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In situ seismic velocity changes in Southern Iceland

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Detecting in situ velocity changes in the crust of the earth before significant earthquakes (pre-seismic changes), for the purpose of predicting earthquakes, has been described as the Holy Grail of seismology, i.e. highly desirable goal but with elusive results. Pre-seismic signals of the order of 10–20%, reported in the 1960ies and 1970ies, have not been convincingly reproduced. Lower level (0.5–3.5%) coseismic and postseismic in situ changes have, however, repeatedly been reported. Due to lack of seismicity prior to significant earthquakes, adequate data are often lacking to test the hypothesis of pre-seismic signals. Using earthquake data in order to detect such signals, errors in earthquake locations and velocity models may give a false-positive temporal signals. For the detection of a low level ($\sim$1.0%) pre-seismic change, good knowledge of seismic structure, high accuracy of earthquake locations, and a continuous high level of seismicity are important factors. The local seismic network of the Icelandic Meteorology Office, the SIL network, is in many respects ideal for studying in situ pre-seismic changes before significant earthquakes. Since the beginning of its operation in 1991, four earthquakes of magnitude $\sim$6.0 and greater have occurred in the region, which may have caused pre-seismic velocity changes in the crust. The original design of the network had a high clock accuracy ($\pm$1 ms). S-waves tend to be very clear, and successful 1D velocity model (SIL model) has been used to locate earthquakes in the area, suggesting relatively simple velocity structure in spite of active tectonic setting. Earthquakes in Southern Iceland during the period 1991 to 2000 are being analyzed. The period includes two large earthquakes in year 2000, both of them of the magnitude 6.5. The analysis involves improving earthquake locations in order to determine if in situ changes do exist in the area (down to $\sim$0.5% significance level), with the ultimate goal of locating them at relatively high spatial resolution ($\sim$10x10x3 km3). With such a high spatial resolution, identification of individual faults approaching failure can possibly be determined. However, with the current uncertainties of earthquake locations in Southern Iceland, in situ changes cannot be constrained at such a high spatial resolution. This requires improvement of earthquake location by approx. an order of magnitude from the current status of SIL catalog locations. We have started applying double-difference method of Waldhauser and Ellsworth (2000), to improve earthquake location accuracy in the area. On spatial resolution scale on the order of the size of the Southern Iceland Lowland ($\sim$70 km), we have been able to measure velocity ratios at $\sim$0.04–0.1% significance (1 σ) with the uncorrected SIL catalog data. Preliminary results can be interpreted to indicate a linear decrease in Vp/Vs ratio by 0.8%, starting in the years 1997–1998 and until 2000 (a yearly change of 0.2–0.3%). These results need to be verified with earthquake locations of improved accuracy, before we can conclude that pre-seismic in situ changes leading up to the two earthquakes of year 2000.