Summary

An important factor in the study of lithospheric deformation is an accurate representation of the kinematics of the Earth's crust. This thesis presents a new inversion method, introduced in the first part of chapter 2, to model the present-day kinematics of the deformation field of the Earth's surface by the use of (space) geodetic measurements of relative motion. The aim of the method is to represent the kinematics of the crustal deformation field without implicitly relating kinematics to the style of deformation at depth and without restrictions about the spatial scale of the region under consideration.

The method inverts relative motions between all pairs of stations of a particular velocity data set (in this thesis mainly GPS data), in a regularized least-squares approach, for the velocity gradient field in crustal blocks and for fault motion on the active faults or block boundaries. The incorporation of fault motion is motivated by the fact that the velocity field of the Earth's crust on short time scales, as represented by space geodetic data, is not necessarily a continuous function of spatial coordinates. Faults accommodate slip and represent boundaries between moving plates or blocks, whatever the deformation at depth may be.

In the second part of chapter 2 the method is tested on a synthetic velocity field. The synthetic velocities sample a region intersected by two, freely slipping faults and represent a deformation field that results from the application of shear stresses assuming an elastic rheology. Results demonstrate that the method works well in obtaining joint estimates of the velocity gradient field and slip on active faults. The data are fit within their error bounds for solutions that are well resolved and have acceptable covariance. Model misfit patterns can be sufficiently minimized and basically can be understood as a combination of lack of data and absence of a constraint on the coupling between fault position and velocity gradient field, the latter as a direct result of the purely kinematic definition of the method.

To investigate the performance of the method in modeling continental deformation patterns it is applied to a relatively dense data set, which samples the Aegean velocity field, as a first application to the real Earth in chapter 3. Comparison between a solution for the lateral velocity gradient field only (I) and a solution for the lateral velocity gradient field and horizontal fault motion (II), in which the main fault zones and plate-boundaries are incorporated, shows that the main differences are found at the areas, where faults accommodate strong slip rates. Besides decrease of the average magnitude, the spatial distribution of the velocity gradient field is different. Further exploration of the trade-off between fault motion and the velocity gradient field shows that parameterization of large faults only renders a continuous deformation solution that probably represents slip on non-parameterized faults combined with distributed deformation in the crust. If only observation sites are used far away from faults, the estimated fault slip reflects predominantly (long term) crustal block motion, i.e. independent of fault locking. If sites are used close to faults, the actual fault motion prevails in the estimate which includes obtaining zero motion if a fault has been locked during the observation period. Insignificant slip rates in combination with strong variations in the velocity gradient near the fault trace suggest fault locking and/or surface creep processes associated with fault activity at depth. Using observation sites close to faults is the only possibility to reduce trade-off effects.

In general, the properties of solution I agree with results from earlier geodetic studies solving for the lateral velocity gradient field on regional and local scale. From comparison of solutions I and II with shallow earthquake and stress data both patterns of agreement and disagreement are found. Possible causes for these discrepancies are errors in the model, errors in the moment tensor estimates or differences between the near surface and deeper crustal deformation, the latter suggesting that combining geodetic data with moment tensor solutions is not straightforward. Solution II enables to define the distribution of crustal deformation in terms of concentrated deformation (i.e. fault motion) confined to the main fault zones of the Aegean region and distributed deformation of fault-bounded blocks. The good agreement between orientations of the derived slip solution and geological observations and geodetic derivations and the consistency found between rotation rate results and young paleomagnetic observations suggest that solution II reflects larger-scale crustal block motion. A new, detailed view on the present-day kinematics of the Aegean crustal deformation field is presented.

To investigate the performance of the method in modeling the kinematics of crustal deformation of larger-scale regions where the interaction of tectonic (micro-)plates determines the surface velocity field, the final application of the method, presented in chapter 4, is to a combination of GPS data sets obtained in Southeast Asia. Although the data densely sample some regions within the plate boundary zones of Southeast Asia, the overall density necessitates to apply a relatively sparse parameterization for the whole model region. Comparison of a solution for the lateral velocity gradient field only (I) with a solution for the lateral velocity gradient field and fault motion (II) shows that the velocity gradient field of solution I is relatively strong at the interiors of the plates, whereas the main deformation features of solution II are located in the plate boundary zones. Inversion for the velocity gradient field and fault motion simultaneously enables the accommodation of localized motion on faults or plate boundaries and offers insight in the distribution of relative plate motion in plate boundary zones in terms of slip, (micro-)block rotation and strain rates.