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Potential usage of met mast datasets for climatic parameters monitoring in Tulcea County, Romania

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Abstract

In order to evaluate the potential usage of high-accuracy climatic data measured continuously in the frame of newly developed renewable energy facilities in Romania for real-time local scale monitoring of climatic parameters, we used 2 years (May 2009 – May 2011) of in-situ climatic datasets measured at 7 met masts locations in Tulcea County. Realization of detailed thematic climatic maps afforded a more focused view of the spatial distribution and of the local patterns for air temperature, relative humidity and pressure, wind speed, direction and energy in the frame of the study site. On the basis of these preliminary results, we emphasize the great potential of similar in-situ real-time measured data to be integrated in the future, together with the data provided by meteorological stations, into complex databases. Their usefulness emerges from their capabilities of being integrated in specialized web-GIS platforms for real-time or near-real-time monitoring of small spatial scale climatic parameters and of contributing to climatic models calibration, weather forecasting, feeding early warning systems for local climatic hazards or to rapid small spatial scale assessment of air pollutants dispersal following different scenarios of wind speed and direction. Further research and initiatives are necessary in the near future for the creation and implementation of these databases in order to become operational.

Keywords: *Renewable energy, real-time monitoring, climatic maps, climatic databases, local conditions.*

Rezumat. Potențialul de utilizare a datelor catargelor meteorologice pentru monitorizarea parametrilor climatici în județul Tulcea, România. În vederea evaluării potențialului de utilizare a datelor climatice de mare acuratețe, măsurate în mod continuu în cadrul noilor parcuri de energii regenerabile din România, pentru monitorizarea în timp real, la scară locală, a parametrilor climatici, am folosit 2 ani (Mai 2009 – Mai 2011) de date climatice măsurate in-situ cu ajutorul a 7 catarge meteorologice amplasate în județul Tulcea. Realizarea unor hărți climatice tematice detaliate ne-a permis o privire mai atentă asupra distribuției spațiale și a paternurilor locale ale temperaturii, umidității relative și presiunii aerului, precum și ale vitezei, direcției și energiei vântului în cadrul ariei de studiu. Pe baza acestor rezultate preliminare, scoatem în evidență potențialul mare al datelor similare, măsurate in-situ în timp real, de a fi integrate în viitor, alături de datele furnizate de stațiile meteorologice, în baze de date complexe. Utilitatea lor reiese din capacitatea acestor baze de date de a fi integrate în platforme web-GIS specializate pentru monitorizarea în timp real a parametrilor climatici locali și de a contribui la calibrarea modelelor climatice, la prognoze, în cadrul sistemelor de avertizare pentru hazarduri climatice sau pentru evaluarea rapidă, la scară locală, a dispersiei poluanților atmosferici în diferite scenarii de viteză și direcție a vântului. În vederea operaționalizării lor, sunt necesare însă, în viitorul apropiat, mai multe studii științifice și inițiative concrete pentru crearea și implementarea acestor baze de date.

Cuvinte-cheie: *Energie regenerabilă, monitorizare în timp-real, hărți climatice, baze de date climatice, condiții locale.*

Introduction

The proper real-time evaluation of the local climatic conditions (air temperature, pressure and humidity, solar radiation, wind speed and direction at different levels above ground level) from a specific area allows real-time air quality monitoring, better understanding of pollutants spreading in the different layers of the lower atmosphere (direction, magnitude and location of air pollutants plumes) and rapid and optimal response regarding integrated and durable management of the environmental factors from a specific region.

Romania is an emerging country regarding the development of renewable energy capacities, especially wind energy, solar energy and hydropower. Wind power has established itself as a mainstream source of electricity generation and plays a central role in the immediate and longer term energy plans. From this point of view, Romania is one of the twenty-four countries worldwide with more than 1.000 MW of installed wind capacity (Wind energy and other renewable energy sources in Romania, 2014), having the highest wind energy potential in the South-East Europe and the second one in Europe, with a predicted total installed capacity of 14.000 MWh (Mihailescu, 2009).

In this context, in the last years, in accordance with the EU community regulations regarding the increase of renewable energy sources share in the total energy consumption (Colesca and Ciocoiu, 2013), hundreds met masts were installed and approximately 60 wind farms (with an average power of 50 MW) were developed in different regions of Romania, especially in Dobrogea and Southern Moldavia (Wind energy and other renewable energy sources in Romania, 2014). These masts are equipped primarily with wind sensors (anemometers and wind vanes) for wind speed and direction measurements and, secondary, with air temperature, pressure and humidity sensors. Moreover, in the frame of the numerous photovoltaic parks, solar radiation is also measured.

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These data have high accuracy as they are measured using professional instruments installed in open exposed areas, with no obstacles or other interferences. All these data are continuously measured and logged by each developer and can be used for other purposes like local air quality monitoring, calibration of climatic models at local scale etc. Furthermore, keeping in mind the relatively scarce territorial coverage of the meteorological stations operated by Romanian Administration of Meteorology (ANM) and the poor quality of the data provided by some of these stations, issued from their faulty location, the data measured in different types of renewable energy facilities (wind farms or photovoltaic power stations) should be considered not an alternative to the meteo stations data, but an add-in to them.

Our goal is to demonstrate the huge potential of the datasets registered by met masts to be integrated, together with the meteo stations data, in larger databases which can be, for example, further integrated in complex web-GIS platforms in order to provide a real-time or near-real-time monitoring of the climatic parameters across extensive regions from Romania. In this purpose, we are using climatic data measured during 2009 -2011 period, provided by 7 masts installed in Tulcea County, for the monitoring of climatic parameters (air temperature, pressure and humidity, solar radiation, wind speed, direction and energy).

Study area

Tulcea County is located in south-eastern Romania, in the northern part of Dobrogea region (Figure 1). It has a surface area of 8500 km^2, covering the Northern Dobrogea Plateau, the Romanian Danube Delta and part of the Black Sea coast. The relief has altitudes between 0 m and 467 m (Monograph of Tulcea, 1980).

From the climatic point of view, Tulcea County is located in a transitional area between the Eastern Europe continental climate and the Balkan Peninsula pre-Mediterranean temperate climate. These particular climatic characteristics are represented by the interference of excessive continental climate, sub-Mediterranean climate and Black Sea influence along the coast: high temperature amplitudes (66.3°C), low precipitation values (below 400 mm), hot and dry summers and cold winters with strong winds (Climate of Romania, 2008). In the Danube Delta, the temperature variations are moderate, air humidity is higher and precipitation values are lower. The coastal area has a milder climate with lower summer and higher winter temperatures.

The mean annual temperatures are varying between 9°C in the higher plateaus and 11.1°C in Danube Delta (Isaccea) and along the coast (Sulina). Precipitations are variable and approximately 55% are registered in the warm season. The mean annual precipitations are comprised between 325 mm at Sulina and 455 mm at Isaccea (Climate of Romania, 2008).

Fig. 1 Tulcea County limits (*green line*) and the locations of the met masts (*pink balloons*) and of the meteorological stations (*green balloons*).

The wind regime is influenced by the development of different types of pressure systems passing the study area (Mediterranean cyclones with trans-Balkans trajectories - Vespremeanu-Stroe and Tătui, 2011) and the relief configuration. The highest frequencies are registered by NE (18.3%), NW (17.1%), E (15.2%) and N (13%) winds, with mean annual speeds up to 5.3 m/s (Climate of Romania, 2008). From this point of view, Tulcea County has a high wind energy potential, issued from the multi-annual mean wind speeds measured at 10 m height of 4 – 6 m/s (Vespremeanu-Stroe et al., 2012).

Data & Methods

In order to monitor climatic parameters distribution in Tulcea County, we used in situ measurements during 24 months (May 2009 – May 2011) from seven meteorological masts, with total heights of 60 and 80 m (Table 1), and from three meteorological stations (Tulcea, Sulina and Sf. Gheorghe) – Figure 1. The seven masts are part of a complex short/medium-term measuring/monitoring system of climatic parameters in Tulcea County used for real-time management of environmental factors in this area. For a good spatial distribution, the meteorological masts were relatively evenly spread across the county area, being installed in open farm land, in the proximity of seven villages: Isaccea, I.C. Brătianu, Nalbant, Beştepe, Sarighiol de Deal, Topolog and Jurilovca (Figure 1, Table 1).

In order to measure air temperature, humidity and pressure, wind speed and direction and solar radiation, each mast was equipped with the following Ammonit instruments: one Hygro-thermal sensor (10 m height), one Barometric Pressure Sensor AB60 (10 m height), 3 Thies anemometer first class (80/60m, 78.5/58.5m and 62/40m height), 2 Thies wind vane compact (78.5/60m and 62/40 m height) and one Pyranometer CMP3 (10 m height). Measured data have been registered with Ammonit Meteo-32 data logger with a sampling rate of 1 Hz as 10 min. averages for all the climatic parameters and transmitted via GSM/GPRS system.

The data transfer, configuration and monitoring were done using Ammonit CALLaLOG software.

Table 1: Location and characteristics of measuring masts.

Site	Location	Height a.s.l. (m)	Tower Height (m)
Isaccea	N45° 15' 03.0" E028° 28' 18.5"	56	60
I.C. Brătianu	N45° 23' 74.8" E028° 04' 26.7"	7	60
Nalbant	N45° 02' 34.8" E028° 34' 82.1"	143	80
Beştepe	N45° 05' 33.2" E029° 00' 13.8"	64	60
Sarighiol de Deal	N44° 42' 63.8" E028° 30' 20.4"	275	80
Topolog	N44° 54' 49.9" E028° 21' 82.2"	336	60
Jurilovca	N44° 46' 92.6" E028° 52' 29.8"	82	60

The measured climatic data from each location formed an individual dataset which was further integrated in a complex database for the entire study area. These data were the input for the analysis and mapping of each climatic parameter distribution across the county area. The thematic maps were realized using either simple interpolation techniques in GIS software (for air temperature, pressure and humidity), or specialized wind energy assessment software (for wind speed, direction and energy) like WindPro 2.7 (Nielsen and Chun, 2000) and WAsP 9.0 (Petersen et al., 1981, 1998; Nielsen and Chun, 1994). Due to some technical problems of installed pyranometers, which resulted in important gaps in the datasets, we decided not to include solar radiation analysis in this study. The calculation of the wind conditions across the study area considered the influence of terrain roughness, obstacles and orography on the wind conditions at defined points of reference according to the method of WINDATLAS (Troen and Petersen, 1988), using similar methodology as described in Tătui, 2014. This physical method allows for the transfer of measured wind speeds from a certain measuring point to another site or even a whole region. Hence, wind data from a meteorological station or a measuring mast with its characteristic terrain conditions (obstacles, roughness and orography) are transformed into regional wind climatology.

Results & Discussion

This section presents the distribution of measured climatic parameters (air temperature, relative humidity and pressure, wind speed, direction and energy) for 2 years over the study area, emphasizing the high accuracy of measurement results and their good potential for regional climate monitoring. Real-time values of similar measurements, integrated in larger datasets, could fill-in the gaps in the distribution of meteorological stations over Romanian territory and lead to proper assessment of local climatic conditions, air quality or location, movement and spreading of air pollutants plumes.

Air temperature, relative humidity and pressure distribution

Multi-annual average air temperature distribution over the study area is relatively uniform, with small differences between different regions of Tulcea County. The analysis of 50 years (1961 – 2003) of data measured at Tulcea and Sulina meteorological stations (Table 2) shows small differences of these values: 10.8°C for Tulcea station and 11.1°C for Sulina meteo station. The multi-annual monthly averages throw out into relief more continental conditions in the eastern and central parts of the county and milder conditions in the western part (as a result of the Black Sea proximity and the presence of vast aquatic areas in the Danube Delta), pointed out by smaller amplitudes and higher air temperature values in both warm and cold seasons registered at Sulina meteo station (Table 2).

Table 2: Multi-annual monthly air temperature averaged for 1961 – 2003 period (*All values are expressed in °C*).

Station	Month												Average	Amplitude
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII		
Tulcea	-1.8	-0.2	4.2	10.3	16.2	19.9	22.2	21.1	17.4	12.6	6.2	1.8	10.8	24.0
Sulina	-0.7	-0.2	4.1	9.6	15.8	20.1	22.5	21.8	17.9	12.7	6.8	2.1	11.1	22.8

The relative uniformity of air temperature distribution discussed above is not so obvious when analyzing 2 years of data (May 2009 – May 2011) measured by the 7 met masts (Figure 2). We can observe higher air temperature values than the multi-annual averages, with differences of more than 1°C between the eastern and south-western parts of the study area (from 12.5°C to 11°C, respectively). Good dispersal of met masts over county area affords a more focused view of air temperature distribution and permits local scale analysis of this distribution.

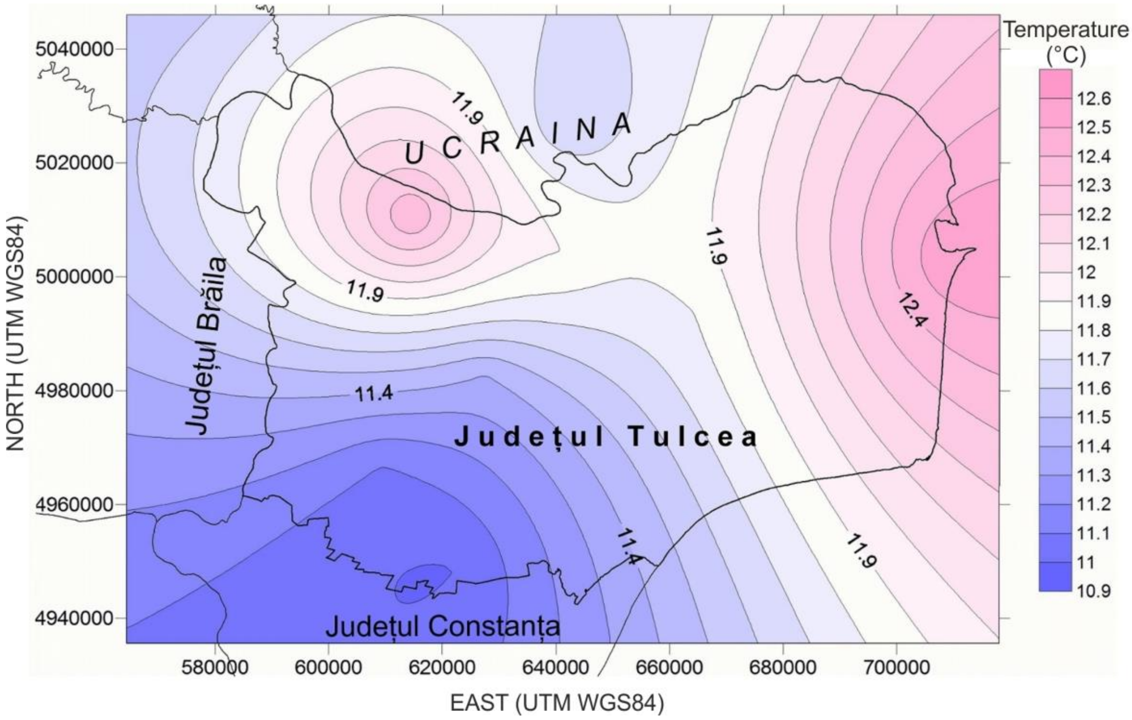

Fig. 2 Air temperature distribution over Tulcea County area (May 2009 – May 2011).

The analysis of the 2-years air relative humidity distribution over the study area (Figure 3) points out the influence of the Black Sea and the Danube Delta aquatic areas on this parameter. The coastal area is characterized by the highest values of air relative humidity (more than 80%), followed by the Danube Delta, with approximately 75% on average. The lowest values are registered in the southern and western parts of the county, decreasing down to 70%.

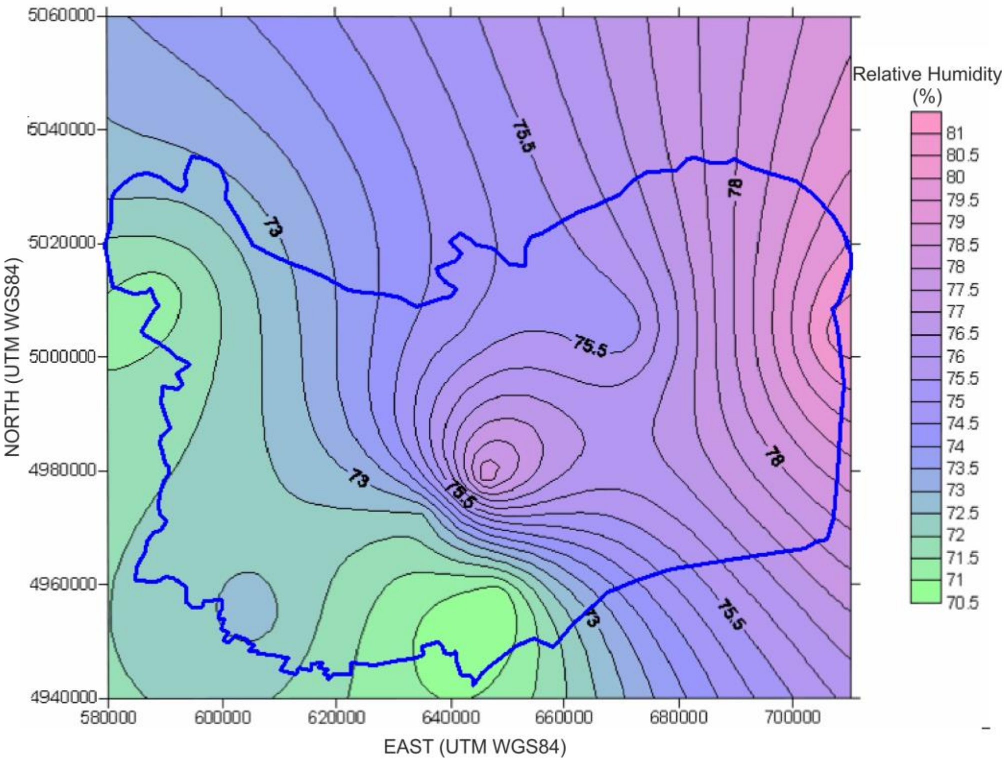

Fig. 3 Air relative humidity distribution over Tulcea County area (May 2009 – May 2011).

Air pressure distribution over the study area (Figure 4) shows distinct patterns between the eastern and western halves of Tulcea County. The eastern part, superposed on Danube Delta and coastal areas, registers air pressure values higher than 1000 hPa, while the western part, dominated by hilly landscapes with higher altitudes, has lower values down to 976 hPa. The real-time local scale monitoring of air pressure distribution could provide important information regarding atmospheric pressure systems pathways and help improving forecasting capabilities at smaller spatial scales.

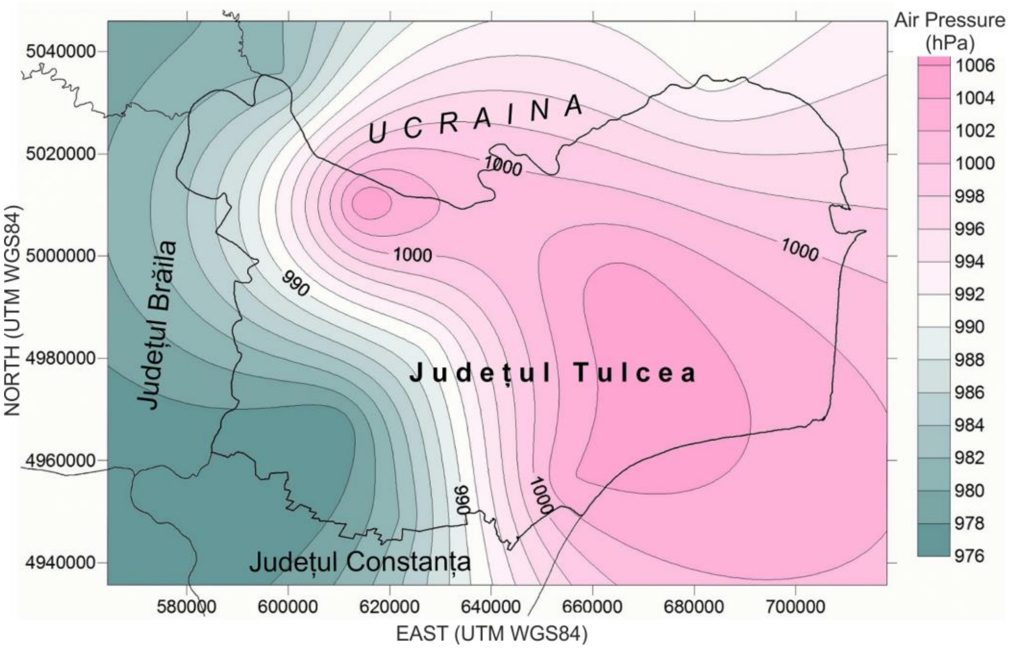

Fig. 4 Air pressure distribution over Tulcea County area (May 2009 – May 2011).

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Wind speed, direction and energy distribution

The Mediterranean cyclones, which follow different tracks over the Pontic region (Black Sea, trans-Balkans), make up over 80% of storm cases on the Romanian coast (Maheras et al., 2009). Their development and movement on different trajectories influence the wind speed and direction characteristics over extensive areas (Vespremeanu-Stroe and Tătui, 2011), including Dobrogea region (Tulcea County, implicitly).

The distribution of the mean wind speeds measured at 80 m height at met masts locations was obtained by specific operations using the professional wind energy software WindPro and is presented in Figure 5. The average wind speed measured during the analyzed 24 months (May 2009 – May 2011) over the study area decreases from 7.5 – 7.9 m/s, along the coast and in the Danube Delta, to 7.0 – 7.5 m/s, on the hills surrounding the Danube Delta and to 6.0 – 7.0 m/s over extensive areas of Tulcea County. The highest average wind speeds are observed in the northern directions (from NW to NE) and the lowest values come along with the western winds.

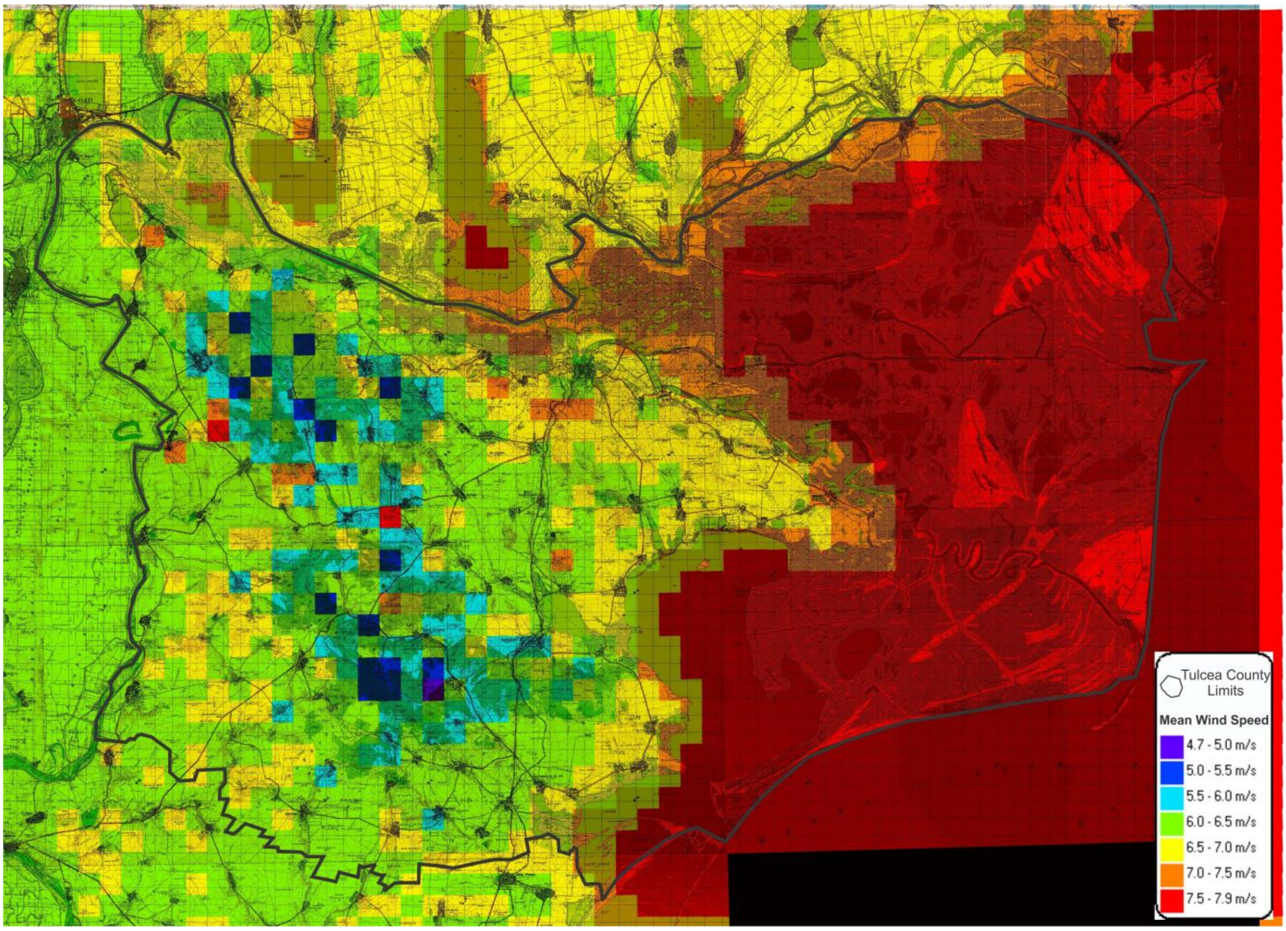

Fig. 5 Mean wind speed distribution at 80 m height over Tulcea County area (May 2009 – May 2011).

The frequency of wind direction at 80 m height (Figure 6) shows different situations over the study area. The prevalent winds are coming from northern directions in the areas close to the Danube Delta (Beștepe, Jurilovca and Sarighiol de Deal masts), with a second maximum from the southern (Beștepe mast) or western (Sarighiol de Deal mast) directions. The other mast locations show no significant prevalence of any wind direction, the frequency roses being relatively evenly represented on all directions. This tiled distribution is related to the topographic conditions specific to each met mast location, which influence wind flows in each area.

The mean wind energy distribution at 80 m height over the study area (Figure 7) follows the same patterns as mean wind speed distribution (Figure 5). The highest values are registered in Danube Delta and along the coast (above 400 W/m^2) and the lowest ones are registered in the central parts of the county (under 200 W/m^2). The largest areas of the county register mean wind energy values between 200 and 400 W/m^2.

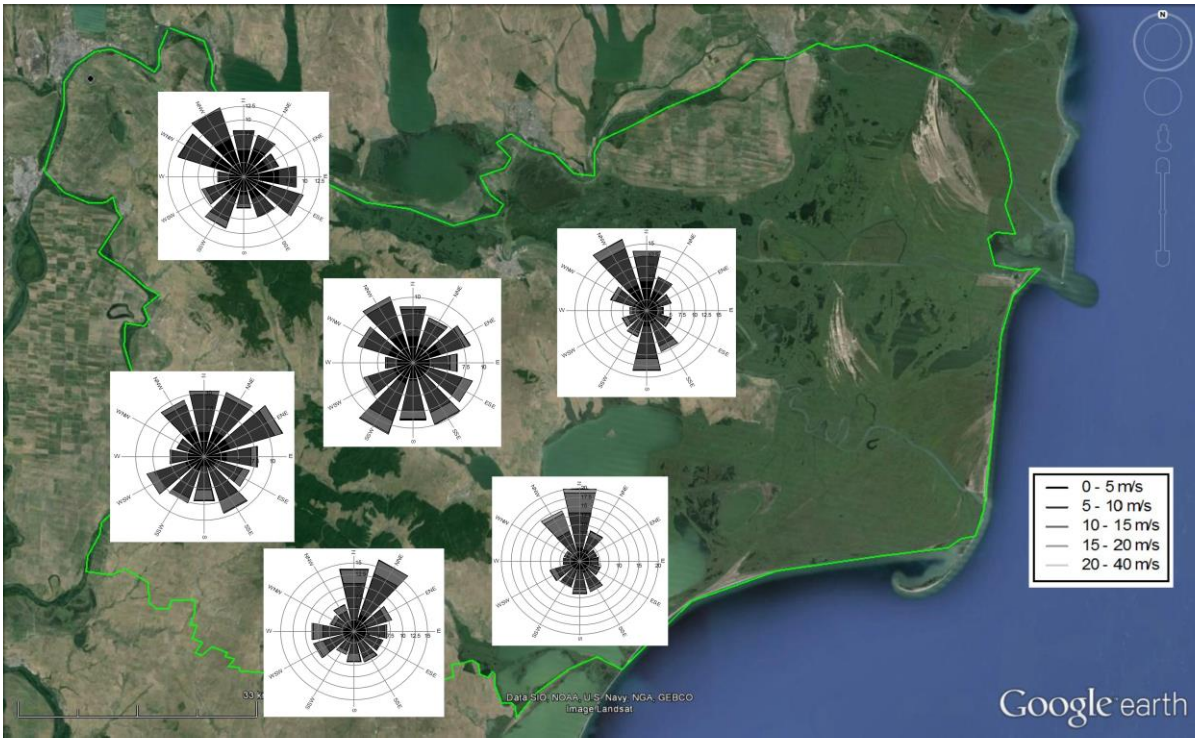

Fig. 6 Mean wind speed frequency distribution at 80 m height over Tulcea County area (May 2009 – May 2011) for selected met masts. *Please notice the masts locations in Figure 1*.

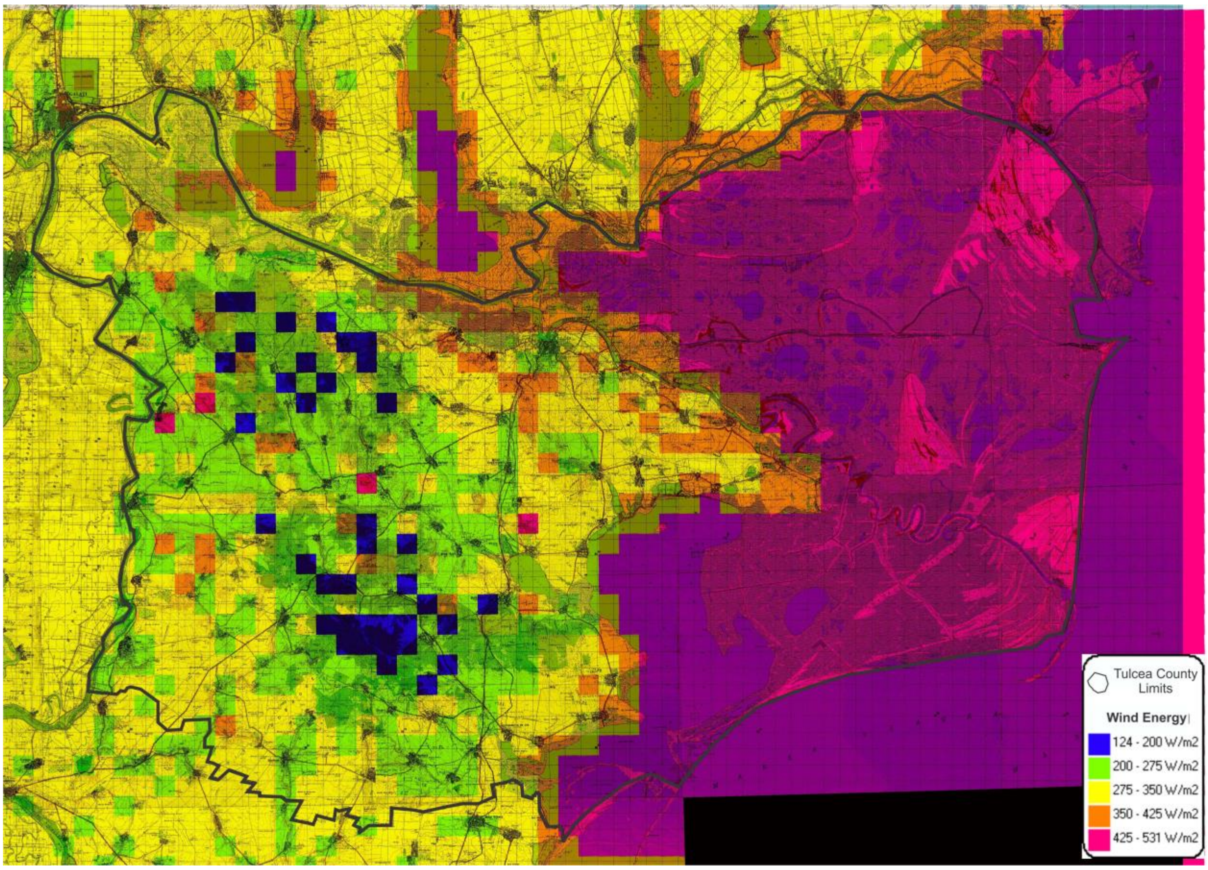

Fig. 7 Mean wind energy distribution at 80 m height over Tulcea County area (May 2009 – May 2011).

They can be considered usable areas for wind energy projects development as they are not part of Danube Delta Biosphere Reserve or any other environmental protected areas. From this point of view, analyzing Figures 5 and 7, we can conclude that the study site has a very good wind energy potential, proved by high averaged wind speeds (more than 6.5 m/s at 80 m height) and energy (more than 300 W/m^2 at 80 m height) registered over extensive usable areas of the county.

Utilizing real-time wind speed and direction data measured at different levels above ground level using meteorological masts in the frame of the wind farms offers us valuable information regarding wind speed vertical profile, wind turbulence, vertical distribution of sea breeze influence (in coastal areas) etc. More practical applications of these data are related to the rapid small spatial scale assessment of air pollutants dispersal following different scenarios of wind speed and direction.

Conclusions

The present article emphasizes the great potential of climatic data measured continuously in the frame of newly developed wind farms and photovoltaic parks in Romania for real-time small spatial scale monitoring of climatic parameters with different purposes ranging from air pollutants dispersal assessment to weather forecast and meteorological warnings. In this context, we presented as study case Tulcea County, utilizing measured climatic datasets for 2 years at 7 met masts locations. Our results clearly show highly suitability of utilizing in-situ measured data for realizing thematic maps regarding the spatial distribution of climatic parameters like air temperature, relative humidity and pressure, wind speed, direction and energy. Good dispersal of met masts over county area afforded a more focused view of their distribution and permitted local scale analysis of their patterns.

Taking into consideration the relatively scarce coverage of the meteorological stations over the Romanian territory and the faulty location of some of these stations, the in-situ real-time measured data like the ones presented in this article can be integrated in the future, together with the data provided by ANM, into complex databases. These databases can be the input for specialized professional web-GIS platforms (for example) capable of real-time or near-real-time monitoring of small spatial scale climatic parameters from a certain region, can contribute to climatic models calibration, can help feeding early warning systems for local climatic hazards etc. In order to achieve these goals, the future challenges will be to find the legal framework to integrate all these data, to convince the owners of wind and solar farms to provide freely these data and to develop suitable algorithms and platforms for integrating, analyzing and broadcasting the data in real-time or near-real-time for different categories of utilizers: local and regional authorities, scientists, open public.

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References

Colesca,S.E., & Ciocoiu,C.N. (2013). An overview of the Romanian renewable energy sector. *Renewable and Sustainable Energy Reviews*, 24, 149-158.

Climate of Romania (2008), Edit. Academiei Române, Bucharest (in Romanian).

Maheras P., Tolika K., & Chiotoroiu B. (2009). Atmospheric circulation types associated with storms on the Romanian Black Sea coast. Application of a new automated scheme. *Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii*, 19(1), 193-198.

Mihailescu, L., (2009). Wind power in Romania. *Renewable Energy Focus,* 10(4), 44-46.

Monograph of Tulcea (1980). Ion, G., Maran, A., Stan, G. and Rusali, N. (eds.), Judeţele Patriei Collection, Edit. Sport-Turism, Bucharest (in Romanian).

Nielsen, P., & Chun, S. (1994). WINDATLAS-SYSTEM user guide, Energi- og Miljødata (EMD).

Nielsen, P., & Chun, S. (2000). WindPRO manual, Energi- og Miljødata (EMD).

Petersen, E.L., Troen, I., Frandsen, K., & Hedegaard, K. (1981). Windatlas for Denmark - A rational method for wind energy siting, Risø-R-428 Report, Risø National Laboratory, Denmark.

Petersen, E., Mortensen, N.G., Landberg, L., Hojstrup, J., & Frank, H. (1998). Wind Power Meteorology, *Wind Energy*, 1, 25-77.

Tătui, F. (2014). Assessment of the long-term wind energy resources in the Southern Bârlad Plateau. An applied climatology study. *Forum Geografic*, XIII(2), 153-163.

Troen, I., & Petersen, E.L. (1988). European Wind Atlas, Risø National Laboratory, Denmark.

Vespremeanu-Stroe, A., & Tătui, F. (2011). North-Atlantic Oscillation signature on coastal dynamics and climate variability of the Romanian Black Sea Coast. *Carpathian Journal of Earth and Environmental Sciences*, 6 (1), 135-144.

Vespremeanu-Stroe, A., Cheval, S., & Tătui, F. (2012). The wind regime of Romania – characteristics, trends and North Atlantic Oscillation influences. *Forum Geografic*, XI(2), 118-126.

Wind energy and other renewable energy sources in Romania (2014). Technical Report 4th edition – October, TPA Horwath and Schoenherr Attoneys at Law.