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The processing of sea-surface temperature measurements for use in the Met O 19 VTPR retrieval programme

by B. R. May

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The processing of sea-surface temperature measurements for use in the Met O 19 VTPR retrieval programme

1. Introduction

A computer programme has been written by staff of the High Atmosphere Branch to carry our retrievals of the vertical temperature and humidity profiles over sea areas from the cloudy radiances observed by the satellite-borne Vertical Temperature Profile Radiometer (VTPR). For the purpose of deducing cloud-free radiances from these cloudy radiances and then accounting for the component of the cloud-free radiances which is emitted by the sea, estimates are required of the mean sea-surface temperature over areas about 550 Km square. This Branch Memorandum describes a simple method of producing these mean temperatures from ship measurements, suitable for use with the VTPR retrieval method.

2. The requirements for mean sea-surface temperatures

The effect of clouds on infra-rad sounding is overcome by using a scanning radiometer to make many observations over a limited area within which it is assumed that a) the atmosphere (and hence clear radiance) is horizontally uniform and b) the observed variation of radiance is due only to the variability of cloud cover. The VTPR is a scanning radiometer making 23 observations in each scan - for the purposes of retrieving atmospheric parameters the observations from eight scans are grouped together into an inner box of 7 x 8 observations and two outer boxes of 8 x 8 observations. The nominal size of each box is about 550 Km square. A typical sequence of VTPR boxes for a south-going (morning pass) of the NOAA spacecraft over the Atlantic Ocean is shown in figure 1: for north-going (evening) passes the sequences would be a mirror image about the north-south axis. At very high and very low latitudes the edge of the VTPR boxes are roughly parallel to the lines of latitude and longitude, whereas at a latitude of about 60°, they are inclined at 45°.

The strict requirement is for an estimate of the mean sea-surface temperature and its standard error for each VTPR box calculated from ship measurements made over the previous few days (the number of days depends upon the frequency with which the observations are made and how rapidly the temperature changes - this has yet to be determined by numerical experiment). It is impractical and expensive in computer time to search for the ship observations made within each specific VTPR box especially as the positions of the boxes changes from day to day. Instead it is more convenient to use a pattern of geographically fixed temperature boxes whose size and shape are approximately the same as the VTPR boxes - it is more efficient in the use of the computer and also allows for continuity of the temperature to be studied and used if required.

As a compromise between the opposing orientations of the VTPR boxes during north - and south-going passages of the NOAA spacecraft it was decided that the temperature boxes should be aligned with their edges north-south and east-west i.e. between parallels of latitude and meridians of longitude. The system which has been adopted is one in which the boxes are bounded by the latitudes 0°, 5°, 10° etc to give a north-south dimension of 550 km and by longitude lines which are chosen so as to make the mean dimension in the east-west direction also about 550 km. The number of boxes and their width in each latitude band are tabulated below.

Latitude band (degs)	Number of temperature boxes in 360° of longitude	Width of each temperature box in longitude (degs)
0- 5	72	5.00
5-10	72	5.00
10-15	70	5.14
15-20	68	5.29
20-25	66	5.45
25-30	64	5.63
30-35	60	6.00
35-40	58	6.21
40-45	54	6.67
45-50	48	7.50
50-55	44	8.18
55-60	38	9.47
60-65	34	10.59
65-70	28	12.86

The 0° longitude meridian is used as an origin for the boxes in all latitude bands.

Initially our retrievals from VTPR radiances are to be confined to the north-eastern Atlantic area within which the telemetry from the VTPR can be received directly from southern England (in figure 1 this area is bounded by the circle passing through Newfoundland) - the temperature boxes covering the area are also shown in figure 1. The approximate agreement between the shape and size of the VTPR and temperature boxes can be seen; for VTPR and temperature boxes at low latitudes whose centres do coincide the area common to them both is about 90% of either area - at 60°N (the most unfavourable circumstance) this figure is about 60%. It is appropriate to mention here that in general the centres of VTPR and temperature boxes do <u>not</u> coincide so that a process of interpolation is required - this is described in the last section of this memo.

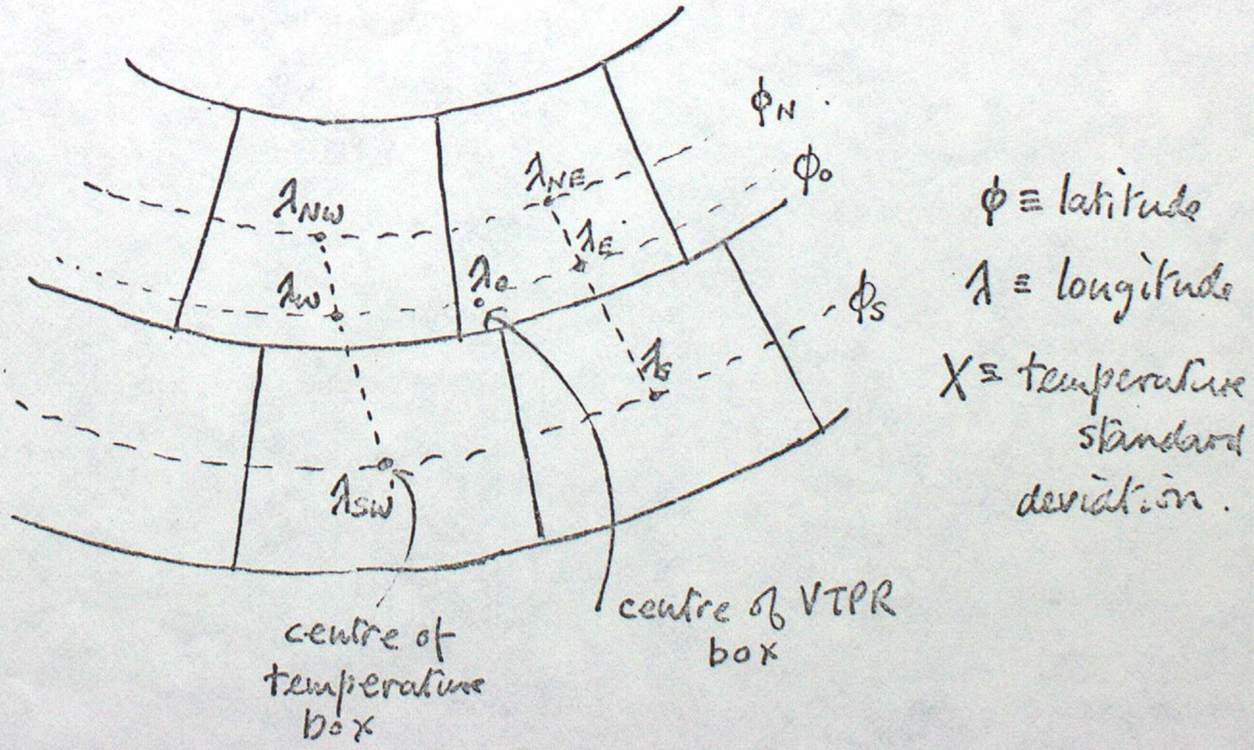
3. <u>Example of use of the method of objective analysis</u>

As an example of the number of sea-surface temperatures available, each temperature box in figure 1 contains the number of observations received at Bracknell during the two-day period 00Z 15 July to 00Z 17 July 1973. These observations are concentrated near the coasts, in the shipping lanes and many are made by the weather ships. The number falls off rapidly towards the tropics. In figure 2 are shown the mean sea-surface temperatures for the boxes plotted at the nominal box centres, to which contours at 2°C intervals have been added. The contours are smooth and free from small-scale structure which indicates that the lack of precise agreement between the positioning of the VTPR and temperature boxes is unlikely to have a serious effect on the interpolated temperatures. The temperature field for this period shows the strong thermal gradient in the Gulf Stream from Newfoundland to Ireland with more gentle gradients to the north and south.

The deduced clear radiance depends directly on the mean sea-surface temperature so that errors in the mean temperature can be used directly to estimate a corresponding error in the radiance. For this reason the standard errors of the mean temperatures are also calculated and have been plotted for this two-day period in figure 3 with contours at 0°.5C intervals. These standard errors really contain two components, one of which arises from the actual errors in the measurements and the other because of the relatively large area over which the means are taken (this latter error shows up particularly near the Gulf Stream where the temperature gradients are large). In the tropical Atlantic large values of standard error also occur -- these arise because only very few (and inaccurate) measurements are available there. In these regions it may be possible to take means over longer periods without introducing serious errors due to real time changes in temperature.

4. Interpolation within the temperature field

It was mentioned previously that it is convenient to use the system of fixed temperature boxes described in the previous sections; however in general the nominal centre of a VTPR box will not coincide with the centre of a temperature box so that a two-dimensional interpolation is required within the temperature field. The formulae for estimating the temperature at the centre of a VTPR box given the temperatures for four "surrounding" temperature boxes are given below.



$$R_1 = \frac{(\phi_0 - \phi_S)}{(\phi_N - \phi_S)}$$

$$\lambda_W = (\lambda_{NW} - \lambda_{SW}) \times R_1 + \lambda_{SW}$$

$$\lambda_E = (\lambda_{NE} - \lambda_{SE}) \times R_1 + \lambda_{SE}$$

$$R_2 = \frac{(\lambda_0 - \lambda_W)}{(\lambda_E - \lambda_W)}$$

$$X(\phi_0, \lambda_W) = (X(\phi_N, \lambda_{NW}) - X(\phi_S, \lambda_{SW})) \times R_1 + X(\phi_S, \lambda_{SW})$$

$$X(\phi_0, \lambda_E) = (X(\phi_N, \lambda_{NE}) - X(\phi_S, \lambda_{SE})) \times R_1 + X(\phi_S, \lambda_{SE})$$

$$X(\phi_0, \lambda_0) = (X(\phi_0, \lambda_E) - X(\phi_0, \lambda_W)) \times R_2 + X(\phi_0, \lambda_W)$$

Acknowledgement:- I wish to acknowledge the assistance of J. S. Campbell in extracting sea-surface temperatures from the data banks

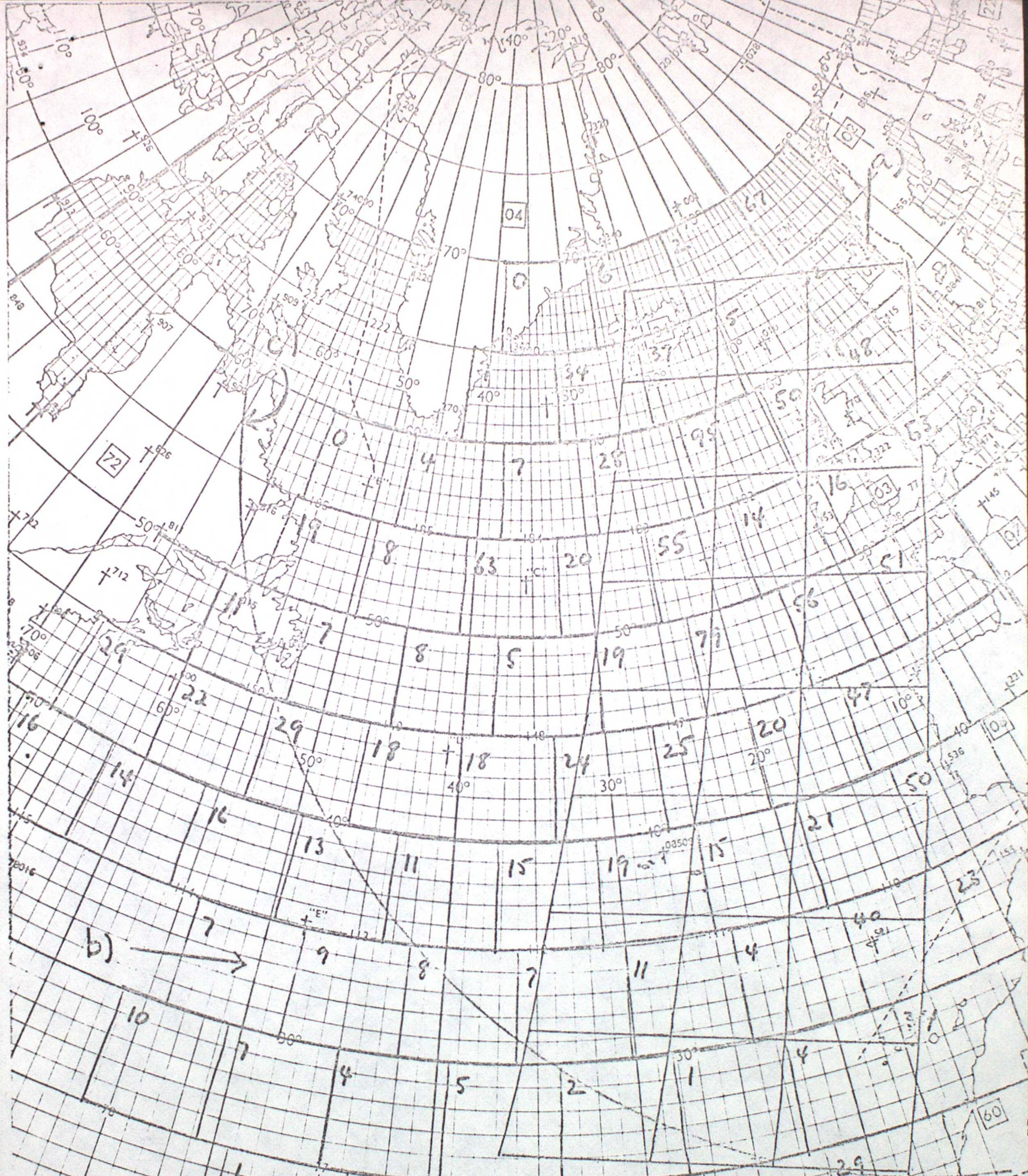


FIGURE 1 a) VTPR BOXES.
b) SEA-SURFACE TEMPERATURE BOXES.
c) BOUNDARY OF VTPR TELEMETRY DIRECT RECEPTION AREA.

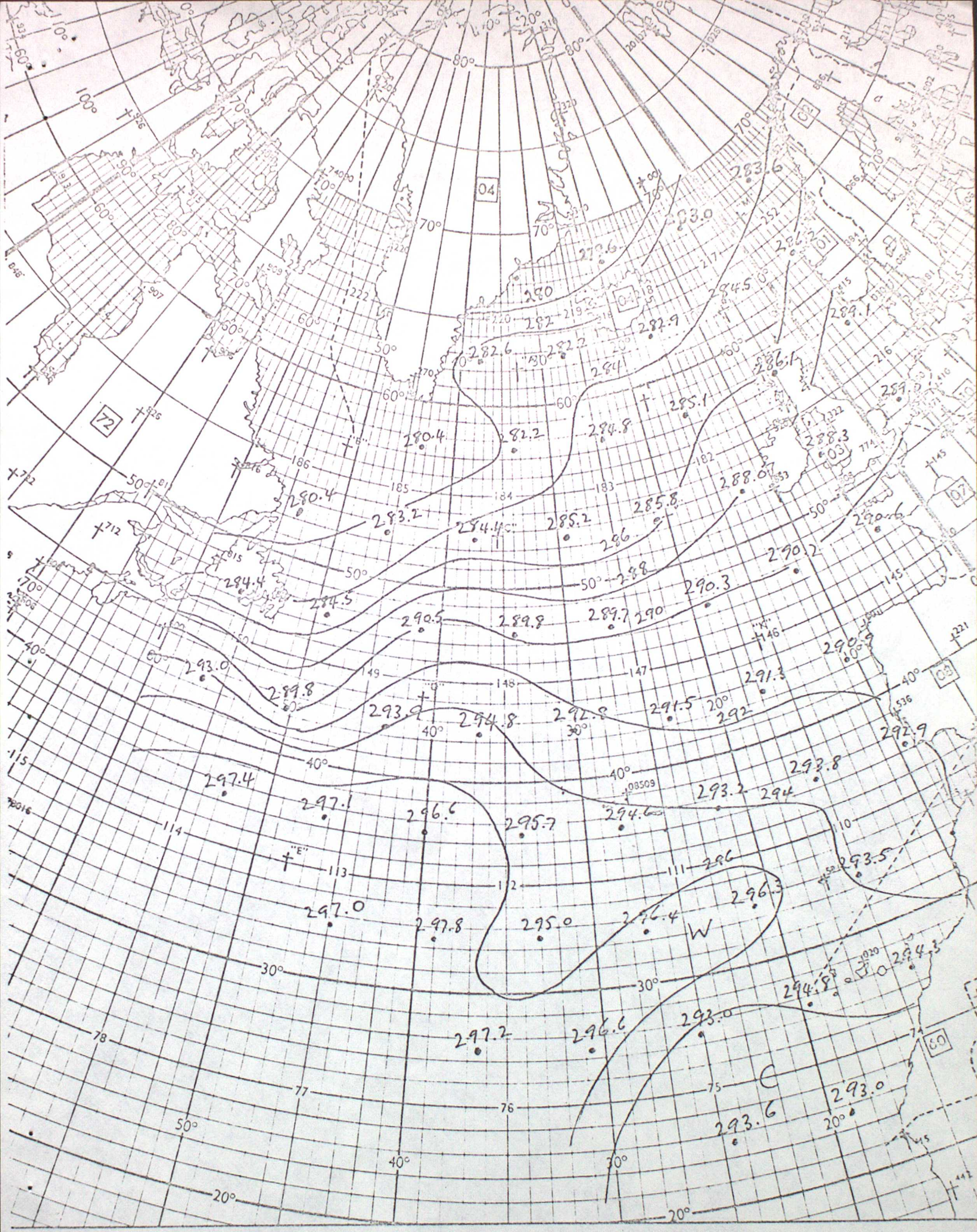


FIGURE 2 MEAN SEA-SURFACE TEMPERATURE FOR THE PERIOD 00Z 15 JULY TO 00Z 17 JULY 1973 (UNITS - DEGS ABSOLUTE)

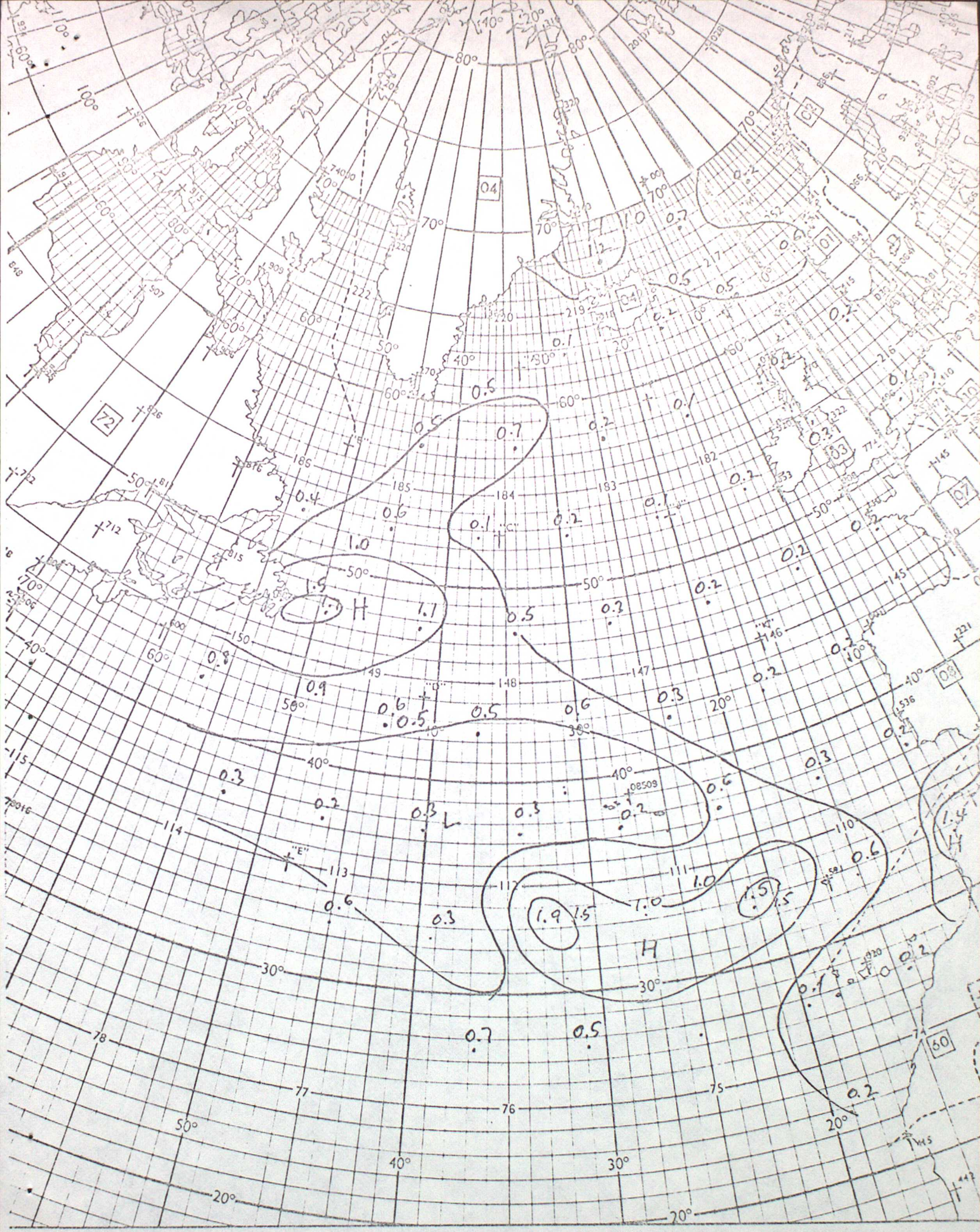


FIGURE 3 STANDARD ERROR OF MEAN SEA-SURFACE TEMPERATURES FOR THE PERIOD 00Z 15 JULY TO 00Z 17 JULY 1973 (UNITS – DEGS C)