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Relocation of the Waldkirch seismic event, December 5, 2004, with regional 1D- and 3D-velocity models in the presence of upper mantle anisotropy

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On December 5, 2004 a strong earthquake occurred near the city of Waldkirch, about 30 km's north of Freiburg, with a local magnitude of ML = 5.4. This seismic event was one of the strongest observed since the ML = 5.7 "Schwäbische Alb" event of September 3, 1978, 30 years before. In the aftermath of the event several institutions (Bens, BGR, LGBR, LED, SED and NEIC) have attempted to relocate this earthquake that came up with a hypocentral depth range of 9 – 12 km which. In fact, as the exact hypocentral location of the Waldkirch – and other events in the area - namely, the seismic depths, are of utmost importance for the further understanding of the seismotectonics as well as of the seismic hazard in the upper Rhinegraben area, one cannot over stress the necessity for a hypocenter relocation as best as possible. This requires a careful analysis of all factors that may impede an unbiased relocation of such an event.

In the present talk we put forward the question whether the Waldkirch seismic event can be relocated with sufficient accuracy by a regional network when, additionally, improved regional 1D- and 3D seismic velocity models for the crust and upper mantle that take into consideration Pn-anisotropy of the upper mantle beneath Germany are employed in the hypocentral determination process.

The seismological work starts with a comprehensive analysis of the dataset available for the relocation of the event. By means of traveltime curves a reevaluation of the observed phases is done and it is shown that some of the big observed traveltime residuals are most likely the consequence of wrongly associated phases as well as of the neglect of the anisotropic Pn traveltime correction for the region. Then hypcocenter relocations are done for 1D vertically inhomogeneous and 3D laterally inhomogeneous seismic velocity models, without and with the anisotropic Pn-traveltime correction included. The effects of the - often not well-known - Moho depth and of the VP/VS-ratio across the study area are investigated. Finally a thorough statistical analysis of the hypocentral relocation accuracy and its sensitivity to various observational and model errors is carried out by (1) the classical calculation of covariances and confidence ellipses for the hypocenter and (2) Monte Carlo relocations with random perturbations of the observed arrivaltimes as well as of the choice of the initial hypocenter in the relocation process.

The correction of the original phase-data leads to a shift of the hypocenter to about 10 to 15 km depth instead of 0 – 5 km for the uncorrected phases.The importance of the phase correction is also supported by the final RMS which is reduced from 2.22 s to 1.00 s for the isotropic case and, even more so, from 2.29 s to 0.75 s for the anisotropic. The reduced traveltime plots indicate also that a common VP /VS-ratio of 1.72 for both the crust and the upper mantle does not fit the crustal Sg-phases well. From subsequent hypocentral relocations with separate VP/VS-ratio for the crust and the upper mantle optimal values of VP /VS = 1.70 former, respective 1.66 for the latter, are obtained. In a subsequent set of relocations of the Waldkirch event the recently established isotropic and anisotropic 3D- crustal and upper mantle seismic velocity models of (Muench, 2009; Muench et al., 2010) are employed. Compared with the previous 1D hypocentral relocations where the optimal depth range found is 14 to 15 km, those of the 3D models lie about one km higher. The slightly lower depth of the 3D-models is most likely a consequence of traveltime effects of the structural velocity inhomogeneities.