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Automated forward mechanical modeling of wrinkle ridges on Mars

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One of the main goals of the InSight mission to Mars is to understand the internal structure of Mars [1], in part through passive seismology. Understanding the shallow surface structure of the landing site is critical to the robust interpretation of recorded seismic signals. Faults, such as the wrinkle ridges abundant in the proposed landing site in Elysium Planitia, can be used to determine the subsurface structure of the regions they deform. Here, we test a new automated method for modeling of the topography of a wrinkle ridge (WR) in Elysium Planitia, allowing for faster and more robust determination of subsurface fault geometry for interpretation of the local subsurface structure.

We perform forward mechanical modeling of fault-related topography [e.g., 2, 3], utilizing the modeling program Coulomb [4, 5] to model surface displacements surface induced by blind thrust faulting. Fault lengths are difficult to determine for WR; we initially assume a fault length of 30 km, but also test the effects of different fault lengths on model results. At present, we model the wrinkle ridge as a single blind thrust fault with a constant fault dip, though WR are likely to have more complicated fault geometry [e.g., 6-8]. Typically, the modeling is performed using the Coulomb GUI. This approach can be time consuming, requiring user inputs to change model parameters and to calculate the associated displacements for each model, which limits the number of models and parameter space that can be tested. To reduce active user computation time, we have developed a method in which the Coulomb GUI is bypassed. The general modeling procedure remains unchanged, and a set of input files is generated before modeling with ranges of pre-defined parameter values.

The displacement calculations are divided into two suites. For Suite 1, a total of 3770 input files were generated in which the fault displacement (D), dip angle (δ), depth to upper fault tip (t), and depth to lower fault tip (B) were varied. A second set of input files was created (Suite 2) after the best-fit model from Suite 1 was determined, in which fault parameters were varied with a smaller range and incremental changes, resulting in a total of 28,080 input files. RMS values were calculated for each Coulomb model. RMS values for Suite 1 models were calculated over the entire profile and for a restricted x range; the latter shows a reduced RMS misfit by 1.2 m. The minimum RMS value for Suite 2 models decreases again by 0.2 m, resulting in an overall reduction of the RMS value of $\sim$1.4 m (18%). Models with different fault lengths (15, 30, and 60 km) are visually indistinguishable. Values for δ, t, B, and RMS misfit are either the same or very similar for each best fit model. These results indicate that the subsurface structure can be reliably determined from forward mechanical modeling even with uncertainty in fault length. Future work will test this method with the more realistic WR fault geometry.

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