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Fog Forecasting and Sea-Surface Temperature

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1. THE SEA-SURFACE TEMPERATURE IN THE NORTHERN NORTH SEA AND THE SOUTH-EASTERN NORWEGIAN SEA.

This paper is a continuation of FINN SPINNANGR's: Om varsling av tåke i Vest-Norge (On Fog Forecasting in Western Norway), Bergens Museums Årbok 1941, Nr. 5. SPINNANGR pointed out that the sea-surface temperature over the North Sea, especially that of the coast water, plays a considerable rôle for the formation and forecasting of fog. The mean sea-surface temperature charts mentioned there, have now been worked out by EGGVIN and are reproduced in Figs. 1—12.

The charts represent the sea-surface temperature in the 5-years period 1935—39, expressed as monthly means. The chief part of the material consists of registrations obtained by means of sea-thermographs, which have been installed by the Fiskeridirektorat in Bergen on board several coasting boats and liners, in the following routes: 1. Oslo —Bergen, 2. Bergen—Kirkenes (Finnmark), 3. Bergen—Stavanger—Rotterdam—Eigerøy (Egersund), 4. Bergen—Newcastle, 5. Bergen—South-Iceland and 6. Bergen—North-Iceland. Furthermore, the material from several research ships and liners using bucket and thermometer has been used.

A great part of the material has been forwarded to us by the International Council for Exploration of the Sea, Copenhagen. We have also got some material from The Geophysical Institute in Bergen. The above material, together with the oceanographic material from the Fiskeridirektorat, is more extensive than any taken in a previous 5-years period in this region.

In a number of positions on the different routes the temperature has been plotted day by day from the thermograms in diagrams. Then the mean temperature for each month was found by means of area calculation. The whole chart is divided into a number of areas, 1° of longitude by ½° of latitude. The material was plotted on a chart for each of the 60 months concerned. Then the monthly mean temperature for each area was computed. In doing this the observations have been reduced to the middle of the month. In the case of disagree-

ments between the thermograph registrations and observations taken on board steamers by bucket and thermometer, the computations have been based on the registrations. Evidently erroneous observations have been neglected.

In drawing the charts EGGVIN has also utilized the charts of temperature, salinity and current worked out on the base of oceanographic researches made by the Fiskeridirektorat during the years 1935—39 between Norway and Scotland—Shetland and in the sea farther north.

In the last four months of 1939 only the material from the Norwegian coast and the route Bergen—South-Iceland was obtainable. Values for the other areas of the chart had to be extrapolated for the months in question.

On the Norwegian coast the temperatures were taken from the thermograms in places situated either in the open sea or at places with free access to the sea. Making this choice all disturbances of purely local nature, which may easily arise in narrow waters and near land, are avoided. The charts, therefore, also near the coast, show the temperatures in the open sea.

Comparing our charts with previous observations we find that a general rise in the sea temperature has taken place from about 1920. In 1940, 1941 and partly also in 1942 the temperature fell again considerably over the regions from where we have observations. This is the case both as regards the temperature in the surface and in the deeper waters. This fact must probably be seen in relation to the extremely cold winters 1940, 1941 and 1942. In late autumn 1942 and in the course of 1943 the temperature in the water masses again rose to about the same values as those in the 5-years period 1935—39. Assuming that the three very hard winters 1940, 1941 and 1942 are a rare phenomenon, we are probably justified in supposing that the relatively high temperature in the sea will last in the near future. These charts, therefore, should give a truer expression for the mean temperature to be expected in future, than would have been the case if the mean charts also had included a longer period where the temperature was considerably lower than in the period considered.

Hitherto we have missed detailed sea-surface temperature charts for each month in the year north of 59° N. We hope therefore that our charts will be a valuable help for the solution of many questions of scientific and technical nature, especially within the oceanography, marine biology and meteorology.

2. FOG FORECASTING AND SEA-SURFACE TEMPERATURE.

The surface temperature, especially that of the coast water, may vary considerably from one year to the other. Thus, according to EGGVIN[1] the sea temperature off the whole Norwegian coast in February —April 1937 was lower than it was in the previous year. In the Korsfjord to the South of Bergen the March temperature in 1937 was 3.3° C lower than in 1936 and 3.8° lower than in 1938. The cause of these low sea temperatures in 1937 was meteorological-oceanographic. During the last half of January extraordinarily strong SE storms were prevailing over Southern Norway, the North Sea and the Danish waters. These strong winds forced Baltic water from the Belts and the Kattegat into the Skagerak, and the current continued towards the West and North-West off Sørlandet and Vestlandet. During the winter 1938 the sea temperature off the coast was much higher than in the two previous years, and minimum occurred in January along the stretch south of Bergen instead of in March as normally. Here we cannot deal further with these variations and their causes.

When using the mean charts in Figs. 1—12 for fog forecasting the meteorologist must take into account such long-lasting variations from the mean, and be in contact with the Oceanographic Division of the Fiskeridirektorat, which from its observation material will be able to predict a month in advance if the sea temperature off Western Norway may be expected to lie above or below the mean.

Furthermore, the meteorologist must take into account the short-lasting variations described below, which may occur.

A wind sets up a current in the ocean, which gets a component to the right of the wind direction in the northern hemisphere. The angle between the wind direction and the current in the sea surface is after EKMAN's theory 45°, provided there be no land intercepting the transport and that the sea is sufficiently deep. In our latitudes the velocity of the current is 1—2 % of the wind velocity. In NW wind along Lindesnes—Jæren, N wind along Vestlandet and NE wind along Møre —Trøndelag a sea-surface current pointing from land is created. The surface water which is thus transported from the coast, must be com-

[1] JENS EGGVIN: The Movements of a Cold Water Front, Fiskeridirektoratets skrifter, Vol. VI. No. 5, 1940.

pensated by water from below. In *summer*, this water is *colder* than the surface water. In northerly wind the sea-surface temperature near the coast may therefore fall considerably from one day to the other, along the coast Lindesnes—Jæren up to 2—3°. Such falls in the surface temperatures are greatest along the coast mentioned, partly because there are no islands to hamper the free transport of surface water out from the coast, and partly because the temperature difference between the surface and e. g. 50 m depth is greater there than farther north. If the northerly wind prevails for some days, the surface temperature may fall much near land. EGGVIN mentions a case where the surface temperature off Jæren in the course of five days, which passed between the registrations, at the end of June 1936 fell from 17.4° to 8.0°, i. e. *9.4°*. During this period the wind was N 5—6 Beaufort.

Also along Vestlandet the temperature-fall near land on account of the N wind may be so considerable that it may cause fog formation along the coast. The sea-surface registrations on board the »Lyra« show some examples hereof. In these cases the sea-surface temperature along the coast and 20—25 km off the coast was some two degrees lower than farther west. A slight and moist northwesterly air current came towards Vestlandet, and the cooling over this fairly narrow belt of colder water near the coast was enough to cause fog. This was observed both on the ship and along the coast (Hellisøy).

The fall in the surface temperature when a N wind is blowing, is not always of the same magnitude. This effect is greatest in June and July, but then it will decrease as the summer warming of the waters penetrates down to greater depths.

We can, however, say that when a N wind has been blowing along Vestlandet and a NW wind along the coast Jæren—Lindesnes of force 5—6 Beaufort for a couple of days, and we then e. g. get SW wind of Tropical air, the probability of fog will usually be *greater* — especially along the coast Jæren—Lindesnes — than if southerly winds had been blowing during the previous days.

In *winter* the surface temperature off Western Norway is *lower* than that at greater depth. When a strong N wind (Vestlandet) or NW wind (Jæren—Lindesnes) is blowing, the surface temperature may therefore *rise* considerably from one day to the other. Thus, at W 6 Beaufort the surface temperature at Lindesnes rose 4.3° from 11th to 12th of January 1936. In winter, therefore, strong northerly winds for a couple of days may to some degree reduce the importance of the coast water for fog formation.

A strong wind which causes a current component in the surface layer directed towards land will press the outer border of the lighter Baltic

water nearer to the coast, and in that way the belt of this water will become narrower. The contrary will be the case when the component is directed from land.

As soon as the wind which causes these variations stops, the sea-surface quickly adopts the temperature normal for the season in question.

If in summer we have a longer fair weather period over Western Norway and the sea to the West, with slight winds, the insolation may cause a considerable rise in the surface temperature. This was the case during the first two weeks of August 1938. The surface temperature rose to above 21° off Sørlandet—Jæren, and to above 20° off Jæren—Bergen. As soon as the fair weather stopped and the wind increased, the waves caused the thin stratum of warm surface water to mix with deeper lying water, and the surface temperature therefore dropped quickly. If a slight current of say continental Tropical air had moved from Middle Europe towards Southern Norway in this case, the probability for fog along the coast Sørlandet—Jæren would have been somewhat less than if the surface temperature had had its normal value.

Keeping in mind the possible variations from the mean mentioned above, the mean charts will be a valuable help in fog forecasting. But it is of course of great importance to increase the number of direct observations (registrations) of the sea-surface temperature as far as possible. All the liners crossing the North Sea must be equipped with a sea-thermograph and they must report an additional group in the weather telegrams giving information about the sea temperature curve between land and the first weather observation, and between the later weather observations. According to the international ship code no weather observations shall be made between land and 60 nautical miles off the coast. These directions must be altered for the liners mentioned. It is of especial interest to know about the surface temperature of the coast water and the weather over this belt.

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Finally, we would like to express our best thanks to the technical assistants at the Oceanographic Division of the Fiskeridirektorat for their valuable help in preparing the material.

Fiskeridirektoratet/Vervarslinga på Vestlandet,
Bergen, August 1944.

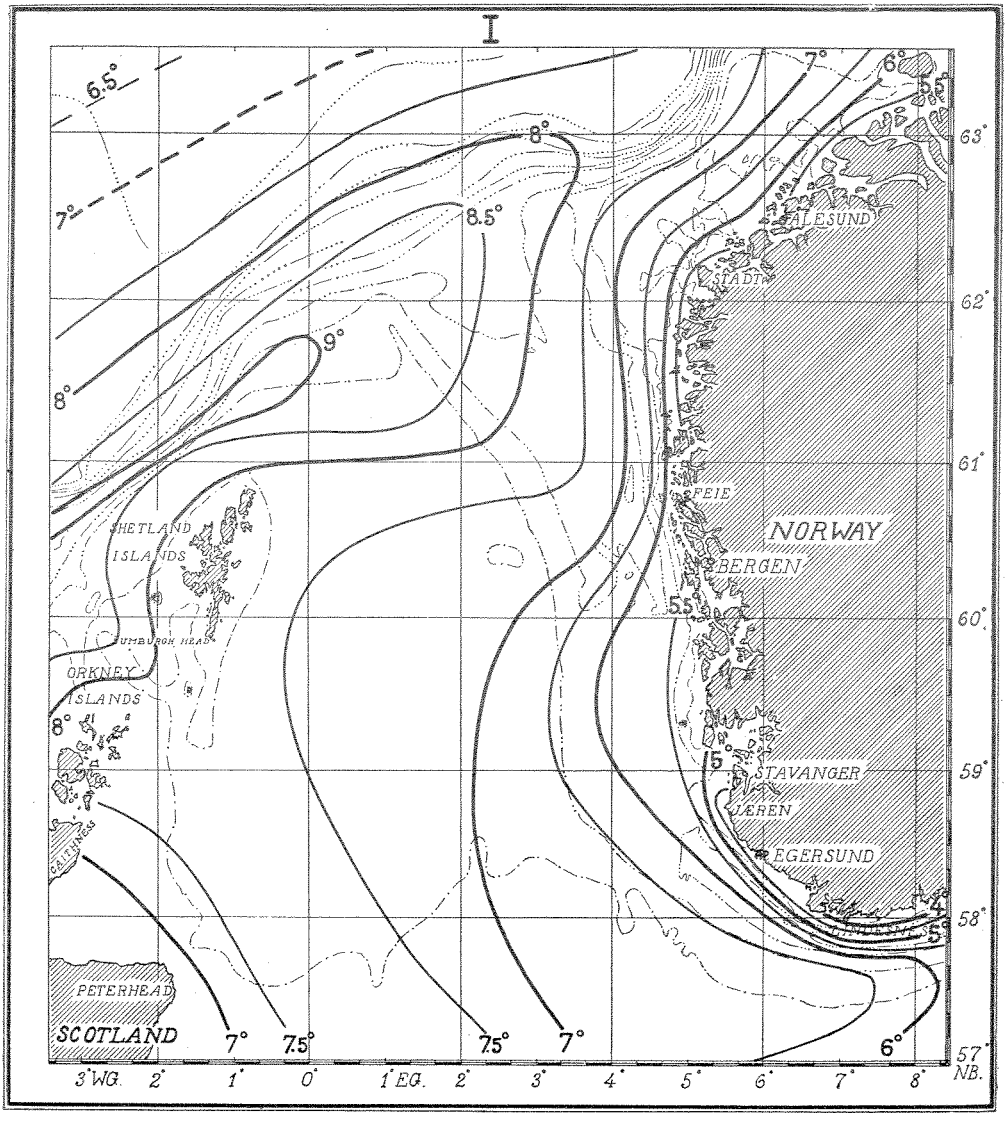

Fig. 1. Mean sea-surface temperature in January. (Thin lines represent the topography of the bottom after Helland-Hansen and Nansen. — · — 100 metres, — · · — 200 metres.)

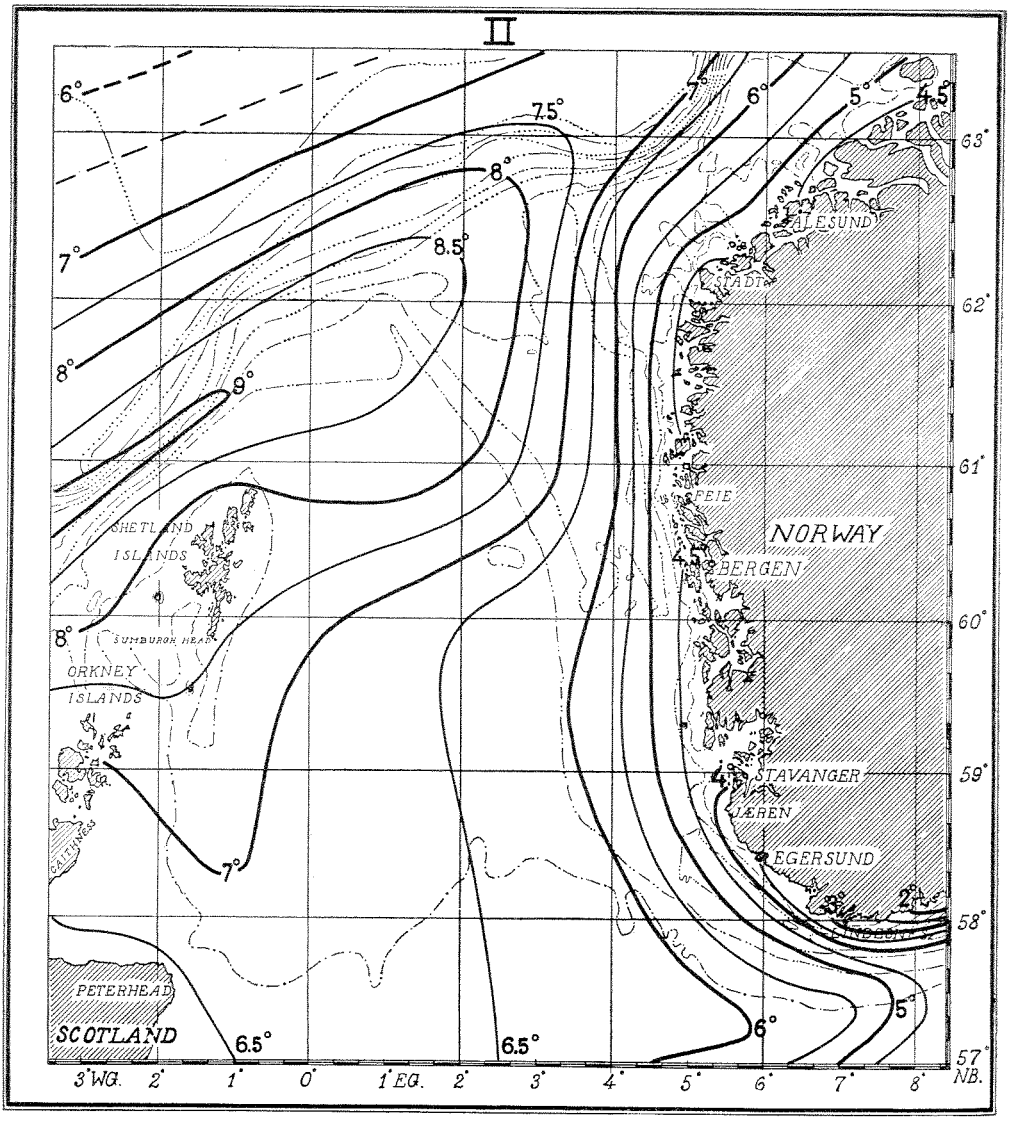

Fig. 2. Mean sea-surface temperature in February.

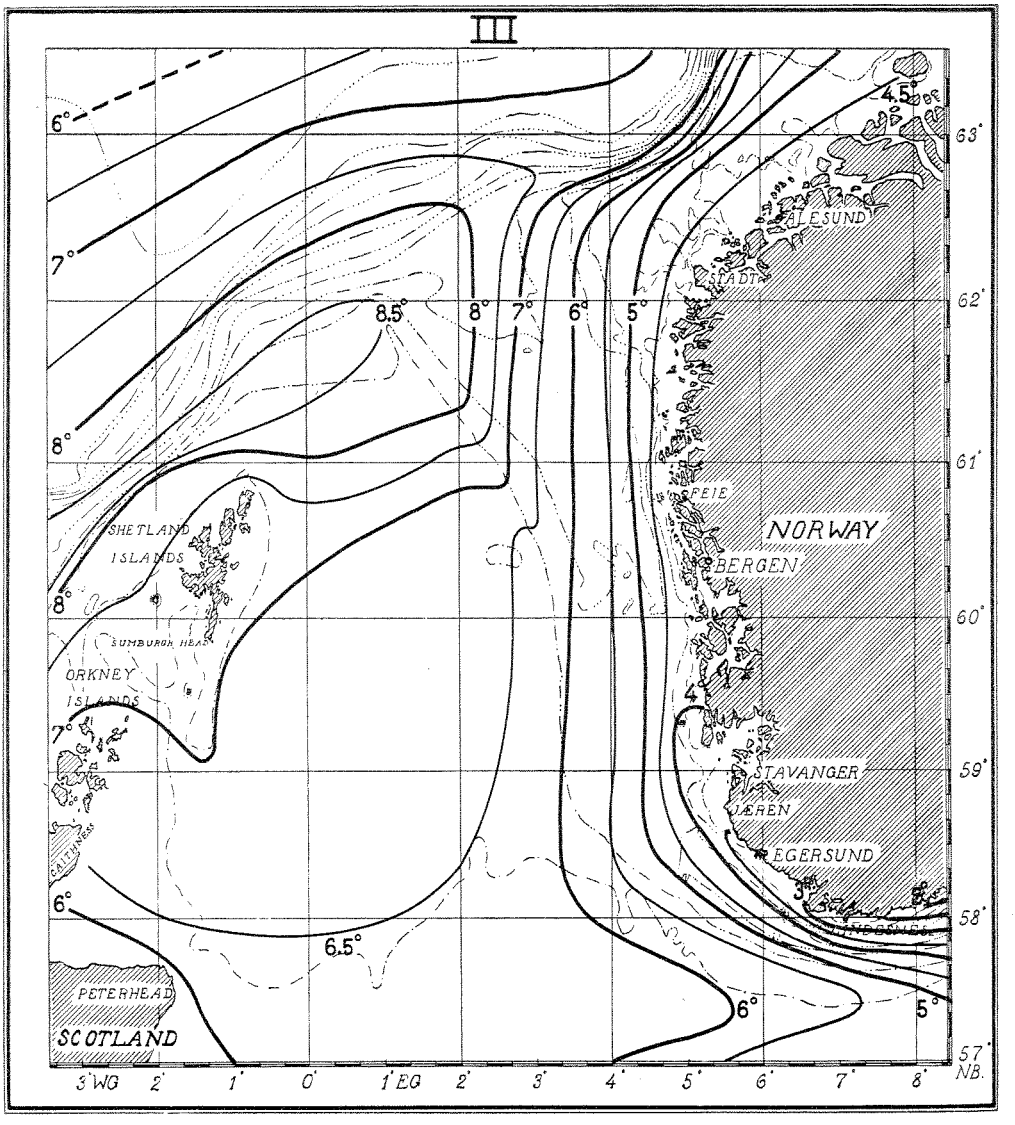

Fig. 3. Mean sea-surface temperature in March.

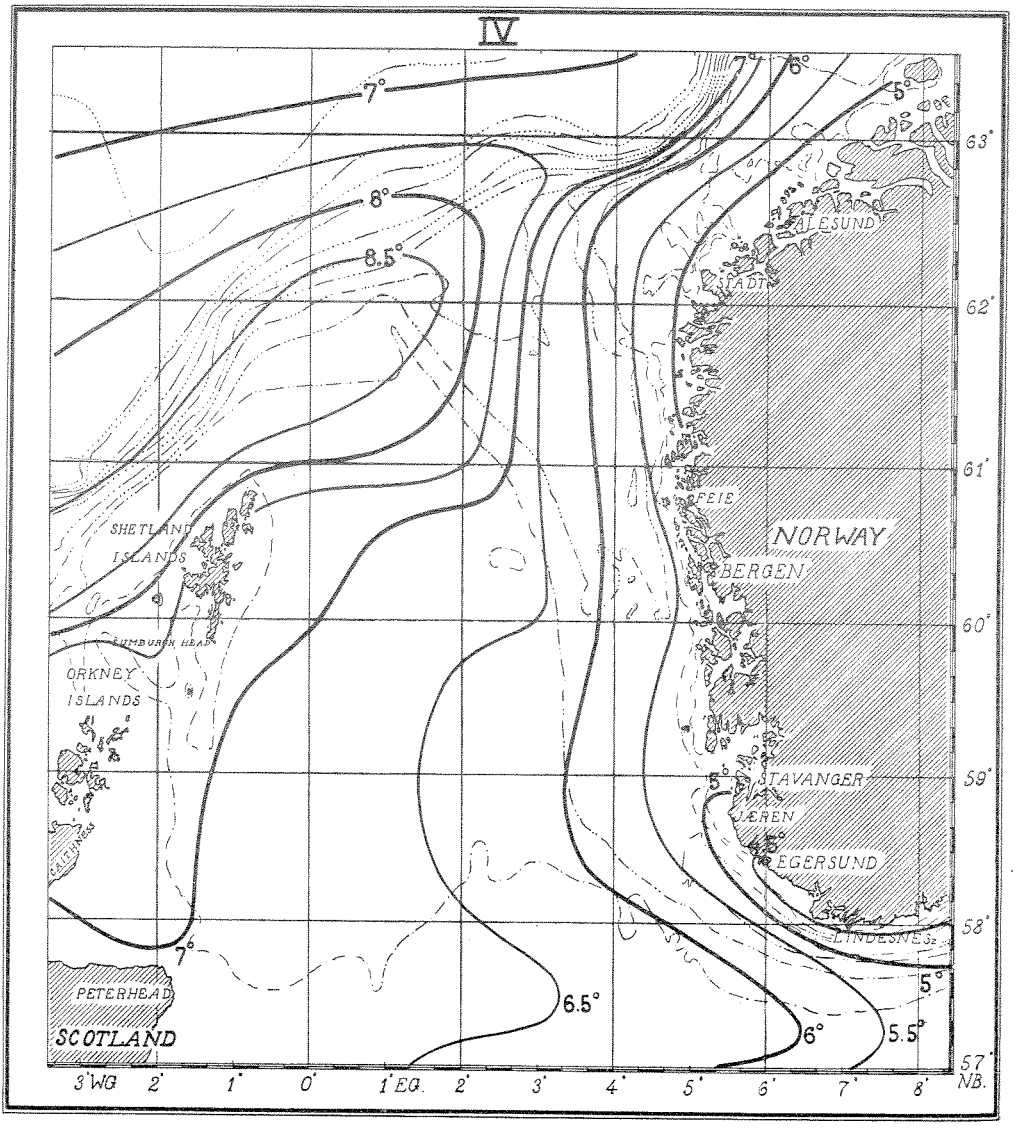

Fig. 4. Mean sea-surface temperature in April.

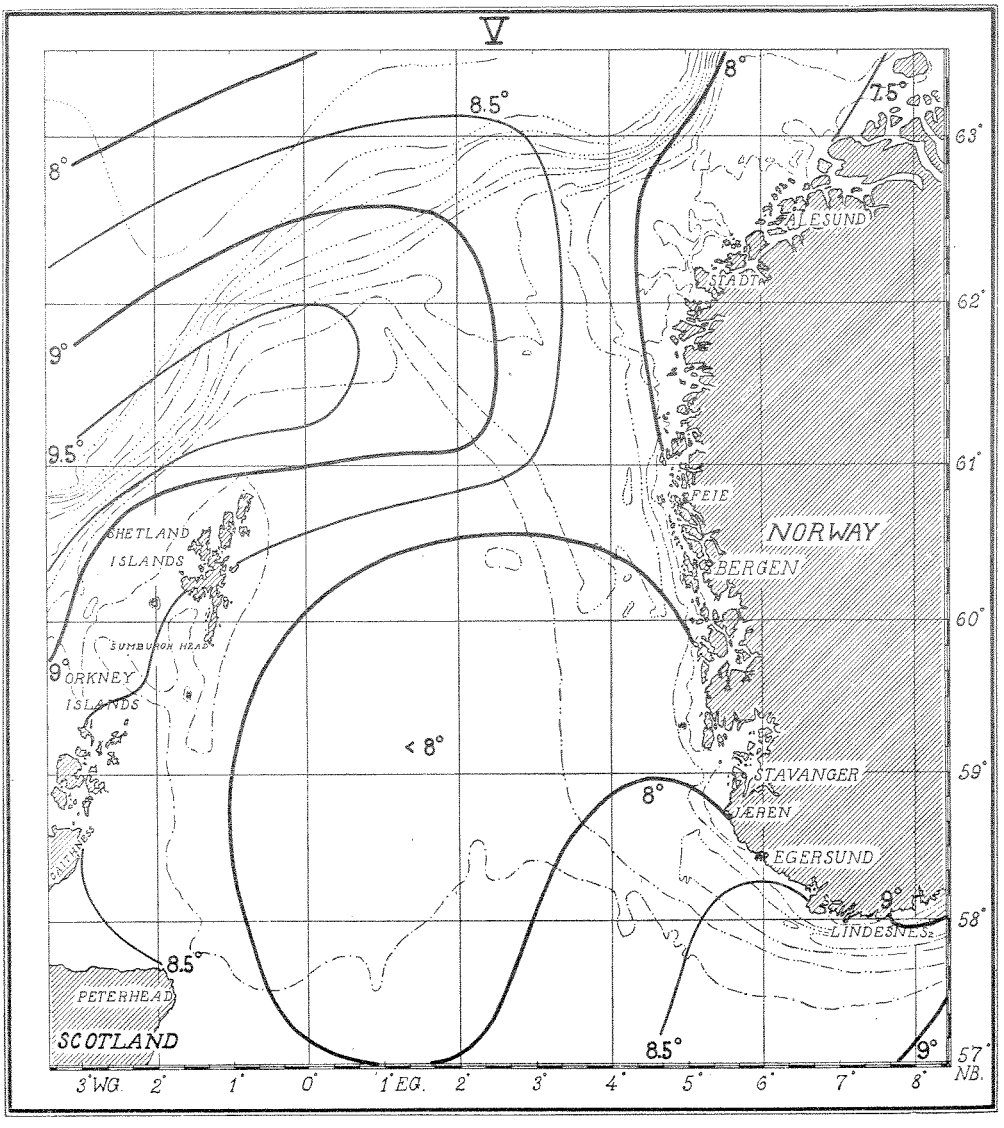

Fig. 5. Mean sea-surface temperature in May.

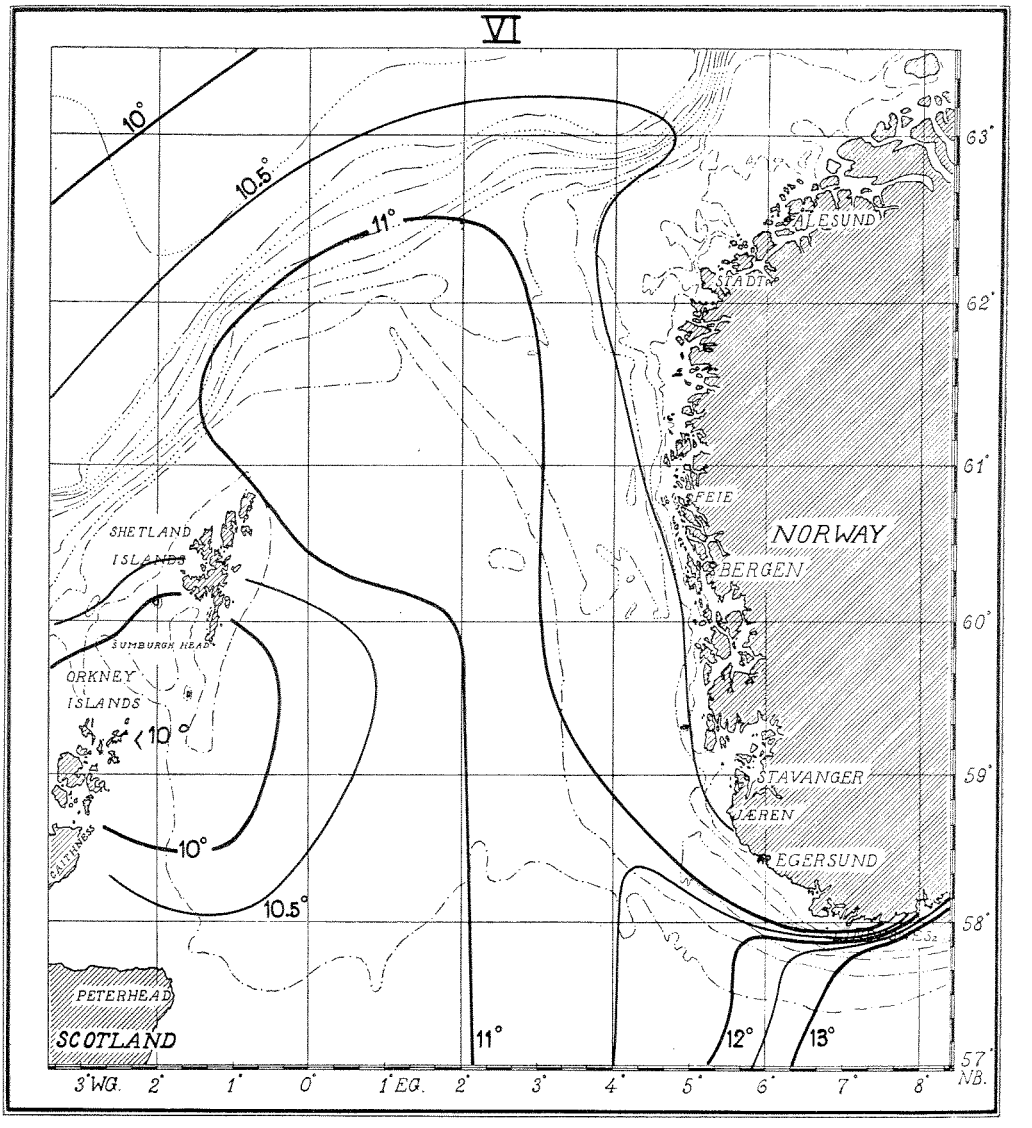

Fig. 6. Mean sea-surface temperature in June.

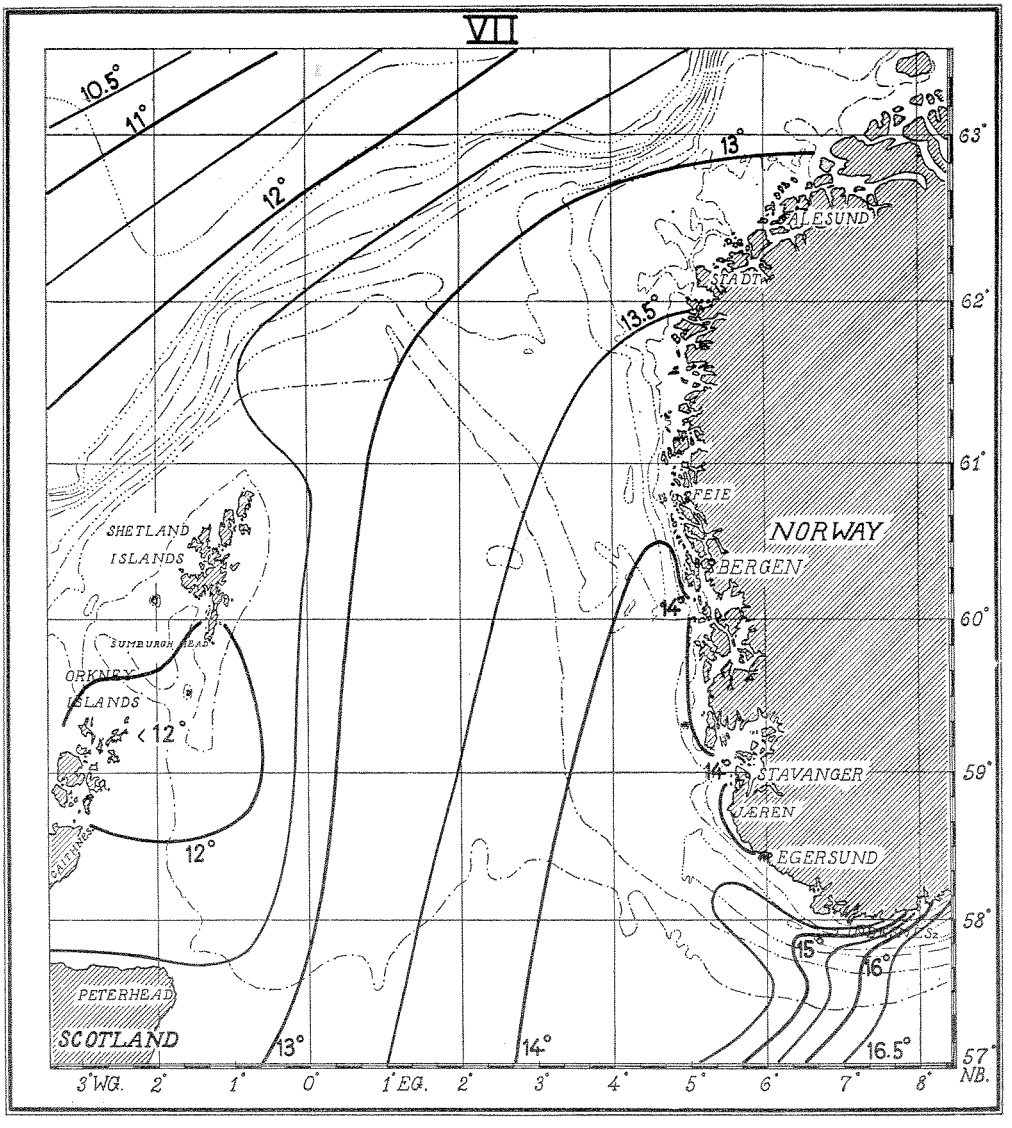

Fig. 7. Mean sea-surface temperature in July.

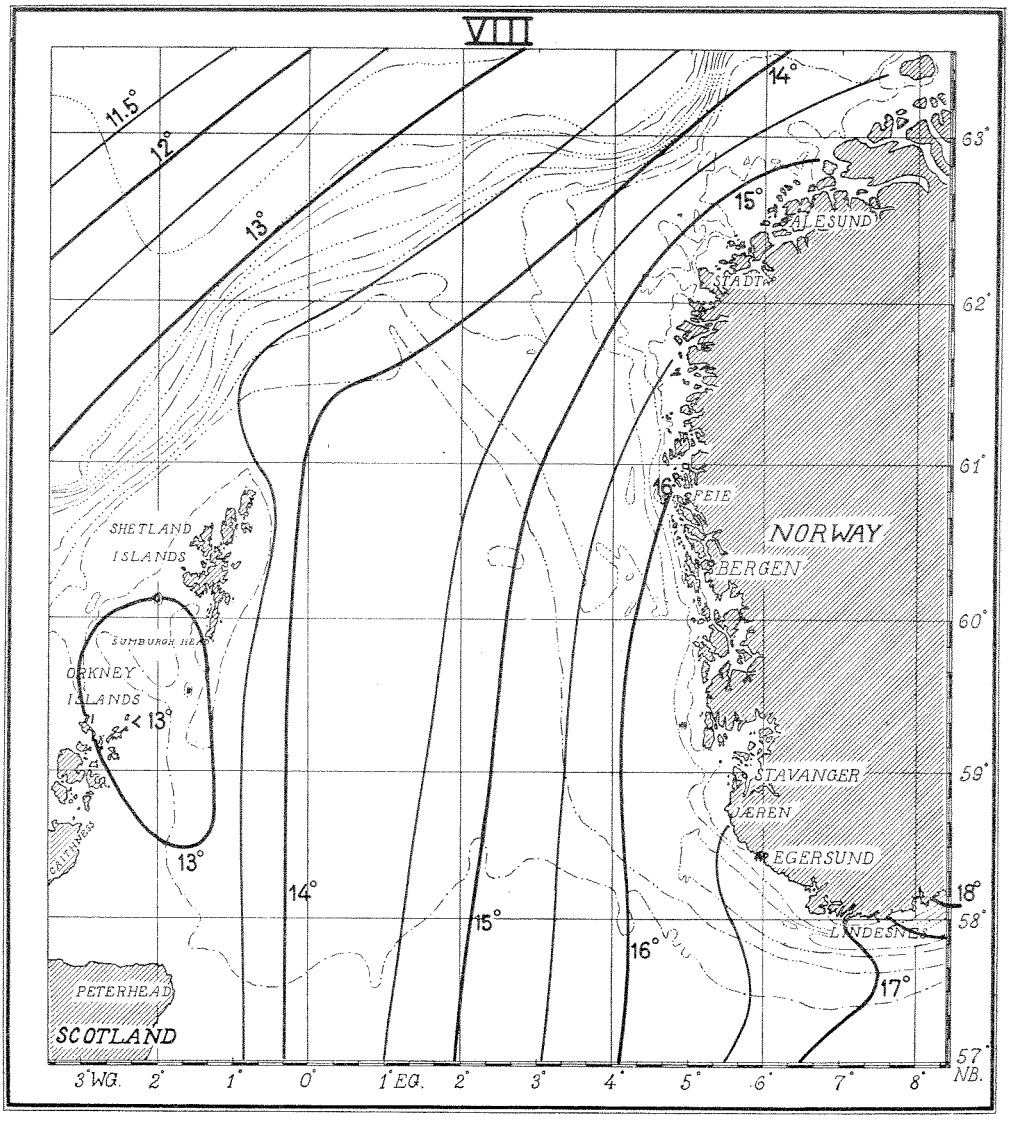

Fig. 8. Mean sea-surface temperature in August.

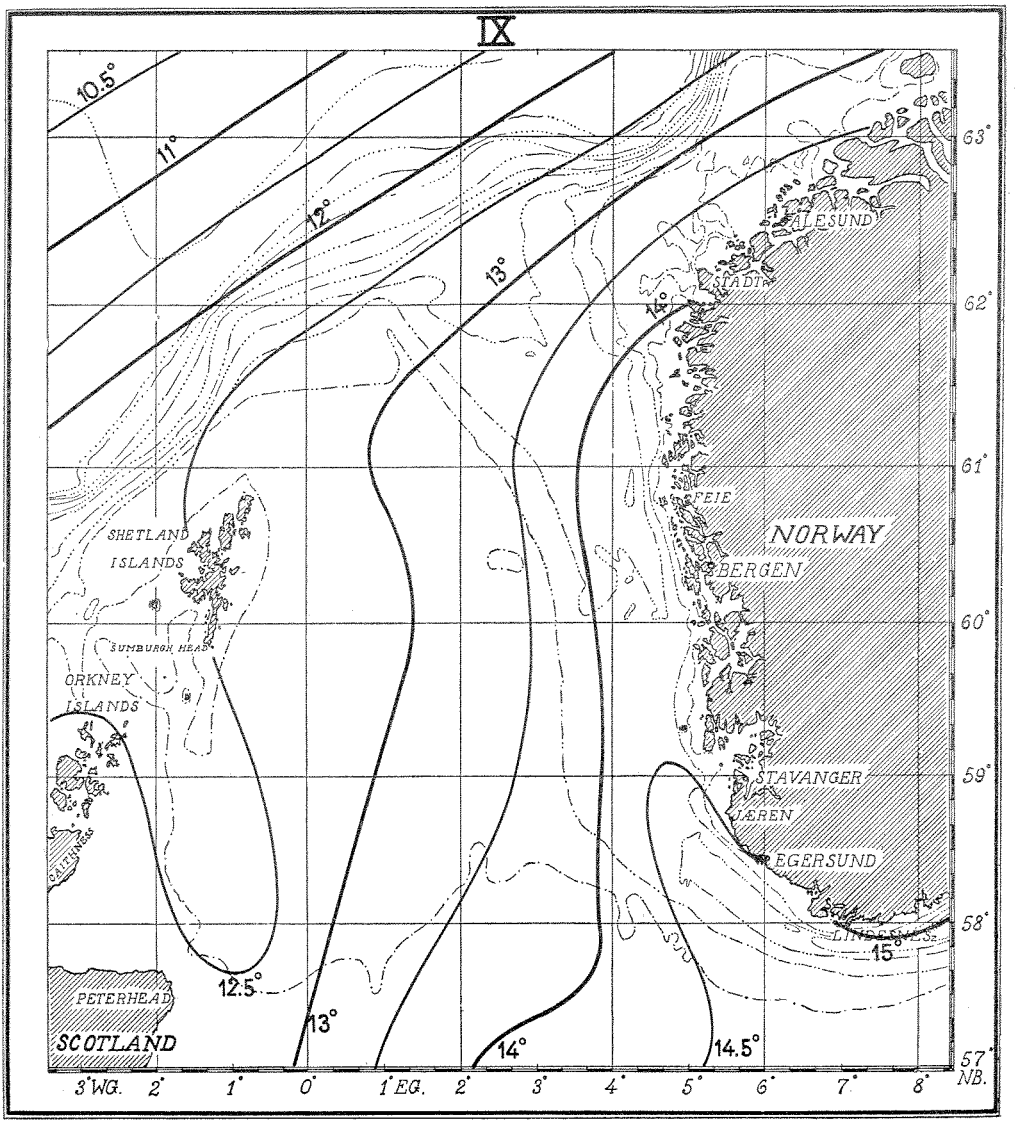

Fig. 9. Mean sea-surface temperature in September.

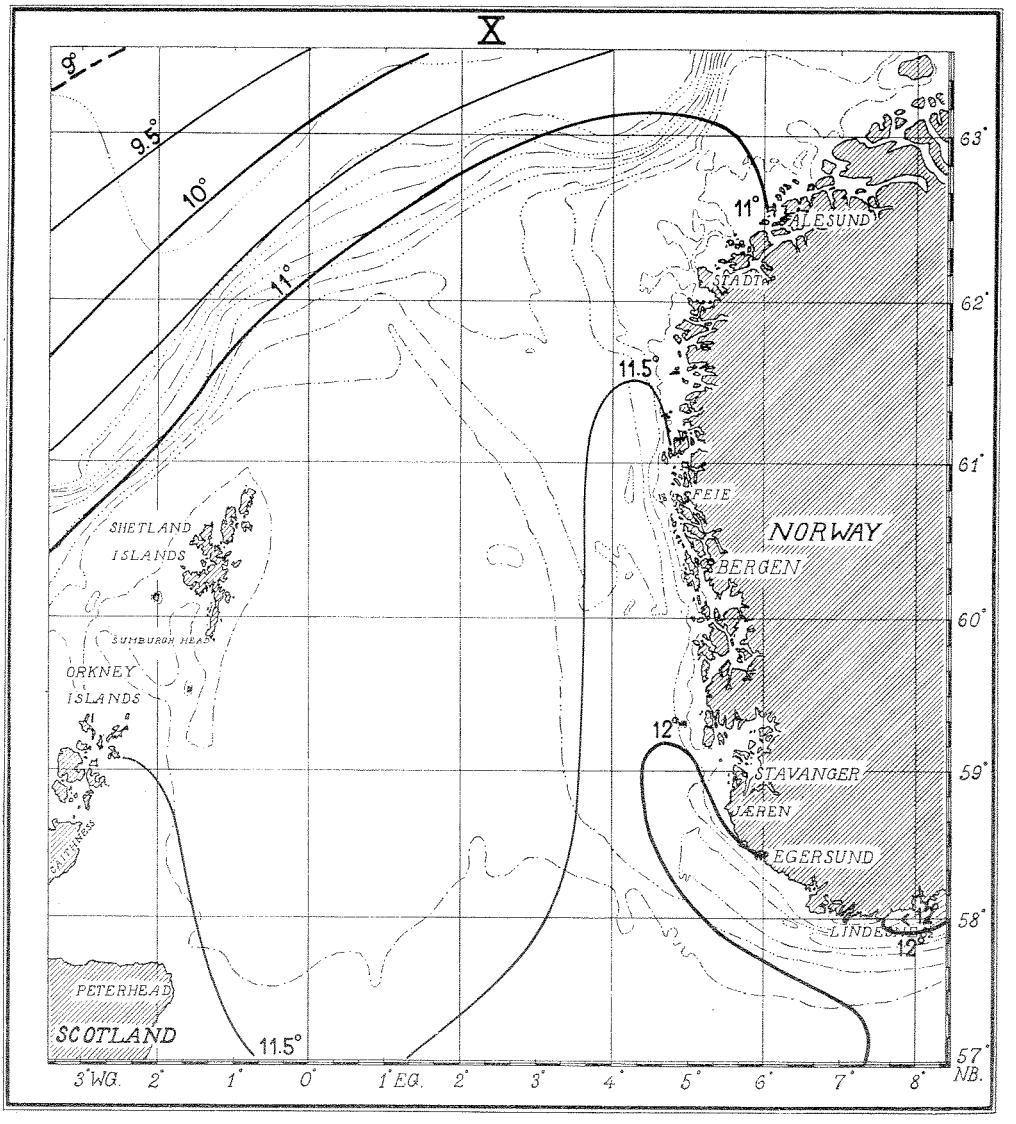

Fig. 10. Mean sea-surface temperature in October.

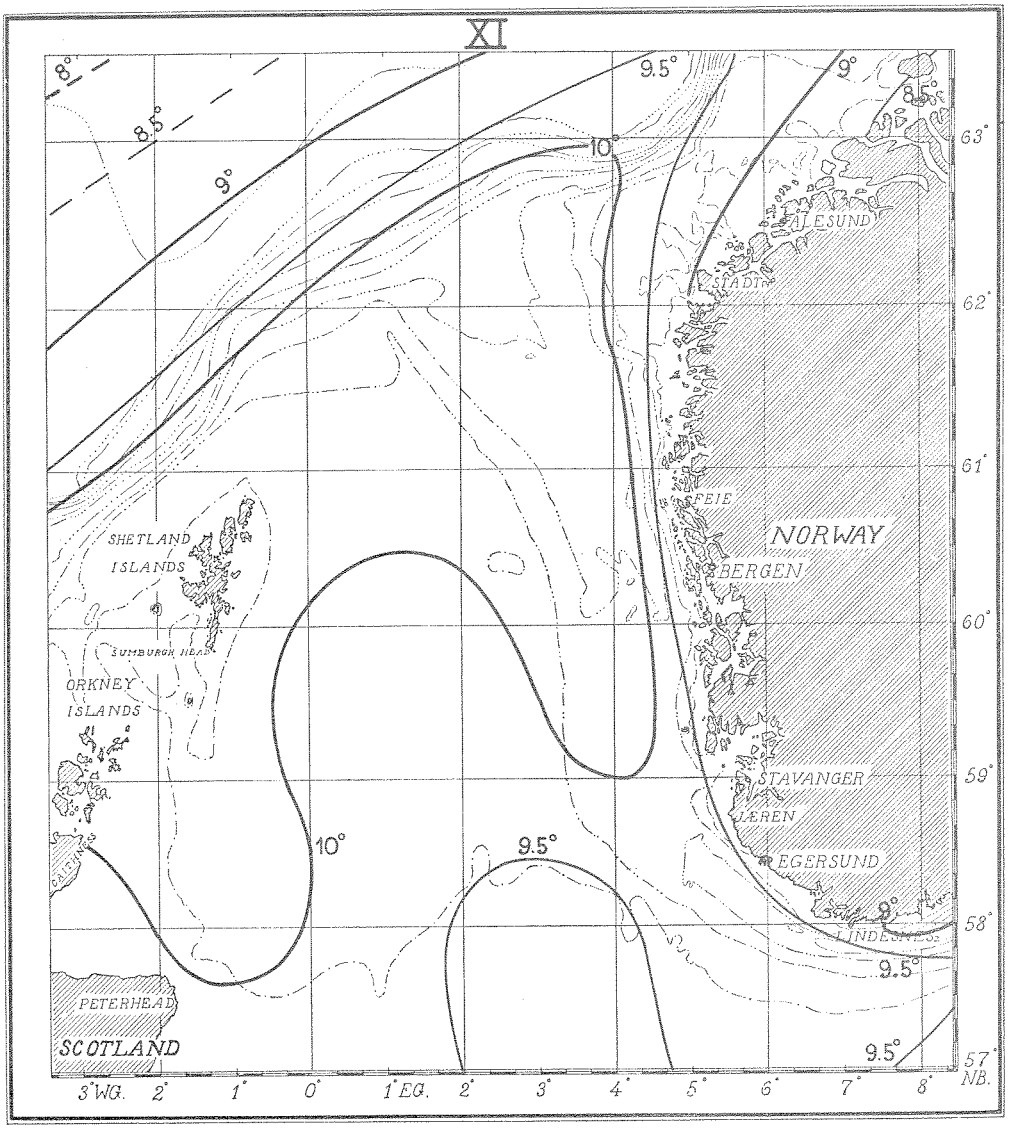

Fig. 11. Mean sea-surface temperature in November.

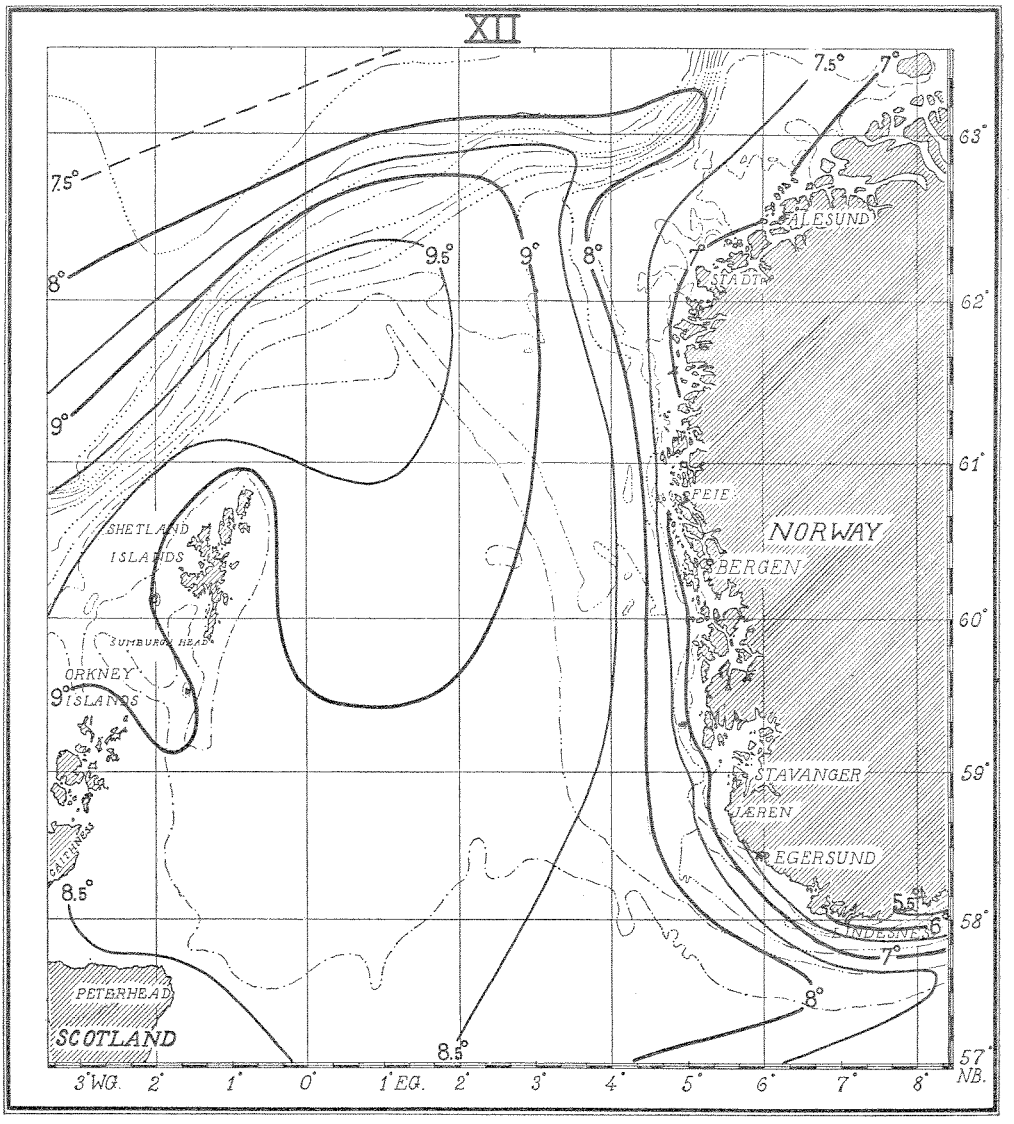

Fig. 12. Mean sea-surface temperature in December.