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Recent advances of VADASE to enhance reliability and accuracy of real-time displacements estimation

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VADASE (Variometric Approach for Displacements Analysis Stand-alone Engine) is a relatively new processing approach (2011), able to estimate in real-time velocities and displacements in a global reference frame (ITRF), using high-rate (1 Hz or more) carrier phase observations and broadcast products (orbits, clocks) collected by a stand-alone GNSS, achieving an accuracy within 1-2 centimetres (usually better) over intervals up to few minutes. VADASE was originally developed within GNSS Seismology, but it was conveniently applied also to structural monitoring.

It is well known from the very beginning that VADASE displacements might be impacted by two different effects: spurious spikes in the velocities due to outliers (in this case, displacements, obtained through velocities integration, are severely corrupted), and trends in the displacements (mainly due to broadcast orbit and clock errors). Moreover, for applications to earthquakes (seismic inversion), it is quite useful to estimate in real-time the so-called coseismic displacement. In fact, this displacement could be in theory estimated also in post-processing mode, using GNSS data collected over suitable long intervals before and after the earthquake; anyway, in case of strong earthquakes (for which VADASE can give significant contributions even quite close to the epicentre, since GNSS does not clip) a significant number of strong replicas usually follow the main shock in a short time, so that it may be (very) difficult to select the mentioned long data intervals.

These three issues (outliers in velocity, trends in displacements and real-time coseismic displacements) were addressed in recent advances of VADASE.

Two strategies were introduced, respectively based on Leave-One-Out Cross Validation (VADASE–LOO) for a receiver autonomous outliers detection, and on a network augmentation strategy to filter common trend out (A–VADASE); they can be combined (1st VADASE–LOO, 2nd A–VADASE) for a complete solution. Moreover, a statistical test, based on the hypothesis of a constant mean level noise of the VADASE velocity estimates over few minutes, and a robust estimation procedure were introduced; they allow both to estimate the duration of an earthquake and the overall coseismic displacement.

The three new VADASE advances were successfully applied to the GPS data collected during the recent three strong earthquakes occurred in Central Italy on August 24, October 26 and 30, 2016, and the results are here presented and discussed.