DATA FROM EXPLORER 17 ON COMPOSITION OF THE UPPER ATMOSPHERE*

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INTRODUCTION

The Explorer 17 aeronomy satellite carried two double-focusing magnetic mass spectrometers designed [*Meadoes*, 1960; *Hall et al.*, 1960; *Spencer and Reber*, 1962] to measure the concentrations of the major neutral-particle constituents of the earth's upper atmosphere. The ambient densities of helium, oxygen, and nitrogen were obtained between north and south latitudes of 58° and from the perigee altitude of 257 km to an altitude in excess of 700 km. Data for various local times, altitudes, and geographic locations have been combined to provide a broader altitude coverage than could have been experienced at any single

TABLE 1.—*Tabulated Mass Spectrometer Data*

The local sun time, angle of attack (α) geographic latitude and longitude are averaged over the 4-minute pass. The stations involved are: BP, Blossom Point, Md.; COL, College, Alaska; FTM, Fort Myers, Fla.; GF, Grand Forks, Minn.; QUI, Quito, Equador; MOJ, Mojave, Calif.; NFL, Newfoundland; OOM, Woomera, Australia; JOB, Johannasburg, South Africa.

Pass and Station	Date	Local Time, hours	α	Geog. Lat.	Geog. Long.
15 BP	4/ 4/63	21.15	6°	38.5°	−75.0°
50 COL	4/ 6/63	0.65	16°	57.0°	−149.0°
80 COL	4/ 8/63	0.99	9°	55.0°	−147.0°
80 FTM	4/ 8/63	4.89	63°	18.0°	−92.0°
118 BP	4/10/63	18.81	70°	37.0°	−72.0°
120 GF	4/11/63	20.32	51°	51.0°	−98.5°
138 BP	4/12/63	2.51	12°	37.0°	−84.0°
152 BP	4/13/63	2.01	14°	39.5°	−68.5°
167 BP	4/14/63	1.65	20°	39.5°	−75.0°
182 BP	4/15/63	1.54	25°	37.0°	−78.0°
183 QUI	4/15/63	3.26	23°	4.5°	−79.0°
197 BP	4/16/63	1.43	27°	34.0°	−81.5°
211 BP	4/17/63	0.53	45°	41.5°	−71.5°
226 BP	4/18/63	0.48	53°	38.5°	−74.0°
241 BP	4/19/63	24.19	62°	38.0°	−79.5°
242 MOJ	4/19/63	0.64	54°	31.0°	−121.5°
254 NFL	4/20/63	22.75	82°	49.0°	−53.0°
270 BP	4/21/63	23.30	80°	41.50°	−71.5°
271 GF	4/21/63	22.88	85°	45.0°	−101.0°
708 NFL	5/20/63	7.18	39°	49.5°	−49.5°
795 OOM	5/26/63	15.81	63°	−34.0°	137.5°
800 JOB	5/26/63	15.90	65°	−37.5°	19.0°
888 JOB	6/ 1/63	13.24	33°	−27.0°	25.0°

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location. Data are presented for helium, atomic oxygen, and molecular nitrogen; molecular oxygen and atomic nitrogen data will be presented and discussed in a later report along with other data obtained under more varied conditions.

EXPERIMENT

The mass spectrometer measured the number densities of the various species which were in its ionizing, or sampling, region. Before reaching this sampling region, however, some of the neutral particles underwent collisions with various parts of the spectrometer structure; thus the number measured by the spectrometer was generally different from the ambient number density. The relationship between the spectrometer measurements and the ambient number densities was found to be a function of particle species, satellite velocity, and the angle between the spectrometer axis and the satellite velocity vector (angle of attack α). Using satellite velocity and angle of attack, both obtained from the tracking stations and the satellite's optical aspect system, calculations have been carried out for each species and have been used to convert the measured quantities to the ambient values presented here. The contribution of residual gas has also been taken into account.

The absolute accuracy of the number density data is ± 40 percent, reflecting laboratory vacuum calibration error and the uncertainties in the ambient number density calculations. The relative accuracy of the data obtained for similar angles of attack is about 5 percent; for data obtained when the angles of attack differ by 70° or more, the relative accuracy is about 30 percent. The mean mass data and the concentration ratios are good to ± 10 percent. Since the relative accuracy of the number density varies with the angle of attack, this quantity, the local sun time, and other pertinent information are given in Table 1.

DATA

Figure 1 shows the ambient number densities of the major constituents plotted as a function of

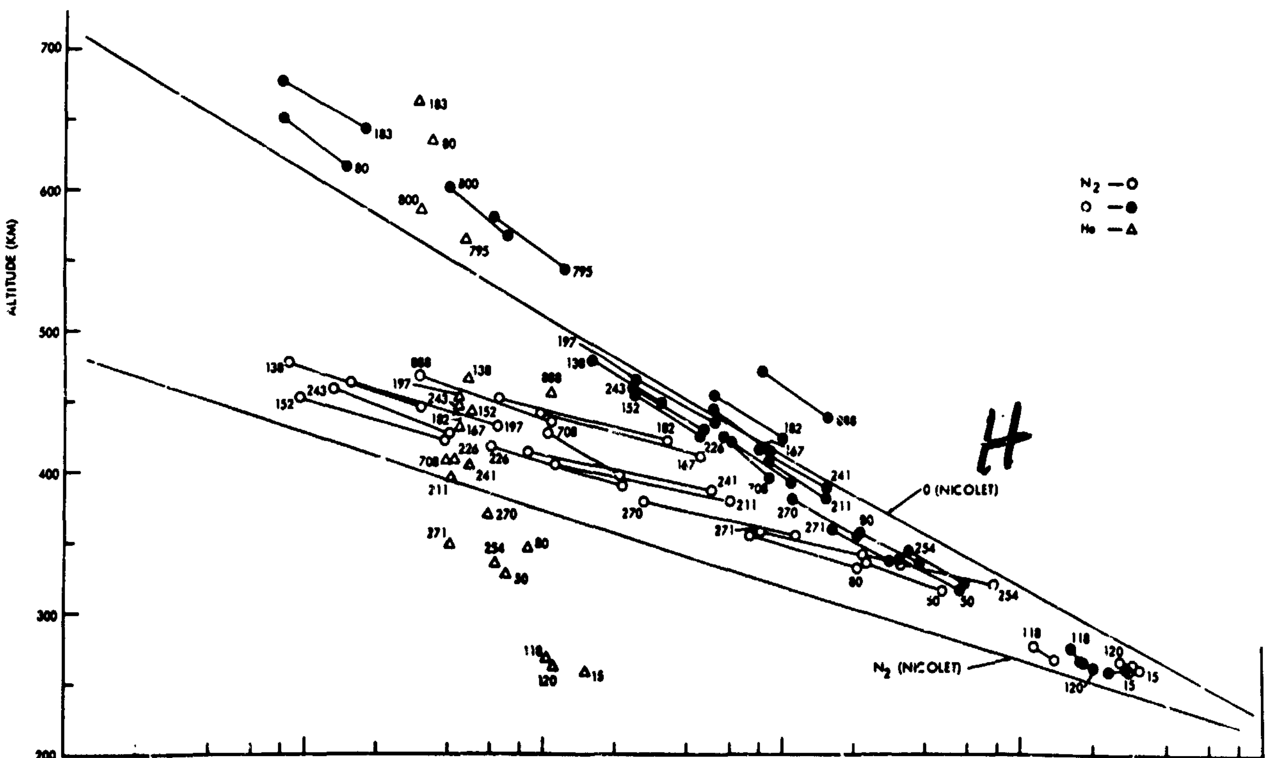

FIGURE 1.—Ambient number densities of the major constituents versus altitude. These data include many local times and geographic locations. The orbit numbers refer to Table 1. Nicolet's model for $T = 700°K$ is included for reference.

altitude for a number of different local times and locations. A single satellite interrogation (pass) is indicated by two data points joined by a straight line for molecular nitrogen and atomic oxygen and by one point for helium. The Nicolet model (private communication) is included for reference.

For the times concerned, the number densities of helium and atomic oxygen are comparable at about 600 km, with helium predominant at higher altitudes. Between 300 and about 600 km, atomic oxygen is the major constituent; in the 250- to 300-km region, molecular nitrogen and atomic oxygen have nearly equal concentrations.

There is, at present, insufficient daytime data to determine scale heights for the sunlit atmosphere. However, during the night at higher altitudes the concentration gradients are consistent with the scale heights for temperatures of 700° to 750°K.

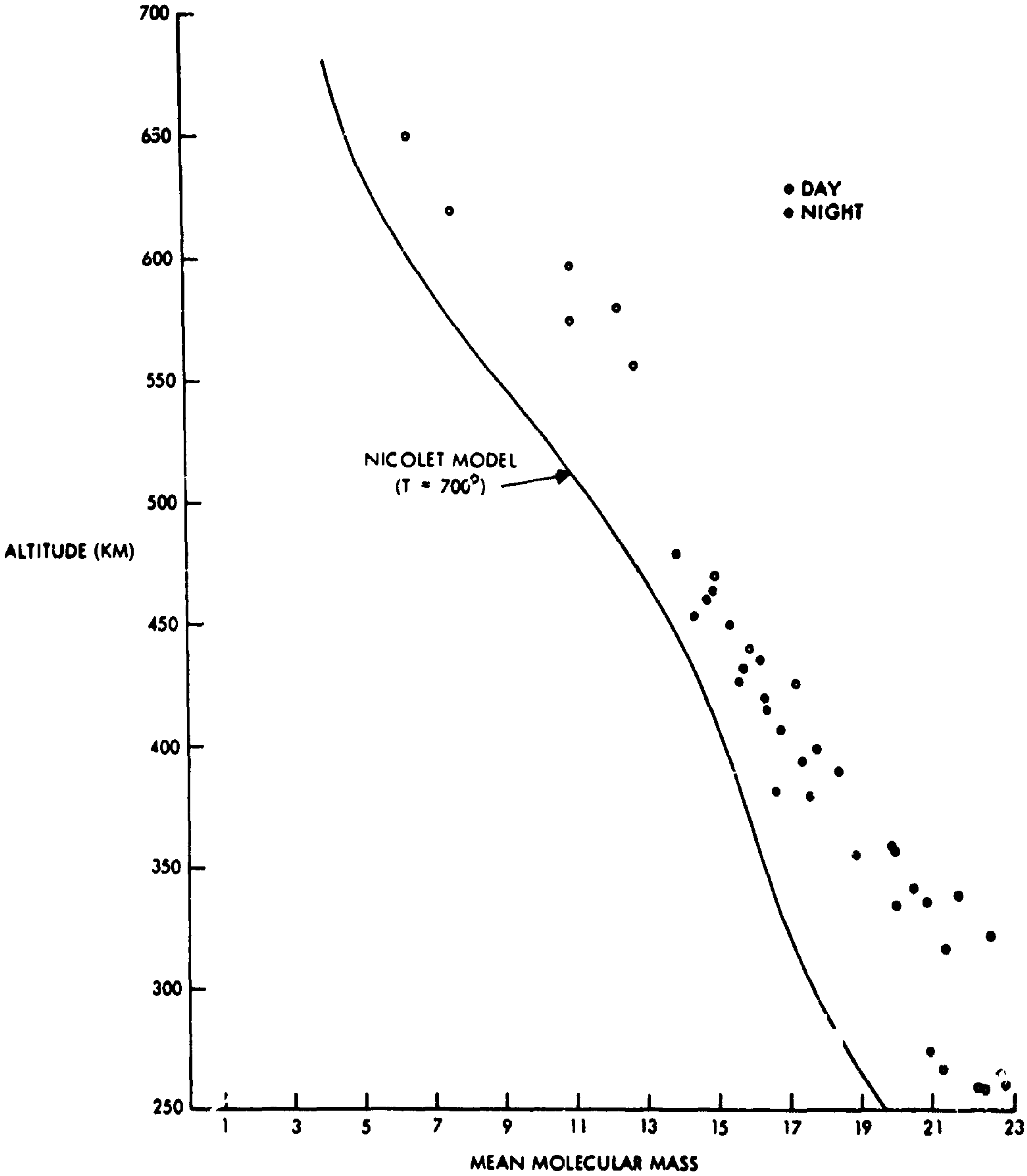

FIGURE 2.—Mean molecular mass versus altitude. The mean mass was calculated using the three major constituents measured, N_2, O, and He. Nicolet's model is included for reference.

There appears to be a deviation from nighttime diffusive equilibrium in the 300- to 350-km altitude range for N_2. This may be indicative of longer times required for N_2 to diffuse at these altitudes; however, as noted above, the data shown are representative of many time and geographic locations and may not provide an accurate instantaneous vertical distribution. It is interesting to note that the data from passes 167, 182, and 183, for which the densities are higher than for other nighttime passes, were obtained shortly after a minor magnetic disturbance which occurred on April 14. All data shown are measured values and are not averaged or smoothed in any way.

Figure 2 shows the variation of mean molecular mass with altitude. These data were calculated using the measurements of helium, atomic oxygen,

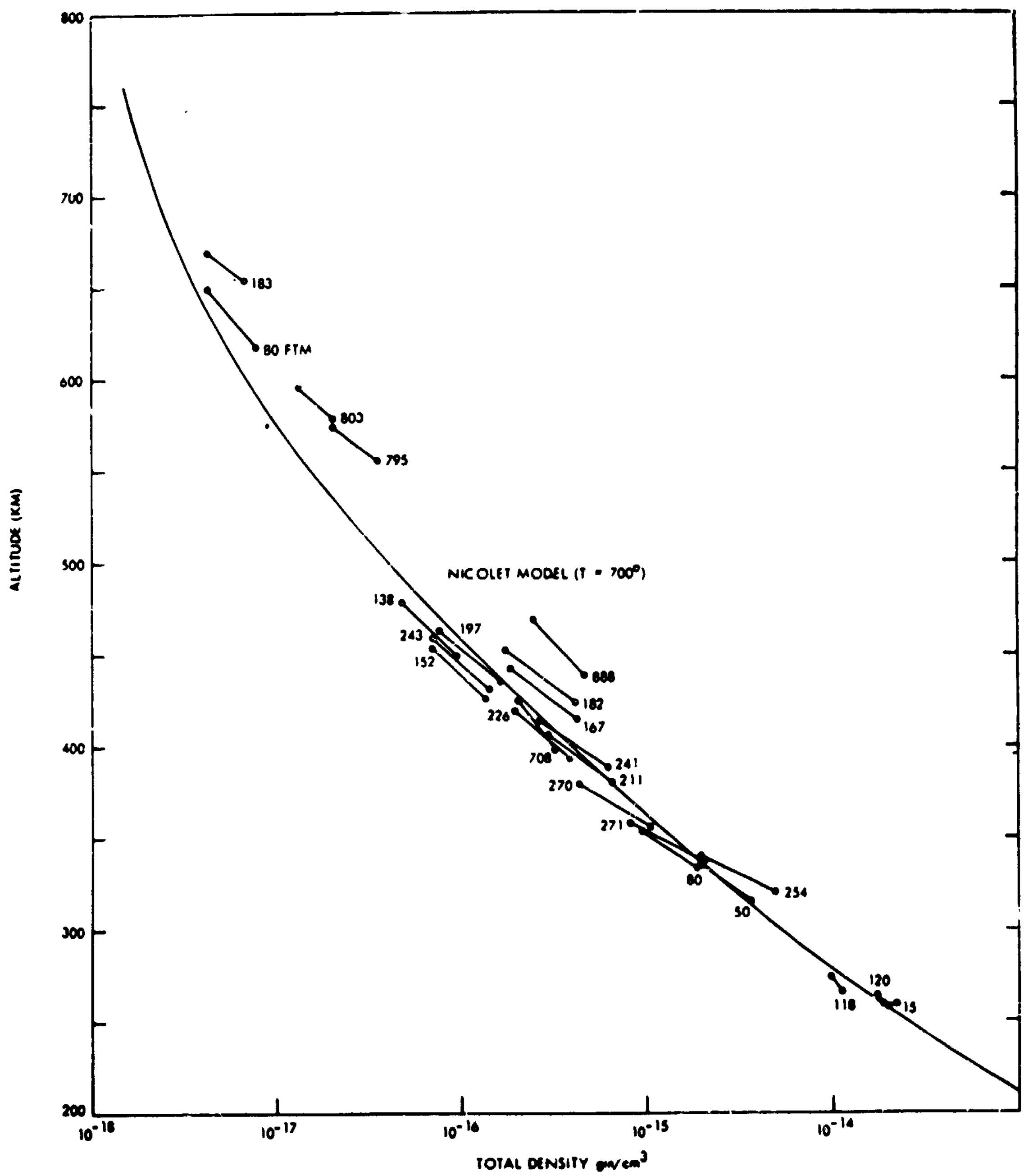

FIGURE 3. Total mass density versus altitude. The total mass density was calculated using the densities for N_2, O, and He. The orbit numbers refer to Table 1. Nicolet's model is included for reference.

and molecular nitrogen only, other measured gases providing a negligible contribution ot the mean mass. The presence of hydrogen, which the instrument was not designed to measure, would reduce the value of the mean mass somewhat at higher altitudes.

The total mass density, shown in Figure 3, was computed by summing the contributions from molecular nitrogen, atomic oxygen, and helium. The results obtained in this way agree with the densities obtained independently by the pressure gage experiments on Explorer 17. This agreement lends support to the calculations relating the concentrations in the sampling region to the ambient number densities, as the pressure gage kinetics have been studied extensively [*Horowitz*,

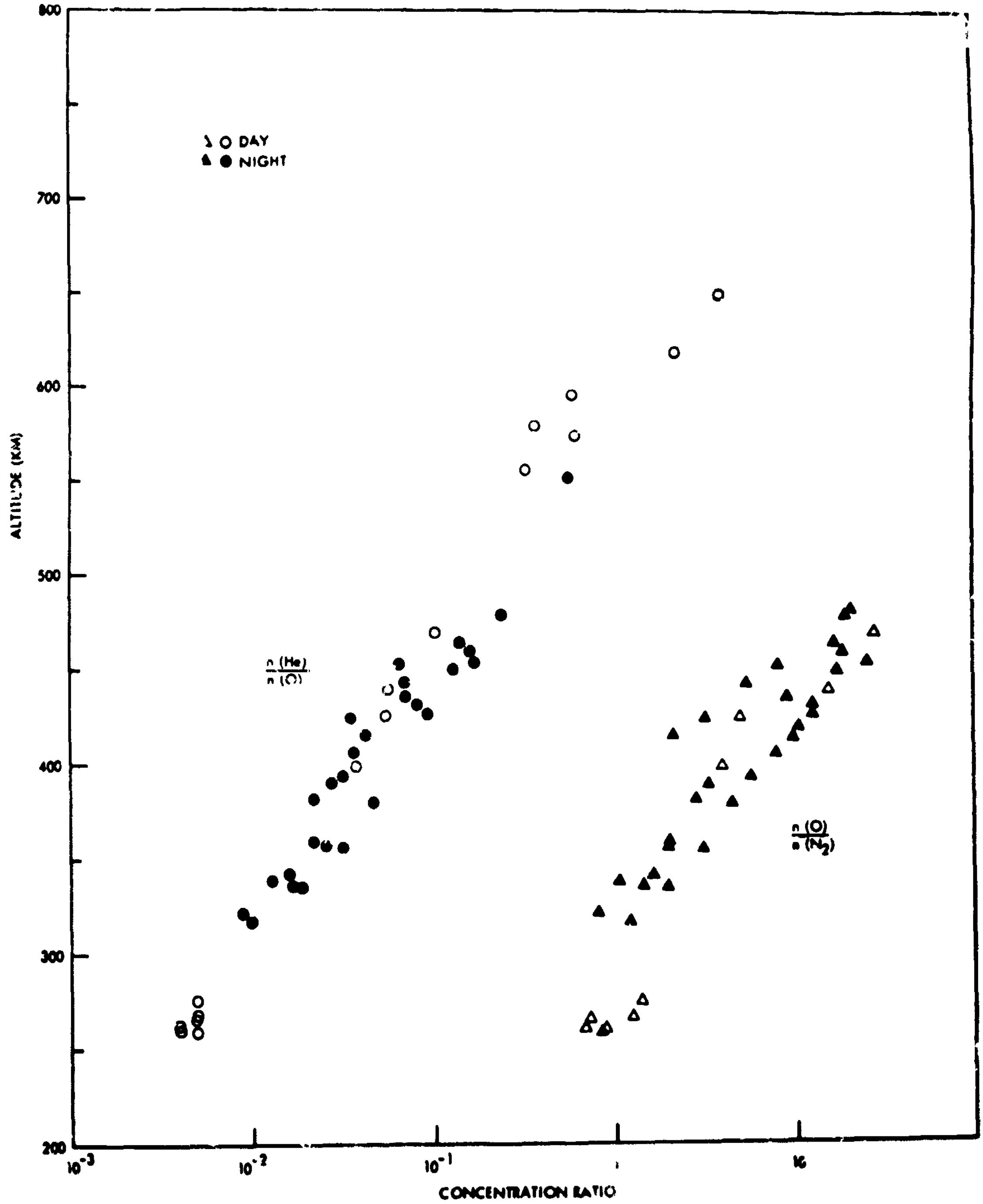

FIGURE 4.—Concentration ratios of the major constituents versus altitude.

1953]. Also, the total density measurements from the mass spectrometers agree in general within a factor of 2 with atmospheric density calculated from satellite drag observations [*Bryant*, 1964].

Figure 4 shows the variation with altitude of the concentration ratios of helium to atomic oxygen and atomic oxygen to molecular nitrogen.

ACKNOWLEDGMENT

I an indebted to Professor Marcel Nicolet for many hours of stimulating discussions about the data from Explorer 17, particularly with respect to extracting the scientifically interesting from the technically involved.

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A NIGHT-TIME MEASUREMENT OF OZONE ABOVE 40 KM*

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The ozone distribution between 40 and 70 km was measured near midnight, May 27, 1960, from Wallops Island, Virginia by means of photometers sensitive to the ultraviolet airglow at wavelengths between 2400 and 2900 A. Below 60 km, the densities are within a factor of two of the daytime photochemical equilibrium, as represented by Johnson's late afternoon measurement of June 14, 1949. Above 60 km, the ozone density increased with altitude, with its maximum increase, a factor of 6 over the day time value, occurring at 63 km.

INTRODUCTION

At high altitudes, above the principal ozone maximum, ozone concentration as a function of altitude should be governed principally by the presence or absence of sunlight, and vary in a predictable manner from day to night and from season to season [*Chapman*, 1930][a,b]. The first direct measurement of the daytime profile was a result of studies of the sun conducted by the Naval Research Laboratory on a V-2 rocket in 1949. Ozone densities up to 70 km were deduced from solar spectra and were consistent with computed photoequilibrium profiles [*Johnson, et al*, 1952]. Chapman also suggested that at high altitudes, above the ozone maximum and below the atomic oxygen maximum, ozone would increase at night as a result of a reaction between atomic and molecular oxygen. Several have treated this problem numerically, including *Nicolet* [1957], *Barth* [1961], *Dütsch* [1961], *Paetzold* [1961], *Wallace* [1962], and *Hunt* [1964], but with varying results, depending on the set of reactions, reaction rates, and initial concentrations which were chosen. Of particular difficulty is the computation of the effects of minor constituents such as hydrogen, nitrogen oxides, and the hydroxyl radical.

Ground based measurements of ozone content at these altitudes have not been satisfactory. Measurements of total ozone content are not particularly helpful since variations in the ozone content below 30 km due to air movements are comparable to the expected night time increase at higher altitudes. However, the discovery of the ultraviolet airglow and a general improvement in the techniques of ultraviolet photometry made a night time measurement of ozone feasible.

In 1957, the Naval Research Laboratory flew an ultraviolet photometer with a response from 2600 to 2900 A, and did observe an ultraviolet airglow layer centered at 101 km [*Tousey*, 1958]. This had been predicted from laboratory observations which showed that the Herzberg bands of molecular oxygen, the visible end of which had been observed in the airglow [*Chamberlain*, 1955], extend to 2563 A in the ultraviolet [*Broida* and *Gaydon*, 1954]. But because an unknown amount of the observed airglow could be due to an OI line at 2972 A, where the filter transmission is still 10 percent of its maximum; the ozone density could not be determined unambiguously.

In May 1960, Goddard Space Flight Center flew a number of ultraviolet photometers, including some whose filters were centered at 2620 A and narrow enough so that the absorption cross section of ozone varied by only 50 percent over the bandwidth of the filter. These data, when interpreted with the aid of an airglow spectrum obtained by T. Stecher (of GSFA), provide an ozone density profile between 40 and 70 km.

INSTRUMENTATION

NASA Aerobee 4.05, one of a series of payloads designed for stellar photometry [*Boggess*, 1961],

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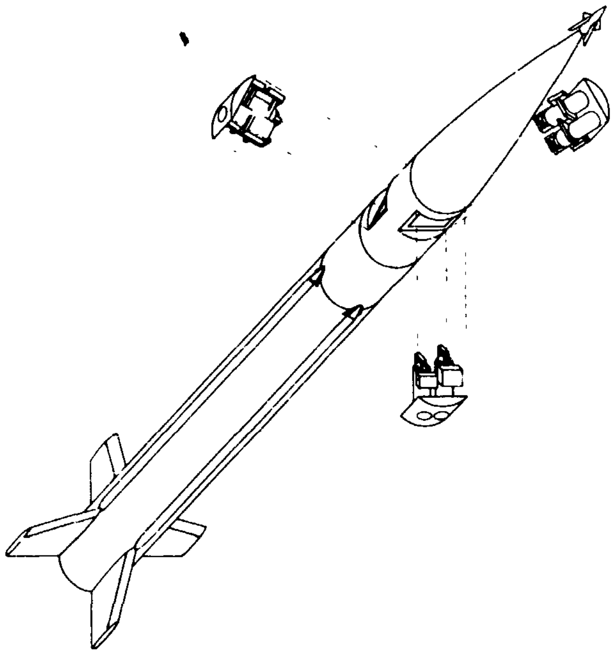

FIGURE 1.—Location of photometers on Aerobee 4.05.

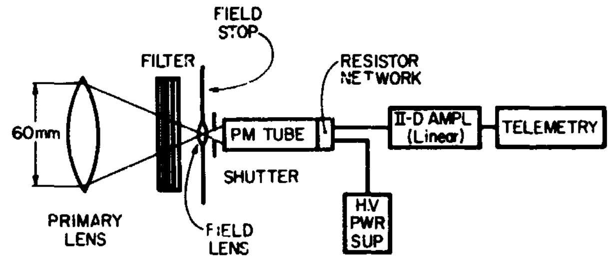

FIGURE 2.—Optical-electrical schematic of a photometer.

contained three pairs of photoelectric photometers, each pair mounted 120 degrees apart around the rocket axis (See Figure 1) looking out at three different angles to that axis: nominally, 75°, 90°, and 105°. One photometer of each pair was sensitive to light in the spectral region centered near 2620 A, while the response of the other was centered near 2260 A, but with their optical axes parallel. Each pair was mounted on a removable door, which, when installed, became an integral part of the rocket skin. Since the principal purpose of this instrumentation was ultraviolet star spectroscopy, 2620 A photometers were preferred to the 2680 A ones (to reduce ambiguity in the interpretation of stellar data due to the strong magnesium doublet at 2800 A). However, to correlate the data from this flight with that of earlier flights, one 2680 A photometer was included. This was mounted on the door containing the 90° photometers, and also looked at 90° with respect to the rocket axis.

The optical system of each photometer was similar and is shown in Figure 2. Calcium fluoride was used for all lenses in the 2260 A units; quartz for those in the 2620 and 2680 A photometers. The field of view had a total width of between 4 to 5°.

Isolation of the 2600 A region was achieved by combining two millimeters of 0.05 percent lead-doped KC1:KBr (1:1) crystal with Cation-X in thin sheets of polyvinyl alcohol [*Childs*, 1961]. Three millimeters of nickel sulfate hexahydrate provided a sharp cutoff for longer wavelengths; one Corning No. 7–54 and one Corning 9–54 filter sharpened the shorter wavelength cutoff. A typical filter had a transmittance of 0.18, an effective wavelength of 2620 A and a 200 A bandwidth.

The 2700 A filter consisted of three Corning 7–54 filters, one sheet of Cation-X and 5 millimeters of nickel sulfate hexahydrate. It has an effective wavelength of 2680 A, a transmittance of 0.16, and a bandwidth of 320 A.

The relative spectral response of the filters (see Figure 4) was measured by C. Childs, formerly of this laboratory, with a recording spectrophotometer, Cary Model No. 14, with an analytical accuracy of ½ of 1 percent for relative spectral transmission, a wavelength calibration of 4A, and a resolving power of 1A. Over the wavelength regions covered by each filter, the photomultiplier was assumed to have a constant sensitivity and the lenses a constant transmissivity. The rela-

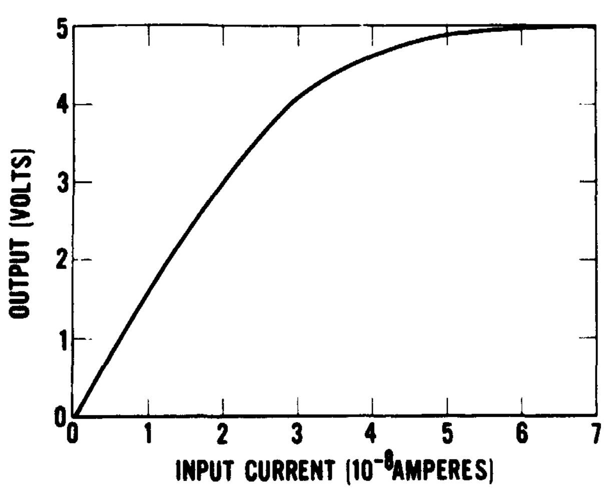

FIGURE 4.—Calibration curve for converter-amplifier.

tive response of the photometers was determined by use of the 2537 A line, to which all three types of photometers respond with an easily measured signal.

The 2680 A photometer used RCA's well-known 1P28 as a detector; all others used EMI's No. 6256B, an end-on fused silica window multiplier with cesium antimonide photocathode. A solenoid-operated shutter between the field stop and multiplier gave optical zero signals several times during the flight. The 1P28 and 6256B's were operated at 1000 and 1200 volts respectively; each detector had its own solid state DC to DC inverter power source with a resistor divider network at the base of each multiplier.

Each photomultiplier output was amplified to the zero to five volt range required by the telemetry system with what was essentially an impedance converter. Designed by G. Baker of th laboratory, the converter-amplifier had an el trometer tube (5886) input stage and ended with an emitter follower, with an overall voltage gain of 2.5 for small signals. It was purposely nonlinear in order to extend the dynamic range. A typical calibration curve is shown in Figure 3. The output voltage went directly to a pulse position modulation telemetry transmitter which relayed the data to the ground receiving equipment.

BASIC DATA

Aerobee-Hi NASA 4.05 was launched at 0030 EST on May 27, 1960 from Wallops Island, Virginia (37°50′ N, 75°29′ W). The vehicle performance was normal: propulsion ended at 52.4 sec after launch at an altitude of 36.6 km with a vertical velocity of 1.84 km/sec and a horizontal velocity of .260 km/sec at an azimuth of 111°. The rocket spun about its longitudinal axis at a rate of 2.16 rps and soon entered a precession cone of 5.7° half angle, whose axis was 15.6° from zenith at an azimuth of 96°, with a period of 75 sec. Aspect during the ascent and free-fall portions of the flight was determined from a combination of data from magnetometers, trajectory information, and horizon and star data from the photometers. Down-leg aspect could not be determined with useful accuracy below the free-fall region. A peak altitude of 215.3±0.2 km was reached 249.4 seconds after launch. Telemetry ceased at 468 sec; no recovery of instrumentation was attempted.

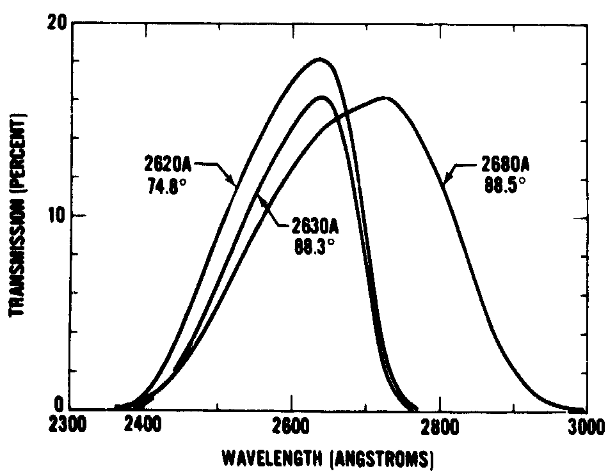

FIGURE 3.—Spectral characteristics of flight filters.

In Figure 5 is a sample of the telemetry record from two of the photometers for a period corresponding to three revolutions of the vehicle, while the airglow layer is still above the rocket. Since these photometers are nearly perpendicular to the rocket axis, the zenith angle of the photometer axis changes from a minimum (76° for the time in Figure 5) as the photometer points skywards, through 90° as it scans the horizon, and to a maximum of 100° as it points earthward. Ozone is relatively opaque around 2600 A, and the airglow in Figure 5 can be seen only when the zenith angle of the photometer is near a minimum. The ozone is relatively transparent to the light passed by the 2260 A filter, and the brightening of the airglow at the horizons can be clearly seen. (The light is probably of wavelengths longer than 2700 A, passed through the long wavelength tail of the 2260 A filter.) The southern horizon appears wider because it is merged with several bright stars in the Milky Way. As the vehicle increased in altitude, the signal from the 2620 A photometer resembled that from the 2260 A photometer, with bright horizons, a less bright sky toward zenith, and a dark earth. Above the airglow layer, the sky was dark (except for the brighter stars) and the earth appeared light. The noise in the record is due partly to the photomultiplier and partly to stars. The records were read at the midpoint between horizons, and analyzed to yield both a distribution of ozone with altitude and the volume emission of the airglow versus altitude.

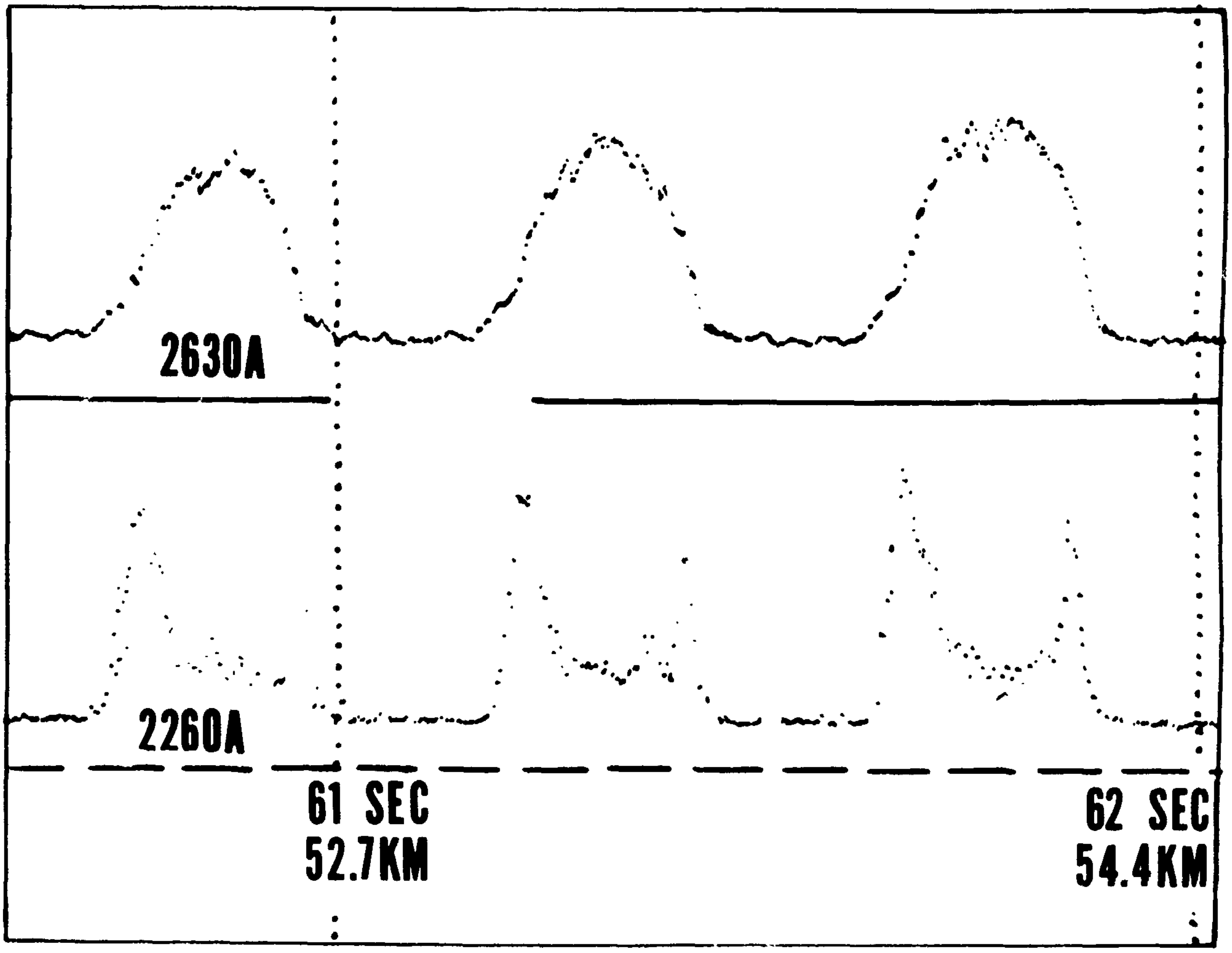

FIGURE 5.—Sample of telemetry record showing roll modulation of the airglow signal. Increasing signal represents increasing light.

The data obtained in the region of interest is shown in Figure 6. Data from 3 of the 7 photometers proved to be useful for ozone measurements. The pass band of the three 2260 A photometers was too wide to permit an accurate determination of an effective cross section for ozone; the down looking 2620 A photometer could not see the airglow while the vehicle was below the airglow layer. Data points for the photometers are shown to indicate the scatter in the raw data. As would be expected, the scatter increased rapidly as the signal rose into the non-linear portion of the amplifier response curve. In addition to the data, the angle of the rocket's longitudinal axis with respect to local zenith is given. The rocket took a spiral path with a zenith angle of 8° at thrust termination (52.4 sec) until it entered

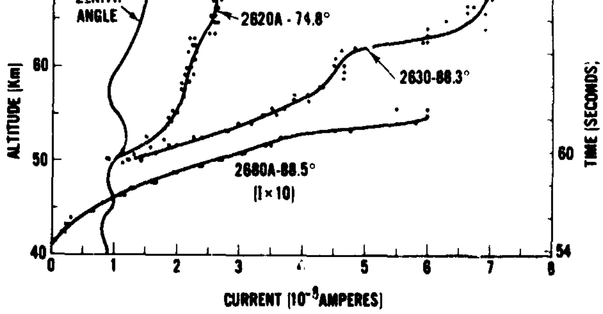

FIGURE 6.—Data from three photometers during the ascent of the rocket. The zenith angle is the angle between the longitudinal axis of the rocket and local zenith; the angle stated for each photometer is the angle between the photometer's optical axis and the rocket's longitudinal axis.

its regular precession cone of motion at about 75 seconds.

OZONE

The ozone content of the atmosphere is obtained from the rate of increase of the airglow signal as the vehicle rose. The energy observed is related to the ozone density in the following manner:

$$n(O_3)=\frac{(\log E_2-\log E_1)n \cos \gamma}{a(h_2-h_1)}$$

where $n(O_3)$ is the number of ozone molecules per cm^3

h_1 and h_2 are the lower and upper ends of the altitude interval,

E_1 and E_2 are energies observed at the corresponding altitudes,

n is Loschmidt's number, 2.687×10^{19} cm^{-3},

γ is the angel between the photometer axis and zenith, and

a is the absorption coefficient, cm^{-1}, base 10.

This was applied to the smooth curves in Figure 6 at one-second intervals.

Since the cross section of ozone varies appreciably over the wavelength interval passed by each filter, some assumption must be made concerning the spectrum of the airglow. For this purpose, the spectrum observed by T. Stecher (private communication) was used, and the absorption coefficient, a, computed for each photometer where

$$a=\frac{\Sigma E_i R_i a_i}{\Sigma E_i R_i}$$

where E_i is the energy in a particular wavelength interval, i,

R_i is the corresponding relative transmission of the filter, and

a_i is the corresponding absorption coefficient.

The absorption coefficients used were from the tabulation of *Inn* and *Tanaka* [1953, 1959] which in the region of interest here are about 10 percent higher than those of Vigroux [1953] and 1 or 2 percent lower than those of *DeMore* and *Raper* [1964]. The effective absorption coefficients calculated on this basis are: 2620 A (88.3°), 114.4 cm^{-1}; 2620 A (74.8°), 113.8 cm^{-1}; and 2630 A (88.5°), 79.48 cm^{-1}.

The resulting ozone density is shown in Figure 7 as a function of altitude. It is felt that the spectral characteristics of the photometers, the airglow and the ozone absorption coefficient are sufficiently well known such that they contribute no more than a total of about 20 percent uncertainty to the number density of ozone. This would be a systematic error which would not affect the shape of the curve.

The angle of the photometers with respect to zenith could easily contribute an uncertainty of 20 percent to both the absolute and relative values of the ozone densities. It is based upon magnetometer data and the assumption that at the end of thrust the rocket axis was aligned with the velocity vector.

The largest source of error is in the character of the data, which contains noise from the photomultiplier dark current, stray pulses, and stars. It is difficult to separate this from the possible temporal and spatial variations of the airglow itself. A temporal variation could be responsible for some of the shape of the curve, but it is unlikely that the airglow would vary sufficiently in the 16 seconds of time that the ozone curve represents, to be responsible for its major features. Spatial variation is not thought to be a major

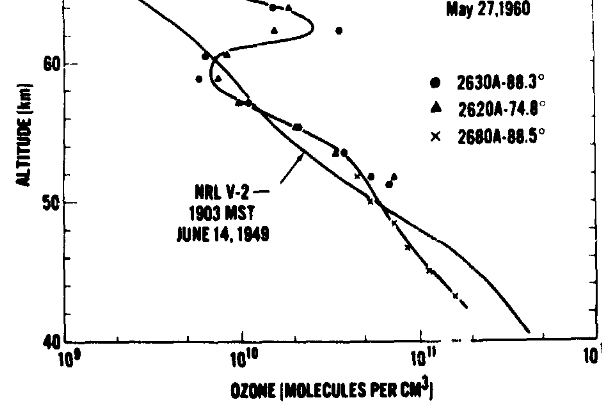

FIGURE 7.—Altitude distribution of ozone.

source of uncertainty in the data since the numbers derived from the two photometers which were looking at different portions of the sky agree reasonably well. The magnitude of the noise-like errors is apparent from the scatter of points about the curve and is on the order of 50 percent.

For comparison the daytime ozone distribution as measured by absorption of the solar spectra between 2500 and 3400 A [*Johnson, et al*, 1952] is shown. The daytime profile was computed using the ozone absorption coefficients of *Ny* and *Choong* [1933], which in the spectral region of interest are 10 to 15 percent higher than those of Inn and Tanaka used for the night time profile.

The most important feature of the profile is the factor of 6 increase in ozone density over the daytime profile above 60 km. While this may be in error by 50 percent or more, it is believed that the shape of the curve does indicate an increase of ozone density at night in this region, and that it is on the order of a half of a magnitude.

Techniques are being developed by various workers to use satellites for the measurement of ozone in this region. *Venkateswaran* [1961], observed the sunlight reflected from Echo I as it emerged from the earth's shadow, using various wavelength pairs between 4700 and 7000 A. His results above 55 km are about a factor of 15 higher than the measurements by *Johnson, et al.* However *Venkateswaran* [1963] states that this method probably gives too high values at levels above the principal ozone maximum.

The second type of observation was made at sunrise and sunset by a satellite borne radiometer with a response center at about 2630 A [*Rawcliffe, et al*, 1963]. At 60 km his data are about 20 percent lower than Johnson's, but approach Johnson's data, and above 80 km are somewhat higher than the trend of Johnson's data.

It is expected that the night time values would be higher. The magnitude of the effect, besides depending on reactions among the various oxygen species and third bodies, depends critically on such things as the initial hydrogen concentrations chosen [*Bates* and *Nicolet*, 1950, and *Wallace*, 1962] and possible reactions involving atomic nitrogen [*Barth*, 1961]. Perhaps the most recent computation of ozone densities has been done by *B. G. Hunt* [1964] using an atmosphere in which he assumes the only reactive constituent is oxygen. (The effects of atomic nitrogen and hydrogen would be to lower the calculated 0 and 0_3 concentrations.) Between 40 and 50 km, Hunt's curve for just before sunrise conditions is as much as 30 percent lower than Johnson's daytime profile, crosses it at 53 km, and reaches a maximum value of 5×10^{10} molecules of 0_3 per cm at 69 km.

AIRGLOW

The other principal result from the analysis of data from these photometers is information concerning the distribution of the airglow. Volume emission can be deduced from the data obtained as the vehicle passes through the emitting region. The energy calibration of the photometers has been used in preparing these curves, (Figure 8) so that they do rightly represent the relative energy in the portion of the spectrum passed by the different filters. Ten arbitrary units represent on the order of one photon cm^{-3} sec $^{-1}$ per A. The airglow as measured by the 2680 A photometer is 2.3 times that sensed by the 2620 A photometers. The airglow measured by the 2260 A photometers is 0.15 times that of the 2620 A photometers; nearly all the energy measured by the 2260 A photometers has come through a long wavelength tail of the filters. This pattern is completely consistent with a spectrum of the airglow horizon obtained by T. Stecher with a spectrograph flown at 0030 local time on July 19, 1963.

The 2680 A filter was similar in construction and characteristics to those flown in March 1957 [*Tousey*, 1958] and November 1959 [*Friedman*, 1961, *Packer*, 1961]. The altitude of maximum

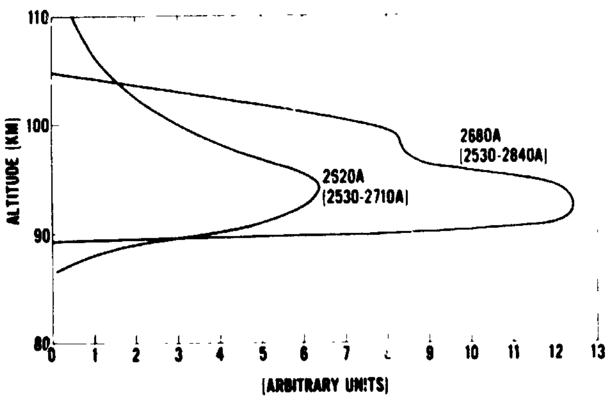

FIGURE 8.—Altitude distribution of the ultraviolet emission.

emission were 101 and 96 km respectively, compared to 92 km for this flight. The zenith intensity for the 1957 flight was 3.4 rayleighs per Angstrom (Dunkelman, private communication) and for the 1959 flight was 1.94 rayleigh per Angstrom. The airglow during the flight of Aerobee 4.05 was somewhat brighter, but within a factor of 10 of these values.

The brighter stars and the Milky Way were readily noted in the records as the photometer scanned across the sky. The signal in the absence of obvious stars indicated that less than 15 percent of the light from extended sources originated above the emission layer indicated in Figure 8.

ACKNOWLEDGMENTS

We thank the following colleagues at Goddard Space Flight Center for their help: Dr. A. Boggess III for making the data from this rocket payload available to us for this purpose; G. Baker and R. M. Windsor for the electronic instrumentation; E. Serra for engineering assistance in the payload preparation; T. Stecher for an advance copy of his airglow spectrum, wlthout which the effective absorption cross section could not have been determined with significant accuracy; L. Dunkelman for the absolute values of the night airglow measurement in March 1957; and Dr. J. E. Kupperian, Jr. for his encouragement and suggestion of analysis of this data.

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SOME ASPECTS OF WIND SHEAR IN THE UPPER ATMOSPHERE*

R. G. ROPER

The wind motions responsible for the shearing of sodium vapor trails ejected from rockets in the 70 to 140 km region of the upper atmosphere are subjected to an analysis based on generally accepted theories of hydrodynamic turbulence. The region from 80 to 100 km is of particular interest in that here the predictions of shear turbulence theory are well substantiated. The energy spectrum of the height shear is found to follow the 4/3 power law proposed by Tchen, and is associated with a vertical correlation distance of approximately 6 km. The existence of an isotropic inertial region of maximum scale 3 km, previously indicated by analysis of meteor data, is confirmed. The vertical scale of the turbulent eddies is found to be the atmospheric pressure scale height, a phenomenon which has been observed by others, but which, as yet, has no satisfactory explanation.

1. TURBULENCE THEORY

The complete development of the relationships used in the analysis of wind shear is beyond the scope of this work; the following, used in conjunction with the references quoted, should provide an adequate background for consideration of the subsequent analysis.

1.1 Energy Spectrum Analysis

If there exists in a turbulent flow field a range of scales which receive energy from larger scale motions and pass it on undiminished to smaller scale motions, then, for this so-called inertial (non-dissipative) range of scales, the only form of energy spectrum function dimensionally possible is

$$E(k) = \alpha\epsilon^{2/3}k^{-5/3} \quad \text{(Kolmogoroff, 1941)}$$

where ϵ is the rate at which the turbulent energy is received by (and leaves) the inertial range of scales, k is the wavenumber vector corresponding to the real space scale r, and α is an absolute constant of order unity.

Batchelor (1953) has shown that, for such an inertial region which also possesses the property of isotropy, the fluid velocity differences measured as a function of the separation r follow the relation

$$[u(x)\text{-}u(x+r)]^2 = 4.82\alpha(\epsilon r)^{2/3} \qquad (1)$$

In real space, the energy spectrum function $E(r)$ is defined by

$$E(r) = [u(x) - u(x+r)]^2 \qquad (2)$$

Tchen (1954) has considered an otherwise isotropic region subjected to a mean shear, and finds that equation 1 is modified, becoming

$$[u(x) - u(x+r)]^2 = a\, r^{4/3} \qquad (3)$$

where a involves α, ϵ, and the mean gradient. Thus, for what may be termed shear turbulence, in real space

$$E(r) \sim r^{4/3} \qquad (4)$$

1.2 Correlation Analysis

An energy spectrum function equivalent to that based on velocity differences can be formulated from the lateral or longitudinal velocity correlations defined as

$$f(r) = \frac{u_f(x)u_f(x+r)}{u_f^2}$$

and

$$g(r) = \frac{u_n(x)u_n(x+r)}{u_n^2} \qquad (5)$$

where $u_f(x)$, $u_f(x+r)$, $u_n(x)$, $u_n(x+r)$ are the turbulent components of the velocity at two points x and $x+r$ respectively, measured parallel (suffix f) and normal (suffix n) to the vector separation r.

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In isotropic turbulence, $u_f^2 = u_n^2 = u_0^2$, the velocity characteristic of the energy bearing eddies of the Kolmogoroff spectrum.

Introduction to the equation of continuity for incompressible fluids leads to the relation

$$g(r) = f(r) + \frac{1}{2} r \frac{\partial f}{\partial r} \quad (6)$$

(von Karman and Howarth, 1938)

between the functions f and g, or, if the turbulence is isotropic in two dimensions only,

$$g(r) = f(r) + r \frac{\partial f}{\partial r} \quad (7)$$

These functions, f and g, may be called Eulerian space correlation functions, and either may be denoted by $R(r)$. If the range of scales under observation is inertial, then $R(r)$ must depend only on ϵ, and the only form dimensionally possible is

$$u_0^2[1-R(r)] \sim \epsilon^{2/3} r^{2/3}$$

i.e.

$$1-R(r) \sim r^{2/3}$$

(for any given flow field, u_0 and ϵ are constant).

Introduction of the relations 6 and 7 above gives, with c a constant

$$f = 1 - cr^{2/3} \quad (8)$$

and

$$g = 1 - 4/3\ cr^{2/3} \quad (9)$$

for three dimensional isotropy

or

$$g = 1 - 5/3\ cr^{2/3} \quad (10)$$

for isotropy in two dimensions only.

Since the variations of the correlation difference function $[1-R(r)]$ with r is the same as that of $E(r)$ in equation 1, we may suppose that the dependence of $[1-R(r)]$ on r will be similarly modified in the presence of a mean shear

i.e.

$$[1-R(r)] \sim r^{4/3} \quad (11)$$

If, in fact, equation 11 is pertinent, then the relationships between f, g, and r (equations 8, 9, 10) will now become

$$f = 1 - ar^{4/3}$$

and

$$g = 1 - 5/3\ ar^{4/3}$$

or

$$g = 1 - 7/3\ ar^{4/3}$$

An indication of the degree of isotropy can be obtained by considering the ratio

$$S = \frac{1-f}{1-g}$$

For two dimensional isotropy

$S = 0.60$ without mean shear

and $S = 0.43$ with mean shear

For three dimensional isotropy

$S = 0.75$ without mean shear

and $S = 0.60$ with mean shear

The relative importance of mean shear will be indicated by the form of either the energy spectrum function $E(r)$, or the correlation difference function $[1-R(r)]$.

2. THE PRACTICAL APPLICATION OF TURBULENCE THEORY

2.1 The Mean Wind Profile

In applying the relations developed above to the wind vectors measured by means of sodium vapor trails ejected as a tracer into the upper atmosphere, the relative importance of the mean motion must not be overlooked. The velocities used in the energy spectrum and correlation analyses of the previous section must be the turbulent velocities, or departures from the mean motion. In normal correlation analysis, the mean value of a set of observations is usually taken as the mean value of the measured data, which, when applied to wind height shear data, would be tantamount to the assumption of a mean wind profile which is constant with height. Such a profile is the exception rather than the rule in meteorological phenomena.

Practically any attempt to prescribe a mean wind profile to the measured winds will be subjective to a certain extent. If one uses a polynomial fit, for example, it must be truncated before it can assume any of the features of the measured profile which are due to the turbulent motions present. From experience based on the measurement of winds in the 75 to 105 km region by means of radio reflections from meteor trails (Elford, 1958, 1964), a quadratic change with height of the mean wind over any given 20 km interval should best describe the contribution of the mean motion without destroying any of the characteristics of the turbulent flow field. In the present analysis, the windspeed/azimuth data are converted to zonal and meridional components, and a polynomial profile of order $Z+1$, where

$$Z=\frac{\text{Total height range covered by data (km)}}{20},$$

is fitted to each. The profiles thus determined are subtracted from the relevant measured profiles to give zonal and meridional turbulent velocities.

2.2 The Determination of E[Δh]

The available sodium trail data lists wind speed and azimuth against height, and usually involves irregularly spaced height intervals. The sampling irregularity exists for two reasons:

a) there is an occasional difficulty in absolutely identifying the same point on the trail in consecutive photographs;

b) the wind profile between consecutive observational heights is linear. This is usually obvious from the photographs, and can easily be allowed for in subsequent analysis.

Whereas equal height interval sampling is not absolutely necessary for subsequent reduction, it does simplify the analysis, and so linear interpolation between the listed data points is used to provide a profile with data points spaced 0.2 km in height.

The energy spectrum function is computed as

$$E(\Delta h_i)=\frac{1}{N}\sum_{k=1}^{N}(u_{k+i}-u_k)^2 \qquad (12)$$

in which

$$N=5(H_2-H_1)-i$$

where $i=1, 2, 3....N$

such that $\Delta h_1=0.2$ km.

$\Delta h_2=0.4$ km

etc.

and H_1, H_2 (in km) are the lower and upper bounds respectively of the region for which $E(\Delta h)$ is being determined. Such partitioning of the height range is necessary since there is considerable variation in the characteristics of the flow over the total height range sampled (usually some 70 to 200 km).

Energy spectrum functions may be calculated using

a) zonal turbulent velocities

b) meridional turbulent velocities

and c) turbulent windspeed.

The turbulent windspeed w is defined here as

w = measured windspeed − ((mean zonal wind)^2+ (mean meridional wind)^2)$^{1/2}$

2.3 Correlation Analysis

The two correlation functions f and g defined in 1.2 refer to turbulent velocity components measured parallel and normal to the separation vector. Since vertical velocities in this region of the upper atmosphere are so much less than the associated horizontal components, the magnitude of the vertical component cannot be determined from sodium trail photographs. (Most workers in this field consider the upper limit for mean plus random vertical motions to be some 10 metres/sec). However, we may redefine f and g in terms of the orthogonal zonal and meridional flow fields, with a view to investigating possible isotropy. This has been done by meteorologists in the past, with at least partial success (see, for example, Hutchings (1955)).

The normalizing factors $\bar{u}_f^2$ and $\bar{u}_n^2$ are best estimated by the standard correlation function definition. The correlation functions f and g then become

$$f(\Delta h_i)=\frac{\sum_{k=1}^{N} u_{k+i}u_k}{\left[\sum_{k=1}^{N} u_{k+i}^2 \ \sum_{k=1}^{N} u_k^2\right]^{1/2}} \qquad (14)$$

where u are the zonal turbulent wind velocities and

$$g(\Delta h_i)=\frac{\sum_{k=1}^{N} v_{k+i}v_k}{\left[\sum_{k=1}^{N} v_{k+i}^2 \ \sum_{k=1}^{N} v_k^2\right]^{1/2}}, \qquad (15)$$

where v are meridional turbulent wind velocities, and N and i are as previously defined for equation 12.

3. PRELIMINARY RESULTS

The analysis of Section 2 has been applied to data obtained from a sodium trail release over the Eglin Air Force Base, Florida (29.6° N, 86.6° W) at 1910 CST on May 21, 1963 (Edwards et al., 1963). In this experiment, wind speed and azimuth were obtained over a height range of 69 to 140 km.

3.1 The Mean Wind Profile

Since the data covers the height range from 69 to 140 km, polynomials of order 4 are fitted to the zonal and meridional measured profiles. These yield mean zonal and meridional profiles

$$u_{mean} = 38.6 - 126h - 244h^2 + 174h^3 + 205h^4$$

$$v_{mean} = -30.4 + 19.8h + 148h^2 - 16.8h^3 - 125h^4$$

where u, v are in metres/sec and h is the normalized height given by

$$h = (2z - z_{min} - z_{max})\ (z_{min} - z_{max})$$

where z is the height variable

z_{max} the maximum and

z_{min} the minimum heights of the available data, all heights being in kilometers.

Normalization of the height range stabilizes the least squares fitting process, and makes the relative importance of the individual terms of the fitted polynomials more obvious than is the case when the mean velocities are expressed as power series in the actual height z. Results are plotted in Figs. 1 and 2.

The meteorological significance of these profiles, in particular the reversal of both the zonal and meridional components above 110 km, cannot be evaluated from consideration of this single firing.

3.2 The Turbulent Wind Profile

As mentioned in Section 2, the 70 to 200 km height range covers a number of characteristically different regions. The wind motions observed below approximately 105 km indicate the presence of small-scale structure, while those above 110 km do not appear to be at all turbulent, even though vertical shear is present. In the results presented here, discussion is confined to the consideration of

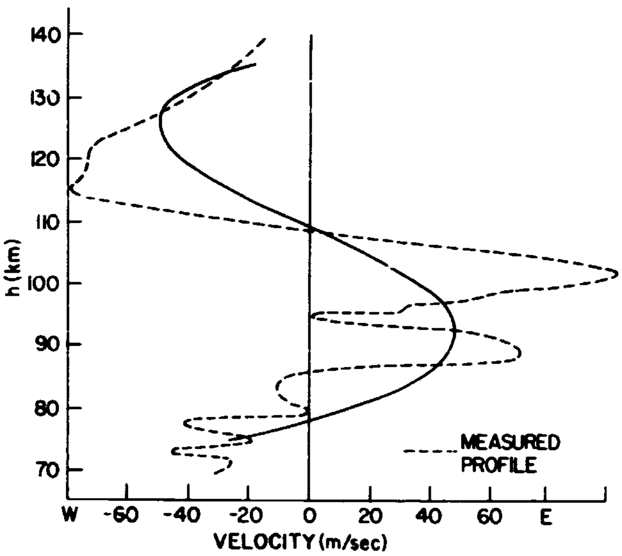

FIGURE 1.—Mean zonal profile.

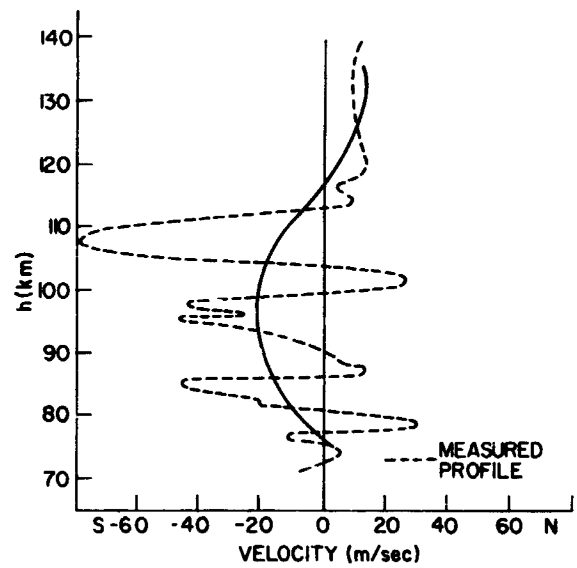

FIGURE 2.—Mean meridional profile.

the region from 80 to 100 km, which has been found to be representative of a turbulent region which can be adequately described by available statistical theories of hydrodynamic turbulence (Blamont and Jager, 1961; Zimmerman, 1962; Roper, 1962).

The measured zonal and meridional profiles, and the deviations from the mean wind for the height range 80 to 100 km are plotted in Figures 3 to 6. Whereas the immediately obvious wave-like nature of the turbulent profile would suggest a wave theory approach as likely to be the most profitable for consideration of the wind motions

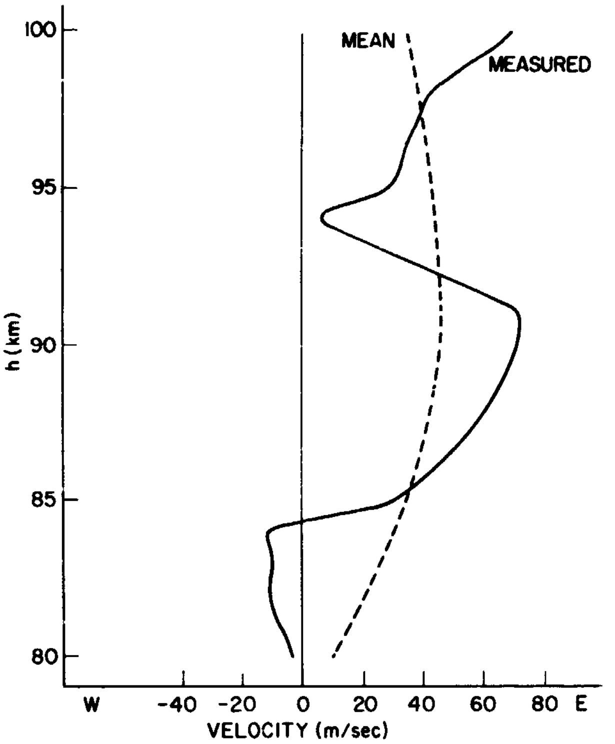

FIGURE 3.—Zonal profile, 80-100 km.

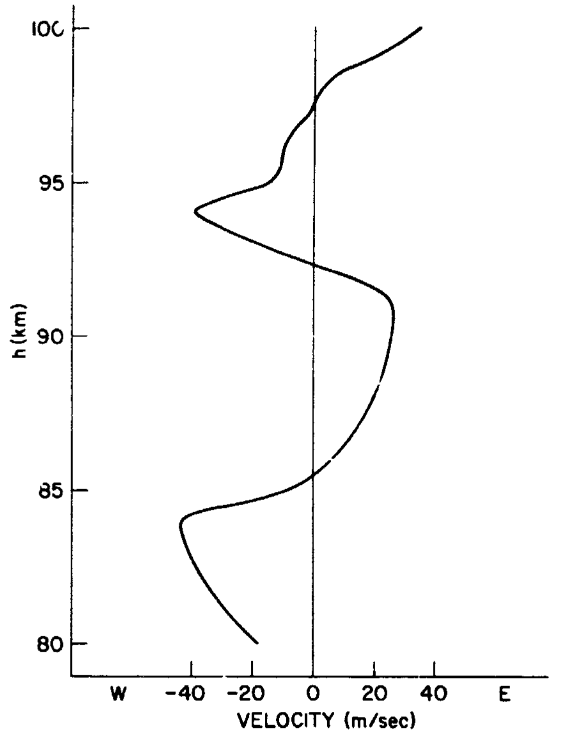

FIGURE 5.—Turbulent zonal profile.

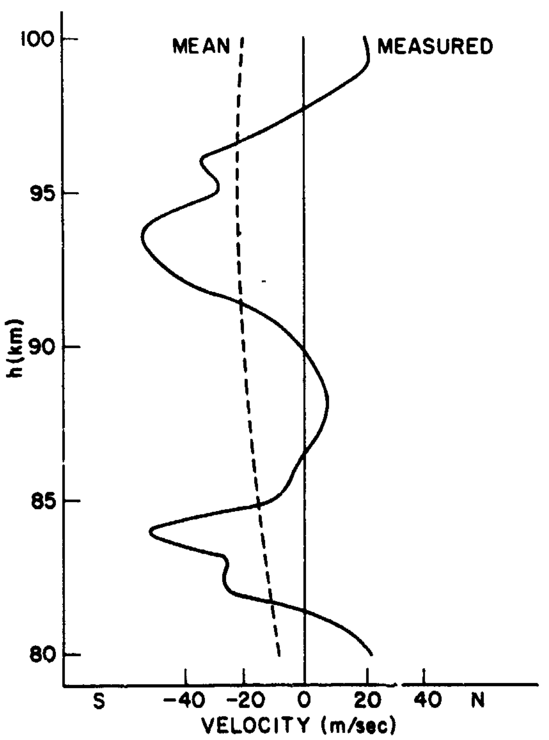

FIGURE 4.—Meridional profile, 80-100 km.

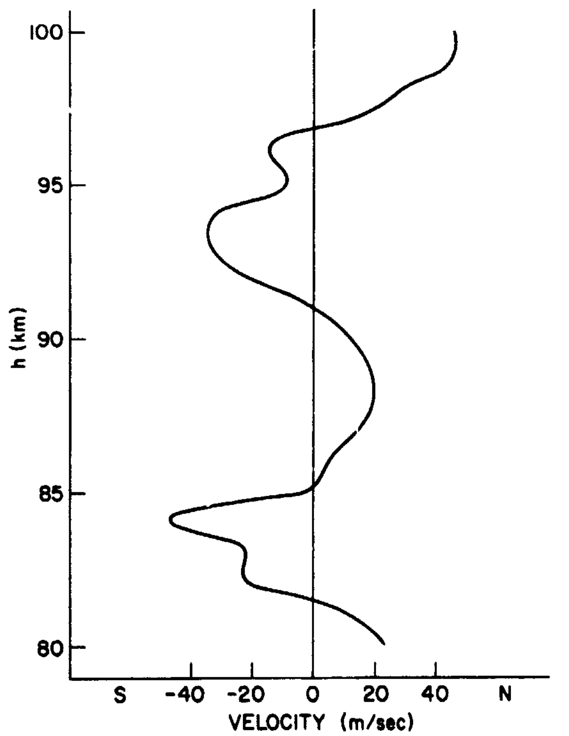

FIGURE 6.—Turbulent meridional profile.

in this region, applications of available wave theories (e.g., Hines, 1959) have not produced consistent results. The possibility of generation of turbulence in the 80 to 100 km region by vertically propagating gravity waves has been proposed by Hines (1963). The purpose of the present work, however, is not to determine the source of the turbulent energy, but rather to substantiate the evidence that the observed shears characterize a region of hydrodynamic turbulence.

3.3 The Energy Spectrum Functions

The energy spectrum functions for the zonal and meridional turbulent wind profiles for the 80 to 100 km region have been computed using the methods described in Sections 2.2 and 2.3. As can be seen from Figures 7 and 8, the velocity difference spectrum $E(\Delta h)$ and the correlation difference function $[1-f(\Delta h)]$ for the zonal turbulent velocities are completely equivalent. This is not surprising, since both functions are solutions of the same equation

$$F = a\Delta h^m$$

(see Sections 1.1 and 1.2).

Similarly for the meridional spectra of Figures 9 and 10. The slope m of the log log plots of both the zonal and meridional $E(\Delta h)$ (or $[1-R(\Delta h)]$) spectrum functions against height difference Δh is constant at 4/3 for separations Δh up to 3 km, indicative of an isotropic region subject to a mean wind shear (Tchen, 1954).

3.4 Isotropy

Since the energy spectrum functions and the correlation difference functions all follow an established (shear) law at small scales in the height range from 80 to 100 km, it is possible to determine the nature of the isotropy at these scales in this region.

Figure 13, curve A, is a plot of the variation of

$$S = \frac{1-f}{1-g}$$

against Δh.

In the region up to a scale of 3.5 km, S has a value of approximately 0.7, indicating an isotropy lying somewhere between two and three dimensional. The increase in S at scales greater than approximately 3 km is due to the breakdown

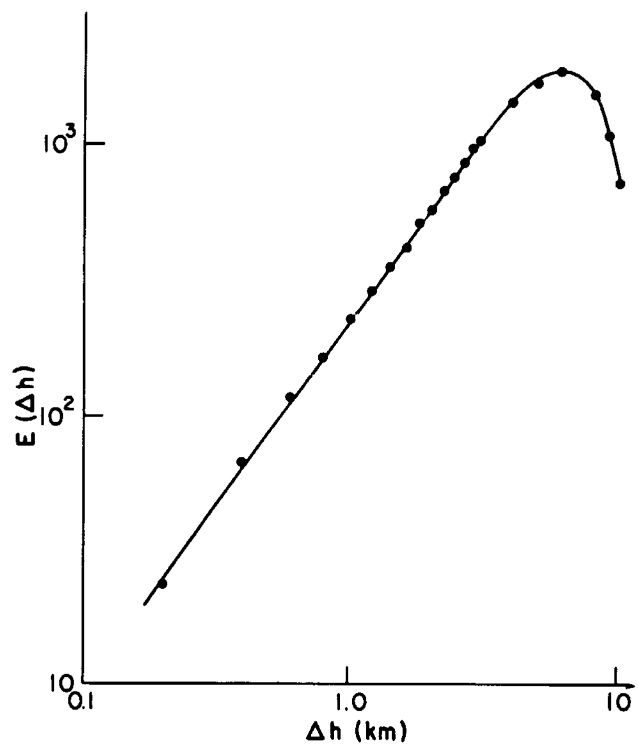

FIGURE 7.—The zonal energy spectrum function.

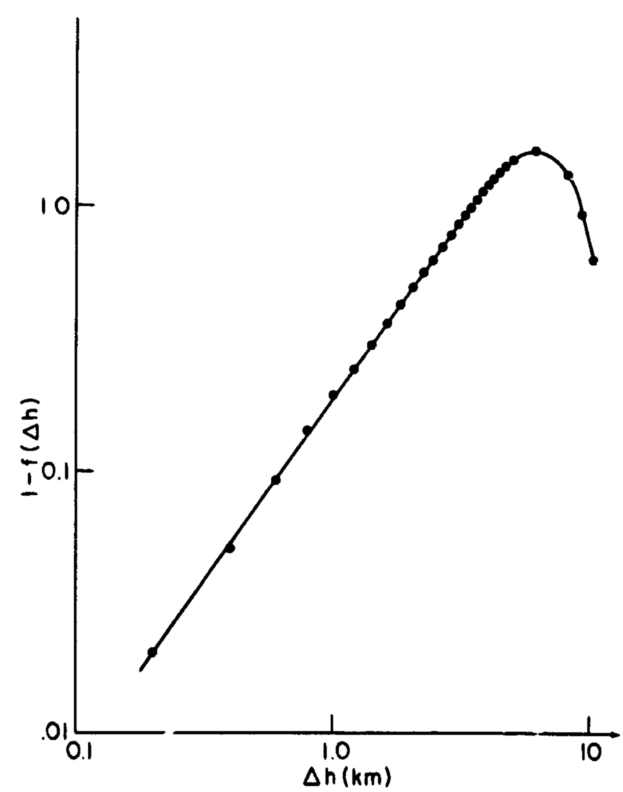

FIGURE 8.—The zonal correlation difference function.

at this scale of the 4/3 power law in both zonal and meridional spectrum functions.

The function S has been found to be quite sensitive to variation in the parameters specifying the mean wind profiles. For example, if, instead of the fourth order polynomial fits to the total height range of the zonal and meridional data, linear mean wind profiles are fitted over the height range 80 to 100 km only, subsequent spectrum analysis yields the S function of curve B of Figure 13. This curve would indicate the existence of three dimensional isotropy for scales up to 3 km. It is possible that the 4th order polynomial fits are, in fact, attributing a small fraction of the random wind variations to the mean motion. However, in order to correlate spectra obtained for different height strata (as is done in the next section), a continuous mean profile is required, and has therefore been used throughout the analysis.

3.5 Vertical Scale

The vertical scale associated with the turbulent wind structure is conveniently defined by the Δh corresponding to the maximum value of either $E(\Delta h)$ or $[1-R(\Delta h)]$. As can be seen from Figures 7, 9 and 11, which are plotted using zonal, meridional and windspeed turbulent velocities respectively, the vertical correlation distance as defined above is not the same for each component, i.e., the wind motions are not isotropic at the maximum of $E(\Delta h)$. However, for the purpose of comparison with stratospheric and lower mesospheric data, where meridional winds are, for the most part, negligible, consideration need only be given to the zonal energy spectrum.

The variation of vertical scale with height in the stratosphere has been determined by Webb (1964) from a series of Robin soundings at Eglin. His results indicate an exponential increase of the vertical scale with height, from approximately 800 metres at 35 km to 2 km at 55 km. He has extrapolated this exponential to a height of 90 km, and finds a vertical scale of 6 km which is the value determined for this height by Greenhow (1959) from a correlation analysis of wind shears determined by means of radio reflections from meteor trails at Jodrell Bank (53°N).

In order to investigate the change with height of the vertical correlation distance in the 80 to 130 km region, the sodium trail data was sub-

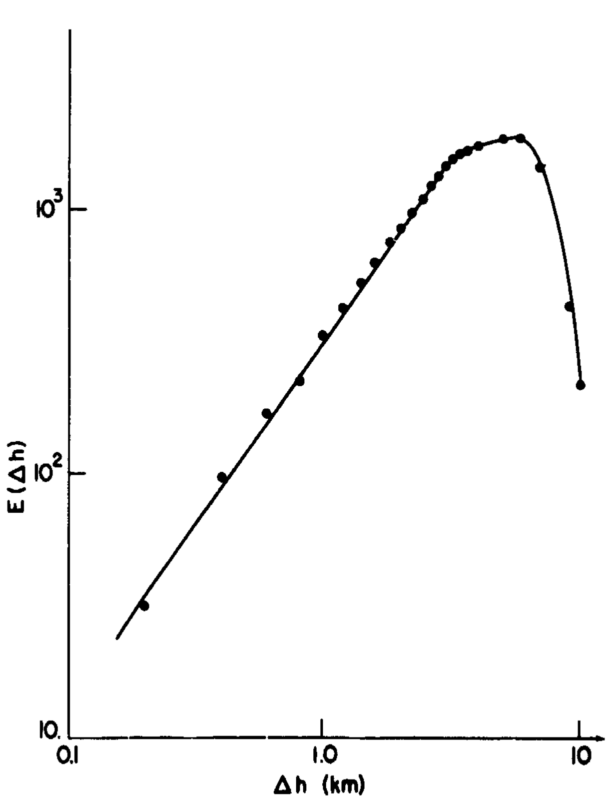

FIGURE 9.—The meridional energy spectrum function.

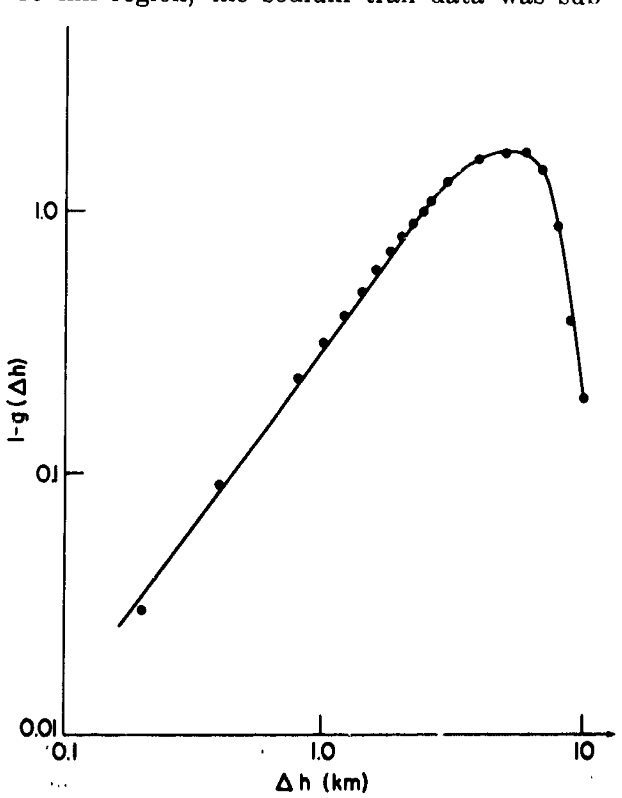

FIGURE 10.—The meridional correlation difference function.

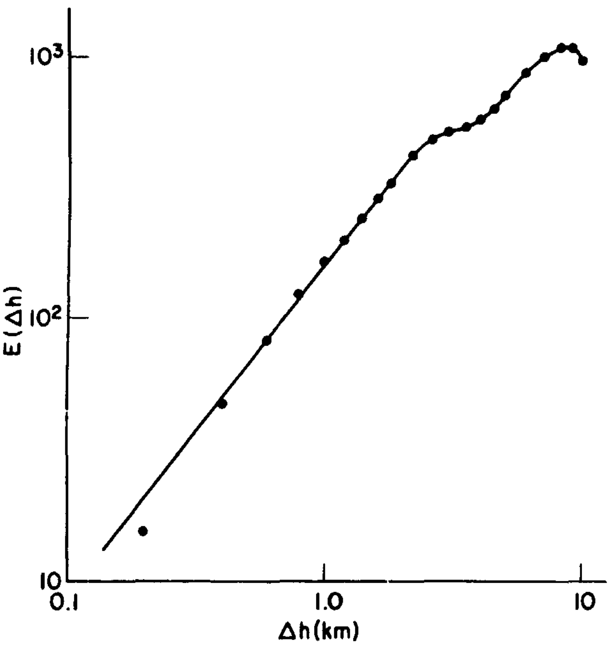

FIGURE 11.—The windspeed energy spectrum function.

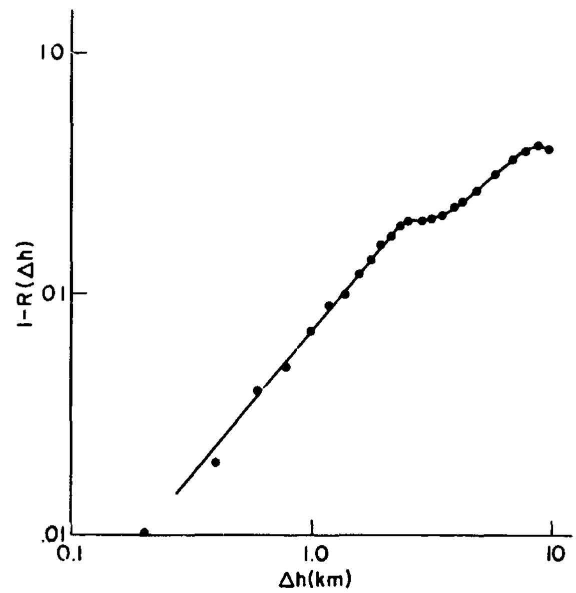

FIGURE 12.—The windspeed correlation difference function

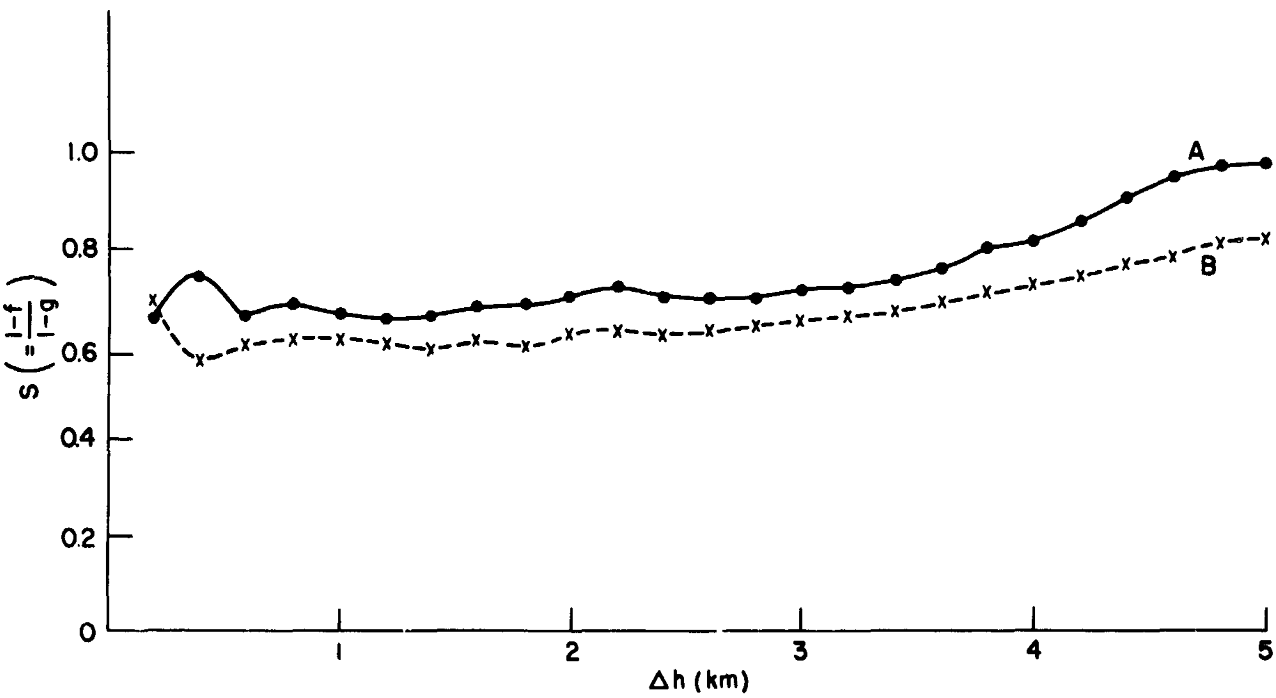

FIGURE 13.—Variation of the isotropy parameter "S" with scale.

jected to a stepwide analysis, starting with the 75 to 95 km height range, and proceeding via the 80 to 100, 85 to 105, etc. ranges to 115 to 135 km. The maxima of the resultant $E(\Delta h)$ curves were then plotted as the vertical sca'es at the midpoints of the respective height ranges. The results are shown in Figure 14, together with Greenhow's determination, and the 7.8 km at 94 km (October, 1961) determined from radio meteor trail shears at Adelaids (35°S) (Roper, 1962). The dashed line is Webb's extrapolated variation. While there is excellent agreement with Webb's proposed exponential increase, there is also good agreement between the vertical scales measured

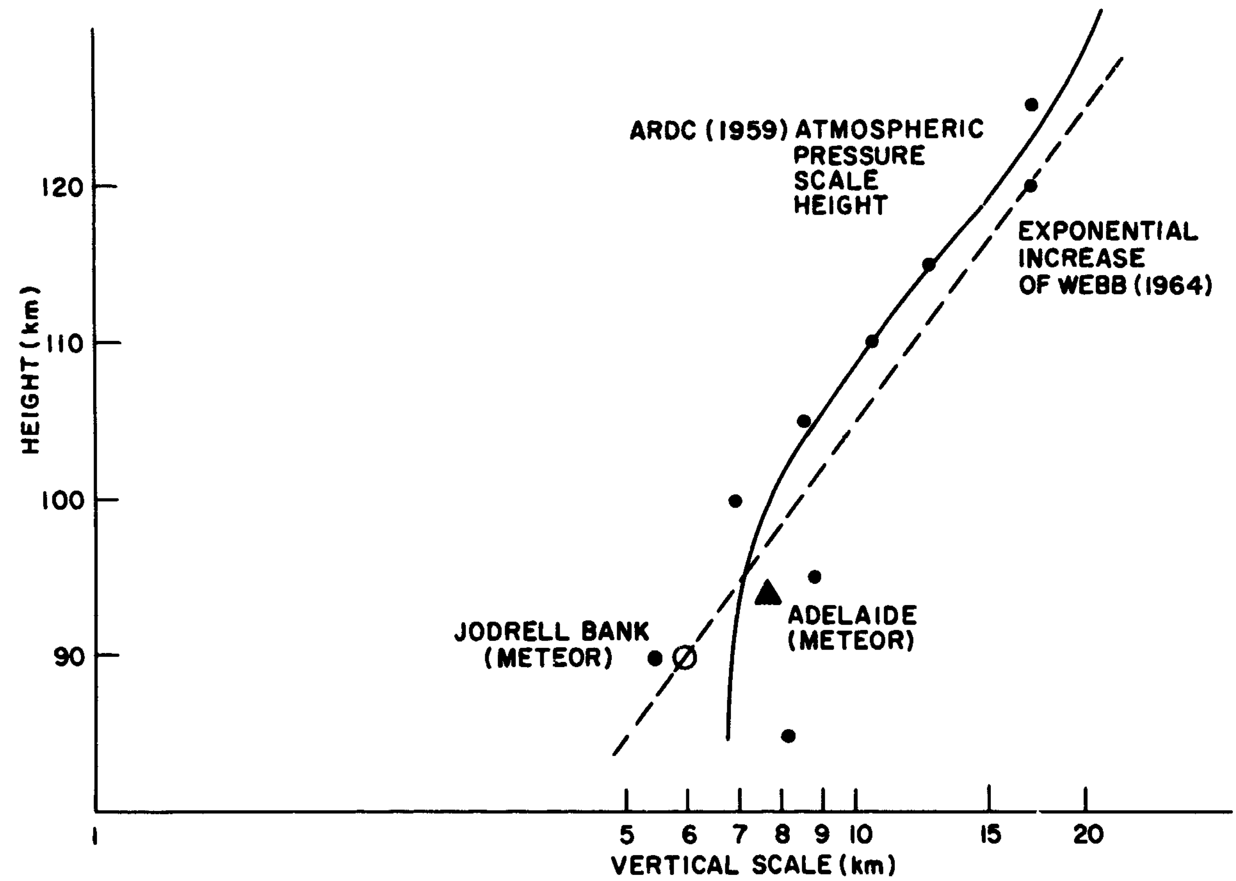

FIGURE 14.—Variation of the vertical scale of the zonal turbulent wind component with height.

at various altitudes for the Eglin firing, and the atmospheric pressure scale height (also shown in Figure 14). This phenomenon has also been observed by others (e.g., Zimmerman (1964)). As yet, no satisfactory explanation for such a dependence has been proposed.

Above 125 km, the magnitudes of the deviations of the measured winds from the mean wind values becomes insignificant. Wind motions at these heights for this particular firing are characteristically nonturbulent.

CONCLUSIONS

The techniques of spectrum analysis based on hydrodynamic turbulence theory can be profitably applied to wind data obtained from sodium trail rocket firings, at least in the height range from 80 to 100 km. The analysis of further firings should indicate whether or not the mean profiles determined as a prelude to spectrum analysis have any meteorological significance.

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APPENDIX I

RESUME OF THE COMPUTER PROGRAM

The computer program has been written in FORTRAN IV for execution on an IBM 7094, and consists of the following routines:

1. The main program SHEAR which reads and does some processing of the input data (which is punched on cards).

SHEAR calls subroutines

a) FIT, which fits polynomial profiles to the zonal and meridional wind velocity/height profiles by the method of least squares, utilizing

b) MATS, to solve the set of independent linear equations

c) The total wind speed profile is calculated by TRADE.

d) OUTPUT performs the energy spectrum and correlation analyses, and printout of same.

e) PAGE is a utility routine which turns and numbers the output pages, and prints an appropriate heading on each.

Input Data

The input data is on punched cards, and is read as follows:

1. Header Card; the information punched on this card is printed at the top of each page of output. The full 72 columns can be used for any type of alphanumeric heading.

2. The parameters specifying the mean zonal and meridional profiles. These determine the order of the polynomial fitted to

a) the zonal (punched in columns 2, 3) and

b) the meridional (punched in columns 5, 6) measured data to determine the mean profile. e.g., a 5 punched in column 3 will fit a polynomial of the form

$$a_1+a_2h+a_3h^2+a_4h^3+a_5h^4$$

to the zonal wind data.

The maximum allowable value of the subscript i in the a_i above is 10.

3. The height range (must be integral, and in km) over which the energy spectrum and correlation analyses are to be performed. This can be any fraction of the height interval covered by the input data, but must not be less than 10 km unless an appropriate spectral range is punched in column 13. The minimum of the height range interval is punched in columns 2 to 5, the maximum in columns 6 to 9. If OUTPUT is required to produce spectra over height differences to other than a maximum of 10 km, the required maximum height difference can be punched in columns 10 to 13. This entry must not exceed the height range specified in columns 2 to 9. If this last field is left blank, spectra to 10 km are output.

4. The trial data, which must not exceed a maximum to minimum height range of 150 km. The data is punched as year, month, day, hour (local time, 24 hour clock), height (km), windspeed (metres/sec), and zaimuth (degrees) as follows

YR	MO	DAY	HOUR	HEIGHT	WINDSPEED	AZIMUTH
3	3	9	14	19	24	29

all integer (YR–HOUR)

must be right adjusted if integer; anywhere in appropriate field if decimal punch is included. (HEIGHT–AZIMUTH)

5. After all data of 4. a blank card to flag "end of data."

6. Further height ranges as for 3 as required.

7. a) If a change in the mean wind profile is required a card with a 2 punched in column 1 may be substituted for any of the cards 6, and followed by a card of format 2 above which specified the new profile. This card is then followed by further height ranges (as for 6.) as required.

7. b) If a completely new set of header plus data cards is to be processed after either stages 5, 6, or 7a, a card with a 1 punched in column 1 will return control to the start of the program, which will then read in the new set of data cards sequenced as from 1 above.

APPENDIX II

Listing of the FORTRAN IV Program

SHEAR 08/

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
C       SODIUM TRAIL HEIGHT SHEAR ANALYSIS PROGRAM
C
C       CALCULATES THE ENERGY SPECTRUM FOR TOTAL SHEAR, AND FOR ZONAL AND
C       MERIDIONAL SHEAR COMPONENTS
C
C       READS INPUT DATA AS FOLLOWS
C       A HEADER CARD, PUNCHED WITH DETAILS OF FIRING TIME, ETC.
C       FORMAT 12A6
C       THE PARAMETERS SPECIFYING THE MEAN ZONAL AND MERIDIONAL PROFILES,
C       FORMAT 213
C       THE HEIGHT RANGE OVER WHICH ANALYSIS IS TO BE PERFORMED, ZMIN,
C       ZMAX, AND THE MAXIMUM OF THE OUTPUT SPECTRAL RANGE DESIRED.
C       FORMAT  1X2F4.0, 14.
C       SPECTRAL RANGE MUST NOT EXCEED ZMAX-ZMIN.
C       IF NO SPECTRAL RANGE IS SPECIFIED, ZMAX-ZMIN MUST BE GREATER THAN
C       10KM, AND SPECTRA WILL BE OUTPUT TO 10KM.
C       THE TRAIL DATA, YEAR MONTH DAY LOCAL TIME (HOURS AND MINUTES,
C       24 HOUR CLOCK) HEIGHT(KM) WIND SPEED(METRES/SEC) WIND AZIMUTH
C       (DEGREES).
C       FORMAT 313, 15, F5.1, 2F5.0
C       A BLANK CARD
C       FURTHER ZMIN, ZMAX AS REQUIRED.  IF A 2 APPEARS IN COLUMN 1,
C       PROGRAM WILL READ NEXT CARD AS NEW PROFILE SPECIFICATION, FOLLOWED
C       BY FURTHER ZMIN, ZMAX CARDS.    IF A 1 APPEARS IN COLUMN 1, THE
C       PROGRAM WILL READ NEXT CARD AS HEADER CARD OF A COMPLETELY NEW SET
C       OF DATA.
C
        DIMENSION BZ(10), BM(10)
        DIMENSION RESULT(12), ZI(750), WINDI(750), AZRADI(750), ZONAL(750),
       1ERID(750),            TZONAL(750,) TMERID(750)
        DIMENSION TSPEED(750), AW(5)
        COMMON ZI, WINDI, AZRADI, ZONAL, ERID, TZONAL, TMERID, TSPEED
        C=0.05
        CS=0.000001
        PI=3.1415926
        TWOPI=2.0*PI
   999  NGO=0
        NI=0
        I=0
        NSUM=0
        ZERO=0.0
        READ     (2,1)RESULT
     1  FORMAT(12AC)
    17  READ     (2,4)NP,NQ
     4  FORMAT (213)
        NFIT=-1
     2  READ(2,3)NGO, ZMIN, ZMAX, NDIFF
     3  FORMAT(II,2F4.0,I4)
        IF(NGO)19, 19, 18
    18  IF(NGO-2)999, 17, 17
    19  CONTINUE
        IF(NDIFF)20, 20, 21
    20  NDIFF=10
    21  MIN=ZMIN+C
        MAX=ZMAX+C
```

SHEAR 08/
EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
      IF(NI)5, 5, 101
C     TRAIL DATA INPUT
    5 READ     (2,6)MYEAR, MONTH, JOUR, LTIME, Z, WIND, AZDEG

    6 FORMAT(3I3, I5, F5.1, 2F5.C)
      IF(MYEAR)100,100, 7
    7 I=I+1
      IF(I-1)11, 11, 8
    8 ZDIFF=Z-ZI(I-1)
      MZ=10.0*Z+C
      LZ=10.0*ZI(I-1)+C
      LDIFF=MZ-LZ
      IF(LDIFF-2)12, 11, 9
   12 WRITE    (3,6)MYEAR, MONTH, JOUR, LTIME, Z, WIND, AZDEG
      WRITE(3,13)
   13 FORMAT(1X/////1X26HDATA CARDS OUT OF SEQUENCE//////1X20HEXECUTION
     1TERMINATED//////1X)
      PRINT 13
      CALL EXIT
C     INTERPOLATION ROUTINE
    9 NPOINT=LDIFF/2-1
      NSUM=NSUM+NPOINT
      GRAD=(WIND - WINDI(I-1) )/ZDIFF
      AZDIFF=AZDEG/57.3-AZRADI(I-1)
      IF(ABS(AZDIFF)-PI)94,94,91
   91 IF(AZDIFF)92,94,93
   92 AZDIFF=AZDIFF+TWOPI
      GOTO94
   93 AZDIFF=AZDIFF-TWOPI
   94 AZGRAD=AZDIFF/ZDIFF
      DO10J=1,NPOINT
      ZI(I)=ZI(I-1)+0.2
      WINDI(I)=WINDI(I-1)+C.2*GRAD
      AZRADI(I)=AZRADI(I-1)+C.2*AZGRAD
      IF(AZRADI(I))95,96,96
   95 AZRADI(I)=AZRADI(I)+TWOPI
   96 IF(AZRADI(I)-TWOPI)98,98,97
   97 AZRADI(I)=AZRADI(I)-TWOPI
   98 CONTINUE
      I=I+1
   10 CONTINUE
   11 ZI(I)=Z
      WINDI(I)=WIND
      AZRADI(I)=AZDEG/57.3
      GO TO 5
  100 NI=I
C     ALL DATA IN.  COMMENCE COMPUTATION
      HDIFF=ZI(NI)-ZI(1)
      HPLUS=ZI(NI)+ZI(1)
C     CALCULATE ZONAL AND MERIDIONAL WIND COMPONENTS
      DO201J=1,NI
      ZONAL(J)=WINDI(J)*SIN(AZRADI(J))
  201 ERID(J)=WINDI(J)*COS(AZRADI(J))
  101 NZ=0
      LMIN=10*MIN
      LMAX=10*MAX
```

```
          SHEAR                                                              08/
        EXTERNAL FORMULA NUMBER  —  SOURCE STATEMENT  —  INTERNAL
      CALL PAGE (RESULT, ZERO)
      DO104J=1,NI
      LZ=ZI(J)*10.0+C
      IF(LZ-LMIN)104,102,102
  102 IF(LZ-LMAX)103,103,104
  103 NZ=NZ+1
  104 CONTINUE
      WRITE      (3,105)NI, NSUM, ZMIN, ZMAX, NZ, NP, NQ
  105 FORMAT(1X/////1X33HTOTAL NUMBER OF INPUT DATA POINTS I8///1X26HINC
     1LUDING INTERPOLATION OF 15,7H POINTS ////1X45HNUMBER OF DATA POINT
     2S WITHIN THE HEIGHT RANGE F5.0,6H KM TO,F5.0,3H KM I8////1X31HEAST
     3 WEST PROFILE SPECIFICATION I5 ///1X33HNORTH SOUTH PROFILE SPECIFI
     4CATION I3 ///1X)
      START=1
      CALL PAGE (RESULT, START)
      WRITE      (3,106)ZMIN, ZMAX
  106 FORMAT(1X50HCALCULATED ZONAL AND MERIDIONAL MEAN WIND PROFILES
     110X12HHEIGHT RANGE F5.0,6H KM TO F5.0,3H KM/1HO
     2/10X 6HHEIGHT 10X5HZONAL 12X10HMERIDIONAL 10X10HWIND SPEED /1X/
     31X,18X,3(4X12HDATA      MEAN,4X) /1X/)
      NHITE=(ZMAX-ZMIN)/20 0-C
      NHITE=NHITE+1
      INK=5*NHITE-1
      NFIT=NFIT+1
      IF(NFIT)202,202,203
C     CALCULATE COEFFICIENTS OF MEAN PROFILE POLYNOMIALS
  202 CALL NORMAL (ZONAL, ERID, ZI, NI, BZ, BM, NP, NQ)
  203 CONTINUE
C     DETERMINE AND PR      CUT MEAN WIND PROFILES
      SUBS=(ZMAX+ZMIN-ZI(1))*5.0+1.0+C
      DO108L=MIN, MAX, NHITE
      IZ=SUBS-FLOAT(L*5)
      J=MAX+MIN-L
      H=J
      S=(2.0*H-HPLUS)/HDIFF+CS
      AZONAL=0.0
      AMERID=0.0
      DO204M=1,10
      AZONAL=AZONAL+BZ(M)*S**(M-1)
      AMERID=AMERID+BM(M)*S**(M-1)
  204 CONTINUE
      MZONAL=AZONAL
      MMERID=AMERID
      MSPEED=SQRT(AZONAL**2+AMERID**2)
      WRITE(3,107)J, ZONAL(IZ), MZONAL, ERID(IZ), MMERID, WINDI(IZ), MSPEED
  107 FORMAT(1XI13,4X,3( F8.0,4XI14,4X),/1X)
  108 CONTINUE
      CALL PAGE (RESULT, START)
      WRITE(3,109)ZMIN, ZMAX
  109 FORMAT(1X,22HTURBULENT WIND PROFILE, 10X12HHEIGHT RANGE F5.0,
     1 6HKM TO F5.0, 3H KM/1X/1X, 10X6HHEIGHT, 10X6HTZONAL, 10X11HTMERIDIONA
     2L, 10X6HTSPEED/1X)
C     DETERMINE AND PRINT CUT TURBULENT WIND PROFILES
      NH=(MAX-MIN)*5+1
      K=(ZMAX-ZI(1))*5.0+2.0+C
      NK=INK
```

SHEAR 087

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
      RMSZ=0.0
      RMSM=0.0
      RMST=0.0
      SUMSQT=0.0
      DO112J=1,NP
      TZONAL(J)=0.0
      TMERID(J)=0.0
      K=K-1
      H=ZMAX-0.2*FLOAT(J-1)
      IH=H+0
      S=(2.0*H-HPLUS)/HDIFF+CS
      NK=NK+1
      DO205M=1,10
      TZONAL(J)=TZONAL(J)+BZ(M)*S**(M-1)
      TMERID(J)=TMERID(J)+BM(M)*S**(M-1)
  205 CONTINUE
      TZONAL(J)=ZONAL(K)-TZONAL(J)
      TMERID(J)=ERID(K)-TMERID(J)
      CALL TRADE(J,K)
C     CALCULATE RMS TURBULENT VELOCITIES FOR THE HEIGHT RANGE ZMIN/ZMAX
      RMSZ=TZONAL(J)**2+RMSZ
      RMSM=TMERID(J)**2+RMSM
      RMST=TSPEED(J)**2+RMST
      SUMSQT=SUMSQT+1.0
      IF(NK-INK)112,112,110
  110 WRITE(3,111)IH, TZONAL(J), TMERID(J), TSPEED(J)
  111 FORMAT(1X, 10X14, 12XF5.0, 11XF8.0, 13XF5.0/1X)
      NK=0
  112 CONTINUE
      CALL PAGE(RESULT, START)
      RMSZ=SQRT(RMSZ/SUMSQT)
      RMSM=SQRT(RMSM/SUMSQT)
      RMST=SQRT(RMST/SUMSQT)
      WRITE (3,206)ZMIN, ZMAX, (BZ(I), I=1, NP)
  206 FORMAT(1X10HNORMALIZED
     1       1X12HHEIGHT RANGE 10XF7.0,7H KM. TO F7.0, 4H KM./1H0/
     2       1X42HCOEFFICIENTS GIVING BEST FIT TO ZONAL DATA/1X/10E11.3)
      WRITE(3,207)(BM(I),I=1,NQ)
  207 FORMAT(1X/1X/
     11X/1X47HCOEFFICIENTS GIVING BEST FIT TO MERIDIONAL DATA/1X/1X10E11
     2.3/1X/)
      WRITE(3,208)RMSZ, RMSM, RMST
  208 FORMAT(1X/1X
     1     1X22HRMS TURBULENT VELOCITY/1X/1X10X5HZONALF11.0,11HMETRES/S
     2E0./1X/1X10X10HMERIDIONAL F6.0,11HMETRES/SEC./1X/1X10X10HWIND SPEE
     3D F6.0,11HMETRES/SEC.)
      CALL PAGE(RESULT, START)
      WRITE      (3,113)ZMIN,ZMAX
  113 FORMAT(1X46HENERGY SPECTRUM OF ZONAL WIND HEIGHT VARIATION,
     110X12HHEIGHT RANGE F5.0,6H KM TO F5.0,3H KM/1X)
C     CALCULATE AND OUTPUT ENERGY SPECTRUM FUNCTIONS
      CALL OUTPUT(TZONAL, NH, NDIFF)
      CALL PAGE (RESULT, START)
      WRITE      (3,114) ZMIN, ZMAX
  114 FORMAT(1X51HENERGY SPECTRUM OF MERIDIONAL WIND HEIGHT VARIATION,
```

SHEAR 08/
EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
      CALL PAGE(RESULT, ZERO)
      DO104J=1,NI
      LZ=ZI(J)*10.0+C
      IF(LZ-LMIN)104,102,102
  102 IF(LZ-LMAX)103,103,104
  103 NZ=NZ+1
  104 CONTINUE
      WRITE     (3,105)NI, NSUM, ZMIN, ZMAX, NZ, NP, NQ
  105 FORMAT(1X/////1X33HTOTAL NUMBER OF INPUT DATA POINTS I8///1X26HINC
     1LUDING INTERPOLATION OF 15,7H POINTS ////1X45HNUMBER OF DATA POINT
     2S WITHIN THE HEIGHT RANGE F5.0,6H KM TO,F5.0,3H KM I8////1X31HEAST
     3 WEST PROFILE SPECIFICATION I5 ///1X33HNORTH SOUTH PROFILE SPECIFI
     4CATION 13 ///1X)
      START=1
      CALL PACE(RESULT,START)
      WRITE     (3,106)ZMIN, ZMAX
  106 FORMAT(1X50HCALCULATED ZONAL AND MERIDIONAL MEAN WIND PROFILES
     110X12HHEIGHT RANGE F5.0,6H KM TO F5.0,3H KM/1HO
     2/10X 6HHEIGHT 10X5HZONAL 13X10HMERIDIONAL 10X10HWIND SPEED /1X/
     31X,18X,3(4X12HDATA       MEAN,4X),/1X/)
      NHITE=(ZMAX-ZMIN)/20.0-C
      NHITE=NHITE+1
      INK=5*NHITE-1
      NFIT=NFIT+1
      IF(NFIT)202,202,203
C     CALCULATE COEFFICIENTS OF MEAN PROFILE POLYNOMIALS
  202 CALL NORMAL (ZONAL, ERID, ZI, NI, BZ, BM, NP, NQ)
  203 CONTINUE
C     DETERMINE AND PRINT CUT MEAN WIND PROFILES
      SUBS=(ZMAX+ZMIN-ZI(1))*5.0+1.0+C
      DO108L=MIN, MAX, NHITE
      IZ=SUBS-FLOAT(L*5)
      J=MAX+MIN-L
      H=J
      S=(2.0*H-HPLUS)/HDIFF+CS
      AZONAL=0.0
      AMERID=0.0
      DO204M=1,10
      AZONAL=AZONAL+BZ(M)*S**(M-1)
      AMERID=AMERID+BM(M)*S**(M-1)
  204 CONTINUE
      MZONAL=AZONAL
      MMERID=AMERID
      MSPEED=SQRT(AZONAL**2+AMERID**2)
      WRITE(3,107)J, ZONAL(IZ), MZONAL, ERID(IZ), MMERID, WINDI(IZ),MSPEED
  107 FORMAT(1XI13,4X,3(  F8.C,4XI4,4X),/1X)
  108 CONTINUE
      CALL PAGE (RESULT, START)
      WRITE(3,109)ZMIN, ZMAX
  109 FORMAT(1X,22HTURBULENT WIND PROFILE, 10X12HHEIGHT RANGE F5.0,
     1 6HKM TO F5.0,3H KM/1X/1X,10X6HHEIGHT, 10X6HTZONAL, 10X11HTMERIDIONA
     2L,10X6HTSPEED/1X)
C     DETERMINE AND PRINT CUT TURBULENT WIND PROFILES
      NH=(MAX-MIN)*5+1
      K=(ZMAX-ZI(1))*5.0+2.0+C
      NK=INK
```

SHEAR 08/

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
      RMSZ=0.0
      RMSM=0.0
      RMST=0.0
      SUMSQT=0.0
      DO112J=1,NH
      TZONAL(J)=0.0
      TMERID(J)=0.0
      K=K-1
      H=ZMAX-0.2*FLOAT(J-1)
      IH=H+C
      S=(2.0*H-HPLUS)/HDIFF+CS
      NK=NK+1
      DO205M=1,10
      TZONAL(J)=TZONAL(J)+BZ(M)*S**(M-1)
      TMERID(J)=TMERID(J)+BM(M)*S**(M-1)
  205 CONTINUE
      TZONAL(J)=ZONAL(K)-TZONAL(J)
      TMERID(J)=ERID(K)-TMERID(J)
      CALL TRADE(J,K)
C     CALCULATE RMS TURBULENT VELOCITIES FOR THE HEIGHT RANGE ZMIN/ZMAX
      RMSZ=TZONAL(J)**2+RMSZ
      RMSM=TMERID(J)**2+RMSM
      RMST=TSPEED(J)**2+RMST
      SUMSQT=SUMSQT+1.0
      IF(NK-INK)112,112,110
  110 WRITE(3,111)IH,TZONAL(J),TMERID(J),TSPEED(J)
  111 FORMAT(1X,10XI4,12XF5.0,11XF8.0,13XF5.0/1X)
      NK=0
  112 CONTINUE
      CALL PAGE (RESULT, START)
      RMSZ=SQRT(RMSZ/SUMSQT)
      RMSM=SQRT(RMSM/SUMSQT)
      RMST=SQRT(RMST/SUMSQT)
      WRITE(3,206)ZMIN,ZMAX,(BZ(I),I=1,NP)

  206 FORMAT(1X10HNORMALIZED
     1         1X12HHEIGHT RANGE 10XF7.0,7H KM.  TO F7.0,4H KM./1H0/
     2         1X42HCOEFFICIENTS GIVING BEST FIT TO ZONAL DATA/1X/10E11.3)
      WRITE(3,207)(BM(I),I=1,NQ)
  207 FORMAT(1X/1X/
     11X/1X47HCOEFFICIENTS GIVING BEST FIT TO MERIDIONAL DATA/1X/1X10E11
     2.3/1X/)
      WRITE(3,208)RMSZ, RMSM, RMST
  208 FORMAT(1X/1X
     1       1X22HRMS TURBULENT VELOCITY/1X/1X10X5HZONALF11.0,11HMETRES/S
     2EC./1X/1X10X10HMERIDIONAL F6.0,11HMETRES/SEC./1X/1X10X10HWIND SPEE
     3D F6.0,11HMETRES/SEC.)
      CALL PAGE (RESULT, START)
      WRITE    (3,113)ZMIN, ZMAX
  113 FORMAT(1X46HENERGY SPECTRUM OF ZONAL WIND HEIGHT VARIATION,
     110X12HHEIGHT RANGE F5.0,6H KM TO F5.0,3H KM/1X)
C     CALCULATE AND OUTPUT ENERGY SPECTRUM FUNCTIONS
      CALL OUTPUT(TZONAL, NH, NDIFF)
      CALL PAGE (RESULT, START)
      WRITE    (3,114) ZMIN, ZMAX
  114 FORMAT(1X51HENERGY SPECTRUM OF MERIDIONAL WIND HEIGHT VARIATION,
```

SHEAR 08/

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL

```
  110X12HHEIGHT RANGE F5.0,6H KM TO F5.0, 3H KM/1X)
   CALL OUTPUT(TMERID, NH, NDIFF)
   CALL PAGE (RESULT, START)
   WRITE      (3,115)ZMIN,ZMAX
115 FORMAT(1X46HENERGY SPECTRUM OF WIND SPEED HEIGHT VARIATION,
  110X12HHEIGHT RANGE F5.0,6H KM TO F5.0,3H KM/1X)
   CALL OUTPUT(TSPEED, NH, NDIFF)
   GOTO2
   END
```

```
/$ID JO2T          RGR    BLDG 11
 $PAUSE
 $EXECUTE          IBJOB
 IBJOB VERSION 2,  7090 - PP - 929
1

0
 $IBJOB          GO
 $IBFTC OUT      M94,XR7
1                OUT
           EXTERNAL FORMULA NUMBER  —  SOURCE STATEMENT  —  INTERN
0
      SUBROUTINE OUTPUT(TSPEED,NH,NDIFF)
C
C     PRODUCES HEIGHT SPECTRUM AND PERFORMS CORRELATION ANALYSIS.
C
      DIMENSION TSPEED(750)
      WRITE(3,1)
    1 FORMAT(1X,10X7HDELTA H,5X10HE(DELTA H),
     15X11HCORRELATION,3X13HSIGNIF     1-G   /1X)
      NEND=5*NDIFF
      LINE=0
      DO125K=1,NEND
      LINE=LINE+1
      DELTAH=FLOAT(K)*0.2
      SUM=0.0
      ENERGY=0.0
      ERGX=0.0
      GJPKXJ=0.0
      SQJ=0.0
      SQJPK=0.0
      DO123J=1,NH
      IF(NH-J-K)124,122,122
  122 JPK=J+K
      ENERGY=ENERGY+(TSPEED(JPK)-TSPEED(J))**2
      SUM=SUM+1.0
      GJPKXJ=GJPKXJ+TSPEED(JPK)*TSPEED(J)
      SQJ=SQJ+TSPEED(J)**2
      SQJPK=SQJPK+TSPEED(JPK)**2
  123 CONTINUE
  124 IF(SUM)117,117,118
  117 G=0.0
      SIGNIF=9.99
      GOTO119
  118 ENERGY=ENERGY/SUM
      G=GJPKXJ/SQRT(SQJ*SQJPK)
      SIGNIF=(1.0-G**2)/SQRT(SUM-1.0)
  119 DIFF=1.0-G
      IF(LINE-50)125,125,116
  116 WRITE(3,2)
    2 FORMAT(1H1/1X)
      WRITE(3,1)
      LINE=0
  125 WRITE(3,115)DELTAH,ENERGY,       G,SIGNIF,DIFF
  115 FORMAT(1X,6XF8.1,  7XF8.1 ,8XF8.3,F11.3,F8.2)
      RETURN
      END
```

```
$IBJOB          GO
$IBFTC NORMAL   M94,XR7
```

```
              NORMAL
           EXTERNAL FORMULA NUMBER   —   SOURCE STATEMENT   —   INTE

       SUBROUTINE NORMAL (ZONAL,ERID,ZI,NI,BZ,BM,NP,NQ)
C
C      DETERMINES BEST FIT PROFILE TO THE NORMALIZED TOTAL HEIGHT RANG
C
       DIMENSION ZONAL(750),ERID(750),ZI(750),BZ(1C),BM(1C),ZINORM(750
       DO1J=1,NI
       ZINORM(J)=(2.0*ZI(J)-ZI(NI)-ZI(1))/(ZI(NI)-ZI(1))
     1 CONTINUE
       CALL FIT (ZONAL,NP,BZ,NI,ZINORM)
       CALL FIT (ERID, NQ,BM,NI,ZINORM)
       RETURN
       END
```

```
$IBJOB          GO
$IBFTC TRADE    M94,XR7
```

```
              TRADE                                                      08/
           EXTERNAL FORMULA NUMBER   —   SOURCE STATEMENT   —   INTERNAL

       SUBROUTINE TRADE(J,K)
C
C      CALCULATES TURBULENT WINDSPEED PROFILE
C
       DIMENSION ZI(750)
       DIMENSION WINDI(750),AZRADI(750),ZONAL(750),ERID(750),TZONAL(750),
      1TMERID(750),TSPEED(750)
       COMMON ZI, WINDI,AZRADI,ZONAL,ERID,TZONAL,TMERID,TSPEED
       TSPEED(J)=WINDI(K)-SQRT((ZONAL(K)-TZONAL(J))**2+(ERID(K)-TMERID(J)
      1)**2)
       RETURN
       END
```

08/17

```
$IBFTC FIT      M94,XR7
```

```
           FIT                                                          08/17
      EXTERNAL FORMULA NUMBER -- SOURCE STATEMENT -- INTERNAL FO

      SUBROUTINE FIT (BLOW,NSPEC,A,N,X)
C
C     FITS A HEIGHT PROFILE SPECIFIED BY NSPEC TO THE MEASURED DATA
C     BLOW, DETERMINING THE COEFFICIENTS A BY THE METHOD OF LEAST
C     SQUARES.  PROFILE FITTED OVER TOTAL HEIGHT RANGE OF INPUT DATA.
C
      DIMENSION BLOW(750), A(10), X(750), S(10,11)
      DO3J=1,10
    3 A(J)=0.0
      IF(NSPEC)100,100,4
    4 NADD=NSPEC+1
      DO10J=1,NSPEC
      DO10K=1,NADD
   10 S(J,K)=0.0
      DO5J=1,NSPEC
      DO5K=1,NSPEC
      DO5I=1,N
    5 S(J,K)=S(J,K)+X(I)**(K+J-2)
      DU6J=1,NSPEC
      K=0
      DO6I=1,N
      K=K+1
    6 S(J,NADD)=S(J,NADD)+X(I)**(J-1)*BLOW(K)
      CALL MATS(S,A,NSPEC,MISS)
      IF(MISS)100,100,7
    7 WRITE(3,8)
    8 FORMAT(1X75HERROR IN INPUT DATA HAS RESULTED IN MATRIX S BEING UNS
     1UITABLE FOR INVERSION ////1X20HEXECUTION TERMINATED ///////)
      PRINT 8
      CALL EXIT
  100 RETURN
      END
```

MATS 08/17

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL FO

```
      SUBROUTINE MATS (S,A,NSPEC,MISS)
C
C     REDUCES THE AUGMENTED MATRIX S TO PRODUCE THE COEFFICIENTS A
C
      DIMENSION S(10,11), A(10)
      MISS=-1
      MM=NSPEC+1
      N=NSPEC
      DO15I=2,N
   70 II=I-1
    7 DO15J=1,II
    8 IF(S(I,J))9,15,9
    9 IF(ABS(S(J,J))-ABS(S(I,J)))11,10,10
   10 R=S(I,J)/S(J,J)
      GOTO 130
   11 R=S(J,J)/S(I,J)
      DO12K=1,MM
      B=S(J,K)
      S(J,K)=S(I,K)
   12 S(I,K)=B
  130 JJ=J+1
   13 DO14K=JJ,MM
   14 S(I,K)=S(I,K)-R*S(J,K)
   15 CONTINUE
      IF(ABS(S(N,N))-1.0E-10)16,16,17
   16 MISS=+1
      GOTO29
   17 A(N)=S(N,MM)/S(N,N)
      DO28I=2,N
      JJ=N-I+1
      B=0.0
      II=N-I+2
      DO25K=II,N
   25 B=B+S(JJ,K)*A(K)
      IF(ABS(S(JJ,JJ))-1.0E-10)16,16,28
   28 A(JJ)=(S(JJ,MM)-B)/S(JJ,JJ)
   29 RETURN
      END
```

08/17

```
$IBFTC MATS      M94,XR7
```

08/17

```
$IBFTC PAGE      M94,XR7
```

PAGE 08/17

EXTERNAL FORMULA NUMBER — SOURCE STATEMENT — INTERNAL FO

```
      SUBROUTINE PAGE (RESULT, START)
C
C     TURNS PAGE, NUMBERS IT, AND WRITES HEADING AS APPEARING
C     ON RESULT CARD.
C
      DIMENSION RESULT (12)
      IF(START)1,1,2
    1 NOP=0
    2 NOP=NOP+1
      WRITE  (3,3) RESULT, NOP
    3 FORMAT (1H1/1X12A6,30X4HPAGE15//)
      RETURN
      END
```

APPENDIX III

Sample Data And Computer Output

PRELIMINARY PAPER EGLIN DATA, MAY 21, 1963. 16/9/64. PROFILE,5,5.

5	5					
80	100					
63	5	21	1910	69.0	34	255
63	5	21	1910	70.6	31	256
63	5	21	1910	71.0	27	270
63	5	21	1910	72.4	43	272
63	5	21	1910	72.6	20	290
63	5	21	1910	77.0	41	256
63	5	21	1910	80.4	25	358
63	5	21	1910	82.0	08	310
63	5	21	1910	82.4	28	202
63	5	21	1910	83.6	27	200
63	5	21	1910	84.0	54	190
63	5	21	1910	85.0	54	194
63	5	21	1910	85.4	30	108
63	5	21	1910	88.0	60	080
63	5	21	1910	91.6	76	095
63	5	21	1910	95.0	50	178
63	5	21	1910	96.0	40	120
63	5	21	1910	96.6	54	150
63	5	21	1910	97.6	40	115
63	5	21	1910	99.0	42	084
63	5	21	1910	99.6	64	078
63	5	21	1910	100.0	58	070
63	5	21	1910	100.8	65	069
63	5	21	1910	102.0	80	079
63	5	21	1910	103.0	93	094

63	5	21	1910	104.0	115	104	
63	5	21	1910	104.2	111	120	
63	5	21	1910	105.0	129	122	
63	5	21	1910	105.6	140	130	
63	5	21	1910	105.8	130	128	
63	5	21	1910	107.0	125	132	
63	5	21	1910	108.0	92	140	
63	5	21	1910	109.0	50	160	
63	5	21	1910	110.0	42	240	
63	5	21	1910	111.0	56	250	
63	5	21	1910	113.0	60	262	
63	5	21	1910	114.0	84	274	
63	5	21	1910	115.0	68	270	
63	5	21	1910	117.2	72	282	
63	5	21	1910	125.0	45	286	
63	5	21	1910	130.0	30	296	
63	5	21	1910	135.0	14	310	
63	5	21	1910	140.0	15	316	
							← BLANK CARD
7 8							← EOF

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. 15/9/64. PROFILE,5 5.

TOTAL NUMBER OF INPUT DATA POINTS 356

INCLUDING INTERPOLATION OF 313 POINTS

NUMBER OF DATA POINTS WITHIN THE HEIGHT RANGE 80. KM TO 100. KM 101

EAST WEST PROFILE SPECIFICATION 5

NORTH SOUTH PROFILE SPECIFICATION 5

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. CONTINUOUS PROFILE,5,5.

CALCULATED ZONAL AND MERIDIONAL MEAN WIND PROFILES HEIGHT RANGE

HEIGHT	ZONAL		MERIDIONAL		WIND SPEED	
	DATA	MEAN	DATA	MEAN	DATA	MEAN
100	70.	34	20.	−21	72.	40
99	56.	37	21.	−21	60.	43
98	42.	39	4.	−22	42.	45
97	39.	41	−11.	−22	41.	47
96	34.	43	−35.	−22	48.	49
95	31.	45	−28.	−22	42.	50
94	6	46	−51.	−22	52.	51
93	31.	46	−51.	−21	59.	51
92	55.	47	−38.	−21	67.	51
91	73.	47	−13.	−21	74.	51
90	72.	46	−1.	−20	72.	50
89	67.	45	4.	−19	67.	49
88	62.	43	8.	−18	63.	47
87	55.	41	5.	−18	55.	45
86	44.	39	−4.	−16	44.	43
85	31.	36	−9.	−15	32.	39
84	−12.	33	−53.	−14	54.	36
83	−9.	29	−25.	−13	27.	32
82	−10.	24	−26.	−11	28.	27
81	−8.	19	10.	−10.	12.	22
80	−3.	14	23.	−8	23.	16

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. CONTINUOUS PROFILE,5,5.

TURBULENT WIND PROFILE HEIGHT RANGE 80. KM TO 100. KM

HEIGHT	TZONAL	TMERIDIONAL	TSPEED
100	35.	41.	42.
99	19.	42.	26.
98	2.	26.	16.
97	−3.	11.	31.
96	−10.	−12.	32.
95	−14.	−6.	29.
94	−40.	−29.	8.
93	−16.	−29.	31.
92	8.	−16.	58.
91	26.	8.	62.
90	25.	19.	52.
89	22.	24.	45.
88	18.	27.	38.
87	13.	24.	33.
86	4.	13.	30.
85	−6.	7.	27.
84	−45.	−38.	18.
83	−39.	−12.	−5.
82	−35.	−14.	0.
81	−28.	20.	3.
80	−18.	31.	10.

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. 15/9/64. PROFILE,5,5.

NORMALIZED HEIGHT RANGE 80. KM. TO 100. KM.

COEFFICIENTS GIVING BEST FIT TO ZONAL DATA

0.386E 02 −0.126E 03 −0.244E 03 0.174E 03 0.205E 03

COEFFICIENTS GIVING BEST FIT TO MERIDIONAL DATA

−0.304E 02 0.198E 02 0.148E 03 −0.168E 02 −0.125E 03

RMS TURBULENT VELOCITY

ZONAL	22. METRES/SEC.
MERIDIONAL	23. METRES/SEC.
WIND SPEED	17. METRES/SEC.

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. CONTINUOUS PROFILE,5,5.

ENERGY SPECTRUM OF ZONAL WIND HEIGHT VARIATION HEIGHT RANGE 80.

DELTA H	DELTA V**2	CORRELATION	SIGNIF	I-G
0.2	24.3	0 979	0.004	0.02
0.4	64.9	0.943	0.011	0 06
0.6	113.7	0.900	0.019	0.10
0.8	169.4	0.851	0.028	0.15
1.0	230.7	0.797	p 037	0.20
1.2	297.1	0 739	0.047	0.26
1.4	369.4	0.676	0.056	0.32
1.6	450.4	0.604	0.066	0.40
1.8	534.8	0.525	0.076	0.47
2.0	619.9	0.449	0.084	0.55
2.2	703.2	0.374	0.091	0.63
2.4	789.0	0 297	0.097	0.70
2.6	877.1	0.217	0.102	0.78
2.8	964.9	0.136	0.106	0.86
3.0	1054.0	0.053	0.108	0.95
3.2	1133.4	−0.023	0.109	1.02
3.4	1209.9	−0.099	0.109	1.10
3.6	1285.2	−0.176	0.107	1.18
3.8	1360.8	−0.257	0.104	1.26
4.0	1436.0	−0.342	0.099	1 34
4.2	1507.0	−0.429	0.092	1.43
4.4	1567.1	−0.514	0.083	1.51
4.6	1614.3	−0.597	0.073	1.60
4.8	1681.4	−0.651	0.066	1.65
5.0	1745.7	−0 696	0.060	1.70
5.2	1804.0	−0.735	0.053	1 74
5.4	1852.3	−0.766	0.048	1.77
5.6	1885.5	−0.788	0.045	1.79
5.8	1897.3	−0.800	0.043	1.80
6.0	1880.3	−0.801	0.043	1.80
6.2	1863.6	−0.795	0.044	1.80
6.4	1847.4	−0.783	0.047	1.78
6.6	1827.7	−0.762	0.051	1.76
6.8	1803.8	−0.730	0.057	1.73
7.0	1775.0	−0.690	0.065	1.69
7.2	1740.9	−0.642	0.073	1.64
7.4	1701.2	−0.588	0.082	1.59
7.6	1656.5	−0.528	0.092	1.53
7.8	1608.4	−0.466	0.100	1.47
8.0	1555.6	−0.401	0.108	1.40
8.2	1497.1	−0.333	0.116	1.33
8.4	1432.6	−0.263	0.122	1.26
8.6	1361.9	−0.190	0.128	1.19
8.8	1285.1	−0.116	1.132	1.12
9.0	1202.6	−0.040	0.135	1.04
9.2	1114.7	0.038	0.136	0.96
9.4	1020.5	0.120	0.135	0.88
9.6	920.9	0.207	0.133	0.79
9.8	819.6	0.296	0.128	0.70
10.0	733.6	0.372	0.122	0.63

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. CONTINUOUS PROFILE,5,5.

ENERGY SPECTRUM OF MERIDIONAL WIND HEIGHT VARIATION HEIGHT RANGE

DELTA H	DELTA V**2	CORRELATION	SIGNIF	I–G
0.2	31.3	0.973	0.005	0.03
0.4	94.1	0.917	0.916	0.08
0.6	164.4	0.853	0.028	0.15
0.8	241.7	0.781	0.040	0.22
1.0	326.3	0.701	0.052	0.30
1.2	418.3	0.612	0.064	0.39
1.4	515.2	0.518	0.076	0.48
1.6	616.0	0.420	0.086	0.58
1.8	723.6	0.316	0.094	0.68
2.0	825.3	0.219	0.100	0.78
2.2	935.1	0.116	0.105	0.88
2.4	1052.2	0.008	0.107	0.99
2.6	1175.9	−0.104	0.106	1.10
2.8	1305.7	−0.219	0.103	1.22
3.0	1429.3	−0.325	0.097	1.33
3.2	1534.6	−0.411	0.091	1.41
3.4	1614.7	−0.479	0.085	1.48
3.6	1667.7	−0.535	0 079	1.54
3.8	1711.0	−0.582	0.074	1.58
4.0	1741.1	−0.617	0.069	1.62
4.2	1756.8	−0.641	0.066	1.64
4.4	1758.3	−0.656	0.065	1.66
4.6	1745.6	−0.662	0.064	1.66
4.8	1776.6	−0.680	0.062	1.68
5.0	1836.6	−0.715	0.056	1.72
5.2	1878.5	−0.733	0.054	1.73
5.4	1900.7	−0.735	0.054	1.74
5.6	1902.8	−0.723	0.056	1.72
5.8	1885.6	−0.699	0.061	1.70
6.0	1853.4	−0.666	0.066	1.67
6.2	1809.8	−0.625	0.073	1.63
6.4	1751.9	−0.573	0.081	1.57
6.6	1679.1	−0.510	0.090	1.51
6.8	1592.6	−0.435	0.100	1.44
7.0	1494.3	−0.350	0.109	1.35
7.2	1385.9	−0.257	0.117	1.26
7.4	1269.8	−0.156	0.123	1.16
7.6	1149.0	−0.051	0.127	1.05
7.8	1028.4	0.057	0.128	0.94
8.0	912.5	0.164	0.126	0.84
8.2	802.4	0.266	0.121	0.73
8.4	697.1	0.366	0.114	0.63
8.6	598.6	0.459	0.105	0.54
8.8	508.4	0.544	0.094	0.46
9.0	427.7	0.620	0.083	0.38
9.2	357.9	0.684	0.072	0.32
9.4	302.8	0.735	0.063	0.27
9.6	260.1	0.774	0.056	0.23
9.8	231.1	0.801	0.050	0.20
10.0	219.4	0.812	0.048	0.19

TRIAL ANALYSIS. EGLIN DATA, MAY 21, 1963. CONTINUOUS PROFILE,5,5.

ENERGY SPECTRUM OF WIND SPEED HEIGHT VARIATION HEIGHT RANGE 80.

DELTA H	DELTA V**2	CORRELATION	SIGNIF	I-G
0.2	15.1	0.993	0.001	0.01
0.4	47.1	0.979	0.004	0.02
0.6	83.2	0.964	0.007	0.04
0.8	122.0	0.947	0 011	0.05
1.0	161.5	0.930	0.014	0.07
1.2	200.6	0.914	0.017	0.09
1.4	240.7	0.898	0.020	0 10
1.6	286.9	0.879	0.024	0.12
1.8	337.0	0.859	0.028	0.14
2.0	382.2	0.841	0.031	0.16
2.2	421.0	0.827	0.034	0.17
2.4	455.3	0.815	0 036	0.19
2.6	483.4	0.805	0.038	0.20
2.8	502.9	0.799	0.039	0.20
3.0	512.5	0.797	0.040	0.20
3.2	517.8	0.796	0.040	0.20
3.4	528.9	0.793	0.041	0.21
3.6	542.8	0.789	0.042	0.21
3.8	561.7	0.783	0.043	0.22
4.0	584.0	0.775	0.045	0.22
4.2	606.6	0.768	0.046	0 23
4.4	628.3	0.761	0.048	0.24
4.6	650.9	0.755	0.049	0.25
4.8	679.5	0.746	0.051	0.25
5.0	712.5	0.734	0.053	0 27
5.2	748.8	0.722	0.056	0.28
5.4	785.1	0.710	0.058	0.29
5.6	818.7	0.700	0.060	0.30
5.8	847.5	0.692	0.062	0.31
6.0	870.6	0.686	0.063	0.31
6.2	894.8	0.680	0.065	0.32
6.4	919.4	0.674	0.066	0.33
6.6	943.4	0.668	0.068	0.33
6.8	968.1	0.661	0.069	0.34
7.0	996.2	0.653	0.071	0.35
7.2	1023.8	0.645	0.073	0.35
7.4	1048.3	0.638	0.075	0.36
7.6	1070.2	0.630	0.077	0.37
7.8	1088.9	0.623	0.078	0.38
8.0	1103.4	0.616	0.080	0.38
8.2	1114.0	0.608	0.082	0.39
8.4	1121.1	0.600	0.084	0.40
8.6	1120.2	0.593	0.086	0.41
8.8	1114.6	0.588	0.087	0.41
9.0	1103.8	0.585	0.089	0.42
9.2	1087.7	0.584	0.090	0.42
9.4	1066.1	0.586	0.090	0.41
9.6	1039.0	0.590	0.090	0.41
9.8	1007.8	0.596	0.090	0.40
10.0	973.4	0.603	0.090	0.40

N64-31451

TEMPERATURE, PRESSURE, DENSITY, AND WIND MEASUREMENTS WITH THE ROCKET GRENADE EXPERIMENT, 1960-1963*

W. SMITH, L. KATCHEN, P. SACHER, P. SWARTZ, AND J. THEON

Complete data from 28 rocket grenade experiments at Wallops Island, Virginia, and Fort Churchill, Canada, are presented. Pressures, temperatures, densities, and winds have been derived directly from the recorded times of explosions and sound arrivals; but no attempt has been made to analyze the meteorological significance of these measurements. Error analyses on 16 of the Wallops experiments are also included.

INTRODUCTION

During the period 1960–1963 a total of 28 rocket grenade experiments were carried out by Goddard Space Flight Center at Wallops Island, Virginia, and Fort Churchill, Canada. It is the purpose of this report to present the complete data from these experiments. The data have been reduced but not analyzed, i.e., the physical measurements (pressure, density, temperature and winds) have been derived directly from recordings of the times of grenade explosions and sound arrivals, and from the rocket trajectories; but no attempt has been made to analyze the measurements for their meteorological significance. Rather, this report should be considered as a record of the unsmoothed, raw measurements which may serve as the basis of further investigation and interpretation of the structure of the atmosphere. This is the first such report since the program started in 1960. As the program continues, future results will be documented in similar fashion.

The grenade experiment is one of the several techniques employed in NASA's Meteorological Rocket Sounding Program, the objective of which is to obtain as representative as possible a sample of the synoptic structure of the mesosphere and lower ionosphere. In order to extend the findings over the widest possible geographic area, and perhaps eventually to attain a global network of soundings, the NASA launchings are coordinated whenever possible with soundings in other parts of the world. The instrumental details and methods of data reduction have been thoroughly described elsewhere.†

EXPERIMENTAL METHOD

One and two pound explosive charges (grenades) are carried aloft in the nosecone of a Nike-Cajun sounding rocket. The grenades are ejected and exploded at 4–6 km intervals. Either a precise radar such as the FPS–16 or a doppler tracking system, or both, are used to determine the rocket position and hence the exact position of the explosion. The time of the explosion is detected by small rocket borne infrared photocells and telemetered to the ground. A ground based array of hot wire microphones with frequency response peaked at 4 cycles per second is used to detect and record the sound waves from each exploding grenade. The measured experimental parameters are the times of the grenade explosions, the positions of the grenade explosions, and the times of arrival of the sound waves at the ground based microphones.

Elevation and azimuth angles are computed for each arriving sound wave front by applying a least-squares fit to the arrival times at the various microphones. Each wave is then analytically traced up through the atmosphere by means of Snell's law. Data from radiosonde ascents or

*Published as *NASA Technical Report* R-211, October 1964.

†Nordberg, W., and Smith W., "The Rocket Grenade Experiment," NASA Technical Note D–2107, March 1964.

from small meteorological rockets obtained at the time of the grenade soundings are used for this tracing up to the first explosion; above this, the results of the experiment itself are used for each successive explosion. This *apparent* position of the *wave* is then compared with the *known* position of the *wave source*, the grenade explosion. The amount by which the sound wave has been displaced horizontally from one explosion to the next is a measure of the average wind velocity vector in the layer between any two adjacent explosions. The average speed of the sound, and hence average temperature between two adjacent explosions, may also be determined. This analysis yields an altitude profile of temperatures and winds as a direct measurement. The temperature profile consists of discrete points, each representing an average value for an altitude layer between grenade explosions. It may be used to derive density and pressure profiles, if the pressure or density is known at a given level at the bottom of the temperature profile; and the latter data are available from the accompanying radiosonde. Pressure is calculated by use of the hydrostatic equation, and the ideal gas law; an integration is performed over the temperature profile starting at the known pressure. The density at any level is then computed from the pressure, temperature, and universal gas constant.

During the period between July 8, 1960 and December 7, 1963, 23 successful rocket grenade soundings were conducted from Wallops Island, Virginia (37° 50′N, 75° 29′W). In addition to offering excellent launch and tracking support, the geographical location of Wallops Island makes it a good middle-latitude observation site. Five soundings were conducted from a sub-arctic range, Fort Churchill, Canada, (58° 47′N, 94° 17′W) in the period between December 1962 and March 1963. Originally, it was planned to distribute

Table 1

Dates, Times, and Locations of GSFC Grenade Experiments 1960-1963

Date	Local Time	Location
8 July 1960	2259	Wallops Island
14 February 1961	1850	Wallops Island
16 February 1961	2126	Wallops Island
5 April 1961	0757	Wallops Island
5 May 1961	1800	Wallops Island
5 May 1961	2354	Wallops Island
13 July 1961	1707	Wallops Island
14 July 1961	1102	Wallops Island
20 July 1961	0530	Wallops Island
16 September 1961	1855	Wallops Island
1 March 1962	1901	Wallops Island
2 March 1962	0615	Wallops Island
23 March 1962	1854	Wallops Island
27 March 1962	1904	Wallops Island
17 April 1962	0428	Wallops Island
6 June 1962	2005	Wallops Island
7 June 1962	2053	Wallops Island
1 December 1962	1625	Wallops Island
4 December 1962	0105	Fort Churchill
6 December 1962	0032	Wallops Island
5 December 1962	2343	Fort Churchill
20 February 1963	1734	Fort Churchill
20 February 1963	1847	Wallops Island
28 February 1963	1547	Fort Churchill
28 February 1963	1711	Wallops Island
8 March 1963	1901	Wallops Island
8 March 1963	1801	Fort Churchill
7 December 1963	0812	Wallops Island

the number of firings about equally between the two sites, but a fire early in 1961 destroyed part of the Fort Churchill launch facility, and it was not operational again until November 1962. Table 1 lists the soundings conducted. Four of the recent firings from each site were conducted nearly simultaneously.

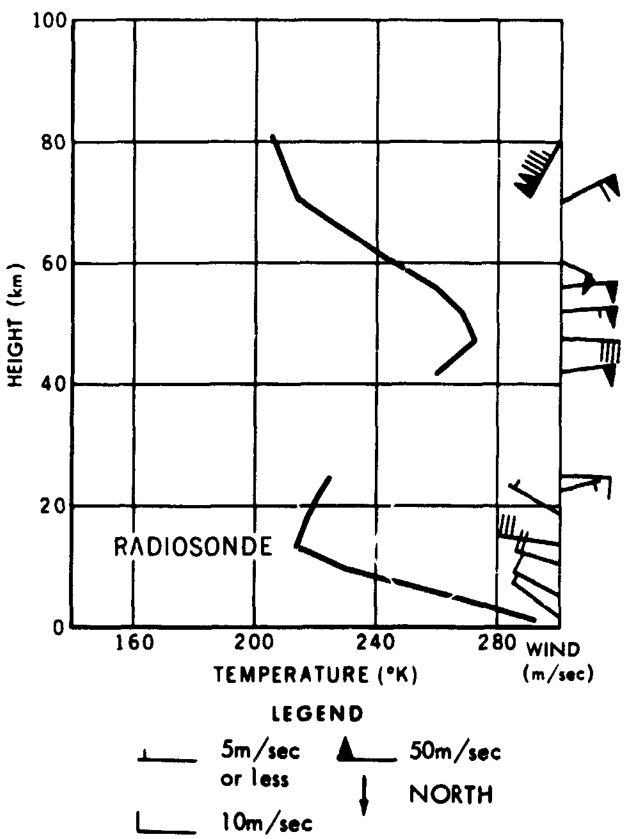
The results of the 28 soundings are presented in Figures 1 through 43. In Figures 1 through 28, the *directly measured* parameters of temperatures and winds are tabulated (actual computer printouts) in the columns on the left side of the page immediately above the graph. Tables of pressure and density *derived* from the temperature profiles are also shown. The temperatures were linearly interpolated between each of the measured points.

Winds and temperatures below 30 km obtained from radiosondes, and below 50 km from smaller meteorological sounding rockets (Arcas* and Hasp† whenever available) launched nearly

*"Data Report of the Meteorological Rocket Network, Spring 1961 Firings," U.S. Army Signal Missile Agency, White Sands Missile Range, New Mexico, September 1961.

†Private Communication from M. J. Parker, Naval Ordnance Laboratory, White Oak, Maryland.

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
82.256477	52.356449	259.43228	41659.187
93.878967	41.380489	272.74658	47575.437
85.262176	57.176998	268.03988	52210.906
84.192276	47.764659	259.17248	56140.277
116.43370	48.733200	244.54368	60321.136
63.638649	58.033428	213.90589	70569.476
208.64318	145.25718	205.61149	81196.117



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2543300	05	.2482000	04	.3835052	01-	.2254700	03
.2643300	05	.2137334	04	.3272117	01-	.2275630	03
.2743300	05	.1843137	04	.2796004	01-	.2296561	03
.2843300	05	.1591645	04	.2392689	01-	.2317491	03
.2943300	05	.1376346	04	.2050514	01-	.2338422	03
.3043300	05	.1191765	04	.1759771	01-	.2359352	03
.3143300	05	.1033298	04	.1512361	01-	.2380283	03
.3243300	05	.8970617	03	.1301517	01-	.2401213	03
.3343300	05	.7797774	03	.1121576	01-	.2422144	03
.3443300	05	.6786743	03	.9677938	02-	.2443075	03
.3543300	05	.5914055	03	.8361840	02-	.2464005	03
.3643300	05	.5159808	03	.7233967	02-	.2484936	03
.3743300	05	.4507097	03	.6266098	02-	.2505866	03
.3843300	05	.3941552	03	.5434443	02-	.2526797	03
.3943300	05	.3450925	03	.4718900	02-	.2547727	03
.4043300	05	.3024784	03	.4102479	02-	.2568658	03
.4143300	05	.2654210	03	.3570777	02-	.2589588	03
.4243300	05	.2331652	03	.3110230	02-	.2611737	03
.4343300	05	.2050637	03	.2712010	02-	.2634241	03
.4443300	05	.1805533	03	.2367629	02-	.2656746	03
,43300	05	.1591495	03	.2069427	02-	.2679251	03
. 343300	05	.1404367	03	.1810893	02-	.2701755	03
.4743300	05	.1240576	03	.1586474	02-	.2724260	03
.4843300	05	.1096353	03	.1404877	02-	.2718758	03
.4943300	05	.9685901	02	.1245812	02-	.2708605	03
.5043300	05	.8553499	02	.1104301	02-	.2698451	03
.5143300	05	.7550246	02	.9784574	03-	.2688297	03
.5243300	05	.6661352	02	.8674291	03-	.2675386	03
.5343300	05	.5872438	02	.7712033	03-	.2652820	03
.5443300	05	.5171588	02	.6849906	03-	.2630252	03
.5543300	05	.4549578	02	.6078186	03-	.2607686	03
.5643300	05	.3997722	02	.5395126	03-	.2581482	03
.5743300	05	.3507529	02	.4798628	03-	.2546492	03
.5843300	05	.3072005	02	.4261343	03-	.2511502	03
.5943300	05	.2685671	02	.3778074	03-	.2476512	03
.6043300	05	.2343572	02	.3343293	03-	.2442092	03
.6143300	05	.2041450	02	.2948384	03-	.2412197	03
.6243300	05	.1775295	02	.2596163	03-	.2382302	03
.6343300	05	.1541136	02	.2282449	03-	.2352406	03
.6443300	05	.1335591	02	.2003429	03-	.2322511	03
.6543300	05	.1155330	02	.1755630	03-	.2292616	03
.6643300	05	.9975435	01	.1535887	03-	.2262720	03
.6743300	05	.8596653	01	.1341322	03-	.2232825	03
.6843300	05	.7393951	01	.1169322	03-	.2202930	03
.6943300	05	.6346729	01	.1017517	03-	.2173034	03
.7043300	05	.5436574	01	.8837577	04-	.2143139	03
.7143300	05	.4650316	01	.7597811	04-	.2132319	03
.7243300	05	.3975242	01	.6518719	04-	.2124513	03
.7343300	05	.3396371	01	.5590007	04-	.2116708	03
.7443300	05	.2900249	01	.4791119	04-	.2108903	03
.7543300	05	.2475274	01	.4104263	04-	.2101098	03
.7643300	05	.2111429	01	.3514024	04-	.2093292	03
.7743300	05	.1800085	01	.3007071	04-	.2085487	03
.7843300	05	.1533808	01	.2571876	04-	.2077682	03
.7943300	05	.1306198	01	.2198481	04-	.2069876	03
.8043300	05	.1111745	01	.1878277	04-	.2062071	03
.8143300	05	.9453360	00	.1611055	04-	.2044250	03

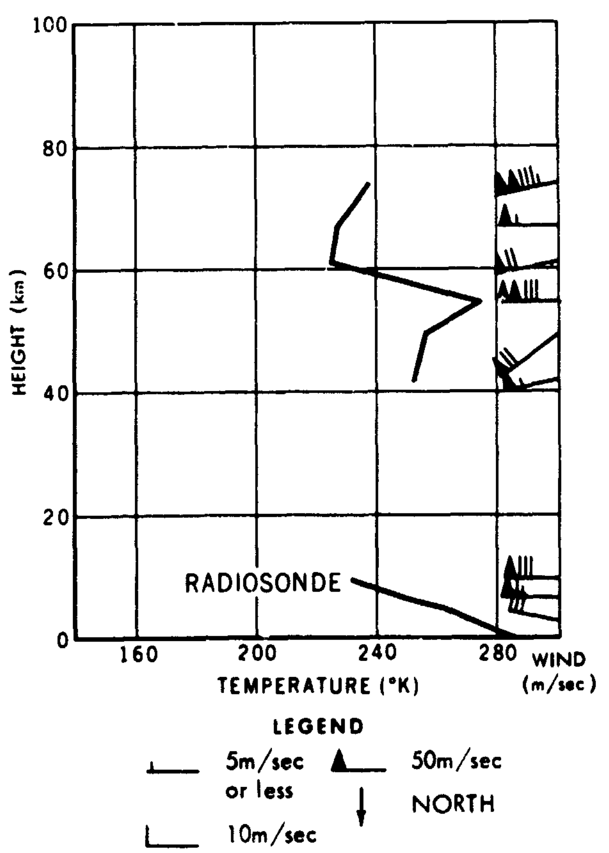
FIGURE 1

simultaneously with the grenade soundings are shown graphically. Winds and temperatures above 40 km from the grenade soundings are shown on the graph.

RESULTS

In the results from these soundings all data points, regardless of our degree of confidence, are presented in tabular form. Some individual data points may be subject to later revision, as there may be occasional errors in some of the records which have not yet been detected. In the preparation of these graphs some data points, where such errors seem obvious, were omitted and the graphs note the omissions. For the most part, these occur at the upper altitude limit of the experiment where the signal-to-noise ratio of detected acoustic waves is poor. Random errors contained in either the measurements or in the data reductions can usually be recognized by comparing two adjacent data points. Since these errors will generally be contained in the parameters (time and space coordinates of the explosion) associated with one individual grenade explosion, the temperature data points both below and above this explosion will contain errors of approximately equal magnitude but opposite sign. Therefore, if large excursions of this nature occur between two adjacent data points, it is very likely that the recordings from the explosion between these two data points were in error.

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
258.25717	53.823459	252.57649	42001.500
233.48279	69.739135	2[illegible]6.26120	49508.047
271.57638	129.50918	274.10839	54864.257
259.95138	72.340553	225.56340	61136.257
272.36947	55.853248	227.78839	67134.976
260.74188	137.33760	237.91288	73796.414



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3045000	05	.1172100	04	.1770008	01-	.2307000	03
.3145000	05	.1012915	04	.1517165	01-	.2325938	03
.3245000	05	.8764247	03	.1302125	01-	.2344876	03
.3345000	05	.7592442	03	.1118990	01-	.2363814	03
.3445000	05	.6585141	03	.9628182	02-	.2382753	03
.3545000	05	.5718173	03	.8294655	02-	.2401691	03
.3645000	05	.4971072	03	.7154511	02-	.2420629	03
.3745000	05	.4326487	03	.6178466	02-	.2439567	03
.3845000	05	.3769690	03	.5341862	02-	.2458506	03
.3945000	05	.3288167	03	.4623898	02-	.2477444	03
.4045000	05	.2871259	03	.4007002	02-	.2496382	03
.4145000	05	.2509887	03	.3476315	02-	.2515320	03
.4245000	05	.2195938	03	.3026265	02-	.2527966	03
.4345000	05	.1902229	03	.2643927	02-	.2532875	03
.4445000	05	.1683143	03	.2310599	02-	.2537784	03
.4545000	05	.1474232	03	.2019901	02-	.2542692	03
.4645000	05	.1291637	03	.1766311	02-	.2547601	03
.4745000	05	.1131990	03	.1545018	02-	.2552509	03
.4845000	05	.9903686	02	.1351853	02-	.2557418	03
.4945000	05	.8702238	02	.1183190	02-	.2562327	03
.5045000	05	.7638526	02	.1025884	02-	.2593998	03
.5145000	05	.6715994	02	.8905447	03-	.2627319	03
.5245000	05	.5914699	02	.7744703	03-	.2660639	03
.5345000	05	.5217455	02	.6747233	03-	.2693960	03
.5445000	05	.4609684	02	.5888430	03-	.2727280	03
.5545000	05	.4073033	02	.5263770	03-	.2695747	03
.5645000	05	.3589853	02	.4776475	03-	.2618348	03
.5745000	05	.3152153	02	.4321850	03-	.2540949	03
.5845000	05	.2756824	02	.3896576	03-	.2463549	03
.5945000	05	.2400886	02	.3505355	03-	.2386149	03
.6045000	05	.2081485	02	.3140903	03-	.2308750	03
.6145000	05	.1797386	02	.2774642	03-	.2256798	03
.6245000	05	.1549716	02	.2388385	03-	.2260507	03
.6345000	05	.1336562	02	.2056503	03-	.2264216	03
.6445000	05	.1153058	02	.1771253	03-	.2267925	03
.6545000	05	.9950316	01	.1526008	03-	.2271634	03
.6645000	05	.8589099	01	.1315100	03-	.2275343	03
.6745000	05	.7417070	01	.1132002	03-	.2283672	03
.6845000	05	.6409877	01	.9718122	04-	.2297870	03
.6945000	05	.5545036	01	.8351683	04-	.2313069	03
.7045000	05	.4801653	01	.7184823	04-	.2328268	03
.7145000	05	.4162011	01	.6187322	04-	.2343466	03
.7245000	05	.3611072	01	.5333694	04-	.2358665	03
.7345000	05	.3136058	01	.4602422	04-	.2373864	03

FIGURE 2

ERROR ANALYSIS

An error analysis was run with the aid of a digital computer on 16 of the 28 experiments reported. The firings considered were the first 16 conducted from Wallops Island. The following nomenclature is used in the error analysis:

Δw = Difference in west coordinate between successive grenade explosions.

Δn = Difference in north coordinate between successive grenade explosions.

h = Difference in altitude between successive grenade explosions.

ω = Wind direction in the layer.

W = Wind speed in the layer.

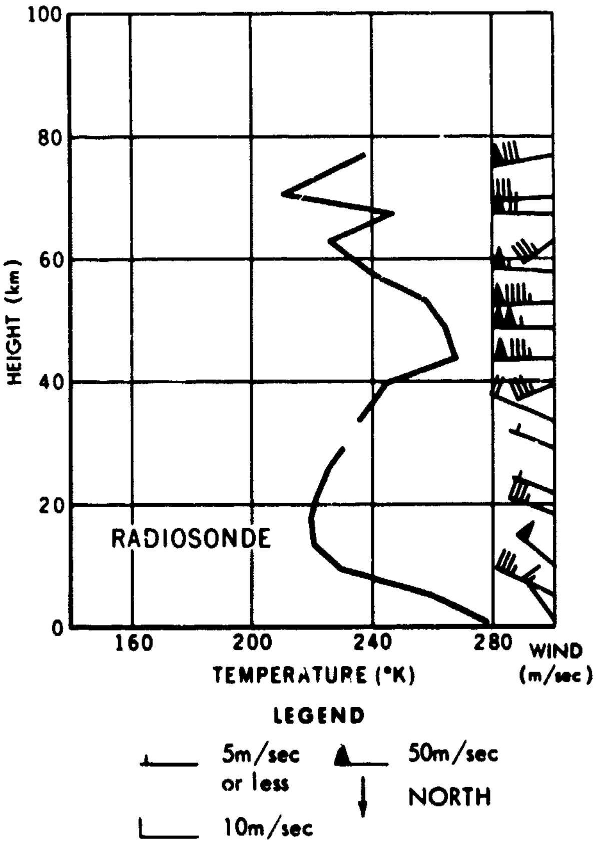
c = Speed of sound in the layer $= k(T)^{1/2}$, where k is a proportionality constant depending on molecular mass, the ratio of specific heats, and the universal gas constant.

ϕ_u = Azimuth angle of sound wave for upper explosion.

τ = Travel time of sound wave in layer.

$K = c_0 \sec\theta_u + W_0 \cos(\phi_u - \omega_0) - W \cos(\phi_u - \omega)$, where c_0 is the mean speed of sound over

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kulvin	HEIGHT meters
292.86309	18.130565	234.89309	33683.750
248.69609	36.597328	243.78259	39602.218
269.17739	83.686485	267.01477	43709.046
272.88568	106.25949	264.04278	48449.386
267.75299	96.220848	258.29199	52904.457
275.55267	53.734848	238.25239	57711.847
235.30198	37.225559	224.72909	63107.707
271.42547	71.667457	246.47889	67362.398
265.22039	40.814918	210.58119	70596.187
259.91388	81.029823	237.40589	77047.812



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3045000	05	.1172100	04	.1770008	01-	.2307000	03
.3145000	05	.1012724	04	.1520784	01-	.2319966	03
.3245000	05	.8757722	03	.1307817	01-	.2332933	03
.3345000	05	.7579851	03	.1125665	01-	.2345900	03
.3445000	05	.6566228	03	.9691282	02-	.2360440	03
.3545000	05	.5693507	03	.8350074	02-	.2375460	03
.3645000	05	.4941439	03	.7201560	02-	.2390480	03
.3745000	05	.4292708	03	.6217047	02-	.2405500	03
.3845000	05	.3732577	03	.5372276	02-	.2420519	03
.3945000	05	.3248481	03	.4646686	02-	.2435539	03
.4045000	05	.2832492	03	.3969752	02-	.2485784	03
.4145000	05	.2477074	03	.3394386	02-	.2542354	03
.4245000	05	.2172744	03	.2912549	02-	.2598923	03
.4345000	05	.1911267	03	.2507462	02-	.2655493	03
.4445000	05	.1684033	03	.2201049	02-	.2665502	03
.4545000	05	.1484003	03	.1944181	02-	.2659232	03
.4645000	05	.1307393	03	.1716853	02-	.2652963	03
.4745000	05	.1151502	03	.1515720	02-	.2646693	03
.4845000	05	.1013933	03	.1337810	02-	.2640420	03
.4945000	05	.8924222	02	.1183270	02-	.2627511	03
.5045000	05	.7850110	02	.1045991	02-	.2614603	03
.5145000	05	.6901172	02	.9241122	03-	.2601694	03
.5245000	05	.6063301	02	.8159643	03-	.2588786	03
.5345000	05	.5321813	02	.7241816	03-	.2560179	03
.5445000	05	.4662762	02	.6450012	03-	.2518494	03
.5545000	05	.4076493	02	.5733930	03-	.2476809	03
.5645000	05	.3555969	02	.5087391	03-	.2435124	03
.5745000	05	.3094737	02	.4504634	03-	.2393439	03
.5845000	05	.2687866	02	.3961082	03-	.2364024	03
.5945000	05	.2330782	02	.3471657	03-	.2338962	03
.6045000	05	.2018126	02	.3038519	03-	.2313899	03
.6145000	05	.1744751	02	.2655686	03-	.2288837	03
.6245000	05	.1506060	02	.2317754	03-	.2263774	03
.6345000	05	.1299073	02	.1998315	03-	.2264789	03
.6445000	05	.1122462	02	.1688529	03-	.2315908	03
.6545000	05	.9730046	01	.1432088	03-	.2367028	03
.6645000	05	.8460633	01	.1218929	03-	.2418147	03
.6745000	05	.7375770	01	.1046653	03-	.2455064	03
.6845000	05	.6416538	01	.9536543	04-	.2344056	03
.6945000	05	.5544697	01	.8650435	04-	.2233048	03
.7045000	05	.[illegible]755990	01	.7808105	04-	.2122040	03
.7145000	05	.[illegible]066359	01	.6615826	04-	.2141312	03
.7245000	05	.[illegible]184554	01	.5561265	04-	.2182890	03
.7345000	05	.[illegible]394846	01	.4690363	04-	.2224468	03
.7445000	05	.[illegible]381307	01	.3968524	04-	.2266046	03
.7545000	05	.[illegible]230991	01	.3368146	04-	.2307625	03
.7645000	05	1933332	01	.2867109	04-	.2349203	03
.7745000	05	1679607	01	.2448927	04-	.2389405	03

FIGURE 3

the microphone array; θ_u is the elevation angle of sound wave for upper explosion; W_0 is the wind speed over the microphone array; and ω_0 is the wind direction over the microphone array.

t = Travel time of sound wave from grenade explosion to ground.

T = Mean temperature in layer.

Δt = Time difference between microphones introduced by changing the time of arrival at one microphone.

ϕ'_u = Elevation angle from ground to apparent position of upper grenade explosion as obtained by ray tracing.

In order to determine the error function, deliberate errors were introduced in the following experimental parameters:

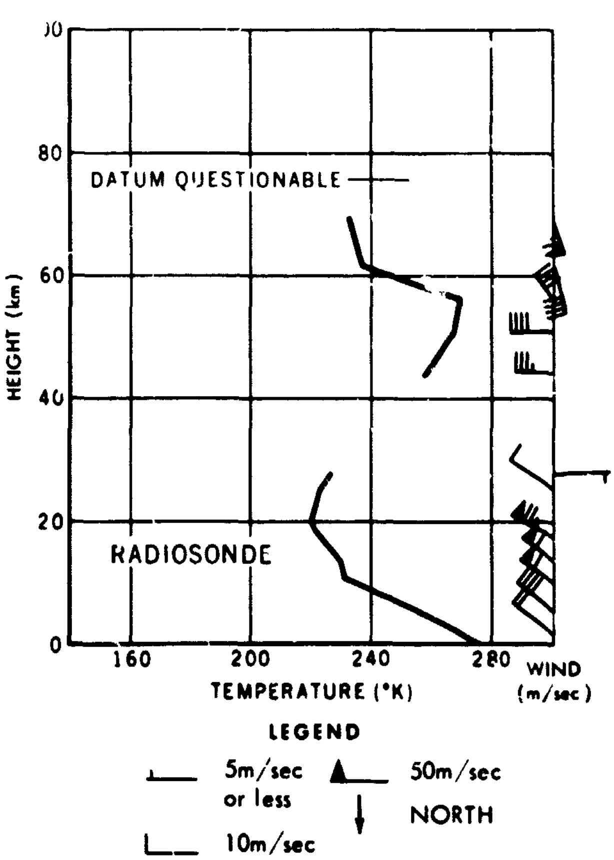
A. Position of grenade explosions

1. North: 200 meters
2. West: 200 meters
3. Up: 50 meters

B. Travel time of sound from explosions to ground: 0.3 second.

C. Time of arrival at one of the 6 microphones relative to the other five microphones: 0.02 second.

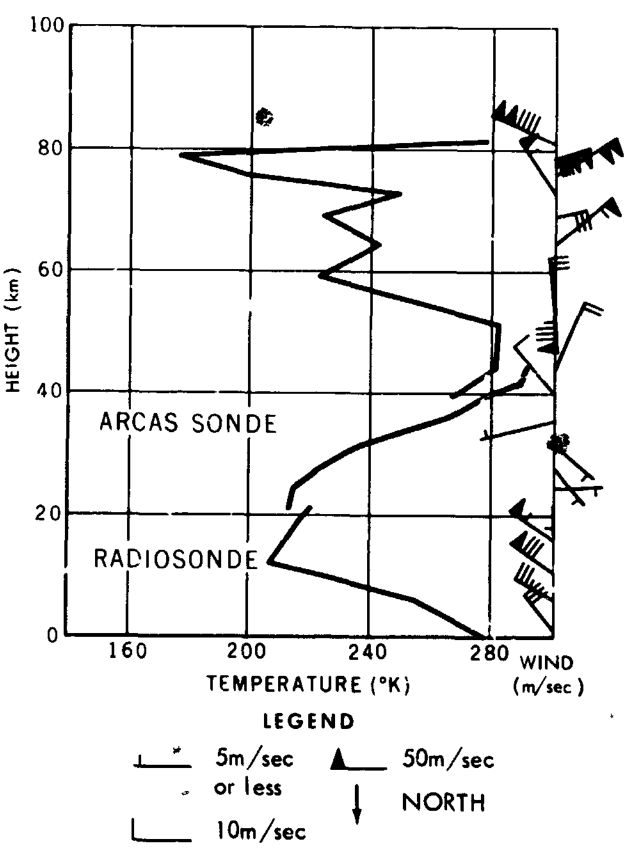
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
278.04568	3[illegible].738597	258.56097	44334.699
267.40359	40.801197	267.20568	51244.250
335.20639	41.921638	269.77447	56138.988
177.28808	39.535289	238.58029	61859.648
160.35488	66.775573	233.18949	69577.523
94.937965	25.101959	49.960929	75558.476



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees kelvin	
.2877900	05	.1516800	04	.2323785	01-	.2274000	03
.2977900	05	.1307983	04	.1986374	01-	.2294032	03
.3077900	05	.1109419	04	.1700349	01-	.2314063	03
.3177900	05	.9765115	03	.1457528	01-	.2334095	03
.3277900	05	.8453935	03	.1251036	01-	.2354107	[illegible]
.3377900	05	.7328085	03	.1075323	01-	.2374159	03
.3477900	05	.6360084	03	.925.697	02-	.2394191	03
.3577900	05	.5526712	03	.7975310	02-	.2414223	03
.3677900	05	.4808323	03	.6881542	02-	.2434255	03
.3777900	05	.4188070	03	.5945215	02-	.2454287	03
.3877900	05	.3652430	03	.5142620	02-	.2474318	03
.3977900	05	.3188796	03	.4453766	02-	.2494350	03
.4077900	05	.2787158	03	.3861788	02-	.2514382	03
.4177900	05	.2438811	03	.3352423	02-	.2534414	03
.4277900	05	.2136335	03	.2913607	02-	.2554446	03
.4377900	05	.1873388	03	.2535110	02-	.2574478	03
.4477900	05	.1644407	03	.2210914	02-	.2591168	03
.4577900	05	.1444530	03	.1932845	02-	.2603670	03
.4677900	05	.1269788	03	.16[illegible]08	02-	.2616191	03
.4777900	05	.1116915	03	.1480257	02-	.2620702	03
.4877900	05	.9830851	02	.1[illegible]719	02-	.2641213	03
.4977900	05	.8658475	02	.1136694	02-	.2655724	03
.5077900	05	.7630761	02	.[illegible]79741	03-	.2[illegible]66236	03
.5177900	05	.6728665	02	.8763659	03-	.2674863	03
.5277900	05	.5935381	02	.7715321	03-	.2680111	03
.[illegible]377900	05	.5237114	02	.6794348	03-	.[illegible]685359	03
.5477900	05	.4622301	02	.5985007	03-	.2690607	03
.5577900	05	.4080211	02	.5273611	03-	.2695855	03
.5677900	05	.3600563	02	.4710670	03-	.2660845	03
.5777900	05	.3170350	02	.4234530	03-	.2608316	03
.5877900	05	.2784159	02	.3798110	03-	.2553787	03
.5977900	05	.2438266	02	.3398800	03-	.2499258	03
.6077900	05	.2109195	02	.3034191	03-	.2444729	03
.6177900	05	.1653705	02	.2702970	03-	.2390200	03
.6277900	05	.1610878	02	.2358614	03-	.2379381	03
.6377900	05	.1399185	02	.2054689	03-	.2372594	03
.6477900	05	.1214860	02	.1789078	03-	.2365410	03
.6577900	05	.1054423	02	.1557581	03-	.2358427	03
.6677900	05	.9148293	01	.1355389	03-	.2351442	03
.6777900	05	.7934166	01	.1179009	03-	.2344457	03
.6877900	05	.6878553	01	.1025200	03-	.2337472	03
.6977900	05	.5949888	01	.9130785	04-	.2270172	03
.7077900	05	.5080049	01	.9010976	04-	.1963818	03
.7177900	05	.4222664	01	.9279656	04-	.1657465	03
.7277900	05	.3379725	01	.6724618	04-	.1351111	03
.7377900	05	.255[illegible]	01	.[illegible]16874	04-	.10[illegible]4756	03
.7477900	05	.1750306	01	.[illegible]958055	04-	.73[illegible]46	02
.7577900	05	.1060[illegible]	01	.5063440	04-	.6130538	02

FIGURE 4

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
322.41619	11.569830	266.27038	39412.546
23.538419	22.253669	280.97079	44079.898
355.26779	28.470070	282.27557	51248.187
178.72689	85.764000	222.41799	59150.648
48.711238	56.003578	242.82579	64569.699
75.535553	30.775518	223.67649	69209.593
327.44299	56.990917	249.57080	72776.789
57.703037	101.52199	198.17269	75793.546
70.997947	147.21499	175.96778	78695.750
292.62289	142.18638	278.37927	81482.250



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2216240	05	.3930000	04	.6212110	01-	.2204000	03
.2316240	05	.3372820	04	.5267826	01-	.2230591	03
.2416240	05	.2900022	04	.4476028	01-	.2257182	03
.2516240	05	.2498031	04	.3810684	01-	.2283774	03
.2616240	05	.2155583	04	.3250441	01-	.2310365	03
.2716240	05	.1863305	04	.2777740	01-	.2336956	03
.2816240	05	.1613388	04	.2378114	01-	.2363548	03
.2916240	05	.1399306	04	.2039613	01-	.2390139	03
.3016240	05	.1215597	04	.1752345	01-	.2416730	03
.3116240	05	.1057680	04	.1508107	01-	.2443321	03
.3216240	05	.9217052	03	.1300076	01-	.2469913	03
.3316240	05	.8044297	03	.1122571	01-	.2496504	03
.3416240	05	.7031186	03	.9[illegible]08521	02-	.2523095	03
.3516240	05	.6154603	03	.8409523	02-	.2549687	03
.3616240	05	.5394973	03	.7295494	02-	.2576278	03
.3716240	05	.4735695	03	.6338545	02-	.2602869	03
.3816240	05	.4162660	03	.5515215	02-	.2629[illegible]	03
.3916240	05	.3663862	03	.4805745	02-	.2656052	03
.4016240	05	.3229344	03	.4188076	02-	.2686321	03
.4116240	05	.2850577	03	.3654019	02-	.2717817	03
.4216240	05	.2519952	03	.3193201	02-	.2749313	03
.4316240	05	.2230891	03	.2794893	02-	.2780810	03
.4416240	05	.1977669	03	.2452039	02-	.2809858	03
.4516240	05	.1754424	03	.2173837	02-	.2811678	03
.4616240	05	.1556557	03	.1927421	02-	.2813498	03
.4716240	05	.1381161	03	.1709129	02-	.2815318	03
.4816240	05	.1225672	03	.1515738	02-	.2817138	03
.4916240	05	.1087815	03	.1344388	02-	.2818959	03
.5016240	05	.9655710	02	.1192541	02-	.2820779	03
.5116240	05	.8571648	02	.1057970	02-	.2822599	03
.5216240	05	.7598558	0[illegible]	.9613975	03-	.2753508	03
.5316240	05	.6714575	02	.8735839	03-	.2677763	03
.5416240	05	.5912643	02	.7916435	03-	.2602017	03
.5516240	05	.5187170	02	.7153335	03-	.2526272	03
.5616240	05	.4532802	02	.6444149	03-	.2450526	03
.5716240	05	.3944418	02	.5786521	03-	.2374781	03
.5816240	05	.3417126	02	.5178136	03-	.2299035	03
.5916240	05	.2946389	02	.4614153	03-	.2224622	03
.6016240	05	.2537562	02	.3907762	03-	.2262282	03
.6116240	05	.2190958	02	.3318757	03-	.2299941	03
.6216240	05	.1896299	02	.2826147	03-	.2337600	03
.6316240	05	.[illegible]645134	02	.2412951	03-	.2375260	03
.6416240	05	.1430491	02	.2065384	03-	.2412919	03
.6516240	05	.1244940	02	.1804301	03-	.2403796	03
.6616240	05	.1081911	02	.1595413	03-	.2362525	03
.6716240	05	.9379494	01	.1407715	03-	.2321254	03
.6816240	05	.8111001	01	.1239370	03-	.2279983	03
.6916240	05	.6995789	01	.1088671	03-	.2238712	03
.7016240	05	.6039248	01	.9104204	04-	.2305929	03
.7116240	05	.5236649	01	.7670169	04-	.2378519	03
.72[illegible]6240	05	.4560417	01	.6481865	04-	.2451109	03
.7316240	05	.3977512	01	.5702452	04-	.2430009	03
.7416240	05	.3449736	01	.5318705	04-	.2259634	03
.7516240	05	.2958911	01	.4933984	04-	.2089239	03
.7616240	05	.2508780	01	.4474105	04-	.1953506	03
.7716240	05	.2107967	01	.3912540	04-	.1876935	03
.7816240	05	.1758501	01	.3402604	04-	.1800485	03
.7916240	05	.1470850	01	.2653400	04-	.1931184	03
.8016240	05	.1256051	01	.1903634	04-	.2298711	03
.8116240	05	.1098134	01	.1434877	04-	.2666238	03

FIGURE 5

It was determined that an error in one of the foregoing parameters for any given grenade will cause wind and temperature errors in the two layers adjacent to the grenade. The temperature errors, in general, will be of opposite sign and approximately equal in magnitude. There are slight errors introduced in the remaining layers above the grenade; however, these are negligibly small. The errors in the temperatures and winds due to errors in the coordinates of the explosions are given by:

$$\frac{\partial W}{\partial \Delta w} = \frac{\sin \omega}{\tau}; \qquad (1)$$

$$\frac{\partial W}{\partial \Delta n} = \frac{\cos \omega}{\tau}; \qquad (2)$$

$$\frac{\partial W}{\partial h} = \frac{\cot \theta'_u}{\tau} \cos (\omega - \phi_u); \qquad (3)$$

$$\frac{\partial c}{\partial \Delta w} = \frac{\sin \phi_u}{c\tau}\left[\frac{h^2 K}{\tau^2 (K^2 - 2c^2)} - \frac{c^2}{K}\right]; \qquad (4)$$

$$\frac{\partial c}{\partial \Delta n} = \frac{\cos \phi_u}{c\tau}\left[\frac{h^2 K}{\tau^2 (K^2 - 2c^2)} - \frac{c^2}{K}\right]; \qquad (5)$$

$$\frac{\partial c}{\partial h} = \frac{1}{c\tau}\left[\frac{h^2 K \cot \theta'_u - hK^2\tau}{\tau^2 (K^2 - 2c^2)} + \frac{c^2 \cot \theta'_u}{K}\right]. \qquad (6)$$

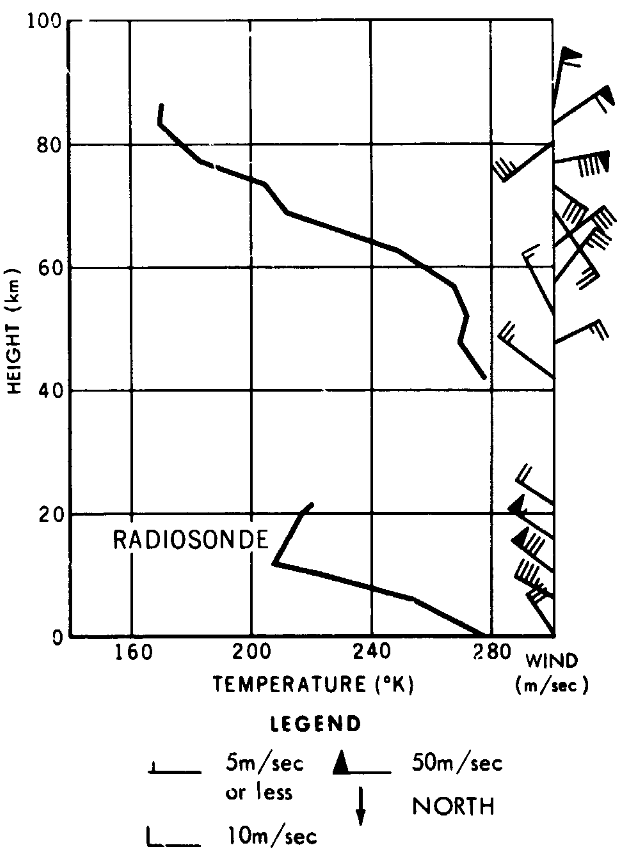
In the error analysis, the north and west coordinates of alternate grenades were changed by –200m, and the up coordinates were changed by –50m. This means that $d\Delta w$ and $d\Delta n$ for adjacent layers were alternatingly +200 and −200, and dh for adjacent layers were alternatingly +50 and −50. The azimuth angle changes slowly with altitude. Generally, $\sin\phi_u$ and $\cos\phi_u$ do not change sign during an experiment; thus the signs of $(\partial c/\partial \Delta w)d\Delta w$ and $(\partial c/\partial \Delta n)d\Delta n$ alternate regularly from layer to layer *as the coordinates of alternate grenade explosions are changed.* This accounts for the regular alternation of the temperature error, since all other signs in the equation for $\partial c/\partial \Delta w$, $\partial c/\partial \Delta n$ remain constant during an experiment. Similarly, it can be seen from the expression for $\partial c/\partial h$ that all the quantities retain the same sign throughout an experiment. Thus, the same regular alternation for the signs of the $(\partial c/\partial h)dh$ will occur for successive grenades.

The situation is different, however, for $\partial W/\partial \Delta w$, $\partial W/\partial \Delta n$, $\partial W/\partial h$. The sign of $\partial W/\partial \Delta w$ depends on the sign of $\sin \omega$ which in turn depends on the value of ω. Since ω may vary from 0 to 360°, $\sin \omega$ may be either positive or negative. The same is true for the sign of $\partial W/\partial \Delta n$, which depends on $\cos \omega$. Hence, we expect no regular alternation from layer to layer in the sign of the wind error. The sign of $\partial W/\partial h$ depends on the sign of $\cos (\omega - \phi_u)$ which in turn depends on the value of $\omega - \phi_u$. Although ϕ_u changes slowly and in general remains in the same quadrant, ω can vary from 0 to 360°, and hence $\omega - \phi_u$ can be positive or negative. Thus, $(\partial W/\partial h)dh$ exhibits no *regular* alternation in sign. In summary, we can see that the signs of $\partial c/\partial \Delta w$, $\partial c/\partial \Delta n$, $\partial c/\partial h$ are constant and hence an error in the coordinates of one individual grenade exposion will cause a positive error in the measured temperatures in the layer below the explosion if a negative error is caused in the layer above the explosion, and vice versa. In general, the magnitudes of the temperature errors caused by an error of the explosion coordinates between two adjacent layers are approximately equal.

However, this does not hold for wind errors. The error functions for the wind speed are proportional to $\sin \omega$, $\cos \omega$ and $\cos(\omega - \phi_u)$, which may vary considerably from layer to layer. The error functions of c, however, are proportional to ϕ_u and θ'_u which do not vary greatly from layer to layer.

The two other parameters of importance to the errors in addition to the grenade explosion coordinates were investigated in a similar manner. These parameters were: the time differences, Δt, between arrival of the sound wave at any two microphones within the array of six; and the travel time, t, of the sound from the explosion to the ground. The parameter Δt is important because the direction of the arriving sound wave front is derived from those differences, while t enters primarily in the calculation of the speed of sound in the layer. An error of .02 second was introduced into the arrival time at one microphone without altering the arrival times at the remaining five microphones, while an error of

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
305.12338	23.382379	277.63378	42586.648
62.641258	23.147178	268.78369	47412.750
333.34677	14.322359	271.82907	52066.699
36.589668	35.042530	267.24627	57085.047
49.854858	39.259758	248.50579	62930.449
139.23439	25.119869	212.77249	68475.398
124.98700	42.308529	205.17138	73241.234
80.707336	89.750587	183.60189	76913.093
234.36670	35.243290	177.44699	79971.343
55.719726	59.271869	170.75879	82893.593
8.8894186	57.672039	171.12059	86514.093



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2216240	05	.3930000	04	.6212110	01-	.2204000	03
.2316240	05	.3372986	04	.5264708	01-	.2232022	03
.2416240	05	.2900583	04	.4471224	01-	.2260045	03
.2516240	05	.2499100	04	.3805162	01-	.2288067	03
.2616240	05	.2157196	04	.3244834	01-	.2316090	03
.2716240	05	.1865451	04	.2772450	01-	.2344112	03
.2816240	05	.1616022	04	.2373374	01-	.2372135	03
.2916240	05	.1402369	04	.2035545	01-	.2400157	03
.3016240	05	.1219020	04	.1748994	01-	.2428179	03
.3116240	05	.1061394	04	.1505465	01-	.2456202	03
.3216240	05	.9256422	03	.1298107	01-	.2484224	03
.3316240	05	.8085272	03	.1121219	01-	.2512247	03
.3416240	05	.7073200	03	.9700505	02-	.2540269	03
.3516240	05	.6197154	03	.8406323	02-	.2568292	03
.3616240	05	.5437630	03	.7296432	02-	.2596314	03
.3716240	05	.4778086	03	.6342969	02-	.2624337	03
.3816240	05	.4204478	03	.5522528	02-	.2652359	03
.3916240	05	.3704854	03	.4815403	02-	.2680382	03
.4016240	05	.3269027	03	.4204973	02-	.2708404	03
.4116240	05	.2888299	03	.3677194	02-	.2736426	03
.4216240	05	.2555232	03	.3220178	02-	.2764449	03
.4316240	05	.2262136	03	.2849439	02-	.2765779	03
.4416240	05	.2001977	03	.2538569	02-	.2747441	03
.4516240	05	.1770357	03	.2259951	02-	.2729103	03
.4616240	05	.1564297	03	.2010414	02-	.2710765	03
.4716240	05	.1381115	03	.1787080	02-	.2692427	03
.4816240	05	.1218960	03	.1577076	02-	.2692742	03
.4916240	05	.1076025	03	.1388775	02-	.2699286	03
.5016240	05	.9501750	02	.1223380	02-	.2705829	03
.5116240	05	.8393294	02	.1078056	02-	.2712373	03
.5216240	05	.7416382	02	.9508106	03-	.2717416	03
.5316240	05	.6552806	02	.8429293	03-	.2708284	03
.5416240	05	.5787592	02	.7470138	03-	.2699152	03
.5516240	05	.5109785	02	.6617671	03-	.2690020	03
.5616240	05	.4509622	02	.5860296	03-	.2680888	03
.5716240	05	.3978245	02	.5190883	03-	.2669982	03
.5816240	05	.3506054	02	.4630360	03-	.2637922	03
.5916240	05	.3085262	02	.4124761	03-	.2605862	03
.6016240	05	.2710788	02	.3669261	03-	.2573802	03
.6116240	05	.2378002	02	.3259410	03-	.2541742	03
.6216240	05	.2082691	02	.2891109	03-	.2509682	03
.6316240	05	.1820652	02	.2567844	03-	.2470110	03
.6416240	05	.1587082	02	.2298381	03-	.2405667	03
.6516240	05	.1378389	02	.2051100	03-	.2341224	03
.6616240	05	.1192489	02	.1824700	03-	.2276781	03
.6716240	05	.1027427	02	.1617922	03-	.2212338	03
.6816240	05	.8813632	01	.1429552	03-	.2147895	03
.6916240	05	.7535142	01	.1240156	03-	.2116768	03
.7016240	05	.6431175	01	.1066498	03-	.2100819	03
.7116240	05	.5482596	01	.9161479	04-	.2084869	03
.7216240	05	.4668439	01	.7861153	04-	.2068920	03
.7316240	05	.3970442	01	.6737739	04-	.2052971	03
.7416240	05	.3367331	01	.5872664	04-	.1997601	03
.7516240	05	.2842369	01	.5107313	04-	.1938859	03
.7616240	05	.2386899	01	.4422905	04-	.1880116	03
.7716240	05	.1994385	01	.3794710	04-	.1831001	03
.7816240	05	.1660844	01	.3195203	04-	.1810876	03
.7916240	05	.1380337	01	.2685397	04-	.1790750	03
.8016240	05	.1144845	01	.2253242	04-	.1770097	03
.8116240	05	.9473875	00	.1889038	04-	.1747210	03
.8216240	05	.7820785	00	.1580120	04-	.1724323	03
.8316240	05	.6442357	00	.1314170	04-	.1707856	03
.8416240	05	.5302585	00	.1081037	04-	.1708856	03
.8516240	05	.4365199	00	.8894120	05-	.1709855	03
.8616240	05	.3594167	00	.7318861	05-	.1710854	03
.8716240	05	.2959742	00	.6025731	05-	.1711206	03

FIGURE 6

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
95.363586	36.568847	244.35820	39675.539
99.608467	45.432167	270.66247	45171.437
83.930687	33.290619	281.09097	50468.437
76.533165	46.691719	278.32437	54984.148
109.12829	34.365276	249.50698	60400.296
114.66099	88.817054	210.09239	66114.382
135.61579	106.67810	194.53720	71025.437
131.85289	54.567546	191.89569	75674.046
90.188316	24.938308	174.47338	80105.984
74.234520	20.360889	163.27510	83904.882
307.88009	143.44909	205.45279	87459.437

HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2578400	05	.2413200	04	.3700353	01-	.2272000	03
.2678400	05	.2079899	04	.3172032	01-	.2284351	03
.2778400	05	.1794152	04	.2721527	01-	.2296703	03
.2878400	05	.1548961	04	.2337031	01-	.2309054	03
.2978400	05	.1338387	04	.2008579	01-	.2321406	03
.3078400	05	.1157391	04	.1727756	01-	.2333757	03
.3178400	05	.1001684	04	.1487445	01-	.2346109	03
.3278400	05	.8676225	03	.1281623	01-	.2358461	03
.3378400	05	.7521005	03	.1105190	01-	.2370812	03
.3478400	05	.6524728	03	.9538205	02-	.2383164	03
.3578400	05	.5664835	03	.8238468	02-	.2395515	03
.3678400	05	.4922059	03	.7121517	02-	.2407867	03
.3778400	05	.4279940	03	.6160859	02-	.2420218	03
.3878400	05	.3724401	03	.5333954	02-	.2432570	03
.3978400	05	.3243745	03	.4614837	02-	.2448773	03
.4078400	05	.2830292	03	.3949431	02-	.2496635	03
.4178400	05	.2476045	03	.3390118	02-	.2544496	03
.4278400	05	.2171629	03	.2918427	02-	.2592358	03
.4378400	05	.1909293	03	.2519363	02-	.2640219	03
.4478400	05	.1682600	03	.2180705	02-	.2688081	03
.4578400	05	.1485607	03	.1903721	02-	.2718684	03
.4678400	05	.1313234	03	.1670737	02-	.2738372	03
.4778400	05	.1161932	03	.1467694	02-	.2758059	03
.4878400	05	.1028997	03	.1290564	02-	.2777747	03
.4978400	05	.9120872	02	.1135886	02-	.2797434	03
.5078400	05	.8090337	02	.1003406	02-	.2808976	03
.5178400	05	.7177329	02	.8921157	03-	.2802850	03
.5278400	05	.6365913	02	.7929931	03-	.2796723	03
.5378400	05	.5644965	02	.7047294	03-	.2790596	03
.5478400	05	.5004524	02	.6261500	03-	.2784470	03
.5578400	05	.4432085	02	.5633871	03-	.2740686	03
.5678400	05	.3916759	02	.5077382	03-	.2687480	03
.5778400	05	.3452941	02	.4566533	03-	.2634273	03
.5878400	05	.3036351	02	.4008368	03-	.2581067	03
.5978400	05	.2662989	02	.3670071	03-	.2527861	03
.6078400	05	.2328744	02	.3286463	03-	.2468603	03
.6178400	05	.2029351	02	.2946266	03-	.2399624	03
.6278400	05	.1761442	02	.2632995	03-	.2330647	03
.6378400	05	.1522481	02	.2345206	03-	.2261668	03
.6478400	05	.1310069	02	.2081494	03-	.2192690	03
.6578400	05	.1121945	02	.1840493	03-	.2123712	03
.6678400	05	.9568949	01	.1602946	03-	.2079714	03
.6778400	05	.8137912	01	.1384308	03-	.2048040	03
.6878400	05	.6903786	01	.1192823	03-	.2016367	03
.6978400	05	.5841890	01	.1025459	03-	.1984693	03
.7078400	05	.4930323	01	.8794822	04-	.1953019	03
.7178400	05	.4153328	01	.7454443	04-	.1941061	03
.7278400	05	.3496239	01	.6293515	04-	.1935379	03
.7378400	05	.2941776	01	.5311029	04-	.1929697	03
.7478400	05	.2474116	01	.4479917	04-	.1924014	03
.7578400	05	.2079498	01	.3783824	04-	.1914634	03
.7678400	05	.1744012	01	.3239898	04-	.1875324	03
.7778400	05	.1457289	01	.2765210	04-	.1836013	03
.7878400	05	.1213048	01	.2352124	04-	.1796702	03
.7978400	05	.1005711	01	.1993715	04-	.1757391	03
.8078400	05	.8306407	00	.1677822	04-	.1724747	03
.8178400	05	.6837085	00	.1405046	04-	.1695269	03
.8278400	05	.5608830	00	.1173032	04-	.1665792	03
.8378400	05	.4585274	00	.9762405	05-	.1636314	03
.8478400	05	.3764528	00	.7550095	05-	.1737066	03
.8578400	05	.3128284	00	.5872879	05-	.1855724	03
.8678400	05	.2629726	00	.4640209	05-	.1974382	03
.8778400	05	.2230478	00	.3768877	05-	.2061788	03

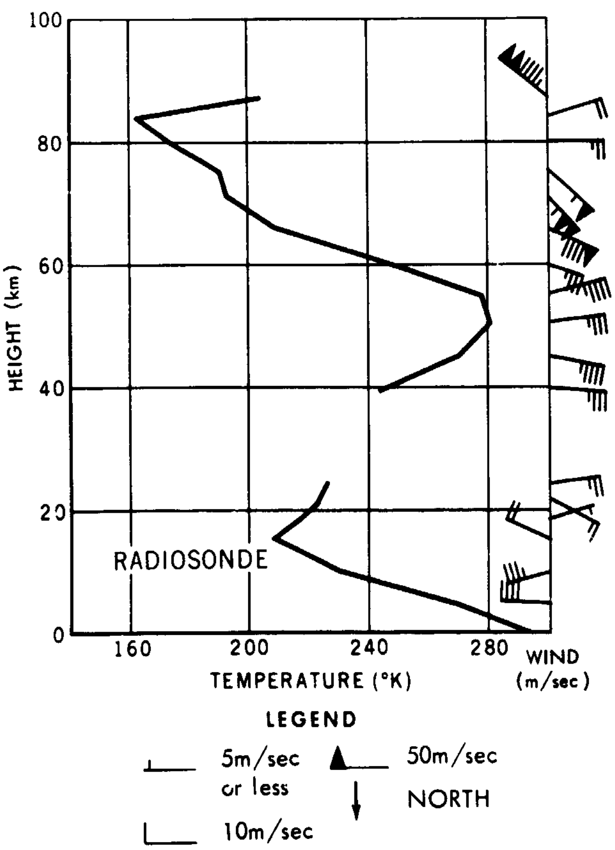


FIGURE 7

.3 second was introduced into t. As in the case of the coordinates of the grenade explosions, these errors were introduced only for alternate grenades.

A typical result of the error analysis is presented in Figures 29 through 38. From a study of these figures, the following conclusions can be reached:

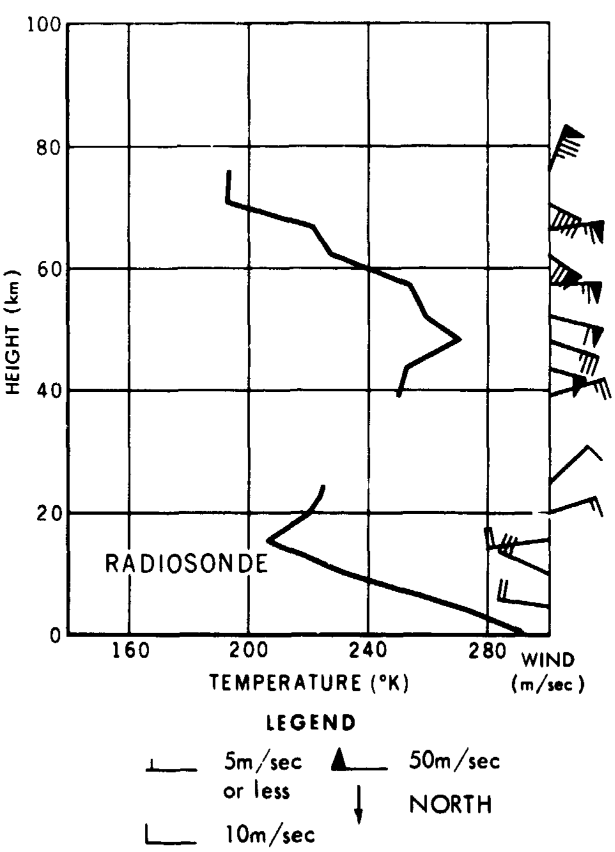
1. Relative errors in the North and West coordinates of 200 meters will significantly affect only winds by about 10 m/sec but not the temperatures.

2. Relative errors in the up coordinates of 50 meters will cause significant errors of about 5°K in temperature, but not in winds.

3. An error of .3 second in t will give rise to large temperature errors—about 10°K—but in general only very small wind errors.

4. An error of .02 in the relative arrival times between microphones will cause the largest errors in both winds and temperatures: 10–40 m/sec and 10–25°K. The error analysis clearly shows that an error introduced into the input parameters of a grenade significantly affects only the layers adjacent to the particular grenade. No significant error is introduced into the calculated winds and temperature for suc-

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
72.464332	25.952299	250.40889	38917.296
104.10459	49.421737	253.16690	43811.046
107.37399	34.035408	270.17877	48008.199
103.76009	62.433387	259.47160	52001.148
87.769149	66.201034	254.37869	57239.000
121.38459	81.264473	228.30349	62182.796
81.096214	62.609947	222.24749	66433.984
113.49089	38.723297	192.81658	70453.382
20.21242	85.848434	194.16389	75561.789



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2520500	05	.2620000	04	.4044156	01-	.2257000	03
.2620500	05	.2256273	04	.3455133	01-	.2275019	03
.2720500	05	.1945424	04	.2955705	01-	.2293039	03
.2820500	05	.1679425	04	.2531675	01-	.2311058	03
.2920500	05	.1451519	04	.2171186	01-	.2329078	03
.3020500	05	.1256009	04	.1864317	01-	.2347097	03
.3120500	05	.1088085	04	.1602760	01-	.2365117	03
.3220500	05	.9436808	03	.1379540	01-	.2383136	03
.3320500	05	.8193558	03	.1188804	01-	.2401156	03
.3420500	05	.7121926	03	.1025624	01-	.2419175	03
.3520500	05	.6197164	03	.8858514	02-	.2437195	03
.3620500	05	.5398240	03	.7659861	02-	.2455214	03
.3720500	05	.4707262	03	.6630730	02-	.2473234	03
.3820500	05	.4108987	03	.5746124	02-	.2491253	03
.3920500	05	.3590073	03	.4991495	02-	.2505710	03
.4020500	05	.3138523	03	.4353885	02-	.2511346	03
.4120500	05	.2744709	03	.3799046	02-	.2516982	03
.4220500	05	.2401129	03	.3316060	02-	.2522618	03
.4320500	05	.2101275	03	.2895479	02-	.2528253	03
.4420500	05	.1840148	03	.2516364	02-	.2547636	03
.4520500	05	.1614030	03	.2172588	02-	.2588168	03
.4620500	05	.1418642	03	.1880140	02-	.2628700	03
.4720500	05	.1249421	03	.1630725	02-	.2669232	03
.4820500	05	.1102198	03	.1424018	02-	.2696510	03
.4920500	05	.9723699	02	.1268902	02-	.2669695	03
.5020500	05	.8567838	02	.1129411	02-	.2642880	03
.5120500	05	.7539936	02	.1004101	02-	.2616065	03
.5220500	05	.6627465	02	.8905282	03-	.2592734	03
.5320500	05	.5820860	02	.7850895	03-	.2583010	03
.5420500	05	.5110126	02	.6918334	03-	.2573287	03
.5520500	05	.4484146	02	.6093878	03-	.2563564	03
.5620500	05	.3933052	02	.5365301	03-	.2553841	03
.5720500	05	.3448105	02	.4721734	03-	.2544117	03
.5820500	05	.3018251	02	.4218128	03-	.2492837	03
.5920500	05	.2634687	02	.3761671	03-	.2440093	03
.6020500	05	.2293145	02	.3346367	03-	.2387350	03
.6120500	05	.1989785	02	.2969275	03-	.2334607	03
.6220500	05	.1721090	02	.2626694	03-	.2282719	03
.6320500	05	.1485621	02	.2281564	03-	.2268473	03
.6420500	05	.1281238	02	.1980114	03-	.2254228	03
.6520500	05	.1103987	02	.1717029	03-	.2239982	03
.6620500	05	.9503990	01	.1487614	03-	.2225737	03
.6720500	05	.8161484	01	.1312699	03-	.2166019	03
.6820500	05	.6975679	01	.1161228	03-	.2092797	03
.6920500	05	.5929215	01	.1022811	03-	.2019574	03
.7020500	05	.5009836	01	.8967269	04-	.1946352	03
.7120500	05	.4216897	01	.7611329	04-	.1930148	03
.7220500	05	.3547518	01	.6394390	04-	.1932786	03
.7320500	05	.2985268	01	.5373604	04-	.1935423	03
.7420500	05	.2512848	01	.4517073	04-	.1938060	03
.7520500	05	.2115796	01	.3798167	04-	.1940698	03
.7620500	05	.1779962	01	.3233403	04-	.1917825	03

FIGURE 8

ceeding grenades, and hence only the layers adjacent to the grenade in question need be considered.

Table 2 gives the average error functions for the 16 firings tabulated by layers. Figures 39 and 40 are graphs of the two functions which are most strongly altitude dependent, $\partial T/\partial \Delta t$ and $\partial W/\partial \Delta t$, showing quite clearly the increase of the error function with altitude.

$\partial W/\partial \Delta h$, etc., by the value of the actual errors in Δw, Δn, h, Δt, and t. The maximum error is calculated by summing all the partial errors:

$$\left(\frac{\partial W}{\partial \Delta w}\, d\Delta w + \frac{\partial W}{\partial \Delta n}\, d\Delta n + \frac{\partial W}{\partial \Delta h}\, d\Delta h + \ldots \text{ etc.}\right)$$

The actual errors in coordinates and times are estimated in the following manner:

The position of the grenade explosion is determined by two totally independent tracking methods, DOVAP and radar. The agreement of these two systems with regard to the coordinates Δn, Δw and h in general is better than 20 meters. The result is a maximum temperature error of 1°K and maximum wind error of 1–2 meters/sec, according to the error functions. The time of the grenade explosion, determined primarily by rocket borne infrared photocells, is telemetered to the ground equipment. The time of grenade explosions may also be determined by ground based flash detectors or radar signal strength records. It has been shown that this time can generally be determined within ±.001 second. The errors in determining the arrival time of the sound at the ground range from ±.001 to ±.010 second. Thus, the maximum error expected in determining the travel time (t) of the sound between explosion and ground is approximately .01 second, which results in a temperature error of 0.3°K and virtually no errors in winds. By far the largest contribution

Table 2

Absolute Average Error Functions

Layer	t + .3 sec		North-200m		West-200m		Up-50m		Δ t + .02 sec	
	Temp. (°K)	Wind (m/sec)	Temp. (°K)	Wind (m/sec)	Temp. (°K)	Wind (m/sec)	Temp. (°K)	Wind (m/sec)	Temp. (°K)	Wind (m/sec)
1	10.1	.5	.9	3.9	.7	9.2	5.4	.8	11.7	12.2
2	10.2	.7	.9	5.3	.7	10.6	5.6	.6	15.2	18.5
3	13.0	1.0	.9	5.2	.8	11.9	6.7	.8	16.3	22.0
4	10.5	1.1	.6	4.6	.6	10.7	5.8	.6	17.8	22.3
5	8.4	.9	.4	2.5	.4	9.5	4.6	.5	12.0	16.9
6	7.7	1.0	.4	3.7	.5	8.7	4.5	.7	15.1	26.4
7	10.0	1.3	.4	6.0	.5	10.6	5.6	.8	16.3	25.3
8	9.2	1.2	.4	6.3	.7	10.3	5.6	.7	20.9	31.9
9	11.7	2.3	.5	5.8	.8	12.1	6.4	.8	21.4	30.5
10	8.3	2.4	.5	8.2	.8	9.3	5.4	.7	22.5	41.1
11	11.5	5.2	.4	9.8	.7	11.4	6.4	.5	22.4	35.2

Figure 41 shows the dependence of $\partial T/\partial \Delta t$ upon zenith angle. As the zenith angle increases, the error function increases nearly linearly. Thus, to make the experiments as accurate as possible, it is desirable that the sound propagation be as nearly vertical as possible. A zenith angle of 0° would, of course, be ideal; however, range safety considerations make this impossible, and at Wallops Island the zenith angles usually lie in the range from 15°—30°. The zenith angles at Fort Churchill are generally less than 10°, and the probable error in the Fort Churchill data is therefore correspondingly less.

The magnitudes of the errors assumed in this analysis were chosen arbitrarily large for convenience in calculation. The actual resulting errors will be much smaller, as will be shown below. The magnitude of the actual errors in the rocket grenade experiment is determined by multiplying the error functions $\partial W/\partial \Delta w$, $\partial W/\partial \Delta n$,

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
136.33490	42.079189	228.35669	37367.250
356.12039	53.882389	294.37728	42735.046
118.10519	139.32998	202.16909	47919.597
138.40469	31.059989	285.11227	52338.449
48.023109	66.104408	293.30438	57617.648
68.479278	68.716514	242.52729	63174.636
87.361854	102.28640	205.54239	67965.382
133.97369	95.964477	172.91769	72516.437
123.23388	43.562007	181.56900	76840.343
141.17219	171.22239	125.93209	80544.648
352.19537	129.04379	163.16378	81035.734

HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2846400	05	.1586000	04	.2408618	01-	.2294000	03
.2946400	05	.1368461	04	.2079310	01-	.2292828	03
.3046400	05	.1180723	04	.1794969	01-	.2291656	03
.3146400	05	.1018716	04	.1549473	01-	.2290484	03
.3246400	05	.8789046	03	.1337503	01-	.2289312	03
.3346400	05	.7582574	03	.1154495	01-	.2288141	03
.3446400	05	.6541552	03	.9965033	02-	.2286969	03
.3546400	05	.5643290	03	.8601077	02-	.2285797	03
.3646400	05	.4[illegible]8221	03	.7423581	02-	.2284625	03
.3746400	05	.4201145	03	.6376097	02-	.2295466	03
.3846400	05	.3640720	03	.5244529	02-	.2418460	03
.3946400	05	.3177682	03	.4355985	02-	.2541454	03
.4046400	05	.2791539	03	.3650016	02-	.2664448	03
.4146400	05	.2466797	03	.3083087	02-	.2787441	03
.4246400	05	.2191586	03	.2623365	02-	.2910436	03
.4346400	05	.1948238	03	.2411885	02-	.2814127	03
.4446400	05	.1721699	03	.2275227	02-	.2636275	03
.4546400	05	.1508478	03	.2137670	02-	.2458423	03
.4646400	05	.1308659	03	.1999130	02-	.2280571	03
.4746400	05	.1122333	03	.1859510	02-	.2102720	03
.4846400	05	.9572001	02	.1570115	02-	.2123877	03
.4946400	05	.8[illegible]24701	02	.1239565	02-	.2311580	03
.5046400	[illegible]	.[illegible]51595	02	.9968864	03-	.2499283	03
.5146400	05	.6282062	02	.8145073	03-	.2686986	03
.5246400	05	.5564427	02	.6794634	03-	.2853071	03
.5346400	05	.4948141	02	.6009412	03-	.2868588	03
.5446400	05	.4403056	02	.5318647	03-	.2884106	03
.5546400	05	.3920617	02	.4710542	03-	.2899624	03
.5646400	05	.3493325	02	.4174818	03-	.2915141	03
.5746400	05	.3114622	02	.3702527	03-	.2930659	03
.5846400	05	.2773782	02	.3383894	03-	.2855708	03
.5946400	05	.2461865	02	.3102645	03-	.2764333	03
.6046400	05	.2176362	02	.2836594	03-	.2672958	03
.6146400	05	.1915813	02	.2585385	03-	.2581582	03
.6246400	05	.1678792	02	.2348657	03-	.2490207	03
.6346400	05	.1464081	02	.2122666	03-	.2402934	03
.6446400	05	.1270827	02	.1903640	03-	.2325733	03
.6546400	05	.1097873	02	.1701027	03-	.2248532	03
.6646400	05	.9436656	01	.1514085	03-	.2171331	03
.6746400	05	.8067246	01	.1342084	03-	.2094130	03
.6846400	05	.6857159	01	.1182824	03-	.2019679	03
.6946400	05	.5794104	01	.1036232	03-	.1947993	03
.7046400	05	.4865287	01	.9033638	04-	.1876308	03
.7146400	05	.4057879	01	.7833776	04-	.1804622	03
.7246400	05	.3359853	01	.6754543	04-	.1732936	03
.7346400	05	.2773628	01	.5527531	04-	.1748136	03
.7446400	05	.2294220	01	.4520387	04-	.1768144	03
.7546400	05	.1901843	01	.3705343	04-	.1788152	03
.7646400	05	.1579958	01	.3044156	04-	.1808160	03
.7746400	05	.1308029	01	.2646293	04-	.1722019	03
.7846400	05	.1068286	01	.2367784	04-	.1571824	03
.7946400	05	.8549683	00	.2095183	04-	.1421629	03
.8046400	05	.6674734	00	.1828935	04-	.1271434	03
.8146400	05	.5180825	00	.1329718	04-	.1357368	03
.8246400	05	.4091609	00	.9736582	05-	.1464016	03
.8346400	05	.3285713	00	.7287936	05-	.1570664	03
.8446400	05	.2668864	00	.5708503	05-	.1628780	03

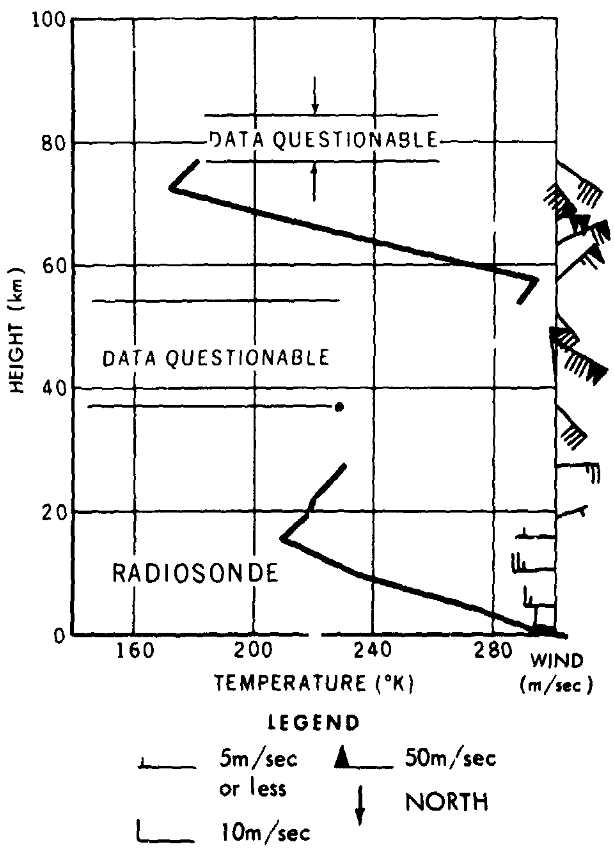


FIGURE 9

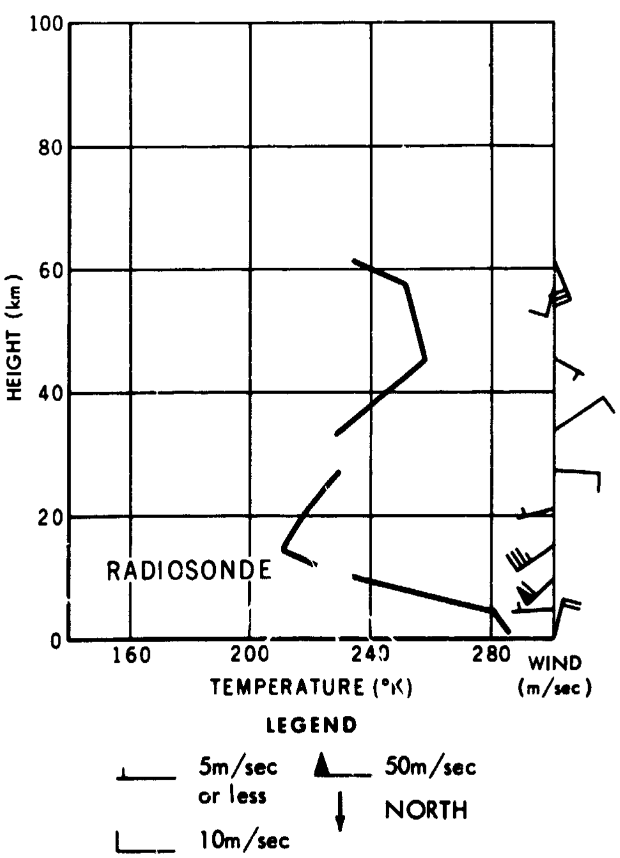
to the total error comes from errors in Δt, which also range from .001 to .010 second, depending upon the background noise level and the altitude of the explosion. The error in Δt is obtained by determining typical discrepancies among a number of independent Δt readings for each explosion. These errors result in temperature errors ranging from 1°K at 40 km to 15°K at 90 km, and wind errors from 1 to 16 m/sec over the same altitude range.

The maximum errors in the 16 soundings considered in this error analysis are presented in Figures 42 and 43, which clearly show the increase of the maximum errors with altitude. This increase is to be expected, since the amplitude of the sound waves will decrease rapidly with increasing altitudes, making it difficult to distinguish the grenade explosion from the background noise level. Since the determination of the relative arrival times between microphones is by far the most critical measured parameter, the largest part of the maximum error is due to the attenuation of the sound wave with altitude.

ACKNOWLEDGMENTS

The authors greatly appreciate the contributions of: Superior Engineering Company in designing and constructing the payload instrumentation for the grenade experiment; Texas Western College in conducting the sound ranging portion of this experiment; and New Mexico State University in operating the DOVAP tracking system.

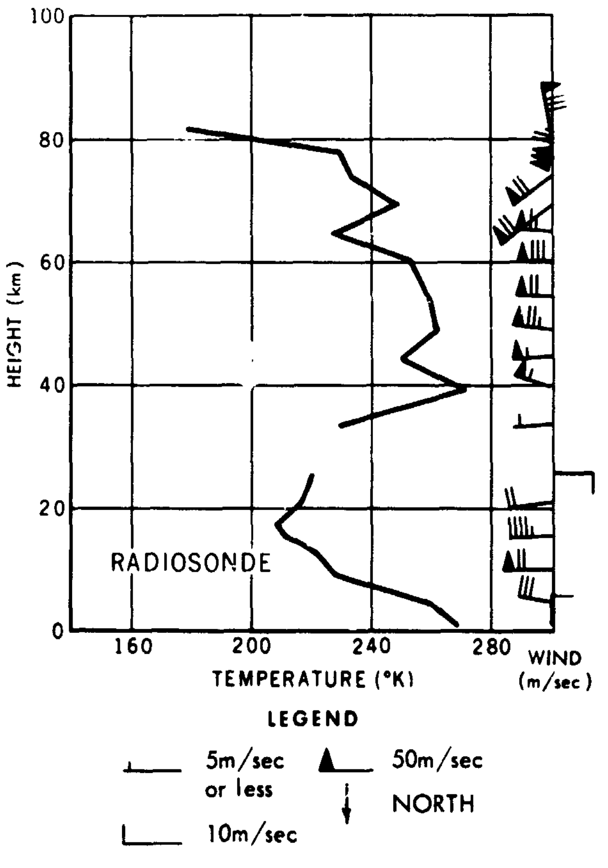
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
54.791648	7.2243499	228.665[illegible]	33187.847
119.66009	4.9561348	257.62[illegible]	45214.898
200.23429	12.105758	251.69139	57547.699
154.18908	29.009319	234.19510	61416.547



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2842900	05	.1585800	04	.2421628	01-	.2281200	03
.2942900	05	.1367266	04	.2087035	01-	.2282346	03
.3042900	05	.1178998	04	.1798754	01-	.2283492	03
.3142900	05	.1016779	04	.1550485	01-	.2284637	03
.3242900	05	.8769845	03	.1336642	01-	.2285783	03
.3342900	05	.7566287	03	.1149845	01-	.2292459	03
.3442900	05	.6534624	03	.9827423	02-	.2316536	03
.3542900	05	.5652446	03	.8413269	02-	.2340614	03
.3642900	05	.4896843	03	.7214396	02-	.2364691	03
.3742900	05	.4248608	03	.6196276	02-	.2388769	03
.3842900	05	.3691600	03	.5330196	02-	.2412846	03
.3942900	05	.3212236	03	.4592231	02-	.2436923	03
.4042900	05	.2799064	03	.3962408	02-	.2461001	03
.4142900	05	.2442411	03	.3424025	02-	.2485078	03
.4242900	05	.2134095	03	.2963086	02-	.2509156	03
.4342900	05	.1867181	03	.2567850	02-	.2533233	03
.4442900	05	.1635784	03	.2228439	02-	.2557310	03
.4542900	05	.1434675	03	.1940888	02-	.2575203	03
.4642900	05	.1258761	03	.1706689	02-	.2570393	03
.4742900	05	.1104189	03	.1499393	02-	.2565583	03
.4842900	05	.9684000	02	.1317473	02-	.2560773	03
.4942900	05	.8491356	02	.1157392	02-	.2555963	03
.5042900	05	.7444053	02	.1016555	02-	.2551154	03
.5142900	05	.6524572	02	.8926745	03-	.2546344	03
.5242900	05	.5717470	02	.7837294	03-	.2541534	03
.5342900	05	.5009164	02	.6879393	03-	.2536724	03
.5442900	05	.4387682	02	.6037321	03-	.2531914	03
.5542900	05	.3842498	02	.5297227	03-	.2527104	03
.5642900	05	.3364340	02	.4646889	03-	.2522294	03
.5742900	05	.2945059	02	.4075542	03-	.2517485	03
.5842900	05	.2575032	02	.3621634	03-	.2477058	03
.5942900	05	.2246321	02	.3218074	03-	.2431835	03
.6042900	05	.1954639	02	.2853272	03-	.2386611	03
.6142900	05	.1696355	02	.2524733	03-	.2340774	03

FIGURE 10

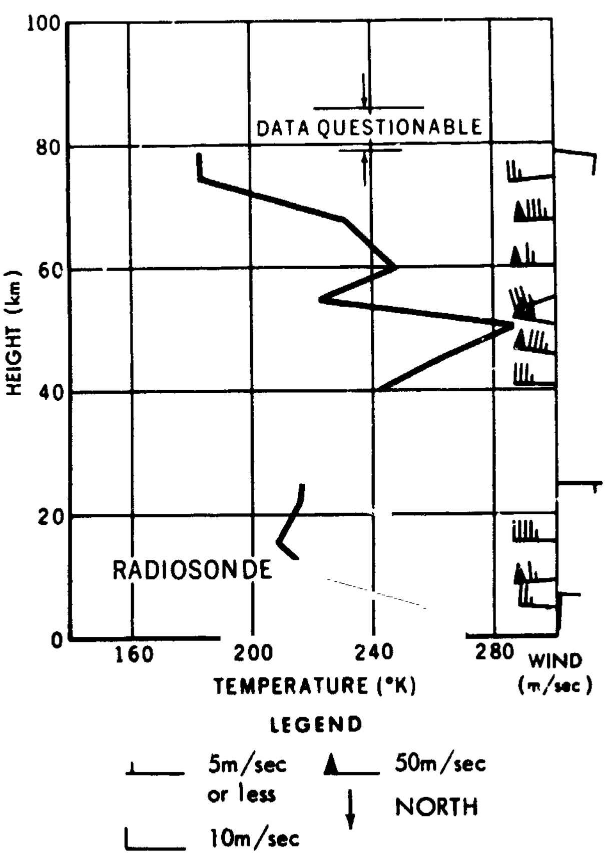
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
262.31097	5.3755097	229.40469	33886.347
299.30877	52.652637	269.77697	39334.250
252.84739	55.973369	249.59349	44584.398
281.27478	73.580688	262.48669	49082.500
273.17938	71.772773	259.51049	54465.949
269.71099	82.195953	253.38369	60122.699
277.13287	65.050956	227.26159	64997.046
242.14248	68.743583	248.01939	69636.343
234.13198	70.978942	234.93168	74051.289
356.45077	80.17173)	230.69918	77846.445
201.99719	175.48089	179.71659	81413.250



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2630580	05	.2000000	04	.3164251	01-	.2202000	03
.2730580	05	.1715696	04	2699560	01-	.2214142	03
.2830580	05	.1473111	04	.2305224	01-	.2226285	03
.2930580	05	.1265935	04	.1970274	01-	.2238427	03
.3030580	05	.1088840	04	.1685504	01-	.2250570	03
.3130580	05	.9373223	03	.1443171	01-	.2262712	03
.3230580	05	.8075743	03	.1236764	01-	.2274855	03
.3330579	05	.6963709	03	.1060799	01-	.2286997	03
.3430579	05	.6014760	03	.9012165	02-	.2325130	03
.3530579	05	.5213426	03	.7570215	02-	.2399237	03
.3630579	05	.4538746	03	.6393074	02-	.2473343	03
.3730579	05	.3967746	03	.5426209	02-	.2547449	03
.3830579	05	.3482122	03	.4627466	02-	.2621555	03
.3930579	05	.3067199	03	.3964011	02-	.2695661	03
.4030579	05	.2704328	03	.3541338	02-	.2660420	03
.4130579	05	.2380297	03	.3162719	02-	.2621976	03
.4230579	05	.2091230	03	.2819980	02-	.2583532	03
.4330579	05	.1833780	03	.2510166	02-	.2545089	03
.4430579	05	.1604879	03	.2230527	02-	.2506645	03
.4530579	05	.1403553	03	.1942990	02-	.2516613	03
.4630579	05	.1228787	03	.1681899	02-	.2545276	03
.4730579	05	.1077430	03	.1458307	02-	.2573940	03
.4830579	05	.9461312	02	.1266489	02-	.2602604	03
.4930579	05	.8318938	02	.1104646	02-	.2623632	03
.5030579	05	.7317564	02	.9737283	03-	.2618104	03
.5130579	05	.6435235	02	.8581313	03-	.2612575	03
.5230579	05	.5657984	02	.7560857	03-	.2607047	03
.5330579	05	.4973458	02	.6660237	03-	.2601518	03
.5430579	05	.4370722	02	.5865544	03-	.2595990	03
.5530579	05	.3839701	02	.5172799	03-	.2586008	03
.5630579	05	.3371573	02	.4561247	03-	.2575177	03
.5730579	05	.2959015	02	.4020024	03-	.2564346	03
.5830579	05	.2595612	02	.3541273	03-	.2553515	03
.5930579	05	.2275664	02	.3117983	03-	.2542685	03
.6030579	05	.1993708	02	.2751859	03-	.2524024	03
.6130579	05	.1743413	02	.2458586	03-	.2470433	03
.6230579	05	.1520127	02	.2191239	03-	.2416843	03
.6330579	05	.1321429	02	.1948014	03-	.2363252	03
.6430579	05	.1145068	02	.1727195	03-	.2309661	03
.6530579	05	.9899216	01	.1508346	03-	.2286430	03
.6630579	05	.8564128	01	.1279872	03-	.2331174	03
.6730579	05	.7429866	01	.1089451	03-	.2375917	03
.6830579	05	.6463218	01	.9301930	04-	.2420661	03
.6930579	05	.5636944	01	.7965514	04-	.2465404	03
.7030579	05	.4921940	01	.6969441	04-	.2460348	03
.7130580	05	.4293678	01	.6153972	04-	.2430704	03
.7230580	05	.3739498	01	.5425858	04-	.2401060	03
.7330580	05	.3251400	01	.4776622	04-	.2371416	03
.7430579	05	.2822566	01	.4190692	04-	.2346478	03
.7530579	05	.2447732	01	.3651528	04-	.2335326	03
.7630579	05	.2121322	01	.3179773	04-	.2324174	03
.7730580	05	.1837257	01	.2767250	04-	.2313021	03
.7830580	05	.1587128	01	.2466969	04-	.2241334	03
.7930580	05	.1361172	01	.2259870	04-	.2098397	03
.8030580	05	.1154859	01	.2057491	04-	.1955461	03
.8130579	05	.9677157	00	.1860039	04-	.1812525	03

FIGURE 11

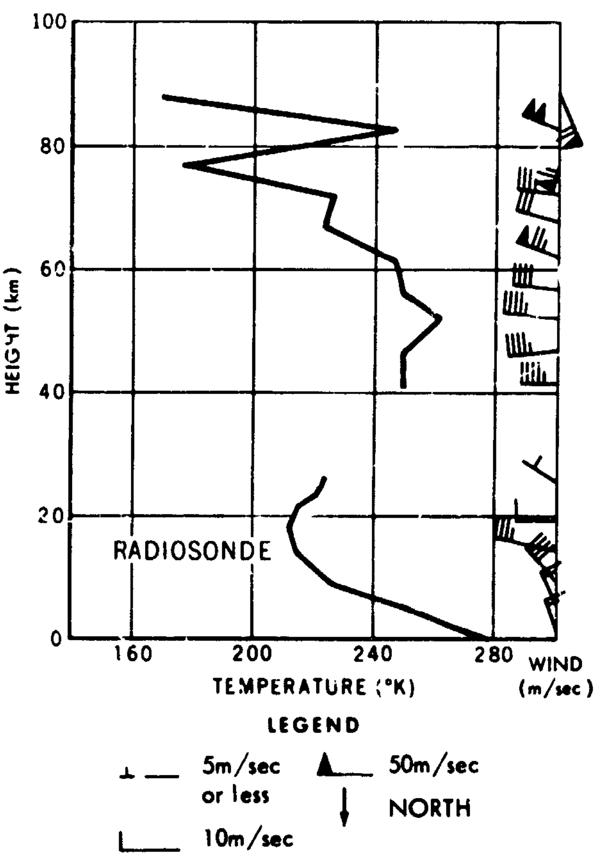
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
274.23077	34.899269	242.51269	40513.449
286.38287	85.033699	263.57437	45697.347
281.50439	101.26220	285.79770	50676.898
243.78489	33.179687	222.30879	54934.796
268.60199	62.581386	247.68548	60029.648
260.13058	85.637725	231.54458	67638.132
259.93988	24.920858	183.24919	74377.484
106.51109	10.605539	183.39129	78539.039
296.23410	234.90919	391.75579	82104.632
150.42019	103.22889	152.16539	85453.297



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2478430	05	.2600000	04	.4192929	01-	.2160300	03
.2578430	05	.2224041	04	.3558897	01-	.2177136	03
.2678430	05	.1904829	04	.3024704	01-	.2193973	03
.2778430	05	.1633445	04	.2574016	01-	.2210810	03
.2878430	05	.1402426	04	.2193269	01-	.2227647	03
.2978430	05	.1205521	04	.1871185	01-	.2244483	03
.3078430	05	.1037483	04	.1598369	01-	.2261320	03
.3178430	05	.8939038	03	.1366990	01-	.2278157	03
.3278429	05	.7710758	03	.1170506	01-	.2294993	03
.3378429	05	.6658746	03	.1003448	01-	.2311830	03
.3478429	05	.5756651	03	.8612332	02-	.2328667	03
.3578429	05	.4982214	03	.7400217	02-	.2345503	03
.3678429	05	.4316613	03	.6365886	02-	.2362340	03
.3778429	05	.3743909	03	.5482224	02-	.2379177	03
.3878429	05	.3250594	03	.4726412	02-	.2396014	03
.3978429	05	.2825198	03	.4079215	02-	.2412850	03
.4078429	05	.2458427	03	.3515725	02-	.2436131	03
.4178429	05	.2143231	03	.3014694	02-	.2476760	03
.4278429	05	.1872701	03	.2591650	02-	.2517389	03
.4378429	05	.1639926	03	.2233464	02-	.2558018	03
.4478429	05	.14[illegible]150	03	.1929377	02-	.2598647	03
.4578429	05	.1265579	03	.1670341	02-	.2639624	03
.4678429	05	.1115287	03	.1447509	02-	.2684253	03
.4778429	05	.9849314	02	.1257417	02-	.2728882	03
.4878429	05	.8716010	02	.1094828	02-	.2773511	03
.4978429	05	.7720464	02	.9554075	03-	.2818141	03
.5078429	05	.6863049	02	.8413115	03-	.2841963	03
.5178429	05	.6078233	02	.7863622	03-	.2692854	03
.5278429	05	.5346258	02	.7322078	03-	.2543746	03
.5378429	05	.4666310	02	.6788785	03-	.2394637	03
.5478429	05	.4037547	02	.6264078	03-	.2245529	03
.5578429	05	.3479388	02	.5350767	03-	.2265400	03
.5678429	05	.3005305	02	.4522272	03-	.2315209	03
.5778429	05	.2604042	02	.3835940	03-	.2365017	03
.5878429	05	.2263203	02	.3265095	03-	.2414826	03
.5978429	05	.1972702	02	.2788477	03-	.2464634	03
.6078429	05	.1721774	02	.2437531	03-	.2460845	03
.6178429	05	.1501787	02	.2144581	03-	.2439631	03
.6278429	05	.1308400	02	.1884810	03-	.2418417	03
.6378429	05	.1133582	02	.1654694	03-	.2397202	03
.6478429	05	.9896233	01	.1451055	03-	.2375988	03
.6578429	05	.8591097	01	.1271035	03-	.2354774	03
.6678429	05	.7448874	01	.1112064	03-	.2333559	03
.6778429	05	.6448914	01	.9747186	04-	.2304971	03
.6878430	05	.5565639	01	.8682091	04-	.2233309	03
.6978430	05	.4780546	01	.7704613	04-	.2161648	03
.7078429	05	.4085400	01	.6810036	04-	.2089986	03
.7178429	05	.3472421	01	.5993764	04-	.2018324	03
.7278429	05	.2934271	01	.5251311	04-	.1946662	03
.7378429	05	.2464043	01	.4578308	04-	.1875001	03
.7478430	05	.2058228	01	.3912701	04-	.1832631	03
.7578430	05	.1715362	01	.3261254	04-	.1832972	03
.7678430	05	.1430568	01	.2718503	04-	.1833314	03
.7778429	05	.1192818	01	.2266286	04-	.1833655	03
.7878429	05	.1001379	01	.1764406	04-	.1977235	03
.7978429	05	.8639777	00	.1175026	04-	.2561610	03
.8078430	05	.7685141	00	.8510464	05-	.3145986	03
.8178430	05	.6974343	00	.6513443	05-	.3730361	03
.8278430	05	.6355071	00	.6452434	05-	.3431271	03
.8378430	05	.5700333	00	.7312438	05-	.2715790	03
.8478430	05	.4945087	00	.8612610	05-	.2000310	03

FIGURE 12

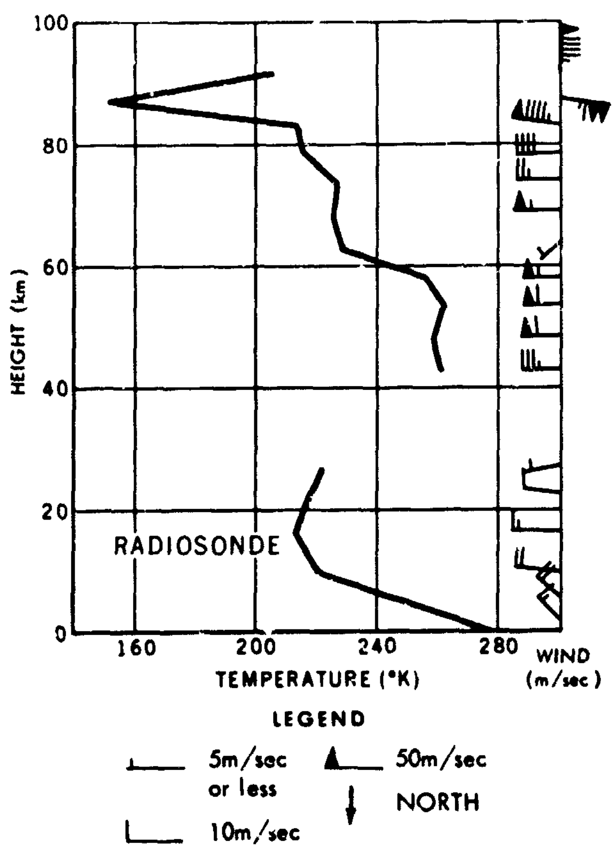
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
268.55438	43.623466	248.86549	41601.949
254.56788	43.215938	249.10910	46958.699
281.43969	43.811149	261.28778	52146.179
281.62848	38.183448	248.15359	56592.386
297.96038	76.103866	246.32100	61921.949
291.15948	27.702018	222.11869	67541.500
284.13769	34.293148	226.46260	72383.437
206.20140	66.652763	177.04888	77000.234
301.35809	97.686676	246.25959	82226.312
165.18818	65.556114	170.25909	87941.312



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2742410	05	.1700000	04	.2655842	01-	.2230000	03
.2842410	05	.1461522	04	.2264750	01-	.2248243	03
.2942410	05	.1258093	04	.1933827	01-	.2266467	03
.3042410	05	.1084331	04	.1653428	01-	.2284731	03
.3142410	05	.9357176	03	.1415513	01-	.2302974	03
.3242410	05	.8084485	03	.1213374	01-	.2321218	03
.3342410	05	.6993215	03	.1041404	01-	.2339461	03
.3442410	05	.6056336	03	.8949085	02-	.2357705	03
.3542410	05	.5251022	03	.7699543	02-	.2375949	03
.3642410	05	.4557963	03	.6632388	02-	.2394192	03
.3742410	05	.3960806	03	.5719868	02-	.2412436	03
.3842410	05	.3445678	03	.4938616	02-	.2430679	03
.3942410	05	.3000799	03	.4268940	02-	.2448923	03
.4042410	05	.2616154	03	.3694223	02-	.2467166	03
.4142410	05	.2283217	03	.3200422	02-	.2485410	03
.4242410	05	.1993932	03	[illegible]	02-	.2489029	03
.4342410	05	.1741614	03	[illegible]	02-	.2489483	03
.4442410	05	.1521290	03	.2128539	02-	.2489938	03
.4542410	05	.1328954	03	.1859089	02-	.2490393	03
.4642410	05	.1161008	03	.1623852	02-	.2490848	03
.4742410	05	.1014626	03	.1412778	02-	.2502017	03
.4842410	05	.8875600	02	.1224561	02-	.2525494	03
.4942410	05	.7774005	02	.1062522	02-	.2548971	03
[illegible]	05	.6817692	02	.9233129	03-	.2572448	03
[illegible]	05	.5986396	02	.8033993	03-	.2595925	03
[illegible]	05	.5260920	02	.7036675	03-	.2604668	03
.5342410	05	.4621137	02	.6251846	03-	.2575127	03
.5442410	05	.4053256	02	.5547204	03-	.2545587	03
.5542410	05	.3549869	02	.4915319	03-	.2516047	03
.5642410	05	.3104264	02	.4349378	03-	.2486507	03
.5742410	05	.2711973	02	.3811744	03-	.2478676	03
.5842410	05	.2368622	02	.3333782	03-	.2475237	03
.5942410	05	.2068438	02	.2915329	03-	.2471799	03
.6042410	05	.1806033	02	.2549032	03-	.2468360	03
.6142410	05	.1576685	02	.2228435	03-	.2464922	03
.6242410	05	.1375504	02	.1962675	03-	.2441583	03
.6342410	05	.1197796	02	.1739797	03-	.2398515	03
.6442410	05	.1040481	02	.1538931	03-	.2355447	03
.6542410	05	.9015226	01	.1358238	03-	.2312379	03
.6642409	05	.7790551	01	.1196003	03-	.2269311	03
.6742409	05	.6713744	01	.1050631	03-	.2226243	03
.6842409	05	.5778324	01	.9030869	04-	.2229105	03
.6942409	05	.4975430	01	.7744866	04-	.2238076	03
.7042409	05	.4286865	01	.6646388	04-	.2247048	03
.7142409	05	.3695956	01	.5707451	04-	.2256019	03
.7242409	05	.3188029	01	[illegible]	04-	.2260274	03
.7342409	05	.2740499	01	.4433988	04-	.2153244	03
.7442409	05	.2337805	01	.3980297	04-	.2046214	03
.7542409	05	.1977428	01	.3552548	04-	.1939184	03
.7642409	05	.1656868	01	.3150534	04-	.1832153	03
.7742409	05	.1380882	01	.2633699	04-	.1826622	03
.7842409	05	.1157901	01	.2059127	04-	.1959055	03
.7942409	05	.9822312	00	.1636125	04-	.2071489	03
.8042409	05	.8417155	00	.1318572	04-	.2223922	03
.8142409	05	.7278067	00	.1076052	04-	.2356355	03
.8242409	05	.6334245	00	.9057814	05-	.2436294	03
.8342409	05	.5504364	00	.8325551	05-	.2303310	03
.8442409	05	.4743636	00	.7614558	05-	.2170325	03
.8542409	05	.4049964	00	.6925412	05-	.2037341	03
.8642409	05	.3421191	00	.6258744	05-	.1904357	03
.8742409	05	.2855101	00	.5615258	05-	.1771373	03

FIGURE 13

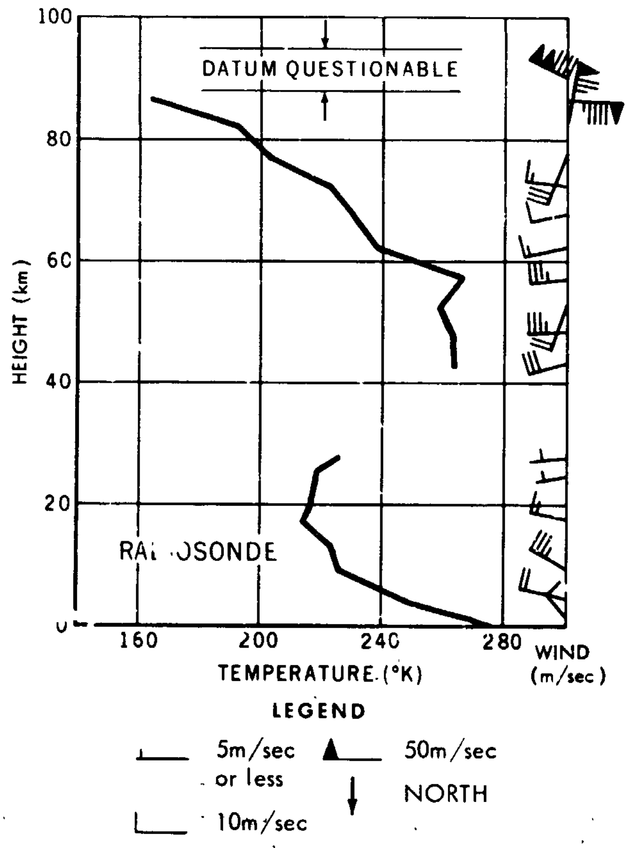
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
262.26339	37.318786	261.81979	42956.867
258.63888	59.576107	258.50137	48370.109
264.73590	57.798050	262.25830	53607.328
264.37527	55.014717	256.49829	58100.378
222.00199	1.9646849	228.56479	63469.269
267.01077	53.975399	225.95019	69130.968
266.96429	27.363178	227.11749	74019.578
259.86737	37.858348	215.65579	78665.953
291.07809	93.457389	213.82579	83089.789
115.27018	117 01439	151.20039	87297.484
355.37219	95.003875	205.23109	91614.125



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2692060	05	.1800000	04	.2833670	01-	.2213000	03
.2792060	05	.1545038	04	.2406393	01-	.2238267	03
.2892060	05	.1330240	04	.2047392	01-	.2263535	03
.2992060	05	1146528	04	.1745157	01-	.2288803	03
.3092060	05	98465	03	.1490217	01-	.2314070	03
.3192060	05	.8599803	03	.1274762	01-	.2339338	03
.3292060	05	.7414078	03	.1092337	01-	.2364605	03
.3392060	05	.6431811	03	9375978	02-	.2389873	03
.3492060	05	.5588272	03	.8061081	02-	.2415140	03
.3592060	05	.4862684	03	.6941795	02-	.2440408	03
.3692060	05	.4237558	03	.5987394	02-	.2465676	03
.3792060	05	.3698137	03	.5172223	02-	.2490943	03
.3892060	05	.3231954	03	.4474827	02-	.2516211	03
.3992060	05	.2828461	03	.3877233	02-	.2541478	03
.4092060	05	.2478712	03	.3364351	02-	.2566746	03
.4192060	05	.2175109	03	.2923492	02-	.2592014	03
.4292060	05	.1911191	03	.2543969	02-	.2617281	03
.4392060	05	.1680204	03	.2240778	02-	.2612290	03
.4492060	05	.1476788	03	.1974128	02-	.2606159	03
.4592060	05	.1297656	03	.1738760	02-	.2600029	03
.4692060	05	.1139952	03	.1531058	02-	.2593899	03
.4792060	05	.1001146	03	.1347814	02-	.2587769	03
.4892060	05	.8791744	02	.1183062	02-	.2588962	03
.4992060	05	.7722527	02	.1036311	02-	.2596136	03
.5092060	05	.6786043	02	.9081320	03-	.2603309	03
.5192060	05	.5965486	02	.7961284	03-	.2610483	03
.5292060	05	.5246212	02	.6982185	03-	.2617656	03
.5392060	05	.4614768	02	.6139661	03-	.2618567	03
.5492060	05	.4058291	02	.5425867	03-	.2605747	03
.5592060	05	.3566801	02	.4792330	03-	.2592927	03
.5692060	05	.3132953	02	.4230331	03-	.2580107	03
.5792060	05	.2750211	02	.3732070	03-	.2567287	03
.5892060	05	.2410731	02	.3290132	03-	.2522002	03
.5992060	05	.2107799	02	.2973449	03-	.2469601	03
.6092060	05	.1837712	02	.2648640	03-	.2417200	03
.6192060	05	.1597495	02	.2353440	03-	.2364800	03
.6292060	05	.1384386	02	.2085705	03-	.2312399	03
.6392060	05	.1196664	02	.1827121	03-	.2281723	03
.6492060	05	.1033289	02	.1580628	03-	.2277458	03
.6592059	05	.8920137	01	.1367078	03-	.2273193	03
.6692059	05	.7698772	01	.1182112	03-	.2268929	03
.6792059	05	.6643095	01	.1021939	03-	.2264664	03
.6892059	05	.5730858	01	.8832686	04-	.2260399	03
.6992059	05	.4943632	01	.7616044	04-	.2261387	03
.7092059	05	.4265180	01	.6563905	04-	.2263775	03
.7192059	05	.3680600	01	.5658296	04-	.2266163	03
.7292059	05	.3176766	01	.4878597	04-	.2268551	03
.7392059	05	.2742458	01	.4207197	04-	.2270938	03
.7492059	05	.2366110	01	.3665335	04-	.2248948	03
.7592059	05	.2038362	01	.3192640	04-	.2224280	03
.7692059	05	.1753177	01	.2776757	04-	.2199612	03
.7792059	05	.1505403	01	.2411364	04-	.2174944	03
.7892059	05	.1290703	01	.2086102	04-	.2155[illegible]4	03
.7992059	05	.1105743	01	.1790597	04-	.2151538	03
.8092059	05	.9470517	00	.1536573	04-	.2147231	03
.8192059	05	.8109328	00	.1318262	04-	.2143094	03
.8292059	05	.6942042	00	.1130039	04-	.2138958	03
.8392059	05	.5914290	00	.1022754	04-	.2014605	03
.8492059	05	.4980278	00	.9303110	05-	.1865769	03
.8592059	05	.4137934	00	.8396304	05-	.1716934	03
.8692059	05	.3379475	00	.7508170	05-	.1568098	03
.8792059	05	.2738231	00	.5999732	05-	.1589997	03
.8892059	05	.2239461	00	.4548786	05-	.1715166	03
.8992059	05	.1857787	00	.3516878	05-	.1840334	03
.9092059	05	.1560318	00	.2765654	05-	.1965502	03

FIGURE 14

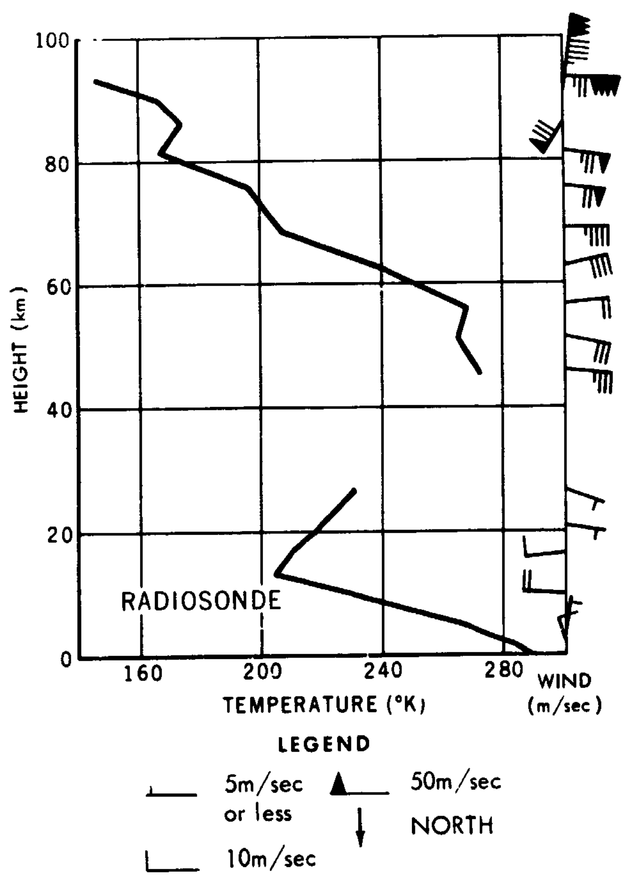
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
245.42630	2[illegible].887029	263.00979	43306.347
265.42379	3[illegible].4[illegible]6920	262.76327	48514.547
201.77038	22.565608	258.15268	52972.699
2[illegible]0.94839	35.262706	265.20490	57276.546
245.89270	17.411869	238.27420	62432.097
240.15739	11.140070	230.01030	67869.835
285.46209	13.573949	222.47969	72556.539
198.87809	30.647968	202.69108	77430.750
3.9694819	74.199607	193.52198	82064.093
92.676124	94.189346	165.26409	86408.437
297.49017	138.35170	287.35989	90139.250



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2911030	05	.1300000	04	.2015304	01-	.2247300	03
.3011030	05	.1119341	04	.1714666	01-	.2274265	03
.3111030	05	.9655342	03	.1461725	01-	.2301230	03
.3211030	05	.8343349	03	.1248473	01-	.2328195	03
.3311029	05	.7[illegible]22092	03	.1[illegible]68318	01-	.2355160	03
.3411029	05	.6262080	03	.9158243	02-	.2382125	03
.3511029	05	.5438643	03	.7864944	02-	.2409090	03
.3611029	05	.4731108	03	.6766029	02-	.2436055	03
.3711029	05	.4102117	03	.5830562	02-	.2463020	03
.3811029	05	.3597061	03	.5032793	02-	.2489986	03
.3911029	05	.3143625	03	.4351252	02-	.2516951	03
.4011029	05	.2751411	03	.3768001	02-	.2543916	03
.4111029	05	.2411617	03	.3268019	02-	.2570881	03
.4211029	05	.2116761	03	.2838708	02-	.2597846	03
.4311029	05	.1860570	03	.2469483	02-	.2624811	03
.4411029	05	.1636719	03	.2168320	02-	.2629717	03
.4511029	05	.1439983	03	.1908028	02-	.2629244	03
.4611029	05	.1266919	03	.1679014	02-	.2628771	03
.4711029	05	.1114675	03	.1477515	02-	.2628297	03
.4811029	05	.9807446	02	.1300223	02-	.2627824	03
.4911029	05	.8628077	02	.1146640	02-	.2621471	03
.5011029	05	.7587737	02	.1012376	02-	.2611129	03
.5111029	05	.6669698	02	.8934279	03-	.2600787	03
.5211029	05	.5859961	02	.7880948	03-	.2590445	03
.5311029	05	.5146551	02	.6939348	03-	.2583781	03
.5411029	05	.4521277	02	.6057844	03-	.2600167	03
.5511029	05	.3975365	02	.5293045	03-	.2616553	03
.5611029	05	.3498315	02	.4628885	03-	.2632939	03
.5711029	05	.3081077	02	.4051591	03-	.2649324	03
.5811029	05	.2712100	02	.3622210	03-	.2608496	03
.5911029	05	.2381[illegible]21	02	.3246239	03-	.2556260	03
.6011029	05	.2086426	02	.2902837	03-	.2504024	03
.6111029	05	.1822569	02	.25[illegible]758	03-	.2451788	03
.6211029	05	.1587519	02	.2304873	03-	.2399551	03
.6311029	05	.1379677	02	.2026009	03-	.2372435	03
.6411029	05	.1197596	02	.1769967	03-	.2357238	03
.6511029	05	.1[illegible]38639	02	.1545000	03-	.2342040	03
.6611029	05	.8999864	01	.1347495	03-	.2326843	03
.6711029	05	.7791455	01	.1174236	03-	.2311646	03
.6811030	05	.6739148	01	.1022459	03-	.2296239	03
.6911030	05	.5823417	01	.8897514	04-	.2280171	03
.7011029	05	.5027149	01	.7735417	04-	.2264103	03
.7111029	05	.4335417	01	.6718712	04-	.2248035	03
.7211029	05	.3[illegible]35071	01	.5830010	04-	.2231967	03
.7311029	05	.3213063	[illegible]	.5082741	04-	.2202315	03
.7411030	05	.2757445	01	.4[illegible]3920	04-	.2161716	03
.7511030	05	.2359697	01	.3[illegible]5695	04-	.2121118	03
.7611030	05	.2013351	01	.3371367	04-	.2080519	03
.7711029	05	.1712561	01	.2924766	04-	.2039921	03
.7811029	05	.1452893	01	.2513901	04-	.2013463	03
.7911029	05	.1230324	01	.2149927	04-	.1993673	03
.8011030	05	.1040178	01	.1835879	04-	.1973884	03
.8111030	05	.8779786	00	.1565296	04-	.1954095	03
.8211030	05	.7397650	00	.1333818	04-	.1932214	03
.8311030	05	.6208957	[illegible]	.1158492	04-	.1867169	03
.8411030	05	.5179291	00	.1001253	04-	.1802124	03
.8511030	05	.4291923	00	.8607770	05-	.1737079	03
.8611030	05	.3531382	00	.7357968	05-	.1672033	03
.8711030	05	.2928459	00	.5420018	05-	.1882334	03
.8811030	05	.2488675	00	.3923858	05-	.2209597	03
.8911030	05	.2163191	00	.2970685	05-	.2536860	03
.9011030	05	.1912646	00	.2326490	05-	.2864123	03

FIGURE 15

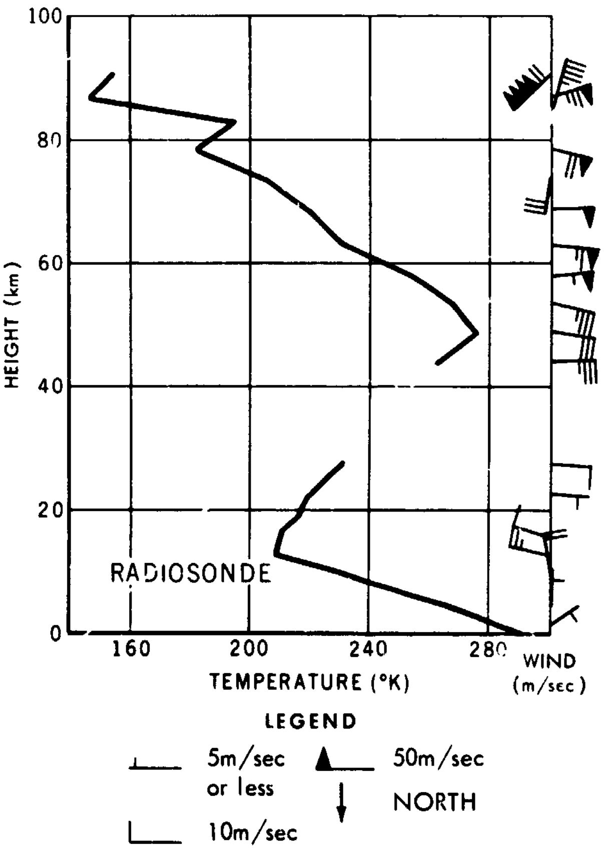
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
100.23349	35.039177	271.12729	45967.500
112.12339	31.985488	265.44738	51428.398
85.151390	20.540390	268.92038	56624.398
76.249366	37.992378	241.96479	62684.597
86.465759	47.108570	208.31379	69435.039
102.19909	72.069656	197.25399	75832.382
100.33849	77.084068	168.90759	81279.049
219.76649	81.912193	174.49778	85927.898
5.6612997	193.16529	167.00509	89940.898
97.556236	223.62478	145.78129	93665.695



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2782370	05	.1700000	04	.2561204	01-	.2312400	03
.2882370	05	.1469582	04	.2193208	01-	.2334384	03
.2982370	05	.1272189	04	.1880904	01-	.2356366	03
.3082370	05	.1102834	04	.1615445	01-	.2378352	03
.3182370	05	.9573240	03	.1389457	01-	.2400336	03
.3282370	05	.8321220	03	.1196778	01-	.2422320	03
.3382370	05	.7242419	03	.1032254	01-	.2444304	03
.3482370	05	.6311593	03	.8915658	02-	.2466288	03
.3582370	05	.5507353	03	.7710869	02-	.2488272	03
.3682370	05	.4811559	03	.6677687	02-	.2510256	03
.3782370	05	.4208802	03	.5790443	02-	.2532240	03
.3882370	05	.3685967	03	.5027484	02-	.2554224	03
.3982370	05	.3231886	03	.4370523	02-	.2576207	03
.4082370	05	.2837027	03	.3804088	02-	.2598191	03
.4182370	05	.2493247	03	.3315073	02-	.2620175	03
.4282370	05	.2193578	03	.2892359	02-	.2642159	03
.4382370	05	.1932052	03	.2526500	02-	.2664143	03
.4482370	05	.1703549	03	.2209460	02-	.2686127	03
.4582370	05	.1503671	03	.1934393	02-	.2708111	03
.4682370	05	.1327794	03	.1711766	02-	.2702367	03
.4782370	05	.1172096	03	.1516882	02-	.2691966	03
.4882370	05	.1034197	03	.1343609	02-	.2681565	03
.4982370	05	.9121133	02	.1189615	02-	.2671164	03
.5082370	05	.8040792	02	.1052812	02-	.2660763	03
.5182370	05	.7086315	02	.9291121	03-	.2657116	03
.5282370	05	.6245859	02	.8168621	03-	.2663800	03
.5382370	05	.5507040	02	.7184333	03-	.2670483	03
.5482370	05	.4857337	02	.6320927	03-	.2677168	03
.5582370	05	.4285786	02	.5563270	03-	.2683852	03
.5682370	05	.3781911	02	.4915637	03-	.2680339	03
.5782370	05	.3333633	02	.4406094	03-	.2635859	03
.5882370	05	.2932304	02	.3942177	03-	.2591379	03
.5982370	05	.2573672	02	.3520461	03-	.2546900	03
.6082370	05	.2253809	02	.3137727	03-	.2502420	03
.6182370	05	.1969090	02	.2790953	03-	.2457940	03
.6282370	05	.1716138	02	.2478020	03-	.2412713	03
.6382370	05	.1491656	02	.2199319	03-	.2362863	03
6482370	05	.1292725	02	.1947090	03-	.2313013	03
.6582369	05	.1116886	02	.1719297	03-	.2263163	03
.6682369	05	.9618718	01	.1514023	03-	.2213313	03
.6782369	05	.8255966	01	.1329464	03-	.2163463	03
.6882369	05	.7061436	01	.1163927	03-	.2113613	03
.6982369	05	.6020476	01	.1010123	03-	.2076419	03
.7082369	05	.5122469	01	.8666698	04-	.2059131	03
.7182369	05	.4352695	01	.7426672	04-	.2041842	03
.7282369	05	.3693669	01	.6356042	04-	.2024554	03
.7382369	05	.3130174	01	.5432774	04-	.2007266	03
.7482369	05	.2648987	01	.4637561	04-	.1989978	03
.7582369	05	.2238624	01	.3953489	04-	.1972690	03
.7682369	05	.1886279	01	.3420963	04-	.1920948	03
.7782369	05	.1582039	01	.2949091	04-	.1868905	03
.7882369	05	.1320369	01	.2531813	04-	.1816861	03
.7982369	05	.1096266	01	.2164086	04-	.1764818	03
.8082369	05	.9052001	00	.1841207	04-	.1712774	03
.8182369	05	.7445886	00	.1529835	04-	.1695625	03
.8282369	05	.6123329	00	.1249243	04-	.1707650	03
.8382369	05	.5042907	00	.1021628	04-	.1719675	03
.8482369	05	.4158986	00	.8367063	05-	.1731700	03
.8582369	05	.3434779	00	.6862448	05-	.1743725	03
.8682369	05	.2836304	00	.5717470	05-	.1728252	03
.8782369	05	.2337[illegible]98	00	.4764040	05-	.1709581	03
.8882369	05	.1922939	00	.3961897	05-	.1690910	03
.8982369	05	.[illegible]78369	00	.3288277	05-	.1672239	03
.9082369	05	.1290085	00	.2774782	05-	.1619749	03
.9182369	05	.1047229	00	.2334559	05-	.1562769	03
.9282369	05	.8435857	01-	.1951745	05-	.1505790	03
.9382369	05	.6706524	01-	.1684508	05-	.1387020	03

FIGURE 16

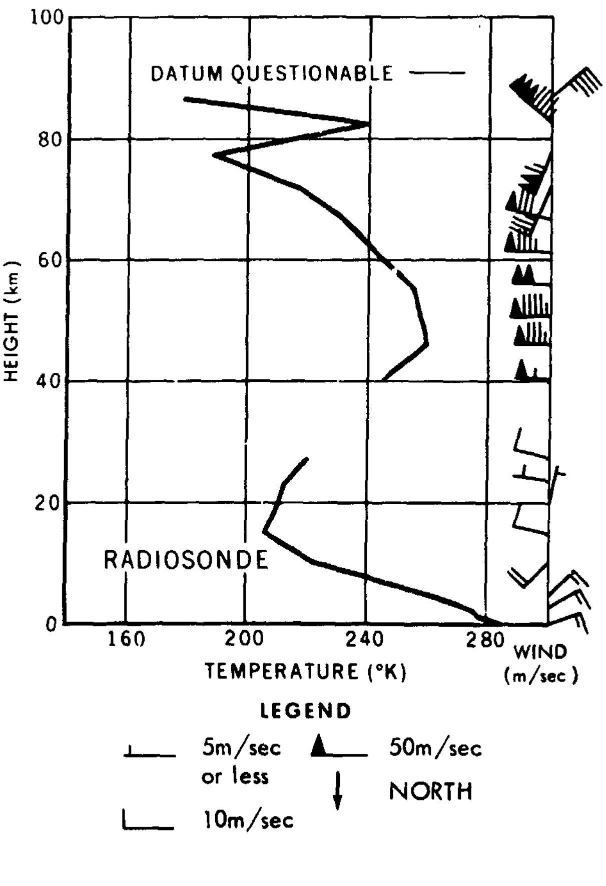
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
88.135818	35.642078	262.44598	43731.648
118.24260	29.022520	275.65139	49039.000
121.08769	36.761146	266.55227	53575.898
80.334419	54.959678	254.40489	57950.200
96.692169	64.717727	231.56219	63171.789
80.894264	51.982868	220.42698	68672.593
192.69558	28.052829	206.80468	73406.648
121.72178	70.112663	182.82728	78311.234
31.833500	44.285537	194.84429	82984.882
70.778137	72.619316	147.24949	86953.234
224.92109	217.80018	154.34379	90628.484



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3128600	05	.1000000	04	.1498425	01-	.2325000	03
.3228600	05	.8653305	03	.1283352	01-	.2349061	03
.3328600	05	.7499351	03	.1100935	01-	.2373123	03
.3428600	05	.6508961	03	.9459506	02-	.2397184	03
.3528600	05	.5657608	03	.8140521	02-	.2421245	03
.3628600	05	.4924644	03	.7016162	02-	.2445307	03
.3728600	05	.4290652	03	.6056169	02-	.2469368	03
.3828600	05	.3746909	03	.5235211	02-	.2493430	03
.3928600	05	.3274960	03	.4532067	02-	.2517491	03
.4028600	05	.2866244	03	.3928911	02-	.2541552	03
.4128600	05	.2511792	03	.3410755	02-	.2565614	03
.4228600	05	.2203976	03	.2964967	02-	.2589675	03
.4328600	05	.1936301	03	.2580888	02-	.2613737	03
.4428600	05	.1703242	03	.2249149	02-	.2638252	03
.4528600	05	.1500085	03	.1962371	02-	.2663134	03
.4628600	05	.1322774	03	.1714400	02-	.2688015	03
.4728600	05	.1167819	03	.1499686	02-	.2712097	03
.4828600	05	.1032229	03	.1313517	02-	.2737778	03
.4928600	05	.9132106	02	.1156246	02-	.2751560	03
.5028600	05	.8078318	02	.1030332	02-	.2731504	03
.5128600	05	.7139951	02	.9173859	03-	.2711448	03
.5228600	05	.6305047	02	.8161490	03-	.2691392	03
.5328600	05	.5562814	02	.7254777	03-	.2671336	03
.5428600	05	.4902878	02	.6455825	03-	.2645803	03
.5528600	05	.4315882	02	.5743182	03-	.2618033	03
.5628600	05	.3794151	02	.5103039	03-	.2590063	03
.5728600	05	.3330998	02	.4528661	03-	.2562493	03
.5828600	05	.2919949	02	.4021824	03-	.2529359	03
5928600	05	.2554564	02	.3580484	03-	.2485612	03
.6028600	05	.2229696	02	.3181136	03-	.2441865	03
.6128600	05	.1941446	02	.2820414	03-	.2398119	03
.6228600	05	.1686231	02	.2495171	03-	.2354372	03
.6328600	05	.1460886	02	.2200091	03-	.2313310	03
.6428600	05	.1263302	02	.1919326	03-	.2293067	03
.6528600	05	.1091084	02	.1672441	03-	.2272824	03
.6628600	05	.9411522	01	.1455585	03-	.2252581	03
.6728600	05	.8107781	01	.1265319	03-	.2232338	03
.6828600	05	.6975484	01	.1098572	03-	.2212095	03
.6928600	05	.5992222	01	.9547134	04-	.2186619	03
.7028600	05	.5138047	01	.8295381	04-	.2157844	03
.7128600	05	.4396759	01	.7194509	04-	.2129069	03
.7228600	05	.3754634	01	.6227959	04-	.2100293	03
.7328600	05	.3199472	01	.5380811	04-	.2071518	03
.7428600	05	.2718522	01	.4676853	04-	.2025057	03
.7528600	05	.2301037	01	.4056556	04-	.1976169	03
.7628600	05	.1939649	01	.3506196	04-	.1907282	03
.7728600	05	.1627946	01	.3019336	04-	.1878394	03
.7828600	05	.1360111	01	.2589994	04-	.1809506	03
.7928600	05	.1135026	01	.2133584	04-	.1853336	03
.8028600	05	.9495193	00	.1760451	04-	.1879048	03
.8128600	05	.7963040	00	.1456454	04-	.1904761	03
.8228600	05	.6694253	00	.1208083	04-	.1930473	03
.8328600	05	.5629857	00	.1025636	04-	.1912328	03
.8428600	05	.4704215	00	.9143498	05-	.1792392	03
.8528600	05	.3882380	00	.8087262	05-	.1672456	03
.8628600	05	.3158847	00	.7088422	05-	.1552520	03
.8728600	05	.2536854	00	.5975985	05-	.1478918	03
.8828600	05	.2029426	00	.4719060	05-	.1498221	03
.8928600	05	.1628251	00	.3738041	05-	.1517524	03
.9028600	05	.1310111	00	.2969896	05-	.1536827	03

FIGURE 17

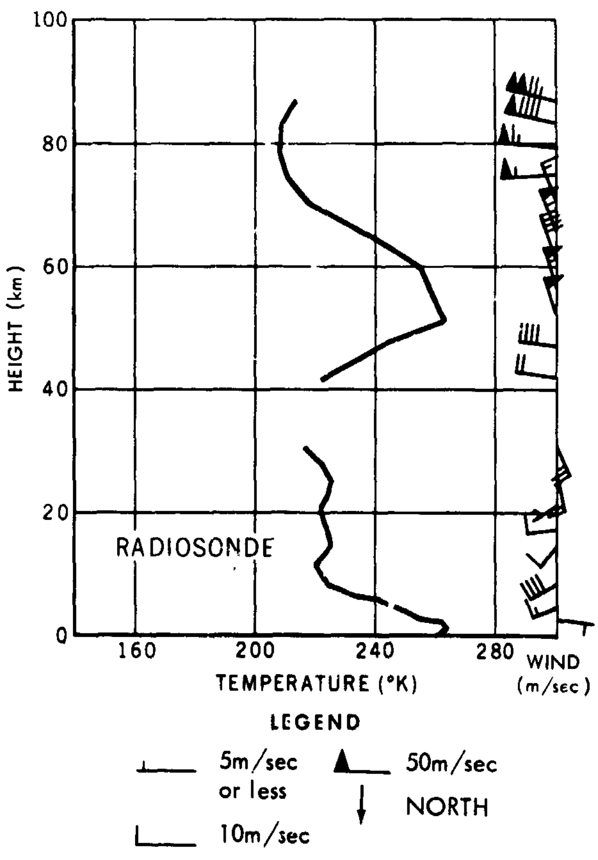
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
273.83029	53.767238	245.67549	40618.347
267.66479	83.497436	259.56347	46206.437
265.29300	94.068039	256.97729	50987.546
283.99978	99.636138	255.52859	55623.097
276.75988	85.044586	241.85888	61199.898
295.78497	80.256599	230.72470	67064.695
216.34069	36.389019	216.65219	72110.546
203.29139	115.02049	188.27578	77416.687
329.80078	196.25229	239.28830	82479.836
46.157417	45.832988	179.11309	86794.796
346.41769	389.29647	271.31540	90863.945



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2889260	05	.1300000	04	.2061350	01-	.2197100	03
.2989260	05	.1115347	04	.1750907	01-	.2219244	03
.3089260	05	.9584243	03	.1489701	01-	.2241388	03
.3189260	05	.8248469	03	.1269536	01-	.2263532	03
.3289260	05	.7109576	03	.1083645	01-	.2285676	03
.3389260	05	.6136999	03	.9264295	02-	.2307820	03
.3489260	05	.5305159	03	.7932451	02-	.2329964	03
.3589260	05	.4592600	03	.6802359	02-	.2352108	03
.3689260	05	.3981302	03	.5841933	02-	.2374252	03
.3789260	05	.3456103	03	.5024425	02-	.2396396	03
.3889260	05	.3004224	03	.4327502	02-	.2418540	03
.3989260	05	.2614878	03	.3732486	02-	.2440684	03
.4089260	05	.2278992	03	.3222819	02-	.2463571	03
.4189260	05	.1988968	03	.2784593	02-	.2488423	03
.4289260	05	.1738276	03	.2409554	02-	.2513276	03
.4389260	05	.1521260	03	.2088084	02-	.2538129	03
.4489260	05	.1333123	03	.1812104	02-	.2562982	03
.4589260	05	.1169791	03	.1574816	02-	.2587835	03
.4689260	05	.1027264	03	.1380759	02-	.2591923	03
.4789260	05	.9021051	02	.1215068	02-	.2586514	03
.4889260	05	.7920117	02	.1069016	02-	.2581105	03
.4989260	05	.6951930	02	.9403056	03-	.2575695	03
.5089260	05	.6100673	02	.8269028	03-	.2570286	03
.5189260	05	.5352674	02	.7264614	03-	.2566944	03
.5289260	05	.4695803	02	.6380881	03-	.2563819	03
.5389260	05	.4119050	02	.5603992	03-	.2560694	03
.5489260	05	.3612704	02	.4921112	03-	.2557569	03
.5589260	05	.3167762	02	.4330075	03-	.2548680	03
.5689260	05	.2775331	02	.3830493	03-	.2524168	03
.5789260	05	.2428479	02	.3384638	03-	.2499656	03
.5889260	05	.2122270	02	.2987159	03-	.2475145	03
.5989260	05	.1852264	02	.2633194	03-	.2450633	03
.6089260	05	.161[illegible]59	02	.2318330	03-	.2426121	03
.6189260	05	.1405455	02	.2035546	03-	.2405438	03
.6289260	05	.1222150	02	.1784144	03-	.2386453	03
.6389260	05	.1061614	02	.1562215	03-	.2367468	03
.6489260	05	.9211609	01	.1366489	03-	.2348484	03
.6589259	05	.7984050	01	.1194040	03-	.2329499	03
.6689259	05	.6912293	01	.1042249	03-	.2310514	03
.6789259	05	.5976166	01	.9114961	04-	.2284157	03
.6889259	05	.5158077	01	.7964442	04-	.2256268	03
.6989259	05	.4444041	01	.6947799	04-	.2228379	03
.7089259	05	.3821849	01	.6050795	04-	.2200490	03
.7189259	05	.3280607	01	.5260566	04-	.2172600	03
.7289259	05	.2808563	01	.4605162	04-	.2124699	03
.7389259	05	.2395546	01	.4029362	04-	.2071221	03
.7489259	05	.2034884	01	.3513436	0[illegible]-	.2017742	03
.7589259	05	.1721051	01	.3052474	04-	.1964264	03
.7689259	05	.1448981	01	.2641856	04-	.1910785	03
.7789259	05	.1218167	01	.2198107	0[illegible]-	.1930707	03
.7889259	05	.1029564	01	.1765646	04-	.2031459	03
.7989259	05	.8773210	00	.1433463	04-	.2132211	03
.8089259	05	.7531704	00	.1175086	04-	.2232964	03
.8189259	05	.6509872	00	.9718126	05-	.2333717	03
.8289259	05	.5645094	00	.8421372	05-	.2335321	03
.8389259	05	.4873984	00	.7732802	05-	.2195864	03
.8489259	05	.4168033	00	.7061230	05-	.2056407	03
.8589259	05	.3525550	00	.6407291	05-	.1916949	03
.8689259	05	.2949986	00	.5667752	05-	.1813290	03
.8789259	05	.2482211	00	.4239283	05-	.203987[illegible]	03
.8889259	05	.2127082	00	.3269587	05-	.2266468	03
.8989259	05	.1849879	00	.2585053	05-	.2493057	03
.9089259	05	.1628287	00	.2090840	05-	.2713116	03

FIGURE 18

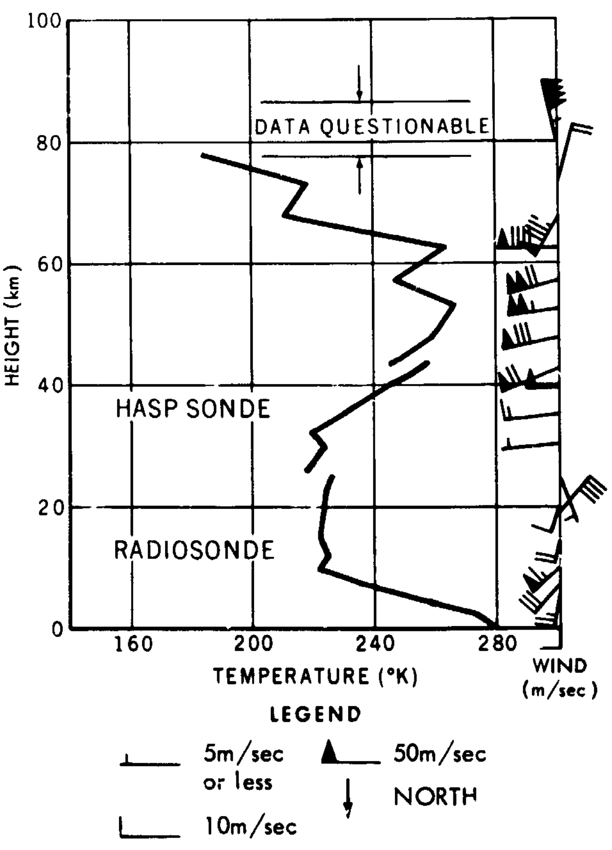
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
290.36468	20.766498	221.75138	41866.148
288.81070	40.355209	242.00459	47108.296
330.36560	48.105667	262.88278	51592.347
334.51089	54.224269	258.55648	55932.187
339.43869	39.816047	254.45228	60114.148
328.10589	55.908588	238.15919	65105.547
333.09668	13.910879	218.05169	70373.898
263.82138	54.381446	210.59829	74878.593
279.66458	64.996559	208.21719	79168.898
294.59338	91.706909	208.93289	83243.593
299.68167	125.85369	212.67819	86702.132



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3064000	05	.1000000	04	.1603978	01-	.2172000	03
.3164000	05	.8557217	03	.1370001	01-	.2176054	03
.3264000	05	.7325066	03	.1170554	01-	.2180108	03
.3364000	05	.6272446	03	.1000484	01-	.2184163	03
.3464000	05	.5372898	03	.8554141	02-	.2188217	03
.3564000	05	.4603895	03	.7316263	02-	.2192271	03
.3664000	05	.3946274	03	.6259631	02-	.2196325	03
.3764000	05	.3383709	03	.5357393	02-	.2200380	03
.3864000	05	.2902301	03	.4586734	02-	.2204434	03
.3964000	05	.2490202	03	.3928237	02-	.2208488	03
.4064000	05	.2137321	03	.3365396	02-	.2212543	03
.4164000	05	.1835045	03	.2884153	02-	.2216597	03
.4264000	05	.1577466	03	.2445319	02-	.2247412	03
.4364000	05	.1359248	03	.2071437	02-	.2286047	03
.4464000	05	.1174197	03	.1759688	02-	.2324682	03
.4564000	05	.1016835	03	.1498948	02-	.2363318	03
.4664000	05	.8826577	02	.1280224	02-	.2401953	03
.4764000	05	.7680436	02	.1094461	02-	.2444802	03
.4864000	05	.6700262	02	.9369423	03-	.2491363	03
.4964000	05	.5860218	02	.8044393	03-	.2537924	03
.5064000	05	.5138202	02	.6926204	03-	.2584465	03
.5164000	05	.4515614	02	.5985374	03-	.2628352	03
.5264000	05	.3971945	02	.5284795	03-	.2618384	03
.5364000	05	.3492161	02	.4664186	03-	.2608415	03
.5464000	05	.3068940	02	.4114649	03-	.2598446	03
.5564000	05	.2695780	02	.3628259	03-	.2588477	3
.5664000	05	.2366912	02	.3197815	03-	.2578618	03
.5764000	05	.2077214	02	.2817140	03-	.2568804	03
.5864000	05	.1822136	02	.2480678	03-	.2558990	03
.5964000	05	.1597043	02	.2183424	03-	.2549176	03
.6064000	05	.1399718	02	.1929444	03-	.2527358	03
.6164000	05	.1224605	02	.1710147	03-	.2494715	03
.6264000	05	.1069561	02	.1513431	03-	.2462073	03
.6364000	05	.9324993	01	.1337218	03-	.2429431	03
.6464000	05	.8115300	01	.1179595	03-	.2396788	03
.6564000	05	.7048782	01	.1040017	03-	.2361194	03
.6664000	05	.6109125	01	.9161846	04-	.2323027	03
.6764000	05	.5282436	01	.8054392	04-	.2284660	03
.6864000	05	.4556648	01	.7065775	04-	.2246694	03
.6964000	05	.3920823	01	.6184899	04-	.2208527	03
.7064000	05	.3365729	01	.5388349	04-	.2176114	03
.7164000	05	.2884390	01	.4653130	04-	.2159568	03
.7264000	05	.2469075	01	.4013393	04-	.2143022	03
.7364000	05	.2111117	01	.3458677	04-	.2126476	03
.7464000	05	.1802936	01	.2976941	04-	.2109930	03
.7564000	05	.1538394	01	.2550018	04-	.2101757	03
.7664000	05	.1312049	01	.2180589	04-	.2096207	03
.7764000	05	.1118569	01	.1864000	04-	.2090657	03
.7864000	05	.9532987	00	.1592791	04-	.2085107	03
.7964000	05	.8122319	00	.1358467	04-	.2082999	03
.8064000	05	.6920720	00	.1156523	04-	.2084756	03
.8164000	05	.5897942	00	.9847768	05-	.2086512	03
.8264000	05	.5027259	00	.8386932	05-	.2088269	03
.8364000	05	.4286470	00	.7132797	05-	.2093621	03
.8464000	05	.3657261	00	.6054459	05-	.2104451	03
.8564000	05	.3123110	00	.5143724	05-	.2112280	03
.8664000	05	.2669252	00	.4373834	05-	.2120100	03

FIGURE 19

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
248.97470	71.465309	244.66299	43146.937
259.58279	82.278358	259.48867	48478.148
257.88967	103.08649	265.55178	53019.250
250.40109	122.64289	247.70709	57394.699
271.84619	91.785987	262.91629	62650.347
212.86879	87.717720	210.57238	68162.734
18.724060	20.152278	217.48979	72900.132
348.64187	202.72158	184.07159	77840.836
132.55758	339.43707	93.948997	82529.546
272.95788	385.39788	327.72747	86532.296



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2604670	05	.2000000	04	.3237469	01-	.2152200	03
.2704670	05	.1709929	04	.2745953	01-	.2169418	03
.2804670	05	.1463812	04	.2332207	01-	.2186635	03
.2904670	05	.1254708	04	.1983436	01-	.2203853	03
.3004670	05	.1076817	04	.1689032	01-	.2221071	03
.3104670	05	.9252830	03	.1440179	01-	.2238289	03
.3204670	05	.7960349	03	.1229550	01-	.2255507	03
.3304670	05	.6856570	03	.1051037	01-	.2272[illegible]5	03
.3404670	05	.5912771	03	.8995484	02-	.2289943	03
.3504670	05	.5104778	03	.7708274	02-	.2307161	03
.3604670	05	.4412218	03	.6613148	02-	.2324379	03
.3704670	05	.3017895	03	.5680284	02-	.2341597	03
.3804670	05	.3307277	03	.4884667	02-	.2358814	03
.3904670	05	.2868072	03	.4205289	02-	.2376032	03
.4004670	05	.2489863	03	.3624479	02-	.2393250	03
.4104670	05	.2163815	03	.3127353	02-	.2410468	03
.4204670	05	.1882424	03	.2701365	02-	.2427686	03
.4304670	05	.1639311	03	.2335919	02-	.2444904	03
.4404670	05	.1429421	03	.2014796	02-	.2471651	03
.4504670	05	.1248333	03	.1739972	02-	.2499461	03
.4604670	05	.1091867	03	.1505138	02-	.2527270	03
.4704670	05	.9564529	02	.1304119	02-	.2555079	03
.4804670	05	.8390687	02	.1131749	02-	.2582888	03
.4904670	05	.7370027	02	.9865980	03-	.2602477	03
.5004670	05	.6479087	02	.8629041	03-	.2615829	03
.5104670	05	.5699818	02	.7552638	03-	.2629181	03
.5204670	05	.5017729	02	.6615231	03-	.2642532	03
.5304670	05	.4420119	02	.5801310	03-	.2654398	03
.5404670	05	.3891117	02	.5186698	03-	.2613614	03
.5504670	05	.3418705	02	.4629228	03-	.2572831	03
.5604670	05	.2997563	02	.4124342	03-	.2532047	03
.5704670	05	.2622805	02	.3667791	03-	.2491263	03
.5804670	05	.2292788	02	.3200282	03-	.2495939	03
.5904670	05	.2006179	02	.2768137	03-	.2524877	03
.6004670	05	.1758143	02	.2398406	03-	.2553816	03
.6104670	05	.1543129	02	.2081503	03-	.2582755	03
.6204670	05	.1356434	02	.1809400	03-	.2611694	03
.6304670	05	.1192634	02	.1603281	03-	.2591526	03
.6404670	05	.1045592	02	.1459073	03-	.2496570	03
.6504670	05	.9100528	01	.1323047	03-	.2401613	03
.6604669	05	.7912295	01	.1195027	03-	.2306656	03
.6704669	05	.6823545	01	.1074836	03-	.2211699	03
.6804669	05	.5846780	01	.9622920	04-	.2116742	03
.6904669	05	.4993262	01	.8210832	04-	.2118631	03
.7004669	05	.4267132	01	.6968768	04-	.2133233	03
.7104669	05	.3650684	01	.5921498	04-	.2147834	03
.7204669	05	.3126745	01	.5037411	04-	.2162436	03
.7304669	05	.2679781	01	.4312238	04-	.2164984	03
.7404669	05	.2291380	01	.3806145	04-	.2097346	03
.7504669	05	.1949340	01	.3345894	04-	.2029707	03
.7604669	05	.1649379	[illegible]	.2928630	04-	.1962069	03
.7704669	05	.1387493	01	.2551587	04-	.1894430	03
.7804669	05	.1158476	01	.2240764	04-	.1801147	03
.7904669	05	.9526619	00	.2062806	04-	.1608935	03
.8004669	05	.7641867	00	.1879198	04-	.1416723	03
.8104669	05	.5936266	00	.1688918	04-	.1224512	03
.8204669	05	.4416710	00	.1490566	04-	.1032300	03
.8304669	05	.3293313	[illegible]	.9241337	05-	.1241528	03
.8404669	05	.2644035	00	.5045758	05-	.1825572	03
.8504669	05	.2257515	00	.3263930	05-	.2409617	03
.8604669	05	.1995179	00	.2321867	05-	.2993661	03

FIGURE 20

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
284.19079	32.374157	222.58299	41977.500
271.21618	29.083198	240.94349	47418.187
302.20727	56.672359	250.83938	52084.347
311.63467	21.642078	262.77108	56597.250
302.11697	3.6421179	261.85049	60956.847
55.247146	20.369548	238.49319	66180.343
127.13758	42.825447	220.66958	71686.445
235.76329	15.062839	209.03039	76435.148
257.93728	34.519538	187.90699	80973.046
300.67657	119.71708	208.01059	85273.843
301.21899	88.249855	198.10629	88936.548

HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2760000	05	.1300000	04	.2085171	01-	.2172000	03
.2860000	05	.1112262	04	.1780973	01-	.2175744	03
.2960000	05	.9519342	03	.1521635	01-	.2179488	03
.3060000	05	.8149743	03	.1300476	01-	.2183232	03
.3160000	05	.6979395	03	.1111814	01-	.2186976	03
.3260000	05	.5979000	03	.9508234	02-	.2190720	03
.3360000	05	.5123596	03	.8134008	02-	.2194464	03
.3460000	05	.4391932	03	.6960573	02-	.2198208	03
.3560000	05	.3765916	03	.5958280	02-	.2201952	03
.3660000	05	.3230128	03	.5101904	02-	.2205696	03
.3760000	05	.2771425	03	.4369975	02-	.2209440	03
.3860000	05	.2378595	03	.3744217	02-	.2213184	03
.3960000	05	.2042064	03	.3209046	02-	.2216928	03
.4060000	05	.1753683	03	.2751216	02-	.2220672	03
.4160000	05	.1506487	03	.2359432	02-	.2224416	03
.4260000	05	.1295342	03	.2008496	02-	.2246837	03
.4360000	05	.1115930	03	.1704704	02-	.2260584	03
.4460000	05	.9635183	02	.1450417	02-	.2314330	03
.4560000	05	.8337308	02	.1237006	02-	.2348077	03
.4660000	05	.7229490	02	.1057441	02-	.2381824	03
.4760000	05	.6281316	02	.9067743	03-	.2413291	03
.4860000	05	.5466085	02	.7822130	03-	.2434498	03
.4960000	05	.4762602	02	.6756566	03-	.2455706	03
.5060000	05	.4154754	02	.5843763	03-	.2476914	03
.5160000	05	.3628858	02	.5060746	03-	.2498122	03
.5260000	05	.3173518	02	.4383786	03-	.2522027	03
.5360000	05	.2779123	02	.3799156	03-	.2548466	03
.5460000	05	.2437178	02	.3297495	03-	.2574905	03
.5560000	05	.2140260	02	.2866334	03-	.2601344	03
.5660000	05	.1862057	02	.2495252	03-	.2627705	03
[illegible]760000	05	.1656052	02	.2197376	03-	.2625593	03
.[illegible]60000	05	.1457086	02	.1934930	03-	.2623482	03
.5960000	05	.1281947	02	.1703727	03-	.2621370	03
.6060000	05	.1127792	02	.1500061	03-	.2619258	03
.6160000	05	.9914414	01	.1333731	03-	.2589746	03
.6260000	05	.8699873	01	.1190908	03-	.2545030	03
.6360000	05	.7616766	01	.1061290	03-	.2500314	03
.6460000	05	.6652800	01	.9438551	04-	.2455598	03
.6560000	05	.5796647	01	.8376431	04-	.2410882	03
.6660000	05	.5038653	01	.7402469	04-	.2371352	03
.6760000	05	.4370616	01	.6509864	04-	.2338993	03
.6860000	05	.3763815	01	.5714909	04-	.2306634	03
.6960000	05	.3269279	01	.5008033	04-	.2274275	03
.7060000	05	.2818931	01	.4380495	04-	.2241917	03
.7160000	05	.2425500	01	.3824390	04-	.2209558	03
.7260000	05	.2082973	01	.3322162	04-	.2184344	03
.7360000	05	.1785787	01	.2880511	04-	.2159823	03
.7460000	05	.1528386	01	.2493629	04-	.2135303	03
.7560000	05	.1305801	01	.2155221	04-	.2110782	03
.7660000	05	.1113483	01	.1862643	04-	.2082630	03
.7760000	05	.9467931	00	.1620010	04-	.2036081	03
.7660000	05	.8020842	00	.1404517	04-	.1989532	03
.7960000	05	.6768652	00	.1213644	04-	.1942984	03
.8060000	05	.5688791	00	.1045058	04-	.1896435	03
.8160000	05	.4773957	00	.8715107	05-	.1908376	03
.8260000	05	.4017105	00	.7158104	05-	.1955100	03
.8360000	05	.3394235	00	.5906981	05-	.2001864	03
.8460000	05	.2879266	00	.4896448	05-	.2048608	03
.8560000	05	.2449343	00	.4119720	05-	.2071286	03
.8660000	05	.2083360	00	.3550499	05-	.2044246	03
.8760000	05	.1768338	00	.3054029	05-	.2017206	03
.8860000	05	.1497709	00	.2621780	05-	.1990166	03

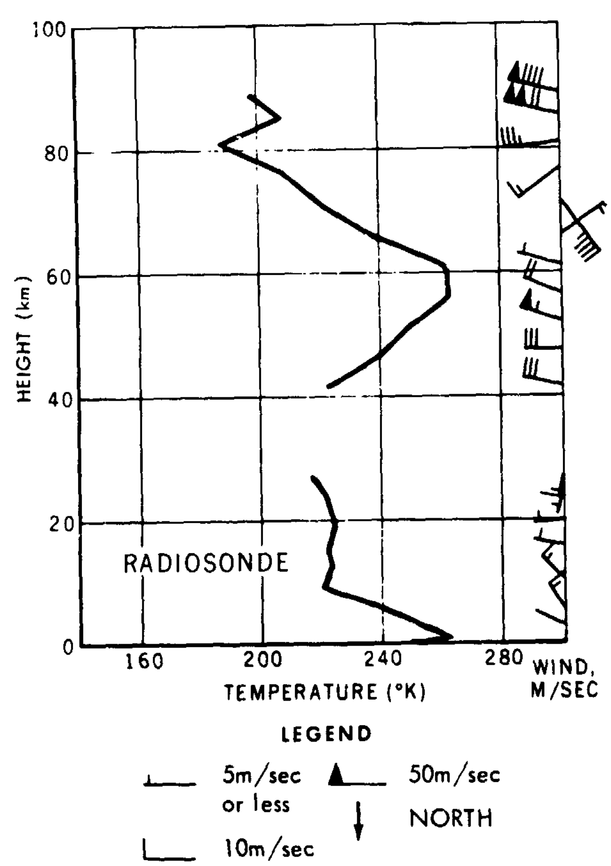
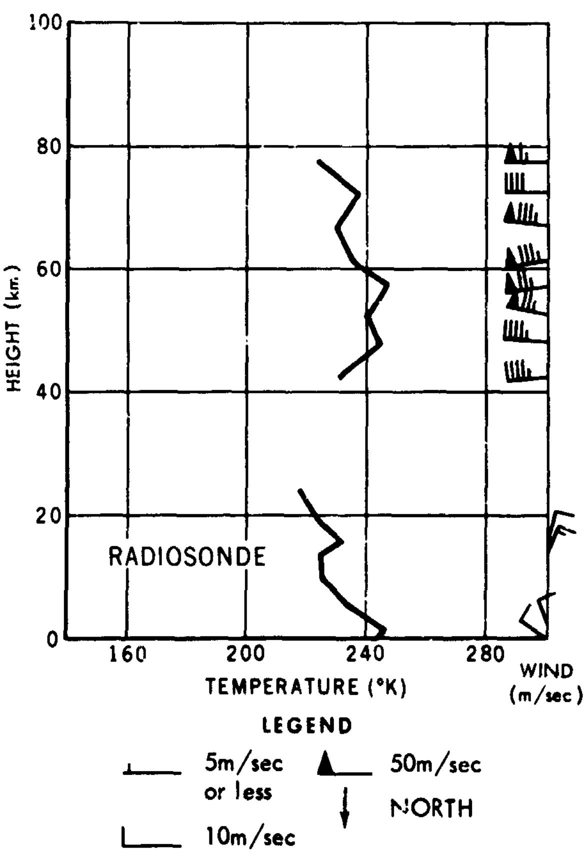


FIGURE 21

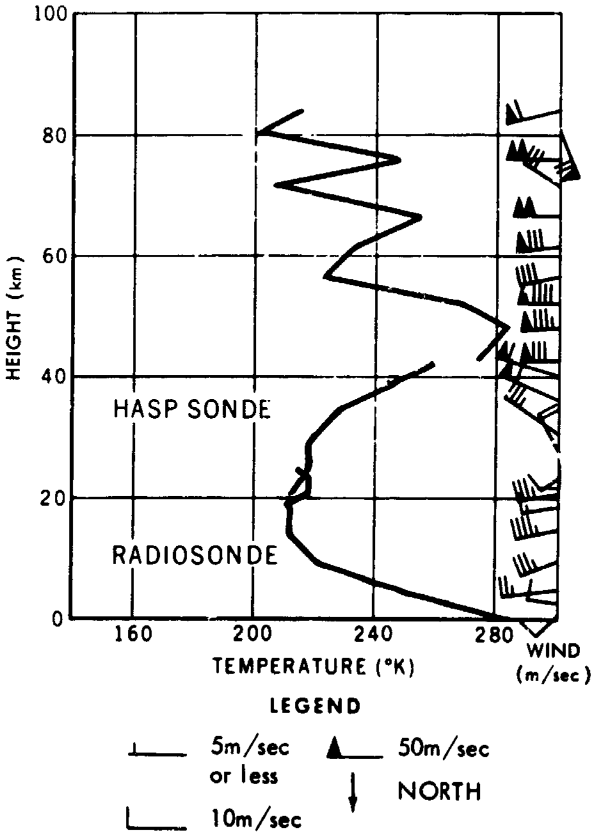
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
262.60537	43.649078	231.49218	42507.648
275.74258	43.370437	244.15739	48028.449
286.31298	76.299484	240.30319	52744.500
254.90879	75.013313	246.50650	57296.250
257.16519	83.688209	235.64189	61691.097
283.97580	82.753585	229.45658	66965.843
268.59268	41.507049	236.89219	72513.195
273.20635	64.814689	223.62619	77263.539



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2907000	05	.1230000	04	.2007083	01-	.2135000	03
.3007000	05	.1049980	04	.1702653	01-	.2148389	03
.3107000	05	.8972328	03	.1445946	01-	.2161779	03
.3207000	05	.7674885	03	.1229242	01-	.2175168	03
.3307000	05	.6571673	03	.1046107	01-	.2188557	03
.3407000	05	.5632642	03	.8911760	02-	.2201947	03
.3507000	05	.4832532	03	.7599644	02-	.2215336	03
.3607000	05	.4150106	03	.6487252	02-	.2228725	03
.3707000	05	.3567466	03	.5543195	02-	.2242115	03
.3807000	05	.3069531	03	.4741181	02-	.2255504	03
.3907000	05	.2643569	03	.4059146	02-	.2268894	03
.4007000	05	.2278827	03	.3478564	02-	.2282283	03
.4107000	05	.1966206	03	.2983853	02-	.2295672	03
.4207000	05	.1698006	03	.2561898	02-	.2309062	03
.4307000	05	.1467947	03	.2196943	02-	.2327822	03
.4407000	05	.1270763	03	.1883275	02-	.2350763	03
.4507000	05	.1101657	03	.1616881	02-	.2373704	03
.4607000	05	.9564090	02	.1390266	02-	.2396645	03
.4707000	05	.8314666	02	.1197187	02-	.2419586	03
.4807000	05	.7238067	02	.1032931	02-	.2441234	03
.4907000	05	.6303553	02	.9025898	03-	.2433062	03
.5007000	05	.5487370	02	.7883706	03-	.2424889	03
.5107000	05	.4774843	02	.6883218	03-	.2416717	03
.5207000	05	.4153059	02	.6007194	03-	.2408544	03
.5307000	05	.3611416	02	.5226069	03-	.2407468	03
.5407000	05	.3141710	02	.4520768	03-	.2421096	03
.5507000	05	.2735351	02	.3914005	03-	.2434725	03
.5607000	05	.2383494	02	.3391550	03-	.2448353	03
.5707000	05	.2078575	02	.2941298	03-	.2461981	03
.5807000	05	.1812616	02	.2581778	03-	.2445937	03
.5907000	05	.1578943	02	.2271910	03-	.2421216	03
.6007000	05	.1373506	02	.1996698	03-	.2396494	03
.6107000	05	.1193125	02	.1752553	03-	.2371773	03
.6207000	05	.1035106	02	.1533240	03-	.2351976	03
.6307000	05	.8971970	01	.1335623	03-	.2340249	03
.6407000	05	.7771385	01	.1162722	03-	.2328523	03
.6507000	05	.6726877	01	.1011542	03-	.2316797	03
.6607000	05	.5818753	01	.8794353	04-	.2305071	03
.6707000	05	.5030152	01	.7632637	04-	.2295962	03
.6807000	05	.4349217	01	.6561099	04-	.2309366	03
.6907000	05	.3763795	01	.5645184	04-	.2322769	03
.7007000	05	.3260031	01	.4861551	04-	.2336173	03
.7107000	05	.2826141	01	.4190465	04-	.2349577	03
.7207000	05	.2452096	01	.3615225	04-	.2362981	03
.7307000	05	.2127892	01	.3150047	04-	.2353372	03
.7407000	05	.1844533	01	.2763365	04-	.2325446	03
.7507000	05	.1596219	01	.2420425	04-	.2297519	03
.7607000	05	.1378956	01	.2116707	04-	.2269593	03
.7707000	05	.1189164	01	.1848115	04-	.2241667	03
.7807000	05	.1024067	01	.1602619	04-	.2226160	03

FIGURE 22

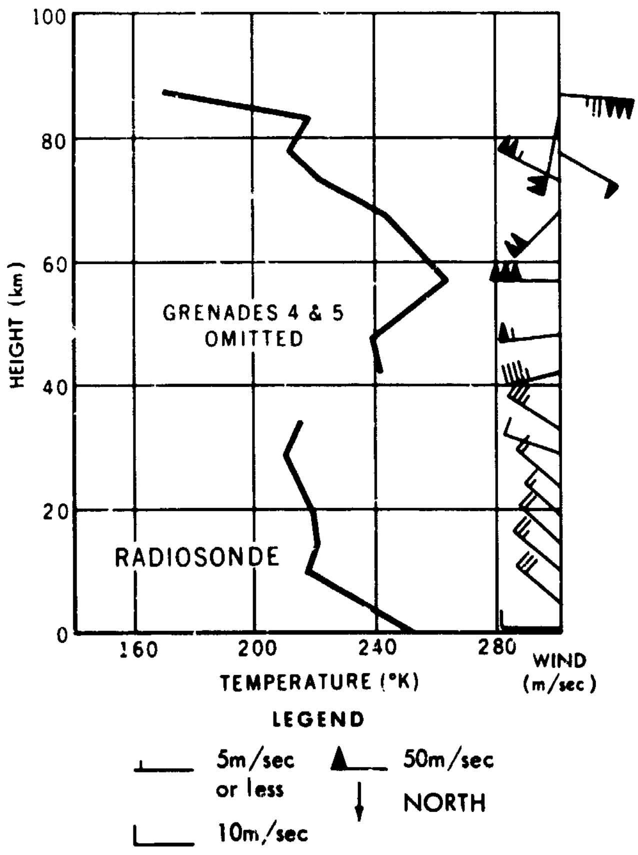
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
263.11258	80.682609	273.56659	42865.167
265.66339	84.451606	282.37439	47969.898
269.63528	91.402267	267.79379	52329.097
240.19299	37.619449	222.63978	56531.949
246.00149	78.274139	233.32418	61522.949
267.05758	102.42919	254.66459	66767.148
314.19027	30.184509	205.86940	71267.734
272.62970	97.967979	247.11109	75924,093
159.61169	68.393969	201.14839	80321.648
252.52330	60.476368	216.76379	84072.484



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu mc⁺ers		TEMPERATURE degrees Kelvin	
.2705400	05	.1700000	04	.2732550	01-	.2167400	03
.2805400	05	.1456068	04	.2302281	01-	.2203340	03
.2905400	05	.1250327	04	.1945241	01-	.2239281	03
.3005400	05	.1076315	04	.1648063	01-	.2275222	03
.3105400	05	.9287427	03	.1399984	01-	.2311163	03
.3205400	05	.8032656	03	.1192299	01-	.2347103	03
.3305400	05	.6963062	03	.1017950	01-	.2383044	03
.3405400	05	.6049082	03	.8711931	02-	.2418985	03
.3505400	05	.5266217	03	.7473405	02-	.2454926	03
.3605400	05	.4594110	03	.6425532	02-	.2490866	03
.3705400	05	.4015797	03	.5536767	02-	.2526807	03
3805400	05	.3517105	03	.4761207	02-	.2562748	03
.3905400	05	.3086161	03	.4137352	02-	.2598688	03
.4005400	05	.2712995	03	.3587465	02-	.2634629	03
.4105400	05	.2389214	03	.3116802	02-	.2670570	03
.4205400	05	.2107735	03	.2713091	02-	.2706511	03
.4305400	05	.1862418	03	.2368948	02-	.2738923	03
.4405400	05	.1647560	03	.2082535	02-	.2756177	03
.4505400	05	.1458660	03	.1832292	02-	.2773432	03
.4605400	05	.1292443	03	.1613461	02-	.2790686	03
.4705400	05	.1146063	03	.1421932	02-	.2807940	03
.4805400	05	.1016957	03	1255938	02-	.2820931	03
.4905400	05	.9020333	02	.1127375	02-	.2787483	03
.5005400	05	.7989696	02	.1010692	02-	.2754035	03
.5105400	05	.7066601	02	.9049115	03-	.2720587	03
.5205400	05	.6240913	02	.8091260	03-	.2687139	03
.5305400	05	.5496276	02	.7364510	03-	.2600057	03
.5405400	05	.4817213	02	.6732833	03-	.2492620	03
.5505400	05	.4197763	02	.6131324	03-	.2385183	03
.5605400	05	.3634995	02	.5559767	03-	.2277747	03
.5705400	05	.3133113	02	.4876170	03-	.2237573	03
.5805400	05	.2698985	02	.4162423	03-	.2258981	03
.5905400	05	.2328390	02	.3557175	03-	.2280388	03
.6005400	05	.2011547	02	.3044540	03-	.2301795	03
.6105400	05	.1740252	02	.2609656	03-	.2323203	03
.6205400	05	.1508088	02	.2231111	03-	.2354852	03
.6305400	05	.1309805	02	.1904848	03-	.2395545	03
.6405400	05	.1140345	02	.1630703	03-	.2436239	03
.6505400	05	.9951336	01	.1399669	03-	.2476932	03
.6605400	05	.8703768	01	.1204413	03-	.2517625	03
.6705400	05	.7620777	01	.1055420	03-	.2515545	03
.6805400	05	.6652808	01	.9628628	04-	.2407126	03
.6905400	05	.5771790	01	.8747527	04-	.2298706	03
.7005400	05	.4973417	01	.7910650	04-	.2190286	03
.7105400	05	.4253410	01	.7117747	04-	.2081867	03
.7205400	05	.3629558	01	.5941173	04-	.2128334	03
.7305400	05	.3112613	01	.4891435	04-	.2216905	03
.7405400	05	.2685535	01	.4058154	04-	.2305475	03
.7505400	05	.2330087	01	.3390765	04-	.2394046	03
.7605400	05	.2030804	01	.2876902	04-	.2457533	03
.7705400	05	.1767939	01	.2617586	04-	.2353014	03
.7805400	05	.1529503	01	.2369826	04-	.2248496	03
.7905400	05	.1314191	01	.2135485	04-	.2143977	03
.8005400	05	.1120713	01	.1914422	04-	.2039458	03
.8105400	05	.9520050	00	.1624230	04-	.2041973	03
.8205400	05	.8101413	00	.1354577	04-	.2083605	03
.8305400	05	.6916559	00	.1133812	04-	.2125236	03
.8405400	05	.5923419	00	.9523534	05-	.2166868	03

FIGURE 23

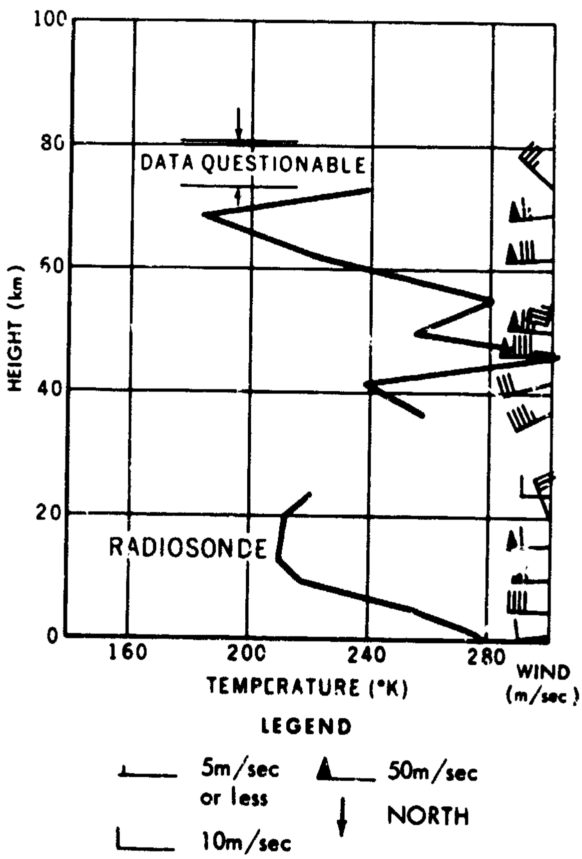
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
262.00698	43.808818	241.95039	42457.347
265.68618	54.826538	238.57479	48063.000
270.27807	148.54609	264.38278	57444.046
227.91558	100.64650	243.20858	67609.046
296.37479	103.47199	222.15139	73349.937
119.05209	51.014370	212.26008	78287.843
196.22400	98.051452	218.47589	83003. 48
91.258529	172.84658	170.39279	87487.[illegible]



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3336000	05	.6200000	03	.9972211	02-	.2166000	03
.3436000	05	.5308386	03	.8429634	02-	.2193875	03
.3536000	05	.4554130	03	.7141151	02-	.2221751	03
.3636000	05	.3914702	03	.6062425	02-	.2249626	03
.3736000	05	.3371486	03	.5157281	02-	.2277502	03
.3836000	05	.2909064	03	.4396118	02-	.2305376	03
.3936000	05	.2514635	03	.3754665	02-	.2333253	03
.4036000	05	.2177547	03	.3212065	02-	.2361129	03
.4136000	05	.1868917	03	.2754573	02-	.2389005	03
.4236000	05	.1641322	03	.2365903	02-	.2416880	03
.4336000	05	.1427284	03	.2059708	02-	.2414144	03
.4436000	05	.1240899	03	.1795226	02-	.2408106	03
.4536000	05	.1078519	03	.1564230	02-	.2402068	03
.4636000	05	.9370995	02	.1362547	02-	.2396030	03
.4736000	05	.8139702	02	.1186506	02-	.2389992	03
.4836000	05	.7070093	02	.1028902	02-	.2393918	03
.4936000	05	.6146928	02	.8843913	03-	.2421429	03
.5036000	05	.5352989	02	.7615113	03-	.2448940	03
.5136000	05	.4669002	02	.6568293	03-	.247645[illegible]	03
.5236000	05	.4076739	02	.5674876	03-	.2503962	03
.5336000	05	.3568511	02	.4911023	03-	.2531472	03
.5436000	05	.3126752	02	.4256810	03-	.2558983	03
.5536000	05	.2743666	02	.3695541	03-	.2586494	03
.5636000	05	.2410943	02	.3213207	03-	.2614005	03
.5736000	05	.2121523	02	.2798032	03-	.2641515	03
.5836000	05	.1867406	02	.2478616	03-	.2624748	03
.5936000	05	.1642286	02	.2197251	03-	.2603917	03
.6036000	05	.1442873	02	.1946020	03-	.2583087	03
.6136000	05	.1260306	02	.1721889	03-	.2562256	03
.6236000	05	.1110367	02	.1522114	03-	.2541426	03
.6336000	05	.9725489	01	.1344208	03-	.2520595	03
.6436000	05	.8509351	01	.1185920	03-	.2499765	03
.6536000	05	.7437282	01	.1045219	03-	.2478935	03
.6636000	05	.6493173	01	.9202692	04-	.2458104	03
.6736000	05	.5662602	01	.8094126	04-	.2437273	03
.6836000	05	.4931009	01	.7144335	04-	.2404541	03
.6936000	05	.4285489	01	.6305248	04-	.2367862	03
.7036000	05	.3716488	01	.5554111	04-	.2331183	03
.7136000	05	.3215905	01	.4882845	04-	.2294503	03
.7236000	05	.2776394	01	.4283998	04-	.2257824	03
.7336000	05	.2391312	01	.3750462	04-	.2221312	03
.7436000	05	.2055812	01	.3253614	04-	.2201281	03
.7536000	05	.1765026	01	.2819057	04-	.2181249	03
.7636000	05	.1513311	01	.2439427	04-	.2161218	03
.7736000	05	.1295699	01	.2108180	04-	.2141187	03
.7836000	05	.1107912	01	.1817609	04-	.2123552	03
.7936000	05	.9472337	00	.1544418	04-	.2136734	03
.8036000	05	.8106761	00	.1313666	04-	.2149916	03
.8136000	05	.6945027	00	.1118551	04-	.2163098	03
.8236000	05	.5955634	00	.9533916	05-	.2176281	03
.8336000	05	.5104408	00	.8284639	05-	.2146495	03
.8436000	05	.4352889	00	.7436367	05-	.2039271	03
.8536000	05	.3680404	00	.6636455	05-	.1932046	03
.8636000	05	.3082299	00	.5384540	05-	.1824822	03
.8736000	05	.2553959	00	.5180250	05-	.1717597	03
.8836000	05	.2100200	00	.4340887	05-	.1685545	03

FIGURE 24

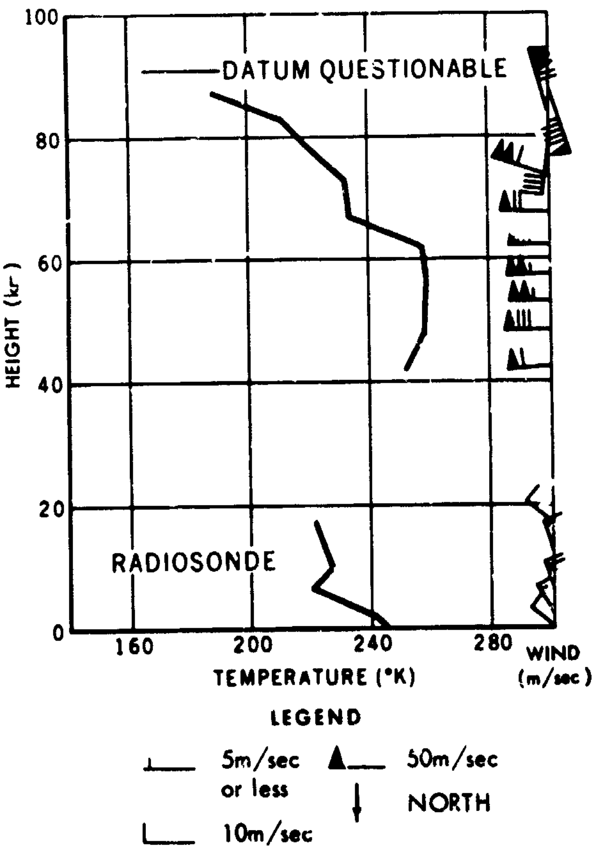
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
232.42788	45.897457	257.57629	37144.296
246.15889	30.189699	238.73149	42062.847
271.00738	89.221633	302.53408	46258.250
277.28488	75.514892	254.42720	50314.047
201.54100	36.999607	280.00747	55151.000
262.58889	77.385620	223.14878	62319.238
248.51348	65.737266	183.39270	69056.632
313.18399	34.554256	239.66099	73325.132
159.90309	280.56689	101.17469	76917.984
22.31157	446.54379	130.91799	80274.734



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2438370	05	.2600000	04	.4115021	01-	.2201200	03
.2538370	05	.2231400	04	.3485163	01-	.2230553	03
.2638370	05	.1918978	04	.2956270	[illegible]-	.2259906	03
.2738370	05	.1653592	04	.2516469	01-	.2289259	03
.2838370	05	.1427677	04	.2145162	01-	.2318612	03
.2938370	05	.1234964	04	.1832402	01-	.2347965	03
.3038370	05	.1070237	04	.1568378	01-	.2377318	03
.3138370	05	.9091546	03	.1345002	01-	.240667	03
.3238370	05	.8080890	03	.1155675	01-	.24360[illegible]	03
.3338370	05	.7040042	03	.9948325	02-	.2465378	03
.3438370	05	.6143538	0	.8579324	02-	.2494731	03
.3538370	05	.5369974	03	.7411849	02-	.2524084	03
.3638370	05	.4701317	03	.6414349	02-	.2553437	03
.3738370	05	.4100641	03	.5593278	02-	.2566590	03
.3838370	05	.3609474	03	.4973676	02-	.2528277	03
.3938370	05	.3155462	03	.4414975	02-	.2489963	03
.4038370	05	.2752930	03	.3911965	02-	.2451649	03
.4138370	05	.2396693	03	.3459816	02-	.2413335	03
.4238370	05	.2085724	03	.2982760	02-	.2436109	03
.4338370	05	.1823906	03	.2455077	02-	.2588186	03
.4438370	05	.1607282	03	.2043421	02-	.2740264	03
.4538370	05	.1426148	03	.1717803	02-	.2890341	03
.4638370	05	.1272433	03	.1472516	02-	.3010461	03
.4738370	05	.1135315	03	.1367726	02-	.2891848	03
.4838370	05	.1008184	03	.1266517	02-	.2773235	03
.4938370	05	.8906867	02	.1168908	02-	.2654623	03
.5038370	05	.7827057	02	.1070200	02-	.2547955	03
.5138370	05	.6869251	02	.9001398	03-	.2600840	03
.5238370	05	.6044756	02	.7935621	03-	.2653725	03
.5338370	05	.5332869	02	.6864254	03-	.2706610	[illegible]
.5438370	05	.4716423	02	.5954444	03-	.2759496	03
.5538370	05	.4178348	02	.5233178	03-	.2781617	03
.5638370	05	.3697095	02	.4766349	03-	.2702296	03
.5738370	05	.3259494	02	.4329264	03-	.2622976	03
.5838370	05	.2862708	02	.3920820	03-	.2543656	03
.5938370	05	.2504010	02	.3539928	03-	.2464335	03
.6038370	05	.2180777	02	.3185506	03-	.2385015	03
.6138370	05	.1890495	02	.2856484	03-	.2305695	03
.6238370	05	.1630821	02	.2550416	03-	.2227684	03
.6338370	05	.1400427	02	.2249697	03-	.2168676	03
.6438370	05	.1197598	02	.1977676	03-	.2109668	03
.6538370	05	.1019659	02	.1732286	03-	.2050660	03
.6638369	05	.8641358	01	.1511565	03-	.1991652	03
.6738369	05	.7287357	01	.1313640	03-	.1932644	03
.6838369	05	.6113454	01	.1136736	03-	.1873636	03
.6938369	05	.5115676	01	.9494836	04-	.1877041	03
.7038369	05	.4307313	01	.7469892	04-	.2008863	03
.7138369	05	.3666746	01	.5967414	04-	.2140685	03
.7238369	05	.3151777	01	.4831794	04-	.2272507	03
.7338369	05	.2729977	01	.4006173	04-	.2374037	03
.7438369	05	.2341850	01	.4102727	04-	.1988587	03
.7538369	05	.1943520	01	.4223537	04-	.1603138	03
.7638369	05	.1532051	01	.4383239	04-	.1017688	03
.7738369	05	.1141682	01	.3777198	04-	.1053012	03
.7838369	05	.8425408	00	.2571152	04-	.1141620	03
.7938369	05	.6361263	00	.1801425	04-	.1230227	03
.8038369	05	.4887637	00	.1312008	04-	.1297838	03

FIGURE 25

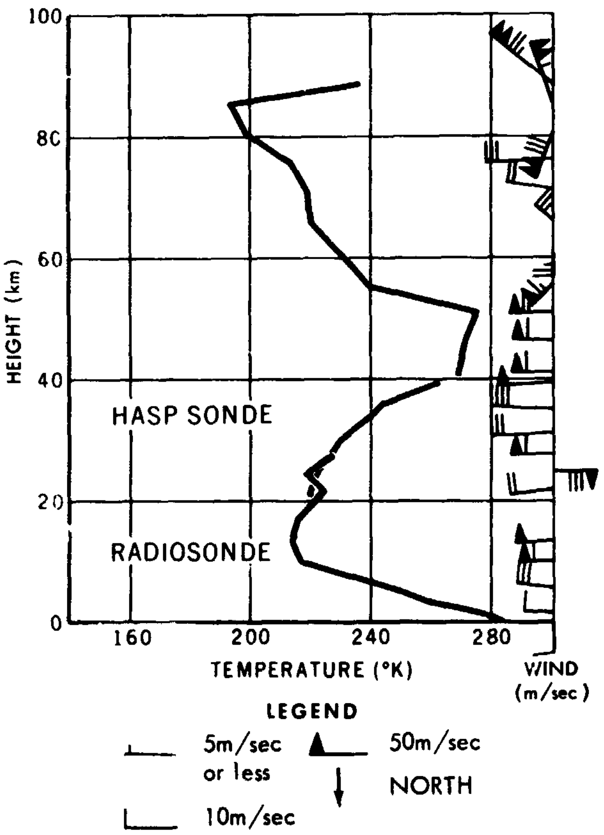
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
260.64889	61.721878	250.75329	42317.437
268.32989	79.007347	257.60409	47971.398
270.38507	104.85550	257.69119	52821.597
262.97647	104.91910	258.43267	57512.750
265.70349	68.107749	256.77227	62055.097
273.74368	70.[illegible]1676	23[illegible]0109	67513.382
306.80477	111.20809	231.48858	73290.437
187.57319	40.743816	220.89549	78[illegible]73.937
346.53317	171.06559	210.96269	83051.187
172.36470	36.968605	188.12139	87622.734
342.[illegible]1950	306.11908	225.62030	91531.937



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3336000	05	.6200000	03	.[illegible]972211	02-	.21[illegible]6000	03
.3436000	05	.5310311	03	.8395465	02-	.[illegible]204128	03
.3536000	05	.4560605	03	.7085906	02-	.22[illegible]2256	03
.3636000	05	.3926991	03	.5999428	02-	.2230385	03
.3736000	05	.3389957	03	.509[illegible]311	02-	.2318513	03
.3836000	05	.2933526	03	.4336652	02-	.2356642	03
.3936000	05	.2544562	03	.3701752	02-	.2394770	03
.4036000	05	.2212232	03	.3167852	02-	.2432899	03
.4136000	05	.1927580	03	.2717647	02-	.2471027	03
.4236000	05	.1683120	03	.2337962	02-	.2[illegible]9040	03
.4336000	05	.1471677	03	.2034425	02-	.[illegible]0165	03
.4436000	05	.1287680	03	.[illegible]771553	02-	.2532282	03
.4536000	05	.1127452	03	.1543729	02-	.2544399	03
.4636000	05	.9878261	02	.1346140	02-	.2556516	03
.4736000	05	.8660679	02	.1174649	02-	.2568632	03
.4836000	05	.7597292	02	.1027431	02-	.2576110	03
.4936000	05	.6656474	02	.9014872	03-	.2576290	03
.5036000	05	.5849947	02	.7910156	03-	.2576470	03
.5136000	05	.5133638	02	.6941098	03-	.2576649	03
.5236000	05	.4505216	02	.6090994	03-	.2576829	03
.5336000	05	.3953874	02	.5343651	03-	.2577763	03
.5436000	05	.3470334	02	.4687274	03-	.2579343	03
.5536000	05	.3046302	02	.4112027	03-	.2580924	03
.5636000	05	.2674410	02	.3607822	03-	.2582504	03
.5736000	05	.2348207	02	.3165832	03-	.2584085	03
.5836000	05	.2061784	02	.2782753	03-	.2581229	03
.5936000	05	.1810079	02	.2446496	03-	.2577574	03
.6036000	05	.1588971	02	.2150563	03-	.2573919	03
.6136000	05	.1394494	02	.1890154	03-	.2570263	03
.6236000	05	.1223354	02	.1668198	03-	.2554835	03
.6336000	05	.1071660	02	.[illegible]485928	03-	.2512567	03
.6436000	05	.9367090	01	.1321032	03-	.2470298	03
.6536000	05	.8165868	01	.1172103	03-	.2428030	03
.6636000	05	.7107123	01	.1037827	03-	.2385762	03
.6736000	05	.6168278	01	.9169767	04-	.234[illegible]494	03
.6836000	05	.5345280	01	.79794[illegible]	04-	.2333[illegible]8	03
.6936000	05	.4630366	01	.692[illegible]	04-	.2329939	03
.7036000	05	.4010297	01	.6006269	04-	.2326109	03
.7136000	05	.3472536	01	.520[illegible]24	04-	.2322279	03
.7236000	05	.3006411	01	.4517613	04-	.231844[illegible]	03
.7336000	05	.2602208	01	.391875[illegible]	04-	.23134[illegible]	03
.7436000	05	.2250595	01	.34[illegible]673	04-	.2292151	03
.7536000	05	.1943949	01	.29822[illegible]	04-	.2270494	03
.7636000	05	.1676850	01	.2596807	04-	.2249638	03
.7736000	05	.1444488	01	.2258305	04-	.2228382	03
.7836000	05	.1242607	01	.1961360	04-	.2207165	03
.7936000	05	.1067454	01	.1700916	04-	.2186373	03
.8036000	05	.9157022	00	.1473119	04-	.2165582	03
.8136000	05	.7844003	00	.1[illegible]74123	04-	.2144790	03
.8236000	05	.6709457	00	.1100504	04-	.2123998	03
.8336000	05	.5728540	00	.9529817	05-	.20941[illegible]7	03
.8436000	05	.4876373	00	.8310452	05-	.2044233	03
.8536000	05	.4134672	00	.7222964	05-	.1934269	03
.8636000	05	.3491320	00	.6255807	05-	.1944305	03
.8736000	05	.2935277	00	.5398202	05-	.1894341	03
.3836000	05	.2468767	00	.4406287	05-	.1951936	03
.8936000	05	.2090307	00	.3556051	05-	.2047860	03
.9036000	05	.178[illegible]488	00	.2898326	0[illegible]	.2143785	03
.9136000	05	.1532389	00	.2383612	05-	.2239710	03

FIGURE 26

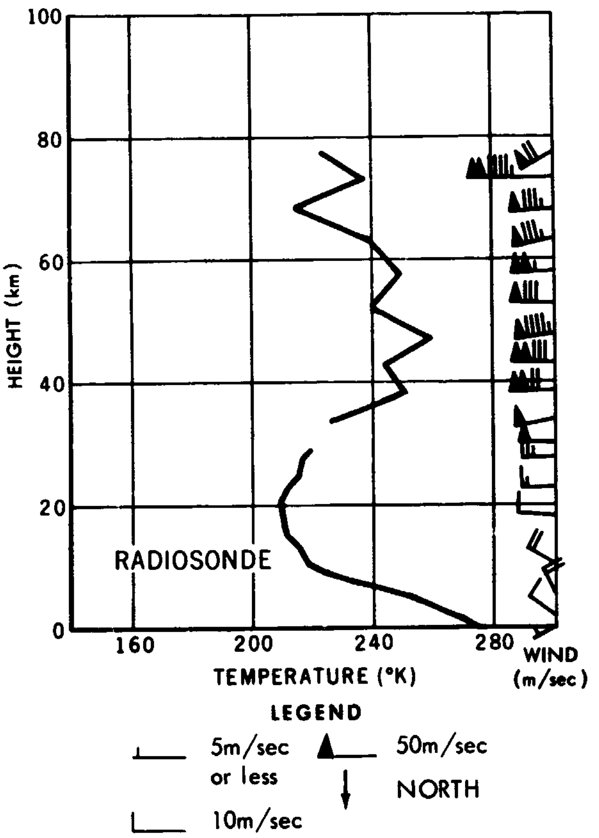
WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
272.15747	61.452530	268.70599	41274.347
274.20068	62.321479	271.26879	46610.097
261.49487	65.586547	275.41629	51168.648
219.41980	64.513748	240.00009	55569.847
180.40618	26.251798	231.82708	60863.097
314.42779	24.592708	220.14679	66444.593
290.04797	20.815719	219.13139	71234.046
265.47329	31.611558	213.91780	76220.437
206.19059	129.47969	199.31849	80953.187
338.90649	103.13029	194.28079	85013.687
302.24038	123.67859	236.12199	88816.648



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.2861200	05	.1400000	04	.2144656	01-	.2274200	03
.2961200	05	.1207758	04	.1824010	01-	.2306805	03
.3061200	05	.1044124	04	.1554905	01-	.2339410	03
.3161200	05	.9045213	03	.1328493	01-	.2372016	03
.3261200	05	.7851555	03	.1137541	01-	.2404621	03
.3361200	05	.6828720	03	.9761163	02-	.2437226	03
.3461200	05	.5950414	03	.8393401	02-	.2469832	03
.3561200	05	.5194665	03	.7231902	02-	.2502437	03
.3661200	05	.4543074	03	.6243422	02-	.2535042	03
.3761200	05	.3980190	03	.5400408	02-	.2567647	03
.3861200	05	.3493015	03	.4679969	02-	.2600253	03
.3961200	05	.3070584	03	.4063046	02-	.2632858	03
.4061200	05	.2703634	03	.3533730	02-	.2665464	03
.4161200	05	.2383794	03	.3088784	02-	.2688681	03
.4261200	05	.2103254	03	.2720417	02-	.2693484	03
.4361200	05	.1856217	03	.2396617	02-	.2698287	03
.4461200	05	.1638622	03	.2111914	02-	.2703091	03
.4561200	05	.1446910	03	.1861522	02-	.2707894	03
.4661200	05	.1277962	03	.1641245	02-	.2712705	03
.4761200	05	.1129141	03	.1445272	02-	.2721803	03
.4861200	05	.9981012	02	.1273288	02-	.2730902	03
.4961200	05	.8826655	02	.1122286	02-	.2740000	03
.5061200	05	.7809284	02	.9896443	03-	.2749098	03
.5161200	05	.6906091	02	.8850407	03-	.2718486	03
.5261200	05	.6092001	02	.8045269	03-	.2638017	03
.5361200	05	.5353250	02	.7292089	03-	.2557548	03
.5461200	05	.4684877	02	.6588956	03-	.2477078	03
.5561200	05	.4082426	02	.5927655	03-	.2399350	03
.5661200	05	.3548117	02	.5185210	03-	.2383909	03
.5761200	05	.3081064	02	.4532013	03-	.2368469	03
.5861200	05	.2673140	02	.3957789	03-	.2353029	03
.5961200	05	.2317159	02	.3453393	03-	.2337588	03
.6061200	05	.2006772	02	.3010693	03-	.2322148	03
.6161200	05	.1736150	02	.2626802	03-	.2302599	03
.6261200	05	.1500172	02	.2290583	03-	.2281672	03
.6361200	05	.1294582	02	.1994970	03-	.2260745	03
.6461200	05	.1115689	02	.1735357	03-	.2239818	03
.6561200	05	.9602200	01	.1507624	03-	.2218891	03
.6661200	05	.8253689	01	.1306363	03-	.2201113	03
.6761200	05	.7090005	01	.1123262	03-	.2198993	03
.6861200	05	.6089808	01	.9657327	04-	.2196873	03
.6961200	05	.5230171	01	.8302110	04-	.2194753	03
.7061200	05	.4491438	01	.7136376	04-	.2192632	03
.7161200	05	.3856251	01	.6141901	04-	.2187362	03
.7261200	05	.3309232	01	.5295972	04-	.2176906	03
.7361200	05	.2837854	01	.4563514	04-	.2166451	03
.7461200	05	.2431929	01	.3929718	04-	.2155995	03
.7561200	05	.2082603	01	.3381647	04-	.2145539	03
.7661200	05	.1781671	01	.2918084	04-	.2127099	03
.7761200	05	.1521521	01	.2528673	04-	.2096252	03
.7861200	05	.1296384	01	.2186688	04-	.2065404	03
.7961200	05	.1101958	01	.1886919	04-	.2034557	03
.8061200	05	.9344162	00	.1624665	04-	.2003709	03
.8161200	05	.7907683	00	.1387856	04-	.1985011	03
.8261200	05	.6683612	00	.1180401	04-	.1972605	03
.8361200	05	.5643328	00	.1002983	04-	.1960198	03
.8461200	05	.4760093	00	.8513952	05-	.1947791	03
.8561200	05	.4023631	00	.6978709	05-	.2008636	03
.8661200	05	.3424943	00	.5631844	05-	.2118658	03
.8761200	05	.2939355	00	.4594754	05-	.2228681	03
.8861200	05	.2541386	00	.3785765	05-	.2338704	03

FIGURE 27

WIND DIRECTION degrees	WIND SPEED m/sec	TEMPERATURE degrees Kelvin	HEIGHT meters
251.04699	49.156208	225.17968	34084.500
266.78720	120.79139	250.57888	38644.847
274.32379	130.62210	243.76129	43035.796
260.92868	95.027588	258.45147	47755.898
274.01498	79.796524	239.92878	52804.097
265.85369	104.42839	248.69580	58055.597
247.35418	84.380134	239.13979	63433.289
262.06008	85.245559	215.70478	68496.437
271.16949	147.49369	236.68159	73204.734
231.80848	67.915214	223.47479	77866.046



HEIGHT meters		PRESSURE nt/sq meters		DENSITY kg/cu meters		TEMPERATURE degrees Kelvin	
.3371160	05	.6000000	03	.8953968	02-	.2334500	03
.3471160	05	.5183956	03	.7897794	02-	.2286723	03
.3571160	05	.4480216	03	.6663348	02-	.2342419	03
.3671160	05	.3885483	03	.5644600	02-	.2398115	03
.3771160	05	.3380882	03	.4800066	02-	.2453811	03
.3871160	05	.2950756	03	.4104183	02-	.2504752	03
.3971160	05	.2577956	03	.3608024	02-	.2489226	03
.4071160	05	.2250448	03	.3169423	02-	.2473699	03
.4171160	05	.1962951	03	.2781987	02-	.2456173	03
.4271160	05	.1710773	03	.2440001	02-	.2442646	03
.4371160	05	.1491077	03	.2112820	02-	.2458645	03
.4471160	05	.1301350	03	.1820931	02-	.2489768	03
.4571160	05	.1137734	03	.1572334	02-	.2520891	03
.4671160	05	.9963715	02	.1360180	02-	.2552013	03
.4771160	05	.8740130	02	.1178769	02-	.2583136	03
.4871160	05	.7666611	02	.1047648	02-	.2549448	03
.4971160	05	.6712982	02	.9307289	03-	.2512757	03
.5071160	05	.5866743	02	.8254546	03-	.2476065	03
.5171160	05	.5117097	02	.7308085	03-	.2439373	03
.5271160	05	.4454194	02	.6458490	03-	.2402682	03
.5371160	05	.3874565	02	.5590685	03-	.2414438	03
.5471160	05	.3373267	02	.4833930	03-	.2431132	03
.5571160	05	.2939739	02	.4183948	03-	.2447826	03
.5671160	05	.2564433	02	.3625076	03-	.2464521	03
.5771160	05	.2239200	02	.3144030	03-	.2481215	03
.5871160	05	.1955870	02	.2752773	03-	.2475300	03
.5971160	05	.1707354	02	.2420378	03-	.2457529	03
.6071160	05	.1489009	02	.2126223	03-	.2439758	03
.6171160	05	.1297344	02	.1866129	03-	.2421987	03
.6271160	05	.1129253	02	.1636349	03-	.2404216	03
.6371160	05	.9817432	01	.1437974	03-	.2378510	03
.6471160	05	.8517133	01	.1272275	03-	.2332226	03
.6571159	05	.7368373	01	.1122961	03-	.2285942	03
.6671159	05	.6355982	01	.9886879	04-	.2239657	03
.6771159	05	.5466049	01	.8681987	04-	.2193373	03
.6871159	05	.4689100	01	.7539841	04-	.2166633	03
.6971159	05	.4025276	01	.6342033	04-	.2211186	03
.7071159	05	.3466127	01	.5353203	04-	.2255739	03
.7171159	05	.2993529	01	.4533761	04-	.2300292	03
.7271159	05	.2592765	01	.3852185	04-	.2344845	03
.7371159	05	.2249351	01	.3331150	04-	.2352455	03
.7471159	05	.1950275	01	.2923446	04-	.2324122	03
.7571159	05	.1688084	01	.2561652	04-	.2295739	03
.7671159	05	.1458590	01	.2241054	04-	.2267457	03
.7771159	05	.1258039	01	.1957375	04-	.2239124	03

FIGURE 28

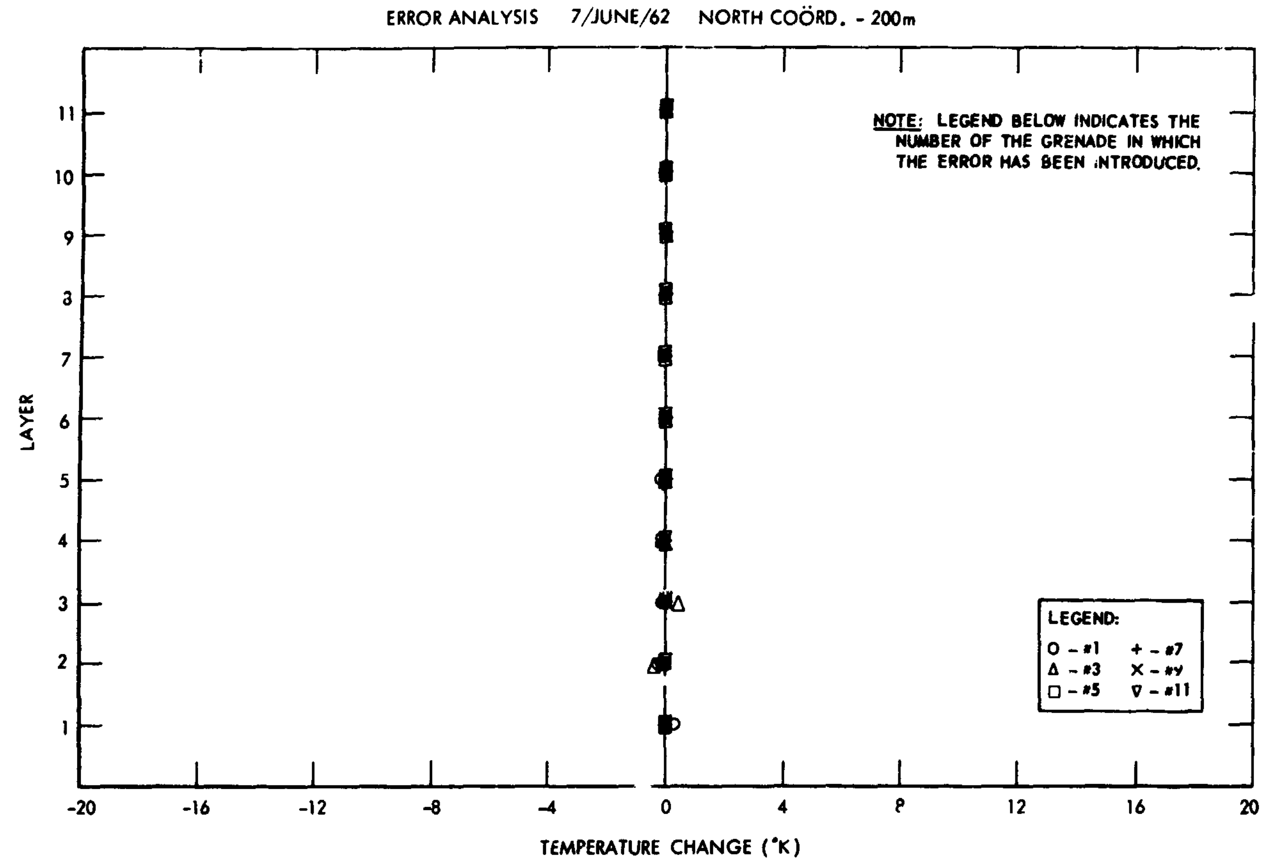


FIGURE 29

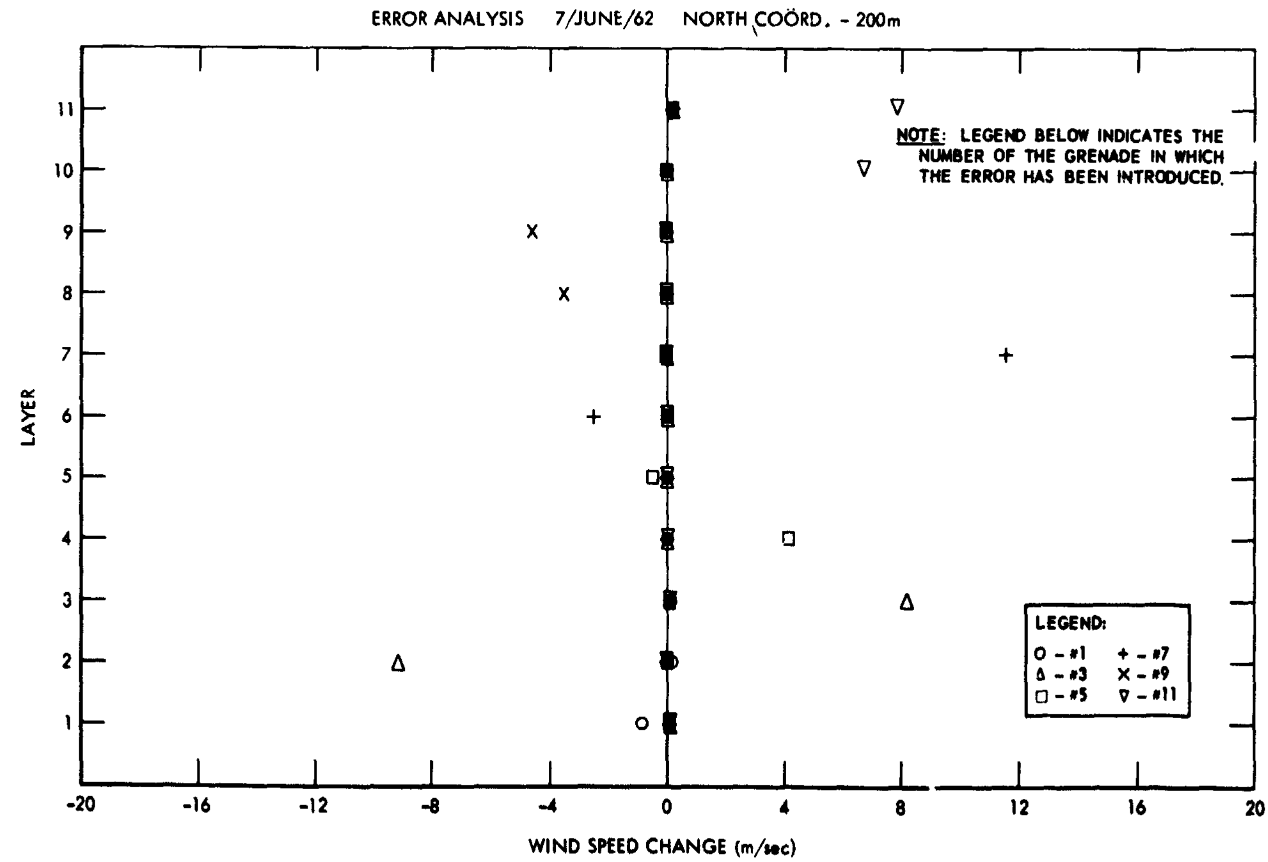


FIGURE 30

ERROR ANALYSIS 7/JUNE/62 WEST COÖRD. - 200m

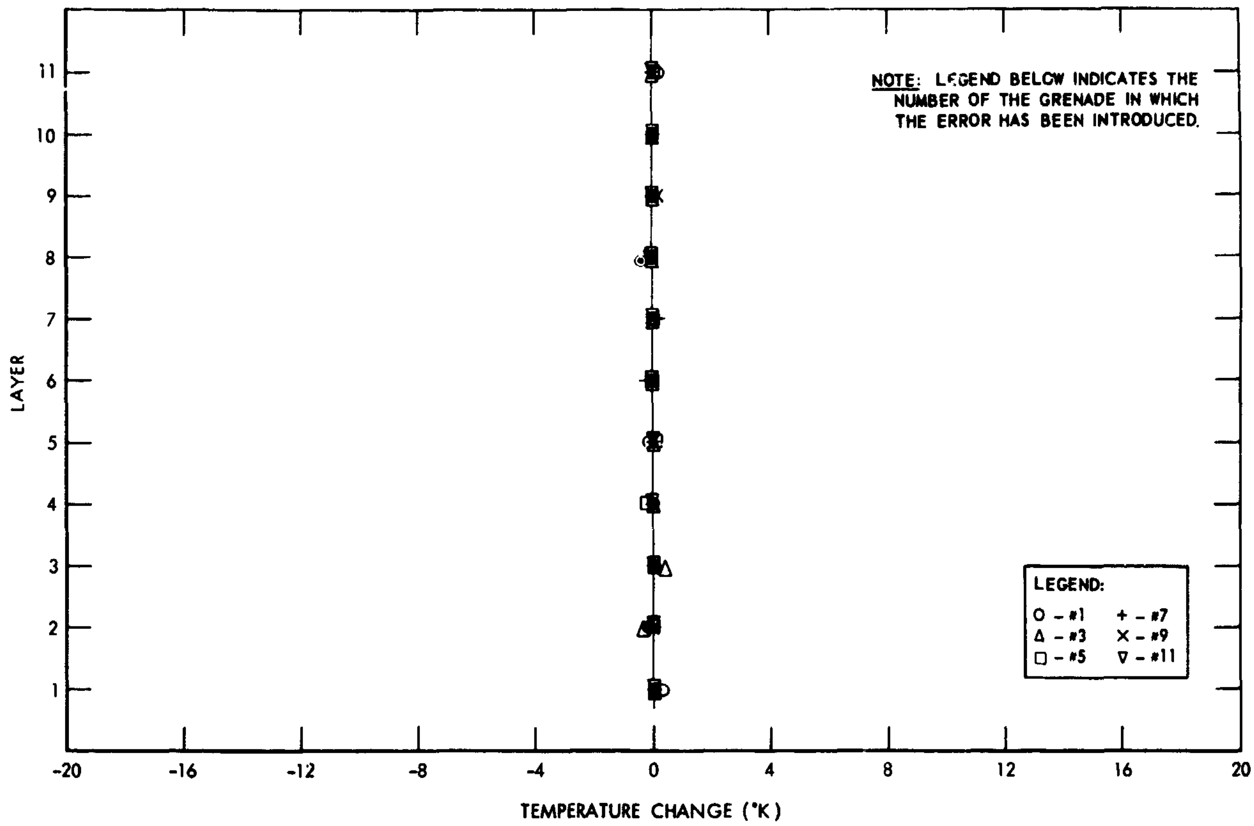


FIGURE 31

ERROR ANALYSIS 7/JUNE/62 WEST COORD. - 200m

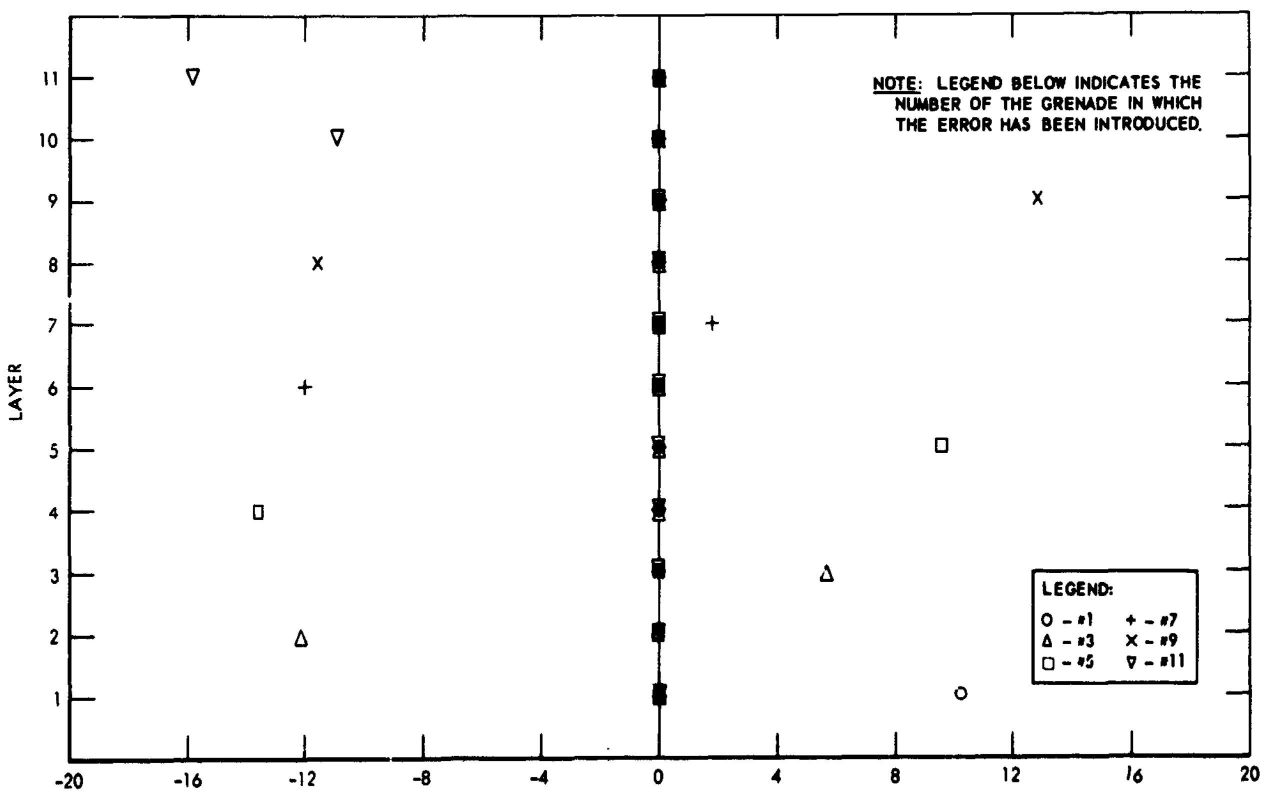


FIGURE 32

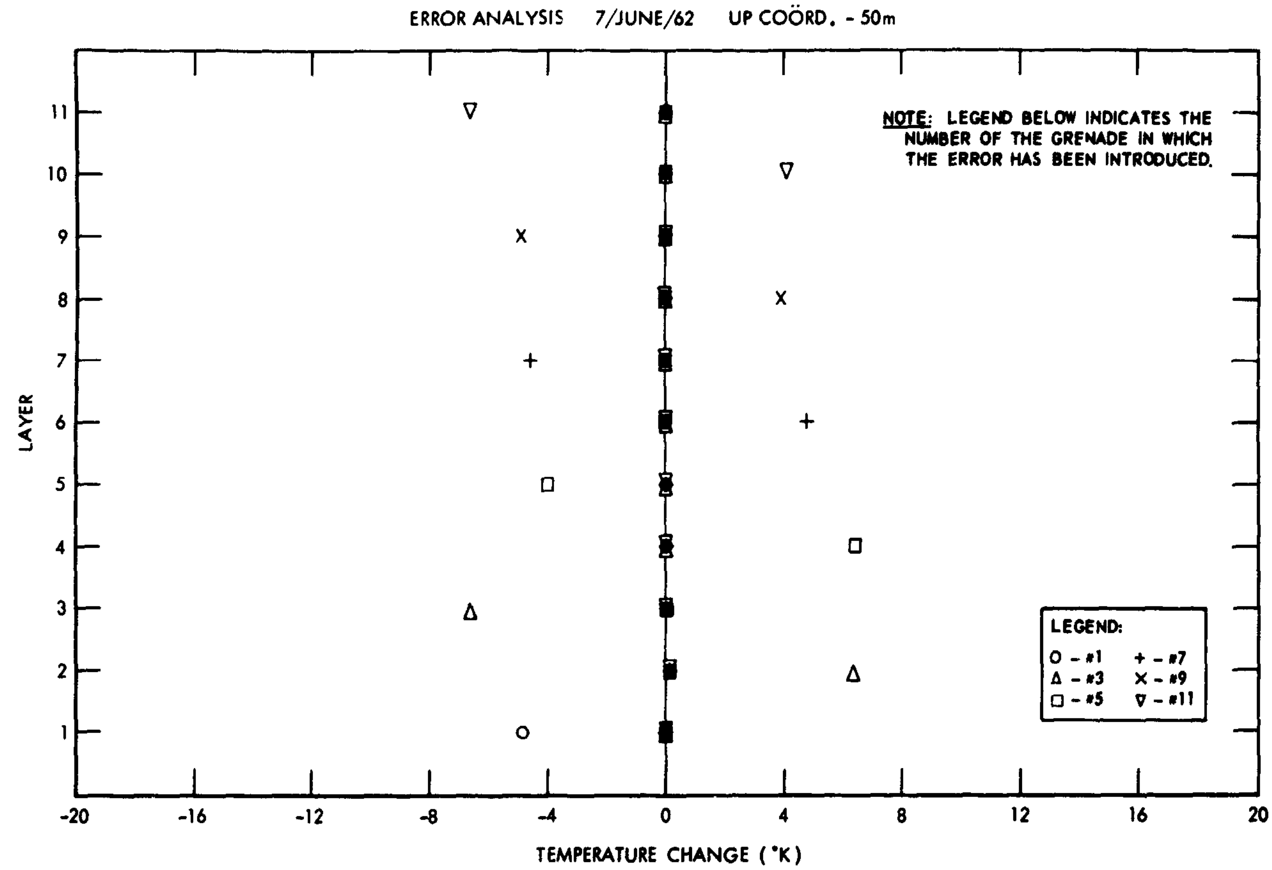


FIGURE 33

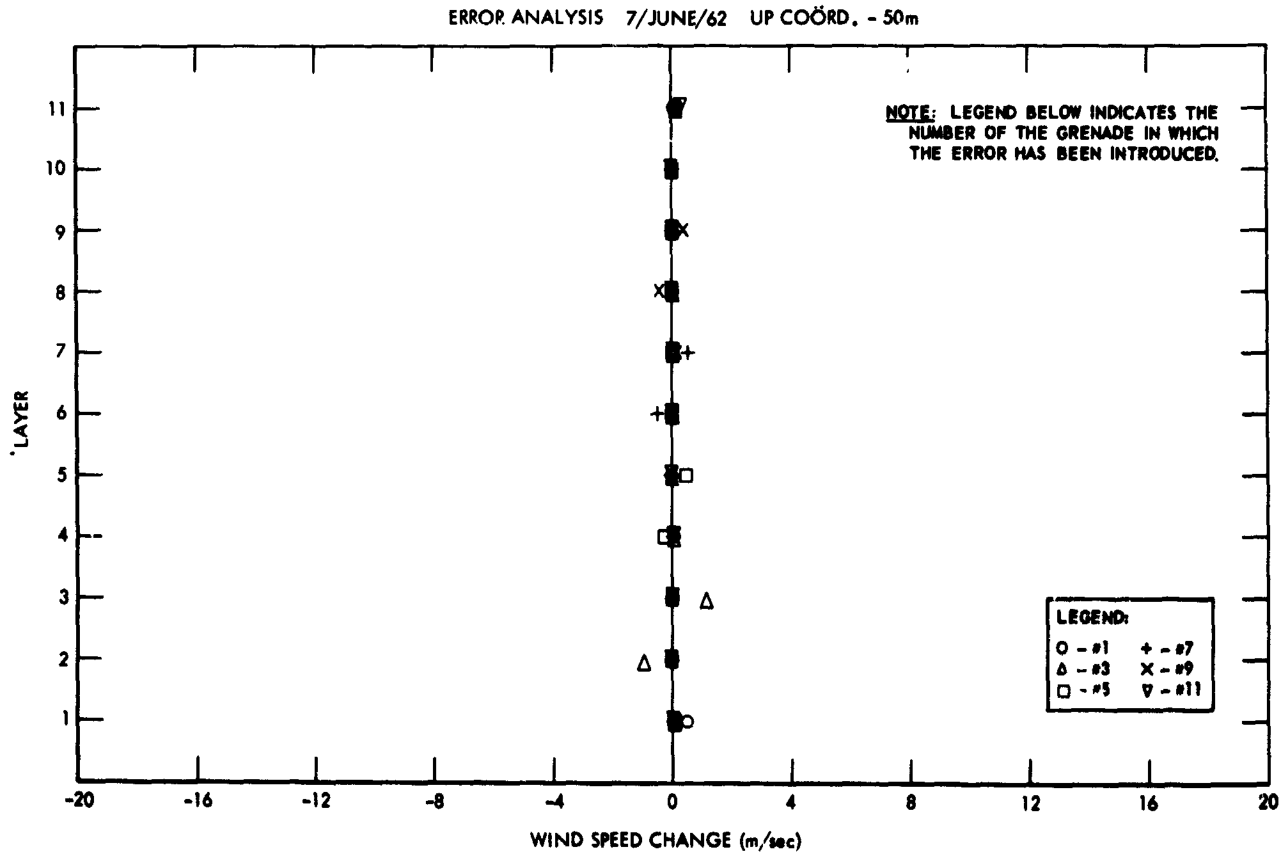


FIGURE 34

ERROR ANALYSIS 7 JUNE/62 t + .3 sec

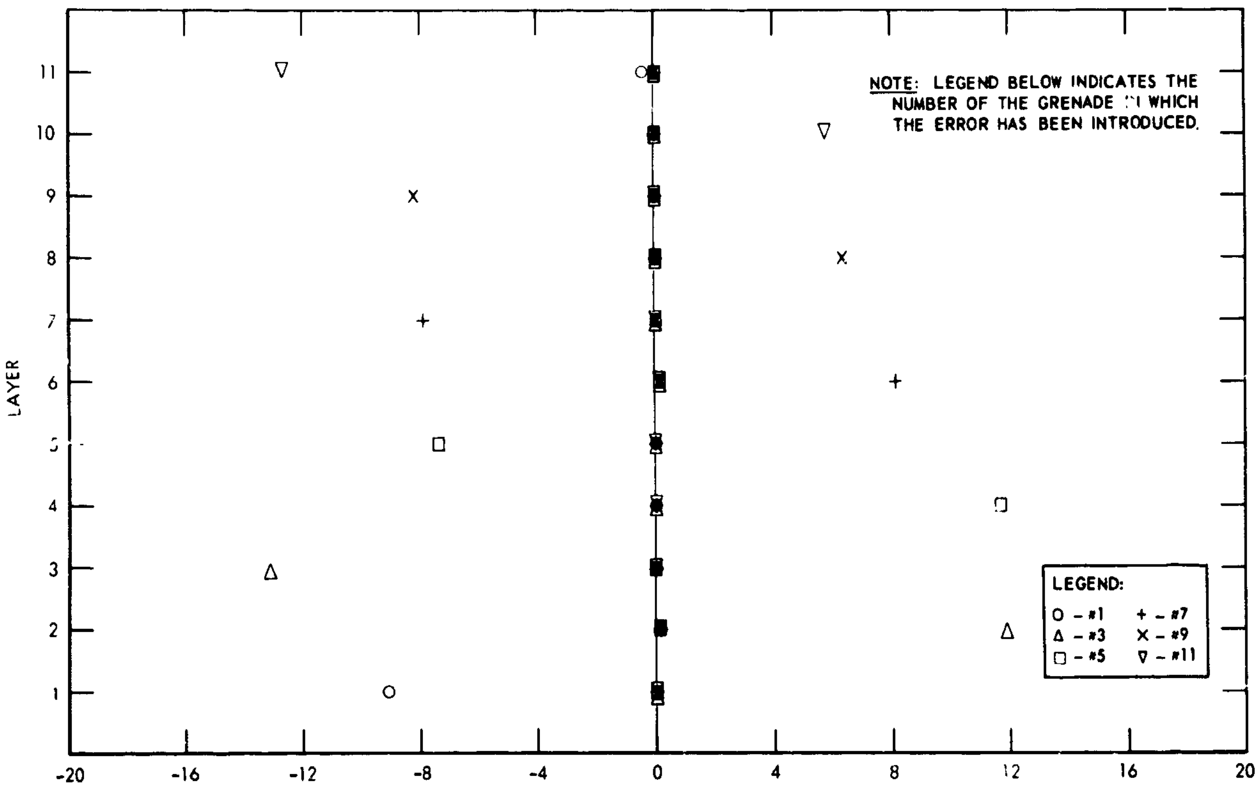


FIGURE 35

ERROR ANALYSIS 7/JUNE/62 t + .3 sec

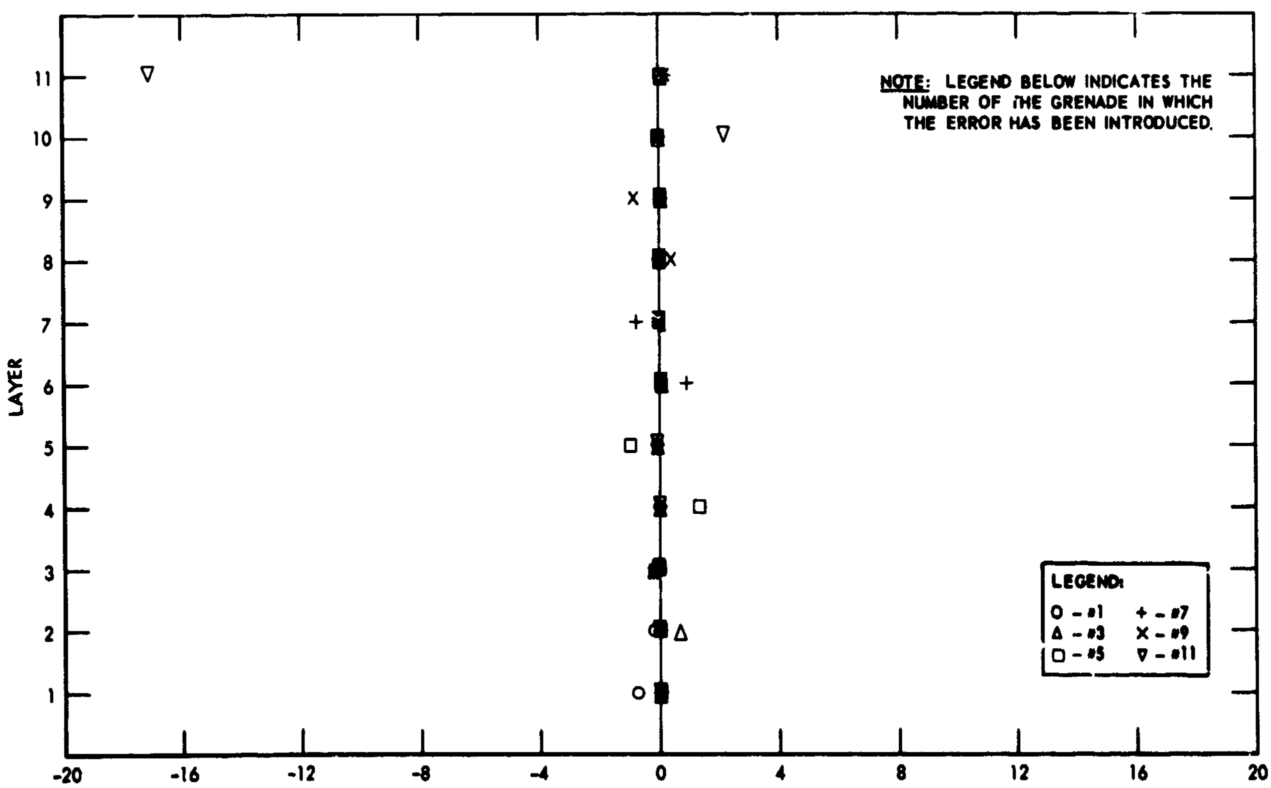


FIGURE 36

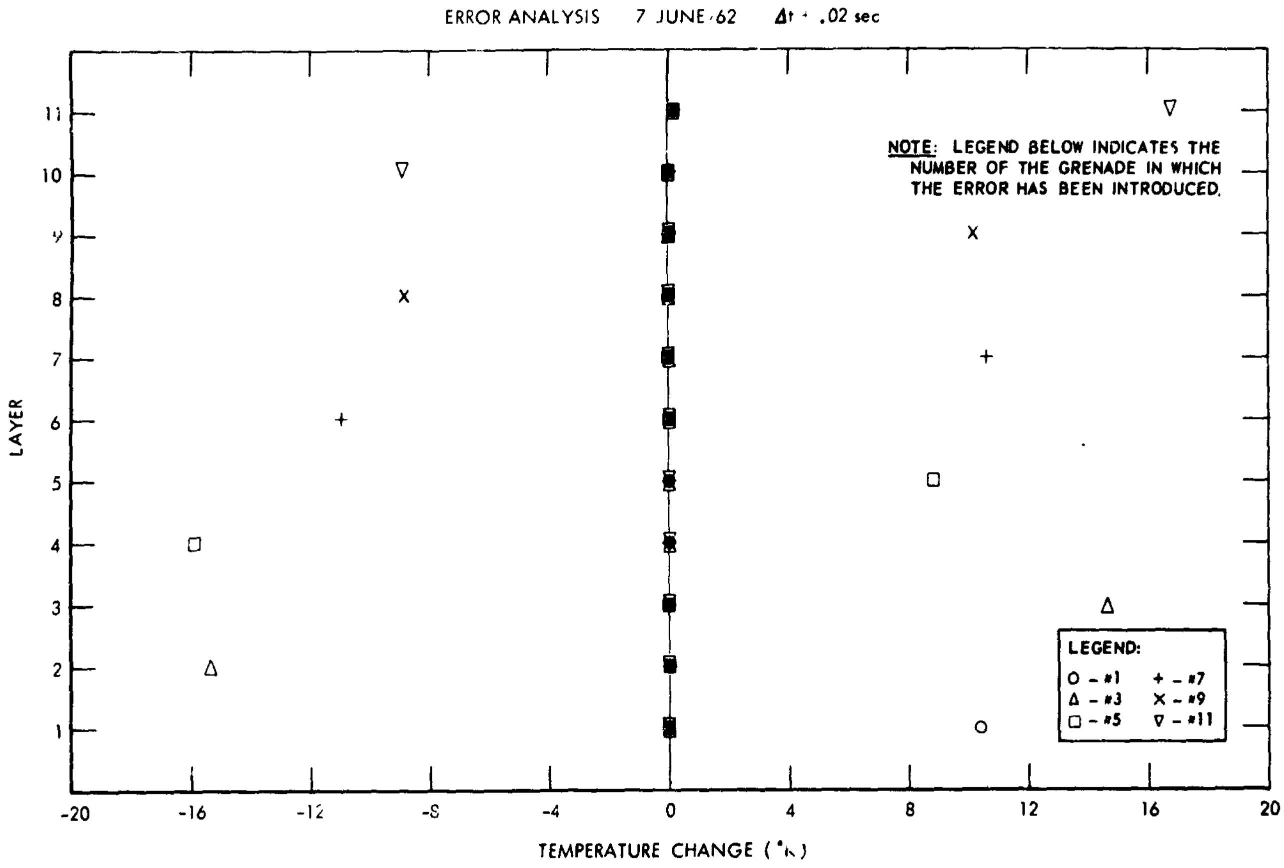


FIGURE 37

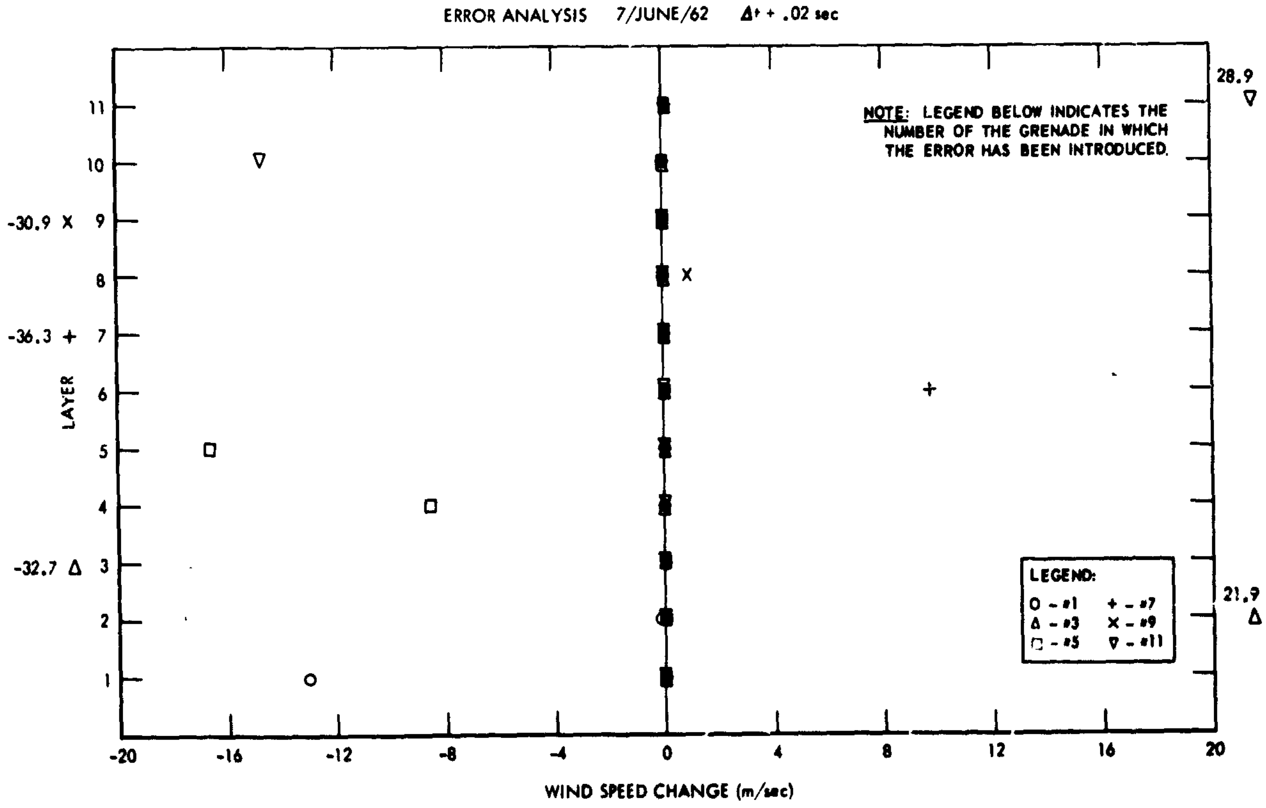


FIGURE 38

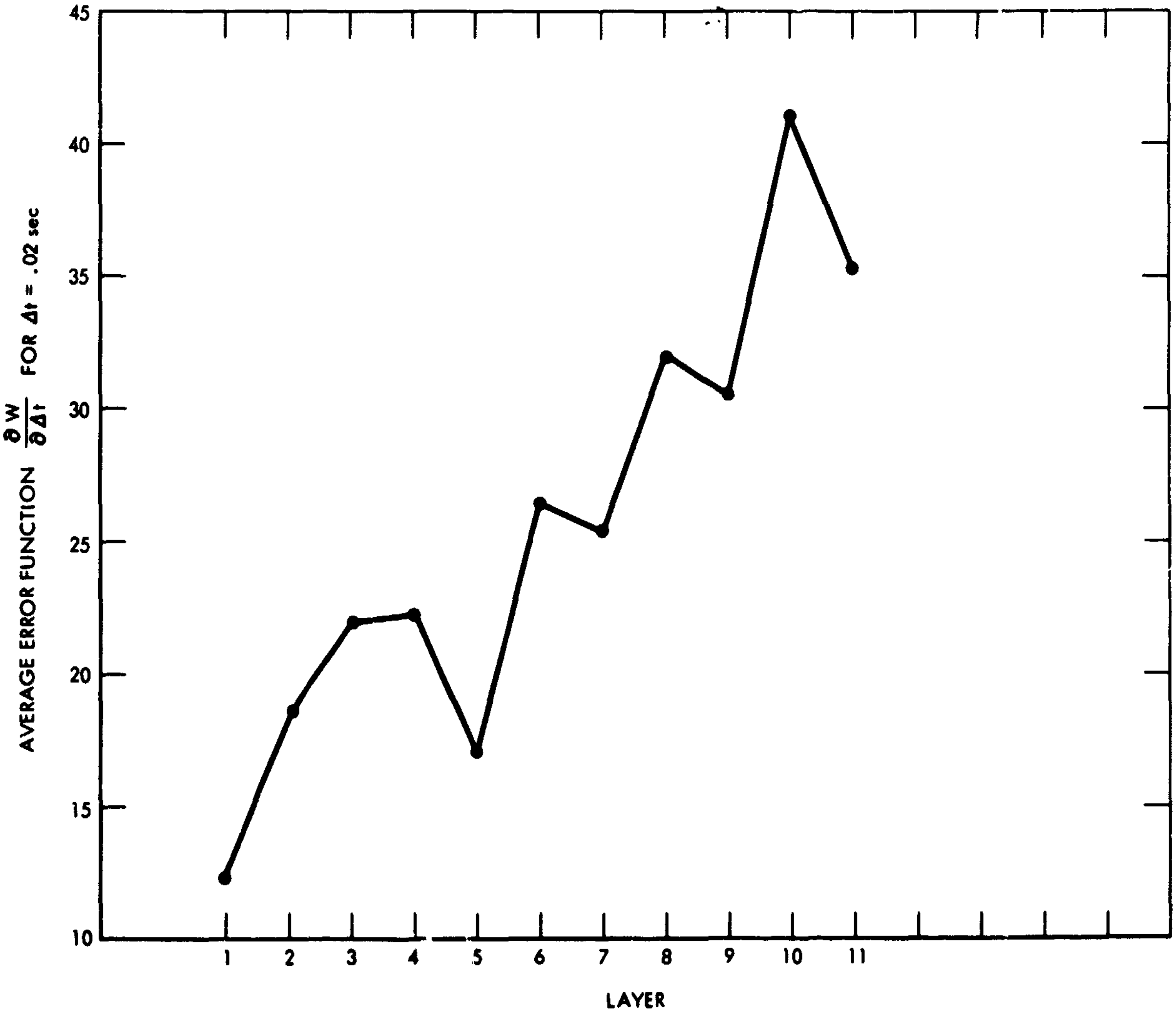


FIGURE 39.—Graph of $\frac{\partial T}{\partial \Delta t}$ vs. layer where $\Delta t = .02$ sec. (average of 16 firings).

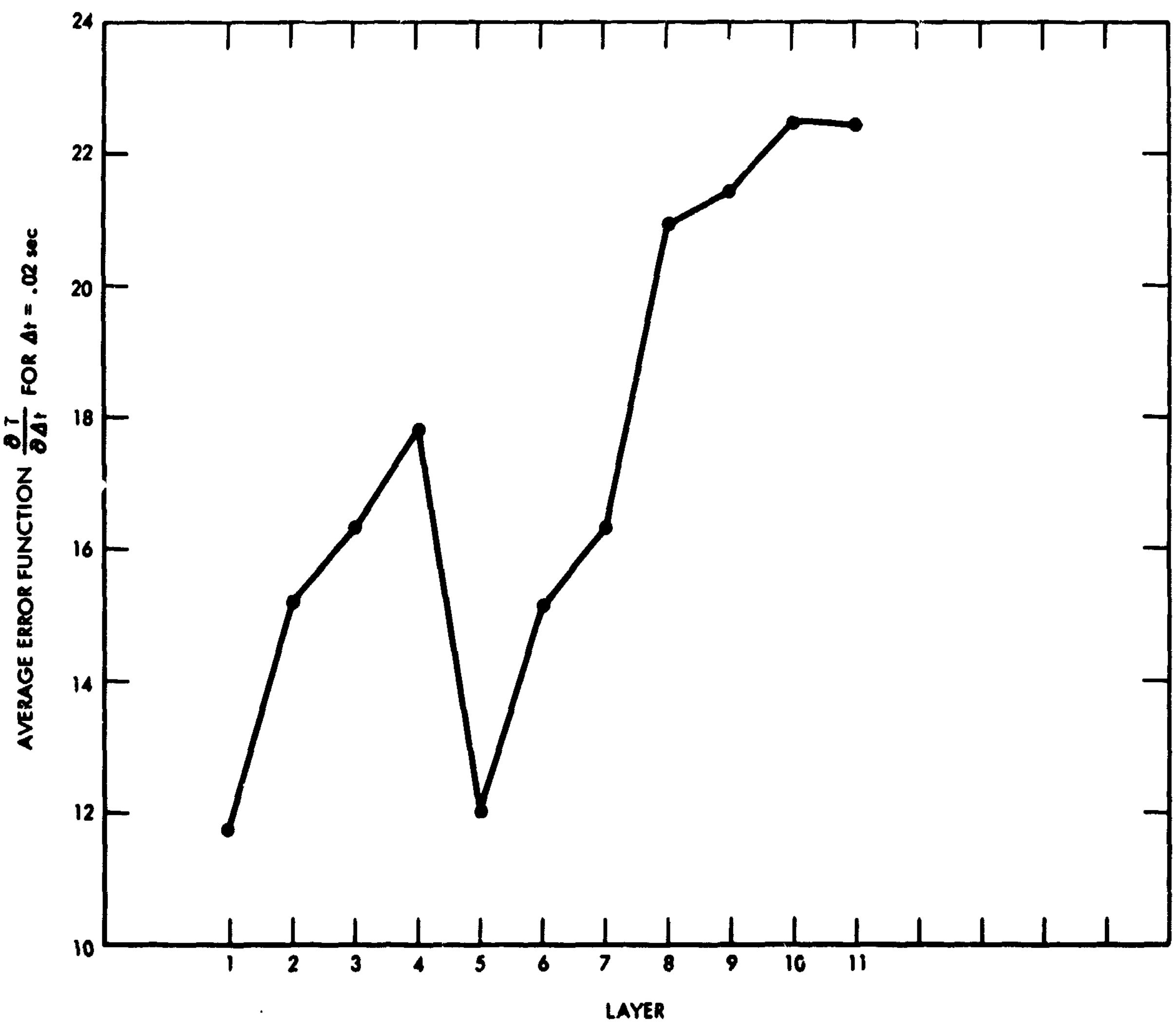


FIGURE 40.—Graph of $\frac{\partial W}{\partial \Delta t}$ vs. layer where $\Delta t = .02$ sec. (average of 16 firings).

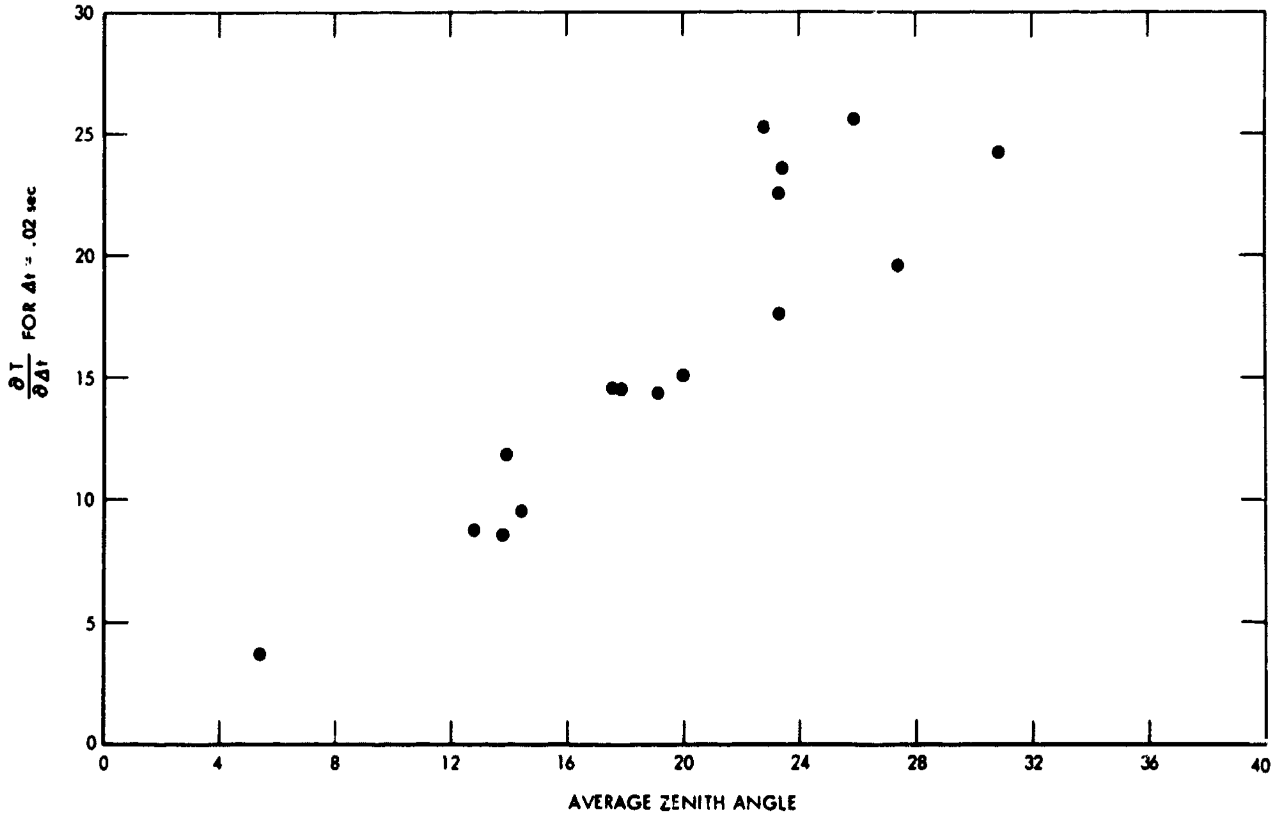


FIGURE 41.—Dependence of $\frac{\partial T}{\partial \Delta t}$ upon zenith angle, where $\Delta t = .02$ sec. for the 16 firings 1960–1963.

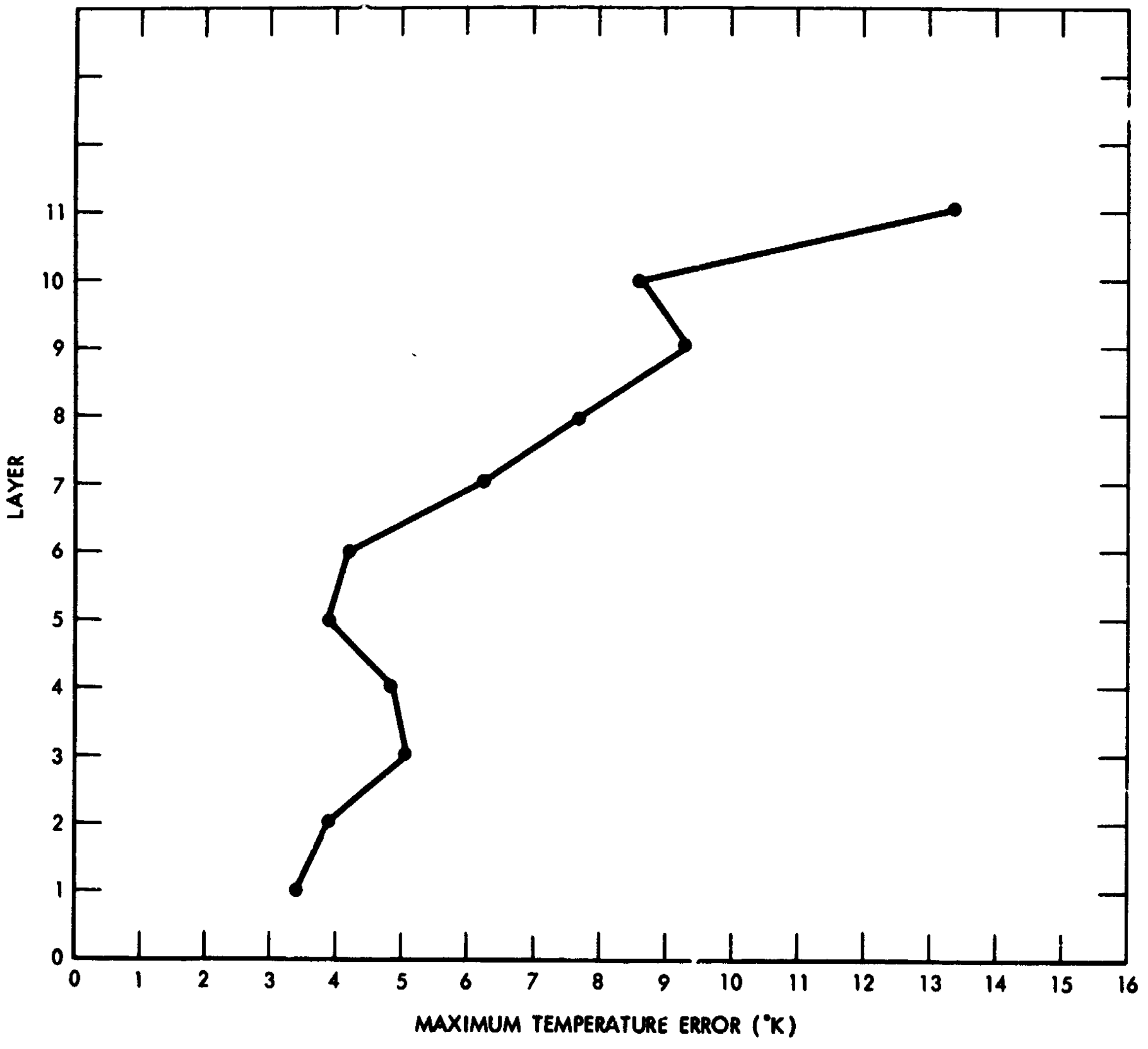


FIGURE 42.—Maximum temperature errors for the 16 firings 1960–1963.

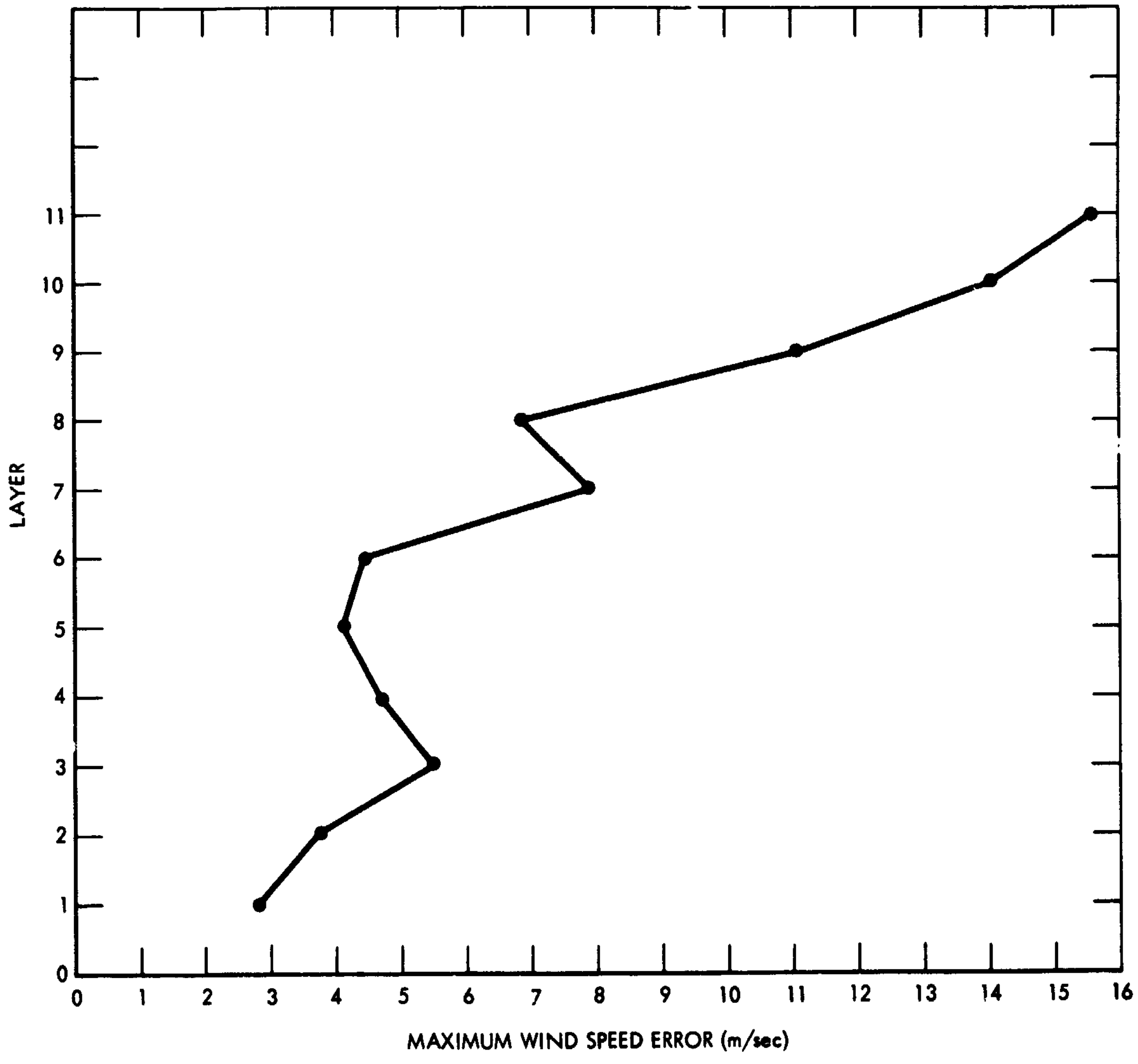


FIGURE 43.—Maximum wind errors for the 16 firings 1960–1963.

NEW KNOWLEDGE OF THE EARTH'S ATMOSPHERE FROM THE AERONOMY SATELLITE (EXPLORER XVII)*

N. W. SPENCER, G. P. NEWTON, C. A. REBER, L. H. BRACE AND R. HOROWITZ

The Explorer XVII satellite performed direct, very localized measurements of the total neutral particle density, the concentration of neutral particle masses 4, 14, 16, 28, and 32 and the temperature and concentration of thermal electrons, between the altitudes of 258 km and 920 km over those regions of the earth where the satellite was accessible to the Minitrack network, and in particular between ±58° latitude. Pressure gages on the satellite showed that the total density at 280 km was about 50 percent lower than is given by the appropriate atmospheric models based on satellite drag measurements. Daily variations in total density are more strongly dependent on a_p (the magnetic index) than had been believed previously. Neutral mass spectrometers showed that *He* is the predominant neutral constituent above 600 km, 0 is predominant between 250 km and 600 km, and N_2 is predominant below 250 km. The scale heights of the various constituents agree in general with the corresponding model atmospheric scale heights. Langmuir probe results confirmed the global extent of thermal non-equilibrium ($T_e > Tg$) and provided high resolution of the diurnal variation of electron temperature and density at several stations. For example, the electron temperatures near the F_2 maximum over Blossom Point show a nighttime value of about 1100° K, followed by a mid-morning maximum of 2800° K and an afternoon plateau of 2200° K. A consistent and strong latitude effect, evident particularly at Blossom Point, caused a significant positive gradient in electron temperature (the order of 25° K/degree of latitude) and an inverse gradient in electron density in a manner approximately in accord with recent theories of Hanson and Dalgarno.

INTRODUCTION

The Explorer XVII satellite, Figure 1, was designed to provide direct measurements of aeronomic parameters as a basis for new studies of the physics of the Earth's upper atmosphere. Thus, instruments were selected for the satellite which would provide both total and relative concentration of the neutral particles, and high-resolution measurements of the electron temperature and density; all of considerable significance in studies of the physical processes controlling the upper atmosphere. These data would help also to (a) clarify and define the structural properties of the atmosphere, previously established primarily through inferences from satellite drag measurements, and (b) investigate the variability and dependence of the atmosphere on solar conditions.

The technological advance of measurement techniques was also an objective of the project, as part of a continuing effort to improve experimental capability. The application of laboratory-developed techniques required engineering as well as measurement technique refinement and adaptation to new environments. The atmospheric data to be obtained, if it were to be of maximum benefit consistent with its timeliness, required computer usage for processing the large quantity of data (the order of 2×10^9 bits of information).

EXPERIMENTS

The choice of experiments to obtain the desired data was based mainly upon laboratory vacuum technique experience; thus both thermionic and cold-cathode pressure gages, derived from proven laboratory sensors, were selected for the measurements of the total neutral particle density. Double-focusing magnetic mass spectrometers were chosen for the measurements of neutral particle concentrations. Two Langmuir probe experiments were employed for measurements of the electron temperature and ion density.

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FIGURE 1.—Artist's conception of Explorer XVII in orbit.

It is of special significance from the point of view of determining local values of the ambient concentrations of constituents that proven laboratory vacuum system techniques were employed in construction of the satellite. For example, to minimize potential sources of contaminating gases, nearly all external surfaces were constructed of stainless steel, and all satellite joints were either welded or utilized copper shear gaskets for vacuum sealing. A significant effort was thus devoted to making the satellite-sensor system a true inside-out ultra-high vacuum system so that the experimenter could be confident that the atmospheric samples measured were not contaminated by materials carried aloft by the satellite.

Pressure Gage Experiments

The density measurements made by the Explorer XVII ionization gages extended to satellite usage the technique employed in rocket manometer experiments (Schultz, Spencer, Reifman, 1948) (Horowitz, Kleitman, 1953) to measure the total atmospheric density. The description of the instrumentation, the calibration technique, and the flight response of the Explorer XVII sensors have been reported (Newton, Pelz, Miller, Horowitz, 1963).

Four independent pressure gage experiments were employed: two Bayard-Alpert type (thermionic cathode) ionization gages and two Redhead type (cold-cathode, magnetic) gages. Each sensor was equipped with a special vacuum sealed orifice that could be opened after the satellite was in orbit. Thus it was possible for the sensor to be properly cleaned, calibrated, sealed under vacuum, and opened on command to the space environment. This procedure, whose validity was previously established through rocket experience, assured the necessary high degree of vacuum cleanliness for the sensors.

The use of both cold and thermionic cathode gages was considered essential because of uncertainties in (a) the response of a hot-cathode gage in a sometimes predominately atomic oxygen environment (not subject to adequate laboratory calibration) and, (b) the general applicability of ionization gages to the high-velocity satellite environment. At the same time, a desirable redundancy was accomplished and valuable studies of the usefulness of the two fundamentally different sensors were made possible. Each pressure gage was provided with an appropriate electrometer amplifier and other electronic support devices which enabled conversion of the sensor output current to a voltage suitable for telemetry. The electronic systems also included provision for in-orbit current calibration of the amplifiers once during each operation of the gages.

Neutral Particle Mass Spectrometers

Two identical double focusing magnetic mass spectrometers were employed for the determination of the local concentrations of atmospheric helium (mass 4), atomic nitrogen (mass 14), atomic oxygen (mass 16), molecular nitrogen (mass 28) and molecular oxygen (mass 32). Although detailed descriptions of the spectrometers are provided elsewhere (Meadows, 1960) (Hall, Howden, Iwasaki, 1960), (Spencer, Reber, 1962), (Reber, Hall, in prep.), the significant features are summarized here. The external ion source, designed to reduce the interactions of the sampled particles with the sensor, was followed by an electrostatic ion lens which focused the relatively high energy ions on the entrance slit of the analyzer. In this way, it was possible for the instrument to accept particles from a 2π steradian solid angle, and up to 12 *ev* kinetic energy. In the magnetic analyzer the beam of ions was separated according to mass, a given mass falling on the appropriate collector electrode in spectrograph fashion.

Each of the spectrometers was provided with a sensitive electrometer and logarithmic amplifier for conversion of the collected ion current to the proper telemetry voltages. Electronic logic circuitry accomplished the required changes in sensitivity and mass-number selection. As with the pressure gages, a vacuum-seal arrangement was adopted which permitted exposure of the spectrometer ion source to the atmosphere after orbit was attained.

The primary data analysis task was to determine the relationship of the measured ion currents to the ambient neutral particle densities. Particles could enter the region of ionization in one of three ways: (1) directly with no collisions; (s) after suffering one or more collisions with surfaces in the source region; (3) by entering the spectrometer analyzer, becoming thermalized, and subsequently being re-emitted. The relationships between the measured ion currents and the ambient atmosphere were computed on the basis of these three mechanisms and the laboratory gas calibrations. The validity of these calculations is demonstrated by the fact that the total mass-density measured by the spectrometer is in satisfactory agreement with that obtained independently by the companion pressure gage experiments described above.

Langmuir Probes

Two independent Langmuir probe systems, based on established techniques and previous rocket usage (Spencer, Brace, Carignan, 1962), (Brace, Spencer, Carignan, 1963), (Nagy, Brace, Carignan, Kanal, 1963) were employed to provide measurements of the ion concentration (N_i), and the electron temperature (T_e) of the ionosphere. Each probe system used a cylindrical electrode (projecting into the plasma) whose potential was varied with respect to the satellite shell. The resulting current to the probe was converted to a voltage suitable for telemetry.

Using the following equation, the temperature was derived from the electron current to the probe as it was swept from the satellite potential to the plasma potential:

$$\frac{d \log_e i_e}{dV} = \frac{e}{kT_e} \qquad (1)$$

To localize the T_e measurement, the electron temperature probe was swept at a rate of 10 sweeps per second; and to maximize the resolution, the voltage was swept in two ranges, 0 to ¾ V and 0 to 1½ V, respectively. As a result, each temperature measurement was completed in less than 400 meters of the satellite path, and to that extent represents a point measurement. The telemetry sampling rate was sufficiently high to permit determination of temperature values as low as 400°K (although the lowest temperatures actually recorded were about 900°K).

The ion density probe was swept from −3 to +2 volts in a 2-second period, which was long compared with the satellite spin period of 0.7 seconds. N_i was derived from the ion current maxima which occurred each time the probe axis was perpendicular to the velocity vector.

Sensor Location

As noted above, the capability to provide measurements of the constituents of the space environment required close adherence to established laboratory vacuum techniques. Thus, in addition to providing a sealed housing which would not itself contaminate the local atmosphere, the eight sensors were located so as to provide maximum separation from each other.

Consideration of sensor orientation with respect to the direction of motion required that the mass spectrometers be located at the two ends of the spin axis to minimize changes in orientation during each mass-sampling sequence. The four pressure gages were distributed uniformly about the spherical satellite to insure that at least one gage would always experience pressure variations due to satellite spin, regardless of the spin axis orientation. One of each type of pressure gage was located on the satellite equator to enable a comparison of the gage responses under identical conditions. The two Langmuir probes were also located on the equator at points nearly diametrically opposite each other.

SUPPORTING SYSTEM

Interpretation of the data from the various sensors required detailed knowledge of the instantaneous angle between any sensor and the direction of motion of the satellite. This information was provided through the use of a multiple optical sensor arrangement, which enabled sensing the direction of the sun and/or moon and the instants of passage, during spin, of the Earth's horizons.

Direct measurement sensors like those employed in Explorer XVII provide time rates-of-change of data requiring high telemetry sampling rates. For example, the spectrometers and pressure gages required 60 samples per second and the "high speed" Langmuir probe required 180 samples per second. To meet these needs a pulse code modulation (PCM) telemetry system capable of 1000 samples per second was selected. This system had the additional advantage of providing a digital format which facilitated computer data processing.

The satellite was powered exclusively by silver-zinc cells, since solar cells presented the possibility of local contamination of the atmosphere. The

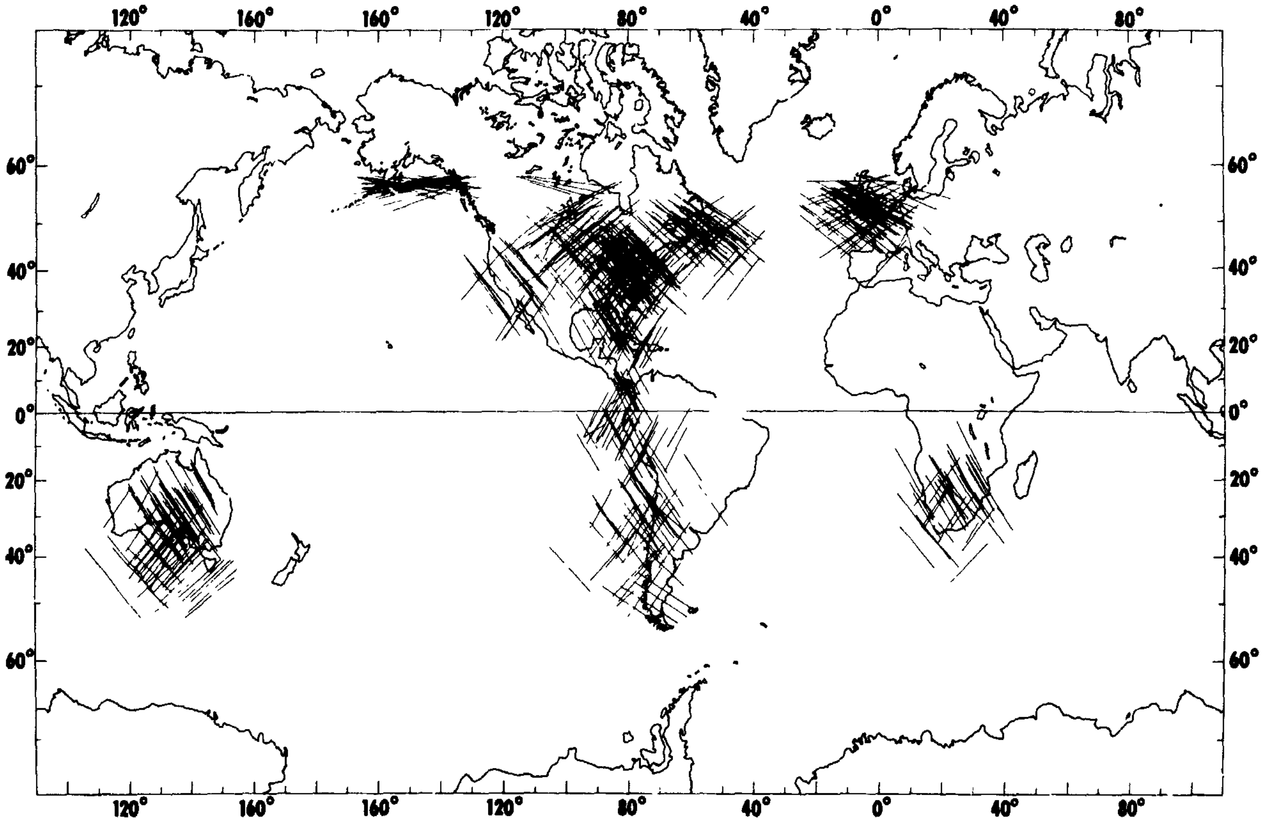

FIGURE 2.—Explorer XVII geographic coverage.

150 pounds of cells which were employed provided adequate energy to operate the entire satellite system for a total of 75 hours. A command-control system permitted the experiments to be turned on for four-minute periods, each of which was terminated by an internal programmer. Because a tape recorder was not employed, responses were confined to geographic regions of approximately 4000 kilometers diameter about each minitrack command station. Figure 2 illustrates the geographic coverage attained by showing the path of the satellite during each data-producing response. Table I summarizes some of the pertinent statistics of the satellite, and other information.

TABLE I.—*Explorer XVII Statistics*

Launch Date	April 3, 1963
Inclination	58°
Perigee	258 km
Apogee Range	920–870 km
Useful lifetime	100 days
Perigee motion	+39° to +58° to −18°
Data responses	650 on command
Telemetry	PCM—8640 bits/sec
Spin rate	90 RPM
Power supply	Chemical
Size and shape	1 meter sphere
Weight	410 pounds

EXPERIMENTAL RESULTS

Pressure Gage Results

As noted above, four independent gage systems were employed on the satellite, and all gages operated in orbit. Three of the gages gave useful and meaningful data during the active lifetime of the satellite. The fourth gage, however, experienced an apparent decrease in sensitivity after opening in orbit and no atmospheric structure data is available at present from this gage. Some of the results from the other three gages for five northern mid-latitude stations, representing approximately 25 percent of the total available data are presented here.

Figure 3 shows the measured atmospheric density over Grand Forks, Minnesota, during a pass at 2000 hours local time and demonstrates typical resolution of the density gage data. It may be

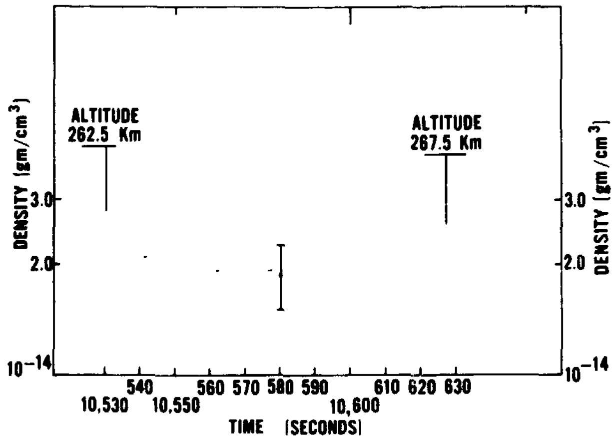

FIGURE 3.—Density data derived from a single pass over Grand Forks, Minn., demonstrating the resolution of the pressure gauge data.

seen that the total altitude change was only 5 km for this pass, and at the average altitude of 265 km, the atmospheric density was 2×10^{-14} gm/cm³. Each point shown is the average of the three independent density measurements. The resolution of the density data from each gage is such that the density was measured every 700 milliseconds or once every six kilometers along the satellite orbit. The observed small scatter of the density data makes quantitative density scale-height determination possible for passes possessing significant altitude changes. The magnitude of the error in the absolute value of the density is ± 25 percent for this pass and can be attributed primarily to uncertainty in the absolute calibration of the sensors in the laboratory. At an altitude of 600 km, the error in the absolute value of the measured density is ± 55 percent for some passes. Generally, the precision of the density measurements is better than ± 20 percent.

Figure 4 (Newton, Horowitz, Priester, 1964) provides a comparison of the atmospheric densities directly measured by the gages in the altitude range 258 to 300 kilometers, to the density obtained from drag observations of Explorer XVII (Bryant, 1964) and Injun 3 (Jacchia, Slowey, 1964). All data are normalized to a height of 280 kilometers for comparison purposes, by using density gradients obtained from the Harris and Priester model with $S=90$.

The Injun 3 data, indicated by squares, were selected for quiet geomagnetic conditions ($A_p=2$), for the time interval of 18 February through

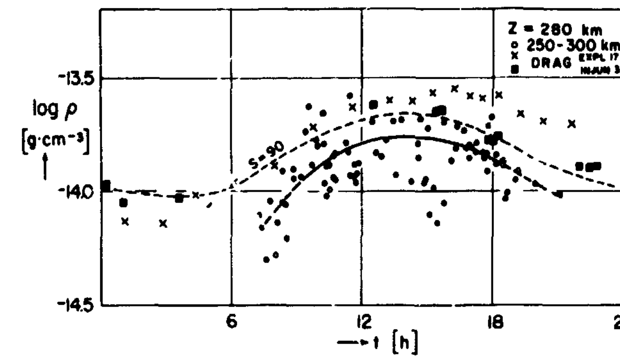

FIGURE 4.—Comparison of directly-measured and drag-derived atmospheric densities.

30 June 1963. During this period, the latitude of the satellite perigee varied between $-40°$ and $+60°$. The drag data from Explorer XVII, indicated by crosses, correspond to the time interval from 3 April to 6 July 1963, when the latitude of the satellite perigee was between $+58°$ and $-20°$. All Explorer XVII data in the figure have been reduced to quiet conditions ($A_p=0$) by using the preliminary linear reduction relation:

$$\log \rho = 0.006\ A_p$$

Further analysis of the gate data indicates, however, that the correlation between density and geomagnetic activity should be a steeper, non-linear relation with the steepest portion applicable for low A_p (Newton, Horowitz, Priester, 1964). Application of the modified relation is expected to (a) remove some of the scatter from the gage data (which reflects real atmospheric variations), and (b) lower the average value of the directly measured densities by a small amount.

It is observed that the densities determined from drag are systematically 40 percent to 50 percent greater than the normalized densities measured by the gages, and that this separation is just outside the combined, stated uncertainties of the two sets of data. This difference is significant but at this time is not considered serious, since it could be accounted for by modest changes in the altitude to which the drag data are assigned, the drag coefficient, or the gage calibration constants.

Figure 5 shows measured atmospheric density-versus-altitude for the altitude range 258 to 600 km. These data result from approximately 60 passes for an A_p between 0 and 10, $F_{10.7}$ between

70 and 100, and most local times. It is seen that considerable variation in the atmospheric density occurs, resulting primarily from the differences in local time, a factor of 5 diurnal variation at 360 km being observed. The Harris and Priester model densities ($S=90$) for 0400 and 1400 hours are shown for comparison purposes.

Continued analysis of the Explorer XVII data is currently underway to further define:

(1) The quiet atmosphere and its variation with local time.

(2) The variations from the quiet atmosphere resulting from solar and geomagnetic disturbances.

(3) Other effects not now apparent.

Mass Spectrometer Experiment Data

Concentrations as a function of altitude are shown in Figure 6 (Reber and Nicolet, 1964) where Nicolet's model (private communication) is lincluded for reference. The data points shown are measured values, converted to ambient number densities. Measurements of each mass taken on the same satellite interrogation are made approximately one minute apart and are shown in the figure joined by straight lines. The numbers refer to orbit numbers. Table II lists pertinent information for the passes shown in the figure.

Of particular interest are the helium concentration vs. altitude, and the altitude regions where helium, atomic oxygen and molecular nitrogen are predominant. It is seen that helium is the major constituent above 600 km, molecular nitrogen is predominant below 250 km, and atomic

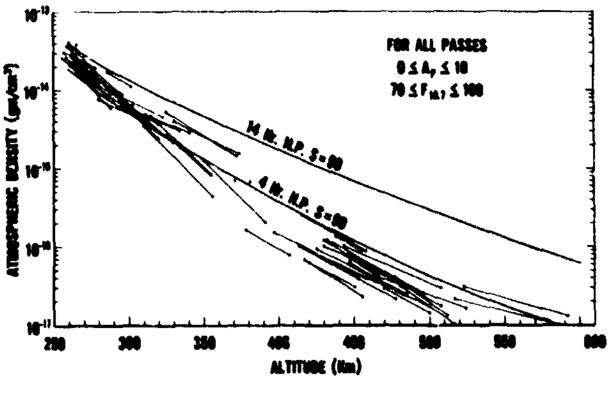

FIGURE 5.—Atmospheric density versus altitude measured by the pressure gauge experiment.

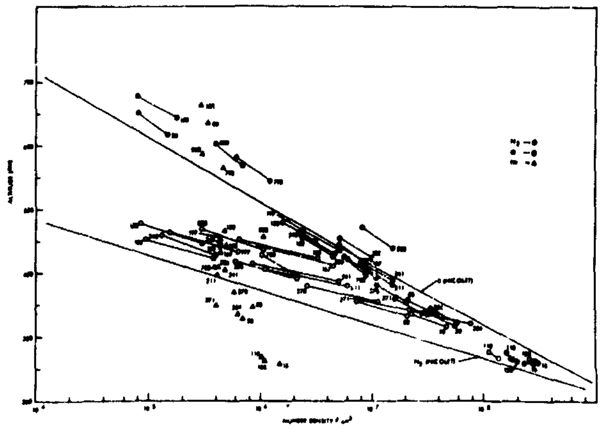

FIGURE 6.—Average daytime and nighttime concentrations of He, O, and N_2 from Explorer XVII mass spectrometer experiment.

oxygen is predominant between these levels. It should be noted that the scale heights of the constituents at higher altitudes correspond to temperatures of about 700° at night.

A possible deviation of the nighttime N^2 distribution from a diffusive equilibrium condition at altitudes less than 400 km is also suggested by this figure. One possible explanation is that the diffusion time in this altitude region is the same order of magnitude as the diurnal variation period. It should also be kept in mind, however, that these data represent a variety of times and geographic locations and thus do not accurately present an instantaneous vertical profile.

Figure 7 shows the variation of mean mass with altitude. The mean mass was computed using the major constituents, N_2, O and He. Hydrogen, which the instrument was not designed to measure, could significantly reduce the value of the mean mass at higher altitudes.

The variation of concentration ratios of helium-to-oxygen and atomic oxygen-to-molecular nitrogen with altitude is shown in Figure 8. The solid lines drawn through the points are averages; as in all the data presented, the points are measured values and are not averaged, nor do they reflect any smoothing. It can be seen here again that helium is the dominant component above 600 km and that molecular nitrogen is predominant below about 250 km.

Langmuir Probe Experiment Results

Figure 9 shows the detailed variation of T_e and

TABLE II.—*Tabulated Mass Spectrometer Data*

Pass & Station	*Date*	*Local Time*	*α*	*Geo. Lat.*	*Geo. Long.*
# 15 BP	4/4/63	21.15 hrs.	6°	38.5°	−75.0°
# 50 COL	4/6/63	0.65	16°	57.0°	−149.0°
# 80 COL	4/8/63	0.99	9°	55.0°	−147.0°
# 80 FTM	4/8/63	4.89	63°	18.0°	− 92.0°
#118 BP	4/10/63	18.81	70°	37.0°	− 72.0°
#120 GF	4/11/63	20.32	51°	51.0°	− 98.5°
#138 BP	4/12/63	2.51	12°	37.0°	− 84.0°
#152 BP	4/13/63	2.01	14°	39.5°	− 68.5°
#167 BP	4/14/63	1.65	20°	39.5°	− 75.0°
#182 BP	4/15/63	1.54	25°	37.0°	− 78.0°
#183 QUI	4/15/63	3.26	23°	4.5°	− 79.0°
#197 BP	4/16/63	1.43	27°	34.0°	− 81.5°
#211 BP	4/17/63	0.53	45°	41.5°	− 71.5°
#226 BP	4/18/63	0.48	53°	38.5°	− 74.0°
#241 BP	4/19/63	24.19	62°	38.0°	− 79.5°
#242 MOJ	4/19/63	0.64	54°	31.0°	−121.5°
#254 NFL	4/20/63	22.75	82°	49.0°	− 53.0°
#270 BP	4/21/63	23.30	80°	41.5°	− 71.5°
#271 GF	4/21/63	22.88	85°	45.0°	−101.0°
#708 NFL	5/20/63	7.18	39°	49.5°	− 49.5°
#795 OOM	5/26/63	15.81	63°	−34.0°	137.5°
#800 JOB	5/26/63	15.90	65°	−37.5°	19.0°
#888 JOB	6/1/63	13.24	33°	−27.0°	25.0°

The local sun time, angle of attack (α), geographic latitude and longitude are averaged over the four minute pass. The stations involved are: BP—Blossom Point, Md.; COL—College, Alaska; FTM—Fort Myers, Fla.; GF—Grand Forks, Minn.; QUI—Quito, Equador; MO.—Mojave, Calif.; NFL—Newfoundland; OOM—Woomera, Australia; JOB—Johannesburg, South Africa.

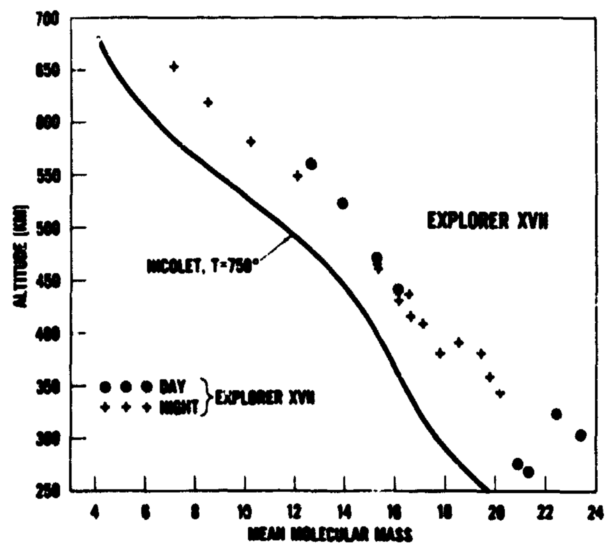

FIGURE 7.—Mean molecular mass versus altitude from mass spectrometer.

N_t, measured during a series of near perigee passes near the F_2 maximum over Blossom Point, Maryland. These data were obtained over the three month satellite lifetime during which the rotation of the orbit plane caused a complete diurnal variation to occur. The data are shown as points or pairs of points, the latter corresponding to the measured values at the beginning and at the end of individual satellite passes.

At first glance one is struck by the lack of correlation between the gross diurnal variations (smoothed curves) and the changes during the individual passes, especially in the afternoon. Since perigee passes such as these can exhibit very little altitude change, this in-pass variation must be largely latitude dependent (10° change in latitude within average pass). The average in-pass change in T_e implies a latitude gradient near Blossom Point of approximately 25° K per degree of latitude, coresponding to about a 10 percent change in T_e within a pass. With few exceptions the changes in T_e within a pass are accompanied by an inverse change in N_t which is even greater than 10 percent.

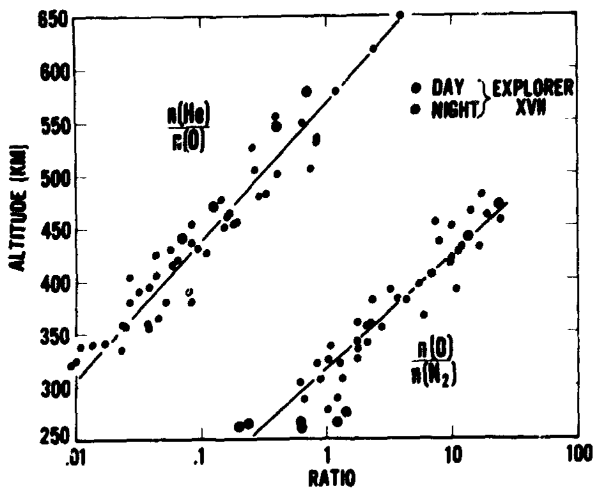

FIGURE 8.—Ratios of n(He)/n(O)n(N₂) versus altitude from mass spectrometer experiment.

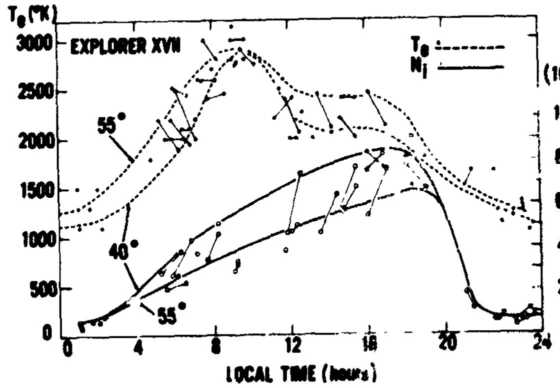

FIGURE 9.—Diurnal variation of T_e and N_i for magnetic latitudes 40–50°N and altitudes 258 to 350 km, from the Langmuir probes.

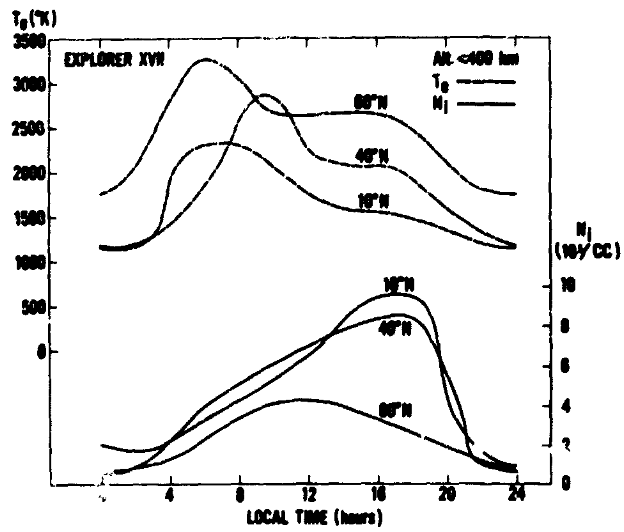

FIGURE 10.—Averaged T_e and N_i showing the diurnal variation above three selected stations; Quito (10°N), Blossom Point (40°N) and College (60°N).

Plots similar to Figure 9 have been prepared from T_e and N_i measurements at two other latitudes (10° N at Quito, 60° N at College), and the resulting gross diurnal variation curves at all three latitudes are shown in Figure 10. These data also correspond to the region of the F_2 maximum (below 400 km).

The T_e variation at the F_2 maximum at all latitudes shown is characterized by a steep morning rise, a midmorning maximum, and afternoon plateau, and a gradual decrease near sunset. The nighttime values of T_e are somewhat variable but are always significantly above the neutral particle temperature (Harris and Priester, 1962), particularly at College, Alaska where the summer night at F_2 altitudes is short or non-existent.

The values of N_i rose gradually throughout the day, reaching a maximum density in the late afternoon, except at College where the maximum occurred in the early afternoon.

It should be noted that the curves in Figure 10 represent direct "in situ" measurements above specific geographic locations during the late spring and summer of 1963, and therefore should not be considered models of the diurnal variation at other altitudes, longitudes, and seasons. However, the analysis of higher altitude data from these sites, as well as data from other sites is now in progress, and it is hoped that these data will help provide a better understanding of the global structure of the ionosphere.

In conclusion, it is clear from the simultaneous measurements that T_e and N_i are related in a generally inverse manner which agrees reasonably well with the inverse square relationship predicted by Hanson (1962) and Dalgarno, et al (1963). The elevated nighttime values of T_e show that there is a heat source for the electrons at night, although its energy content is only a few percent of that required to cause the electron temperatures observed in the daytime (Brace, Spencer, Dalgarno, 1964).

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