Development of automatic hypocenter determination method combined with machine learning in JMA

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The Japan Meteorological Agency (JMA) unified earthquake catalog has been widely used for over 25 years in earthquake research and disaster prevention. Following the 2011 M_w9.0 Tohoku earthquake and the subsequent increase in seismicity over a wide area, JMA started operating an automatic hypocenter determination method (PF method; Tamaribuchi, 2018) in April 2016 to efficiently handle the simultaneous occurrence of earthquakes. In recent years, the expansion of ocean-bottom seismic networks (S-net, N-net) has progressed, and further improvements in processing efficiency are essential to better capture seismicity in the Japan Trench and Nankai Trough regions.

The automatic hypocenter determination method primarily uses time series analysis with an autoregressive model (AR-AIC method) to detect P- and S-wave arrival times. However, the AR-AIC method detects discontinuities in waveforms, which also captures non-seismic noise, leading to false detections and uncertainties in hypocenter locations. Recently, many deep learning-based models for phase identification and picking have been proposed, leveraging large datasets of seismic waveforms. In this presentation, we report on the development of an automatic hypocenter determination method that incorporates machine learning into the PF method, based on Tamaribuchi et al. (2023).

In this method, a convolutional neural network was applied to distinguish between P-waves, S-waves, and noise in the waveforms read by the conventional AR-AIC method. Additionally, ensemble learning was utilized to remove false detections from the automatically determined earthquake catalog. As a result, while maintaining the number of accurate hypocenter determinations, the method successfully reduced incorrectly picked P-waves from 1.6% to 0.6%, incorrectly picked S-waves from 4.2% to 1.6%, and false detections by approximately 80%.

While this method focuses on reducing false picks and false detections, challenges remain during periods of high seismicity, such as immediately after a large earthquake, when seismic waves from multiple earthquakes overlap, making detection with conventional methods difficult. Additionally, not only is the estimation of hypocenter locations important, but the rapid estimation of focal mechanisms is also crucial for understanding the stress field in detail after a large earthquake. Therefore, further developments are underway, including models that detect seismic waves from continuous waveforms by learning from the past JMA unified earthquake catalog (Naoi et al., 2024) and models for detecting first-motion polarity for focal mechanism analysis (Shimojo, in progress). Through these efforts, we aim to contribute to a more detailed understanding of seismicity and stress fields.

References

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