Calibration Test of Sodar PA0 SC

Serial No.: 239

Site: Georgsfeld,(Germany)

Contracted by

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Project No.: VC14206
Report No.: RSV16014.A1
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Revision History

Revision No.	Date	Status	Amendment
A0	27.07.2016	Final report	---
A1	22.08.2016	Final report	Chapter 8.3 added; Spelling errors corrected

Note: The last revision replaces all previous versions of the report.

Contents

Disclaimer:

We hereby state, that the results in this report are based upon generally acknowledged and state-of-the-art methods and have been neutrally conducted to the best of our knowledge and belief. No guarantee, however, is given and no responsibility is accepted by Deutsche WindGuard Consulting GmbH for the correctness of the derived results. The work presented in this report complies with the present day valid standards and guidelines and the corresponding quality management system of Deutsche WindGuard. Any partial duplication of this report is allowed only with written permission of Deutsche WindGuard Consulting GmbH. The results of the following report refer to the investigated test object only.

This report covers 88 pages.

1 Introduction

The PA0 sodar is a sodar system (sodar=sound detection and ranging) for wind measurements in the lower atmosphere. The device provided by the French company Remtech, designed with consideration for the needs of the wind energy industry. This report describes a test of the accuracy of the RSD (Remote Sensing Device) with the serial number 239 against conventional wind measurements with mast mounted cup anemometers and conventional wind vanes.

The calibration describes the accuracy of the measurements of the RSD for the environmental conditions present at the test site during the test period. The environmental conditions present at an application of the RSD may deviate from the conditions present at the Calibration Test.

The reported Calibration Test follows the latest requirements as developed in the frame of the ongoing revision of the standard IEC 61400-12-1 [2]. The test took place at a special test station for remote wind sensing devices in Eastern Friesland, where a 135 m high met mast is available.

Before the official test period no preliminary intercomparison between RSD and reference has been done. The valid data of the RSD that were measured during calibration were not filtered.

This report covers 88 pages.

2 Measurement Site and Met Mast

The measurement is located near the village Georgsfeld, approximately 5 km north-west of Aurich, in the region Eastern Frisia, which is in the north west of the German state of Lower Saxony. The distance to the North Sea is approximately 20 km.

The area around the met mast position is characterised by flat terrain. The terrain height at the met mast location is about 6 m above sea level. The best fit of a plane to the terrain up to 5km distance going through the bottom of the mast has no significant slope. The maximum deviation of the terrain to this plane is 11 m.

The landscape is characterised by farmland with closed appearance. The land development in the environment mainly consists of small villages, with tree rows along roads and field borders. Noteworthy are the town of Aurich (40 000 inhabitants) 5 km to the South East and a forest 1 km to the North West. In a distance 70 m to the mast an earth dike with low trees runs from South West to North East.

A map of the measurement site is given Figure 2.1. Photos of the met mast and a panoramic view of the site are shown in Figure 2.2 and Figure 2.3.

Figure 2.1: Map of the measurement site. The wind turbines E-126 limit the measurement sector. The met mast and is marked by a black square with the black dots marking the anchor points of the guy wires. The RSD was located on the field northwest of the met mast (circle).

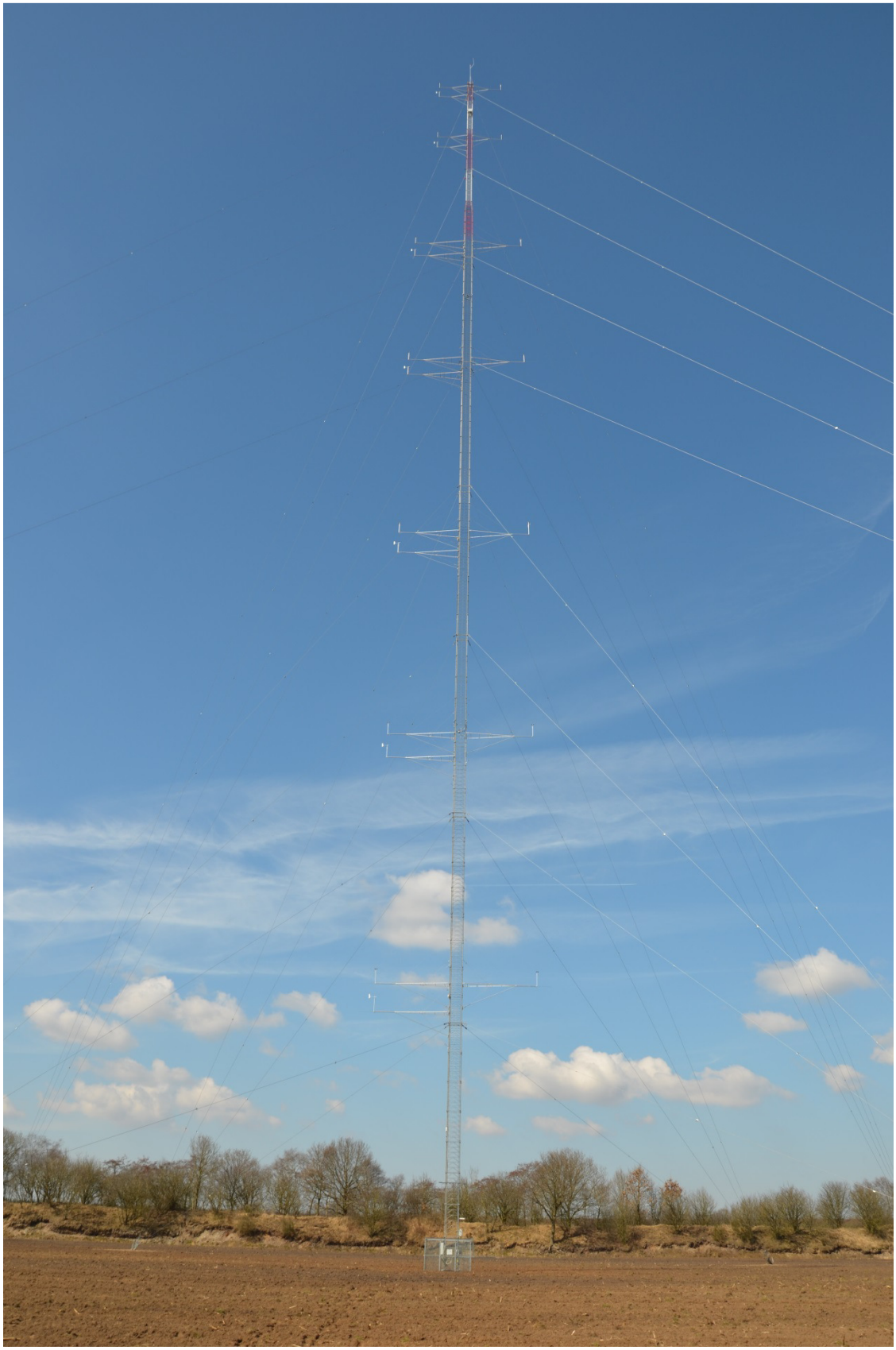

Figure 2.2: Photo of the 130 m high met mast near Georgsfeld, looking in direction southwest.

N=0° E=90°

E=90° S=180°

Figure 2.3: Panoramic view of the measurement site taken 13 m from the bottom of the met mast (continued).

S=180° W=270°

W=270° N=360°

Figure 2.3: Panoramic view of the measurement site taken 13 m from the bottom of the met mast (end).

During the measurement, the RSD was installed 138.5 m west of the met mast (Figure 2.4).

The met mast is positioned about 357 m west of a test wind turbine. The test wind turbine and other neighbouring turbines influence the airflow at the mast at easterly and south westerly wind directions. The coordinates and the resulting wake effects calculated according IEC 61400-12-1 for power performance measurements [1] can be seen in detail in Table 2.1. From all these wakes, an undisturbed and applicable sector of 253° to 29° remains for testing the RSD. The measurement sector must be reduced further for some reference sensors due to mast effects (see Table 2.2). The RSD was aligned to 83°. The bearing was taken over an edge of the frame of the RSD.

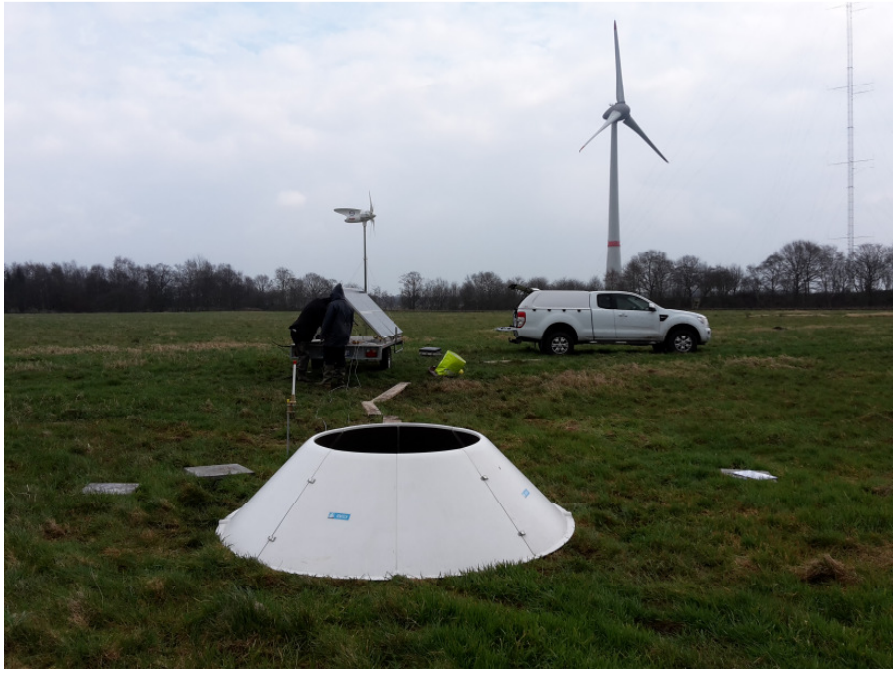

Figure 2.4: The RSD under test installed next to the met tower.

The met mast is equipped with several cup and ultrasonic anemometers as well as wind vanes in different heights above ground. The airflow at the positions of the anemometers and vanes is significantly influenced by flow disturbance caused by the mast and neighbouring sensors (blockage effects, flow acceleration effects). The least influence occurs at the cup anemometer of type Thies First Class Advanced which is mounted at 135 m height above ground at the top of the met mast. An individual wind direction depending correction has been applied to the wind speed measurements of the cup and ultrasonic anemometers which are mounted on side booms to the mast (all mounting heights except 135 m). Those correction functions have been determined empirically. The cup anemometers are of class 0.9A according to reference [1], [3]. The cup and also the ultrasonic anemometers have been calibrated in a wind tunnel according to DKD and MEASNET [4]. One of the calibration wind tunnels of DWG is applied by the German authority for controlling units, Physikalisch-Technische Bundesanstalt (PTB), for defining the unit m/s in airflow measurements. A more accurate tracing back of the anemometer measurements is currently not possible. The ultrasonic anemometers were calibrated for different horizontal and vertical orientations. The wind measurements with the mast follow the requirements of IEC 61400-12-1 [1].

A list of the undertaken comparisons of sensors of the met mast and measurements of the RSD are given in Table 2.2. From the table, the disturbed sectors caused by the mast and the neighbouring turbines and the chosen evaluation sectors can be seen. The positions of the laser beams in dependence of the measuring height have been taken into account for the calculation of the disturbed sectors. Table 2.3 shows the specifications of the sensors mounted at the met mast.

Object	Position		Rotor diameter D	Distance from met mast	Direction from met mast	Met Mast in Wake	
	X	Y				from	to
	[m]	[m]	[m]	[m]	[deg]	[deg]	[deg]
Met mast	2595735	5931491	---	---	---	---	---
RSD	2596092	5931456	---	138.5	276	---	---
E-126 E2	2596091	5931472	127	356.5	93	58	128
E-126-1	2595429	5930971	127	603.4	210	183	237
E-126-2	2594786	5930479	127	1387.4	223	205	242

Table 2.1: Position of met mast, RSD and neighbouring turbines. All coordinates are given in Gauß-Krüger coordinates (Bessel-Ellipsoid).

RSD	met mast sensor					RSD Complete sector		evaluation sector	
Selected Height	signal	meas-urement height [1]	boom ori-ent.	in mast wake					
				from	to	From	To	from	to
[m]	[-]	[m]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
140[2]	V1	135.0	cen-tral	-	-	242 135	58 164	242 135	29 164
120	V3	120.4 100.3	225	29	62	242 134	58 165	329 134 242	29 165 310
100	V5	100.3 82.2	225	30	62	242 133	58 166	242 133	30 166
80	V6	82.2 60.4	225	31	64	242 132	58 166	242 132	31 166
60	V8	60.4 40.3	225	31	64	242 131	58 167	242 131	31 167
40	V9	60.4 40.3	225	31	64	242 130	58 168	242 130	31 168
140	Dir1	129	225	29	54	242 135	58 164	242 135	29 164
120	Dir2	118.3	225	29	62	242 134	58 165	329 134 242	29 165 310
100	Dir3	98.2	225	30	62	242 133	58 166	242 133	30 166
80	Dir4	80.1	225	31	64	242 132	58 166	242 132	31 166
60	Dir5	58.2	225	31	64	242 131	58 167	242 131	31 167
40	Dir5	38.2	225	31	64	242 130	58 168	242 130	31 168

Table 2.2: List of the undertaken comparisons, sensors/channels of met mast and RSD measurements with measuring heights, orientation of sensor mounting booms and sector restrictions due to wake effects of the mast and neighbouring turbines, as well as effective evaluation sectors. For some measuring heights of the RSD, no corresponding sensor at the mast exists.

[1] *interpolated between upper and lower height to RSD level (except for top height of RSD)*
2 Interpolated between 140m and 120m of RSD level

Sensor	Height	Type	Serial	Calibration
Cup Anemometer v1	135.0 m	Thies First Class Adv.	06130299	1511083
Cup Anemometer v2	131.0 m	Thies First Class Adv.	06130298	1511082
Cup Anemometer v3	120.4 m	Thies First Class Adv.	06130297	1511081
Cup Anemometer v5	100.3 m	Thies First Class Adv.	06130295	1511079
Cup Anemometer v6	82.2 m	Thies First Class Adv.	06130294	1511084
Cup Anemometer v8	60.4 m	Thies First Class Adv.	06130292	1511086
Cup Anemometer v9	40.3 m	Thies First Class Adv.	06130291	1511087
Wind vane dir1	129.0 m	Thies First Class 4.3150.00.140	06130155	1521311
Wind vane dir2	118.3 m	Thies First Class 4.3150.00.140	06130156	1521312
Wind vane dir3	98.2 m	Thies First Class 4.3150.00.140	06130157	1521307
Wind vane dir4	80.1 m	Thies First Class 4.3150.00.140	06130158	1521308
Wind vane dir5	58.2 m	Thies First Class 4.3150.00.140	06130161	1521306
Wind vane dir6	38.2 m	Thies First Class 4.3150.00.140	06130159	1521310
Temperature T1/H1	130.6 m	Galtec + Mela KRC3/6.ME	84231	IK15_001
Temperature T4/H2	18.3 m	Galtec + Mela KRC3/6.ME	84232	IK15_002

Table 2.3 Sensor specification list of mast mounted sensors which were used for calibration.

3 Set-Up of the RSD, Data Collection and Data Processing

3.1 Set-Up of the RSD

The evaluated measurement period was from 2016-05-04 to 2016-07-21. The RSD was supplied by solar panels and a small wind turbine (which was not activated) in the measurement period. The basic information and key settings of the RSD are shown in the following table. The settings have not been changed in the measurement period.

Evaluated measurement period	2016-05-04 to 2016-07-21
RSD model	PA0 SC
Unit serial number	239
Beam angle from vertical	25°
Selected measurement heights	40 m, 60 m, 80 m, 100 m, 120 m, 140 m
North orientation during test	83°
Power supply	Solar
Firmware	V9.06.3

Table 3.1 Basic information and key settings of the tested RSD

The vertical and horizontal alignment of the RSD was adjusted by staff member of DWG at the start of the measurement. The horizontality was adjusted with the use of a water level. The horizontal orientation was controlled by a compass over the outer edge of the sodar. The horizontal orientation was 83°. The alignment did not change during the course of the measurements.

The RSD and the data acquisition system of the met mast have been synchronised to UTC time at the beginning of the campaign. During the measurement period, the time was synchronised by GPS.

3.2 Data Collection

The RSD stores data files in ASCII/text format converted into columns instead of data blocks thanks to the conversion software SodarWinPro provided by Remtech.

3.3 Data Processing

3.3.1 Extrapolation of Horizontal Wind Speed Component and its Standard Deviation as Measured by Anemometer

The RSD allows measurement height selection in integer meter values user's selectable steps. During this experiment 20 m layers was chosen. To evaluate the horizontal wind speed of same height levels the wind speeds of cup anemometers have been interpolated.

For this, a power law has been adjusted to the measurements of the horizontal wind speed component of cup anemometer for adjacent sensors (e.g. 135 m and 120.4 m) measurement height within each 10-minute period:

$$\alpha_v = \frac{\ln\left(\frac{v_{Anemometer,h_1}}{v_{Anemometer,h_2}}\right)}{\ln\left(\frac{h_1}{h_2}\right)} \quad (1)$$

$$v_{Anemometer,interpolated} = v_{Anemometer,h_1}\left(\frac{h_{interpolation}}{h_1}\right)^{\alpha_v}$$

where

α_v:	power law exponent in terms of the horizontal wind speed component
h_1:	measurement height of anemometer below height of reference
h_2:	measurement height of anemometer above height of reference
$h_{interpolated}$	interpolation height
$v_{Anemometer,h_1}$:	measurement of horizontal wind speed component of anemometer at height h_1
$v_{Anemometer,h_2}$:	measurement of horizontal wind speed component of anemometer at height h_2
$v_{Anemometer,interpolated}$:	interpolated wind speed

3.3.2 Correction of Wind Speeds Measured by Boom Mounted Anemometers

The anemometers on the mast mounted below the mast top are influenced by the flow blockage effects and flow acceleration effects caused by the mast. These mast effects on the anemometer measurements have been corrected by empirically determined corrections.

3.3.3 Wind Shear

A power law has been adjusted to the measurements of the horizontal wind speed component of the RSD at two measurement heights as close to a pair of successive measurement heights at the met mast within each 10- minute period (see eq. (1)). The wind shear exponents determined from the measurements of the RSD have been compared to the wind shear exponents determined from the mast measurements.

3.3.4 Wind Direction

The wind directions measured by the RSD as average of 10-minute periods have been compared directly to the measurements with the vanes at the nearest measurement heights of the mast. Small deviations in the measurement heights of the RSD and the heights of the reference sensors on the mast have been ignored.

3.4 Data Filtering

The following data filtering has been applied for the comparison of the measurements of the RSD and the mast based sensors:

- No filtering has been applied for the RSD data which was making itself the decision for valid data (invalid data were quoted with -9999).
- Only wind directions, where the RSD and the reference sensor are exposed to free wind conditions (no wake effects), have been considered, i.e. the measurement sector according to Table 2.2 has been applied.
- Only wind speeds above 4 m/s as measured by the reference anemometer have been considered for the following reasons:
    - The wind tunnel calibration of the cup anemometer has been performed in the wind speed range 4-16 m/s according to MEASNET [4]. Despite the limitation of the wind tunnel calibrations to 16 m/s, the wind speed was not limited for testing the RSD in order to gain indications for the accuracy at higher wind speeds.
    - At low wind speeds, the cup anemometer measurements are linked to higher uncertainties.
    - Lower wind speeds are less relevant as hardly any energy is produced by wind turbines below 4 m/s.

It is noted that the derived results are valid only for these filters. Thus, the evaluated accuracy of the RSD can be expected in a later application only if the above flag filter of the RSD is applied.

4 Results of Calibration Test

4.1 Accuracy of the RSD in Terms of Availability

A total amount of 10534 10-minute periods was covered by the evaluated measurement period.

For availability evaluation the RSD has been considered as measurement without met mast. That means no wind directions or wind speed filters have been applied. The so evaluated data availability at the different measurement heights is shown in Figure 4.1. During the test the RSD operated without malfunction.

As can be seen in Figure 4.1, the availability of horizontal wind speed has values of up to about 80% for measurement heights between 40 m and 100 m. Over 100 m the data availability decreases with increasing measurement height.

The data availability depends on weather during test, because during too heavy rain the sodar writes “-9999” for values of horizontal wind speed.

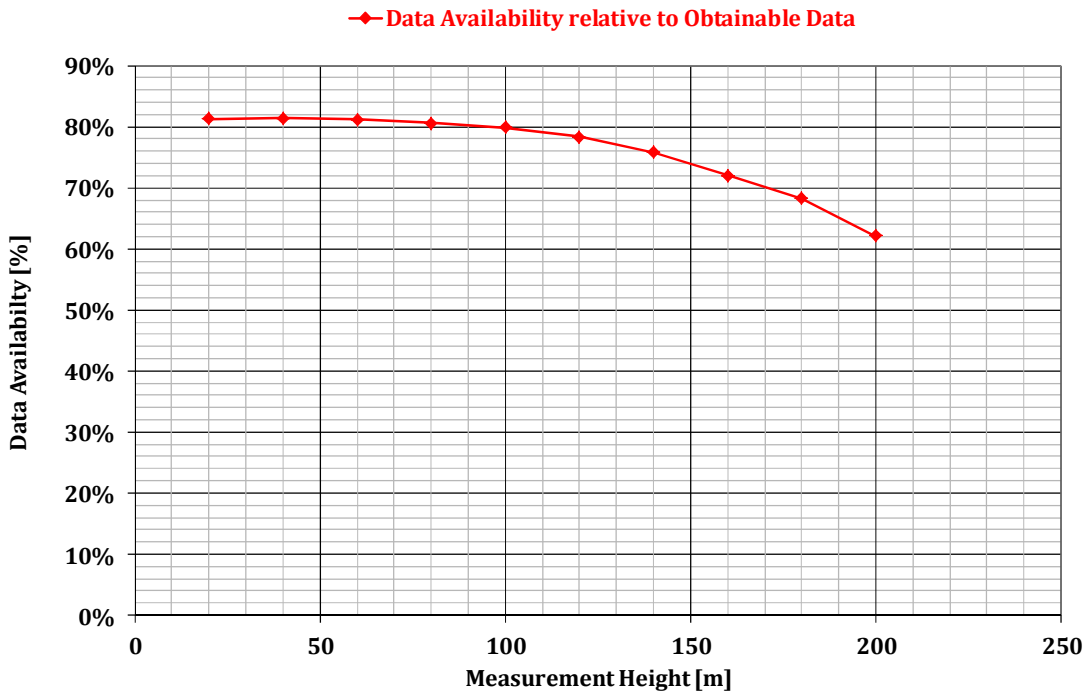

Figure 4.1 Availability of measurement of the horizontal wind speed component at different heights as measured by RSD.

4.2 Accuracy in Terms of the Horizontal Wind Speed Component

Detailed results of the comparison of cup anemometer measurement and measurement of the RSD in terms of the horizontal wind speed component are presented in the following sub chapters. The results can be summarised as follows:

- For the measurement heights between 140 m to 80 m the 10-minute mean values of the horizontal wind speed component as measured by the RSD and by cup anemometers show a good correlation (square of correlation coefficient about 0.95 to 0.96). Due to site effects the correlation decreases for lower measurement heights (for 60 m to about 0.94 and for 40 m to 0.89).
- For measurements height between 140 m and 60 m the horizontal wind speed component of the RSD is slightly overestimated with about 1.7% or 0.1m/s.
- For measurements height between 140 m and 60 m the horizontal wind speed component of the RSD show values of standard deviation of deviation of about slightly above 6%.
- The scatter plots of horizontal wind speed components show a good accuracy with a pleasable precision.

As the statistics gained from the 10-minute data can in principle be influenced by the distribution of data within the measurement period, the measurements of the RSD have been bin averaged against the cup anemometer measurements, and the bin wise deviation between the measurements has been analysed. For measurement heights between 140 m to 100 m the bin wise deviation of horizontal wind speed between met mast and RSD is higher than the uncertainty of the cup anemometer measurements for bins between 4 m/s - 7 m/s (Figure 4.4, Figure 4.6, Figure 4.8). For wind speeds between 7 m/s – 14 m/s the bin wise deviation is in the main smaller than uncertainty of anemometer. The tendency for overestimating the horizontal wind speed component decreases with decreasing measurement height (Figure 4.2). For 80 m and 60 m the horizontal wind speed component is mostly lower than uncertainty of anemometer measurement (Figure 4.8, Figure 4.10).

As the measurements with the cup anemometers are traced back to national standards, the comparison between the cup anemometers and the RSD can be used in order to define an uncertainty of the wind speed measurement of the RSD. The following uncertainty components have been considered in order to evaluate the uncertainty of the measurements of the RSD:

- Wind tunnel calibration of the cup anemometers
- Classification of the cup anemometers according to IEC 61400-12-1
- Cup anemometer mounting effects
- Uncertainty of correction of mast effects on anemometers
- Bin wise deviation of RSD and cup anemometer measurements
- Statistical uncertainty of bin average of deviation of RSD and cup anemometer measurements

The different uncertainty components have been treated as independent uncertainties for the evaluation of the total uncertainty of the measurements of the RSD as gained from the comparison.

Total results like shown in right column of Table 4.1, etc. are given in expanded uncertainty. The expanded uncertainty assigned to the measurement results is obtained by

multiplying standard uncertainty by the coverage factor k=2. It has been determined in accordance with DAkkS-DKD-3. The value of the measurand lies within the assigned range of values with a probability of 95%. To get the single uncertainty (k=1) with confidence of 68%, the expanded uncertainty has to be divided by two.

The resulting wind speed dependent uncertainties of the measurements of the horizontal wind speed component by the RSD are in the order of about 3-6% (expanded uncertainty k=2) in most wind speed bins for all measurement heights. The variation of the uncertainty reaches from 2.7% to 18% for the different measurement heights and wind speed bins (Table 4.1 to Table 4.6)

It is noted that the uncertainty of the RSD as resulting from this comparison does not reflect all uncertainties of the system during an application at another site. The following additional uncertainties should be considered for an application of the system:

- The RSD measurements are influenced by environmental conditions, like e.g. wind shear. Thus, there is an additional uncertainty due to different environmental conditions during the calibration and during the application of the RSD.
- Mounting errors of the RSD during an application (vertical alignment)

Detailed ambient conditions dependent on wind speed and wind direction which were present during the test can be seen in Appendix A.

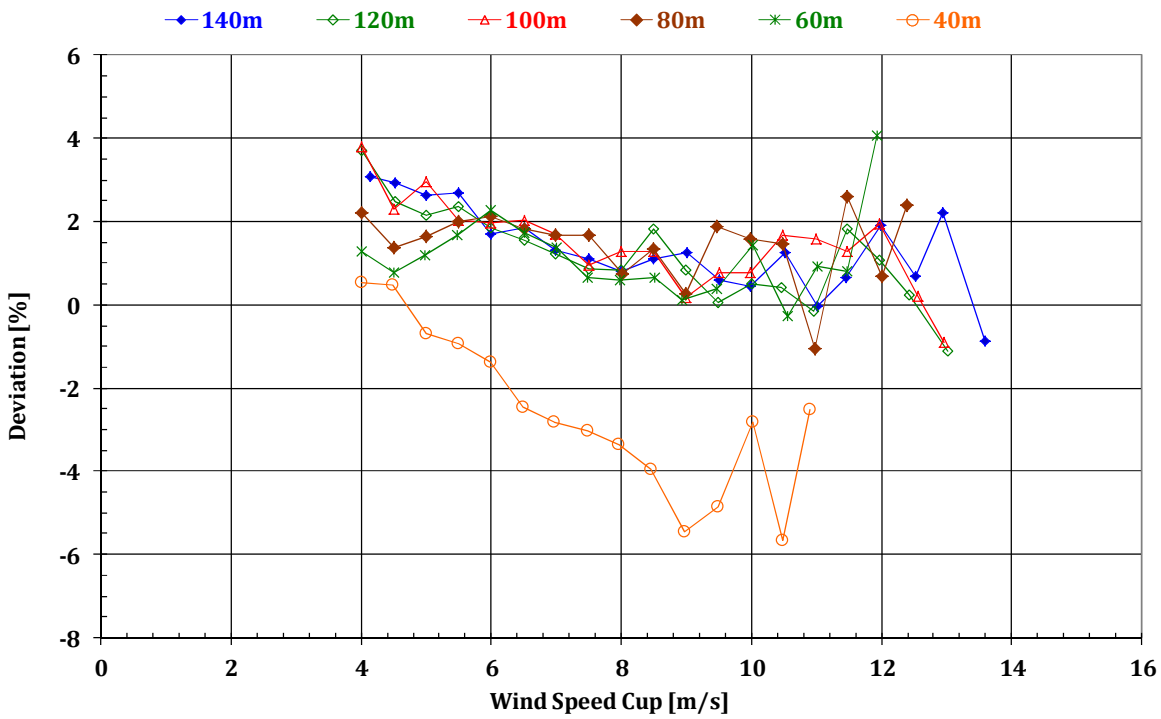

Figure 4.2 Overview of bin averaged deviations of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at several heights. A positive sign of the shown deviation represents higher values measured by RSD.

4.2.1 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 140 m Measurement Height

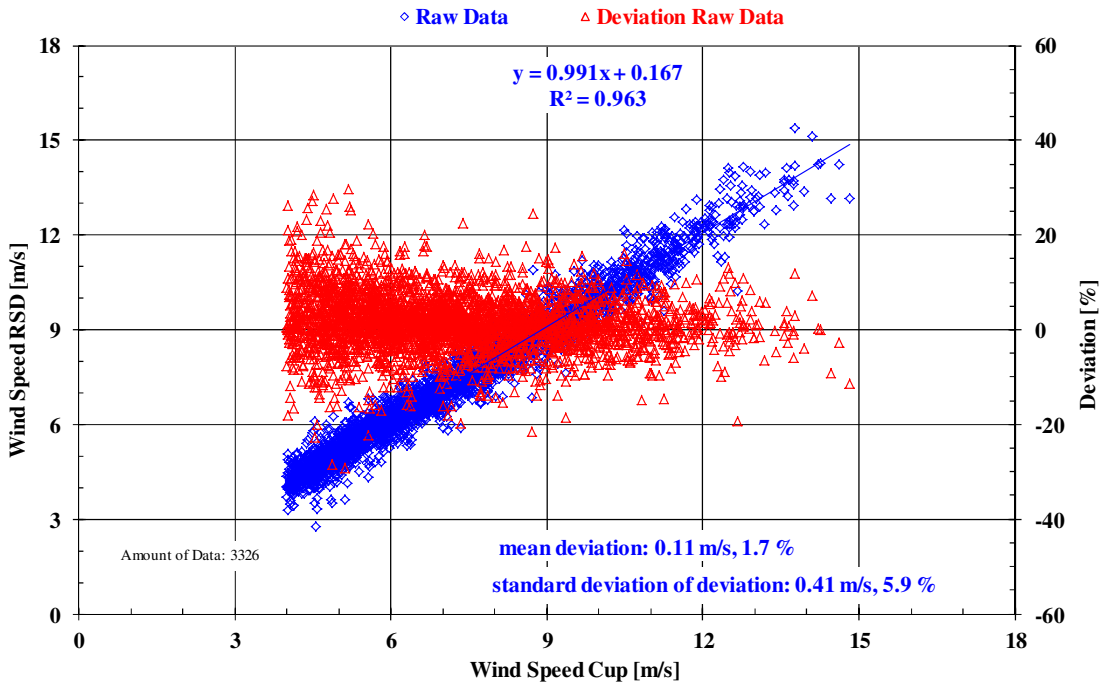

Figure 4.3 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 140 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

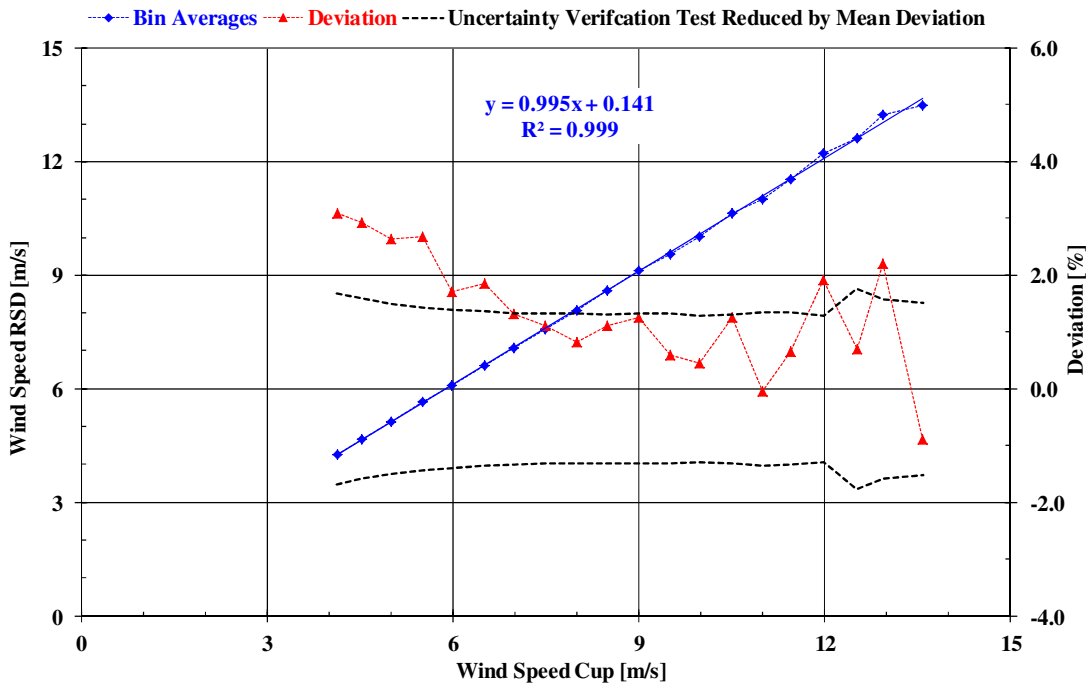

Figure 4.4: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 140 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.135	4.262	125	5.113	3.292	0.339	0.030	0.127	3.4	0.139	7.0	0.290
4.528	4.661	241	6.123	2.777	0.430	0.028	0.133	3.2	0.144	6.7	0.302
5.007	5.139	304	6.706	3.491	0.434	0.025	0.132	3.0	0.150	6.1	0.304
5.506	5.654	284	6.801	4.335	0.376	0.022	0.148	2.9	0.158	6.1	0.335
5.994	6.096	314	7.206	4.819	0.377	0.021	0.102	2.8	0.167	4.4	0.264
6.504	6.624	295	7.965	5.319	0.384	0.022	0.120	2.7	0.177	4.6	0.299
6.991	7.082	314	8.219	5.821	0.375	0.021	0.091	2.7	0.187	3.7	0.261
7.497	7.581	276	9.055	5.888	0.396	0.024	0.083	2.6	0.198	3.5	0.259
7.999	8.064	223	9.549	6.776	0.453	0.030	0.065	2.6	0.211	3.1	0.248
8.492	8.586	206	10.896	6.833	0.466	0.032	0.094	2.6	0.223	3.4	0.291
9.003	9.116	158	10.756	7.584	0.499	0.040	0.114	2.6	0.237	3.7	0.329
9.506	9.562	137	11.186	7.619	0.532	0.045	0.057	2.6	0.251	2.9	0.275
9.979	10.024	120	11.145	9.072	0.442	0.040	0.046	2.6	0.258	2.7	0.274
10.514	10.645	95	12.170	9.648	0.512	0.053	0.132	2.6	0.276	3.6	0.381
11.006	11.001	77	12.257	9.212	0.597	0.068	-0.005	2.7	0.297	2.7	0.297
11.449	11.523	52	12.837	10.452	0.501	0.069	0.074	2.7	0.308	3.0	0.342
11.983	12.213	38	13.123	11.455	0.382	0.062	0.229	2.6	0.310	4.6	0.554
12.526	12.613	30	14.128	10.215	0.893	0.163	0.087	3.5	0.441	3.8	0.475
12.947	13.233	17	14.152	12.323	0.521	0.126	0.286	3.2	0.409	5.4	0.704
13.585	13.465	10	14.136	12.776	0.410	0.130	-0.120	3.0	0.411	3.5	0.475
13.924	14.341	6	15.402	13.367	0.785	0.321	0.417	5.2	0.728	8.0	1.108
14.449	13.876	3	14.253	13.148	0.630	0.364	-0.573	5.8	0.844	9.8	1.422

Table 4.1 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 140 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.2.2 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 120 m Measurement Height

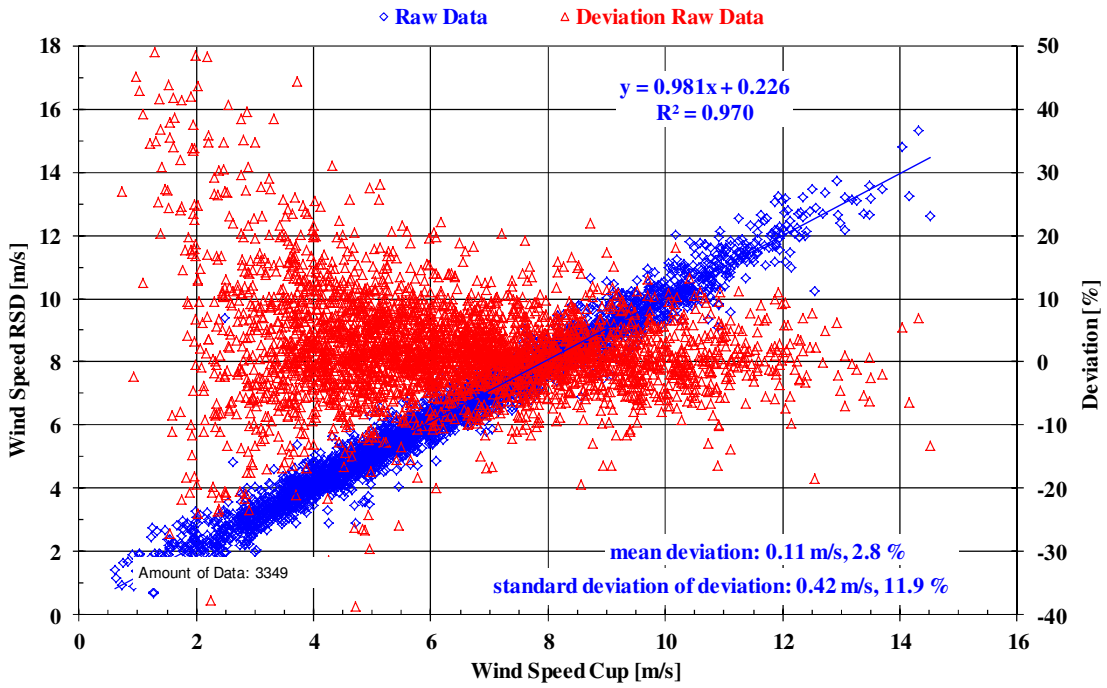

Figure 4.5 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 120 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

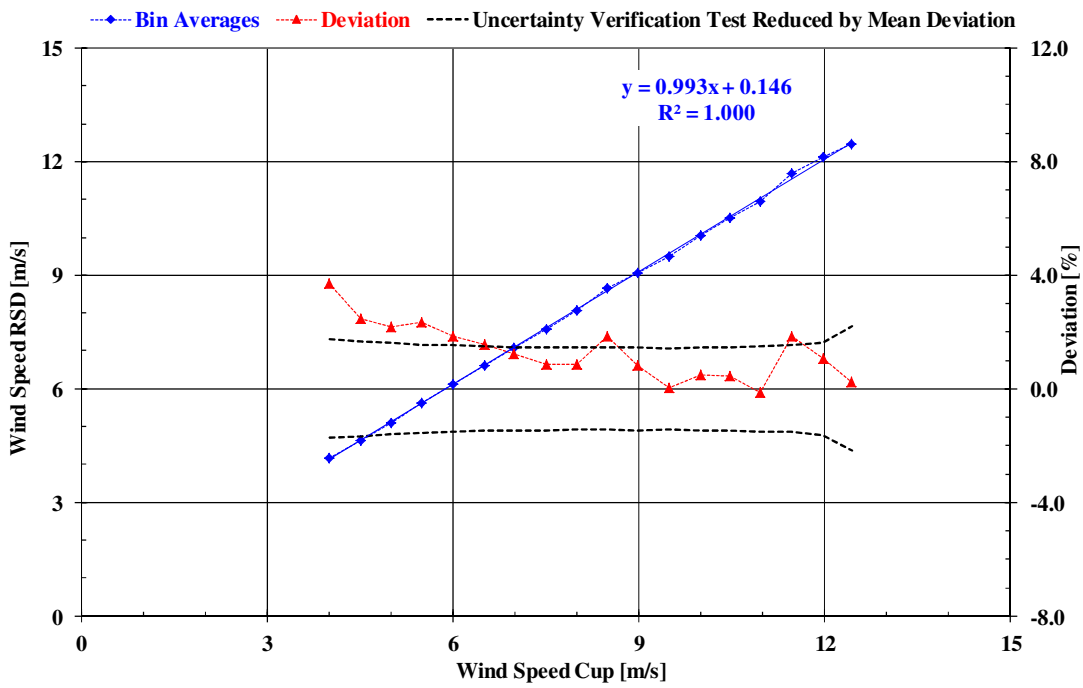

Figure 4.6 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 120 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.007	4.156	219	5.120	3.230	0.343	0.023	0.149	3.5	0.139	8.2	0.328
4.517	4.629	243	5.790	2.900	0.408	0.026	0.112	3.4	0.152	6.0	0.271
5.002	5.111	265	6.590	3.490	0.425	0.026	0.108	3.2	0.161	5.4	0.270
5.503	5.633	251	6.750	4.040	0.369	0.023	0.130	3.1	0.171	5.7	0.311
6.002	6.113	253	7.550	4.720	0.381	0.024	0.111	3.0	0.182	4.8	0.287
6.511	6.612	243	7.950	5.710	0.355	0.023	0.101	3.0	0.193	4.3	0.279
6.991	7.078	265	8.660	5.790	0.371	0.023	0.086	2.9	0.204	3.8	0.268
7.505	7.568	204	9.060	6.480	0.418	0.029	0.064	2.9	0.219	3.4	0.253
7.994	8.061	173	9.450	7.000	0.399	0.030	0.067	2.9	0.230	3.3	0.266
8.491	8.646	171	10.630	6.910	0.435	0.033	0.155	2.9	0.244	4.7	0.395
8.983	9.058	127	10.540	7.470	0.536	0.048	0.075	2.9	0.263	3.4	0.302
9.486	9.490	131	10.950	8.260	0.486	0.042	0.004	2.9	0.271	2.9	0.271
10.010	10.060	81	12.010	9.170	0.504	0.056	0.051	2.9	0.292	3.1	0.310
10.469	10.514	75	11.800	9.320	0.537	0.062	0.045	2.9	0.307	3.1	0.320
10.965	10.948	59	12.120	9.100	0.607	0.079	-0.016	3.0	0.331	3.0	0.333
11.467	11.677	31	12.660	10.630	0.490	0.088	0.210	3.1	0.350	4.8	0.547
11.979	12.106	29	13.230	10.970	0.599	0.111	0.127	3.3	0.390	3.9	0.466
12.438	12.466	14	13.470	10.230	0.816	0.218	0.029	4.4	0.544	4.4	0.547
13.027	12.882	6	13.720	12.170	0.576	0.235	-0.145	4.6	0.596	5.1	0.663
13.468	13.098	6	13.570	12.640	0.383	0.156	-0.370	3.4	0.453	6.4	0.867

Table 4.2 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 120 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.2.3 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 100 m Measurement Height

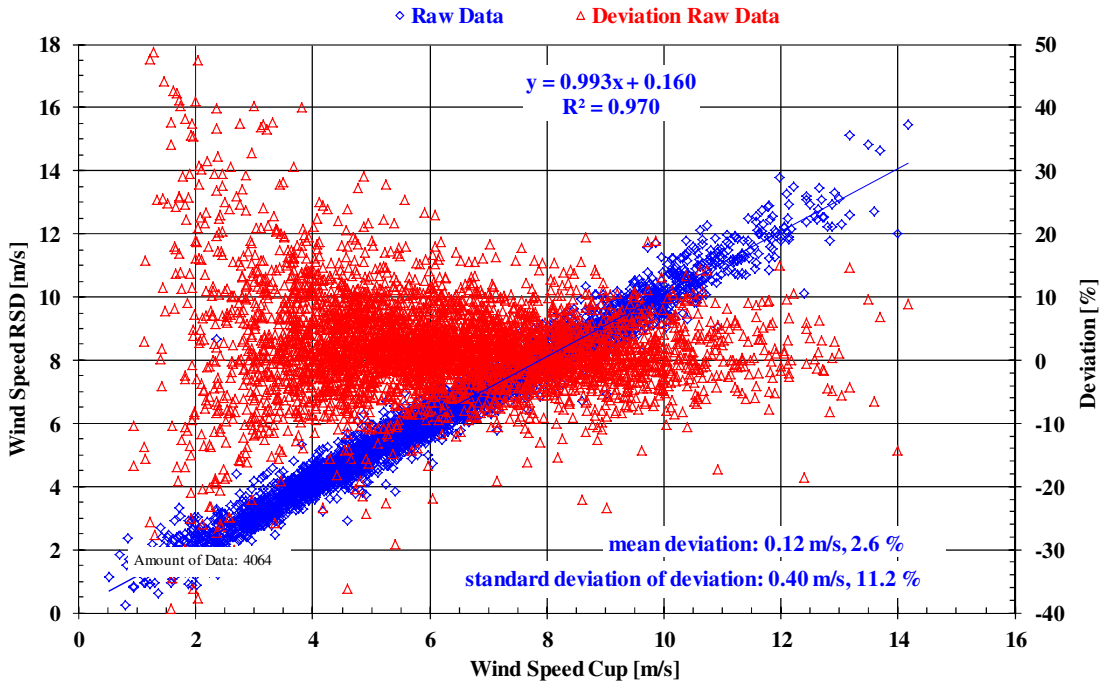

Figure 4.7 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 100 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

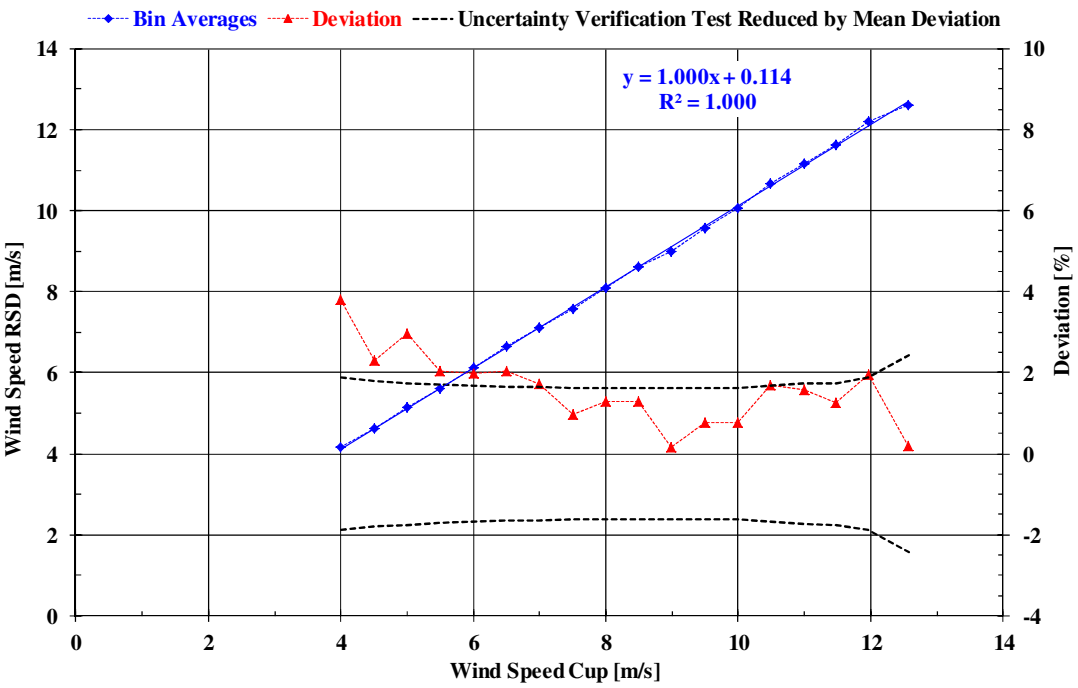

Figure 4.8 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 100 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.001	4.152	249	5.330	3.200	0.356	0.023	0.152	3.8	0.151	8.5	0.339
4.508	4.612	329	5.680	2.930	0.358	0.020	0.104	3.6	0.162	5.9	0.264
5.000	5.148	339	6.700	3.720	0.383	0.021	0.148	3.5	0.175	6.9	0.344
5.500	5.612	314	6.970	3.840	0.365	0.021	0.112	3.4	0.188	5.3	0.292
6.002	6.120	382	7.480	4.720	0.376	0.019	0.118	3.4	0.201	5.2	0.310
6.503	6.636	323	7.700	5.670	0.335	0.019	0.133	3.3	0.214	5.2	0.341
6.992	7.112	294	8.300	5.780	0.370	0.022	0.120	3.3	0.229	4.7	0.332
7.506	7.579	257	8.910	6.430	0.373	0.023	0.072	3.2	0.244	3.8	0.283
8.006	8.109	216	9.370	6.860	0.413	0.028	0.103	3.2	0.259	4.1	0.331
8.494	8.603	190	10.350	6.710	0.452	0.033	0.109	3.2	0.275	4.1	0.350
8.985	9.000	161	10.170	6.910	0.502	0.040	0.015	3.2	0.291	3.3	0.293
9.498	9.571	136	11.550	8.250	0.494	0.042	0.073	3.2	0.306	3.6	0.339
9.987	10.064	96	11.720	9.020	0.514	0.052	0.077	3.3	0.326	3.6	0.360
10.483	10.659	71	12.270	9.310	0.584	0.069	0.177	3.4	0.351	4.8	0.498
10.994	11.167	35	11.980	9.040	0.540	0.091	0.174	3.5	0.382	4.7	0.517
11.478	11.624	28	12.760	10.690	0.582	0.110	0.146	3.5	0.402	4.3	0.496
11.965	12.198	26	13.790	10.860	0.702	0.138	0.233	3.8	0.449	5.4	0.648
12.568	12.593	12	13.470	10.110	0.853	0.246	0.026	4.8	0.608	4.9	0.610
12.962	12.844	9	15.110	11.790	0.977	0.326	-0.117	5.5	0.718	5.8	0.755
13.593	14.050	3	14.810	12.710	1.164	0.672	0.457	10.4	1.413	12.4	1.682

Table 4.3 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 100 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.2.4 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 80 m Measurement Height

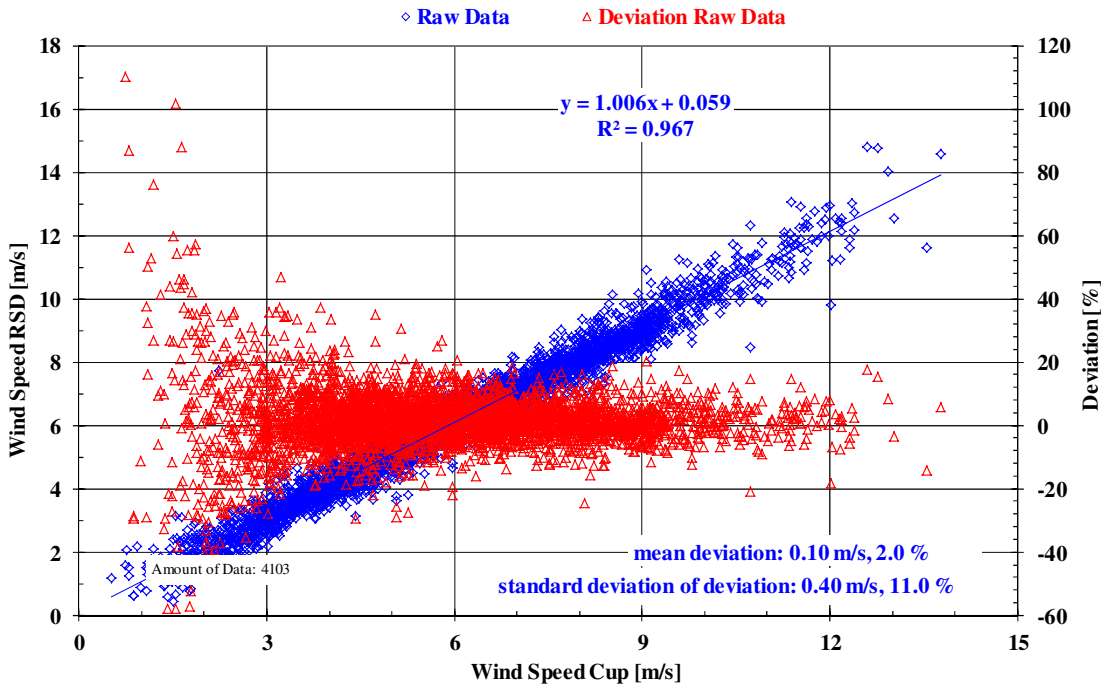

Figure 4.9 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 80 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

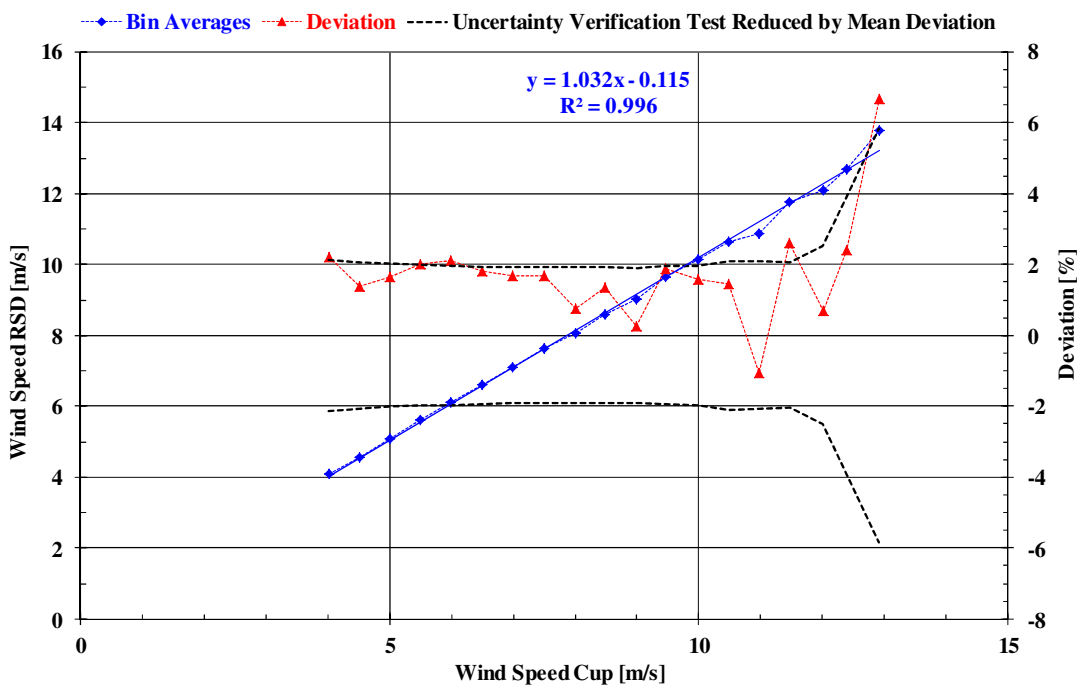

Figure 4.10 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 80 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.011	4.099	301	5.380	3.050	0.363	0.021	0.089	4.3	0.171	6.1	0.246
4.502	4.564	356	6.410	3.120	0.374	0.020	0.062	4.1	0.186	5.0	0.224
4.999	5.081	383	6.710	3.600	0.349	0.018	0.082	4.0	0.202	5.2	0.259
5.499	5.609	404	7.180	3.810	0.364	0.018	0.110	4.0	0.218	5.6	0.310
5.993	6.119	370	7.370	4.660	0.403	0.021	0.127	3.9	0.235	5.8	0.345
6.502	6.620	328	7.660	5.340	0.368	0.020	0.119	3.9	0.252	5.3	0.346
6.980	7.096	276	8.190	5.880	0.344	0.021	0.116	3.8	0.269	5.1	0.355
7.500	7.627	241	9.030	6.370	0.409	0.026	0.126	3.8	0.288	5.1	0.383
8.009	8.069	211	9.340	6.100	0.457	0.031	0.060	3.8	0.307	4.1	0.329
8.487	8.602	170	10.130	7.310	0.446	0.034	0.114	3.8	0.324	4.7	0.397
8.996	9.019	147	10.910	8.090	0.468	0.039	0.023	3.8	0.343	3.8	0.346
9.463	9.641	84	11.240	8.590	0.540	0.059	0.178	3.9	0.368	5.4	0.513
9.985	10.144	55	11.370	8.610	0.552	0.074	0.159	3.9	0.394	5.1	0.507
10.485	10.639	39	12.310	8.480	0.677	0.108	0.153	4.2	0.440	5.1	0.536
10.981	10.865	21	11.770	9.910	0.550	0.120	-0.116	4.2	0.458	4.7	0.514
11.470	11.770	29	13.060	10.640	0.583	0.108	0.300	4.1	0.472	6.6	0.763
12.011	12.094	16	12.940	9.800	0.795	0.199	0.083	5.0	0.602	5.2	0.625
12.398	12.695	6	14.800	11.610	1.155	0.472	0.297	7.9	0.979	9.2	1.145
12.916	13.777	3	14.750	12.560	1.115	0.644	0.861	11.7	1.506	17.7	2.287

Table 4.4 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 80 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.2.5 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 60 m Measurement Height

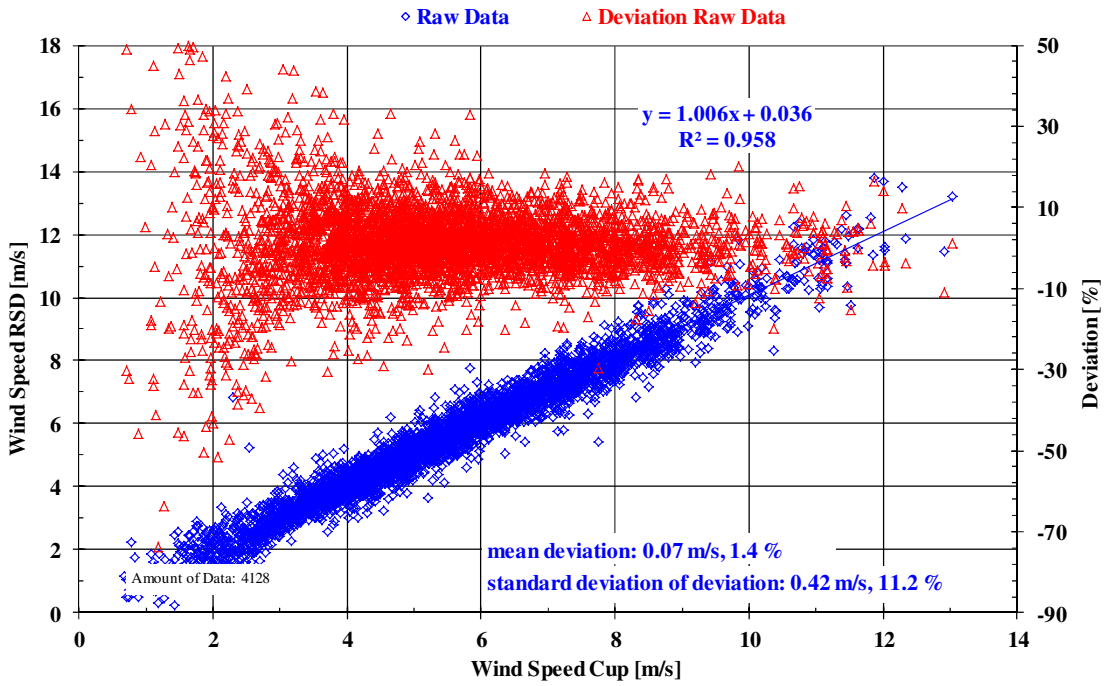

Figure 4.11 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 60 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

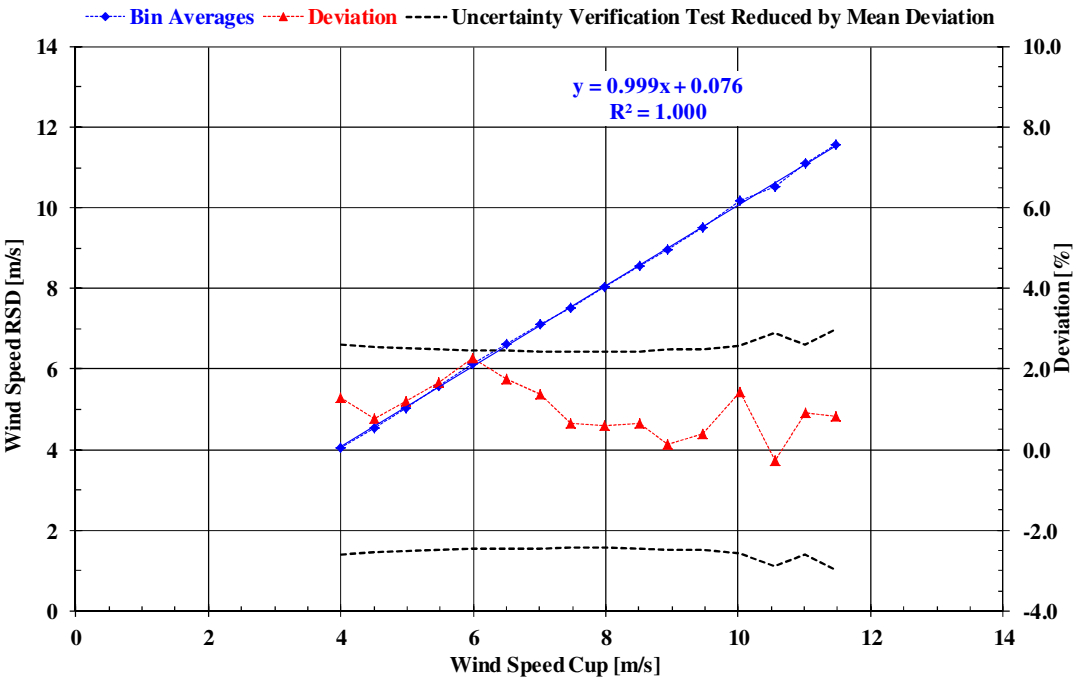

Figure 4.12 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 60 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.000	4.052	387	5.210	2.800	0.361	0.018	0.052	5.2	0.207	5.8	0.232
4.501	4.535	422	6.190	3.160	0.402	0.020	0.035	5.1	0.229	5.3	0.239
4.979	5.039	431	6.430	3.650	0.387	0.019	0.059	5.0	0.250	5.6	0.277
5.486	5.577	431	7.110	4.120	0.403	0.019	0.091	5.0	0.272	6.0	0.328
5.989	6.124	353	7.760	4.610	0.426	0.023	0.136	4.9	0.296	6.7	0.401
6.501	6.615	276	7.650	5.070	0.396	0.024	0.114	4.9	0.319	6.0	0.391
7.005	7.100	268	8.320	5.770	0.453	0.028	0.096	4.9	0.342	5.6	0.392
7.474	7.522	224	8.750	5.440	0.469	0.031	0.049	4.9	0.365	5.0	0.377
7.987	8.035	178	9.250	7.030	0.445	0.033	0.048	4.9	0.388	5.0	0.400
8.509	8.563	134	9.880	6.840	0.514	0.044	0.054	4.9	0.416	5.1	0.430
8.940	8.951	64	10.260	7.950	0.523	0.065	0.011	5.0	0.445	5.0	0.445
9.469	9.506	67	11.120	8.240	0.572	0.070	0.036	5.0	0.469	5.0	0.474
10.023	10.167	35	11.840	8.920	0.564	0.095	0.144	5.1	0.516	5.9	0.591
10.549	10.519	20	12.240	8.320	0.850	0.190	-0.030	5.8	0.609	5.8	0.612
11.012	11.113	30	12.390	9.690	0.591	0.108	0.100	5.2	0.572	5.5	0.606
11.474	11.567	14	12.630	9.760	0.776	0.207	0.093	6.0	0.684	6.2	0.709
11.931	12.417	6	13.810	11.350	1.116	0.456	0.485	9.1	1.084	12.2	1.455

Table 4.5 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 60 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.2.6 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 40 m Measurement Height

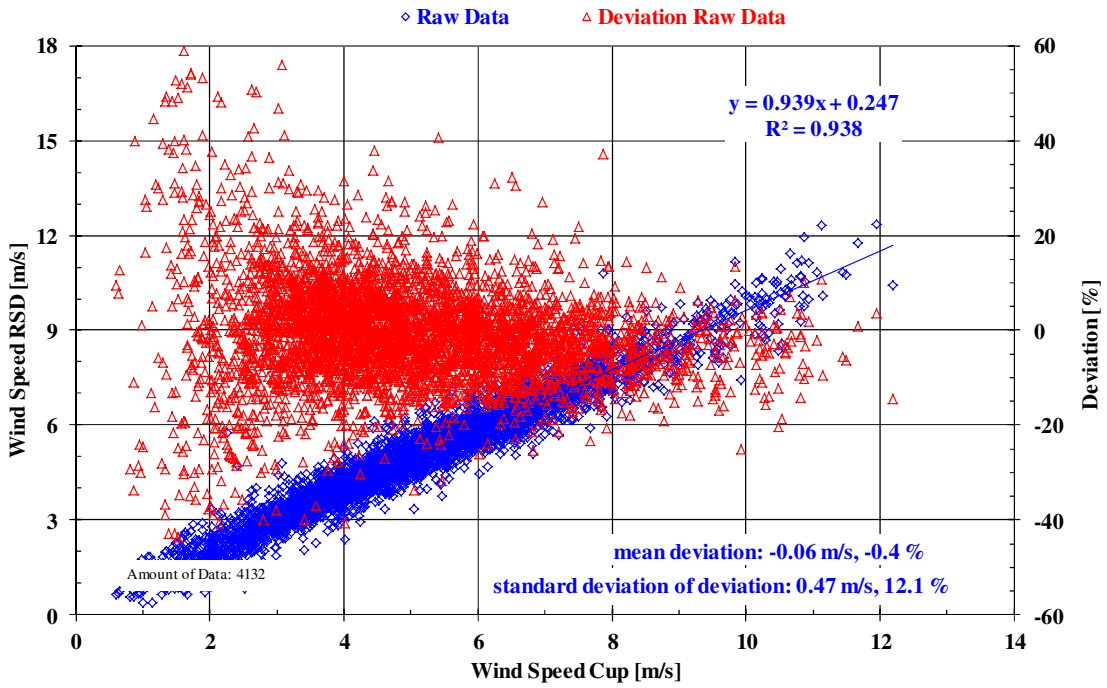

Figure 4.13 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 40 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

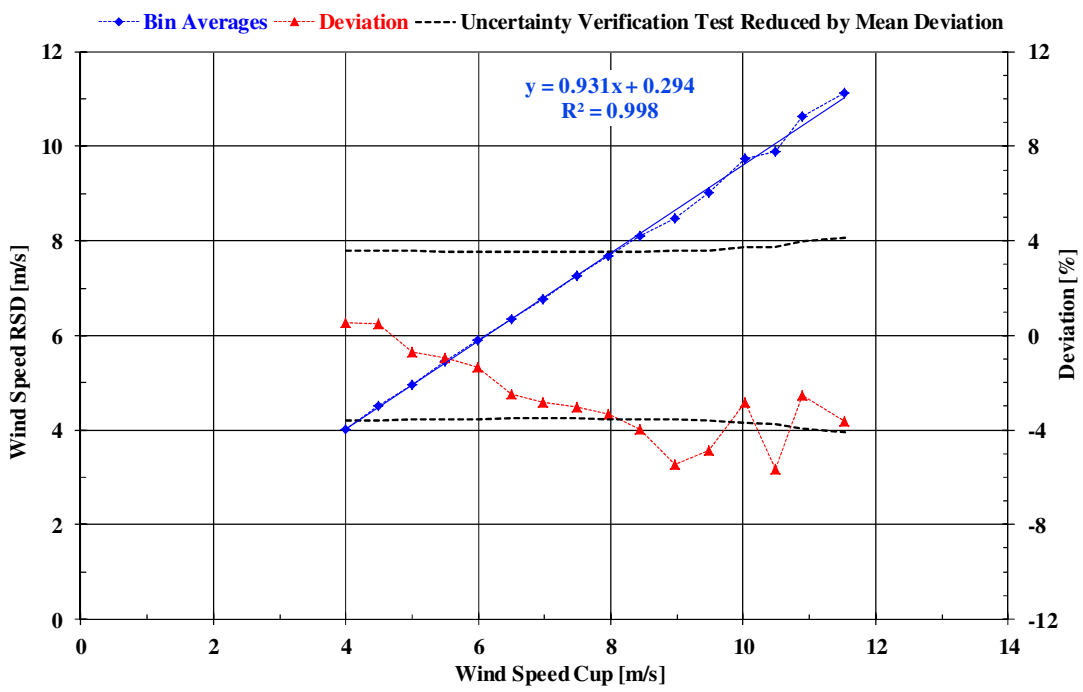

Figure 4.14 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 40 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
3.998	4.019	485.000	5.420	2.380	0.412	0.019	0.021	7.2	0.289	7.3	0.292
4.493	4.515	458.000	6.140	3.360	0.445	0.021	0.022	7.2	0.322	7.2	0.325
4.995	4.960	379.000	6.590	3.350	0.459	0.024	-0.035	7.1	0.356	7.3	0.363
5.495	5.444	324.000	7.610	3.740	0.496	0.028	-0.051	7.1	0.390	7.3	0.403
5.988	5.906	311.000	8.170	4.460	0.461	0.026	-0.082	7.1	0.423	7.6	0.454
6.497	6.337	282.000	8.610	5.070	0.511	0.030	-0.160	7.0	0.458	8.6	0.559
6.973	6.776	223.000	8.850	5.090	0.570	0.038	-0.197	7.1	0.492	9.0	0.630
7.485	7.259	152.000	9.140	5.890	0.537	0.044	-0.226	7.0	0.527	9.3	0.694
7.958	7.692	111.000	10.810	6.280	0.640	0.061	-0.267	7.1	0.566	9.8	0.778
8.448	8.113	80.000	9.730	6.790	0.547	0.061	-0.335	7.1	0.598	10.6	0.897
8.975	8.485	43.000	9.830	7.110	0.520	0.079	-0.490	7.1	0.640	13.0	1.170
9.490	9.028	40.000	9.940	7.900	0.598	0.095	-0.462	7.2	0.685	12.1	1.150
10.027	9.745	28.000	11.160	7.440	0.730	0.138	-0.282	7.4	0.746	9.3	0.935
10.478	9.885	24.000	11.420	8.340	0.790	0.161	-0.593	7.5	0.784	13.6	1.422
10.900	10.626	15.000	12.310	9.270	0.839	0.217	-0.274	7.9	0.863	9.4	1.022
11.533	11.117	3.000	11.760	10.770	0.558	0.322	-0.417	8.2	0.951	11.0	1.264

Table 4.6 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 40 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3 Accuracy of the RSD in Terms of Wind Shear

Wind shear exponents have been calculated for each 10-minute period from the measurements of the RSD and the measurements of the met mast at nearly same measurement heights as explained in chapter 3.3.3.

Detailed results of the comparison of shear exponents are presented in the following sub chapters.

The following conclusions can be drawn:

- The comparison of the shear exponents derived from the measurements of the RSD and the cup anemometer measurements for each 10-minute period shows poor correlation (Figure 4.15, Figure 4.17, Figure 4.19, Figure 4.21, Figure 4.23 and Figure 4.25). The square of the correlation coefficient is about 0.37 to 0.6 in the different height ranges.
- The bin-averaged wind shear exponents derived from the measurements of the RSD and the cup anemometer measurements show a moderate to good correlation with a squared correlation coefficient of about 0.91 – 0.97 for measurement height between 40m and 135m.
- The standard deviation of deviation of the mean shear exponents gained by RSD slightly increase with increasing measurement height from 0.133 to 0.214.

In all height levels, the bin averaged difference in wind shear exponent between cup anemometers and RSD shows strong wind shear dependence. The RSD overestimates wind shear at low shear exponents and underestimates at high wind shears. The shear exponents where overestimation changes to underestimation is at all heights about 0.2 to 0.4.

The comparison of the shear exponents measured by the cup anemometers and by the RSD can be used in order to define an uncertainty of the measurement of the wind shear of the RSD. The following components have been considered in order to evaluate this uncertainty:

- Wind tunnel calibration of cup anemometers
- Classification of the cup anemometers according to IEC 61400-12-1
- Cup anemometer mounting effects
- Uncertainty of correction of mast effects on anemometers
- Bin wise deviation of RSD and cup anemometer measurements in terms of the wind shear
- Statistical uncertainty of bin average of deviation of RSD and cup anemometer measurements in terms of the wind shear

The respective uncertainties of the two cup anemometer measurements applied to evaluate the reference wind shear have been cumulated under careful and conservative consideration of the correlation of the uncertainties between the cup anemometers. The uncertainty components listed above have then been treated as independent uncertainties for the evaluation of the total uncertainty of the wind shear measurement by the RSD as gained from the comparison.

The resulting standard uncertainty of the RSD measurements in terms of the wind shear exponents is below 0.1 *(k=2)* for a shear range of 0.1 to 0.4 in all height ranges with the exception of wind shear between 40 and 60 m and between 140 m and 120 m. This is considered as good. For negative wind shear and high wind shear above 0.5 uncertainty

increases significantly to values of 0.3 and more. This is considered unfavourably for sites with such wind shear conditions.

4.3.1 Accuracy of RSD in Terms of Wind Shear between 140 m and 120 m

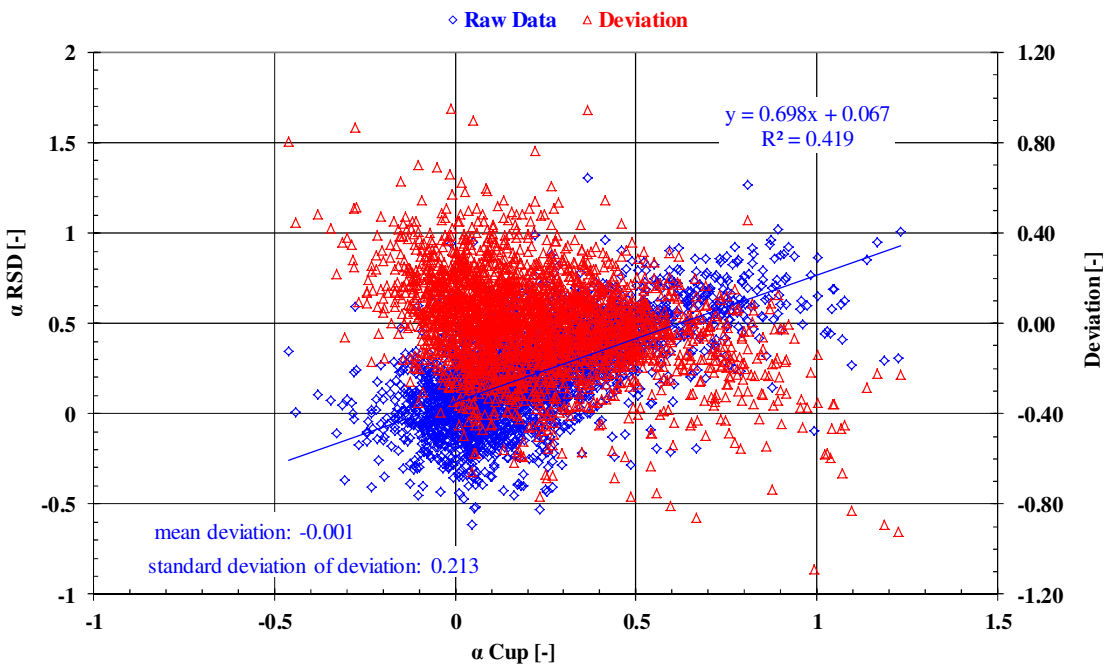

Figure 4.15: Scatter plot of shear exponents as measured by RSD between 140 m and 120 m height against cup anemometer measurements between 135 m and 120.3 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

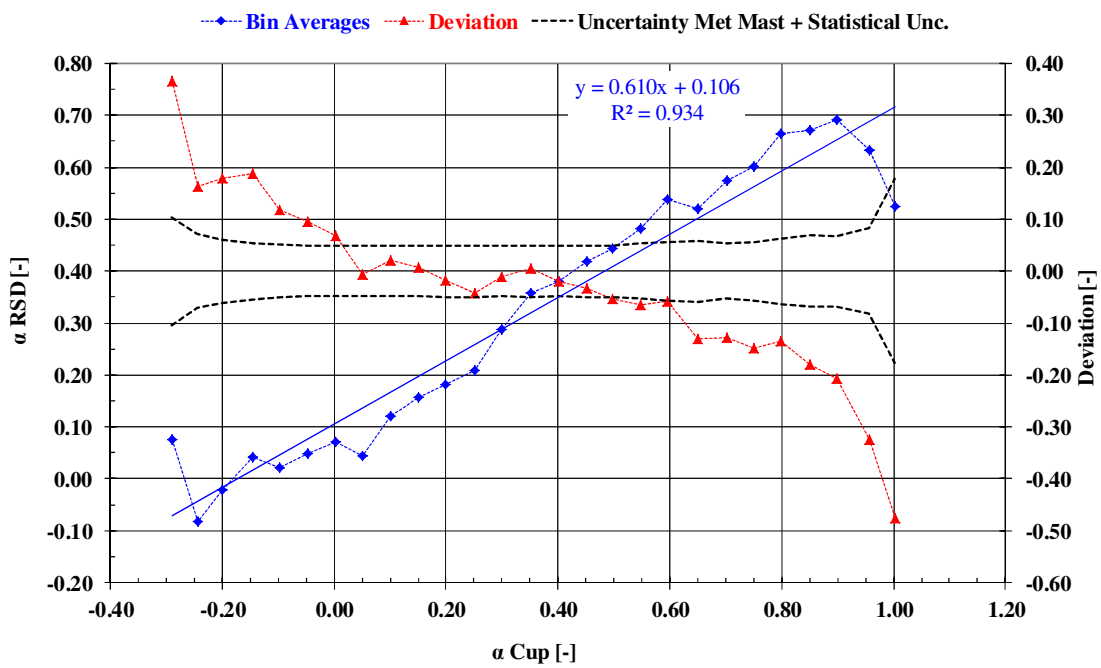

Figure 4.16: Bin analysis of shear exponents measured by RSD between 140 m and 120 m against cup anemometer measurements between 135 m and 120.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.290	0.076	8	0.590	-0.368	0.268	0.092	0.366	0.762
-0.244	-0.082	10	0.239	-0.405	0.164	0.054	0.162	0.355
-0.200	-0.022	18	0.268	-0.349	0.164	0.039	0.178	0.376
-0.145	0.042	45	0.475	-0.387	0.181	0.027	0.187	0.390
-0.097	0.021	86	0.600	-0.453	0.191	0.021	0.118	0.257
-0.048	0.048	156	0.640	-0.432	0.169	0.014	0.096	0.216
0.003	0.072	212	0.940	-0.474	0.206	0.014	0.069	0.169
0.050	0.044	251	0.947	-0.613	0.215	0.014	-0.007	0.099
0.100	0.120	258	0.682	-0.396	0.195	0.012	0.020	0.105
0.150	0.157	221	0.681	-0.455	0.210	0.014	0.007	0.099
0.200	0.181	184	0.985	-0.403	0.213	0.016	-0.018	0.105
0.250	0.208	202	0.876	-0.530	0.229	0.016	-0.042	0.130
0.300	0.289	171	0.819	-0.283	0.171	0.013	-0.011	0.100
0.351	0.357	155	1.309	-0.222	0.189	0.015	0.006	0.099
0.401	0.380	134	0.964	-0.050	0.160	0.014	-0.021	0.106
0.451	0.419	115	0.900	-0.241	0.168	0.016	-0.032	0.118
0.498	0.443	99	0.848	-0.282	0.161	0.016	-0.054	0.147
0.547	0.481	60	0.823	-0.193	0.195	0.025	-0.066	0.170
0.596	0.537	46	0.913	-0.214	0.219	0.032	-0.059	0.163
0.651	0.520	34	0.859	-0.196	0.201	0.035	-0.130	0.285
0.702	0.573	36	0.861	0.197	0.151	0.025	-0.129	0.279
0.750	0.602	32	0.922	0.248	0.172	0.031	-0.148	0.317
0.799	0.665	23	1.265	0.237	0.204	0.042	-0.134	0.297
0.851	0.670	14	0.962	0.317	0.187	0.049	-0.181	0.386
0.898	0.691	17	1.022	0.144	0.208	0.049	-0.207	0.435
0.956	0.633	5	0.869	0.496	0.140	0.067	-0.323	0.667
1.002	0.525	5	0.862	-0.097	0.382	0.171	-0.476	1.017

Table 4.7: Bin analysis of shear exponents measured by RSD between 140 m and 120 m against cup anemometer measurements between 135 m and 120.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3.2 Accuracy of RSD in Terms of Wind Shear between 140 m and 100 m

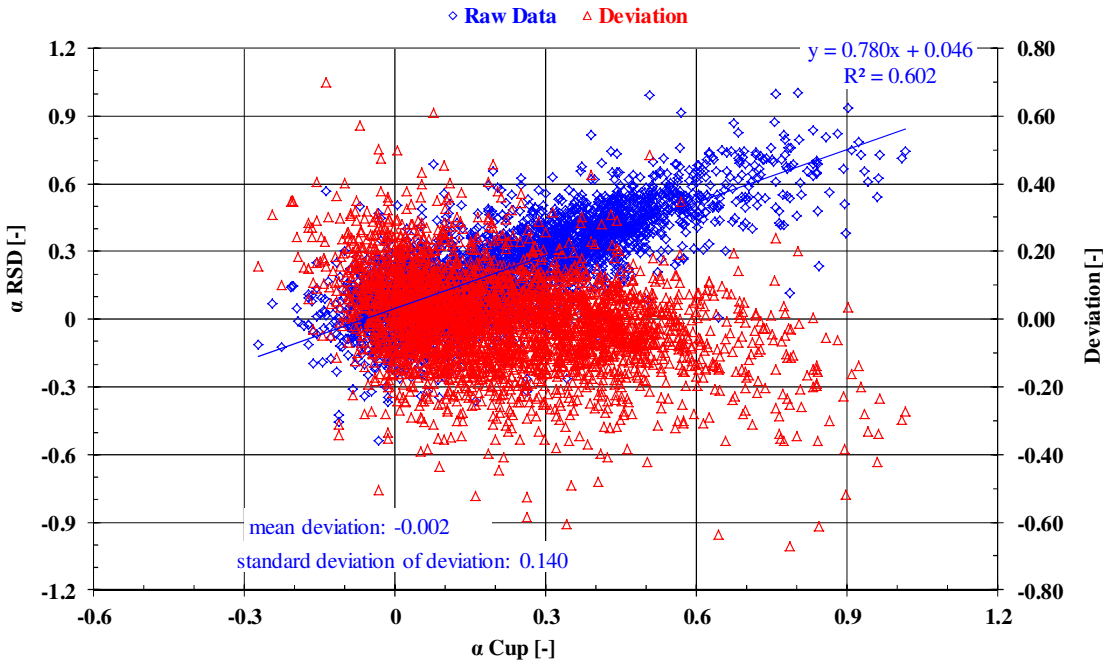

Figure 4.17: Scatter plot of shear exponents as measured by RSD between 140 m and 100 m height against cup anemometer measurements between 135 m and 100.3 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

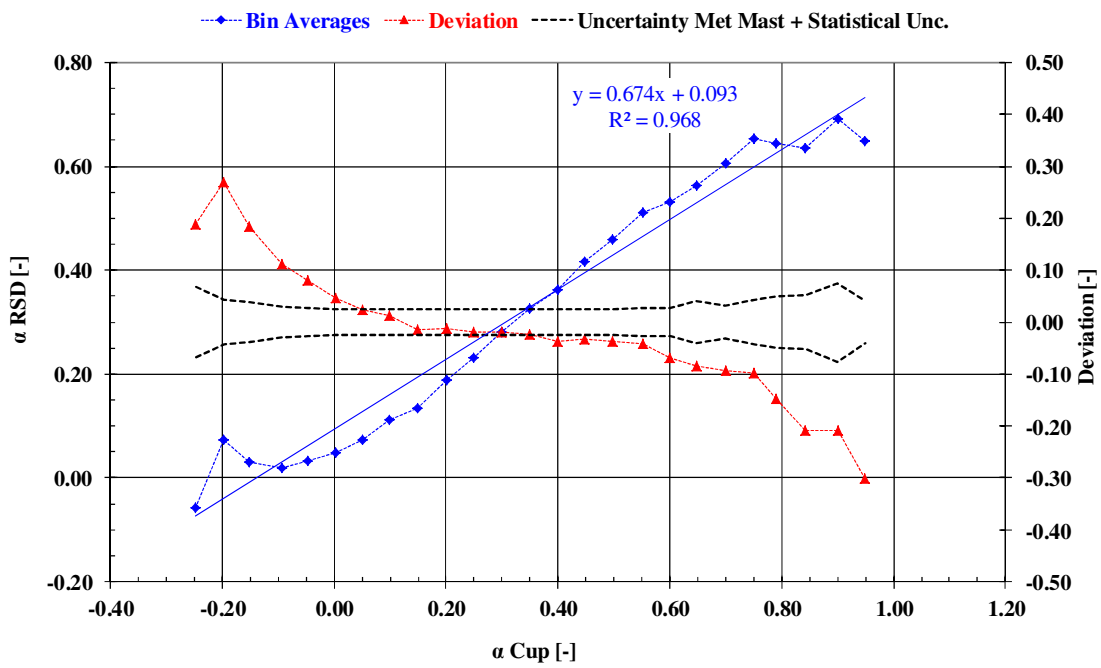

Figure 4.18: Bin analysis of shear exponents measured by RSD between 140 m and 100 m against cup anemometer measurements between 135 m and 100.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.247	-0.058	3	0.067	-0.126	0.108	0.063	0.189	0.401
-0.198	0.073	6	0.146	-0.028	0.081	0.037	0.270	0.548
-0.152	0.031	26	0.565	-0.194	0.155	0.030	0.183	0.374
-0.093	0.019	68	0.301	-0.454	0.146	0.017	0.112	0.232
-0.046	0.033	173	0.501	-0.538	0.139	0.011	0.079	0.167
0.003	0.048	278	0.503	-0.366	0.138	0.008	0.046	0.105
0.050	0.073	324	0.487	-0.340	0.128	0.007	0.023	0.068
0.099	0.112	305	0.686	-0.348	0.142	0.008	0.013	0.057
0.150	0.134	285	0.504	-0.362	0.121	0.007	-0.015	0.059
0.201	0.189	240	0.652	-0.239	0.147	0.009	-0.013	0.057
0.249	0.231	221	0.624	-0.322	0.142	0.009	-0.018	0.063
0.300	0.281	214	0.630	-0.059	0.119	0.008	-0.019	0.063
0.350	0.326	208	0.676	-0.265	0.129	0.009	-0.024	0.070
0.400	0.363	194	0.816	-0.077	0.116	0.008	-0.037	0.089
0.448	0.415	180	0.741	0.081	0.112	0.008	-0.033	0.083
0.498	0.460	112	0.992	0.082	0.103	0.010	-0.038	0.092
0.551	0.511	75	0.916	0.238	0.121	0.014	-0.041	0.098
0.600	0.531	46	0.709	0.307	0.097	0.014	-0.069	0.148
0.647	0.562	29	0.869	0.007	0.172	0.032	-0.085	0.188
0.700	0.606	29	0.826	0.401	0.114	0.021	-0.093	0.197
0.750	0.653	19	0.999	0.415	0.147	0.035	-0.098	0.213
0.791	0.644	19	1.005	0.115	0.189	0.043	-0.147	0.310
0.843	0.635	12	0.838	0.235	0.157	0.046	-0.208	0.429
0.901	0.692	7	0.936	0.379	0.191	0.072	-0.209	0.444
0.949	0.648	6	0.730	0.538	0.074	0.033	-0.301	0.608

Table 4.8: Bin analysis of shear exponents measured by RSD between 140 m and 100 m against cup anemometer measurements between 135 m and 100.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3.3 Accuracy of RSD in Terms of Wind Shear between 120 m and 100 m

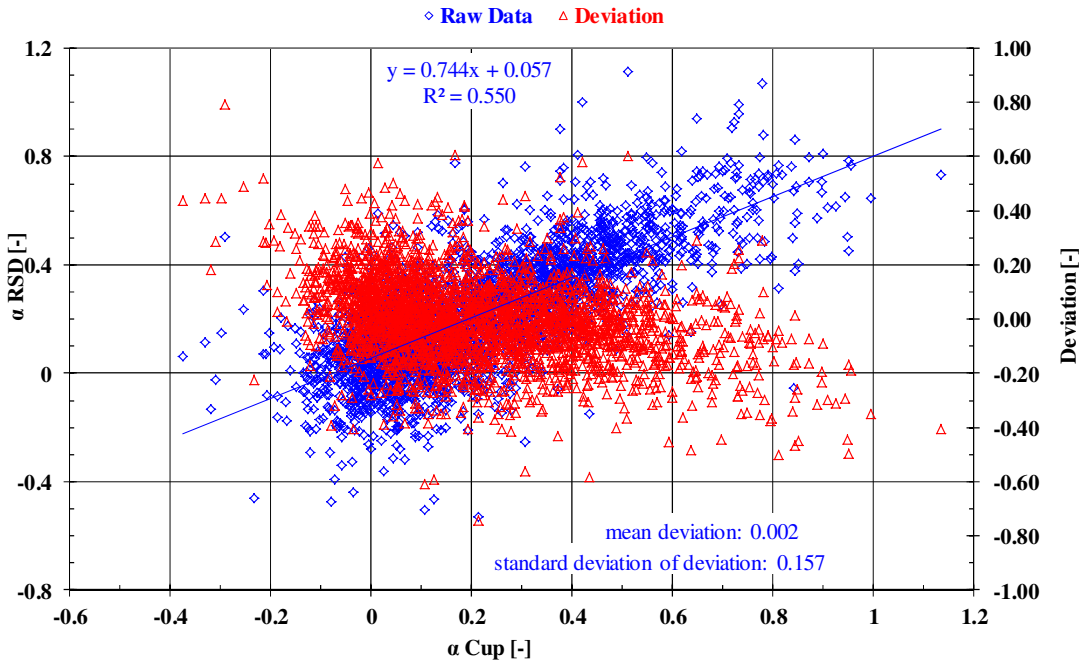

Figure 4.19: Scatter plot of shear exponents as measured by RSD between 120 m and 100 m height against cup anemometer measurements between 120.3 m and 100.3 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

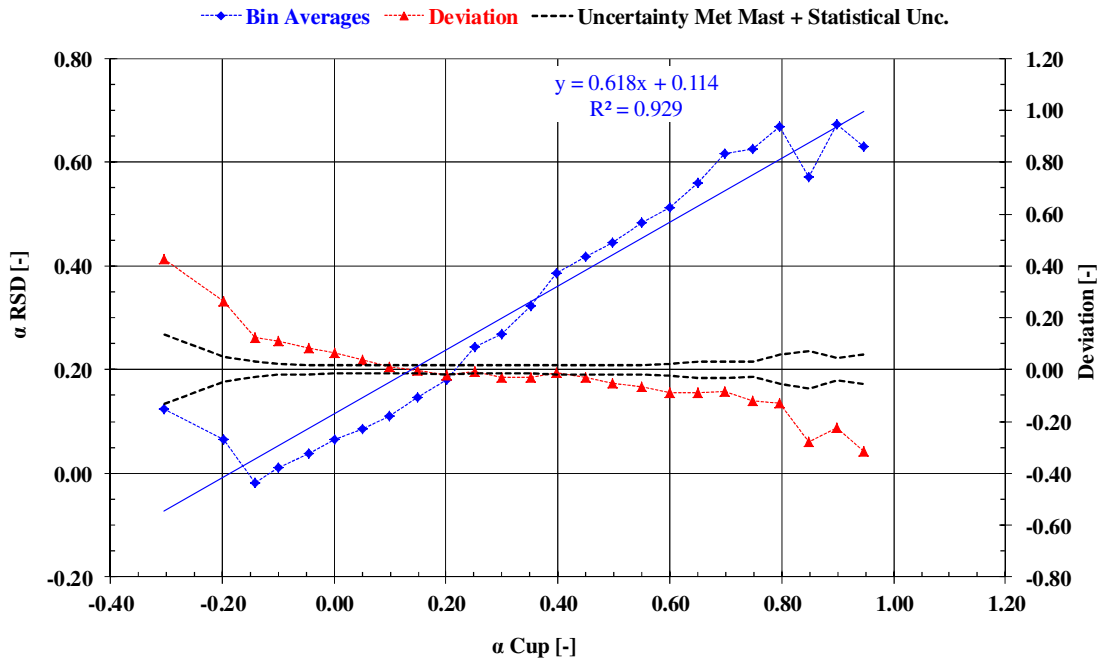

Figure 4.20: Bin analysis of shear exponents measured by RSD between 120 m and 100 m against cup anemometer measurements between 120.3 m and 100.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.304	0.124	4	0.503	-0.134	0.278	0.133	0.428	0.896
-0.197	0.065	10	0.305	-0.162	0.142	0.046	0.263	0.534
-0.141	-0.019	20	0.175	-0.203	0.116	0.027	0.122	0.252
-0.099	0.010	69	0.271	-0.474	0.138	0.017	0.109	0.221
-0.046	0.038	149	0.431	-0.440	0.154	0.013	0.084	0.173
0.001	0.065	251	0.590	-0.362	0.134	0.008	0.063	0.130
0.050	0.085	293	0.548	-0.317	0.153	0.009	0.035	0.077
0.099	0.110	267	0.541	-0.502	0.150	0.009	0.011	0.038
0.150	0.146	235	0.774	-0.212	0.149	0.010	-0.004	0.033
0.201	0.181	193	0.607	-0.528	0.160	0.012	-0.019	0.052
0.251	0.243	175	0.703	-0.145	0.136	0.010	-0.007	0.035
0.299	0.269	169	0.764	-0.255	0.146	0.011	-0.031	0.070
0.351	0.322	152	0.653	-0.060	0.124	0.010	-0.028	0.065
0.398	0.386	158	1.000	0.120	0.141	0.011	-0.012	0.042
0.450	0.418	127	0.721	-0.149	0.129	0.011	-0.031	0.071
0.497	0.446	89	1.113	0.089	0.131	0.014	-0.051	0.109
0.549	0.482	70	0.797	0.247	0.119	0.014	-0.067	0.139
0.600	0.513	44	0.819	0.142	0.126	0.019	-0.087	0.180
0.651	0.560	28	0.941	0.152	0.160	0.030	-0.091	0.192
0.699	0.616	27	0.927	0.253	0.159	0.029	-0.082	0.177
0.749	0.626	31	0.991	0.389	0.149	0.027	-0.123	0.253
0.797	0.668	14	1.069	0.312	0.199	0.054	-0.129	0.281
0.849	0.572	12	0.861	-0.053	0.248	0.071	-0.277	0.573
0.899	0.673	5	0.809	0.574	0.091	0.040	-0.225	0.459
0.946	0.629	6	0.785	0.453	0.135	0.055	-0.317	0.643

Table 4.9: Bin analysis of shear exponents measured by RSD between 120 m and 100 m against cup anemometer measurements between 120.3 m and 100.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3.4 Accuracy of RSD in Terms of Wind Shear between 100 m and 80 m

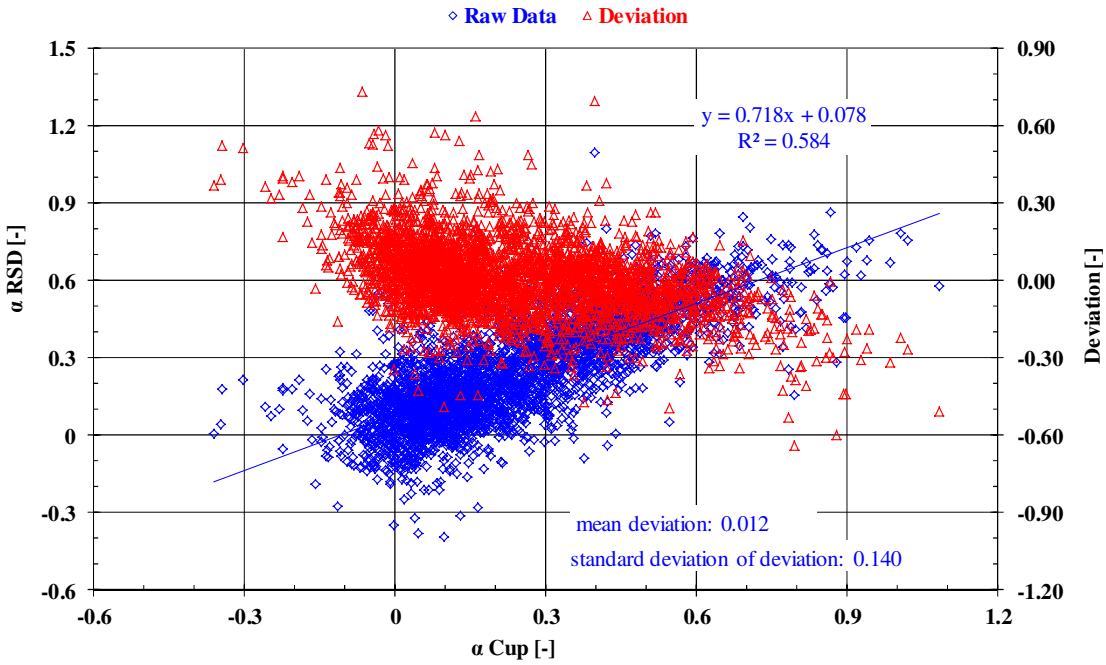

Figure 4.21: Scatter plot of shear exponents as measured by RSD between 100 m and 80 m height against cup anemometer measurements between 100.3 m and 82.2 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

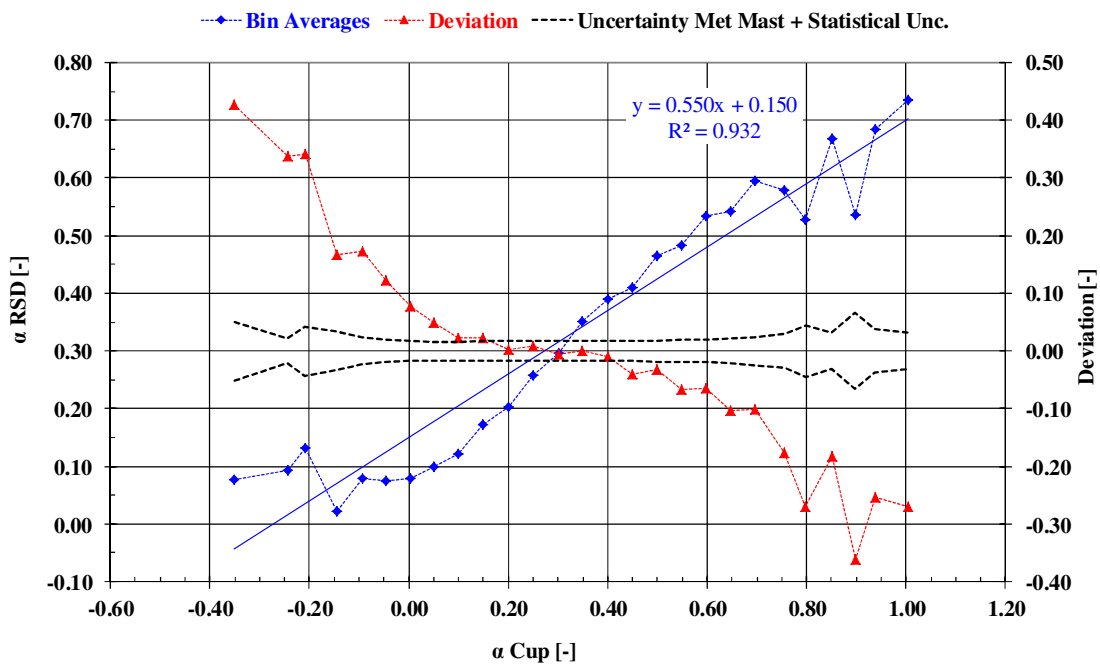

Figure 4.22: Bin analysis of shear exponents measured by RSD between 100 m and 80 m against cup anemometer measurements between 100.3 m and 82.2 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.350	0.076	3	0.178	0.007	0.090	0.048	0.427	0.859
-0.244	0.093	3	0.108	0.072	0.019	0.014	0.338	0.677
-0.209	0.132	6	0.215	-0.055	0.100	0.040	0.341	0.687
-0.146	0.022	15	0.255	-0.188	0.115	0.030	0.167	0.341
-0.094	0.079	49	0.326	-0.275	0.123	0.018	0.172	0.348
-0.047	0.076	136	0.669	-0.171	0.138	0.012	0.122	0.248
0.002	0.079	244	0.544	-0.349	0.130	0.008	0.077	0.157
0.050	0.100	355	0.489	-0.381	0.124	0.006	0.050	0.105
0.099	0.122	371	0.664	-0.395	0.120	0.006	0.023	0.056
0.150	0.172	323	0.796	-0.314	0.136	0.007	0.022	0.055
0.200	0.203	229	0.639	-0.130	0.138	0.009	0.003	0.036
0.249	0.257	227	0.753	-0.064	0.135	0.009	0.008	0.039
0.301	0.296	210	0.595	-0.026	0.125	0.009	-0.006	0.037
0.350	0.350	205	0.601	-0.013	0.117	0.008	0.001	0.035
0.399	0.390	210	1.094	-0.092	0.129	0.009	-0.009	0.040
0.449	0.409	165	0.701	0.006	0.101	0.008	-0.040	0.088
0.499	0.465	139	0.782	0.182	0.111	0.009	-0.033	0.075
0.549	0.482	99	0.690	0.052	0.105	0.010	-0.066	0.138
0.599	0.534	76	0.765	0.283	0.099	0.011	-0.064	0.135
0.647	0.542	49	0.784	0.315	0.099	0.014	-0.104	0.212
0.696	0.595	35	0.848	0.345	0.114	0.019	-0.102	0.209
0.755	0.579	18	0.757	0.344	0.102	0.025	-0.177	0.359
0.798	0.528	16	0.739	0.158	0.167	0.042	-0.270	0.548
0.851	0.668	13	0.865	0.524	0.097	0.027	-0.183	0.372
0.897	0.536	6	0.730	0.281	0.168	0.064	-0.361	0.735
0.938	0.685	3	0.753	0.621	0.066	0.034	-0.254	0.513
1.005	0.736	3	0.783	0.670	0.058	0.027	-0.269	0.542

Table 4.10: Bin analysis of shear exponents measured by RSD between 100 m and 80 m against cup anemometer measurements between 100.3 m and 82.2 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3.5 Accuracy of RSD in Terms of Wind Shear between 80 m and 60 m

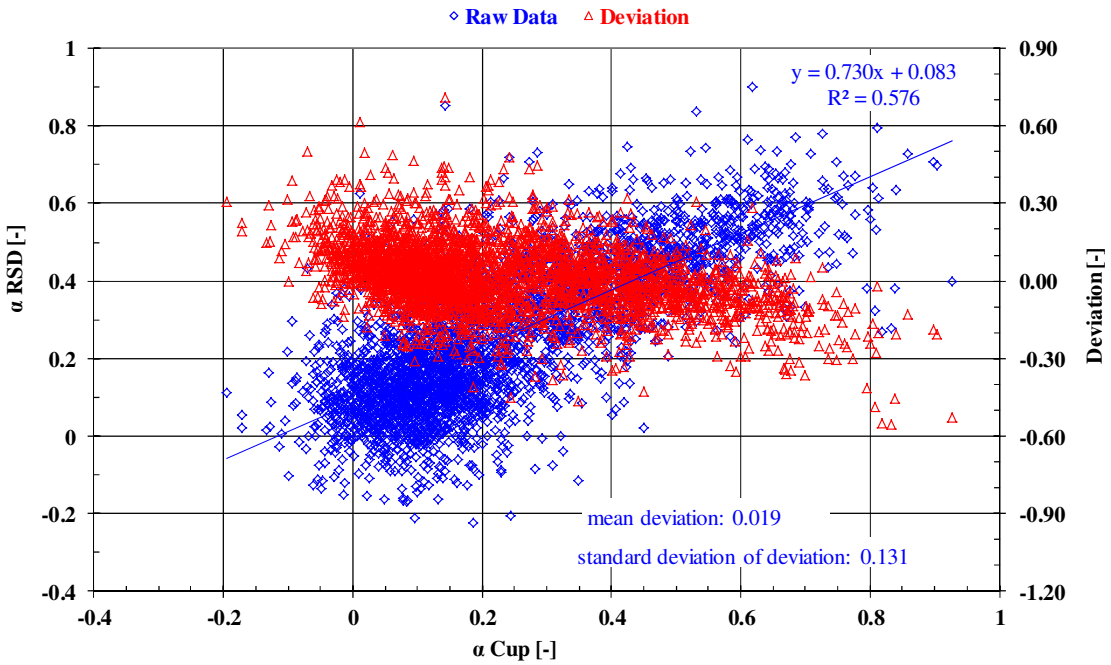

Figure 4.23: Scatter plot of shear exponents as measured by RSD between 80 m and 60 m height against cup anemometer measurements between 82.2 m and 60.4 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

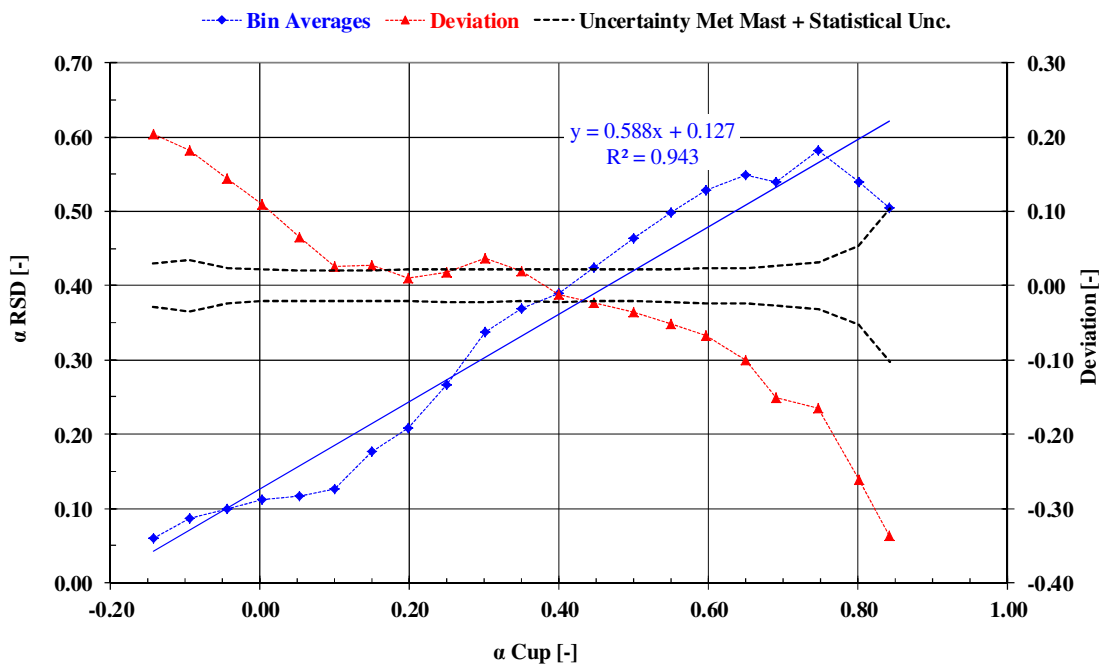

Figure 4.24: Bin analysis of shear exponents measured by RSD between 80 m and 60 m against cup anemometer measurements between 82.2 m and 60.4 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.143	0.061	6	0.162	0.015	0.057	0.022	0.204	0.412
-0.095	0.086	13	0.296	-0.103	0.108	0.029	0.181	0.369
-0.044	0.099	83	0.431	-0.138	0.114	0.013	0.143	0.290
0.003	0.112	192	0.624	-0.156	0.108	0.008	0.109	0.222
0.052	0.117	338	0.552	-0.163	0.105	0.006	0.065	0.135
0.100	0.125	431	0.559	-0.213	0.116	0.006	0.025	0.065
0.149	0.177	400	0.853	-0.162	0.127	0.006	0.028	0.069
0.197	0.207	286	0.606	-0.224	0.137	0.008	0.010	0.047
0.249	0.266	206	0.721	-0.205	0.148	0.010	0.017	0.056
0.301	0.338	189	0.732	-0.086	0.130	0.010	0.037	0.086
0.349	0.369	170	0.650	-0.114	0.114	0.009	0.020	0.058
0.400	0.389	168	0.746	0.055	0.120	0.009	-0.011	0.049
0.447	0.423	172	0.693	0.021	0.100	0.008	-0.024	0.064
0.499	0.463	123	0.735	0.205	0.088	0.008	-0.035	0.083
0.549	0.498	88	0.836	0.272	0.091	0.010	-0.051	0.112
0.596	0.528	74	0.900	0.240	0.107	0.012	-0.068	0.143
0.650	0.549	65	0.736	0.309	0.098	0.012	-0.101	0.207
0.691	0.539	32	0.771	0.332	0.103	0.018	-0.152	0.308
0.747	0.582	18	0.779	0.436	0.097	0.024	-0.165	0.335
0.801	0.539	11	0.793	0.269	0.157	0.049	-0.262	0.534
0.843	0.505	4	0.727	0.277	0.211	0.101	-0.338	0.706

Table 4.11: Bin analysis of shear exponents measured by RSD between 80 m and 60 m against cup anemometer measurements between 82.2 m and 60.4 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.3.6 Accuracy of RSD in Terms of Wind Shear between 60 m and 40 m

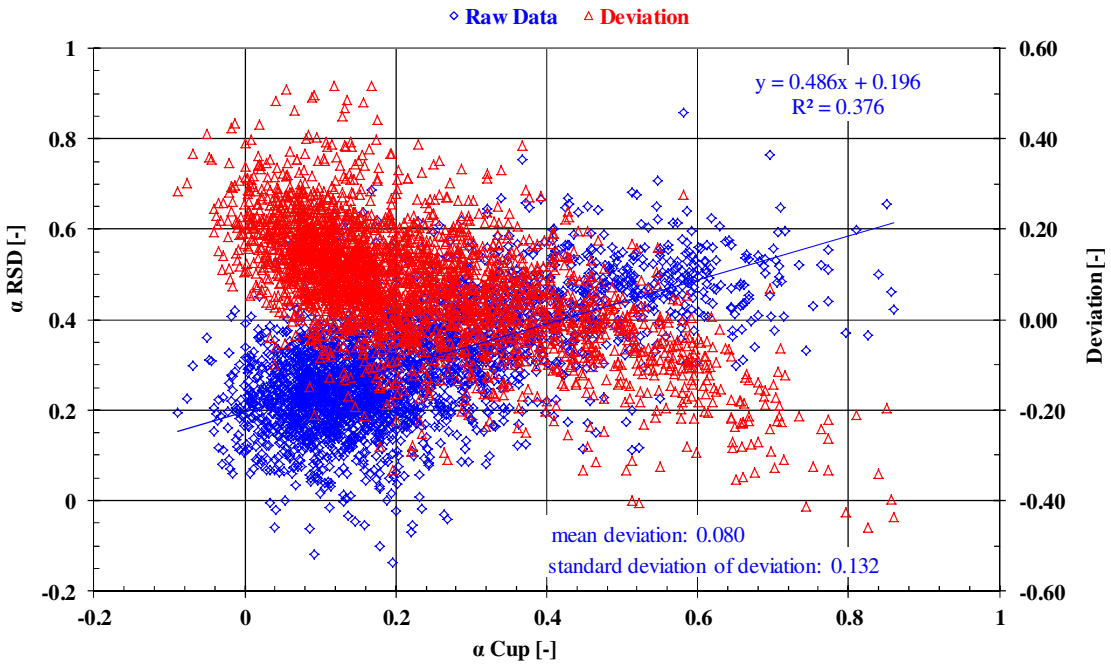

Figure 4.25: Scatter plot of shear exponents as measured by RSD between 60 m and 40 m height against cup anemometer measurements between 60.4 m and 40.3 m height and the deviation between both shear exponents. Each point represents a 10-minute period.

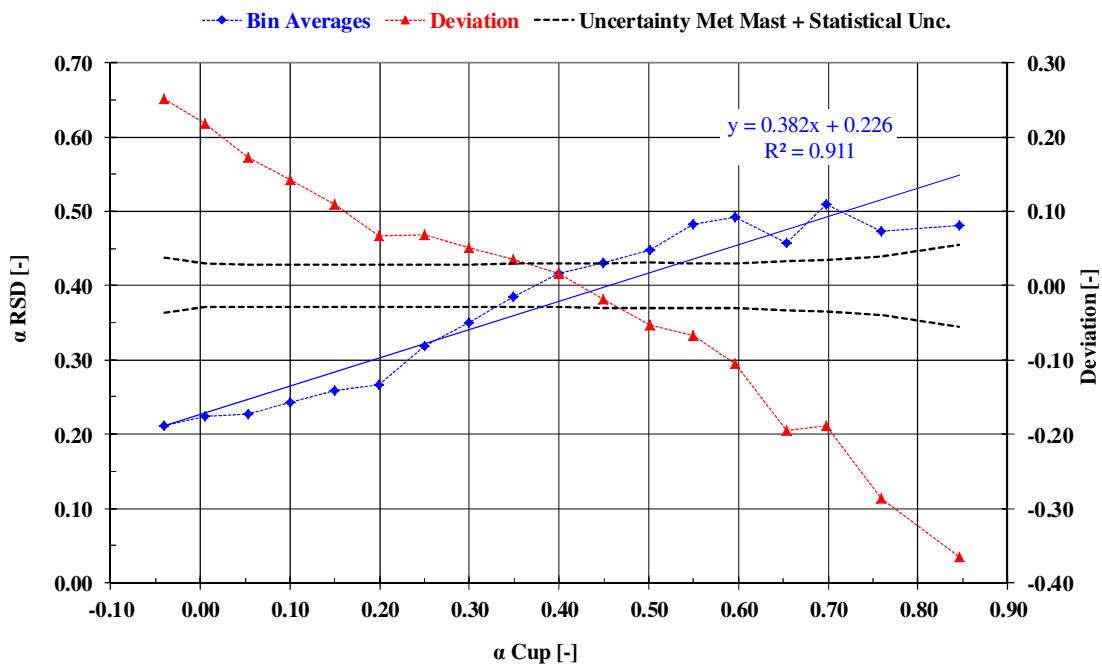

Figure 4.26: Bin analysis of shear exponents measured by RSD between 60 m and 40 m against cup anemometer measurements between 60.4 m and 40.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

α (Reference)	α (RSD)	number of data sets	α (RSD) max	α (RSD) min	α (RSD) std	α (RSD) std/sqrt(n)	α (RSD) - α (Reference)	uncertainty (*k* =2) α (RSD)
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
-0.040	0.211	14	0.360	0.081	0.084	0.024	0.251	0.507
0.006	0.225	106	0.452	0.059	0.087	0.009	0.219	0.442
0.054	0.227	261	0.564	-0.059	0.092	0.006	0.173	0.350
0.100	0.242	474	0.635	-0.118	0.094	0.004	0.142	0.289
0.150	0.258	439	0.686	-0.055	0.104	0.005	0.109	0.224
0.199	0.267	300	0.563	-0.138	0.113	0.006	0.068	0.147
0.250	0.318	226	0.617	-0.041	0.113	0.007	0.068	0.147
0.300	0.350	203	0.645	0.081	0.104	0.007	0.051	0.116
0.349	0.385	158	0.754	0.123	0.106	0.008	0.036	0.092
0.399	0.416	118	0.665	0.186	0.096	0.009	0.017	0.068
0.450	0.431	100	0.668	0.115	0.104	0.010	-0.019	0.070
0.501	0.447	72	0.681	0.112	0.107	0.013	-0.054	0.124
0.550	0.483	59	0.707	0.224	0.086	0.011	-0.067	0.146
0.597	0.491	58	0.858	0.304	0.085	0.011	-0.106	0.220
0.653	0.457	26	0.607	0.297	0.080	0.017	-0.196	0.397
0.698	0.509	21	0.765	0.339	0.097	0.021	-0.189	0.385
0.759	0.473	7	0.553	0.332	0.077	0.027	-0.287	0.579
0.846	0.481	5	0.654	0.367	0.109	0.047	-0.366	0.739

Table 4.12: Bin analysis of shear exponents measured by RSD between 60 m and 40 m against cup anemometer measurements between 60.4 m and 40.3 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4 Accuracy of the RSD in Terms of Wind Direction

The wind direction as measured by the RSD and by the met mast is compared for measurement heights of 140 m , 120 m, 100 m, 80 m, 60 m, 40 m in the following sub chapter. The following conclusions can be drawn:

- The wind direction as measured by the RSD and by the vane correlates good with squared correlation coefficient of 0.998 – 0.999. Hardly any outlier data is observed in the respective scatter plot, see Figure 4.27, Figure 4.29, Figure 4.31, Figure 4.33, Figure 4.35 and Figure 4.37.
- The RSD shows value of mean deviation of -2.60° to 0.42°.
- Overall, the wind direction measurement of the RSD is considered as good.

4.4.1 Wind Direction at 140 m Height

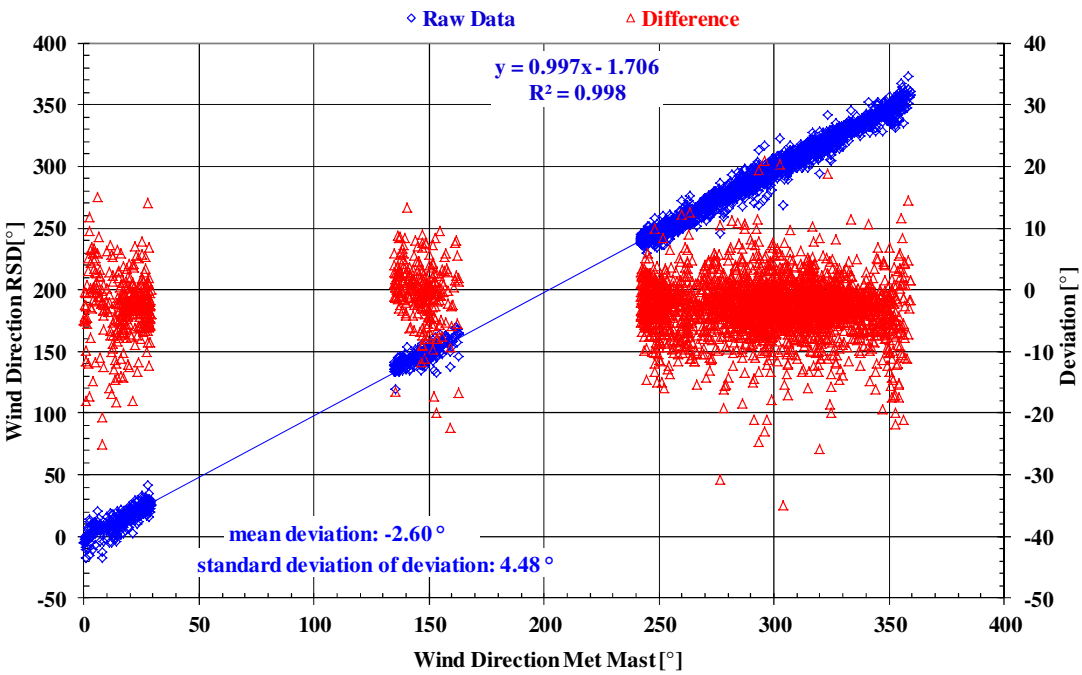

Figure 4.27: Scatter plot of wind direction as measured by RSD at 140 m height above ground against vane readings at 129 m measurement height.

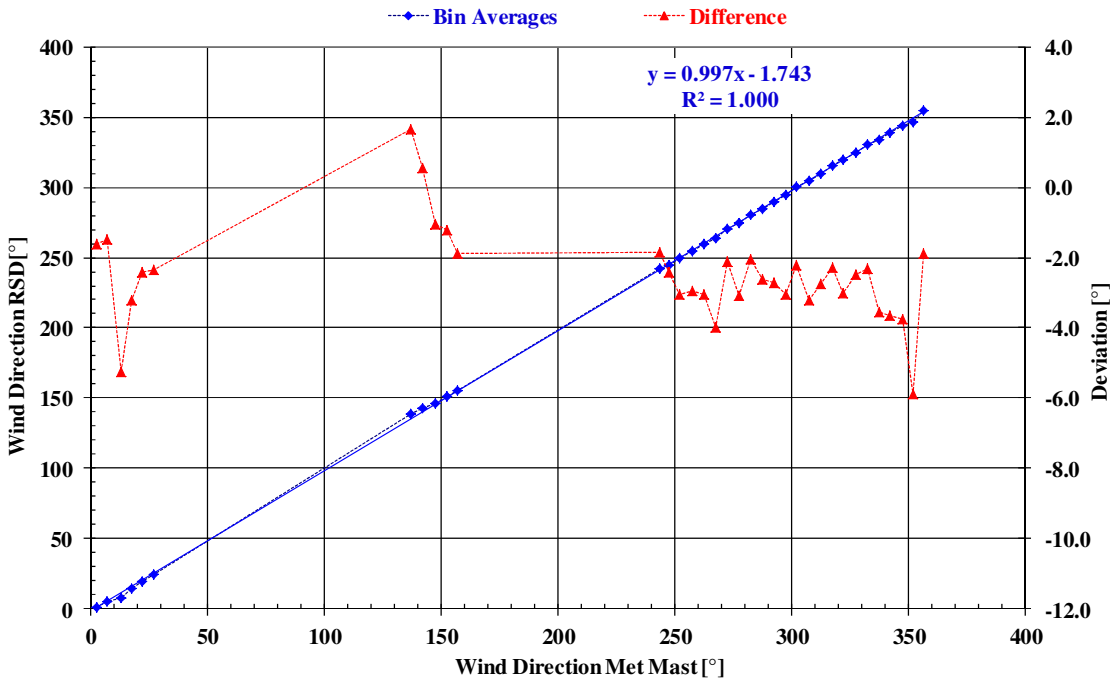

Figure 4.28: Bin analysis of wind direction as measured by RSD at 140 m height above ground against vane readings at 129 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.510	0.881	42	14	-17	7.683	1.186	-1.629	6.556	7.321
7.178	5.688	32	21	-17	7.244	1.281	-1.491	6.742	7.371
12.818	7.550	40	21	-5	6.496	1.027	-5.268	6.521	12.390
17.495	14.263	76	24	2	4.145	0.475	-3.232	6.249	8.990
22.232	19.815	65	29	3	4.216	0.523	-2.417	6.270	7.917
27.098	24.762	101	42	16	3.680	0.366	-2.336	6.228	7.785
137.069	138.721	61	148	119	4.340	0.556	1.652	6.263	7.082
142.316	142.864	44	154	135	3.752	0.566	0.548	6.278	6.373
147.635	146.577	78	156	135	4.317	0.489	-1.058	6.259	6.607
152.424	151.200	50	164	133	5.503	0.778	-1.224	6.369	6.823
157.247	155.368	19	163	137	6.148	1.411	-1.879	6.888	7.846
161.882	162.273	11	170	146	6.813	2.054	0.391	7.457	7.498
243.549	241.696	92	249	230	3.250	0.339	-1.853	6.223	7.243
247.354	244.927	123	258	234	3.882	0.350	-2.428	6.225	7.895
252.321	249.264	106	261	236	4.498	0.437	-3.057	6.239	8.734
257.659	254.696	69	272	246	4.567	0.550	-2.964	6.269	8.628
262.477	259.429	77	276	250	5.012	0.571	-3.048	6.284	8.755
267.671	263.692	52	274	251	4.705	0.652	-3.979	6.297	10.148
272.548	270.425	80	280	256	4.839	0.541	-2.123	6.266	7.568
277.466	274.385	91	287	246	5.238	0.549	-3.081	6.283	8.801
282.637	280.598	107	295	266	4.516	0.437	-2.039	6.241	7.455
287.366	284.738	145	298	268	4.288	0.356	-2.628	6.221	8.143
292.636	289.921	165	313	269	5.238	0.408	-2.715	6.233	8.266
297.435	294.397	237	317	273	4.453	0.289	-3.039	6.208	8.688
302.317	300.102	166	323	269	4.741	0.368	-2.215	6.224	7.640
307.422	304.208	130	317	289	4.475	0.392	-3.215	6.224	8.949
312.635	309.871	163	320	299	3.655	0.286	-2.764	6.207	8.312
317.535	315.252	202	328	294	3.926	0.276	-2.283	6.209	7.707
322.335	319.303	175	342	305	4.257	0.322	-3.032	6.213	8.682
327.370	324.885	122	335	314	3.868	0.350	-2.484	6.221	7.962
332.378	330.050	100	345	321	3.383	0.338	-2.328	6.214	7.765
337.758	334.200	65	341	325	3.350	0.416	-3.558	6.231	9.459
342.342	338.676	71	352	327	4.252	0.505	-3.666	6.271	9.648
347.687	343.928	69	352	328	4.023	0.484	-3.759	6.265	9.787
352.128	346.250	68	360	331	6.569	0.797	-5.878	6.379	13.375
356.813	354.938	32	373	335	7.700	1.361	-1.875	6.713	7.690

Table 4.13 Bin analysis of wind direction as measured by RSD at 140 m height above ground against vane readings at 129 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4.2 Wind Direction at 120 m Height

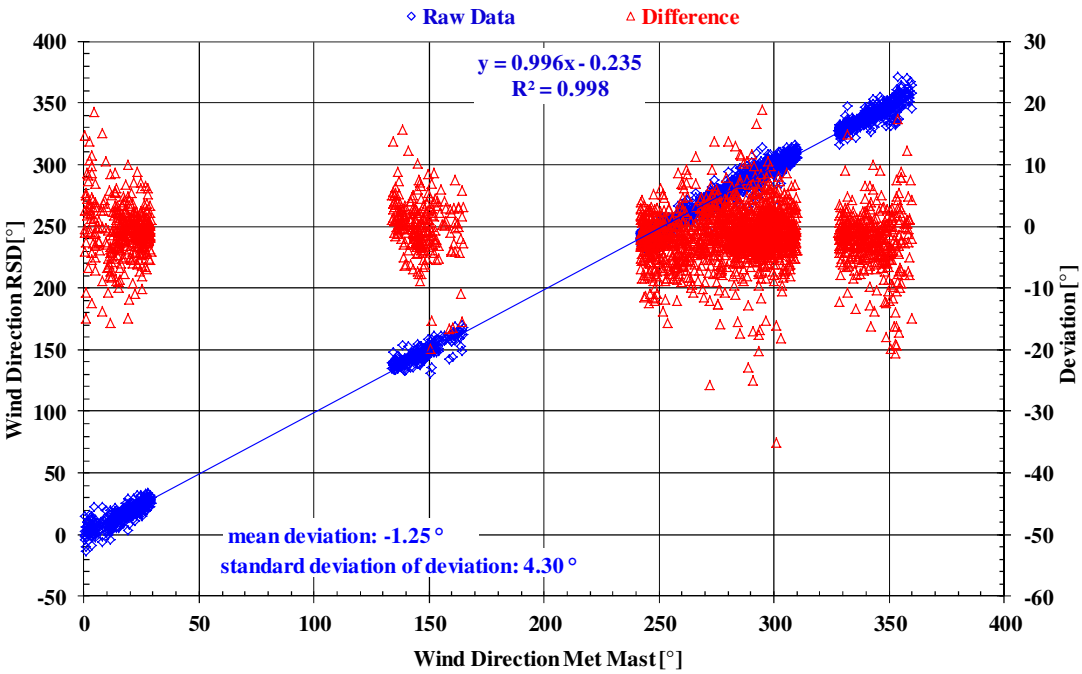

Figure 4.29: Scatter plot of wind direction as measured by RSD at 120 m height above ground against vane readings at 118.3 m measurement height.

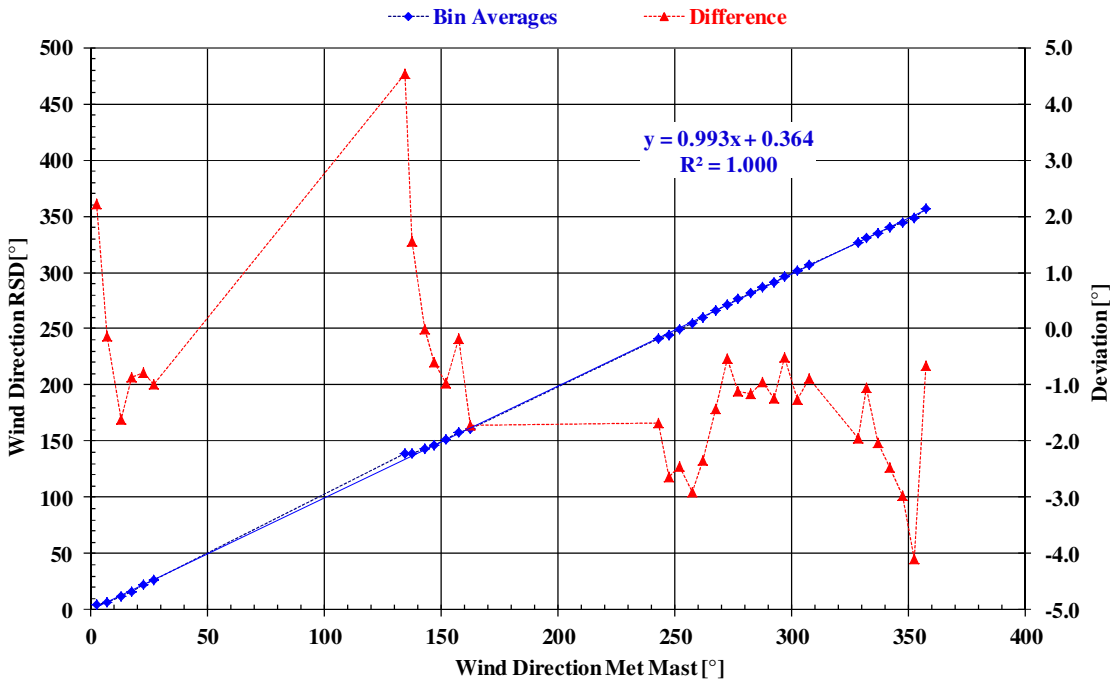

Figure 4.30: Bin analysis of wind direction as measured by RSD at 120 m height above ground against vane readings at 118.3 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.381	4.605	43	23	-14	7.139	1.089	2.223	6.530	7.900
7.256	7.111	27	23	-6	6.314	1.215	-0.144	6.589	6.595
12.970	11.351	57	22	-4	5.702	0.755	-1.619	6.331	7.111
17.368	16.513	78	29	4	4.404	0.499	-0.855	6.247	6.477
22.744	21.968	95	32	11	3.508	0.360	-0.776	6.220	6.410
26.948	25.953	107	34	15	3.109	0.301	-0.994	6.205	6.516
134.460	139.000	10	148	135	3.559	1.125	4.540	6.583	11.215
137.337	138.895	57	154	133	3.250	0.430	1.558	6.245	6.979
143.002	143.000	52	155	134	3.726	0.517	-0.002	6.262	6.262
147.203	146.619	63	158	137	4.316	0.544	-0.584	6.261	6.370
151.975	151.000	32	161	131	5.902	1.043	-0.975	6.495	6.781
157.675	157.500	12	162	142	5.368	1.550	-0.175	7.023	7.032
162.620	160.900	20	170	144	6.648	1.487	-1.720	6.809	7.629
243.248	241.576	85	247	232	3.223	0.350	-1.672	6.222	7.063
247.391	244.750	116	253	233	3.925	0.364	-2.641	6.222	8.162
252.148	249.690	84	257	238	3.868	0.422	-2.457	6.240	7.943
257.531	254.622	74	267	246	3.752	0.436	-2.909	6.235	8.528
262.007	259.672	67	271	251	4.544	0.555	-2.336	6.285	7.831
267.811	266.377	61	277	258	4.251	0.544	-1.434	6.270	6.895
272.384	271.844	77	288	246	5.371	0.612	-0.540	6.292	6.384
277.261	276.146	96	287	261	4.830	0.493	-1.116	6.248	6.635
282.667	281.516	126	296	269	3.917	0.349	-1.152	6.223	6.636
287.509	286.560	134	299	266	4.592	0.397	-0.949	6.232	6.515
292.785	291.548	199	309	266	4.665	0.331	-1.238	6.218	6.692
297.277	296.766	218	314	281	3.830	0.259	-0.511	6.203	6.287
302.414	301.144	153	310	266	4.811	0.389	-1.270	6.229	6.727
307.659	306.772	127	316	298	3.254	0.289	-0.887	6.206	6.455
328.769	326.829	35	332	316	3.073	0.519	-1.940	6.268	7.372
332.000	330.939	82	347	321	3.584	0.396	-1.061	6.231	6.582
337.317	335.280	75	346	322	3.637	0.420	-2.037	6.222	7.438
342.345	339.870	69	353	326	4.566	0.550	-2.475	6.273	7.991
347.516	344.551	69	355	331	3.998	0.481	-2.965	6.264	8.626
352.480	348.393	56	371	331	7.862	1.051	-4.087	6.509	10.450
357.409	356.750	32	370	345	6.185	1.093	-0.659	6.546	6.678

Table 4.14 Bin analysis of wind direction as measured by RSD at 120 m height above ground against vane readings at 118.3 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4.3 Wind Direction at 100 m Height

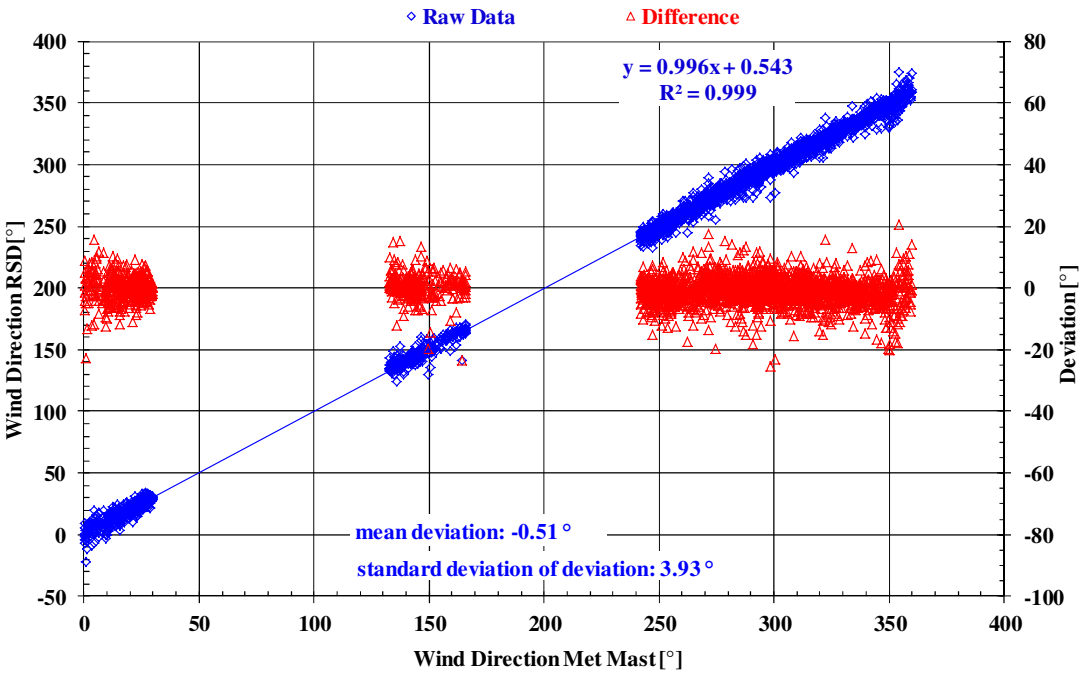

Figure 4.31: Scatter plot of wind direction as measured by RSD at 100 m height above ground against vane readings at 98.2 m measurement height.

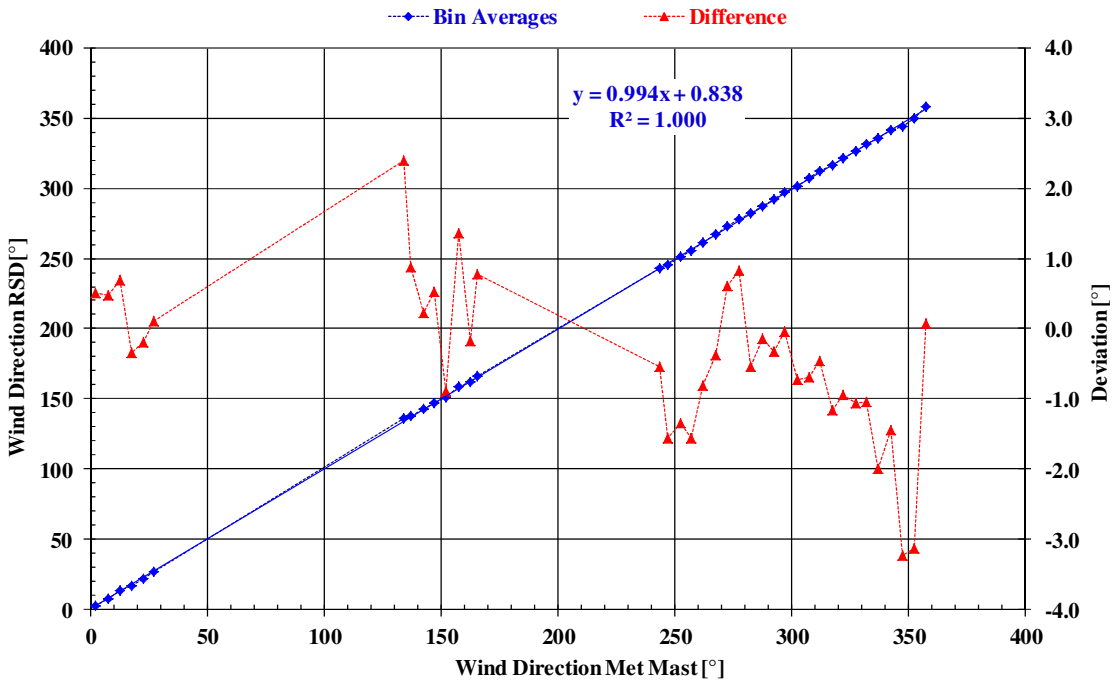

Figure 4.32: Bin analysis of wind direction as measured by RSD at 100 m height above ground against vane readings at 98.2 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.250	2.762	42	20	-22	7.190	1.109	0.512	6.527	6.607
7.426	7.903	31	20	-3	5.641	1.013	0.477	6.563	6.632
12.632	13.319	69	24	0	5.234	0.630	0.687	6.282	6.431
17.460	17.125	80	26	4	4.051	0.453	-0.335	6.232	6.267
22.499	22.310	126	31	10	3.120	0.278	-0.190	6.205	6.217
27.247	27.347	121	34	21	2.676	0.243	0.100	6.202	6.206
133.835	136.233	43	149	130	3.228	0.492	2.398	6.260	7.886
137.075	137.946	56	153	124	4.052	0.541	0.871	6.280	6.517
142.540	142.772	57	153	135	3.306	0.438	0.232	6.244	6.261
146.906	147.426	47	160	130	5.340	0.779	0.519	6.365	6.449
152.090	151.200	20	159	136	5.268	1.178	-0.890	6.549	6.787
157.489	158.842	19	166	149	3.976	0.912	1.353	6.423	6.969
162.536	162.357	28	168	141	5.431	1.026	-0.179	6.519	6.529
165.730	166.500	10	171	163	2.550	0.806	0.770	6.387	6.570
243.447	242.903	72	250	233	3.190	0.376	-0.544	6.228	6.323
247.312	245.760	100	254	232	3.843	0.384	-1.552	6.227	6.958
252.535	251.186	86	260	239	4.208	0.454	-1.349	6.245	6.803
257.199	255.635	74	265	245	3.884	0.451	-1.564	6.242	6.981
262.265	261.462	52	274	245	4.941	0.685	-0.804	6.333	6.534
267.629	267.246	69	280	253	5.039	0.607	-0.383	6.278	6.325
272.533	273.138	94	289	255	4.787	0.494	0.605	6.267	6.383
277.405	278.226	93	294	269	3.940	0.409	0.820	6.233	6.446
282.554	282.009	112	296	270	3.873	0.366	-0.545	6.221	6.316
287.618	287.476	143	301	273	4.128	0.345	-0.143	6.219	6.225
292.685	292.365	203	306	273	3.977	0.279	-0.321	6.207	6.240
297.269	297.229	210	308	273	3.652	0.252	-0.040	6.203	6.204
302.382	301.654	133	311	277	3.867	0.335	-0.728	6.217	6.385
307.643	306.959	146	318	293	3.426	0.284	-0.684	6.207	6.356
312.326	311.872	195	322	302	3.386	0.242	-0.454	6.199	6.265
317.364	316.197	183	324	306	2.808	0.208	-1.167	6.197	6.622
322.293	321.347	150	338	306	3.693	0.302	-0.946	6.212	6.494
327.601	326.549	102	335	318	3.245	0.321	-1.052	6.214	6.560
332.196	331.158	76	347	322	3.570	0.410	-1.038	6.237	6.574
337.322	335.329	76	347	325	3.489	0.400	-1.993	6.228	7.395
342.603	341.155	71	354	328	4.318	0.512	-1.448	6.259	6.897
347.366	344.141	64	353	329	4.649	0.581	-3.225	6.289	9.009
352.372	349.240	50	375	330	8.618	1.219	-3.132	6.584	9.088
357.572	357.651	43	374	346	6.256	0.954	0.079	6.427	6.429

Table 4.15 Bin analysis of wind direction as measured by RSD at 100 m height above ground against vane readings at 98.2 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4.4 Wind Direction at 80 m Height

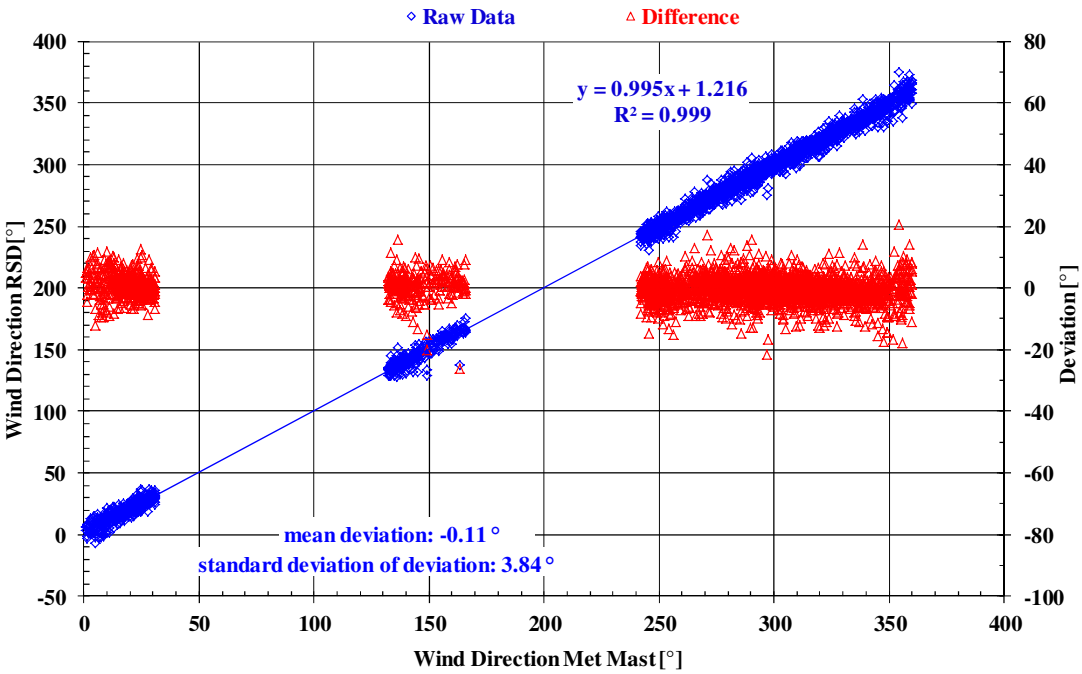

Figure 4.33: Scatter plot of wind direction as measured by RSD at 80 m height above ground against vane readings at 80.1 m measurement height.

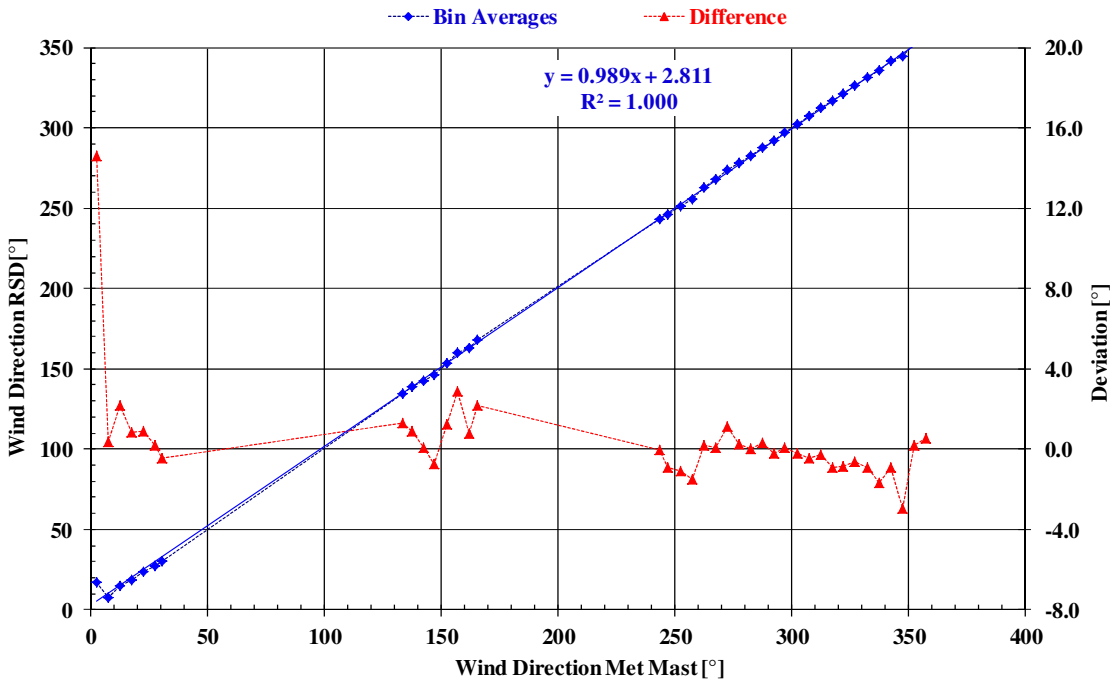

Figure 4.34: Bin analysis of wind direction as measured by RSD at 80 m height above ground against vane readings at 80.1 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.700	17.333	30	358	-3	64.496	11.775	14.633	6.393	29.957
7.361	7.732	41	18	-7	5.736	0.896	0.371	6.442	6.485
12.649	14.797	69	24	2	4.530	0.545	2.148	6.280	7.608
17.337	18.170	88	25	9	2.987	0.318	0.833	6.212	6.432
22.483	23.405	158	37	14	3.513	0.280	0.922	6.204	6.472
27.438	27.626	99	37	19	2.919	0.293	0.188	6.209	6.220
30.500	30.053	19	36	24	2.877	0.660	-0.447	6.321	6.384
133.574	134.860	43	145	129	3.211	0.490	1.286	6.258	6.766
137.653	138.544	68	152	128	4.112	0.499	0.891	6.252	6.501
142.471	142.537	41	154	131	4.817	0.752	0.066	6.332	6.334
146.971	146.226	31	156	129	6.360	1.142	-0.745	6.591	6.758
152.510	153.762	21	160	147	3.948	0.862	1.252	6.398	6.871
157.246	160.125	24	167	155	3.083	0.629	2.879	6.327	8.555
162.096	162.893	28	170	137	5.852	1.106	0.796	6.573	6.763
165.540	167.700	10	175	164	3.561	1.126	2.160	6.573	7.865
243.461	243.446	56	251	234	3.115	0.416	-0.014	6.233	6.233
247.194	246.298	104	258	231	4.351	0.427	-0.896	6.234	6.487
252.522	251.455	99	262	240	4.207	0.423	-1.068	6.237	6.593
257.437	255.947	57	263	241	4.357	0.577	-1.489	6.268	6.940
262.360	262.532	47	273	254	4.717	0.688	0.172	6.310	6.320
267.775	267.857	77	278	257	4.195	0.478	0.082	6.252	6.254
272.504	273.613	80	288	264	4.046	0.452	1.109	6.248	6.629
277.784	278.020	98	290	268	4.071	0.411	0.237	6.237	6.254
282.410	282.431	102	295	270	4.046	0.401	0.022	6.232	6.232
287.503	287.818	143	302	271	4.061	0.340	0.315	6.218	6.250
292.586	292.387	222	306	278	3.659	0.246	-0.198	6.201	6.214
297.256	297.326	193	308	275	3.696	0.266	0.070	6.205	6.207
302.436	302.204	137	311	294	3.554	0.304	-0.231	6.211	6.228
307.677	307.205	166	319	292	3.545	0.275	-0.472	6.204	6.275
312.591	312.301	176	320	299	3.325	0.251	-0.290	6.200	6.227
317.459	316.528	163	326	307	3.124	0.245	-0.931	6.200	6.474
322.089	321.222	135	335	307	3.747	0.322	-0.867	6.213	6.450
327.355	326.709	103	340	315	3.659	0.360	-0.647	6.222	6.355
332.394	331.476	82	343	322	3.179	0.351	-0.918	6.219	6.485
337.377	335.680	75	353	325	4.671	0.539	-1.697	6.270	7.130
342.687	341.761	71	353	331	3.889	0.462	-0.927	6.243	6.512
347.481	344.500	64	354	330	5.454	0.682	-2.981	6.328	8.694
352.695	352.875	40	375	335	6.977	1.103	0.180	6.503	6.513
357.442	357.982	57	373	338	6.556	0.868	0.540	6.388	6.479

Table 4.16 Bin analysis of wind direction as measured by RSD at 80 m height above ground against vane readings at 80.1 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4.5 Wind Direction at 60 m Height

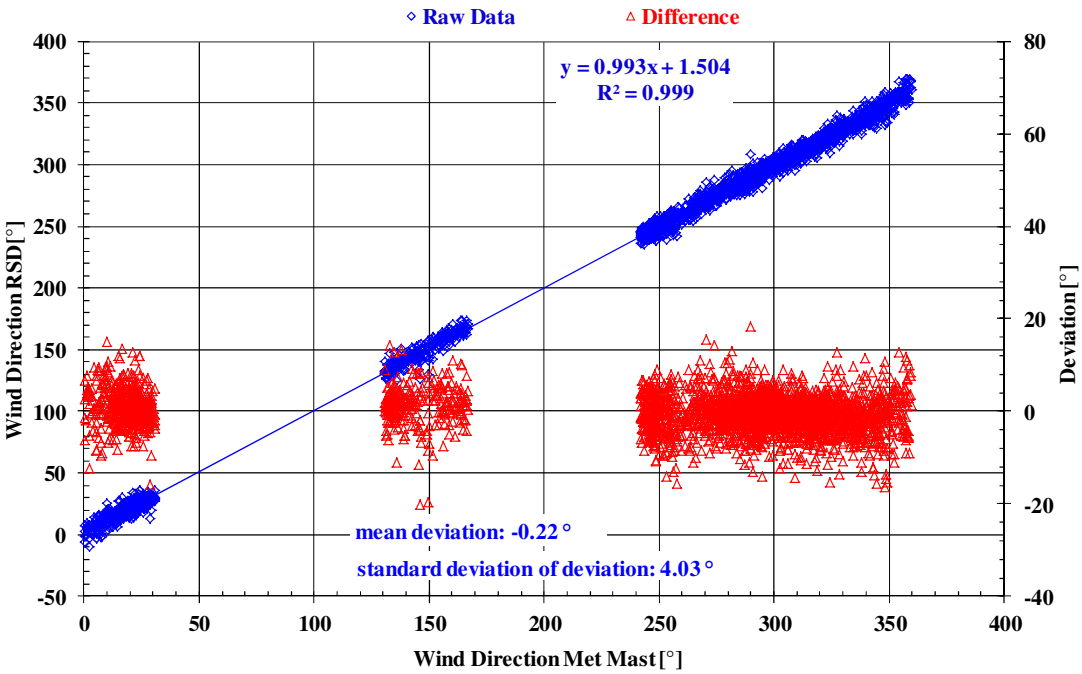

Figure 4.35: Scatter plot of wind direction as measured by RSD at 60 m height above ground against vane readings at 58.2 m measurement height.

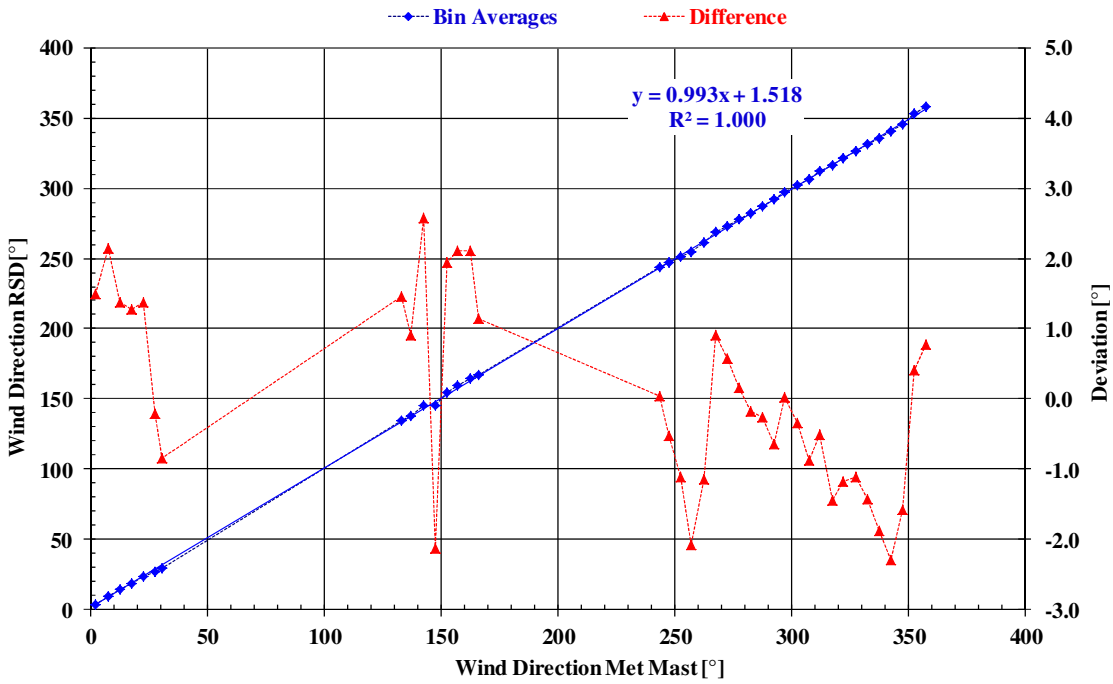

Figure 4.36: Bin analysis of wind direction as measured by RSD at 60 m height above ground against vane readings at 58.2 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.254	3.750	28	14	-10	4.812	0.909	1.496	6.429	7.091
7.307	9.442	43	25	-3	6.367	0.971	2.135	6.420	7.710
12.743	14.118	76	27	4	4.360	0.500	1.375	6.261	6.839
17.502	18.781	96	30	11	3.634	0.371	1.279	6.226	6.731
22.447	23.826	149	36	13	3.777	0.309	1.379	6.211	6.795
27.405	27.194	93	35	13	3.499	0.363	-0.212	6.222	6.236
30.473	29.636	11	36	27	2.420	0.730	-0.836	6.341	6.558
132.965	134.431	65	147	126	3.527	0.437	1.466	6.233	6.888
136.943	137.848	46	151	125	4.492	0.662	0.904	6.318	6.572
142.391	144.971	34	153	139	3.261	0.559	2.579	6.263	8.114
147.404	145.280	25	157	126	7.813	1.563	-2.124	6.903	8.106
152.556	154.500	18	160	142	4.681	1.103	1.944	6.541	7.609
157.255	159.364	33	167	149	3.920	0.682	2.109	6.319	7.598
162.686	164.793	29	174	156	4.126	0.766	2.107	6.344	7.616
166.108	167.250	12	174	162	3.519	1.016	1.142	6.465	6.856
243.504	243.537	54	250	235	3.664	0.499	0.033	6.263	6.264
247.565	247.034	118	258	238	4.375	0.403	-0.531	6.232	6.322
252.600	251.493	75	261	239	4.881	0.564	-1.107	6.276	6.654
257.069	255.000	54	266	242	5.366	0.730	-2.069	6.347	7.577
262.671	261.526	38	272	254	4.183	0.679	-1.145	6.322	6.724
267.678	268.587	63	279	254	4.616	0.582	0.910	6.277	6.535
272.482	273.056	71	288	263	4.687	0.556	0.575	6.272	6.376
277.565	277.726	84	290	267	4.331	0.473	0.161	6.241	6.249
282.454	282.274	106	295	274	4.206	0.408	-0.180	6.233	6.244
287.667	287.403	144	308	275	4.491	0.374	-0.265	6.224	6.246
292.648	292.004	224	302	278	3.380	0.226	-0.643	6.199	6.331
297.325	297.347	176	306	281	3.732	0.281	0.022	6.204	6.204
302.419	302.068	146	313	290	3.463	0.287	-0.351	6.208	6.247
307.493	306.617	141	316	295	3.631	0.306	-0.876	6.210	6.452
312.346	311.839	155	320	300	3.484	0.280	-0.507	6.207	6.290
317.522	316.083	157	324	306	3.334	0.266	-1.439	6.202	6.837
322.242	321.066	122	333	309	4.045	0.366	-1.176	6.222	6.652
327.392	326.290	93	340	315	4.370	0.453	-1.102	6.245	6.622
332.513	331.091	88	344	324	3.489	0.372	-1.422	6.223	6.842
337.491	335.623	69	351	325	4.560	0.549	-1.868	6.267	7.296
342.743	340.456	68	351	329	4.641	0.563	-2.287	6.284	7.773
347.390	345.810	63	359	332	5.631	0.709	-1.581	6.341	7.086
352.450	352.861	36	367	341	5.571	0.929	0.411	6.411	6.463
357.370	358.140	43	369	348	6.042	0.921	0.770	6.423	6.605

Table 4.17 Bin analysis of wind direction as measured by RSD at 60 m height above ground against vane readings at 58.2 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.4.6 Wind Direction at 40 m Height

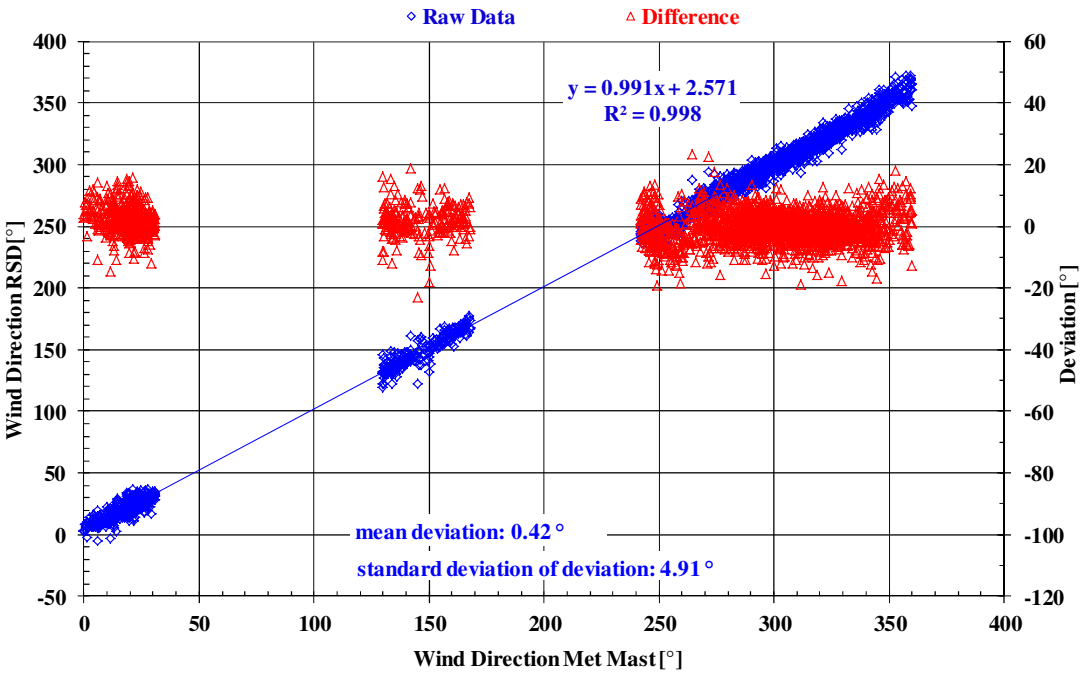

Figure 4.37: Scatter plot of wind direction as measured by RSD at 40 m height above ground against vane readings at 38.2 m measurement height.

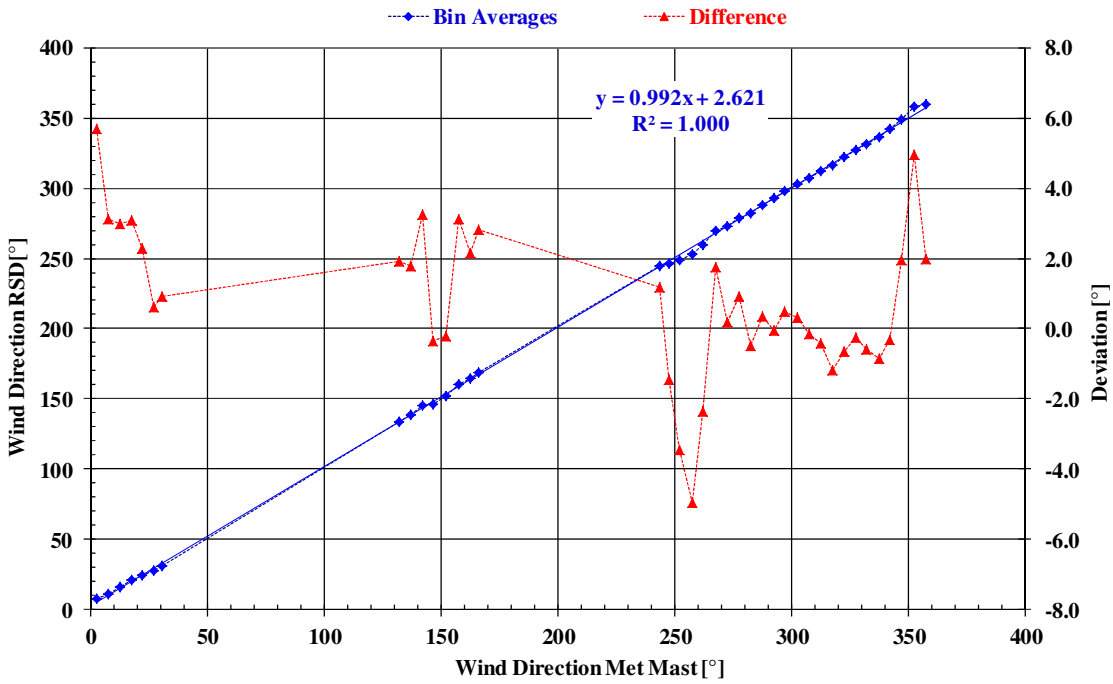

Figure 4.38: Bin analysis of wind direction as measured by RSD at 40 m height above ground against vane readings at 38.2 m measurement height.

Dir (Reference)	Dir (RSD)	number of data sets	Dir (RSD) max	Dir (RSD) min	Dir (RSD) std	Dir(RSD) std/sqrt(n)	Dir (RSD) - Dir (Reference)	uncertainty (*k*=2) (calibration)	uncertainty (k=2) Dir (RSD)
[°]	[°]	[-]	[°]	[°]	[°]	[°]	[°]	[°]	[°]
2.442	8.125	24	16	-2	4.174	0.852	5.683	6.353	13.021
7.644	10.750	36	23	-5	5.123	0.854	3.106	6.384	8.907
12.776	15.773	66	29	-3	5.945	0.732	2.997	6.336	8.722
17.676	20.755	102	34	11	4.670	0.462	3.078	6.244	8.769
22.145	24.443	122	37	11	4.623	0.419	2.298	6.236	7.746
27.185	27.808	73	37	17	4.098	0.480	0.623	6.254	6.377
30.507	31.429	14	35	28	2.344	0.626	0.921	6.299	6.563
132.146	134.053	57	149	119	5.601	0.742	1.907	6.346	7.404
137.297	139.065	31	148	128	4.697	0.844	1.768	6.375	7.289
141.843	145.095	21	161	139	5.558	1.213	3.252	6.583	9.255
146.750	146.389	18	160	122	9.056	2.135	-0.361	7.431	7.466
152.305	152.095	21	167	132	7.355	1.605	-0.210	6.808	6.821
157.563	160.667	30	169	154	3.994	0.729	3.103	6.349	8.879
162.470	164.609	23	171	153	3.799	0.792	2.139	6.367	7.671
166.221	169.053	19	177	161	4.314	0.990	2.832	6.483	8.608
243.402	244.595	42	255	236	4.874	0.752	1.193	6.374	6.806
247.380	245.925	93	262	230	6.056	0.628	-1.455	6.318	6.956
252.219	248.769	52	257	237	4.409	0.611	-3.450	6.314	9.353
257.481	252.531	32	270	241	6.975	1.233	-4.950	6.614	11.906
262.085	259.735	34	288	249	7.708	1.322	-2.350	6.604	8.106
267.717	269.481	54	281	254	5.859	0.797	1.765	6.350	7.265
272.644	272.831	59	294	259	6.587	0.858	0.186	6.404	6.415
277.546	278.451	71	292	261	5.498	0.652	0.904	6.309	6.563
282.487	282.011	89	293	272	4.484	0.475	-0.475	6.251	6.323
287.607	287.953	148	297	276	3.911	0.321	0.345	6.213	6.251
292.655	292.588	199	304	282	3.842	0.272	-0.067	6.208	6.210
297.264	297.738	149	307	281	4.302	0.352	0.474	6.219	6.290
302.360	302.678	149	315	291	4.102	0.336	0.317	6.218	6.250
307.560	307.426	115	317	296	3.914	0.365	-0.134	6.223	6.229
312.428	312.026	152	325	293	4.117	0.334	-0.401	6.216	6.267
317.435	316.250	136	328	303	4.477	0.384	-1.185	6.223	6.659
322.450	321.790	100	334	309	4.700	0.470	-0.660	6.252	6.390
327.457	327.221	77	337	312	4.584	0.522	-0.236	6.271	6.289
332.269	331.689	74	345	324	3.705	0.431	-0.580	6.243	6.350
337.409	336.545	66	350	326	4.814	0.593	-0.864	6.295	6.528
342.230	341.913	69	354	328	5.651	0.680	-0.317	6.335	6.366
347.250	349.196	46	361	334	6.622	0.976	1.946	6.467	7.547
352.608	357.560	25	371	346	5.952	1.190	4.952	6.574	11.887
357.677	359.657	35	372	347	7.199	1.217	1.980	6.603	7.699

Table 4.18 Bin analysis of wind direction as measured by RSD at 40 m height above ground against vane readings at 38.2 m measurement height. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test.

4.5 Correction of Horizontal Wind Speed

The evaluation of the tested RSD showed an overestimation of the horizontal wind speed larger than the reference uncertainty in all measurement heights. Therefore a correction function was calculated and applied to the measured data. The same correction function (**y=0.977x + 0.034**) was applied to the 10-min average values of horizontal wind speed component in every height level of RSD between 60 m and 140 m.

The correction function was calculated by creating a linear regression of horizontal wind speed component measured by the reference anemometer as function of measurand by the RSD of each height. The results were averaged to **y=0.977x + 0.034**.

The calibration procedure as in chapter 4.2 is applied to the corrected data. The results are shown in the following figures and tables. The correction has the following effects on the results:

- The mean deviation is reduced to the range between -0.04 m/s and -0.01 m/s (-0.5 % to 0.0 %)
- Uncertainties (*k*=2) in the range below 8 m/s were reduced by about 2 % to 3 % for measurement heights 140 m to 100 m and by 0 % to 2 % for the measurement heights of 60 m and 80 m. Above 8 m/s no systematic improvement or regression of uncertainties occurs, with changes varying between -2 % and 2 % of uncertainty (*k*=2) between different wind speed bins.
- Correlation and scatter are not influenced by the correction.

It is noted that the uncertainty of the RSD as resulting from this comparison does not reflect all uncertainties of the system during an application at another site. The following additional uncertainties should be considered for an application of the system:

- The RSD measurements are influenced by environmental conditions, like e.g. wind shear. Thus, there is an additional uncertainty due to different environmental condi-tions during the calibration and during the application of the RSD.
- Mounting errors of the RSD during an application (vertical alignment)

Detailed ambient conditions dependent on wind speed and wind direction which were present during the test can be seen in Appendix A. These are the same as for the uncorrected data presented in chapter 4.2.

4.5.1 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 140 m Measurement Height (correction applied)

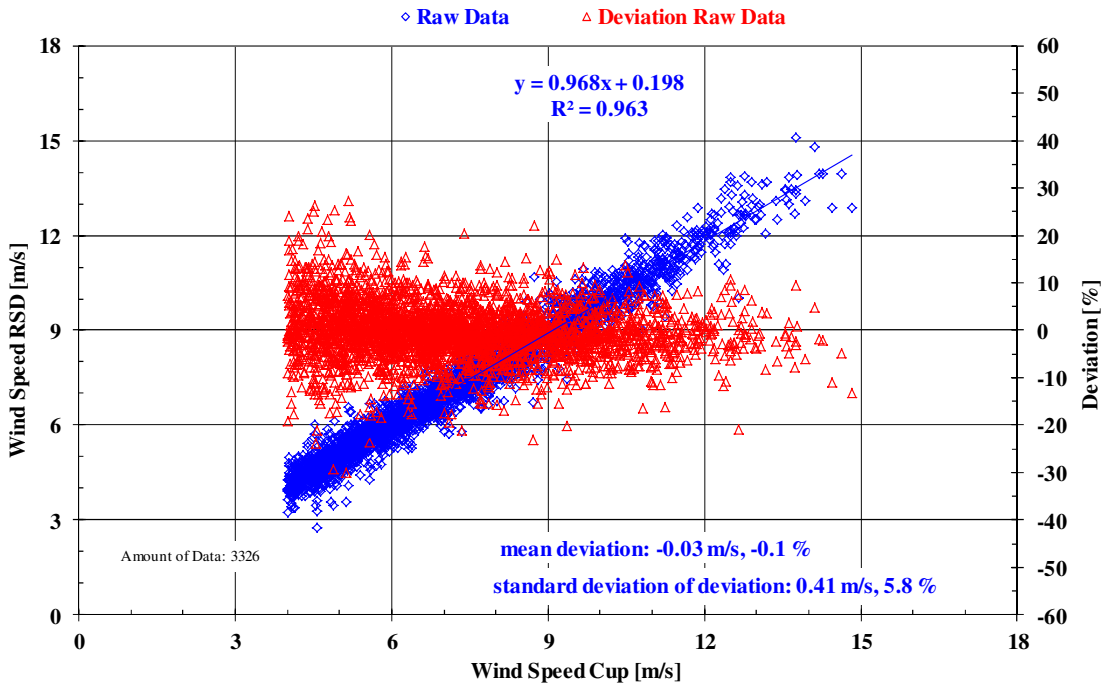

Figure 4.39 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 140 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

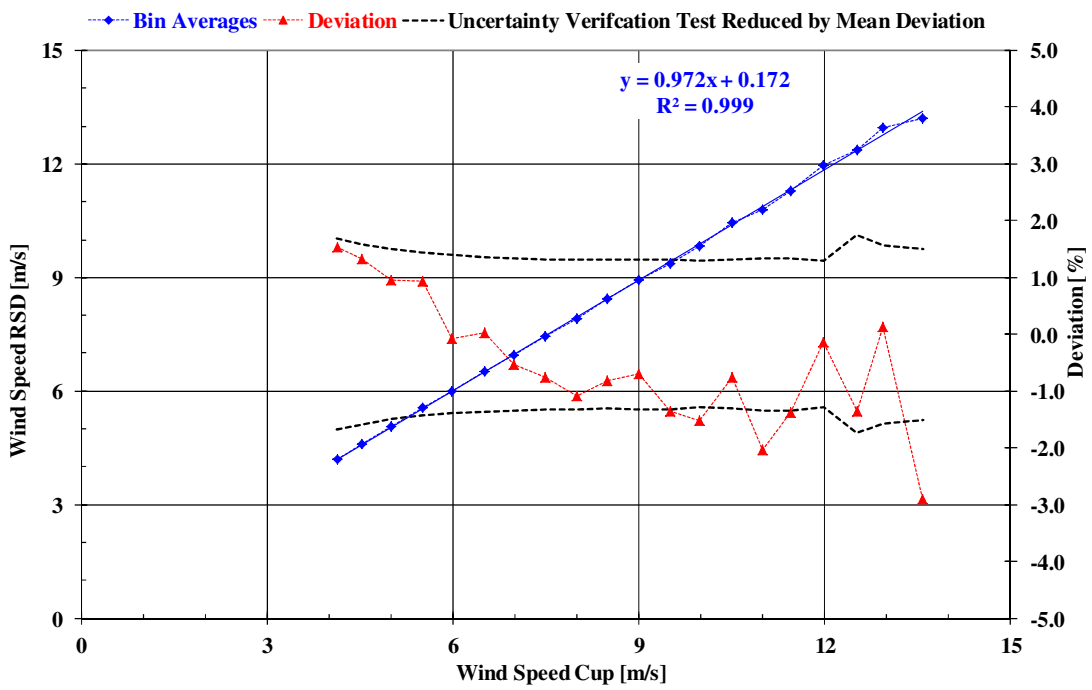

Figure 4.40: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 140 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.135	4.198	125	5.030	3.251	0.332	0.030	0.063	3.4	0.139	4.5	0.188
4.528	4.587	241	6.016	2.747	0.420	0.027	0.060	3.2	0.144	4.1	0.187
5.007	5.055	304	6.586	3.445	0.424	0.024	0.048	3.0	0.150	3.6	0.178
5.506	5.558	284	6.679	4.269	0.367	0.022	0.052	2.9	0.158	3.4	0.189
5.994	5.990	314	7.074	4.742	0.368	0.021	-0.004	2.8	0.167	2.8	0.167
6.504	6.506	295	7.816	5.230	0.375	0.022	0.002	2.7	0.177	2.7	0.177
6.991	6.953	314	8.064	5.721	0.367	0.021	-0.038	2.7	0.187	2.9	0.201
7.497	7.440	276	8.880	5.786	0.387	0.023	-0.057	2.6	0.198	3.1	0.229
7.999	7.913	223	9.364	6.654	0.443	0.030	-0.086	2.6	0.211	3.4	0.273
8.492	8.423	206	10.680	6.710	0.455	0.032	-0.070	2.6	0.222	3.1	0.262
9.003	8.941	158	10.543	7.443	0.487	0.039	-0.062	2.6	0.237	3.0	0.267
9.506	9.377	137	10.963	7.478	0.520	0.044	-0.129	2.6	0.250	3.8	0.359
9.979	9.828	120	10.923	8.898	0.432	0.039	-0.151	2.6	0.257	4.0	0.396
10.514	10.434	95	11.924	9.460	0.500	0.051	-0.079	2.6	0.275	3.0	0.317
11.006	10.782	77	12.009	9.034	0.584	0.067	-0.224	2.7	0.296	4.9	0.537
11.449	11.292	52	12.576	10.245	0.489	0.068	-0.157	2.7	0.306	3.8	0.439
11.983	11.966	38	12.856	11.226	0.373	0.060	-0.018	2.6	0.310	2.6	0.312
12.526	12.357	30	13.837	10.014	0.872	0.159	-0.169	3.5	0.436	4.4	0.552
12.947	12.963	17	13.861	12.073	0.509	0.123	0.016	3.1	0.405	3.1	0.406
13.585	13.190	10	13.844	12.516	0.401	0.127	-0.395	3.0	0.407	6.5	0.889
13.924	14.046	6	15.081	13.094	0.767	0.313	0.122	5.1	0.716	5.4	0.756
14.449	13.591	3	13.959	12.880	0.616	0.356	-0.858	5.7	0.829	13.2	1.905

Table 4.19 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 140 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

4.5.2 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 120 m Measurement Height (correction applied)

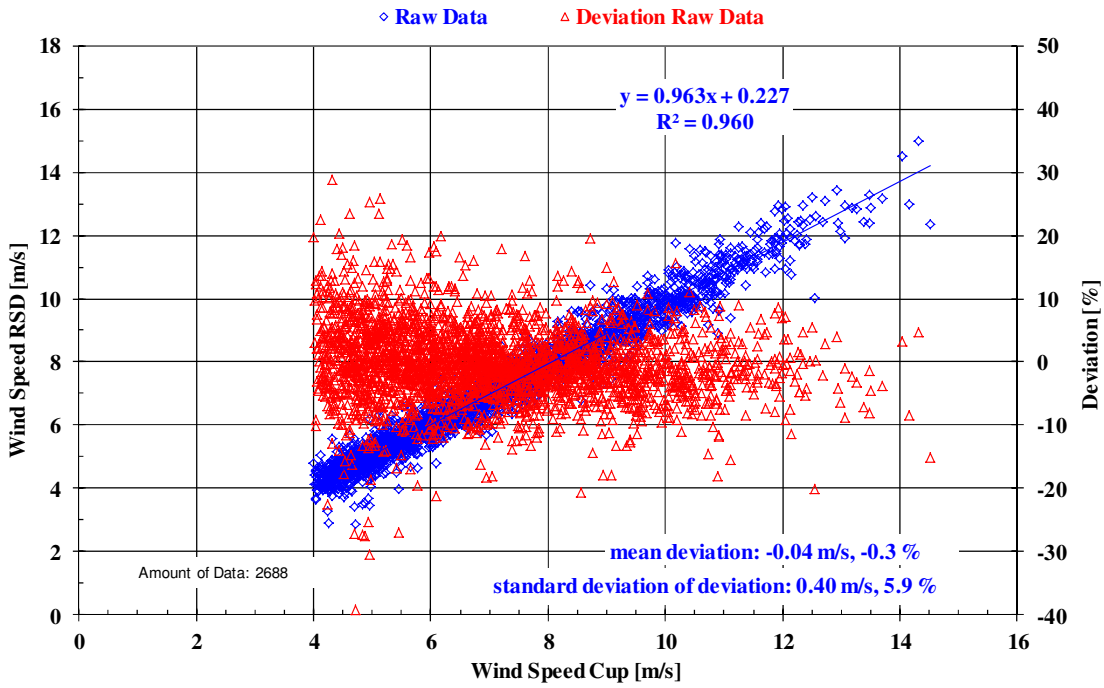

Figure 4.41 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 120 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

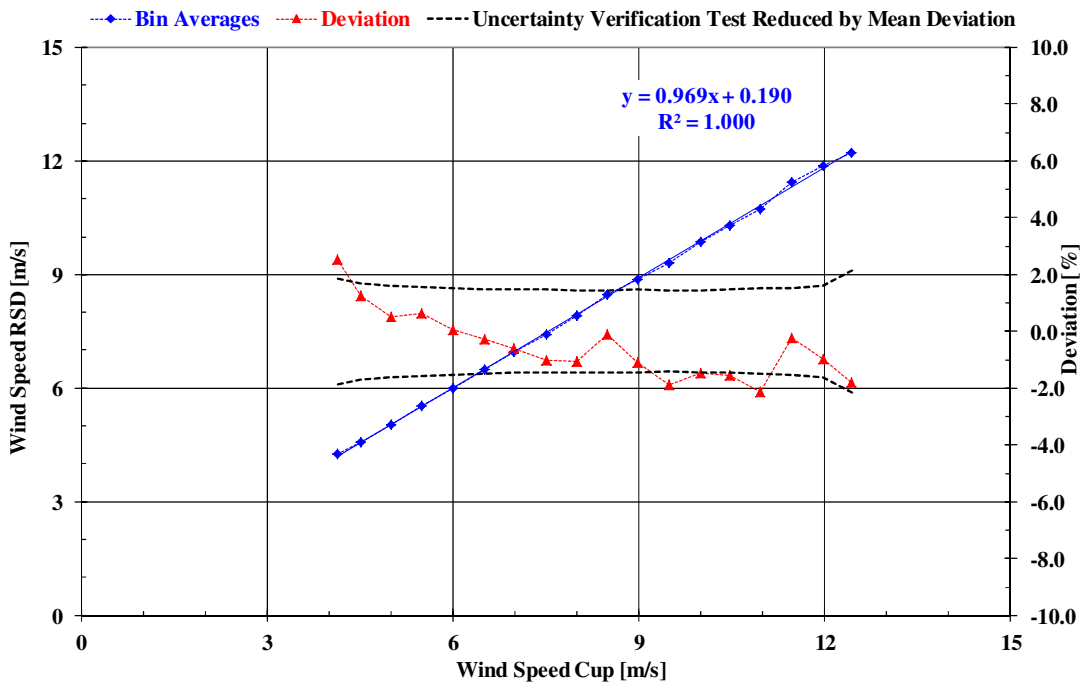

Figure 4.42: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 120 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.145	4.250	69	5.036	3.278	0.292	0.035	0.104	3.716	0.154	6.260	0.259
4.523	4.580	231	5.691	2.867	0.394	0.026	0.057	3.358	0.152	4.199	0.190
5.002	5.027	265	6.472	3.444	0.416	0.026	0.025	3.218	0.161	3.367	0.168
5.503	5.538	251	6.629	3.981	0.361	0.023	0.034	3.108	0.171	3.351	0.184
6.002	6.007	253	7.410	4.645	0.372	0.023	0.004	3.034	0.182	3.038	0.182
6.511	6.493	243	7.801	5.613	0.347	0.022	-0.017	2.966	0.193	3.014	0.196
6.991	6.949	265	8.495	5.691	0.363	0.022	-0.042	2.920	0.204	3.160	0.221
7.505	7.428	204	8.886	6.365	0.409	0.029	-0.076	2.915	0.219	3.555	0.267
7.994	7.910	173	9.267	6.873	0.389	0.030	-0.084	2.876	0.230	3.567	0.285
8.491	8.482	171	10.420	6.785	0.425	0.032	-0.009	2.868	0.244	2.877	0.244
8.983	8.884	127	10.332	7.332	0.524	0.046	-0.100	2.918	0.262	3.667	0.329
9.486	9.306	131	10.732	8.104	0.475	0.041	-0.180	2.851	0.270	4.752	0.451
10.010	9.863	81	11.768	8.993	0.493	0.055	-0.147	2.913	0.292	4.131	0.413
10.469	10.306	75	11.563	9.140	0.525	0.061	-0.163	2.923	0.306	4.274	0.447
10.965	10.731	59	11.875	8.925	0.593	0.077	-0.234	3.005	0.329	5.218	0.572
11.467	11.442	31	12.403	10.420	0.479	0.086	-0.025	3.039	0.349	3.070	0.352
11.979	11.861	29	12.960	10.752	0.585	0.109	-0.117	3.233	0.387	3.780	0.453
12.438	12.214	14	13.194	10.029	0.797	0.213	-0.224	4.312	0.536	5.619	0.699
13.027	12.619	6	13.438	11.924	0.563	0.230	-0.407	4.512	0.588	7.712	1.005
13.468	12.831	6	13.292	12.383	0.374	0.153	-0.637	3.335	0.449	10.032	1.351

Table 4.20 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 120 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

4.5.3 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 100 m Measurement Height (correction applied)

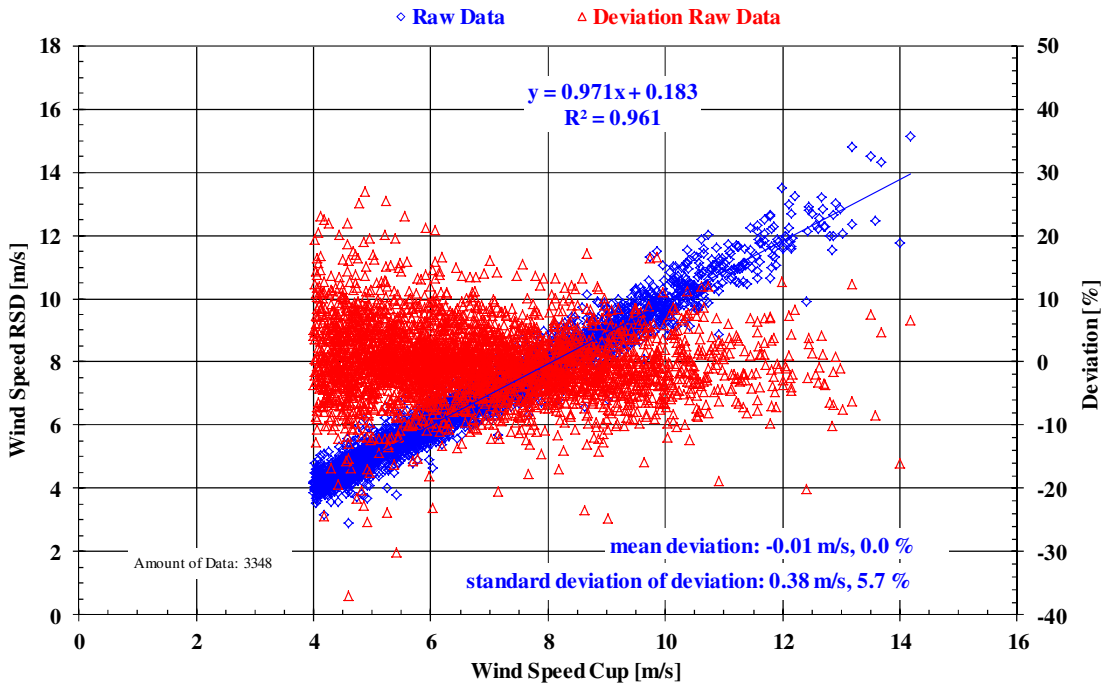

Figure 4.43 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 100 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

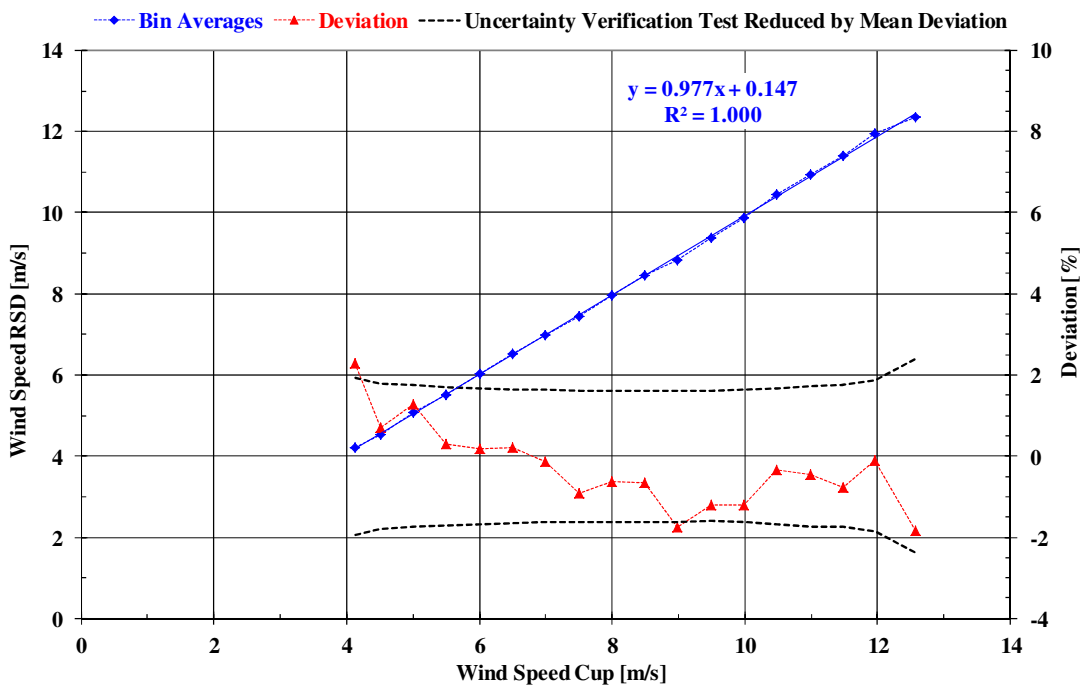

Figure 4.44: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 100 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.128	4.222	125	5.183	3.160	0.321	0.029	0.094	3.859	0.159	5.968	0.246
4.508	4.540	329	5.583	2.897	0.350	0.019	0.032	3.593	0.162	3.864	0.174
5.000	5.063	339	6.580	3.668	0.374	0.020	0.064	3.499	0.175	4.325	0.216
5.500	5.517	314	6.844	3.786	0.357	0.020	0.017	3.420	0.188	3.474	0.191
6.002	6.014	382	7.342	4.645	0.368	0.019	0.011	3.348	0.201	3.370	0.202
6.503	6.517	323	7.557	5.574	0.327	0.018	0.014	3.295	0.214	3.323	0.216
6.992	6.982	294	8.143	5.681	0.362	0.021	-0.010	3.273	0.229	3.284	0.230
7.506	7.438	257	8.739	6.316	0.364	0.023	-0.068	3.242	0.243	3.714	0.279
8.006	7.956	216	9.188	6.736	0.403	0.027	-0.050	3.233	0.259	3.462	0.277
8.494	8.439	190	10.146	6.590	0.441	0.032	-0.055	3.228	0.274	3.478	0.295
8.985	8.827	161	9.970	6.785	0.490	0.039	-0.158	3.233	0.290	4.770	0.429
9.498	9.384	136	11.318	8.094	0.483	0.041	-0.113	3.216	0.305	4.004	0.380
9.987	9.866	96	11.484	8.847	0.502	0.051	-0.121	3.253	0.325	4.052	0.405
10.483	10.448	71	12.022	9.130	0.571	0.068	-0.035	3.341	0.350	3.406	0.357
10.994	10.945	35	11.738	8.866	0.528	0.089	-0.049	3.461	0.380	3.574	0.393
11.478	11.391	28	12.501	10.478	0.569	0.108	-0.088	3.480	0.399	3.802	0.436
11.965	11.952	26	13.507	10.644	0.686	0.135	-0.013	3.726	0.446	3.733	0.447
12.568	12.338	12	13.194	9.911	0.834	0.241	-0.230	4.767	0.599	6.010	0.755
12.962	12.583	9	14.796	11.553	0.954	0.318	-0.379	5.444	0.706	7.988	1.035
13.593	13.761	3	14.503	12.452	1.137	0.657	0.168	10.177	1.383	10.472	1.423

Table 4.21 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 100 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

4.5.4 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 80 m Measurement Height (correction applied)

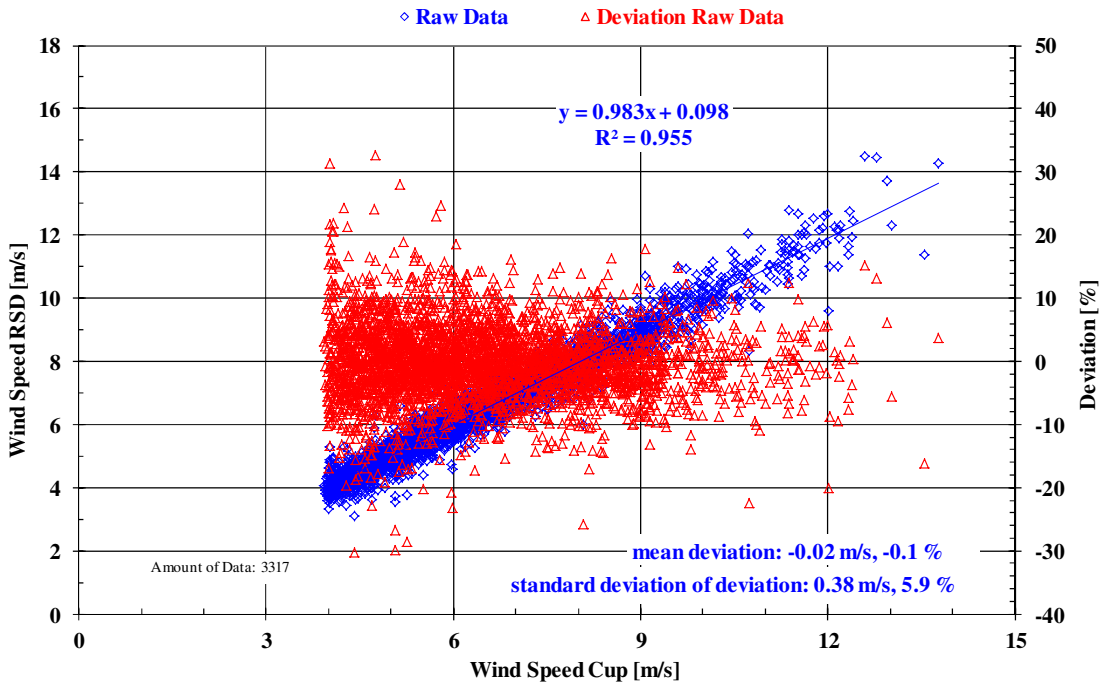

Figure 4.45 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 80 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

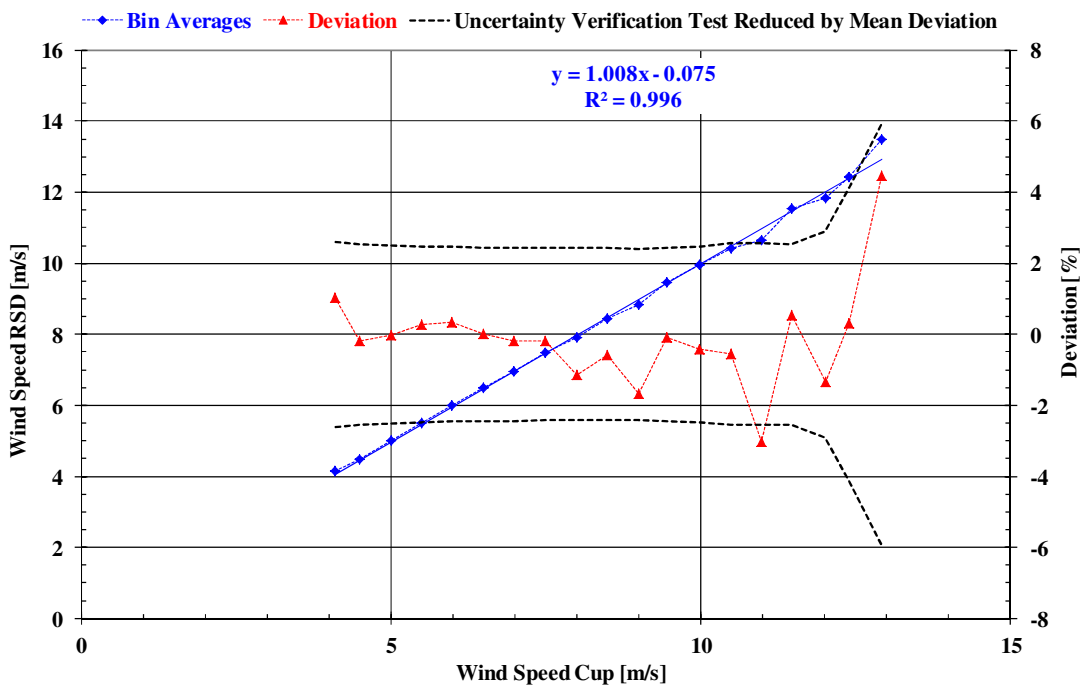

Figure 4.46: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 80 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.108	4.150	176	5.290	3.336	0.327	0.025	0.042	5.230	0.215	5.615	0.231
4.502	4.493	356	6.297	3.082	0.365	0.019	-0.009	5.090	0.229	5.106	0.230
4.999	4.998	383	6.590	3.551	0.341	0.017	-0.001	5.009	0.250	5.010	0.250
5.499	5.514	404	7.049	3.756	0.355	0.018	0.015	4.956	0.273	4.986	0.274
5.993	6.012	370	7.234	4.587	0.393	0.020	0.020	4.924	0.295	4.968	0.298
6.502	6.502	328	7.518	5.251	0.359	0.020	0.000	4.887	0.318	4.887	0.318
6.980	6.967	276	8.036	5.779	0.336	0.020	-0.013	4.863	0.339	4.877	0.340
7.500	7.485	241	8.856	6.257	0.400	0.026	-0.015	4.855	0.364	4.871	0.365
8.009	7.917	211	9.159	5.994	0.447	0.031	-0.092	4.850	0.388	5.366	0.430
8.487	8.438	170	9.931	7.176	0.436	0.033	-0.050	4.842	0.411	4.982	0.423
8.996	8.845	147	10.693	7.938	0.457	0.038	-0.151	4.834	0.435	5.879	0.529
9.463	9.453	84	11.015	8.426	0.528	0.058	-0.009	4.893	0.463	4.897	0.463
9.985	9.945	55	11.142	8.446	0.539	0.073	-0.040	4.934	0.493	4.999	0.499
10.485	10.428	39	12.061	8.319	0.661	0.106	-0.057	5.124	0.537	5.239	0.549
10.981	10.649	21	11.533	9.716	0.538	0.117	-0.332	5.109	0.561	7.914	0.869
11.470	11.533	29	12.794	10.429	0.569	0.106	0.063	5.062	0.581	5.179	0.594
12.011	11.850	16	12.676	9.609	0.777	0.194	-0.161	5.789	0.695	6.379	0.766
12.398	12.437	6	14.494	11.377	1.128	0.461	0.039	8.297	1.029	8.320	1.032
12.916	13.494	3	14.445	12.305	1.089	0.629	0.578	11.823	1.527	14.827	1.915

Table 4.22 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 80 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

4.5.5 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 60 m Measurement Height (correction applied)

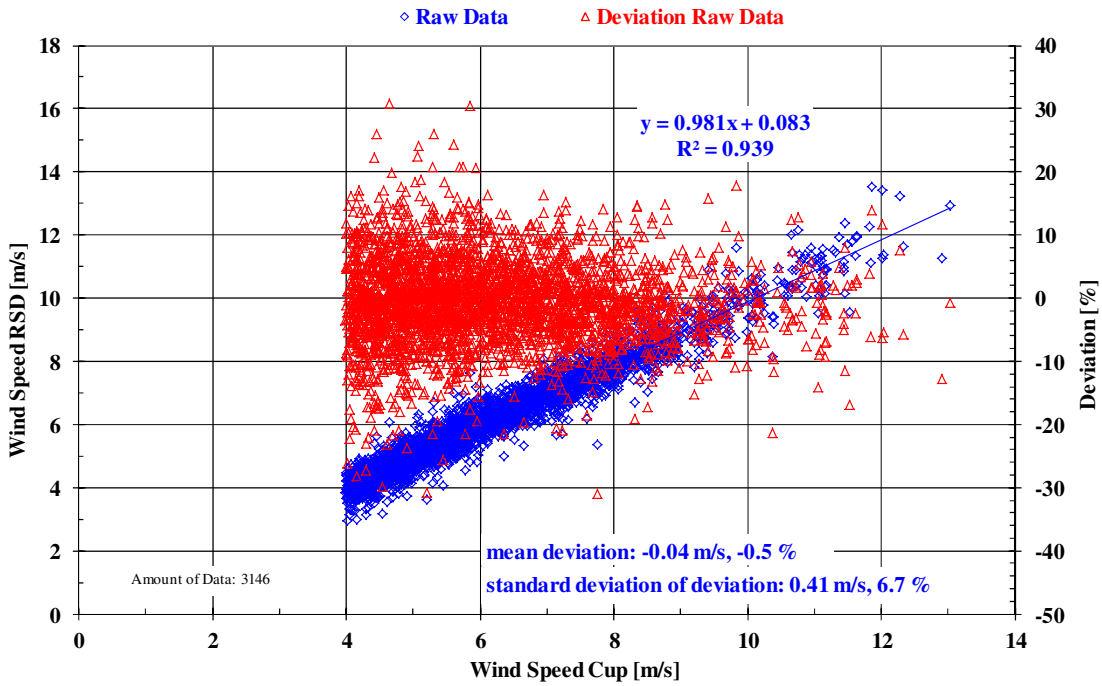

Figure 4.47 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 60 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

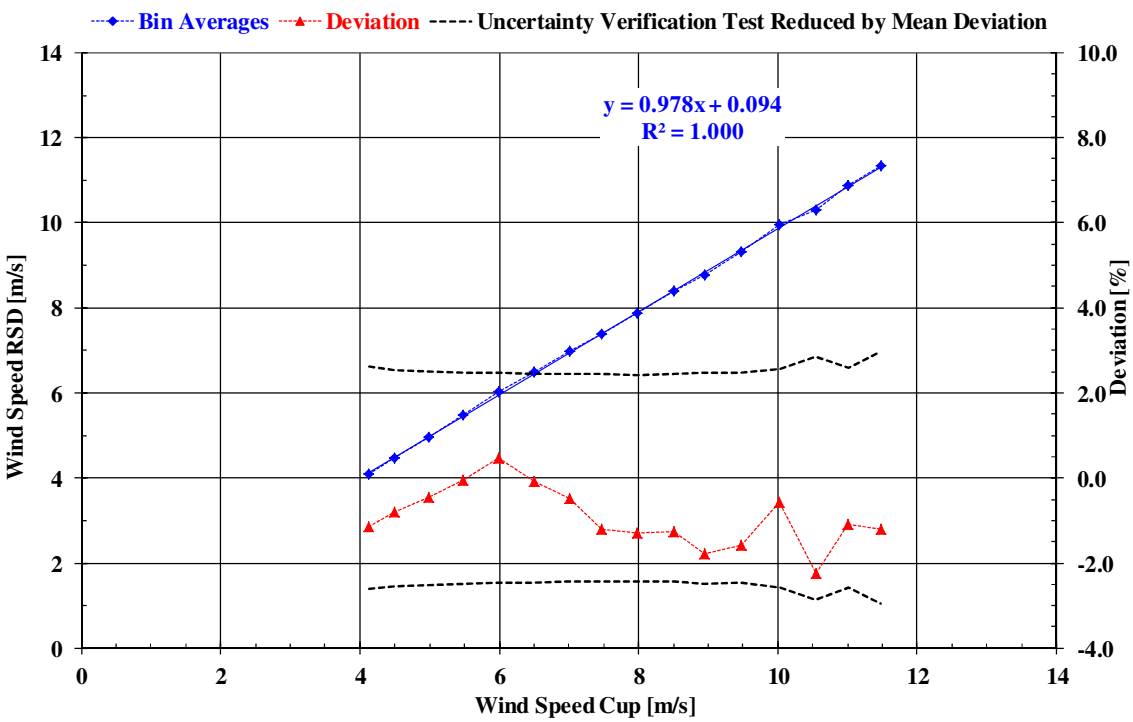

Figure 4.48: Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 60 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

v (Reference)	v (RSD)	number of data sets	v (RSD) max	v (RSD) min	v (RSD) std	v (RSD) std/sqrt(n)	v (RSD) - v (Reference)	uncertainty (*k* =2) (calibration)		uncertainty (*k* =2) v (RSD)	
[m/s]	[m/s]	[-]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]	[m/s]	[%]	[m/s]
4.130	4.083	189	4.899	2.965	0.348	0.025	-0.047	5.223	0.216	5.706	0.236
4.501	4.465	422	6.082	3.121	0.392	0.019	-0.036	5.085	0.229	5.326	0.240
4.979	4.957	431	6.316	3.600	0.378	0.018	-0.023	5.015	0.250	5.096	0.254
5.486	5.483	431	6.980	4.059	0.393	0.019	-0.003	4.964	0.272	4.965	0.272
5.989	6.018	353	7.616	4.538	0.416	0.022	0.029	4.933	0.295	5.027	0.301
6.501	6.497	276	7.508	4.987	0.387	0.023	-0.005	4.900	0.319	4.902	0.319
7.005	6.971	268	8.163	5.671	0.443	0.027	-0.034	4.886	0.342	4.980	0.349
7.474	7.383	224	8.583	5.349	0.458	0.031	-0.090	4.876	0.364	5.443	0.407
7.987	7.884	178	9.071	6.902	0.435	0.033	-0.103	4.855	0.388	5.495	0.439
8.509	8.400	134	9.687	6.717	0.502	0.043	-0.109	4.884	0.416	5.510	0.469
8.940	8.780	64	10.058	7.801	0.511	0.064	-0.160	4.966	0.444	6.128	0.548
9.469	9.321	67	10.898	8.084	0.559	0.068	-0.148	4.942	0.468	5.852	0.554
10.023	9.967	35	11.602	8.749	0.551	0.093	-0.056	5.132	0.514	5.254	0.527
10.549	10.311	20	11.992	8.163	0.830	0.186	-0.238	5.726	0.604	7.288	0.769
11.012	10.891	30	12.139	9.501	0.577	0.105	-0.121	5.175	0.570	5.624	0.619
11.474	11.335	14	12.374	9.570	0.758	0.203	-0.139	5.908	0.678	6.384	0.732
11.931	12.165	6	13.526	11.123	1.091	0.445	0.234	8.933	1.066	9.753	1.164

Table 4.23 Bin analysis of 10-minute averages of the horizontal wind speed component measured by RSD against cup anemometer measurements at 60 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD. The right column shows the total expanded uncertainty (k=2) of the RSD as derived from the test. A correction offset of y= 0.977x + 0.034 was applied to horizontal wind speed component of RSD.

4.6 Accuracy of the RSD in Terms of Sigma w

The standard deviation of the vertical wind speed component *sigma w* as measured by the RSD and by the ultra-sonic anemometers is compared for measurement heights of 130 m and 100 m in the following sub chapter. The following conclusions can be drawn:

- The RSD shows similar results for both evaluated measurement heights of 130 m and 100 m. For values of sigma w below 0.2 the deviation between RSD and reference shows significant high values.
- The squared correlation is between about 0.72 for measurement height of 130 m and 0.78 for measurement height of 100 m.

4.6.1 Accuracy of RSD in Terms of 10-Minute Averages of sigma w at 130 m Measurement Height

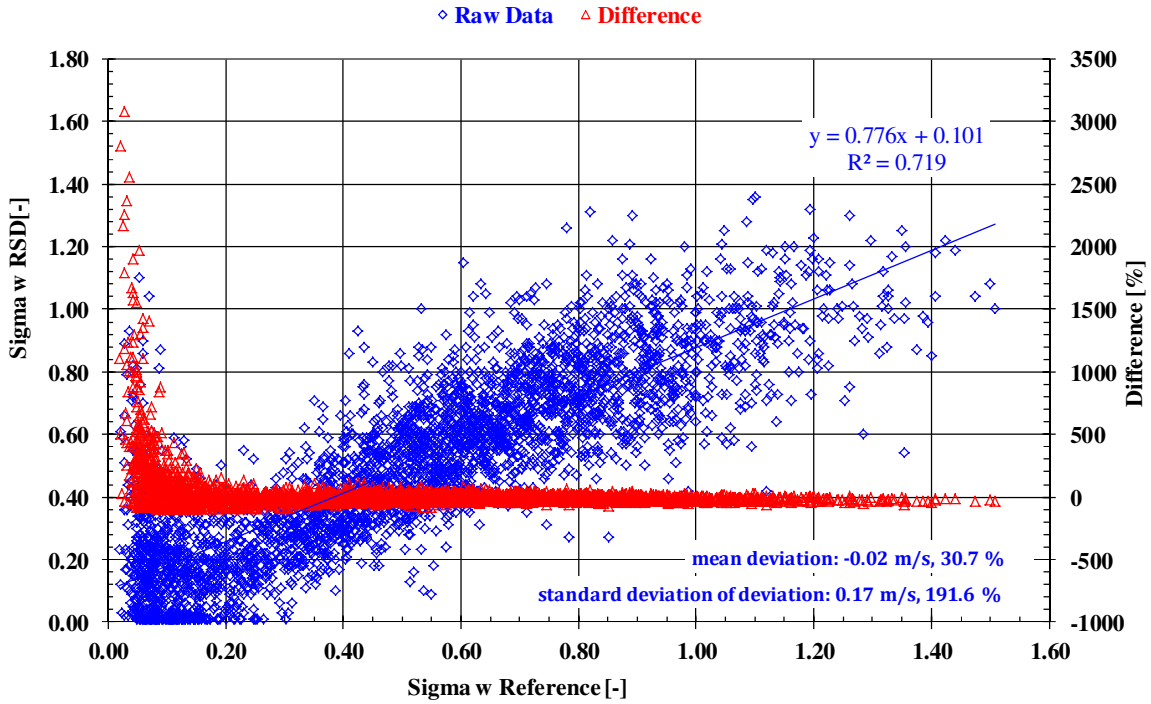

Figure 4.49 Scatter plot of standard deviation of vertical wind speed component (sigma w) as measured by RSD at 140 m against ultra-sonic anemometer readings at 130 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

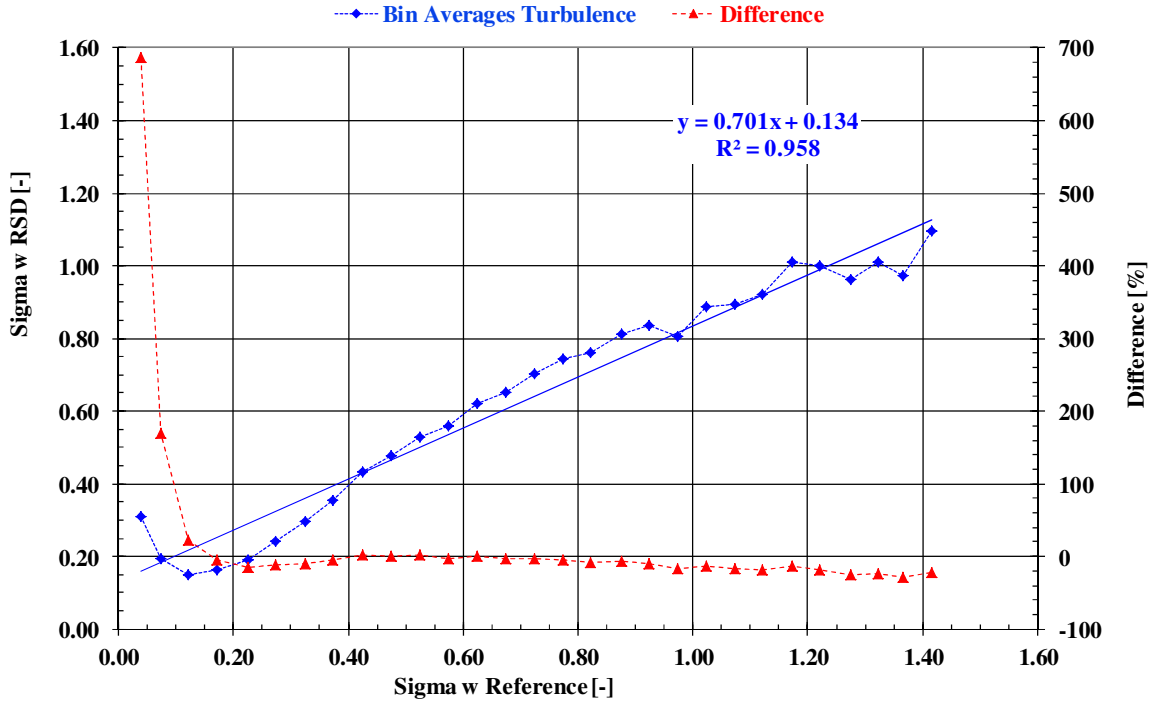

Figure 4.50: Bin analysis of 10-minute averages of standard deviation of vertical wind speed component (sigma w) measured by RSD in 140 m against ultra-sonic measurement at 130 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

4.6.2 Accuracy of RSD in Terms of 10-Minute Averages of sigma w at 100 m Measurement Height

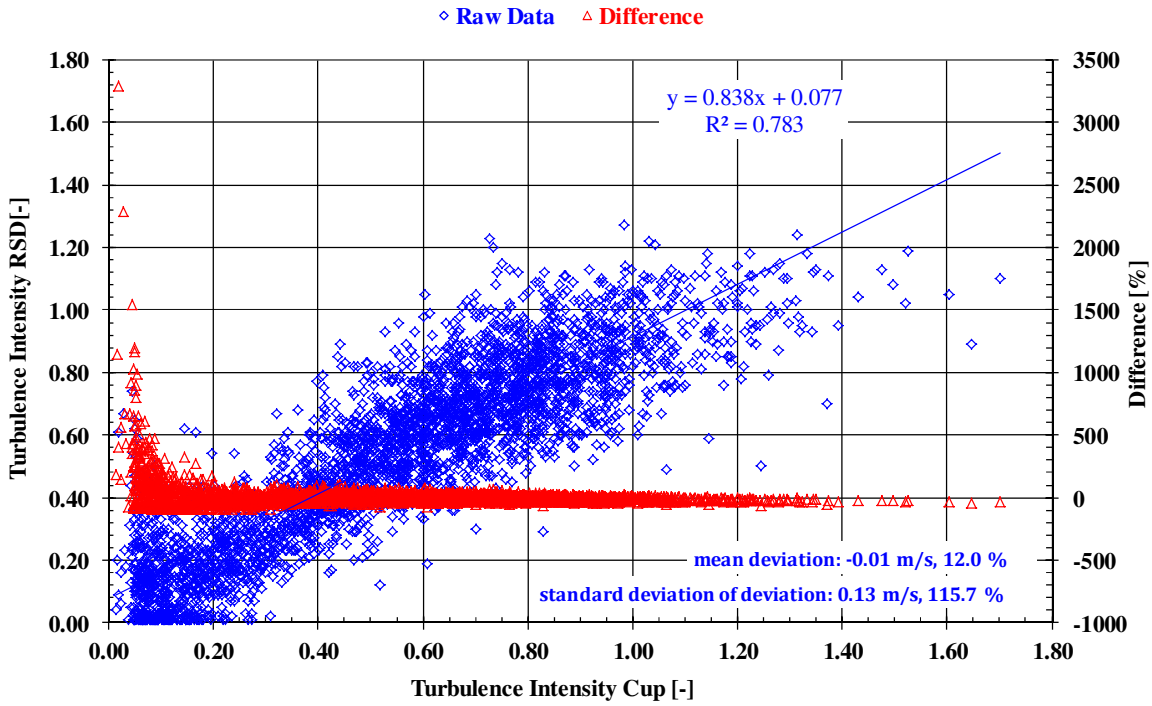

Figure 4.51 Scatter plot of standard deviation of vertical wind speed component (sigma w) as measured by RSD at 100 m against ultra-sonic anemometer readings at 100 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

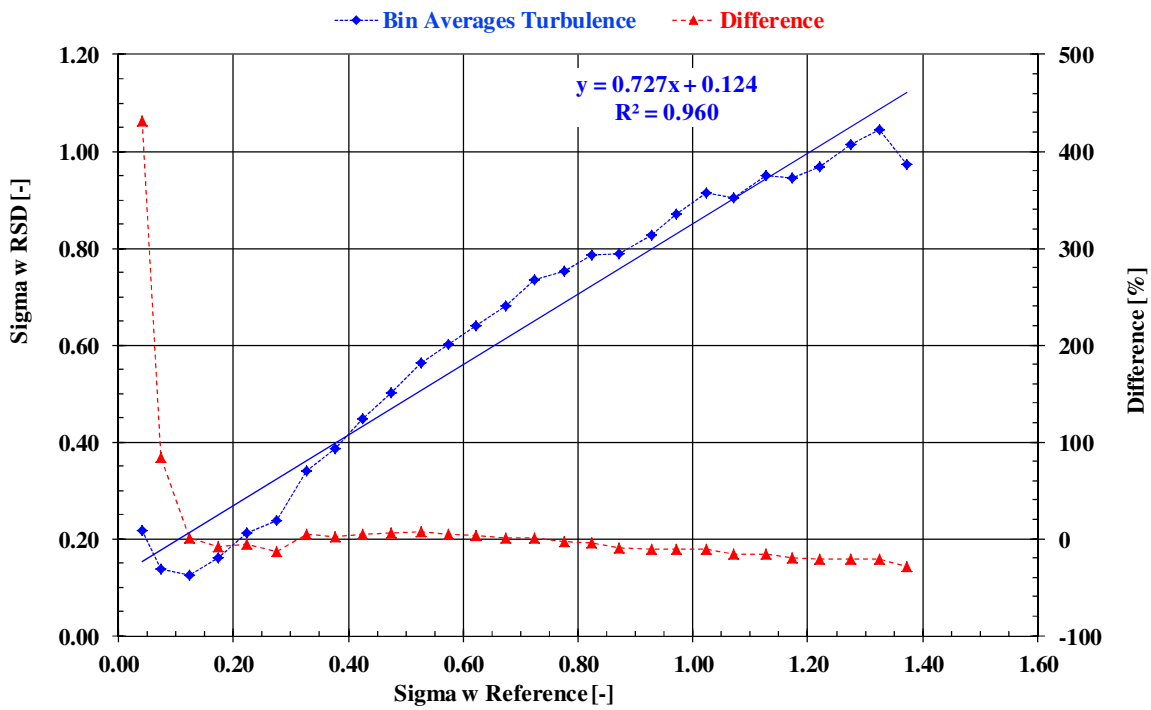

Figure 4.52: Bin analysis of 10-minute averages of standard deviation of vertical wind speed component (sigma w) measured by RSD in 100 m against ultra-sonic measurement at 100 m height above ground. A positive sign of the shown deviation represents higher values measured by RSD.

5 Conclusions

The accuracy of the sodar of type PA0, serial number 239, has been tested against cup anemometers mounted between 40 m and 135 m measurement height on a 135 m high met tower in flat terrain. The met mast is equipped with cup anemometers of high accuracy class and vanes at height levels of about 135 m, 131 m, 120 m, 100 m, 80 m 60 m 40 m and 20 m. All anemometers have been calibrated according to MEASNET by Deutsche WindGuard Wind Tunnel Services GmbH. The respective wind tunnel of Deutsche WindGuard is applied by the German Authority for the standardisation of units, Physikalisch-Technische Bundesanstalt (PTB), as German reference for the definition of the unit m/s in airflow measurements. A more accurate reference for cup anemometers is not available. The anemometers on the mast are mounted according to IEC 61400-12-1 [1] and the extended requirements of the draft revision of IEC 61400-12-1 [2]. Mast influences at the lower measurement heights like blockage and flow acceleration effects have been corrected empirically. Wind directions with the sensors of the mast or with the RSD in wakes of the mast or of neighbouring wind turbines have been excluded from the test. There has been no preliminary intercomparison period before the official start of the calibration period.

The data evaluation covers a calibration, which describes the accuracy of the tested sodar unit under the conditions during the test.

The main results of the calibration are:

- Depending on measurement height, the database consists of 2688 to 3348 10-minute datasets (1080 are required). However only wind speed bins up to 14.4 m/s are completed (up to 16 m/s is required). Therefore, the database available for the verification test at hand does not fulfil the completeness criteria of the draft IEC 61400-12-1, ed. 2. This deviation is not serious as completed test allows a good estimation of the instruments performance.
- The RSD shows a good correlation to cup anemometer measurements in terms of 10-minute averages of the horizontal wind speed component. At heights 140 m to 80 m measurement height the square of correlation coefficient is 0.95 to 0.96. At lower heights of 60 m and 40 m the correlation decreases to 0.94 and 0.89, respectively.
- The instrument overestimates slightly, with mean deviation of the measurements of the horizontal wind speed component measured by the tested RSD and by the reference cup anemometers is with 1.7 % or 0.1 m/s.
- The overestimation is more significant with wind speeds lower than 7 m/s and decreases within the uncertainty of the reference measurement uncertainty.
- The resulting wind speed dependent uncertainties of the measurements of the horizontal wind speed component by the RSD are in the order of about 3-6% (expanded uncertainty k=2) in most wind speed bins for all measurement heights. The variation of the uncertainty reaches from 2.7% to 18% for the different measurement heights and wind speed bins
- A correction with a height independent function y=0.977·x +0.034 m/s reduces the mean deviation to less than 0.5 m/s. Uncertainties (k=2) in the range below 8 m/s were reduced by about 2 % to 3 % for measurement heights 140 m to 100 m and by 0 % to 2 % for the measurement heights of 60 m and 80 m. Above 8 m/s no systematic improvement or regression of uncertainties occurs, with changes varying between -2 % and 2 % of uncertainty (k=2) between different wind speed bins.

- The wind direction as measured by the RSD correlates good to the wind direction as measured by vane on the met mast (squared correlation coefficient above 0.998).
- The RSD shows a data availability of about 80 % up to 100 m. Above 100 m the availability decreases to 62 % at 200 m. Especially during too heavy rain the instrument discards measurement values.
- Erroneous data occurred by heavy rain are recognized by the RSD itself reliable so a post filtering was not necessary.

It is pointed out that all shown uncertainties of the measurement of the RSD represent two standard uncertainties (expanded uncertainty k=2) as it is required according to DWG's accreditation for calibrations of RSD's. In contrast to that, it is common practice to apply only the single standard uncertainty of wind measurements for most applications throughout the wind energy industry as for instance in case of wind resource assessments or wind turbine power curve tests. The expanded uncertainty (k=2) with the confidence of 95% has the twice uncertainty. To get the single uncertainty (k=1) with confidence of 68%, the expanded uncertainty has to be divided by two.

6 Literature

[1] IEC 61400-12-1, Wind turbines, Part 12-1: Power performance measurements of electricity producing wind turbines, 2005

[2] IEC 61400-12-1, ed. 2, CDV, Wind turbines, Part 12-1: Power performance measurements of electricity producing wind turbines, 2nd Commentary Draft of the second edition, July 2015

[3] Thies First Class Advanced, Summary of Cup Anemometer Classification according to IEC 61400-12-1, Deutsche WindGuard Wind Tunnel Services GmbH, 2008-12-22

[4] MEASNET; Cup Anemometer Calibration Procedure, Version 2, October 2009

7 Acknowledgement

Thanks belong to Enercon, especially Mr. Jürgen Stoltenjohannes, to make available the test site and met mast for the measurements.

8 Appendix A, Ambient Conditions at Calibration Test

8.1 Ambient conditions dependent on wind speed

This chapter presents detailed ambient conditions during test dependent on wind speed.

Height 140.0 m	Depen-dency	shear exponent alpha 135m-100m		Turbulence Intensity I		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspee d [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.13	0.125	0.240	0.126	0.056	322.9	58.2	14.81	2.93	-1.22	0.81	1.203	0.015	8.700	13.465	0.419	3.012
10	4.53	0.131	0.217	0.123	0.057	319.4	51.0	14.75	2.86	-1.20	0.86	1.204	0.014	7.962	10.931	0.143	2.944
11	5.01	0.157	0.216	0.113	0.055	311.2	49.2	14.03	2.87	-1.07	0.97	1.208	0.015	8.284	12.922	0.163	2.891
12	5.51	0.207	0.242	0.108	0.051	304.5	44.2	14.07	2.80	-1.02	1.09	1.207	0.014	9.455	12.931	0.279	2.561
13	5.99	0.205	0.204	0.106	0.049	298.9	41.3	13.75	2.90	-0.98	0.91	1.208	0.015	7.395	9.587	0.241	2.140
14	6.50	0.242	0.215	0.100	0.052	298.7	42.9	13.88	3.43	-0.87	1.00	1.208	0.017	8.170	9.445	0.307	2.063
15	6.99	0.243	0.195	0.097	0.050	298.6	40.7	13.16	3.68	-0.80	0.98	1.212	0.017	8.367	8.712	0.341	1.645
16	7.50	0.257	0.196	0.096	0.053	301.0	42.9	13.07	3.93	-0.77	0.99	1.212	0.019	7.799	8.958	0.264	1.644
17	8.00	0.251	0.209	0.107	0.047	298.5	48.9	12.95	4.51	-0.99	0.88	1.212	0.021	5.214	6.425	0.247	1.638
18	8.49	0.246	0.202	0.101	0.052	303.8	53.6	12.85	4.81	-0.70	1.23	1.213	0.022	6.633	6.975	0.215	1.490
19	9.00	0.258	0.194	0.107	0.051	301.5	49.6	12.03	4.22	-0.74	1.15	1.215	0.019	5.708	5.870	0.299	1.408
20	9.51	0.290	0.188	0.099	0.045	302.2	55.5	11.82	4.50	-0.69	1.18	1.215	0.020	6.252	5.989	0.201	1.507
21	9.98	0.327	0.171	0.107	0.043	314.2	47.6	10.78	4.02	-0.75	1.03	1.220	0.017	5.921	5.051	-0.088	1.188
22	10.51	0.301	0.157	0.109	0.036	322.1	50.2	11.77	4.77	-0.82	0.98	1.213	0.021	5.484	4.434	-0.079	1.504
23	11.01	0.332	0.211	0.102	0.045	314.4	53.0	11.62	4.76	-0.63	1.22	1.215	0.020	6.376	6.196	-0.176	1.449
24	11.45	0.382	0.213	0.098	0.047	317.4	57.5	12.01	5.06	-0.46	1.22	1.213	0.021	7.233	5.772	0.002	1.466
25	11.98	0.357	0.211	0.093	0.055	310.6	65.0	13.18	4.35	-0.42	1.20	1.207	0.019	7.404	6.770	0.289	1.560
26	12.53	0.295	0.189	0.116	0.048	327.1	60.2	14.26	5.34	-0.88	0.97	1.201	0.023	5.419	4.908	-0.215	1.480
27	12.95	0.461	0.274	0.086	0.049	184.7	89.2	14.74	5.21	-0.24	1.24	1.200	0.022	7.529	5.026	1.187	1.647
28	13.59	0.242	0.079	0.124	0.032	307.6	11.6	9.06	3.05	-1.45	0.35	1.223	0.014	3.520	1.608	-1.297	0.406
29	13.92	0.274	0.118	0.137	0.038	305.0	6.8	10.61	2.84	-1.22	0.48	1.217	0.013	5.117	1.745	-	-
30	14.45	0.289	0.073	0.133	0.015	299.7	12.4	10.20	4.66	-1.05	0.14	1.218	0.023	4.100	2.381	-	-
	Total	**0.232**	**0.216**	**0.106**	**0.051**	**305.2**	**48.3**	**13.28**	**3.873**	**-0.89**	**1.03**	**1.210**	**0.018**	**7.445**	**9.447**	**0.220**	**2.098**

Table 8.1 Average and standard deviation of measured ambient conditions in 140 m during test

Height 120.0 m	Depen-dency [-]	shear exponent alpha 135m-100m		Turbulence Intensity I		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspeed [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	4.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	5.00	0.018	0.102	0.135	0.053	344.0	52.3	15.66	2.65	-1.46	0.88	1.199	0.013	7.970	11.708	-0.033	3.281
12	5.50	0.123	0.195	0.117	0.058	324.8	55.3	14.92	2.79	-1.14	1.01	1.204	0.014	8.453	11.917	-0.082	2.855
13	6.00	0.183	0.243	0.109	0.053	307.9	53.6	14.61	2.82	-0.92	1.13	1.204	0.014	9.866	13.535	0.141	2.554
14	6.51	0.201	0.227	0.109	0.049	296.5	46.4	14.23	2.77	-0.98	1.00	1.206	0.014	8.599	10.916	0.386	2.549
15	6.99	0.212	0.229	0.106	0.049	291.3	48.9	14.61	2.92	-0.94	0.97	1.204	0.015	8.022	10.495	0.256	2.216
16	7.50	0.236	0.208	0.098	0.052	293.8	43.0	14.10	3.40	-0.80	1.08	1.208	0.017	8.461	9.950	0.375	1.981
17	7.99	0.238	0.219	0.099	0.053	289.8	46.3	13.78	3.65	-0.77	0.94	1.209	0.017	7.390	8.709	0.529	1.643
18	8.49	0.240	0.214	0.101	0.054	297.6	51.0	13.97	3.96	-0.79	1.16	1.207	0.019	6.826	8.062	0.421	1.741
19	8.98	0.240	0.195	0.109	0.049	296.1	55.7	14.11	4.59	-0.87	1.11	1.207	0.022	5.985	7.385	0.400	1.712
20	9.49	0.214	0.200	0.108	0.054	302.2	57.7	14.09	4.07	-0.70	1.38	1.207	0.020	6.208	6.557	0.271	1.548
21	10.01	0.268	0.227	0.102	0.048	296.8	56.3	13.17	4.11	-0.61	1.29	1.210	0.018	5.796	6.270	0.283	1.372
22	10.47	0.270	0.176	0.109	0.039	307.1	54.4	12.82	4.23	-0.83	1.14	1.212	0.019	5.647	5.757	-0.070	1.499
23	10.96	0.339	0.219	0.105	0.038	323.8	59.3	12.95	3.99	-0.64	1.22	1.209	0.017	6.790	7.124	-0.069	1.493
24	11.47	0.334	0.202	0.105	0.046	312.4	63.0	13.52	4.71	-0.42	1.31	1.207	0.019	6.661	5.488	0.386	1.525
25	11.98	0.353	0.209	0.101	0.042	332.4	58.8	13.36	4.64	-0.57	1.12	1.207	0.020	7.143	4.913	-0.329	1.516
26	12.44	0.388	0.218	0.092	0.049	339.8	73.7	15.12	4.51	-0.25	1.22	1.199	0.019	8.555	5.331	0.415	1.368
27	13.03	0.304	0.198	0.114	0.038	301.1	67.1	16.17	3.48	-0.81	0.79	1.193	0.015	4.390	4.651	0.061	1.772
28	13.47	0.214	0.118	0.131	0.050	295.4	61.4	14.25	5.42	-1.01	0.98	1.200	0.023	4.179	5.283	0.370	2.047
	Total	**0.223**	**0.220**	**0.107**	**0.051**	**302.2**	**53.3**	**14.13**	**3.65**	**-0.85**	**1.11**	**1.206**	**0.017**	**7.544**	**9.552**	**0.246**	**2.100**

Table 8.2 Average and standard deviation of measured ambient conditions in 120 m during test

Height 100.0 m	Depen-dency [-]	shear exponent alpha 120m-80m		Turbulence Intensity I		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspeed [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	4.51	0.141	0.206	0.127	0.060	324.7	57.7	15.53	2.98	-1.06	1.17	1.201	0.015	11.452	14.923	0.545	3.242
11	5.00	0.165	0.207	0.127	0.062	317.6	51.9	14.40	2.68	-1.06	1.06	1.206	0.014	9.820	12.980	-0.481	2.597
12	5.50	0.167	0.205	0.119	0.057	311.7	47.9	14.09	3.02	-1.05	0.86	1.206	0.016	7.894	10.558	-0.594	2.526
13	6.00	0.194	0.200	0.113	0.049	306.7	42.2	13.59	2.82	-0.99	0.96	1.210	0.014	7.742	9.237	-0.630	2.239
14	6.50	0.250	0.226	0.115	0.054	303.1	45.0	13.21	3.37	-0.85	1.00	1.212	0.017	7.751	9.187	-0.547	1.869
15	6.99	0.259	0.202	0.105	0.055	300.2	45.5	13.29	3.84	-0.72	1.09	1.211	0.018	8.316	8.614	-0.539	1.578
16	7.51	0.249	0.186	0.116	0.055	299.9	44.3	13.20	4.10	-0.83	1.02	1.211	0.019	7.339	7.874	-0.530	1.668
17	8.01	0.260	0.214	0.120	0.049	306.3	56.5	13.48	4.85	-0.79	1.27	1.209	0.023	6.944	8.051	-0.288	1.716
18	8.49	0.264	0.200	0.123	0.057	310.0	53.2	13.04	4.94	-0.72	1.26	1.212	0.023	5.929	6.763	-0.427	1.599
19	8.98	0.253	0.208	0.126	0.049	308.1	53.1	12.84	4.68	-0.81	1.23	1.212	0.021	5.554	5.400	-0.454	1.504
20	9.50	0.289	0.185	0.120	0.047	307.7	58.9	12.36	4.70	-0.69	1.27	1.213	0.021	5.778	6.862	-0.492	1.608
21	9.99	0.279	0.177	0.129	0.037	322.1	48.8	12.34	4.82	-0.98	0.80	1.212	0.020	5.172	3.501	-0.557	1.352
22	10.48	0.347	0.197	0.119	0.045	318.5	61.7	13.39	4.77	-0.51	1.22	1.207	0.021	7.224	5.643	-0.110	1.677
23	10.99	0.295	0.174	0.132	0.050	323.0	54.3	12.27	5.28	-0.86	0.97	1.211	0.023	5.338	3.912	-0.226	1.445
24	11.48	0.245	0.154	0.131	0.042	313.2	53.4	12.60	5.22	-1.20	0.70	1.210	0.024	4.651	3.330	-0.637	1.628
25	11.97	0.227	0.125	0.138	0.041	306.0	51.6	13.84	5.12	-1.17	0.62	1.202	0.023	3.604	4.367	-0.459	1.078
26	12.57	0.202	0.103	0.148	0.041	307.8	46.4	13.10	5.45	-1.28	0.74	1.206	0.024	3.515	4.127	-0.868	1.340
27	12.96	0.210	0.079	0.157	0.037	312.9	23.6	9.53	4.56	-1.59	0.39	1.221	0.020	3.258	1.818	-1.589	0.742
28	13.59	0.235	0.054	0.151	0.029	312.2	26.2	10.21	5.22	-1.38	0.38	1.219	0.023	3.644	1.819	-1.071	0.742
	Total	**0.232**	**0.206**	**0.120**	**0.054**	**308.6**	**50.0**	**13.42**	**4.02**	**-0.89**	**1.07**	**1.209**	**0.019**	**7.421**	**9.090**	**-0.459**	**2.008**

Table 8.3 Average and standard deviation of measured ambient conditions in 100 m during test

Height 80.0 m	Depen-dency [-]	shear exponent alpha 100m-60m		Turbulence Intensity I		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspeed [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	4.50	0.222	0.218	0.133	0.060	322.2	56.0	14.65	2.90	-1.05	0.95	1.204	0.015	9.656	12.889	0.031	2.839
11	5.00	0.190	0.184	0.126	0.061	317.7	51.0	14.49	2.85	-1.03	1.00	1.205	0.014	10.264	11.979	-0.493	2.591
12	5.50	0.233	0.226	0.122	0.057	309.1	47.8	13.57	3.02	-0.95	0.90	1.209	0.016	7.529	10.251	-0.544	2.467
13	5.99	0.257	0.210	0.118	0.053	309.1	43.5	12.94	3.14	-0.85	0.99	1.213	0.016	7.843	8.325	-0.503	1.916
14	6.50	0.264	0.210	0.117	0.056	301.4	47.9	13.64	3.49	-0.77	1.13	1.209	0.017	7.611	8.547	-0.419	1.911
15	6.98	0.275	0.199	0.121	0.056	300.6	51.7	13.13	4.26	-0.68	1.27	1.212	0.020	8.380	9.110	-0.403	1.702
16	7.50	0.272	0.205	0.128	0.052	307.5	50.5	13.51	4.54	-0.79	1.17	1.210	0.021	6.721	7.241	-0.367	1.843
17	8.01	0.243	0.187	0.140	0.046	311.0	49.6	13.25	5.10	-1.04	0.98	1.211	0.024	4.371	4.948	-0.361	1.730
18	8.49	0.257	0.169	0.139	0.052	308.6	55.1	13.33	5.10	-0.92	1.06	1.209	0.022	4.757	4.762	-0.497	1.584
19	9.00	0.264	0.177	0.133	0.044	325.2	54.1	12.96	4.76	-0.88	1.10	1.209	0.022	5.596	5.473	-0.306	1.471
20	9.46	0.261	0.169	0.136	0.038	308.7	53.5	13.10	4.91	-0.96	0.97	1.209	0.021	4.805	4.201	-0.602	1.535
21	9.99	0.253	0.142	0.141	0.035	324.0	49.6	13.55	4.80	-1.07	0.63	1.207	0.021	5.096	3.368	-0.512	1.416
22	10.49	0.211	0.117	0.156	0.038	316.6	49.1	11.93	5.48	-1.30	0.63	1.212	0.025	4.282	3.342	-0.512	1.569
23	10.98	0.200	0.106	0.145	0.040	310.5	49.0	12.80	5.16	-1.23	0.90	1.209	0.023	4.238	4.917	-0.652	1.610
24	11.47	0.187	0.090	0.162	0.041	299.6	34.5	11.67	4.70	-1.39	0.40	1.212	0.021	3.062	3.180	-0.772	1.203
25	12.01	0.158	0.045	0.156	0.040	307.0	46.6	13.78	5.40	-1.48	0.28	1.203	0.024	2.300	3.272	-0.912	1.106
26	12.40	0.198	0.049	0.167	0.033	310.0	21.2	9.59	4.13	-1.51	0.37	1.221	0.018	3.906	1.930	-1.529	0.677
27	12.92	0.182	0.084	0.146	0.041	331.8	41.0	12.45	7.41	-1.46	0.43	1.210	0.032	3.217	2.097	-0.694	0.467
	Total	**0.245**	**0.197**	**0.128**	**0.054**	**310.1**	**50.0**	**13.44**	**4.06**	**-0.92**	**1.04**	**1.209**	**0.019**	**7.115**	**8.685**	**-0.439**	**2.015**

Table 8.4 Average and standard deviation of measured ambient conditions in 80 m during test

Height 60.0 m	Depen-dency [-]	shear exponent alpha 80m-40m		Turbulence Intensity I		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspeed [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	4.50	0.269	0.209	0.134	0.062	321.6	57.6	14.45	3.12	-0.92	1.04	1.206	0.016	10.303	11.246	-0.140	1.958
11	4.98	0.279	0.216	0.134	0.060	313.7	49.4	13.64	3.05	-0.91	0.95	1.209	0.015	8.966	9.862	-0.347	1.759
12	5.49	0.286	0.210	0.127	0.059	310.5	49.3	13.41	3.23	-0.75	1.08	1.210	0.017	8.356	9.669	-0.289	1.751
13	5.99	0.284	0.206	0.128	0.057	304.5	51.2	13.47	3.61	-0.67	1.26	1.210	0.018	8.633	9.288	-0.113	1.583
14	6.50	0.264	0.185	0.141	0.053	305.0	49.8	13.18	4.14	-0.82	1.16	1.211	0.019	6.493	7.631	-0.169	1.356
15	7.00	0.238	0.176	0.150	0.047	307.3	47.8	13.38	4.57	-0.98	1.08	1.210	0.021	5.313	6.009	-0.261	1.390
16	7.47	0.246	0.176	0.150	0.049	302.1	55.5	13.85	4.80	-0.93	1.12	1.208	0.022	5.071	5.858	-0.051	1.390
17	7.99	0.244	0.148	0.156	0.047	321.6	51.3	13.47	5.19	-1.07	0.88	1.207	0.023	4.466	4.741	-0.160	1.289
18	8.51	0.213	0.121	0.157	0.035	315.5	47.0	12.93	4.78	-1.22	0.60	1.209	0.021	4.047	3.938	-0.415	1.353
19	8.94	0.212	0.111	0.155	0.033	319.9	50.6	13.45	5.10	-1.21	0.59	1.207	0.022	4.345	3.655	-0.508	1.060
20	9.47	0.177	0.098	0.159	0.035	304.8	53.5	14.37	4.76	-1.36	0.61	1.204	0.021	3.511	4.132	-0.411	1.167
21	10.02	0.171	0.093	0.162	0.030	319.9	46.4	12.95	5.25	-1.42	0.53	1.209	0.024	4.006	3.102	-0.626	1.199
22	10.55	0.155	0.072	0.166	0.037	296.0	35.4	11.92	4.20	-1.45	0.35	1.213	0.020	3.126	2.822	-0.541	1.243
23	11.01	0.150	0.057	0.178	0.032	301.3	36.4	11.32	5.32	-1.53	0.25	1.213	0.024	2.795	2.614	-0.323	0.933
24	11.47	0.158	0.046	0.172	0.036	304.3	42.7	13.15	5.33	-1.44	0.34	1.205	0.024	2.223	3.407	-0.535	0.876
25	11.93	0.157	0.038	0.172	0.034	310.9	22.3	9.67	4.39	-1.58	0.34	1.222	0.018	3.671	1.622	-1.374	0.644
	Total	**0.254**	**0.185**	**0.142**	**0.053**	**310.4**	**50.5**	**13.45**	**4.14**	**-0.94**	**1.03**	**1.209**	**0.019**	**6.766**	**8.135**	**-0.252**	**1.530**

Table 8.5 Average and standard deviation of measured ambient conditions in 60 m during test

Height 40.0 m	Depen-dency [-]	shear exponent alpha 60m-40m		Turbulence Intensity I		Availabilty RSD		Wind direction		Air temperature T at 131 m		T difference 131m-18m		air density		wind veer dir129m-dir39m		Flow Inclination angle	
Bin-No.	Windspeed [m/s]	avg [-]	std [-]	avg [-]	std [-]	avg [%]	std [%]	avg [deg]	std [deg]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m3]	std [kg/m3]	avg [deg]	std [deg]	avg [deg]	std [deg]
9	4.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	4.49	0.328	0.215	0.145	0.061	287.7	196.0	314.4	54.1	13.78	3.57	-0.67	1.16	1.209	0.017	10.209	10.421	-0.121	1.900
11	4.99	0.289	0.216	0.152	0.062	340.5	237.5	316.9	54.9	13.75	3.74	-0.72	1.21	1.208	0.019	9.087	9.244	-0.163	1.793
12	5.50	0.242	0.181	0.160	0.052	291.9	218.8	315.9	49.6	13.56	3.70	-0.90	1.17	1.209	0.018	6.750	7.941	-0.246	1.759
13	5.99	0.215	0.165	0.167	0.043	303.7	227.2	302.5	50.7	13.65	4.04	-1.06	1.02	1.209	0.019	4.759	5.724	-0.141	1.613
14	6.50	0.209	0.131	0.172	0.038	294.4	215.7	311.4	45.8	13.39	4.28	-1.19	0.67	1.209	0.020	4.526	4.899	-0.268	1.519
15	6.97	0.214	0.121	0.177	0.039	272.2	178.5	312.9	45.3	13.32	4.76	-1.23	0.57	1.209	0.021	3.727	3.982	-0.241	1.307
16	7.48	0.196	0.113	0.178	0.038	284.2	195.9	307.8	46.7	13.89	5.18	-1.31	0.53	1.206	0.023	3.413	3.736	-0.152	1.495
17	7.96	0.190	0.104	0.171	0.032	300.1	187.5	315.5	51.0	13.81	5.10	-1.27	0.69	1.206	0.023	3.824	4.312	-0.391	1.312
18	8.45	0.162	0.089	0.172	0.031	296.0	185.4	311.4	49.0	13.81	5.14	-1.44	0.31	1.206	0.023	3.262	3.224	-0.446	1.131
19	8.97	0.154	0.076	0.175	0.031	294.0	173.4	300.7	50.9	14.38	4.80	-1.46	0.27	1.205	0.022	2.726	3.029	-0.578	1.201
20	9.49	0.134	0.059	0.169	0.028	372.2	212.5	305.0	47.1	13.34	4.71	-1.54	0.25	1.208	0.021	3.679	3.168	-0.587	1.112
21	10.03	0.130	0.056	0.181	0.029	341.8	161.5	299.4	34.7	11.55	4.77	-1.53	0.29	1.214	0.022	3.062	2.315	-0.449	1.371
22	10.48	0.163	0.053	0.177	0.030	312.8	208.1	305.5	44.1	13.03	5.69	-1.45	0.31	1.206	0.026	3.000	2.939	-0.295	0.822
23	10.90	0.135	0.059	0.179	0.033	324.4	218.2	297.5	32.7	11.64	4.71	-1.53	0.33	1.212	0.022	1.913	3.082	-0.542	0.912
24	11.53	0.155	0.039	0.180	0.029	381.4	256.9	308.5	21.5	9.86	4.28	-1.55	0.34	1.221	0.018	4.033	1.509	-1.165	1.050
	Total	**0.230**	**0.168**	**0.165**	**0.048**	**303.0**	**212.1**	**311.2**	**49.6**	**13.57**	**4.32**	**-1.06**	**0.95**	**1.208**	**0.020**	**5.751**	**7.114**	**-0.242**	**1.585**

Table 8.6 Average and standard deviation of measured ambient conditions in 40 m during test

8.2 Ambient conditions dependent on wind direction

This chapter presents detailed ambient conditions during test dependent on wind direction.

Height 140.0 m	Dependency [-]	shear exponent α 135m-100m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	3	0.0969	0.2085	0.114	0.020	12.913	2.516	-1.869	0.476	1.206	0.010	3.781	4.914	-1.716	2.435
2	7	0.1369	0.1930	0.107	0.047	14.196	2.542	-1.291	1.265	1.201	0.010	8.388	6.285	-1.475	2.386
3	13	0.1018	0.1598	0.075	0.042	15.271	2.472	-1.263	1.020	1.201	0.014	7.885	6.121	-1.620	1.560
4	17	0.1299	0.1805	0.092	0.030	16.279	3.204	-1.444	0.972	1.194	0.014	5.395	5.824	-0.869	1.933
5	22	0.0891	0.1816	0.103	0.033	17.408	2.823	-1.552	0.424	1.187	0.011	4.357	5.018	-1.502	1.628
6	27	0.2936	0.2623	0.084	0.041	17.293	3.071	-0.627	1.356	1.188	0.013	8.748	6.076	-0.994	1.106
28	137	0.3332	0.2951	0.093	0.070	17.177	5.076	-0.112	1.446	1.193	0.025	8.784	8.036	1.882	1.570
29	142	0.3839	0.3069	0.065	0.057	17.106	4.636	0.417	1.575	1.191	0.021	12.731	9.084	2.166	0.972
30	148	0.4100	0.3241	0.061	0.055	17.312	3.976	0.785	1.716	1.193	0.020	14.013	10.112	2.023	1.361
31	152	0.3595	0.2861	0.086	0.058	16.146	4.224	0.307	1.708	1.198	0.025	16.266	14.642	2.385	1.223
32	157	0.3704	0.3210	0.098	0.074	14.114	3.633	0.190	1.285	1.206	0.025	11.828	13.369	3.159	2.920
33	162	0.3897	0.2577	0.087	0.082	15.281	4.871	0.371	1.048	1.195	0.026	10.612	20.094	3.621	1.884
49	244	0.2594	0.1825	0.099	0.051	15.143	2.180	-0.895	0.601	1.201	0.011	7.730	10.499	1.080	1.214
50	247	0.2014	0.1957	0.092	0.049	14.731	2.122	-0.849	0.779	1.201	0.012	7.665	9.984	1.169	1.186
51	252	0.2169	0.1997	0.088	0.049	14.923	1.915	-0.773	0.805	1.201	0.011	7.030	9.432	0.915	1.447
52	258	0.2436	0.2249	0.100	0.051	14.881	1.952	-0.713	0.790	1.202	0.010	8.100	10.486	0.597	1.511
53	262	0.2966	0.2343	0.078	0.048	14.049	1.616	-0.350	1.064	1.206	0.011	11.914	11.540	0.786	1.408
54	268	0.2384	0.2947	0.101	0.051	14.896	1.900	-0.673	0.956	1.202	0.009	9.469	13.580	0.897	1.509
55	273	0.2004	0.2099	0.107	0.056	15.366	1.901	-0.770	1.032	1.202	0.009	9.415	13.293	1.014	1.784
56	277	0.1685	0.1878	0.104	0.049	15.142	2.367	-0.781	0.991	1.203	0.011	9.773	15.979	0.754	1.385
57	283	0.2313	0.2452	0.106	0.052	15.132	2.620	-0.843	0.895	1.204	0.011	7.734	14.656	0.996	1.954
58	287	0.2898	0.2299	0.097	0.052	14.384	3.059	-0.683	0.972	1.207	0.014	9.694	13.784	1.183	1.890
59	293	0.2268	0.2036	0.111	0.051	13.939	3.778	-0.899	1.127	1.209	0.017	6.398	11.769	0.580	1.698
60	297	0.2233	0.1936	0.116	0.045	13.413	2.615	-0.995	0.780	1.212	0.012	5.718	8.455	0.414	1.952
61	302	0.2598	0.1717	0.116	0.051	12.359	2.985	-0.905	0.774	1.216	0.014	6.477	6.786	0.091	1.908
62	307	0.2589	0.2060	0.113	0.054	11.000	3.268	-0.974	0.796	1.222	0.013	7.408	6.598	-0.268	1.821
63	313	0.2301	0.1821	0.123	0.056	9.696	2.916	-1.051	0.850	1.227	0.013	7.199	6.453	-0.292	1.939
64	318	0.2287	0.1600	0.117	0.051	9.369	2.924	-0.964	0.900	1.228	0.013	7.975	7.174	-0.185	1.854
65	322	0.2405	0.1817	0.129	0.050	9.789	3.032	-1.175	0.650	1.226	0.013	5.367	5.062	0.016	2.178
66	327	0.2514	0.1879	0.113	0.050	10.351	2.674	-1.124	0.556	1.225	0.011	5.060	5.260	-0.540	2.519
67	332	0.2339	0.1520	0.105	0.046	10.276	2.603	-1.061	0.631	1.224	0.011	4.761	4.230	-0.637	1.475
68	338	0.2114	0.1700	0.106	0.031	11.119	2.840	-1.226	0.329	1.220	0.012	4.086	3.635	-1.010	1.631
69	342	0.2109	0.1776	0.108	0.038	11.285	3.469	-1.232	0.377	1.218	0.014	4.465	4.512	-1.332	1.766
70	348	0.1890	0.1610	0.121	0.036	10.750	3.623	-1.348	0.415	1.218	0.013	6.236	5.303	-1.385	2.055
71	352	0.0591	0.1086	0.139	0.036	13.779	3.664	-1.884	0.399	1.209	0.010	6.396	6.158	-0.183	3.523
72	357	0.0589	0.1232	0.124	0.030	13.904	3.057	-1.907	0.402	1.208	0.011	4.378	6.035	-1.199	3.117
	Total	**0.232**	**0.216**	**0.106**	**0.051**	**13.284**	**3.873**	**-0.895**	**1.028**	**1.210**	**0.018**	**7.445**	**9.447**	**0.220**	**2.098**

Table 8.7 Average and standard deviation of measured ambient conditions in 140 m during test

Height 120.0 m	Dependency [-]	shear exponent α 135m-100m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	2	0.0962	0.2166	0.115	0.030	13.631	2.675	-1.735	0.784	1.203	0.010	4.956	6.008	-2.021	2.577
2	7	0.1163	0.1825	0.109	0.057	14.541	2.408	-1.241	1.487	1.202	0.010	8.889	6.432	-1.592	2.560
3	13	0.0792	0.1420	0.084	0.038	15.996	2.240	-1.513	1.027	1.196	0.013	6.798	6.467	-1.262	1.945
4	17	0.1280	0.1840	0.096	0.031	16.683	3.488	-1.457	0.606	1.191	0.015	5.041	5.533	-1.100	1.818
5	23	0.2169	0.2831	0.089	0.036	17.259	2.815	-0.817	1.469	1.188	0.012	7.981	6.896	-1.278	1.298
6	27	0.3054	0.2460	0.091	0.044	17.637	2.744	-0.580	1.355	1.187	0.011	9.868	6.308	-0.768	1.524
27	134	0.2570	0.3317	0.103	0.074	17.708	5.589	0.066	1.517	1.190	0.029	8.297	5.732	1.822	1.888
28	137	0.3873	0.2983	0.088	0.064	17.084	4.793	0.184	1.585	1.193	0.023	10.404	9.112	2.132	1.226
29	143	0.3920	0.3254	0.062	0.057	17.659	4.529	1.001	1.709	1.190	0.021	15.740	11.156	2.262	0.845
30	147	0.3564	0.3126	0.071	0.056	17.105	4.482	0.819	1.773	1.196	0.024	14.654	11.841	2.042	1.358
31	152	0.3329	0.3116	0.108	0.060	15.125	4.080	-0.297	1.309	1.203	0.027	10.610	11.326	2.376	1.571
32	158	0.4501	0.2586	0.090	0.058	14.024	4.015	0.175	1.184	1.204	0.024	13.736	16.031	4.090	3.195
33	163	0.4768	0.2951	0.097	0.078	16.408	4.350	0.377	1.093	1.192	0.020	8.260	13.612	2.982	1.229
49	243	0.2244	0.1970	0.105	0.050	14.932	2.216	-0.926	0.700	1.201	0.012	7.145	9.312	1.212	1.258
50	247	0.1960	0.1931	0.093	0.051	14.780	2.145	-0.781	0.847	1.202	0.012	7.416	8.892	1.167	1.329
51	252	0.2016	0.1874	0.094	0.052	14.851	1.752	-0.760	0.789	1.202	0.010	7.410	10.427	0.720	1.365
52	258	0.2844	0.2118	0.087	0.052	14.540	2.051	-0.432	0.960	1.205	0.011	10.323	10.841	0.538	1.369
53	262	0.2249	0.2379	0.093	0.053	14.559	2.047	-0.514	1.064	1.203	0.012	9.746	12.236	0.975	1.323
54	268	0.2202	0.2058	0.106	0.057	14.788	1.834	-0.607	1.064	1.204	0.008	9.856	14.237	1.078	1.723
55	272	0.1502	0.1823	0.123	0.048	15.523	2.019	-1.042	0.888	1.201	0.009	6.565	12.452	0.933	1.950
56	277	0.1835	0.2023	0.106	0.049	15.131	2.410	-0.797	0.942	1.203	0.011	9.956	15.744	0.804	1.500
57	283	0.2591	0.2269	0.102	0.055	14.866	2.543	-0.620	1.145	1.205	0.011	11.320	15.234	0.977	1.912
58	288	0.2416	0.2155	0.105	0.053	14.242	3.609	-0.729	1.160	1.207	0.016	7.451	12.877	1.069	2.030
59	293	0.2125	0.1855	0.119	0.046	13.425	3.157	-1.024	0.797	1.212	0.014	5.269	7.167	0.406	1.634
60	297	0.2247	0.1753	0.126	0.045	13.380	2.491	-1.054	0.636	1.212	0.012	4.934	5.525	0.312	1.965
61	302	0.2493	0.1862	0.119	0.052	11.581	3.476	-0.910	0.809	1.220	0.015	7.220	6.552	-0.173	1.815
62	308	0.2260	0.1944	0.123	0.056	10.497	2.852	-1.104	0.797	1.224	0.012	6.391	6.050	-0.366	1.809
66	329	0.2223	0.1431	0.116	0.044	10.440	2.392	-1.143	0.575	1.223	0.010	4.091	5.078	-0.406	1.974
67	332	0.2190	0.1584	0.113	0.046	10.290	2.666	-1.079	0.640	1.224	0.012	4.783	3.809	-0.830	1.478
68	337	0.2119	0.1749	0.114	0.040	10.963	2.732	-1.216	0.369	1.221	0.011	4.147	3.710	-1.174	1.710
69	342	0.2012	0.1744	0.118	0.033	11.332	3.757	-1.249	0.350	1.217	0.015	5.035	5.270	-1.264	1.836
70	348	0.1442	0.1540	0.129	0.035	11.178	3.814	-1.473	0.471	1.216	0.012	6.419	5.681	-1.464	2.291
71	352	0.0524	0.1226	0.145	0.039	14.245	3.208	-1.939	0.363	1.208	0.010	5.545	6.270	-0.048	3.618
72	357	0.0919	0.1670	0.122	0.027	13.739	2.956	-1.898	0.427	1.206	0.010	5.006	4.513	-1.055	2.400
	Total	**0.223**	**0.220**	**0.107**	**0.051**	**14.128**	**3.646**	**-0.852**	**1.110**	**1.206**	**0.017**	**7.544**	**9.552**	**0.246**	**2.100**

Table 8.8 Average and standard deviation of measured ambient conditions in 120 m during test

Height 100.0 m	Dependency [-]	shear exponent α 120m-80m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	2	0.1338	0.1689	0.117	0.039	13.480	2.744	-1.441	1.314	1.204	0.010	7.298	6.458	-0.395	2.664
2	7	0.0855	0.0884	0.106	0.056	14.596	2.358	-1.447	1.130	1.202	0.011	6.513	7.371	-0.791	1.925
3	13	0.0919	0.1491	0.095	0.036	16.289	2.550	-1.571	0.829	1.193	0.013	8.083	6.616	0.032	1.990
4	17	0.1738	0.2185	0.092	0.034	16.745	3.248	-0.970	1.471	1.190	0.014	6.794	6.995	0.006	1.323
5	22	0.2325	0.2393	0.093	0.037	17.678	2.730	-0.756	1.412	1.187	0.011	8.135	7.036	0.205	1.164
6	27	0.2761	0.2168	0.097	0.045	17.292	2.833	-0.775	1.117	1.188	0.012	10.201	7.789	0.628	1.503
27	134	0.3247	0.3016	0.094	0.061	18.721	5.263	0.478	1.761	1.185	0.024	11.726	11.363	2.495	1.600
28	137	0.3156	0.3038	0.091	0.063	16.893	4.429	0.500	1.793	1.193	0.022	12.374	12.719	2.155	1.070
29	143	0.3743	0.3359	0.077	0.055	17.304	5.334	0.772	1.705	1.195	0.028	14.058	9.839	1.787	0.926
30	147	0.3598	0.2823	0.093	0.059	17.209	4.419	0.168	1.548	1.193	0.024	11.253	11.193	1.710	1.574
31	152	0.2122	0.2597	0.127	0.051	14.448	2.789	-0.691	1.140	1.204	0.025	7.081	12.008	1.940	1.956
32	157	0.4835	0.2659	0.092	0.040	15.089	3.792	0.401	1.152	1.198	0.021	15.774	13.276	2.660	2.370
33	163	0.5247	0.2580	0.097	0.064	16.151	3.876	0.604	0.943	1.192	0.018	14.507	12.182	1.762	0.860
34	166	0.5947	0.2144	0.094	0.040	18.456	1.936	0.188	0.840	1.182	0.007	9.470	8.715	1.786	0.370
49	243	0.2433	0.1981	0.096	0.056	14.819	2.391	-0.690	0.878	1.202	0.014	9.664	10.714	-1.155	1.077
50	247	0.1960	0.1494	0.101	0.054	15.006	1.811	-0.808	0.821	1.201	0.010	6.274	8.365	-1.110	1.240
51	253	0.2219	0.2011	0.105	0.052	14.919	1.977	-0.693	0.930	1.201	0.012	7.457	11.125	-1.445	1.348
52	257	0.2819	0.2340	0.091	0.057	14.343	1.823	-0.325	1.072	1.205	0.010	11.638	12.511	-1.232	1.368
53	262	0.2140	0.2192	0.103	0.057	14.663	2.093	-0.513	1.118	1.202	0.012	11.121	15.511	-1.073	1.331
54	268	0.2268	0.1923	0.116	0.054	15.130	2.059	-0.694	1.135	1.202	0.009	10.565	16.615	-1.077	2.601
55	273	0.2084	0.2090	0.114	0.057	15.496	2.379	-0.575	1.389	1.202	0.010	13.099	19.214	-1.072	1.844
56	277	0.2030	0.1854	0.117	0.053	15.397	2.070	-0.884	0.956	1.203	0.009	8.008	13.300	-1.045	1.659
57	283	0.2700	0.2080	0.113	0.055	14.394	2.777	-0.806	0.880	1.207	0.012	6.855	8.488	-0.715	1.849
58	288	0.2395	0.1854	0.120	0.048	14.100	3.504	-0.934	0.832	1.208	0.016	5.539	8.566	-0.694	1.527
59	293	0.2110	0.1680	0.131	0.049	13.353	3.078	-1.032	0.752	1.212	0.014	4.871	6.034	-0.866	1.824
60	297	0.2375	0.1765	0.132	0.044	13.029	2.933	-1.037	0.654	1.214	0.013	5.265	5.627	-1.055	1.687
61	302	0.2670	0.1977	0.128	0.055	11.471	3.251	-0.944	0.805	1.221	0.014	6.910	6.386	-1.073	1.815
62	308	0.2298	0.1856	0.140	0.058	10.528	3.069	-1.101	0.811	1.223	0.014	7.148	6.802	-0.808	2.462
63	312	0.2351	0.1581	0.138	0.059	9.128	2.852	-0.968	0.925	1.229	0.012	7.844	7.055	-0.766	2.005
64	317	0.2167	0.1570	0.141	0.052	9.551	2.908	-1.138	0.708	1.227	0.013	6.173	5.542	-0.513	1.826
65	322	0.2458	0.1820	0.150	0.049	9.955	2.833	-1.197	0.569	1.226	0.011	4.907	4.558	-0.188	1.937
66	328	0.2246	0.1732	0.130	0.049	10.274	2.702	-1.158	0.558	1.225	0.011	4.511	4.484	-0.747	2.027
67	332	0.2391	0.1656	0.120	0.047	10.313	2.442	-1.087	0.610	1.224	0.010	3.770	4.056	-1.082	1.419
68	337	0.2350	0.1981	0.126	0.038	11.336	2.955	-1.222	0.365	1.219	0.012	4.707	4.222	-1.068	1.560
69	343	0.2208	0.1844	0.127	0.035	11.260	3.637	-1.230	0.390	1.217	0.015	4.839	6.333	-0.994	1.746
70	347	0.1372	0.1618	0.147	0.035	11.642	4.076	-1.563	0.418	1.215	0.013	6.959	5.454	-0.505	2.135
71	352	0.0813	0.1169	0.158	0.044	14.331	3.396	-1.977	0.342	1.207	0.010	5.400	5.791	0.570	3.668
72	358	0.0893	0.1557	0.133	0.028	14.141	2.832	-1.847	0.408	1.205	0.010	4.433	4.741	-0.660	2.367
	Total	**0.232**	**0.206**	**0.120**	**0.054**	**13.416**	**4.019**	**-0.886**	**1.075**	**1.209**	**0.019**	**7.421**	**9.090**	**-0.459**	**2.008**

Table 8.9 Average and standard deviation of measured ambient conditions in 100 m during test

Height 80.0 m	Dependency [-]	shear exponent α 100m-60m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	3	0.1924	0.1437	0.130	0.042	13.047	2.768	-1.464	1.297	1.207	0.011	5.057	6.628	-1.121	2.417
2	7	0.1660	0.1040	0.099	0.054	14.510	1.869	-1.664	0.698	1.203	0.011	7.890	6.260	-0.284	2.061
3	13	0.1440	0.1298	0.107	0.036	16.541	2.901	-1.518	0.826	1.190	0.013	7.477	7.726	0.202	1.724
4	17	0.2604	0.2144	0.084	0.040	16.833	2.698	-0.227	1.953	1.191	0.011	10.014	10.301	-0.063	1.244
5	22	0.2132	0.1846	0.105	0.038	17.760	2.839	-1.032	0.963	1.186	0.012	8.994	8.490	0.243	1.142
6	27	0.3035	0.1715	0.102	0.046	17.073	3.055	-0.777	0.768	1.188	0.013	10.673	7.620	1.121	1.643
7	31	0.3176	0.1926	0.120	0.052	15.377	2.959	-0.912	0.738	1.195	0.012	11.185	10.420	1.362	1.577
27	134	0.2682	0.2653	0.125	0.066	18.998	6.022	-0.341	1.568	1.184	0.028	6.346	8.730	2.482	1.713
28	138	0.4031	0.2821	0.084	0.055	17.003	4.878	0.738	1.725	1.196	0.025	12.546	11.303	1.820	1.058
29	142	0.4097	0.2931	0.101	0.053	18.419	4.728	0.311	1.716	1.188	0.024	11.673	9.575	1.812	1.048
30	147	0.2763	0.2477	0.122	0.066	16.470	4.735	-0.451	1.191	1.193	0.026	7.175	9.056	1.774	1.839
31	153	0.2853	0.2482	0.128	0.044	14.762	3.074	-0.299	1.402	1.202	0.025	9.481	13.948	2.141	1.969
32	157	0.4873	0.2549	0.105	0.036	15.707	4.081	0.328	1.091	1.197	0.022	12.921	9.315	2.127	2.219
33	162	0.5846	0.1639	0.093	0.061	16.842	3.345	0.772	0.941	1.191	0.017	15.664	9.658	1.683	0.652
34	166	0.5504	0.1738	0.092	0.053	16.508	1.988	0.694	1.161	1.193	0.015	14.910	11.355	1.548	0.454
49	243	0.2492	0.1741	0.105	0.056	15.033	2.362	-0.789	0.801	1.202	0.014	7.191	9.400	-1.105	1.053
50	247	0.2054	0.1693	0.106	0.054	14.965	1.870	-0.739	0.908	1.201	0.011	7.465	10.922	-1.154	1.239
51	253	0.2596	0.2240	0.101	0.052	14.593	1.874	-0.506	1.071	1.204	0.011	9.660	12.542	-1.558	1.391
52	257	0.2835	0.2410	0.107	0.063	14.440	1.540	-0.384	1.115	1.204	0.008	11.618	14.929	-0.888	1.325
53	262	0.2219	0.2021	0.118	0.053	14.934	2.235	-0.768	0.949	1.200	0.013	8.709	14.974	-1.033	2.104
54	268	0.2013	0.1918	0.116	0.051	15.422	2.098	-0.653	1.236	1.202	0.009	12.110	17.726	-0.876	2.099
55	273	0.2119	0.1679	0.131	0.059	15.390	2.573	-0.895	1.053	1.202	0.012	6.760	12.386	-1.108	1.999
56	278	0.2328	0.1926	0.120	0.050	14.995	2.117	-0.905	0.831	1.204	0.008	6.292	9.766	-1.048	1.636
57	282	0.2566	0.2039	0.123	0.054	14.292	3.167	-0.816	0.934	1.207	0.013	6.359	8.530	-0.705	1.873
58	288	0.2218	0.1879	0.129	0.046	14.061	3.364	-1.010	0.756	1.209	0.015	4.836	6.392	-0.799	1.537
59	293	0.2278	0.1709	0.137	0.048	13.166	3.176	-1.027	0.715	1.213	0.014	5.033	5.328	-0.888	1.754
60	297	0.2296	0.1777	0.140	0.045	12.819	3.192	-1.016	0.724	1.215	0.014	5.401	6.506	-0.945	1.828
61	302	0.2476	0.1880	0.140	0.054	11.402	3.053	-1.002	0.810	1.221	0.013	6.465	6.592	-1.082	1.849
62	308	0.2311	0.1755	0.143	0.065	10.040	3.035	-0.940	0.932	1.225	0.014	8.272	7.407	-0.842	2.450
63	313	0.2414	0.1646	0.149	0.056	9.052	2.876	-1.075	0.808	1.229	0.012	6.777	6.121	-0.708	1.868
64	317	0.2395	0.1733	0.157	0.045	9.591	2.970	-1.242	0.589	1.227	0.013	4.955	3.788	-0.458	1.877
65	322	0.2744	0.1841	0.163	0.047	10.103	2.708	-1.234	0.536	1.225	0.011	4.965	4.234	-0.232	2.185
66	327	0.2581	0.1779	0.140	0.048	10.348	2.955	-1.149	0.602	1.225	0.013	4.568	4.555	-0.687	1.834
67	332	0.2938	0.1787	0.132	0.048	10.642	2.524	-1.101	0.530	1.222	0.011	3.504	4.612	-1.059	1.371
68	337	0.2278	0.1766	0.140	0.035	11.296	3.230	-1.269	0.336	1.219	0.012	4.797	5.040	-1.063	1.735
69	343	0.2245	0.1865	0.144	0.035	11.097	3.682	-1.273	0.372	1.218	0.014	5.196	5.408	-0.791	1.829
70	347	0.1138	0.1192	0.157	0.037	12.551	4.072	-1.702	0.343	1.211	0.013	5.986	5.318	-0.348	2.952
71	353	0.1467	0.1516	0.156	0.045	14.273	3.206	-1.784	0.768	1.207	0.010	4.288	4.934	-0.657	2.587
72	357	0.1834	0.1543	0.148	0.042	14.308	2.811	-1.643	1.117	1.204	0.010	6.060	6.550	-0.244	2.894
	Total	**0.245**	**0.197**	**0.128**	**0.054**	**13.444**	**4.064**	**-0.917**	**1.039**	**1.209**	**0.019**	**7.115**	**8.685**	**-0.439**	**2.015**

Table 8.10 Average and standard deviation of measured ambient conditions in 80 m during test

Height 60.0 m	Dependency [-]	shear exponent α 80m-40m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	2	0.3294	0.1109	0.163	0.062	12.134	2.464	-1.644	0.557	1.210	0.008	4.825	4.549	-0.655	1.499
2	7	0.2666	0.1448	0.136	0.070	14.730	1.967	-1.501	1.218	1.200	0.010	9.137	10.105	-0.778	1.555
3	13	0.2837	0.1686	0.120	0.049	16.755	2.445	-0.758	1.823	1.190	0.010	9.982	8.086	-0.783	1.114
4	18	0.2795	0.1681	0.106	0.040	17.170	2.872	-0.618	1.487	1.189	0.012	10.311	10.300	-0.763	0.858
5	22	0.2442	0.1291	0.117	0.039	17.632	2.848	-1.070	0.856	1.187	0.012	8.656	7.592	-0.622	1.002
6	27	0.3226	0.1619	0.120	0.046	16.906	3.272	-0.843	0.785	1.188	0.013	10.003	7.572	0.069	1.110
7	30	0.3358	0.1677	0.132	0.068	16.030	4.225	-0.598	1.177	1.191	0.016	11.659	7.097	0.327	1.142
27	133	0.3685	0.2566	0.119	0.065	18.809	5.395	0.201	1.770	1.188	0.027	9.060	9.874	1.055	1.335
28	137	0.4491	0.2689	0.109	0.055	17.589	5.451	0.502	1.776	1.195	0.029	9.741	7.741	0.927	0.919
29	142	0.3404	0.2343	0.130	0.056	18.566	4.239	-0.272	1.343	1.187	0.021	7.626	7.339	1.384	0.794
30	147	0.2434	0.2188	0.154	0.069	15.669	4.474	-0.744	1.123	1.196	0.027	5.880	8.641	1.155	1.635
31	153	0.3552	0.2384	0.135	0.041	16.092	3.755	0.166	1.395	1.194	0.023	10.778	10.154	1.833	1.261
32	157	0.4659	0.1978	0.117	0.046	15.373	3.641	0.319	1.132	1.198	0.020	12.970	10.962	1.707	1.665
33	163	0.5616	0.1575	0.085	0.034	16.880	3.344	1.018	1.095	1.192	0.019	18.534	10.705	1.819	0.617
34	166	0.5684	0.1102	0.105	0.053	17.830	1.801	0.711	1.061	1.183	0.005	16.808	13.531	1.301	0.564
49	244	0.2627	0.1511	0.123	0.064	14.778	2.413	-0.671	0.885	1.201	0.013	7.669	9.271	-0.336	1.008
50	248	0.2681	0.1840	0.106	0.052	14.689	1.991	-0.553	1.050	1.203	0.012	8.949	11.715	-0.538	0.864
51	253	0.2656	0.2087	0.110	0.053	14.876	1.866	-0.570	1.090	1.202	0.011	8.619	12.301	-0.722	1.104
52	257	0.1850	0.1656	0.124	0.060	14.687	1.807	-0.552	1.282	1.203	0.010	12.007	19.278	-0.542	1.082
53	263	0.2107	0.1824	0.133	0.050	15.727	2.314	-0.930	0.841	1.197	0.012	6.132	12.693	-0.033	1.304
54	268	0.2432	0.2019	0.122	0.048	14.856	2.026	-0.823	0.869	1.204	0.009	7.870	10.707	0.408	1.326
55	272	0.1669	0.1319	0.147	0.047	15.427	2.314	-1.219	0.544	1.202	0.011	3.744	7.441	0.005	1.328
56	278	0.2232	0.1799	0.133	0.053	15.288	2.279	-0.887	0.931	1.203	0.009	4.930	8.173	-0.203	1.360
57	282	0.2391	0.1929	0.136	0.047	13.978	3.303	-0.998	0.729	1.209	0.014	4.610	6.207	0.045	1.243
58	288	0.2145	0.1632	0.140	0.046	13.676	3.484	-0.986	0.755	1.210	0.016	5.051	5.538	0.108	1.101
59	293	0.2322	0.1731	0.144	0.048	12.876	3.305	-0.986	0.780	1.214	0.015	5.518	5.767	-0.081	1.294
60	297	0.2215	0.1787	0.146	0.049	12.767	3.159	-1.004	0.769	1.215	0.014	5.660	6.708	-0.129	1.486
61	302	0.2385	0.1910	0.150	0.060	11.108	3.323	-0.928	0.924	1.222	0.014	7.008	7.741	-0.252	1.482
62	307	0.2361	0.1892	0.157	0.055	10.132	3.496	-1.078	0.823	1.224	0.016	6.738	6.222	-0.532	1.763
63	312	0.2229	0.1624	0.171	0.050	9.175	2.885	-1.236	0.646	1.228	0.012	5.289	4.468	-0.357	1.525
64	318	0.2422	0.1645	0.172	0.041	9.298	2.840	-1.259	0.556	1.228	0.012	4.889	3.361	-0.349	1.598
65	322	0.2652	0.1796	0.176	0.045	10.445	2.637	-1.274	0.534	1.224	0.011	4.612	4.021	-0.458	2.112
66	327	0.2626	0.1685	0.162	0.042	9.902	2.685	-1.209	0.603	1.226	0.011	4.042	3.956	-0.535	1.439
67	333	0.2888	0.1758	0.155	0.039	10.835	2.617	-1.147	0.509	1.222	0.011	3.412	4.872	-0.843	1.089
68	337	0.2037	0.1428	0.157	0.031	11.229	3.192	-1.321	0.330	1.219	0.011	4.481	5.319	-1.206	1.544
69	343	0.1800	0.1253	0.164	0.034	11.405	4.044	-1.375	0.340	1.217	0.015	5.746	4.862	-1.226	1.795
70	347	0.1661	0.1464	0.170	0.038	12.880	4.271	-1.525	0.903	1.210	0.014	5.360	5.995	-1.252	1.918
71	352	0.1707	0.1703	0.173	0.044	14.538	2.959	-1.777	0.809	1.204	0.010	5.886	4.833	-0.318	3.218
72	357	0.2424	0.1468	0.182	0.038	13.948	2.848	-1.769	1.017	1.205	0.010	4.349	5.912	-0.856	1.490
	Total	**0.2541**	**0.1854**	**0.142**	**0.053**	**13.454**	**4.138**	**-0.936**	**1.034**	**1.209**	**0.019**	**6.766**	**8.135**	**-0.252**	**1.530**

Table 8.11 Average and standard deviation of measured ambient conditions in 60 m during test

Height 40.0 m	Dependency [-]	shear exponent α 60m-40m		Turbulence Intensity I		Air temperature T at 131 m		T difference 131m-18m		Air density		wind veer dir129m-dir38m		Flow Inclination angle	
Bin-No.	Direction [deg]	avg [-]	std [-]	avg [-]	std [-]	avg [°C]	std [°C]	avg [°C]	std [°C]	avg [kg/m³]	std [kg/m³]	avg [deg]	std [deg]	avg [deg]	std [deg]
1	2	0.3863	0.2097	0.199	0.066	13.814	2.924	-0.955	1.895	1.200	0.011	9.292	9.593	-0.465	1.523
2	8	0.2821	0.1588	0.148	0.071	16.331	2.333	-0.294	2.398	1.192	0.008	12.797	14.108	-1.129	1.413
3	13	0.3064	0.1312	0.172	0.061	16.799	2.476	-1.037	1.302	1.188	0.010	9.539	7.645	-0.684	1.031
4	18	0.2815	0.1453	0.149	0.051	17.098	2.964	-0.817	1.185	1.189	0.013	9.172	8.855	-0.569	0.896
5	22	0.2675	0.1213	0.155	0.044	17.890	2.699	-1.141	0.777	1.185	0.011	8.279	7.334	-0.517	1.039
6	27	0.3385	0.1797	0.156	0.052	17.265	3.577	-0.638	1.106	1.186	0.014	10.619	9.961	0.112	1.188
7	31	0.3990	0.1559	0.140	0.053	16.198	3.257	-0.305	1.259	1.190	0.018	10.008	4.794	0.681	0.936
27	132	0.2799	0.2250	0.155	0.054	20.925	4.024	-0.412	1.564	1.178	0.019	6.232	7.158	1.299	1.330
28	137	0.3013	0.2056	0.149	0.046	20.492	4.173	-0.411	1.357	1.180	0.020	6.426	6.757	1.200	1.220
29	142	0.3200	0.2342	0.152	0.045	19.853	4.458	-0.092	1.621	1.181	0.022	6.686	7.764	1.294	0.933
30	147	0.2171	0.1579	0.159	0.049	17.128	3.821	-0.755	1.154	1.189	0.024	6.889	8.026	1.370	1.612
31	152	0.3289	0.2389	0.165	0.085	16.066	4.357	-0.291	1.145	1.198	0.027	7.443	7.401	2.254	1.935
32	158	0.4773	0.2028	0.118	0.042	16.852	3.762	0.810	1.184	1.194	0.022	15.727	10.649	1.742	0.870
33	162	0.5573	0.1340	0.108	0.031	16.706	3.189	0.862	0.861	1.193	0.019	16.348	7.383	1.633	0.411
34	166	0.5580	0.1070	0.118	0.038	16.130	3.041	0.810	0.777	1.198	0.018	15.753	6.842	1.530	0.373
49	243	0.2873	0.1739	0.119	0.063	14.669	2.090	-0.465	1.072	1.204	0.012	11.014	12.475	-0.723	0.967
50	247	0.2366	0.1712	0.134	0.057	15.212	2.168	-0.778	0.989	1.200	0.013	6.630	10.773	-0.489	0.967
51	252	0.1951	0.1663	0.157	0.050	15.224	1.901	-1.037	0.868	1.200	0.011	2.229	6.695	-0.707	1.364
52	257	0.1807	0.1722	0.145	0.051	15.453	1.434	-1.050	0.669	1.199	0.008	3.078	8.909	-0.644	0.999
53	262	0.1582	0.1401	0.156	0.047	15.689	2.210	-1.237	0.558	1.197	0.010	1.600	6.711	0.032	1.481
54	268	0.1792	0.1494	0.148	0.043	15.050	2.125	-1.074	0.685	1.202	0.010	4.252	6.739	0.432	1.515
55	273	0.1367	0.1026	0.164	0.040	15.512	2.310	-1.311	0.463	1.201	0.010	2.242	4.822	-0.033	1.256
56	278	0.1661	0.1360	0.156	0.039	15.178	2.914	-1.159	0.643	1.204	0.012	2.992	5.489	-0.200	1.461
57	282	0.1734	0.1383	0.155	0.035	14.096	3.626	-1.199	0.559	1.209	0.015	3.536	5.110	0.011	1.347
58	288	0.2056	0.1679	0.156	0.041	13.157	3.517	-1.033	0.744	1.212	0.016	5.201	5.851	0.055	1.072
59	293	0.1896	0.1614	0.157	0.037	13.053	3.225	-1.093	0.698	1.213	0.015	4.963	5.675	-0.067	1.346
60	297	0.1914	0.1751	0.163	0.045	12.596	3.492	-1.144	0.684	1.216	0.015	4.605	6.017	-0.228	1.718
61	302	0.1934	0.1598	0.171	0.041	11.491	3.556	-1.183	0.681	1.220	0.015	4.477	5.453	-0.256	1.607
62	308	0.1867	0.1518	0.181	0.044	9.873	3.582	-1.318	0.560	1.225	0.016	5.029	4.554	-0.554	1.755
63	312	0.1892	0.1231	0.191	0.037	9.444	2.994	-1.390	0.504	1.227	0.013	4.478	3.541	-0.292	1.682
64	317	0.2288	0.1472	0.186	0.037	9.385	2.725	-1.304	0.513	1.228	0.011	4.377	3.305	-0.539	1.620
65	322	0.2151	0.1180	0.192	0.039	10.216	2.936	-1.384	0.434	1.224	0.013	3.761	3.393	-0.443	1.973
66	327	0.2495	0.1517	0.177	0.039	9.959	2.772	-1.258	0.554	1.226	0.011	3.490	4.064	-0.524	1.339
67	332	0.2387	0.1284	0.173	0.034	10.903	2.715	-1.291	0.370	1.222	0.011	4.151	5.755	-0.994	1.117
68	337	0.1662	0.1119	0.177	0.032	11.475	3.438	-1.443	0.347	1.218	0.011	5.679	4.988	-1.145	1.976
69	342	0.1834	0.1091	0.183	0.035	11.729	4.552	-1.429	0.377	1.216	0.016	5.142	4.431	-1.222	2.086
70	347	0.1577	0.1032	0.199	0.034	12.665	3.880	-1.782	0.343	1.209	0.013	4.559	4.160	-0.724	2.476
71	353	0.2400	0.1436	0.197	0.039	13.965	2.865	-1.747	1.121	1.203	0.010	6.472	6.342	-1.147	1.474
72	358	0.3188	0.1414	0.225	0.030	12.715	3.001	-1.905	0.463	1.209	0.010	3.129	4.134	-0.886	1.601
	Total	**0.2297**	**0.1678**	**0.165**	**0.048**	**13.573**	**4.322**	**-1.063**	**0.949**	**1.208**	**0.020**	**5.751**	**7.114**	**-0.242**	**1.585**

Table 8.12 Average and standard deviation of measured ambient conditions in 40 m during test

8.3 Accuracy in Terms of the Horizontal Wind Speed Component without wind speed limitation

This chapter represents the results of the comparison of cup anemometer measurement and measurement of the RSD in terms of the horizontal wind speed component. It is similar to chapter 4.2 with the difference that no wind speed filter has been applied.

8.3.1 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 140 m Measurement Height

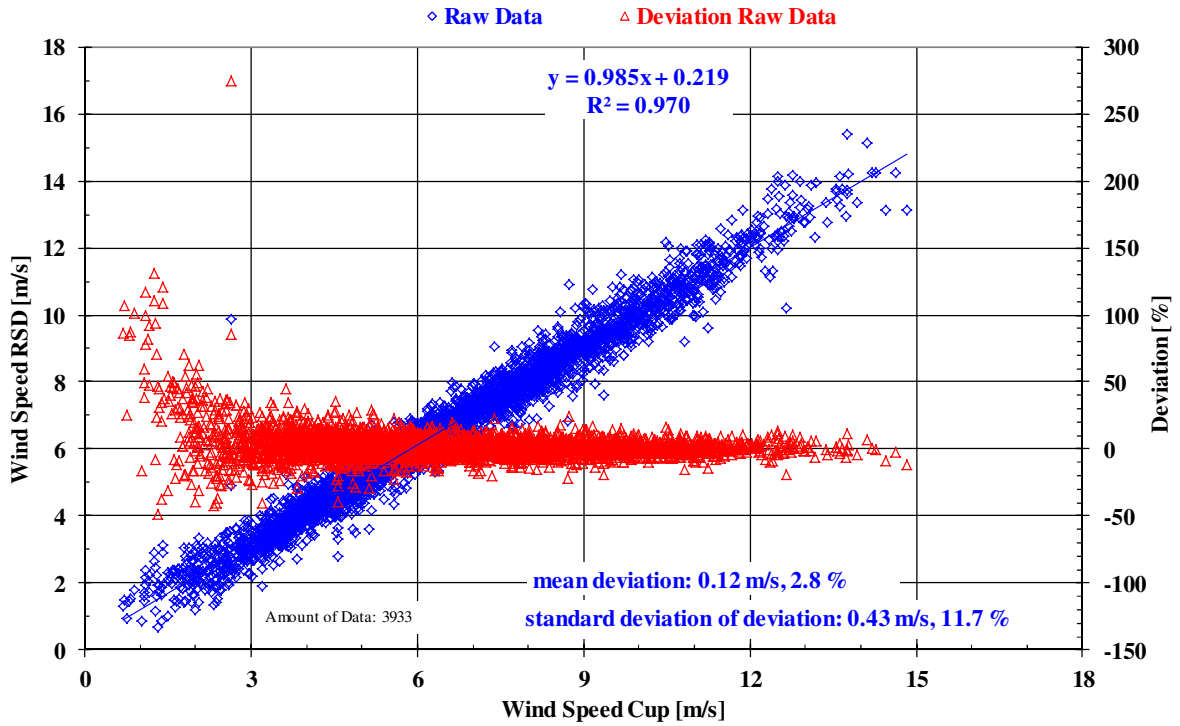

Figure 8.1 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 140 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

8.3.2 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 120 m Measurement Height

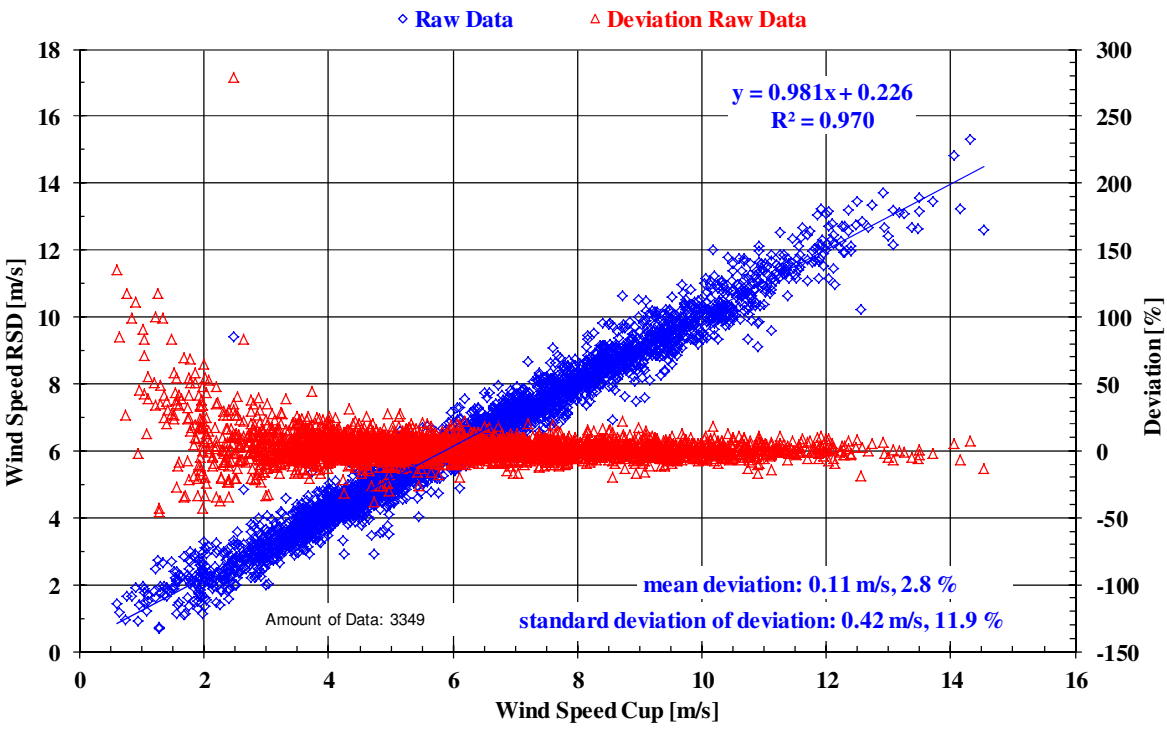

Figure 8.2 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 120 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

8.3.3 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 100 m Measurement Height

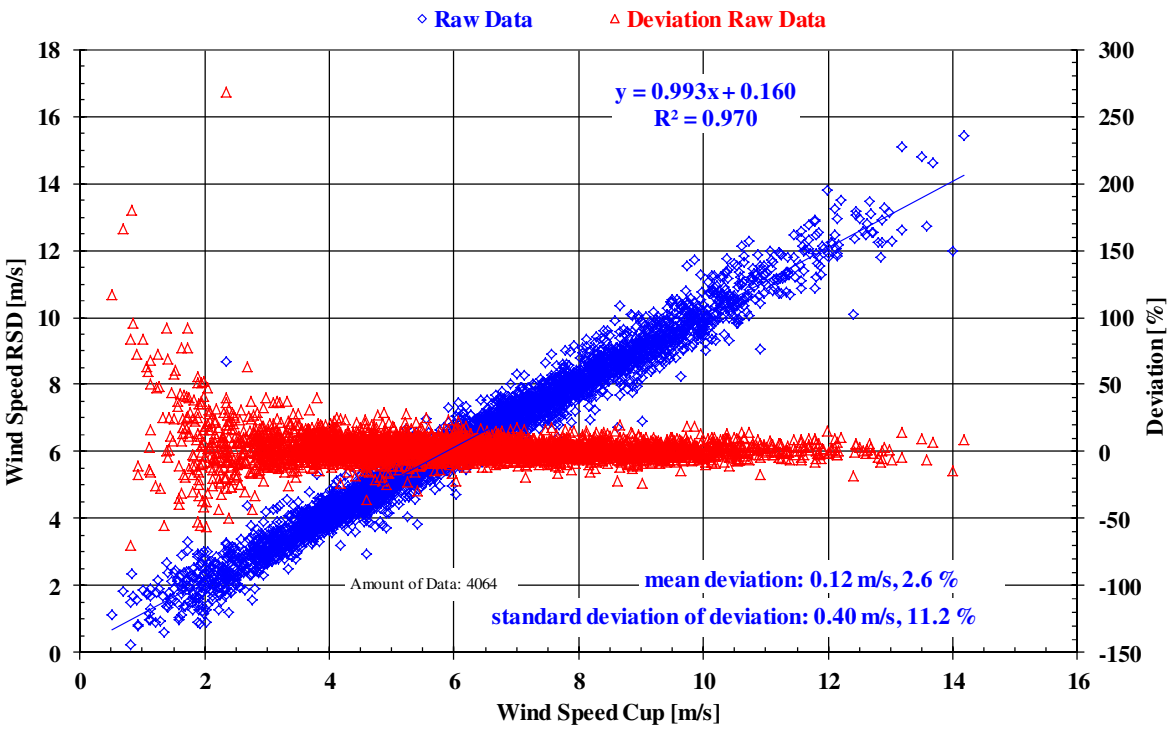

Figure 8.3 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 100 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

8.3.4 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 80 m Measurement Height

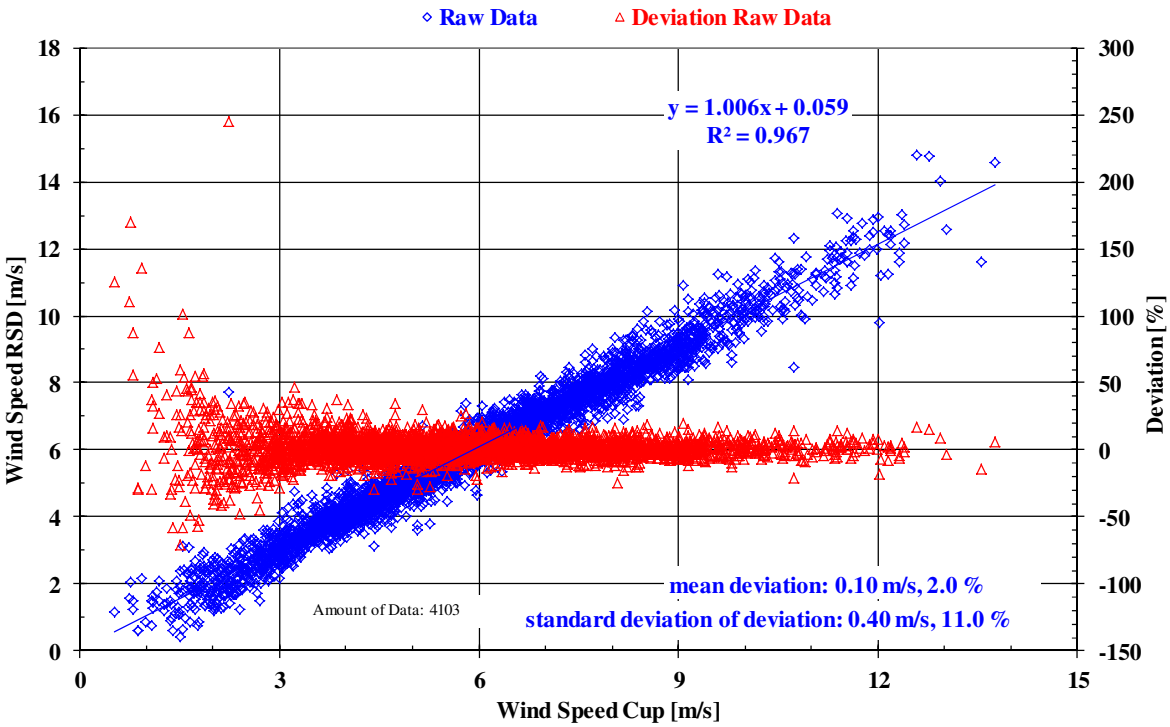

Figure 8.4 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer

readings at 80 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

8.3.5 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 60 m Measurement Height

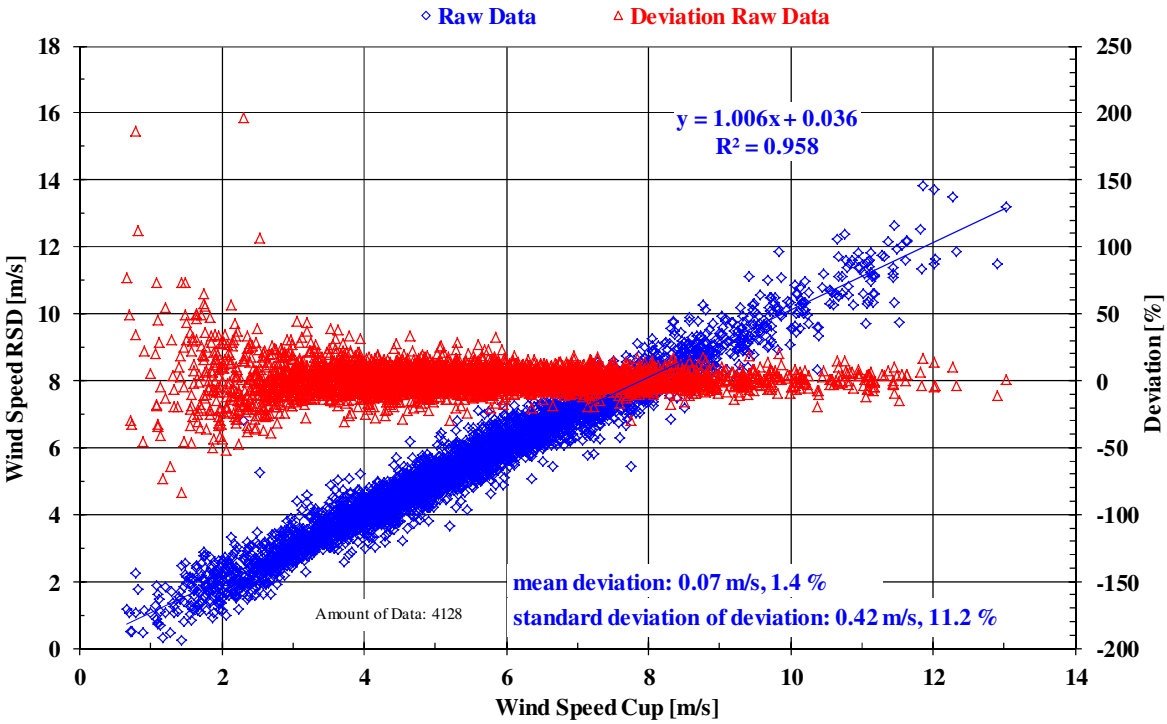

Figure 8.5 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 60 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.

8.3.6 Accuracy of RSD in Terms of 10-Minute Averages of the Horizontal Wind Speed Component at 40 m Measurement Height

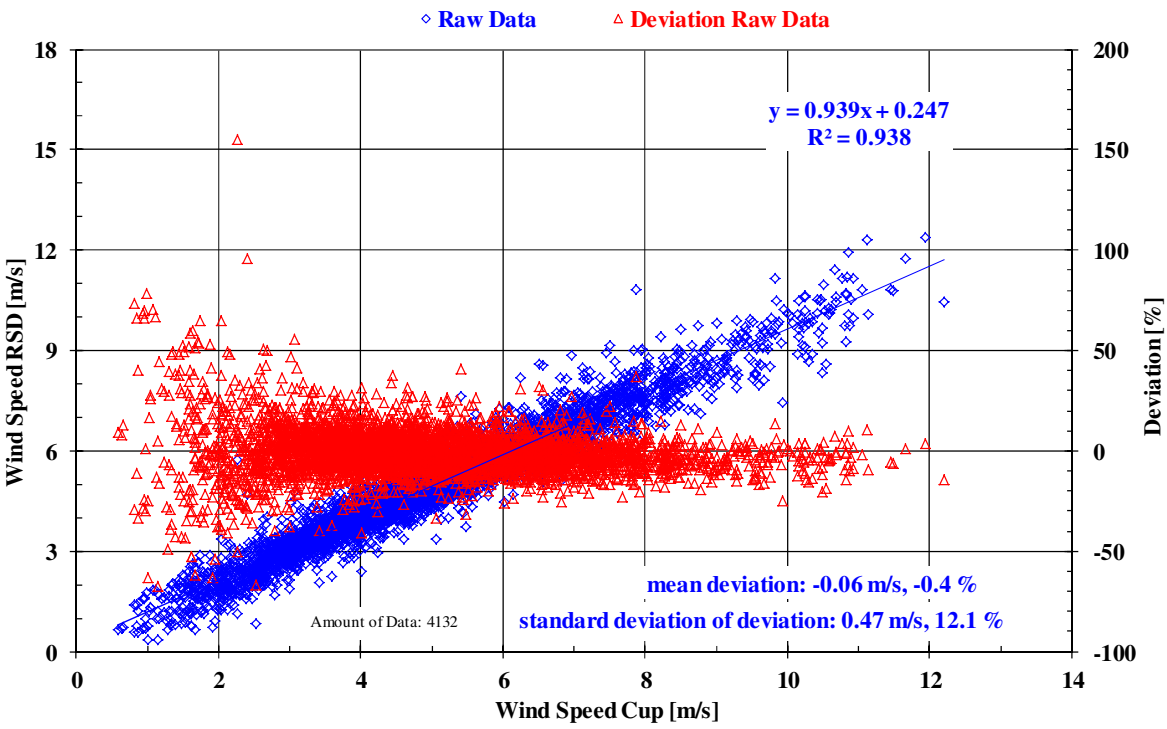

Figure 8.6 Scatter plot of horizontal wind speed component as measured by RSD against cup anemometer readings at 40 m height above ground and the deviation between both values in percent of the wind speed. Each point represents a 10-minute average.