DEUTSCHE WINDGUARD

Observed Reduction of Sensitivities of Windcube Measurements by Vector Averaging

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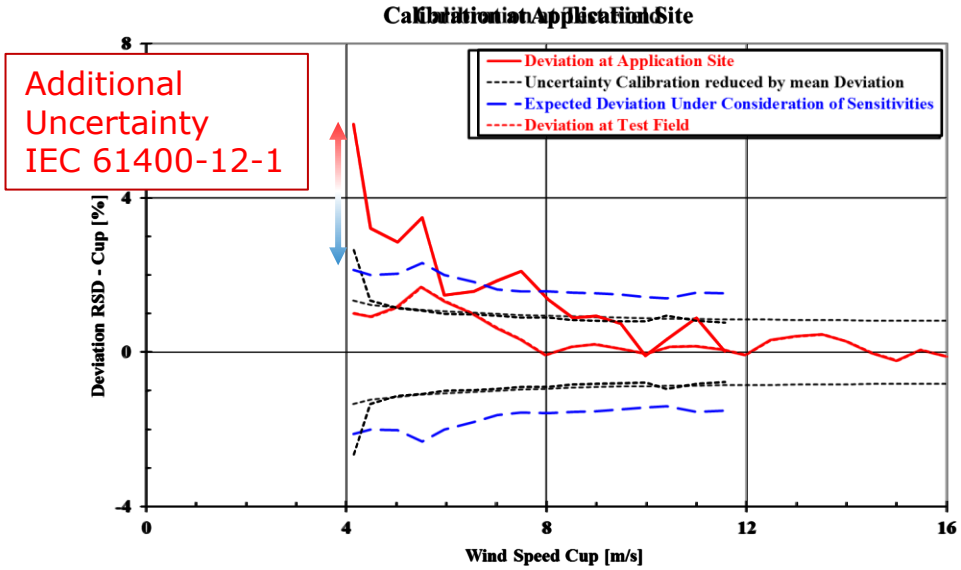
Outlook

- Background: Encountered Difficulties
- Difference Between Scalar and Vector Averaging
- Effects of Averaging Method on
  - Sensitivities
  - Classification
  - Calibration
- Conclusions

Encountered Difficulties

As part of a power curve test the following measurements were made:

1. Windcube calibrated on test field against 135 m mast
2. Windcube calibrated on application site against 130 m mast

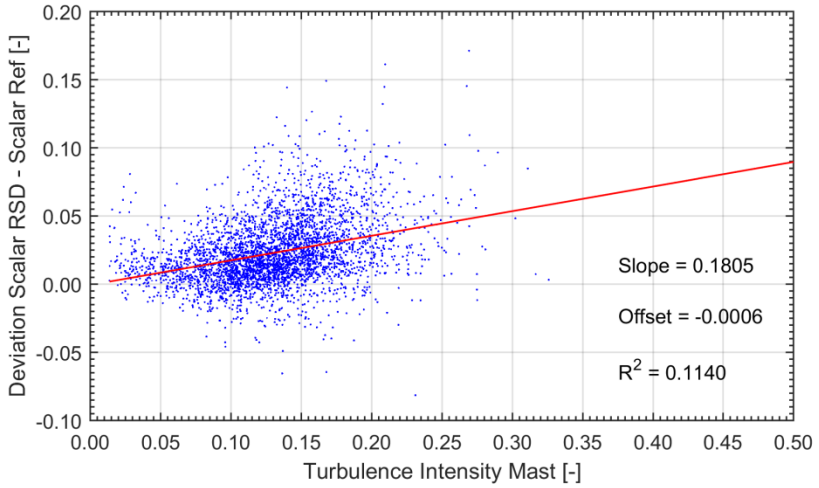


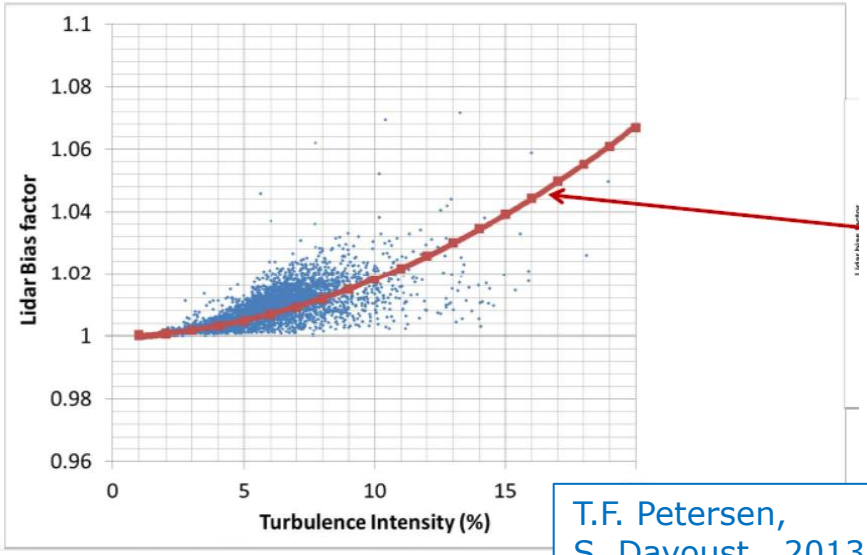
Observations:

- At test field Windcube agrees reasonable well with mast
- At application site Windcube overestimates wind speed
- Additional Deviation not explained by sensitivities
- High additional uncertainty according to IEC 61400-12-1

Sensitivity Analysis

- Dependency of Deviations between lidar and cup as function of TI investigated
- Sensitivity slope on TI higher than in previous sensitivity analysis (was 8%, now 18%)
- Reminded by size and shape of effect on the discussion made by nacelle lidars in 2013.
- Idea: Ground based lidars are affected by uncorrelated longitudinal TI in probe volumes
- Solution: Vector Average





T.F. Petersen,
S. Davoust, 2013

Scalar Average / Vector Average

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Scalar Average

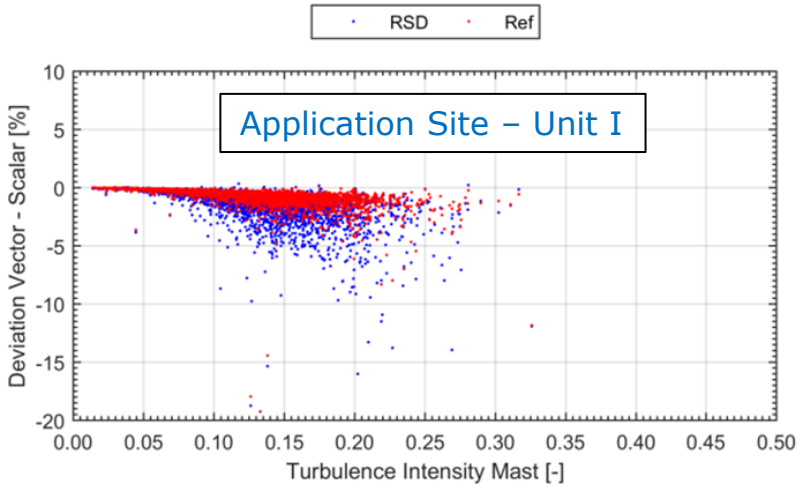
1. Measurement of radial wind speed
2. Reconstruct horizontal wind speed
3. Average over 10-minute interval

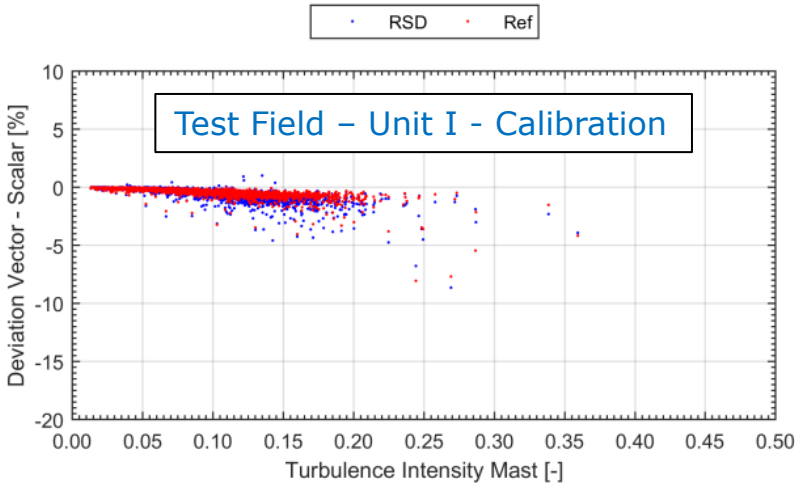
Vector Average

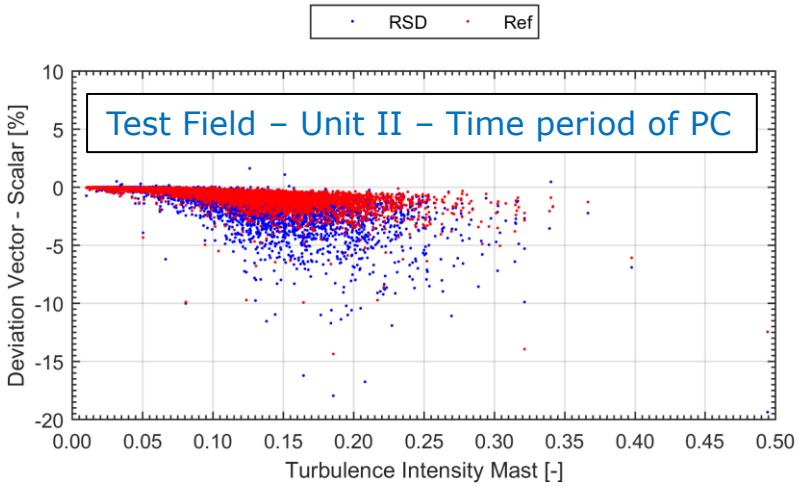
1. Measurement of radial wind speed
2. Average over 10-minute interval
3. Reconstruct horizontal wind speed

Comparison Vector to Scalar Average

- Difference vector to scalar of Windcube larger than with cup anemometer
- Same unit different at different times
- Different units at different sites but same time behave similar

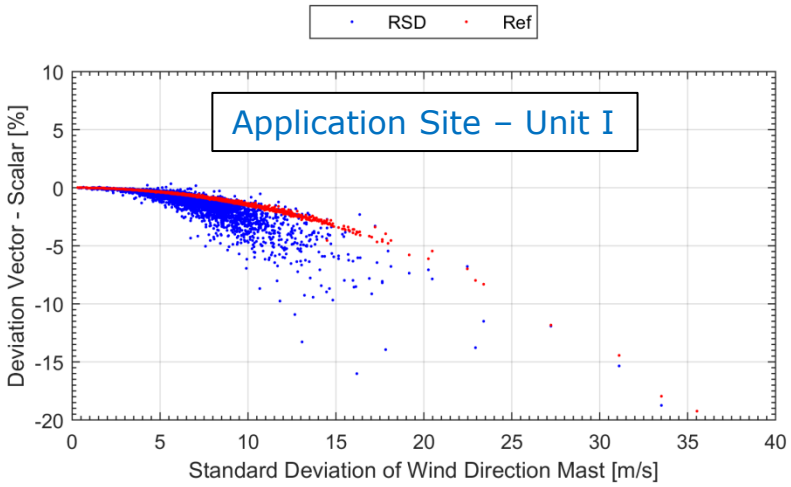


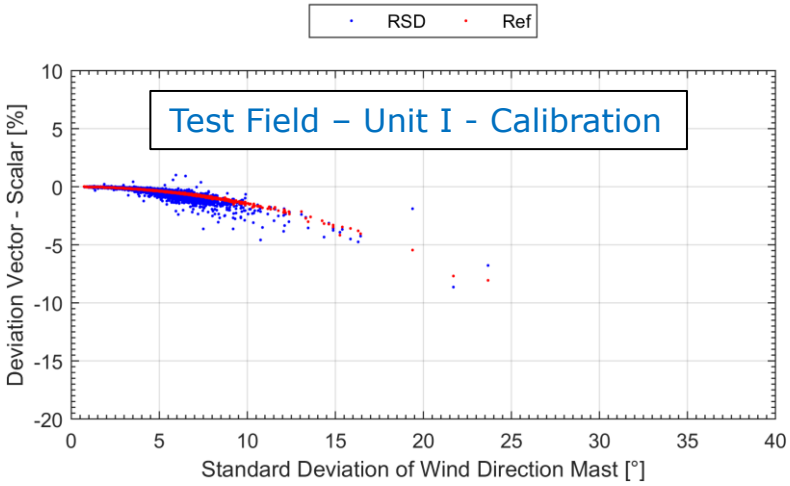


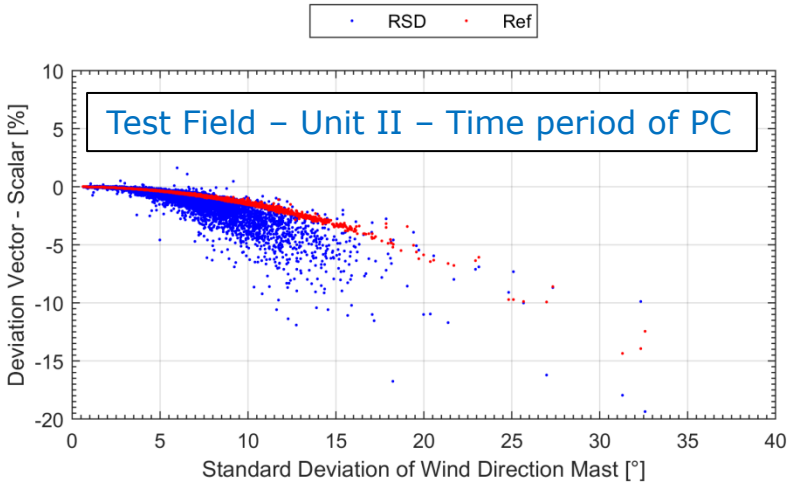


Comparison Vector to Scalar Average

- For a point measurement, difference between scalar and vector averaging driven by variation of wind direction
- Larger deviations between averaging method for the Windcube







Sensitivity on Turbulence Intensity

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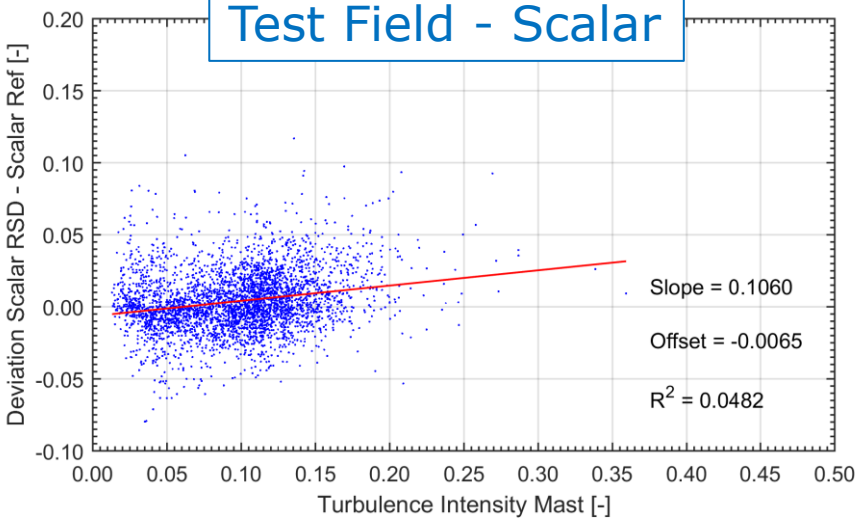
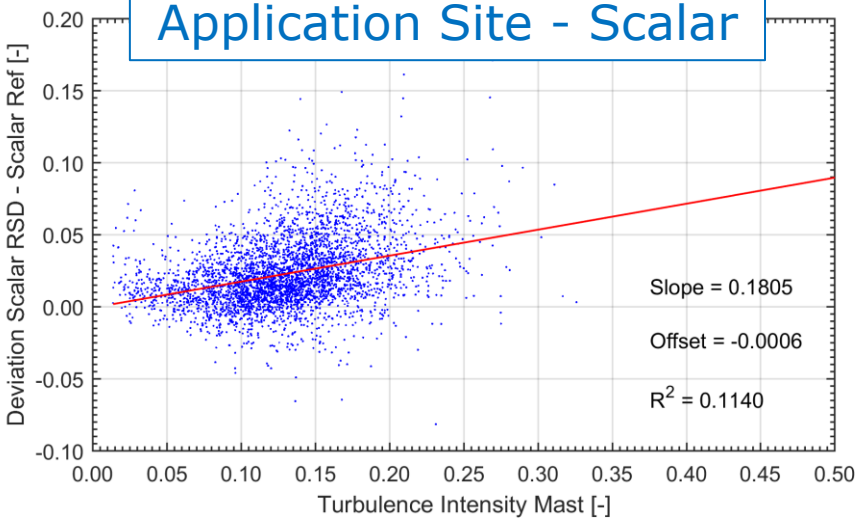
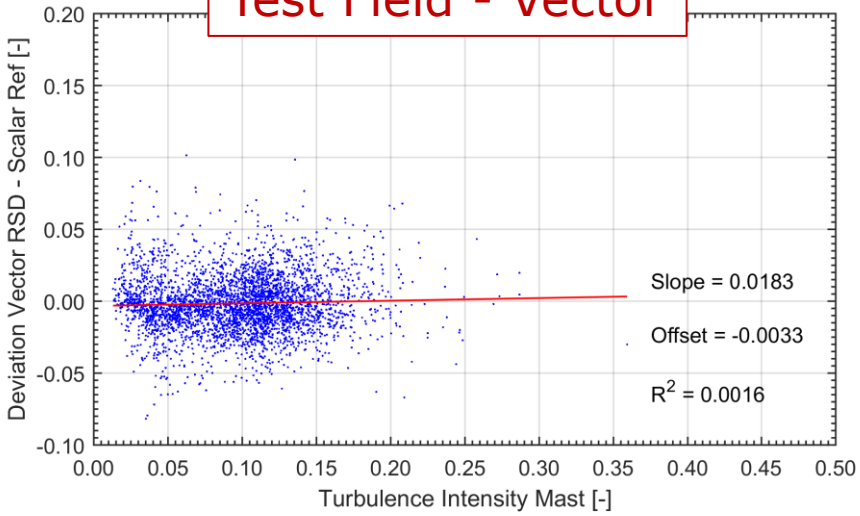
Test Field - Scalar



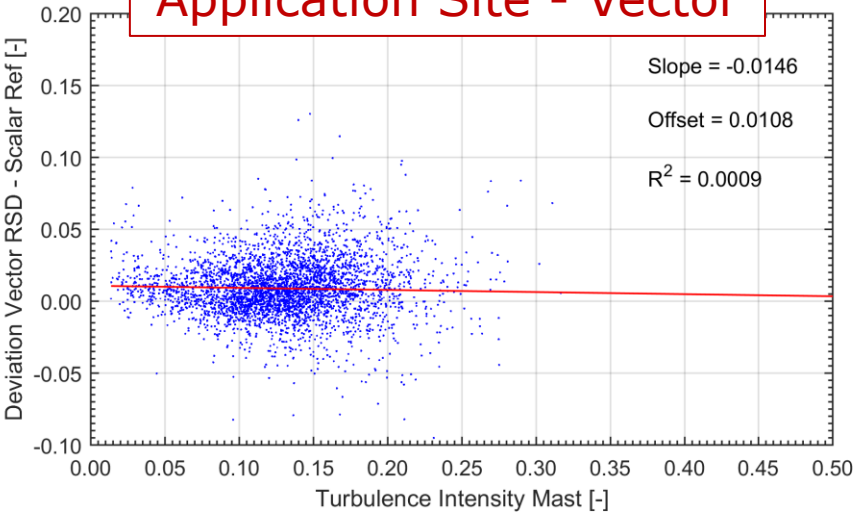
Application Site - Scalar



Test Field - Vector



Application Site - Vector



Sensitivity on Wind Shear

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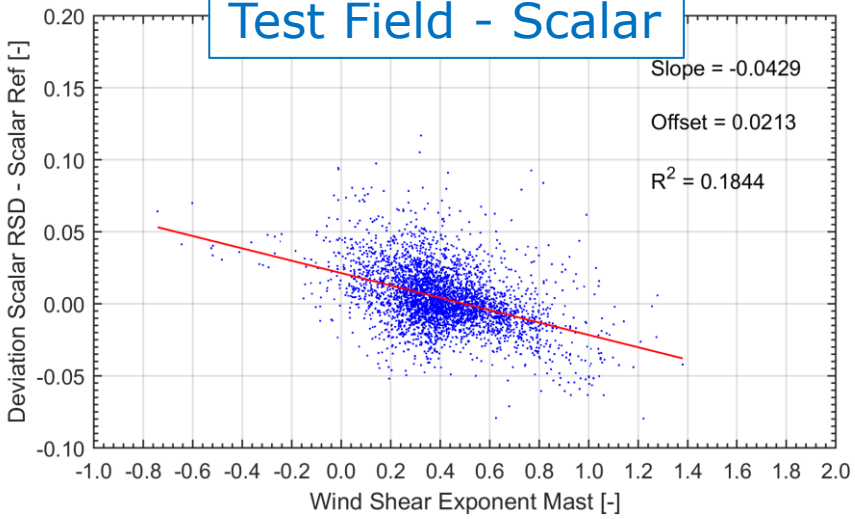
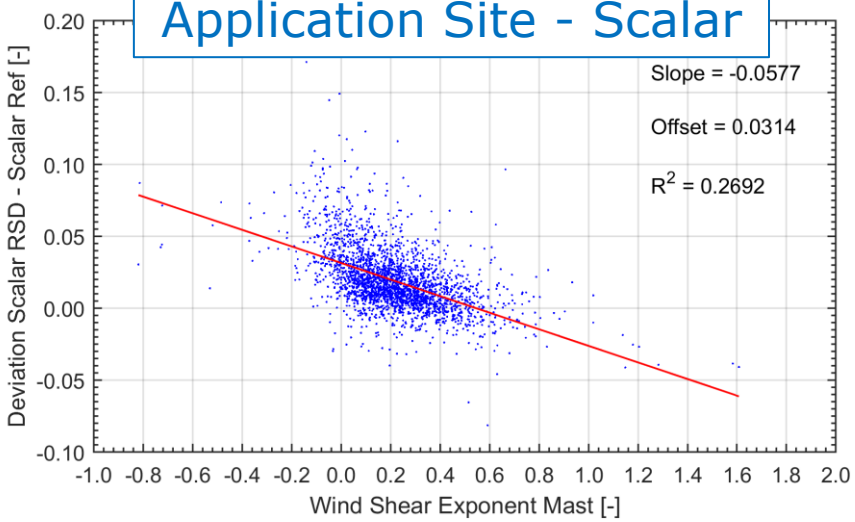
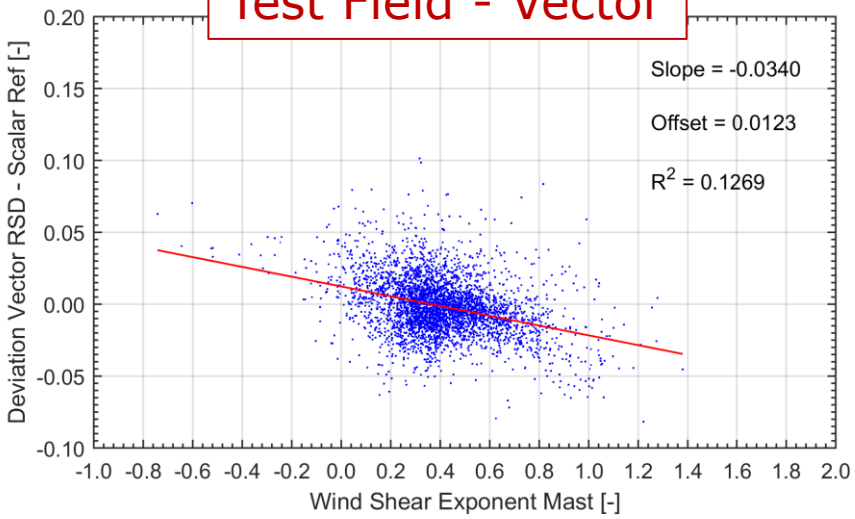
Test Field - Scalar



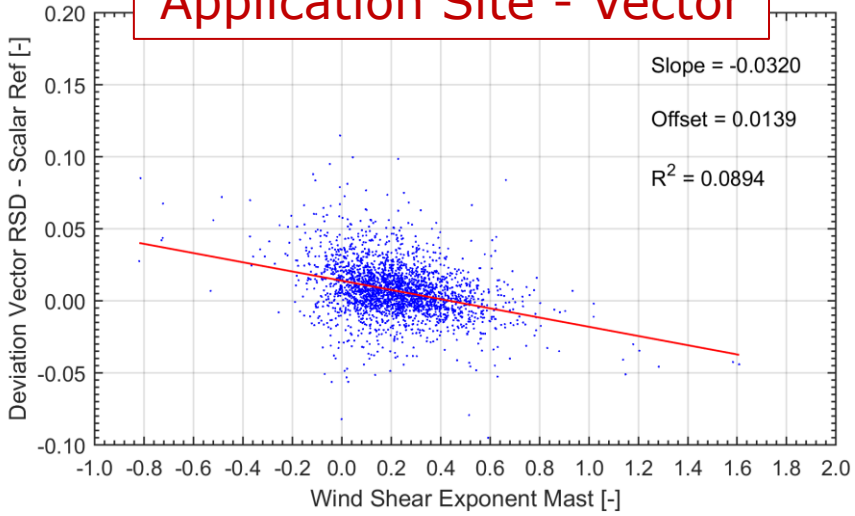
Application Site - Scalar



Test Field - Vector



Application Site - Vector



Classification of Windcube

- Full classification according to IEC 61400-12-1, Ed. 2, requires at least three measurements:
  - At least two different units
  - At least one unit at two sites
- Timeline

2013	First classification analysis for Windcube V2
2017-2018	Two classification measurements on one unit at two sites
	-> Full classification on scalar average
2018	Evaluation of 2017/18 classifications based on vector average

Classification Results: Sensitivities

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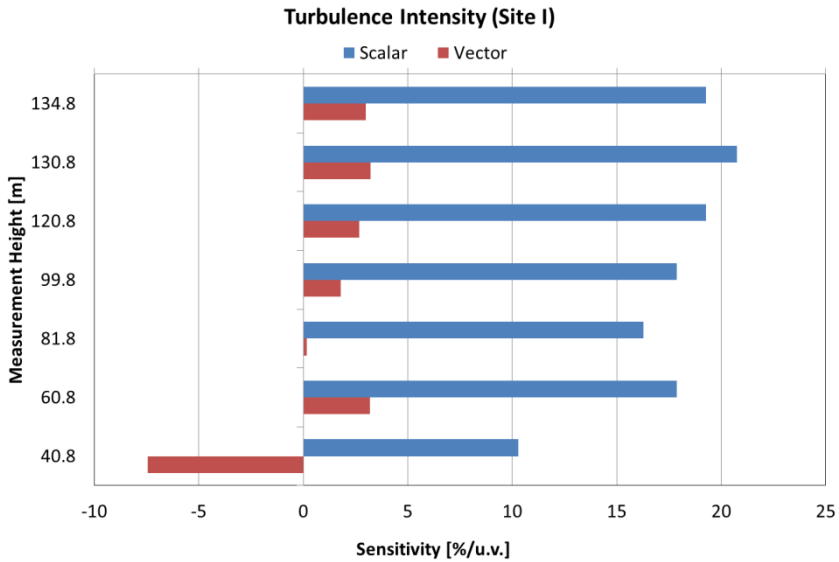
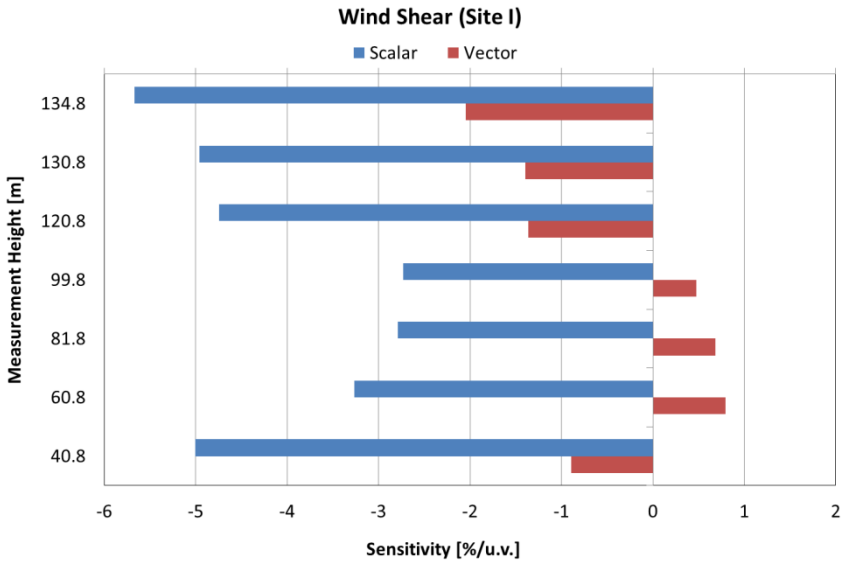
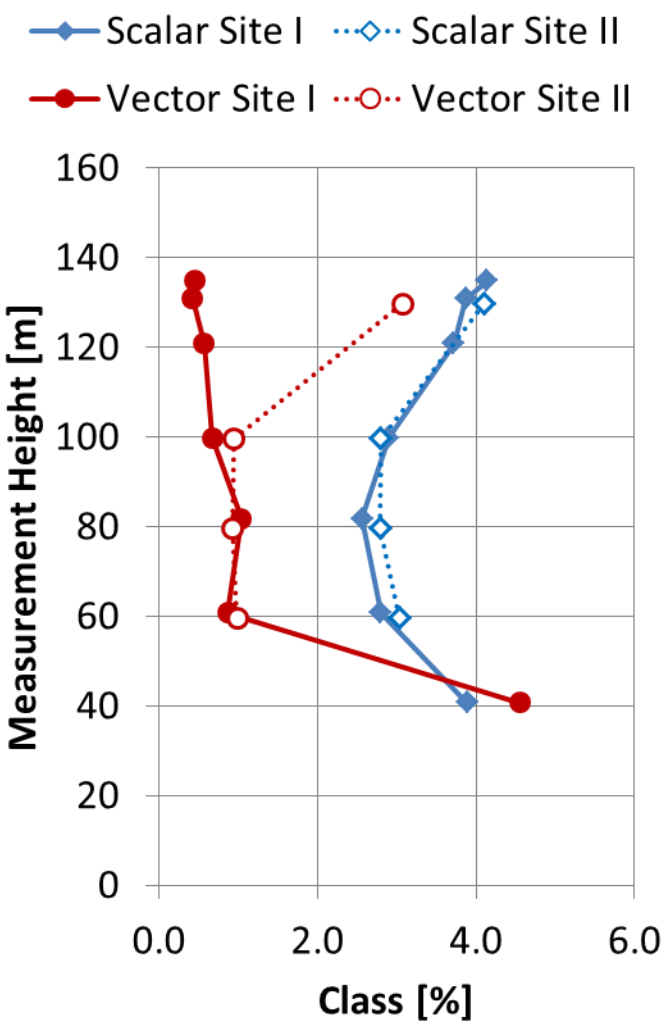
Variable	Unit of Variable (u.v.)	Site I (134.8 m)		Site II (129.7 m)	
		Scalar	Vector	Scalar	Vector
		[%/u.v]	[%/u.v]	[%/u.v]	[%/u.v]
Turbulence Intensity	[-]	**19**	3.0	**17**	6.8
Wind Shear	[-]	**-3.5**	-2.0	**-3.7**	**-3.5**
Wind Direction	[°]	-0.0023	**-0.0035**	0.012	0.008
Precipitation	[%]	-	-	**0.013**	**0.010**



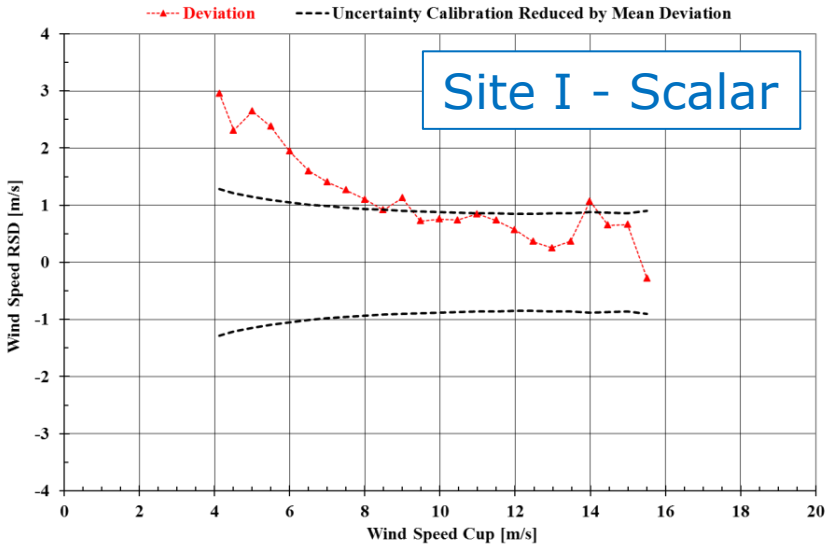


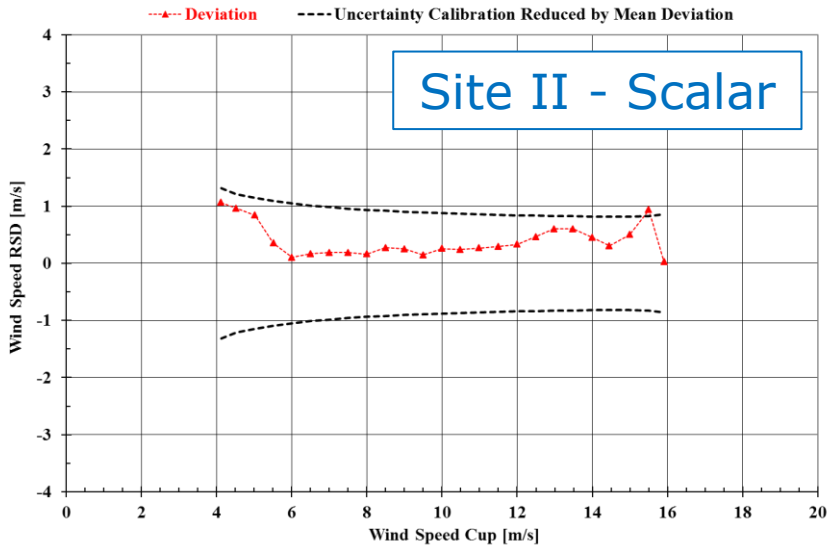
Classification Results: Classes

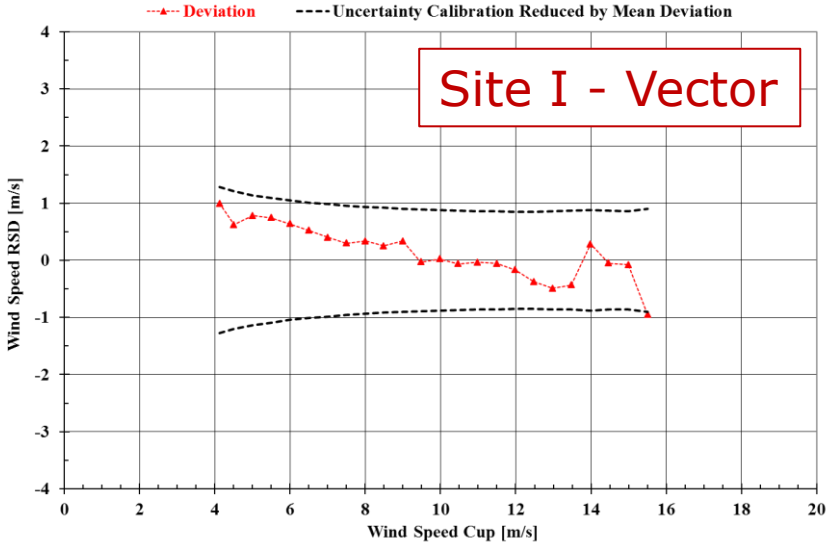
- Vector averaging reduces classes
- Good agreement between sites, except:
  - Top height: Wind Shear not significant at Site I
  - 40 m at Site I influenced by site effects
- Final classification for vector averaging is missing one measurement
- Final classification will use all significant variables at all sites
  -> reduced variation between sites

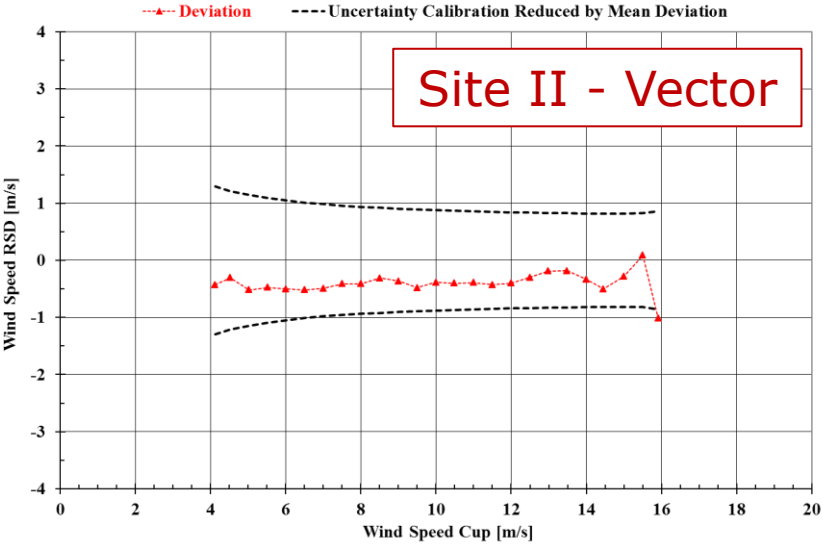


Classification Results: Calibrations









Conclusions

- Vector averaging reduces sensitivities of Windcube data significantly compared to scalar averaging
- Likely the same is true for other monostatic RSDs (as similar sensitivities on TI and shear observed as in case of scalar Windcube)
- At calibrations agreement of cup anemometers to RSDs improved by vector averaging (tendency to small overestimation of wind speed removed)
- Scalar averaging definition of wind speed in IEC is kept by tracing back RSDs to cup anemometers, even in case of implementing vector averaging in RSDs

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Thank you for your attention

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