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Abstract

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On the Dynamic Characteristics of the Subpolar Front in the North Atlantic

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In oceanography there is no single opinion as to what should be taken as the criterion for defining a front in the ocean on the basis of a dynamic characteristic. By this characteristic we define the position of a front on some horizontal surface as the zone where the horizontal gradients of the velocity of the horizontal current are maximal. However, for the practical establishment of the position of a front we adopt a formally different condition: the maximum horizontal gradient of the vertical velocity of the current; it is obvious that this criterion in essence does not differ from the preceding one, since, by the condition of conservation of continuity of motion, a discontinuity in the velocity of the horizontal current must be accompanied by a discontinuity in the vertical velocity. The use of the latter characteristic is expedient in that, simultaneously with determining the position of the front, a picture of the vertical motions is obtained, and the study of the vertical circulation in the region of the front is of special interest.

The criterion adopted by us was used to calculate the position of the subpolar front in the North Atlantic. The vertical velocity was determined by the formula

$$w = \frac{1}{f}\left(\beta \int_0^z v_r\,dz - \operatorname{rot} T_a - \frac{\beta}{f} T_{ax}\right), \tag{1}$$

where f is the Coriolis parameter; β is the latitudinal variation of the Coriolis parameter; v_r is the velocity of the gradient-convective current along the z axis; T_a is the tangential wind stress at the sea surface (T_{ax} is the component of the wind stress along the x axis); the z axis is directed vertically downward, the origin is located at the sea surface; the x axis is directed eastward, and the y axis northward.

The values of the vertical velocity were calculated for spring (March–April) and autumn (August–September) 1958 at the horizons 100, 200, 300, and 400 m. The quantities v_r entering into formula (1) were found by the Helland-Hansen–Sandström method; the 1500 m horizon was adopted as the reference surface. The density field was determined on the basis of observational data from the expeditionary vessels *Mikhail Lomonosov*, *Anton Dohrn*, and *Gauss*,

Figure 1

Figure 1: Figure 1

which worked under the IGY program in spring and autumn 1958. The wind necessary for calculating T_a was computed from atmospheric pressure, which was taken from the monthly mean charts for 1958 obtained in the World Maps Department of the Central Forecasting Institute. The transition from wind velocity to tangential stress was made according to the well-known Neumann formula.

After calculating the vertical velocities, their horizontal gradients were found, and then, for spring and autumn, the coordinates of the points where the gradient values were maximal were determined. To determine the position of the front on a horizontal surface, the depth of 200 m was chosen because, according to the characteristics of the water masses, the front is expressed here most clearly.

sharply. The results of the calculation of the spring front are presented in Fig. 1. Here, for comparison, the positions of the front determined according to a static criterion are shown: one line gives the points with the greatest horizontal density gradients, the other separates two different water masses identified as a result of $T{-}S$ analysis. As can be seen, the position calculated on the basis of the criterion we adopted agrees quite satisfactorily with the positions obtained by using static characteristics and which may be regarded as reference ones.

Fig. 1. *a*—calculated position of the subpolar front in the North Atlantic for spring at a depth of 200 m; *b* and *v*—lines of the position of the front determined from the maximum horizontal density gradient (*b*) and from the difference in types of water masses (*v*); *g*—isolines of vertical velocities (in $1 \cdot 10^{-4}$ cm/sec); the region of water sinking is hatched.

The calculated position of the autumn front also corresponds well to the position found from the distribution of density, temperature, and salinity of the waters. Thus, the method we used can in a number of cases be recommended for determining frontal zones.

After calculating the position of the front on a horizontal surface, the degree of its intensity at different horizons was estimated. The front reaches its greatest intensity at 200 m; at 300 and 400 m the front is less pronounced. In the near-surface layers of the ocean its sharpness is the least.

According to the well-known Margules formula

$$\operatorname{tg}\gamma = \frac{f}{g}\frac{\rho V - \rho' V'}{\rho' - \rho} \tag{2}$$

for spring and autumn the inclination of the frontal surface relative to the

Figure 2

Figure 2: Figure 2

horizon was determined. In formula (2), ρ, V and ρ', V' are the mean values of density and of the component of the gradient-convection current velocity in the layers respectively above and below the separation surface; the component V is directed along the frontal surface; the values of V were determined in the same way as the quantities of the components v_r. At different points of the front the angle of inclination is 0°12—0°23, i.e., in depth–

Fig. 2. Mean positions of the spring (a) and autumn (b) fronts at a depth of 200 m. The numbers along the front line indicate the mean velocities of displacement of the front from spring to autumn.

the front is situated very gently. An estimate of the slope of the frontal surface, made from the indicated static characteristics, leads to similar results.

On the basis of seasonal changes in the position of the front at a depth of 200 m, the velocities of its displacement were found. From spring to autumn the velocity values are 1-4 cm/sec (Fig. 2). These magnitudes correspond to the values of the velocity components of the geostrophic current normal to the front. It is interesting to note that in spring and autumn the front occupies approximately the same position.

Thus, the calculations carried out made it possible to establish the spatial position of the subpolar front in the North Atlantic and its seasonal variability. At the same time, it may be assumed that the front does not undergo significant seasonal displacements along its entire extent, but the configuration of the front changes considerably.

The calculation of vertical motions in the frontal zone showed that an integral part of the general dynamics of the waters here consists of upward motions that persist throughout the year and, to a significant extent, determine the high biological productivity of the frontal zone.

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Note: Figure translations are in progress. See original paper for figures.