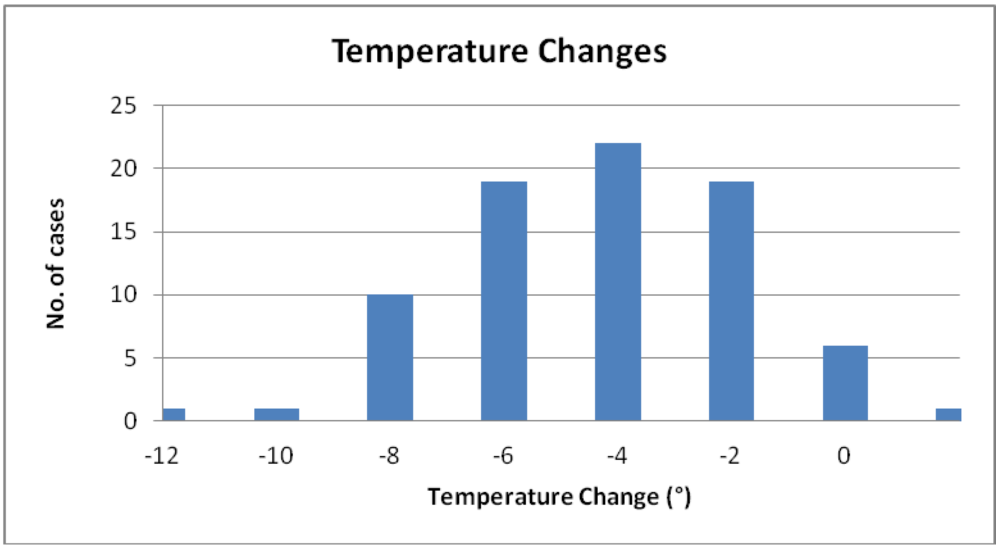


Figure 12: Relative humidity and Dew Point Temperature Changes with the arrival of coastal breezes in Tallong.

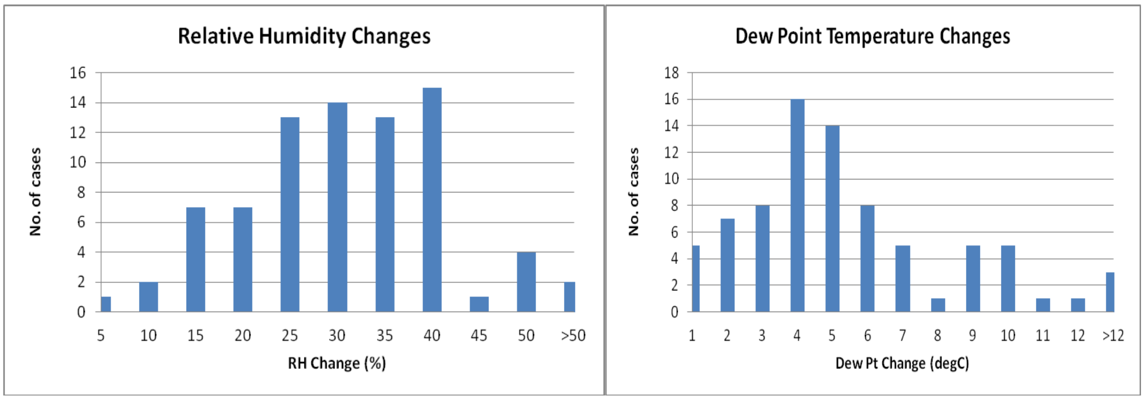


Figure 13: Atmospheric pressures versus time of day and months at Tallong.

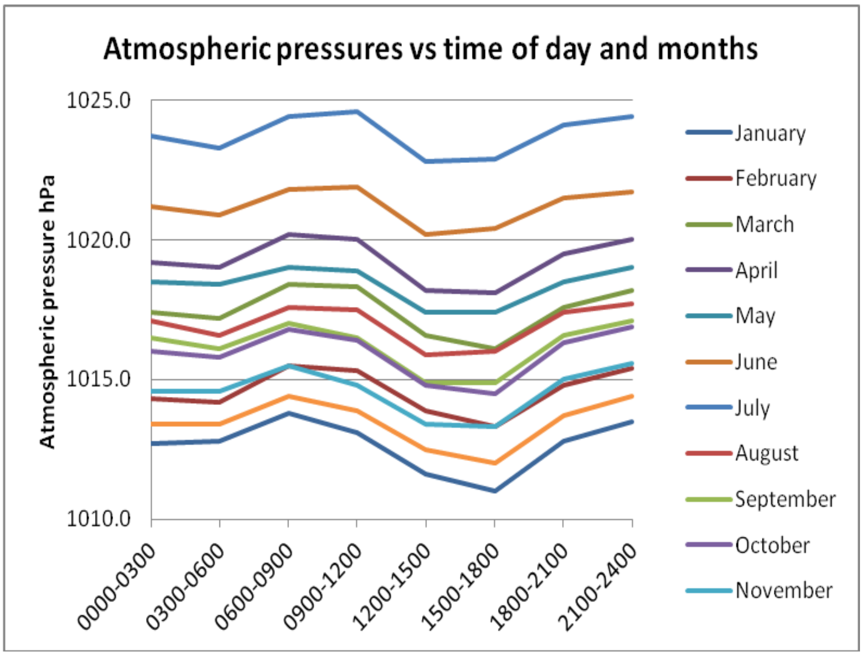


Figure 14: Dry bulb temperatures versus time of day and months at Tallong.

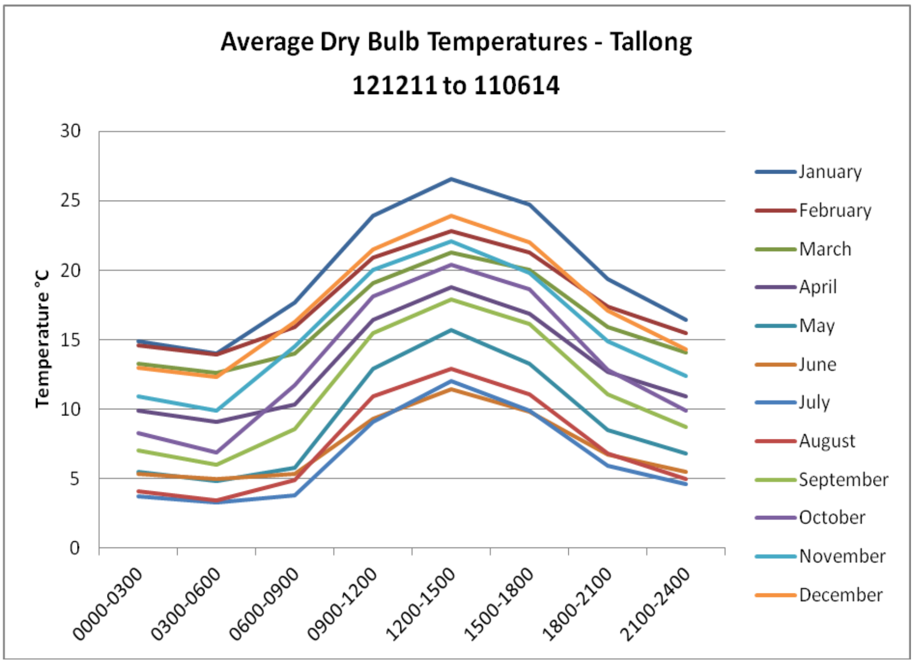


Figure 15: Comparison of average temperatures across the region

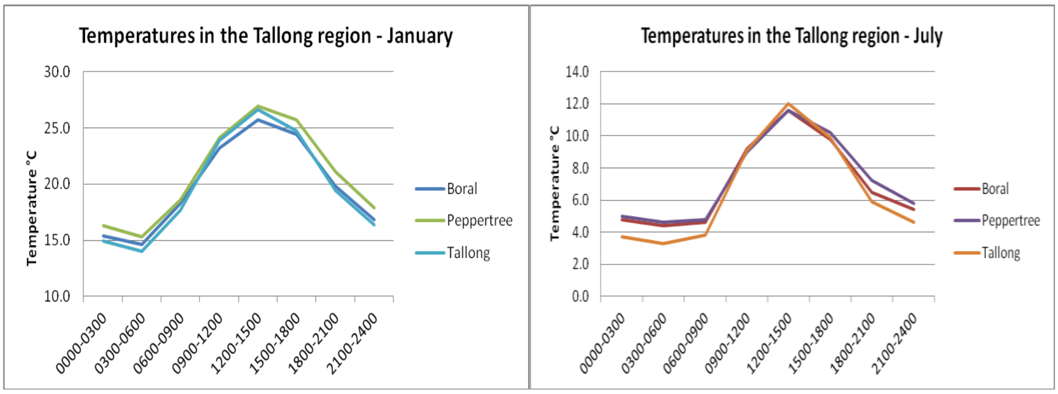


Figure 16: Mean sea level atmospheric pressure map (from the Australian Bureau of Meteorology)

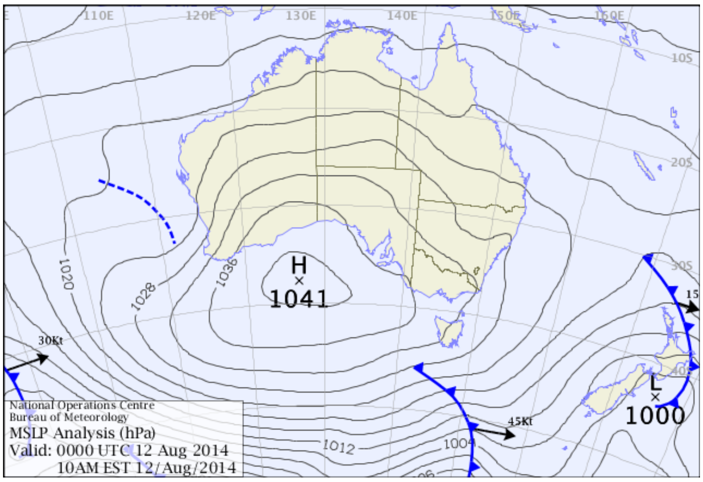


Figure 17: August 2014 Minimum Temperatures

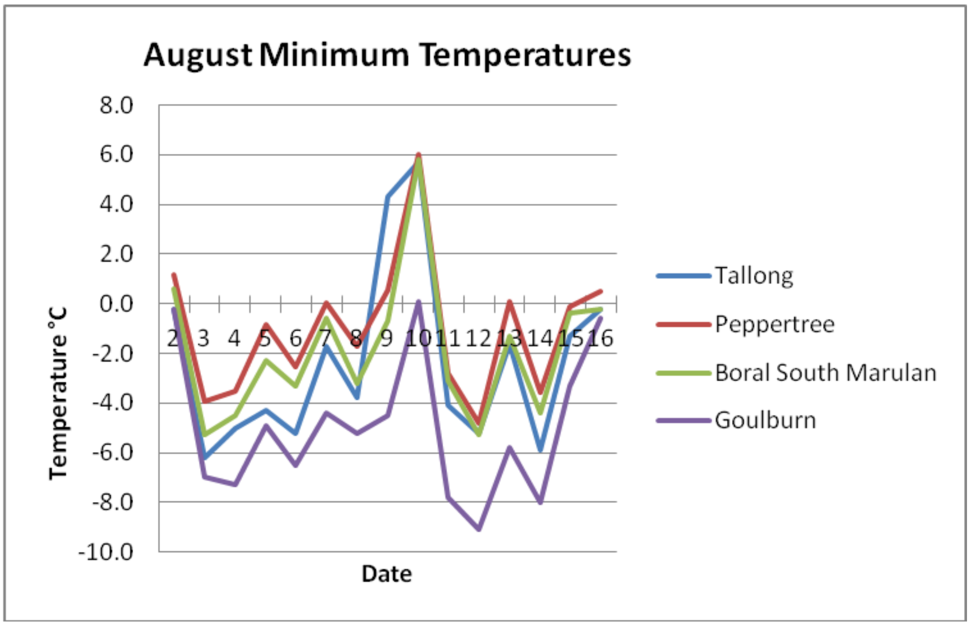


Figure 18: Solar radiation at Peppertree Quarry, South Marulan

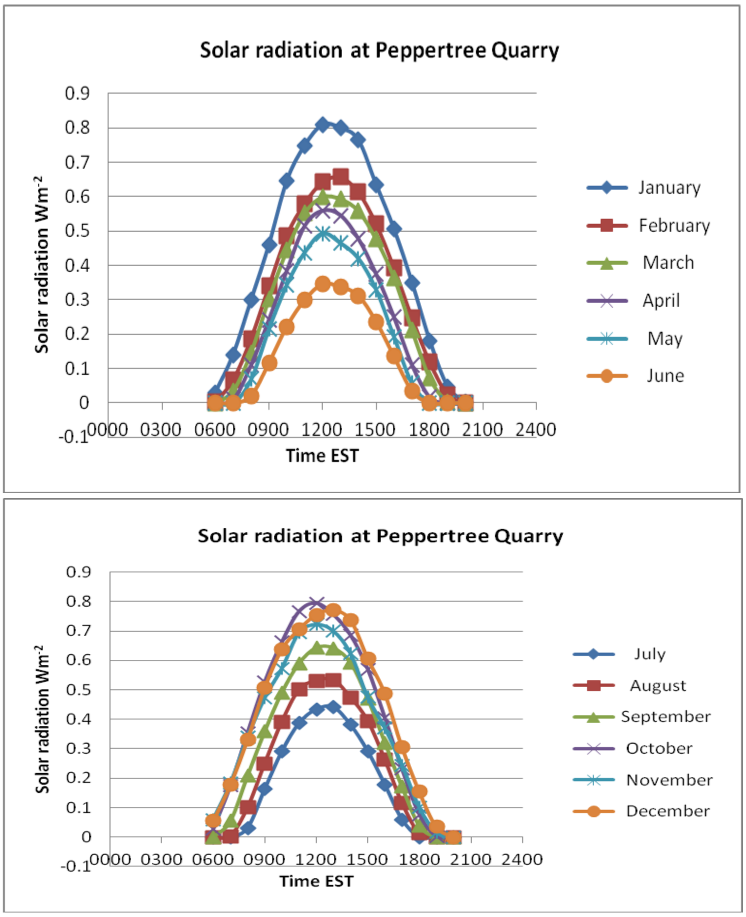
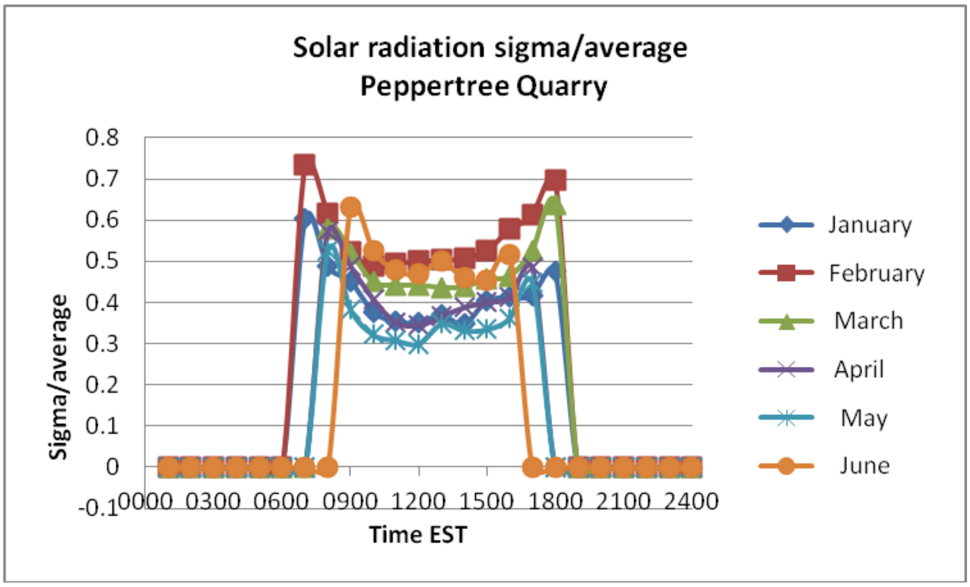


Figure 19: Solar radiation - ratio of σ to the average at Peppertree Quarry, South Marulan where σ = standard deviation



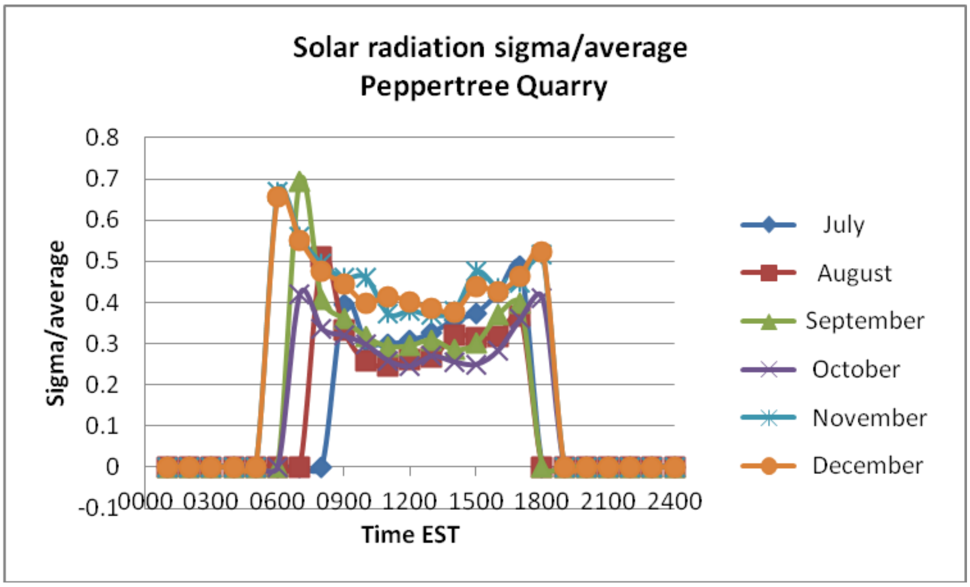


Table 1: Geographic locations of stations and meteorological data in the Tallong region

Station Name	**Geographic co-ordinates °**		**Rain gauge Altitude m**	**UTM Co-ordinates m**		**Observation Duration**	**Data Type**
Charles	150.19566	-34.77409	640	6148425.3	243361.9	1919 to 1968	Daily rainfall
Onslow	150.19390	-34.77904	636	243216.3	6147871.9	1968 to 2009	Daily rainfall
Black	150.14907	-34.79092	627	239150.2	6146438.5	2004 to 2013	Daily rainfall
Darda	150.11468	-34.76478	627	235919.5	6149247.9	1999 to 2013	Daily rainfall
Kettle	150.08179	-34.73036	641	232796.7	6152980.2	1992 to 2013	Daily rainfall
Tallong Village - BOM	150.08664	-34.71974	624	233206.9	6154170.7	1895 to 1936	Daily rainfall
Eyers	150.08519	-34.70932	660	233041.1	6155323.1	2003 to 2011	Daily rainfall
Clark	150.09201	-34.69578	634	233622.1	6156843.5	2006 to 2014	T,RH,Dew,u,θ,Rain, Daily rain
Botticchio	150.10297	-34.71486	629	234686.9	6154755.4	1998 to 2013	Daily rainfall
Leese	150.10872	-34.72306	685	235239.9	6153861.1	2001 to 2013	Daily rainfall
Woods	150.12735	-34.72105	676	236940.3	6154133.2	2002 to 2013	Daily rainfall
Montgomery	150.05625	-34.75513	614	230538.3	6150163.1	1966 to 2013	Daily rainfall
Peppertree	150.03400	-34.75800	603	256527.3	6150569.8	2012 to 2014	T,RH,u,θ,Rain,Radiation
Boral Cement	150.01190	-34.76770	618	226518.9	6148648.8	2008 to 2014	T,RH,u,θ,σ_θ,Rain
Wingello	150.15803	-34.69355	683	239664.5	6157263.4	2011 to 2013	Daily rainfall

Where	**T**	**RH**	**u**	**θ**	**Rain**	**σ_θ**	**Radiation**	**Dew**
	Temperature	Relative Humidity	Wind Speed	Wind Direction	Rain	Wind direction Standard Deviation	Solar Radiation	Dew Point Temperature

Table 2: Rainfall statistics over all months for 2006-2013 at selected stations

Address	**Statistic Name**	**1095 Caoura Rd Black**	**593 Caoura Rd Darda**	**Kettles Lane Kettle**	**1183 Highland Way Woods**	**957 Highland Way Leese**	**432 Longpoint Rd Montgomery**	**66 Railway Parade Botticchio**	**467 Mulwaree Dr Clark**
Monthly	Mean	66.9	63.0	61.5	65.9	66.9	59.9	72.8	60.8
	Median	47.9	44.2	41.5	49.8	47.8	45.6	55.8	45.9
	Maximum	305.2	260.1	261.5	308.0	254.5	290.1	271.5	268.7
	Max Date	June 2007	June 2007	June 2007	June 2007	June 2007	June 2007	June 2007	June 2007
	Decile 1	20.0	22.6	19.0	17.5	22.3	18.0	23.0	20.6
	Decile 9	141.4	135.4	141.6	148.5	155.0	123.3	157.8	128.3
Annual	Mean	802.3	756.5	738.1	791.1	802.6	717.3	873.0	729.5
	Median	820.2	794.1	748.0	746.0	845.5	742.1	899.0	728.0
	Maximum	998.7	983.3	951.5	1097.0	1046.5	919.5	1064.3	943.3
	Max Year	2007	2007	2007	2007	2007	2007	2007	2007

Table 3: Total rainfall statistics over all months and years for all stations

Address	Statistic Name	1639 Caoura Rd Charles	1582 Caoura Rd Onslow	1095 Caoura Rd Black	593 Caoura Rd Darda	Kettles Lane Kettle	Tallong Village BOM	1183 Highland Way Woods	957 Highland Way Leese
Monthly	Mean	79.6	62.7	64.5	59.7	57.4	59.9	63.4	61.3
	Median	52.5	43.7	47.9	45.5	41.6	45.6	49.8	45.5
	Maximum	595.6	479.0	305.2	260.1	261.5	470.6	308.0	254.5
	Max Date	May 1943	March 1995	June 2013	June 2007	June 2007	May 1925	June 2007	June 2007
	Decile 1	10.9	8.5	14.07	15.8	14.0	9.6	16.5	17.0
	Decile 9	177.5	129.8	130.3	128.5	110.5	124.7	123.0	139.6
Annual	Mean	965.2	863.2	774.1	691.1	688.6	719.3	760.9	735.4
	Median	910.6	834.1	748.8	663.6	654.8	668.0	735.5	699.0
	Maximum	2028.2	1609.1	998.7	983.3	951.5	1187.6	1097.0	1046.5
	Max Year	1950	1978	2013	2007	2007	1900	2007	2007
Database		1919 to 1991	1991 to 2009	2004 to 2013	1999 to 2013	1992 to 2013	1895 to 1936	2002 to 2013	2001 to 2013

Table 3 continued: Total rainfall statistics over all months and years for all stations

Address	Statistic Name	432 Longpoint Rd Montgomery	66 Railway Parade Botticchio	100 Mulwaree Dr Eyers	467 Mulwaree Dr Clark	BOM_Caoura Rd	Boral_ South Marulan	Wingello
Monthly	Mean	62.2	64.7	63.9	60.8	77.6	58.1	77.4
	Median	47.1	51.0	49.5	45.9	52.0	44.8	62.5
	Maximum	403.6	271.5	263.0	268.7	567.4	228.5	320.0
	Max Date	March 1978	June 2013	June 2007	June 2007	February 1960	June 2013	February 2013
	Decile 1	13.4	15.1	16.0	20.6	9.0	19.6	20.5
	Decile 9	142.6	131.7	116.9	128.3	168.9	108.5	144.5
Annual	Mean	740.1	776.6	696.7	729.5	931.0	726.7	929.3
	Median	734.1	712.8	693.0	728.0	851.0	739.3	864.0
	Maximum	1372.1	1064.3	911.0	943.3	1734.9	917.0	1087.0
	Max Year	1974	2007	2007	2007	1950	2010	2013
Database		1966 to 2013	1998 to 2013	2003 to 2011	2006 to 2013	1919 to 1974	2008-2013	2011-2013

Table 4: Monthly rainfall statistics over all years for all stations

Month	**Observation**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
Station Name	**Duration**												
Statistic	**Mean**												
Charles	1919 to 1991	95.2	105.4	96.2	83.9	85.2	92.5	58.2	52.9	55.5	78.3	72.4	79.9
Onslow	1991 to 2009	76.8	107.7	81.7	32.4	42.6	79.2	36.6	48.9	59.2	54.0	74.6	61.0
Black	2004 to 2013	72.6	115.0	64.5	58.2	29.6	107.2	30.6	28.5	39.1	57.8	88.9	82.2
Darda	1999 to 2013	59.3	111.9	70.1	35.8	27.9	75.4	36.0	36.6	43.3	59.1	76.8	82.1
Kettle	1992 to 2013	61.1	104.5	61.1	40.0	37.2	69.7	39.0	37.4	38.8	53.4	73.7	72.6
Tallong Village - BOM	1895 to 1936	67.7	60.5	70.5	53.7	62.4	64.1	70.7	44.5	46.8	52.3	46.9	70.7
Eyers	2003 to 2011	58.9	107.3	50.7	30.0	41.3	73.1	34.0	31.0	41.1	60.2	85.9	83.1
Clark	2006 to 2013	59.4	132.5	66.4	39.1	35.7	103.4	34.6	30.5	37.5	43.6	68.9	78.0
Botticchio	1998 to 2013	64.1	130.5	79.4	43.6	32.3	79.6	44.6	36.3	43.7	67.1	79.8	81.8
Leese	2001 to 2013	59.9	125.0	77.5	37.2	33.5	72.2	37.6	31.1	40.5	62.4	79.3	79.3
Woods	2002 to 2013	70.3	146.4	69.6	37.5	36.9	84.5	36.0	34.7	42.8	48.3	82.5	71.5
Montgomery	1966 to 2013	74.4	84.6	72.0	59.0	54.1	64.1	40.0	51.0	46.2	60.4	73.3	60.5
South Marulan	2008 to 2013	66.6	132.3	72.3	45.4	38.3	72.8	26.1	32.7	38.6	55.2	58.5	88.0
Wingello	2011 to 2013	65.3	251.0	85.7	63.3	48.7	158.0	27.3	27.3	47.0	44.0	73.0	38.7
Statistic	**Median**												
Charles	1919 to 1991	86.7	80.8	68.6	65.3	45.5	48.0	34.0	31.5	40.6	54.9	56.4	61.5
Onslow	1991 to 2009	81.5	109.8	58.5	23.0	21.3	41.5	27.5	27.0	52.0	37.5	70.8	53.0
Black	2004 to 2013	77.4	108.2	50.8	40.4	21.9	73.6	29.2	21.8	42.9	58.2	58.2	77.3
Darda	1999 to 2013	56.8	99.7	55.0	32.9	22.5	45.8	27.8	33.6	39.6	45.8	65.8	63.0
Kettle	1992 to 2013	65.0	93.0	50.5	30.0	28.0	51.0	29.5	30.0	39.0	41.3	70.0	62.5
Tallong Village - BOM	1895 to 1936	50.6	38.8	47.8	49.6	34.1	48.7	43.3	28.9	39.5	40.1	46.4	70.3

Table 4 continued: Monthly rainfall statistics over all years for all stations

Station Name	**Duration**												
Statistic	**Median**												
Eyers	2003 to 2011	60.0	117.0	55.0	23.0	41.0	46.0	29.0	29.0	39.0	59.0	83.0	74.0
Clark	2006 to 2013	62.4	138.8	47.7	37.7	34.8	70.3	33.4	28.3	38.2	45.5	49.0	65.6
Botticchio	1998 to 2013	68.0	122.5	62.0	43.0	22.5	52.0	32.0	30.0	43.0	44.0	59.5	60.5
Leese	2001 to 2013	51.5	112.0	55.0	29.5	28.5	56.5	30.0	22.5	38.0	50.0	73.0	58.0
Woods	2002 to 2013	66.0	127.0	66.0	42.5	23.5	54.5	33.0	28.0	42.0	41.0	76.0	70.0
Montgomery	1966 to 2013	66.0	73.7	51.0	41.0	40.3	34.8	30.0	32.3	42.8	56.0	68.0	48.8
South Marulan	2008 to 2013	67.8	151.3	42.3	43.3	23.5	37.0	23.8	37.8	35.3	51.8	47.5	76.8
Wingello	2011 to 2013	64.0	304.0	70.0	63.0	47.0	84.0	25.0	13.0	53.0	26.0	75.0	37.0
Month	**Observation**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
Station Name	**Duration**												
Statistic	**Maximum/Year**												
Charles	1919 to 1991	258.1/1972	541.5/1956	499.4/1978	246.0/1974	595.6/1943	426.0/1922	472.4/1922	283.2/1938	284.7/1951	349.3/1959	412.5/1961	274.1/1920
Onslow	1991 to 2009	139.4/1992	262.0/2001	479.0/1995	105.0/1974	158.0/1995	426.0/1997	129.5/2001	365.5/1998	139.0/1995	142.0/1999	185.5/2007	136.4/1991
Black	2004 to 2013	111.3/2006	228.6/2013	198.8/2012	171.1/2004	78.0/2010	305.2/2013	54.0/2006	69.4/2011	79.5/2013	111.0/2004	185.8/2005	205.1/2010
Darda	1999 to 2013	109.0/2006	200.4/2013	223.3/2012	93.3/2009	89.7/2003	260.1/2007	89.5/1999	67.0/2001	75.8/2005	210.8/1999	181.2/2007	215.4/2010
Kettle	1992 to 2013	127.3/2006	203.0/2012	177.0/2012	100.1/1994	91.4/1992	261.5/2007	98.0/1999	164.0/1998	81.0/2005	192.0/1999	176.0/2007	241.0/2010
Tallong Village - BOM	1895 to 1936	339.3/1911	306.8/1898	342.4/1914	180.4/1927	470.6/1925	210.0/1925	306.8/1922	244.4/1899	124.7/1916	273.5/1916	142.4/1917	238.0/1920
Eyers	2003 to 2011	116.0/2006	163.0/2007	95.0/2003	102.0/2009	105.0/2003	263.0/2007	60.0/2006	62.0/2011	89.0/2005	123.0/2004	159.0/2007	182.0/2010
Clark	2006 to 2013	118.2/2006	211.4/2003	202.4/2012	89.2/2009	70.0/2010	268.7/2007	59.6/2006	58.5/2011	60.4/2013	83.9/2008	157.0/2007	194.7/2010
Botticchio	1998 to 2013	132.0/2006	228.0/2013	255.5/2012	128.5/2009	111.0/2003	271.5/2013	97.5/2005	83.5/2010	68.5/2005	238.5/1999	192.5/2007	217.0/2010
Leese	2001 to 2013	140.0/2006	214.5/2013	240.5/2012	118.0/2009	111.0/2003	254.5/2007	80.0/1999	69.0/2001	77.0/2005	219.5/1999	189.5/2007	191.0/2010
Woods	2002 to 2013	155.5/2006	274.0/2013	141.5/2012	75.5/2009	107.5/2003	308.0/2007	86.5/2001	76.0/2001	91.0/2004	119.5/2004	171.5/2007	162.0/2010
Montgomery	1966 to 2013	214.6/1976	225.6/1971	403.6/1978	262.1/1974	149.9/1974	290.1/2007	139.8/1991	245.1/1974	144.0/1967	189.5/1976	190.8/1969	210.3/2010
South Marulan	2008 to 2013	91.5/2013	188.0/2010	210.0/2012	78.0/2009	108.5/2010	228.5/2013	40.0/2011	49.5/2011	58.0/2013	99.5/2008	108.5/2010	205.5/2010
Wingello	2011 to 2013	87.0/2013	320.0/2013	160.0/2012	65.0/2013	84.0/2011	310.0/2013	39.0/2011	67.0/2011	65.0/2013	81.0/2011	84.0/2013	47.0/2011

Table 5: The frequency if occurrence of rainfall rates (mm/hr) in the Tallong region

Station	Date Start	End	Rainfall Rates (mm/hr) 0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	> 6.	Number of Observations
Peppertree Quarry	230212	170414	47.46	16.82	8.72	7.06	8.52	4.47	1.56	1.77	3.63	963
Boral South Marulan	010108	030414	52.12	15.93	9.30	6.06	5.99	3.84	1.95	1.36	3.44	3020
Mulwaree Drive	121211	130414	56.86	16.90	5.81	5.75	6.29	2.64	1.68	1.80	2.28	1669

Table 6: Statistics on the high rainfall rates (> 6 mm/hr)

	Rainfall rates (mm/hr)		
		Station	
Statistic	**Peppertree Quarry**	**Boral South Marulan**	**Mulwaree Drive**
Average	9.5	10.6	9.4
Median	8.0	9.3	7.2
Decile 1	7.0	6.5	6.6
Decile 9	13.8	16.5	12.6
Maximum	24.0	34.5	35.0

Table 7: Examples of simultaneous observations of high rainfall rates (mm/hr)

Station	Date	Daily 15 minute index	Rainfall rates (mm/hr)
Peppertree Quarry	231212	64	24.0
Boral South Marulan	231212	64	23.5
Mulwaree Drive	231212	64	7.2
Peppertree Quarry	240213	80	10.0
Boral South Marulan	240213		0.0
Mulwaree Drive	240213	80	35.0

Table 8: Specific days of high rainfall observations

Date - Year	2012			2013						
Month	**February**	**March**		**February**				**June**		
Day	**3**	**1**	**8**	**23**	**24**	**23 and 24**	**25**	**24**	**25**	**26**
Station										
Onslow										
Wingello	35.0	73.0	56.0	124.0		124.0	55.0	28.0	120.0	108.0
Black	28.8	62.4	48.0	28.0	96.0	124.0	28.2	26.4	142.0	74.0
Woods	36.0	14.0	56.0	22.0	107.0	129.0	45.0	37.0	100.0	78.0
Darda	26.0	7.3	*	17.1	97.0	114.1	31.8	32.0	110.0	41.0
Leese	28.0	71.0	46.0	23.5	88.5	112.0	33.5	16.0	108.0	68.0
Botticchio	33.0	73.0	64.0	20.0	93.0	113.0	42.0	29.0	104.0	69.0
Clark	28.3	66.8	44.5	16.0	70.0	86.0	43.5	20.2	94.0	69.0
Kettle	36.0	38.0	49.0	16.0	92.0	108.0	35.0	38.0	108.0	41.0
Montgomery	36.0	71.5	12.8	134.0		134.0	17.0	19.5	109.5	54.8
Peppertree	23.0*	64.5	39.0	10.5	94.0	104.5	12.0	15.5	98.0	41.0
Boral Cement	26.0	73.5	38.0	10.5	91.0	101.5	5.0	14.0	112.5	48.0

* next to station Boral Cement *= Not available

Table 8 continued: Specific days of high rainfall observations

Date - Year	2014							
Month	March	August						
Day	25	17	18	19	Total	26	27	Total
Station								
Onslow	52.0							
Wingello	90.0							
Black	36.0**	21.0	96.0	8.6	125.6	31.0	31.6	62.6
Woods	85.0	19.0	100.0	10.0	129.0	51.0	41.0	92.0
Darda	71.5	18.0	77.0	7.8	102.8	32.5	26.0	58.5
Leese	75.0	*	*	*		*	*	
Botticchio	74.0		110.0	14.0	124.0	29.0	56.0	85.0
Clark	62.0	13.8	86.3	10.1	110.2	24.0	48.7	72.7
Kettle	75.0		110.0	?	110.0	61.0		61.0**
Montgomery	76.5	53.5	48.0	5.5	107.0	52.0		52.0
Peppertree	66.5	12.5	76.5	5.0	94.0	20.5	27.0	47.5
Boral Cement	69.0	14.5	80.0	4.5	99.0	24.5	25.0	49.5

** nearby *= Not available

Table 9: Operating periods for the automatic weather stations in the Tallong region

Automatic weather station operating periods

Station	Start Date	End Date
Clark	12/12/2011	11/06/2014
Boral Cement	1/01/2008	11/06/2014
Peppertree Quarry	23/02/2012	11/06/2014

Table 10: Comparison of the Peppertree Quarry and Boral Cement meteorological data

		Differences between Peppertree Quarry and Boral Cement meteorological data						**Differences between Peppertree and Clark**		
		Dates <22-02-2012			**Dates > 22-02-2012**			**Dates 23-02-2012 to 11-06-2014**		
		Same Location			**Separate Locations**					
		Absolute Differences (Boral Cement - Peppertree)						**Absolute Differences (Peppertree-Clark)**		
		Average	S.D.	No. of Obs	Average	S.D.	No. of Obs	Average	S.D.	No. of Obs
Temperature	(°C)	0.16	0.17	27925	0.48	0.50	19454	0.97	0.81	76084
Speed	(m/s)	0.30	0.29	25755	3.13	3.47	19154	2.72	1.45	60227
Direction	(°)	8.88	11.11	25755	17.55	22.34	19154	34.13	32.62	60227
Direction S.D.	(°)	4.66	6.00	25755	8.63	7.42	19154			
Rain	(mm)	0.03	0.31	27925	0.04	0.24	20160	0.02	0.18	78906
		Actual Differences (Boral Cement - Peppertree)						**Actual Differences (Peppertree-Clark)**		
		Average	S.D.	No. of Obs	Average	S.D.	No. of Obs	Average	S.D.	No. of Obs
Temperature	(°C)	-0.09	0.21	27925	-0.19	0.67	19454	0.44	1.19	76084
Speed	(m/s)	-0.12	0.40	25755	2.30	4.07	19154	2.71	1.46	60227
Direction	(°)	-4.96	13.33	25755	1.18	28.39	19154	-1.12	47.20	60227
Direction S.D.	(°)	-3.04	6.96	25755	4.25	10.56	19154			78906
Rain	(mm)	0.01	0.31	27925	0.01	0.24	20160	0.00	0.18	78906
Total obs	27926				20183			**Total obs**		78906
No. of calms Boral Cement	2042				667			**No. of calms Peppertree**		4376
No. of calms Peppertree	466				461			**No. of calms Clark**		17822

Table 11: Atmospheric pressure variations at Tallong

Tallong at 1.2m   Dates : 121211 to 110614
Atmospheric Pressure (hPa)
Time (EST.)

Month	**0000-0300**	**0300-0600**	**0600-0900**	**0900-1200**	**1200-1500**	**1500-1800**	**1800-2100**	**2100-2400**	**Average**		**Extreme**	
									Minimum	**Maximum**	**Minimum**	**Maximum**
January	1012.7	1012.8	1013.8	1013.1	1011.6	1011.0	1012.8	1013.5	1009.4	1016.0	990.7	1025.2
	6.0	6.2	6.2	6.3	6.1	6.1	6.1	6.1	standard	deviations		
	1116	1116	1116	1116	1116	1116	1116	1116	number	of	observations	
February	1014.3	1014.2	1015.5	1015.3	1013.9	1013.3	1014.8	1015.4	1012.0	1017.2	996.1	1025.0
	5.7	5.5	5.6	5.9	5.5	5.8	5.7	5.6	standard	deviations		
	1020	1020	1020	1020	1020	1020	1020	1020	number	of	observations	
March	1017.4	1017.2	1018.4	1018.3	1016.6	1016.1	1017.6	1018.2	1014.8	1020.2	1001.2	1027.5
	4.9	4.7	4.8	4.9	5.0	4.7	4.7	4.7	standard	deviations		
	1116	1116	1116	1116	1116	1116	1116	1116	number	of	observations	
April	1019.2	1019.0	1020.2	1020.0	1018.2	1018.1	1019.5	1020.0	1016.9	1021.8	1003.7	1035.3
	5.4	5.5	5.5	5.5	5.4	5.5	5.3	5.3	standard	deviations		
	1080	1080	1080	1080	1080	1080	1080	1080	number	of	observations	
May	1018.5	1018.4	1019.0	1018.9	1017.4	1017.4	1018.5	1019.0	1016.3	1021.0	995.2	1036.8
	11.0	11.1	11.5	11.5	10.8	10.7	11.2	11.2	standard	deviations		
	1116	1116	1116	1116	1116	1116	1116	1116	number	of	observations	
June	1021.2	1020.9	1021.8	1021.9	1020.2	1020.4	1021.5	1021.7	1018.6	1024.0	998.3	1033.2
	7.0	6.9	7.1	7.2	7.0	6.8	6.8	6.8	standard	deviations		
	852	852	852	852	852	852	852	852	number	of	observations	
July	1023.7	1023.3	1024.4	1024.6	1022.8	1022.9	1024.1	1024.4	1021.4	1026.3	1005.0	1037.5
	6.9	7.1	7.2	7.1	7.1	6.8	6.7	6.7	standard	deviations		
	744	744	744	743	744	744	744	744	number	of	observations	
August	1017.1	1016.6	1017.6	1017.5	1015.9	1016.0	1017.4	1017.7	1014.0	1020.1	1003.0	1028.4
	5.4	5.6	5.6	5.6	5.1	5.1	4.9	5.1	standard	deviations		
	732	732	732	732	732	732	732	732	number	of	observations	
September	1016.5	1016.1	1017.0	1016.5	1014.9	1014.9	1016.6	1017.1	1013.1	1019.6	997.2	1034.3
	7.7	8.1	8.1	8.2	7.7	7.3	7.5	7.5	standard	deviations		
	720	720	720	720	720	720	720	720	number	of	observations	
October	1016.0	1015.8	1016.8	1016.4	1014.8	1014.5	1016.3	1016.9	1012.2	1020.0	996.9	1033.2
	6.5	6.8	7.0	6.9	6.3	6.2	6.3	6.3	standard	deviations		
	744	744	744	744	744	744	744	744	number	of	observations	
November	1014.6	1014.6	1015.5	1014.8	1013.4	1013.3	1015.0	1015.6	1011.7	1017.7	1000.9	1029.0
	5.2	5.1	5.3	5.4	5.2	5.2	5.3	5.3	standard	deviations		
	720	720	720	720	720	720	720	720	number	of	observations	
December	1013.4	1013.4	1014.4	1013.9	1012.5	1012.0	1013.7	1014.4	1010.3	1016.9	993.1	1029.3
	6.3	6.2	6.3	6.3	6.0	6.1	5.8	5.8	standard	deviations		
	984	984	984	984	984	984	984	984	number	of	observations	

Table 12: Dry Bulb Temperature variations at Tallong

Tallong Dates: 121211 to 110614
Dry Bulb Temperature at 1.2m (°C)
Time (EST)

Month	**0000-0300**	**0300-0600**	**0600-0900**	**0900-1200**	**1200-1500**	**1500-1800**	**1800-2100**	**2100-2400**	**Average**		**Extreme**	
									Minimum	Maximum	Minimum	Maximum
January	14.9	14.0	17.7	23.9	26.6	24.7	19.4	16.4	12.8	28.2	2.5	40.1
	3.1	3.4	4.3	5.9	6.4	6.4	4.8	3.6	standard	deviations		
	1116	1116	1116	1116	1116	1116	1116	1116	number	of	observations	
February	14.6	13.9	15.9	20.9	22.8	21.3	17.4	15.5	12.7	24.6	5.7	39.4
	2.7	2.8	3.3	4.6	5.7	5.5	3.7	2.8	standard	deviations		
	1020	1020	1020	1020	1020	1020	1020	1020	number	of	observations	
March	13.3	12.6	14.0	19.1	21.3	20.0	15.9	14.1	11.4	22.6	3.6	30.1
	2.8	2.9	3.1	3.6	4.1	4.1	2.8	2.5	standard	deviations		
	1116	1116	1116	1116	1116	1116	1116	1116	number	of	observations	
April	9.9	9.1	10.3	16.4	18.8	16.9	12.7	10.9	7.7	20.0	-0.2	28.0
	3.5	3.9	3.7	3.5	3.7	3.8	3.0	3.1	standard	deviations		
	1080	1080	1080	1080	1080	1080	1080	1080	number	of	observations	
May	5.5	4.8	5.8	12.9	15.7	13.3	8.5	6.8	3.2	16.5	-2.7	23.3
	3.3	3.5	3.6	3.6	3.4	3.6	2.7	3.0	standard	deviations		
	912	912	902	900	900	900	900	911	number	of	observations	
June	5.3	5.0	5.3	9.3	11.4	9.8	6.7	5.5	3.1	12.4	-4.3	16.5
	3.3	3.5	3.5	2.4	2.1	2.4	2.5	2.9	standard	deviations		
	852	852	852	852	852	852	852	852	number	of	observations	
July	3.7	3.3	3.8	9.1	12.0	9.9	5.9	4.6	1.4	12.9	-5.3	17.4
	3.1	3.5	3.7	2.7	2.2	2.9	2.6	2.9	standard	deviations		
	744	744	744	743	744	744	744	744	number	of	observations	
August	4.1	3.4	4.9	10.9	12.9	11.1	6.8	5.0	1.3	14.1	-4.5	20.3
	3.6	3.7	4.2	3.0	3.1	3.3	2.9	3.1	standard	deviations		
	732	732	732	732	732	732	732	732	number	of	observations	
September	7.0	6.0	8.6	15.5	17.9	16.1	11.1	8.7	4.4	19.2	-3.9	25.6
	4.1	4.3	4.7	3.9	4.1	4.3	3.6	3.8	standard	deviations		
	720	720	720	720	720	720	720	720	number	of	observations	
October	8.3	6.9	11.7	18.1	20.4	18.6	12.8	9.9	5.1	21.8	-2.6	32.1
	4.3	4.6	5.2	5.0	4.8	5.1	4.3	4.0	standard	deviations		
	744	744	744	744	744	744	743	744	number	of	observations	
November	10.9	9.9	14.5	20.0	22.1	19.8	14.9	12.4	8.8	23.5	1.2	36.0
	3.4	3.5	4.6	5.7	5.7	5.7	4.5	3.7	standard	deviations		
	720	720	720	720	720	720	720	720	number	of	observations	
December	13.0	12.3	16.3	21.5	23.9	22	17.1	14.3	10.9	25.5	1.6	38.2
	3.7	3.7	4.1	5.2	5.6	5.9	4.8	3.8	standard	deviations		
	972	972	972	972	981	984	984	984	number	of	observations	

Table 13: Minimum temperatures in the region during August, 2014

	Minimum Temperatures (°C)			
	Tallong	**Peppertree**	**Boral South Marulan**	**Goulburn**
Height	**1.2m**	**2m**	**1.2m**	**1.2m**
August				
2	-0.2	1.2	0.6	-0.2
3	-6.2	-3.9	-5.3	-7.0
4	-5.0	-3.5	-4.5	-7.3
5	-4.3	-0.8	-2.3	-4.9
6	-5.2	-2.6	-3.3	-6.5
7	-1.7	0.0	-0.6	-4.4
8	-3.8	-1.7	-3.2	-5.2
9	4.3	0.6	-0.7	-4.5
10	5.7	6.0	5.8	0.1
11	-4.1	-2.8	-3.1	-7.8
12	-5.2	-4.8	-5.3	-9.1
13	-1.6	0.1	-1.3	-5.8
14	-5.9	-3.6	-4.4	-8.0
15	-1.3	-0.1	-0.4	-3.3
16	-0.2	0.5	-0.2	-0.6

Table 14: Temperature difference (2-10m) data from Peppertree Quarry

Peppertree Quarry Dates :230212 to 110614
Dry Bulb Temperature Difference (°C)
Time (EST.)

Month	**0000-0300**	**0300-0600**	**0600-0900**	**0900-1200**	**1200-1500**	**1500-1800**	**1800-2100**	**2100-2400**	**Average**		**Extreme**	
									Minimum	**Maximum**	**Minimum**	**Maximum**
January	0.3	0.4	-0.1	-0.7	-0.8	-0.4	0.2	0.3	-1.1	0.9	-1.6	3.4
	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.4	standard deviations			
	720	693	730	742	744	744	744	738	number of observations			
February	0.3	0.3	0.0	-0.4	-0.4	-0.1	0.2	0.3	-0.7	0.8	-1.5	4.0
	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	standard deviations			
	692	652	692	756	756	755	740	726	number of observations			
March	0.4	0.4	0.1	-0.3	-0.3	0.0	0.4	0.4	-0.6	0.9	-1.5	2.8
	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	standard deviations			
	967	883	948	1095	1114	1104	1094	1017	number of observations			
April	0.6	0.6	0.3	-0.2	-0.3	0.2	0.6	0.6	-0.5	1.3	-1.3	3.9
	0.5	0.5	0.4	0.3	0.4	0.3	0.4	0.5	standard deviations			
	857	862	858	1064	1079	1075	1037	912	number of observations			
May	0.9	0.9	0.5	-0.1	-0.3	0.3	0.8	0.9	-0.5	1.8	-1.3	4.7
	0.6	0.6	0.5	0.3	0.3	0.4	0.6	0.6	standard deviations			
	707	687	740	887	893	879	842	784	number of observations			
June	0.6	0.5	0.4	0.0	-0.1	0.3	0.6	0.6	-0.4	1.3	-1.1	3.1
	0.5	0.4	0.4	0.3	0.3	0.3	0.5	0.6	standard deviations			
	576	561	640	704	703	685	636	605	number of observations			
July	0.8	0.7	0.5	-0.1	-0.2	0.3	0.7	0.7	-0.4	1.6	-1.0	3.2
	0.5	0.4	0.5	0.3	0.3	0.4	0.4	0.4	standard deviations			
	693	679	695	740	742	742	714	699	number of observations			
August	0.8	0.8	0.5	-0.3	-0.3	0.2	0.7	0.8	-0.6	1.7	-1.2	3.9
	0.5	0.6	0.5	0.3	0.3	0.3	0.5	0.6	standard deviations			
	709	703	705	732	732	732	723	722	number of observations			
September	0.8	0.8	0.3	-0.4	-0.4	0.1	0.6	0.8	-0.7	1.6	-1.4	3.1
	0.6	0.6	0.5	0.3	0.3	0.3	0.5	0.6	standard deviations			
	680	659	688	720	720	719	717	700	number of observations			
October	0.7	0.8	0.0	-0.5	-0.5	0.0	0.6	0.7	-0.8	1.6	-1.4	3.2
	0.5	0.5	0.4	0.3	0.3	0.3	0.5	0.6	standard deviations			
	723	719	731	744	744	743	736	722	number of observations			
November	0.5	0.5	-0.2	-0.7	-0.7	-0.2	0.3	0.4	-1.0	1.1	-2.0	2.8
	0.5	0.5	0.3	0.4	0.4	0.3	0.3	0.4	standard deviations			
	660	662	708	720	720	720	720	707	number of observations			
December	0.4	0.4	-0.2	-0.7	-0.8	-0.4	0.3	0.4	-1.1	1.1	-1.6	3.2
	0.4	0.4	0.4	0.3	0.4	0.4	0.3	0.5	standard deviations			
	717	683	738	744	744	744	742	738	number of observations			

Table 15: Temperature inversions (2-10m) vs wind directions at Peppertree Quarry

Peppertree Quarry Dates :230212 to 110614
Temperature Inversions (°C) (2-10m) vs.Wind directions

DIRECTION	0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	1.0-1.2	1.2-1.4	>1.4	TOTAL
N	0.83	1.2	0.79	0.48	0.2	0.2	0.05	0.11	3.87
NNE	0.83	0.97	0.31	0.15	0.03	0.03	0.01	0.01	2.36
NE	0.76	0.84	0.25	0.1	0.02	0.02	0.01	0.01	2.02
ENE	1.55	1.37	0.48	0.25	0.08	0.06	0.01	0.02	3.83
E	3.63	2.32	0.91	0.42	0.13	0.09	0.02	0.04	7.55
ESE	3.64	1.24	0.41	0.2	0.11	0.08	0.05	0.06	5.78
SE	2.81	1.15	0.48	0.23	0.07	0.06	0.04	0.03	4.88
SSE	2.1	0.99	0.35	0.11	0.07	0.03	0.01	0.03	3.69
S	0.92	0.54	0.26	0.1	0.06	0.06	0.02	0.05	2.01
SSW	0.63	0.56	0.39	0.1	0.04	0.03	0.04	0.05	1.84
SW	0.52	0.46	0.29	0.14	0.1	0.07	0.02	0.07	1.68
WSW	0.95	1.75	1.52	0.57	0.21	0.15	0.09	0.18	5.42
W	2.6	4.43	5.15	1.71	0.84	0.81	0.38	0.96	16.88
WNW	1.61	2.65	3.03	2.69	1.89	2.24	1.05	2.44	17.59
NW	1.23	1.66	1.75	2.08	1.6	1.87	1.08	2.08	13.35
NNW	0.99	1.5	1.2	1.45	0.72	0.67	0.27	0.47	7.27
TOTAL	25.62	23.64	17.54	10.79	6.19	6.47	3.15	6.61	44526

Number of calm periods = 4204

Table 16: Frequency of occurrence of Pasquill stability categories at Peppertree Quarry

Dates : 230212 to 110614
Frequency (%) of occurrence of
Pasquill stability categories

Stability Category	Night	Day
A	0.00	8.89
B	0.00	11.81
C	0.02	27.84
D	51.96	51.46
E	34.67	0.00
F	9.49	0.00
G	3.87	0.00

Night = Starts in the 15 minute period in which Sunset occurs
Day = Starts in the 15 minute period in which Sunrise occurs

Table 17: Frequency of occurrence of Pasquill stability categories vs. wind directions at Peppertree Quarry

Peppertree Quarry Dates :230212 to 110614
Pasquill stability categories vs. Wind directions

DIRECTION	A	B	C	D	E	F	G	TOTAL
N	0.24	0.22	0.54	2.35	0.58	0.11	0.07	4.12
NNE	0.28	0.29	0.60	1.13	0.38	0.09	0.03	2.80
NE	0.29	0.29	0.42	0.74	0.35	0.12	0.02	2.23
ENE	0.35	0.37	0.77	1.98	0.57	0.17	0.06	4.29
E	0.46	1.01	2.33	5.32	0.97	0.33	0.06	10.49
ESE	0.47	1.05	1.89	3.97	0.82	0.34	0.07	8.61
SE	0.34	0.38	1.25	2.48	0.60	0.20	0.10	5.35
SSE	0.34	0.44	1.02	1.32	0.60	0.18	0.07	3.98
S	0.28	0.35	0.34	0.41	0.29	0.26	0.05	1.99
SSW	0.25	0.20	0.27	0.40	0.33	0.18	0.06	1.68
SW	0.19	0.21	0.31	0.48	0.25	0.18	0.04	1.67
WSW	0.20	0.36	1.24	3.39	0.55	0.14	0.07	5.97
W	0.20	0.29	1.77	12.34	1.69	0.40	0.29	16.98
WNW	0.20	0.20	0.65	7.60	3.64	1.19	0.57	14.05
NW	0.19	0.16	0.38	4.81	3.52	0.51	0.21	9.79
NNW	0.26	0.18	0.40	2.97	1.84	0.25	0.11	6.01
TOTAL	4.53	6.02	14.19	51.70	17.01	4.65	1.90	76131

No. of calm periods = 4464

Table 18: Solar radiation at Peppertree Quarry, South Marulan

Peppertree Quarry 230212 to 110614 Solar radiaton (W/m2) Time EST**															
Month	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
January	0.029	0.140	0.298	0.459	0.645	0.748	0.808	0.799	0.764	0.634	0.505	0.350	0.180	0.046	0.001
February	0.002	0.067	0.187	0.339	0.487	0.580	0.642	0.656	0.613	0.520	0.392	0.248	0.118	0.024	0
March	0	0.035	0.146	0.302	0.444	0.552	0.599	0.593	0.559	0.476	0.364	0.212	0.072	0.003	0
April	0	0.010	0.110	0.242	0.384	0.514	0.558	0.545	0.477	0.374	0.249	0.111	0.017	0	0
May	0	0	0.068	0.214	0.343	0.437	0.492	0.464	0.420	0.329	0.192	0.058	0	0	0
June	0	0	0.021	0.116	0.222	0.299	0.345	0.337	0.312	0.236	0.135	0.035	0	0	0
July	0	0	0.031	0.163	0.291	0.387	0.434	0.441	0.381	0.292	0.178	0.060	0	0	0
August	0	0.003	0.100	0.250	0.392	0.501	0.531	0.534	0.474	0.395	0.262	0.115	0.012	0	0
September	0	0.055	0.208	0.359	0.491	0.590	0.643	0.642	0.592	0.471	0.321	0.171	0.039	0	0
October	0.026	0.174	0.354	0.527	0.663	0.767	0.795	0.756	0.686	0.571	0.405	0.231	0.077	0.002	0
November	0.060	0.183	0.339	0.473	0.573	0.695	0.722	0.700	0.623	0.475	0.370	0.244	0.101	0.015	0
December	0.055	0.178	0.331	0.507	0.637	0.705	0.754	0.770	0.736	0.606	0.486	0.305	0.155	0.035	0