Modeling Local and Regional Wave Propagation

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Overview

Seismograms reflect the combined effects of the source, recording instrument, ambient noise, and the propagation path. Especially at distances smaller than 10° the appearance of seismograms varies strongly because of the underlying crustal structure. This complicates record interpretation and phase identification severely. However, for earthquakes with small magnitudes, close distance records are the only ones available with sufficient signal.

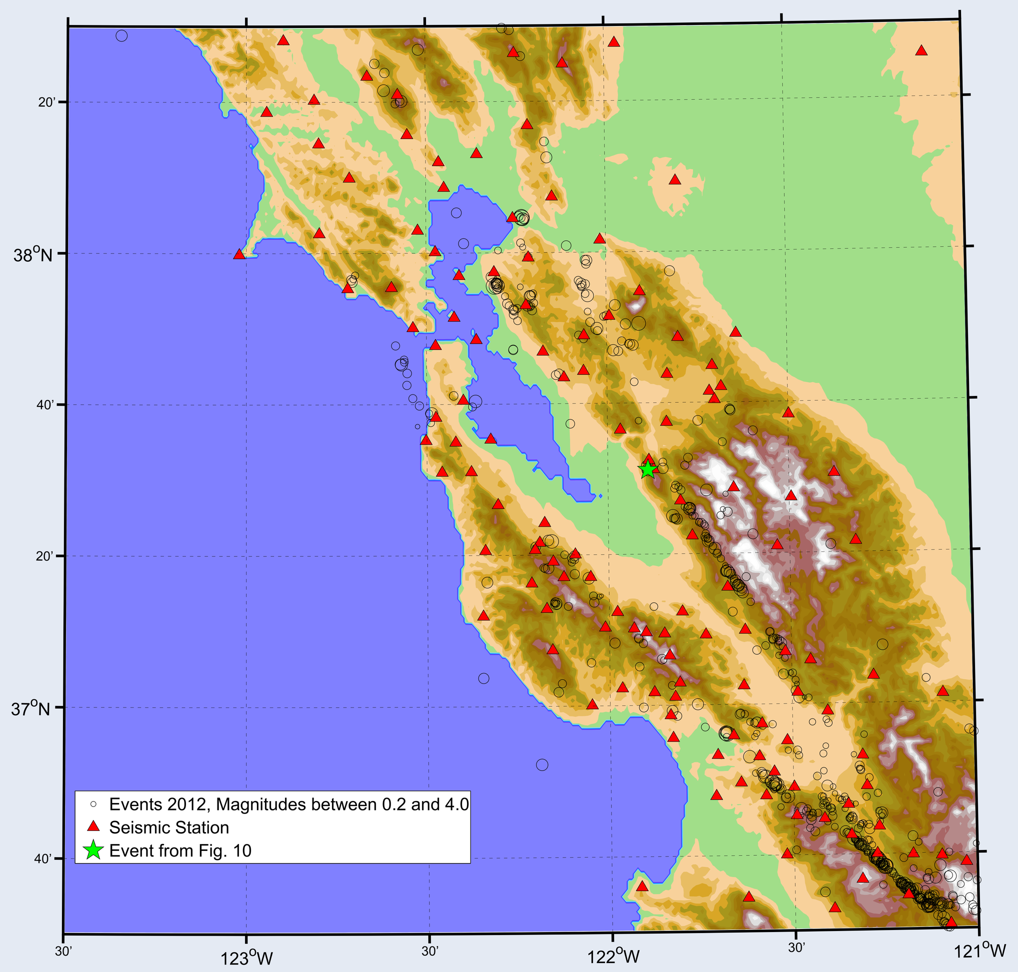

Fig.1: Stations of Northern California Seismic Network with Events recorded in 2012

Due to the use of only Pg and Sg, localization cannot always be ensured. Using additional regional phases, also for depth estimation, can improve the result. At local and regional distances the challenge lies in robustly detecting and identifying these phases correctly, which are usually superimposed by the coda of the P- and S-phase and sometimes even arrive simultaneously. Synthetic seismograms can support our understanding how and when those phases can be used.

Model and Method

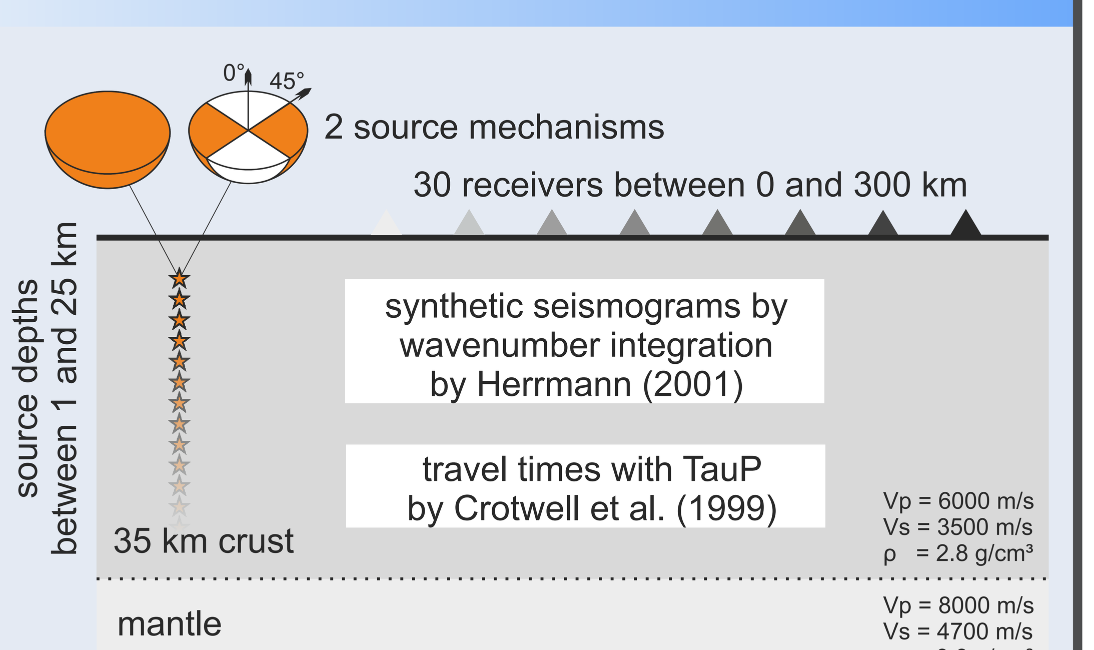

Fig.2: Model and Methods

Explosion Source

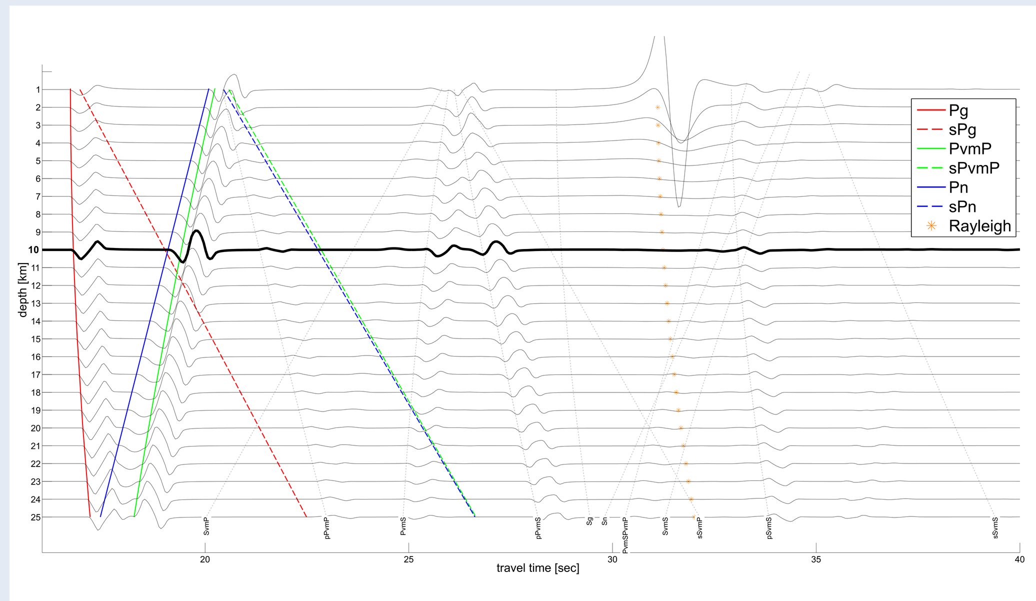

Fig.3: Synth. Seismograms at 100 km Distance

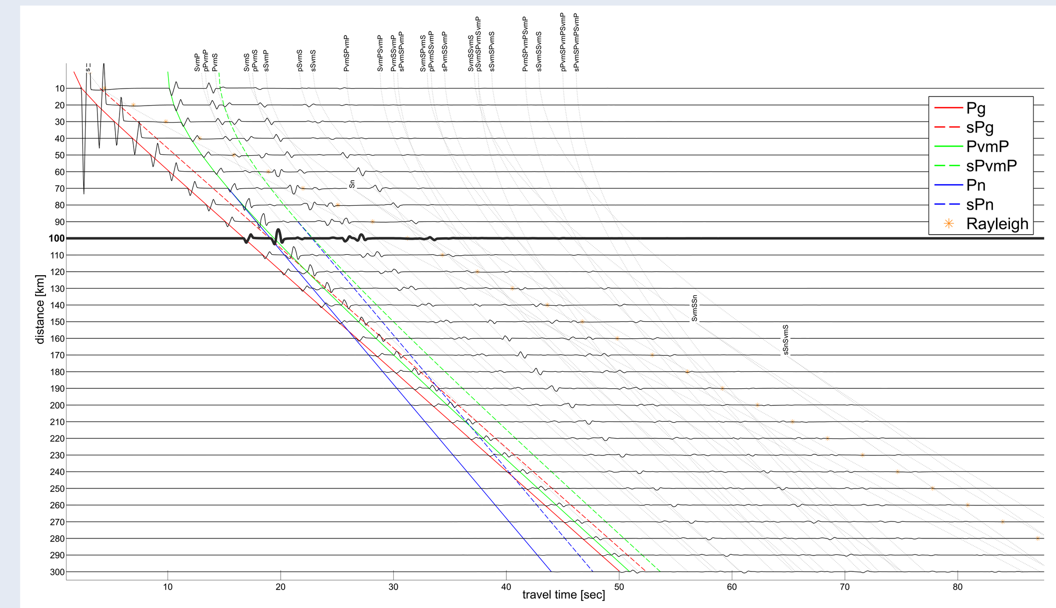

Fig.4: Synth. Seismograms for 10 km Depth

Both figures above show the synthetic seismograms of the vertical component calculated for an explosion source at different depths (Fig. 4) and different distances (Fig. 5). All traces are normalised to the lowest trace in each plot. The by far strongest phase visible is a regional Rayleigh phase at shallow depths. For shallow depths the time difference between the first arriving Pg phase and the later arriving PvmP (PmP) and Pn permits identification. However, PvmP and Pn arrive almost simultaneously at 100 km distance and are not separable. But comparison with the distance plot clearly shows that the PvmP phase is stronger developed by far. Regional depth phases like sPg, sPn and sPvmP are not generated as an explosion source does not emit S waves.

Strike Slip Source at 0° and 45° Azimuth

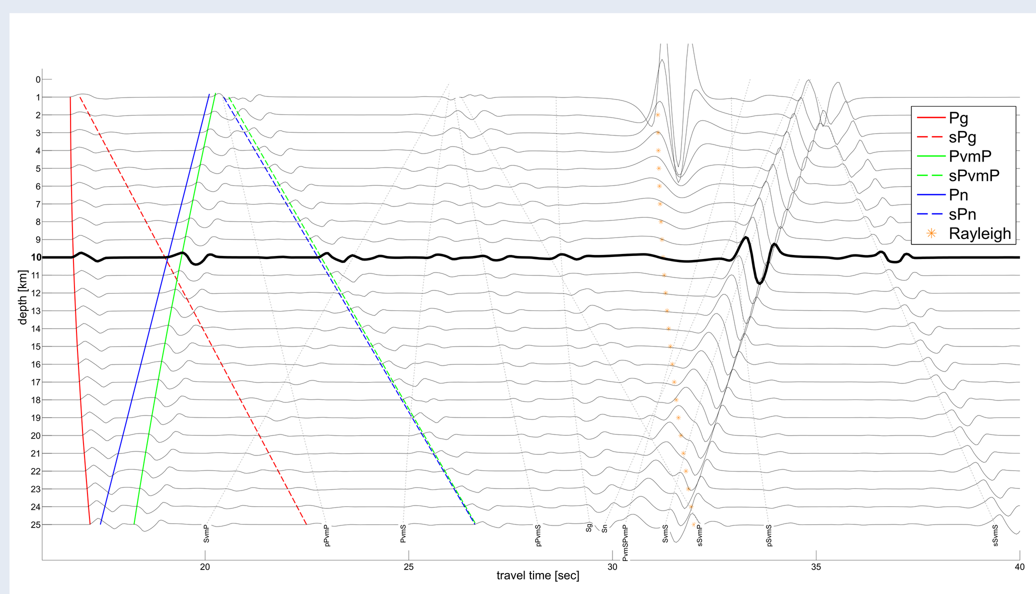

Fig.5: Synth. Seismograms at 100 km Distance at 0°

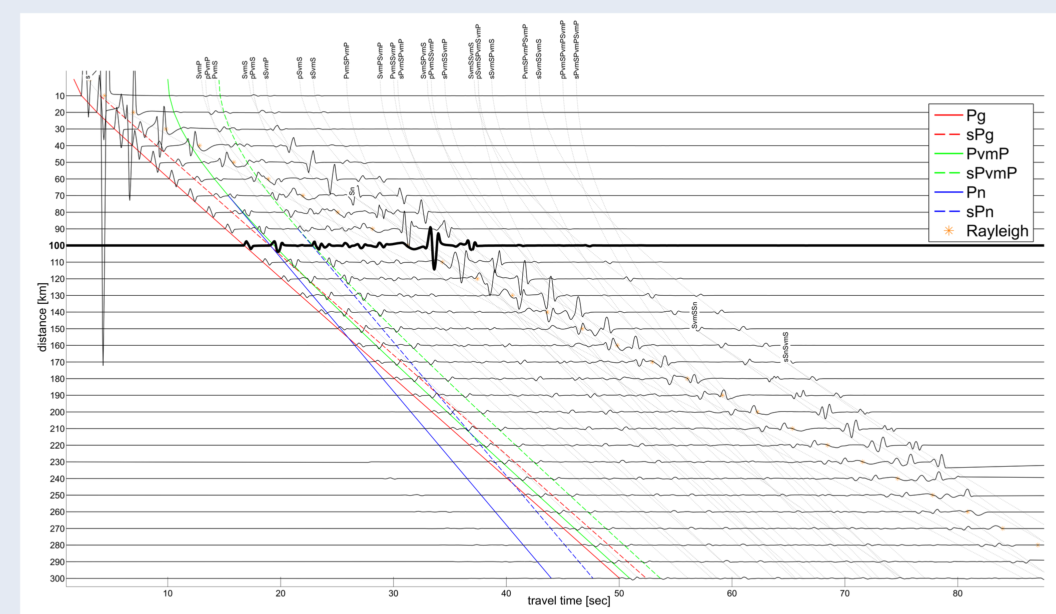

Fig.6: Synth. Seismograms for 10 km Depth at 0°

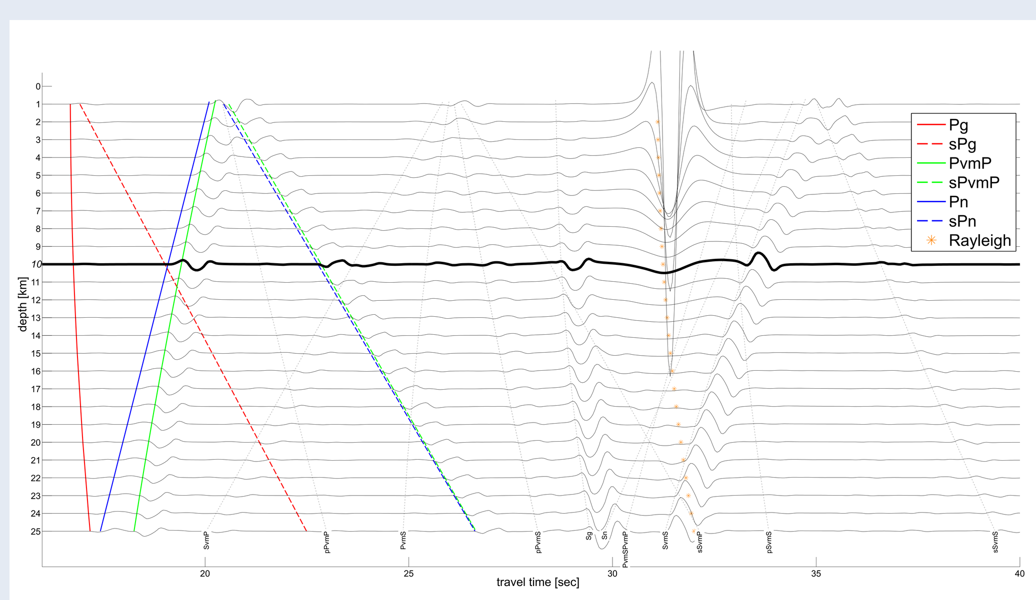

Fig.7: Synth. Seismograms at 100 km Distance at 45°

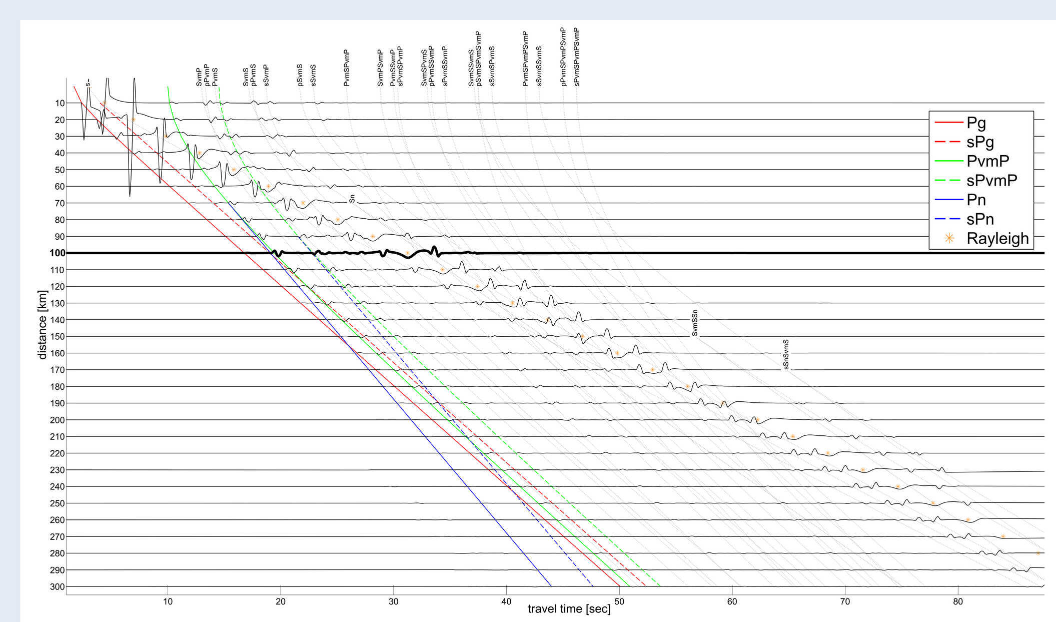

Fig.8: Synth. Seismograms for 10 km Depth at 45°

The figures above show synthetic seismograms for a strike slip source with 45° strike and 90° dip at 2 different azimuths for the vertical component. All four plots are normalised to their respective lowest trace. The signals at 0° (Fig. 6 and 7) are generally stronger than at 45° azimuth (Fig. 8 and 9) and are scaled separately for better visibility. Again the most prominent feature for shallow depths is the Rayleigh phase which attenuates with depth. As can be expected with the source mechanism used P arrivals are better visible at 0° azimuth and S arrivals at 45° azimuth. Interestingly there is almost no difference in the PvmP arrival.

Local and Regional Phases

Beyond direct phases normally used for localization, there are other useful phases according to literature: Pg with its reflection sPg (e.g. Ma & Eaton (2011)) as well as PvmP with sPvmP, the so called regional depth phases.

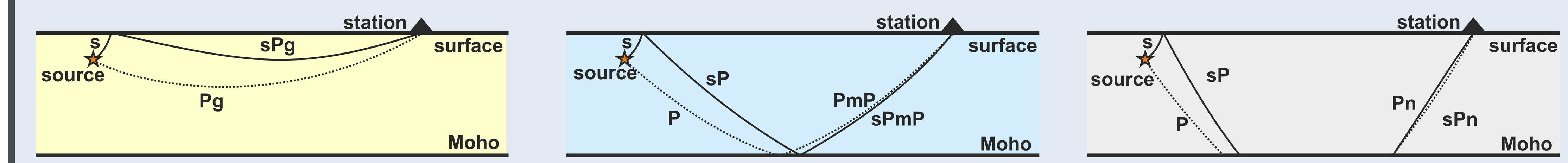

Fig.9: Regional depth phases adapted from Ma & Eaton (2011)

Amongst others, Ma & Motazedian (2012) mention that events at very shallow depths also generate strong Rayleigh waves.

Results and Outlook

Although the model used for seismogram calculation is rather simple, identification of phases can be already quite complicated if the station is at an unfavorable distance or azimuth. In the real crust seismograms get even harder to read.

Figure 10 shows a data example from the Northern California Seismic Network with calculated arrivals for the assumed strongest phases. If you compare synthetic with real seismograms, it becomes clear that the real seismograms show a more complex signal, where single phases are even harder to identify. Further research will explore the possible usage of additional local phases for localization especially source depth. Also different ways to improve phase identification will be evaluated.

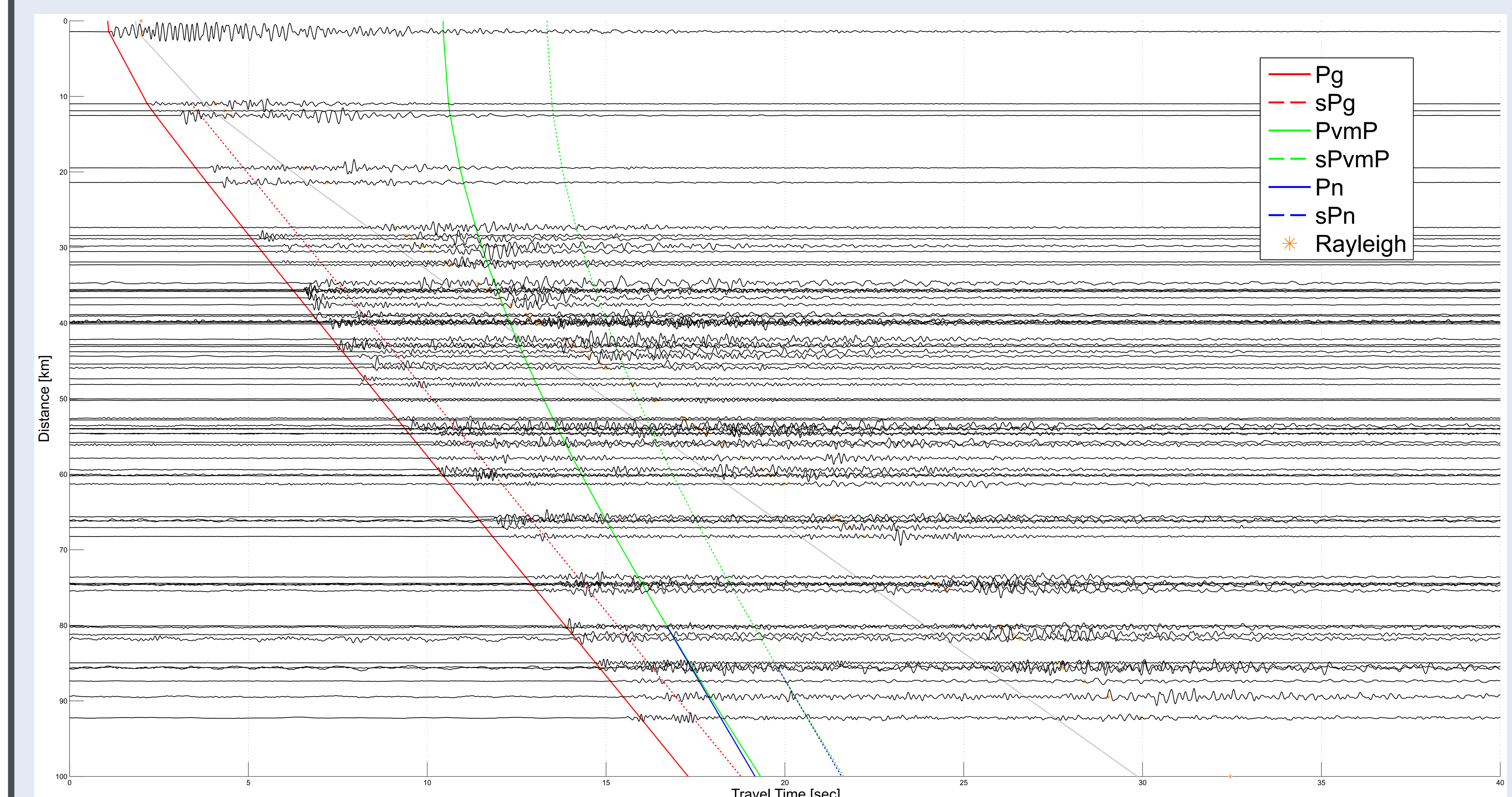

Fig.10: Earthquake 15/01/2012 at 6.1 km Depth, Ml 2.2 from NCSN

References

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