Assessment of model generated wind energy potential in Poland.

Katarzyna Starosta, Andrzej Wyszogrodzki

Institute of Meteorology and Water Management – National Research Institute. PL-01-673 Warsaw, 61 Podleśna str.; katarzyna.starosta@imgw.pl; andrzej.wyszogrodzki@imgw.pl

Summary

The aim of this paper is to show the suitability of using numerical model wind speed forecasts for the wind power industry applications in Poland. Based on the six months January-June climatology of wind speed data, potential energy zones within the area of Poland have been assessed. For the practical interpretation and further post-processing, results of the numerical model COSMO at 2.8km resolution were verified against data from 60 SYNOP stations.

The verification is performed by comparison of wind rose plots from model simulations and observations at individual station locations. The good agreement is observed over the most homogeneous zone with highly preferred wind speed for the wind energy potential. The smaller agreement is observed at the coastal stations and in the large urban agglomerations.

1 Introduction

In accordance with the guidelines of the European Union, the use of Renewable Energy Sources (RES) increased significantly in the last few years. This embraces tendency of the energy production in a close proximity to the end customers. Thus in addition to large wind farms many small installations have been created in residential areas, farmlands and small businesses. RES technologies have currently high overhead due to investment costs, which translates to a long financial recovery period. Therefore, an appropriate selection of location and even the characteristics of the source of energy is an important issue. At the end of 2015 year, up to 2/3 of RES installations in Poland were based on the wind energy [1].

Estimation of the wind energy potential for the selected location is a key factor and at the same time one of the most difficult steps in making decision in the process of implementation of RES installations. More over the natural processes of climate change and scattered growth of urban zones where consumption of energy is the highest contributes to the increased uncertainty in the development of RES industry.

Since the wind energy is natural weather element highly variable in time and space, it requires detailed studies using different approaches. The climatology of wind speed data is the first criterion for assessing the location of the wind farm. However the typical station network routinely used for this purpose is vastly sparse and does not allow for reliable estimation of spatial and temporal variability of renewable energy resources, especially in the areas affected by the topography or in the close proximity to urban locations.

On the other hand the meteorological models are helpful in estimating the energy resources in the locations where there is lack of measurements or when sensor network does not provide complete data. Currently running operational numerical weather prediction (NWP) models increases their spatial resolution allowing for more adequate representation of the meteorological conditions, even those prevailing within the urban area. Application of numerical model allows for a more detailed study on the role of the individual processes such as radiation properties and wind flow structure, affecting the local climate diversity. Before use of gridded data for estimate the potential energy zones, numerical weather model analysis and forecasts must be verified against the measurements at the available network stations.

2 SYNOP stations and COSMO model configuration.

Currently, RES in Poland are calculated either by the local climatology or as the result of interpolation of current measurements from nearby weather stations.

The annual distribution of the wind energy potential on Figure 1 (i.e. the map "Zones of wind energy in Poland" from [2] Lorenc 1996) based on wind speed data collected between 1976-2005 provide the basic information for investors in the first stage of the selection of wind farms location.

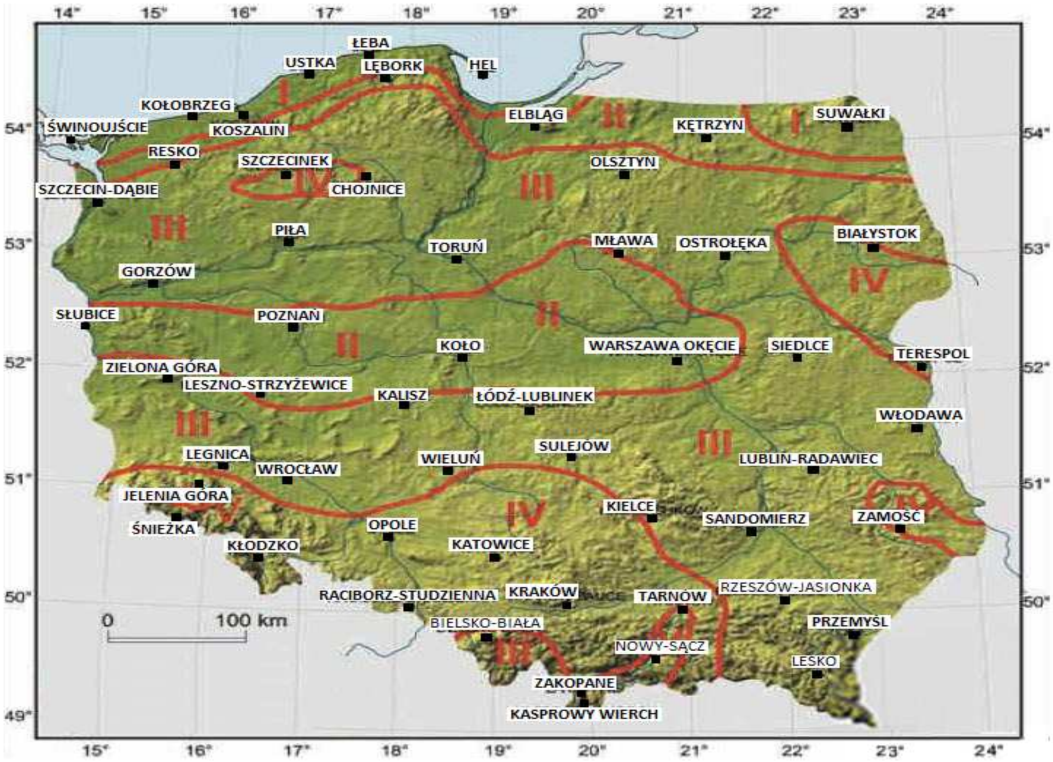

Figure 1: Zones of wind energy in Poland from Lorenc 1996.

Zone	Name of zones	Numbers of synop stations
I	extremely favourable	6
II	very favourable	10
II	favourable	21
IV	less favourable	9
V	unfavourable	3

The Polish Institute Meteorology and Water Management – National Research Institute (IMWM-NRI) runs an operational model COSMO (Consortium for Small-scale Modelling) employing two nested domains at horizontal resolutions of 7 km and 2.8 km (as seen on Figure 2) with 78 hour and 36 hour forecast respectively.

Both models runs four times per day starting at 00, 06, 12, 18 UTC. The COSMO model forecast require provision of the initial state (IC) and boundary conditions (BC) for the whole simulation. The input data are obtained from global ICON model working on icosahedral-hexagonal grid, which runs operationally four times per day at Deutscher Wetterdienst (DWD). The highest spatial resolution of ICON model over Europe equal to 13 km with the forecast time span of at least 78 hours.

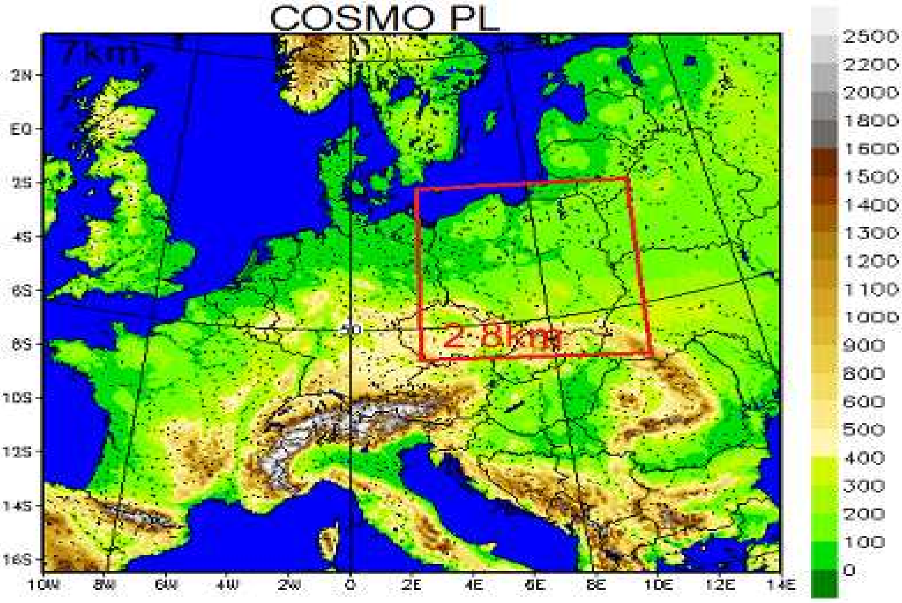

Figure 2: COSMO model domains at 7.0 km and 2.8 km horizontal resolution.

Implemented in COSMO model observational data assimilation (DA) system is based on the nudging technique and allows for ingesting weather data measurements - as e.g. these carried out on SYNOP stations - to improve forecast's quality. Data used in the assimilation cycle of the operational COSMO model at IMWM-NRI are acquired from the WMO/GTS network by the SkyGlobus system.

3 Case study results

In order to make a fair assessment of the reliability of results obtained with the COSMO model, it is necessary to verify model forecasts with available measurements.

In the current section, the 24 hour COSMO 2.8km model forecasts (starting at 00UTC) were compared with continuous observations carried out at 60 SYNOP stations collected in the first half of the 2014 year between January and June. The station locations and their description is presented at Figure 1.

Region/ city stations	Calm %		Average m/s		Resultant vector deg/%		Dominant direction		Dominant class speed m/s	
	synop	model	synop	model	synop	model	synop	model	synop	model
Zone I 6	0.73	0.42	3.93	4.79	161/16	170/19	S,W,E	S	0.5_2.1	3.6_5.7
Zone II 10	3.31	0.51	3.73	3.73	130/9	161/13	E,W	SE,W,E	3.6_5.7	3.6_5.7
Warszaw	11.14	0.48	3.37	2.90	60/10	141/8	W,SEE	SE	0.5_2.1	0.5_2.1
Zone III 21	2.95	0.60	3.22	3.55	148/6	174/10	W,E	W,SE	0.5_2.1	0.5_2.1
Zone IV 9	5.03	1.17	2.89	3.37	232/1	166/5	S, W, E	S,W	0.5_2.1	0.5_2.1

Table 1: The characteristics of the wind in the individual zones

Table 1 contains the wind characteristic of SYNOP data and model forecast in the diverse energy zones from Figure 1 and at the urban location within the city of Warsaw. The best agreement in terms of average wind speed and wind direction is seen in Zone II, the lesser agreement is observed in the Zone IV and at the urban location in Warszawa. In order to better interpret the above statistics we have computed additional results in the form of wind roses generated from NWP model and SYNOP stations, averaged within each zone. A wind rose is a concise and illustrative product analyzing wind speed and wind direction at a certain location. It provides information about the frequency of winds at certain speed ranges and particular direction, as well as its time percentage. In current calculations the WRPLOT View program was utilized to generate appropriate plots [3].

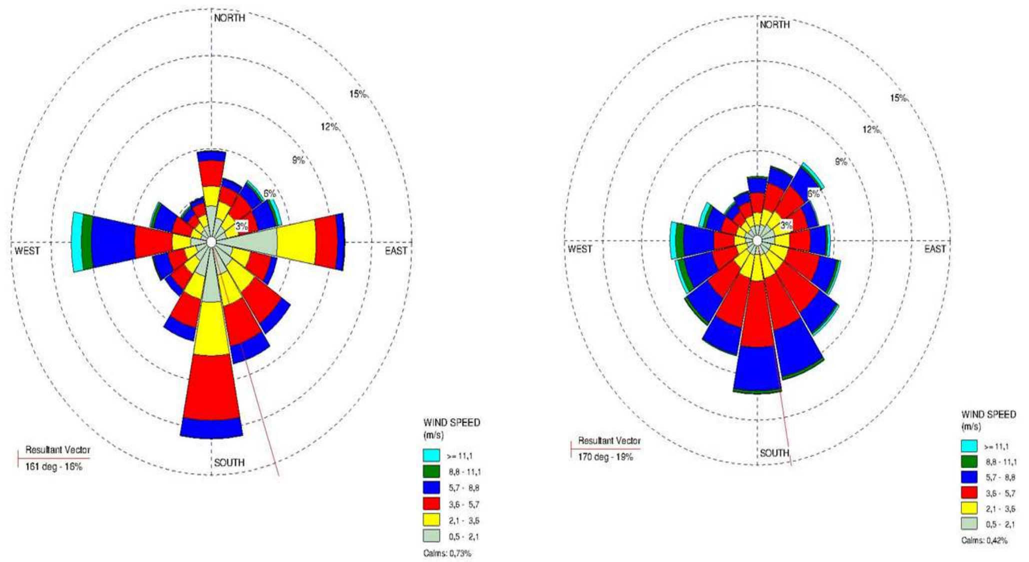

Figure 3: Wind roses for Zone I (6 stations) averaged between January-June 2014: SYNOP stations (left), COSMO model (right)

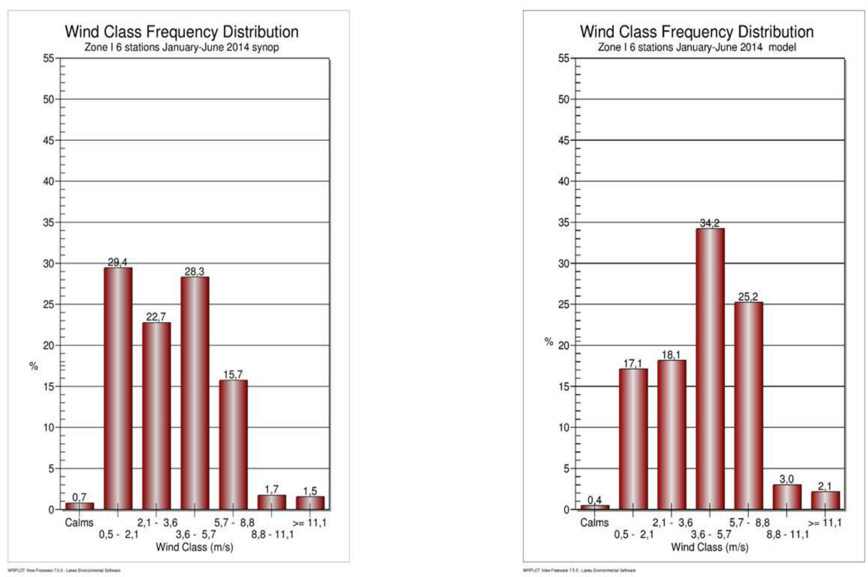

Figure 4: As in Figure 3 but wind class frequency distribution

Zone I (extremely favorable), covers the seaside area in Poland and north-eastern corner of the country. In the analyzed period, 65% of the forecasted winds were very favorable for the production of energy. In this zone, the wind directions are very diverse. The average wind speed predicted in the model is significantly higher than the observed one. The maximum wind speed of synoptic data from the selected wind directions are higher than data from the model. This situation is associated with the coastal station locations, and requires more detailed research for each location.

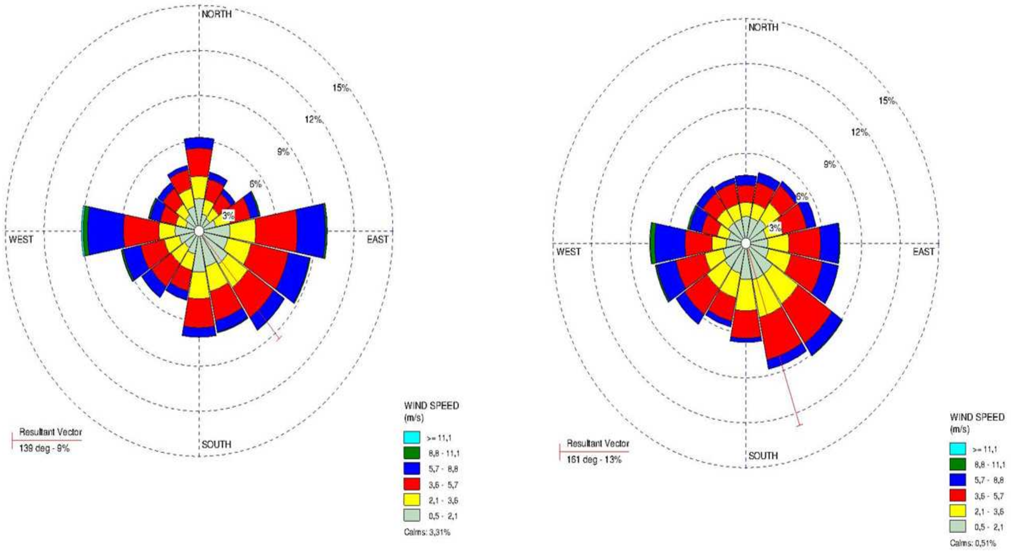

Figure 5: Wind roses for Zone II (10 stations) averaged between January-June 2014: SYNOP stations (left), COSMO model (right)

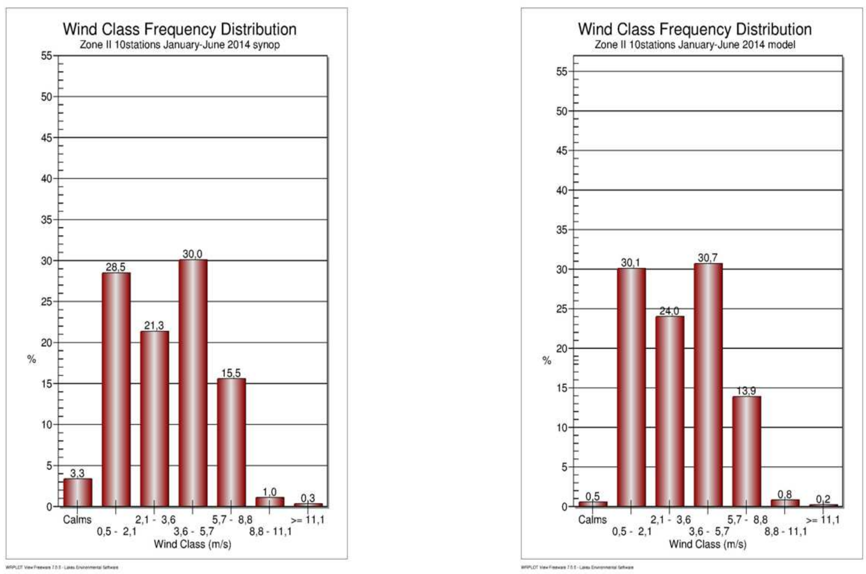

Figure 6: As in Figure 5 but but wind class frequency distribution.

Zone II (very favorable area) - is the most homogeneous with highly preferred situation of wind speed. It covers a continuous area of the central Polish lowlands and is the only zone where the dominant is the class of wind speed range 3.6-5.7 m/s for both prediction and observation. In this zone, the average value of wind speed predicted from COSMO model is the same as from observations. The consistency is also observed analyzing frequency distribution of particular wind speed classes.

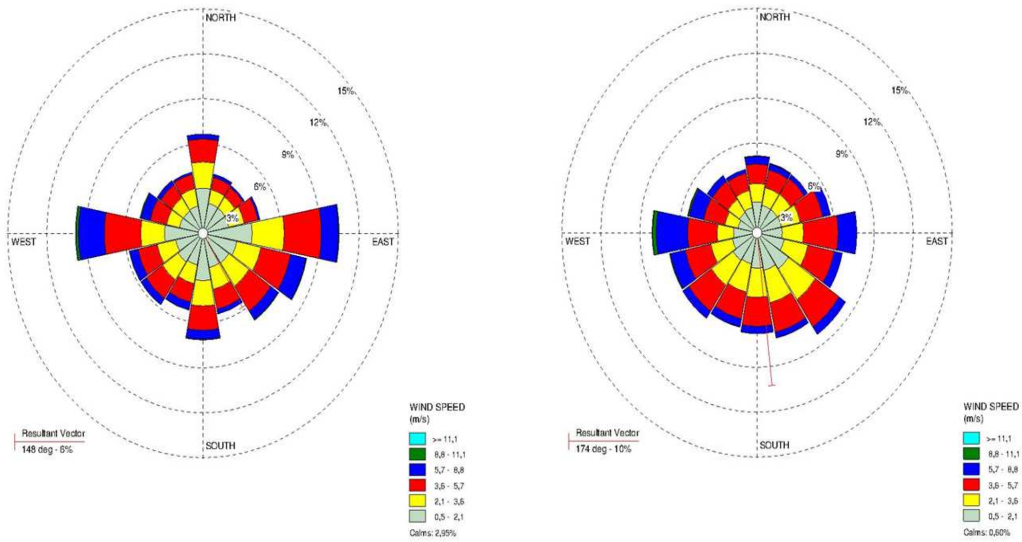

Figure 7: Wind roses for Zone III (21 stations) averaged between January-June 2014: SYNOP stations (left), COSMO model (right)

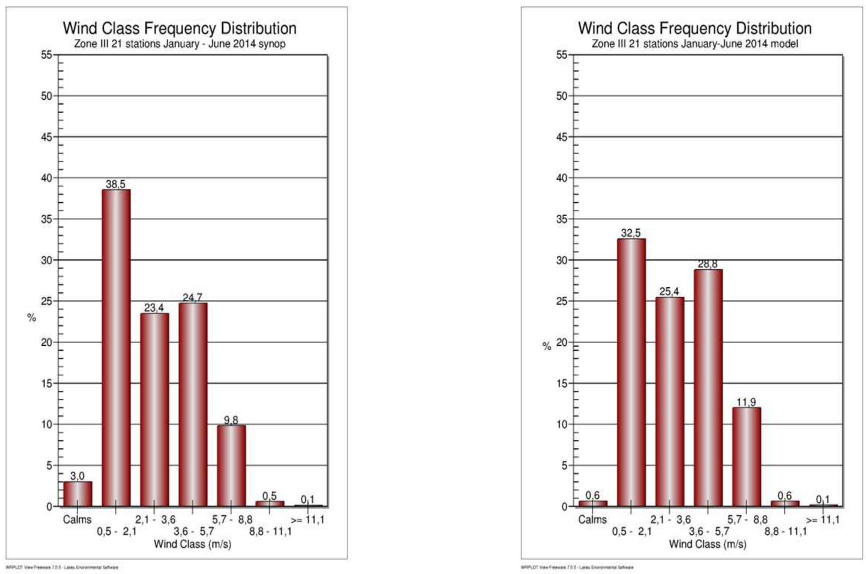

Figure 8: As in Figure 7 but wind class frequency distribution

Zone III (favorable) covers the largest and very diverse area, including lake districts, upland areas and the low mountains. We are observing in this zone a slightly higher wind speed forecasts than the observed average wind speed. The maximum values for wind speed are higher for the observations. In this zone, the lowest class of the observed wind speed show higher frequency of the distribution then the model forecast one.

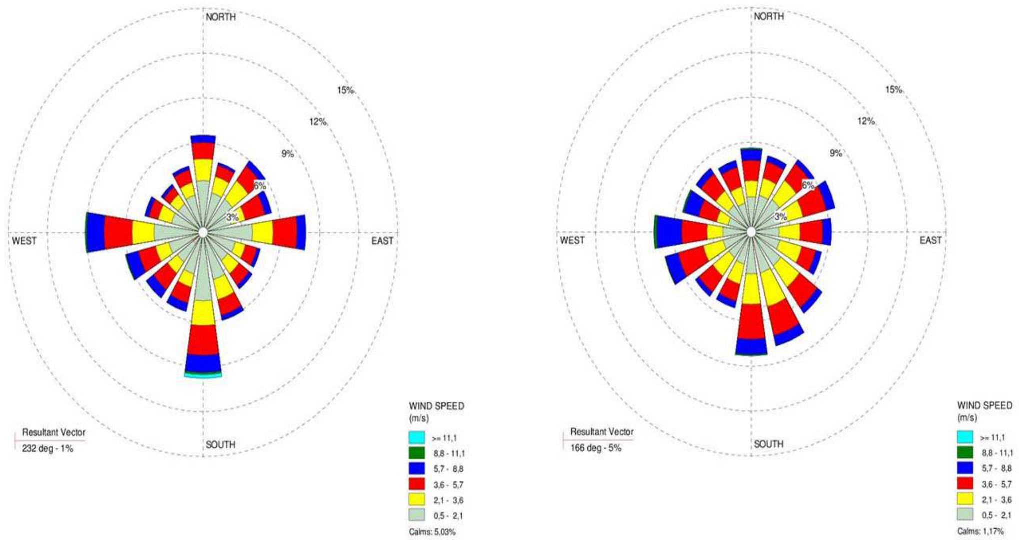

Figure 9: Wind roses for Zone IV (9 stations) averaged between January-June 2014: SYNOP stations (left), COSMO model (right)

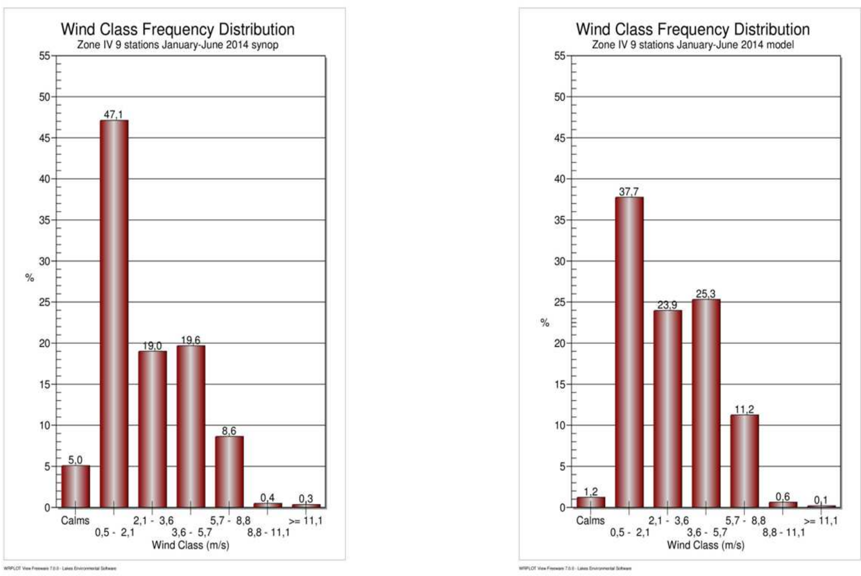

Figure 10: As in Figure 9 but wind class frequency distribution

Zone IV (less favorable) includes foothill and mountain areas with highlands and plateaus in the eastern part of the country. Due to the nature of the zone observed wind directions are varied. In this zone there is also a significant amount of (5%) calms with little or no air movement. A bit higher speeds are predicted in the model than observed at the stations.

The zone V Including mountainous terrain is unfavorable for wind energy, and has been omitted from the current analysis.

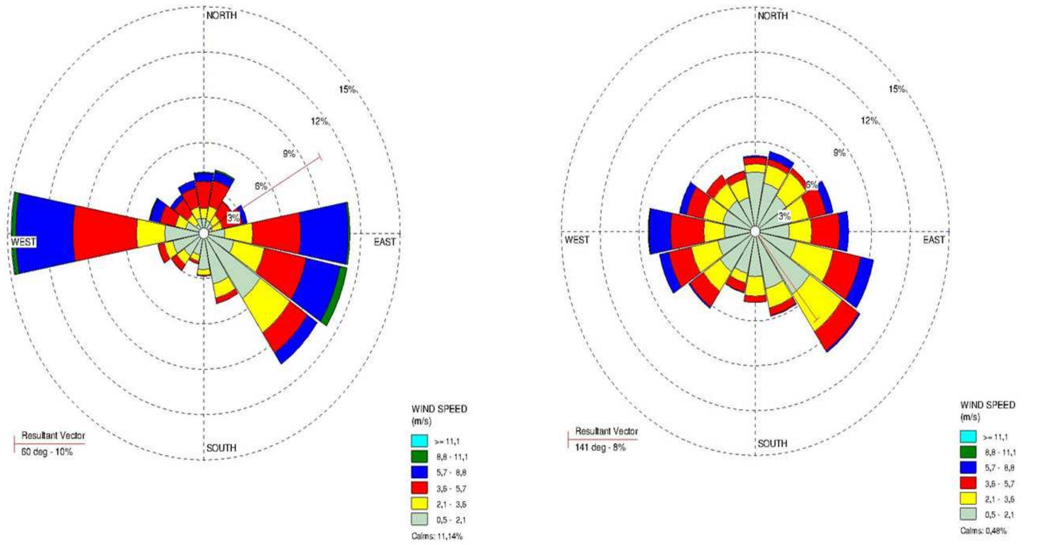

Figure 11: Wind roses for Warszawa averaged between January-June 2014: SYNOP stations (left), COSMO model (right)

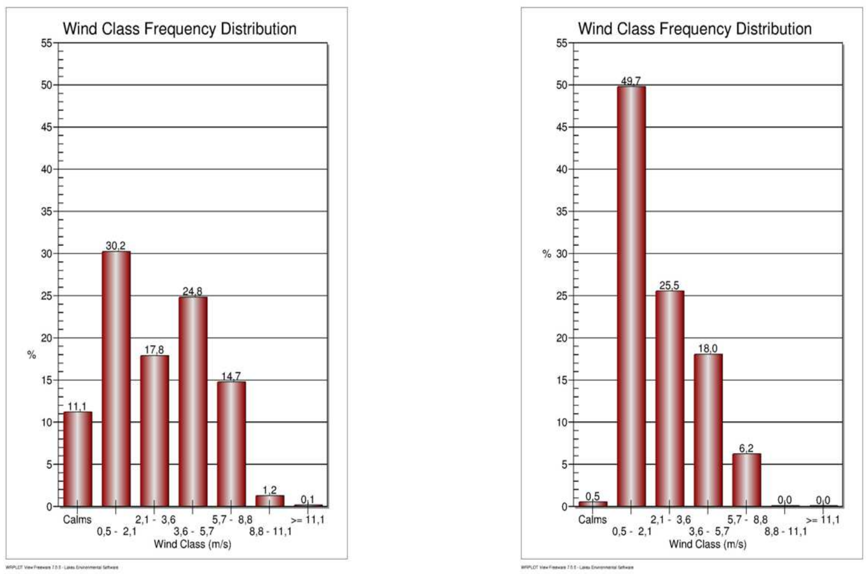

Figure 12: As in Figure 11 but wind class frequency distribution

Synoptic station in Warszawa is located in the south-western part of the city, at the Okęcie airport. A big urban agglomeration as Warszawa shows higher errors than the average error for the same zone. At the weather station there is observed significant amount of calms (11%). In the model, this translates into a very large percentage of small-wind speed (50%).

4 Summary and Outlook

Our motivation to perform presented here analysis of the COSMO model wind forecast as the source of energy potential in the area of Poland was the increased interest in renewable energy applications, which is associated with recent EU guidelines. An increasing awareness about the benefits of clean energy, results in the intensified development of traditional wind farms, as well as in micro installations and smart grids. The presented wind rose analysis depicts in each of the wind zones the frequency occurrence of particular classes of wind speed and wind direction for a given location and time period. In the comparison with synoptic measurements we observe larger number of listed periods of silence, which in the model is generally at the level below 1%. The interpolation of model gridded data into the point station locations enhances this effect by allowing greater spread of the wind directions and generally reduced maximum speed of the wind. The largest forecast errors are observed in the Zone I and are associated with the coastal effects at the interface between land and sea. Whereas in other zones forecast errors are much smaller. In the zone III, we observe the underestimation of the lower wind speeds by the model and overestimation of the greater wind speed amplitudes. Large urban agglomerations as Warszawa produces significantly higher errors than the average errors in the same zone. The complex structure of the urban areas is currently a challenge for the generation of representative urban meteorology and will be the subject of further investigations.

References

[1] Energy Regulatory Office - http://www.ure.gov.pl/ (in polish)

[2] Lorenc H., 1996, Struktura i zasoby energetyczne wiatru w Polsce, Materiały Badawcze, Seria: Meteorologia -25, IMGW, Warszawa (in polish).

[3] Lakes environmental software _WRPLOT View - *http : //www.weblakes.com/products/wrplot/*