Application of the Swiss Projection System in GIS Software

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Table of content

1 The Swiss Reference System and Map Projection

This short introduction gives the main parameters and facts about the Swiss reference systems and their realisations used in the twentieth century. These are the system CH1903 and its realisation (reference frame) LV03 which is based on triangulation measurements and the modernisation CH1903+ and its realisation LV95 which are based on GNSS measurements. For scientific purposes and for data exchange there exists as well the reference system CHTRS95 and its realisations CHTRFyy, which are aligned to the European reference system ETRS89.

Vertical reference systems and frames are not considered in this short overview.

1.1 CH1903/LV03

Since 1903, Switzerland uses as official map projection an oblique Mercator projection on the Bessel ellipsoid. The reference system (later named CH1903) is defined by the ellipsoidal coordinates of the fundamental station and projection centre at the old observatory in Berne. In the original publication (Rosenmund, 1903), the latitude of the fundamental station was fixed to

$$\varphi_0 = 46° \ 57' \ 8.660'' \text{ North}$$

The longitude of the fundamental station was originally fixed to 0° (use of the meridian of Berne). Later, the longitude was determined as

$$\lambda_0 = 7° \ 26' \ 22.50'' \text{ East of Greenwich}$$

The dimensions of the Bessel ellipsoid are the following:

Semi major axis:	a = 6'377'397.155 m
Semi minor axis:	b = 6'356'078.96325 m
inverse flattening:	1/f = 299.1528128

Originally, the projection centre obtained the plane coordinates 0 /0. The east axis was denominated "y" and the north axis "x". Later, the so called "military coordinates" were introduced, where the projection centre obtained the coordinates (false easting and northing) y=600'000 m and x=200'000 m. The purpose of this system was to avoid negative numbers inside Switzerland and to avoid confusion between easting and northing (easting is always bigger than northing in and around Switzerland). These military coordinates were adopted later as well in cadastral and national survey. But in some regions the original coordinate system (nominated now "civilian coordinates") were still used for decades.

The reference system CH1903 was realised by a classical triangulation network with some additional astronomical and distance observations, densified by cadastral survey. This reference frame was later called LV03 (Landesvermessung 1903) or in French and Italian MN03.

The original publication of the reference system and the projection formulas are given in Rosenmund (1903). The main parts of it in a more modern presentation (swisstopo, 2008) can be downloaded from the swisstopo website at http://www.swisstopo.admin.ch/internet/swisstopo/en/home/topics/survey/sys/refsys.parsysrelated1.2487.downloadList.82881.DownloadFile.tmp/swissprojectionen.pdf .

Due to the limitations of the measuring and calculation techniques used for its realisation, LV03 has distortions in the order of 1m or more relative to the fundamental station. These could easily be detected with the upcoming of GPS in the late 1980ies. At the same time it was possible for the first time to relate CH1903 to global reference systems such as WGS84 (except from the European triangulation solutions ED50 and ED79). The first national GPS campaign in 1987 was called GRANIT (Kahle et al., 1993) and the determined transformation parameters out of 12 points are called the GRANIT87-Parameters. It is a 7-parameter transformation with 3 rotations and one scale factor. These parameters were widely used until 1997 but have lost their importance today. We don't recommend their use anymore but often, they are still implemented in GIS software. The GRANIT87-parameters eliminate a global scale factor and a general rotation of LV03. But the distortions show a much more complicated image and the remaining residuals after the transformation are not much smaller than without applying the scale and rotations.

1.2 CH1903+/LV95

Realising the distortions of LV03, it was decided in the early 1990ies to modernise the national reference system and to establish a new reference frame LV95 (Landesvermessung 1995, resp. MN95 in French and Italian) which is more compatible with the modern GNSS techniques.

The reference system CH1903+ was chosen in a way that it is the same as the original CH1903 for all practical purposes. Only the definitions were transferred from the old observatory in Berne, which no longer exists, to the new fundamental station in Zimmerwald. Basically, the ellipsoidal coordinates of Zimmerwald determine CH1903+. But they were chosen in a way that the coordinates of the old fundamental station in Berne remain unchanged. All necessary parameters and projection formulas are identical in CH1903 and CH1903+. This implies as well that the projection centre of the Swiss map projection remains at the old observatory of Berne and that the Bessel ellipsoid is used as a reference surface. It was only necessary to give new Easting (2'600'000 m) and Northing (1'200'000 m) values to the projection centre in order to be able to distinguish the coordinates in both systems. Since the denomination of the coordinate axis with y and x often was a source of confusion, it was decided to call them E and N in LV95.

The reference frame LV95 is realised by GNSS measurements and should replace LV03 in the near future. The transition from LV03 to LV95 is done stepwise for each canton and it should be completed in 2016 for all applications in national and cadastral surveying.

For the modelling of the differences between LV03 and LV95, the whole country and the surrounding areas were split into more than 11'000 triangles. Each of these triangles defines a local affine transformation between the two reference frames. We call this method FINELTRA (finite element transformation) and the defining dataset CHENyx06.

Since FINELTRA is not one of the standard methods for modelling distortions of reference frames, usually it is not implied directly in GIS- or GNSS-software. Therefore, a derived model of the distortions in form of a regular grid (CHENyx06.GRD) was developed and is available in various formats such as NTv2 for GIS or GSF or CSCS for GNSS software and receivers. The differences between the direct application of FINELTRA or the use of the gridded distortions are usually better than 2 cm - except for some little regions with very large local distortions in LV03.

1.3 CHTRS95/CHTRFyy

CHTRS95 (Swiss Terrestrial Reference System 1995) is the Swiss version of the European Terrestrial Reference system ETRS89. Until now, both systems are exactly identical and will remain it unless there is a strong necessity to change. CHTRS95 uses the GRS80 ellipsoid as a reference and moves together with the stable part of the Eurasian tectonic plate. This results in time dependant rotation parameters to the global reference system ITRS.

The realisations of the CHTRS95 are updated after each larger national GNSS campaign. Until now, the following reference frames were published: CHTRF95, CHTRF98, CHTRF2004 and CHTRF2010. All these reference frames are all fixed on the coordinates of the fundamental station in Zimmerwald in ETRF93 for the Epoch 1993.0.

For the transformation between CHTRS95 and CH1903+ a simple 3-parameter transformation with only a geocentric translation is used. The scale and orientation in both systems are identical. The parameters are the following:

$$\mathbf{X_{CH1903+} = X_{CHTRS95} - 674.374\ m}$$
$$\mathbf{Y_{CH1903+} = Y_{CHTRS95} - 15.056\ m}$$
$$\mathbf{Z_{CH1903+} = Z_{CHTRS95} - 405.346\ m}$$

These are our official transformation parameters and can be used without any restrictions for the transformation to/from ETRS89. We call them the LV95-parameters. Neglecting the influence of global plate tectonics, they are as well an approximation for the transformation to/from ITRS or WGS84.

For the accurate transformation from the realisation of CH1903 to CHTRS95, a 2-step procedure is necessary: first eliminate the distortions of LV03 with FINELTRA or a grid approximation and then in a second step apply the above mentioned translation.

2 The Swiss projection in GIS and GNSS applications

2.1 Direct implementation of the Swiss projection

Today, most systems support directly the Swiss projection formulas and parameters as developed by Rosenmund (1903) and swisstopo. But it can be found under various names such as:

- Swiss projection
- Swiss Oblique Mercator
- Oblique Mercator (Rosenmund)
- Swiss grid
- Switzerland
- CH1903 LV03
- CH1903+ LV95
- LV03
- LV95

If not specified, the parameters are those of LV03 with the coordinates in Berne set to 600'000/200'000. Most systems allow the modification of the parameters and therefore it is easy for most applications to just change the false easting and northing to obtain coordinates in LV95 with an accuracy of around 1 m.
A thing to check always when using the Swiss projection in GIS are the implemented transformation parameters. Many systems still use the outdated GRANIT87 parameters as default for the transformation from LV03 to WGS84 (or ETRS89). This gives an accuracy in the order of 1 m. The correct way for the transformation would be to transform first LV03 to LV95 with the distortion model (FINELTRA or the grid approximation) and then use the LV95 parameters to reach ETRS89. At swisstopo there is available a version of the distortion grid (CHENyx06_ETRS.GRD) that transforms directly from LV03 into ETRS89 with an accuracy of around 2 cm in 1 step.

2.2 Approximation of the Swiss projection

In some GIS or calculation software the Swiss projection formulas are not implemented explicitly and the user has to define the Swiss projection and reference system manually. In this case, there exist several workarounds.
For the oblique Mercator projection there exist several other formula sets than the ones introduced in Switzerland. The most known alternatives are the ones by Hotine (applied in Malaysia) and by Laborde (for Madagascar). The defining parameters may be different from the Swiss formula but the results are the same for all practical purposes.
The original **Hotine Oblique Mercator** projection is implemented in most GIS. In order to use it in Switzerland, one can introduce all the official parameters of the Swiss projection except for the false easting. This has to be set to a value of -9'419'820.5907 m to obtain the same results as with the Swiss projection formulas. We do not recommend to use this option.
A sub-version of the Hotine formulas is the **Hotine Oblique Mercator (Azimuth Center)**. If this is available in your system, it is the best option to choose. All the official parameters of the Swiss projection can be used directly (including the false Easting). But there are 2 additional parameters to be defined: A scale factor which has to be set to 1.0 and the azimuth of the touching line in the projection centre, which has to be set to 90°. Exactly the same is valid if you can choose the **Laborde** projection.
If in your system no formulas at all for an oblique Mercator projection are available, the best alternative is to use a **Lambert Conformal Conic** projection with 1 standard parallel. All the official Swiss parameters may be used, but the obtained differences with respect to the official oblique Mercator projection may reach up to 3 metres.
For the transformation to a global system, we recommend to use always the LV95-parameters, independently if you use the LV95 or the LV03 reference frame. If you are working in LV03 on the submetre level, the distortions have to be modelled with FINELTRA or the distortion grid. There is no application where we recommend the use of the GRANIT87 parameters anymore.

3 The EPSG codes

The "OGP Surveying & Positioning Committee" (OGP = International Association of Oil & Gas producers) maintains an extensive database of geodetic reference systems, map projections and transformation parameters. Before their integration into OGP in 2005 this group was known as EPSG (European Petroleum Survey Group). This EPSG database is freely available and is widely used by software developers for coordinate transformation. Often, the EPSG identifiers (codes) are used as reference for the description of the implied coordinate systems and transformations. Therefore, it is useful to give a summary of all EPSG codes that have a connection with the Swiss reference frames. Here, we give the descriptions of version 8.4 (May 2014) of the EPSG database.

Table "Ellipsoids"

7004	Bessel ellipsoid; used in CH1903 LV03 and CH1903+ LV95
7048	GRS80 (Geodetic Reference System 1980); used in CHTRS95, ETRS89 and ITRS

Table "Geodetic Datums"

6801	CH1903 (Bern); the original definition of CH1903 with respect to the prime meridian Berne
6149	CH1903; the today official definition of CH1903 with respect to the Greenwich meridian
6150	CH1903+; the redefinition of the reference system for LV95 with all the defining constants transferred to Zimmerwald; the projection centre remains the same as in CH1903
6151	CHTRS95; identical with ETRF93, at epoch 1993.0
6258	ETRS89; European Reference System 1989; individual frames (ETRFyy) are not distinguished
6306	Bern 1938; a variation of CH1903 with different ellipsoidal coordinates for the fundamental station in Berne; it was never used officially; no practical use

Table "Coordinate Operation Methods"

9814	Swiss Oblique Cylindrical; official Swiss projection formulas

Table "Map Projections"

19923	Swiss Oblique Mercator 1903C; official Swiss map projection for LV03 with "Civilian coordinates" (Berne = 0 / 0)
19922	Swiss Oblique Mercator 1903M; official Swiss map projection for LV03 with "Military coordinates" (Berne = 600'000 / 200'000)
19950	Swiss Oblique Mercator 1995; official Swiss map projection for LV95 (Berne = 2'600'000 / 1'200'000)

Table "Projected Coordinate Reference Systems" (CRS)

21780	CH1903 LV03 (civilian coordinates, prime meridian of Berne); don't use anymore
21781	CH1903 LV03 (military coordinates)
21782	CH1903 LV03 (civilian coordinates, prime meridian of Greenwich)
2056	CH1903+ LV95

Table "Geographic CRS"

4149	CH1903, geographical coordinates (lat./long.)
4150	CH1903+, geographical coordinates (lat./long.)
4151	CHTRS95, geographical coordinates (lat./long.)
4933	CHTRS95, geographical coordinates (lat./long.) plus ellipsoidal height
4932	CHTRS95, geocentric cartesian coordinates

Table "Transformations"

15486	CH1903 to CH1903+; NTv2 distortion grid
1646	CH1903 to ETRS89 (1); LV95-Parameters, rounded to 10 cm as published by EUREF. May be used as a rough approximation
1753	CH1903 to WGS84 (1); GRANIT87-Parameters; use not recommended
1766	CH1903 to WGS84 (2); same as 1646 (rounded LV95 parameters)
1509	CH1903+ to CHTRF95; LV95-Parameters
1647	CH1903+ to ETRS89; LV95-Parameters
1676	CH1903+ to WGS84 (1); LV95-Parameters
1511	CHTRF95 to WGS84 (1); Identity