Relative transparency of sea water in the Green-fjord Bay (Spitsbergen)

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Abstract

The results of the analysis of spatial-time variability of relative transparency (depth of disappearance of a standard white Sechi disk) in the Green-fjord Bay (Spitsbergen archipelago) are presented. The data covers the period from 1986 to 1990 and were obtained during carrying- out of the oceanographic monitoring by experts of Barentsburg research station (Murmansk HydroMeteorogical Management) in frame of the program of standard coastal supervision. Some conclusions about the reasons of spatial and time variability of relative transparency depending from change of external conditions are presented.

Key words: Spitsbergen, Sechi disk depth, spatial and time structure of relative transparency

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Introduction

The water masses of the fjords of West-Spitsbergen island (Svalbard) are the product of a complex interaction of warm and salt Atlantic waters (AW) and the waters of local origin, including the continental runoff (river runoff, melting glaciers and tundra snow cover tundra). River runoff and melt water from glaciers are the main sources of suspended particles in the water fjords. The river waters with low specific density are distributed in the surface layer of the fjords. At the same time there is a redistribution of suspended sediments in the depth and distance from a shore (edge of the glacier) regulated predominantly by the size and weight of the particles (Lisitsin 1994, Ivanov et al. 2007, Vlasenkov et Makshtas 2008). At the same time, desalination of the sea water surface layers and radiation heating limits the impact of

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wind. Therefore, wind and its involvement into the process of redistribution of particles in depth, due to the great stability of the surface layer. In this case, the main role in mixing are belongs to baroclinic circulation, tides and horizontal turbulent diffusion. The degree of the water surface layers turbidity is important factor for the processes of climatic scale (Appel et Gudkovich 1979, Lindemann et al. 1999, Reimnitz et al. 1995, Vlasenkov et Makshtas 2008). Suspended particles captured (incorporated) by sea ice during its formation, affect the rate of sea ice melting during the subsequent spring and summer period. Joint assessment of the water transparency, suspended particles concentration, state and variability of sea ice cover and fjords oceanographic conditions allow to monitor this process and evaluate it quantitatively. Practical output are (1) parameterization of sea ice melting process in the framework of a wide spectrum of sea-ice models, (2) assessment of the character and degree of contamination of the fjords of the archipelago, (3) and analysis of suspended particles dynamic.

The relative transparency of sea water (the depth of the "disappearance" of the standard white Sechi disk) is an important optical characteristic, which allows, in addition to temperature and salinity, to classify surface water masses and estimate the intensity of continental runoff. If such measurements are carried out regularly over a long period, it is possible to use them as indirect (additional) indicators of a long-term variability of oceanographic regime and classify the reasons causing this variability.

Material and Methods

In the period from 1986 to 1990, detailed studies of the oceanographic conditions of the Green-fjord Bay were carried out using a network of reference stations. The location of the stations is shown in Fig.1, and the coordinates and depths in Table 1. Since 1990, unfortunately, such work has no longer been carried out.

Observations on this network of oceanographic stations carried out once a month from June to October, which made it possible to form a time series of data about the relative transparency and analyze the seasonal and long-term variability of this characteristic.

We also used direct measurements of underwater irradiance in the 400-700 nm range (photosynthetic active radiation) obtained in 2006 by an expedition from the Arctic and Antarctic Research Institute in the Green-fjord Bay.

Results

The results of 5 year monitoring of relative transparency of sea water are shown in Table 2.

An increase of the relative transparency values was found from the shallow part (south) of the Green-fjord Bay in the direction of the open part of Is-fjord Bay (north). Dispersion analysis confirmed the significance of line trends for each year. Estimates of the coefficient A (the slope of the trend line) and the coefficient of determination R^2 in the linear regression equations are shown in Table 2 as well.

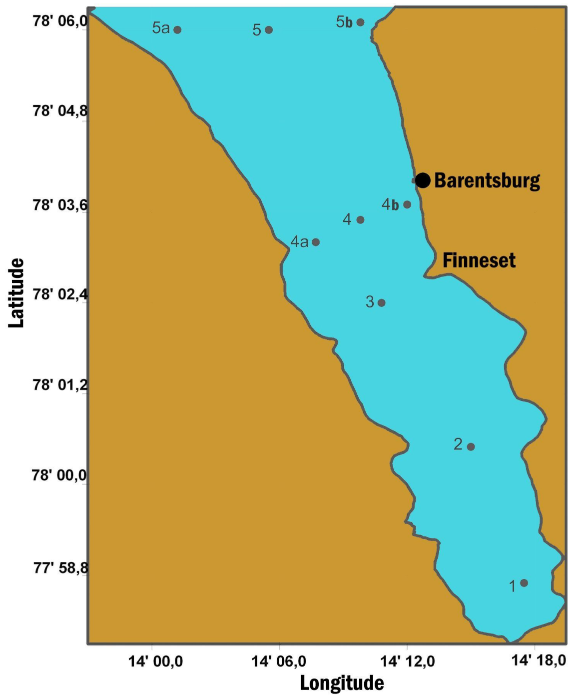

Fig. 1. Location of oceanographic stations on reference network in the Green-fjord Bay.

Station number	Latitude	Longitude	Depth (m)
8*	78° 10.8’	13° 49.8’	361
7*	78° 09.2’	13° 53.0’	415
6*	78° 07.8’	13° 56.5’	300
5	78° 06.0’	14° 05.5’	153
5a	78° 06.0’	14° 01.2’	198
5b	78° 06.1’	14° 09.8’	155
4	78° 03.5’	14° 09.8’	144
4a	78° 03.2’	14° 07.7’	139
4b	78° 03.7’	14° 12.0’	127
3	78° 02.4’	14° 10.8’	144
2	78° 00.5’	14° 15.0’	84
1	77° 58.7’	14° 17.5’	62

Table 1. Coordinates and depths of oceanographic stations of the reference network.
Note: * Station number 6, 7, 8 are located in the Is-fjord.

Year	Sechi disk depth (station number in according to Fig. 1)							A	R^2
	1	2	3	4	5	6	7		
1986	10.5	10	10	10.5	12.5	12.5	13.0	0.54	0.77
1987	8	6.5	7.5	7.5	12	12	12.5	1.04	0.64
1988	1	2	4	5	6	8.5	10	1.29	0.92
1989	4	5.5	7.5	9.5	9	10.5	12	1.50	0.98
1990	1.5	5.5	4.5	5.5	6.5	15	14	2.09	0.80

Table 2. Change of Sechi disk depth (m) and estimates of regression equations for each year (A, R^2).

Such a distribution of the relative transparency contributes to the following explanations. The several major rivers and streams (Bryude, Aldegonda, Breferna, Grøn-fjord, Grøn) flow into the southern (shallow) part of the fjord. The largest glaciers (Aldegonda, West and East Grøn) are located there as well. Thus, the basic volumes of particulate matter are observed in the southern part of the Green-fjord Bay. Increasing the values of the coefficient "A" during the analyzed period indicates strengthening of spatial inhomogeneities of the oceanographic conditions in the Green-fjord Bay. Maximum interannual variability is observed in the southern part of the Bay (1-10 m) compared to the north (10-14 m). This is due to the influence of the continental runoff, the variability of which is maximal in the southern part of the fjord, where the largest glaciers and rivers are located.

Distributions of the relative transparency for the each station for the period 1986-1990 have more complex character in comparison with the spatial distribution of the it characteristics in the waters of the Green-fjord Bay. However, for all stations, one general regularity related to minimum values of the relative transparency was observed in 1988. Moreover this minimum was observed also at the oceanographic stations located in the adjacent waters of the Is-fjord Bay (stations № 6, 7). In the southern part (station № 1, 2) it was 1-2 m, in the central (stations № 3, 4), 4-5 m in the north (stations № 5) 6 m, and in Is-fjord Bay (stations № 6, 7) it reached 8-10 m. This might be due to the thickness of the snow cover, which was maximal in the spring of 1988 (*see* Fig. 2a) when compared the previous and subsequent years. Such maximum is attributed to an increased expenditure of river water, bringing to the Green-fjord Bay the maim mass of suspended particles. This is indirectly confirmed by the values of the salinity of surface water, which reached their minimum in 1988 (*see* Fig. 2b), indicating that significant volumes of fresh water were delivered to the Green-fjord Bay.

General feature of the seasonal variability of the relative transparency of the Green-fjord Bay waters is a reduction the relative transparency of the water in September-October in comparison with the values observed in July-August, which is associated with different amounts of liquid precipitation during these months. As follows from Fig. 3 and an evidence from available data (Solovjanova et al. 2005, Killingtveit et al. 2002), the maximum values of liquid precipitation are observed in September and October, which should lead to an increase in river flow (autumn flooding), and, as a consequence, to an increased flow of suspended particles into the water of the Bay.

Thus, the character of the spatial distribution of relative transparency in the Green-fjord Bay, in general, is consistent with our previous results obtained in the Belsund, Kongs-fjord and Hornsund Bays (Ivanov et al. 2005, Ivanov et al. 2007).

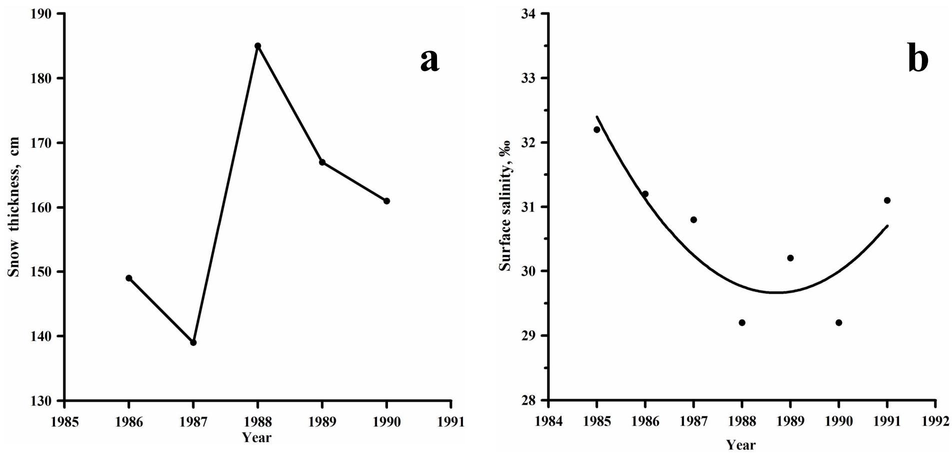

Fig. 2. Interannual variability of the maximum thickness of the snow cover (a) and salinity in the surface water layer (b).

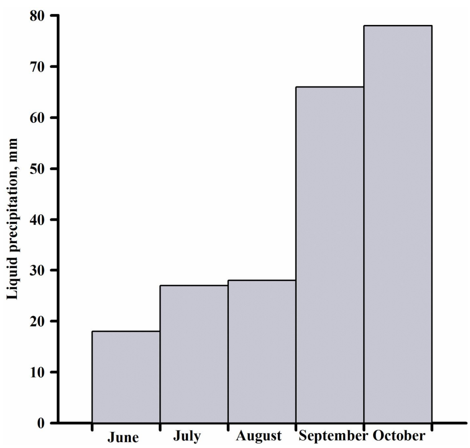

Fig. 3. Monthly amounts of liquid precipitation in the (mean data, 1985-1990).

In August 2006, the Arctic and Antarctic Research Institute (AARI) expedition carried out measurements of underwater irradiance using a PAR (photosynthetic active radiation, 400-700 nm) sensor within the area of the Green-fjord Bay. The attenuation coefficient of solar radiation was calculated from the data for surface layer water. The results are shown in Fig. 4.

The maximum values of attenuation coefficient (1.7 m^{-1}) were recorded in the southern and south-eastern part of the fjord. There was the zone of maximum spatial variability of the attenuation coefficient in the area “Cape Finesset - traverse Barentsburg settlement” (distance of about 2 km). North of this area, its value does not exceed 0.5 m^{-1}. This area of maximum spatial variability (frontal zone) can be considered as a natural border between the surface water of river origin and surface waters of the marine origin. Thus, the constancy of the structure of the surface water masses of the Green-fjord Bay may be confirmed.

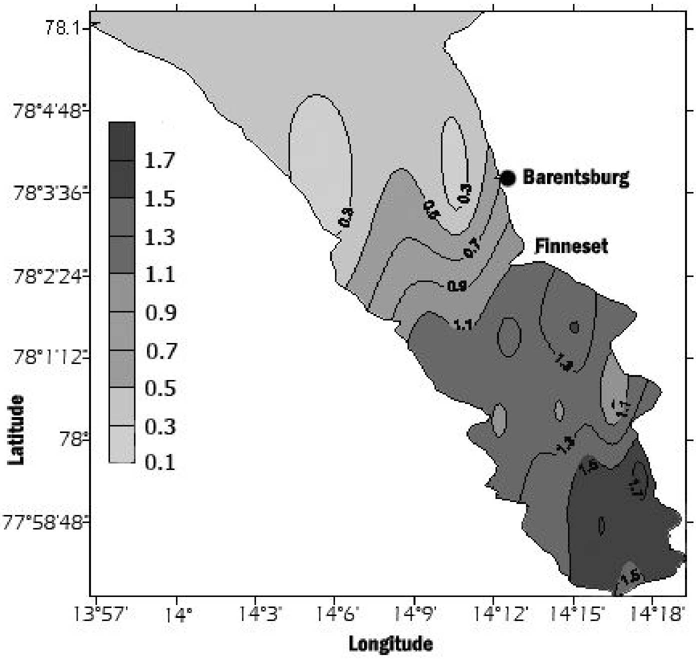

Fig. 4. Distribution of attenuation coefficient (m^{-1}) of solar irradiance in the surface layer.

Discussion

The results obtained demonstrate the regularity and features of the distribution of relative transparency in the Green-fjord Bay in space and time. These data can be used to indirectly estimate the amount of suspended particles in the surface layer. Our previous studies performed in other fjords of the Western Spitsbergen Island (Ivanov et al. 2005), as well as in the Finland Bay of the Baltic Sea (Ivanov et Pavlov 2008), as well as studies performed in the Arctic seas (Vlasenkov et Makshtas 2008), have shown the prospect using data on relative transparency to estimate the concentration of suspended particles.

Using the data available, we formulate a number of conclusions, which, because of the limited data series and their internal heterogeneity, are, of course, preliminary character:

(1) Analysis of the relative transparency data allows, in a first approximation, to estimate its spatial and temporal variability in the waters of the Green-fjord Bay.

(2) Water transparency increases regularly from the southern part of the Bay to its deep part of the north.

(3) The attenuation coefficient may be additional characteristic to assess of the river borders spread.

(4) Seasonal and long-term variability of the relative transparency of sea water, as a first approximation, due to the variability of external meteorological factors and especially the regime of precipitation.

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