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VADASE: a new approach for real-time fast displacement detection - First application to Taiwan High-Rate GNSS Network

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The aim of this work is to show new possibilities for GNSS Permanent Network data processing offered by VADASE (Variometric Approach for Displacements Analysis Standalone Engine) to retrieve waveforms and coseismic displacements in real-time when an earthquake occurs. The main advantage of using GNSS receiver, in a complementary way with traditional seismic network, is that it can work without being affected by saturation, which commonly influence seismometers and accelerometers close to strong earthquake epicenters.

VADASE was originally proposed in 2010 ([4],[5]) as the third way in GPS Seismology (in addition to Precise Point Positioning and Instantaneous Differential Positioning). The approach is based on time single differences of carrier phase observations continuously collected at high rate (1 Hz or higher) using a standalone GPS receiver and standard GPS broadcast products (orbits and clocks) that are available in real-time. Hence, one receiver works in standalone mode and the epoch-by-epoch displacements (equivalent to velocities) are estimated. Then, they are summed over the time interval when the earthquake occurred to retrieve coseismic displacements and waveforms. Considering time intervals limited to few minutes, the receiver displacements can be ascertained at a few centimeters accuracy level in real-time.
The effectiveness of this approach was recognized by DLR (German Aerospace Agency), and VADASE was awarded the DLR Special Topic Prize and the Audience Award at the European Satellite Navigation Competition 2010.
Moreover, VADASE potential was proven in the dramatic occasion of the Japanese earthquake occurred on March 11, 2011 ([3]-[6]); in fact VADASE was able to provide the first estimates of the displacements suffered at the IGS sites of MIZU and USUD [7], as soon as the data of these stations were available. The results were then confirmed by several other solutions based on the renown (DP, PPP) approaches.
More recently, VADASE was applied with very promising results to GPS single frequency data in occasion of the Emilia Earthquake (Italy, M=6.0 - May 20, 2012) [2] and also to Galileo single and dual frequency data [1].
VADASE, in principle, can be embedded into the receiver firmware and work in real-time. In this respect, at present, in the frame of an investigation project, VADASE has been implemented within the last release of the firmware of Leica Geosystems GR receivers.

Here we present the application of the VADASE methodology to data collected at several permanent stations of Taiwan High-Rate GNSS Network in occasion of recent earthquakes occurred on June 2, 2013 (south-west of Buli, M=6.2, USGS) and October 31, 2013 (south-west of Hualian, M=6.3, USGS).
Furthermore a solutions comparison with results obtained from co-located accelerometers and seismometers is shown and all the kinematic parameters are investigated. In particular, estimated velocities from VADASE are directly compared with seismometers dataset. Then, VADASE velocities are derived to perform a comparison with data collected by accelerometers. Finally, a comparison in terms of displacements obtained from all the instruments is carried out. With these tests a new strategy to integrate traditional seismic network with the information coming from GNSS data can be better assessed.

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