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A sensitivity analysis on seismic tomography data with respect to CO_2 saturation of a CO_2 geological sequestration field

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Monitoring CO_2 migration and storage in geological formations is important not only for the stability of geological sequestration of CO_2 but also for efficient management of CO_2 injection. Especially, geophysical methods can make in situ observation of CO_2 to assess the potential leakage of CO_2 and to improve reservoir description as well to monitor development of geologic discontinuity (i.e. fault, crack, joint, etc.). Geophysical monitoring can be based on wireline logging or surface surveys for well-scale monitoring (high resolution and nallow area of investigation) or basin-scale monitoring (low resolution and wide area of investigation). In the meantime, crosswell tomography can make reservoir-scale monitoring to bridge the resolution gap between well logs and surface measurements. This study focuses on reservoir-scale monitoring based on crosswell seismic tomography aiming describe details of reservoir structure and monitoring migration of reservoir fluid (water and CO_2). For the monitoring, we first make a sensitivity analysis on crosswell seismic tomography data with respect to CO_2 saturation. For the sensitivity analysis, Rock Physics Models (RPMs) are constructed by calculating the values of density and P and S-wave velocities of a virtual CO_2 injection reservoir. Since the seismic velocity of the reservoir accordingly changes as CO_2 saturation changes when the CO_2 saturation is less than about 20%, while when the CO_2 saturation is larger than 20%, the seismic velocity is insensitive to the change, sensitivity analysis is mainly made when CO_2 saturation is less than 20%. For precise simulation of seismic tomography responses for constructed RPMs, we developed a time-domain 2D elastic modeling based on finite difference method with a staggered grid employing a boundary condition of a convolutional perfectly matched layer. We further make comparison between sensitivities of seismic tomography and surface measurements for RPMs to analysis resolution difference between them. Moreover, assuming a similar reservoir situation to the CO_2 storage site in Nagaoka, Japan, we generate time-lapse tomographic data sets for the corresponding CO_2 injection process, and make a preliminary interpretation of the data sets.