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Remote Sensing Measurement Height Verification

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Abstract

Deutsche WindGuard (DWG) developed a method to verify the measurement height of a remote sensing device (RSD) in comparison to a met mast. The same data is used as in a calibration of the wind speed measurement of an RSD according to the upcoming revision of IEC 61400-12-1, ed. 2 [1]. The method is based on correlation between time series unlike a previous proposed method based on sensitivity to wind shear [2].

Measurement Height Estimation

From concurrent time series of 10-min wind speed averages at the RSD, the reference anemometer at approx. same height, and one anemometer either 20 m above (*up*) or below (*down*) the following is calculated:

1) Calculate 10-min time-series of wind shear exponent from anemometers
2) Construct wind speed time series at arbitrary heights with wind shear exponent
3) Calculate the estimated measurement height (EMH) as the height with the highest agreement between RSD and constructed wind speed.
4) Define the difference between EMH and the target height of the RSD as measurement height error (MHE)

The following metrics are available to measure agreement between the time series:

|diff| average absolute difference between RSD and constr. time series

|dev| average relative difference

σ diff standard deviation of absolute differences

σ dev standard deviation of relative differences

R correlation between RSD and constr. time series.

Metrics |diff| and |dev| are not advisable as height independent measurement error is misinterpreted as height error.

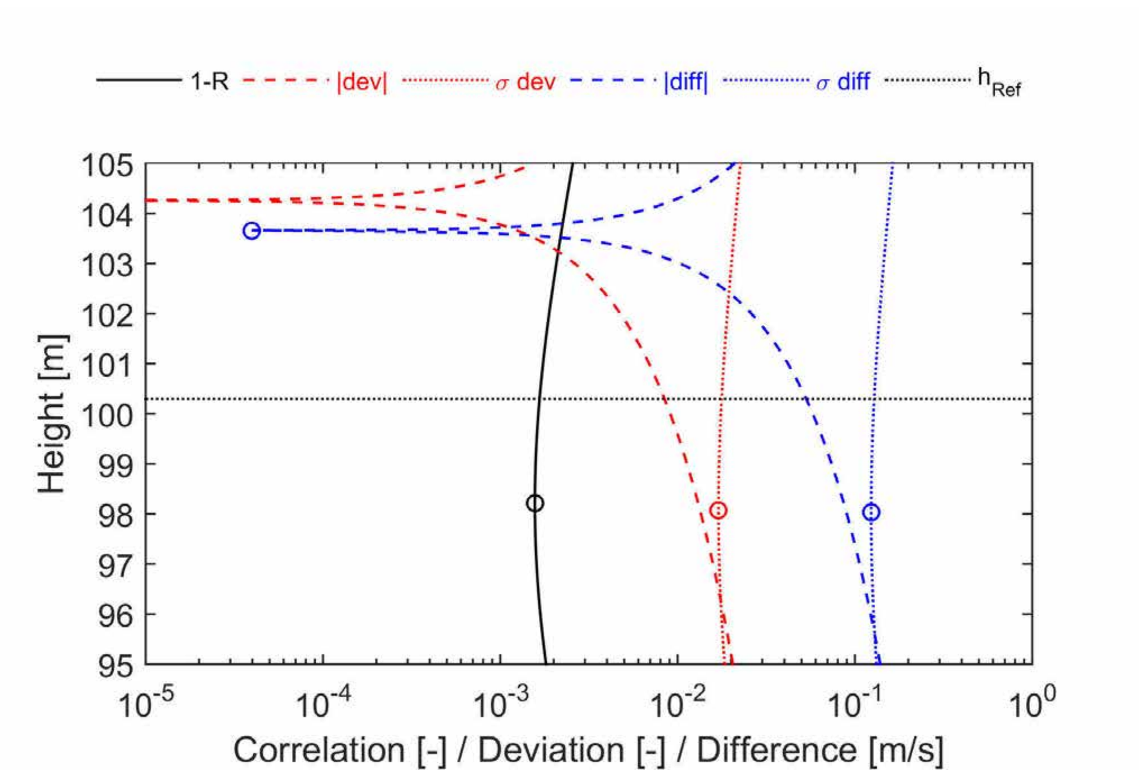

Fig. 1: Example of height estimation metrices. Circles mark the EMH. Correlation R is plotted as (1-R) to encompass all metrices in one graph.

Verification of Method

The described method was tested the following measurement set ups:

1. Using the met mast of DWG's calibration station for RSDs, which consists of 6 height levels between 40 m and 135 m with at least 2 anemometers at each level. Applying the method on the backup anemometer of each height, the height error can be estimated for an instrument, which measurement height is known. In this case, the method reproduces the expected height difference within 1 m of accuracy (Fig. 2).

2. A second test was set up, where two LiDARs where used. One measured at 60 m, 80 m and 100 m to function as the reference instrument. The other measured at heights with differences of about 1 m to 2 m between two consecutive measurement heights. Thus the MHE could be estimated with a larger height difference between reference instrument and tested RSD. Again the method could detect the expected height error within 1 m accuracy (Fig. 3).

In all results there is also calculated the height error based on a multilinear regression of the deviation between RSD and reference sensor with regard to wind speed and wind shear [2].

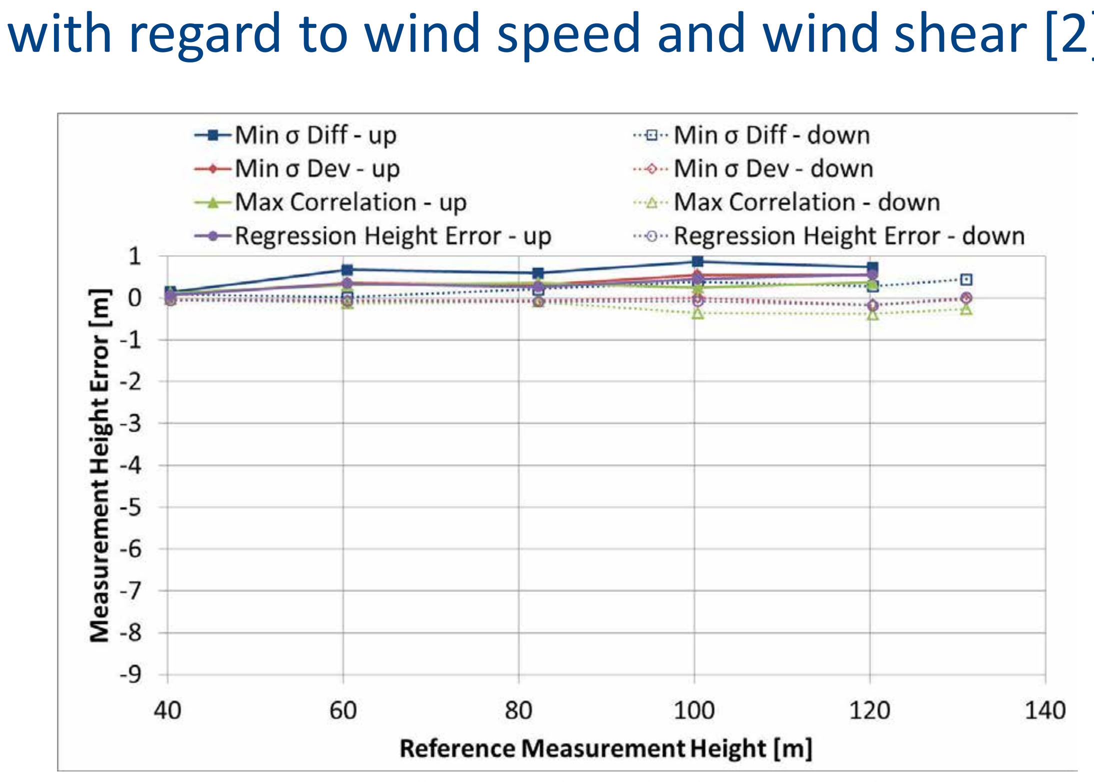

Fig. 2: Verification of method applied to secondary anemometers on DWG's RSD calibration mast .

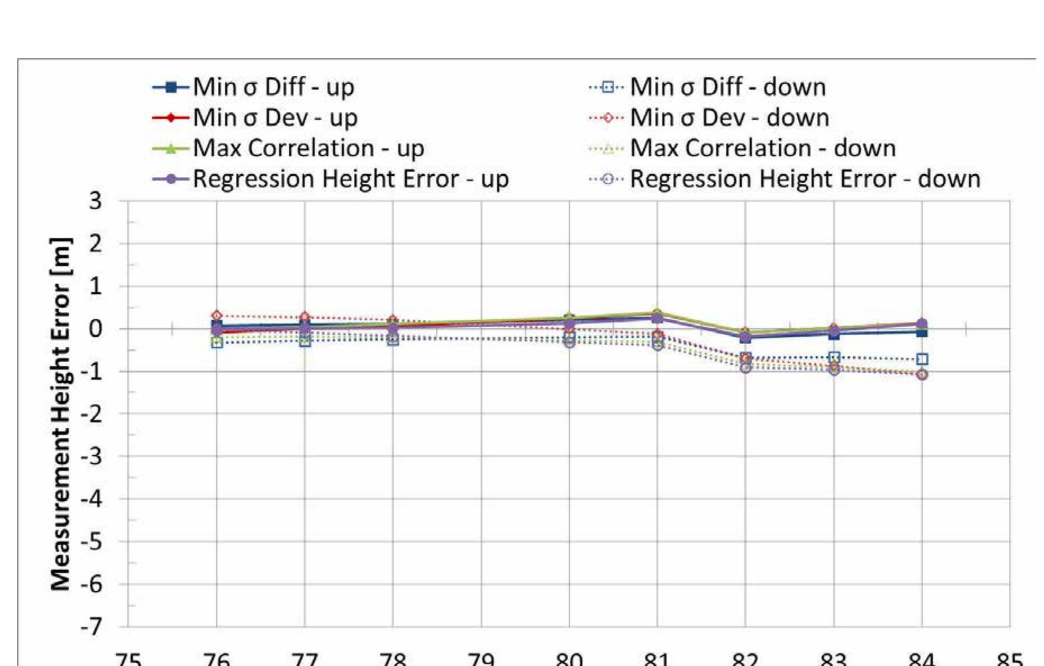

Fig. 3: Verification of method applied to two LiDARs.

Application of Method

Having gained some confidence in the method by the tests above, the method was applied on the data collected during a number of calibration measurements with DWG's RSD calibration mast. A height error of 3 m to 5 m is observed for three tested RSDs (Fig. 4).

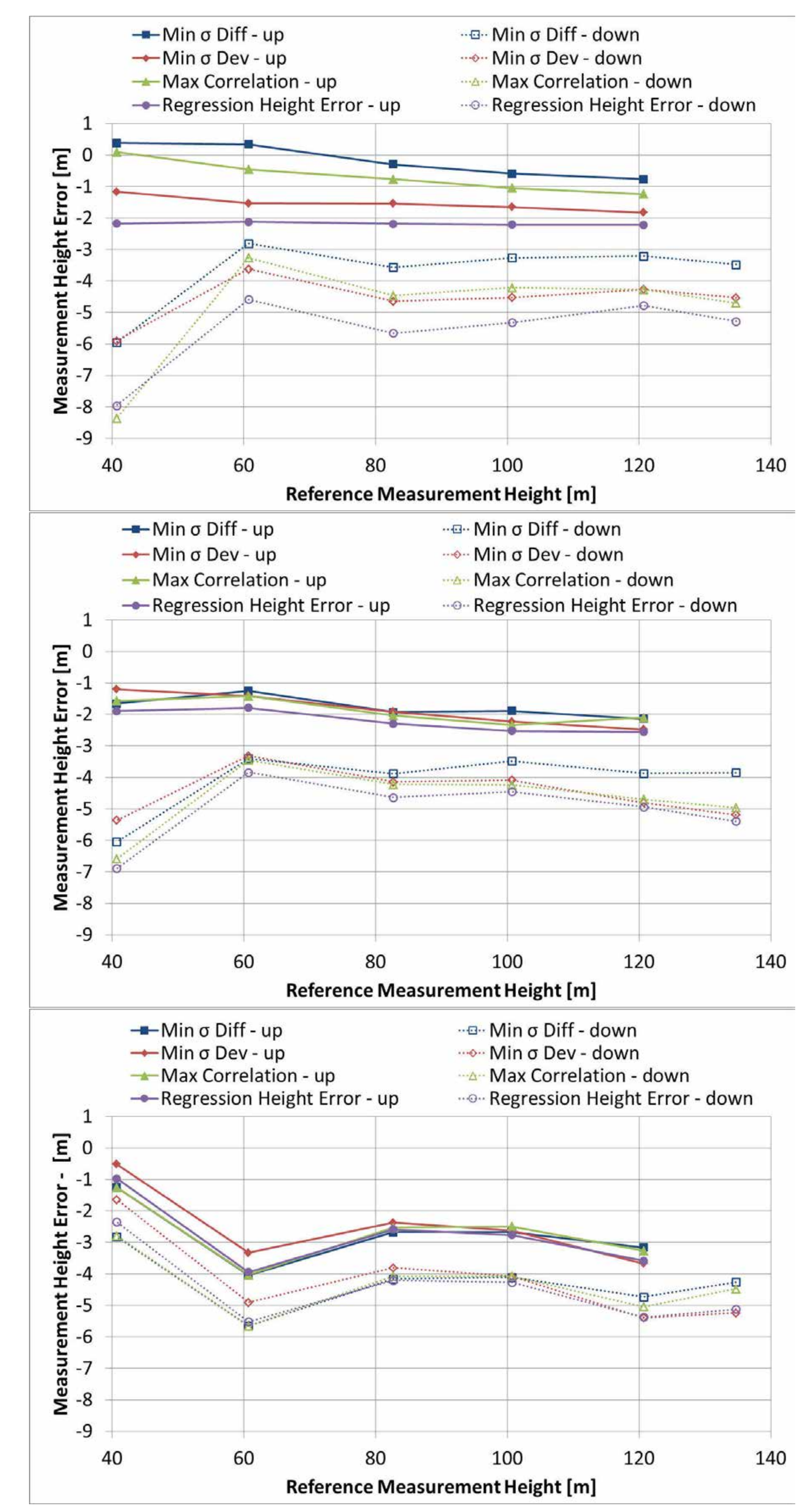

Fig. 4: Application of method on three LiDAR instruments with DWG's RSD calibration mast as reference.

Conclusions

A new method to derive the measurement height error of a remote sensing device was successfully developed. In a control test on known height errors, these height errors could be reproduced by the method with a deviation less than 1 m. In a first test of RSDs against a met mast, height errors of 3 m to 5 m were detected.

References

1. Draft CDV IEC 61400-12-1, Ed. 2, July 2015
2. Gottschall, J.; Courtney, M.: Risø-Report; No. 1732(EN); 2010

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