Campaign and vectors, geoid and leveling. Combined adjustment

NORWEGIAN MAPPING AUTHORITY

SPATIAL DATA – FOR BENEFIT OF THE SOCIETY

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Background

NN2000, our new height system for gravity related heights

- Only 23 % of the points in our reference network (Stamnett and Landsnett) are levelled
- For points not levelled NN2000 heights will be derived from ellipsoidal heights and a fitted geoid model (height reference model)
- The accuracy of the NN2000-heights on these points in our reference network depends on the accuracy of the ellipsoidal heights.
- All available observations, vector as well as campaigns, should be used.

DEFINITION OF TERMS

Frequently used in this presentation

- Campaign measurement
  - After processing the result is coordinates
  - Many points processed at a time
  - Usually several days of observation times
  - Advanced academic university software (Gipsy, Bernese, Gamit)

- Vector measurement
  - After processing the result is coordinate differences (vectors)
  - Usually only one vector is processed at a time
  - Usually only hours of observation time
  - Commercial software (GPPS, GeoLab, LineComp, SKI ...)

CAMPAIGN MEASUREMENTS

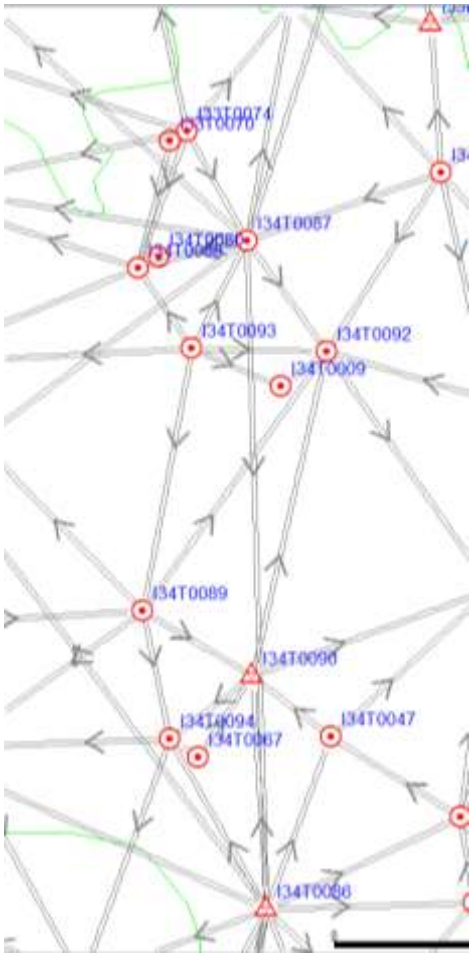
A part of the IGS05-project

- 5 – 7 days of measuring
- Processed by use of Bernese GPS-software
- Constrained to the Norwegian permanent stations
  - Epoch: 31th of July 2009
  - Coordinated based on daily solution back to 2000
- Measured in 2009 and 2010
- Spatial distribution of 30 km

VECTOR MEASUREMENTS

In the first and second order reference network. (Stamnett and Landsnett)

- Observed from 1994 – 2009
- Processed in the year of observation by use of different commercial software
- Length from 3 – 20 km
- About 90% measured and processed by Norwegian Mapping Authorities
  - About 10% from external organisations
- Used in the calculation of the our reference network



HOW TO COMBINE

Vector- and campaign measurement

- Calculation of ellipsoidal heights H_{ell} and height differences dH_{ell}
  - H_{ell} from campaigns. The co-variances must be derived from the 3D-file.
  - dH_{ell} from vectors.

- Corrections
  - IGS05-N
    - Correct the vectors for land uplift
  - EUREF89 (ETRS-89)
    - Correct the campaigns for land uplift
    - Unknown offset between the datum

- Variance component estimation
  - Weight model for the vectors
  - Weight model for the campaigns

VARIANCE COMPONENT ESTIMATION

For the ellipsoidal height difference in the vectors

The method of Olav Mathisen (Based on least square adjustment)

$$C = C_0 + k_1 C_1 + k_2 C_2 + k_3 C_3 + \ldots$$

where

$$C_1 = I, \quad C_2 = \begin{bmatrix} d_1^{\,2} & & & \\ & d_2^{\,2} & & \\ & & d_3^{\,2} & \\ & & & .. \end{bmatrix} \quad og \quad C_3 = \begin{bmatrix} dh_1^{\,2} & & & \\ & dh_2^{\,2} & & \\ & & dh_3^{\,2} & \\ & & & \ldots \end{bmatrix}$$

Giving as a middle

$$C = 1.0cm^2 + 0.1cm^2 D_{km}^{\,2} + 2.5cm^2 dH_{km}^{\,2}$$

VARIANCE COMPONENT ESTIMATION

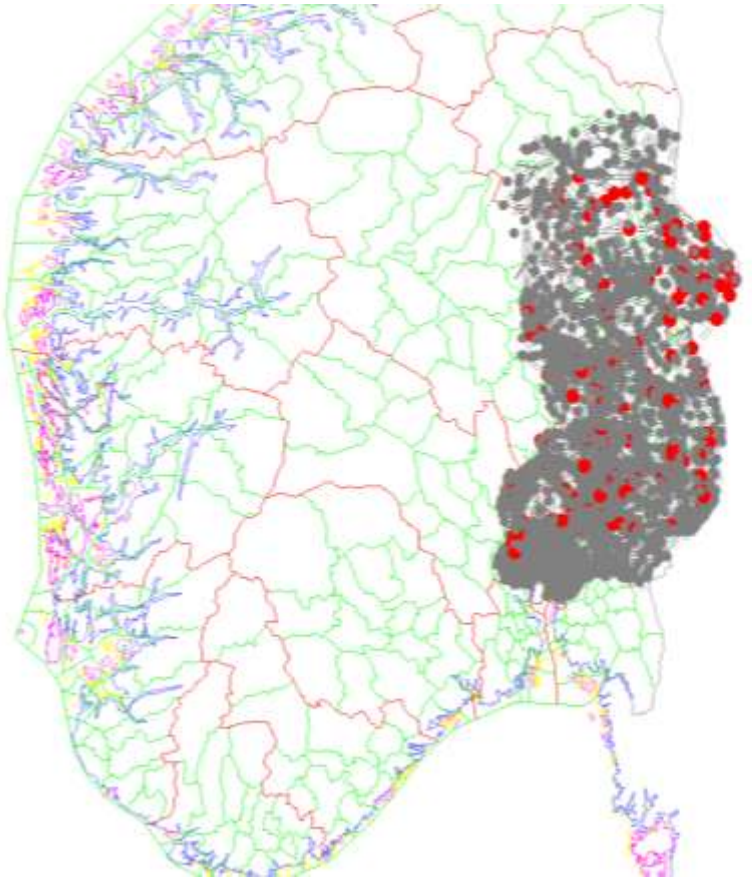
For campaign measurement

- “Simplified estimator” by Caspary 1988
  - Call the campaigns one group of observations and the vectors an other group
  - Calculate the sum of redundancy for each group. (1)
  - Calculate the weighted sum of squared residuals for each group (2)
  - Calculate the a posteriori variance of unit weight for each group by dividing (2) by (1).
  - Iterate the adjustment and redefine the unit weight observation until a posteriori variance is unity for both groups.

- Result
  - The Bernese variances must be multiplied by more than 100.
  - Using 100 gives in average a standard deviation of 9 mm in Hedmark and 4 mm in Rogaland

REFERENCE NETWORK HEDEMARK

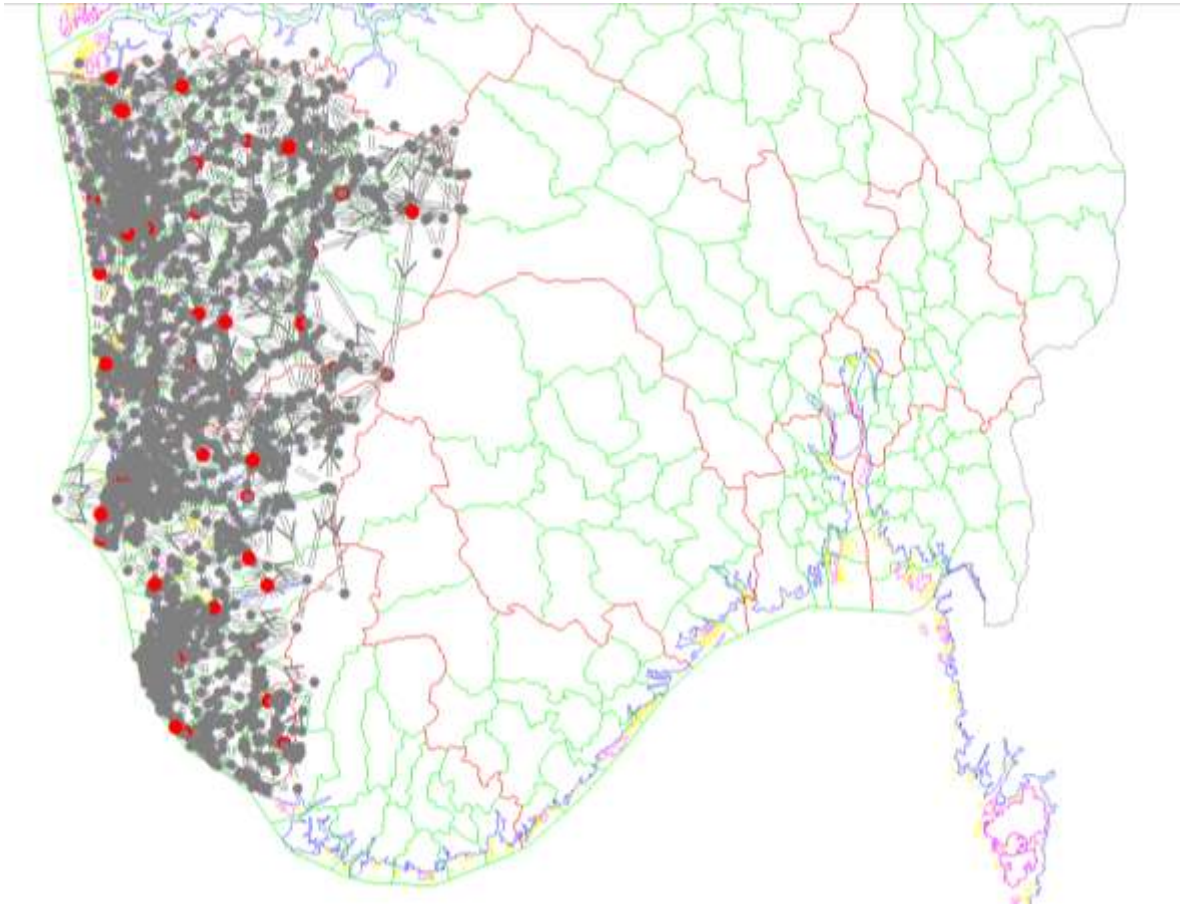
Campaign points in red.



- 131 campaigns
- 8506 vectors
- 2640 points

REFERENCE NETWORK ROGALAND

Campaign points in red.



- 44 campaigns
- 6325 vectors
- 2047 points

CAMPAIGN HEIGHTS VERSUS VECTOR HEIGHTS

Global test

Rogaland	
Point	Deviation
B36T0200	0,035
A32T0425	0,019
B36T0608	0,019
B39T0175	-0,015
C38T0434	-0,023
A33T0192	0,014
A37T0017	-0,023
B35T0620	0,012
B36T0589	-0,009
C36T0245	0,011

Hedmark	
Point	Deviation
H31T0244	0,057
I31N0100	-0,063
G34T0751	0,020
G35T1298	0,023
I31N0111	-0,029
H30N0019	0,032
H30N0009	0,033
I33N0069	0,027
H33T0466	-0,019
H29T0187	-0,020
H35T0238	0,017

COMBINED ADJUSTMENT OF NN2000-HEIGHTS

Observation equations

For vectors

$$dh_{ell} + n = (H_2 - H_1) + (\mathrm{mod}_2 - \mathrm{mod}_1) + (s_2 - s_1)$$

NN2000 heights

Geoid heights from NKG2004

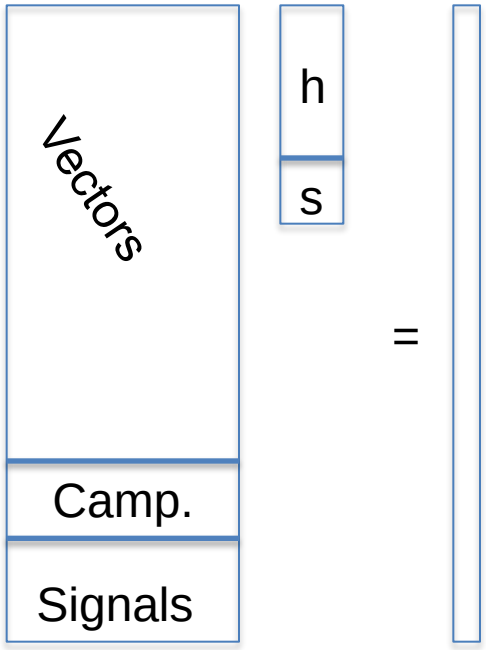
Unknown signals

For campaigns

$$h_{ell} + n = H + \mathrm{mod} + s$$

COMBINED ADJUSTMENT. NN2000 HEIGHTS KNOWN

Schwatz method



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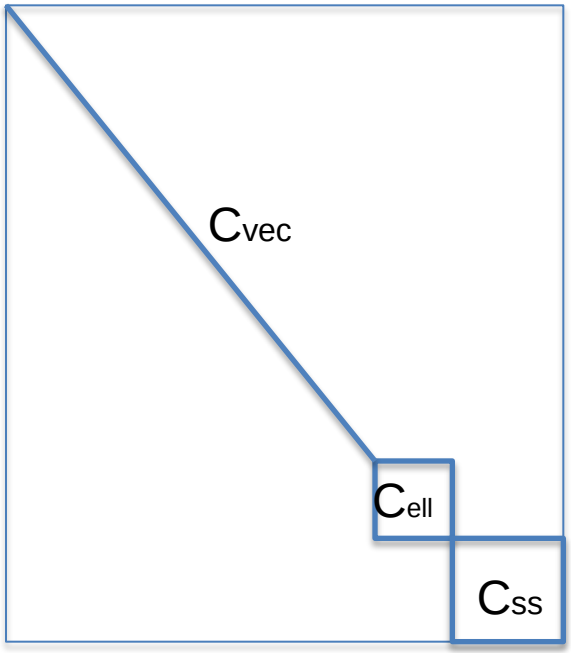
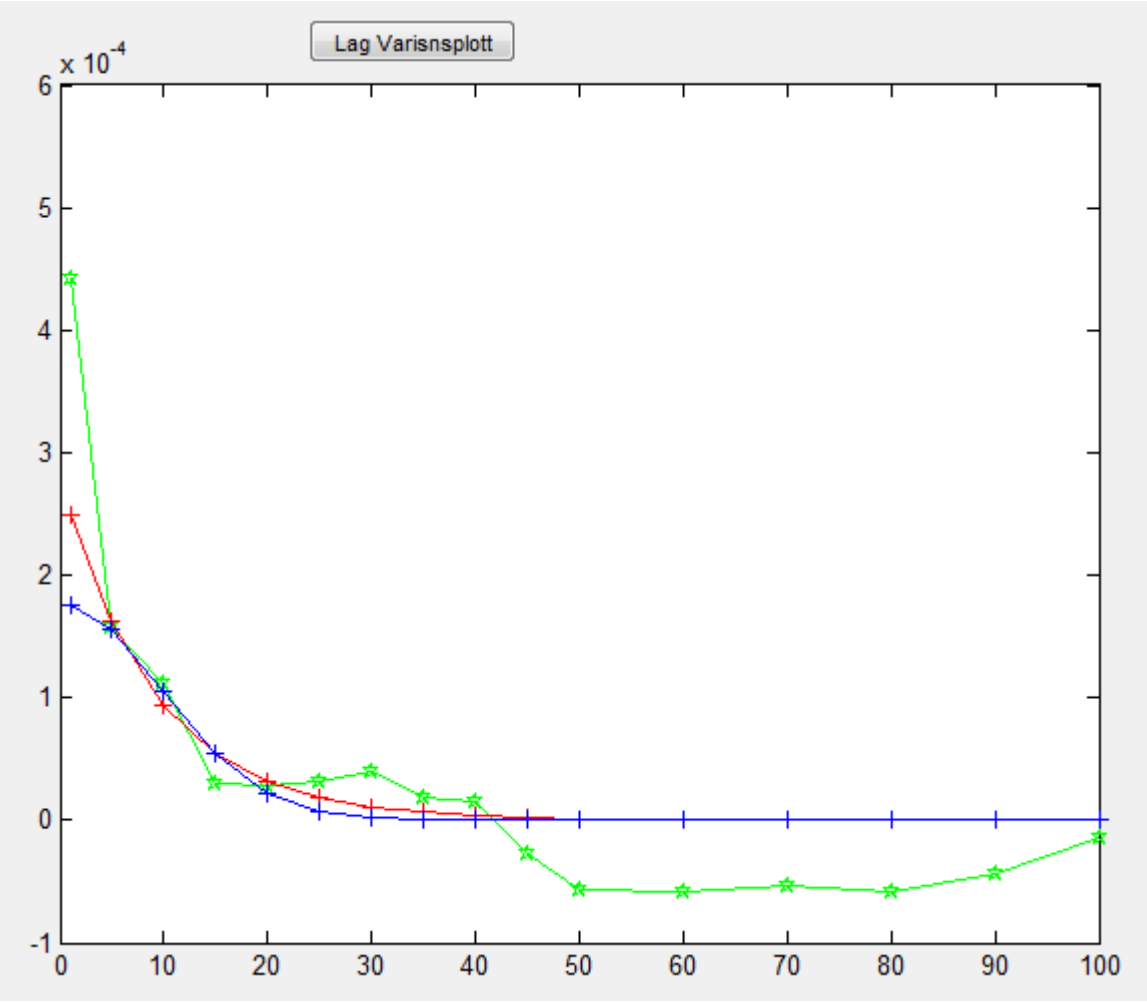


A · X = L

C

VARIANCE PLOT FOR HEDMARK

Based on residuals: Geoid model ÷ (ellipsoidal height ÷ normal height)



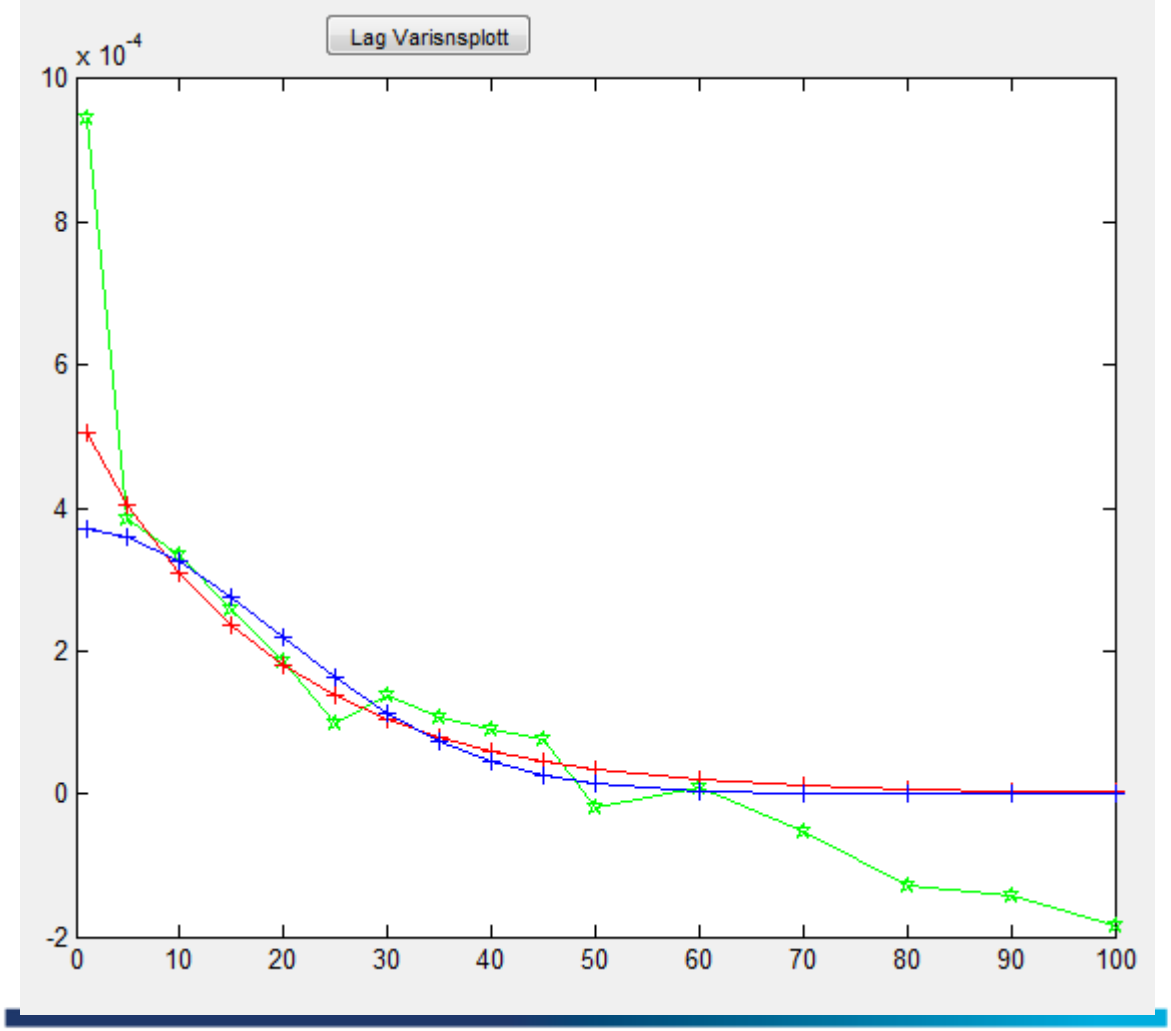
Observed

$\sigma^2 e^{-\beta D}$

$\sigma^2 e^{-\beta D^2}$

VARIANCE PLOT FOR ROGALAND

Based on residuals: Geoid model ÷ (ellipsoidal height ÷ normal height)



Observed

$\sigma^2 e^{-\beta D}$

$\sigma^2 e^{-\beta D^2}$

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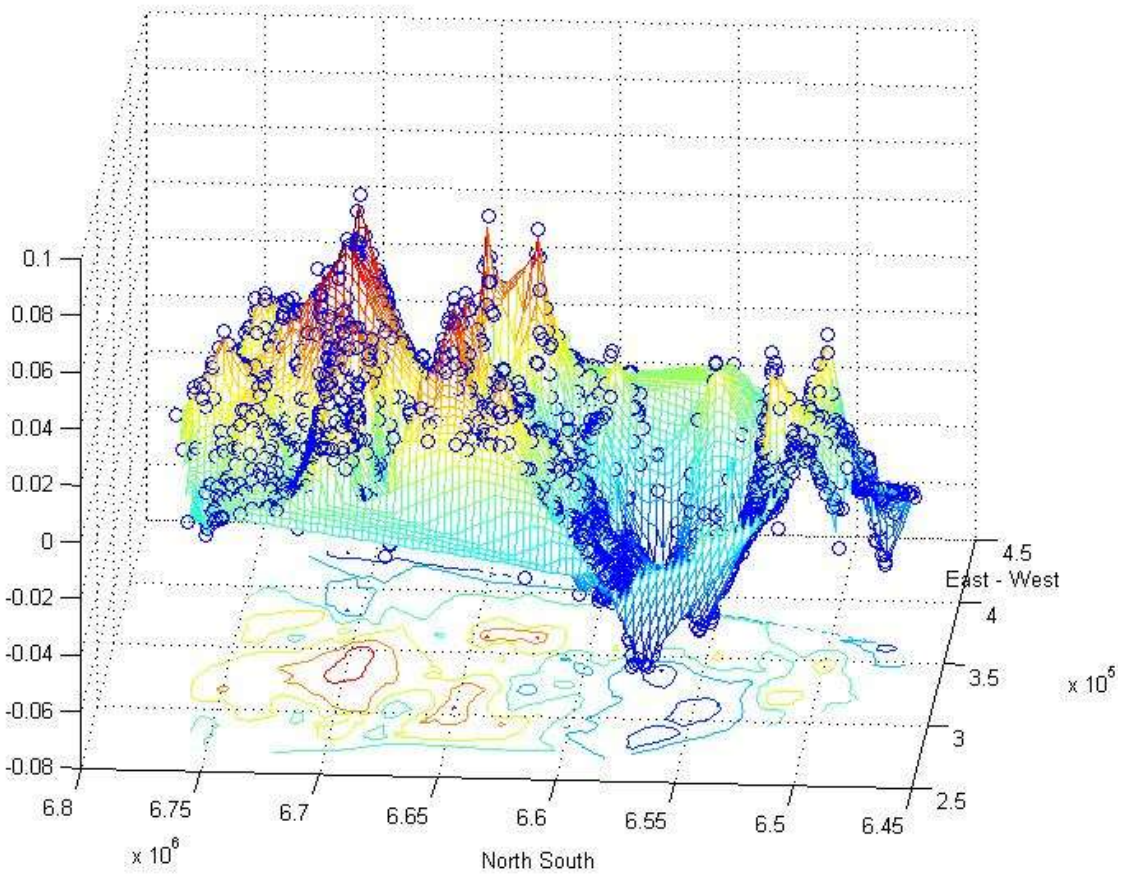
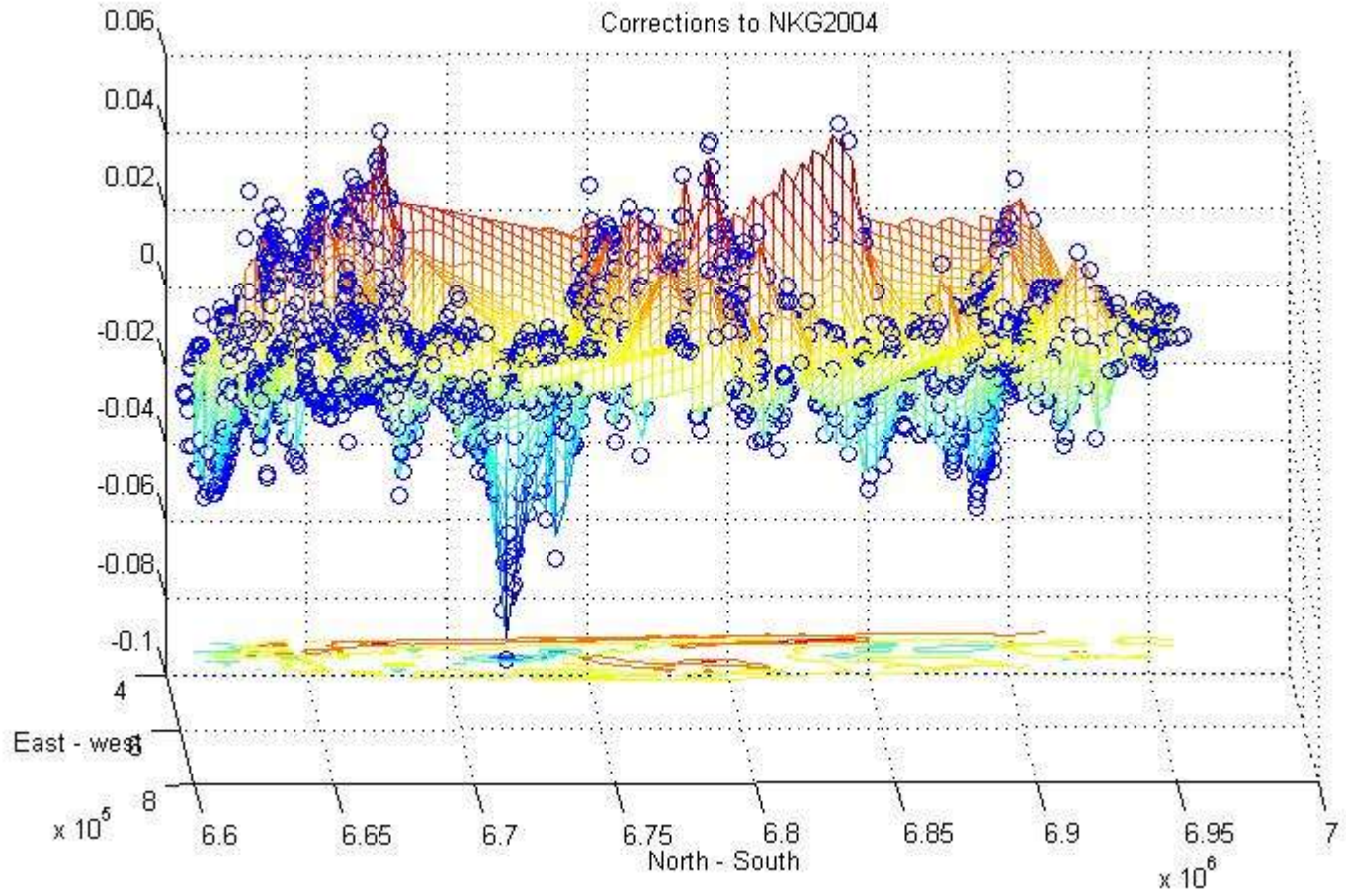
SIGNALS

Rogaland



SIGNALS

Hedmark



LEVELLING CHECK ROGALAND

What fits best to the levelling net?

Point	Camp - Vectors	Camp - Levelling	Vectors - Levelling	T-value	Remark
B36T0200	0,035	0,038	0,003	9,3	Dynamited close by
A32T0425	0,019	0,004	-0,015	0,8	17 vectors in 4 setups
B36T0608	0,019	0,025	0,006	5,8	20 vectors in 4 setups
B39T0175	-0,015	-0,074	-0,063	17,0	4 cm diff forward and backward
C38T0434	-0,023	0,000	0,023	0,3	8 vectors in 2 setups
A33T0192	0,013	0,005	-0,008	0,1	
A37T0017	-0,023	0,021	0,042	5,3	Incorrect levelling?
B35T0620	0,012	0,002	-0,010	0,6	21 vectors and 3 setups
B36T0589	-0,009	0,012	0,021	3,4	34 vectors in 7 setups
C36T0245	0,011	-0,004	-0,015	0,1	15 vectors in at least 4 setups

LEVELLING CHECK HEDMARK

What fits best to the levelling net?

Point	Camp - Vectors	Camp - Levelling	Vectors - Levelling	T-value	Remark
H31T0244	0,057	0,004	-0,061	0,0	Lev. and campaign unreliable.
I31N0100	-0,063	-0,036	0,027	1,1	Unstable stone?
G34T0751	0,020	-0,001	0,021	0,2	40 vectors in at least 11 setups
G35T1298	0,023	0,019	-0,004	1,8	40 vectors in at least 3 setups
I31N0111	-0,029	0,012	0,041	1,1	6 vectors in 2 setups
H30N0019	0,032	0,001	-0,031	0,1	5 vectors in 2 setups
H30N0009	0,033	0,026	-0,007	0,1	5 vectors in 1 setup
I33N0069	0,027	0,008	-0,019	0,6	5 vectors in 1 setup
H29T0187	-0,020	-0,015	0,005	2,9	14 vectors in at least 3 setups
H35T0238	0,017	0,008	-0,015	0,6	8 vectors in at least 2 setups

CONCLUSIONS

Different techniques controls each other

- The network of vectors may control campaign measurement and vice versa
- NN2000-heights and geoid models may give an extra control of both vector- and campaign measurement
- Vector- and campaign measurement may reveal errors in the levelled heights

- Thank you for your attention!