METEOROLOGICAL PREPROCESSING FOR AIR POLLUTION IMPACT ASSESSMENT

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INTRODUCTION

In many East-European countries the wind measurements are still made using the out_of_date Wild anemometers. This data can not be directly used to supply many broadly exploited modeling tools, particularly air pollution impact assessment or regulatory models, because of the rough resolution in both wind velocity and wind direction data. Only discrete values are produced by this instrument and respectively archived. In addition these data contain considerable observational (random) errors. In spite of these disadvantages, the Wild anemometer data contain useful information and very often is the only available information about the meteorological regime in many regions.

In the paper a pre-processing procedure of such data is described yielding a set of continuous values for the wind parameters. It is based on the use of random number generator taking into account the specific way of measurement. To every measured value some new values are associated. They are received randomly supposing that they are distributed in previously determined intervals taking into account that the observer determines the direction of the wind vane (direction) and the slope of the plate (velocity) practically "by eye".

The procedure is applied to the data measured in the climatic station "Pernik" near Sofia in the frame of a German-Bulgarian Twinning Project conducted by EPAs of both countries. The aim is to produce 3-component wind rose with high resolution as required by German air quality regulations. 10-year period of climatic observations (3 times a day) is used for the purpose. The results are presented and discussed.

WIND MEASUREMENTS WITH WILD ANEMOMETER

According to the manuals for performing such measurements (*Stanev,* 1969) they are in fact observations. Two elements of the instrument must be observed – the vane and the plate. The position of the vane according to four sticks oriented to the four world directions shows the direction from where the wind is blowing. Usually, 8- or 16-class scale is used. The 8-class scale shows the four cardinal points (one-lettered headings - N, E, S, W with respective azimuths of 0°(360°), 90°, 180° and 270°) and the four intermediate directions (two-lettered headings - NE, ES, SW, NW with respective azimuths of 45°, 135°, 225° and 315°). In the 16-class scale new eight intermediate directions are added (three-lettered headings - NNE, ENE, ESE, SSE, SSW, WSW, WNW, NNW with respective azimuths of 22.5°, 67.5°, 112.5°, 157.5°, 202.5°, 247.5°, 292.5° and 337.5°). The observer must follow the wind vane fluctuations during 2 minutes and to determine by eye the mean position of the vane among the four sticks. It is quite clear that observational errors are quite possible. The direction measurements are relatively more confident when the real wind direction is close to the four cardinal points and the wind vane fluctuates around one of the fore sticks of the instrument. The determination of the intermediate two-letter directions is less confident. The determination of the three-letter directions is the least confident. All this is reflected in climatic wind roses, the probability of the three-letter directions is usually less than the other two classes.

The determination of the wind velocity shows analogous shortcomings. The observer must keep his eyes at the hanging plate and to follow its fluctuations according to the wind-velocity scale. The measuring scale is a sector-like comb with 7 long and short teeth. He has to determine by eye the mean position of the plate between the teeth. This position can coincide with a particular tooth or to be between two neighboring teeth. There is a special table for converting the tooth number in wind velocity with a preciseness of 1 ms^{-1}. It is obvious that, like the case of wind direction measurement, observational errors are quite possible, too. Usually, the probability the mean plate position to be determined as lying between two neighboring teeth is rather less than the cases to be determined as showing particular tooth. This leads to appearance of gaps in the wind speed histogram as it can be seen later.

All this shows that applying such data for air pollution application can lead to big errors in calculated fields in both cases of short-term and long-term calculations. The different probability for observational errors when wind is blowing from various directions with various speeds leads to wrong wind roses because different errors are related with particular values of the wind azimuth and wind velocity. Because of the low resolution both in direction and speed, this data can not be used in some comprehensive models as well.

PRE-PROCESSING ALGORYTHM AND RESULTS

A method for overcoming these shortcomings is described here leading to some improvement in both resolution and probability non-homogeneity. The mean idea is to use a generator of random numbers as to replace the values of the azimuth and velocity of particular measurement with new values (or set of values) lying in specific intervals around original data. This leads to improvement of the data resolution. The proper choice of interval boundaries can improve the error probability non-homogeneity.

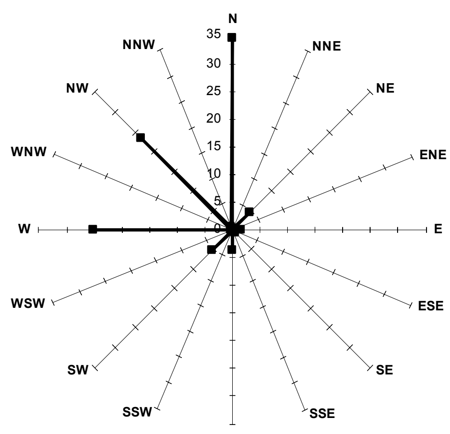

Figure 1. Wind rose for station Pernik (1991-2000) built from the row data.

Here, the simplest way for determining of interval lengths is applied - they are proportional to the probability of the discrete values determined from the respective histograms. There is a small difference between the direction and speed. While the real direction rose reflects the properties of the general atmosphere circulation together with the particular features of the location (orography, roughness, and obstacles) and contains general but smooth non-homogeneity, the real speed histogram must obey the well studied Gamma or Weibull distribution. The row data histograms, together with reflecting the specific peculiarities of the location, contain gaps between the sizable frequencies. This is demonstrated in Figure 1 and Figure 3 where the direction rose and the speed histogram obtained from the 10-year measurements in climatic station Pernik (measurements at 7:00, 14:00 and 21:00 LT, 16-direction wind scale) are presented. The features of wind roses and speed histograms in all stations equipped with Wild anemometer are similar.

In processing the wind direction the following assumptions are made:

- 30-degree intervals are prescribed to the main directions;
- 25-degree intervals are prescribed to the two-letter directions;
- 17.5-degree intervals are prescribed to the three-letter directions;
- the directions are placed in the middle of the intervals.

The standard random number generator is used producing numbers with homogeneous distribution in the interval [0,1]. The random numbers are scaled properly and new values replacing the particular measured wind direction are received. In the particular case, to every row data 6 new values are produced - the new series contains about 25000 cases. The 16- and 36-scale wind roses that are calculated from this data are given in Figure 2.

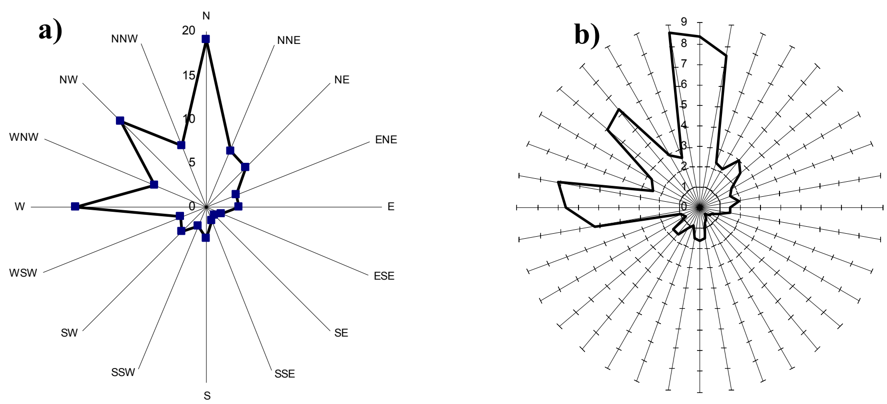

Figure 2. Wind roses for station Pernik (1991-2000) built from the processed data.
a) 16-class rose; b) 36-class rose.

An attempt to fit the Pernik row data wind speed frequency histogram with the Gamma and Weibull distribution is made using the well known Statgraphics software package, results presented in Figure 3. It is clearly seen that the histogram contains deep gaps at 2, 4, 6, 8 ….m/s. The quality of fitting is quite bad, as can be seen in Table 1. In the Table the parameters of the tested distributions are shown together with the values of a statistic reflecting the closeness between the empirical and theoretical distributions. From the big variety of tests the Kolmogotrov-Smirnov D is chosen, that presents the maximum distance between the both cumulative distributions. Obviously, the smaller D, the better fitting. The values of D for the row data are quite big and the hypothesis for closeness of the wind speed row data to both distributions is rejected with high probability.

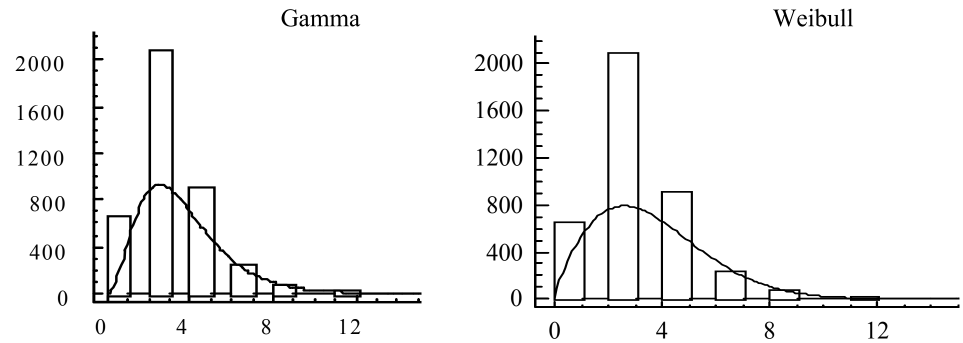

Figure 3. Fitting the row data wind speed frequency histogram of station Pernik (1991-2000).

Table 1. Distribution parameters and Kolmogorov-Smirnov D-statistics for station Pernik

	Sample volume	Gamma distribution shape	scale	D	Weibull distribution shape	scale	D
Row data	4026	3.2813	0.9060	0.2814	1.7925	4.0833	0.2759
Processed data	25456	2.2297	0.8325	0.0518	1.4837	2.9843	0.0710

The wind speed data is processed in analogous way replacing the row data with homogeneously randomized one/ones in the following intervals:

(0.6÷1.8), (1.9÷4.0), (4.1÷6.0), (6.1÷8.0), 8.1÷10.0), (10.1÷15), (15.1÷20).

The intervals become large at big velocities and the presentation is not very precise there but they are much less probable and do not have impact on creating high pollution levels. The new data histogram and fitting distributions are shown in Figure 4, distribution parameters and Goodness-of-Fit statistics displayed in the last row of Table1. The D-values are much less than those of the row data and the new data is fitted very well by the both Gamma and Weibull distributions.

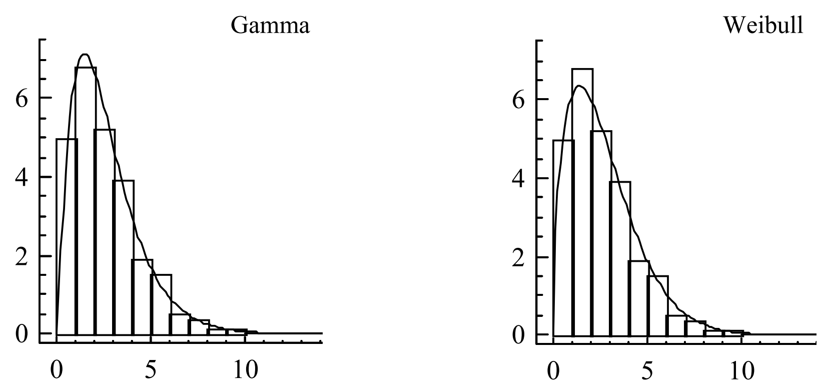

Figure 4. Fitting the processed data wind speed histogram of station Pernik (1991-2000).

CONCLUSION

The described procedure for pre-processing of row wind data obtained by Wild anemometer produces a set of continuous wind parameters values, similar to those obtained by automatic anemometer. It is based on the use of random numbers generator - to every measured value for the speed and the direction some new random value/values is associated lying in previously determined intervals. The intervals are set taking into account the manner of measurement (the possible observational errors) and the statistical properties of such data.

The procedure is demonstrated on a 10-year data set from the climatic station “Pernik” near Sofia. The processed data shows rather good characteristics and can be used in different contemporary air pollution models both as individual values or climatic input (wind roses).

This procedure is built-in in the Bulgarian short-term dispersion models GAS_E and AER_E. Those are Gaussian-type models used for environmental impact assessment. Description of the models can be fined in *Doncheva et al.* (1993), *Doncheva-Simeonova and Kolarova* (1996), *Ivancheva et al.* (1998) and *Syrakov et al.* (1998).

Recently, this algorithm was applied to prepare high-resolution wind data for Pernik, necessary in the frame of the German-Bulgarian Twinning Project conducted by EPAs of both countries (PHARE Twinning Project BG99EN02 - Support of Air Quality Management at Local Level). The results of using processed data are presented in *Moldenhauer et al.* (2002).

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