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Seismic ambient noise study at Bouillante geothermal system, French Antilles

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Seismic ambient noise analyses have been shown to be able to image structural features of the crust and to monitor underground changes of seismic wave ground velocity. We present results of cross-correlation techniques at Bouillante geothermal field, French Antilles, the largest French high-enthalpy geothermal system exploited for electrical power from 3 collocated productive wells. Two power plants generate electricity and fluid extraction rate varies with time and wells are sometimes closed for equipment maintenance. Under the support of the French Environment and Energy Management Agency (ADEME) and the French Research Agency (ANR), BRGM has been analyzing seismic data from a network comprising 5 broadband seismological stations set-up at Bouillante area since 2004. Amongst the large number of earthquakes recorded, we show that no single earthquake could be related to the fluid exploitation. Instead, they are due to the intense regional seismicity. Despite the small number of stations, surface wave travel times computed from ambient noise cross-correlation for about a year suggest that the velocity structure is consistent with the conceptual model of hot (250°C) and permeable (fractured) geothermal reservoir of Bouillante. We show at several instances that changes of the fluid extraction rate have spatial and temporal slight perturbations on medium wave velocity. For example, when the production stops for maintenance, velocity increases by several percent and with larger amplitude at stations within 1 km distance from the production wells and lower amplitudes (by more than 50 %) at stations further than 2 km from the production wells. In addition, we note that velocity perturbations have a delay of at most 1 day at further stations. We discuss several mechanisms to explain those observations like pressure and stress variations in the geothermal system. The results suggest that the inferred velocity changes, owing the fine sensibility of the inter-correlation method, do not produce stress changes strong enough to trigger micro-seismicity in the Bouillante area. The perturbation (e.g., due to phase change in the hot fluid, change in porosity and fracture closure) would propagate through the fracture system with a speed depending on its structural features. More observations using additional stations would allow us to increase our knowledge of the velocity structure around the geothermal field and understand physical mechanisms behind those controlled perturbations.