INTERNATIONAL COUNCIL FOR
THE EXPLORATION OF THE SEA

C.M. 1968/C:11
HYDROGRAPHY COMMITTEE

A SYNOPTIC NUMERICAL SST ANALYSIS SCHEME

by

Captain W.S. HOUSTON, Jr., U.S. Navy

and

Lieutenant Commander L.C. SAMPLES, U.S. Navy

United States Fleet Weather Central, Rota, Spain

LIST OF FIGURES

In response to ICES Resolution (C.Res. 1967/1:16) the Commander, United States Naval Weather Service Command, charged Fleet Weather Central (FWC), Rota, Spain, with production of an experimental synoptic sea surface temperature analysis scheme utilizing computers at Rota. The scheme was to prepare current SST analyses and compute routine SST mean and SST anomalies for the water areas covered by the ICES Atlas (1905-1954).

Proven basic computer techniques and subroutines used at U.S. Fleet Numerical Weather Central, Monterey, California, were utilized in development of the Rota scheme. Since the output of the scheme was to be computer-drawn contoured charts, a base map was required encompassing the area prescribed in the original Resolution. The Monterey grid is a 63 x 63 square matrix which can be adapted to fit any square geographical area within the northern hemisphere. Therefore, to cover the ICES area with a square, satisfying meaningful data limitations, a base map scale of 1:7.5 million was chosen. Any polar steoreographic projection map scale would have been acceptable. In the grid system used, map scale determines grid mesh length and vice versa; therefore, a mesh length of approximately 25 miles resulted. Figure 1 illustrates the ICES area as a subset of the computer grid, henceforth called the FWC Rota ICES grid. Since no computer-plotter base charts were available covering the area desired by ICES, an acetate overlay was prepared depicting geography. In practice, contours are drawn on blank white translucent paper by the computer, the acetate superimposed and reproduction accomplished by the Ozalid process providing a chart with geography and isotherm contours. Figure 2 is an example of a recent FWC ICES area SST analysis.

The relatively small map scale was questioned in considering the North Sea and prompted discussions with various potential users who had agreed to evaluate the charts for their local use. However, primarily due to lack of data in the North Sea (as will be discussed in detail later), the prospect of a larger scale was abandoned.

Initially, computation of anomalies required digitization of long-term monthly mean isotherms from the ICES Atlas (1905-1954). This was accomplished by hand, simply picking values from charts by month at each one degree latitude and longitude intersection. Long-term climatology obtained thusly was then machine analyzed, using FNWC Monterey analyses as first guess (to be described in "VOTE" section), and smoothed to produce monthly climatological fields. The example shown for March in Figure 3 depicts data extracted solely from the ICES Atlas. As other, more detailed, climatological data became available, they, too, were digitized and introduced into the climatological field. For example, Dr. Malmberg of Iceland, provided detailed sea surface temperature long-term monthly means for water areas adjacent to Iceland. The U.S. Naval Oceanographic Office Publication 700 was used as a source of climatological data for the remainder of the Atlantic with a resulting composite of ICES, Icelandic and NavOceano climatological data. The additional data, coupled with a slight modification of computation, produced a different and, it is hoped, more representative climatological field for the FWC Rota ICES area. An example of this latest composite is shown in Figure 4 illustrating climatology for August.

The approach used in numerical analysis of sea surface temperature data is dictated by several factors, the most important being data, geography, density and data reliability. Geography plays a significant role in determining boundary conditions since true sea surface temperature values are unavailable over land. In order to force isotherms to approximate real climatological conditions, the computer must "think" data are available over land which may be used in interpolation. This requirement may be satisfied by inserting values over land which are representative of off-shore conditions, then by interpolation, the computer can provide more significance and detail along shorelines. These refinements will be added to the ICES analyses when the next increment of climatological data are inserted.

Because of rather sparse data and questionable validity, FWC Rota uses a "vote technique". All ships' SST observations received during a twelve-hour period and all SST data extracted from bathythermograph soundings during a sixty-hour period are considered. Observations passing a "gross error check" are given equal weight in the analyses; however, observations are introduced with respect to time, i.e., newest observations have the last vote, thereby insuring portrayal of the latest possible SST features based on the most recent observations.

VOTE TECHNIQUE

In addition to those observations mentioned above, data to be analyzed include sea surface temperature observations from ART (Airborne Radiation Thermometer) collectives and CTEM collectives (SST observations taken periodically during a day and transmitted once daily by U.S. Navy ships).

To be used in analysis, geographical positions of observations must be converted by the computer from latitude and longitude to I-J coordinates on the ICES computer grid. The data (I-J and temperature values) then are ready for the "vote".

Prior to analysis however, a "guess field" is required. As is true in most hand-analysis systems, the most recent analysis for a given area normally is used by the computer as "history" or as a "first guess". In the event a previous ICES SST analysis is unavailable, a capability exists for extraction of the ICES grid area from a Monterey hemispheric sea surface temperature analysis which then would be used as the "first guess". Again, paralleling hand-analysis techniques, a significant modification in detail of isotherms results in machine analysis when "history" is changed. Continuity is then lost between successive analyses.

In addition to being used as history, the "guess field" is used as a standard in the gross error check. Observed data are compared with interpolated values extracted from the guess field at corresponding geographical locations. Any differences between values of the guess field (the standard) and reported temperature values cause observations to be rejected as erroneous. Subsequent to all data passing through the gross error check, analysis or "voting" is commenced.

Analysis involves generation of a "difference field", a 63 x 63 matrix in parallel with the guess field matrix. Initialization of the program sets all of the grid points in the difference field to zero. In voting, each observation passing the gross error check exercises a positive, negative or neutral vote. The vote has a value assigned called the "weight or adjust factor". The vote or adjust factor is applied algebraically to each of the four grid points in the difference field surrounding the observation data point. The sign of the weight is dependent on the sum of the guess field value and the difference field value versus the value of the observed temperature. Application of the vote in the difference field modifies the difference field which is considered in the next observation's vote and in subsequent passes through the data. Upon completion of a pass through all the observed data, the difference field contains cumulative tallies of votes at each grid point affected by observed data. Figure 5 graphically illustrates the procedure.

To insure a realistic analysis presentation in sparse data areas, reference is made to long-term climatology. After each pass through observed data, each grid point in the difference field is checked to determine the existence or influence of data during the current analysis. Where no effect occurred (no data observed), a climatology adjust factor is used to further modify the difference field. Climatology then is used in lieu of data and is given a vote in the same manner as described above. Consequently upon completion of a pass through data and through climatology, the difference field contains cumulative tallies of votes for data and votes for climatology. Upon completion of the routine just described, the difference field is then smoothed to spread out effects of data and to minimize gross differences or noise while retaining desired significance. Additional complete passes through the vote and smoothing procedure discussed above complete the analysis portion of the program.

Values of votes assigned to data and climatology as well as the number of passes through the routine are arbitrarily determined to cause values at each grid point to eventually approach or oscillate about data values (either observed or climatological in sparse data areas). The concept of grid point values approaching observed data values results from the philosophy that reported SST observations are notoriously poor and therefore must not be trusted implicitly.

The climatological adjust factor currently being used is chosen to be half the value of the data adjust factor which permits a slow return to climatology where no data are reported for prolonged periods. Climatological data as used in these analyses are computed by day from monthly mean long-term climatology fields as discussed earlier.

MEANS

Sea surface temperature means are computed for five, ten, fifteen and thirty-day time increments. Twelve-hour analysis fields made during a given time period are simply added together, then the sum is divided by the number of fields used in the summation as determined by the length of time involved.

Examples of mean charts terminating on 30 August 1968 for each of the time increments are shown in Figures 6 through 9.

ANOMALIES

To compute SST anomalies, required long-term climatological fields are compiled for desired time periods by interpolation within two adjacent months, assuming data for a stated month are representative of conditions prevailing on the fifteenth day of the same month. After computation of the long-term climatological field for the desired time period, it is subtracted from the current SST mean field computed for a corresponding time increment.

SST anomaly charts are made for the same time increment as the mean charts. Examples for each time increment are shown in Figures 10 through 13.

IMPROVEMENTS

In earlier discussion of the analysis technique, the method of handling climatological data was mentioned. A new system is being devised which will utilize standard deviations from SST monthly means to determine the weight given observations and the value assigned as the gross error tolerance. By computing adjust factors and gross error tolerances as functions of standard deviations, the procedure should permit more realistic assignment of weighting factors in adjustment for climatology. This system will be particularly influential in low-data density areas or in rapidly fluctuating water-mass boundary areas. A recognized problem in development of a system such as described is availability of good climatological studies from which meaningful deviations may be obtained. Further research is to be done by FWC Rota personnel in procurement of these data.

As stated initially, SST analyses discussed herein were intended to be experimental and developmental for evaluation by ICES. Routine production of the analyses has shown repeatedly that deficiencies exist in this scheme as well as any real-time synoptic environmental analysis scheme due to data sparsity. Figure 14 illustrates coverage of reported observations received at FWC Rota during a 48-hour period ending at ooZ on 5 September 1968. The large areas where no data were reported are areas where climatology alone determines the contour pattern. Roughly 150 to 200 unique reports are received each twelve hours in the FWC Rota ICES computer area consisting of roughly 1.5 million square miles of water area averaging approximately one report per 10,000 square miles. Since data density partially determines grid mesh size requirements, it is readily apparent that at present most of the ICES area (particularly the North Sea) cannot support a mesh size greater than the 25 miles currently used.

It is well known that many ships are underway at all times in the North Sea, yet, the sparsity of data in the North Sea on the coverage chart is obvious. It is perhaps less well known that many of those ships underway do take and transmit meteorological observations (including SST) which, unfortunately, are not necessarily relayed to all potential users. Observations routinely transmitted in Northern Europe all too often do not find their way to FWC Rota in Southern Spain. Much research is being done to obtain all reported data at Rota and circuitry is being changed to optimize data coverage. Improvement is expected within the next several months and the coverage charts should reflect the difference with more "dots" in the North Sea.

Since adoption of the ICES resolution which prompted these analyses, significant success has been achieved in collaboration with several ICES member institutions in cooperative collection and dissemination of synoptic oceanographic data. Routine bathythermograph soundings are now being received from several relatively remote geographical areas and there is hope for continued improvement in bathythermograph data collection. Since few synoptic oceanography analysis centers exist, little effort has been expended internationally for wide, real-time dissemination of SST or other hydrographic observations. Most oceanographic research is being done with historical data which has no great urgency. With the continuously accelerating requirements for commercial application of oceanographic forecasts, additional resources must be allocated for real-time synoptic dissemination of raw oceanographic data so that real-time analyses may be generated.

In conclusion, development of this synoptic SST scheme, though still under evaluation, has illustrated that these charts have application in commercial fisheries or other mercantile functions and that continued research and development will prove to be of significant value. Much discussion has been generated between various ICES members and Rota personnel to further improve the analyses. Constructive discussions of this sort are extremely fruitful and will further development of operational hydrography: ICES must concur with this reasoning or FWC Rota would not have been invited to present this paper.

At present, SST analyses produced routinely for the North Atlantic and transmitted by radio facsimile are derived by methods discussed herein. Improvements in the scheme have been made continuously as new ideas have been generated.

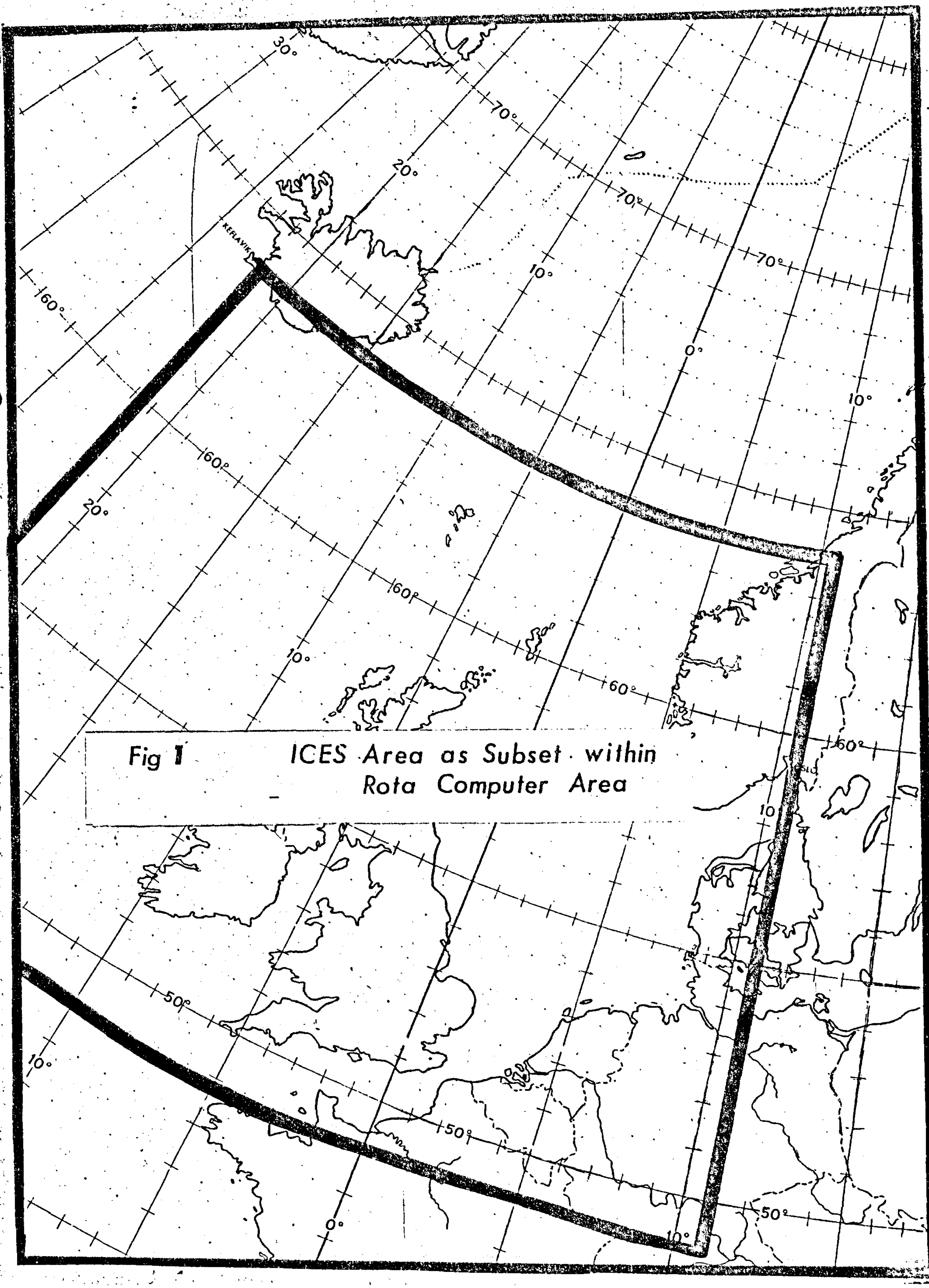


Fig 1 ICES Area as Subset within Rota Computer Area

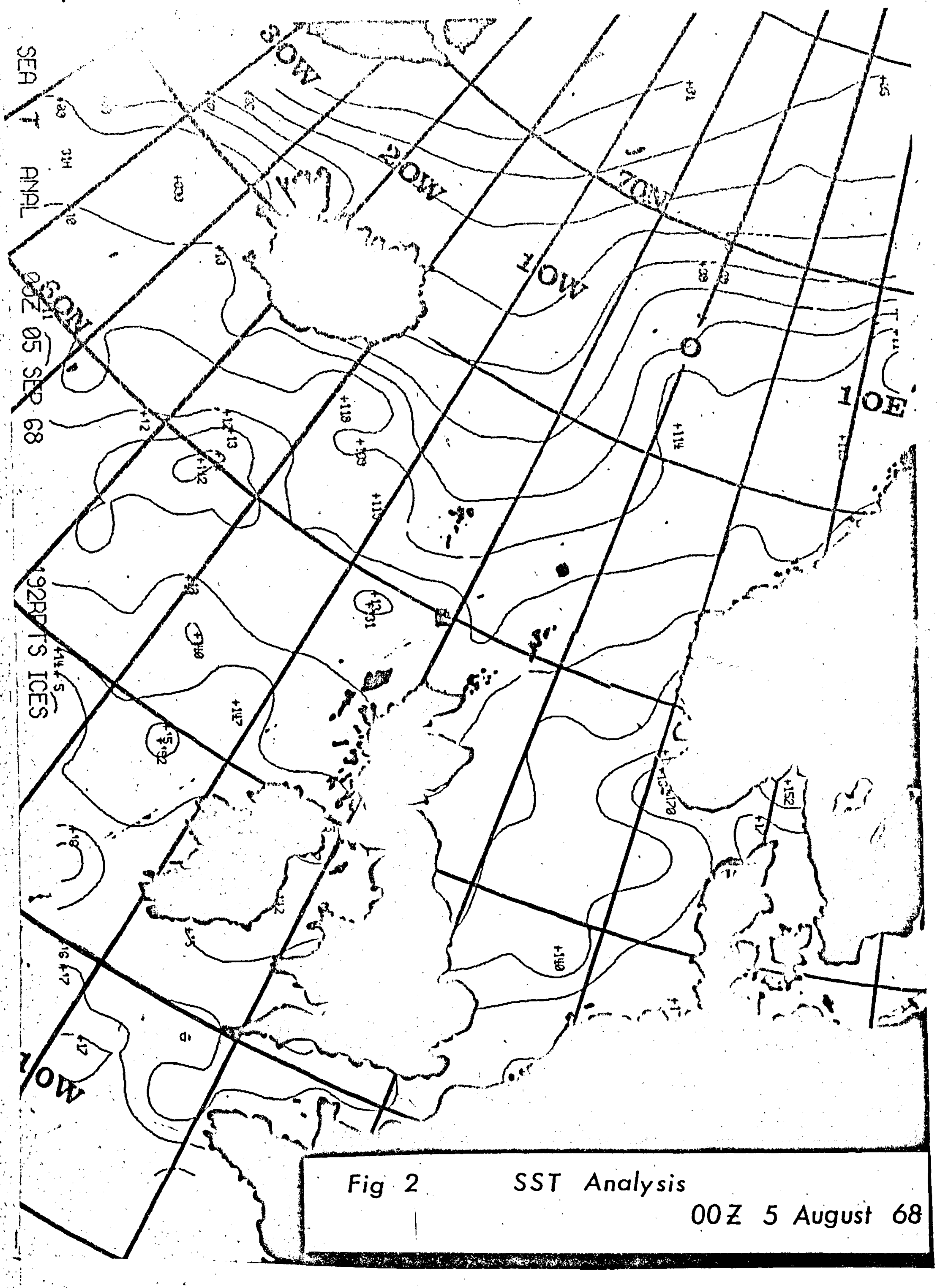


Fig 2 SST Analysis

00Z 5 August 68

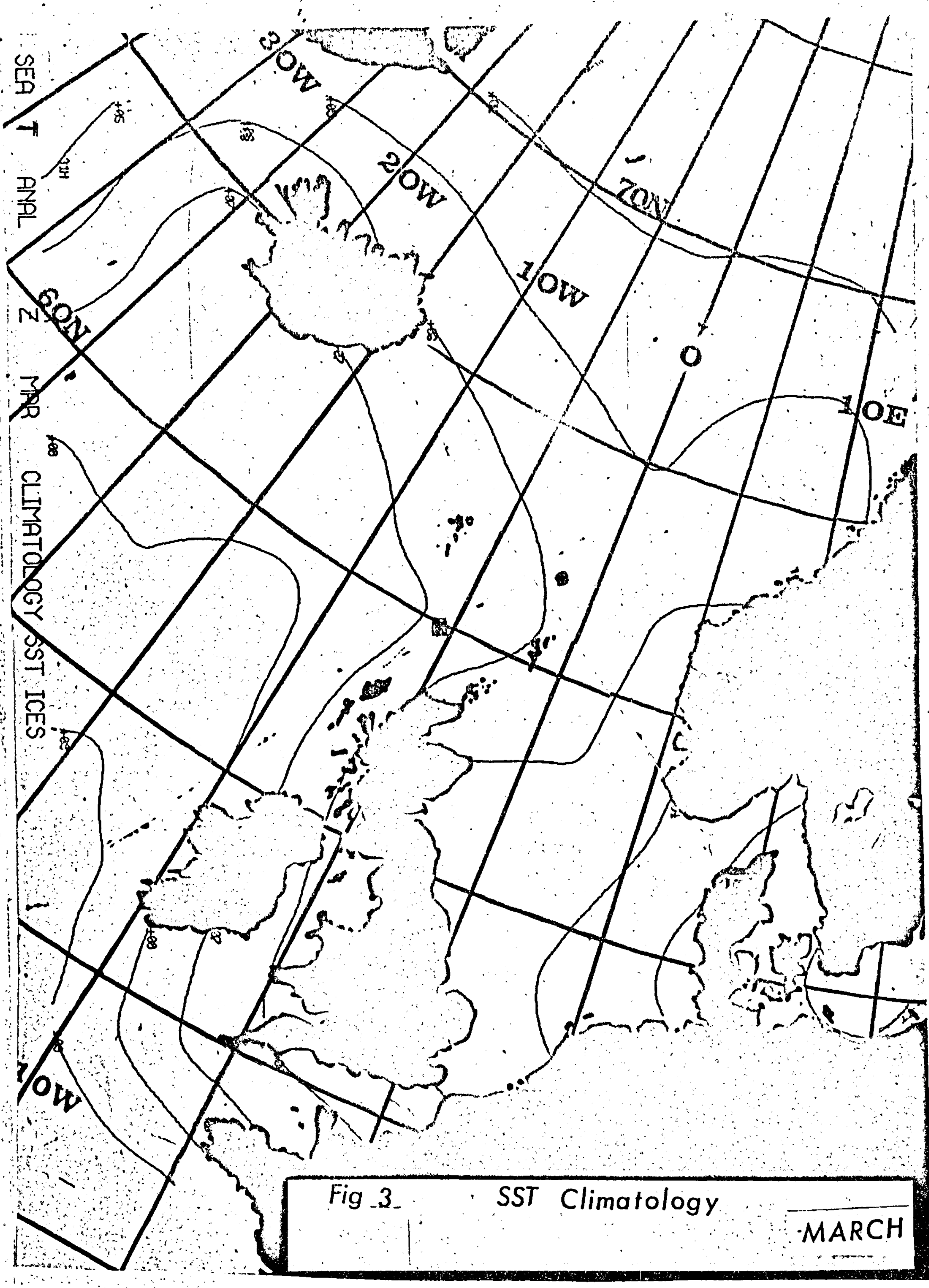


Fig 3 SST Climatology MARCH

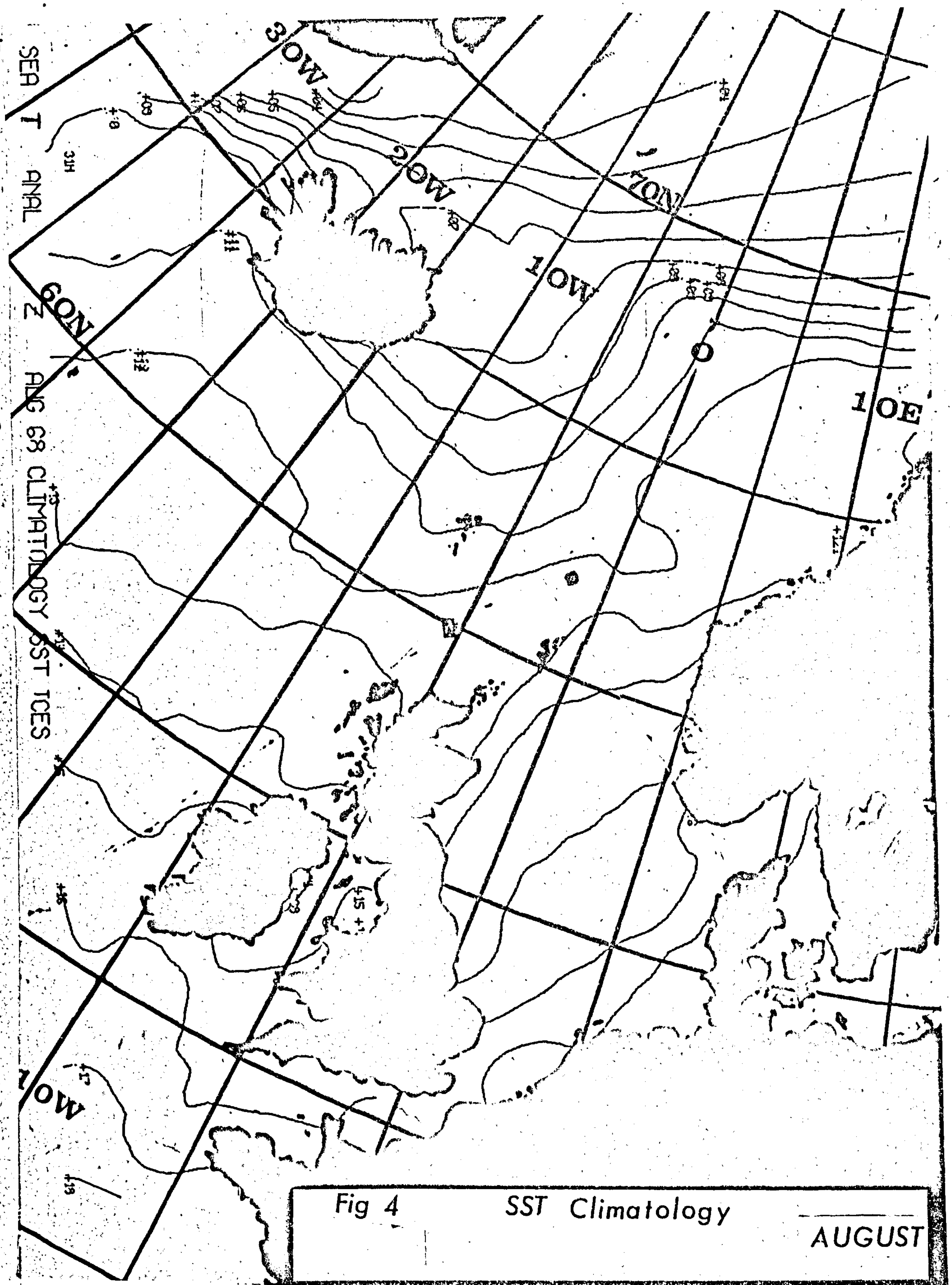
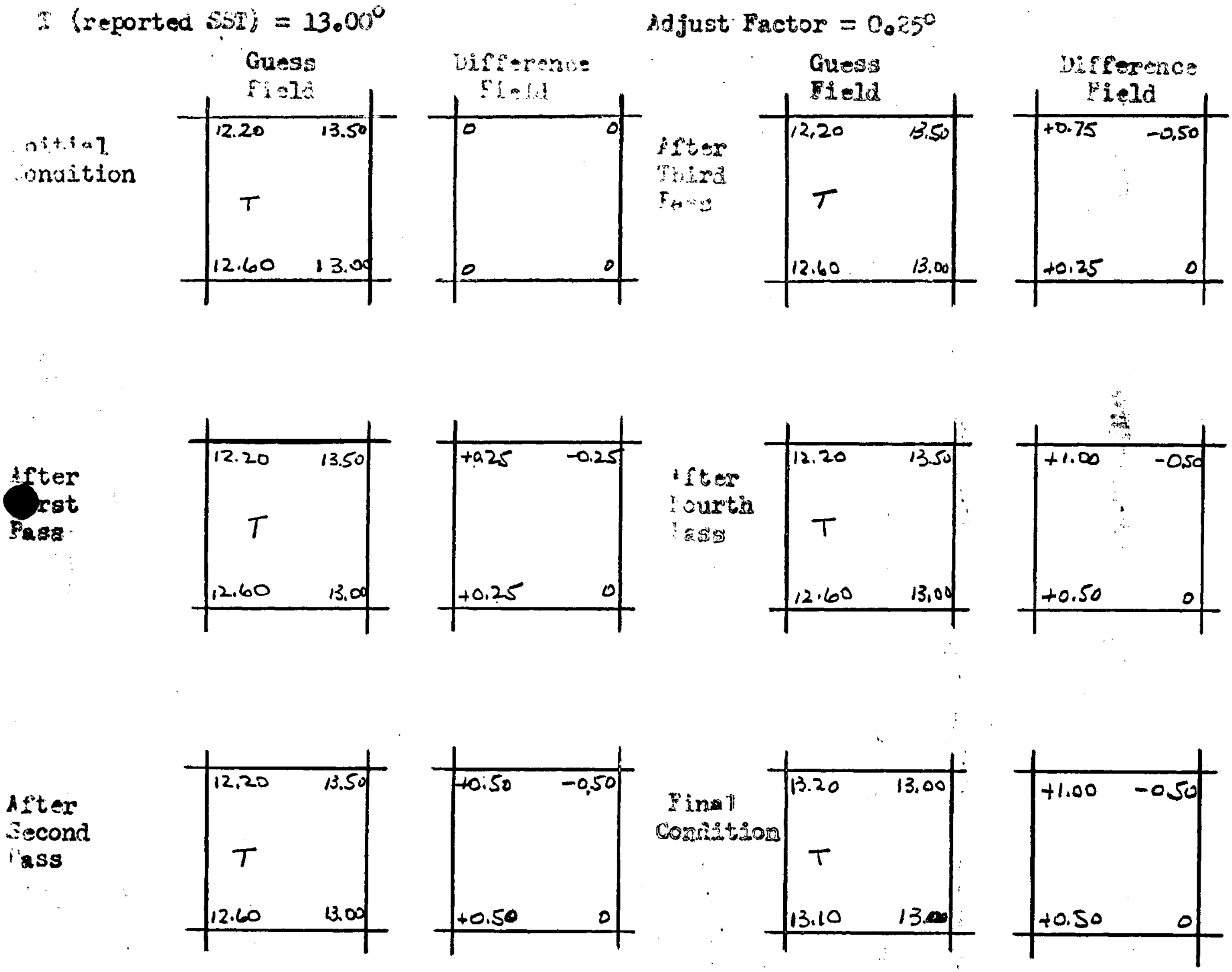


Fig 4 SST Climatology AUGUST



After passing through data prescribed number of times and smoothing, final values at each grid point in difference field will be added to the guess field thereby modifying the guess field to reflect changes caused by new data.

Newly analyzed field will approach value of T or oscillate within 0.25° (adjust factor) of the value of T.

DESCRIPTION OF "VOTE" PROCEDURE

FIGURE 5

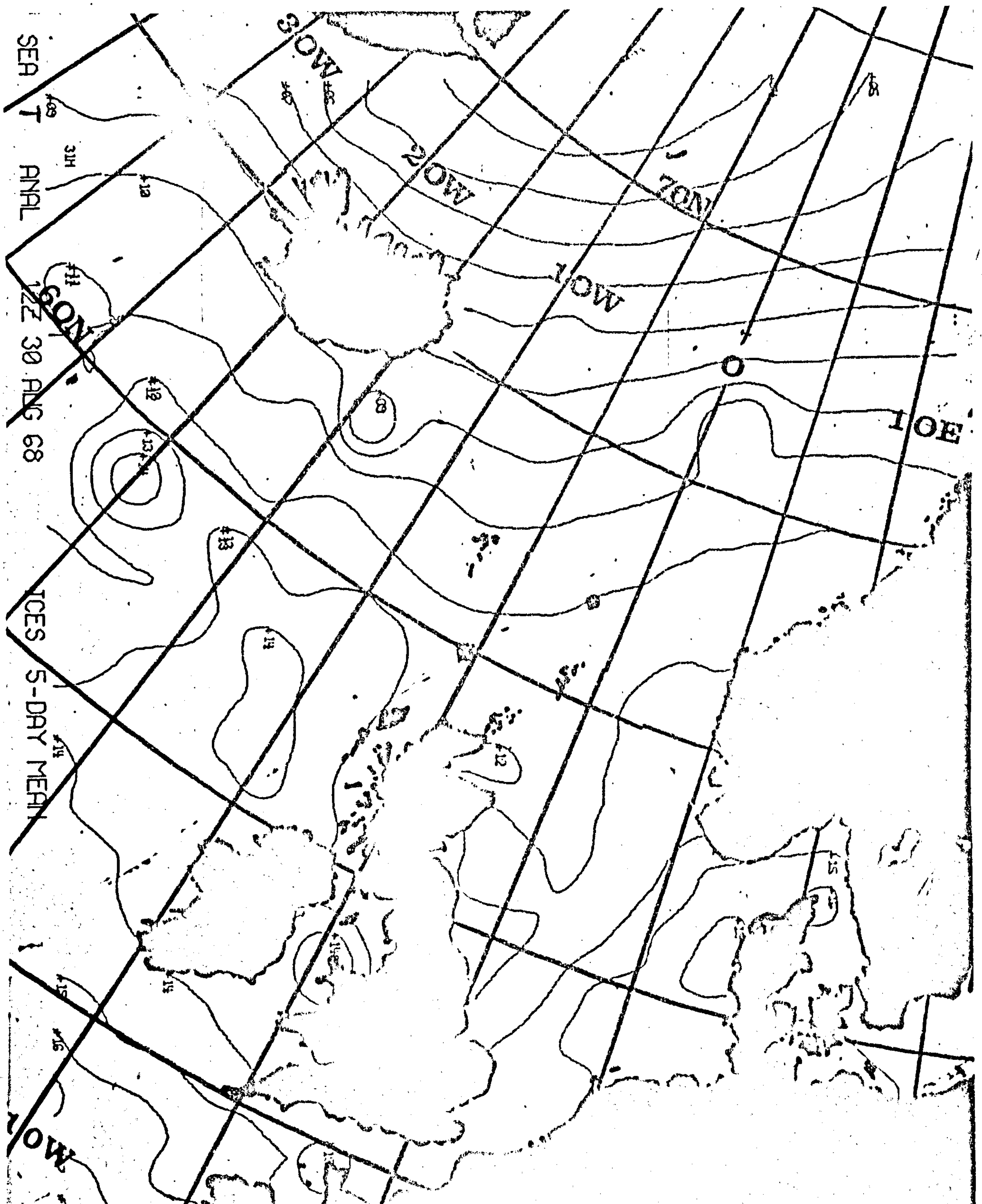


Fig 6 5 Day SST Mean

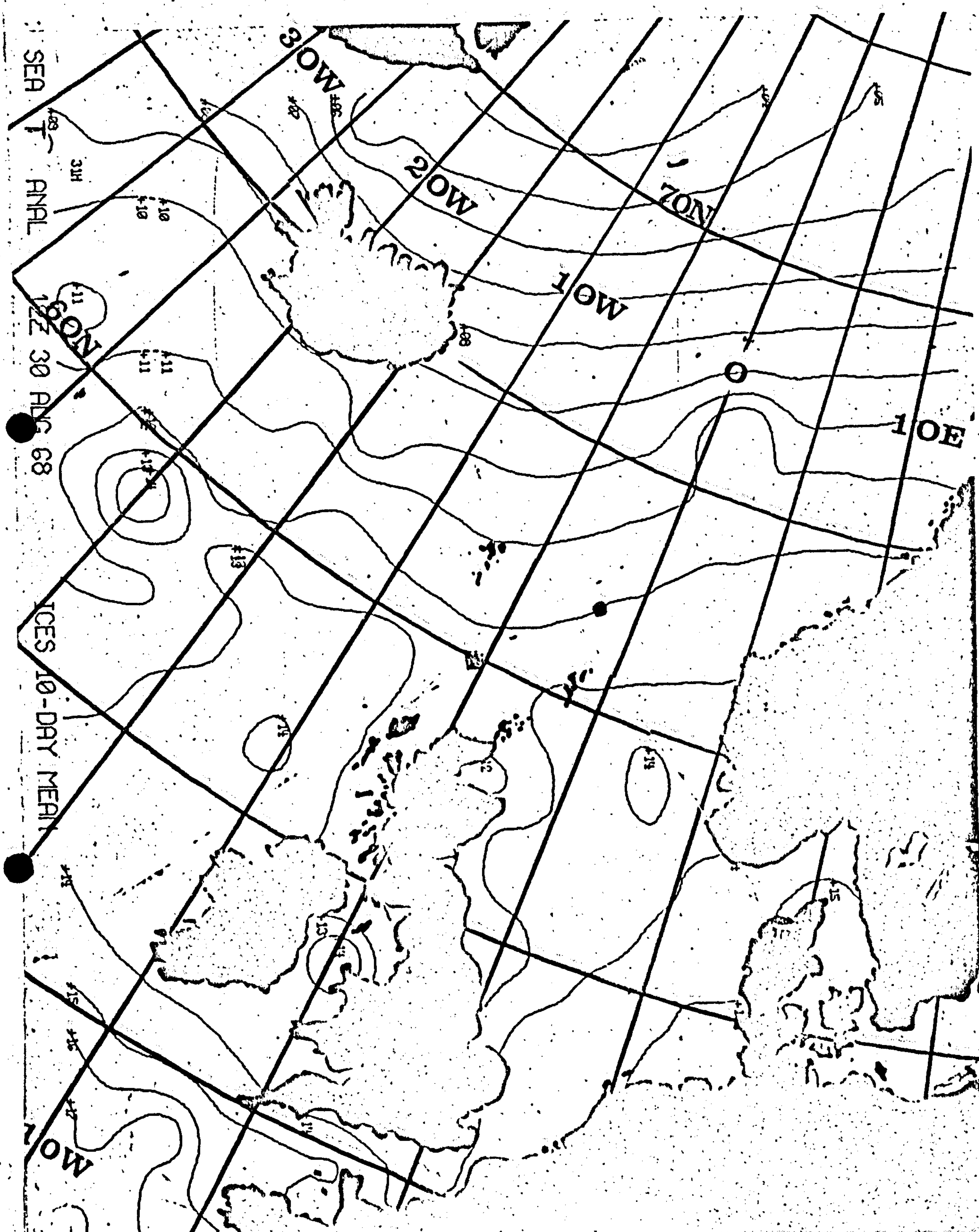


Fig 7 10 Day SST Mean

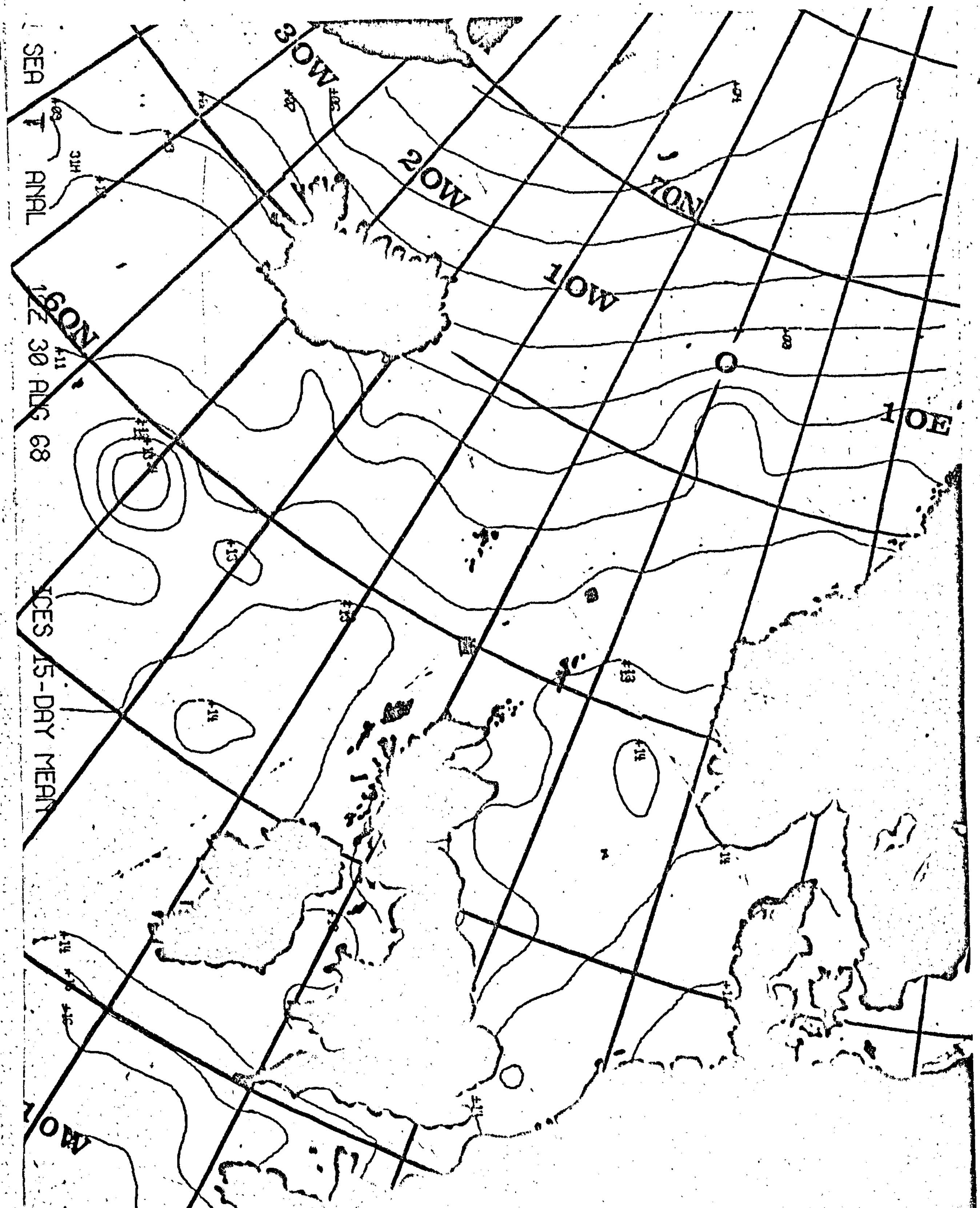


Fig 8 15 Day SST Mean

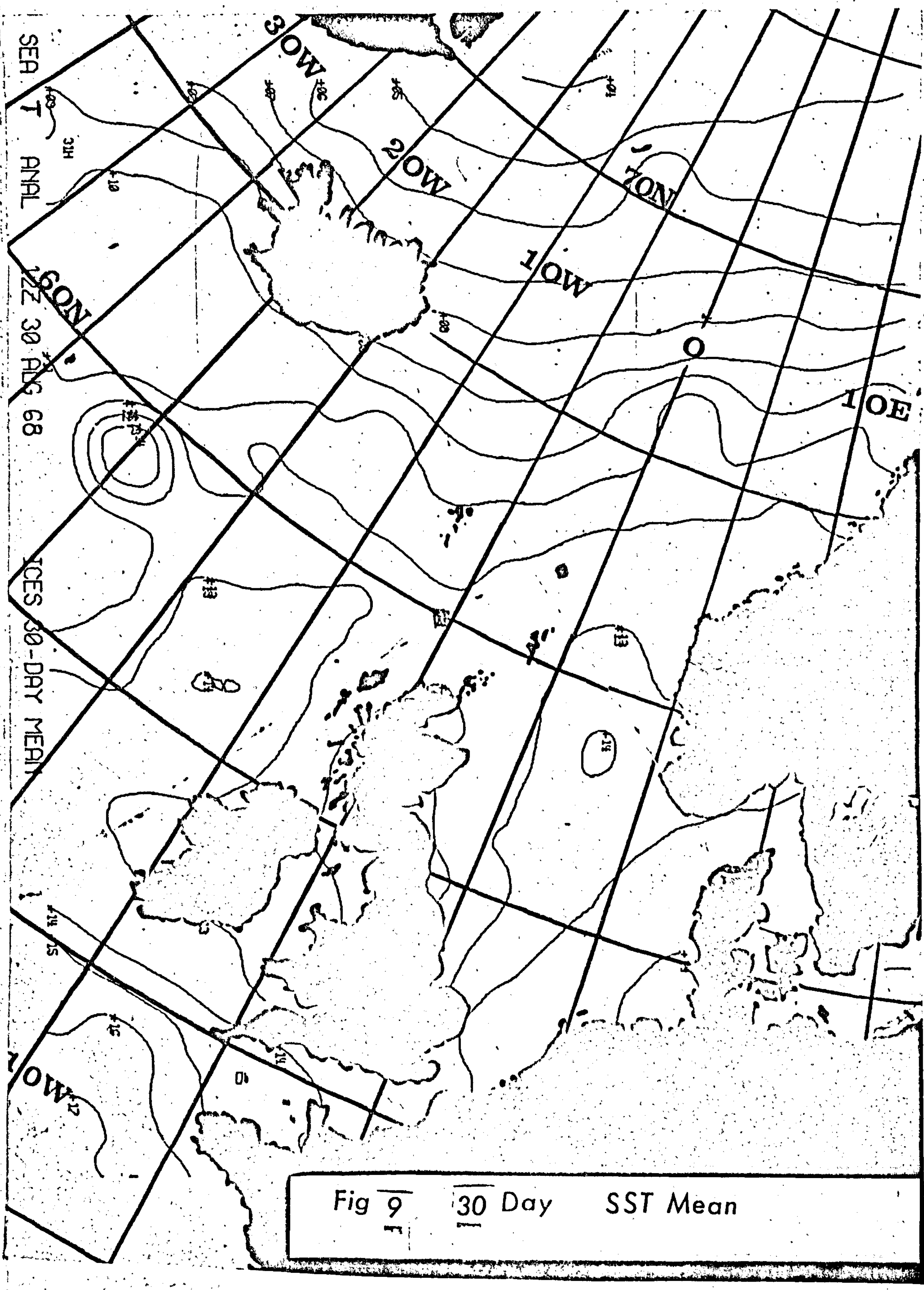


Fig 9 30 Day SST Mean

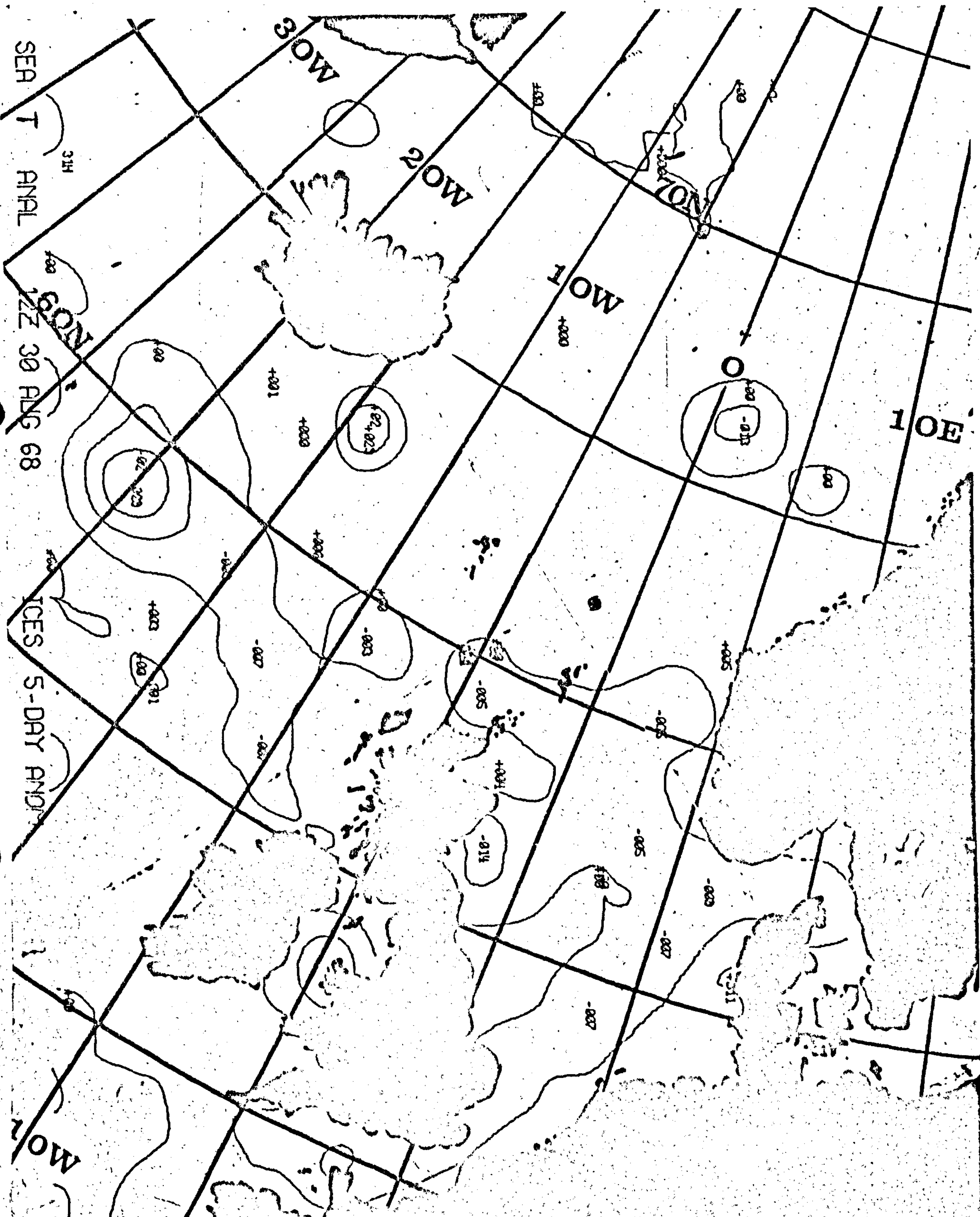


Fig 10 5 Day SST Anomaly

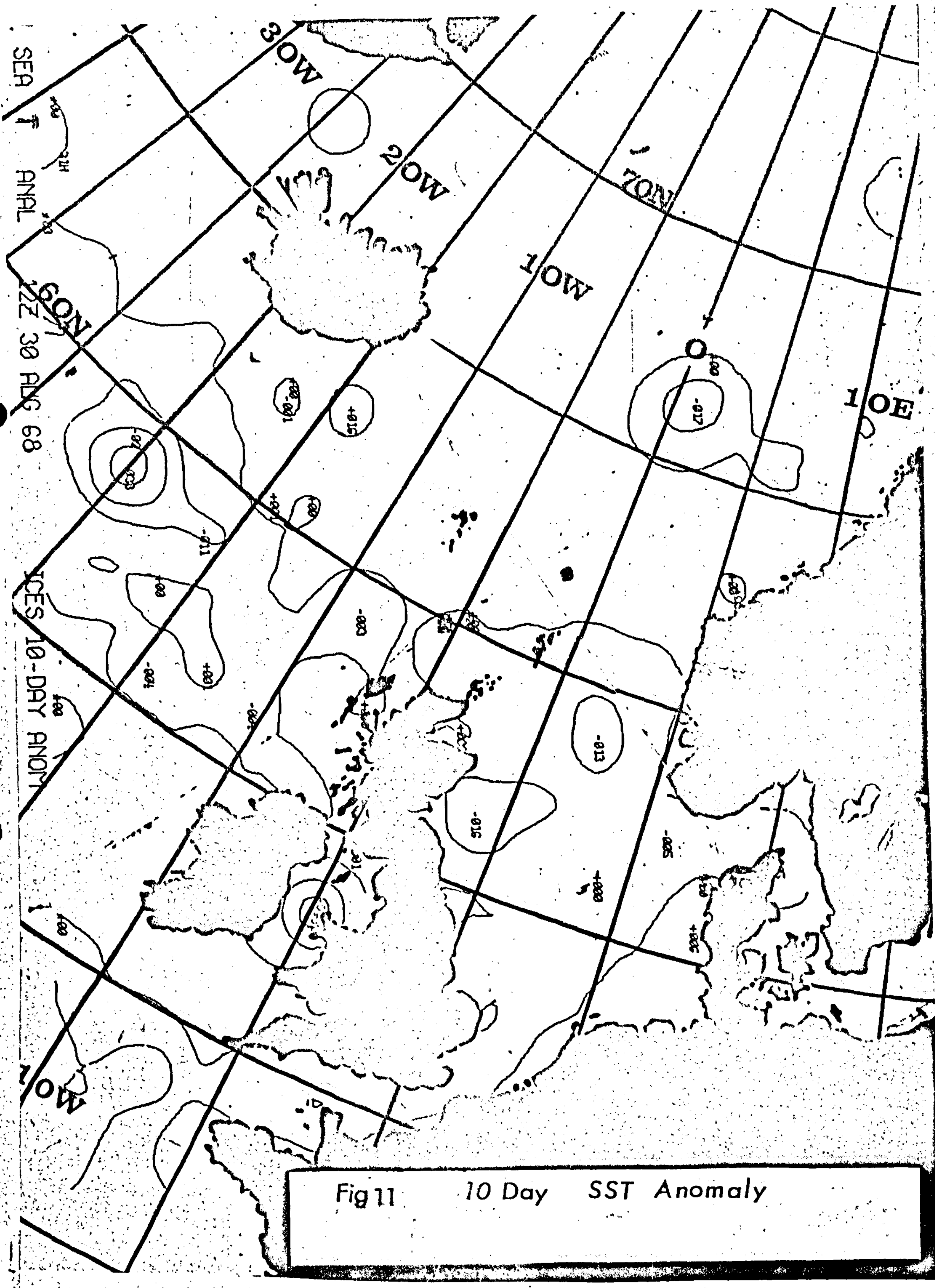


Fig 11 10 Day SST Anomaly

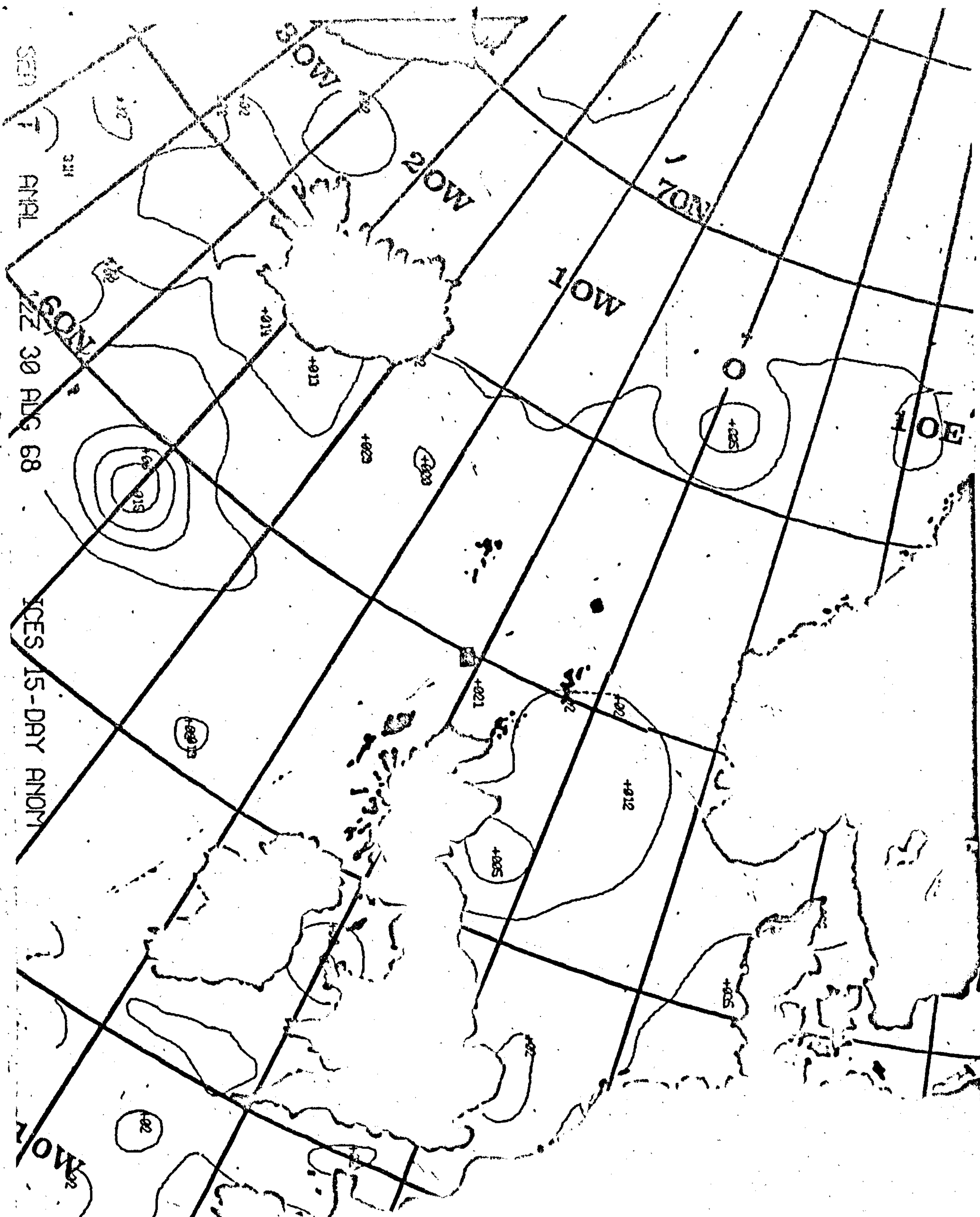


Fig 12 15 Day SST Anomaly

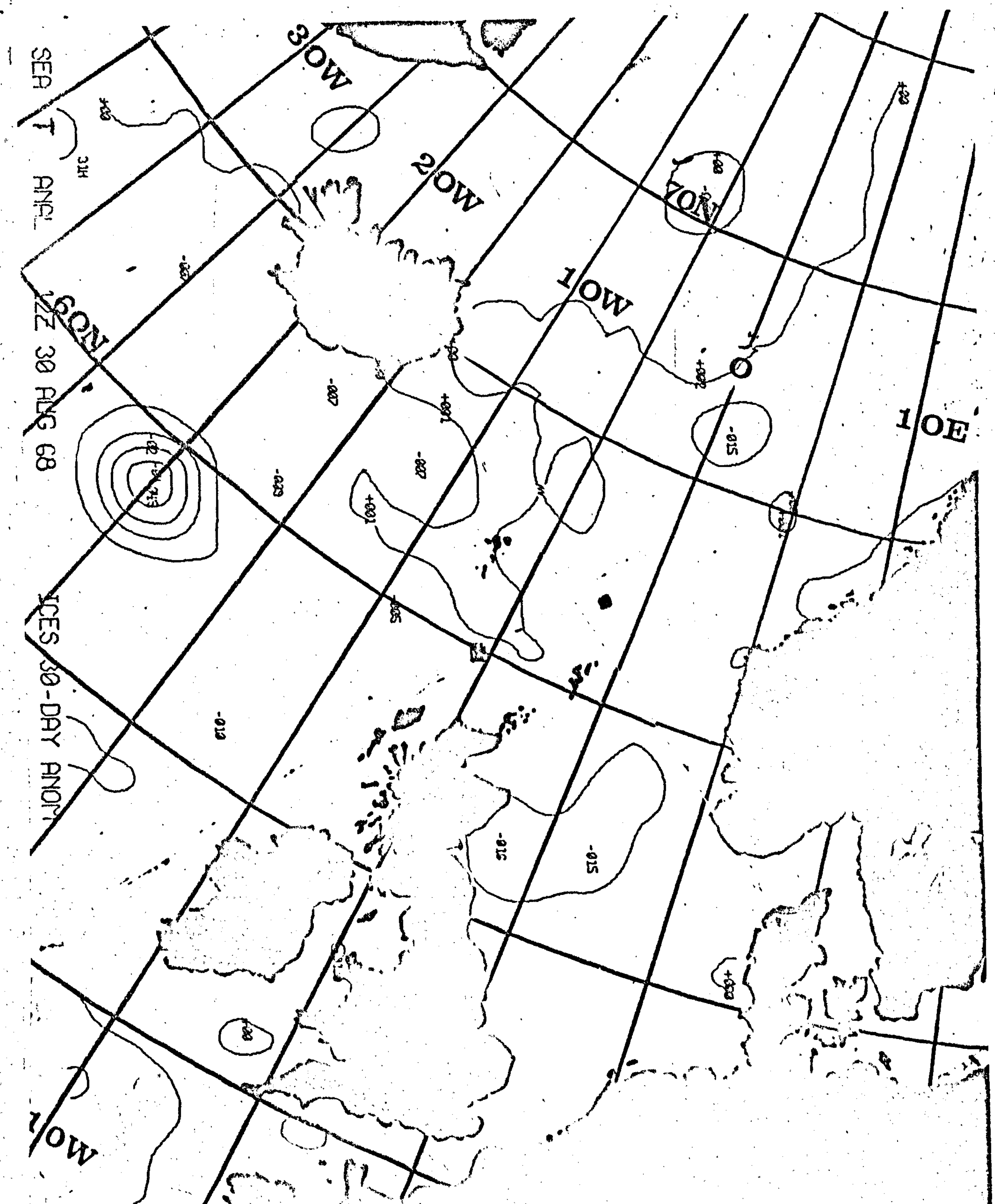


Fig 13 30 Day SST Anomaly

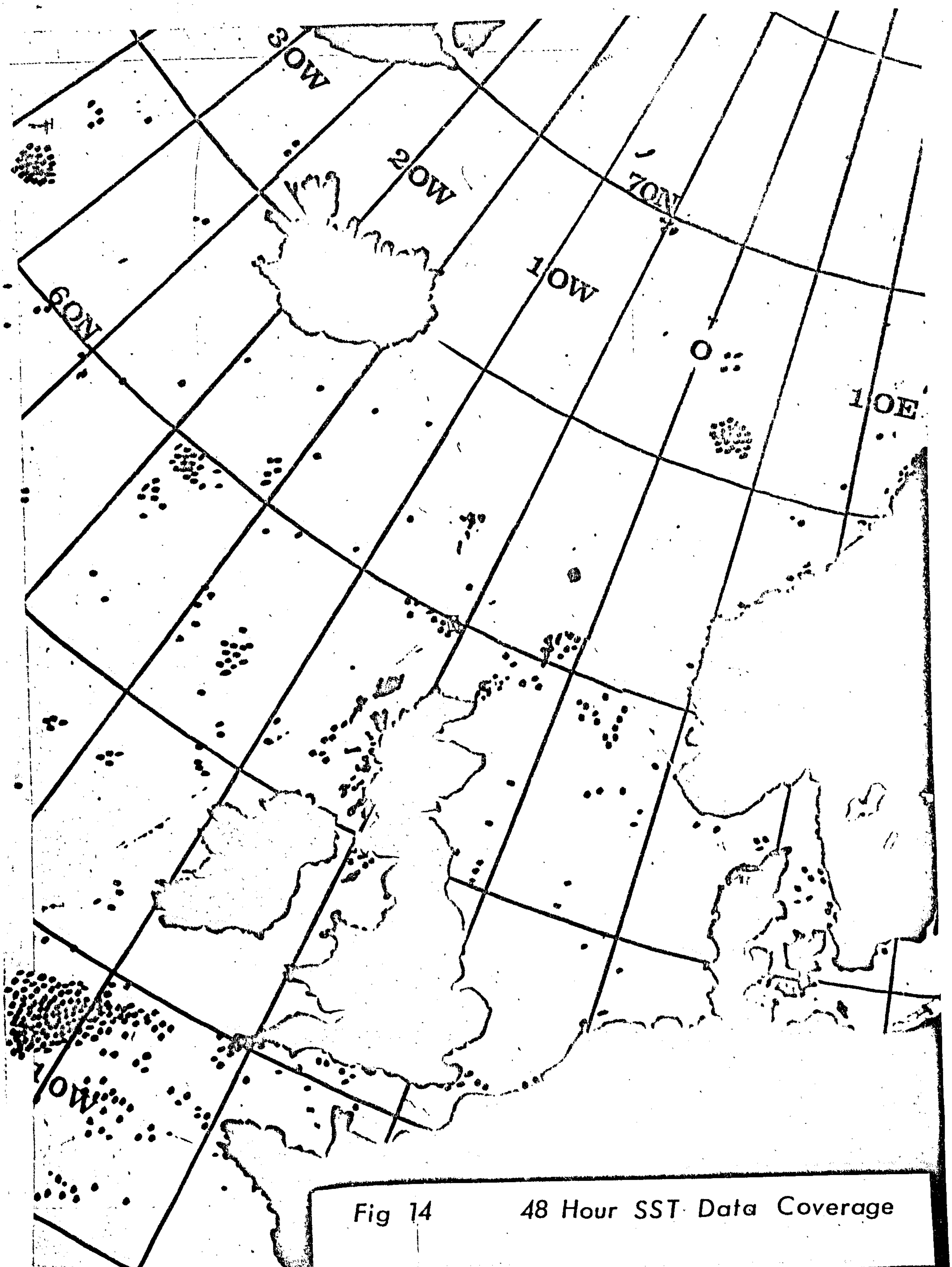


Fig 14 48 Hour SST Data Coverage