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COASTAL DYNAMICS OF THE WESTERN YAMAL

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Long-term monitoring of coastal dynamics in the Western Yamal, at the Marre-Sale key site has shown a mean coastal retreat at 1.7 m/yr, with the maximum 3.3 m/yr and the minimum 0.5 m/yr. The time-dependent variations in the retreat rate show cyclic patterns. The change in beach and shoreface elevation in thermal erosion coasts reaches 0.7 m and can be either positive or negative. First quantitative estimates give 0.3 m maximum elevation change of accumulative surfaces.

INTRODUCTION

The coastal dynamics in the western Russian Arctic has been insufficiently explored. The problem is especially topical for the western Yamal coast with the initiated development of Kruzenshtern and Kharasavey gas-condensate fields and prospected construction of related structures for condensed gas processing and transport. The coastal erosion of the West Yamal was monitored in different field campaigns at capes Burunnyi, Kharasavey, and Marre-Sale, as well as within the Baidaratskaya Guba pipeline traverse [*Voskresensky and Sovershaev, 1998; Vasiliev et al., 2001*]. Note that the monitoring was mostly restricted to measuring the retreat rates of the coastal cliff edges.

STUDY AREA AND METHODS

Integrate studies of coastal dynamics around the Marre-Sale weather station are carried out since 1978 by the Institute of Earth's Cryosphere (Tyumen). The coast is composed of Late Pleistocene deposits of 15–30 m high sea terraces (II and III), with saline marine clay at base of the section and sand in the upper part. The area belongs to the zone of continuous permafrost. The mean annual temperature of frozen ground ranges from –2.5 to –6.0 °C.

The monitoring parameters at the site included meteorology and marine hydrology, dynamics of permafrost conditions, coastal retreat rate (measured yearly against fixed benchmarks and by repeated laser transit survey of cliff edge and cliff base locations), and shoreface elevation (leveled yearly along a fixed coast-orthogonal profile).

RESULTS

Climate warming in the Arctic since the 1970s is accompanied by changes in sea hydrodynamics. According to data from the Marre-Sale weather station over this period, the spring break-up of the seaice cover begins at approximately same dates, except for natural variations, while freeze-up has moved to later dates. Correspondingly, the ice-free period when the coast is exposed to hydrodynamic forcing has become longer (20 days longer on average for 1970 through 2010). Note that this increase is attributed to the fall season when the coast is strongly eroded by frequent storms.

The monitored sea-wave parameters (height, period, wavelength, and duration) show no regular increase associated with climate warming. Therefore, one may expect no steady acceleration of coastal erosion, even if warming continues and the period of active coastal dynamics becomes ever longer. See Fig. 1 for average annual coastal retreat rates measured over 4.5 km of the coast.

The coastal retreat rate at Marre-Sale changes periodically rather than increasing since the late 1970s (Fig. 1). Erosion was most rapid in 1998–1999 and 2006–2010 but slowest in 1978–1979 and 1999–2000, the average being 1.7 m/yr. The retreat rate does not experience direct climate forcing [*Vasiliev et al., 2006*]. The effect of climate is rather implicit, via local changes in synoptic conditions, in atmospheric pressure and wind (and related fetch). A close relationship between coastal erosion in the Kara Sea and the total wind-wave energy was discovered earlier

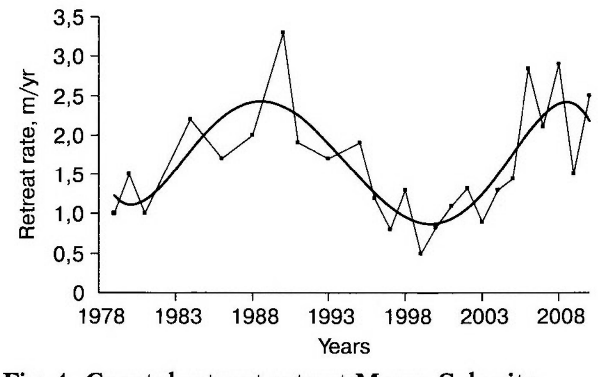

Fig. 1. Coastal retreat rate at Marre-Sale site.
Heavy line is approximation.

Table 1. **Long-term average coastal erosion rate at West Yamal**

Area	Cliff height, m	Lithology	Coastal erosion rate, m/yr			Reference
			max.	min.	av.	
Between Skuratov and Burunnyi Capes	8	Clay with sand interbeds	–	–	0.8	[*Voskresensky and Sovershaev, 1998*]
Burunnyi Cape	14	Clay	2.5	0.6	1.2	[*Vasiliev et al., 2006*]
Kharasavey Cape	10–25	Clay with sand interbeds, sand	4.5	0.4	–	[*Solomatin, 1992*]
			–	–	2,0	[*Kamalov et al., 2002*]
			3.0	0.5	1.4	[*Vasiliev et al., 2006*]
			2.3	0.51	1.3	[*Yuriev, 2009*]
Beluzhii Cape	to 40	Sand	1.0	0.5	–	[*Voskresensky and Sovershaev, 1998*]
Marre-Sale Cape	10–30	Sand over loam	–	–	1.8	[*Troitsky and Kulakov, 1976*]
			1.8	1.0	1.6	[*Shur et al., 1984*]
			3.3	0.5	1.7	[*Vasiliev et al., 2001*]
Southwestern coast of Baidaratskaya Guba Gulf	10–25	Sand over loam	0.9	0.05	0.4–0.5	[*Dubikov, 1997*]
	6–10	Sand, peat	0.7	0.3	–	

[*Vasiliev et al., 2006*] and confirmed through recent observations. Coastal retreat data from the West Yamal obtained by different authors are synthesized in Table 1.

There has been very little research of beach and shoreface elevation changes. Yearly elevation monitoring has been carried out at Marre-Sale since 2006 to a sea depth of 1.5 m by repeated leveling in early September, the heights (depths) being tied to a fixed elevation reference (Fig. 2). The datum is the waterline position at the time of measurements in 2006. The maximum beach elevation change (0.5 m) was observed in 2006–2007. In the shoreface, especially near the shore, the respective maximum was 0.6 m. Note that elevation change in the shoreface (at least close to the beach) can be either positive or negative. The sea-floor was eroded and subsided in 2006–2009, but it uplifted by aggradation in 2009–2010 after long storms.

The maximum beach elevation change as a consequence of brief post-storm events at Marre-Sale was estimated proceeding from geological conditions. Drilling stripped a 0.05–0.1 m thick pebble marker bed lying under 0.6 m thick sand and over an inclined surface of dense heavy clay with signature of erosion. Pebble layers normally form during maximum storm wave cutting and pebble deposition. Thus, the magnitude of wave-induced elevation change is measured as the total sand and pebble thickness, i.e., 0.7 m. This estimate roughly corresponds to that obtained during studies along the pipeline traverse of the Baidaratskaya Guba Gulf (0.5–0.7 m).

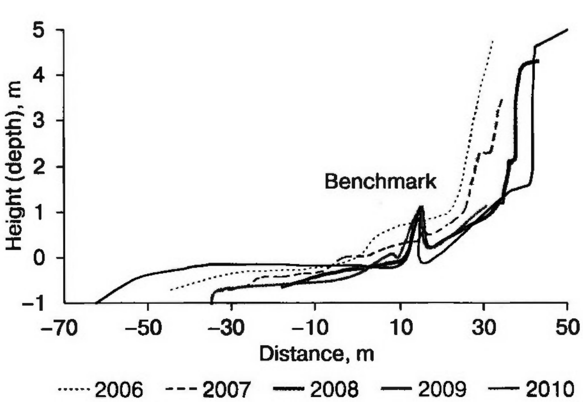

Fig. 2. Shoreface elevation change at Marre-Sale site.

The maximum sea-floor change on offshore beach was about 2 m [*Dubikov, 1997*]. These are approximate reference estimates for the whole West Yamal area.

An elevation change in low accumulative surfaces was observed at the Marre-Sale Koshki site where about 0.3 m of sand was deposited by long storms in 2010. The sand deposits have fully covered the earlier landforms and made a large sand field in place of the laida. Thus, the aggradation rate was 0.3 m/yr. This appears to be the only quantitative estimate of elevation change in marine aggradation surfaces.

CONCLUSIONS

• Long-term average coastal retreat rate has been monitored and estimated to reach 1.7 m/yr at the Marre-Sale site. The slowest rate of 0.5 m/yr was measured at the site of the Baidaratskaya Guba gas pipeline traverse.

• The maximum beach elevation change is 0.7 m; that of shoreface can be either positive or negative and is generally 0.6 m in magnitude, but can reach 2.0 m along offshore beach.

• The maximum elevation change observed in accumulative surfaces is 0.3 m.

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COASTAL EROSION AS A DESTABILIZING FACTOR OF CARBONATE BALANCE IN THE EAST SIBERIAN ARCTIC SEAS

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The carbonate balance in the Arctic seas of East Siberia is in reciprocal relationship with climate change and destructive coastal dynamics. Thermal and wave erosion of permafrost coast associated with global warming destabilizes the marine CO_2 – carbonate system by increasing dramatically the partial pressure of CO_2 in coastal waters to 800–900 ppm and facilitating its release into air. The ongoing warming and growing activity of coastal processes can reduce the ability of the eastern Arctic seas for CO_2 uptake.

INTRODUCTION

Arctic seas are important regulators of atmospheric carbon dioxide in the Northern Hemisphere. In the summer season they may be expected to act as sinks of excess CO_2, but there is evidence [*Razumov, 2003; Pipko et al., 2005*] that the surface waters are oversaturated with CO_2 which evades into the atmosphere in some areas of Arctic seas. The potential of seawater for CO_2 uptake from the atmosphere depends on the relative percentages of components in the CO_2 – carbonate system, or the carbonate balance. This balance in coastal-shelf waters is subject to the influence of climate-controlled erosion processes in the permafrost coast.

EFFECT OF COASTAL EROSION ON THE CARBONATE BALANCE OF COASTAL-SHELF WATERS IN ARCTIC SEAS

The uptake of atmospheric CO_2 by the eastern Arctic seas and increasing fluxes of organic carbon and carbonates (dissolved or solid) affect the seawater carbonate balance. In the East Siberian seas, the rapidly retreating coast with high contents of ground ice is the main source of terrigenous input to the shelf. Coastal erosion (mainly by thermal processes and waves) supplies about $4 \cdot 10^6$ tons of organic carbon into the Laptev and East Siberian seas, which is more than in all other Arctic seas [*Grigoriev et al., 2006*]. A part of carbon dioxide that is absorbed from the air and released in organic carbon oxidation is spent on dissolving calcium carbonate, whereby seawater becomes more alkalic. The water alkalinity in the East Siberian Sea did not change much from the 1920s to the early 1950s but it grew by the early 1990s (by 0.21 mg·equivalent/liter on average and by 0.25–0.40 mg·equivalent/liter in the southern sea part).

Carbon dioxide can either evade from seawater or invade into it at specific weather conditions in the ice-free season with moderate winds and calm spells. For instance, $CaCO_3$ saturation west of the Kolyma Delta is within 0.77 while the CO_2 partial pressure is from 89 to 164 ppm [*Razumov, 2003*]. This pressure being almost 2–4 times as low as the atmospheric