



Seismic velocity and crustal thickness inversions: Moon and Mars

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We present results from new inversions of seismic data arrival times acquired by the Apollo active and passive experiments. Markov chain Monte Carlo inversions are used to constrain (i) 1-D lunar crustal and upper mantle velocity models and (ii) 3-D lateral crustal thickness models under the Apollo stations and the artificial and natural impact sites. A full 3-D model of the lunar crustal thickness is then obtained using the GRAIL gravimetric data, anchored by the crustal thicknesses under each Apollo station and impact site. To avoid the use of any seismic reference model, a Bayesian inversion technique is implemented. The advantage of such an approach is to obtain robust probability density functions of interior structure parameters governed by uncertainties on the seismic data arrival times. 1-D seismic velocities are parameterized using C1-Bézier curves, which allow the exploration of both smoothly varying models and first-order discontinuities. The parameters of the inversion include the seismic velocities of P and S waves as a function of depth, the thickness of the crust under each Apollo station and impact epicentre. The forward problem consists in a ray tracing method enabling both the relocation of the natural impact epicenters, and the computation of time corrections associated to the surface topography and the crustal thickness variations under the stations and impact sites. The results show geology-related differences between the different sites, which are due to contrasts in megaregolith thickness and to shallow subsurface composition and structure. Some of the finer structural elements might be difficult to constrain and might fall within the uncertainties of the dataset. However, we use the more precise LROC-located epicentral locations for the lunar modules and Saturn-IV upper stage artificial impacts, reducing some of the uncertainties observed in past studies. In the framework of the NASA InSight/SEIS mission to Mars, the method developed in this study will be used to constrain the Martian crustal thickness as soon as the first data will be available (late 2018). For InSight, impacts will be located by MRO data differential analysis, which provide a known location enabling the direct inversion of all differential travel times with respect to P arrival time. We have performed resolution tests to investigate to what extent impact events might help us to constrain the Martian crustal thickness. Due to the high flexibility of the Bayesian algorithm, the interior model will be refined each time a new event will be detected.