

Appendix M

Development of Air Dispersion

Modelling Meteorological Data

Sets for Cape Preston

DEVELOPMENT OF AIR DISPERSION MODELLING METEOROLOGICAL DATA SETS FOR CAPE PRESTON

**Prepared for
Air Assessments
by
Environmental Alliances Pty Ltd**

April 2008



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2. Results of preliminary comparison between TAPM and measured winds

1. INTRODUCTION

This document describes the procedure for developing a meteorological data set for use in modelling emissions for the Balmoral South Project, Cape Preston.

2. MEASURED DATA

The data from the Cape Preston Main and Island sites were supplied by Maunsell as either 5 or 10 minute averages. The station locations are shown in Table 1.

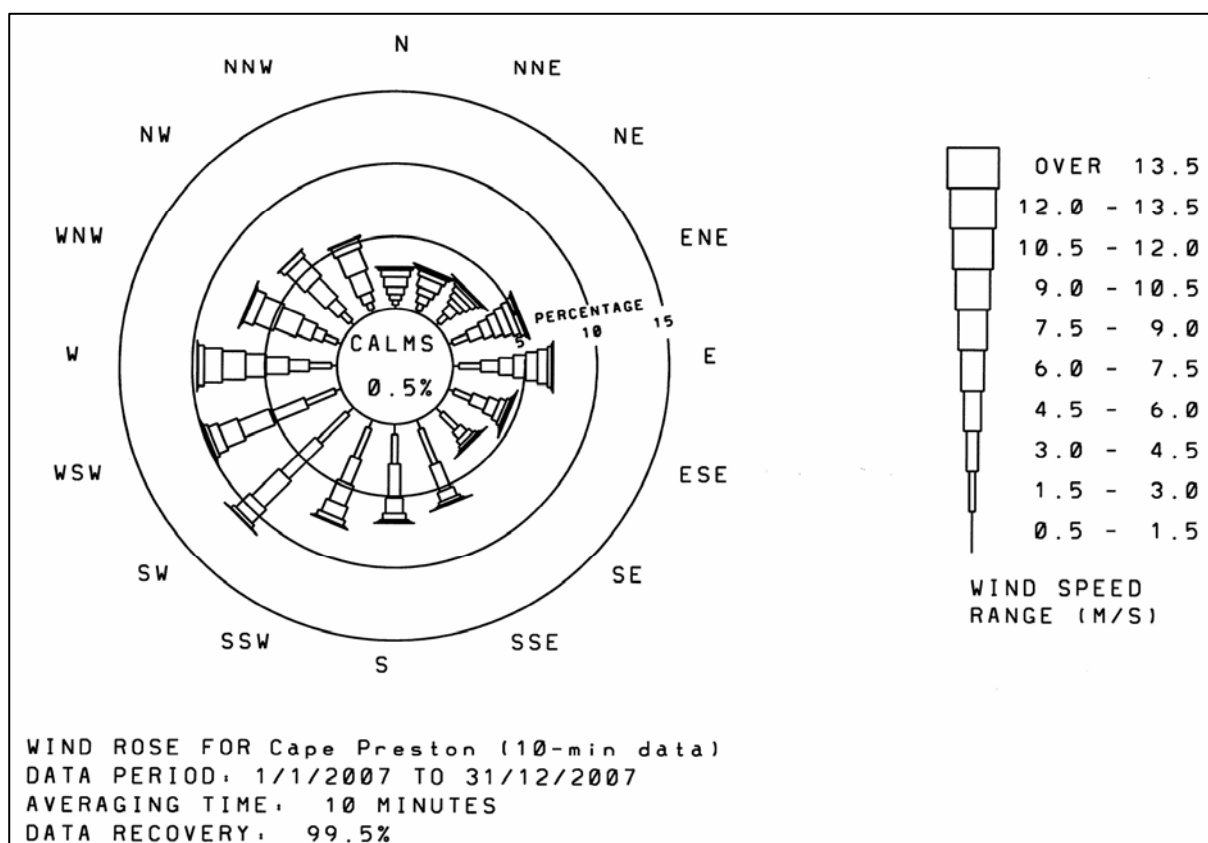
Table 1 Meteorological monitoring station locations

Station	E/N	Lat/Long (deg,min,sec)	Lat/Long (deg,min)	Lat/Long (deg)	GDA94 (m)
Main Station	Easting	116° 8'59.82"E	116° 8.9970'E	116.149950° E	411,688
	Northing	21° 3'35.27"S	21° 3.5878'S	21.059797° S	7,670,999
Preston Island Station	Easting	116°11'38.27"E	116°11.6378'	116.1940°	416,130
	Northing	20°49'28.57"S	20°49.4762'S	20.8246°	7,697,054

The measured data were consolidated into 10-minute averages, then 1-hour averages for modelling use. Scalar averaging was used for all parameters except for wind direction, where vector averaging was used.

The most recent 12 month period was 1/1/2007 to 31/12/2007. This was used for the modelling input files. The data recovery over this period was 99.5 %.

A wind rose and matrix of this period for the Main Station site is shown in Figure 3. This indicates that 30.6 % of all winds are from the SW to W with the remainder of wind directions reasonably evenly spread (2.9 to 7.7 % per 32 point compass arc). The percentage of calms (wind speeds < 0.5 m/s) is low compared to other Western Australian sites at 0.5% and average wind speeds fairly high at 4.8 m/s. A contributing factor to this is likely to be the low surface roughness and mild elevation of the measurement site as illustrated in Figure 2.



*** WIND SPEED - WIND DIRECTION PERCENTAGE OCCURRENCE MATRIX ***

WIND SPEED RANGE (M/S)	WIND DIRECTION SECTOR																TOTALS
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
OVER 13.5																	0.1
12.0 - 13.5				0.2	0.1												0.4
10.5 - 12.0		0.1	0.1	0.3	0.3	0.1						0.1	0.4	0.1			1.5
9.0 - 10.5	0.2	0.2	0.2	0.5	0.7	0.1			0.1	0.1		0.3	1.3	0.7		0.1	4.5
7.5 - 9.0	0.5	0.4	0.4	0.6	0.8	0.2	0.1	0.1	0.1	0.4	0.3	0.7	1.6	1.4	0.4	0.7	8.7
6.0 - 7.5	0.7	0.7	0.4	0.7	0.9	0.4	0.2	0.2	0.4	0.9	1.4	1.4	1.4	1.6	1.8	1.6	14.8
4.5 - 6.0	0.5	0.5	0.4	0.7	1.0	0.8	0.4	0.7	1.1	1.5	2.6	2.3	1.6	1.1	1.8	1.5	18.4
3.0 - 4.5	0.4	0.6	0.7	1.0	1.2	1.1	0.6	1.9	2.3	1.9	3.3	2.6	1.4	0.8	1.1	0.7	21.6
1.5 - 3.0	0.4	0.5	0.7	1.1	1.5	1.3	1.5	2.6	2.1	2.3	2.8	2.2	1.5	0.9	0.8	0.5	22.6
0.5 - 1.5	0.2	0.2	0.3	0.3	0.4	0.4	0.6	0.7	0.7	0.6	0.6	0.4	0.4	0.3	0.3	0.2	6.7
TOTALS	2.9	3.1	3.3	5.4	6.9	4.5	3.5	6.3	6.9	7.7	11.0	9.9	9.7	7.0	6.3	5.3	

CALMS (LESS THAN 0.5 M/S): 0.5%
 DATA RECOVERY: 99.5%
 AVERAGING TIME: 10 MINUTES

*** SUMMARY STATISTICS ***

	MEAN (M/S)	STD. DEV. (M/S)	MAX. (M/S)
SCALAR WIND SPEED	4.8	2.5	19.2
NORTHERLY COMPONENT	-0.2	3.3	-12.0
EASTERLY COMPONENT	-1.0	4.2	15.7

Figure 1 Wind speed and direction frequency occurrence rose and matrix for Cape Preston main anemometer



Figure 2 Views of Cape Preston main anemometer site surrounds

3. DEVELOPMENT OF METEOROLOGICAL DATA SET FOR MODELLING

3.1 OUTLINE

The process for developing the meteorological data was:

1. Run TAPM with nudging from the Main station¹. Export from TAPM the CALMET land use and terrain file, surface file and upper file. (It should be noted that the TAPM 3-D wind field which, when produced from nudging, is likely to produce unrealistically wind transitions between the nudged location at the horizontal and vertical extents of the nudged/assimilated data, is not used for modelling, as further described below).
2. Estimate correction factor to apply to TAPM wind speeds.
3. Create a continuous record of wind speed and direction at the Main site over the modelling year from the measured data but substituting with corrected TAPM data where data gaps.
4. Estimate cloud cover over the modelling year taking the maximum of BoM cloud data from the Port Hedland and Learmonth Airports - Cape Preston is approximately 260 kms WSW of Port Hedland and 250 km NE of Learmonth.. (Taking the maximums may potentially over-estimate cloud cover, however this was to compensate for occasional missing data in cloud cover records which would contribute to under-estimating cloud cover).
5. Estimate monthly sea surface temperatures over the modelling year from DOLA satellite maps.
6. Use the above input data to enable CALMET to create a three dimensional file of meteorological parameters over the domain for the modelling year over a domain from the coast to the Balmoral South Project site .

Details on each of these steps is provided in the following sections.

3.2 TAPM

TAPM was run with the following parameters:

- Soil moisture set to a drier value of 0.1 g/g (from defaults of 0.15 g/g) as discussed for CSIRO modelling of dispersion at the Burrup Peninsula area (see Physick and Blockley 2001).
- Grid nests at 31x31 at 25000m, 10000m, 3000m & 1000m, and 20 vertical levels output to 18 levels (6000m).
- Where wind nudging, 5 km radius and 3 vertical levels (ie 100 m).
- Where soil type was coarse sand, this was changed to sandy clay loam which is more typical of the region.

¹ A preliminary analysis of the comparison between TAPM-predicted winds and measured is described in Appendix 2. The results from this comparisons was used to determine the process for developing the meteorological data set which was subsequently followed.

3.3 ADJUSTMENT OF TAPM WIND SPEED DATA

Since the measured wind data set was incomplete due to occasional missing data, data from TAPM had to be substituted for these. For wind speeds, the results of the data comparisons are shown in Figure 3, viz:

- in pink, the correlation between the measured data and TAPM data (even with measured data assimilated) – this indicates a reasonable correlation at low wind speeds but a considerable under-estimation of the higher wind speeds by TAPM;
- in blue, a Q-Q plot of the measured data and TAPM data (excluding pairs where the measured data was missing) – this indicates that the TAPM wind speeds began to be under-estimated after 3 m/s; and
- in yellow, a Q-Q plot of the measured data the TAPM data corrected using Equation 1 to bring wind speeds > 3 m/s into alignment with the measured wind speeds:

$$WS_{TAPMadj} = WS_{TAPM} + 0.69 (WS_{TAPM} - 3.0) \quad \text{for } WS_{TAPM} > 3.0 \text{ m/s} \quad \text{Equation 1}$$

where-

$WS_{TAPMadj}$ = adjusted TAPM wind speeds used to substitute for missing data in measured wind speeds (m/s); and

WS_{TAPM} = original TAPM wind speeds.

3.4 TAPM WIND DIRECTION DATA

A comparison of the measured wind directions with those from TAPM is shown in Figure 4. The TAPM winds are a little biased anti-clockwise for measured winds between about 180° and 360°, however the general correlation is good and no corrections were applied to the TAPM data where required to be substituted.

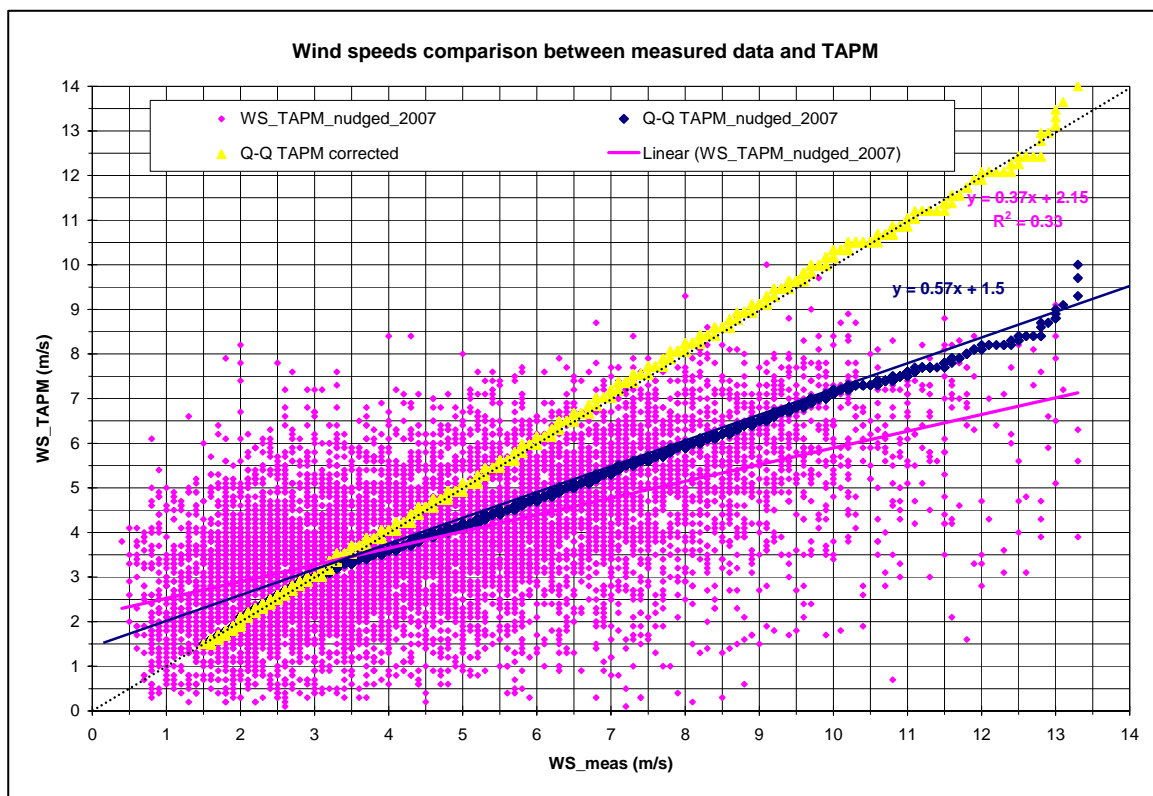


Figure 3 Wind speeds comparison between measured data and TAPM

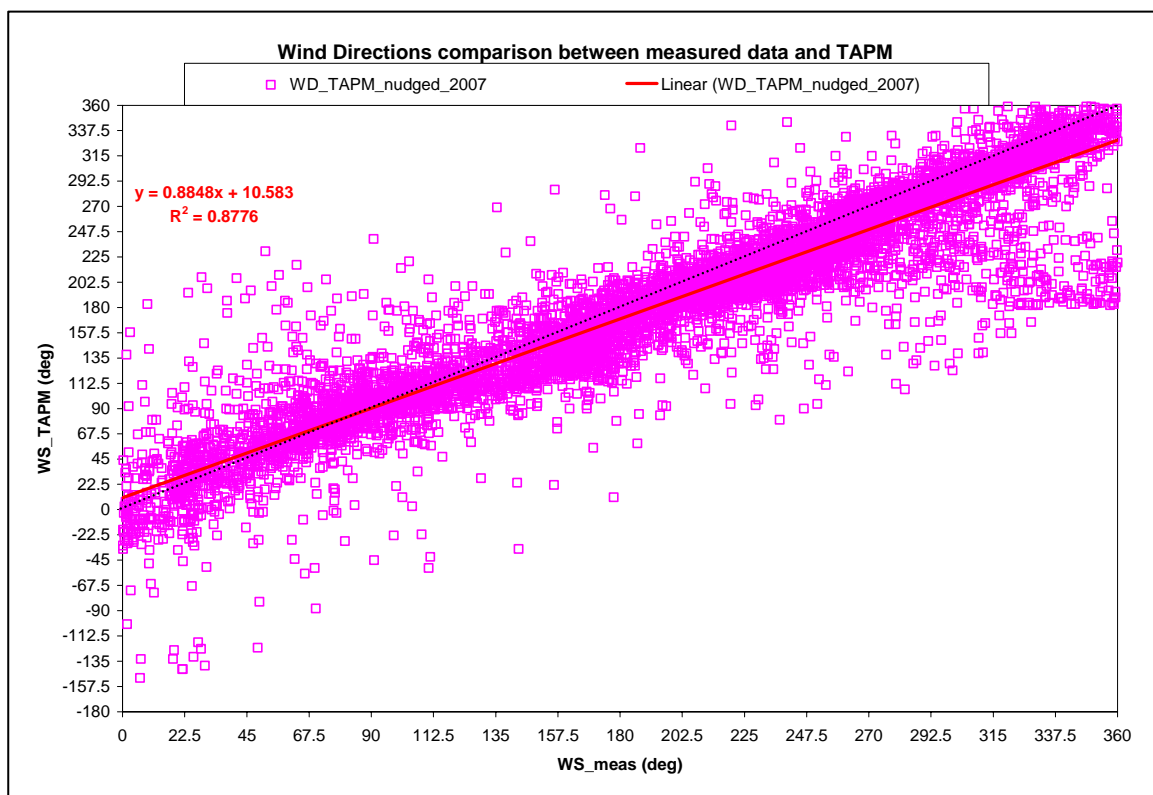


Figure 4 Wind directions comparison between measured data and TAPM

3.5 SEA SURFACE TEMPERATURES

These as estimated from DOLA maps from offshore of Cape Preston, are shown in Table 2.

Table 2 Estimated monthly sea surface temperatures for Cape Preston

Month-year	Temp (C)
Jan-07	31
Feb-07	31
Mar-07	31
Apr-07	32
May-07	28
Jun-07	26
Jul-07	23
Aug-07	23
Sep-07	24
Oct-07	26
Nov-07	28
Dec-07	29

3.6 CALMET SETTINGS

The key CALMET settings were:

- Grid domain size of 40 x 40 km at 1 km spacing (see Figure 5).
- Surface roughness changed from defaults of 0.4 m for land to 0.1 m.
- Bowen ratios changed from defaults of 1.0 for land to 3.0.
- 6 vertical levels at 20, 80, 200, 380, 680, 1200 m.
- Biases (surface versus upper) of -1, -1, -0.66, -0.33, 0, 0.33.
- Power law extrapolation for upper winds.

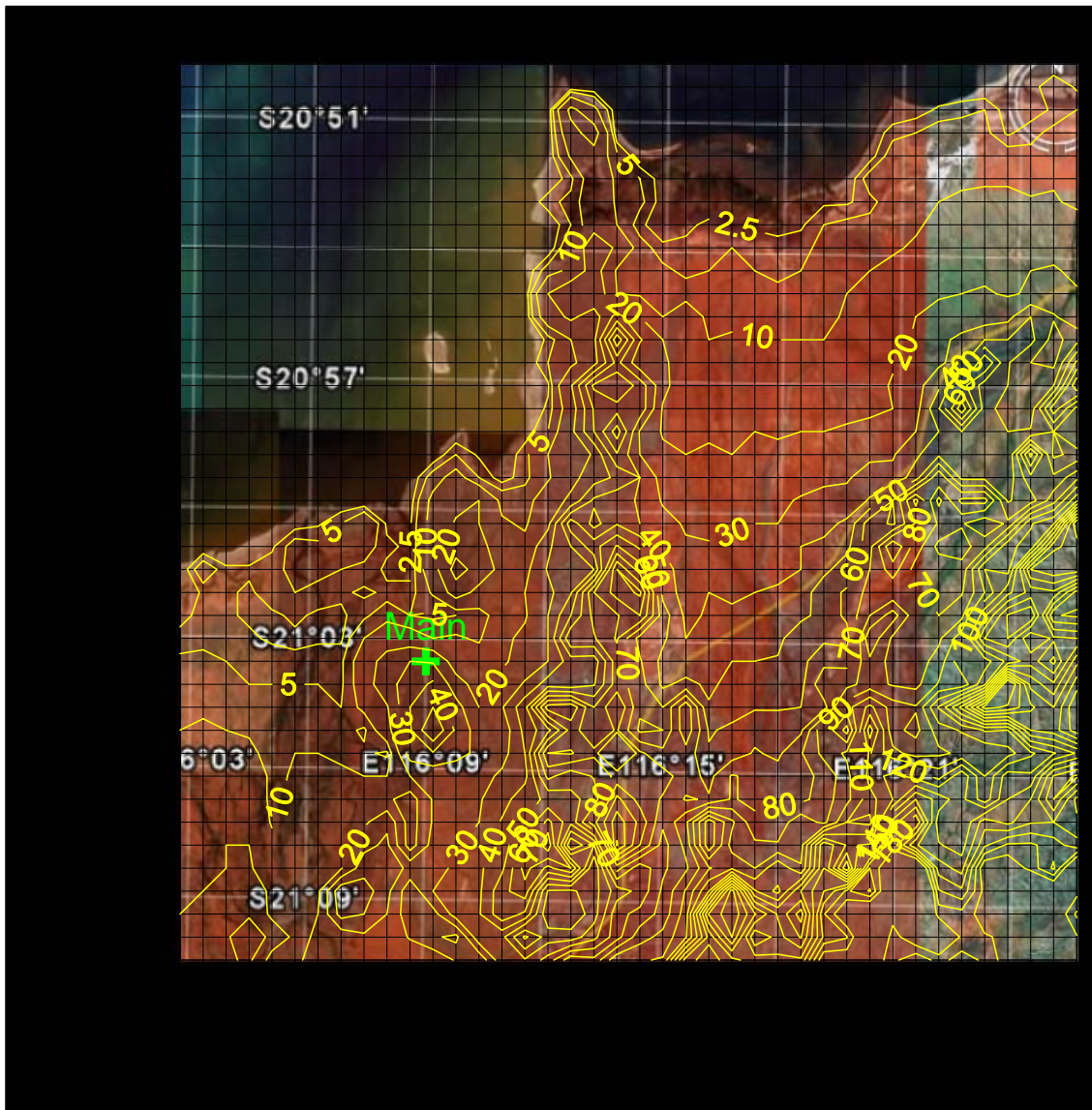


Figure 5 CALMET grid domain showing terrain contours

4. REFERENCES

Physick, W. and Blockley, A., 2001, "An Evaluation Of Air Quality Models For The Pilbara Region", June 2001.

Appendix 1 Meteorological data details

Table 3 Percentage occurrence of wind directions with stability class

Stab	Direction sector															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
1	0.11	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.05	0.01	0.01	0.01	0.00	0.00	0.00
2	0.22	0.15	0.21	0.24	0.30	0.40	0.24	0.29	0.35	0.57	0.57	0.31	0.27	0.25	0.32	0.26
3	0.56	0.41	0.43	0.66	0.74	0.53	0.35	0.49	0.63	1.08	1.10	0.70	1.23	2.04	1.96	1.59
4	1.55	1.80	1.56	3.30	3.52	1.61	0.94	1.26	1.87	3.06	4.16	4.58	5.25	3.25	2.40	2.63
5	0.19	0.34	0.39	0.48	0.82	0.99	0.42	1.36	1.83	1.47	3.07	2.60	1.31	0.51	0.37	0.23
6	0.58	0.58	0.42	0.98	1.19	1.16	1.42	2.85	2.23	1.74	1.92	1.84	1.51	1.18	1.03	0.55
Tots	3.22	3.31	3.03	5.66	6.58	4.69	3.38	6.26	6.91	7.97	10.82	10.03	9.59	7.24	6.07	5.25

Table 4 Percentage occurrence of wind speeds with stability class

Stab	Wind Speed range (m/s)															
	0.5	1.5	3	4.5	6	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5
1	0.10	0.00	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.08	0.38	1.60	2.31	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.03	0.34	1.20	2.49	4.35	2.88	2.13	0.90	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.02	0.13	2.41	4.70	10.88	12.53	6.69	3.58	1.37	0.41	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.05	2.87	10.47	3.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.24	3.77	14.67	2.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tots	0.48	4.66	22.85	22.50	18.82	15.41	8.82	4.49	1.55	0.41	0.00	0.00	0.00	0.00	0.00	0.00

Table 5 Percentage occurrence of daily hour with stability class

Stab	Time of day (hour range)												TOTS
	2	4	6	8	10	12	14	16	18	20	22	24	
1	0.00	0.00	0.00	0.00	0.00	0.15	0.08	0.03	0.00	0.00	0.00	0.00	0.3
2	0.00	0.00	0.00	0.00	0.75	2.47	1.40	0.29	0.02	0.01	0.00	0.00	4.9
3	0.00	0.00	0.00	0.31	2.75	2.47	4.84	3.70	0.37	0.08	0.00	0.00	14.5
4	1.77	1.91	2.19	3.69	4.83	3.25	2.01	4.32	7.95	6.38	2.47	1.97	42.7
5	2.58	2.75	2.73	2.19	0.00	0.00	0.00	0.00	0.00	1.06	2.81	2.27	16.4
6	3.98	3.68	3.41	2.15	0.00	0.00	0.00	0.00	0.00	0.80	3.06	4.09	21.2

Table 6 Percentage occurrence of mixing height with stability class

Stab	Height (m)																					
	0 -50	51 -100	101 -150	151 -200	201 -250	251 -300	301 -350	351 -400	401 -450	451 -500	501 -550	551 -600	601 -650	651 -700	701 -750	751 -800	801 -850	851 -900	901 -950	951 -1500	1501 -2000	
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	0.0	0.0	0.1	0.1	0.2	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	1.2	0.0
3	0.2	0.1	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.5	0.7	0.7	0.9	0.9	1.0	0.8	4.0	0.0	
4	0.4	0.4	0.5	1.4	1.4	1.6	2.6	3.3	2.5	2.1	2.0	2.1	1.9	1.8	1.8	1.8	1.7	1.9	1.9	9.6	0.2	
5	0.5	0.6	3.1	4.4	3.7	2.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	13.2	4.8	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Totals	14.3	5.9	7.0	6.2	5.7	5.0	4.5	4.2	3.4	2.9	2.8	3.0	2.7	2.7	2.8	3.0	2.9	3.1	3.0	14.8	0.2	

Table 7 Percentage occurrence of mixing height with daily hour

Hour of day	Height (m)																				
	0 -50	51 -100	101 -150	151 -200	201 -250	251 -300	301 -350	351 -400	401 -450	451 -500	501 -550	551 -600	601 -650	651 -700	701 -750	751 -800	801 -850	851 -900	901 -950	951 -1500	1501 -2000
0	1.3	0.6	0.5	0.3	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	1.2	0.6	0.7	0.3	0.3	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.1	0.6	0.6	0.5	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.3	0.3	0.5	0.4	0.3	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1.1	0.5	0.5	0.4	0.4	0.2	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	1.1	0.5	0.5	0.5	0.4	0.3	0.3	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1.0	0.6	0.5	0.4	0.4	0.3	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.8	0.4	0.4	0.5	0.4	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.1	0.0	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.0
9	0.0	0.0	0.0	0.2	0.4	0.3	0.3	0.5	0.4	0.4	0.3	0.3	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.4
10	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.4	0.3	0.5	0.4	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.4	0.3	0.4	0.5	0.3	0.3	0.3	0.9	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.4	1.7	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	2.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.3	2.3	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	2.1	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	2.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.4	0.3	0.3	0.3	0.3	1.6	0.0
18	0.0	0.0	0.0	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.9	0.0
19	0.4	0.3	0.3	0.4	0.4	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0
20	0.9	0.3	0.5	0.4	0.5	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	1.2	0.3	0.5	0.5	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	1.4	0.4	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	1.5	0.4	0.5	0.4	0.2	0.3	0.2	0.2	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 2 Results of preliminary comparison between TAPM and measured winds

The results from a preliminary comparison between TAPM-predicted winds and measured data for the Main Station site are summarised in Table 8 and Figure 6 and Figure 7 below.

Table 8 Results of TAPM runs for December 2006

TAPM parameters	Wind Speeds	Wind directions
Opt 1. TAPM with no assimilation (base case).	TAPM under predicts wind speeds > about 3 m/s by about factor of 2.	TAPM winds correlated with measured fairly well.
Opt 2. As above nudged.	TAPM under predicts wind speeds > about 3 m/s by about factor of 1.5 but better correlation than Opt 1.	As for Opt 1 but slightly better correlation.
Opt 3. As for 1 but 5 grid nests used (5 th nest at 300m)	Slightly worse correlation than Opt 1.	As for Opt 1 but marginally better correlation.

In conclusion:

- The assimilated data noticeably improves TAPM's wind speed predictions, but they are still underestimated for wind speeds greater than about 3 m/s.
- There is no benefit going to a 5th nest.
- TAPM's wind direction predictions are quite good.

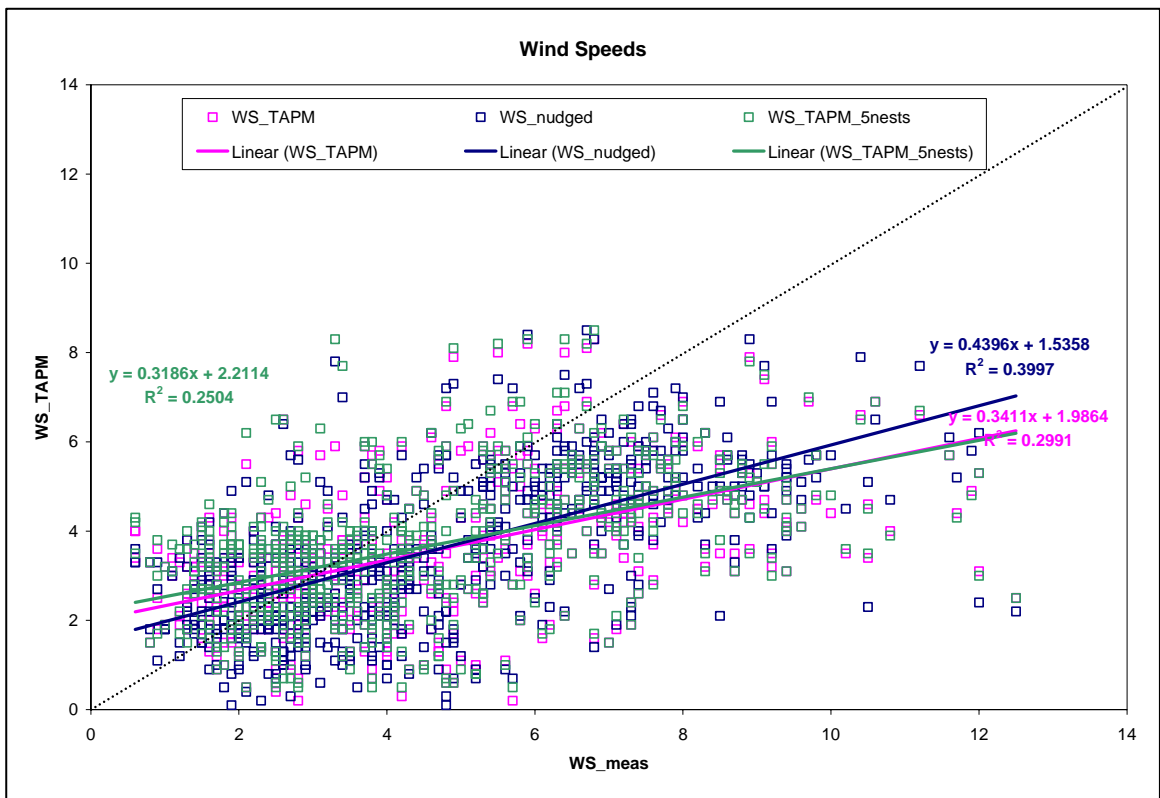


Figure 6 TAPM wind speeds versus measured data

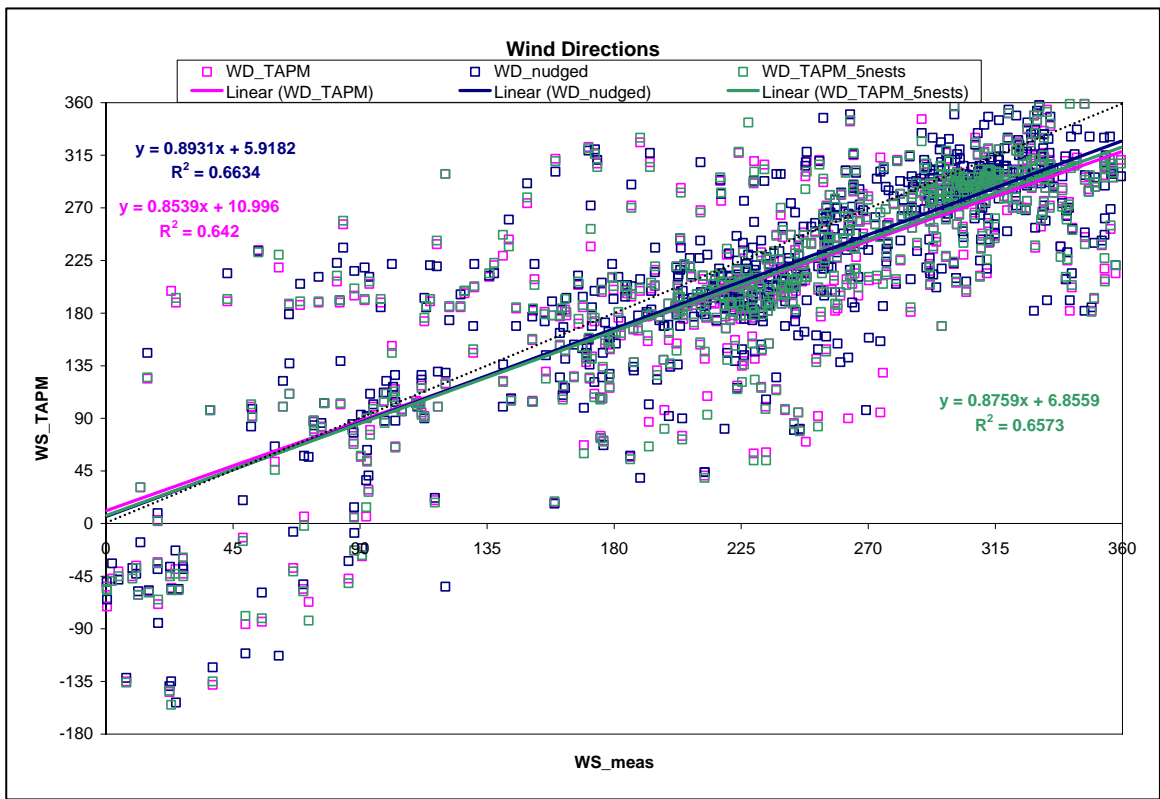


Figure 7 TAPM wind directions versus measured data

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