Height determination using GNSS

- guidelines for different survey applications

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Questions from the user community

- Can GNSS be used to establish new points in the national height system RH 2000, or to connect remote local networks to the system, (or is connection using levelling needed)?
- If so, which method should be used?
- And what level of uncertainty may be expected?

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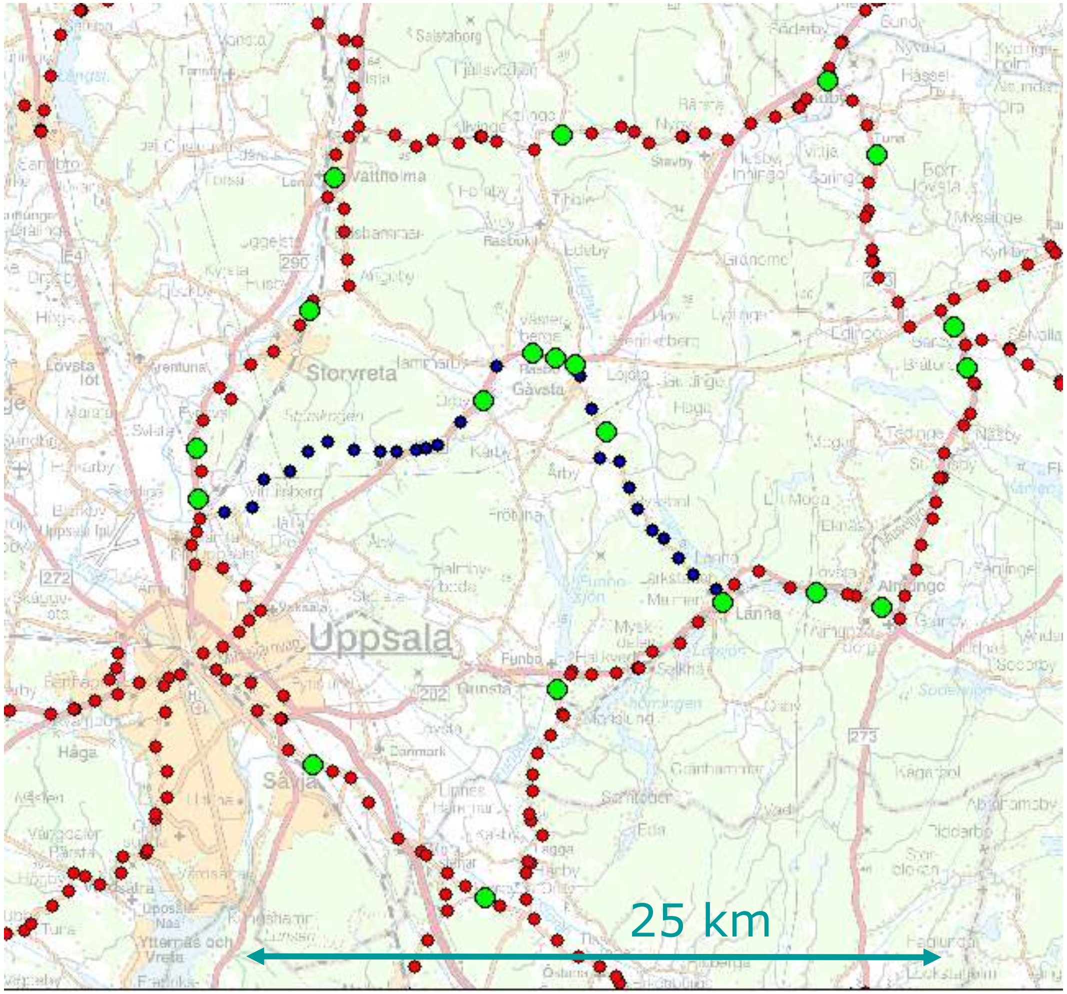
Different survey methods

Sub-project 1: Establish points in RH 2000 using static GNSS surveying in campaign style approach

Sub-project 2: Establish points in RH 2000 using static GNSS observations, and applying SWEPOS® automated post processing service

Sub-project 3: Uncertainty level and methodology when using SWEPOS network RTK service.

Test-area for static survey



- well marked bench marks in the national height system RH 2000
- small village connected using motorized levelling
- area with open terrain (farming land), but still difficult to find appropriate points!
- good conditions to evaluate the results.

Observations for the test-data set

February 18-20, 2008

- observations 2*24h, with re-centering of the setup
- Modern commercial standard antennas of good quality (here Leica AX 1202 GG)
- same antenna type at all sites
- 5 sites in the local network, 15 in the surrounding leveling loop

March 17-20, 2008

- observations 2*24h, with re-centering of the setup
- Dorne Margolin choke ring antennas
- not exactly the same antenna type at all sites (Ashtech and Javad copies of AOAD/M_T)
- the same 5 sites in the local network, and 6 of the previous ones in the surrounding leveling loop

➢ A data set useful for simulation of various survey strategies Included point; session length; observations divided into sub-networks; used antenna type; etc.

➢ In order to find a reasonable practical useful method!

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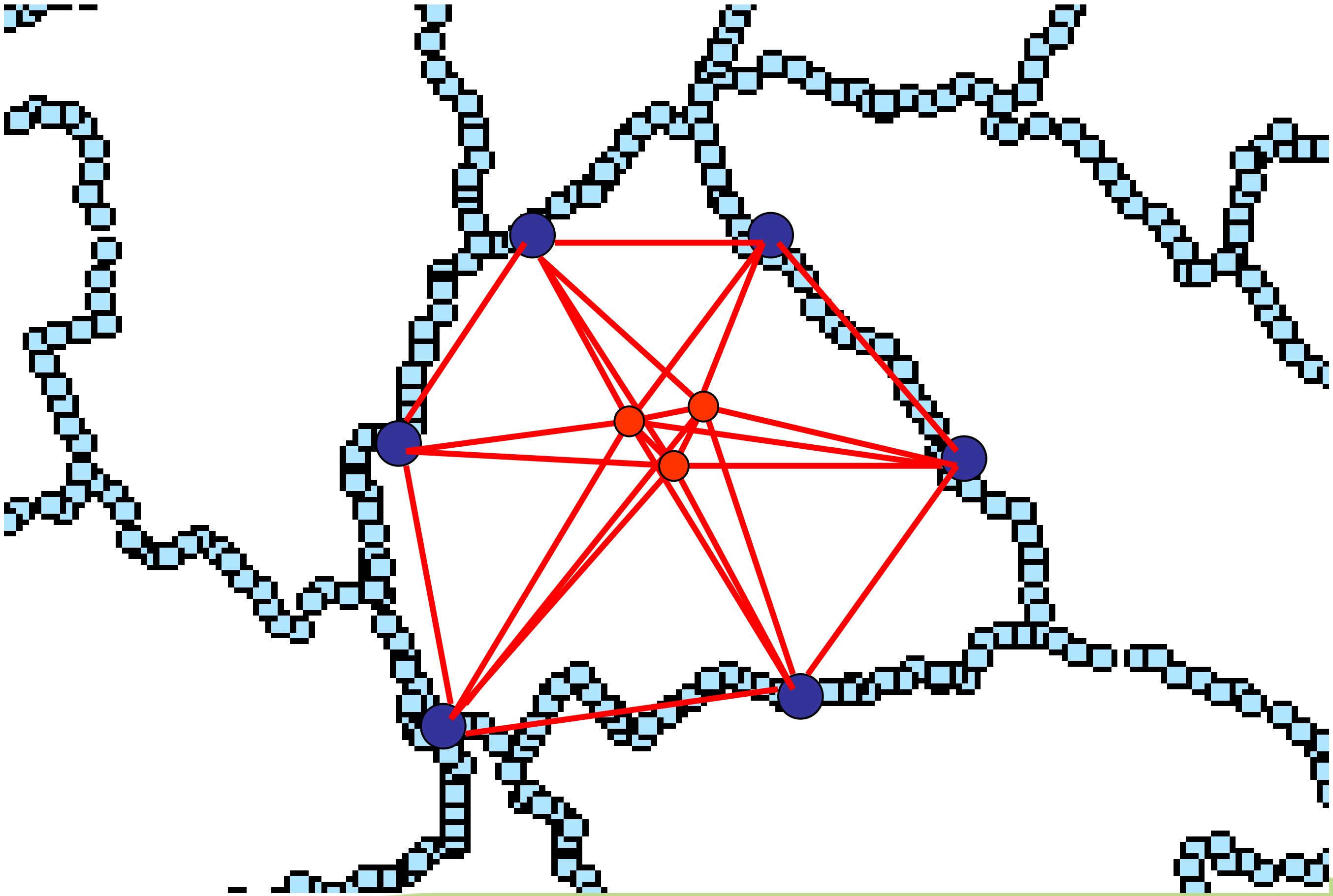
Establish points in RH 2000 through a local control network surveyed using static GNSS



Principle sketch

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Summary of the results sub-project 1

The table is based on putting togeather calculation of some 100 networks

Number of sessions in the network	L1 / Lc in GPS-processing	Session duration (h)	Number of computed networks	RMS of height error for a single point (mm)
1	L1	2	24	5
1	L1	3	16	5
1	L1	6	8	5
1	Lc	3	16	6
3	L1	3	15	6
2	L1	3	15	7
2	Lc	3	15	5

Lc, ionosphere free linear combination of L1 and L2, also known as L3

Uncertainty in height determination of a single point (RMS of height error).
A network including 3-5 new points has been computed and fit to 6 known points in RH 2000 (from surrounding leveling loop) by an inclined plane (1-dim, 3 par).
The network is observed and computed in 1, 2 or 3 sessions using 11 or 6 receivers
The same type of modern standard antennas are used on all sites.

Guiding principles when establishing points in RH 2000, using GNSS network approach

- Make sure that chosen known points are stable (monuments in bedrock, or check the stability using levelling to a close by point)
- Use 6 known points (1 dof / unknown parameter to get reliable result in the fit using inclined plane)
- For the application of connecting a local height network to national RH 2000 – determine minimum 3 new points
- Observe in open areas – eccentric setup is often needed (the tie determined using levelling)
- Use an elevation cut-off angle of 12 - 15° in the baseline processing
- Use the same modern type of antennas on all points. (Older antenna types often have individual differences, and are often of less homogenous quality)
- Measure the antenna height before and after the survey session
- A session length of 3 hours is recommended

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Conclusions

- In this experiment, ”new” points could be established in RH 2000 at the 5 mm uncertainty level (RMS).
- Similar results was achieved using Dorne Margolin type antennas – when exactly the same type was used.
- The method has been commonly used. Here we got somewhat better results compared to the RIX95-project (ca 11 mm), but there shorter observation sessions was used.
- 5 – 8 mm (1 σ) may be a reasonable estimation of the uncertainty level for the method
- Simultaneous observations give a slightly better result compared to division into sub-sessions?
- Various error sources are present, e.g: errors in the leveling, errors in the geoid model, multipath, other disturbances in the GNSS-observations

Different survey methods

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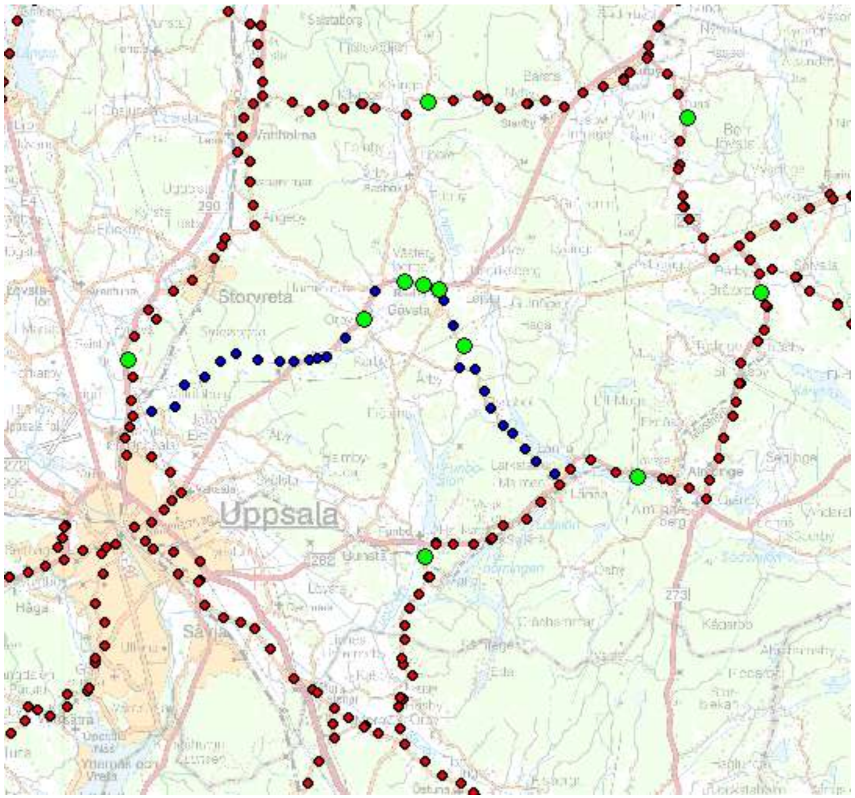
Sub-project 3: Uncertainty level and methodology when using SWEPOS network RTK service.

2. Establish points in RH 2000 using static GNSS observations, and applying SWEPOS® automated post processing service



- Test data from the same 11 sites (6+5), observed 2*24h using both the standard (Leica AX 1202GG) and the DM-antennas respectively
- Geoid model SWEN08_RH2000
- Computation done through SWEPOS automated processing service

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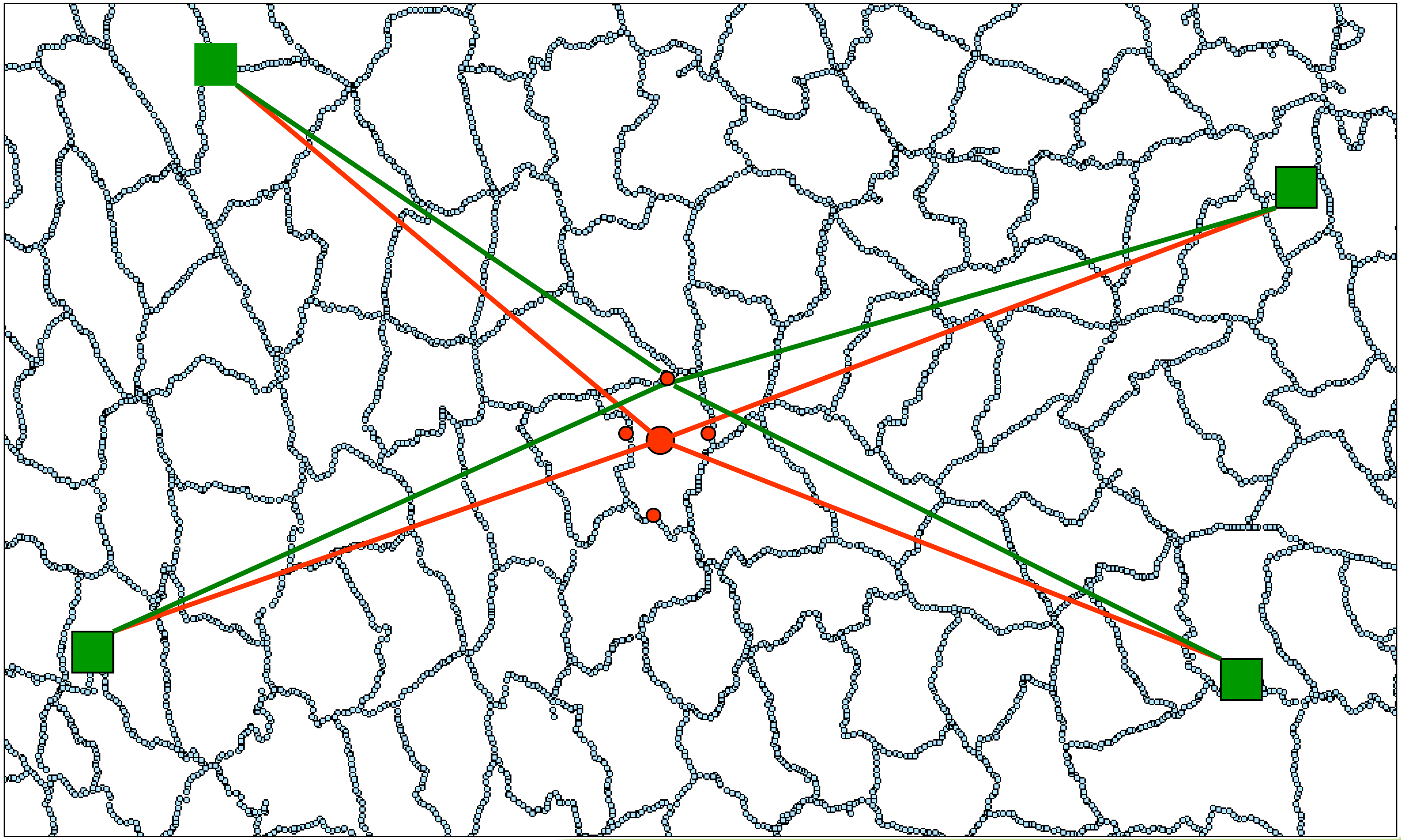
Height determination using SWEPOS® automated post processing service



Principle sketch

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Results using standard antennas

No regional fit, Leica antennas day 1, (mm)						
Session duration	RMS	Std dev	max diff	min diff	diff max-min	shift
2 h	21,6	4,3	-1,6	-47,7	46,1	-20,1
3 h	21,3	4,3	-6,2	-40,5	34,3	-20,1
4 h	21,2	4,3	-8,7	-35,9	27,2	-20,3
6 h	21,0	4,3	-7,8	-33,3	25,5	-20,2

5 new points, RMS (difference = computed – known height), standard deviation of the difference (repeatability), max and min of the differences, and mean of the differences.

In the processing, 5 SWEPOS stations were included Lovö, Mårtsbo, Norrköping, Leksand and Karlstad

Results using Dorne Margolin-antennas

No regional fit, DM choke ring antennas day 1, (mm)						
Session duration	RMS	Std dev	max diff	min diff	diff max-min	shift
2 h	11,9	4,3	11,7	-25,1	36,8	-9,3
3 h	11,5	4,4	17,4	-20,7	38,1	-9.5
4 h	11,4	4,3	11,9	-23,9	35,8	-9,4
6 h	10,7	4,4	6,8	-19,4	26,2	-9,1

Results standard antennas after regional fit applying inclined plane

Regional fit (1D, 3-par), Leica antennas, day 1, (mm)						
Session duration	RMS	Std dev	max diff	min diff	diff max-min	shift
2 h	8,2	8,0	10,8	-27,5	38,3	-2,0
3 h	6,8	6,6	10,4	-20,6	31,0	-2,0
4 h	6,0	6,0	8,8	-14,3	23,1	-1,2
6 h	6,1	6,0	8,4	-12,2	20,6	-1,8

Resultas Dorne Margolin antennas after regional fit applying inclined plane

Regional fit (1D, 3-par), DM choke ring antennas, day 1, (mm)						
Session duration	RMS	Std dev	max diff	min diff	diff max-min	shift
2 h	7,9	5,7	4,1	-19,9	24,0	-5,5
3 h	7,4	5,1	3,0	-15,1	18,1	-5,5
4 h	6,7	5,1	5,8	-13,7	19,5	-4,5
6 h	7,4	3,8	-0,7	-14,7	14,0	-6,4

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Guiding principles while establish points in RH 2000, using SWEPOS post processing service

- Observation duration minimum 2 h, preferably 3 h
- Observe in open areas – eccentric setups is often needed (the tie determined using leveling)
- SWEPOS post processing service apply an elevation cut-off angle of 10°, so fairly open sky from the points are recommended. (solve for atmospheric delays and apply elevation dependent weighting)
- Measure the antenna height before and after the survey session
- If several receivers are used, make sure that all antennas are of the same type
- Make sure that possibly included known points are stable (preferably monuments in bedrock)

Conclusions

- New points was determined at an uncertainty level of 20-25 mm (1 σ) using modern standard antennas. For the DM choke ring antennas the uncertainty level was 10-15 mm.
- Applying regional fit to included (minimum 4) known points in the national network, the uncertainty was reduced to 8 – 10 mm (1 σ) for booth antenna types.
- Our experience from this method, using standard antennas and short observation duration is limited. More experiences would be desired.
- The method is simple since the user can carry out the job using only one or few receivers, and computation is done using SWEPOS processing service.

Different survey methods

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SWEPOS Network RTK Service

Uncertainty values based on:

- CLOSE-RTK project – an extensive analysis of error sources in network RTK, and its impact on the performance
- Evaluation based on SWEPOS monitoring stations; standard service (70 km) and project adapted service (10-20 km)
- Experience from the user community

Summary

Survey method	Uncertainty in height in RH 2000 for single new point (mm), (1 σ)
GNSS, static campaign style	5-8
SWEPOS post processing service	12-20
SWEPOS post processing service + regional fit to RH 2000 height network	8-10
SWEPOS RTK service, standard service	27-30
SWEPOS RTK service, Project adapted service	15-19

Summary of estimated expected uncertainty for a new determined point in RH 2000, using the described method.

For network RTK service, an estimated uncertainty in the geoid model of 10-15 mm has been added

Conclusions

The method using static GNSS surveying in campaign style approach is used to establish points in RH 2000 for further measurement with leveling or GNSS.
This method can also be used for connection of small and remote local netwoks to RH 2000, where connection using leveling is not reasonable.

The method described in sub-project 2 can also be used to establish single points in RH 2000 with one reciever for further measurements with leveling or GNSS.

SWEPOS RTK service is the most suitable method to use in situations where an uncertainty of 30 mm is sufficient.

It is to be noted that the results regarding static measurements are mainly based on the described test measurements carried out at one occasion and at one location.

Reports are available at: www.lantmäteriet.se >maps > geodesy and GPS >Reports/publications

Thanks for listening !

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