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Double single-force model to characterize the detachment and impact of a landslide: application to the 07-02-2021 Uttarakhand, India landslide

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Landslides begin with the detachment of a mass and end with its impact at lower altitude. To simultaneously model seismic signals produced by these processes, we consider a double single-force model. We applied this source model to the seismic signals generated by the landslide in Uttarakhand, India, on February 7th, 2021. We model the seismic recordings at 12 seismic stations located at less than 100 km epicentral distance. We perform the source inversion by fitting low-frequency (0.08-0.15 Hz) three component (vertical, radial, transversal) waveforms in the time and simultaneously their amplitude spectra in the frequency domain. We compare our results with those obtained for a single-force model applied to each pulse separately. Our results identify two energetic pulses separated by a time delay of ~1 minute. The amplitude of the second pulse, interpreted as the impact, is ~3 times larger than the first one, and of opposite sign. Together with visual observations of the landslide itself, our results confirm that the first pulse was produced by the detachment of the rock mass and the second one by the impact of the mass in the valley. The orientations of the single forces are consistent with the slope geometry and the direction of the debris flow. We discuss statistical measures of fit of the two different inversion approaches and the possible strengths and weaknesses of the new double single-force model.