"Determination of the hourly wind speed field over complex terrain in Southern Uruguay"

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ABSTRACT: Numerical and physical modelling techniques are applied jointly to deduce the velocity wind field up to the meteorogical microscale in Southern Uruguay. The calculated wind velocities in some points are verified against measurements taken with cup anemometers.

1. Introduction.

Wind climate determination is the common problem in wind power evaluation programs. The wind velocity long time series are known in stations of the weather net. The weather stations are usually located in sites with little interest for installation of wind power conversion systems (WECS). In Uruguay as in other places, the sites of principal interest for wind power exploitation are over complex terrain zones where measurements of wind velocity do not exist. Druyan,L., 1985 suggest a summary of methods to deduce the wind velocity field. Such methods can be classified in subjective and objective methods. The first one, justified where very scarce data are available, use the observation of tree deformation or other forest indicators to deduce the wind velocity. Between the objective methods on site direct measuring for short periods (Barros et.al.,1983), physical modelling when some data are known near to the place of interest (Neal,D.,1979) and extrapolation of routine meteorological data by mass consistent models (Endlich, et.al., 1982), cab be mentioned as well as another method mentioned in Tombrou,M.,et.al., 1990.
The methodology applied to estimate the hourly wind field in Southern Uruguay up to the meteorological microscale uses a combination of numerical and physical modelling. As will be explained later the numerical model is a mass consistent code to solve the mean wind velocity field at 5 to 30 km side mesh and the physical model allows determining the mean velocity and the turbulence characteristics of the flow over the complex terrain at meteorological microscale.
The field measurements with which wind mean velocity and direction used for comparision with model results were obtained, will be described.

2. Numerical model.Method description.

The numerical model used is a mass consistent code. This model uses as data the hourly mean wind velo ity time series

Fig. 1 - Zone of study

vectors and $a_{i,j}$ are the coordinates of the vector V_i-V_m in the e_j base. The aforementioned calculations are applied to the vectors V_m and e_j. In this case the frame of reference is composed by the eigenvectors of the covariance matrix of the data (e_j

$$V_i = V_m + \sum_{i=1}^{i=n} a_{i,j} \cdot e_j$$

vectors). The results obtained applying the methodology to the three or four eigenvectors with higher eigenvalues shows little difference with the results obtained for all the eigenvectors. Table 1 shows the mean velocity values calculated using the three eigenvectors with higher eigenvalues and all eigenvectors at different sites.
Fig. 2 shows the mean velocity field obtained at 30m over the terrain in the grid nodes with 15km mesh size.

3. Physical model.

The physical modelling was used to solve the wind velocity field up to the meteorological microscale. Thus, it was necessary to simulate the Atmospheric Boundary - Layer flow (ABL) and the terrain.

The ABL was modelled for "high wind"

	Nº of vectors	
Site	3	10
C. del Toro	26.6	27.2
Caracoles	27.5	27.8
Animas	24.0	24.6
José Ignacio	24.0	24.6
Aigua	23.0	23.4

Table 1 - Calculated mean velocity values.

conditions, which meant a turbulent, steady, thermically neutral and aerodynamically rough flow. The obtained mean velocity profile was adjusted to a

The characteristic roughness length in the zone to be studied is 5cm and the heigth of the boundary-layer was initially estimated in 600m.
The method reported first in Counihan, 1969 and later in Robins, 1979 for ABL simulation was used. The physical modelling was made in a wind tunnel with a 1.2x1.6x3.6m test section. The measurements of velocity were made with a TSI hot-wire anemometer. The mean velocity was calculated from the anemometer indication and the calibration curve. The mean square root and the power spectral density of the anemometer signal was obtained from a spectra analyzer Hewlett-Packard 3582A. The hot-wire probe was positioned using a four freedom degrees robot. Fig. 3, 4 and 5 show the mean velocity profile, intensity of turbulence profile and the longitudinal scale length of the turbulence profile. It is wortwhile to points out that the turbulence characteristics did not vary after eight heights of simulated ABL, as is reported in Robins, 1979, but the mean velocity profile changed up to 12 heights of ABL simulated downstream from the ABL simulation system. Cataldo, 1992 gives more details about this physical simulation.
The terrain was modelled to scale 1/6000 as was deduced before. The models were

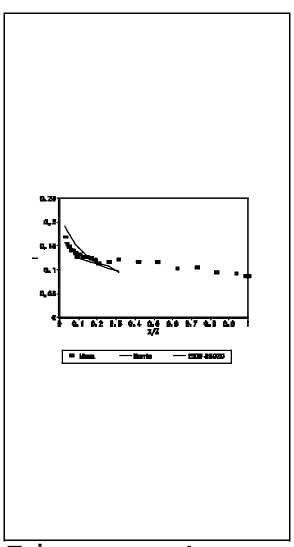


Fig. 4 - Intensity of turbulence.

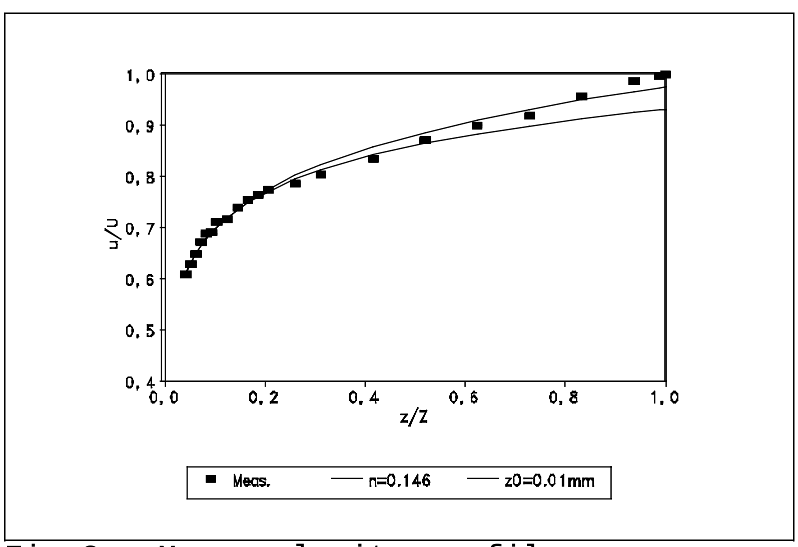
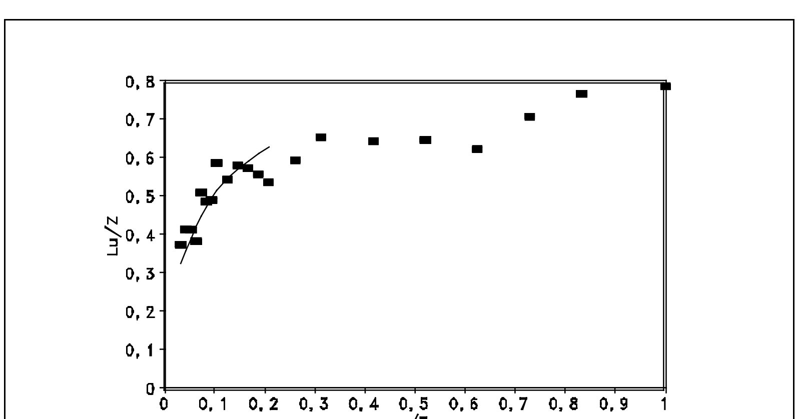


Fig.3 - Mean velocity profile.

constructed following the method described in Neal, 1979 and they were located where the flow in the wind tunnel was able to be considered self-preserving. The



5. Calculation vs. measurements comparisons. Results and discussion.

Applying the speed-up factors deduced from the physical model to the wind velocity time series obtained from the numerical modelling the wind velocity time series was obtained at the sites where there are field measurements. Thus, several statistical parameters of these time series were obtained at the different sites, specially for the interval of time with field measurements. The same statistical parameters were calculated for the field measurements.
Table 2 shows the calculated and measured mean velocity values. The first one was obtained for one year period while the measurements were taken during three to six months.

Site	Mean cal. vel. (m/s)	Mean meas. vel. (m/s)	Dif. (%)
C. del Toro	27.2	25.8	5.3
S. de Animas	24.6	24.5	0.4
S. de Caracoles	27.8	29.5	-5.5
José Ignacio	24.6	24.5	0.2

Table 2 - Mean velocities.

A maximun difference of 5.5% can be observed. The change of sign in the difference can be assigned to different seasonal mean velocity value.
Figs. 6, 7, 8 and 9 show the probability density function calculated and measured for the Cerro del Toro, Animas, José Ignacio and Sierra de Caracoles sites. In the two first cases the calculated and measured probability functions present the peak at the same velocity value, while in José Ignacio site the measured peak is lower than the calculated one and in Sierra de Caracoles site the opposite is founded. In all cases a calculated function smoother than the measured one is observed, which to the elimination of experimental errors from the calculations can be assigned.
Table 3 shows the energy calculated with the wind velocity time series calculated and measured at the considered points using the perfomance curve of a real wind turbine.

Site	Cal. (kw.h/year)	Meas. (kw.h/year)
C. del Toro	773508	853400
S. de Caracoles	724452	1004772
José Ignacio	572904	551442

Tabla 2 - Calculated energy.

7. Conclusions.

The described method provides a relatively fast and low cost tool that provides a good estimation of the wind mean velocity in complex terrain regions of interest in the choice of locations for WECS. This can be deduced from the preliminary results presented in this paper. The mean problems and control system operation prior of the installation.

Two difficulties should be pointed out about this method: 1)the results are highly dependent on the data quality, but following the principal components method used in this paper the quality can be studied; and 2)the kind of terrain can limit the test

Fig. 7 - Calculated and Measured probability in Animas site.

Fig. 9 - Calculated and Measured wind velocity probability density in Sierra de Caracoles site.

Fig. 8 - Calculated and Measured wind velocity probability density in José Ignacio site.

directions of the models, which may imply that the speed-up factors for those directions must be assumed.

This method provides a fast and low cost tool to make a first relatively conservative estimation of the available wind power in extensive zones of complex terrain.

8. References.

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