# Status of UELN and steps on the way to EVRS 2007

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## Abstract

Since 1998 a lot of new data has been integrated in UELN – especially more than 7000 points of Scandinavia. Additional data are expected. So the publication of a new UELN solution is indicated. The datum of the UELN-95/98 solution was realized by the geopotential number of one benchmark in the Netherlands representing the NAP level. The level of the new UELN datum should be defined by the geopotential values of the UELN-95/98 solution of several points in Europe. Choosing points in countries with the same measurements as 1998 we will get a minimum of height changes in the network.

## 1. Development of UELN since 1998

The last results of a UELN adjustment were handed over to the participating countries January 1999. The name of the solution is UELN-95/98. This solution was the base for the first realization of a European Vertical Reference System (EVRS).
Since that time a lot of new data was included into the network (see Figure 1). UELN has been extended to the East by the first order levelling networks of

- Estonia (1999)
- Latvia (1999)
- Romania (1999)
- Lithuania (2000)
- Bulgaria (2003)

Additionally the network blocks of some countries have been replaced by new data, which are more topical. The following countries are concerned:

- Switzerland (2002)
- Denmark (2004 - new preprocessed data of the epoch 1980-1995)
- The Netherlands (2004)
- Finland (2005)
- Norway (2005)
- Sweden (2005)

Besides that the handing over of a new levelling epoch of Poland is announced for 2006.
The amount of data changes calls for a new realization of the EVRS – may be under the name EVRF2007.

## 2. New data of Scandinavia

### *2.1 Description of the data*

Up to the year 2005 the Scandinavian levelling data belonged to the oldest measurements in the UELN. Because of the postglacial land uplift the data were reduced to the common epoch 1960. In July/August 2005 new levelling data of Finland, Sweden and Norway were delivered to the UELN data base. Together with the measurements the land uplift model NKG 2005 LU was provided (ÅGREN, SVENSSON 2006). This model was used for the reduction of the measurements to the epoch 2000 in the adjustment of the "Baltic Ring" by the Nordic Geodetic Commission (NKG). The same reduction has been used in the UELN adjustment. Table 1 shows the numbers of the points and measurements in the different epochs.

*Table 1: Numbers of points and measurements in the different epochs*

| Country | Measure-ments | points | lines | nodal points | epoch |
|---|---|---|---|---|---|
| Norway | 361 | 393 | 341 | 354 | 1915-1971 |
| | 313 | | 294 | | 1972-2004 |
| Sweden | 5811 | 6040 | 4093 | 3390 | 1977-2003 |
| Finland | 653 | 594 | 192 | 133 | 1966-2004 |

The remeasurement of the levelling network of Norway has not been finished yet. So the data of Norway belong to two different epochs. One group contents old measurements in order to get a complete continuous network for the adjustment.
Figure 2 shows the network configuration of the Scandinavian part of UELN. Sweden has with more than 3000 nodal points the densest part of the network.

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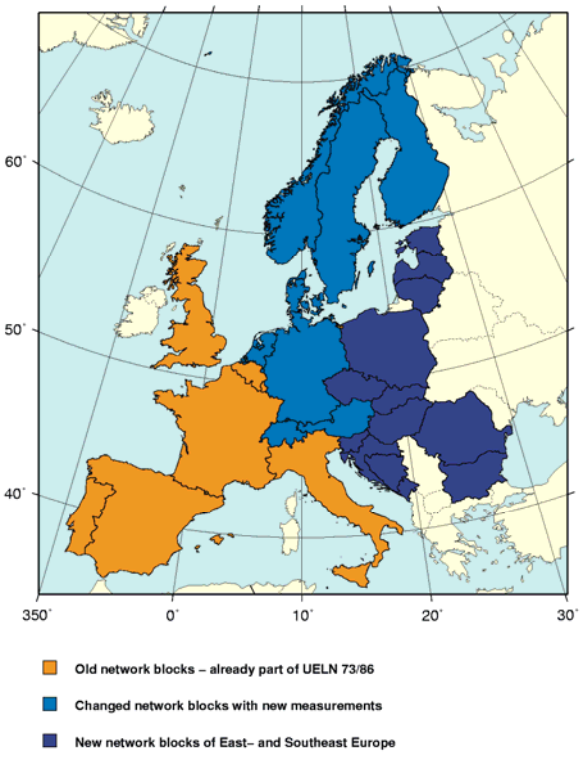


*Figure 1: UELN status April 2006*

## *2.2 Adjustment results*

The 4 groups of measurements were analyzed in a separate adjustment. The 2 groups of Norway were introduced in the adjustment with different a-priori standard deviations for 1 km levelling which had been stated by the NKG.

- epoch 1915-1971 $s_0$ = 1.36 kgal·mm·
- epoch 1972-2004 $s_0$ = 1.11 kgal·mm

The groups of the other national networks were introduced with

- $s_0$ = 1.00 kgal·mm

The free adjustment of

6040 points and 7140 measurements

resulted in an

a-posteriori $s_0$ of 1 km = 1.035 kgal·mm.

The following a-posteriori standard deviations of 1 km levelling were computed by variance component estimation:

- Norway 1915-1971 1.58 kgal·mm
- Norway 1972-2004 1.30 kgal·mm
- Finland 1966-2004 0.74 kgal·mm
- Sweden 1977-2003 1.00 kgal·mm.

The weight ratio between the 2 Norwegian groups after the adjustment differs from the a-priori values. The reason is a modification in the land uplift model NKG2000LU in comparison with the version that has been used in the NKG adjustment of the Baltic Ring.

After including the new Scandinavian data into UELN adjustment the following parameters were found:

| | |
|---|---|
| Number of datum points: | 13 |
| Number of unknowns: | 7225 |
| Number of measurements: | 9542 |
| Number of condition equations: | 1 |
| Degrees of freedom: | 2318 |
| A-posteriori standard deviation referred to 1 km levelling distance in kgal·mm: | 1.07 |
| Mean value of the standard deviation of the adjusted geopotential numbers ($\hat{=}$ heights), in kgal · mm: | 17.19 |
| Average redundancy: | 0.243 |

13 points in Europe were used as previously datum points (see chapter 3).

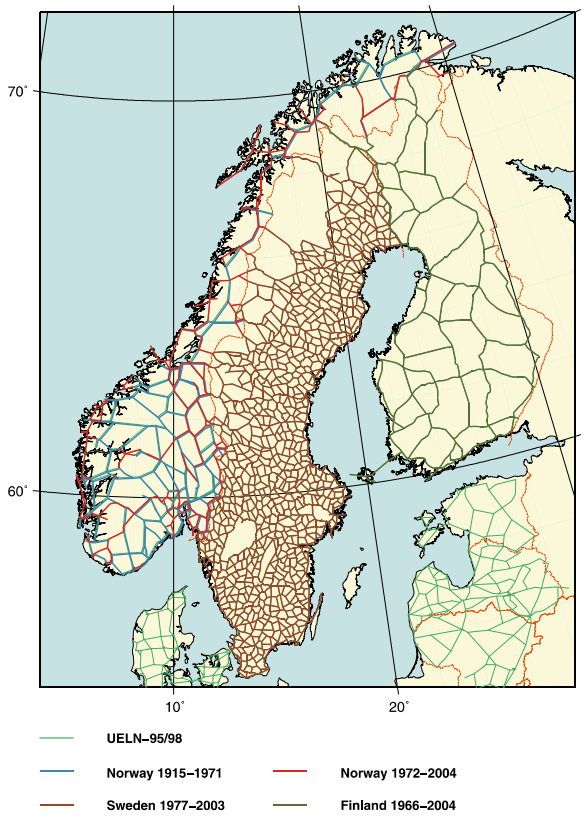


*Figure 2: Scandinavian part of UELN*

## *2.3 Comparison of differences of adjusted heights with velocities from the land uplift model*

Now the UELN data base contains 2 levelling epochs for each of the Scandinavian countries. So there is the possibility to compare the difference of the UELN-95/98 height, which is reduced to the epoch 1960 and the new UELN height reduced to epoch 2000 with the velocity of the point that is given by the land uplift model NKG 2005 LU. Figure 3 shows velocity differences calculated by

$$vdif=(H2000_{NEW}-H1960_{UELN\text{-}95/98})/40years - v_{NKG}$$

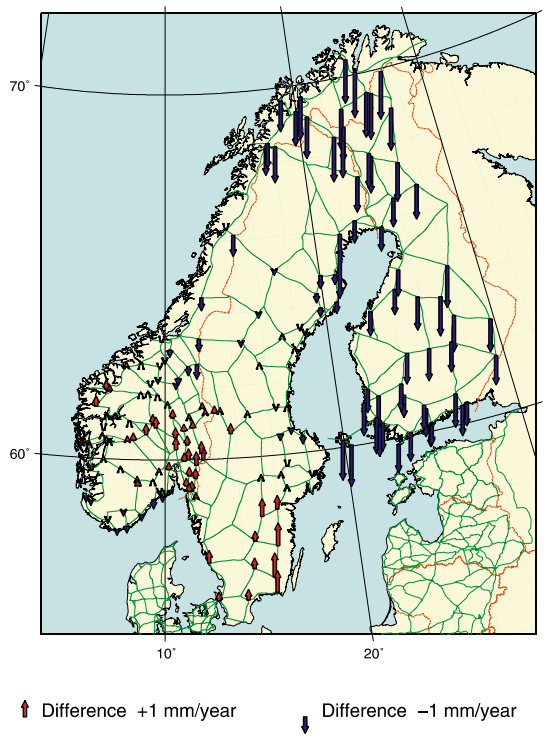


*Figure 3: Comparison between velocities derived from height differences between the epochs 1960 and 2000 and velocities of NKG 2005 LU*

The differences in Norway and Sweden are quite small, but in Finland all differences are higher than 2 mm/year. In principle these differences could be caused by errors in the measurements of both networks and errors in both land uplift models. In this case the large differences in Finland can be explained by errors in the 2nd Precise Levelling of Sweden in conjunction with the few border connections between Sweden and Finland and the consequential unfavourable error propagation (ÅGREN, SVENSSON 2006) This fact has been shown also in comparisons with oceanography over the Åland sea (MÄKINEN, EKMAN 1996). In any case figure 3 shows again the importance of closing the Baltic Ring.

## 3. Datum realization of EVRS2007

### *3.1 Retrospective view*

The previous datum of the EVRS based on the UELN-95/98 solution, which was realized by one benchmark in the Netherlands that represented the NAP level. The same point had been used already as datum in the UELN-73/86 adjustment. This former UELN variant contained only 2 big loops of the Dutch network. In order to have comparable results the datum point was kept in the adjustment of 1998 even it wasn't the datum point of the national network. The identifier of the UELN datum point was 000A2530 (not to be confused with the datum point of the national network 000A2350).

### *3.2 Present status*

In 2004 the previous network block of the Netherlands was replaced by the data of the 5th Primary Levelling, which was observed between 1996 and 1999. This data set doesn't contain the old UELN datum point. A preliminary substitute point was chosen which is located in the near of the old one and didn't move between the different measurement epochs of the Netherlands. But the new levelling epoch shows considerable height changes compared with the old measurements. These height changes are propagated over connection measurements to the neighbouring countries to whole UELN.

### *3.3 New datum realization*

Although the height changes are only in the dimension of 1 cm they give the occasion to state that the realization of the UELN datum by only one benchmark is neither contemporary nor advantageous.
On the one hand there isn't a forcible scientific reason for keeping the new UELN datum realization on the old level. On the other hand there is a popular wish of all users of geodetic networks that the coordinates change as few as possible. The user community in the European Union has just begun to notice EVRS and make use of the potentials of a European height system. So it would be an inconvenient moment for changing all the heights. That's why the datum of EVRS2007 should be kept on the old NAP level represented by 000A2530. That can be achieved by a couple of points, whose geopotential numbers of the UELN-95/98 adjustment are to be fixed. The following condition equation is introduced for these *n* points:

$$\sum_{i=1}^{n} (c_{P2007} - c_{P95/98}) = 0 \qquad (1)$$

In some adjustment variants the effect of different numbers and distributions of datum points was analyzed. A couple of sample points located in all participating countries of the UELN project was set in order to compare the height changes depending on the chosen datum points. In every case a free adjustment was performed – that means there are only constant vertical offsets of the adjusted heights between the different solutions. In the end the choice of several datum points in countries without height changes since 1998 leads to minimal height variations in the network.

As example the effect of

a) one datum point in the Netherlands (stable substitute point in the near of the former datum point)
b) 13 datum points in Europe (only in countries with the same data as in the UELN-95/98 so-

lution, no points in Great Britain because of the weak connection to the main land)
shall be demonstrated.
The distribution of the sample points and of 13 datum points is presented in Figure 4. Figure 5 diagrams the height changes to the UELN-95/98 solution of the sample points for the 2 variants:
Figure 5 doesn't show the sample points in Scandinavia. Because of the different reference epochs and the accompanied height changes they couldn't diagram in the same scale.

## 4. Conclusions

After including a lot of new data into UELN a new realization of the EVRS is necessary.
The level of the datum of EVRS2007 should be kept on the level of UELN-95/98. That can be achieved by the selection of a couple of identical points, whose geopotential values are to be fixed. These points should be stable marked, located in the stable part of the European part plate and connected by precise levellings.

Apart from that stations of the European Combined Geodetic Network (ECGN) can be used for observing the time evolution of EVRS2007.

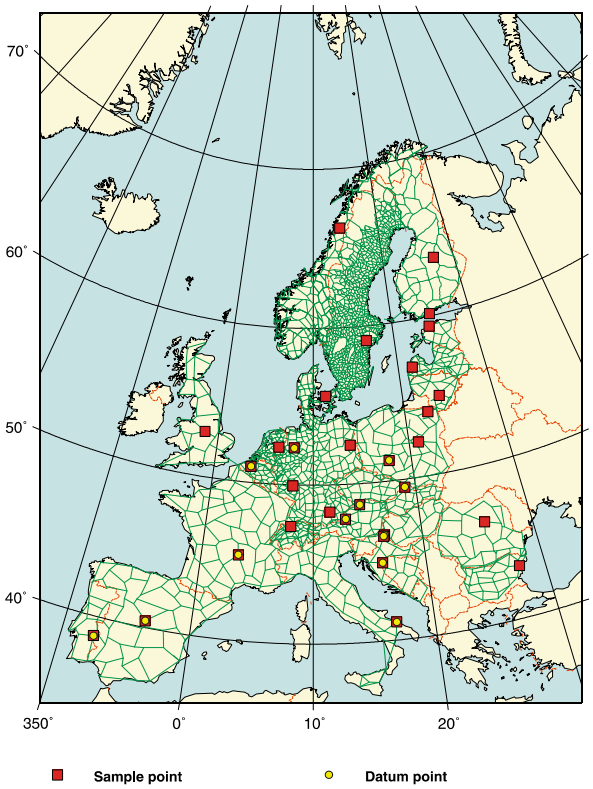


*Figure 4: Distribution of sample points and datum points*

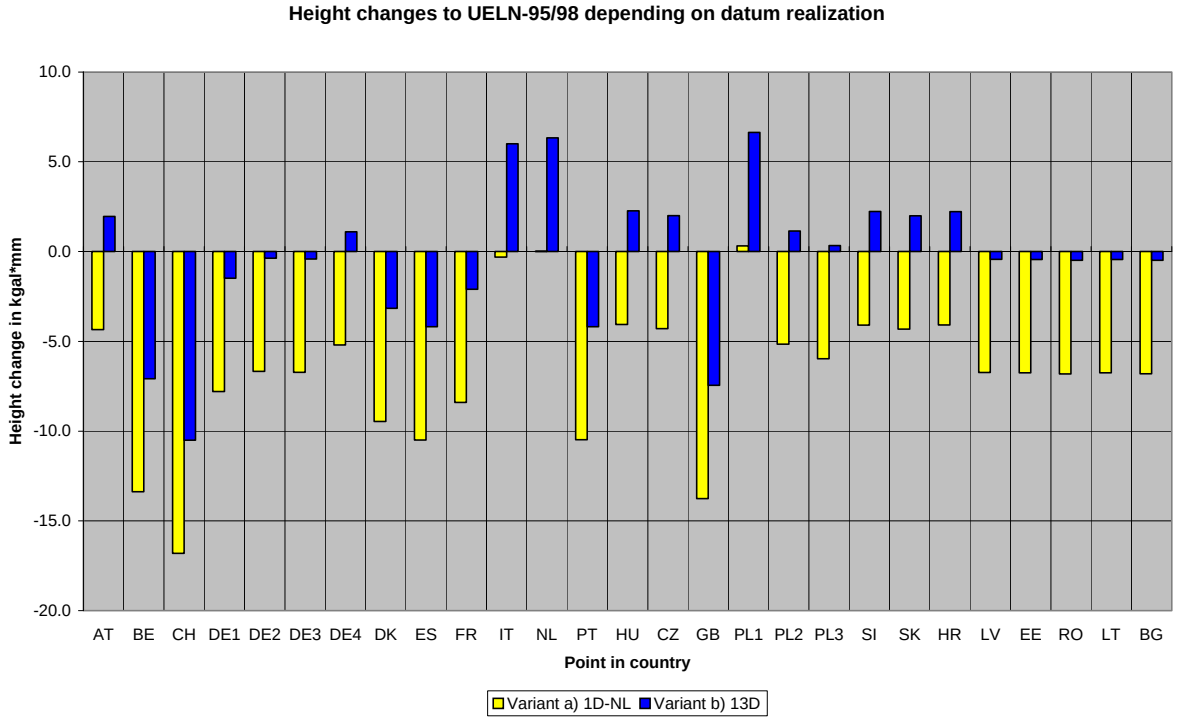


*Figure 5: Height changes to UELN-95/98 depending on datum realization*

## 5. References


ÅGREN, J., SVENSSON, R. (2006): Land Uplift Model and System Definition for the RH 2000 Adjustment of the Baltic Levelling Ring. The 15th General Meeting of the Nordic Geodetic Commission, Copenhagen, May 29-June 2, 2006

AUGATH, W. (1994): *Proposals for a European Task Force on Vertical Datums within the EUREF-Subcommission.* Presented at the EUREF Symposium, June 8-10,1994, Warsaw. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 54, S. 171-175, München 1994.

AUGATH, W. (1996): *UELN-2000 - Possibilities, Strategy, Concepts - or: How should we realize a European Vertical System?* Presented at the EUREF Symposium in Ankara, May 22-25, 1996. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 57, S. 170-174.

BROUWER, F. J. J., DEMIN, E. J. (1994): *On the Definition of a European Vertical Datum.* EUREF Symposium in Warsaw, June 8-10, 1994, Poland. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 54, S. 176-183, München 1994.

EKMAN, M., MÄKINEN, J. (1996): *Mean sea surface topography in the Baltic Sea and its transition area to the North Sea: A geodetic solution and comparisons with oceanographic models.* Journal of Geophysical Research 101: 11993-11999.

EHRNSPERGER, W., KOK, J. J. (1986): *Status and Results of the 1986 Adjustment of the United European Levelling Network - UELN-73.* Paper contributed to the Symposium on Height Determination and Recent Crustal Movements in Western Europe, Federal Republic of Germany, Sept. 15-19, 1986.

LANG, H., SACHER, M. (1995): *Status and Results of the Adjustment and Enlargement of the United European Levelling Network 1995 (UELN-95).* EUREF Symposium Kirkkonummi, Finland, May 3-6, 1995. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 56, S. 86-96, München 1995.

LANG, H., SACHER, M. (1996): *Status and Results of the Adjustment and Enlargement of the United European Levelling Network 1995 (UELN-95).* EUREF Symposium Ankara, Turkey, May 22-25, 1996. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 57, S. 163-169, München 1996.

LANG, H., SACHER, M., SCHOCH, H. (1997): *Status and Results of the Adjustment and Enlargement of the United European Levelling Network 1995 (UELN-95).* EUREF Symposium Sofia, Bulgaria, June 04-07, 1997. Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 58, S. 85-90, München 1997.

MÄKINEN, J. (2004) *Some remarks and proposels on the re-definition of the EVRS and EVRF*. Paper presented to the meeting of the Technical Working Group of the IAG Subcommission for the European Reference Frame (EUREF), Bratislava, June 1, 2004

MARTI, U., SCHLATTER, A. (2002): *The new Height System in Switzerland.* IAG Proceedings of the Symposium on Vertical Reference Systems, Cartagena, Colombia, Springer-Verlag (in press)

SACHER, M., LANG, H., IHDE, J. (1998): *Status and Results of the Adjustment and Enlargement of the United European Levelling Network 1995 (UELN-95).* Presented at the EUREF-Symposium in Bad Neuenahr-Ahrweiler, 1998.

SACHER, M., IHDE, J., CELMS, A., ELLMANN, A. (1999): *The first UELN stage is achieved, further steps are planned*. Presented at the Symposium of the IAG Subcommission for Europe (EUREF) in Prague, June 2-4, 1999.

SACHER, M., IHDE, J., CORCODEL, S. (2000): *Status of the UELN/EVS Data base and Results of the Last UELN adjustment.* Report on the Symposium of the IAG Subcommission for Europe (EUREF), Tromsø, 22-24 June 2000, Veröffentlichung der Bayerischen Kommission für die Internationale Erdmessung, Heft Nr. 61, S. 126-131, München 2000.

SACHER, M., IHDE, J., MARTI, U.,C, SCHLATTER,A. (2003): *Status Report of the UELN/EVS Data base* Report on the Symposium of the IAG Subcommission for Europe (EUREF), Ponta Delgada, 5-8 June 2002, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 29, S.140-146 Frankfurt am Main 2003

SACHER, M., BELYASHKI, T., LIEBSCH, G:, IHDE, J. (2004) *Status of the UELN/EVRS Data base and Results of the last UELN adjustmemt.* Report on the Symposium of the IAG Subcommission for Europe (EUREF), Bratislava, 2-5 June 2004, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 35, S.172-179 Frankfurt am Main 2005

SACHER, M., LIEBSCH, G:, IHDE, J., LUTHARDT, J. (2005) *Steps on the way to UELN05 and Enhancements of the web-based Geodetic Information and Service System.* Presented at the Symposium of the IAG Subcommission for Europe (EUREF) in Vienna, June 2-4, 2005

SCHOCH, H. (1995): *Beschreibung des Programmsystems HOENA.* Institut für Angewandte Geodäsie, Leipzig, März 1995 (not published).