Perdigão–2017: experiment layout

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Summary: This is the document on the location of the scientific equipment deployed in Perdigão-2017, comprising a total of 55[1] ground based instruments and many more sensors (344[2]) installed at or close to the meteorological towers[3], 50 in total. This document, the information in Perdigão web site and two companion Excel workbooks are the complete set of references on the experiment layout. To to the best of our knowledge, the information in these three documents is complete and accurate, with no need for consulting any other source.
This is version 1, identified by a watermark along the diagonal; any future version and changes will be referenced relatively to this version.

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[1]See Table 8 in page 26. These footnotes will stay, until a couple of open questions is answered.
[2]See section 2.4, Table 7 in page 17.
[3]See Table 2, page 6.

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Abstract

This is the document on the location of the scientific equipment deployed in Perdigão-2017, comprising a total of 55[4] ground based instruments and many more sensors (344[5]) installed at or close to the meteorological towers[6], 50 in total. This document, the information in Perdigão web site and two companion Excel workbooks are the complete set of references on the experiment layout. To to the best of our knowledge, the information in these three documents is complete and accurate, with no need for consulting any other source.
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[5]See section 2.4, Table 7 in page 17.
[6]See Table 2, page 6.

1 Introduction

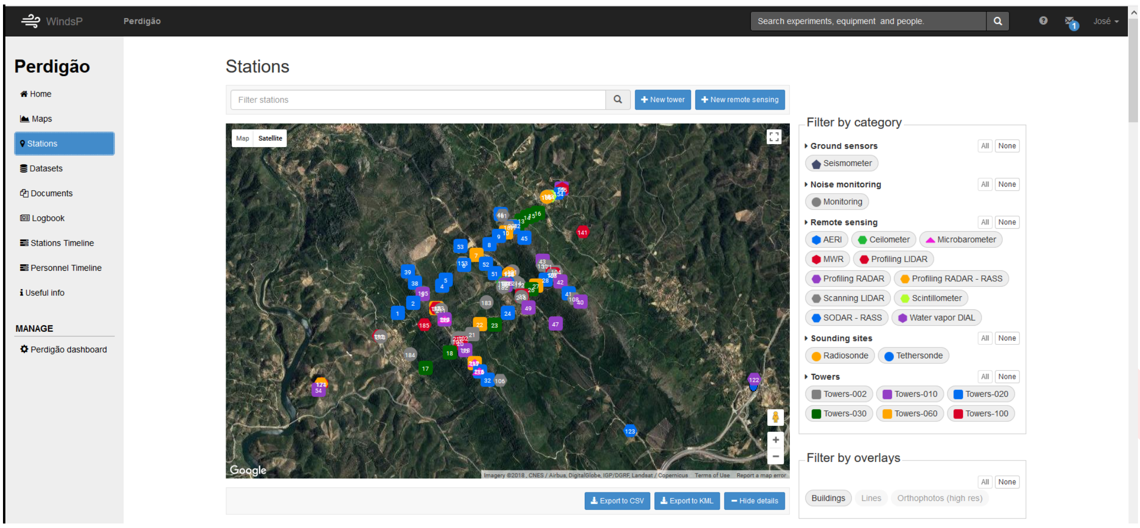

Figure 1: Perdigão layout, as available at http://perdigao.fe.up.pt under Stations

In the terminology of Perdigão Webpage[7] the equipment (called *Stations*) is organized under five categories:

- *Towers*, which includes the lattice towers and the corresponding scientific equipment;
- *Sounding sites*;
- *Remote sensing*;
- *Noise monitoring*; and
- *Ground sensors*.

There are 105 stations: 50 meteorological towers, numbered from 1 to 55 (Table 2), and 55ground based equipment, station numbers between 101 and 218 (Table A.4).

The location was determined by measurements or derived from the measured location of nearby equipment. In all cases the accuracy was the highest achievable with the current technology and accurate enough to the foreseeable use of the experimental data.

1.1 The purpose of this document

This document is the main reference on the location of the scientific equipment used in Perdigão-2017. For instance, all data in the previous report by Menke and Mann [2017], laser survey of the sonic anemometers on the meteorological masts, was thoroughly checked, updated and completed with the missing locations of some anemometers and all the remaining equipment in Perdigão.

[7] Originated from WindsP

1.1.1 Corrections and future versions

The information is in three documents

1. the present report;
2. the Perdigao webpage (`http://perdigao.fe.up.pt`);
3. the Excel workbooks *Towers and Sonics*, *Remote Sensors* and *NETCDF Towers*.

The information in the present document is complete and accurate[8]. To show differences to future versions, a watermark on all pages identifies the document version and future versions will always identify the differences to previous versions.

1.2 Conventions and nomenclature

1.2.1 Geodesic system PT-TM06/ETRS89 - European Terrestrial Reference System 1989

The geodesic system used throughout the document is the European Terrestrial Reference System 1989. The parameters of the Universal Transversal Mercator for Portugal mainland since 2006 are as in Table 1. Information prior to 2006 is obsolete.

Table 1: Parameters of the Universal Transversal Mercator for Portugal

Spheroid GRS80	Semi-major axis: a = 6 378 137 m
	Semi-minor axis: b = 6 356 752.314 140 m
	Inverse flattening: f = 298.257 222 101
Map projection:	transverse Mercator
Origin (Latitude)	$39°40'5.73''$ N
Origin (Longitude)	$8°7'59.19''$ W

Source: PT-TM06/ETRS89 - European Terrestrial Reference System 1989 (*In Portuguese*)

1.2.2 Height, altitude and elevation

In the literature, *height* and *altitude* often refer, but not always to terrain height above the mean sea level, and can be confusing. For the sake of clarity, here we will use *terrain elevation* or simply *elevation* when referring to terrain height with respect to the mean sea level; i.e., elevation stands as a synonymous for terrain height above mean sea level. Height, unless stated otherwise, will be the height above the ground level.

1.2.3 A note on accuracy, error, precision and uncertainty

The geographical location of the equipment was assessed by a large variety of instruments, including smartphones. The Leica system owned by DTU was the most accurate

[8]This not true about version 1, all authors must have the opportunity to read the document carefully and complete some information still missing.

equipment available and was extensively used for measuring the location of almost all the scientific equipment. The accuracy of the Leica system posed a series of new questions that are addressed in the present document and call for decisions, to make the location data both final and valuable for years to come. For instance:

1. Leica system enables the determination of the geographical location to an accuracy of 2 mm; however, at the present it is hard to envisage the need for such a high accuracy in future usage of the Perdigão data.

2. The uncertainty of latitude and longitude is lower than terrain elevation uncertainty.

3. In general, latitude and longitude are given with two decimal figures (1 cm) and terrain elevation with one decimal (1 dm) figure.

Concerning the words accuracy, error, precision or uncertainty, their meaning is as established by for Standardization and Commission [2008].

1.2.4 Worksheet and workbook

A *worksheet* is a single spreadsheet, i.e. cells organized by rows and columns. A *workbook* is a file that contains one or more worksheets, accessed via separate tabs on the bottom of the *workbook* window. A *worksheet* begins with row number 1 and column A. Each cell can contain a number, text or formula. A cell can also reference another cell in the same or another *worksheet*, which can be in the same *workbook* or a different *workbook*.

1.3 Contents

The document is organized in 3 sections and two appendices, A and B. After the introductory section 1, here coming to the end, section 2 is concerned with the tower based equipment, whereas section 3 deals with all the remaining, ground based equipment. The appendices are on the location of the equipment (Tables in Appendix A) and on the contents of the Excel workbooks, *Towers and Sonics*, *Remote Sensors* and *NETCDF Towers* (in Appendix B).

2 Tower based equipment

This section, on the meteorological towers and the measuring equipment installed on or close to the towers, is organized into 4 subsections. First (subsection 2.1) the conventions used to name the towers are introduced. Subsection 2.2 is concerned with the location of the sonic anemometers. Subsection 2.3 deals with the tower location and how it was determined from the location of the sonic anemometers. The inventory and location of all the remaining equipment on the towers was found mostly by interpretation of the NetCDF files associated to each meteorological tower, and is the subject of subsection 2.4.

2.1 Towers identification

Towers were identified by three alternative conventions (Table 2):

Perdigao: Numbering, from 1 to 55; however, towers 19, 30, 31, 44 and 48 were not erected or instrumented and there was a total of 50 towers.

DTU: Composed word, `@@@@_##`, where the letters @@@@ (up to 4) identify the tower location and the two digits ## are the tower number per tower location:

- `trnw`: transect North-West, numbered from 1 until 16;
- `trse`: transect South-East, numbered from 1 until 13 (`trse_03`, `trse_14` and `trse_15` were not installed);
- `risw`: ridge South-West, numbered from 1 until 8;
- `rine`: ridge North-East, numbered from 1 until 7 (`rine_05` was not installed);
- `vall`: valley, numbered from 1 until 7 (`vall_02` was not installed).

NCAR: Composed word, @@@##, where the letters @@@ (up to 3) identify the tower location and the two digits ## are the tower number per tower location

- tnw: transect North-West, numbered from 1 until 16;
- tse: transect South-East, numbered from 1 until 13 (tse03, tse14 and tse15 were not installed);
- rsw: ridge South-West, numbered from 1 until 8;
- rne: ridge North-East, numbered from 1 until 7 (rne05 was not installed);
- v: valley, numbered from 1 until 7 (v02 was not installed).

Table 2 shows the equivalence between the three conventions. Two towers (`Extreme_SW` and `Extreme_NE`), located outside the main perimeter of the site, were named without complying with any of these three conventions.

The total number of towers was 50: 3 (100 m height), 6 (60 m), 8 (30 m), 20 (20 m), 12 (10 m) and 1 (2m).

Table 2: Tower numbers and identification

	Codes					
#	Perdigao	NCAR	DTU	Location	Height	Manag
1	1	tnw01	trnw_01	transect northwest	20	NCAR
2	2	tnw02	trnw_02	transect northwest	20	NCAR
3	3	tnw03	trnw_03	transect northwest	10	NCAR
4	4	tnw04	trnw_04	transect northwest	20	NCAR
5	5	tnw05	trnw_05	transect northwest	20	NCAR
6	6	tnw06	trnw_06	transect northwest	20	NCAR
7	7	tnw07	trnw_07	transect northwest	60	NCAR/DTU
8	8	tnw08	trnw_08	transect northwest	20	NCAR
9	9	tnw09	trnw_09	transect northwest	10	NCAR
10	10	tnw10	trnw_10	transect northwest	60	NCAR/DTU
11	11	tnw11	trnw_11	transect northwest	20	NCAR
12	12	tnw12	trnw_12	transect northwest	30	ARL
13	13	tnw13	trnw_13	transect northwest	30	ARL
14	14	tnw14	trnw_14	transect northwest	30	ARL
15	15	tnw15	trnw_15	transect northwest	30	ARL
16	16	tnw16	trnw_16	transect northwest	30	ARL
17	17	tse01	trse_01	transect southeast	30	NCAR
18	18	tse02	trse_02	transect southeast	30	NCAR
	19	—	—	*Not installed*	—	—
19	20	tse04	trse_04	transect southeast	100	NCAR/DTU
20	21	tse05	trse_05	transect southeast	2	NCAR/DTU
21	22	tse06	trse_06	transect southeast	60	NCAR/DTU
22	23	tse07	trse_07	transect southeast	20	NCAR
23	24	tse08	trse_08	transect southeast	20	NCAR
24	25	tse09	trse_09	transect southeast	100	NCAR/DTU
25	26	tse10	trse_10	transect southeast	30	NCAR
26	27	tse11	trse_11	transect southeast	60	NCAR/DTU
27	28	tse12	trse_12	transect southeast	20	NCAR
28	29	tse13	trse_13	transect southeast	100	NCAR/DTU
	30	—	—	*Not installed*	—	—
	31	—	—	*Not installed*	—	—
29	32	rsw01	risw_01	ridge southwest	20	NCAR
30	33	rsw02	risw_02	ridge southwest	20	NCAR
31	34	rsw03	risw_03	ridge southwest	60	NCAR/DTU
32	35	rsw04	risw_04	ridge southwest	10	NCAR
33	36	rsw05	risw_05	ridge southwest	10	NCAR
34	37	rsw06	risw_06	ridge southwest	60	NCAR/DTU
35	38	rsw07	risw_07	ridge southwest	20	NCAR
36	39	rsw08	risw_08	ridge southwest	20	NCAR
37	40	rne01	rine_01	ridge northeast	10	NCAR
38	41	rne02	rine_02	ridge northeast	20	NCAR
39	42	rne03	rine_03	ridge northeast	10	NCAR
40	43	rne04	rine_04	ridge northeast	10	NCAR
	44	—	—	*Not installed*	—	—
41	45	rne06	rine_06	ridge northeast	20	NCAR
42	46	rne07	rine_07	ridge northeast	20	NCAR
43	47	v01	vall_01	valley	10	NCAR

to be continued on the next page

continuation from the previous page

#	Codes Perdigao	NCAR	DTU	Location	Height	Manag
	48	—	—	*Not installed*	—	—
44	49	`v03`	`vall_03`	valley	10	NCAR
45	50	`v04`	`vall_04`	valley	10	NCAR
46	51	`v05`	`vall_05`	valley	20	NCAR
47	52	`v06`	`vall_06`	valley	20	NCAR
48	53	`v07`	`vall_07`	valley	20	NCAR
49	54	`Extreme_SW`	`Extreme_SW`	southwest	10	ARL
50	55	`Extreme_NE`	`Extreme_NE`	north east	10	ARL

Source: *LaTeX NETCDF Towers/Latex TowerName* *30-04-2018 19:02*

Note on future tower identification

Please note the following:

1. These three conventions were created independently from each other and are included here for completeness and allow crossing information from different sources.
2. It is not intended that they all three be used in the future; we strongly recommend that the DTU convention be dropped in favour of NCAR, which using the same *rationale* (location and tower number per location) identifies the same tower with less digits.
3. It is recommended that in every future publication a combination of both Perdigao and NCAR nomenclature be used, where, for instance tower 20 is identified as tower 20/tse04. It should not be identified as tower 19, because it was the 19th tower installed, or for instance, as tower number 4, because it was tower number 4 of those 6 used in that publication.
4. Tower identification should prevail forever and when faced with different publications, the reader will know that the authors are referring to the same tower. Data files are identified based on either nomenclature.

2.2 Sonic anemometers

The sonic anemometers (installed at the end of booms, attached to the lattice tower, Fig. 2) had their position determined by measuring four locations: two on the boom and two on the anemometer, Fig. 3. The measuring equipment was a Leica system, comprised of the following units: (1) Leica MultiStation MS50, (2) Leica Viva GS14 - GNSS Smart Antenna, (3) Leica CRT16 Bluetooth Cap and (4) Leica GRZ121 360 Reflector PRO Surveying Prism. Based on these measurements, the following information (available in worksheet *Anemometers*, see section B.1.2) was determined for every anemometer:

- angle α (in degrees), the boom alignment between the boom and the geographical north, measured clockwise;
- tilt, the angle of the boom in degrees towards the horizontal plane;
- easting and northing, the eastward and the northward-measured distances; and

- two different heights (elevations)[9] above the mean sea level,
  - z_{boom}, the elevation of the boom centre line;
  - z_0(int.), the terrain elevation, determined by interpolation from the terrain lidar scanning in 2015; and
  - z_0(mea.), the terrain elevation on top of the tower concrete foundation, as measured by the Leica system and included as reference.

Figure 2: Tower (N. 41/riNE02) with sonics (RMY81000) mounted vertically at the end of the booms.

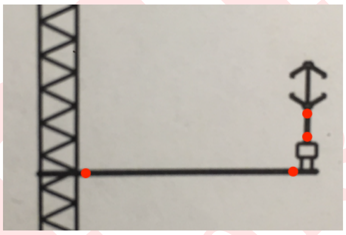

Figure 3: Measurement points on boom and sonic (Ref Menke and Mann [2017])

2.2.1 Measurements uncertainty

According to Menke and Mann [2017], the location (easting, northing and elevation) of every single sonic anemometer was measured to the precision of 1 cm or even 2 mm. However, reporting the positioning of every anemometer to the accuracy achieved by the Leica system is needless, because higher deviations did certainly occur during the course of the measurements by temperature changes and stresses acting on the metal structure (guy-wires and lattice tower). The accuracy achieved by the measuring system cannot be matched when it comes to construction and erection of the lattice towers or installation of the sonic anemometers.

[9] See section 1.2.2 on height, altitude and elevation.

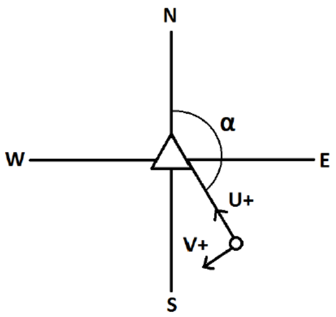

Figure 4: Boom direction and wind vectors (Ref Menke and Mann [2017])

In an attempt to assess the uncertainty of the measurement procedures, the standard deviation of easting, northing, elevation and boom direction of all sonic anemometers on the same mast and direction were determined (worksheet *Tower location* in workbook *Towers and sonics*), with the summary of those results in Table 3. The average of the standard deviation of both easting and northing was of an order of 10^{-1} m, and the average of standard deviation of direction and elevation were 1.25 degree and 0.03 m; whereas the maxima of each variable could be up about 5× the average. These values are an indicator of the good quality of the work performed by Samortecnica, during the construction and erection of the towers, and by the technicians from DTU, NCAR and INEGI during the installation of the equipment. Otherwise, it would have not been possible to achieve deviations of only a few dm between sensors along distances up to 100 m above the ground.

Table 3: Average and maximum of standard deviation of easting, northing, direction and elevation

	Sensor Location			
	Easting	Northing	Direction	Elevation (asl)
Average	0,10	0,06	1,25	0,03
Maximum	0,44	0,38	5,23	0,26

The coordinates of the sonic anemometers as measured appear in worksheet entitled *Anemometers* (section B.1.2). The coordinates in worksheets entitled *Tower location* (section B.1.3) are copies from worksheet *Anemometers* ((linked by formulae). Any future change of the measured values, if necessary, should be in this worksheet.

2.2.2 Handling the missing data

The coordinates of 10 out of a total of 185 sonics were not measured. Two situations were encountered:

Situation 1: Easting and northing could not be determined. However, z_{boom}, angle and tilt were measured, and the solution was to assume that easting and northing were identical to the anemometer immediately above. This was the case of the following sonics at 2 m above the ground, where, due to the vegetation there was no clearance for operation of the Leica system:

1. TW03 2M / tnw03.2m (blue cells for tower 03, line 11)

2. TW04 2M / tnw04.2m (blue cells for tower 04, line 14)
3. TW06 2M / tnw06.2m (blue cells for tower 06, line 30)
4. TW07 2M / tnw07.2m does not exist (blue cells for tower 07, line 38)
5. Tower 50, for the anemometer placed 2 meters above ground. Estimate coordinates for the sonic can be found in line 226 of Worksheet *Tower location*.
6. TW51 2M / v05.2m (blue cells for tower 51, line 229)
7. TW53 2M / v07.2m (blue cells for tower 53, line 237)

Apart from these 7 sonics, there was no easting and northing also in the case of sonic TW28 10M tse12.10m (orange cells for tower 28, line 158), and easting and northing were from the tower location, derived from the location of the anemometer above (line 159).

Situation 2: no measurements.

This only applied to anemometer TW07 12M / tnw07.12m (line 43) and here the height above the ground was assumed equal to 12 m, the nominal value, and all others variables were taken as the average value of the remaining anemometers on the tower.

2.2.3 Location of 185 sonics

QUESTIONS ON LOCATION OF SONIC ANEMOMETERS
Questions

1. Every single sonic anemometer should have its location exactly as measured, including:

   (a) Easting, northing, height above the ground, direction and tilting; or

   (b) Easting, northing, height above the ground and direction.
   Tilting must be ignored, because it was very low and was measured only to ascertain that the boom was on a horizontal plane and the sonic anemometer was aligned. The heigth of the sonic, h_s above the ground was determined by:

   $$h_s = z_{boom} + sonic_{offset} - z_t(int.) \tag{1}$$

   where $sonic_{offset}$, in Table 4, is the vertical distance between the boom and the centre of the sonic sensors. $z_t(mea.)$ the terrain height derived from the terrain scanning campaign in 2015 was included here only as reference. The terrain elevation measured by the Leica system, because *is situ*, was considered more accurate.
   Table 9, in Appendix A.1, shows the location for all 185 sonic anemometers.

2. There is no need to know the exact location of every single sonic anemometer, and easting, northing, height above the ground and direction should be treated as follows:

   (a) The easting and northing of all sonic anemometers must be averaged, yielding one single location for all sonic anemometers at the same tower; i.e. a vertical line going through the centre of all sonic anemometers.

   $$E_{st_i} = \frac{1}{N_i}\sum_{k=1}^{N_i} E_k \tag{2}$$
   $$N_{st_i} = \frac{1}{N_i}\sum_{k=1}^{N_i} N_k \tag{3}$$

   where N_i is the number of anemometers on tower i.

   (b) Only the height above the ground and the direction of each anemometer must be preserved.

3. Which location should be used as the tower location?

   (a) See section 2.3.1.

Tables 4 and 5 show the distribution of 185 sonic anemometers. by manufacturers and ownership, whereas the location as measured by the Leica system, can be found in Table 9. $h_s(agl)$ is the actual height of the sonic (geometric centre of the sonic sensors) above the ground level, in centimetre. This is a value of no consequence on the identification of the instrument and the corresponding data files, where the instrument is identified by its nominal height, in metre.

Table 4: Sonics anemometers: manufacturers and models and height offset

Manufacturer/model	Height offset (m)	Quantity
CSAT3	0,080	11
CSAT3A	0,000	24
Gill WM Pro	0,669	51
GillWM	0,819	40
METEK	0,660	15
RMY81000	0,520	42
?		2
Total		185

Source: *Towers and Sonics/Count Sonics*
05-02-2018 13:12

Table 5: Sonics anemometers: owners

Owner	Quantity
NCAR	31
OU	3
??	58
ARL	63
DTU	14
UND	16
UPORTO	10
Total	185

Source: *Towers and Sonics/Count Sonics*
05-02-2018 13:12

2.3 Towers

There were two types of towers: the ARL towers and those supplied by Samortecnica with heights from 10 up to 100 m (Table 6). The latter were all lattice structures constructed in an equilateral triangular pattern. Tower 21 (2 m height) was an exception; it was a final attempt to have some measurement equipment at a location thought to be important.

Table 6: Characteristics of Samortecnica towers

Tower height (m)	Triangular pattern			
	side a_i (cm)	height b_i (cm)	height b_i^* (cm)	radius r_i (cm)
100	60	17.32	51.96	34,64
60	55	15.87	47.61	31,75
30, 20, 10	45	12.99	38.97	25,98

Because there was no measurement of the tower location and this was required as the reference location of other instruments also installed at or near the tower, the tower location was determined from the location of the sonic anemometers as described in the following section.

2.3.1 Tower location

The sonics were installed at the end of a boom (attached to one side of the lattice tower, Fig. 2), at a distance ℓ equal to 2 m, measured between the closest vertex of the equilateral triangle and the vertical axis (centre) of the sensors in the sonic anemometer (Fig. 5). The boom direction with respect to the geographical North, is given by α, E and N are the easting and northing, and subscripts t and s refer to tower and sensor.

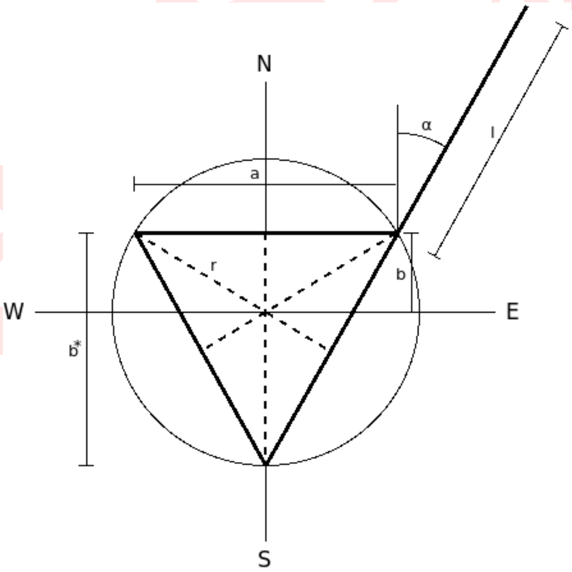

Figure 5: Triangle in circle

Because the area of the large equilateral triangle (side a) is identical to the area of the three (or six) small triangles within

$$b^* = 3b \; . \tag{4}$$

Also, in the case of the large triangle,

$$(b^*)^2 + (a/2)^2 = a^2 \; , \tag{5}$$

which, after substitution in (4) yields

$$b = a/\sqrt{12} \tag{6}$$

the distance (b) between the boom and the centre of the tower, as a function of the triangle side. The radius of the circle, r, is equal to $r = a/\sqrt{3}$.

The average location of all sonics on a tower is:

$$E_{st_i} = \frac{1}{N_i}\sum_{k=1}^{N_i} E_k \tag{7}$$

$$N_{st_i} = \frac{1}{N_i}\sum_{k=1}^{N_i} N_k \tag{8}$$

and the centre of the circle (the tower centre) is located at

$$E_t = \frac{1}{N_i}\sum_{k=1}^{N_i}\left[E_k \underbrace{-(\ell + a_i/2)\sin(\alpha_k)}_{E_1} - \underbrace{b_i\cos(\alpha_k)}_{E_2}\right] \tag{9}$$

$$N_t = \frac{1}{N_i}\sum_{k=1}^{N_i}\left[N_k \underbrace{-(\ell + a_i/2)\cos(\alpha_k)}_{N_1} + \underbrace{b_i\sin(\alpha_k)}_{N_2}\right] \tag{10}$$

where N_i is the number of sonic anemometers on tower i, E_k and N_k are the easting and northing of anemometer k and α_k is the boom direction, and a_i and b_i depend on the tower size (Table 6).

QUESTIONS ON TOWERS' REFERENCE LOCATION
Questions

- Which location should be used as the tower location?

  1. the location 2a in the previous box, i.e. the vertical axis of all sonics (equations (7) and (8))? or
  2. the vertical axis going through the centre of the equilateral triangle of the lattice tower pattern (equations (9) and (10))?

ANSWER: See next box.

DECISION ON TOWER LOCATION
The reference location of the tower should be the location of the vertical axis going through the centre of the sonic anemometers, instead of the geometrical centre of the lattice tower, because:

1. the location of the vertical axis going through the centre of the sonic anemometers was determined with a lower uncertainty than the geometric centre of the actual (lattice) tower;
2. this is the location that really matters (if the objective is an accurate location of the sonics);
3. this not only should be the geographic location of the sonics but of all the sensors on the tower.

Table 10 shows the location of all towers (geometrical centre of the lattice structure, called *Lattice tower*) and the location of the vertical axis going through the centre of sensors (called *Sonic tower*). Both lattice towers and sonic towers share the same terrain elevation and differ on the actual location (i.e. Easting and Northing).

In the case of towers where not all booms were on the same direction, towers were split into *a* and *b*, which was the case of towers 2, 4, 5, 14, 23, 28 and 51. In this case, the distance between towers (Dist stow) is also shown. This distance is about 4 m long in the case of the booms were opposed to each other (180° apart), which was the case of towers 2, 4, 5, 23, 28 and 51. In summary, there was a total of 50 lattice towers or 56 sonic towers.

2.4 Other tower based sensors

Because it was the most reliable source on the equipment actually installed and operating at every tower, the number and type of sensors was determined mainly by post-processing the meta-data information in XML, after editing the contents of the NetCDF files of every tower[10]. However, the information here is not complete, because the ARL towers (i.e., towers 12, 13, 14, 15 and 16, and the towers number 54 and 55, named `Extreme_SW` and and `Extreme_NW`) had an independent data acquisition system, and a list of questions need to be answered yet.

The results in this section can be found in the Excel workbook, entitled *NetCDF Towers* (Appendix B.2). Table 11, on page 35, contains the information on every tower.

2.4.1 The equipment on towers with the NCAR data acquisition system

In total, there were at least 344 sensors installed on these 48 towers (Table 7), distributed as follows:

- Sonic anemometers, 195 (this number differs from 185 in section 2.2 and Table 9)
- Barometer, 14
- Radiometer, 14
- Hygrothermometer, 51
- Wetness Sensor, 13
- CO2/H2O Gas Analyzer, 17
- Soil Heat Flux/Moisture Sensor, 15
- Soil temperature, 1
- Thermohygrometer, 5
- Pyrgeometer. See worksheet *Questions* ??

ACTION IS NEEDED

- These numbers are not final, until the list of equipment on towers 12, 13, 14, 15, 16, 54 and 55 is known (see section 2.4.2) and meaning of some variables in the NetCDF files is clarified.

[10] Later, it was found that a record of the equipment installed on every tower was maintained by Steve Oncley (available at https://wiki.ucar.edu/display/perdigao/Tower+Sensor+Serial+Numbers), see page 19

ACTION IS NEEDED (NCAR, Steve Oncley)

- Question on the interpretation of Pyrgeometer. See worksheet *Questions* in workbook *Towers and Sonics*.

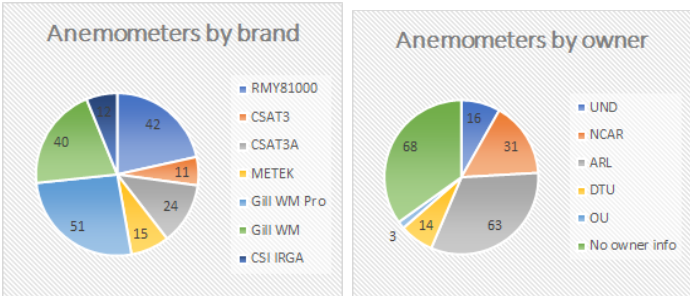

Figure 6: Anemometer by brand and owner

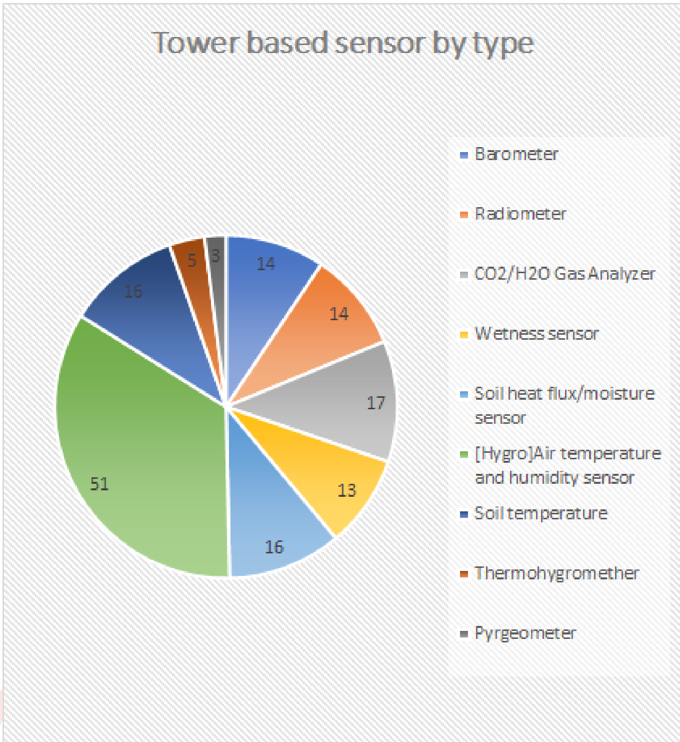

Figure 7: Tower based sensor by type

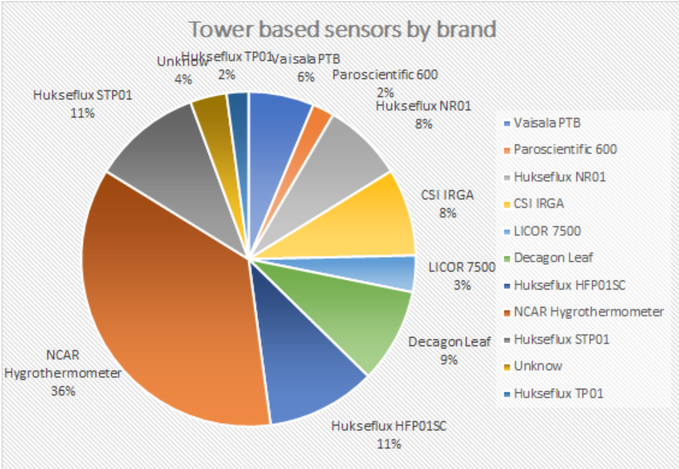

Figure 8: Tower based sensor by brand

Table 7: Sensors on towers

Tower		*Sonic anemometer*	*Barometer*	*Radiometer/Pyranometer*	*Hygrothermometer*	*Wetness Sensor*	*CO2/H2O Gas Analyser*	*Soil Heat Flux/Moisture Sensor*	*Soil temperature*	*Thermohygrometer*	*Pyrgeometer*	*Total*
01	tnw01	3	1									4
02	tnw02	4		1		1	1	1	1			9
03	tnw03	2			2							4
04	tnw04	7										7
05	tnw05	8		1	2	1	1	1	1			15
06	tnw06	7										7
07	tnw07	9			4							13
08	tnw08	3										3
09	tnw09	3		1		1	1	1	1			8
10	tnw10	5			5							10
11	tnw11	3			3							6
12	tnw12	8	?	?	?	?	?	?	?	?	?	8
13	tnw13	8	?	?	?	?	?	?	?	?	?	8
14	tnw14	8	?	?	?	?	?	?	?	?	?	8
15	tnw15	8	?	?	?	?	?	?	?	?	?	8
16	tnw16	8	?	?	?	?	?	?	?	?	?	8
17	tse01	3		1		1	1	1	1			8
18	tse02	3		1		1	1	1	1			8
20	tse04	7			7							14
21	tse05	2		1		1	1	1	1			7
22	tse06	5	1		5							11

to be continued on the next page

continuation from the previous page

Tower		*Sonic anemometer*	*Barometer*	*Radiometer/Pyranometer*	*Hygrothermometer*	*Wetness Sensor*	*CO2/H2O Gas Analyser*	*Soil Heat Flux/Moisture Sensor*	*Soil temperature*	*Thermohygrometer*	*Pyrgeometer*	*Total*
23	tse07	3	1	1		1	1	1	1			9
24	tse08	2	1									3
25	tse09	7			7							14
26	tse10	2	1									3
27	tse11	5			4							9
28	tse12	3		1			1	1	1			7
29	tse13	7			7							14
32	rsw01	2	1									3
33	rsw02	2	1									3
34	rsw03	5	1		5							11
35	rsw04	1	1	1		1	1	1	1			7
36	rsw05	1	1									2
37	rsw06	5								5		10
38	rsw07	2										2
39	rsw08	2	1									3
40	rne01	2					1	1	1		1	6
41	rne02	2										2
42	rne03	1										1
43	rne04	1										1
45	rne06	2	1	1		1	1	1	1			8
46	rne07	3		1		1	1	1	1			8
47	v01	3	1	1			1	1	1		1	9
47	v01	3	1	1			1	1	1		1	9
49	v03	3					1					4
50	v04	2		1		1	1	1	1		1	8
51	v05	3										3
52	v06	3				1	1	1	1			7
53	v07	7	1	1		1	1	1	1			13
54	`Extreme_SW`	?	?	?	?	?	?	?	?	?	?	?
55	`Extreme_NE`	?	?	?	?	?	?	?	?	?	?	?
	Total	195	14	14	51	13	17	16	16	5	3	344

Source: *Convert Summary To Latex/Latex Sensors Total* *08-02-2018 15:17*

NOTES: the difference between the total number of sonics in this table (Table 7) and Table 9 is because of the 10 IRGASON Integrated CO2 and H2O Open-Path Gas Analyzer and 3-D Sonic Anemometer that simultaneously measure three-dimensional wind speed, and absolute carbon dioxide and water vapor, air temperature, barometric pressure and sonic air temperature.

2.4.2 The equipment on the ARL towers (nos. 12, 13, 14, 15, 16, 54 and 55)

The list of equipment on the ARl towers (nos. 12, 13, 14, 15 and 16; and nos. 54 and 55) is not complete. The information of 8 sonic anemometers per tower was as in section 2.2, Table 9.

ACTION IS NEEDED (ARL, Ed Creegan)

- The list of equipment installed on ARL towers is missing.

2.5 To be completed

There are a couple of actions needed, before this list is complete:

1. Confirmation of sensors installed on ARL towers.
2. Values in Table 7 need to be compared with information on page 19, a copy of Steve's blog available at Tower Sensor Serial Numbers, Created by Steven Oncley, last modified on Mar 16, 2018.
3. After this is done, Table 11 can also be completed.

Tower Sensor Serial Numbers, Created by Steven Oncley, last modified on Mar 16, 2018

The following 5 pages is the information collected by Steve Oncley during the installation and later updated. This is an independent source that must be compared with the information in Table 7.

Tower Sensor Serial Numbers

Skip to end of metadata

- Created by Steven Oncley, last modified on Mar 16, 2018

Go to start of metadata

Some distance measurements at bottom of this page.

tnw01

- 20m: RMY(ARL) #1359
- 10m: RMY(ARL) #645
- 2m: PTB220 #U4110003 (B8)
- 2m: RMY(ARL) #712
- Mote #55

tnw02

- 20m: CSAT3A#2044 ; EC150#1233; EC100 #1313
- 20m: NR01 #1980
- 10m: CSAT3A#2036; EC100 #1817
- 10m: TRH #43
- 2m: RMY #004590
- 2m: TRH #117, #31
- mote #20
- soils: Tsoil#012; Qsoil#012; Gsoil#H023010(06); TP01#200592(06)

tnw03

- 10m: METEK (DTU): 2007 08017/01 Teardown: 10m METEK USA-14 # 200708017/01
- 10m: TRH #124
- 2m: METEK (DTU): 2007 09007/01 2m Metek USA-14 #200709007/01
- 2m: TRH #1
- mote #5 Mote #5, DSM # 208

tnw04

- 20m: RMY(ARL) #4132
- 12m: RMY(ND) #2552
- 10m: RMY(ND) #4593
- 8m: RMY(ND) #4552
- 6m: RMY(ND) #4592
- 4m: RMY(ARL) #923
- 2m: RMY(ARL) #1256
- mote #NONE (not enough left!)

tnw05

- 20m: CSAT3A #2049
- 20m: EC150 #1384
- 20m: EC100 #1696
- 20m: NR01 #2540
- 12m: RMY #650
- 10m: CSAT3A #2047
- 10m: EC100 # 1798
- 10m: Mote ID37
- 8m: RMY #1377
- 6m: RMY #1360
- 4m: RMY #498
- 2m: RMY #495
- Soil Mote ID07
- TSoil #009
- ECHO EC5 #001
- TP01 #200669
- Heat Flux #H023009

tnw06

- 20m: RMY #633
- 12m: RMY #1369
- 10m: RMY #1376
- 8m: RMY #1372
- 6m: RMY #635
- 4m: RMY #1338
- 2m: RMY #639
- Mote #28

tnw07

- 60m: TRH#125/#58
- 60m: Gill #164808
- 40m: TRH#129
- 40m: Gill #164807
- 30m: DSM
- 30m: Gill #164805
- tnw07t; mote #32
- 20m: TRH#102
- 20m: Gill #164804
- 10m: TRH#42/#64
- 10m: Gill #164803
- 2m: TRH#123
- tnw07b; mote #31

tnw08

- 20m: RMY(ND) #1294

- 10m: RMY(ND) #3984
- 2m: RMY(ND) #3410
- mote #27

tnw09

- 10m: CSAT3A #2035; EC150 #1392; EC100 #1693
- 10m: NR01 #2536
- 2m: RMY (ARL) #1374
- Soils: mote #15, TP #200675,HF #H943149, TS #001, QS#E10

tnw10

- 60m: TRH#128
- 40m: TRH#23/#53
- 30m: DSM tnw10; mote#
- 20m: TRH#118
- 10m: TRH#105
- 2m: TRH#124/#119

tnw11

- 20m: RMY (ARL) 4131 > 638
- 10m: RMY (ARL) 4133 > 932
- 2m: RMY (ARL) 4135
- mote #12

tse01

- 20m: CSAT3A# , EC150#, EC100# Teardown: 20m CSAT3A # 2032, EC150 # 1385, EC100 # 1690
- 20m: NR01 NR01-T2 # 2539 LW #009
- 2m: CSAT3A#, EC100# 10m CSAT3A #2045, EC100 # 1796
- mote# Soil mote #30, ECHO #003, PIC QS03, TSoil # 008 PIC TS08, HFT #H103642 PIC TP09
- DSM 217

tse02

- 30m: CSAT3A#2037, EC150#1383, EC100 #1687 Teardown: 30m CSAT3A #2037, EC150#1383 EC100 # 1687 NR01 -T2 #2533, LW # 001
- 20m: NR01 #2533
- 10m: CSAT3A # 2050, EC100 #1813 10m CSAT3A # 2050, EC100 # 1813
- Mote Soil #25, TP #15, QS #08, HF#13, TS #17 Soil Mote # 25, TP01 # 200668 PIC TP07, ECHO # 027 PIC QS08, HFT 3.1 # H103634 PIC HF13, TSoil # 017 PIC TS17
- DSM 218

~~tse03~~ (skipped in numbering, doesn't exist)

tse04

- 100m: TRH#24, #111
- 80m: TRH#31, #116
- 70m: tse04t; Mote #17
- 60m: TRH#108, #125
- 40m: TRH#47, #24, #110
- 20m: TRH#60, #104
- 10m: TRH#68
- 2m: TRH#104, #60
- 2m tse04b; Mote #57

tse05

- 2m: CSAT3A#1006 ; EC150 #1386 ; EC100 #1706
- 2m: NR01#1424
- 2m: nanobarometer #123998
- mote #24
- soils: Tsoil #TS09; Qsoil #QS13; Gsoil #HF08; TP01 #TP04

tse06

- 60m: TRH#8/#29
- 40m: TRH#100
- 30m: DSM tse06; mote #60
- 20m: TRH#1, #32
- 10m: TRH#43, #115
- 2m: TRH#67, #23; nano #123996

tse07

- 20m: CSAT3A #P1004/EC100 ~~#1700~~ #1702/EC150 ~~#1387~~ #1389
- 20?m: nr01 #1980; wetness
- 10m: CSAT3 #1550 (OU), since none of 3x NCAR CSAT3's worked!
- 2m: nano #123997
- Soil: mote#51, TP02, HF16, TS11, QS17, since TS12 was bad

tse08 (USB2 didn't work in 422 mode)

- 20m: METEK #0102122234
- 10m: METEK #2007 19011/01
- 2m: nano #122850
- mote #48

tse09

- 100m: TRH#112

- 80m: TRH#117/#126
- 70m: DSM tse09t; mote#
- 60m: TRH#41
- 40m: TRH#63
- 20m: TRH#21
- 10m: TRH#122
- 2m: TRH#103
- DSM tse09b; mote#

tse10

- 30m: METEK #0102 12 2235
- 10m: METEK #2007 09006/01
- 2m: PTB220 #NCAR0003 (B3)
- mote #53

tse11

- 60m: TRH#121
- 40m: TRH#110/#25
- 30m: DSM tse11; mote#
- 20m: TRH#116/#42
- 10m: TRH#113
- 2m: TRH#120/#24

tse12 (needs soil installed, cables connected to DSM and dressed)

- 20m: EC150#1390, EC100#1704, CSAT3A#2043, NR01#2534
- 10m: CSAT3[OU]#1552
- Soil: mote#23, TP12, HF03, TS14, QS02

tse13

- 100m: TRH#111, #56
- 80m: TRH#33, #44
- 70m: DSM tse13t; mote#
- 60m: TRH#127, #17
- 40m: TRH#55
- 20m: TRH#3
- 10m: TRH#107
- 2m: TRH#119, #106
- DSM tse13b; mote#

~~tse14~~ (never instrumented)

~~tse15~~ (never instrumented)

rsw01

- 20m: METEK#010212 236
- 10m: METEK#2007 08015/01
- 2m: PTB220#U4110004 (B9)
- mote#19

rsw02

- 20m: RMY#1368 (had spikes in ops testing, but seemed okay out of the box) Teardown: 20m RMY #1257
- 10m: RMY#499 (had problems receiving commands in ops testing) 10m RMY #00499
- 2m: Setra#6919221 (was labeled rsw03?, but rain washed off) 2m Pressure # 6919221
- mote#12
  Mote # 44, DSM # 257(RSW02X), DSM (w/ Analog input) CPU 000092 (no number on box)

rsw03

- 60m: TRH#48
- 40m: TRH#51
- 30m: DSM rsw03; mote#
- 20m: TRH#56, #33
- 10m: TRH#126, #08
- 2m: TRH#25, #108
- 2m: Setra#6919220 (labeled rsw02)

rsw04

- 10m: CSAT3A #P1008/EC100 #1816; Li7500 #0813
- 2m: Setra #6919218
- Rad: mote#47, Rswin#940181, Rswout#040740, Rlwin#030675, Rlwout#970379
- Soil: mote#, TP16, HF19, TS03, QS13

rsw05

- 10m: METEK (DTU) #0102122233 Teardown: 10m Metek USA-14 #0102122233
- 2m: Setra #6919219 2m Pressure #6919219
- mote #6 Mote #6, DSM #22 FLUX ARRAY (siesmometer) #5007328 IICLOCK - 130 CLOCK 4192

rsw06

- 60m: TRH#40
- 40m: TRH#46
- 30m: DSM rsw06; mote#
- 20m: TRH#65, #31, #15
- 10m: TRH#5
- 2m: TRH#109

rsw07

- 5: CSAT3A #1244; EC100 #1823
- 10m: CSAT3 #1121
- mote #11

rsw08

- 20m: METEK#
- 10m: METEK#
- 2m: PTB220#S0610002 (B5)
- mote #

rne01

- 10m: EC150#1807, EC100#1799, CSAT3A#1007
- Rad: mote#43, Rswin#970380, Rswout#970377, Rlwin#100225, Rlwout#100226
- Soil: mote#22, TP17, HF18, TS06, QS05

rne02

- 20m: RMY#1354 (ARL)
- 10m: RMY#725 (ARL)
- mote#29

rne03

- 10m: EC100#1807, CSAT3A#P1005
- mote#33

rne04

- 10m: RMY(OU) #4130
- Mote #10

~~rne05~~ (won't be installed)

rne06

- 20m: CSAT3A #2033; EC100 #1821; Li7500 #1166
- 20m: NR01 #2537
- 10m: CSAT3 #1120
- Soil: mote#38, TP#, HF#H993563, TS#007, QS#E015

rne07

- 20m: CSAT3A #1009; EC150 #1388; EC100 #1701
- 20m: NR01 #2538
- 10m: CSAT3A #2046; EC100 #1818
- Soil: mote#18, TP21, HF04, TS02, QS04

v01

- 10m: EC100 #1696, EC150 #1386, CSAT3A #2031
- 10m: NR01 #2451
- 2m: CSAT3 #1124
- 2m: PTB220 #S0610003 (B6)
- Mote Soil #42, TP18, QS19, TS16, HF14

~~v02~~ (won't be installed)

v03

- 10m: CSAT3A #1003, EC150 #1433, EC100 #1810
- 2m: CSAT3A #2051, EC100 #1800
- Mote #41

v04

- 10m: CSAT3A #1001; EC100 #1815
- 10m: LiCor #1167
- 2m: CSAT3 #1550
- Rad: mote #16, Rsw.in #970378; Rlw.in #050824; Rsw.out #030676; Rlw.out #940186
- Soil: mote #52, TP14, HF05, TS13, QS07

v05

- 2m: METEK #2005 05007/01
- 10m: METEK #2007 08011/01
- 20m: METEK #2007 09004/01
- Mote # 34

v06

- 20m: CSAT3A #2048, EC100 #1822
- 20m: LiCor #1164
- 20m: NR01 # 1979
- 10m: CSAT3 #1119
- 2m: CSAT3 #1123
- Soil: mote #58, TP03, HF02, TS15, QS16

v07b

- 12m: RMY #646
- 8m: RMY #1330
- 6m: RMY #726
- 4m: RMY #1353
- Soil: mote #50, TP13, TS20, QS18, HF12

- 2m: PTB220 #491125 (B10)
- 2m: CSAT3(OU) #1553

v07t

- 20m: Li7500 #1163
- 20m: NR01 #2535
- 10m: CSAT3 #1123
- Mote #49

(all should have holes taped or puttyed)

Initially, all RMY and METEK set with "north" pointing along boom away from tower, so "north" is approximately SE, but this changed later.

Distance from center of boom to vertical center of array (measured in ops center):

- RMY81000: 52cm
- METEK: 66cm
- CSAT3: 8cm
- CSAT3AW: 0cm

Base distances, measured on tse09, tse10, tse11:

- 100m: inside of metal "U" channel to bottom of first tower section: 12.4cm
- 60m: inside of metal "U" channel to bottom of first tower section: 4cm (different construction)
- 30m (assume for 10&20 as well): inside of metal "U" channel to bottom of first tower section: 12.4cm
- Distances to top of concrete vary from 0.6cm more (thickness of the metal U channel on top of the concrete), to 4cm less (U channel embedded down into the concrete).

3 Ground based equipment

The contents of the present section was derived from Workbook entitled *Ground Based Equipment*, in section B.3.

Data control procedures There were two sources of information on the location data of the ground based equipment:

1. values in PerdigÃ£o web site (as of May 2017), collected in different occasions; and
2. values measured during the last days of the IOP, available in Google Workbook *Remote Sensors*[11].

Coordinates of the same equipment in these two sources were compared, and if differences were higher than 10 m (stations 101, 105, 111, 112, 113, 123, 124, 131, 133, 144, 151, 152, 153, 154, 161, 162, 163, 212 and 215), the data were submitted to additional checking, including the observation of photos.

The terrain elevation that was missing (stations: 109, 115, 121, 122, 125, 132, 141, 142, 144, 156, 157, 162, 181, 182, 183, 184, 185, 191, 201, 211, 212, 213, 214 and 215) in Google Workbook *SENSOR-COORD*, with the measurements during the last days of the IOP, was obtained from the airborne terrain (laser) scanning in 2015. These values are identified by *ts* to distinguish from those obtained by the Leica system (m).

The contents and current state of worksheet is in Table 12.

Identification The code name in Perdigao web site is composed of two parts: part 1, a mixture of initials and digits for identification of the equipment; and part 2, with the owner (name of the participating institution) between parenthesis. The code name, category and type are major attributes, to find and easily access information on any station.

Final values

Values in Perdigão web site are final, and as in Table 12. Owners or main users of these equipments were contacted to check the final values. The name of the person, date and time of this final check is shown in the observation field of the equipment: *Validated and checked by NAME on DAY/MONTH/YEAR hour:minute UTC.*

The coordinates are made available to 10^{-2} m (centimetre) and 10^{-1} m (decimetre) in the case of terrain elevation.

3.1 Remote sensing

Most of the ground based equipment, Table 8, was remote sensors (39 out of 55), which included 20 scanning lidars, 8 profiling lidars, 1 profiling radar, 1 profiling radar - RASS, 2 sodar - RASS, 1 water vapour DIAL, 1 atmospheric emitted radiance interferometer, 3 microwave radiometer, 1 ceilometer and 1 scintillometer.

[11] This workbook, used during the last days of the IOP, is now a worksheet in the Excel workbook called *Ground Based Equipment*.

Table 8: Ground based equipment

#	Equipment	Owner
20	Scanning LIDAR	DTU, UO, UND, ARL, DLR, WindForS, CU
8	Profiling LIDAR	CU, UC Boulder, Enercon, Leosphere
1	Profiling RADAR	NCAR, NCAS
1	Profiling RADAR - RASS	NCAR
2	SODAR - RASS	NCAR
1	Water vapor DIAL	NCAR
2	Radiosonde sites	NCAR, IPMA, ARL, UND
1	Atmospheric Emitted Radiance Interferometer	OU
3	Microwave radiometer	OU, DLR, UND
2	Tethersonde	ARL, UC Boulder
9	Noise monitoring terminal	Enercon, DLR
1	Ceilometer	UND
3	Seismometer	CU
1	Scintillometer	ARL
55	Total	

CU – Cornell University (USA); DLR – Institute of Atmospheric Physics (Germany); DTU – Danish Technical University (Denmark); Enercon GmbH (Germany); IPMA – Portuguese Institute for Sea and Atmosphere (Portugal); Leosphere (France); NCAR – National Center for Atmospheric Research (USA); NCAS – National Centre for Atmospheric Science (UK); OU – University of Oklahoma (USA); UC Boulder – University of Colorado (Boulder) (USA); UND – University of Notre Dame (USA); UO – University of Oldenburg (Germany); US ARL – United States Army Research Laboratories (USA); WindForS – WindForS Wind Energy Research Cluster (Germany).

3.2 Noise monitoring terminals

The noise monitoring terminals comprised four stations (181, 182, 183 and 184) from Enercon and five microphone units (211, 212, 213, 214 and 215) from DLR.

3.3 Sounding sites

Sounding sites refers to locations of both radio (two locations, 125 and 156) and the tethered sondes (two locations also, 143 and 157).

3.4 Seismometers

Three seismometers (stations 216, 217 and 217) were the last subset included in the ground based equipment.

References

ISO International Organization for Standardization and ICE International Electrotechnical Commission. Guide 98-3. uncertainty of measurement. part 3: Guide to the expression of uncertainty in measurement (gum:1995), 2008. URL http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=45315.

Robert Menke and Jakob Mann. Perdigão laser scanning report. Technical report, DTU, 2017.

A Tables

A.1 Location of sonics

Table 9: Location of sonic anemometers

N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model(sn)	
	Tower height: 20 m							
1	tnw01.2m	32 611.27	4623.15	297.84	141.81	2.04	RMY81000	712
2	tnw01.10m	32 611.25	4623.15	297.84	143.92	9.94	RMY81000	645
3	tnw01.20m	32 611.31	4623.22	297.86	141.83	20.01	RMY81000	1359
	Tower height: 20 m							
4	tnw02.2m	32 802.56	4751.43	392.38	305.19	2.03	RMY81000	4590
5	tnw02.10m	32 805.95	4749.07	392.38	125.09	9.92	CSAT3A	2036
6	tnw02.20m	32 805.95	4749.09	392.39	127.35	19.99	CSAT3A	2044
	Tower height: 10 m							
7	tnw03.2m	32 917.67	4860.89	486.77	110.15	2.26	METEK 2007	09007/01
8	tnw03.10m	32 917.67	4860.89	486.77	111.75	10.24	METEK 2007	08017/01
	Tower height: 20 m							
9	tnw04.2m	33 160.42	4962.95	395.21	125.96	2.11	RMY81000	1256
10	tnw04.4m	33 160.42	4962.96	395.21	126.49	4.28	RMY81000	923
11	tnw04.6m	33 160.45	4962.96	395.21	125.94	5.95	RMY81000	4592
12	tnw04.8m	33 160.44	4962.95	395.21	126.24	8.10	RMY81000	4552
13	tnw04.10m	33 160.43	4962.96	395.21	125.99	10.25	RMY81000	4593
14	tnw04.12m	33 157.20	4965.45	395.06	307.61	12.52	RMY81000	2552
15	tnw04.20m	33 157.14	4965.30	395.07	303.38	20.31	RMY81000	4132
	Tower height: 20 m							
16	tnw05.2m	33 202.15	5042.62	367.86	317.05	2.13	RMY81000	495
17	tnw05.4m	33 202.15	5042.64	367.85	316.71	4.07	RMY81000	498
18	tnw05.6m	33 202.17	5042.67	367.85	317.17	6.24	RMY81000	1360
19	tnw05.8m	33 202.17	5042.65	367.85	317.52	8.33	RMY81000	1377
20	tnw05.10m	33 202.19	5042.52	367.88	317.26	10.20	CSAT3A	2047
21	tnw05.12m	33 202.17	5042.67	367.85	316.88	12.24	RMY81000	650
22	tnw05.20m	33 205.01	5039.67	368.54	136.67	19.53	CSAT3A	2049
	Tower height: 20 m							
23	tnw06.2m	33 434.16	5224.15	333.85	115.91	2.36	RMY81000	639
24	tnw06.4m	33 434.17	5224.19	333.85	116.47	4.17	RMY81000	1338
25	tnw06.6m	33 434.17	5224.18	333.85	117.09	6.30	RMY81000	635
26	tnw06.8m	33 434.16	5224.17	333.85	117.58	8.33	RMY81000	1372
27	tnw06.10m	33 434.17	5224.14	333.85	118.07	10.40	RMY81000	4593
28	tnw06.12m	33 434.16	5224.12	333.86	118.23	12.29	RMY81000	2552
29	tnw06.20m	33 434.14	5224.11	333.86	118.64	20.35	RMY81000	4132
	Tower height: 60 m							
30	tnw07.4m	33 587.28	5351.15	286.49	126.51	4.00	METEK	0
31	tnw07.6m	33 587.28	5351.17	286.49	127.23	5.84	RMY81000	0
32	tnw07.8m	33 587.28	5351.14	286.49	126.67	7.85	RMY81000	0
33	tnw07.10m	33 587.19	5351.35	286.50	126.43	10.14	Gill WM Pro	0
34	tnw07.12m	33 587.18	5351.36	286.50	124.81	11.99	RMY81000	0
35	tnw07.20m	33 587.19	5351.44	286.50	124.48	20.01	Gill WM Pro	0
36	tnw07.30m	33 587.11	5351.51	286.50	123.43	29.85	Gill WM Pro	0

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N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model(sn)	
37	tnw07.40m	33 587.10	5351.52	286.50	122.57	40.08	Gill WM Pro	0
38	tnw07.60m	33 587.03	5351.58	286.50	121.14	56.85	Gill WM Pro	0
	Tower height: 20 m							
39	tnw08.2m	33 749.54	5479.01	339.38	126.67	2.54	RMY81000	3410
40	tnw08.10m	33 749.49	5479.10	339.42	125.98	10.69	RMY81000	3984
41	tnw08.20m	33 749.55	5479.12	339.43	125.90	20.38	RMY81000	1294
	Tower height: 10 m							
42	tnw09.2m	33 864.02	5587.71	388.20	108.94	1.66	RMY81000	1374
43	tnw09.10m	33 864.09	5587.83	388.24	106.65	9.40	CSAT3A	2035
	Tower height: 60 m							
44	tnw10.10m	33 952.00	5627.95	413.47	118.88	9.86	Gill WM Pro	0
45	tnw10.20m	33 952.05	5628.03	413.50	116.75	19.51	Gill WM Pro	0
46	tnw10.30m	33 952.07	5628.09	413.51	116.31	29.61	Gill WM Pro	0
47	tnw10.40m	33 952.09	5628.17	413.53	114.65	39.87	Gill WM Pro	0
48	tnw10.60m	33 952.12	5628.24	413.55	114.07	56.66	Gill WM Pro	0
	Tower height: 20 m							
49	tnw11.2m	34 042.92	5696.15	437.00	153.54	2.50	RMY81000	4135
50	tnw11.10m	34 043.05	5696.30	437.00	150.23	10.63	RMY81000	932
51	tnw11.20m	34 043.08	5696.31	437.00	151.63	20.96	RMY81000	638
	Tower height: 30 m							
52	tnw12.2m	34 095.92	5717.03	421.33	92.70	2.13	GillWM	0
53	tnw12.4m	34 095.95	5717.01	421.33	92.40	4.16	GillWM	0
54	tnw12.6m	34 096.00	5717.02	421.31	92.32	6.15	GillWM	0
55	tnw12.8m	34 096.02	5717.03	421.30	91.47	8.24	GillWM	0
56	tnw12.10m	34 095.74	5717.09	421.37	91.05	9.74	GillWM	0
57	tnw12.12m	34 095.78	5717.11	421.35	90.70	11.85	GillWM	0
58	tnw12.20m	34 095.58	5717.21	421.38	88.84	19.63	GillWM	0
59	tnw12.30m	34 095.38	5717.30	421.41	90.17	27.30	GillWM	0
	Tower height: 30 m							
60	tnw13.2m	34 140.58	5777.09	384.73	270.70	1.18	GillWM	0
61	tnw13.4m	34 140.58	5777.09	384.73	270.62	3.09	GillWM	0
62	tnw13.6m	34 140.59	5777.08	384.72	270.45	5.11	GillWM	0
63	tnw13.8m	34 140.60	5777.06	384.73	270.39	7.16	GillWM	0
64	tnw13.10m	34 140.93	5777.07	384.42	270.13	9.24	GillWM	0
65	tnw13.12m	34 140.94	5777.08	384.42	270.61	11.17	GillWM	0
66	tnw13.20m	34 141.39	5777.09	384.34	270.15	19.07	GillWM	0
67	tnw13.30m	34 141.74	5777.18	384.27	270.70	26.90	GillWM	0
	Tower height: 30 m							
68	tnw14.2m	34 222.96	5816.54	348.98	138.96	2.81	GillWM	0
69	tnw14.4m	34 222.98	5816.55	348.98	107.09	3.87	GillWM	0
70	tnw14.6m	34 222.99	5816.57	348.98	106.74	5.86	GillWM	0
71	tnw14.8m	34 223.00	5816.58	348.98	107.31	7.91	GillWM	0
72	tnw14.10m	34 222.72	5816.70	349.00	106.04	9.66	GillWM	0
73	tnw14.12m	34 222.75	5816.69	349.00	106.23	11.61	GillWM	0
74	tnw14.20m	34 222.49	5816.73	349.02	104.40	19.37	GillWM	0
75	tnw14.30m	34 222.25	5816.77	349.04	105.10	27.13	GillWM	0
	Tower height: 30 m							
76	tnw15.2m	34 273.24	5843.31	330.26	81.07	2.17	GillWM	0

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N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model(sn)	
77	tnw15.4m	34 273.25	5843.31	330.26	80.77	4.18	GillWM	0
78	tnw15.6m	34 273.25	5843.32	330.26	80.61	6.16	GillWM	0
79	tnw15.8m	34 273.25	5843.31	330.26	80.24	8.22	GillWM	0
80	tnw15.10m	34 272.94	5843.31	330.37	79.78	9.88	GillWM	0
81	tnw15.12m	34 272.94	5843.30	330.37	79.93	11.84	GillWM	0
82	tnw15.20m	34 272.62	5843.24	330.49	79.10	19.47	GillWM	0
83	tnw15.30m	34 272.26	5843.25	330.57	76.17	27.17	GillWM	0
	Tower height: 30 m							
84	tnw16.2m	34 350.06	5868.89	306.65	88.33	1.65	GillWM	0
85	tnw16.4m	34 350.06	5868.89	306.65	88.27	3.68	GillWM	0
86	tnw16.6m	34 350.06	5868.90	306.65	88.00	5.69	GillWM	0
87	tnw16.8m	34 350.06	5868.89	306.65	87.86	7.73	GillWM	0
88	tnw16.10m	34 349.75	5868.91	306.65	87.42	9.49	GillWM	0
89	tnw16.12m	34 349.75	5868.90	306.65	87.61	11.43	GillWM	0
90	tnw16.20m	34 349.41	5868.86	306.65	87.55	19.19	GillWM	0
91	tnw16.30m	34 349.10	5868.88	306.65	88.73	26.99	GillWM	0
	Tower height: 20 m							
92	tse01.2m	32 960.82	3942.29	252.69	117.50	9.91	CSAT3A	0
93	tse01.20m	32 960.89	3942.30	252.69	115.93	28.79	CSAT3A	0
	Tower height: 30 m							
94	tse02.10m	33 260.15	4138.29	372.36	112.57	8.62	CSAT3A	2050
95	tse02.30m	33 260.07	4138.26	372.30	111.28	27.71	CSAT3A	2037
	Tower height: 100 m							
96	tse04.10m	33 394.24	4258.92	473.04	137.73	10.30	Gill WM Pro	0
97	tse04.20m	33 394.20	4258.91	473.03	135.05	19.93	Gill WM Pro	0
98	tse04.30m	33 394.17	4258.93	473.03	135.00	27.81	Gill WM Pro	0
99	tse04.40m	33 394.22	4258.88	473.03	134.57	37.05	Gill WM Pro	0
100	tse04.60m	33 394.17	4258.86	473.02	134.88	57.16	Gill WM Pro	0
101	tse04.80m	33 394.14	4258.83	473.01	135.42	77.29	Gill WM Pro	0
102	tse04.100m	33 394.11	4258.74	473.00	136.33	97.29	Gill WM Pro	0
	Tower height: 2 m							
103	tse05.2m	33 497.76	4425.85	422.46	135.43	1.54	CSAT3A	1006
	Tower height: 60 m							
104	tse06.10m	33 636.63	4487.32	387.90	148.37	15.47	Gill WM Pro	0
105	tse06.20m	33 636.61	4487.33	387.90	147.75	21.45	Gill WM Pro	0
106	tse06.30m	33 636.59	4487.36	387.90	147.13	29.58	Gill WM Pro	0
107	tse06.40m	33 636.58	4487.37	387.90	146.06	39.40	Gill WM Pro	0
108	tse06.60m	33 636.56	4487.44	387.89	143.38	57.37	Gill WM Pro	0
	Tower height: 20 m							
109	tse07.10m	33 818.24	4566.09	348.30	286.70	10.21	CSAT3	1550
110	tse07.20m	33 821.93	4564.96	349.22	107.46	19.31	CSAT3A	P1004
	Tower height: 20 m							
111	tse08.10m	33 977.68	4634.05	341.45	123.53	9.85	METEK 2007	19011/01
112	tse08.20m	33 977.69	4634.02	341.45	124.80	19.84	METEK	102122234
	Tower height: 100 m							
113	tse09.10m	34 153.34	4845.14	305.37	154.80	10.38	Gill WM Pro	0
114	tse09.20m	34 153.27	4844.87	305.35	154.91	20.51	Gill WM Pro	0
115	tse09.30m	34 153.19	4844.85	305.34	155.12	30.14	Gill WM Pro	0

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N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model	(sn)
116	tse09.40m	34 153.07	4844.81	305.33	156.21	40.60	Gill WM Pro	0
117	tse09.60m	34 152.88	4844.76	305.32	156.83	60.15	Gill WM Pro	0
118	tse09.80m	34 152.77	4844.55	305.30	156.90	80.28	Gill WM Pro	0
119	tse09.100m	34 152.59	4844.49	305.28	158.77	97.47	Gill WM Pro	0
	Tower height: 30 m							
120	tse10.10m	34 274.41	4923.06	332.92	137.08	10.36	METEK	2007 09006/01
121	tse10.30m	34 274.28	4922.83	332.88	136.76	29.27	METEK	0102 12 2235
	Tower height: 60 m							
122	tse11.10m	34 334.59	4972.80	355.12	136.17	12.53	Gill WM Pro	0
123	tse11.20m	34 334.49	4972.98	355.11	134.71	19.96	Gill WM Pro	0
124	tse11.30m	34 334.39	4973.17	355.11	133.29	29.84	Gill WM Pro	0
125	tse11.40m	34 334.23	4973.38	355.09	131.43	39.83	Gill WM Pro	0
126	tse11.60m	34 333.94	4973.79	355.05	128.68	56.81	Gill WM Pro	0
	Tower height: 20 m							
127	tse12.10m	34 446.38	5048.37	414.65	337.88	9.79	CSAT3	1552
128	tse12.20m	34 448.07	5044.25	414.65	157.42	19.71	CSAT3A	2043
	Tower height: 100 m							
129	tse13.10m	34 536.23	5111.79	452.91	129.57	10.02	Gill WM Pro	0
130	tse13.20m	34 536.18	5111.74	452.91	129.91	20.02	Gill WM Pro	0
131	tse13.30m	34 536.12	5111.66	452.90	131.15	30.12	Gill WM Pro	0
132	tse13.40m	34 536.09	5111.59	452.89	131.75	40.03	Gill WM Pro	0
133	tse13.60m	34 535.96	5111.51	452.88	133.47	60.15	Gill WM Pro	0
134	tse13.80m	34 535.76	5111.43	452.86	135.36	79.97	Gill WM Pro	0
135	tse13.100m	34 535.63	5111.33	452.84	137.73	97.04	Gill WM Pro	0
	Tower height: 20 m							
136	rsw01.10m	33 730.51	3803.29	472.10	136.18	9.38	METEK	2007 08015/01
137	rsw01.20m	33 730.47	3803.33	472.10	136.38	19.91	METEK	010212 236
	Tower height: 20 m							
138	rsw02.10m	33 633.48	3901.19	478.17	145.68	10.14	RMY81000	1368
139	rsw02.20m	33 633.52	3901.21	478.17	143.33	20.06	RMY81000	499
	Tower height: 60 m							
140	rsw03.10m	33 569.60	4006.76	472.95	147.09	9.97	Gill WM Pro	0
141	rsw03.20m	33 569.72	4006.80	472.92	145.55	19.79	Gill WM Pro	0
142	rsw03.30m	33 569.85	4006.84	472.90	143.94	29.58	Gill WM Pro	0
143	rsw03.40m	33 569.98	4006.89	472.87	142.33	40.13	Gill WM Pro	0
144	rsw03.60m	33 570.16	4006.93	472.84	140.43	56.76	Gill WM Pro	0
	Tower height: 10 m							
145	rsw04.10m	33 453.60	4169.17	473.74	164.17	9.92	CSAT3A	P1008
	Tower height: 10 m							
146	rsw05.10m	33 195.80	4548.30	479.11	147.49	9.98	METEK	0102122233
	Tower height: 60 m							
147	rsw06.10m	33 087.91	4686.07	482.49	154.14	10.30	Gill WM Pro	0
148	rsw06.20m	33 087.93	4686.04	482.49	143.87	20.36	Gill WM Pro	0
149	rsw06.30m	33 087.95	4686.05	482.49	142.67	30.21	Gill WM Pro	0
150	rsw06.40m	33 087.99	4686.09	482.49	141.85	40.19	Gill WM Pro	0
151	rsw06.60m	33 088.07	4686.09	482.49	149.34	57.15	Gill WM Pro	0
	Tower height: 20 m							
152	rsw07.10m	32 822.84	5000.95	490.47	124.57	10.48	CSAT3	1121

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N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model(sn)	
153	rsw07.20m	32 822.79	5000.90	490.47	124.93	20.37	CSAT3A	1244
	Tower height: 20 m							
154	rsw08.10m	32 734.34	5141.92	488.88	152.11	10.28	METEK	0
155	rsw08.20m	32 734.39	5141.88	488.88	151.21	20.31	METEK	0
	Tower height: 10 m							
156	rne01.10m	34 886.81	4772.73	453.56	108.86	10.02	CSAT3A	1007
	Tower height: 20 m							
157	rne02.10m	34 737.43	4877.21	458.26	166.47	10.41	RMY81000	725
158	rne02.20m	34 737.48	4877.16	458.25	164.97	20.21	RMY81000	1354
	Tower height: 10 m							
159	rne03.10m	34 630.65	5025.52	461.66	122.83	9.56	CSAT3A	P1005
	Tower height: 10 m							
160	rne04.10m	34 414.87	5281.94	454.01	130.34	10.20	RMY81000	0
	Tower height: 20 m							
161	rne06.10m	34 178.25	5565.27	451.10	168.32	9.87	CSAT3	1120
162	rne06.20m	34 178.30	5565.22	451.11	166.69	19.72	CSAT3A	2033
	Tower height: 20 m							
163	rne07.10m	33 886.53	5851.99	466.90	161.55	10.61	CSAT3A	2046
164	rne07.20m	33 886.60	5852.00	466.89	159.98	20.03	CSAT3A	1009
	Tower height: 10 m							
165	v01.2m	34 575.05	4503.62	330.60	135.00	1.89	CSAT3	1124
166	v01.10m	34 575.07	4503.54	330.60	134.69	9.92	CSAT3A	2031
	Tower height: 10 m							
167	v03.2m	34 235.99	4696.82	307.68	128.03	1.92	CSAT3A	2051
168	v03.10m	34 235.97	4696.85	307.66	127.78	9.90	CSAT3A	1003
	Tower height: 10 m							
169	v04.2m	33 951.14	4978.78	295.68	124.15	2.09	CSAT3	1001
170	v04.10m	33 951.14	4978.78	295.68	123.41	10.01	CSAT3A	2031
	Tower height: 20 m							
171	v05.2m	33 811.59	5125.80	291.59	319.33	2.27	METEK 2005	05007/01
172	v05.10m	33 814.75	5122.53	291.59	134.02	10.01	METEK 2007	08011/01
173	v05.20m	33 814.75	5122.56	291.59	133.45	20.02	METEK 2007	09004/01
	Tower height: 20 m							
174	v06.2m	33 704.27	5238.11	288.59	126.84	2.12	CSAT3	1123
175	v06.10m	33 704.18	5238.12	288.63	127.33	10.00	CSAT3	1119
176	v06.20m	33 704.35	5238.11	288.63	126.35	20.02	CSAT3A	2048
	Tower height: 20 m							
177	v07.2m	33 388.58	5457.11	281.52	113.04	2.08	CSAT3	1553
178	v07.4m	33 388.62	5457.10	281.52	112.81	4.18	RMY81000	1353
179	v07.6m	33 388.62	5457.11	281.52	112.70	5.92	RMY81000	726
180	v07.8m	33 388.62	5457.09	281.52	112.66	7.97	RMY81000	1330
181	v07.10m	33 388.46	5457.21	281.52	113.39	9.92	CSAT3	1123
182	v07.12m	33 388.62	5457.04	281.51	113.66	11.88	RMY81000	646
183	v07.20m	33 388.56	5457.11	281.52	113.85	20.01	CSAT3	0
	Tower height: 10 m							
184	Extreme SW	31 630.72	3670.69	217.76	0.00	10.00	RMY81000	0
	Tower height: 10 m							
185	Extreme NE	34 643.46	6174.68	260.27	172.00	9.40	0	0

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N.	Name	Easting	Northing	Elevation[1]	α	$h_s(agl)$	Model(sn)

Source: *Towers and Sonics/Latex Sonics 08-02-2018 16:42*

(1) Elevation is identical to z_{boom}, as in Menke and Mann [2017]. See also section 1.2.2

A.2 Location of towers

Table 10: Tower location

N.	Terrain elevation	α	Sonic tower Easting	Sonic tower Northing	Lattice tower Easting	Lattice tower Northing	Dist tow	Dist vtow
01	297.85	142.52	32 611.28	4623.17	32 610.03	4625.02	2.23	–
02	392.38	185.88	32 804.82	4749.86	32 804.31	4750.42	0.76	–
02a	392.38	305.19	32 802.56	4751.43	32 804.45	4750.25	2.23	4.12
02b	392.39	126.22	32 805.95	4749.08	32 804.23	4750.50	2.23	–
03	486.77	110.95	32 917.67	4860.89	32 915.64	4861.81	2.23	–
04	395.17	177.37	33 159.50	4963.65	33 158.83	4964.31	1.59	–
04a	395.21	126.12	33 160.43	4962.96	33 158.71	4964.37	2.23	4.06
04b	395.07	305.50	33 157.17	4965.38	33 159.06	4964.19	2.23	–
05	367.95	291.32	33 202.57	5042.21	33 203.56	5040.95	1.59	–
05a	367.86	317.10	33 202.17	5042.63	33 203.59	5040.91	2.23	4.10
05b	368.54	136.67	33 205.01	5039.67	33 203.39	5041.20	2.23	–
06	333.85	117.43	33 434.16	5224.15	33 432.25	5225.30	2.23	–
07	286.50	124.81	33 587.18	5351.36	33 585.41	5352.79	2.28	–
08	339.41	126.18	33 749.53	5479.08	33 747.81	5480.50	2.23	–
09	388.22	107.80	33 864.06	5587.77	33 861.98	5588.57	2.23	–
10	413.51	116.13	33 952.07	5628.10	33 950.09	5629.24	2.28	–
11	437.00	151.80	34 043.02	5696.25	34 042.08	5698.28	2.23	–
12	421.35	91.21	34 095.80	5717.10	34 093.57	5717.28	2.23	–
13	384.55	270.47	34 140.92	5777.09	34 143.14	5776.94	2.23	–
14	349.00	110.23	34 222.77	5816.64	34 220.76	5817.51	2.19	–
14a	348.98	138.96	34 222.96	5816.54	34 221.60	5818.30	2.23	0.25
14b	349.00	106.13	34 222.74	5816.66	34 220.64	5817.40	2.23	–
15	330.36	79.71	34 272.97	5843.29	34 270.76	5843.02	2.23	–
16	306.65	87.97	34 349.78	5868.89	34 347.55	5868.94	2.23	–
17	252.69	116.72	32 960.86	3942.30	32 958.93	3943.41	2.23	–
18	372.33	111.93	33 260.11	4138.28	33 258.09	4139.23	2.23	–
20	473.02	135.57	33 394.18	4258.87	33 392.69	4260.63	2.31	–
21	422.46	135.43	33 497.76	4425.85	33 496.29	4427.53	2.23	–
22	387.90	146.54	33 636.59	4487.36	33 635.47	4489.35	2.28	–
23	348.76	197.08	33 821.93	4564.96	33 820.13	4565.66	1.93	–
23a	348.30	286.70	33 818.24	4566.09	33 820.41	4565.58	2.23	3.86
23b	349.22	107.46	33 821.93	4564.96	33 819.85	4565.75	2.23	–
24	341.45	124.17	33 977.69	4634.04	33 975.92	4635.39	2.23	–
25	305.33	156.22	34 153.02	4844.78	34 152.25	4846.96	2.31	–
26	332.90	136.92	34 274.35	4922.95	34 272.92	4924.66	2.23	–
27	355.10	132.86	34 334.33	4973.22	34 332.77	4974.89	2.28	–
28	414.65	247.65	34 448.07	5044.25	34 447.34	5046.35	2.23	–
28a	414.65	337.88	34 446.38	5048.37	34 447.34	5046.35	2.23	4.45
28b	414.65	157.42	34 448.07	5044.25	34 447.34	5046.35	2.23	–

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			Virtual tower		Tower		Dist	Dist
N.	Elevation	α	Easting	Northing	Easting	Northing	tow	stow
29	452.88	132.70	34 535.99	5111.58	34 534.42	5113.26	2.30	–
32	472.10	136.28	33 730.49	3803.31	33 729.05	3805.01	2.23	–
33	478.17	144.51	33 633.50	3901.20	33 632.31	3903.09	2.23	–
34	472.90	143.87	33 569.86	4006.84	33 568.65	4008.77	2.28	–
35	473.74	164.17	33 453.60	4169.17	33 453.12	4171.35	2.23	–
36	479.11	147.49	33 195.80	4548.30	33 194.71	4550.25	2.23	–
37	482.49	146.37	33 087.97	4686.07	33 086.85	4688.04	2.27	–
38	490.47	124.75	32 822.82	5000.93	32 821.06	5002.30	2.23	–
39	488.88	151.66	32 734.37	5141.90	32 733.42	5143.92	2.23	–
40	453.56	108.86	34 886.81	4772.73	34 884.75	4773.57	2.23	–
41	458.26	165.72	34 737.46	4877.19	34 737.03	4879.37	2.23	–
42	461.66	122.83	34 630.65	5025.52	34 628.85	5026.84	2.23	–
43	454.01	130.34	34 414.87	5281.94	34 413.26	5283.48	2.23	–
45	451.11	167.51	34 178.28	5565.25	34 177.92	5567.45	2.23	–
46	466.90	160.77	33 886.57	5852.00	33 885.95	5854.14	2.23	–
47	330.60	134.85	34 575.06	4503.58	34 573.57	4505.24	2.23	–
49	307.67	127.91	34 235.98	4696.84	34 234.30	4698.30	2.23	–
50	295.68	123.78	33 951.14	4978.78	33 949.36	4980.13	2.23	–
51	291.59	195.60	33 813.70	5123.63	33 813.20	5124.18	0.74	–
51a	291.59	319.33	33 811.59	5125.80	33 813.14	5124.20	2.23	4.54
51b	291.59	133.74	33 814.75	5122.55	33 813.23	5124.18	2.23	–
52	288.62	126.84	33 704.27	5238.11	33 702.56	5239.55	2.23	–
53	281.52	113.16	33 388.58	5457.11	33 386.59	5458.10	2.23	–
54	0.00	0.00	31 630.72	3670.69	31 630.59	3668.47	2.23	–
55	260.27	172.00	34 643.46	6174.68	34 643.28	6176.90	2.23	–

Source: *Towers and Sonics/Latex Towers* *05-02-2018 14:57*

(1) Elevation is identical to z_{boom}, as in Menke and Mann [2017]. See also section 1.2.2

A.3 Equipment on towers

Table 11: Towers and equipment ?**Incomplete**?

Tower	Equipment	Height (agl)	Orientation	Equipment	
Source:	*NETCDF Towers/NETCDF Towers Summary*		*14-11-2017 19:42*		
01	Datalogger	1.5 m			
tnw01	3D Sonic anemometer	2.04 m	141.81	RMY8100	
	3D Sonic anemometer	9.94 m	143.92	RMY8100	
					To remove
					To remove
	3D Sonic anemometer	20.01 m	141.83	RMY8100	
	Barometer	2 m		Vaisala	To add
02	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
tnw02	Datalogger	1.5 m			
	3D Sonic anemometer	2.03 m	305.19	RMY8100	
	3D Sonic anemometer	9.92 m	125.09	CSAT3	
	3D Sonic anemometer	19.99 m	127.35	CSAT3	
	Radiometer	20 m		Hukseflux NR01	
	CO2/H2O Gas Analyzer	20 m		CSI IRGA	
	3D Sonic anemometer	20 m		CSI IRGA	To add
	Wetness Sensor	20 m		Decagon Leaf	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
03	Datalogger	1.5 m			
tnw03	3D Sonic anemometer	2 m		METEK	
					To remove
					To remove
	3D Sonic anemometer	10.24 m	111.75	METEK	

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Tower	Equipment	Height (agl)	Orientation	Equipment	
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
04	Datalogger	1.5 m			
tnw04	3D Sonic anemometer	4.28 m	126.49	RMY81000	
	3D Sonic anemometer	5.95 m	125.94	RMY81000	
	3D Sonic anemometer	8.1 m	126.24	RMY81000	
	3D Sonic anemometer	10.25 m	125.99	RMY81000	
	3D Sonic anemometer	12.52 m	307.61	RMY81000	
					To remove
					To remove
	3D Sonic anemometer	20.31 m	303.38	RMY81000	
	3D Sonic anemometer	2m		RMY81000	To add
05	Soil heat flux/moisture sensor			Hukseflux HPF01SC	
tnw05	Datalogger	1.5 m			
	3D Sonic anemometer	2.13 m	317.05	RMY8100	
	3D Sonic anemometer	4.07 m	316.71	RMY8100	
	3D Sonic anemometer	6.24 m	317.17	RMY8100	
	3D Sonic anemometer	8.33 m	317.52	RMY8100	
	3D Sonic anemometer	10.2 m	317.26	CSAT3	
	3D Sonic anemometer	12.24 m	316.88	RMY8100	
	3D Sonic anemometer	19.53 m	136.67	CSAT3	
	Radiometer	20 m		Hukseflux NR01	
	3D Sonic Anemometer	20 m		CSI IRGA	To add
	CO2/H2O Gas Analyzer	20 m		CSI IRGA	
	Wetness Sensor	20 m		Decagon Leaf	To add
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
06	Datalogger	1.5 m			
tnw06	3D Sonic anemometer	2 m		RMY8100	
	3D Sonic anemometer	4.17 m	116.47	RMY8100	
	3D Sonic anemometer	6.3 m	117.09	RMY8100	
	3D Sonic anemometer	8.33 m	117.58	RMY8100	
	3D Sonic anemometer	10.4 m	118.07	RMY8100	
	3D Sonic anemometer	12.29 m	118.23	RMY8100	
					To remove
					To remove
	3D Sonic anemometer	20.35 m	118.64	RMY8100	
07	3D Sonic anemometer	3.34 m	126.51	METEK	
tnw07	3D Sonic anemometer	5.32 m	127.23	RMY8100	
	3D Sonic anemometer	7.33 m	126.67	RMY8100	
	3D Sonic anemometer	9.47 m	126.43	Gill WindMaster	
	3D Sonic anemometer	10.16 m	126.50	RMY8100	
	Datalogger	12 m			
	3D Sonic anemometer	20.01 m	124.48	Gill WindMaster	
	3D Sonic anemometer	29.85 m	123.43	Gill WindMaster	
	3D Sonic anemometer	40.08 m	122.57	Gill WindMaster	
	3D Sonic anemometer	56.85 m	121.14	Gill WindMaster	
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
08	Datalogger	1.5 m			
tnw08	3D Sonic anemometer	2.54 m	126.67	RMY8100	
	3D Sonic anemometer	10.69 m	125.98	RMY8100	
					To remove
					To remove
	3D Sonic anemometer	20.38 m	125.90	RMY8100	
09	Datalogger	1.5 m			
tnw09	3D Sonic anemometer	1.66 m	108.94	RMY8100	
	3D Sonic anemometer	9.4 m	106.65	CSAT 3	
					To remove
					To remove
					To remove
	Radiometer	10 m		Hukseflux NR01	To add
	Wetness Sensor	10 m		Decagon Leaf	To add
	CO2/H2O Gas Analyzer	10 m		CSI IRGA	To add
	3D Sonic anemometer	10 m		CSI IRGA	To add
	Soil Heat flux/moisture sensor			Hukseflux HFP01SC	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
10	3D Sonic anemometer	9.86 m	118.88	Gill WindMaster	
tnw10	Datalogger	12 m			
	3D Sonic anemometer	19.51 m	116.75	Gill WindMaster	
	3D Sonic anemometer	29.61 m	116.31	Gill WindMaster	
	3D Sonic anemometer	39.87 m	114.65	Gill WindMaster	
	3D Sonic anemometer	56.66 m	114.07	Gill WindMaster	
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
11	Datalogger	1.5 m			
tnw11	3D Sonic anemometer	2.5 m	153.54	RMY8100	
	3D Sonic anemometer	10.63 m	150.23	RMY8101	
					To remove
					To remove
	3D Sonic anemometer	20.96 m	151.63	RMY8100	
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
12					
tnw12					
13					
tnw13					

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment
14 tnw14				
15 tnw15				
16 tnw16				

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
17	Datalogger	1.5 m			
tse01	3D Sonic anemometer	9.91 m	117.50	CSAT3	
	Radiometer	20 m		Hukseflux NR01	Not 20m but 30m
	3D Sonic anemometer	28.79 m	115.93	CSAT 3	
	CO2/H2O Gas Analyzer	30 m		CSI IRGA	
	3D Sonic anemometer	30 m		CSI IRGA	To add
	Wetness sensor	30 m		Decagon Leaf	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
18	Soil heat flux/moisture sensor			Hukseflux HFP01SC	To add
tse02	Datalogger	1.5 m			
	3D Sonic anemometer	8.62 m	112.57	CSAT3	
					To remove
	3D Sonic anemometer	27.71 m	111.28	CSAT3	
	CO2/H2O Gas Analyzer	30 m		CSI IRGA	
	3D Sonic anemometer	30 m		CSI IRGA	To add
	Radiometer	30 m		Hukseflux NR01	To add
	Wetness Sensor	30 m		Decagon Leaf	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
19					
20	3D Sonic anemometer	10 m	137.73	Gill WindMaster	
tse04	Datalogger	12 m			

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	3D Sonic anemometer	20 m	135.05	Gill WindMaster	
	3D Sonic anemometer	30 m	135.00	Gill WindMaster	
	3D Sonic anemometer	40 m	134.57	Gill WindMaster	
	3D Sonic anemometer	60 m	134.88	Gill WindMaster	
					To remove
	3D Sonic anemometer	78 m	135.42	Gill WindMaster	
	3D Sonic anemometer	100 m	136.33	Gill WindMaster	
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	80 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	100 m		NCAR Hygrothermometer	To add
21	Datalogger	1.5 m			
tse0	3D Sonic anemometer	2 m		CSAT3	
					To remove
					To remove
					To remove
					To remove
	CO2/H2O Gas Analyzer	2 m		CSI IRGA	To add
	3D Sonic anemometer	2 m		CSI IRGA	To add
	Radiometer	2 m		Hukseflux NR01	To add
	Soil Heat Flux/moisture sensor			Hukseflux STP01	
	Wetness Sensor	2m		Decagon Leaf	
	Soil temperature	1/4/6/9 cm		Hukseflux HFP01SC	

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
22	3D Sonic anemometer	10 m	148.37	GillWindMaster	
tse06	Datalogger	12 m			
	3D Sonic anemometer	20 m	147.75	GillWindMaster	
	3D Sonic anemometer	30 m	147.13	GillWindMaster	
	3D Sonic anemometer	40 m	146.06	GillWindMaster	
	3D Sonic anemometer	55 m	143.38	GillWindMaster	60M from NETCDF
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
	Barometer	2 m		Paroscientific	To add
23	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
tse07	Datalogger	1.5 m			
					To remove
	3D Sonic anemometer	10 m	286.70	CSAT3	
	3D Sonic anemometer	30 m	124.80	CSAT3	Height 20M from NETCDF
	CO2/H2O Gas Analyzer	20 m		CSI IRGA	To add
	3D Sonic anemometer	20 m		CSI IRGA	To add
	Wetness Sensor	20 m		Decagon Leaf	To add
	Radiometer	20 m		Hukseflux NR01	To add
	Barometer			Paroscientific	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
24	Datalogger	1.5 m			
tse08					To remove

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	3D Sonic anemometer	10 m	123.53	METEK	
					To remove
					To remove
	3D Sonic anemometer	20 m	124.80	METEK	
	Barometer	2 m		Paroscientific	To add
25	3D Sonic anemometer	10 m	154.80	Gill WindMaster	
tse09	Datalogger	12 m			
	3D Sonic anemometer	20 m	154.91	Gill WindMaster	
	3D Sonic anemometer	30 m	155.12	Gill WindMaster	
	3D Sonic anemometer	40 m	156.21	Gill WindMaster	
					To remove
	3D Sonic anemometer	60 m	156.83	Gill WindMaster	
	3D Sonic anemometer	80 m	156.90	Gill WindMaster	
					To remove
	3D Sonic anemometer	100 m	158.77	Gill WindMaster	
	Air temperature and humidity sensor	2m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	80 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	100 m		NCAR Hygrothermometer	To add
26					To remove
tse10	Datalogger	1.5 m			
					To remove
	3D Sonic anemometer	10 m	137.08	METEK	

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
					To remove
					To remove
	3D Sonic anemometer	30 m	136.76	METEK	
	Barometer	2 m		Vaisala	To add
27	3D Sonic anemometer	10 m		Gill WindMaster	
tse11	Datalogger	12 m			
	3D Sonic anemometer	20 m		Gill WindMaster	
	3D Sonic anemometer	30 m		Gill WindMaster	
	3D Sonic anemometer	40 m		Gill WindMaster	
	3D Sonic anemometer	55 m		Gill WindMaster	60M in NETCDF
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
28	Soil heat flux/moisture sensor			Hukseflux HFP01SC	To add
tse12	Datalogger	1.5 m			
					To remove
	3D Sonic anemometer	10 m		CSAT3	
	3D Sonic anemometer	20 m		CSAT3	
	CO2/H2O Gas Analyzer	20 m		CSI IRGA	To add
	3D Sonic anemometer	20 m		CSI IRGA	To add
	Radiometer	20 m		Hukseflux NR01	To add
	Soil temperature	1/4/6/9cm		Hukseflux STP01	To add
29	3D Sonic anemometer	10 m		Gill WindMaster	
tse13	Datalogger	12 m			

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	3D Sonic anemometer	20 m		Gill WindMaster	
	3D Sonic anemometer	30 m		Gill WindMaster	
	3D Sonic anemometer	40 m		Gill WindMaster	
	3D Sonic anemometer	60 m		Gill WindMaster	
	3D Sonic anemometer	80 m		Gill WindMaster	
	3D Sonic anemometer	95 m		Gill WindMaster	100m in NETCDF
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	80 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	100 m		NCAR Hygrothermometer	To add
30					
31					
32					To remove
rsw01	3D Sonic anemometer	10 m		METEK	
	3D Sonic anemometer	20 m		METEK	
	Barometer	2 m		Vaisala	To add
33					To remove
rsw02	3D Sonic anemometer	10 m		RMY8100	
	3D Sonic anemometer	20 m		RMY8100	
	Barometer	2 m		Vaisala	To add

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Tower	Equipment	Height (agl)	Orientation	Equipment	
34	Datalogger	8 m			
rsw03	3D Sonic anemometer	10 m		Gill WIndMaster	
	3D Sonic anemometer	20 m		Gill WIndMaster	
	3D Sonic anemometer	30 m		Gill WIndMaster	
	3D Sonic anemometer	40 m		Gill WIndMaster	
	3D Sonic anemometer	55 m		Gill WIndMaster	60M in NETCDF
	Air temperature and humidity sensor	2 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	10 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	20 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	40 m		NCAR Hygrothermometer	To add
	Air temperature and humidity sensor	60 m		NCAR Hygrothermometer	To add
	Barometer	2m		Vaisala	To add
35	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
rsw04	Datalogger	1.5 m			
					To remove
	Radiometer	10 m			
	CO2/H2O Gas Analyzer	10 m		LICOR 7500	
	3D Sonic anemometer	10 m		CSAT3	
	Barometer	2 m		Vaisala	Pending review. To add
	Wetness Sensor	?		Decagon Leaf	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	
36	Datalogger	1.5 m			
rsw05					To remove
					To remove
					To remove
	3D Sonic anemometer	10 m		METEK	

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	Barometer	2 m		Vaisala	To add
37					To remove
rsw06					To remove
	3D Sonic anemometer	10 m		GillWindMaster	
					To remove
					To remove
					To remove
					To remove
	Datalogger	12 m			
					To remove
	3D Sonic anemometer	30 m		Gill WindMaster	
					To remove
					To remove
	3D Sonic anemometer	40 m		GIllWindMaster	
					To remove
	3D Sonic anemometer	55 m		Gill WindMaster	60M in NETCDF
					To remove
	3D Sonic Anemometer	20 m		GillWindMaster	To add
	Thermohygrometer	2 m		NCAR	To add
	Thermohygrometer	10 m		NCAR	To add
	Thermohygrometer	20 m		NCAR	To add
	Thermohygrometer	40 m		NCAR	To add
	Thermohygrometer	60 m		NCAR	To add
38					To remove
rsw07					To remove
	3D Sonic anemometer	10 m		CSAT3	

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continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	3D Sonic anemometer	20 m		CSAT3	
39					To remove
rsw08	3D Sonic anemometer	10 m		METEK	
	3D Sonic anemometer	20 m		METEK	
	Barometer	2 m		Vaisala	To add
40	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
rne01	Datalogger	1.5 m			
					To remove
	3D Sonic anemometer	10 m		CSAT3	
	CO2/H2O Gas Analyzer	10 m		CSI IRGA	To add
	3D Sonic anemometer	10 m		CSI IRGA	To add
	Soil temperature	1/4/6/9/10 cm		Huksenflux STP01	To add
	Pyrgeometer			Hukseflux TP01	To add
41					To remove
rne02	3D Sonic anemometer	10 m		RMY8100	
	3D Sonic anemometer	20 m		RMY8100	
42	Datalogger	1.5 m			
rne03					To remove
					To remove
					To remove
	3D Sonic anemometer	10 m		CSAT3	
43	Datalogger	1.5 m			
rne04					To remove

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
					To remove
					To remove
	3D Sonic anemometer	10 m		RMY8100	
44					
45					To remove
rne06	3D Sonic anemometer	10 m		CSAT3	
	3D Sonic anemometer	20 m		CSAT3	
	Radiometer	20 m		Hukseflux NR01	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
	Barometer				To add
	Wetness sensor			Decagon leaf	To add
	CO2/H2O Gas Analyzer			LICOR 7500	To add
	Soil heat flux/moisture sensor			Hukseflux HFP01SC	To add
46					To remove
rne07	3D Sonic anemometer	10 m		CSAT3	
	3D Sonic anemometer	20 m		CSAT3	
	CO2/H2O Gas Analyzer	20 m		CSI IRGA	To add
	3D Sonic anemometer	20 m		CSI IRGA	
	Radiometer	20 m		Hukseflux NR01	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	
	Wetness sensor	20 m		Decagon leaf	To add
	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
47	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
v01	Datalogger	1.5 m			

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
	3D Sonic anemometer	2 m		CSAT3	
	Radiometer	10 m		Hukseflux NR01	
	CO2/H2O Gas Analyzer	10 m		CSI IRGA	
	3D Sonic anemometer	10 m		CSI IRGA	To add
	3D Sonic anemometer	10 m		CSAT3	
	Barometer	2 m		Vaisala	To add
	Soil temperature	1/4/6/9 cm		Hukseflux STP01	To add
	Pyrgeometer				Review
48					
49	Datalogger	1.5 m			
v03	3D Sonic anemometer	2 m		CSAT3	
					To remove
	CO2/H2O Gas Analyzer	10 m		CSI IRGA	
	3D Sonic anemometer	10 m		CSI IRGA	To add
	3D Sonic anemometer	10 m		CSAT3	
50	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
v04	Datalogger	1.5 m			
	3D Sonic anemometer	2 m		CSAT3	
	Radiometer	10 m			Radiometer available?
	CO2/H2O Gas Analyzer	10 m		LICOR 7500	
	3D Sonic anemometer	10 m		CSAT3	
	Wetness sensor			Decagon Leaf	To add
	Soil temperature	1/4/6/9cm		Hukseflux STP01	To add
	Pyrgeometer				Review

to be continued on the next page

continuation from the previous page

Tower	Equipment	Height (agl)	Orientation	Equipment	
51	3D Sonic anemometer	2 m		METEK	
v05	3D Sonic anemometer	10 m		METEK	
	3D Sonic anemometer	20 m		METEK	
52	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
v06	Datalogger	1.5 m			
	3D Sonic anemometer	2 m		CSAT3	
	3D Sonic anemometer	10 m		CSAT3	
	3D Sonic anemometer	20 m		CSAT3	
	Wetness sensor	20 m		Decagon Leaf	To add
	CO2/H2O Gas Analyzer	20 m		LICOR 7500	To add
	Soil temperature			Hukseflux STP01	To add
53	Soil heat flux/moisture sensor			Hukseflux HFP01SC	
v07	Datalogger	1.5 m			
	3D Sonic anemometer	2 m		CSAT3	
	3D Sonic anemometer	10 m		CSAT3	
	3D Sonic anemometer	20 m		CSAT3	
	3D Sonic anemometer	12 m		RMY81000	To add
	3D Sonic anemometer 4 m		RMY81000	To add	
	3D Sonic anemometer 6 m		RMY81000	To add	
	3D Sonic anemometer 8 m		METEK	To add	
	CO2/H2O Gas Analyzer 20 m		LICOR 7500	To add	
	Wetness Sensor 20 m		Decagon Leaf	To add	
	Barometer 2 m		Vaisala	To add	
	Radiometer 20 m		Hukseflux NR01	To add	
	Soil temperature 1/4/6/9 cm		Hukseflux STP01		

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Tower	Equipment	Height (agl)	Orientation	Equipment
54				
Extre				
55				
Extre				

A.4 Location of ground based equipment

Table 12: Location of ground based equipment

#	Station	Acronym	Equipment	Easting	Northing	Elevation (asl)	
1	101	LRWS #1 - WS_riSW_trSE_SW (DTU)	Scanning LIDAR	33356,32	4277.56	470.4	m
2	102	LRWS #2 - WS_riSW_trSE_NE(DTU)	Scanning LIDAR	33426,19	4324.08	480.3	m
3	103	LRWS #3 - WS_ruSW_trSE_NE (DTU)	Scanning LIDAR	34526,35	5103.50	452.3	m
4	104	LRWS #4 - WS_riNE_trSE_NE (DTU)	Scanning LIDAR	34578,94	5147.69	454.9	m
5	105	LRWS #5 - WS_riSW_trNW_NE (DTU)	Scanning LIDAR	32926,47	4874.29	485.9	m
6	106	LRWS #6 - WS_riSW_tw32 (DTU)	Scanning LIDAR	33888,66	3798.01	486.3	m
7	107	LRWS #7 - WS_riNE_trNW_SW (DTU)	Scanning LIDAR	33990,61	5695.30	437.1	m
8	108	LRWS #8 - WS_riNE_tw40 (DTU)	Scanning LIDAR	34804,57	4807.90	452.8	m
9	111	ZephIR - 447 (Cornell)	Profiling LIDAR	32379,29	4339.22	236.8	m
10	112	SpiDAR - OliveCoop (Cornell)	Profiling LIDAR	32383,41	4337.69	236.8	m
11	113	SpiDAR - Ridge (Cornell)	Profiling LIDAR	33086,87	4688.73	482.5	ts
12	114	ZephIR - 423 (Cornell)	Profiling LIDAR	33996,03	5117.96	309.1	m
13	115	Galion (Cornell)	Scanning LIDAR	34001,73	5116.44	309.5	m
14	121	Radar wind profiler & RASS (NCAR)	Profiling RADAR - RASS	31654,24	3743.27	223.7	ts
15	122	Radar wind profiler (NCAR/NCAS)	Profiling RADAR	37056,75	3827.09	288.6	ts
16	123	Sodar-RASS (NCAR)	SODAR - RASS	35506,98	3177.27	361.9	m
17	124	Water vapor DIAL (NCAR)	Water vapor DIAL	33998,70	5126.68	310.5	m
18	125	Radiosonde site (NCAR)	Radiosonde	33994,22	5113.10	310.5	ts
19	131	CLAMPS - Halo lidar (Oklahoma)	Scanning LIDAR	33956,03	4997.84	296.2	m
20	132	CLAMPS - AERI (Oklahoma)	AERI Atmospheric Emitted Radiance Interferometer	33953,49	5007.43	296.6	m
21	133	CLAMPS - MWR (Oklahoma)	Microwave radiometer	33948,34	5004.68	296.1	m
22	141	Windcube V1 68 BEEHIVE (Colorado)	Profiling LIDAR	34910,57	5638.86	259.7	ts
23	142	Windcube Profiler V1 49 (Colorado)	Profiling LIDAR	33954,64	5002.00	295.8	ts
24	143	Tethersonde (Colorado)	Tethersonde	33981,84	5004.07	298.4	ts
25	151	USA01 (Notre Dame)	Scanning LIDAR	34409,80	5222.82	447.8	m
26	152	USA2 (Notre Dame)	Scanning LIDAR	34008,00	5132.02	311.1	m
27	153	USA3 (Notre Dame)	Scanning LIDAR	33419,47	5252.65	334.0	m

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#	Station	Acronym	Equipment	Easting	Northing	Elevation (asl)	
28	154	`Sodar-RASS (Notre Dame)`	SODAR - RASS	34606,96	6117.91	258.4	m
29	155	`MWR (Notre Dame)`	Microwave radiometer	34651,07	6170.54	259.8	m
30	156	`Radiosonde (Notre Dame)`	Radiosonde	34647,65	6170.11	259.9	ts
31	157	`Ceilometer (Notre Dame)`	Ceilometer	33922,69	5007.21	294.3	ts
32	161	`USA04 (ARL)`	Scanning LIDAR	33907,88	5844.70	460.8	m
33	162	`USA05 (ARL)`	Scanning LIDAR	99999	99 999	9999	ts
34	163	`USA06 (ARL)`	Scanning LIDAR	34491,89	6083.23	265.5	m
35	164	`Scintillometer (ARL)`	Scintillometer	34495,70	6076.55	268.0	m
36	165	`Tethersonde (ARL)`	Tethersonde	34467,77	5214.76	458.2	m
37	171	`Scanning Lidar #1 (DLR)`	Scanning LIDAR	34467,77	5214.76	458.2	m
38	172	`Scanning Lidar #2 (DLR)`	Scanning LIDAR	34128,46	4982.50	323.2	m
39	173	`Scanning Lidar #3 (DLR)`	Scanning LIDAR	33127,27	4690.54	480.2	m
40	174	`Microwave Radiometer (DLR)`	Microwave radiometer	31667,27	3745.01	222.9	m
41	181	`E-NMT01`	NMT Noise monitoring terminal	34037,51	5141.69	317.5	ts
42	182	`E-NMT02`	NMT Noise monitoring terminal	33922,64	4951.74	296.4	ts
43	183	`E-NMT03`	NMT Noise monitoring terminal	33716,76	4763.67	359.5	ts
44	184	`E-NMT04`	NMT Noise monitoring terminal	32771,15	4111.60	250.4	ts
45	185	`Windcube (ENERCON)`	Profiling LIDAR	32945,76	4479.03	367.9	ts
46	191	`Windcube (Leosphere)`	Profiling LIDAR	34536,39	5112.86	453.1	ts
47	201	`ZSW Scanning Lidar (WindForS)`	Scanning LIDAR	34039,10	5719.85	436.1	ts
48	211	`Microphone #1 (DLR)`	NMT Noise monitoring terminal	33151,63	4665.10	475.2	ts
49	212	`Microphone #2 (DLR)`	NMT Noise monitoring terminal	33365,30	4311.11	481.0	ts
50	213	`Microphone #3 (DLR)`	NMT Noise monitoring terminal	32396,13	4328.29	238.1	ts
51	214	`Microphone #4 (DLR)`	NMT Noise monitoring terminal	34089,21	5005.14	312.8	ts
52	215	`Microphone #5 (DLR)`	NMT Noise monitoring terminal	34145,57	4833.54	303.8	ts
53	216	`Seismometer (Cornell)`	Seismometer	33630,20	3909.50	482.0	ts
54	217	`Seismometer (Cornell)`	Seismometer	33564,47	4012.26	479.0	ts
55	218	`Seismometer (Cornell)`	Seismometer	33196,44	4557.34	477.0	ts

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continuation from the previous page

#	Station	Acronym	Equipment	Easting	Northing	Elevation (asl)

Source: *Remote Sensors/Latex RemoteSensors* *06-02-2018 22:56*

B Contents and organisation of Excel workbooks

There is a total of three Workbooks, each the subject of a separate section: on the location of sonic anemometers (section B.1), the data in the NetCDF files (section B.2) and the location of the ground based equipment (section B.3).

B.1 Towers and Sonics

The *Towers and Sonics* workbook is organized into six worksheets. The main worksheets are *Anemometers* (section B.1.2), with the coordinates of the sonic anemometers as measured, and *Tower location* (section B.1.3), with the determination of the tower location, as described in section 2.3.1.

Data values are linked to worksheet *Anemometers* by formulae, and any future change of the measured values, if necessary, should be in worksheet *Anemometers*.

B.1.1 Worksheet 1: Introduction

The rationale behind the background colour of some cells is the following:

yellow
original data

green
updated data

red
does not exist

orange
does not exist (used to mark the non-existent towers)

blue, blank
needs to be completed

B.1.2 Worksheet 2: Anemometers

A total of 252 lines and 15 columns (from A to P) with the following headings:

(A) Name: name, compound word with TW## ##M, where the first two digits ## are the tower number from 01 until 54, and the second ## are the nominal height above the ground level.

(B) NCAR name: name, as in the NCAR data catalogue.
Compound word, @@@## ##m, where the letters @@@ (up to 3) identify the tower location (tnw, transect North-West, numbered from 1 until 16; tse, transect South-East, numbered from 1 until 13; rsw, ridge South-West, numbered from 1 until 8; rne, ridge North-East, numbered from 1 until 7; v, valley, numbered from 1 until 7), the first two digits ## are the tower number per tower location and the last two ## are the nominal height above the ground level. Two additional towers, Extreme SW and Extreme NE, do not follow this naming convention.

(C) Easting: the eastward-measured distance in Portuguese coordinate system PT-TM06.

(D) Northing: the northward-measured distance in Portuguese coordinate system PT-TM06.

(E) zboom: height (above sea level) of the boom centre line in Portuguese coordinate system PT-TM06.

(F) zt(int): interpolated terrain terrain height (above sea level) from laser survey in 2015 at sonic position.

(H) Direction: angle α, the boom alignment in degrees towards geographical north, measured clockwise.

(I) Tilt: angle in degrees towards the horizontal plane (inclination).

(J) Sonic type: sonic anemometer manufacturer and model

(K) Owner: owner

(L) Serial number: serial number

(M) Height offset: distance (vertical) between the boom and the centre of the sonic sensors

(N) Number: number, counting

(P) RMY box orientation:

The coordinates for sonic anemometers were first copied from Appendix in [Menke and Mann, 2017, page 9] (yellow cells), checked and completed with new measurements carried out in later stages (green cells). The dialogue that took place during this process is in worksheet entitled *Pending questions*.

B.1.3 Worksheet 3: Tower location

A total of 247 lines and 47 columns (from A to AU) with the following headings:

(A) Name: name, compound word with TW## ##M, where the first two digits ## are the tower number from 01 until 54, and the second ## are the nominal height above the ground level.

(B) NCAR name: name, as in the NCAR data catalogue.
Compound word, @@@## ##m, where the letters @@@ (up to 3) identify the tower location (tnw, transect North-West, numbered from 1 until 16; tse, transect South-East, numbered from 1 until 13; rsw, ridge South-West, numbered from 1 until 8; rne, ridge North-East, numbered from 1 until 7; v, valley, numbered from 1 until 7), the first two digits ## are the tower number per tower location and the last two ## are the nominal height above the ground level. Two additional towers, Extreme SW and Extreme NE, do not follow this naming convention.

(C) Easting (m): the eastward-measured distance in Portuguese coordinate system PT-TM06.

(D) Northing (m): the northward-measured distance in Portuguese coordinate system PT-TM06.

(E) zboom: height (above sea level) of the boom centre line in Portuguese coordinate system PT-TM06.

(F) zt(int): interpolated terrain terrain height (above sea level) from laser survey in 2015 at sonic position.

(G) z0(meas): interpolated terrain terrain height (above sea level) from laser survey in 2015 at sonic position.

(H) Direction: angle α, the boom alignment in degrees towards geographical north, measured clockwise.

(I) Tilt: angle in degrees towards the horizontal plane (inclination).

(J) Sonic type: sonic anemometer manufacturer and model

(K) Owner: owener of the equipment

(L) Serial number: Equipment serial number

(M) Height offset: distance between the boom and the centre of the sonic sensors (Table 4)

(N) Height: tower height.

(O) Length (a): length of the lattice tower triangular section (Table 6)

(P) Distance (b): distance between the boom and the centre of the lattice tower (Fig. 5 and equations (7) and 8).

(Q) Boom length: length of the boom.

(R) East 1: term as in equation (9).

(S) North 1: term as in equation (10).

(T) East 2: term as in equation (9).

(U) North 2: term as in equation (10).

(V) WindsP ID: sensor identidication in WindsP

(W) Height (agl): location of the sensor, height above ground level

(X) Tower location / Easting: the eastward-measured distance in Portuguese coordinate system PT-TM06.

(Y) Tower location / Northing: the northward-measured distance in Portuguese coordinate system PT-TM06.

(Z) Direction: angle α, the boom alignment in degrees towards geographical north, measured clockwise.

(AA) Elevation (asl): terrain elevation

(AB) Easting: the eastward-measured distance in Portuguese coordinate system PT-TM06.

(AC) Northing: the northward-measured distance in Portuguese coordinate system PT-TM06.

(AD) Easting: Standard deviation of Easting of sonic anemometers on a tower.

(AE) Northing: Standard deviation of Northing of sonic anemometers on a tower.

(AF) Direction: Standard deviation of boom angle (α) of sonic anemometers on a tower.

(AG) Height (agl): Standard deviation of terrain elevation.

(AH) Easting: Standard deviation of Easting of tower location.

(AI) Northing: Standard deviation of Northing of tower location.

(AJ) Distance: Distance between sonic and lattice tower centre

B.1.4 Worksheet 4: Pending questions

The list of questions that arose during the course of the work.

A total of 20 lines and 4 columns (from A to D) with the following headings:

N.: questions numbered sequentially

Question: the actual question, ending with the name of person, date and time.

Answer: the answer, ending with the name of person, date and time.

Action: the action, ending with the name of person, date and time.

B.1.5 Worksheets 5, 6, 7 and 8: LaTeX...

Worksheets 5, 6, 7 and 8 are conversion of the Excel worksheets into LaTeX commands:

Worksheet 6: LaTeX TowerName the LaTeX commands for Table 2.1, on page 5.

Worksheet 7: LaTeX Towers converts the data in Worksheet *Tower location* in Table 10, on page 33.

Worksheet 8: LaTeX Sonics converts the data in Worksheet *Tower location* in Table 9, on page 28.

B.2 NetCDF Towers

The workbook is organized into a total of 48 worksheets. The first 6 (described in sections B.2.1 to B.2.7) are the results of the data in the remaining 43 worksheets, with the interpretation of the NetCDF files. Subsection B.2.7 is the user's guide of these 43 worksheets.

A common access type to the datasets collected in NetCDF is by XML files that contain the name, description and the units measured by the sensors placed in each station and for each sensor in the station. After discarding the additional information, the merging the NETCDF files into a HTML file gives us the information from all the towers.

B.2.1 Worksheet 1: Introduction

This is the short introduction to the Workbook and its contents. The cell background colours identify the following situations:

yellow
original data from NetCDF

dark green
WindsP data (as of 2017-10-10) identical to NETCDF data, no action needed.

red
wrong information in WindsP (as of 2017-10-10), to be removed from WindsP

orange
incomplete information in WindsP (as of 2017-10-10), update @WindsP after answer to pending questions

dark blue
information on Dataloggers

purple, unnecessary information, no action

B.2.2 Worksheet 2: Totals Summary

A clean and final view of the results, with hyperlinks to every tower.

B.2.3 Worksheet 3: Questions

A list of questions, waiting for answers.

B.2.4 Worksheet 4: Sonics *vs* NetCDF

The number and distribution of sonic anemometers per tower found by when analysis of the NetCDF files is identical to the list of anemometers whose location was measured. That was the purpose of this worksheet, from lines 1 to 549, and columns A to AI.

Four tables:

1. Table 1 (from columns A to G), with the total number of sonics; merging of information in Menke and Mann [2017] (Table A.1 and A.3); and (from columns I to L), comparison between information from sections 2.2 and 2.4, to make sure that all anemometers in Table A.1 are also in NetCDF files.
2. Table 2 (from columns N to S), with the information on all sensors identified by interpretation of the NetCDF files.
3. Table 3 (from columns U to X), with the information on non-sonic sensors.
4. Table 4 (from from lines 1 to 15 and columns Z to AI), number of sensors per manufacturer, model and owner.

B.2.5 Worksheet 5: (total) Sonics+Based Sensor

One table with the total and type of sensor per tower. Lines 1 to 50, per tower, and columns B to K, per equipment. This table contains the total numbers of sensors used in Perdigão and is the major source of information for final numbers in the abstract of the present document and Table 7. One tower per line and one type of sensor per column.

B.2.6 Worksheet 6: NetCDF Towers Summary

The summary of the 43 worksheets, described in section B.2.7. All towers in sequential order (line 1 up to line 493) with the description of the equipment on every tower, from columns A to G.

(A) Tower: tower name and number;

(B) ID Code: the code given to the equipment in WindsP;

(C) Equipment: the equipment located at different heights and measuring different variables in the tower;

(D) Above the ground: height above the ground.

(E) Orientation: the equipment orientation (in degrees);

(F) Equipment: manufacturer and model of the equipment.

(G) Comments: Comments.

Two additional (small tables) with the:

1. List of equipment still missing in *WindsP* inventory and corresponding web links (lines 2 to 8, and columns J to L).
2. Towers with information still pending (lines 10 to 15, and column J)
3. Towers not available (lines 10 to 15, and columns K and L).

B.2.7 Worksheets 7 to 49: Tower @@@##

tnw##, ts##, ...: 43 worksheets (one per tower, named in accordance with the NCAR convention, section 2.1. The structure of these 43 worksheets is identical and organized in three major blocks.

Block 1: columns A, B and C (in yellow), with the raw data retrieved from the NETCDF files, with the following columns:

(A) Name: name created according with the NCAR convention as in section 2.1. The name is made of three or four parts separated by underscores: the first part are the initials, two or three letters, part of the variable name and enough for identification of the variable; second part, the nominal height (agl) of the sensor in meters and ending with the meter symbol m; and part three, the identification of the tower where the sensor is installed.

(B) Description: description of the measured variable and instrument used.

(C) Units: the units measured by the equipment; The second one is the raw data being transformed in a more clear way to understand the data and the colour scheme presented before have been applied consistently. This process was made by splitting the *Name* field from the first table containing the following columns:

Block 2: columns E to L (in green), the interpretation of the NetCDF data, mostly by splitting the composed names that identify the variables.

(E) Variable: the variable measured by the equipment;

(F) Height: the height of the equipment in the tower;

(G) Tower: tower name and number;

(H) Equipment: the equipment located at different heights and measuring different variables in the tower;

(I) Type: the equipment type: if anemometer, barometer, wetness sensor and so on;

(J) Subtype: the equipment subtype. Let us say: if we have an anemometer, the subtype is sonic;

(K) WindsP?: a green or red fill means if the equipment is at WindsP or not;

(L) Comments: a cell for questions and comments regarding each line. Comments like *To add* and *Need review* helped us to follow the path and remain with a guideline;

The third and final table is a summary of the work done in the second table and compared to the information we had in WindsP. The table was retrieved from WindsP and 2 columns were added: equipment and comments. This table is also the sum of the work done in the two previous tables and is ready to go to the *Summary* sheet since it has all the vital information that we need. The structure remained like this:

Block 3: columns N to S , the summary of the sensors installed on the tower,

(N) ID Code: the code given to the equipment in WindsP;

(O) Equipment: this equipment name is the type of equipment and not the name. The name is given below;

(P) Above the ground: the height of the equipment in the stations;

(Q) Orientation: the equipment orientation (in degrees);

(R) Equipment: the equipment name according to the NETCDF data;

(S) Comments: a section for questions and comments regarding each line in order to keep all the information and needs in the *Summary* sheet too;

B.3 Ground Based Equipment

The Excel/Google workbook is organized into the 5 following worksheets, subject of separate subsections in this appendix:

Remote sensors[12]**:** location of ground based equipment measured with Leica System and other GPS based devices, including smartphones.

Count sensors: summary of sensors per type.

in WindsP: data in WindsP.

Compare: comparison between data in Google/Workbook called *Remote sensors* and in *WindsP*.

Colour index: rationale behind the background colour of some cells.

yellow
original data

green
updated data

red
does not exist

orange
data converted from UTM-29N coordinates to PTM-06

blue, blank
needs to be completed

Pending questions: list of questions and corresponding answers that occurred during the course of the work.

B.3.1 Worksheet 1: Remote sensors

The information that was measured in PTM-06 coordinates is more accurate, and is to be taken as reference for the coordinates. The location of the equipment measured in UTM-29N coordinates, not as accurate, was converted to PTM-06 (orange cells in columns I and J).

This is the data (item 2, section 3), measured during the last days of the IOP, available in Workbook *SENSOR-COORD/Remote sensors*.

A total of 69 lines and 10 columns (from A to K) with the following headings:

(A) Station: station number as in the http://windsp.fe.up.pt/experiments/3/stations

(B) Institution: owner's instrument

(C) Instrument: instrument

(D) Code name: name, often colloquial, used to identify the location or the equipment

(E) Source of measurement: measurement equipment, DTU Laser GPS or not

(F) Easting (m): the eastward-measured distance in Portuguese coordinate system PT-TM06 or UTM-29N.

(G) Northing (m): the northward-measured distance in Portuguese coordinate system PT-TM06 or UTM-29N.

(H) Elevation (m): elevation is the synonymous of terrain height and is referenced against the mean sea level (see section 1.2.2 in page 3.

(I) Easting-PTM06 (m): the eastward-measured distance in Portuguese coordinate system PT-TM06.

(J) Northing -PTM06 (m): the northward-measured distance in Portuguese coordinate system PT-TM06.

(K) and (L) Elevation (m): elevation is the synonymous of terrain height and is referenced against the mean sea level (see section 1.2.2 in page 3.

(M) Comments: Comments.

B.3.2 Worksheet 2: in WindsP

This is the data in WindsP web site (as of 26 January 2018).

B.3.3 Worksheet 3: Compare

The comparison between data in Worksheet 2 and final data in WindsP (5 February 2018).

B.3.4 Worksheet 4: LaTeX RemoteSensor IOP

For copying of data in *Worksheet 1: Remote sensors* to LaTex Table.

B.3.5 Worksheet 5: LaTeX RemoteSensor

For copying of data in *Worksheet 3: Compare* to Table 12.

B.3.6 Worksheet 6: Tyler-Rebecca

The verification of data.

B.3.7 Worksheet 7: Count Equipment

Counting the number of scientific instruments. Data in Table 8.

B.3.8 Worksheet 8: Contacts

Contacts (names and email addresses).