REPUBLIC OF CROATIA
CROATIAN METEOROLOGICAL AND HYDROLOGICAL SERVICE
CROATIAN MARITIME METEOROLOGICAL DEPARTMENT - SPLIT

WINDS AT THE HVAR METEOROLOGICAL STATION WITH PARTICULAR EMPHASIS ON STRONG AND GALE FORCE WINDS AND SAFETY OF BOATS AND SHIPS

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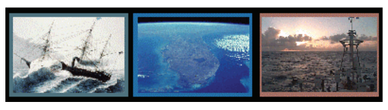

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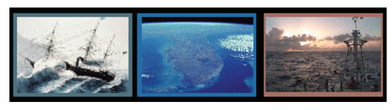
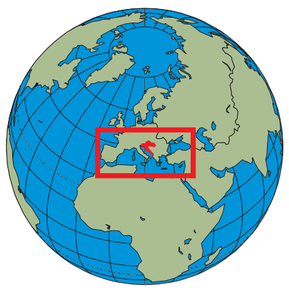


ADRIATIC SEA



The Adriatic Sea is the northernmost gulf of the Mediterranean, which penetrates deeply towards the Middle Europe. It extends for **783 km** between the Dinaric-Balcanic mountains on the north-east and the Apennine peninsula on the south-west, having the mean width of **248 km**, and area is **138.595 km²**.
Geographically it is situated between **40.07 N** and **18.35 E** in the Otranto strait and towards the north, in the Gulf of Trieste up to **45.47 N** and **13.35 E**.

In 1858, the great explorer and famous meteorologist Grgur Bučić(1) founded the meteorological station of Hvar (in the church tower of Saint Venerada) because he was well conscious of the importance of being acquainted with climate and weather in the Adriatic. Since then the station has been functioning for 150 years with short interruptions. Because of the length of meteorological data series and because of the history of this station, we shall describe and explore the winds on the island of Hvar giving a special review to strong and gale winds which cause pronounced waves (wavy - 4, wavy 5 and stormy - 6) and reduce safety of boats and vessels in the Adriatic.

THE WIND ANALYSIS ON HVAR

The island of Hvar belongs to the group of the island of Central Dalmatia. It extends in the direction NW-W towards east in the length of 68 km (Figure 1). The station of Hvar is situated on the NW peak of the island of Hvar (latitude =4310' and longitude =1627', height above sea level = 20m). The nearest point of the island to the coast is on its eastern side (only 4 km)), near the cape od Matjašević. On the northern side there is the channel of Hvar and on the southern side there is the channel of Vis, Korčula and Neretvanski channel.

The wind in the Adriatic (on the island of Hvar) often determines general weather situation, so that if we speak about the characteristic winds, we should mention weather with south wind (jugo), weather with north wind (bura), weather with tramontana (NW), or with burin or mistral. It should be mentioned that jugo and bura (tramontana - NW) are the main winds on the open sea of the Central Adriatic, therefore on the island of Hvar, too.

Croatian marine meteorological service is a modern service based on the maritime tradition, the science of meteorology, technology and telecommunications.
Our basic objective is protection and safety of human lives and navigation at sea as well as of numerous activities going on on seas, islands and littoral.

The town of Hvar and the meteorological station itself are protected from south-western side by the islands Pakleni otoci (Vodnjak Mali, Vodnjak Veli, Travnac, Parûanac, Borovac, Sveti Klement, Dobri, Vlaka, Stambedar, Planikovac, Borovac 2, Gojca, Marinkovbac and Jerolim) and the island of Galeönik which is located at the southern entrance into the port of Hvar

Number of days with wind according to Beaufort scale (Bf) and according to months, for the island of Hvar (1858 - 2006)

month Bf	1	2	3	4	5	6	7	8	9	10	11	12	Year
0	14	8	19	18	16	9	24	36	25	9	8	17	*203*
1	442	349	352	410	418	419	465	520	542	476	367	451	*5211*
2	1066	913	922	988	1194	1238	1300	1358	1212	1166	1029	1019	*13405*
3	1115	1039	1201	1225	1327	1424	1519	1424	1298	1084	1023	1109	*14788*
4	725	766	865	801	794	715	669	652	660	707	718	697	*8769*
5	314	292	290	274	193	149	115	113	140	251	275	296	*2702*
6	296	256	313	261	198	124	95	105	140	290	378	349	*2805*
7	159	147	185	135	91	37	24	21	52	131	187	189	*1358*
8	64	45	54	46	27	8	5	6	16	49	75	69	*464*
9	21	16	20	9	9	1	1	0	5	14	27	36	*159*
10	0	1	2	0	0	0	0	0	0	0	3	0	*6*
11	1	3	3	0	1	0	0	0	0	2	0	2	*12*
12	0	0	0	0	0	0	0	0	0	0	1	0	*1*
Sum	*4203*	*3827*	*4207*	*4149*	*4252*	*4115*	*4193*	*4199*	*4065*	*4170*	*4083*	*4217*	***49883***

From Table is evident that the greatest number of days with wind force 3 Bf (weak wind) is 30%, then follows the wind force 2 Bf - 27%, moderate wind - 17,65%, strong wind force 6 Bf - 5,64%, very strong wind force 7 Bf - 2,75%, stormy wind force 8 BF - 0,93% and strong stormy wind force 9 Bf - 0,32%. Wind force 10 Bf occurred in only 6 days, wind force 11 Bf in 12 days and there was only one day with wind force 12 Bf (hurricane) registered in the examined period of 136 years.

It is also evident that the wind force 6-12 Bf occurred in 9,25% of days, while the wind force 0-5 Bf occurred in 90,74% of days. For columns according to months, the greatest number of days with wind force of 6 Bf was registered in November, then in December and March, while the smallest number of days with 6 Bf was registered in July, August, June and September. Naturally, these months are the most favourable for maritime activities and fishing, especially of blue Adriatic fish which has been tradition for thousands of years. The identical conclusion is obtained also for days with wind force 6 Bf. For find force 8 Bf the greatest number of days has December, followed by November and according to days with stormy and strong winds January and March. The summer period is the most favourable because the probability of wind force 8 Bf in July and August is insignificant (one case in 100 years), then follows June (7 cases in 10 years) and September (1,5 cases in 10 years).

Table of marginal values (for warnings at sea) for the navigation of certain boats and ships (Tabain, Hodžić)

Ship type	Wind	Waves	State of the sea a
	Knots (Bf)	*m*	*(WMO)*
For big ships	56-71 kn(11-12 Bf)	6.1 - 9.1	7
For two-masted ships	41-55 kn (9-10 Bf)	4.0 - 6.1	6
For "leut"	28-40 kn(7-8 Bf)	2.5 ñ 4.0	5
For "gajeta"	17-27 kn(5-6 Bf)	1.25 - 2.5	4
For "pasara"	7-16 kn(3-4 Bf)	0.5 - 1.25	3

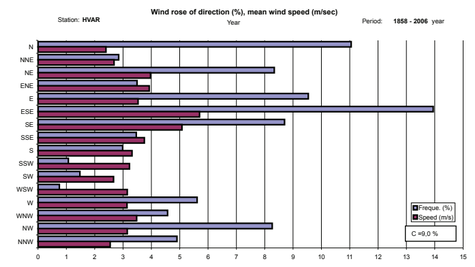
According to the proposed marginal safety in the Adriatic and results, in the region of Hvar gajeta could not navigate 55 days in average, leut 15 days, trabakul about two days and big ships one day in 10 years. Naturally, this analysis has no value for the open sea of the Central Adriatic but for the region of Hvar only.
It is obvious that the greatest number of cases of strong and stormy winds occurs during the winter period (80 days) and in autumn (52 days), in spring (49 days) , while in summer only two cases have been recorded in the available series of data from the period 1858-2006.

Number of days according to Beaufort scale for years and months, for the island of Hvar (1858-2006)

Bf.	1	2	3	4	5	6	7	8	9	10	11	12	Year
0-1-2	1522	1270	1293	1416	1628	1666	1789	1914	1779	1651	1404	1487	18819
3-4	1840	1805	2066	2026	2121	2139	2188	2076	1958	1791	1741	1806	23557
5-6	610	548	603	535	391	273	210	218	280	541	653	645	5507
7-8	223	192	239	181	118	45	29	27	68	180	262	258	1822
9-10	21	17	22	9	9	1	1	0	5	14	30	36	165
11-12	1	3	3	0	1	0	0	0	0	2	1	2	13

From Table it results that there are 138 days for the wind scale from 0-1-2 Bf and 173 days for weak and moderate winds (3-4 Bf). There are in average 11,04% of moderate and strong winds and only 3,61% of strong and stormy wind, while to the class of strong stormy and hurricane winds (9-12 Bf) goes only 0,356%, or 4 cases in 10 years only.

With regard to safety of boats and ships in the Adriatic and in order to reduce the rate of accidents, margin states of winds and waves were proposed as in Table 6, namely limits for safety of navigation were stated with regard to the Beaufort scale and the scale of wind speed in m/sec and height of waves (probable significant height of waves).

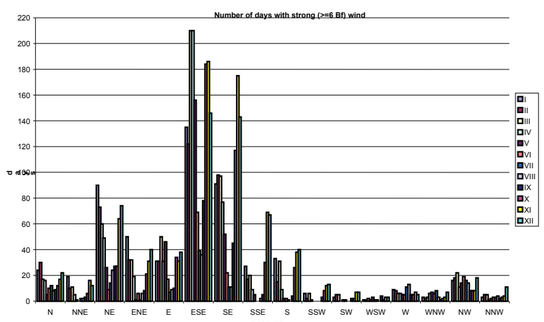


According to annual wind rose and results, the most frequent direction is ESE (13,9%), dominant direction of jugo on the island of Hvar. Then N 11,05%, E 9,53%, SE 8,69%, NE 8,33% and NW 8,26% wind, while 9,05% goes to the calm. Jugo (ESE, SE, SSE and S) annual average of 28,95%.The sum of tramontana, mistral and etesian directions we shall obtain the amount of 29,23%, wind directions which belong to bura (NNE, NE and ENE) have amount of 14,65%. Three basic groups of dominant winds in the Adriatic are represented in Hvar with 72,83%.

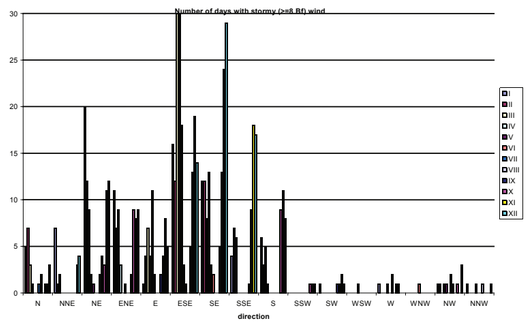
Wind frequencies for the 1st, 2nd, 3rd and 4th quadrant for the period 1858-1907, 1908-1957 and 1958-2006 in relation to mean frequencies for the period 1858 -2006, for the island of Hvar

Quadrant	I				II				III				IV				Calm
	BURA - LEVANT				JUGO - OŠTRO				LEBI - PULENAT West wind				MISTRAL - ETEZIAN - TRAMONTANA				
direction / period	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N_Z	C
1858-2006	2,8	8,3	3,5	9,5	13,9	8,7	3,5	3,0	1,1	1,5	0,8	5,6	4,6	8,3	4,9	11,0	9,0
	24,1				29,1				9,0				26,6				
1858-1907	18,0	18,0	5,7	29,5	23,7	24,1	29,0	33,3	9,1	46,7	50,0	37,5	45,7	7,3	4,1	18,0	3,3
	0,8				110,1				-143,3				52,4				
1908-1957	35,7	15,7	57,1	42,1	36,7	20,7	45,7	16,7	27,3	46,7	25,0	37,5	47,8	24,1	39,0	4,5	3,1
	35,0				96,4				81,9				67,2				
1958-2006	7,1	15,7	22,9	11,6	7,2	10,3	5,7	20,0	0,0	26,7	0,0	2,5	21,7	3,6	2,0	6,4	7,8
	11,5				-43,2				29,2				-26,5				

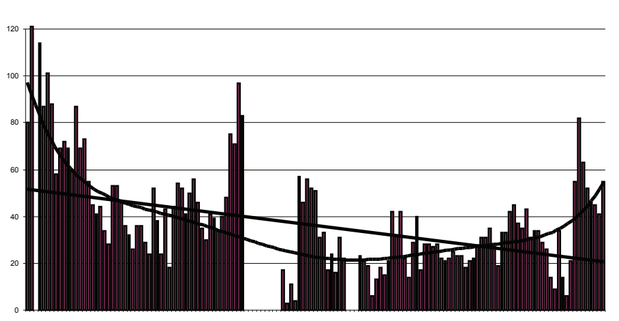
Comparing the mean values for the directions of the 1st, 2nd, 3rd and 4th quadrant from the 50-year series (1858-1907) with those from the 150-year series (1858-2006), it can be observed that there is but insignificant difference between the mean values for the 1st quadrant, where the most pronounced positive difference was determined for the eastern wind. Namely, the eastern wind surpasses significantly the mean value of 150- year series. The value of the wind from the 4th quadrant is bigger than the mean value, with a special accent on direction WNW. There is even more positive difference for the 2nd quadrant where the most pronounced wind is SSE and S (jugo and oötro). In the third quadrant shortage of wind directions WSW and SW has been noticed, as there are nearly 50% less of these winds in comparison with the mean value from the series of 150 years.



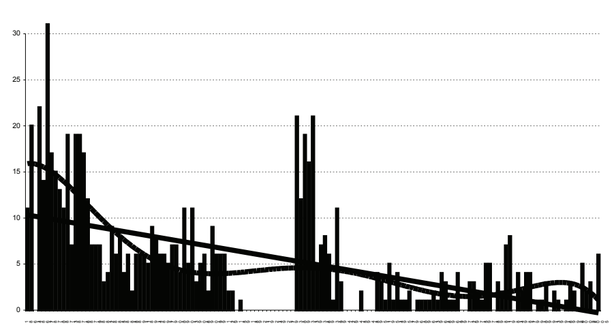
Presentation of days with strong (6 Bf) winds according to wind directions and months for the island of Hvar (in the period 1858-2006) with respective tables.



Presentation of days with stormy (8 Bf) winds according to wind directions and months for the island of Hvar (in the period 1858-2006) with respective tables.

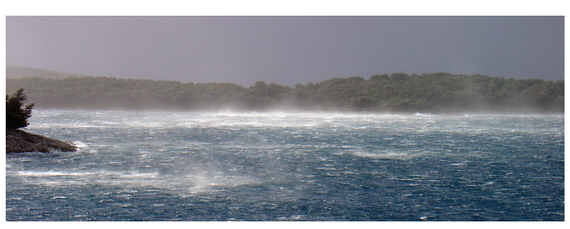


Number of days with strong wind (6 Bf) according to years, for the station of Hvar (1858-2006).



Number of days with stormy wind (8 Bf) according to years, for the station of Hvar (1858-2006)

CONCLUSION



In this paper we compared the directions of the wind on Hvar over three 50-year series: 1858-1907, 1908-1957, and 1958-2006. It was stated that the frequency of directions in the first 50-year series exceeds the mean values over the 150-year period. In the other two series the difference between frequencies was negative, i.e. less than those over the150-year series, it is especially marked in relation between the third and referential series. In the 2nd and the 3rd series values of *jugo* and *bura* are especially lowered. Similarly, continuous reduction in number of days with strong (6Bf.) and gale force (8 Bf.) winds was determined. Both phenomena could be linked with weakening of cyclonic and frontal activity in connection with different position and influence of Eurasian anticyclone over the Adriatic. This connection should be certainly looked for in future interactive and correlated research of marine meteorological characteristics, phenomena and baric formations of temperate latitudes over the Adriatic and its close proximity.

By researching the wind direction, force (Bf) and speed (m/sec) from 150-year series (1858 - 2006 and only partially incomplete) at the Hvar meteorological station, one of the things we determined is that ESE is the most dominant and the most frequent direction for *jugo* (sirocco), whereas N is the most marked direction for northern winds and *bura* (bora). Thereby, when the directions for *jugo* are added up (ESE, SE, SSE and E) we get the mean annual amount of 28.9% and for directions (N, NNW, NW and WNW) *maestral* (mistral), *tramontana* - etesian winds, the amount of 29.2%, which symmetrically balances the effects of these two quadrants (2nd and 4th) in the wind rose of Hvar.
By analyzing the mean speeds we determined that the highest speeds are for ESE and SE, N, and WNW directions. The highest speeds over 40 m/sec value refer to directions of *jugo* and *tramontana.*
The most frequent wind directions in winter are ESE and N, in summer NW, in spring ESE and SE and in autumn ESE, when NW becomes less frequent and N direction more frequent.
Actually, in the cold part of the year ESE direction is mostly marked and in the warm part of the year the direction of *maestral* (mistral) - etesian winds, prevails.

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