"The Circulation of the Surface Waters of the North Atlantic Ocean." By H. N. DICKSON, B.Sc. Communicated by Sir JOHN MURRAY, K.C.B., F.R.S. Received March 23,—Read May 17, 1900.

(Abstract.)

In this paper an attempt is made to investigate the normal circulation of the surface waters of the Atlantic Ocean north of 40° N. lat., and its changes, by means of a series of synoptic charts showing the distribution of temperature and salinity over the area for each month of the two years 1896 and 1897.

The temperature observations discussed (numbering over 16,000) were obtained from the meteorological and hydrographical departments of the countries bordering on the North Atlantic, and special arrangements were made with the officers of a number of ships for the continuous supply of samples of surface waters for analysis.

The salinity of the samples obtained was determined by volumetric estimations of the amount of chlorine present. Over 4,000 samples were dealt with in this way, and special attention was devoted to ascertaining the accuracy of the methods employed. A large number of estimations were also made of sulphates present in the waters, and the limits of variation from a definite ratio of chloride salinity to sulphate salinity determined.

The specific gravity of over 500 of the samples was determined with the pyknometer, and a formula connecting the results of these determinations with the salinities derived from chlorines investigated.

The numerical results of the chemical and physical determinations are exhibited in a table, forming a substantial addition to the material available for the discussion of oceanographical problems of this kind.

The principal conclusions arrived at with reference to the circulation may be summed up as follows :—

1. The surface waters along the whole of the eastern seaboard of North America north of (about) lat. 30° N., consisting partly of water brought from the equatorial currents by the Gulf Stream, and partly of water brought down by the Labrador current, are drifted eastward across the Atlantic towards south-western Europe, and banked up against the land outside the continental shelf. This continues all the year round, but it is strongest in summer, when the Atlantic anticyclone attains its greatest size and intensity; and the proportion of Gulf Stream water is greatest at that season.

2. The drifts in the northern part of the Atlantic area are under the control of the cyclones crossing it. The circulation set up accordingly reaches its maximum intensity in winter, and almost dies out in summer. In winter the drifts tend to the south-eastward from the

mouth of Davis Strait, eastward in mid-Atlantic, and north-eastward in the eastern region. In spring and autumn the movement is more easterly over the whole distance, and a larger quantity of water from the Labrador stream is therefore carried eastward.

3. The water banked up in the manner described in (1) escapes partly downwards, partly southwards, and partly northwards. It occupies the whole of the eastern basin of the North Atlantic, and to the north it extends westward to Davis Strait, being confined below 300 fathoms depth by the ridges connecting Europe, the Faeroes, Iceland, and Greenland. Above that level it escapes northward by a strong current through the Faeroe-Shetland Channel and between Faeroe and Iceland, and by the two branches of the Irminger stream, one west of Iceland the other west of Greenland.

(As it seems desirable that this northerly current should have a distinctive name, it might be well to call it the European stream, and its branches the Norwegian, Irminger, and Greenland streams respectively.)

The strength and volume of the European stream is liable to considerable variation, according to the form and position of the Atlantic anti-cyclone, which causes the amount of banked up water, and the proportions escaping northward and southward, to vary. It is also modified by the strength and direction of the surface drifts in its course. It is, however, always strongest in summer.

4. The Norwegian stream is by far the largest branch of the European, and it traverses the Norwegian Sea and enters the Arctic Ocean. The warm water thus sent northward melts enormous quantities of ice, and the fresh water derived from the ice moves southward in autumn, chiefly in a wide surface current, between Iceland and Jan Mayen, which may entirely cover other parts of the Norwegian stream. Part of the surface water also comes southward through the Denmark Strait, but the amount is much smaller, probably chiefly because the melting of the ice is slower, and the channel is longer blocked.

The Greenland branch of the European current also causes melting of ice in Davis Strait, but the warm winds from the American continent and the water received from the land are probably more effective in increasing the volume of the Labrador current.

5. The water from the melted ice is spread over the surface of the North Atlantic during late autumn and winter by the increasing drift circulation, and it is gradually absorbed by mixing with the underlying water.

6. The circulation described is liable to extensive irregular variations, corresponding to variations in the atmospheric circulation.