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BREEZE CIRCULATION IN VARNA IN THE PERIOD 1990–2010

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Елисавета Пенева, Светлана Иванова, Росен Пенчев. БРИЗОВА ЦИРКУЛАЦИЯ ВЪВ ВАРНА В ПЕРИОДА 1990–2010 г.

В това изследване са използвани данни за вятъра от над 600 000 телеграми в код МЕТАР от летище Варна за периода 1990–2010 г., с цел да се изучат характеристиките на бризовата циркулация във Варна. В резултат са получени розите на вятъра за целия период, както и на силния вятър. Видно е, че доминиращите посоки на вятъра са западна, северна и изток-югоизточна. Получени са и сезонните рози на вятъра, които показват, че за студената част от годината са характерни западни и северни ветрове, а за топлата част на годината доминират ветрове с източна компонента. Осреднените характеристики на бриза (максимална стойност, час на обръщане) се получават от денонощния цикъл на зоналната компонента на вятъра. Получените в изследването резултати потвърждават и допълват други изследвания на ветровия режим по българското Черноморие.

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Elisaveta Peneva, Svetlana Ivanova, Rosen Penchev. BREEZE CIRCULATION IN VARNA IN THE PERIOD 1990–2010

In this paper the data for the wind coming from more than 600 000 METAR telegrams of the Varna airport in the period 1990–2010 are used in order to investigate the characteristics of the breeze circulation in Varna. In result the wind roses for the whole period, as well as the strong wind roses are presented. It was found that the dominating winds are western, northern and east-southeastern. Seasonal wind roses show that the west and north direction of wind characterize the cold part of the year, and during the warm part – the eastern wind predominates. The averaged characteristics of the breeze (maximum speed and time of reversal) are seen in the diurnal cycle of the summer zonal wind component. The findings of the paper confirm and complement other studies of the wind regime along the Bulgarian Black Sea coast.

Keywords: Black Sea coast climate, breeze, wind regime
PACS numbers: 92.60.Ry, 91.50.Cw, 92.60.Gn

1. INTRODUCTION

The breeze circulation is a well-known event which is an element of the climate of the ocean or other large basins coast. It is a mesoscale to local event and originates from the pressure gradient differences created over the sea and land surfaces, due to the different thermal properties [1, 2]. During the day the so called daily (or sea) breeze develops with direction near the coast from the sea to the land. The night (or land) breeze on the contrary directs from the land to the sea. The circulation engages not only the near-surface air but also develops in height to close a full circulation cell (Fig. 1). On average, the daily breeze is more intense than the night one. This wind is well expressed usually in summer seasons in the absence of global atmosphere circulation processes (as for example cyclones, anticyclones, fronts, divergence or convergence lines etc.) [2]

In Bulgaria the breeze is very common over the Black Seaside. It is observed in summer due to the significant temperature gradient between land and sea and the low intensity of the global atmosphere circulation. The daily breeze usually has speed about 3–4 m/s, and the night one – 2 m/s [3, 4]. The breeze could penetrate to Dobrich area and could influence the whole Burgas plain [5, 6].

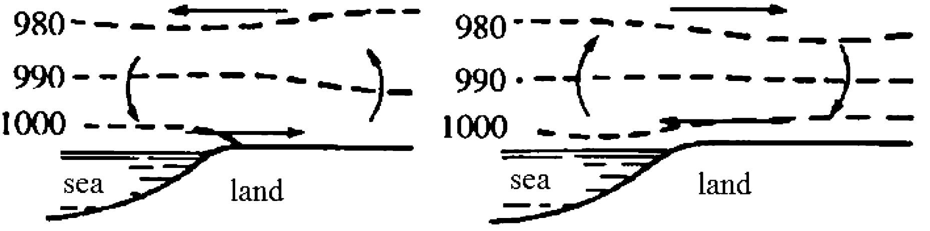

Fig. 1. General scheme of establishment of the breeze circulation

The breeze is very important for the climate along the Bulgarian Black Sea coast: it limits the thermal heat in the afternoon summer hours and suppresses the summer convective cloudiness [3, 5]. It also freshens the air and contributes to decrease the anthropogenic pollution.

The aviometeorological service at the airports near the coast pays a special attention to the breeze as the varying speed and direction could cause complications in the air traffic [7]. Also, in summer the traffic is more intense due to the tourism. That is why the breeze characteristics are important in regard to the speed, direction, time of reversal. Very important is to know how the process develops in vertical direction, but the lack of data prevents this investigation.

In order to study well the long-term characteristics of the breeze circulation data with fine resolution in time for long period are needed. In this study we use the data measured in Varna airport in the period 1990–2010. The temporal resolution ranges from half an hour to 10 minutes in different periods.

2. DATA USED IN THE STUDY

Varna airport is located on the west side of city Varna, 2 km from Aksakovo district and 1.5 km from village Topoli (Fig. 2). Very important factor is the nearness of the Varna lake, situated about 4 km in southern direction, almost parallel to the runaway track, with length 13 km and width 1.5–2 km. The lake is connected to the sea and in general this creates a channel for the sea air to penetrate inland. As seen in Fig. 2 the channel is oriented in south-east direction in respect to the airport.

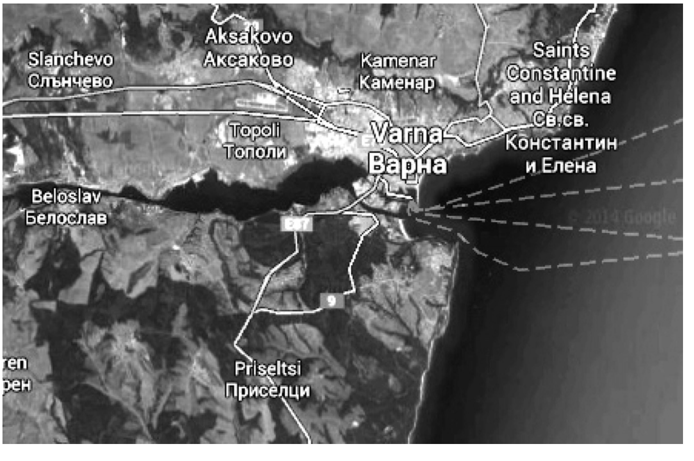

Fig. 2. Location of Varna airport near city of Varna and the Black Sea

The measurements on the airport are in accordance to the World Meteorological Organization (WMO) and the International Civil Aviation Organization (ICAO) regulations [8]. During the period 1990–2010 the measurement system was upgraded two times (1996, 2008) which led to differences in the data formats and temporal resolution. For the last ~10 years the Varna airport has been equipped with an Automatic Meteorological Observing System VAISALA (AMOS), which measures a number of meteorological characteristics (Fig. 3). The wind speed and direction are measured by three wind sensors, located along the runaway track at about 70 m distance. The wind is standardly measured at 10 m height.

The wind speed is measured by the anemometer WAA151 [9], and the wind direction by weather vain WAV151 in 16 scales. The error in taking measurements is 0.5 m/s (1 knot). The data are collected in the meteorological station MILOS 500, and their processing and visualization are performed by the meteorological server (CDU). The data to construct the METAR code are coming from only one of the three wind sensors depending on the current runaway for takeoff and landing. That is why the data could come from three different sources, at distance 2 km from each other. In our study we will consider this difference insignificant as the measurements are large volume (more than 600 000 as seen from Table 1). The data for wind speed and direction are averaged for 10 minutes interval, as standard.

In the period 1990–1996 the temporal resolution of the data is 30 minutes, as issued by the Vaisala system. During the period 199–2008 the system is upgraded to Vaisala-Midas 600 and the change of software led to the change in the data formats, data are measured every 10 minutes. Since 2008 the system was upgraded again to Vaisala-AviMet and the METAR telegrams are issued again every 30 minutes. There are also some periods with missing data: February 1992; January, February and March 1995, July 2007; July and October 2009, as well as in general several days near New year eve.

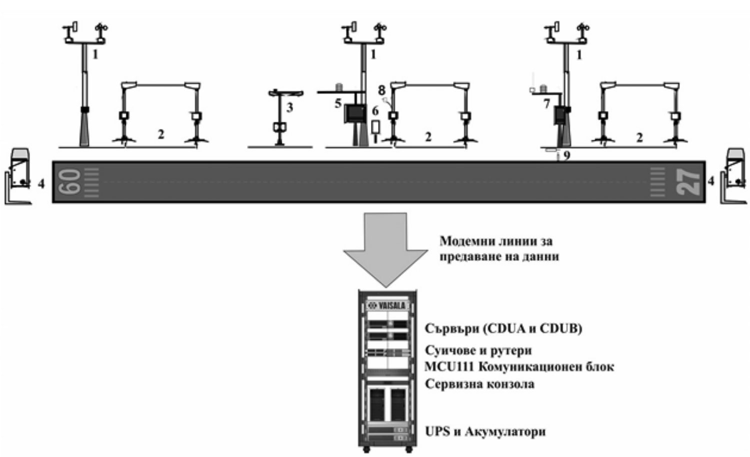

Fig. 3. Automatic Meteorological Observing System at Varna airport: 1 – wind speed and direction sensor at 10 m; 2 – Transmisionmeter; 3– combined instrument to determine the current weather (F12P); 4 – laser distance meter (LIDAR); 5 – automatic meteorological station to measure temperature, humidity, and air pressure; 6 – Rain gauge; 8 – Illumination sensor; 9 – Runaway track temperature sensor

3. WIND ROSE FOR THE PERIOD 1990–2010

The large amount of data is processed in order to obtain the average wind rose for the period 1990–2010. The Table 1 summarizes the number of measurements for each year, and the percentage of no-wind and strong wind weather conditions.

Table 1. A summary of wind data for the period 1990–2010 (strong wind is defined when $V > 8$ m/s)

Year	Number of measurements	Number of no-wind	% no-wind	Number of strong wind	% strong wind
1990	17454	2036	11.66	444	2.54
1991	16965	1372	8.09	764	4.5
1992	16015	1356	8.47	529	3.3
1993	17485	1742	9.96	723	4.13
1994	18652	2462	13.21	462	2.48
1995	13218	1867	14.12	385	2.91
1996	17225	2663	15.46	1083	6.29
1997	47902	3616	7.55	784	1.64
1998	49601	4320	8.71	1378	2.78
1999	48705	4862	9.98	1643	3.37
2000	52690	5856	11.11	1695	3.21
2001	50988	4294	8.42	2243	4.40
2002	48890	4692	9.6	1652	3.38
2003	48222	4128	8.56	1500	3.12
2004	18206	6111	3.57	496	2.72
2005	17460	5381	30.82	498	2.85
2006	52463	4557	8.68	1745	3.33
2007	37891	3509	9.26	1582	4.18
2008	23081	3946	17.09	1599	6.93
2009	16764	3247	19.34	761	4.54
2010	18712	3695	19.75	1084	5.79
1990–2010	617922	76243	12.34	22021	3.56

The Table 1 reflects different algorithms when measuring no-wind conditions, and this is a problem in the data: it varies from 10 to 30 %. The annual number of strong wind cases (wind speed >8 m/s) is more uniform, usually about 3–4 % of the cases. It could be noted that during 1996 and 2008 the strong wind observations were more frequent 6–7 %. However, as the updates of the system were performed in 1996 and 2008, this result is to be checked using other independent data.

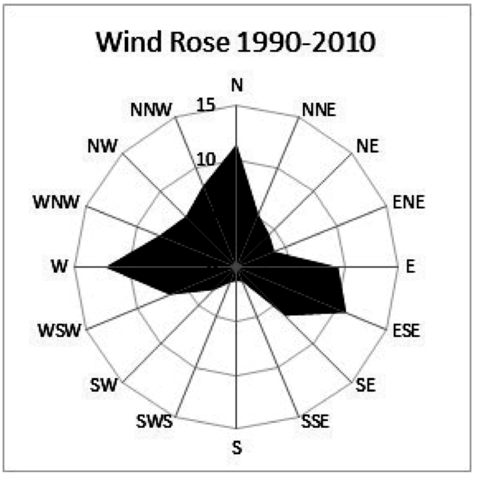

Fig. 4. Wind rose for all measurements in the period 1990–2010

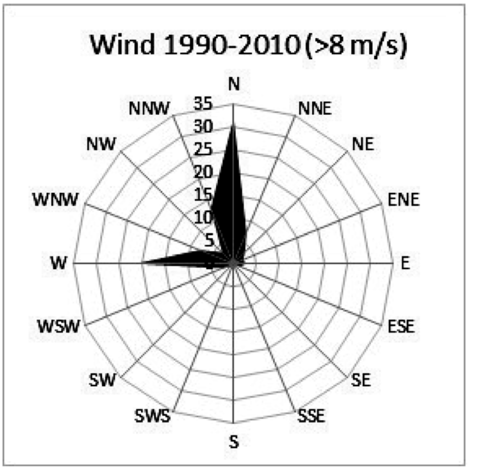

Fig. 5. Wind rose for the cases with $V > 8$ m/s in the period 1990–2010

These data were used to construct the wind rose (Fig. 4) and the strong wind rose (Fig. 5). It is seen that the most frequent directions for the wind in Varna are west, north and east-southeast direction: each ~10 % of cases (Fig. 4). The strong wind defined as the wind speed exceeding 8 m/s blows only from north (30 %), west (20 %) and north-northwest (15 %).

4. SEASONAL WIND ROSES

The data give possibility to construct seasonal wind roses in order to investigate seasonal changes in the dominating wind direction. The average estimates for the seasons are defined as following: winter is the average for the months January, February and December from the previous year (DJF); spring – the average for March, April and May (MAM); summer – June, July and August (JJA); and autumn – September, October and November (SON). The corresponding seasonal wind roses are given in Fig. 6a to 6d. One can note that the winter (Fig. 6a) and autumn (Fig. 6d) roses are similar, and this is also valid for the spring (Fig. 6b) and summer (Fig. 6c) wind roses. The conclusion is that the wind regime is similar in the cold part of the year, and respectively in the warm part of the year. The cold part is characterized by dominating winds from north (15 %) and west (15 %) and the east wind about 5 % of the cases: the north-west quarter of the wind rose is populated. On the contrary, during the warm part the branch of east-southeast appears (~15 %) and the north and west wind is less frequent (~10 % each). The conclusion is that the east-southeast direction in the warm part wind rose reflects the breeze circulation development.

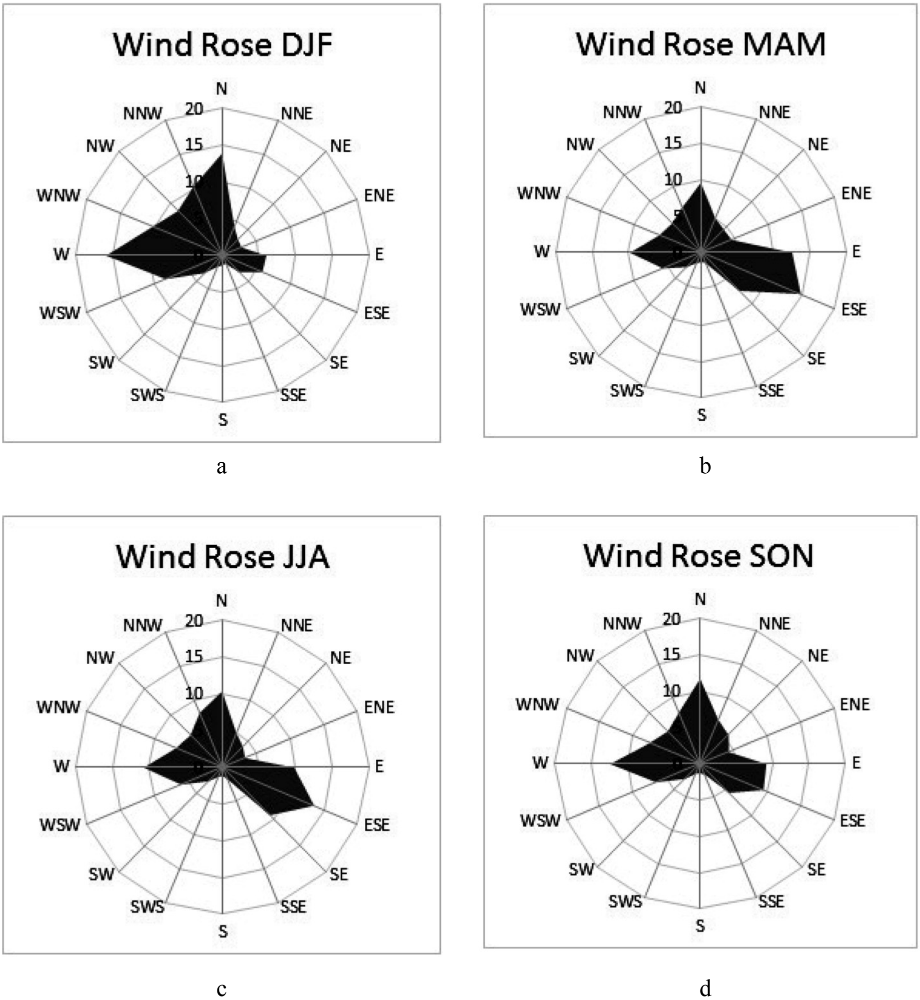

Fig. 6. Seasonal Wind roses of 1990–2010 for: a) the winter months – December, January and February; b) the spring months – March, April and May**;** c) for the summer months – June, July and August; d) the autumn months – September, October and November

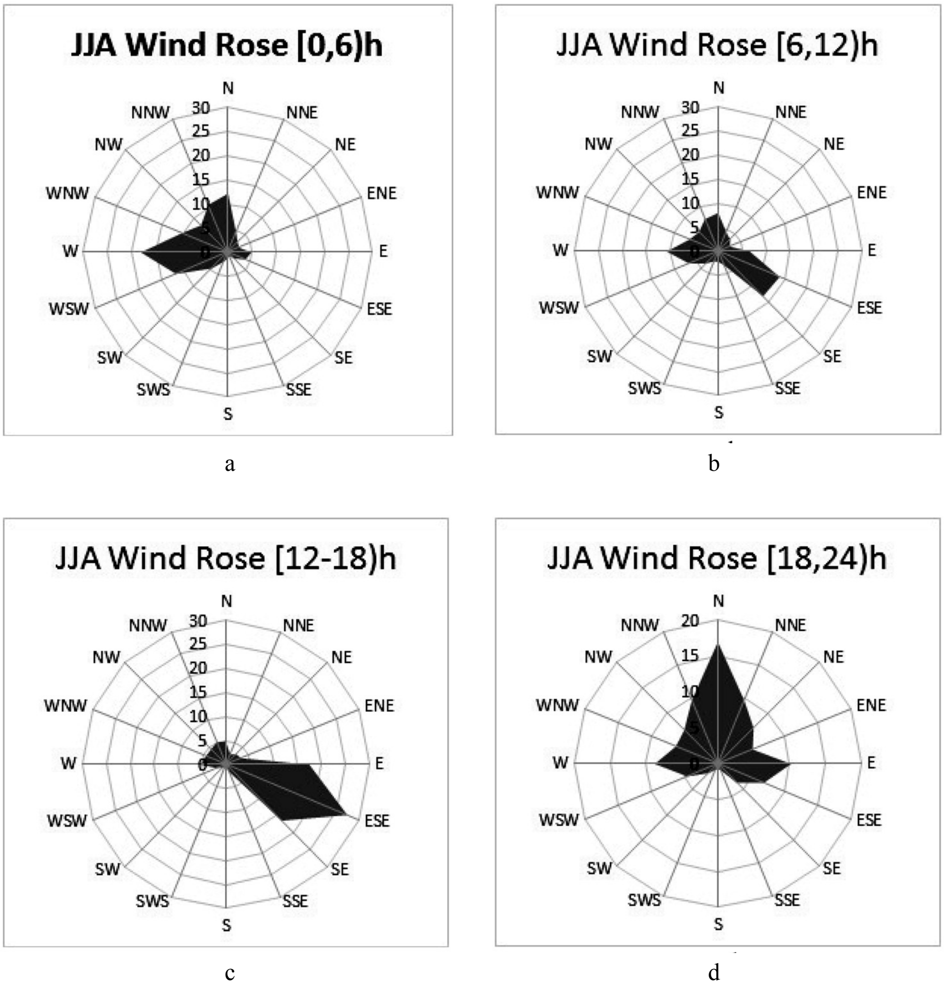

Fig. 7. Wind rose for the summer months of 1990–2010 in the time interval:
a) [0–6)UTC; b) [6–12)UTC; c) [12–18)UTC; d) [18–24)UTC

5. DIURNAL WIND ROSES IN SUMMER PERIOD

In order to further elaborate the summer wind processes and to confirm the reversing wind direction during the day we have subtracted the summer wind rose (Fig. 6c) in 4 parts for different hour intervals: [0,6), [6,12), [12,18) and [18,24). Note that all time units are given in UTC, as reported in the METAR code telegrams. The corresponding 6-hourly wind roses are shown in Fig. 7a to 7d. During the first 6-hours interval (Fig. 7a) the wind blows dominantly from west (17 %). Further in the day (Fig. 7b and Fig. 7c) the east-southeast direction is significantly presented

(25 %) and in the evening (Fig. 7d) the north wind takes place (16 %). The E, ESE and SE direction in Fig. 7b and 7c corresponds to the daily breeze appearance. Obviously the wind is oriented by the channel connected Varna bay and Varna lake which is located east-southeast in respect to the Varna airport (Fig. 2).

In order to determine better the time of reversal and the average breeze speed the diurnal cycle of the zonal component of the wind is calculated. Only the summer months JJA in the period 1990–2010 are taken into account. The zonal component is calculated from the vector speed and angle as the projection in west-east direction, thus it is positive for the western wind and negative for the eastern. Then it is averaged in one hour intervals during the day. The result is shown in Fig. 8. It is seen that the night breeze is much less intense than the daily breeze (less than half). Maximal night breeze develops around 6 UTC (the average estimate is 1 m/s), and maximal daily breeze – around 14 UTC (mean speed ~2.5 m/s). Note that these are average estimates, so the actual wind speed could be much more. The time of reversal of the direction is 9 and 21 UTC.

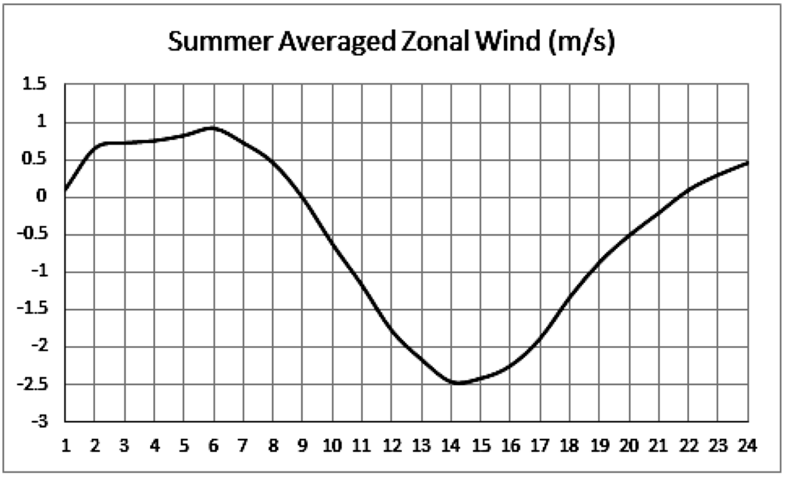

Fig. 8. Diurnal cycle of the zonal wind component in summer JJA months of 1990–2010

5. CONCLUSIONS

In this paper the data for the wind coming from METAR telegrams of the Varna airport in the period 1990–2010 are used in order to investigate the characteristics of the breeze circulation in Varna. The data are obtained by the Automatic Meteorological Observing System VAISALA installed at the airport, which has been updated 2 times in the period (in 1996 and 2008). These updates led to a change in the data formats and standards which differences we tried to uniform to some extent. However, some inconsistences could still be presented. As the paper focusses on long-term average statistics and not the interannual variability, we could consider the data rather consistent.

It was found that the dominating winds are western, northern and east-southeastern, and each of them prevails in a certain season: the west and north direction of wind characterize4s the cold part of the year, and during the warm part – the wind with eastern component is dominant. The breeze circulation is significantly presented in summer, which is seen by the dominating west direction in the night wind rose, and dominating east-southeast direction in the day wind rose. The wind intensity and the reversal time of the breeze are determined from the diurnal cycle of the zonal wind component: the breeze reaches maximal values at 6 and 14 UTC, and it reverses the direction in 9 and 21 UTC.

The findings of the paper confirm and complement other studies of the wind regime along the Bulgarian Black Sea coast. [3][5]

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