SPATIAL INFLUENCE OF RAINFALL AND SEA LEVEL ON SEISMIC VELOCITY BASED ON SEISMIC AMBIENT NOISE MONITORING

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出版情報：Kyushu University, 2021, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

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論 文 名　：**SPATIAL INFLUENCE OF RAINFALL AND SEA LEVEL ON SEISMIC VELOCITY BASED ON SEISMIC AMBIENT NOISE MONITORING**
（降雨と海水面変動が微動モニタリングで得られる地震波速度の時空間変化に与える影響に関する研究）

区　　分　：甲

論 文 内 容 の 要 旨

External perturbations from the environment cause changes in the Earth's crust. Even minor perturbation can bring the crust's local stress closer to failure if the rocks are critically stressed. Thus, evaluating the area where the crust is susceptible to these external perturbations is pivotal. Recently, the crust condition can be evaluated from seismic velocity monitoring utilizing seismic passive sources. Variations in seismic velocity could reflect the perturbation induced by environmental factors (e.g., rainfall, snow, and sea level). However, the effect of observation location has not been widely considered. The Earth's crust is neither homogeneous nor flat. Therefore, the impact of these disturbances is likely to vary in different locations. This study investigated the influence of (1) rainfall and (2) ocean (as indicated by sea level variability) on seismic velocity changes (Vs) monitored in the Chugoku and Shikoku regions, southwestern Japan, by considering the station locations. This dissertation contains four chapters with the descriptions of each chapter as follows:

Chapter 1 describes the research background, the motivation, and the importance of the work. Identifying the location where Vs changes are susceptible to rainfall and ocean could be beneficial for earthquake and industry monitoring systems. Therefore, I aim to address the following research issues: (1) If geographical features and (2) lithology contribute to the impact of rainfall on the Vs changes. (3) Whether sea level could influence the estimated Vs velocity changes at land stations. (4) If yes, the possible mechanisms that could explain the influence of sea level.

Chapter 2 describes the investigation of the rainfall influence on Vs changes at seismometers in the study area. The perturbation from rainfall is controlled by the infiltration process that varies depending on the near-surface condition. Moreover, rainfall can influence Vs changes through direct loading and diffusion mechanism. To investigate these two mechanisms, I introduced two steps analysis. Step 1 is an investigation of rainfall infiltration indication. In step 1, I first distinguished the rainfall time series from sea level and atmospheric pressure through a bandpass filter. Next, I applied cross-correlation analysis between the filtered time series of rainfall and Vs change, using the frequency band from step 1. A clear negative correlation between Vs changes and rainfall implies a possibility of rainfall infiltration at that particular location. Moreover, the time-lag from the cross-correlation process implies the near-surface condition related to lithology permeability. I further investigated the possibility of pore pressure diffusion in step 2. In step 2, I calculated the correlation coefficient between Vs change and a modelled pore pressure change from rainfall time-series. A strong negative correlation between the modelled pore pressure changes and Vs changes indicates that the Vs variations are triggered by pore pressure diffusion in the deep formation. By selecting the highest negative correlation between Vs change and the modelled pore pressure, I obtained the optimum hydraulic diffusion rate. The proposed approach in Chapter 2 can be used to evaluate the area where the crust (as indicated by the Vs changes) is susceptible to rainfall perturbation.

Chapter 3 describes the evaluation of how sea level variability influences Vs changes at inland stations. In this work, I analyzed each pair of seismic stations. I introduced three steps analysis. Step 1 distinguishes the cycle of sea level from atmospheric pressure through a bandpass filter. Since atmospheric pressure tends to cause deformation both on the coast and inland sites, it is necessary to distinguish the sea level cycle from the atmospheric pressure. Next in step 2, I evaluated the influence of sea level on the seismic velocity changes by calculating the correlation coefficient of the two time series for all station pairs. Furthermore, from each station pair, I defined the inland closest station's distance to the ocean. The seismic station pair with the same proximity to the coast were grouped, and the correlations were averaged based on the seismic station's proximity. Finally, in step 3, I evaluated the correlations concerning the station's proximity based on the statistical approach. The scatterplot from step 3 shows a decreasing trend between the averaged correlation and the station's proximity, this indicates the influence of sea level decreases with increasing station's distance from the coast. The increasing sea level deforms the ocean floor, affecting the stress in the adjacent coast. The stress change induced by the ocean loading may extend at least dozens of kilometers from the coast. The correlation between sea level and inland Vs change is negative or positive. Although it is difficult to clearly interpret the correlation based on simple model, they could depend on the in situ local stress, the orientation of dominant crack, and hydraulic conductivity. This study shows that seismic monitoring may be useful for evaluating the perturbation in the crust associated with an external load.

Chapter 4 describes the summary of the key findings and the research implication. In this chapter, I addressed the research questions stated in Chapter 1. From the investigation in Chapter 2, I found that rainfall tends to influence Vs changes estimated at the location with gentle topography (Chugoku). Meanwhile, there are no clear indications observed in the steep mountains (Shikoku). Near surface lithology such as high permeable rocks and fractured granite rocks allow rainfall to percolate deeper and influence Vs change. From Chapter 3, it is found that sea level variability can influence inland Vs changes through inland deformation induced by ocean loading. The observed correlations between Vs change and sea level from each station pair could be caused by in situ stress condition, crack's orientation, and hydraulic conductivity. Knowing where Vs changes are prone to the perturbation from rainfall and ocean can be useful for earthquake and industry monitoring systems. Such information can be used for the evaluation of earthquake triggering mechanisms and induced seismicity for industrial activities.