Adv. Space Res. Vol. 8, No. 4, pp. (4)201–(4)204, 1988
Printed in Great Britain.

0273–1177/88 $0.00 + .50

LAY-FUNCTIONS FOR *F*2 PROFILES

L. Bossy,* R. R. Gamache** and B. W. Reinisch**

**Université Catholique de Louvain, B-1348 Louvain-la Neuve, Belgium*
***University of Lowell Center for Atmospheric Research, Lowell MA 01854, U.S.A.*

INTRODUCTION

Modern ionosondes /1/ calculate the vertical electron density profiles in real time providing a good data base for the global modeling of the ionospheric electron density distribution. The Digisonde 256 outputs the profiles in form of coefficients for a polynomial representation /2/ for each of the layers. When first publishing their results, Reinisch and Huang /3/ mentioned the possibility of substituting LAY functions for the polynomial profile presentations. In this paper we study the fitting of LAY functions profiles obtained in real time by Digisondes at Argentia, Newfoundland (47°N, 54°W), Richfield, Utah (39°N, 112°W) and Natal, Brazil (5.7°S, 65°W). We use the technique proposed in /4/ to determine the LAY parameters SC and HX. Because of its efficiency this algorithm lends itself to real time processing.

FITTING OF LAY FUNCTIONS AND IMPLEMENTATION

The representation of the electron density profile of the F2 layer by a single LAY function is discussed. The LAY function used for this purpose has described in Reference 4. The advantage of the LAY function fit of the profile is that in general the entire F2 profile is well represented by one LAY function, defined by only four parameters foF2 (critical frequency), H_{max} (peak height), HX (height parameter) and SC (scale parameter) /4/. Other methods like the ULCAR Chebyshev polynomial representation requires five coefficients plus the beginning and ending frequency of the layer. Titheridge's POLAN true height analysis program /5/, in its preferred mode (6), uses six coefficients per point plus the starting frequency and height; in the POLAN polynomial mode used in the Digisonde (a 4th order polynomial), 11 parameters are needed to represent the F2 profile.

LAY function fitting was performed for some three thousand electron density height profiles which were calculated from ionograms with the POLAN method using a fourth order polynomial expansion of the F2 profile. The form of the LAY function always assures a good fit at the layer peak, but it must be checked how far down in frequency the fit is acceptable. We defined error thresholds of 3 km, 5 km and 10 km to determine the lower frequency limit of the fit. The 3 km threshold resulted in too narrow frequency intervals for which the fit is acceptable, and 10 km appears too coarse a measure. With a 5 km error, the LAY functions can describe almost the entire F2 region, so we decided to select the 5 km threshold for further analysis.

Our LAY analysis program computes and records the average absolute error per point in km, together with the number of frequency points and the threshold frequency fminLAY. The values of foE, foF1 (when present), foF2, and the inflection point of the F2 profile are saved to study the range of the LAY fits. From the parameters, the ratios HX/H_{max} and $(H_{max}-HX)/SC$ are calculated and stored. Since the profiles are available, we also calculate the factor G from $H(0.5) = G\ H_{max}$, where H(0.5) is the height where the electron density is $N = 0.5\ N_{max}\ F2$. The G factors found for the profiles are compared with the value G = 0.8 suggested by Gulyaeva /6/.

Figure 1 is an example of the LAY function fits to a profile from Richfield, Utah, October 11, 1984 at 20:09 UT (12:09 LT). Here the particular LAY function plotted is for fitting points at $f_1 = 0.90*foF2$ and $f_2 = 0.65*foF2$ and is shown along with the profile.

*Also Institut d'Aeronomie Spatiale, B-1180, Bruxelles, Belgium

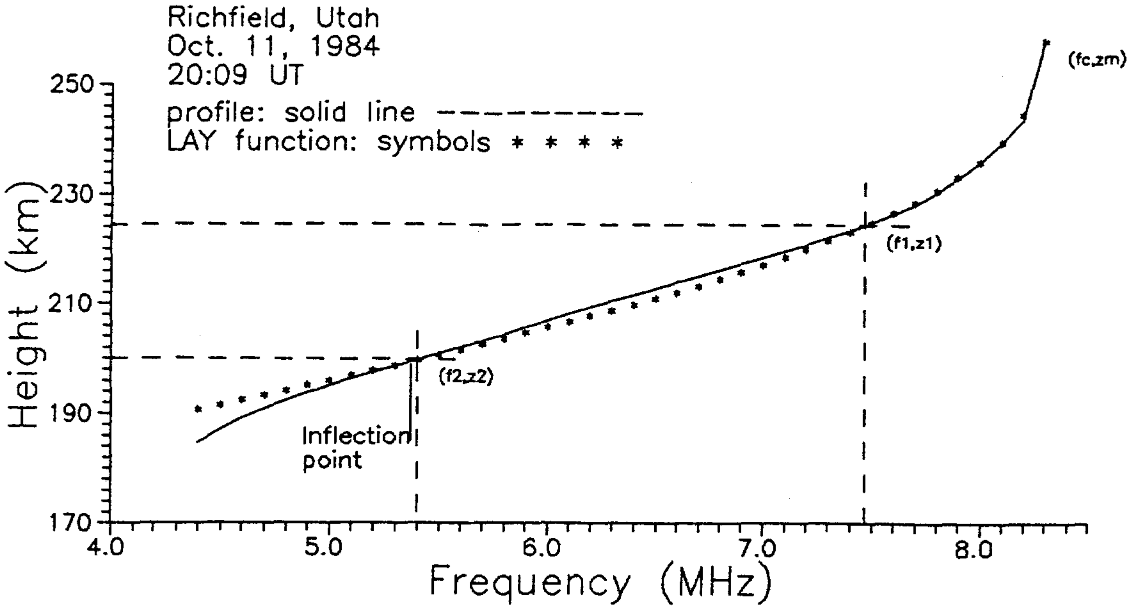

Figure 1. Fitting LAY function profile. The three selected points were (8.3 MHz, 285 km), (7.5 MHz, 224 km), and (5.4 MHz, 200 km). The LAY function approximates the F2 profile to frequencies well below the inflection point. foFl for this ionogram is 4.3 MHz.

This fit has an average absolute error per point of 1.08 km with a 5 km maximum error, and agrees with the profile. The LAY parameters for this F2 profile are HX = 197 km and SC = 20.5 km.

DOMAIN OF VALIDITY OF THE FIT

Our studies show that most of the time the LAY functions, with 5 km maximum error, represent the entire F2 layer down to f = foE or foFl during the day, and to the first scaled ionogram frequency during the night. The solid lines in Figure 2 represent the median values for Argentia, Richfield and Natal of the ratio fminLAY/foF2. For Argentia, we analyzed profile data for February/March, May/June and October/November 1986 (the upper three curves in Figure 2). The dashed lines represent the ratios foFl/foF2 during daytime when the Fl layer exists. The Argentia data show fminLAY to be within 5% of foFl, i.e. not more than about 200 kHz above foFl. Without an Fl layer, fminLAY reaches down to the lower F region. The horizontal lines at 70.7% for the Argentia curves indicate the level where the electron density N is half the maximum density of the layer.

DIURNAL VARIATIONS OF LAY PARAMETERS

For modeling purposes, it is desirable that the LAY parameters do not vary too rapidly as a function of time, and that characteristic parameter values exist for each season and time of day. Figure 3 shows the diurnal variations of the median values for R = HX/Hmax, expressed in percent. For Argentia, the median R lies generally between 70 and 80%, except during noontime in summer, when R dips down to 60%. The relatively large data set for

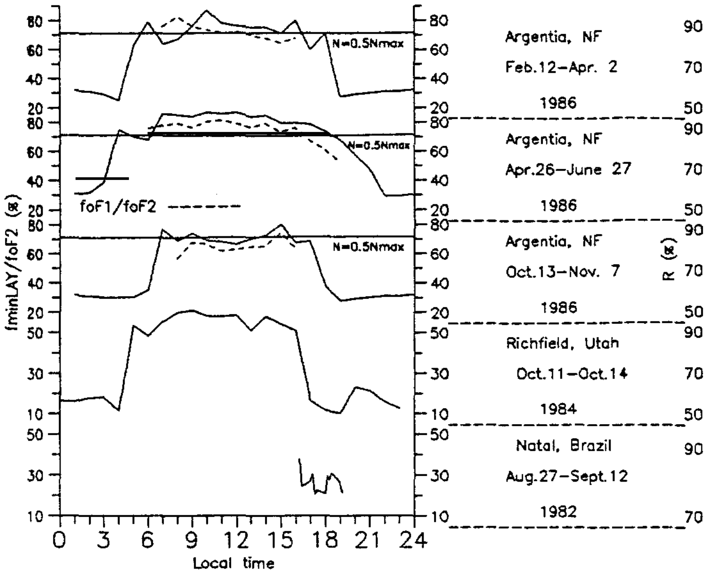

Figure 2. Diurnal variation of median fminLAY/foF2. The dashed lines show the ratios foF1/foF2, indicating that fminLAY is generally within 200 kHz of foF1.

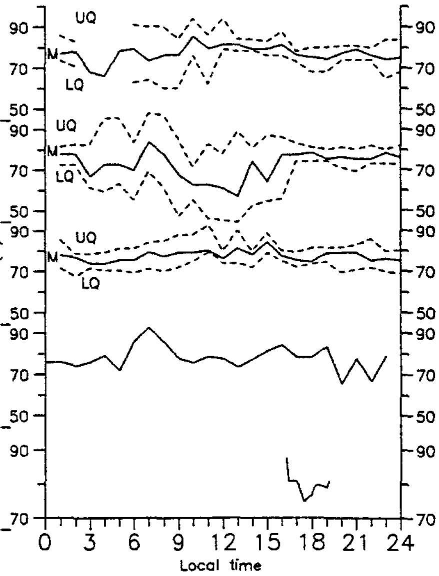

Figure 3. Diurnal variation of median for R=HX/Hmax. The upper and lower quartiles (UQ and LQ) indicate a 10% spread in HX/Hmax.

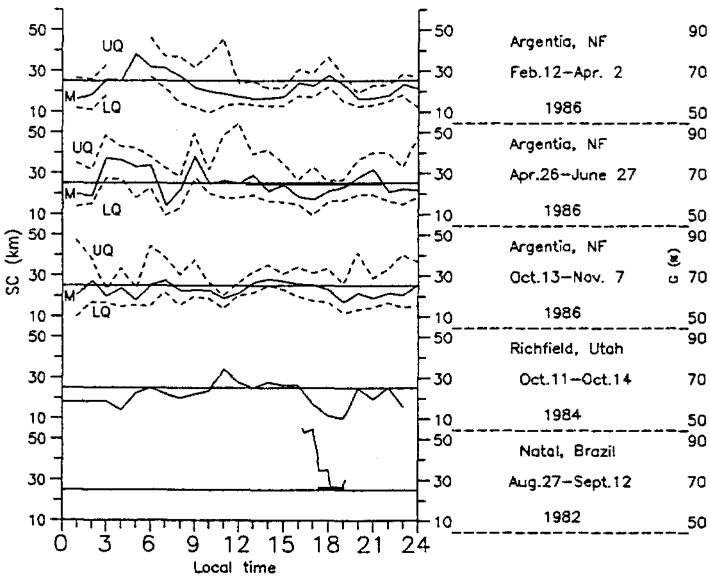

Figure 4. Diurnal variation of median SC. The median SC values for the mid latitude stations lie between 25 km ±10 km.

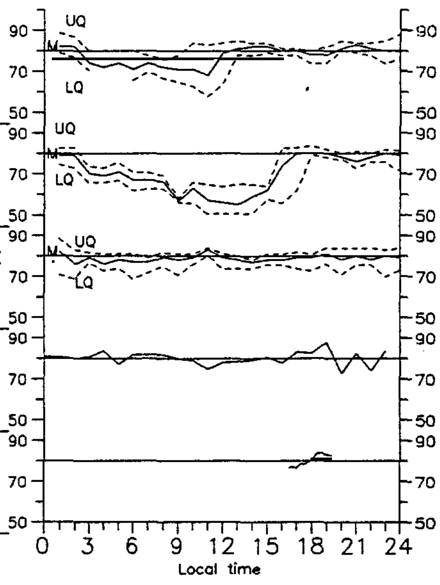

Figure 5. Diurnal variation of median G factor. G is close to 80% unless foF1 > 0.707*f_c.

Argentia allowed to determine the spread in R by calculating the upper and lower quartiles, marked UQ and LQ respectively. It is interesting to see, that for periods of small diurnal variations the data spread is also small.

The relatively large R variations for Richfield are possibly the result of the small data sample (only four days). For the equatorial station Natal, the available median R values all lie between 75 and 85%.

The median scale heights SC are generally confined to values between 25 km ±10 km, at least for Argentia and Richfield. The spread in SC values for Argentia, as indicated by the upper and lower quartiles, is at times considerable making it difficult to select a suitable SC for modeling purposes. The equatorial data for 1982 (high sunspot number) show a very different behavior, at least during the three hour period from 1630 to 1930 LT. SC decreases rapidly from 60 to 25 km. It would be necessary to study a larger equatorial data set to test the diurnal variation of SC at the equator.

Since all the data were available in the computer, we also calculated the Gulyaeva G factor /6/. The median values for the three stations discussed for the LAY fittings are shown in Figure 5. For fall, the G-value is close to 80% on all three stations. However, substantial deviations exist in early spring and summer at Argentia, when during daytime the median value dips below 60%. Of course, this is the effect of the F1 layer. In summer foF1 is consistently larger than 0.707 foF2, i.e. N(foF1) > 0.5 N_{max}, during the day (Figure 2), and the F2 layer shape factor G is ill defined.

CONCLUSIONS

The F2 layer profiles can be expressed in terms of LAY functions with parameters HX/Hmax and SC that have a fairly small diurnal variation in their median values. Our studies could be expanded to express the entire E-F1-F2 profile as a linear combination of LAY functions, and investigate whether the LAY parameters HX/Hmax and SC still maintain a systematic behavior.

REFERENCES

1. B. W. Reinisch, New Techniques in Ground-Based Ionospheric Sounding and Studies, Radio Sci. 21, #3, 331-341 (1986).

2. B. W. Reinisch, R. R. Gamache, X. Huang and L. F. McNamara, Real Time Electron Density Profiles from Ionograms, This Issue (1987).

3. B. W. Reinisch and Huang Xueqin, Automatic Calculation of Electron Density Profiles from Digital Ionograms. 3. Processing of Bottomside Ionograms, Radio Sci. 18, #3, 477-492 (1983).

4. L. Bossy, The Determination of LAY-Parameters for a Given Profile, Adv. in Space Res. Vol. 7, No. 6, p. 35 (1987).

5. J. E. Titheridge, Ionogram Analysis with the Generalized Program POLAN, Rept. UAG-93, World Data Center A (S.T.P.), Boulder, CO (1985).

6. T. L. Gulyaeva, Implementation of a New Characteristics Parameter into the IRI Sub-Peak Electron Density Profile, Adv. Space Res., 2, No. 10, 191-194 (1983).

ACKNOWLEDGEMENT

The work of the University of Lowell authors was in part supported by the Air Force Geophysics Loboratory, Hanscom Air Force Base, Massachusetts.