Measuring Ionospheric Response to Solar Flare with Dynasondes

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Progress in understanding of X-rays, UV and EUV in solar flares over the past 5-10 years is getting to the point where accurate high-time-resolution dynamic models describing the ionospheric response become feasible. Ground measurements can play a significant role in validating them. Dynasonde analysis products are well positioned to contribute in this effort.

In Dynasonde data analysis, special attention is paid to complete use of phase information in the radio echo. Dynasonde analysis yields excellent statistics of recognized echoes (up to several thousand per ionogram recording). An echo is defined by 7 parameters (two angles of arrival, group range, Doppler, polarization, phase range, amplitude), each with its individual uncertainty estimate. Processing the list of the echo parameters instead of traditional amplitude-based image analysis is a distinctive property of a Dynasonde system. Accuracy of the physical parameters and rich statistics of recognized echoes provide conditions for dependable inversion procedure, 'NeXtYZ', which produces the true vertical profile of ionization. It can be used in an obvious way to characterize ionospheric effects of prolonged solar flares at a post HF blackout/fade off stage. When flare effects are in their maximum, the ionospheric E- and lower F-region radio echoes may be not available. The profile inversion procedure is not particularly reliable in this situation regarding the vertical position of the F layer peak. There is, however, enough information in the detected echoes to provide dependable estimates for change of the F region ionization and for the jump in the D-E layers ionization. This paper demonstrates how this can be done using the list of the physical parameters of the echoes preserved for every sounding session in the Dynasonde database.

One of the powerful (X2.7) solar flares of 2015, which occurred on May 5 at 22:00 UT, is used as an example. Ionospheric measurements were performed by Wallops Island and San Juan Dynasondes. The echo parameters allow calculating a 2% increase in the electron density between sounding sessions 22:08 and 22:10 UT, which is attributed to a specific real altitude in the F layer (269.5 km) using the reliable electron density profile obtained from the data of the pre-impact session. The same calculation is performed for a significant altitude range in the F layer, about several tens km. Note that the time of detection of every echo can be calculated with absolute accuracy 0.16 s. This information allows comparison of the measured ionization disturbances to high-time-resolution dynamic models describing the ionospheric response to energetic photon fluxes from solar flares. Another parameter of the echoes (their amplitude expressed in dB as a function of the radio frequency) allows revealing at the same time almost quadruple increase of the electron density at 100 km real altitude, in the "invisible" lower E layer.