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The mast on the house

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SYNOPSIS An often encountered problem when preparing the basic input data for a wind atlas is the correction for the influence of the house or hut on which the mast – whose data forms the basis of this wind atlas – is placed. The paper will describe an experiment, where this problem has been addressed. The knowledge gained will be used to give guide-lines as to the use of the WA^{S}P program to correct the observations. Should the house/hut simply be treated as an extension of the mast, should the house/hut be treated as a hill with speed-up effects, or should the house/hill be ignored completely?
The paper will show that the house/hut should indeed be treated as a hill with speed-up effects. Placing meteorological masts on houses or huts is common practice in quite a few countries in the world. The problem is therefore one which most people involved in detailed wind resource assessment will face sooner or later.

INTRODUCTION

In many areas of the world it is common practice to place the mast measuring wind speed and direction on top of the synoptic weather station. This is done mainly to avoid the weather station blocking the flow from certain directions. A different problem emerges, however, since the house itself affects the flow reaching the mast in quite significant ways. This is the problem which will be discussed in this paper. This problem has not been studied in great detail previously, but various guide-lines have been devised [1]. To make these guide-lines firmer, Risø decided to carry out an experiment shedding some light on the problem.

The viewpoint in this papers is to see whether it is possible to use WA^{S}P [2] to calculate the effect of the weather station on the measurements.

THE EXPERIMENT

The experiment was carried out at the Test Station for Wind Turbines at Risø National Laboratory and consisted of 3 masts: one on top of a standard container (6058 × 2438 × 2591 mm (L×W×H)), one to the west of the container and one to the east, cf Figure 1. Each mast was equipped with a sonic anemometer, a wind vane and 3 (container) or 4 (west and east) cup anemometers. Data was collected for a period of 38 days, covering a wide variety of atmospheric stability conditions. The area to the east and west of the experimental set-up was fairly homogeneous farmland. Some snowfall did occur, so the ground was covered by snow part of the time. In the following the roughness of the terrain has been set to 5 cm to the east as well as to the west.

The Data

In the following sections all heights will be normalised with the height of the container (2591 mm). All wind speeds will be nor-

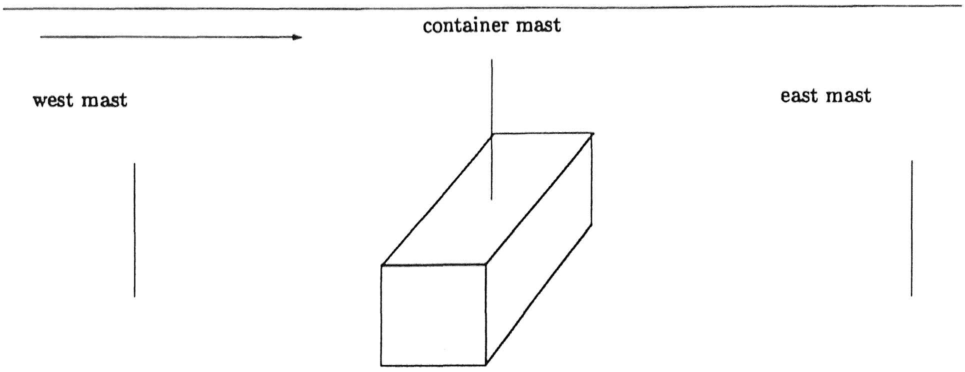

Figure 1: The experimental set-up.

malised with the wind speed from the west mast, interpolated to the height of the container measurement using the logarithmic wind profile:

$$u(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right) \quad (1)$$

The resulting wind is considered the undisturbed one for westerly directions. This approach generalises the data in such a way that the results can be applied to any hut/mast configuration. For information on the actual heights and conversion factors, see Table 1.

To be able to compare model results with observations, only winds which come from the west sector (255–285°) are analysed.

MODELLING

In the following, three approaches to correcting for the influence of a house/hut on a mast placed on top of the house/hut will be described. The results of these different approaches will be compared to the measurements.

The first approach assumes that the house/hut is so small that the flow will not be disturbed at all. This is probably the approach most people estimating the wind resource unknowingly take when using data provided by a meteorological service, since heights are given as the height of the instrument above ground level, but information about whether the mast is placed on a house/hut is generally not available. The only effect of the house/hut is then to add to the height above ground level of the mast. This means that the undisturbed up-stream wind remains undisturbed and the correction factor is 1.

The second approach assumes that the house/hut acts as a hill which compresses the stream-lines and thereby speeds-up the wind, this means that the nominal height of the mast on the container must be reduced by the height of the container. The last approach assumes that the flow is forced along the house/hut, but not over-speeded at all, the height is then the height of the anemometer above the house/hut, the correction factor will be 1 again. In the following the nomenclature depicted in Figure 2 will be used.

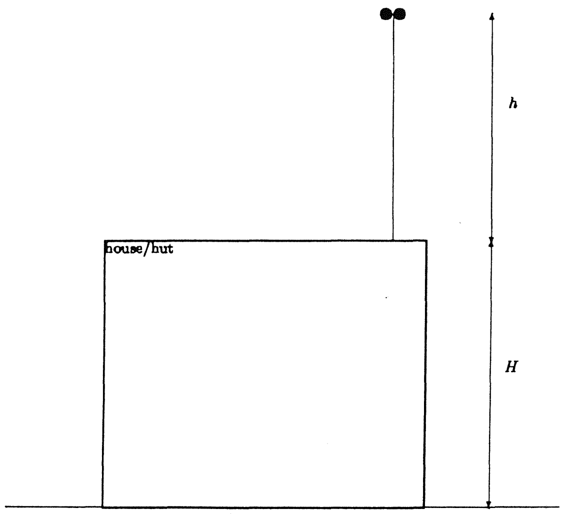

Figure 2: The definition of h and H.

Approach 1: $H + h$

Taking Approach 1, it is assumed that the house/hut has no effect on the flow. The

Table 1: Heights agl (above ground level) in metres. Column 1 is the height agl as it was measured at the experiment, column 2 the height agl assuming the container is a hill (the height of the container (2.591 m) is subtracted from the nominal height). Column 3 gives for the container mast the interpolation factor applied to the west mast observation; 'uw(x)' designates the measurement from the west mast at height x. The interpolation factors are determined using the logarithmic wind profile assuming neutral conditions, cf Equation 1.

	no hill $H+h$	hill h	comparison
west	0.75	0.75	
	1.75	1.75	
	4.37	4.37	
	6.00	6.00	
container	3.38	0.79	1.02 uw(0.75)
	4.46	1.87	1.02 uw(1.75)
	6.12	3.53	0.95 uw(4.37)
east	0.75	0.75	
	1.75	1.75	
	4.37	4.37	
	6.00	6.00	

only effect is that it adds to the height above ground level of the mast, such that the height is $H + h$. This gives a correction factor of 1.0 for all heights. As mentioned earlier, this is probably the approach most people unknowingly take. Studying Figure 3 it can be seen that the approach does well in predicting the level furthest away from the house/hut, but the two lower levels are not predicted very well. Scaling this to standard heights (10-12 m) and typical huts/houses, the anemometer would be located around the middle measurement and the effect on the wind speed would be an over-speeding of more than 3%, resulting in a *over-prediction* of the energy density of 9%. This is clearly a number that must be taken seriously.

Approach 2: Hill + h

Until now, the unofficial guide-line for dealing with the mast-on-the-house problem has been to treat the house/hut as a hill with the actual dimensions of the house/hill in question, input this to WA^{S}P and use the output from the program to correct the measurements. This must clearly be wrong, since WA^{S}P is a potential flow model, which can not model correctly the separation generated by "hills" of such steepness. The results of modelling the house/hut in this way are shown in Figure 4, and it can be seen that – as expected – the agreement with the measurements is poor.

A more realistic way of using WA^{S}P is to "fill in" the space where the separation is expected to influence the flow, in such a way that the flow becomes more physically correct, when modelled by the program. The rule-of-thumb (and it is only a rule-of-thumb) says that such a filled-in hill should have a slope of 1 : 5 in front and 1 : 2 at the back. This is depicted in Figure 5. Again, the problem is that the WA^{S}P model is a potential flow model. One consequence of this is that there is no difference between flows which come from opposite directions, and it can be seen from the figure that the over-speeding caused by the (steep) 1 : 2 slope does indeed produce too high factors for two of the three points. A more realistic physical approach would be to assume the 1 : 5 slope on both sides of the hill, this is also depicted in Figure 5. Studying Figure 4, it can be seen, that we now obtain excellent agreement with the observations for two of the three points. The most likely reason for the disagreement between the measurements at the lowest point and the model is that this close to the container, it can no longer be regarded as a "smooth hill", and the actual shape of the container now plays a dominant role.

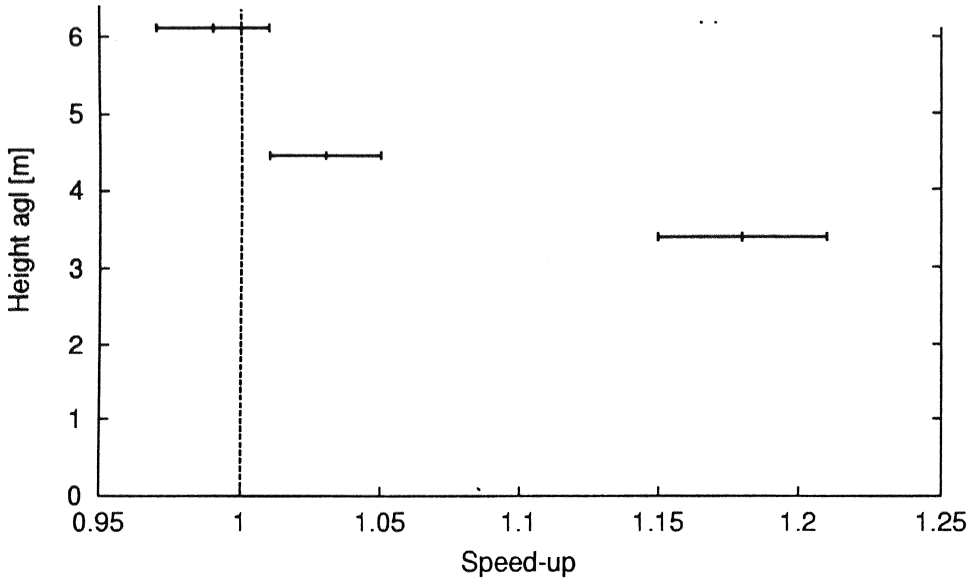

Figure 3: Comparison of the result of taking Approach 1. The measurements are the horizontal error-bars and Approach 1 is the vertical line. If the model had agreed with the measurements the points and the line should coincide.

Approach 3: h

The final approach states that there is no over-speeding at all. From the findings of Approach 2 this is seen clearly not to be the case. Approach 3 can therefore – on this ground alone – be discarded as an approach that produces results in good agreement with the measurements. For completeness, however, the results of taking this approach are shown in Figure 4.

DISCUSSION

It is clear from the above that the container should be considered as a hill. The only angle-of-attack of the wind investigated in this paper is the one perpendicular to the longest side of the container. No basis has been given for drawing any conclusions as to modelling the flow from other angles of attack. To get an idea of the variation with direction, the speed-up for the three anemometers on the container is plotted in Figure 6. From this it can be seen that WA^{S}P actually does produce quite good results for all sectors, except for the 90° one, where the flow has passed the container before it hits the mast; measurements from the east mast would be needed to explain this sector.

To be able to say that the above recommendations are firm, more experimental evidence is needed. Such experiments should cover different sizes of houses/huts and different ranges of height-of-mast to height-of-house/hut ratios.

CONCLUSIONS

This study has shown that it is possible to use WA^{S}P to correct measurements taken from masts for the influence of the house/hut on which they are placed. The procedure is as follows:

- generate a hill from the house/hut with an added 1 : 5 slope on both sides of the house/hill.
- enter this into WA^{S}P as `OROGRAPHY`
- use WA^{S}P to calculate the speed-up
- correct the measurements accordingly

It was also demonstrated that the old guide-lines were not correct, the effect var-

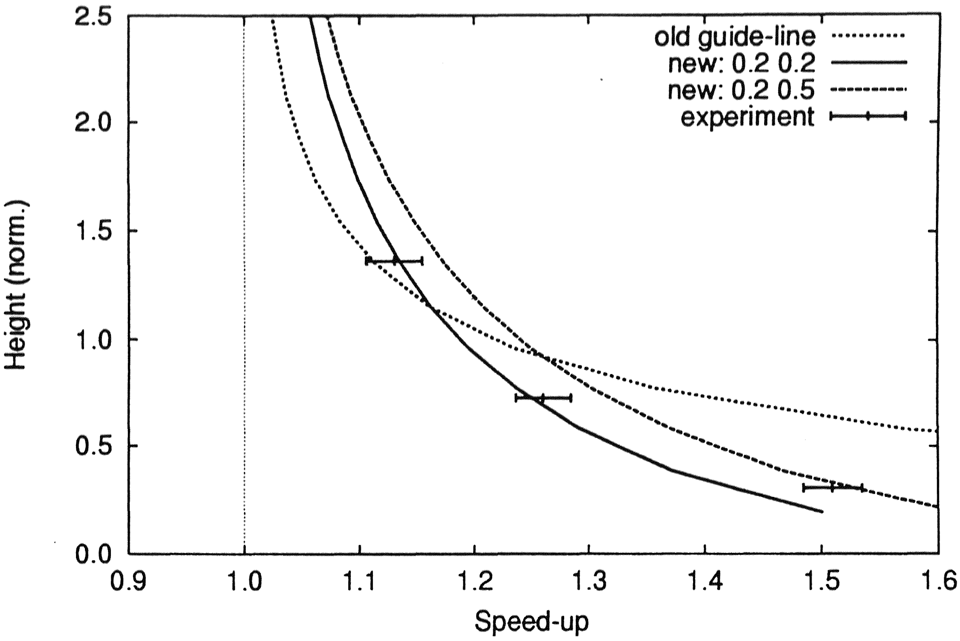

Figure 4: Comparison of the relative speed-up versus the normalised height for the measurements and the suggested model (Approach 2). The measurements are marked by pluses with horizontal error-bars, the old guide-line is plotted using the thick dotted line, the two new models (taking Appr. 2) are plotted using the thick dashed line and the solid line (see legend for details). The vertical dotted line at $x = 1$ is the result of Approach 3. The speed-up is the wind speed measured at the container mast divided by the wind speed measured at the west mast, heights are normalised with the height of the container.

ied with the height of the mast relative to the house/hut.

Furthermore, it was demonstrated that the most commonly taken approach could result in over-predictions of the energy density of 5-10%.

ACKNOWLEDGEMENTS

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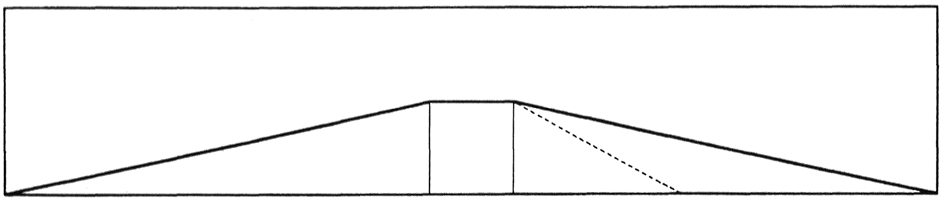

Figure 5: The two different "hills" considered in Approach 2. The thick line is the 1 : 5 slope in front and at the back, whereas the dashed line is the 1 : 2 slope at the back. The square box in the middle is the container seen from the side.

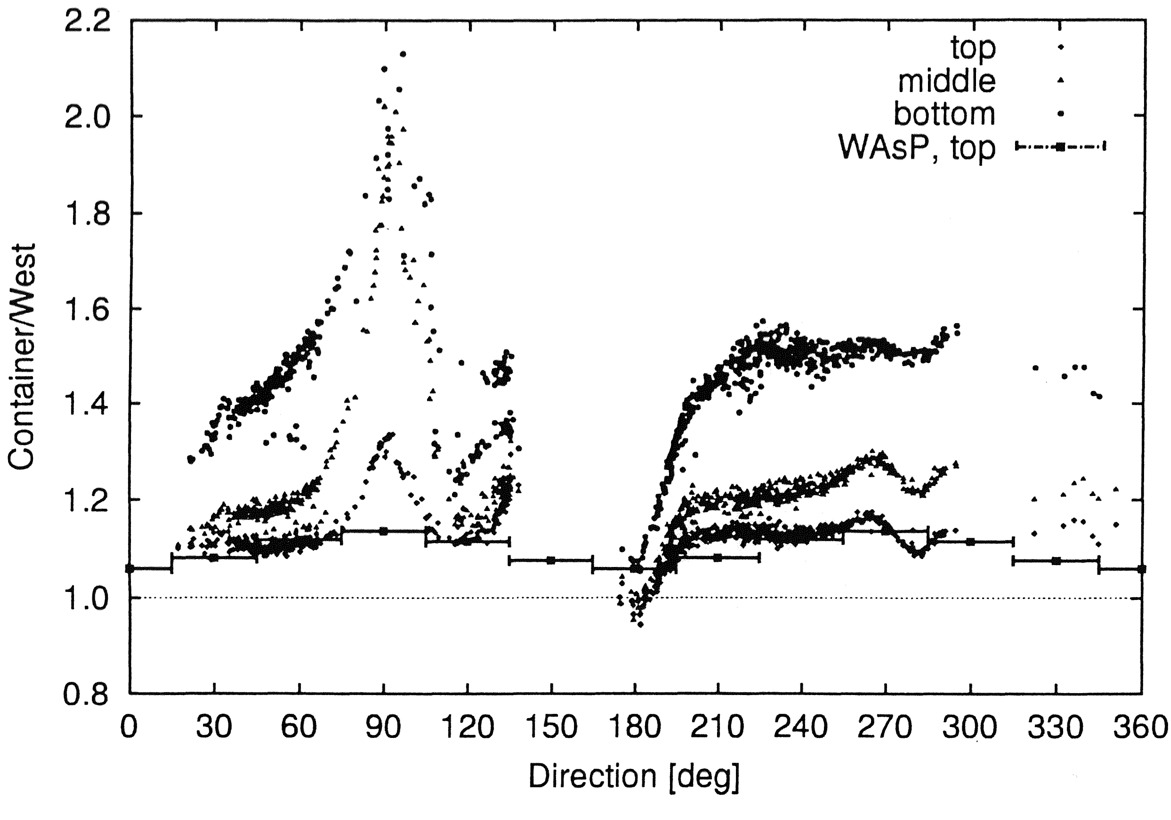

Figure 6: The speed-up factors for all directions, using the measurement on the container normalised by the measurement at the west mast. The results for all sectors using WAsP to predict the top measurements are shown as horizontal error-bars.