On the lower ionospheric perturbation for the two earthquakes which occurred offshore the Pacific Ocean of Japan in November 2016 on the basis of VLF propagation data observed at multiple stations and wave-hop theoretical computations

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There have been published many papers on VLF characteristics to study seismo-ionospheric perturbations. Usually VLF records (amplitude and/or phase) are used to investigate mainly the temporal change of VLF propagation anomalies with special attention to one particular propagation path. The most important advantage of this paper is the simultaneous use of several propagation paths. A succession of earthquakes (EQs) happened in the Tohoku area; two earthquakes (EQs) in November 2016. The first EQ with M (magnitude) = 6.1 (depth 42 km) happened close to the coast line on 11 November (UT). The second EQ was recorded in the sea on 21 November (UT) with M = 6.9 (depth 11 km). Because the EQ epicenters are not far from the VLF transmitter (with the call sign of JJY in Fukushima prefecture), we can utilize simultaneously 8 observing stations of our network all over Japan. Together with the use of theoretical computations based on wave-hop theory, we are successful in tracing both the temporal and spatial evolutions of the ionospheric perturbation associated with this succession of EQs. It is found that the ionospheric perturbation begins to appear about 10 days before the EQs, and this perturbation becomes most developed 3-1 days before the EQ. When the perturbation is most disturbed, the maximum change in vertical direction is depletion in the VLF ionospheric height of the order of 8km, and its horizontal scale (or its radius) is about 350km. Finally, we try to comment on the generation mechanism of seismo-ionospheric perturbations.

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