



## Resolving dynamic ground motions with high-rate GNSS and implications for data fusion in broadband seismology and Earthquake Early Warning

Roland Hohensinn<sup>1</sup>, Nikolaj Dahmen<sup>1,2</sup>, John Clinton<sup>2</sup>, Alain Geiger<sup>1</sup>, and Markus Rothacher<sup>1</sup>

<sup>1</sup>ETH Zurich, Institute of Geodesy and Photogrammetry, Zurich, Switzerland (rolandh@ethz.ch)

<sup>2</sup>ETH Zurich, Swiss Seismological Service (SED), Zurich, Switzerland

In this paper we highlight the potential of geodetic high-precision and high-rate GNSS (*Global Navigation Satellite System*) sampling (1 to 100 Hz) for resolving seismic ground motions, of both the near and the far field of an earthquake. The analysis of the budget and characteristics of the error of high-rate GNSS displacement time series yields results, discussion, and conclusions on the sensitivity and waveform resolvability as well as on the derivation of a minimum detectable displacement (in the statistical sense).

Based on these analyses, we show how GNSS can contribute to optimal broadband displacement and velocity waveform products by means of data fusion by combining measurements taken from co-located sensors – e.g. accelerometers or gyroscopes – in real-time, near real-time and postprocessing mode. Concerning the inclusion of GNSS for such an analysis, we also briefly explore the ability of GNSS to record signals from different earthquake magnitudes and epicentral distances. We show that high-rate GNSS is sensitive to displacements down to the level of a few millimeters, and even below – an example also comes from the detection of very small vibrations from 100 Hz GNSS data.

We analyze measurements of synthesized signals obtained from experiments with a shake table, as well as from real data from strong earthquakes, namely the 6.5  $M_w$  event of 2016 near the city of Norcia (Italy) and the 7.0  $M_w$  Kumamoto earthquake of 2016 (Japan). Based on these data and our main findings, we finally discuss the role of GNSS in Earthquake Early Warning in terms of a fast hypocenter localization and reliable magnitude estimation.