

Rupture directivity of strike-slip earthquakes on landslide distribution: A case study of the Kumamoto 2016 Earthquake

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The 2016 Kumamoto earthquake (M_{JMA} 7.1) triggered hundreds of landslides in central Kyushu (Japan), some extending over hundreds of meters. Here, we combine 240 records of the dense seismic network in Kyushu with the earthquake-triggered landslide inventory to investigate the effect of the Kumamoto earthquake on landslide triggering.

The detailed landslide inventory, the seismic network with full azimuthal coverage and the local topography provide a unique opportunity to analyze the triggering factors.

The expected spatial distribution of earthquake-triggered landslides is described by classical models (e.g. Harp & Wilson, 1995) and is based on the Arias intensity with respect to the rupture distance alone. Topography (slope) and lithology also affect the occurrence of landslides. The landslides of this NW-SE striking strike-slip event are more concentrated to the Northeast of the rupture zone, though similar topographic and lithological conditions exist in other locations surrounding the rupture zone.

Indeed, the rupture directivity effect causes spatial variations in seismic amplitudes around a fault and cause differences between the strike-normal and strike-parallel components of horizontal ground motion. We identify an area affected by the directivity effect of the strike-slip event to the northeast of the rupture zone. This area covers most of the landslides both in numbers and slid area and is characterized by lower frequencies and higher energies in the seismic waveforms.

This contrasts to previous assumptions that relate landslide distribution to the acceleration based Arias intensity which is more affected by higher frequencies (> 1 Hz), whereas energy is a velocity-derived metric, and dominated by lower frequencies (< 1 Hz).

In combination with high-resolution Digital Elevation Models, we demonstrate that the crowns of the landslides are located in areas of steep slopes and elevated median amplification factors (MAF). Other regions provide similar characteristics, but lack increased landslide activity.

We show a preferred orientation of the landslides normal to the rupture plane, which is governed by the directivity effect and not by the aspect of the topography. We conclude that slope, MAF, high frequency ground measures (Arias intensity, PGA) and lithology are insufficient to explain the occurrence and distribution of landslides for the Kumamoto event. The inclusion of directivity, low frequency shaking intensity measure (energy magnitude, PGV) allows better modelling of the size and location of the landslides for a strike-slip event.

Keywords: Earthquake-induced landslides, Landslides distribution and orientation, Earthquake rupture directivity