ELSEVIER

Marine Geology 220 (2005) 83–100

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

A contemporary sediment and organic carbon budget for the Kara Sea shelf (Siberia)

A.C. Gebhardt [a,*], B. Gaye-Haake [b], D. Unger [c], N. Lahajnar [b], V. Ittekkot [c]

[a] *Alfred Wegener Institute for Polar and Marine Research, Columbusstraße, 27515 Bremerhaven, Germany*
[b] *Institute for Biogeochemistry and Marine Chemistry, University of Hamburg, Bundesstraße 55, 20146 Hamburg, Germany*
[c] *Centre for Marine Tropical Ecology, Fahrenheitstraße 6, 28359 Bremen, Germany*

Received 9 December 2003; received in revised form 16 June 2005; accepted 24 June 2005

Abstract

It has recently been realized that the Arctic undergoes drastic changes, probably resulting from global change induced processes. This acts on the cycling of matter and on biogenic elements in the Arctic Ocean having feedback mechanisms with the global climate, for example by interacting with atmospheric trace gas concentration. A contemporary budget for biogenic elements as well as suspended matter for the Arctic Ocean as a baseline for comparison with effects of further global change is, thus, needed. Available budgets are based on the late Holocene sedimentary record and are therefore quiet different from the present which has already been affected by the intense anthropogenic activity of the last centuries.

We calculated a contemporary suspended matter and organic carbon budget for the Kara Sea utilizing the numerous available data from the recent literature as well as our own data from Russian-German SIRRO (Siberian River Run-off) expeditions. For calculation of the budgets we used a multi-box model to simplify the Kara Sea shelf and estuary system: input was assumed to comprise riverine and eolian input as well as coastal erosion, output was assumed to consist of sedimentation and export to the Arctic Ocean. Exchange with the adjacent seas was considered in our budget, and primary production as well as recycling of organic material was taken into account. According to our calculations, about 18.5×10^6 t yr^{-1} of sediments and 0.37×10^6 t yr^{-1} of organic carbon are buried in the estuaries, whereas 20.9×10^6 t yr^{-1} sediment and 0.31×10^6 t yr^{-1} organic carbon are buried on the shelf. Most sources and sinks of our organic carbon budget of the Kara Sea are in the same order of magnitude, making it a region very sensitive to further changes.

Keywords: POC; DOC; TSM; sediment budget; carbon budget; carbon cycle; Arctic Ocean; Kara Sea

1. Introduction

Since the Industrial Revolution, large amounts of carbon dioxide have been released into the atmosphere by the burning of fossil fuels and by massive

* Corresponding author. Tel.: +49 471 4831 1946.
E-mail address: cgebhardt@awi-bremerhaven.de (A.C. Gebhardt).

0025-3227/$ - see front matter
doi:10.1016/j.margeo.2005.06.035

changes in land use (7.7×10^6 t yr^{-1}, Mackenzie, 1998), intensifying the natural greenhouse effect and leading to global warming (Albritton and Meira Filho, 2001). The Arctic Ocean is a region susceptible to global change. Variations in ice formation may be directly related to increase of summer melt rather than to changes in wind direction and circulation (Laxon et al., 2003). The Arctic basin receives large amounts of freshwater from the rivers draining Northern Eurasia and North America, of which the Yenisei, Lena, Ob, Mackenzie, Yukon and Pechora rivers are the major ones (Holmes et al., 2002; Meade, 1996; Milliman and Meade, 1983). Ice formation and freshwater supply interact and influence physical properties such as radiation and heat budget. At the same time, their variations induce changes in the cycling of biogenic elements which, in turn, influence atmospheric trace gas concentrations. There are indications that recent anthropogenic activity has already had an impact on water discharge and, thus, on the carbon budget of the Arctic. Dam building in the 1950s and 1960s has, probably, reduced water discharge and changed its seasonality (Bobrovitskaya et al., 1997, 2003). The overall trend summarizing all available Arctic discharge data may, however, be an increase due to melting of permafrost soils (Peterson et al., 2002). Budgets are required as basic studies to estimate the impact of future changes because such changes strongly affect element cycling on the shelves and may change their role in the global cycles (Holmes et al., 2000).

In this study we summarize the available literature data in combination with our measurements in the Kara Sea in order to obtain a contemporary particulate carbon budget for the Kara Sea.

The role of continental shelves in the marine carbon cycle is still not well known and the subject of extensive discussions. Modern shelves make up <8% of the total ocean surface area, but account for about 10% to 33% of the global primary production (Wollast, 1991). Many studies on the role of shelves in the global carbon cycle have been carried out during the last decades, (e.g. Bender et al., 1989; Canfield et al., 1993a,b; De Haas et al., 2002; Frankignoulle and Borges, 2001; Milliman, 1991; Smith and Hollibaugh, 1993; Wollast, 1998), but results vary widely due to the different settings of the shelves. Berner (1982, 1989) pointed out that about 83% of the organic matter buried in marine sediments are buried in deltaic-shelf environments. Eisma et al. (1985) found that only 7% to 10% of the riverine sediment reaches the deep sea. Most of the river-delivered sediment is trapped on the inner shelves according to Milliman (1991). Wollast (1991) calculated total sedimentation in the pelagic, semipelagic and shelf provinces, pointing out that more sediment accumulates on the shelf than in the other realms. De Haas et al. (2002), in contrast, suggest that >95% of the primary production is recycled and remineralized in the water column and in the upper few centimetres of the sediment on the shelves. They further show that most of the accumulated organic matter is resuspended, transported over the shelf edge and laid down in canyons and on the shelf slope, from where it is eventually transported to the pelagic realm and buried in deep sea fans. They conclude that most of the present day shelf areas do not play an important role in the burial of organic matter. Smith and Hollibaugh (1993) postulate that in the coastal zones respiration exceeds primary production by 1.4%, a point which is confirmed by measurements of terrestrial, rather refractory, riverine particulate and dissolved organic matter mineralized on coastal shelves. Only locally, in areas of upwelling or bottom anoxia, are relatively large amounts of organic carbon being stored (e.g. shelves off Somalia, Yemen and Oman, see De Haas et al., 2002 and references therein).

The Arctic Ocean accounts for only 1.5% of the global ocean (Aagaard, 1994), but contains about 20% (i.e. 5×10^6 km^2) of the world's continental shelves (Macdonald et al., 1998). This means that nearly 30% of the Arctic Ocean's area is floored by continental shelves, compared to <8% in the global ocean (Wollast, 1991). With these large continental shelves (Fig. 1), the Arctic Ocean plays an important role in the global organic carbon cycle.

Shelves and continental margins, as the interface between land and open ocean, are the most important areas within the ocean in terms of the throughput of terrestrial material (e.g. Milliman, 1991; Romankevich, 1994; Smith and Hollibaugh, 1993) and primary production (e.g. Wollast, 1991). The Arctic shelves are not as well understood as other shelf areas due to sparse data. Only during recent decades have the Arctic shelves been paid more attention to, mostly due to a general interest in Arctic contaminant transport.