Seismic Waveforms from the Democratic People's Republic of Korea on September 3, 2017

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On 3 September 2017 at around 12:30, the Japan Meteorological Agency reported that the seismic waves with an explosive source were detected. The source location was in the area of the Democratic People's Republic of Korea (DPRK) nuclear test site. In a statement by its official news agency, the DPRK announced that it had conducted a sixth nuclear explosive test. We used the seismic waveforms observed by F-net and Hi-net in Japan, and analyzed source characteristics of this explosive event.

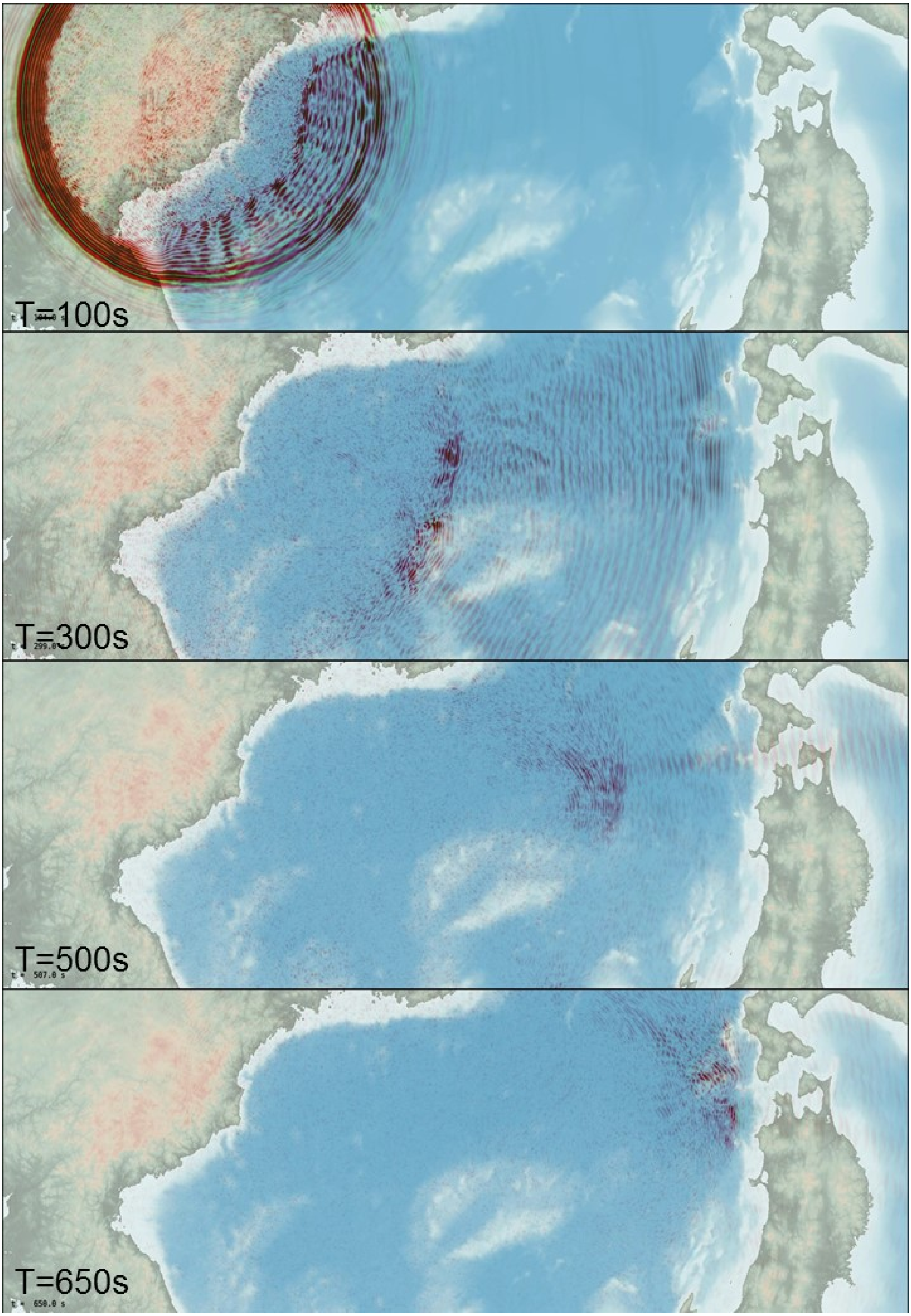
The seismic signals show the sharp onset of P-wave arrival, and very small S-wave amplitude. This is the typical feature of the explosive source. The surface waves with dominant period of 10-20 s were followed a few hundred seconds later. We applied band-pass filter to the seismic records in order to characterize the frequency dependent waveform properties. The long-period component (20-50s) shows that there are two wave trains. Based on the velocity and particle motion, the first train is the surface wave of the explosion at 12:30. The second wave train arrived about 8 minutes later, and with the same velocity to the first wave train. The short-period component (2-5Hz) shows that the distinct P-waves, very small S-waves, and emergent signal 400 s after the P-wave arrival with duration of 200 s.

We performed seismic waveform inversion using long-period waveforms with fixed location at the DPRK nuclear test site. The Green's function was computed by the 1D velocity structure (ak135). The first wave train was explained well by the isotropic mechanism. The moment magnitude determined from the inversion of the surface wave was estimated to be 4.9. Compared to the past nuclear tests in 2013 and 2016, the amplitude was about 10 times larger and the moment magnitude was 0.7 - 0.8 larger. This is the largest explosive event in the DPRK. The second long-period wave train was dominant in the vertical component, which can be explained as a collapse of the test site.

The emergent and long-duration signals observed in the short-period content seems to be unusual. The large amplitude was observed in the Northern Tohoku and Southern Hokkaido. The amplitude was larger in the west coast of the region. This is different distribution from the P-wave amplitude, which has larger amplitude in Chugoku and Tohoku regions. The arrival time was also puzzling: it was slower than the surface wave of the explosive event, and faster than the P-wave of the second event. We interpreted this waveform as T-phase, which travels in the sea water.

T-phase travels in the channel of low velocity at the depth of 1000-3000 m. A wave is refracted in this channel due to the velocity contrast, and it travels longer distance due to the smaller attenuation. The bathymetry data of Japan sea shows the Japan sea basin with depth around 3000m covers between North Korea and Northern Tohoku. The area where the large amplitude of T-phase observed was consistent with the spread of Japan sea basin. We have performed the numerical simulation of seismic wave propagation by finite difference method (FDM). The travel time of the T-phase was consistent with the velocity traveling in the Japan sea basin. This result suggests that the large T-phase was generated by the DPRK nuclear test and observed in the Northern Tohoku and Southern Hokkaido, due to the seafloor bathymetry.

キーワード：核実験、北朝鮮、T相
Keywords: nuclear explosion, the Democratic People's Republic of Korea , T-phase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