

ESM DATABASE

ENGINEERING STRONG MOTION DATABASE

RAPPORTI TECNICI INGV

ESM processing tool users' manual



ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

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ESM processing tool users' manual

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Cover | *In copertina* Home page of the ESM database

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Abstract

The behaviour of the ground surface and of structures subjected to earthquakes can be estimated analysing the accelerograms of seismic records. The ground motion is strongly dependent on several factors and the ability to record, characterize and extract the main features of waveforms is essential to better understand these dependencies. One of the most difficult steps of this analysis is the waveforms' processing. Its purpose is the estimation and the removal of noise in the records, to evaluate reliable ground motion.

In this framework a processing tool fully integrated within the Engineering Strong Motion (ESM) database was designed [Paolucci et al., 2011; Luzi et al., 2016].

In the last decade the number of waveforms is sharply increased and so is the time it takes to process them. To solve this issue a possible solution is to broaden the number of qualified people involved in the processing. The main aim of this tutorial is to teach the largest number of people how to use the ESM processing tool and to provide some important guidelines for the thresholds of the parameters to set. In the text a step-by-step processing routine is depicted with a description of the purpose for each parameter. In addition, a suite of explanatory examples with peculiar situations is given.

Keywords Waveform processing; Engineering Strong Motion database; Strong motion data

Introduction

The essential data for earthquake engineering are the accelerograms of moderate-to-strong earthquakes [Housner, 1970]. They are the starting point to understand the behaviour of the ground and of structures subjected to earthquakes. Accelerograms (or strong-motion records) consist in the acceleration time series of the ground sampled several times per second in three mutually orthogonal directions.

Starting from the late 1990s hundreds of strong-motion records were made available worldwide through online databases [Pacor et al., 2011]. This huge number of records witnesses a significant variability of the ground motion depending on several factors (both event parameters like size and focal mechanism, and station characteristics). For this reason, the ability to record, characterize and extract the main features of waveforms is essential to develop methods in order to mitigate seismic risk.

It is important to stress that the unprocessed waveforms are not the exact reproduction of the ground motion, as they are affected by noise of various origins. The purpose of the strong-motion data processing is the estimation and the removal of noise in the records, to evaluate reliable ground motion for standard or specific applications.

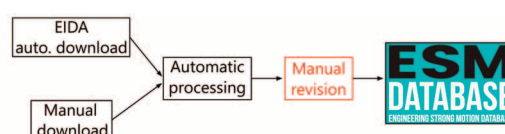
Nowadays several codes for strong-motion data processing exist. The drawback of the available codes is that they are not integrated with seismological databases and so the users must provide themselves a dataset of waveforms. Additionally, sometimes it is necessary to convert the waveforms into specific formats suited for the processing codes.

In this framework a processing tool fully integrated within the Engineering Strong Motion (ESM) database was designed [Paolucci et al., 2011; Luzi et al., 2016]. The main aim of this tutorial is to teach the largest number of people how to use the ESM processing tool and to provide some important guidelines for the thresholds of the parameters to set.

1. ESM database

The Engineering Strong Motion (ESM) database was developed within the Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation (NERA) project (2010 – 2014, Seventh Framework Programme of the European Commission) [Luzi et al., 2016] complementary to the Rapid Response Strong-Motion Database (RRSM) [Cauzzi et al., 2016]. It consists of a database that collects data from several networks of strong-motion data operators in the Euro-Mediterranean region with the goal of creating a long-term infrastructure. The database was designed for a large variety of stakeholders (expert seismologists, earthquake engineers, students, and professionals) with a user-friendly and straightforward web interface. The strategy adopted for ESM is to publish only manually revised data, to ensure the maximum data quality and reliability (Figure 1).

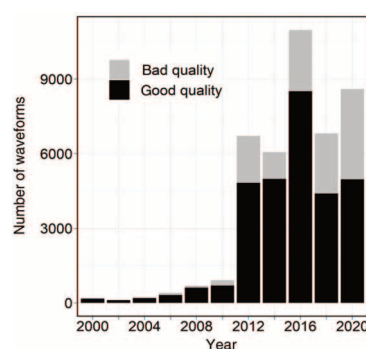
Figure 1 ESM database overview flowchart.



Most of the waveforms that are currently uploaded in ESM are automatically downloaded from the European Integrated Data Archive (EIDA) [Strollo et al., 2021] although for some other networks a manual upload is still required (e.g., IT, TK networks). The availability of continuous data streams allows the access to seismic signals in quasi-real time and to progressively populate the ESM database through semiautomatic procedures. All the waveforms uploaded in the database are then automatically processed adopting the same scheme designed to process the Italian ACcelerometric Archive (ITACA) [Paolucci et al., 2011; Pacor et al., 2011].

One of the main issues of this strategy is for sure the time necessary to manually revise the waveforms. Over the past decade, the number of waveforms has been strongly increased and the problem has significantly sharpened (Figure 2).

Figure 2 Time evolution of the number of waveforms since 2000 [Mascandola et al., 2023].



So far, the manual processing was done by the ESM working group of the INGV, but in order to keep up with the number of waveforms the main aim of this tutorial is to establish common rules for the ESM data processing to all the users with database write properties (administrators' users).

2. Access the ESM processing tool

The ESM processing tool is accessible from the ESM database home page (<https://esm-db.eu/>). If one has an administrator authorization, in order to be recognized it is necessary to do the

“Administrator login” clicking on the dedicated button on the upper-right side of the webpage (Figure 3).



Figure 3 Home page of the ESM database.

A new window will open (Figure 4), in the first row the institutional email address is required while in the second row it is necessary to type the password, then click on the “Login” button. To check if you are correctly logged-in, in the upper-right part of the ESM webpage instead of the login button the username and the logout buttons should be present.

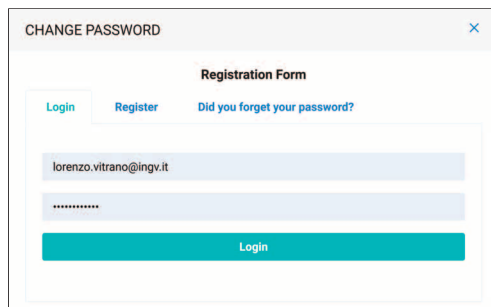


Figure 4 Login window of the ESM database.

On the other hand, if you want to use the processing tool as anonymous user (namely no registration is required) you can simply click on the processing button present in the middle of the ESM home page (Figure 3).

Anonymous users have the access to all the public waveforms, where “public” means EURO-MED networks processed accelerometric records. They can process and save these waveforms in their local computer memory.

Administrator users have the access to all the waveforms of specific networks (depending on the user) and have the authorization to process them and save them into the ESM database.

Anonymous user:

- Access to **all public**¹ waveforms
- No-authorization to modify the content of the database²

Administrator user:

- Access to **all waveforms of specific networks**
- Authorization to modify the content of the database

The administrators have the possibility to open the waveforms that have not already been manually revised, process and then publish them (with a good or bad quality flag).

¹Public = EURO-MED networks processed accelerometric records.

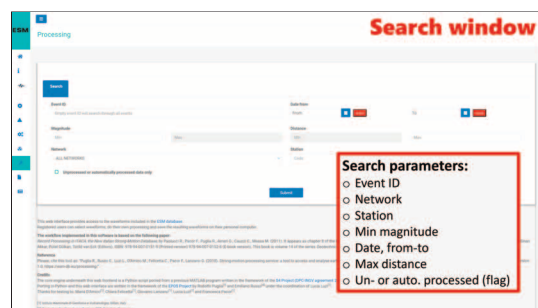
²Possibility to process and save in the local memory of the computer.

Only the members of the ESM staff (see INGV WG in https://esm-db.eu/#/about/who/the_wg) are authorized as administrators for all the networks in the database. However, authorization has also been granted to network administrators and/or contact persons for the networks under their responsibility. In this way they can contribute to the manual processing of ESM and, if necessary, certify the goodness of the processing carried out by the ESM staff. In special cases, one can make a request (temporary or permanent) to be an administrator of one or more networks by sending an email to esmdb@ingv.it with the justified request.

3. Perform an ESM database search

The first panel of the processing tool that will appear is designed to search the waveforms stored in the ESM database (Figure 5).

Figure 5 “Search” panel of the ESM processing tool.



From this panel it is possible to query the ESM database to search for waveforms specifying one of the following parameters:

- Event id: each event of the ESM database is associated with a unique ESM-code called “event-id” (e.g., INT-20220922_0000080; EMSC-20200808_0000154).
- Network: network code/s of the waveform/s of interest (e.g., IT, CH).
- Station: station/s code/s of the waveform/s of interest (e.g., CMRN, STSP).
- Min magnitude: the minimum magnitude of event/s. All types of magnitude are considered (M_w, M_l, M_b, M_s, M).
- Date, from-to: the time range during which the event/s occurred.
- Max distance: the maximum source-to-site epicentral distance.
- Unprocessed or automatically processed data only: checkbox accessible only to administrator user.

3.1 Example 1: single waveform search

As an example, to perform the search of a single waveform, it is necessary to fill the fields related to the event id, the network and the station. In this example the waveform related to the event EMSC-20200224_0000188 recorded by the GRIS station, belonging to the IV network, is searched (Figure 6).

After clicking the “Submit” button the “Search Results” tab containing the searched waveform and its primary metadata will appear (Figure 7).

One of the most important fields to consider is the “Processing”. Four values are possible for this field (only two for anonymous users):

- Manual (**green check**): the waveform has already been manually revised.
- Bad quality (**red check**): the waveform has already been manually revised and labelled as a bad quality.

- Automatic (**yellow check**): the waveform has not already been manually revised. This possibility is available only for administrator users.
- Not processed (**grey check**): the automatic processing of the waveform failed.

To open the waveform and start processing it is necessary to press on the “GO” button on the right side of the table.

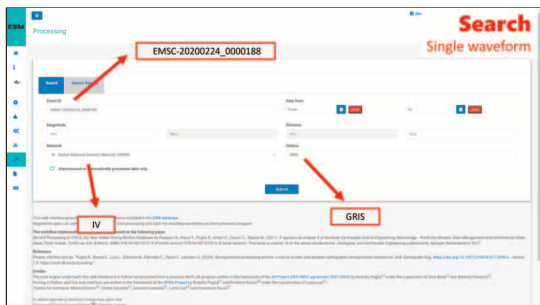


Figure 6 Search example of a single waveform.

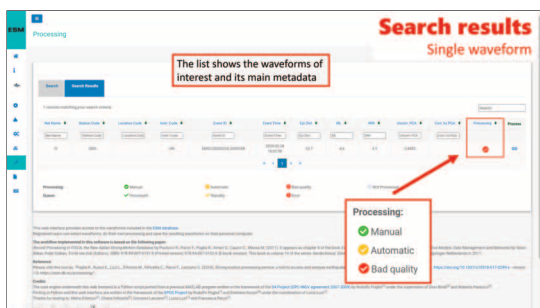


Figure 7 “Search Results” panel.

3.2 Example 2: single event search

The most common situation is when several waveforms relative to a single event must be processed.

In this case, the only necessary parameter for the research is the ESM “event-id”. In this specific example the waveforms related to the event EMSC-20200224_0000188 are searched.

After clicking on the “Submit” button on the “Search Results” tab, a list of 10 waveforms (each page) corresponding to the event of interest and their metadata will appear (Figure 8). It is possible to filter the waveform list by writing additional input in the boxes below the name of each field.

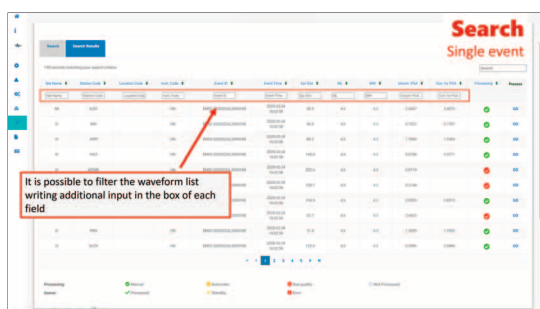


Figure 8 “Search Results” panel with the list of waveforms corresponding to the performed query.

For example, it could be useful to filter the waveforms based on the instrument type. This is possible by typing the code of the instrument of interest (e.g., EH for short-period seismometers). Another possibility is to sort the waveforms based on one of the reported fields using the small

arrows located at the right side of each field name. This is very convenient when there are several waveforms related to a single event and a criterion is needed to start processing them. In these cases, it is possible to sort the waveforms in ascending order of epicentral distance (another common choice is the PGA).

Usually, when processing a lot of waveforms, it is practical to open more than one at the same time. This is feasible simply by pressing the “GO” button on two or more waveforms. For each opened waveform a dedicated tab will open.

4. Processing tool graphic interface

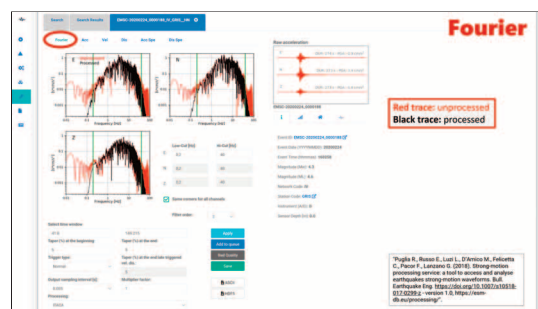
Once a waveform is opened in the processing tool, it is possible to examine it thanks to the six following panels, each one containing different information:

- Fourier
- Acceleration
- Velocity
- Displacement
- Acceleration spectra
- Displacement spectra

4.1 Fourier panel

In the Fourier panel the Fourier spectra of each component are present (Figure 9). The red traces are referred to the unprocessed waveform while the black ones to automatically processed ones [Paolucci et al., 2011].

Figure 9 Fourier panel of the waveform EMSC-20200224_0000188_IV_GRIS__HN.



4.2 Acceleration panel

In the acceleration panel the accelerometric records of each component are present (Figure 10). The red traces are referred to the unprocessed waveform while the black ones to the automatically processed [Paolucci et al., 2011].

The values on the abscissa on the top of the records refer to the waveform relative time with respect to the start of the unprocessed record. The values written on the abscissa at the bottom of records refer to the absolute time.

At the bottom right side of the recording box of each waveform the Peak Ground Acceleration (PGA) of the unprocessed (red) and processed (black) traces is visible (Figure 10). The plots show an estimate of both P and S phase arrivals based on theoretical calculations of travel times within a simplified crustal medium (Table 1).

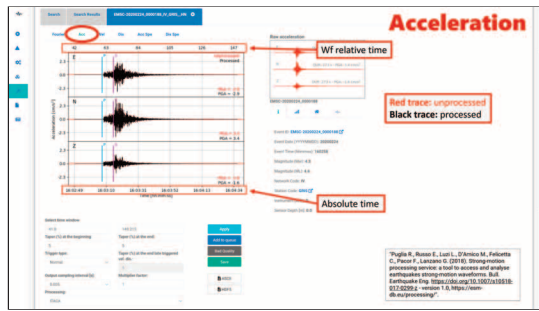


Figure 10 Acceleration panel of the waveform EMSC-20200224_0000188_IV_GRIS__HN.

Depth [Km]	Vp [Km/s]	Vs [Km/s]
≤ 30	5.7	3.2
> 30	8.0	4.5

Table 1 P and S-wave velocity values used for the theoretical picking.

The visualization of the P and S phase arrivals may help the users to check whether the event is correctly associated with the waveform, especially in case of multiple events recorded in the same trace. It should give a rough idea of the expected time window in the record in which the seismic signal is expected and it has no influence on the waveform trimming.

The velocity and displacement panels are organized in the same way. In the “Acc Spe” and “Dis Spe” panels the accelerometric and the displacement response spectra are plotted.

In every panel, it is always possible to consult four tabs containing pieces of information useful to correctly interpret the waveform. More in detail, in the first tab there is some general information (Figure 11).

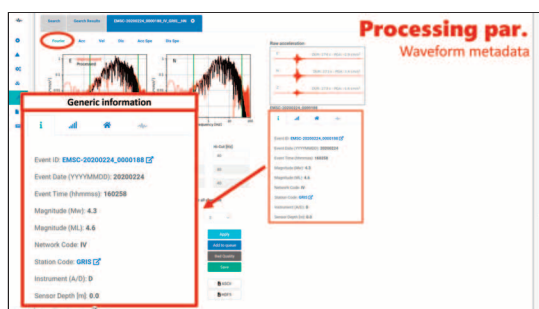


Figure 11 “Generic information” box of the waveform EMSC-20200224_0000188_IV_GRIS__HN.

In the second tab the parameters related to the event are present. In the third one there is the station information while in the fourth and last tab there is the waveform information. Above these four boxes the unprocessed accelerogram plots (the three red traces in the box) are present. For what concerns the processing parameters they are located in two different parts of the webpage. In the following paragraphs these parameters are going to be shortly described while the way to set them will be explained in the next chapter.

The parameters relative to the frequency domain are visible only in the Fourier panel (Figure 9), on the right of the Z-component spectrum (Figure 12).

Here you can set the low-cut (high-pass) and high-cut (low-pass) filters measured in Hertz. By default, the values are the same for all channels, but it is possible to set different values by unchecking the checkbox “Same corners for all channels”. The possibility to change the filter order is also provided. Other parameters are in the bottom half of the page (Figure 13).

Figure 12 Filtering parameters of the ESM processing tool.

	Low-Cut [Hz]	Hi-Cut [Hz]
E:	0,1	40
N:	0,1	40
Z:	0,1	40
<input checked="" type="checkbox"/> Same corners for all channels		
Filter order:	2	

Figure 13 Processing parameter of the ESM processing tool: time window, taper, trigger type, output sampling interval, multiplier factor, processing.

Select time window	41.8	149.215
Taper (%) at the beginning:	5	Taper (%) at the end:
Trigger type:	Normal	Taper (%) at the end late triggered vel. dis.:
Output sampling interval [s]:	0.005	Multiplier factor:
Processing:	ITACA	

In the time window there is also the possibility to set the “Taper” (both at the beginning and at the end), the “Trigger type” (normal/late), the output sampling interval (s), the “Multiplier factor” and finally the type of “Processing”. These parameters will be described in detail in the chapter “5. Processing workflow”, sub-chapter “5.3 Additional settings”.

Command buttons are visible on the right, and they are necessary to assign inputs or execute the waveform processing. Anonymous and administrator users have different buttons (Figure 14).

Figure 14 Commands of the ESM processing tool. For anonymous users there are only the possibility to apply the new settings and locally save the processed waveform.

<input type="button" value="Apply"/>	<input type="button" value="Apply"/>
<input type="button" value="ASCII"/>	<input type="button" value="Add to queue"/>
<input type="button" value="HDF5"/>	<input type="button" value="Bad Quality"/>
	<input type="button" value="Save"/>
	<input type="button" value="ASCII"/>
	<input type="button" value="HDF5"/>

ANONYMOUS USERS ADMINISTRATOR USERS

Please note: if a waveform tab is closed without applying “Save” for administrators (or downloading for anonymous users) all the processing parameters will be lost.

- Apply: run the processing applying the user defined parameters.
- Add to queue: store the waveform in a temporary queue to eventually save the manually processed data all at once in a second time (only for administrator users).
- Bad quality: flag the automatically processed waveform as “bad quality” and delete from the database the related auto-processing data. Only the unprocessed record is stored in the database (only for administrator users).
- Save: save the manually processed waveform, its metadata and the associated ground motion parameters into the database (only for administrators).
- ASCII: download the waveforms as .asc file.
- HDF5: download the waveforms as .h5 file.

4.3 Example 3: opening a new waveform while processing

In every moment during the manual processing, it is possible to open a new window without losing the currently setting parameters. This could be useful when comparing two or more waveforms. In order to do this, there are two possibilities. If the new waveform of interest is part of the result of the previous search query it is possible to simply go back to the “Search Results” panel and open it. Otherwise, if the waveform of interest is not a result of the previous query it is possible to go back to the “Search” panel and perform a new one. In this case the results of the previous query will be lost, but the selected waveform tab will remain open (Figure 15).

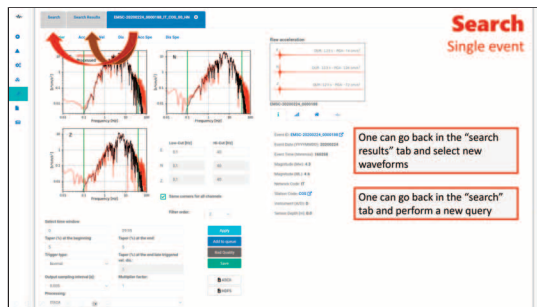


Figure 15 In every moment it is possible to go back to the “Search Results” and open one or more new waveforms or to the “Search” panel and perform a new query without losing the processing values of the current one.

5. Processing workflow

Generally, it is not possible to identify the “ideal” processing for an individual record, as assumptions always need to be made and a certain degree of subjectivity is involved. Boore and Bommer provide an extensive overview of techniques for processing strong-motion data and the consequences of applying different approaches, from the perspective of engineering applications [Akkar & Bommer, 2006; Boore & Bommer, 2005; Shakal et al., 2005]. Because of this subjectivity, it is important for administrator users to maintain consistency of the processed data in the ESM database. In agreement with the institutions that are part of the ORFEUS network some rules have been established and a best practice suggested. All these considerations have been collected and reported here.

The workflow can be divided into the following four steps:

- a. Waveform trimming
- b. Waveform filtering
- c. Additional adjustments
- d. Download/Finalization

This workflow will be described using the IT.SGIUB.00.HNE.D.IT-2002-0075 waveform as an example (Appendix A to see how ASCII filenames work).

When an automatically processed waveform is opened for the first time it is always important to check all the panels (Acc., Vel., etc.), at least briefly, to have a basic overview before starting to change any parameter. Default values are proposed, like the length of the time window and the filter corners.

5.1 Waveform trimming (time domain)

It is always better to avoid saving excessively long records because the waveforms are usually used for engineering applications (e.g., 2D soil response, non-linear analysis). This means that

for longer durations a longer computational time will be required. On the other side it is important to not trim the record where the seismic signal is present.

5.1.1 Start time

Check the expected arrival time of the P-waves and **try to leave about 10-20s of pre-event signal**.

As shown in Figure 16, the P-wave first-arrival is at about 60 seconds from the record start and so the new start time is set at 45 seconds (Figure 16 and Figure 17). To implement this adjustment to the waveform and update the plots the user must click on the “Apply” button.

Figure 16 Velocimetric time series for the three components. The expected P-waves arrival is slightly after 55s. The red dashed line identifies the selected start time (45s).

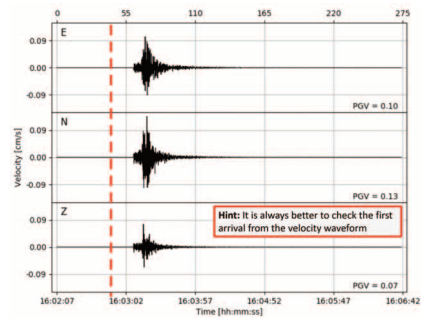


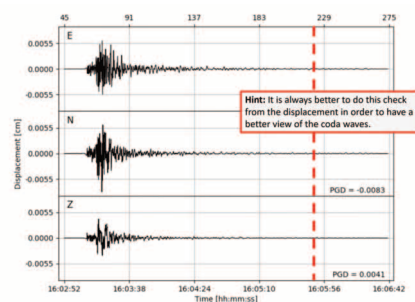
Figure 17 Set of the time window, start time.

5.1.2 End time

Check from the displacement window the time at which the seismic signal is no more distinguishable from the noise and always keep a few seconds to keep coda waves.

In the example, the coda waves are visible until about 185 seconds. To keep a margin of some seconds an end-time equal to 220s has been set (Figure 18 and Figure 19). As for the start time it is necessary to click on the “Apply” button to update the images.

Figure 18 Displacement time series for the three components. The red dashed line identifies the selected end time (220s).



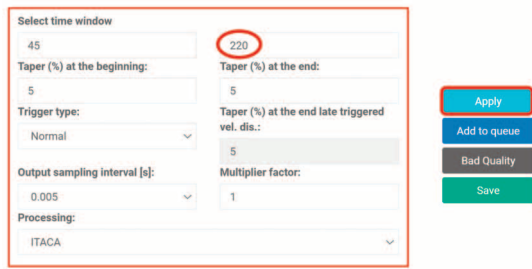


Figure 19 Set of the time window, end time.

5.2 Waveform filtering (frequency domain)

5.2.1 Low frequency

The impact of low-frequency noise (<1 Hz) can have a strong influence on strong-motion intensity measures such as ground velocities, displacements, and response spectra ordinates. By default, the automatic processing sets the high-pass corner depending on the event magnitude [Puglia et al., 2018] (Table 2).

MR	hp (Hz)
< 3.5	0.25
3.5 ≤ M < 4.0	0.20
4.0 ≤ M < 4.5	0.15
4.5 ≤ M < 5.5	0.10
5.5 ≤ M < 6.0	0.07
6.0 ≤ M < 6.5	0.05
6.5 ≤ M < 7.0	0.04
7.0 ≤ M < 8.0	0.03
M ≥ 8.0	0.025

Table 2 Default values for the low-pass corner.

The low-frequency cutoff, the lowest frequency for which the data are reliable in terms of signal-to-noise ratio, can be visually determined in two ways:

1. Visually evaluate where the red trace (unprocessed waveform) of the Fast Fourier Amplitude Spectra (FAS) deviates from the omega-square model.
2. Visually inspect the velocity and the displacement time series.

Best practice: for digitally recorded waveforms is to set a low-cut threshold not above 0.25-0.3 Hz. Greater values would imply a loss of useful information.

In the example in Figure 20, the low-frequency part of the spectra is satisfactory, in order to keep as signal as possible low-cut corner value has been manually refined to 0.1 Hz. In other situations (more noisy waveforms, Figure 21) this value will have to be increased.

In order to apply this new modification, click the dedicated “Apply” button.

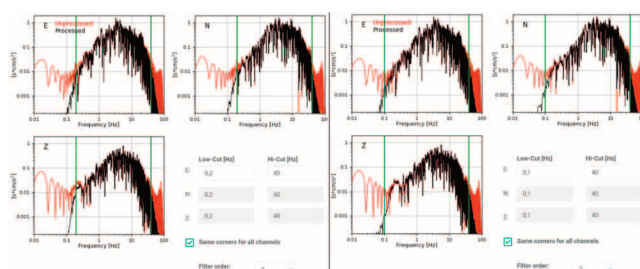
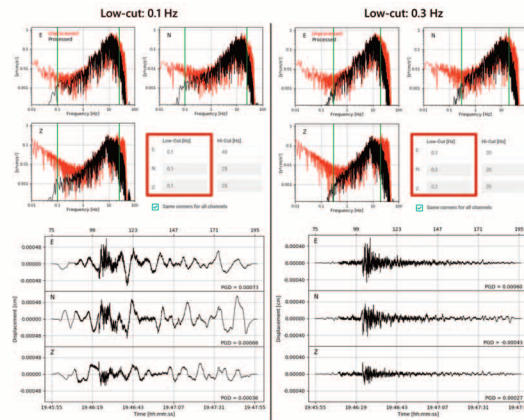


Figure 20 The Fourier spectra for each component before (left) and after (right) the modification of the low-cut filter.

Figure 21 Left: Waveform filtered with a low-cut value of 0.1Hz; Right: Waveform filtered with a low-cut value of 0.3Hz. In this waveform (INT-20230510_0000193_C1_ACO1__HN) the action of the low-cut filter to decrease the background noise can be observed, in particular in the displacement record.



5.2.2 High frequency

By default, the low-pass corner is always automatically set at 40 Hz.

The highest usable frequency is constrained by the sampling rate of the instrument (Nyquist frequency).

The high-frequency noise is generally less relevant compared to the low one.

Best practice: set the high-cut value not below 20-25 Hz.

In the waveform being examined the default value of 40 Hz has been maintained.

5.2.3 Additional parameters

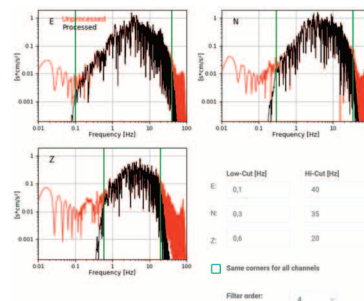
There could be cases when the level of noise may be different from component to component. Unchecking the checkbox “Same corners for each channel” it is possible to set different filter corners and to change the filter order (Figure 22).

Best practice: leave the same cut-off frequencies for the three channels (at least for the two horizontal components). Only in some cases should this be changed.

Best practice: keep the default filter order (mandatory for records uploaded in ESM). Only in exceptional cases should this be changed.

In the examples these parameters have been maintained as default.

Figure 22 Example in which different filter values are applied to each component and a filter order equal to 4 is set (these values have been discarded and are only shown as an example).



5.3 Additional settings

The other additional settings that only in a few exceptions could be changed by the users are the taper percentage, the trigger type and the multiplier factor. If not necessary it is always better to keep these parameters by default.

5.3.1 Taper

As default, a co-sinusoidal taper is applied both at the beginning and the end of the signal in time windows equal to the 5% of the total length of the record. It ensures that time histories start and end from zero initial conditions. Sometimes if the seismic signal is very close to the beginning of the record it could be useful to reduce the length percentage.

Best practice: keep the default values.

5.3.2 Trigger

Although few, some analogic records triggered by S-phase arrival (late-triggered records) are present in ESM (Figure 23). Once they are identified, the automatic processing of these records is slightly different to preserve the seismic signal [Paolucci et al., 2011]. The trigger setting allows the user to change the automatic processing.

Best practice: keep as default, it is automatically identified.

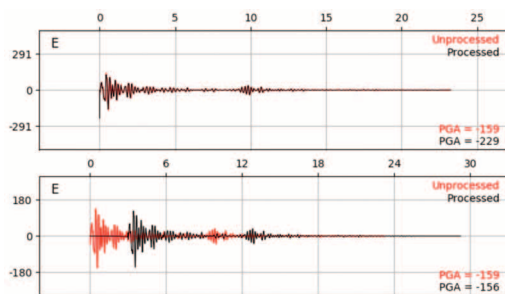


Figure 23 The accelerometric records of the same event (IT-1997-0105) of two collocated instruments. Above: late-triggered analogic record (NCR). Below: normal-triggered digital record (NCR2).

5.3.3 Sampling interval

In ESM all the records are by default automatically sampled every 0.005 s [Paolucci et al., 2011] but this value can be manually changed during the manual revision.

Best practice: for local saving, keep as default. For administrators do not change.

5.3.4 Multiplier factor

The multiplier factor gives the user the possibility to artificially increase/decrease the amplitude of the record (Figure 24). This could be useful (in very rare situations) to solve technical problems of the instrument or to obtain a waveform which is compatible with a target spectrum.

Best practice: unless known instrument problems or particular purposes, keep as default.

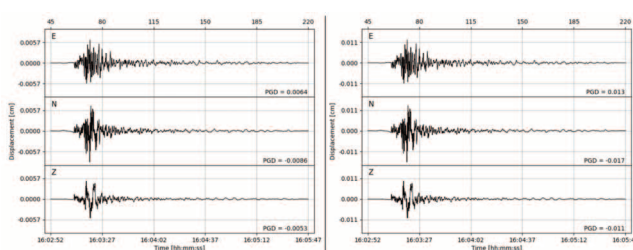


Figure 24 Example of application of the “Multiplier factor”. From the y-axis it is possible to check the difference in the amplitude values.

5.3.5 Processing

Currently only the ITACA automatic pre-processing type is available [Puglia et al., 2018] but in the near future the eBASCO method is going to be implemented [Schiappapietra et al., 2021]. This preprocessing scheme allows to remove the baseline of strong motion records using a piecewise linear detrending without applying any filtering to remove the low-frequency content of the signal. This method is particularly useful for near source records.

5.4 Download/Finalization

Once the processing is satisfactory, users can download the waveforms and the related metadata in the ASCII or HDF5 file format (Figure 25A).

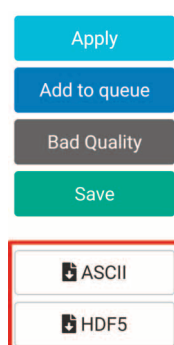


Figure 25A Download buttons.

By clicking on the ASCII button, a .zip folder will be downloaded. This folder contains, for each component, the following .asc files:

- Unprocessed acceleration (*ACC.CV.ASC)
- Processed acceleration (*.ACC.MP.ASC)
- Processed velocity (*.VEL.MP.ASC)
- Processed displacement (*DIS.MP.ASC)
- Acceleration response spectra of the processed waveform (*.SA.MP.ASC)
- Displacement response spectra of the processed waveform (*.SD.MP.ASC)

Read Appendix A to see how ASCII filenames work.

By clicking on the HDF5 button a .h5 file designed to store and organize a large amount of data will be downloaded. In this file all the information related to the waveform are stored (Appendix B to see how these files are structured).

At the end of the manual processing, the administrator users can interact with the ESM database in three different ways (Figure 25B):

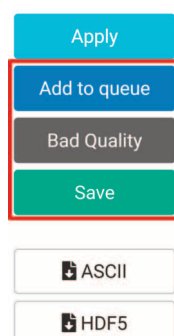


Figure 25B Database-interaction buttons.

- “Bad Quality” button: processed waveforms/spectra, related metadata and ground motion parameters will be deleted. The unprocessed waveform will be labelled as bad quality.
- “Save” button: the processed waveform, the related metadata and the ground motion parameters will be stored in the ESM database. The waveform will be labelled as good quality.
- “Add to queue” button: the processed waveform will be temporarily stored in a queue to be saved in the ESM database at the end of the processing session. This possibility could be useful to save several waveforms all at once. If a waveform is added to the queue a symbol will appear on the left of the waveform tab and the queue panel will appear (Figure 26).



Figure 26 When a waveform is added to the queue, a new tab will appear after the other waveforms' panel.

From the “Queue” panel, clicking on the “Process Queue” button, all the waveforms in the queue will be saved all at once.

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APPENDIX A

ASCII filenames

Example of ASCII filename in ESM for the unprocessed (CV) acceleration (ACC) waveform recorded by the sensor “00” of the “SGUIB” station belonging to the “IT” network during the seismic event “IT-2002-0075. The instrument is a High Broad Band (H) accelerometer (N) North-South (N) oriented ([D’Amico et al., 2021]; pag. 17-18).



Figure 27 Example of ASCII filename.

APPENDIX B

HDF5 files

Structure of the ESM ASDF file in the HDF5 container. In yellow, the information about an arbitrary number of seismic events stored in a single QuakeML. In green, the seismic waveforms are stored per station together with the necessary meta information in the form of an FDSN StationXML document. In red, the response spectra and metadata related to stations, events, waveforms, processing, credits, and license are hierarchically stored in the auxiliary data section ([D'Amico et al., 2021]; pag. 20-21-22).

ESM HDF5 CONTAINER

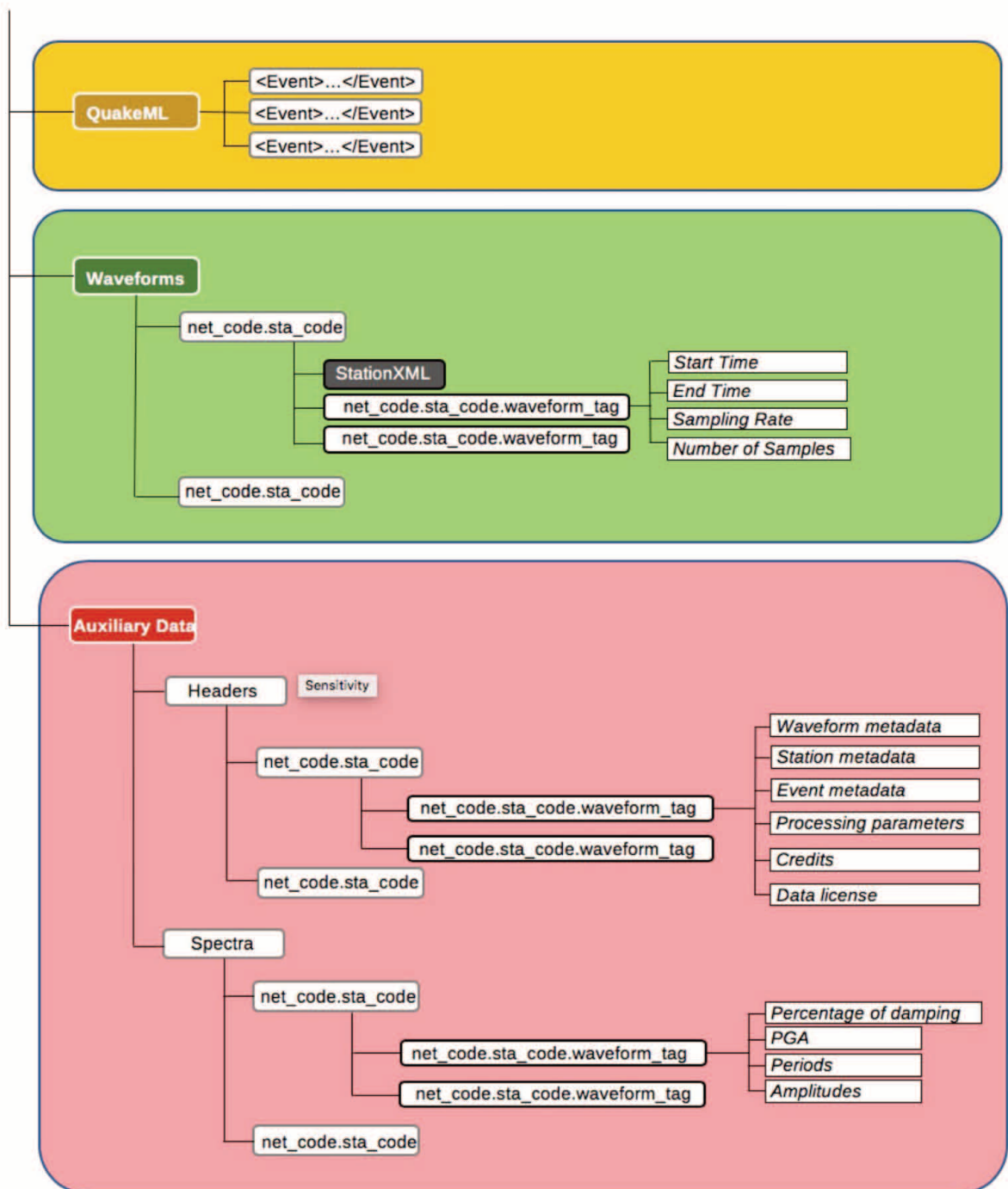


Figure 28 Structure of the ESM ASDF file in the HDF5 container.

APPENDIX C

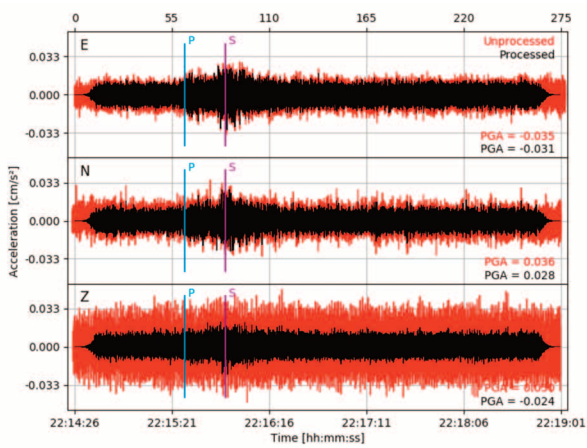
Guidelines and examples

In this appendix a series of recommendations are listed. A collection of significant waveforms is presented to give the reader an outline of typical problems which affect the records.

Through the experience in manual processing gained over time a general list of conditions that a high quality waveform must respect has been drawn up:

- All metadata provided
- No zero or empty channels
- Sufficient pre-event and coda
- High signal-to-noise ratio (SNR)
- Only one event per record
- Reasonable frequency passband (i.e., at least 0.4 - 20 Hz)
- No pre- or post-event transients
- PGA and PGD values consistent between channels
- Peak values that are physically reasonable
- No spikes in the time series
- Sensible shape for Acceleration and Displacement spectra

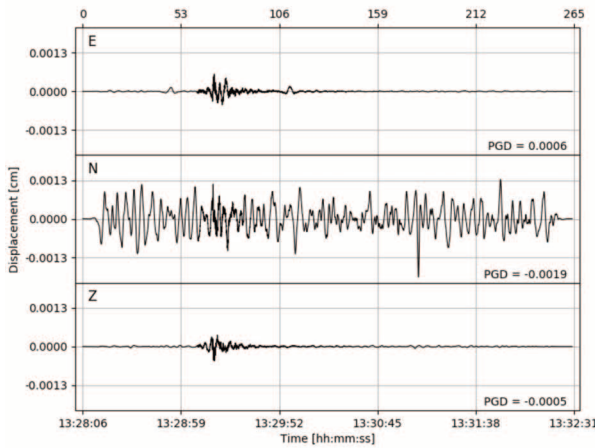
The examples illustrated below can be useful for those approaching waveform processing for the first time.



Event-id: INT-20230306_0000303
 Network: KO
 Station: KHMN

Very noisy waveforms or instrument malfunctioning.

Bad quality

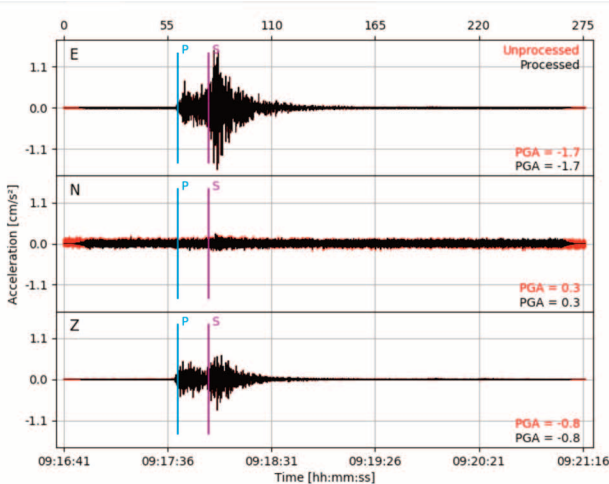


Event-id: INT-20230417_0000127
 Network: RA
 Station: PYAD

One noisy component.

HINT: try to set different filter values for the problematic channel to save the waveform.

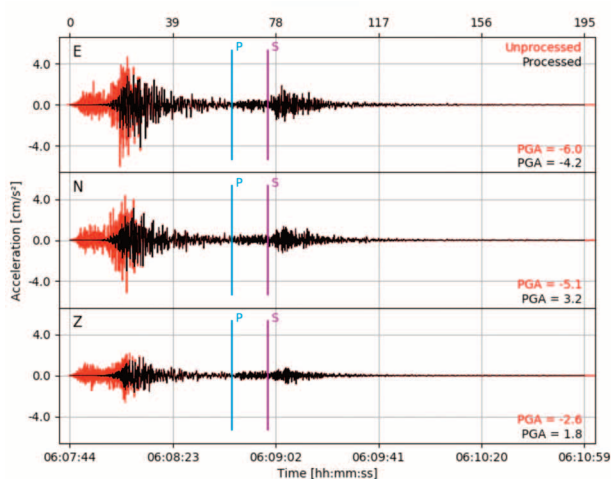
Bad quality



Event-id: INT-20230405_0000102
 Network: PA
 Station: BRU2

One channel is not working correctly.

Bad quality

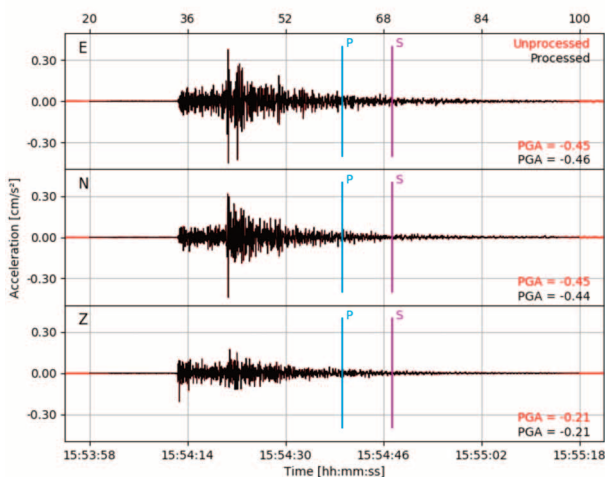


Event-id: INT-33301931
 Network: IV
 Station: ITCC

Multiple events.

HINT: Trim around the second event (the one identified by the theoretical picking, the first one will be stored in another record).

Good quality

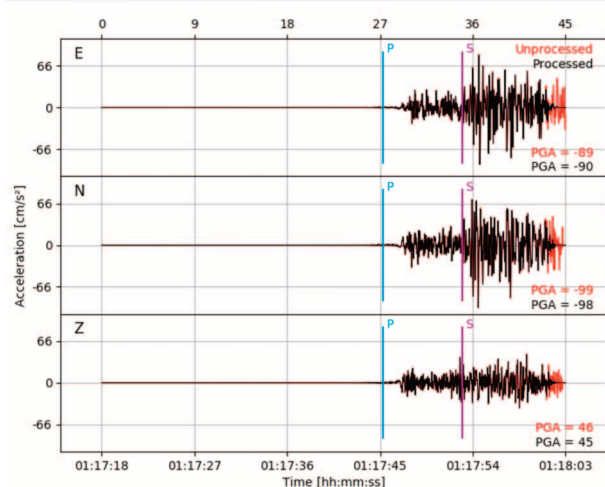


Event-id: EMSC-20190630_0000089
 Network: PA
 Station: BRU2

Theoretical picking completely wrong, probably due to incorrect origin time.

HINT: The picking does not influence the waveform.

Good quality

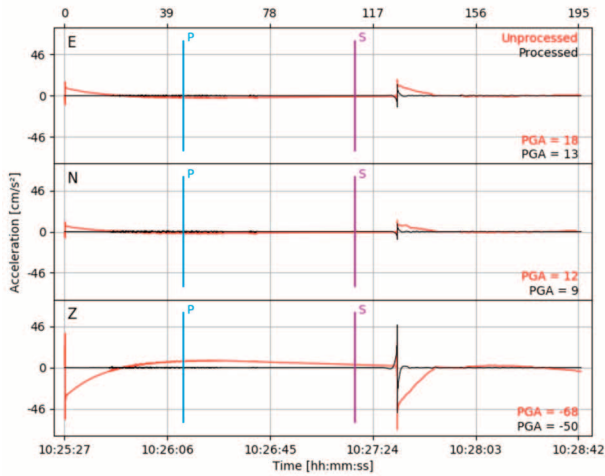


Event-id: INT-20230206_0000008
 Network: TK
 Station: 2707

Truncated waveform.

Please note: This record was manually uploaded in ESM; it is not from EIDA.

Bad quality

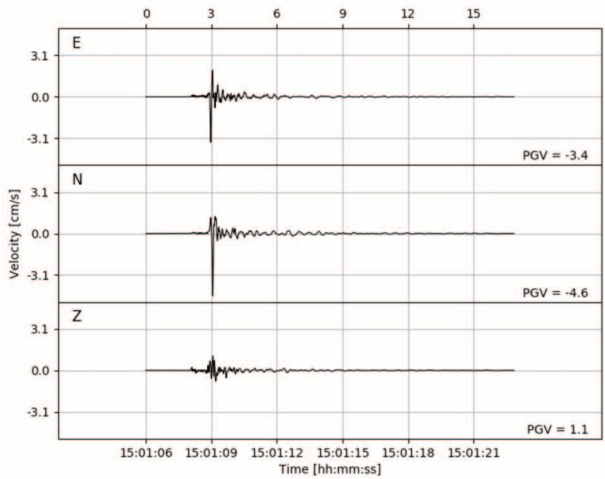


Event-id: INT-20230206_0000222
 Network: TK
 Station: 0720

This waveform presents two spikes.

HINT: in the time domain trim away the spikes to view lower amplitudes. Sometime the spike “hides” the real seismic record.

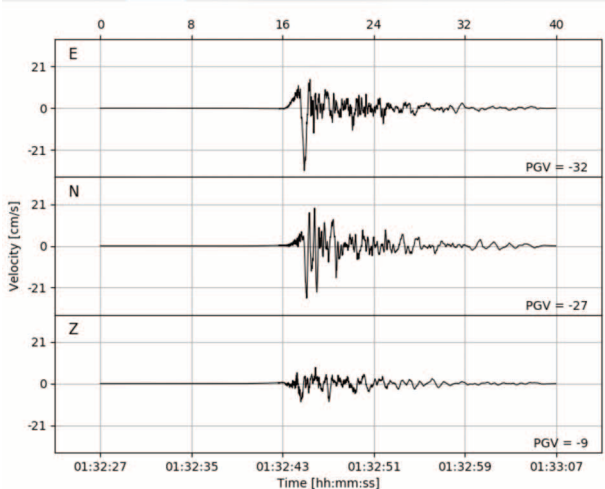
Bad quality



Event-id: IT-2011-0064
 Network: IT
 Station: STS

Impulsive event.

Good quality



Event-id: IT-2009-0009
 Network: IT
 Station: AQA

Low-frequency velocity pulse.

Good quality

Table 3 Examples of significant waveforms (Please note: users can have a better view of the waveforms in the ESM database).

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