OIASA application to oblique radio-sounding data recorded in Korea

D. Sabbagh[1,2], A. Ippolito[2], C. Scotto[2], T. Bullett[3,4], J. Mabie[3,4], V. Sgrigna[1]
[1] Università degli Studi Roma Tre, Dipartimento di Matematica e Fisica, Roma, Italy
[2] Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy
[3] University of Colorado, Boulder, CO, USA
[4] National Centers for Environmental Information, Boulder, CO, USA
e-mail address: dario.sabbagh@ingv.it

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The Oblique Ionogram Automatic Scaling Algorithm (OIASA) has been applied to a data set of oblique ionograms recorded by the Vertical Incidence Pulsed Ionospheric Radar, Version 2 (VIPIR2) ionosonde receiver in Korea. These ionograms are the result of the real-time oblique radio-soundings performed every 15 minutes since September 12, 2016 (day 256) between the Japanese National Institute of Information and Communications Technology (NICT) ionospheric station of Kokubunji (35.71°N, 139.46°E) and the Korean Space Weather Center (KSWC) station of Icheon (37.14°N, 127.55°E).

A set of 288 poor-quality test mode ionograms has been selected for this study, and the results are presented. In order to scale the Maximum Usable Frequencies (*MUF*s) between the receiving and the transmitting ionosondes, a filtering procedure for the ionograms noise reduction has been applied in combination with an image recognition technique. Vertical equivalent ionograms have been then obtained using Martyn's equivalent path theorem, and processed by Autoscala.

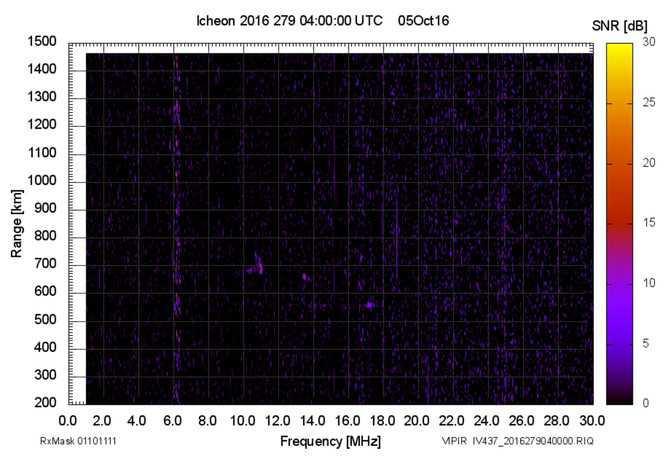

Fig. 1a

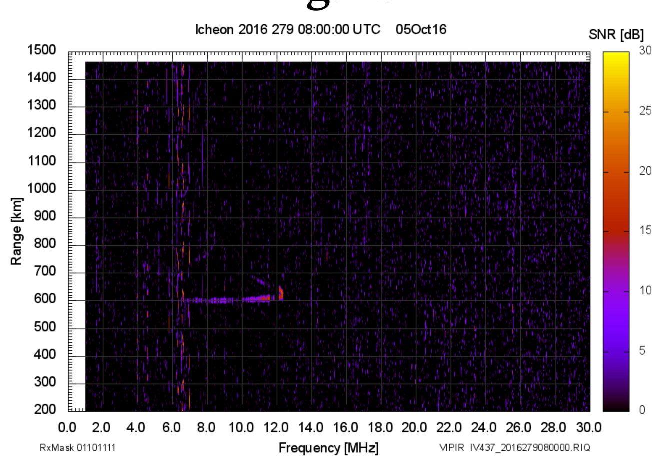

Fig. 1b

1. Data set

The oblique ionogram automatic scaling procedure described in Ippolito et al. [2015, 2016] has been applied to a new set of oblique ionograms pertain to the 1079.3 km radiolink between Kokubunji (Japan) and Icheon (Korea). A set of 288 ionograms, recorded every 15 minutes during October 5, November 3, and November 19 (days 279, 308, and 324), 2016, has been selected.

As shown in Fig. 1, the data quality is still poor, as they are considered test-mode ionograms. Indeed, about 44.8% of the ionograms analyzed have no or little information (Fig. 1a), while in many other cases they suffered a lack of information for some frequency intervals (Fig. 1b), which contribute to a difficult distinction of o- and x- traces, and *MUF* recognition as well.

2. Filtering procedure

As the ionograms are affected to significant noise (Fig. 2a, day 279, 07:30:00 UTC), a double filtering procedure has been applied before processing the data in order to retrieve ionospheric information.

At first the amplitude signals is stored in a proper matrix. As shown in Fig. 2b, a first filter cuts signals below a fixed threshold T_1. The result is a new matrix with only 0 and 1 values, corresponding to absence or presence of the information, respectively.

Then a second filter cuts the vertical lines for which there is information in at least a fixed fraction T_2 of elements, respect to the total number of elements in a matrix column (Fig. 2c).

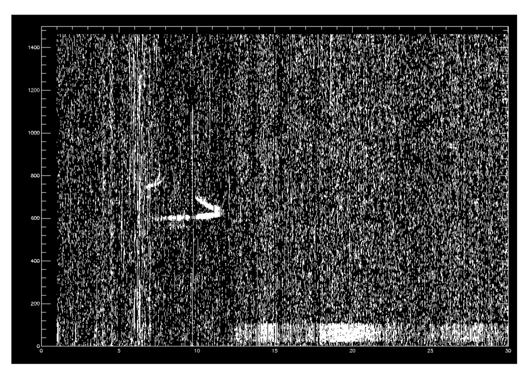

Fig. 2a

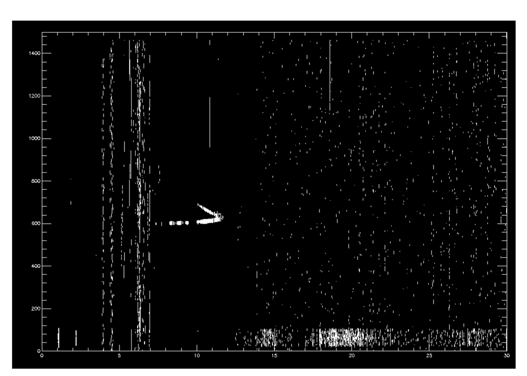

Fig. 2b

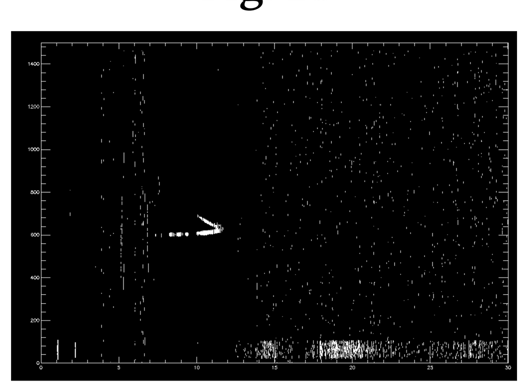

Fig. 2c

3. Automatic scaling of the *MUF*

After the application of the filtering procedure described above, OIASA software has been applied in order to scale the *MUF* values from the ionograms o-trace, thanks to an image recognition technique based on the maximum contrast method.

This method also provides a criterion for discarding ionograms that do not have sufficient information. Indeed, only if the maximum correlation C_{max} is larger than a fixed threshold C_t, are the selected curves considered representative of the traces due to reflection in the F2 region, and a *MUF* value is provided.

4. Oblique to vertical ionograms conversion

Once OIASA has selected the ionograms with sufficient information, an oblique to vertical conversion procedure has been applied to each autoscaled ionogram. Applying the secant law and the Martyn's equivalent path theorem to each matrix element in which there is information, the equivalent vertical ionograms have been obtained. An isotropic horizontally homogeneous and flat ionosphere is assumed, and the curvature of the Earth is also considered.

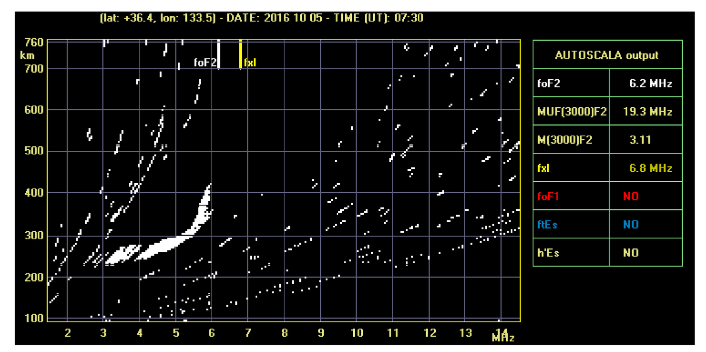

Fig. 3a

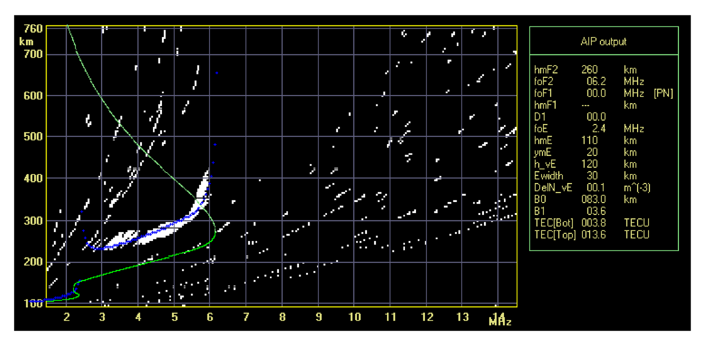

Fig. 3b

5. Autoscala application to the equivalent vertical ionograms

The equivalent vertical ionograms obtained are then analyzed by a special version of Autoscala. This operation enables deriving all the ionospheric parameters over the midpoint of the oblique ray path (Fig. 3a). An electron density profile $N_e(h)$ at the same point is also estimated by Autoscala, using the Adaptive Ionospheric Profiler (AIP), as shown in the example in Fig. 3b.

6. Results

In order to choose proper values for T_1, T_2, and C_t, the OIASA performance has been tested in different conditions. Qualitative preliminary tests has suggested to set C_t=200, and to perform further quantitative tests on four different combinations of T_1 and T_2. In Tab. 1-4 are reported the results obtained setting the values 6.0 dB and 6.5 dB for T_1 and the values 0.1 and 0.2 for T_2.

The tests are performed assessing the ability of an operator and of OIASA to scale the *MUF* from the input filtered ionograms, and are based on the comparison between the *MUF* values manual scaled and those autoscaled by OIASA, when both are able to scale the same ionogram. In accordance with the URSI standard, *MUF* autoscaled values in the range of 0.5 MHz from the manual scaled ones are defined as "accurate", while values in the range of 1.5 MHz are defined as "acceptable".

It can be clearly seen how the best results are obtained for T_1=6.5 dB and T_2=0.1 (Tab. 3), as it allows to have the best result in terms of false positive event percentage (8.0%, Tab. 3a) and percentage of ionograms accurately autoscaled (38.9%, Tab. 3b). The percentage of ionograms acceptably autoscaled (66.7%, Tab. 3b) is the greatest, too. In these conditions OIASA selects 137 ionograms, which are converted in vertical equivalent ones and scaled by Autoscala. The special version of Autoscala used has been able to scale all the ionograms, regardless of the accuracy of the autoscaled *MUF* values, even though in some cases (about 12.4%) it has not been able to retrieve a $N_e(h)$.

Tab. 1a 6.0 dB – 0.1	Scaled by OIASA # of cases	%	Discarded by OIASA # of cases	%
Discarded by the operator	12	8.6	116	78.4
Scaled by an operator	128	91.4	32	21.6
Total	140		148	

Tab. 1b 6.0 dB – 0.1	Scaled by OIASA and the operator # of cases	%
Accurate	37	28.9
Acceptable	74	57.8
Total	128	

Tab. 2a 6.0 dB – 0.2	Scaled by OIASA # of cases	%	Discarded by OIASA # of cases	%
Discarded by an operator	12	8.6	114	77.0
Scaled by an operator	128	91.4	34	23.0
Total	140		148	

Tab. 2b 6.0 dB – 0.2	Scaled by OIASA and the operator # of cases	%
Accurate	39	30.5
Acceptable	76	59.4
Total	128	

Tab. 3a 6.5 dB – 0.1	Scaled by OIASA # of cases	%	Discarded by OIASA # of cases	%
Discarded by an operator	11	8.0	118	78.1
Scaled by an operator	126	92.0	33	21.9
Total	137		151	

Tab. 3b 6.5 dB – 0.1	Scaled by OIASA and the operator # of cases	%
Accurate	49	38.9
Acceptable	84	66.7
Total	126	

Tab. 4a 6.5 dB – 0.2	Scaled by OIASA # of cases	%	Discarded by OIASA # of cases	%
Discarded by an operator	11	8.0	117	77.5
Scaled by an operator	126	92.0	34	22.5
Total	137		151	

Tab. 4b 6.5 dB – 0.2	Scaled by OIASA and the operator # of cases	%
Accurate	47	37.3
Acceptable	83	65.9
Total	126	

7. References

Ippolito, A., C. Scotto, M. Francis, A. Settimi, and C. Cesaroni (2015), Automatic interpretation of oblique ionograms, Adv. Space Res., 55, 1624–1629.
Ippolito, A., Scotto, C., Sabbagh, D., Sgrigna, V., Maher, P. (2016). A procedure for the reliability improvement of the oblique ionograms automatic scaling algorithm. Radio Sci. 51, doi:10.1002/2015RS005919.