International Council for
the Exploration of the Sea

C.M. 1977 / C : 26
Hydrography Committee

The calculation of absolute currents from hydrographic data alone

by
Friedrich Schott
Institut für Meereskunde
University of Kiel, F.R. Germany

1. The method

The classical problem of physical oceanographers has been to obtain the distribution of velocity from the observed density field. The assumption of geostrophy allows the calculation of the vertical shear of the horizontal velocity, which upon vertical integration produces an integration constant that must be determined by some further constraint. The usual way to overcome this difficulty is the application of conservation of certain properties. The method we presented (Stommel and Schott, 1977) depends also upon the conservation law of some property such as density, assuming that cross-isopycnal mixing is negligible. But it also assumes that potential vorticity is conserved and that relative vorticity is small. The relation between the slopes h_x, h_y of density surfaces h (x, y) and absolute currents u, v then is found to be

$$uh_{xz} + v(h_y - \beta z/f)_z = 0.$$

Inserting the geostrophic currents u', v' with respect to a reference level where the unknown absolute currents are u_o, v_o and writing the above formula for several depths z_j gives us an overdetermined system for the calculation of u_o, v_o:

$$u_o h_{xz_j} + v_o (h_{yz_j} - \frac{\beta}{f}) = -u_j' h_{xz_j} - v_j' (h_{yz_j} - \frac{\beta}{f}).$$

This means that absolute horizontal currents - and by use of the conservation law also the vertical currents - can be calculated merely from the vertical derivatives of the isopycnal slopes and from geostrophic currents.

This simple relation implies that the current vector has to turn with depth (beta spiral), similar to what an Ekman current does. The sense of rotation, in the big mid-ocean gyres, has to be cyclonic with decreasing depth.

2. Problems in application to existing data

We applied this method to data sets from the North Atlantic (points A, B in fig. 1) and South Atlantic and from the Pacific. It was found that the open ocean circulation, in fact, seems to be governed by the vorticity balance law underlying our model. However, the available data showed two major problems for the analysis:

1. We had to calculate the meridional and zonal gradients between single sections which were taken in different seasons or even many years apart.

2. Super-imposed on this distortion of slopes by seasonal or long-period fluctuations was the effect of eddy noise with scales of the order of 100 km which especially spoiled the weak zonal slopes in our subtropical sections.

In subpolar regions with deep-reaching vertical convection in wintertime the conservation equation has to be supplemented by a local in-situ source term describing the density increase. We found, with data from the I.G.Y. atlas of DIETRICH (1969) for point C in fig. 1, that this cooling effect is so strong that the beta-effect cannot govern this spiral any more. The cooling effect also generates a current spiral which, however, turns anticyclonic with decreasing depth. With existing data we were only able to explain the overall change of current direction with depth by use of some budget estimates of heat and water flux through the surface. A more accurate evaluation of the cooling spiral is not as easy as the beta-spiral analysis and needs more data on the air-sea interaction processes.

3. Proposed "sections of opportunity"

More hydrographic data from the eastern North Atlantic along fixed sections are needed to reduce the influence of seasonal and larger-scale fluctuations and to eliminate eddy noise.

It would be very helpful when research ships could run along agreed-upon sections and do hydrographic stations. Three sections are proposed along which station data should be obtained (fig. 1):

one north-south section along 20°W which is about along the axis of the eastern basin, from 55°N down to 35°N;
one east-west section along 50°N between 13°W and 27°W;
one east-west section along 40°N between 13°W and 27°W.

For hydrographic station data taken along one of these sections the following recommendations apply:

1. Time: any time of year would be good
2. Station spacings: Less than 50 km to get rid of eddy wiggles
3. Type of measurement: STD data are preferred, because they allow better determination of depths of isopycnal surfaces than hydrocasts but these are also welcome.
4. Depth range: Main emphasis between 100 m and 1500 m but deeper data welcome.
5. Sections preferred: The cross in the Iberian Basin, i.e. the part 35°-45°N of the N-S section and the section 13°W to 27°W is the most interesting one at present.

The perfect case would be when both legs could be worked up at the same time.

References

Dietrich, G. (1969) Atlas of the hydrography of the northern North Atlantic Ocean. 140 pp. Copenhagen

Stommel, H. and F. Schott (1977) The beta spiral and the determination of the absolute velocity field from hydrographic station data. Deep-sea Res. 24, 325-329.

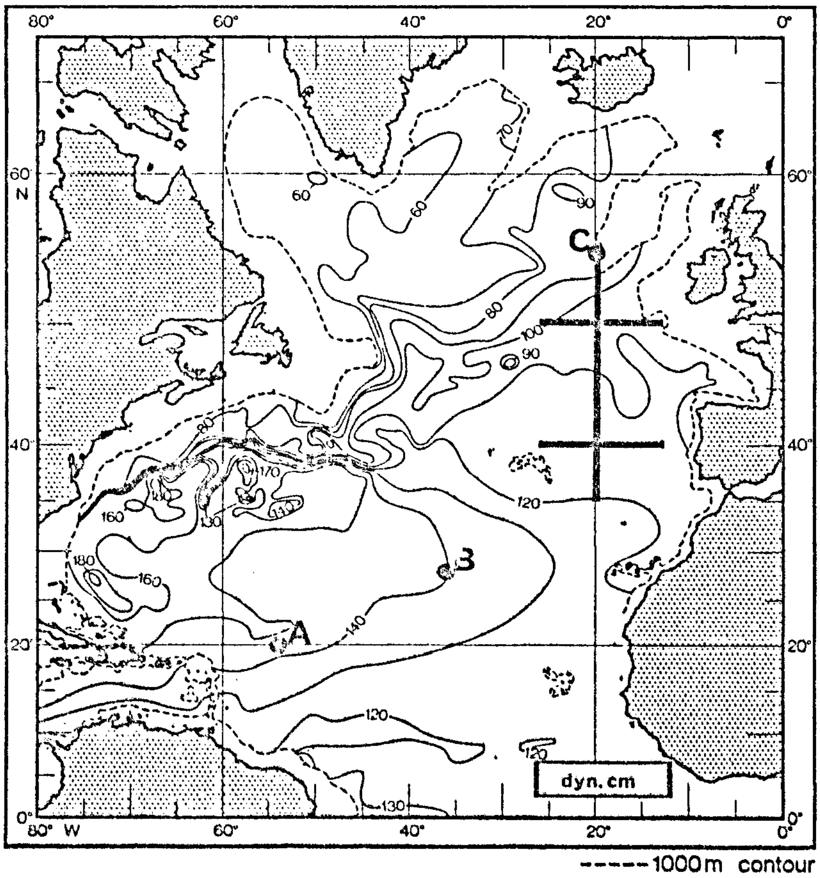

Fig. 1: Dynamic topography of 1500 db relative to 100 db with points A, B, C where current spirals were analysed.