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Genesis and morphology of sand spits of the Eastern Gulf of Finland and their development under natural and anthropogenic impact

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Traditionally the coastal zone of the easternmost (Russian) part of the Gulf of Finland has not been considered as an area of active litho- and morphodynamics, but recent study has shown that within some coastal segments coastal processes can be rather active due to complex of geological, geomorphic, hydrometeorological and technogenic. One of the most interesting places from litho-dynamic point of view is located in the southern coastal zone to east of St.Petersburg Flood Protective Facility. Both natural (waves, currents, coast and near-shore erosion, longshore sand drift) and anthropogenic (submarine sand exploration, recreation, hydrotechnical construction) factors play an important role in coastal processes.

The areas of very active erosion of sandy beaches adjoin here with segments of modern sand spit development. Sand cusps and hooked spits of study area are among the most remarkable morphologic coastal forms of the Eastern Gulf of Finland. Sand cusps of some hundreds meters long and some tens of meters wide represents so called longshore sand waves. The cusps move eastward along the shoreline in the vicinity of Bolshaya Izhora village. Sand cusp moving causes the alteration of erosion and accretion phases of coastal development along the shoreline. The process is accompanied by growing and degradation of sand spits.

In the western part of the area - along the latitudal coastal segment - low cliffs (up to 5-7 m) are forming as a result of intense erosion. The rate of shoreline retreat here is up to 0.6 m/year. For the first time the acceleration of erosion processes was reported in late 1980-s, after 15 years of submarine sand exploration within so called London Shallow, which is located to the west of study area. As a result of submarine sand exploration the sediment flow drastically decreased. In 1990-s sand exploration stopped, but recently it has started again.

In front of Bolshaya Izhora village coastal dynamics is much more complicated.

The bottom surface of near-shore bottom is covered by fine – to medium-grained size sands. Surface sediments of the near-shore zone are represented by sands. Longshore sediment flow of eastern direction is not only observed according to morphology of the shoreline but also was calculated according to grain-size parameters changing.

The most interesting zone from the lithodynamic point of view is located between the changing of shoreline direction from lattittudal to south-eastern and the mouth of Tchernaya River, where during last 20 years the shoreline gained complicated wave-like shape.

An important feature of observed sand cusps is an increasing of its size (length and amplitude) in the eastern direction. The first (western) cusp juts out into the land for 15 m, it is followed by strait shoreline segment of 100 m long. The second cusp is am amplitude 30 m and length 250 m; for the third and forth (eastern) cusps these parameters are 70 m and 400 m and 100 m and 900 m appropriately. Described morphological elements correspond to the alteration of different lithodnamic zones – transit (strait coastal segments), accretion (jutting out seaward at the distal parts of cusps) and erosion (concave parts of the shoreline, adjacent to accretion areas from the east).

Yearly shoreline GPS-surveys have shown that the western cusp moved eastward to 33 m since 2007 to 2009, the nest cusp migrated to 26 m during the same period of time. Retrospective analysis of remote sensing data during 15 years (since 1989 to 2004) gives appropriate shifts of 315 m and 200 m. It means that the average annual shift of cusps were 20 m/year and 13 m/year correspondingly.

In order to explain the nature of the longshore sand waves, observed in the vicinity of Bolshaya Izhora village, we assume that they have originated from the small initial perturbation, which has been increasing with the time. Conditions determining such a development can be found from the well known equation of the coastline evolution (Pelnard-Considere, 1956; Leont'yev, 2005)

Obtained result means that the shoreline perturbation will decay if the angles of wave incidence are small, and vice versa, it will grow with the time if the angles are large. Hereby, the longshore sand waves can develop if the resulting energy flux deviates from the shore normal on the large enough angle exceeding 45. Such situation can

be observed under conditions of winds blowing predominantly along the coast.
Within the area around Bolshaya Izhora village the western and south-western winds are most frequent. Besides in the eastern segment of study area the shoreline turns south. As a result the waves come to the coast under a very large angle, while the big amount of sand on the near-shore bottom provides a source of material for the development and growing of the shoreline structures. In conclusion, let us pay attention on the fact that the shorter the perturbation length [U+F06C] (higher k value), the faster the growth of shoreline disturbance. The reason is that sediment flux gradient along the shorter structure is higher. However sediment flux possesses inertia and must have some time to react to changes in the shoreline contour. So the length of appearing disturbances should not be too small. The optimal size of the structure probably is a result of equilibrium of many factors, which control the regional coastal zone dynamics.
Studied features of coastal development are very important as the coastal zone adjacent to Bolshaya Izhora village is planning to be the place of construction of a large recreation complex with several artificial islands and high level of anthropogenic impact.