Ionospheric effects of the cosmic gamma-ray burst on 29 March 2003

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Cosmic gamma-ray bursts (GRBs) are signals from energetic explosions at cosmological distances. Several authors calculated effects of a GRB on the ionosphere. According to their calculations, the peak of ionization takes place in the height interval from 25 km to 35 km, but significant ionization occurs up to the height of D region (50-90 km). The radio waves on HF and lower VHF bands are partially absorbed in the passage of the ionosphere due to collision of electrons with ambient heavy particles. Most of the absorption occurs in the D region where the product of the electron density and the electron-neutral collision frequency attains a maximum. Since the number density of the neutral particles within the D region is relatively constant over time, the total amount of absorption depends on variations in the local electron density. Here we report evidence for the ionospheric effects of a strong gamma-ray burst on 29 March 2003 (GRB030329) based on HF and VHF radio wave observations.

GRB030329 started at 11:37:15 UT and lasted for more than 25 sec. At Nishi-Harima Astronomical Observatory (NHAO) the cosmic noise is recorded at 38 MHz with a riometer and a horizontal dipole antenna. At the time of GRB030329 we observed a weak but definite sudden decrease in the strength of the cosmic noise. Since no such decrease at the same sidereal time was found in the recordings on other days, this decrease is not a feature inherent in the cosmic noise but sudden cosmic noise absorption (SCNA). The starting time of this SCNA is well coincident with the occurrence time of GRB030329. This SCNA lasted for about 12 min and the magnitude of absorption was about 0.09 dB (2%) compared with the levels just before and after this SCNA. Since the zenith angle of the GRB030329 was about 26 degrees at NHAO, the ionosphere within the antenna beam was presumably well irradiated by GRB030329. Solar origin of the observed SCNA is ruled out because of the nighttime and no solar X ray flare recorded by GOES at the time of GRB030329. We therefore conclude that the observed SCNA resulted from a transient D-region ionization caused by GRB030329.

We found another piece of evidence for the ionospheric effect of GRB030329 in the recordings of the output of a continuous-wave (CW) transmitter. A CW signal of 8 MHz is transmitted from the University of Electro-Communications at Chofu and the field amplitude and frequency deviation of this 8 MHz signal are recorded at Kure, about 690 km west of Chofu. The one-hop transmission path from Chofu to Kure crosses the D region twice and can be used to measure the variations in the D-region absorption. We found an unusual sudden field-amplitude decrease at the time of GRB030329. Such a phenomenon, called a shortwave fadeout (SWF), is primarily caused by an absorption enhancement in the D region. The field intensity of the 8 MHz signal decreased by 20-25 dB and the duration of the SWF was about 40 min. Since the starting time of the SWF is well coincident with the occurrence time of GRB030329, the SWF must have been triggered by the D region absorption enhancement due to GRB030329. No sudden frequency deviation (SFD) was observed in association with this SWF. The SFD is normally related to electron density enhancements occurring above the D region. No SFD observed therefore implies that the ionization enhancement occurred in the D region and below.

Checking the TEC observations by the GPS microwave signals we found no abrupt change in TEC at the time of the GRB030329. Since the major contribution to TEC comes from the F region, this means that GRB030329 had no appreciable effect to the F region.

Our radio observations given here indicate that the ionization effects of GRB030329 took place in the D region and below as suggested by the theoretical calculations. Finally, it is of great interest that an explosion at a cosmological distance makes detectable effects on the ionosphere, a part of the Earth's environment.