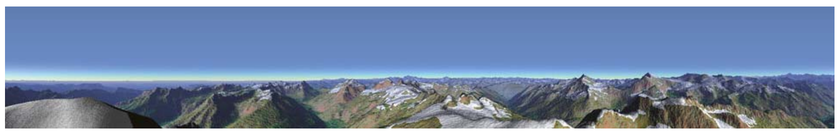

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EUREF'05: Release of the new National Height Network of Switzerland LHN95

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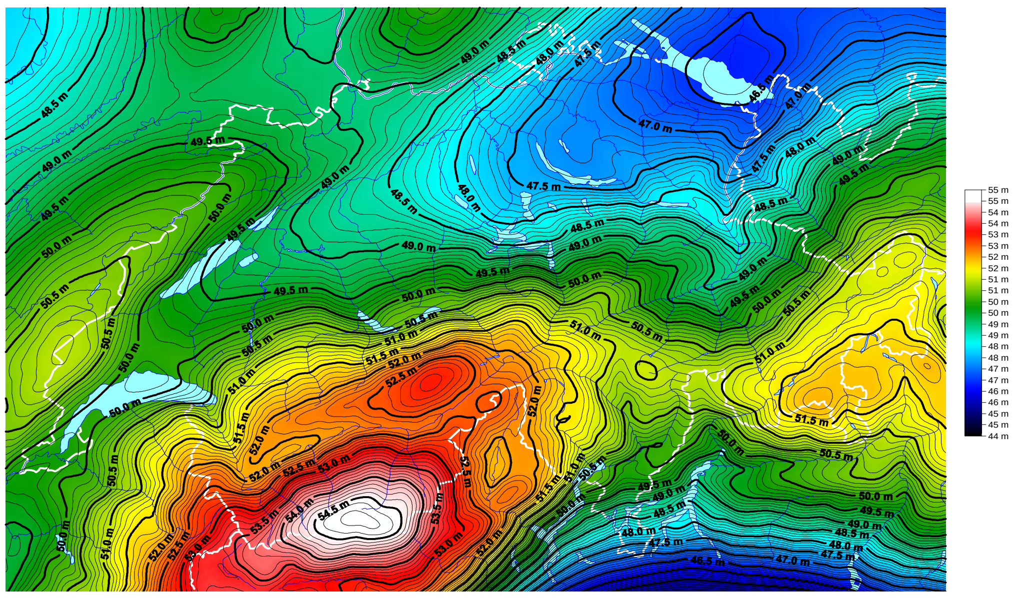
Abstract

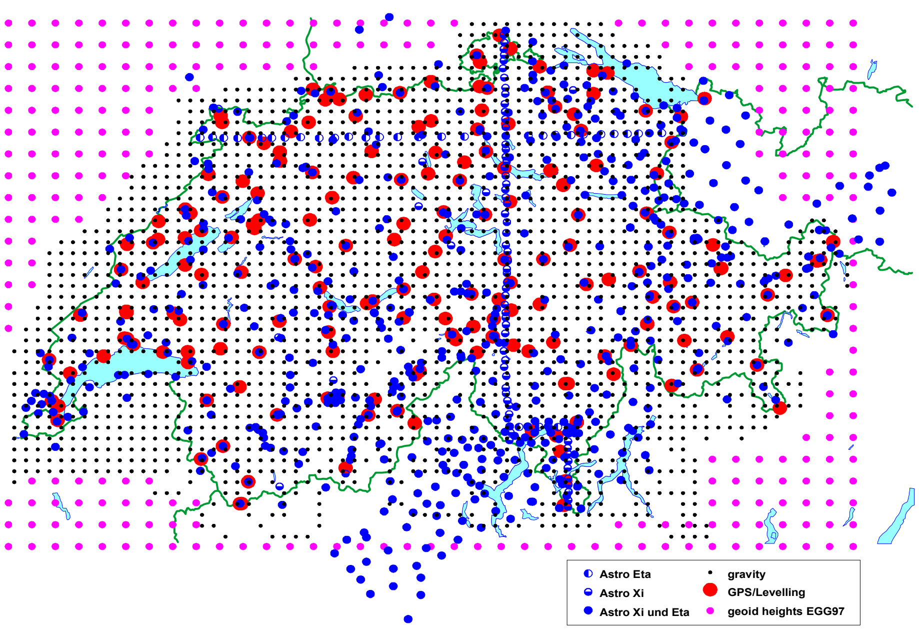
With the introduction of the new geoid model of Switzerland (CHGeo2004), the consistency between the ellipsoidal heights based on GPS observations and the orthometric heights resulting from precise levelling (and gravity) has now been achieved. Furthermore, the gravity-field-related vertical reference frame completes the new national survey in Switzerland, LV95. On March 18, 2005, the results of the new National Height Network LHN95 were presented to the geodetic community for the first time. They will now be available to all surveyors interested in applying GNSS-based height determination, even though LHN95 is not officially in use for cadastral surveying.
Besides the realization of the geoid model and the vertical reference frame, the poster presentation shows the differences to the old official heights LN02, the differences along the national borders to our neighboring countries, and the relationship to the European vertical system.

The new geoid model of Switzerland CHGeo2004

The recently released national geoid model CHGeo2004 of Switzerland was determined by combining gravity, vertical deflections and GPS/levelling. Its accuracy (1σ) is in the order of 2-3 cm as could be verified by comparisons with independent data. In regions outside of Switzerland where there are no Swiss observations, the existing geoid models of neighboring countries were introduced directly into the adjustment. Besides the standard models (topography and global geopotential model EGM96), a simple 3D density model of the Earth's crust was introduced for the reduction of the observations. This is the same mass model which was used in the reduction of orthometric heights which is important for obtaining a consistent height system.
The method for the interpolation of the residual field (co-geoid) was basically a least squares collocation with a slight modification such as to minimize the differences between the gravimetric/astrogeodetic solution and the GPS/levelling solution. These differences are in the order of 6 cm (rms)
The model was released in a geoid version and in a quasi-geoid version in order to be compatible with an orthometric as well as with a normal height system and to perform transformations to the height systems of neighboring countries.
The official geoid model that was released to the surveyor community is based primarily on GPS/levelling, since the use of the geoid model is mainly for GNSS height determination with the aim of being consistent with levelling.



The new geoid model of Switzerland CHGeo2004

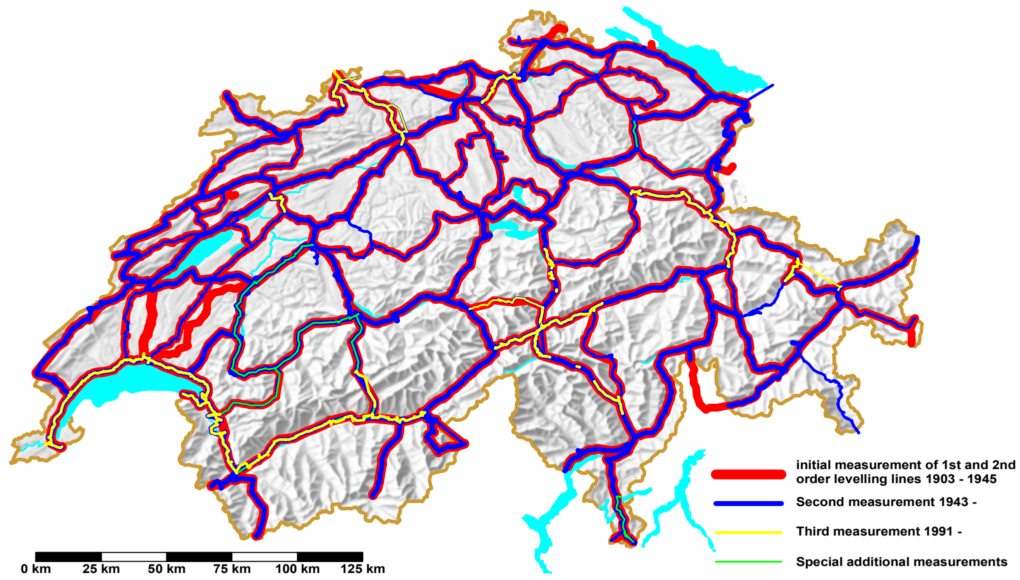


Input dataset for CHGeo2004

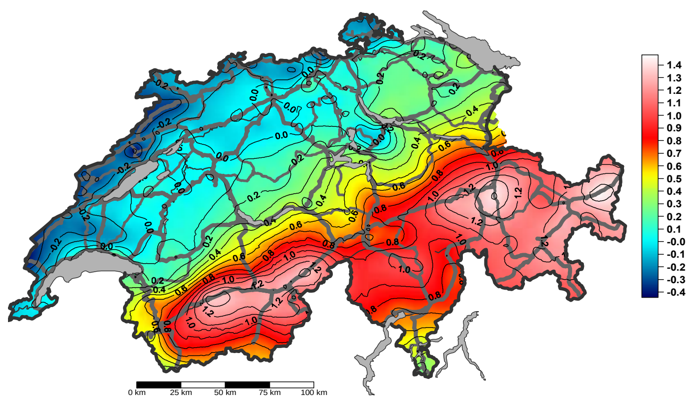
Realization of LHN95

Dataset and kinematic adjustment

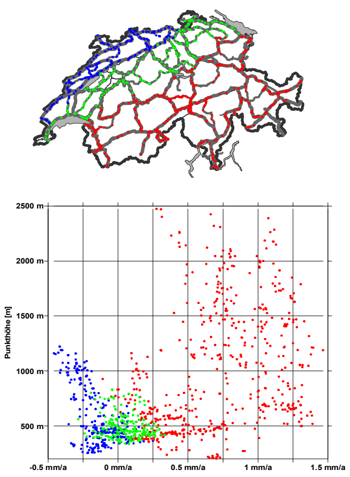
The kinematic adjustment of the potential differences between 1600 selected stations along approx. 10,000 km of repeatedly observed precision levelling lines forms the backbone of the LHN95. The adjustment is based on the fundamental reference point Zimmerwald, where the discrepancy of the geopotential numbers to the UELN-73 solution amounts to 0.102 gpu. This difference stems from the definition of the datum for LHN95, which was chosen so that the value of the old Swiss vertical datum (Repère Pierre du Niton: h = 373.60 m) remains the same.
The result of the adjustment of the 3380 observations, including a total of 2750 unknowns (potential numbers and their temporal changes), was a standard deviation of 1.4 mgpu for the unit of weight. This corresponds to a standard deviation of 1.4 mm for the length of 1 km with a height difference of 100 m.
The vertical velocities are set to zero at the arbitrarily chosen reference benchmark in Aarburg. The resulting vertical velocities show significant amounts of up to 1.5 mm/a, especially in the Alpine areas.
The geopotential numbers are the basic values for the computation of the orthometric heights of LHN95. As an alternative, normal heights based on these values may also be derived.



Precise levelling lines from 1902 to 2004 used for the kinematic adjustment



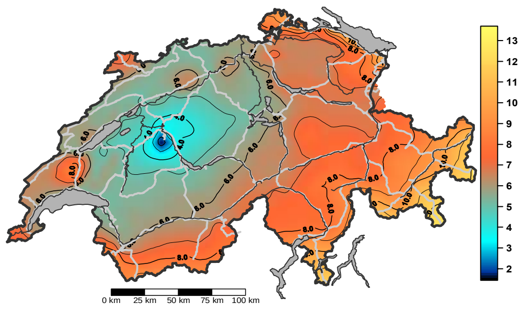
Model of height changes from the kinematic adjustment [mgpu/a]



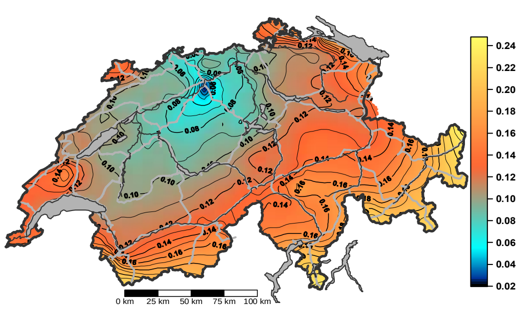
Above: regional distribution
Below: vertical velocities versus altitude

A model of recent height changes for Switzerland can be computed from the discrete individual results of the selected benchmarks. The greatest recent uplifts occur in the Alps. There is no indication for a correlation with the altitude of the point (above right).

The maximal standard deviation of the adjusted geopotential numbers relative to the fundamental point Zimmerwald reaches 14 mgpu. The largest standard deviation of the geopotential changes amount up to 0.25 mgpu/a (≅ 0.25 mm/a). These values can be observed at the margins of the networks, especially at the end of open levelling lines.



Accuracy (1σ) in [mgpu] of the geopotential numbers relative to the fundamental point Zimmerwald



Accuracy (1σ) in [mgpu/a] of the vertical velocities relative to the kinematic reference in Aarburg swisstopo

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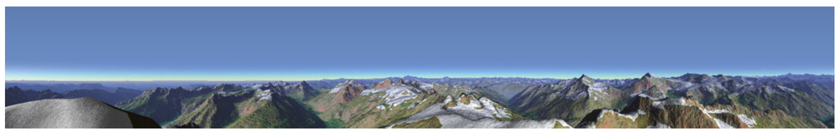
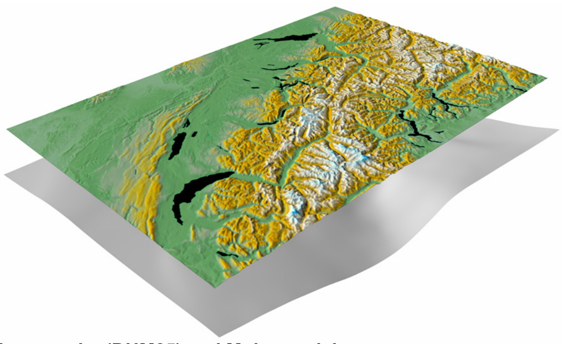
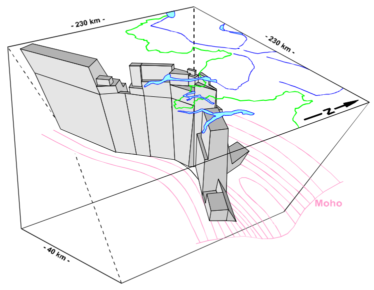


From geopotential numbers to orthometric heights

In order to obtain orthometric heights LHN95 from the geopotential numbers, the mean gravity along the plumbline must be determined. Besides surface gravity and a topographic model, also simple models of the density distribution in the Earth's crust are applied. The following models were used for computing the LHN95 heights:
Digital terrain model: DHM25, density models: moho depth, Ivrea Body, Po sediments, lakes, glaciers and quaternary sediments of rivers.
These are the same mass models which were used for computing the geoid model CHGeo2004.

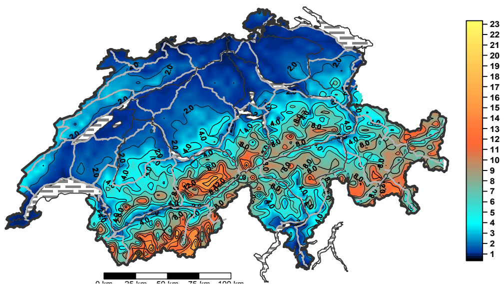


Topography (DHM25) and Moho model

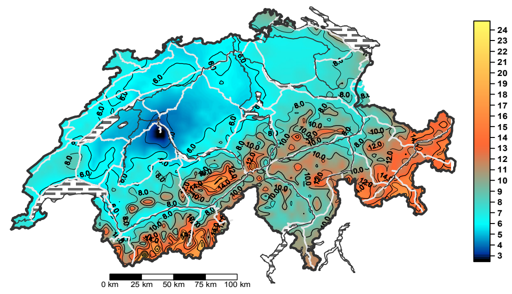


Model of the Ivrea Body

The computation of orthometric heights from geopotential numbers leads to a slight decrease in accuracy as compared to the normal heights (free of hypotheses) and the geopotential numbers respectively. The reason can be found in the limited accuracy of the known mass models and the observed gravity. The loss of accuracy is ultimately correlated with the height of the point.



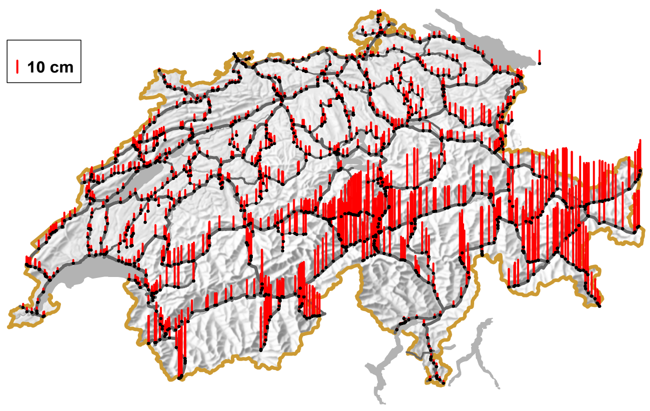
Estimated influence of the mean gravity on the standard deviation of the resulting heights [mm]



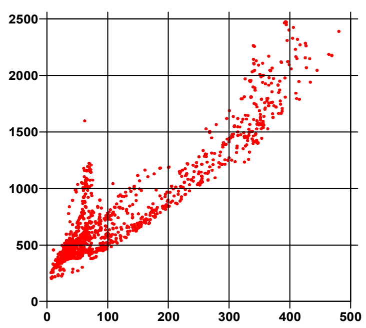
Standard deviation of the orthometric heights relative to the fundamental point Zimmerwald [mm]

Comparison with normal heights

The differences between the orthometric and the normal heights may also be computed along the national height network. There is a strong correlation with the altitude. Furthermore, these differences correspond to the differences between the geoid and the quasi-geoid models.



Differences between orthometric and normal heights



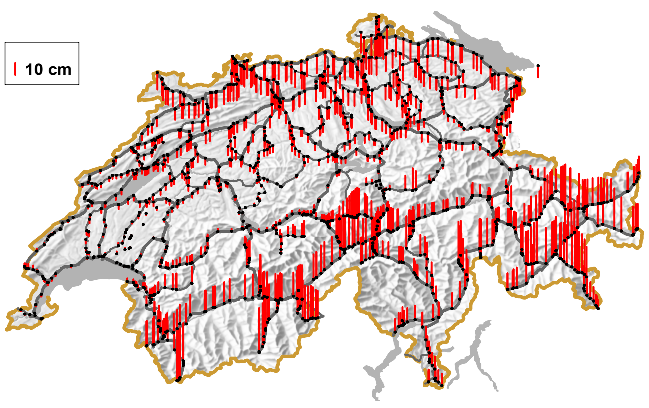
Heights [m] versus differences [mm]

Difference to the official heights LN02

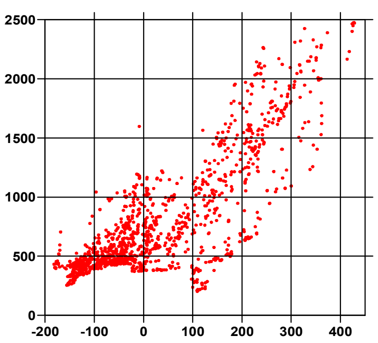
The differences to the still valid official heights used in cadastral surveying can be explained by the following three reasons:

1. Different kinds of heights:
   The official heights LN02 are based on nodal points. Their official values are derived from pure levelling observations during the years 1864 to 1891.
2. Influence of the Alpine uplift:
   The influence of the Alpine uplift since the period 1864 to 1891 (initially observed epoch) amounts to over 10-15 cm
3. Network distortion of the initial determination from 1864 to 1891:
   An analysis of this distortion can be found in the next paragraph (see upper right)

The differences along the national levelling network reach values of -20 to +45 cm.



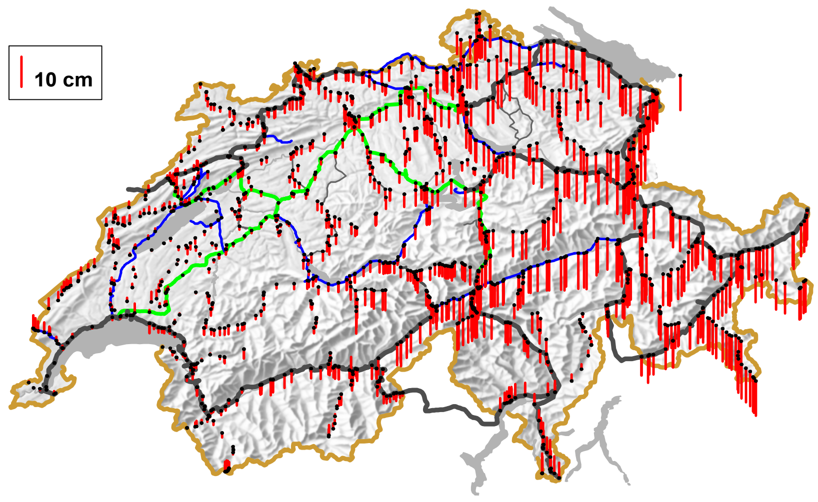
Differences between LHN95 and the official heights LN02



Heights [m] versus differences [mm]

An analysis of the official heights LN02

An analysis of the network distortions of LN02 can only be carried out if heights at the epoch 1880 are computed together with the existing observations and the kinematic model. The resulting differences to the official heights of LN02 range between -13 and +9 cm.



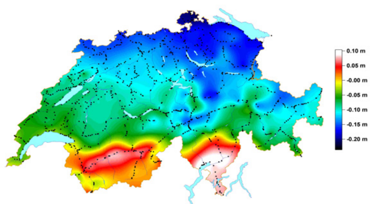
The distortions in the old levelling network LN02

HTRANS: Height transformation between LHN95 and LN02

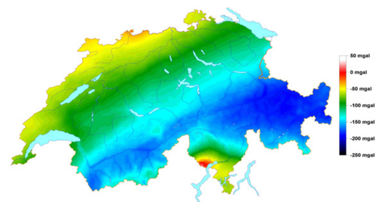
For the optimal use of GNSS observation methods in height determination, swisstopo developed the software HTRANS. It allows a point by point transformation between LHN95 and LN02.
The difference of LHN95 minus LN02 is split up into a position-dependent part (LN02 minus normal heights) and a height-dependent part (LHN95 minus normal heights).

$$H_{LHN95} - H_{LN02} = (H_{LHN95} - H_{Norm}) - (H_{LN02} - H_{Norm}) = f_{LN02-Norm}(y,x) - \Delta g_{Boug}(y,x) \cdot H + f_{rest}(y,x)$$

The height-dependent part is modelled basically by the product of the height of the point times the Bouguer anomaly and the remaining residuals are taken into consideration in a residual surface $f_{Rest}(x,y)$. Thus the program is based on three interpolation surfaces: $f_{Norm-LN02}(x,y)$, $f_{Rest}(x,y)$ and the Bouger anomalies Δg_{Boug}.

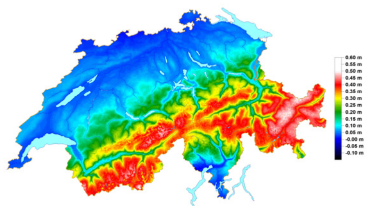


$f_{Norm-LN02}$ (x,y): normal height minus LN02

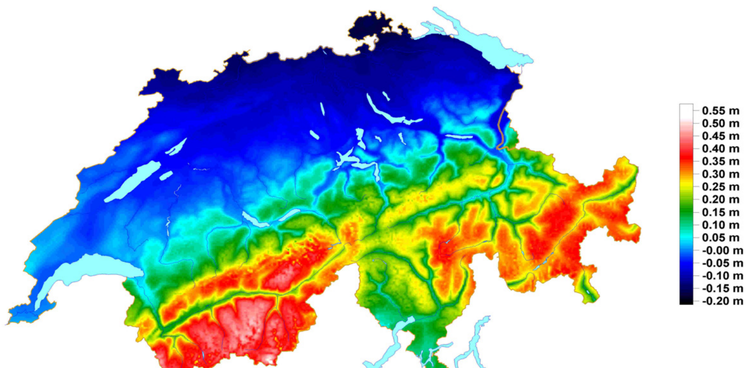


Δg_{Boug}: Bouguer anomalies

$f_{Rest}(x,y)$: residual surface height dependency

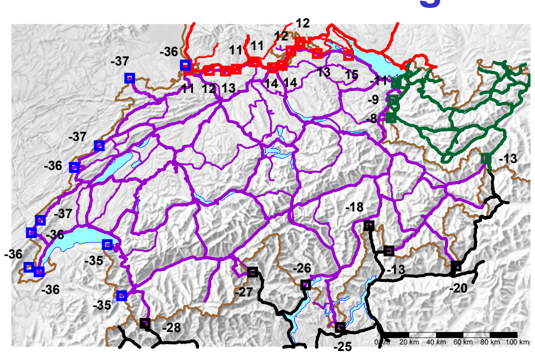


Height-dependent part: LHN95 minus normal height

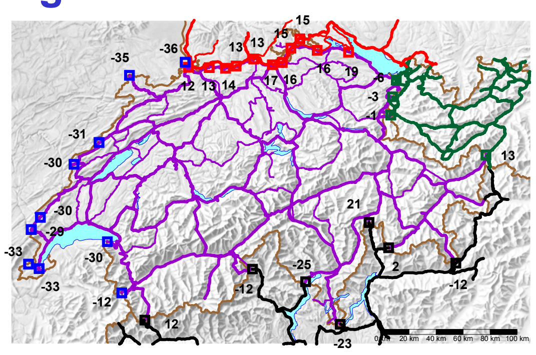


Total surface LHN95 minus LN02: computed as a raster from the program HTRANS

Difference to the neighboring countries



Differences Swiss normal height LHN95 minus height of neighboring country [cm]



Differences Swiss orthometric height LHN95 minus height of neighboring country [cm]

The two figures show the differences between the normal heights (left) and the orthometric heights (right) to the heights of the neighboring countries. A better agreement can be obtained with the normal heights since Germany and France use normal or normal-orthometric heights. A very good agreement can be found especially between France and Switzerland after taking into consideration an offset of -36 cm.
The normal-orthometric heights (Status 130) were used for the comparison to Germany.