DETERMINATION OF WIND SPEED PROFILE PARAMETERS IN THE SURFACE LAYER USING A MINI-SODAR

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INTRODUCTION

Recent improvements on acoustic wind profilers allow to carry out wind measurements with a vertical spatial resolution equal to a few meters (typically 5 m). This is due to the use of higher frequencies (4500 hz in the present study) which favor smaller errors in the wind velocity. However, the vertical range of the mini-sodar is reduced since higher acoustic frequencies are attenuated much more in the atmosphere than lower ones. This not a restriction in our work since the main objective has been to study the wind speed profiles U(z) in the surface layer above an urban area. This lower part of the urban boundary layer has a great influence on the dispersion of pollutants emitted close to the ground; Rotach (1997, 1999).

Thus, with the mini-sodar, we measured the vertical profile of wind speed U and direction. Measurements obtained in the Marseille city (France) will be presented. They have been carried out in the framework of the UBL/CLU-Escompte experiment, which aimed at documenting the structure of the urban boundary layer (UBL) in connection with the urban canopy thermodynamics during a summer period with low wind and breeze, from June 5 to July 15, 2001, Mestayer (2002). In order to check the performances of the profiler in a simple atmospheric flow case, a series of observations was carried out on a flat terrain over a rural zone. Comparison with sonic anemometers set up on high mast will be shown.

DESCRIPTION OF THE TWO OBSERVATION SITES

The urban station was located at the south of Marseille city (1.5 Million of inhabitants) at 4 km from the city centre, inside an institute. The closest distance to the sea is 2.5 km in the West direction. So see breeze effects are perceptible on the wind profiles. The mini-sodar was put on a flat roof of a building (25 meter height). The emission power was 150 W with a frequency equal to 4500hz, the vertical resolution being 5m (see Picture 1). A 30 meter height mast was installed on the ground and close to the mini-sodar building, with a sonic anemometer at the top.

In order to check the performances of the profiler in a simpler atmospheric flow case, a series of observations was carried out on a flat and clear terrain over a rural zone (see Picture 2).

Picture 1. View of the mini-sodar in the urban station (Marseille, France

Picture 2. View of the mini-sodar and the mast in the rural station

Comparisons with the results of one sonic anemometer set up on a 39 meter height mast will be shown.

For both sites the maximum height of detection was generally about 150 m (not 200 m as announced by the manufacturer), except during rainy days, for which the quality of the data was very poor. In the urban site case, one expected the background noise emitted by the urban zone could lower the S/N ratio. However, the quality of the echo signal was sufficient to perform measurements up to 150 meter height. This is mainly due to the difference between the mini-sodar emission frequency (4500 Hz) and the urban background noise which is in the 10-1500 Hz frequency range.

COMPARISONS WITH A SONIC ANEMOMETER RESULTS

Figures 1-2 show the comparison between mini-sodar and sonic wind speed measurements (U in the horizontal direction) during one week of each experimental campaign. (June 2001 for the urban station, April 2002 for the rural station). In the rural case (Figure 2), there is a good agreement, the statistics of comparison are for the correlation coefficient r=0.815, for the bias B=0.093 m/s and for the root mean square difference C=0.733 m/s, which is similar to other studies (Crescenti, 1997). Figure 1 shows the same agreement, r=0.967 B=0.538 and C=1.769, indicating the mini-sodar was running correctly, it provided accurate results despite the noisy background emitted by the city, in particular for low wind speed, the values reported in the above figures are in the range 0-6 m/s. In the rural station, much higher wind speed values were observed and the agreement is better. However, we have to say the best agreement for the urban case is obtained if we plot the mini-sodar fifth level values (25 m above the flat roof of the 25 m height building) with the sonic anemometer results (at 30 m above ground).

Figures 3-4 show the comparison for the r.m.s. values of the vertical wind speed fluctuations (rmsW) for the same periods as in Figures 1-2. The overall agreement is found to be similar in the rural and in the urban cases, excepted for low values, which are overerestimated by the mini-sodar. No explanations are found at this time, but we think the mini-sodar results have to be analysed carefully since low rmsW values occurs at low wind speed, with low echo intensity. Further works are needed to analyse this point.

DETERMINATION OF WIND SPEED PROFILE PARAMETERS IN THE SURFACE LAYER

The pattern of air flows over a region may be complicated. For example in the case of Marseille city, there is a conjunction, in spring and summer, of see breezes (in the West-East direction) and the Mistral wind blowing from the north. So, in the daytime, large variations of wind direction can be observed and strong shears exist in the boundary layer. In such cases, it was not possible to detect ‘well established’ vertical profiles of the horizontal wind speed U(z) as illustrated in Figure 5. However, during days with stable wind directions, we observed ‘well defined’ wind speed profiles U(z) (with U values increasing continuously with height z) as shown in Figure 6.

For such vertical profiles U(z), we have determined both the friction velocity u* and the roughness length z0 using a least square minimisation fit of the error function

$$\Im(u^*, z0) = \sum (U_i^{\text{mod}} - U_i^{obs})^2$$

where U_i^{mod} is the value given by the logarithmic law at level i of the mini-sodar

$$U_i^{\mathrm{mod}} = \frac{u^*}{k} Ln \frac{(z_i - d)}{z0}$$

and d is the displacement height.

Each minimisation fit was applied for several consecutive wind profiles. So the parameters u* and z0 have been optimised from data observed during one hour and with fixed d value. Result are shown in Figures 7-8 for one specific hour. In the rural case, we found u^*_{sodar}=0.6 m/s and the average value given by the sonic anemometer is u^*_{sonic}=0,9 m/s (at 39 m height above ground). In the urban case, the values are u^*_{sodar}=0.91 and u^*_{sonic} =0.79 m/s (at 30m height above ground). The agreement is better in the urban case. The comparison between the two mini-sodar results shows the urban value is greater, which is not the case for the sonic anemometer results. If we look at Figures 7-8, we see the speed profile varies more strongly in the urban case than in the rural case, which indicate a greater u* values close to the ground for the urban case. It is hard to conclude with only one point of comparison and other data will have to be used next. The optimised roughness length z0 are 2.8 and 0.05 m respectively for the urban and rural cases. These values are physically plausible if we look at other works, as for example Grimmond (Grimmond, 1998).

The effect of the displacement height seems not to be important for the case presented in Figure 7. There is no large differences if we take d=h, h being the building height, or d=h-3m. We have to say that the minimisation fit is much more difficult if we try to determine simultaneously the three parameters u*, z0 and d.

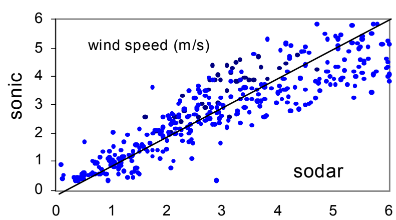

Figure 1. Mean wind speed, comparison sodar (fifth level)/sonic at the urban station.

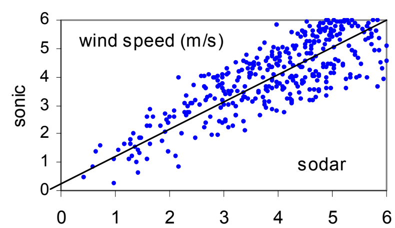

Figure 2. Mean wind speed, comparison sodar /sonic at the rural station.

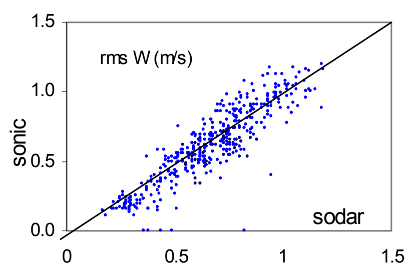

Figure 3. rms value of the vertical wind speed W, comparison sodar (fifth level)/sonic at the urban station.

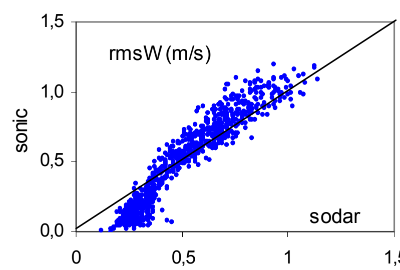

Figure 4. rms value of the vertical wind speed W, comparison sodar /sonic at the rural station.

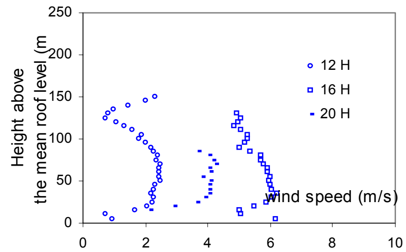

Figure 5. Vertical profiles of the horizontal wind speed observed at the urban station during one day with large wind direction variations.

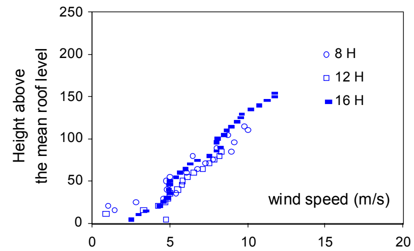

Figure 6. Vertical profiles of the horizontal wind speed observed at the urban station during one day with stable direction.

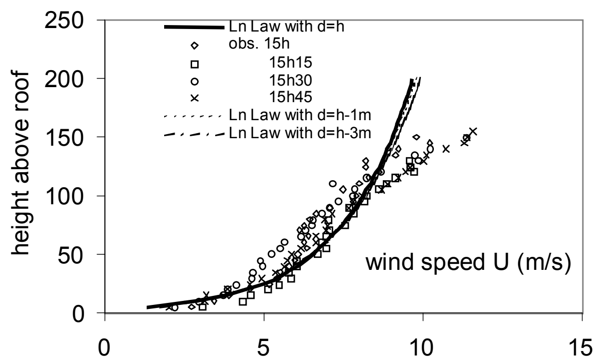

Figure 7. urban site: Ln law profiles obtained using the optimised parameters u=0.91 m/s and z0=2.8 m, compared to observed values. Three displacement heights have been used d=h, h-1m and h-3m, h being the building height.*

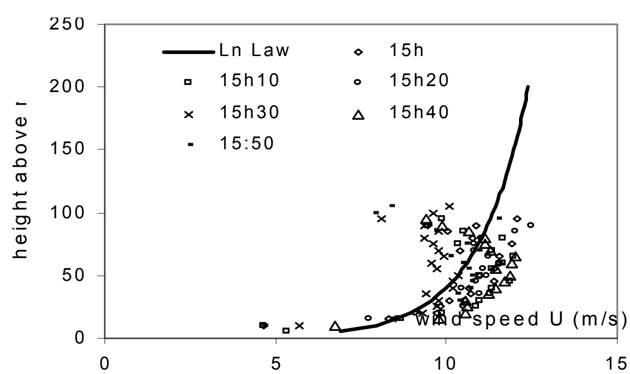

Figure 8. rural site: Ln law profiles obtained using the optimised parameters u=0;6 m/s and z0=0.05 m, compared to observed values. The displacement height d=0 m*

CONCLUSION

The mini-sodar results compare well with sonic anemometer observations, even in the background noise of an urban environment. In our study, there was no corruption of the data and with our system it was possible to perform measurements up to 150m. We have looked at the potentiality of the mini-sodar to determine the friction velocity and the roughness length. The first results are encouraging, however other analyses will have to be carried out next.

REFERENCES

Crescenti G.H., 1997 : A look back on two decades of doppler sodar comparison studies, Bulletin of the A.M.S., **78**, 651-673

Grimmond C., King T., Roth M. and Oke T., 1998: Aerodynamic roughness of urban areas derived from wind observation, Boundary Layer Meteorology, 89, 1-24

Mestayer P. and Durand P., 2002 :'The UBL/CLU-Escompte experiment : description and first results, the AMS Fourth Symposium on Urban Environment, May 2002, Norfolks, Virgina

Rotach M. and De Haan P., 1997 : On the urban aspect of the copenhagen data set, Int. J. Env. Poll, **8**, 279-286