Wettermast Hamburg: Applying Mixing Length Models at a Heterogeneous Location

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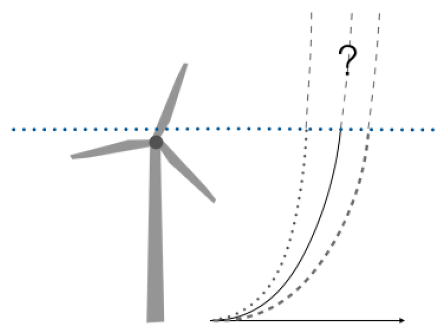
Introduction

Mixing length models have been introduced in an attempt to extend the wind profile description beyond the surface layer to heights of 100 m or higher.

How well are those models able to predict the wind speed at turbine heights and above? This is evaluated using data taken at the Wettermast Hamburg site.



Measurement facility: Wettermast Hamburg

- Solid cylindrical mast (300 m) and secondary mast (12 m)
- Located at the easterly outskirts of Hamburg, Germany: Rural landscape to the east and urban surroundings to the west (Fig. 2)
- Equipped with meteorological instruments in 9 levels (2 m to 280 m)
- Continuous measurements since 1995

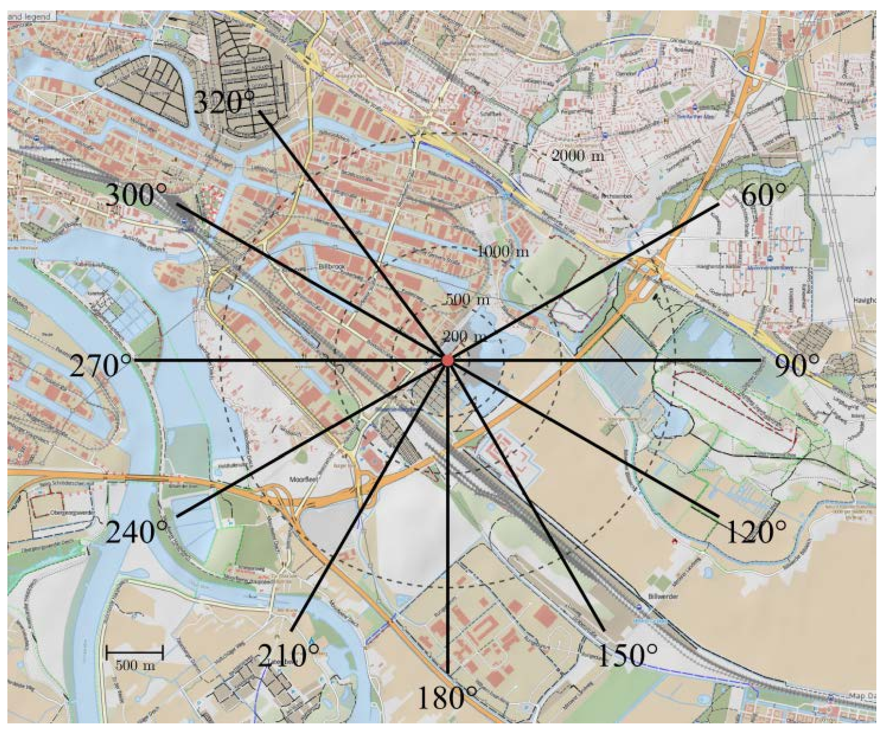


Fig. 2: Map of location and surroundings of Wettermast Hamburg.

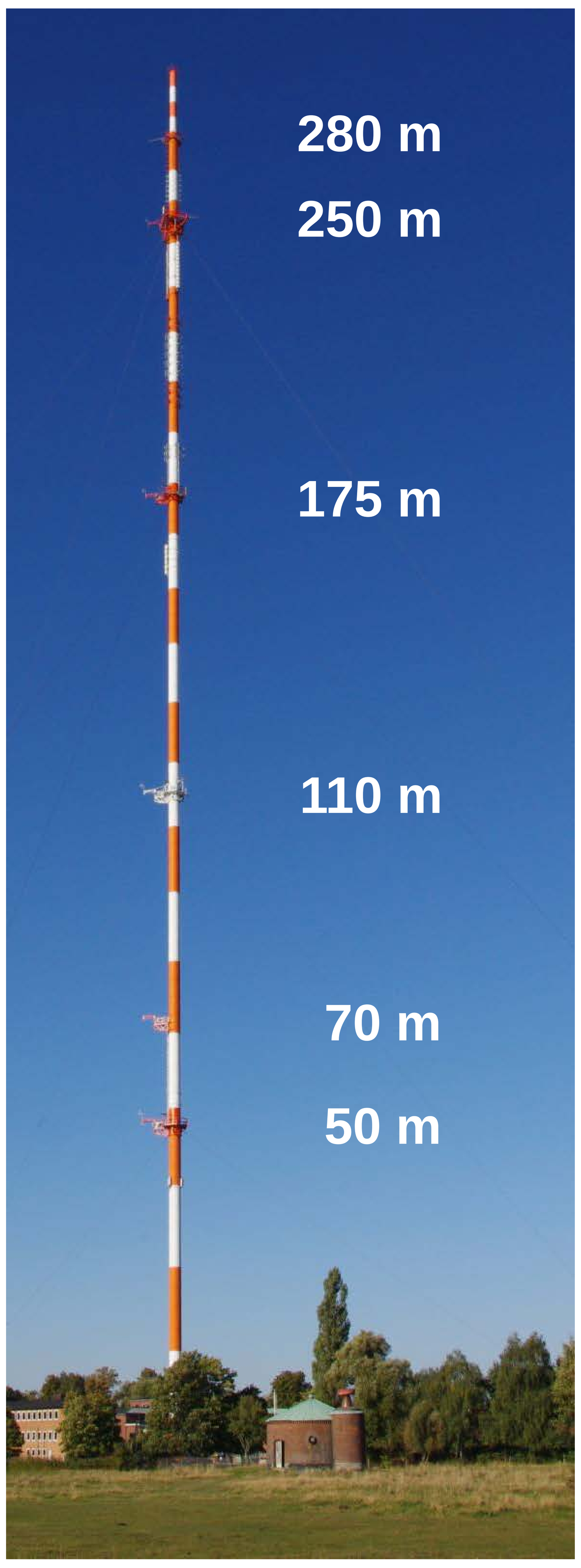


Fig. 1: Picture of main mast (Image courtesy of I. Lange).

Measurement Data

- October 2000 until March 2012
- Different stability categories based on Obukhov length
- Wind direction sector 90° to 150°: meadows, flat vegetation (z_0 = 0.16 m)
- Complete profiles between 10 m and 250 m used

	Obukhov length interval (m)	Number of profiles
very unstable (vu)	$-50 \geq L > -100$	2 266
unstable (u)	$-100 \geq L > -200$	2 382
near unstable (nu)	$-200 \geq L > -500$	2 247
neutral (n)	$\|L\| \geq 500$	14 342
near stable (ns)	$500 \geq L > 200$	7 930
stable (s)	$200 \geq L > 50$	7 063
very stable (vs)	$50 \geq L > 10$	2 138

Tab. 1: Stability parameter limits and resulting number of profiles in each category

Evaluation of mixing length models

Models to extend wind profile formulation beyond the boundary layer proposed by Gryning et al. (2007) and Peña et al. (2010) based on extension of mixing length formulation.

- Below 110 m good agreement for both models
- Larger deviations for very stable and very unstable categories
- Deviations between measurement and predicted wind speed by means of RMSE and average bias, normalized with average wind speed at respective height
- RMSE smallest for both approaches in unstable stratification in 110 m and 175 m
- Average Bias shows frequent underestimation of wind speed by Gryning approach;
  less underestimation by Peña model
- Errors are smallest for unstable stratification with convective boundary layer extending beyond measuring heights;
  larger deviations in stable stratification, increasing with height

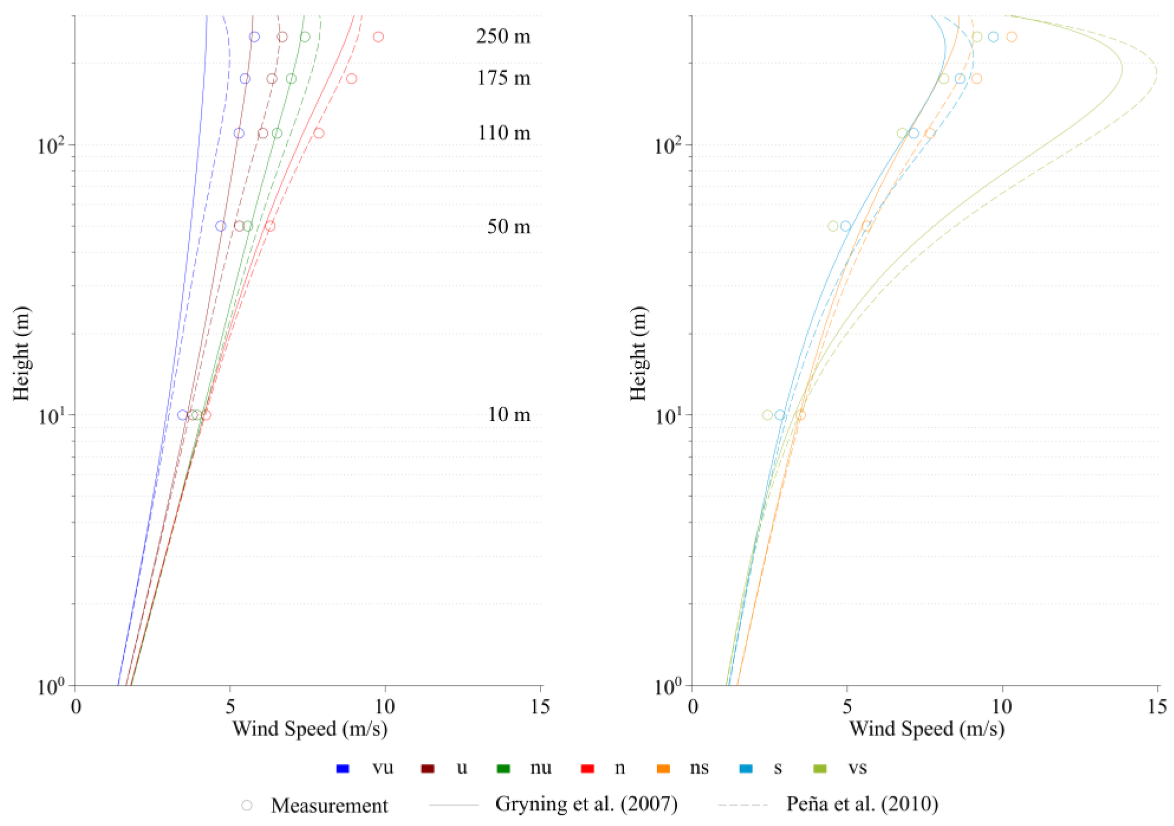


Fig. 3: Measured and modeled wind speed profiles

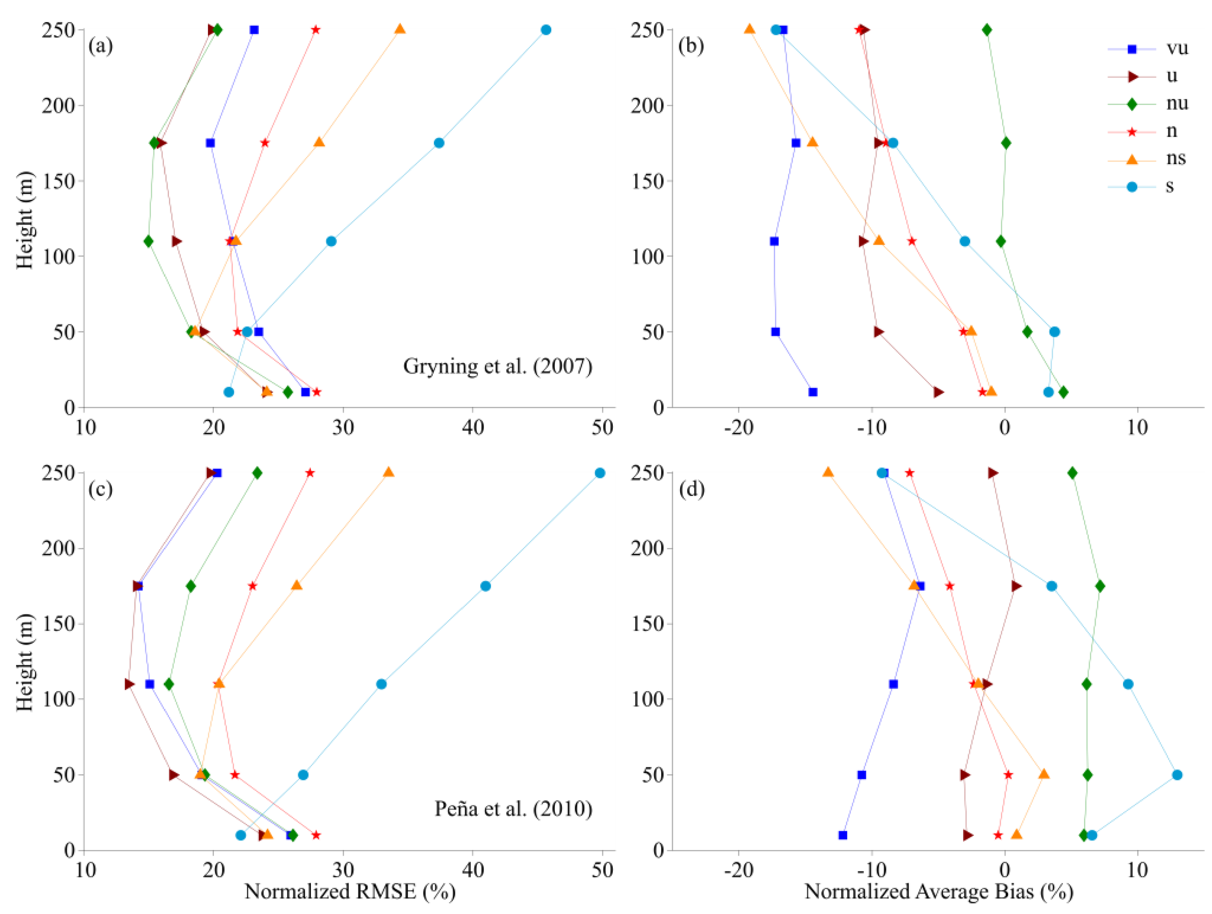


Fig. 4: .Error estimates of model results from comparison with measurements

Conclusion

- Wettermast Hamburg provides long term profile measurements at unique location
- Best prediction of wind speed in unstable stratification
- Errors are larger in stable stratification and increase with height
- Average bias of Peña model closer to zero
- Height of boundary layer only approximated → measurements would be beneficial
- Overall, both are good estimations of wind speeds at higher levels at this location

References

Gryning et al. (2007): On the extension of the wind profile over homogeneous terrain beyond the surface boundary layer. *Bound.-Layer Meteor.* 124(2):251–268

Peña et al. (2010) Comparing mixing-length models of the diabatic wind profile over homogeneous terrain. *Theoretical and Applied Climatology* 2010; 100(3-4):325–335

Further Information

For more Information and current measurement data visit www.wettermast-hamburg.zmaw.de

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