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The INGV software for the automatic scaling of foF2 and MUF(3000)F2 from ionograms: A performance comparison with ARTIST 4.01 from Rome data

Michael Pezzopane*, Carlo Scotto

Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Rome, Italy

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Abstract

The performance of a computer program, called Autoscala, for the automatic scaling of foF2 and MUF(3000)F2 from ionograms has been extensively tested. Results of comparisons between automatically and manually scaled data are shown both for Autoscala and for ARTIST (release 4.01). Particular attention has been paid to the cases in which the ionograms have a truncated trace. The problem of the rejection of bad quality ionograms has been also considered. The analysis of data shows that the reliability of values automatically given as output by Autoscala is good. For the data set considered Autoscala seems to operate better than ARTIST.

Keywords: Ionosonde; Ionogram scaling; Automatic scaling; Ionosphere monitoring

1. Introduction

Recently the INGV (Istituto Nazionale di Geofisica e Vulcanologia) developed an ionosonde, called AIS (Advanced Ionospheric Sounder), with minimum transmitted power (less than 200 W) and consequently less weight, size, power consumption, and hardware complexity. In November 2002 this ionosonde was installed at the ionospheric station of Gibilmanna (Zuccheretti et al., 2003; Bianchi et al., 2003).

In the last years, due to the growing interest in real time mapping and short term predictions, the need for immediate availability of good scaled data became more and more important. For this reason, together with the ionosonde, the INGV developed a computer program, called Autoscala, for the automatic scaling of critical frequency foF2 and MUF(3000)F2 from ionograms. The main characteristic of Autoscala is that it is based on image recognition technique, and does not use information on polarization. Thanks to these characteristics Autoscala can be easily applied to any kind of ionosonde.

Another important characteristic of Autoscala is that in the case of a truncated trace, if the digital information of the ionogram is considered sufficient, the software is able to reconstruct it, giving more reliable foF2 and MUF(3000)F2 output values. This characteristic of Autoscala is shown here for a case of an artificially truncated trace correctly reconstructed by the software.

Since the first phase of Autoscala development attention has been paid to the quantitative evaluation of the performance of the algorithms by comparing the output from Autoscala with the corresponding result obtained by a well experienced operator. This kind of evaluation has demonstrated the reliability of the

*Corresponding author.
E-mail address: pezzopane@ingv.it (M. Pezzopane).

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software for quiet conditions ($Kp \leqslant 4$) (Scotto and Pezzopane, 2002, 2004).

In this article, the performance of Autoscala and ARTIST (Reinisch and Huang, 1983; Gilbert and Smith, 1988), are comparatively evaluated using as a reference the data obtained according to the standard URSI interpretation. The used data set is constituted by 4326 ionograms, including a wide range of ionospheric conditions, recorded by the DPS4 (Digital Portable Sounder 4, produced by University of Lowell, Massachusetts, USA) installed at the ionospheric station in Rome and autoscaled by ARTIST. These ionograms were automatically scaled by Autoscala and manually scaled by a well experienced operator. Autoscala uses ionograms in RDF file format as input (Pezzopane, 2004) and so, before applying Autoscala to ionograms recorded by the ionosonde DPS4, a format change was necessary. In this change of format the information on polarization was also removed.

In addition, a comparison between Autoscala and ARTIST was performed for disturbed conditions on the occasion of the strong ionospheric storm which occurred on 29 October 2003.

2. Autoscala: reconstruction of truncated traces

The trace of the F2 region can appear on ionograms basically in three different ways, identifying three different classes:

(1) the trace is very clear and foF2 can be easily scaled from the vertical asymptote (Fig. 1a);
(2) the trace near the critical frequency is not clearly recorded owing to interference, absorption or scattering (Fig. 1b);
(3) the trace is completely lost due to defects of the ionosonde or some ionospheric reasons (Fig. 1c).

For the ionograms belonging to class (1) the software limits itself to identifying the trace. For the ionograms belonging to class (3) the program establishes that the identification of the trace is not possible and consequently no output is produced.

As regards the ionograms belonging to class (2), Autoscala is designed to reconstruct (when possible) the truncated trace giving as output MUF(3000)F2 and an extrapolated value of foF2. In order to test the capability of the software to do this reconstruction we carried out a study by artificially truncating some good traces. As an example of the procedure, Fig. 2a shows a good quality ionogram with the values of foF2 and MUF(3000)F2 correctly scaled by Autoscala; Fig. 2b shows the same ionogram artificially truncated, and Fig. 2c the reconstructed trace with the corresponding autoscaled values. From Figs. 2a and c the correspondence of the values can be seen as evidence of a correct reconstruction by Autoscala.

3. Performance comparison between Autoscala and ARTIST 4.01

A test was performed using a wide data set of 4326 ionograms recorded from January 1 to June 30, 2003 by the ionosonde DPS4 installed at the ionospheric station in Rome and autoscaled by ARTIST. These ionograms, including of a wide range of ionospheric conditions, were automatically scaled by Autoscala and manually scaled by an operator.

The tests were performed separately for the two characteristics produced as output from Autoscala.

3.1. Test for the foF2 characteristic

With reference to the processing data set of 4326 ionograms, the following five subsets were considered:

(1) Subset C (definite values). Composed of ionograms for which the operator was able to scale foF2 as a definite value, using neither descriptive nor qualificative letters.
(2) Subset D (deteriorated traces). Composed of ionograms for which the traces were deteriorated but the operator was able to scale foF2; this subset includes the following separate cases:
    (a) the trace near the critical frequency is not clearly recorded owing to interference, or absorption; in this case the operator scaled foF2 as a doubtful value;
    (b) the ordinary trace is obscured by absorption, interference or blanketing and an extraordinary component is clearly visible; in these cases the standard URSI (International Union of Radio Science) recommends deriving the critical frequency foF2 of the ordinary trace from the extraordinary one.
(3) Subset F (spread F). Composed of ionograms for which a spread F condition was observed.
(4) Subset T (truncated traces). Composed of ionograms for which the trace near the critical frequency is not clearly recorded owing to interference or absorption. In these cases it is possible to obtain the most reliable value for foF2 by extrapolation. This subset includes the ionograms for which the extrapolated frequency range is greater than 10% of foF2.
(5) Subset I (impossible). Composed of ionograms for which the operator was not able to observe the F2 trace for different reasons.