RIUNIONE PLENARIA PROGETTO SECURE

Evoluzione temporale dell'attenuazione coda/S waves in funzione della frequenza nell'Appennino Centrale.

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SECURE

Aim of the study

- One of the focuses of **WP2.2** is the impact of **Total Attenuation** on the ground motion in Central Italy

- This can affect the variability of ground motion in the central Apennines before, during, and after the occurrence of significant earthquakes.

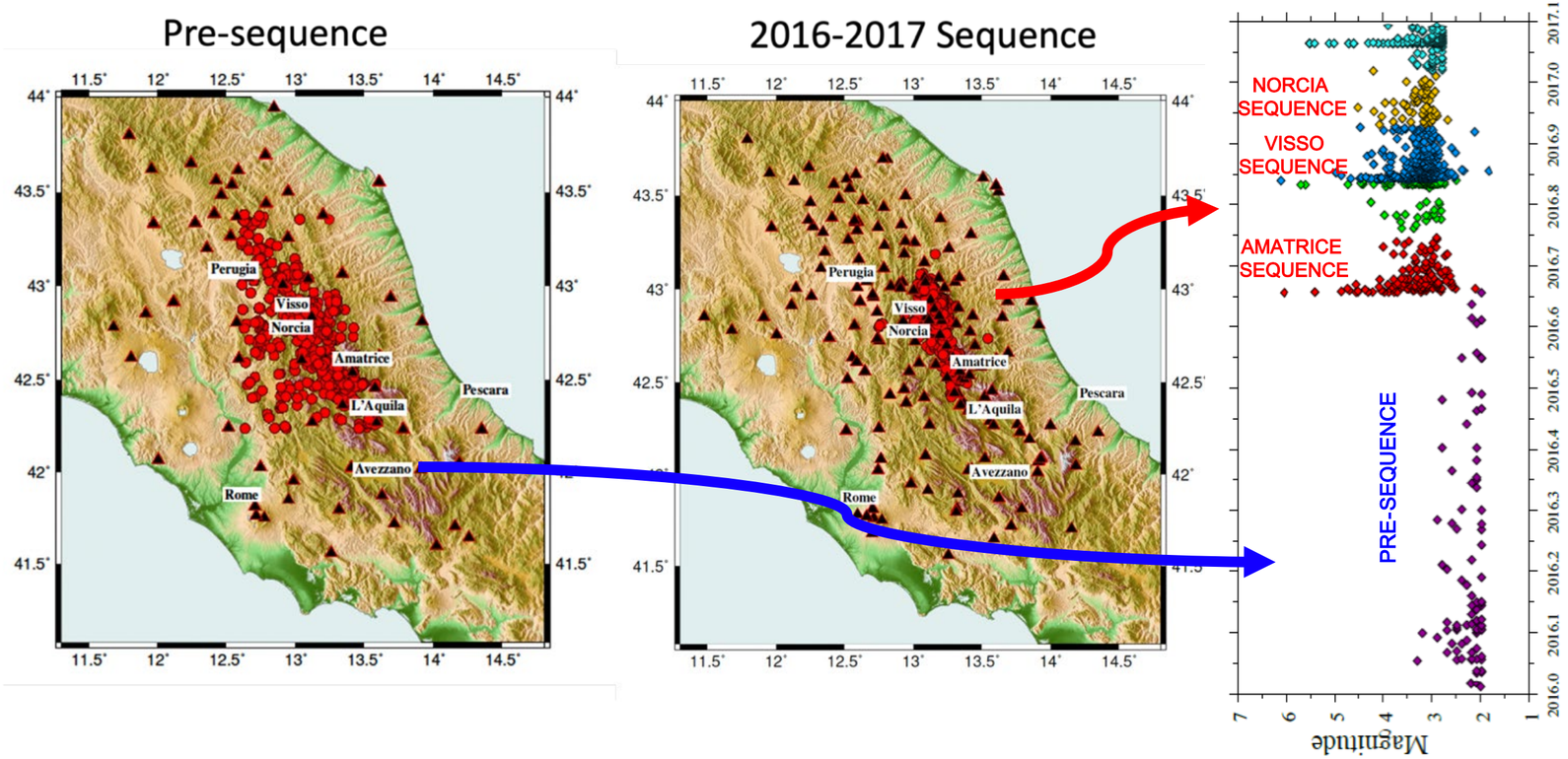
- Study of the Total Attenuation in Central Italy using the Coda Normalization Method

- Temporal (and spatial) variation of the attenuation and its frequency dependence

Dataset

- Study focused on the sequence of large earthquakes occurred in the Central Apennines in 6–7 months during 2016–2017 (Amatrice Mw 6.0 - Visso Mw 5.9 – Norcia Mw 6.5)

- The sequence dataset was sub-divided into three separate sequences following the mainshock of Amatrice, Visso and Norcia



Attenuation of seismic waves

•Seismic attenuation describes the energy loss experienced by seismic waves as they propagate. It is controlled by the temperature, composition, melt content, fractures of the rocks through which the waves travel.

$$\frac{1}{Q(\omega)} = -\frac{\Delta E}{2\pi E} \quad \Rightarrow \quad \frac{1}{Q(\omega)} = -\frac{\Delta A}{\pi A}$$

•The overall attenuation is given by:

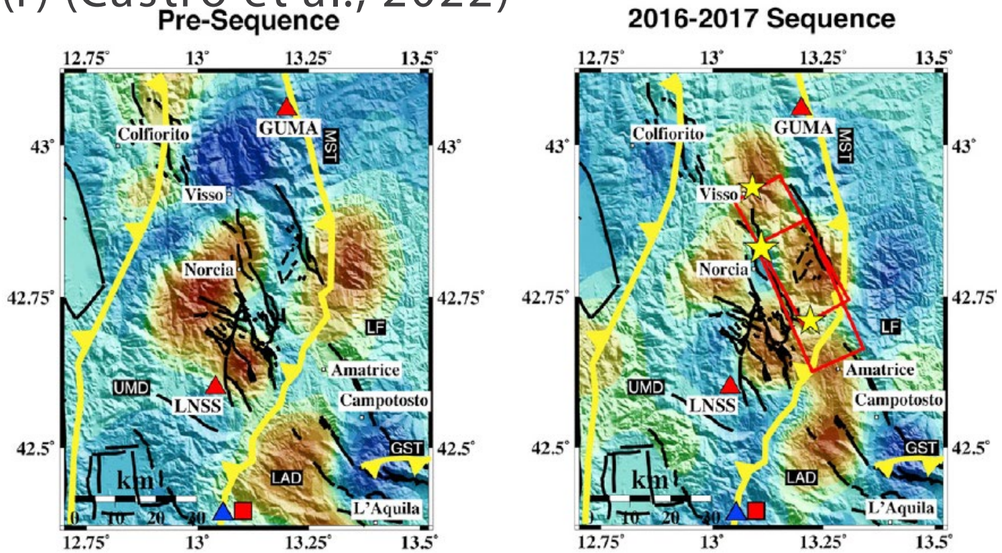
$$Q_{tot}^{-1} = Q_i^{-1} + Q_{Sc}^{-1}$$

where Q and Q are intrinsic attenuation (absorption) and the scattering loss, inverse of the quality factor Qsc and Qi

Attenuation in the Central Apennines

- Other studies on the attenuation of the area have been done, both for frequency dependence and for spatial variations

- Analysis of Q^{-1}_c Gabrielli et al., 2022, 2023, of S-wave with random vibration theory (Akinci et al., 2022), of Q with the Generalized inversion technique (Morasca et al., 2023) and of $\kappa(r)$ (Castro et al., 2022)



Gabrielli et al., 2022

Akinci et al., 2022 Q from RVT	Qt(f) Pre-Seq = 95 ± 30 f 0.5 ±0.12 Qt(f) Amatrice = 115 ± 45 f 0.50 ±0.12 Qt(f) Visso = 55 ± 5 f 0.80 ±0.025 Qt(f) Norcia = 75 ± 15 f 0.65±0.1
Pacor et al., 2016 (L'Aquila region) Q from GIT	Q(f)=(290±3)f(0.16±0.01)
Morasca et al, 2023 Q from GIT	Qr(f)=(247± 12.8)f(0.38± –0.03)
Malagnini et al., 2011 (L'Aquila 2009) Empirical regional attenuation functional	Q(f)=140 f0.25
Gabrielli et al., 2022 Coda Waves Attenuation	Qc(f) = (128 ± 10)f(0.75±0.06)

Coda Normalization Method

We measured the Total Quality Factor Q of the S waves using the Coda Normalization Method (CN – Aki and Chouet (1975))

The technique consists of the normalization of the amplitudes of the direct S waves for the coda amplitude measured at a fixed time tc, and the elimination of site effects, source power, and instrumental response:

$$\frac{1}{\pi f} ln \left[\frac{A_s(f,t_c)}{A_c(f,t_c)}\right] = -Q_s^{-1} v_s^{-1} r \; - \; \gamma \left[\frac{\ln(r)}{\pi f}\right] + \frac{\ln P(f)}{\pi f}$$

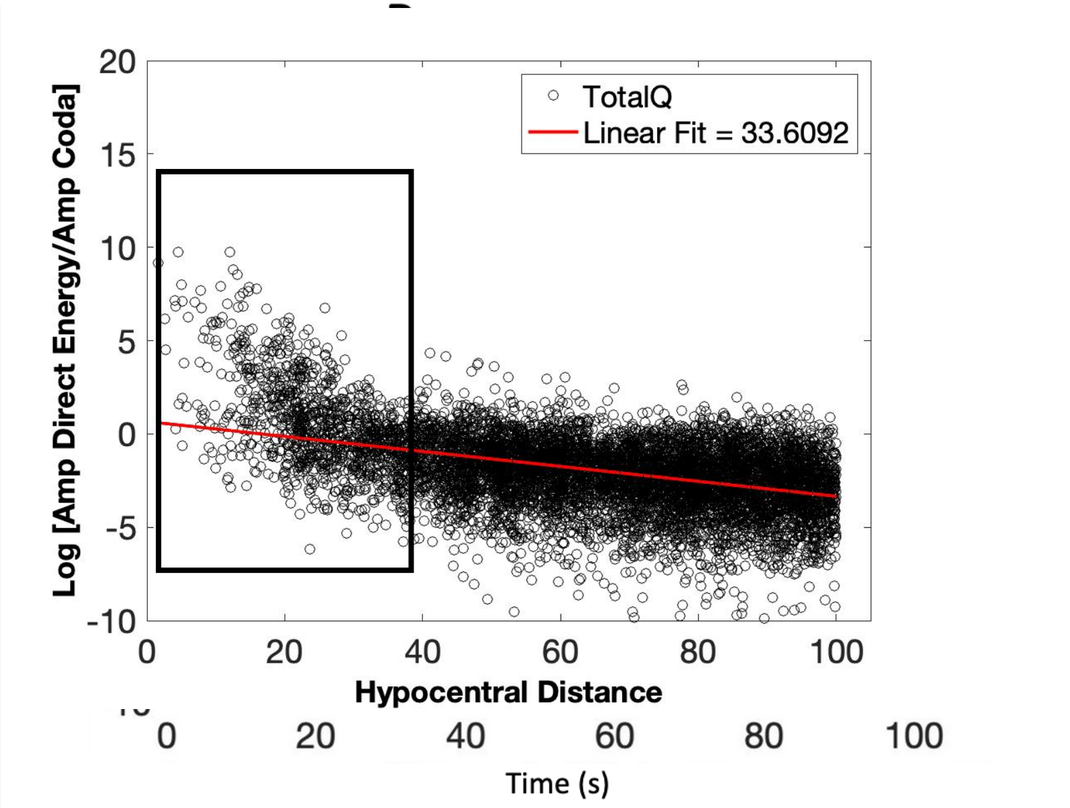
Where $P(f) = t^{-n} exp(-2\pi f Q_c^{-1} t_c)$; As and Ac are the amplitude of the S-wave and coda wave, respectively, f is the frequency, tc the coda wave lapse time, vs the S-wave speed (here 3.5s), r the source-receiver distance, n the envelope spectral decay, Qc the coda quality factor, and γ the geometrical spreading.

Coda Normalization Method

- Frequencies = 1.5 - 3 - 6 -12 Hz
- Selected waveforms with a SNR>3
- tc the coda wave lapse time (75s)
- Body wave and Coda wave window (10 s)
- r the source-receiver distance (0-100 km)
- Qs is obtained by the linear fit of the plots of the quantity ln(As/Ac):

$$Q_S = \frac{-\pi f}{(slope) * v}$$

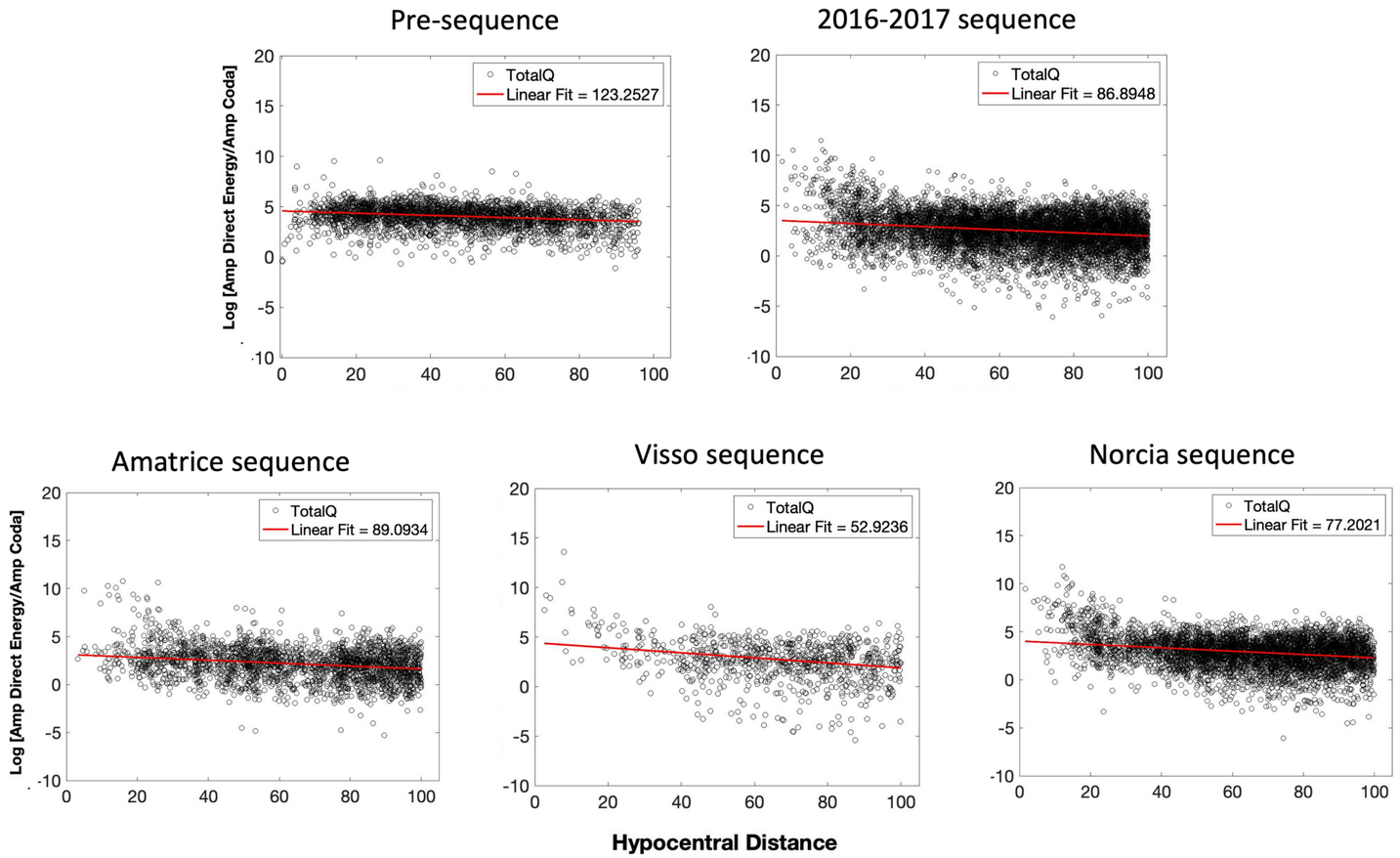
- γ the geometrical spreading (from 1.1 to 0.5 with decreasing hypocentral distance)



Results

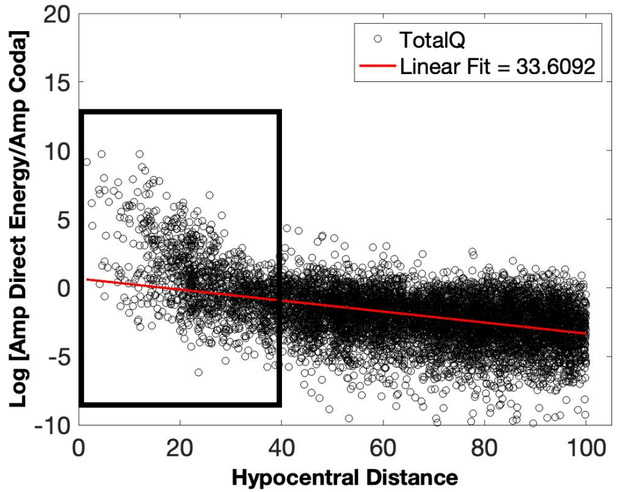
- We evaluate the temporal variation of Q for the pre-sequence, the 2016-2017 sequence, and the three sub-sequences.
- We notice a variation of the Q values among the different sequences (123 during the pre-sequence, 55 during Visso)
- 2016 and Norcia sequences show very high energies at lower hypocentral distances

Central Frequency of 1.5Hz

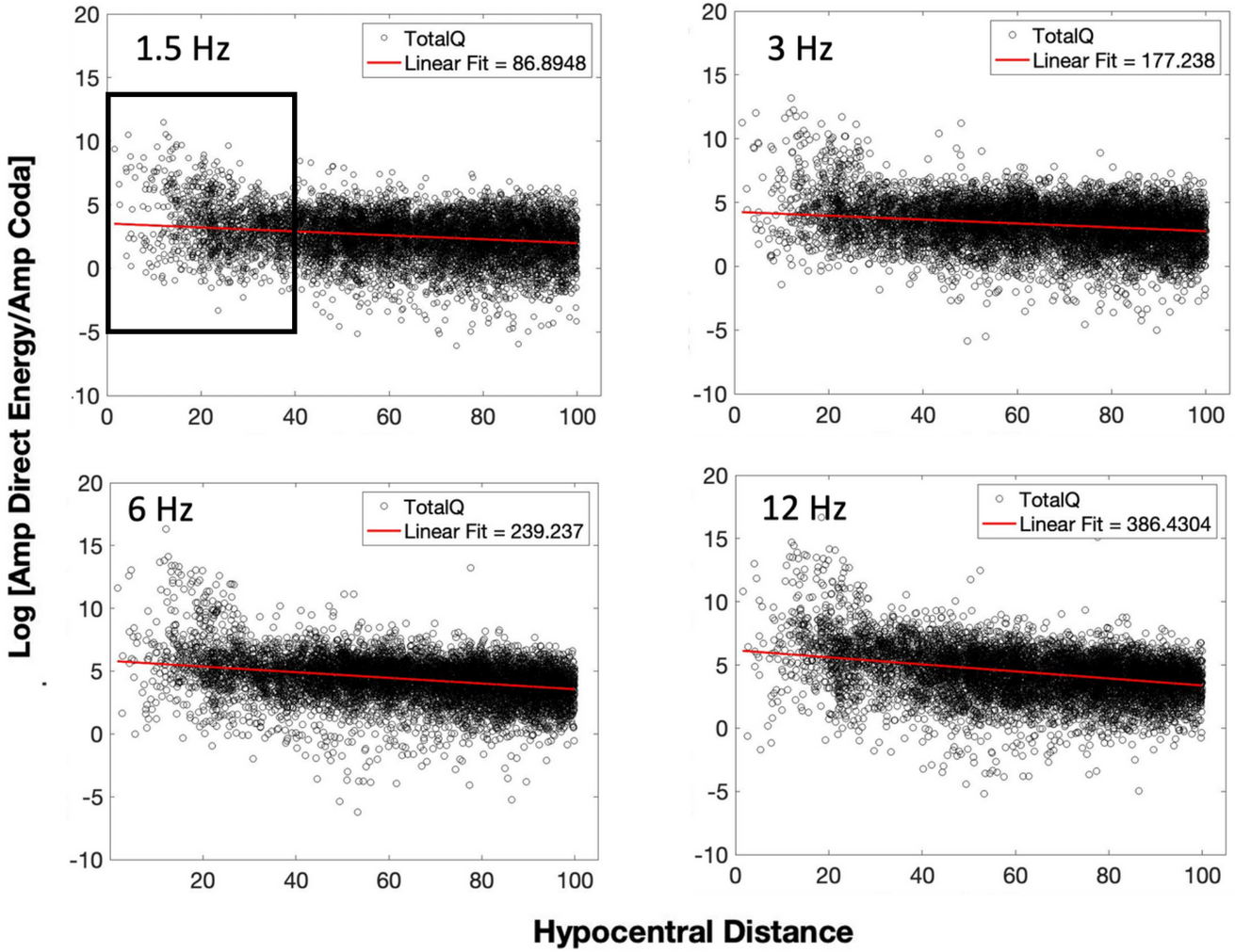


Results

- There is an increment of the Q values with increasing frequencies
- The behaviour at lower hypocentral distances at 1.5 Hz is less visible at higher frequencies

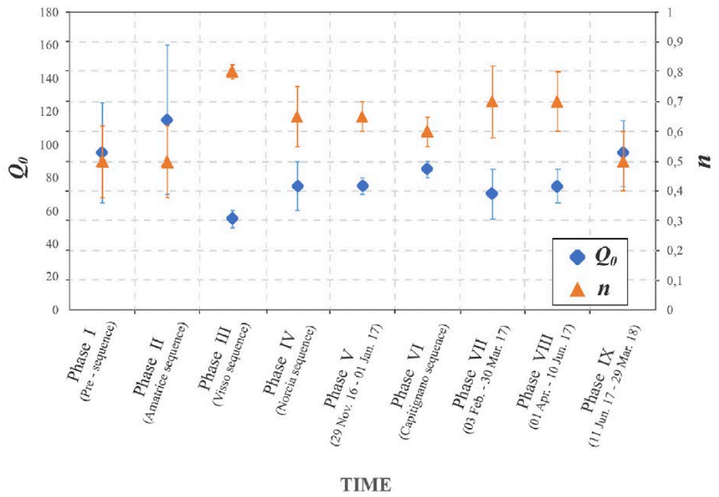


2016 -2017 Sequence



Results

- At each sequence, there is a variation of the Q values, as much as the n values.
- Q_0 is decreasing during the sequence, particularly in the Visso phase (Q_0 = 53)
- The values are coherent with previous studies on the S wave attenuation (Akinci et al. 2022)



Akinci et al., 2022

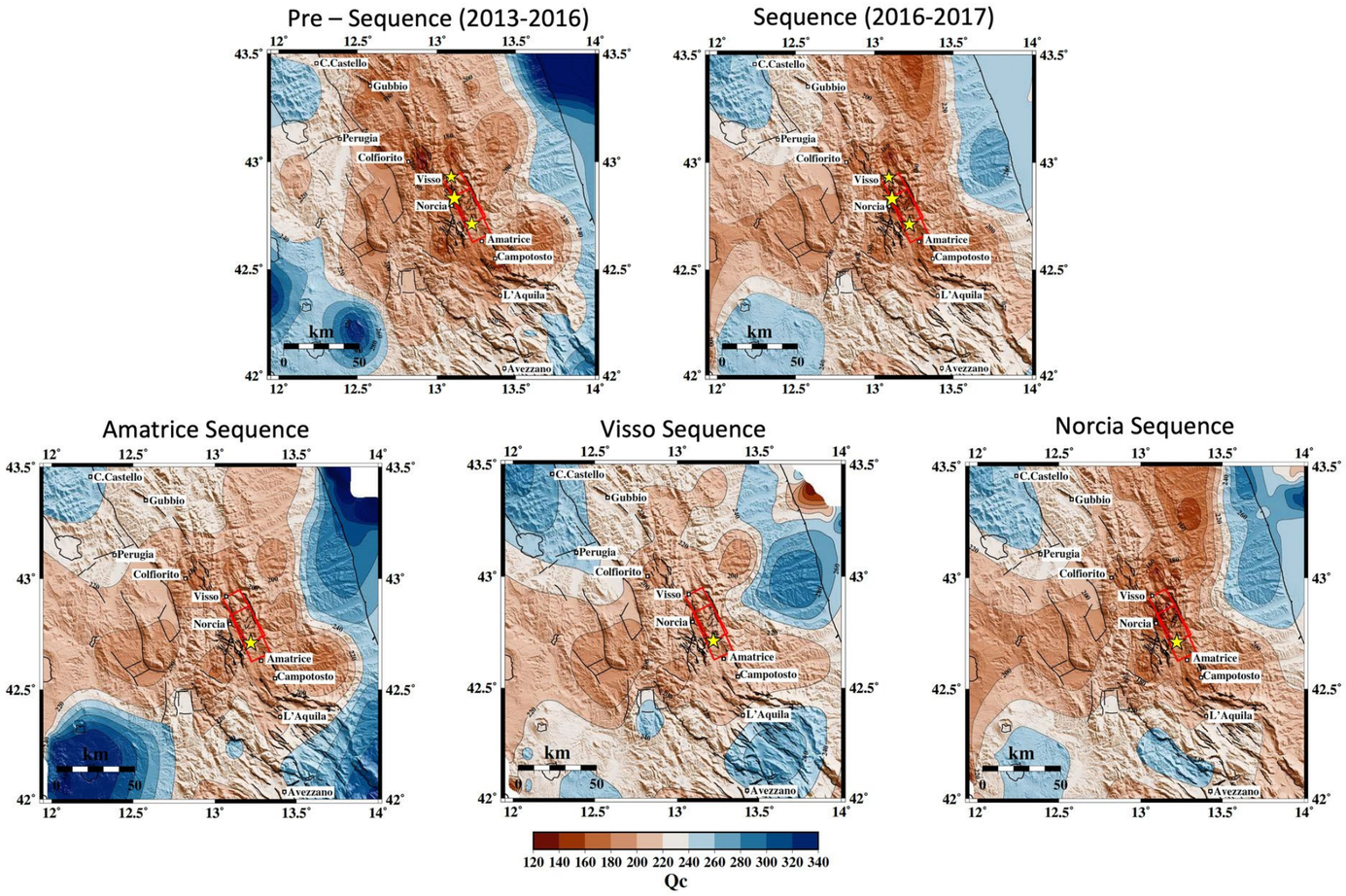
	This Study	Akinci et al., 2022
Pre-Sequence	$95.1 \pm 25\ f^{0.54 \pm 0.11}$	$95 \pm 30\ f^{0.5 \pm 0.12}$
2016-2017 Sequence	$77 \pm 20\ f^{0.64 \pm 0.15}$	
Amatrice Sequence	$101 \pm 25\ f^{0.57 \pm 0.15}$	$115 \pm 45\ f^{0.50 \pm 0.12}$
Visso Sequence	$53 \pm 11\ f^{0.8 \pm 0.12}$	$55 \pm 5\ f^{0.80 \pm 0.025}$
Norcia Sequence	$73 \pm 20\ f^{0.7 \pm 0.15}$	$75 \pm 15\ f^{0.65 \pm 0.1}$

Spatial variation of Attenuation

- We evaluate the spatial variation of the Attenuation by a regionalization approach, performing a weighted average at each block (block size: 5kmx 5km)

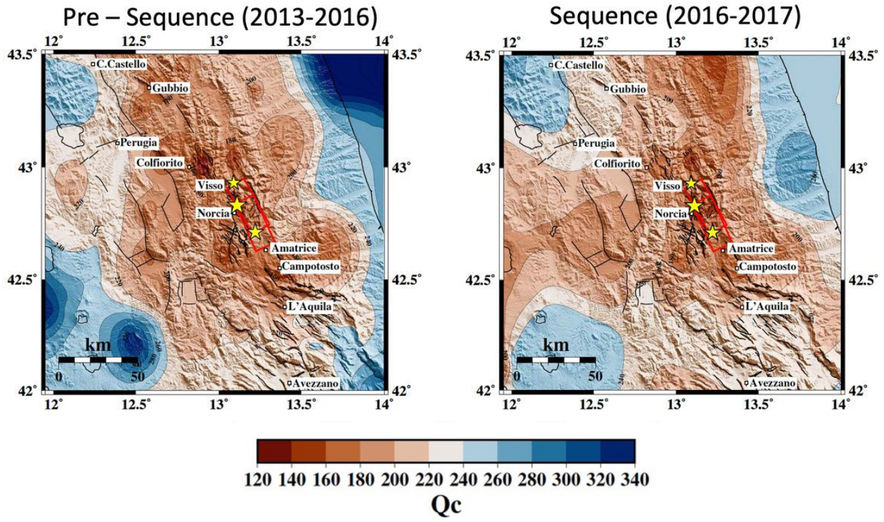
- To plot, we applied analytical kernels (Del Pezzo et al., 2016)

- There is a variation during the sequences in the spatial distribution of the attenuation, with low Q anomalies (high attenuation) moving from west to east and then north

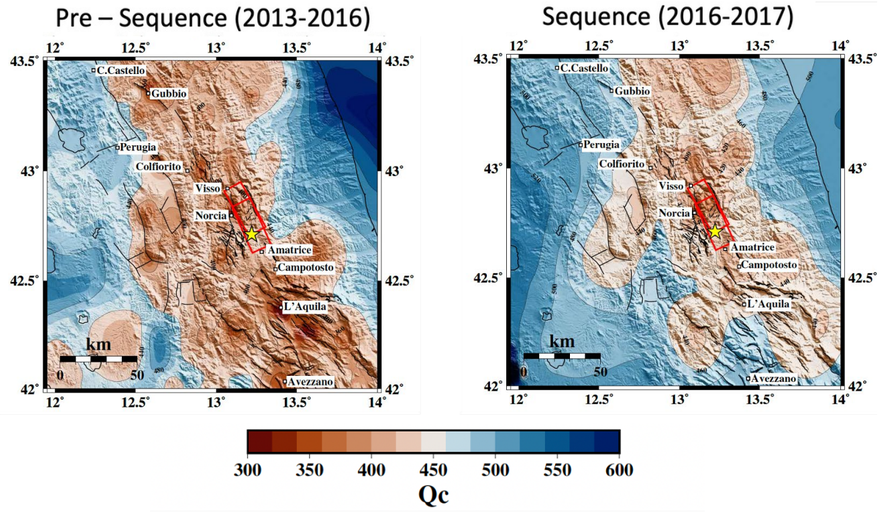


Results

1.5 Hz



6 Hz

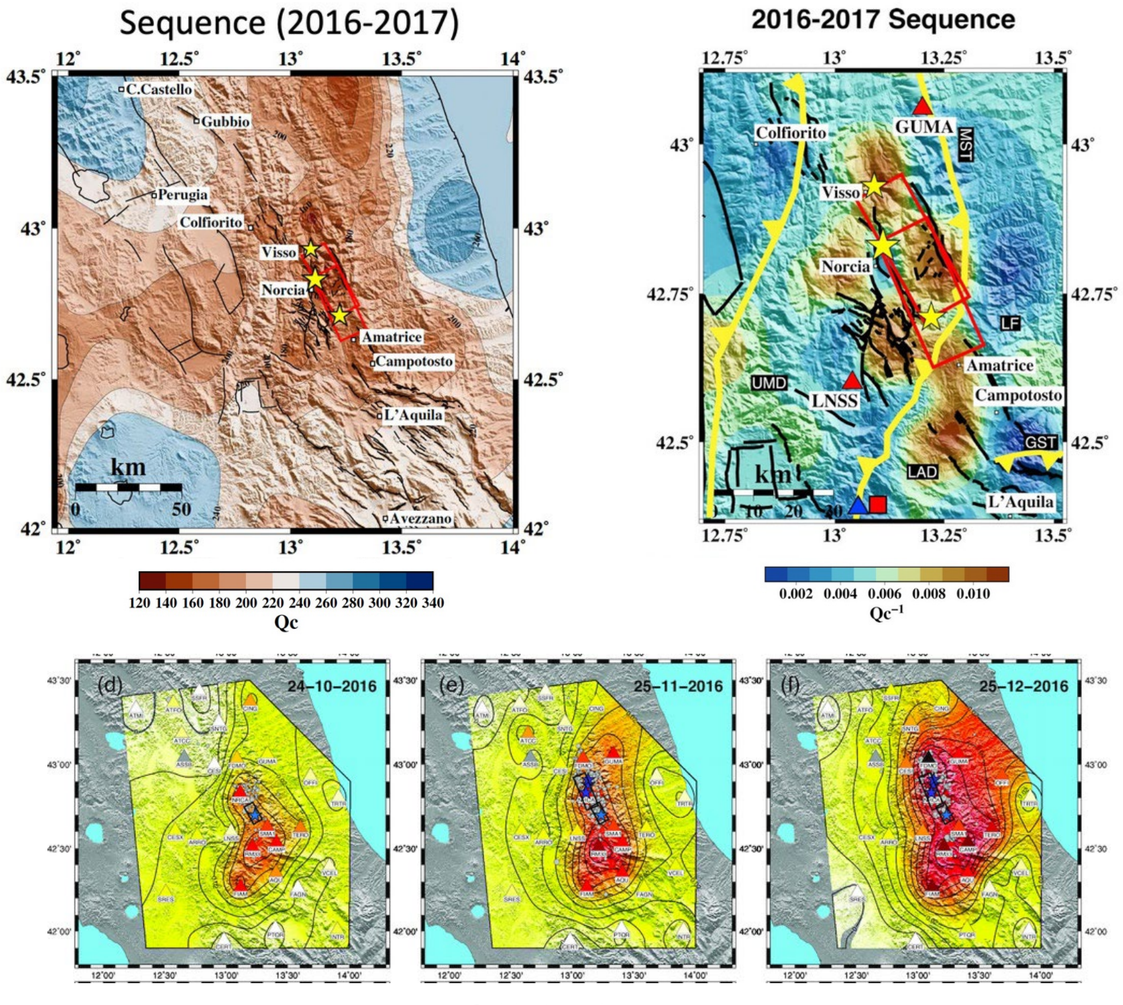


Pre-Sequence	102 ± 13 $f^{0.67\pm0.05}$
2016-2017 Sequence	114 ± 17 $f^{0.69\pm0.06}$
Amatrice Sequence	$127 \pm f^{0.68}$
Visso Sequence	$134 \pm f^{0.63}$
Norcia Sequence	$115 \pm f^{0.69}$

Spatial variation of Attenuation

- The comparison with other attenuation studies confirms the spatial variation of the Q, with an increment in attenuation in the activated fault plane during the sequence

- An anomaly with an NS direction shows a similar pattern to the drop in velocity variations observed by Soldati et al. (2019)



Gabrielli et al. 2022

Soldati et al., 2019

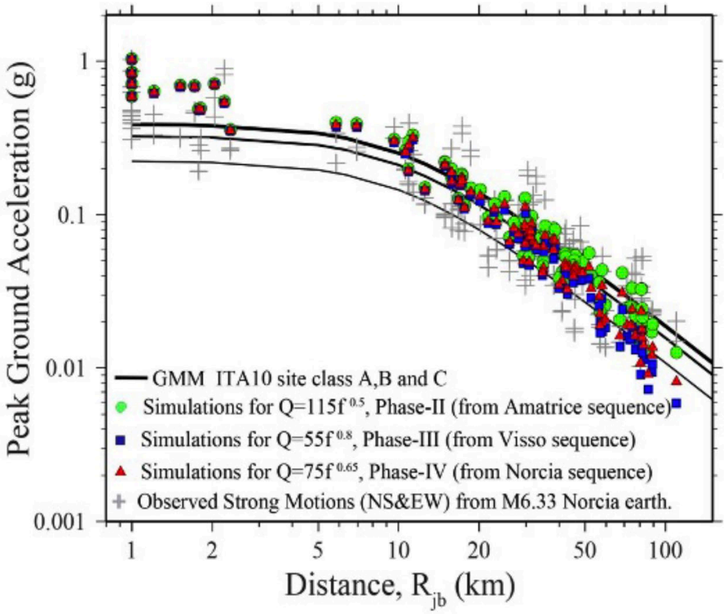
Conclusions

- We notice a temporal variation in the Q values and of the frequency dependence.
- Q is decreasing during the sequence, particularly during the Visso phase – probably related to fluid distribution during the sequence
- The temporal variation of Q is also visible with the spatial variation of attenuation
- This new spatial variation is coherent with previous studies but highlights other areas where the attenuation is propagating during the sequence (as the NS anomaly)

Future Steps

- Increase of the Central Apennines Dataset (focus on the Adriatic Coast and Tirrenic areas)

- The attenuation values are going to be used as input to study their impact on the calculation of PGA values using stochastic simulations (WP3)



From Akinci et al., 2022


Thank you