EFFORTS TO PRODUCE REALISTIC IONOGRAMS FROM ELECTRON DENSITY PROFILES IN THE F1 REGION

L.A. McKinnell(1) and A.W.V. Poole(2)
(1)Hermann Ohlthaver Institute for Aeronomy, Department of Physics and Electronics, Rhodes University,
Grahamstown, 6140, South Africa
Email: L.McKinnell@ru.ac.za

(2) As (1) above, but Email: A.Poole@ru.ac.za

ABSTRACT

The authors have developed a new neural network (NN) based model, called the LAM model, for predicting the bottomside ionospheric electron density profile for Grahamstown (33.3°S, 26.5°E), South Africa. Archived electron density profile descriptions that were derived from a Lowell Digisonde (DPS) were used for the development of the LAM model. It was found that profiles determined from these descriptions exhibited an unnatural step at the F1-F2 boundary, which produced unrealistic ionograms in the F1 region. This paper discusses a smoothing technique that was implemented in the LAM model and tested on actual DPS profiles. This technique proved to be successful in smoothing the F1-F2 boundary and producing realistic ionograms for all states of the F1 layer.

INTRODUCTION

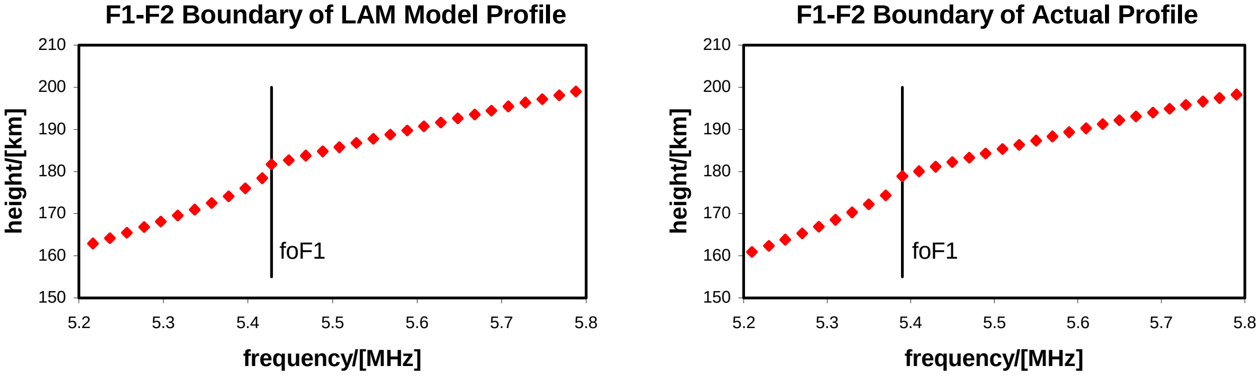
We have developed a new neural network (NN) based model [1], called the LAM model, for predicting the bottomside ionospheric electron density profile for Grahamstown (33.3°S, 26.5°E), South Africa. The archived ionospheric dataset for Grahamstown contains five years of electron density profile data, derived from digisonde (DPS) measurements. These DPS ionograms were scaled using the automatic scaling software, Artist, developed by the University of Massachusetts Lowell Center for Atmospheric Research (UMLCAR). Artist provides a description of the electron density profile in the form of a set of Chebyshev coefficients for each layer. In conjunction with the peak parameters for each layer, the coefficients are used in an analytical equation [2] to determine the real height at each given frequency. Since the LAM model was developed using archived DPS data, the same Chebyshev method was employed to determine the profile after the required parameters have been predicted.

We have found that any profile determined by using this Chebyshev method will exhibit an unnatural step at the F1-F2 boundary. Although this method ensures that the peak height of the F1 layer, hmF1, is equal to the starting height of the F2 layer, hsF2, the derivative of the profile, dh/df, tends to infinity at the critical frequency of the F1 layer, foF1. Therefore the virtual height at foF1 will tend to infinity, which means that there will always be a cusp on the ionogram at this frequency, which is seldom true for the F1 region. This paper discusses an attempt to modify the predicted profile in the F1 region to overcome this problem and produce realistic ionograms.

Two examples of the unnatural F1-F2 boundary are shown in fig.1, one is an actual DPS profile and the other a LAM model predicted profile. The profiles have been enlarged to show only the area surrounding the F1-F2 boundary and the vertical line identifies the location of the foF1 value.

MODIFYING THE PROFILE

The condition on an ionogram where a F1 cusp is not well defined and an accurate foF1 value cannot be scaled is referred to as an L condition. Ionograms from twenty-five years prior to 1998 were measured with a chirpsounder located at the Grahamstown station and manually scaled. Instances of L condition were recorded for this data. We have used this information to train a NN (“F1 Probability NN”) to predict the probability of the existence of a F1 layer, including when to expect an L condition. The F1 Probability NN can also provide us with information regarding the number of hours in a particular day over which a definite F1 layer can be expected.



a) b)

Fig. 1. The area surrounding the F1-F2 boundary of a profile is shown for a) a LAM model predicted profile and b) an actual DPS profile. At foF1 the slope of the profile tends to infinity, which explains the unnatural step in the profile at the F1-F2 boundary.

Using this information a smoothing technique was applied to the profiles. The main function of the technique is to smooth out the F1-F2 boundary, however we found that this also resulted in more realistic ionograms. Briefly, the technique involves fitting a third order polynomial between two points on the profile, f1 and f2, located on either side of foF1. The location of f1 and f2 appeared to be dependent on the requirement for a sharp cusp on the ionogram. After examining many ionograms, we decided on a sharp cusp limit of three hours. Therefore, we allow for a sharp foF1 cusp on the ionogram from three hours after the definite F1 start hour to three hours before the definite F1 end hour. The definite F1 start and end hours are determined by the F1 probability NN. The profile is determined at discrete frequency intervals of 0.02MHz, and f1 and f2 are located at n points before and m points after foF1 respectively. The values of n and m vary according to the type of input set; where an L condition is expected n and m were chosen to be 10 and 50, where a sharp cusp is expected n and m were chosen to be 6 and 3, and at times between the L and sharp cusp conditions n and m were chosen to be 3 and 50.

This smoothing technique is applied whenever a F1 layer is inserted into the profile, irrespective of whether that layer is in the L condition state or not.

RESULTS

Fig.2 and fig.3 each show an example of a predicted LAM model profile before and after the smoothing technique was applied. The example shown in fig.2 is for an input set where we would expect a sharp foF1 cusp to appear on the ionogram and fig.3 is for an input set where an L condition state has been predicted as probable.

CONCLUSION

This smoothing technique has been successfully applied to both actual DPS profiles and LAM model predicted profiles. By using this technique a smooth transition between the F1 and F2 layers is accomplished as well as more realistic ionograms in the F1 region.

Future plans include revisiting all Grahamstown DPS ionograms and developing more stringent conditions under which f1 and f2 are selected. Also, the three hour limit that is used for deciding times when a sharp cusp would be expected, was determined after a cursory look at many ionograms. A more rigid criterion could be determined if more information was extracted from the available archived ionograms. Neural networks could possibly be employed for this task.

REFERENCES

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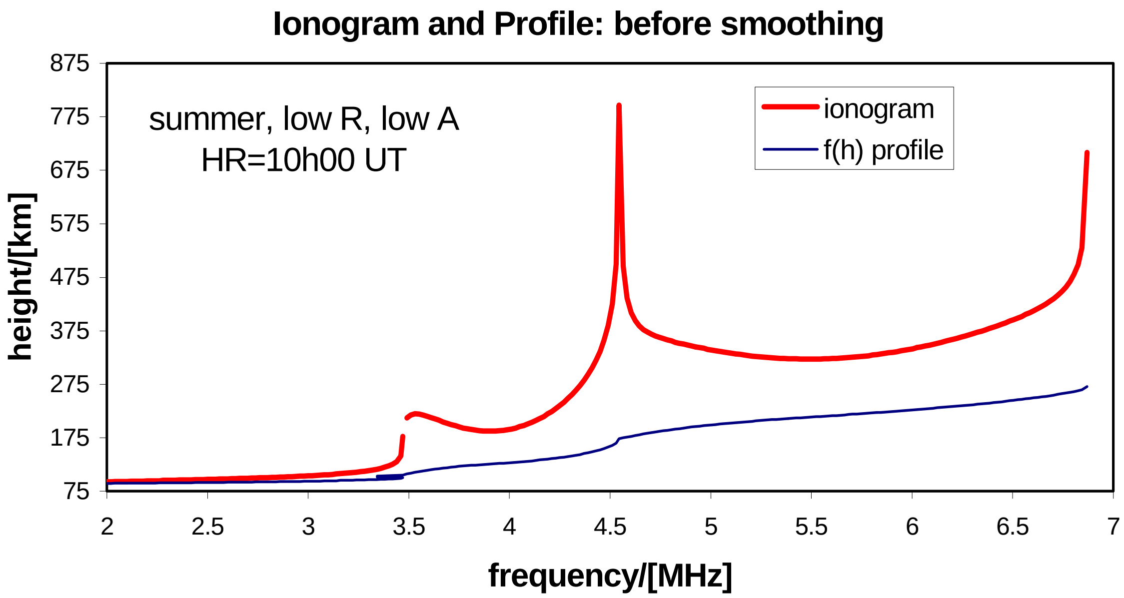
[2] X. Huang and B.W. Reinisch, “Vertical Electron Density Profiles from the Digisonde Network”, *Advances in Space Research*, vol. 18, pp. 121-129, 1996.



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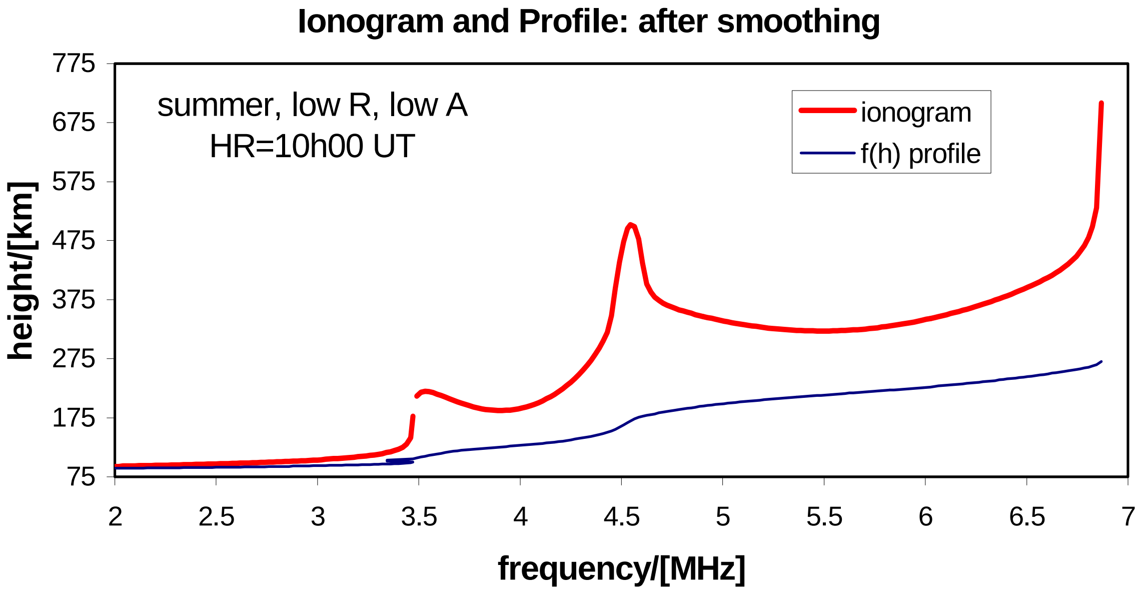
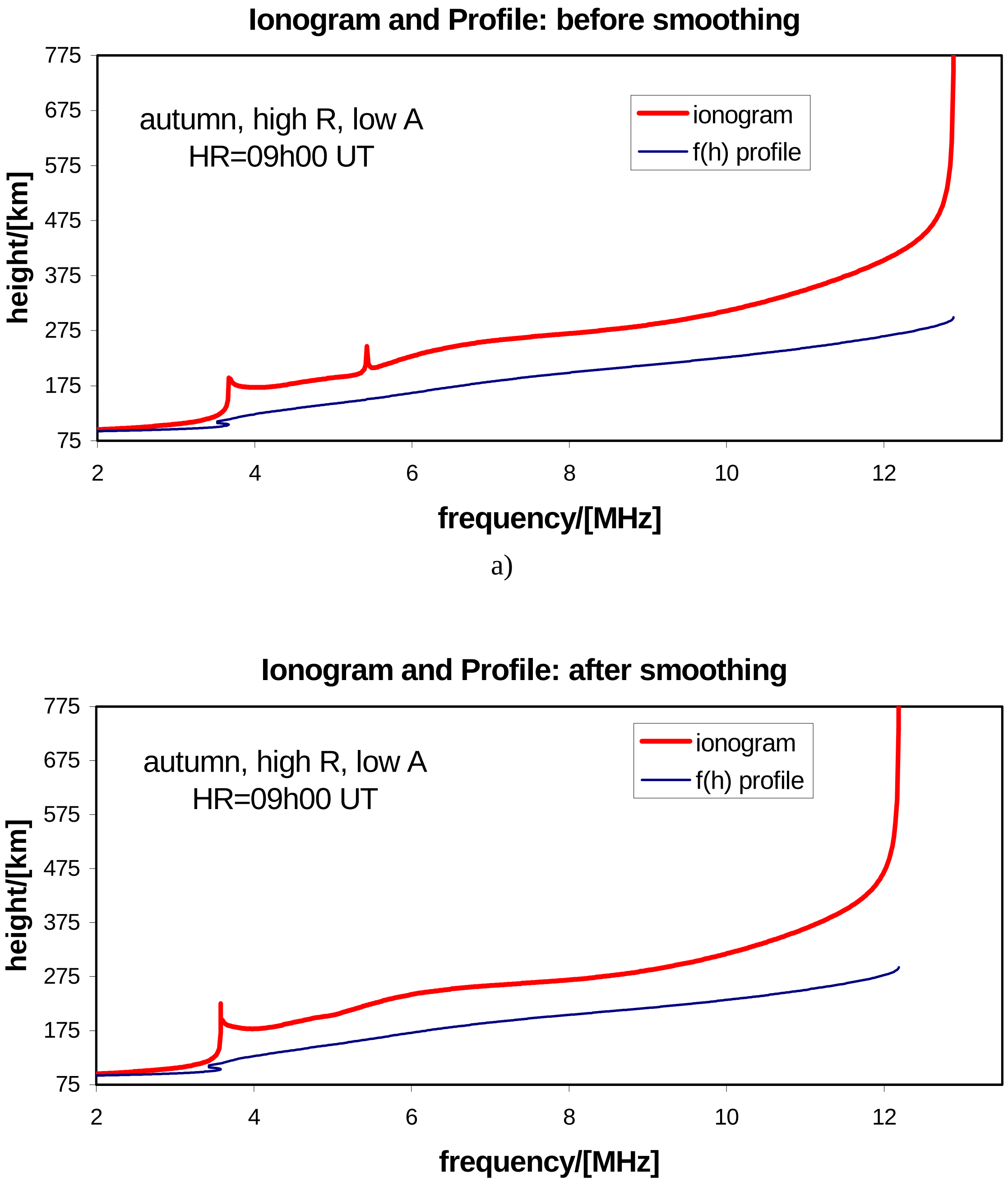


b)

Fig. 2. A LAM model predicted profile with its equivalent ionogram for Grahamstown at 10h00 UT on a summer day at low solar (R) and magnetic (A) activity. This is an area of the input space where we would expect a cusp at foF1 on the ionogram. Figure a) is before the smoothing technique has been applied and figure b) is after.



a)

b)

Fig. 3. A LAM model predicted profile with its equivalent ionogram for Grahamstown at 09h00 UT on an autumn day at high solar (R) and low magnetic (A) activity. This is an area of the input space where an L condition state was predicted as probable. Figure a) is before the smoothing technique has been applied and figure b) is after.