APPENDIX B16:C

APPENDIX B16:C – TAPM Validation

A1 Graphical evaluation of model performance

The Bureau of Meteorology (BOM) operates a meteorological monitoring station at the SCA, There are two other BOM monitoring stations in the study area. There is a monitoring station located inland at Nambour, approximately 15 km southwest of the SCA. There is also a monitoring station located about 3 km from the coast at Tewantin, approximately 24 km from the SCA. The evaluation of model performance was carried out at each station, with emphasis being on the SCA station.

The annual, seasonal and daily wind speeds and wind directions recorded at this site from 1995 to 2010 are presented as wind roses in Figure A1 to Figure A3, respectively. The winds are characterised by an average wind speed of 4.6 m/s and maximum wind speeds of 19.0 m/s. The strongest winds tend to be from the northwest and southeast quadrants throughout the year.

The seasonal distribution of winds indicates that winds the strongest winds are from the southeast and tend to occur in summer and autumn. In winter there is a strong predominance of winds from the northwest. In spring the airport experiences winds from all directions, with a slight preference for northerly or southeast winds.

The observed winds are predominantly southerly between 6am and midday, with south-easterlies and north/north-easterlies increasing between midday and 6pm. After midday light winds begin to blow from the south-westerly quadrant and become more frequent between midnight and 6am. This diurnal change in wind directions is characteristic of the coastal location of the airport.

A2 Statistical measures of model performance

A2.1 Root mean square error (RMSE)

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

The RMSE can be described as the standard deviation of the difference for hourly predicted and observed pairings at a specific point. The RMSE is a quadratic scoring rule which measures the average magnitude of the error. The difference between predicted and corresponding observed values are each squared and then averaged over the sample. Finally, the square root of the average is taken. Since the errors are squared before they are averaged, the RMSE gives a relatively high weight to large errors. This means the RMSE is most useful when large errors are particularly undesirable. Overall, the RMSE is a good overall measure of model performance, but since large errors are weighted heavily (due to squaring), its value can be distorted. RMSE is equal to the unit of the values being analysed i.e. an RMSE of 1.2 for wind speed equal to 1.2 m/s.

A2.2 Systematic root mean square error ($\mathrm{RMSE_s}$)

$$\mathrm{RMSE_S} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{P}_i - O_i)^2}$$

The $\mathrm{RMSE_s}$ is calculated as the square root of the mean square difference of hourly predictions from the regression formula and observation pairings, at a specific point. The regressed predictions are taken from the least squares formula. The $\mathrm{RMSE_s}$ estimates the model's linear (or systematic) error. The systematic error is a measure of the bias in the model due to user input or model deficiency, i.e. data input errors, assimilation variables, choice of model options, etc.

A2.3 Unsystematic Root Mean Square Error ($RMSE_u$)

$$\mathrm{RMSE}_U = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{P}_i - P_i)^2}$$

The $RMSE_u$ is calculated as the square root of the mean square difference of hourly predictions from the regression formula and model prediction value pairings, at a specific point. The $RMSE_u$ is a measure of how much of the difference between predictions and observations resulting from random processes or influences outside the legitimate range of the model. This error may require model refinement, such as new algorithms or higher resolution grids, or that the phenomena being simulated cannot be fully resolved by the model.

Ultimately for 'good' model performance, the RMSE should be a low value, with most of the variation explained in the observations. Here, the systematic error $RMSE_s$ should approach zero and the unsystematic error, $RMSE_{u,}$ should approach the RMSE since:

$$\mathrm{RMSE}^2 = \mathrm{RMSE}_S^2 + \mathrm{RMSE}_u^2$$

A2.4 Mean error (ME) and Mean absolute error (MAE)

The ME is simply the average of the hourly modelled values minus the hourly observed values. It contains both systematic and unsystematic errors and is heavily influence by high and low errors.)

The MAE measures the average magnitude of the errors in a set of predictions, without considering their direction. It measures accuracy for continuous variables. Expressed in words, the MAE is the average over the verification sample of the absolute values of the differences between predictions and the corresponding observation. The MAE is a linear score which means that all the individual differences are weighted equally in the average. The MAE and the RMSE can be used together to diagnose the variation in the errors in a set of predictions. The RMSE will always be larger or equal to the MAE; the greater difference between them, the greater the variance in the individual errors in the sample. If the RMSE=MAE, then all the errors are of the same magnitude Both the MAE and RMSE can range from 0 to ∞. They are negatively-oriented scores, therefore lower values are better.

Skill measure statistics are given in terms of a score, rather than in absolute terms.

A2.5 Index of agreement

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

The IOA is calculated using a method described in Willmott (1982). The IOA can take a value between 0 and 1, with 1 indicating perfect agreement. The IOA is the ratio of the total RMSE to the sum of two differences: the difference between each prediction and the observed mean, and the difference between each observation and observed mean. From another perspective, the IOA is a measure of the match between the departure of each prediction from the observed mean and the departure of each observation from the observed mean.

(Note: N is the number of observations, P_i are the hourly model predictions, O_i are the hourly observations, O_{mean} is the observed observation mean, and $\hat{P}_i = a + bO_i$ is the linear regression fitted with intercepts *a* and slope *b*.)

A model's skill can be measured by the difference in the standard deviation of the modelled and observed values.

SE is indicative of how much of the standard deviation in the observations is predicted to be due to random/natural processes (unsystematic) in the atmospheric boundary layer. (i.e. turbulence).

SV shows how closely the modelled standard deviation matches the observed standard deviation.

SR takes into account systematic and unsystematic errors in relation to the observed standard deviation.

Skill is determined by the following benchmarks:

- SKILL_E (se) = (RMSE_U/StdvOBS) < 1 shows skill
- SKILL_V (sv) = (Stdv_MOD/Stdv_OBS) close to 1 shows skill
- SKILL_R (sr) = (RMSE/Stdv_OBS) < 1 shows skill

A3 Statistical evaluation of model performance

Table A1 and Table A2 shows that on average, the model is able to adequately predict the meteorological conditions at the SCA and the Tewantin monitoring site. However, the model shows a more limited range of predicted values, as indicated by the lower standard deviation for the meteorological variables other than wind vector components, as well as frequently being unable to simulate the lowest and highest values for the meteorological variables.

The probability distribution functions for wind speed, wind direction, temperature, relative humidity as well as the north-south and east-west wind decomposition, are plotted in Figure A4. The plots compare TAPM predictions with the SCA monitoring data for 2009. The results show that TAPM overestimates the occurrence of light winds and fails to capture the high wind speeds—this is typical of TAPM. TAPM overestimates the occurrence of south-westerly winds in 2009; while underestimating west and north-westerly wind frequency.

Table A3 shows that the wind direction at the Nambour monitoring station is not representative of the observed data. On average the east-west wind component is modelled in the opposite direction to the measured data (0.21 m/s east predicted by the model, and 0.5 m/s west observed). Similarly the north-south component of the wind is predicted to be in the opposite direction to the observed data (0.38 m/s north predicted by the model, and 0.1 m/s south observed). The average wind speed at Nambour is low (1.84 m/s), and the component averages are very small. As the wind speeds are small at Nambour and our sensitive receptors are located close to the airport (where the model performs adequately), we conclude that the poor performance of TAPM at simulating wind speeds at Nambour will not have a large affect on the performance of the dispersion modelling.

Table A1 Evaluation of observed and modelled data at the Airport monitoring station

Data	Parameter	Average	Standard deviation	Minimum	Maximum
Observed	Wind speed (m/s)	4.54	2.2	0	12.9
Modelled		3.79	1.7	0	9.8
Observed	Temperature (°C)	20.6	5.3	1.8	34.8
Modelled		21.5	3.4	9.6	30.9
Observed	Relative Humidity (%)	74.5	15.9	13.0	97.0
Modelled		77.7	13.3	16.1	99.7
Observed	U vector (m/s)	-0.92	3.2	-11.3	9.3
Modelled		-1.10	2.6	-7.7	7.8
Observed	V vector (m/s)	0.39	3.8	-11.9	11.6
Modelled		0.72	3.0	-8.3	8.1

Table A2 Evaluation of observed and modelled data at the Tewantin monitoring station

Data	Parameter	Average	Standard deviation	Minimum	Maximum
Observed	Wind speed (m/s)	2.85	1.95	0	10.83
Modelled		2.44	1.04	0	6.60
Observed	Temperature (°C)	20.92	4.75	4.40	34.90
Modelled		21.34	3.59	9.40	31.90
Observed	Relative Humidity (%)	74.40	14.63	13.0	97.0
Modelled		79.36	14.02	18.10	100.0
Observed	U vector (m/s)	-0.79	1.96	-7.45	4.70
Modelled		-0.51	1.61	-4.35	5.16
Observed	V vector (m/s)	0.37	2.71	-9.72	8.33
Modelled		0.60	1.96	-5.16	6.24

Table A3 Evaluation of observed and modelled data at the Nambour monitoring station

Data	Parameter	Average	Standard deviation	Minimum	Maximum
Observed	Wind speed (m/s)	1.84	1.67	0	8.61
Modelled		2.21	0.99	0	7.20
Observed	Temperature (°C)	20.40	5.17	3.1	38.7
Modelled		21.03	4.20	7.9	36.2
Observed	Relative Humidity (%)	73.14	19.10	11.0	100.0
Modelled		74.51	17.88	15.0	100.0
Observed	U vector (m/s)	-0.50	1.52	-7.11	7.46
Modelled		0.21	1.48	-4.39	6.09
Observed	V vector (m/s)	-0.10	1.52	-7.31	4.44
Modelled		0.38	1.86	-5.34	5.12

Table A4 to Table A5 present statistical measures of model performance at the SCA, Nambour and Tewantin.

The statistical measures show that TAPM does an adequate job of simulating the meteorological conditions at the SCA monitoring site. The wind directions predicted by TAPM at the Nambour monitoring site are not a good representation of the winds observed. The fact that Nambour is a considerable distance from the SCA, and experiences light winds, means that inaccuracies in the modelled wind direction at Nambour will have little effect on the dispersion results.

Considering the difficulties in comparing modelled and observed data, these results show that TAPM is able to simulate meteorological conditions within the study area adequately. It is therefore a suitable model to use to drive the meteorological component required for the assessment of air quality impacts from development of the SCA.

Table A4 Evaluation of model performance for annual data at the Airport

Statistical measure	Wind speed (m/s)	Temperature (°C)	Relative humidity (%)	U vector (m/s)	V vector (m/s)
intercept	1.42	9.82	39.69	-0.58	0.47
slope	0.52	0.57	0.51	0.56	0.65
rmse	1.82	2.90	13.47	2.36	2.16
rmse_s	1.30	2.48	8.40	1.45	1.34
rmse_u	1.27	1.49	10.53	1.86	1.69
ioa	0.78	0.89	0.77	0.83	0.89
se	0.57	0.28	0.66	0.58	0.45
sv	0.77	0.64	0.84	0.80	0.79
sr	0.82	0.55	0.85	0.73	0.58
MAE	1.42	2.17	10.90	1.73	1.65
ME	-0.75	0.97	3.17	-0.18	0.33

Table A5 Evaluation of model performance for annual data at Nambour

Statistical measure	Wind speed (m/s)	Temperature (°C)	Relative humidity (%)	U vector (m/s)	V vector (m/s)
intercept	1.57	5.85	23.07	0.46	0.47
slope	0.34	0.74	0.70	0.49	0.89
rmse	1.41	2.23	13.16	1.66	1.38
rmse_s	1.16	1.47	5.83	1.21	0.51
rmse_u	0.80	1.68	11.80	1.14	1.28
ioa	0.70	0.94	0.86	0.74	0.82
se	0.48	0.32	0.62	0.60	0.84
sv	0.59	0.81	0.94	0.77	1.23
sr	0.84	0.43	0.69	0.87	0.91
MAE	1.17	1.73	10.16	1.30	1.10
ME	0.36	0.63	1.37	0.71	0.49

Table A6 Evaluation of model performance for annual data at Tewantin

Statistical measure	Wind speed (m/s)	Temperature (°C)	Relative humidity (%)	U vector (m/s)	V vector (m/s)
intercept	1.51	6.63	28.67	-0.10	0.39
slope	0.33	0.70	0.68	0.52	0.57
rmse	1.60	1.98	11.98	1.58	1.67
rmse_s	1.38	1.47	6.81	0.98	1.18
rmse_u	0.81	1.33	9.86	1.24	1.19
ioa	0.69	0.94	0.82	0.78	0.86
se	0.42	0.28	0.67	0.63	0.44
sv	0.53	0.76	0.96	0.82	0.72
sr	0.82	0.42	0.82	0.80	0.62
MAE	1.27	1.54	9.53	1.25	1.30
ME	-0.41	0.42	4.97	0.28	0.23

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Statistical measure	Wind speed (m/s)	Temperature (°C)	Relative humidity (%)	U vector (m/s)	V vector (m/s)

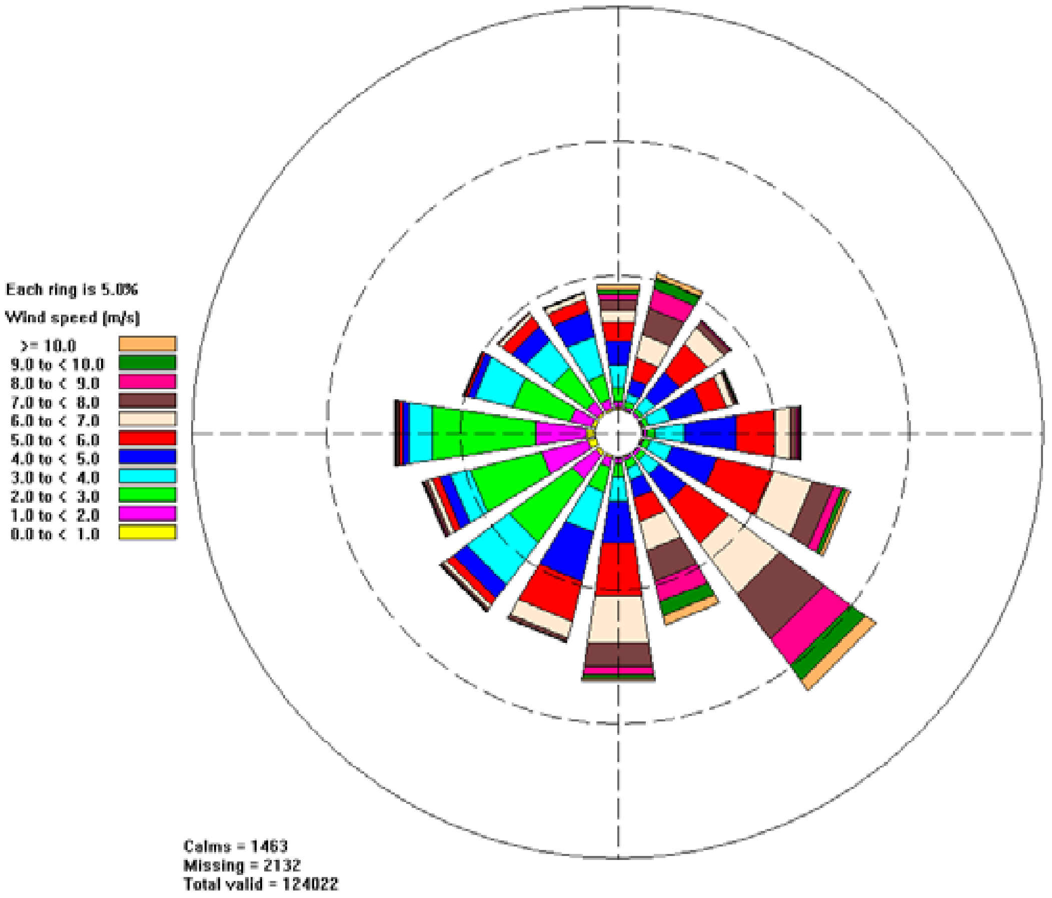

Figure A1 Annual windrose at Sunshine Coast Airport 1995-2010

Location: Sunshine Coast Airport	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose	**Period:** 1995-2010	**Prepared by:** Michael Burchill	**Date:** September 2012

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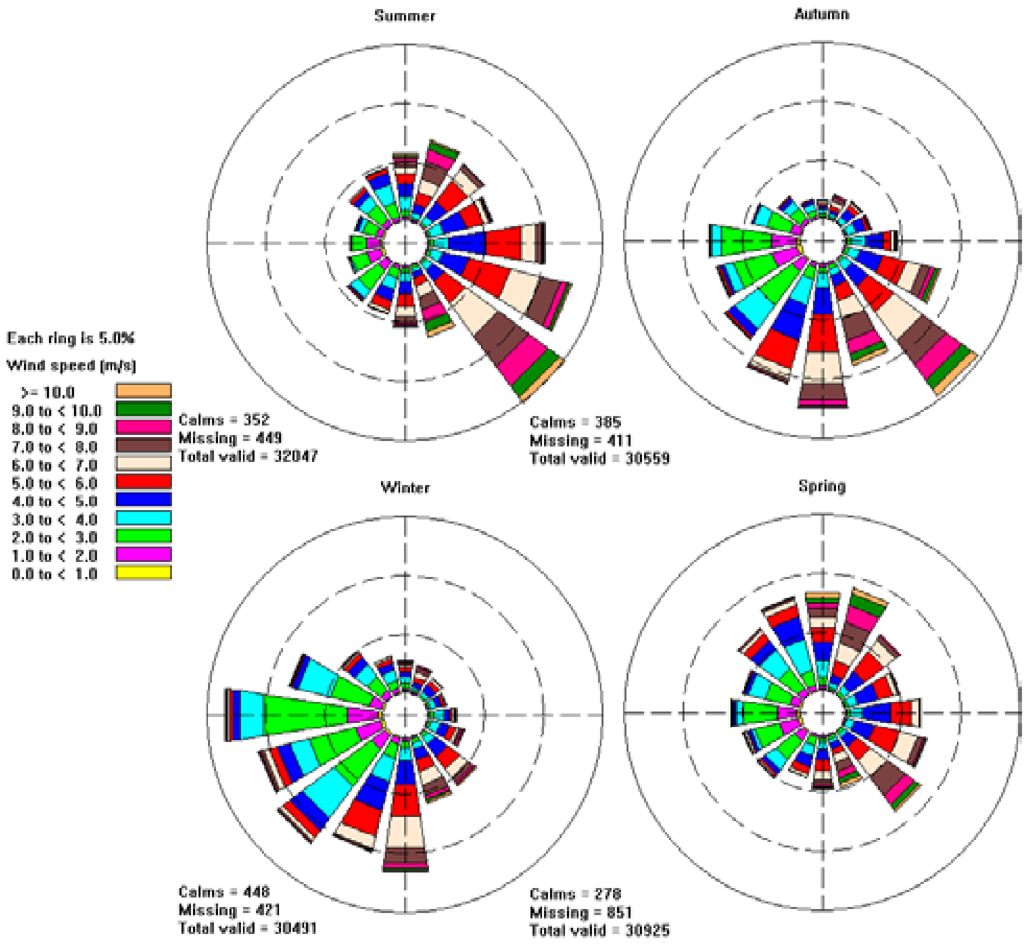

Figure A2 **Seasonal windrose at Sunshine Coast Airport 1995-2010**			
Location: Sunshine Coast Airport	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose	**Period:** 1995-2010	**Prepared by:** Michael Burchill	**Date:** September 2012

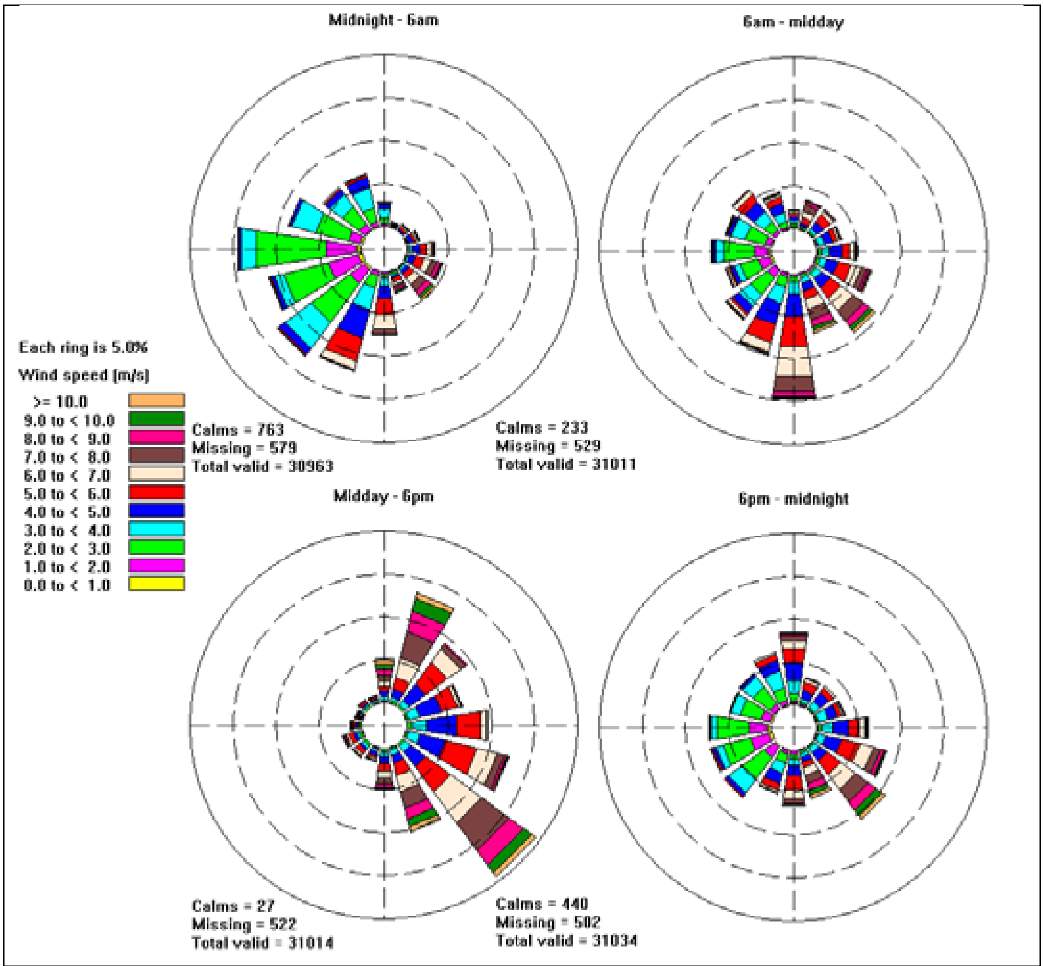

Figure A3 Diurnal windrose at Sunshine Coast Airport 1995-2010

Location: Sunshine Coast Airport	**Averaging period:** 1-hour	**Data source:** TAPM	**Units:** m/s and °
Type: Wind rose	**Period:** 1995-2010	**Prepared by:** Michael Burchill	**Date:** September 2012

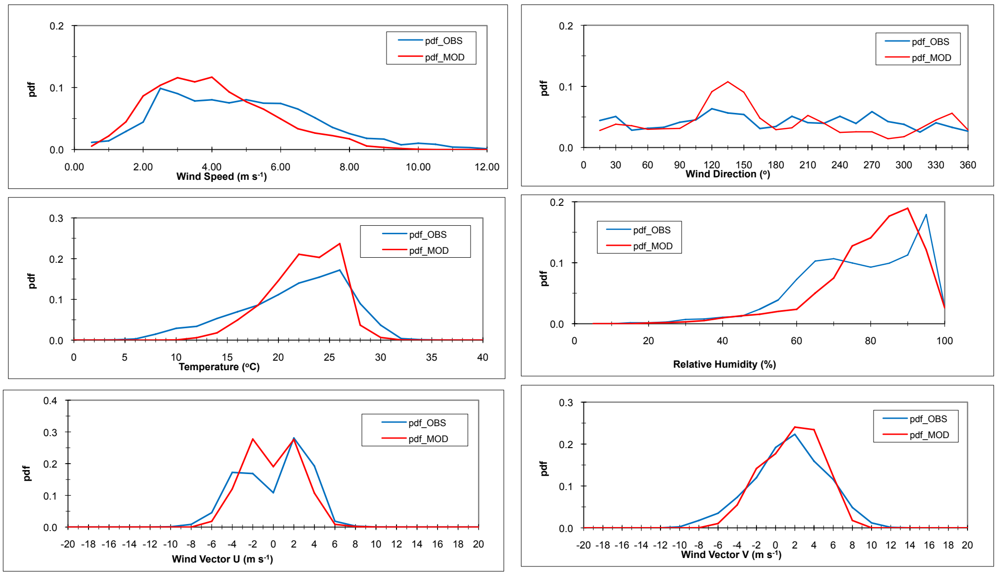

Figure A4	**Probability distribution function plots of Sunshine Coast Airport**		
Location: Sunshine Coast Airport	**Averaging period:** 1-hour	**Data source:** BOM met station and TAPM	**Units:** m/s and °
Type: Pdf plots	**Period:** 1999	**Prepared by:** Michael Burchill	**Date:** January 2013