

Siberian Shelf Sediments Contain Clues to Paleoclimate Forcing

The Earth's heat budget is the result of a complex interaction that depends on the atmosphere, the oceans, and how this heat is exchanged geographically. Most people today are somewhat aware of a number of problems that may arise from global warming. However, to what extent these changes will occur remains a major issue in climate prediction. Obviously, one of the imminent features of the global climate system is the natural, steep temperature gradient that exists between the cold polar regions—where the Earth is most easily able to release heat—and the much warmer, lower latitudes. If one follows the more recent litera-

ture, there seems to be little doubt that future temperature increase will first be detected in the Arctic [Dickson, 1999], due to the various temperature-related processes that occur there [Johannessen et al., 1995; Grotelund et al., 1998].

The Arctic is a unique environment, providing insight into various processes that are key to understanding more than just the regional climate. Through its influence on both the atmospheric heat balance and subpolar oceanic circulation, the Arctic is indeed of global importance in today's climate system. The extreme temperature gradients between ice-covered continents and seas in the north and the inflow-

ing saline and relatively warm Atlantic surface waters of the south (Nordic Heat Pump) promote the formation of dense, deep waters in the Norwegian, Greenland, and Iceland Seas (Nordic Seas). These waters then flow southward back into the deep North Atlantic as an integral part of the world-spanning "Global Ocean Conveyor Belt" (Figure 1). The "effectiveness" of this Nordic Heat Pump, that is, how much of this northwardly advected surface water is being transferred into the deep, depends on surface conditions in the Nordic Seas.

It is now widely accepted that change in surface water salinity is the major driving force that can perturb our present climate. An example for such a situation may be the onset of the most recent cold phase, the "Little Ice Age," the period from 1400 AD to 1850 AD that ended the "Medieval Warm Period" (commencing ~900 AD). Historical data indicate

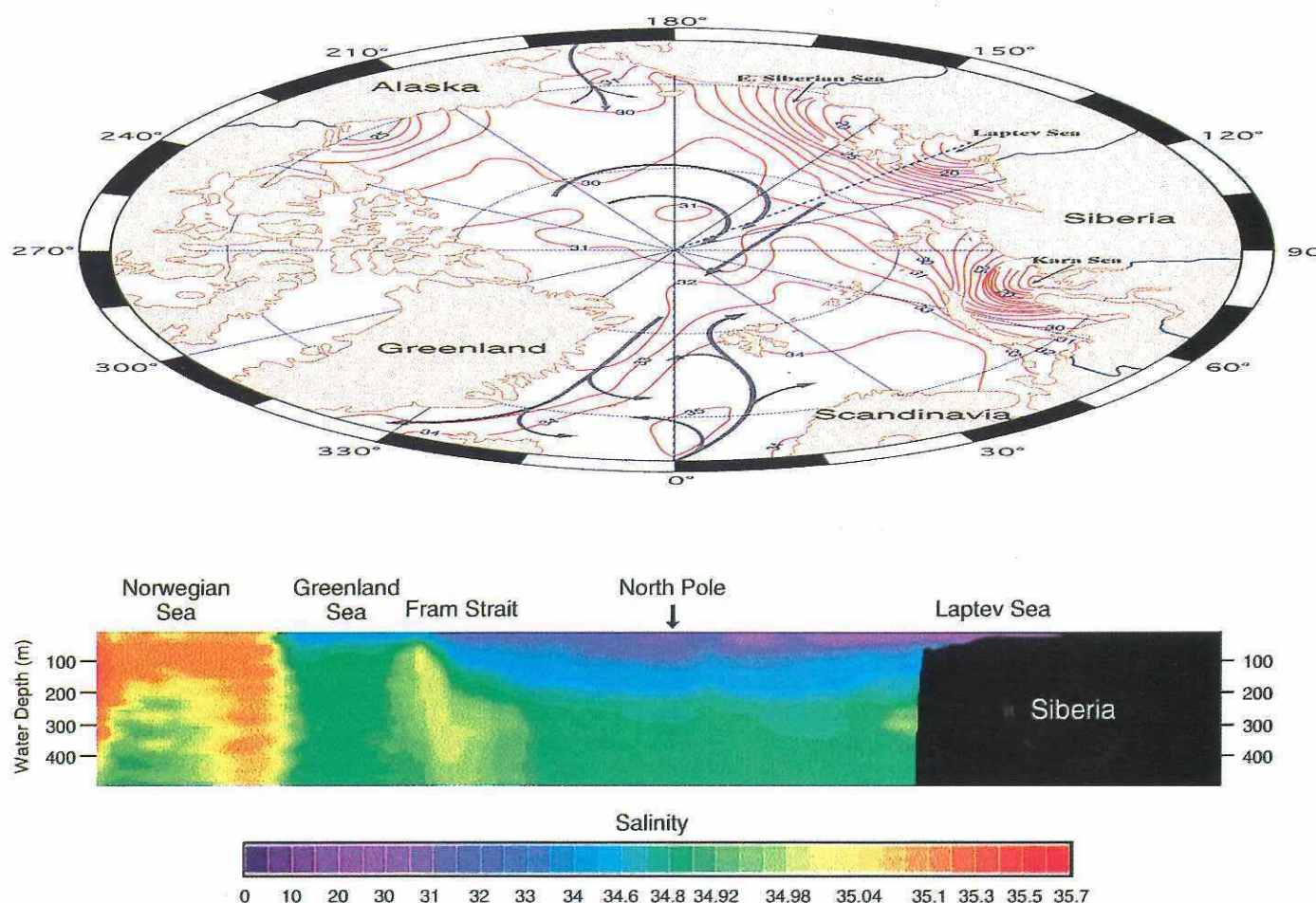
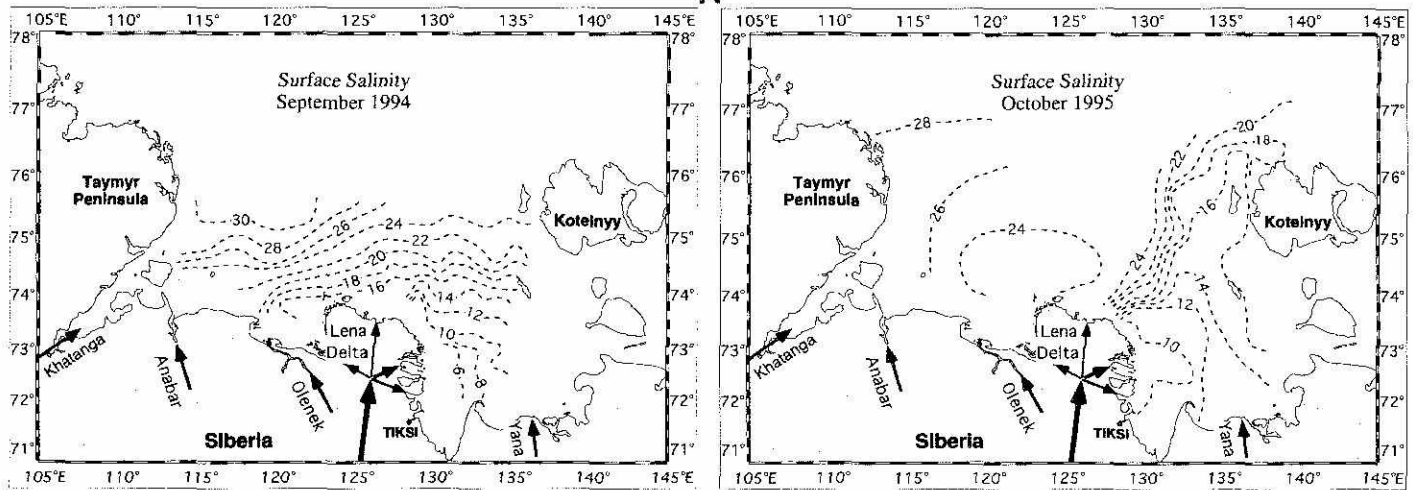


Fig. 1. Surface ocean circulation and average summer surface water salinities (60 s to 80 s) in the Arctic Ocean, its shelf seas, and in the adjacent Nordic Seas. The cross-section below shows the structure of the upper 500 m (drawn along the stippled line), revealing the characteristic low-saline halocline; data from EWG [1998].

A



B

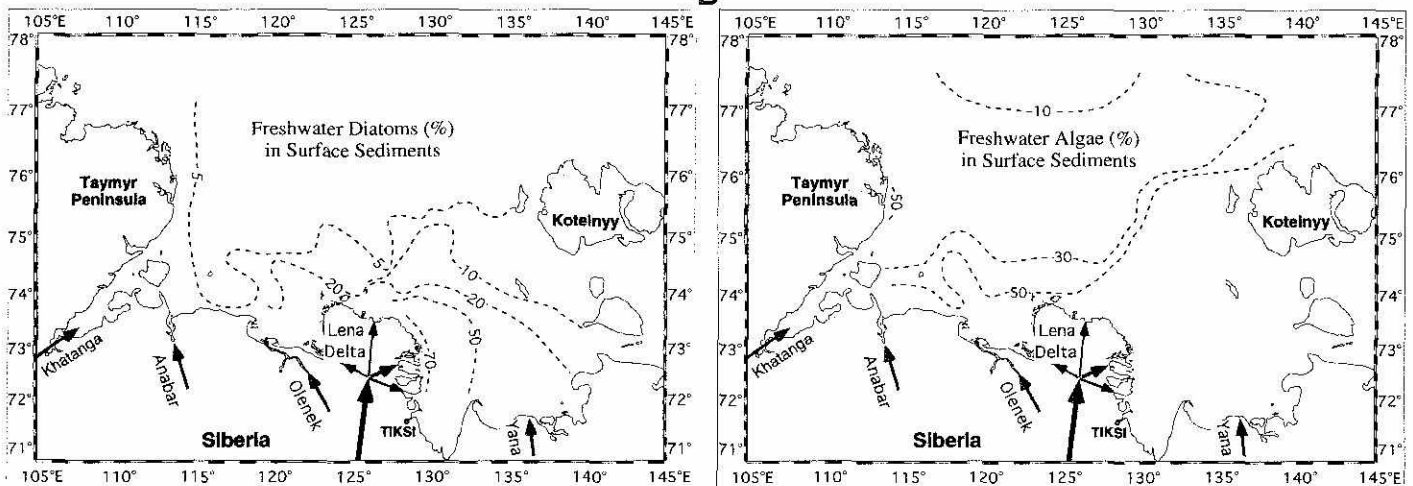


Fig. 2. a) Surface salinity of the Laptev Sea for late summer 1994 and early fall 1995 (from Dmitrenko et al. [1999]). The two different patterns recognized are a consequence of the interannual variations in river runoff, indicating that in 1994 the northeasterly spread of riverine freshwater on the eastern Laptev Sea shelf was comparatively reduced. b) The distribution of freshwater-indicating aquatic microfossils (diatoms and organic-walled palynomorphs) in surface sediments naturally reflects the average of many years. Therefore, their pattern closely resembles the average salinity depicted in Figure 1. Because of this good resemblance between the two different parameters, downcore microfossil investigations will provide the opportunity to thoroughly investigate also longer-term, past changes in Siberian river runoff to the Arctic Ocean.

that during the early part of the Little Ice Age, Viking settlements that flourished on Greenland in the Medieval Warm Period were abandoned, the climate in northwestern Europe deteriorated, and the sea-ice margin in the Nordic Seas moved much further eastward than it is at present [Lamb, 1979]. Looking at the modern water mass relationship between the Arctic Ocean and the Nordic Seas (Figure 1), it seems evident that the freshwater budget of the Arctic Ocean may upset the efficiency of the Nordic Heat Pump, and thus probably is responsible for worsening conditions of Nordic life during the most recent cold phase.

Oceanographic studies on tracer chemistry in the Arctic Ocean have shown that a considerable part of the riverine freshwater is contained in the Arctic halocline and the overlying sea-ice cover [Bauch et al., 1995] and is delivered mainly by the large Siberian rivers (e.g., the Ob, Yenisey, and Lena)

[Aagaard and Carmack, 1989]. A substantial part of Arctic sea ice is produced on the large and broad Siberian shelves, such as the Laptev Sea. The sea ice then drifts across the eastern Arctic Ocean with the riverine freshwater toward Fram Strait within a few years. In this respect, the Laptev Sea is of particular interest for studying past changes in freshwater input to the Arctic because it has open access to the eastern Arctic Ocean unlike, for instance, the rather enclosed Kara Sea. Thus, from the paleoclimatological point of view, an issue that deserves further study is the critical temporal variability of those environmental factors in the Laptev Sea that exert the most influence on the surface salinity of the Arctic Ocean and the adjacent Nordic Seas.

Due to intensive investigations carried out in the Laptev Sea during the past 6 years, this region is now probably the most comprehensively studied shelf in the Arctic [Kassens et al., 1999]. Salinity on this shelf is strongly influ-

enced by the large amounts of riverine runoff discharged during early summer, the largest proportion of which stems from the Lena River. On average, this discharge affects mainly the eastern shelf (Figure 1). However, on a shorter timescale basis, substantial interannual variability is recognized in the surface salinity (Figure 2a). Thus, changeable river runoff may also strongly affect the various Arctic processes such as sea-ice budget, surface ocean conditions, and circulation. In this scenario, climate on longer timescales would also be affected.

Micropaleontological tools can help to recognize past changes in surface ocean properties in the Arctic. For a region such as the Laptev Sea, fossil groups that on the basis of their ecology can be used as either freshwater and/or marine indicators are especially worthy of study. Diatoms (siliceous algae) and dinoflagellate cysts/green algae (organic-walled aquatic palynomorphs) are two groups with

such paleoenvironmental potential. As is evident from their distribution in surface sediments of the Laptev Sea (Figure 2b), both freshwater groups reflect quite well the general pattern as given by the surface salinities (Figures 1, 2a). The palynomorphs are particularly promising in this respect as they have a very good chance of remaining preserved in these dominantly organic-rich sediments.

Using these micropaleontological methods downcore will most likely open up new perspectives on the interpretation of past climate variability in the Arctic region and beyond on different timescales. The sediment material recovered to date from the Laptev Sea spans only the present warm phase, which allows one to investigate the time interval of the past 10,000 years [Bauch *et al.*, 1999]. However, it is within the imminent interest of the paleoclimatic community also to better understand the causes that eventually changed the Arctic from warmer conditions in the earlier Cenozoic to the well-known stepwise intensification in glacial conditions during the last 3 million years [Driscoll and Haug, 1998]. Drilling for longer sediment cores in crucial areas such as the Laptev Sea shelf is thus a necessary prerequisite. There is no doubt that once this task is fulfilled microfossils will be among the important tools for understanding the stratigraphic framework and reconstructing past environmental conditions in the high Arctic.

Acknowledgments

The paleoenvironmental studies in the Laptev Sea are part of the project "Laptev Sea System" funded by the German and Russian ministries of science and technology. The authors are grateful to all participants who helped collect data during various expeditions to the Laptev Sea and, in particular, to the cruise chiefs, I. Dmitrenko, H. Kassens, and L. Timokhov.

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