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Long-term variations in the Barents Sea frontal zones according to the data on oceanographic observations and model calculations

by

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Abstract

A successful management of marine ecosystem resources depends on the understanding of the principles and peculiarities of its functioning. The Barents Sea, rich in different species of commercial fish, takes the intermediate position between arctic and boreal oceanic systems which causes the existence of expanded frontal zones. The data earlier published indicate that the functioning of the Barents Sea ecosystem as an unit and the crop yield variations in the most important commercial species of the Barents Sea fish are related to variations in the sharpening of the frontal zones.

In the paper we represent the results of the studies of long-term changes in the parameters of the Barents Sea frontal zones. Indexes of the frontal zones spatial extent are suggested and the model calculations of the water circulation are made. We analyzed variability in the water dynamics and characteristics of the frontal zones, as a result, we found a direct relationship between them. We also found a decrease in the extent of the frontal zones against increasing temperature in the Barents Sea in the recent decades. Based on the data received, possible consequences of the climatic variations in the ecosystem of the Barents Sea and commercial fish species are discussed.

Introduction

The oceanographic conditions of the Barents Sea are mostly caused by degree and intensity of interaction between Atlantic and Arctic waters, which provide the sea with expanded frontal zones (Fig. 1). The Polar frontal zone is the most evident among them; it separates warm and high salty Atlantic waters from cold and freshened Arctic waters.

The structure of the Barents Sea frontal zones on the observation data before 1985 had a detailed analysis previously (Ozhigin, 1989). At present PINRO data base has been replenished by both new and retrospective data. This allows us to turn to the subject on the Barents Sea frontal zones in order to get more reliable information about their structure and space-time variability of their parameters.

The aim of the study is to analyze features of interannual variations in thermal frontal zones parameters. In order to reach this aim, the following tasks were solved:

- to work out an integrated indicator (index), which characterizes a spacial development of the Polar frontal zone;
- to study its interannual variability;
- to analyze conjugation between the index stated and the calculated currents of the Barents Sea.

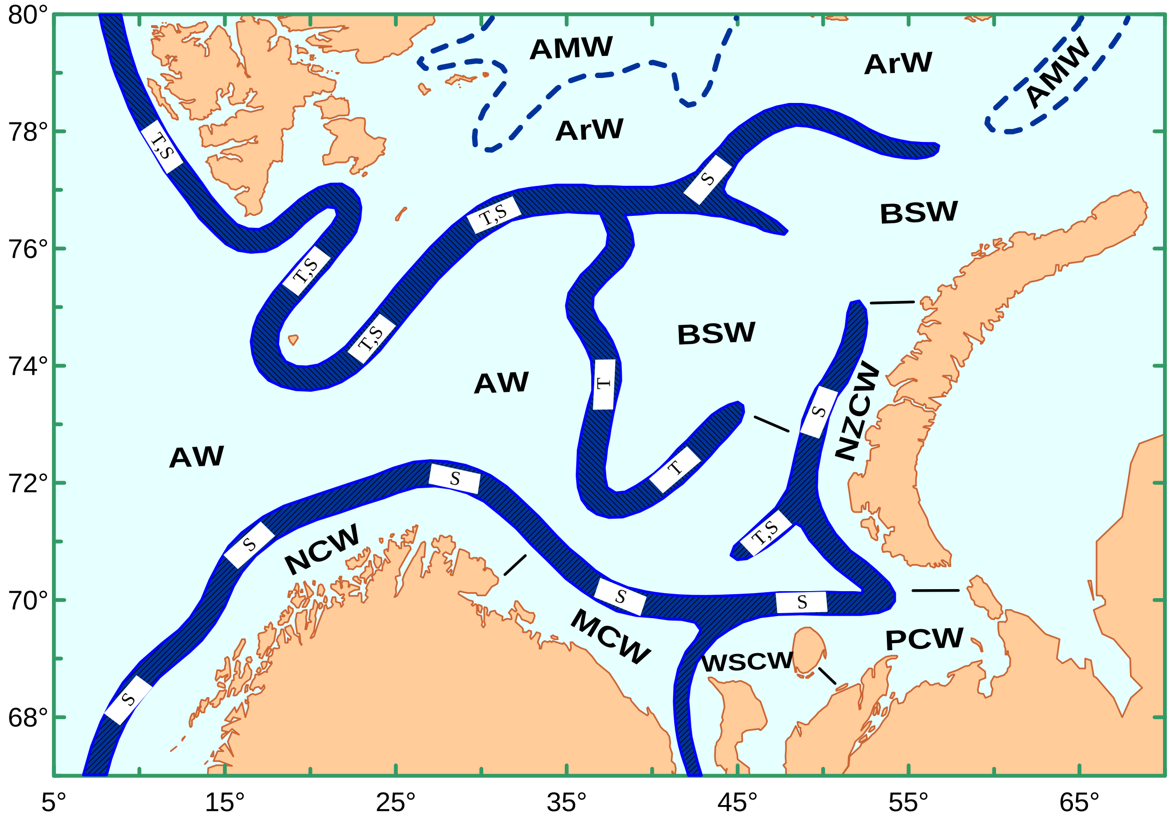

Fig. 1. Frontal zones and water masses of the Barents Sea (Ozhigin and Ivshin, 1999):
T: thermal fronts; S: haline fronts; T,S: thermohaline fronts; AW: Atlantic Water; AMW: Atlantic Modified Water; ArW: Arctic Water; BSW: Barents Sea Water; NCW: Norwegian Coastal Water; MCW: Murman Coastal Water; WSCW: White Sea Coastal Water; PCW: Pechyora Coastal Water; NZCW: Novaya Zemlya Coastal Water.

Materials and methods

We chose a warm year period (August-September) for the analysis of variability in the frontal zones parameters, as the international ecosystem survey is carried out in this period and, as a result, the Barents Sea is more completely and readily covered by oceanographic stations.

Thermal frontal zones in August-September are more evident under the seasonal thermocline at depths of 50-100 m (Ozhigin, 1989) in the western and central parts of the sea, on the border between Atlantic and Arctic waters.

The calculation of the length/width index of the thermal frontal zone was based on the following. For the area 73-78º N and 15-30º E, the fields of horizontal gradients in water temperature were calculated in the nodes with an interval 10' in latitude and 30' in longitude. The choice of this area was reasoned by a more sharpened horizontal temperature gradient and approximately even spatial coverage by oceanographic stations in this period. The length index of the frontal zone corresponds to the number of grid nodes, in which gradients exceeded a critical value of 0.04º C/km (see Fig. 2). Calculations were made according to the date on water temperature at 50 m depth for August-September 1983-2004.

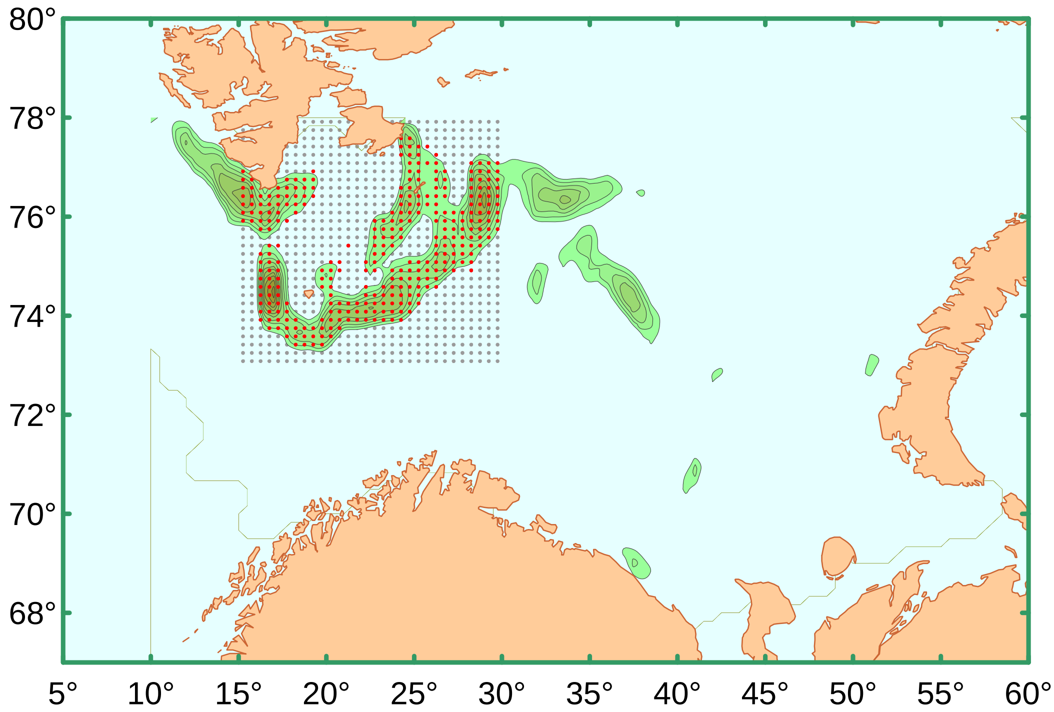

Fig. 2. The long-term mean location of thermal frontal zones at 50 m depth in August-September. The area of calculations is marked by grey points. The increase in critical water temperature gradient (more than 0.04º C /km) in the node is marked by red points.

In the study we analyzed conjugation between the length/width index of the frontal zone and volume fluxes in the Barents Sea main currents. The calculation of water circulation was made with a numerical hydrodynamic model (Trofimov, 2000). Water fluxes were calculated for the whole water column from the surface to the bottom through sections which cross the main currents (Table 1).

Table 1. Sections used for calculation of water fluxes

No. of section	Current crossed	Position of the section	
		Latitude	Longitude
1	The Norwegian Current	along 68º00'N	06-12ºE
2	The Spitsbergen Current	along 73º40'N	12-16ºE
3	The North Cape Current	70º40'-73º20'N	along 20ºE
4	The Bear Island Current	along 74º20'N	20-25ºE

Results

The calculated length/width index of the frontal zone showed a high degree of its variability (Fig. 3). Thus in 1983 the square of the area with high temperature gradients took around 400 grid nodes, whereas in 1997 – less than 250 nodes (Fig. 4).

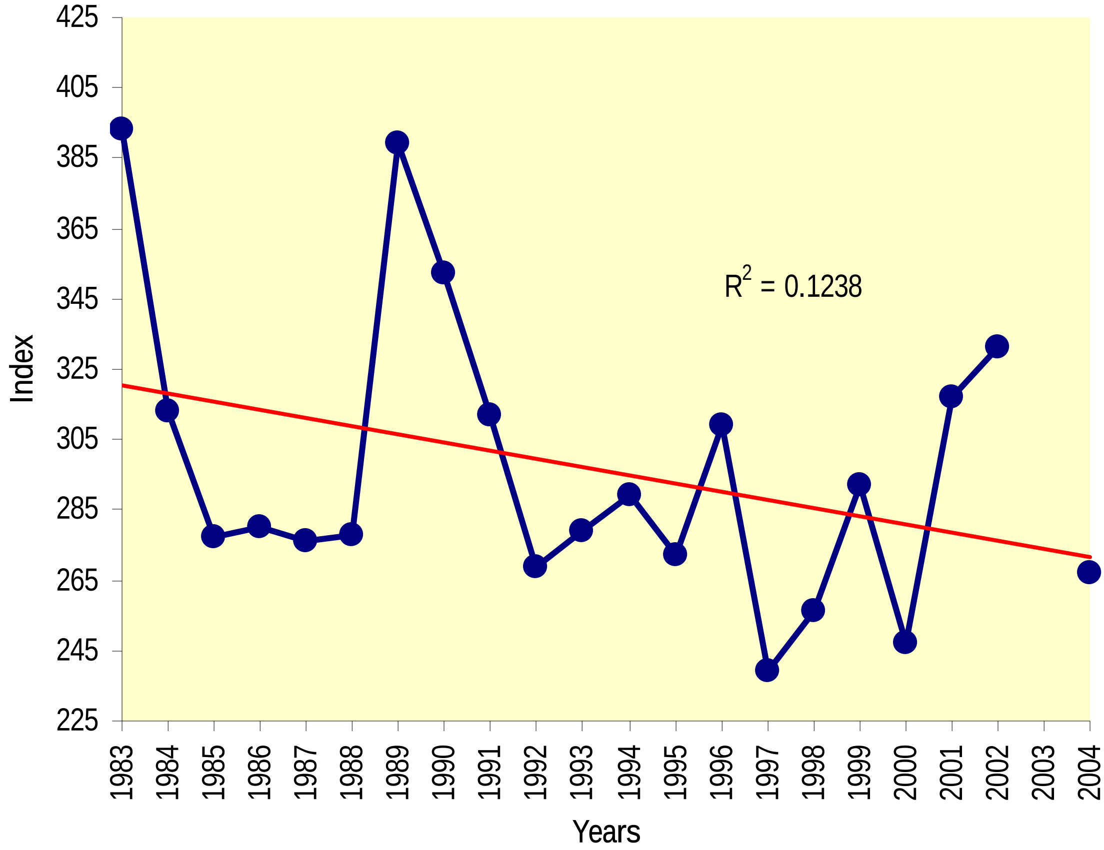

Fig. 3. Interannual variations of the frontal zone length index at a depth of 50 m in August-September 1983-2004.

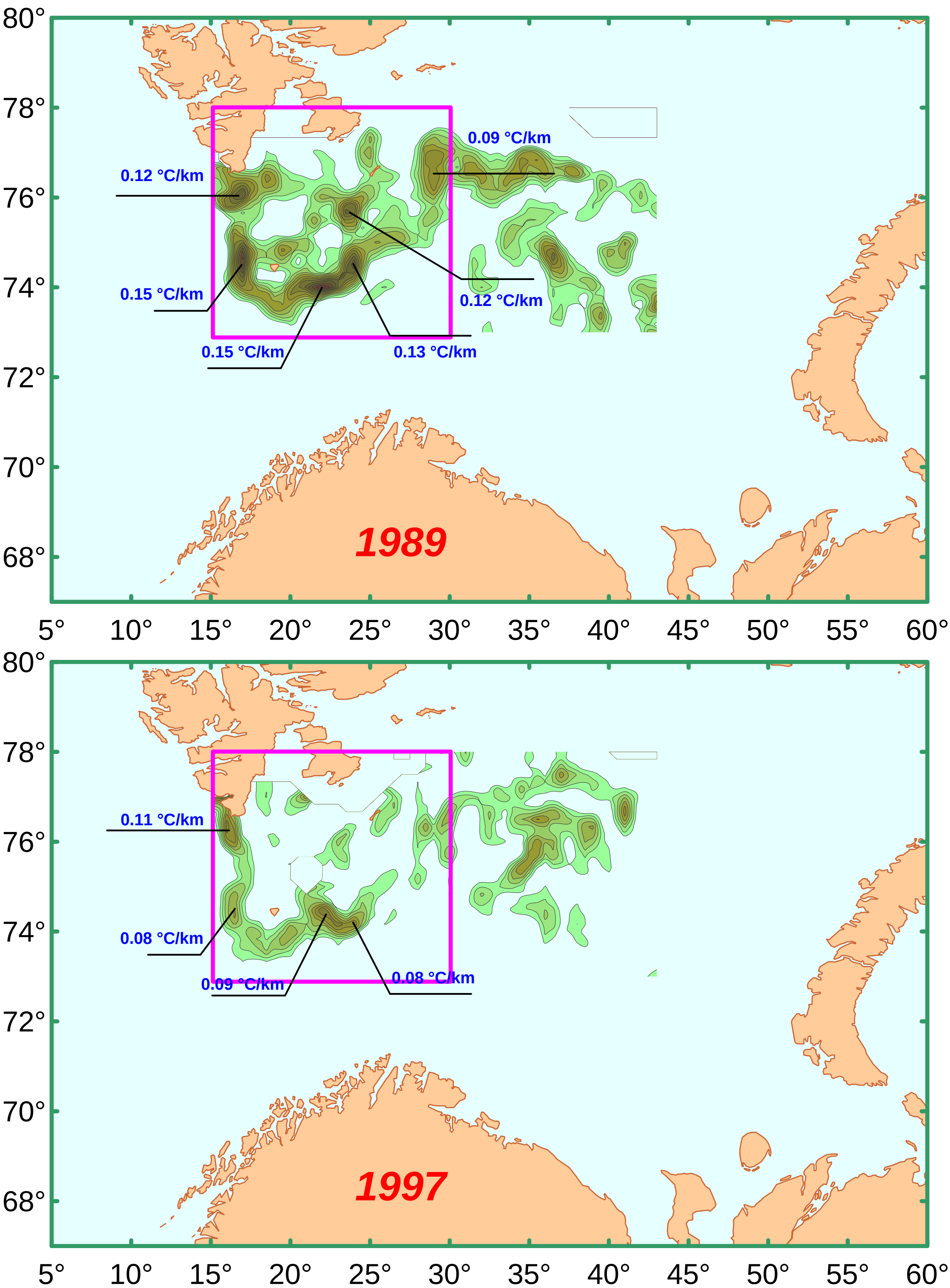

Fig. 4. Position of the thermal frontal zone in 1989 and 1997. The calculation area is marked by a frame.

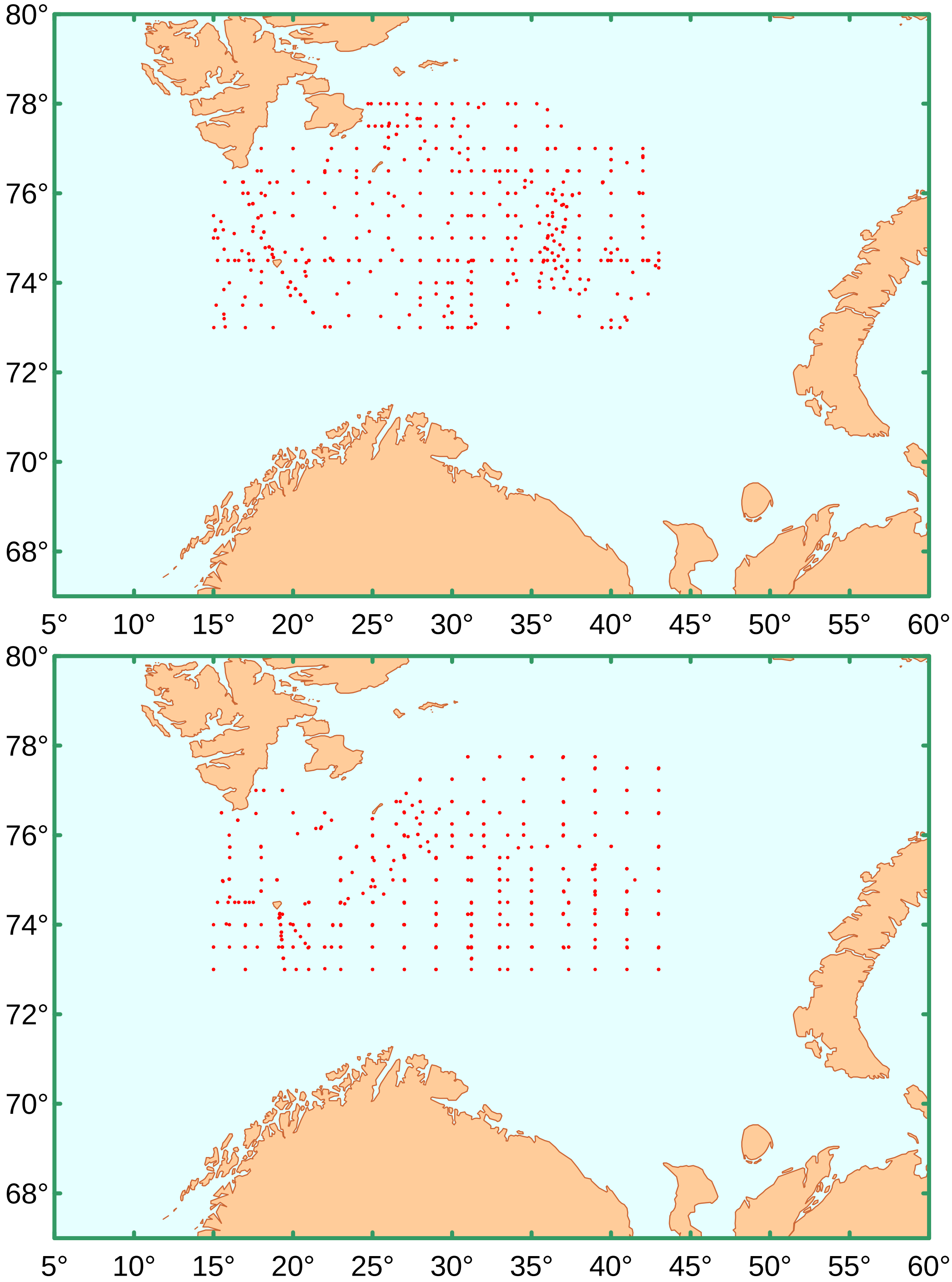

Fig. 4b. Position of oceanographic stations in the calculation area in 1989 (upper figure) and 1997 (lower figure).

The analysis of interannual variability of the index showed a trend. Its contribution into the dispersion amounted to 12 %. It is evident that the index amplitude in the first half of the row is higher than in the second one. One of the possible reasons of such oscillations can be the fact that till 1993 waters with different temperatures were observed equiprobably in the Barents Sea (Fig. 5).

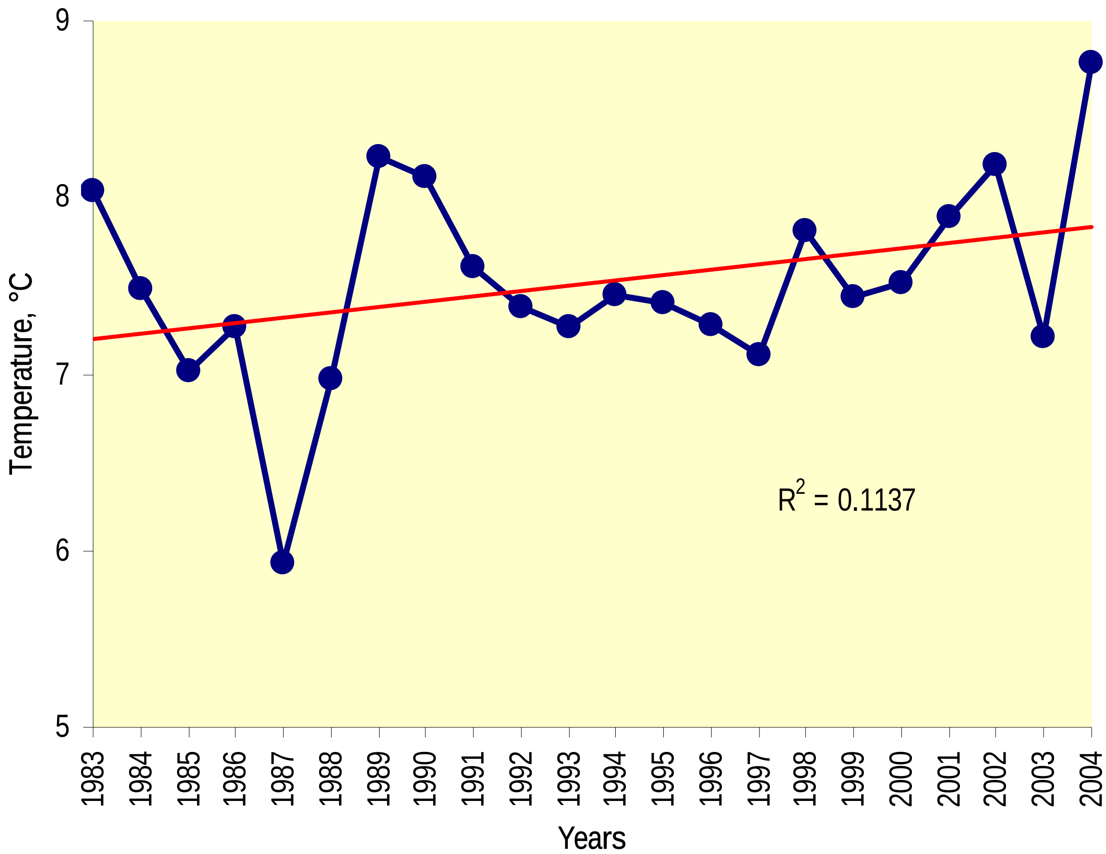

Fig. 5. Interannual variations of water temperature in the 0-50 m layer in the Kola section in August-September 1983-2004.

The second half of the years can be characterized as a period with rather high temperatures. Long periods with the same temperatures (high or low) make a situation, which is characterized by a decrease in contrasts in water temperature, that is decrease in horizontal temperature gradients and, as a result, it brings to smearing of frontal zones.

The mean length indexes of the frontal zone in different parts of the studied time series differ significantly (Fig. 6).

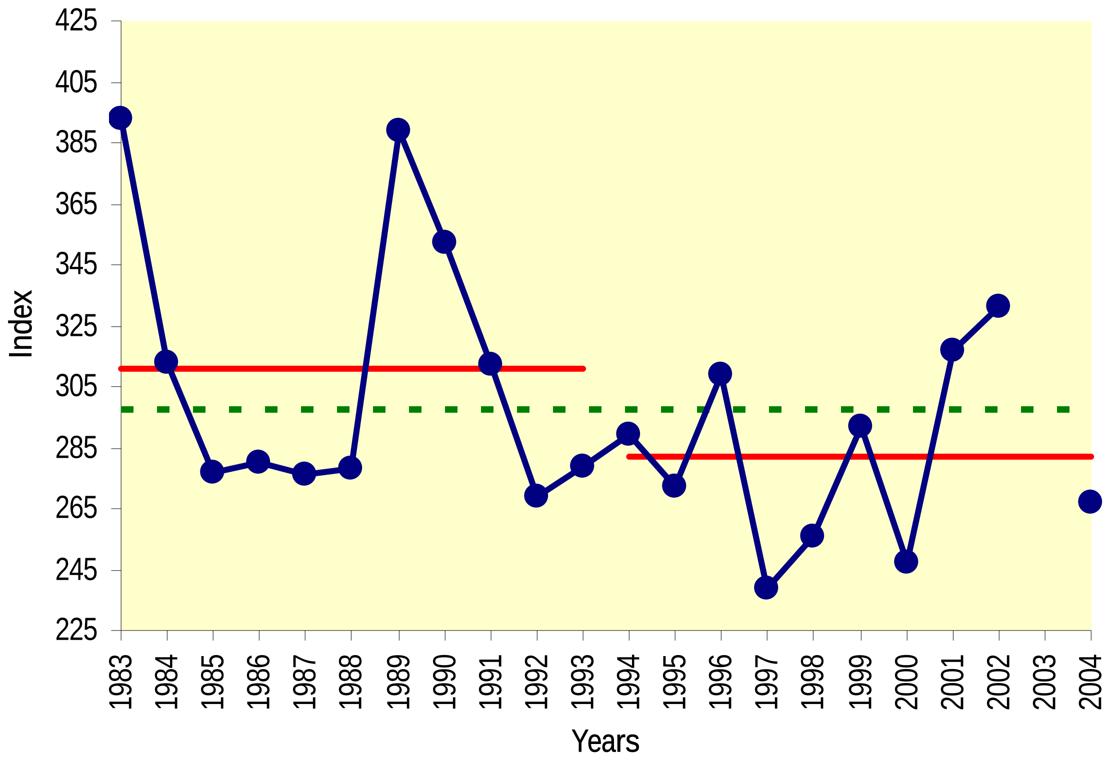

Fig. 6. Interannual variations of the frontal zone length index at a depth of 50 m in August-September, its mean value for the period 1983 to 2004 (green line dotted) and mean values in 1983-1993 and 1994-2004 (red line).

As is obvious from the diagram, the difference of the mean indexes for periods 1983-1993 and 1994-2004 amounts to around 30 grid nodes, which corresponds to 10% compared to the mean index for the whole period studied.

We analyzed conjugation of the index with the calculated water fluxes in the Barents Sea main currents (Fig. 7). The water fluxes were averaged for different months before August-September, and significant relations were sought.

The correlation analysis showed that there were significant relations between parameters studied. The correlation coefficients were more than 0.7 for the most number of chosen sections and they were lower only for the section crossing the North Cape Current. The latter can be conditioned by a non-completely correct choice of the section position. So the southern part of the section occupies partly the coastal waters (see Fig. 1), and their contribution into the total flux can have a negative effect on the relation quality.

Though different periods were used for the averaging of the water fluxes at the estimation of the studied relations, there is a definite regularity. We must note that the averaging periods shift to the period (August-September) of the frontal zone length index calculation, when we move north and east.

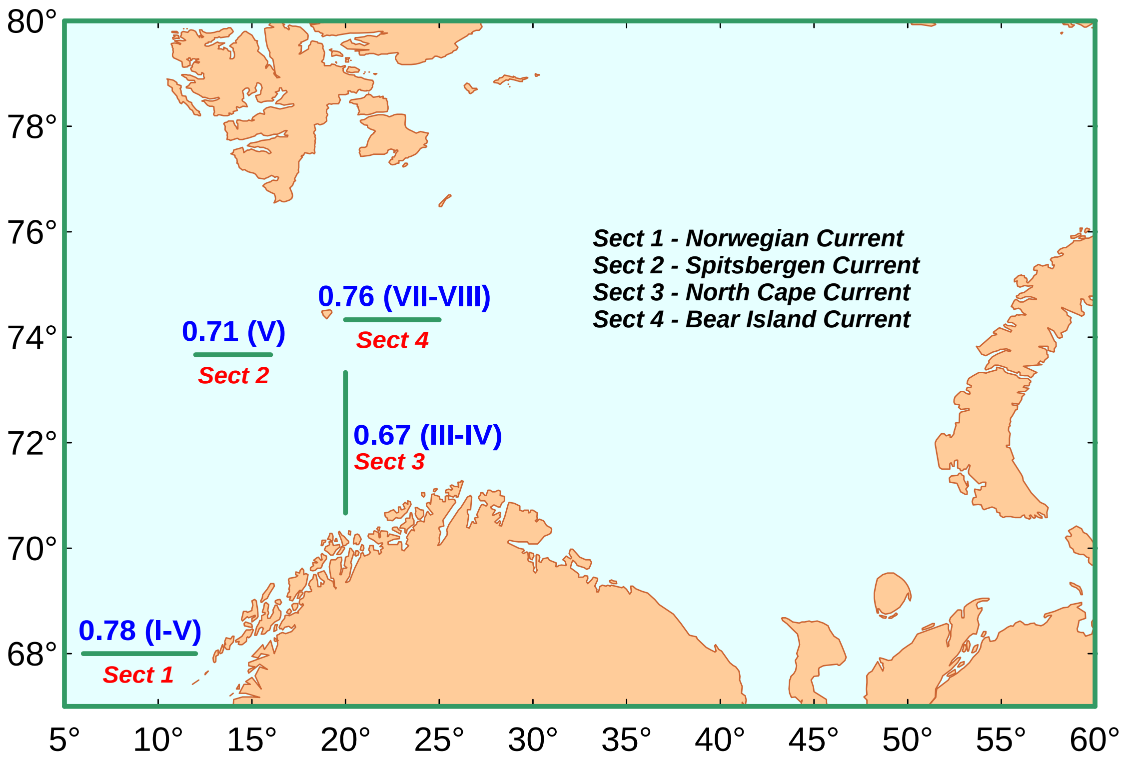

Fig. 7. Correlation coefficients between the frontal zone length index and the water fluxes in the main currents. The averaging period is shown in brackets.

Conclusions

We calculated the length/width index of the frontal zone for August-September for the period 1983-2004, and a negative trend into its interannual variations was found, which explains about 12% of the total variability (dispersion). We found a great difference in mean values of the length/width index of the frontal zone between 1983-1993 and 1994-2004, which is obviously conditioned by a total warming in the Barents Sea waters in the last period.

Based on the analysis of correlation, we found a statistically significant positive relationship between the index suggested and the water fluxes in the Barents Sea main currents, received as a result of hydrodynamic modeling.

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