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Variations and healing of the seismic velocity (Beno Gutenberg Medal Lecture)

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Scattering of waves leads to a complexity of waveforms that is often seen by seismologists as a nuisance. And indeed, the complicated wave paths of multiple scattered waves makes it difficult to use these waves for imaging. Yet, the long wave paths of multiple scattered waves makes these waves an ideal tool for measuring minute velocity changes. This has led to the development of coda wave interferometry as a tool for measuring small velocity changes in the laboratory and with field data. Combined with the use of noise cross correlations—seismic interferometry—this method is even more useful because it follows for a quasi-continuous measurement of velocity changes. I will show examples of detecting velocity changes in the laboratory, the earth's near surface, and in engineered structures. Perhaps surprisingly, the seismic velocity is not constant at all, and varies with the seasons, temperature, precipitation, as the weather does. In addition, the seismic velocity usually drops as a result of deformation. Most of these changes likely occur in the near surface or the region of deformation, and a drawback of using strongly scattered waves is that it is difficult to localize the spatial area of the velocity change. I will present laboratory measurements that show that a certain spatial localization of the velocity change can be achieved. One of the intriguing observations is that after deformation the seismic velocity recovers logarithmically with time. The reason for this particular time-dependence is the presence of healing mechanisms that operate at different time scales. Since this is feature of many physical systems, the logarithmic healing is a widespread behavior and is akin in its generality to the Gutenberg-Richter law.