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# A STATISTICAL MODEL OF THE LOWER IONOSPHERE

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ABSTRACT: This report analyzes, as a group, measurements of the electron density profile in the lower ionosphere. Approximately 15 years of measurements were analyzed and an effort is made to develop a preliminary time-varying ionospheric model for use in determining VLF and LF propagation predictions.

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ACKNOWLEDGEMENT

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In order to estimate the performance of the Minimum Essential Emergency Communications Network (MEECN), it is necessary to determine the time-availability of each individual link. Some links in the system are LF-VLF radio communications systems, whose time availability depends primarily on the temporal statistics of the signal-to-noise ratio (S/N). The variation of LF-VLF S/N is not sufficiently well known for good system design and analysis, so the Office of MEECN System Engineer has organized the Tri-Service Propagation Program to develop the required information.

The main uncontrollable determinant of LF-VLF signal strength is the profile (height variation) of the electron density in the extreme lower ionosphere, because it is here that the VLF radio waves are reflected. Most of the sophisticated computer programs that have been developed for computing LF and VLF field strength require a model of the lower ionosphere as input. The accuracy of the field strength prediction (and through it, the accuracy of the link time-availability calculation) depends on the accuracy of the ionospheric model used.

There is no available model of the lower ionosphere which depicts realistically the variation of the ionosphere with hour, season, latitude, and sunspot number. However, during the past 15 years, many measurements of the electron density have been made at various locations and times. These measurements have not been analyzed as a group, nor incorporated into a synoptic, statistical model useful for LF-VLF communications link analysis. This report analyzes the available data, assesses its usefulness, and provides a preliminary time-varying ionospheric model.

### 2. SELECTION AND VALIDATION OF DATA REDUCTION TECHNIQUES

Previous experience has shown that a simple exponential model of the electron density in the lower ionosphere is adequate to describe LF-VLF radio propagation in most cases (see equation (ES-1) in section 3). Rules for scaling the parameters for such a model from measured electron density profiles were developed. They were validated by comparing propagation parameters computed for a sample of ten representative measured profiles with the same parameters computed for the scaled exponential approximation. For these ten profiles, the magnitude of the principle reflection coefficient errors averaged less than 1 dB for the important angles of incidence for LF-VLF propagation. This resulted in an average error of about 1 dB in field strength for a 5000 km path. The error increases with path length. An error of this size from the scaling procedure is acceptable because it is smaller than the random variation of signal strength.

## 3. DERIVATION OF THE MODEL

Four hundred and seventy measured profiles of electron density in the D-region were retrieved from the report and journal literature, and were scaled to determine the statistical distribution and correlation that could be derived from emperical data. A multi-parameter linear regression of the model parameters on significant geophysical parameters was performed using a standard statistical approach. The resulting model has the form:

$$N(h) = N_0 \exp (\alpha (h - h_w) \qquad \text{(ES-1)}$$

where

$$N_0 = 1.43 (10^7) \exp (-0.15 h_w)$$

so that $h_w$ is the standard reference height. The gradient, $\alpha$ and $h_w$ will depend on time (hour and month), latitude, and solar activity.

$$\alpha = \alpha_c + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 \quad \text{and} \qquad \text{(ES-2)}$$

$$h_w = h_c + h_1 x_1 + h_2 x_2 + h_3 x_3 + h_4 x_4$$

The $\alpha_i$ and $h_i$ are coefficients determined by a multidimensional linear regression on the independent variables $x_i$. These variables are:

$x_1 = \cos (\frac{t - 12}{24} 2\pi)$, where t is the local time (hour), t = 1,24.

$x_2 = \cos (L)$, where L is the latitude (radians).

$x_3 = \pm \cos (\frac{m - 1/2}{12} 2\pi)$, where m is the month (January = 1, ... December = 12.)

(Use + for northern hemisphere, - for southern hemisphere.)

$x_4 = S$, where S is the sunspot number (12 month running average of Zurich sunspot number).

The analysis was also done for $x_1$ = cos (sun's zenith angle) but the residual error in both h and $\alpha$ was greater (slightly) for this set of variables. Table ES-1 gives the resulting values for $\alpha_i$ and $h_i$.

Table ES-1. Values of Coefficients for Statistical Electron Density Model

| i | c | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| $h_i$ | 71.8 | 3.83 | 6.85 | 0.085 | 0.047 |
| $\alpha_i$ | 0.210 | 0.036 | 0.082 | -0.050 | 0.00045 |

Statistical tests show that all coefficients except $h_3$ are significantly different from zero.

## 4. COMPARISONS OF MODEL VARIATIONS WITH VLF PROPAGATION EXPERIENCE

The model predicts a day-to-night variation in reference height, $h_0$, of less than 8 km. Measured VLF propagation data suggests that this variation should be about 15 km. This is the biggest deficiency of the preliminary model. It appears to be caused by too few, or too inaccurate, nighttime profiles.

However, the

- variation of reference height with sunspot number,
- variation of reference height with latitude, and
- the day and night values of the slope parameter, $\alpha$,

are all consistent with LF-VLF propagation experience -- at least qualitatively.

## 5. CONCLUDING REMARKS AND RECOMMENDATIONS

The dependence of lower ionosphere reflection properties on sunspot number, season, and latitude shown by the analysis in this report will be useful for predicting LF-VLF field strength (and thus VLF link time availability) The apparent poor quality of the measurements of electron density at low altitudes at night resulted in unrealistically small day-to-night change in reflection height. To make a practical model useful for LF-VLF signal-to-noise predictions, the following steps are recommended:

1. Remove local time from the list of independent variables, and instead put in a fixed variation with time which has the required day-to-night variation, as determined by propagation data.
2. Filter the data by making subjective, but careful, judgments about the quality of the data, indicated by the experimental method and controls. Discard the profiles judged to be unreliable.
3. Continue to add high quality profiles to the data base as they become available.
4. Then recompute the coefficients for the remaining variables, separately for day and night.

A realistic time-varying model of the lower ionosphere is necessary for reliable calculations of the time-availability of LF-VLF links in the MEECN system.

APPENDIX

The profile data, and sources of the profiles used in the report are listed in the Appendix.

# A STATISTICAL MODEL OF THE LOWER IONOSPHERE

## ABSTRACT

Four hundred and seventy measured profiles of electron density in the lower ionosphere were retrieved from the literature. Scaling rules were developed for fitting the profiles with an exponential approximation, and were validated by comparing LF-VLF field strengths computed with the approximations and the full measured profiles. The coefficients for a multidimensional linear regression on the parameters of the exponential model were calculated using standard techniques. The seasonal, latitudinal, and sunspot number variations of the reference height are consistent with long-path VLF measurements. The day-to-night variations of reference height and gradient are qualitatively correct, but are not large enough. This discrepancy is traced to the nighttime profiles. Further analysis to improve the model is recommended.

## 1. THE NEED AND POTENTIAL FOR A MODEL OF THE LOWER IONOSPHERE

In order to estimate the performance of the Minimum Essential Emergency Communications Network (MEECN), it is necessary to determine the time-availability of each individual link. Some links in the system are LF-VLF radio communications systems whose time availability depends primarily on the time distribution of the signal-to-noise ratio (S/N). The main uncontrollable determinant of LF-VLF signal strength is the profile (height variation) of the electron density in the extreme lower ionosphere, because it is here that the VLF radio waves are reflected. So most of the sophisticated computer models that have been developed for computing LF and VLF field strength require specification of a model of the lower ionosphere.

Since the computer field strength is to be compared with the noise, the ionospheric model should vary realistically with the same parameters which affect the noise -- the time (hour, season) and geographic location. No satisfactory time-varying, worldwide model of the lower ionosphere exists. Several attempts have been made to develop "average" profiles for day and night (see, for example, Bain and May, 1967). Berry and Jones (DCA, 1974b, Appendix) made a preliminary attempt at a time-varying model. More recently (DCA, 1974a), Morfitt prepared a table recommending "descriptive electron density profiles" for various latitudes and seasons for day and night. These profiles "describe the limited amount of propagation data to varying degrees of exactness." However, the table is incomplete, especially at night, and it is clear that the recommended profiles will not reproduce the known seasonal variations in LF-VLF signal strengths.

During the past 15 years, a number of experimenters have attempted to measure the electron density in the lower ionosphere. The measurement methods include direct measurements of electron density by rockets and indirect radio sensing techniques using rockets or ground-based "radar". Two ground-based techniques use HF radio waves: the partial reflection technique (e.g., Gardner and Pawsey, 1953; Belrose, et al., 1967) and the wave interaction or cross-modulation technique (e.g., Smith, 1967). Multi-frequency VLF sounders are used at both steep (e.g., Gossard, 1967) and oblique (e.g., Morfit, 1973) incidence. Finally field strength as a function of distance from the transmitter can be used to deduce the electron density profile (e.g., DCA, 1975). The Appendix lists many more references for each experimental method.

The low values of electron density in the lower ionosphere make its measurement difficult (Booker and Smith, 1970). None-the-less, there have been enough such attempts to make it worthwhile to try to analyze all measurements and integrate them into a synoptic quantitative description.

In this report, all applicable measurements that were found are used. The usual hopeful assumption is made: if the sample is large enough, errors made in individual measurements will "average out" so that the resulting sample mean represents the true mean ionosphere, and the distribution of the data about the mean approximates the true distribution. That assumption should eventually be tested by comparing calculated LF-VLF field strengths with measured values for particular paths.

This appears to be the first attempt to organize all the data into a quantitative model. The usual reasons given for not doing it are that the data are not sufficiently accurate, have not been validated by replication (various experimental methods may give different results), have not been taken in enough different points in space and time, and do not extend low enough in altitude to be useful in long-path VLF propagation studies. Most of the reasons except the last can be tested and perhaps circumvented by statistical analysis. The last reason is the most inhibiting -- but can be tested only after the model has been developed -- by comparing theoretical propagation calculations made with the model with actual measurements.

## 2. SELECTION AND VALIDATION OF DATA REDUCTION TECHNIQUES

Two measured D-region profiles are shown in Figure 1 (Profiles 70 and 167 of Appendix). The fact that measured D-region electron densities are usually shown in this format emphasizes that the most important variation is with height. Given a large number of profiles like those shown in Figure 1, which were measured at various geographic locations and times, how can the average profile and the variation of profiles with important causative geophysical parameters be summarized? That is the problem being addressed.

A brute force approach might be to consider a four dimensional grid (latitude, longitude, altitude, and time) and to fit some function to the data values we have, recognizing the important time cycles (diurnal, annual, and sunspot cycle). Even a cursory examination of this approach shows that it requires orders of magnitude more data than are available.

A more refined approach is to choose a mathematical form whose values depend on parameters, determine the values of these parameters for the measured data, and analyze the geophysical dependence of these parameters.

Berry and Jones (DCA, 1974b) used a model which consisted of an exponential function of height, plus a Chapman layer. This model required six parameters, and could be fit quite well to profiles like the one labeled A in Figure 1. Scaling the parameters from profiles is quite difficult, especially if the shape is like that of profile B in Figure 1.

### 2.1 The Exponential Profile

A much simpler model for theoretical purposes was suggested by Wait and Spies (1964). Calculations show that the parameters which most affect VLF propagation are the height of reflection and gradient of electron density at that height. These two parameters are explicit in the "exponential profile"

$$N(h) = N_0 \exp [\alpha(h - h_0)] \qquad (1)$$

where $N_0$ is the electron density at height $h_0$ and $\alpha$ is the slope on semi-log paper. The rationale is that the lower edge of most profiles can be approximated by a straight line on the semi-log paper for a height range of several kilometers. Theoretical calculations have shown (Crain, 1970; Gambill and Rutherford, 1971) that most of the contribution to reflection of LF and VLF waves occurs within a height range of perhaps 5 kilometers.

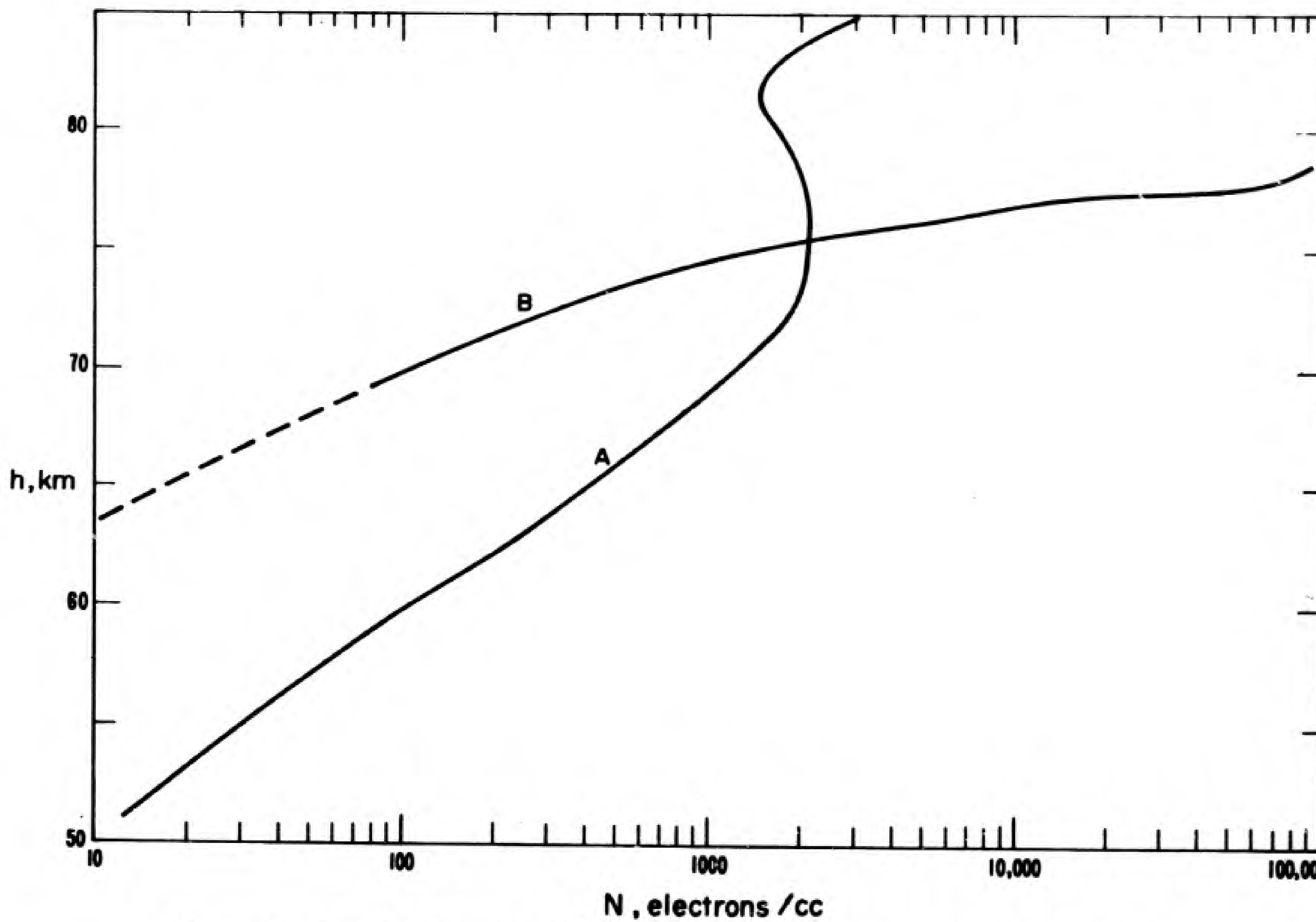


Figure 1. Example of daytime (A) and nighttime (B) electron density profiles.

The Naval Electronics Laboratory has had considerable success matching theoretical propagation calculations to measured field strengths by using such exponential profiles. Thus, this simple model, which requires only three parameters for complete specification, was selected for a first attempt. If it does not prove satisfactory, more complicated models can be tried later.

As will be seen, even profiles such as profile A in Figure 1 can be fitted with an exponential. The argument is that, even for these, the oblique reflection often takes place well below the nose of the profile, so that the departure from an exponential higher up is not significant. Of course, there will be times when electron density in the reflection region is considerably non-linear, but if these times are sufficiently rare, they will not invalidate a statistical model.

## 2.2 Scaling Rules

Having chosen to fit the profiles with a straight line (on a log scale), the choice of the proper height at which to determine the slope of the line becomes critical, because the slope is an important determinant of the reflection coefficient magnitude. For theoretical work, Wait and Spies (1964) chose to fix $N_0$ so they could deal with only two parameters -- $h_0$ and $\alpha$. They chose the height $h_w$ at which

$$\omega_r(h_w) = 2.5\ (10^5). \qquad (2)$$

Here, $\omega_r(h) = 3.18\ (10^9)\ N(h)/\nu(h)$, (3)

N is the electron density, and $\nu$ is the electron neutral collision frequency. It is important to notice that for a truly exponential profile, such a choice is entirely arbitrary: given one set of $N_0$, $h_0$, and $\alpha$, the same profile can be represented at any other height $h_1$ by finding the corresponding $N_1$ using formula (1).

However, for determining an exponential electron density profile which adequately represents an experimentally measured profile for propagation calculations, selection of the height at which to determine the slope can be critical, because this slope may change considerably in a distance of 10 or 15 km.

Gambill and Rutherford (1971) have made a number of calculations which show that most of the energy of a VLF or LF wave incident at an angle $\phi$ on the ionosphere is reflected near the height where

$$\frac{\omega_r}{\omega} = \sqrt{2}\,\cos^2\phi\,, \tag{4}$$

where $\omega = 2\pi f$ is the radio frequency. This was originally suggested by Field and Engle (1965). Unfortunately, this criterion is a function of radio frequency and angle of incidence, and the ionospheric model should not be a function of these parameters. In the next paragraph it is shown that the dependence on f and $\phi$ is sufficiently weak that average values can adequately represent the range of interest to LF-VLF.

An adequate approximation for the collision frequency is (Wait and Spies, 1964)

$$\nu = 5\ (10^6)\ \exp\,[-0.15(h-70)] = 1.8\ (10^{11})\ \exp\,(-0.15h) \tag{5}$$

Assume $\nu = d\ \exp\,[-.15(h - h_o)]$ and that $N(h) = N_o\ \exp\,(\alpha\ (h - h_o))$. The reflection height, $h_r$, is found by solving (4) using (3):

$$\frac{3.18(10^9)\ N_o\ \exp\,(\alpha\ (h - h_o))}{2\pi f\ d\ \exp\,(-0.15\ (h - h_o))} = \sqrt{2}\,\cos^2\phi\ ,\ \text{or} \tag{6}$$

$$\exp\,[(\alpha + 0.15)\ (h - h_o)] = 2.8(10^{-9})\ f\ \frac{\cos^2\phi}{N_o}\ d, \tag{7}$$

Taking the natural logarithm of each side and rearranging yields:

$$h = h_o + \frac{1}{\alpha + 0.15}\ \ln\frac{2.8(10^{-9})d}{N_o} + \frac{\ln(f\ \cos^2\phi)}{\alpha + 0.15}. \tag{8}$$

The radio frequency and angle of incidence affect only the last term on the right. The denominator of the term, $\alpha + 0.15$, varies from 0.3 to 1.2 (DCA, 1975). Choosing 0.5 as a typical value, the reflection height variation with f and $\phi$ is $2\ \ln\,(f\ \cos^2\phi)$ km -- a factor of 2 variation in $f\ \cos^2\phi$ changes the reference height only 1.4 km. For example if f = 30 kHz, the height would be within 1.4 km of the correct height for frequencies from 15 kHz to 60 kHz. Similarly, $\phi$ = 81° will cover angles from 77° to 84° -- and these are by far the most important angles of incidence for long-path VLF-LF propagation.

Therefore, equation (4) with f = 30 kHz and $\phi$ = 81° was used to determine the scaling height. The scaling procedure was as follows:

1. If the lower portion of the profile shows electron density increasing, or constant, as the height decreases, discard the profile.
2. Otherwise find the lowest height that satisfies equation (4).
   If this height exists on the measured profile, use it and go to 3.
   If the height is below the measured profile,
   a. if there is an established slope to the profile near the bottom, extrapolate it to the height that satisfies equation (4), and proceed to 3.
   b. Otherwise, discard the profile.
3. Record the height and N at the required height.
4. Fit (by observation) a straight line tangent to the profile at the selected height. Determine $\alpha$ for this straight line.

## 2.3 Validation of Scaling Rules

Since the ionospheric model is being developed for use in propagation predictions, the salient test of the adequacy of this procedure is comparison of propagation parameters computed for the entire measured profile and the exponential fit. From some 280 profiles collected at the time of the test, a stratified sample was selected: one night and one day profile from each season (winter, summer, equinox) from each of three latitude zones (high, medium, low). There were not enough profiles from low latitudes to do this, so the test was made with 10 test profiles (numbers 70, 159, 167, 169, 247, 250, 300, 317, 343, and 372 from the Appendix).

The electron density and the parameters for an exponential fit were scaled from each profile using the rules above. Then ionospheric reflection coefficients for both representations of each profile were computed for radio waves with frequencies of 20, 40, and 60 kHz incident on the ionosphere at angles of 50°, 60°, 70°, 75°, 78°, 82°, and 84°. The three larger angles in this list are the most important for long-distance VLF and LF propagation.

The values for the measured profile and its exponential fit were compared to determine the error caused by the exponential approximation. For the amplitude of the reflection coefficient, the error (in dB) is

$$20 \log \frac{|R \text{ (for exponential fit)}|}{|R \text{ (for measured profile)}|}$$

where R is the computed reflection coefficient for each case.

The phase error was defined to be

$$\phi(\text{exponential fit}) - \phi(\text{measured profile})$$

where $\phi$ is the computed phase of the reflection coefficients. The errors were computed for each frequency as a function of angle of incidence. To determine if there were any consistent bias in the scaling procedure, the errors were averaged. The results for the most important reflection coefficient ($_{\parallel}R_{\parallel}$) are shown in Figure 2. The fact that the overall average of the error is small indicates that there is no bias in the scaling procedure.

For estimating the effects of the errors on field strength predictions, the average of the absolute value of the errors is more important. This average is shown for each frequency in Figure 3. In general, the errors are larger for smaller angles of incidence. This could be expected from the scaling rules, since the height at which the electron density gradient was scaled was the "correct" one for an angle of 81°. The errors are also larger for the higher frequencies than for the lower frequencies.

The large errors for small angles of incidence are not too disturbing, because the model is to be used for calculation of field strengths at long distances. For these calculations, angles between 80° and 85° are most important, since the limiting grazing angles for wave hop theory are about 81° or 82° and the real part of the eigen angles of the important wave guide modes are greater than 80° also.

The probable error in field strength can be estimated from the error in reflection coefficients using notions from the wave hop theory. In this theory, the reflection coefficient (in dB) is multiplied by the hop number, so the error in a hop would just be the hop number times the error in the reflection coefficient. The first hop is usually the largest for distances from 1000 to about 3000 km, so the error in field strength in this region should be about the same as the error in the grazing reflection coefficient.

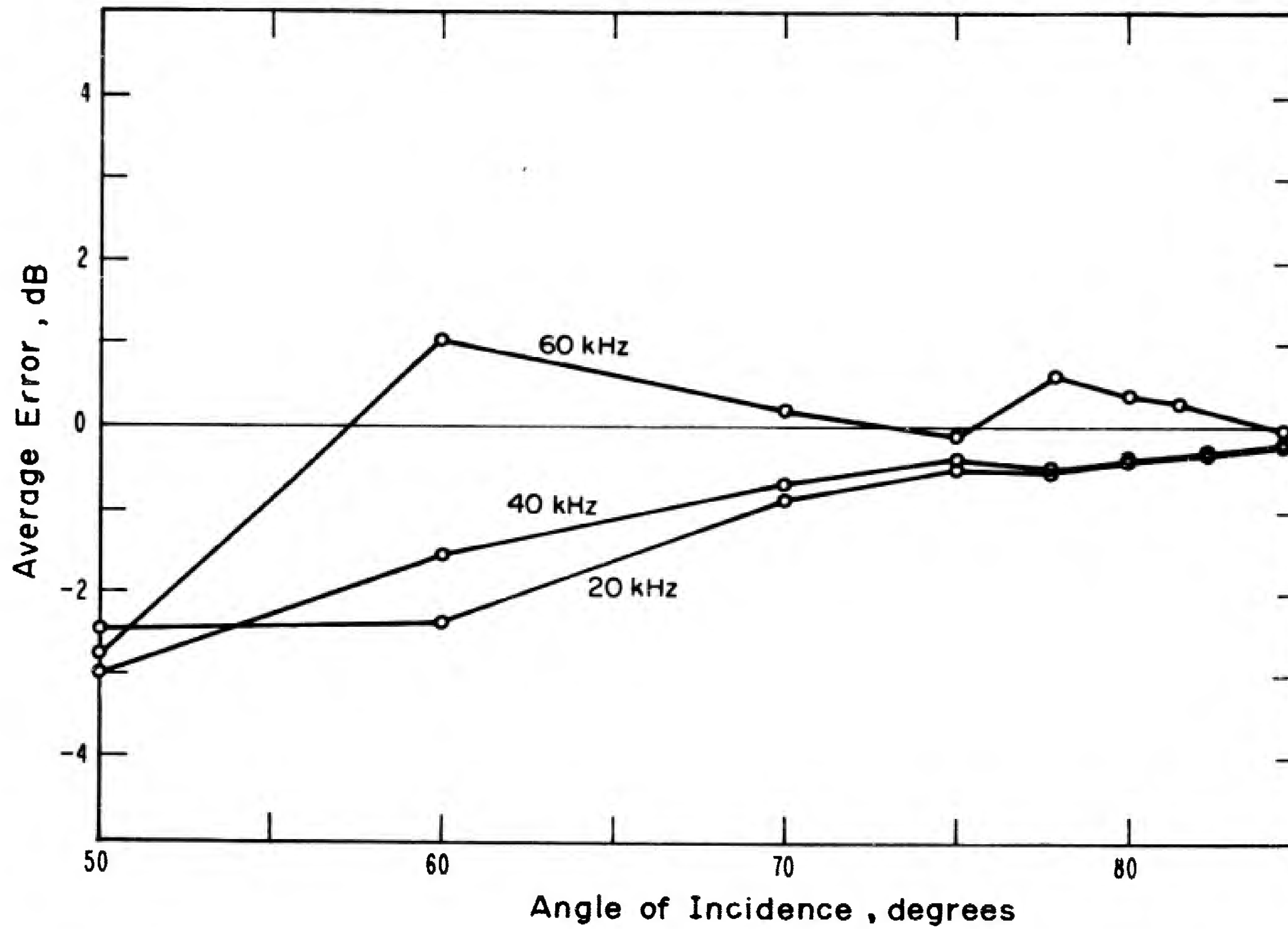


Figure 2. Ten-profile mean of the error in the principle reflection coefficient using the exponential approximation to measured profiles. The mean error, in dB, is shown as a function of angle of incidence for three frequencies.

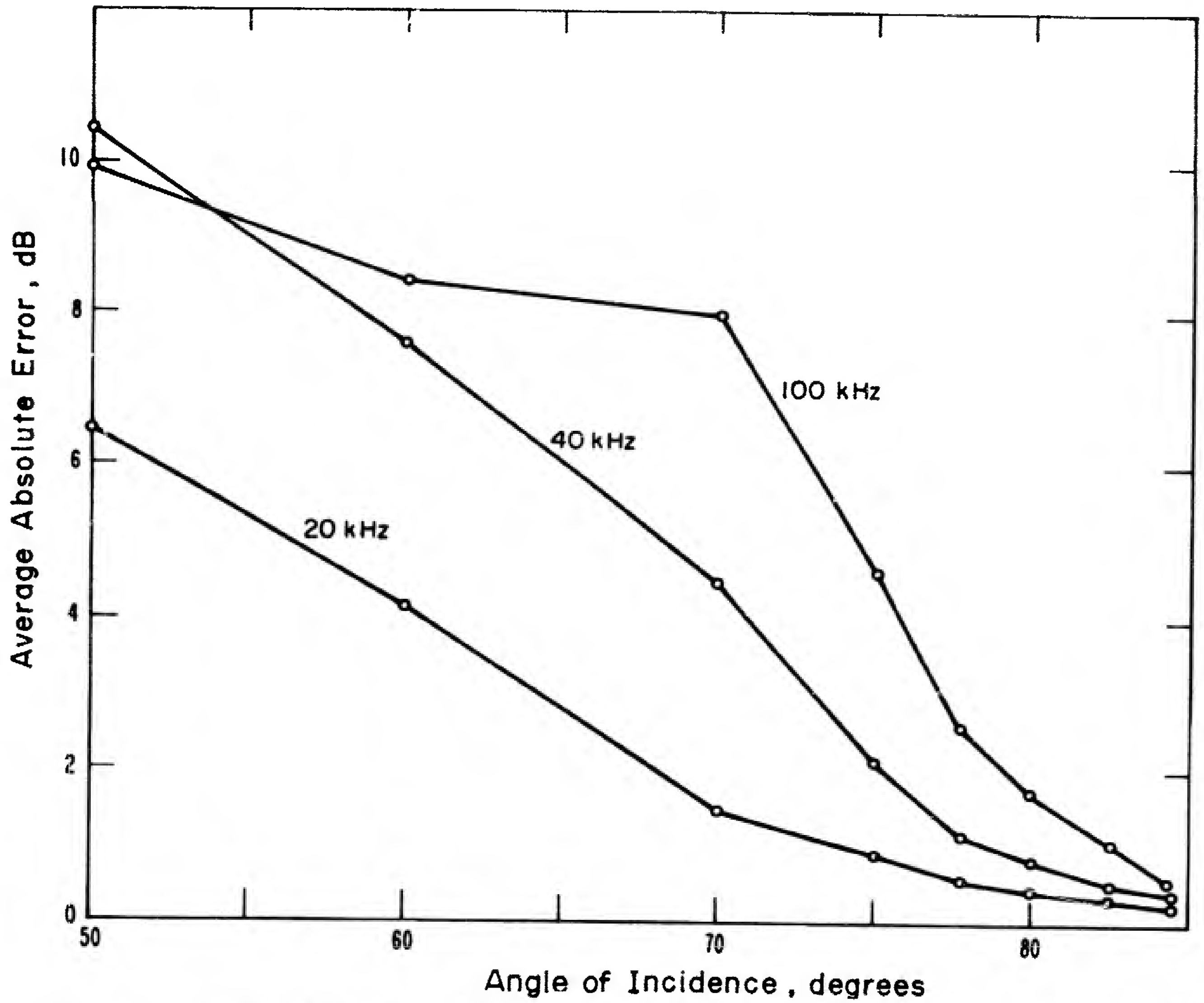


Figure 3. Ten-profile average of the absolute value of the error in the principle reflection coefficient using the exponential approximation to measured profiles. The error in dB is shown as a function of angle of incidence for three frequencies.

From about 3000 km to 5000 km, the second hop predominates, and the error should be twice the error in the reflection coefficient. Between about 5000 km and 7000 km, the error should average about 3 times the error in the reflection coefficient, etc.

Three of the profiles were selected for further testing. One was the profile with the smallest errors in reflection coefficients (profile 167). The second was a profile whose errors most nearly matched the average values (profile 70) and the third was the profile with the largest errors in reflection coefficients (profile 300). The field strength as a function of distance was computed for these three profiles for frequencies of 20, 40, and 60 kHz using the wave hop theory program (Berry and Herman, 1971). The results for 40 kHz are shown in Figures 4, 5, and 6.

Figure 4 is the best case; the field strength curve for the exponential profile can barely be separated from that for the complete profile. The average case is shown in Figure 5. The separation between the two curves gradually increases with distance, but even at 6000 km the difference is acceptable for many practical purposes. The worst case is shown in Figure 6, where the two field strengths are far apart from 5000 km onward.

Notice that in all three cases, even in the worst case, the locations of relative maxima and minima in the two curves are nearly coincident.

The magnitude of errors in field strength can be easily seen in Figure 7, where they are given (in dB) as a function of distance for all three cases. Recall (Figure 3) that the average error in reflection coefficient for grazing incidence was under 1 dB. Thus for the average case (profile 70), the error in field strength from 1000 to 3000 km averages less than 1 dB. From 3000 to 5000 km, the error is between 1 and 2 dB, and so forth. The error in the worst case increases quickly with distance to over 5 dB beyond 5000 km.

The errors in field strength at 20 kHz and 60 kHz are shown in Figures 8 and 9, respectively. These calculations show that the errors in field strength can be estimated accurately from the reflection coefficient errors.

It is interesting to go back and look at the profiles which produced the best, average, and worst results. Profile 167, the best fit, is shown in Figure 10. It is easy to see why the exponential fit (also shown in Figure 10) is an adequate approximation, especially when you note how closely it

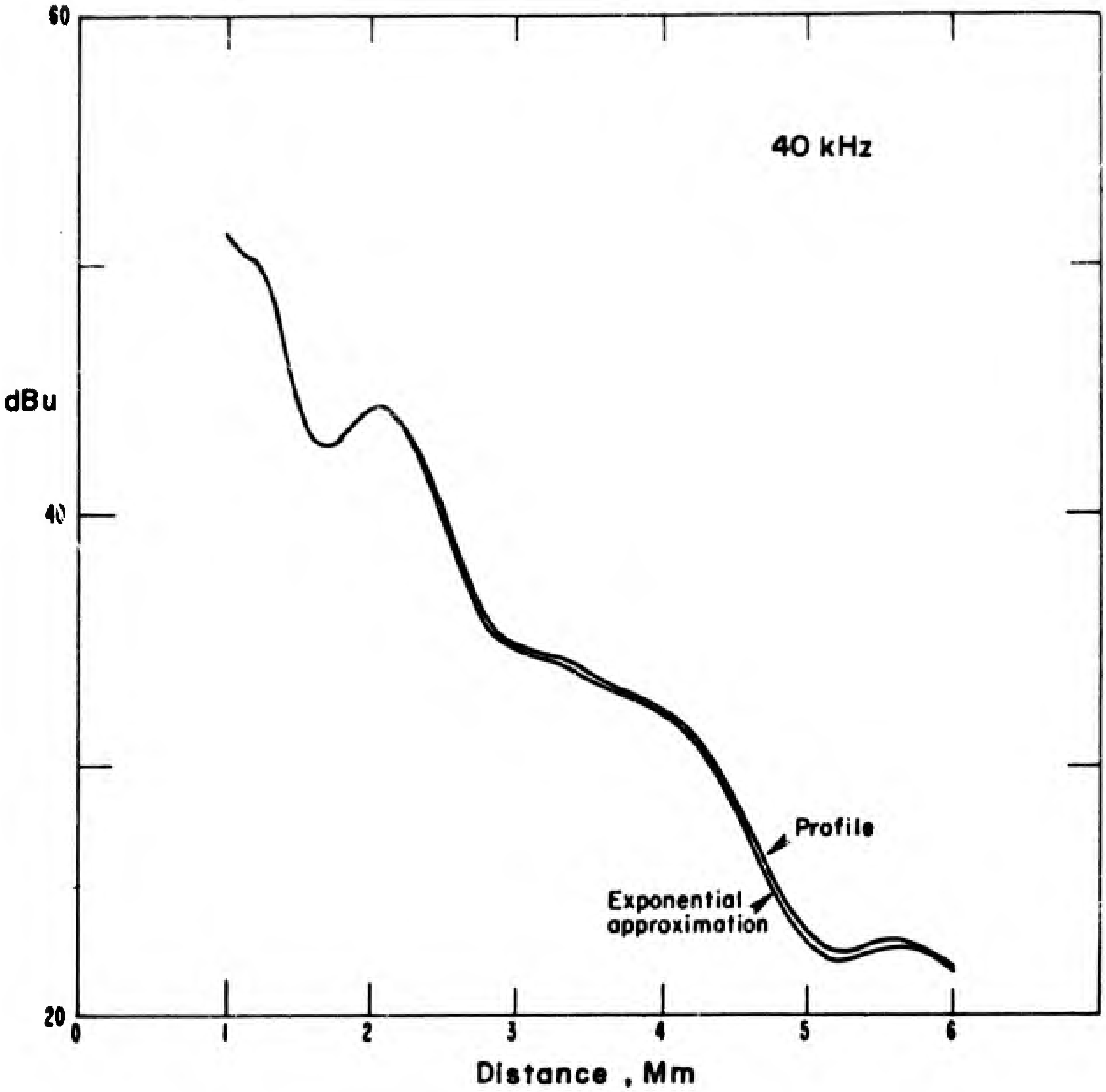


Figure 4. 40 kHz field strength as a function of distance for measured profile 167, and for the exponential approximation to it.

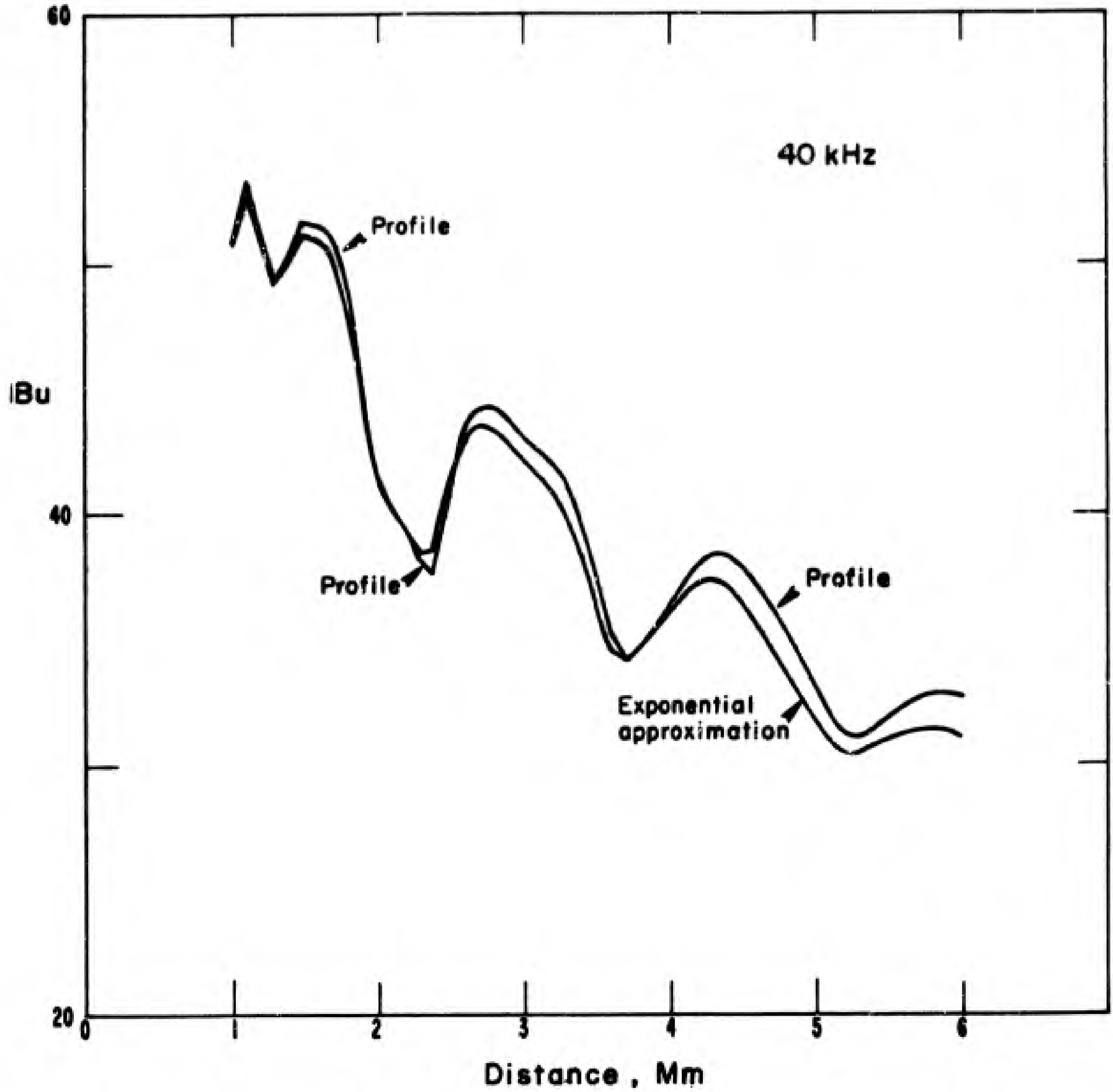


Figure 5. 40 kHz field strength as a function of distance for measured profile 70, and for the exponential approximation to it.

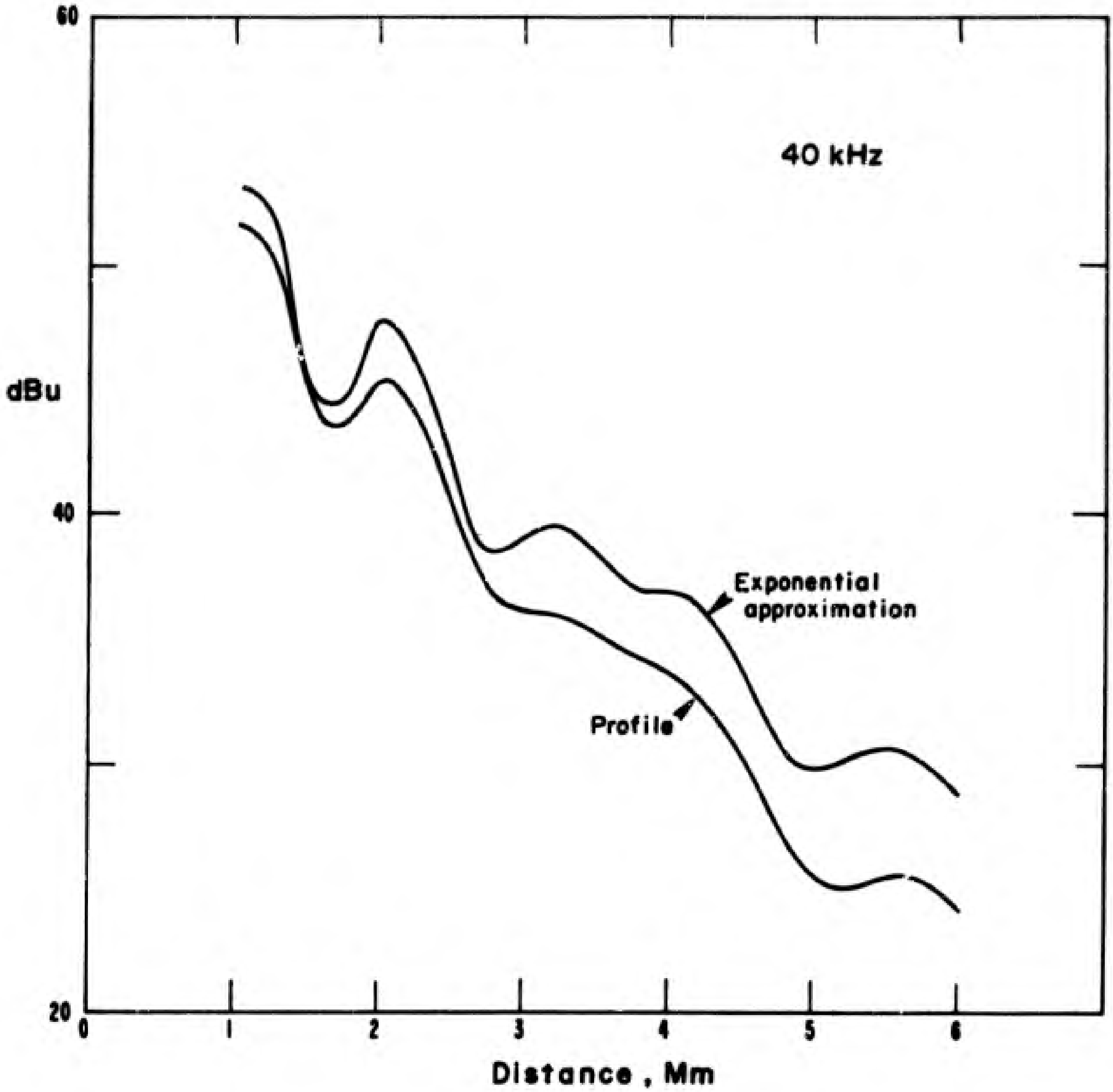


Figure 6. 40 kHz field strength as a function of distance for measured profile 300, and for the exponential approximation to it.

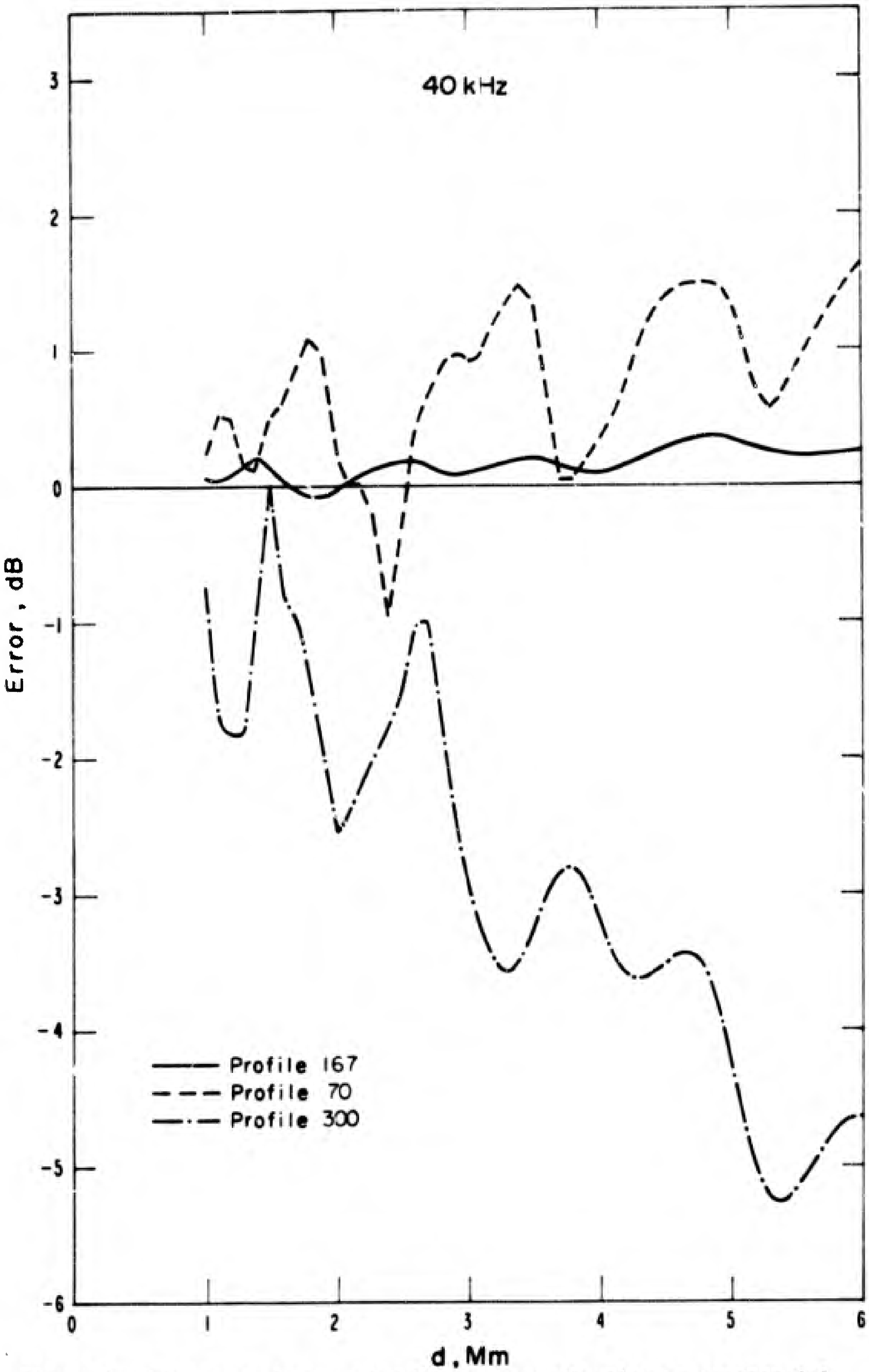


Figure 7. The error in computed field strength using an exponential approximation to a measured electron density profile for a frequency of 40 kHz.

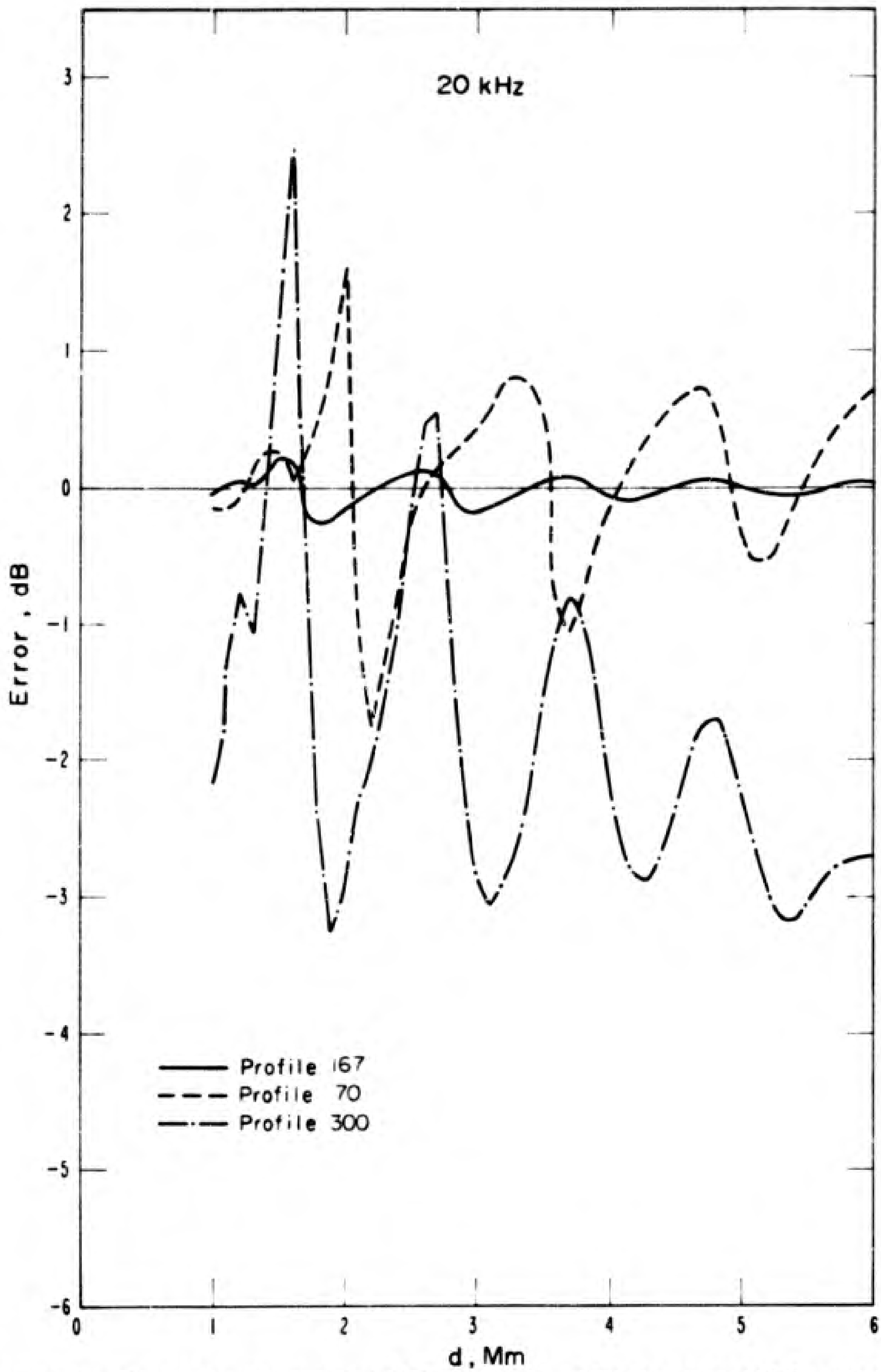


Figure 8. The error in computed field strength using an exponential approximation to a measured electron density profile for a frequency of 20 kHz.

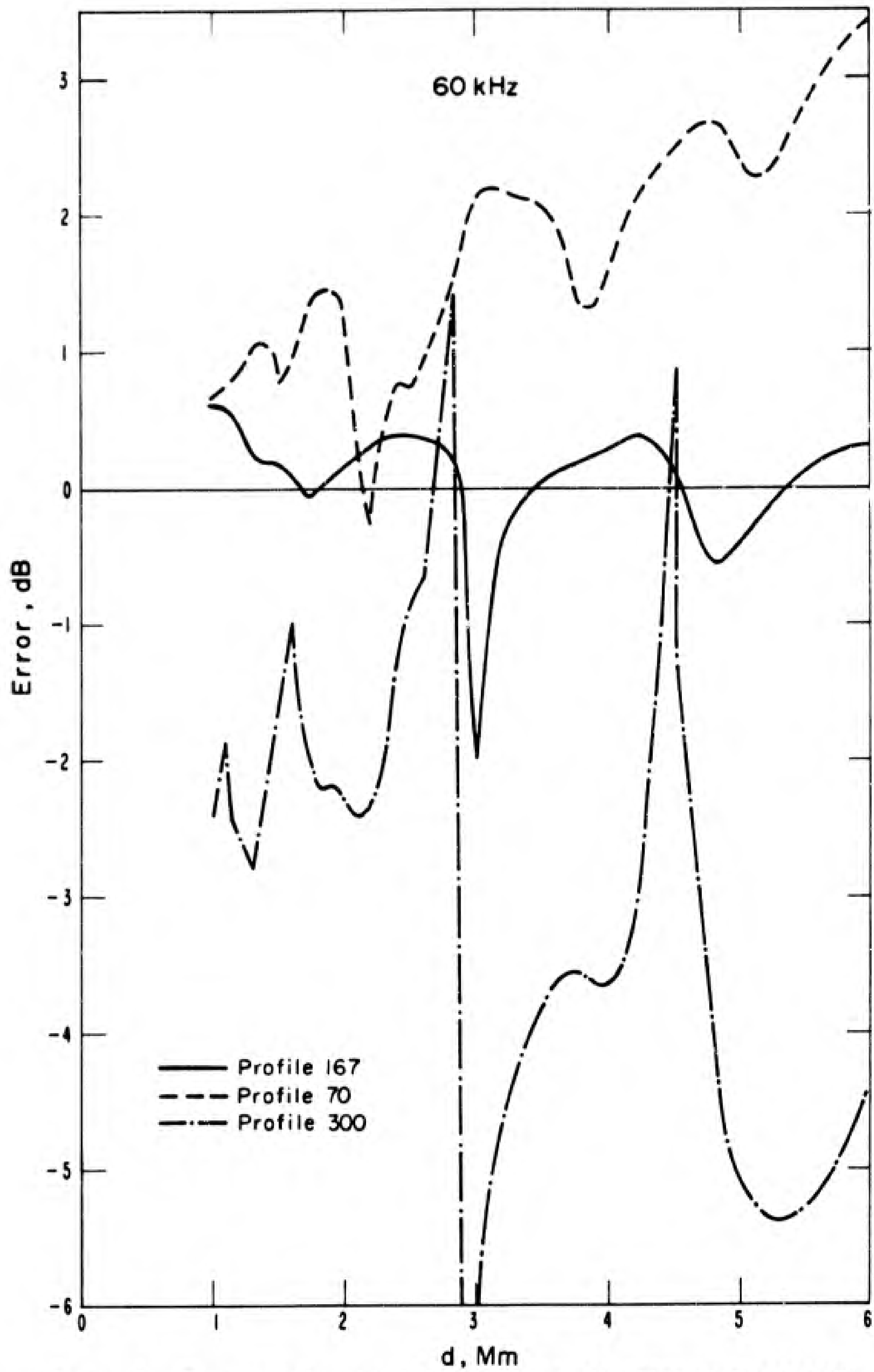


Figure 9. The error in computed field strength using an exponential approximation to a measured electron density profile for a frequency of 60 kHz.

follows the measured profile for many kilometers on each side of the reflection region (marked by an X on the profile).

The fit which produced average errors is shown in Figure 11. The measured profile departs significantly from the straight line fit above 73 km, which leads to larger errors in reflection coefficients for more sharply incident radio waves.

The worst-fit profile is shown in Figure 12. It is obvious that this profile is very unlike the exponential profile also shown on the figure. If all, or even very many, real profiles had the shape of profile 300, the selected scaling process would clearly be inadequate -- and the model would probably need to be more complicated. However, the statistical test conducted with 10 profiles indicates that profiles like the one in Figure 12 are rare.

These tests showed that the exponential model and the scaling procedure are sufficiently accurate, since the average errors in field strength are less than or comparable to the natural variation of VLF-LF propagation over paths less than 6000 km long.

## 3. DERIVATION OF THE MODEL

The journal and report literature yielded 470 profiles which could be scaled according to the rules in the previous section. The Appendix contains a list of the sources of the profiles, and lists the parameters scaled from the profiles and other necessary information about them such as location, time, and experimental method.

Standardized computer programs exist for performing sophisticated statistical analyses of data. OMNITAB II, produced by the National Bureau of Standards (Hogben, et al., 1971), was used. The analysis is essentially a multidimensional linear regression. The independent variables must be chosen so that, to the extent possible, their influence on the model parameters is linear. Physical reasoning and previous studies of the D region provide clues to the appropriate variables. A final choice follows experimentation with various combinations using the OMNITAB program.

### 3.1 Selection of Regression Variables

The daytime D region is produced by direct radiation from the sun. Theoretical analysis (Davies, 1965) and experimental analysis (Reid, 1969) have shown that the electron density correlates well with cos $\chi$, where $\chi$ is

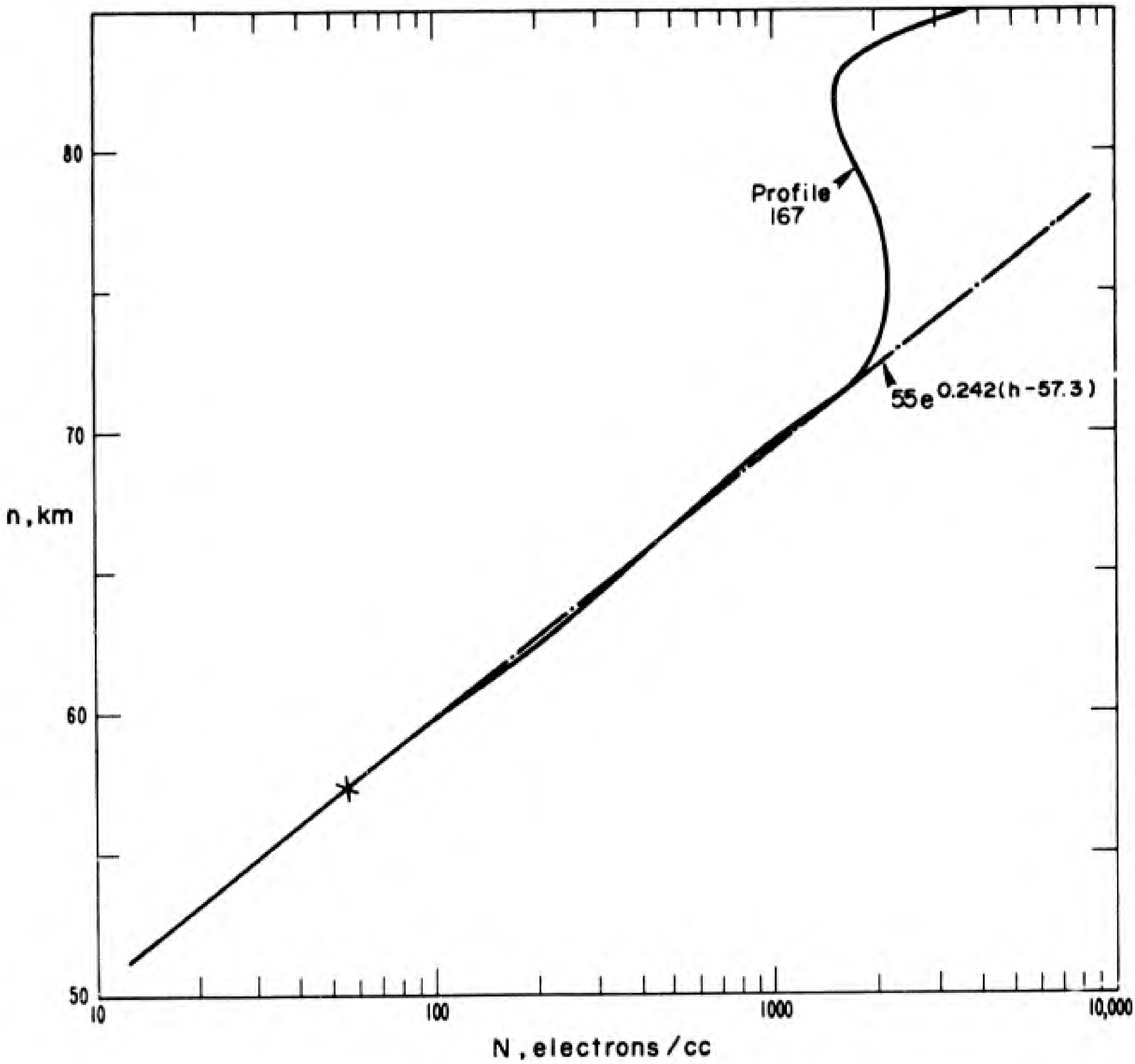


Figure 10. Measured electron density profile 167, and the scaled exponential approximation to it.

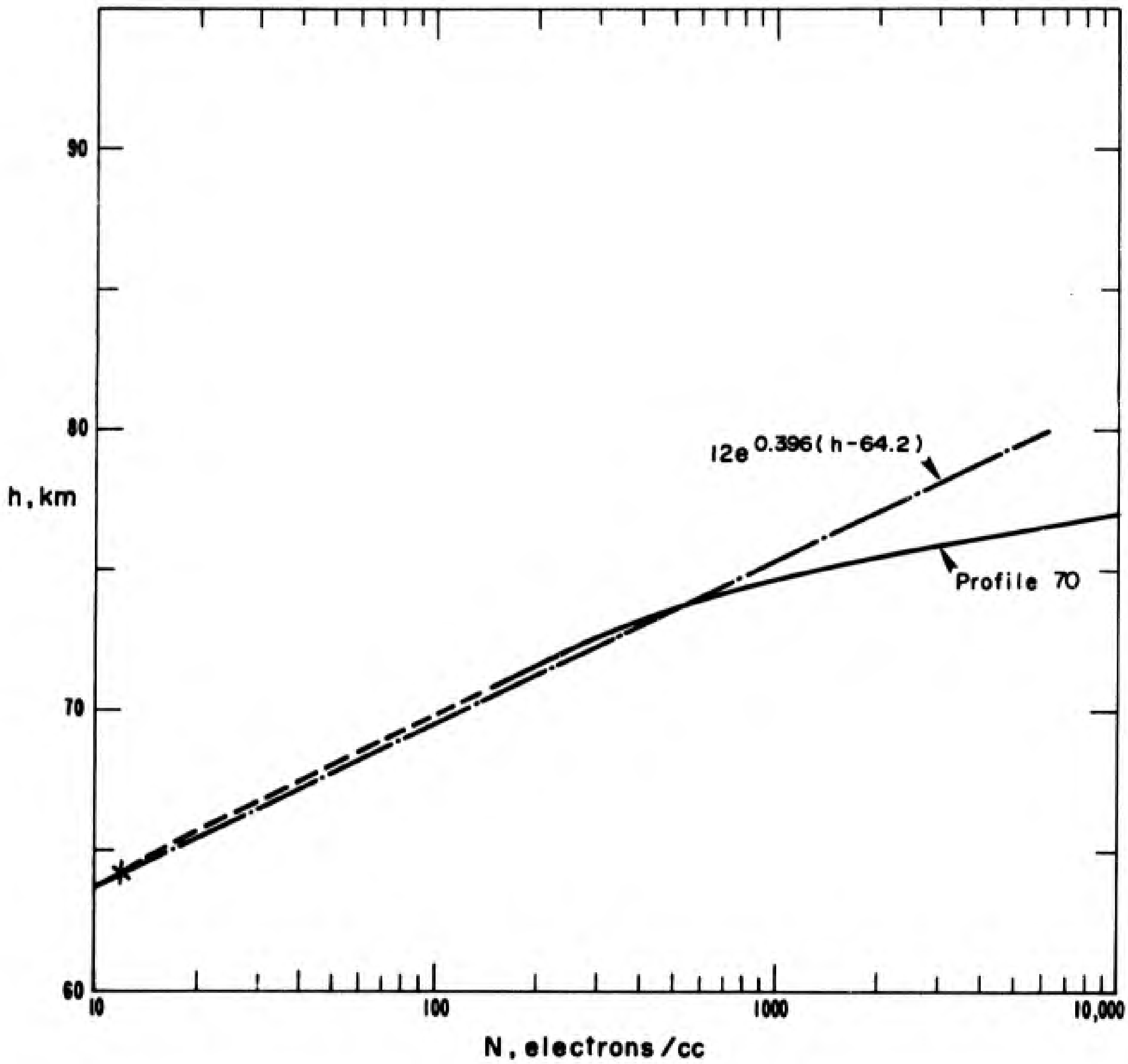


Figure 11. Measured electron density profile 70, and the scaled exponential approximation to it.

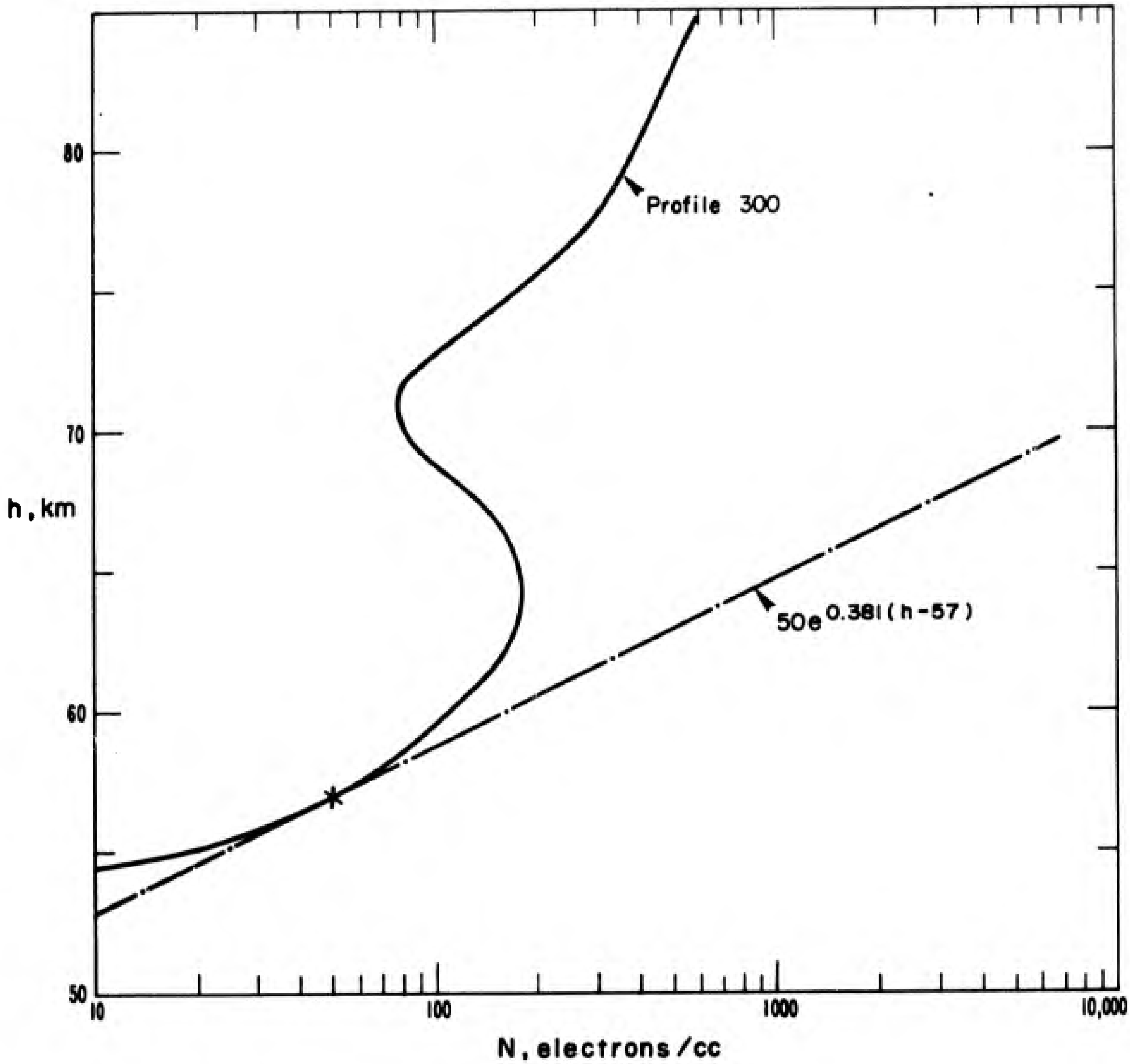


Figure 12. Measured electron density profile 300, and the scaled exponential approximation to it.

the zenith angle of the sun. The zenith angle depends on local time, latitude, and season, so it incorporates in one variable many of the things that influence the D region.

An alternative choice for representing the diurnal variation is the local time. In order to keep the variable cyclic, let the independent variable be cos $(2\pi(t-12)/24)$ where t is the local hour. This choice has the advantage of being independent of season and latitude, other potential independent variables. Tests with OMNITAB showed that the residual error was smaller if local time rather than sun's zenith angle was used to represent the diurnal variation.

LF-VLF propagation also varies with season, which indicates that the lower ionosphere depends on season. Numbering the months from 1 to 12 beginning with January yields a numerical variable which represents the seasons. A complication is that the year is a cycle, but the month numbers have a discontinuity between December and January. That is, in nature, December and January are very much alike, but in the numbering scheme they are as different as possible, being numbered 12 and 1 respectively. This difficulty is avoided by choosing $\pm$ cos $(2\pi(m - 1/2)/12)$ as the independent variable instead of the month number. The plus sign is used in the northern hemisphere, and the minus sign in the southern hemisphere so that the seasons will be similar in behavior. January 15 is winter in the northern hemisphere and the variable has the value +1. In order that winter in the southern hemisphere (June 15) have the same value, use the negative sign.

Watt (1967) suggests that VLF phase velocity varies like the cosine of latitude. This also has the advantage of treating north and south latitude the same. So cos (latitude) was chosen as an independent variable.

Following the practice at high frequencies, the 12 month running average of the Zurich sunspot number was used as an independent variable.

It was necessary to choose carefully the height at which the parameters were scaled as discussed in section 2.2. However, once the three parameters, $N_o$, $h_r$, and $\alpha$, are known, one of them can be discarded by transforming to the standard reference height $h_w$ (the height where $\omega_r/\omega = 2.5\ (10^5)$). This also makes it easier to compare the results with the literature.

### 3.2 The Regression Model

The model is therefore to have the form

$$N(h) = N_o \exp(\alpha (h - h_w)) \quad (9)$$

where

$$N_o = 1.43 (10^7) \exp(-0.15 h_w) \quad (10)$$

so that $h_w$ is the standard reference height. The gradiant $\alpha$ and $h_w$ will depend on time (hour and month), latitude, and solar activity.

$$\alpha = \alpha_c + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 \quad \text{and} \quad (11)$$

$$h_w = h_c + h_1 x_1 + h_2 x_2 + h_3 x_3 + h_4 x_4 \quad (12)$$

The $\alpha_i$ and $h_i$ are coefficients determined by a multidimensional linear regression on the independent variables $x_i$. These variables are:

$x_1 = \cos\left(\frac{t - 12}{24} 2\pi\right)$ , where t is the local time (hour), t = 1, 24.

$X_2 = \cos(L)$, where L is the latitude (radians).

$x_3 = \pm \cos\left(\frac{m - 1/2}{12} 2\pi\right)$, where m is the month (January = 1, ...December = 12.

(Use + for northern hemisphere, - for southern hemisphere.)

$x_4 = S$, where S is the sunspot number (12 month running average of Zurich relative sunspot number).

The analysis was also done for $x_1$ = cos (sun's zenith angle) but the residual error in both $h_w$ and $\alpha$ was greater (slightly) for this set of variables. Table 1 gives the resulting values for $\alpha_i$ and $h_i$.

Table 1: Values of Coefficients for Statistical Electron Density Model.

| i | c | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| $h_i$ | 71.8 | -3.83 | 6.85 | 0.085 | -0.047 |
| $\alpha_i$ | 0.210 | -0.036 | 0.082 | -0.050 | 0.00045 |

What is the significance of $\alpha_c$ and $h_c$? They are the values of $\alpha$ and $h_w$ at 0600 and 1800 hours on March 15 and September 15 at $\pm$ 90° latitude if the sunspot number is 0.

## 4. COMPARISONS OF MODEL VARIATIONS WITH VLF PROPAGATION EXPERIENCE

The implications of the regression analysis are shown in Tables 2, 3, and 4. The coefficient of the month term for height is small (not significantly different from zero).

Watt (1967, p. 265) estimates that the phase velocity of a 16 kHz signal increases about one part in $10^{-3}$ as the sunspot number goes from 0 to 100. This corresponds to a 5 to 10 km decrease in reference height (Wait and Spies, 1964). Coefficient $h_4$ above would cause a reference height decrease of 4.7 km, which is consistent with the propagation data.

Table 2 shows the values of $h_w$ as a function of hour and latitude. The variation from midnight (t = 0) to noon (t = 12) is only about 8 km. The mid-latitude noon values of 70 to 72.5 km are consistent with those determined for long path VLF propagation; namely, 70 km (DCA, 1974a) to 75 km (DCA, 1975). However, the nighttime heights are 7-10 km lower than heights deduced from long-path propagation data (DCA, 1974a, 1975). This may be caused by the much smaller data pool for nighttime profiles, by less accurate measurements at night because of the high noise level, or by smoothing of the data in the statistical analysis.

Figure A3 of the Appendix shows the distribution of scaled heights $h_w$ for the nighttime profiles. The mean value is 77.2 km -- much lower that is suggested by VLF propagation data. Measurement of low-level electron density is notoriously difficult. These difficulties are compounded at night by high-noise levels, and perhaps by a more variable (in space and time) lower ionosphere. It is likely that the lower parts of the nighttime profiles used are inaccurate.

Watt (1967, p. 365) estimates an increase at 10 kHz of about $2(10^{-3})$ in phase velocity relative to the speed of light as latitude increases from 0° to 90°. This corresponds to about 7 to 12 km decrease in reference height (Wait and Spies, 1964). Table 2 shows about 7 km decrease in reference height between 0° to 90° latitude.

The other model parameter, $\alpha$ , is equal to $\beta$ -0.15, where $\beta$ is the parameter most often mentioned in the literature. Propagation measurements lead to daytime estimates of $\beta$ that range from 0.3 to 0.5 (DCA, 1974a, 1975); that is, $\alpha$ is estimated to range from 0.15 to 0.35. The daytime (t = 12) values in Tables 3 and 4 are mostly in this range. The winter

Table 2: Values of $h_w$ computed using equation (4) and Table 1, assuming it is equinox, and that the sunspot number is 30.

| | | Local Time (hours) | | | |
|---|---|---|---|---|---|
| | | 0 | 6 | 12 | 18 |
| Latitude ° | 0 | 81.1 | 77.2 | 73.4 | 77.2 |
| | 30 | 80.1 | 76.3 | 72.5 | 76.3 |
| | 60 | 77.7 | 73.8 | 70.0 | 73.8 |
| | 90 | 74.2 | 70.4 | 66.6 | 70.4 |

Table 3: Values of $\alpha$ computed using equation (3) and Table 1, and assuming that it is January, and that the sunspot number is 30.

| | | Local Time (hours) | | | |
|---|---|---|---|---|---|
| | | 0 | 6 | 12 | 18 |
| Latitude ° | 0 | 0.293 | 0.257 | 0.221 | 0.257 |
| | 30 | 0.282 | 0.246 | 0.210 | 0.246 |
| | 60 | 0.252 | 0.216 | 0.180 | 0.216 |
| | 90 | 0.211 | 0.175 | 0.139 | 0.175 |

Table 4: Values of $\alpha$ computed using equation (3) and Table 1, assuming that it is July, and that the sunspot number is 30.

| | | Local Time (hours) | | | |
|---|---|---|---|---|---|
| | | 0 | 6 | 12 | 18 |
| Latitude ° | 0 | 0.376 | 0.340 | 0.304 | 0.340 |
| | 30 | 0.365 | 0.329 | 0.293 | 0.329 |
| | 60 | 0.335 | 0.299 | 0.263 | 0.299 |
| | 90 | 0.294 | 0.258 | 0.222 | 0.258 |

mid-latitude value of $\alpha$ is about 0.2, and the summer noon value is about 0.27.

Nighttime values of $\beta$ determined from propagation measurements range from 0.3 to 1.2, corresponding to values of $\alpha$ between 0.15 and 1.05 (DCA, 1975). The $(t = 0)$ values in Tables 3 and 4 range from 0.21 to 0.38.

## 5. CONCLUDING REMARKS AND RECOMMENDATIONS

Summarizing, the multiparameter regression analysis results in variations of the model reference height with latitude and sunspot number that are consistent in direction and magnitude with those deduced from propagation data. However the day-to-night change in reference height is only about half as large as the diurnal change indicated by propagation measurements. The model values for the gradient of electron density, $\alpha$, are consistent with the most-often-used propagation values, but do not have as large a range.

It is likely that the small number, and/or poor quality of the nighttime profiles caused the day-to-night variation of $h_w$ to be only half as large as is indicated by propagation data. The following recommended steps would probably improve the model:

1. Remove local time from the list of independent variables, and, instead, put in a fixed variation with time which has the required day-to-night variation, as determined by propagation data.
2. Filter the data by making subjective, but careful, judgements about the quality of the data, indicated by the experimental method and controls. Discard the profiles judged to be unreliable.
3. Continue to add high quality profiles to the data base as they become available.
4. Then recompute the coefficients for the remaining variables, separately for day and night.

A realistic time-varying model of the lower ionosphere is necessary for reliable calculations of the time-availability of LF-VLF links in the MEECN system.

## 6. REFERENCES


Bain, W.C., and B.R. May (1967), D region electron density distributions from propagation data, MF, LF, and VLF Radio Propagation, Conference Publication No. 36, IEE, London.

Belrose, J.S., I.A. Bourne, and L.W. Hewitt, (1967), A critical review of the partial reflection experiment, Ground-based radio wave propagation studies of the lower ionosphere, Conference Proceedings, (Defence Research Board, Canada).

Berry, L.A., and J.E. Herman, (1971), A wave hop propagation program for an anisotropic ionosphere, OT/ITS RR 11, Office of Telecommunications, Boulder, Colorado.

Booker, H. G., and E. K. Smith, (1970), A. comparative study of ionospheric measurement techniques, J. Atmos. Terr. Phys., 32, No. 4, 467-497.

Crain, C.M., (1970), Ionospheric probing with long wavelength radio waves, J. Atmos. Terr. Phys., 32, 551-566.

Davies, K. (1965), Ionospheric Radio Propagation, NBS Monograph 80, (Superintendent of Documents, US Government Printing Office, Washin on, D. C. 20402).

DCA (1974a), Comparison of predicted VLF/LF signal levels with propagation data, 960-TP-74-5, (Defense Communications Agency).

DCA (1974b), LF/VLF field strengths and radio noise at high latitudes: Comparisons of measurements and predictions, 960-TP-74-43 (Defense Communications Agency).

DCA (1975), Determination of effective ionospheric electron density profiles for VLF/LF propagation. 960-TP-75-37, (Defense Communications Agency).

Field, E.C., and R.D. Engel (1965), The detection of daytime nuclear bursts below 150 km by prompt VLF phase anomalies, Proc. IEEE 53, No. 12, 2009-2017.

Gambill, B., and R. Rutherford (1971), WEDCOM propagation model improvements, DASA 2682, (GE-TEMPO, Santa Barbara, California).

Gardner, F.F., and J.L. Pawsey, (1953), Study of the ionospheric D region using partial reflections, J. Atmos. Terr. Phys. 3, 321.

Gossard, E.E., (1967), The structure of the atmosphere near 90 km from short path VLF measurements, Ground-based radio wave propagation studies of the lower ionosphere, Conference Proceedings, (Defence Research Board, Canada).

Hogben, D., S. T. Peavy, and R. N. Varner, (1971), OMNITAB II User's Reference Manual, National Bureau of Standards, Tech. Note 552.

Morfitt, D.G., (1973) Computer techniques for fitting electron density profiles to oblique-path VLF propagation data, NELC TR 1854, (Naval Electronics Laboratory Center, San Diego, California).

Reid, G.C., (1969), Review of daytime electron density profiles, University of Illinois Aeronomy Report No. 32.

Smith, R.A., (1967), Small perturbation wave interaction in the lower ionosphere, Ground-based radio wave propagation studies of the lower ionosphere, Conference Proceedings, (Defence Research Board, Canada).

Wait, J.R. and K.P. Spies, (1964), Characteristics of the earth-ionosphere waveguide for VLF radio waves, NBS Technical Note 300, (National Bureau of Standards, Boulder, Colorado).

Watt, A.D. (1967), VLF Radio Engineering, (Pergamon Press, Inc., New York).

## APPENDIX

## D-Region Data Base

Table A2 lists the lower ionosphere electron density profiles used in the analysis, along with the parameters $N_0$, $h_r$, and $\alpha$ scaled from the profiles using the scaling rules in Section 2.2. Other relevant data is also listed. (Table A1 defines the column headings of Table A2.) The last column of Table A2 contains a reference to the source of the profile. The full list of references follows Table A2.

Figure A1 shows histograms of the scaled parameter $\alpha$ and the reference height $h_w$ (height satisfying equation (2)) for all the data.

Figures A2 and A3 show histograms of the same parameters for day hours only and night hours only. For figures A2 and A3, sunrise and sunset data have been deleted.

Table A1: Definition of column headings in Table A2.

| Column | Heading |
|---|---|
| A | Profile reference number |
| B | Year of observation |
| C | Month of observation |
| D | Day of observation (00 means unknown or irrelevant) |
| E | Reference height for scaling $\alpha$ |
| F | Electron density (electrons/cc) at reference height |
| G | Exponential profile slope parameter, $\alpha$ |
| H | Geographic latitude of observation, degrees (south is negative) |
| I | Local time of observation (hour = 1, 24) |
| J | Sunspot number for month of observation |
| K | Methods of observation: 1 = partial reflection<br>2 = rocket<br>3 = wave interaction<br>4 = LF-VLF reflection<br>5 = other |
| L | Magnetic disturbance indicator: undisturbed = 1<br>disturbed = 2 |
| M | Solar eclipse indicator: no eclipse = 1; eclipse = 2 |
| N | Collision frequency profile applicable to observation |
| O | Geographic longitude of observation (degrees east) |
| P | Reference to source document |

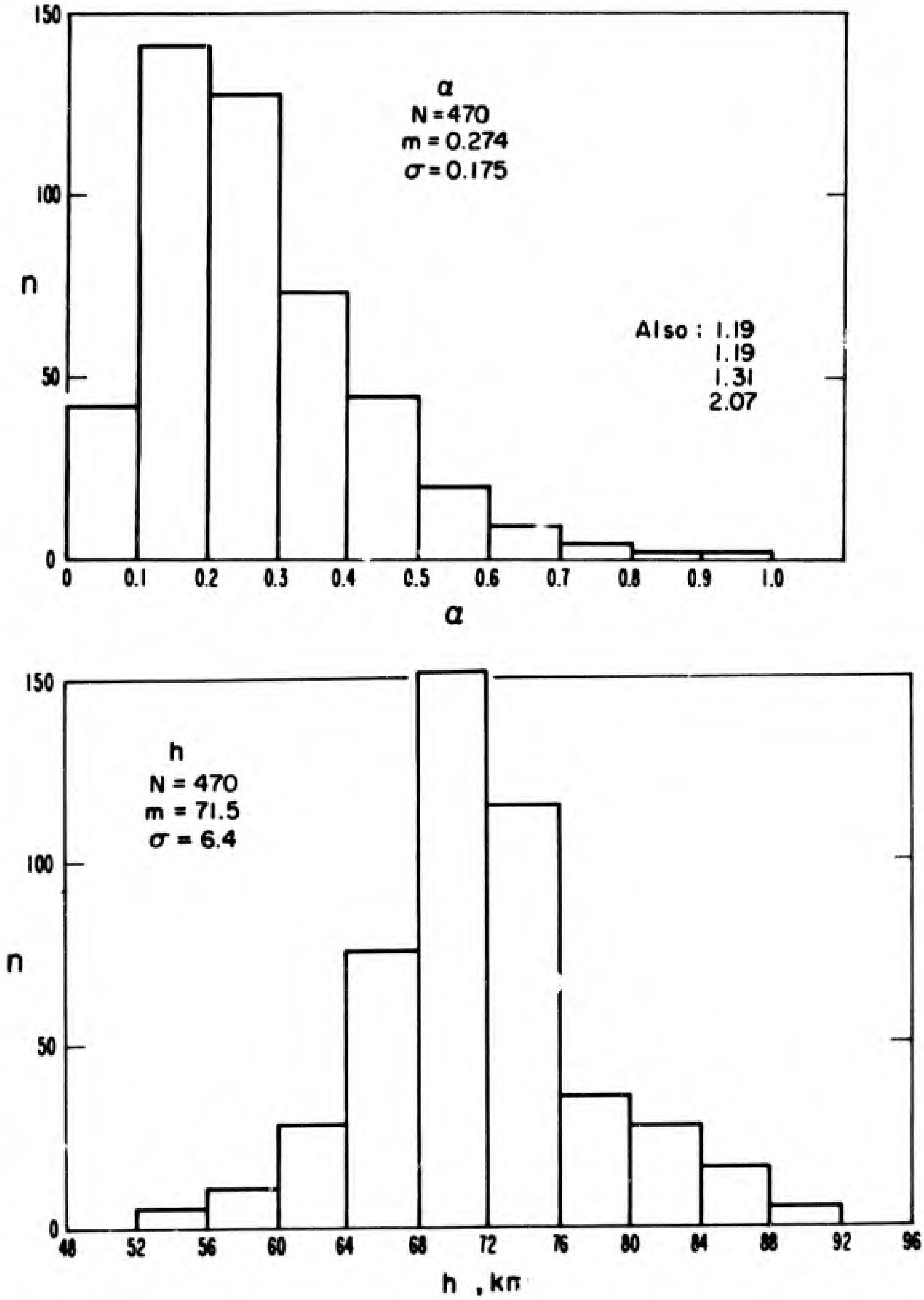


Figure A1. Distribution of scaled α, and reference height $h_w$ for all 470 profiles used in the study. The number of observations, N, the mean, m, and the standard deviation, σ, are shown on the figure.

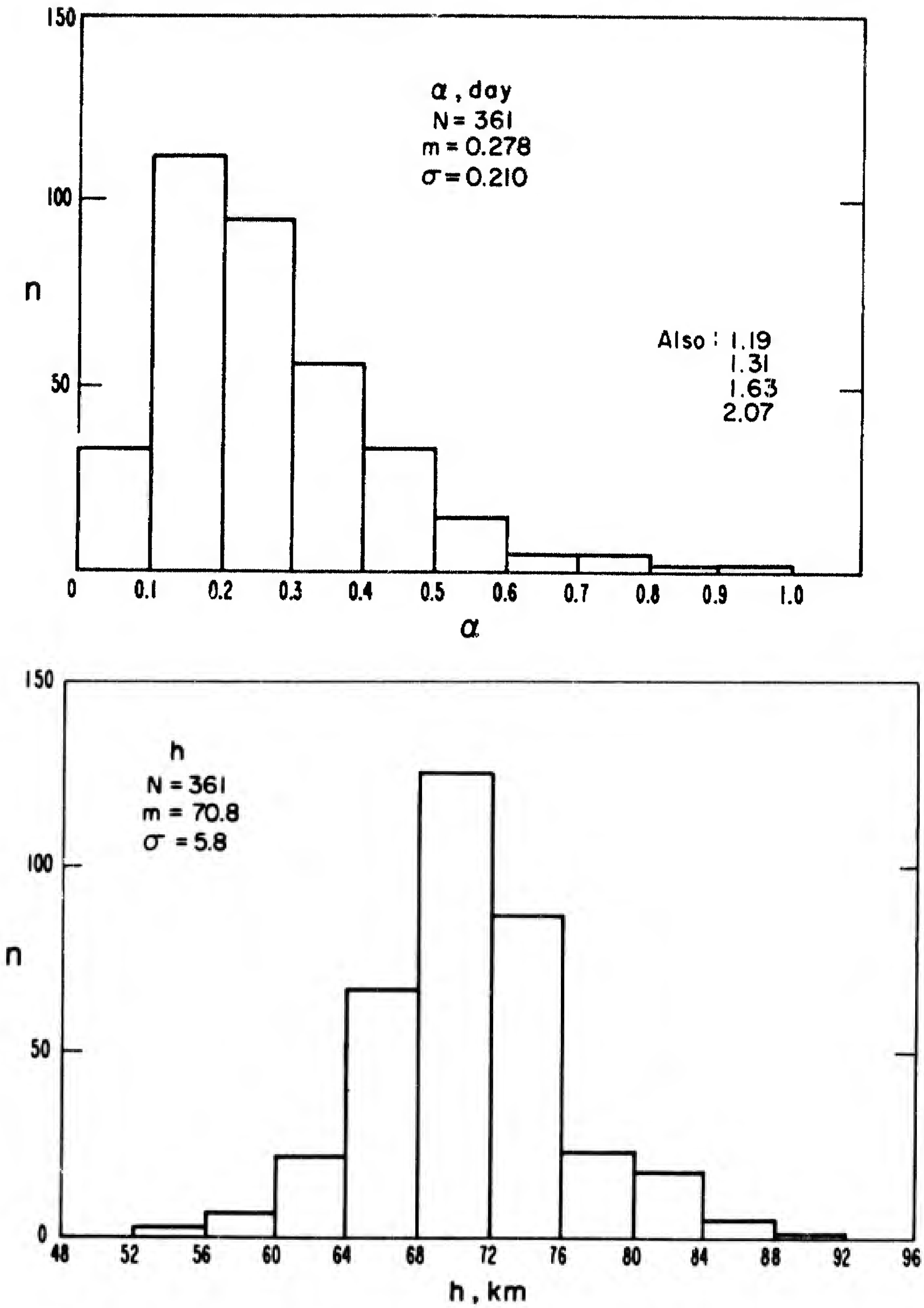


Figure A2. Distribution of scaled α, and the reference height $h_w$ for daytime profiles used in the study. The number of observations, N, the mean, m, and the standard deviation, σ, are shown on the figure.

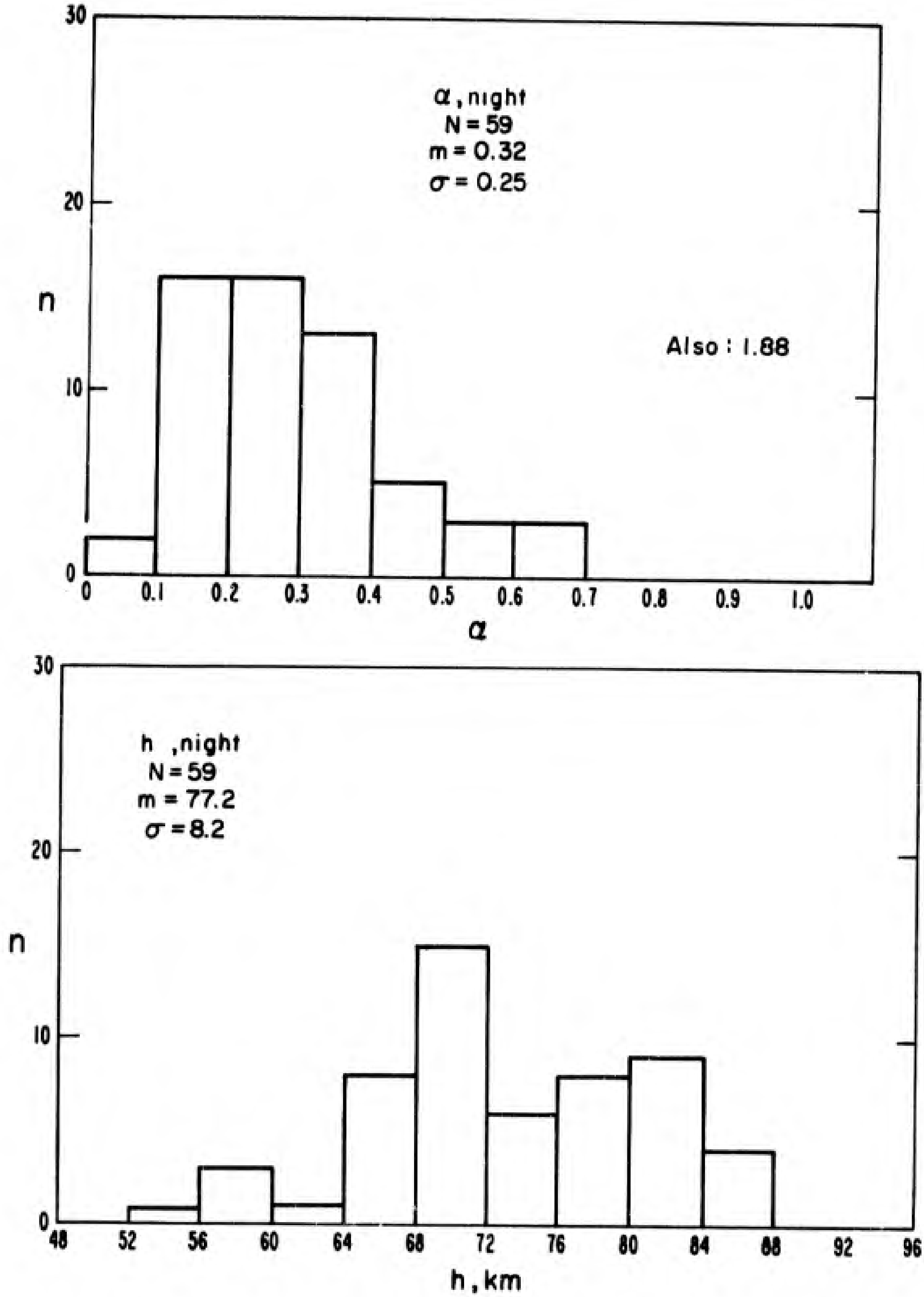


Figure A3. Distribution of scaled α, and reference height $h_w$ for nighttime profiles used in the study. The number of observations, N, the mean, m, and the standard deviation, σ, are shown on the figure.

TABLE A2: D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 49 | 07 | 00 | 80.2 | 2.2 | .659 | 51.5 | 0315 | 108 | 4 | 1 | 1 | 41 | 359.4 | Thomas and Harrison (1970) |
| 3 | 49 | 07 | 00 | 76.6 | 3.8 | .474 | 51.5 | 0325 | 108 | 4 | 1 | 1 | 41 | 359.4 | " " " " |
| 4 | 49 | 07 | 00 | 68.0 | 14.0 | .487 | 51.5 | 0335 | 108 | 4 | 1 | 1 | 41 | 359.4 | " " " " |
| 5 | 49 | 07 | 00 | 63.5 | 27.0 | .519 | 51.5 | 0400 | 108 | 4 | 1 | 1 | 41 | 359.4 | " " " " |
| 6 | 49 | 07 | 00 | 65.4 | 19.5 | .589 | 51.5 | 0340 | 108 | 4 | 1 | 1 | 41 | 359.4 | " " " " |
| 7 | 49 | 07 | 00 | 59.2 | 50.0 | .346 | 51.5 | 0430 | 108 | 4 | 1 | 1 | 41 | 359.4 | " " " " |
| 8 | 52 | 05 | 06 | 66.2 | 15.0 | .625 | 33.9 | 1200 | 52 | 1 | 1 | 1 | 6 | 151.2 | Gardner and Pawsey (1953) |
| 9 | 52 | 05 | 11 | 65.0 | 19.0 | .608 | 33.9 | 1200 | 52 | 1 | 1 | 1 | 6 | 151.2 | Gardner and Pawsey (1953) |
| 10 | 57 | 04 | 00 | 61.2 | 61.0 | .198 | 40.0 | 1200 | 174 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 12 | 57 | 07 | 04 | 49.7 | 440.0 | .225 | 58.8 | 1216 | 191 | 2 | 2 | 1 | 7 | 265.8 | Kane (1961) |
| 13 | 57 | 07 | 00 | 61.5 | 98.0 | .107 | 40.0 | 1200 | 191 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 14 | 57 | 07 | 00 | 64.0 | 51.0 | .902 | 52.4 | 1200 | 191 | 4 | 1 | 1 | 8 | 358.8 | Bain and May (1967) |
| 15 | 57 | 12 | 00 | 75.2 | 5.8 | .097 | 40.0 | 0000 | 200 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 16 | 58 | 11 | 26 | 53.1 | 108.0 | .415 | 69.7 | 2100 | 181 | 3 | 1 | 1 | 32 | 19.0 | Holt, Landmark and Lied (1960) |
| 17 | 59 | 08 | 21 | 64.9 | 33.5 | .499 | 69.7 | 1130 | 151 | 1 | 1 | 1 | 31 | 19.0 | " " " " " |
| 18 | 59 | 08 | 22 | 65.3 | 31.0 | .451 | 69.7 | 1130 | 151 | 1 | 1 | 1 | 31 | 19.0 | " " " " " |
| 19 | 59 | 08 | 26 | 62.1 | 51.0 | .541 | 69.7 | 1240 | 151 | 1 | 1 | 1 | 31 | 19.0 | " " " " " |
| 20 | 59 | 08 | 26 | 54.5 | 85.0 | .415 | 69.7 | 2120 | 151 | 3 | 1 | 1 | 31 | 19.0 | " " " " " |
| 21 | 59 | 08 | 31 | 63.0 | 45.0 | .633 | 69.7 | 1355 | 151 | 1 | 1 | 1 | 31 | 19.0 | " " " " " |
| 22 | 59 | 09 | 17 | 62.7 | 24.5 | .247 | 58.8 | 1237 | 146 | 2 | 1 | 1 | 11 | 265.8 | Adey and Heikkila (1960) |
| 23 | 60 | 03 | 27 | 60.5 | 80.0 | .054 | 60.0 | 0730 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington et al. (1963) |
| 24 | 60 | 03 | 27 | 63.0 | 85.0 | .078 | 60.0 | 0830 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington and Thrane (1961) |
| 25 | 60 | 03 | 27 | 60.3 | 86.0 | .075 | 60.0 | 0930 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington et al. (1963) |
| 26 | 60 | 03 | 27 | 59.8 | 94.0 | .146 | 60.0 | 1030 | 122 | 3 | 1 | 1 | 7 | 11.1 | " " " " |
| 27 | 60 | 03 | 27 | 59.5 | 100.0 | .127 | 60.0 | 1130 | 122 | 3 | 1 | 1 | 7 | 11.1 | " " " " |
| 28 | 60 | 03 | 27 | 60.5 | 100.0 | .113 | 60.0 | 1200 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington and Thrane (1963) |
| 29 | 60 | 03 | 27 | 60.1 | 88.0 | .127 | 60.0 | 1430 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington et al. (1963) |
| 30 | 60 | 03 | 27 | 60.2 | 85.0 | .111 | 60.0 | 1530 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington et al. (1963) |
| 31 | 60 | 08 | 28 | 58.4 | 127.0 | .114 | 60.0 | 1200 | 102 | 1 | 1 | 1 | 7 | 11.1 | Barrington and Thrane (1963) |
| 32 | 60 | 09 | 22 | 56.0 | 60.0 | .142 | 39.7 | 1532 | 98 | 2 | 1 | 1 | 20 | 140.1 | Yonezawa (1961) |
| 33 | 60 | 11 | 27 | 60.1 | 88.0 | .107 | 60.0 | 1200 | 88 | 3 | 1 | 1 | 7 | 11.1 | Barrington and Thrane (1963) |
| 34 | 61 | 02 | 20 | 51.2 | 142.0 | .067 | 45.4 | 1200 | 75 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1964) |
| 35 | 61 | 02 | 21 | 54.0 | 91.0 | .522 | 45.4 | 1200 | 75 | 1 | 1 | 1 | 11 | 284.1 | " " |
| 36 | 61 | 02 | 22 | 55.0 | 84.0 | .956 | 45.4 | 1200 | 75 | 1 | 1 | 1 | 11 | 284.1 | " " |
| 37 | 61 | 03 | 07 | 62.0 | 30.0 | .387 | 45.4 | 1200 | 69 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Cetiner (1962) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 61 | 03 | 08 | 60.0 | 40.0 | .224 | 45.4 | 1200 | 69 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Cetiner (1962) |
| 40 | 61 | 05 | 01 | 52.0 | 73.0 | .050 | 45.4 | 1040 | 60 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Burke (1964) |
| 41 | 61 | 06 | 00 | 59.5 | 43.0 | .284 | 45.4 | 1200 | 56 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1964) |
| 42 | 61 | 07 | 14 | 59.5 | 43.0 | .284 | 45.4 | 1100 | 53 | 1 | 1 | 1 | 10 | 284.1 | Belrose (1964) |
| 43 | 61 | 08 | 17 | 69.0 | 8.0 | .204 | 37.9 | 2206 | 52 | 2 | 1 | 1 | 20 | 284.5 | Smith (1966) |
| 44 | 61 | 09 | 20 | 65.6 | 82.0 | .157 | -31.2 | 1351 | 52 | 4 | 1 | 1 | 36 | 136.3 | Hall and Bullough (1963) |
| 45 | 61 | 10 | 27 | 75.0 | 3.2 | .174 | 37.9 | 0435 | 51 | 2 | 1 | 1 | 20 | 284.5 | Smith (1965) |
| 46 | 61 | 11 | 00 | 57.7 | 55.0 | .132 | 45.4 | 1200 | 50 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 47 | 61 | 12 | 00 | 59.5 | 39.0 | .115 | 45.4 | 1200 | 49 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1965) |
| 48 | 61 | 12 | 18 | 61.2 | 30.0 | .060 | 45.4 | 1200 | 49 | 1 | 1 | 1 | 20 | 284.1 | Mechtly and Smith (1968b) |
| 49 | 61 | 12 | 20 | 68.5 | 9.5 | .061 | 45.4 | 1200 | 49 | 1 | 1 | 1 | 20 | 284.1 | Mechtly and Smith (1968b) |
| 50 | 61 | 12 | 00 | 65.0 | 19.0 | .070 | 45.4 | 1200 | 49 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 51 | 62 | 01 | 00 | 61.0 | 39.0 | .109 | 45.4 | 1200 | 45 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 52 | 62 | 03 | 01 | 53.4 | 93.0 | .544 | 45.4 | 1145 | 40 | 1 | 1 | 2 | 11 | 284.1 | Belrose and Cetiner (1962) |
| 53 | 62 | 03 | 09 | 64.8 | 16.0 | .369 | 45.4 | 1200 | 40 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Cetiner (1962) |
| 54 | 62 | 03 | 00 | 58.0 | 52.0 | .136 | 45.4 | 1200 | 40 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1965) |
| 55 | 62 | 06 | 00 | 58.4 | 49.0 | .152 | 45.4 | 1200 | 38 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 56 | 62 | 07 | 00 | 56.6 | 62.0 | .107 | 45.4 | 1200 | 37 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1965) |
| 57 | 62 | 07 | 00 | 55.1 | 78.0 | .095 | 45.4 | 1200 | 37 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 58 | 62 | 08 | 11 | 56.8 | 120.0 | .115 | 60.0 | 1450 | 35 | 1 | 1 | 1 | 32 | 11.1 | Holt (1963) |
| 59 | 62 | 08 | 15 | 70.4 | 7.4 | .162 | -31.2 | 0050 | 35 | 4 | 1 | 1 | 34 | 136.3 | Hall and Fooks (1965) |
| 60 | 62 | 08 | 18 | 51.4 | 240.0 | .165 | 69.3 | 0809 | 35 | 2 | 2 | 1 | 14 | 16.0 | Jesperson, Haug & Landmark (1966) |
| 61 | 62 | 08 | 00 | 58.0 | 51.0 | .106 | 45.4 | 1200 | 35 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 62 | 62 | 09 | 00 | 56.2 | 62.0 | .182 | 45.4 | 1200 | 33 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1965) |
| 63 | 62 | 10 | 21 | 60.0 | 135.0 | .221 | 40.8 | 1210 | 31 | 3 | 1 | 1 | 16 | 282.1 | Rowe et al. (1970) |
| 64 | 62 | 10 | 21 | 56.6 | 200.0 | .081 | 40.8 | 1239 | 31 | 3 | 1 | 2 | 16 | 282.1 | Rowe et al. (1970) |
| 65 | 62 | 11 | 07 | 77.8 | 2.1 | .408 | 37.9 | 0525 | 30 | 2 | 1 | 1 | 20 | 284.5 | Smith (1963) |
| 66 | 62 | 11 | 30 | 71.3 | 5.7 | .197 | 37.9 | 0557 | 30 | 2 | 1 | 1 | 20 | 284.5 | Smith (1963) |
| 67 | 62 | 11 | 30 | 55.2 | 78.0 | .120 | 45.4 | 1200 | 30 | 1 | 1 | 1 | 11 | 284.1 | Belrose and Bourne (1967) |
| 68 | 62 | 12 | 05 | 62.2 | 27.5 | .131 | 37.9 | 1700 | 30 | 2 | 1 | 1 | 20 | 284.5 | Smith (1963) |
| 69 | 62 | 12 | 11 | 54.0 | 39.0 | .166 | 69.3 | 0427 | 30 | 2 | 2 | 1 | 14 | 16.0 | Jesperson et al. (1964) |
| 70 | 62 | 12 | 14 | 64.2 | 12.0 | .396 | 69.3 | 2152 | 30 | 2 | 2 | 1 | 14 | 16.0 | Jesperson, Haug & Landmark (1966) |
| 71 | 63 | 02 | 27 | 55.0 | 74.0 | .248 | 37.9 | 1430 | 30 | 2 | 1 | 1 | 20 | 284.5 | Smith (1963) |
| 72 | 63 | 03 | 08 | 63.1 | 19.0 | .227 | 37.9 | 0950 | 30 | 2 | 1 | 1 | 29 | 284.5 | Aikin (1972) |

## TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73 | 63 | 04 | 09 | 63.5 | 18.6 | .302 | 37.9 | 1530 | 29 | 2 | 1 | 1 | 29 | 284.5 | Aikin, Kane and Troim (1964) |
| 74 | 63 | 04 | 12 | 75.0 | 3.3 | .260 | 37.9 | 0030 | 29 | 4 | 1 | 1 | 20 | 284.5 | Cartwright (1964) |
| 75 | 65 | 04 | 00 | 56.0 | 60.0 | .230 | -44.0 | 1200 | 37 | 1 | 1 | 1 | 13 | 170.0 | Gregory and Manson (1969) |
| 76 | 63 | 07 | 20 | 69.0 | 10.0 | .576 | 58.8 | 1503 | 28 | 2 | 1 | 2 | 11 | 265.8 | Smith et al. (1965) |
| 77 | 63 | 07 | 20 | 65.1 | 17.1 | .403 | 58.8 | 1513 | 28 | 2 | 1 | 2 | 11 | 265.8 | " " " " |
| 78 | 63 | 07 | 20 | 67.2 | 55.0 | .496 | 58.8 | 1540 | 28 | 2 | 1 | 2 | 11 | 265.8 | " " " " |
| 79 | 63 | 07 | 20 | 58.9 | 50.2 | .098 | 58.8 | 1605 | 28 | 2 | 1 | 2 | 38 | 265.8 | Crouse (1964) |
| 80 | 63 | 07 | 20 | 65.7 | 17.5 | .197 | 58.8 | 1605 | 28 | 2 | 1 | 2 | 38 | 265.8 | Crouse (1964) |
| 81 | 63 | 07 | 20 | 55.2 | 70.0 | .299 | 58.8 | 1610 | 28 | 2 | 1 | 2 | 11 | 265.8 | Smith et al. (1965) |
| 82 | 63 | 07 | 26 | 54.5 | 100.0 | .144 | 58.8 | 1605 | 28 | 2 | 1 | 1 | 38 | 265.8 | Crouse (1964) |
| 83 | 65 | 07 | 00 | 58.0 | 53.0 | .218 | -44.0 | 1040 | 28 | 1 | 1 | 1 | 13 | 170.0 | Gregory and Manson (1969) |
| 86 | 63 | 09 | 12 | 55.6 | 147.0 | .291 | 69.3 | 0720 | 27 | 2 | 2 | 1 | 14 | 16.0 | Jesperson, Haug & Landmark (1966) |
| 87 | 63 | 10 | 25 | 67.9 | 12.5 | .261 | 58.8 | 2000 | 26 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 88 | 63 | 10 | 31 | 51.5 | 133.0 | .156 | 30.4 | 1200 | 26 | 2 | 1 | 1 | 20 | 273.3 | Sagalyn, Smiddy & Sullavin (1967) |
| 89 | 65 | 10 | 00 | 59.1 | 40.0 | .272 | -44.0 | 1200 | 26 | 1 | 1 | 1 | 13 | 170.0 | Gregory and Manson (1969) |
| 90 | 63 | 11 | 04 | 61.5 | 35.0 | .314 | -30.5 | 1100 | 24 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne, Loch & Bourne (1967) |
| 91 | 65 | 12 | 00 | 77.4 | 12.0 | .149 | 74.7 | 0000 | 21 | 1 | 1 | 1 | 35 | 265.1 | Belrose, Bode and Hewitt (1964) |
| 92 | 65 | 12 | 00 | 54.2 | 70.2 | .204 | -44.0 | 1200 | 26 | 1 | 1 | 1 | 13 | 170.0 | Gregory and Manson (1969) |
| 93 | 64 | 01 | 00 | 65.0 | 54.0 | .224 | 40.8 | 1200 | 20 | 3 | 1 | 1 | 16 | 282.1 | Ferraro and Lee (1966) |
| 94 | 64 | 01 | 00 | 67.0 | 40.0 | .184 | 40.8 | 1030 | 19 | 3 | 1 | 1 | 16 | 282.1 | " " " " |
| 95 | 64 | 01 | 00 | 65.3 | 48.5 | .378 | 40.8 | 1130 | 19 | 3 | 1 | 1 | 16 | 282.1 | " " " " |
| 96 | 64 | 01 | 00 | 64.0 | 61.0 | .144 | 40.8 | 1230 | 19 | 3 | 1 | 1 | 16 | 282.1 | " " " " |
| 97 | 64 | 01 | 00 | 64.7 | 56.0 | .154 | 40.8 | 1340 | 19 | 3 | 1 | 1 | 16 | 282.1 | " " " " |
| 98 | 64 | 02 | 18 | 65.0 | 55.0 | .492 | 40.8 | 1200 | 18 | 3 | 1 | 1 | 16 | 282.1 | " " " " |
| 99 | 64 | 03 | 12 | 57.6 | 39.0 | .189 | 69.3 | 0358 | 15 | 2 | 2 | 1 | 14 | 16.0 | Jesperson, Haug & Landmark (1966) |
| 100 | 64 | 03 | 15 | 64.4 | 13.0 | .224 | 69.3 | 0344 | 15 | 2 | 2 | 1 | 14 | 16.0 | " " " " " |
| 101 | 64 | 03 | 00 | 22.0 | 65.6 | .127 | 69.3 | 0000 | 15 | 2 | 1 | 1 | 14 | 16.0 | " " " " " |
| 102 | 64 | 03 | 00 | 59.3 | 32.5 | .126 | 69.5 | 1000 | 15 | 1 | 1 | 1 | 14 | 19.3 | Haug (1966) |
| 103 | 64 | 03 | 00 | 57.5 | 42.0 | .129 | 69.5 | 1200 | 15 | 1 | 1 | 1 | 14 | 19.3 | Haug (1966) |
| 104 | 64 | 03 | 00 | 72.0 | 6.4 | .457 | 74.7 | 1200 | 15 | 1 | 1 | 1 | 11 | 265.1 | Belrose, Bourne and Hewitt (1967) |
| 105 | 64 | 03 | 00 | 73.3 | 4.8 | .298 | 74.7 | 0645 | 15 | 1 | 1 | 1 | 11 | 265.1 | " " " " " |
| 106 | 64 | 07 | 00 | 80.2 | 1.8 | .376 | 74.7 | 0000 | 11 | 1 | 1 | 1 | 11 | 265.1 | " " " " " |
| 107 | 64 | 03 | 00 | 75.2 | 5.8 | .097 | 40.0 | 0000 | 10 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 108 | 64 | 03 | 00 | 60.0 | 74.0 | .253 | 40.0 | 0600 | 14 | 4 | 1 | 1 | 9 | [illegible]0.0 | " " |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 109 | 64 | 03 | 00 | 60.0 | 74.0 | .253 | 40.0 | 0800 | 14 | 4 | 1 | 1 | 09 | 00.0 | Deeks (1966) |
| 110 | 64 | 03 | 00 | 60.0 | 74.0 | .253 | 40.0 | 1000 | 14 | 4 | 1 | 1 | 9 | 00.0 | " " |
| 111 | 64 | 03 | 00 | 60.2 | 76.0 | .310 | 40.0 | 1200 | 14 | 4 | 1 | 1 | 9 | 00.0 | " " |
| 112 | 64 | 04 | 16 | 59.5 | 40.0 | .188 | 37.9 | 1605 | 13 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968) |
| 113 | 64 | 06 | 22 | 62.0 | 33.0 | .208 | -30.5 | 1420 | 10 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne, Loch & Bourne (1967) |
| 114 | 64 | 06 | 22 | 61.0 | 39.0 | .078 | -30.5 | 1440 | 10 | 3 | 1 | 1 | 34 | 151.5 | " " " " " " |
| 115 | 64 | 06 | 22 | 61.0 | 37.5 | .128 | -30.5 | 1540 | 10 | 3 | 1 | 1 | 34 | 151.5 | " " " " " " |
| 116 | 64 | 06 | 24 | 63.5 | 25.0 | .419 | -30.5 | 1235 | 10 | 3 | 1 | 1 | 34 | 151.5 | " " " " " " |
| 117 | 64 | 07 | 15 | 79.1 | 1.8 | .616 | 37.9 | 0300 | 10 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968) |
| 118 | 64 | 07 | 15 | 76.5 | 2.5 | .697 | 37.9 | 0420 | 10 | 2 | 1 | 1 | 20 | 284.5 | Mechtly (1972) |
| 119 | 64 | 07 | 15 | 61.2 | 29.0 | .384 | 37.9 | 0525 | 10 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968) |
| 120 | 64 | 07 | 00 | 64.6 | 19.0 | .127 | 74.7 | 0000 | 10 | 1 | 1 | 1 | 11 | 265.1 | Belrose, Bourne and Hewitt (1967) |
| 121 | 64 | 07 | 00 | 62.9 | 26.0 | .160 | 74.7 | 1200 | 10 | 1 | 1 | 1 | 11 | 265.1 | Belrose, Bourne and Hewitt (1967) |
| 122 | 64 | 08 | 00 | 57.5 | 86.0 | .084 | 69.5 | 0600 | 10 | 1 | 1 | 1 | 14 | 19.3 | Haug (1966) |
| 123 | 64 | 08 | 00 | 59.5 | 66.0 | .109 | 69.5 | 1200 | 10 | 1 | 1 | 1 | 14 | 19.3 | " " |
| 124 | 64 | 08 | 00 | 61.5 | 46.0 | .151 | 69.5 | 1700 | 10 | 1 | 1 | 1 | 14 | 19.3 | " " |
| 125 | 64 | 08 | 26 | 52.8 | 100.0 | .143 | 37.9 | 1200 | 10 | 2 | 1 | 1 | 20 | 284.5 | Bourdeau et al. (1966) |
| 126 | 64 | 08 | 00 | 59.4 | 55.0 | .095 | 40.0 | 1200 | 10 | 4 | 1 | 1 | 15 | 50.0 | Krashushkin and Knyazeva (1970) |
| 127 | 64 | 08 | 00 | 60.4 | 122.0 | .282 | 40.0 | 1200 | 10 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 128 | 64 | 09 | 01 | 61.2 | 35.0 | .559 | -30.5 | 1715 | 10 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne, Loch & Bourne (1967) |
| 129 | 64 | 09 | 00 | 63.3 | 13.5 | .176 | 60.0 | 1200 | 10 | 1 | 1 | 1 | 1 | 11.1 | Thrane et al. (1968) |
| 130 | 64 | 10 | 00 | 64.8 | 18.0 | .085 | 35.2 | 0645 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 131 | 64 | 10 | 00 | 63.0 | 24.0 | .331 | 35.2 | 0810 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 132 | 64 | 10 | 00 | 61.5 | 29.0 | .297 | 35.2 | 0935 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 133 | 64 | 10 | 00 | 60.7 | 43.0 | .315 | 35.2 | 1100 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 134 | 64 | 10 | 00 | 60.4 | 33.0 | .340 | 35.2 | 1130 | 10 | 3 | 1 | 1 | 18 | 25.0 | Thrane et al. (1968) |
| 135 | 64 | 10 | 00 | 61.5 | 30.0 | .418 | 35.2 | 1230 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 136 | 64 | 10 | 00 | 61.5 | 30.0 | .382 | 35.2 | 1300 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 137 | 64 | 10 | 00 | 62.0 | 27.0 | .354 | 35.2 | 1400 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 138 | 64 | 10 | 00 | 63.0 | 23.0 | .323 | 35.2 | 1500 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 139 | 64 | 10 | 00 | 66.2 | 19.5 | .307 | 35.2 | 1600 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 140 | 64 | 10 | 00 | 65.0 | 17.0 | .090 | 35.2 | 1700 | 10 | 3 | 1 | 1 | 18 | 25.0 | " " " " |
| 141 | 64 | 10 | 07 | 64.5 | 17.5 | .236 | 37.9 | 1804 | 10 | 2 | 1 | 1 | 20 | 284.5 | Smith (1966) |
| 142 | 64 | 10 | 08 | 79.5 | 1.6 | .405 | 37.9 | 0523 | 10 | 2 | 1 | 1 | 20 | 284.5 | Smith (1966) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 143 | 64 | 10 | 27 | 60.4 | 41.0 | .267 | 58.8 | 1200 | 10 | 2 | 2 | 1 | 11 | 265.8 | Ulwick et al. (1968) |
| 144 | 64 | 10 | 27 | 64.4 | 26.0 | .410 | 58.8 | 1200 | 10 | 2 | 2 | 1 | 11 | 265.8 | Ulwick et al. (1968) |
| 145 | 64 | 11 | 19 | 61.3 | 30.0 | .104 | 37.9 | 1520 | 10 | 2 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972) |
| 146 | 64 | 11 | 23 | 65.0 | 16.0 | .248 | 37.9 | 1207 | 10 | 2 | 1 | 1 | 20 | 284.5 | Bourdeau et al. (1966) |
| 147 | 65 | 12 | 00 | 62.1 | 25.0 | .085 | 37.9 | 1000 | 10 | 1 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1967b) |
| 148 | 64 | 12 | 00 | 74.2 | 6.5 | .189 | 40.0 | 0000 | 12 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 149 | 64 | 12 | 00 | 62.4 | 50.0 | .112 | 40.0 | 1200 | 12 | 4 | 1 | 1 | 9 | 00.0 | Deeks (1966) |
| 150 | 64 | 00 | 00 | 69.2 | 10.0 | .529 | 58.8 | 0000 | 12 | 2 | 2 | 1 | 11 | 265.8 | Belrose and Bourne (1967) |
| 151 | 64 | 00 | 00 | 66.0 | 15.0 | .259 | 58.8 | 0000 | 12 | 2 | 1 | 1 | 11 | 265.8 | Belrose and Bourne (1967) |
| 152 | 65 | 01 | 08 | 81.0 | 1.5 | .205 | -30.5 | 1935 | 12 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne, Loch & Bourne (1967) |
| 153 | 65 | 01 | 08 | 66.4 | 17.0 | .490 | -30.5 | 1903 | 12 | 3 | 1 | 1 | 34 | 151.5 | " " " " " " |
| 154 | 65 | 01 | 08 | 66.2 | 16.5 | .119 | -30.5 | 1920 | 12 | 3 | 1 | 1 | 34 | 151.5 | " " " " " " |
| 155 | 65 | 01 | 08 | 65.9 | 9.7 | .172 | -30.5 | 1925 | 12 | 3 | 1 | 1 | 40 | 151.5 | Smith et al. (1967) |
| 156 | 65 | 01 | 08 | 68.1 | 7.1 | .197 | -30.5 | 1930 | 12 | 3 | 1 | 1 | 40 | 151.5 | Smith et al. (1967) |
| 157 | 65 | 01 | 08 | 83.5 | 1.0 | .304 | -30.5 | 1941 | 12 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne, Loch & Bourne (1967) |
| 158 | 65 | 02 | 06 | 53.2 | 100.0 | .137 | 74.7 | 1200 | 12 | 1 | 1 | 1 | 11 | 265.1 | Hewitt (1969) |
| 159 | 65 | 02 | 08 | 62.0 | 28.0 | .176 | 74.7 | 1200 | 12 | 1 | 1 | 1 | 11 | 265.1 | " " |
| 160 | 65 | 02 | 11 | 75.0 | 4.0 | .240 | 74.7 | 1200 | 12 | 1 | 1 | 1 | 11 | 265.1 | " " |
| 161 | 65 | 03 | 08 | 71.8 | 6.5 | .253 | 58.8 | 0000 | 13 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 162 | 65 | 03 | 09 | 63.1 | 22.5 | .219 | 58.8 | 0000 | 13 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 163 | 65 | 03 | 16 | 72.5 | 5.4 | .362 | -12.8 | 1151 | 13 | 2 | 1 | 1 | 18 | 281.8 | Aikin and Blumle (1968) |
| 164 | 65 | 03 | 18 | 67.8 | 13.0 | .254 | -12.8 | 0141 | 13 | 2 | 1 | 1 | 18 | 283.1 | " " " " |
| 165 | 65 | 03 | 18 | 74.7 | 4.3 | .432 | -12.8 | 1138 | 13 | 2 | 1 | 1 | 18 | 282.0 | " " " " |
| 166 | 65 | 03 | 20 | 65.0 | 18.5 | .237 | -12.9 | 0820 | 13 | 2 | 1 | 1 | 18 | 282.0 | Mechtly et al. (1969) |
| 167 | 65 | 03 | 20 | 57.3 | 55.0 | .242 | -13.0 | 1204 | 13 | 2 | 1 | 1 | 18 | 282.1 | Smiddy and Sagalyn (1967) |
| 168 | 65 | 03 | 21 | 53.2 | 72.0 | .136 | 69.3 | 0659 | 13 | 2 | 2 | 1 | 14 | 16.0 | Jesperson et al. (1968) |
| 169 | 65 | 03 | 22 | 78.8 | 2.1 | .282 | -13.0 | 0349 | 13 | 2 | 1 | 1 | 18 | 282.2 | Smiddy and Joyalyn (1967) |
| 170 | 65 | 03 | 24 | 69.6 | 9.0 | .303 | -11.4 | 1207 | 13 | 2 | 1 | 1 | 18 | 281.6 | Aikin and Blumle (1968) |
| 171 | 65 | 03 | 26 | 67.6 | 12.0 | .228 | -10.2 | 1113 | 13 | 2 | 1 | 1 | 18 | 280.6 | " " " " |
| 172 | 65 | 03 | 27 | 64.2 | 20.0 | .260 | -12.2 | 2000 | 13 | 2 | 1 | 1 | 18 | 281.2 | " " " " |
| 173 | 65 | 03 | 00 | 70.5 | 8.0 | .720 | -19.3 | 0730 | 13 | 1 | 1 | 1 | 19 | 17.7 | Haug and Thrane (1967) |
| 174 | 65 | 03 | 00 | 60.4 | 33.0 | .134 | 58.8 | 0800 | 13 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 176 | 65 | 03 | 00 | 69.0 | 10.0 | .727 | -19.3 | 0915 | 13 | 1 | 1 | 1 | 19 | 17.7 | Haug and Thrane (1967) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 177 | 65 | 03 | 00 | 66.6 | 15.0 | .551 | -19.3 | 1100 | 13 | 1 | 1 | 1 | 19 | 17.7 | Haug and Thrane (1967) |
| 178 | 65 | 03 | 00 | 60.2 | 31.0 | .116 | 58.8 | 1200 | 13 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 179 | 65 | 03 | 00 | 64.6 | 20.0 | .388 | -19.3 | 1350 | 13 | 1 | 1 | 1 | 19 | 17.7 | Haug and Thrane (1967) |
| 180 | 65 | 03 | 00 | 65.0 | 18.5 | .366 | -19.3 | 1435 | 13 | 1 | 1 | 1 | 19 | 17.7 | " " " " |
| 181 | 65 | 03 | 00 | 65.5 | 17.5 | .361 | -19.3 | 1525 | 13 | 1 | 1 | 1 | 19 | 17.7 | " " " " |
| 182 | 65 | 03 | 00 | 69.1 | 10.0 | .449 | -19.3 | 1600 | 13 | 1 | 1 | 1 | 19 | 17.7 | " " " " |
| 183 | 65 | 03 | 00 | 70.1 | 8.0 | .513 | -19.3 | 1650 | 13 | 1 | 1 | 1 | 19 | 17.7 | " " " " |
| 184 | 65 | 03 | 00 | 75.2 | 3.7 | .401 | -19.3 | 1827 | 13 | 1 | 1 | 1 | 19 | 17.7 | Thrane et al. (1968) |
| 185 | 65 | 03 | 00 | 59.5 | 40.0 | .103 | 45.4 | 1510 | 13 | 1 | 1 | 1 | 11 | 284.1 | Belrose, Hewitt and Bunker (1969) |
| 186 | 65 | 03 | 00 | 70.9 | 7.4 | .265 | 74.7 | [illegible] | 13 | 1 | 1 | 1 | 11 | 265.1 | Belrose, Bourne and Hewitt (1967) |
| 187 | 65 | 03 | 00 | 61.0 | 20.0 | .113 | 60.0 | 1200 | 13 | 1 | 1 | 1 | 2 | 11.1 | Thrane et al. (1968) |
| 188 | 65 | 04 | 05 | 59.8 | 40.0 | .134 | -29.6 | 0846 | 14 | 2 | 1 | 1 | 18 | 284.8 | Mechtly et al. (1969) |
| 189 | 65 | 04 | 09 | 56.5 | 67.0 | .075 | -44.6 | 1418 | 14 | 2 | 1 | 1 | 18 | 282.2 | " " " " |
| 190 | 65 | 04 | 12 | 68.6 | 11.0 | .383 | -58.5 | 1214 | 14 | 2 | 1 | 1 | 18 | 282.0 | " " " " |
| 191 | 65 | 04 | 00 | 77.5 | 3.8 | .318 | -19.3 | 0000 | 14 | 5 | 1 | 1 | 9 | 17.7 | Gruschwitz (1974) |
| 192 | 65 | 04 | 00 | 68.8 | 19.0 | .059 | -19.3 | 0600 | 14 | 5 | 1 | 1 | 9 | 17.7 | " " |
| 193 | 65 | 04 | 00 | 61.1 | 62.0 | .124 | -19.3 | 1200 | 14 | 5 | 1 | 1 | 9 | 17.7 | " " |
| 194 | 65 | 04 | 00 | 71.5 | 12.5 | .110 | -19.3 | 1800 | 14 | 5 | 1 | 1 | 9 | 17.7 | " " |
| 195 | 65 | 04 | 00 | 66.4 | 8.0 | .284 | 60.0 | 1200 | 14 | 1 | 1 | 1 | 2 | 11.1 | Thrane et al. (1968) |
| 196 | 65 | 05 | 19 | 59.8 | 28.0 | .173 | -31.2 | 1433 | 15 | 4 | 1 | 1 | 21 | 136.3 | Hall (1973) |
| 197 | 65 | 05 | 28 | 61.0 | 24.0 | .123 | -35.0 | 1200 | 15 | 1 | 1 | 1 | 21 | 173.0 | Gregory and Manson (1967) |
| 198 | 65 | 05 | 27 | 60.5 | 35.0 | .158 | 58.8 | 1759 | 15 | 1 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 199 | 65 | 05 | 27 | 58.7 | 46.0 | .236 | 58.8 | 1759 | 15 | 2 | 1 | 1 | 11 | 265.8 | Belrose, Bourne and Hewitt (1967) |
| 200 | 65 | 05 | 30 | 75.0 | 3.0 | .239 | -35.0 | 1733 | 15 | 2 | 1 | 1 | 12 | 175.0 | Kane and Troim (1967) |
| 201 | 65 | 06 | 14 | 70.6 | 6.5 | .627 | 37.9 | 0413 | 15 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968a) |
| 202 | 65 | 06 | 17 | 59.8 | 39.0 | .119 | 37.9 | 1641 | 15 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968) |
| 203 | 65 | 06 | 22 | 76.0 | 29.0 | .390 | 37.9 | 2300 | 15 | 2 | 1 | 1 | 20 | 284.5 | Smith (1970) |
| 204 | 65 | 06 | 26 | 56.0 | 73.0 | .109 | 45.4 | 1200 | 15 | 4 | 1 | 1 | 11 | 284.1 | Belrose and Segal (1967) |
| 205 | 65 | 09 | 01 | 70.0 | 7.4 | .236 | 37.9 | 0617 | 17 | 2 | 1 | 1 | 20 | 284.5 | Heikkila et al. (1967) |
| 206 | 65 | 09 | 11 | 66.0 | 16.0 | .358 | 35.2 | 1200 | 17 | 1 | 1 | 1 | 33 | 25.0 | Thrane (1966) |
| 207 | 65 | 09 | 11 | 67.9 | 12.5 | .380 | 35.2 | 1510 | 17 | 1 | 1 | 1 | 33 | 25.0 | " " |
| 208 | 65 | 09 | 11 | 68.6 | 11.0 | .408 | 35.2 | 1604 | 17 | 1 | 1 | 1 | 33 | 25.0 | " " |
| 209 | 65 | 09 | 11 | 65.8 | 16.5 | .181 | 35.2 | 1612 | 17 | 1 | 1 | 1 | 33 | 25.0 | " " |
| 210 | 65 | 09 | 15 | 61.2 | 30.0 | .140 | 37.9 | 1528 | 17 | 2 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 211 | 65 | 09 | 00 | 64.1 | 18.8 | .225 | 35.2 | 0910 | 17 | 1 | 1 | 1 | 19 | 25.0 | Haug and Thrane (1967) |
| 212 | 65 | 09 | 00 | 66.0 | 16.0 | .346 | 35.2 | 1015 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 213 | 65 | 09 | 00 | 66.8 | 14.0 | .363 | 35.2 | 1200 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 214 | 65 | 09 | 00 | 63.5 | 21.0 | .252 | 35.2 | 1335 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 215 | 65 | 09 | 00 | 68.9 | 10.0 | .380 | 35.2 | 1445 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 216 | 65 | 09 | 00 | 67.6 | 12.0 | .268 | 35.2 | 1535 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 217 | 65 | 09 | 00 | 68.0 | 11.5 | .280 | 35.2 | 1645 | 17 | 1 | 1 | 1 | 19 | 25.0 | " " " " |
| 218 | 65 | 11 | 10 | 71.3 | 7.2 | .132 | 30.4 | 2210 | 22 | 2 | 1 | 1 | 18 | 273.3 | Sagalyn, Smiddy & Sullivan (1967) |
| 219 | 65 | 11 | 17 | 72.8 | 5.0 | .209 | 30.4 | 2320 | 22 | 2 | 1 | 1 | 18 | 273.3 | Sagalyn et al. (1967) |
| 220 | 65 | 12 | 15 | 62.8 | 24.0 | .083 | 37.9 | 1200 | 24 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Shirke (1968) |
| 221 | 66 | 01 | 10 | 59.2 | 40.0 | .159 | 37.9 | 1200 | 28 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Shirke (1968) |
| 222 | 66 | 02 | 22 | 60.2 | 25.0 | .276 | 69.3 | 1929 | 31 | 2 | 2 | 1 | 28 | 16.0 | Jesperson et al. (1968) |
| 223 | 66 | 02 | 24 | 60.5 | 24.0 | .337 | 69.3 | 0015 | 31 | 2 | 2 | 1 | 28 | 16.0 | " " " " |
| 224 | 66 | 03 | 09 | 62.5 | 14.9 | .234 | 69.3 | 2320 | 34 | 2 | 2 | 1 | 2 | 16.0 | " " " " |
| 225 | 66 | 03 | 10 | 70.0 | 5.1 | .384 | 69.3 | 2326 | 34 | 2 | 2 | 1 | 2 | 16.0 | " " " " |
| 226 | 66 | 03 | 22 | 67.4 | 7.2 | .696 | 69.3 | 0004 | 34 | 2 | 2 | 1 | 2 | 16.0 | " " " " |
| 227 | 66 | 04 | 07 | 70.6 | 6.2 | .203 | 37.9 | 2301 | 37 | 2 | 1 | 1 | 20 | 284.5 | Heikkila et al. (1967) |
| 228 | 66 | 05 | 15 | 63.2 | 30.0 | .278 | 38.0 | 1151 | 41 | 2 | 1 | 1 | 27 | 23.6 | Jesperson and Pederson (1970) |
| 229 | 66 | 05 | 16 | 64.2 | 20.0 | .274 | 35.2 | 1530 | 41 | 1 | 1 | 1 | 19 | 25.0 | Thrane (1966) |
| 230 | 66 | 05 | 20 | 62.8 | 25.0 | .291 | 36.8 | 1000 | 41 | 2 | 1 | 1 | 2 | 21.9 | Kane (1969) |
| 231 | 66 | 05 | 20 | 65.0 | 17.5 | .359 | 36.8 | 1045 | 41 | 2 | 1 | 2 | 18 | 21.9 | " " |
| 232 | 66 | 05 | 20 | 70.5 | 7.5 | .258 | 36.8 | 1130 | 41 | 2 | 1 | 2 | 18 | 21.9 | " " |
| 233 | 66 | 05 | 20 | 64.8 | 19.0 | .335 | 36.8 | 1215 | 41 | 2 | 1 | 2 | 18 | 21.9 | " " |
| 234 | 66 | 05 | 20 | 61.5 | 30.0 | .261 | 36.8 | 1300 | 41 | 2 | 1 | 2 | 18 | 21.9 | " " |
| 235 | 66 | 05 | 20 | 67.2 | 20.0 | .692 | 35.2 | 1010 | 41 | 1 | 1 | 2 | 19 | 25.0 | Haug et al. (1970) |
| 236 | 66 | 05 | 20 | 64.1 | 20.0 | .464 | 35.2 | 1055 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 237 | 66 | 05 | 20 | 62.8 | 25.0 | .260 | 35.2 | 1105 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 238 | 66 | 05 | 20 | 66.3 | 15.0 | .222 | 35.2 | 1137 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 239 | 66 | 05 | 20 | 57.5 | 53.0 | .061 | 38.0 | 1140 | 41 | 2 | 1 | 2 | 19 | 23.6 | " " " " |
| 240 | 66 | 05 | 20 | 57.6 | 54.0 | .100 | 35.2 | 1215 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 241 | 66 | 05 | 20 | 63.2 | 24.0 | .387 | 35.2 | 1225 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 242 | 66 | 05 | 20 | 57.5 | 58.0 | .104 | 35.2 | 1235 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |
| 243 | 66 | 05 | 20 | 56.0 | 71.0 | .148 | 38.0 | 1239 | 41 | 2 | 1 | 2 | 19 | 23.6 | " " " " |
| 244 | 56 | 05 | 20 | 52.0 | 143.0 | .073 | 35.2 | 1255 | 41 | 1 | 1 | 2 | 19 | 25.0 | " " " " |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 245 | 66 | 05 | 20 | 63.5 | 22.0 | .375 | 35.2 | 1305 | 41 | 1 | 1 | 1 | 19 | 25.0 | Haug et al. (1970) |
| 246 | 66 | 05 | 20 | 56.5 | 63.0 | .088 | 38.0 | 1100 | 41 | 2 | 1 | 1 | 19 | 23.6 | " " " " |
| 247 | 66 | 06 | 14 | 71.8 | 5.6 | .567 | 37.9 | 0418 | 45 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1968a) |
| 248 | 66 | 06 | 26 | 47.8 | 137.0 | .177 | 69.3 | 1200 | 45 | 2 | 1 | 1 | 14 | 16.0 | Riedler (1969) |
| 249 | 66 | 06 | 26 | 52.0 | 208.0 | .197 | 69.3 | 2247 | 45 | 2 | 2 | 1 | 11 | 16.0 | Pederson, Troim and Kane (1970) |
| 250 | 66 | 07 | 15 | 63.3 | 22.5 | .195 | 74.7 | 1200 | 50 | 1 | 1 | 1 | 11 | 265.1 | Hewitt (1969) |
| 251 | 66 | 07 | 17 | 56.0 | 67.0 | .108 | 74.7 | 1200 | 50 | 1 | 1 | 2 | 11 | 265.1 | Hewitt (1969) |
| 252 | 66 | 07 | 00 | 51.3 | 83.0 | .057 | -43.6 | 1200 | 50 | 1 | 1 | 1 | 2 | 172.8 | Austin (1971) |
| 253 | 66 | 09 | 28 | 69.3 | 9.0 | .584 | 58.8 | 1200 | 63 | 2 | 2 | 1 | 11 | 265.8 | Ulwick et al. (1968) |
| 254 | 66 | 09 | 28 | 66.5 | 15.0 | .410 | 58.8 | 1200 | 63 | 2 | 2 | 1 | 11 | 265.8 | Ulwick et al. (1968) |
| 255 | 66 | 10 | 20 | 52.2 | 115.0 | .082 | 31.6 | 1728 | 68 | 2 | 1 | 1 | 18 | 130.5 | Oya and Obayashi (1966) |
| 256 | 66 | 10 | 20 | 52.0 | 125.0 | .082 | 31.6 | 1734 | 68 | 2 | 1 | 1 | 18 | 130.5 | Oya and Obayashi (1966) |
| 257 | 66 | 11 | 05 | 63.6 | 17.5 | .786 | -32.2 | 0955 | 70 | 2 | 1 | 1 | 20 | 307.8 | Ulwick (1972) |
| 258 | 66 | 11 | 10 | 60.2 | 51.0 | .158 | -32.2 | 1700 | 70 | 1 | 1 | 1 | 20 | 307.8 | Von Biel et al. (1970) |
| 259 | 66 | 11 | 10 | 62.5 | 19.0 | .285 | -32.2 | 1745 | 70 | 1 | 1 | 1 | 20 | 307.8 | Von Biel et al. (1970) |
| 260 | 66 | 11 | 12 | 68.8 | 8.0 | .469 | -32.2 | 0954 | 70 | 2 | 1 | 2 | 20 | 307.8 | Ulwick (1972) |
| 261 | 66 | 11 | 12 | 68.0 | 9.4 | .515 | -32.2 | 1010 | 70 | 2 | 1 | 2 | 18 | 307.8 | Mechtly, Seino and Smith (1969) |
| 262 | 66 | 11 | 12 | 69.0 | 8.2 | .438 | -32.2 | 1011 | 70 | 2 | 1 | 2 | 18 | 307.8 | Mechtly, Seino and Smith (1969) |
| 263 | 66 | 11 | 12 | 75.0 | 3.3 | 1.186 | -32.2 | 1014 | 70 | 2 | 1 | 2 | 18 | 307.8 | Mechtly, Seino and Smith (1969) |
| 264 | 66 | 11 | 12 | 59.8 | 39.0 | .245 | -32.2 | 1200 | 70 | 2 | 1 | 2 | 18 | 307.8 | Mechtly (1972) |
| 265 | 66 | 11 | 20 | 57.8 | 36.0 | .183 | 69.3 | 0138 | 70 | 2 | 2 | 1 | 28 | 16.0 | Jesperson et al. (1968) |
| 266 | 66 | 12 | 13 | 51.0 | 148.0 | .061 | 32.3 | 1200 | 73 | 2 | 1 | 1 | 20 | 253.5 | Hale, Hoult and Baker (1968) |
| 267 | 66 | 00 | 00 | 83.9 | 2.5 | .458 | 40.0 | 0000 | 50 | 4 | 1 | 1 | 15 | 50.0 | Krasnushkin and Knyazeva (1970) |
| 268 | 67 | 01 | 31 | 63.7 | 18.0 | .357 | 37.9 | 1200 | 75 | 2 | 1 | 1 | 20 | 284.5 | Sechrist et al. (1969) |
| 269 | 67 | 03 | 04 | 59.6 | 22.0 | .204 | 69.3 | 0058 | 82 | 2 | 1 | 1 | 2 | 16.0 | Jesperson et al. (1967) |
| 270 | 67 | 03 | 12 | 70.0 | 7.0 | .338 | 8.6 | 1857 | 82 | 2 | 1 | 1 | 20 | 76.9 | Prakash et al. (1968) |
| 271 | 67 | 03 | 12 | 75.8 | 2.7 | .478 | 8.6 | 1857 | 82 | 2 | 1 | 1 | 20 | 76.9 | Prakash et al. (1968) |
| 272 | 67 | 03 | 15 | 59.6 | 22.0 | .154 | 69.3 | 0046 | 82 | 2 | 1 | 1 | 2 | 16.0 | Jesperson et al. (1968) |
| 273 | 67 | 04 | 27 | 57.0 | 56.0 | .352 | 45.4 | 1200 | 85 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1970) |
| 274 | 67 | 05 | 03 | 53.0 | 98.0 | .279 | 45.4 | 1220 | 87 | 1 | 2 | 1 | 11 | 284.1 | Belrose (1970) |
| 276 | 67 | 07 | 00 | 61.0 | 24.3 | .141 | -44.0 | 1200 | 92 | 1 | 1 | 1 | 21 | 173.0 | Austin and Manson (1969) |
| 277 | 67 | 09 | 27 | 62.0 | 31.0 | .170 | 40.0 | 1432 | 95 | 2 | 1 | 1 | 18 | 9.0 | Sturges (1973) |
| 278 | 67 | 10 | 07 | 69.0 | 10.0 | .277 | 40.0 | 1550 | 95 | 2 | 1 | 1 | 18 | 9.0 | Sturges (1973) |
| 279 | 67 | 10 | 13 | 62.2 | 41.0 | .289 | 69.3 | 0550 | 95 | 2 | 1 | 1 | 14 | 16.0 | Folkestad et al. (1969) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 280 | 67 | 10 | 24 | 63.7 | 21.0 | .271 | 18.5 | 1314 | 95 | 2 | 1 | 1 | 18 | 292.8 | Sagalyn and Wand (1971) |
| 281 | 67 | 10 | 27 | 61.6 | 31.0 | .228 | 18.5 | 1314 | 95 | 2 | 1 | 1 | 18 | 292.8 | Booker and Smith (1970) |
| 282 | 67 | 11 | 20 | 59.5 | 20.7 | .183 | 69.3 | 0137 | 97 | 2 | 1 | 1 | 2 | 16.0 | Riedler (1968) |
| 283 | 67 | 11 | 00 | 63.2 | 19.5 | .260 | 6.9 | 1200 | 97 | 5 | 1 | 1 | 20 | 81.0 | Mitro and Chakrabarty (1971) |
| 284 | 67 | 12 | 29 | 58.4 | 47.0 | .247 | 40.8 | 1300 | 101 | 3 | 1 | 1 | 25 | 282.1 | Lee and Ferraro (1969) |
| 285 | 67 | 12 | 30 | 57.6 | 59.0 | .181 | 45.4 | 1200 | 101 | 1 | 1 | 1 | 11 | 284.1 | Belrose et al. (1968) |
| 286 | 67 | 12 | 00 | 57.3 | 49.0 | .132 | 40.8 | 0900 | 102 | 3 | 1 | 1 | 25 | 282.1 | Rowe et al. (1969) |
| 287 | 67 | 12 | 14 | 57.2 | 51.2 | .165 | 40.8 | 0900 | 102 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 288 | 68 | 01 | 08 | 57.1 | 51.5 | .212 | 40.8 | 1500 | 102 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 289 | 68 | 01 | 01 | 53.9 | 108.0 | .222 | 45.4 | 1200 | 103 | 1 | 1 | 1 | 11 | 284.1 | Belrose et al. (1968) |
| 290 | 68 | 01 | 02 | 47.1 | 290.0 | .073 | 45.4 | 1200 | 103 | 1 | 1 | 1 | 11 | 284.1 | Lee and Ferraro (1969) |
| 291 | 68 | 01 | 05 | 57.5 | 55.0 | .330 | 40.8 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | Lee and Ferraro (1969) |
| 292 | 68 | 01 | 15 | 54.8 | 82.0 | .500 | 45.4 | 1200 | 103 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1970) |
| 293 | 68 | 01 | 16 | 59.0 | 40.0 | .230 | 37.9 | 1400 | 103 | 2 | 1 | 2 | 20 | 284.5 | Aikin (1972) |
| 294 | 68 | 01 | 16 | 62.1 | 25.0 | .289 | 37.6 | 1430 | 103 | 2 | 1 | 2 | 20 | 284.5 | Aikin (1972) |
| 295 | 68 | 01 | 18 | 59.2 | 35.0 | .211 | 40.8 | 0900 | 103 | 3 | 1 | 1 | 25 | 282.1 | Lee and Ferraro (1969) |
| 296 | 68 | 01 | 18 | 60.4 | 29.0 | .123 | 40.8 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 297 | 68 | 01 | 18 | 58.0 | 45.0 | .338 | 40.8 | 1300 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 298 | 68 | 01 | 18 | 59.2 | 35.0 | .211 | 40.8 | 1500 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 299 | 68 | 01 | 22 | 58.0 | 45.0 | .318 | 40.8 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 300 | 68 | 01 | 22 | 57.0 | 50.0 | .381 | 40.8 | 1300 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 301 | 68 | 01 | 22 | 59.2 | 36.0 | .194 | 40.8 | 1500 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 302 | 68 | 01 | 23 | 59.0 | 39.0 | .188 | 40.5 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 303 | 68 | 01 | 23 | 57.7 | 48.0 | .277 | 40.8 | 1300 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 304 | 68 | 01 | 23 | 57.7 | 48.0 | .277 | 40.8 | 1500 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 305 | 68 | 01 | 30 | 59.0 | 38.0 | .230 | 40.8 | 0900 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 306 | 68 | 01 | 30 | 59.0 | 38.0 | .230 | 40.8 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 307 | 68 | 01 | 30 | 55.3 | 67.0 | .144 | 40.8 | 1300 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 308 | 68 | 01 | 30 | 55.2 | 46.0 | .217 | 40.8 | 1500 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 309 | 68 | 01 | 31 | 59.2 | 36.0 | .183 | 40.8 | 0900 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 310 | 68 | 01 | 31 | 59.2 | 36.0 | .183 | 40.8 | 1100 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 311 | 68 | 01 | 31 | 57.5 | 50.0 | .240 | 40.8 | 1300 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 312 | 68 | 01 | 31 | 57.5 | 50.0 | .240 | 40.8 | 1500 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 313 | 68 | 01 | 00 | 59.0 | 40.0 | .258 | 40.8 | 1200 | 103 | 3 | 1 | 1 | 25 | 282.1 | " " " " |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 314 | 68 | 02 | 22 | 76.0 | 3.0 | .331 | 37.9 | 0009 | 103 | 2 | 1 | 1 | 20 | 284.5 | Smith (1970) |
| 315 | 68 | 02 | 22 | 76.5 | 2.6 | .184 | 37.9 | 0130 | 103 | 2 | 1 | 1 | 20 | 284.5 | " " |
| 316 | 68 | 02 | 22 | 77.0 | 2.5 | .527 | 37.9 | 0300 | 103 | 2 | 1 | 1 | 20 | 284.5 | " " |
| 317 | 68 | 02 | 22 | 72.0 | 6.0 | .184 | 37.9 | 0430 | 103 | 2 | 1 | 1 | 20 | 284.5 | " " |
| 318 | 68 | 02 | 22 | 73.7 | 4.0 | .367 | 37.9 | 0602 | 103 | 2 | 1 | 1 | 20 | 284.5 | " " |
| 319 | 68 | 03 | 08 | 57.1 | 54.0 | .134 | 8.6 | 1200 | 105 | 2 | 1 | 1 | 20 | 76.9 | Kane (1969b) |
| 320 | 68 | 03 | 08 | 68.5 | 9.0 | .216 | 8.6 | 1755 | 105 | 2 | 1 | 1 | 20 | 76.9 | Kane (1969b) |
| 321 | 68 | 03 | 22 | 57.0 | 60.0 | .365 | 40.8 | 1230 | 105 | 3 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 322 | 68 | 03 | 22 | 57.0 | 60.0 | .365 | 40.8 | 1230 | 105 | 1 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 323 | 68 | 03 | 25 | 61.0 | 32.0 | .214 | 45.4 | 0945 | 105 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1969) |
| 324 | 68 | 03 | 25 | 54.2 | 85.0 | .148 | 45.4 | 1010 | 105 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1969) |
| 325 | 68 | 03 | 25 | 57.5 | 50.0 | .243 | 40.8 | 1100 | 105 | 3 | 1 | 1 | 5 | 282.1 | Cole, Ferraro and Lee (1969) |
| 326 | 68 | 03 | 25 | 57.2 | 52.0 | .428 | 40.8 | 1130 | 105 | 3 | 1 | 1 | 5 | 282.1 | " " " " " |
| 327 | 68 | 03 | 25 | 57.2 | 52.0 | .428 | 40.8 | 1130 | 105 | 1 | 1 | 1 | 5 | 282.1 | " " " " " |
| 328 | 68 | 03 | 25 | 56.5 | 59.0 | .411 | 40.8 | 1230 | 105 | 3 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 329 | 68 | 03 | 25 | 59.6 | 39.0 | .223 | 40.8 | 1230 | 105 | 1 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 330 | 68 | 03 | 25 | 57.6 | 55.0 | .416 | 40.8 | 1430 | 105 | 3 | 1 | 1 | 5 | 282.1 | Cole, Ferraro and Lee (1969) |
| 331 | 68 | 03 | 25 | 58.0 | 45.0 | .360 | 40.8 | 1430 | 105 | 1 | 1 | 1 | 5 | 282.1 | Cole, Ferraro and Lee (1969) |
| 332 | 68 | 04 | 02 | 57.0 | 59.0 | .407 | 40.8 | 1030 | 107 | 3 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 333 | 68 | 04 | 02 | 58.0 | 45.0 | .318 | 40.8 | 1030 | 107 | 1 | 1 | 1 | 5 | 282.1 | Cole et al. (1969) |
| 334 | 68 | 07 | 08 | 61.0 | 34.0 | .478 | 45.4 | 1200 | 105 | 1 | 1 | 1 | 11 | 284.1 | Montbriand and Belrose (1972a) |
| 335 | 68 | 07 | 08 | 49.5 | 178.0 | .168 | 45.4 | 1240 | 105 | 1 | 1 | 2 | 11 | 284.1 | Montbriand and Belrose (1972c) |
| 336 | 68 | 07 | 08 | 49.5 | 178.0 | .281 | 45.4 | 1300 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 337 | 68 | 07 | 08 | 54.0 | 100.0 | .233 | 45.4 | 1330 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 338 | 68 | 07 | 08 | 57.5 | 60.0 | .265 | 45.4 | 1400 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 339 | 68 | 07 | 08 | 58.8 | 55.0 | .213 | 45.4 | 1455 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 340 | 68 | 07 | 24 | 63.0 | 23.0 | 1.190 | 37.9 | 0450 | 105 | 2 | 1 | 1 | 20 | 284.5 | Mechtly and Smith (1970) |
| 341 | 68 | 07 | 24 | 61.0 | 29.0 | .248 | 37.9 | 0530 | 105 | 2 | 1 | 1 | 20 | 284.5 | " " " " |
| 342 | 68 | 07 | 24 | 62.0 | 25.0 | .399 | 37.9 | 1636 | 105 | 2 | 1 | 1 | 20 | 284.5 | " " " " |
| 343 | 68 | 07 | 24 | 64.9 | 16.5 | 1.308 | 37.9 | 1235 | 105 | 2 | 1 | 1 | 20 | 284.5 | " " " " |
| 344 | 68 | 08 | 21 | 52.3 | 125.0 | .101 | 37.9 | 1440 | 105 | 2 | 1 | 2 | 20 | 284.5 | Aikin (1972) |
| 345 | 68 | 08 | 21 | 50.9 | 150.0 | .105 | 37.9 | 1440 | 105 | 2 | 1 | 2 | 20 | 284.5 | Aikin (1972) |
| 346 | 68 | 08 | 21 | 61.5 | 27.0 | .251 | 37.9 | 1440 | 105 | 2 | 1 | 2 | 20 | 284.5 | Rowe (1972) |
| 347 | 68 | 08 | 29 | 56.7 | 61.0 | .158 | 8.6 | 1415 | 105 | 2 | 1 | 1 | 20 | 76.9 | Prakash et al. (1971) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 348 | 68 | 08 | 29 | 54.6 | 86.0 | .118 | 8.6 | 1415 | 105 | 2 | 1 | 1 | 20 | 76.9 | Prakash et al. (1971) |
| 349 | 68 | 07 | 00 | 60.4 | 48.0 | .201 | 40.0 | 1200 | 105 | 4 | 1 | 1 | 11 | 50.0 | Krasnushkin and Knyazeva (1970) |
| 350 | 68 | 10 | 21 | 56.0 | 65.0 | .177 | 40.8 | 1710 | 110 | 3 | 1 | 2 | 25 | 282.1 | Rowe et al. (1970) |
| 351 | 68 | 10 | 21 | 52.0 | 122.0 | .091 | 40.8 | 1739 | 110 | 3 | 1 | 2 | 25 | 282.1 | " " " " |
| 352 | 68 | 10 | 21 | 51.4 | 142.0 | .075 | 40.8 | 1801 | 110 | 3 | 1 | 2 | 25 | 282.1 | " " " " |
| 353 | 68 | 10 | 24 | 54.3 | 59.0 | .154 | 67.8 | 2150 | 110 | 2 | 2 | 1 | 28 | 20.4 | Derblom and Ladell (1973) |
| 354 | 68 | 10 | 25 | 76.5 | 15.0 | .442 | 74.7 | 1200 | 110 | 1 | 1 | 1 | 11 | 265.1 | Belrose, Hewitt & Bunker (1969) |
| 355 | 68 | 10 | 26 | 60.0 | 37.0 | .176 | 74.7 | 1200 | 110 | 1 | 1 | 1 | 11 | 265.1 | " " " " " |
| 356 | 68 | 10 | 29 | 56.0 | 62.0 | .146 | 74.7 | 1200 | 110 | 1 | 2 | 1 | 11 | 265.1 | " " " " " |
| 357 | 68 | 10 | 31 | 51.5 | 135.0 | .453 | 74.7 | 1200 | 110 | 1 | 1 | 1 | 11 | 265.1 | " " " " " |
| 358 | 68 | 11 | 01 | 55.2 | 71.0 | .359 | 74.7 | 1200 | 111 | 1 | 1 | 1 | 11 | 265.1 | " " " " " |
| 359 | 68 | 11 | 04 | 63.4 | 17.5 | .220 | -44.0 | 1230 | 111 | 1 | 1 | 1 | 21 | 173.0 | Von Biel (1971) |
| 360 | 68 | 11 | 19 | 56.5 | 60.0 | .645 | 58.8 | 0200 | 111 | 2 | 2 | 1 | 11 | 265.8 | Ulwick, Baker & Sellers (1970) |
| 361 | 68 | 00 | 00 | 63.0 | 50.0 | .202 | 51.5 | 1200 | 105 | 4 | 1 | 1 | 8 | 359.4 | Thrane (1972) |
| 362 | 69 | 01 | 18 | 58.5 | 32.0 | .137 | 69.3 | 2324 | 110 | 2 | 2 | 1 | 28 | 16.0 | Derblom et al. (1973) |
| 363 | 69 | 01 | 31 | 61.6 | 27.0 | .227 | 37.9 | 1200 | 110 | 2 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972) |
| 364 | 69 | 02 | 06 | 63.3 | 19.0 | .783 | 37.9 | 1209 | 110 | 2 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972) |
| 365 | 69 | 02 | 25 | 46.2 | 200.0 | .340 | 50.0 | 1521 | 110 | 2 | 2 | 1 | 28 | 15.0 | Jesperson et al. (1969) |
| 366 | 69 | 02 | 25 | 51.1 | 82.0 | .351 | 50.0 | 2237 | 110 | 2 | 2 | 1 | 28 | 15.0 | Jesperson et al. (1969) |
| 367 | 69 | 03 | 20 | 51.7 | 140.0 | .081 | 45.4 | 1200 | 108 | 1 | 1 | 1 | 11 | 284.1 | Belrose (1970) |
| 368 | 69 | 04 | 14 | 45.5 | 345.0 | .112 | 58.8 | 1528 | 106 | 2 | 2 | 1 | 11 | 265.8 | Megil et al. (1971) |
| 369 | 69 | 04 | 14 | 64.0 | 22.0 | .597 | 58.8 | 2319 | 106 | 2 | 2 | 1 | 11 | 265.8 | Megil et al. (1971) |
| 370 | 69 | 04 | 17 | 61.0 | 30.0 | .258 | 37.9 | 1600 | 106 | 1 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972) |
| 371 | 69 | 06 | 19 | 56.7 | 58.0 | .257 | 57.2 | 1006 | 106 | 2 | 1 | 1 | 23 | 352.7 | Bain and Harrison (1972) |
| 372 | 69 | 08 | 05 | 73.7 | 4.7 | .344 | 58.8 | 2136 | 106 | 2 | 1 | 1 | 11 | 265.8 | Dean (1972) |
| 373 | 69 | 09 | 10 | 60.9 | 32.0 | .475 | 37.9 | 1546 | 105 | 1 | 1 | 1 | 20 | 284.5 | Mechtly, Bowhill and Smith (1972 |
| 374 | 69 | 10 | 00 | 58.1 | 45.0 | .270 | 40.8 | 1200 | 104 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 375 | 69 | 11 | 02 | 71.2 | 6.5 | .397 | 58.8 | 0500 | 105 | 1 | 2 | 1 | 11 | 265.8 | Belrose (1972) |
| 376 | 69 | 11 | 02 | 67.0 | 12.5 | .318 | 58.8 | 0600 | 105 | 1 | 2 | 1 | 11 | 265.8 | " " |
| 377 | 69 | 11 | 02 | 51.5 | 146.0 | .403 | 58.8 | 0700 | 105 | 1 | 2 | 1 | 11 | 265.8 | " " |
| 378 | 69 | 11 | 02 | 49.1 | 194.0 | .548 | 58.8 | 0800 | 105 | 1 | 2 | 1 | 11 | 265.8 | " " |
| 379 | 69 | 11 | 02 | 45.0 | 360.0 | .369 | 58.8 | 0900 | 105 | 1 | 2 | 1 | 11 | 265.8 | " " |
| 380 | 69 | 11 | 02 | 46.4 | 275.0 | .567 | 58.8 | 1510 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 381 | 69 | 11 | 03 | 62.8 | 25.0 | .374 | 58.8 | 0000 | 105 | 1 | 2 | 1 | 11 | 265.8 | Belrose (1972) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | F | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 382 | 69 | 11 | 03 | 52.4 | 130.0 | .206 | 58.8 | 0005 | 105 | 2 | 2 | 1 | 11 | 265.8 | Ulwick (1972) |
| 383 | 69 | 11 | 03 | 57.7 | 50.0 | .317 | 58.8 | 0657 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 384 | 69 | 11 | 03 | 58.9 | 51.0 | .751 | 58.8 | 0730 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 385 | 69 | 11 | 03 | 54.1 | 85.0 | .397 | 58.8 | 0752 | 105 | 2 | 2 | 1 | 11 | 265.8 | Ulwick (1972) |
| 386 | 69 | 11 | 03 | 42.0 | 260.0 | .140 | 58.8 | 1254 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 387 | 69 | 11 | 04 | 64.7 | 18.0 | .343 | 58.8 | 0000 | 105 | 1 | 2 | 1 | 11 | 265.8 | Belrose (1972) |
| 388 | 69 | 11 | 04 | 51.8 | 150.0 | .286 | 58.8 | 1530 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 389 | 69 | 11 | 04 | 51.0 | 90.0 | .214 | 58.8 | 1638 | 105 | 2 | 2 | 1 | 11 | 265.8 | Dean (1972) |
| 390 | 69 | 11 | 04 | 55.8 | 68.0 | .278 | 58.8 | 1708 | 105 | 2 | 2 | 1 | 11 | 265.8 | Ulwick (1972) |
| 391 | 69 | 11 | 05 | 66.8 | 15.0 | .317 | 58.8 | 0000 | 105 | 2 | 2 | 1 | 11 | 265.8 | Belrose (1972) |
| 392 | 69 | 11 | 18 | 51.2 | 150.0 | .236 | 45.4 | 1250 | 105 | 1 | 1 | 2 | 11 | 284.1 | Montbriand and Belrose (1972c) |
| 393 | 69 | 11 | 18 | 53.7 | 98.0 | .177 | 45.4 | 1330 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 394 | 69 | 11 | 18 | 55.0 | 82.0 | .183 | 45.4 | 1400 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 395 | 69 | 11 | 18 | 56.4 | 67.5 | .212 | 45.4 | 1430 | 105 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 396 | 69 | 12 | 00 | 57.9 | 46.0 | .182 | 40.8 | 0900 | 106 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 397 | 69 | 12 | 00 | 57.5 | 40.0 | .421 | 40.8 | 1038 | 106 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 398 | 69 | 12 | 00 | 66.5 | 57.0 | .220 | 40.8 | 1200 | 106 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 399 | 69 | 12 | 00 | 56.6 | 57.0 | .234 | 40.8 | 1430 | 106 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 400 | 69 | 12 | 00 | 56.8 | 56.5 | .420 | 40.8 | 1500 | 106 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 401 | 69 | 12 | 00 | 67.9 | 35.0 | .091 | 40.0 | 1200 | 60 | 4 | 1 | 1 | 15 | 50.0 | Krashushkin and Knyazeva (1970) |
| 402 | 70 | 01 | 02 | 60.4 | 34.0 | .247 | 8.6 | 1212 | 106 | 2 | 1 | 1 | 20 | 76.9 | Somayajulu et al. (1971) |
| 403 | 70 | 01 | 00 | 54.7 | 77.0 | .135 | 40.8 | 1200 | 106 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 404 | 70 | 02 | 00 | 57.1 | 54.0 | .190 | 40.8 | 1200 | 106 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 405 | 70 | 03 | 01 | 56.0 | 74.0 | .082 | 45.4 | 1003 | 106 | 1 | 1 | 1 | 11 | 284.1 | Montbriand and Belrose (1972c) |
| 406 | 70 | 03 | 01 | 52.0 | 145.0 | .353 | 45.4 | 1009 | 106 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 407 | 70 | 03 | 01 | 52.9 | 123.0 | .273 | 45.4 | 1017 | 106 | 1 | 1 | 2 | 11 | 284.1 | " " " " |
| 408 | 70 | 03 | 07 | 63.6 | 20.0 | .324 | 37.9 | 1045 | 106 | 2 | 1 | 1 | 20 | 284.1 | Mechtly and Sechrist (1972) |
| 409 | 70 | 03 | 07 | 59.9 | 38.0 | .126 | 40.8 | 1309 | 106 | 3 | 1 | 2 | 11 | 282.1 | Rowe et al. (1970) |
| 410 | 70 | 03 | 07 | 61.2 | 30.0 | .103 | 40.8 | 1328 | 106 | 3 | 1 | 2 | 11 | 282.1 | Rowe et al. (1970) |
| 411 | 70 | 03 | 07 | 71.3 | 5.6 | .837 | 37.9 | 1339 | 106 | 2 | 1 | 2 | 20 | 284.5 | Mechtly, Sechrist & Smith (1972) |
| 412 | 70 | 03 | 07 | 63.2 | 25.0 | .374 | 44.9 | 1340 | 106 | 1 | 1 | 1 | 11 | 297.7 | Belrose et al. (1972) |
| 413 | 70 | 03 | 07 | 64.2 | 20.0 | .471 | 44.9 | 1340 | 106 | 2 | 1 | 1 | 11 | 297.7 | Belrose et al. (1972) |
| 414 | 70 | 03 | 07 | 58.8 | 44.0 | .240 | 40.8 | 1413 | 106 | 3 | 1 | 2 | 11 | 282.1 | Rowe et al. (1970) |
| 415 | 70 | 03 | 07 | 68.1 | 12.0 | .170 | 44.9 | 1504 | 106 | 2 | 1 | 2 | 11 | 297.7 | Belrose, Ross & McNamaro (1972) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 416 | 70 | 03 | 07 | 65.0 | 18.0 | .471 | 44.9 | 1504 | 106 | 1 | 1 | 2 | 11 | 297.7 | Belrose, Ross & McNamaro (1972) |
| 417 | 70 | 03 | 11 | 58.2 | 48.0 | .494 | 40.8 | 1310 | 106 | 3 | 1 | 1 | 11 | 282.1 | Rowe, Ferraro and Lee (1970) |
| 418 | 70 | 03 | 19 | 59.3 | 38.0 | .149 | 8.6 | 0827 | 106 | 2 | 1 | 1 | 20 | 76.9 | Aikin et al. (1972) |
| 419 | 70 | 03 | 19 | 58.0 | 45.0 | .147 | 8.6 | 1017 | 106 | 2 | 1 | 1 | 20 | 76.9 | " " " " |
| 420 | 70 | 03 | 19 | 60.1 | 34.0 | .223 | 8.6 | 1509 | 106 | 2 | 1 | 1 | 20 | 76.9 | " " " " |
| 421 | 70 | 05 | 22 | 59.7 | 38.5 | .115 | 45.4 | 0545 | 106 | 1 | 1 | 1 | 11 | 284.1 | Coyne and Belrose (1972b) |
| 422 | 70 | 05 | 22 | 57.1 | 46.0 | .155 | 45.4 | 0810 | 106 | 1 | 1 | 1 | 11 | 284.1 | Coyne and Belrose (1972) |
| 423 | 70 | 05 | 22 | 55.9 | 69.0 | .185 | 45.4 | 1020 | 106 | 1 | 1 | 1 | 11 | 284.1 | Coyne and Belrose (1972b) |
| 424 | 70 | 05 | 22 | 55.0 | 43.0 | .225 | 45.4 | 1200 | 106 | 1 | 1 | 1 | 11 | 284.1 | Coyne and Belrose (1972) |
| 425 | 70 | 05 | 22 | 56.9 | 47.0 | .209 | 45.4 | 1600 | 106 | 1 | 1 | 1 | 11 | 284.1 | " " " " |
| 426 | 70 | 05 | 22 | 50.8 | 70.0 | .045 | 45.4 | 1750 | 106 | 1 | 1 | 1 | 11 | 284.1 | " " " " |
| 427 | 70 | 06 | 24 | 57.2 | 51.5 | .337 | 40.8 | 0755 | 105 | 3 | 1 | 1 | 5 | 282.1 | Ferraro, Lee and Cohen (1972) |
| 428 | 70 | 06 | 24 | 60.0 | 52.0 | .208 | 45.4 | 0755 | 105 | 1 | 1 | 1 | 5 | 284.1 | Ferraro, Lee and Cohen (1972) |
| 429 | 70 | 06 | 26 | 56.9 | 60.0 | .350 | 40.8 | 1110 | 105 | 3 | 1 | 1 | 4 | 282.1 | Belrose and Coyne (1972) |
| 430 | 70 | 06 | 26 | 58.2 | 67.0 | .258 | 45.4 | 1200 | 105 | 1 | 1 | 1 | 4 | 284.1 | Belrose and Coyne (1972) |
| 431 | 70 | 07 | 00 | 57.4 | 60.0 | .185 | 40.8 | 1430 | 104 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 432 | 70 | 07 | 00 | 56.7 | 57.0 | .352 | 40.8 | 1200 | 104 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 433 | 70 | 08 | 04 | 64.2 | 25.0 | .328 | 59.3 | 1305 | 101 | 2 | 1 | 1 | 28 | 16.0 | Thrane (1972) |
| 434 | 70 | 08 | 10 | 70.0 | 10.0 | .295 | 67.8 | 0040 | 101 | 2 | 1 | 1 | 28 | 20.4 | Derblom et al. (1973) |
| 435 | 70 | 08 | 00 | 56.5 | 58.0 | .438 | 40.8 | 1200 | 101 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 436 | 70 | 07 | 00 | 55.6 | 58.0 | .169 | 40.8 | 0800 | 104 | 3 | 1 | 1 | 25 | 282.1 | Ferraro et al. (1974) |
| 437 | 70 | 07 | 00 | 56.0 | 56.5 | .182 | 40.8 | 0830 | 104 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 438 | 70 | 07 | 00 | 56.7 | 50.0 | .280 | 40.8 | 0900 | 104 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 439 | 70 | 07 | 00 | 56.3 | 52.0 | .192 | 40.8 | 1000 | 104 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 440 | 70 | 07 | 00 | 57.0 | 46.0 | .280 | 40.8 | 1230 | 104 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 441 | 70 | 09 | 00 | 57.0 | 55.0 | .449 | 40.8 | 1200 | 97 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 442 | 70 | 10 | 00 | 56.9 | 55.0 | .324 | 40.8 | 0930 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 443 | 70 | 10 | 00 | 59.5 | 37.0 | .201 | 40.8 | 1000 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 444 | 70 | 10 | 00 | 56.9 | 55.0 | .066 | 40.8 | 1038 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 445 | 70 | 10 | 00 | 57.2 | 52.0 | .410 | 40.8 | 1430 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 446 | 70 | 10 | 00 | 58.6 | 40.0 | .201 | 40.8 | 1500 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 447 | 70 | 10 | 00 | 57.5 | 49.3 | .293 | 40.8 | 1200 | 94 | 3 | 1 | 1 | 25 | 282.1 | " " |
| 448 | 70 | 10 | 00 | 57.2 | 52.0 | .146 | 40.8 | 1300 | 96 | 3 | 1 | 1 | 25 | 282.1 | Ferraro et al. (1974) |
| 449 | 70 | 11 | 00 | 57.2 | 52.5 | .135 | 40.8 | 1200 | 89 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |

TABLE A2 (continued): D-Region Profiles: Data and Scaled Parameters

See Table A1 for Column Headings

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 450 | 71 | 01 | 22 | 46.4 | 265.0 | .104 | 32.3 | 1200 | 80 | 2 | 1 | 1 | 20 | 253.5 | Mitchell et al. (1972) |
| 451 | 71 | 01 | 26 | 49.0 | 177.0 | .037 | 32.3 | 0955 | 80 | 2 | 1 | 1 | 20 | 253.5 | Mitchell et al. (1972) |
| 452 | 71 | 01 | 28 | 64.0 | 39.0 | .341 | 6.6 | 1040 | 80 | 2 | 1 | 1 | 20 | 76.9 | Prakash (1972) |
| 453 | 71 | 01 | 28 | 61.9 | 60.2 | .318 | 8.6 | 1110 | 80 | 2 | 1 | 1 | 20 | 76.9 | Prakash (1972) |
| 454 | 71 | 01 | 00 | 58.8 | 41.0 | .245 | 40.8 | 1200 | 80 | 3 | 1 | 1 | 25 | 282.1 | Rowe (1972) |
| 455 | 71 | 02 | 01 | 47.0 | 230.0 | .143 | 32.3 | 1200 | 78 | 2 | 1 | 1 | 20 | 253.5 | Mitchell et al. (1972) |
| 456 | 71 | 03 | 27 | 59.5 | 50.0 | .096 | 45.4 | 0930 | 74 | 1 | 1 | 1 | 11 | 284.1 | Coyne and Belrose (1972) |
| 457 | 71 | 03 | 27 | 58.0 | 58.2 | .127 | 45.4 | 1200 | 74 | 1 | 1 | 1 | 11 | 284.1 | " " " " |
| 458 | 71 | 03 | 27 | 55.3 | 78.0 | .057 | 45.4 | 1455 | 74 | 1 | 1 | 1 | 11 | 284.1 | " " " " |
| 459 | 71 | 10 | 18 | 59.1 | 48.0 | .175 | 45.4 | 1200 | 66 | 1 | 1 | 1 | 37 | 284.1 | Tanenbaum et al. (1973) |
| 460 | 71 | 10 | 20 | 57.2 | 62.0 | .165 | 45.4 | 1200 | 66 | 1 | 1 | 1 | 37 | 284.1 | " " " " |
| 461 | 71 | 10 | 25 | 61.2 | 34.5 | .267 | 45.4 | 1200 | 66 | 1 | 1 | 1 | 37 | 284.1 | " " " " |
| 462 | 71 | 10 | 26 | 55.5 | 60.0 | .244 | 45.4 | 1147 | 66 | 1 | 1 | 1 | 39 | 284.1 | Belrose et al. (1972) |
| 463 | 71 | 10 | 29 | 60.2 | 29.0 | .136 | 45.4 | 1200 | 66 | 1 | 1 | 1 | 39 | 284.1 | Belrose et al. (1972) |
| 464 | 72 | 12 | 05 | 62.9 | 21.0 | .223 | 37.9 | 1200 | 55 | 2 | 1 | 1 | 20 | 284.5 | Mecthly et al. (1973) |
| 465 | 73 | 01 | 16 | 59.5 | 36.0 | .191 | 37.9 | 1200 | 51 | 2 | 1 | 1 | 20 | 284.5 | Mechtly et al. (1973) |
| 466 | 67 | 12 | 00 | 57.3 | 49.0 | .132 | 40.8 | 1500 | 102 | 3 | 1 | 1 | 25 | 282.1 | Rowe et al. (1969) |
| 467 | 67 | 12 | 14 | 57.2 | 51.2 | .165 | 40.8 | 1500 | 102 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 468 | 68 | 01 | 08 | 57.1 | 51.5 | .212 | 40.8 | 1500 | 102 | 3 | 1 | 1 | 25 | 282.1 | " " " " |
| 469 | 60 | 03 | 27 | 60.5 | 80.0 | .054 | 60.0 | 1630 | 122 | 3 | 1 | 1 | 7 | 11.1 | Barrington et al. (1963) |
| 470 | 60 | 03 | 27 | 59.8 | 94.0 | .146 | 60.0 | 1230 | 122 | 3 | 1 | 1 | 7 | 11.1 | " " " " |
| 471 | 60 | 03 | 27 | 59.8 | 94.0 | .146 | 60.0 | 1330 | 122 | 3 | 1 | 1 | 7 | 11.1 | " " " " |
| 472 | 64 | 09 | 01 | 61.2 | 35.0 | .559 | -30.5 | 1730 | 10 | 3 | 1 | 1 | 34 | 151.5 | Smith, Coyne and Loch (1967) |
| 473 | 64 | 09 | 01 | 61.2 | 35.0 | .559 | -30.5 | 1742 | 10 | 3 | 1 | 1 | 34 | 151.5 | " " " " " |
| 474 | 64 | 09 | 01 | 61.2 | 35.0 | .559 | -30.5 | 1752 | 10 | 3 | 1 | 1 | 34 | 151.5 | " " " " " |
| 475 | 65 | 04 | 00 | 61.1 | 62.0 | .124 | -19.3 | 0900 | 14 | 5 | 1 | 1 | 9 | 17.7 | Gruschwitz (1974) |
| 476 | 65 | 04 | 00 | 61.1 | 62.0 | .124 | -19.3 | 1500 | 14 | 5 | 1 | 1 | 9 | 17.7 | " " |
| 477 | 65 | 03 | 00 | 60.4 | 33.0 | .134 | 53.8 | 1630 | 13 | 1 | 1 | 1 | 11 | 265.8 | " " |



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## SOURCES OF PROFILES

Adey, A.W., and W.J. Heikkila (1961), Rocket electron density measurements at Fort Churchill, Canada, Can. J. Phys., 39, 219-221.

Aikin, A.C. (1965), Formation of the equatorial ionospheric D-region, Proceedings of the Second International Symposium on Equatorial Aeronomy (ed. F. de Mindonga), 1-13.

Aikin, A.C. (1972), Ionoization sources of the ionospheric D and E regions Aeron. Report No. 48, (ed. Sechrist and Geller, U. of Ill., Urbana, Ill.), 96-103.

Aikin, A.C., J.A. Kane, and J. Truim (1964), Some results of rocket experiments on the quiet D-region, J. Geophys. Res., 69, 4621-4628.

Aikin, A.C. and L.J. Blumle (1968), Rocket measurements of the E-region electron concentration distribution in the vicinity of the geomagnetic equator, J. Geophsy. Res., 73, 1617-1626.

Aikin, A.C., R.A. Goldberg, Y.V. Somayajulu, and M.B. Avadhanulu (1972), Electron and positive ion density altitude distributions in the equatorial D-region, J. Atmosph. Terr. Phys., 34, 1483-1494.

Austin, C.L. (1971), A direct measuring differential phase experiment, J. Atmosph. Terr. Phys., 33, 1667-1674.

Austin, C.L., and A.H. Manson (1969), On the nature of the irregularities that produce partial reflections of radio waves from the lower ionosphere (70-100 km), Radio Sci., 4, 35-40.

Bain, W.C., and B.R. Moy (1967), D-region electron density distributions from propagation data, Proc. IEEE, 114, 1593-1597.

Bain, W.C., and M.D. Harrison (1972), Model ionosphere for D-region at summer noon during sunspot maximum, Proc. IEE, 119, 790-796.

Barrington, R.E., and E. Thrane (1961), The determination of D-region electron densities from observations of cross-modulation., Tech. Note T-67, Norwegion Defence Research Establishment, August 1961.

Barrington, R.E., E.V. Thrane, and B. Bjelland (1963), Diurnal and seasonal variation in D-region electron densities derived from observations of cross-modulation, Can. J. Phys., 41, 271.

Belrose, J.S. (1963), Present knowledge of the lowest ionosphere, AGARDO graph 74: Propagation of radio waves at frequencies below 300 kc (ed. Blackband) Pergamon.

Belrose, J.S. (1964), Present knowledge of the lowest ionosphere in Propagation of radio waves at frequencies below 300 kc/s, (ed. W.T. Blackband, Macmillon, New York).

Belrose, J.S. (1965), The lower ionospheric regions, Chap. 3 of Physics of the Earth's Upper Atmosphere (ed. Hines, Poghis, Hartz, Fejer), 46-72.

Belrose, J.S. (1970), Radio wave probing of the ionosphere by the partial reflection of radio waves (from heights below 100 km), J. Atmos. Terr. Phys., 32, 567-596.

Belrose, J.S. (1972), Ionization changes in the D-region associated with the Solar Cosmic Pay (SCR) event of 2 November 1969, Proceedings of COSPAR Symposium on Solar Particle Event of November 1969, AFCPL Special Report No. 144, 243-255.

Belrose, J.S., L.R. Bode, and L.W. Hewitt (1964), Physical properties of the polar winter mesosphere obtained from low-frequency propagation and partial reflection studies, Radio Sci. 68D, 1314-1323.

Belrose, J.S., I.A. Bourne, and L.W. Hewitt (1966), The winter variability of electron desity in the lower ionosphere over Ottawa. A discussion of results and possible cause, Electron Density Profiles in the Ionosphere and Exosphere, (ed. Frihogen), 48-60, (North Holland).

Belrose, J.S., and I.A. Bourne (1967), The electron density and collision frequency height profile for the lower part of the ionosphere (The D and lower E regions), Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc., Defence Research Board, Canada), 79-96.

Belrose, J.S., I.A. Bourne, and L.W. Hewitt (1967), A prelimanary investigation of diurnal and seasonal changes in electron distribution over Ottawa, Churchill, and Resolute Bay, Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc., (Defence Research Board, Canada), 167-188.

Belrose, J.S., I.A. Bourne, and L.W. Hewitt (1967), A critical review of the partial reflection experiment, Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc., (Defence Research Board, Canada), 125-151.

Belrose, J.S., and M. L. Burke (1964), Study of the lower ionosphere using partial reflections, 1. Experimental technique and method of analysis, J. Geophys. Res., 69, 2799-2818.

Belrose, J.S., M.J. Burke, T.N.R. Coyne, and J.E. Reed (1972), D-region measurements with the differential-absorption, differential-phase partial-reflection experiments, J. Geophys. Res. 77, 4829-4838.

Belrose, J.S., and E. Cetoner, (1962), Measurement of electron densities in the ionosphere D-region at the time of a 2+ solar flare, Nature, 195, 688-690.

Belrose, J.S., and T.N.R. Coyne (1972), A comparison of two ground-based techniques for measuring D-region electron densities, Aeron. Report No. 48, (ed. Sechrist & Geller, U. of Ill.), 326-330.

Belrose, J.S., L.W. Hewitt, and R. Bunker (1968), The partial reflection experiment as a tool for synoptic D-region research; and results of recent studies related to winter variability, Conference Digest, Third conference on Meteorological and Chemical Factors in D-region Aeronomy, Univ. of Ill., 322.

Belrose, J.S., L.W. Hewitt, and R. Bunker (1969), Regular and irregular diurnal variations of electron number density in the lower ionosphere over Resolute Bay, The Polar Ionosphere and Magnetospheric Processes, 285-298, (ed. Shovli).

Belrose, J.S., D.B. Ross, and A.G. McNamara (1972), Ioniozation changes in the lower ionosphere during the solar eclipse of 7 March 1970, J. Atmosph. Terr. Phys., 34, 627-640.

Belrose, J.S., and B. Segal (1967), Some comments on the determination of D-region electron density distribution from the reflection of long waves, Ground Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc. (Defence Research Board, Canada), 167-188.

Berthelier, J.J., and M. Pirre (1972), Rocket measurements of Antarctic D-region electron density during the 28 January 1967 PCA event. Proceedings of COSPAR Symposium on Solar Particle Event of November 1969, AFCRL Special Report No. 144, 277-290.

Booker, H.G., and E.K. Smith (1970), A comparative study of ionospheric measurement techniques, J. Atmosph. Terr. Phys., 32, 467-497.

Bourdeou, R.E., A.C. Aikin, and J.L. Donley (1966), Lower ionosphere at sunspot minimum, J. Geophys. Res., 71, 727-740.

Bowhill, S.A., and C.G. Kleimon (1965), NASA University Program Review Conference, NASA Special Pub. SP-85, (U.S. Govt. Printing Office, Washington, D.C.).

Cartwright, D.C. (1964), A 10-kilocycle per second Doppler observation of the intermediate layer of the nighttime ionosphere, J. Geophys. Res., 69, 4031-4035.

Cole, A.R., A.J. Ferroro, and W.S. Lee (1969), Comparison of two groundbased D-region experiments, Nature, 222, 761-763.

Coyne, T.N.R., and J.S. Belrose (1972a), The diurnal and seasonal variation of electron densities in the midlatitude D-region under quiet conditions, Radio Sci., 7, 163-174.

Coyne, T.N.R., and J.S. Belrose (1972b), The diurnal and seasonal variation of electron densities in the midlatitude D-region under quiet conditions, Aeron. Report No. 48, (ed. Sechrist and Geller, Univ. of Ill., Urbana, Ill.), 342-352.

Crouse, P.E. (1964), Methods for obtaining electron density profiles from capacitive ionospheric rocket probes, Penn State Ionos. Research Lab. Sci. Report No. 208.

Dean, W.A. (1972), Electron density profiles for the 1969 PCA event, Proceedings of COSPAR Symposium on Solar Particle Event of November 1969, ARCRL Special Report No. 144, 291-305.

Deeks, D.G. (1966), D-region electron density distributions in middle latitudes deduced from the reflection of long radio waves, Proc. Roy. Soc. A, 291, 413-437.

Derblom, H., and L. Ladell (1973), D-region parameters at high latitudes obtained from rocket experiments, J. Atmosph. Terr. Phys., 35, 2123-2130.

Ferraro, A.J., and J.S. Lee (1966), Electron density and collision frequency measurements of the D-region with radio wave phase and amplitude interaction, Electron Density Profiles in the Ionosphere and Exosphere, (ed. Frihagen), (North - Holland, Amsterdam), 69-82.

Ferraro, A.J., H.S. Lee, and D.J. Cohen (1972), A comparison if two groundbased techniques for measuring D-region electron densities, PT-I, Aeron. Report No. 48, (ed. Sechrist and Geller, University of Ill., Urbana, Ill.) 320-325.

Ferraro, A.J., H.S. Lee, N. Rowe, and A.P. Milva (1974), An experimental and theoretical study of the D-region 1. Mid-latitude D-region electron density profiles from the radio wave interaction experiment, J. Atmosph. Terr. Phys., 36, 741-754.

Folkestad, K., B. Landmark, C. Skovic, and J. Kane (1969), Results of rocket measurements in the lower auroral ionosphere, J. Atmosph. Terr. Phys., 31, 835-844.

Friedman, H. (1959), Rocket observations of the ionosphere (summary paper), Proc. IRE, 47, 272-280.

Gardner, F.F., and J.L. Pawsey (1953), Study of the ionospheric D-region using partial reflection, J. Atmosph. Terr. Phys. 3, 321-344.

Gregory, J.B., and A.H. Manson (1967), Mesospheric electron number densities at 35° S latitude, J. Geophys. Res., 72, 1073-1080.

Gregory, J.B., and A.H. Manson (1969), Seasonal variation of electron densities below 100 km at mid-latitudes - II, electron densities and atmospheric circulation, J. Atmos. Terr. Phys. 31, 703-729.

Cruschnitz, E.H. (1974), Model investigations of radio wave propagation in the lower ionosphere to determine electron densities from MF pulse sounding, Radio Sci. 4, 659-667.

Hale, L.C., D.P Hoult, and D.C. Baker (1968), A summary of blunt probe theory and experimental results in Space research VIII, Proceeding of the Tenth Plenary Meeting of COSPAR, London, 25-28.

Hall, J.E. (1973), Lower ionosphere electron densities from rocket measurements employing LF radio propagation and dc probe techniques, Planet. Space Sci., 21, 119-131.

Hall, J.E., and K. Bullough (1963), A rocket-borne low-frequency propagation experiment to determine D-region electron densities, Nature, 200, 642-644.

Hall, J.E., and J. Fooks (1965), The electron distribution in the quiet D-region derived from rocket measurements of low-frequency propagation, Planet. Space Sci., 13, 1013-1030.

Haug, A. (1966), Electron densities in the auroral zone D-layer during quiet ionospheric conditions, Electron Density Profiles in the Ionosphere and Exosphere, (ed. Frihagen), (North Holland, Amsterdam), 61-65.

Haug, A., and E.V. Thrane (1967), D-region electron densities deduced from measurements of partial reflections at a middle latitude and at a low latitude station, Ground Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc. (Defense Research Board, Canada). 189-196.

Haug, A., M. Jesperson, J.A. Kane, and E.V. Thrane, (1970), Electron densities measured by the partial reflection method compared with simultaneous rocket measurements, J. Atmos. Terr. Phys., 32, 1139-1142.

Heikkile, W.J., J.A. Fejer, J. Hugill, and W. Calvert (1967), Comparison of ionospheric probe techniques, Space Research VII, 395-405.

Hewitt, L.W. (1969), Ionization increases associated with the small solar proton events of 5 February 1965 and 16 July 1966, Can. J. Phys., 47, 131-134.

Holt, O. (1963), Some experimental studies of the ionospheric D-region at high latitudes, Norwegion Defence Research Establishment, Tech. Note No. 3.

Holt, O., B. Landmark, and F. Lied (1960), Observations of electron density and collision frequency in the D-region during polar radio blackout conditions, Norwegion Defence Research Establishment, Tech. Note No. 2.

Hunt, B.G. (1973), A generalized aeronomic model of the mesosphere and lower thermosphere including ionospheric processes, J. Atmosph. Terr. Phys., 35, 1755-1798.

Jesperson, M., A. Haug, and B. Landmark (1966), Electron density and collision frequency observations in the Arctic D-region, Electron Density Profiles in Ionosphere and Exosphere, (ed. Frehagen), 27-30, (North Holland).

Jesperson, M., J.A. Kane, and B. Landmark (1968), Electron and positive ion density measurements during conditions of auroral absorption, J. Atmos. Terr. Phys., 30, 1955-1963.

Jesperson, M., and B. Møller Perderson (1970), Ionospheric observations during the annular solar eclipse of 20 May 1966 - III Four D-region electron density profiles measured by rocket techniques, J. Atmos. Terr. Phys., 32, 1859-1863.

Jesperson, M., J. Troem, and B. Landmark (1969), Electron density observations during the PCA event of 25 February 1969, Intercorrelated Satellite Observations Related to Solar Events, (ed. V. Minno and D.F. Page), (Riedel, Dordreche, Holland), 515-519.

Jesperson, M., O. Peterson, J. Rybner, B. Bjelland, B. Holt, and B. Landmark (1964), Electron density and collision frequency in the lower D-region during auroral absorption, 1963, Electron Density Distributions in the Ionosphere and Exosphere (ed. Thrane) 22-35, (North Holland).

Kane, J.A. (1961), Re-evaluation of ionospheric electron densities and collisional frequencies derived from rocket measurements of refractive index and attenuation, J. Atmos. Terr. Phys., 23, 338-347.

Kane, J.A. (1969a), D-region electron density measurements during the solar eclipse of May 20, 1966, Planet. Space Sci., 17, 609-616.

Kane, J.A. (1969b), D-region radio measurements at the magnetic equator, NASA Report X-615-69-499, (N70-14217).

Kane, J.A., and J. Troim (1967), Rocket measurements of D-region electron number densities at sunrise, J. Geophys. Res., 72, 1118-1120.

Knecht, R.W. (1963), The distribution of electrons in the lower and middle ionosphere, Proc. of XIV URSI General Assembly.

Krasnushkin, P.E., and N.L. Kolesnikov, (1962), Investigation of the lower ionosphere by means of long radio waves and low frequency probes installed in a rocket. Detection of a new ionospheric layer, Doklady Akademii nauk SSR, 146, 596-599, (Trans. Aerospace Infor. Div., Lab. Congress, A.D. Report 16-207).

Krasnushkin, P.E., and T.A. Knyazeva (1970), Diurnal, seasonal, and 11-year variations of the electron density in the lower ionosphere, Geomap. Geron. 10, 789-796.

Lee, H.A., and A.J. Ferraro (1969), Winter D-region electron concentration and collision frequency features obtained with high-power interaction measurements, J. Geophys. Res., 74, 1184-1194.

Mechtly, E.A., (1972), Changes of electron density with zenith angle, with sunspot cycle, and during eclipses, Aeron Report No. 48, (ed. Sechrist and Geller, Univ. of Ill. Urbana, Ill.) 353-358.

Mechtly, E.A., S.A. Bowhill, and L.G. Smith (1972), Changes of lower ionosphere electron concentrations with solar activity, J. Atmos. Terr. Phys., 34, 1899-1907.

Mechtly, E.A., M. Mukunda Rav, D.O. Skaperdos, and L.G. Smith (1969), Latitude variations of the lower ionosphere, Radio Sci., 4, 517-120.

Mechtly, E.A., C.F. Sechrist, Jr., and L. G. Smith (1972), Electron loss coefficients for the D-region of the ionosphere from rocket measurements during the eclipses of March 1970 and November 1966, J. Atmosph. Terr. Phys., 34, 641-646.

Mechtly, E.A., K. Seino, and L.G. Smith (1969), Lower ionosphere electron densities measured during the solar eclipse of November 12, 1966, Radio Sci., 4, 371-375.

Mechtly, E.A., and J.S. Shirke (1968), Rocket electron concentration measurements on winter days of normal and anomalous absorption, J. Geophys. Res., 73, 6243-6247.

Mechtly, E.A., and L.G. Smith (1968a), Growth of the D-region at sunrise, J. Atmosph. Terr. Phys, 30, 363-369.

Mechtly, E.A., and L.G. Smith (1968b), Seasonal variation of the lower ionosphere at Wallops Island during the IQSY, J. Atmosph. Terr. Phys., 30, 1555-1561.

Mechtly, E.A., and L.G. Smith (1970), Changes of lower ionosphere electron densities with solar zenith angle, Radio Sci., 5, 1407-1412.

Mechtly, E.A., L.G. Smith, and G.W. Henry (1973), Rocket observations of the winter anomaly, Summary of paper presented at COSPAR, Konstanz, F.R.G., Quoted by B.W. Denny and S.A. Bowhill, Partial Reflection Studies of D-Region Winter Variability, Univ. of Ill. Aeronomy Report No. 56.

Megill, L.R., G.W. Adams, J.C. Haslett, and E.C. Whipple (1971), Measurement of the effective electron loss rates in the D-region during polar cap absorption events, J. Geophys, Res., 76, 4589-4595.

Mitchell, J.D., L.C. Hale, R.V. Olson, J. Randhawa, and R. Rubio (1972), Positive ions and the winter anomaly, Radio Sci., 7, 175-179.

Mitra, A.P., and D.K. Chakrabarty (1971), Models of lower ionosphere electron density profiles, Space Research XI, 1013-1018.

Montbriand, L.E., and J.S. Belrose (1972a), Effective electron loss rates in the lower D-region during the decay of solar x-ray flare events, Radio Sci., 7, 133-142.

Montbriand, L.E., and J.S. Belrose (1972b), Effective electron loss rates in the lower D-region during the decay phases of solar x-ray (SXR) flare events, Aeron. Report No. 48, (University of Ill., Urbana, Ill.), 290-297.

Montbriand, L.E., and J.S. Belrose (1972c), Effective electron loss rates in the lower D-region during the decay of solar x-ray flare events, Radio Sci., 7, 133-142.

Nertney, R.J. (1953), The lower E and D-region of the ionosphere as deduced from long radio wave measurements, J. Atmos. Terr. Phys., 3, 92-107.

Nicolet, M., and A.C. Aikin (1960), The formation of the D-region of the ionosphere, J. Geophys, Res., 65, 1469-1483.

Oya, H., and T. Oboyashi (1968), Observation of the microstructure of the ionospheric electron density profile by gyro-plasma probe, Space Research VIII, 332-338.

Pederson, A., J. Troim, and J.A. Kane (1970), Rocket measurements showing removal of electrons above the mesopause is summer at high latitude, Planet and Space Sci., 18, 945-947.

Phelps, A.V. (1960), Propagation constants for elecromagnetic waves in weakly ionized, dry air, J. App. Phys, 31, 1723-1729.

Prakash, S., B.H. Subbaraya, and S.P. Gupta (1968), A study of the equatorial E-region during evening twilight using a longwire probe, J. Atmos. Terr. Phys., 30, 1193-1207.

Prakash, S., B.H. Subbaraya, and S.P. Gupta (1971), Investigation of the daytime lower ionosphere over the equator using Langmuir probe and plasma noise probe, J. Atmosph. Terr. Phys., 33, 129-135.

Prakash. S., B.H. Subbaraya, and S.P. Gupta (1972), Electron density profiles in the equatorial lower ionosphere at Thumba, Aeron Report No. 48, (ed. C.F. Sechrist. Jr., and M.A. Geller, Univ. of Ill., Urbana, Ill.) 359-363.

Riedler, W. (1969), Auroral rocket research in Scandinavia, Small Rocket Instrumentation Techniques, Proceedings of Eleventh Plenary Meeting of the Committee on Space Research, Tokyo.

Rowe, J.N. (1972), Model studies of the lower ionosphere, Ionospheric Research Sci. Report 406, (Penn. State. Univ.).

Rowe, J.N., A.J. Ferraro, and H.S. Lee (1969), Changes in electron density and collision frequency at University Park, Pennsylvania during the stratospheric warming of 1967-68, J. Atmos. Terr. Phys. 31, 1077-1084.

Rowe, J.N., A.J. Ferraro, and H.S. Lee (1970), Variation of electron density in the D-region, Nature, 226, 1116-1117.

Rowe, J.N., A.J. Ferraro, H.S. Lee, R.W. Kreplin, and A.P. Mitra (1970), Observations of electron density during a flare, J. Atmosph. Terr. Phys., 32, 1609-1614.

Sagalyn, R.C., M. Smiddy, and W.P. Sullavin (1967), Experimental investigation of the nighttime E-region, Space Research, Vol. VII, (ed. R.L. Smith-Rose), 448-463.

Sagalyn, R.C., M. Smiddy, W.P. Sullavin, R. Wand, G. Thome, L.M. Lalonde, and H.C. Carlson (1968), Paper presented at spring URSI meeting, Washington, D.C.

Sagalyn, R.C., and R.H. Wand (1971), Daytime rocket and Thomson scatter studies of the lower ionosphere, J. Geophys. Res., 76, 3783-3799.

Sechrist, C.F., E.A. Mechtly, and J.S. Shirke (1969), Coordinated rocket measurements of the D-region winter anomaly -- I. Experimental results, J. Atmos. Terr. Phys., 31, 145-153.

Smiddy, M., and R.C. Sagalyn (1967), Investigation of electrical phenomena in the equatorial ionosphere, Space Research, Vol. VII, (ed. R.L. Smith-Rose), 428-445.

Smith, L.C. (1963), A dc probe for rocket measurements in the ionosphere, Geophys. Corp. of America, Tech. Report 63-19-N.

Smith, L.C. (1965), Rocket observations of sporadic E and related features of the E-region, G.C.A. Tech. Report, 15-22-N.

Smith, L.C. (1966), Rocket observations of sporadic E and related features of the E-region, Radio Sci., 1, 178-182.

Smith, L.C. (1970), A sequence of rocket observations of night-time sporadic-E, J. Atmosph. Terr. Phys., 32, 1247-1257.

Smith, L.C., C.A. Accardo, L.H., Weeks, and P.J. McKinnon (1965), Measurements in the ionosphere during the solar eclipse of 20 July 1963, J. Atmosph. Terr. Phys., 27, 803-809.

Smith, R.A., T.N.R. Coyne, R.C. Loch, and I.A. Bourne (1967), Small perturbation wave interaction in the lower ionosphere. Pt 3, Measurements of electron densities, Ground Based Radio Wave Propagation Studies of the Lower Ionosphere, Conf. Proc., (Defence Research Board, Canada), 335-358.

Smith, L.C., L.H. Weeks, and P.J. Mckinnon (1966), Investigation of the D and E regions of the ionosphere during the international quiet sun year, NASA Report No. CR-391.

Somayajulu, Y.V., and A.C. Aikin, Jr. (1969), Rocket measurements of changes in the ionization in the lower ionosphere and solar x-rays during a solar flare event, Aeron Report No. 32, (ed. C.F. Sechrist, Jr., Univ. of Ill., Urbana, Ill.), 373-375.

Somayajulu, Y.V., M.B. Avadhanulu, K.S. Zalpure, and S.C. Gary (1971), Some preliminary results of rocket sounding of the D-region at the geomagnetic equator, Space Research XI, Leningrad, USSP, (ed. Kondvatyev, Rycroft, and Sagan), 1131-1137.

Sturges, D.J. (1973), An evaluation of ionospheric probe performance -- II. The influence of vehicle wake effects on electron density and temperature measurements, Planet Sp. Sci., 21, 1049-1071.

Tanenbaum, B.S., J.H. Shariro, and J.E. Reed (1973), Phase-difference distributions in a D-region partial-reflection experiment, Radio Sci., 8, 437-448.

Thomas. L., and M.D. Harrison (1970), The electron density distributions in the D-region during the night and pre-sunrise period, J. Atmos. Terr. Phys.), 32, 1-14.

Thomas, L., P.M. Gondhalekar and M.R. Bowman (1973), The negative-ion composition of the daytime D-region, J. Atmosph. Terr. Phys., 35, 397-404.

Thrane, E.V. (1966), Experimental studies of the stucture of the ionospheric D-region, Norwegion Defence Research Establishment, Report No. 54.

Thrane, E.V. (1972), Information on the D- and E-region electron density profiles, Radio Sci. 1, 143-152.

Thrane, E.V. and W.R. Piggott (1966), The collision frequency in the E- and D-regions of the ionosphere, J. Atmosph. Terr. Phys. 28, 721-737.

Thrane, E.V., A. Hany, B. Bjelland, M. Anastassiades, and E. Tsagakis (1968), Measurements of D-region electron densities during the International Quiet Sun Year, J. Atmosph. Terr. Phys, 30, 135-150.

Ulwick, J.C. (1972), Highlights of COSPAR Symposium on November 1969 solar particle event, Aeron. Report No. 48 (ed. Sechrist and Geller, Univ. of Ill, Urbana, Ill.) 405-415.

Ulwick, J.C. (1972), Eclipse rocket measurements of charged particle concentrations, J. Atmosph. Terr. Phys., 34, 659-665.

Ulwick. J.C., K.D. Baker, and B. Sellers (1970), Rocket measurements in a PCA event, Space Research X, Prague, (ed. Donohue, Smith, and Thomas), 25-830.

Ulwick, J.C., W. Pfister, and K.D. Baker (1968), Rocket measurements of bremstrahlung x-rays and related parameters during auroral absorption events, Space Res., VIII, 171-177.

Von Biel (1971), Determination of D-region electron densities within the scattering region, J. Geophys. Res., 76, 5365-5367.

Von Biel, H.A., W.A. Flood, and H.G. Camnitz (1970), Differential phase partial-reflection technique for the determination of D-region ionization, J. Geophys. Res., 75, 4863-4870.

Yonezawa, T. (1962), Probe measurements of the electron and positive ion densities in the E and R region by rockets, Proc. NATO Advanced Study Inst. on Electron Density Profiles in the Ionosphere and Exosphere, Skeikampen, Norway, (ed. B. Moehlum, Pergamon, London).