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Calibrating Magnitude Scales for Mars

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The NASA InSight Discovery Program mission will deploy a lander with geophysical and meteorological sensors on the Martian surface at the end of 2018, including a highly sensitive very-broadband seismometer. In anticipation of the planned data return, we define and calibrate six marsquake magnitude scales, which include current knowledge on the interior structure of Mars and the expected environment and instrument noise: (1) local magnitude, ML_M, (2) P-wave magnitude, $mb_{p,M}$ and (3) S-wave magnitude, $mb_{s,M}$, each defined at 3 seconds and calibrated for distances up to 10^o, or from 5^o to 100^o, respectively; (4) surface-wave magnitude, MS_M, at 20 seconds, and (5) moment magnitudes, $Mw_{b,M}$ and (6) $Mw_{full,M}$, at 10 to 100 seconds, calculated from the displacement spectrum for either body- or body- and surface-waves, respectively; scales (4) to (6) are valid for distances from 5^o to 180^o. We regress stable magnitude calibrations of the six scales in terms of the seismic moment for Mw4.0 by correcting filtered phase amplitudes for attenuation with distance and source depth, using a dataset of 2,600 randomly distributed marsquakes simulated with a spectral element method for 13 published 1D structural models of the Mars interior. We successfully validate these relations with an independent test dataset ($1.0 \leq Mw \leq 8.0$) whose seismograms are superimposed on the realistic noise predicted by the InSight noise model. We expect that small marsquakes ($<$Mw3.0) at epicentral distances of $\Delta > 15^o$ are hidden in Mars background noise and are probably undetectable.