Rainfall-inducing deep formation pore pressure change: insight from seismic velocity monitoring

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Under critically stressed rock conditions, a small change in pore pressure generates cracks, triggering an earthquake. Aside of natural causes, various industrial activities including Carbon Capture Storage (CCS) can induce seismicity. Hence, monitoring pore pressure conditions in CCS project is important. Crustal pore pressure in the deep formation is known to vary in response to external perturbations such as snow and rainfall. Here, we investigated the response of crustal pore pressure to rainfall in southwestern Japan based on daily seismic velocity derived from seismic ambient noise monitoring. To consider the area heterogeneity, we directly compared rainfall and seismic velocity obtained at each location. We used a band-pass filter to distinguish rainfall variability from sea level and atmospheric pressure and calculated the cross-correlation between rainfall and variations in S-wave velocity (Vs). A mostly negative correlation between rainfall and Vs changes indicates groundwater recharge by rainfall, which increases pore pressure. The correlations differ between locations, where most of the observation stations with clear negative cross-correlations were in areas of granite (Fig. 1a). Meanwhile, we could not observe clear correlations in steep mountain areas, which could be due to water flows through the river without infiltration. This suggests that geographical features contribute to the imprint of rainfall on deep formation pore pressure. We further modeled pore pressure change from rainfall data based on diffusion mechanism. A strong negative correlation between pore pressure estimated from rainfall and Vs indicates that Vs variations are triggered by pore pressure diffusion in the deep formation (Fig. 1b). The results show hydraulic diffusion rate that controls the diffusion mechanism spatially varies across Chugoku and Shikoku regions. Through this approach, we can evaluate the heterogeneity of the deep formation, which could be useful for CO2 injection monitoring in the CCS project.

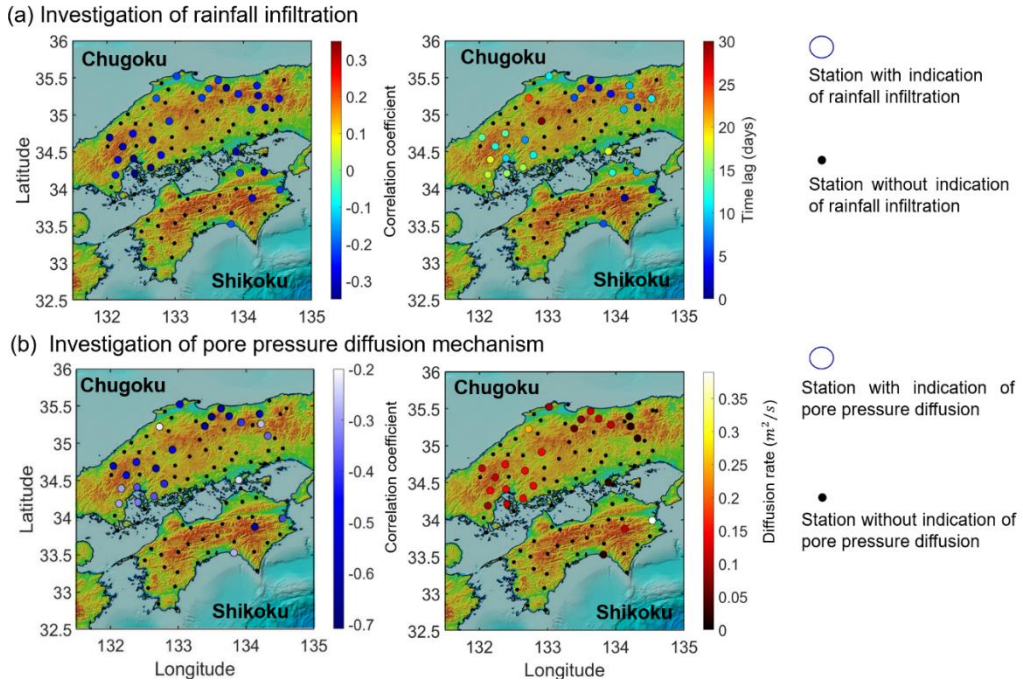

Fig.1. The influence of rainfall at the Chugoku and Shikoku region (southwestern Japan). Panel (a) represent the correlation coefficient between Vs changes and rainfall (left) and the time required for groundwater replenishment (right). (b) The correlation coefficient between Vs changes and modeled pore pressure from rainfall (left), and the diffusion rate that controls pore pressure diffusion mechanism (right).