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DATA PROCESSING AND PROBABILITY MODELS OF WIND GUSTS

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Abstract - This paper deals with a measurement of wind gusts, data processing and its role in modern meteorology and connected branches. It describes some measuring devices and methods how the data are processed. It shows how to create probability map of wind gusts and graphical results.

Keywords: Wind gusts, measurement, distribution model

1. Introduction

Measurement and prediction of the force of wind gusts has become an area of interest for further research and interest after huge wind storms, mainly interested parties were insurance companies due to indications of riskier areas, where is a greater incidence of wind gusts with the average size and potential to make damage. The storms, together with floods are the largest source of damage in the Central Europe, for example - the last big storm in November 2004 destroyed large parts of the Tatra Mountains forests in Slovak republic and recently a similar storm in the Czech Republic left behind enormous damage to forests due to heavy winds. Wind is, inter alia, one of the major players involved in erosion and weathering of rocks. The main goal is the identification of high risk areas and the prediction of damage caused by these events.

2. Measuring of wind gust

The main parameters of wind are speed and direction. The default parameters are determined at a height of 10 m above ground, in some cases (in particular evaporation, temperature and ice phenomena in the flows and reservoirs, etc.) on other levels (usually 2 m above the level of the water or ground). The simplest device for measuring wind direction is a weathervane and for wind speed its cup anemometer, see Fig.1 and Fig.2. Wind direction (from where the wind flows) is deducted according to the position of the direction on the wind rose, wind velocity is determined by the scale metal plate (weight 200 g, size 300x150 mm) hung loosely on the horizontal axis associated with the direction labels. Principle of cup wind speed sensor is very simple. It counts rotations of cups and external counter and electronics will convert it to wind speed at m/s.

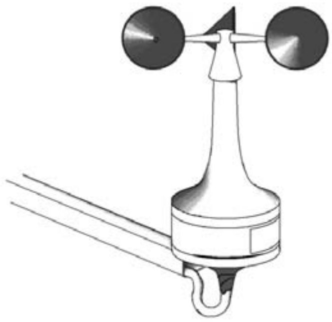

Fig. 1. Wind speed sensor Vaisala WAA 151.

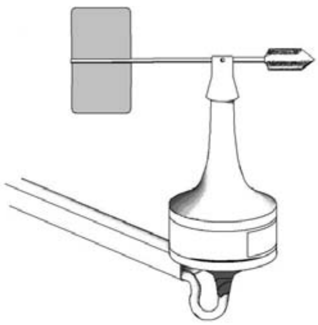

Fig. 2. Wind direction sensor Vaisala WAV 151.

Wind velocity changes significantly in the time, that's why it often indicates the average wind speed (for a certain period, such as 15 or 60 minutes) and the impact wind velocity (maximum speed in a single collision). Wind direction is given under the direction to where the wind blows, using a precise azimuth (0 to 360°), or in meteorology through the world's pages (usually with an accuracy to 22.5°, ie with a resolution on the S, N, W, E, NW and etc.).

Measured wind gusts are short-term maximum rate of flow caused by fluctuations in the specific meteorological conditions due to a strong flow over an uneven surface or where barriers to wind are. Wind - especially wing gusts can be affected by other meteorological events like bigger storms, movement of cold and hot fronts or local thermal change, which should leads to stronger winds or gusts. Wind gusts are estimated or recently measured at selected stations using special anemometers, based on principle of Pitot tube. Today, the automated stations measured continuously and wind gusts are recorded to the database, which is then sent to a central node.

3. Methodic and procedures

Data (wind speed, direction and date) have been exported from the central database of Czech hydrometeorology institute in format of Microsoft Excel. The measured data was in two sets, consisting of the entire wind data collection of individual stations in the West Bohemian region. Data were measured in period of 15 minutes. In the complete data there was a lack of diversity because some stations are still the old type and data was only stored for 1 hour. This creates a certain imbalance between the values but not affect the processing of final results.

First step was to clean up the data from the error of measuring instruments or recording errors. This was done on the basis of considerations about the maximum possible size of the impact of wind in our geographical conditions. On this basis, it has been established interval with measured wind gusts, values outside this interval were deleted and they weren't substitute by any other value, so there was created an empty space in the table. If the values were close to the maximum value of the interval, they were examined and assessed independently by meteorological events that occurred in specific time, such as the transition front or greater storm. This procedure can add error to probability models, but errors at essential file must be deleted, because for creation of models are used highest values of wind from every year or month. So some outlier value can destroy objectivity of whole probability model.

The error values cleanup was made by simple macros in Microsoft Excel. The proposed macros were based on the assumption that if the values of wind velocity will be organized by size, at the top of the table will be the greatest value. If the greatest values will be significantly out of interval, they will be sought in the original table and will be deleted. It is also based on the assumption that the error of device will be really small, less than 1%, otherwise these instruments and recording methods weren't be used by Czech hydrometeorology institute.

After removal of errors and putting the table in the original layout, it was performed basic statistical evaluation and the creation of probability model. The results of individual values should determine which method is the best model for determining the probability of impact of wind gust with the return period of 5, 10, 15, 20, 25, 30, 40, 50, 75 and 100 years.

4. Used distribution models

For comparison were selected 5 probability models: Gumbel distribution, Weibull distribution, logarithmic - normal distribution, and two special meteorological distributions - Lieblein method for the year maximum and analysis of individual storms. This comparison has been made on a small file containing only West bohemia and Carlsbad region. This region contains 10 professional meteorological stations and other amateurs or automaticity measuring machines. Stations are marked at central database by GPS position and represented by sign, for example - station Cheb has sign as L3CHEB01. First part of sign is station type, second means name of station or its acronym and third is number of station in city. The third part is for example for larger cities, where are more than one station.

Tab. 1 shows output of distributions models with time of return 50 years of wind gust (probability models) created for station Primda and Cheb. It also shows comparison between distribution model created from source data of years 1959 to 2007 and distribution model based on data of years 2000 to 2007. Same is for Tab. 2 with difference at time of return 5 years.

Table 1. Example of data table of probability models with time of return 50 years.

	Wind speed [m/s]			
	Station L2PRIM01 Primda		**Station L3CHEB01 Cheb**	
Time section(years)	1959-2007	2000-2007	1991-2007	2000-2007
	Results of distribution models			
Gumbel	49,41	45,21	34,91	29,89
Weibull	46,32	40,13	33,67	53,49
Lognormal	46,75	40,36	33,91	33,59
Lieblien	48,19	44,69	33,31	28,67
Ind. storm	49,25	45,76	36,38	30,63

Table 2. Example of data table of probability models with time of return 5 years.

	Wind speed [m/s]			
	Station L2PRIM01 Přimda		**Station L3CHEB01 Cheb**	
Time section(years)	1959-2007	2000-2007	1991-2007	2000-2007
	Results of distribution models			
Gumbel	38,59	35,11	24,99	25,99
Weibull	38,86	34,92	25,12	28,08
Lognormal	38,44	34,75	28,18	26,04
Lieblien	42,95	37,43	29,67	26,07
Ind. storm	27,76	31,05	24,21	18,31

Graphical result of probability models are at Fig. 3 and Fig. 4. Its geographical map of West Bohemia, part of Czech Republic, with colored areas, where is higher risk of wind speeds and gusts above normal state. Scale is from red (to 50 m/s) to light green (under 32 m/s). Fig. 1 is again for probability model with time of return 50 years and Fig. 2 for time of return 5 years.

For creation of geographical maps were used data from 8 professionals stations (Cheb, Primda, As, Plzen, Marianske Lazne, Klatovy, Karlovy Vary) and 2 automatic stations (near Bezverov and Klinovec). Basically more data for creation of maps is better, but for suitable resolution and exact picture is good to have 10 stations for area similar to this part of Czech republic. Colored areas are mathematically interpolated by software ESRI ArcGIS. Geographical materials and other topography were granted by Czech Hydrometeorology institute, whole project is making at cooperation with them.

Simple result is that for accurate probability model is needed long time data from stations and for approximate output is useful to have about 10 years of data. Mostly this is problem of different system of measuring wind and change of technology of storage data, because most of meteorological institutes changed their technology about 15 or 20 years ago from paper tables with data or magnetic tapes to modern computer equipment and also sometimes station is moved to another location. Problem with data will be slowly solved, because some institutes are working to digitalize paper tables for easily access to old data.

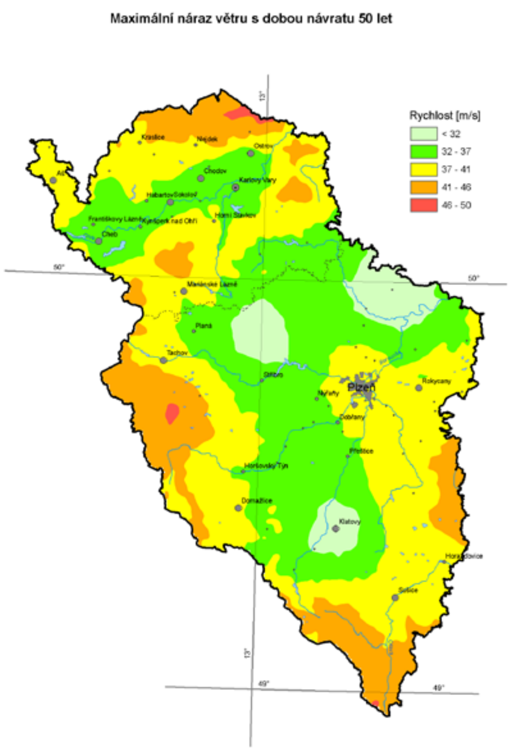

Fig. 3. Probability geographical models with time of return 50 years.

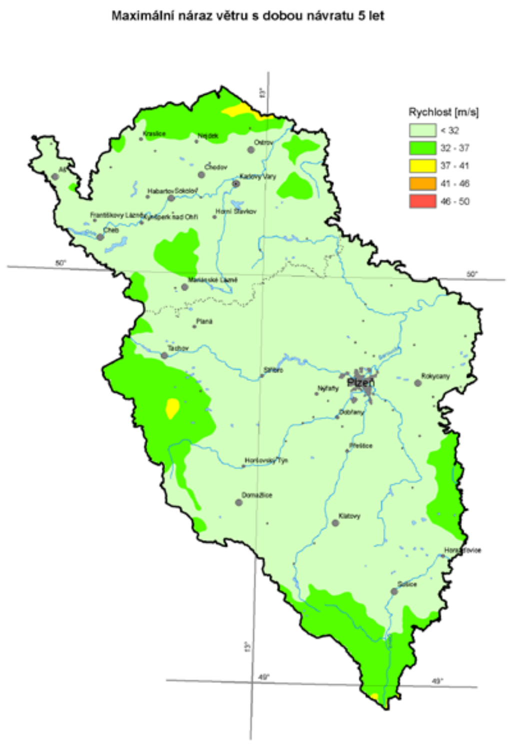

Fig. 4. Probability geographical models with time of return 5 years.

5. Conclusion

In this work was presented data processing method for processing wind gusts and making probability models and maps. The procedure, methodology and the entire results of the West bohemia region is given in my diploma work [1]. This procedure is feasible also on a larger scale, for example on the whole Czech Republic or Central Europe. The main criterion is only a long continuous time series data base file. The disadvantage can be set with extreme amounts of data, which contains errors, and these errors may reflect to results.

In practice, this methodology can be exercised in developing probabilistic geographic maps, where will be marked regions with a greater incidence of wind events and their probable direction of impact.

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