

D. Roten^{1,2}, D. Fäh¹, K.B.Olsen², L.F. Bonilla³ and D. Giardini¹ Email: <daniel.roten@sed.ethz.ch>

¹ Swiss Seismological Service, ETH Zurich, Switzerland; ² San Diego State University, San Diego, United States; ³ Institut de Radioprotection et de Sûreté Nucléaire, Paris, France

Introduction

Numerical simulations have shown for long that deep sedimentary basins may significantly amplify long-period ground motion. Two different effects can be distinguished depending on the basin geometry:

- (1) In *shallow* valleys, the resonance period is proportional to the basin depth and varies with the position along the basin (1-D case).
- (2) In *deep* valleys, the fundamental resonance period is independent of the position along the basin, but the highest amplification occurs in the basin center. This **2-D resonance** involves three fundamental modes (Fig. 1a), and the resulting amplifications are much higher than in the 1-D case (Bard & Bouchon, 1985).

The *critical shape ratio* provides a mean to distinguish between 1-D and 2-D resonance in sedimentary basins (Fig. 2b) depending on the velocity contrast and the ratio between basin depth and width (Bard & Bouchon, 1985).

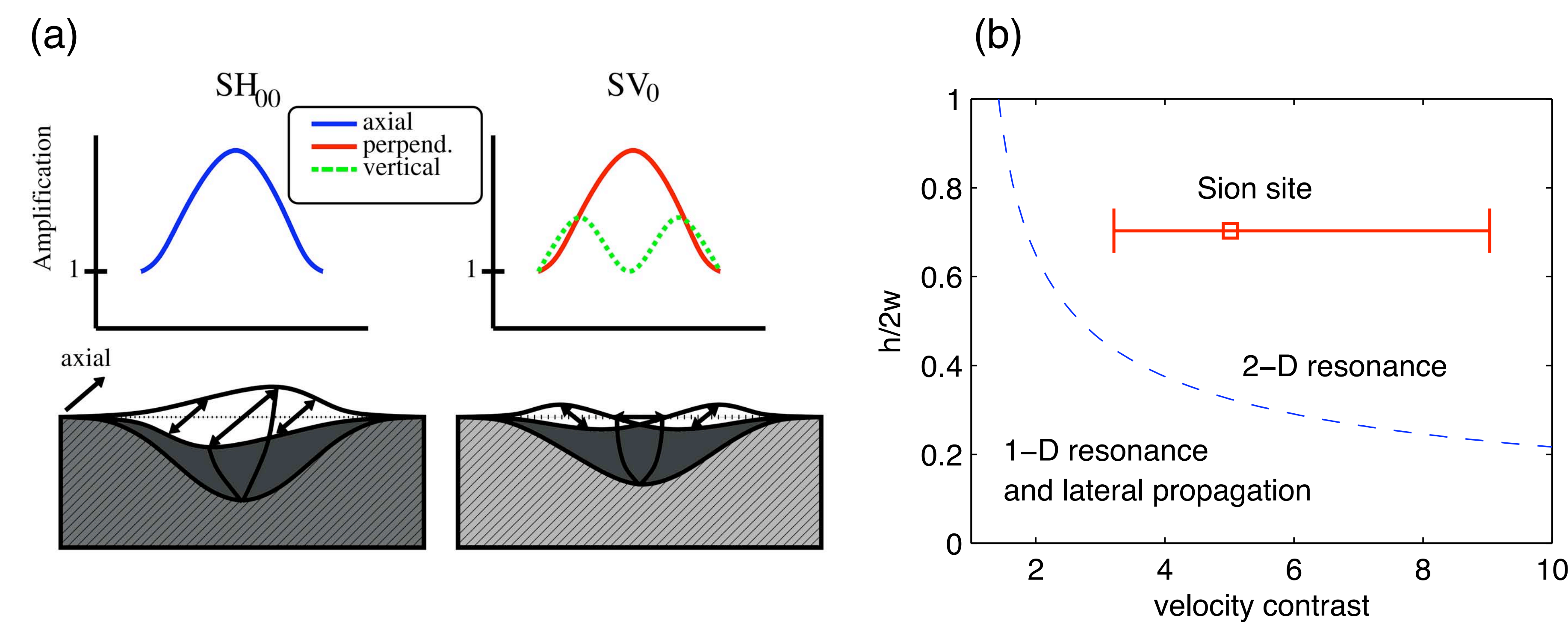


Figure 1: (a) Fundamental modes SH₀₀ and SV₀ of 2-D resonance. (b) Critical shape ratio and shape ratio of the Sion site for a range of estimated velocity contrasts.

Records of local earthquakes

We are analyzing the seismic response of the Rhône valley near the city of Sion in Southern Switzerland (Fig. 2). The shape ratio suggests that the development of 2-D resonance must be expected for this site (Fig. 1b). To identify the resonance frequencies we recorded a number of local earthquakes on a temporary array.

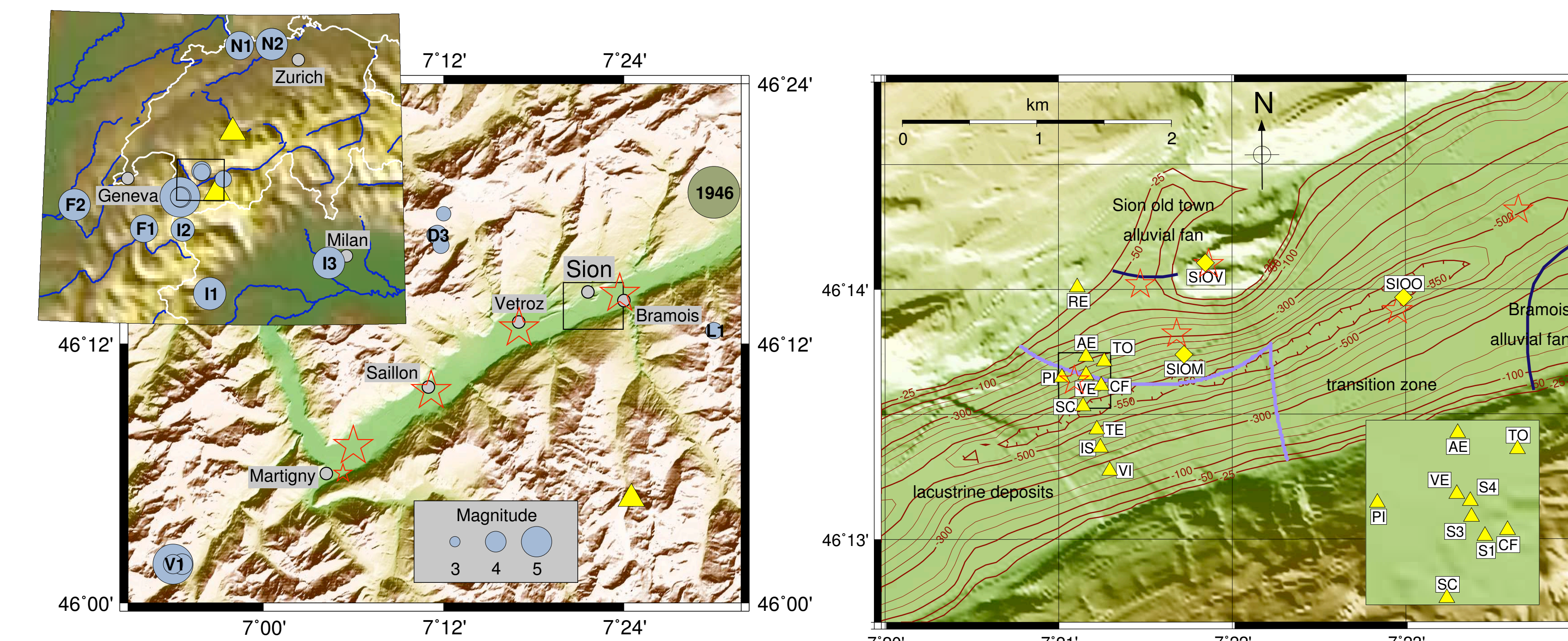


Figure 2: Recorded earthquakes (left) and location of temporary stations (right).

Observed spectral ratios

- To isolate the different modes of 2-D resonance site-to-reference spectral ratios were computed for the directions parallel and perpendicular to the valley axis and the vertical component (Fig. 3).
- On the axial (parallel to the valley axis) direction, a fundamental frequency of approximately 0.55 Hz is observed, regardless of the local sedimentary thickness.
- The maximum amplification occurs in the basin center, which is consistent with the SH₀₀ fundamental mode of 2-D resonance (Fig. 1).
- On the direction perpendicular to the valley axis, the fundamental mode SV₀ can be identified at ~0.60 Hz. This mode is also visible on the vertical axis (Fig. 3).

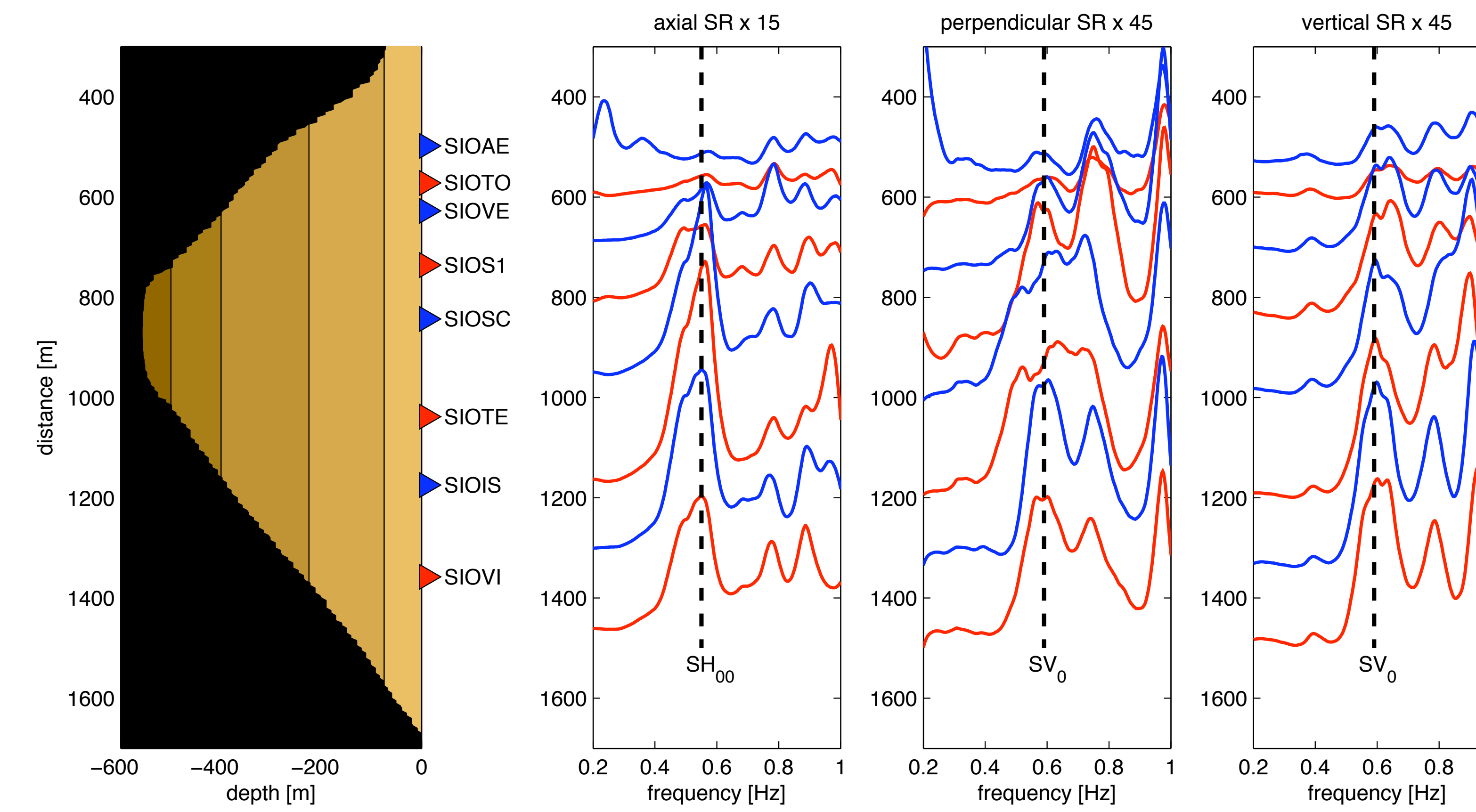


Figure 3: Spectral ratios computed from records of a local M_L 4.0 event.

Simulated site response

- We performed 3-D FD simulations (Olsen, 1994) of four recorded and one historical M 6.1 earthquake.
- Spectral ratios computed from synthetic ground motion exhibit properties similar to the observed site response.
- The simulated 2-D resonance frequencies are slightly lower than the observed values (SH₀₀ = 0.45 Hz and SV₀ = 0.50 Hz).

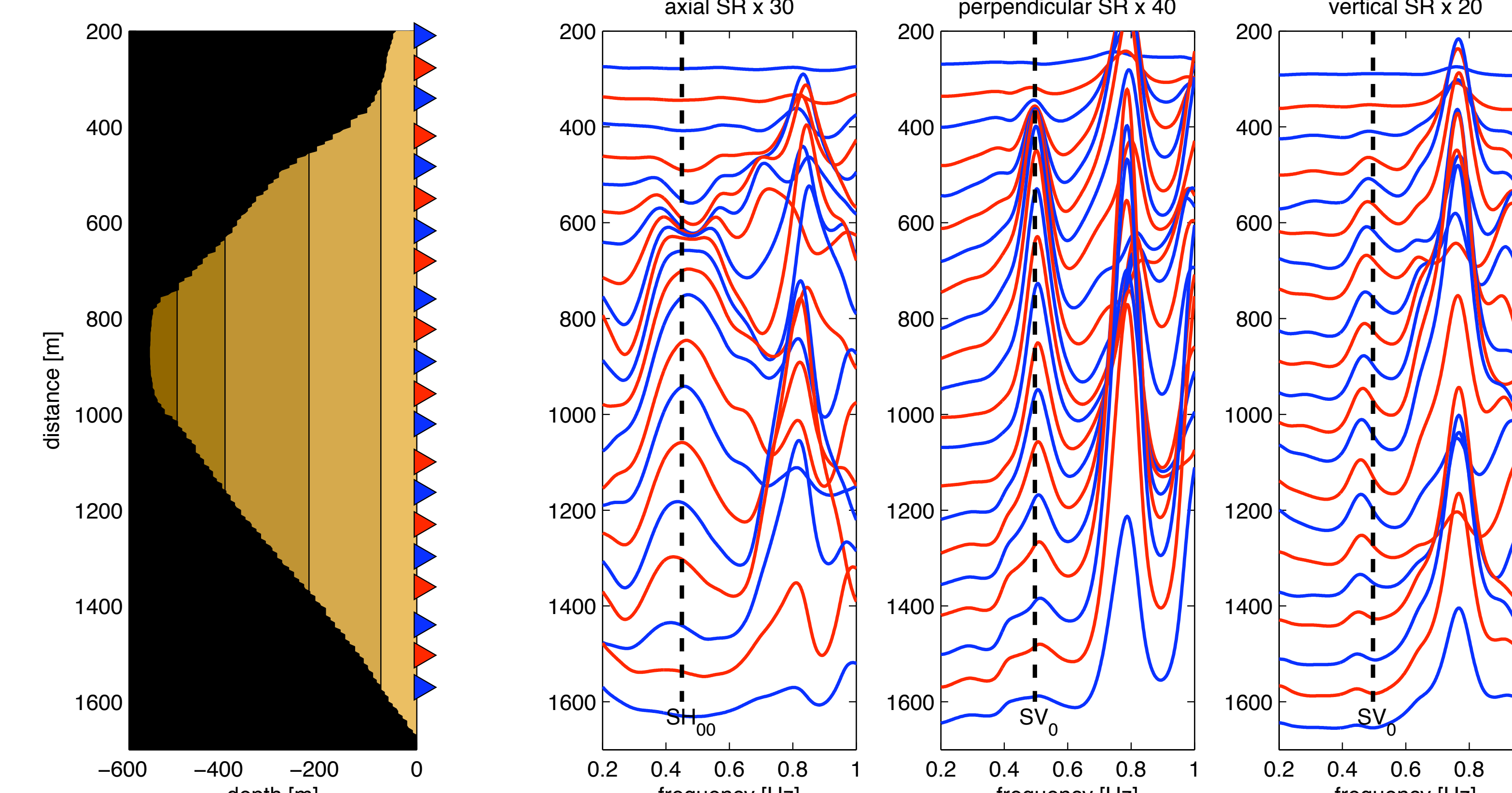


Figure 4: Spectral ratios calculated from a simulated M 4.0 event.

Nonlinear soil behavior

- During strong ground motion the long-period part of the signal may be altered by nonlinear behavior of the soil.
- We convolved synthetic seismograms with the transfer function of the basin and propagated them through a nonlinear layer of 10 meters thickness using the program NOAH (Bonilla et al., 2005).
- The results suggest that the amplification of spectral accelerations (SA) at 0.5 Hz is reduced by more than ~50% for rock SA of 1 ms⁻² (Fig. 5a).
- Nevertheless, the absolute SA are still exceeding the applicable design spectra at 0.5 Hz for simulated events with M ≥ 6.0 (Fig. 5b).

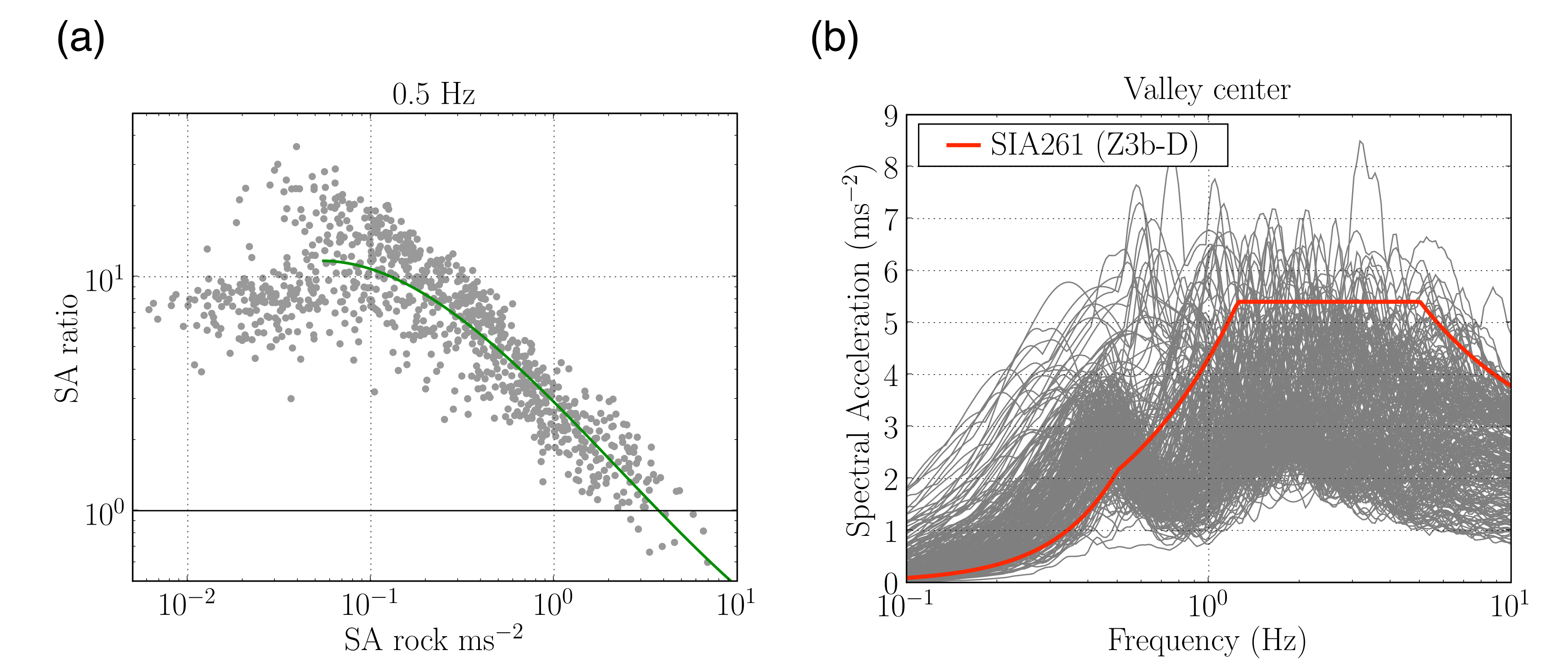


Figure 5: (a) Spectral acceleration (SA) ratio as a function of SA on rock at 0.5 Hz. (b) Absolute SA for simulated events with M ≥ 6.0 compared to applicable Swiss design spectra SIA261.

Conclusions

- Spectral ratios computed from recorded ground motion reveal significant average amplification levels of up to 12 at 0.5 Hz.
- Rotation of components to the directions perpendicular and parallel to the valley axis allows to isolate the SH₀₀ and SV₀ fundamental modes of 2-D resonance, confirming previous observations made from ambient noise (Roten et. al, 2006).
- Spectral ratios computed from simulated ground motion are able to reproduce the main characteristics of the observations.
- Simulations of nonlinear soil behavior show that exceedance of design spectra may occur during strong ground motion despite increased damping. This reflects the large long-period amplification at the frequencies of 2-D resonance.

References

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