Wind Atlas for South Africa (WASA)

Western Cape and parts of Northern and Eastern Cape

Station and Site Description Report

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April 2014

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1 Introduction

As part of the "Wind Atlas for South Africa" project, site inspection trips were carried out by the Council for Scientific and Industrial Research (CSIR) and Risø DTU in April and June of 2011. A total of 10 sites featuring instrumented 60-m masts were visited; the present report summarises the findings of the site inspection teams. Figure 1 shows the positions and names of the 10 WASA mast sites.

Figure 1. Overview map of the southernmost part of South Africa, showing the location of the 10 meteorological masts referred to in the text (Image © 2011 AfriGIS (Pty) Ltd., Tele Atlas, Europa Technologies and Google Inc.).

The purpose of the site inspection trips is to assure the quality of the mast installations, as well as to provide those mast, site and land cover characteristics which are necessary for the subsequent analysis of the meteorological data. The main characteristics of each mast and site, which have been measured, calculated or recorded, are:

- Position and elevation of the mast site
- Boom and instrument heights above ground level
- Magnetic declination and meridian convergence at the site
- Sensor boom and lightning rod directions
- Photographic documentation of mast design and installation
- Photographic documentation of mast surroundings (panoramic view)

In addition, elevation maps have been constructed for each site from SRTM 3 data and a summary of the wind observations have been compiled; these are presented in Appendix B below.

Photographic documentation of land cover types around and en route between the mast sites have also been recorded; this may aid in the interpretation of land cover codes and the construction of roughness length maps from databases of land cover.

2 Mast and site characteristics

The information presented in this section is necessary for the reliable data analysis and wind flow modelling at the 10 sites and their surroundings.

2.1 Mast positions

The positions of the meteorological masts were determined using handheld GPS receivers. One to three readings were taken (the latter corresponding approximately to the three legs of the mast) and averaged to find the position of the mast, see Table 1.

Table 1. Mast coordinates and elevations. The datum used is WGS 84; elevations are determined by the WAsP 10.1 flow model from SRTM 3 maps with 5-m height contours.

Mast ID	Longitude [°E]	Latitude [°S]	Elevation [m a.s.l.]	Easting [m]	Northing [m]	UTM zone
WM01	16.664410	28.601882	152	662743.2	6834989.4	33
WM02	19.360747	31.524939	824	344361.1	6511054.9	34
WM03	18.419916	31.730507	242	255549.9	6486539.1	34
WM04	18.109217	32.846328	22	229440.3	6362045.0	34
WM05	19.692446	34.611915	288	380119.2	6169215.6	34
WM06	20.691243	32.556798	1581	471013.8	6397802.7	34
WM07	22.556670	32.966723	1047	645479.5	6351326.6	34
WM08	24.514360	34.109965	110	270725.8	6222861.2	35
WM09	25.028380	31.252540	1806	312257.8	6540733.5	35
WM10	28.135950	32.090650	925	607193.9	6448951.8	35

The terrain elevation of the mast sites were subsequently determined using height contour maps created for the WAsP flow modelling (Mortensen *et al.*, 2011). The 5-m height contour elevation maps were derived from Shuttle Radar Topography Mission (SRTM) 3 arc-second data. Version 10.1 of WAsP was used, which has an improved site elevation determination procedure.

2.2 Bearings and directions

The Universal Transverse Mercator coordinates of a mast site and of points around this site refers to the Cartesian *grid coordinate system*; this system is also used for the vector elevation and roughness length maps used for the microscale flow modelling. The local angle between the *y*-axes of the grid coordinate system (G) and of the *geographical coordinate system* (T) is called the meridian convergence (C); and $T = G + C$. For the UTM coordinate system, the convergence can be simply calculated from the latitude and longitude of the site, see Table 2.

The magnetic declination (D) at each mast site was determined by taking the compass bearing between two known points; from a viewpoint looking towards the masts itself. Knowing the grid coordinates of these two points, the geographical (true) bearing can be calculated by adding the convergence to the grid bearing (angle). Given the true bearing

(T) and the compass bearing (M), the declination (D) can be calculated as $D = T - M$. This value may be compared to the value derived from topographical maps published by the Chief Directorate: Surveys and Mapping (now National Geo-spatial Information, NGI), see Table 2.

All compass (magnetic) bearings (M) have been transformed to true bearings (T) using $T = M + D$, where D is the magnetic declination. The magnetic declination is westerly (and therefore negative) for all the sites in South Africa, i.e. the magnetic north M lies to the west of geographic north T (when seen from the site).

Table 2. Meridian convergence, magnetic declination, anemometer boom direction and lightning rod direction.

Mast ID	**Meridian conver-gence**	**Magnetic declination (measured)**	**Magnetic declination (NGI map)**	**Boom direction (measured)**	**Boom direction (logger)**	**Lightning rod direction**
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM01	−0.80	−19.5	−19.4	264	262	025
WM02	0.86	−24.5	−22.9	134	132	199
WM03	1.36	−24.2	−23.0	114	113	178
WM04	1.57	−23.4	−24.0	262	263	057
WM05	0.74	−26.0	−25.0	181	182	305
WM06	0.17	−24.9	−22.7	356	357	105
WM07	−0.85	−26.1	−23.7	134	134	327
WM08	1.39	−29.6	−26.7	138	138	057
WM09	1.02	−24.9	−24.6	245	246	177
WM10	−0.60	−28.9	−25.8	203	203	349

The alignment of the wind direction vanes during installation was done using a compass; the recorded wind directions are therefore initially referenced to magnetic north. During data calibration, the wind directions are converted and referenced to the geographical coordinate system. Table 2 lists the anemometer boom direction determined as described above, as well as the calibrated direction read from the data logger when aligning the wind vane along the boom. The anemometer boom direction is defined here as the direction in which the cup anemometer points.

Comparison of the two boom directions in Table 2, provide an independent evaluation of the calibration expression used to transform the wind direction data measured at the mast. In general, the differences are quite small, i.e. between 0.2 and 1.8 degrees, and with a mean value of 0.6 degrees.

A lightning protection system has been installed at the top of each mast, as may be seen from the photographs in Appendix B. This system will distort the wind flow when the wind comes from the direction of the system. This direction, i.e. the bearing of a line from the top anemometer through the vertical part of the lightning protection system, is also given in Table 2.

2.3 Mast characteristics

The design and characteristics of the 60-m masts are described elsewhere; a sketch is shown in Appendix C. Photos taken during the site inspection trip may serve to verify that actual installations are done according to this master design.

The actual anemometer heights have been determined in the field using laser distance meters. Table 3 lists the anemometer heights on the 10 masts, i.e. the height of each cup anemometer rotor above the top of the concrete mast foundation. The top of the mast foundation is about 5-10 cm higher than the terrain surface, see Table 3.

Table 3. Cup anemometer heights above foundation level on the 10 masts. The boom heights were determined using laser distance meters; the heights listed below refer to the height of the cup anemometer rotor plane above the top of the foundation.

Mast ID	Level '62'	Level '60'	Level '40'	Level '20'	Level '10'	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM01	61.85	60.47	40.27	20.17	10.21	0.05
WM02	61.85	60.45	40.31	20.17	10.12	0.05
WM03	61.85	60.26	40.29	20.15	10.09	0.10
WM04	61.85	60.45	40.24	20.12	10.39	0.05
WM05	61.85	60.51	40.38*	20.31	10.25	0.05
WM06	61.85	60.23	40.27	20.22	10.11	0.05
WM07	61.85	60.33	40.22	20.20	10.12	0.05
WM08	61.84	60.94	37.17	20.13	10.15	0.12
WM09	61.80	60.26	39.24	19.89	10.15	0.13
WM10	61.85	60.80	40.23	20.09	10.08	0.04

* The 40-m anemometer on WM05 was 3 m lower until 2010-10-07 14:30.

3 Topographical characteristics

Some topographical information was prepared before, or recorded during, the site visits. The maps shown in the present report refer to the Universal Transverse Mercator (UTM) system and the datum used is World Geodetic System 1984 (WGS 84).

3.1 Surrounding terrain and mast photos

In Appendix B, the terrain surrounding each mast is shown in panoramic photographs; starting from 000°, photos were taken clockwise for every 30° at sites WM01 to WM07. For stations WM08 to WM10, sector photographs for every 45° were taken. Note that the directions given in these figures refer to the magnetic north direction. Photos of the measurement levels and of the entire mast are also given in Appendix B.

3.2 Elevation maps

Elevation maps for each site were constructed from Shuttle Radar Topography Mission (SRTM) 3 arc-second data, using Surfer 10. Overview maps cover 20×20 km^2, with 20-

or 10-m height contours; detailed site maps cover 4×4 km^2, with 5-m contours. These maps are shown for each station in the descriptions below. The maps are preliminary and will be verified against other elevation information – especially close to the masts.

3.3 Land cover maps

The land cover was checked against print-outs of Google Earth imagery and photos were taken of characteristic land cover types. Preliminary land cover maps may be constructed from this information, but these should be verified on basis of ordinary topographical maps and data bases of land cover.

4 Wind-climatological characteristics

The observed wind climate, i.e. the wind rose and wind speed distributions, is shown for each station in Appendix B. The observed wind climates were constructed using the WAsP Climate Analyst, version 2.0.132. Table 4 shows the status of the meteorological measurements at the time of writing.

*Table 4. Status of measurements as of 1 October 2013. The **Recovery** column shows the overall data recovery rate for the top-level anemometer/wind vane only; and the **Years** column show the available measurement period in years.*

Mast ID	Province	Data start	Data start	Days until	Recovery	Years
		Date	Time	**1 Oct 2013***	[%]	[y]
WM01	N Cape	2010-06-23	20:20	1196	100.0	3.27
WM02	N Cape	2010-06-30	13:10	1189	93.4	3.25
WM03	W Cape	2010-06-24	15:40	1195	100.0	3.27
WM04	W Cape	2010-05-18	18:00	1115	100.0	3.05
WM05	W Cape	2010-05-20	16:50	1230	98.6	3.37
WM06	N Cape	2010-09-17	15:10	1110	99.9	3.04
WM07	W Cape	2010-05-28	16:20	1222	97.0	3.35
WM08	E Cape	2010-08-04	13:00	1154	87.4	3.16
WM09	N Cape	2010-09-01	14:30	1126	86.1	3.08
WM10	E Cape	2010-08-05	14:00	1153	84.1	3.16

* WM04: until 6 June 2013, where the station ceased operation.

For the subsequent wind atlas analysis, a high recovery rate can be obtained by selecting another (shorter) data period or by filling in data based on the wind measurements at other levels on the mast.

4.1 Meteorological data download

Meteorological data from the 10 measurement stations can be downloaded from the web site wasadata.csir.co.za/wasa1/WASAData. Download is free of charge, but requires registration.

The WASA data download site also contains links to the *WASA Wind Atlas download site*, which contains results from the micro- and mesoscale modelling, as well as further information, reports and tools.

5 Conclusions and recommendations

In general, the mast installations were found to be of a high standard and no changes were made to the installations during the site visits, except for removal of birds' nests in a few places.

The mast positions were generally confirmed to within a few tens of meters, except for mast 5, 9 and 10 where the new positions are about 100-300 m from the old ones. The coordinates given in Table 1 refer to the coordinates obtained during the site inspection trips.

The boom directions – and thereby the calibration expressions used for wind direction measurements – were confirmed at all stations to be within 2 degrees, and there is no need to change the calibration expressions. The lightning system rod directions turned out to be more difficult to determine accurately, so these directions are associated with a slightly larger uncertainty.

The boom and cup anemometer heights were mostly quite easy to determine; however, the top anemometer height was not measured directly and is estimated from photos and the known dimensions of the associated hardware.

6 Acknowledgements

The Wind Atlas for South Africa project is an initiative of the Government of South Africa – Department of Minerals and Energy (now DoE) and the project is co-funded by:

- UNDP-GEF through the South African Wind Energy Programme (SAWEP)
- Royal Danish Embassy

The South African National Energy Development Institute (SANEDI) is the Executing Agency, coordinating and contracting contributions from the implementing partners: Council for Scientific and Industrial Research (CSIR), University of Cape Town (UCT), South African Weather Service (SAWS), and DTU Wind Energy (formerly Risø DTU).

7 References

Mortensen, N.G., D.N. Heathfield, O. Rathmann and M. Nielsen (2011). *Wind Atlas Analysis and Application Program: WAsP 10 Help Facility*. Risø National Laboratory for Sustainable Energy, Technical University of Denmark, Roskilde, Denmark. 356 topics.

Errata and additions

Second edition (February 2012): boom directions for WM01-WM04 corrected by 180°. Label '°N' changed to '°S' in Appendix B. Some minor editorial changes.

Third edition (December 2012): boom directions reported for WM05 corrected by 3.7° based on new compass measurements. Table 2, Table 13 and text updated accordingly. Tables, statistics and graphics updated to 2 years of data. Minor editorial changes.

Fourth edition (April 2014): Tables, statistics and graphics updated to 3 years of data. Minor editorial changes.

A Additional resources

SANEDI's Wind Atlas for South Africa site, www.wasaproject.info, contains general information about the Wind Atlas for South Africa project (WASA).

The WASA data are displayed at the CSIR Online site, http://www.wasa.csir.co.za/.

The WASA download site, wasadata.csir.co.za/wasa1/WASAData, contains all the 10-min data collected at the 10 meteorological masts. Download is free of charge.

The magnetic declination at a site can also be estimated using the magnetic declination calculator provided by NOAA's National Geophysical Data Center (NGDC).

Shuttle Radar Topography Mission (SRTM) elevation and water body (SWBD) data sets can be downloaded from dds.cr.usgs.gov/srtm/. Download is free of charge.

The Municipal Demarcation Board web site, www.demarcation.org.za, contains data defining the borders of South African provinces, districts and municipalities. Download in several different formats is free of charge.

B Station descriptions and photos

The following 10 sections list the mast and site characteristics for the 10 meteorological masts. Elevation maps of the surrounding terrain and the observed wind climates at 62 m above ground level are also shown. Finally, each section contains photographs of the surrounding terrain and of the mast installation. The stations are:

WM01 Alexander Bay

WM01	16.66441°E	28.60188°S	152 m	E 662743 m	N 6834989 m	UTM 33

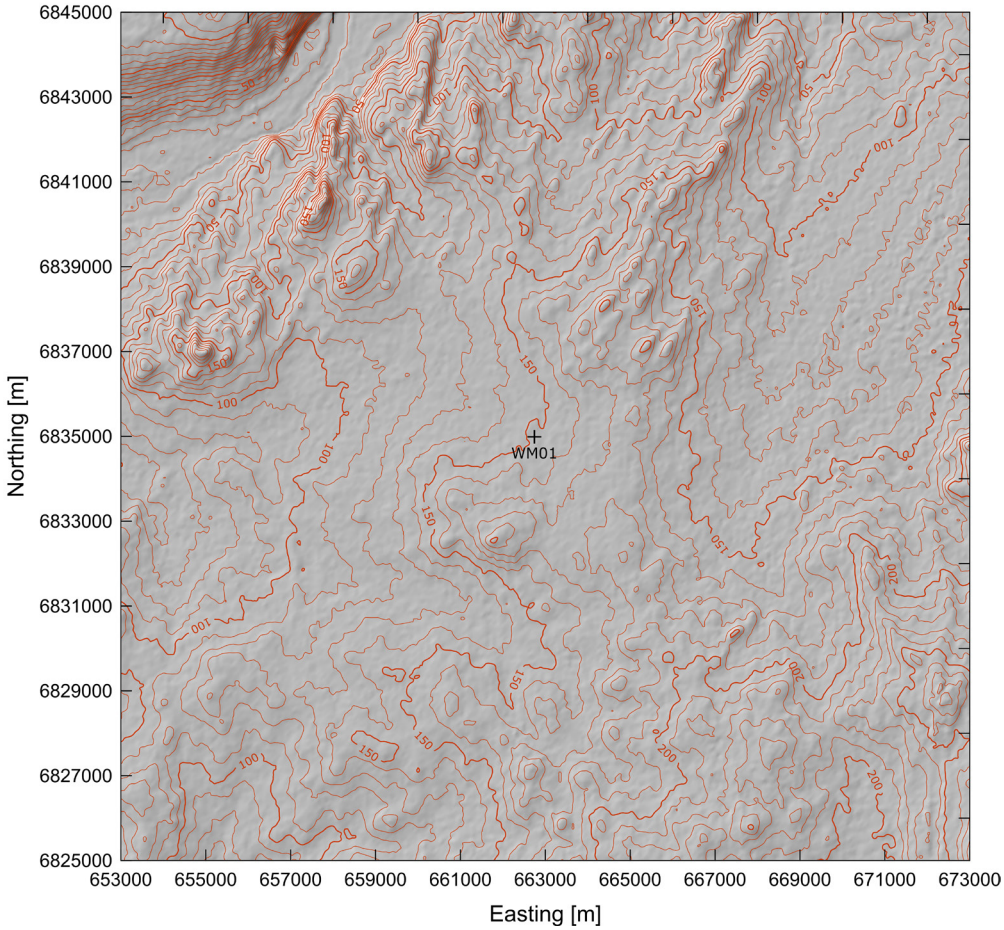


Figure 2. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 5. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM01	−0.80	−19.5	−19.4	264	262	025

Table 6. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 01	61.85	60.47	40.27	20.17	10.21	0.05

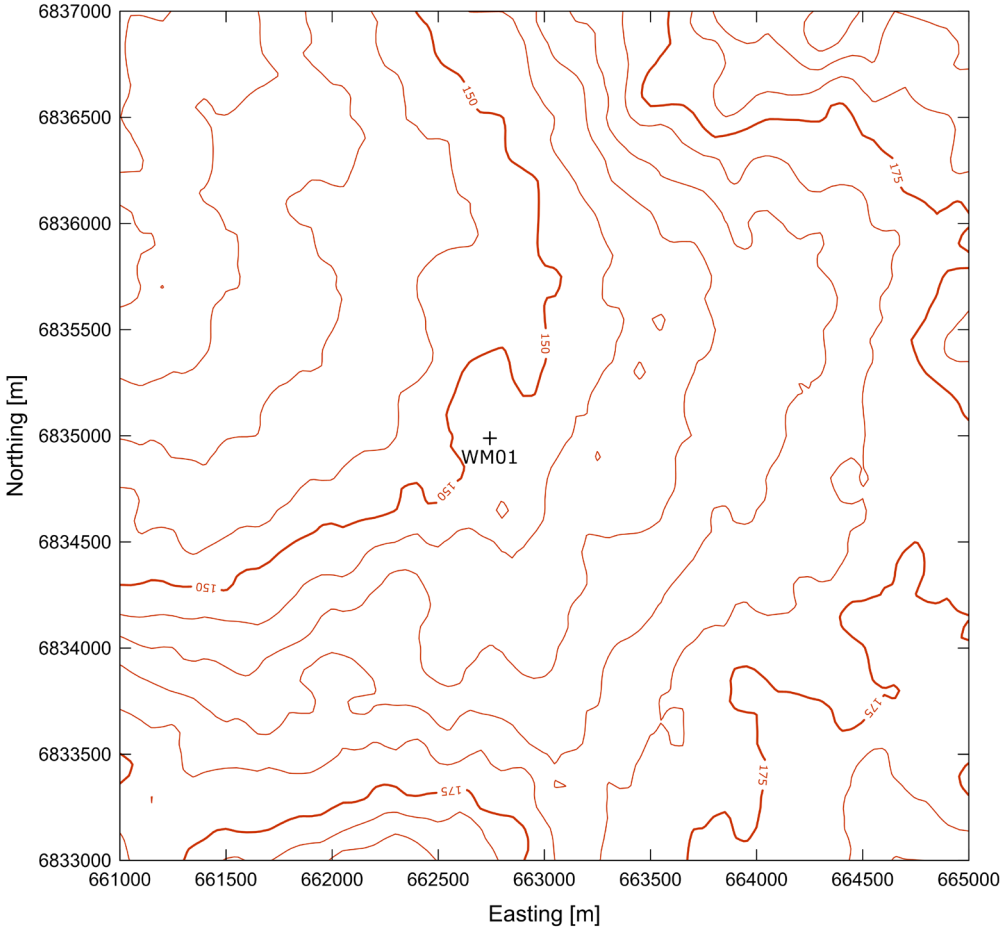


Figure 3. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m height contours.

Observed wind climate

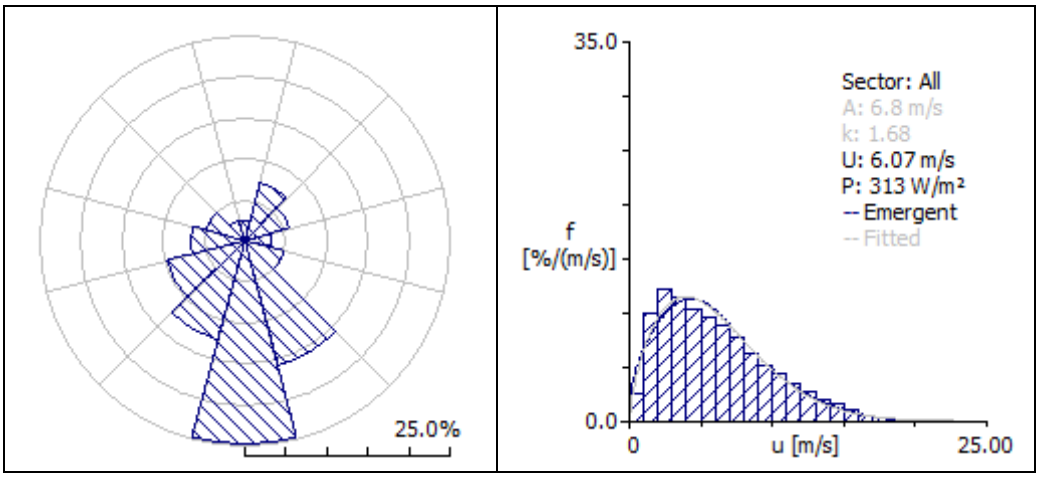
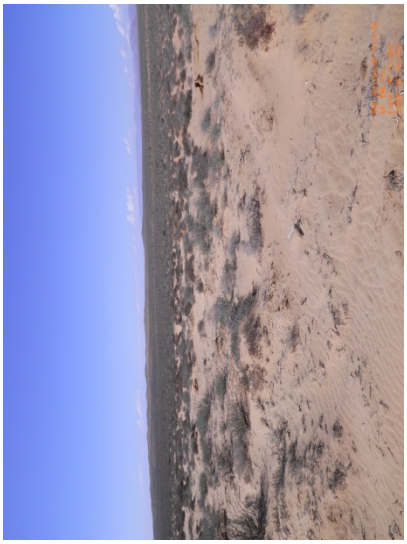
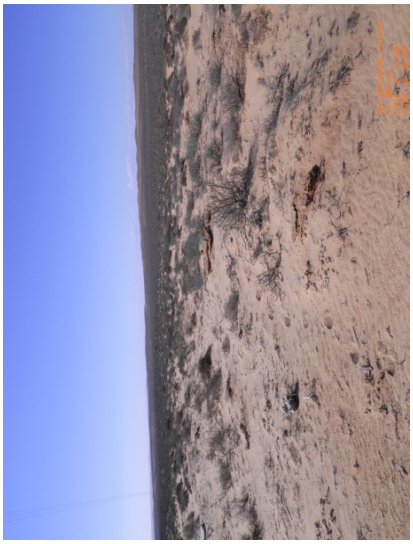
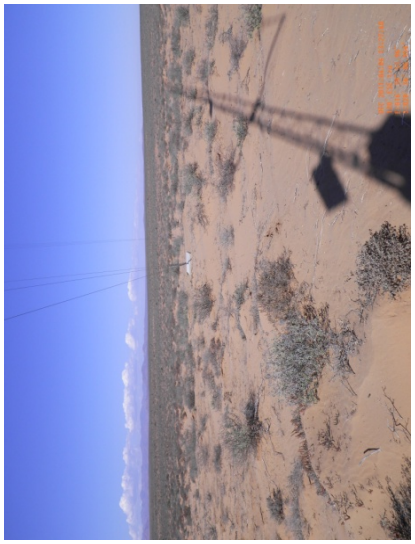
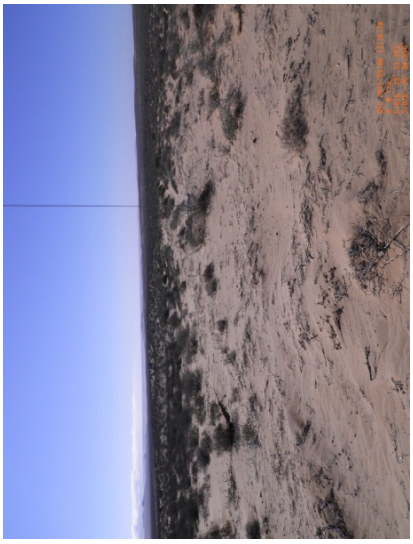
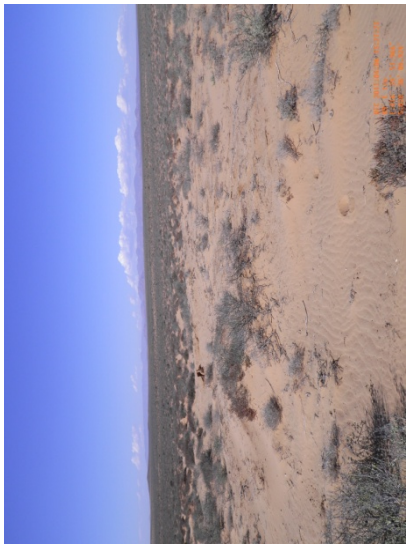
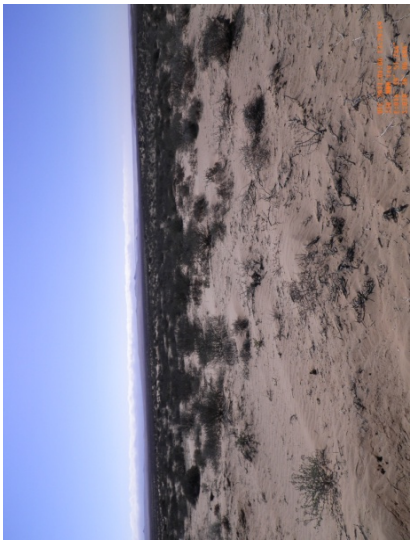
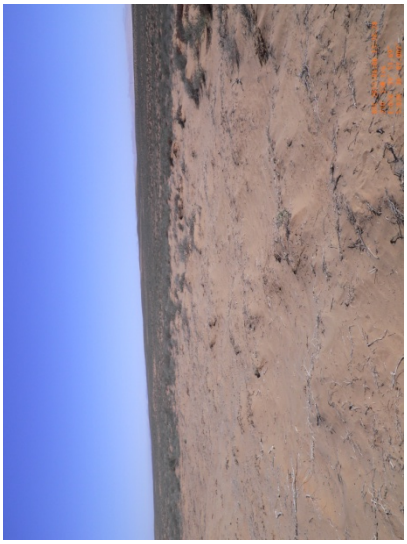


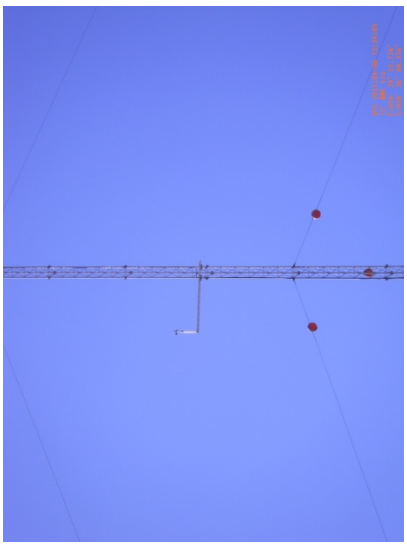
Figure 4. Wind rose and wind speed distribution for WM01 Alexander Bay at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

 060	 150
 030	 120
 000	 090

 240	 330
 210	 300
 180	 270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	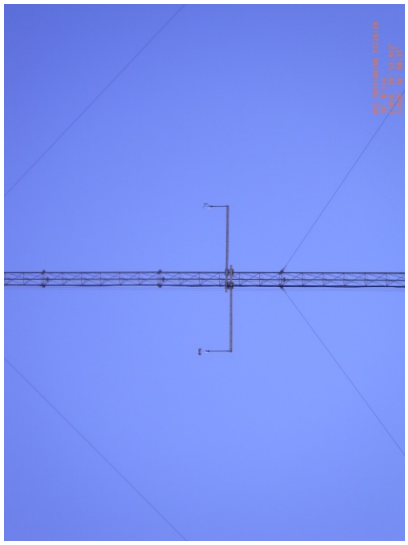
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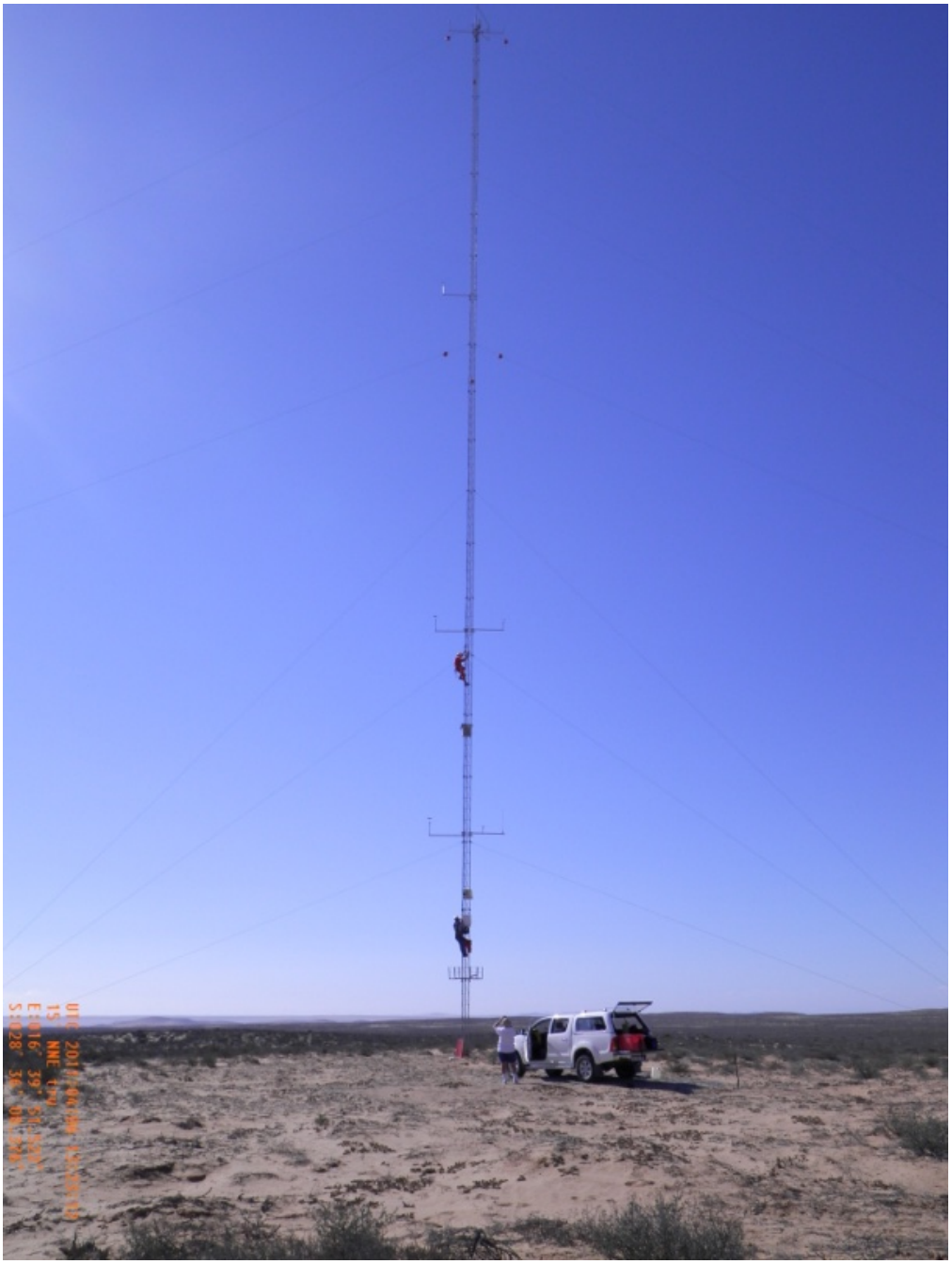


Tower Full View

WM02 Calvinia

WM02	19.36075°E	31.52494°S	824 m	E 344361 m	N 6511055 m	UTM 34

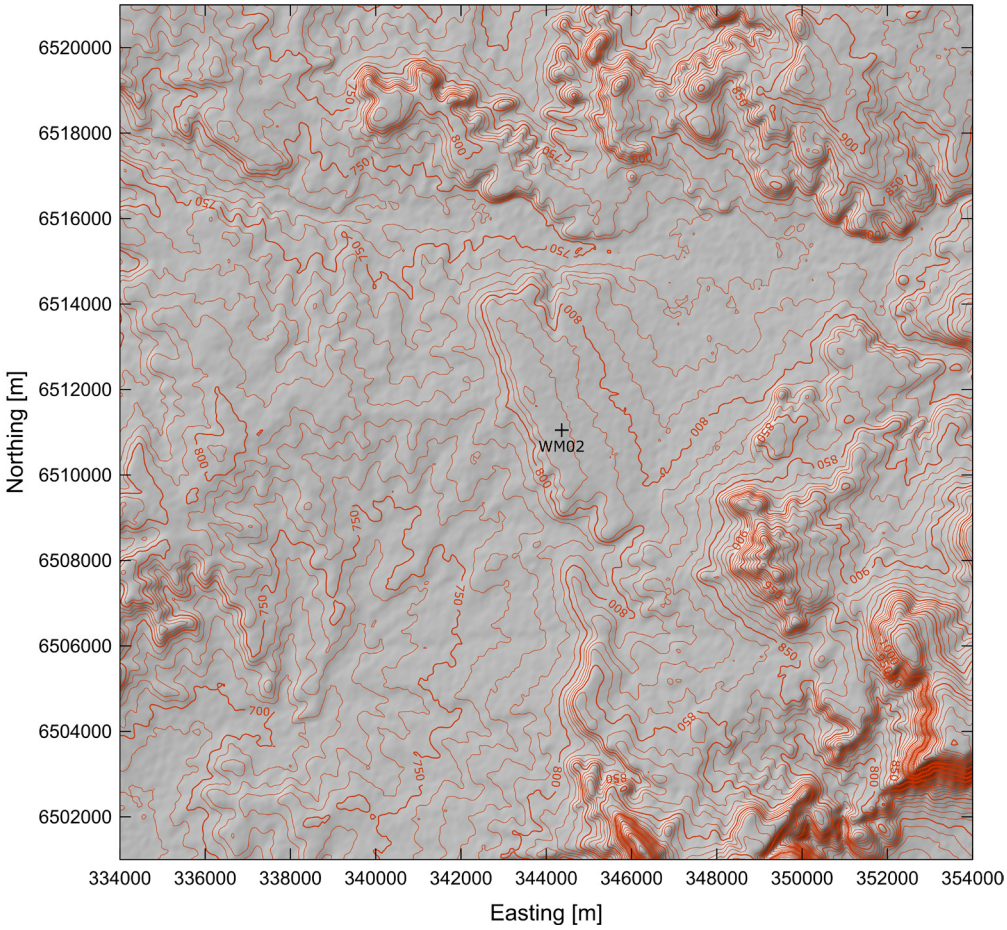


Figure 5. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0.0%.

Site and mast characteristics

Table 7. Convergence, magnetic declination, cup boom and lightning rod direction.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM02	0.86	−24.5	−22.9	134	132	199

Table 8. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 02	61.85	60.45	40.31	20.17	10.12	0.05

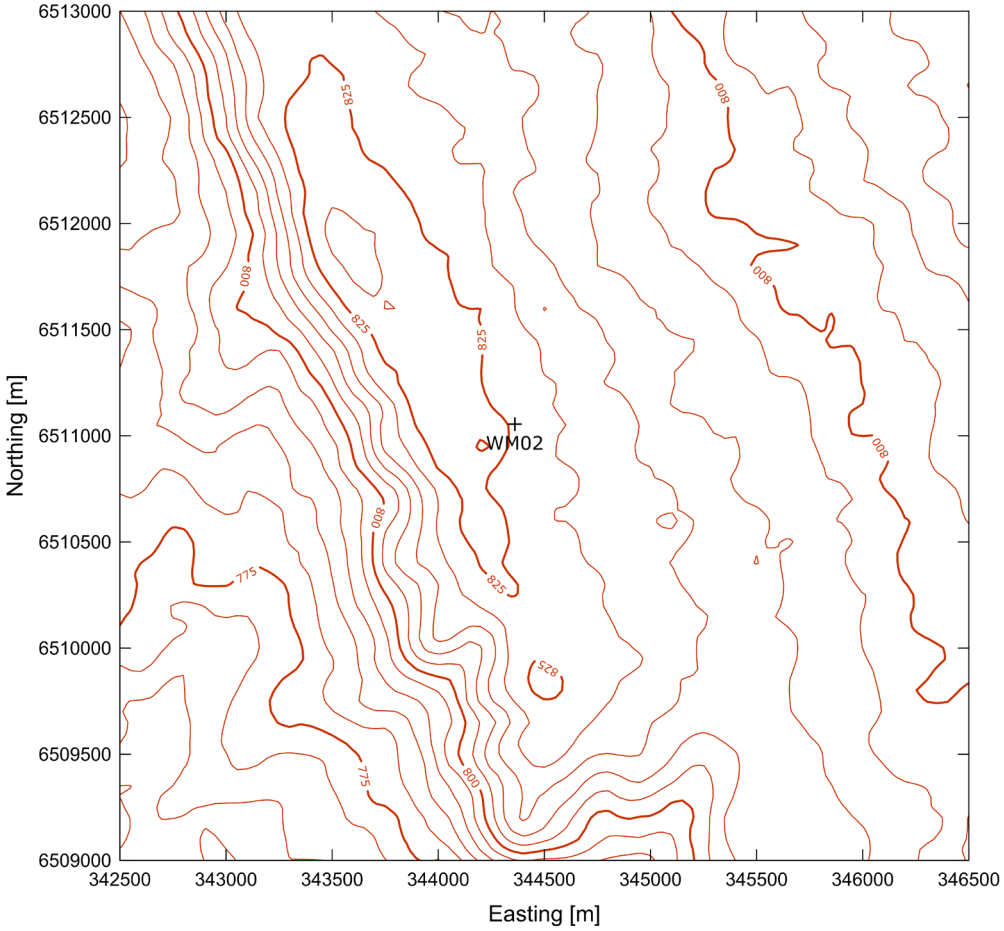


Figure 6. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m height contours.

Observed wind climate

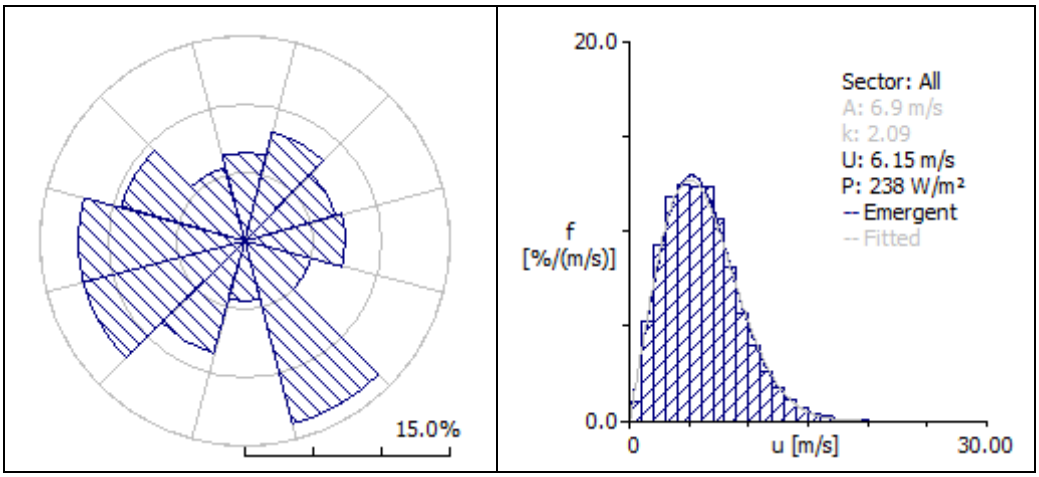
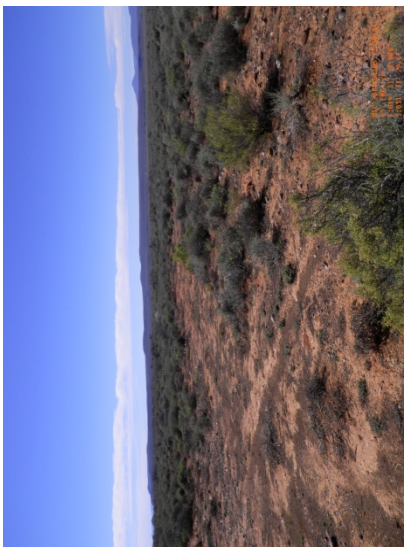
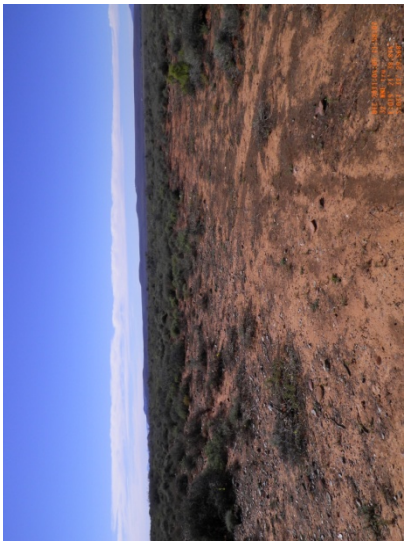
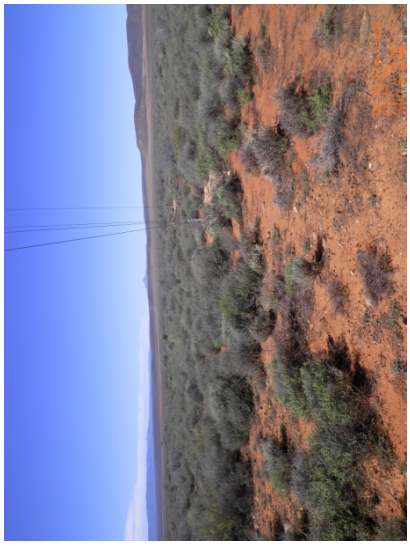
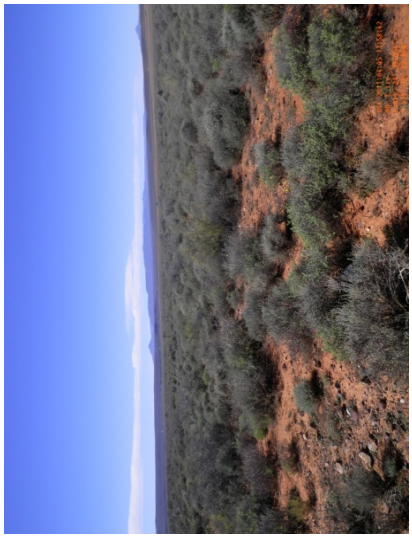


Figure 7. Wind rose and wind speed distribution for WM02 Calvinia at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

 060	 150
 030	 120
 000	 090

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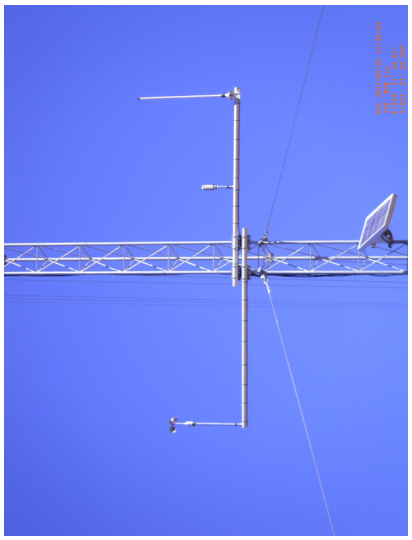
 210	 300
 180	 270

2/4



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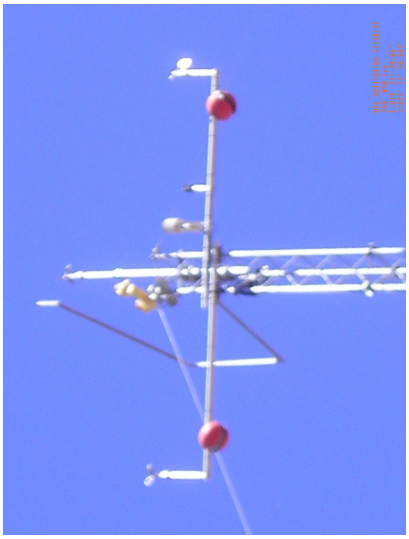
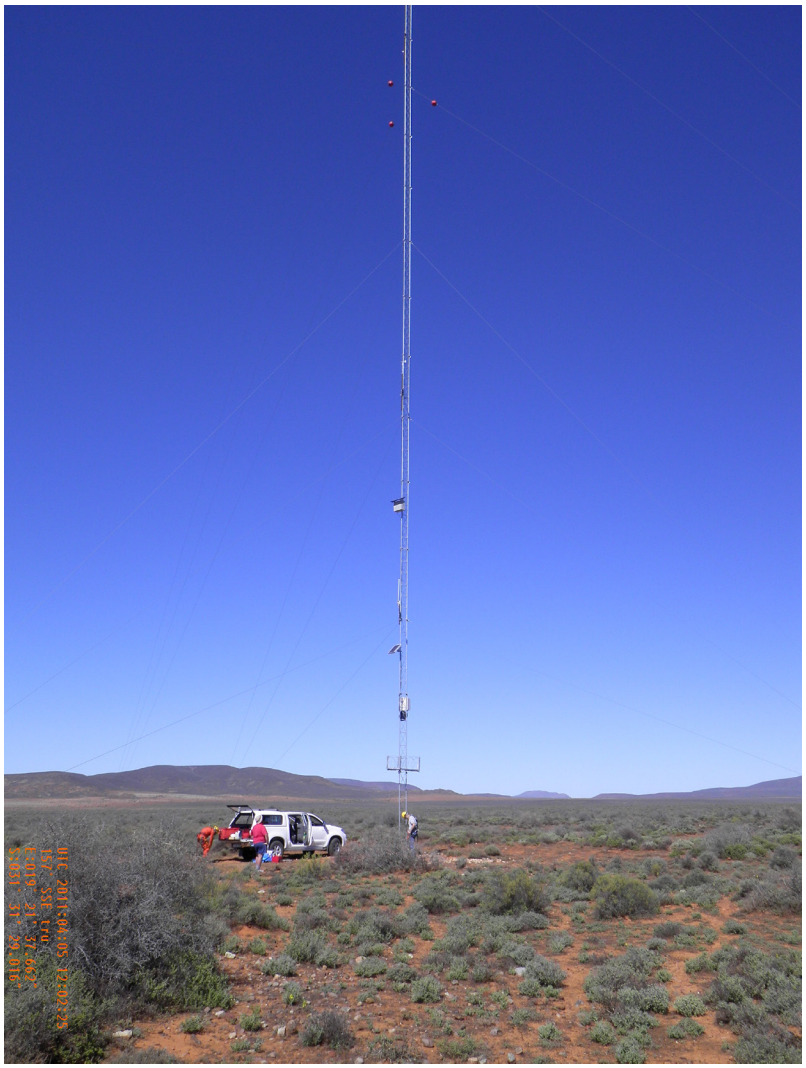


1/4 (top)

3/4



Tower Full View

WM03 Vredendal

WM03	18.41992°E	31.73051°S	242 m	E 255550 m	N 6486539 m	UTM 34

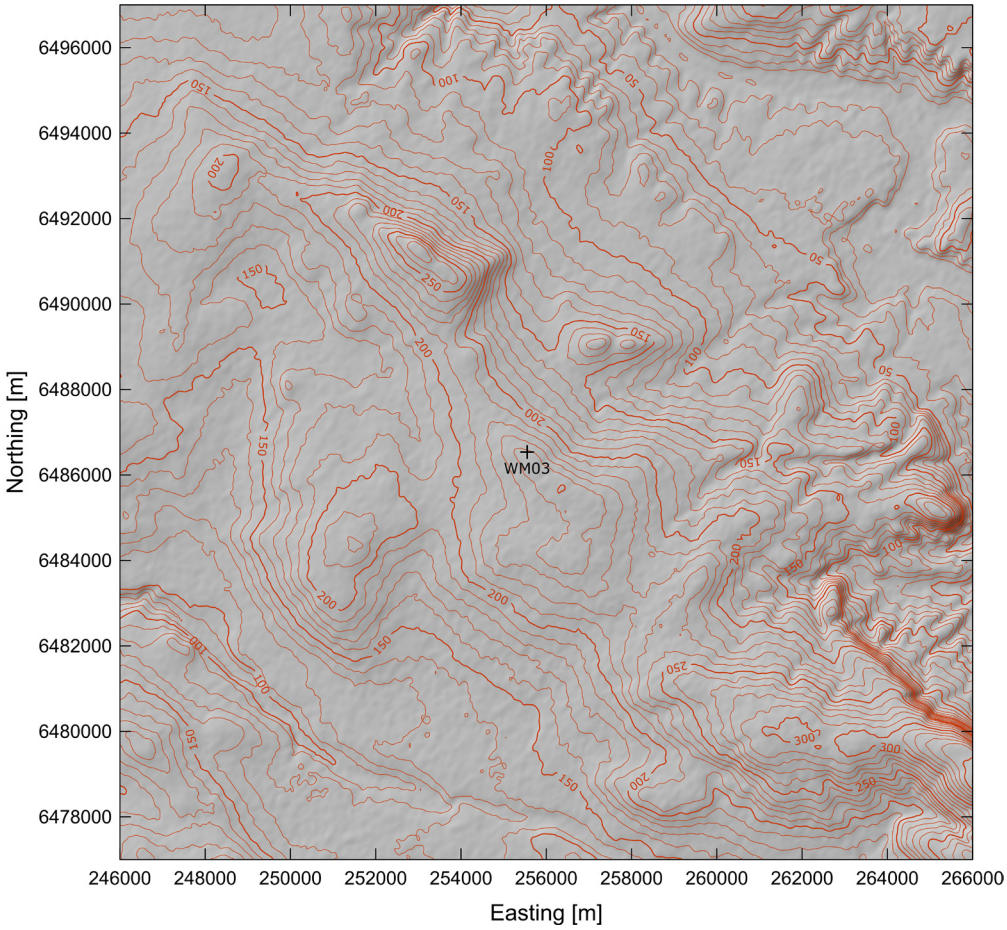


Figure 8. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0.0%.

Site and mast characteristics

Table 9. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM03	1.36	−24.2	−23.0	114	113	178

Table 10. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 03	61.85	60.26	40.29	20.15	10.09	0.10

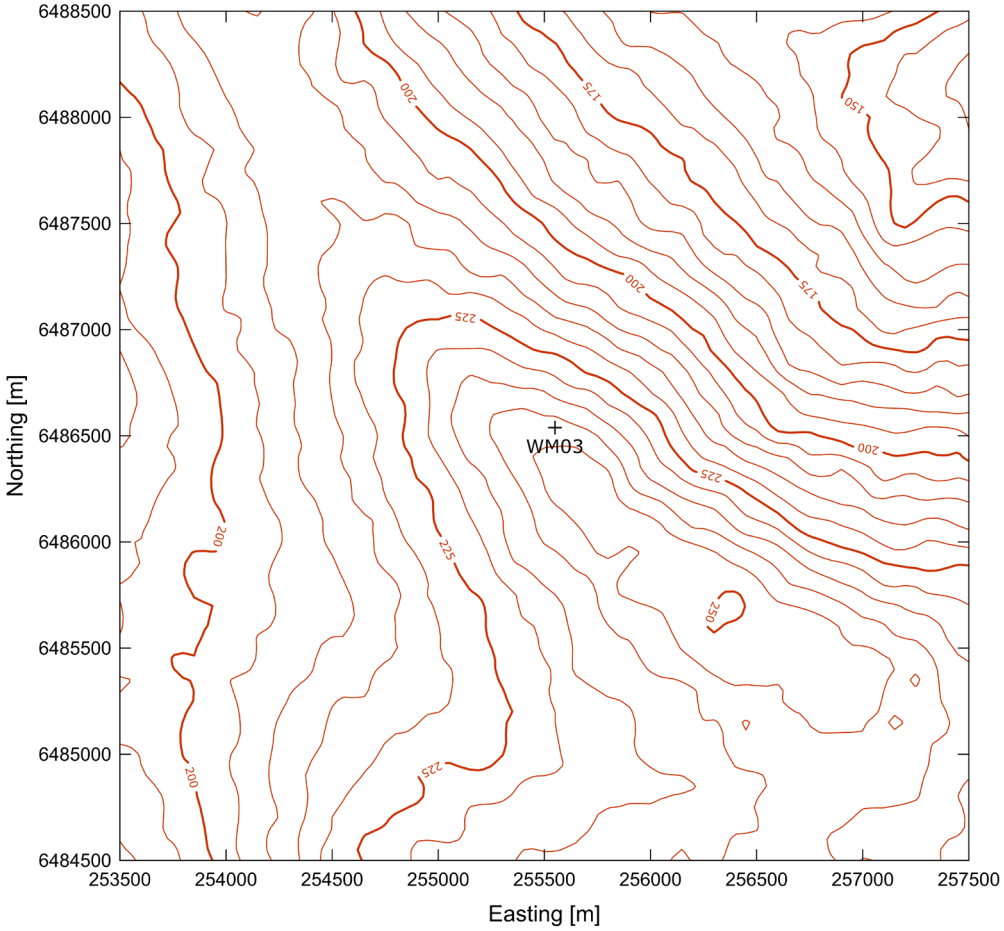


Figure 9. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m height contours.

Observed wind climate

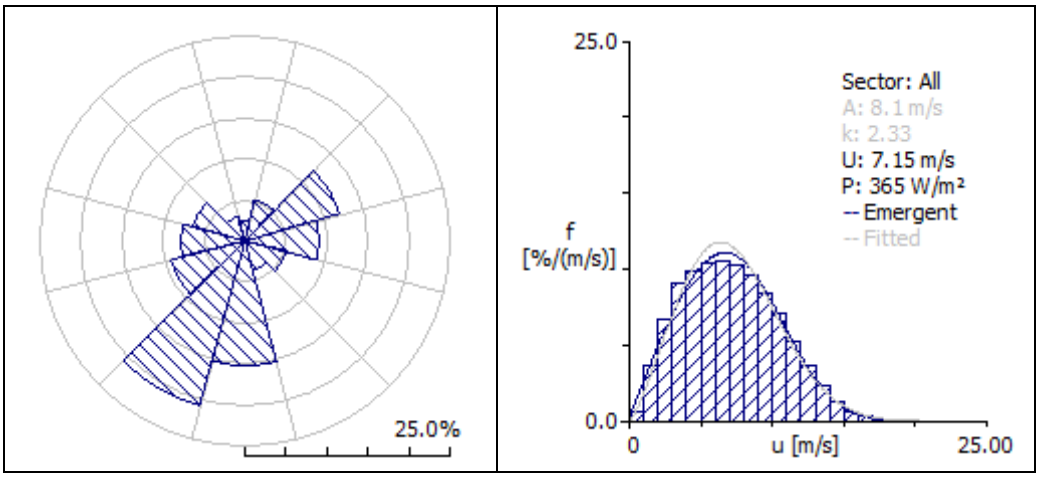
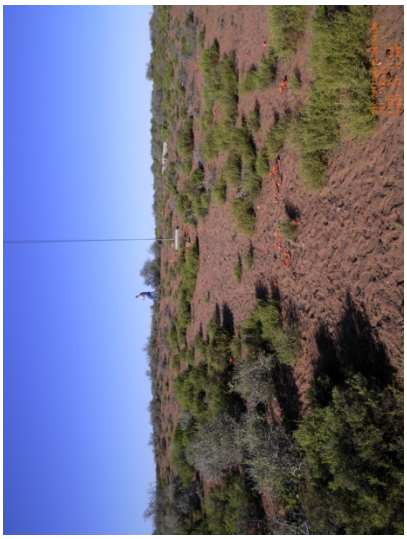


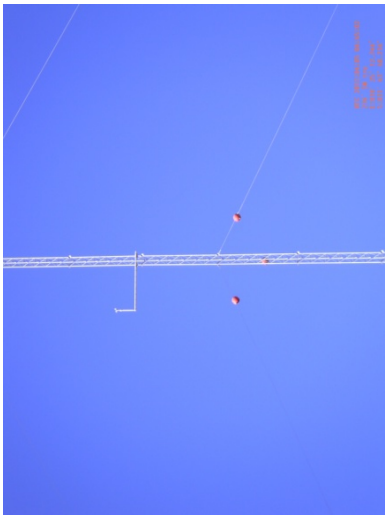
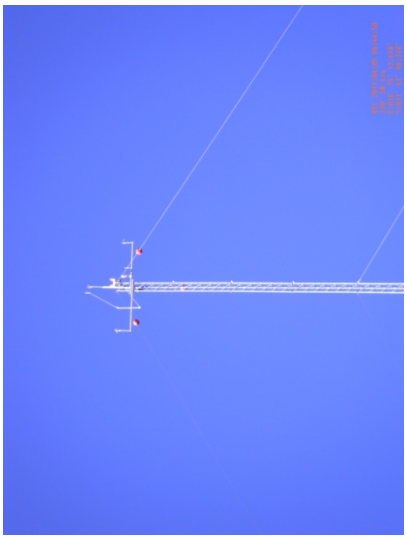
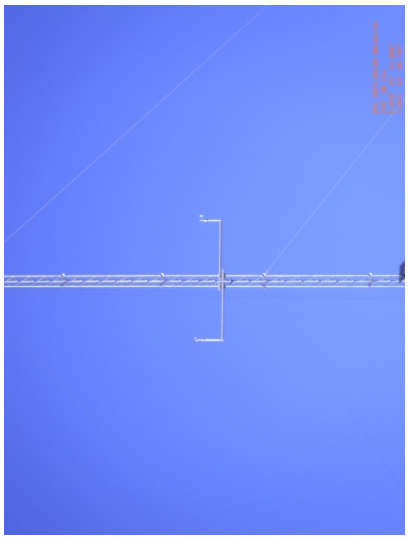
Figure 10. Wind rose and wind speed distribution for WM03 Vredendal at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

 060	 150
 030	 120
 000	 090

 240	 330
 210	 300
 180	 270

 2/4	 4/4 (bottom)
 1/4 (top)	 3/4

Tower Full View

WM04 Vredenburg

WM04	18.10922°E	32.84633°S	22 m	E 229440 m	N 6362045 m	UTM 34

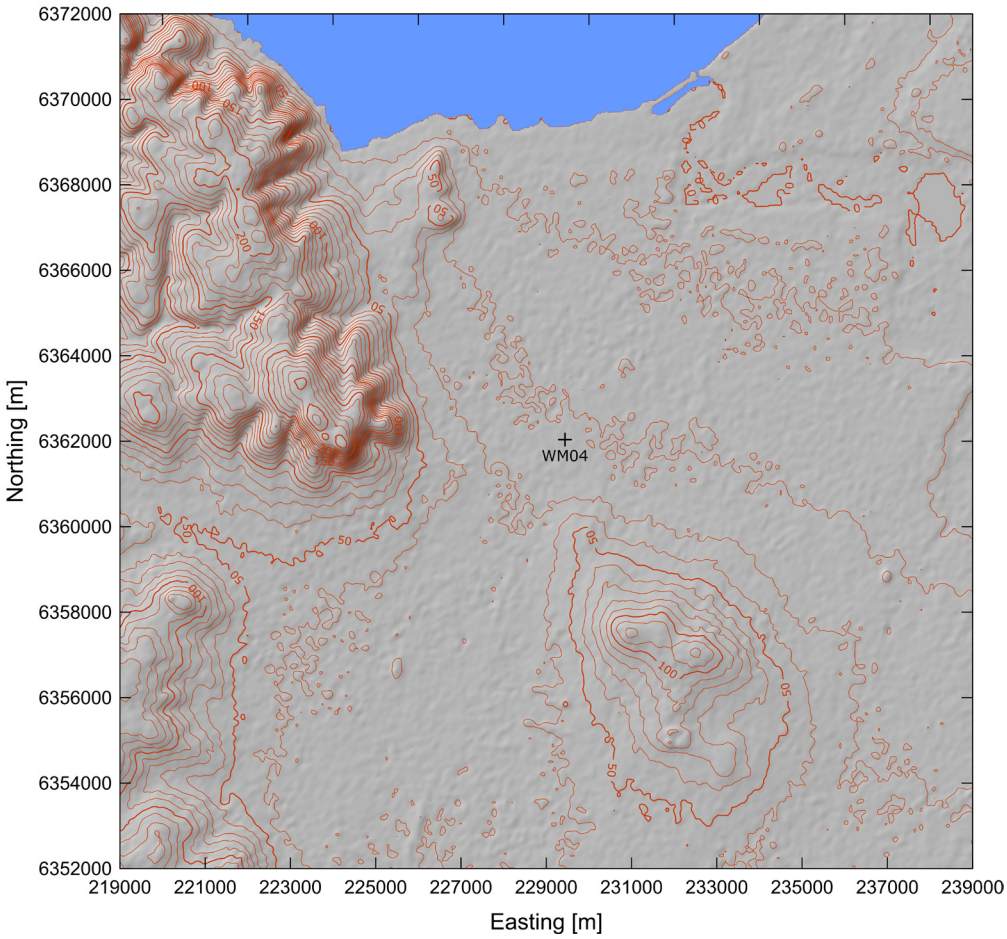


Figure 11. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 11. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM04	1.57	−23.4	−24.0	262	263	057

Table 12. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 04	61.85	60.45	40.24	20.12	10.39	0.05

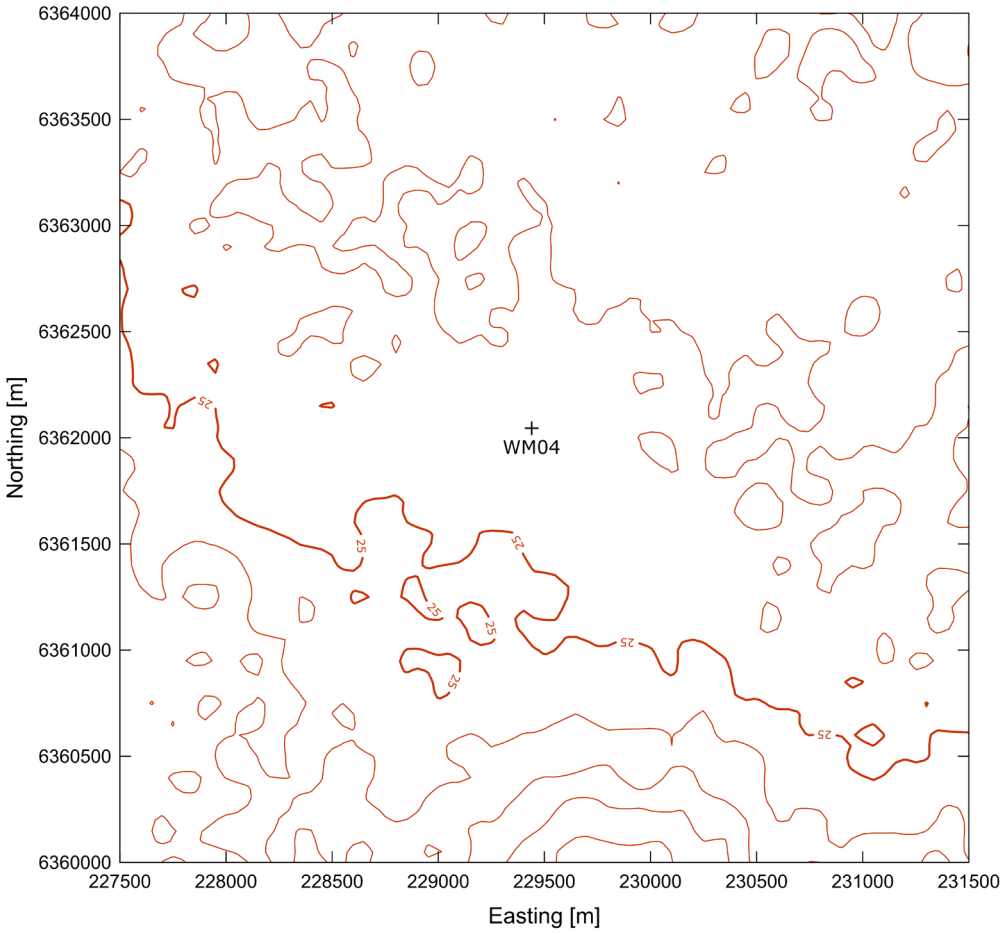


Figure 12. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

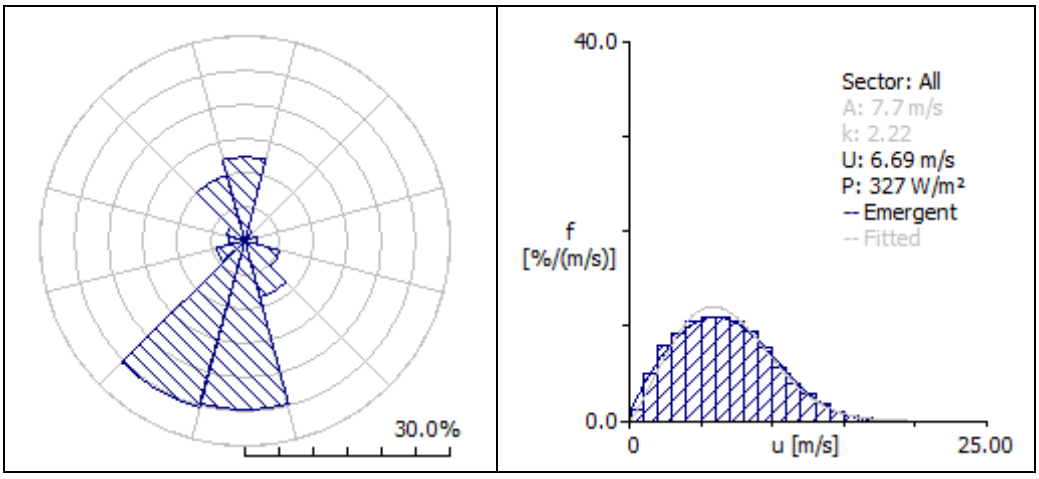
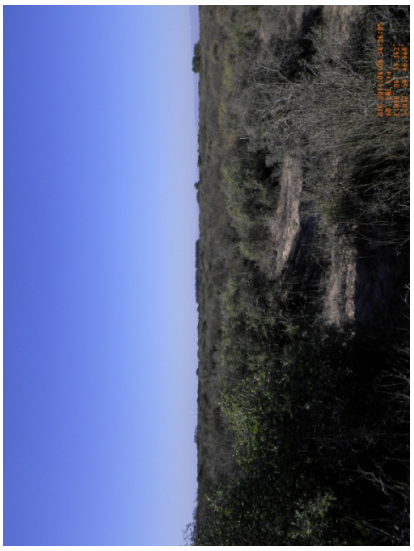
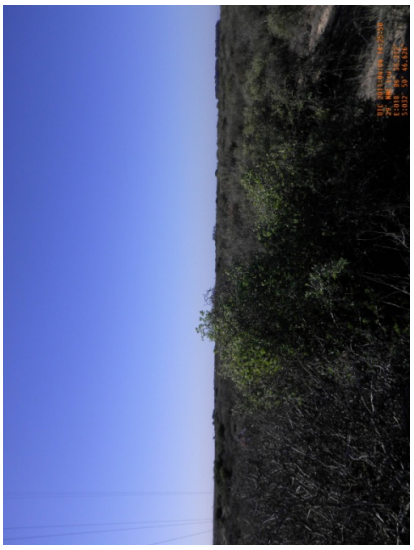
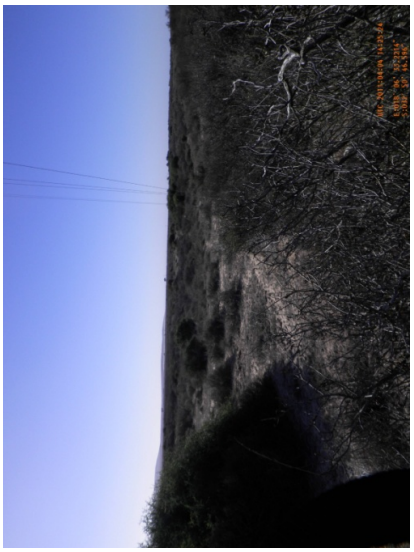
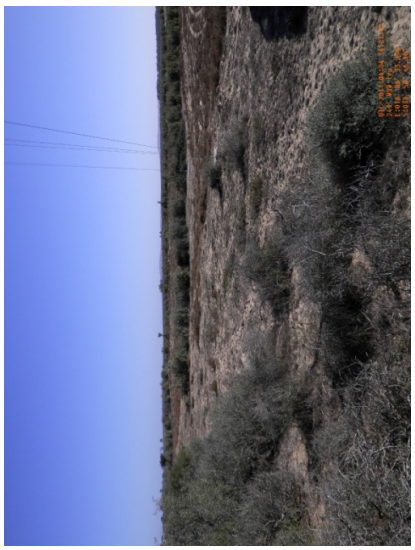
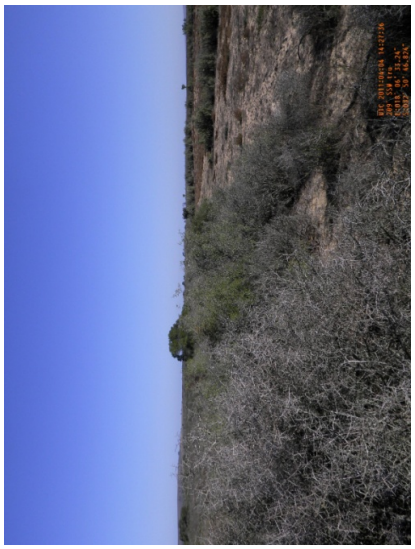


Figure 13. Wind rose and wind speed distribution for WM04 Vredenburg at 62 m a.g.l. The data shown represent a 3-year period from June 2010 to May 2013.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

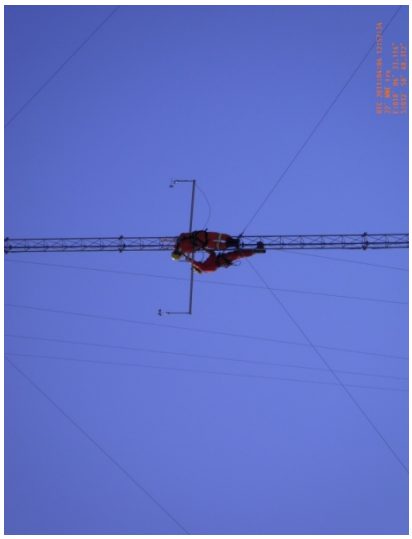
 060	 150
 030	 120
 000	 090

 240	 330
 210	 300
 180	 270

2/4

4/4 (bottom)

1/4 (top)



3/4

Tower Full View

WM05 Napier

WM05	19.69245°E	34.61192°S	288 m	E 380119 m	N 6169216 m	UTM 34

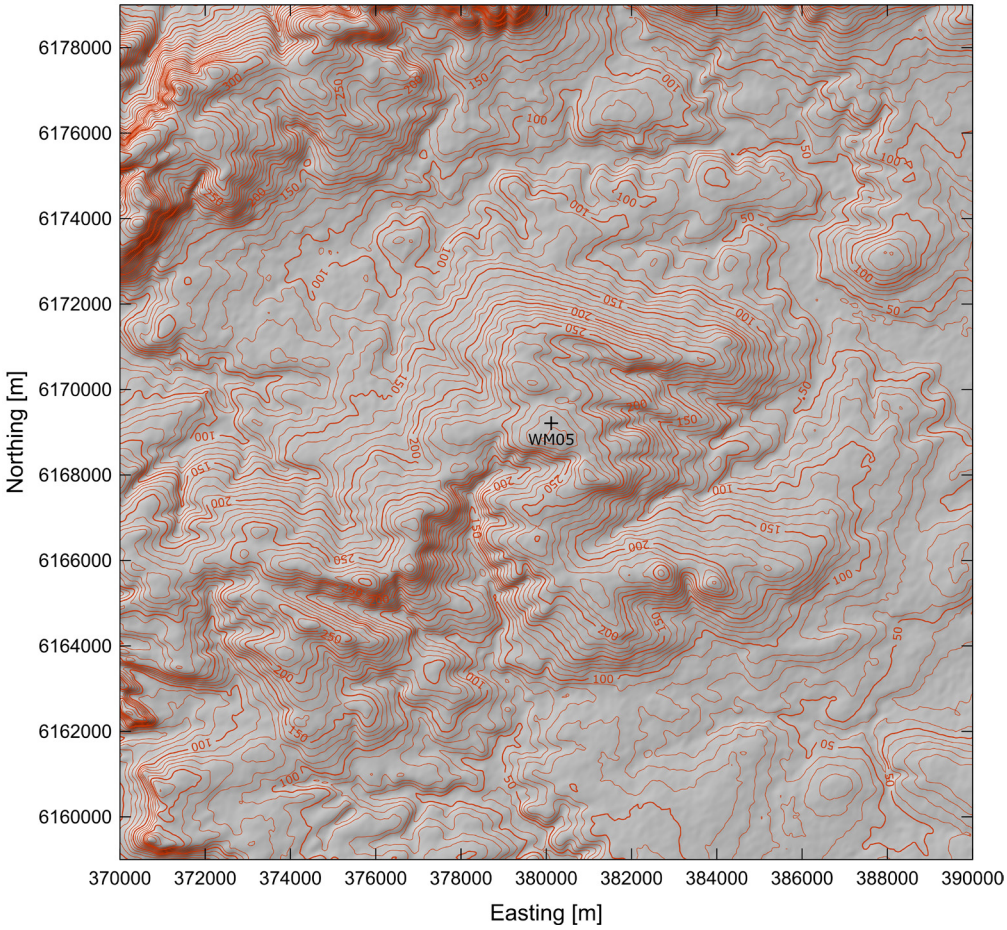


Figure 14. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 13. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM05	0.74	−26.0	−25.0	181	182	305

Table 14. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 05	61.85	60.51	40.38	20.31	10.25	0.05

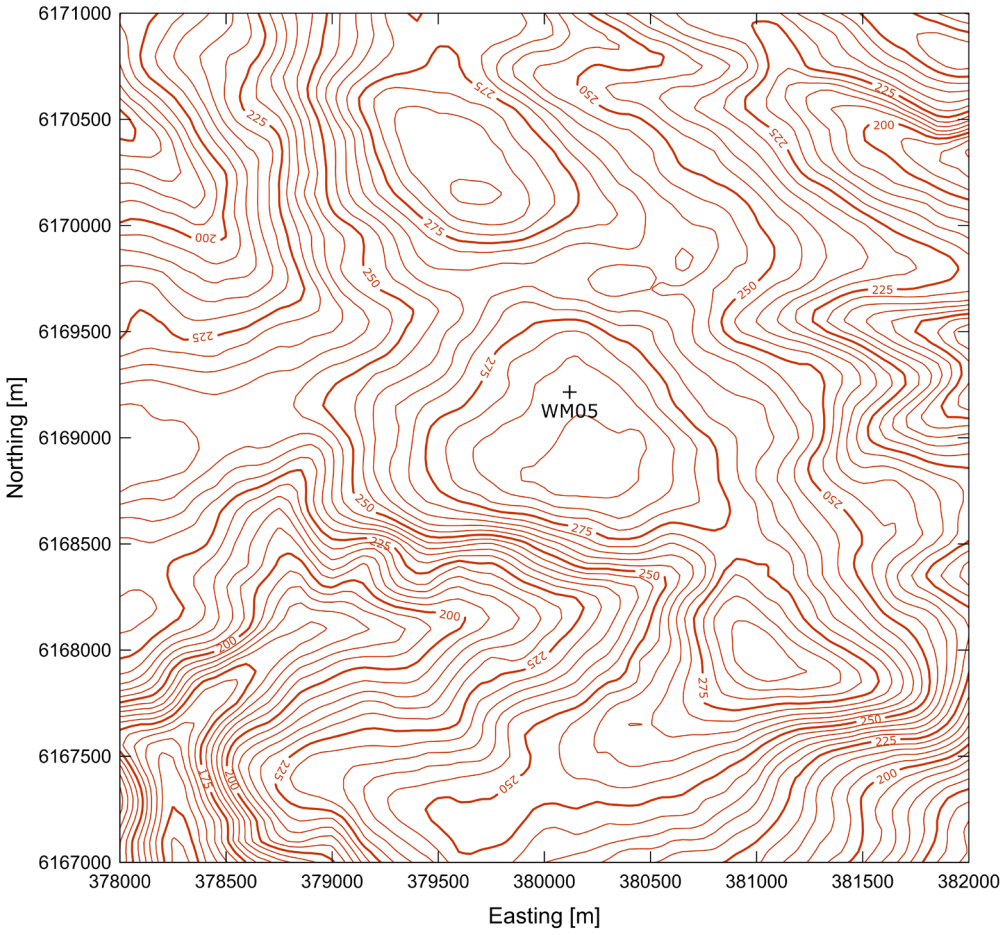


Figure 15. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

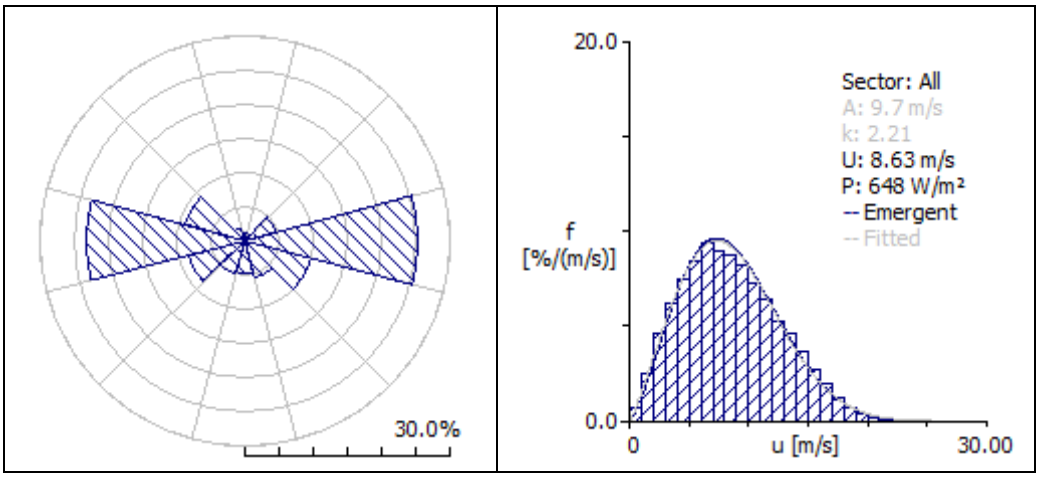
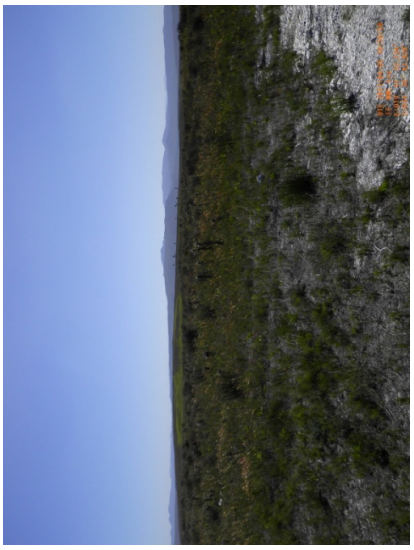
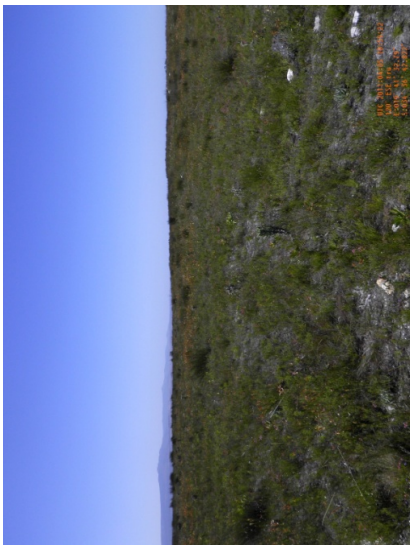
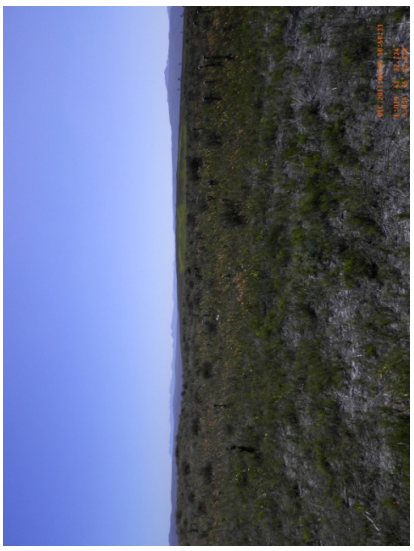
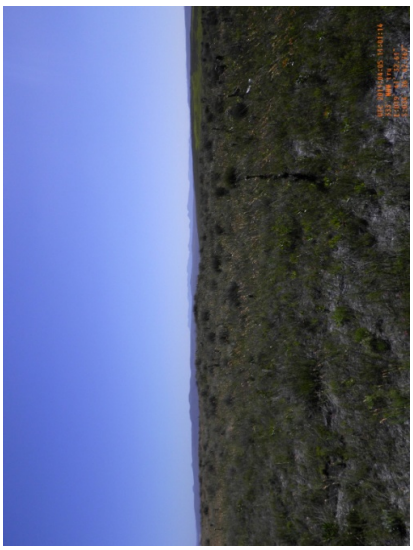
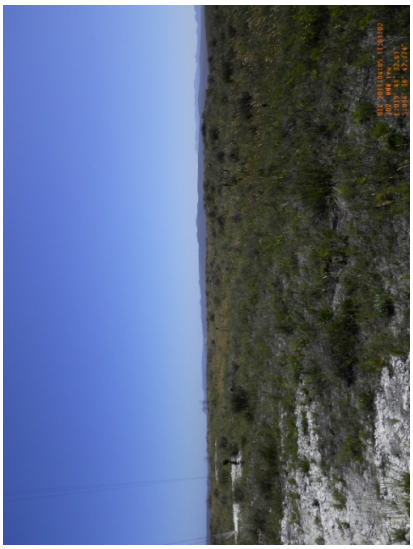


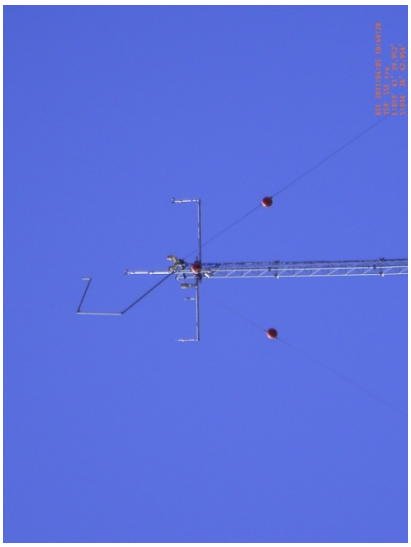
Figure 16. Wind rose and wind speed distribution for WM05 Napier at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

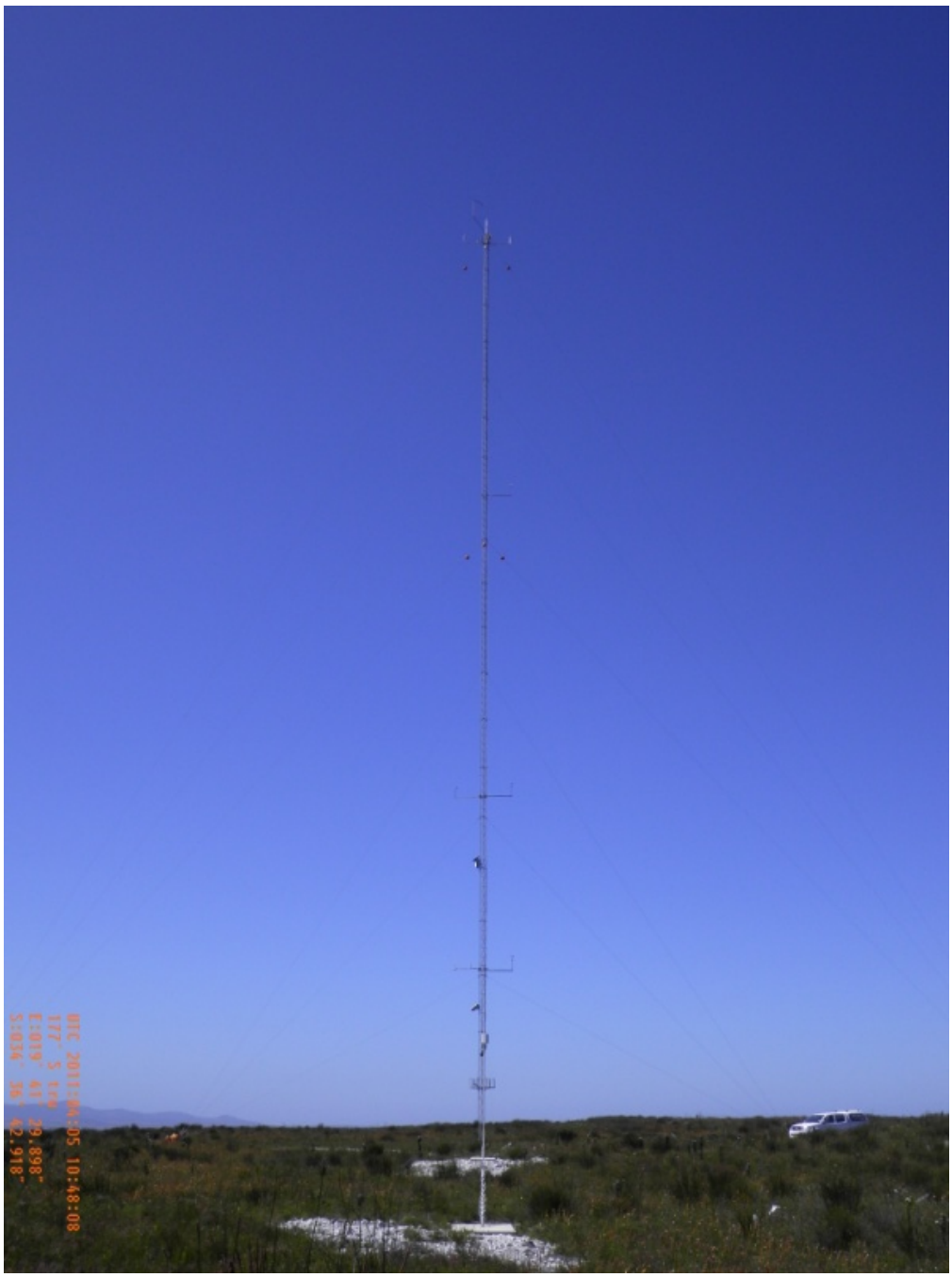
Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

 060	 150
 030	 120
 000	 090

 240	 330
 210	 300
 180	 270

2/4	 4/4 (bottom)
 1/4 (top)	 3/4



Tower Full View

WM06 Sutherland

WM06	20.69124°E	32.55680°S	1581 m	E 471014 m	N 6397803 m	UTM 34

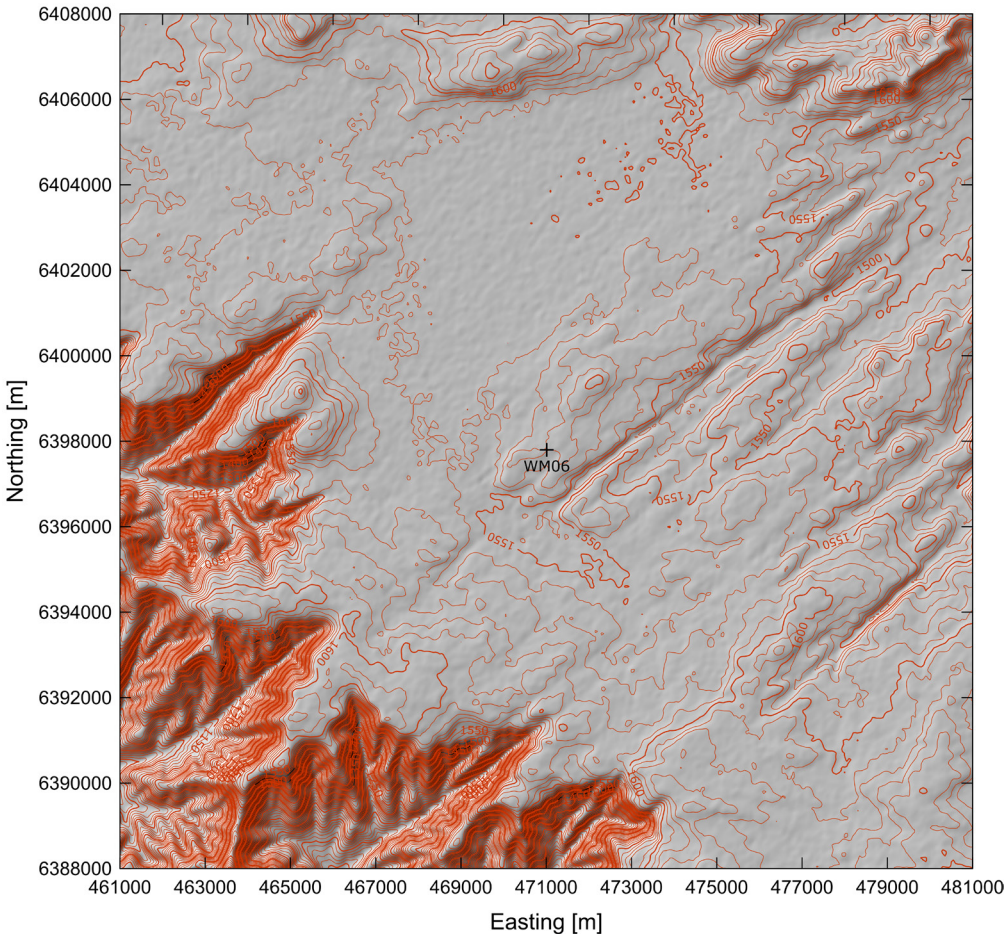


Figure 17. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 15. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM06	0.17	−24.9	−22.7	356	357	105

Table 16. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 06	61.85	60.23	40.27	20.22	10.11	0.05

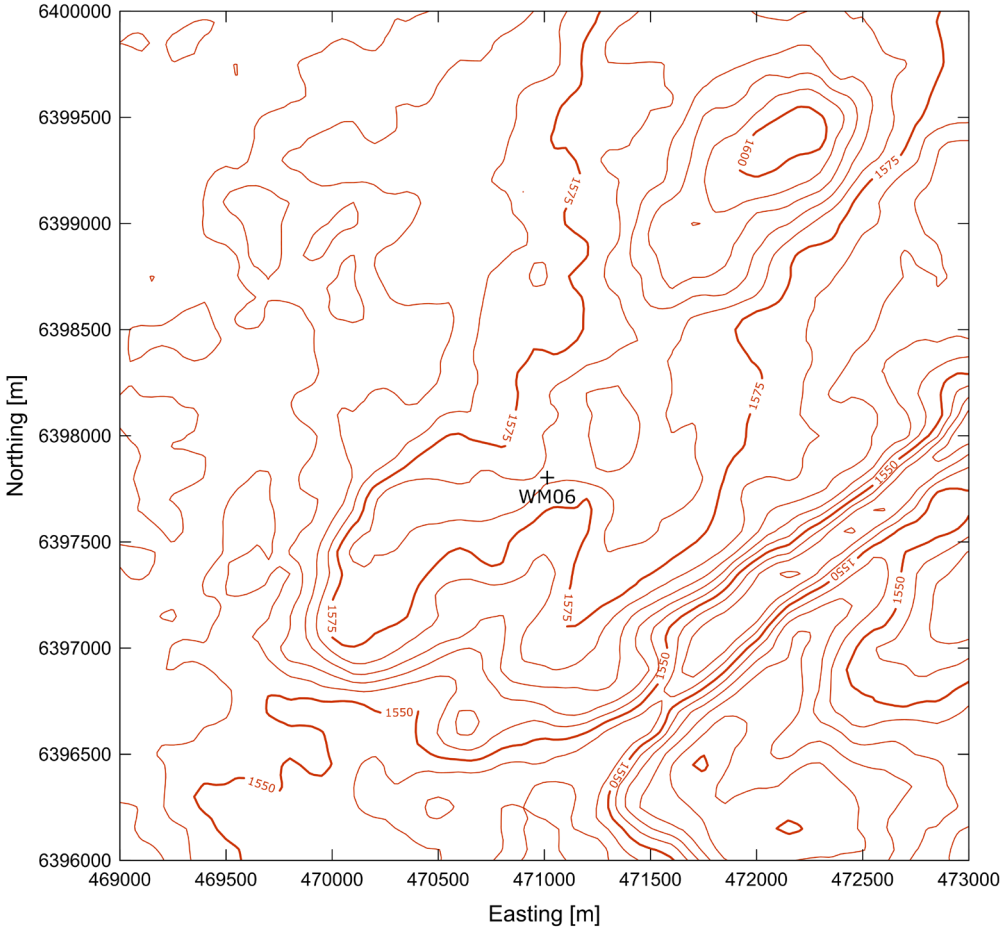


Figure 18. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

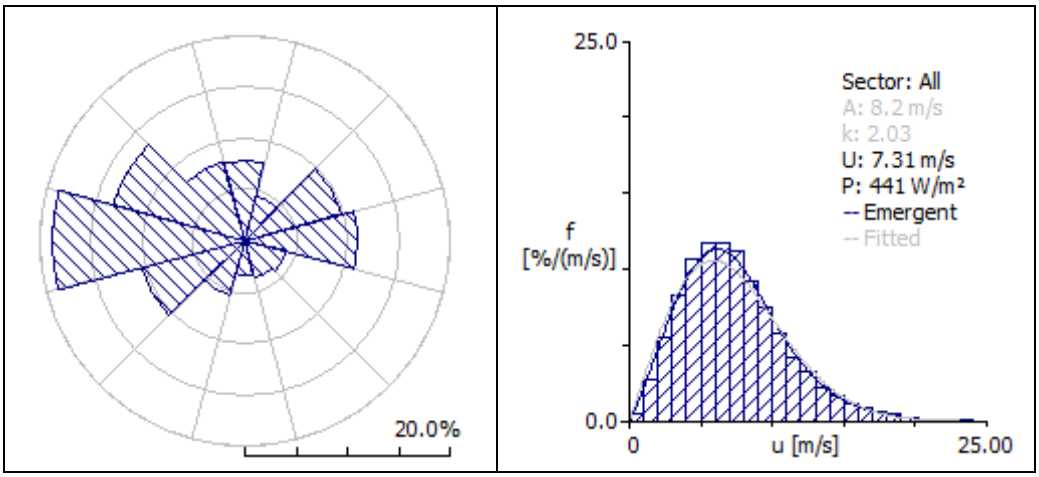


Figure 19. Wind rose and wind speed distribution for WM06 Sutherland at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

060

150

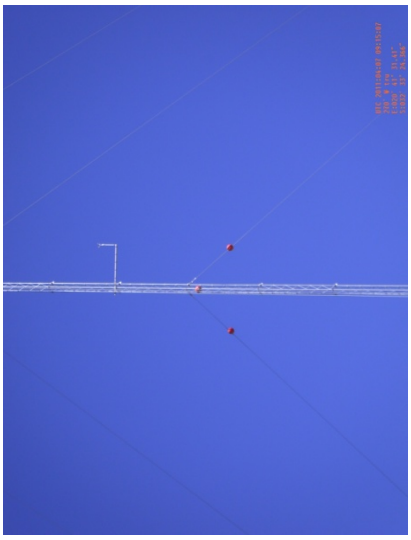
030

120

000

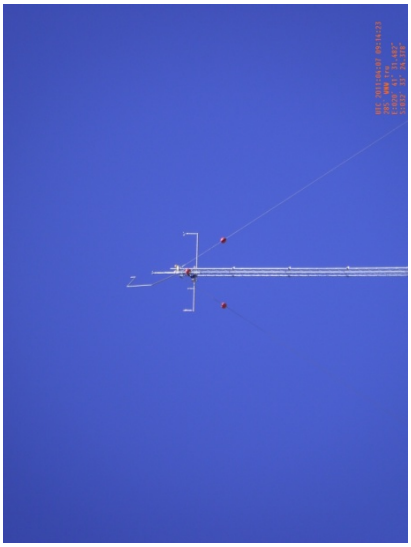
090

 240	 330
 210	 300
 180	 270



2/4

4/4 (bottom)



1/4 (top)

3/4

Tower Full View

WM07 Beaufort West

WM07	22.55667°E	32.96672°S	1047 m	E 645480 m	N 6351327 m	UTM 34

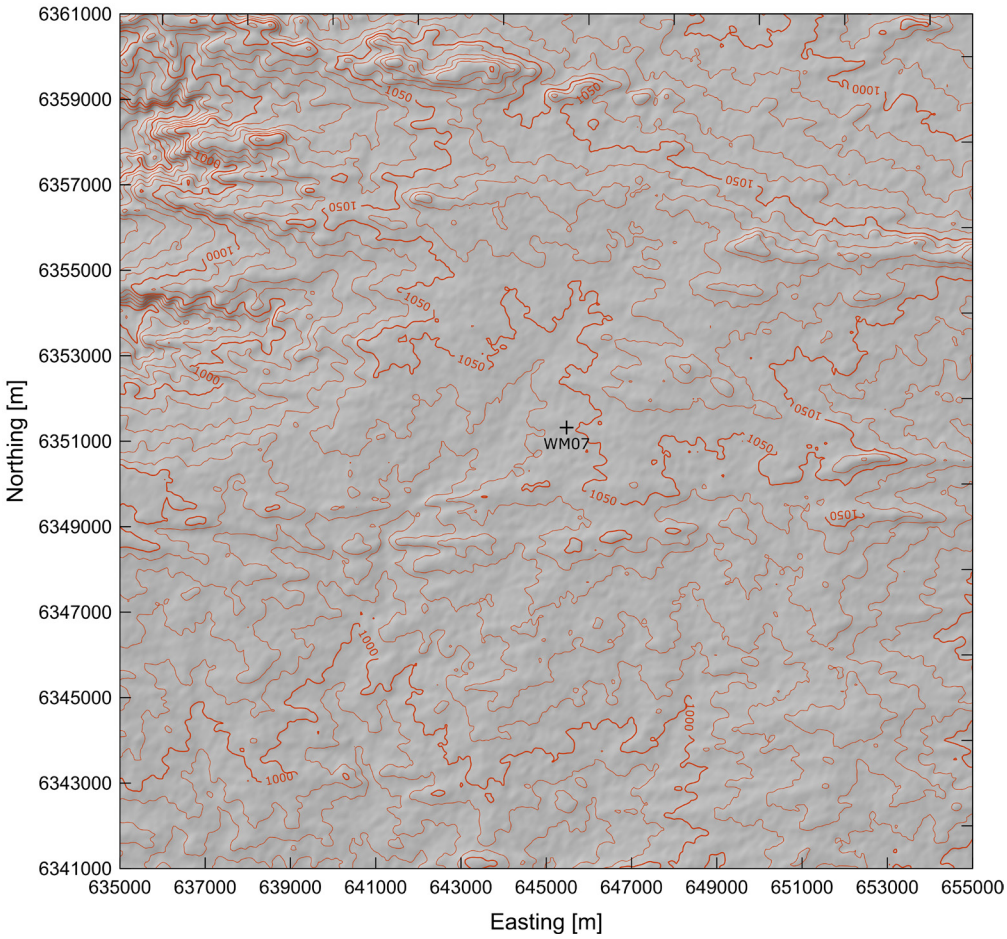


Figure 20. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 17. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM07	−0.85	−26.1	−23.7	134	134	327

Table 18. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 07	61.85	60.33	40.22	20.20	10.12	0.05

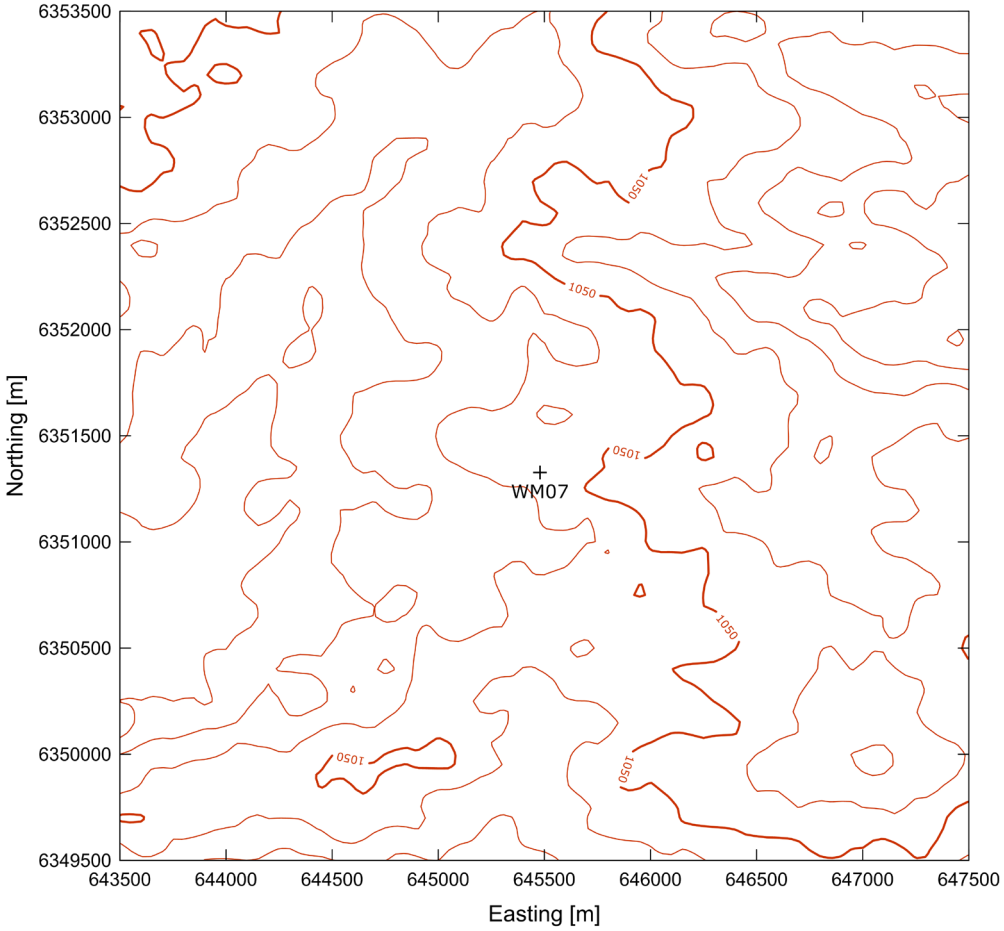


Figure 21. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

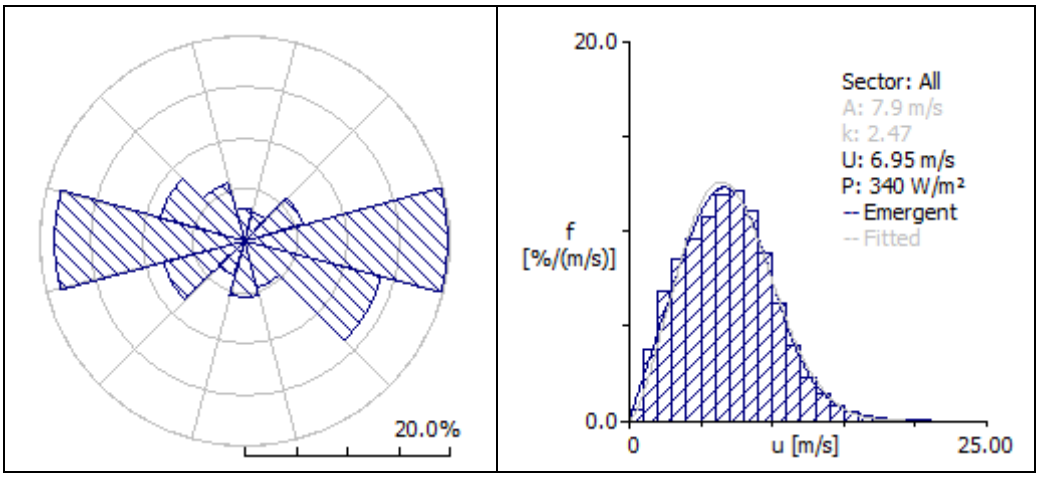
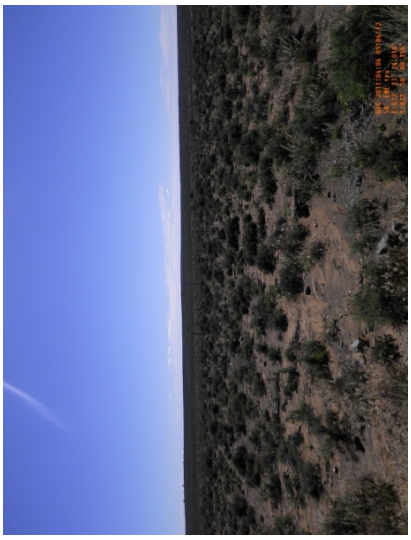


Figure 22. Wind rose and wind speed distribution for WM07 Beaufort West at 62 m a.g.l. The data shown represent a 3-year period from October 2010 to September 2013.

Sector photographs

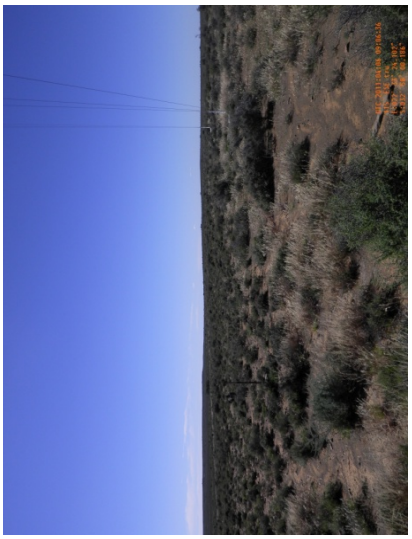
The sector photographs on the following two pages refer to magnetic directions.



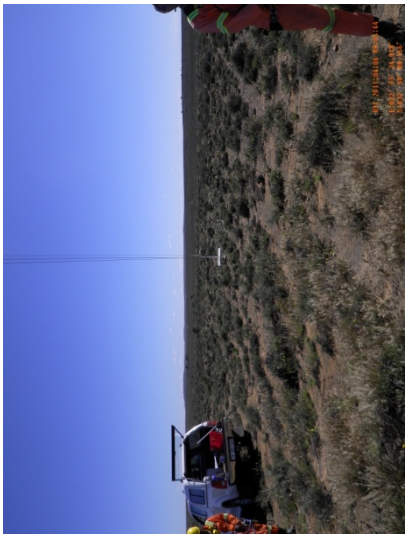
060

150

030

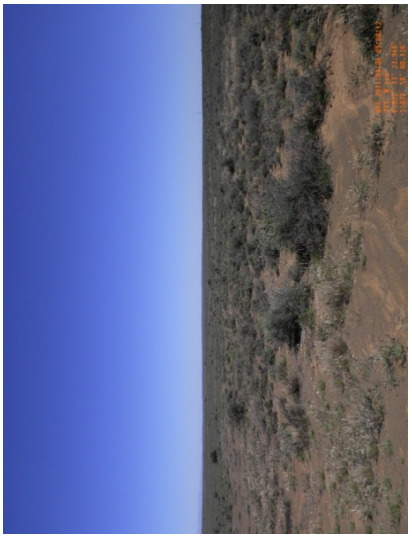


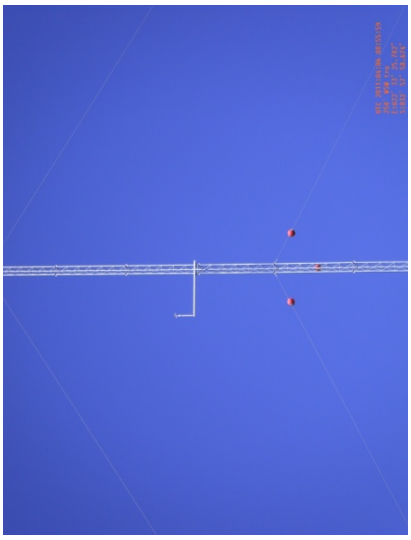
120



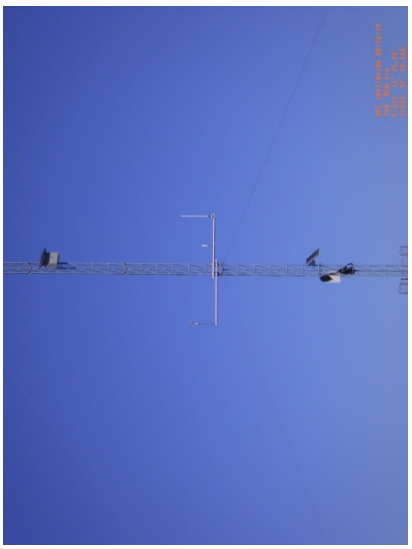
000

090

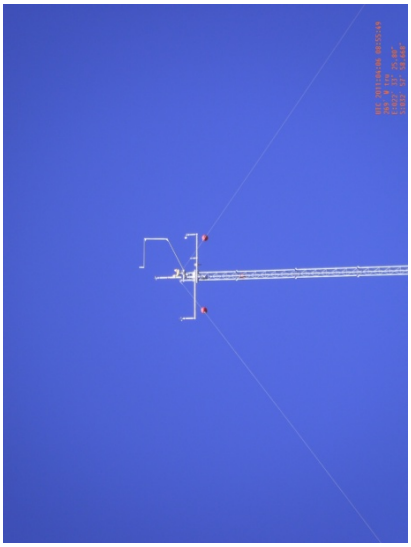
 240	 330
 210	 300
 180	 270



2/4



4/4 (bottom)



1/4 (top)

3/4

Tower Full View

WM08 Humansdorp

WM08	24.51436°E	34.10997°S	110 m	E 270726 m	N 6222861 m	UTM 35

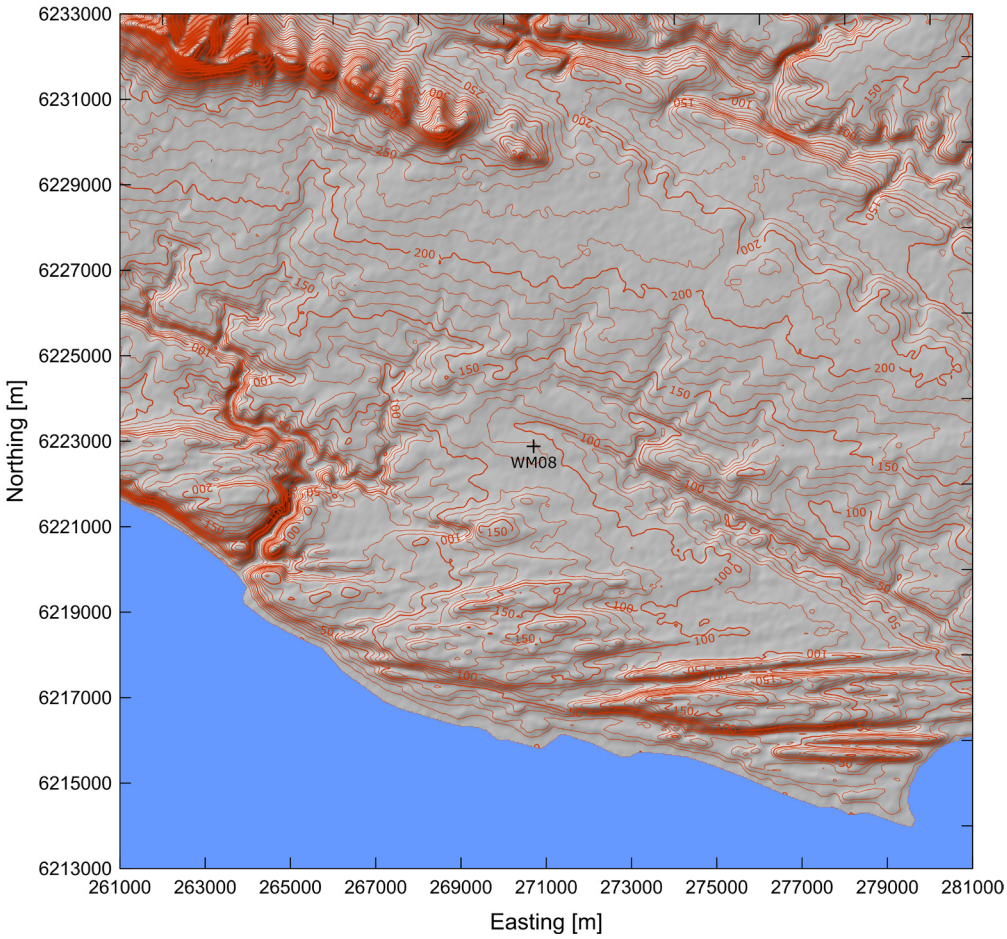


Figure 23. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 19. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM08	1.39	−29.6	−26.7	138	138	057

Table 20. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 08	61.84	60.94	37.17	20.13	10.15	0.12

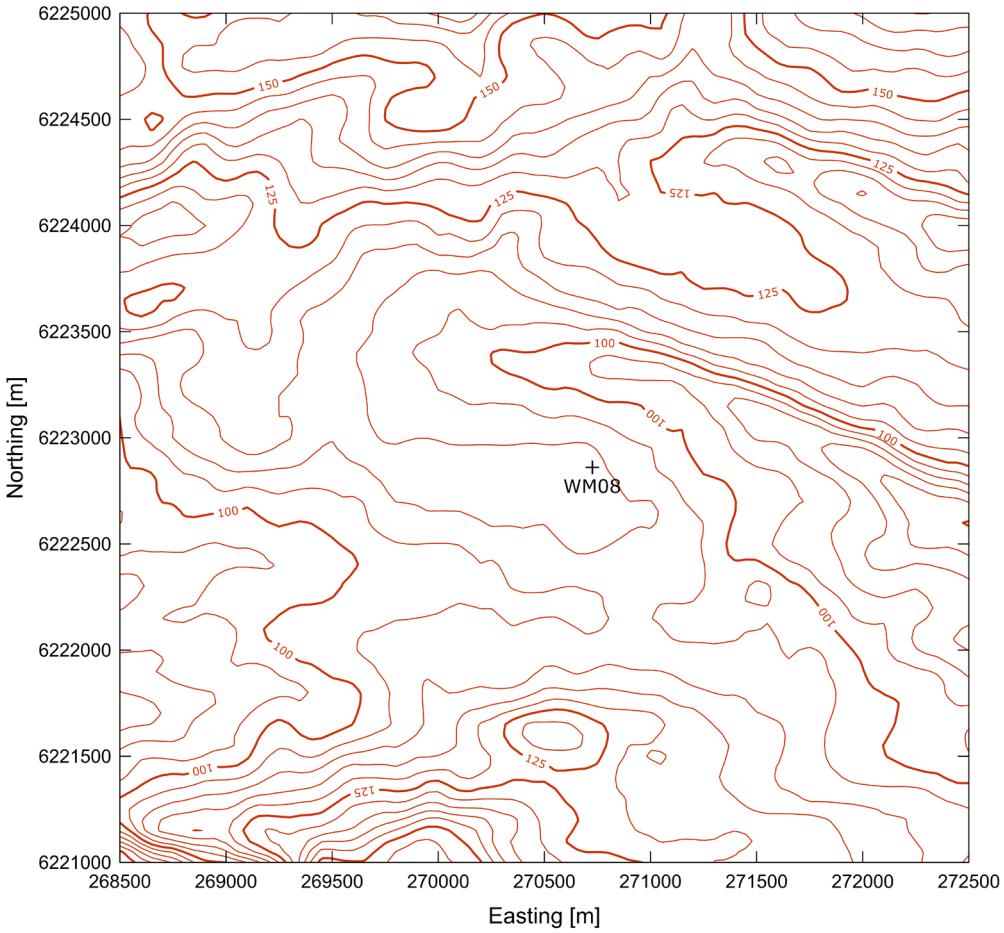


Figure 24. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

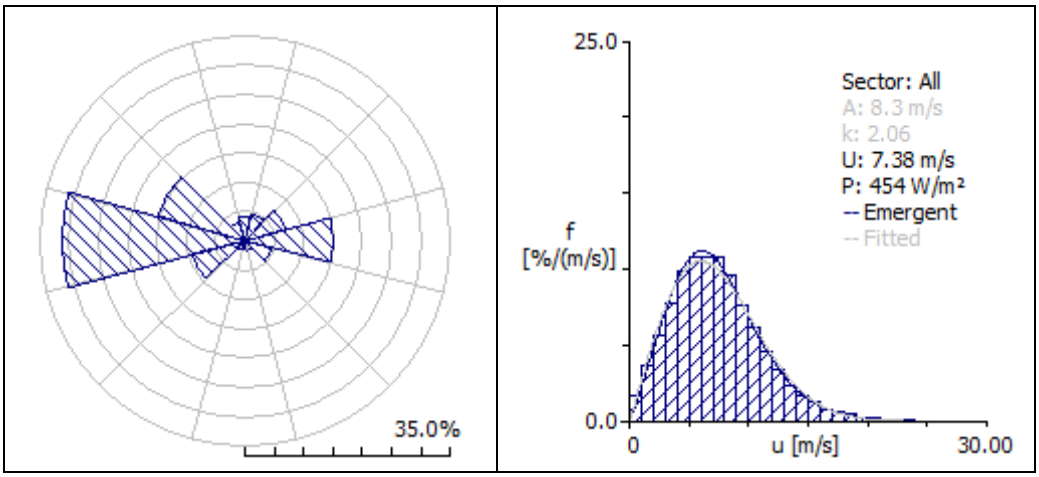
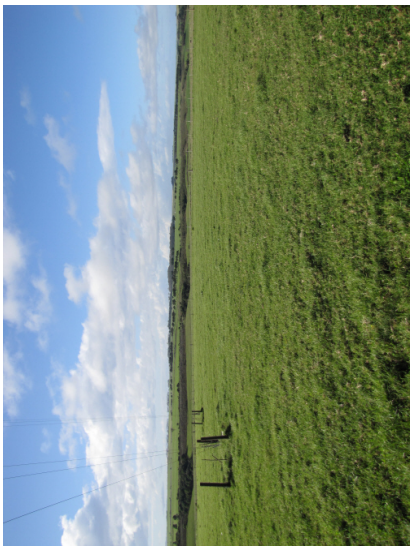


Figure 25. Wind rose and wind speed distribution for WM08 Humansdorp at 62 m a.g.l. The data shown represent a 2-year period from October 2010 to September 2012.

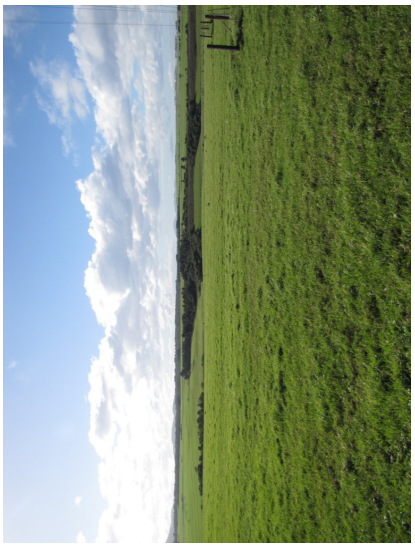
Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

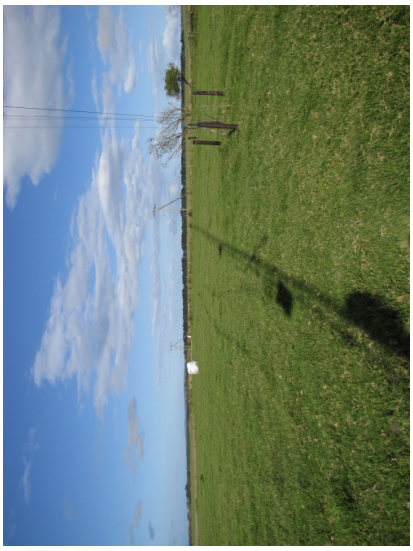


090

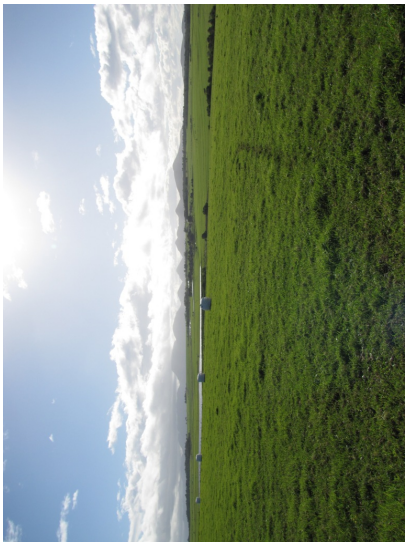
225



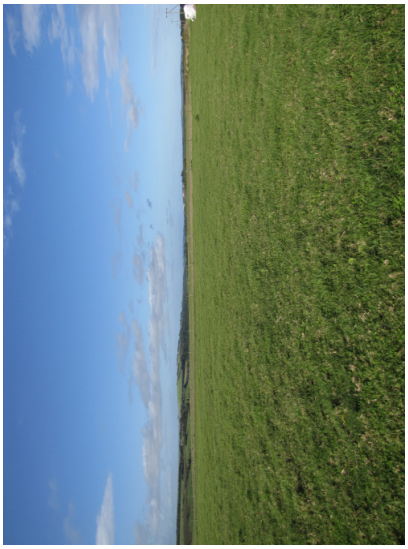
045



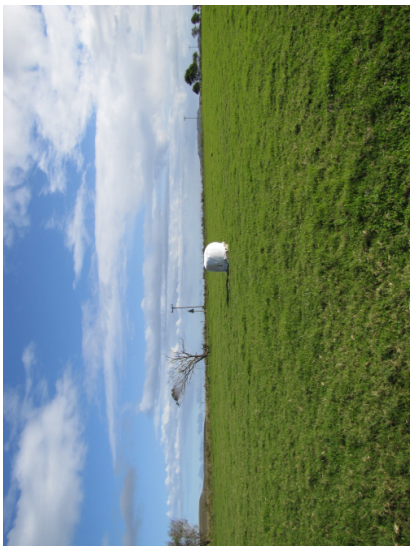
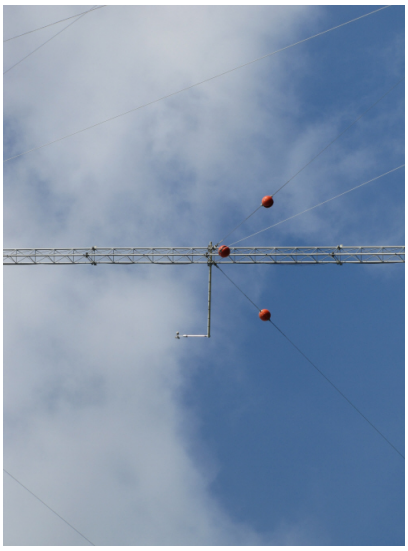
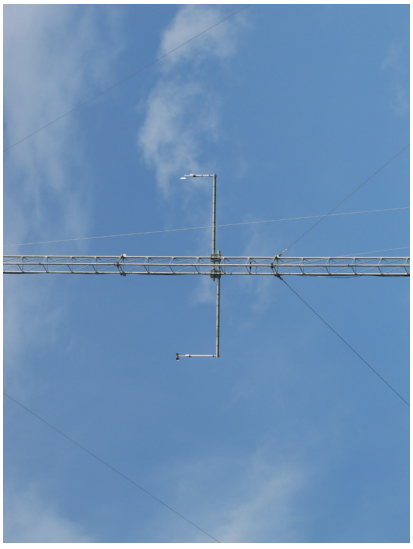
180



000



135

 270	 315
 2/4	 4/4 (bottom)
 ¼ (top)	 3/4

Tower Full View

WM09 Noupoort

WM09	25.02838°E	31.25254°S	1806 m	E 312258 m	N 6540734 m	UTM 35

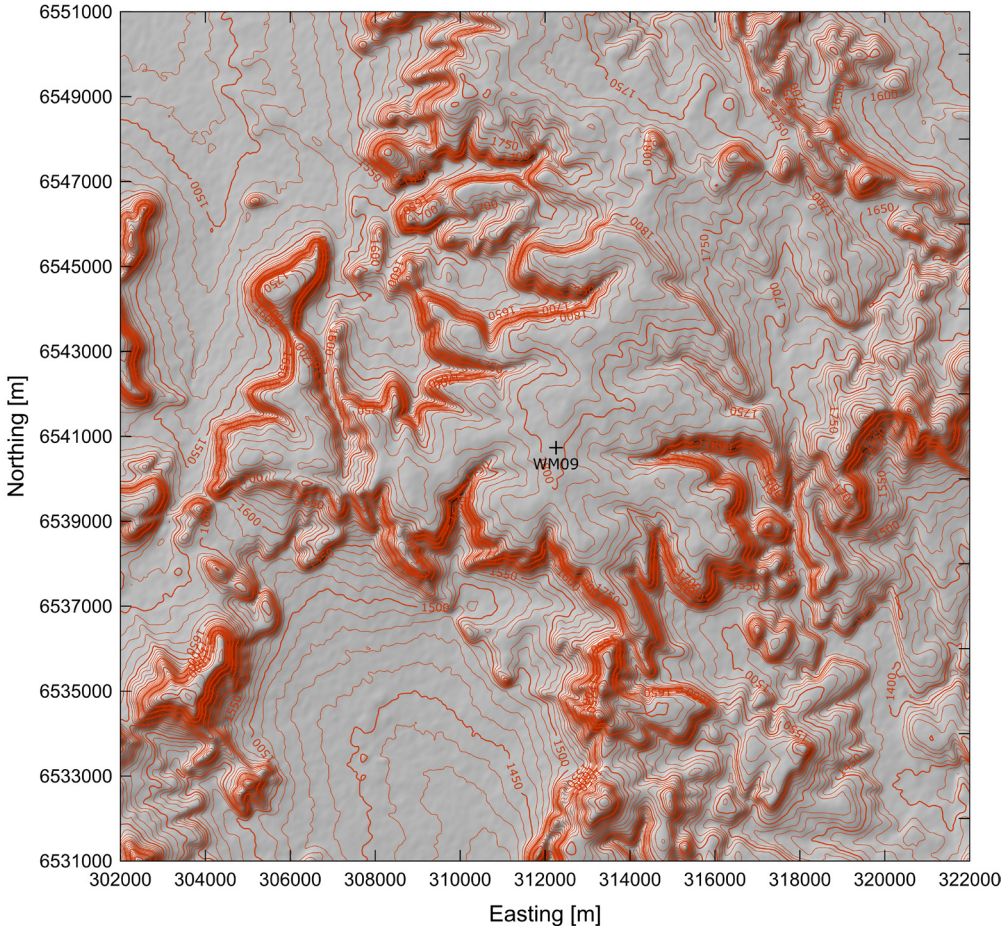


Figure 26. Elevation map from SRTM3 data, covering 20×20 km^2, with 10-m contours. The ruggedness index for the site is 4.0%.

Site and mast characteristics

Table 21. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM09	1.02	−24.9	−24.6	245	246	177

Table 22. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 09	61.80	60.26	39.24	19.89	10.15	0.13

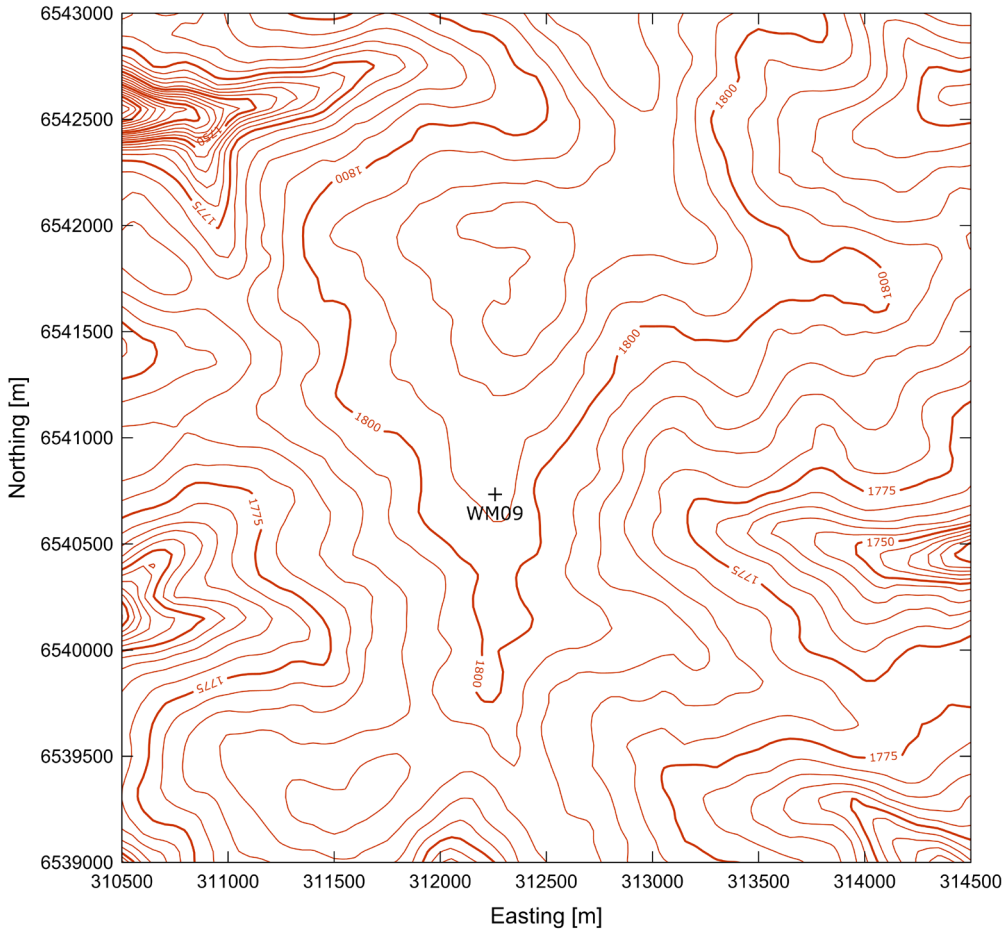


Figure 27. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

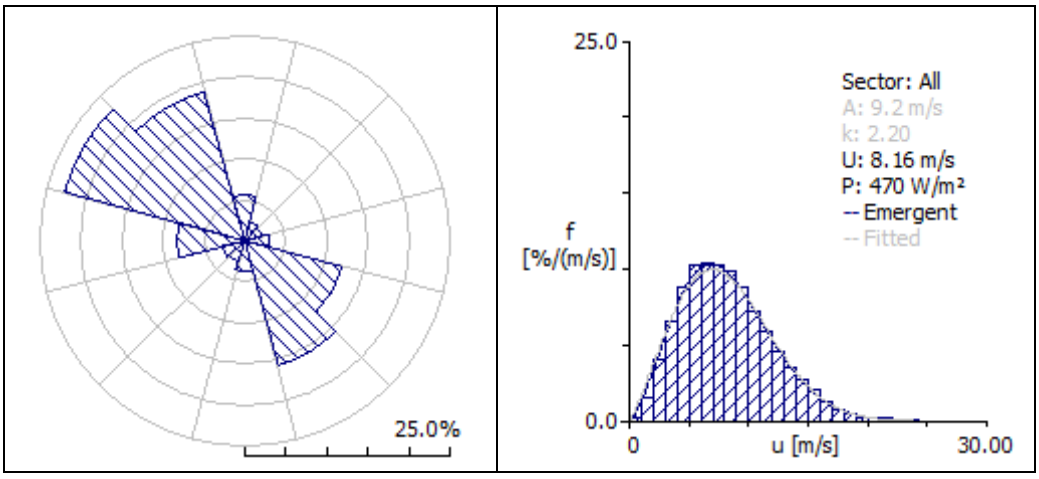
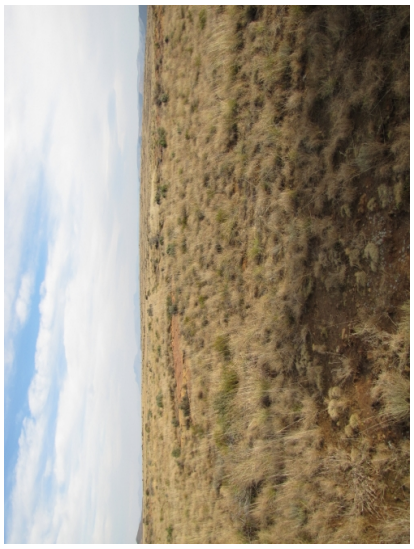
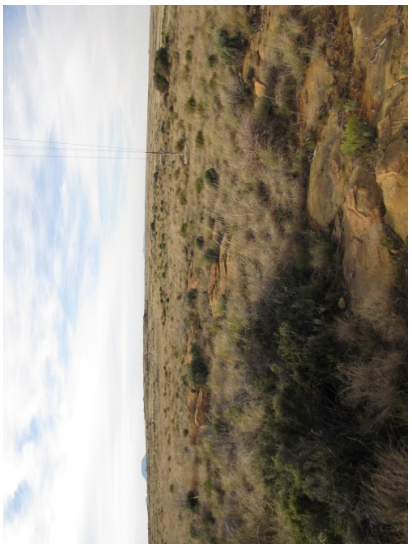
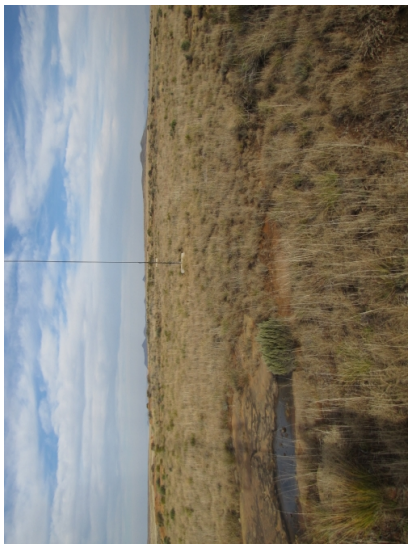


Figure 28. Wind rose and wind speed distribution for WM09 Noupoort at 62 m a.g.l. The data shown represent a 2-y period from Oct 2010 to Sep 2013 – less the year 2011.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions.

 090	 225
 045	 180
 000	 135

270

315

2/4

4/4 (bottom)

1/4 (top)

3/4

Tower Full View

WM10 Butterworth

WM10	28.13595°E	32.09065°S	925 m	E 607194 m	N 6448952 m	UTM 35

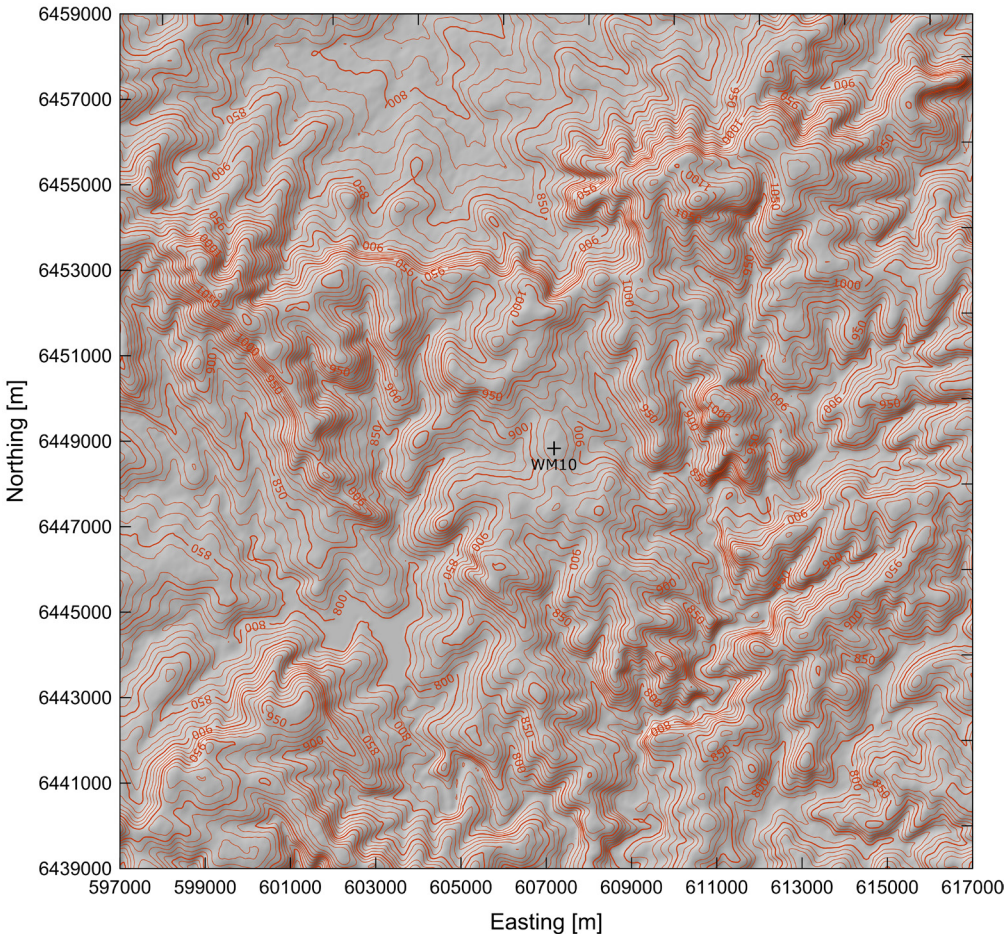


Figure 29. Elevation map from SRTM3 data, covering 20×20 km^2, with 20-m contours. The ruggedness index for the site is 0%.

Site and mast characteristics

Table 23. Convergence, magnetic declination, cup boom and lightning rod directions.

Mast ID	Meridian converg.	Declination (measured)	Declination (NGI)	Boom (meas.)	Boom (logger)	Lightning rod
	[°]	[°]	[°]	[°] (true)	[°] (true)	[°] (true)
WM10	−0.60	−28.9	−25.8	203	203	349

Table 24. Anemometer heights above mast foundation and foundation height.

Mast ID	Level ‘62’	Level ‘60’	Level ‘40’	Level ‘20’	Level ‘10’	ΔTerrain
	[m]	[m]	[m]	[m]	[m]	[m]
WM 10	61.85	60.80	40.23	20.09	10.08	0.04

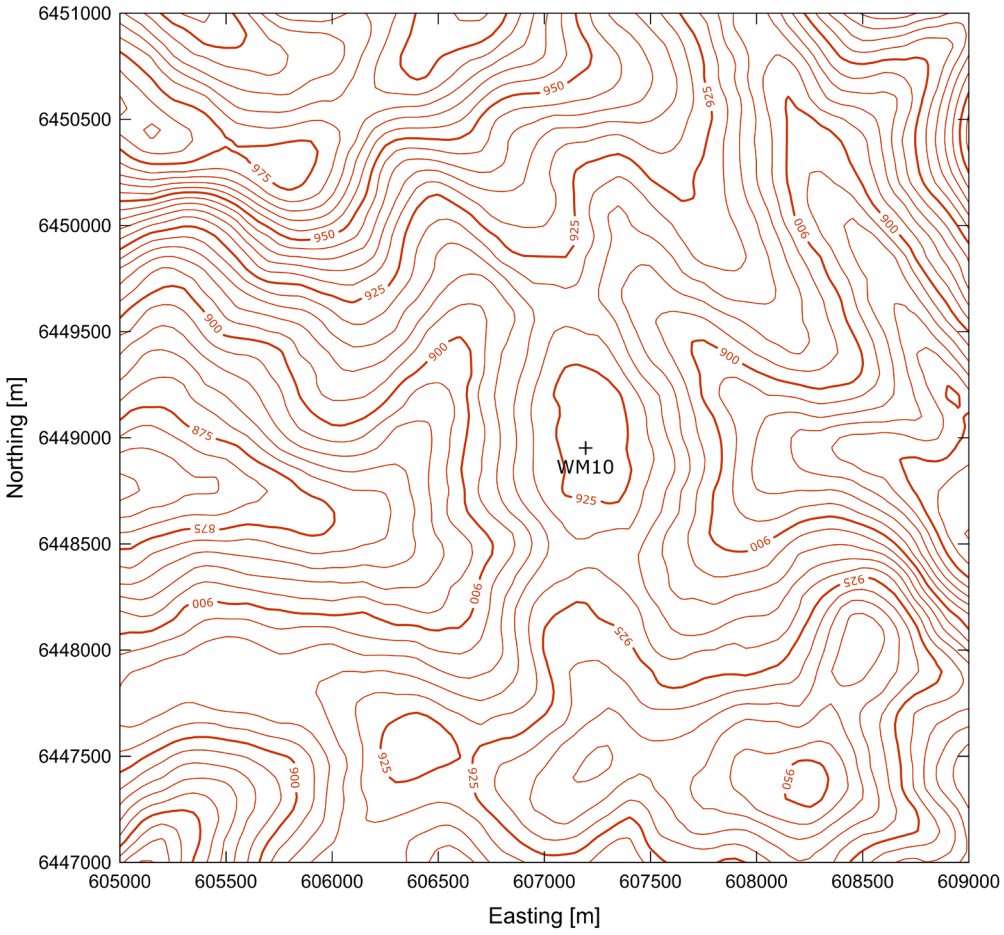


Figure 30. Elevation map from SRTM3 data, covering 4×4 km^2, with 5-m contours.

Observed wind climate

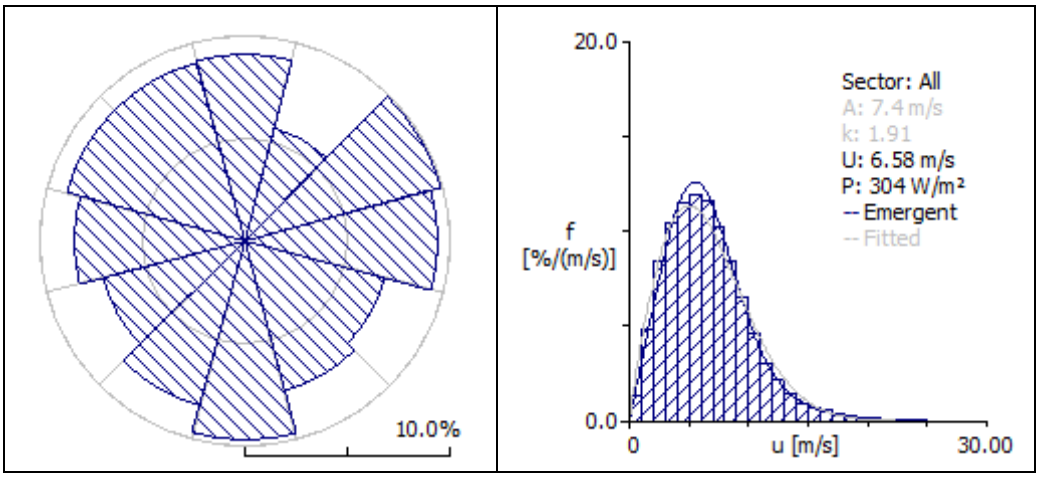


Figure 31. Wind rose and wind speed distribution for WM10 Butterworth at 62 m a.g.l. The data represent a 2-y period from Mar 2011 to Feb 2012 and Oct 2012 to Sep 2013.

Sector photographs

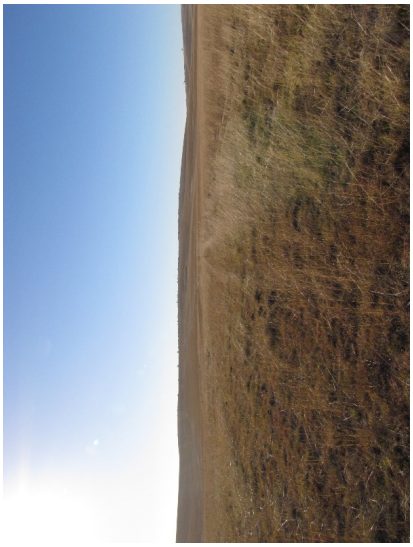
The sector photographs on the following two pages refer to magnetic directions.

090

225

045

180

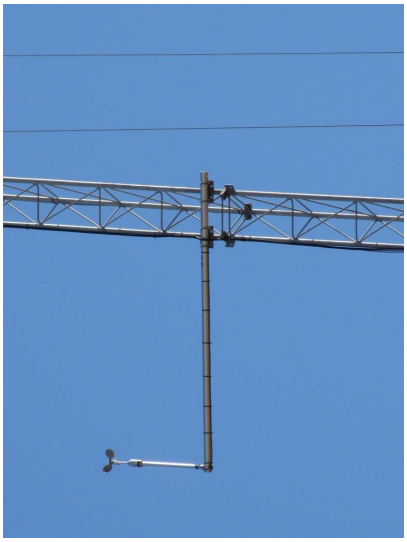


000

135

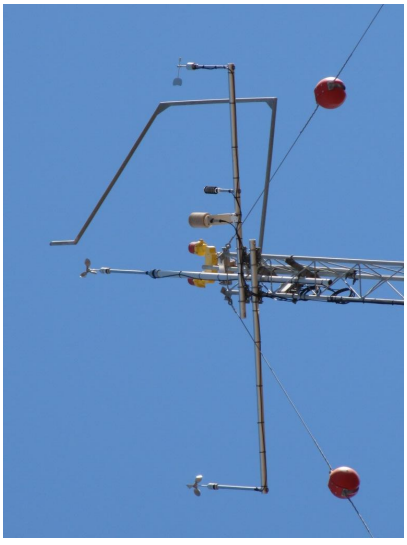
270

315



2/4

4/4 (bottom)



1/4 (top)

3/4

Tower Full View

C Mast design

The original mast design and arrangement of instruments is shown in Figure 32. Actual anemometer heights and boom directions for each mast are given in the present report.

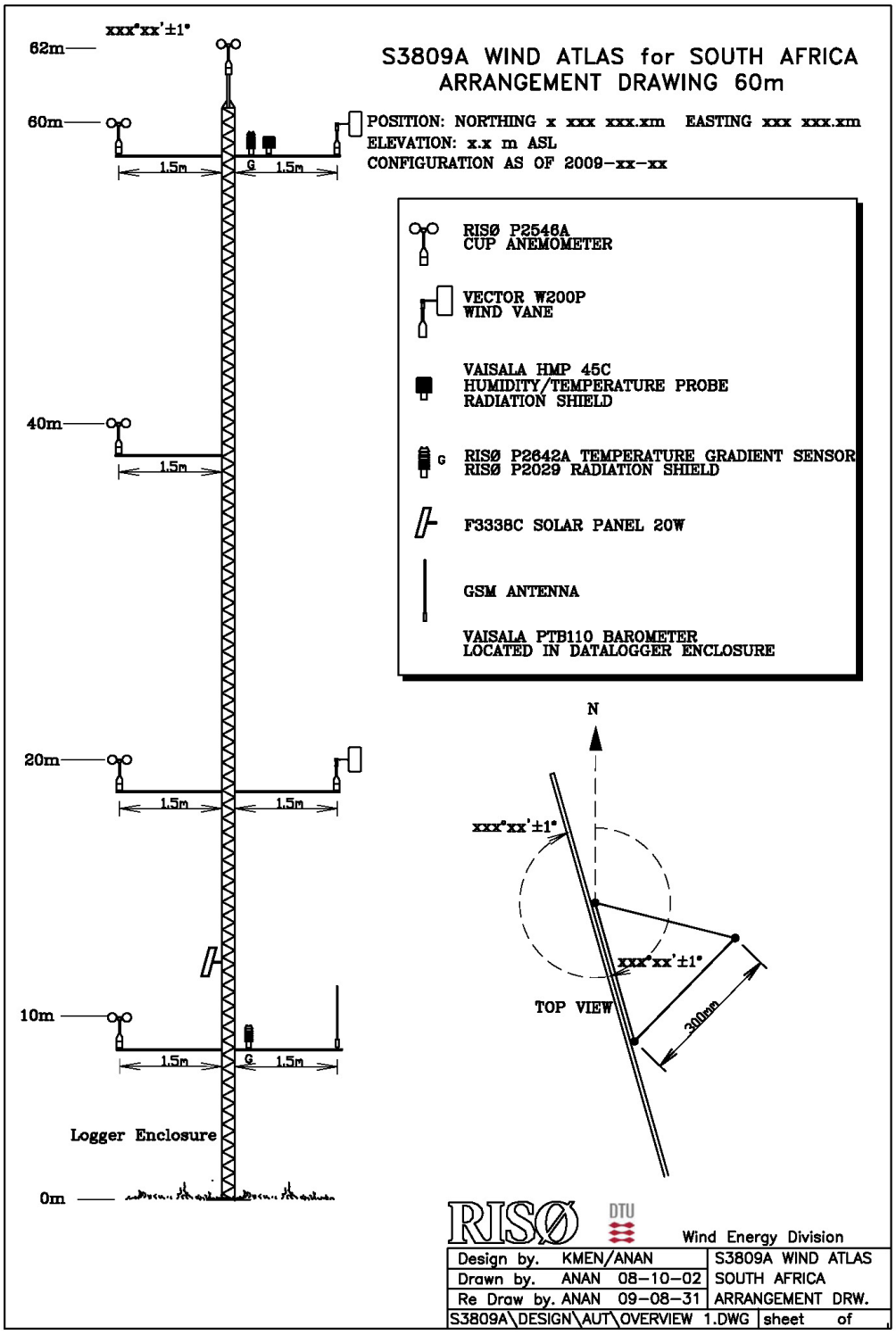


Figure 32. Mast design and arrangement drawing (Anker B. Andersen, pers. comm.)