NEURAL NETWORKS AND LONG-TERM TRENDS IN foF2

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ABSTRACT

In this paper we make use use of Neural Networks to establish the average behaviour of the ionosphere for several stations that have a long data record, under specific conditions. This allows a predicted behaviour, based on the known influences of season, local time, solar and magnetic activity, which is then subtracted from the measured values, after which the residuals are investigated for long-term trends by means of linear regression. The stations investigated are Grahamstown (32.3°S, 26.5°E), Sodankyla (67.4°N, 25.4°E), Concepcion (36.1°S, 74.2°W) and Slough (52.4°N,1.6°W). Varying degrees of negative trends are found for the noon foF2 for all four stations.

LONG-TERM TRENDS

Several authors have recently shown evidence of long-term changes in the ionosphere at certain stations [1], [2], [3]. Because of the extreme variability of the ionosphere due to diurnal, seasonal, solar cycle and magnetic activity influences, an overriding problem has been the isolation of the long-term trends from these effects. Some sort of averaging procedure is required so that one can compare the average behaviour at two different times, separated by many years, being certain that the same conditions apply in each case in respect of the known dependencies. In this paper we make use of a Neural Network to learn the average behaviour of the foF2 under specific conditions, at a specific station that has a long data record. The NN will then provide predicted behaviour, based on the aforementioned known influences, which is then subtracted from the measured values. The residuals are investigated for long-term trends by means of linear regression. Since the Neural Network has no input to indicate epoch, it is unaware of any long-term trend, which is consequently preserved in the residuals if they are ranked chronologically. Details of this method, one of two methods we have used to provide a detailed look at the long-term trends on foF2 for the Grahamstown station, are given in [4].

The technique is thus very powerful, since it allows one not only to evaluate long-term trends, but to evaluate them for different combinations of season, solar and/or magnetic activity. Furthermore, since the yearly decline is specified in terms of the coefficient of the dependent variable in a linear regression, it is possible to determine a standard error for each evaluation, which is a good measure of the confidence with which one can view the results.

The parameter foF2 is chosen for analysis because of its ready availability. Not all stations show significant changes, however, we have found that where present, the changes are themselves dependent on the four influences mentioned earlier. The technique is applicable to any hour, or any season, but for illustrative purposes we report the percentage decrease per annum for 12h00 noon (local time) for four stations, averaged over all solar, magnetic and seasonal variations. The residuals plotted in Figs. [1] to [4] are calculated according to DfoF2% = [foF2(meas) - foF2(NN)] * 100/foF2(NN], and are plotted chronologically against time. The regression line fits the linear function DfoF2% = m * year + C, which yields m as the average percentage rate of change in foF2 per year.

We have found that all four of these stations show a negative trend in the noon values of foF2 over the periods of time indicated. The following table summarises the findings:

Station	Data period	trend m/[%/year]	Uncertainty/[%/year]
Grahamstown	1973-2000	-0.175	+/- 0.015
Sodankyla	1957-1989	-0.165	+/- 0.013
Concepcion	1957-1994	-0.101	+/- 0.012
Slough	1947-1995	-0.0252	+/- 0.0068

In this paper, we are only reporting our findings with regard to the negative trend in foF2, without any attempt at an explanation, since our results support those given in [2] and [3]. We do note, however, that [3] gives a small, but positive trend in foF2 at Slough. We feel that our small, but negative trend at Slough is reliable since it is significant well within the error in m, calculated according to standard regression practice.

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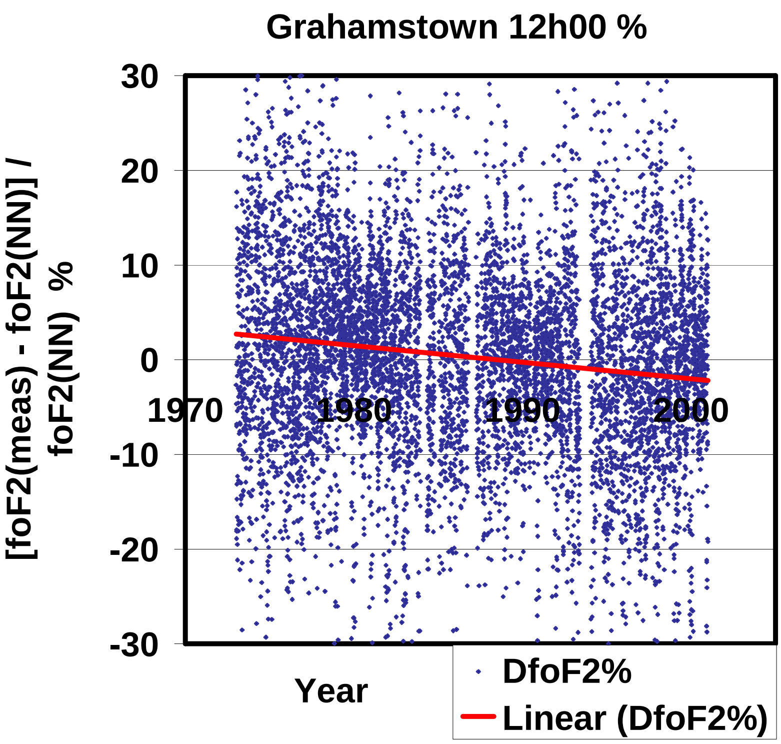

Fig. 1. Residuals and regression line for Grahamstown.

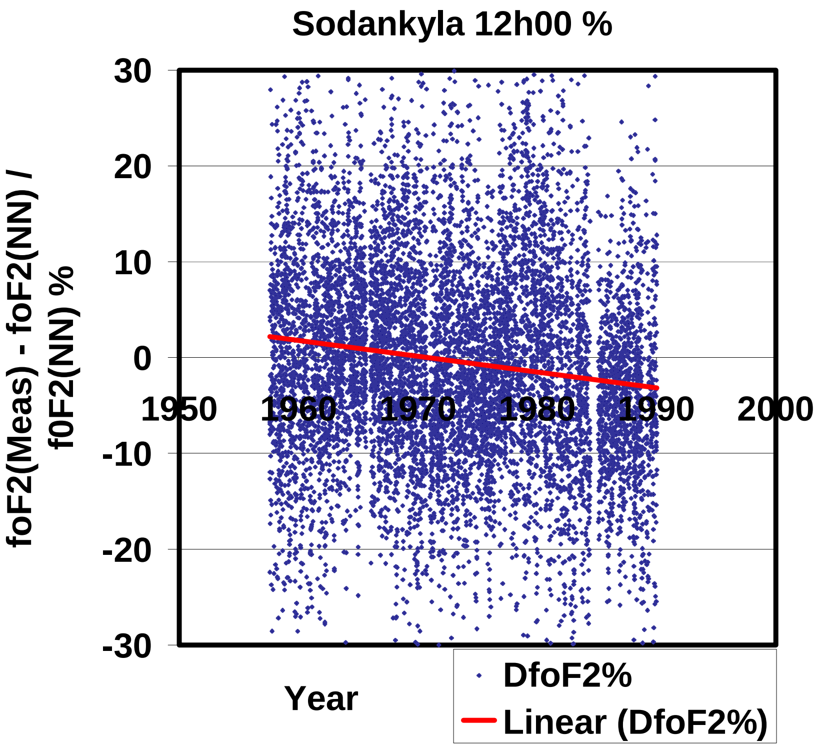

Fig. 2. Residuals and regression line for Sodankyla.

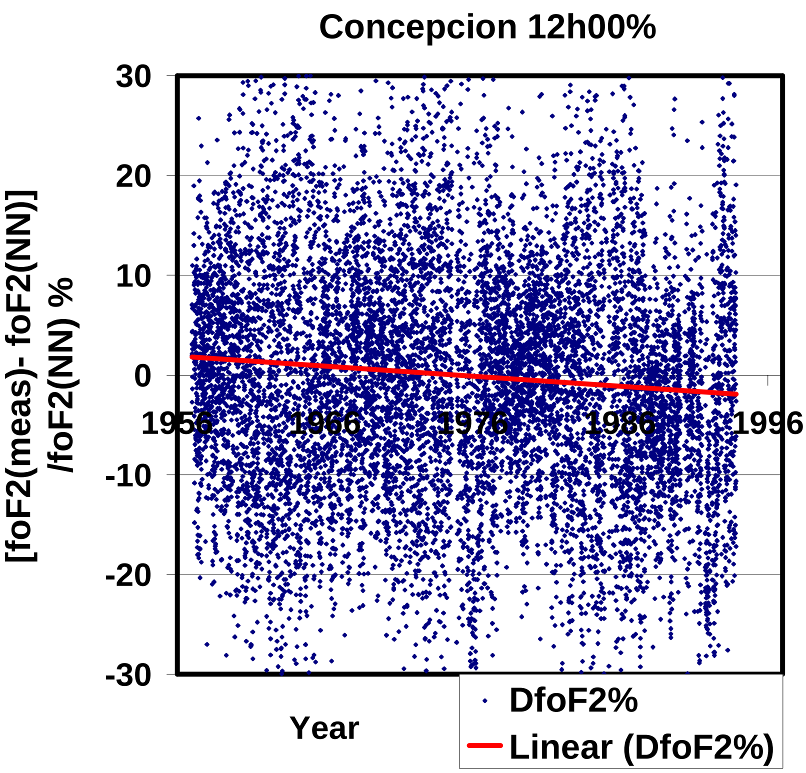

Fig. 3. Residuals and regression line for Concepcion.

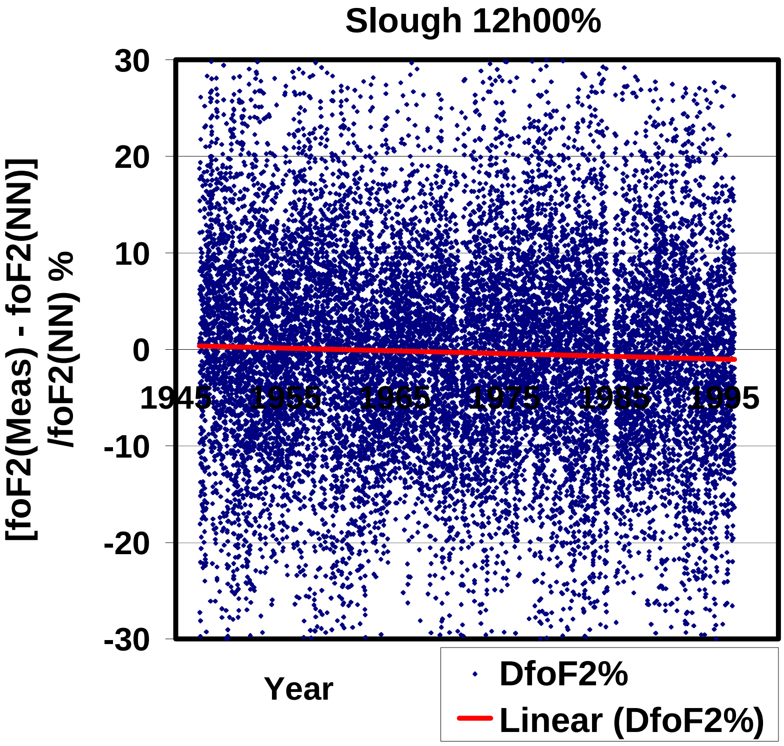

Fig. 4. Residuals and regression line for Slough.