Crustal Deformation

W. AUGATH

General trend

The determination of crustal deformation takes profit from the general progress in the field of reference systems and their realisation. Due to the fact that modern reference systems are realised on a kinematic basis with the parameters x,y,z and the corresponding velocities, these results can also be used for the determination of crustal deformation.

In the last period 1999-2003 further progress have been reached in:

- **developing** global geodetic models of kinematics [e.g. APKIM-model of Drewes (1999) and Angermann and Drewes (2000)] including the border zones [Heidbach (2000), Klotz (2000)],
- **measurements,** especially with global space techniques like SLR, VLBI and GPS [see section I or e.g. Angermann et al. (2002), Campell et al. (2002), Tesmer (2000), Seemüller et al. (2002)],
- **geodetic infrastructure** realised with fundamental stations, the IGS and his continental and national densifications.

Classic methods of measurement have mostly been replaced by space-based techniques and are only used today on a local basis or in areas where satellite techniques are not available. In the field of vertical deformation the precise levelling remains important but mainly as precise representation of the geometry 50..100 years ago [e.g. Sacher et al. (2000)]. On the other hand repeated absolute gravity measurements are increasingly in use for the determination of height changes [e.g. Torge et al. (1999)].

Meanwhile the high density of permanent geodetic infrastructure allows the connection of all regional and local projects and campaigns to the ITRS/ ITRF. This leads not only to a higher quality of the results without additional costs. The possibility of the determination of deformations on a local, regional as well as on a global level with the same data set leads to advantages in the methodology, too [e.g. the local NNSAT-project, Augath et al. (2001)].

The level of communication also allows the monitoring of relevant points up to real time. Last but not least the level of interpretation of geodetic results takes profit from the higher quality of the results in general and especially from longer time series.

Projects and campaigns

The projects and campaigns in the last period are spread over the whole world and continue former activities. Due to the technical progress and the additional observation period of four years, the results are more reliable so that their interpretation come to the fore.

On the global level e.g. Grafarend and Ardalan (2001) determine significant changes of fundamental geodetic parameters of the World Geodetic Datum 2000. Krumm and Grafarend (2002) define datum-free deformation measures and analyse the co-ordinates of ITRF networks. Fennoscandia [Göbell et al. (1999)] and Southeast Alaska [Bölling et al. (2001)] are used as test areas with post glacial rebound effects and actual geodetic measurements for the explanation of measured land uplift rates with geophysical models.

The stability of the European plate leads to a concentration of the activities on border zones and areas outside the so-called “stable part” of Europe. In Germany two areas remain, the North Sea Coast where the height component is of special interest [Augath et al. (2001)] with special investigations including GPS signal validation and the integration of Water Vapour Radiometer measurements. Horizontal movements are being investigated in the Rheingraben [Heck (2000)] including the integration of classical and GPS-observations. The determination of height changes also is the main focus of the Alp-traverse [e.g. Schmitt and Lemp (2001) and Marchesini and Schmitt (1999)]. The interesting areas of Eastern Europe are being investigated within the CERGOP-activities. This project combines permanent and epoch-based GPS observations in order to determine the velocity field and present day tectonic deformations in the Central European area. A uniform solution combining all previous solutions was derived [Becker et al. (2002a) and Becker et al. (2002b)]. Studies on GPS data analysis and the integration of additional sensors both for the CERGOP and the WEGENER project were analysed in [Becker, Bruyinx and Frenandez (2002) and Becker, Häfele and Pesec (2002)].

A special focus on Romania is given by Dinter and Schmitt (2000) and Dinter et al. (2001).

The main activities around Europe are concentrated on border zones: e.g. Island [Völksen (2000)], Adriatic Sea [Altiner et al. (1999)], the West Hellenic and

Calabrion Arc [Kaniuth et al. (1999)] and various areas in Turkey [Altiner et al. (1999].

Asia constitutes an important area of investigations with the projects CATS and GEODYSSEA.

New results from the CATS (Central Asian Tectonic Sciences) project confirm the current high rates of tectonic deformation far north of the India-Eurasia suture zone and quantify the partitioning of deformation within the seismically active Tien Shan and Northern Pamirs [Reigber et al. (2001)]. Regional deformation rates have increased considerably within the study area since the onset of shortening 20-25 million years ago. The virtually undeformed Tarim block rotates with respect to stable Eurasia. There are plans to extend the existing network to other tectonically active areas of the Eurasian plate.

GPS-observed displacement vectors derived in the framework of the GEODYSSEA network confirmed that Sundablock constitutes a stable tectonic block moving approximately east with respect to Eurasia at a velocity of 12 +/- 3 mm/yr [Michel et al. (2001)]. No significant motion has been detected along the northern boundary to South China.

In Thailand and Malaysia a combined network for national control network purposes as well as for kinematics was realized as densification of GEODYSSEA [Becker et al. (2000)].

South America is another important area of investigations due to the activities of DGFI and GFZ.

The international Central and South America Geodynamics project CASA supervises the border zones between the Caribbean and South American plate with GPS [Drewes (2002)]. Within this area the behaviour of selected reference stations are investigated, too [Kaniuth et al. (2002)].

The results of the SAGA (South American Geodynamic Activities) network contribute to a better understanding of the earthquake deformation cycle as well as to a better understanding of mountain building processes [Klotz et al. (2001)]. The present-day deformation of this area is dominated by transient effects related to subduction earthquakes. Most of the transient deformation can be explained by interseismic, co-seismic, and post-seismic phases of interplate thrust earthquakes. The area of the great 1960 Mw 9.5 Chile earthquakes shows a pronounced postseismic deformation 40 years after the event and a significant change in the displacement field with time.

An additional area of scientific research is Antarctica. Dietrich et al. (2001) report about the realisation of the ITRF co-ordinates and velocities from repeated GPS-campaigns (SCAP project 1995-1998).

Most of the reports are based on GPS-measurements which meanwhile have reached an excellent performance especially with permanent observations.

The activities for modern kinematic height networks, as proposed in the European EVS 2000-project [Augath et al. (2002)], include not only repeated national levellings and the results of GPS-permanent stations. In addition precise gravity measurements and extractions from tide gauge observations are included, too, with the goal of a higher reliability of the results.

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