Storm surges as a forcing factor of coastal erosion in the western and eastern Russian Arctic

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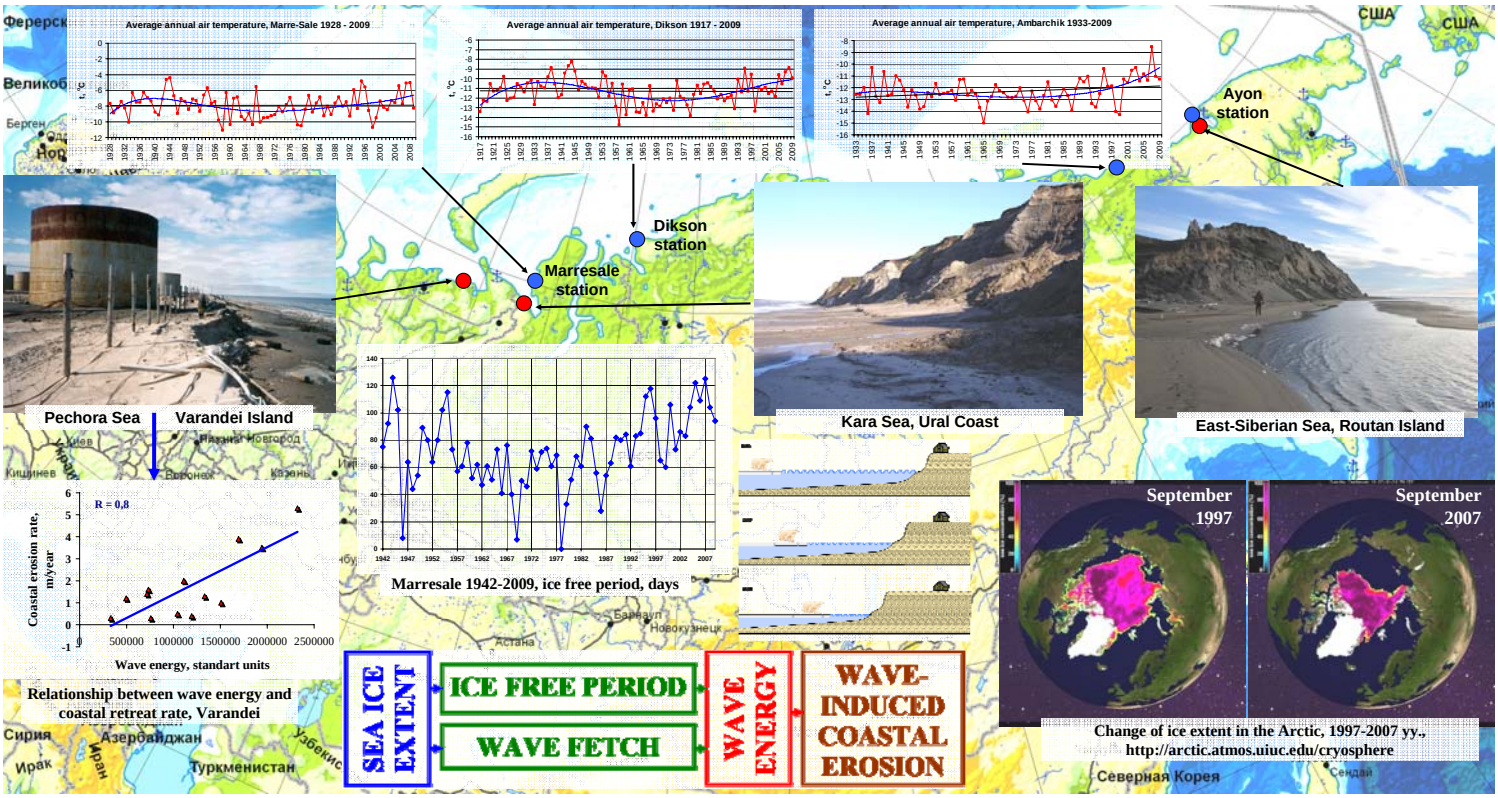


The evolution of Arctic coasts over the coming decades will be governed by changes in the natural environment caused by the effects of climate warming. Rising temperatures are altering the arctic coastline by reducing sea ice and permafrost thawing, and larger changes are projected to occur as this trend continues. This is an important topic to pursue given the direct impacts to human communities and infrastructure already being felt along Arctic coasts. About half of the Russian Arctic coast is composed of ice-rich permafrost deposits. The mean annual coastal retreat rate is 1-5 m per year, but at single sites can exceed 25 m for some years.

In general, the exact processes which affect thermal-erosion coasts and the intensity of these processes are determined by a combination of and interaction between thermal and wave-energy factors. Thermal energy is transmitted to the frozen coast via radiative and sensible heat fluxes from the air and water. Correspondingly, higher air and water temperatures, together with longer durations of ice-free seas and positive air temperatures, affect the stability of frozen coasts.

The wave-energy factor acts via the direct mechanical impact of sea waves on the shore. In arctic seas the wind-induces waves are predominate. The effectiveness of this factor is determined by storm-driven sea surge intensity as well as by the length of the stormiest period. Conversely, surge intensity substantially depends on the fetch, which is intrinsically linked to sea-ice extent.

Popov-Sovershaev wind-energetic method of calculation of wave energy

Calculation of wave energy for "deep" sea:

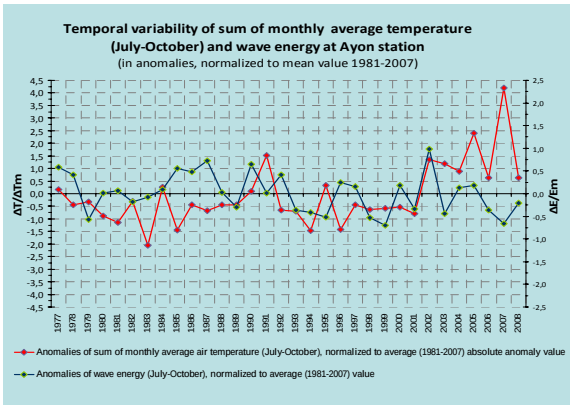
$$E_{0d} = 3 \times 10^{-6} V_{10}^{3} x$$

Calculation of wave energy for "shallow" sea:

$$E_{0s} = 2 \times 10^{-6} \left(\frac{gH}{V_{10}^{2}} \right)^{1,4} V_{10}^{5}$$

Kinematic index of shallowness $\frac{gH}{V_{10}^{2}} \leq 3$ **("water depth hampers formation of wind-induced waves")**

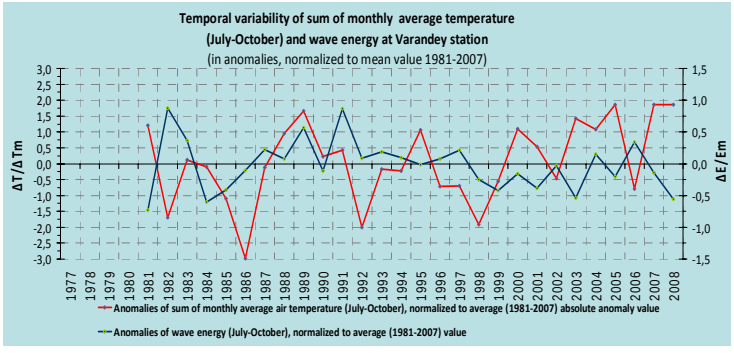
Wave fetch limit: $x_{\lim} = 3V_{10}^{2}$.

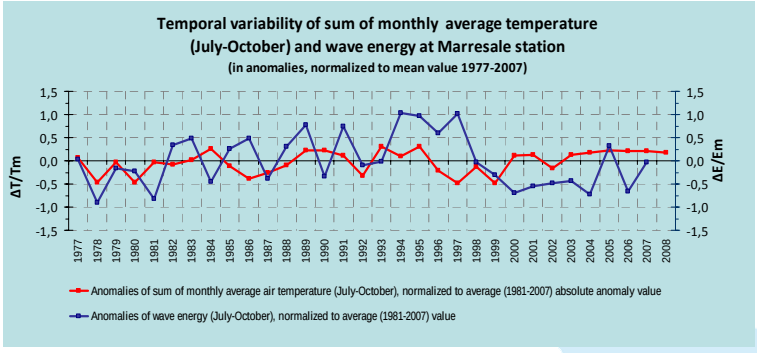


The minimum area of sea ice extent in the northern hemisphere during the last 30 years has changed from 6 to 3.5 million square kilometers. In September, 2007, sea ice area achieved its historical minimum for the period of satellite observation (since 1978). Less extensive sea ice creates more open water and longer fetches, allowing stronger wave generation by winds and increasing wave-induced erosion along arctic shores. Therefore, the acceleration of erosion and thermo-abrasion of the coast can be caused by the increase of the air and water temperatures and by the wind-wave activity increases.

Coastal dynamics have been observed at key sites in the western and eastern sectors of Russian Arctic. We have calculated annual wave energy variations for the last 30 years. Hindcast analysis has revealed that warming events have not always lead to an increase in wave energy or to acceleration of coastal erosion. For example, in the Arctic regions that we studied, in half of the cases warm periods were characterized on one hand by reduced ice cover and growth of open water area, and, on the other hand, by decreased wind-wave activity. As a result no acceleration in coastal retreat was observed. Furthermore, in the western sector of the Russian Arctic the wave fetch was limited by the presence of islands, while in the eastern one by wave acceleration limit.

Thus, expectations of catastrophic acceleration of coastal erosion in Arctic are probably exaggerated.





Ogorodov, S.A. (2002) Application of wind-energetic method of Popov-Sovershaev for investigation of coastal dynamics in the Arctic. In: Arctic Coastal Dynamic. Report of an International Workshop. Potsdam (Germany) 26-30 November 2001. Reports on Polar and Marine Research. Edited by V. Rachold et al. Bremerhaven. Vol. 413, 37-42.