## Ionospheric and seismic effects caused by the North Korea nuclear tests realized on 2006-2017

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Using data from GPS/GLONASS receivers and seismic networks, we studied the ionospheric and lithospheric effects caused by six underground nuclear tests realized in North Korea on 2006-2017. To investigate the ionospheric disturbances, we analyzed data from several continuous GNSS-networks (GPS and GLONASS) operating in Asia - Western Pacific region: IGS, GEONET, FEB RAS and FEFU complex geodynamic network, a set of stations belonging to China and South Korea GNSS-networks. Sites close to the Korean Peninsula were selected for the analysis. Series of total electron content (TEC) in the ionosphere were calculated on the base of dual-frequency phase measurements of GNSS receivers. To detect disturbances caused by the nuclear tests, TEC series were filtered in the range of periods from 1 to 10 minutes. Despite the small magnitudes of seismic events associated with the nuclear tests, we were able to identify ionospheric disturbances which were most likely generated by these explosions. Such disturbances were detected for 4 out of 6 nuclear tests. The main parameters of the disturbances were determined. From our analysis we concluded that characteristics of ionospheric disturbances that are usually observed after earthquakes.

For seismic analysis, we used data from the broadband seismic station networks located at distances up to 23 degrees from the Korean Peninsula: II, IC, IU, TW, JP, G, KS, and KG given by IRIS, and regional seismic network BY. The frequency content of P and surface Rayleigh waves registered by 46 broadband stations was analyzed. For some events, the P-wave frequency content showed the prevalence of low frequencies in spectra (~0.45 Hz). The peak frequencies of the surface Rayleigh waves was in the 0.05-0.45 Hz range. Preliminary analysis of the peak frequencies spatial distribution showed that the continental massive area is characterized by the relatively high frequencies (0.14-0.50 Hz) while for the areas adjacent to marginal seas the low values of peak frequencies are observed (from 0.13 Hz and less). Acknowledgments. We are deeply indebted to Scripps Orbit and Permanent Array Center (SOPAC) for the IGS-network data, to Geospatial Information Authority of Japan for GEONET network data, to Korea Astronomy & Space Science Institute for access to GNSS data on the Korean Peninsula, CCU CC FEB RAS for access to data from the FEB RAS and FEFU complex geodynamic network; Institute of Earthquake Forecasting, China Earthquake Administration for access to GNSS data in China. The facilities of the IRIS Data Management System, and specifically the IRIS Data Management Center, and Baikal Regional Seismological Center and Sakhalin Branch of Federal Research Center Geophysical Survey RAS were used to get waveform and metadata required in this study. This work was performed with budgetary funding of Basic Research program II.16 and was also partially supported by RFBR grants 17-45-388072\_p\_a, 17-45-388049\_p\_a, 17-55-53110\_GFEN\_a, 19-05-00889\_a.

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