

## Introduction

In order to investigate conditions for offshore wind power generation in the German coastal areas, three research platforms were constructed in the North Sea (FINO1 and 3) and the Baltic Sea (FINO2). Measurement masts at each platform are equipped with a range of meteorological sensors at heights of 30 m to 100 m above sea level. Standardized analysis and interpretation of the data is necessary to compare the results of the different platforms and will improve the knowledge of the marine ambient conditions at the three locations. Standards given in the IEC can only be partly applied as some requirements are not applicable to offshore masts e.g. due to the wake of the structure. One aim of the FINO-Wind project is the correction and standardisation of offshore mast measurements. All three FINO masts, which are either square or triangular shaped and have different boom constellations, are intensively investigated by comparison with remote sensing techniques as Light Detection and Ranging (LiDAR), Computational Fluid Dynamics (CFD) calculations, the Uniform Ambient Mastflow (UAM)-method [1] and wind tunnel measurements. As an example of the topics in FINO-Wind an analysis of different possible mast corrections is performed and discussed.

## UAM correction

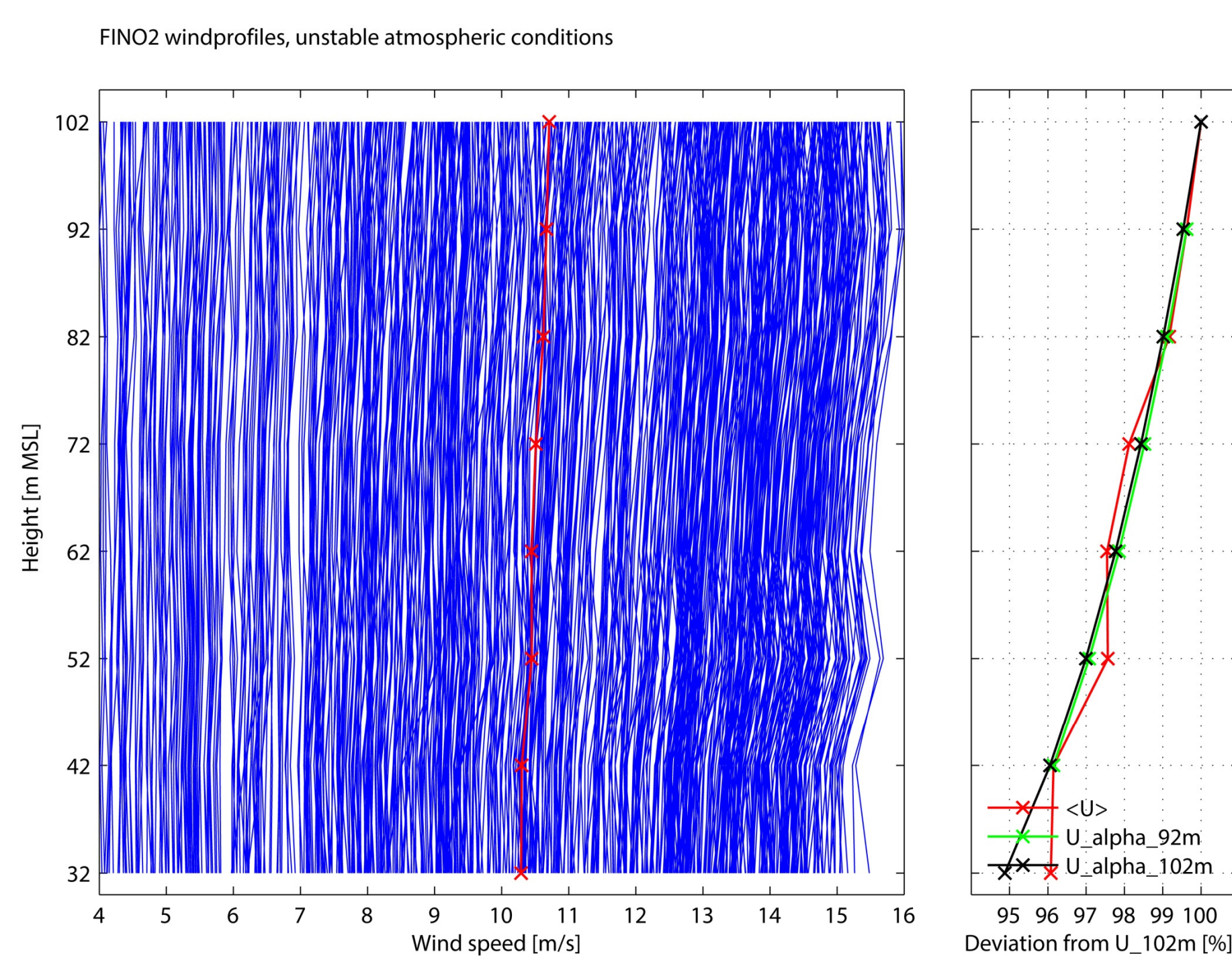


Fig. 1: Based on the assumption that the vertical profile of horizontal wind speed almost vanishes during unstable atmospheric conditions and that any deviation from that is due to mastflow distortion a mast correction can be derived. A logarithmic wind profile is calculated from measurements from the least disturbed wind direction sector during unstable conditions. This profile is applied to the top-anemometer measurement or any other wind direction during unstable conditions to calculate the undisturbed wind speed at every boom. The ratios of the calculated and measured wind speeds result in mast correction factors after bin-wise averaging with regard to wind direction.

## LiDAR mast correction

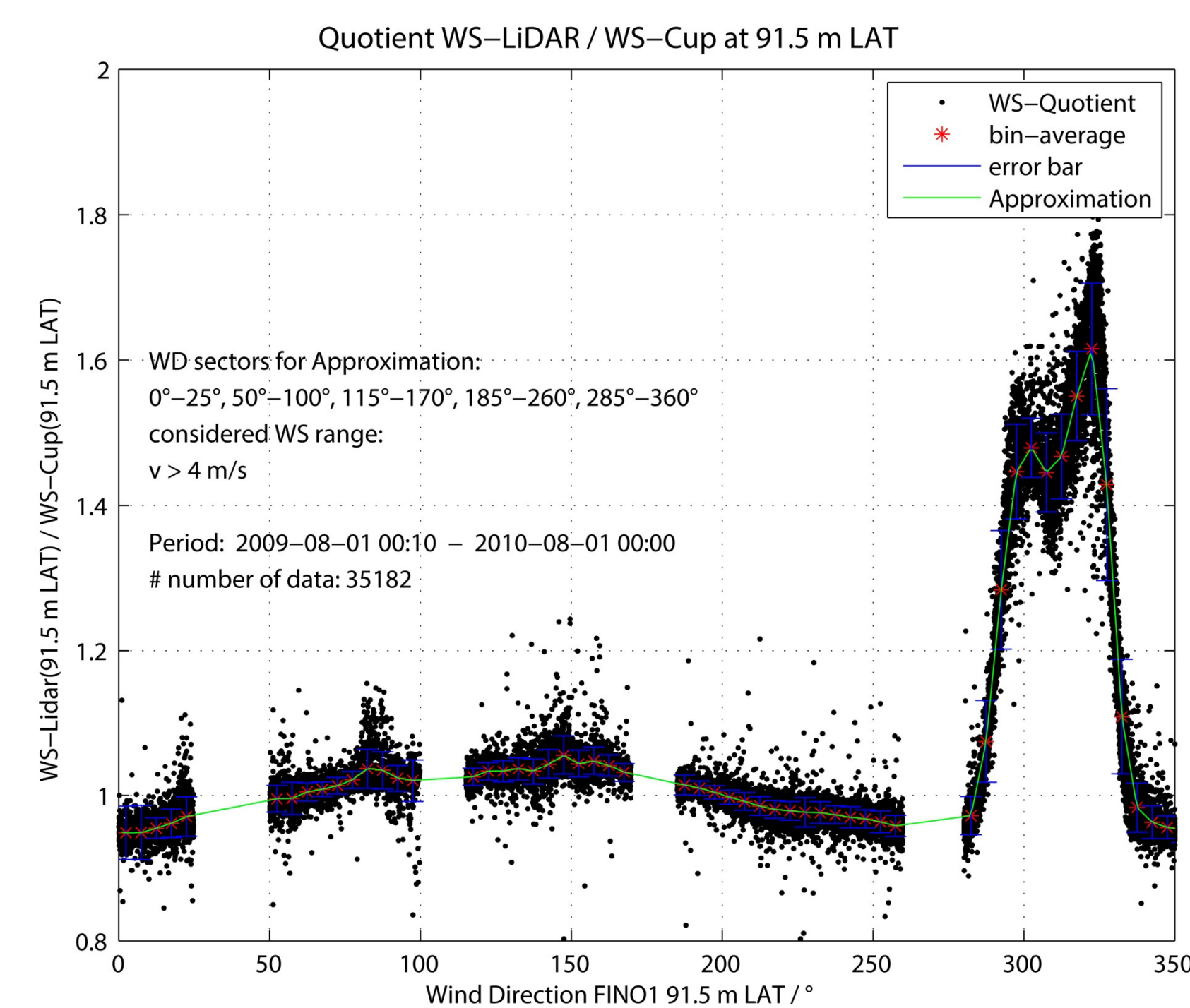


Fig. 2: Prerequisite for a LiDAR based mast correction is the assumption that the LiDAR measurement is undisturbed. Datasets with one of the LiDAR beams downwind of the mast are removed as the gaps show in the picture on the left. The mast correction function can be derived from the mean bin-wise quotient from LiDAR and cup-anemometer wind speed measurements. The black dots are showing every single wind speed quotient, the red crosses reflect the bin average values. By interpolating the bin mean values correction factors for every wind direction can be derived.

## CFD calculations – wind tunnel tests

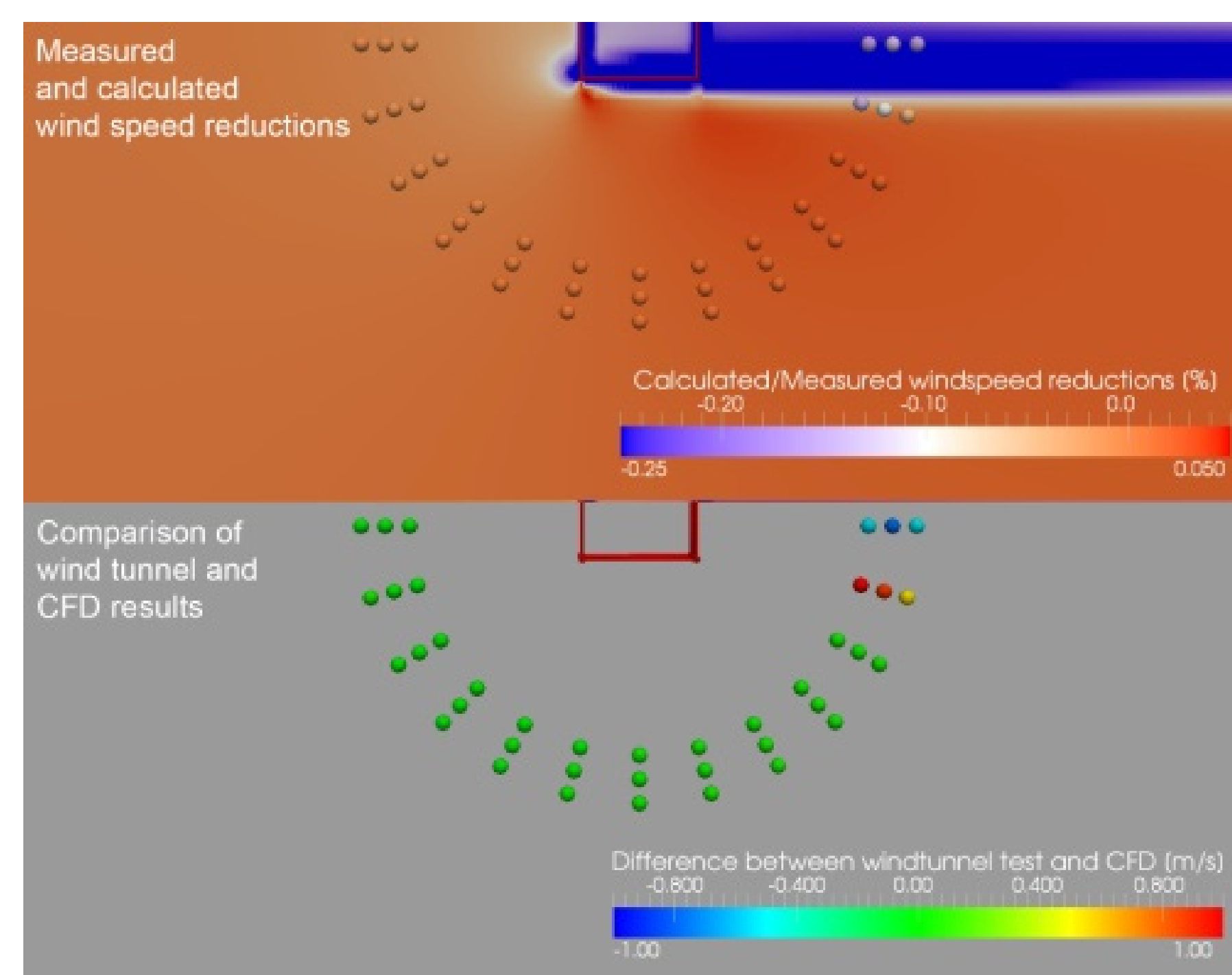


Fig. 3: Wind speed reductions calculated by CFD methods are in good agreement with wind tunnel measurements of a simplified mast segment model. Followed by this study CFD calculations of detailed 10 m FINO1 mast segments were carried out with OpenFoam®. Turbulence was considered by using the k-ε Re-Normalisation group-model [2]. The ratios of the modeled inflow wind speeds and the wind speeds calculated at the cup-anemometer positions are derived for different inflow directions and shown in Fig. 5.

## Composed wind speed method

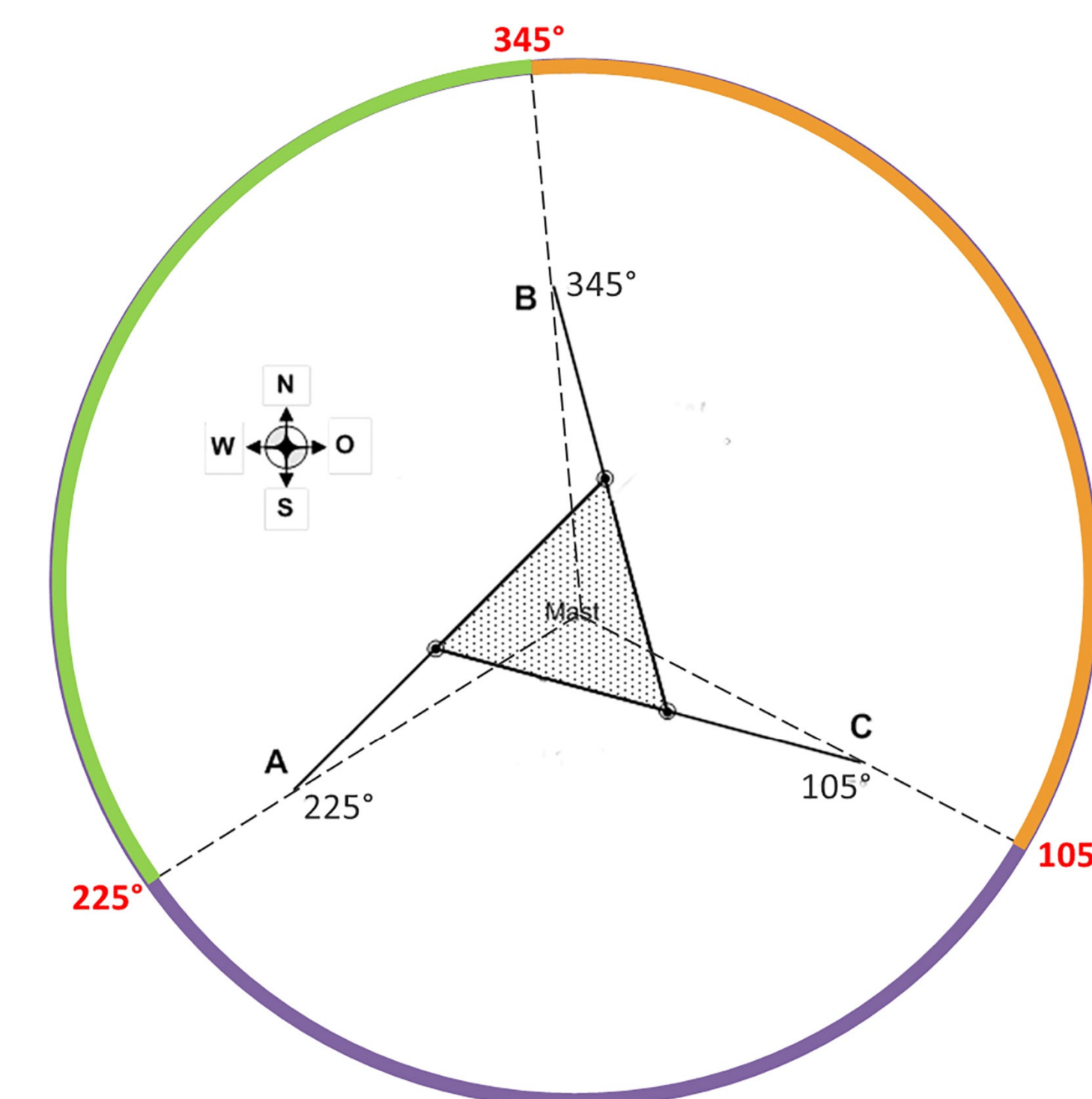


Fig. 4: If a triangular shaped mast and an instrumentation set-up with three cup-anemometers orientated to three different directions is available an alternative is the calculation of a composed wind speed. If the wind flow approaches from the wind direction interval 225°-345° (between boom A and B) the average of cup at boom A and B would be calculated - the same applies for the wind direction intervals 345°-105° (between B and C) and 105°-225° (between C and A). Wind speed lowering flow distortion effects at one cup-anemometer are compensated by wind speed increasing flow distortion effects at the second cup-anemometer.

## Results

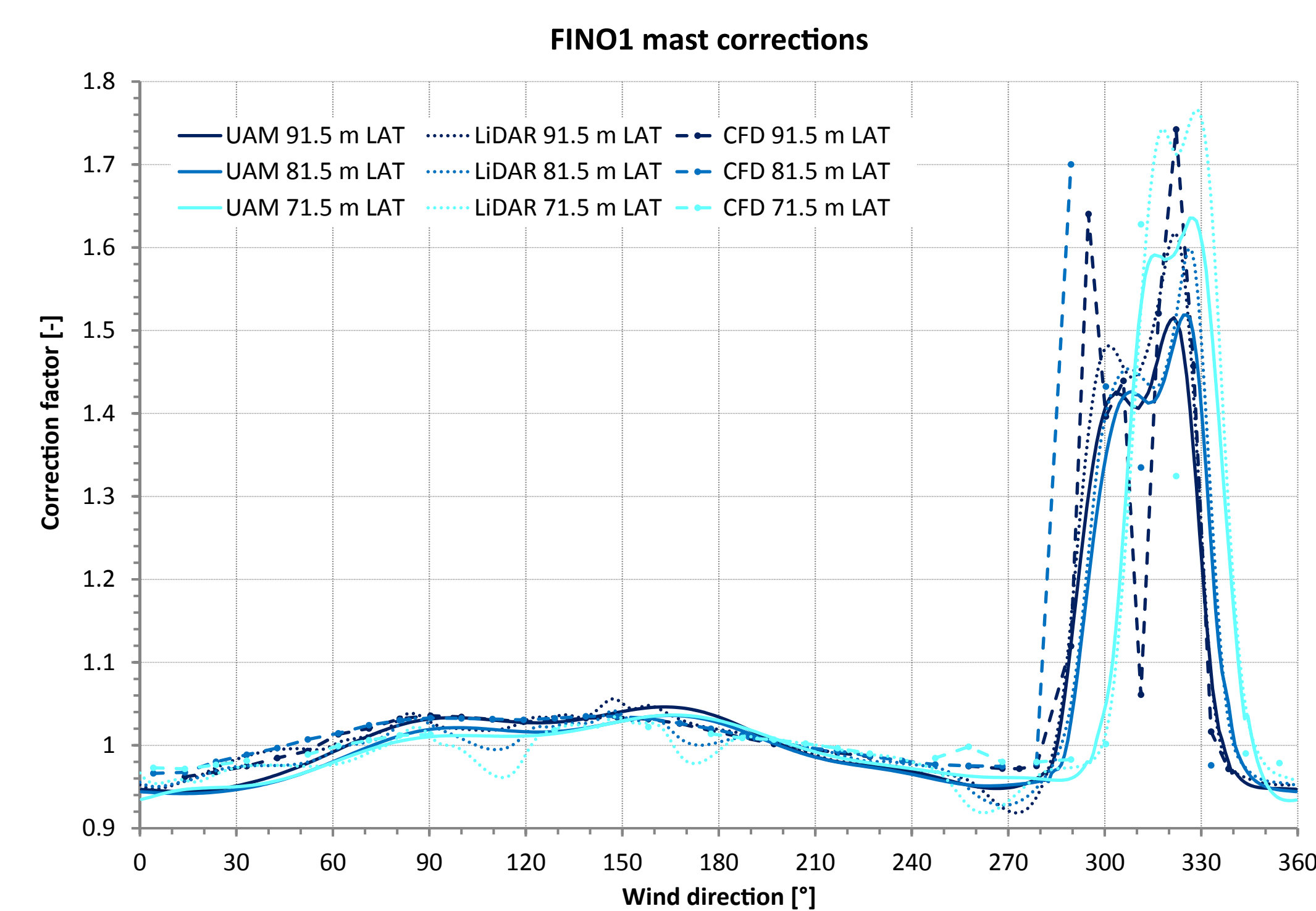


Fig. 5: Mast correction factors derived for FINO1 from UAM, LiDAR and CFD method.

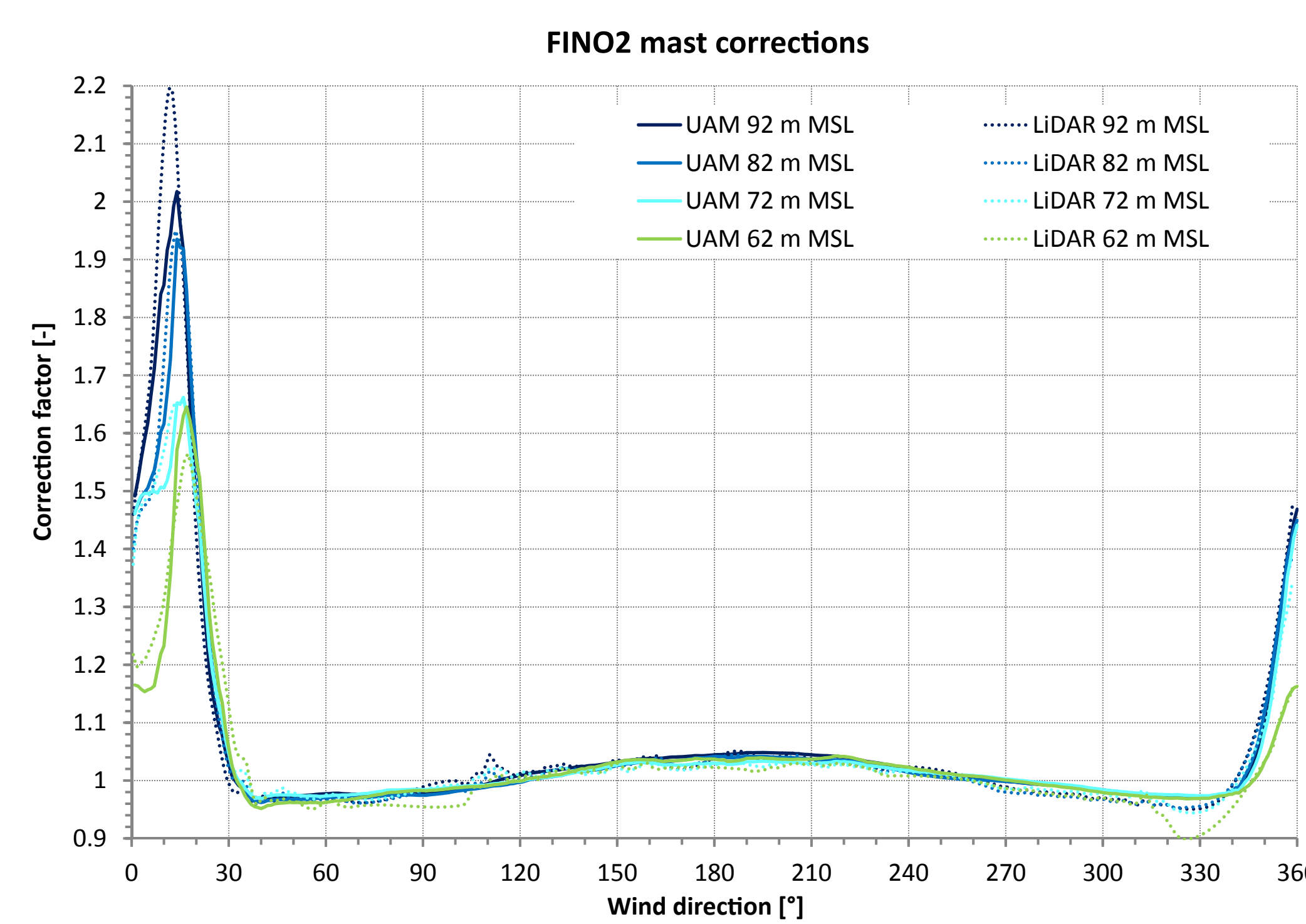


Fig. 6: Mast correction factors derived for FINO2 from UAM and LiDAR method.

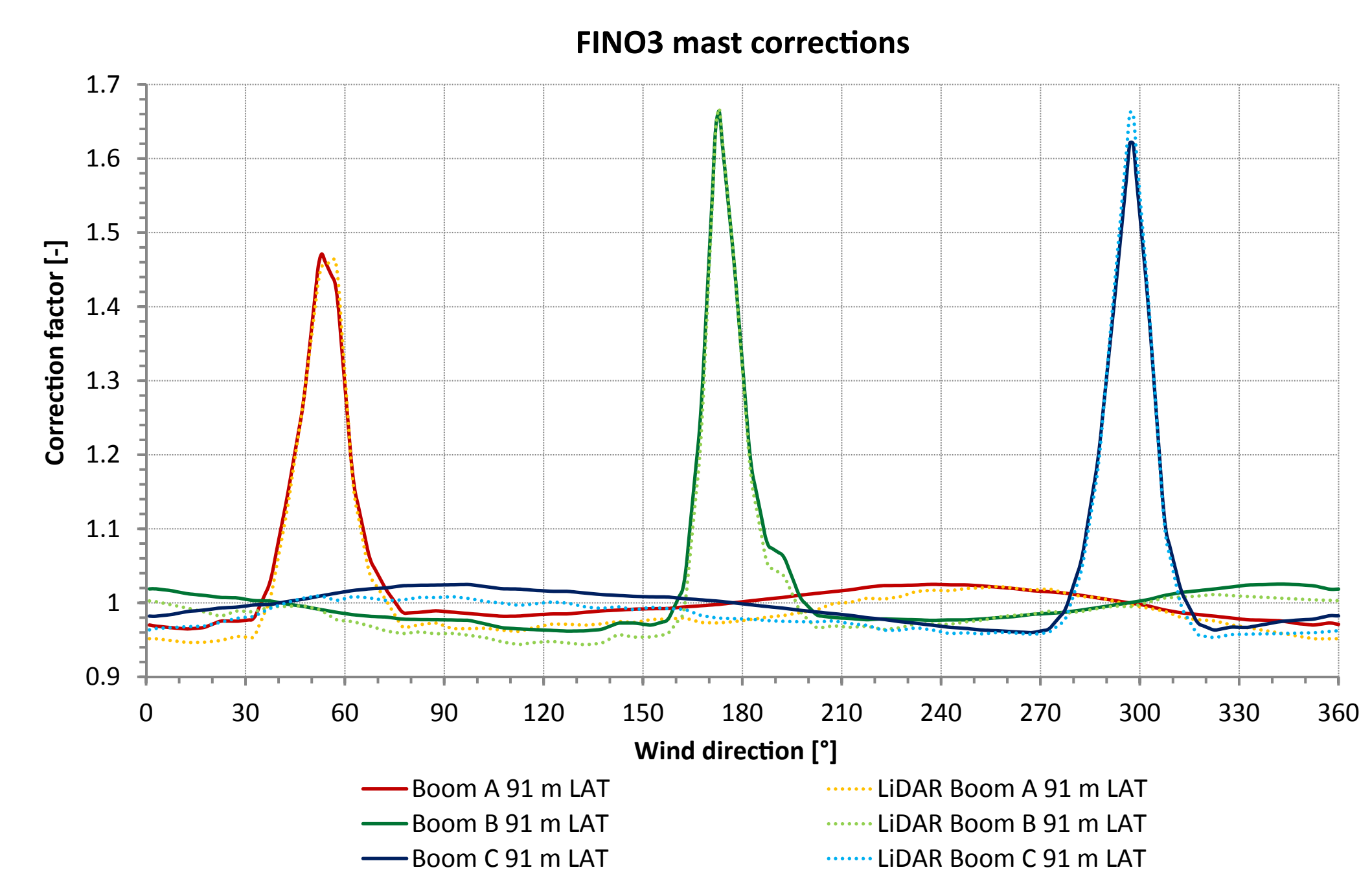


Fig. 7: Mast correction factors derived for FINO3 from LiDAR method (dotted line). For comparison the ratio of the composed and the measured wind speed is also shown (continuous line).

## Conclusions and Outlook

All of the derived mast corrections show similar mast distortion effects for each of the FINO masts with large wind speed reduction for the anemometers if downwind of the mast and slight wind speed reduction if upwind of the mast. The anemometers receive speed-up effects during lateral inflow. For each of the FINO masts one distinctive mast correction method with least uncertainties can be identified and shall be applied to measured wind speeds in the future. Wind farms are being erected close to each FINO platform, therefore at a next step wake field situations for each mast from existing and planned wind farms in the surroundings shall be investigated in order to estimate these effects on the measurements.

## Acknowledgements

The FINO-Wind research project is funded under the 'Wind Energy' initiative of the German Federal Ministry for the Economic Affairs and Energy and project management Projektträger Jülich for the period 2013 to 2015.



- [1] A. Westerhellweg, T. Neumann, V. Riedel, FINO1 Mast Correction, DEWI Magazin, 2012.
- [2] F. Wilts, B. Canadillas, F. Kinder, T. Neumann, CFD calculations of FINO1 mast effects, CEWE 2014, Hamburg.