

From Passive to Active Control Point Networks – Evaluation of Accuracy in Static GPS Surveying

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Background and motivation

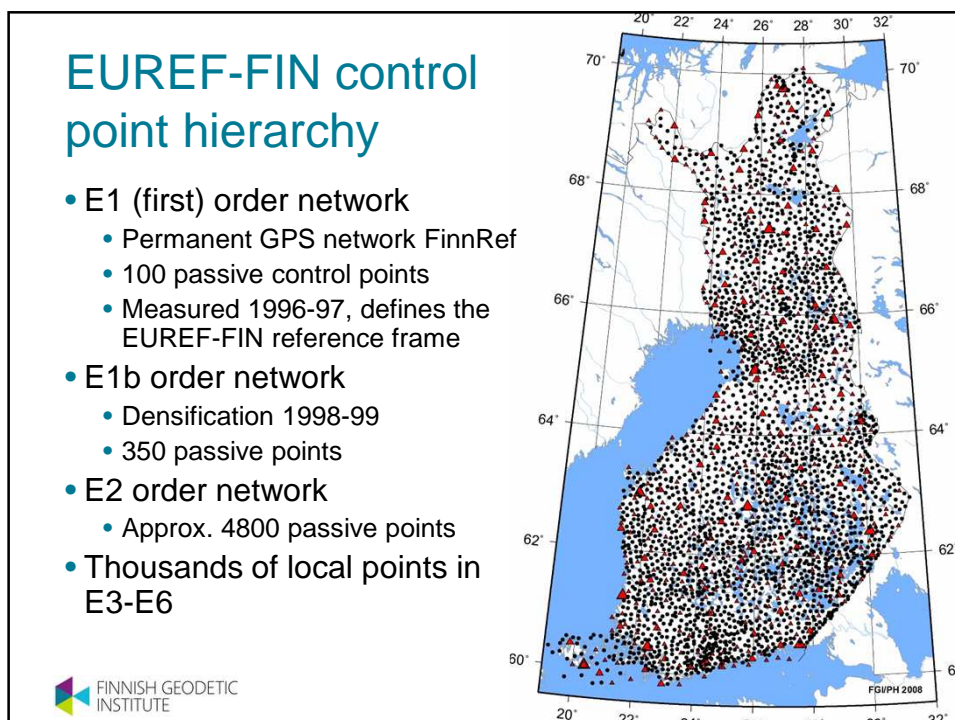
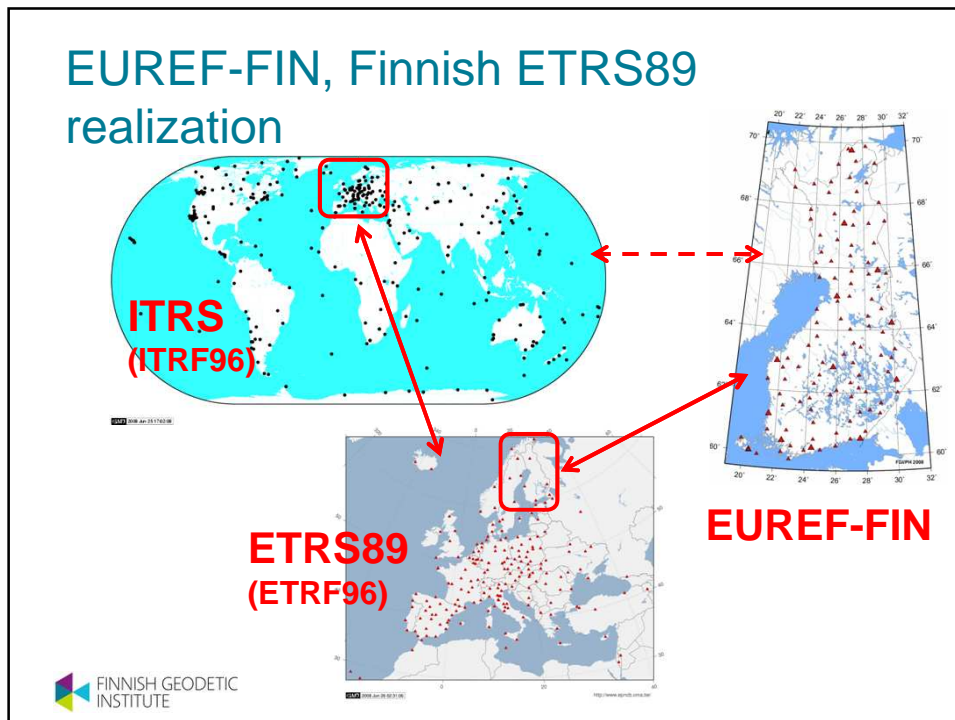
- Finnish Geodetic Institute (FGI) together with National Land Survey (NLS) responsible of creating and maintaining of Finnish reference frames
 - In the past control point measurements made hierarchically in Finland (traditional way): first order network defines the RF, second order network tied directly to that, third order network tied to second order, etc. Measurements neglecting the hierarchy were not allowed.
 - Situation has changed with satellite positioning: measurements not anymore dependent on distance between the points and new positioning services (network RTK) available:
 - + Cost-effective measurements
 - + One GNSS equipment enough
 - Results do not have classification in EUREF-FIN
 - Non-hierarchical measurements neglecting the EUREF-FIN hierarchy (points are not tied to the nearest points but further away to active stations from the area of interest)
- Compatibility with hierarchically measured control points?



Control points

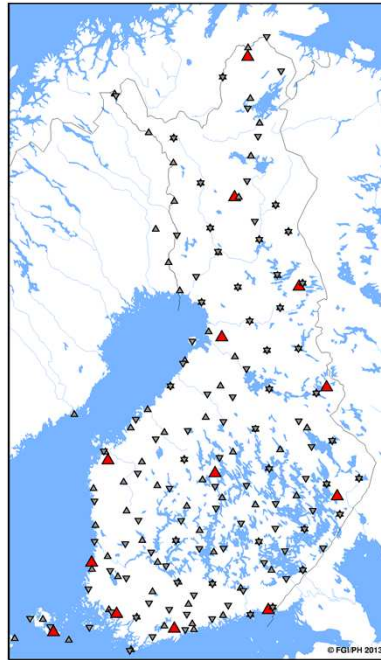
- Passive control points
 - Markers on the ground
 - Coordinates refer to some physical point on the marker
- Active control points
 - Permanently fixed GNSS equipment that collect GNSS observations continuously
 - Coordinates (usually) refer to antenna reference point (ARP)
 - Antenna-related
 - Accuracy may be destroyed/coordinates may change after equipment change or failure → **requires monitoring**





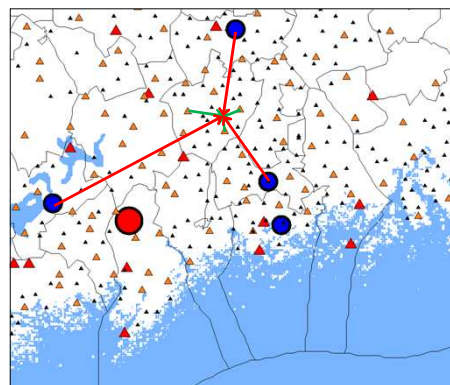
Active GNSS networks

- Scientific network FinnRef (governmental)
 - 13 stations since mid-90's
 - Currently under renewal to be GNSS capable
- Network RTK services (private companies)
 - Trimnet (previously VRSnet.fi)
 - Approx. 90 stations nationwide
 - Since 2000
 - SmartNet
 - Approx. 100 stations nationwide
 - Since 2011



Hierarchical vs. non-hierarchical measurements

- Hierarchical measurement
 - Fixing to the **nearest higher order points**
- Non-hierarchical measurements
 - Fixing **only to active stations** → hierarchy of passive points neglected
 - **Baselines** to active stations **much longer** → requires longer occupation times
- **Compatibility between the two ways of measuring?**



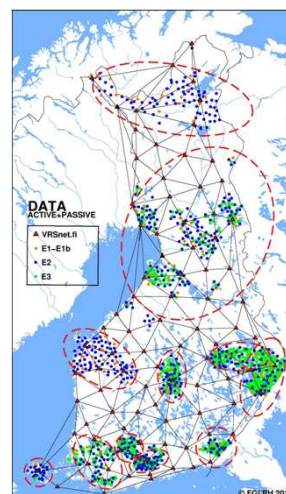
Interstation distance for active stations (large circles) is much longer than for passive control points (triangles)

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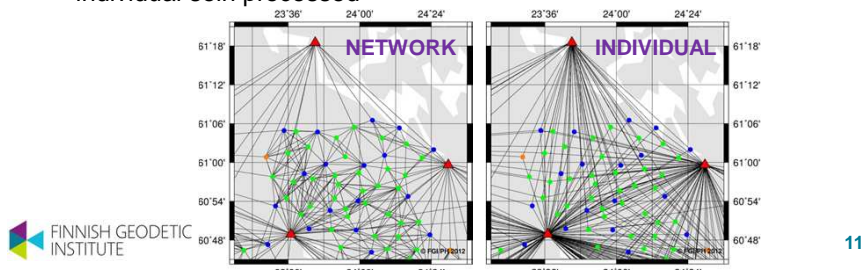
GPS data

- GPS measurements from 2006-2010
 - Approx. 1500 passive points in E1-E3
 - 11 separate subnets (dashed circles in the Figure)
- Original measurements done **with hierarchical measurements** i.e. reference coordinates for the points determined by fixing to the nearest higher order passive points
- **Official coordinates** for some E2-E3 points determined with the same data



GPS processing

- Standard/default settings with Trimble Total Control
 - IGS precise orbits, CODE global ionosphere maps,...
- Measurements **fixed only to nearest active stations** (VRSnet.fi)
- Sessions **processed as network (closed loops) and individual (point-wise) solutions** (Figures below)
 - Baseline lengths 0.4-261km, averages: 18km (network solution) and 51km (individual solution)
 - Average occupation time 2-3h depending on solution type (minimum set to 30 minutes)
 - Approx. 10000 baselines for network soln and 7500 baselines for individual soln processed



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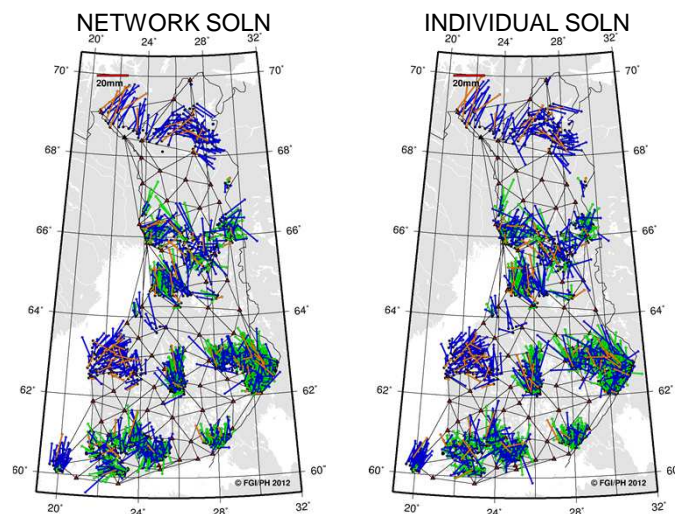
Results

- Some preprocessing (e.g. outliers removed,...)
- Additional verification of occupation times
- Results compared to official, hierarchically measured, coordinates

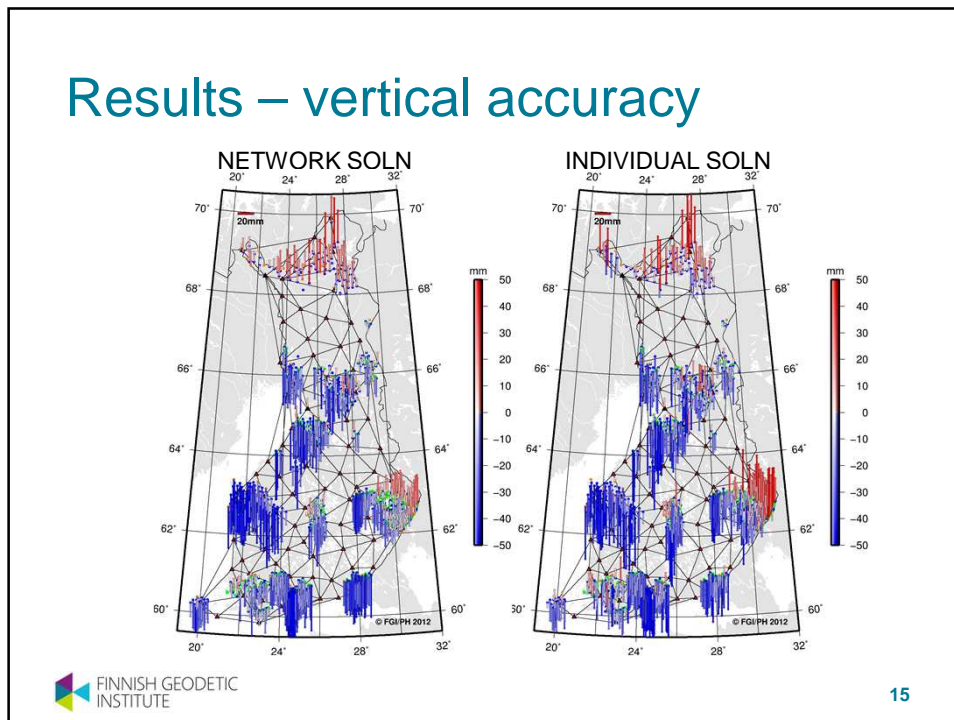
	Network solution (n=1400)			Individual solution (n=1401)		
	N (mm)	E (mm)	U (mm)	N (mm)	E (mm)	U (mm)
Min	-15.40	-17.60	-79.80	-20.90	-21.70	-73.00
Max	27.40	20.10	60.10	27.30	20.10	66.40
Mean	4.68	-0.34	-14.32	5.10	-0.30	-13.07
Stdev	±6.64	±6.02	±21.09	±7.21	±6.42	±23.55
Rms	±8.13	±6.03	±25.50	±8.83	±6.43	±26.93
95%	±16.20	±12.20	±49.20	±17.59	±13.10	±52.00

- Results from different solution types (network/individual) quite equal – network solution only slightly better
- Rms roughly 1cm in horizontal coordinates and 3cm in height (ellipsoidal)

Results – horizontal accuracy



Results – vertical accuracy



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Analysis – solution type

- Results from different solution types (network/individual) quite equal – network solution only slightly better
- Correlation between solutions high ($R^2 \approx 0.7$)
 - roughly 2/3 of the errors can be attributed to some common sources (and only 1/3 to differences caused by the solution types)
 - some systematics (biases) in data

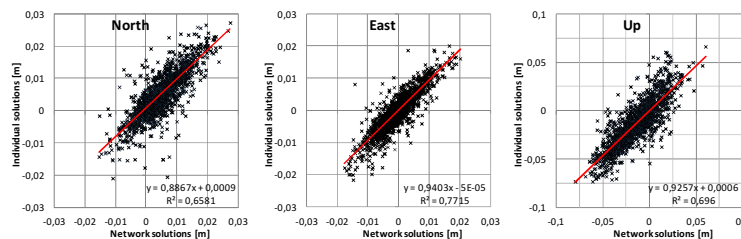
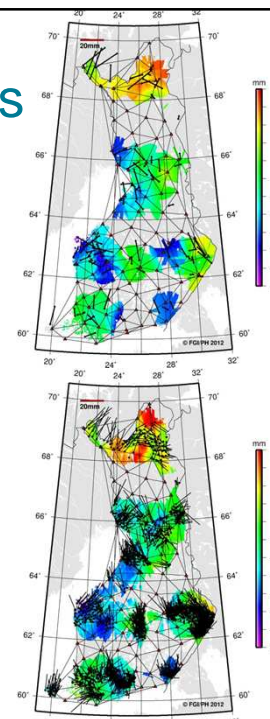


Figure 6. Correlation between network and individual solutions for North (left), East (middle) and up (right) components.

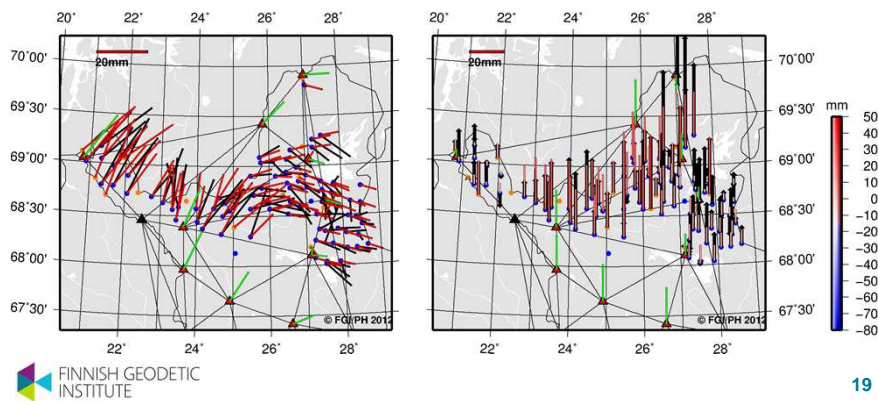
Analysis – coordinate class

- Official E1 coordinates define the EUREF-FIN reference frame → residuals at E1 points should reveal possible differences in the active GNSS network and defining passive control points
- Residuals similar between the E1 and E2-E3 coordinate classes (Figures: E1 on top, E2-E3 below, vectors: horizontal residuals, color map: vertical) → suggests that most of the residuals at E2-E3 points originate from E1 or fiducial (active) points



Analysis – simulations (1/2)

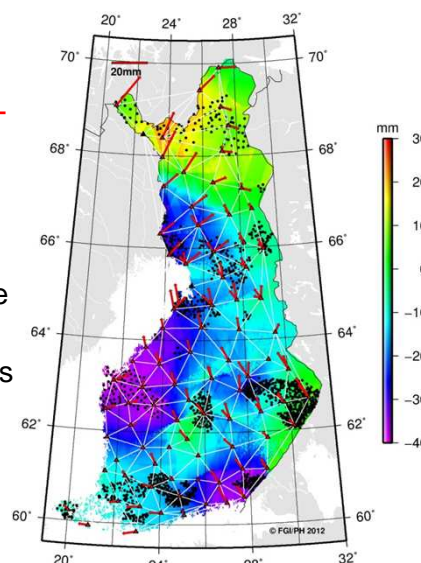
- Simulation done by constraining the official E1 coordinates and propagating E1 residuals to the other points (E2-E3 and fiducial active stations)



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Analysis – simulations (2/2)

- The simulation suggests that the **agreement between active and passive network is in the order of 5-10mm in horizontal and 25mm in vertical coordinates**
- For horizontal part this is a good result but for vertical coordinates some improvements could be made
- Most likely reason for the small disagreement in vertical coordinates is the **post-glacial rebound** effect that is changing the heights constantly in Northern Europe



Conclusions

- Ignoring the coordinate hierarchy one may expect approx. 1cm accuracy (rms) in horizontal and 2-3cm accuracy in vertical coordinates
- Some systematics remain between passive and active networks that are most likely caused by post-glacial rebound. By correcting this effect accuracy could be improved.
- The results were utilized when official guidelines in Finland were renewed – good compatibility means that now also active stations can be used as fiducial stations