PECULIARITIES OF COASTAL EVOLUTION IN THE WESTERN AND EASTERN RUSSIAN ARCTIC

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Future changes in coastal dynamics both in the western and eastern parts of the Russian Arctic will be determined by global climate warming. Mean air temperature is expected to increase over the world by 1-2^{0}C after 100 years, however in the Arctic this increase could reach 4-8^{0}C. Positive temperature anomalies of up to 2^{0}C relatively to the period 1966-1995 are already registered at present time in high-latitude regions.

One of the serious consequences of changes in climate is the rise of the mean sea level. This leads to the shift of the wave erosion base to higher horizons and entails the general displacement of the shoreline toward the land.

Other important features of changes in coastal dynamics over the XXI century will be the decrease in the sea-ice cover and the increase in the duration of the ice-free season in the Arctic Seas. As a result the wind fetches and the depths to which the wind waves are developed will increase. This in turn stimulates the growth of both the dimensions of stormy waves and the total duration of wave impact on the coasts over the year.

Finally, global warming will trigger the intense thawing of permafrost, which consolidates the fine friable deposits forming the abrasion cliffs. Due to the increase in the activity of thermal abrasion and erosion the flux of solid material into the coastal zone will also noticeably increase.

Mathematical modeling of the evolution of Arctic coasts over the period of the nearest century (Leont'yev, 2003, 2004) shows that global changes can lead to distinct (sometimes opposite) consequences for the coasts situated in different Arctic regions. On the whole one can distinguish between the response of the morphodynamic systems located in the Western and Eastern parts of Russian Arctic.

Western region. The edge of the drifting ice in the Barents Sea is observed during the last decades at a relatively large distance from the continent in summer. It presumably does not form an obstacle in the way of generation of wind waves affecting the coasts. Hence, any visible increase in wave parameters is not expected here in the future. This means that the morphodynamic evolution can hardly change significantly in qualitative sense. In particular, if the abrasion cliff is high enough as compared with expected sea level rise (about 0.5 m to the end of century, Church et al., 2001), the principal features of the coastal profile geometry existing at present time will be kept.

Coastal recession in the Barents Sea can slightly accelerate mainly due to the growth of the total duration of storm events over the year and (to a smaller extent) the rise of sea level. Changes will be most pronounced on low coasts (where the washover during the storm may produce breaches of coastal barriers) and on coasts exposed to technological impact. In particular, in the Varandey site (Pechora Sea) the rate of coastal recession (2.5 m/year at present) is expected to exceed 3 m/year by the end of this century, what is partly due to aeolian deflation caused by numerous destructions of the vegetative cover.

The total annual flux of terrigenic material into the Barents Sea is estimated at present as 50 million tons, but according to Pavlidis et al. (2005) it can achieve 70-75 million tons at the end of XXI century (the main reason is the increasing thawing of glaciers covering the islands of Novaya Zemlya).

In the Kara Sea a warming-up of the water is expected due to the increasing inflow of Atlantic water masses into the Kara Basin. The point is that the strait between Novaya Zemlya and

Franz Josef Land will be free of ice during a longer period. At present this period is about 2.5-3 months, but at the end of the XXI century it can exceed 4 months. Warming of water will reinforce the thermal abrasion of coasts in western Yamal. Here the rate of recession is on average 1.5-2.0 m/year at present. However in the second half of the XXI century the frozen cliffs with an ice content of more than 30 % will retreat with rates of 3-4 m/year (Pavlidis et al., 2005).

At the same time the dynamics of sedimentary coasts in Baydaratskaya Bay will presumably not change significantly, and recession rates will remain at 0.5-1.5 m/year. This is due to the orientation of the coasts relative to the directions of dominant winds and storms. The coasts inside the bay are mainly influenced not by onshore but by oblique winds blowing along the NW-SE axis of the bay. Here losses of sediments due to offshore transport down the slope are not as large as, for instance, in Varandey (Leont'yev, 2003).

Eastern region. A remarkable feature of the Laptev and East Siberian Seas is the exceptional shallowness of the continental shelf. This condition is favorable for the development of storm surges, which quite often attain the height of 2 m. The associated water level gradients induce a seaward flow near the bottom, which balances the onshore mass flux created by wind shear stress at the free surface. Such a return current or outflow is a very important mechanism of seaward sediment transport contributing to coastal erosion.

Another principal feature of the coasts in the region of interest is the wide spread occurrence of thermal-abrasion cliffs composed of fine sediments with rather high ice-content. It might be expected that climate warming accompanied by thawing of ice could lead to very high rates of coastal recession. However, it should be taken into consideration that the thermal component of thermal abrasion only provides the material to be carried away by the hydrodynamic mechanisms (waves and currents). The latter can transport sediments only up to a certain limit. Hence, whatever the potential of thermal abrasion determined by the thermal impact, the volume of lost material would be controlled mostly by the potential of storm activity, as in the case of pure abrasion.

At present time very severe ice conditions visibly restrict the wave activity in the Laptev and East Siberian Seas. During the summer season the width of the ice-free water band at the coasts does not exceed 70 km in average. At the end of the current century the wind fetch is assumed to increase up to 200 km. As estimations indicate, this would entail an increase in deep-water wave heights by 1.5-1.7 times (Leont'yev, 2004). However, waves approaching the coast decay over the shallow and gentle bed slope and become more uniform in height. Hence despite of appreciable growth of the open-sea storm parameters the wave heights closer to the shore would not change markedly. So the hydrodynamic component of thermal-abrasion would not be enhanced very remarkably.

These peculiarities determine a non-linear dependence between the thermal-abrasion potential and the actual coastal recession, which will increase more slowly. Nevertheless the modeling performed for series of typical coasts in the Laptev and East Siberian Seas shows that the recession rates may increase by 1.4-1.5 times at the end of the XXI century (Leont'yev, 2004). The models also leads to the conclusion that the rate of thermal abrasion is in inverse proportionality to the square root of the effective cliff height (which might be after thawing of ice).

According to Pavlidis et al. (2005) the total sediment flux into the Laptev Sea due to thermal abrasion can be estimated as 18 million tons per year at the end of the century. Presumably, a sediment mass of the same order of magnitude will be delivered into the East Siberian Sea.

At cape Billings and in eastern regions located in the Chukchi Sea lagoon-type coasts are widespread. A common feature of those lagoon systems is a coastal bar separating the lagoon from the sea which is composed of coarse sand, gravel or pebble. At present time ice conditions limit the wave impact on the coast considerably. The continental shelf at these coasts is not as shallow as in the eastern regions considered earlier, and so a future widening of the ice-free water area would lead to a noticeable increase in wave heights both in the open sea and in near-shore zone.

The model shows, that the coastal evolution in this case would be accompanied by a significant reshaping of the coastal profile. This process would lead to the development of berm, which could form a natural structure protecting the coast from further erosion (Leont'yev, 2004). A similar behavior has been observed in certain circumstances as a result of sea-level rise (Cowell et al., 1995, Forbes et al., 1995). In the present case, however the sea-level changes are of secondary importance and the appearance of berm is mainly due to the increase in storm parameters.

Thus it may be concluded that changes in the coastal evolution caused by global environmental changes can be expected to be more various and dramatic in the Eastern Arctic. Coastal dynamics in the Western Arctic will show a more conservative behavior in the future.

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