Annual Report 2007 – Chalmers

to the NKG Working Group on Geodynamics

The part of activities of the Department of Radio and Space Science at Chalmers University of Technology that is relevant for the NKG Working Group is reported. It comprises the activities within the research group on Space Geodesy. A list of their publications in 2007 is given at the end of the report. In addition, a short status report on the Gravimeter site at Onsala Space Observatory is given below.

Space Geodesy and Geodynamics

Staff

Senior researchers: Rüdiger Haas, group leader, Jan Johansson, adjoint professor, and Hans-Georg Scherneck, PhD-students: Susana Garcia Espada, Martin Lidberg (until Nov. 2007), Tobias Nilsson, Tong Ning, Per Anders Olsson, Surat Pramualsakdikul, Carsten Rieck.

The focus of our research is geodynamical phenomenon and atmospheric processes. We address these research topics by theoretical work and observations where we use primarily space geodetic and geophysical techniques, and microwave radiometry. The range of research topics includes Earth rotation variations over sub-diurnal to decadal time scales, terrestrial reference frames, inter- and intraplate tectonic motions, crustal deformation due to oceanic and atmospheric loading, glacial isostatic adjustment, distribution and variation of atmospheric water vapour for short term applications such as weather forecasting as well as long term climate monitoring and research.

GPS antenna mounted on an industrial robot. The robot is used to simulate movements, such as during seismic events.

A new geodetic reference frame for the Nordic countries

In collaboration with the National Land Survey of Sweden we established a new geodetic reference frame for the Nordic countries. It is based on a homogenous analysis of more than a decade of continuous GPS observations. The results provide the state of the art velocity field of global isostatic adjustment (GIA) in Fennoscandia.

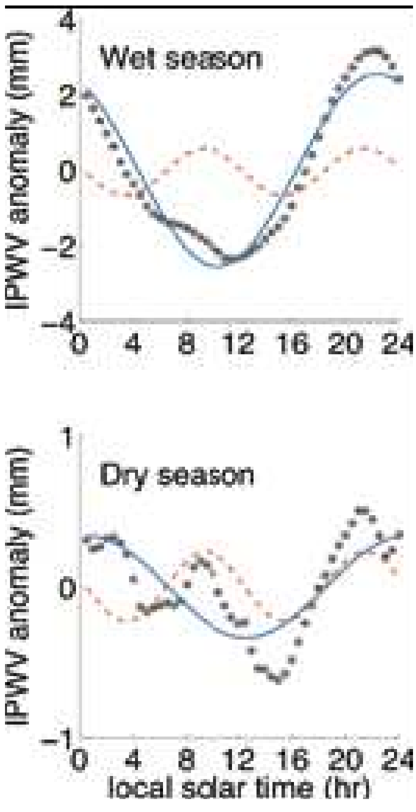
GPS measurements of water vapour for weather forecasting

The amount of water vapour in the atmosphere varies rapidly in space and time. Local weather forecasts for the next few hours (sometimes referred to as nowcasting) can therefore gain in accuracy from additional observations of the water vapour. We developed an operational data analysis based on basic research where GPS signals are used both for measuring the 3D motion of the Earth's crust and the simultaneous atmospheric propagation delay. This application is now used by the Swedish Meteorological and Hydrological Institute (SMHI) for more than 200 GPS stations in the Nordic countries within the European project E-GVAP. The National Land Survey of Sweden delivers data from 140 stations in the SWEPOS network and we have the overall responsibility for the data analysis.

SMHI is now starting to assess the influence on the quality of weather forecasts from these new results.

Diurnal and semi-diurnal signatures in the integrated precipitable water vapour (IPWV) in the tropical region

We analysed several years of GPS data from sites in the tropical region to investigate diurnal and semidiurnal variations in the integrated precipitable water vapour content. It was found for most sites that the diurnal signatures were more dominant than the semi-diurnal ones. Stations close to the equator show relatively large seasonal variations.



Example for diurnal and semi-diurnal variation in IPWV at Lae (Papua Ny-Guinea) derived from GPS data analysis (black circles). The diurnal signal (blue line) is stronger than the semi-diurnal (red dashed line). Both are stronger *during wet seasons than during dry seasons*.

High-rate GPS-measurements for seismic observations

We simulate seismic events with an industrial robot and measure its movements with a high-rate GPS equipment mounted on the robot. The analysis gives insight into the potential for seismic studies. This is of importance for the future combined use of the independent
American GPS and European Galileo systems.

Simulations for VLBI2010

VLBI2010 is the planned next generation geodetic Very Long Baseline Interferometry (VLBI) system that is currently designed by an international working group. Our contribution to this work is the simulations of atmospheric propagation delays using turbulence models. These simulations are used to assess different VLBI2010 designs.

The VLBI-group. Left to right: Gunnar Elgered, head of department, Mikael Lindqvist, Roger Hammargren, Hans-Georg Scherneck, Tong Ning, Tobias Nilsson, Karl-Åke Johansson, Surat Pramualsakdikul

Status Report on the Gravimeter Facility at Onsala Space Observatory

In autumn 2006 the Board on Science Infrastructure of the Swedish Research Council has decided to finance the acquisition of a superconducting gravimeter and its necessary housing as a component of the National Facility for Radioastronomy at Onsala Space Observatory. With this step, the observatories facilities together provide the infrastructure of a Fundamental Geodetic Station.

In 2007 we started with kind consulting advice from Jürgen Neumeyer to prospect for a suitable location. The area is rich of crystalline outcrop and poor of sediment. At some 100 m there is a low-lying wetland and at a few 100 m there is the coast of Kattegat. The criterion for the siting were: healthy bedrock, low elevation but above ground level, maximum 100 m distance from the existing absolute gravimeter pillar, low exposure to wind. In summer 2007 with the help of Luleå University of Technology we performed a ground-penetrating radar survey in order to trace visible cracks and joints from the surface to about 10 m depth. From the two candidate locations (see figure *Onsala Space Observatory*) 1 was dismissed due partly to its exposure to wind, partly to the vicinity of the telescope (a mass dipole of two times 45 tons at 10 m height worth of ±50 nGal during slewing), and partly to plans to establish a new radioastronomical antenna array (LOFAR) to the NW of location 1.

Later on, cores were retained from two drill holes that confirmed the few subhorizontal fractures seen in the radar survey. In all other respects, the bedrock, a low-metamorphic gneiss with veins of amphibolite, appears to have a low frequency of fractures.

The hut will be surrounded by an insulating screen in order to move the seasonal temperature gradient outward away from the piers. The atmosphere in the hut will become temperature stabilised, and it will heat the rock surface below the hut.

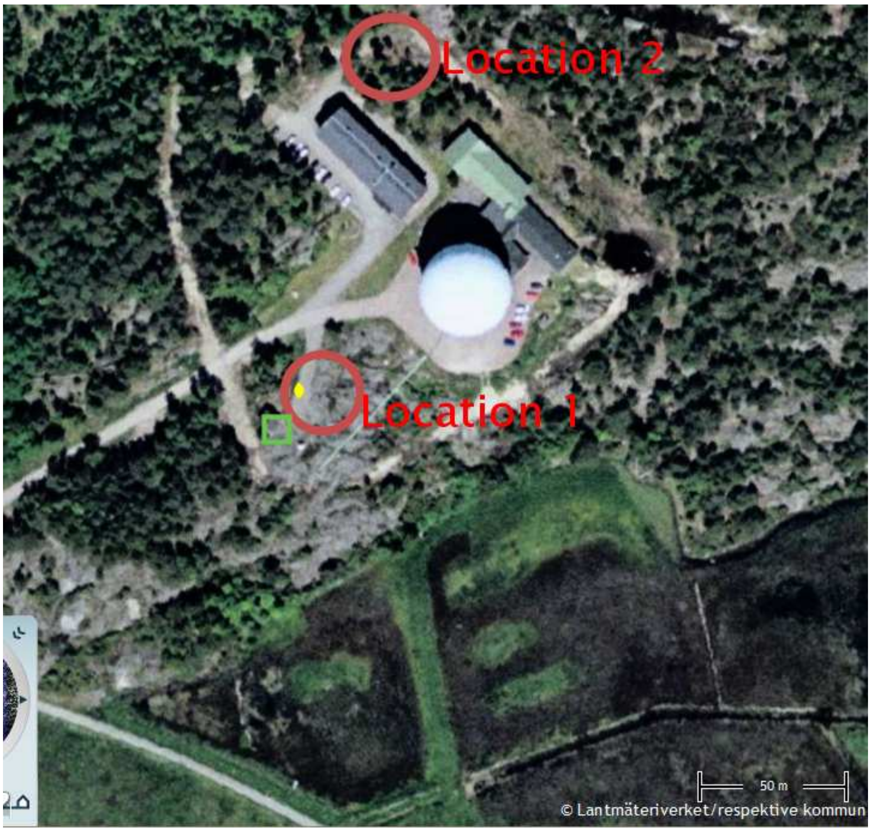
The cored drill holes will serve for ground water monitoring. In the figure *Onsala Space Observatory* near Location 2 between the centre of the red circle and the centre of the facing building a 2.5 m deep bed of sediments has been excavated in early 2008. The depression may hold between 40 and 50 m^3 of water. At the beginning of some dry weeks recently, the dimple was pumped empty of water. Afterwards it was observed that ground water from below the building slowly bleeds into the hole at less than 1 m^3 per day. The hole will be furnished with a regulated pump, and the gravel plane NE of the building will be covered with asphalt in order to reduce water mass variations. The water from the roof of the building will be collected off of the building instead of the infiltration in the sediment bed currently practiced. Temperature sensors will be placed into the rock and into the pillars. We also have plans to install an optical anchor (inspired by Agnew and Wyatt) in order to monitor vertical motion of the platform due to ground temperature variations.

Back-on-the-envelope calculations show that the staff working in the building, the parked cars, and the radio telescope may cause small but in principle measurable perturbations. As for the telescope, motion is irregular in time, and the effect peaks at a few nGal. We may decide to log all telescope manoeuvres. Periodicities in conjunction with staff working schedules are especially cumbersome as they will perturb manly the diurnal solar gravity tides. The recipe to land on a level below 1 mGal is that the gravimeter sensor has to be placed at 1.9 m above ground. People at the ground level of the building will then have no influence. Staff with offices on the first floor must use their cars to come to work and park them at appropriate places as to mutually compensate the attraction effects. Other staff will have to park their cars away from the area. The times when staff moves from the first to the ground floor are probably irregular enough as to randomise the phase of this human wave.

The piers for absolute and superconducting gravimeters will indeed be put on one 1.5 m high concrete block with 15 m^2 cross-section. The foundation design not only helps to minimise the disturbances mentioned previously, but also simplifies ground preparation; the rock surface can be flattened by blasting instead of cutting it with diamond-encrusted rope.

Gravimetry site preparation. Arrows show drill holes "Hål" where cores were retained, and in which ground water level will be monitored. The gravimeter pillars will be erected immediately behind the right arrow after preparation of a flat rock surface. The partly water-filled depression near the truck is in the process of becoming 2.5 m deep until the solid rock surface is touched. The

plane on which the truck is standing will be covered with asphalt, but only after the rainwater piping of the building seen to the left has been revised. The pond to the right will be drained by a small canal.
Photo from Feb. 11, 2008.



Onsala Space Observatory. The 20m-telescope is visible as a huge white structure in the centre. The building to the NW of the telescope houses administration and research staff. Location 2 is the one where the Superconducting Gravimeter site, also equipped with an absolute gravimeter pier, will be constructed. All vegetation and soil has been cleared away from the area of Location 2 and up to thebuidling with the light-coloured roof. The existing absolute gravity platform is at the position of the green rectangle near Location 1.
Aerial imagery from 2003.

Publications 2007

Peer reviewed scientific articles

Bergstrand, S.; Scherneck, H-G.; Lidberg, M. et al. (2007). BIFROST: Noise properties of GPS time series. in *"Dynamic Planet: Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools", IAG Symposium, Cairns, Australia, 22-26 August, 2005, Series: International Association of Geodesy Symposia, Springer. Eds. Paul Tregoning, Chris Rizos.* 130 p. 123-130. ISBN/ISSN: 978-3-540-49349-5.

Lidberg, M.; Johansson, J. M.; Scherneck, H-G. et al. (2007). An improved and extended GPS-derived 3D velocity field of the glacial isostatic. *J. of Geodesy.* 81 (3) p. 213-230.

Nilsson, T.; Gradinarsky, L.; Elgered, G. (2007). Water vapour tomography using GPS phase observations: Results from the ESCOMPTE experiment. *Tellus.* 59A p. 674-682.

Nothnagel, A.; Cho, J-H.; Roy, A. et al. (2007). WVR calibration applied to European VLBI observing sessions. in *"Dynamic Planet: Monitoring and Understanding a Dynamic Planet with Geodetic and Oceanographic Tools",* *IAG Symposium, Cairns, Australia, 22-26 August, 2005, Series: International Association of Geodesy Symposia, Springer. Eds. Paul Tregoning, Chris Rizos.* 130 p. 152-157. ISBN/ISSN: 978-3-540-49349-5.

Pramualsakdikul, S.; Haas, R.; Elgered, G. et al. (2007). Sensing of diurnal and semi-diurnal variability in the water vapour content in the tropics using GPS measurements. *Meteorological Applications.* 14 (4) p. 403-412.

Stoew, B. ; Nilsson, T.; Elgered, G. et al. (2007). Temporal correlations of atmospheric mapping function errors in GPS data analysis. *J. of Geodesy*. 81 (5) p. 311-323.

Wresnik, J.; Haas, R.; Böhm, J. et al. (2007). Modeling thermal deformation of VLBI antennas with a new temperature model. *J. of Geodesy.* 81 (6-8) p. 433-441.

PhD-Thesis

Lidberg, M. (2007). *Geodetic Reference Frames in Presence of Crustal Deformations.* PhD-Thesis, New Series No. 2705, Department of Radio and Space Science, Chalmers University of Technology, Göteborg, 2007. ISBN 978-91-7385-024-7/ISSN 0346-718x.

Additional publications

Haas, R.; Wager, J.; Mujunen, A. et al. (2007). e-VLBI data transfer from Onsala and Metsähovi to the Bonn correlator. *Proc. of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien.* (79) p. 27-32.

Haas, R.; Hagström, M.; Nilsson, T. et al. (2007). The IVS Technology Development Center at the Onsala Space Observatory. *International VLBI Service for Geodesy and Astrometry 2006 Annual Report, eds. D. Behrend and K. Baver, NASA/TP-2007-214151.* p. 263-265. Haas, R.; Scherneck, H-G.; Nilsson, T. (2007). The IVS Analysis Center at the Onsala Space Observatory. *International VLBI Service for Geodesy and Astrometry 2006 Annual Report, eds. D. Behrend and K. Baver, NASA/TP-2007-214151.* p. 224-227.

Haas, R.; Elgered, G. (2007). The IVS Network Station Onsala Space Observatory. *International VLBI Service for Geodesy and Astrometry 2006 Annual Report, eds. D. Behrend and K. Baver, NASA/TP-2007-214151.* p. 81-84.

Jakobson, E.; Ohvril, H.; Elgered, G. (2007). Diurnal variability of precipitable water in the Baltic region. *Proc. of the Fifth Study Conf. on BALTEX, Ed. H.J. Isemer, International BALTEX Secretariat, GKSS Research Center, Geesthacht, Germany.* (38) p. 119-120. Moya Espinosa, M.; Haas, R. (2007). SATTRACK - A Satellite Tracking Module for the VLBI Field System. *Proc. of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien.* (79) p. 53-58.

Nilsson, T.; Gradinarsky, L.; Elgered, G. (2007). Measurements of Atmospheric Scintillations Induced by Water Vapor. *Proc. of the Seventh International Conf. on Electromagnetic Wave Interaction with Water and Moist Substances ISEMA 2007, Ed. Seichi Okamura.* p. 259-264.

Nilsson, T.; Elgered, G.; Johansson, J. M. et al. (2007). Estimating Climate Trends Using GPS. *Proc. of the Fifth Study Conf. on BALTEX, Ed. H.J. Isemer, International BALTEX Secretariat, GKSS Research Center, Geesthacht, Germany.* (38) p. 15-16.

Nilsson, T. ; Haas, R.; Elgered, G. (2007). Simulations of atmospheric path delays using turbulence models. *Proc. of the 18th European VLBI for Geodesy and Astrometry Working Meeting, edited by J. Böhm, A. Pany, and H. Schuh, Geowissenschaftliche Mitteilungen, Schriftenreihe der Studienrichtung Vermessung und Geoinformation, Technische Universität Wien.* (79) p. 175-180.

Pramualsakdikul, S. (2007). *GPS Measurements of Atmospheric Water Vapour in a Low-Latitude Region.* Göteborg: Chalmers University of Technology. ISBN/ISSN 1652-9103. Licentiate thesis.