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Shear-wave Attenuation Structure of Central Anatolia Using (IMS&KOERI data) Full Seismogram Envelope

T1.2-O7

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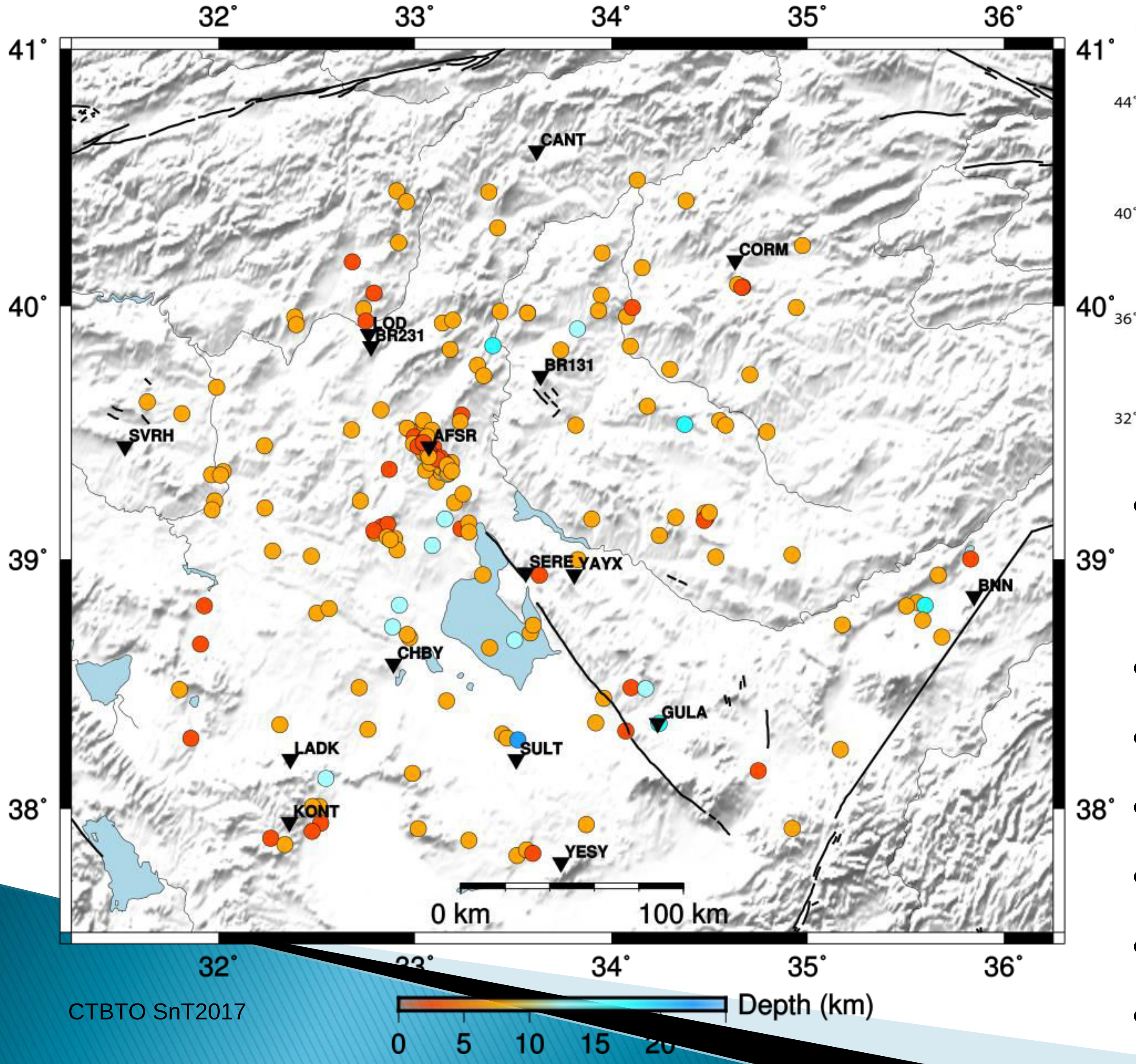
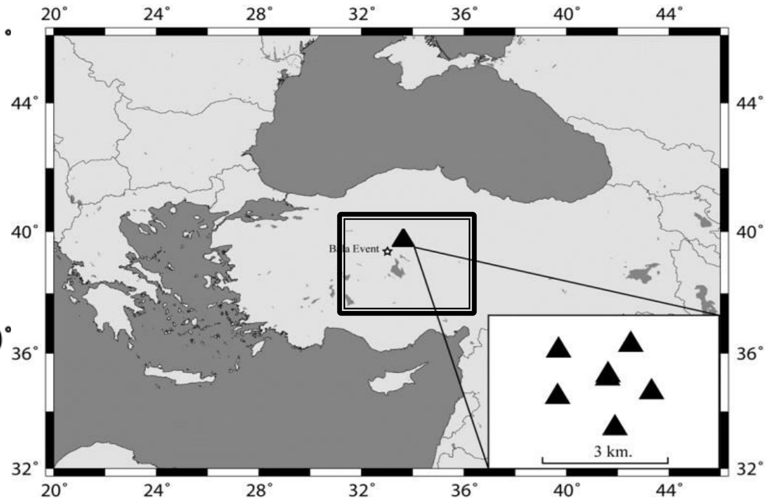
Introduction

- The goal of the study is to obtain the attenuation structure in the region of Central Anatolia, Turkey.
- 2005 and 2007 moderate size earthquakes and recent earthquakes that occurred near Ankara (recorded by IMS array) and its vicinity show that there should be more research on these areas in order to get a better picture of the crustal structure and the seismic hazard of the region.
- In this study, we aim to find the total attenuation in region by measuring the Scattering and Intrinsic attenuation amount using the Multiple Lapse Time Window Method (Hoshiba, 1993)

Study Area and Data





- Data from Broadband stations of IMS BRTR Array and KOERI national network stations were used.
- Total of 16 Broadband Stations
- Sampling Rate : 40 & 50 sps
- 177 events with SNR > 3
- Hypocentral Distances : 15 - 150 km
- Magnitudes (ML) : 2.8 – 4.6
- Depth < 20 km

Multiple Lapse Time Window Method (MLTW)

- The integrated energy density over three consecutive time windows from the S-wave arrival time is evaluated as a function of source–receiver distance (Fehler et al., 1992; Hoshiba, 1991;Carcole and Sato, 2010).

- The observed energy density is compared with the synthesized one to obtain two seismic wave attenuation parameters; Le^{-1} (Extinction Length) and seismic albedo (B_0), defined as the dimensionless ratio of scattering loss to total attenuation.

- MLTW method is based on the assumption that coda wave energy is distributed uniformly within a spherical volume behind the S wave front (Hoshiba, 1993).

Multiple Lapse Time Window Method (MLTW)

- The integrated energy density over three consecutive time windows

$$e_{1obs}(r_m) = \int_{t_s}^{t_s+15s} F_{obs}(r_m, t)dt,$$

$$e_{2obs}(r_m) = \int_{t_s+15s}^{t_s+30s} F_{obs}(r_m, t)dt,$$

$$e_{3obs}(r_m) = \int_{t_s+30s}^{t_s+45s} F_{obs}(r_m, t)dt,$$

- $F_{obs}(r_m, t)(mean - squared\ amplitudes)$ is integrated for time windows 0-15, 15-30 and 30-45 seconds measured from the S wave onset. The three time integrals are represented as $e_{1obs}(r_m), e_{2obs}(r_m), and\ e_{3obs}(r_m)$, respectively. (Hoshiba, 1993)

Multiple Lapse Time Window Method (MLTW)

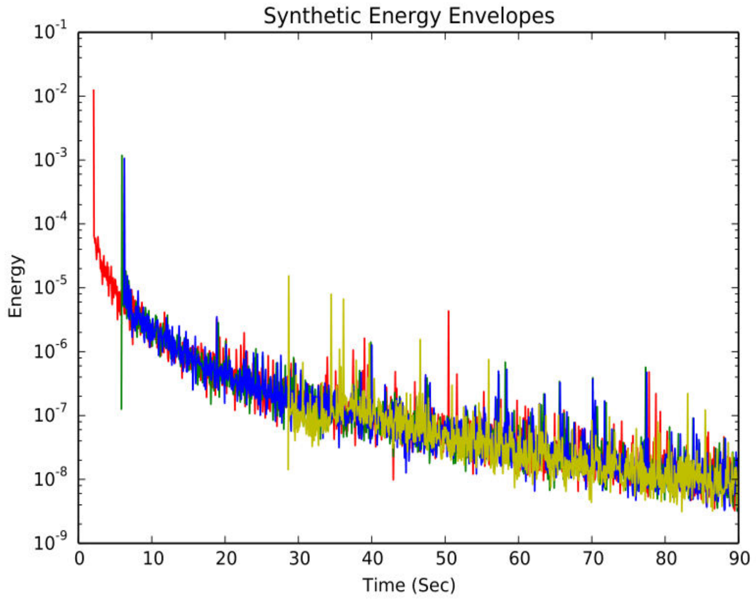
- Use Coda Normalization (Aki, 1980a) to correct for site amplification and source size

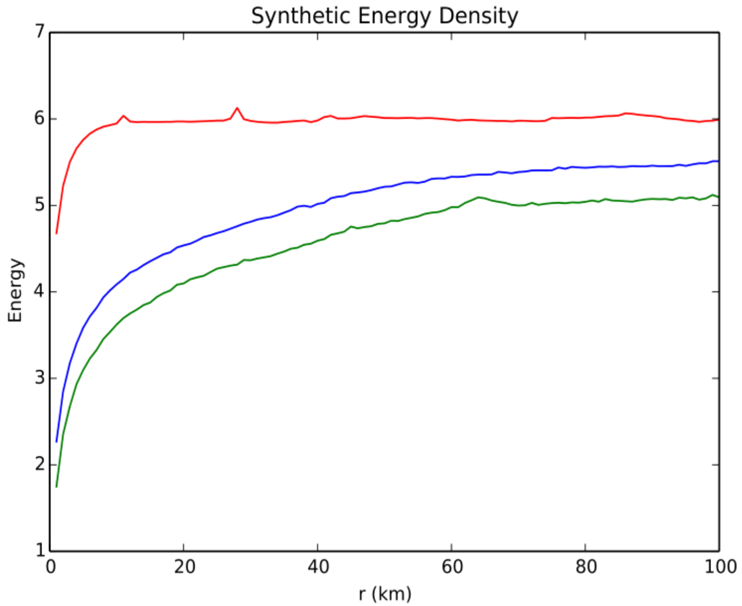
$$\overline{E}_{n\,obs}(r_m) = \frac{e_{n\,obs}(r_m)}{F_{obs}(r_m, t_{ref})} \quad (n = 1, 2, and\ 3)$$

- where t_{ref} is a fixed reference lapse time; t_{ref} is chosen based on the condition, $t_{ref} \geq 2r/v$ for all r_m. The technique is based on the assumption that the distribution of coda wave energy at $t = t_{ref}$ is nearly uniform, which holds for weak scattering media (Hoshiba et al., 1991).

Multiple Lapse Time Window Method (MLTW)

- Generate synthetic seismogram envelopes according to a velocity model
- Apply the previous procedures to the synthetic data in order to obtain synthetic energy integrals.
- Synthetic seismogram envelopes are simulated using Hoshiba's Fortran code.





Left figure shows the simulation of Synthetic Energy envelopes by running the Hoshiba's code. Hypocentral distances are denoted by different colors. On the right we see the energy integrals calculated from the left figure.

Multiple Lapse Time Window Method (MLTW)

- In order to estimate the best Le^{-1} , B_0 pair, observed energy curves for all sites are fitted to the simulated energy curves.

- Residuals are calculated using the following formula;

$$residual(L_e^{-1}, B_0) = \sum_{(i=1)}^{I} \frac{a_i^2}{I} + \sum_{j=1}^{J} \frac{b_j^2}{J} + \sum_{k=1}^{K} \frac{c_k^2}{K}$$

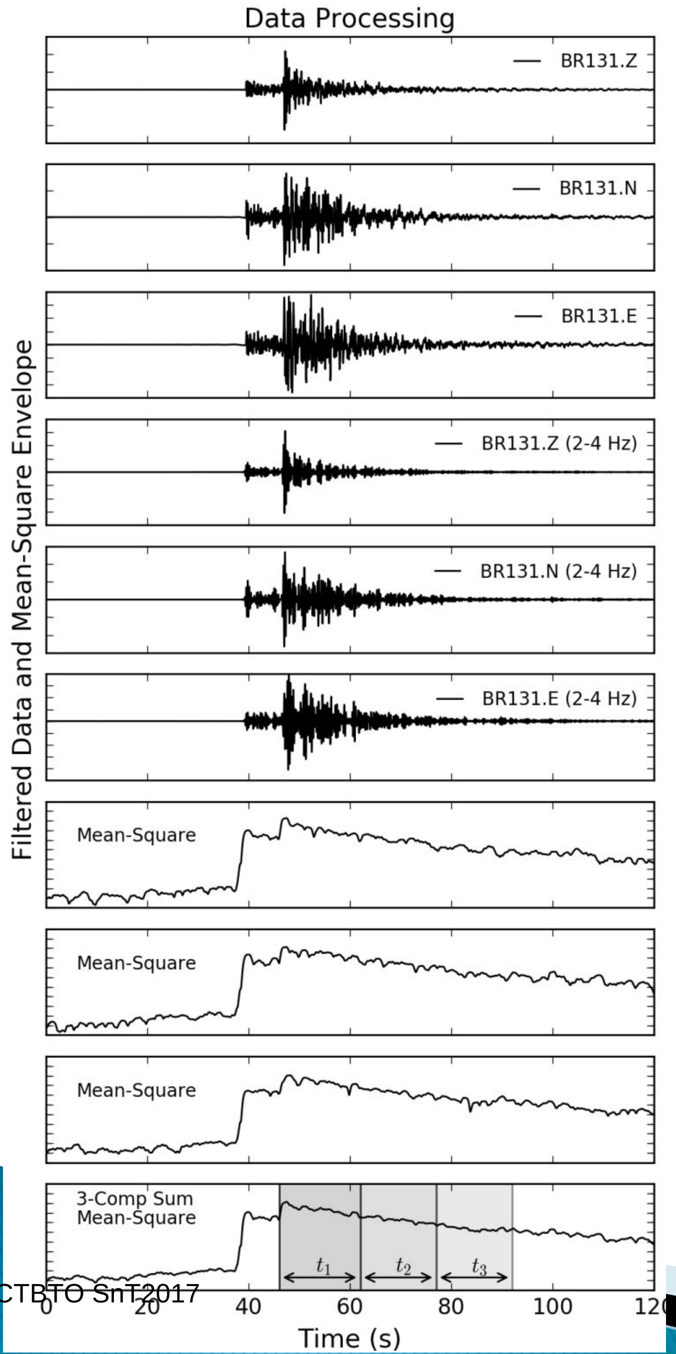
where a_i, b_j, and c_k are $(\log_{10}[4\pi r^2 E_{n\ obs}(r)] - \log_{10}[4\pi r^2 E_{n\ syn}(r)])$ for n=1, 2, and 3

Multiple Lapse Time Window Method (MLTW)

- Final Attenuation Quality factors for total, intrinsic and scattering are determined from the best B_0 and L_e^{-1} values by the following equations,

$$Q_t{}^{-1} = \frac{L_e^{-1}\omega}{\beta}, \quad Q_s{}^{-1} = \frac{B_0 L_e^{-1}\beta}{\omega},$$

$$Q_i{}^{-1} = \frac{(1 - B_0)L_e^{-1}\beta}{\omega}$$



Data Preparation

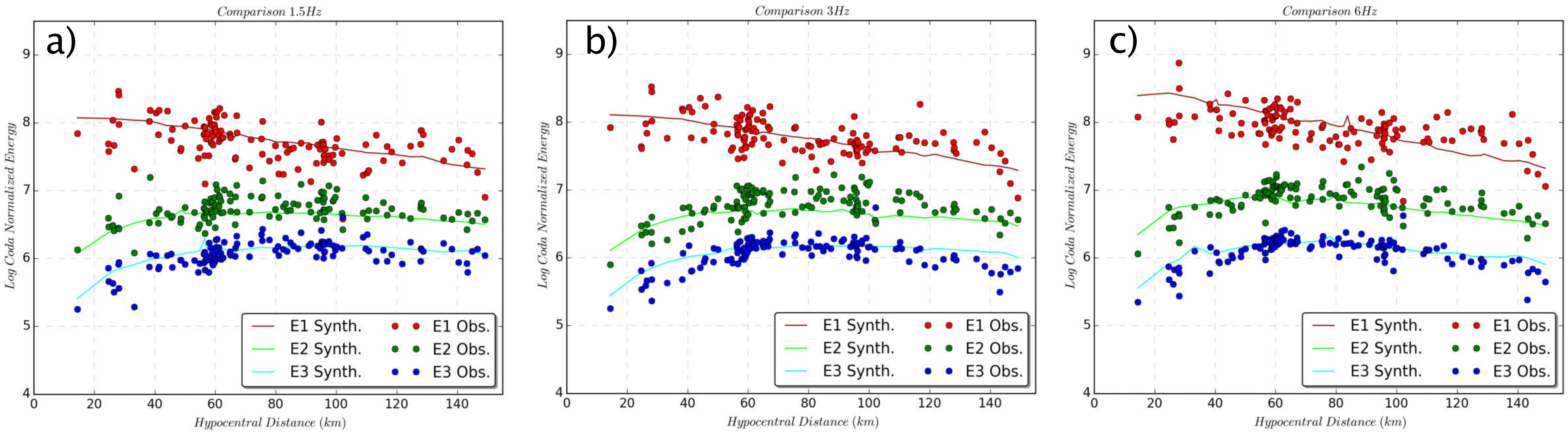
- Raw 3-component broadband waveforms

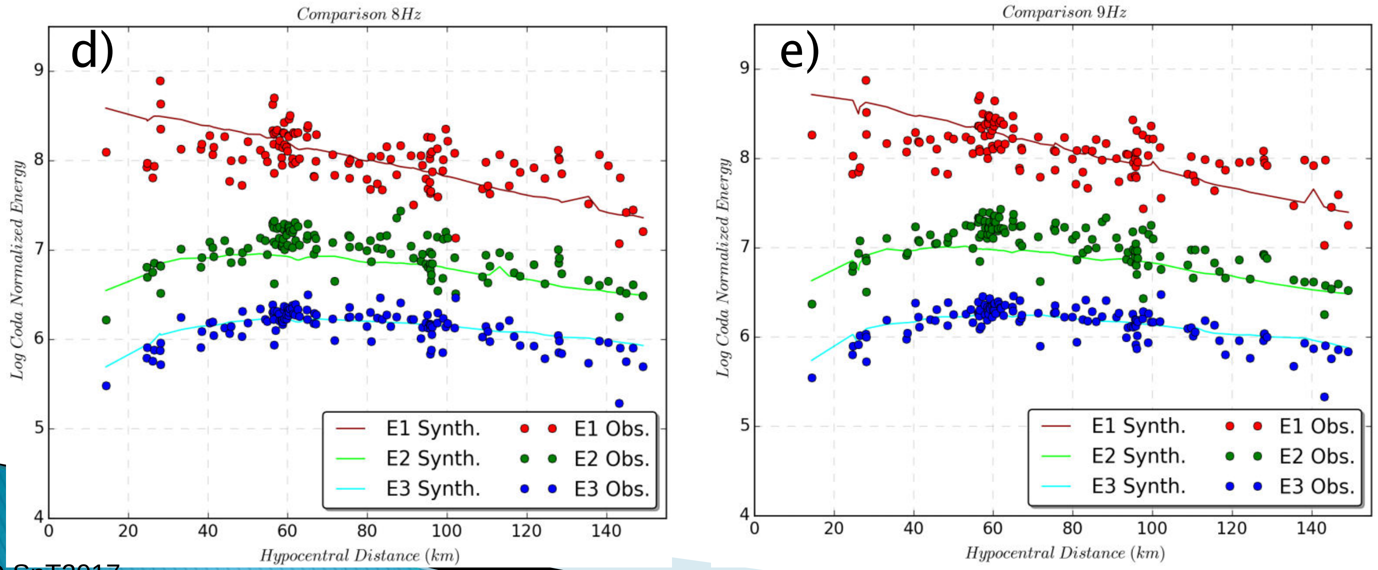
- Bandpass filtered waveforms
- (Center Frequencies 1.5, 3, 6, 8, 9 Hz)

- Mean square calculated waveforms.
- 3-component mean squares are summed up into a single envelope.
- t_1 ,t_2 ,t_3 represents three time windows from S-wave onset (0-15, 15-30, 30-45 s).

Observed and Best-Fitting Energy – Distance Curves

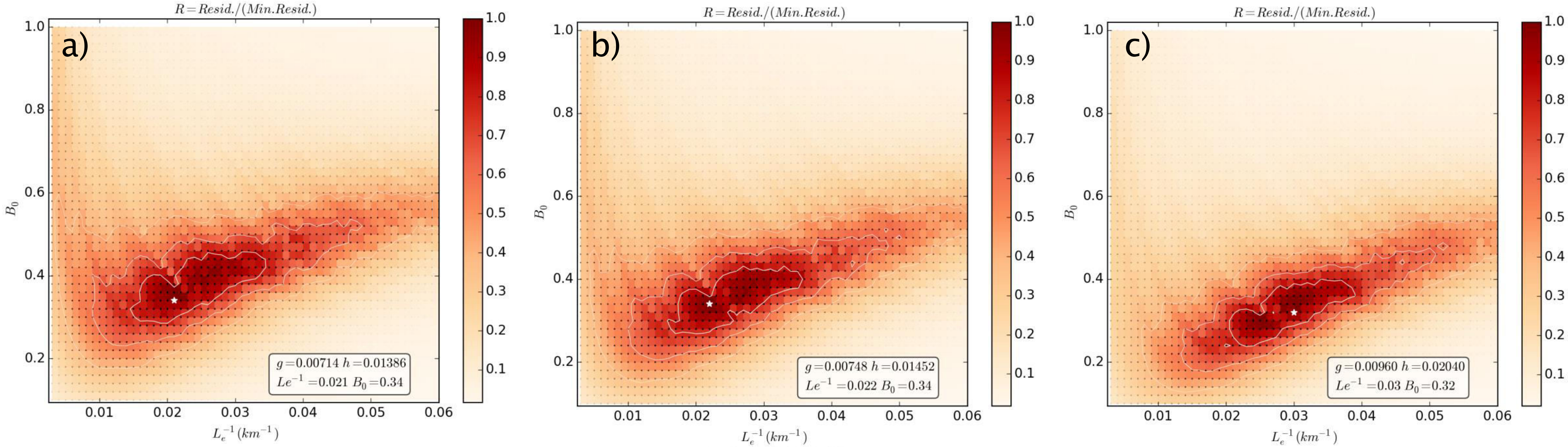
IMS- BR131

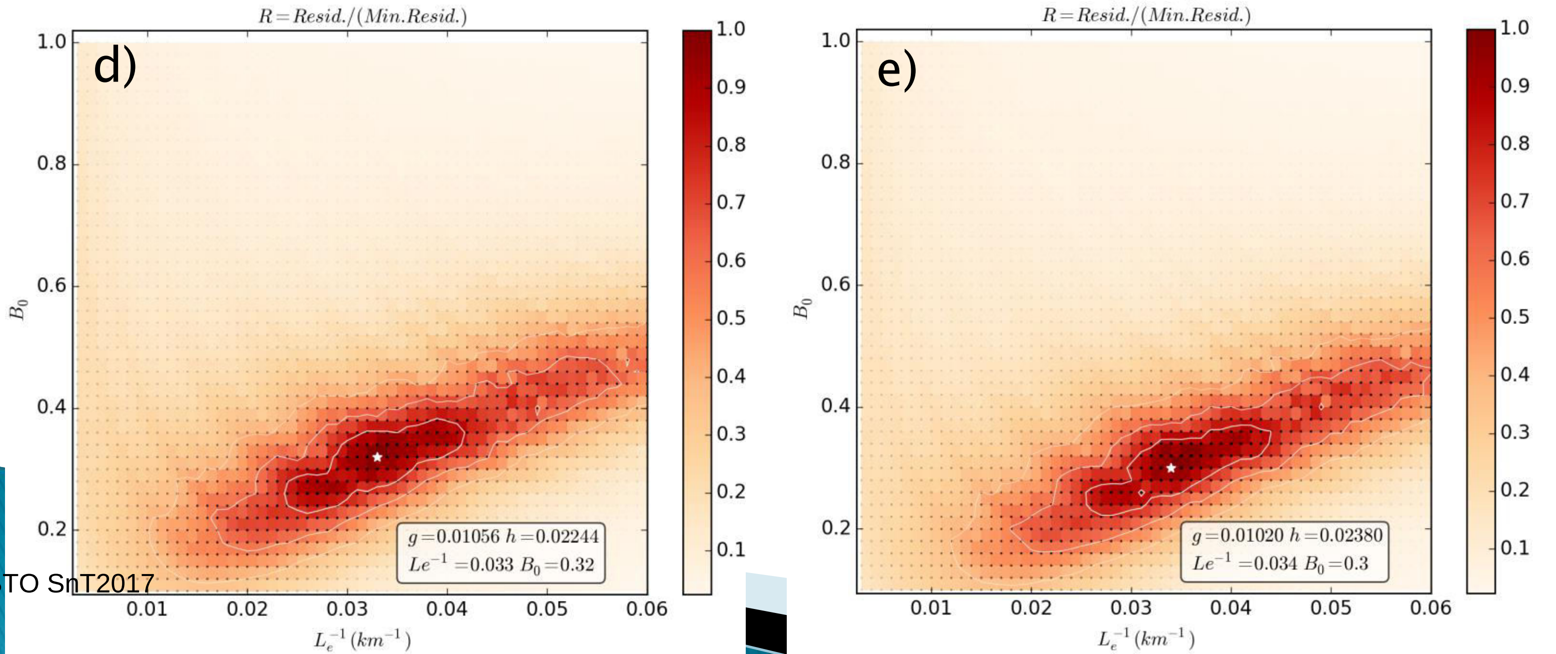




Figures show the energy integral corrected for geometrical spreading versus hypocentral distance. The circles are the observed energy integrals, $4\pi r^2 E_{1obs}$, $4\pi r^2 E_{2obs}$ and $4\pi r^2 E_{3obs}$ respectively. Solid lines show the synthetic integrals for the best pair of L_e^{-1} and B_0 which give the minimum residuals.

Residual Maps

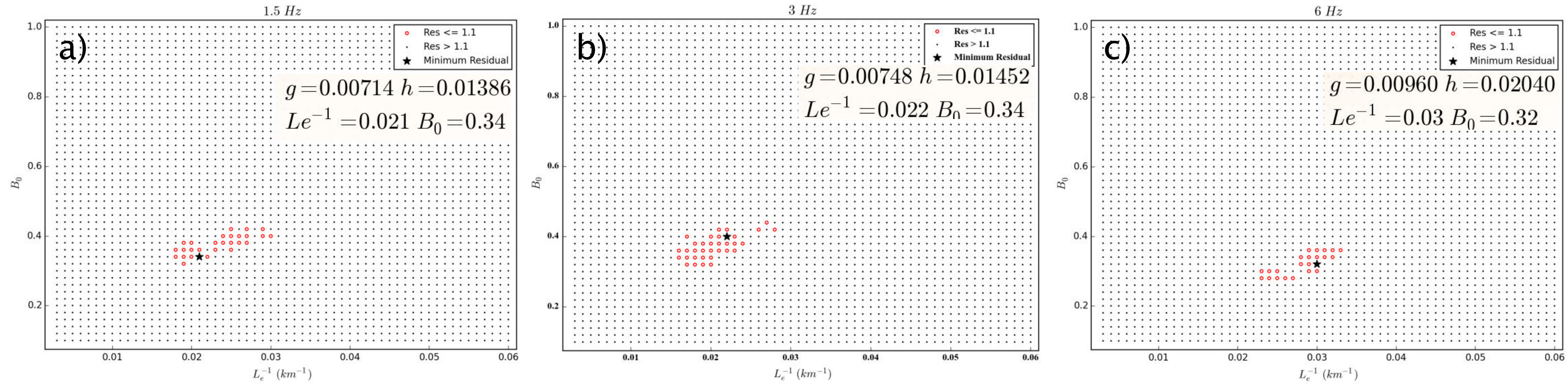


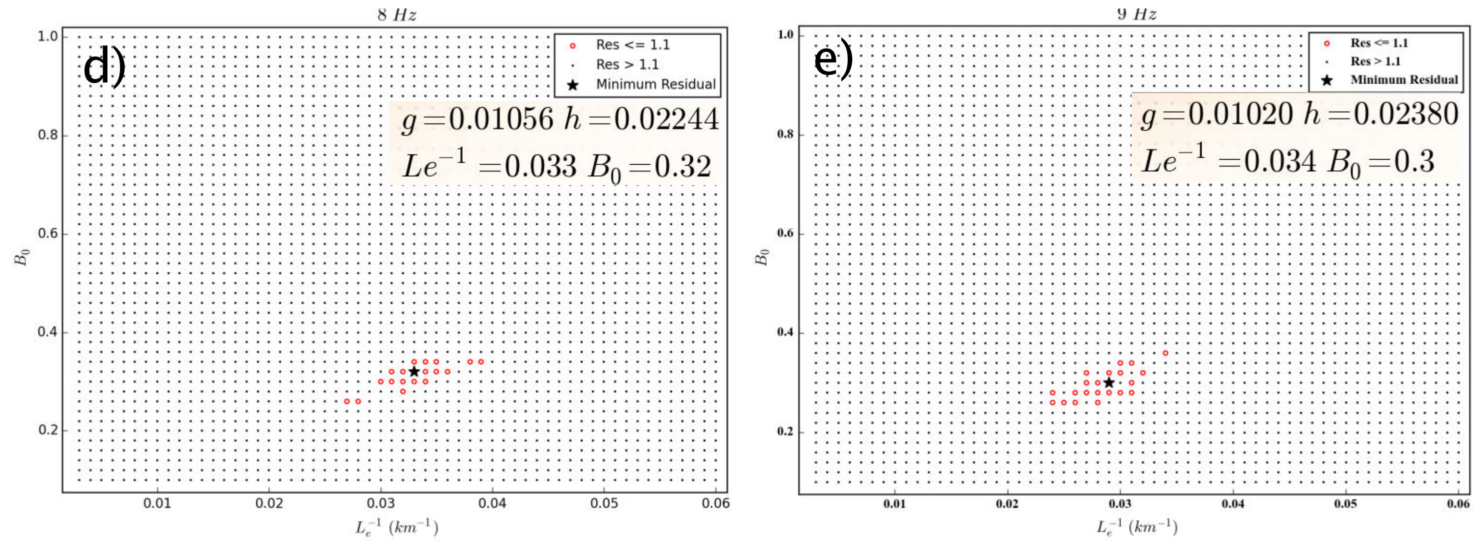


Using 2668 pairs of Le^{-1}, B_0 Residual Maps of best fitting process for station BR131. a, b, c, d, and e represents frequencies, 1.5, 3, 6, 8, 9 Hz. respectively.

Residual Maps

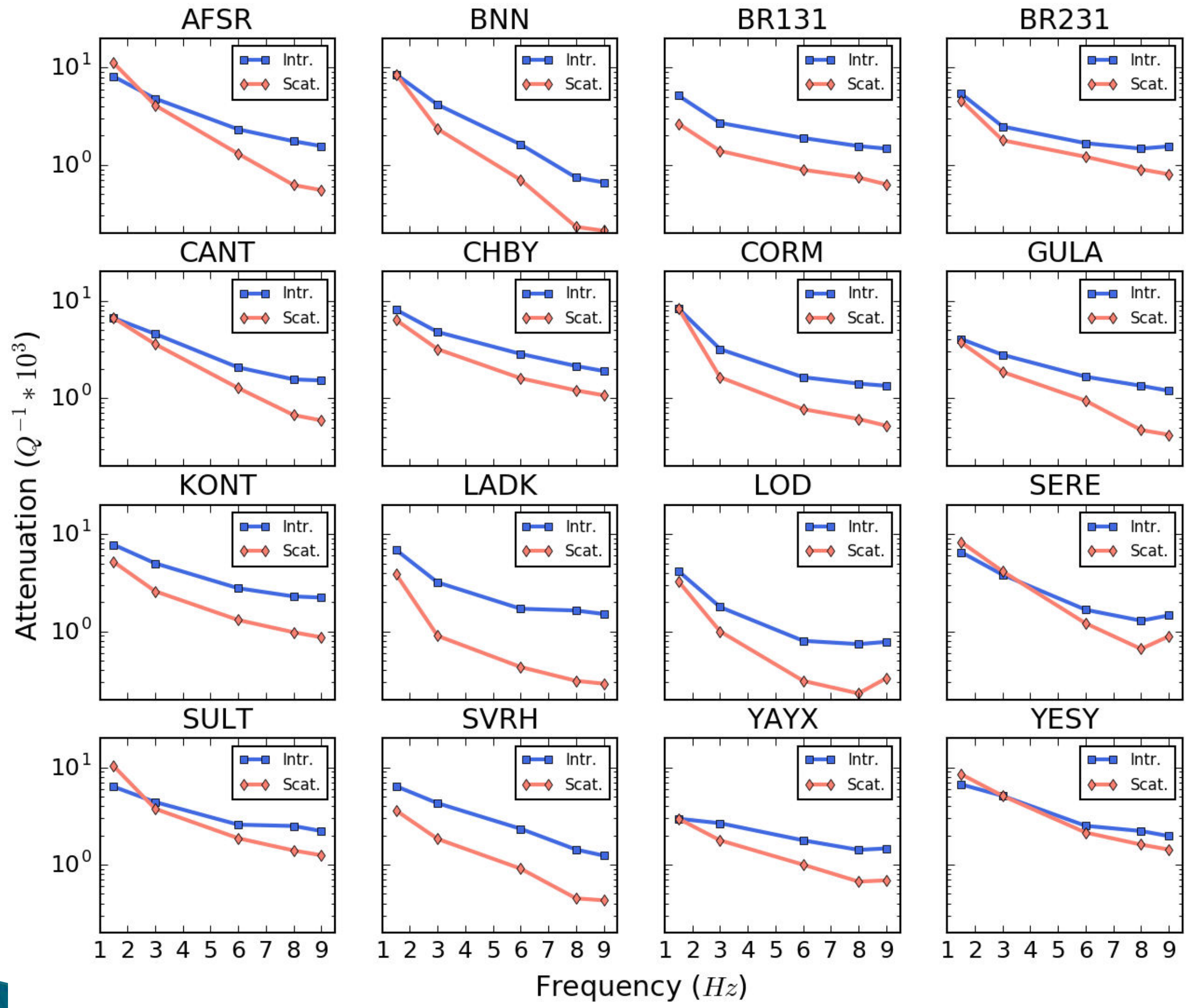
IMS-BR131

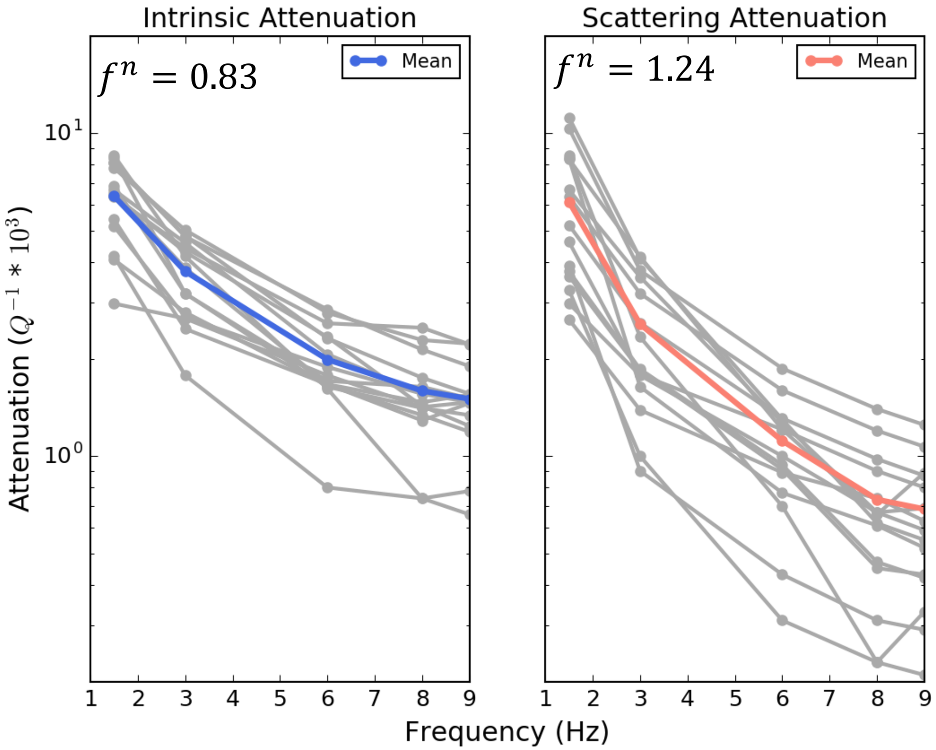




Frequency (Hz)	Le^{-1}	B_0	Qs^{-1} ($*10^3$)	Qi^{-1} ($*10^3$)	Qt^{-1} ($*10^3$)
1.5	0.021 (-0.003, +0.009)	0.34 (-0.02, +0.08)	2.42	4.71	7.13
3.0	0.022 (-0,006, +0.006)	0.34 (-0,08, +0.04)	1.27	2.46	3.73
6.0	0.03 (-0.007, +0.003)	0.32 (-0.04, +0.04)	0.81	1.73	2.54
8.0	0.033 (-0,006, +0.006)	0.32 (-0.06, +0.02)	.67	1.43	2.1
9.0	0.034 (-0.005, +0.005)	0.3 (-0.04, +0.06)	0.58	1.35	1.93

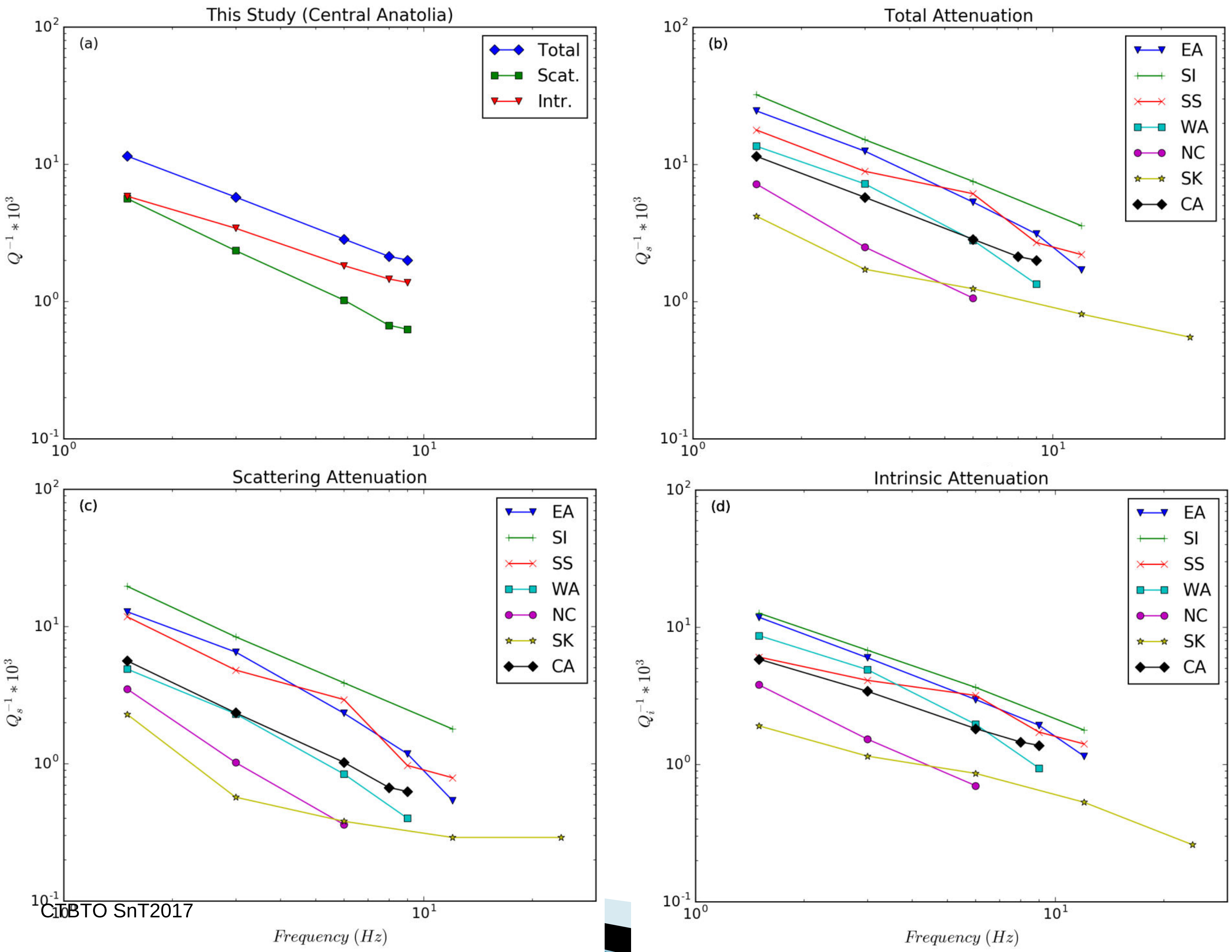
Final Attenuation Results





Frequency (Hz)	Qs^{-1} ($*10^3$) (SD)	Qi^{-1} ($*10^3$) (SD)
1.5	5.61 (±2.46)	5.84 (±1.47)
3.0	2.34 (±1.12)	3.41 (±0.93)
6.0	1.02 (± 0.43)	1.82 (±0.48)
8.0	0.67 (± 0.35)	1.45 (±0.44)
9.0	0.62 (± 0.31)	1.37 (±0.39)

Comparison with other regions



EA – Eastern Anatolia (Akinci et al, 2000)
SI – Southern Italy (Tuvè et al, 2006)
SS – Southern Spain (Akinci et al, 1995)
WA – Western Anatolia (Akinci et al, 1995)
NC – Northern Chili (Hoshiba et al,2001)
SK – South Korea (Chung et al, 2006)
CA – Central Anatolia (This study)

Summary

- Results show that intrinsic attenuation is dominant over scattering attenuation in this region in the frequency range (1.5 – 9 Hz.)
- Scattering attenuation is more frequency dependent than intrinsic attenuation. Frequency dependency degree is found as 0.83 and 1.24 for intrinsic and scattering attenuation respectively.
- High intrinsic attenuation is consistent with previous studies conducted in the region.

Thank You …