What eBASCO does and what problem it solves

eBASCO (**e**xtended **BAS**eline **CO**rrection) removes the baseline of strong-motion records by means of a piecewise linear detrend of the velocity time history.
Differently from common processing schemes, eBASCO does not apply any filtering to remove the low-frequency content of the signal. This approach preserves the long-period near-source ground-motion featured by one-side pulse in the velocity trace and an offset at the end of the displacement trace (fling-step). For such reason, the software is very suitable for the identification of fling-containing strong-motion waveforms.

In the current version, eBASCO adjust the long-period distortion of the signal (due to instrumental effects, ground rotation or tilting) by means of a trilinear detrending of the velocity time series.

Cut of the accelerometric waveforms

The eBASCO procedure is very sensitive to the preliminary cut of the accelerometric waveforms needed to isolate the uncorrected earthquakes records; a bad cutting may cause unwanted distortion of the signal.
As default, eBASCO provides an automatic cut of the three components of the accelerometric waveform between the 5% and the 90% of the energy release. Otherwise, the User can manually set the second to be cut after the beginning and before the end of the signal.
After that all the components are reduced to the same length according to their maximum start-time and minimum end-time.

Selection of Time Correction Points

The baseline shift is subdivided in 3 time-windows: 1) *pre-event window* between the time of the first sample T_0 and the time T_1 from which the ground moves toward the final displacement (the so-called permanent displacement); 2) *transient window* containing the strong phase of the motion between T_1 and the time T_2 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 the two correction points T_1 and T_2 follows a recursive procedure described in Chao et al. (2010), Wu and Wu (2007) and modified in D'Amico et al. (2019). T_1 can be sampled before of the 5% of the acceleration energy distribution (logarithmically spaced between the 0.001% and the 5%), while T_2 can be sampled after a further time point T_3, which represents the time at which the ground has just reached the final deformation. T_3 can be logarithmically sampled between the 50% and the 95% of the acceleration energy release.

Tri-Linear Detrending

For each time window eBASCO applies a linear detrend of the velocity trace. The amplitude of the first sample is preliminarily subtracted from the whole acceleration so that the velocity equals zero in T_0. After that, the signal distortion in the pre-event window is removed by subtracting from the velocity trace a regression line [1] crossing the first sample $V(T_0)=0$:

$$V_i(t) = A_i t \qquad [1]$$

where A_i is the slope of the line fitting the velocity between T_0 and T_1.
A further least-squares fitting [2] if used to remove the velocity drift in the post-event window:

$$V_f(t) = V_{0,f} + A_f t \qquad [2]$$

where $V_{0,f}$ is the ordinate intercept and A_f is the slope of the line fitting the velocity between T_2 and T_{end}.
The baseline correction [3] in the transient window is the line between $V_i(T_1)$ and $V_f(T_2)$; $V_i(T_1)$ and $V_f(T_2)$ are the last point of the detrending line in the "pre-event" [1] and the first point of the detrending line in the "post-event" [2], respectively.

Selections of the best solution
The velocity time series determined by all the T_1 and T_2 correction points combinations are differentiated to obtain the acceleration.

Because inappropriate combinations of correction points might generate spurious spikes in the acceleration trace, a threshold on the amplitudes in T_1 and T_2 should be set. As default, eBASCO considers as "acceptable" an acceleration waveform in which the relative difference between the amplitude in T_1 and T_2 before and after the eBASCO processing is lower than the 25%. Only the "acceptable" solutions are double integrated to obtain the ground displacement.

Finally, to guarantee that the eBASCO displacement waveform if flat after T_3, a "flatness indicator" (Wu and Wu, 2007) is defined [3] considering the displacement trace between T_3 and T_{end}:

$$f = \frac{r}{|b| \times \sigma} \qquad [3]$$

In which r is the linear correlation coefficient of the displacement amplitudes, b is the slope of the linear fit, and σ is the variance of the residual displacement respect to the mean value. The more the absolute value of r and b tends to 1 and 0, respectively, and σ tends to lower values, the flatter the displacement waveform is.
At the end, we consider as "best solution" the eBASCO displacement characterized by the maximum f-value over all the combinations of the T_1 and T_3 time points.

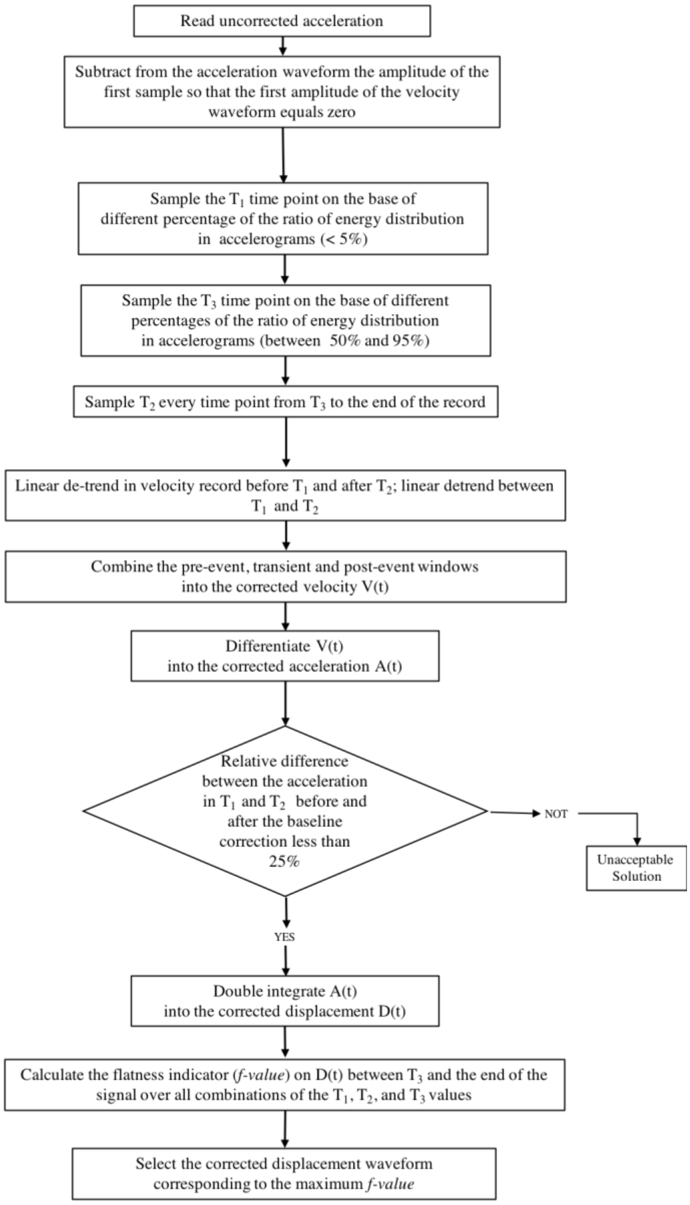

FIGURE 1: flowchart of the eBASCO procedure, modified after D'Amico et al. (2019).

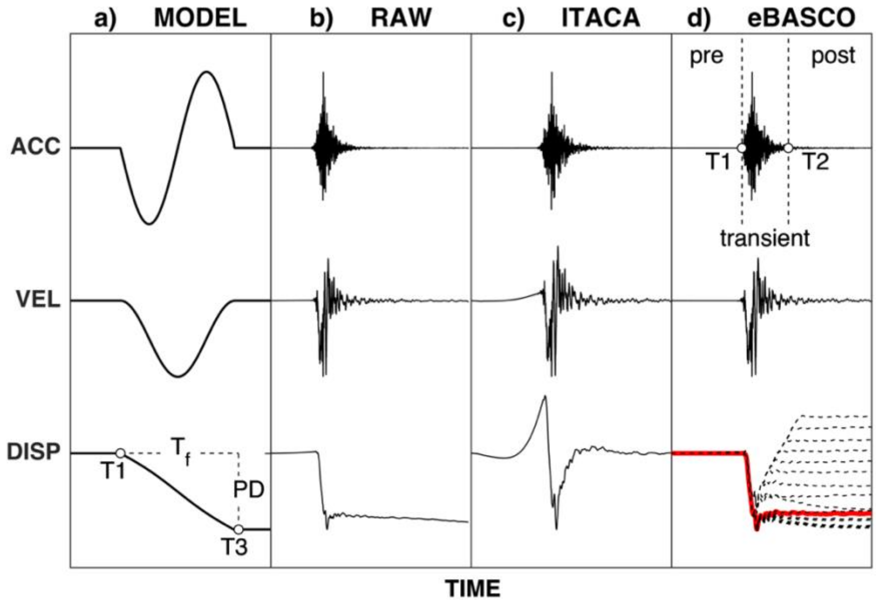

FIGURE 2: example of acceleration waveforms processed by means of eBASCO (vertical component recorded at the station T1214 during the M_w6.5 Norcia earthquake). a) analytical model of the fling-step in terms of acceleration, velocity, and displacement; b) uncorrected waveforms; c) waveforms corrected through the broad-band ITACA processing schemes (Paolucci et al., 2011); d) waveforms corrected by the eBASCO tri-linear detrend. Pre-, transient- and post-event windows are highlighted by their limits set at T_1 and T_2. T_3 represents the time at which the ground displacement just reached the final offset. T_f and PD are the period of the sine pulse and the amplitude of the permanent displacement, respectively. Red line: eBASCO ground displacement corresponding to the optimal choice of T_1 and T_2 time correction points (maximum f-value); dashed black lines: solution set corresponding to different combinations of T_1 and T_2 correction points.

Input

eBASCO requires an input file containing the waveforms to be processed and related metadata. The input file must be in the Adaptable Seismic Data Format (ASDF, https://seismic-data.org/); both the name and the structure of the ASDF volume should be the same as those adopted by the ITalian ACceleration Archive (version 3.1, http://itaca.mi.ingv).

The ASDF volume should contains:

```
ASDF file [format version: 1.0.2]: 'IT.CLO.00.HG.EMSC-20161026_0000095.h5' (774.7 KB)
        Contains 1 event(s)
        Contains waveform data from 1 station(s).
        Contains 2 type(s) of auxiliary data: Headers, Spectra
```

FIGURE 3: example of ASDF input-file content for the waveforms recorded by the station CLO during the event EMSC-20161026_0000095.

1) event data from one event

```
[Event: 2016-10-26T19:18:06.000000Z | +42.909,  +13.129 | 5.9 mw

                   resource_id: ResourceIdentifier(id="smi:esm.mi.ingv.it/fdsnws/event/1/query?event_id=EMSC-20161026_0000095")
                    event_type: 'earthquake'
         event_type_certainty: 'known'
                 creation_info: CreationInfo(agency_id='INGV', author='Engineering Strong-Motion database (ESM)', author_uri=ResourceIdentifie
r(id="smi:data.datacite.org/10.13127/ESM"), creation_time=UTCDateTime(2019, 5, 3, 12, 7, 29, 638129))
          preferred_origin_id: ResourceIdentifier(id="smi:esm.mi.ingv.it/fdsnws/event/1/query?origin_id=EMSC-20161026_0000095-01")
       preferred_magnitude_id: ResourceIdentifier(id="smi:esm.mi.ingv.it/fdsnws/event/1/query?magnitude_id=EMSC-20161026_0000095-M2")
 preferred_focal_mechanism_id: ResourceIdentifier(id="smi:esm.mi.ingv.it/fdsnws/event/1/query?focal_mechanism_id=EMSC-20161026_0000095-P1")
                                ---------
           event_descriptions: 2 Elements
                      origins: 1 Elements
                   magnitudes: 1 Elements]
```

FIGURE 4: example of ASDF input-file content related to the event data for the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

2) waveforms data from one station for which the ASDF tag naming is:

'location_code'_'channel_code'_'event_id'_'processing_type'_'file_type'

Following the Seed manual v 2.4

- **location_code** is the code which indicates the station location (0 to 2 characters); in file names, the *location_code* '00' (double-zeros) is always replaced by an empty string

- **channel_code** indicates the instrument type and the ground-motion component and has 3 digits:
  - 1st digit for the band code (in our case H = High Broad Band i.e. sample rate within the range 80-250 Hz);
  - 2rd digit indicates the instrument code: N, L, G = accelerometer (the codes are the ones used as a convention by many networks),
  - 3th digit indicates the orientation code: e.g. Z N E (traditional Vertical, North-South, East-West), Z 2 3 (orthogonal components but nontraditional orientations), etc.

- **event_id** is the event identifier
- **processing_type** is either *mp* or *ap* (manual or mutomatic processing using the schema by Paolucci et al, 2011) or *cv* (unprocessed accelerations converted in physical units). Details on the automatic processing can be found in Puglia et al., 2018.

- file_type is either *acc* (acceleration), vel (velocity) or *dis* (displacement) for time series, as well as *sa* (acceleration) or *sd* (displacement) for response spectra.

all characters in lower-case and not alphanumeric characters of 'event_id' are replaced by underscores

```
In [43]: ds.waveforms.IT_CLO
Out[43]:
Contents of the data set for station IT.CLO:
    - Has a StationXML file
    - 12 Waveform Tag(s):
        00_hge_emsc_20161026_0000095_acc_cv
        00_hge_emsc_20161026_0000095_acc_mp
        00_hge_emsc_20161026_0000095_dis_mp
        00_hge_emsc_20161026_0000095_vel_mp
        00_hgn_emsc_20161026_0000095_acc_cv
        00_hgn_emsc_20161026_0000095_acc_mp
        00_hgn_emsc_20161026_0000095_dis_mp
        00_hgn_emsc_20161026_0000095_vel_mp
        00_hgz_emsc_20161026_0000095_acc_cv
        00_hgz_emsc_20161026_0000095_acc_mp
        00_hgz_emsc_20161026_0000095_dis_mp
        00_hgz_emsc_20161026_0000095_vel_mp
```

FIGURE 6: example of ASDF input-file tags related to waveforms recorded by the station CLO during the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

```
In [40]: ds.waveforms.IT_CLO["00_hge_emsc_20161026_0000095_acc_cv"]
Out[40]:
1 Trace(s) in Stream:
IT.CLO.00.HGE | 2016-10-26T19:18:02.740000Z - 2016-10-26T19:20:06.995000Z | 200.0 Hz, 24852 samples

In [42]: ds.waveforms.IT_CLO["00_hge_emsc_20161026_0000095_acc_cv"][0].data
Out[42]:
array([-0.017216, -0.01485 , -0.008701, ..., -0.630292, -0.604747,
       -0.518652], dtype=float32)
```

FIGURE 7: example of ASDF input-file content related to the waveform (EW component) recorded by the station CLO during the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

3) auxiliary data providing a header with station/event/waveform metadata, as well as displacement and acceleration response spectra amplitudes of waveforms processed by the ITACA procedure (Paolucci et al., 2011)

```
Data set contains the following auxiliary data types:
        Headers (1 item(s))
        Spectra (1 item(s))
```

```
In [48]: ds.auxiliary_data.Headers.IT_CLO["00_hge_emsc_20161026_0000095_acc_cv"]
Out[48]:
Auxiliary Data of Type 'Headers'
        Path: 'IT_CLO/00_hge_emsc_20161026_0000095_acc_cv'
        Data shape: '(0,)', dtype: 'float64'
        Parameters:
                availability_code: 0
                band_instrument: HG
                baseline_correction: b'BASELINE NOT REMOVED'
                channel_azimuth_north_deg: 90
                channel_inclination_horiz_deg: 0
                data_citation: Luzi L, Puglia R, Russo E & ORFEUS WG5 (2016). Engineering Strong Motion Database. I
stituto Nazionale di Geofisica e Vulcanologia, Observatories & Research Facilities for European Seismology. doi: 10
.13127/ESM
                data_creator: ESM working group
                data_license: CC-BY3_0-IT (http://creativecommons.org/licenses/by/3.0/deed.en)
                data_license_html: <a rel="license" href="http://creativecommons.org/licenses/by/3.0/"><img alt="Cr
eative Commons License" style="border-width:0" src="https://i.creativecommons.org/l/by/3.0/88x31.png" /></a><br /><
span xmlns:dct="http://purl.org/dc/terms/" property="dct:title">The website RANDownlad</span> by <a xmlns:cc="http:
//creativecommons.org/ns#" href="http://www.protezionecivile.it" property="cc:attributionName" rel="cc:attributionU
RL">Italian Civil Protection Department - Presidency of the Council of Ministers</a> is licensed under a <a rel="li
cense" href="http://creativecommons.org/licenses/by/3.0/">Creative Commons Attribution 3.0 Unported License</a>.
                database_version: 0.5
                date_time_first_sample_precision: b'milliseconds'
                earthquake_backazimuth_degree: 324.4
                epicentral_distance_km: 10.8
                event_availability_code: 0
                event_id: EMSC-20161026_0000095
                fault_distance_km: 3.1
                filter_order: b''
                filter_type: b''
                focal_mechanism: NF
                focal_mechanism_description: Normal faulting
                header_format: b'0.1'
                high_cut_frequency_hz: b''
                hw_xx_distance_km: 1.6
                hw_yy_distance_km: 3.1
```

FIGURE 8: example of ASDF input-file content related to the auxiliary data of the unprocessed waveform (EW component) recorded by the station CLO during the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

The TABLE 1 indicates the header parameters in the auxiliary data which are mandatory for the eBASCO processing.

Header parameters	**examples**
date_time_first_sample_precision:	milliseconds
instrument_analog_digital:	D
late_normal_triggered:	NT
location:	00
network:	CLO
stream:	HGE

TABLE 1: header parameters that are mandatory for the eBASCO processing.

```
In [57]: ds.auxiliary_data.Spectra.IT_CLO
Out[57]:
6 auxiliary data item(s) of type 'Spectra/IT_CLO' available:
        00_hge_emsc_20161026_0000095_acc_mp
        00_hge_emsc_20161026_0000095_dis_mp
        00_hgn_emsc_20161026_0000095_acc_mp
        00_hgn_emsc_20161026_0000095_dis_mp
        00_hgz_emsc_20161026_0000095_acc_mp
        00_hgz_emsc_20161026_0000095_dis_mp

In [58]: ds.auxiliary_data.Spectra.IT_CLO["00_hge_emsc_20161026_0000095_acc_mp"]
Out[58]:
Auxiliary Data of Type 'Spectra'
        Path: 'IT_CLO/00_hge_emsc_20161026_0000095_acc_mp'
        Data shape: '(2, 105)', dtype: 'float32'
        Parameters:
                damping: 0.05
                pga_cm_s_2: -179.955087

In [59]: ds.auxiliary_data.Spectra.IT_CLO["00_hge_emsc_20161026_0000095_acc_mp"].data[0]
Out[59]:
array([ 0.01    ,  0.02    ,  0.022   ,  0.025   ,  0.029   ,  0.03    ,
        0.032   ,  0.035001,  0.036   ,  0.04    ,  0.041999,  0.044001,
        0.045   ,  0.046   ,  0.048001,  0.05    ,  0.054999,  0.059999,
        0.064998,  0.067002,  0.069999,  0.075002,  0.08    ,  0.084998,
        0.090001,  0.095003,  0.1     ,  0.109999,  0.120005,  0.130005,
        0.132996,  0.139997,  0.149993,  0.16    ,  0.17001 ,  0.179986,
        0.190006,  0.2     ,  0.220022,  0.239981,  0.25    ,  0.26001 ,
        0.280034,  0.290023,  0.30003 ,  0.32    ,  0.34002 ,  0.350017,
        0.359971,  0.379939,  0.4     ,  0.419992,  0.439947,  0.450045,
        0.459982,  0.480077,  0.5     ,  0.550055,  0.59988 ,  0.650195,
        0.667111,  0.69979 ,  0.750188,  0.8     ,  0.85034 ,  0.90009 ,
        0.949668,  1.      ,  1.10011 ,  1.20048 ,  1.30039 ,  1.40056 ,
        1.49925 ,  1.6     ,  1.70068 ,  1.798561,  1.901141,  2.      ,
        2.197802,  2.398082,  2.5     ,  2.597403,  2.801121,  3.003003,
        3.205128,  3.401361,  3.496503,  3.597122,  3.802281,  4.      ,
        4.201681,  4.405286,  4.608295,  4.807692,  5.      ,  5.494505,
        5.988024,  6.493506,  6.993007,  7.518797,  8.      ,  8.474576,
        9.009009,  9.523809, 10.      ], dtype=float32)
```

FIGURE 9: example of ASDF input-file content related to the acceleration response spectrum recorded by the station CLO (EW component) during the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

Output

The eBASCO output is an ASDF volume containing uncorrected waveforms ('_cv') together with waveforms either processed by the ITACA procedure ('_mp') and eBASCO ('_mb'). The displacement and acceleration spectra (5% damped) calculated over 105 periods from 0.01 to 10 seconds are also stored in the eBASCO output.

The ASDF tag naming of the output is:

'location_code'_'channel_code'_'event_id'_'processing_type'_'file_type'_'mp_mb_processed'

```
ASDF file [format version: 1.0.2]: 'IT.CLO.00.HG.EMSC-20161026_0000095.h5_mp_mb_processed' (1.4 MB)
        Contains 0 event(s)
        Contains waveform data from 1 station(s).
        Contains 2 type(s) of auxiliary data: Headers, Spectra

In [5]: ds2.waveform_tags
Out[5]:
{'00_hge_emsc_20161026_0000095_acc_cv',
 '00_hge_emsc_20161026_0000095_acc_mb',
 '00_hge_emsc_20161026_0000095_acc_mp',
 '00_hge_emsc_20161026_0000095_dis_mb',
 '00_hge_emsc_20161026_0000095_dis_mp',
 '00_hge_emsc_20161026_0000095_vel_mb',
 '00_hge_emsc_20161026_0000095_vel_mp',
 '00_hgn_emsc_20161026_0000095_acc_cv',
 '00_hgn_emsc_20161026_0000095_acc_mb',
 '00_hgn_emsc_20161026_0000095_acc_mp',
 '00_hgn_emsc_20161026_0000095_dis_mb',
 '00_hgn_emsc_20161026_0000095_dis_mp',
 '00_hgn_emsc_20161026_0000095_vel_mb',
 '00_hgn_emsc_20161026_0000095_vel_mp',
 '00_hgz_emsc_20161026_0000095_acc_cv',
 '00_hgz_emsc_20161026_0000095_acc_mb',
 '00_hgz_emsc_20161026_0000095_acc_mp',
 '00_hgz_emsc_20161026_0000095_dis_mb',
 '00_hgz_emsc_20161026_0000095_dis_mp',
 '00_hgz_emsc_20161026_0000095_vel_mb',
 '00_hgz_emsc_20161026_0000095_vel_mp'}
```

FIGURE 10: example of ASDF output-file waveforms tags related to the acceleration response spectrum recorded by the station CLO (EW component) during the Mw5.9 earthquake of the 26/10/2016 (event_ID: EMSC-20161026_0000095).

How eBASCO.py run

Example of command line

usage example: python eBASCO.py [options]

usage example: python eBASCO.py --ifile=[INPUT_DIR]/IT.CLO.00.HG.EMSC-20161026_0000095.h5 --ofldr=[OUTPUT_DIR] --t1=5 --t2=20 --t3=20 --eps=0.25 --mfst=1.5 --mfnd=2.0 --ca=0 --cz=0 --ta=5 --he=35 --hn=35 --hz=35 --fo=2'

options	description	default	format
ifile	*ASDF file containing the waveforms to be processed*	*	str
ofldr	*Folder containing the ASDF file with eBASCO processed waveforms*	*	str
t1	*number of T1 correction points samples*	5	int
t2	*number of T2 correction points samples*	20	int
T3	*number of T3 correction points samples*	20	int
eps	*maximum threshold of the relative difference between acceleration in T1 and T2 correction point before and after the eBASCO processing*	0.25	float
mfst	*multiplier factor to cut the beginning of the waveform on the base of the energy criterion*	1.5	float
mfnd	*multiplier factor to cut the end of the waveform on the base of the energy criterion*	2.0	float
ca	*seconds to cut from the beginning of the waveforms; ca is used only if different from the default value, otherwise eBASCO use the energy criterion to cut the strong-phase of motion between the 5% and the 95% of the energy release*	0	float
cz	*seconds to cut from the end of the waveforms; cz is used only if different from the default value, otherwise eBASCO use the energy criterion to cut the strong-phase of motion between the 5% and the 95% of the energy release*	0	float
ta	*percentage of the signal length to set the time window at the beginning of the waveform where a cosine taper will be applied*	5	float
he	*cutoff frequency of the low-pass Butterworth filter (first component)*	35	float
hn	*cutoff frequency of the low-pass Butterworth filter (second component)*	35	float
hz	*cutoff frequency of the low-pass Butterworth filter (third component)*	35	float
fo	*Butterworth filter order*	2	float
pro	*Type of Processing (default = 'manual2')*	manual2	str

TABLE 2: Command line options of eBASCO.py

Some examples of eBASCO outcomes for strong-motion records of moderate-to-large worldwide events, compared to geodetic or interferometric data are provided below.

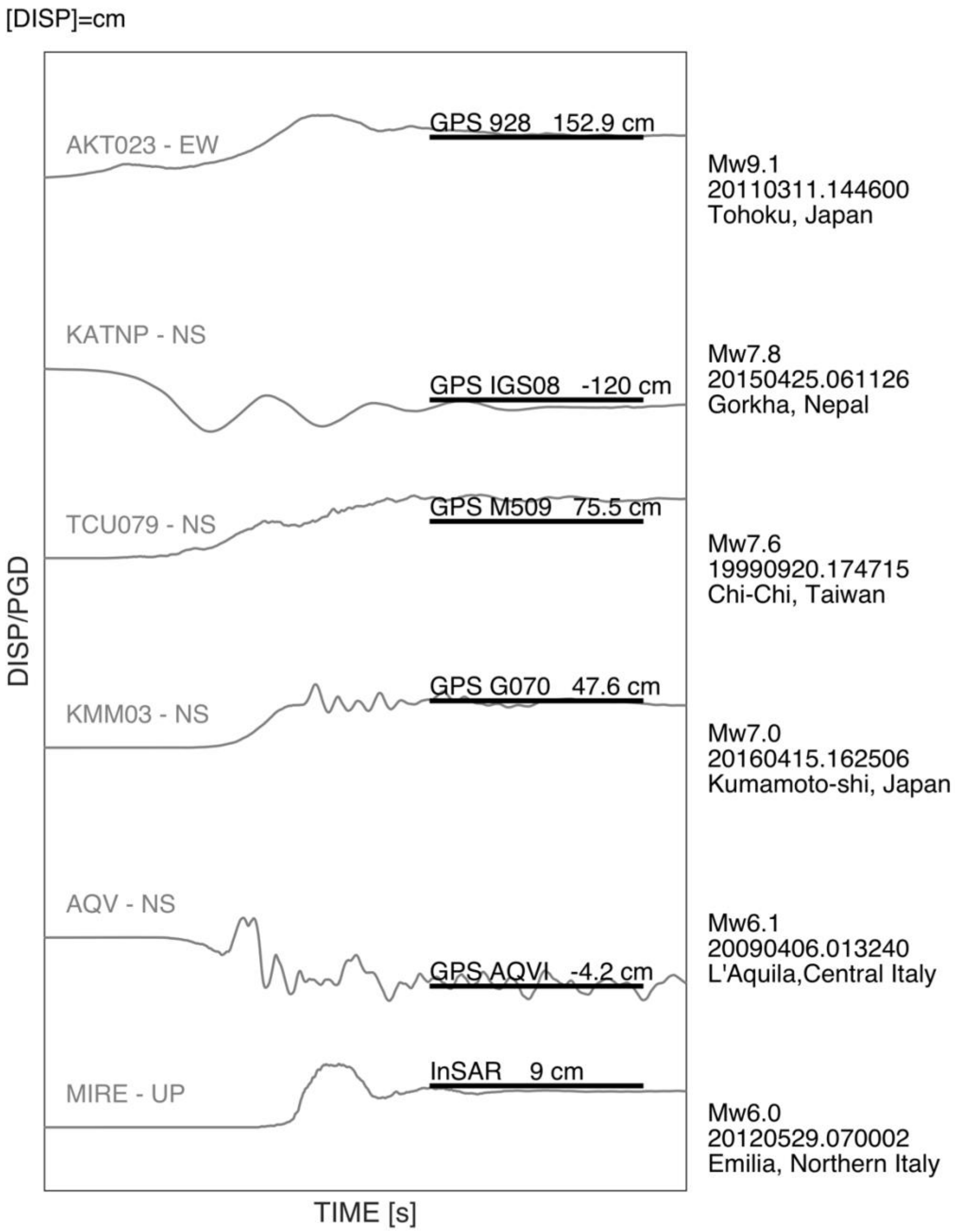

FIGURE 11: example of eBASCO.py displacement waveforms for moderato-to-large earthquakes worldwide recorded compared with nearby Global Position System (GPS) or Interferometric Synthetic Aperture Radar (InSAR) measurements.

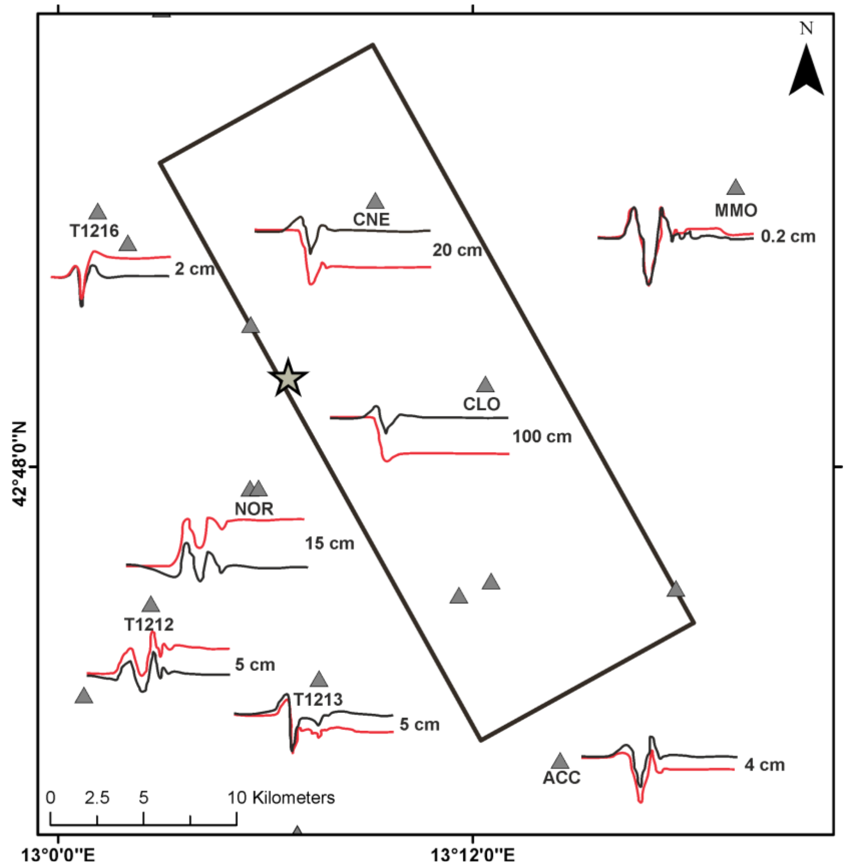

FIGURE 12: Comparison between ground displacement obtained by the ITACA processing scheme (black) and eBASCO (red) for near-source records of the 30 October 2016, Mw6.5 earthquake.

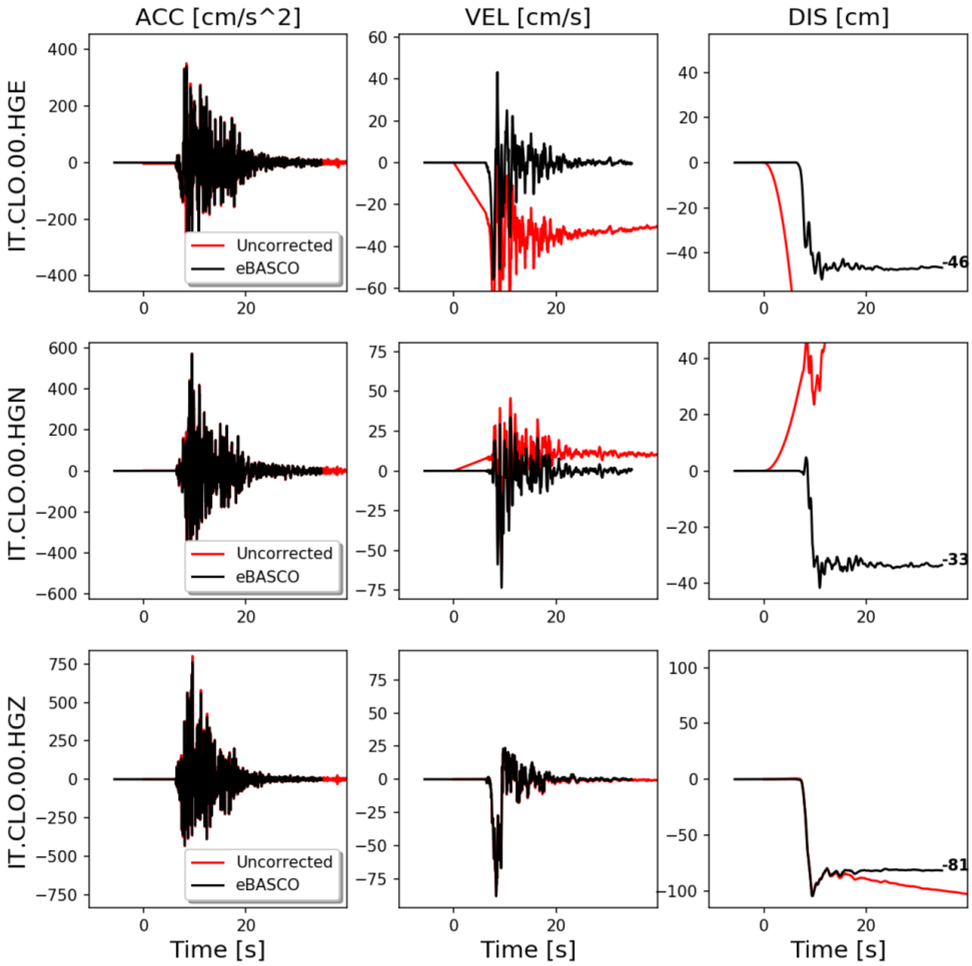

FIGURE 13: Comparison between uncorrected (red) and eBASCO (black) displacement waveforms (EW, NS, and UD components) related to the station CLO records of the 30 October 2016, Mw6.5 earthquake. The values close to the waveforms are the static displacements in centimeters.

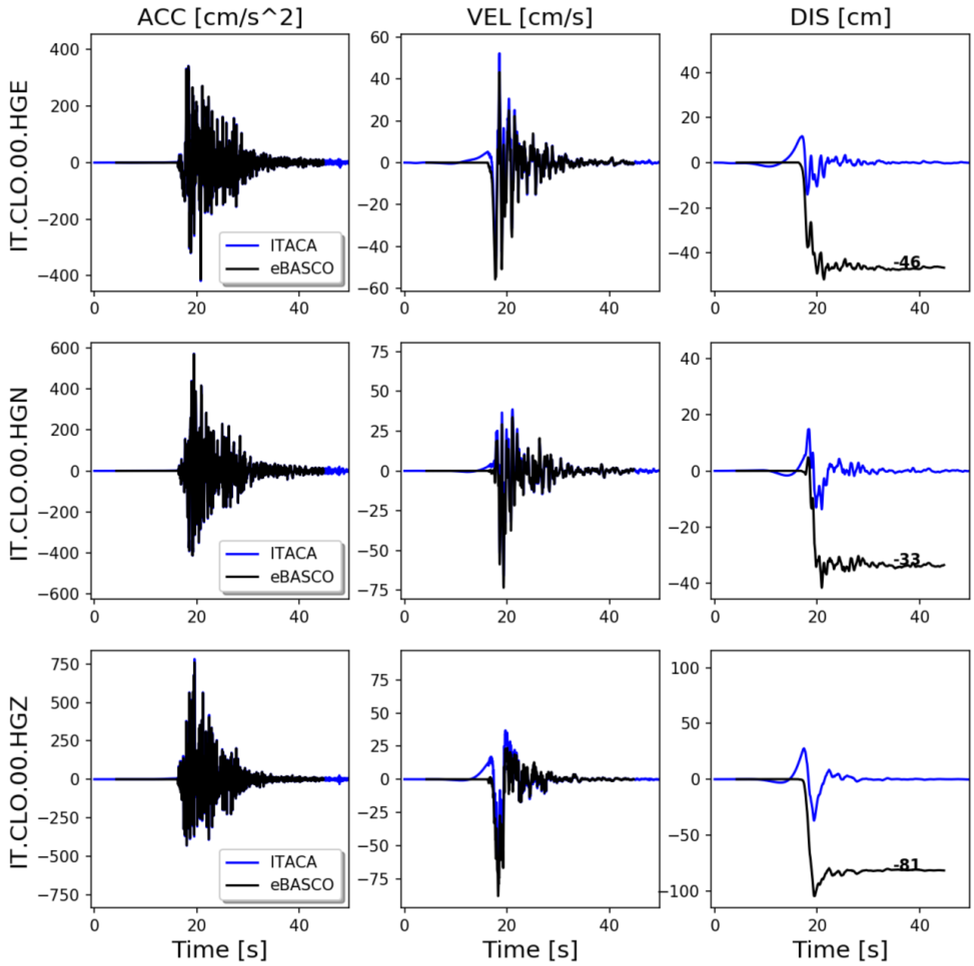

FIGURE 14: Comparison between eBASCO (black) and ITACA (blue) displacement waveforms (EW, NS, and UD components) related to the station CLO records of the 30 October 2016, Mw6.5 earthquake. The values close to the waveforms are the static displacements in centimeters.

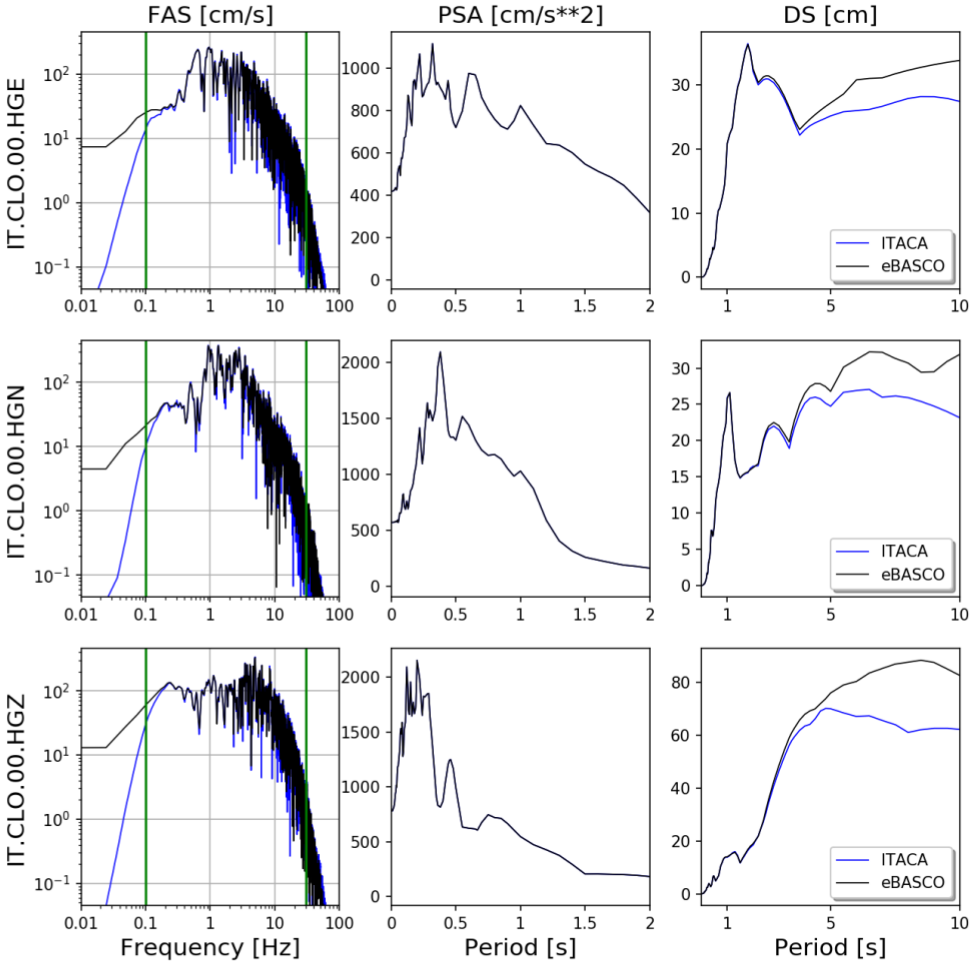

FIGURE 15: Comparison between eBASCO (black) and ITACA (blue) Fourier spectra (FAS), Pseudo Acceleration response Spectra (PSA) and Displacement response Spectra (SD) 5% damped (EW, NS, and UD components) related to the station CLO records of the 30 October 2016, Mw6.5 earthquake. Green lines indicate the low-cut and the high-cut cutoff frequency of the broad-band ITACA processing.

FAQs and ways to ask for support

Any form of feedback or suggestions at maria.damico@ingv.it are welcomes, as well as support requests for eBASCO.py Users.

Instructions on how to install eBASCO.py

eBASCO.py (version 1.0) is a python2.7 code wich need the following dependencies:

- pyasdf==0.4.0
- obspy==1.1.1
- numpy==1.16.2
- scipy==1.2.1
- matplotlib==2.2.4
- psutil==5.6.2

License information

Disclaimer of Warranties

The eBASCO codes removes the baseline of strong-motion records. It is particularly suitable for fling-step containing near-source records. The User can easily process three component accelerometric waveforms stored in ASDF volumes by means of automatic or manual choice of the processing parameters.

eBASCO is provided on an As Is, with all faults and As Available basis, without any warranties of any kind. We specifically do not warrant that eBASCO is complete, accurate, reliable or secure in any way, suitable for or compatible with any of your contemplated activities, devices, operating systems, browsers, software or tools, or that their operation will be free of any viruses, bugs or program limitations.

The strong motion records processed by eBASCO are devoted to qualified users. No warranty, implicit or explicit is attached to eBASCO data and metadata. Every risk due to the improper use of data or related information is assumed by the User.

Citation

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General Overview

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