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Monitoring short-term dynamic motion with single-frequency observations from a low-cost GNSS receiver

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In the last few decades, GNSS observations have frequently been used in Structural Health Monitoring (SHM) and Earthquake Early Warning (EEW) systems. The primary advantage of high-frequency GNSS techniques is to detect displacements directly in a terrestrial reference frame compared to conventional geotechnical sensors. Among GNSS techniques, the real-time kinematic (RTK) has predominantly been employed in dynamic displacement monitoring because it provides high accuracy simultaneously. Nevertheless, an external GNSS infrastructure is essential in RTK applications to achieve high positioning accuracy, which restricts its use in possible mega earthquake events. On the other hand, Precise Point Positioning (PPP), which can provide high positioning accuracy with a standalone GNSS receiver on a global scale, emerged as an alternative to traditional GNSS techniques. However, the requirement of an external internet connection for real-time PPP applications is the main restriction of this technique in the employment of possible mega earthquake events like the RTK technique. Instead, the variometric approach (VA) can provide high accuracy in determining dynamic behaviors with a standalone GNSS receiver and broadcast ephemeris only, which means it doesn't require any external infrastructure and connection. Furthermore, the emergence of new navigation systems, such as Galileo and BeiDou, brings considerable opportunities to improve the performance of the VA technique in detecting dynamic behaviors. Thanks to progress in GNSS receiver technology, low-cost GNSS receivers have been introduced and taken considerable attention from the GNSS community. Their more compact design makes low-cost GNSS receivers very usable for establishing monitoring networks in harsh environments, such as high-rise buildings and bridges. In this context, this study aims to evaluate the capability of the VA technique with a low-cost GNSS receiver in detecting horizontal dynamic motion simultaneously. For this purpose, this study employs single-frequency (SF) observations of GPS, GLONASS, Galileo, and BeiDou satellites from the u-blox ZED-F9P receiver for the VA technique. Harmonic motions from 5 to 20 mm with frequencies between 0.3 and 5.0 Hz were generated by a single-axis shake table to analyze the capability of the SF-VA technique in detecting structural motion. Also, a simulation of Mw 6.9 Kobe, 1995 earthquake was performed using the shake table to understand the feasibility of the SF-VA technique in possible EEW systems. In the evaluation, displacements from the Linear Variable Differential Transformer (LVDT) were selected as the reference to assess the capability of the SF-VA technique. The results indicated that

the peak frequency value of short-term harmonic oscillations up to 5 Hz can be detected with the SF-VA technique adopting GNSS observations from the low-cost receiver. Besides, the results demonstrated that the SF-VA technique can determine the strong ground motions resulting from mega earthquakes at mm-level.