Wind Atlas for South Africa (WASA)

Northern Cape Province

Station and Site Description Report for Four Meteorological Masts in the Northern Cape Province

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Abstract As part of the “Wind Atlas for South Africa Phase 3” project, site inspections were carried out by the Council for Scientific and Industrial Research (CSIR) and DTU Wind Energy in October of 2019. Observers from the South African National Energy Development Institute (SANEDI),the Department of Mineral Resources & Energy (DMRE) as well as two observers from the United Nations Development Programme (UNDP) also attended.. Two sites featuring instrumented 60-m masts were visited; the present report summarises the findings of the site inspection teams. The results from the other two sites (Pofadder and Strydenburg) were recorded during the same inspection trip, but only carried out by CSIR personnel. The main results are descriptions and documentation of the meteorological masts, the measurement and recording instruments and the site conditions. For each site, the location and magnetic declination have been determined, as well as the instrument boom directions on the mast. Elevation maps have been constructed to show the surrounding terrain and photos taken to document the land cover. The observed wind rose and wind speed distribution is to be calculated after a full year’s data has been recorded.

WASA Station and Site Description Report for four meteorological masts in the Northern Cape Province

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1 Introduction

As part of the “Wind Atlas for South Africa Phase 3” project, a site inspection trip was carried out by the Council for Scientific and Industrial Research (CSIR) to all four instrumented 60-m WASA 3 masts during 8 – 12 October 2019, with DTU Wind Energy, SANEDI and the DMRE joining on 10 and 11 October, visiting masts WM19 and WM18 on the respective dates. Figure 1.1 shows the positions and names of the nine WASA 1 and five WASA 2 mast positions, with the four WASA 3 masts featuring in the north-western part of the map below. Figure 1.2 shows the positions of the WASA 3 masts in more detail.

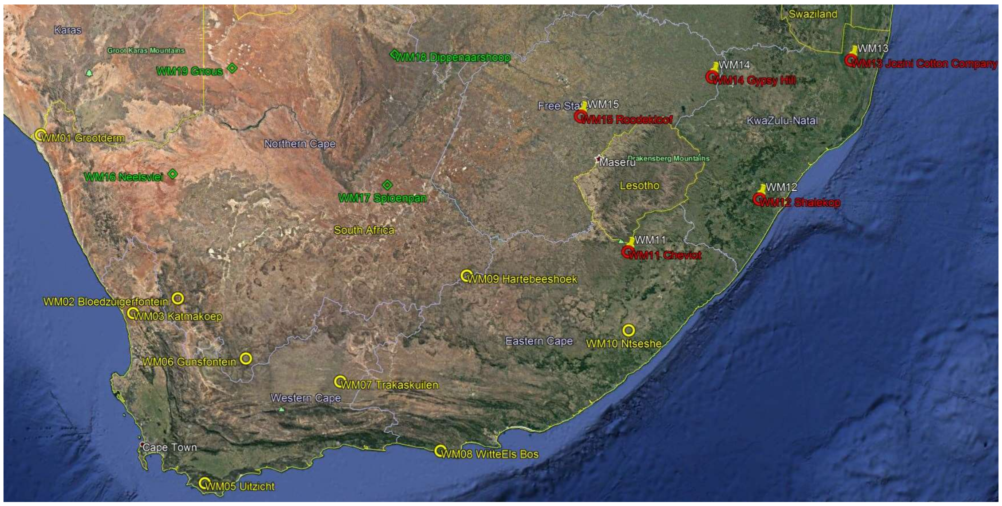


Figure 1.1: Overview map of the southern-most part of South Africa, showing the location of the 19 met. masts referred to in the text and the Wind Atlas for South Africa study area (Image © 2016 AfriGIS (Pty) Ltd., Data SIO, NOAA, US Navy, NGA, GEBCO, Image Landsat / Copernicus and Google Inc.).

Figure 1.2: Detailed map showing the four new meteorological masts referred to as WASA 3 (Image © 2016 AfriGIS (Pty) Ltd., Data SIO, NOAA, US Navy, NGA, GEBCO, Image Landsat / Copernicus 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 A0 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 four WASA 3 sites and in their surroundings.

2.1 Mast locations

The locations of the meteorological masts were determined using GPS receivers. One to three readings were taken (the latter corresponding approximately to the three legs of the mast) and averaged to find the location of the mast, see Table 2.1.

Table 2.1: Mast coordinates and elevations. The datum used is WGS 84; elevations are determined by the WAsP flow model from SRTM3 maps with 5-m height contours.

Mast ID	Longitude [°E]	Latitude [°S]	Elevation [m a.s.l.]	Easting [m]	Northing [m]	UTM zone
WM 16	19.357042	29.444360	1,073	340,654	6,741,658	34J
WM 17	23.519533	29.757876	1,196	743,631	6,705,384	34J
WM 18	23.655421	27.597376	1,478	762,101	6,944,582	34J
WM 19	20.568330	27.726700	848	457,450	6,932,997	34J

The terrain elevation of the mast sites were subsequently determined using height contour maps created for the WAsP flow modelling (Mortensen et al., 2014). The 5-m height contour elevation maps were derived from Shuttle Radar Topography Mission (SRTM) 3 arc-second data. Version 12 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 calculated from the latitude and longitude of the site, see Table 2.2.

The magnetic declination (D) at each mast site was determined by taking the compass bearing between two 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 2.2.

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

All compass (magnetic) bearings (M) have been transformed to true bearings (T) using D, 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 2.2: Convergence, magnetic declination, boom direction and lightning rod directions.

Mast ID	Meridian convergence, C [°]	Magnetic declination, D* [°]	Boom direction, (true north) [°]	Lightning rod direction, (true north) [°]
WM16	0.81	−20.69	60 m 67.3 20 m 61.3	336.0
WM17	−1.25	−22.51	60 m 341.5 20 m 337.5	202.0
WM18	−1.23	−19.53	60 m 72.5 20 m 68.5	195.0
WM19	0.20	−18.80	60 m 102.2 20 m 96.2	270.0

* *As per NOAA magnetic declination calculator*

The wind direction vanes were mounted on the booms with the N mark on the vane body directly over the boom, facing inward towards the mast. This method was used to make it easier to install the vane and accurately line it up with the boom. The direction of the boom is then accurately determined from the ground. Mast WM17 was an exception, as the boom was facing directly in a magnetic N-S direction, so the wind vane was mounted on the South side of the mast, with the N mark facing outwards.

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, taking into account the directions of the booms. Table 2.2 lists the True North anemometer boom direction determined as described above. The boom direction is defined here as the side of the boom direction onto which the cup anemometer has been mounted.

The different directions measured for the 60 m and the 20 m booms is a result of all four masts having a measure of spiralling from bottom to top.

A lightning protection system has been installed at the top of each mast, as may be seen from the photographs in Appendix A. 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.

2.3 Mast characteristics

The design and characteristics of the 60-m masts are described elsewhere; a sketch is shown in Figure 15. 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, see Table 3.

Table 3 lists the anemometer heights on the 4 masts, i.e. the height of each cup anemometer rotor above the terrain next to the main concrete foundation of the mast. The top of the mast foundation at three of the masts are more or less level with the surrounding terrain surface, except for mast 18, which has a foundation of about 19 cm below the terrain surface.

Table 2.3: Cup anemometer heights above foundation level on the 4 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 terrain surface.

Mast ID	**Level '62'** [m]	**Level '60'** [m]	**Level '40'** [m]	**Level '20'** [m]	**Level '10'** [m]	**ΔTerrain** [m]
WM 16	61.84	60.22	39.97	19.94	10.02	0
WM 17	61.35	60.22	39.98	19.98	9.99	0
WM 18*	61.12	60.29	40.01	20.00	10.00	−0.19
WM 19	61.89	60.39	40.07	20.18	10.14	0

** Mast base from where heights were measured is ± 19 cm lower than surrounding ground levels*

3 Topographical characteristics

Some topographical information was prepared before, or recorded during the site visits.

3.1 Surrounding terrain and mast photos

In Appendix A, the terrain surrounding each mast is shown in panoramic photographs; starting from 000°, photos were taken clockwise for every 45°. 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 A.

3.2 Elevation Maps

Elevation maps for each site were constructed from Shuttle Radar Topography Mission (SRTM) 3 arc-second data, using Surfer 12. Overview maps cover 20 × 20 km^2, with 20 m or 10 m height contours and 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 distribution, is shown for each station in Appendix A The observed wind climates were constructed using the WAsP Climate Analyst, version 3.01.0043.

Table 4.1 shows the status of the meteorological measurements at the time of writing.

Table 4.1: Status of measurements as of 31 October 2019. The "%" column is the data recovery rate and the Notes column show the fraction of one year used for the wind rose and wind speed distribution plots.

Mast ID	**Province**	**Data start** Date	**Data start** Time	**Days until** 31 October 2019	**Recovery** [%]	**Notes**
WM 16	Northern Cape	2018-10-25	15:10	372	100	
WM 17	Northern Cape	2018-11-09	17:00	355	97.3	*
WM 18	Northern Cape	2018-11-08	12:30	356	100	
WM 19	Northern Cape	2018-10-24	15:30	373	100	

* *Anemometer at 60m level faulty for 103.5 days*

Meteorological data from the five measurement stations can be downloaded from the WASA download web site wasadata.csir.co.za/wasa1/WASAData

5 Conclusions and recommendations

In general, the mast installations were found to be of a high standard and no changes other than regular maintenance were made to the installations during the visits.

The mast positions were generally confirmed to within a few tens of meters. The coordinates given in Table 2.1 refer to the coordinates obtained during the site inspection trips.

The different boom directions were established during installation of instruments and thereby the calibration expressions used – were confirmed at most stations to within a few degrees, and there is no need to change the calibration expressions. The WASA 3 masts tend to show slightly more spiralling than the WASA 1 and WASA 2 masts, resulting in the 20m and 60m booms having an average difference of 4° – 6°. Repeat measurements will be done at all stations during the next annual site visit, as the Site Description visit took place before the required annual checking and re-tensioning of mast guy wires as done by the mast contractor.

The boom and cup anemometer heights were mostly quite easy to determine; and the top anemometer height was determined by physically measuring the distance from the support pole cup on the vertical boom to the bottom of the 60m horizontal boom, with the anemometer on its support pole being a known height.

6 Acknowledgements

The Wind Atlas for South Africa project is an initiative of the Government of South Africa – Department of Minerals and Energy (now DMRE) and the project is funded by the United Nations Development Agency.

The South African National Energy Development Institute (SANEDI) is the Executing Partner, 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.

7 References

Mortensen, N.G., D.N. Heathfield, O. Rathmann and Morten Nielsen (2014). Wind Atlas Analysis and Application Program: WAsP 11 Help Facility. Department of Wind Energy, Technical University of Denmark, Roskilde, Denmark. 366 topics.

Mortensen, N.G., Hansen, J.C., Kelly, M.C., Prinsloo, E., Mabille, E., & Szewczuk, S. (2014). Wind Atlas for South Africa (WASA) Station and Site Description Report. Roskilde: DTU Wind Energy. (DTU Wind Energy E; No. 0071). 72 pp.

Appendix A Station descriptions and photos

The following four sections list the mast and site characteristics for the four meteorological masts of WASA 3. 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:

- WM16 Pofadder (page 8)
- WM17 Strydenburg (page 14)
- WM18 Kuruman (page 20)
- WM19 Upington (page 26).

A.1 WM16 – Pofadder

WM16	19.357042°E	29.444360°S	1,073 m	E 340,654 m	N 6,741,659 m	UTM 34J

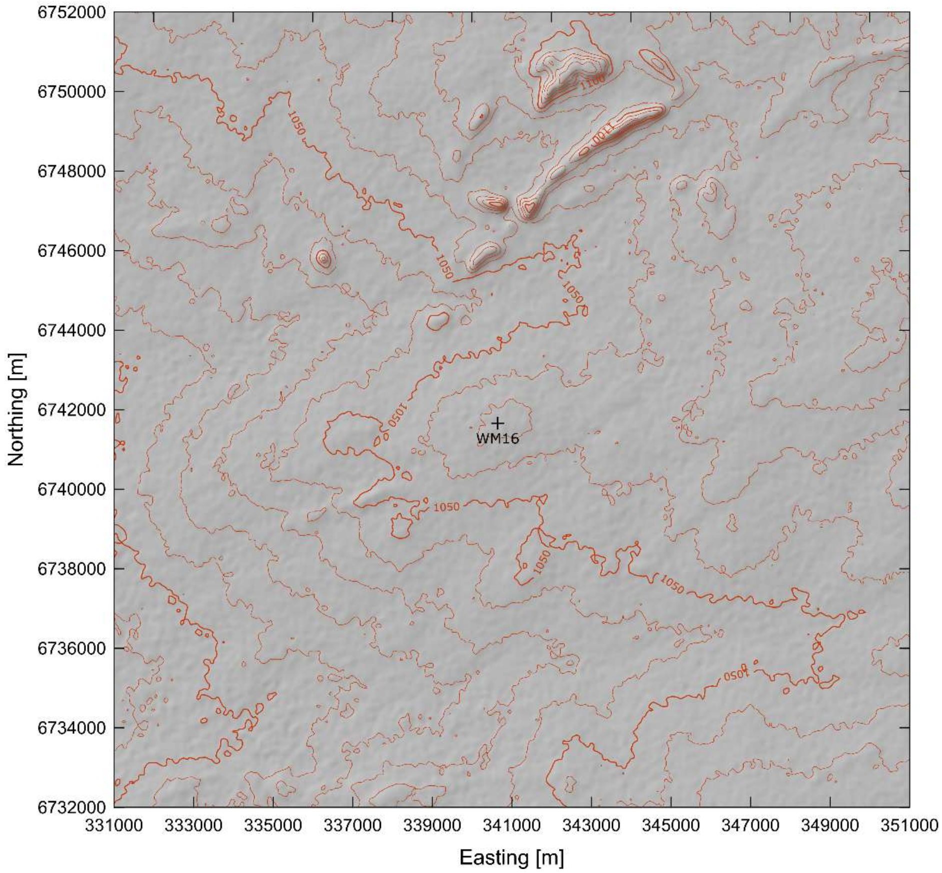


Figure A.1.1: Elevation map from SRTM3 data that covers a 20 km by 20 km area with 10 m elevation contours. The ruggedness index for the site is 0 %.

Site and mast characteristics

Table A.1.1: Convergence, magnetic declination, boom direction and lightning rod directions.

Mast ID	Meridian convergence, C [°]	Magnetic declination, D [°]	Boom direction, (true north) [°]	Lightning rod direction (true north) [°]
WM16	0.81	−20.69	60 m 67.3 20 m 61.3	336.0

Table A.1.2: Anemometer heights above ground foundation and foundation height.

Mast ID	Level '62' [m]	Level '60' [m]	Level '40' [m]	Level '20' [m]	Level '10' [m]	ΔTerrain [m]
WM 16	61.84	60.22	39.97	19.94	10.02	0

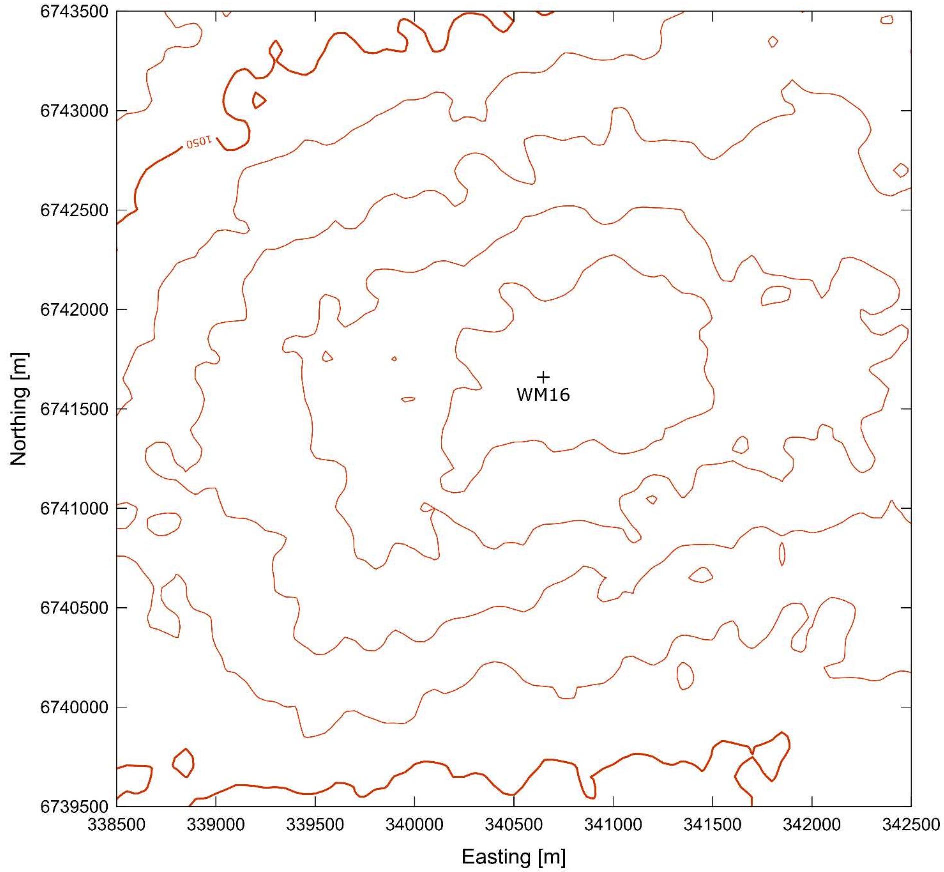


Figure A.1.2: Elevation map from SRTM3 data, covering 4×4 km2, with 5-m height contours.

Observed wind climate

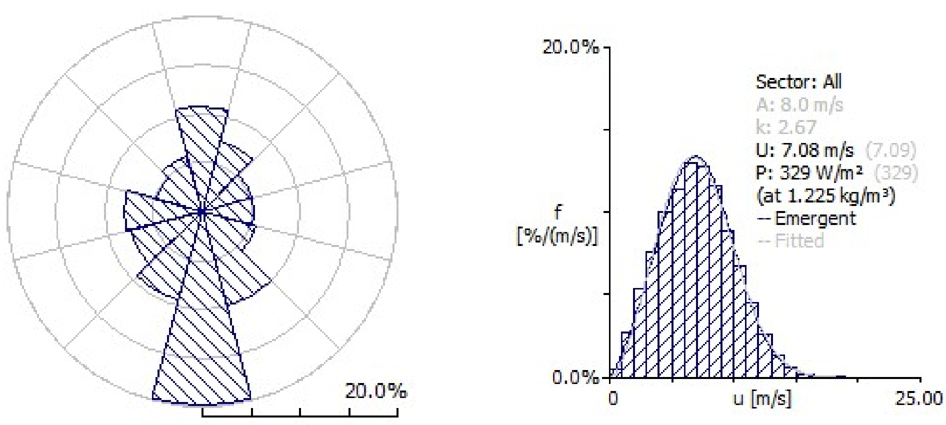
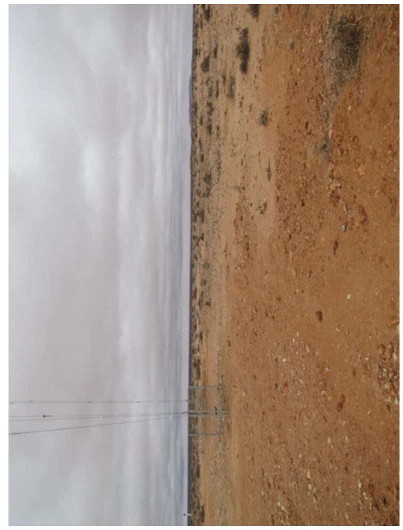
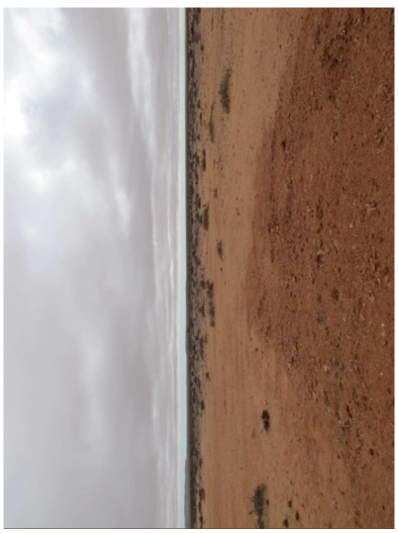
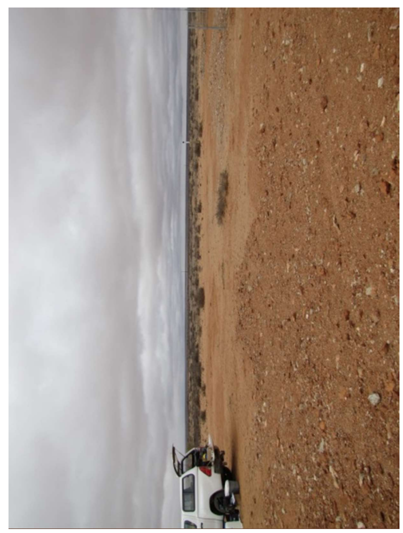
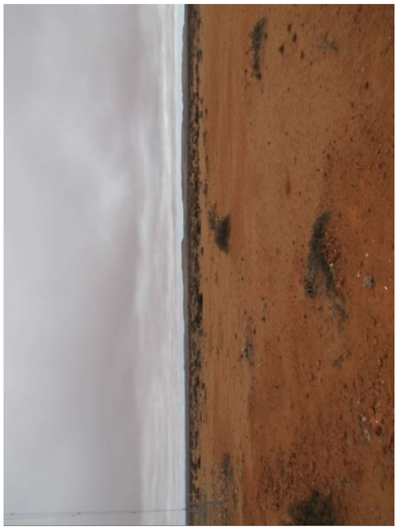
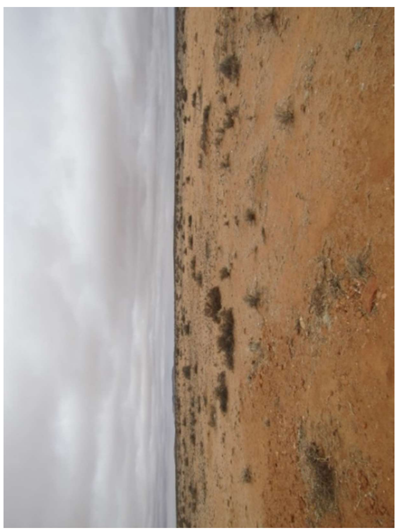
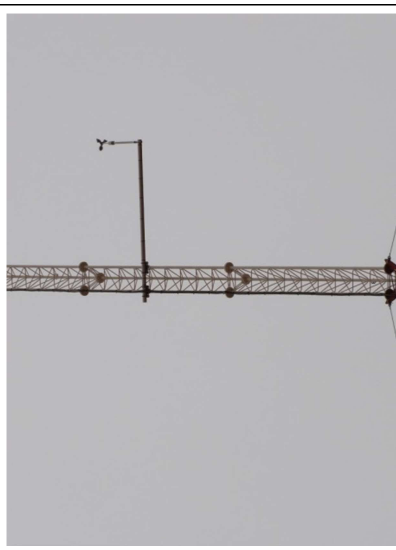


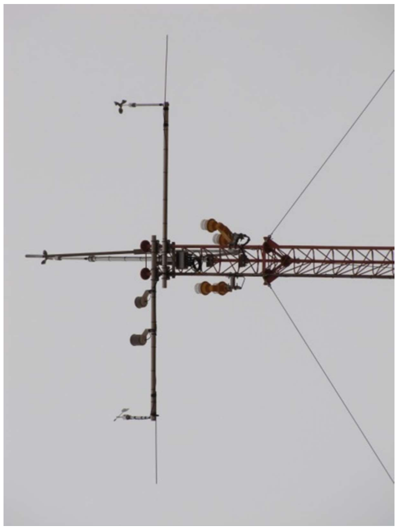
Figure A.1.3: Wind rose and wind speed distribution for WM16 (Pofadder) at 62 m a.g.l. The data shown represent a period of one year, from 2018-11-01 to 2019-10-31.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions, followed by photos of each of the boom levels.

 090	 225
 045	 180

 000	 135
 270	 315
 2/4	 4/4 (bottom)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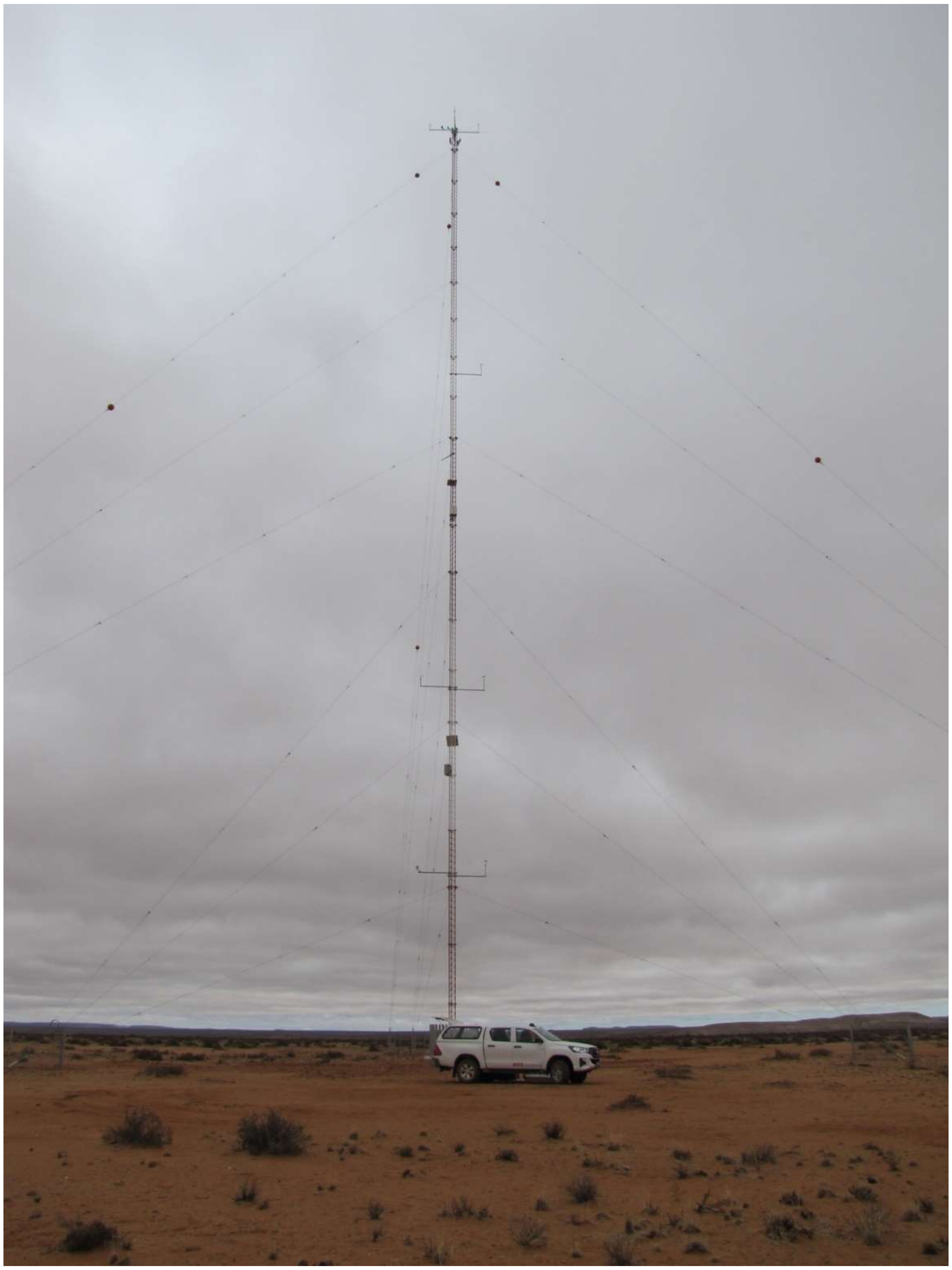


Tower Full View

A.2 WM17 – Strydenburg

WM17	23.519533°E	29.757876°S	1,196 m	E 743,631 m	N 6,705,384 m	34J

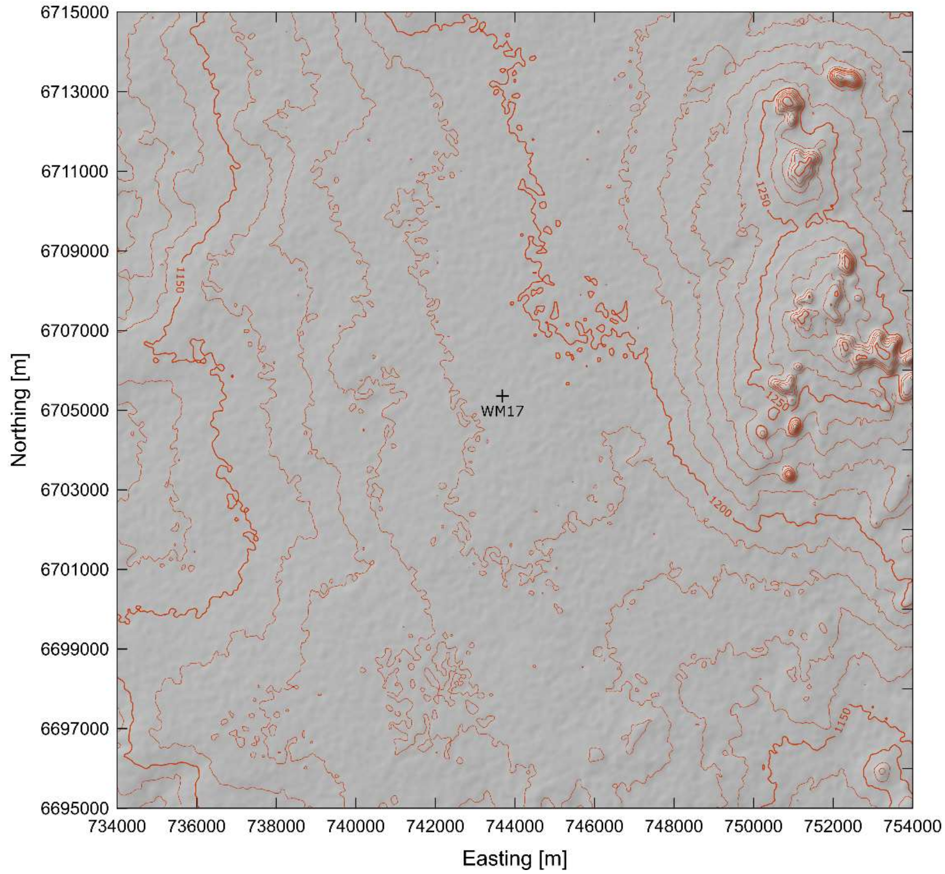


Figure A.2.1: Elevation map from SRTM3 data that covers a 20 km by 20 km area with 10 m contours. The ruggedness index for the site is 0.0 %.

Site and mast characteristics

Table A.2.1: :Convergence, magnetic declination, boom direction and lightning rod directions.

Mast ID	Meridian convergence, C [°]	Magnetic declination, D [°]	Boom direction, (true north) [°]	Lightning rod direction (true north) [°]
WM17	-1.25	-22.51	60 m 341.5 20 m 337.5	202.0

Table A.2.2: Anemometer heights above ground foundation and foundation height.

Mast ID	Level '62' [m]	Level '60' [m]	Level '40' [m]	Level '20' [m]	Level '10' [m]	ΔTerrain [m]
WM 17	61.35	60.22	39.98	19.98	9.99	0

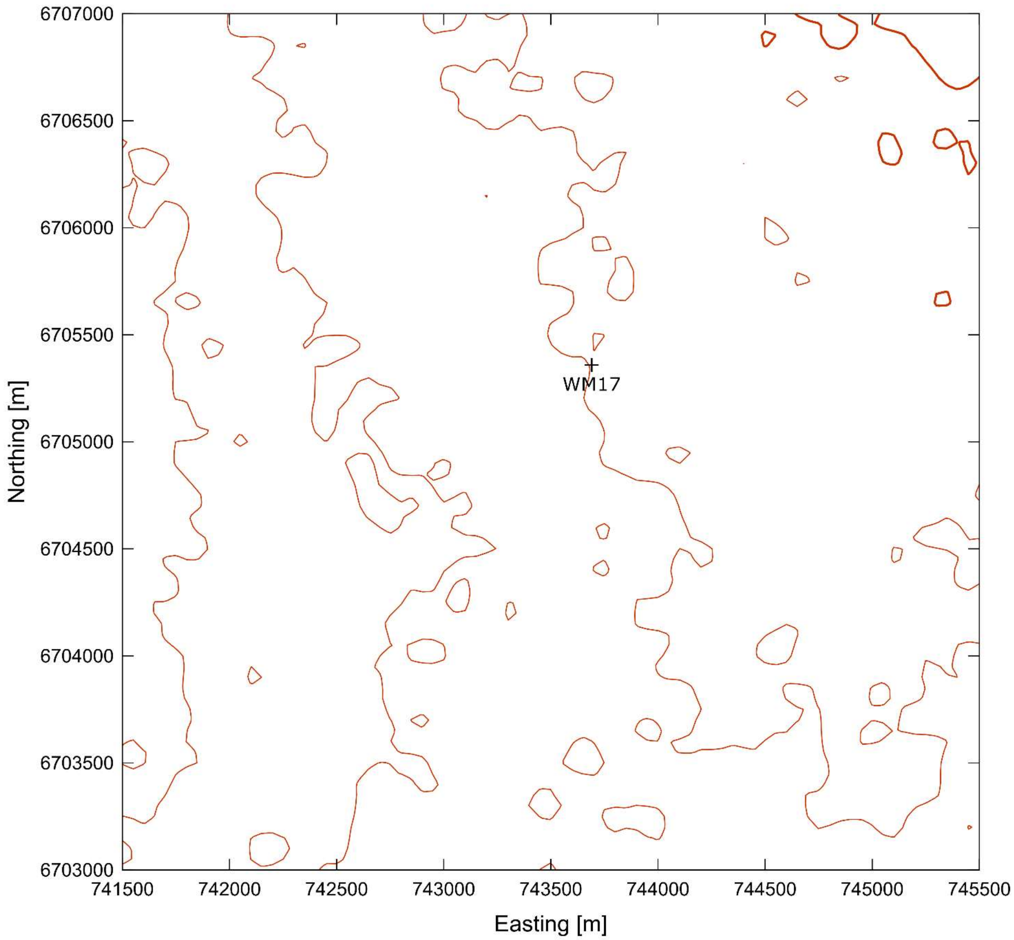
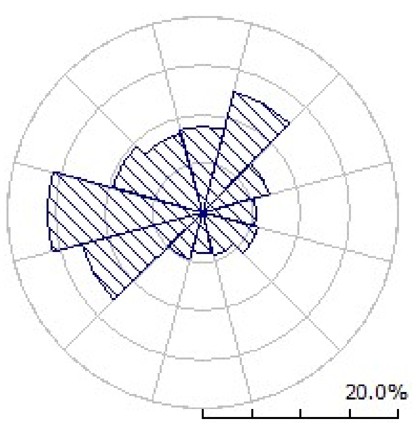


Figure A.2.2: Elevation map from SRTM3 data, covering 4×4 km2, with 5-m height contours.

Observed wind climate



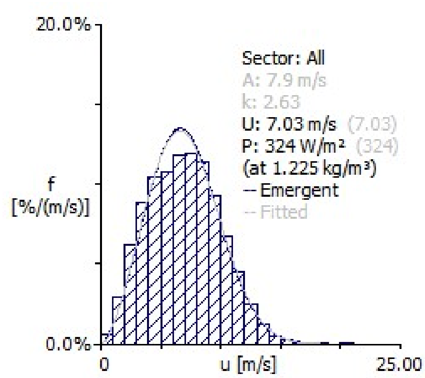
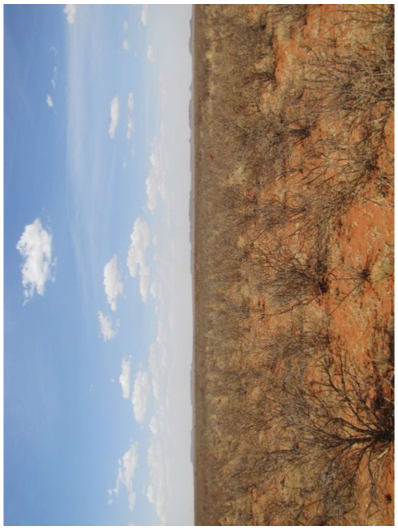
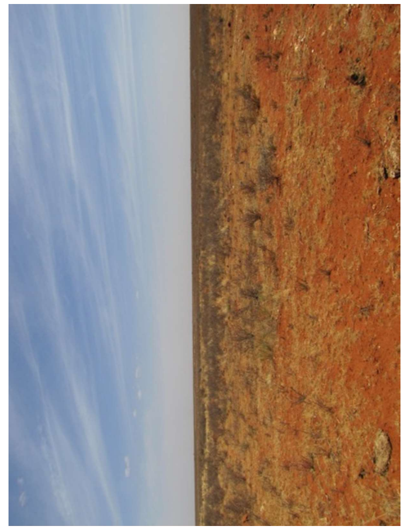
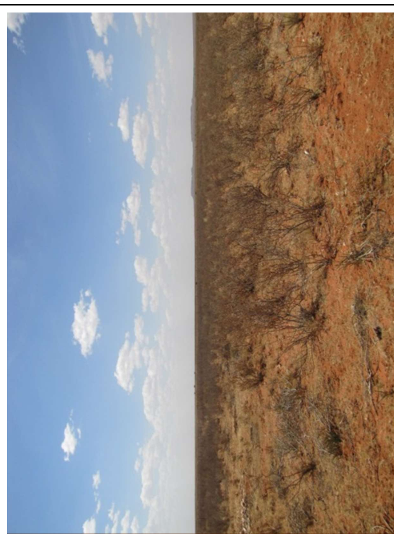
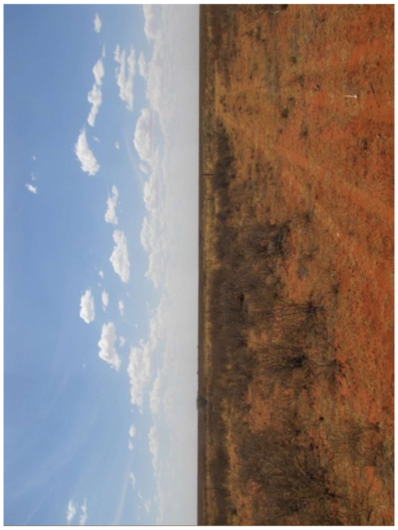
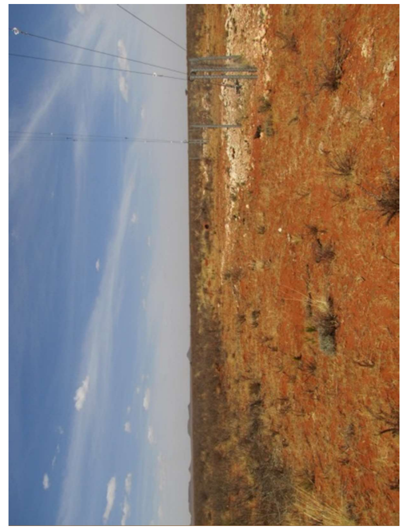
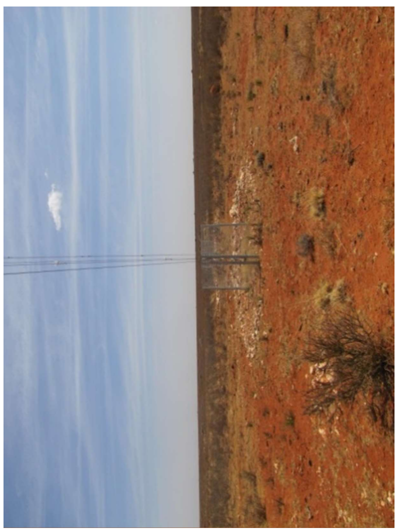
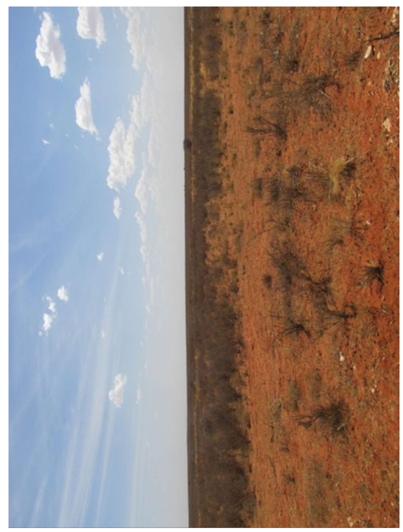
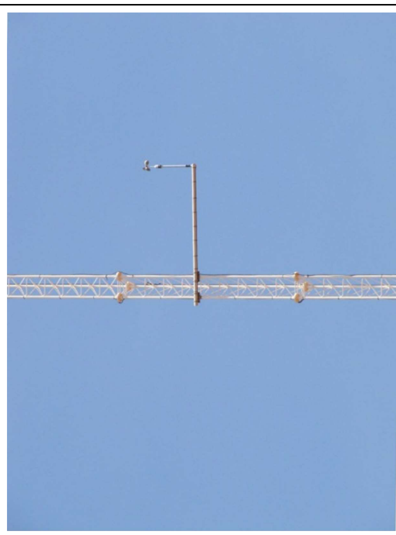
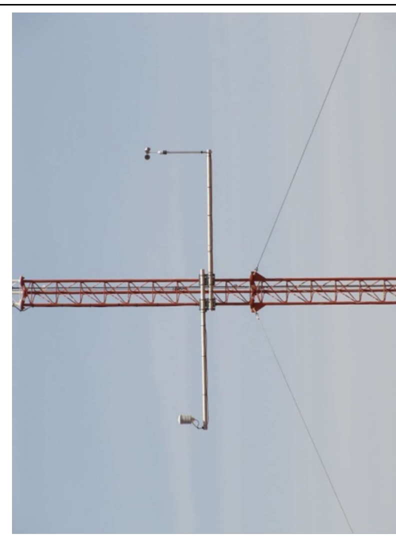


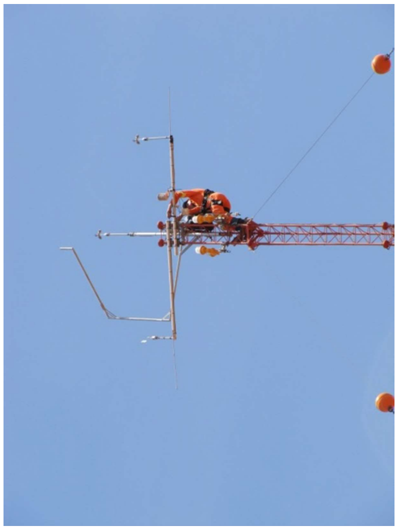
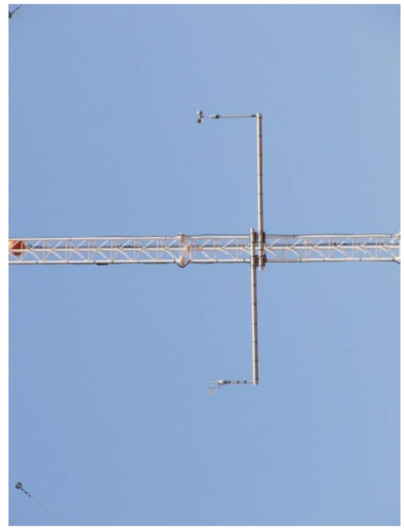
Figure A.2.3: Wind rose and wind speed distribution for WM17 (Strydenburg) 62 m a.g.l. The data shown represent a period of one year, from 2018-11-01 to 2019-10-31.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions, followed by photos of each of the boom levels.

 090	 225
 045	 180

 000	 135
 270	 315
 2/4	 4/4 (bottom)

 1/4 (top)	 3/4

Tower Full View

A.3 WM18 – Kuruman

WM18	20.568330°E	27.591376°S	1,478 m	E 762,106 m	N 6,944,582 m	UTM 34J

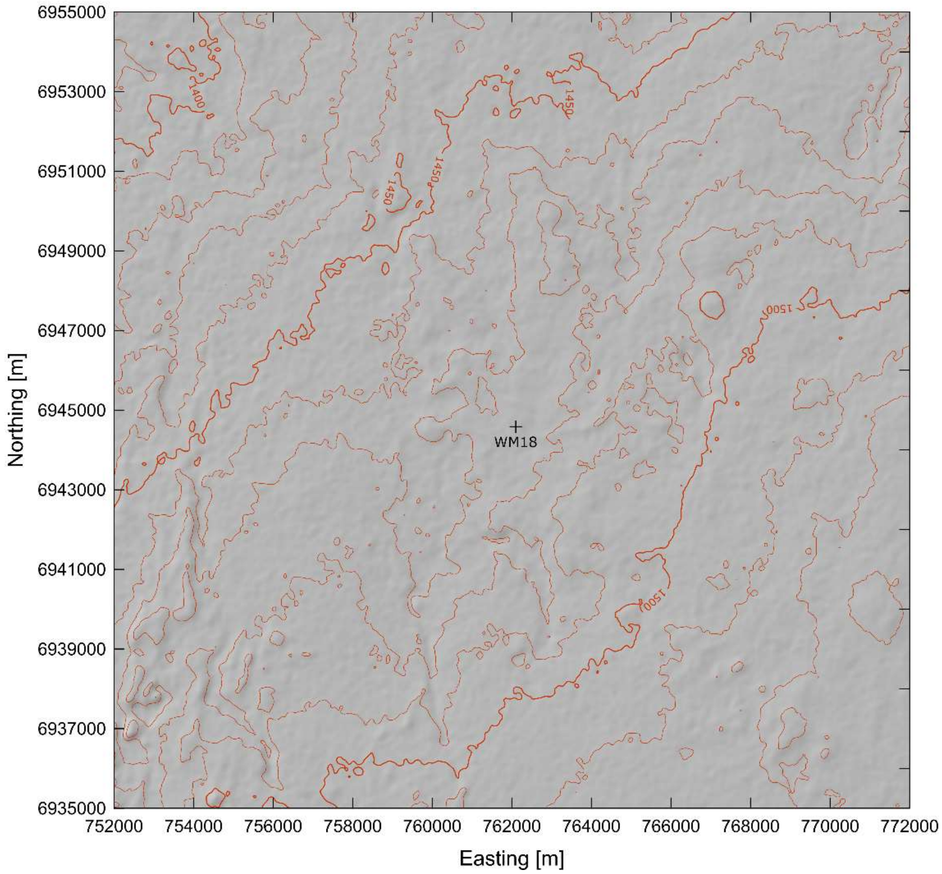


Figure A.3.1: Elevation map from SRTM3 data that covers a 20 km by 20 km area with 10-m contours. The ruggedness index for the site is 0.0 %.

Site and mast characteristics

Table A.3.1: Convergence, magnetic declination, boom direction and lightning rod directions.

Mast ID	Meridian convergence, C [°]	Magnetic declination, D [°]	Boom direction, (true north) [°]	Lightning rod direction (true north) [°]
WM18	-1.23	−19.53	60 m 72.47 20 m 68.47	195.0

Table A.3.2: Anemometer heights above ground foundation and foundation height.

Mast ID	Level '62' [m]	Level '60' [m]	Level '40' [m]	Level '20' [m]	Level '10' [m]	∆Terrain [m]
WM 18*	61.12	60.29	40.01	20.00	10.00	-0.19

** Mast base from where heights were measured is ± 19 cm lower than surrounding ground levels*

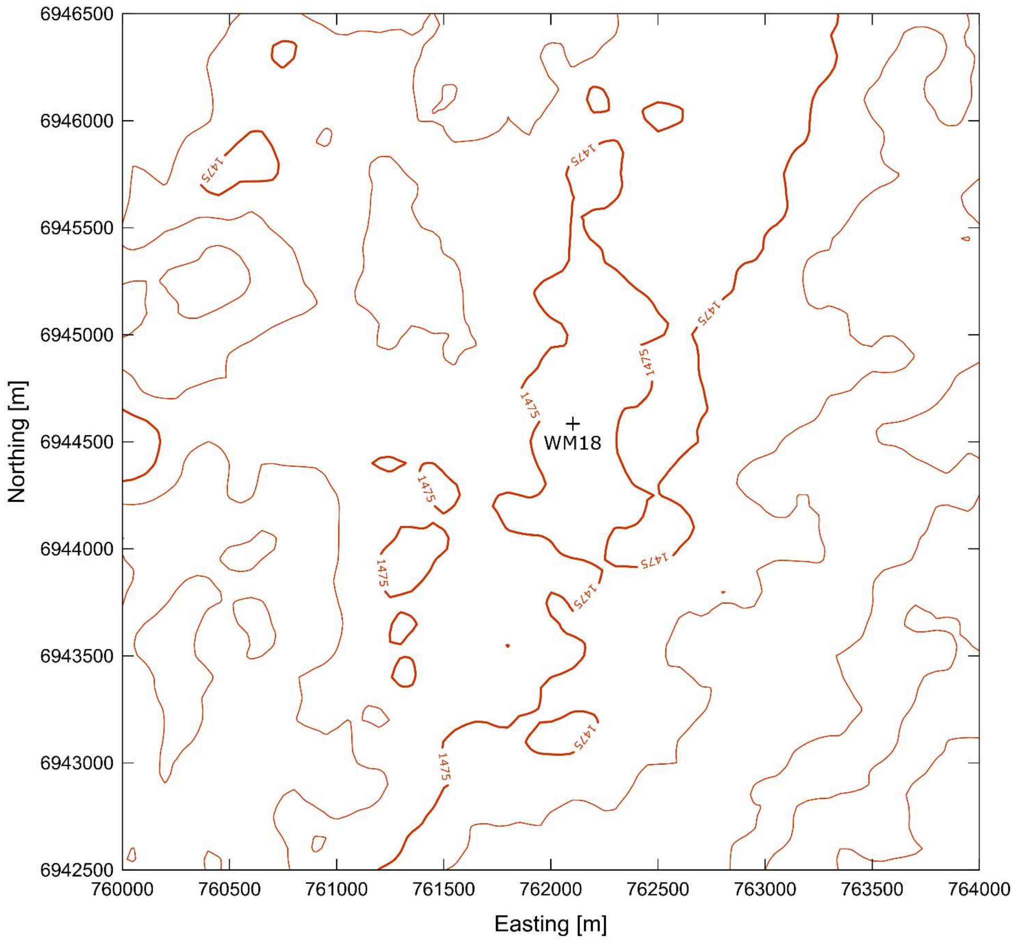


Figure A.3.2: Elevation map from SRTM3 data, covering 4×4 km2, with 5-m height contours.

Observed wind climate

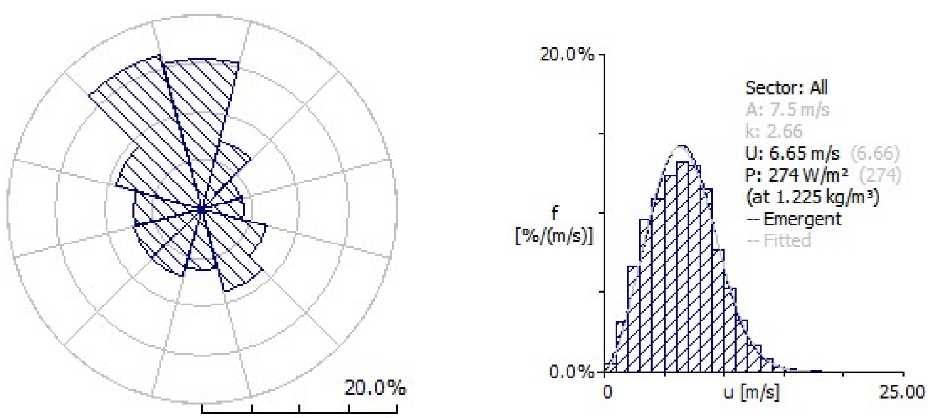
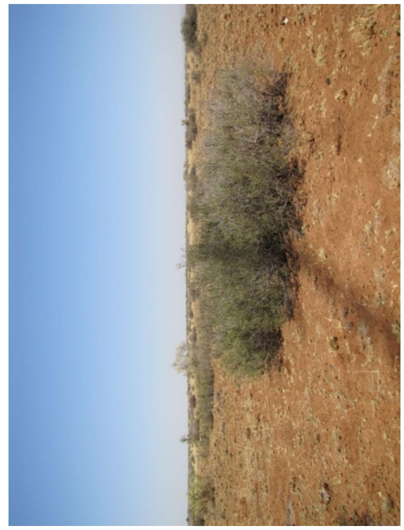


Figure A.3.3: Wind rose and wind speed distribution for WM18 (Kuruman) at 62 m a.g.l. The data shown represent a period of one year, from 2018-11-01 to 2019-10-31.

Sector photographs

The sector photographs on the following two pages refer to magnetic directions, followed by photos of each of the boom levels.

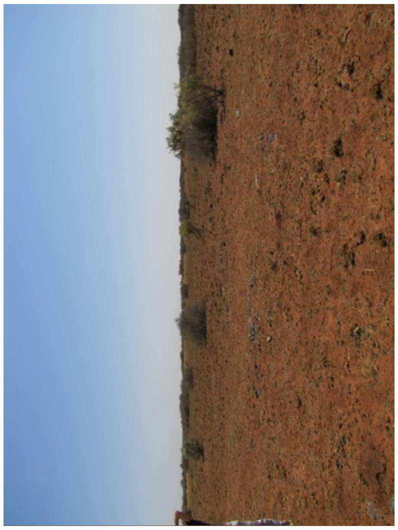
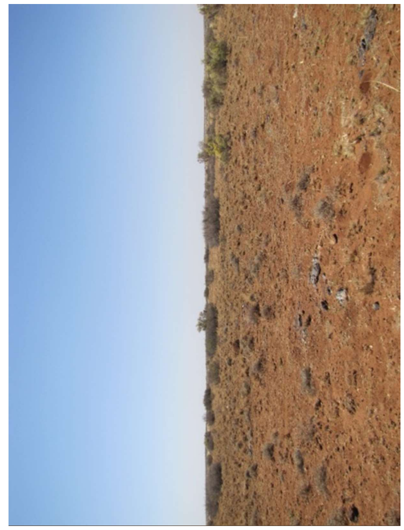
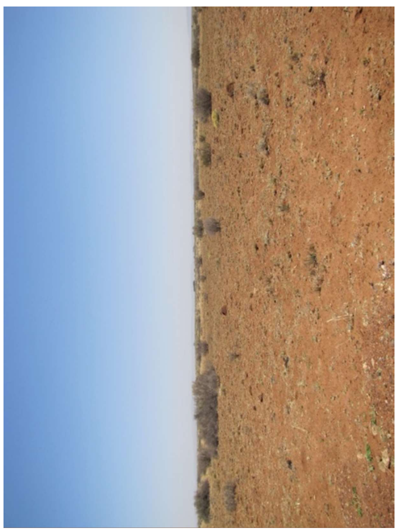
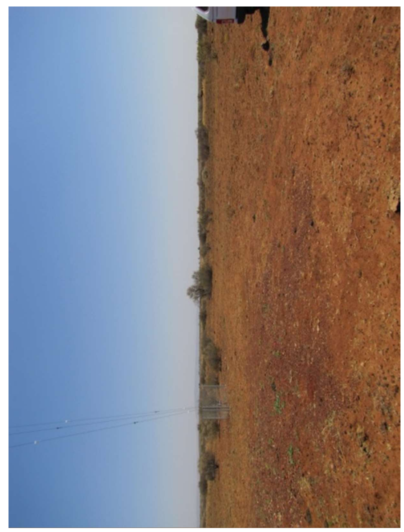
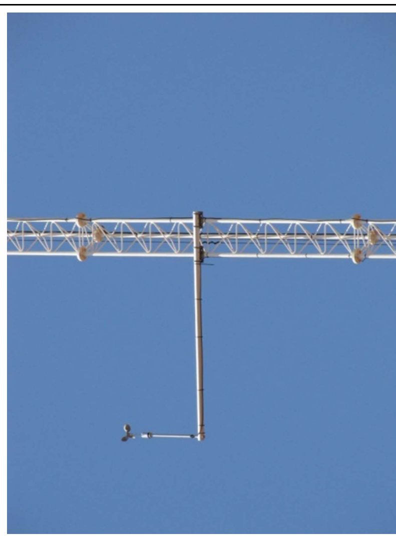
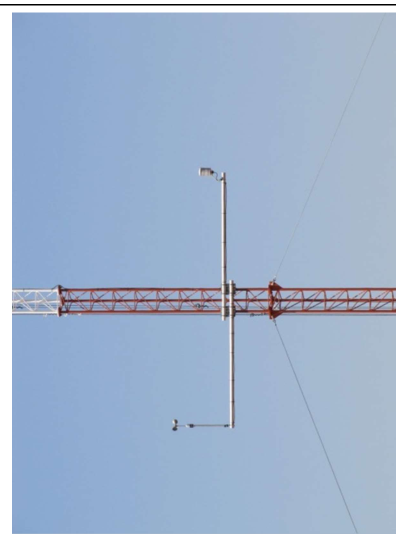
090

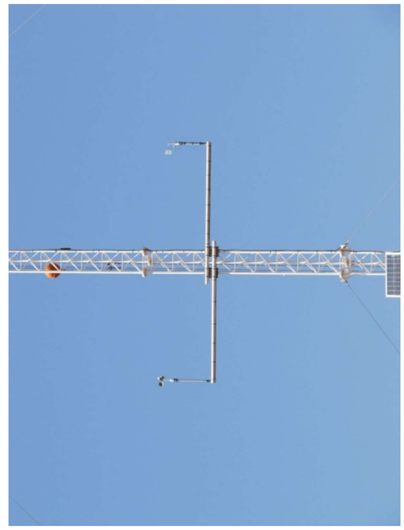


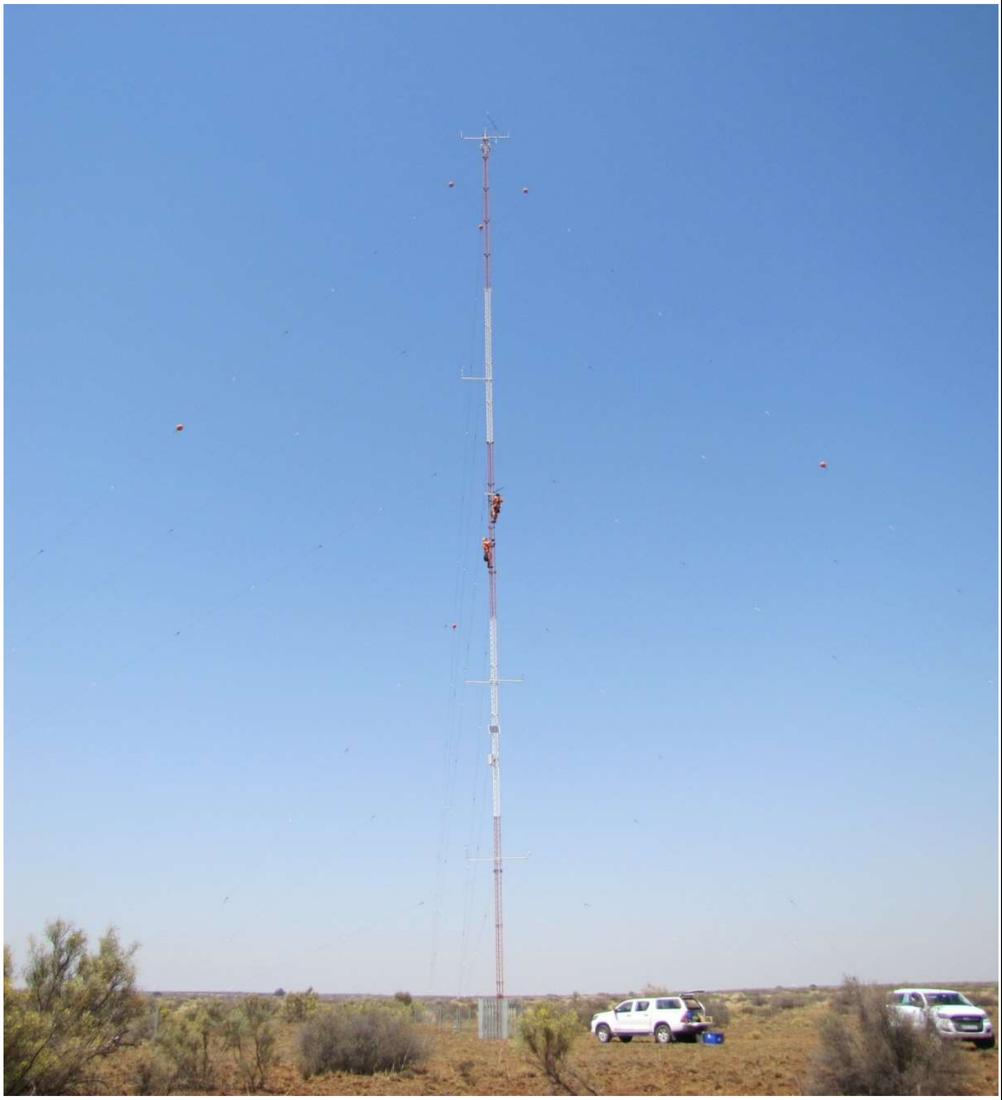
225

045

180

 000	 135
 270	 315
 2/4	 4/4 (bottom)

	
1/4 (top)	3/4



Tower Full View

A.4 WM19 – Upington

WM19	29.54348°E	27.726700°S	848 m	E 457,450 m	N 6,932,997 m	UTM 34J

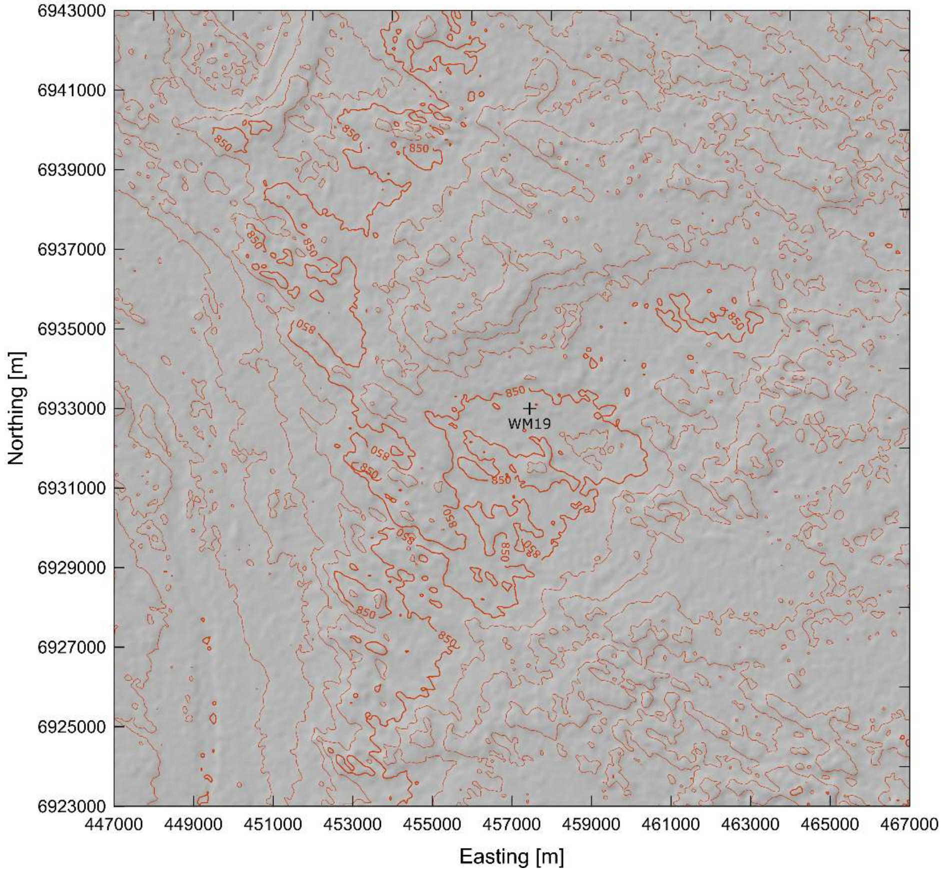


Figure A.4.1: Elevation map from SRTM3 data that covers a 20 km by 20 km area with 10-m contours. The ruggedness index for the site is 0.0 %.

Site and mast characteristics

Table A.4.1: Convergence, magnetic declination, boom direction and lightning rod directions.

Mast ID	Meridian convergence, C [°]	Magnetic declination, D [°]	Boom direction, (true north) [°]	Lightning rod direction (true north) [°]
WM19	0.20	−18.80	60 m 102.2 20 m 96.2	270.0

Table A.4.2: Anemometer heights above ground foundation and foundation height.

Mast ID	Level '62' [m]	Level '60' [m]	Level '40' [m]	Level '20' [m]	Level '10' [m]	∆Terrain [m]
WM 19	61.89	60.39	40.07	20.18	10.14	0

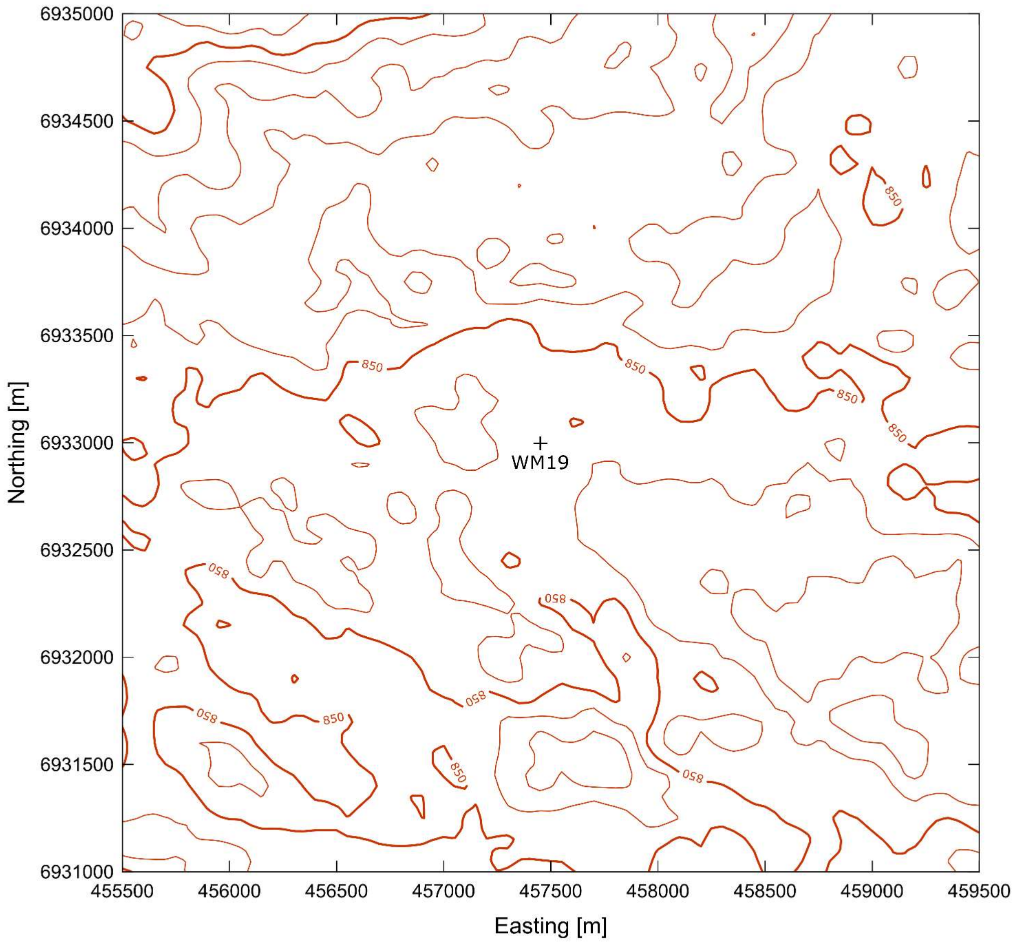
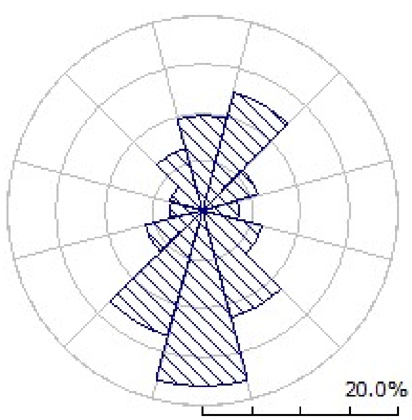


Figure A.4.2: Elevation map from SRTM3 data, covering 4×4 km2, with 5-m height contours.

Observed wind climate



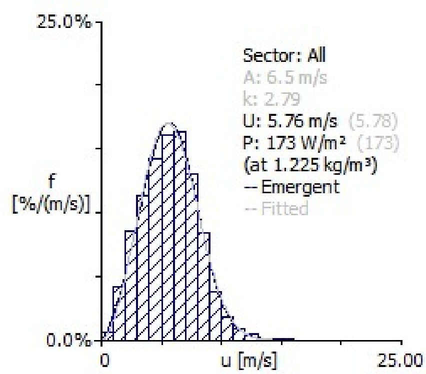
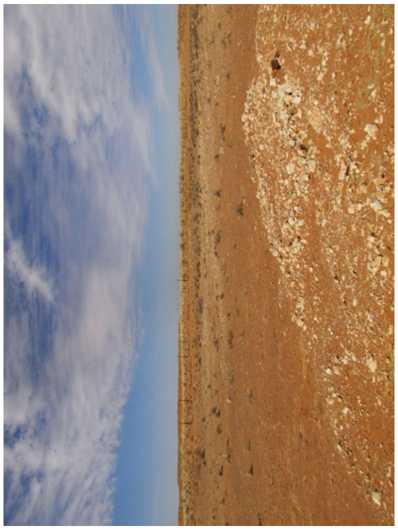
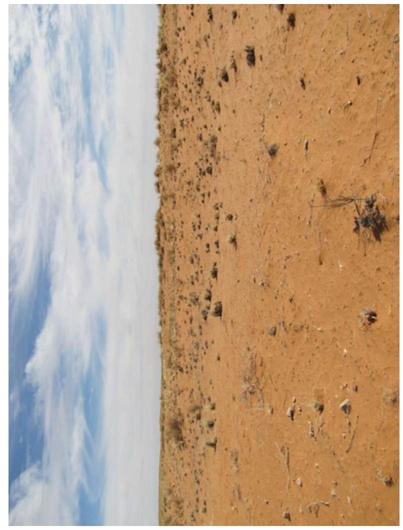
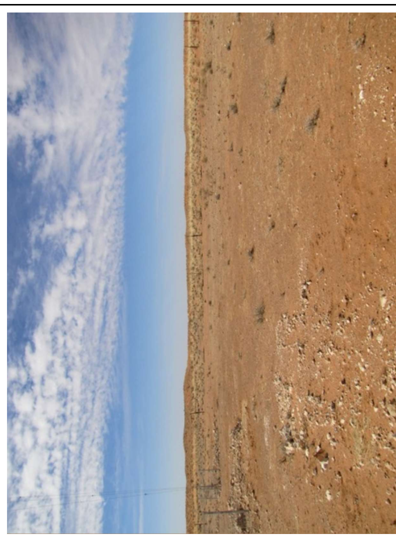
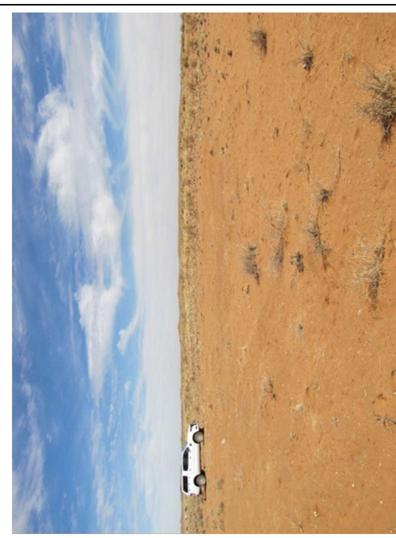
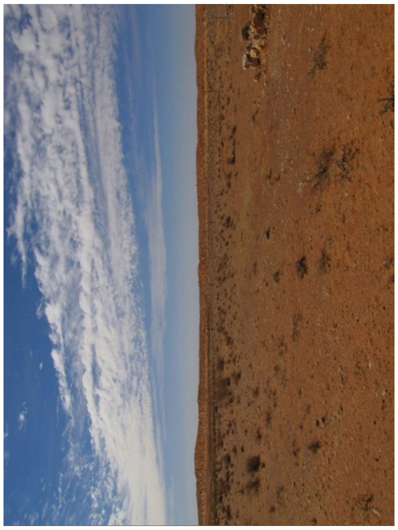
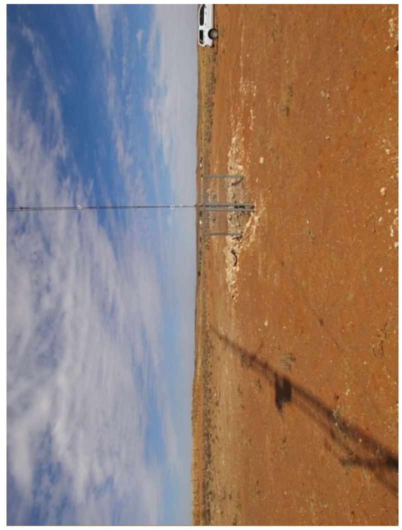
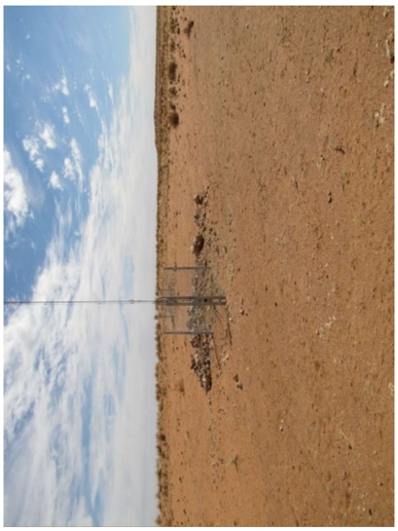
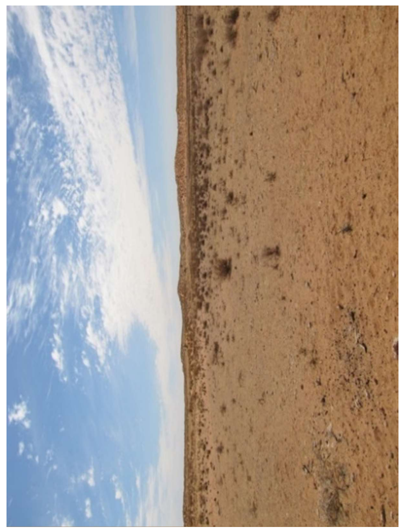
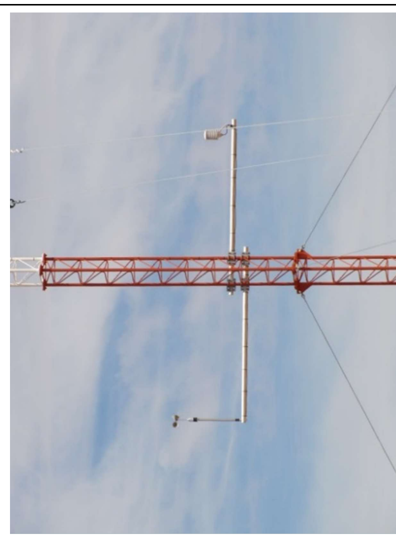


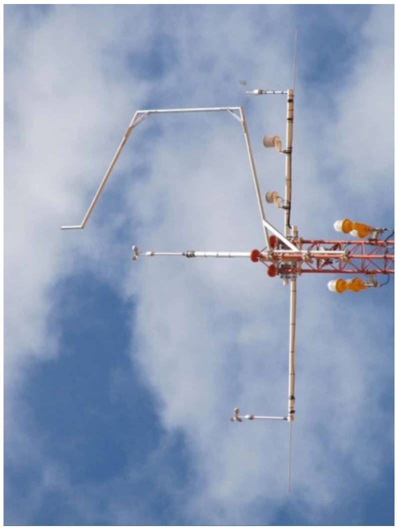
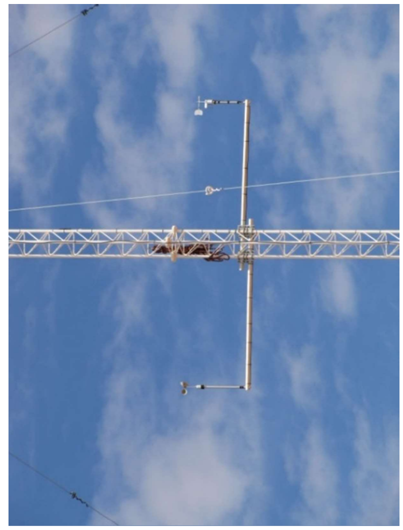
Figure A.4.3: Wind rose and wind speed distribution for WM19 (Upington) at 62 m a.g.l. The data shown represent a period of one year, from 2018-11-01 to 2019-10-31.

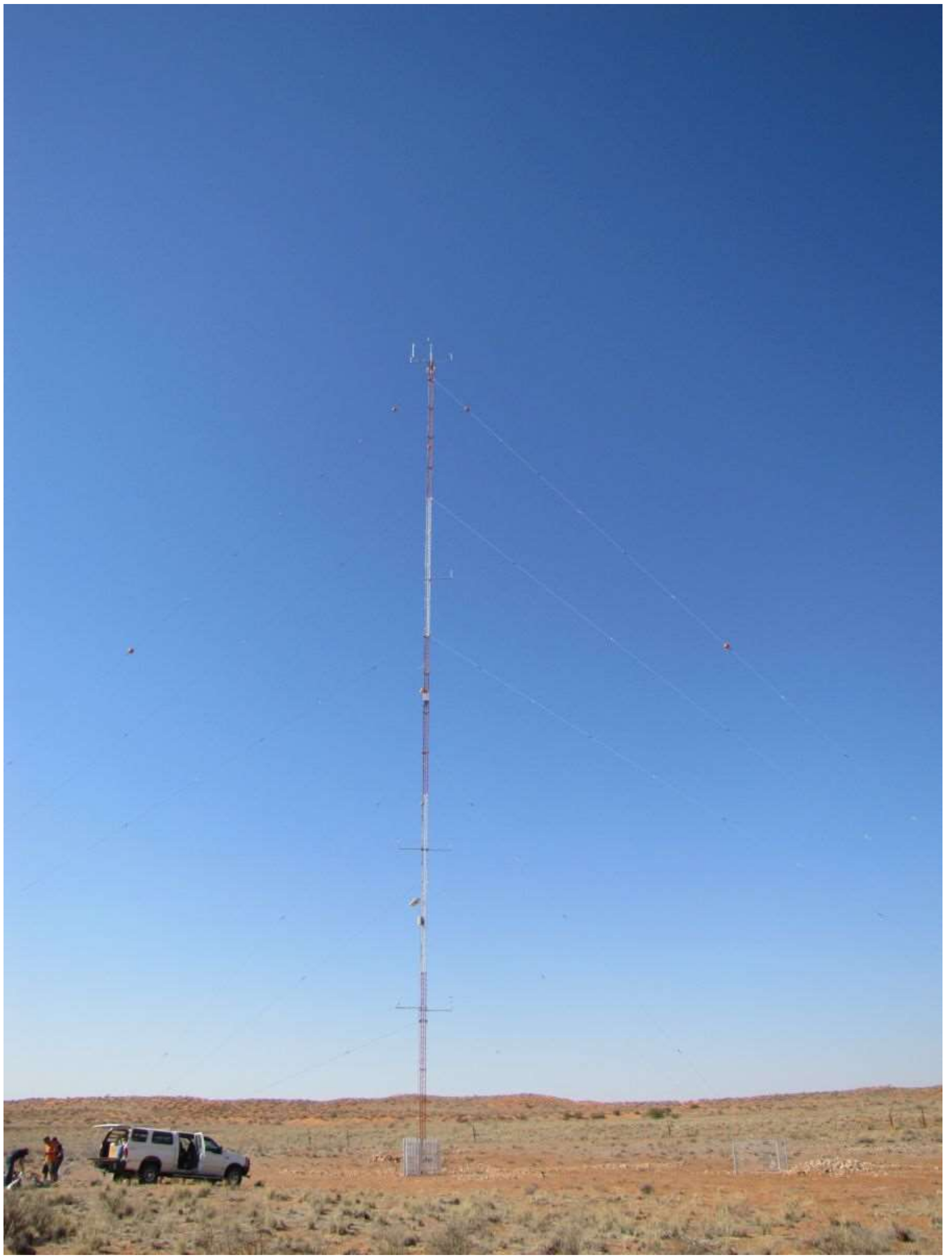
Sector photographs

The sector photographs on the following two pages refer to magnetic directions, followed by photos of each of the boom levels.

	
090	225
	
045	180

 000	 135
 270	 315
 2/4	 4/4 (bottom)

	
1/4 (top)	3/4



Tower Full View

Appendix B Mast design

The original mast design and arrangement of instruments is shown in Figure B.1. The actual dimensions and characteristics of each mast are given in the present report.

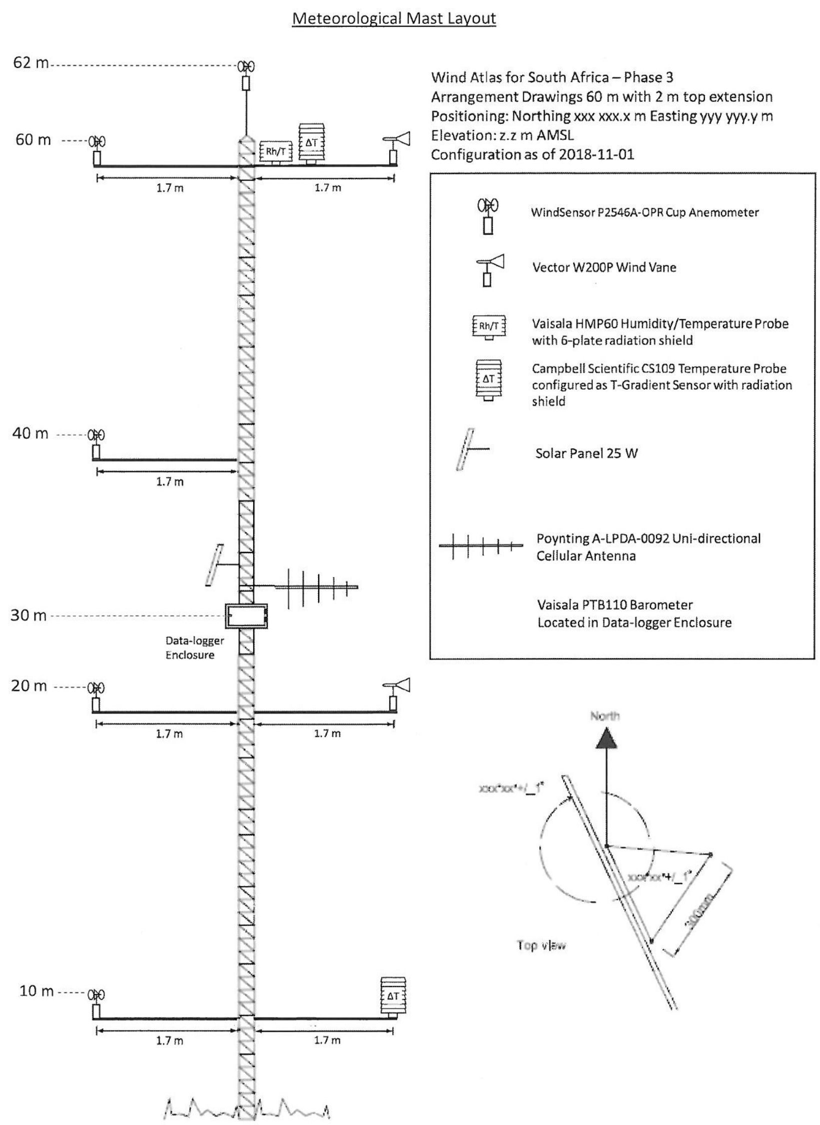


Figure B.1: Mast design and arrangement drawing.