I. Strong Ground Motion Measurements

Objective: To analyze and interpret data from strong ground motion accelerographs. This is the data which is also used to construct “attenuation” curves.

Background — Typical seismographs are sensitive to ground velocity because of the nature of their transducers. The sensitivities of these instruments are however designed to record weak ground motions of the order of microns of displacement. The limited dynamic range of these instruments coupled with the limited-dynamic range of the telemetry and digital recording systems (~45 dB) only allows the instrument to record earthquakes over 3 to 4 orders of magnitude range. Hence they can not faithfully record on-scale, the large ground motions recorded in the near-source epicentral range of infrequent large earthquakes.

As you may suspect, strong accelerations are of most importance to the engineering community because this quantity can be related to forces of seismic waves on structures. Also because strongest ground motions are recorded in the near-vicinity of an earthquake, 10 to 100 km, peak ground accelerations (PGA) contain all the near-, mid- and far-field contributions of the waveform including the largest values that provide time series of motions that can be input to structural engineering determinations of building response.

To acquire data on earthquake strong ground motion, accelerographs are designed to be sensitive to horizontal accelerations of 0.001 to >1.0 g (1g = ~980 cm/s/s), i.e., they are sensitive to motions of nearby M4+ events and stay on scale during large earthquakes when the short-period recording systems are saturated.

Lab: For this lab we want to analyze SGM data by interpreting both analog and digital data recorded from some large normal faulting earthquakes.

Analyze the SGM records selected from six moderate to large earthquakes by measuring the peak accelerations, signal characteristics, and spectra (from digital records of these same data).

Attached are analog accelerograms from:

1. 1935, Helena, Mt., M\$ 6, R = 5 km;
2. 1962, Cache Valley, UT. M\$ 5.7, R = 20 km;
3. 1978, Thessaloniki, Greece, M\$ 6.4, R = 10 km to fault and 5 km to epicenter;
4. 1980; Campania-Basilicata (Naples), Italy, M\$ 6.3, B03 R = 50 km, BZ4 R = 32 km, and CL3 R = 20 km.
5. 1983 Borah Peak Idaho, aftershock, M\$ 5.1, R = 20 km to epicenter and 1 km to fault.
The records are aligned as 1-vertical, 2-north and 3-east. Timing is relative to the arbitrary turn-on time of the acceleragraph and is not coordinated to GMT. Note that engineers call these data recorded in time as time series of the events, while seismologists call it a seismogram.

Because accelerographs are triggered, i.e., they are only turned on when a sensor in the instrument exceeds a threshold of ground motion and this is usually after the relatively small P-wave pulses, much of the ordinary body waves (P and some S) are lost as some of these instruments do not have pre-trigger memories. Hence the signals will be primarily that of the S waves and surface waves. For reference, these data and their interpretations were published as:


For this lab we will follow much of the analyses of strong ground motion in:


**Procedure:**

1. Using the analog strong ground motion records, measure the following quantities (with a mm scale) for each earthquake and put in a tabular form:

   i) peak ground accelerations, PGA, (all channels),
   ii) the bracketed duration,
   iii) given the distance to the station what is the likely phase-type for each peak value,
   iv) the average frequency of the peak acceleration value (from a visual inspection).

2. Then compare the peak horizontal acceleration, PHA, values to the two generally accepted empirical wave attenuation expressions for PHA. For this simply write a MatLab script to calculate and plot these empirical curves for:

   a) the Boore et al., (1993) with coefficients for large earthquakes (eq. 3.26, Kramer, p. 89) and
   b) for an attenuation scale for earthquakes in extensional regimes, such as the Basin and Range (Spudich, et al., 1999).

   Both Matlab scripts can be found in: /home/jfarrell/GG5330/Lab8/1/

   \[ R = \text{distance in km between the recording station and the closed point on the fault rupture.} \]

   Note: The Cache Valley and Helena earthquakes did not experience surface faulting so the default distance, R, is to the epicenter.
II. Strong Ground Motion Data (SGM) -- Frequency Domain Analyses

Objective: To analyze strong ground motion accelerographs in the frequency domain using spectral analysis. This is the data that is used to compare with spectral curves of buildings.

1a. Using the digital data from an aftershock of the Borah Peak, ID earthquake, BOR, plot the SGM data in MatLab and compare it to the analog copy. Note you may truncate the data to get a shorter record to make the same scale.

1b. Run a spectral analysis of each channel using the Spectra subroutine from the MatLab signal analysis tool kit. The spectral data are frequently called the spectral response of the earthquake, a quantity that engineers use to specify the limitations of the site to peak accelerations throughout the frequency range of the source. Frequencies on the abscissa can be specified by a percentage of the Nyquist frequency, the folding frequency. We have provided a MatLab script to do this.

Note that engineers also define a damped spectra where damping are in units of % damping and are applied systematically to the spectra to damp the long periods more than the short periods. Note that $\beta$ in the damped harmonic oscillator is the same as in the equations for motion of a building or a ground response. Damping is generally specified at 5%.

Note the spectral peaks (peaks in the spectral domain) and their associated frequencies. Which components have the maximum values and why? Also note the shape of the spectra. Does it look anything like the theoretical shape from source theory?

You may wish to perform a spectral analysis on a data set that is truncated, i.e. windowed around the S- or the P-wave pulse (this can be done by editing the trace and eliminating the data before and after the window). How do the spectra change for these narrower windows? Comment on why the spectra will be different/alike for the windowed data.

2. Next calculate the velocity and displacement spectra of these data staying in the frequency domain and make plots of these spectral. Use MatLab or Maple.

3. Then transform all three of the spectra back into the time domain to get the time series for acceleration, velocity and displacement and plot out the three components using MatLab plotting at the same time scale (like in the examples).

Data:
The digital data for the events are stored in: /home/jfarrell/GG5330/Lab8/II/ this is a version without the header written in a Matlab format, i.e., accl1.mat. A copy of the header is attached.