Chapter 9

Summary

In this study, global high-resolution P-wave velocity models were obtained for the Earth's crust and mantle using travel time tomography. Improvements to previous models were achieved by incorporating additional data and advancing the method to use 3-D reference models.

The newly compiled data set consists of a selection of travel times from the updated EHB catalog (Engdahl *et al.*, 1998), which forms a set of 445,000 events from the ISC bulletins and NEIC data up to September 2004. Compared to the original catalog of 1998 it has more than doubled and contains significantly more regional phases. From this catalog, 17.7 million first and later-arriving P phases and additionally 1.5 million core phases were selected. The selection was extended by 14,000 events from the EMSC bulletins for the period 1998-2003. Furthermore, over 200,000 newly picked, high-accuracy arrival times were incorporated originating from recordings of seismic networks and temporary experiments in Europe and North America which did not report arrival times to the ISC. The picking of the arrival times was performed with the automatic arrival time picker of Sandoval *et al.* (2004a) based on the adaptive stacking method of Rawlinson and Kennett (2004).

Methodologically, besides a standard 1-D Earth reference model, 3-D reference models were used based on a combination of tomography models that use travel time residuals and models that use independent observations from surface waves, normal modes and long period body waves. This approach was used, so far, only by Widiyantoro *et al.* (2000) for S tomography. But in addition, here the selected events were relocated in the respective 3-D reference model using a directed grid-search technique (Sambridge and Kennett, 1986) to establish consistency between travel times and event parameters.

The details and results of these improvements are described in Chapters 3 to 8:

In Chapter 3, the impact of the new regional data (up to the year 1998) contained in the EHB catalog was investigated in a regional Pn tomography study of the crust and uppermost mantle beneath Europe. This analysis showed that for P velocities in the crust and uppermost mantle anomalies of a minimum lateral extent of $0.4°$ can be resolved and for S velocities anomalies of $0.8°$ providing detailed images of the crust and uppermost mantle structure that could not be obtained in a previous study (Bijwaard *et al.*, 1998) using the original EHB catalog. Furthermore, in this study S travel times were used for tomography and tomographic inversions were performed with a 3-D reference model (CRUST2.0 (Bassin *et al.*, 2000) and CUB1.1 (Shapiro and Ritzwoller, 2002)). These inversions show that the data have enough resolving power to change the reference model in regions of good ray coverage whereas otherwise the reference model is reobtained. Besides that, shortcomings of the 1-D Earth reference model ak135 (Kennett *et al.*, 1995) were observed which is too slow for upper mantle shear velocities.

Chapter 4 deals with the newly picked arrival time data of temporary and permanent seismic stations in Europe which did not report arrival times to the ISC and therefore were not used in previous studies. The high quality of these arrival times is revealed in station averages of teleseismic arrivals that reflect the velocity variations directly beneath the stations and is confirmed by lower station standard deviations of residuals than for the ISC data. As a by-product, the error of the ISC data could be determined to be on the order of 0.7 s.

In Chapter 5, the use of 3-D reference models was extended to global travel time tomography and investigated in more detail. In the crust and upper mantle (< 300 km) the model CUB2.0 (Ritzwoller *et al.*, 2002b) was used. The crustal velocities of CUB2.0 are based on CRUST2.0 (Bassin *et al.*, 2000) but were modified in the surface wave tomography to fit the surface wave phase and group velocity observations. Furthermore, for the deeper parts of the mantle, S20RTS (Ritsema *et al.*, 1999) was incorporated as 3-D reference model. As inversions with this combined reference model showed, regions in the mantle exist where ray sampling is sufficient to obtain a tomographic model comparable to the one using ak135 as reference model. But where ray sampling is not sufficient to allow for larger deviations from the reference model, the small-scale Earth structure observed using a 1-D reference model is overprinted by the long wavelength 3-D reference model. Therefore, in a further tomographic inversion the long wavelength reference model was combined with the model obtained from travel time tomography using a 1-D reference model. However, before combining the models, the anomalies in the travel time tomography model were enhanced to correct for underestimation of model amplitudes due to regularization. The resulting model combines the long wavelength structure as ”seen” by long period seismic information with the detailed mantle structure obtained from short period data. Using a 3-D reference model also has the advantage, that the inversion model now implicitly contains more realistic velocities in areas that were not well constrained by P travel times.

In Chapter 6, the influence of the newly picked data for seismic stations in Europe and additional information from core phases not used previously was studied. Due to the additional data, more detail is seen in the upper 400 km, particularly in regions with few seismic stations and/or earthquakes. Furthermore, features that were already observed earlier are enhanced. Besides that, the core phases help to constrain anomalies in the lowermost mantle and greatly improve imaging of the hot upwelling beneath Central Europe which is suggested to be the source of recent volcanism in the area (Goes *et al.*, 1999).

In Chapter 7, focus is on North America and the newly incorporated data for seismic stations in that regions. The Earth’s structure is imaged in high resolution comparable to regional tomographic studies and due to the new data set the remnants of the Farallon plate, an ancient oceanic plate, could be located in the upper mantle transition zone.

Finally in Chapter 8, an application of the new high-resolution tomography model was presented. Tests with well-located events demonstrate that the new model predicts, particularly at regional distances, arrival times better than a 1-D velocity model, and that consequently epicenter mislocations and origin time errors are significantly reduced due to the new model. The relocation of the global earthquake data set used in this study corrects earthquake locations for 3-D Earth structure not taken into account by the original locations obtained with ak135 as reference model. In addition, a better focussing of earthquakes in narrower clusters is achieved due to the new tomography model, particularly in the deeper parts of subducted slabs (> 150 km depth).