https://doi.org/10.17895/ices.pub.19271993

APPENDIX B

THE HYDROGRAPHY OF THE FÆROE-SHETLAND CHANNEL IN 1902 AND 1903

BY

B. HELLAND-HANSEN

WITH 4 FIGURES IN THE TEXT

(TRANSLATED FROM THE GERMAN BY *H. M. KYLE*)

Since August 1902, a rich material has been collected during several seasonal cruises in the Færoe-Shetland Channel which forms part of the Scottish region in the international investigations of the sea. This material has been worked up and has now been published in two larger papers: "Hydrographical Investigations of the Færoe-Shetland Channel and the Northern Part of the North Sea during 1902" by the present author, and "Scottish Hydrographic Research during 1903" by A. J. Robertson. As the results of these investigations are also of importance for the other North European seas, a short summary of the contents of the papers mentioned will be given in the following pages.

The observations in the Channel have been made along two almost parallel lines: a northern from a point N. W. of Shetland to the Færoes, and a southern, which runs from a point S. of the Færoes to Fair Island between the Orkneys and Shetlands. Schematic sections along the more southerly of these two lines are shown in the Figures 1—4 (p. 15) for four different periods. Only one complete series of observations in the Channel is available for the winter half-year, viz. for December 1902, as heavy storms have rendered work impossible in the other months of the seasonal cruises.

The peculiarities of the hydrographical conditions in the Channel, which have appeared each time during the investigations of these two years, are as follows: the Atlantic Stream ("Gulf Stream") has always been passing through the Channel as a surface-current on its way towards the Norwegian Sea; water from the western part of the Norwegian Sea has been streaming on the surface round the north of the Færoes into the western part of the Channel; and lastly the heavy cold bottom-water, which fills the depths of the entire, large basin of the Norwegian Sea, was pressing along the bottom of the Channel. The dimensions of these different water-masses and their mutual relations, change greatly within a tolerably brief space of time, as the figures clearly show. The regional variations have also been found to be very great, so that it is necessary to have stations quite close to one another in order to be able to follow the variations. As the network of Scottish observation-stations has been fairly complete, however, it has been possible to study these variations in a much better way than hitherto.

If we investigate the Atlantic Stream, first of all, we find that it changes very greatly in extent, in rapidity of flow and partly also in direction. Its main portion is represented

in the figures by trebly crossed lines, indicating water of higher salinity than 35·25 ‰. The Stream enters the Channel from the Atlantic in a direction varying between north-east and south-east, and when in the Channel, follows a more northerly course along the Shetland bank. In August 1903, the Stream came along the southern section, so that Fig. 4 gives partly a longitudinal section through the Stream whilst the other figures are cross-sections. In 1902 and 1903, the Stream was limited as a rule to the eastern half of the Channel in the neigbourhood of the Shetland Isles, which may have been quite surrounded by the strongly saline Atlantic water. From time to time, indeed, the Stream fills almost the whole surface of the Channel between the Færoes and the Shetlands; but these are obviously only exceptional cases. The depth of the water which streams through the Channel into the Norwegian Sea, can in general be placed at 5—600 m.; the relatively unmixed Atlantic water, with a salinity of over 35·25 ‰, has a depth varying between 200 and 500 m. With the help of V. Bjerknes' dynamic theory, numerous approximations have been calculated for the rapidity of the Stream's flow[1]. These calculations have given the following results amongst others: in August 1902, the average rapidity on the surface was about 10 sea-miles per 24 hours (0·2 m. per second); in December of the same year, it was probably a little less; in May 1903, it was about 15 sea-miles (0·3 m. per second) and again about 10 s. m. in the following August. The rapidity of flow varies but little in the upper few hundred meters; sometimes the greatest rapidity of flow is at a depth of about 100 m. Great masses of water are therefore carried by the Stream into the Norwegian Sea. An attempt to calculate this quantity for August 1902 gave 4,000,000 m^3 per second.

The Atlantic Stream send offshoots into the North Sea, partly through the opening between Scotland and Shetland, partly round the north of Shetland. A distinct periodicity occurs in this inflow of Atlantic ocean-water into the North Sea. It has long been known, that the northern North Sea plateau (north of the Dogger Bank) was covered by water of very high salinity, which in summer had a temperature as low as ca. 7° C.; the true North Sea water of lower salinity lies above this bottom-water as a layer 40—60 m. thick. The temperature remains almost the same throughout the whole year, but was a little higher in December 1902 than, for example, in August. Regular observations have now shown, that this North Sea bottom-water is of Atlantic origin and that it comes into the North Sea almost exclusively in the winter half-year. In December 1902, it began, as a branch of the Atlantic Stream, to pour into the North Sea round the north of Shetland; later, in the first months of 1903, it possibly came mainly to the south of Shetland. The Atlantic water was then cooled down in the North Sea during the cold period of the year; in winter, the temperature at the bottom is a little higher than in summer, as the minimum spreads but slowly down into the depths. This water remains for the most part in the North Sea throughout the whole summer until the next winter; its movements in all probability are but slow. The same conditions are probably repeated regularly and not restricted to the two years spoken of here. The low bottom-temperature occasionally found in summer by earlier investigations speak in favour of this. The reason why the inflow of the Atlantic ocean-water through the

[1]) According to the method, described in Sandström and Helland-Hansen's paper: Ueber die Berechnung von Meeresströmungen (Report on Norwegian Fishery and Marine Investigations. II. 4. 1903.)

Færoe-Shetland Channel into the North Sea, is at its maximum in winter (in March in 1903, according to Robertson) and minimum in summer, must be sought for in several different circumstances. Thus, the magnitude and the direction of the Atlantic Stream play some part; secondly, the force with which the East Icelandic Polar Stream opposes the Atlantic Stream; also, the amount of inflow of freshwater from the Baltic

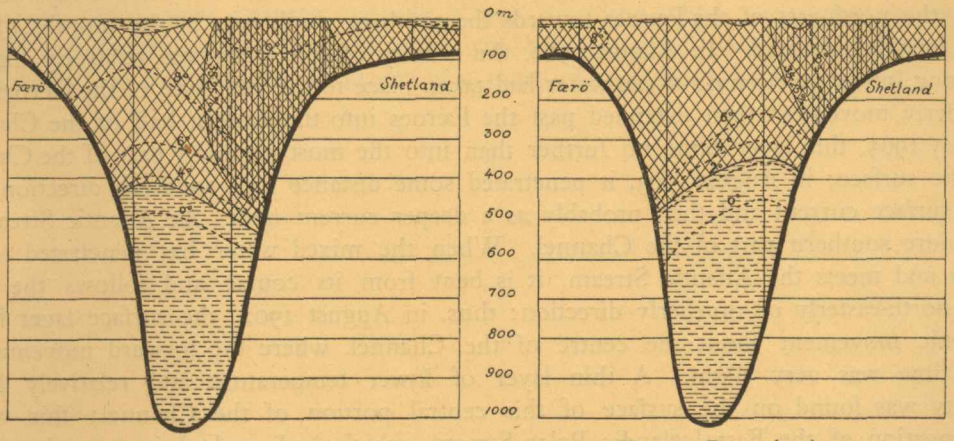

Fig. 1. August 1902[1]).

Fig. 2. December 1902.

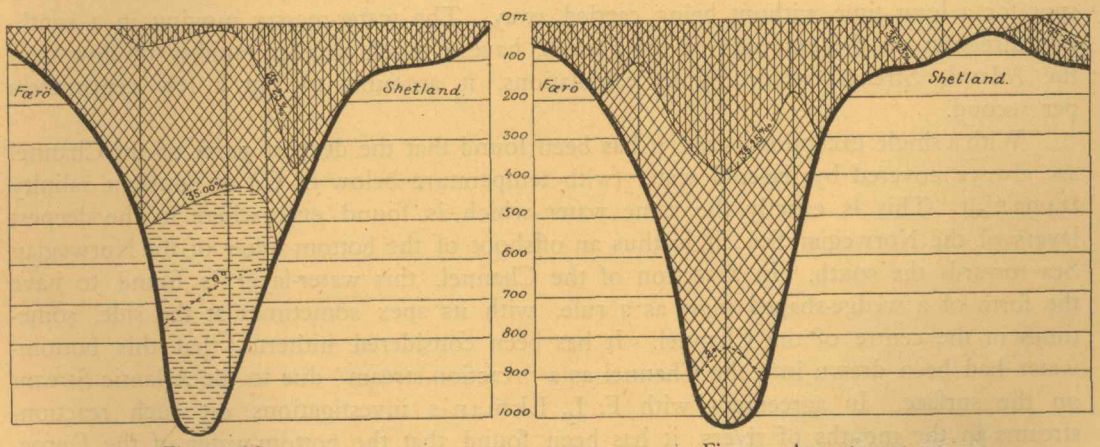

Fig 3. May 1903.

Fig. 4. August 1903.

N.B. The single broken lines represent water of 34—35 ‰ salinity.
The doubly crossed lines, water of 35—35·25 ‰ salinity.
The trebly crossed lines, water of higher salinity than 35·25 ‰.

Stream and so on. The explanation may also lie partly in the general circumstance, that the coastal water, when cooled in winter, presses backward towards the land, and again in summer, when warmed and thus of less density, spreads out from the land over the surface, just as observers have found it in the North Sea.

[1]) Where 0° stands in Figure 1, there should be 10°.

It is well-known, that a portion of the Atlantic ocean-water always streams between the Færoes and Iceland into the south-western part of the Norwegian Sea and there mixes with other water of less salinity, mostly from the East Icelandic Polar Stream. This mixed water runs mainly in an easterly direction; from it, a larger or smaller portion bends southwards into the Færoe-Shetland Channel after passing round the north of the Færoes. The impression was gained, that the masses of water were always tending from the north-east of the Færoes towards the south or south-east, in the months of 1902 and 1903 investigated. In August 1902, the salinity of this water was relatively high, as a strong inflow of Atlantic ocean-water had taken place to the west side of the Færoes; the southerly movement then extended past the Færoes into the western half of the Channel. In May 1903, this layer came no further than into the most northerly part of the Channel on the surface; in August 1903, it penetrated some distance in a southerly direction, first as a surface current and then probably as a deeper current under the Atlantic Stream in the more southern part of the Channel. When the mixed water has penetrated to the south and meets the Atlantic Stream, it is bent from its course and follows the latter in a north-easterly or northerly direction; thus, in August 1902, the surface layer had a cyclonic movement about the centre of the Channel, where the forward movement at that time was very slight. A thin layer of lower temperature and relatively lower salinity was found on the surface of this central portion of the Channel; this was a prolongation of the East Icelandic Polar Stream, which had pushed its way through a narrow opening to the north-east of the Færoes; probably it has remained at the same spot for a long time without being carried away. The water-masses moving in a southerly direction on the east side of the Færoes, have a much smaller rapidity of flow than the Atlantic Stream; according to calculations, it amounts to but a few centimeters per second.

With a single exceptional case, it has been found that the deepest parts of the Channel are always covered by ice-cold water (with temperature below 0° C.) of constant salinity (34·92 ‰). This is exactly the same water which is found everywhere in the deepest layers of the Norwegian Sea; it is thus an offshoot of the bottom-water of the Norwegian Sea towards the south. In a section of the Channel, this water-layer is found to have the form of a wedge-shaped mass as a rule, with its apex sometimes at the side, sometimes in the centre of the Channel. It has been considered hitherto, that this bottom-water had been drawn into the Channel as a "reaction-stream" due to the Atlantic Stream on the surface. In agreement with F. L. Ekman's investigations on such reaction-streams in the mouths of rivers, it has been found that the bottom-water of the Færoe-Shetland Channel rose higher towards the surface in the southern than in the northern part. This appears to have been the case also in December 1902, though to a small extent, and again in May 1903, but not in the two August months. It is probable that the bottom-water often moves like an "active" stream; calculations with regard to the deepest layers, have given a rapidity of flow of several centimeters in the second. It has also appeared, that temperature variations may be relatively large (several tenths of a degree) within a short time, in depths as great as 1000 m. Thus in August 1903, the bottom-water generally present had quite disappeared from the southern part of the Channel (see Fig. 4); at 1000 m., the salinity was then 35·03 ‰ and the temperature

1·7° C. As Robertson believes, the unusual bottom-water was a continuation of the mixed water from the northern part of the Channel.

It will be clearly seen from the figures, that very important variations occur in the hydrographical position, not only during the year but even in the same month, when one year is compared with another. (See Figs 1 and 4, for example, both sections being for August). It is only when the investigations will have extended over a larger number of years, that clearness will be gained regarding which variations are perhaps periodic and occur so that their regularity may be ascertained, what their cause is, and which variations on the other hand are of a more chance character.