MARINE FLOODS IN THE CASPIAN SEA'S NORTHERN PART

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ABSTRACT

Wind-induced changes in the level of the northern Caspian Sea are described.

Caspian Sea is a reservoir with a constantly changing background level. Because of its being isolated from the Ocean the water balance of the sea is mostly dependent upon the flow of its rivers, which is in turn linked to global climate changes and the general damping of North Atlantic, Arctic and European regions creating the main features of Caspy's hydrological conditions. Thus, the substantial level fluctuations peculiar to Caspy in particular present an extremely complex sum of numerous components - general damping and evaporation from the surface of practically the whole of the northern hemisphere. Tectonic processes contribute a lot to the character of the fluctuations and recently industrial development started the further aggravation of the situation. Bottom surficial samplings prove the fact that within the last five centuries high- and low-level periods changed each other several times and the average range of the fluctuations is equal to that of 6 meters. This century's range amounts to 3.57 m (Figure 1).

Temporary non-periodical level fluctuations of anaemobaric nature (the so-called "sgony" and "nagony") occur throughout all the expanse of the coastline. It is respectively 1.5 m. and 5 to 7 m. high in southern and northern parts.

As to the Northern Caspy, there can be two certain regions distinguished which are characterized by the topmost value of sgony/nagony-fluctuations. These are western and north-western coastal parts to the north of the Astrakhan peninsula, including the estuary of the Volga river, and the north-eastern coastal part from the Ural mouth to Buzachy peninsula (Figure 2).

Nagon is a flow of wind-driven waters directed by "moryana" - a strong wind blowing from the sea to the coast and constant in direction and the time of duration. Nagons form a long wave-line flooding coastal sites. Villages, industrial and agricultural structures, roads and electrotransmitting communications are constantly being affected. It also often ruins fisheries and navigational devices.

Sgon or ebb is initiated and further on influenced by the wind blowing from the opposite direction. It causes drainage of the coastal shallow reservoirs and results in fish perishing.

As a rule sgony and nagony commence simultaneously in Caspy's northern part at different sites and are characterised by the similar weather conditions and processes. For instance, if nagon appears in the north-west, there is sure to be the ebb going on in the north-eastern part and vice versa.

Wind waves rising during the powerful floods and ebbs at the depths division line (dividing the Northern and the Middle parts of Caspy) grow as high as 5 to 6 meters and present a severe danger for ships belonging to the "river-sea" types enduring at the most 2.5 meter high waves.

The depths in the Northern parts of Caspy do not exceed 10 meters pitch, i.e., identical to the range of sgon/nagon fluctuations. Bottom and coast declivities are at that very insignificant (not more than 10 to 20 cm per km). The coastline here is a flat accumulative valley with vast sand banks. Hence, when some substantial floods occur the territories contiguous to the coast turn to be inundated at the length of 30-50 kilometers. On the contrary, during the ebb (sgon) kilometers and kilometers of land lay dry even farther than the usual coast bounds.

The synoptical processes' development causes the most intense storm activity in the Northern Caspy and is characterised first of all by the co-activity of the enforcing anti-cyclone formations moving to Kazakhstan and Middle Asia along the ultrapolar axis (primo) and a sufficiently obvious cyclonal activity upon the territories of the Europe-Pacific Region, the Black Sea and Northern Caucasus (secondo). The more intensive cyclone enforcement and anti-cyclone deepening become, the more vividly is storm activity expressed in the "intervening" zone.

Within the period of instrumentally supported observations there were 11 most prominent storm inundations registered in the Northern Caspy when the level rise was detected as exceeding the average values in height at more than one meter (Table 1).

The highest of them occurred between November 10-13, 1952, along the north-western side. All the way along from the town of Caspyisky (or Lagan) to the Bryanskaya Cosa the rise-level exceeded the average one at 4.5 m. A vast low-lying territory to the north and north-west from Caspy (17,000 km^2) was flooded, and in addition to this the sea protruded from 25 to 50 km in to the land. The intensity of the level rise at Bryanskaya Cosa site reached even 20 cm per hour. The ultimate rise at the sites was as follows: island Tyulenyi, 24.86m abs.; Bryanskaya Cosa, 24.68m abs.; Cochubey station, 24.53m abs.

That flood had a dramatic aftermath: according to the eye-witnesses' testimonies the water rushed along the natural indentations in a form of a 2 meter high wave at a stream velocity of 18 to 25 km/hour. Scores of fishing boats were swept away by the wave far into the wilderness. An uncountable quantity of cattle perished and people perished too.

This is how they describe it:

Chistaya Banka island: "On November 11 at 0.20 a.m. the island was all deep under the water... The depth amounted to 1.5 m. One could see the water splashing at the window-sills and all the machinery was carried upstairs..."

Tulenyi island: "... over half of the island is covered with water... Houses, industrial objects and all have drowned; the navigational devices are flooded".

Ganyushkino village: "On November 12 there was a severe wind blowing from the south-east; its speed amounted to 25 m/sec. A real wall of water was driven with the wind and the village and the adjoining sites were all flooded. Some people perished..."

The town of Caspyisky (Lagan): "The water was rushing at unbelievable speed, carrying along all it met and devastating the place. A few houses were actually swept along. All the transport boats and fishers were torn off the anchors and also carried far away into the steppe."

On its way to the west Caspian waters reached at some places the railway line Kizlyar-Astrakhan and washed it away at Ulan-Khall, White Lake, Cochubey for at least 50-70 meters in length. Commercial train communication was disconnected for three days.

The flood was caused by a persistent stormy wind from the east and south-east and the storm covered not only the northern regions but the Middle Caspy as well. Some hydrometeorological observational stations registered the wind velocity that had not occurred for the previous 40 years. At the peak of the nagon the wind power in the north-west reached the point of 12 balls. Nothing the like has yet been observed since then up to the present (Figure 2).

As can be seen from table 1, inundations like this take place in the north-western Caspy not more than once in 10 years (over 1 meter rise). Less intensive floods (less than 1m) may be observed once or twice a month (especially in autumn and winter). In summer nagony in the northern Caspy occur but seldom.

There is a lack of scientific information concerning north-eastern Caspy's nagony. Regular observations have not been carried out here for decades due to the complicated conditions in which the observations have to be carried out.

According to the scanty data from Prorva meteorological station (1933-1934) the peak level was observed on June 19,1934 and was equal to -24.75 m.abs., i.e., 168 cm higher than the average of this year. At Zhilaya Cosa station (1935-1937) the maximum was registered on June 11,1936 (-24.25 m.abs.).

The most powerful nagon occured on October 1958. Because of the stormy wind (20-28 m/sec) from the south-west and west directions all the coastline from Guriev (Ural river mouth) to Prorva station was inundated (20-30 km.). The thickness of water layer on the territory amounted to 0.25 to 1.1 m and the maximum rise (1.7m) was marked near the oil pipeline Teren'-Uzek (26.25m. abs.).

Nagon of March 25-26 1958, judging by the remaining traces of it, shifted the coastline to 35-40 km eastward from Prorva.

Sgony in North Caspy are also scarcely explored and mostly due to the extremely insignificant declivity of the bottom and the coast. The border of the drained territories unlike that of the inundated ones is faint and unevenly drawn. The water recedes remaining in hollows in the form of pools and lakes. The sand banks are bared and the area of the islands and banks increases although the definite border of the drained territories is difficult to distinguish, as a rule. The more sure method of defining the intensity of sgony is level registration, yet it does not always work as well. During the sgonys of high intensity registration is complicated by the sea's stepping back to several kilometres from the point of observation thus making it actually impossible. The levels in the remaining pools and lakes do not reflect the real values at the moment of the lowest level fall.

Substantial sgony in the north-west Caspy were observed nine times within the period from 1937 to 1994, i.e., once in six years (table 1). The most remarkable of them was observed on October 1,1978 when the sea level fell at Tulenyi island to -30.14m. abs.

That is what the witnesses say about one sgon in the North-East Caspy: "In the fall of 1935 our fisher was floating to the south of Prorva. On October 29 at night a strong west wind began to blow and the water was gradually driven away westwards. On October 31 the boat touched the bottom. In addition to that the boat was attacked by the drifting ice which formation began with the shallowing of the coastal waters. The fishers had to take measures and protect the boards from being pierced through. Yet the ice dried up on approaching the boat. We found ourselves being captives in the boat lying on the absolutely dry surface. And it was only on November 6 that the wind quietened and the water began to return."

The most complicated hydrological situation was to be observed during the whole year 1977 when the average level of Caspy fell to the lowest pitch (the first time for the whole 500 previous years) and was equal to -29.00m. abs. These low background levels accompanied by the frequent sgony created a crisis situation in the most shallow northern part of Caspy. The fish would perish and the transport was paralyzed.

Background levels' fluctuations linked to the changes of the income and expenditure parts of water balance seriously influence the intensity of sgony/nagony. Due to this fact within the period 1976-1994 the critical level points presenting danger for sea and river transport were re-calculated (in 1976, 1977, 1982, 1990, 1991, 1994).

Systematic scientific researches were started in the North Caspy in the end of the last century. And the information accumulated by the time allows the researchers to arrive at certain conclusions as far as the precise assessment of the fluctuations is concerned.

S.I.Kan was the first to suggest the method of short-term forecasting of North Caspy's levels (Kan 1948). The method is based upon working out the empiric interdependence between the sea level and the sgon/nagon-winds velocities and the value of the baric gradient. The direction of research work chosen proved to be effective and the modified method is still of great use in sea-floods' forecasting.

Sheremetevskaya developed another method of forecasting based on the study of atmospheric pressure presented as the expansion factors of Chebyshev's polynominal theorem (Sheremetevskaya 1964). The pressure is measured at 25 different points for the following characteristic situations: strong nagony and sgony, some slight level fluctuations. The worked out functions allow us to forecast sea level changes 6 to 24 hours beforehand. It is proved that the intensity of sgony and their values are dependent on the depth of the place, hence the most substantial sgony take place at the depth-division line (2-3 m isobats). As the average sea level gets lower zones of maximum sgon/nagon values are shifted seawards, and as the average rises they move landwards. Due to this it appears impossible to use long observations' data to get precise statistical characteristics of the processes applied to some definite point.

Substantial changes of sgon/nagon level fluctuations in North Caspy may occur at the level falling lower than that of 30 to 31m and the eastern part of the sea separates from the western one.

Observations of the levels and currents on the sections perpendicular to the coastline proved that at the very beginning of nagon its maximum height zone is distributed along the coast at some definite depth and further on it shifts landwards and vice versa for sgons - seawards. The maximum nagon zone is usually to be found not far from the coast and as to sgon's maximum - close to the territory with 2 to 3 m isobat. It was also found that there exists a critical at-coastal depth where sgony and nagony are compensated by a bottom gradient current. When the winds are strong the depth is detected as 1.5-1.9 m. The higher the wind velocity is, the higher is the critical depth value. For territories with depths lower than the critical one all the water flow from the surface to the bottom is moved windwards and the latter process causes the highest level rise for nagon and the lowest one - for sgon. The values characteristic to sgony and nagony for the insignificant land and coast declivities have the tendency of decreasing throughout all the way from the critical depth area both seawards and landwards.

A detailed description of sgon/nagon level fluctuations characteristics for the northern part of Caspy is given by Scriptunova and Gershtansky (Scriptunova 1967; Gershtansky 1978).

Gershtansky did some research work on the mechanism of sgon/nagon formation and on the conditions accompanying the transformation of surficial waters' profiles at their different phases for the shallow coasts, estuaries and the deeper sea areas (Gershtansky 1978; Gershtansky and Kazakov 1980). His suggestions touched on the typification of the synoptical processes leading to the north-western Caspy's flooding and the opportunities of its usage for forecasting. Unfortunately, the author considered but the situations with the Caspy's background levels low and it was thought they were only going to get as low as -30 to 32 m. abs.

There were also developed other methods of sea floods' forecasting for the northern part of Caspy but all of them require precise and detailed information on the actual conditions of the atmosphere pressure, wind directions and velocities and the levels which are difficult to collect.

For decades observations of the coastline movement and research works on the flooded territories for sgon/nagon conditions were carried out only episodically. It was only in 1964 that aviation was for the first time used for observational purposes, and satellite photography was for the first time exploited in 1980. With their help the borders of inundated areas were registered and marked on maps.

The author of this article in 1986 carried out pioneering research work on the formation of nagony in winter time when some part of the coastal territory is covered with ice. It was found out that only "pripuy" - the stationary ice tied tight to the land has a serious influence upon the character of nagony (restrains the process). That ice cover is formed only in severe winters and is actually spread over the whole of the northern part of the sea. It is such a solid formation that it is even able to withstand storms. At the thickness of the ice layer equal to 30 cm and more the wave of nagon coming from the open sea is quickly subdued by pripuy and reaches the land rather weakened. The wider the pripuy zone is, the more effectively are the waves subdued. In warm winters the ice layer is very fragile and uneven so that strong winds easily break it through and the drifting ice slows but short wind waves while the longer ones go through without any hindrance. Then the flood is as strong as it may be in any other season.

Litvin Y.A. carried out some estimations of sgon/nagon parameters in the north-western Caspy basing them on the statistical analysis of hydrometeorological information. He presented an estimation of energetical characteristics for storms causing substantial nagony and their statistical parameters. For the basis of the estimations there was taken the sum of products of storm activity durations multiplied by the square of the wind velocities' projection on one of the effective nagony directions /E/:

$$E = \sum_{i=1}^{n}\left[\left(v\cos\varphi\right)2\Delta t\right]$$

The storm analysis and the comparison of E values with the values of nagony level rises allow us to state the lowest range of dangerous nagony. It is equal to 3000 (E=3000). With E<3000 the nagony height as a rule does not exceed 0.4 m. The danger of serious flood formation increases with E>3000. The earlier arrived at conclusions concerning the lessening of nagony's height in winter in comparison with that of the other seasons (2 to 2.5 times) were quantitatively proved. The energetically identical storms were compared.

1978 opened the epoch of the next serious sea transgression. By the beginning of 1995 the total rise of the background water level compared with the lowest one observed in 1977 (29.00 m.abs) has already amounted to approximately 2.5 m. Caspy's transgression is still going on. The low-lying territories formerly inundated but episodically have become by now part of the sea. Now we have the territories constantly being flooded where the water would not reach even during the most dramatic inundations. Nagony have increassed substantially in the estuaries of Volga and Ural rivers. The sea transgression has led to disappearing of the so-called buffer zone between delta and the sea that used to slow nagon waves during the periods of the low sea levels thus preventing the floods from penetrating into the delta. Now when the sea level is constantly rising the most important scientific-technological task is to develop and to practically realize a complex system of activities aimed at the protection of the shores and mouths from floods. The task calls for serious scientific researches and further studying of the dangerous natural phenomena.

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Table 1. The Most Significant Sgony And Nagony in the North-Western Part of the Caspian Sea

Nagony						Sgony		
Year	Date	Maximum Level m.abs	Rise Value m	Intensity of the Rise cm/hr	Flood Zone Width km	Year	Date	Minimum Level m.abs
1877			3.6					
1910	25-27 Nov		3.6			1957	09.10	-29.83
1952	10-13 Nov	-24.53	4.5	to 20	to 50	1960	21.01	-29.92
1960	19-20 Nov	-26.95	2.0	4-10	10-17	1963	26.11	-29.90
1981	27-30 Dec	-26.16	1.8	to 14	to 40	1964	29.01	-30.00
1984	25-28 Jan	-26.84	1.5	4-14	20-30	1965	26.10	-29.80
1989	17-18 Apr	-26.20	1.4	4-9	20-30	1977	13.09	-30.04
1991	03.06	25.95	1.1	5	20-25	1977	02.10	-30.02
1992	08.04	-25.78	1.4	4-7	15-20	1978	01.10	-30.14
1993	2-3	-25.76	1.4	3-4	12-17	1981	03.02	-29.73
1994	7-9 Apr	-25.20	1.8	to 12	25-30			

Figure 1. Secular variations of the Caspian Sea level

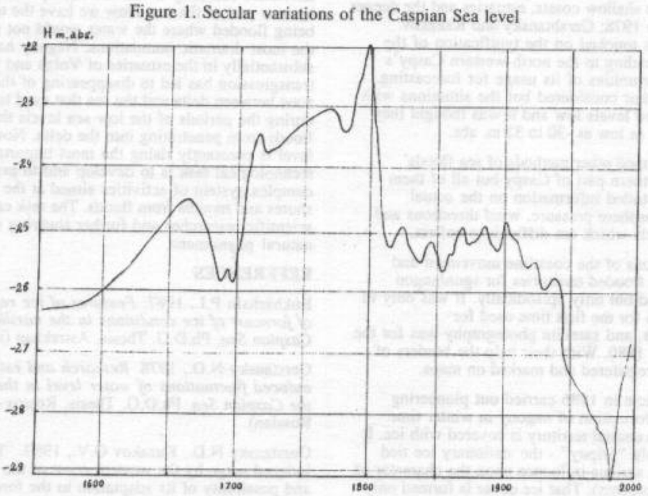

Figure 2. Hydrosynoptical conditions of flooding in the north-westerly part of the Caspian Sea on November 10-13, 1952.