ArcticNet Annual Scientific Meeting 2015
7-11 December 2015, Vancouver, BC

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Quantifying organic carbon and sediment fluxes to the Arctic Ocean during the Holocene: the contribution of coastal erosion

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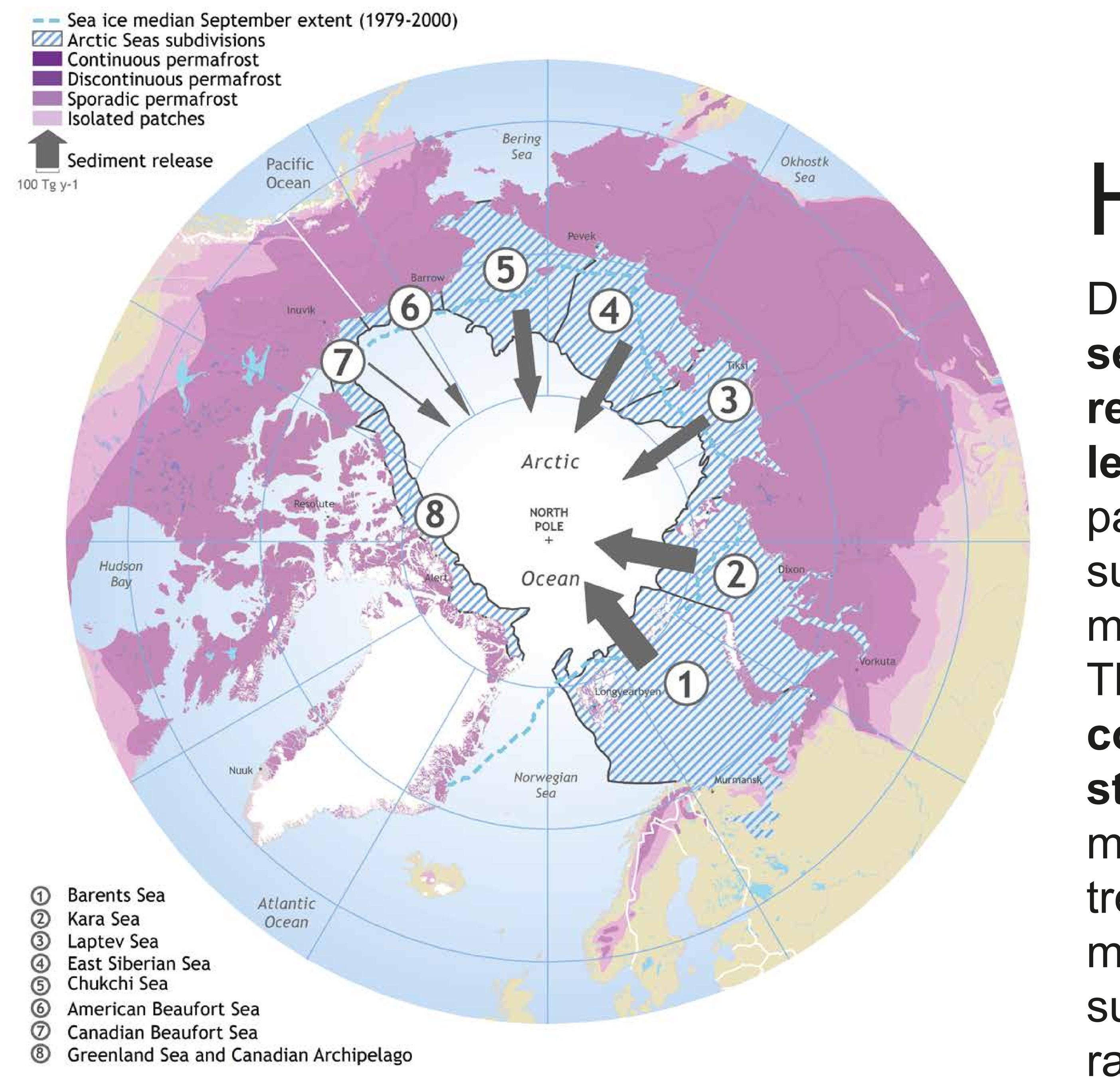
Coastal erosion delivers sediment, particulate and dissolved organic matter and nutrients to the nearshore zone (photo taken by M. Krautblatter on Herschel Island, Canada).

Background

Arctic coasts are permafrost coasts. With **erosion rates as high as 25 m·yr^{-1}**, the release of organic carbon and nutrients from permafrost coasts has dramatic impacts on the **global carbon cycle**, on nearshore food webs and on local communities which are still relying on the marine biological resources. However, the **fate of the terrestrial material,** the contribution to greenhouse gas emissions and ocean acidification, **and the impact on nearshore ecosystems is poorly constrained**.

Permafrost distribution in the Northern Hemisphere. 24% of the land mass is in the permafrost zone (pink). Source: IPA



Modern sediment release (Tg yr^{-1}) from coastal erosion into the Arctic Ocean divided by marginal sea areas.

Modern situation

Recent flux estimates of sediment and particulate organic carbon (POC) from coastal erosion into the Arctic Ocean are **~430 Tg** (10^{12} gram) **sediment per year and 4.9-14 Tg POC per year.** This is comparable to if not higher than riverine fluxes. However, it is important to note that the fate of sediment and organic carbon once eroded from the cliff remains largely unknown and the **release of dissolved organic carbon (DOC)** from melting ground ice in permafrost **has not been estimated yet**.

Material supply from coastal erosion in the past is difficult to quantify as it depends on erosion of a coastline whose original configuration is not known and on a variety of mechanisms difficult to assess in the geological past (e.g. isostatic adjustment).

Holocene

During the Holocene, the **delivery of sediment, POC and DOC varied in response to climate and relative sea level changes**. For example, large parts of the circum-arctic shelves were subaerially exposed in the last glacial maximum and became flooded rapidly. Thus, **early Holocene erosion of coastal permafrost deposits was stronger than today** and released more terrestrial material. With the retreat of the coastline, the depocenters moved further southward and thereby successively reduced accumulation rates in the distal shelf areas.

In some parts of the Arctic, glacioisostatic rebound was significant so that global transgression was outpaced and therefore led to reduced shore line retreat. In the **middle Holocene**, **sediment fluxes were more variable** than today due to rising sea level and spatio-temporally variable flooding of bathymetric features and coastline adjustments.

Quantitative estimates of erosion rates along Arctic coasts throughout the Holocene are still sparse and need substantial improvement to clarify the fate of terrigenous material in the Arctic Ocean.

Table: Modern sediment and organic carbon contribution from coastal erosion into the Arctic Ocean per year. Length of coastline, erosion rate, and OC content are from Lantuit et al. (2012).

Sea sector	Length of coastline [km]	Weighted mean coastal erosion rate [m y^{-1}]	**Modern sediment release [Tg y^{-1}]**	Weighted mean organic carbon content [weight %]	**Modern organic carbon release [Tg y^{-1}]**	Reference
Chukchi Sea	7,398	0.41	70	2.79	0.80	Rachold et al. (2004)
American Beaufort Sea	3,376	1.15	2.1-3.3	5.70	0.15-0.18	Jorgenson and Brown (2005), Ping et al. (2011)
Canadian Beaufort Sea	5,672	1.12	5.6	2.43	0.06-0.19	Hill, 1991, Couture, 2010
Barents Sea and White Sea	17,965	0.42	119	0.92	0.80	Rachold et al. (2004)
Kara Sea	25,959	0.68	109	1.51	0.35-1.0	Rachold et al. (2004), Vasiliev et al. (2005), Streletskaya et al. (2009)
Laptev Sea and East Siberian Sea	16,927	0.73	58.4	1.63	0.66-3.7[a]	Rachold et al. (2004); Günther et al. (2013); Vonk et al. (2012)
East Siberian Sea	8,942	0.87	66.5	1.64	2.2-7.3[a]	Rachold et al. (2004),Vonk et al. (2012)
Total	**86,239[b]**	**0.68**	**430.6-431.8**	**2.05**	**4.9-14.0**	

[a] Vonk et al. (2012) report for the Laptev and East Siberian Sea together. We have corrected their organic carbon flux to the marine system (22 Tg y^{-1}) for the estimated input of organic carbon from subsea erosion (11 Tg y^{-1}) and subsequently corrected for shelf area (East Siberian Sea 987,000 km^2, Laptev Sea 500,000 km^2) in order to obtain a value of 3.7 Tg y^{-1} for the Laptev Sea, and 7.3 Tg y^{-1} for the East Siberian Sea. [b] From the total classified coast length of 101,447 km in Lantuit et al. (2012) the here missing 15,208 km account for bedrock coasts (i.e. without erosion) of northern Greenland, Svalbard, and the northern fringe of the Canadian Arctic Archipelago directly facing the Arctic Ocean.

References

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