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Analysis of High-Rate GPS Data Collected During the L'Aquila Seismic Sequence

Serpelloni E.[1,3*], Devoti R.[1], Cavaliere A.[2,3]

1) Istituto Nazionale di Geofisica e Vulcanologia – CNT, 2) Istituto Nazionale di Geofisica e Vulcanologia – Bologna, 3) INGV-Sezione Precari *serpelloni@bo.ingv.it

High-Rate GPS Data

Five days before the April, 6 M5.8 L'Aquila main-shock, a few GPS receivers recording at 10 Hz and 1 Hz sampling rates have been installed by INGV in the area affected by the seismic swarm in place by mid-January 2009. These data allowed us to measure, for the first time in Italy, the dynamic co-seismic displacements with periods ranging from fractions of seconds to several minutes and the full time spectra of the surface co-seismic deformation with GPS instruments. Immediately after the earthquake we processed data for continuous GPS stations in Italy distributing high-rate (HR) data, together with available HR data from the INGV-RING stations (Fig. 1). We use TRACK, the kinematic module of the GAMIT/GLOBK software, to perform epoch-by-epoch solutions of 30 sec, 1 sec and 0.1 sec GPS data and obtain 3D time series of surface displacements. TRACK uses floating point LC (L3) observations and the Mebourne-Wubena Wide Lane combination, with ionospheric constraints, to determine integer ambiguities at each epoch, and requires a fixed station and one, or more, kinematic stations. Since that the only two stations recording 10 Hz data were located in the epicentral area, and no external sites were available, we realized a Matlab® tool to generate virtual far field reference stations at 10 Hz sampling, by interpolating the available 1 Hz RINEX data.

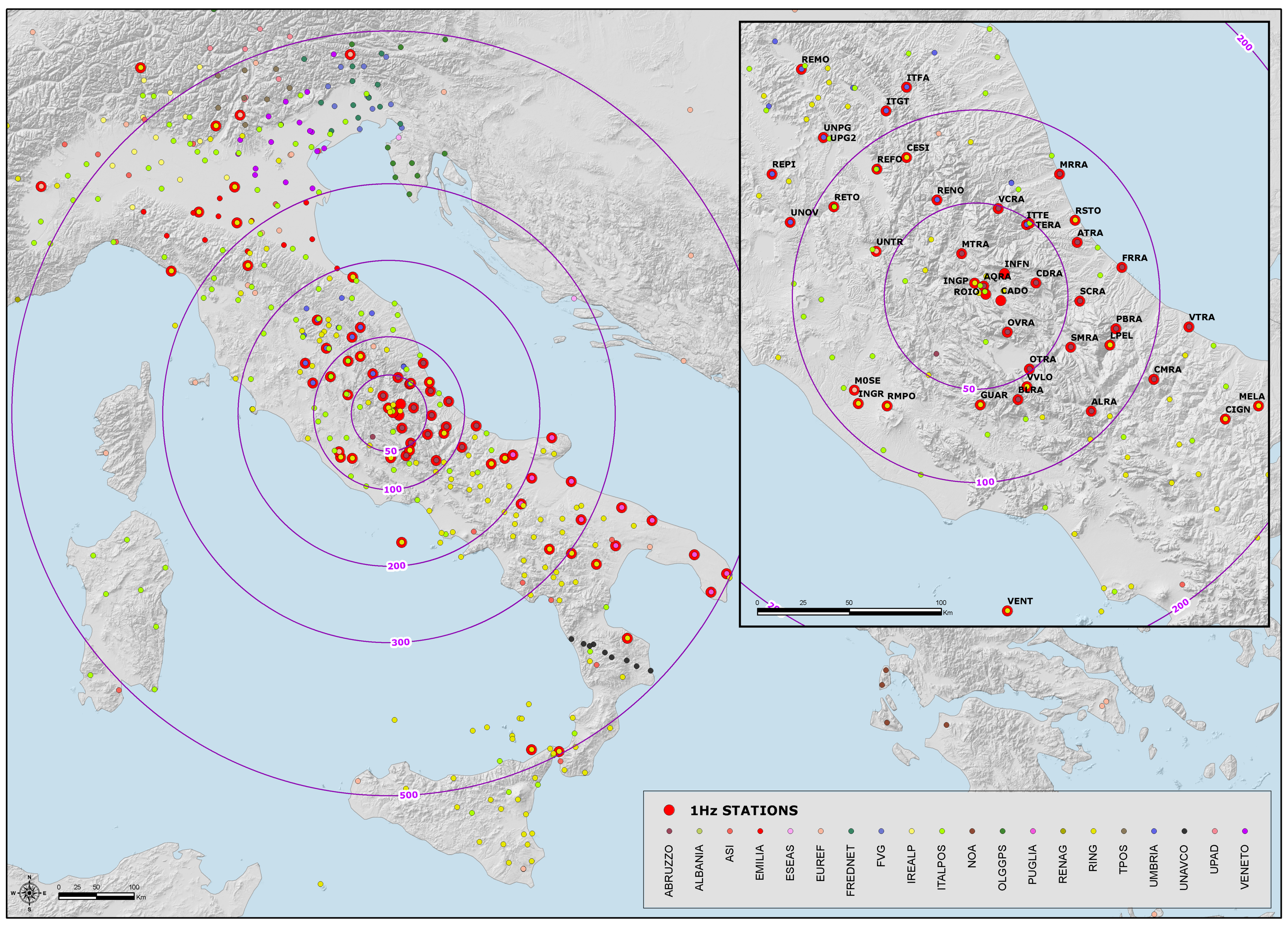


Fig. 1 - Continuous GPS networks routinely processed at INGV-Bologna with the GAMIT software. Red circles display stations for which 1 Hz sampling data were available for the 6th of April. Circles show distances in Km from the L'Aquila epicenter.

Post-Processing

HR GPS data are severely affected by multipath noise, which can reach the same magnitude of the co-seismic displacements (Fig.2), and need to be removed consistently. For this reason, we investigate the effect of time filters and realize a Matlab® tool to apply sideral filtering to the raw time series.

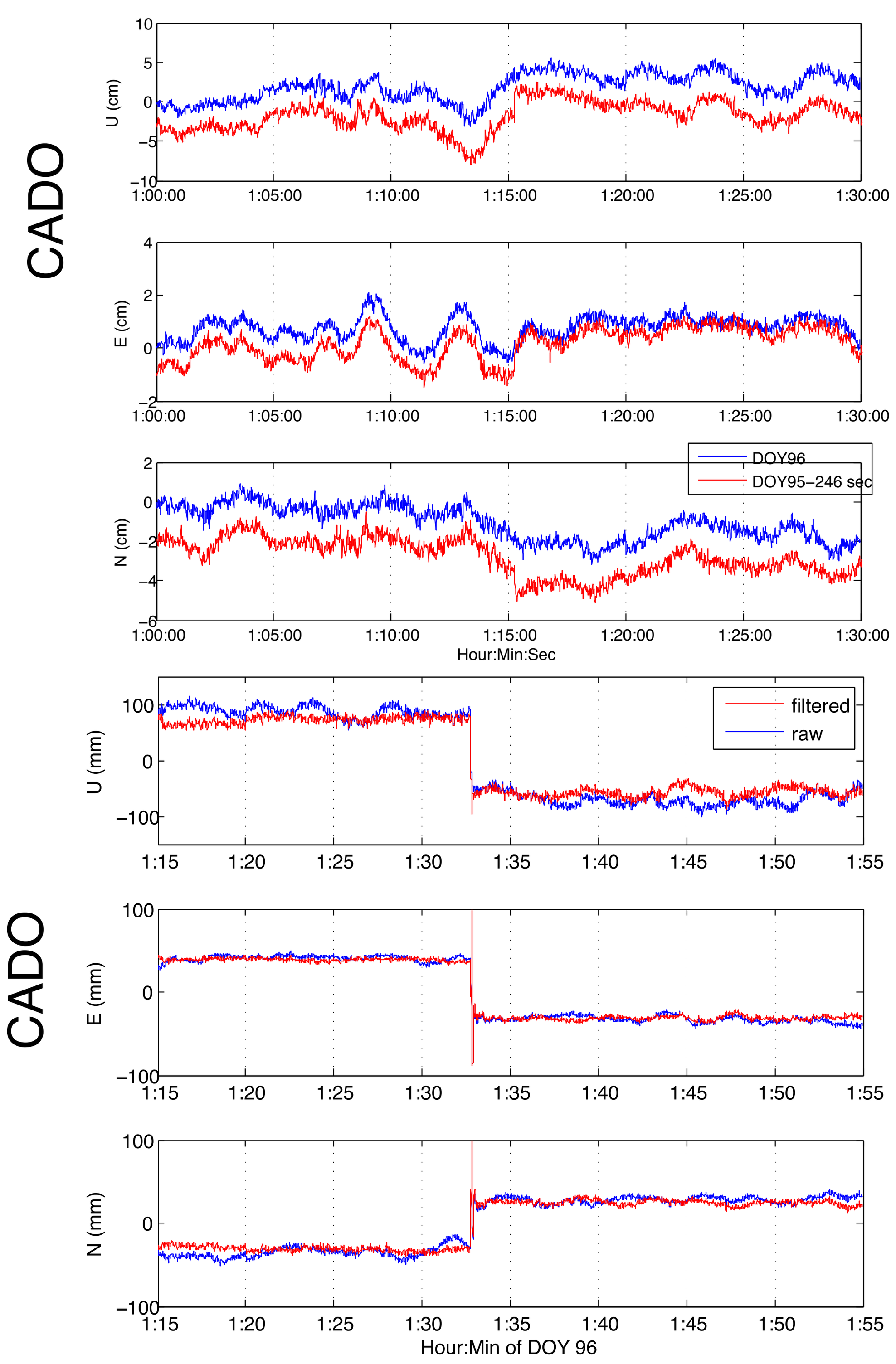


Fig. 2 - [upper] Doy 095 (red) and doy 096 (blue) shifted by the sideral time. [lower] Raw (grey) and filtered (red) 1-Hz time-series. The signal-to-noise ratio is improved by application of a sideral filter, obtained by processing 095 and 096 data using the same satellites to compute the sideral-time shift, and filtering the low-frequency signal.

Results

The epoch-by-epoch analysis of GPS data provide new key information that can be used to study different aspects of earthquake phenomena. Standard 30 sec or higher rate 1 sec data provide the "pure" co-seismic static displacements, not affected by early afterslip deformation. 0.1 sec data provide the higer frequency dynamic response of the stations, and can be useful for GPS seismology. Please follow A. **Avallone et al.** presentation in this Session.

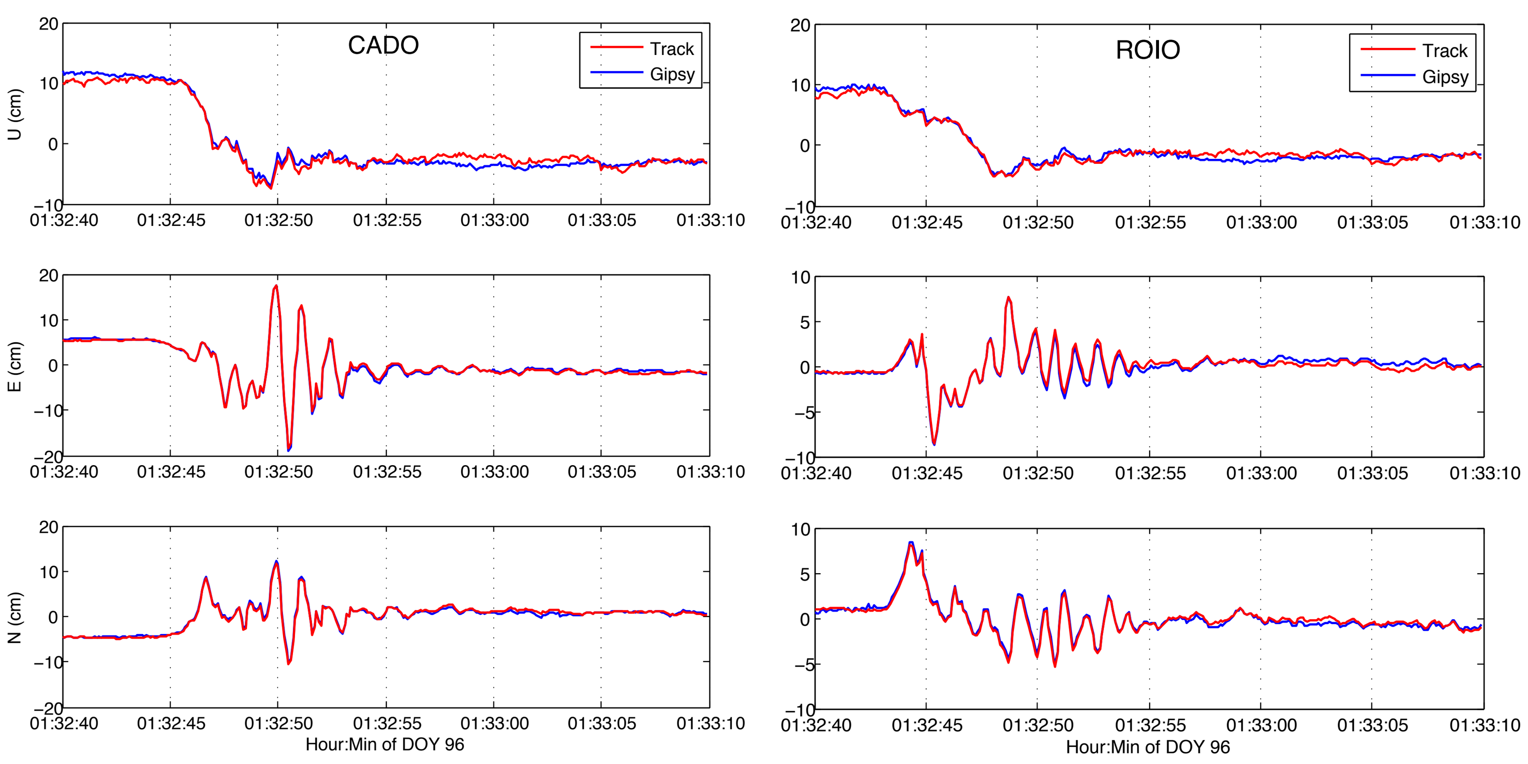
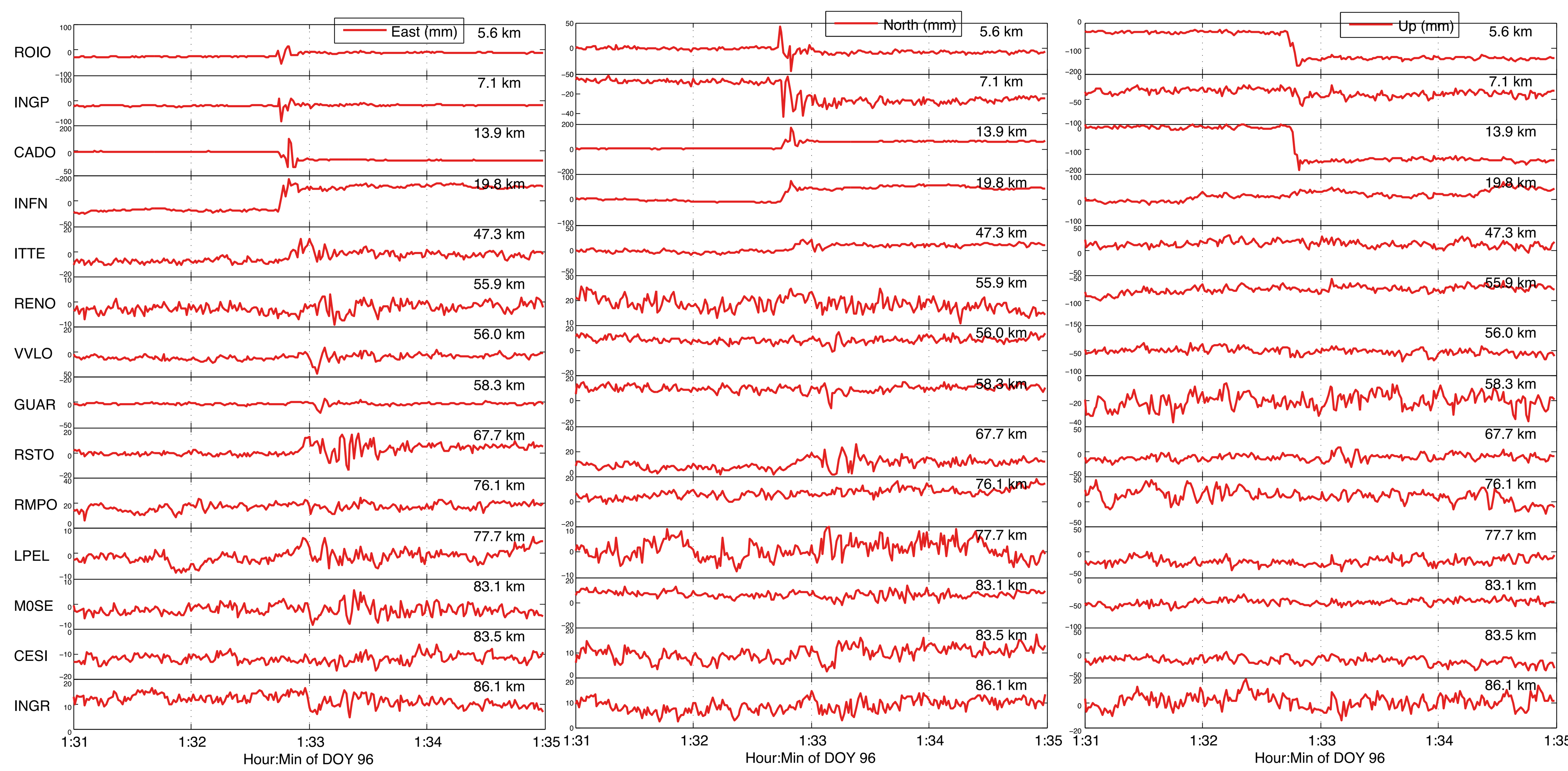


Fig. 3 - 10 Hz position time series of stations CADO and ROIO, in the epicentral area, obtained by using two different processing approaches. TRACK uses a relative kinemaric differential positioning, with epoch-by-epoch ambiguity solution, while GIPSY uses the PPP approach, without solving for phase ambiguity. TRACK uses a "virtual" far-field 10Hz reference station obtained by interpolation of the original 1Hz data.

Fig. 4 - 1 Hz GPS time-series for the 1:31 - 1:35 time interval of stations at increasing distance from the main-shock epicenter (see Fig. 1). The arrival of surface waves can be clearly seen at distances of ~80 km, at least in the horizontal coponents.



Displacements

HR GPS data provide "real-time" co.-seismic displacements, and epoch-by-epoch GPS solutions (of 30 sec or 1 sec) provide the pure co-seismic static displacements, not affected by potential early afterslip. The next figures show the horizontal and vertical co-seismic displacements and the co-seismic slip-distributions obtained using 3 different set of data.