



Geodetic Research in the Alps: A contribution of the Bavarian Academy of Sciences and Humanities.

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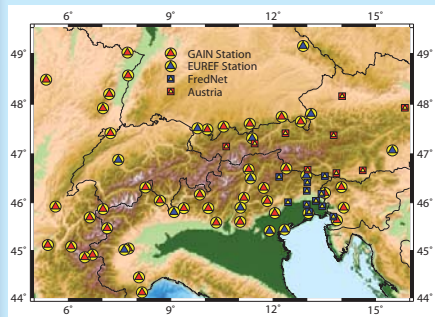
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Geodesy is a part of the earth sciences that is mainly concerned with measuring and describing the Earth's surface and its gravity field. Due to modern techniques with increased accuracy and high resolution in time and space it is also a valuable tool for monitoring geodynamic processes that have an impact on the figure of the Earth or its gravity field.

The Alps have been formed by the collision of the African and the Eurasian plate and consists of mountains formed by folding. It is a zone of diverse geodynamic processes of the crust. Some zones are characterized by high seismic activity with earthquakes that endanger people's life and can cause severe damages to the infrastructure. Another aspect is that global warming increases the melting of the alpine glaciers and therefore influences the hydrosphere of the Alps. Modern geodetic techniques like GNSS (Global Navigation Satellite System, e.g. GPS) or gravity surveys are an important tool for monitoring geodynamic processes and related mass changes (e.g. in the cryosphere) in the Alps.

The ALPS-GPSQUAKENET Project

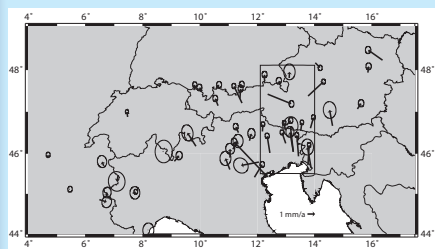
This project has been initiated in 2004 and has been co-funded by the European Union's Interreg IIIB Alpine Space program. A network - known as the Geodetic Alpine Integrated Network (GAIN) - consisting of 40 permanently observing GPS sites has been installed during a three year period with partners from the alpine countries and delivers up to today valuable data for monitoring crustal deformation in the Alps. Together with permanent GPS sites of other research



groups (e.g. Austria, EUREF and FredNet) the network has been densified and is monitored since then. With an accuracy of a few millimetres position changes can be resolved with a very high temporal resolution.

Figure 1: The distribution of the analysed permanent GPS sites in the alpine region.

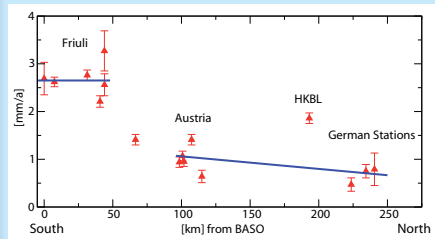
The first analysis of the data shows an only very slowly deforming crust. So far only horizontal signals were clearly identified, while a significant vertical signal could not be extracted indicating a very small signal for the vertical of less than 1 or 2 mm/a. The complete horizontal deformation can be seen in figure 2, where the horizontal movements



(given in millimetres per year) are displayed relative to the Eurasian plate.

Figure 2: Horizontal velocity field of the GAIN with 95% confidence ellipses related to the Eurasian plate. The box marks the so-called profile zone.

Figure 2 shows a much higher spatial resolution in the Eastern Alps than in the Western Alps due to the larger amount of permanent GPS sites. Larger signals are visible in the Eastern Alps, especially in the region of Friuli where the Friuli Deformation Network is installed (FreDNet). The area marked as profile zone shows the largest deformation with a similar pattern (northward motion). While the Italian sites show an average motion of about 2.5 mm/a the signal clearly decreases to about 1 mm/a in the region of Austria and decreases even further



to the North (see Fig. 3). This compression can possibly generate stress that is released in earthquakes or it is used for building up mountains.

Figure 3: Northward motion plotted against the distance of the station BASO. Velocities are expressed relative to the stable part of Eurasia.

Gravimetry

The gravity field of the Earth is generated by all masses of the Earth system. The intensity of the field at a certain location is measured by the method of gravimetry. The observed gravity value strongly depends on the surrounding masses. Therefore gravimetry can be used as a tool to observe mass distribution and transport and dedicated observation station exist around the world. Examples of observable signals are temporal variations in continental water storage or glacier melting. The equipment ranges from heavy stationary instruments permanently installed at well selected places to small mobile devices and there are so called absolute gravimeters (measuring the absolute gravity value of about 9.81 ms^{-2} to about eight decimals) as well as relative ones (where only gravity differences between two or more stations can be observed).

Related to the already mentioned ALPS-QUAKENET project, absolute gravity values have been determined in collaboration with the German Bundesamt für Kartographie und Geodäsie (BKG). Repeated observations after time intervals of several years reveal temporal gravity variations. Picture 1 shows the mobile absolute gravimeter A10 owned by BKG during the initial observation at mount Wartsteinkopf in 2005. The first repeat measurements are planned for 2011.

Picture 1: The mobile absolute gravimeter A10 owned by the BKG during measurement close to the GPS pillar (in the background) of the GAIN station at mount Wartsteinkopf in 2005.



A different project has just started on Vernagtfermer glacier in Ötztal, Austria. Mass variations of the glacier are well known from long glaciological records. Thus the glacier is a perfect validation area for local gravimetric studies. In the coming years repeated gravity measurements are planned to exploit the capacity of the gravimetric method and contribute to local mass balance studies. Picture 2 shows a relative gravimeter of type LaCoste&Romberg (LCR-G) at a reference point situated on solid rock in vicinity of the glacier. A collocated GPS antenna serves as master station for precise positioning of all gravity measurements.

Picture 2: A relative gravimeter LCR-G observing at a reference station on solid rock.



Picture 3 shows two LCR-G gravimeters simultaneously observing gravity differences between the reference station and points on a traverse over the glacier surface. With such differences changing over the years, the mass balance of the glacier can be studied.

Picture 3: Field work on the glacier surface.

