## OPTIMIZED TECHNOLOGY FOR GPS HEIGHT DETERMINATION

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## GPS Height Determination

GPS heighting involves :

-GPS measurement of ellipsoidal heights/ height differences

-Application of an appropriate (quasi)geoid model

-Attachment of orthometric/normal heights to a vertical datum

Determining is the extent of application area (Global, Regional, Local), and required accuracy



## Factors of GPS Height Accuracy

-Satellite Constellation
-Satellite Associated Errors (Orbits, Clock Bias)
-Signal Propagation Errors (Ionosphere, Troposphere)
-Receiver Associated errors (Clock Bias, Antenna Phase Center Offsets/Variations)
-Station Associated Errors (Surrounding, Centring, Signal Multipath and Diffraction)
-Secondary Effects (Solid Earth Tides, Ocean and Atmospheric Loading etc.
-(Quasi)Geoid Model Errors
-Uncertainties in attachment to Vertical Datum



## GPS Measurement of Height Differences

Assuming real accuracy level of 1 cm the average minimal observation times are :

-Baselines in range of 50 – 100 km at least 48 hours

-Baselines in range of 20 – 50 km at least 24 hours

-Baselines under 20 km at least 8 hours

Shorter baselines (well under 20 km) can be measured in special reduced observing mode



## Observation of Baseline Dyads and Triplets

Combination of 2 or more shorter observation sessions separated by constant time intervals

Dyada – combination of 2 sessions
Triplet – combination of 3 sessions

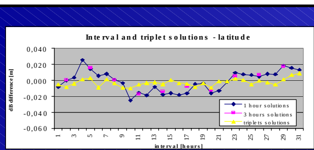
Appropriate session duration (ambiguity resolution)

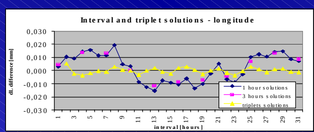
Optimization of separation time interval

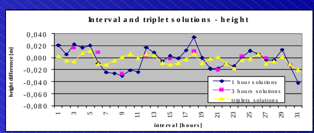
Best triplet results achieved with 60-90 min. sessions measured in separation of 6-8 hours



## Comparison of interval and triplet solutions

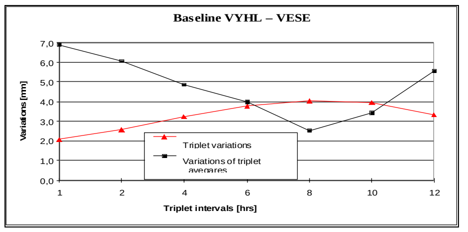


## Accuracy of Baseline Dyads and Triplets

| Accuracy of a baseline height component | 1 hour sessions repeated | | | |
|---|---|---|---|---|
| | after 1 hour | after 2 hours | after 8 hours | after 12 hours |
| s.d. of dyada averages [m] | 0,0115 | 0.0097 | 0.0063 | 0.0082 |
| s.d of triplet averages [m] | 0.0097 | 0.0085 | 0.0038 | 0.0074 |
| s.d. of adjusted triplets [m] | 0.0100 | 0.0087 | 0.0045 | 0.0070 |







## Sněžník Network

Founded in 1992

**Czech Part**

Highest Point SCZE 1424 m
Lowest Point VLAS 446 m
Longest Baseline 13659 m
Max. Height Diff. 978 m

**Measurement Techniques**

GPS
Levelling
Gravimetry
EDM
Astronomy



## Optimized Accuracy of Sněžník Network

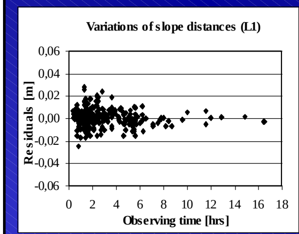
Southern Part

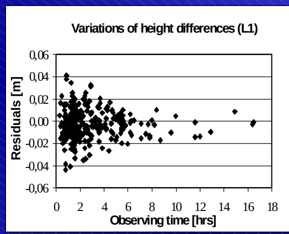
| Station | Accuracy [mm] | | | BERNESE - SKI, L1 solution | | |
|---|---|---|---|---|---|---|
| | s (B) | s (L) | s (H) | dX [m] | dY [m] | dZ [m] |
| 0025 TVDR | 1.4 | 1.4 | 2.5 | -0.0005 | -0.0022 | -0.0033 |
| 0026 KLEP | 0.8 | 0.7 | 1.3 | 0.0010 | 0.0001 | -0.0019 |
| 0027 VYHL | - | - | - | 0.0000 | 0.0000 | 0.0000 |
| 0028 MALI | 1.6 | 1.9 | 2.7 | 0.0037 | 0.0006 | -0.0015 |
| 0029 LOMA | 1.5 | 1.2 | 2.6 | 0.0001 | 0.0003 | 0.0018 |
| 0030 ROUD | 1.4 | 1.4 | 2.2 | 0.0018 | -0.0003 | 0.0000 |
| 0031 VESE | 1.0 | 1.0 | 1.5 | -0.0008 | -0.0002 | -0.0028 |
| 0120 VLAS | 1.3 | 1.5 | 2.1 | -0.0007 | -0.0012 | -0.0001 |
| 0201 DMOR | 1.2 | 1.2 | 1.9 | -0.0003 | 0.0004 | 0.0004 |
| Std. dev. (components) | 1.3 | 1.3 | 2.1 | 0.0015 | 0.0009 | 0.0017 |
| Std. deviation (mean) | 1.6 | | | 0.0014 | | |



## Variations of Slope Distance and Height Residuals vs. Observing Time

Sněžník Network






## GPS Antenna Field Test

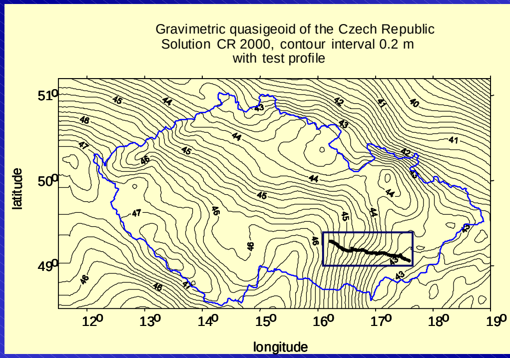


## Testing of Quasigeoid Heights

$$H_L = H_{GPS} - \Delta\zeta$$

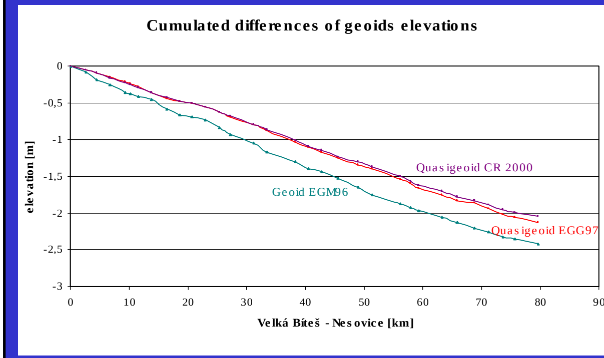
| point | H - levelling | H - computed | difference |
|---|---|---|---|
| 0025 TVDR | 807,432 | 807,426 | 0,006 |
| 0026 KLEP | 1085,171 | 1085,166 | 0,005 |
| 0027 VYHL | 992,942 | 992,937 | 0,005 |
| 0028 MALI | 734,354 | 734,354 | 0,000 |
| 0029 LOMA | 634,878 | 634,878 | 0,000 |
| 0031 VESE | 719,560 | 719,562 | -0,002 |
| 0201 DMOR | 623,562 | 623,555 | 0,007 |

## Gravimetric Quasigeoid and Levelling Section



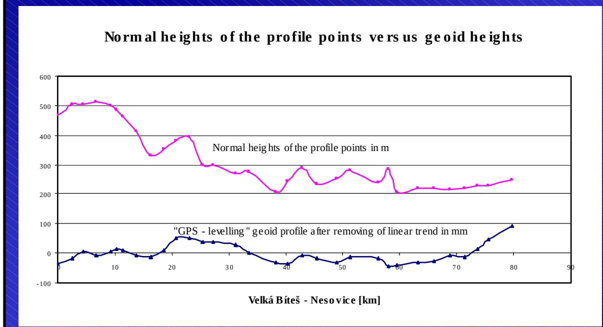



## Differences of (Quasi)Geoids Elevations






## Detailed Quasigeoidal Section






## Triplet Height Difference Accuracies

### 3. subsection

| Baseline from | Baseline to | Baseline length [m] | Height difference [m] | Residuals v1 [mm] | Residuals v2 [mm] | Residuals v3 [mm] | Accuracy $s_i$ [mm] | Accuracy $s_h$ [mm] |
|---|---|---|---|---|---|---|---|---|
| 21 | 22 | 2300 | -53,2 | -0,2 | 5,5 | -5,4 | 5,5 | 3,1 |
| 22 | 23 | 2798 | 19,2 | -2,0 | 5,6 | -3,7 | 5,0 | 2,9 |
| 23 | 24 | 2047 | 24,7 | 3,8 | -2,7 | -1,2 | 3,4 | 2,0 |
| 24 | 25 | 3609 | -39,1 | -0,1 | 0,8 | -0,6 | 0,7 | 0,4 |
| 25 | 26 | 1713 | 43,8 | 4,8 | -1,6 | -3,3 | 4,3 | 2,5 |
| 26 | 27 | 1412 | -75,5 | 2,1 | 2,3 | -4,3 | 3,8 | 2,2 |
| 27 | 28 | 3252 | 12,2 | 1,7 | -1,4 | -0,4 | 1,6 | 0,9 |
| 28 | 29 | 2281 | 0,1 | 1,3 | 1,1 | -2,4 | 2,1 | 1,2 |
| 29 | 30 | 2514 | -3,2 | -6,7 | 9,3 | -2,7 | 8,3 | 4,8 |
| 30 | 31 | 2061 | 2,1 | -2,5 | -3,0 | 5,6 | 4,8 | 2,8 |
| 31 | 32 | 2334 | 9,5 | 7,9 | -0,2 | 3,3 | 10,0 | 5,8 |
| 32 | 33 | 1732 | 1,9 | -9,8 | 5,8 | 3,9 | 8,5 | 4,9 |
| 33 | 34 | 1354 | 7,1 | -13,4 | 3,6 | 9,8 | 12,0 | 6,9 |
| 34 | 35 | 2117 | 10,6 | 10,8 | -1,1 | -9,8 | 10,3 | 6,0 |



## Conclusions

- GPS heighting – complicated procedure, becames currently used
- Reduction of observation times - dyads, triplets demanding as to timing and organisation
- Triplet ellipsoidal height difference accuracies :
  - baseline up to 5 km – RMS under 5 mm
  - baseline up to 15 km - RMS under 8 mm
- Substantial productivity increase (5 receivers + 24 hours = 15 - 25 new points)