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Variations of climate, frontal zones and recruitment to major commercial fish stocks in the Barents Sea

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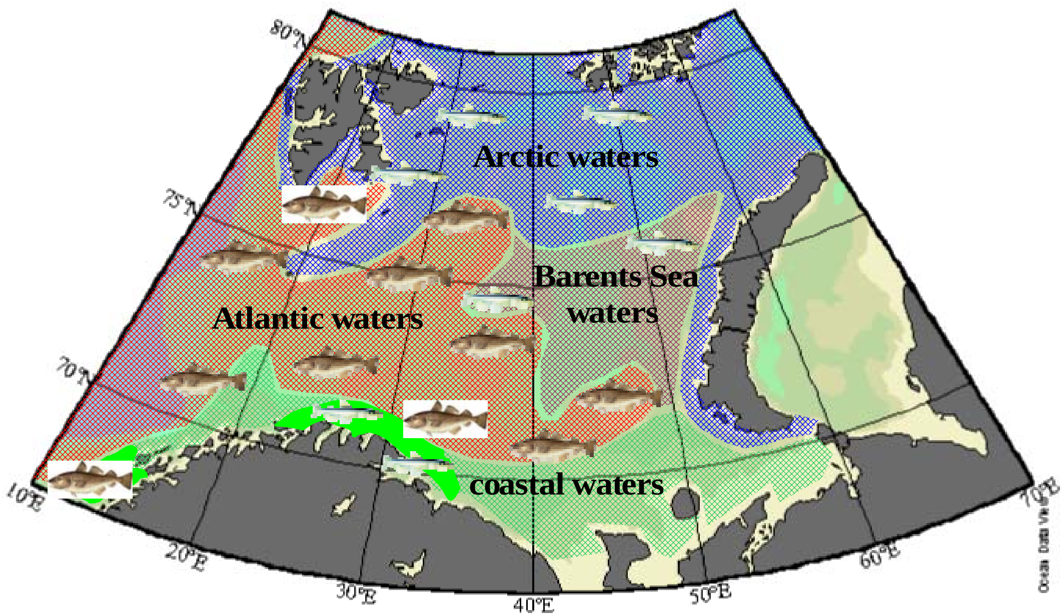
Introduction

The Barents Sea is characterized by a good water exchange with the North Atlantic and Arctic oceans and has a number of water masses with different features. Interaction of these water masses makes quite a vivid picture of frontal zones in the sea. It is thought that owing to interaction between the boreal and Arctic waters, the ecosystem of the sea is noted for a high biological production and is rich in organisms important for the fisheries.

Capelin, the pelagic species, migrate for feeding to the cold Arctic and Barents Sea waters but spawn in the warm coastal waters of the North Norway. Northeast Arctic cod, the demersal species, feed and spawn in the warm coastal and Atlantic waters. Both cod and capelin distribution varies depending on climate conditions and related to frontal zones in the periods of feeding and wintering.



Water masses distribution (Loeng, 1991). Feeding areas and **spawning grounds** of cod and capelin.

Introduction

Until recently, there have been no scientific publications on interannual variability in parameters of thermal frontal zones in the Barents Sea as well as on the effect of such variability on biological and fisheries productivity of the sea.

Nowadays there is a following hypothesis (Titov, 2001). The largest increase of horizontal temperature gradients in the frontal zones occurs in the periods with relatively extensive ice coverage in the Barents Sea while heat advection by Atlantic currents is getting stronger. An index indicating sharpening of the Barents Sea frontal zones based on the Barents Sea ice coverage and temperature in the upper 200 m layer of the Kola Section was suggested.

An increase in this index coincides in time with a decrease in oxygen content in the bottom layer in the Kola Section that may be a consequence of higher biological productivity in the photic layer and settling of organic matter to the bottom. Relationships between variations in the above index and strength of capelin and cod yearclasses were found to be significant.

On the whole, sharpening of the frontal zones was perceived as an indicator of interaction strength between the Arctic and boreal oceanic systems.

The purpose of this paper is to estimate year-to-year variability in characteristics of the frontal zones under the effect of climate fluctuations and to show the relationship between such variability and biological and fisheries productivity of the Barents Sea.

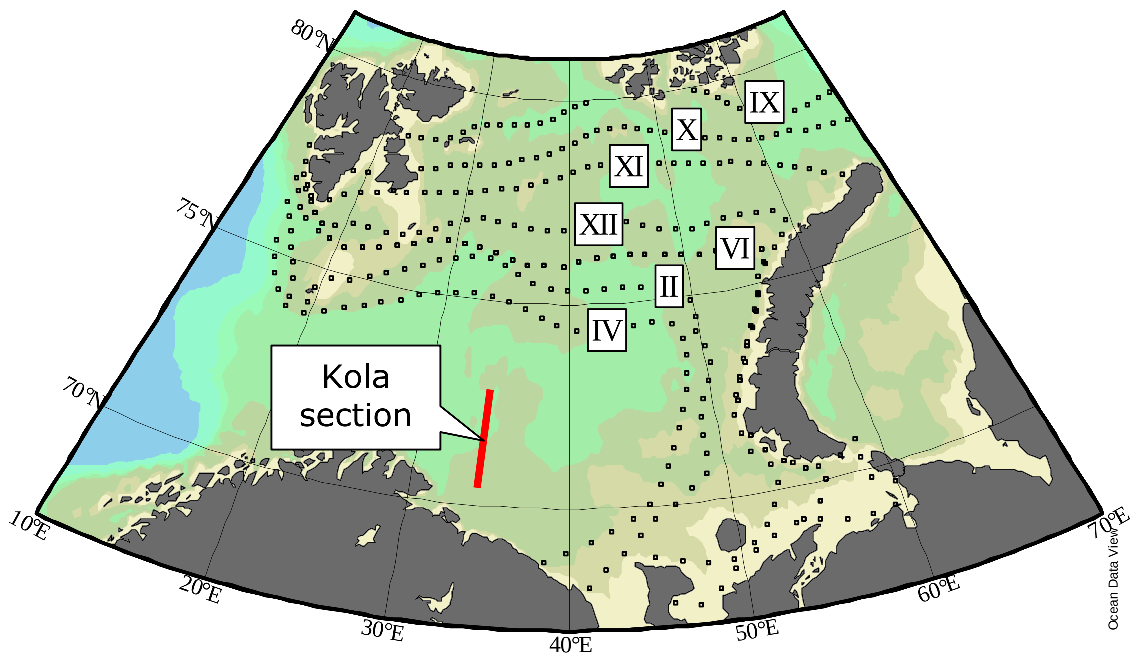
Material

The study is based on temperature data at the surface, 50 and 100 m, and in the bottom layer in July–November 1951-2003 (about 20 000 stations).

In July-November the ice edge is located to the north of the Polar front, which makes it possible to get a correct estimation of the frontal zones characteristics.

Time series of averaged (July–November) monthly anomalies of water temperature (upper 200m layer), oxygen saturation (bottom layer) in the Kola section and ice coverage in the Barents Sea were used.

The anomalies were normalized by dividing the averaged anomalies by relevant standard deviations.

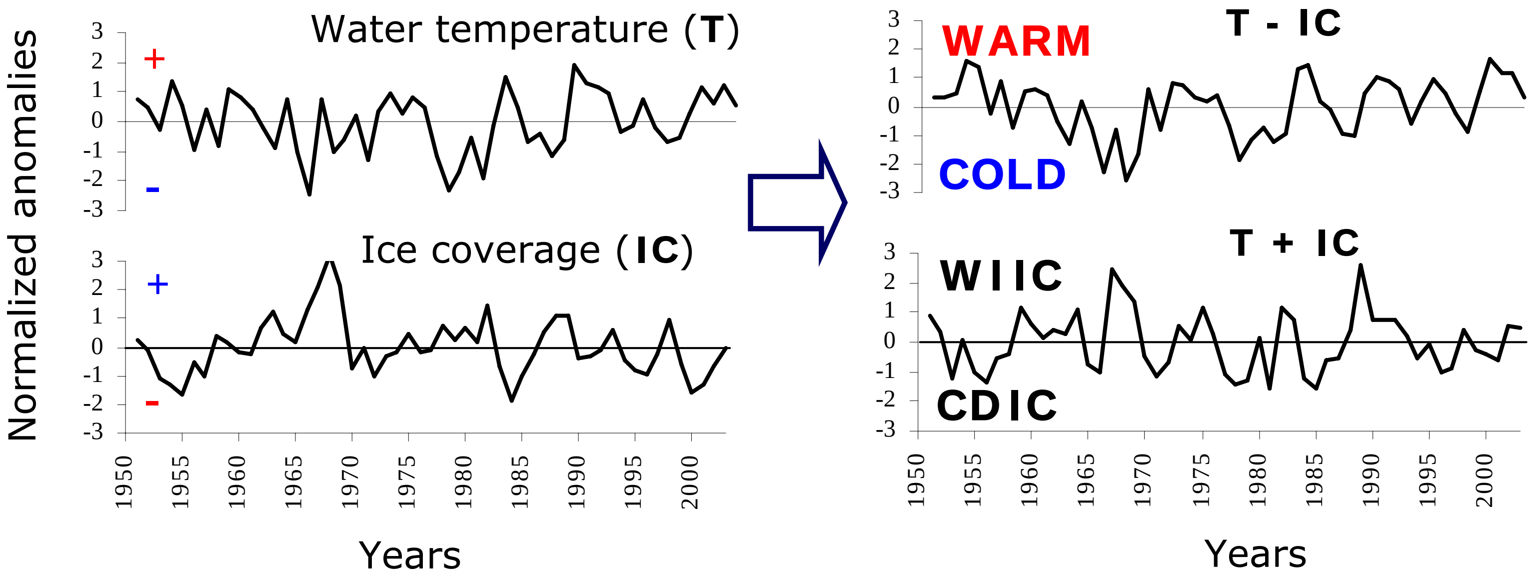


Ice coverage in different months (PINRO data) and Kola section locations

Methods

Based on normalized temperature and ice coverage anomalies, the years (1951-2003) were divided into 4 groups:
1) **WARM**-years that is warmer-than-normal with decreased ice coverage;
2) **COLD**-years that is colder-than-normal with increased ice coverage;
3) **WIIC**-years that is warmer-than-normal with increased ice coverage;
4) **CDIC**-years that is colder-than-normal with decreased ice coverage.

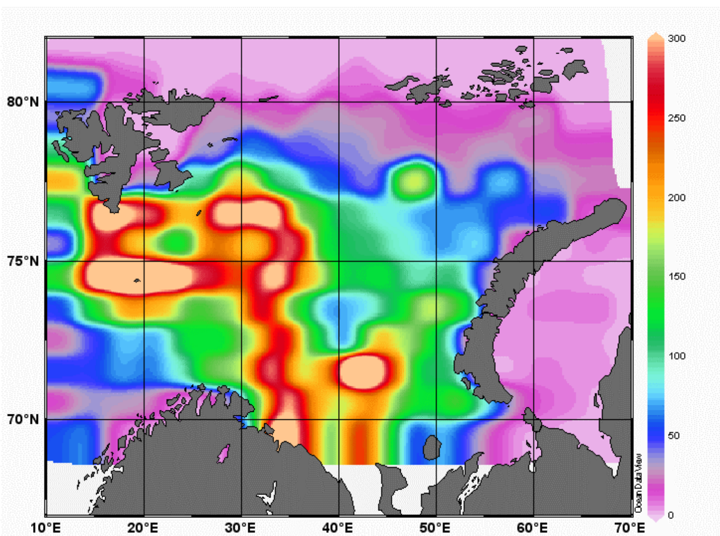
This grouping was implemented by calculating sums and differences of normalized temperature and ice coverage anomalies that gave two new time series. The **WIIC** group is comprised by the years in which temperature exceeded its "balance" value typical at a certain ice coverage values. It means that ice coverage in the Barents Sea was larger than normally observed at certain thermal condition.



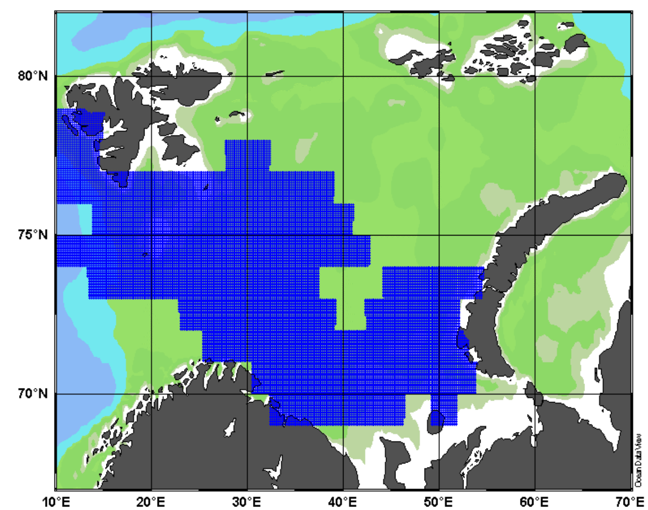
Methods

Initial temperature data was also divided into 4 groups according to the selected types of years.

Since data coverage in some areas of the Barents Sea was not good enough both in space and time, the sea area was divided into “squares” of about 60x60 miles. Only those “squares” that had at least 100 observations were used to calculate absolute values of horizontal temperature gradients.



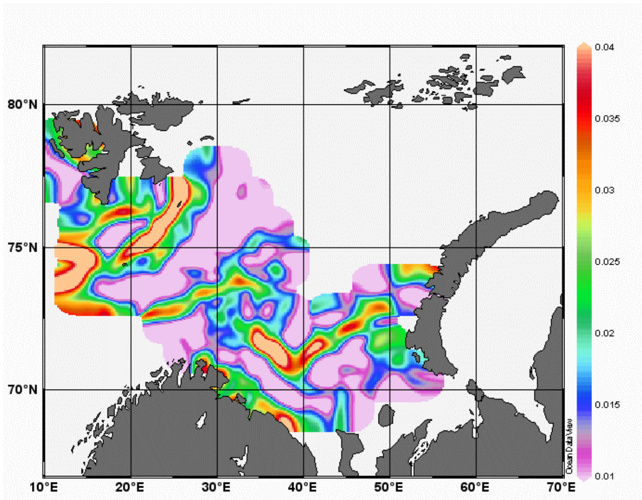
Density of observations on water temperature in the Barents Sea in July-November of WARM-years



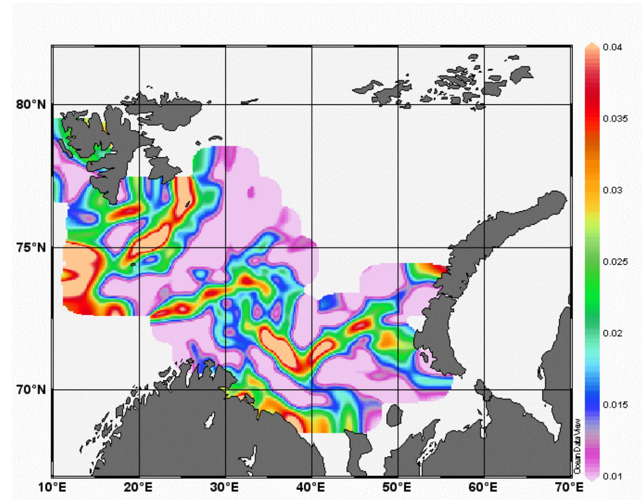
Areas in the Barents Sea that have at least 100 measurements of temperature in “square” of 60x60 miles.

Results

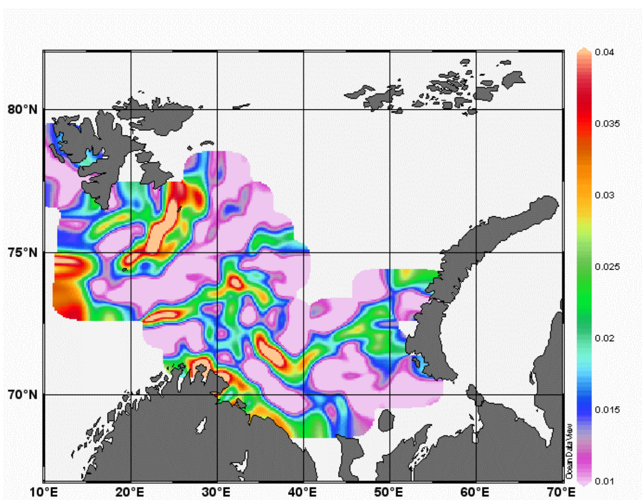
WARM



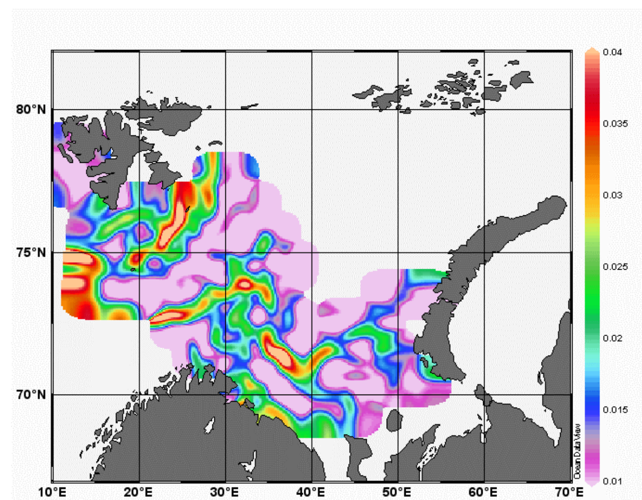
WIIC



CDIC



COLD

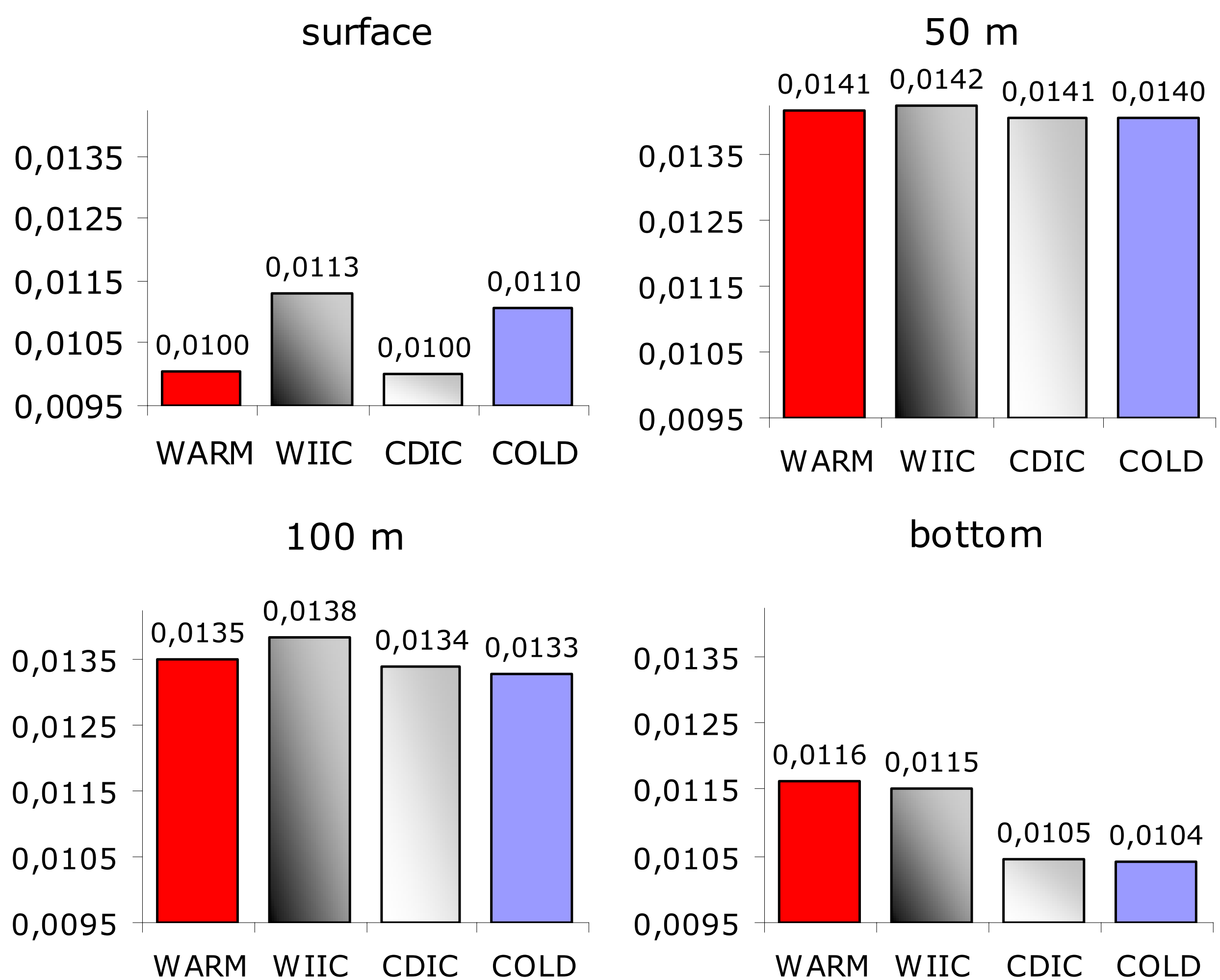


Average horizontal gradients of temperature (°C/km) in the bottom layer in years that differ in climatic conditions

Results

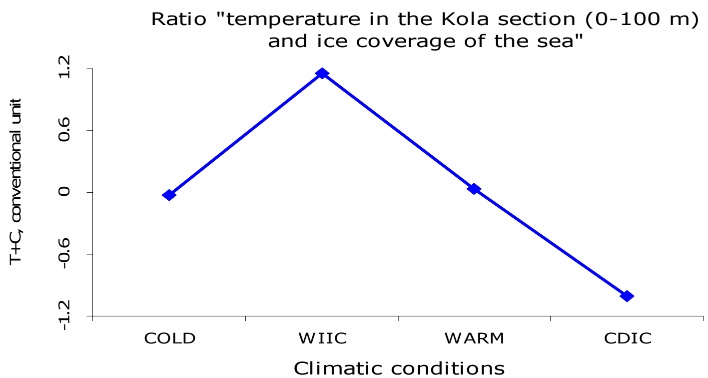
The highest gradients for all groups of years were typical of 50 and 100 m depths and difference between year types is barely visible.

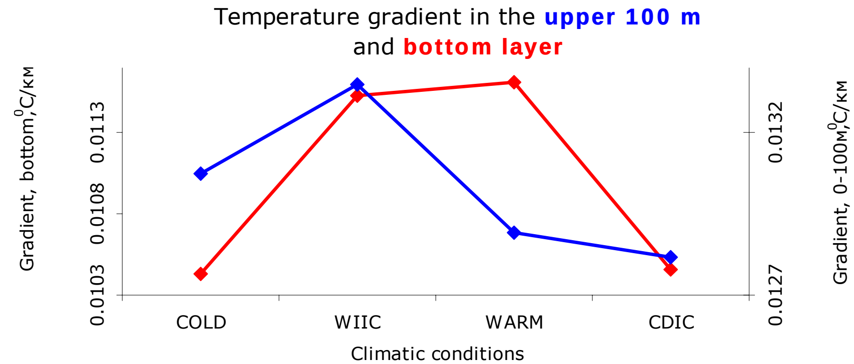
At the surface and in the bottom layer gradients were considerably lower. The most sharpened frontal zones at the surface were typical of WIIC- and COLD-years and in the bottom layer of WARM- and WIIC-years.



Temperature gradients (°C/km) at different depths averaged over the study area and years that differ in climatic conditions

Results/Discussion





Climate / Interaction of oceanic systems → **Frontal zones**

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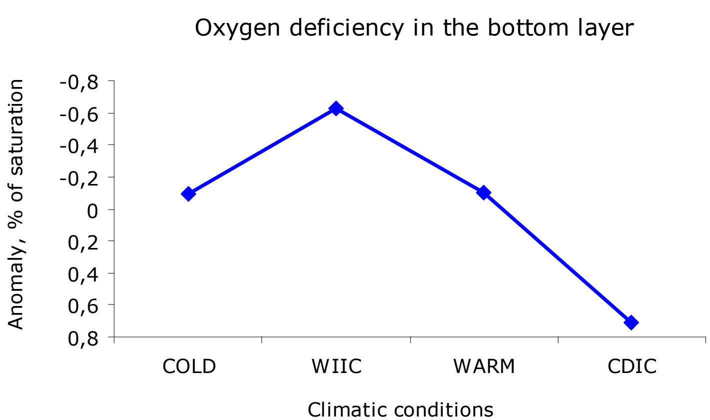
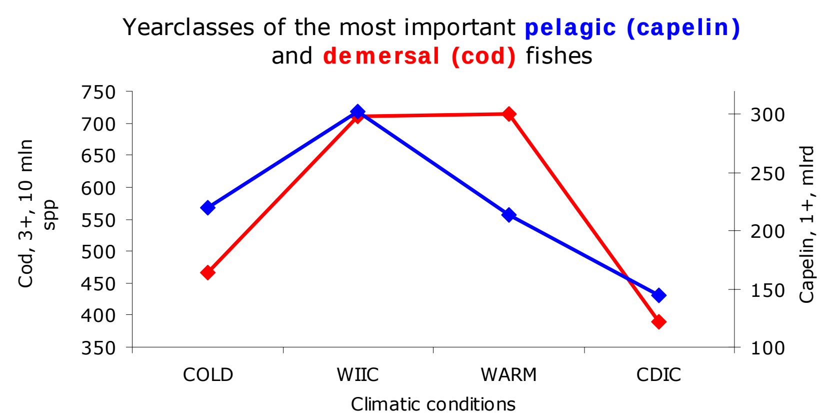
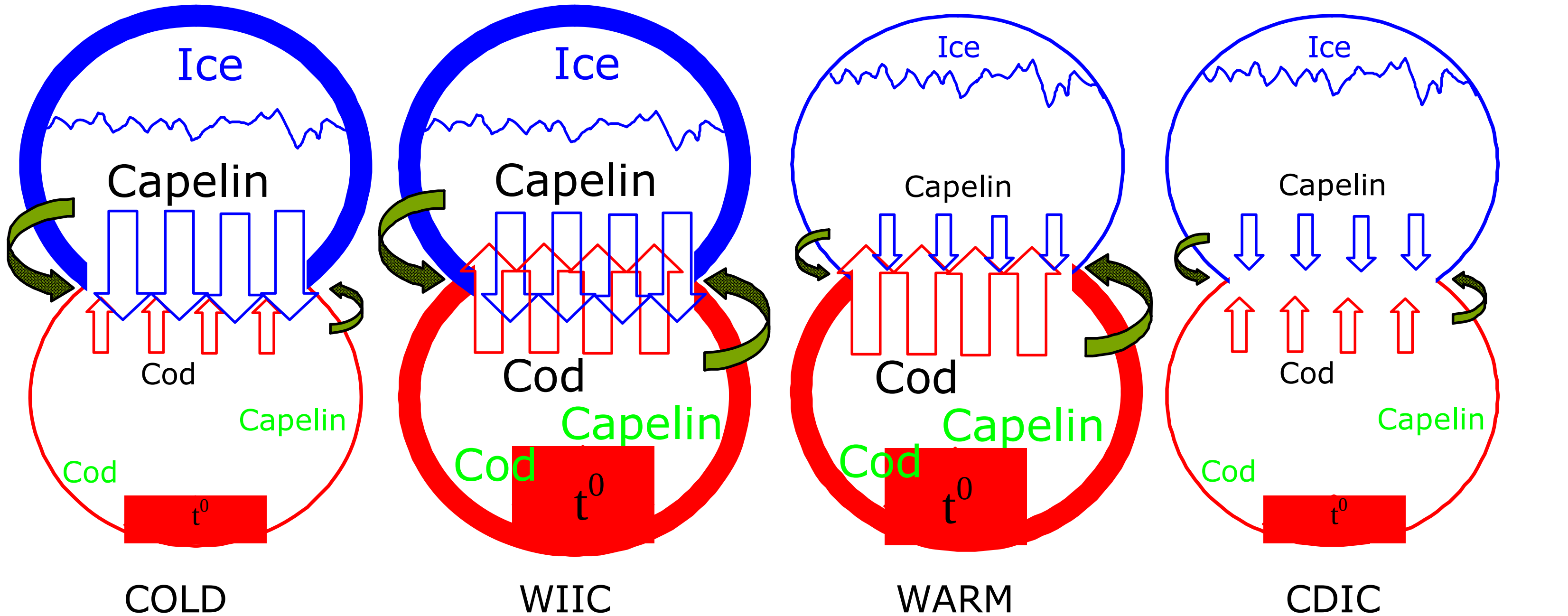
Primary production / Settling of organic matter to the bottom → **Recruitment**

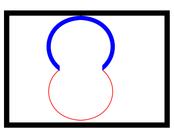




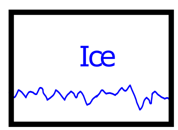
Presumable cause-and-effect relationships in the Barents Sea ecosystem

Discussion

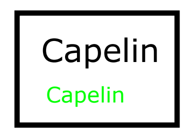




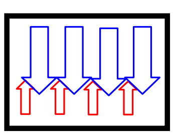
Effect of the **Arctic** and **boreal** oceanic systems



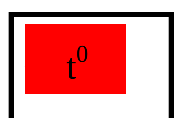
Ice coverage



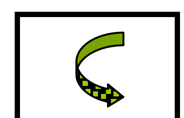
Favourable/Unfavourable conditions in the **spawning** and **nursery** areas



Sharpening of frontal zones



Intensity of heat advection



Intensity of organic matter settling to the bottom

Idealized scheme of the relationships between climate changes, environmental conditions, settling of organic matter and strength of cod and capelin yearclasses in the Barents Sea ecosystem

Conclusions

The hypothesis (Titov, 2001) according to which maximum sharpening of frontal zones occurs in the WIIC-years in general has been advocated.

The lowest oxygen saturation of water in the bottom layer is observed in WIIC-years that may be a consequence of the increased primary production and/or settling of organic matter from pelagic waters to the bottom.

WIIC-years are characterized by the appearance of rich yearclasses of capelin and Northeast Arctic cod, the most important fish species.

Sharp frontal zones in the bottom layer and rich cod yearclasses are also typical of warm years.

The transition from cold to warm climatic conditions is probably the most productive stage of the Barents Sea ecosystem functioning.

The strength of interaction between oceanic systems manifesting itself in the sharpening of frontal zones is one of the important factors governing the functioning of the Barents Sea ecosystem.