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CHANGES IN STORM FREQUENCY IN THE MEDITERRANEAN SEA REGION

Abstract: Storms in the European part of the Mediterranean Sea Basin are characterized in the paper. Data on storm days comes from the years 1986-2008, from fourteen stations located on the coast and on islands of the Mediterranean Sea (Gibraltar, Valencia, Palma de Majorca, Marseille, Ajaccio – Corsica, Cagliari – Sardinia, Palermo – Sicily, Naples, Luqa – Malta, Thessaloniki, Athens, Souda – Crete, Rhodes Airport – Rhodes and Larnaca – Cyprus). The greatest number of storm days was noted in Corsica (870 - on the average 37,8 per year) and the least in Gibraltar (371 – 16,1). In most of the examined stations storms took place most frequently in the fall (from 19 to 46%). The smallest number of storm days was observed in winter (western and central part of the region) and in summer (eastern part). From a year-to-year analysis of storm days, it was found that their trend, at almost at all the stations, is negative. The strongest negative trend was observed in Valencia, Naples and Cagliari (-8,5 days/10 years). A growing trend, reaching 3 storm days/10 years, was only found in Cyprus.

Key words: storms, Southern Europe, Mediterranean Sea, year, seasons, change trends in time.

INTRODUCTION

The Mediterranean climate characterizes the southern coast of Europe and Mediterranean islands. It makes part of the subtropical climate zone, according to climate classification by W. Okołowicz, 1969 and 1991). The Mediterranean climate is characterized by hot and dry summers and quite warm and wet winters. Beyond the region of the Mediterranean Sea, this type of climate is also to be found in other parts of the world, e.g. in California, on the southern coast of Australia and Africa, on the Black Sea Coast (*Słownik meteorologiczny*, 2003).

The examined area is characterized by a mean temperature oscillating from 5°C to 13°C in January and from 22°C to 28°C in July. Precipitation mainly occurs in the colder half of the year. At that time, humid masses of polar sea air shift from the west. Summer has no significant precipitation. At that time, dominate dry masses of equatorial air (Martyn, 1992).

Large water vapour reserves in the air, average temperature values and domination of low barometric patterns create favourable conditions for the occurrence of storms in the colder part of the year. In turn, domination of dry air masses and high barometric patterns, despite high temperature values, suppress the development of storms in the summer. Shifts of low pressure patterns begin in the fall. The lows have enormous reserves of warm temperature. The sea, intensely warmed up by the summer, is the source of warm temperature. This situation generates a strong fall-winter storm activity.

According to Martyn (1992), three main areas of cyclogenesis take place in the area of the Mediterranean Sea. The most active, taking into consideration low barometric patterns, is its middle part. Here, the Bay of Genoa and the Ligurian Sea distinguish themselves by, on the average, 60 lows per annum. The second cyclogenesis area encompasses the Ionian Sea with, on the average, 51 lows per annum. The third is the area surrounding Cyprus with, on the average, 28 lows per annum. These three regions distinguish themselves with greater storm activity (Table 1).

The region being analyzed is classified in Europe, alongside mountain areas, as having the greatest number of storms (Stopa, 1962). It should be stressed that literature on the frequency of storm occurrence in longer measuring periods, e.g. twenty years, is quite limited.

The objective of the paper is to present a year-long occurrence of storms on the southern coast of Europe and islands of the Mediterranean Sea, from Gibraltar to the west and Cyprus to the east (Fig. 1). An important element is also description of the trend with a number of storm days during the 23-year period (1986–2008) and its forecast for the future. For a region "living" from tourism such a forecast is especially significant. A reliable forecast is associated with an analysis of a long measurement series. In the examined region, the longest period with available cohesive data was the 23-year period.

DATA AND METHODS

Fourteen stations were chosen for the research. Five are located on the southern coast of Europe (Gibraltar, Valencia in Spain, Marseille in France, Naples in Italy, Athens Thessaloniki in Greece). Eight are located on islands of the Mediterranean Sea (Palma de Majorca, Ajaccio in Corsica, Cagliari in Sardinia, Palermo in Sicily, Luqa in Malta, Souda Airport in Crete, Rhodes Airport in Rhodes and Larnaca in Cyprus), (Fig. 1). Data describing the number of storm days (each day with at least one storm) in the period of 1986-2008 were used for the analysis. Also examined were the change trends

Table 1. The number of storm days, percentage of storm days and slope coefficients of simple regressions during the year and in particular seasons of the year in chosen towns on the Mediterranean Sea coast and islands on the Mediterranean Sea.

Stations	Location		Year			Spring			Summer			Autumn			Winter		
	Longi-tude	Lati-tude	Storm days	Average annual	*a*	Storm days	%	*a*	Storm days	%	*a*	Storm days	%	*a*	Storm days	%	*a*
Gibraltar	-5,35	36,15	371	16,1	-0,0958	88	23,7	**0,1206**	37	10,0	-0,1107	121	32,6	-0,0504	125	33,7	-0,0553
Valencia	-0,46	39,50	474	20,6	-0,8597	95	20,0	-0,1443	176	37,1	-0,3053	172	36,3	-0,3468	31	6,6	-0,0632
Palma Mallorca	2,73	39,55	581	25,3	-0,2915	102	17,6	-0,0949	112	19,3	-0,0366	267	45,9	-0,0949	100	17,2	-0,0652
Marseille	5,23	43,45	447	19,4	-0,0524	88	19,7	**0,082**	141	31,6	-0,1453	174	38,9	**0,0178**	44	9,8	-0,0069
Ajaccio Corsica	8,80	41,91	870	37,8	-0,0642	199	22,9	-0,1047	190	21,8	-0,1206	344	39,5	**0,1107**	137	15,8	0,0504
Cagliari Sardinia	9,05	39,25	841	36,6	-0,6215	194	23,1	-0,1927	171	20,3	-0,0761	313	37,2	-0,2945	163	19,4	-0,0583
Palermo Sicily	13,10	38,18	690	30,0	-0,336	123	17,8	-0,0613	77	11,2	**0,0623**	303	43,9	-0,2372	187	27,1	-0,0998
Naples	14,30	40,85	851	37,0	-0,7609	175	20,5	-0,1591	180	21,2	-0,2421	325	38,2	-0,1966	171	20,1	-0,163
Luqa Malta	14,48	35,85	724	31,5	-0,2105	92	12,7	-0,082	41	5,7	-0,0375	320	44,2	-0,0069	271	37,4	-0,084
Thessaloniki	22,96	40,51	645	28,0	-0,1512	165	25,6	-0,1107	322	50,0	-0,1897	121	18,7	**0,2026**	37	5,7	-0,0534
Athens	23,73	37,90	423	18,4	-0,1383	103	24,3	-0,1117	61	14,4	-0,0642	150	35,5	**0,1235**	109	25,8	-0,086
Souda Airport Crete	24,11	35,48	444	19,3	-0,0524	101	22,7	-0,0721	12	2,7	-0,0138	149	33,6	**0,0217**	182	41,0	**0,0119**
Rhodes Airport Rhodes	28,08	36,40	515	22,4	**0,003**	120	23,3	-0,1146	10	1,9	-0,0217	139	27,0	**0,0662**	246	47,8	**0,0731**
Larnaca Cyprus	33,63	34,88	723	31,4	**0,3093**	218	30,1	**0,1206**	28	3,9	**0,003**	191	26,4	**0,1749**	286	39,6	**0,0109**

a – directional coefficient of the regression line (bold showing an upward trend of storm days) of (a) storm days, expressed by the simple regressions $y = ax + b$ (a – slope coefficient, b – absolute term), expressed in days/10 years.

Fig.1. Location of the 14 chosen stations: Gibraltar, Valencia, Palma – Mallorca, Marseille, Ajaccio – Corsica, Cagliari – Sardinia, Palermo – Sicily, Naples, Luqa – Malta, Thessaloniki, Athens, Souda – Crete, Rhodes Airport – Rhodes and Larnaca – Cypr

Source: Europe: 1983, PPWK, Warsaw

RESULTS

During the 23 year period, most storms occurred in Ajaccio (870 – 37,8 on the average, in a year), in Naples (851 – 37), in Cagliari (841 – 36,6) and in Luqa (724 – 31,5). Numerous storms also occurred in Larnaca (723 – 31,4). The most stormy stations, besides Larnaca on Cyprus, are concentrated in the middle of the Mediterranean Sea (Table 1).

Both the western and the eastern borders of the Mediterranean Sea are characterized by a smaller number of storm days. In most of the localities, it was a value below 500 days. The least storms, in the entire examined area, occurred Gibraltar (371 – 16,1). It is interesting that in Warsaw, during the same period of time, the number of storms days (605 – 26,3) was average in comparison with the examined stations

In the examined area, except for Gibraltar, Thessaloniki and Cyprus, dominate autumn storms. They comprise from 19 to 46% of the annual storms (Table 1). Majority of them occurred in Palma de Majorca and the least precisely in Thessaloniki. Autumn storms are of thermal or frontal origin. The frequency of winter storms oscillates powerfully – from 6 to 48% of the storms in a year (Table 1). The greatest number of storms was observed in Gibraltar (34%) and in the eastern part of the Mediterranean Sea (40 – 48%).

In the spring, storms are characterized by the smallest variability, from 13 to 30%, in the scale of a year (Table 1). The most took place in Cyprus and the least in Malta. Spring was not the most stormy time of the year in any of the examined locations.

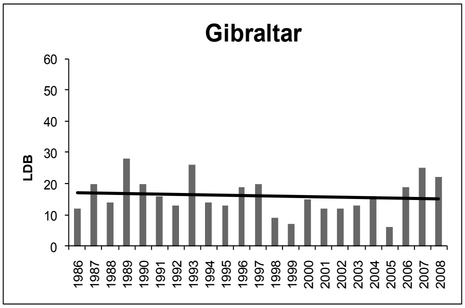
In the summer, the storm frequency range is even greater than in winter and varies between 2 to 50% of storms in the year (Table 1). Minimal storm activity takes place in Rhodes and maximum in Thessaloniki.

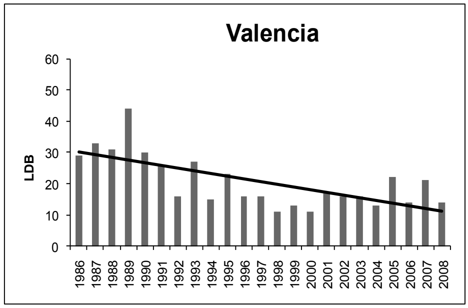
In examining storm variability in the chosen locations, on as many as twelve of them we observe a decrease of the storm activity in the analyzed years 1986-2008. This decrease was not similar and oscillated between -0,5 (Marseille and Souda in Crete) even up to -8,5 days/10 lat (Valencia, Naples and Cagliari in Sardinia). A significant increase of the storm activity took place only in Larnaca in Cyprus (3 days/10 years). It was minimal in Rhodes (0,03 days/10 years), (Table 1, Fig. 2).

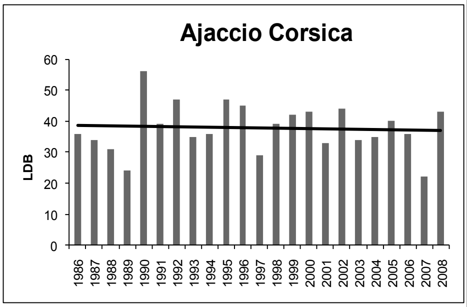
In analyzing storm development during particular seasons of the year it is possible to observe an increase in the number of storm days in Marseille and Corsica as well as the eastern part of the Mediterranean Sea in Greece and Cyprus. There was a small increase from 0,1 to 2 days/10 years (Table 1) in the seven locations. However, in majority of the stations the number of storm days decreased from -0,1 (Marseille, Luqa in Malta, Souda in Creete and Rhodes) to - 3,5 days/10 years (Valencia, Naples, Cagliari in Sardinia and Palermo in Sicily), (Table 1, Fig. 2). Autumn is a special time of the year because, at that time, both the negative trend (Valencia) and the positive trend (Thessaloniki) have the highest values (Table 1).

Among the examined stations, individual characteristics distinguish Gibraltar and Thessaloniki. They include a very low frequency of storm days in Gibraltar (371 – average in a year 16,1). This may be explained by the fact that, from the Atlantic Ocean, through the Straits of Gibraltar, shift very few low barometric patterns, i.e. just four. Thus, despite the vicinity of the Cordillera Betica and the Atlas Range, conditions do not favour storm occurrence. This area also distinguishes itself by smaller atmospheric precipitation.

On the other hand, Thessaloniki is characterized by and extraordinarily high number of summer storms which amounts to 50% of all summer days (Table 1). Such high intensity of storm activity maintains itself despite an


Gibraltar
LDB


Valencia
LDB


Ajaccio Corsica
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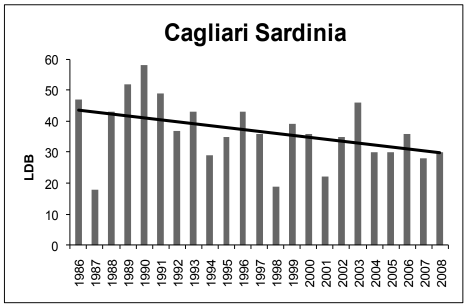
Cagliari Sardinia
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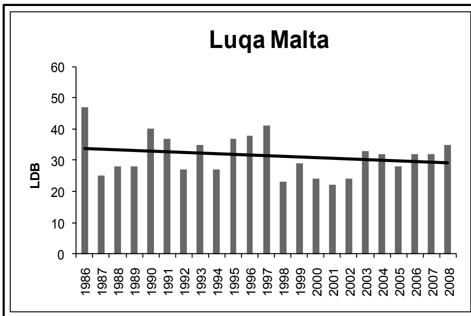
Luqa Malta
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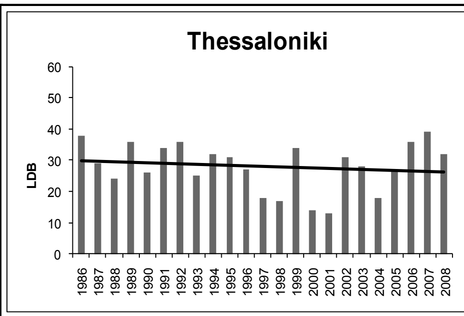
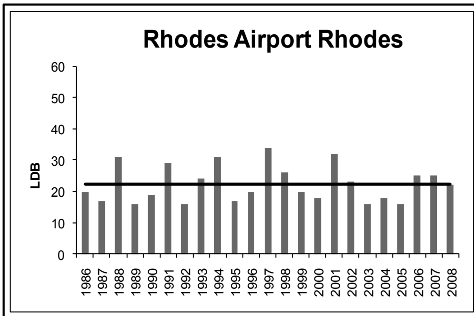
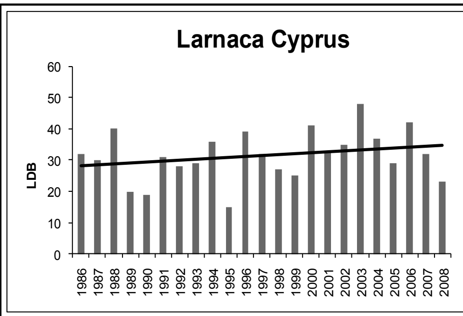

Thessaloniki
LDB


Rhodes Airport Rhodes
LDB


Larnaca Cyprus
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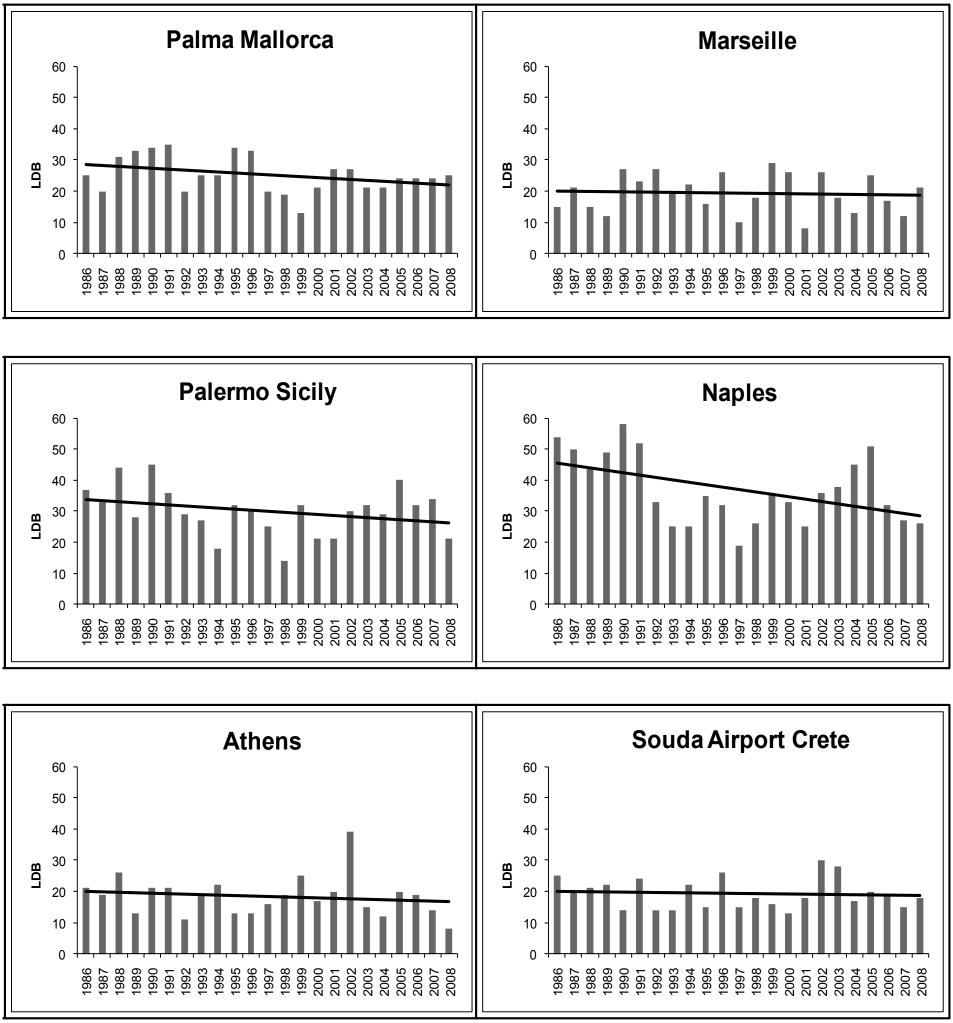

Fig. 2. Variability of the number of storm days with a linear trend in chosen towns of Southern Europe and islands on the Mediterranean Sea (1986-2008)

influx of hot and arid continental equatorial air masses from Africa and the Arabian Peninsula and stable barometric patterns which suppress the growth of cloudiness. In the entire examined area, Thessaloniki distinguishes itself by the lowest frequency of winter storms, even though, in the neighbouring stations they are six times more frequent.

CONCLUSIONS

A strong variability of location and time of storm frequency has been observed in the Mediterranean Sea Basin. It is associated with regional atmospheric circulation. On the other hand, local geographic conditions, e.g. insular location, varied surface features – the mountains of Corsica, Sardinia, Sicily, Cyprus and the vicinity of Mount Vesuvius in Naples, also have a strong impact.

In the next few years, lesser storm activity is to be expected in the five locations of the western and central part of the Mediterranean Sea, i.e. Valencia, Palma de Majorca, Cagliari in Sardinia, Naples and Luqa in Malta. On the other hand, there should be a greater frequency of storms only in Larnaca in Cyprus (Table 1, Fig. 2).

To a lesser degree, storms, being a hazardous atmospheric phenomenon, will endanger locations on the coast and islands of the Mediterranean Sea which are visited by tourists. Nevertheless, climate changes may have impact on the intensity of the phenomenon itself. Storms, even though occurring more rarely, may have a violent course.

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