National Report of Finland

MATTI OLLIKAINEN[1], JAAKKO MÄKINEN[1] , JORMA JOKELA[1] and RUIZHI CHEN[2]

[1]Department of Geodesy and Geodynamics, [2]Department of Navigation and Positioning
Finnish Geodetic Institute,
Geodeetinrinne 2, FIN-02430 Masala, Finland
Jaakko.Makinen@fgi.fi, Matti.Ollikainen@fgi.fi, Jorma.Jokela@fgi.fi, Ruizhi.Chen@fgi.fi

1. GPS observations

The Finnish permanent GPS network FinnRef consists of 13 permanent GPS stations. The network is the bagbone 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 belong to the network of the *International GPS Service* (IGS). In 2002 a new permanent station was established close to the Degerby tide gauge, at Aland.

The data recorded in the EPS stations (Metsähovi, Vaasa, Joensuu, Sodankylä) are transferred automatically to the EPN computing centre in Germany. The data is 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.

Absolute gravity observations have been made at five EUREF® stations, viz. in Metsähovi, Vaasa, Joensuu, Virolahti and Sodankylä. The JILAg-5 of the FGI and several FG5 gravimeters have been used. The series in Metsähovi contains by now more than 80 occupations since 1988.

The use of RTK by surveyors is growing fast and therefore the FGI did a study in 2000, financed by the Ministry of Agriculture and Forestry, to investigate the quality of RTK. 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 and the measurement procedure.

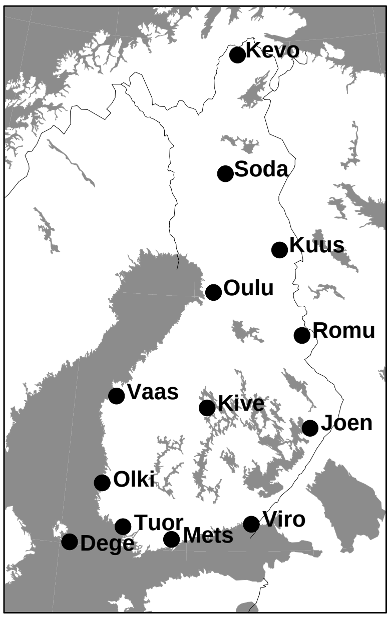

Fig. 1 The Finnish permanent GPS network, FinnRef®.

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 Coordinates system (*Kartastokoordinaatti-järjestelmä, 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.

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.

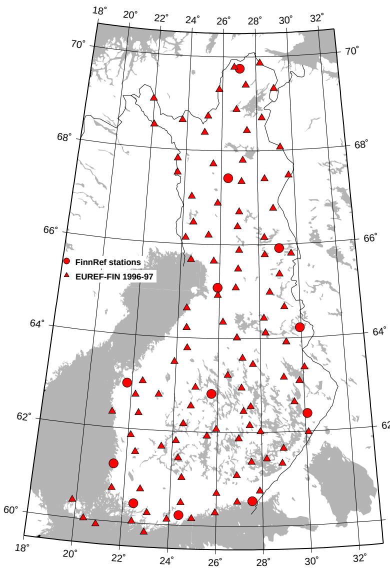

Fig. 2. The Finnish permanent GPS-network and the stations of the EUREF-FIN densification in 1996-97.

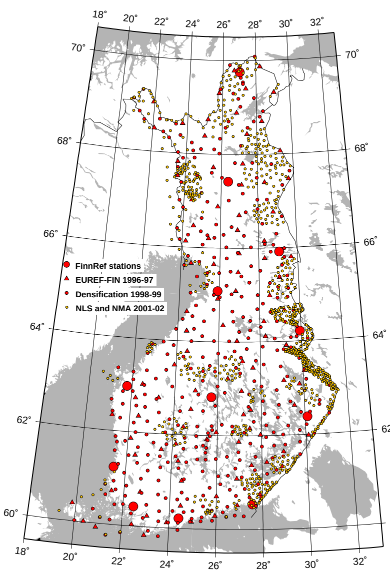

Fig. 3. The lower-order EUREF-densifications in 1998-2001. The densification 1998-99 was made by the FGI. The densifications in 2000-01 by the National Land Survey (NLS) and the National Maritime Administration (NMA).

3. Precise levelling

Two national precise levellings have been carried out in Finland (Fig. 4) The Third Levelling is in progress and its field work will be completed in 2004. As a result a new national height system will be created.

The vertical laser rod comparator has been working well and it has been used to calibrate all rods of the FGI used in the Third Levelling. In addition, invar rods used in Baltic countries and by several domestic users have been calibrated. A system calibration comparator for digital levels was designed and constructed.

A test field was built at Metsähovi for precise levelling instruments. Three test series were carried out using simultaneously the Zeiss DiNi12 and Wild N3 instruments.

Land uplift rates (vertical velocities) determined from the three precise levellings are shown in Fig. 5.

A common adjustment of the levelling networks of the Nordic countries was prepared. Land uplift models for the adjustment were studied. A new data base was established at Kort- og Matrikelstyrelsen, in Copenhagen. The co-operation was carried out in the Working Group for Height Determinationsof 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 Working Group in 2002.

Finnish and the Swedish levelling networks were connected over the Aland Sea using GPS techniques in June 2002. The field work was coordinated by the NKG Working Group of the Satellite geodesy. The observations were made by the staff of the FGI and Lantmäteriet (Gävle).

In 2002 Finnish and Russian precise levelling networks were connected at two places in Lapland. The tie across the border was levelled simultaneously by a Finnish and a Russian levelling team.

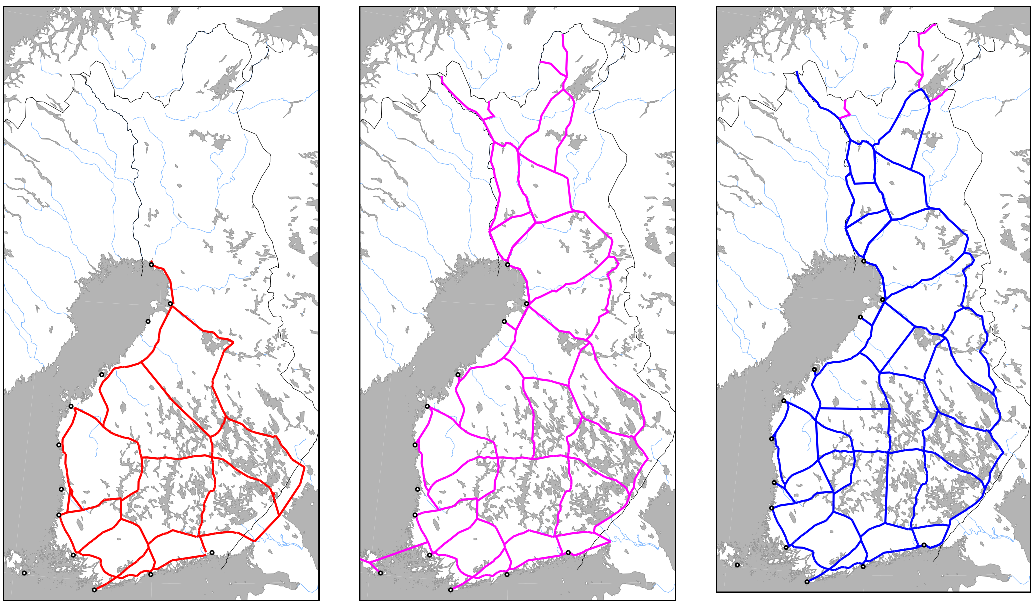

Fig. 4. Networks of the three precise levellings in Finland. The representation is in part schematic, with straight lines connecting nodal points. Tide gauges are shown by circles.
Left: First Levelling (1892–1910). Accuracy estimated from loop misclosures is 1.3 mm/√km. Mean epoch is 1902. Middle: Second Levelling (1935–1975). Accuracy estimated from loop misclosures is 0.7 mm/√km. Mean epoch is 1950. Right: Third Levelling (1978–), status after field work of 2002. The lines levelled in 2002 are indicated by a different hue. Accuracy estimated from loop misclosures is 0.8 mm/√km. Mean epoch is 1991.

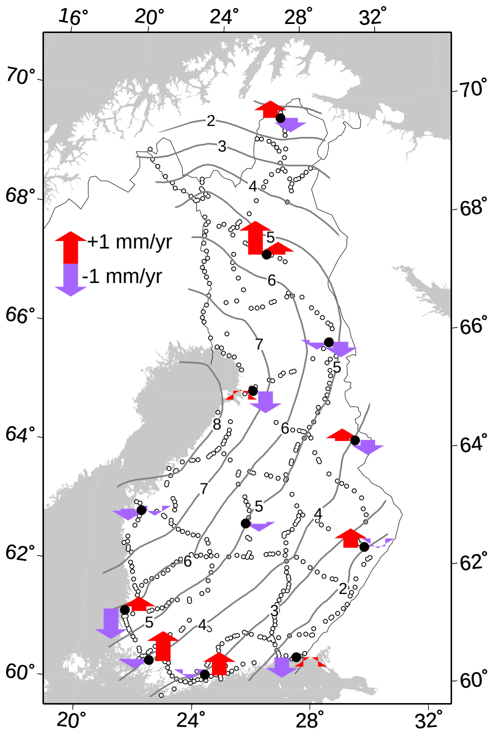

Fig 5. The isobases give the vertical rebound rates relative to mean sea level, in mm/yr, from the three precise levellings in Finland. The tide gauge at Hanko (59º49'N, 22º58'E) provides the starting value 2.73 mm/yr. Only bench marks in bedrock are used (open circles). The solid circles show the permanent GPS stations. Rebound rates from BIFROST GPS and FinnRef® processing have been divided by 1.06 and shifted to give best fit to levelling. Columns give the residuals GPS minus levelling, BIFROST to the left and FinnRef® to the right of the station mark.

4. Metrology and standardization

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. 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).

Calibration facilities for EDM instruments at the standard and calibration baselines in Nummela were maintained by projection and control measurements. Calibration facilities for horizontal and automated vertical calibration of levelling rods and system calibration of precise levelling were maintained in Masala.

The scale of the Eggemoen baseline in Norway was studied by performing a scale transfer from the Nummela Standard Baseline with high precision EDM in May. In September the scale was transferred further to the new Novoberde baseline in Kosovo. The measurements were performed by the Norwegian Mapping Authority.

In co-operation between the FGI and the Posiva Ltd. a 511-m EDM baseline was established at the Olkiluoto nuclear power plant; the space distances have been measured with the Kern Mekometer ME5000 of the Helsinki University of Technology. The baseline is a part of a GPS network used for local crustal deformation studies since 1994. The purpose is to confirm the scale of GPS observations and to improve the quality of GPS measurements. Calibrations with high precision EDM twice per year during GPS observation campaigns will be continued.

5. Navigation and Positioning

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.

6. Metsähovi Research Station

The Metsähovi research station 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.

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 Rangin Service (ILRS). During 2002, 18 different satellites were observed, number of observed orbits was 735 and the total number of the accepted observations was 84676. 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.

The astronomical VLBI system of Metsähovi Radio Observatory of the Helsinki University of Technology is being upgraded also for geodetic work by adding five based 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 exxisting 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.

7. Maintenance of the national I-order triangulation network and EUREF sites

I-order triangulation network

The FGI performed measurements for the first order triangulation in 1919-1987. The coordinates of the latest adjustment were computed in the ED87 system. Almost 400 I-order stations formed the basis for mapping of Finland. The most important stations are today those 91 stations which were connected to the ETRF89 by GPS observations in 1996-97 (Fig. 2).

The usability of the triangulation stations has been studied since 1988, starting with the oldest stations. More than 70 % have been checked so far. In the check measurements all the central and auxiliary markers are sought out. The relative positions of them are determined with 1 mm inaccuracy using tacheometer measurements and 3D net adjustments; at some places a new orientation is determined with GPS measurements. Using the results we estimate the stability of the station, and we obtain accurate centring elements for eccentric observation sites. The triangulation stations checked in 1988-2003 are shown in Fig. 6.

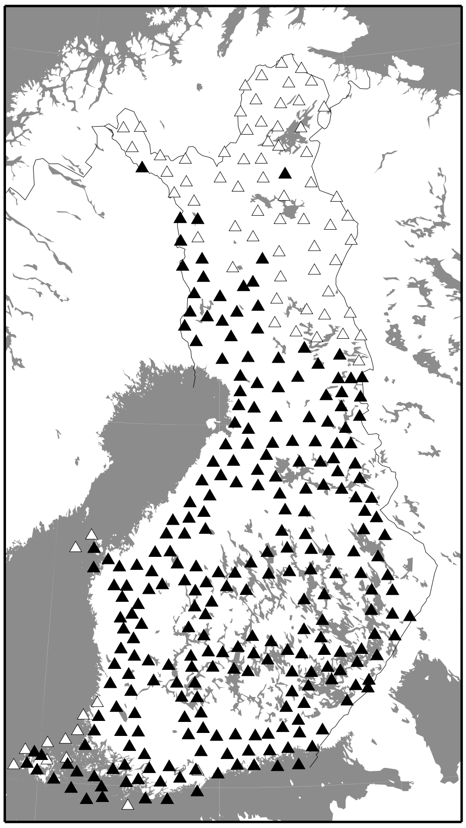

Fig 6. The Finnish I-order triangulation network. The stations checked in 1988-2003 are marked with black triangles.

EUREF-sites

The EUREF sites observed in Finland have been measured in three campaigns: EUREF89 (4 sites), EUVN (9 sites) and EUREF-FIN (19 sites). The number of EUREF sites, which have been accepted by the EUREF sub-commission as enlargement of EUREF is today 20. More than one half of the stations (12 sites) are used continuously because the sites belong to the Finnish permanent GPS-network, FinnRef®. The location of the GPS antennas and the auxiliary markers are checked at these stations by an interval of two years. One part of the sites (5) is located in the vicinity of tide gauges. The height of these station markers is levelled by an interval of three years. The remaining 3 sites have no scheduled checking program.

Bibliography

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.

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.

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/

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

JOKELA, J., A. BUGA, R. PUTRIMAS and V. TULEVICIUS (2002): Analysis of repeated calibration of Kyviskes baseline. Geodezija ir kartografija, Vol. XXVIII, No. 4, pp. 125-130.

JOKELA J., P. ROUHIAINEN and M. TAKALO (2002): Length - geodesy. Finnish National Standards Laboratories Annual Report 2001. Publ. of the CMA J2/2002, p. 41-42.

JOKELA J. (2002): Some contemporary activities in geodetic metrology in the FGI. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki). pp.275-277.

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

KOIVULA H. and M. OLLIKAINEN (2002): Uusi valtakunnallinen koordinaatisto: EUREF-FIN. Maanmittaus 1-2/2002, pp. 7-19. (in Finnish)

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.

LEHMUSKOSKI P. and P. ROUHIAINEN (2002): Lisäyksiä ja korjauksia Suomen tarkkavaaitusten linjastoon 2000-2001. Geodeettisen laitoksen tiedote no. **25**, 26 pp. (In Finnish)

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, p. 18-22

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., 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 - Sedond 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. ISBN 951-45-7992-5.

MÄKINEN, J., H. KOIVULA, M. POUTANEN and 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., 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.

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.

POUTANEN, M., H. KOIVULA, 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.

SAARANEN, V. and J. MÄKINEN (2002): Determination of postglacial rebound from the three precise levellings in Finland: status in 2002. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki). pp. 171-174.

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, 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.

TAKALO M. and P. ROUHIAINEN (2002): On System Calibration of Digital Levels. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen, H. Suurmäki). pp. 278-283.

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.

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, S. WILLIAMS (2002): Results of the Sixth International Comparison of Absolute Gravimeters ICAG-2001. Metrologia **39**, 407-424.

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