MONITORING CRUSTAL DEFORMATIONS IN SATAKUNTA USING GPS MEASUREMENTS

Sonja Nyberg, Markku Poutanen, Ulla Kallio

Finnish Geodetic Institute, Geodeetinrinne 2, 02430 Masala, Finland, sonja.nyberg@fgi.fi

INTRODUCTION

The Geo-Satakunta research program was launched in 2002 to carry out interdisciplinary studies on regional bedrock and to apply the results e.g. in land use planning in the district of Satakunta, located in southwestern Finland. The geological diversity of the Satakunta bedrock offers exceptional possibilities for the stress field study.

In order to obtain information on contemporary crustal deformations a regional GPS network was established in 2002, and the network was later (2005-2006) expanded southwards (Figure 1 and 2). We have carried out three annual campaigns in 2003-2008. The first results of the GPS time series are presented here.

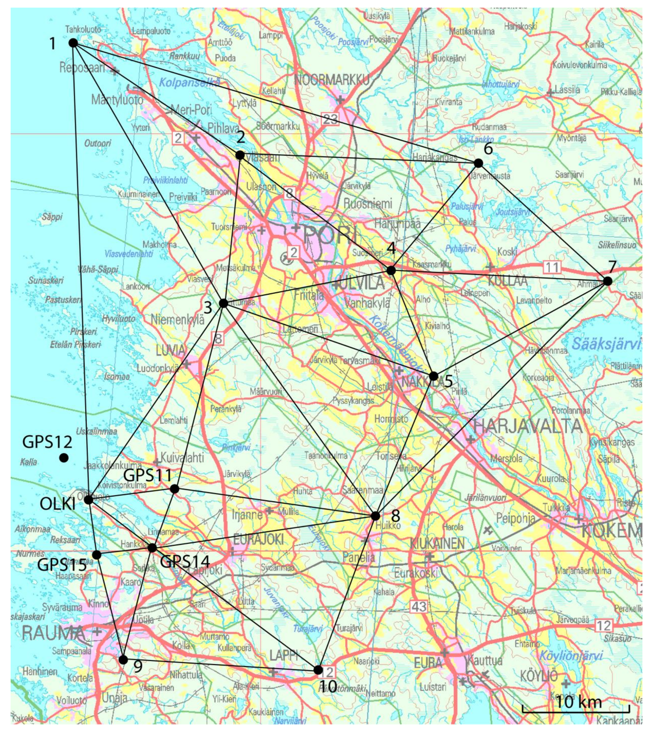

Figure 1 (left) Geo-Satakunta GPS network consists of 13 concrete pillars and of the Olkiluoto permanent GPS station. The baseline lengths range from five to 65 km.

Base map © National Land Survey, license number 51/MML/09

Figure 2 (right) The GPS pillars are made of reinforced concrete on-site. All the pillars are attached to the solid bedrock with iron bars. Ashtech Z12 and μZ dual frequency receivers and Ashtech Dorne Margolin Choke Ring antenna were used.

GPS DATA PROCESSING

The GPS data processing was carried out using Bernese 5.0 software. Single baselines were computed using:

- L3 frequency for data screening and final solution
- QIF-ambiguity resolution (Dach., et al, 2007)
- 15 deg cut off angle and Niell troposphere model
- individual absolute antenna calibration values

Olkiluoto permanent station was kept fixed in the final network adjustment.

BASELINE LENGTH TIME SERIES

The main features of the baseline length time series are presented in Figure 4.

- On the average the baseline lengths varied less than 2.0 mm
- In a few cases the scatter as low as 1.0 mm
- Largest scatter observed at baselines from the site 5, where obstacles are limiting the visibility
- None of the observation sites is significantly more uncertain than the others (Figure 3)
- No seasonal variation observed as in Olkiluoto time series (e.g. Kallio et al., 2009)

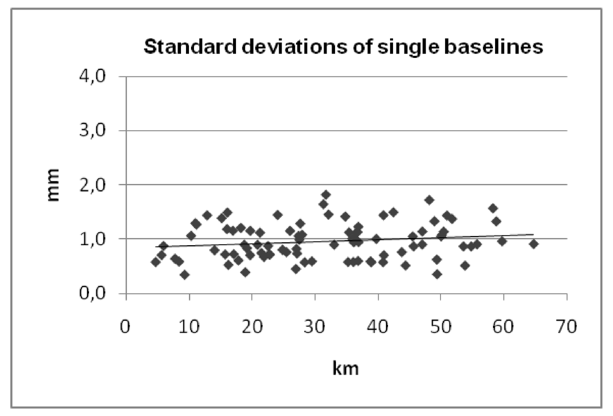

Figure 3. *The standard deviations as a function of baseline length show no outlying observations.*

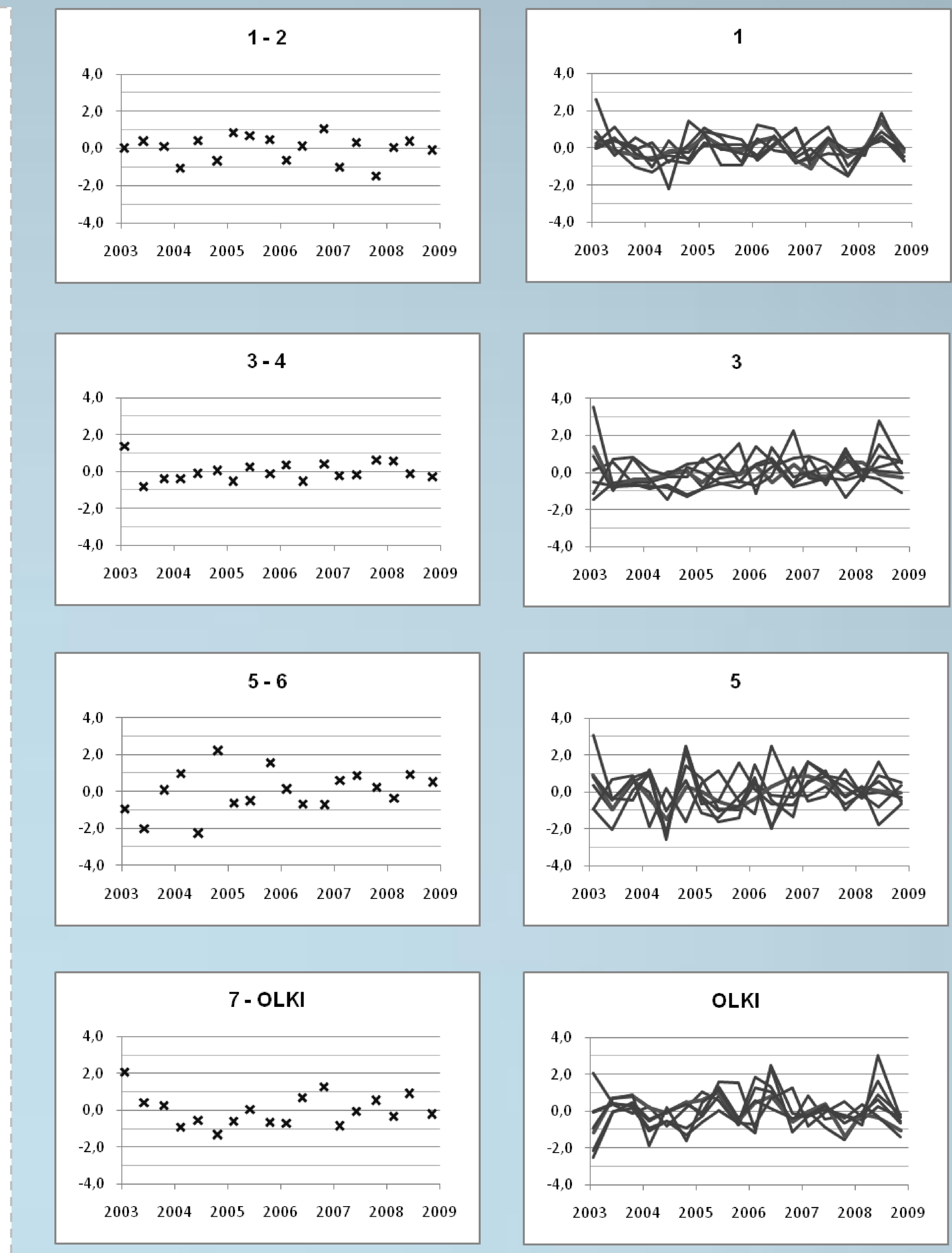

Figure 4. *Baseline length time series (deviation from the mean in millimetres). A single baseline on the left, all baselines from a single pillar on the right.*

HORIZONTAL VELOCITIES

The horizontal velocities (Tables 1 and 2) were estimated using the same least squares free network adjustment model as in Olkiluoto deformation analysis (Kallio et al., 2009). The 3σ criterion was used to test the statistical significance of the estimated velocities, which roughly corresponds the 99% confidence level.

Table 1. *The estimated horizontal velocities for the sub-network with longest history (statistically significant velocities in bold)*

	North (mm/a)		East (mm/a)	
Pillar	Velocity	St.dev x3	Velocity	St.dev x3
1	-0.08	0.21	-0.07	0.15
2	0.03	0.21	-0.06	0.12
3	-0.17	0.18	**-0.13**	**0.12**
4	-0.13	0.18	-0.02	0.12
5	0.04	0.21	0.07	0.12
6	**0.24**	**0.21**	0.04	0.15
7	0.00	0.24	**0.17**	**0.15**
OLKI	0.06	0.24	0.01	0.15

- Estimated velocities (max 0.3 mm/a) mostly statistically insignificant, but of the same order of magnitude as detected in Olkiluoto deformation studies.
- The velocities for the southern part of the network are more uncertain because of shorter time series.

Table 2. *The estimated horizontal velocities for the whole network*

	North (mm/a)		East (mm/a)	
Pillar	Velocity	St.dev x3	Velocity	St.dev x3
1	-0.10	0.24	0.03	0.18
2	0.12	0.24	0.11	0.18
3	-0.13	0.21	0.03	0.15
4	-0.11	0.24	0.05	0.18
5	0.11	0.24	0.16	0.18
6	**0.32**	**0.24**	0.15	0.18
7	0.00	0.24	0.11	0.18
8	0.18	0.69	0.19	0.48
9	0.24	0.45	-0.23	0.33
11	0.18	0.57	-0.38	0.39
12	-0.22	0.42	-0.13	0.30
14	-0.30	0.42	-0.04	0.30
15	-0.31	0.46	-0.14	0.39
OLKI	0.01	0.21	0.08	0.15

GEOLOGICAL CONSIDERATIONS

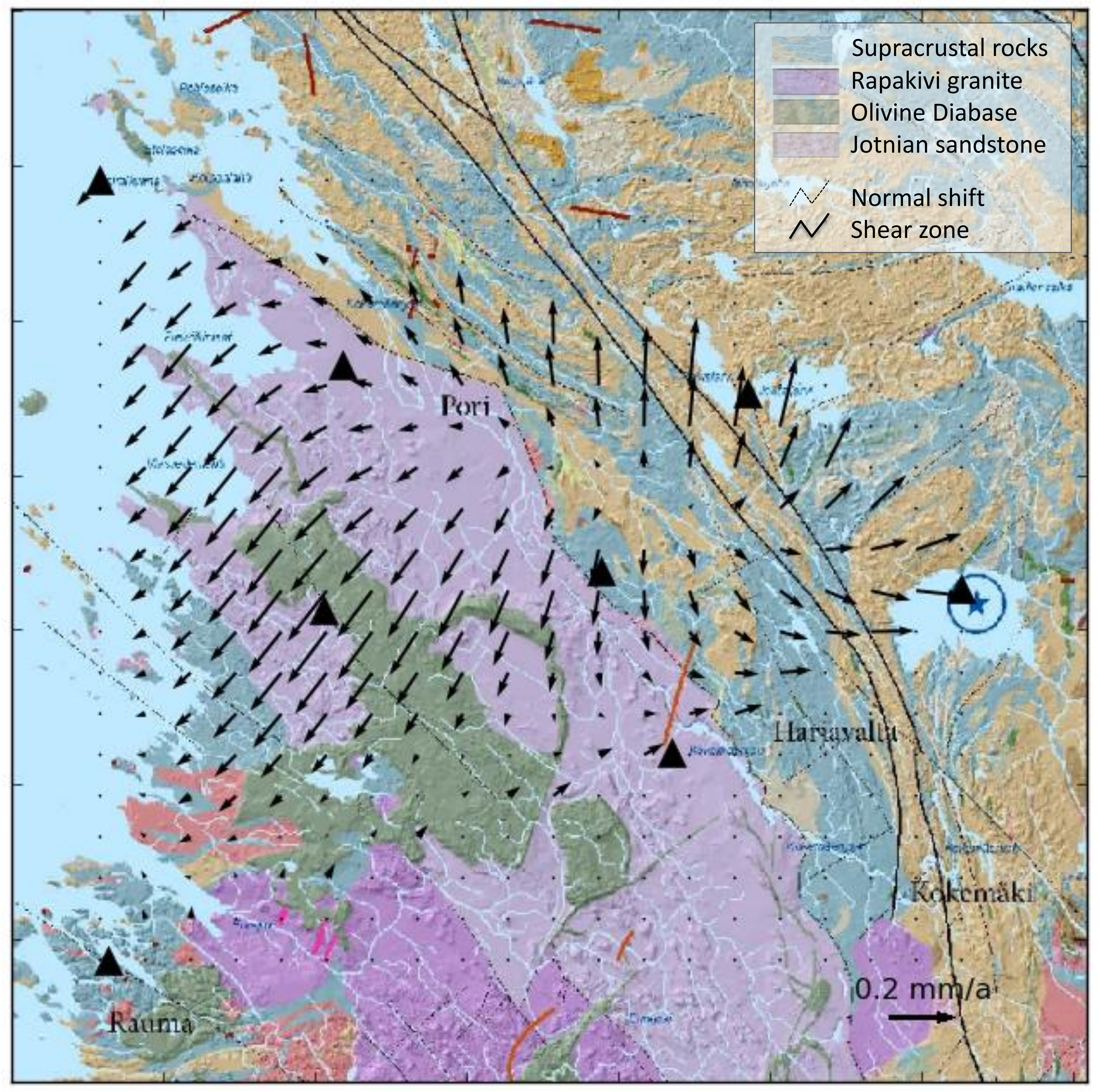

Figure 5. *For illustration of the results the station velocities (Table 1) were interpolated in a grid and plotted as a velocity vector field. When overlaying the vectors on the geological information the possible change seems to take place in the vicinity of geologically interesting features, like the major shear zones and the Jotnian sandstone. Base map © Geological Survey of Finland .*

CONLUSIONS

On the basis of six years of measurements we have achieved a detection threshold of 0.3 mm/a for single-site motion. Using the subnet with the longest history the threshold diminishes to about 0.2 and 0.1 mm/a in the N and E components, respectively. A more sophisticated statistical analysis is needed to draw any definite conclusions about motions, as well as longer time series. We plan to continue our activities in the area also in the future. GPS observing campaigns in the network, combined with the activity at the Olkiluoto, will be the basis of the upcoming research.

REFERENCES

Dach, R., Hugentobler, U., Fridez, P. & Meindl, M. 2007. Bernese GPS Software. Version 5.0. Astronomical Institute. University of Bern.

Kallio, U., Ahola, J., Koivula, H., Jokela J. & Poutanen, M. 2009. GPS Operations at Olkiluoto, Kivetty and Romuvaara in 2008. Posiva Working Report 2009-75. Posiva Oy.