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Geostrophic Circulation of Water in the Labrador and Newfoundland Areas in Spring-Summer 1981

by

V. A. Borovkov and B. P. Kudlo
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street, Murmansk, USSR

Abstract

An important task of oceanology aimed to investigate reproduction of commercial fish of the Northwest Atlantic is to obtain regular data on horizontal circulation of water; these data are necessary for improving our knowledge of phyto-, zoo- and ichthyoplankton drift and also for determining conditions of survival of the next generations of fish. The present paper deals with specific features of surface circulation in Divisions of the South Labrador, Newfoundland and the Flemish Cap Bank in spring/summer 1981.

Materials and methods

Due to some difficulties with instrumental measurements of currents the only way to tackle the task is to use indirect methods based on hydrodynamic models. An essential disadvantage of such methods is that any of these models, however perfect they are, allow us to obtain only a certain approximation to real conditions. This fact as well as shortcomings of the input data for calculations stipulate the necessity to approach qualitative characteristic of circulation with great care, thereby limiting the possibility of its analysis within a qualitative aspect. Nevertheless, the qualitative results are also of great value if they reflect correctly the corresponding features of the actual field of oceanic water movement.

Taking these remarks into consideration the authors decided to abandon calculations based on compound models and turned to a well-tried in an oceanologic practice dynamic method. This method resulting from the model of geostrophic movement proved itself in a good light in long-term investigations of water circulation in the Labrador and Newfoundland areas. Papers of the participants of the International Ice Patrol Program contributed to its wide application, these papers showed that charts of calculated currents reproduce in a large scale the field of water movement which is well-known from long-term observations on drift of vessels, ice and icebergs; it also conforms to the water masses distribution (Smith, Sole and Mosby,1937). Correctness of this method was confirmed by further investigations of water circulation in this area, besides, an additional evidence in favour of the dynamic method was obtained during those investigations. In particular, comparing dynamic topography of the sea surface with the data on surface currents in the Flemish Cap area obtained with modern instruments it was determined that that method reflected the qualitative picture of mesoscale circulation of surface waters over the bank (Kudlo and Borovkov,1980). Taking the dynamic method as a designed one we can not by-pass the question of determining the reference surface on which according to the demands of the method a condition of immobility or neglrctably weak water movement should be observed. Solving of this problem is complicated by lack of measurements of vertical speed profile and also by lack of a reliable objective method for determination of water layer with zero or minimal speed which would be able to use data of usual oceanographic observations. In this connection it's worth saying that the results of qualitative control for calculations of surface currents in tha Labrador and Newfoundland areas testify that the reference surface taken in a layer from 200 to 1000-2000 m usually to a certain extent complies with necessary requirements.

An additional indirect evidence that in the shelfy zones of the areas mentioned and also over the Flemish Cap Bank currents become weak from the depths about 200 m may serve the fact that the boundary of the area with grounds containing fine silty particles is situated mainly in depths from 150-170 to 200-250 m. Absence of silty fractions in sediments of lesser depths is related, apparently, to greater mobility of water near bottom on banks shoals and also on the coastal part of the shelf.

Considering all the above mentioned for assessing specific features of the surface currents field in the shelfy zone of the Labrador and Newfoundland areas and also over the Flemish Cap Bank in spring/summer 1981 the 200-m layer had been taken for the reference surface. Materials of standard deep-water observations on temperature and salinity of water collected during cruises of the PINRO vessels (Table 1) were taken as the initial ones.

Calculation of the dynamic heights for each station were made in accordance with the standard program on the PINRO "Minsk-32" electronic computer. In order to reduce the dynamic heights of the shallow-water stations to the reference level we used the method recommended by M.M.Somov (1937). The results of calculations are presented as schemes of dynamic topography of sea surface relating to the periods of observations. Dynamic horizontals on all the charts are plotted with the interval of 2 dynamic cantimeters.

In order to assess the dynamic state of the Labrador Current we calculated the values of volume transport through the parts of some oceanographic sections crossing this current. A stepped reference surface approximating the continental slope topography and that of the shelf edge was used in those calculations. The results of calculations were compared with mean long-term values of water transport taken from curves of seasonal changes of the characteristics mentioned.

Table 1 Information on standard hydrologic observations in the Northwest Atlantic areas carried out by the PINRO vessels in March/July 1981

Vessel, cruise No	Period of observations	Area of observations	Number of stations with t^{o}, S‰ measurements
"Gemma",23	March 22 - July 1	3 KLMN	310
"N.Kononov", 4/81	June 1 - July 28	2J, 3 KLMNO	176
"Persey III", 24	May 29 - June 14	3 LNO	39

Results

Analysing the data obtained it would be expedient to start with characterizing the most large-scale feature of horizontal circulation of the Labrador Current waters. In the dynamic topography of the surface reconstructed on base of June (Fig.1) and July (Fig.2) observations this current appeared as a stretched pencil of dynamic horizontals the densest concentration of which corresponds to the core of the stream. On the part of the current from the South Labrador to the northern edge of the Grand Newfoundland Bank the current moved as a comparatively wide flow the maximal speed of which were localized in the vicinity of the shelf edge. Over the northern slopes of the Grand Bank the current divided into two separate branches - coastal and main. A relatively weak coastal branch doubled the Avalon peninsula by its usual trajectory moving southward along the eastern coast and westward - along the southern coast. The main branch of the current spreading to the south along the eastern slopes of the Grand Bank in June weakened noticeably because of separation of peripheral streams. Branching off streams from the left wing of the current took place also on parts of the eastern slopes of the North Newfoundland Bank.

Parallel with unequal attenuation of the current along the trajectory which is conditioned by tearing off the streams the charts presented reveal irregular speed pulses both in the core and in the current wings. These pulses correspond to an interchange of convergence and divergence zones connected with undulating disturbances of geostrophic streams. A part of such disturbances (deformations of stream lines in the Northeast Newfoundland shelf area may serve as an example, see Figs 1 and 2) according to the character of its occurence conforms to non-stationary meanders which are formed, apparently, due to dynamic instability of movement. We can't exclude, though, that some disturbances, especially small-scale ones, from the last part may be a consequence of some unevoidable errors in the input data and/or a distorting effect of internal waves, tidal and inertial fluctuations.

All the features of speed changes in surface water geostrophic movement along the trajectory of stream are revealed in the geostrophic integral transport distribution as well.

Thus, a decrease of surface speed along the main branch in June (Fig.1) corresponded to general decrease of water transport in the Flemish Cap Deep (section Flemish Cap) up to the "tail" of the Grand Bank (section CG-2) composing in late June / early July 4.1Sv (Table 2).

Table 2 Labrador Current transport, its norms and anomalies on standard sections of the Northwest Atlantic in 1981 (according to the data of 23 cruise of R/V "Gemma")

Section, part, layer	Period	Transport, 10^{-6} m^3 x c^{-1}		
		1981	norm	anomaly
Flemish Cap, H_1GH_2, 0-bottom	June 29-30	7.0	3.3	3.7
4-A, 4-12 stat.,0-1000m	April 9	3.7	4.8	-1.1
CG-3,11-14 stat.,0-2000m	April 8	8.9	5.3	3.6
CG-3,11-14 stat.,0-2000m	May 11	7.7	4.4	3.3
CG-2,12-15 stat.,0-1000m	July 4	2.9	2.9	0

Comparing transport in April through sections 4-A and CG-3 with corresponding surface speeds a southward increase of transport which conforms to longitudunal pulsation of speed of surface geostrophic movement was indicated on some parts of the trajectory of current.

The picture of surface circulation expressed by the dynamic topography scheme (Fig.1) has a specific feature - a system of anticyclonic rotation of water that is located over the Grand Bank shoals and over the Flemish Cap Bank. According to their position and direction of rotation these vortices conform to well-known from some theoretical and experimental works addies or Taylor columns which present one of the forms of adaptation of streams to topographic impediments of seamountains or sea hills type. The character of evolution of one of the indicated dynamic formations in the period from late March to earl early July is shown on Fig.3. From this picture we may conclude that the main tendency of anticyclonic geostrophic vortex evolution in the surface layer over the Flemish Cap Bank consisted of the increase of vortical formation size and that of water rotation speed in the field of the vortex. Besides, from the figure one can see that the center of the anticyclone was displaced spatially at the same time remaining in the limits of the zone with depths not exceeding 300-400 m. Taking into consideration frequency of surveys we may judge also on stability of anticyclonic form of circulation over the Flemish Cap Bank in the period of observation.

All the features of structure of surface water geostrophic movement may be considered as an indication of the fact that in 1981 there existed favourable conditions for accumulation in the boundaries of the Flemish Cap Bank both ichthyoplankton of the main commercial fishes inhabiting this area and zooplankton on which fish larvae and fries feed. In accordance with the cinclusion (Kudlo, Borovkov, 1977; Kudlo and Boytsov,1979) about a significant role of passive hydrobios condition of accumulation in reproduction of Flemish Cap cod it follows that cod generation which appeared in 1981 should be an abundant one. Hence, we may expect an abrupt increase of the Flemish Cap cod stock in 1984-85 when the main mass of fish of that generation will be of commercial size.

Conclusions

Geostrophic circulation of water in shelfy zones of the South Labrador areas in June and also in those of Newfoundland in June/July 1981 had the typical structure which is characterized by a combination of a system of meandering streams of the Labrador Current and anticyclonic vortical formations over the Grand Bank shoals and also over the Flemish Cap Bank.

In spring/summer 1981 the surface water geostrophic circulation over the Flemish Cap Bank had a stable anticyclonic character which is a sign of favourable conditions for ichthyoplankton generation survival and for formation of abundant generation of the Flemish Cap cod.

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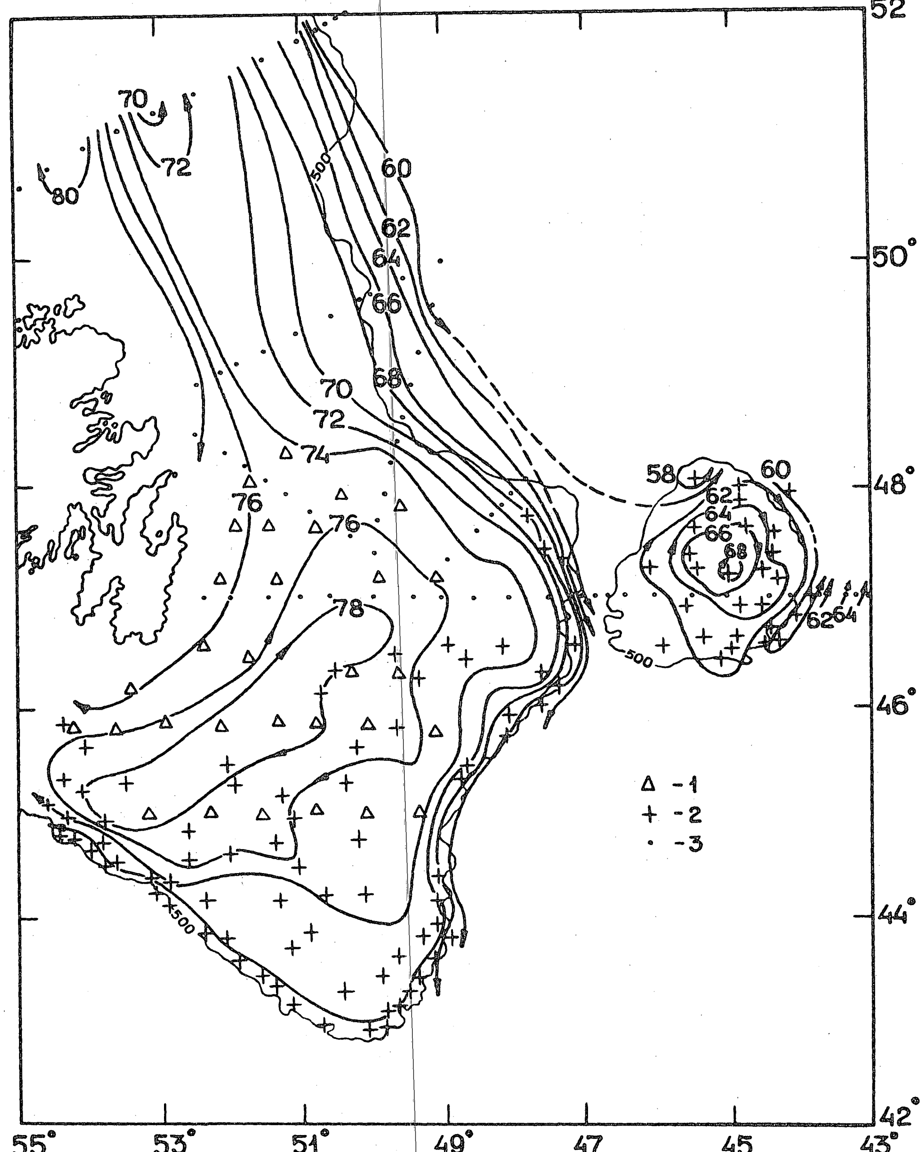

Fig.1. Conditional dynamic topography (in dyn.cm) of sea surface relatively to 200 m layer in areas of Newfoundland and the Flemish Cap Bank in the period 29 May-1 July 1981.
1 - 24 cruise of R/V "Persey III" stations, 29.05-14.06;
2 - 4/81 cruise of R/V "N.Kononov" stations, 1-29.06;
3 - 23 cruise of R/V "Gemma" stations, 20.06-1.07.

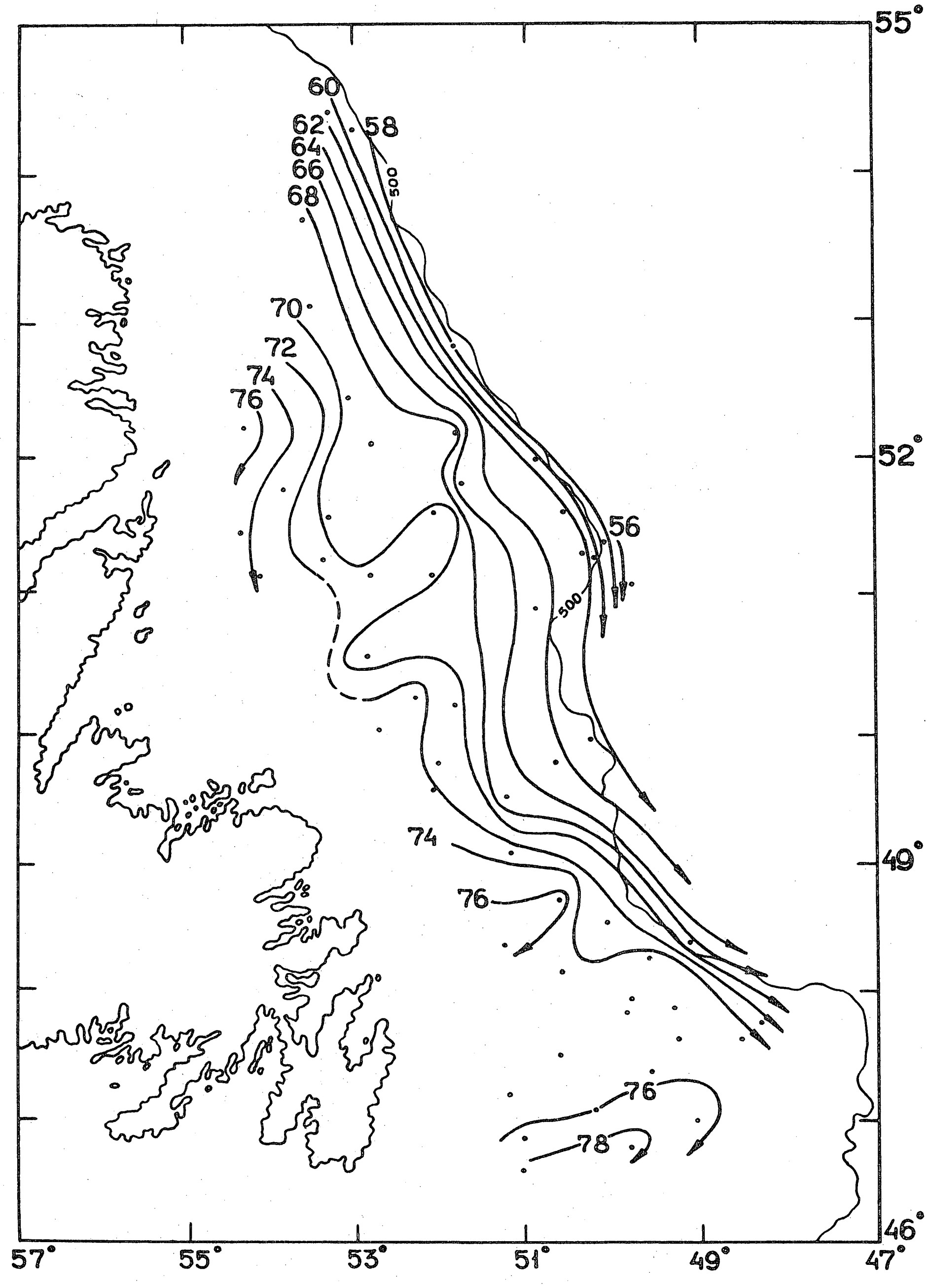

Fig.2. Conditional dynamic topography (in dyn.cm) of sea surface relatively to 200 m layer in areas of the South Labrador and Newfoundland in the period 5-28 July 1981 (acc. to 4/81 cruise of R/V "N.Kononov" data).

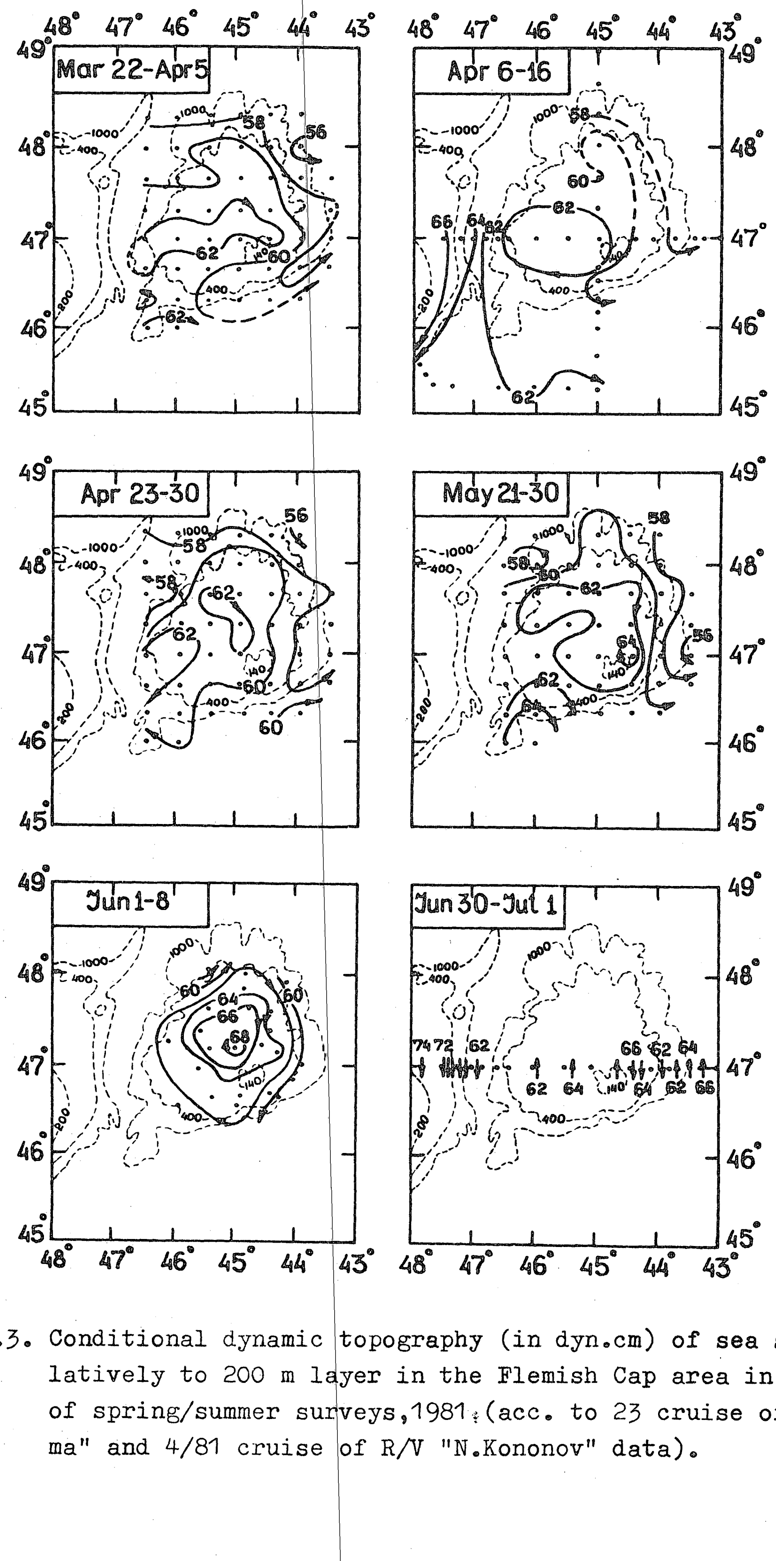

Fig.3. Conditional dynamic topography (in dyn.cm) of sea surface relatively to 200 m layer in the Flemish Cap area in the periods of spring/summer surveys,1981 (acc. to 23 cruise of R/V "Gemma" and 4/81 cruise of R/V "N.Kononov" data).