



LONDON, METEOROLOGICAL OFFICE.

Met.O.19 Branch Memorandum No. 7.

The production of mean daily radiance and high-level thickness charts from Nimbus E data. By HUNT,R.D.

London, Met.Off., Met.O.19 Branch Mem.No.7, [1974], 33cm.Pp.8, pls.6.6 Refs.

FGZ

National Meteorological Library
and Archive

Archive copy - reference only

Met O 19 Branch Memorandum (No 7)



0119734

The production of mean daily radiance and high-level
thickness charts from Nimbus E data

R D Hunt

Permission to quote from this unpublished memorandum should be obtained from the
Head of Met O 19, Meteorological Office, Bracknell, Berks, RG12 2SZ.

THE PRODUCTION OF MEAN DAILY RADIANCE AND
HIGH-LEVEL THICKNESS CHARTS FROM NIMBUS E DATA

HA/IG/8

R.D. Hunt

Introduction

This report describes work done in the High Atmosphere branch to produce objectively analysed charts of radiances and thicknesses from data originating from the Selective Chopper Radiometer (SCR) on the Nimbus E satellite. The data used in the work was sent to Bracknell from the Clarendon Laboratory at Oxford on a series of magnetic tapes and covered two periods early in 1973, one just before a stratospheric warming and one at the end of the same warming.

Temperature profiles, and hence thicknesses, were retrieved from the measured radiances using the maximum probability method of retrieval and the fields for both northern and southern hemispheres were analysed objectively using polynomial fitting techniques. Each field was produced from data measured over a 24 hour period.

Data used in the study

Each 7-track magnetic tape sent from Oxford was copied onto a 9-track tape belonging to the Meteorological Office for use on the 360/195 machine. The tapes contained information from the SCR for a 24 hour period of observations from Nimbus 5, the data consisting of calibrated radiances for each of the sixteen SCR channels with orbit and observation identification (i.e. time, latitude and longitude), and various raw data and housekeeping data not used in this work. (Details of the SCR instrument on Nimbus E can be found, for example, in the Nimbus E User's Guide¹). It was found that most of the tapes did not contain a full 24 hours data but, in fact, a few hours less. This was not thought to have a large effect on the results to be described below.

For the five channels in the $15\frac{1}{4}$ CO_2 band which measure radiation emitted from the highest parts of the atmosphere, i.e. the four B channels and the A1 channel, radiances are given on the tapes at 16 second intervals, whereas the 16 second values for the remaining channels were found by taking means of the four second values read from the tapes. There were, on average, just under 4000

16-second observations over the entire globe on each daily tape.

The dates covered by the tapes were from 18-22 January and 12-16 February 1973. These were chosen because there were days when significant changes were occurring in the stratosphere at the beginning and at the end of a stratospheric warming.

Retrieval Method and Analysis

It was decided from a study of the weighting functions which determine the layers in the atmosphere from which the measured radiances are emitted (fig. 1) that the B12, B23 and B34 channels (the 'differenced' B channels) and the B4 and A1 channels were unlikely to be affected by the presence of cloud beneath the satellite and, for this reason, only the radiances from these five channels were used in the retrieval process. The maximum probability method, described, for example by Fleming and Smith² and Rodgers³, was used to determine temperature profiles 'defined at 50 points from the earth's surface to about 0.5 mb, from the radiance measurements. Report HA/IG/3⁴ describes the division of the earth into seven groups defined by latitude and season (i.e. latitude and hemisphere) and the derivation of covariance matrices from samples of rocket-sonde and radio-sonde soundings for each group necessary for the maximum probability method to be carried out.

Each daily tape was read and the relevant information was extracted from them. The 'differenced' B channel radiances were calculated using the formulae

$$R_{ij} = R_i + f_{ij} (R_i - R_j)$$

where the R_{ij} (R_{12} , R_{23} and R_{34} in this case) are the required differenced radiances, R_i ($i = 1, 4$) are the radiances measured on the B_i th channels and f_{ij} are constants provided by the Clarendon Laboratory. On each 16 second observation, a very rough quality check was performed. This merely consisted of checking that the R_{12} and R_{23} radiances were within reasonable limits determined by inspection. Although this is clearly not an entirely rigorous check it seemed to be adequate for the purpose of this work.

The observation was then placed into the correct latitude - season group in order that the correct covariance matrix could be used in the retrieval and a temperature profile determined at the usual 50 points on a pressure scale defined

by $P_{n+1} = 1013.246 \exp(-n/5)$, $n = 0, 1, \dots, 49$ was retrieved. The profile was used to calculate six thicknesses, 1000-300 mb, 300-100 mb, 100-30 mb, 30-10 mb, 10-3 mb and 3-1 mb, at the observation point. Clearly, the 1000-300 mb thickness was determined entirely from correlations with higher parts of the atmosphere i.e. entirely from the sample statistics, as none of the channels measured radiance emitted from these lower regions; however it was calculated for general interest and completeness.

Having retrieved the various thicknesses from the radiance measurements, the observations were then sorted into northern and southern hemisphere groupings in preparation for the objective analysis. The latitude and longitude co-ordinates of each observation were translated into co-ordinates on a 61 x 61 square grid centred on the pole and which describes the octagon used in the operational analyses in Met 0 2. The analysis was then performed for each thickness field and radiance field using a system involving the fitting of orthogonal polynomials to the observations. Dixon et al ⁵ describe details of this technique. A background field is necessary to provide values on the grid where there are no observations. For the first day in each sequence, these background fields were made constant with values by inspection found to be appropriate to the equatorial regions where, due to the geometry of the satellite orbits, there is sparser data coverage. This tends to produce fields which are rather rough in these tropical regions, features with wavenumber 12 corresponding to the 12 daily orbits being clearly visible. On other days in the sequences, the previous days' analyses were used as background fields.

Figure 2 shows diagrammatically the steps involved in the retrieval and analysis procedure for one day's data.

Results

The first result of interest concerned channel B⁴. A study of the analysed radiance fields for the A¹ and B⁴ channels revealed that there was a consistent difference between them of about 12 radiance units. Bearing in mind the similarity of the weighting functions for these channels, this discrepancy was suspiciously

large and subsequent communication with Clarendon Laboratory confirmed that B⁴ was in error and thereafter it was not used.

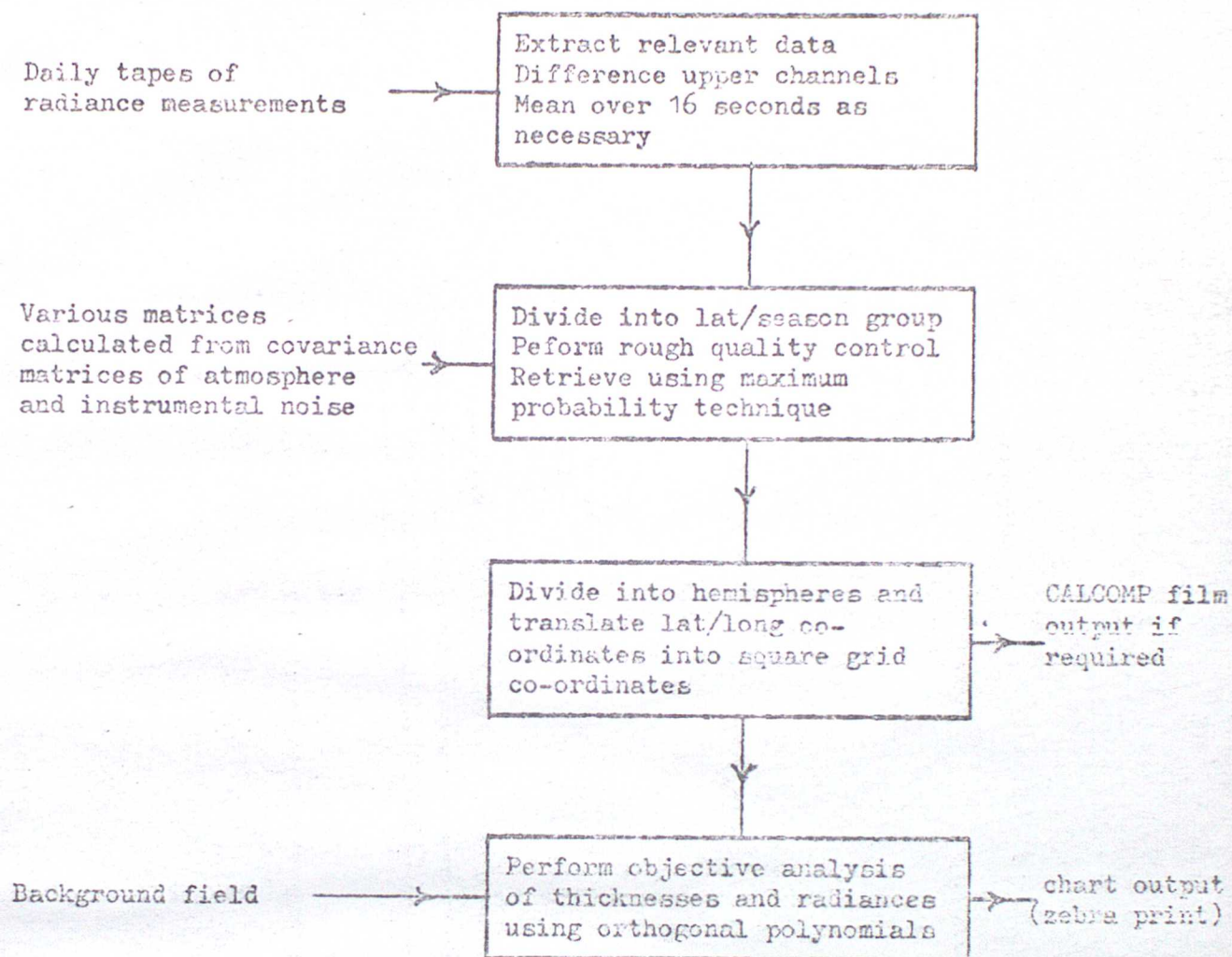
For the purpose of comparison, some high-level thickness charts for the particular dates were drawn using radio-sonde data. The 100-30 mb and 30-10 mb charts could be drawn without much difficulty using midnight data on each day. Above 10 mb, observations come mainly from rocket-sondes, but as there are insufficient of these to produce thickness charts, difficulties arose when trying to assess the accuracy of the satellite data at these very high levels.

Figures 3-7 show some results of the work. Figure 3 is an example of an objectively analysed radiance field, in this case the B12 radiance field for the northern hemisphere for 14/2/73. The same radiance field for the previous day was used as the background field. Note the fairly rough appearance of the field in equatorial regions compared to the smoothness in higher latitudes. Figures 4 and 5 show the 100-30 mb thickness field for the northern hemisphere on the same day, fig.4 being the objectively analysed field using data derived from the Nimbus 5 measurements and fig.5 being the subjectively analysed field from radio-sonde data at 0000Z.

Clearly, north of about 30°N there is reasonable agreement between the charts derived from different data. Both the positions and the values of the high thickness areas to the north-east of the British Isles and in the vicinity of the Bering Sea are similar on both charts (it must be stressed here that comments cannot be made about the correctness of either chart but only about the similarities or otherwise between them). The cold pool, centred near 70°N, 80°E in fig.5 is placed slightly further west and the value at the centre is significantly less in fig.4. In fact, the discrepancy at the centre is just over 20 decametres. Other points of agreement are the ridge over the Great Lakes (although slightly further west in fig.5), the ridge south-east of the cold pool already described and the trough over southern Greenland.

Figure 2

Diagrammatic representation of retrieval and analysis procedure



Quite large differences between the charts exist in tropical regions, fig.4 having much higher thickness values in these areas. This may be as a result of a poor background field initially (this was the third day in the sequence), or possibly because of a poor statistical sample used in the calculation of the covariance matrices. Further study of these and other results will be necessary to determine the correct reason.

Figures 6 and 7 are 30-10 mb thickness charts for the northern hemisphere both objectively analysed from satellite data, fig.6 being for the 19 January 1973 and fig.7 being for the 22 January 1973. Firstly it should be pointed out that fig.6 is for the second day and fig.7 for the fifth day in a sequence of five days and it would appear that the roughness in the tropical regions has become slightly less marked as the sequence has progressed. This is particularly apparent over west Africa for instance. Secondly, there is a clear continuity between the two charts with a general eastward movement of most of the major features.

Interesting features are the elongated, almost 'S-shaped' cold pool in the centre of the charts and the two high thickness areas one centred near the Bering Strait and the other over southern Europe. It is these latter two areas which are of special interest. The value at the centre of the warm region over the Bering Strait has decreased by 10 decametres from fig.6 to fig.7 whereas the value at the centre of the warm region over southern Europe has increased over the period by the same amount. This latter centre has also moved appreciably north-eastwards. In fact, this warm region moved further north-eastwards over subsequent days and intensified considerably, the period being at the beginning of a stratospheric warming.

Whilst based on obviously limited evidence, the way that the important trends have been brought out by these charts particularly with respect to the beginning of the stratospheric warming is promising.

Conclusions

This report describes some preliminary work performed with Nimbus E data and concerned entirely with that part of the atmosphere above cloud level. The initial impression is certainly a favourable one although, of course, there is much detail to look at and far more cases need to be studied.

Future work will involve a) direct comparison of satellite data and radio-sonde/rocket-sonde data on a quantitative basis (this has already been carried out for the days covered by this study) and b) the study of different retrieval methods with a view to improving the final analyses, particularly in interesting periods such as stratospheric warmings. Again, the difficulties in knowing the 'true' state of the atmosphere at these high levels with limited radio-sonde coverage and extremely limited rocket-sonde coverage must be stressed. Any inferences about the accuracy of satellite data from comparisons with 'conventional' data must be made bearing in mind the errors in the conventional data as well. A further important task will be to improve the statistics used in the retrievals. This will entail an increase in the amount of radio-sonde/rocket-sonde sample ascents employed in the calculation of the covariance matrices. The production of these samples is described in HA/IG/1.

Acknowledgement

The author would like to acknowledge the assistance given by members of the Clarendon Laboratory Oxford for making available the necessary data used in this work.

References

- 1) Nimbus E Users Guide. Goddard Space Flight Center, Greenbelt, Maryland
- 2) Fleming, H.E. and Smith, W.L. Inversion techniques for remote sensing of atmospheric profiles. Fifth Symposium on Temperature, Washington, D.C., June 21-24, 1971, pp 2239-2250.
- 3) Rodgers, C.D. Remote sounding of the atmospheric temperature profile in the presence of cloud. University of Oxford, Clarendon Laboratory Mem. 69 3, 1969.

- 4) Hunt, R.D. Thickness retrievals using various sets of weighting functions and values of instrumental noise. Met O 19 internal report HA/IG/3, 1973.
- 5) Dixon, R; Spackman, E.A., Jones, I. and Anne Francis. The Global Analysis of Meteorological Data using Orthogonal Polynomial Base Functions. Journal of Atmos. Sci, Vol 29, No.1, pp 609-622, May, 1972.
- 6) Barwell, B.R. and Hoskin, G.C. Vertical temperature profiles of the troposphere and stratosphere on punched cards. Met O 19 internal report HA/IG/1, 1972.

Normalised Weighting Functions for Number E

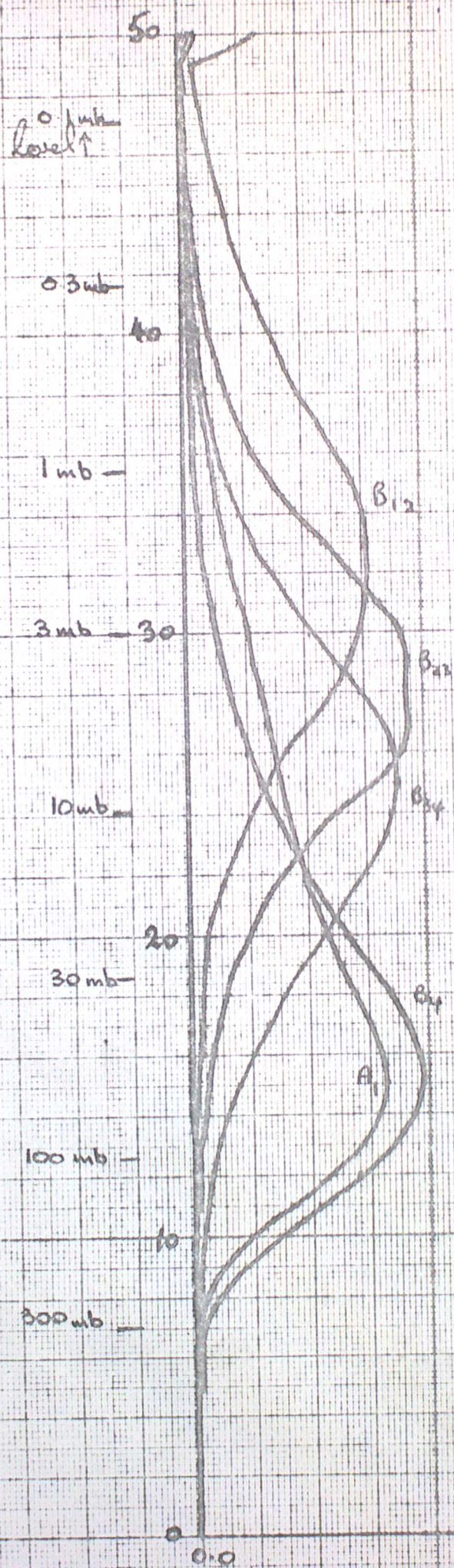


Figure 1

$\frac{d}{dE} \rightarrow$

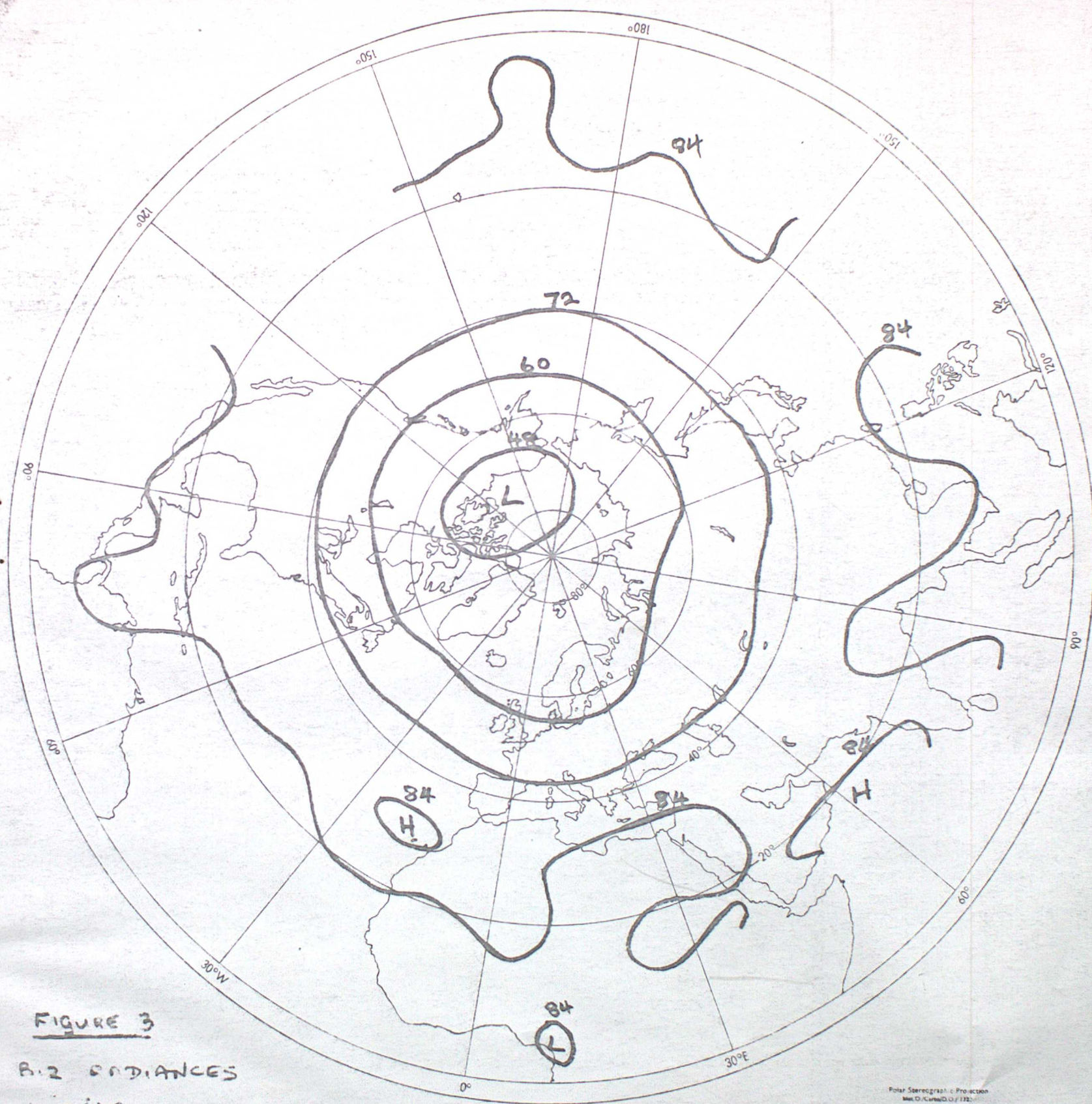


FIGURE 3

B.2 RADIANCES

14/2/73

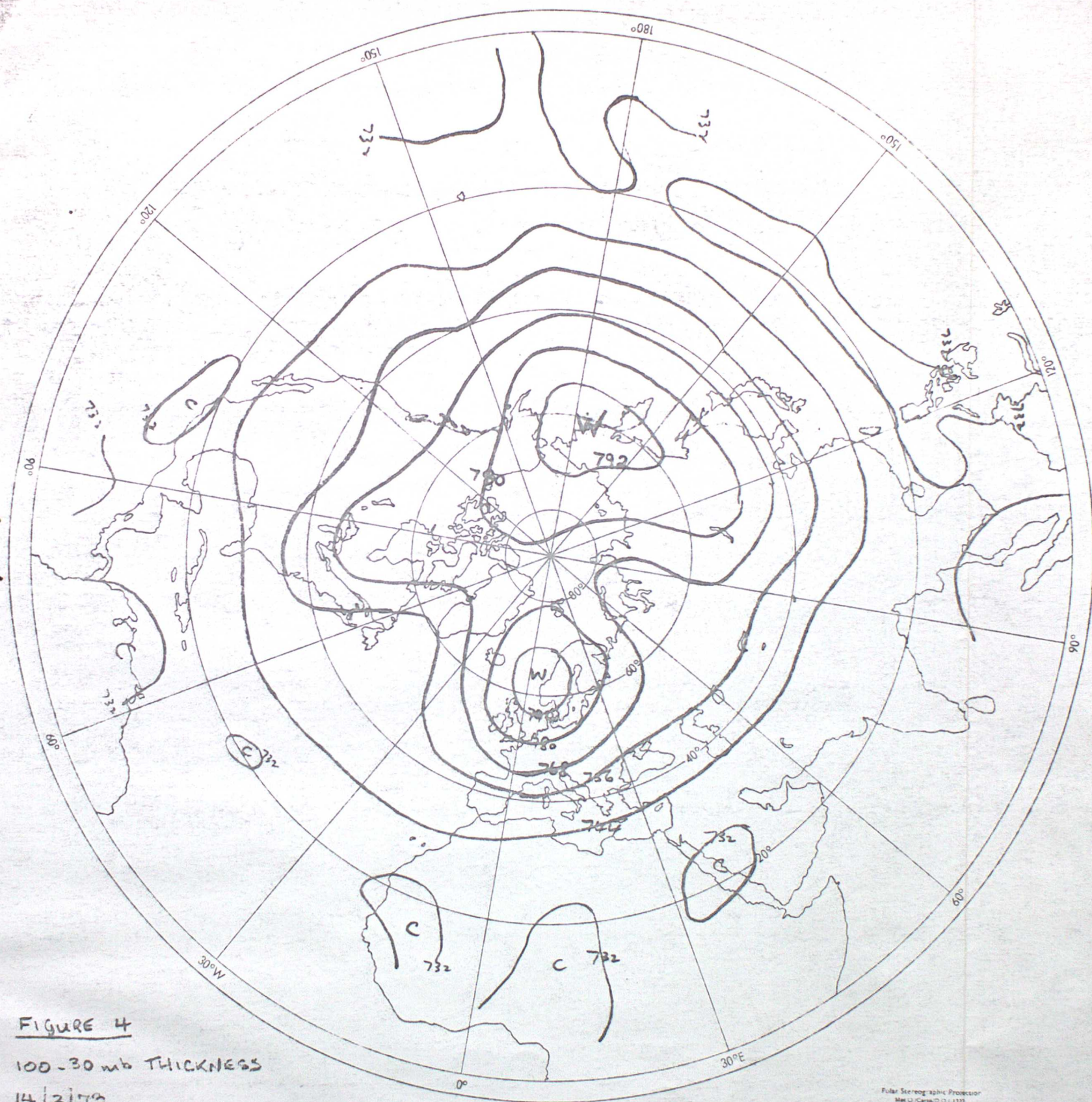


FIGURE 4

100-30 mb THICKNESS

14/2/73

FROM NIMBUS E DATA

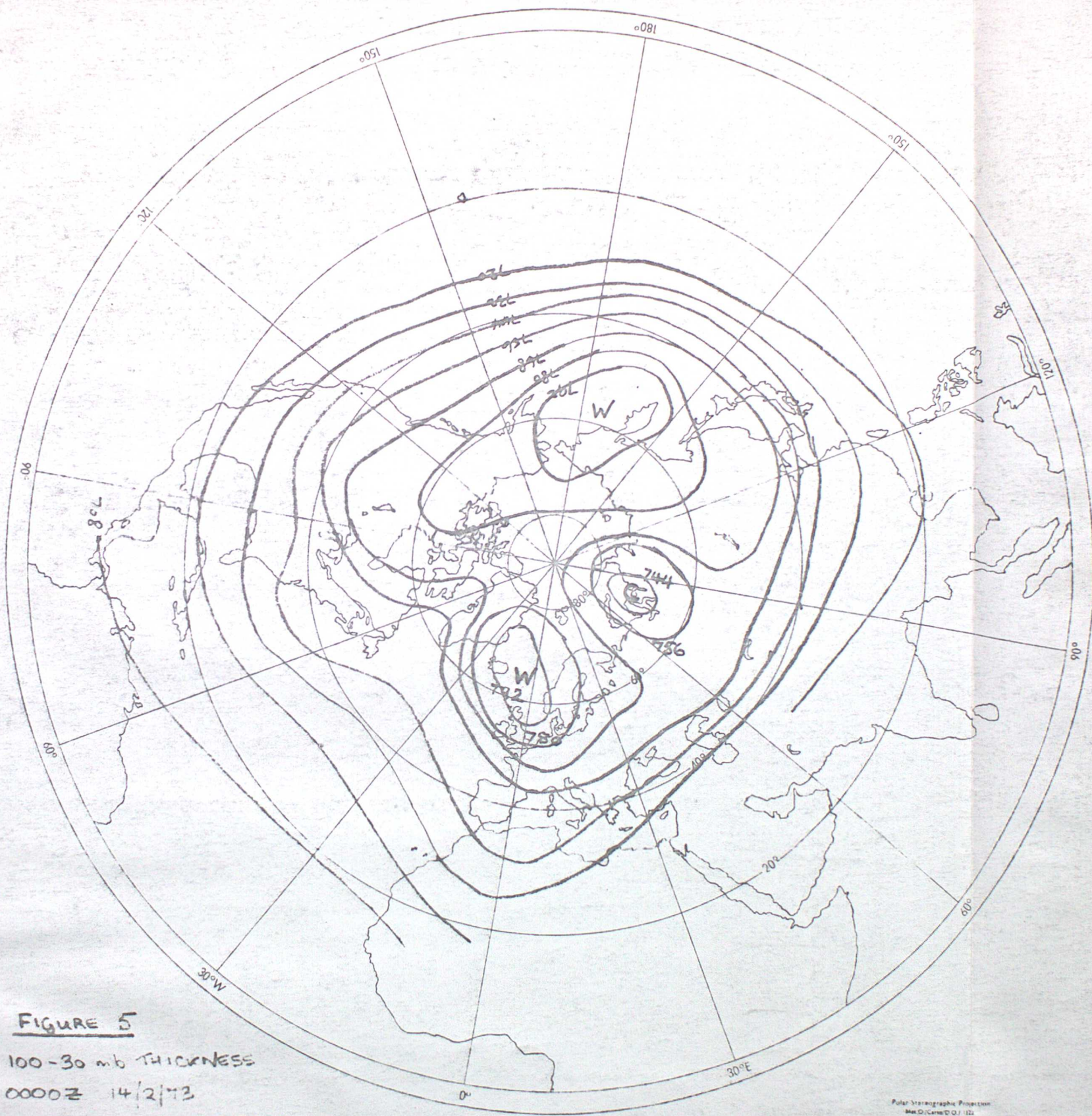


FIGURE 5

100-30 mb THICKNESS

0000Z 14/2/73

FROM RADIO-SOUNDE DATA

Polar Stereographic Projection
Map D/Cover 0.1/122





FIGURE 1

30-10 mb THICKNESS

22/1/79

SATELLITE DATA

Polar Stereographic Projection
Map O-Carus, 0-12 / 1122