Introduction to Earthquake Seismology

Assignment 2

Department of Earth and Atmospheric Sciences **EASA-462**

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Particle Motion – Rayleigh

Goals:

- **To become familiar with three-dimensional representations of ground motion**
- **To identify Rayleigh-wave motion**
- **To use Rayleigh-wave motion to define the direction (back azimuth) from the seismograph to the signal source**

Background:

The largest arrivals on a broadband seismogram for shallow earthquakes are the surface waves. Because of their large amplitude, they were denoted as the 'M' or main phase in early seismological nomenclature. There are two types of surface waves – Love and Rayleigh, names after the researchers who derived their properties from solving the equations of elastic wave theory. A. E. H. Love considered transverse S-wave propagation trapped in a low-velocity waveguide at the surface. Lord Rayleigh (John William Strutt) discovered a special signal that exists in a medium with a free surface and which is the result of interference of P- and vertically polarized S waves. Rayleigh waves also exist in a medium with a free surface and with velocity increasing with depth in which case they exhibit dispersion, e.g., signal frequencies propagate with different velocities.

The characteristics of these signals are as follow:

Love Waves:

- Particle motion in a horizontal place in a direction perpendicular to the ray (transverse)
- Dispersion varies between the shear-wave velocity at depth at low frequencies (long periods) and the shear-wave velocity at the surface at high frequencies.

Rayleigh Waves:

- Particle motion is in the vertical – radial plane
- Particle motion is elliptically polarized, e.g., a plot of the Z vs R as a function of increasing time traces out an ellipse
- The particle motion of the fundamental mode is retrograde elliptical (see figure below)
- For the fundamental mode, dispersion varies between 0.91 times the shear-wave velocity at depth at low frequencies (long periods) to 0.91 times shear-wave velocity at the surface at high frequencies.

The properties in the identification of these signals. The Rayleigh wave appears last and is seen on the horizontal and on the vertical traces. The Love-wave motion is purely horizontal. On a N-S particle motion plot, the Love wave motion will be perpendicular to the the wave propagation direction and the Rayleigh-wave motion will be parallel. By it self the N-S particle motion cannot resolve the direction of propagation since it can also be in the opposite direction. Fortunately the retrograde elliptical motion of the Rayleigh wave can resolve the propagation direction.

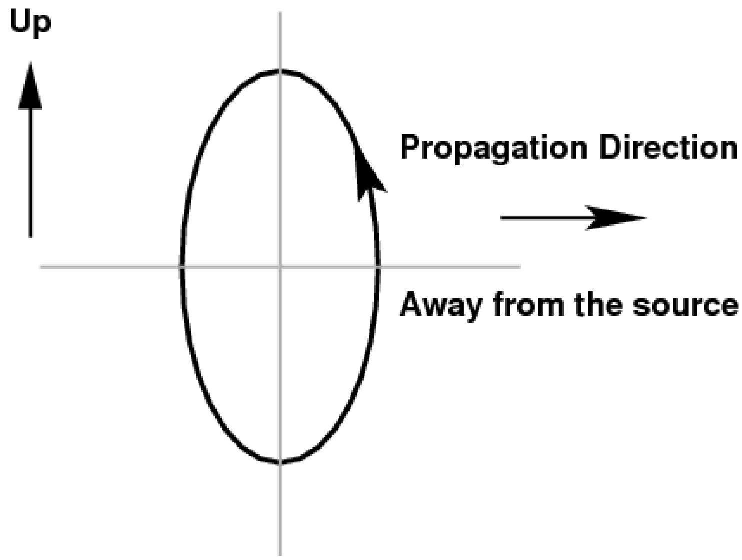


Fig. 1. Sketch of Rayleigh-wave particle motion. The arrow indicates the the direction of motion as time increases. This is an ellipse. The corresponding time series would show a maximum on the horizontal component when the vertical motion is zero

What you must do:

This exercise will focus on the $\mathbf{M_W}$ =5.6 British Columbia earthquake of January 9, 2007 as recorded by the SLU instruments at Indiana University in Bloomington, IN. (Figure 2). If you look carefully your will see a large arrival on the NS-component at about 800 seconds from the beginning and another set of arrivals about 1000 seconds from the beginning. The first is the Love wave, and the second is the Rayleigh wave.

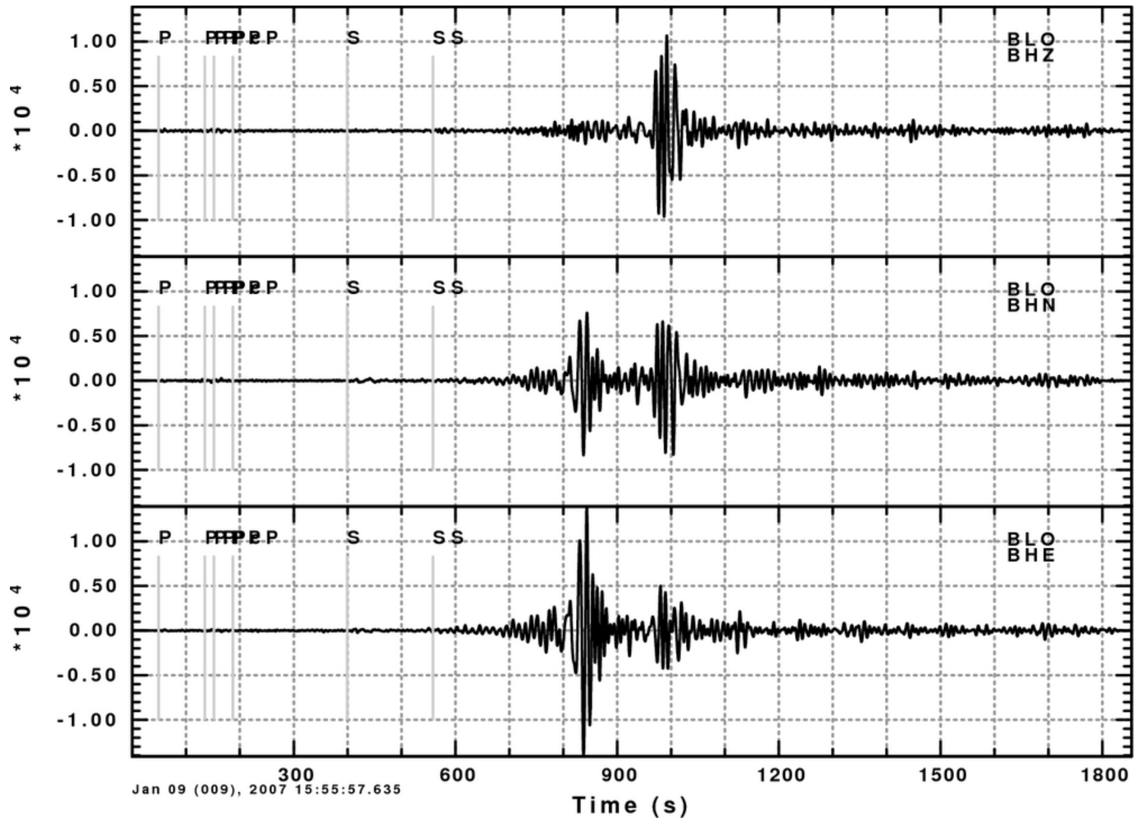


Fig. 2. Three component raw seismograms at BLO. The arrival markers are predicted arrival times for the Earth.

The assignment is to plot the particle motion of the Love and Rayleigh waves. To assist you, the traces are windowed to zoom in on these arrivals.

On the work pages you will see the windowed seismograms for the two arrivals.

Each seismogram figure consists of three components of ground motion, e.g., Z – positive is up, N – positive is north, and E – positive is east. The seismograms are plotted as a function of absolute time, with the first trace point having the time listed on the time-stamp at the bottom right. Time increases from left to right, and the numbers represent an offset with respect to the absolute time marker.

For each trace,

- Examine the traces, and determine the range of amplitudes to use for the plot scales.
- Now mark the axes on the plot grids in the same way. Use the same scale for all particle motion plots on a page. The reason for this requirement is to be able to convey the relative sense of amplitudes that you see on the plots – which just happen to be plotted with the same scale on the y-axis. Be NEAT!
- Now pick the amplitudes from the trace. Given the simple appearance of these traces, I would mark the traces at the4-second intervals given by the dotted grid lines.
- For a given time value you will have 3 numbers, e.g., one for each trace. To assist in making the plot, you may wish to read all amplitudes first, put them in a table such as

Time (sec)   Amp-Z Amp-N Amp-E

- Now plot the motion in terms of N vs E, Z vs N and Z vs E as a function of increasing time. You may wish to indicate the time offset or to use arrows to indicate increasing time.
- Once you have completed the plots, determine the direction of Rayleigh-wave propagation from the Rayleigh-wave particle motion

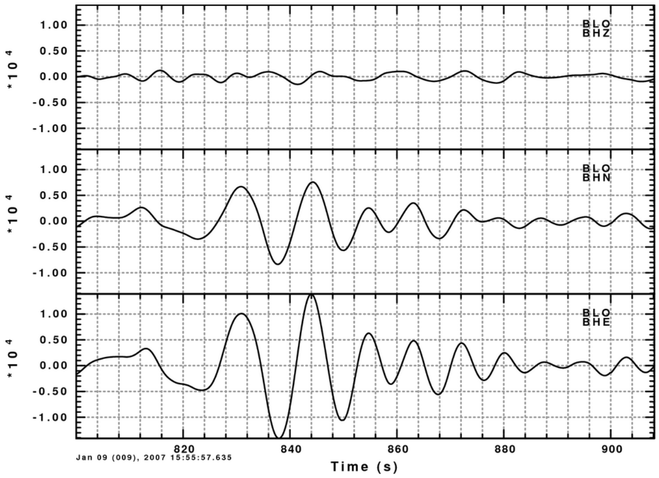
What you must submit:

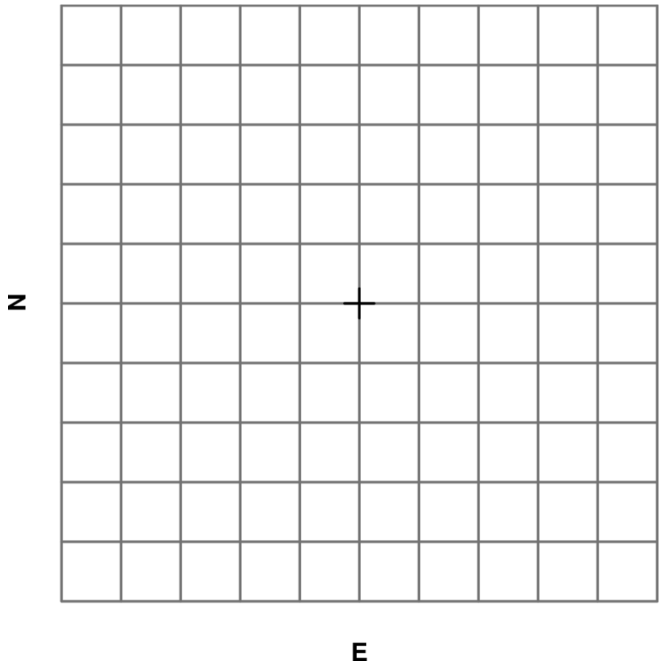
1. **The particle motion plots**
2. **You must determine the direction to the source from the seismograph station**

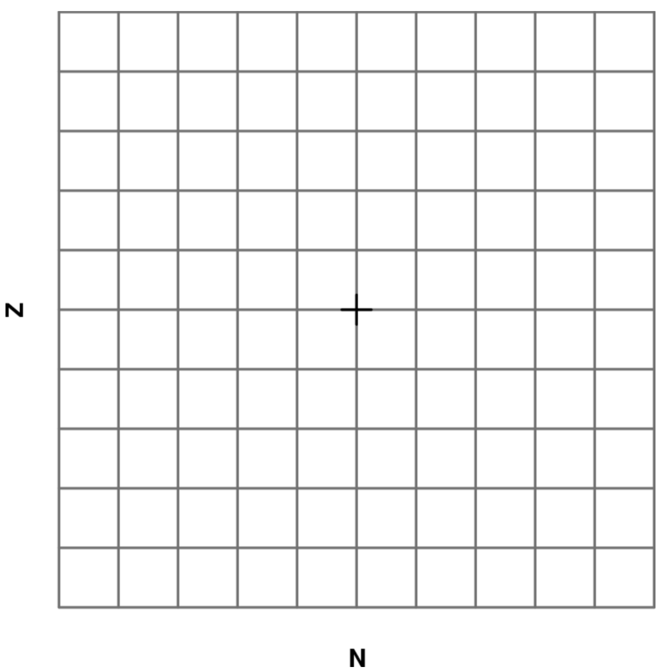
Thought problem:

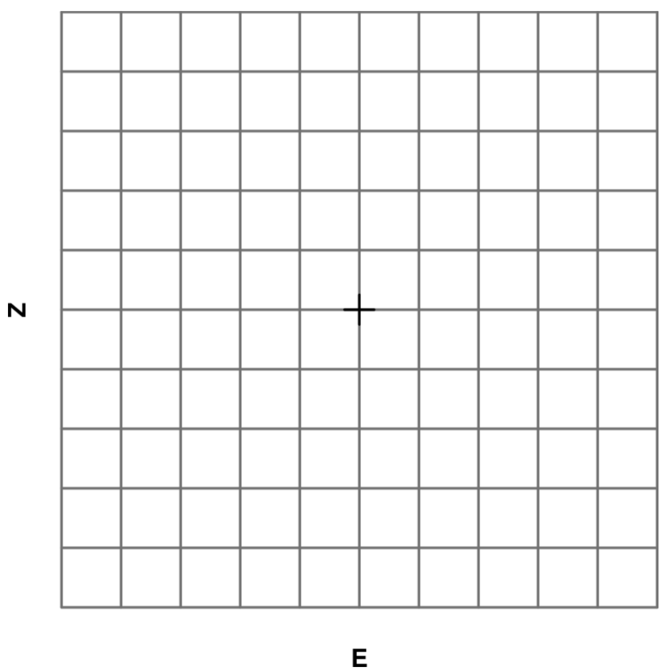
Modern seismographs measure 3 perpendicular components of ground motion, typically Z, N and E. If you have a seismograph at the South Pole, SPA, how would you characterize the component – is there any meaning to Z, N and E.

Love-wave particle motion plot









Rayleigh-wave particle motion plot