High Frequency Attenuation of S-waves in Eastern Alps

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ABSTRACT

Anderson and Hough (1984) proposed an empirical model for the shape of acceleration spectra obtained with strong-motion data from local earthquakes, observing that the logarithm of the spectrum exhibits a linear trend over the corner frequency of the recorded event. A similar trend, quantified by the spectral decay parameter k, can be observed also for weak-motion data when the recording bandwidth is sufficiently large. Although, at least for some datasets, an event dependence can not be excluded for k, the spectral decay was generally interpreted in terms of propagation effects considering both station- and distance-dependent contributions. Given a set of recording stations and assuming a simplified stratigraphy, consisting of a single layer with relatively strong attenuation properties overlying deeper less attenuating materials, the station-dependent contribution would be related to the specific propagation path beneath the site. Conversely, the distance-dependent part of the k parameter, roughly common to all of the station-to-site paths, would be associated to the deeper propagation. Anderson and Hough (1984) proposed a linear dependence of k on the epicentral distance R: $k=k_0+k_1*R$, where k0 is the station-dependent term and k_1 is the slope, common to all the stations. Anderson (1991) proposed a more general approach, imposing that the distance-dependent term is a smooth function of R, close to zero for 0 distance. A numerical method can be used to evaluate k for a finite number of distances R_i by the joint inversion of all the estimated values of k. For each distance, the $k_j(Ri)$ estimated values are obtained by a linear regression of the S-wave acceleration spectra of all earthquakes recorded at all stations with epicentral distance R_i.

In this poster, we make the comparison of the two methods using the data of 11 short-period seismic stations of the North Eastern Italy network managed by the department "Centro Ricerche Sismologiche" of the "Istituto Nazionale di Oceanografia e di Geofisica Sperimentale". The analysis is performed on 302 earthquakes (1263 3D traces) recorded in the period 1994-2007. The obtained values of k_0, approximately ranging from 0.015 and 0.055 s, are compatible with the results obtained with a smaller dataset by Franceschina et al. (2006). The estimated slope, k_1 = 0.00013 s/km, is consistent with high-frequency Q values ranging from 2200 and 2560, when S-wave velocities between 3.0 and 3.5 km/s are hypothesized for the deeper part of the crust. In addition, the site-dependent term of k is proportional to the mean of the Nakamura's ratio on a large frequency band, obtained independently for the same stations by Bragato and Slejko (2005) and Barnaba et al. (2008).

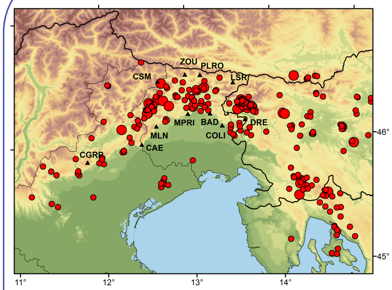

Fig.1 Epicenters of the 302 selected earthquakes (red dots) and location of the stations used in this study.

DATA-SET

- Data recorded during 1994-2007 at short period stations of the North-Eastern Italy (NEI) network, managed by the Department "Centro Ricerche Sismologiche" of the "Istituto Nazionale di Oceanografia e di Geofisica Sperimentale"

302 earthquakes ($3.0 \le M_D \le 5.6$)
11 stations
1260 records (horizontal components)
epicentral distances: $0 \le R \le 250$ km

DATA PROCESSING

- Instrumental correction
- Band pass filtering (0.8 – 30/50 Hz)
- Time window on direct S-waves
- 5% cosine taper and FFT
- Smoothing (0.5 Hz half-width window)

THE SPECTRAL DECAY PARAMETER k

- Anderson & Hough (1984) observed that the logarithm of the acceleration spectrum of strong-motion data exhibits a linear trend with frequency over the corner frequency of the event and characterized the linear decay by the spectral decay parameter k.

OBSERVATION

- Examples of acceleration spectra from strong- and weak-motion data recorded at stations of the NEI network:

_ station BAD (Bernadia)
_ Kobarid 1998 sequence
mainshock (M_D=5.6; R=31.3 km)
aftershock (M_D=3.2; R =39.9 km)

- Anderson & Hough (1984) model, can also be employed for weak-motion data

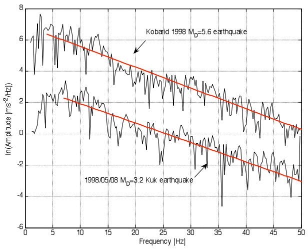

Fig.2 Acceleration spectra (EW component) of two events of the Kobarid 1998 sequence recorded at Bernadia station.

THE DISTANCE DEPENDENCE OF k

- Anderson & Hough (1984) proposed a linear dependence of k on the epicentral distance R $k=k_0+k_1R$ where k_0 depends on the subsurface geological structure beneath the station-site and k_1 depends on predominantly horizontal S-wave propagation through the crust. k_0 can also be correlated with a general soil-type classification of the station-site (alluvium, consolidated sediments, rock).
- Anderson (1991) proposed a more general relation $k=k_0+k_t(R)$ where the station-independent term, $k_t(R)$, can be assumed to be a smooth function of R, close to 0 for 0 distance.
- Different numerical methods can be applied to calculate k_t for a finite number of distances R_i using the joint inversion of the couples (R_i, $k_j(R_i)$) of all the earthquakes recorded from the stations at all the epicentral distances R_i. In this work we applied:

  1) a multi-linear regression assuming $k=k_0+k_1R$ with station-dependent k_0 terms and a station-independent k_1 term;

  2) a generalized inversion of the couples (R_i, $k_j(R_i)$) with constraints w_1 and w_2 such that increasing w_1, $k_t(R=0)$ -> 0 while increasing w_2, $d^2k_t(R)/dR^2$ -> 0; w_1=0 or w_2 =0 means the constraint removal.

- In Fig.3 the results obtained with method 1) and 2) (with different values of the constraints w_1 and w_2) are compared to each other for 6 stations of the network. Fig.3 shows that:

  a) w_1 influences the function $k_t(R)$ for distances smaller than 15 km, where the small number of data does not allow an accurate fit;

  b) w_2 modifies the smoothness of the curve, but does not outline any characteristic trend; the curve with high values of w_2 is almost coincident with the linear fit.

- The results obtained with the generalized inversion confirm both the values of k_0 (approximately ranging from 0.015 to 0.055 s for the 11 stations considered here) and the linear increase of k with epicentral distance (k_1=0.00013 s/km).

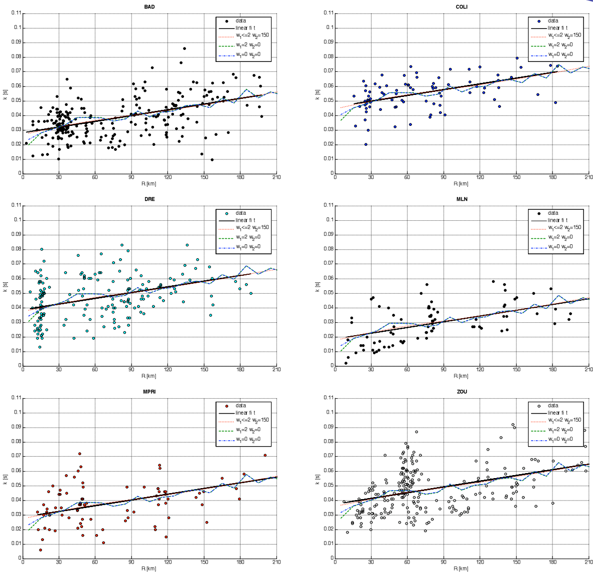

Fig.3 k as a function of R using the multi-linear fit (black line) and the generalized inversion of Anderson (1991) with: $0 \le w_1 \le 2$, w_2=150 (red line); w_1=2, w_2=0 (green line) e w_1= w_2=0 (blue line) for 6 stations of the NEI seismic network.

GENERAL ATTENUATION MODEL

- The spectral decay k is generally interpreted in terms of propagation, considering both the near-surface prevailing vertical propagation beneath the site (k_0 terms) and the predominantly horizontal propagation of the ray-path through deeper crustal layers (k_1); k_1 can be considered independent on the analyzed stations, and it can be related to the quality factor Q and the S-waves velocity, V_S, in the deeper part of the crust.
- The obtained values of k_0 have mean=0.036 s and std=0.010 s, coherently with the results of Franceschina et. al (2006), who estimated k_0 = (0.03 ± 0.01) s for the two stations of the network BAD and ZOU. These values were obtained by a disjoint regression using a smaller dataset (54 events). The stability of this result indicates that stations of the NEI network (all installed on "rock-sites") are however characterized by a not negligible attenuation.
- Assuming S-waves velocities ranging between 3.3 and 3.6 km/s in the seismogenic layer (Gentile et al., 2000), the increase of k with epicentral distance obtained in this work (k_1=0.00013 s/km) can be explained assuming a quality factor Q at high frequency (f>10Hz) ranging between 2120 and 2310.

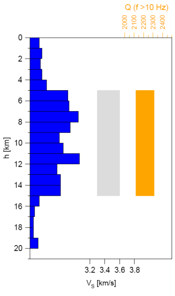

Fig.4 Number of M≥3 earthquakes vs. depth; grey bar: range of velocity in the seismogenic layer; orange bar: corresponding Q.

NEAR-SURFACE ATTENUATION

- The obtained values of k_0 are well correlated with the mean of the Nakamura's ratio obtained for the same stations in the frequency bands 1-8 Hz (Bragato & Slejko 2005) and 0.2-10 Hz (Barnaba et al. 2008).
- k_0 is significantly different from 0 also in cases of negligible values of H/V. For example, for <H/V> = 1 we have k_0=0.024 s or k_0=0.030 s, depending on the considered frequency band.

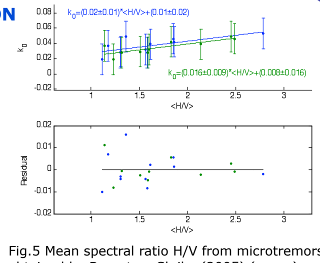

Fig.5 Mean spectral ratio H/V from microtremors obtained by Bragato e Slejko (2005) (green) and Barnaba et al. (2008) (blue), compared with k_0.

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