IMPROVING IDENTIFICATION OF REGIONAL DEPTH PHASES IN SPARSE NETWORKS

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Regional Depth Phases

Regional depth phases such as sPg, sPmP and sPn in combination with their reference phases Pg, PmP and Pn 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	Local Magnitude
Pg & sPg	< 100 km	> 1.5
PmP & sPmP	200 -300 km	> 2.0
Pn & sPn	> 300 km	> 4.0

Ray paths of the regional depth can be seen in Figure A. 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 difficult or impossible to recover them from the seismic records, even using common methods like band pass filtering.

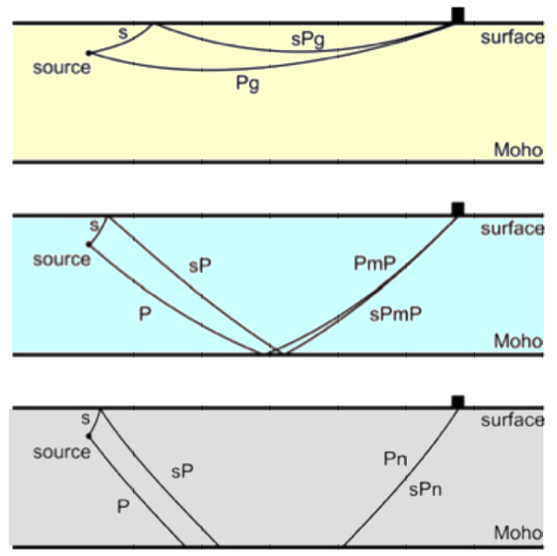


Figure A: Regional Depth Phases adapted from Ma & Eaton (2011)

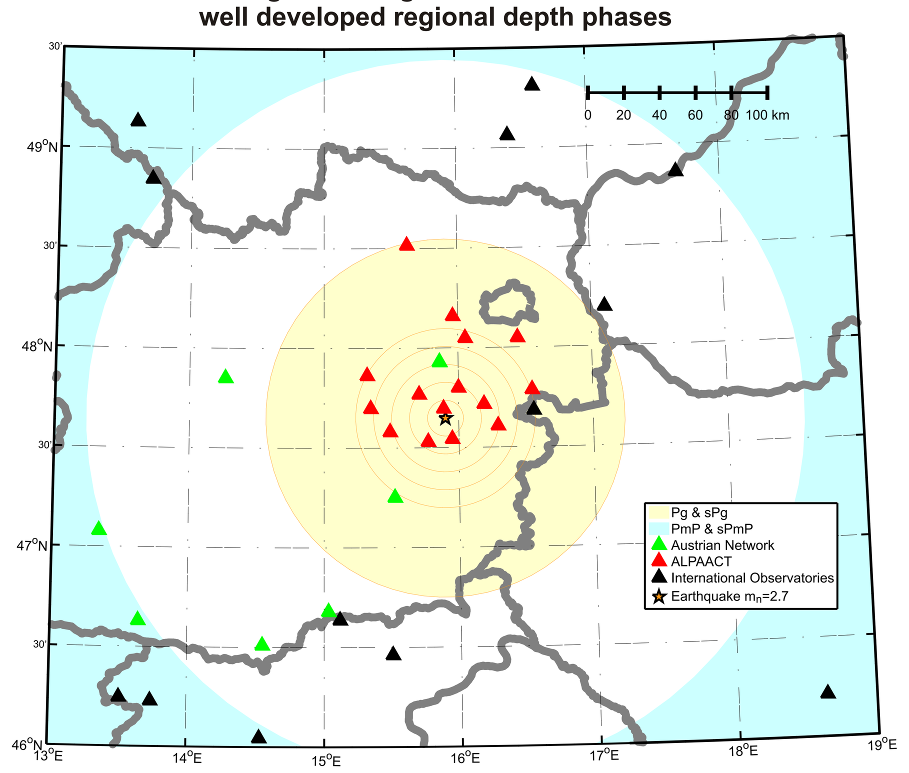
Region & Seismic Data

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 the vicinity with 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 B.

The location of the earthquake with the highest magnitude (2.7) in the data set is shown in Figure B. The depth was estimated at 10.3 km by the ZAMG (Zentralanstalt für Meteorologie und Geodynamik). Also Figure B shows the stations used and the areas in which regional depth phases should be developed well. Figure C shows the vertical component at each station after bandpassfiltering. Additionally it shows the travel times for our phases of interest calculated with the TauP Toolkit by Crotwell et.al (1999). In both figures the yellow area shows the distance at which sPg and Pg phases should be well developed. The blue area shows the same for sPmP and PmP phases.

Figure B: Region with zones of well developed regional depth phases



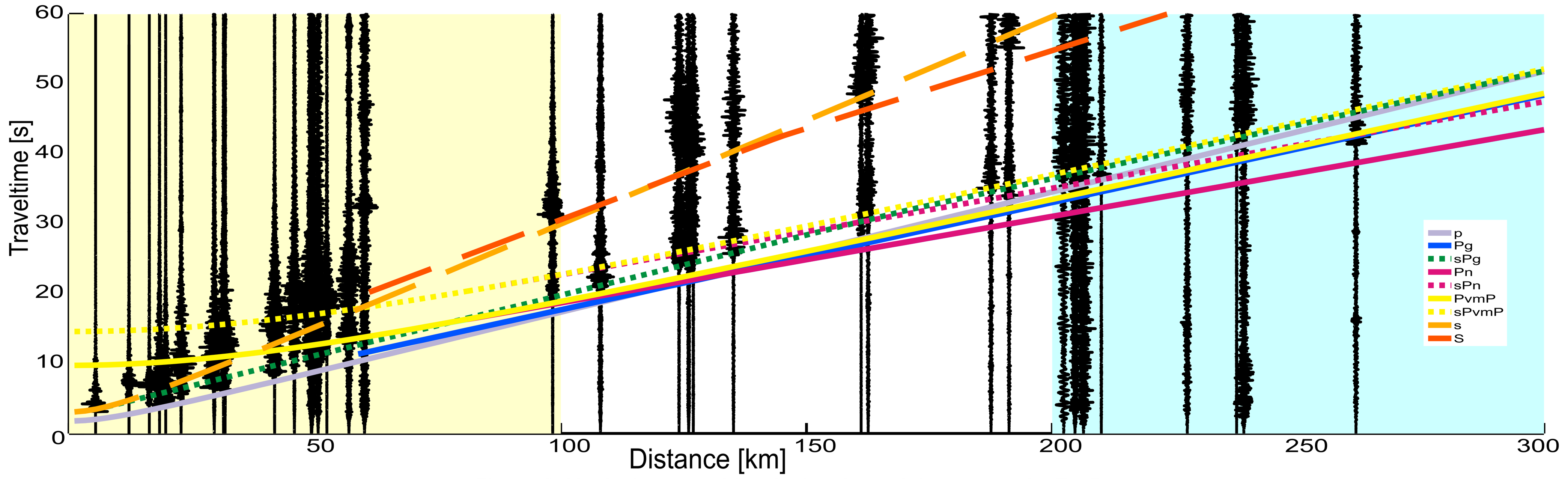


Figure C: Vertical traces with calculated travel time curves by TauP

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 arrival time for a given depth. We determine earthquake depth by stacking along predicted traveltimes for different depths and searching for the maximum

Before stacking we resample all data to the same frequency, rotated the traces to the ray coordinate system (ZNE to LQT) and calculated the envelope(Figure D). Depth phases are difficult to identify on individual traces or envelopes

The result is shown in figure E. The grey line shows the result for the 4 stations given in figure D. 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.

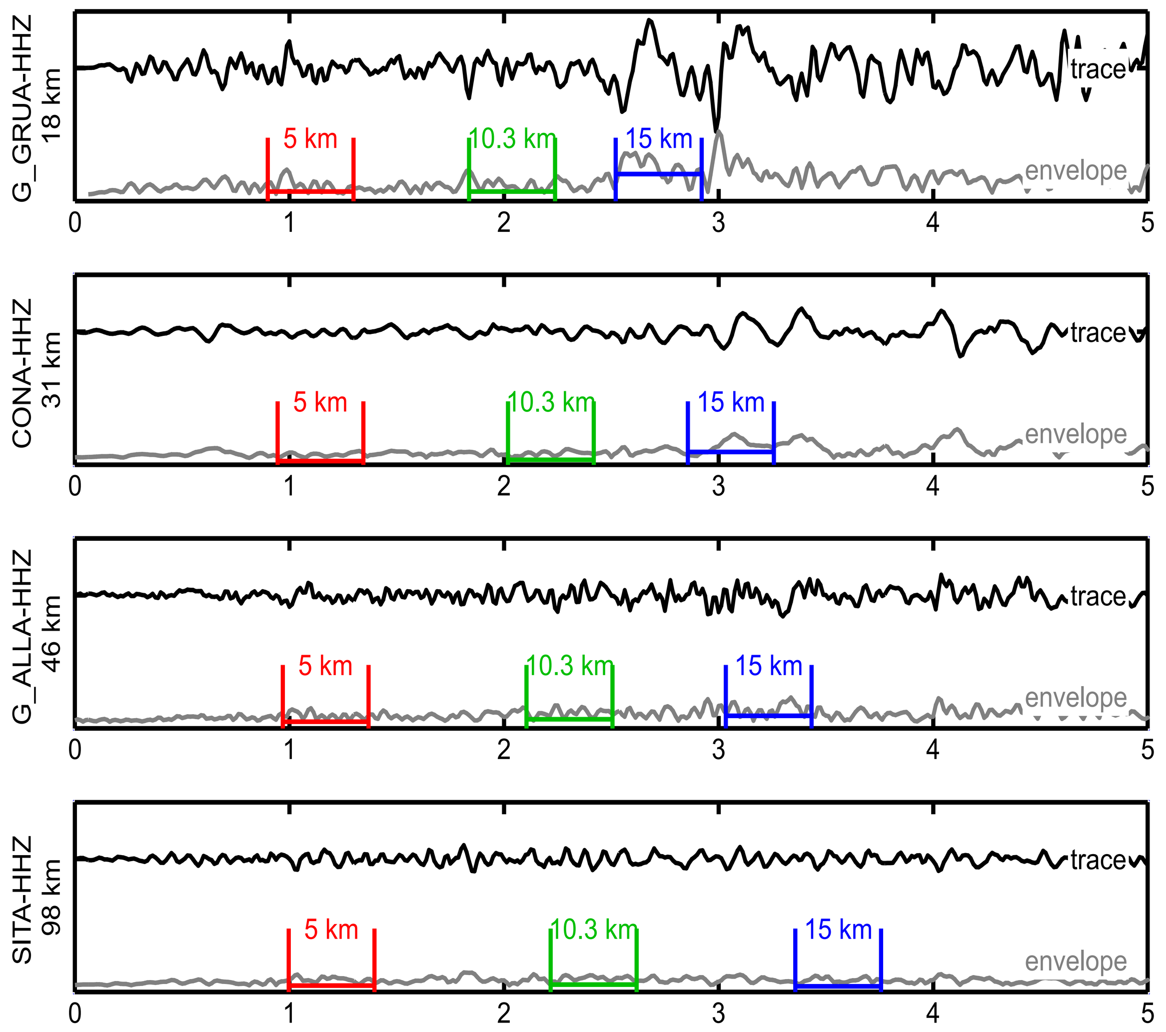
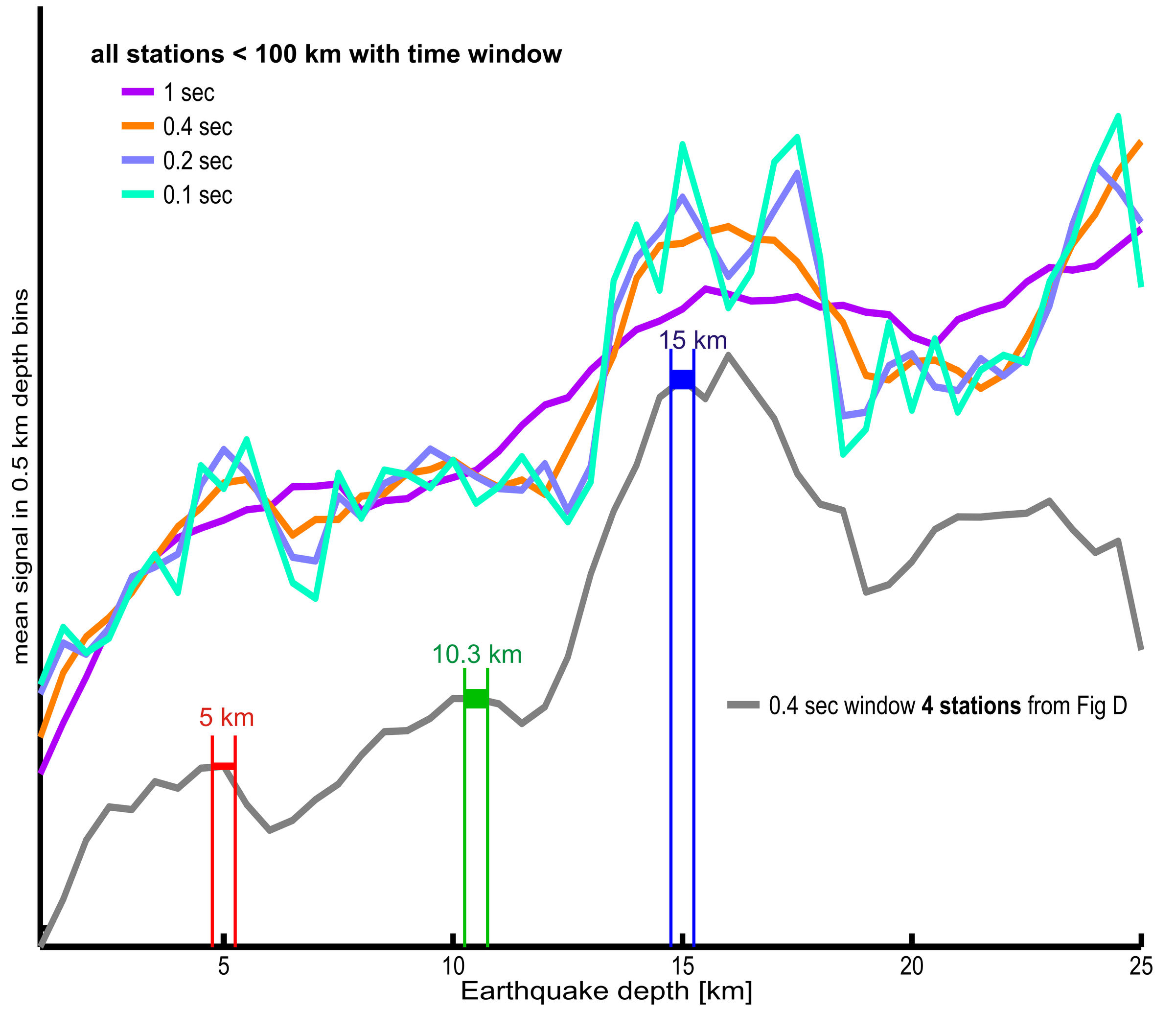


Figure D: Z-traces (black) with envelopes (grey) of 4 stations with sPg moveout for different depths with a sourrounding 0.4 second time window

Figure E: Stacked depth phases for all stations <100km with varying time windows & for 4 Stations (see Fig. D) in grey



Polarization Filtering

We also 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 F shows an example how this filter works on earthquake data. The first part shows the time and frequency dependent filter which gets calculated from the original traces. Part 2 to 4 show the original trace compared to the filtered trace. For reference phase onsets calculated with TauP Toolkit are shown as well.

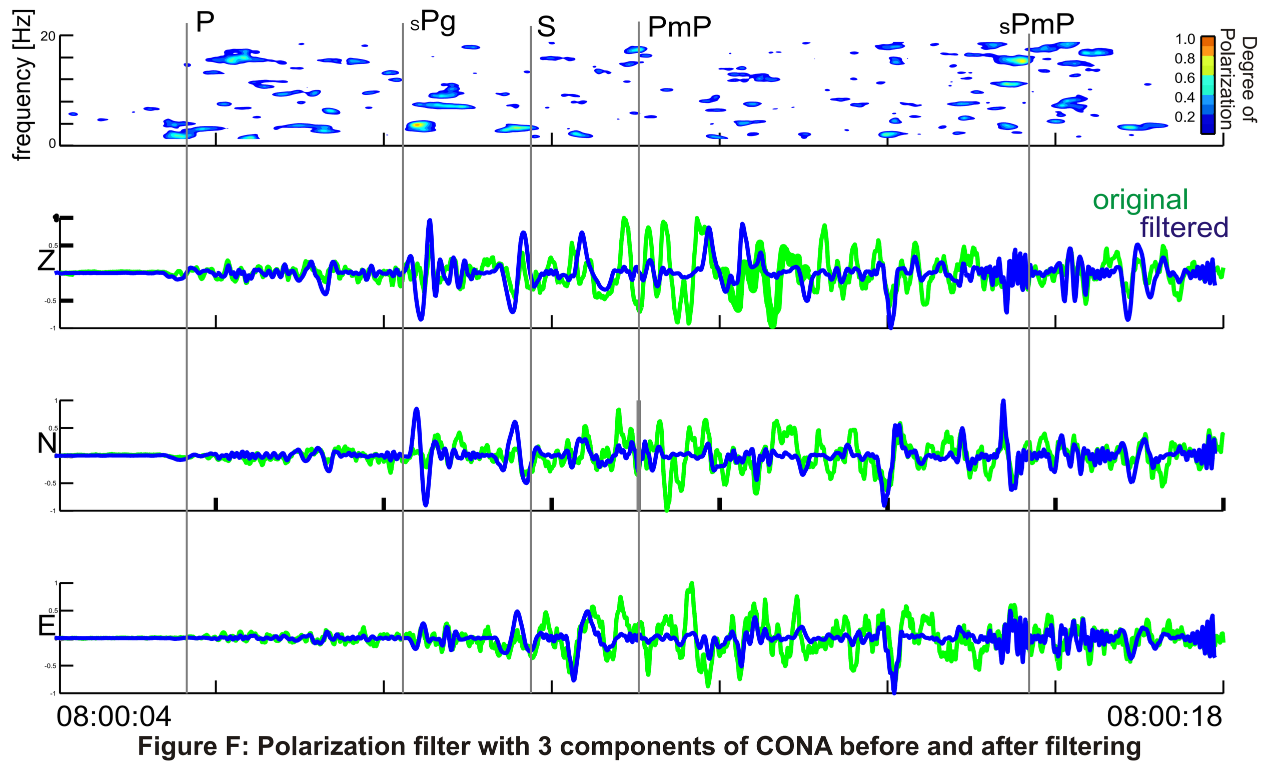


Figure F: Polarization filter with 3 components of CONA before and after filtering

Summary & Further Research

Regional depth phases allow to estimate earthquake depth even if only one depth phase with corresponding reference phase can be identified. The data used in this research does 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 (see figure E), at least for the sPg phases tested. Another approach to this problem was to use a polarization filter, which should strengthen the signal given from depth phases.

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 macro seismic 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 and tested thoroughly. Improvements can be made in combination with other techniques. One possibility is to use the polarization filter before stacking. Correlation and cepstrum technique should also be investigated. A different approach can be made through array processing. An array at a distance where regional depth phases develop well, could help with the identification of phases e.g. GERESS in Germany.

References

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