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STUDY OF THE WIND REGIME IN THE NORTH WESTERN PART OF THE BLACK SEA

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ABSTRACT

The paper proposes an analysis of the wind measurements collected from five stations located in the north-western part of the Black Sea, with a total time span of about 60 years. The considered data sets are in situ measurements using anemometers. The way that the stations are placed with respect to each other could offer important information about how different the wind speed can be offshore, on the shore and inland. The study also takes into consideration long lasting wind storms for all stations in the defined period. Based on the obtained results, it can be concluded that the data sets have some similarities that might better describe the wind regime trends in the north-western coastal regions of the Black Sea. The results may also be promising for offshore wind energy extraction in the near future.

Keywords: marine environment, wind regime, statistical analysis, Romanian nearshore, powerful wind storms

1. INTRODUCTION

In order to characterize a small area in terms of the wind action, it is necessary to know the main directions of various events and their distribution. Nonetheless, for a larger area, such as the north-west coast of the Black Sea, the different types of wind action for the entire region need to be known and they can depend on many factors.

The direct interaction between land and sea will produce breezes. This phenomenon is specific to the coastal zone, it occurs because of differences in temperature of the land and the sea water. This phenomenon has its maximum in the warm season of the year, but frequency and direction vary from one region to another. As well as local wind breezes, mountain or valley wind circulation around the north-west part may have a remarkable impact on the atmospheric circulation in the coastal area. Breezes speed ranges from 1-3 m/s along the shoreline to 3-5 m/s offshore.

It has to be highlighted also that all the data considered in the present study are public since they were obtained from Internet [1] and they have as primary source WMO. Thus, the paper brings together five data sets, three being along the shore, offering a spatial view of how the wind values may vary from north to south and not only from the offshore to inland [2]. The technique proposed by [3] was considered to fill the gaps in the data sets.

Table 1. Start and end date of the data set for each station

Station	Date of the first value	Date of the last value
Constanta	01.01.1952	31.12.2015
Sulina	01.01.1952	31.12.2015
Odesa	16.02.1953	31.12.2015
Platform Gloria	01.04.1983	31.05.2012
M.Kogalniceanu	20.06.1973	31.12.2015

At this point, it has to be underlined that, one data set is from an offshore Oil Platform Gloria and the inland one is at more than 16 km from the shore, located in the middle of the field. The other three stations that are on the shore are located at: Constanta, Sulina and Odesa, respectively.

Table 2. Mean wind value per set and number of values considered to perform the analysis [1, 4]

Stations	Mean value per set	Values	Total Values (with gaps)
Constanta	3.50	277141	280938
Sulina	6.24	248404	251671
Odesa	4.14	519836	524595
M. Kogalniceanu	4.44	623813	627594
Gloria Platform	7.68	59689	62283

For the first and fifth figures, the mean calculations were done using at least 630 values per year (that is 1.7 measurements per day). Nevertheless, the data sets do not have the same time span, as all of them are missing some years. For example, Platform Gloria, which was a drilling platform, has almost 30 years of measurements because it started collecting wind data in 1983 and stopped in 2012. M. Kogalniceanu started collecting wind data in 1975 and still is doing today.

In Figure 1, the graphs show how the mean wind value changed through the years. These changes may vary with the topography that is around the stations or just on the weather. At Constanta, the mean wind speed suffered a decline, from almost 4 m/s to 2m/s, this started in 2005 and still continues. This phenomenon might be related to the new constructions that were developed in that period around the weather station.

2. METHODOLOGY AND RESULTS

The baseline for this study is to see the differences and the general wind flow at a larger scale that can result from comparing the offshore wind to the onshore or inland wind. It should be assumed that the wind speeds between the offshore and inland data will differ greatly based on the roughness factor of the sea in comparison to the land. The data sets were analyzed from different perspectives to contribute to the understanding of how the wind speed varies from offshore to onshore and inland.

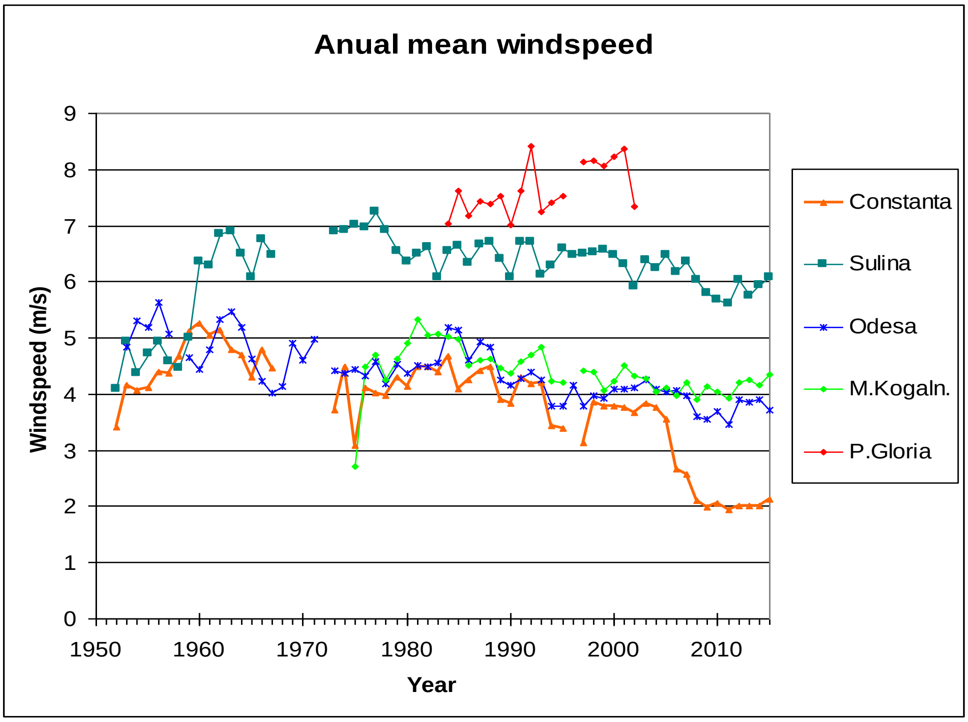

Fig. 1. Annual mean wind speed and trend lines for the five data sets

The wind rose reprezentations are based on the statistics of the daily wind vector. It shows how the wind frequency distribution varies from site to site, but there are some similarities between the stations. The wind rose shows that Constanta and M. Kogalniceanu have similar patterns, as well as Odesa and Sulina that are closely followed by Gloria. Even so, the topography will influence the wind distribution and, in this case, the Gloria Platfrom is not influenced by anything, showing the “clearest” wind distribution, but this is valid only for the offshore. On the shore, Odesa and Sulina have almost simmilar distributions, but, because Sulina has a bigger distribution value for the north and south, this might imply that this station is located more to the offshore than inland, as the general offshore wind distribution tends to have this behavior.

A comparison between Constanta and M.Kogalniceanu might not be ideal, but they do have similar particularities. In the case of M.Kogalniceanu, being an inland station, the topography might be responsible for the well developed west distribution, with a slight trend to north and south, whereas Constanta seems to have three well developed wind distributions on the north, south and west. Thus, by looking at the data and comparing the wind roses of P.Gloria and M.Koglaniceanu to Constanta ones, the graph tends to have a mixed distribution of the two. However, because Constanta station is surounded by buildings, its distribution might not completely reaveal the truth.

Nonetheless, the data used in this study could be used as an input for the SWAN model to estimate diferent environmental conditions that may occur in a given period or time, depending on the case. Based on the wind data, the simulation may show the wave average spectral phase. That, in turn, may be useful to estimate the wave power energy in regard to a potential wave farm [6, 7].

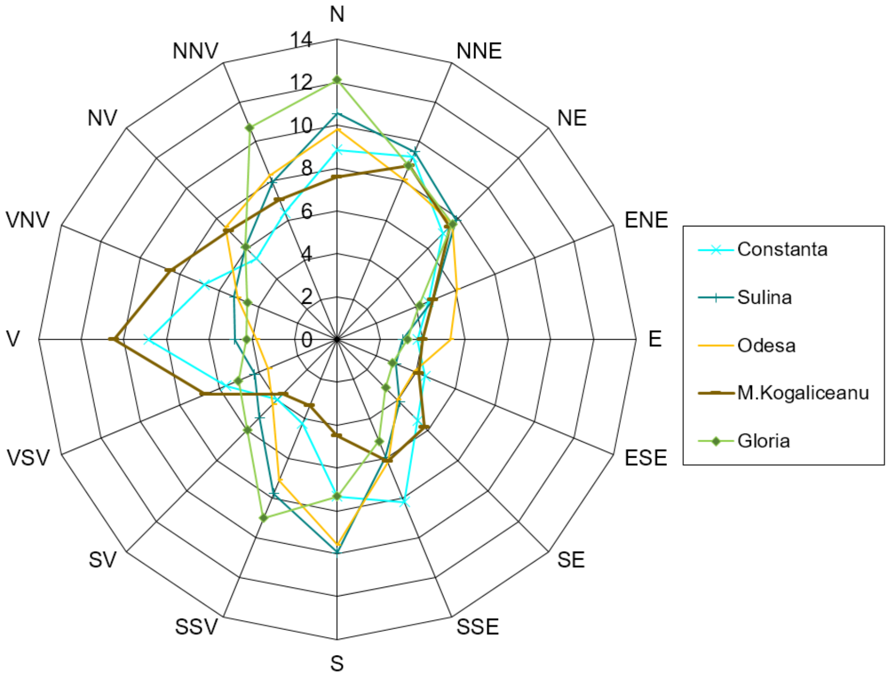

Fig. 2. Wind direction frequency distribution for all the considered stations

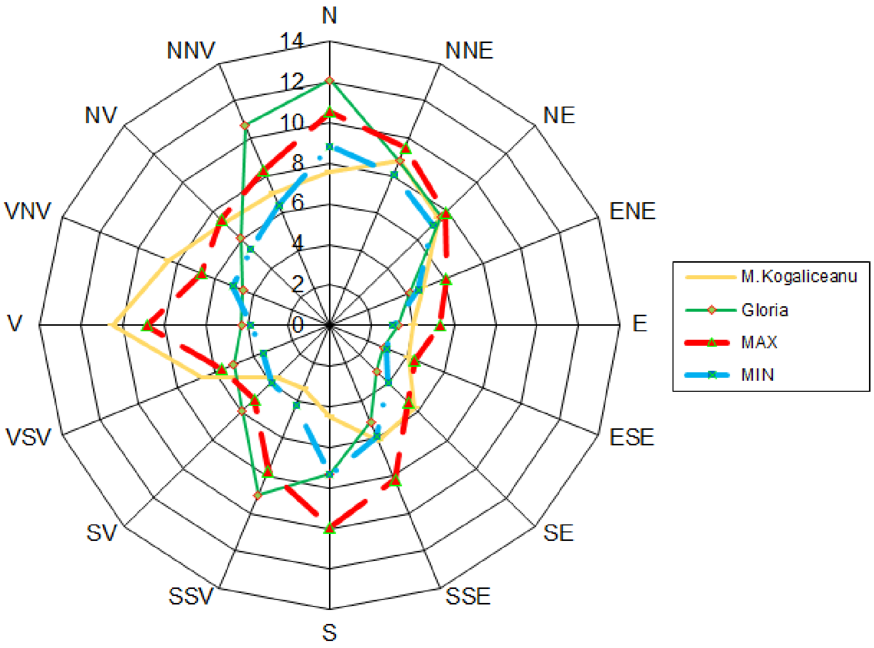

Fig. 3. Wind direction frequency distribution for the maximum and minimum values of Constanta, Sulina and Odesa, as well for the inland and offshore stations

Based on the wind rose results, it seems that all the stations have almost the same distribution in wind speed in the NNE - NE direction. Thus, giving the Constanta Port orientation, this phenomenon could be taken into account and the wind data (and also the storm periods) may also be used as an input to SWAN when modelling the wave patterns that occur at the entrance of the harbor. By knowing the results (e.g. wave period, wave height and direction), the vessel traffic in the port entrance could be improved and different problems could be prevented (for example, collisions or different hazards) [8, 9, 10].

A more clear comparison between the offshore and inland wind distributions can be observed in the wind rose below. For a better understanding, the maximum and minimum wind values are displayed also in the wind rose, for the three stations that are on the shore (Odesa, Sulina and Constanta).

The distributions of wind speed classes were obtained from daily means of the speed modules.

In Figure 4, the way that the wind speed distribution values evolve might show where the stations are located. For example, the Platform Gloria graph has lower wind speed values, in the range 0 to about 6.5 m/s than the rest and more values higher than 6.5 m/s. This would mean that the station is the farthest away from the shore or that Gloria is the most exposed site from those considered in the present analysis. Thus, it would be possible to say that, depending on the wind speed distribution values, for each graph when the slope starts descending, the graphs would show where or how exposed it is. If the sites would be arranged by how exposed to the wind they are, the list would be: Gloria, Sulina, Constanta, Odesa and M. Kogalniceanu.

A closer look shows that the graphs describing Odesa and M.Kogalniceanu seem to be close (even if one is on the shore and the other one is inland), but the small split that starts at 7 m/s shows that they are different and that the graph coresponding to Odesa has more values with speeds between 7 m/s and 12 m/s. This can be because Odesa is on the shore and it is more exposed to these velocities than M. Kogalniceanu.

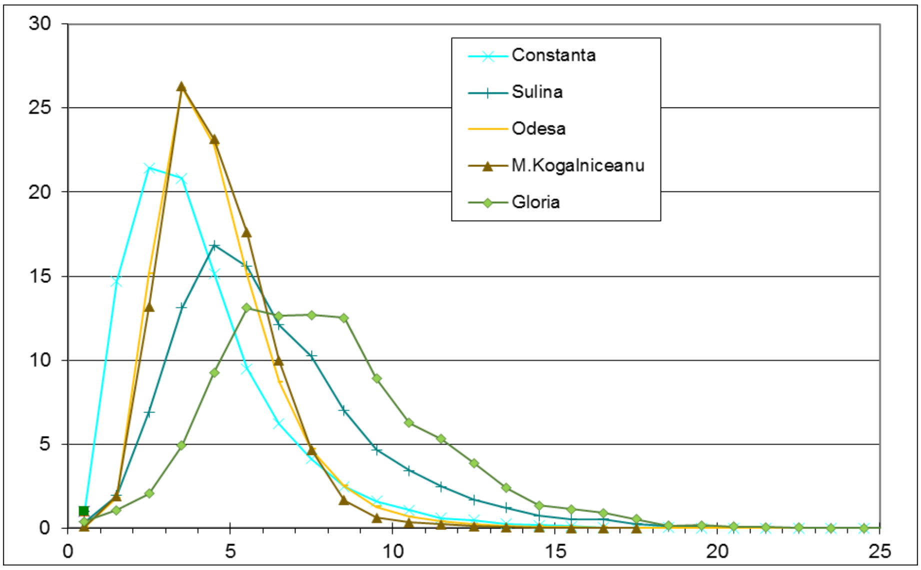

Fig. 4.Daily mean wind speed for Constanta, Sulina, Odesa M.Kogalniceanu and Gloria

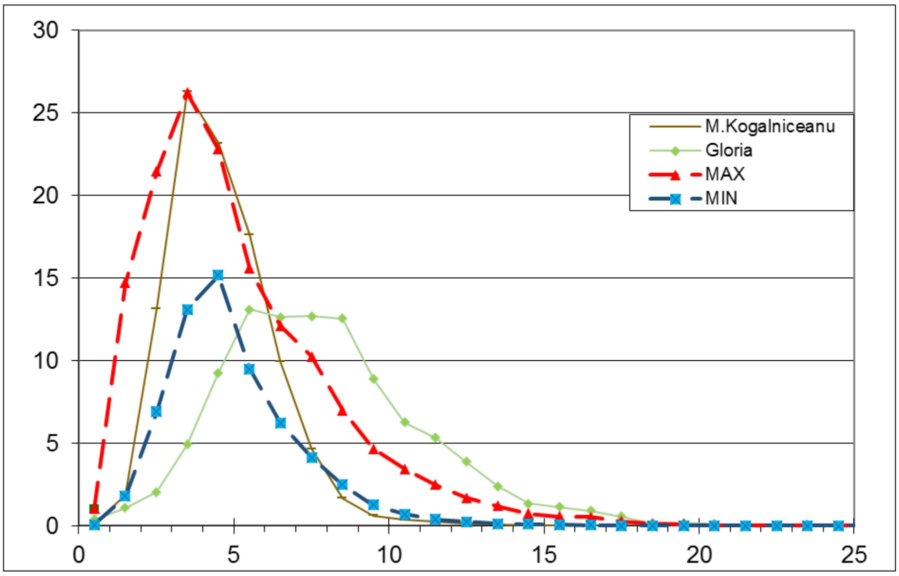

Fig. 5. Analysis of daily mean wind speed data for M. Kogalniceanu, Gloria and for the maximum and minimum onshore values

The comparison between the offshore and inland data sets may offer a clear view of how the terrain roughness affects the wind speed. M. Kogalniceanu sites in an open field with high crops, which means that the roughness length is 0.25, whereas Gloria has a roughness length of 0.0002, which corresponds to open water (sea/ocean).

The slopes of the 4 graphs show how a station is more prone to more powerful wind speeds or the other way around. When comparing the graph from M.Kogalniceanu with the rest, the decline of the graph is the fastest and shows that it has lower values of wind speeds that go over 7 m/s than the rest. In respect to this, Gloria has lower values at lower wind speeds then the rest, but it has a lot more values over 6 m/s.

When trying to predict the impact of the storms on the shore and on the marine environment or coastal traffic, the off-shore and harbour operations, the wind observation must cover large coastal sectors. At a regional scale, Copernicus services may provide available predictions, but at a small scale, the coastal vulnerability to storm flooding, erosion and landslides is great. Beside the wind monitoring, the coast needs high-resolution remote observation and numerical modelling in order to produce an appropriate blend of prevention and ways to mitigate the impact [11, 12].

For Sulina, the wind velocity classes are almost stable, but the upper speed class values (10.5 – 16.5 m/s) are getting smaller. Even so, in this data set the wind speed values go up to 19.5 m/s and the overall percentage in wind speed that goes over 10.5 m/s is almost 20%, whereas the second two onshore stations may have less than 5%. At the beginning of the data set, there is a notable period when the wind speed distribution for 0 to 3 m/s was about 40%, corresponding, probably, to a calmer period.

For Odesa, the wind speed value for 4.5 m/s class corresponds to more than 50% of the distribution. Thus, comparing the overall distribution among the three onshore stations, Odesa’s distribution is in the middle.

As for Gloria, the wind speeds that are 9 m/s and over, occupying 30% of the range; the calms and breezes are less the 10% and the rest of 60% is divided between 4.5 m/s and 7.5 m/s classes.

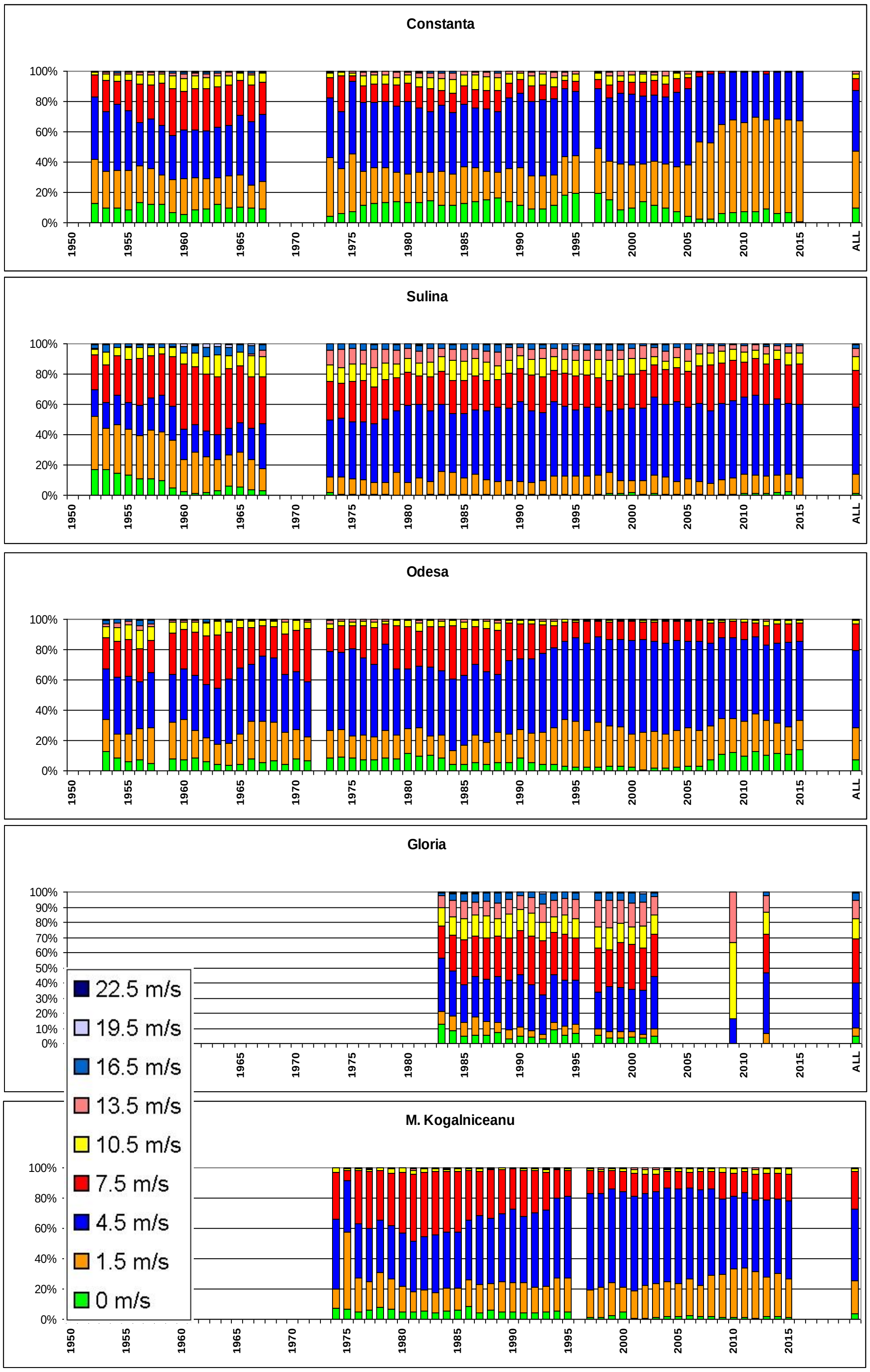

Fig. 6. Multiannual wind speeds distribution with mean wind values for each data set

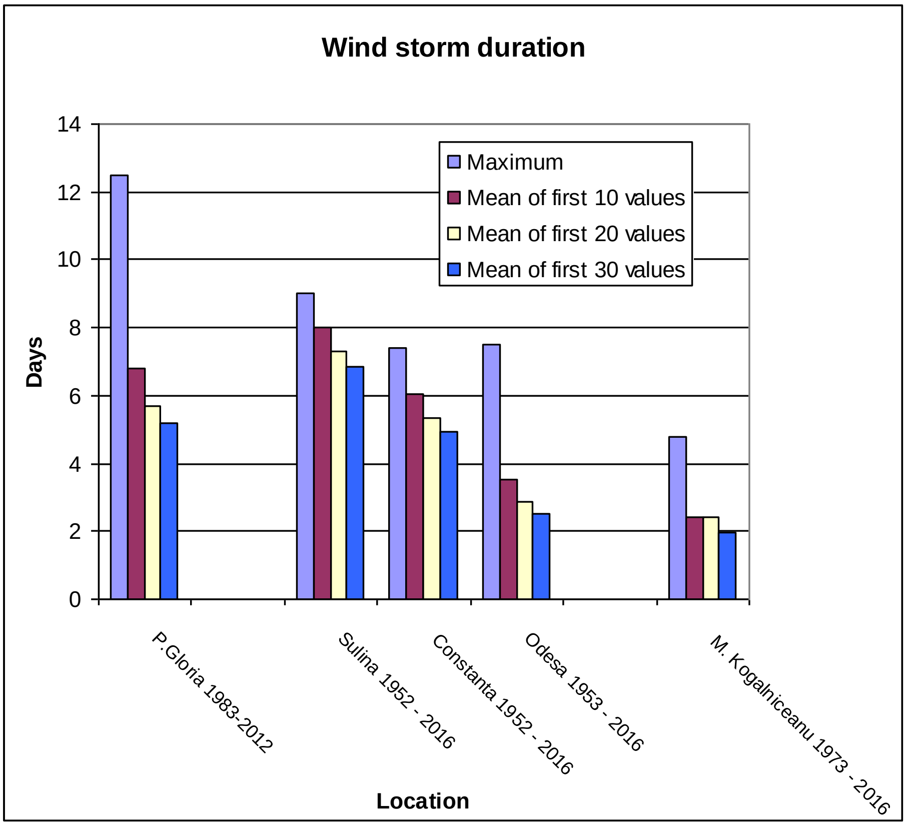

Fig. 7. Wind storm duration for each station

The wind classes of the inshore station do not vary as much, but then again the data is showing that the wind distribution for the values 0 - 6 m/s is probably the smallest one averaging 75%.

In this study, a storm was considered to be a lapse with wind speeds greater than 7 m/s.

As for the extreme storms that occur from time to time, the biggest registered storm was clearly at the Platform Gloria, lasting for 12 days. The storm duration values show a trend that, at first, may not seem likely, but after the three averages of the first 10, 20 and 30 storm duration values, there may be pattern. Even if Gloria site is located offshore and it is exposed to powerful storms, in this case related to the biggest long-lasting one, Sulina seems to have more long-lasting storms as the first 10 averaged values result in an eight day storm, whereas Gloria has a value of almost 7 [13].

3. CONCLUDING REMARKS

The present paper tries to present, in a comprehensive way, the general wind conditions over the offshore, onshore and inland areas in the north-western part of the Black sea basin, based on a 60-year analysis.

Based on this analysis and on the obtained results, there is a shift of distribution to small values. Along the shore, based on the three onshore stations, the general wind distribution is from north and south, with some influences from the west, NW and NE. The inland station has the most distinct wind distribution as the biggest influence is from the west, NNE and SSE. Nevertheless, the wind distribution values from the NNE and NE is almost the same as for the rest of the stations. These occurrences may suggest that, from those directions, the wind is not obstructed by anything for all the sites.

The offshore wind distribution has bigger values and it is from the N, NE and SSW. Here, the inland distinctive wind distribution is not present as that wind distribution might be well tied to the topography and, in this case, there is none.

The most interesting results are related to the variation in time for the wind characteristics of long series of data inland, on shore and offshore. These results can be further analyzed by integrating the data into a model and by using longer series of data obtained directly (in situ) and indirectly (estimates satellite).

Finally, it can be highlighted that the results obtained in the present work are generally in line with some previous studies related to the wind conditions in the basin of the Black Sea, which were focused especially on the western side of the sea and on the Romanian nearshore, but they were reported to shorter time periods analyses [14, 15, 16].

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