WIND PROFILES FOR THE ATMOSPHERIC BOUNDARY LAYER IN DIFFERENT STABILITY CONDITIONS

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MOTIVATION

Currently, there is an increasing need for expressions for the wind speed variation in the atmospheric boundary layer, for a variety of applied research as well as modeling studies. In addition to pollution dispersion and scalar transport, analysis of wind power generation or loading on buildings and bridges might be mentioned.

OBJECTIVE

To evaluate the performance of a formulation for the wind speed profile in the atmospheric boundary layer in different atmospheric stability conditions using measurements from tall masts obtained in neutral and diabatic conditions.

OBSERVATIONAL DATA

1) **Høvsøre** (Denmark) testing station for wind turbines (rural area) on a 116m meteorological mast and a 160m nearby light-mast (at 10, 40, 60, 80, 100, 116 and 160m).
2) **Hamburg** (Germany) (residential and urban areas) on a TV tower and a nearby small mast (at 12, 50, 110, 175 and 250m) .

The information needed for the wind speed calculations was obtained from Gryning et al. (2007) .

Stability Class	Range of L (m)	Mean L (m)	z_0 (m)	U_{*0} (m/s)	h (m)
Høvsøre					
1	-100 to -50	-71	0.018	0.340	500
2	-200 to -100	-142	0.013	0.367	500
3	-500 to -200	-275	0.012	0.405	500
n	L>500; L<−500	neutral	0.014	0.388	320
4	200 to 500	323	0.013	0.358	280
5	50 to 200	108	0.008	0.249	200
6	10 to 50	24	0.0013	0.152	200
Hamburg - urban					
1	-200 to -100	-148	0.45	0.553	570
2	-500 to -200	-322	0.55	0.659	600
3	L>500; L<−500	neutral	0.65	0.671	800
n	200 to 50	349	0.43	0.436	1000

WIND PROFILES

The profiles of wind speed are functions of the relative height (z/h, where h is the atmospheric boundary layer height), the friction velocity (u_*) and the stability parameter (h/L, where L is the Obukhov length) (Ulke, 2000).

Stable conditions (h/L > 0):

$$\bar{u}(z)=\frac{u_{*0}}{k}\left\{\ln\frac{z}{z_0}-\left[1-6.9\frac{h}{L}\right]\left[\frac{z-z_0}{h}\right]-\frac{6.9}{2}\frac{h}{L}\left[\frac{z^2}{h^2}-\frac{z_0^2}{h^2}\right]\right\}$$

Unstable conditions (h/L < 0):

$$\bar{u}(z)=\frac{u_{*0}}{k}\left\{\ln\frac{z}{z_0}+\ln\left[\frac{(1+\mu_0^2)(1+\mu_0)^2}{(1+\mu^2)(1+\mu)^2}\right]+2\left[\tan^{-1}\mu-\tan^{-1}\mu_0\right]+\frac{2L}{33h}\left[\mu^3-\mu_0^3\right]\right\}$$

u_{*0}: surface friction velocity, z_0: surface roughness length, k: von Karman's constant.
The coefficients of the atmospheric stability factors are from Wieringa (1980).

$$\mu=\left(1-22\frac{h}{L}\frac{z}{h}\right)^{1/4} \qquad \mu_0=\left(1-22\frac{h}{L}\frac{z_0}{h}\right)^{1/4}$$

RESULTS

Comparison between the measurements and the calculated wind speeds

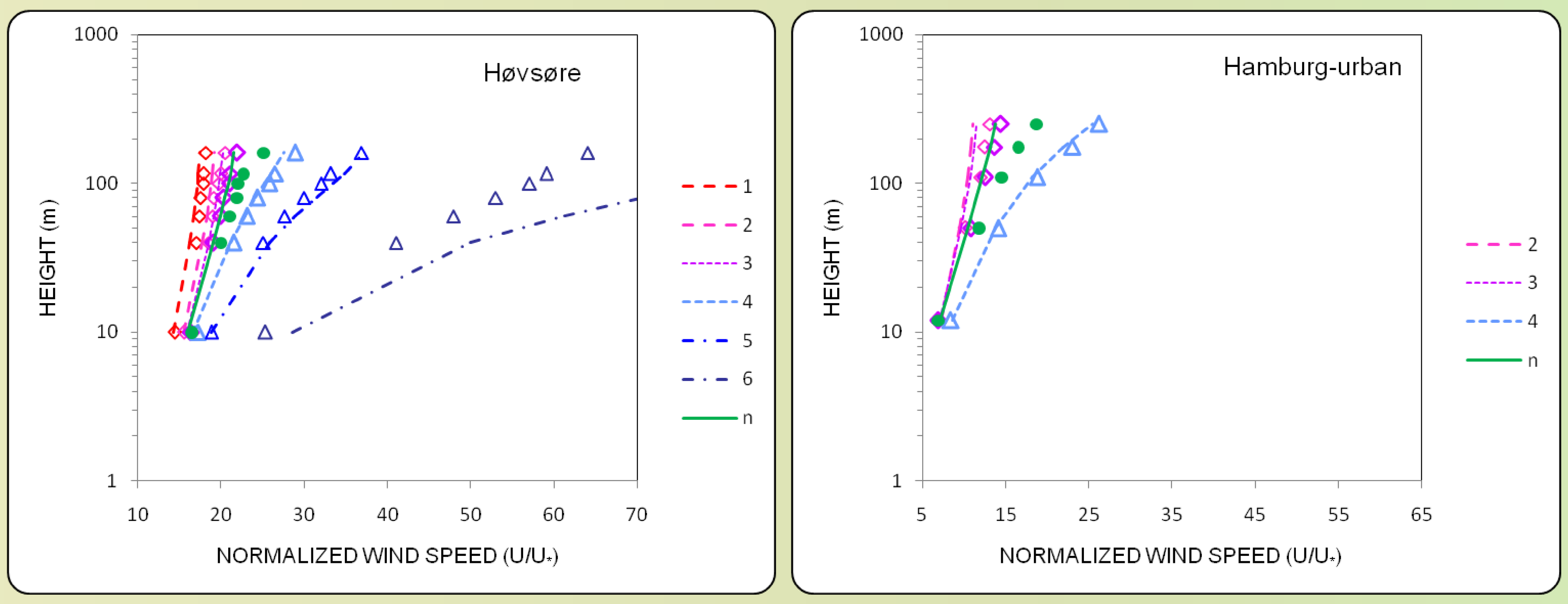

Figure 1. Comparison of normalized wind profiles (lines) with measurements (symbols) as a function of stability for Høvsøre (left panel) and Hamburg (right panel)

Dispersion plots

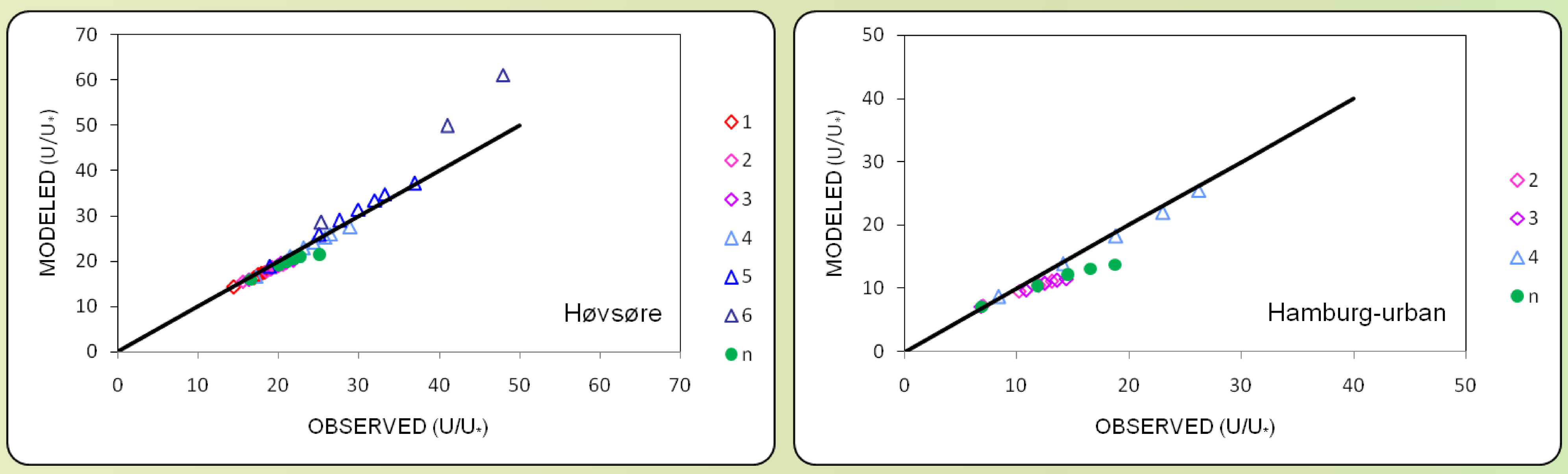

Figure 2. Comparison of modeled normalized wind profiles with measurements as a function of stability (symbols) for Høvsøre (left panel) and Hamburg (right panel). The line indicates the best fit.

Statistics for the comparison of predicted and observed wind speeds

STATISTIC	*OBS*	*MODEL*
MEAN	22.20	23.20
SIGMA	11.62	17.23
BIAS	0	-1
NMSE	0	0.08
CORR	1.	0.983
FA2	1.	1.
FB	0.	-0.044

DISCUSSION

In general, the measurements are slightly underpredicted with the applied wind profile formulation under most of the stability conditions at both sites. During strong stable conditions at the rural site, the opposite behavior is observed.
The slight underestimation appears more evident at the urban location. The departure from the best fit on neutral conditions might be related to the assumption of null buoyancy flux in the whole atmospheric boundary layer instead of the actual stability condition.

CONCLUSIONS

❖The wind speed profiles for the atmospheric boundary layer show a very good performance and can be considered as an alternative to the power law profile or the frequent extension of the Monin-Obukhov logarithmic profile beyond the surface layer in applied studies.
❖ Further evaluation will be carried out with the Cabauw tower data.

References:
Gryning, S-E., E. Batchvarova, B. Brümmer, H. Jørgensen and S. Larsen, 2007: On the extension of the wind profile over homogeneous terrain beyond the surface boundary layer. Boundary-Layer Meteorol., 124, 251-268.
Ulke, A. G., 2000: New turbulent parameterization for a dispersion model in the atmospheric boundary layer. Atmospheric Environment, 34, 1029-1042.
Wieringa, J., 1980: A revaluation of the Kansas mast influence on measurements of stress and cup-anemometer overspeeding. Boundary-Layer Meteorol., 18, 411-430.

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