Seismic Envelopes of Coda Decay for Q-coda Attenuation Studies of the Gargano Promontory (Southern Italy) and Surrounding Regions

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Abstract: Here, we describe the dataset of seismic envelopes used to study the S-wave Q-coda attenuation quality factor Qc of the Gargano Promontory (Southern Italy). With this dataset, we investigated the crustal seismic attenuation by the Qc parameter. We collected this dataset starting from two different earthquake catalogues: the first regarding the period from April 2013 to July 2014; the second regarding the period from July 2015 to August 2018. Visual inspection of the envelopes was carried out on recordings filtered with a Butterworth two-poles filter with central frequency f0 = 6 Hz. The obtained seismic envelopes of coda decay can be linearly fitted in a bilogarithmic diagram in order to obtain a series of single source-receiver measures of Qc for each seismogram component at different frequency fc. The analysis of the trend Qc(fc) gives important insights into the heterogeneity and the anelasticity of the sampled Earth medium.

Keywords: seismic envelopes; Q-coda attenuation; seismic coda decay; Gargano Promontory (Southern Italy); seismic analysis code (SAC)

1. Summary

The dataset is a collection of seismic envelopes computed from the seismograms of 280 earthquakes occurred in the Gargano area (Southern Italy) and recorded by both the OTRIONS (OT) and INGV (IV) seismic networks. The selected earthquakes belong to two bulletins: the first refers to earthquakes that occurred from June to September 2013; the second refers to earthquakes that occurred from July 2015 to August 2018. All of these earthquakes belong to a seismic database that was recently released and described [1–3] together with the seismic bulletins, station locations, velocity model [3], and seismograms.

Seismic attenuation estimates are calculated from the decay of coda waves that constitute the end of the seismic recording for local and regional events. The coda waves start after the S waves and are composed of incoherent waves scattered by inhomogeneities. The amplitude of coda waves is thought to decrease because of the seismic attenuation (both intrinsic and scattering) and because of the geometrical spreading of the wave front. Aki and Chouet [4] showed that, assuming that coda waves are single-scattered S waves, at short source-receiver distances, the coda amplitude decay A(fc, t) is given by:

\[
\log A(fc, t) \propto -\frac{\pi f_c t}{Qc(fc)}
\]

that is a linearly decreasing function of the time t elapsed from the origin time of the earthquake for a given central frequency fc. Therefore, Qc can be estimated by the slope of
the linear regression in Equation (1) in a selected time window called a lapse time window $t_L$. On the seismogram $S(t)$, the seismic coda decay $A(f_c, t)$ can be evaluated by the seismic envelope calculated using the Hilbert transform $HS(t)$, as follows:

$$A(f_c, t) = \sqrt{H[S(t)]^2 + S(t)^2}.$$  

(2)

The dependence of $A(f_c, t)$ on $f_c$ is obtained by band-pass filtering the signal $S(t)$ around $f_c$. In this work, we release the seismic envelopes $A(f_c, t)$ cut between the time $T3$, marked on the seismogram after the S-wave arrival time, until time $T4$, marked on the seismogram before an energy bump or an irregularity of the coda decay or when the coda waves are indistinguishable from the noise content. All released envelopes are band-pass filtered with a two-pole Butterworth filter, considering 11 values of $f_c = [2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16]$ Hz and a bandwidth $\left[\frac{f_c}{\sqrt{2}}; f_c \sqrt{2}\right]$, following Bianco et al. [5]. Times $T3$ and $T4$ were manually marked on seismogram envelopes filtered with central frequency $f_c = 6$ Hz and bandwidth $[4.2; 8.5]$ Hz.

The first dataset of envelopes (http://dx.doi.org/10.17632/w9hsj2whzm.1#folder-7a9 17d26-6be4-4014-8103-a8760541264a, accessed on 5 September 2021), which consists of the recordings of the period from June to September 2013, was already used for the first 2D $Q_c$ study [6] of the Gargano Promontory (Southern Italy). It consists of the recordings of 89 microearthquakes, with magnitudes ranging between 0.8 and 1.8, that were recently used to study the Gargano stress field [7] and the rheology of the Gargano crust [8].

The second dataset of envelopes (http://dx.doi.org/10.17632/w9hsj2whzm.1#folder- 7a917d26-6be4-4014-8103-a8760541264a, accessed on 5 September 2021), which consists of the recordings of the period from July 2015 to August 2018, was used in a 3D study of $Q_c$ ([9]) of the Gargano Promontory and surrounding areas (Southern Italy). It consists of the recordings of 191 microearthquakes, with magnitudes ranging between 1 and 2.8, that were recently used to study the Gargano active faults [10].

The manual work behind the time markers recognizing procedure is very expensive in terms of time costs. Nevertheless, we think that with this manual time marking procedure we obtained a very robust dataset of time envelopes with respect to an automatic time cut of seismic recordings. The released datasets of seismic envelopes can be very useful for seismological studies of intrinsic and scattering attenuation of Southern Italy, the Adriatic Sea, and other surrounding regions at different time lapse windows $t_L$.  

2. Data Description

2.1. First Envelope Dataset

The compressed folder Seismic_Envelopes_2013.zip contains 89 folders named with a numerical code $(YYMMDDHHmm)$ each of them related to the earthquake origin time $(YY = \text{year}, MM = \text{month}, DD = \text{day}, HH = \text{hour}, mm = \text{minute})$ (see Table 1).

Table 1. Contents of the folder Seismic_Envelopes_2013.

| First Dataset | Event Folders |
|---------------|---------------|
| Seismic_Envelopes_2013 | 201306031549 |
|                | 201306050513 |
|                | 201306061512 |
|                | …            |

Each event’s folder collects the time envelope files in data format (.dat) named as follows: “envSTNM.COM.fc.LAPSE.dat” $(STNM = \text{station name}, COM = \text{component}, fc = \text{central frequency})$ (see Table 2).
Table 2. Contents of the event folder.

| Event Folder | Envelope File |
|--------------|---------------|
| 201306031549 | envOT01.EHE.f02.LAPSE.dat |
|              | envOT01.EHE.f03.LAPSE.dat |
|              | envOT01.EHE.f04.LAPSE.dat |
|              | ... |

Each envelope file is made of two columns: time (s) from absolute midnight and amplitude in (counts/s) (see Table 3).

Table 3. Contents of the envelope file.

| Envelope File | File Content |
|---------------|--------------|
| envOT01.EHE.f02.LAPSE.dat | (Time s) (Amplitude counts/s) |
|                | 56,998.7383 148.276596 |
|                | 56,998.7422 151.102402 |
|                | 56,998.7461 154.158295 |
|                | ... |

The envelope file in Table 3 is plotted in Figure 1.

![Figure 1. Plot of the first envelope file in Table 3, as an example.](image)

2.2. Second Envelope Dataset

The compressed folder Seismic_Envelopes_2015_2018.zip contains 191 folders named with a numerical code (YYMMDDHHmm) each of them related to the earthquake origin time (YY = year, MM = month, DD = day, HH = hour, mm = minute) (see Table 4).

Table 4. Content of the folder Seismic_Envelopes_2015_2018.

| Event Folders          | First Dataset |
|------------------------|---------------|
| Seismic_Envelopes_2015_2018 | 201607031216 |
|                        | 201507040338 |
|                        | 201507201850 |
|                        | ... |

Each event’s folder collects the time envelope files in text format (.TXT) named as follows: “SN.STNM.COM.D.YYYY,JuD,hh/mm/ss.FCfc.TXT” (SN = station network, STNM = station name, COM = component, YYYY = year, JuD = Julian day, hh:mm:ss = hours:minutes:seconds of the recording origin time, fc = central frequency) (see Table 5).
Table 5. Content of the event folder.

| Event Folder | Envelope File |
|--------------|---------------|
| 201607031216 | RM.OT03..EHE.D.2015,184,10:35:01.FC02.TXT |
|              | RM.OT03..EHE.D.2015,184,10:35:01.FC02.TXT |
|              | RM.OT03..EHE.D.2015,184,10:35:01.FC02.TXT |
|              | ...           |

Each envelope file is made of two columns: amplitude in (counts/s) and time (s) elapsed from the origin time of the event (see Table 6).

Table 6. Content of the envelope file.

| Envelope File                  | (Amplitude counts/s) | (Time s) |
|-------------------------------|----------------------|----------|
| RM.OT03..EHE.D.2015,184,10:35:01.FC02.TXT | 5549.86621          | 6.40     |
|                               | 5474.11377          | 6.41     |
|                               | 5359.18904          | 6.42     |
|                               | ...                 | ...      |

The first envelope file in Table 6 is plotted in Figure 2.

Figure 2. Plot of the first envelope file in Table 6, as an example.

3. Methods

The two datasets described in Sections 2.1 and 2.2 were collected by using the SAC (Seismic Analysis Code) software [11,12]. Starting from the original seismogram in Figure 3, a filtering procedure is applied by using a two-pole Butterworth filter considering a central frequency $f_c = [2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16]$ Hz and a band-width $\frac{f_c}{\sqrt{2}}; \frac{f_c}{\sqrt{2}}$, thereby obtaining 11 new files for each seismogram component (for an example, see Figure 4). To each filtered seismogram, the SAC function “ENVELOPE” was applied, which computes the envelope function using a Hilbert transform using Equation (2) (for an example, see Figure 5). The released datasets are the envelopes cut inside the $[T_3, T_4]$ time window, as shown in Figure 1. To these files, a linear regression in Equation (1) was applied to retrieve the $Q_c$ value at each frequency [6]. A discussion about errors and uncertainties can be found in [9].
To these files, a linear regression in Equation (1) was applied to retrieve the $Q_0$ value at each frequency [6]. A discussion about errors and uncertainties can be found in [9].

Three-component seismograms at station OT01, as an example. Over each record, the origin time in absolute time is overwritten; the X-axis is time (s), the Y-axis is amplitude (counts/s). The P-wave marker (IPU0) and S-wave marker (IS) are overwritten.

Three-component seismograms at station OT01, filtered with $f_c = 6$ Hz and band-width [4.24; 8.48] Hz, as an example. Over each record, the origin time in absolute time is overwritten; the X-axis is time (s), the Y-axis is amplitude (counts/s).

Envelopes of the filtered seismograms in Figure 4. Over the first record, the T3 and T4 markers are overwritten; the X-axis is time (s), the Y-axis is amplitude (counts/s).

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