URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

Detecting Ionospheric Anomalies before Earthquakes by Machine Learning Technique

Kakeru Matsuki[(1)], Yasuhide Hobara*[(1)], and Hendy Santosa[(2)]

(1) The University of Electro-Communications
1-5-1, Chofugaoka, Chofu, 182-8585, Japan
(2) Bengkulu University, Bengkulu, Indonesia
Email: hobara@ee.uec.ac.jp

Detecting pre-earthquake ionospheric signatures have been a challenging task because the ionosphere is highly variable both in space and time. Previous studies reported unusual variations of the atmospheric and ionospheric parameters before some of the earthquakes. However, there are anomalous values even without around earthquake occurrence timings, which may be due to various external forcing parameters such as space weather and atmospheric origins. Therefore, these effects must be removed to extract more efficiently the ionospheric signatures due to earthquake preparation process.

In this paper we use one of the machine learning techniques so-called NARX-NN (Nonlinear Auto Regressive with eXogenous Input - Neural Network) [1], one of the system identification methods that can predict output value to improve the detection efficiency of the ionospheric anomaly before earthquakes around Japan.

We use the long-term nighttime data of VLF transmitter (JJY, Fukushima) electric amplitude continuously recorded at Nakashibetsu (NSB), Hokkaido, Japan by UEC to detect the lower ionospheric anomalies. Firstly, we chose 10 external forcing parameters thought to be affect the properties of the lower ionosphere (D-region) as NARX-NN inputs. And the VLF transmitter electric amplitude is set as a target time series for prediction. Secondly, the data from 2012 to 2015 are used to predict the one step ahead (OSA) value of VLF amplitude. Finally, we examine the difference in amplitude between OSA and actual values around every seismic events occurrence time to identify anomalies.

As a result, anomalous value (large difference in predicted and actual values) has been identified before some earthquakes but with variabilities not only around earthquake occurrence time. Then we carried out the superposed epoch analysis applied to the all 29 earthquakes and found that the median value of difference in amplitude increases from around 1 week before earthquake reaching a peak value ~ 4 days before, only when two input parameters (mesospheric temperature and the amount of Ozone) were removed. This may suggest that the pre-earthquake anomaly may be associated with atmospheric variability indicating the coupling from the lithosphere to the ionosphere through the atmosphere during the earthquake preparation processes.

References

[1] Santosa, H., and Y. Hobara, “One day prediction of nighttime VLF amplitudes using nonlinear autoregression and neural network modeling,” Radio Sci., 52, 132–145, doi:10.1002/2016RS006022, 2017.