WIND SPEED PARAMETERS ESTIMATION FOR POLAND AS A RESULT OF MEZOSCALE MODELING

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Presentation plan

- Introduction to wind speed modelling methods and Weibull distribution statistical analyses,
- Presentation of statistical analyses of real data acquired from SYNOP dispatch and data from GEM model,
- Results of calculations,
- Conclusions.

Use of wind speed modeling

Recognizing and extrapolation of wind speed is essential for many issues like:

- wind energy sector,
- air polution modeling,
- outdoor bioaerosols transport modeling.

Two-parameter Weibull distribution is considered the most appropriate to characterize wind speed frequency distribution.

Relation between wind speed and height

- Average wind speeds as a function of height above the ground create a wind profile in a given area.
- Wind speed values - extrapolation based on the wind profile created on the basis of measurements.
- Commonly used for this purpose Hellman's exponential law - can be expressed as a formula: [2]

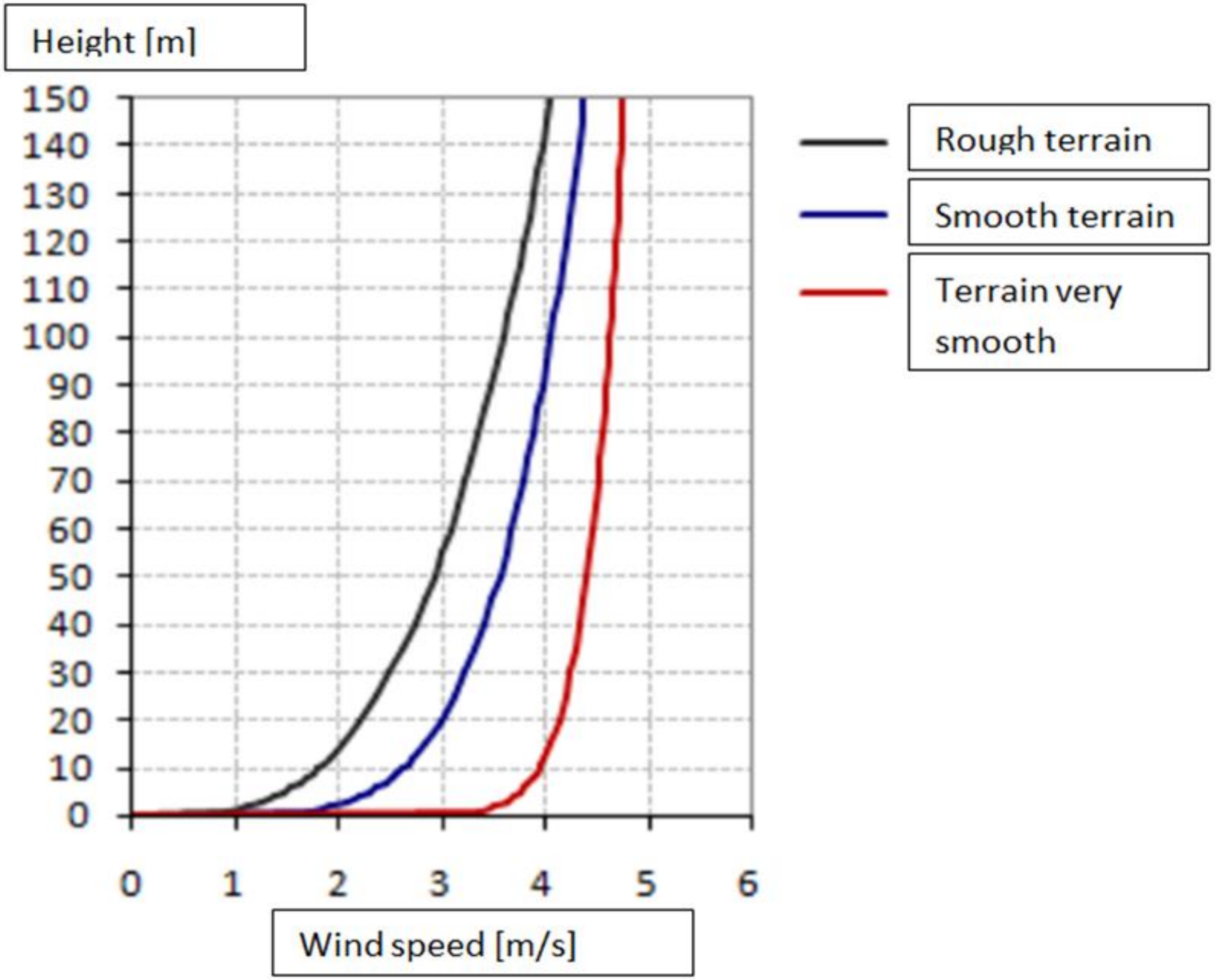
$$\frac{v_1}{v_2} = \left(\frac{h_2}{h_1}\right)^{\alpha}$$

- V1 – wind speed on level h1,
- V2 – wind speed on level h2,
- α – Hellman’s expotential factor; expression of horizontal wind speed variation in a function of level above ground.

Relation between wind speed and height - continued

- α depends on many issues, such as aerodynamic terrain roughness, terrains cover, overall climat at the place, time of day etc.
- If wind speed values are known on two or more levels, there is possibility of use log-linear model for calculation of α exponential factor. Data are being logarithmed to fit to a linear model. Model's slope coefficient is used as α coefficient. Depending on data, α calculated so can be incorrect.
- If known wind speed at only one height – α has to be estimated.
- High possibility of error when estimating wind speed – for example extrapolation of wind speed at 80 m from wind speed known at 10 m has 10% to 30 % probability of mistake.

Wind speed profile in planetary boundary layer [3]



Two-parameter Weibull distribution

- Two-parameter Weibull distribution is considered the most appropriate to characterize wind speed frequency distribution,
- Mentioned Weibull distribution is commonly used for wind speed distribution description,
- Especially good for medium wind speeds description,
- Mentioned distribution describes only empirical experience, not atmosphere phisics, haven't been proven also by any statistical law.

Two-parameter Weibull distribution - continued

- Weibull distribution is a continuous probability distribution, in which probability of phenomena occurence changes in a function of time. Two parameter Weibull distribution is characterized być coefficients k and α. [1]
- Weibull distribution equation for wind speed: [4]

$$f(V) = \frac{k}{\alpha}\left(\frac{V}{\alpha}\right)^{k-1} \exp\left(-\left(\frac{V}{\alpha}\right)^{k}\right)$$

- Where: k - shape parameter, α – scale parameter, V – wind speed

Weibull distribution parameters

- Shape parameter k is strongly related with average wind speed - the breadth of the spectrum of wind speed distributions. It describes wind speed variation in relation to average wind speed value in analyzed time period. It varies from 1 to 3,5. These of 2,5 or 3,0 describe places of small to medium wind speed variation. Low values of k, like 1,5, 1,25, 1,0 are specific for locations of large variation of wind speed.
- Commonly k place in range of 1,6 to 2,4.
- Alpha parameter shows how „big" overally are wind speeds.

Data and data processing

- Data used in work are wind speeds that have been forecasted by mesoscale meteorological model GEM and data aquired from SYNOP dispatch.
- Among the model data, series of wind speed values were selected for three different heights above ground, equal: 10 m, 60 m and 160 m, for a period of one year at points of meteo stations in: Lębork, Łeba, Suwałki, Warszawa, Wrocław Strachowice and Zielona Góra.

Analyzed points on map

Data and data processing -continued

- For this purpose a script in R language was written. It read wind speed from the model, for each point and height, for analyzed year. The sequences of corresponding dates, wind speeds and directions were written.
- For model data and measurement data, Weibull distribution parameters were calculated. For this purpose a program in R language was written, which used library fitdistrplus, containing procedures of distribution fitting and Weibull parameters distribution estimation.
- Fitdistrplus gives possibility to calculate with methodes such as: maximum likelihood, moment matching, quantile matching, maximum goodness-of-fit.

Aim of the work

- Assessment of fitting to Weibull distribution of wind speeds on three heights,
- Assessment of usefulness of four analysed methodes of estimation of Weibull distribution parameters,
- Assessment of compability of the model data form 10 m with measured data from SYNOP dispatch,
- Assessment of differences in values of Weibull distribution parameters, regarding the height.

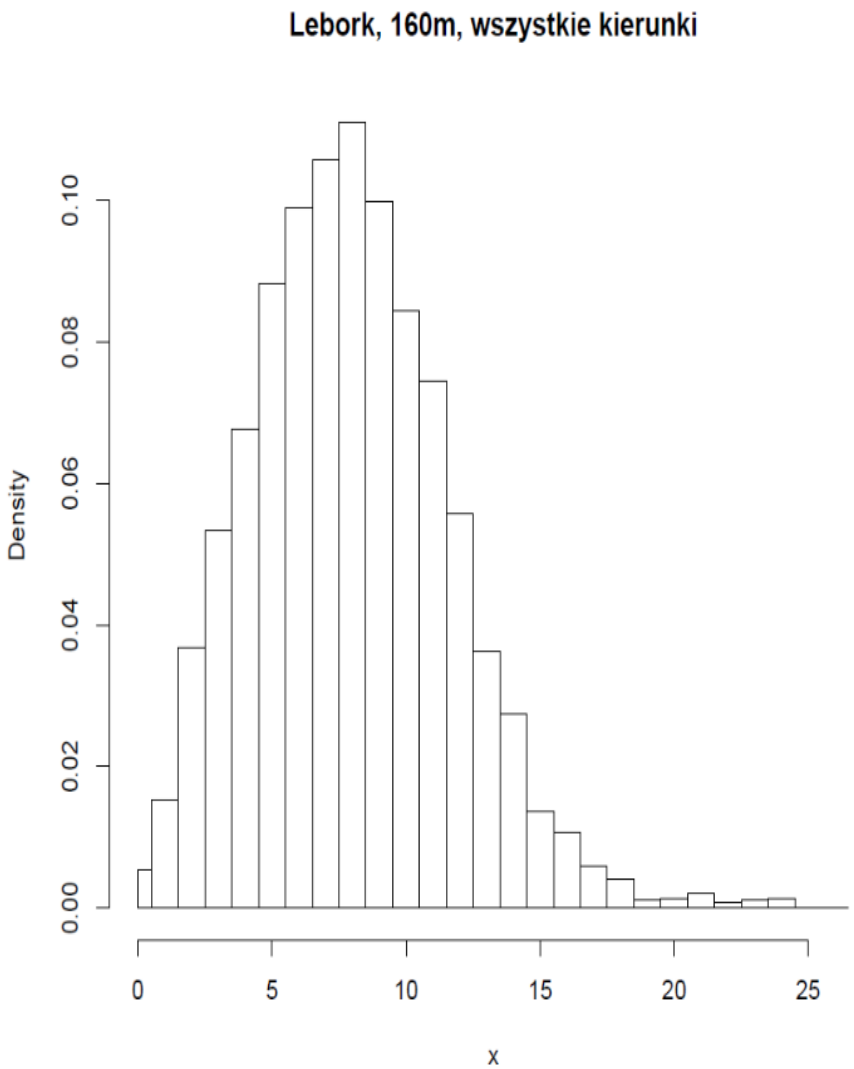
Results of the work

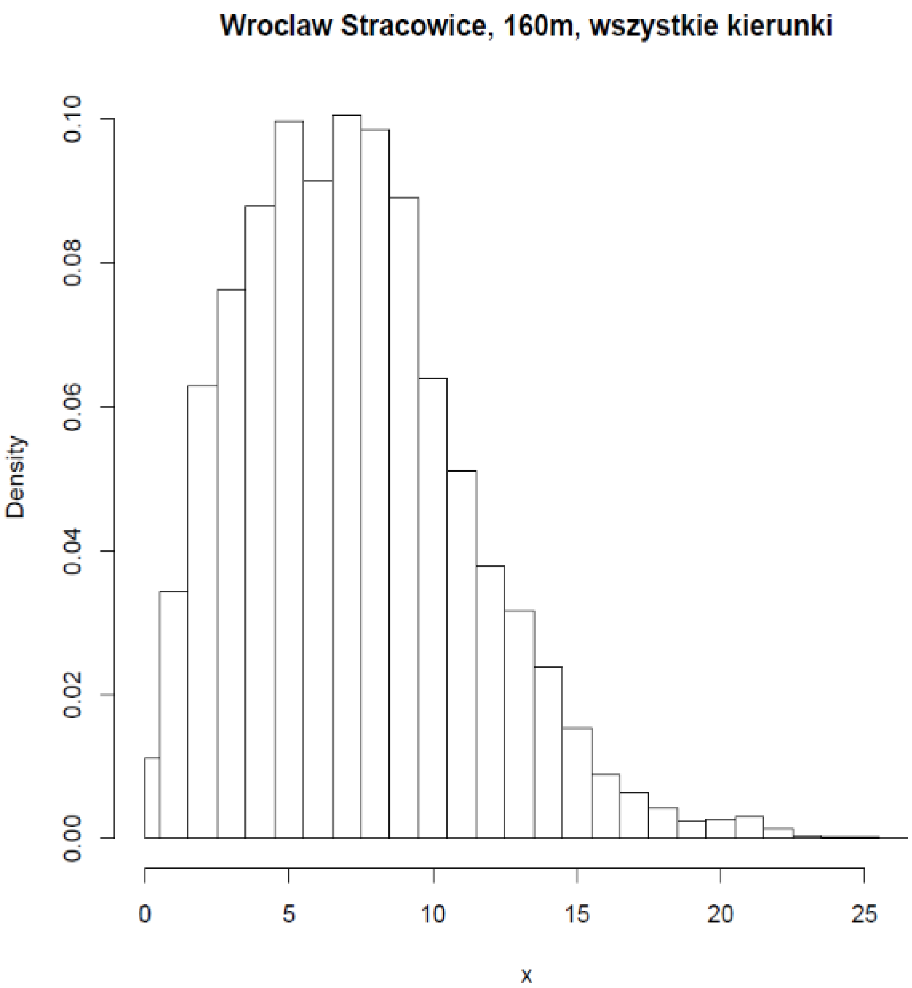
- Weibull wind speed frequency histograms for results of modeling and for SYNOP stations data, for analyzed year period at all mentioned points at three heights,
- Estimated Weibull distribution parameters,
- Charts of Weibull distribution, p-p, q-q and cdf (cumulative distribution function) for all data mentioned above,
- scatter plots, comparing modeled data with these measured at SYNOP station.

Weibull parameters estimation results

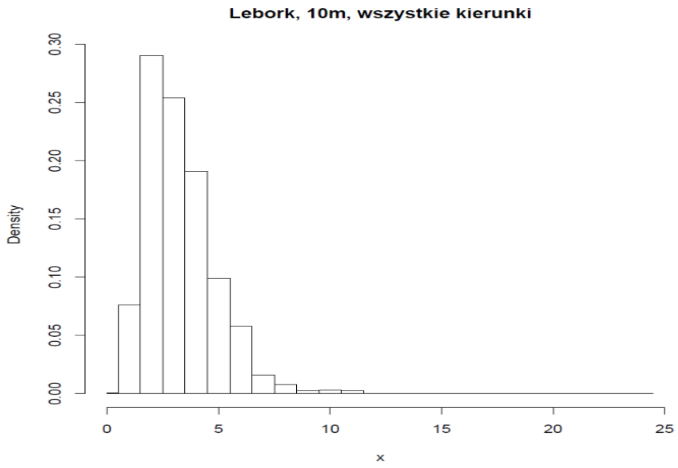
	Lębork	Łeba	Suwałki	Warszawa	Wrocław	Zielona Góra
Poziom 10 m	k=2.22367 α=3.69743	k=2.09544 α=5.66472	k=2.18803 α=4.60317	k=2.06053 α=4.01736	k=1.98781 α=4.0324	k=2.1904 α=3.72479
Poziom 60 m	k=2.38800 α=6.73439	k=2.2358 α=8.11317	k=2.37893 α=7.23649	k=2.23177 α=6.67782	k=2.05001 α=6.52111	k=2.29967 α=6.66344
Poziom 160 m	k=2.31024 α=9.02310	k=2.20473 α=9.94361	k=2.28595 α=9.06978	k=2.13516 α=8.55266	k=1.92884 α=8.1883	k=2.17879 α=8.75553
Pomiar	k=1.67631 α=3.64123	k=1.80455 α=5.68351	k=1.87722 α=3.93505	k=1.3798 α=3.27653	k=1.65369 α=3.46273	k=2.42397 α=3.43916

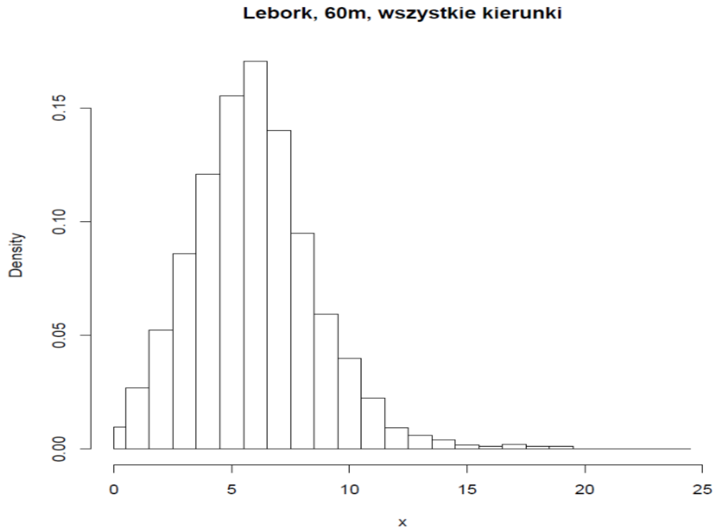
Example Result: Differences in wind speed distributions, wind speed value magnitudes, wind speed values

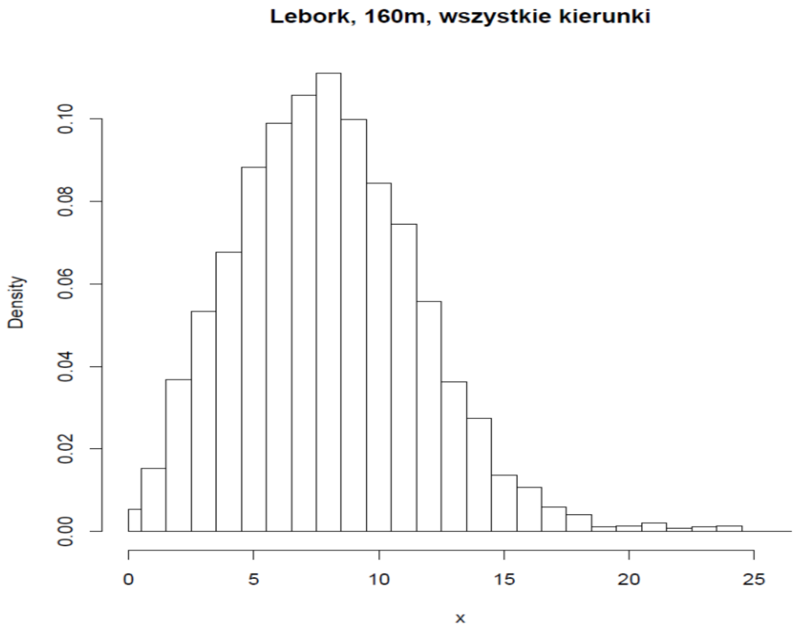




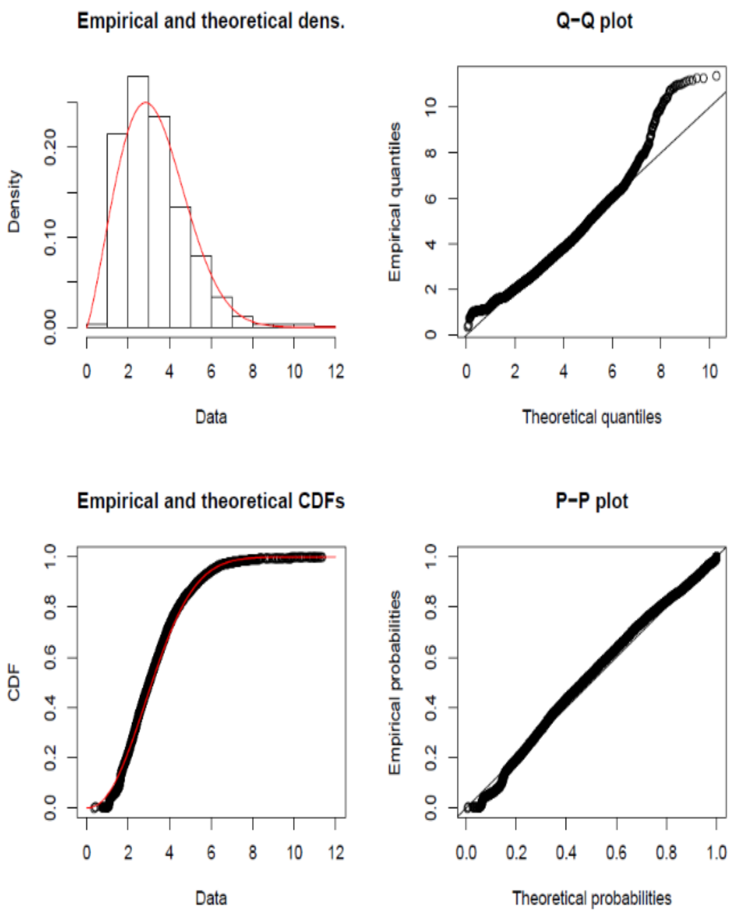
Differences in wind speeds at different levels above ground, example of model data of Lębork

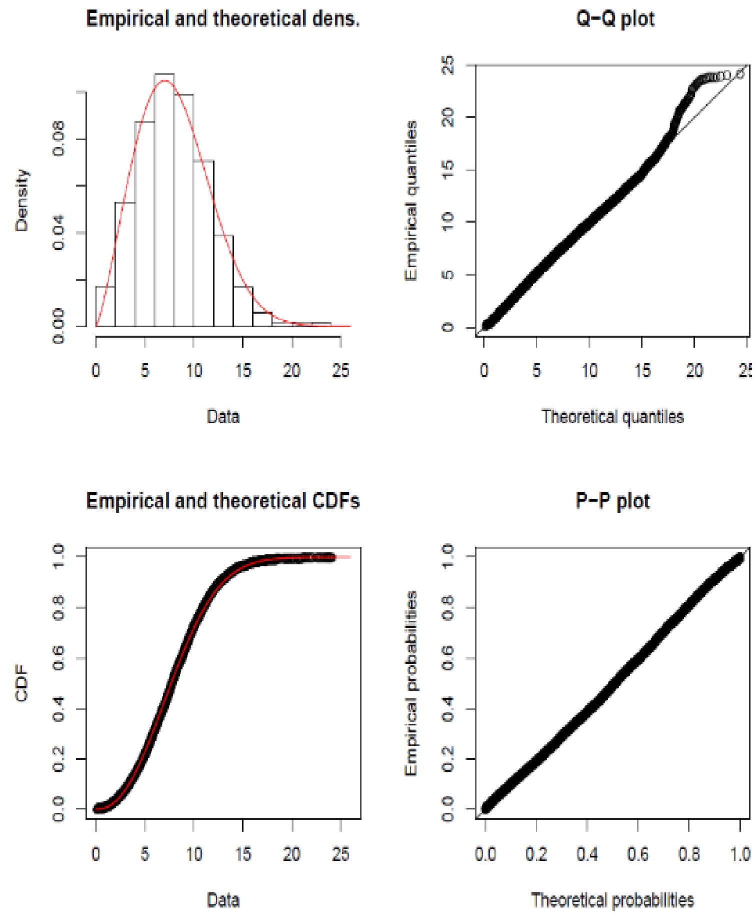




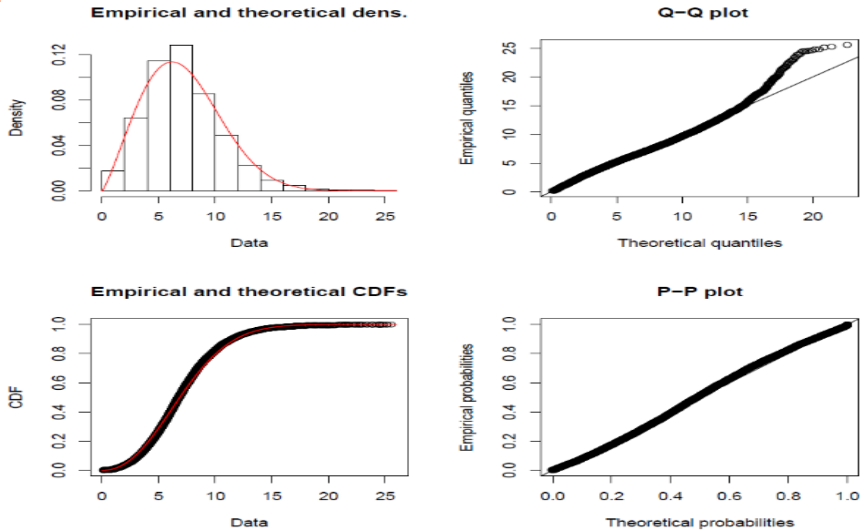


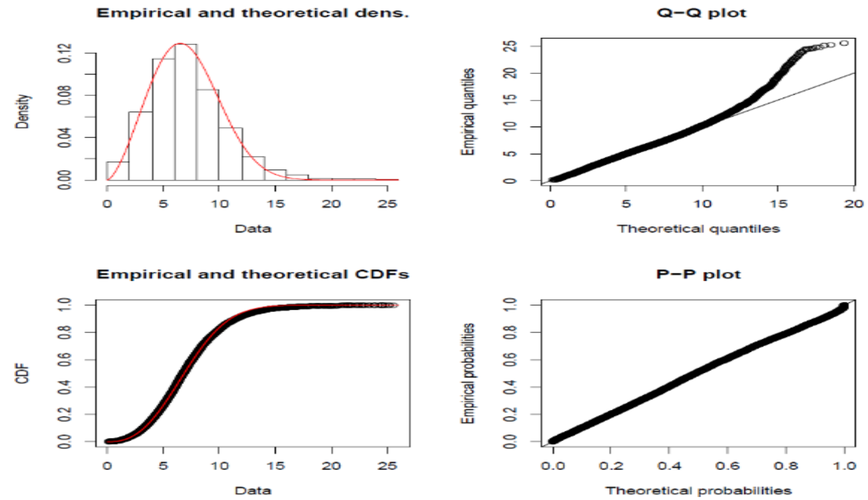
Differences in fitness to Weibull distribution (different heights, example of Lębork 10 m and Lębork 160 m)

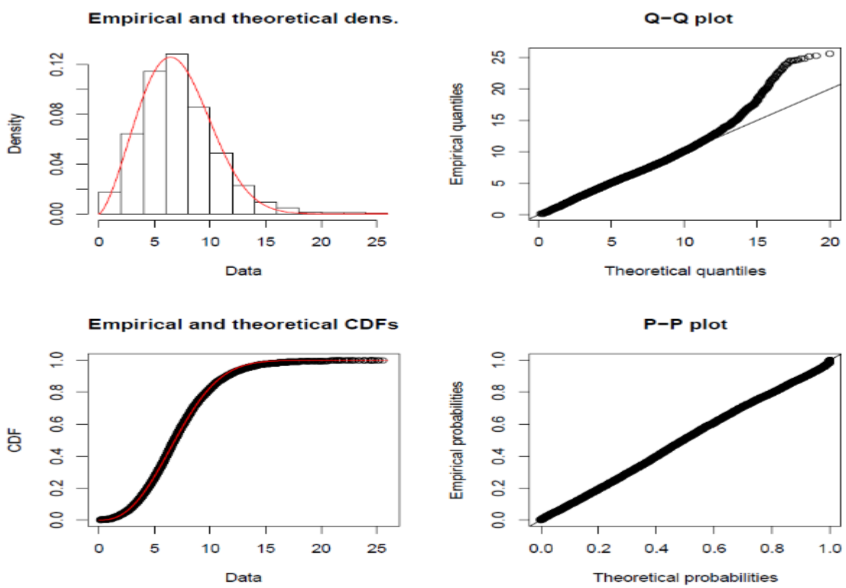


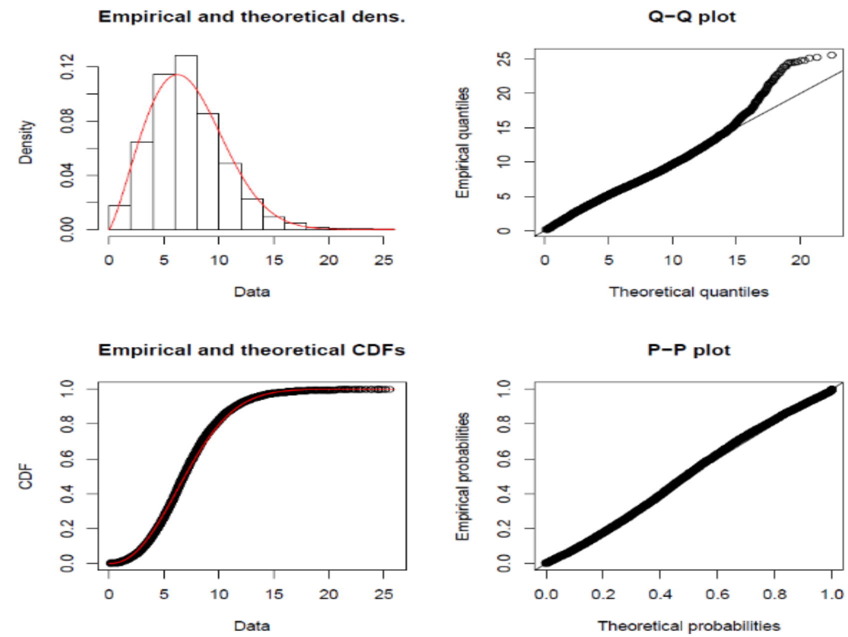


Comparison of results – methods: max. likelihood, moment matching, quantile matching, max. Goodness of fit)









Results of the work

- Weibull distribution – proper assessment of wind speed distribution at every analyzed height.
- The values at biggest height – best fitness to Weibull distribution.
- Results from model for10m – in average less fitted to Weibull distribution than data measured in SYNOP station.
- Model data for Warsaw and Wrocław at 10 m – least compatible of all model data with Weibull distribution, the most – these from Suwałki, at all three heights.
- Data measured at station Zielona Góra – least compatible of all measured data with Weibull distribution.
- Data from the rest locations – very compatible.

Results of the work - continued

- The values of scale parameters – always increasing with the height.
- The values of shape parameters – commonly the lowest for 10 m and often the highest for 60 m. Only at point Wrocław – the lowest value of shape parameter at 160 m.
- None of analysed methods of Weibull distribution parameters estimation was considered the most appropriate.
- Model- slight problems only with description of very low and very high values of wind speeds. At 10 m height – the most problematic. For 160 m – the smallest problems occured and only for the highest speed values.

Results of the work - continued

- Lowest Weibull shape parameters characterised Wrocław, the highest – Lębork, the highest wind speeds were noticed at Łeba station.
- Measured wind speeds values in Zielona Góra and Suwałki are the most compatible with the data from the model.
- Model data for Zielona Góra had probably the most compatible distributions with these for measured wind speeds.
- For stations Lębork and Łeba, despite of small distance between them – quite significant differences between histograms of wind speeds at 10 m and similar at higher levels have been observed. Shape parameters – similar at all heights, scale parameters – at the highest only. Probably – similar shape of wind speed distribution at highest levels for near points.

CONCLUSIONS

- Weibull distribution – proper wind speed distribution assessment at every analysed case.
- The most accurate at highest level, the least accurate at the lowest.
- Values of scale parameters – risen with the height at all analyzed points.
- For Lębork and Łeba – disturbance in results at lowest levels probably caused by too strong impact of interaction of planetary boundary layer with the ground.

Conclusions- continued

- Differences between wind distributions occured for measured and model data for seaside meteo stations – probably because of impact of Baltic Sea near.
- Discrepancy for stations at Warszawa and Wrocław- probably caused by urban heat island effect. The same effect also occured for Zielona Góra, but impact of heat island was weaker.
- Generaly – performance of the model was less or more disturbed by impacts of sea or mountains, but also by urban developent and urban heat island.
- Controlling of the model performance by comparing model data with measured data seems to be important.

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