Considerations about the ionospheric effects of the 1999 eclipse

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Abstract
The 1999 eclipse provided a unique opportunity to study the delay of the ionospheric response to the changes of the solar ionizing radiation. Previous eclipse experiments were based on the assumption that the solar disc was a uniform source of the ionizing radiation. In the recent era of the space observations this assumption is obsolete. In the present work the temporal runs of the solar high energy radiation intensities have been computed on the basis of space observations and they have been compared with the electron density measurements of the ionospheric E-region carried out by the ionosonde at Sopron, Hungary, which was crossed by the totality zone. The delays between radiation and electron concentration in the decreasing as well as increasing parts of the curves contain informations about the dynamics of recombination and ionization processes.

INTRODUCTION

The total solar eclipses offer extraordinary opportunities to study dynamical processes of the terrestrial atmosphere (Boitman et al. 1999; Liu et al. 1999; Tsai and Liu, 1999; Afraimovich et al. 2000). Among the most spectacular processes parallel to the eclipse are the decrease and increase of the ionospheric electron density. Of course, this parameter has a diurnal variation but the ionising solar radiation disappears in the evening and re-appears in the morning so smoothly and gradually that the ionospheric response gets smeared, it is difficult to recognize its genuine nature. However, the temporal proceeding of the coverage of radiating surface is much better defined during a total solar eclipse.

By using this consideration there were previous attempts to study the atmospheric effects of the total eclipse. These earlier studies were based on the assumption that the solar radiation intensity is equally distributed over the surface of the solar disc like that in the visible wavelength domain. However, in the era of the space observatories it became clear that this is a fairly naive an unappropriate assumption in the domain of high energy radiation which is responsible for the ionisation of the atmosphere. The shorter is the wavelength the more intermittent its distribution. In the far ultraviolet and X-ray domains the volumes above the active regions are bright and those above quiet regions are faint or dark.

For this reason it appears appropriate to assume that the uneven distribution of high energy intensity on the solar disc may result in a specific fine structure of the temporal run of the integrated solar intensity in the given wavelength domain. Furthermore, if such a fine structure could be related to the occasional fine structure in the temporal run of the ionospheric electron density, then the characteristic time of the ionospheric response could be determined more precisely and the dynamics of the ionization/recombination processes could be studied on a much finer timescale.

OBSERVATIONAL MATERIAL AND PROCEDURE

For the above purpose the SOHO/EIT 304A, 171A and 195A (Delaboudinière et al., 1995) and Yohkoh SXT observations (Tsuneta et al., 1991) are the most suitable, because these instruments provide full-disc images at short wavelengths (no full disc TRACE mosaic was available for the given moment). The ionospheric impact was monitored by the ionosonde of the Geodetic and Geophysical Research Institute at Sopron (Fig.1.) which, by chance, was crossed by the totality zone.

The ideal case would be if full disc observations were available in those wavelengths which are considered to be most effective in ionizing the atmosphere (for instance Lyman-beta). However, the list of observed wavelengths is given by the programs of the spaceborn instruments so the high energy distributions should be represented by existing full disc images of the observed wavelengths. Observations closest in time to the maximum phase at Sopron (10:47 UT) were selected for the above mentioned wavelengths.

A simulation program has been adopted to these images to obtain the temporal runs of the intensities in the region of the ionosonde. An artificial lunar disc has been progressively shifted by one minute steps along the solar disc and the intensities of the uncovered pixels have been summed up (i.e. the uncovered surface intensity has been integrated) at each step.

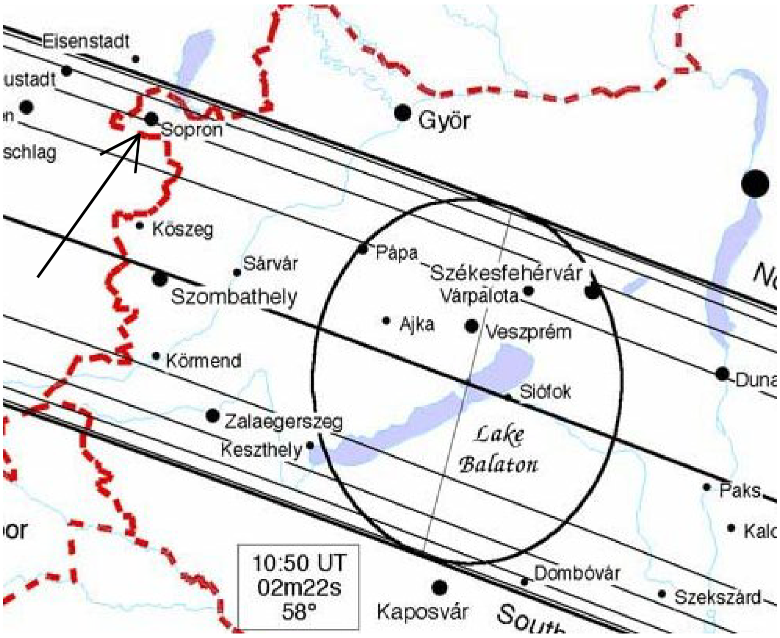

Figure 1. Map of the Western region of Hungary affected by the total solar eclipse. The location of the ionosonde is indicated by an arrow.

RESULTS AND DISCUSSION

As a result, two curves can be compared, those of the electron density of the ionospheric E-layer measured by the Sopron ionosonde and the integrated solar high-energy flux measured by the Yohkoh SXT (we represent here by this latter one the high energy flux in general). The scaling of the curves may be arbitrary for the sake of easier comparison. The direct data of the ionosonde are plasma frequencies which can be converted to electron densities, whereas the intensity data of the solar image (those of the image pixels) were only taken into account in the common 8-bit units, because in the present context only the temporal run is relevant but not the absolute intensities. The scaling of the two curves were so transformed that both their stationary (out of eclipse) and minimum values match with each other, furthermore, the ionosonde curve has been smoothed with a 5-point sliding mean (Figure 2.).

A somewhat disappointing feature of the solar intensity curve is that it does not exhibit the fine structure which might have been expected on account of the highly inhomogeneous intensity distribution, and not only the SXT-curve, the UV-curves of EIT are even smoother. However, these smooth curves are also suitable to study the response because of the above mentioned arbitrary scaling. We considered the delays of the ionospheric values from the corresponding solar intensity values.

It is remarkable that the delay of the ionospheric curve on the descending wing is longer than that on the ascending one. This is no surprise, they are resulted by different mechanisms, the former is related to the rate of the recombination processes whereas the latter one is related to the ionization rate.

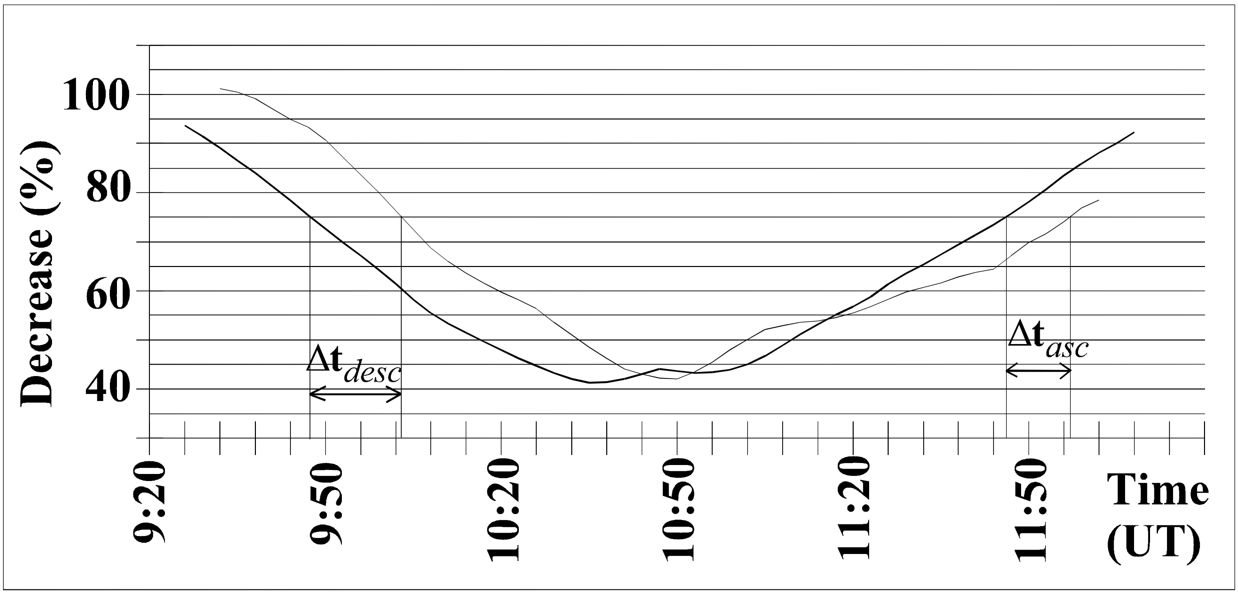

Figure 2. Temporal runs of the solar SXT (Yohkoh) integrated intensity (thick line) as well as the electron density of the ionospheric E-layer in the region of Sopron, Hungary (thin line).

To determine the above delay times, two arbitrary depression values have been chosen about the middle of the wings, namely at 70% and 75%,. Fig.2. indicates the relevant Δt_{desc} and Δt_{asc} delays for the 75% depressions. For these two values the delay times were 14.2 min and 15.6 min on the descending phase as well as 11.3 min and 11 min on the ascending phase respectively. This means that the characteristic times of the ionospheric responses are: 15min for the recombination processes and 11min for the ionization processes with a precision of about a half minute.

These delay times will provide a tool for a further analysis of the effective cross sections of ionospheric processes. Details of a possible interpretation will be discussed elsewhere.

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