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ACCURACY COMPARISON OF IONOGRAM INVERSION METHODS

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ABSTRACT

Results obtained with a new inversion method /1/ have been compared with the inversions as given by the ARTIST approach /2/. Future generalizations are suggested.

COMPARISON

72 selected Millstone Hill ionograms have been inverted and recomputed using 8 parameters (ARTIST) and 9 parameters /1/ respectively. Out of a total number of 140 observations made between 03 and 08 UT during July 1989 these fulfil the requirements of /1/ and the additional demand that (foF2-foE) be greater than 5.0 MHz.

The virtual heights $h'_c(f)$ were recomputed using both sets of parameters and compared with the observed corrected virtual heights $h'*(f)$ /1/. In the following, results of the ARTIST method are identified by A, those of the new method by B.

Tables 1 and 2 (in the Appendix) show the mean errors $(h'*-h'_c)$ of the virtual heights and the relevant dispersions.

With our method B, the values of the dispersions indicates that the errors are rarely higher than 10 km with the exception of the neigbourhood of foF2 where it may go up to 20 km. Some improvement might be obtained by better weighting the data near foF2 in the first step of /1/.

ARTIST ends up with errors of at least twice these values. In the vicinity of foF2 even errors of 80 km could appear; this is often due to underestimating of foF2.

The differences between the real heights, (h_A-h_B), are summarized in Table 3 (in the Appendix). In the central part of the frequency domain our new method yields heights comparable to those given by ARTIST. Near foF2 and near foE, ARTIST heights are generally the greatest; the dispersion of the differences increases near fmin, it is maximum near foE.

COMPARISON OF GEOPHYSICAL PARAMETERS.

We use hourly medians of some parameters and describe their dispersion by the mean of both quartile ranges (which together cover 50 % of the individual values). These data appear in Table 4 (in the Appendix).

The dispersion ranges of the two methods are rather similar. We claim however, an advantage of our method B is the fact that the medians of h_V, of Thickness and of h (fmin) vary less with the hour such that it yields a better geophysical representation. The lower hmF2 values found with ARTIST could be attributed to the fact that foF2 is often underestimated.

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On the other hand, the retardation (h'-h) at fmin allows a more critical evaluation since h'(f) cannot be less than h(f). Near fmin this difference is nearly proportional to the slope of the profile at the height of the top of the valley. With ARTIST we often found slightly negative individual values, even negative medians at 05, 06 and 07 UT.

Finally, even if in its present shape our method may not be optimal near foE, it ends up with a reasonable variation with time of <dh/df>, the mean slope between foE and foE + 0.5 MHz.

COMPARISON OF INDIVIDUAL INVERSIONS.

Inversion methods A (ARTIST) and B (ours) are compared in typical situations considered in Figures 1 to 4 [the broken vertical line gives the position of fmin].

Figure 1 refers to an ionogram for which both inversion methods lead to only small errors in the range between fmin and foF2 (apart from the vicinity of foF2). The differences (h_A-h_B) reach about 10 km near fmin, they are smallest near 4 MHz; the difference between the peak heights is less than 4 km. The experimental data thus lead to quite equivalent profiles. Between fmin and foF2, the A- and B-profiles are quite similar apart from a shallow maximum between fmin and 4 MHz shown by ARTIST. In the (foE, fmin) domain, the h_V values are equal but the profile shapes are different: quadratic with ARTIST, linear with our method. The differences are lower than 10 km, only the slopes at the h_V level differ significantly: 30 km/MHz for A, 10 km/MHz for B. [Such values are not unlikely /3,4/].

Comparable conditions were found in Figures 2 and 3 only that ARTIST gives larger differences between observed and recomputed ionograms. The profiles are again quite similar between 4 MHz and foF2. At fmin the difference between the two profiles is 25 km, ARTIST values being lower in Figure 2 but greater in Figure 3. In the first case the real heights between foE and fmin are surprisingly low (h_V = 166 km). In the other case, the errors of ARTIST are about 5 times larger than those of our method, furthermore h(fmin) > h'*(fmin) and the minimum of h(f) in the vicinity of 1 MHz is at least questionable.

The reason for these discrepancies and questionable features between foE and fmin in the A-profiles is probably that an implicit analytical extrapolation is performed in the ARTIST method.

The case of Figure 4 has been selected because in this ionogram the virtual heights are questionable at some frequencies and because the virtual height as function of the frequency is more involved than in other ionograms. With both methods, the absolute differences $|h'_*-h'_c|$ are always less than 20 km. At 7.2 MHz, ARTIST gives a difference greater than 300 km (only a fraction of this value is plotted). The A real heights are systematically less than those of B, in particular at fmin (about 40 km). Furthermore, A makes h_V = 110 km which is certainly unrealistic. There exists, obviously, some similarity between Figures 4 and 2 only that in Figure 4 the discrepancies are more pronounced.

CONCLUSIONS.

Evaluation of the over-all accuracy of the new analytical method B shows that it reproduces the input data with only small uncertainties, normally less than 10 km. Some exceptions were found in the very neighbourhood of foF2. Compared to method A (ARTIST) the gain in accuracy is by about a factor of 3. Our analysis further proves that the DIGISONDE data are very coherent so that efforts towards improved inversion methods are well justified.

The precision of our inversion method is due to the use of two functions in h(f) where the first mainly describes the neighborhood of foF2 while the second is more concerned with the low frequencies.

Our tentative virtual height extrapolation between foE and fmin may be seen as an important constraint in any inversion process. Unrealistic profiles in this region are so avoided and the gradient at the top of the valley takes a reasonable value. Our extrapolation takes account of the gradient of the virtual heights at fmin; the method allows an estimate of h_V, the top-height of the valley, which is a most important geophysical parameter needed in any inversion method. During the night period considered, the mean values of h_V varied smoothly with the hour.

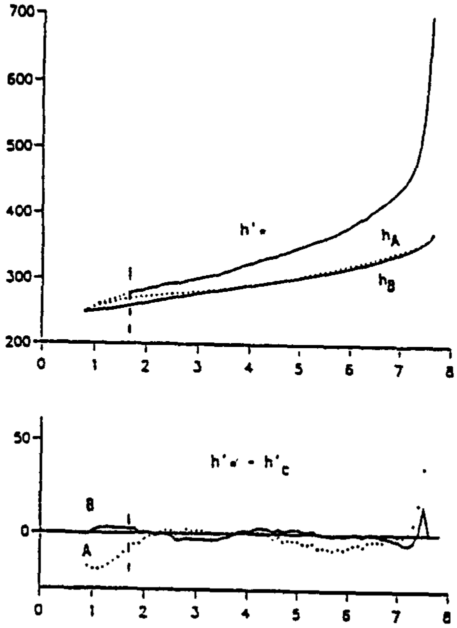

Fig. 1. Millstone Hill 1989, 182, 04UT
foE = 0.810, foF2 A = 7.612
fmin = 1.700, B = 7.637
hmF2 A = 370.2, h_v A = 247.8, h(fmin) A = 269.2
B = 373.8 B = 247.3 B = 258.3

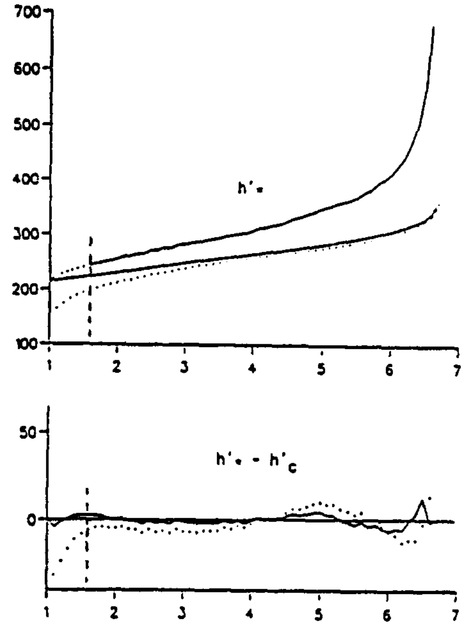

Fig. 2. Millstone Hill 1989, 193, 08UT
foE = 1.010, foF2 A = 6.699
fmin = 1.600, B = 6.654
hmF2 A = 360.5, h_v A = 153.6, h(fmin) A = 199.0
B = 355.2 B = 214.8 B = 224.4

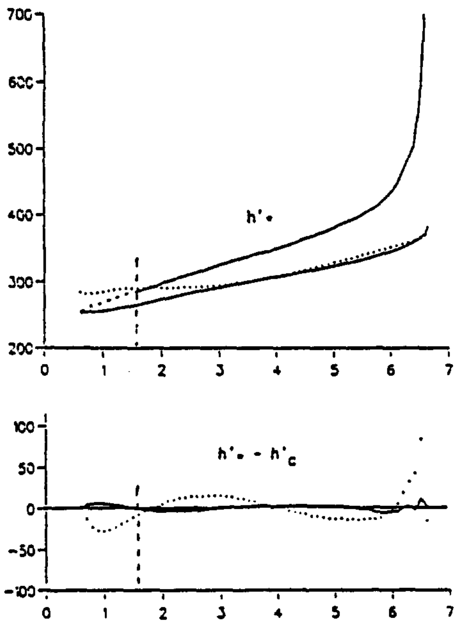

Fig. 3. Millstone Hill 1989, 202, 06UT
foE = 0.610, foF2 A = 6.601
fmin = 1.600, B = 6.641
hmF2 A = 370.4, h_v A = 284.2, h(fmin) A = 290.5
B = 382.8 B = 252.3 B = 265.4

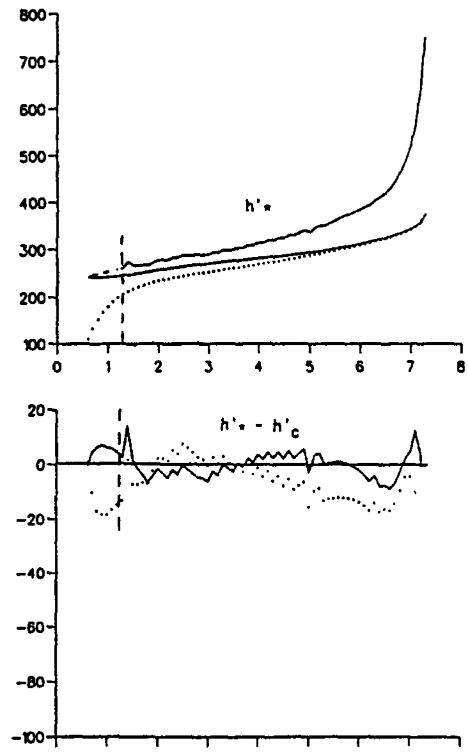

Fig. 4. Millstone Hill 1989, 188, 06UT
foE = 0.610, foF2 A = 7.204
fmin = 1.300, B = 7.296
hmF2 A = 362.8, h_v A = 109.9, h(fmin) A = 206.3
B = 375.3 B = 239.8 B = 245.0

As further developments are needed: evaluation of the effect of uncertainties in foE, better definition of the extrapolation / iteration process; extension to cases where virtual height input is missing in a larger frequency range (by absorption, blanketing or interference). A thesaurus of earlier inversion results could be helpful to this end.

Even when all data are at hand, the effect of the underlying ionization must be removed carefully till the virtual profile has taken the characteristic shape near foE. When this is done, the new method may be applied in most ionospheric situations.

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