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PERIODIC WIND COMPONENTS AT METEOR HEIGHTS

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BY
R. G. ROPER
W. G. ELFORD

MARCH 1965

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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R. G. Roper* and W. G. Elford†

ABSTRACT

21667

The measurement of winds in the height range from 80 to 100 km by means of radio reflections from the ionized trails of meteors is a well established technique. Until recently, however, the full potential of this technique had not been realized. The purpose of this report is to demonstrate the power of an analysis developed by Groves (1959), which has been applied to the data collected at Adelaide (35°S) for the thirteen months from December, 1960 to December, 1961, inclusive. The results show that the most significant periodic zonal and meridional wind components are the 24 hour and 12 hour, with a smaller 8 hour component occasionally present. In general, the vertical component is random, with an amplitude from one to two orders of magnitude less than that of the horizontal wind.

Author

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ACKNOWLEDGMENTS

The authors are indebted to the University of Adelaide and the Radio Research Board (Australia) for providing the facilities and finance for the Adelaide Meteor Project, and one of us (R. G. Roper) to the C.S.I.R.O. for a post-graduate scholarship, and to the National Academy of Sciences - National Research Council (U.S.A.) for a post-doctoral fellowship which has enabled the continuation of this work.

R. G. Roper
W. G. Elford

CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	iv
INTRODUCTION	1
The Meteor Data	1
The Analysis	2
Application of the Groves Analysis to the Meteor Data	3
The Presentation of the Results	3
Reduction of Actual Data	4
DISCUSSION	5
FUTURE WORK	6
REFERENCES	6
Figures 1 - 16	7-28
Appendix I	29-41
Appendix IA	42-45
Appendix II	46-59

PERIODIC WIND COMPONENTS AT METEOR HEIGHTS

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INTRODUCTION

The purpose of this report is two-fold, presenting as it does a summary of upper atmosphere wind measurements carried out at Adelaide (35°S) during 1961, as well as documenting the computer programs used in the computation and analysis of these winds. The measurements were obtained from the radio observation of drifting meteor trails, and have revealed a detailed picture of the diurnal and seasonal motion of the atmosphere throughout the height range from 80 to 100 km.

The Meteor Data

The Adelaide Meteor Project employs a combination of continuous wave and pulse techniques to measure the position and line of sight drift of each meteor trail observed. A description of the method has been given by Robertson, Liddy and Elford (1953).

The parameters measured by the system are

a. the line of sight drift of the trail.

b. the direction cosines of the reflection point on the trail relative to NS and EW axes.

c. the radar range of the echo point, and

d. the time of occurrence of the echo.

The echo rate is not constant with time; an average of 5 useable wind echoes per hour was obtained during the 1961 survey. To obtain enough data for analysis, records were taken for an average of nine consecutive days about the middle of each month. The mean height of all echoes for each month was 93 (±1) km, and reliable winds were obtained for the height range 80 to 100 km.

The Analysis

In his meteor wind analysis, Groves (1959) sets up a wind model against which the meteor data is matched. The parameters specifying the model are the coefficients of the polynomial wind variations with height and time. These are conveniently expressed in tabular form.

Zonal	Meridional	Vertical
a_{10}	a_{20}	a_{30}
$a_{11}\ S$	$a_{21}\ S$	$a_{31}\ S$
$a_{12}\ S^2$	$a_{22}\ S^2$	$a_{32}\ S^2$
.	.	.
.	.	.
.	.	.
$a_{1n}\ S^n$	$a_{2n}\ S^n$	$a_{3n}\ S^n$
$b_{10}\ \sin\omega t$	$b_{20}\ \sin\omega t$	$b_{30}\ \sin\omega t$
$c_{10}\ \cos\omega t$	$c_{20}\ \cos\omega t$	$c_{30}\ \cos\omega t$
$b_{11}\ S\ \sin\omega t$	$b_{21}\ S\ \sin\omega t$	$b_{31}\ S\ \sin\omega t$
$c_{11}\ S\ \cos\omega t$	$c_{21}\ S\ \cos\omega t$	$c_{31}\ S\ \cos\omega t$
.	.	.
.	.	.
$b_{1n}\ S^n\ \sin\omega t$	$b_{2n}\ S^n\ \sin\omega t$	$b_{3n}\ S^n\ \sin\omega t$
$c_{1n}\ S^n\ \cos\omega t$	$c_{2n}\ S^n\ \cos\omega t$	$c_{3n}\ S^n\ \cos\omega t$

where S is the normalized height given by

$$S = (2h = z_{max} - z_{min})/(z_{max} - z_{min})$$

with z_{max}, z_{min} the maximum and minimum heights respectively over which the profile is fitted and h is the height variable within the range z_{min}, z_{max}.

If the variations with height in the prevailing wind and the component of period $T = 2\pi/\omega$ are taken as

a polynomial of order 2 in the EW direction

" 3 in the NS direction

and a constant in the vertical (constant with height, not time)

then 24 parameters (a_{ij}, b_{ij}, c_{ij}) are required to specify the motion. These parameters are determined by matching the data to the model, using the method of least squares.

Application of the Groves Analysis to the Meteor Data

No attempt will be made here to present the mathematics of the analysis; the reader is referred to Groves (1959). The IBM 7094 FORTRAN IV program which performs this analysis of the meteor data is listed as program ERG in Appendix I. The number of parameters best specifying the height profiles have been arrived at by trial and error. In this context, the parameters "best" specifying the profiles are the coefficients of the minimum order polynomials which adequately represent the height structure of the mean motion. Calculating the coefficients of the terms of higher order than necessary is extremely wasteful in terms of computer execution time. For example, the calculation for a total of 70 periodic components of the coefficients of a cubic variation with height of the zonal (EW) component, a quartic variation of the meridional (north south), and a constant vertical wind (30 coefficients in all for each periodicity) for 1000 line of sight drifts measured over 9 days takes 42 minutes of execution time on an IBM 7094 Model 2. Assumption of a quadratic zonal, cubic meriodinal and constant vertical variation (24 coefficients) results in an execution time of 22 minutes, a little over half that of the previous computation. Attempting to over-specify the variations in the wind can also cause the matching process to become unstable, and this has been observed with (3,4,0) profiles. No such instability has been encountered in any of the months so far processed with a (2,3,0) profile.

The Presentation of the Results

The digital output from program ERG (consisting of the amplitude and phase of each periodic component, together with the RMS error in each, for each of 16 heights in the range from 75 to 105 km) is both listed and written on magnetic tape. This tape provides input for the plotter program listed in

Appendix II. The program PLOT writes a low density binary tape suitable for use on the EAI Data Plotter. All the graphs presented in this report are copies of those produced by the EAI machine.

The following are definitions of the quantities presented graphically in the next section.

a. The wind amplitude spectrum (for a given height). The amplitude of each periodic component is plotted against period for each of the three wind components (zonal, meridional and vertical).

b. The "specific" energy spectrum (for a given height). The "specific" wind energy is the wind energy per unit mass, calculated for any one period τ as the sum of the squares of the zonal (u), meridional (v), and vertical (w) amplitudes of period τ.

i.e.,

$$E_\tau = u_\tau^2 + v_\tau^2 + w_\tau^2 \text{ (metres/sec)}^2$$

Reduction of Actual Data

An average of 800 echoes for each of the months from December, 1960 to December, 1961, inclusive, have been subjected to the analysis outlined in the previous sections.

The following parameters were used as a basis for the analysis for each month.

1. Only those echoes falling within the height range 75 to 105 km were processed.

2. Both prevailing and periodic zonal components were allowed up to a quadratic variation with height over this height range.

3. Similarly, both prevailing and periodic meridional components were allowed up to a cubic variation.

4. The vertical component was considered to be constant with height, but able to vary with time.

5. Amplitudes and phases of periodic components were calculated for the range of from 0.5 cycles/day to 4 cycles/day (48 hour to 6 hour periods) in increments of 0.05 cycles per day.

The following features have been chosen as being most descriptive of the characteristics of the periodic motion in the height range from 80 to 100 km.

a. The variation of the wind energy spectrum with height, as measured at 83, 91 and 97 km.

b. The amplitude spectra for zonal, meridional and vertical components as measured at the mean monthly echo height of 93 km.

The six graphs for each month from December, 1960 to December, 1961 appear as Figures 1a to 14f, inclusive.

DISCUSSION

Insufficient time has as yet been spent on examination of the results to justify any detailed interpretation. However, the spectra presented in Figures 1 to 14 confirm without exception that the dominant periodic components in the winds at these levels are the diurnal (24 hour) and semidiurnal (12 hour) components. At the latitude of Adelaide (35°S), the 24 hour is, in general, of comparable magnitude to the 12 hour, except at the equinoxes, where the 24 hour predominates. There is evidence in some months of a significant 8 hour component which, when it appears, has an amplitude somewhat less than those of the 24 or 12 hour components.

Although the main concern of this report is to investigate the presence of periodic motions, some reference to the prevailing wind components is pertinent. The zonal winds are shown for three heights in Figure 15. The bars about each plotted point represent the RMS deviation. It can be seen that over the height range 80-100 km the zonal wind is predominantly toward the East. The only strong wind reversal occurs at the upper level, where the wind is toward the West during the winter of 1961. No significant reversals occur at the other levels but the wind has its maximum eastwards amplitude in the spring at 91 km and in the summer at 83 km. As a result of the rapid change in the zonal wind with height the seasonal patterns at 83 and 99 km are almost opposite in phase. This behavior is also reflected in the wind gradients which have maximum values of +4 m/sec/km in summer and -4 m/sec/km in winter.

In contrast to the zonal winds, the meridional winds shown in Figure 16 exhibit an annual behavior which is similar at all levels. In general, northward winds occur during summer and southward winds during winter. A similar meridional variation is found for these levels at Jodrell Bank (53°N) and Mawson (68°S). Thus the meridional flow at these levels is consistent with a

horizontal movement of air from the summer to the winter pole. The Adelaide results show that the meridional wind increases with height over the range 80-100km and that above 90km the amplitude of the meridional wind is comparable to that of the zonal wind.

It should be remembered, when further interpreting these results, that one year's data is not by itself sufficient to justify a detailed analysis on a seasonal basis. The results presented here, while considerably more detailed, are still complementary to those already published covering the years 1952 to 1958 (Elford, 1959).

FUTURE WORK

The application of the analysis proposed by Groves to the winds measured by the radio meteor method has been shown here to provide a powerful tool in the investigation of periodic atmospheric motions for the height range from 80 to 100km. The demonstrated domination of this wind regime by solar influence is only one of the many possible products of the analysis. It is hoped that attention can be given some time in the future to the determination of, for example, the magnitude of the lunar influence on winds at this height. For the present, attention is being given to the more detailed interpretation of the results already obtained.

REFERENCES

Robertson, D. S., Liddy, D. J. and Elford, W. G., J. Atmos. Terr. Phys., 4, 255, 1953

Groves, G. V., J. Atmos. Terr. Phys., 16, 344, 1959

Elford, W. G., Planet Space Sci., 1, 94, 1959

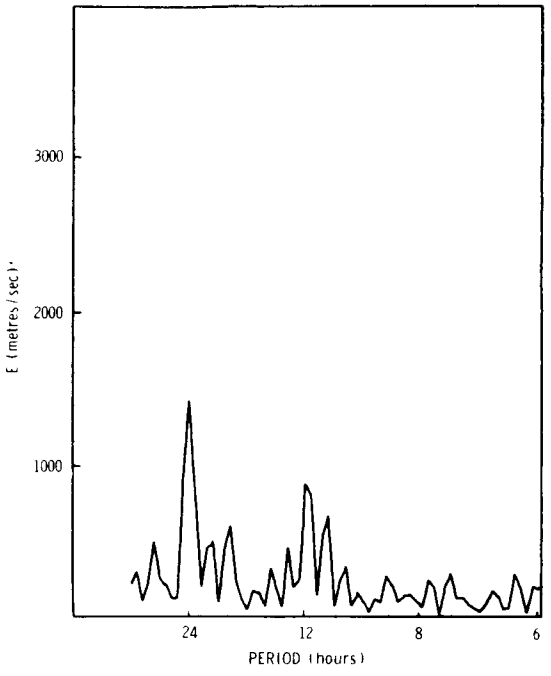


Figure 1a. Wind Energy Spectrum at 83km. December, 1960.

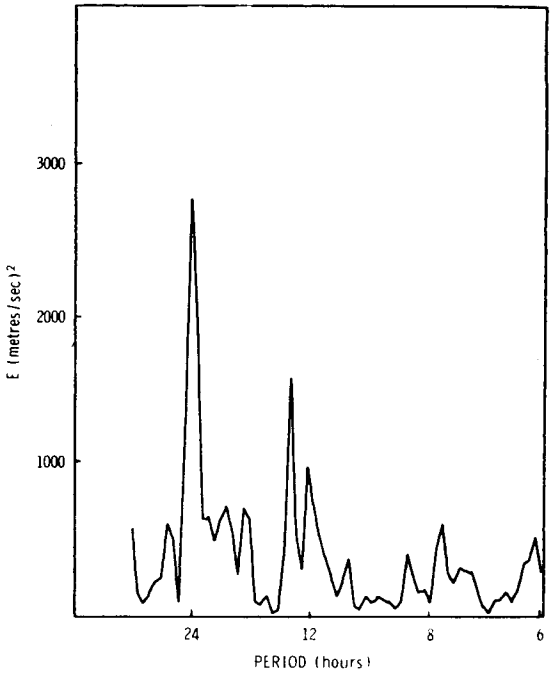


Figure 1b. Wind Energy Spectrum at 91km. December, 1960.

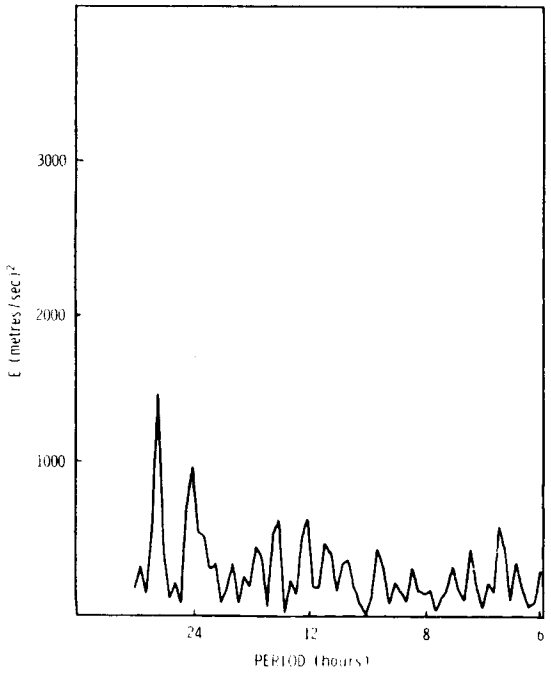


Figure 1c. Wind Energy Spectrum at 97km. December, 1960.

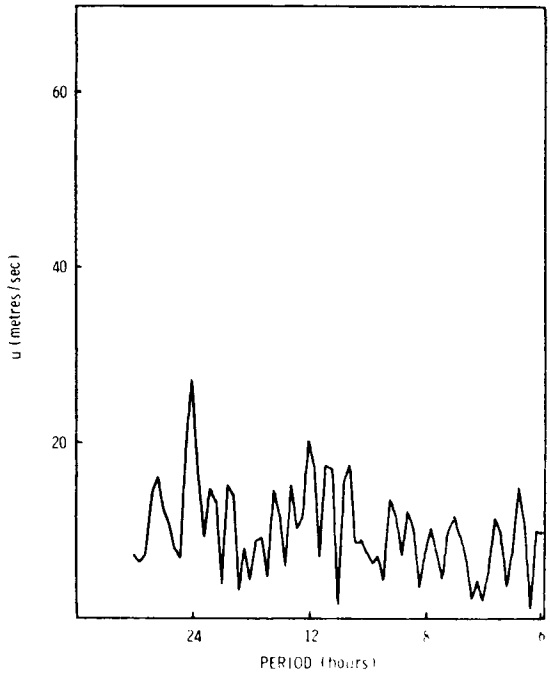


Figure 1d. Zonal amplitude spectrum at 93km. December, 1960.

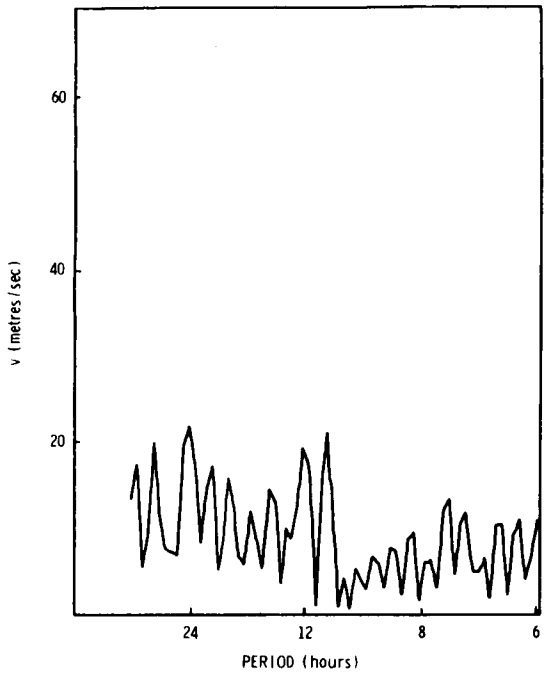


Figure 1 e. Meridional amplitude spectrum at 93km. December, 1960

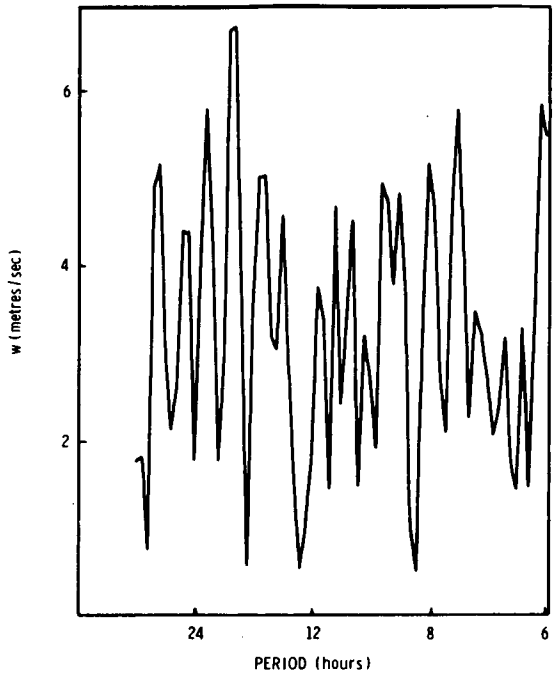


Figure 1f. Vertical amplitude spectrum at 93km. December, 1960.

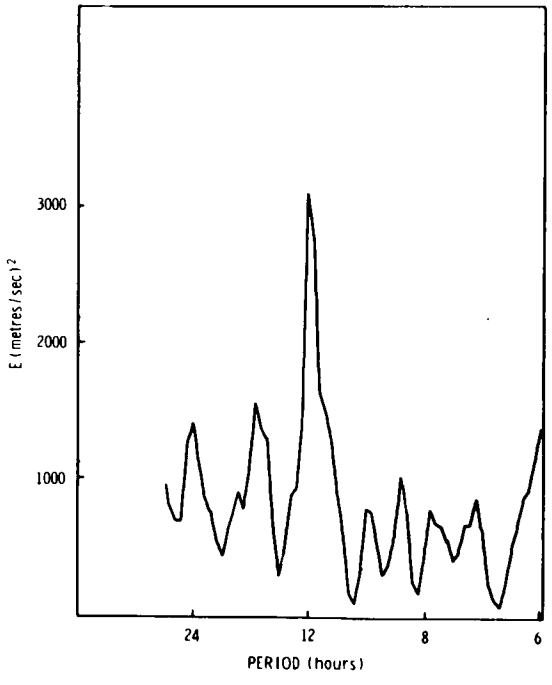


Figure 2a. Wind Energy Spectrum at 83km. January, 1961.

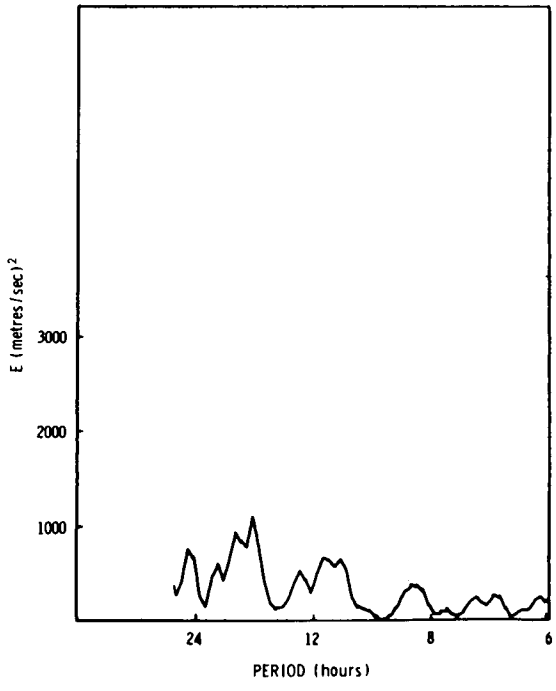


Figure 2b. Wind Energy Spectrum at 91km. January, 1961.

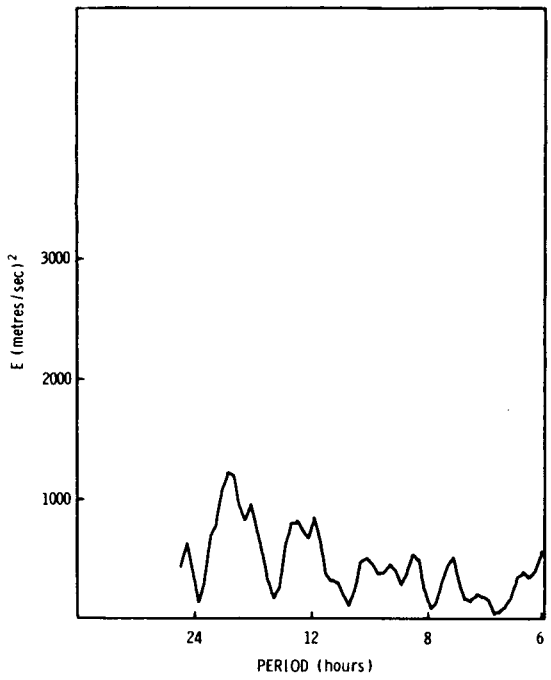


Figure 2c. Wind Energy Spectrum at 97km. January, 1961.

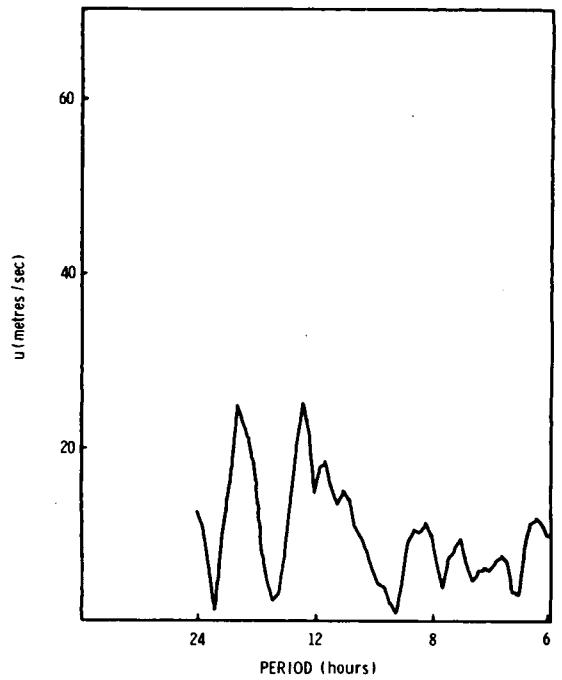


Figure 2d. Zonal Amplitude Spectrum at 93km. January, 1961.

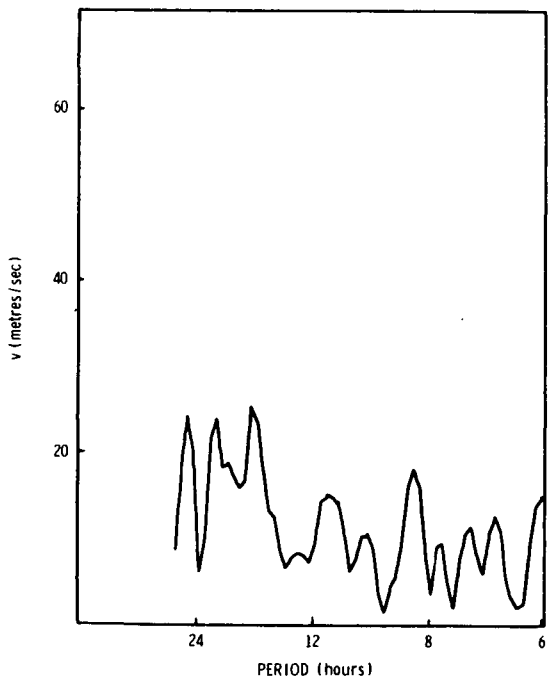


Figure 2e. Meridional Amplitude Spectrum at 93km. January, 1961.

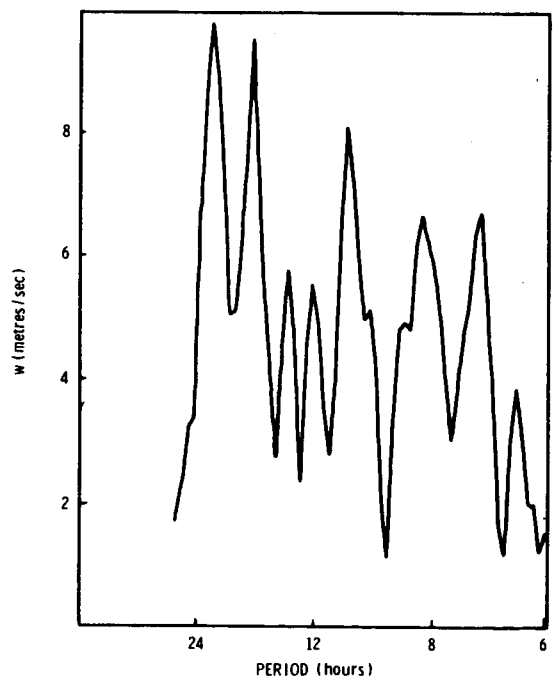


Figure 2f. Vertical Amplitude Spectrum at 93km. January, 1961.

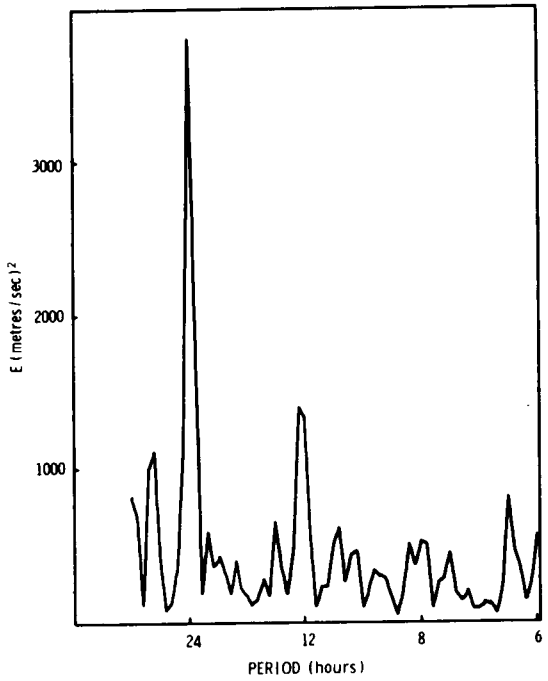


Figure 3a. Wind Energy Spectrum at 83km. February, 1961.

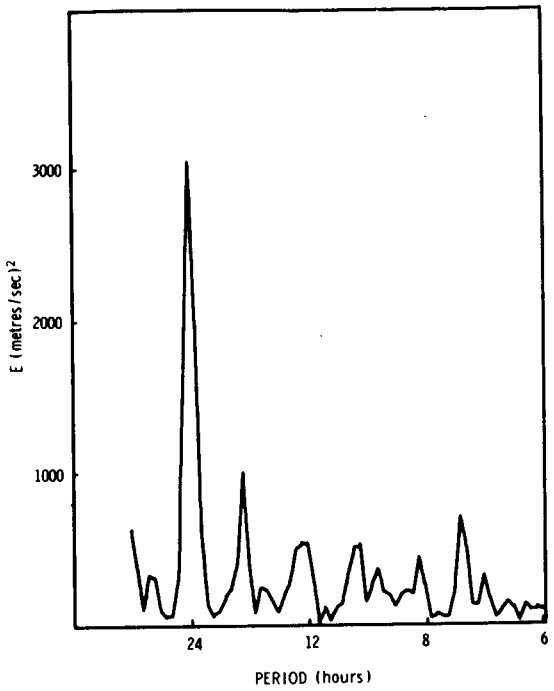


Figure 3b. Wind Energy Spectrum at 91km. February, 1961.

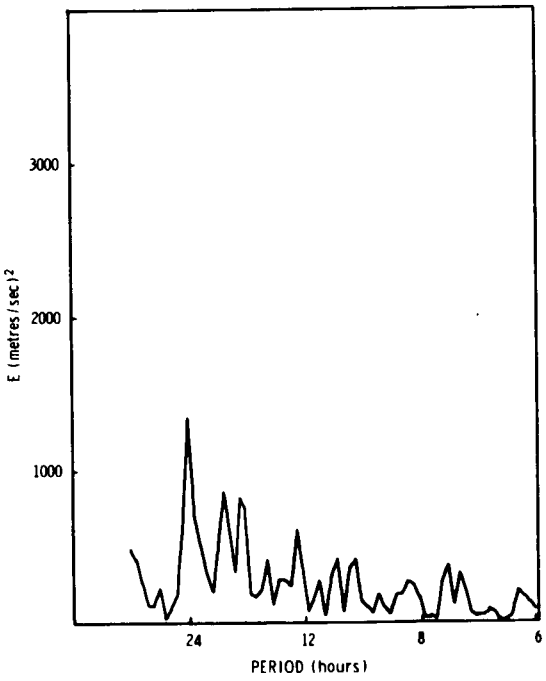


Figure 3c. Wind Energy Spectrum at 97km. February 1961.

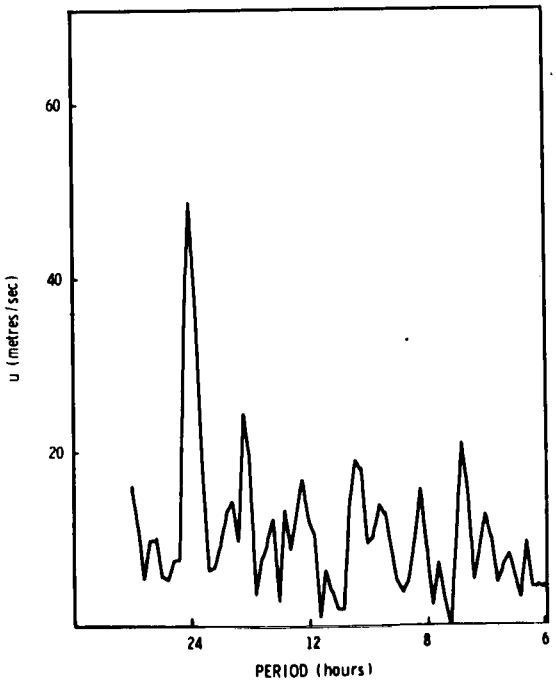


Figure 3d. Zonal Amplitude Spectrum at 93km. February, 1961.

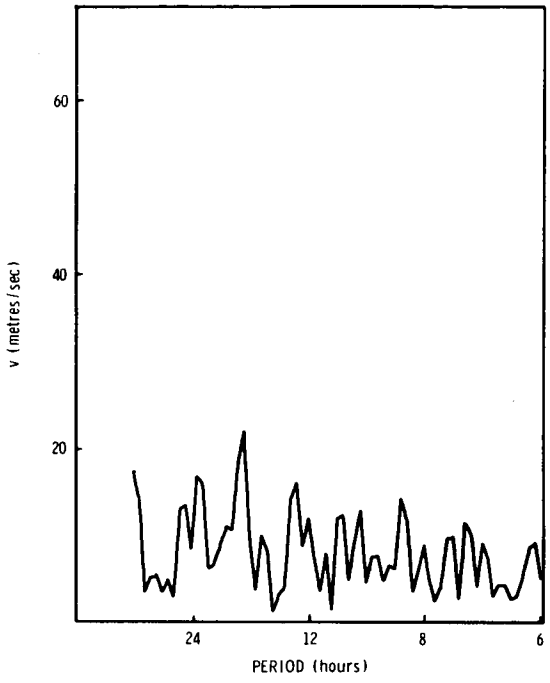


Figure 3e. Meridional Amplitude Spectrum at 93km. February, 1961.

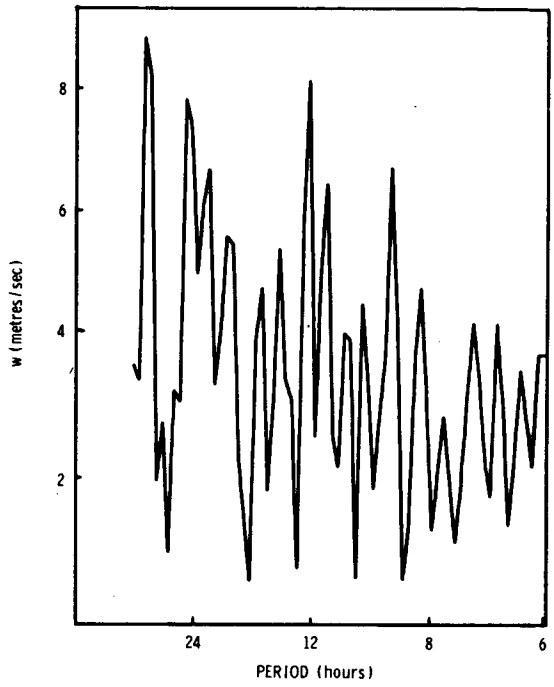


Figure 3f. Vertical Amplitude Spectrum at 93km. February, 1961.

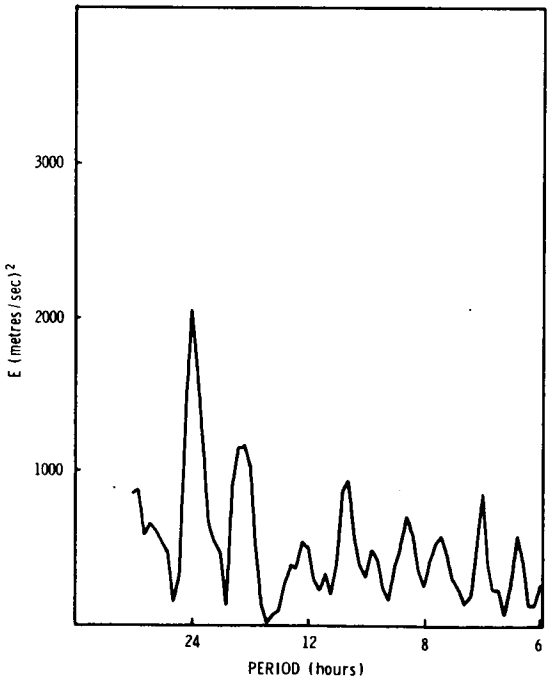


Figure 4a. Wind Energy Spectrum at 83km. March, 1961.

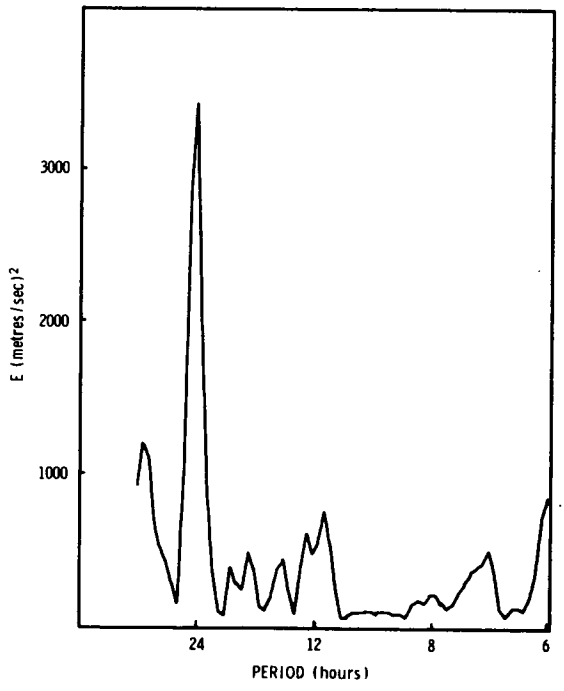


Figure 4b. Wind Energy Spectrum at 91km. March, 1961.

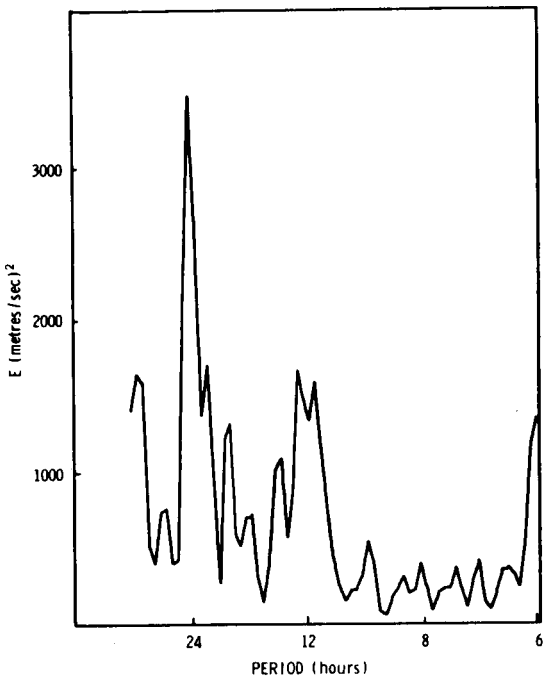


Figure 4c. Wind Energy Spectrum at 97km. March, 1961.

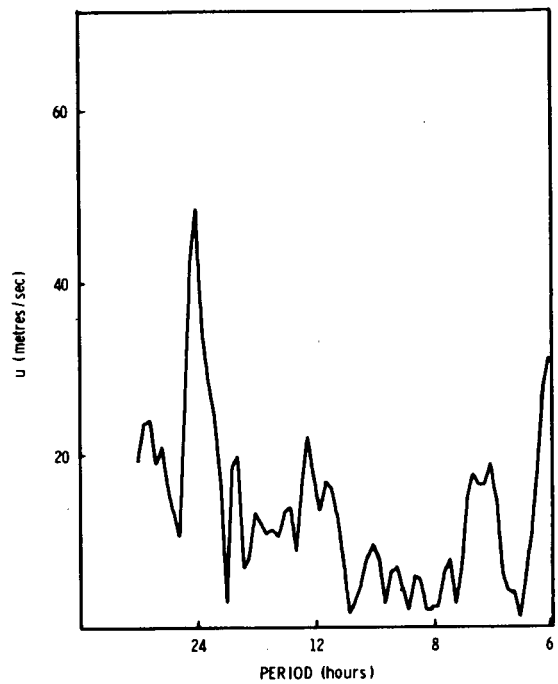


Figure 4d. Zonal Amplitude Spectrum at 93km. March, 1961.

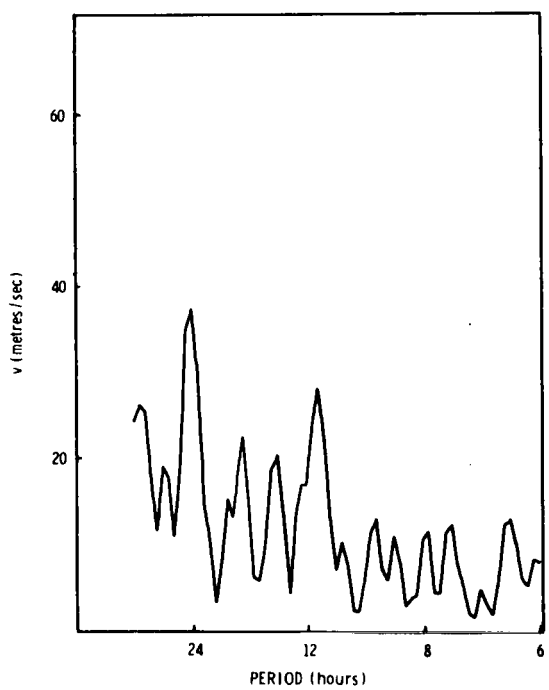


Figure 4e. Meridional Amplitude Spectrum at 93km. March, 1961.

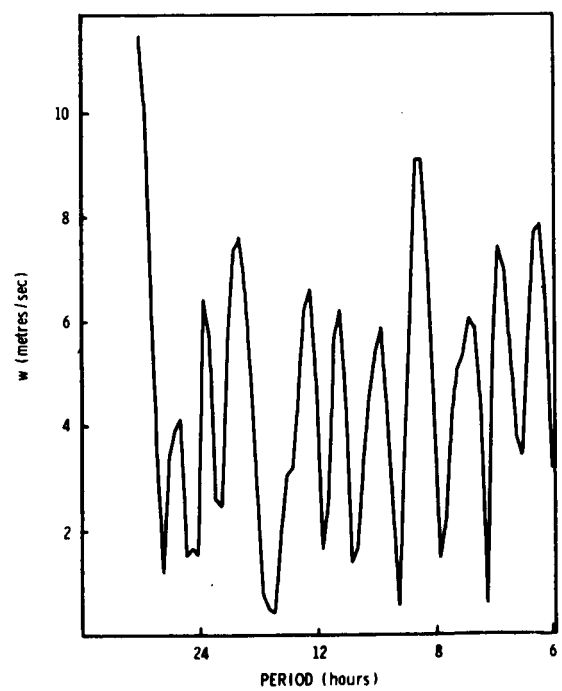


Figure 4f. Vertical Amplitude Spectrum at 93km. March, 1961.

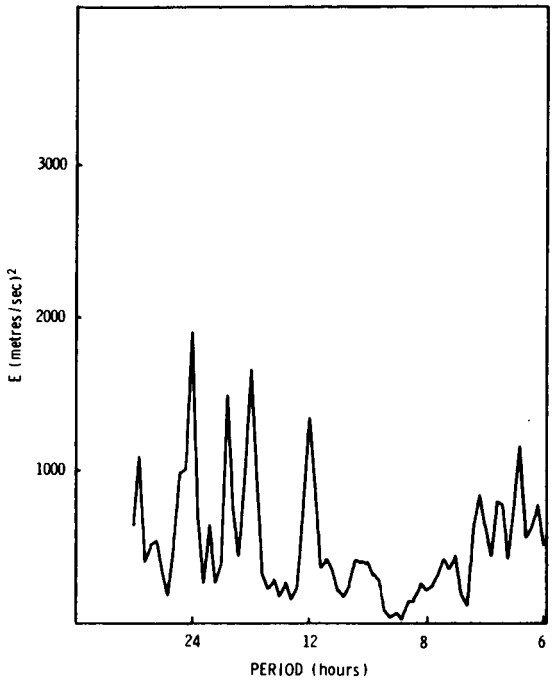


Figure 5a. Wind Energy Spectrum at 83km. April, 1961.

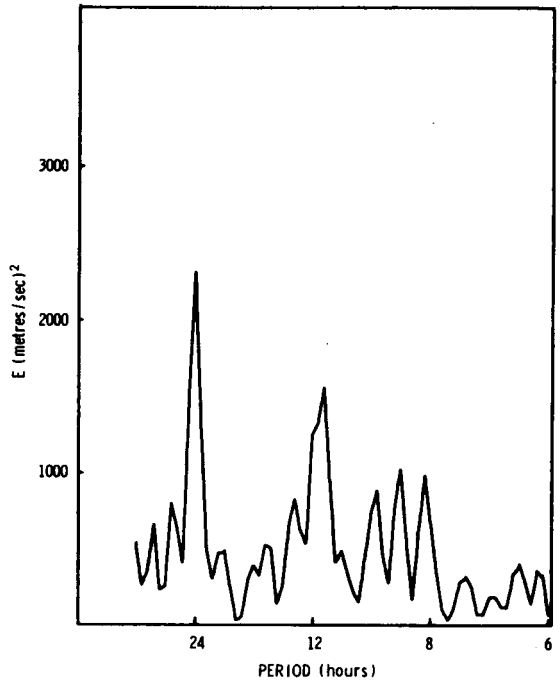
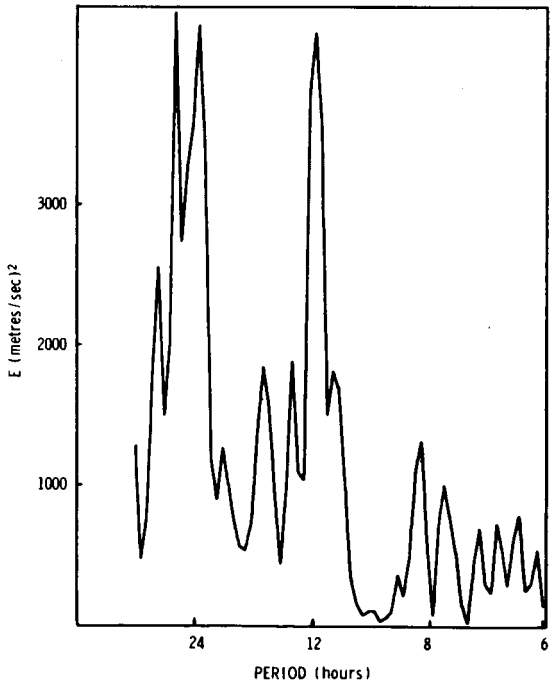


Figure 5b. Wind Energy Spectrum at 91km. April, 1961.



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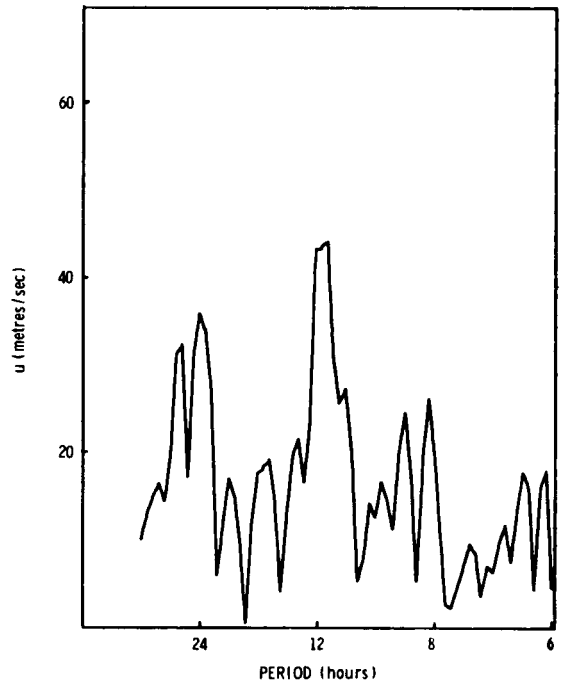

Figure 5d. Zonal Amplitude Spectrum at 93km. April, 1961.

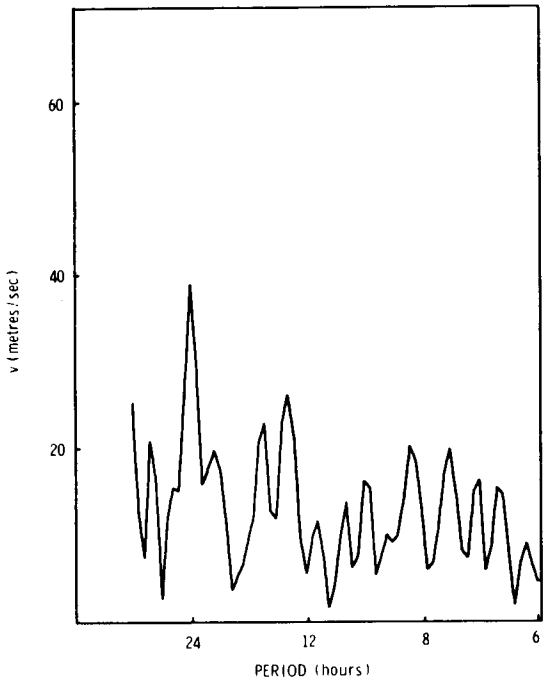

Figure 5e. Meridional Amplitude Spectrum at 93km. April, 1961.

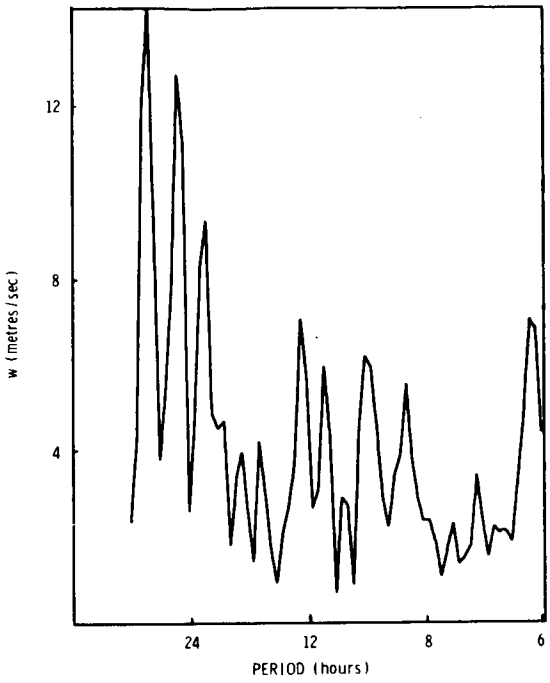

Figure 5f. Vertical Amplitude Spectrum at 93km. April, 1961.

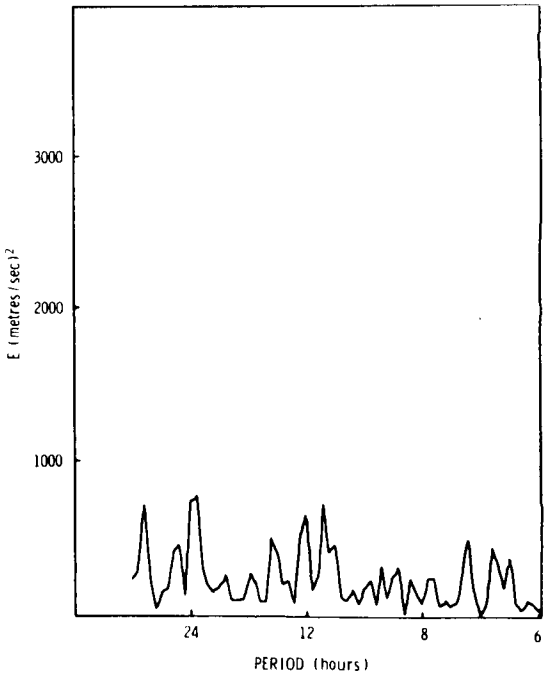

Figure 6a. Wind Energy Spectrum at 83km. May, 1961.

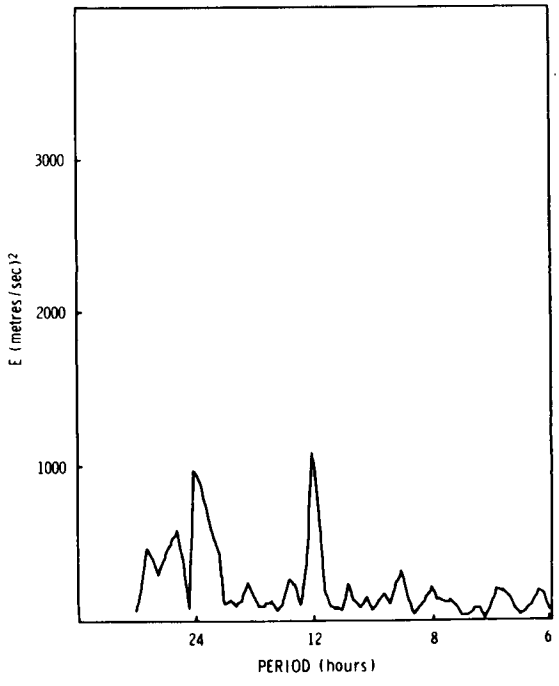

Figure 6b. Wind Energy Spectrum at 91km. May, 1961.

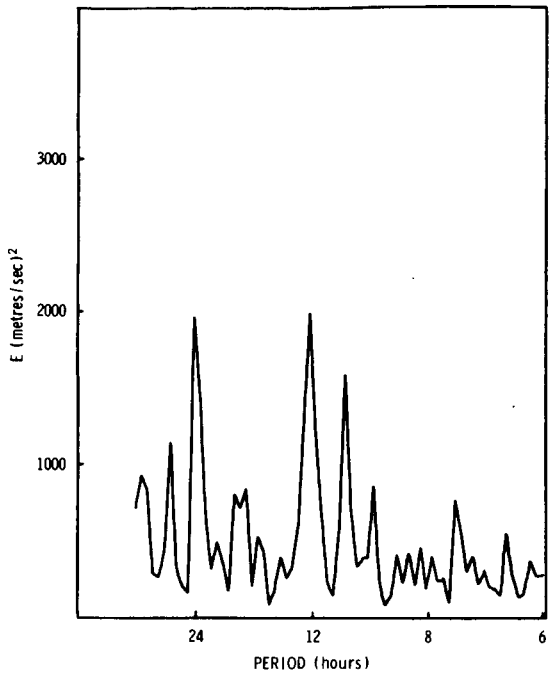

Figure 6c. Wind Energy Spectrum at 97km. May, 1961.

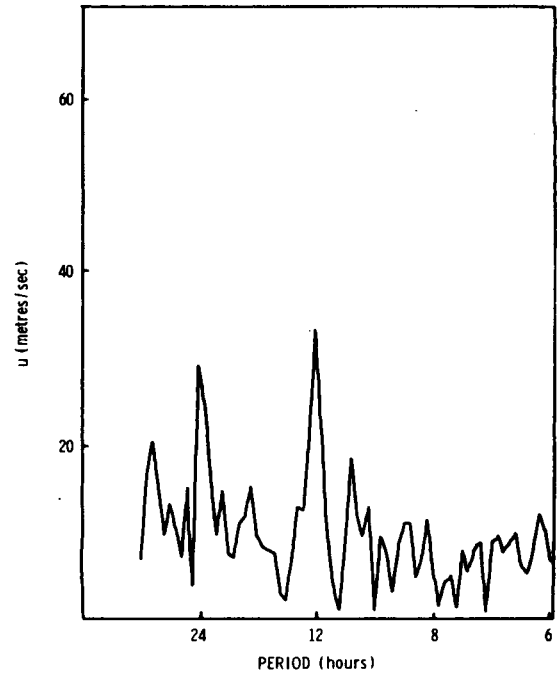

Figure 6d. Zonal Amplitude Spectrum at 93km. May, 1961.

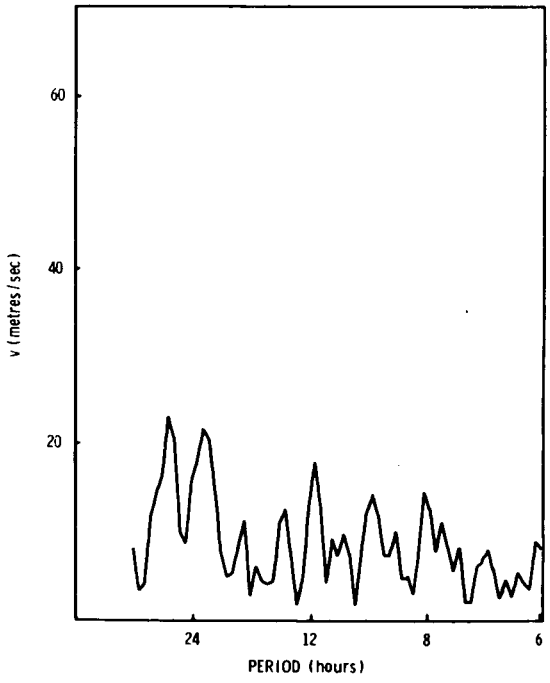

Figure 6e. Meridional Amplitude Spectrum at 93km. May, 1961.

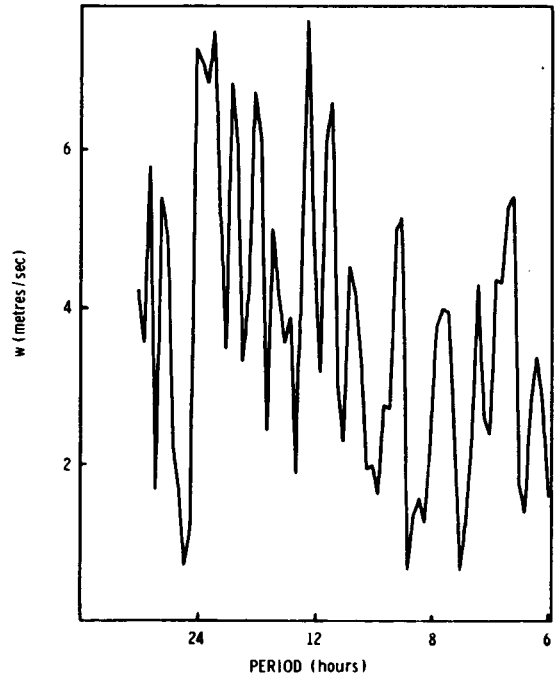

Figure 6f. Vertical Amplitude Spectrum at 93km. May, 1961.

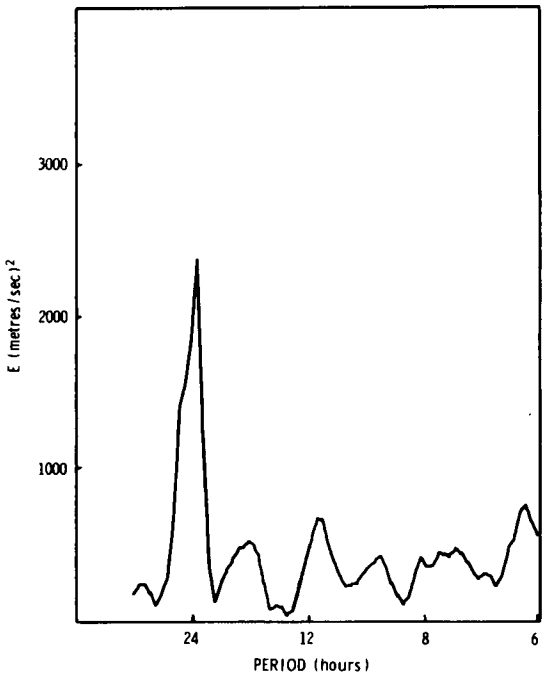

Figure 7a. Wind Energy Spectrum at 83km. June, 1961.

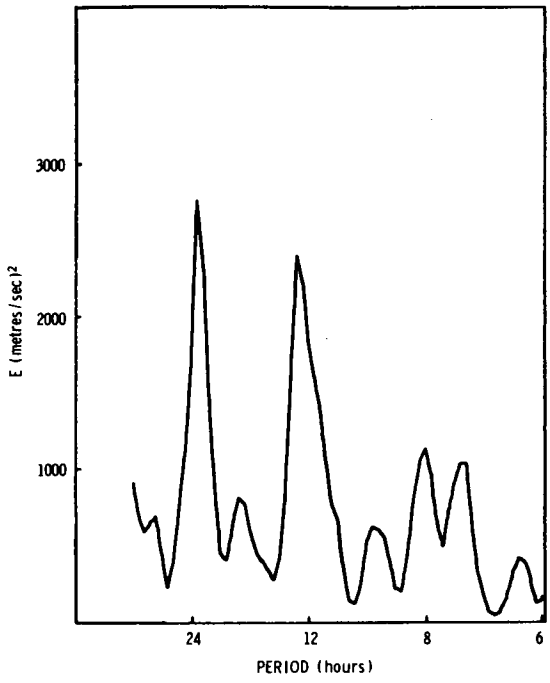

Figure 7b. Wind Energy Spectrum at 91km. June, 1961.

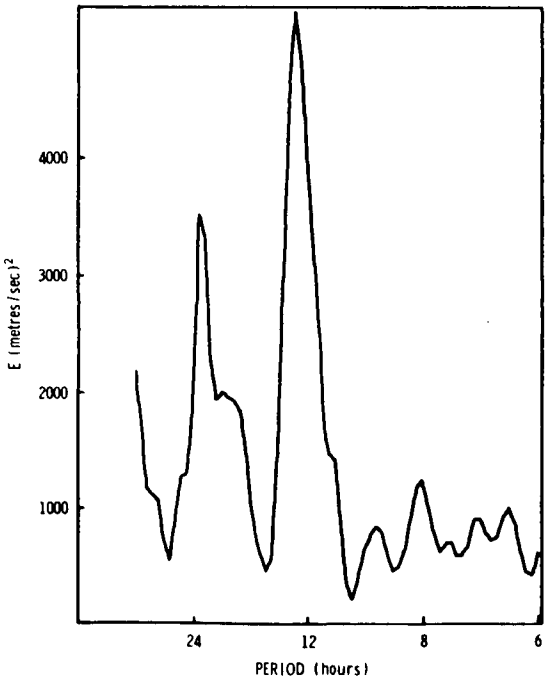

Figure 7c. Wind Energy Spectrum at 97km. June, 1961.

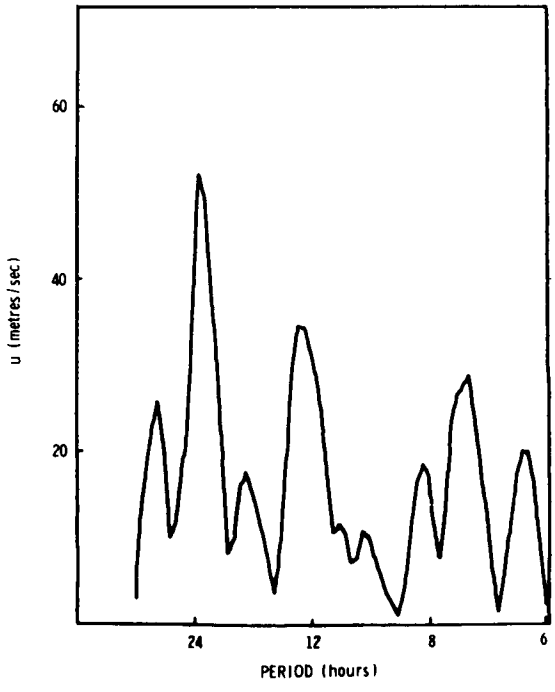

Figure 7d. Zonal Amplitude Spectrum at 93km. June, 1961.

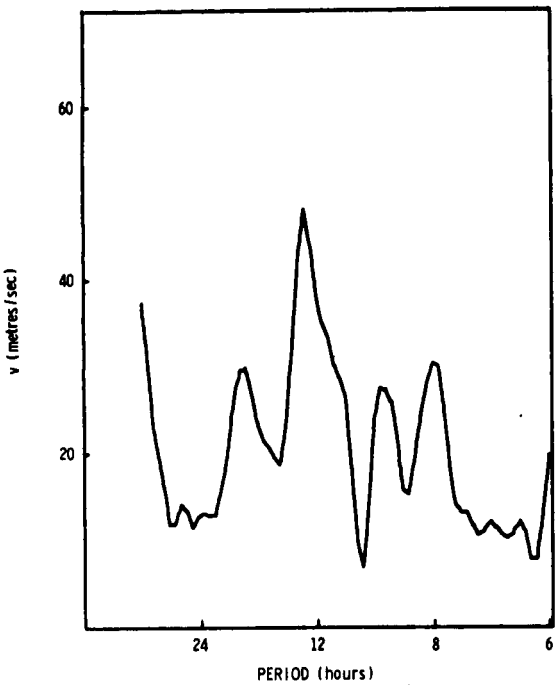

Figure 7e. Meridional Amplitude Spectrum at 93km. June, 1961.

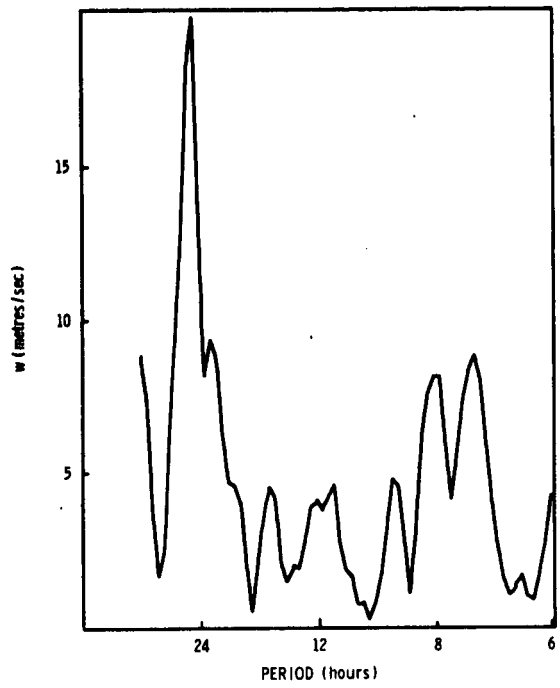

Figure 7f. Vertical Amplitude Spectrum at 93km. June, 1961.

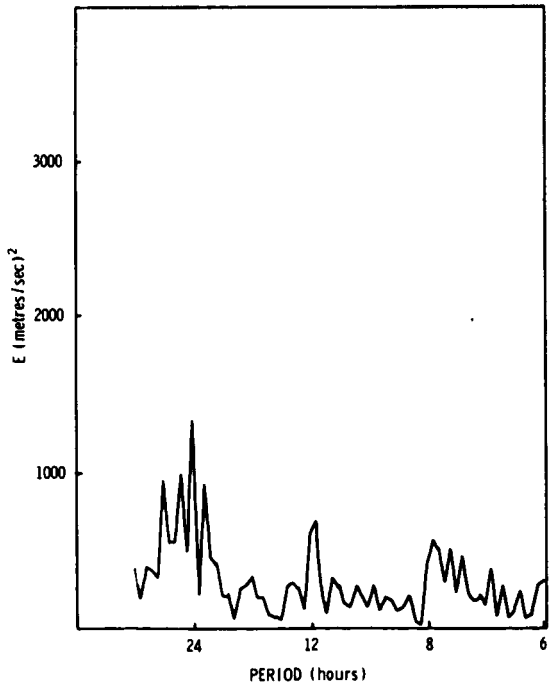

Figure 8a. Wind Energy Spectrum at 83km. July, 1961.

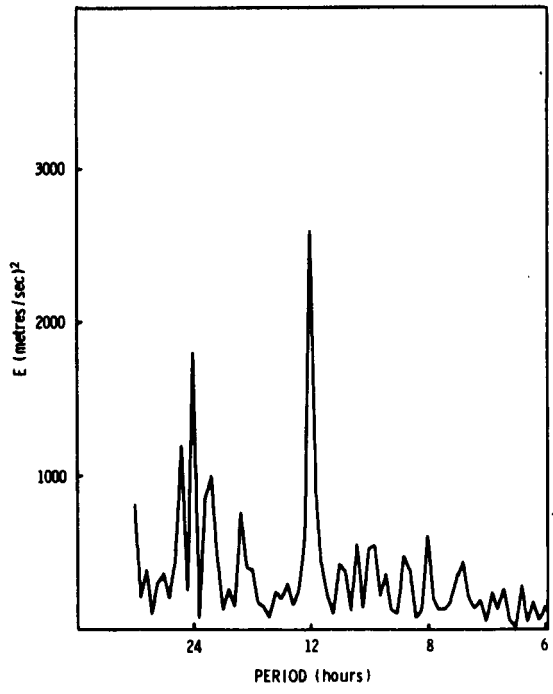

Figure 8b. Wind Energy Spectrum at 91km. July, 1961.

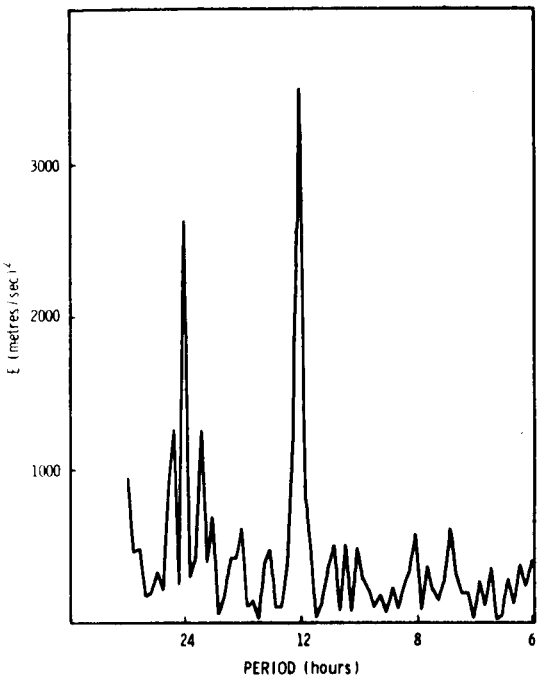

Figure 8c. Wind Energy Spectrum at 97km. July, 1961.

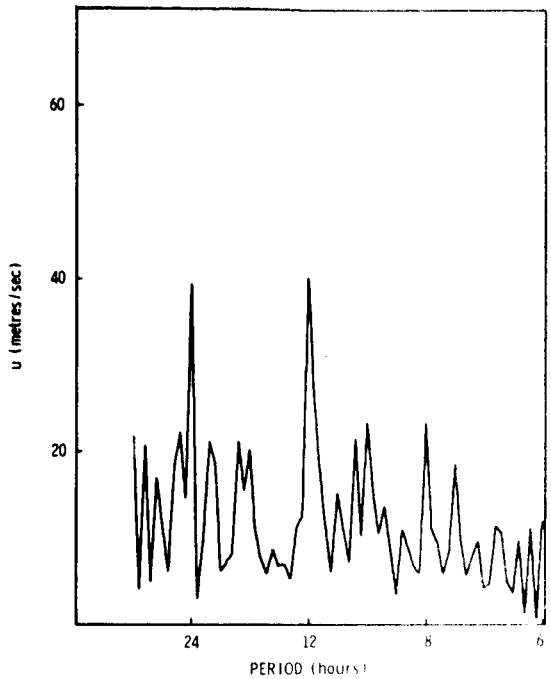

Figure 8d. Zonal Amplitude Spectrum at 93km. July, 1961.

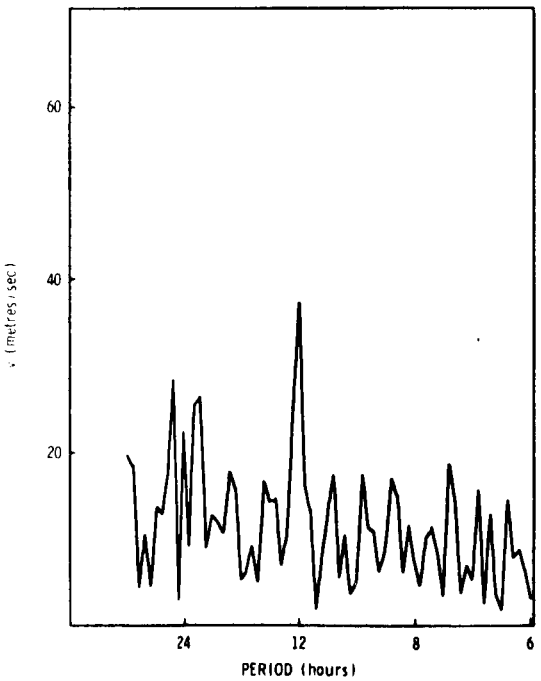

Figure 8e. Meridional Amplitude Spectrum at 93km. July, 1961.

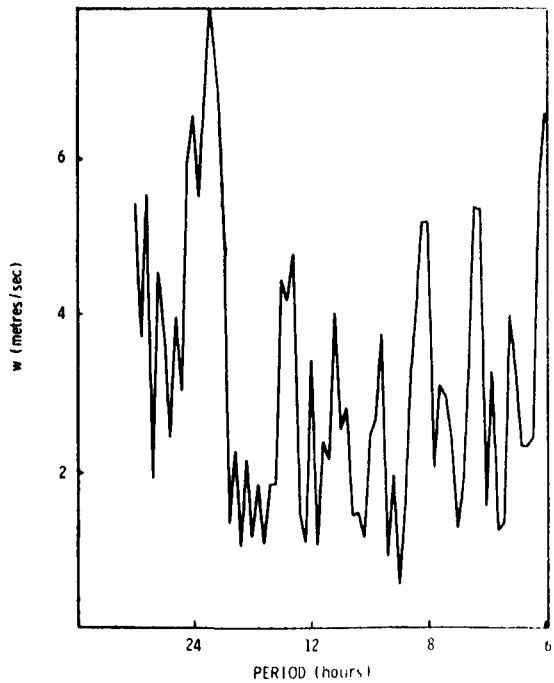

Figure 8f. Vertical Amplitude Spectrum at 93km. July, 1961.

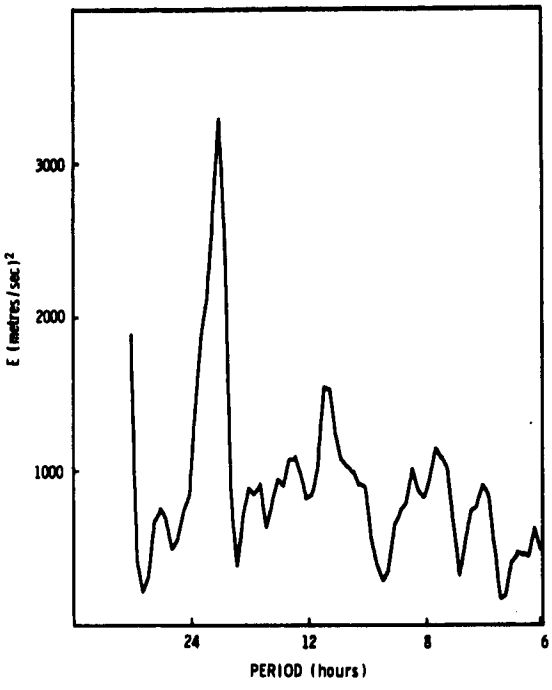

Figure 9a. Wind Energy Spectrum at 83km. August (1st-6th), 1961.

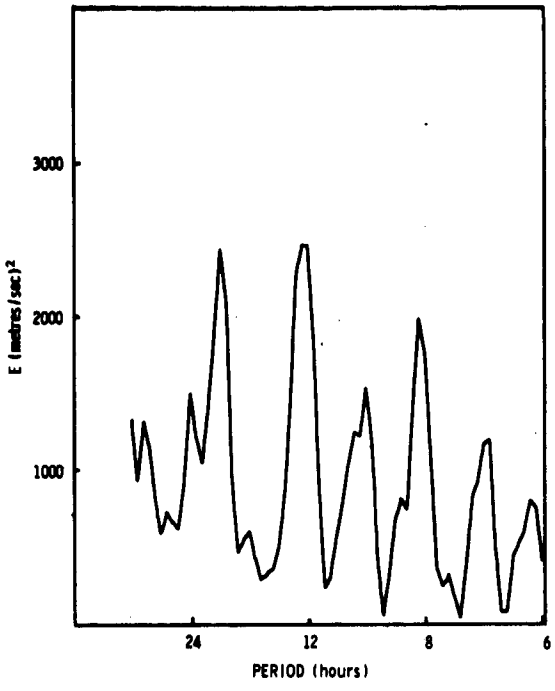

Figure 9b. Wind Energy Spectrum at 91km. August (1st-6th), 1961.

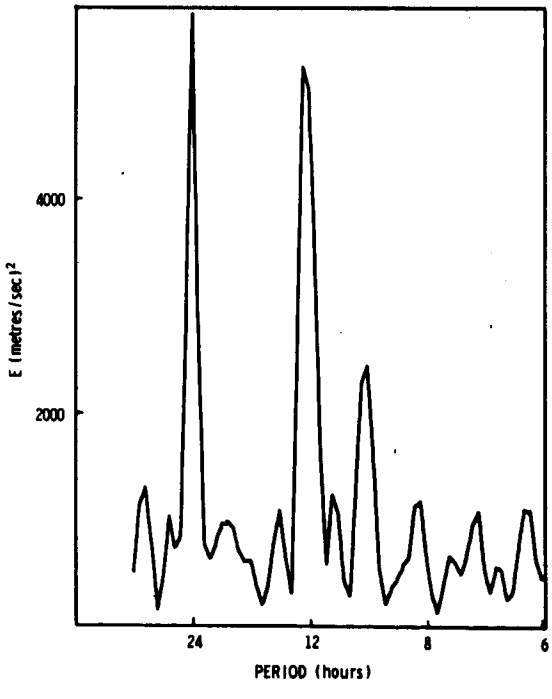

Figure 9c. Wind Energy Spectrum at 97km. August (1st-6th), 1961

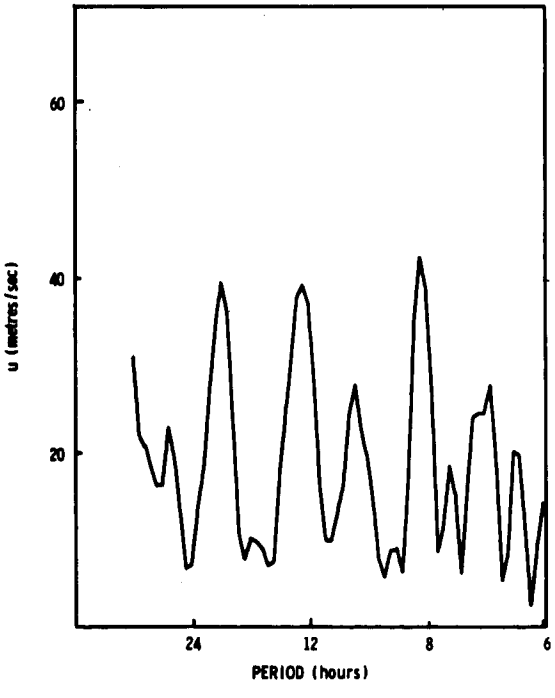

Figure 9d. Zonal Amplitude Spectrum at 93km. August (1st-6th), 1961.

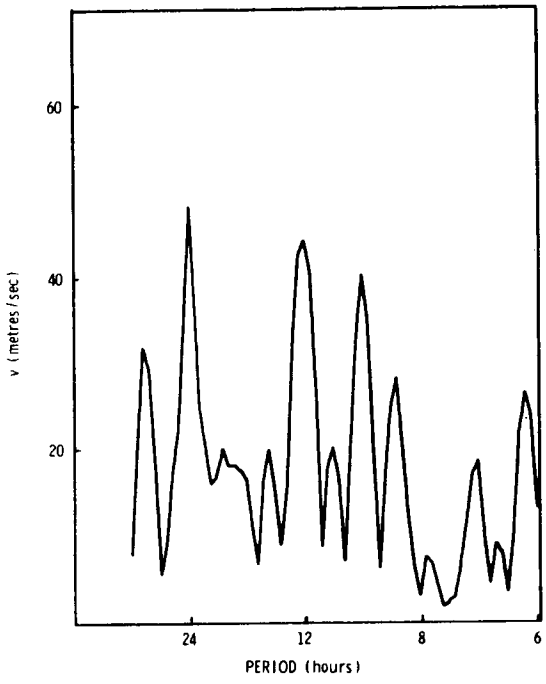

Figure 9e. Meridional Amplitude Spectrum at 93km. August (1st - 6th), 1961.

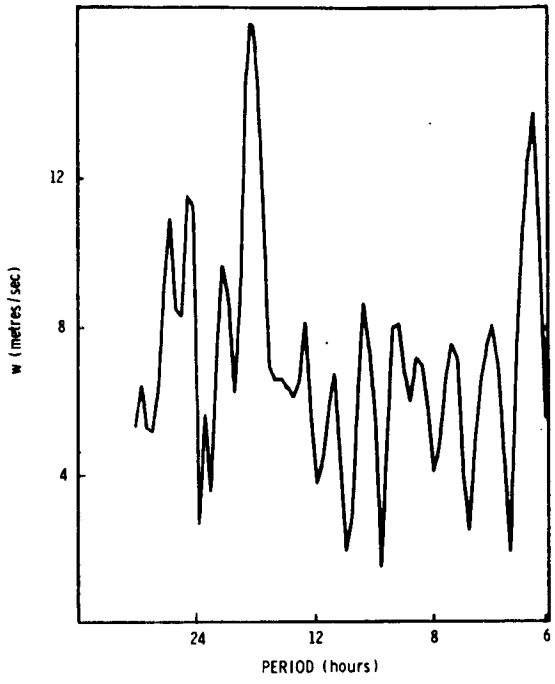

Figure 9f. Vertical Amplitude Spectrum at 93km. August (1st - 6th), 1961.

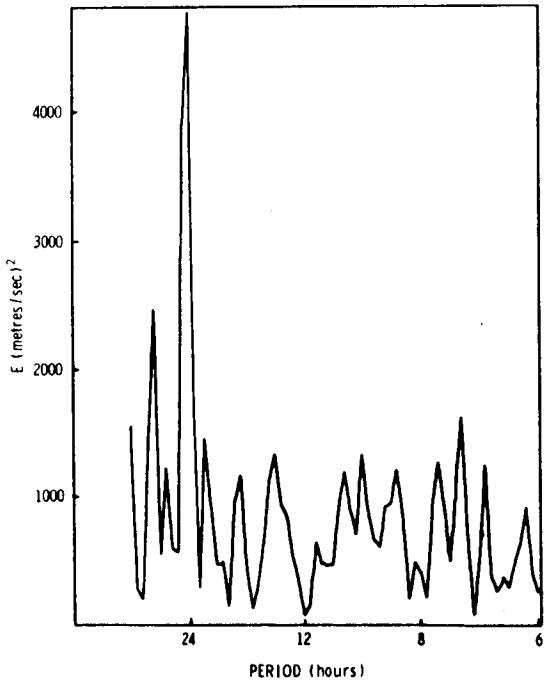

Figure 10a. Wind Energy Spectrum at 83km. August (17th - 24th), 1961.

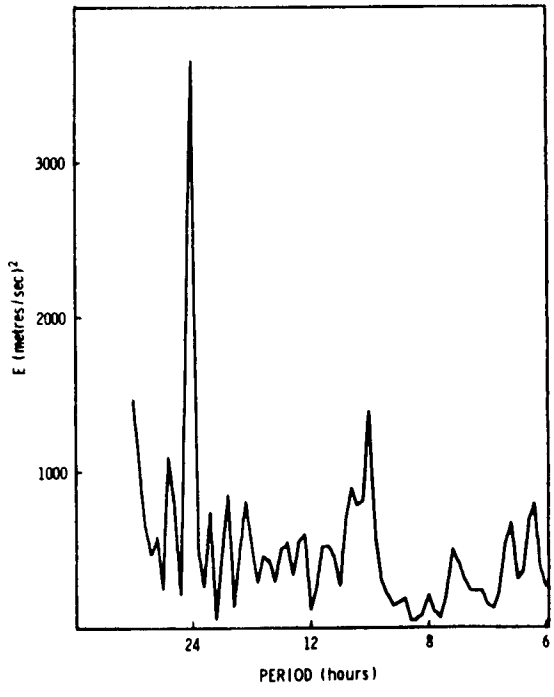

Figure 10b. Wind Energy Spectrum at 91km. August (17th - 24th), 1961.

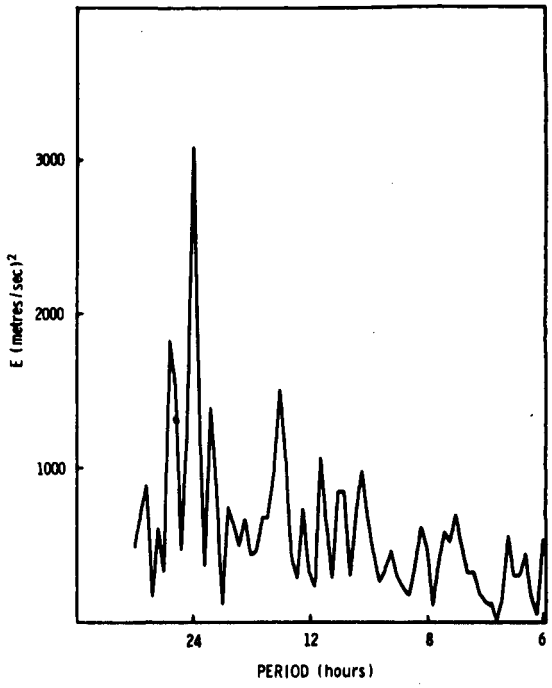

Figure 10c. Wind Energy Spectrum at 97km. August (17th - 24th), 1961.

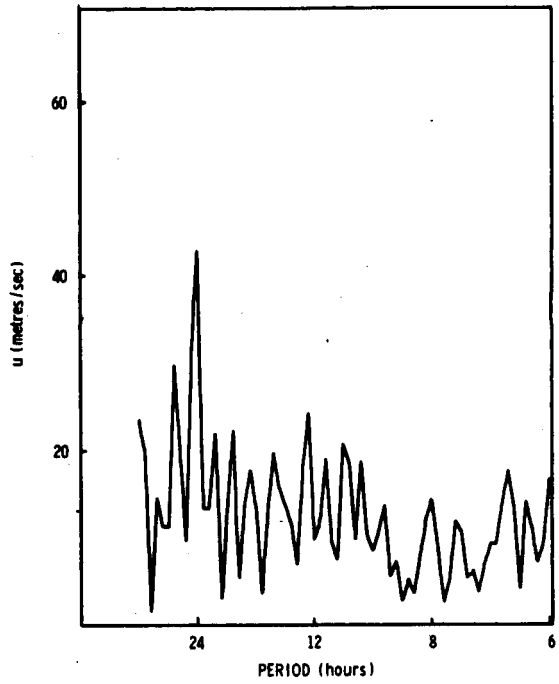

Figure 10d. Zonal Amplitude Spectrum at 93km. August (17th - 24th), 1961.

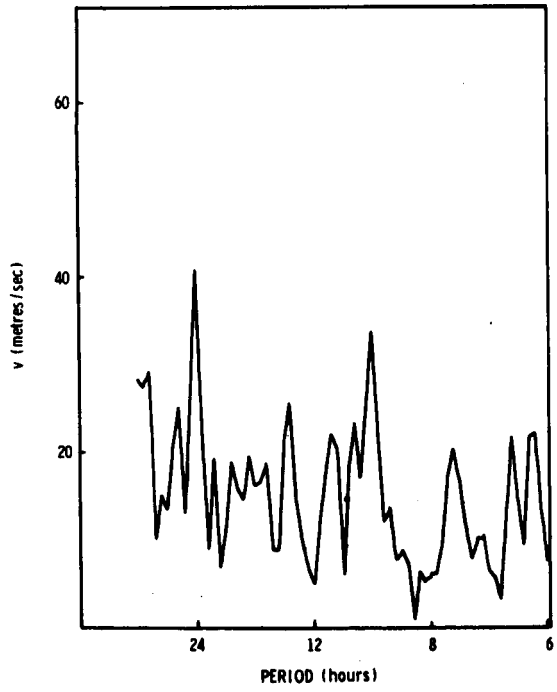

Figure 10e. Meridional Amplitude Spectrum at 93km. August (17th - 24th) 1961.

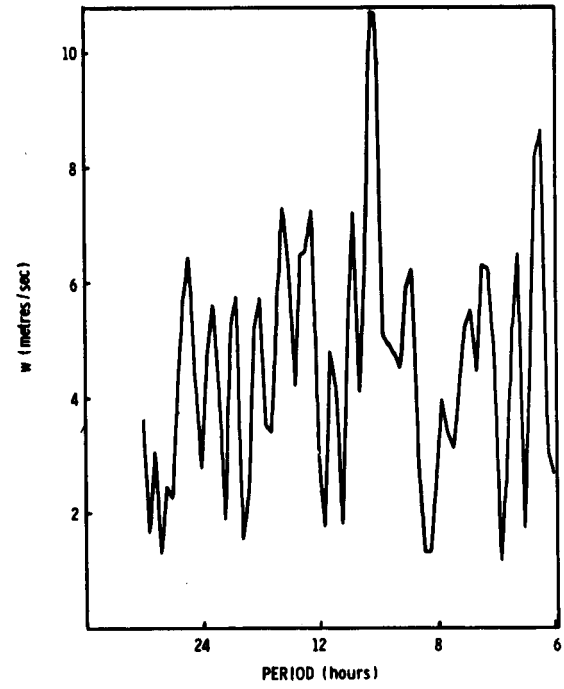

Figure 10f. Vertical Amplitude Spectrum at 93km. August (17th - 24th), 1961.

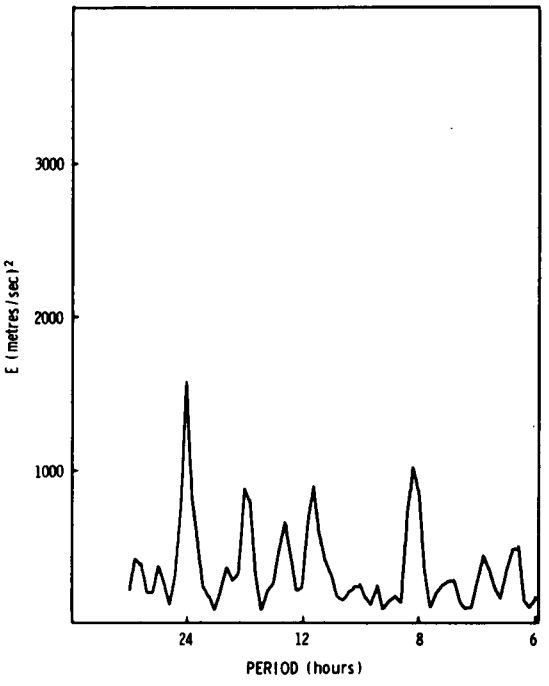

Figure 11a. Wind Energy Spectrum at 83km. September, 1961.

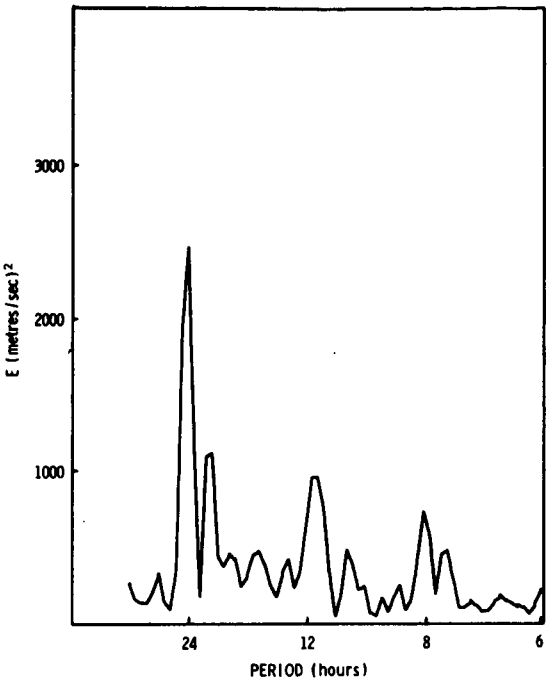

Figure 11b. Wind Energy Spectrum at 91km. September, 1961.

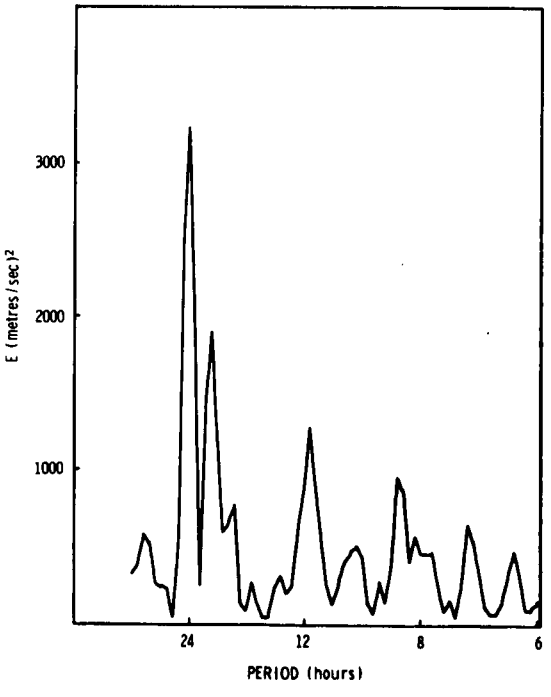

Figure 11c. Wind Energy Spectrum at 97km. September, 1961.

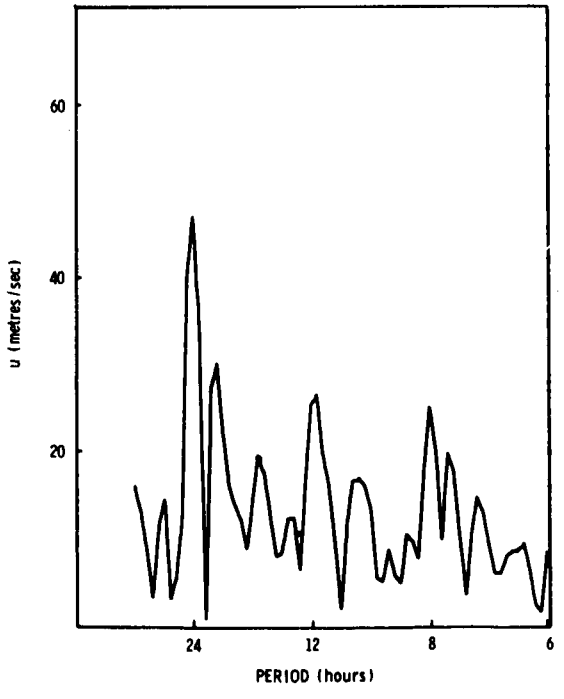

Figure 11d. Zonal Amplitude Spectrum at 93km. September, 1961.

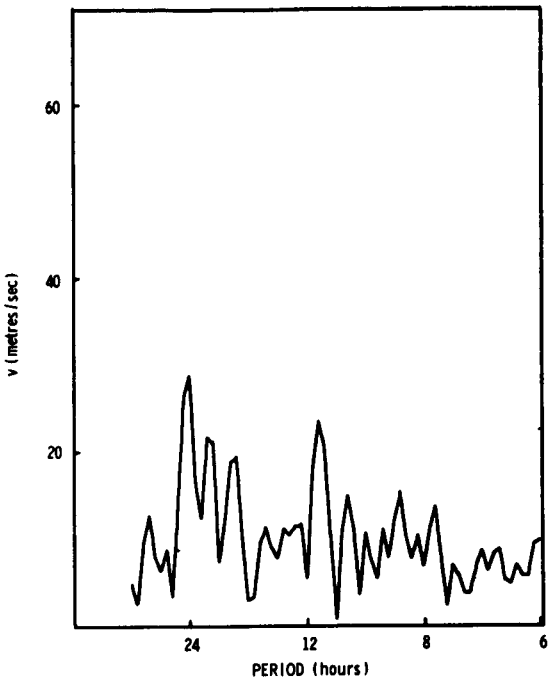

Figure 11e. Meridional Amplitude Spectrum at 93km. September, 1961.

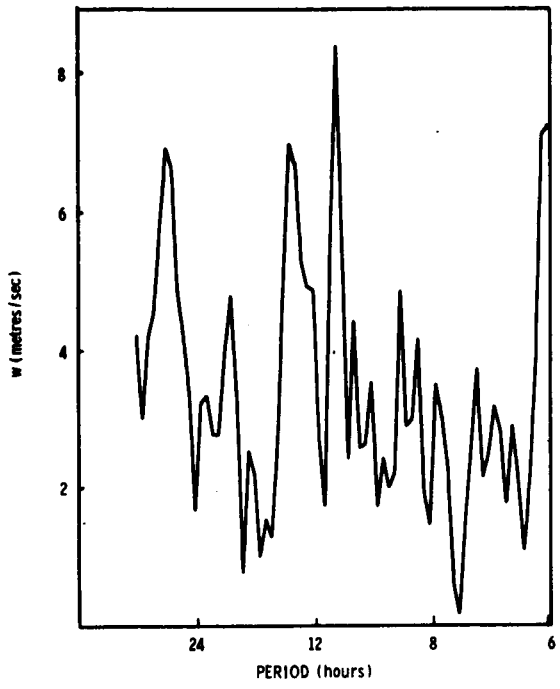

Figure 11f. Vertical Amplitude Spectrum at 93km. September, 1961.

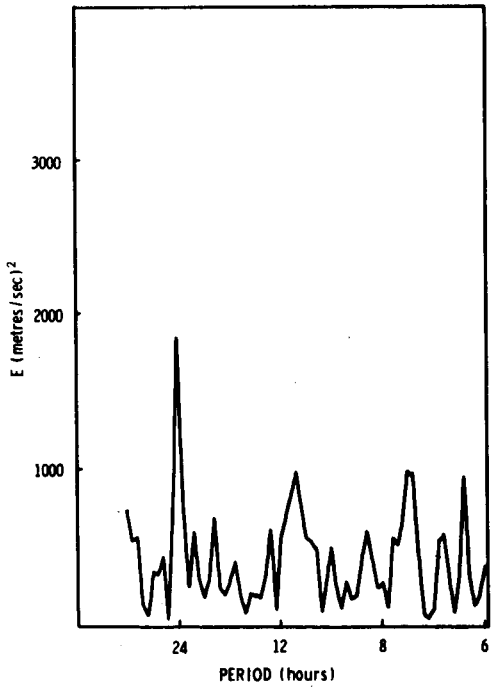

Figure 12a. Wind Energy Spectrum at 83km. October, 1961.

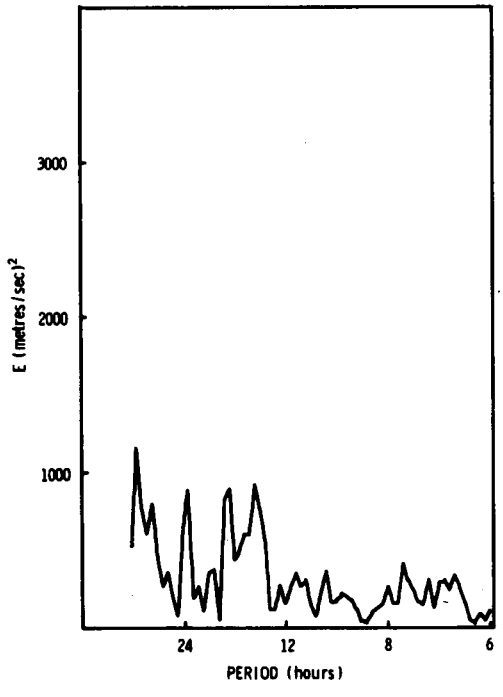

Figure 12b. Wind Energy Spectrum at 91km. October, 1961.

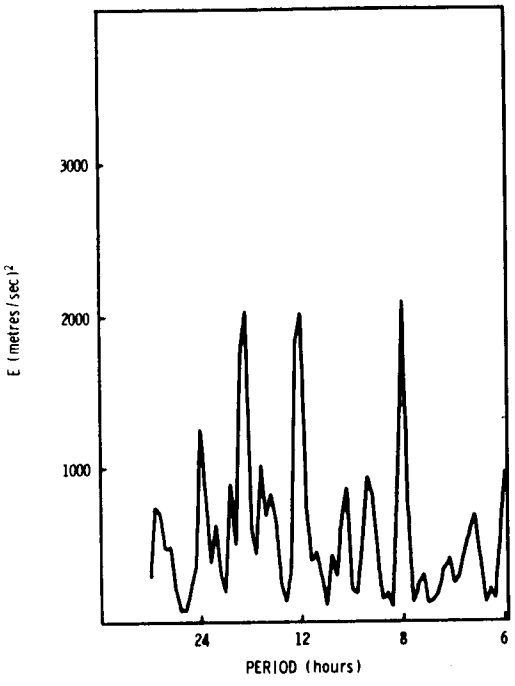

Figure 12c. Wind Energy Spectrum at 97km. October, 1961.

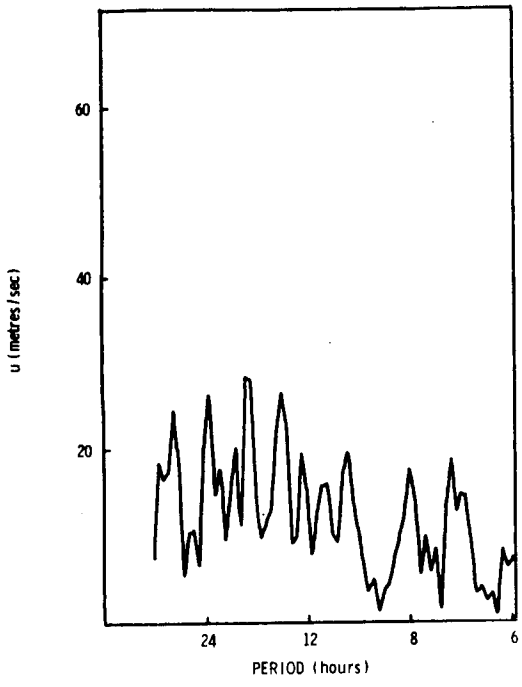

Figure 12d. Zonal Amplitude Spectrum at 93km. October, 1961.

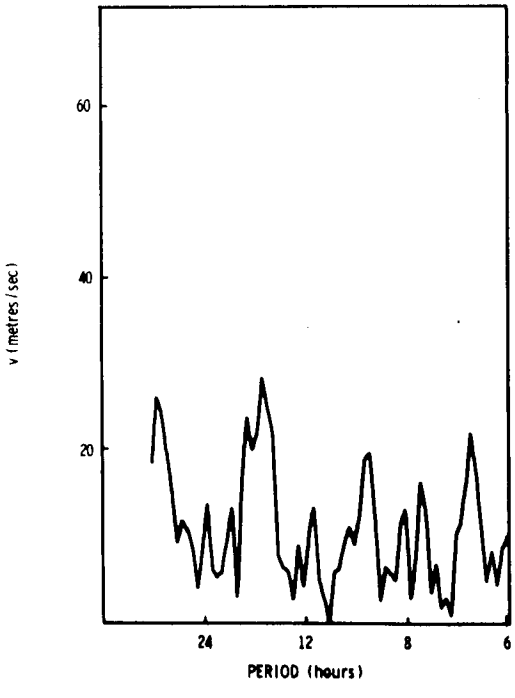

Figure 12e. Meridional Amplitude Spectrum at 93km. October, 1961.

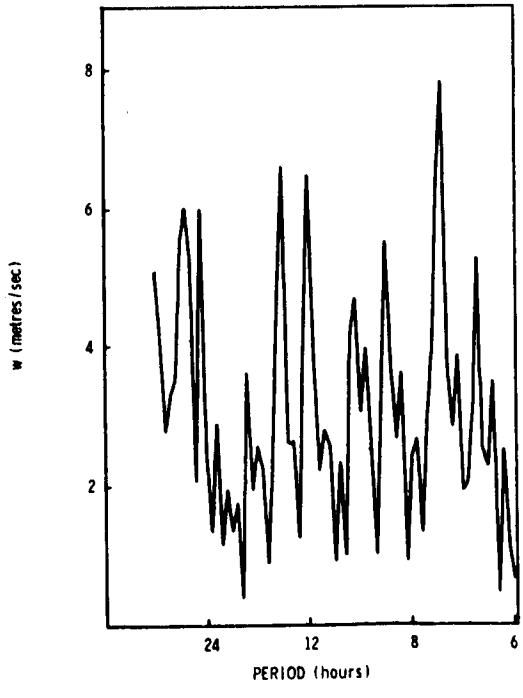

Figure 12f. Vertical Amplitude Spectrum at 93km. October, 1961.

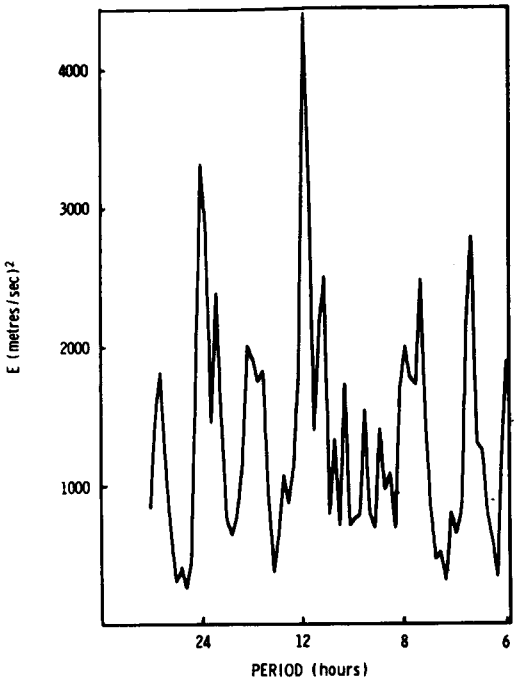

Figure 13a. Wind Energy Spectrum at 83km. November, 1961.

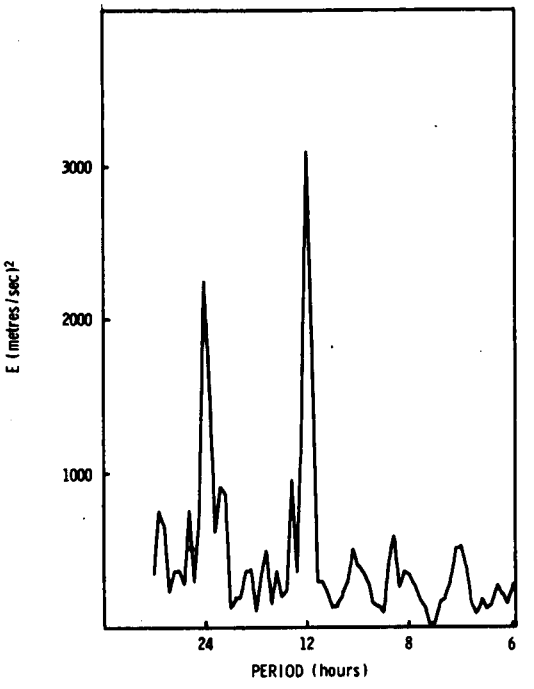

Figure 13b. Wind Energy Spectrum at 91km. November, 1961.

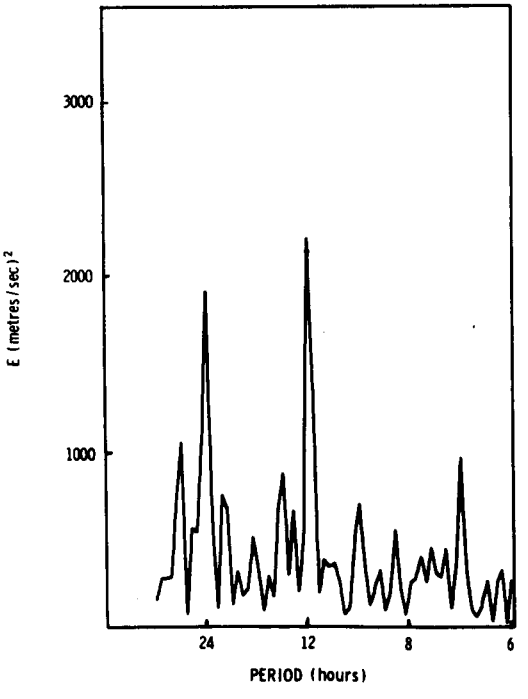

Figure 13c. Wind Energy Spectrum at 97km. November, 1961.

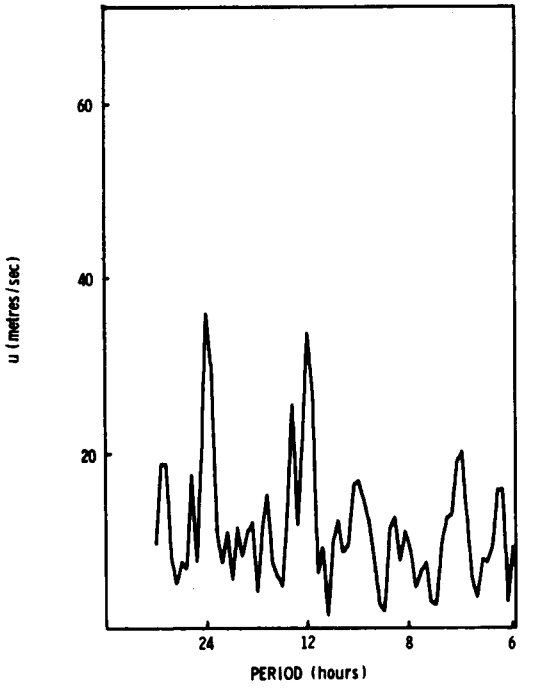

Figure 13d. Zonal Amplitude Spectrum at 93km. November, 1961.

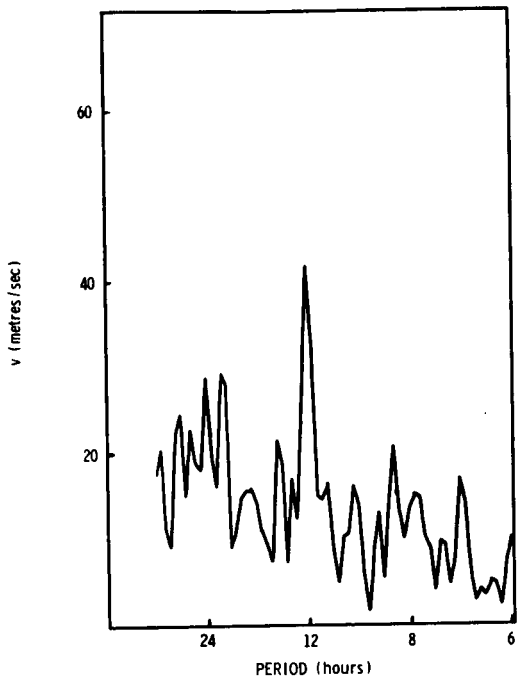

Figure 13e. Meridional Amplitude Spectrum at 93km. November, 1961.

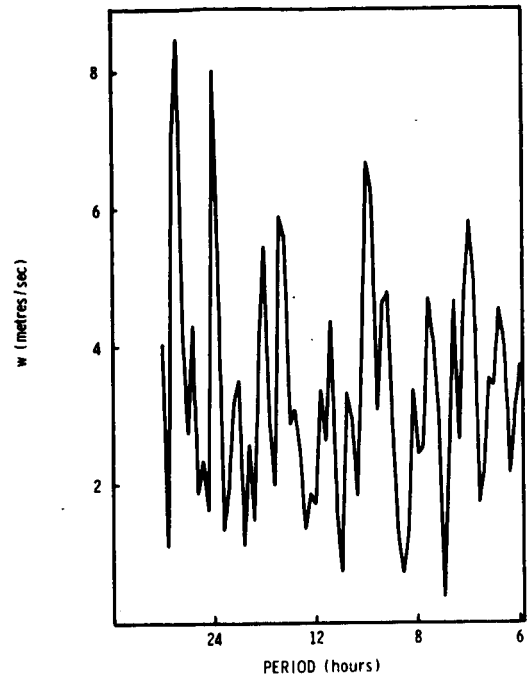

Figure 13f. Vertical Amplitude Spectrum at 93km. November, 1961.

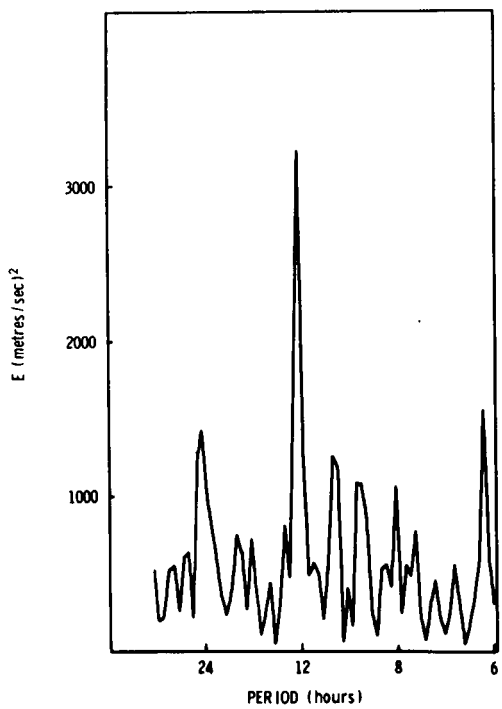

Figure 14a. Wind Energy Spectrum at 83km. December, 1961.

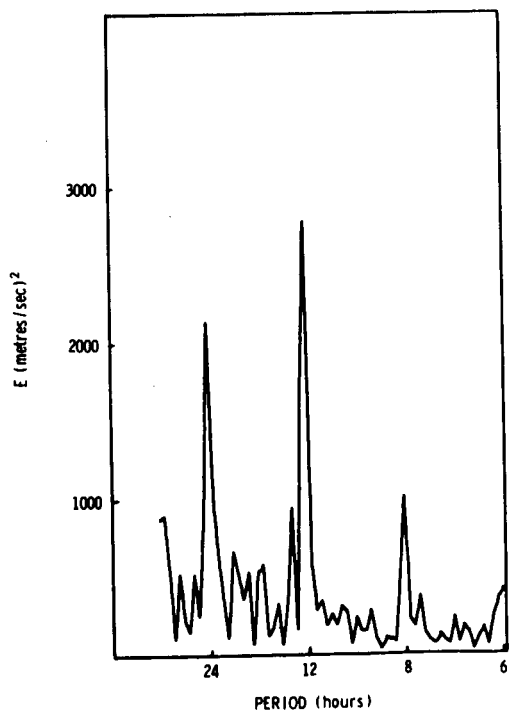

Figure 14b. Wind Energy Spectrum at 91km. December, 1961.

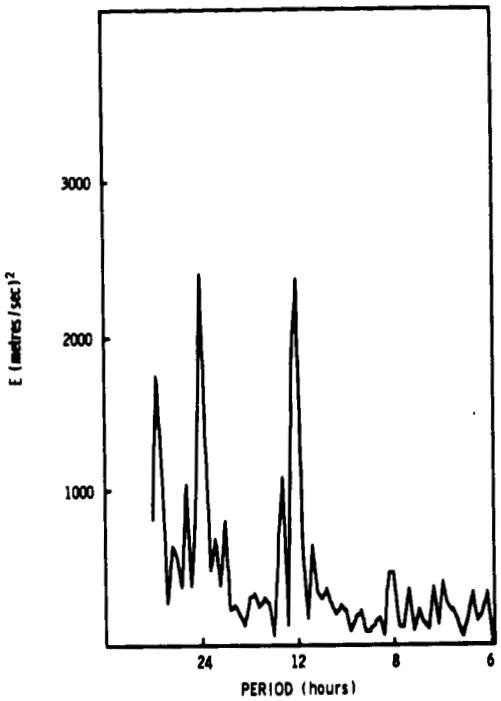

Figure 14c. Wind Energy Spectrum at 97km. December, 1961.

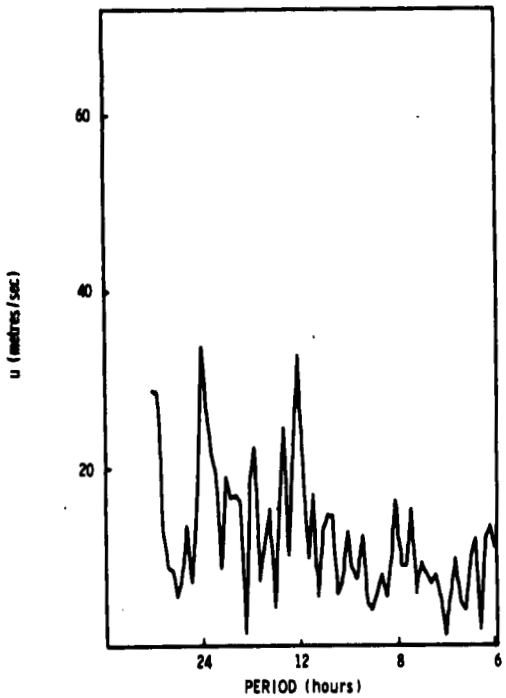

Figure 14d. Zonal Amplitude Spectrum at 93km. December, 1961.

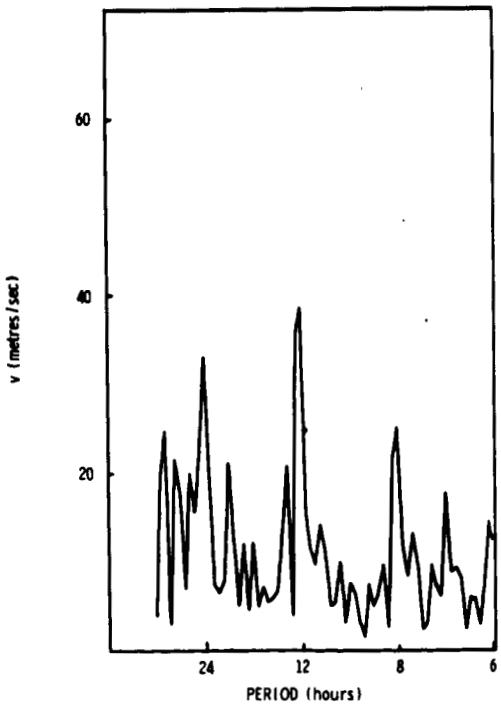

Figure 14e. Meridional Amplitude Spectrum at 93km. December, 1961.

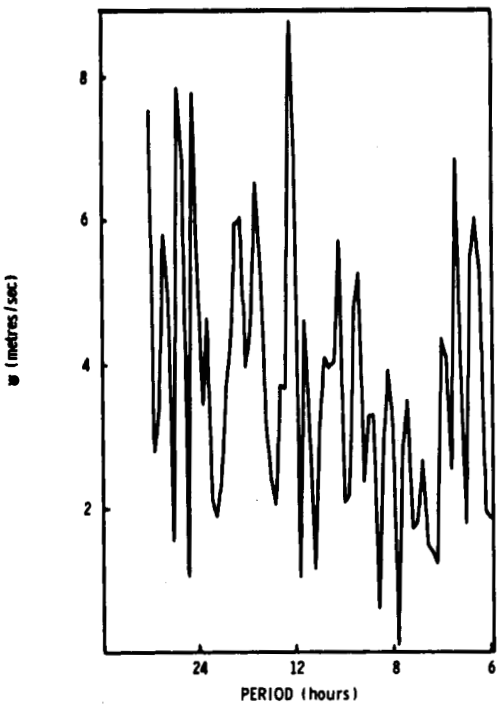

Figure 14f. Vertical Amplitude Spectrum at 93km. December, 1961.

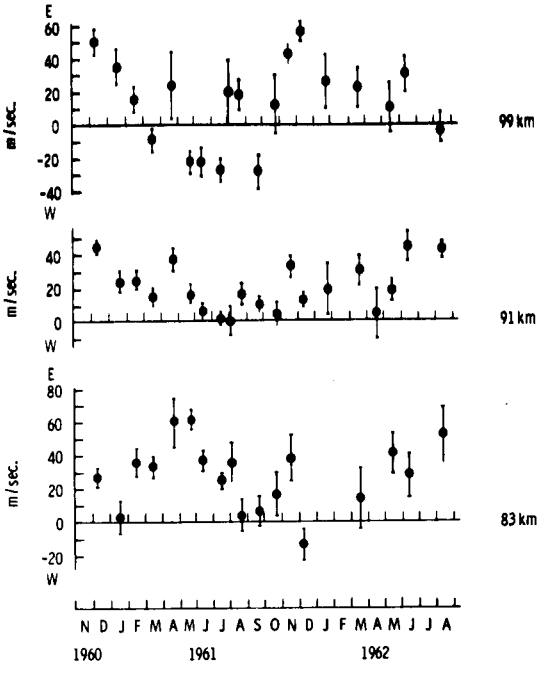

Figure 15 Zonal Winds

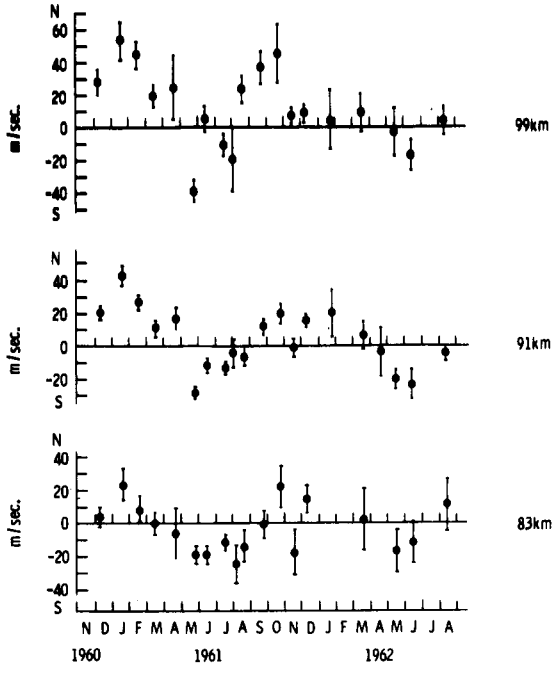

Figure 16 Meridional Winds

APPENDIX I

Listing of the IBM 7094 FORTRAN IV Spectrum Analysis Program.

```
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$PAUSE
$EXECUTE        IBJOB
$IBJOB          GO,LOGIC,MAP
$IBFTC ERG      M94,XR7,LIST
C     ERG (ELFORD, ROPER, GROVES) METEOR WIND SPECTRUM ANALYSIS.
C
C     ROUTINE SPECTRUM ANALYSIS.
C     OPTIMIZED DATA HANDLING FORTRAN IV PROGRAM.
C     DATA OUTPUT FROM 1190A TO BE ON TAPE 2.
C     MAXIMUM OF 2000 ECHOES, ALL FROM ONE MONTH.
C
C     DATA ON TAPE 2 CONSISTS OF
C     HEADER CARD , REPRODUCED AT THE TOP OF EACH PAGE OF OUTPUT.
C     FORMAT 12A6
C     OUTPUT TAPE DESIGNATION.  FORMAT 6A6.
C     HEIGHT RANGE, ZMIN-ZMAX.  FORMAT 1X2F4.0
C     NEXT CARD NORMALLY HAS A ZERO OR BLANK IN COLUMN 1.  IF SEVERAL
C     SEGMENTS OF A SPECTRUM ARE REQUIRED, A 1 IS PUNCHED IN COLUMN 1.
C     STARTING FREQUENCY FOR PERIODOGRAM, IN CYCLES/DAY (NORMALLY 0.5),
C     END FREQUENCY (NORMALLY 4.0), AND THE FREQUENCY INCREMENT
C     (NORMALLY 0.05).   FORMAT I1,3F5.2
C     DATA OUTPUT 1190A.   MAXIMUM OF 2000 CARDS.
C     A BLANK CARD TO FLAG END OF ECHO DATA.
C     IF A 1 HAS BEEN PUNCHED IN COLUMN 1 OF THE FREQUENCY RANGE
C     AND INCREMENT CARD, THEN FURTHER CARDS SPECIFYING THE SPECTRUM
C     INTERVALS AND INCREMENTS FOLLOW, EACH WITH A 1 IN COLUMN 1.
C     THE LAST OF THESE CARDS (IF ANY) MUST CONTAIN A ZERO OR BLANK
C     IN COLUMN 1 TO TRIGGER THE OPERATOR REMOVE TAPE MESSAGE.
C
C     ANY COMPLETE SET OF CARDS ABOVE MAY BE FOLLOWED BY ANOTHER
C     SET, COMMENCING FROM, AND INCLUDING, HEADER CARD.
C
C
      DIMENSION KHT(20)
      DIMENSION RESULT(12)
      DIMENSIONQ(24,24),A(24, 48),R(24,24),P(24),D(24),AC(24)
      DIMENSION SIGMA(24)
      DIMENSION LTHMM(2000),EL3M(2000),EM3M(2000),ZM(2000),VELM(2000),
     1 JOM(2000)
      DIMENSION TAPE(6)
      DIMENSION FINIS(126)
      COMMON A, R, NOP,ZMIN,MIN,ZMAX,MAX,       SUM,NP,NQ,NR,NAO,NBO,NCO,
     1NA,NB,NC,       AC,RESULT,PERIOD
      COMMON KHT,NHT,MY,MO
C
C     THIS SECTION OF THE PROGRAMME READS PROCESSING PARAMETERS.
C
 6000 CONTINUE
      IPRINT=0
      LOAD=-1
      M=0
      ZERO=0.0
      NPASS=0
      NOGO=0
      NOP=0
      READ          (2,31)RESULT
   31 FORMAT(12A6)
      READ              (2,31)TAPE
      NP=1
```

```
      NQ=1
      NR=1
      READ          (2,2)ZMIN,ZMAX
    2 FORMAT(1X2F4.0)
      MIN=ZMIN
      MAX=ZMAX
      IF(ZMAX-ZMIN-31.0)39,39,40
   40 WRITE                (3,41)
   41 FORMAT(1X37HHEIGHT RANGE EXCEEDS ALLOWABLE 30 KM.///1X21HEXECUTION
     1 TERMINATED.////////)
      PRINT 41
      GOTO 300
   39 KHT(1)=MIN
      NHT=(ZMAX-ZMIN)/2.0+1.0
  865 READ(2,866)IBIT,START,ENDIT,STEP
  866 FORMAT(I1,3F5.2)
      NUMPAS=(ENDIT-START)/STEP+1.6
      ENDIT=ENDIT-0.0001
      CYCLE=START-STEP
      LOAD=LOAD+1
      IF(LOAD)700,700,1
  700 DO70I=2,NHT
      KHT(I)=KHT(I-1)+2
   70 CONTINUE
      NA0=2
      NA=2
      NAHOLD=NA
      NB0=3
      NB=3
      NC0=0
      NC=0
      N=24
      NE=25
      N2=48
      NA0E=3
      NA0T=4
      NAE=3
      NA2=4
      NB0E=4
      NB0T=6
      NBE=4
      NB2=6
      NC0E=1
      NC0T=0
      NCE=1
      NC2=0
       PRINT 2000,TAPE
 2000 FORMAT(1X4HLOAD 6A6,32HON B6, AND PUSH START WHEN READY /1H1/1X)
      PAUSE
      REWIND 46
      CALL DNSHI
    1 WRITE(16)RESULT,KHT(1),NHT
      PRINT 7193,NUMPAS
 7193 FORMAT(1X30HNUMBER OF PASSES THIS SEGMENT I6///////)
      IF(LOAD)3,3,999
    3 READ     (2,4)UR,MP,MQ,JO,LTIMH,LTIMM,EL,EM,EL3,EM3,Z,LEVEL,LT,
     1NFL,NFM,VEL,MCS,MX
    4  FORMAT(F7.0,4I3,I2,4F5.2,F4.0,2I3,2I5,F5.0,2I3)
      IF(UR)999,999,5
    5 IF(Z-ZMAX)6,6,3
```

```
    6 IF(Z-ZMIN)3,7,7
    7 M=M+1
      MY=MP
      MO=MQ
      JOM(M)=JO
      LTHMM(M)=LTIMH*100+LTIMM
      EL3M(M)=EL3
      EM3M(M)=EM3
      ZM(M)=Z
      VELM(M)=VEL
      GOTO 3
  999 CYCLE=CYCLE+STEP
      PERIOD=24.0/CYCLE
      NA=NAHOLD
      DO38I=1,24
      P(I)=0.0
      AC(I)=0.0
      DO38L=1,24
      Q(I,L)=0.0
   38 CONTINUE
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
C
C     NEXT COMES PROCESSING OF ECHO DATA TO PRODUCE COLUMNS D AND P,
C     AND MATRIX Q.
C
      IRUN=0
   60 IRUN=IRUN+1
      JO=JOM(IRUN)
      LTHM=LTHMM(IRUN)
      EL3=EL3M(IRUN)
      EM3=EM3M(IRUN)
      Z=ZM(IRUN)
      VEL=VELM(IRUN)
      CALL TIME (MY,MO,JO,LTHM,PERIOD,T)
      DCL=EL3
      DCM=EM3
      DCN=SQRT (1.0-EL3**2-EM3**2)
      S=(2.0*Z-ZMAX-ZMIN)/(ZMAX-ZMIN)
      S=S+0.000001
      VEL=-VEL
      SUMP=0
      SUMQ=0
      SUMR=0
      NCOUNT=0
      SUMSA0=1
      IF(NAOT)110,110,84
   84 DO8K=2,NAOT,2
      SUMSA0=SUMSA0+S**K
    8 CONTINUE
      SUMSA    =1
      DO9K=2,NA2,2
    9 SUMSA=SUMSA+S**K
      SUMP=SUMP+SUMSA
  110 SUMP=SUMP+SUMSA0
      SUMSB0=1
      IF(NBOT)130,130,114
  114 DO11K=2,NBOT,2
      SUMSB0=SUMSB0+S**K
   11 CONTINUE
```

```
      SUMSB=1
      DO12K=2,NB2,2
   12 SUMSB=SUMSB+S**K
      SUMQ=SUMQ+SUMSB
  130 SUMQ=SUMQ+SUMSB0
      SUMSC0=1
      IF(NCUT)160,160,135
  135 DO14K=2,NCUT,2
      SUMSC0=SUMSC0+S**K
   14 CONTINUE
      SUMSC=1
      DO15K=2,NC2,2
   15 SUMSC=SUMSC+S**K
      SUMR=SUMR+SUMSC
  160 SUMR=SUMR+SUMSC0
      WF=1.0/((DCL**2)*SUMP+(DCM**2)*SUMQ+(DCN**2)*SUMR)
      SUM3=SUM3+WF*VEL**2
      DO20K=1,NAOE
      NCOUNT=NCOUNT+1
   20 D(NCOUNT)=DCL*(S**(K-1))
      DO21K=1,NAE
      NCOUNT=NCOUNT+1
   21 D(NCOUNT)=DCL*(S**(K-1))*SIN (T)
      DO22K=1,NAE
      NCOUNT=NCOUNT+1
   22 D(NCOUNT)=DCL*(S**(K-1))*COS (T)
      DO23K=1,NBOE
      NCOUNT=NCOUNT+1
   23 D(NCOUNT)=DCM*(S**(K-1))
      DO24K=1,NBE
      NCOUNT=NCOUNT+1
   24 D(NCOUNT)=DCM*(S**(K-1))*SIN (T)
      DO25K=1,NBE
      NCOUNT=NCOUNT+1
   25 D(NCOUNT)=DCM*(S**(K-1))*COS (T)
      DO26K=1,NCOE
      NCOUNT=NCOUNT+1
   26 D(NCOUNT)=DCN*(S**(K-1))
      DO27K=1,NCE
      NCOUNT=NCOUNT+1
   27 D(NCOUNT)=DCN*(S**(K-1))*SIN (T)
      DO28K=1,NCE
      NCOUNT=NCOUNT+1
   28 D(NCOUNT)=DCN*(S**(K-1))*COS (T)
      DO29J=1,N
      P(J)=P(J)+WF*VEL*D(J)
   29 CONTINUE
      DO30J=1,N
      DO30K=1,N
      Q(J,K)=Q(J,K)+WF*D(J)*D(K)
   30 CONTINUE
      IF(IRUN-M)60,5894,5894
C
C     INVERSION OF Q, AND FORMATION OF COEFFICIENT COLUMN AC.
C
 5894 DO101J=1,N
      DO101K=1,N
      A(J,K)=Q(J,K)
  101 CONTINUE
      DO102J=1,N
```

```
      DO102K=NE,N2
      IF(J-K+N)108,107,108
  107 A(J,K)=1.0
      GOTO102
  108 A(J,K)=0.
  102 CONTINUE
      CALL MATSIN (N,MISS)
      IF(MISS)1103,1103,1102
 1102 CALL PAGE (RESULT,PERIOD)
      WRITE              (3,1104)N,N
 1104 FORMAT(1H0              /1X53H ***** ERROR IN INPUT DATA HAS RESULTE
     1D IN MATRIX  Q(I3,1H,I3,34H ) BEING UNSUITABLE FOR INVERSION./////
     21X30HPROGRAMME CANNOT BE CONTINUED.////////)
      PRINT 1104
      GOTO300
 1103 CONTINUE
      DO103K=1,N
      DO103J=1,N
  103 AC(K)=AC(K)+P(J)*R(J,K)
      DO104J=1,N
      DO104K=1,N
      SUM1=SUM1+AC(J)*AC(K)*Q(J,K)
  104 CONTINUE
      DO105J=1,N
      SUM2=SUM2+AC(J)*P(J)
  105 CONTINUE
      SUM=(SUM1-(2.0*SUM2)+SUM3)/FLOAT (M-N)
      DO106J=1,N
  106 SIGMA(J)  =SQRT (R(J,J)*SUM)
C
C     PRELIMINARY OUTPUT.
C
      NOGO=NOGO+1
      IF(NOGO-1)71,71,72
   71 CALL PAGE (RESULT,ZERO)
      WRITE          (3,200)
  200 FORMAT(1H ////1X48H VARIATION OF UPPER ATMOSPHERE WINDS WITH HEIGH
     1T//1X51H BASED ON GROVES ANALYSIS, WITH ERROR DETERMINATION////)
      WRITE          (3,201)M,N,MAX,MIN
  201 FORMAT(1H ////1X32H NUMBER OF METEORS PROCESSED   =I5////1X33H NUM
     1BER OF INPUT PARAMETERS     = I4////
     2 1X27H HEIGHT RANGE,    MAXIMUM   I5,1X11H  MINIMUM   I5,
     3 1X15H  KILOMETRES.    ///)
      WRITE (3,202)NA0,NA
  202 FORMAT(1X20H EAST - WEST PROFILE   2I3/1X)
      WRITE              (3,203)NB0,NB
  203 FORMAT(1X20H NORTH-SOUTH PROFILE2I3/1X)
      WRITE              (3,204)NC0,NC
  204 FORMAT(1X20H VERTICAL PARAMETERS2I3)
   72 CALL PAGE (RESULT,PERIOD)
      WRITE              (3,206)
  206 FORMAT(1X25H COLUMN MATRIX AC(K)      /1X)
      J=0
      DO205I=1,N
      J=J+1
      IF(J-50)208,208,207
  207 J=0
      CALL PAGE (RESULT,PERIOD)
      WRITE              (3,206)
  208 WRITE              (3,209)AC(I),SIGMA(I)
  209 FORMAT(1X25XF7.2,3XF7.1)
```

```
205 CONTINUE
    CALL PAGE (RESULT,PERIOD)
    CALL VARY
    NPASS=NPASS+1
    WRITE              (3, 299) NPASS
299 FORMAT(1X12H END OF PASSI5)
    IPRINT=IPRINT+1
    IF(IPRINT-10)281,280,280
280 IPRINT=0
    PRINT 299,NPASS
281 IF(CYCLE-ENDIT)999,300,300
300 NHT6=6*NHT+6
    DO301I=1,NHT6
301 FINIS(I)=0.0
    WRITE      (16)(FINIS(I),I=1,NHT6)
    IF(IBIT)332,332,865
332 END FILE 46
    REWIND 46
    PRINT 333, (TAPE(IOUT),IOUT=1,6)
333  FORMAT(1X6HREMOVE/1X/1X 6A6,39HFROM        B6,AND HOLD AS FILE TA
   1PE.   ///1X16HTHEN PUSH START.////1X,10X12HMANY THANKS.////////)
    PAUSE
    GOTO 6000
    END
```

```
$IBFTC VARY     M94,XR7,LIST
      SUBROUTINE VARY
C     CALCULATES THE AMPLITUDE AND PHASE OF THE PERIODIC COMPONENT,
C     TOGETHER WITH THE MOST PROBABLE ERROR IN EACH.
C     PRINTS THESE OUT AT 2KM INTERVALS OVER THE HEIGHT RANGE SPECIFIED.
C
      DIMENSION A(24,48),R(24,24)
      DIMENSION AC(24),AU(20),PH(20),ERAMP(20),ERPH(20),RESULT(12)
      DIMENSION UO(20), EO(20), KHT(20)
      COMMON A, R, NOP,ZMIN,MIN,ZMAX,MAX,       SUM,NP,NQ,NR,NAO,NBO,NCO,
     1NA,NB,NC,       AC,RESULT,PERIOD
      COMMON KHT,NHT,MY,MO
      NAOE=NAO+1
      NBOE=NBO+1
      NCOE=NCO+1
      KEND=0
      NSIGN=-1
      IDENT=1
      WRITE              (3,597)
  597 FORMAT(1X39HEAST - WEST COMPONENTS OF THE MEAN WIND//)
   98 WRITE              (3,87)(KHT(I),I=1,NHT)
   87 FORMAT(1X8HHEIGHT  I5,16I7)
      WRITE              (3,871)
  871 FORMAT(1X)
      IT=0
      KA=KEND
      DO128KZ=MIN,MAX,2
      IT=IT+1
      UO(IT)=0.0
      Z=KZ
      S=(2.0*Z-ZMAX-ZMIN)/(ZMAX-ZMIN)
      S=S+0.000001
      DO106K=1,NAOE
      KUA=K+KA
  106 UO(IT)=UO(IT)+AC(KUA)*S**(K-1)
      SIGUO=0.0
      DO107K=1,NAOE
      DO107L=1,NAOE
  107 SIGUO=SIGUO+S**(K-1)*S**(L-1)*R(K,L)*SUM
      EO(IT)=SQRT (SIGUO)
      KEND=KA+NAOE
      NUMNA=0
      SI=0.0
      CO=0.0
      SIGCOS=0.0
      SIGSIN=0.0
      SIGSC=0.0
      NUMNA=NUMNA+NA
      NUSIN=NP+NUMNA
      KSTART=KEND
      NAEND=NA+1
      KEND=KSTART+NAEND
      DO110K=1,NAEND
      KS=K+KSTART
      SI=SI+AC(KS)*S**(K-1)
      KC=KS+NUSIN
  110 CO=CO+AC(KC)*S**(K-1)
      SINSQJ=SI**2
      COSSQJ=CO**2
      SUMSQJ=SINSQJ+COSSQJ
      AU(IT)=SQRT (SUMSQJ)
```

```
      FJ=PERIOD
      IF(CO    )114,111,115
  111 IF(SI    )113,113,112
  112 PH(IT)=FJ/4.0
      GOTO116
  113 PH(IT)=FJ*0.75
      GOTO116
  114 PH(IT)=FJ*0.5+(FJ/6.28318)*ATAN (SI/CO)
      GOTO116
  115 PH(IT)=(FJ/6.28318)*ATAN (SI/CO)
  116 IF(PH(IT))117,118,118
  117 PH(IT)=FJ+PH(IT)
  118 DO119K=1,NAEND
      DO119L=1,NAEND
      KS=K+KSTART
      LS=L+KSTART
      KC=KS+NUSIN
      LC=LS+NUSIN
      SIGSIN    =SIGSIN    +S**(K-1)*S**(L-1)*R(KS,LS)
      SIGSC    =SIGSC    +S**(K-1)*S**(L-1)*R(KS,LC)
  119 SIGCOS    =SIGCOS    +S**(K-1)*S**(L-1)*R(KC,LC)
      PROD=2.0*SI    *CO    *SIGSC
      SIGPH    =(COSSQJ*SIGSIN    +SINSQJ*SIGCOS    -PROD)*SUM/SUMSQJ**2
      SIGAMP    =(SINSQJ*SIGSIN    +COSSQJ*SIGCOS    +PROD)*SUM/SUMSQJ
      ERPH(IT)=SQRT (SIGPH)*FJ/6.28318
  121 ERAMP(IT)=SQRT (SIGAMP)
  128 CONTINUE
      KEND=KEND+NUSIN
      WRITE                (3,123)(UO(IT),IT=1,NHT)
  123 FORMAT(1X6HMEAN  16F7.0)
      WRITE                (3,1230)(EO(IT),IT=1,NHT)
 1230 FORMAT(1X6HERROR 16F7.0)
      WRITE                (3,871)
      WRITE                (3,124)(AU(IT),IT=1,NHT)
  124 FORMAT(1X6HAMP    16F7.0)
      WRITE                (3,1230)(ERAMP(IT),IT=1,NHT)
      WRITE                (3,871)
      WRITE                (3,125)(PH(IT),IT=1,NHT)
  125 FORMAT(1X5HPHASE16F7.1)
      WRITE                (3,1250)(ERPH(IT),IT=1,NHT)
 1250 FORMAT(1X5HERROR16F7.1)
      WRITE                (3,872)
  872 FORMAT(1X/1X)
      WRITE(16)       IDENT,MY,MO,PERIOD,KHT(1),NHT,(UO(IT),IT=1,NHT),
     1 (EO(IT),IT=1,NHT),(AU(IT),IT=1,NHT),(ERAMP(IT),IT=1,NHT),
     2 (PH(IT),IT=1,NHT),(ERPH(IT),IT=1,NHT)
      IF(NSIGN)129,131,133
  129 NAOE=NBOE
      NA=NB
      NSIGN=0
      IDENT=2
      WRITE                (3,598)
  598 FORMAT(1X39HNORTH-SOUTH COMPONENTS OF THE MEAN WIND//)
      GOTO98
  131 NAOE=NCOE
      NA=NC
      NSIGN=1
      IDENT=3
      WRITE                (3,599)
  599 FORMAT(1X39HVERTICAL    COMPONENTS OF THE MEAN WIND//)
      GOTO98
  133 RETURN
      END
```

```
$IBFTC MATSIN  M94,XR7,LIST
      SUBROUTINE MATSIN (N,MISS)
C
C     INVERSION OF MATRIX OF ORDER N, UP TO 70 X 70.
C
C     PROCEEDS VIA A METHOD OF GAUSSIAN ELIMINATION, DESTROYING
C     THE AUGMENTED MATRIX A IN THE PROCESS.
C
      DIMENSION A (24,48), X(24,24)
      COMMONA,X
      MISS=-1
      MM=2*N
      DO 15 I=2,N
 70   II=I-1
 7    DO 15 J=1,II
 8    IF (A(I,J))9,15,9
 9    IF (ABS (A(J,J))-ABS (A(I,J)))11,10,10
 10   R=A(I,J)/A(J,J)
      GO TO 130
 11   R=A(J,J)/A(I,J)
      DO 12 K=1,MM
      B=A(J,K)
      A(J,K)=A(I,K)
 12   A(I,K)=B
 130  JJ=J+1
 13   DO 14 K=JJ,MM
 14   A(I,K)=A(I,K)-R*A(J,K)
 15   CONTINUE
      IF (ABS (A(N,N))-1.0E-10)16,16,17
   16 MISS=1
      GOTO 29
   17 DO28J=1,N
      KK=N+J
      X(N,J)=A(N,KK)/A(N,N)
      DO28I=2,N
      JJ=N-I+1
      B=0.
      II=N-I+2
      DO 25 K=II,N
 25   B=B+A(JJ,K)*X(K,J)
      IF (ABS (A(JJ,JJ))-1.0E-10)16,16,28
 28   X(JJ,J)=(A(JJ,KK)-B)/A(JJ,JJ)
   29 RETURN
      END
```

```
$IBFTC PAGE     M94,XR7,LIST
      SUBROUTINE PAGE (RESULT,PERIOD)
C
C     TURNS PAGE, NUMBERS IT, AND WRITES HEADING AS APPEARING
C     ON RESULT CARD.
C
      DIMENSION RESULT(12)
      DIMENSION A(24,48), B(24,24)
      COMMON A, B, NOP
      NOP=NOP+1
      IF(PERIOD)2,2,3
    2 WRITE              (3,5)RESULT,NOP
    5 FORMAT(1H1/1X12A6,10X17HSPECTRUM ANALYSIS3X4HPAGEI5///)
      GOTO4
    3 FREQ=24.0/PERIOD
      WRITE              (3,1)RESULT,PERIOD,NOP,FREQ
    1 FORMAT(1H1/1X12A6,10X6HPERIODF8.2,5HHOURS7X4HPAGEI5//
     11X82X9HFREQUENCYF8.4,12H CYCLES/DAY.///)
    4 RETURN
      END
```

```
$IBFTC TIME     M94,XR7,LIST
      SUBROUTINE TIME (MY,MO,JO,LTHM,PERIOD,T)
C
C     CALCULATES TIME OF ECHO WITH RESPECT TO INPUT PERIODICITY.
C
      LTIMH=LTHM/100
      LTIMM=LTHM-LTIMH*100
      TMINIT=(JO-1)*1440+LTIMH*60+LTIMM-8
      THOUR=TMINIT/60.0
      NEWDAY=THOUR/PERIOD
      T=(THOUR/PERIOD-FLOAT (NEWDAY))*6.28318
      RETURN
      END
```

```
$IBMAP DNSHI    M94/2,XR7
       ENTRY    DNSHI
 DNSHI SDHB     6
       TRA      1,4
       END
```

APPENDIX IA

Listing of the IBM 7094 FORTRAN IV
Master Tape Production Program.

```
$IBFTC COPY     M94,XR7,LIST
      SUBROUTINE COPY
      DIMENSIONUO(20),EO(20),AU(20),ERAMP(20),PH(20),ERPH(20),RESULT(12)
      REWIND 47
      READ(17)RESULT,KHT,NHT
      WRITE(16)RESULT,KHT,NHT
    1 READ(17)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      WRITE(16)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      IF(MO)2,2,1
    2 REWIND 47
      RETURN
      END
```

```
$IBSYS
$ID J02T        RGR   BLDG 1.  COPY ERG OUTPUT TAPES ONTO MASTER TAPE.
$PAUSE
$EXECUTE        IBJOB
$IBJOB          GO,LOGIC,MAP
$IBFTC MASTER   M94,XR7,LIST
C
C     COPIES OUTPUT TAPES FROM ERG ONTO ONE FILE TAPE.
C
      DIMENSION TAPE(14)
      DATA (TAPE(I),I=1,14)/6HAM0850,6HAM2354,6HAM2283,6HAM2321,6HAM2224
     1,6HAM2177,6HAM2247,6HAM2107,6HAM1033,6HAM2266,6HAM2436,6HAM2153,
     16HAM2299,6HAM2391/
      CALL DNSHI
      PRINT 1
    1 FORMAT(1X31HLOAD TAPE   AM2850   ON B6, AND  /1X)
      DO3I=1,14
      PRINT 2,TAPE(I)
    2 FORMAT(1X10HLOAD TAPE A6,23H ON B7, THEN PUSH START////////)
      PAUSE
      CALL COPY
    3 CONTINUE
      KHT=0
      NHT=0
      WRITE(16)(TAPE(I),I=1,12),KHT,NHT
      END FILE 46
      REWIND 46
      PRINT 4
    4 FORMAT(1X61HREMOVE AM2850 FROM B6, AM2391 FROM B7, AND PUSH START
     1TO EXIT////////)
      RETURN
      END
```

```
$IBMAP DNSHI    M94/2,XR7,LIST
DNSHI  SAVE     (1,2,3,4,5,6,7)I
       SDHB     6
       SDHB     7
       TRA      1,4
       END
```

APPENDIX II

Listing of the IBM 7094 FORTRAN IV
Plotter Program.

```
$IBSYS
$ID J02T        RGR    BLDG 1.  WRITES PLOTTER TAPES FROM ERG MASTER.
$PAUSE
$EXECUTE        IBJOB
$IBJOB          GO,LOGIC,MAP
$IBFTC PLOT     M94,XR7,LIST
C     PLOT ROUTINE MK IV   METEOR WIND ENERGY PERIODOGRAM.
C     INCLUDES INTERPOLATION ROUTINE.
C     READS ERG MASTER TAPE  (B7)
C     WRITES PLOTTER TAPE (B6)
C     HAS PROVISION FOR REPORT SIZE OUTPUT GRAPHS.
C     READS TAPE 2 DATA AS FOLLOWS
C     YEAR,MONTH FOR WHICH OUTPUT IS DESIRED.  FORMAT 2I3
C     MODE,POSITION SPECIFICATION,HEIGHT FOR WHICH SPECTRUM IS REQUIRED,
C     ORDINATE NORMALIZATION       FORMAT  2I1,I3,I6
C     MODE SELECTION
C     0  TOTAL ENERGY, EW**2 + NS**2 + VERTICAL**2
C     1  EW AMPLITUDE
C     2  EW PHASE
C     3  NS AMPLITUDE
C     4  NS PHASE
C     5 VERTICAL AMPLITUDE
C     6  VERTICAL PHASE
C     7  EW AMPLITUDE**2
C     8  NS AMPLITUDE**2
C     9  VERTICAL AMPLITUDE**2
C     UP TO SIX GRAPHS CAN BE PLOTTED AT REDUCED SCALE (OUTPUT
C     APPROPRIATELY POSITIONED ON PAGE 8 X 11).  IF NO POSITION
C     SPECIFICATION, OUTPUT GRAPH WILL FILL FULL PAGE.
C     IF NO ORDINATE NORMALIZATION IS SPECIFIED, OUTPUT GRAPH WILL
C     AUTOMATICALLY FILL FRAME.
C     CONTINUE WITH AS MANY OF THESE CARDS AS REQUIRED
C     A  BLANK  CARD    RETURNS CONTROL TO THE START OF THE PROGRAM
C     FOR MULTIPLE  MONTH HANDLING.
C     A NEGATIVE HEIGHT FLAGS END OF DATA, AND OPERATOR REMOVE TAPE
C     MESSAGES.
      DIMENSION TAPE(12),X(2000),Y(2000)
      COMMON/AMPS/UO(20),EO(20),AU(20),ERAMP(20),PH(20),ERPH(20),
     1RESULT(12)
      COMMON/XY/NJ,NX(2000),NY(2000)
      C1=0.1
      C=C1
      TWOPI=6.2832
      PRINT 1
    1 FORMAT(1X21HLOAD   A M 2316 ON B6/1X/1X22HAND   A M 2850   ON B7/1
     1X/1X18HSCRATCH TAPE ON B4                                        /1
     1X/1X25HAND PUSH START WHEN READY///////)
      PAUSE
      REWIND 44
      REWIND 46
      REWIND 47
      CALL DNSHI
    2 IOUT=0
      WRITE(3,1000)
 1000 FORMAT(1H1/1X)
C
C     DETERMINE MONTH TO BE PROCESSED
C
      READ(2,4)MYEAR,MONTH
    4 FORMAT(2I3)
C
```

```
C       SEARCH TAPE ON B7 FOR DATA REQUIRED
C
        CALL SEARCH(MYEAR,MONTH)
C
C       COPY REQUIRED DATA ONTO B4 (SCRATCH TAPE)
C
        CALL COPY
C
C       READ PROCESSING PARAMETERS
C
      3 READ(2,4)MODE,KPUT,IH,NYMAX
        JUSE=0
        NTYPE=2
        IF(IH)300,2,5
      5 REWIND 44
C
C       SET UP FRAME FOR OUTPUT GRAPH
C
        CALL FRAME
        IF(KPUT )71,71,70
     70 CALL SIX(KPUT)
     71 CALL IBDRAW
C
C       READ AND PROCESS ERG OUTPUT
C
        READ(14)RESULT,KHT,NHT
        IT=0
        I=(IH-KHT)/2+1
      7 IT=IT+1
        X(IT)=0.0
        Y(IT)=0.0
        IF(MODE)10,10,11
     10 DO90J=1,3
        READ(14)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
       1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
       2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
        IF( MO  )100,100,80
     80 Y(IT)=Y(IT)+AU(I)**2
     90 CONTINUE
        X(IT)=24.0/PERIOD
        GOTO7
     11 GOTO(12,13,14,15,16,17,18,19,20),MODE
     12 JUSE=1
        NTYPE=0
        GOTO21
     13 JUSE=1
        NTYPE=1
        GOTO21
     14 JUSE=2
        NTYPE=0
        GOTO21
     15 JUSE=2
        NTYPE=1
        GOTO21
     16 JUSE=3
        NTYPE=0
        GOTO21
     17 JUSE=3
        NTYPE=1
        GOTO21
```

```
   18 JUSE=1
      NTYPE=2
      GOTO21
   19 JUSE=2
      NTYPE=2
      GOTO21
   20 JUSE=3
      NTYPE=2
   21 DO9J=1,3
      READ(14)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      IF( MO  )100,100,8
    8 IF(J-JUSE)9,22,9
   22 IF(NTYPE-1)23,24,25
   23 Y(IT)=AU(I)
      GOTO9
   24 PHASE=(PH(I)/PERIOD)*TWOPI
      Y(IT)=PHASE
      GOTO9
   25 Y(IT)=AU(I)**2
    9 CONTINUE
      X(IT)=24.0/PERIOD
      GOTO7
C
C     SET UP ARRAY FOR PROCESSING BY IBDRAW.
C     LINEAR INTERPOLATION BETWEEN DATA POINTS
C     USED TO PROVIDE FILLERS TO OVERCOME PLOTTER PEN INERTIA.
C     ADDITIONAL FILLER ROUTINES INCLUDED IN IBDRAW.
C
  100 IT=IT-1
      BIGY=0.0
      DO102J=1,IT
      IF(Y(J)-BIGY)102,102,101
  101 BIGY=Y(J)
  102 CONTINUE
      IBIGY=BIGY+1.05
      IF(IBIGY-NYMAX)202,202,201
  201 NYMAX=IBIGY
  202 YMAX=NYMAX
      XMAX=X(IT)
      XMULT=4000.0/XMAX
      YMULT=4000.0/YMAX
      NX(1)=X(1)*XMULT
      NY(1)=Y(1)*YMULT
      NI=1
      NJ = 1
  105 NI=NI+1
      IF(NI-IT)109,109,107
  109 NJ = NJ + 1
      NSIGNX=( ABS( X(NI)- X(NI-1)))/( X(NI)- X(NI-1))+C
      YGRAD=(Y(NI)-Y(NI-1))/(X(NI)-X(NI-1))*(YMULT/XMULT)
      NPOINT=(XMULT*(X(NI)-X(NI-1)))/2.0-1.0+C1
      DO106I=1,NPOINT
      NX(NJ)=NX(NJ-1)+2*NSIGNX
      YBIT=NY(NJ-1)
      NY(NJ)=YBIT+YGRAD*2.0+C1
      IF(NJ-2000)108,107,107
  108 NJ=NJ+1
  106 CONTINUE
      NX(NJ)=X(NI)*XMULT
```

```
      NY(NJ)=Y(NI)*YMULT
      IF(NJ-2000)105,107,107
  107 CONTINUE
      MAXX=XMAX+C
      MAXY=YMAX+C
      IF(KPUT )73,73,72
   72 CALL SIX(KPUT)
   73 CALL IBDRAW
      IOUT=IOUT+1
      IF(IOUT-4)1071,1071,1070
 1070 IOUT=0
      WRITE(3,1000)
 1071 CONTINUE
      WRITE(3,104)RESULT,IH,MAXX,MAXY,IBIGY,KPUT, NI,NJ,JUSE,NTYPE,MODE
  104 FORMAT(1X12A6,/1X/1X6HHEIGHT I6,/1X/1X6HXMAX  I6,/1X/1X6HYMAX  I6/
     11X/1X6HBIGY  I6/1X/1X6HKPUT   I6/
     2 1X/1X2HNI I5,3H NJ I5, 5H JUSE I5, 6H NTYPE I5,5H MODE I5  //1X)
      GOTO3
  300 REWIND 44
      REWIND 46
      REWIND 47
      PRINT 301
  301 FORMAT(1X27HREMOVE   A M 2316   FROM B6/1X/1X24HAND   A M 2850   F
     1ROM B7/1X/1X22HAND PUSH START TO EXIT///////)
      PAUSE 7
      RETURN
      END
```

```
$IBMAP  IBDRAW  M94/2,XR7
IBDRAW  SAVE    (1,2,3,4,5,6,7)I
*               AWAIT COMPLETION OF ALL IOEX ACTIVITY
CHAN    EQU     2                       NO OF CHANNELS TO CLEAR
TWO     EQU     2
        AXT     TWO,4                   DO TWICE
CLEAR   AXT     CHAN,2
NEXT    XEC     LOAD,2                  GET CHANNEL INDEX TO IR1
        ZET*    .CHXAC                  TEST CHANNEL
        TRA     *-1                     BUSY
        TIX     NEXT,2,1                GO TO NEXT CHANNEL
        TIX     CLEAR,4,1               ONCE MORE TO MAKE SURE
        ERB     ZERO                    TURN TRAPS OFF
*               ALL I/O NOW UNDER CONTROL OF IBDRAW
        SDLB    6
        AXT     12000,4
        STZ     REC+12000,4
        TIX     *-1,4,1
        LXA     T,1
        TXI     *+1,1,-1
        AXT     0,2
        AXT     12000,4
        STZ     COUNT
        CAL     SELECT
        SLW     REC
 GO1    WTBB    6
        RCHB    CMD
        TCOB    *
        TRCB    *+2
        TRA     TUBE
        BSRB    6
        TCOB    *
        TRA     GO1
TUBE    NOP
        CLA     NX,2
        ALS     18
        ORA     NY,2
        SLW     TIME
        ORA     READ
        SLW     REC
 GO1A   WTBB    6
        RCHB    CMD
        TCOB    *
        TRCB    *+2
        TRA     OUTR
        BSRB    6
        TCOB    *
        TRA     GO1A
OUTR    NOP
        AXT     12000,4
        STZ     REC+12000,4
        TIX     *-1,4,1
        AXT     12000,4
        CLA     TIME
        ORA     REDROP
        SLW     REC
        TXI     *+1,4,-15
GO      STZ     SW1
        CLA     NY,2
        STO     TIME2
        CLA     NY+1,2
```

```
        STO     TIME
        SUB     NY,2
        STO     F1
        SSP
        SUB     =11
        TMI     OUT4
        CLA     F1
        TPL     ADDIT
SUBIT   CLA     F1
        ADD     =11
        TPL     OUT
        STO     F1
        TZE     OUT
        CLA     TIME2
        SUB     =11
        STO     TIME2
        CLA     NX,2
        ALS     18
        ORA     TIME2
        ORA     REDROP
        SLW     FOG
        SLW     REC+12000,4
        TIX     SUBIT,4,5
        SXA     *+2,1
        TSX     OUTK,1
        AXT     **,1
        TRA     SUBIT
ADDIT   CLA     F1
        SUB     =11
        STO     F1
        TMI     OUT
        TZE     OUT
        CLA     TIME2
        ADD     =11
        STO     TIME2
        CLA     NX,2
        ALS     18
        ORA     TIME2
        ORA     REDROP
        SLW     FOG
        SLW     REC+12000,4
        TIX     ADDIT,4,5
        SXA     *+2,1
        TSX     OUTK,1
        AXT     **,1
        TRA     ADDIT
OUT     STZ     SW69
        CLA     NX,2
        ALS     18
        ORA     TIME
        ORA     REDROP
        SLW     FOG
        SLW     REC+12000,4
        TIX     *+4,4,5
        SXA     *+2,1
        TSX     OUTK,1
        AXT     **,1
        CLA     SW69
        TZE     *+2
        TRA     NAT2
```

```
        STL     SW69
        TRA     OUT+1
OUT4    CLA     NX,2
        ALS     18
        ORA     TIME
        ORA     REDROP
        SLW     FOG
        SLW     REC+12000,4
        TIX     *+4,4,5
        SXA     *+2,1
        TSX     OUTK,1
        AXT     **,1
NAT2    TXI     *+1,2,-1
        TIX     GO,1,1
        PXA     0,4
        STO     F1
        CLA     =12000
        SUB     F1
        ALS     18
        STD     CMD1
 GO2    WTBB    6
        RCHB    CMD1
        TCOB    *
        TRCB    *+2
        TRA     END
        BSRB    6
        TCOB    *
        TRA     GO2
 END    WEFB    6
*               REINSTATE CONTROL OF I/O BY IOEX
ENABLE  NULL
        TCOA    *
        RDCA
        TCOB    *
        RDCB
        NZT     .TRPSW
        ENB*    .TRAPX
        RETURN  IBDRAW
OUTK    NOP
OUTK2   WTBB    6
        RCHB    CMD2
        TCOB    *
        TRCB    *+2
        TRA     END1
        BSRB    6
        TCOB    *
        TRA     OUTK2
END1    AXT     12000,4
        STZ     REC+12000,4
        TIX     *-1,4,1
        AXT     12000,4
        CLA     FOG
        ORA     REDROP
        SLW     REC
        TXI     *+1,4,-15
        TRA     1,1
        BCI     1,0013))
FMT     BCI     1,(1X,(1
CMD1    IORT    REC+10,,**
CMD     IORT    REC,,5
CMD2    IORT    REC,,12000
```

```
CMD10   IORT    REC,,150
XY      CONTRL  XY
        USE     XY
T       BSS     1
NX      BSS     2000
NY      BSS     2000
        USE     PREVIOUS
SELECT  OCT     600000040000
REDROP  OCT     600000600000
UP      OCT     000000100000
DOWN    OCT     000000200000
READUP  OCT     600000500000
READ    OCT     600000400000
REC     BSS     12000
YAWL    BSS     100
F1      BSS     100
SW1     BSS     1
TIME2   BSS     1
SW69    BSS     1
FOG     BSS     10
COUNT   BSS     1
TIME    BSS     1
        AXC     4,1     CHANNEL  E  INDEX
        AXC     3,1     CHANNEL  D  INDEX
        AXC     2,1     CHANNEL  C  INDEX
        AXC     1,1     CHANNEL  B  INDEX
        AXC     0,1     CHANNEL  A  INDEX
LOAD    NULL
ZERO    PZE
        END
```

```
$IBFTC FRAME    M94,XR7,LIST
      SUBROUTINE FRAME
C
C     SETS UP FRAME FOR OUTPUT GRAPH
C
      COMMON/XY/NJ,NX(2000),NY(2000)
      NJ=1632
      NX(1)=0
      NY(1)=4030
      DO500I=2,403
      NX(I)=NX(I-1)+10
      NY(I)=NY(I-1)
  500 CONTINUE
      DO5000I=403,408
      NX(I+1)=NX(I)
      NY(I+1)=NY(I)
 5000 CONTINUE
      DO501I=409,811
      NX(I)=NX(I-1)
      NY(I)=NY(I-1)-10
  501 CONTINUE
      DO5001I=811,816
      NX(I+1)=NX(I)
      NY(I+1)=NY(I)
 5001 CONTINUE
      DO502I=817,1218
      NX(I)=NX(I-1)-10
      NY(I)=NY(I-1)
  502 CONTINUE
      DO5002I=1218,1223
      NX(I+1)=NX(I)
      NY(I+1)=NY(I)
 5002 CONTINUE
      DO503I=1224,1626
      NX(I)=NX(I-1)
      NY(I)=NY(I-1)+10
  503 CONTINUE
      DO5003I=1626,1631
      NX(I+1)=NX(I)
      NY(I+1)=NY(I)
 5003 CONTINUE
      RETURN
      END
```

```
$IBFTC SEARCH  M94,XR7,LIST
      SUBROUTINE SEARCH(MYEAR,MONTH)
C
C     SEARCHES TAPE ON B7 FOR APPROPRIATE YEAR,MONTH.
C
      COMMON/AMPS/UO(20),EO(20),AU(20),ERAMP(20),PH(20),ERPH(20),
     1RESULT(12)
  100 READ(17)RESULT,KHT,NHT
      IF(KHT)1,1,2
    1 REWIND 47
      GOTO100
    2 READ(17)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      IF(MO)100,100,3
    3 IF(MY-MYEAR)2,4,2
    4 IF(MO-MONTH)2,5,2
    5 BACKSPACE 47
      BACKSPACE 47
      RETURN
      END
```

```
$IBFTC COPY     M94,XR7,LIST
      SUBROUTINE COPY
C
C     COPIES DATA REQUIRED BY PLOT FROM B7 ONTO B4 (SCRATCH TAPE)
C
      COMMON/AMPS/UO(20),EO(20),AU(20),ERAMP(20),PH(20),ERPH(20),
     1RESULT(12)
      REWIND 44
      READ(17)RESULT,KHT,NHT
      WRITE(14)RESULT,KHT,NHT
    1 READ(17)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      WRITE(14)IDENT,MY,MO,PERIOD,K,L,(UO(IR),IR=1,NHT),
     1(EO(IR),IR=1,NHT),(AU(IR),IR=1,NHT),(ERAMP(IR),IR=1,NHT),
     2(PH(IR),IR=1,NHT),(ERPH(IR),IR=1,NHT)
      IF(MO)2,2,1
    2 END FILE 44
      REWIND 44
      RETURN
      END
```

```
$IBFTC SIX      M94,XR7,LIST
      SUBROUTINE SIX(KPUT)
C
C     REDUCED SCALE GRAPHS (REPORT SIZE, PAGE 8 X 11)
C     SIX PER PLOTTER TABLE SHEET.
C
      COMMON/XY/NJ,NX(2000),NY(2000)
      AX1=1280.0
      AX2=2560.0
      AY=1720.0
      XMULT=0.24
      YMULT=0.32
      GOTO(1,2,3,4,5,6),KPUT
    1 ADDX=0.0
      ADDY=0.0
      GOTO7
    2 ADDX=0.0
      ADDY=AY
      GOTO7
    3 ADDX=AX1
      ADDY=0.0
      GOTO7
    4 ADDX=AX1
      ADDY=AY
      GOTO7
    5 ADDX=AX2
      ADDY=0.0
      GOTO7
    6 ADDX=AX2
      ADDY=AY
    7 DO8I=1,NJ
      R=NX(I)
      NX(I)=R*XMULT+ADDX
      R=NY(I)
      NY(I)=R*YMULT+ADDY
    8 CONTINUE
      RETURN
      END
```

```
$IBMAP DNSHI    M94/2,XR7,LIST
DNSHI  SAVE     (1,2,3,4,5,6,7)I
       SDHB     4
       SDHB     7
       TRA      1,4
       END
```