Fling-step recovering from near-source waveforms and ground displacement attenuation models

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METHODOLOGY

Fling-step recovering

eBASCO[(1)] (extended **BAS**eline **CO**rrection) removes the baseline of strong-motion records by means of a trilinear detrending of the velocity time series.

Selection of the Time Correction Points

An automatic procedure breaks the baseline shift in three time-windows (Figure 1): 1) *pre-event window* between the time of the first sample T_0 and time T_1 from which the ground moves toward the so-called permanent displacement; 2) *transient window* between T_1 and time T_2 containing the strong phase of the motion, in which the ground has already reached the permanent displacement; 3) *post-event window* from T_2 and the end of the signal (T_{end}). The selection of T_1, T_2 and T_3 follows a recursive procedure. T_1 is sampled before the 5% of the acceleration energy distribution, whereas T_3 is sampled between the 50% and the 95% of the energy distribution. T_2 is then sampled between T3 and the end of the signal.

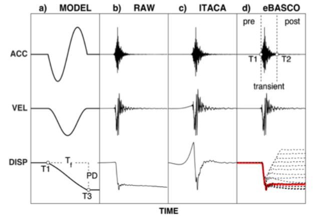

Figure 1

Tri-Linear Detrending

A regression line is used to remove the signal distortion in the pre-event window, whereas a further least-squares fitting is used to remove the velocity drift in the post-event window. Finally, the line between the velocity amplitude in T_1 and T_2 is used for the baseline correction in the transient window.

Selection of the best solution

We use a "flatness indicator" f to guarantee that the eBASCO displacement is flat after time T_3. We select as best solution the eBASCO solution characterized by the maximum f-value over all T_1,T_2 and T_3 time points combinations.

VALIDATION

We compare displacement waveforms from eBASCO with GPS signals recorded at nearby stations or InSAR data:

Cross-correlation analysis between GPS[(4)] **and strong motion time histories:** 1) between time T1 and T2 gives the similarity of both signals in the dynamic part of the ground motion; 2) Between time T3 and the end of the signal allows the reliability of eBASCO to be tested.

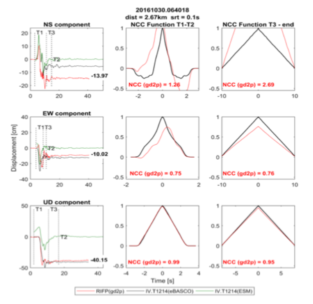

Figure 2

Comparison between coseismic displacements obtained from eBASCO and GPS and InSAR data:

We compare different earthquakes worldwide with $6 \leq M_w \leq 9.1$; The amplitude and sense of movement of the permanent displacements are consistent.

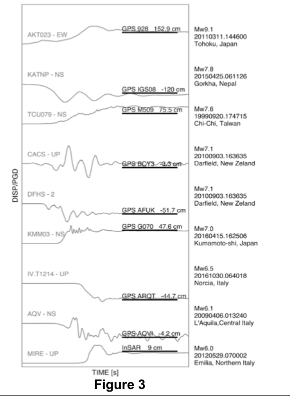

Figure 3

NEAR SOURCE DATASET[(2)]

The waveforms of the near-source dataset NESS1[(2)] are processed following a standard procedure which removes the low frequency content of the signal[(3)].

After processing NESS1 by means of eBASCO, we obtain a subset of fling-step containing near-source records with: Mw >= 5.5; Depth <= 40 km; Available information on the finite-fault model; and available strong-motion records in epicentral areas and in free-field conditions.

The dataset covers distances up to 140 km, with the bulks of records in the M_w range 6.5-7.0 and R_{JB} 0-30 km. Strike-slip events dominate the database.

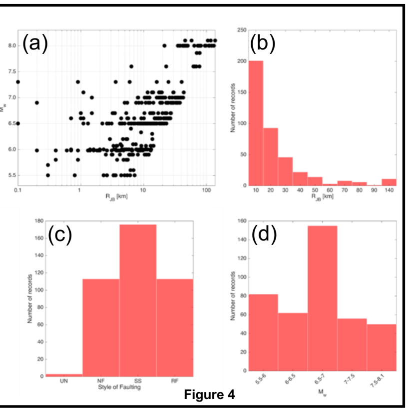

Figure 4

eBASCO VS NESS1

To highlight the difference between the two processing schemes, we compare peak ground values (PGA, PGV, PGD) and spectral displacements values (Sd) obtained from eBASCO and from the NESS1[(2)] database.

PGD_{eBASCO} are larger than PGD_{NESS1} because eBASCO preserves the information related to both the static and dynamic displacement. PGV and PGA are not affected by the new processing scheme, as they are related to higher frequencies.

In terms of Sd, differences between the approaches are evident from T = 2s and amplify at longer T (>4s)

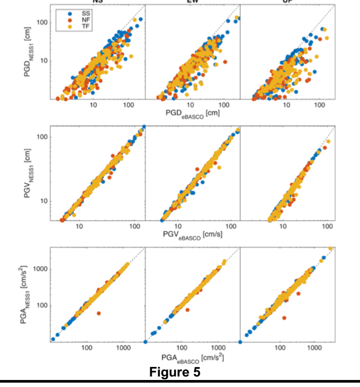

Figure 5

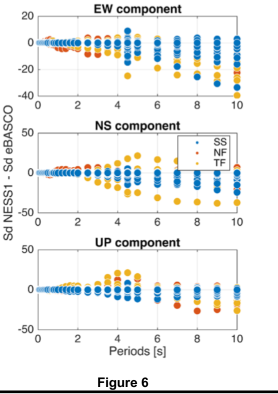

Figure 6

ATTENUATION MODELS

We develop attenuation models for PGD, using the NESS1 database processed following both the standard procedure[(3)] (ITACA in fig.7) and eBASCO. The attenuation models in fig.7 confirm the results presented in fig.5: PGD_{eBASCO} is generally larger than PGD_{NESS1}. The attenuation models show that PGD is strongly dependent on both the fault mechanism and ground-motion component. We calibrate a preliminary attenuation model for permanent displacement (fig.8) assuming the same functional form of Burks and Baker[(5)]. Our dataset and model tend to be overestimated by the Burks and Baker model. Their dataset consists of a combination of observations and simulations from only strike-slip and reverse faults, which may affect their attenuation model. Further studies are ongoing.

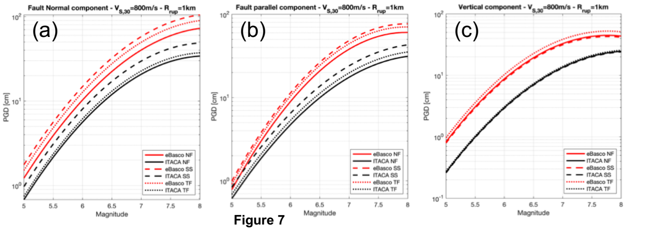

Figure 7

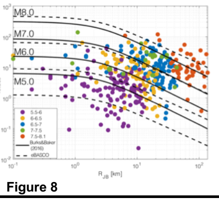

Figure 8

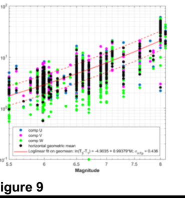

Figure 9

To optimize the processing, we calibrate a preliminary relationship between the difference of correction points T_3 and T_1 and Mw. The difference should be interpreted as the time of the fling pulse, but further studies are required.

CONCLUSIONS

We applied the eBASCO procedure to the near-source strong-motion records of the NESS1[(2)] dataset to preserve the low-frequency content of accelerometric waveforms. The standard data processing provides a band-pass filtering that significantly alter both the dynamic and the static displacement recorded in near-source condition. In the frequency domain, the eBASCO processing provides displacement spectral ordinates higher than those obtained by applying a standard procedure [(3)], especially for T>2-4s.

The eBASCO processing allows us to compile a subset of about 400 three-component fling-step containing waveforms useful for the calibration of attenuation models specifically tailored for the low-frequency content of the ground-motion.

(1) D'Amico, M., Felicetta, C., Schiappapietra, E., Pacor, F., Gallovič, F., Paolucci, R., ... & Luzi, L. (2019). Fling Effects from Near-Source Strong-Motion Records: Insights from the 2016 M w 6.5 Norcia, Central Italy, Earthquake. *Seismological Research Letters*, *90*(2A), 659-671.

(2) Pacor, F., Felicetta, C., Lanzano, G., Sgobba, S., Puglia, R., D'Amico, M., ... & Iervolino, I. (2018). NESS1: A worldwide collection of strong-motion data to investigate near-source effects. *Seismological Research Letters*, *89*(6), 2299-2313.

(3) Paolucci, R., Pacor, F., Puglia, R., Ameri, G., Cauzzi, C., & Massa, M. (2011). Record processing in ITACA, the new Italian strong-motion database. In *Earthquake data in engineering seismology* (pp. 99-113). Springer, Dordrecht.

(4) INGV RING Working Group (2016), Rete Integrata Nazionale GPS, doi:10.13127/RING.

(5) Burks, L. S., & Baker, J. W. (2016). A predictive model for fling-step in near-fault ground motions based on recordings and simulations. *Soil Dynamics and Earthquake Engineering*, *80*, 119-126.