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# Discussion on seismically triggered avalanches on Mars

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## Motivations

A few facts:

- On May 5, 2022, the martian SEIS seismometer recorded an unprecedented $M_W^{Ma}$4.7 Marsquake [1].
- The epicenter is located at 3.0°S, 171.9°E.
- The areas is barely flat with only a few N-S tectonic-like features.
- Most unfilled impact craters and ridges show dust avalanches (a.k.a. Slope streaks).

⇒ We investigate the post-seismic outcomes in terms of avalanche triggering under today's Mars conditions.

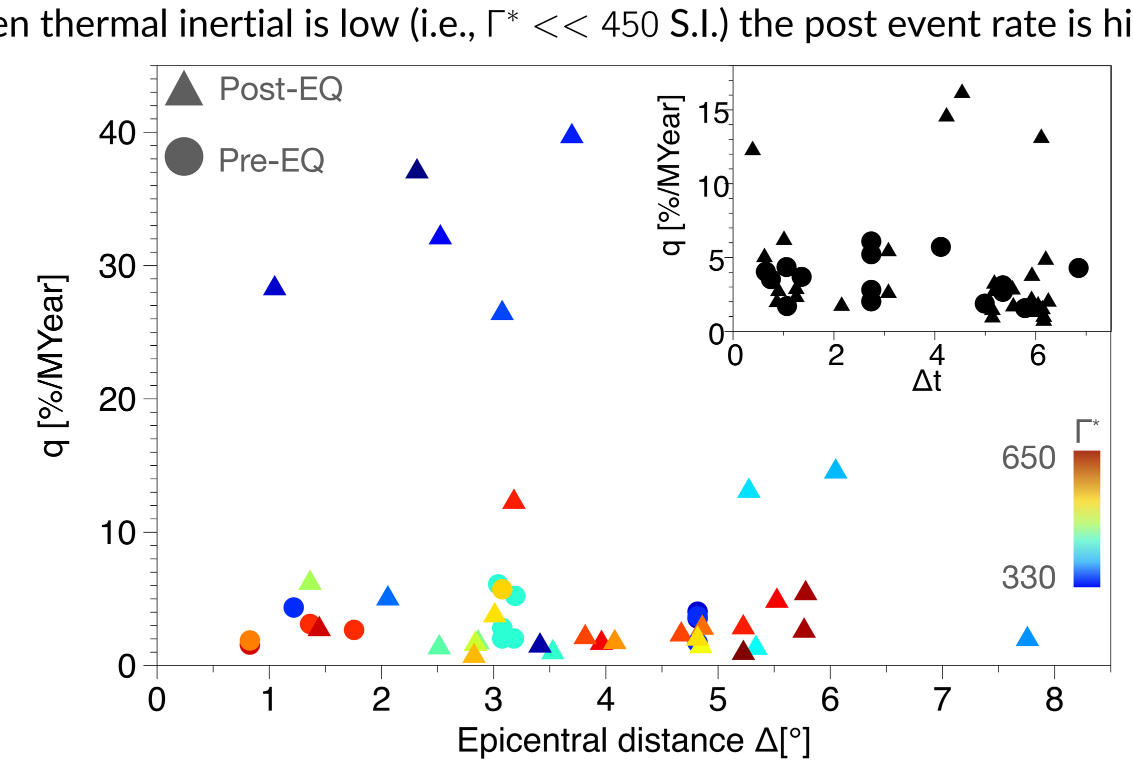
## Methods

Using orbital images from CTX and HiRISE cameras, both onboard MRO spacecraft:

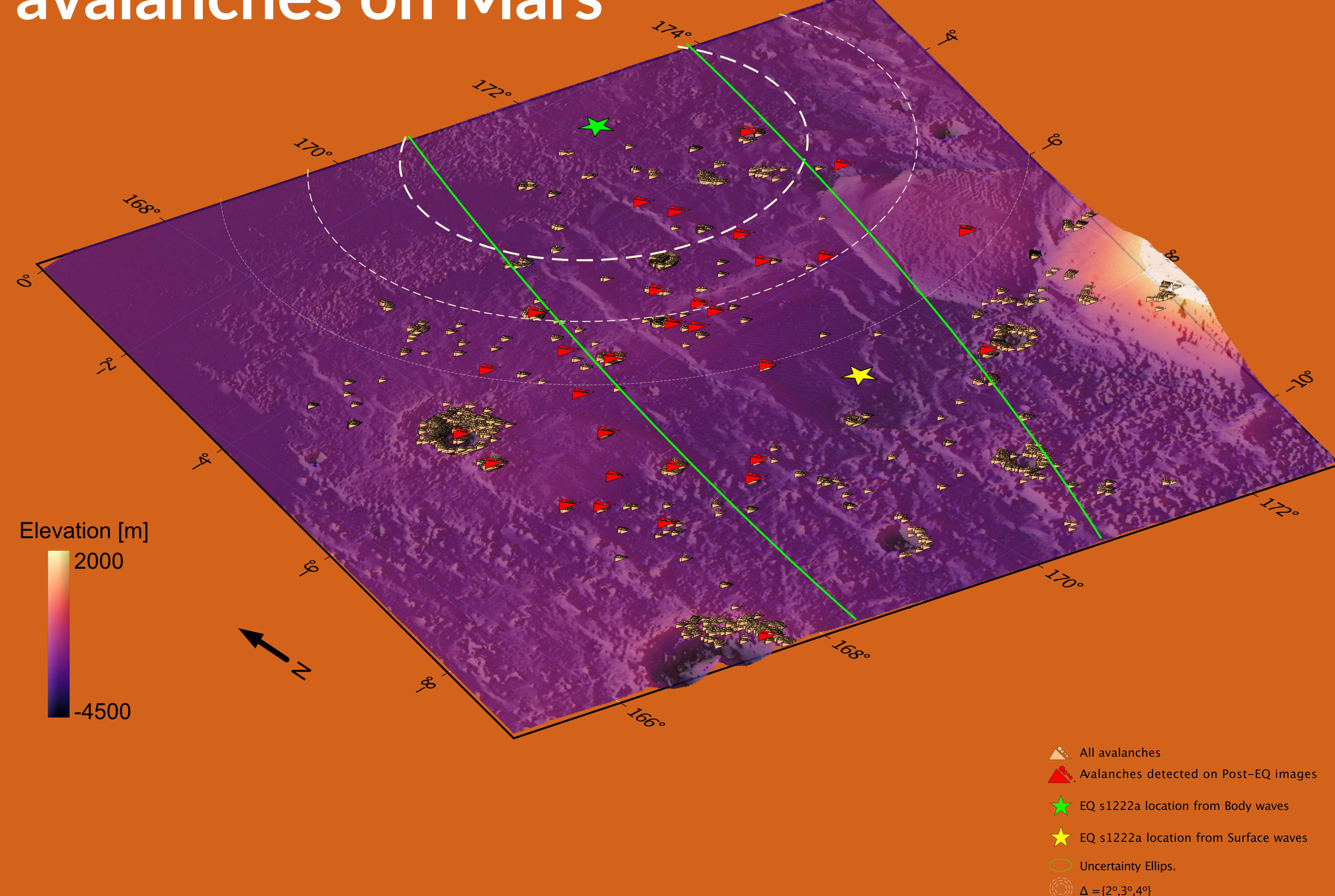
- We investigate all CTX and HiRISE images around $\pm 4°$ away from the estimated epicenter, and mapped all detectable avalanches over the 2005–2022 period.
- We requested dedicated new orbital observations targeted towards the most favorable areas for avalanches from the previous task.
- For each available pairs of images we computed the avalanche rate as defined $q_{ava} = \Delta n/(n \times \Delta t)$, where $\Delta n$ is the number of new avalanches between two images, $n$ being the number of avalanches seen on both images, and $\Delta t$ being the time span between the two images expressed in martian year [2].
- We integrated additional orbital data such as elevation (from MOLA and HRSC) as well as thermal inertial from THEMIS.

## Results

- Almost 4500+ avalanches have been identified in the area of interest.
- about 200 new avalanches have been detected over over the 2005–2021 period
- about 100 avalanches are detected on the post-event images with respect to their 2005–2021 period counterparts
- Most avalanches are seen inside impact crater walls.
- Pre-event nominal avalanche rate $q_{ava}$ = $2.6_1^6$ %.MYr$^{-1}$
- When thermal inertial is high (i.e., $\Gamma^* > 450$ S.I.) the post event rate is not higher
- When thermal inertial is low (i.e., $\Gamma^* << 450$ S.I.) the post event rate is higher




As on Earth, **seismic activity** with favorable geology may be responsible for triggering **avalanches on Mars**



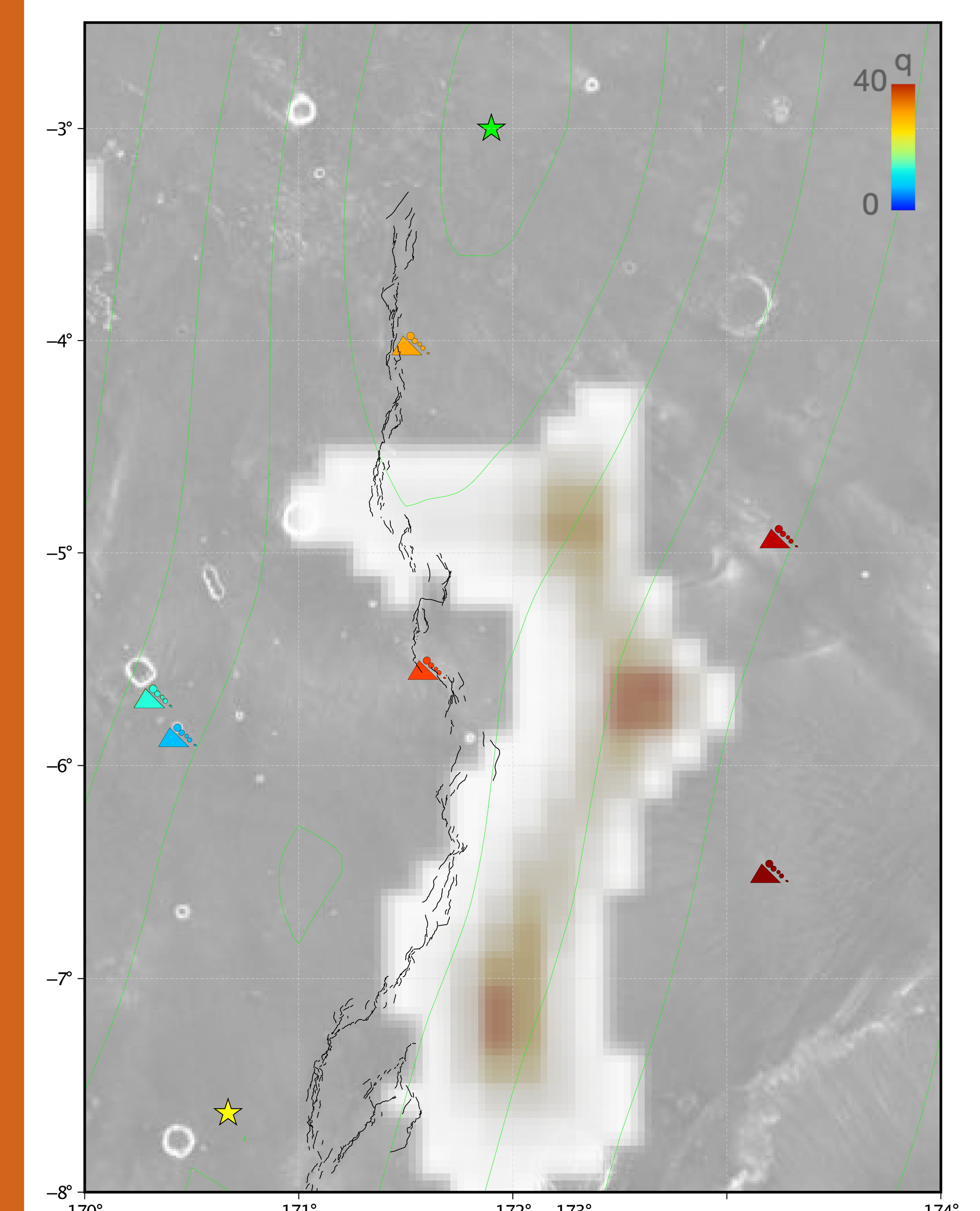

## Supplementary material

### Triggering and ground motion estimates

The epicentral distance is far from being the only parameter that controls the avalanche rates. Local geology, fractures and historical events will have a significant effect on the aftermaths of the earthquake [3]. On Mars, subsurface properties can be derived through the thermal inertial, which is the related to how solar energy is absorbed and resulting heat propagates within the subsurface. Hence this is strongly correlates with the material properties as $\Gamma \equiv \sqrt{\kappa_e(1-p)\rho C(T)}$, where $\kappa_e$ is the effective thermal conductivity, $p$ the porosity, $\rho$ the density and $C(T)$ specific heat capacity. So, we observe that avalanches are formed mostly over low thermal inertia terrains, which correspond to unconsolidated terrains, and or granular material. Following the hypothesis of seismic induced avalanches, one can relate ground deformation with avalanche rate. Following previous approaches of [4, 5], we can relate the ground motion with epicentral distance Δ through:

$$G(\Delta) = \frac{K}{(\alpha + \Delta/D)^n}, \tag{1}$$

where K and $\alpha$ are empirical parameters, and with $n$ = {2,1.7,1.5} for the acceleration, velocity and displacement respectively [5]. This leads to evaluate the new EQ location with respect to the avalanche rates as a function of the epicentral offset with $n = 2$ using a maximum likelihood function with a Laplacian distribution of errors [6], to find the best marsquake location that explains the avalanche rates for $\Gamma^* > 430$SI.

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