# Early Detection of Debris Flow Occurrence Based on Water Level and Seismic Ambient Noise Measurements

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**Abstract: We developed an early detection system for debris flow occurrence based on seismic ambient noise measurements. The system consists of seismic ambient noise measurements, water level, and rain gages. The system continuously monitors relationship between ambient noise vibration, water levels, and precipitation. Debris flow occurrence would be detected as an irregular event among measurements. We installed the system along a mountain stream and monitored several months and established empirical relationship based on supervised machine learning.**

**Keywords:** ***Debris flow, Early detection, Seismic ambient noise, Supervised machine learning, Geophone*.**

## Introduction

Chino and Suwa Cities in Japan repeatedly experienced serious debris flow and the early warning system of the debris flow is needed. Residents of the areas often reported that they experienced rumbling sound prior to the debris flow. It appears that the gravels flowed down and caused rumbling sound prior to the deadly debris flow. We intend to detect the rumbling sound prior to the deadly debris flow and issue early warning by seismic ambient noise measurements. Figure 1 illustrates the concept of the system. Water flow generates seismic ambient noise, and we assume the vibration level of the ambient noise relates to water level under normal circumstances (a). Based on the residents' experience, gravel flow makes rumbling sound prior to the deadly debris flows. The rumbling sound is likely accompanied by ground motion and ambient noise vibration would be irregularly high (b). When a landslide caused the natural damming of the stream, both water and vibration levels would come to low compared with rain gauge (c). It is difficult to experimentally establish quantitative threshold of irregular events such as the deadly debris flow or natural damming since those events only rarely occurred. We apply machine learning to regular data and establish statistical models of regular phenomena. Irregular events can be detected as events away from the prediction.

## Monitoring System

The monitoring system consists of water level gauges, rain gauges, and three-component velocity sensors (geophone). The water level and rain gauges use LPWA (Low Power Wide Area), whereas the geophones use LTE (Long Term Evolution) to upload monitoring data to a cloud server (Ishitsuka et al., 2023). The water level gauges upload water level every three minutes, whereas the geophones upload waveform data with 100 Hz sampling every minute. Solar panels provide all electric power. The cloud server calculated averaged ambient noise vibration amplitude every minute from 100 Hz sampling waveform data.

## Amplitude and Water Level

Figure 2 shows an example of monitoring data from September to November 2024. Both water level and

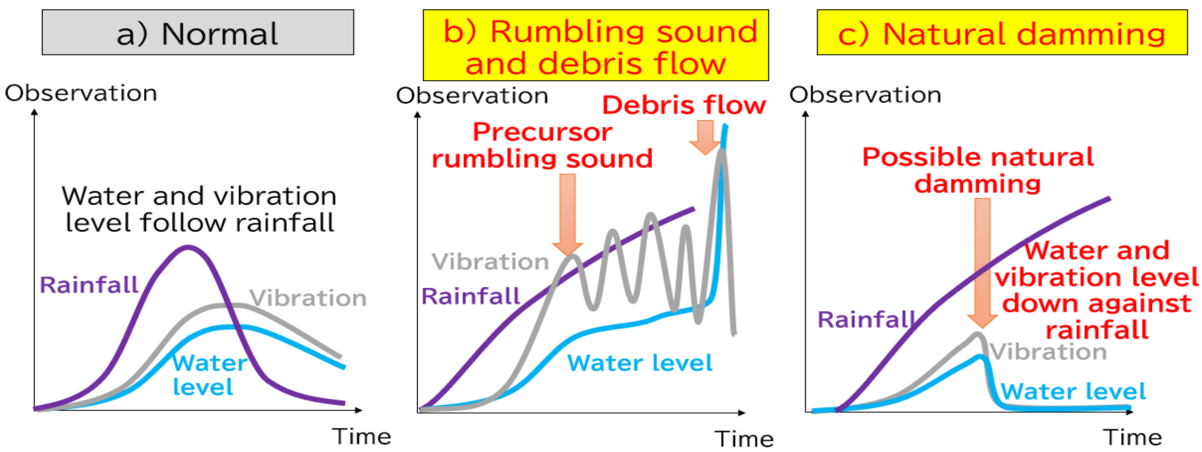


*Figure 1, Concept of the early detection system of debris flow occurrence in mountain streams.*

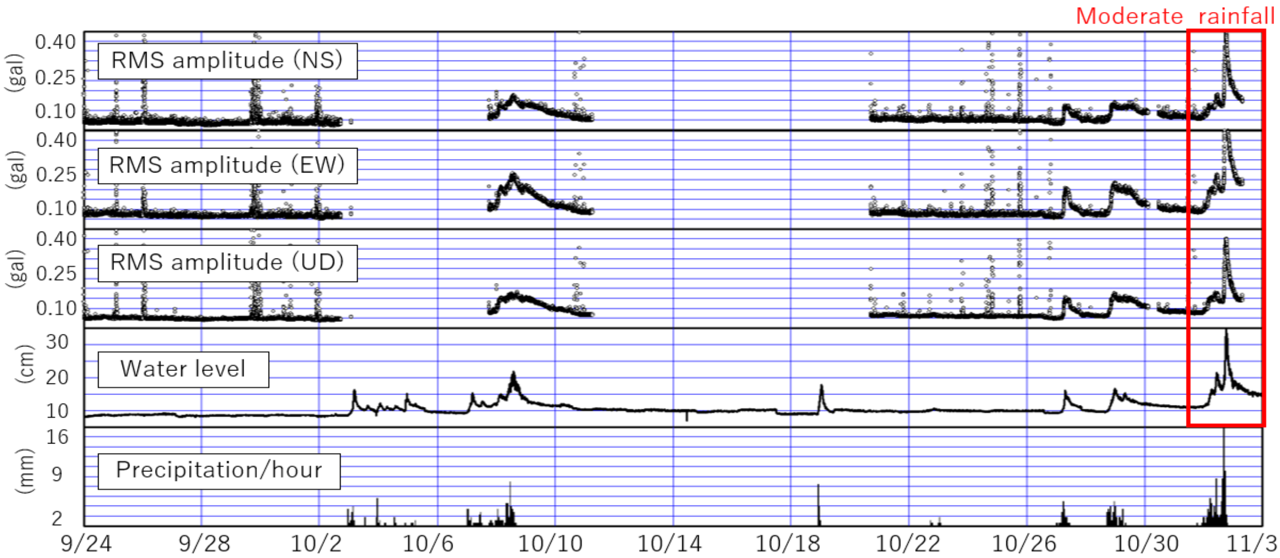


*Figure 2, Monitoring data from the end of September to the beginning of November 2024.*

ambient noise vibration amplitude increased associated with rainfall. Note that the amplitude includes large irregular data due to artificial noises. Figure 3 zoomed in the amplitude and water level on November 1st to 2nd when there was moderate rainfall. There is a clear relationship between the amplitude and water level, and it implies that water flow generated seismic ambient noises.

## Detect irregular events by ML

We assume the amplitude and water level has linear relationship and debris flow occurrence can be detected as irregular events as follows: 1) Calculated linear regression between amplitude and water level. 2) Predicted ambient noise amplitude using the linear regression and compared it with observed amplitude. Figure 4a compares observed and predicted amplitude based on the linear regression. The predicted amplitude is not linearly related to observed one in the acceleration range between 0.01 and 0.02 gal. We applied supervised machine learning (ML) to obtain more accurate empirical relationship. Figure 4b shows the prediction from the supervised ML in which data and target were water level and amplitude respectively. Predicted acceleration came to more linearly related to the observed one. Figure 4 used time history of water level and rain gauges for data. The ML could predict more accurately.

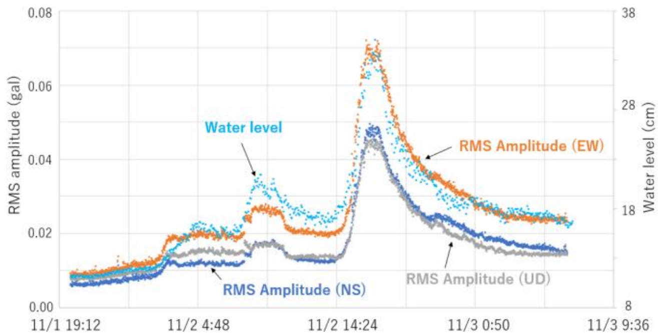


*Figure 3, Amplitude and water level on November 1st to 2nd.*

## Conclusions

We installed the integrated early warning system for debris follow. An empirical relationship between ambient noise vibration amplitude, water level and rain gages, was established based on supervised machine learning. The debris flow would be detected as irregular events deviate from empirical prediction.

## References

Ishitsuka, O., Konishi, C., Hayashi, K., Suzuki, H., & Tanazawa, Y. (2023). Development of a compact real-time seismograph system. Proceedings of the 147th SEGJ Conference (in Japanese).

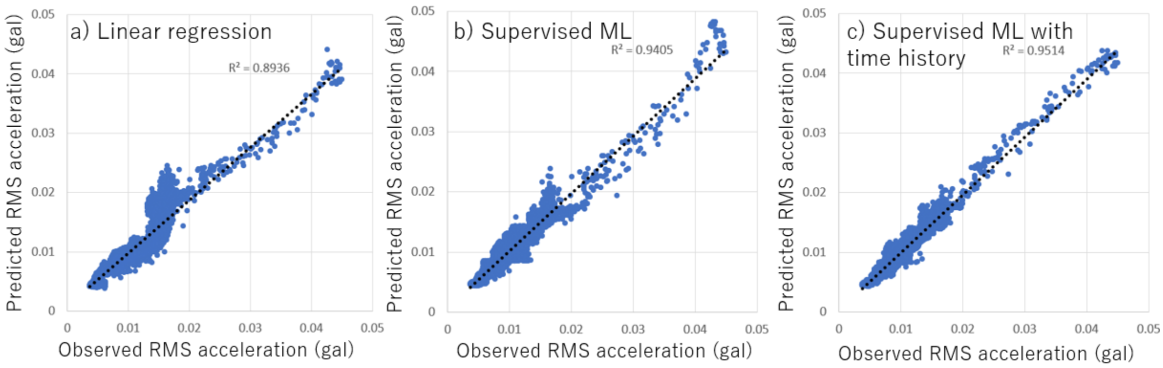


*Figure 4, Observed and predicted RMS amplitude using different empirical prediction approaches.*