Improving Identification of Regional Depth Phases in Sparse Networks

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Overview

Regional depth phases such as sPg and sPmP in combination with their reference phases Pg and PmP can be used to estimate focal depths of regional earthquakes, if they can be identified. In principle, a single station with one phase pair may be sufficient for accurately determining earthquake depth from the difference in their arrival times. Different studies, e.g. Ma & Eaton (2011) show that regional depth phases develop differently well depending on epicentral distance and magnitude:

Phases	Distance	Magnitude
Pg & sPg	< 100 km	> 1.5
PmP & sPmP	200 -300 km	> 2.0

Ray paths of the regional depth can be seen in Figure 1 . The challenge lies in robustly detecting and identifying the phases, within the coda of the P-phase. Sedimentary basins, for example, may render these phases complex (Ma 2010), and it may prove complicated to recover them from the seismic records.

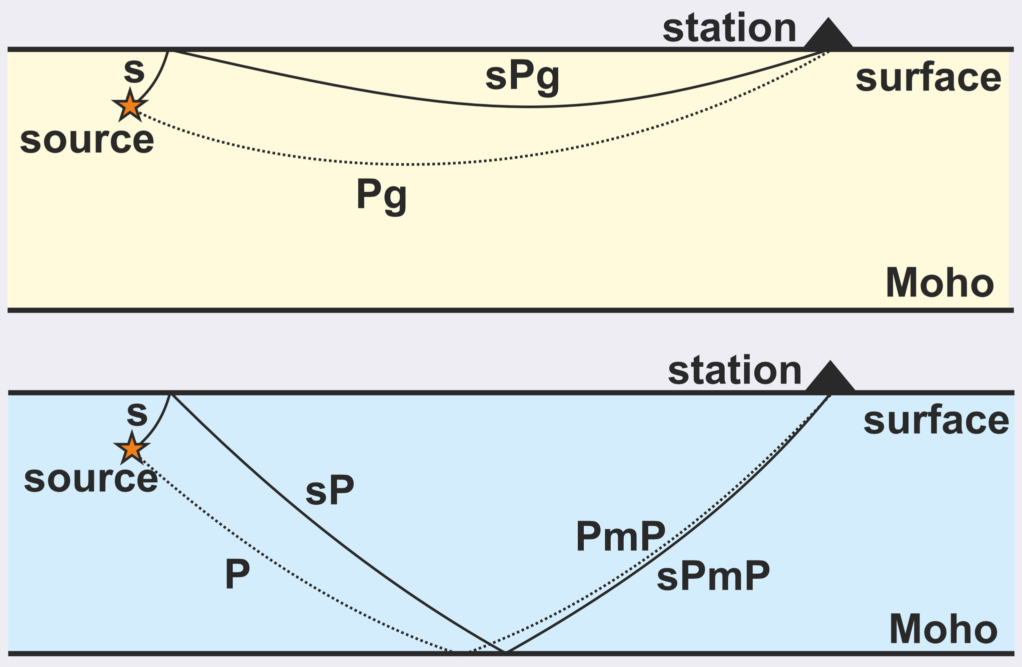

Fig.1: Regional Depth Phases adapted from Ma & Eaton (2011)

Polarization Filtering

We use a polarization filter presented by Schimmel & Gallart (2004), which was shown to increase signal-noise-ratio substantially in refraction data. The filter is based on the assumption that noise is less polarized than the signal; polarization weighing can thus increase the number of identifiable phases. Figure 2 shows how this filter works on earthquake data. The first part shows the time and frequency dependent filter which is calculated from the original ZNE-traces. Part 2 to 4 show the original trace compared to the filtered trace. Phase onsets calculated with TauP Toolkit by Crotwell et.al (1999) are shown as reference.

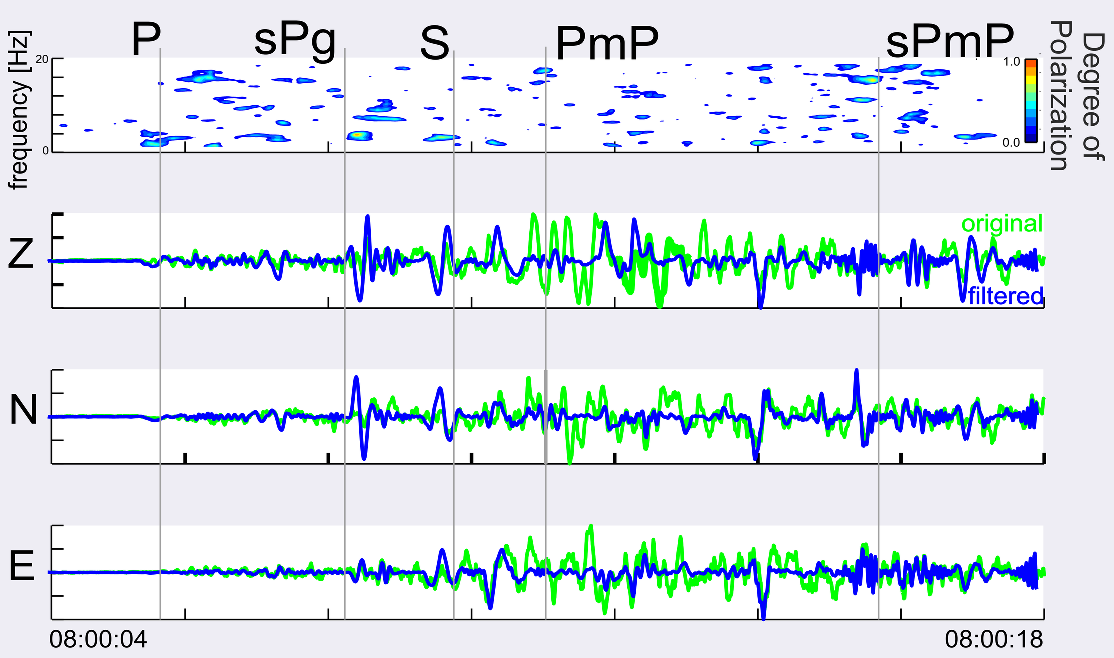

Fig.2: Polarization filter

Region and Seismic Data

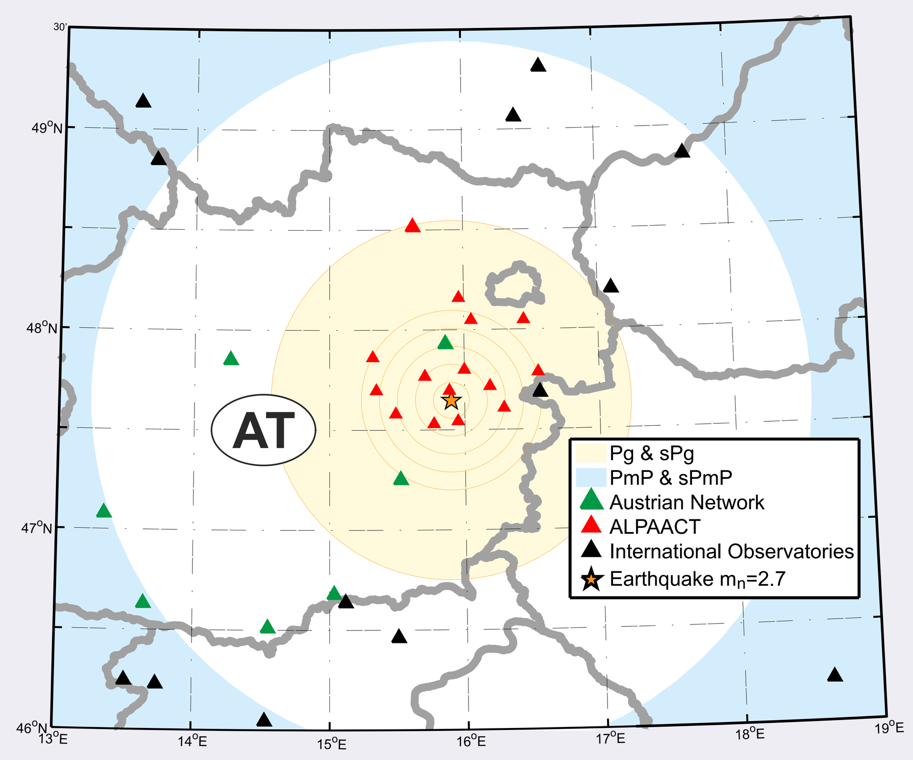

Fig.3: Areas of well developed regional depth phases

The study area is situated at the transition of the Eastern Alps to the Pannonian basin and the Western Carpathians. The Vienna Basin is, due to its vicinity to Vienna, one of the most densely populated and developed areas in the region. Instrumentally recorded seismicity in the area is weak, with a maximum instrumentally recorded magnitude of around 5. There are historical records of stronger earthquakes though, and even larger events have been suggested based on paleoseismicity (Hintersberger et.al 2010).

The Austrian seismological network is built of very-high quality stations, but their station density is relatively sparse. For our research we added data from surrounding international observatories as well as from the ALPAACT network (Mertl & Brückl 2010), which continuously recorded broadband data at additional 17 locations, shown in Figure 3 .

The location of the earthquake with the highest magnitude (2.7) in the data set is shown in Figure 3 . The depth was estimated at 10.3 km by the ZAMG (Zentralanstalt für Meteorologie und Geodynamik). This figure also marks the stations used and the areas in which regional depth phases should be developed well. The yellow area shows the distance at which sPg and Pg phases should be well developed. The blue area delimits the same for sPmP and PmP phases.

Depth Phase Stacking

The time difference between depth phases and their reference phases changes with distance and with depth. If the distance is given one can estimate depth from the arrival time of depth phases or calculate the arrival time for a given depth e.g. with the TauP Toolkit by Crotwell et.al (1999).

As depth phases are hard to identify in our data set, we try to get depth information without picking the phases themselves. At first we resample all data to the same frequency, rotate the traces to the ray coordinate system (ZNE to LQT) and calculate the envelope as can be seen in Figure 4 (a). Then we determine earthquake depth by stacking along predicted traveltimes for different depths and in the end search for the maximum.

The result is shown in Figure 4 (b). The grey line shows the result for the 4 stations given in Figure 4 (a). The coloured lines show the result of the same calculation but with all stations in a distance of less than 100 km. At first one notices, that the energy in the trace grows with depth. For longer time windows the result gets smoother. For all time windows there is a maximum around 15 km which would indicate the earthquake being at this depth. At the depth of 10.3 given by the bulletin there is only a local maximum which can not be seen at all time window lengths.

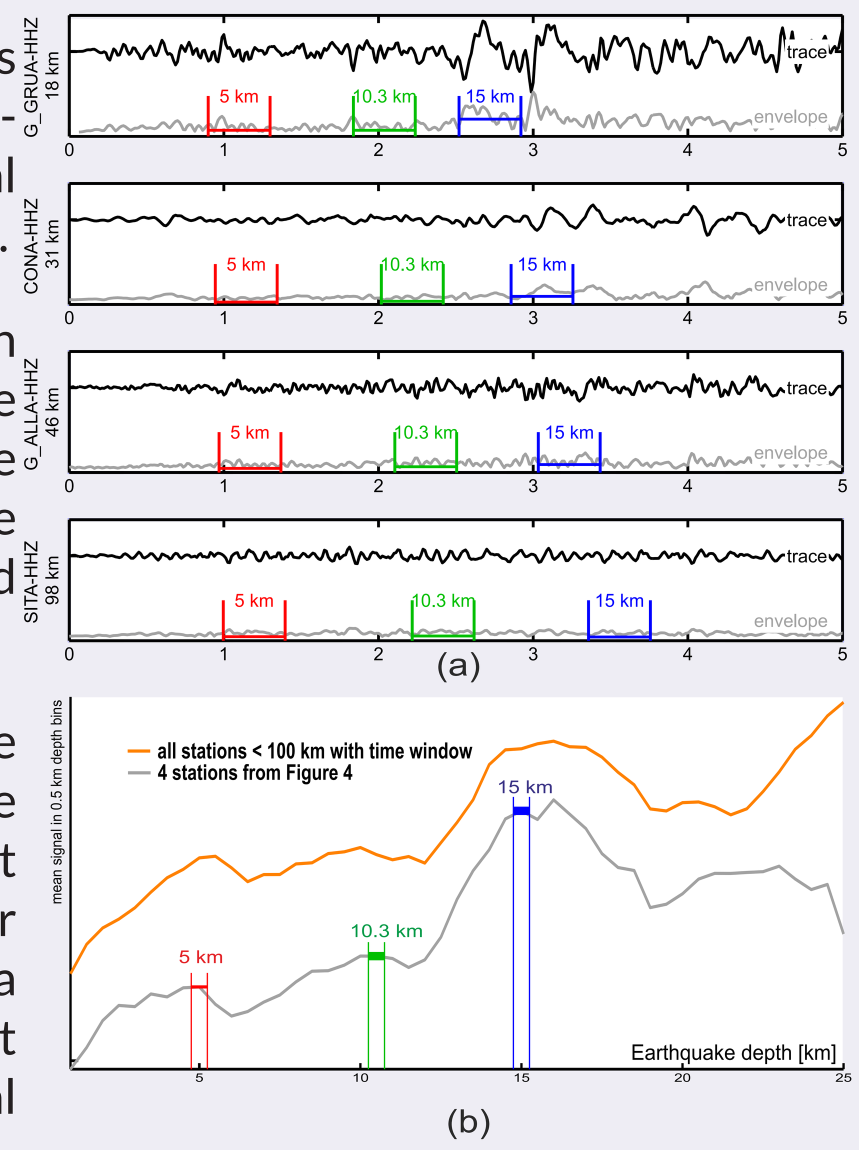

Fig.4: (a) Z-Traces (b) Stack

Current Research - Northern California

The San Andreas fault in Northern California is one of the most studied areas in seismology worldwide. Due to its numerous earthquakes and a very dense seismic station network it is a well suited area for testing.

To confirm our result from Austria, we selected 9 earthquakes between magnitude 2 to 4 with depths between 5 and 15 km recorded by th Northern California Seismic Network. One example is shown in Figure 5.

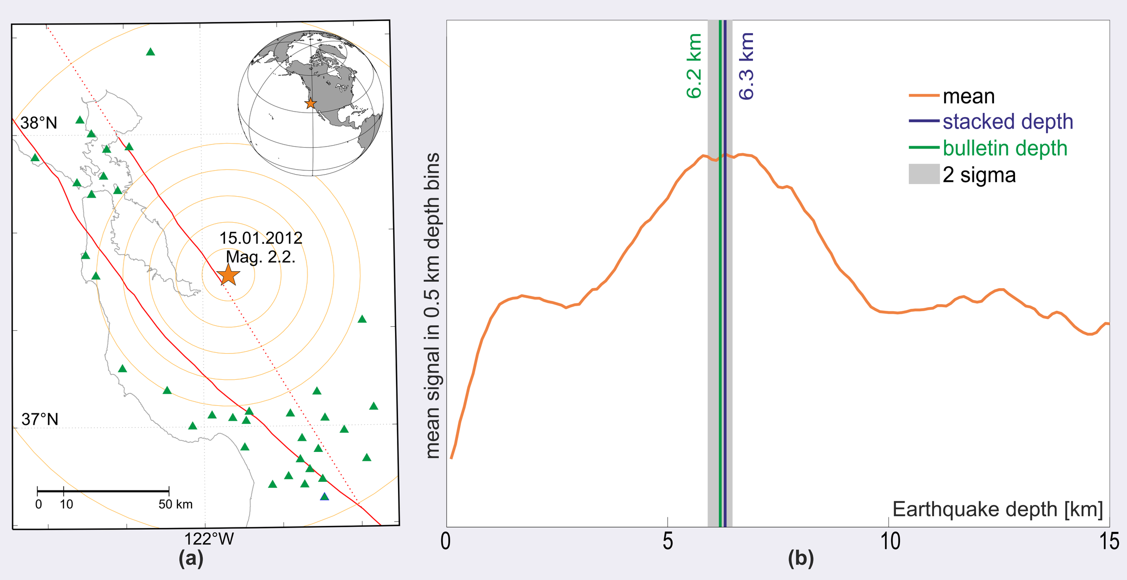

Fig.5: (a) Area and Stations (b) Depth Phase Stack

Results from depth phase stacking in Northern California are encouraging. Most events show approximatly the depth given in the bullentin, although less stations than for the localisation are used.

Analysis with an even bigger catalog of events from this area, containing more and smaller earthquakes, remains to be done still.

Summary and Further Research

Regional depth phases allow to estimate earthquake depth even if only a single depth phase with corresponding reference phase can be identified. The data used in this research do not let us identify any depth phases directly. Different methods for enhancing the depth phases were applied. One method was to stack the depth phases corresponding to their calculated move out. Preliminary results show that this method could also work in sparser networks than the one used, at least for the sPg phases tested.

The signal-to-noise ratio can be further enhanced by a polarization filter. This technique can be very useful for regional network processing. The Zentralanstalt für Meteorologie und Geodynamik (ZAMG) can not always derive earthquake depth from seismometer data, and has to set the earthquake depths in the bulletin from a priori knowledge.

Efforts have been made to get a better picture of earthquake depths in Austria e.g. by Lenhardt et.al (2007) where the depths were estimated from macroseismic data. Nevertheless the method used in that paper is not suitable for automated determination of earthquake parameters.

To improve the identification of depth phases, further research has to be done. The depth phase stacking has to be improved, possibly in combination with other techniques, and tested thoroughly on a larger dataset.

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