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Distinguishing between a pure static offset and “saw-tooth” shape of the very-long period (VLP) displacement at volcanoes

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Very-long-period (VLP) seismic signals on volcanoes are thought to represent the ground response to mass transport of magmatic fluids inside a volcanic edifice. In vast majority of papers they are reported as simple-shaped (similar to Ricker wavelet) zero-mean transients. A group of authors reported the “saw-tooth” shaped series of VLP displacements with the “fall time” (signal duration before it diminishes measured from the maximum amplitude) of several hundred seconds. The other group of authors reported a “ramp-shaped” VLP source-time history, highlighting their inability to determine the trend of the signal far beyond the instrument response corner frequency. It is important to note that even minimal frequency filtering will covert the “staircase-shaped” displacement of a series of offset events into a “saw-tooth” scenario. Since these two scenarios lead to different conceptual models, the ability to distinguish between them is crucial for our understanding of the VLP seismic activity on volcanoes. This work is aimed to address this issue.

Our ability to measure the static displacement offsets of seismic signals (like ones in the near field of typical earthquakes) is limited for the small-amplitude seismic events of relatively long duration, such as long (LP) and very-long- period (VLP) events on volcanoes. In particular, the smaller the ratio between the signal amplitude and the dominant period is, the more difficult is to recover the static offset of the ground motion - the main reason being the limited bandwidth of the instrument in the combination with the long period natural (mainly microseisms) and instrumental noise. Recent advances in instrumental seismology reported successful measurements of static offsets by applying median filter. The offsets as small as several micrometres were recovered in the case of LP events with the rise time to the final offset of 1-2 s. This threshold is at least an order of magnitude higher for VLP events with the rise time 20-30 s. Median filter methodology was chosen because a standard highpass frequency filter destroys a static offset (DC spectral component) – in the best case scenario, it produces a “saw-tooth” shaped signal from the originally shaped “ramp” or “staircase” signal. On the other hand, the median filter is limited by its time-window length and it does not reveal the true nature of the signal beyond this length – it is particularly problematic for recovering slowly diminishing “saw-tooth” VLP signals , such as reported in the literature. In order to be able to address this issue and distinguish between the “staircase” and “saw-tooth” scenarios, we propose the methodology where we combine frequency and variable length median filters. The proposed method successfully distinguishes between the real and artificial signal behaviour at the times after the initial displacement step. It was robustly tested using synthetic data and then applied to a real case VLP scenario.