Geodetic Operations in Finland 2000 – 2003

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GPS measurements

by
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1. Permanent GPS network

The Finnish permanent GPS network FinnRef® consists of 13 permanent GPS stations. The network is the backbone of the Finnish realisation of the EUREF frame, referred as to EUREF-FIN. Four stations in the FinnRef network belong to the *EUREF permanent GPS-network* (EPN), and one station belongs to the network of the *International GPS Service* (IGS). Through these stations FinnRef® creates a connection to the global reference frames.

The observations obtained by FinnRef® stations can be used for studying the movements of the Earth's crust. In 2002 a new permanent station was established close to the Degerby tide gauge, at Åland.

The data recorded in the EPS stations (Metsähovi, Vaasa, Joensuu, Sodankylä) are transferred automatically to the EPN data centre in Germany. The data are also transferred daily to the Onsala Space Research Station in Sweden for the BIFROST project.

All FinnRef® stations are used in the computation of the joint Nordic GPS network. FinnRef® forms the backbone for Finnish GPS point densifications and enables the study of the crustal motions of the Earth. By the end of 2003 all stations except two (Kivetty and Romuvaara) will be attached to the precise levelling network.

The absolute gravity observations have been made at five GPS stations, viz. in Metsähovi, Vaasa, Joensuu, Virolahti and Sodankylä. The measurements were made with JILAg-5 owned by the FGI and with several FG5 gravimeters. The absolute gravity has been observed in Metsähovi more than 80 times since 1988, three times in Sodankylä, twice in Vaasa and once in Virolahti and Joensuu.

The field calibration of all the GPS antennas of FinnRef® were performed in 1999. The results can be found in a Master's thesis of Helsinki University of Technology (Kylkilahti, 1999).

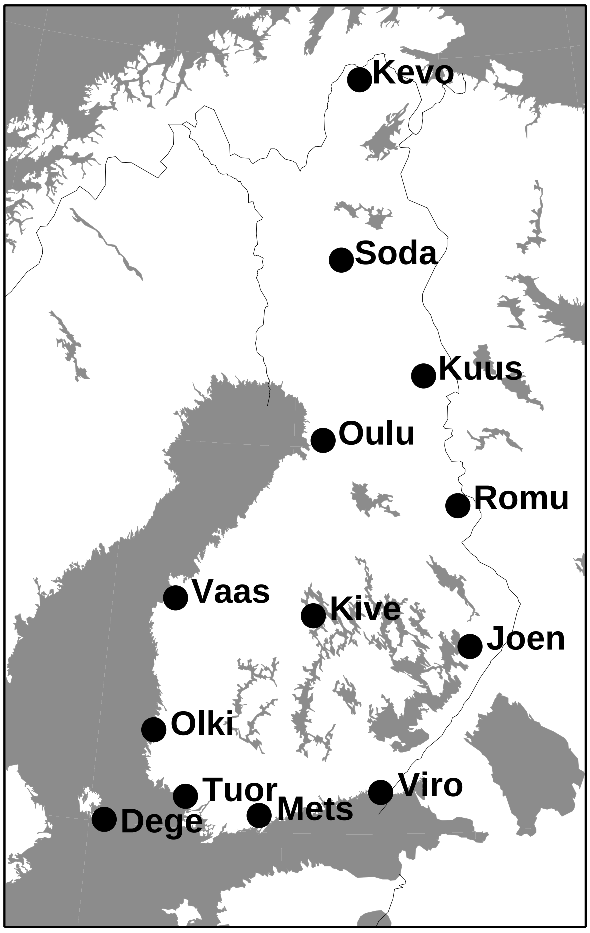

Fig. 1. The Finnish permanent GPS network FinnRef®.

Fig. 2. The permanent GPS station of Virolahti. (Photo: Ruizhi Chen)

2. The densification of the EUREF network and introducing the EUREF reference frame

Nineteen EUREF-points measured by the FGI were accepted as official EUREF-points at the meeting of the EUREF subcommission in Prague, June 5, 1999. They are the 12 FinnRef® stations, 5 GPS-observation pillars close to tide gauges and 2 first-order triangulation points.

Observations in the FinnRef® network are the basis of the densification. The 100 points of its first phase define the EUREF-FIN coordinate system. They are mostly first-order triangulation points, which reliably tie Finland's current system to EUREF.

This choice also helps to preserve the points. In the second phase, about 350 points were measured in 1998–1999, and the results published in 2001. The points of the second phase are intended as easily used starting points for surveying and mapping. They are mostly lower-order triangulation points of the *National Land Survey* of Finland (NLS).

The work on taking the new reference frame into use was continued during the year. The new frame, which is based on the European ETRS89-system, is referred as to EUREF-FIN. The FGI and the NLS established a working group for the purpose in 2000. The working group prepared the first recommendation (JHS 153), in which the definition of the EUREF-FIN frame and the datum transformation parameters between EUREF-FIN and the National Grid Coordinate System (*Kartasto-koordinaattijärjestelmä, kkj*) are published.

The working group continued its work for the second recommendation, which contains the new map projection, coordinate transformation methods and formulas between plane coordinates. The second recommendation will be published in 2003.

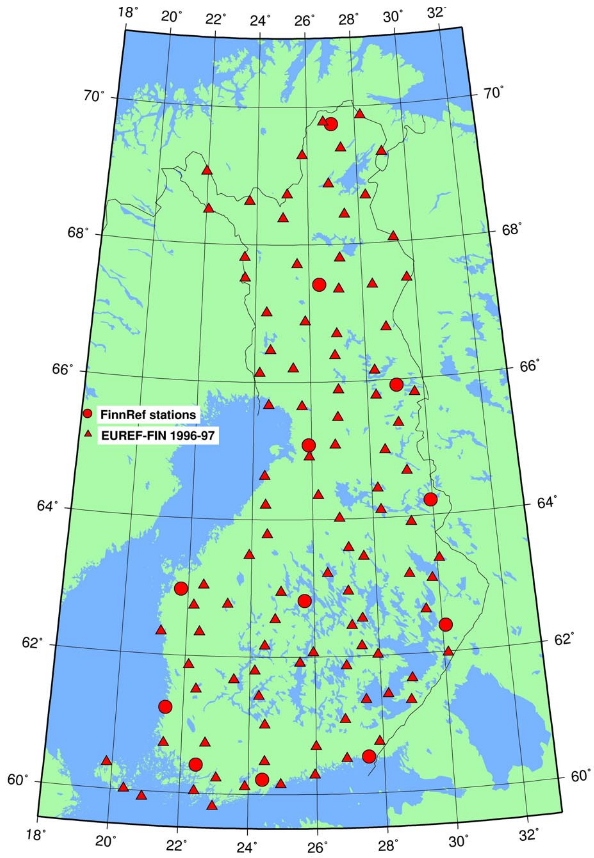

Fig. 3. The Finnish permanent GPS-network and the stations of the EUREF-FIN densification in 1996–97.

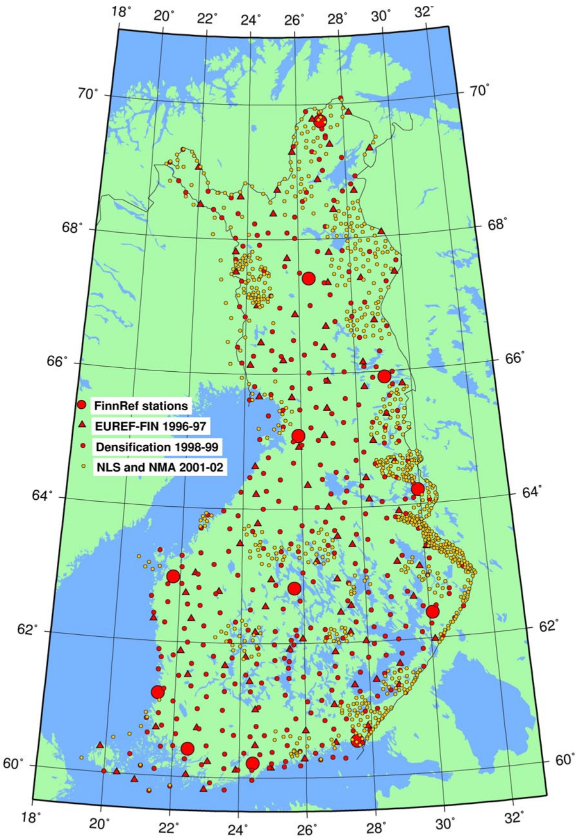

Fig. 4. The lower-order EUREF-densifications in 1998–2001. The densification 1998–99 was made by the FGI. The densifications in 2000–01 by the National Land Survey (NLS) and the National Maritime Administration (NMA)

3. GPS/levelling

A GPS campaign was performed in 2002 between Finland and Sweden, across the Åland archipelago. In addition to the Nordic Permanent GPS network, a total of ten levelling benchmarks were included in the campaign. Two of them were in continental Finland, three on Åland main island, one on Märket island at the borderline between Finland and Sweden, and four in Sweden. The purpose of the campaign was to connect the levelling networks of the two countries and the results are to be used in the common adjustment of the Nordic levelling network.

4. Real Time Kinematic GPS (RTK)

The use of RTK by surveyors is growing fast and therefore the FGI made a study in 2000, financed by the Ministry of Agriculture and Forestry, to investigate the quality of RTK for general mapping purposes. The RTK equipment from 5 different manufacturers; Javad, Trimble, Leica, DSNP, and Spectra Precision were tested at two test fields. One was the FGI's photogrammetric test field in Sjökulla and the second one the Klaukkala test field of the Institute of Geodesy of the Helsinki University of Technology (HUT).

The accuracy results correspond well with the values promised by the manufacturers: ±(10 mm + 1…2 ppm) plane and ±(15…20 mm + 2 ppm) height. The RTK equipment predicts the measurement accuracy well, but full control is only obtained by repeated measurements and visiting points with known coordinates. The quality of the measurements is influenced by many factors.

These factors come with the GPS-system itself, the choice of RTK equipment, the measurement environment, the accurateness of the user and the measurement procedure.

The FGI has used GPS positioning in gravity survey since 1996. The orthometric heights of the gravity stations have been determined by the GPS/levelling method using a geoid model. The mean accuracy in height determination has been mainly within 10–30 cm compared to the levelled heights. The ordinary RTK method was tested in the survey of 2002 in order to find more accurate and effective positioning method. RTK measurements were implemented as a standard RTK surveying with radio and GSM modems.

Additionally, the Virtual Reference Station (VRS) method was also tested. The VRS concept has been used since 2000 in Finland and nowadays there are two different networks operational. A private Finnish company Geotrim Ltd. has started to establish a network to provide VRS service.

Fig. 5. The lighthouse of Märket located on the borderline between Finland and Sweden. (Photo: Hannu Koivula)

Fig. 6. The GPS-antenna in the tower of the lighthouse. (Photo: Hannu Koivula)

Both positioning methods gave a good accuracy and no problems appeared but productivity of the ordinary RTK is not that good as in VRS method. When used in adequate conditions, it is possible to achieve 5 cm accuracy in the determination of orthometric heights.

The RTK method was used as a tool for photogrammetric research. During 2000–2002 approximately 2000 points were measured to check the terrain model, which was created by the airborne laser scanning method. The RTK has been used also to check the geometric quality of the databases of geographic information at several test areas.

5. Extension of the photogrammetric test field

The Finnish Geodetic Institute has developed in Kirkkonummi, near the Metsähovi station, a permanent test field to control the spatial quality of airborne images. Originally the test field has also GPS-benchmarks covering an area of 1 km^2. These signalised points are used for estimating the geometrical accuracy of aerial photogrammetry. In the summer of 2000 the GPS-network was extended with 12 new benchmarks. These new benchmarks were measured with GPS and they cover the area of 4x5 km. It is now possible to do airborne boresight calibration of the GPS/IMU system with this extended test field.

Fig. 7. Positioning of the gravity station by the RTK method. (Photo: Pasi Häkli)

Bibliography

Ahola, J. (2001): Ionosfäärimallin vaikutuksesta lyhyiden GPS-vektoreiden ratkaisuun. Maanmittaus 1–2/2001:49–53. (in Finnish)

Bilker, M. and H. Kaartinen (2001): The Quality of Real-Time Kinematic (RTK) GPS Positioning. Rep. Finn. Geod. Inst. **2001:1**, Kirkkonummi, 2001. 25 p.

Bilker, M. (2002): RTK GPS – Experiences from practice. Finnish Journal of the Surveying Sciences, Volume **20**, no. 1–2, 2002, pp. 22–31.

Bilker, M. (2002): RTK GPS – Quality in the field. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 254–258.

Häkli, P. (2002): Comparison of different GPS positioning methods used in gravity survey by FGI in 2002. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 265–274.

Jivall, L., H. Koivula, E. Asenjo, A. Engfelt, P. Häkli, M. Lidberg and M. Poutanen (2002): The Åland GPS Levelling Campaign. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 222–226.

Johansson, J.M., J.L. Davis, H.-G. Scherneck, G.A. Milne, M. Vermeer, J.X. Mitrovica, R.A. Bennett, M. Ekman, G. Elgered, P. Elosegui, H. Koivula, M. Poutanen, B.O. Rönnäng, and I.I. Shapiro (2002): Continuous GPS measurements of postglacial adjustment in Fennoscandia, 1. Geodetic results. J. Geophys. Res. **107**, B8.

Koivula, H. (2002): Finnish permanent GPS network – A tool for postglacial rebound studies. Finnish Journal of the Surveying Sciences, Volume **20**, no. 1–2, 2002, pp. 12–21.

Koivula, H. (2002): GPS-havaintosuureet ja -yhtälöt, GPS-laskenta. GPS-Meteorologia Seminaari, Ilmatieteen laitos, 27.11.2002. Toim. (S. Haarala ja R. Keränen) s. 17–20. (in Finnish)

Koivula, H. ja M. Ollikainen (2002): Uusi valtakunnallinen koordinaatisto: EUREF-FIN. Maanmittaus 1–2/2002:7–19. (in Finnish)

Kylkilahti, A. (1999): The antenna calibration of the Finnish permanent GPS network (FinnRef). Master's thesis, Helsinki University of Technology, Department of Surveying, 1999.

Ollikainen, M. (2001): Tasokoordinaattijärjestelmän uudistamisen tekninen toteutus. Maanmittaustieteiden päivät 8.–9.11.2001. Espoo. Maanmittaustieteiden seuran julkaisuja N:o **39**, s. 21–32. (in Finnish)

Ollikainen, M. (2002): GPS:n avulla havaittavia geofysikaalisia ilmiöitä. GPS-Meteorologia Seminaari, Ilmatieteen laitos, 27.11.2002. (Toim. S. Haarala ja R. Keränen) s. 21–32. (in Finnish)

Ollikainen, M., H. Koivula and M. Poutanen (2000): The densification of the EUREF network in Finland. Publ. Finn. Geod. Inst., **129**, 61 pp.

Ollikainen, M., H. Koivula and M. Poutanen (2000): The Densification of the EUREF Network in Finland. IAG, Section I – Positioning, Commission X – Global and Regional Geodetic Networks, Sub-Commission for Europe (EUREF). Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Prague, 2–5 June 1999. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung der Bayerische Akademie der Wissenschaften, Astronomisch-Geodätische Arbeiten, Heft Nr. **60**. München. pp. 114–122.

Ollikainen, M., H. Koivula ja M. Poutanen (2001): EUREF-FIN -koordinaatisto ja EUREF-pistetihennykset Suomessa. Geodeettisen laitoksen tiedote **24**. Masala. 35 s. (in Finnish)

Ollikainen, M., H. Koivula and M. Poutanen (2002): The second phase densification of the EUREF network in Finland. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 196–200.

Ollikainen, M., M. Vermeer and J. Kääriäinen (2000): National report of Finland. IAG, Section I – Positioning, Commission X – Global and Regional Geodetic Networks, Sub-Commission for Europe (EUREF). Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Tromsø, 22–24 June 2000. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung der Bayerische Akademie der Wissenschaften, Astronomisch-Geodätische Arbeiten, Heft Nr. **61**. München. p. 260.

Poutanen, M. (2002): GPS-järjestelmä, radat, mittaukset ja virhelähteet. GPS-Meteorologia Seminaari, Ilmatieteen laitos, 27.11.2002. (Toim. S. Haarala ja R. Keränen) s. 4–16. (in Finnish)

Poutanen, M., H. Koivula and M. Ollikainen (2001): On the periodicity of GPS time series. International Association of Geodesy Symposia, Vol. 125. Vistas for Geodesy in the New Millennium. (Eds J. Ádám and K.-P. Schwarz). IAG 2001 Scientific Assembly, Budapest, Hungary, September 2–7, 2001. pp. 388–392. Springer-Verlag Berlin Heidelberg New York.

Poutanen, M. and M. Ollikainen (2002): The Finnish National Report 1998–2001. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 32–41.

Poutanen, M. and H. Suurmäki (Ed.) (2002): Proceedings of the XIV General Meeting of the Nordic Geodetic Commission. Finnish Geodetic Institute, Masala. 300 pp.

Precise levelling

by
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To create and maintain the height system in Finland, two national precise levellings have been carried out. The National Board of Public Roads and Waterways executed the First Levelling of Finland during 1892–1910. This levelling extended to the line Joensuu–Kajaani–Oulu–Tornio. The FGI made the Second Levelling of Finland during 1935–1975 and it covered the whole country. As a result of the Second Levelling, the N60 height system was created. Its zero point is adjusted to the mean sea level in Helsinki in 1960.0 and also the land uplift is computed according to the year 1960.

The Third Levelling of Finland was started in 1978 and it has progressed now so that field measurements will be completed in 2004. The precise levelling network of Finland has been connected to Sweden in 8 places, to Norway in 5 places and to Russia in 2 places and the last 4 places to Russia will be connected in 2003. At the present moment the closing errors of the loops give the mean error of ±0.9 mm/√km. As a result of the Third Levelling a new height system will be created.

During 1999–2002 the Third Levelling was continued as follows:

Year	Levelling (km)	Relevelling (km)
1999	402	0
2000	363	151
2001	404	0
2002	480	57
Total	1649	208

In year 2000 lines between Aavasaksa and Muonio were relevelled due to an unexpected large closing error of the loop. In addition, the loop was divided. In 2002 the line Ruosniemi–Mäntyluoto tide gauge was relevelled. According to the agreement with the Finnish Institute of Marine Research, ties of all Finnish tide gauges from the precise levelling net were levelled in 2001.

A test field for precise levelling instruments was built at Metsähovi in 2000. After several tests in 2000 and 2001 Zeiss DiNi12 digital levelling instruments were taken into service and they replaced in 2001 the spirit levelling instruments Wild N3 in the Third Levelling.

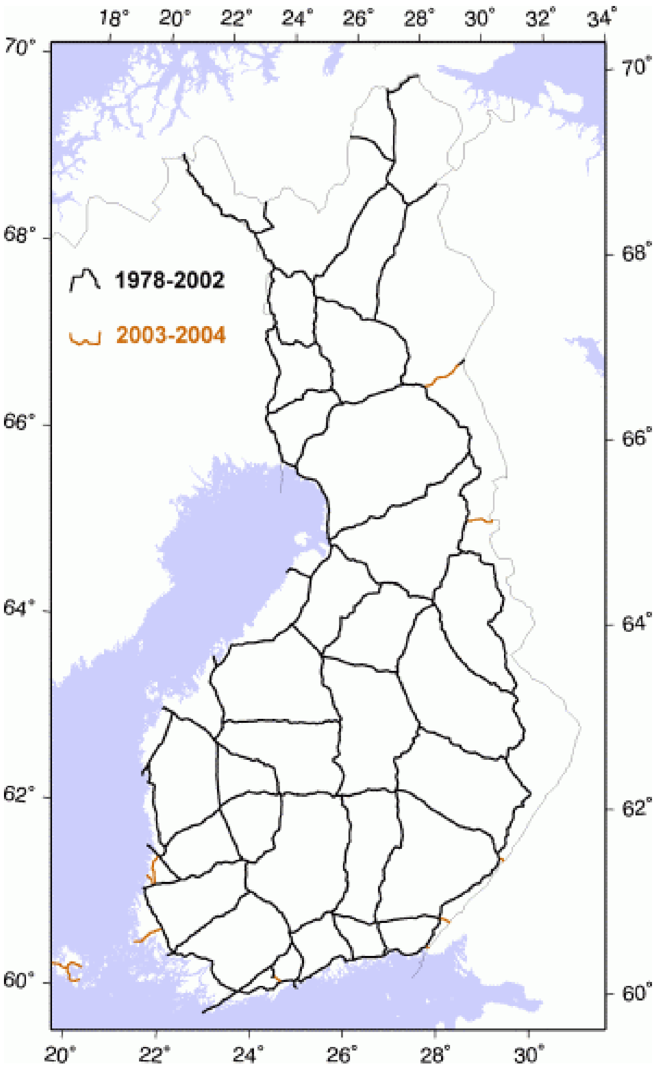

Fig. 1. Network of the Third Levelling of Finland.

The vertical laser rod comparator has operated well and it has been used to calibrate all rods of the FGI used in the Third Levelling. In addition, the invar rods used in Baltic countries and by other domestic users have been calibrated. The system calibration comparator has been designed to calibrate the digital levels and is now in full service.

On the basis of the repeated precise levellings, which are connected to the tide gauges, the land uplift can be determined. After completion the Third Levelling the new and more accurate land uplift values can be determined also in Lapland. Today, the land uplift is also studied using the observations from the permanent GPS network (FinnRef®).

The common adjustment of the levelling networks of the Nordic countries was prepared. A new data bank was established in Kort- og Matrikelstyrelsen, in Copenhagen. The co-operation was realised in the Working Group for Height Determination (WGH), under the umbrella of the Nordic Geodetic Commission (NKG). The General Assembly of the NKG nominated a special researcher of the FGI as chairman for the WGH in 2002.

The Finnish and the Swedish levelling networks were connected over Åland Sea using GPS techniques in June 2002. The field work was coordinated by the NKG Working Group for Satellite Geodesy. The observations were carried out by the team of the FGI and the Swedish Land Survey, Gävle.

In 2002 the Finnish and Russian precise levelling networks were connected crossing the border at two places in Lapland. The levelling measurements were carried out by a Finnish and a Russian levelling team.

Bibliography

Jivall, L. H. Koivula, E. Asenjo, A. Engfelt, P. Häkli, M. Lidberg and M. Poutanen (2002): The Åland GPS Levelling Campaign. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 222–226.

Lehmuskoski, P. and P. Rouhiainen (2000): Lisäyksiä ja korjauksia Suomen tarkkavaaitusten linjastoon 1998–1999. Geodeettisen laitoksen tiedote no. **22**. 31 pp.

Lehmuskoski, P. and P. Rouhiainen (2002): Lisäyksiä ja korjauksia Suomen tarkkavaaitusten linjastoon 2000–2001. Geodeettisen laitoksen tiedote no. **25**. 26 pp.

Mäkinen, J. (2001): A note on the treatment of the permanent tidal effect in the European Vertical Reference System. In: J.A. Torres and H. Hornik (eds), Report on the Symposium of the IAG Subcommission for Europe (EUREF) held in Tromsø, 22–24 June, 2000. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung, Astronomisch-Geodätische Arbeiten 61, 111–113.

Mäkinen J., H. Koivula, M. Poutanen and V. Saaranen (2001): Contemporary postglacial rebound in Finland: comparison of GPS results with repeated precise levelling and tide gauge results. Gravity, Geoid and Geodynamics. Banff, Alberta, Canada, July 31–August 5, 2000. 6 pp

Takalo, M. (2000): Tarkan korkeudenmääritysken automaatiosta. Lectio Praecursoria 25. elokuuta 2000. Maanmittaus **1–2/2000**, pp. 60–64. (in Finnish)

Takalo, M. (2000): On Automation in Precise Height Determination. Acta Polytechnica Scandinavica, Civil Engineering and Building Construction Series No. **119**. Espoo 2000. 28 pp.

Gravity and the geoid

by
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1. Absolute gravity measurements

The FGI has three absolute gravity meters: JILAg-1, JILAg-5, and FG5 no. 221, the last-mentioned delivered in 2003. They track the free fall of a corner cube retroreflector in a vacuum chamber. Distance is measured by a laser interferometer and time is based on a rubidium standard.

Regular absolute measurements in Metsähovi with the JILAg-5 have been continued, typically once or twice per month. A number of FinnRef®-stations were occupied. FGI took part in the UNIGRACE project (Unification of gravity systems of Central and Eastern European Countries), concluded in 2001. The absolute site at the Finnish Antarctic base Aboa φ = 73º03' S, λ = 13º24' W), first measured in 1994 was reoccupied in 2001. The work was part of the Finnish Scientific Antarctic Expedition Finnarp 2000. In 2001 FGI also participated in the Sixth International Comparison of absolute gravimeters (ICAG 2001) at the BIPM (Bureau International des Poids et Mesures) in Sèvres. Absolute gravity stations 1999–2003 are collected in Table 1.

Table 1. Absolute gravity stations observed by FGI in 1999–2003.

Station	Country	Year
Metsähovi	Finland	1999–2003
Moxa, Wettzell	Germany	1999
Virolahti, Joensuu, Vaasa	Finland	1999
Krokowa, Józefosław, Borowa Góra	Poland	2000
Cluj, Belis, Constanța	Romania	2000
Wettzell	Germany	2000
Aboa	Antarctica	2001
Paarl, Sutherland	South Africa	2001
Sèvres (A, A2, B, B1)	France	2001
Vilnius, Klaipéda, Panevéžys	Lithuania	2002

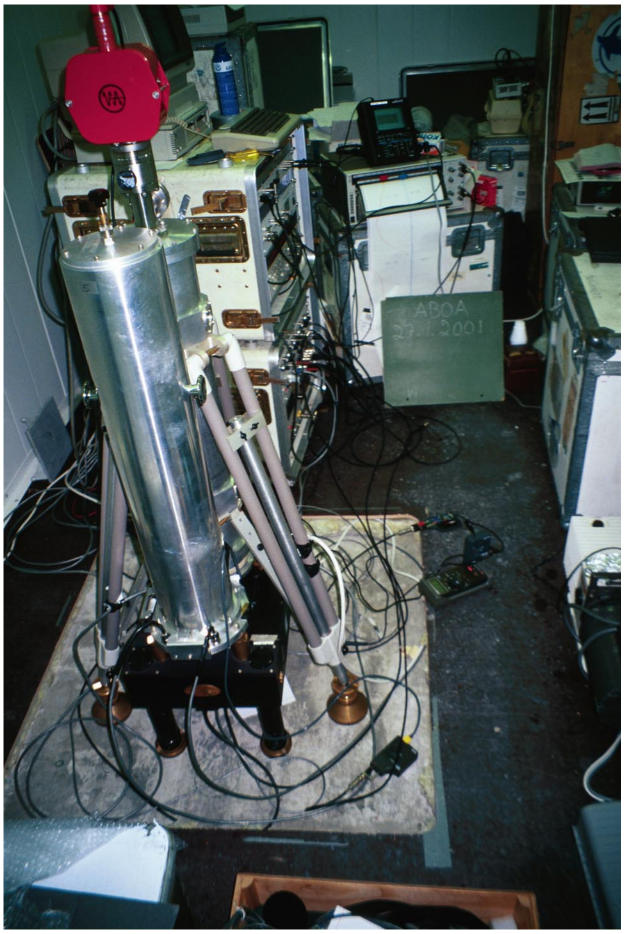

Fig. 1. JILAg-5 at the Finnish Antarctic base Aboa. Photo: J. Mäkinen

2. Gravity surveys

Airborne survey of the Baltic Sea

A major airborne gravity survey was performed in August–September 1999 over the Gulf of Finland and the Baltic proper. The purpose was to fill the large gaps in the existing gravity coverage, an essential prerequisite for, e.g., the computation of precision geoids. The total length of the flight lines was about 18000 km. The work was a co-operation between all Nordic and Baltic countries, coordinated by the National Survey and Cadastre of Denmark.

Densification surveys

The national gravity net of Finland measured by FGI covers the whole territory with a density of at least 1 station/25 km^2. It is being densified in cooperation with the Geological Survey of Finland. The target is 2 to 6 stations/km^2 and the work is primarily performed in areas of particular geological interest. FGI measured 1548 new stations in 1999–2002. Special emphasis was on studies of GPS positioning and height determination, using Real Time Kinematic (RTK) and Virtual Reference System (VRS) GPS, and digital geoid models.

3. Fennoscandian land uplift gravity lines

The Finnish section (Kalajoki–Kuhmo) of the line along 65ºN was measured in 1999 and 2000. Comparing the results with the first round of measurements (1975–1980), the ratio between gravity change and land uplift (relative to the geoid) was estimated to be –0.20 ± 0.06 µgal/mm (one-sigma) The ratio agrees with results obtained on the line 63ºN.

The Finnish section (Vaasa–Joensuu) of the line 63ºN was measured in 1999 and 2002. In 2002 the work was performed together with the Estonian Land Board. Results obtained 1966–2002 in international cooperation are shown in Figure 3.

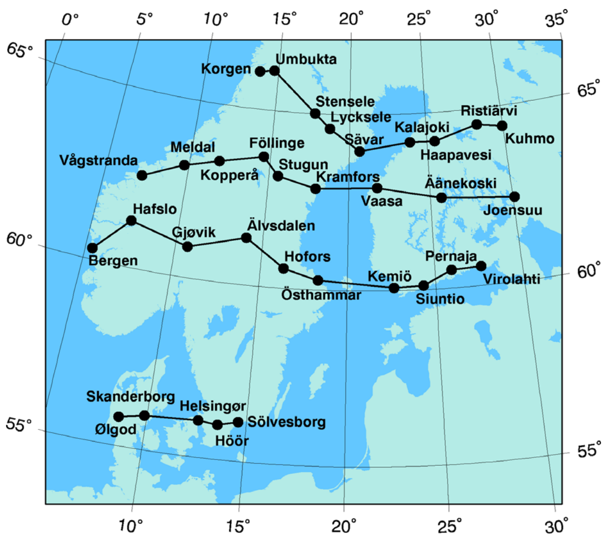

Fig. 2. The Fennoscandian land uplift gravity lines.

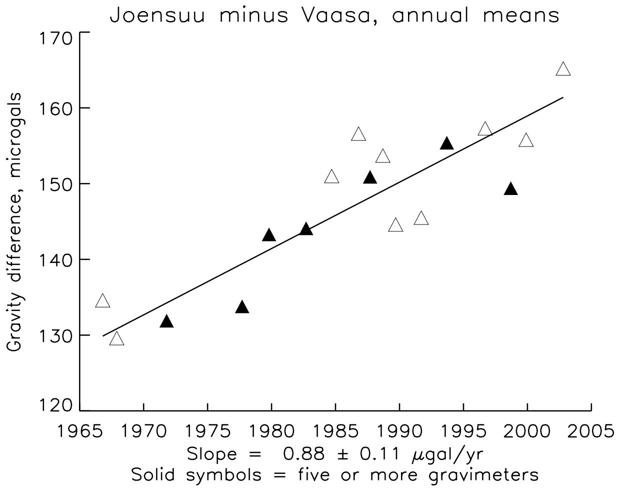

Fig. 3. Change in the observed gravity difference between sites in Joensuu and Vaasa on the land uplift gravity line 63ºN in 1966–2002. Gravity is decreasing at both stations, but more so in Vaasa where land uplift is about 5 mm/yr larger than in Joensuu.

4. Superconducting gravimetry

The superconducting gravimeter GWR T020 in Metsähovi measures temporal variations in gravity, as small as 10^{-12} g. The gravimeter has been recording continuously since August 1994. After removing the influence of e.g. tidal variations and polar motion from the record other geodynamical phenomena can be studied.

The variable loading and attraction by the Baltic Sea was computed using realistic water-level models, based on tide gauge data around the Baltic Sea. The influence of atmosphere on gravity was studied using the HIRLAM air-pressure grid provided by the Finnish Meteorological Institute.

Using the HIRLAM grid and the local barometric measurements a correction to the gravity observed with the superconducting gravimeter is computed. Combining the air-pressure grid and sea level data (without need to make assumptions on barometric response) was especially successful. Load models verified by the gravity record have then been applied to GPS observations.

Gravity variations associated with the local hydrology have been studied in cooperation with the Laboratory of Rock Engineering of the Helsinki University of Technology, with the Geological Survey of Finland and with the

Finnish Environment Institute. Groundwater level (in bedrock), precipitation, and soil moisture are measured, and bedrock fractures mapped. The work is in part financed by the Academy of Finland.

The superconducting gravimeter has also been used as a long-period seismometer. All earthquakes with a magnitude larger than 7 have been analyzed for irregularities in free oscillations, 5 to 10 events globally every year. Microseismicity has been monitored, and influences of large weather fronts, downpours and storms studied.

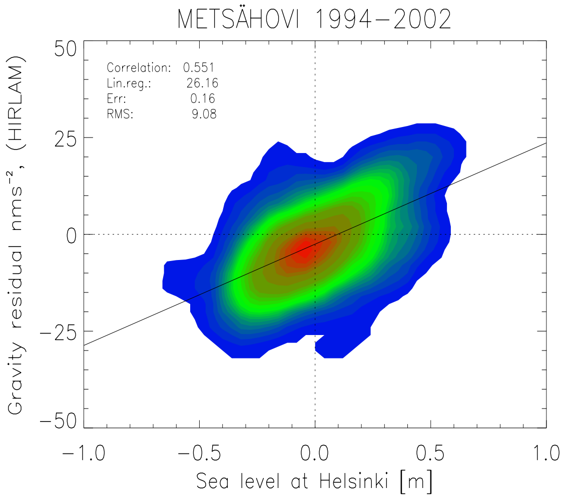

Fig. 4. Regression of the 59152 hourly gravity residuals of the superconducting gravimeter at Metsähovi on the sea level at Helsinki tide gauge (1994–2002). Point distribution is shown as a colour coded density (red is highest).

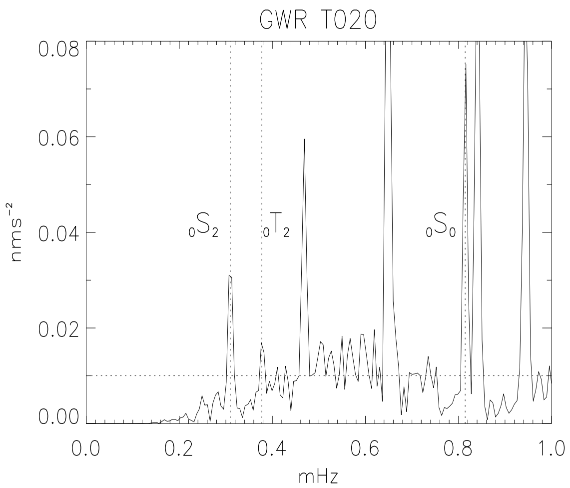

Fig. 5. The part of the spectrum of Earth's free oscillation, excited by the earthquake in Peru on June 23, 2001 (8.4 M). The gravest spheroidal ($_0S_2$), toroidal ($_0T_2$) and radial ($_0S_0$) modes are shown.

The superconducting gravimeter in Metsähovi is one of 18 similar instruments participating in the Global Geodynamics Project (GGP) 1997–2003. By agreement, the data is sent to the GGP data center (http://etggp.oma.be).

5. Satellite gravimetry

The CHAMP, GOCE and GRACE satellites probe the gravity field of the Earth. The final report on usability of the data from them, especially for geodetic operations in Finland and neighboring areas was completed. The work was continued in co-operation with the Institute of Geodesy of the Stuttgart University, partly funded by the Academy of Finland.

6. Geoid models

The NKG96 model and the GPS/levelling observations were used to determine a new geoid model, which can be used to transform the heights from the ETRS89 to the national N60 height system. The model, referred as to FIN2000, was obtained fitting a 4th degree polynomial surface to the height differences between GPS/levelling and spirit levelling. The RMS of the residuals in the surface fit was ± 28 mm.

During 2001–2002 the National Land Survey (NLS) reduced GPS-coordinates observed in 1990's in order to get them in the ETRF89 frame. Among these stations there are 154 stations, which were connected to the second and third order levelling network. The ETRF89 coordinates and the orthometric heights at these stations were used to test the FIN2000 geoid model. The RMS of the height differences between GPS/levelled and orthometric heights was ±29 mm. The result confirms that the accuracy of the geoid heights obtained from the FIN2000 model is better than 10 cm all over the country.

Methods for geoid determination were studied. Geoid models computed for Finland and Sweden were compared, augmented with geopotential models EIGEN-1S, EIGEN-2 and TEG-4 derived from CHAMP data.

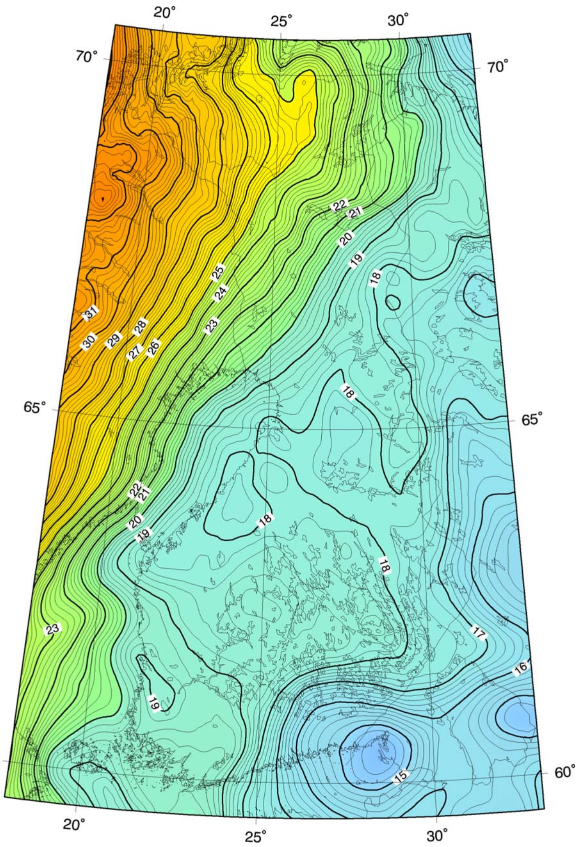

Fig. 6. The FIN2000 geoid model

Bibliography

Bilker, M., J. Mäkinen, M. Poutanen, R. Forsberg, H.-G. Scherneck and M. Vermeer (2001): A proposal to use the Baltic Sea area as a test field for the gravimetric satellites. IAG Scientific Assembly, Budapest, Hungary 2–7.9.2001. 6 pp.

Bilker, M. and M. Poutanen (2002): The gravity satellite missions CHAMP, GRACE, and GOCE and their use in Finland. Final Report for TEKES of the PAINOSAT-project, diaarinro: 1309/401/00, Päätösnro: 40264/01, Finnish Geodetic Institute, March 2002.

Bilker, M., M. Poutanen and M. Ollikainen (2002): Comparison of geoid models over Fennoscandia. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 131–137.

Bilker, M., M. Ollikainen and M. Poutanen, (2003): Evaluation of Geoid Models with GPS/levelling Points in Sweden and Finland. In: C. Reigber, H. Lühr, P. Schwintzer (Eds.) First CHAMP Mission Results for Gravity, Magnetic and Atmospheric Studies, 1st CHAMP Science Meeting, 21–24 January, 2002, Potsdam, Germany. Berlin : Springer, 2003.

Lázaro, C., J. Mäkinen, J. Osório, L. Bastos, P. Baptista and G. Hein (2000): Precise gravity measurements in Azores Islands. In: B. Ducarme and J. Barthélemy (eds), Proceedings of the Workshop: High Precision Gravity Measurements with Application to Geodynamics, and Second GGP Workshop. Munsbach Castle (Grand Duchy of Luxembourg), March 24th to 26th, Cahiers du Centre Européen de Géodynamique et de Séismologie, vol. **17**, 229–238.

Mäkinen, J. (1999): UNIGRACE COPERNICUS Programme. Progress report 1998 for Finland. Proceedings of the 2nd UNIGRACE Working Conference, Warsaw, Poland, 22–23 February 1999. Warsaw University of Technology, Reports on geodesy 2(43), 37–39.

Nawa, K., N. Suda, Y. Fukao, T. Sato, Y. Tamura, K. Shibuya, H. McQueen, H. Virtanen H. and Kääriäinen J. (2000): Incessant excitation of the Earth's free oscillations, global comparison of superconducting gravimeter record. Phys. Earth Planet. Interiors **120**, 289–297.

Ollikainen, M. (2002): The Finnish geoid model FIN2000. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 111–116.

Robertsson, L., O. Francis, T. M. vanDam, J. Faller, D. Ruess, J.-M. Delinte, L. Vitushkin, J. Liard, C. Gagnon, Guo You Guang, Huang Da Lun, Fang Yong Yuan, Xu Jin Yi, G. Jeffries, H. Hopewell, R. Edge, I. Robinson, B. Kibble, J. Mäkinen, J. Hinderer, M. Amalvict, B. Luck, H. Wilmes, F. Rehren, K. Schmidt, M. Schnull, G. Cerutti, A. Germak, Z. Zabek, A. Pachuta, G. Arnautov, E. Kalish, Y. Stus, D. Stizza, J. Friederich, J.-M. Chartier and I. Marson (2001): Results from the Fifth International

Comparison of Absolute Gravimeters, ICAG97. Metrologia **38**,71–78.

Ruotsalainen, H. (2000): Some principles used in relative gravity survey of the Finnish Geodetic Institute, Nordic Geodetic Commission, Working group for geoid determination. Tallin, Estonia, November 16–17, 2000. 9 pp. Submitted to the proceedings.

Ruotsalainen, H. (2002): Developing a new version of the interferometrically recording long fluid level tilt meter of FGI, Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 102–104.

Ruotsalainen, H. (2002): The Fennoscandian land uplift gravity lines – a tool for the Nordic geodynamical studies. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 107–110.

Vesala, T., S. Sevanto, P. Paatero, E. Nikinmaa, M. Perämäki, T. Ala-Nissilä, J. Kääriäinen, H. Virtanen, J. Irvine and J. Grace (2000): Do tree stems shrink and swell with the tides?, Tree Physiology, **20**, 565–578, 2000. Heron Publishing – Victoria Canada.

Virtanen, H. (2000): On the observed hydrological environmental effects on gravity at the Metsähovi station, Finland. Bull. Inf. Mar. Terr. **133**:10369–10375.

Virtanen, H. (2000): On the observed hydrological environmental effects on gravity at the Metsähovi station, Finland. In B. Ducarme and J. Barthélemy (eds): Proceedings of the Workshop: High Precision Gravity Measurements with Application to Geodynamics, and Second GGP Workshop. Munsbach Castle (Grand Duchy of Luxembourg), March 24th to 26th. Cahiers du Centre Européen de Géodynamique et de Séismologie, Vol. **17**, 169–175.

Virtanen, H. (2001): Hydrological studies at the gravity Station Metsähovi in Finland. Journal of the Geodetic Society of Japan, Vol. **47**, No.1, 328–333.

Virtanen, H. (2002): Summary of observations in Metsähovi 1994–2001 with T020. Bull. Inf. Mar. Terr. **135**:10605–10606.

Virtanen, H., and J. Mäkinen (2003): The effect of the Baltic Sea level on gravity at the Metsähovi station. Journal of Geodynamics, Vol **35**, No.4–5, 553–565.

Virtanen, H. and J. Mäkinen (2002): Air pressure and Baltic Sea loading corrections to gravity data at Metsähovi, Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 148–153.

Vitushkin, L., M. Becker, Z. Jiang, O. Francis, T. M. van Dam, J. Faller, J.-M. Chartier, M. Amalvict, S. Bonvalot, N. Debeglia, S. Desogus, M. Diament, F. Dupont, R. Falk, G. Gabalda, C. G. L. Gagnon, T. Gattacceca, A. Germak, J. Hinderer, O. Jamet, G. Jeffries, R. Käker, A. Kopaev, J. Liard, A. Lindau, L. Longuevergne, B. Luck, E. N. Maderal, J. Mäkinen, B. Meurers, S. Mizushima, J. Mrlina, D. Newell, C. Origlia, E. R. Pujol, A. Reinhold, Ph. Richard, I. A. Robinson, D. Ruess, S. Thies, M. Van Camp, M. Van Ruymbeke, M. F. de Villalta Compagni and S. Williams (2002): Results of the Sixth International Comparison of Absolute Gravimeters ICAG-2001. Metrologia **39**, 407–424.

Metrology and standardization

by
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The Finnish Geodetic Institute is the National Standards Laboratory of acceleration of free fall and length. Metrological research and measurements include maintenance and development of national gravity network, absolute and relative gravity measurements, and continuous recording of temporal gravity variations with a superconducting gravimeter. We also maintain and develop horizontal, vertical and 3D reference frames. Calibration and research subjects include instruments and systems used in height determination, geodetic baselines and electronic distance measurement instruments.

In 2002 the Finnish Geodetic Institute entered the Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration and measurement certificates issued by national metrology institutes. Requirements of the ISO/IEC 17025 ja ISO 9001 standards were implemented in the new quality management system of the National Standards Laboratories, described in the quality manual. Participation in the EUROMET Quality System Forum was arranged by the Centre for Metrology and Accreditation (MIKES).

1. Acceleration of free fall

The activities in the acceleration of the free fall are reported together with the gravity work in Bilker et al. in this volume.

2. Levelling technology

Instruments and systems used in height determination are calibrated and researched with a horizontal and an automated vertical laser rod comparator, and as system calibration of digital levelling (Table 1). For system calibration new observation pillars were built in the comparator laboratory in 2000 and 2002. Traceability has been transferred in Estonia, Latvia, Lithuania, Iceland and Sweden, and to several customers in Finland.

Fig. 1. Calibration of digital precise levelling system Zeiss DiNi12. (Photo M. Takalo)

Table 1. Number of calibrations made with the FGI rod and system calibration comparator.

Year	Invar rods	Digital levels	Standard bars
1999	27	0	0
2000	26	0	0
2001	57	2	4
2002	26	7	2

3. Standard baselines and calibration baselines

The *Gödöllő* Standard Baseline was established in 1986 in co-operation between the FGI and the Institute of Geodesy, Cartography and Remote Sensing (FÖMI) in Hungary. The location is the same as for the old National Comparison Baseline (since 1938). The new baseline was first measured with the Väisälä Interference Comparator up to 432 m and multiplied to 864 m with a Kern Mekometer ME3000 in 1987. After this mostly a Kern Mekometer ME5000 has been used in the regular control of this fairly stable baseline.

To confirm the stability, a remeasurement of the baseline was performed in 1999, again in co-operation between the two parties, and using both traditional and modern methods. A comparison between the results of 1987 and 1999 is summed up in Table 2. All differences between the underground markers are ≤ 0.1 mm and insignificant, and small and controllable between the users' markers on the observation pillars. The results prove this baseline on an old railway ground extremely stable.

Table 2. Gödöllő Standard Baseline, comparison of final results (mm-parts of lengths) showing extreme stability of underground markers and excellent repeatability of measurements.

Interval (m)	Väisälä & ME5000 1999	Väisälä & ME3000 1987	Users' markers 1999	Users' markers 1987
0 – 24	17.00	17.06	12.56	12.61
0 – 216	18.66	18.76	25.38	25.74
0 – 432	18.35	18.40	22.16	22.60
0 – 864	32.12	32.16	42.14	42.18
216 – 432	99.69	99.64	96.78	96.86
432 – 864	13.77	13.76	19.98	19.58

The old *Vääna* Calibration Baseline in Estonia was measured with high precision EDM in 2000. It consists of 7 observation pillars (distances 192 to 1680 m) and 7 more benchmarks on the ground (distances 24 to 1728 m).

The *Kyviškės* Calibration Baseline in Lithuania was remeasured with high precision EDM in 2001. This 6-pillar 1320-m baseline at the Darius and Girėnas squadron airport was established in 1996 and first measured in 1997. In 2001 the baseline was also expanded to a multi-purpose test field by founding and measuring a new observation station (no. 7) at the other side of the airstrip. All differences between 1997 and 2001 are ≤ 1.0 mm and insignificant (Table 3).

Table 3. Kyviškės Calibration Baseline, lengths (mm) with extended uncertainties.

Interval	June 1997	October 2001
1 – 2	100 163.5 ±0.4	100 163.3 ±0.2
2 – 3	260 011.6 ±0.6	260 012.0 ±0.3
3 – 4	760 204.1 ±0.8	760 203.3 ±0.5
4 – 5	180 093.4 ±0.4	180 093.1 ±0.3
5 – 6	20 010.0 ±0.4	20 010.0 ±0.3

In 2002, five scale transfer measurements were performed from the *Nummela* Standard Baseline in Finland to three baselines. For *Eggemoen*, Norway (960 m) and *Novobërdë*, Kosovo (1830 m) the transfer standard was the precise distancer Kern Mekometer ME5000 of the Norwegian Mapping Authority (Statens kartverk). Similar instrument of the Laboratory of Geodesy of the Helsinki University of Technology was used for the *Olkiluoto* baseline (511 m) of Posiva Ltd. This baseline is a part of a ten stations GPS network and serves in controlling the scale of the network for deformation studies.

The 5-pillar 840-m *Nummela* Calibration Baseline in Finland can be freely used with self-service principle. It serves in routine calibrations, when extreme accuracy is not required. It was remeasured using high precision EDMs and scale transfer from the Nummela Standard Baseline in autumn 2000. All variations in the control measurements during 1977–2000 have been within 2 mm.

The 14th interference measurements of the *Nummela* Standard Baseline are planned for the year 2005, and preparations for these have already been started by planning new working premises. The traceability of measurements with the Väisälä Interference Comparator has already been greatly improved, since the absolute calibrations of quartz gauges can now be performed (in addition to some NMIs abroad) in the CMA in Finland. Preparations for international comparisons in geodetic metrology are also proceeding.

Fig. 2. Controlling the scale of a local GPS network for deformation studies with high precision EDM. (Photo S. Ahola)

Bibliography

Ahola, J. (2002): Monitoring local crustal deformations using high precision GPS network. In Poutanen, M. and H. Suurmäki (Ed.) Proceedings of the 14th General Meeting of the Nordic Geodetic Commission, October 1–5, 2002, Espoo, Finland, pp. 76–79.

Jokela, J., A. Būga, R. Putrimas and V. Tulevičius (2002): Analysis of repeated calibration of Kyviskės baseline. Geodezija ir kartografija, **XXVIII:4,** 125–130.

Jokela, J., J. Kääriäinen, J. Mäkinen ja M. Takalo (1999): Geodeettinen laitos geodeettisten suureiden mittanormaalilaboratoriona. Maanmittaustieteiden seuran julkaisu **36,** 25–41.

Jokela, J., M. Poutanen, J.Z. Zhao, W.L. Pei, Z.Y. Hu and S.S. Zhang (2000): The Chengdu Standard Baseline. Publ. Finn. Geod. Inst. **130**, 46 p.

Jokela, J., M. Poutanen, Zs. Németh and G. Virág (2001): Remeasurement of the Gödöllő Standard Baseline. Publ. Finn. Geod. Inst. **131**, 37 p.

Jokela, J., P. Rouhiainen and M. Takalo (2002): Length – geodesy. Finnish National Standards Laboratories Annual Report 2001. Publ. of the CMA J2/2002, pp. 41–42.

Jokela, J. (2002): Some contemporary activities in geodetic metrology in the FGI. In Poutanen, M. and H. Suurmäki (Ed.) Proceedings of the 14th General Meeting of the Nordic Geodetic Commission, October 1–5, 2002, Espoo, Finland, pp. 273–275.

Lassila, A., J. Jokela, M. Poutanen and J. Xu (2003): Absolute calibration of quartz bars of Väisälä interferometer by white light gauge block interferometer. Metrology in the 3rd Millennium, XVII IMEKO World Congress, June 22–27, 2003, Dubrovnik, Croatia. Submitted to the proceedings.

Mäkinen, J., H. Ruotsalainen and H. Virtanen (2002): Acceleration of free fall. Finnish National Standards Laboratories Annual Report 2001. Publ. of the CMA J2/2002, pp. 18–22.

Robertsson, L., O. Francis, T. M. vanDam, J. Faller, D. Ruess, J.-M. Delinte, L. Vitushkin J. Liard, C. Gagnon, Guo You Guang, Huang Da Lun, Fang Yong Yuan, Xu Jin Yi, G. Jeffries, H. Hopewell, R. Edge, I. Robinson, B. Kibble, J. Mäkinen, J. Hinderer, M. Amalvict, B. Luck, H. Wilmes, F. Rehren, K. Schmidt, M. Schnull, G. Cerutti, A. Germak, Z. Zabek, A. Pachuta, G. Arnautov,

E. Kalish, Y. Stus, D. Stizza, J. Friederich, J.-M. Chartier and I. Marson (2001): Results from the Fifth International Comparison of Absolute Gravimeters, ICAG97. Metrologia **38**, 71–78.

Takalo, M. (1999): Verification of automated calibration of precise levelling rods. Rep. of the FGI **99:7.** 36 p.

Takalo, M. (2000): Error sources in rod calibration. Ingenieurvermessung 2000. XIII. International Course on Engineering Surveying. München, 13.–17. März 2000. Contributions. Gg.; K. Schnädelbach/ M. Schilcher. Pages 425–432.

Takalo, M. (2000): Experiences of automated calibration of levelling rods in Finland. Finnish Journal of the Surveying Sciences, **18:1–2,** 18–26.

Takalo, M. (2000): On automation in precise height determination. Acta Polytechnica Scandinavica, Civil Engineering and Building Construction Series Ci 119. Espoo 2000. 28 p.

Takalo, M. (2000): Tarkan korkeudenmääri-tyksen automaatiosta. Lectio Praecursoria, August 25, 2000. Maanmittaus **75:1–2,** 60–64.

Vitushkin, L., M. Becker, Z. Jiang, O. Francis, T. M. van Dam, J. Faller, J.-M. Chartier, M. Amalvict, S. Bonvalot, N. Debeglia, S. Desogus, M. Diament, F. Dupont, R. Falk, G. Gabalda, C. G. L. Gagnon, T. Gattacceca, A. Germak, J. Hinderer, O. Jamet, G. Jeffries, R. Käker, A. Kopaev, J. Liard, A. Lindau, L. Longuevergne, B. Luck, E. N. Maderal, J. Mäkinen, B. Meurers, S. Mizushima, J. Mrlina, D. Newell, C. Origlia, E. R. Pujol, A. Reinhold, Ph. Richard, I. A. Robinson, D. Ruess, S. Thies, M. Van Camp, M. Van Ruymbeke, M. F. de Villalta Compagni and S. Williams (2002): Results of the Sixth International Comparison of Absolute Gravimeters ICAG-2001. Metrologia **39**, 407–424.

Geodynamics

by
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1. Studies of the deformation of Earth's crust

BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea Level and Tectonics) project continued. The research area of the project covers whole Fennoscandia. The aim of the project is to develop models for the mechanism of the post glacial rebound. Researchers in United States, Canada, Great Britain, Sweden and the FGI take part in the BIFROST project.

The basic observation data is collected from the permanent GPS station in the area, which is why the data from the FinnRef stations is transferred daily to the Onsala Space Research Station in Sweden.

The study of the land uplift was continued by computing the land uplift values between Metsähovi and other FinnRef stations from the GPS observations. The GPS determinations were used together with the observations obtained by the superconducting gravimeter to study the atmospheric loading effect. The periodical change of the GPS time series was studied in order to detect an explanation for the behaviour of the GPS results.

2. Local deformation studies

In co-operation with the Finnish POSIVA company, the Finnish Geodetic Institute established three highly precise GPS monitoring networks in 1994–1995. The networks are *Olkiluoto* (measured 14 times in 1995–2002), *Kivetty* (11 times) and *Romuvaara* (11 times), located around permanent GPS stations carrying the same name. The networks have a diameter of 2…3 km.

The largest baseline change rates are 0.4…0.6 mm/yr (in absolute value), barely exceeding the accuracy of the GPS observations. The strain parameters solved are smaller than their standard errors. In order to get more reliable results, the measurements will be repeated this year and in coming years.

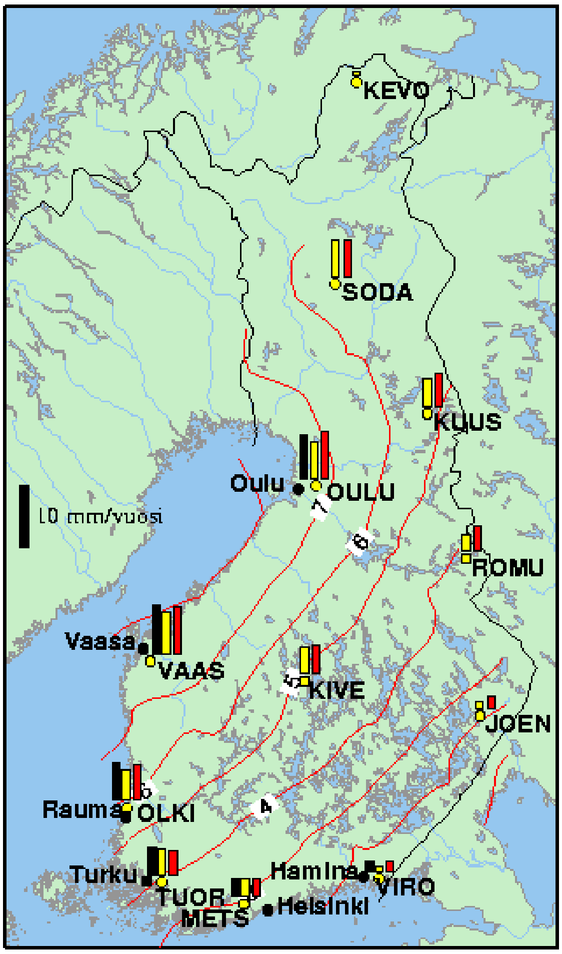

Fig. 1. Land uplift values in Finland determined with GPS (red/rightmost column), repeated precise levelling (yellow/middle column), tide gauge time series (black/leftmost column).

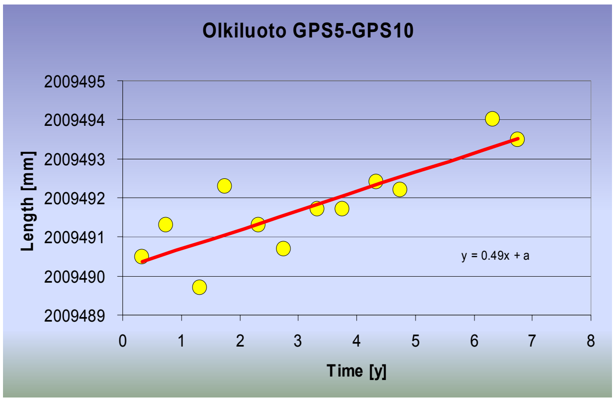

Fig. 2. Baseline change in the Olkiluoto network. The rate obtained is about 0.5 mm/y.

Studies on the complex fracture zone in Kolari, North Finland were continued. The GPS network (at approximately $\varphi = 67°03'$ N, $\lambda = 24°04'$ E) over *Nuottavaara* fault was re-observed in June 2000. Previous measurements had been performed in 1991, 1992 and 1995. No significant movements have been detected.

The two micro-networks ($\varphi = 67°10'$ N, $\lambda = 24°24'$ E) over the postglacial fault at *Pasmajärvi*, observed in June 2002, were re-levelled in September 2001. This work was prompted by an M = 2.9 earthquake (epicentre $\varphi = 67°10.8'$ N, $\lambda = 24°36.4'$ E, depth 4.0 km) in the same fracture zone on May 2, 2001.

3. Research into Baltic Sea level variations

A study on the sea surface topography of the Baltic Sea and its temporal and spatial variations was published as a part of a doctoral thesis. In the work data from satellite radar altimetry of ERS-1 and ERS-2 were combined with the GPS observations made at tide gauges around the Baltic Sea. By sea surface topography is meant the decimetre-class deviations of sea level from an equipotential surface, caused by sea currents, prevailing winds and, most importantly, the steric effects due to the change in salinity.

The work was continued as a co-operation with an oceanographer from the Finnish Institute of Marine Research to understand the oceanographic reasons for temporal and spatial variations of the sea surface topography. This work belonged to the Baltic Sea Level Project, a co-operative project between researchers from all countries around the Baltic Sea. The developed method allows monitoring of sea level variations also on open sea, out of reach of coastal tide gauges. The knowledge on the sea surface topography is also needed when vertical datums and datum zero points of various countries are connected.

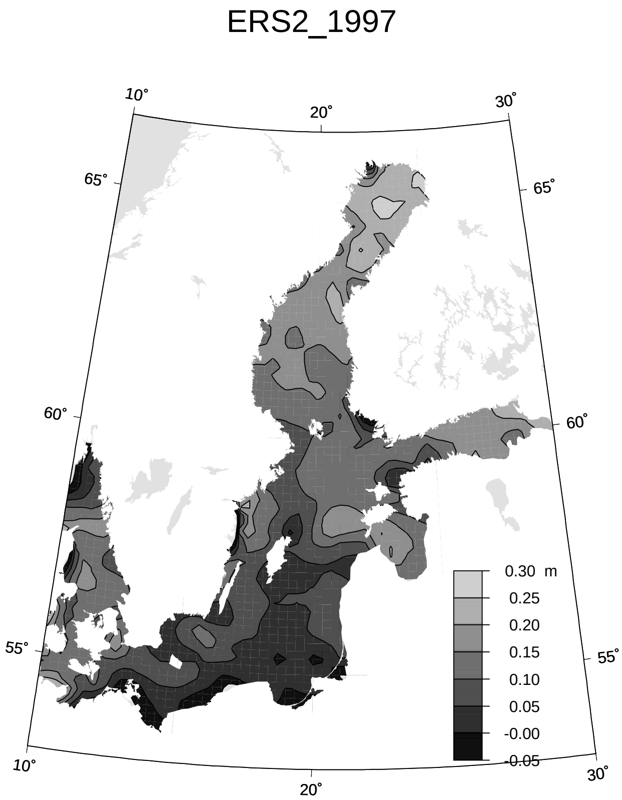

Fig. 3. Sea surface topography of the Baltic Sea derived from satellite altimetry.

4. Long interferometrically recording water tube tilt meter

The development work of the old interferometrically recording water tube tilt meter continued. The original system was built at the Finnish Geodetic Institute 1970–1983. A prototype of a fiber-optic Fizeau-type fluid level interferometer with computer recording CCD camera system was constructed in 2002–2003.

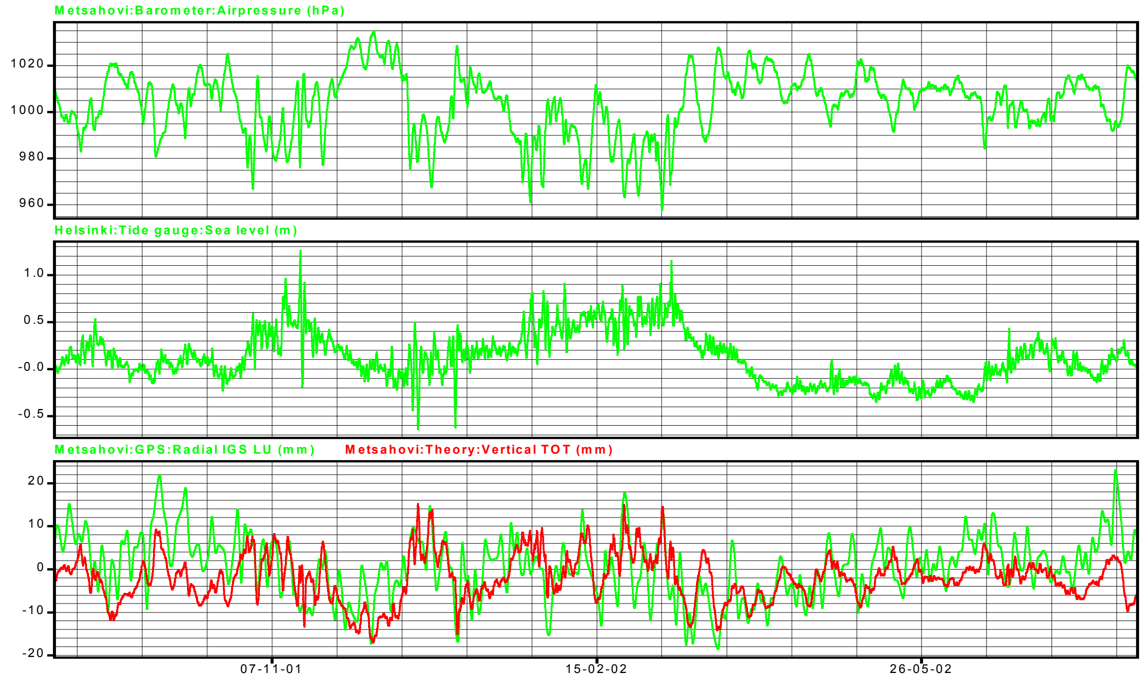

Fig. 4. Top: Air pressure at Metsähovi [hPa] from September 2001 to July 2002**. Middle:** Sea level [m] at the nearest (30km) tide gauge in Helsinki.. **Bottom:** IGS radial GPS component [mm] (green). Calculated vertical motion (red). The reduction of RMS is 13%.

Phenomena to be measured cause fluid level tilt oscillations between a few nanometers and a few tens of micrometers at one end pot. Especially the behaviour of the instrument because of thermal expansion, air pressure sealing was concerned. Mechanical and material stability of a newly rebuilt tube and end pot/tube joint has been studied.

Thermal stability recording in the clinometric station Lohja (Tytyri mine), where the old water tube tilt meter pair (NS & EW) was located, was started again, now using an automatic high resolution (~0.05 ºC) temperature logger to find out whether circumstances are suitable for the highest accuracy earth tides and crustal tilt recording. Analysis of the old water tube system data from the EW- and NS-water tube tilt meter recordings were continued.

Bibliography

Ahola, J. (2001): Nuottavaaran siirroksen deformaatiotutkimus GPS-mittausten avulla. Diplomityö, Teknillinen korkeakoulu. Espoo. 83 sivua. (in Finnish)

Ahola, J. (2002): High Precision GPS Network for Deformation Studies. Finnish Journal of the Surveying Sciences, Volume **20**, no. 1–2, 2002, pp. 3–11.

Ahola, J. (2002): Monitoring Local Crustal Deformations Using High Precision GPS Network. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 76–79.

Ahola, J. (2003) Suomen kallioperä kohoaa yhä. *Tietohippu* 1/2003, pp. 14–16. (in Finnish)

Jevrejeva, S., A. Rüdja and J. Mäkinen (2001): Postglacial rebound in Fennoscandia: new results from Estonian tide gauges. In: M. Sideris (ed), Gravity, Geoid and Geodynamics 2000, IAG International Symposium, Banff, Alberta, Canada, July 31–August 5, 2000. IAG Symposia 123, 193–198. Springer.

Johansson, J.M., J.L. Davis, H.-G. Scherneck, G.A. Milne, M. Vermeer, J.X. Mitrovica, R.A. Bennett, M. Ekman, G. Elgered, P. Elosegui, H. Koivula, M. Poutanen, B.O. Rönnäng, and I.I. Shapiro (2002):

Continuous GPS measurements of postglacial adjustment in Fennoscandia, 1. Geodetic results. J. Geophys. Res. **107**, B8.

Koivula, H. and Ruotsalainen H. (2001): A plan to study atmospheric loading with an interferometrically recording water tube tiltmeter and with precise GPS measurements. Gravity Geoid and Geodynamic. Banff, Alberta, Canada, July 31–August 5, 2000. On line-proceedings http://www.ucalgary.ca/~sideris/GGG2000/ GGG2000.html (Session 7, Dynamics of Gravity and Deformation Fields).

Koivula, H., M. Ollikainen, M. Poutanen, J. Mäkinen (2002): FinnRef®: Status and use for postglacial rebound studies. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 71–75.

Milne, G.A., J.L. Davis, J.X. Mitrovica, H.-G. Scherneck, J.M. Johansson, M. Vermeer and H. Koivula (2001): Space-Geodetic Constraints on Glacial Isostatic Adjustment in Fennoscandia. Science, Vol. **291**, 23 March 2001, pp. 2381–2385.

Mäkinen, J. (2000): Bounds for the difference between a linear unbiased estimate and the best linear unbiased estimate. Phys. Chem. Earth A 25, 693–698.

Mäkinen, J. (2000): Geodynamical studies using gravimetry and levelling. Academic Dissertation. Yliopistopaino, Helsinki, 82 p.

Mäkinen, J. (2002): A bound for the Euclidean norm of the difference between the best linear unbiased estimator and a linear unbiased estimator. Journal of Geodesy **76**, 317–322.

Mäkinen, J., H. Koivula, M. Poutanen and V. Saaranen (2000): Contemporary postglacial rebound in Finland: comparison of GPS results with repeated precise levelling and tide gauge results. Gravity, Geoid and Geodynamics. Banff, Alberta, Canada July 31–August 5, 2000. Submitted to the proceedings, 6 pp.

Mäkinen, J., H. Koivula, M. Poutanen, V. Saaranen (2001): Contemporary postglacial rebound in Finland: comparison of GPS results with repeated precise levelling and tide gauge results. Gravity, Geoid and Geodynamics. Banff, Alberta, Canada, July 31–August 5, 2000. On line-proceedings http://www.ucalgary.ca/~sideris/GGG2000/ GGG2000.html (Session 3, Geodynamic Applications of GPS).

Mäkinen, J., J. Ahola, J. Jokela, H. Koivula, M. Ollikainen, M. Poutanen, V. Saaranen, M. Takalo, M. Vermeer (2002): Postglacial rebound and crustal deformation in Finland: Recent geodetic results. Lithosphere 2002 – Second Symposium on the Structure, Composition and Evolution of the Lithosphere in Finland. Programme and Extended Abstracts, Espoo, Finland, November 12–13, 2002. Institute of Seismology, University of Helsinki, Report S-42, 146 pages.

Mäkinen, J., H. Koivula, M. Poutanen ja V. Saaranen (2003): Vertical Velocities in Finland from Permanent GPS Networks and from Repeated Precise Levelling. Journal of Geodynamics, Vol **35**, No.4–5.

Ollikainen, M. and J. Kakkuri (2000): GPS Operations at Olkiluoto, Kivetty and Romuvaara for 1999. Working Report **2000-18**. Posiva Oy. Helsinki. 151 pp.

Ollikainen, M, H. Koivula, J. Kakkuri (2001): GPS Operations at Olkiluoto, Kivetty and Romuvaara for 2000. Working Report **2001-16**. Posiva Oy. Helsinki. 35 pp.

Ollikainen, M., J. Ahola and H. Koivula (2002): GPS Operations at Olkiluoto, Kivetty and Romuvaara for 2001. Working Report **2002-16**. Posiva Oy. Helsinki. 215 pp.

Poutanen, M. (Ed.) (2001): IAG International Symposium on Recent Crustal Movements. Book of Abstracts, 107 pp.

Poutanen, M. (2000): Sea surface topography and vertical datums using space geodetic techniques. Doctoral thesis, University of Helsinki. Also in: Publ. Finn. Geod. Inst. **128**, 148 pp.

Poutanen, M. (2000): The Baltic Sea Level Project and sea surface topography. Presented in the meeting of the Geoid determination working group of the Nordic Geodetic Commission, Tallinn, Estonia, 16.–17.11. 2000. 5 pp. To be published in the proceedings.

Poutanen, M. (2002): The new challenges in GPS geodynamics. NKG Autumn School in Fevik, Norway, 2000. , Statens kartverk – Geodetic publications **2001:1**, 89–112.

Poutanen, M. and J. Kakkuri (2000): The sea surface topography of the Baltic – A result from the Baltic Sea Level Project (IAG SSC 8.1). In Geodesy beyond 2000 – The challenges of the first decade. (Ed. K.-P. Schwarz). Springer Verlag, Berlin, Heidelberg, p. 289–294.

Ruotsalainen, H. (2001): Modernizing the Finnish Long Water-Tube Tiltmeter, Journal of the Geodetic Society of Japan, Vol 47, No 1, pp.28–33

Scherneck, H.-G., J.M. Johansson, G. Elgered, J.L. Davis, B. Jonsson, G. Hedling, H. Koivula, M. Ollikainen, M. Poutanen, M. Vermeer, J.X. Mitrovica, and G.A. Milne (2002): BIFROST: Observing the Three-Dimensional Deformation of Fennoscandia. In Ice Sheets, Sea Level and the Dynamic Earth, (Eds. J.X. Mitrovica and B.L.A. Vermeersen). American Geophysical Union, Geodynamics Series, Volume 29, Washington, D.C., p. 69–93.

Scherneck, H.-G., J.M. Johansson, R. Haas, S. Bergstrand, M. Lidberg, H. Koivula, G.A. Milne and J. Davis (2002): BIFROST Project: From geodetic positions to strain rates. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 62–65.

Scherenck, H.-G., J.M. Johansson, H. Koivula, T. van Dam, J.L. Davis (2003): Vertical crustal motion observedin the BIFROST project. *Journal of Geodynamics* **35**, no. 4–5, pp. 425–441.

Virtanen, H. and J. Mäkinen (2002): Air pressure and Baltic Sea loading corrections to gravity data at Metsähovi, Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 148–153.

Virtanen, H. (2002): Itämeren ja ilmakehän aiheuttama kuormitus maankuoreen. GPS-Meteorologia Seminaari, Ilmatieteen laitos, 27.11.2002. Toim. (S. Haarala ja R. Keränen) s. 33–39. (in Finnish)

Navigation and Positioning

by
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In 2001 a new department, Navigation and Positioning started at the FGI. Its research topics are the new Global Navigation Satellite System (GNSS) technologies, intelligent navigation, multi-sensor positioning and real time mapping systems. During 2001 the focus was on defining the research topics of the department and on planning the research projects.

Preparations were started in cooperation with the European Space Agency (ESA) to establish a Ranging and Integrity Monitoring Station (RIMS) of the European Geostationary Navigation Overlay Service (EGNOS) in Finland. The RIMS will ensure the quality of the EGNOS service in Finland. The station has passed the Infrastructure Acceptance Reviewer (IAR) carried out on the 31st of Jan. 2003 by ESA. It is now in test operation.

The development of a system to receive the EGNOS SIS (Signal In Space) using a Pocket PC was started at the end of 2001 under an ESA contract. The development work is important for the EGNOS users in Nordic countries because it will make it possible to access the EGNOS services on the fly over the wireless network and the Internet, without the limitation of the low elevation angles to the geostationary satellites

Study on the integration of the satellite positioning technologies and cellular positioning technology has been carried out based on the simulations of a cellular network and a driving environment in a city canyon with different building heights. The combination of the satellite measurements and cellular measurements makes it possible to locate a mobile user with only two satellite measurements with the aided of two cellular measurements. Therefore the integration can increase significantly the positioning availability in a degraded environment such as city centers where four satellites in view is normally not available. Furthermore, the integration can improve the positioning accuracy as well especially when the GDOP (Geometric Dilution of Precision) is poor.

Bibliography

Toran, F., J. Ventura-Traveset and R. Chen (2002): The ESA SISNeT Technology: Real-Time Access to the EGNOS Services through Wireless Networks and the Internet. Proceedings of ION GPS 2002,, September 24–27, Portland, Oregon, US, pp 863–873.

Chen, R. (2002): Integration of satellite and cellular positioning technologies. Proceedings of the ION National Technical Meeting, 28–30 January, 2002, San Diego, CA, pp. 312 –322.

Chen, R., F. Toran and J. Ventura-Traveset (2003): Access to the EGNOS Signal In Space Over Mobile-IP. GPS Solutions (2003) Vol **7**, No. 1 (in press). Published on-line at http://link.springer.de/link/service/journals/10291/contents/03/00050/.

Metsähovi Research Station

by
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The Metsähovi research station ($\varphi = 60°13'$N, $\lambda = 24°24'$E) was founded in 1978 and it has through the years become an essential part of the activities of the FGI. The measurements made at the station serve both the Institute's own research and the international scientific community.

Currently, there are the following instruments in the Metsähovi station: satellite laser ranging, GPS and GLONASS receivers, DORIS beacon and a superconducting gravimeter. Absolute gravity is regularly measured in the gravimetric laboratory building. During 2001 the Helsinki University settled a seismometer in the station. The instrument is working in the same building where the superconducting gravimeter is located.

During the year 2002 the preparations for the VLBI (*Very Long Baseline Interferometry*) observations were made in co-operation with the Metsähovi Radio Observatory of the Helsinki University of Technology.

In the vicinity, at the Kylmälä village, there is a photogrammetric test field that has been used since 1995 for developing photogrammetric testing methods and quality control of imaging systems.

The satellite laser used today was acquired in 1994. It consists of one meter telescope, made by the *Latvian University* in Riga, and mode locked Nd:YAG laser with 50 ps pulse length. The pulses reflect from prisms onboard various geodetic and remote sensing satellites. The ranging data show a precision of about ±20 mm. The ranging data ae submitted to the International Laser Ranging Service (ILRS). During 2002, 18 different satellites were observed (Table 1), number of observed orbits was 735 and the total number of the accepted observations was 84676 (Table 2). Preparations for daytime observations were continued. The equipments were updated and a narrow-band interference filter was tested. Daytime observations are planned to start in 2003, which means an essential increase in the degree of use.

Table 1. SLR observations in Metsähovi in 2002.

Satellite	*Nr. of orbits*	*Observ-ations*	*Deviation (m)*
Topex	124	20202	0.033
ERS-2	96	10074	0.015
Ajisai	89	17121	0.029
Envisat	71	6459	0.014
Jason	68	6922	0.015
GFO-1	66	5332	0.015
Lageos-1	62	5498	0.018
Lageos-2	46	4238	0.018
Stella	40	4211	0.015
Grace-A	18	1049	0.013
Starlette	17	1644	0.016
Grace-B	16	810	0.013
Champ	15	951	0.014
Reflector	2	84	0.069
Starshine-3	2	44	0.026
Glonass-86	1	22	0.021
Glonass-87	1	8	0.018
Beacon-C	1	7	0.028
Total:	735	84676	

Table 2. The SLR observations: the number of the tracked satellite passes and normal points by the SLR in 2000–2002.

	2000	2001	2002	2000–2002
No. of passes	537	544	735	1816
No. of normal points	9498	10488	84676	104662

The astronomical VLBI system of Metsähovi Radio Observatory of the Helsinki University of Technology is being upgraded also for geodetic work by adding five baseband converters, a cooled S/X receiver, a removable subreflector and the cable delay and phase calibration units. The Cassegrain telescope with a radome has a primary paraboloid dish with a diameter of 13.7 m and a focal length of 5.08 m. The cooled, axially positioned and removable, S/X converter (15 K) and feed will be constructed by a Spanish company TTINorte. The existing data acquistion terminal is of type VLBA4. The geodetic VLBI system will be an important addition to the existing space geodetic and related instrumentation at the observatory (GPS, GLONASS, SLR, DORIS, a superconducting gravimeter, an absolute gravimeter and a seismometer).

Since 1992 the permanent GPS receiver has been operational. The data have been submitted to the *International GPS Service* (IGS) and to the computation centre of the *EUREF Permanent GPS Network* (EPN). Metsähovi is also included in the computation of the *International Terrestrial Reference Frame* (ITRF).

A GPS/GLONASS receiver was purchased in 1998. The GLONASS data have been used since then in the *International GLONASS Experiment* (IGLOS).

The DORIS beacon has worked since 1991 in the vicinity, in Sjökulla, at the Kylmälä village. The station has been used for the determination of the orbits of the SPOT and the TOPEX/POSEIDON satellites in co-operation with the French Space Agency (CNES).

Currently, the data collected by various observation instruments in the Metsähovi station are stored in several international data banks and used in the following international scientific projects:

- IGS: *International GPS Service,*
- EPN: *EUREF permanent GPS-network,*
- IGLOS: *International GLONASS experiment,*
- DORIS: *Doppler Orbitography by Radiopositioning Integrated on Satellite,*
- ILRS: *International Laser Ranging Service,*
- GGP: *Global Geodynamics Project,*
- ICET: *International Center for Earth Tides.*

Bibliography

Paunonen, M. (2000): Calibration of a common optics, single channel satellite laser rangefinder at Metsahovi. 12th International Workshop on laser ranging, Matera, Italy, 13–17 November 2000. (To be published in the proceedings).

Paunonen, M. (2002): Satellite Laser ranging and geodetic VLBI at Metsähovi: Status report. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki), pp. 236–240.

Geodetic Activities of the National Land Survey of Finland

by
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Introduction

During 1999–2002 the main geodetic activities of the National Land Survey (Maanmittaus-laitos) were still concentrated on maintaining and densifying both the horizontal and the vertical control networks.

Within the NLS control surveys are done by Uusimaa and North Ostrobothnia District Survey Offices. The NLS was reorganized in 1999 and all field work were concentrated into District Survey Offices.

Some operations were done on international borders, namely on the border between Finland and Norway and between Finland and Russia. The NLS took also part in working groups where instructions and guidelines for new coordinate system and map projection were determined.

The new organisation of the NLS

The new organisation came effective in 1999.

Today the NLS consists of 13 District Survey Offices, five national operational units and the central administration. The NLS has staff over 2000, of whom over 80% are employed in the District Survey Offices. The NLS is a governmental agency subordinate to the Ministry of Agriculture and Forestry.

District Survey Offices provide expert assistance in matters pertaining to land, real estate and maps. They carry out land surveys and help to prepare deeds of sale and provide assistance in applications for registration of title of property. They also supply cadastral information. The Offices gather and update data on the maps covering their areas for the topographic database. District Survey Offices are (see also Fig.1):

1. Uusimaa District Survey Office (DSO)
2. Varsinais-Suomi DSO
3. Häme DSO
4. Pirkanmaa-Satakunta DSO
5. Southeastern Finland DSO
6. South Savo DSO
7. North Savo DSO
8. North Karelia DSO
9. Central Finland DSO
10. Ostrobothnia DSO
11. North Ostrobothnia DSO
12. Kainuu-Koillismaa DSO
13. Lapland DSO

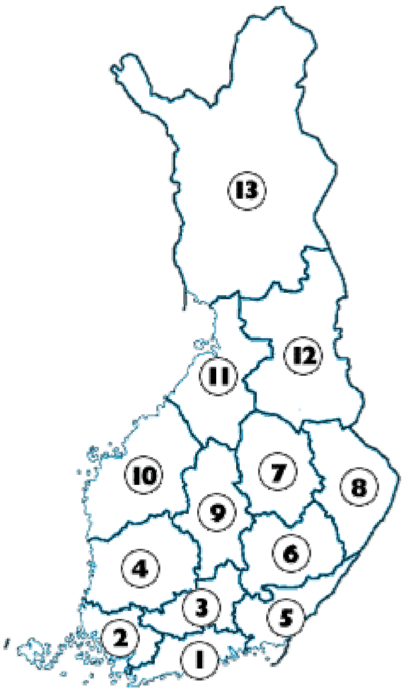

Fig. 1. District Survey Offices and their operation areas.

NLS's national operational units are responsible for development and research in their own areas, coordination of activities and nationwide services. The units are located in

Helsinki as well as the central administration. Units are:

- The Development Centre
- The Aerial Image Centre
- The Computer Centre
- Administrative Services
- Sales and Marketing Services

Control Surveys

The NLS is responsible for Finland's horizontal and vertical control networks. Within the NLS control surveys are done by the Uusimaa District Survey Office in the southern part of Finland and the North Ostrobothnia District Survey Office in the northern part of Finland.

The horizontal control network is still based on the first order triangulation network measured by the Finnish Geodetic Institute (FGI) and partly by the NLS. The basis for the vertical control network is the precise levellings made by the FGI.

In the work of maintaining and densifying the horizontal control network Ashtech Z12 and TPS Legacy GPS receivers were used. Amounts of measured GPS stations are seen in table 1.

In order to maintain and densify the vertical control network II and III order levellings were performed. Wild NA3000 digital levels and GPCL3 invar bar staffs were used in this work. Amounts of levelled benchmarks are seen in table 2.

Total lengths of levelling lines were 1079 km (1999), 1014 (2000), 758 km (2001) and 676 km (2002), altogether 3527 km.

Coordinates, heights and other information of the measured stations and benchmarks are stored in database and archive. The database includes approximately 25 000 horizontal control points and approximately 50 000 vertical control points.

Other activities of NLS

In 1999 border measurements in Finnish – Russian border were completed. Total of 592 boundary marks were measured by GPS.

The international boundary inspection between Finland and Norway was completed in 2001. The inspection is done every 25th year. All geodetic measurements were done in ETRS89 -system. In fact during this inspection some EUREF-FIN densification points were determined (Tätilä, 2002).

Two employees of the NLS took part in a working group whose topic was the modernization of the Finnish national coordinate systems. In its report the working group recommended EUREF – FIN (realisation of the ETRS89 system in Finland) for Finland's new national coordinate system. Projected (horizontal) coordinate system should be based on Transverse Mercator projection; UTM-like system for national mapping purposes (the hole Finland in one zone) and Gauss-Krüger with 1º zone width for other purposes.

The new coordinate system will be introduced in the near future. Preparations for the change of the coordinate system have been started on some areas, for instance control points database will be changed, GPS measurements have been recently connected to the EUREF-FIN points, some old GPS-measurements were reprocessed etc. But, most of the work is still ahead.

Table 1. GPS stations measured by NLS during 1999–2002.

Year	Uusimaa DSO	North Ostrobothnia DSO	Total
1999	548	249	797
2000	519	223	742
2001	510	203	713
2002	537	211	748
Total	2114	886	3000

Table 2. The levellings completed by NLS during 1999–2002.

Year	Uusimaa DSO	North Ostrobothnia DSO	Total
1999	523	237	760
2000	454	206	660
2001	421	196	617
2002	428	194	622
Total	1826	833	2659

References

Tätilä, Pekka (2002), personal comment.

Gravity Operations of the Geological Survey of Finland

by
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Geological Survey of Finland (GTK) continued applying gravity measurements to bedrock research, to exploration of metallic ores and industrial mineral deposits, and environmental studies. In regional gravity surveys, the station interval is usually 400 to 1000 m (1 to 6 stations per sq. km). Gravity profiles are measured normally with a station spacing of 20 m. Local gravity surveys are conducted on regular grids usually of 20 m x 100 m. In addition, to our own measurements, the data of the Finnish Geodetic Institute and those compiled in international projects are utilized. GTK contributed to and benefited from a substantial demand in Finland for commercial gravity work.

In the three-year period 2000–2002, the number of gravity stations measured by GTK is as follows:

1. Regional gravity measurements: 27136 stations, 7700 sq. km
2. Profile measurements: 36179 stations, 735 km
3. Systematic measurements: 66264 stations, 125 sq. km.

GTK has currently one Scintrex CG-5, one Scintrex CG-3M, two Scintrex CG-3, and four Worden gravimeters in use. A quality system for gravity measurements was formulated, documented and taken into use. Among other things, the calibration and behavior of the gravimeters are regularly checked on the Masala–Vihti calibration line of the Finnish Geodetic Institute.

A computer program was designed to utilize the 25 m x 25 m digital elevation model of the Finnish National Land Survey to calculate terrain corrections for gravity data. The radius for the terrain correction used in the above measurements is 18.8 km.

GTK contracted and supervised T. Hokkanen and M. Pirttivaara from the Helsinki University of Technology to model some potential applications of gravity gradiometry in order to focus interest onto the development of new gravity gradiometers (Hokkanen et Pirttivaara, 2002).

In bedrock research, targets include major fault and shear zones, stratigraphic cross-sections, greenstone belts, metamorphic zoning, mafic and granitic intrusions and meteorite impact craters (e.g. Elo 2000 and 2001; Lanne et al., 2002). It also is very important to provide additional information to deep seismic soundings such as FIRE (Finnish Reflection Seismic Experiment, Kukkonen et al. 2002). Important targets in exploration currently include ore-bearing mafic intrusions and kaolin deposits. The following two applications are categorized under the title of environmental geophysics (Elo and Vanhala, 2001; Vanhala et al., 2000). During the last decade, the gravity method has increasingly been used in estimating overburden thickness mostly in conjunction of assessing groundwater resources. As a new application, a combination of accurate GPS and gravity measurements to monitor the compaction and density changes of dump heaps is under development.

In applying gravity methods to the study of meteorite impact structures GTK cooperated with the Universities of Helsinki, Finland; Tartu, Estonia; and Kiel, Germany; State Company ”Mineral” and Northwest Regional Geological Centre, St. Petersburg, Russia (Elo et al., 2000; Plado, 2000; Werner et al. 2002).

GTK cooperates currently also with the University of Oulu in a project the aim of which is to create a three-dimensional crustal model for the SVEKALAPKO area by joint interpretation of seismic tomographic, gravity, aeromagnetic, petrophysical and geological data (Kozlovskaya et al., 2002).

The importance of petrophysical data in geological modelling of gravity anomalies was emphasized e.g. by Korhonen and Säävuori (2000) and Ruotoistenmäki (2001 and 2002).

A major achievement was the compilation of the Fennoscandian 2.5 km and 2.5 km Bouguer anomaly grid and the printing of the corresponding Bouguer anomaly map of the Fennoscandian Shield 1: 2 000 000 by the Geologial Survey of Finland as the coordinator, Swedish Geological Survey, the Norwegian Geological Survey and Ministry of Natural Resources of Russian Federation (Korhonen et al. 2002). The Finnish Geodetic Institute and the Swedish and Norwegian National Boards of Survey participated in the project. Denmark, Estonia, Latvia and Lithuania contributed gravity data. In addition to Bouguer anomaly, the insert maps and diagrams summarize available data on bulk density of the Fennoscandian Shield and the correlation of induced magnetisation and bulk density. The Bouguer anomaly map together with the corresponding magnetic and geological maps constitute the basis for developing a Fennoscandian crustal model as envisioned by Juha Korhonen (Korhonen and Säävuori, 2000).

Altogether, during the three-year period 2000–2002, the geological applications of gravity measurements were fully alive and the prospects for future application are as good as they get.

References

Elo, S., 2000. Gravity anomalies in Finland due to crustal and upper mantle sources. In: Pesonen, L. J.; Korja, A. & Hjelt, S.-E. (eds.) Lithosphere 2000: a symposium on the structure, composition and evolution of the lithosphere in Finland, Espoo, Otaniemi, October 4–5, 2000: programme and extended abstracts. Institute of Seismology. University of Helsinki. Report S-41, 53–57.

Elo, S.; Zhdanova, L.; Chepik, A.; Pesonen, L. J.; Philippov, N. and Shelemotov, A., 2000. Comparative geophysical description and modelling of Lappajärvi and Jänisjärvi impact structures, Fennoscandian Shield. In: Plado, J. & Pesonen, L. J. (eds.) Meteorite impacts in Precambrian shields, May 24–28, 2000, Lappajärvi–Karikkoselkä–Sääksjärvi, Finland: programme and abstracts. Espoo: Helsinki: Geological Survey of Finland: University of Helsinki, 35.

Elo, S., 2001. Gravimetriset tutkimukset Eurajoella ja Olkiluodossa vuonna 2000. Abstract: Gravimetric investigations in Eurajoki and Olkiluoto, 2000. Posiva. Työraportti 2001-05. 5 p. + 17 app.

Elo, S. and Vanhala, H., 2001. Geofysiikan uudet ympäristösovellukset. Abstract: Environmental geophysics in the GTK. In: Idman, H. & Rönkä, E. (eds.) Kestävä kehitys – tutkimuksen haasteet ja mahdollisuudet: GTK-SYKE -tutkimus-seminaari 12.9.2001. Geologian tutkimus-keskus. Tutkimusraportti 153, 86–94.

Hokkanen, T. and Pirttivaara, M., 2002. Esimerkkejä painovoiman ja sen vertikaaligradientin mallintamisesti (Examples of modelling gravity and its vertical gradient). Loppuraportti. Geologian tutkimuskeskuksen tilaama tutkimus. Teknillinen Korkeakoulu, Espoo. 24 varsinaista sivua ja 25 liitesivua.

Korhonen, J.V. and Säävuori, H., 2000. Fennoscandian Crustal Model as Reflected by the Petro-physical Interpretation of the Potential Field Anomalies. In: Pesonen, L. J., Korja, A. & Hjelt, S.-E. (eds.) Lithosphere 2000: a symposium on the structure, composition and evolution of the lithosphere in Finland, Espoo, Otaniemi, October 4–5, 2000: programme and extended abstracts. Institute of Seismology. University of Helsinki. Report S-41, 85–90.

Korhonen, J.V., Aaro, S., All, T., Elo, S., Haller, L.Å.†, Kääriäinen, J., Kulinich, A. Skilbrei, J.R., Solheim, D., Säävuori, H.,Vaher, R., Zhdanova, L. and Koistinen, T., 2002. Bouguer Anomaly Map of the Fennoscandian Shield 1 : 2 000 000. Geological Surveys of Finland, Norway and Sweden and Ministry of Natural Resources of Russian Federation, 2002. ISBN 951-960-818-7.

Lanne, E., Lehtimäki, J., Vanhala, H. and Väisänen, U., 2002. Geophysical characteristics of Precambrian fracture zones – a case study from Rovaniemi, northern Finland [Electronic resource]. In: Senos Matias, M. & Grangeia, C. (eds.) 8th Meeting EEGS-ES, Environmental and Engineering Geophysics, 8–12 September 2002, Aveiro, Portugal: proceedings. Aveiro: Universidade de Aveiro, 431–434. Optical disc (CD-ROM).

Kozlovskaya, E., Pirttijärvi, M., Hjelt, S-E., Korhonen, J.V., Elo, S. ja Yliniemi, J., 2002. The research project: 3-D Crustal Model of the Finnish Part of SVEKALAPKO Research Area. In: Lahtinen, Korja, Arhe, Eklund, Hjelt and Pesonen (eds.), Lithosphere 2002: second symposium on the structure, composition and evolution of the lithosphere in Finland, Espoo, Otaniemi, November 12–13, 2002: programme and extended abstracts. Institute of Seismology. University of Helsinki. Report S-42, 55–58.

Kukkonen, I.; Heikkinen, P.; Ekdahl, E.; Korja, A.; Hjelt, S-E.; Yliniemi, J.; Berzin, R. and FIRE Working Group, 2002. Project FIRE: deep Seismic Reflection Sounding in Finland 2001–2005. In: Lahtinen, Korja, Arhe, Eklund, Hjelt and Pesonen (eds.), Lithosphere 2002: second symposium on the structure, composition and evolution of the lithosphere in Finland, Espoo, Otaniemi, November 12–13, 2002: programme and extended abstracts. Institute of Seismology. University of Helsinki. Report S-42, 67–70.

Plado, J., 2000. Gravity and magnetic signatures of meteorite impact structures. Dissertationes Universitatis Tartuensis 10. Tartu. 43 pages plus three offprints.

Ruotoistenmäki, T.; Mänttäri, I. and Paavola, J., 2001. Characteristics of Proterozoic late-/ post-collisional intrusives in Archaean crust in Iisalmi–Lapinlahti area, central Finland. In: Autio, S. (ed.) Geological Survey of Finland, Current Research 1999–2000. Geological Survey of Finland. Special Paper 31, 105–115.

Ruotoistenmäki, T., 2002. Petrophysical Characteristics of Igneous Rocks in Finland Compared tio Igneous Rocks in Subareas of the Seismic Reflection Profile FIRE-1. In: Lahtinen, Korja, Arhe, Eklund, Hjelt and Pesonen (eds.), Lithosphere 2002: second symposium on the structure, composition and evolution of the lithosphere in Finland, Espoo, Otaniemi, November 12–13, 2002: programme and extended abstracts. Institute of Seismology. University of Helsinki. Report S-42, 117–118.

Vanhala, Heikki; Lohva, Jaana; Lahti, Mari; Jokinen, Tarmo; Lehtimäki, Jukka; Elo, Seppo; 2000. An integrated geophysical study of groundwater monitoring system around a large landfill area. In: EAGE 62nd conference and technical exhibition, Glasgow, Scotland, 29 May – 2 June 2000: extended abstracts. Vol. 1: Oral presentations. Houten: European Association of Geoscientists & Engineers , 4 p.

Werner, S.C., Plado, J., Pesonen, L.J., Janle, P. and Elo, S., 2002. Potential fields and subsurface models of Suvasvesi North impact structure, Finland. Physics and Chemistry of the Earth, Parts A/B/C, Vol. 27, 1237–1245.

Geodetic activities at the Department of Surveying, Institute of Geodesy, Helsinki University of Technology

by
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The Institute of Geodesy is the only place in Finland offering an academic level education in geodesy. Geodesists from HUT are found in academia and research, in industry and in public, frequently municipal, administration.

On September 1, 2000 the Chair of Geodesy was vacated by Prof. Teuvo Parm by his retirement, and filled by appointment of Prof. Martin Vermeer.

Research:

In 2000, a test net around Espoo and Klaukkala was used in studying the use of Real Time Kinematic GPS (RTK-GPS) in various environments (urban, forested, various baseline lengths) and in testing communication modems and data storing and handling under field conditions. Also the accuracy of the "Virtual RTK-GPS" concept was investigated.

During the reporting period, our multi-theodolite system (Spatial Intersection Method) for 3-D optical precision measurements was further developed, updated, tested and used.

Work on automation in precise height determination and calibration of levelling equipment was continued and led to one doctoral dissertation (2001).

Research was done on system calibration of the automatic target recognition of a robotic tacheometer.

Notable events:

In May 2001 HUT's Surveying Department's Institute of Geodesy was commissioned to re-measure (modernize) the base network of the city of Kajaani. This included the determination of transformation parameters from the local system to kkj and to the geocentric EUREF-FIN. The work was done by second and third year students as part of the curriculum under the leadership of Institute staff.

In May 2003, a similar undertaking took place in the city of Lappeenranta.

On 8–9 November 2001 the Surveying Science Fair under the title "Co-ordinate Systems in a Time of Change" was held on HUT's premises.

On 1–5 October 2002, the 14th General Meeting of the Nordic Geodetic Commission (NKG) was held on the premises of HUT. See Fig. 1.

Fig. 1. HUT Rector, Prof. Paavo Uronen addresses the Nordic Geodetic Commission 14th General meeting.

On 26–30 August 2002 the IAG International Gravity and Geoid Commission held its symposium in Thessaloniki, Greece. Prof. Martin Vermeer acted as a co-convener.

Ph.D dissertation:

Mikko Takalo, 2000: "On automation in precise height determination".

Licentiate dissertation:

Jaana Järvinen, 2001: "Utilisation of GPS Satellite Measurement Methods in Data Acquisition for GIS Applications".

Education:

In 2002 a new major was introduced: Positioning and Navigation. A new course "Methods of navigation" was introduced. See Fig. 2.

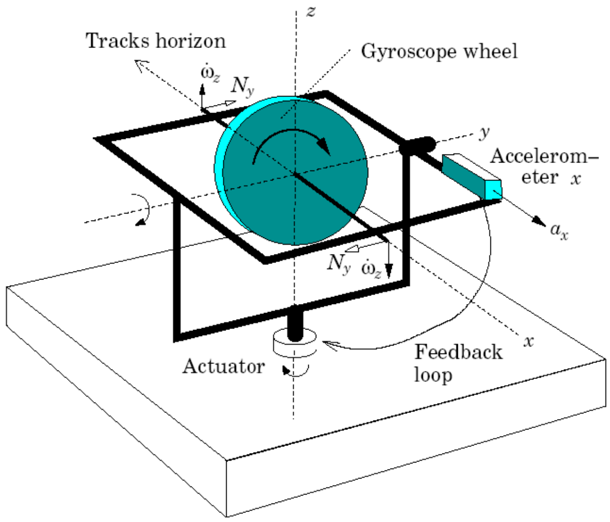

Fig. 2. A Schuler feedback loop used in inertial navigation.

During the reporting period the content of the Fundamental Geodesy course was developed to contain more modern material, e.g, on satellite geodesy and on the geophysical use and applications of geodesy. Training exercises were modernized to contain Matlab-based material. This is all part of a drive to dispel the "stuffy" image of the field and continue geodesy's illustrious history as a science educated in Finland also into the 21st century.

Our graduate program currently holds four students, three of whom are young researchers employed at the Finnish Geodetic Institute. This is but one example of our close and mutually fruitful co-operation. The fourth graduate student is employed at a small GPS technology firm and working on a related subject.

As part of the graduate program we organize post-graduate seminars together with the HUT Institute of Photogrammetry and Remote Sensing using HUT earmarked funding. Lasting four days in autumn, two days are dedicated to geodesy, one of which has a foreign invitee lecturing and the other, graduate students presenting their own work. These successful seminars saw Jean-Marie Becker in 2000, Kai Borre in 2001 and József Ádám in 2002 as geodetic lecturers.

Publications and presentations (English language only):

During the reporting period, Docent, Ass. Prof. Jaakko Santala acted as editor-in-chief of "Finnish Journal of the Surveying Sciences" of which on average one double issue per year appeared.

Santala, Jaakko and Seppo Tötterström: On Testing RTK-Network Virtual Concept. FIG XXII International Congress, Washington, D.C. USA, April 19–26 2002.

Santala, Jaakko and Vahur Joala: On the Calibration of a Ground-based Laser Scanner. FIG Working Week in Paris, France, April 11–16 2003.

Vermeer, Martin: Ideas on a consistent conceptual framework for tidal reductions in gravity, geopotential and positioning. Pres. at the Workshop "Instrumentation and Metrology in Gravimetry", Münsbach, Luxembourg, October 2002.

Vermeer, Martin: The elusive stationary geoid. Pres. at the Workshop "Earth Gravity Field from Space", Berne, Switzerland, March 2002.

Vermeer, Martin: Review of the GPS deformation monitoring studies commissioned by Posiva Oy on the Olkiluoto, Kivetty and Romuvaara sites, 1994–2000. Helsinki: STUK Säteilyturvakeskus, 2002. 21 (STUK-YTO-TR-reports 186).