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COMPARISONS OF STRATOSPHERIC ENERGETICS DERIVED FROM OBJECTIVE ANALYSES AND FROM THE CHART SERIES DRAWN BY THE STRATOSPHERIC ANALYSIS GROUP

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1. Introduction

Use has been made of the objective analyses at stratospheric levels for research purposes (Taylor and O'Neill 1977). It is known that on occasions these analyses can be considerably in error and would therefore produce unreliable results. In an attempt to assess the quality of the objective analyses, they have been compared with the 20 mb chart series drawn by the Stratospheric Analysis Group (SAG) for the period of a month, January 1977.

During these comparisons, the new technique of digitising the hand drawn chart was used. A test was carried out to estimate the confidence in the grid point fields obtained by varying the total number of points used in the digitisation process.

2. Objective analyses

Twice daily objective analyses over the octagon grid are produced operationally by Met O 2 (Flood (1977)). Human intervention is incorporated in all tropospheric levels (1000-100 mb) (Singleton (1975)). The stratospheric levels 200-10 mb are influenced by this intervention up to 100 mb. Above that level some control is exerted by the Stratospheric Analyses Group, who monitor the operational output and, when required, modify the background fields to reduce the differences between man and machine. Normally this is restricted to checking the positions and contour heights of the centres of highs and lows.

These analyses are stored in the octagon grid point format (3209 points) and are readily available for computation (Taylor (1976)).

3. Hand drawn chart series

This daily series of charts at 50, 20 and 10mb are constructed using radio sonde data and occasional rocket sonde data (Watson (1976)). The 50 mb charts are completed usually within 2 days of the observation time; the 10 mb charts may take one month to finalise, especially in mid-winter.

The charts are, of course, in an analogue form and the height and temperature fields must be reduced to a set of numbers in order to compute the stratospheric energetics.

4. Method of Digitising chart series

The process to convert each chart into an octagon grid point data-set is as follows. The chart is placed on the table of the D Mac Pencil follower and every contour line or isotherm is "followed" while x and y coordinates are sensed at regular time intervals, and punched out on paper tape. This paper tape is then processed using the PDP11-40 in Met O 22 which, a) detects and corrects any parity errors in the paper tape, b) converts the x, y coordinates into latitude/longitude positions and c) produces a magnetic tape of these values.

Finally the magnetic tape is processed by COSMOS using an interpolation programme devised by Met O 20 (N Saker) which produces a 3209 octagon grid point array of either geopotential heights or temperatures. It is then possible to Fourier analyse these data points and compute wave amplitudes and phases of the major wave motions. Geostrophic winds can be calculated from these height fields, from which kinetic energies can also be calculated.

5. Results

The 20 mb SAG charts were digitised for the odd dates in January 1977 and the wave amplitudes and kinetic energies were calculated for the first 4 wave numbers on each day.

The 20 mb objective analyses were also treated similarly and Figures 1 and 2 shows the variation of the amplitude of WN1 and WN2 for both analyses at three latitudes through the month.

In general the objective analyses show greater amplitudes but overall the developments with time are similar. The objective analyses at the beginning of the month had a deeper polar vortex which caused the larger amplitudes in WN1 and WN2 at 75°N.

The meridional variations for one day (3 January) can be seen in Figure 3. Three profiles, of $\bar{u}$, KE(1) and KE(2) are presented. KE(1) and KE(2) are the kinetic energies in wave numbers 1 and 2. Again all values for the objective analyses are higher at latitudes north of about 70°N.

Figure 4 shows a time/latitude section of WN1 amplitude throughout the month for the objective and hand drawn analyses. Both show maxima around 70°N on 8 January and near 60°N on 27 January with the objective analyses values between 10-20% higher.

Figure 5 shows the variation through January of the mean difference and standard deviation, over the 3209 octagon grid points, between the two sets of height fields. The range of differences lies between -3 and -9½ dam with standard deviations of about 9 dam (apart from the anomalous 20 dam on 27 January).

One question that required answering was the size of the errors, both in the height differences and the energetics, caused by errors in the digitisation process. A test was made on the 20 mb chart for 15 January by digitising a second and a third time. Each time the number of points used to define the field was different. On the first digitisation, the number of points used was 249; the second time 546 and the third time 637.

Mean geopotential height differences, from the objective analysis, were calculated for the second and third digitisations and also between the first and 3rd and 2nd and 3rd digitisations. They are shown below:

	Mean	SD
1st (249pts) - objanal	-7.47	9.70
2nd (546) - objanal	-6.02	9.47
3rd (637) - objanal	-5.82	9.53
1st - 3rd	-1.66	4.36
2nd - 3rd	-0.28	2.67

It can be seen that an increase in the number of points used reduced the mean difference slightly; there was a small difference between the 1st and 3rd and very little mean difference or standard deviation between the second and third.

The energetics calculated from the three digitisations and the objective analysis are shown in the table below:

20 mb 15 Jan 1977

		1st (249pts)	2nd (546)	3rd (637)	Objanal
$\bar{u}$	(19-89°N) m sec^{-1}	3.2	3.1	3.4	5.7
$\bar{u}$	(61-89°N " "	-13.7	-14.5	-14.5	-17.2
Zonal KE	(19-89°N) JM^{-2} mb^{-1}	644	784	753	946
Eddy KE	(19-89°N) " "	1245	1222	1103	1146

Again there is little difference between the second and third trials and most difference between the 1st and objective analysis.

Figures 6a and b present the KE(1), KE(2) & AMP(1)-(2) profile for the original trial (249 points), for the 3rd (637 points) and for the objective analysis. One can see that there is more energy present in the 3rd trial, but the objective analysis energies are still much larger. The large increase in KE(1) south of 35°N for the objective analyses is caused by a bad analysis. Because a cosine/latitude weighting function is used to calculate areal means the effect of the bad analysis is to produce a grossly inflated mean KE(1).

During the month of January 1977, the kinetic energies were not particularly large compared with the rest of the winter. It was thought worthwhile to repeat the process for a day with large KEs present. The 25 December 1977 was chosen at 50 mb, in order that three analyses could be compared ie the objective analysis, the hand drawn (SAG) analysis and the Berlin (SRG) analysis.

Figure 7 shows the mean zonal wind and the kinetic energy in WN1 for all three analyses as a function of latitude. Features to note in the $\bar{u}$ profile are the easterly mean wind north of 79°N from the SAG analysis and the large westerly mean wind south of 30°N from the objective analysis. The KE(1) profile is remarkably similar for all three analyses, with the spread of average KE(1) between all analyses within 7%. The mean KE(2)s from the SAG and SRG analyses ere considerably smaller than the objective analysis KE(2). The differences being most marked at low latitudes and between 60 and 80°N, where the KE(2) from the objective analysis was greater than both hand drawn charts.

SAG's easterly wind at high latitudes was caused by a slight wariation of height gradient near the pole while the strong westerly low latitude wind from the objective charts is caused again by a bad analysis at low latitudes.

6. Discussion & Conclusions

From the results presented it would appear that the original digitisation of the 20 mb charts did not have enough points. On average 200-300 pts were used, mainly at latitudes north of 40°N. For the second and third trials, more emphasis was put on the insertion of points at lower latitudes.

It is likely that the differences shown in figures 1-4 may have been smaller if more points had been used originally. Probably about 600-700 pts, many of them at low latitudes, are needed to define the height fields with sufficient accuracy for realistic energy calculations to be made.

During January 1977, the objective analysis at 20 mb was in considerable error at times, especially over low latitudes. During this month, the phase of the QBO was strong and easterly and the SAG analyses reflected this by drawing a high contour region at 20 to 30°N separating the westerlies to the north and easterlies to the south. The objective analysis tended to draw westerlies down to its boundary at 15°N, especially over Africa. This caused the anomolously high KE(1)'s at low latitudes at times. The objective analyses' heights at 20-30°N were also higher than the SAG's heights. This could be caused by the lack of quality control of stratosphere data. Also the Pacific data at ØØZ is in daylight and will tend to give higher temperatures and heights because of the lack of temperature correction or undercorrection in Japanese and American sondes.

The kinetic energies at high latitudes derived from the objective analyses were higher than those from the SAG charts. This was caused by a deeper polar vortex at the beginning of January, but on 15 January, the difference between the SAG and the objective analysis' KE(1) at 53°N (figure 6A) was probably caused by the difference in position of two vortices at 55° and 60°N. One of these vortices lay over the Atlantic with few observations to define it. A slight difference in latitude of the centre could have been the cause of the large (20%) variation in KE.

If the Kinetic energy budget is so sensitive to the positions of such low centres, then on these occasions, it is doubtful if the peak value of the KE profile can be produced to better than 20%.

Care must be exercised when using objectively analyses charts to calculate the energetics of the stratosphere. Any conculsions drawn from such a study must be broad in outline and be restricted to medium and high latitude regions.

References

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Taylor B.F. & O'Neill A (1977) "A study of the Major Stratospheric Warming of 1976-77". MRCP 434

Taylor B.F. (1976) A preliminary analysis of stratospheric energetics for 1975/76 based on machineable data". Met O 19 Branch Memorandum No 33.

Watson, N.R. (1976) "Present and future stratospheric analysis in the High Atmosphere Branch of the Meteorological Office" MRCP 402

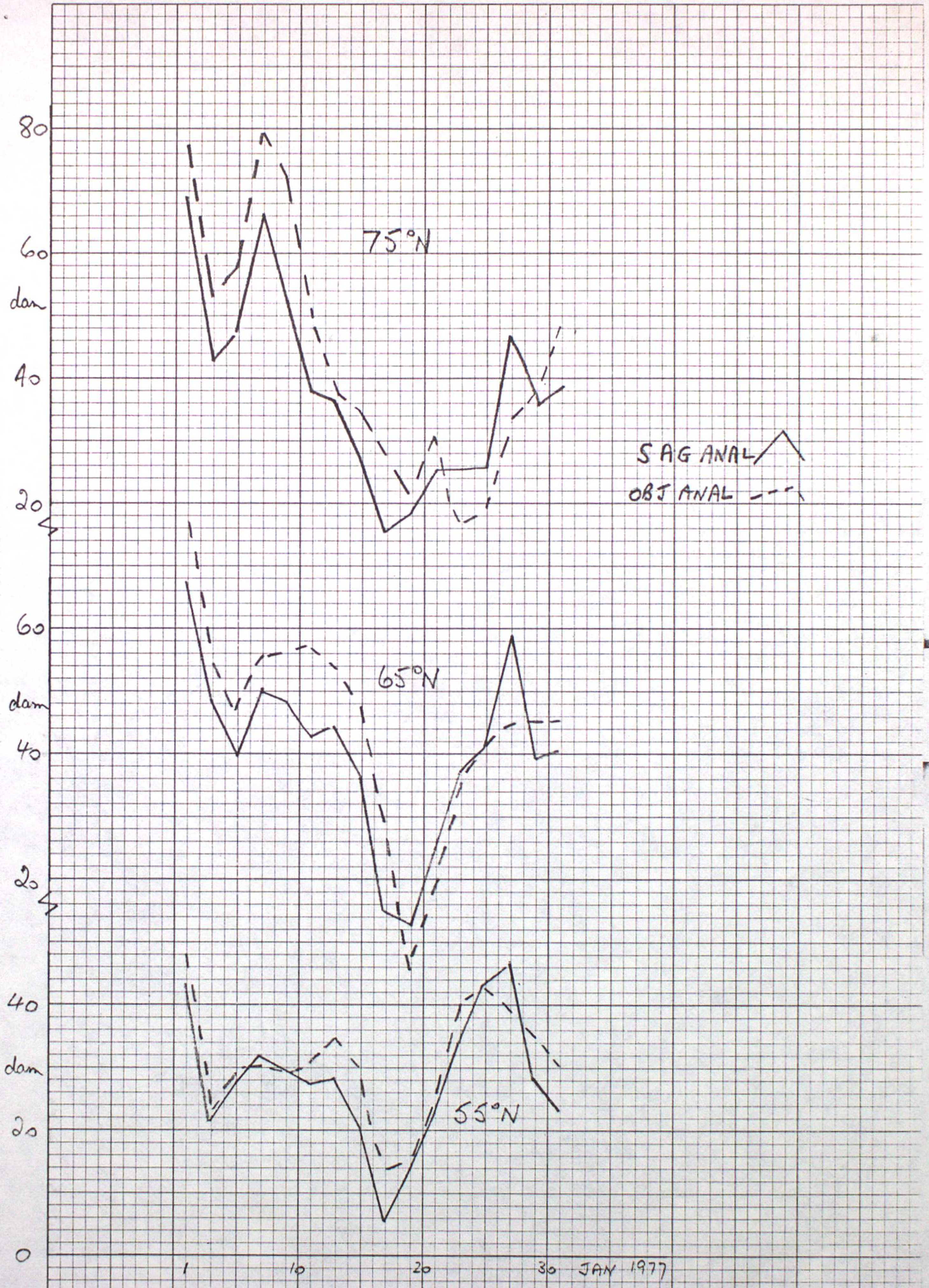

FIGURE 1 VARIATION OF AMPLITUDE OF WAVENUMBER ONE AT THREE LATITUDES FOR 20mb DURING JANUARY 1977.

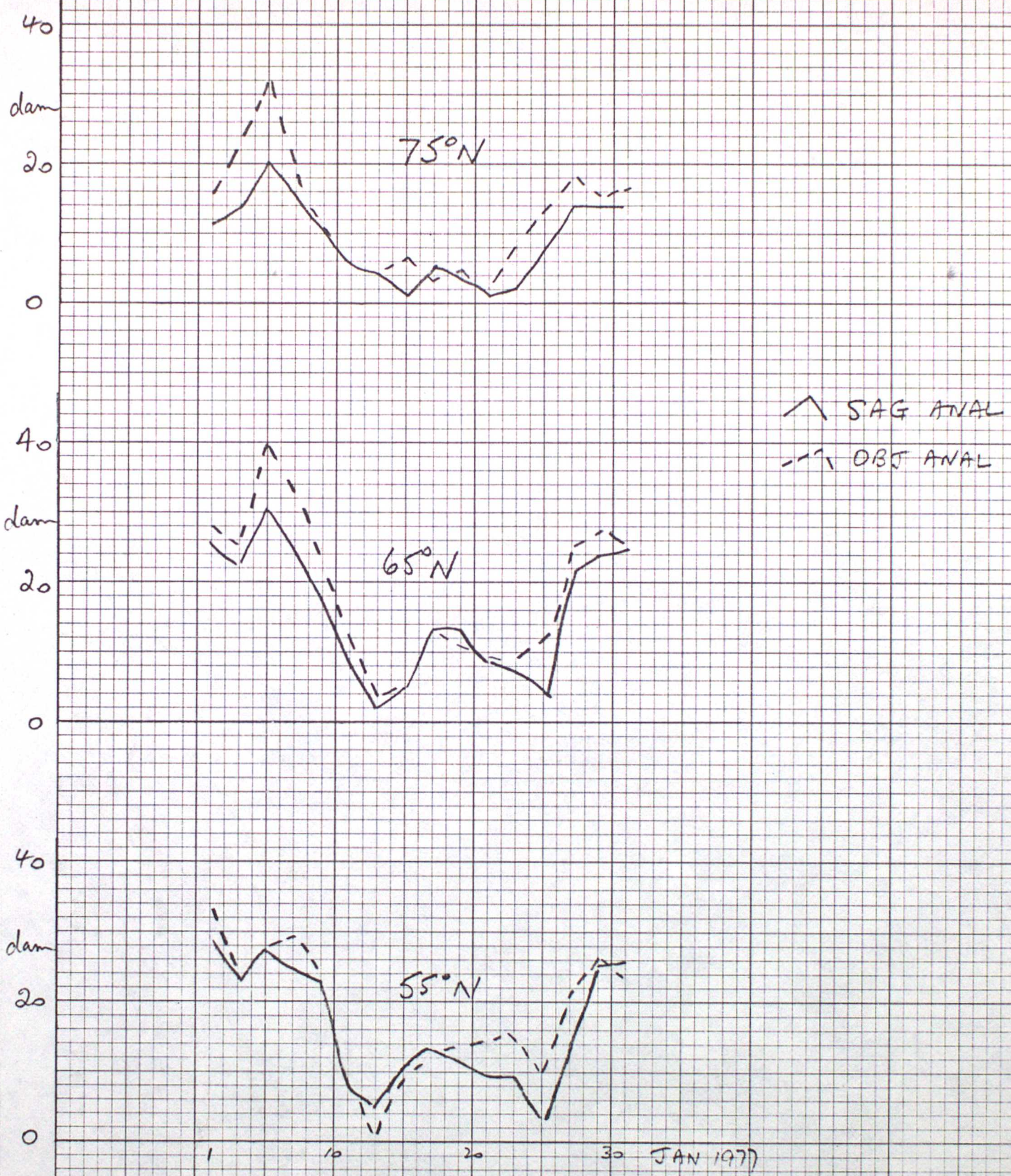

FIGURE 2 VARIATION OF AMPLITUDE OF WAVENUMBER TWO AT THREE LATITUDES FOR 20mb DURING JANUARY 1977

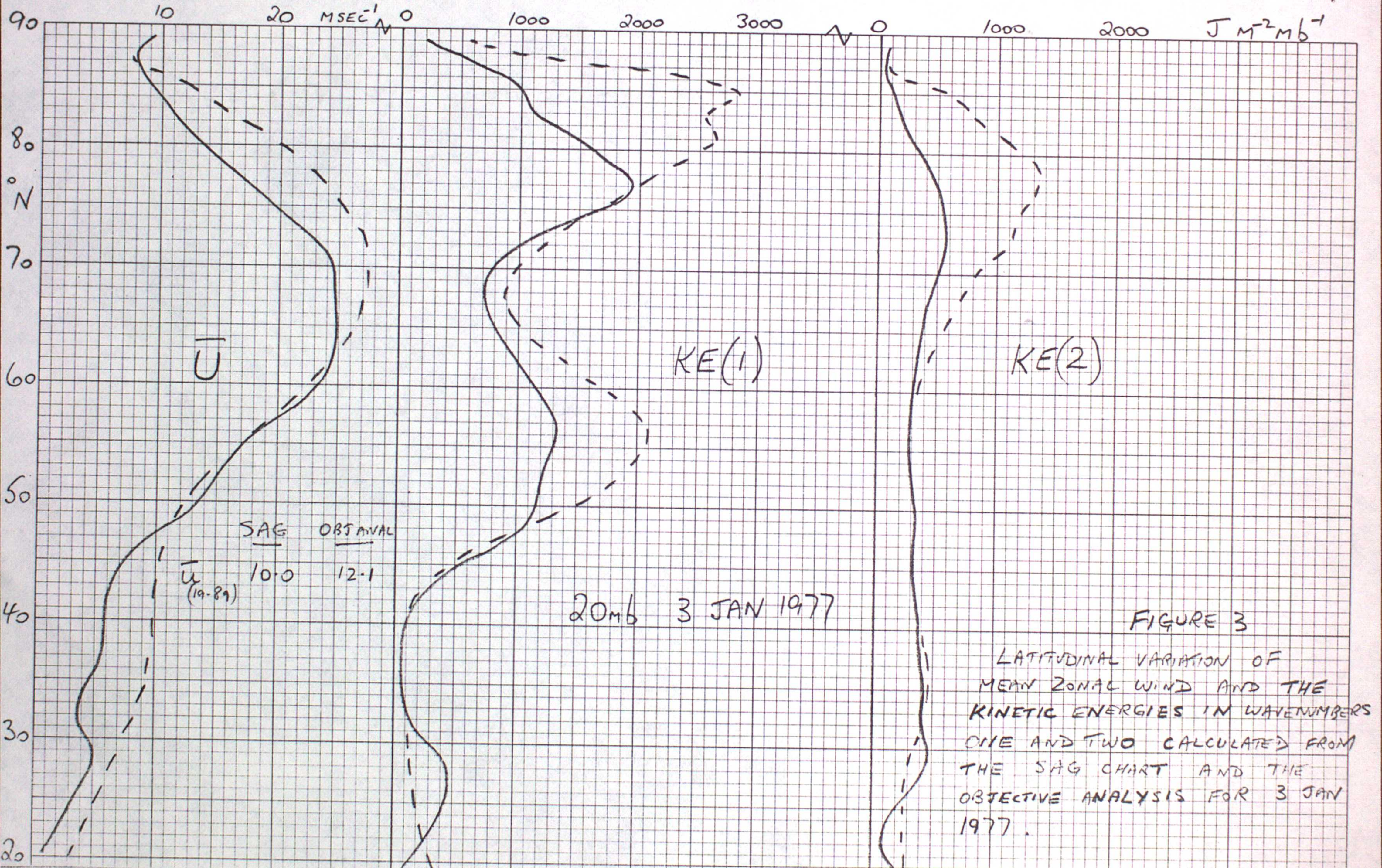

FIGURE 3

LATITUDINAL VARIATION OF MEAN ZONAL WIND AND THE KINETIC ENERGIES IN WAVENUMBERS ONE AND TWO CALCULATED FROM THE SAG CHART AND THE OBJECTIVE ANALYSIS FOR 3 JAN 1977.

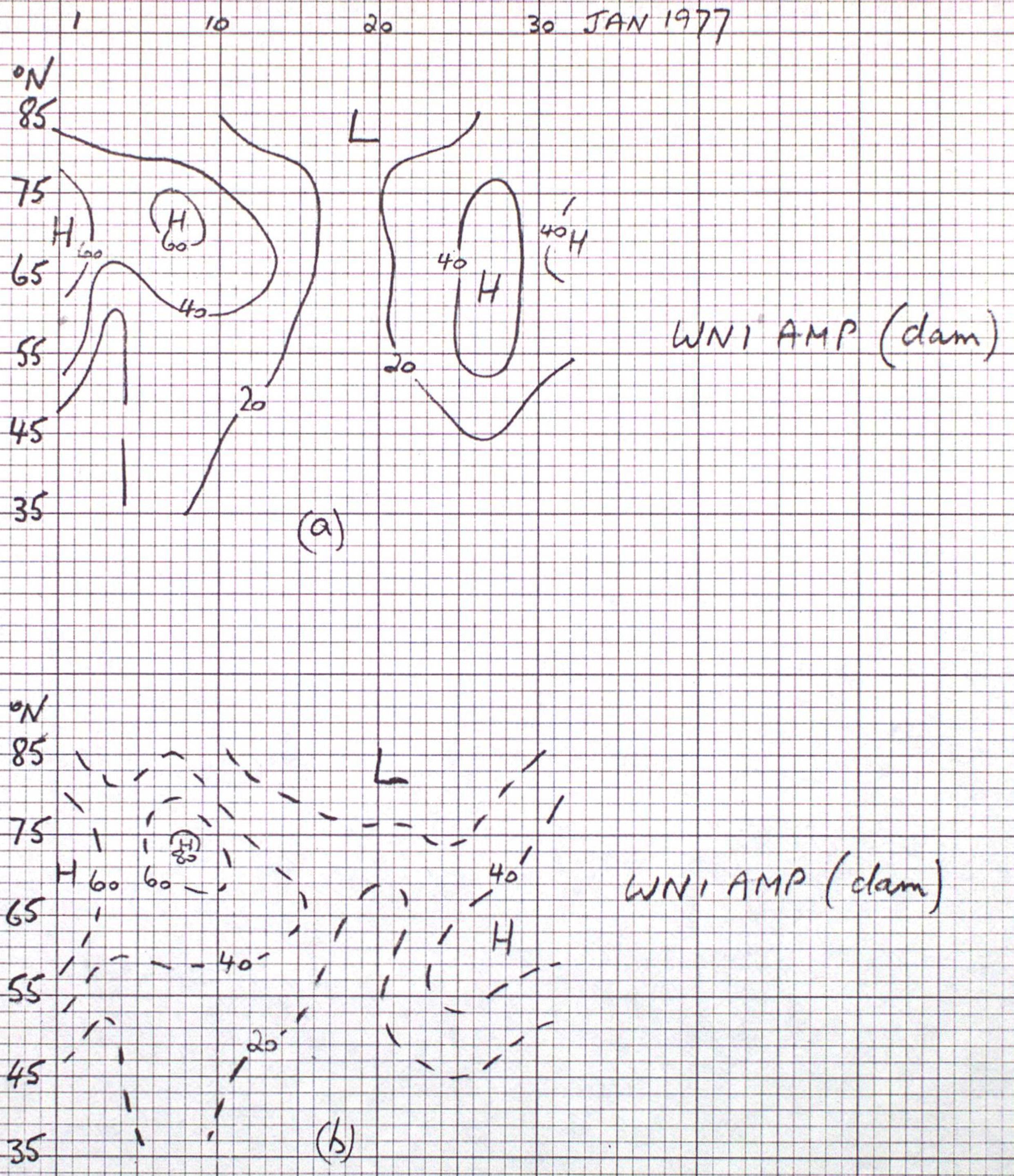

FIGURE 4 VARIATION OF AMPLITUDE OF WAVE NUMBER ONE AT 20mb THROUGH JAN 1977 FROM a) CHARTS PRODUCED BY S.A.G and b) OBJECTIVE ANALYSES

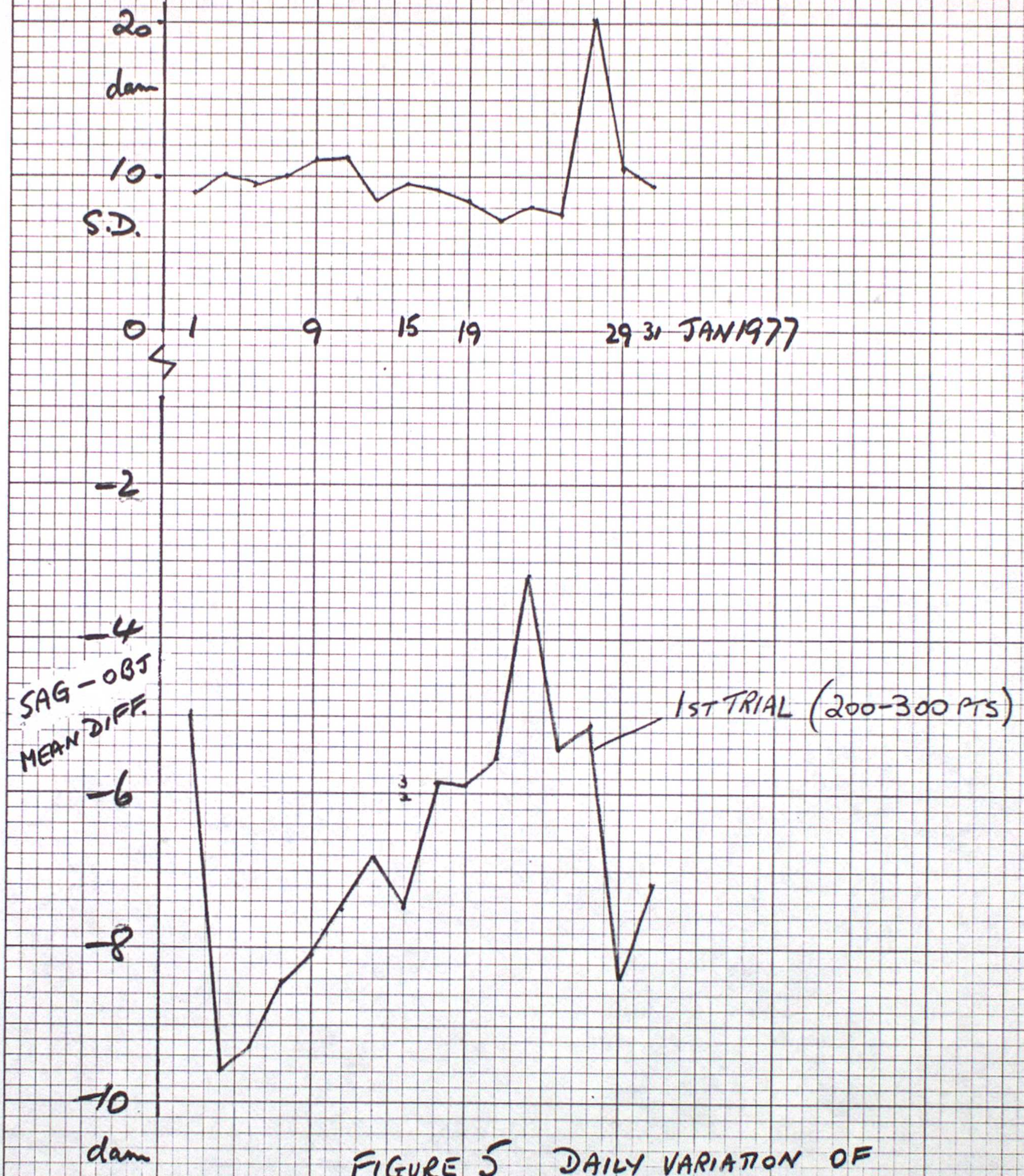

FIGURE 5. DAILY VARIATION OF MEAN DIFFERENCE (SAG MINUS OBJANAL) AND STANDARD DEVIATION THROUGHOUT JANUARY AT 20mb. FOR 15 JAN THE MEAN DIFFERENCE FOR THE SECOND AND THIRD TRIAL IS SHOWN.

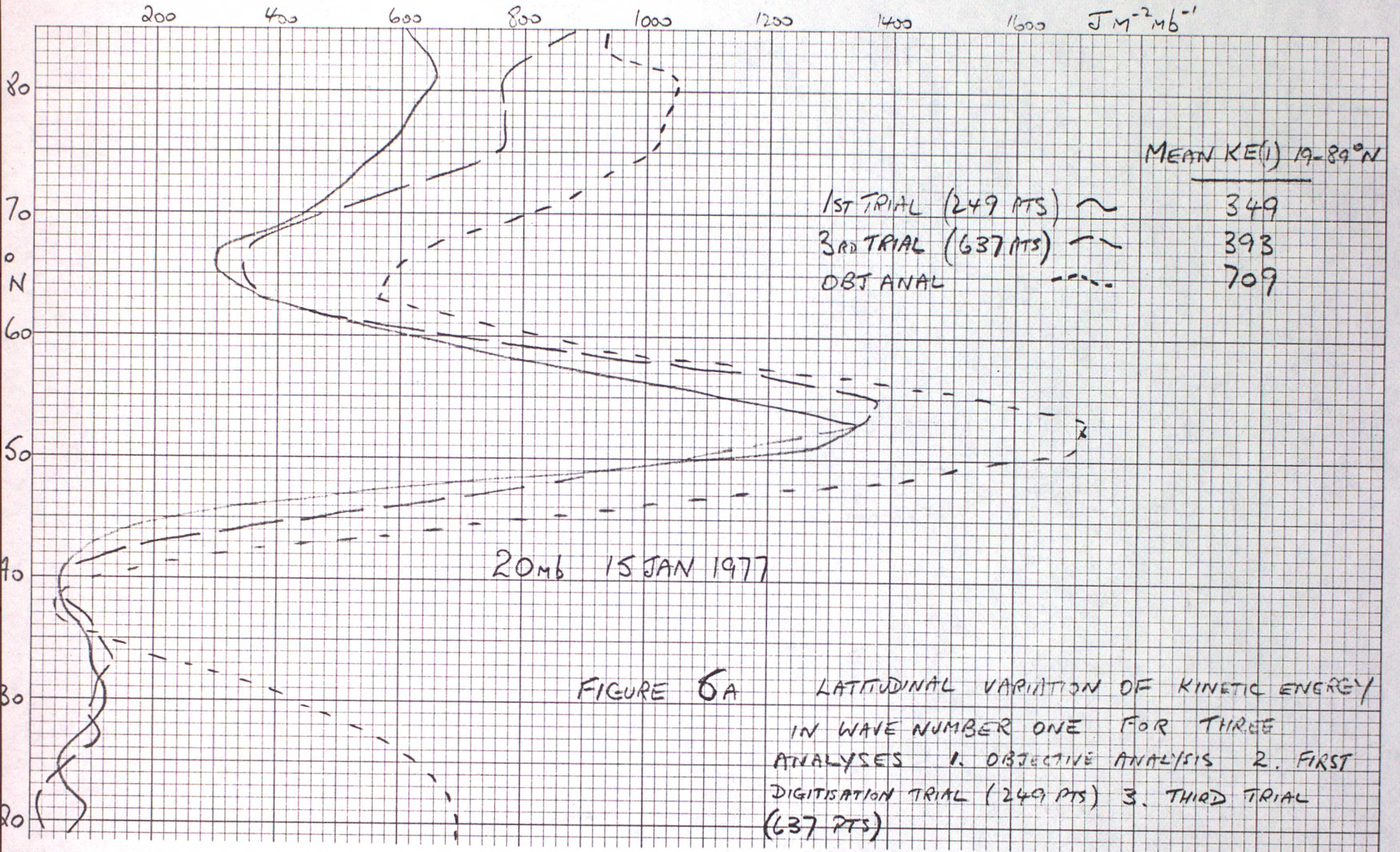

FIGURE 6A LATITUDINAL VARIATION OF KINETIC ENERGY IN WAVE NUMBER ONE FOR THREE ANALYSES 1. OBJECTIVE ANALYSIS 2. FIRST DIGITISATION TRIAL (249 PTS) 3. THIRD TRIAL (637 PTS)

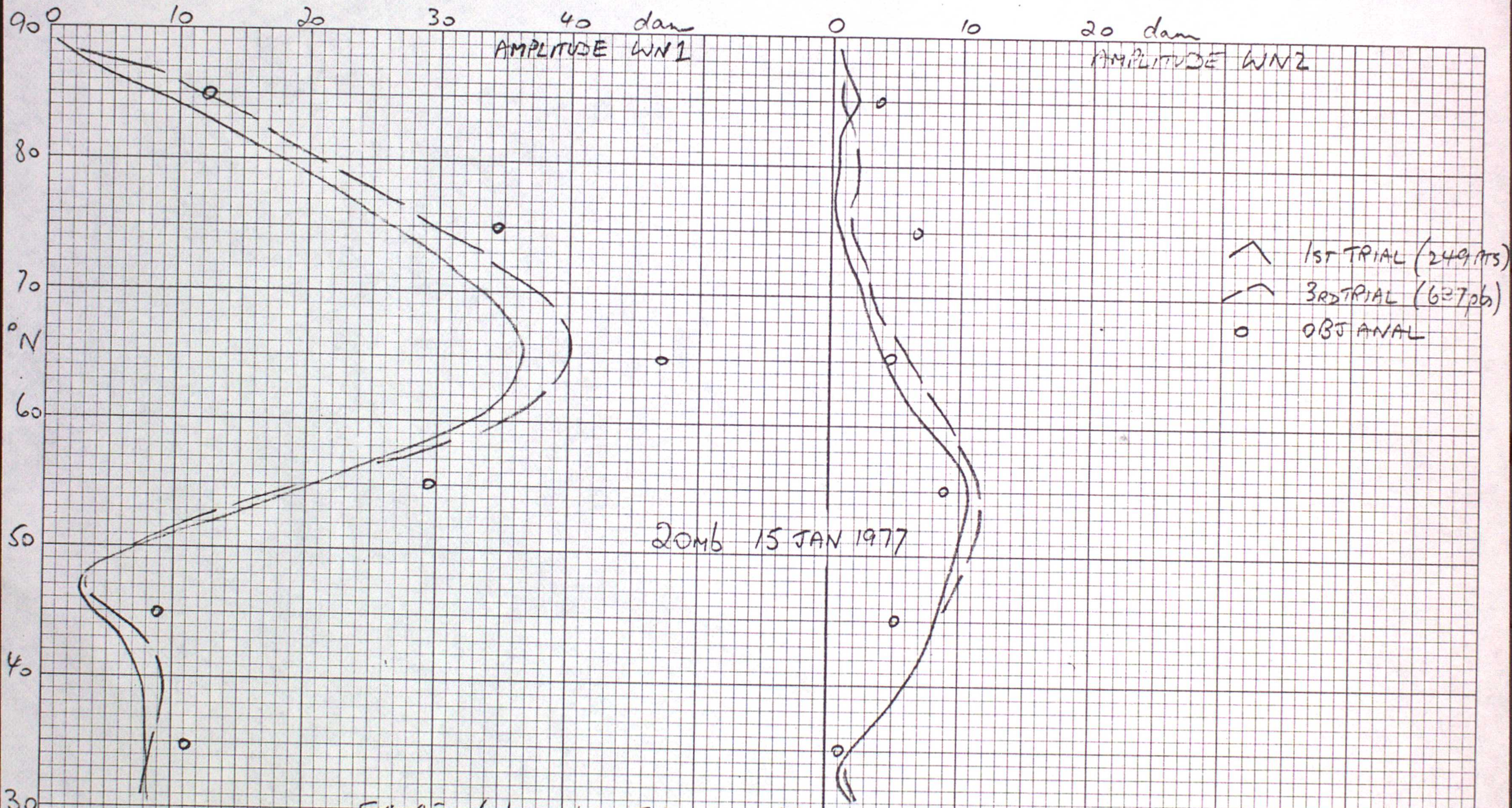

FIGURE 6b LATITUDINAL VARIATION OF AMPLITUDES OF WAVENUMBERS ONE AND TWO FOR FIRST AND THIRD TRIAL AND OBJECTIVE ANALYSIS — 20mb 15 JAN 1977

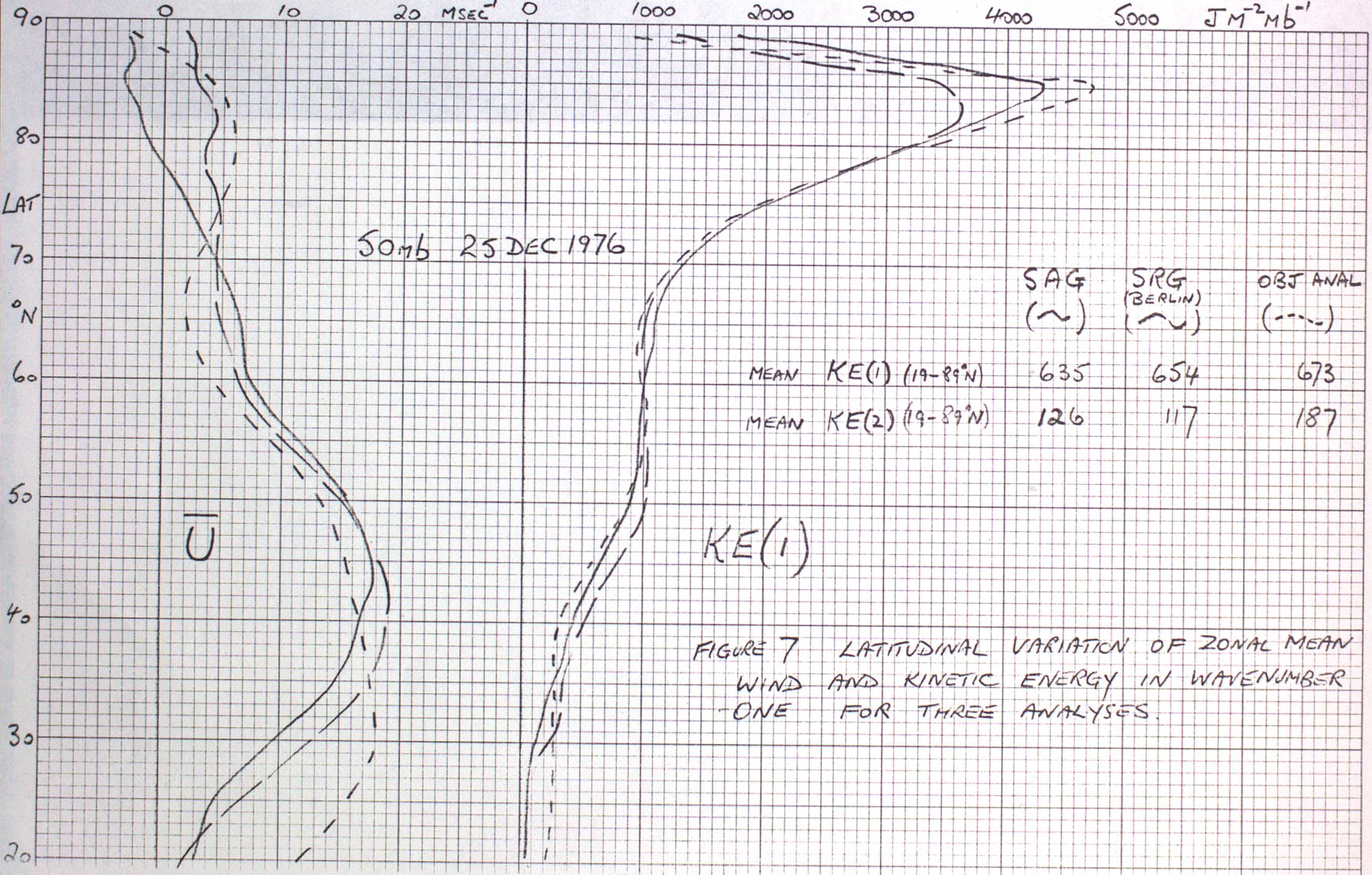

FIGURE 7 LATITUDINAL VARIATION OF ZONAL MEAN WIND AND KINETIC ENERGY IN WAVENUMBER ONE FOR THREE ANALYSES.