CHCGN activities in Switzerland

Activities for a Swiss Combined Geodetic Network

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1 Introduction

The combination of different geodetic networks and observation types is of great importance on a national and on a European level. The consistency of the different spatial reference frames, the height systems and the geoid is a main objective for all European national agencies working in the field of geodesy.

On the European level the two projects ECGN [Ihde, 2002], handling different observation techniques at fundamental stations, and EUVN-DA [Kenyeres, 2002], dealing with a densification of the networks, are covering these aspects. The contribution of the Federal Office of Topography (swisstopo) to these two projects is shown in section 7.

On the national level swisstopo is working in the same direction since several years. The project with the working title Swiss Combined Geodetic Network (CHCGN) is the counterpart to the ECGN project. Comparable to the densification project EUVN-DA are the CHGeoid2003 activities, which will help to achieve consistency between the Swiss reference system CHTRS95, the height system LHN95 and the Swiss geoid model CHGEOxx (xx presently 98).

2 The reference frame LV95

There are a total of 206 well-monumented control stations serving as the basis for the reference frame [Vogel et al. 2003]. Furthermore an array of 29 permanent GPS receivers (AGNES network) is used to maintain the reference frame. The definition of the Swiss reference frame, which is aligned to ETRF93, is explained in [Wiget et al., 1996].

The final set of coordinates defining the reference frame LV95, which is a static reference frame in contradiction to the dynamic reference frame CHTRF95, are derived with classical GPS campaigns from 1988 - 1994 using the Bernese GPS Software [Hugentobler et al., 2001]. Since that time many additional GPS observations were collected either from campaigns or from the AGNES network (see Table 1). Since 2002 it is possible to process GPS campaigns together with the AGNES sites in a semi-automated way. This includes the data handling (RINEX files, satellite orbits, etc.), the automated setting of the processing options (baseline selection, ambiguity resolution strategy, observation types L1, L2 or ionosphere-free linear combination L3) and the generation of a processing log-file in html.

GPS data / Campaigns	Campaigns / Stations	Date
LV95	24 campaigns, 278 points	1988 - 1995
LV95 densification	32 campaigns, 134 points	1995 - 1998
CHTRF98++	8 campaigns, 215 points	1998 - 2002
EUVN97	1 campaign, 217 points	1997
AGNES	4.5 years permanent observed 85 points	1998 - 2003

Table 1: GPS campaigns used for the generation of a combined solution

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All these GPS campaigns are adjusted in a rigorous way based on the combination of normal equations. The scheme is given in Figure 1. Only a single campaign (the very first GPS campaign NEO88 with partly L1-only receivers in 1988) was excluded from the combination, because of too many outliers. Velocities are estimated in the sequential adjustment of the AGNES data. They don't exceed the level of 1-2 mm/year horizontally. The coordinate set of the mean epoch was then introduced as input to the combined adjustment. In this solution no velocities were solved for.

Approximately 136 sites have a connection to levelling points.

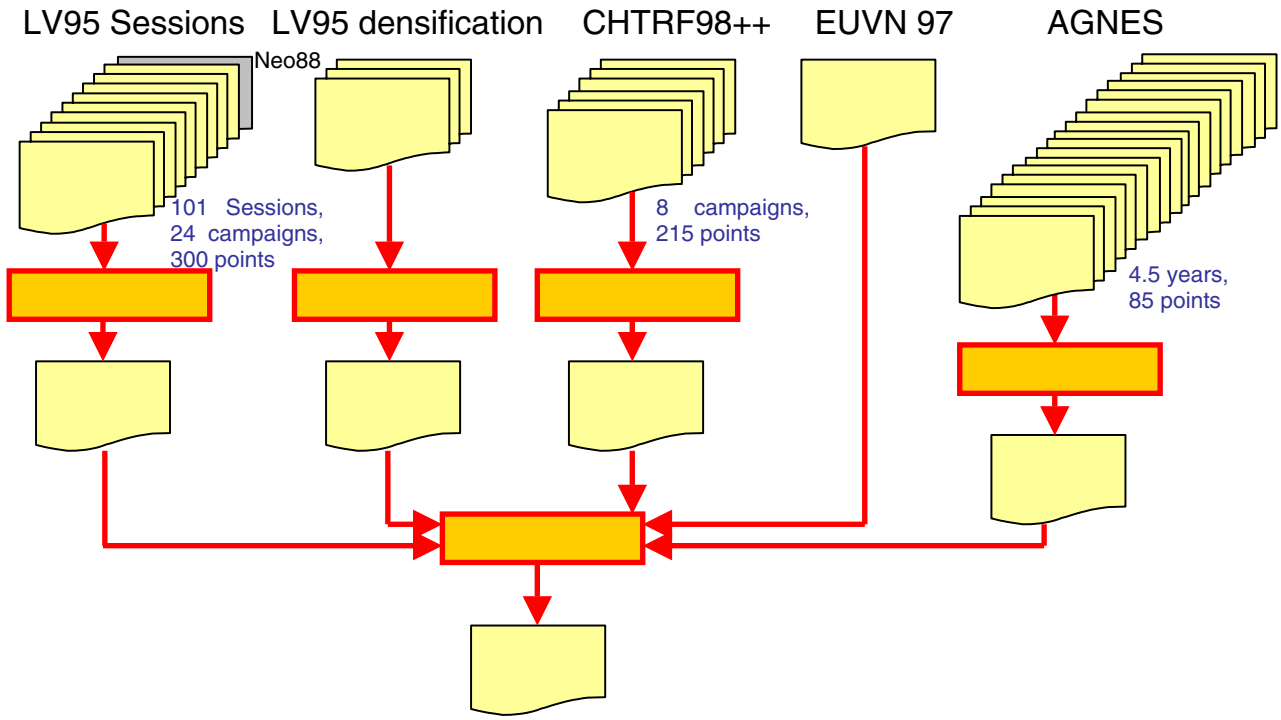

Figure 1:Combination scheme of the GPS observations based on normal equations

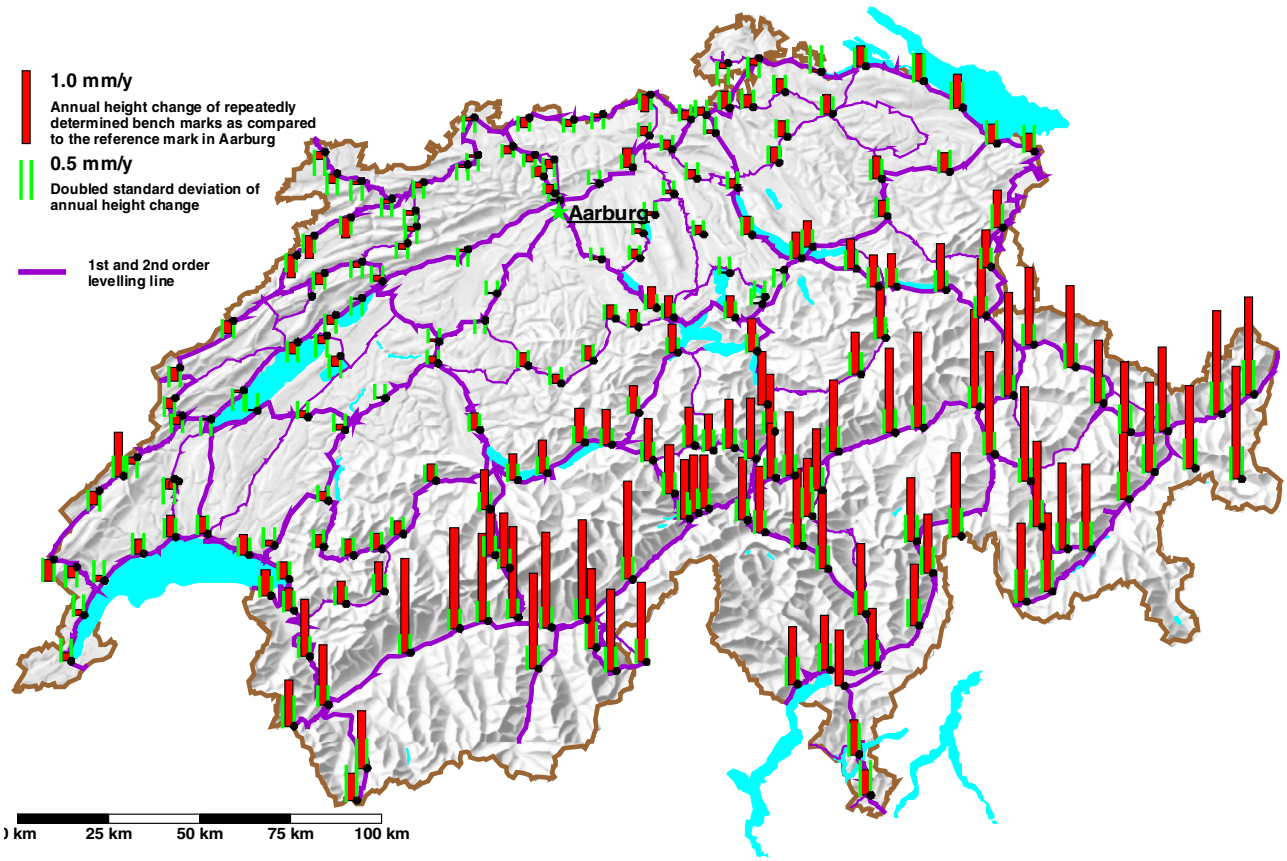

Figure 2:Vertical movements determined from the analyses of the levelling network LHN95

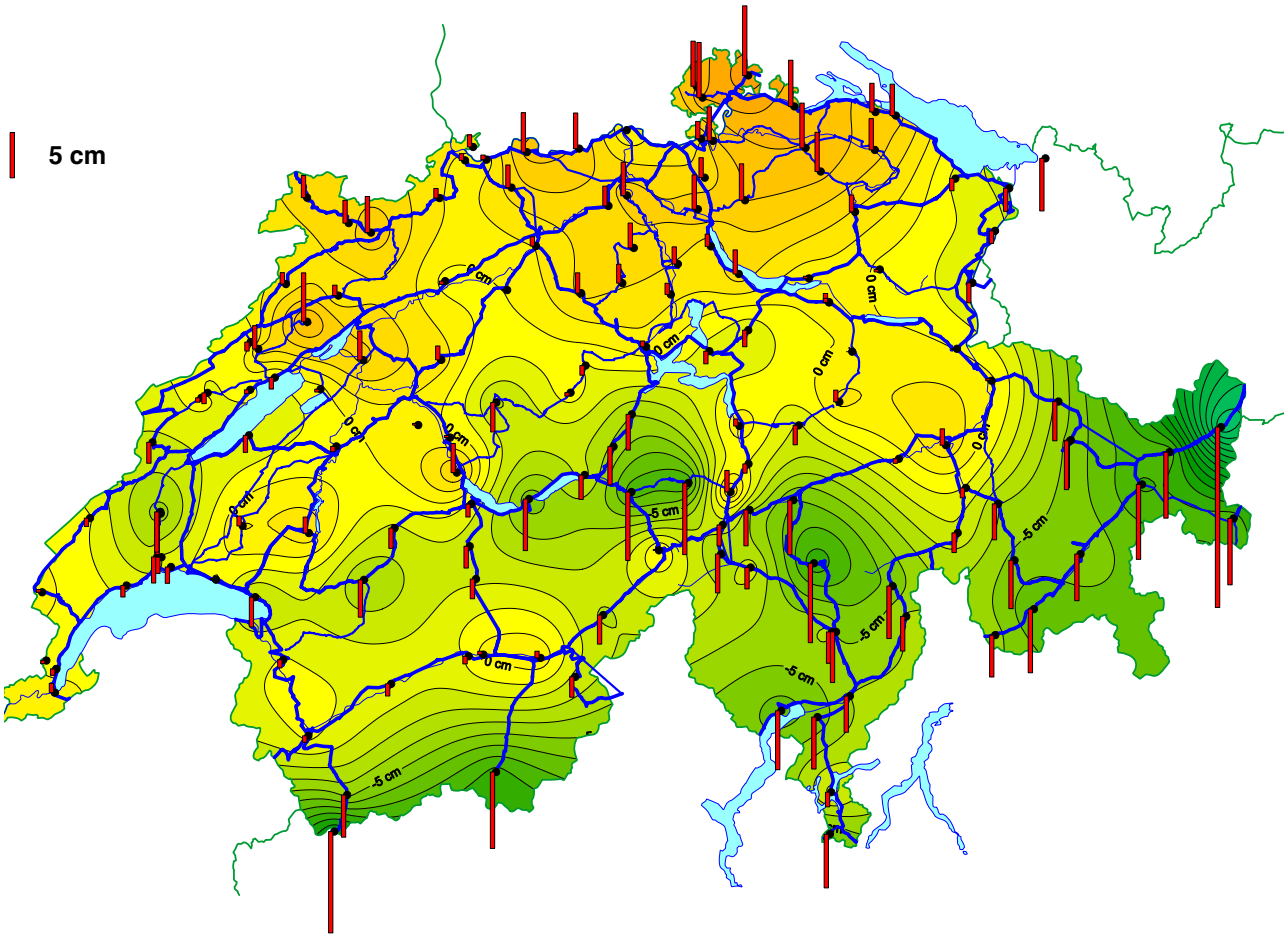

Figure 3:Differences of the GPS–levelling points with respect to the geoid

3 The height reference frame LHN95

The concept of the new national height network LHN95 is based on the combined kinematic adjustment of repeated levelling (measured since 1903) and gravity data. The orthometric heights of LHN95 should then be consistent with heights from GPS and the corresponding geoid. The height reference system was described in the previous national report *[Schneider et al., 2002*].

Most of the levelling lines are observed twice, some even three times. A result of the kinematic adjustment is given in Figure 2. It is clearly visible that the Alps in Switzerland are rising with a rate of up to 1.5 mm / year.

4 The Swiss geoid CHGEO98

The geoid model CHGEO98 is based on the work of *[Marti, 1997].* The main characteristics of the geoid model can be expressed as:

- Observations used:
  - about 600 deflections of the vertical (status 1996)
  - about 70 GPS/Levelling stations (status 1996)
  - about 3500 gravity measurements (status 1980)
- Models (Remove) used:
  - Elevation model DHM25 (status 1996) + DTED1
  - Moho model (1994)
  - Ivrea model (1989)
  - Additional models (Po-Sediments, glaciers ...)
- Accuracy:
  - 2 - 3 cm in the flat areas
  - 3 - 5 cm in the Alps

5 Differences of GPS-levelling points with respect to the geoid

The differences of the GPS–levelling points with respect to the geoid are shown in Figure 3. The systematic trend of +5 cm (north-west) and -8 cm (south-east) is obvious. Furthermore there are also some irregularities in certain areas (e.g. in the center of the Alps or near the eastern border to Austria).

Possible reasons are problems with the mass models and digital terrain models used for the geoid computation and also errors in older measurements of the deflection of the vertical.

An attempt was also carried out, to make a rigorous combination of geoid estimates, levelling and GPS heights using the full variance-covariance matrix *[Marti, 2002].* Depending on the variances and the correlations the residuals are differently distributed between each technique. Such an approach is useful, if no systematic errors are present.

In order to compute a geoid which is consistent to the different observations, it is planned to use also gravity data (after a serious analysis of possible outliers) and to analyse the effect of the different observations by computing different geoids (gravity-only geoid, astro-only geoid, GPS-levelling-only geoid).

6 Planned observations 2003: CHGeoid2003

In order to solve the problems of the systematic differences shown in the previous section a densification campaign CHGeoid2003 is planned. 37 new GPS-levelling sites will be measured in 2003. The main focus is to densify the network in areas near the border and in areas were un-reasonable large discrepancies between GPS, levelling and geoid are observed. Due to the fact that the sites are close to the levelling points it is not always possible to guarantee perfect visibility for GPS for all sites in the Alpine area. It is therefore planned to observe at least 3 x 24-hour sessions to guarantee a reliable GPS height estimation.

For the network of sites with measured deflections of the vertical, it is planned to carry out new measurements in October 2003 for approximately 50 sites using the new automated zenith camera of the teams at the ETH Zurich and the University of Hannover *[Hirt et al., 2002].*

7 Contribution to EUREF

Beside the activities of improving the consistency between GPS, levelling and the

geoid on the territory of Switzerland in a very densified way, Switzerland contributes to the two EUREF projects ECGN and EUVN-DA, which are partly addressing the similar goals.

7.1 ECGN

Switzerland contributed to the call of participation to the European combined Network (ECGN) *[Ihde, 2002]* with a proposal beginning in 2003.

All proposed activities are related to the fundamental station Zimmerwald. Many of the observations are performed already today. Some other observations are still on the "pendence list". A concrete list of actions and responsible organisations, respectively persons is given in Table 2.

	Geodetic observations	Type	Interval	responsible organisation
1	SLR observations (dual color)	permanent	24 h	AIUB
2	Positioning using GNSS (GPS, GLONASS, GALILEO)	permanent	24 h	swisstopo
3	Astro geodesy (digital zenith camera)	repeated (epochs)	10 years	IGP ETHZ
4	Optical astronomy with CCD arrays (link to astronomical reference system; project CQSSP)	epochs	sub-yearly	AIUB
5	Absolute gravity measurements (FG5)	repeated (epochs)	yearly	metas
6	High-frequency gravity variations (tidal gravimeter)	permanent	1 min	IGP ETHZ
7	Gravity field related heights and relative vertical velocity (links to the EVRS)	repeated epochs	10 years	swisstopo
8	Meteorology (air temp., pressure, humidity) WV radiometry / spectrometry	permanent epochs	24 h repeated	AIUB IGP ETHZ
9	Eccentricities through local network and through links to the national reference networks	repeated	yearly	swisstopo

Table 2: Planned actions within ECGN for station Zimmerwald and responsible organizations/persons

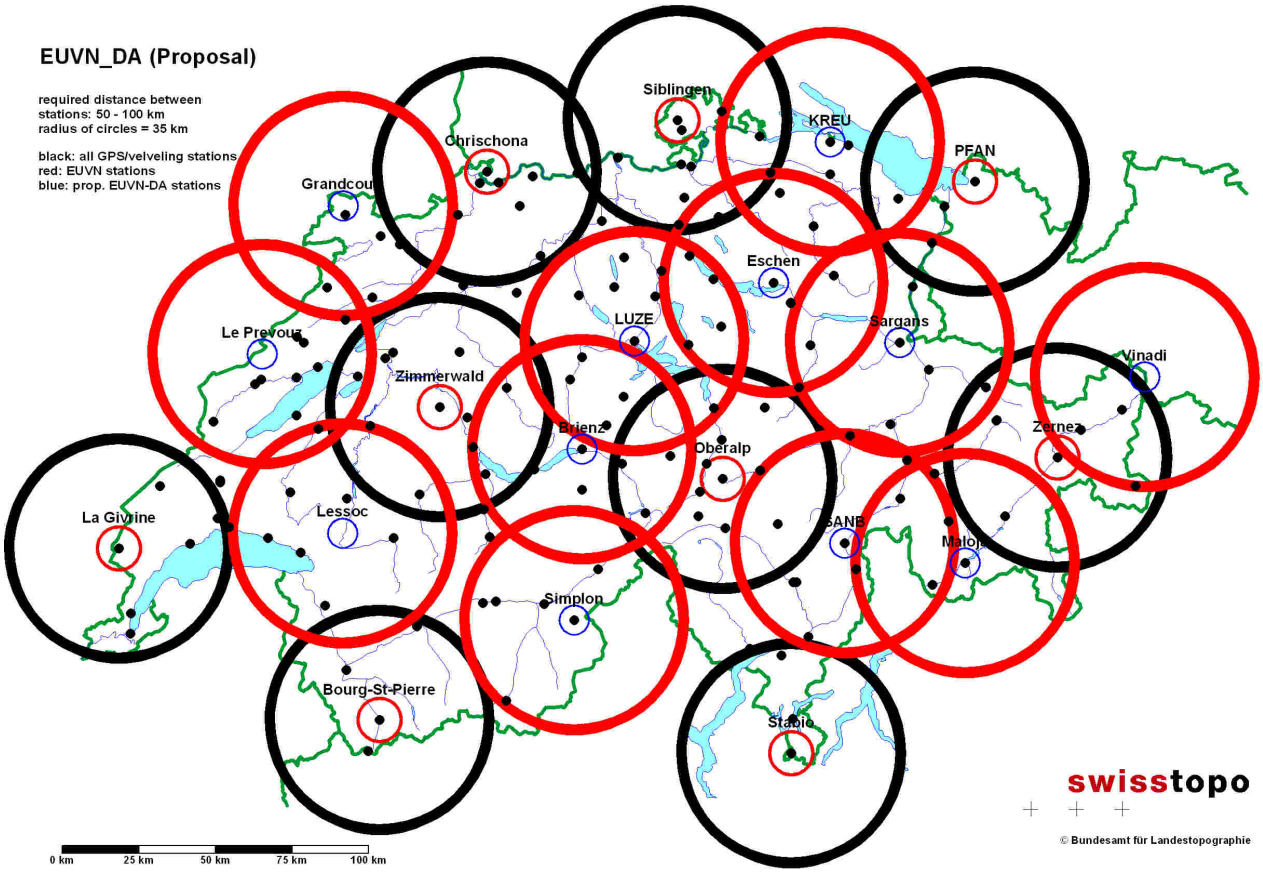

Figure 4:Proposed contribution of Switzerland to EUVN-DA

7.2 EUVN-DA

An extraction of the dense Swiss national reference networks is provided to EUREF in the framework of EUVN-DA. Figure 4 shows the proposed sites. In addition to data of the 9 sites provided already to EUVN it is planned to provide the data of additional 12 sites. With these sites the density of the network is decreased from below 100 km to below 35 km.

8 Conclusion

To achieve consistency between different observation techniques is a great challenge for all groups working in the field of geodesy. A success is only possible with a perfect team work between the specialists of the different areas.

It was shown that on the national level much work was done in order to approach that goal.

On the European level the two projects ECGN and EUVN are heading in similar directions. Switzerland appreciates to give its contribution to both projects.

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