1^{st} Workshop on the
International Geodynamics and Earth Tide Service (IGETS)

18-20 June 2018, Potsdam (Germany)

Programme

Monday, 18 June 2018

Introduction to IGETS Workshop

12:00-14:00 Reception of participants and registration

14:00-14:10 Welcome by Local Organizing Committee Christian Voigt

14:10-14:20 Welcome by IAG president Harald Schuh

14:20-14:30 Welcome by IGETS Chair Hartmut Wziontek

Session 1 – IGETS Station Reports (Part I)

14:30-14:50 Station Report for Apache Point, New Mexico, 2016-2018 – David Crossley (Jacques Hinderer)

14:50-15:10 Station report of superconducting gravimeters in Chinese mainland – Heping Sun, Jianqiao Xu, Xiaodong Chen, Jiangcun Zhou and Xiaoming Cui

15:10-15:30 Report on the stations Sutherland (South Africa) and Zugspitze (Germany) – Christian Voigt, Hartmut Pflug, Pieter Fourie and Christoph Förste

15:30-15:50 Status of Strasbourg (France) and Djougou (Benin) superconducting gravimeter stations – Jean-Paul Boy, Jacques Hinderer, Séverine Rosat, Frédéric Littel and Jean-Daniel Bernard

15:50-16:20 Coffee Break

Session 1 – IGETS Station Reports (Part II):

16:20-16:40 Superconducting Gravimeter (SG) Measurement in Cibinong Station (Station Report) – Erfan Dany Variandy, Dyah Pangastuti and Antonius Bambang Wijanarto (Hartmut Wziontek)

16:40-17:00 Station Report on gravity stations Wettzell and Bad Homburg (Germany), Medicina (Italy) and AGGO/La Plata (Argentina) – Hartmut Wziontek, Axel Rülke, Ilona Nowak and Reinhard Falk

17:00-17:20 10 years SG gravity time series at Conrad Observatory (Austria) – Bruno Meurers

17:20-17:40 Station report: OS, Onsala, Sweden – Hans-Georg Scherneck and Marcin Rajner

17:40-18:00 Superconducting gravimeters during 2014-2018 at Metsähovi geodetic research station, Finland – Heikki Virtanen and Arttu Raja-Halli

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Tuesday, 19 June 2018

Session 1 – IGETS Station Reports (Part III):

09:00-09:20 Pecný, station report – Vojtech Pálinkáš, Miloš Vaľko and Jakub Kostelecký

09:20-09:40 Report on the Borowa Gora (BG) IGETS Station – Przemyslaw Dykowski, Marcin Sekowski, Jan Krynski and Monika Wilde-Piórko

09:40-10:00 Station report CD034, Moxa Observatory – Thomas Jahr

10:00-10:20 The McDonald Geodetic Observatory Superconducting Gravimeter – Clark R. Wilson

10:20-10:40 Continuous gravity in volcanic geothermal fields: contribution to gravity tidal models – Philippe Jousset, Kristján Ágústsson, Jean-Daniel Bernard, Vincent Droin, Kemal Erbas, Ásgrímur Guðmundsson, Andreas Güntner, Gylfi Páll Hersir, Jacques Hinderer, Arthur Jolly, Egill Júlíusson, Ingvar Þór Magnússon, Sigurður H. Markússon, Nolwenn Portier, Florian Schäfer, Tilo Schöne, Freysteinn Sigmundsson and Richard Warburton

10:40-11:10 Coffee Break

Session 2 – IGETS Data Products (Part I):

11:10-11:30 Production of IGETS Level 3 data at EOST – Jean-Paul Boy

11:30-11:50 IGETS Level 1-3 Products – David Crossley (Jacques Hinderer)

11:50-12:10 Can we reliably detect SG scale factor changes far below the one per mill accuracy level? – Bruno Meurers

12:10-12:30 On the drift-free SG time series and comparisons of absolute gravimeters – Vojtech Pálinkáš, Hartmut Wziontek, Reinhard Falk and Miloš Vaľko

12:30-12:50 Drift and steps in the data of the superconducting gravimeter SG056 at BFO – Clara Bützler and Thomas Forbriger

12:50 -13:10 The IGETS Data Base – Status Report – Christoph Förste and Christian Voigt

13:10-14:00 Lunch

14:00 Photoshooting – Elisabeth Gantz

14:00-15:30 Tour around historic Telegrafenberg Potsdam including pendulum hall and great refractor – Christoph Förste

15:30-16:00 Coffee Break

Session 2 – IGETS Data Products (Part II):

16:00 -18:00 General discussion moderated by Hartmut Wziontek

Topics:

- IGETS data and seismological services,
- Evaluation of preprocessed data provided by IGETS,
- Recent progress in tidal analysis by Klaus Schüller,
- Documentation of supplemental information.

Wednesday, 20 June 2018

Session 3 – Scientific Applications of IGETS Data (Part I):

09:00-09:20 Intercomparison of a dense meter-scale network of superconducting gravimeters at the J9 gravimetric observatory of Strasbourg, France – Jacques Hinderer, Séverine Rosat, Florian Schäfer, Umberto Riccardi, Jean-Paul Boy, Philippe Jousset, Frédéric Littel and Jean-Daniel Bernard

09:20-09:40 Self-noise correlation analysis of Superconducting Gravimeters at the J9 gravimetric observatory of Strasbourg, France – Séverine Rosat, Jacques Hinderer and Frédéric Littel

09:40-10:00 Uncertainty analysis of gravity time series reduction – Michal Mikolaj, Marvin Reich and Andreas Güntner

10:00-10:20 Hydro-gravity signals, from large to small – Jeffrey Kennedy

10:20-10:50 Coffee Break

Session 3 – Scientific Applications of IGETS Data (Part II):

10:50-11:10 Study on temporal variation in FCN period and its possible mechanism – Xiaoming Cui, Heping Sun, Jianqiao Xu, Jiangcun Zhou and Xiaodong Chen

11:10-11:30 Determination of the Earth's mantle structure from low-period seismic surface waves recorded by superconducting and spring gravimeters at the Borowa Gora Observatory – Monika Wilde-Piórko, Przemyslaw Dykowski, Marcin Polkowski, Marcin Sekowski, Marek Grad and Jan Krynski

11:30-11:50 Monitoring the Gravity Changes in an Urban Area Using gPhoneX 108 Relative Gravimeter – Branislav Hábel, Juraj Papčo, Juraj Janák and Miloš Vaľko

11:50-12:10 Comparison of Tilt and SG-Gravity Residuals at Conrad Observatory (Austria) – Gábor Papp, Hannu Ruotsalainen, Bruno Meurers, Judit Benedek and Roman Leonhardt

12:10-12:30 The Baltic Sea tidal and ocean tidal loading models compared with earth tide tilt observations - case Lohja, Finland – Hannu Ruotsalainen and Maaria Nordman

12:30 End of workshop

Abstracts

See following pages sorted alphabetically by authors.

Status of Strasbourg (France) and Djougou (Benin) superconducting gravimeter stations

Jean-Paul Boy [(*)], Jacques Hinderer [(*)], Séverine Rosat [(*)],
Frédéric Littel [(*)] and Jean-Daniel Bernard [(*)]

[(*)] EOST/IPGS (UMR 7516 CNRS/Univ. de Strasbourg), 5, rue René Descartes, 67084 Strasbourg Cedex, France.

We present here the current status of the two permanent gravity stations managed by EOST, Strasbourg, France.

The first instrument, the GWR CO26, was installed in June 1996 in the fort J9 in the vicinity of Strasbourg, and has been working without interruption since. The only main issues over these 23 years of operation was a failure of the tilt compensation in late 2009 – early 2010. This instrument replaced an earlier TT70 model, T005, which was installed in 1987, making Strasbourg the longest SG time series (more than 30-years) worldwide. Regular measurements with the absolute gravimeter FG5 #206 allow proper estimation of the SG calibration and assessment of the instrumental drift.

In February 2016, a new instrument GWR iOSG023, was installed in J9, and is currently registering in parallel with the GWR CO26. This instrument has a heavier sphere than the classical iOSG instrument in order to reduce its noise level. After this testing phase, it will replace the aging CO26.

The second instrument, the GWR OSG60, was installed in July 2010 near Djougou (Benin) and has been working without large interruption since. This instrument is the only instrument of the IGETS network currently in operation in the equatorial band, and the second in Africa with Sutherland.

Production of IGETS Level 3 data at EOST

Jean-Paul Boy [(*)]

[(*)] EOST/IPGS (UMR 7516 CNRS/Univ. de Strasbourg), 5, rue René Descartes, 67084 Strasbourg Cedex, France.

EOST is responsible of producing IGETS Level 3 datasets, i.e. gravity residuals after correcting for geophysical contributions, such as solid Earth tides, ocean tidal loading, Polar Motion, atmospheric loading, from the Level 2 products. Most of theses loading models are already available at the EOST loading service (http://loading.u-strasbg.fr)

In this presentation, we first show a comparison of the Level 2 data produced by the University of French Polynesia to our preprocessing for a set of stations, including Strasbourg, in order to discuss the different preprocessing strategies.

The aim of the paper is not only to present the corrections applied for the production of the Level 3 data, but also to encourage a discussion regarding the current modeling and the possible improvements.

- We choose to have a combined tidal model for each individual station: A nominal solid Earth tide model and FES2014b or NAO99b ocean tidal loading model for the long-period tides, and an adjusted model for the sub-daily tides, as a result of a tidal analysis.
- The Polar-Motion and Length-Of-Day induced gravity variations are modeled for both the Solid Earth response (delta factor of 1.16) and a self-consistent static ocean response.
- Global atmospheric loading is modeled using both ECMWF 3-hourly surface pressure and the local barometric record, assuming an inverted barometer assumption or the dynamic ocean model TUGO-m.
- We also show the impact of modeling global hydrology loading effects.
- When available, we model the instrument drift using the Absolute Gravity measurements.

Bützler, C., T. Forbriger

Drift and steps in the data of the superconducting gravimeter SG056 at BFO

The superconducting gravimeter SG056 at BFO works since September 2009 and contains two sensors. We analyzed the drift of the gravimeter. Therefore we corrected the data from tides and air pressure and corrected steps caused by interventions in the instrument. We calculated a linear trend in the remaining signal. This trend is $(11.0 \pm 0.7)\,\frac{\mu\text{Gal}}{\text{year}}$ for the upper sensor. Within the accuracy range of the investigation there is no trend left in the signal of the lower sensor. In comparison with absolute gravity data it becomes clear that this trends represent the drift of the instrument.

If steps are different for both sensors they can clearly be seen in the "sensor difference" (the difference between the signals of both sensors). For the investigation of the drift of the gravimeter there were four different data sets at our disposal: two data sets directly coming from the data acquisition of the gravimeter and the level 1 and level 2 data from IGETS. While analyzing the sensor difference for all the data sets we could find some steps in the level 2 data from IGETS which were not there in the other data sets. I would like to show these steps and discuss them with you.

We also studied which intervention in the instrument causes steps and which one does not. Therefore we looked for entries in the .log-files of the instrument and in the handwritten instrument book at the days where steps occurred. We could find entries for all steps, but there was not always a big intervention. For example for one step the only intervention we found was that the door to the SG-chamber was open for about two hours, which let the temperature in the SG-chamber fall. Compared to this the two changes of the cool-head only caused very small steps.

Contributions to IGETS Workshop 18-20 June 2018

Session 1. Station Reports

Crossley, D., 2018. Station Report for Apache Point, New Mexico, 2016-2018.

Session 2. IGETS Level 1-3 Products

Crossley, D., 2018. Use of a gravity correcting function to assist in the ICET preparation of 1 minute data.

Abstract: This will repeat of some of the presentation made in 2016 at the Trieste G-ET Symposium: "Processing SG data according to the requirements of the IGETS database, with Apache Point as an example", by David Crossley and Tom Murphy. Some information with files has been sent to IGETS.

Session 3. Station Reports

Crossley, D., 2018. Assessing local hydrology corrections to SG data in the absence of hydrology ground truth.

Abstract: There is no substitute for local hydrology observations such as soil moisture measurements, ET observations, or water table heights to constrain models providing the gravity effect of water movement. Yet many sites have limited or no access to such measurements and the user must maximize the information provided by rainfall and local meteorological observations. This contribution reviews the approaches that have been made in the literature and applies the methods to Apache Point SG data.

D. Crossley, St. Louis, April 14, 2018.

The first session:

Station report of superconducting gravimeters in Chinese mainland

Sun Heping[1,2] Xu Jianqiao[1] Chen Xiaodong[1] Zhou Jiangcun[1] **Cui Xiaoming[1]**

1. *State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan 430077, China*
2. *University of Chinese Academy of Sciences, Beijing 100049, China*

Superconducting gravimeter (SG) has been widely used to monitor temporal variations of the Earth gravity field. In Chinese mainland, there are currently in totally six SG instruments to be running, in which three SGs separately located in Wuhan, Lhasa and Lijiang cities are maintained by the Institute of Geodesy and Geophysics (Chinese Academy of Sciences), others belong to the Institute of Seismology, State Seismological Bureau and Wuhan University. The situations for the SG instruments and performance assessments such as calibration and response problems will be introduced here. Besides, some applications in Erath's interior structure and geodynamics related to temporal variations of the Earth gravity field will be also briefly introduced.

The third session:

Study on temporal variation in FCN period and its possible mechanism

Cui Xiaoming[1] Sun Heping[1,2] Xu Jianqiao[1] Zhou Jiangcun[1] Chen Xiaodong[1]

1. *State Key Laboratory of Geodesy and Earth's Dynamics, Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan 430077, China*
2. *University of Chinese Academy of Sciences, Beijing 100049, China*

We synthesize the gravity observation series including the diurnal tidal waves to check the detectability of resonance variation caused by period change of Free Core Nutation (FCN). Then we use long series from 20 global SG stations to study the temporal variation of FCN resonance in the Earth tide. Based on normalized time-frequency transformation, we corrected the atmospheric and oceanic effects from retrograde annual nutation term fitted from VLBI observations with which the temporal variation in FCN period is determined. According to theoretical analysis with core-mantle coupling, the possible correlation and mechanism between geomagnetic fluctuations and FCN is discussed.

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Contribution to Session 1:

Title: Report on the Borowa Gora (BG) IGETS Station

Authors: Przemyslaw Dykowski[1], Marcin Sekowski[1], Jan Krynski[1], Monika Wilde-Piorko[1]

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Abstract: The Borowa Gora Geodetic-Geophysical Observatory is a unique observatory in Poland that plays a fundamental role in maintaining national gravimetric and geodetic control. The gravimetric as well as geodetic and geophysical infrastructure of the Observatory will be introduced. Continuous gravity observation with highest precision, as achieved by the combination of absolute gravity observations using the A10-020 with the records of the iGrav-027 superconducting gravimeter contribute significantly to the Global Geodetic Observing System (GGOS) of IAG and fulfill basic requirement for core stations of new Global Absolute Gravity Reference System.

Current operational status of the gravimetric instrumentation at the BG Observatory will be presented. The presentation also includes current up-to-date activities regarding the evaluation of a transfer function and drift for the tide recording gravimeters as well as first uploads to the IGETS database.

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Session 2: IGETS Data Products

Christoph Förste[1] and Christian Voigt[1]

[1] Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences

The IGETS Data Base – Status Report

Abstract:

GFZ operates the IGETS data base of worldwide high-precision SG records. The current status of the data base is shown including the contributing stations and sensors and the various data products from levels 1 to 3. The process of DOI assignments for contributing stations is described. Finally, the documentation and user statistics of the data base are shown.
The discussion should focus on the data exchange with the absolute gravity data base at BKG and seismological networks like e.g. FDSN or IDA. In addition, a strategy how to address and convince more geodynamic station operators to contribute to IGETS should be discussed.

Monitoring the Gravity Changes in an Urban Area Using gPhoneX 108 Relative Gravimeter

Branislav Hábel, Juraj Papčo, Juraj Janák, Miloš Vaľko

Relative gravimeter gPhoneX 108 was installed in the building of Faculty of Civil Engineering of the Slovak University of Technology in Bratislava in January 2016. It is the first instrument of this type in Slovakia. Gravimeter belongs to a technical equipment of Laboratory for Modeling Geospatial Objects and Phenomena as a part of the University Science Park, which is focused on the monitoring of changes in the spatial position of buildings using satellite and terrestrial geodetic methods. Instrument is located in the centre of the city and is placed on the first underground floor of the building. In addition to geodynamics research, this also enables observing the other phenomena related to the structural movements of the building together with its inside activity, and environmental noise. Relative gravity measurements are supported by permanent GNNS station, inclination sensor, local weather station, and FG5 absolute gravity observations. Our aim is to introduce the first results of monitoring the gravity changes using gPhoneX 108 and to assess the quality of gravity records on the basis of artifacts in the data, a noise analysis in different time periods and unsuitability of the gravity measurements for geodynamic research. In the near future, the gravimeter will be moved to a new location in Hurbanovo, an integrated geodetic and geophysical observatory, lying about 85 km away from Bratislava to the southeast. After moving the instrument to Hurbanovo station we plan to become a contributor to IGETS service and database.

Intercomparison of a dense meter-scale network of superconducting gravimeters at the J9 gravimetric observatory of Strasbourg, France

J. Hinderer[1]*, S. Rosat[1], Schäfer[2], F., Riccardi[3], U., Boy[1], J.-P., Jousset[2], P., F. Littel[1], J.-D., Bernard [1]

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Abstract

This study is devoted to the intercomparison of a dense meter-scale network of superconducting gravimeters (SG) operating in 2017 at the J9 gravimetric observatory of Strasbourg (France): 6 iGrav instruments (iGrav006, iGrav15, iGrav29, iGrav30, iGrav31, iGrav32), the iOSG-23 and the old-type compact C026 gravimeter. Even if we never had all gravimeters running side by side on the same duration, we had simultaneous parallel records with 6 different instruments on specific periods.
We first pay attention to the relative calibration among the various SGs and will show how this way of calibrating SGs differs from the usual AG/SG calibration we performed in July 2017 using FG5#206 from Micro-g Solutions Inc. We also present the results for the time delays of the different instruments using cross-correlation analysis. We will show the differences in the residual gravity signals after subtraction of the solid Earth and ocean tides, air pressure and polar motion contributions. A clear hydrological signal is then visible which will be compared to existing models. Finally the respective noise levels will be compared.

Thomas Jahr

Institute of Geosciences, Friedrich-Schiller-Universität Jena

Status report CD034, Moxa Observatory

Two parts can be reported: the changes and the actual situation of the Geodynamic Observatory Moxa and of the superconducting gravimeter CD034 which is now running since nearly 20 years at the observatory. Following points can be summarized for the observatory: two new boreholes were drilled in front of the observatory in 2013; they can be used for hydrological experiments (reported in Triest 2016). Since March 2017 the new station engeneer MSc Niklas Wennemuth is working at the observatory. New laser strainmeters and a tiltmeter is operating close to the SG location. The contract between the university Jena and the BKG (Frankfurt) about the GPS permanent station was renewed until 2022. The canvas on the roof above the SG location was reconditioned in 2016. The protection radius against wind power mills is confirmed to 10km around the observatory (2016) by the district office of east Thuringia, the negotiations were supported by the legal department of the university Jena but this problem is certainly not solved for ever. New geoelectric measurements are just carried out for improving the hydrological model for the SG data correction (actual work for a master thesis). For the SG following points can be concluded: the instrument is running fine after some problems in 2013 (reported in Warzaw), however, we have had problems with the compressor in 2017 (failure in electronics). There was no stable situation: due to this failure helium consumption increased by a factor of seven. University Jena solved this problem by funding a new one (in a short time), and all additional data (tilt, neck-temps, …) are again available after the interruption. Liquid helium direct from the University (deep temp. Physics) is available after some problems with delivery in 2015. We have to refill the Dewar (125 liter) after approx. 16 months. The SG recording is successful over a long time without any gaps.

Continuous gravity in volcanic geothermal fields: contribution to gravity tidal models

Philippe Jousset (1), Kristján Ágústsson (2), Jean-Daniel Bernard (6), Vincent Droin (4), Kemal Erbas (1), Ásgrímur Guðmundsson (3), Andreas Güntner (1), Gylfi Páll Hersir (2), Jacques Hinderer (6), Arthur Jolly (7), Egill Júlíusson (3), Ingvar Þór Magnússon (2), Sigurður H. Markússon (3), Nolwenn Portier (6), Florian Schäfer (1), Tilo Schöne (1), Freysteinn Sigmundsson (4), and Richard Warburton (5)

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(7) GNS, Wellington, New Zealand

In volcanic and hydrothermal geosystems, mass and stress changes follow processes that we want to understand, as they provide us with better volcanic hazard assessment to mitigate the risk and a better estimation of geothermal resources to sustain our energy needs. Although it is not always straightforward to estimate such changes on active volcanic systems, the exploitation of geothermal volcanic systems modifies mass and stress distributions in and around the hydrothermal reservoir with better constrained boundary conditions.

The combined continuous recording of the gravity field and ground motion with sufficient accuracy in active volcano-tectonic setting allows a better understanding of the mass and stress transfer mechanisms, that produce short term gravity changes and local seismic activity. We aim at a better understanding of geothermal systems processes by addressing short term mass changes within geothermal reservoirs in relation with external solicitations such as anthropogenic (reservoir exploitation) and natural forcing (local and regional earthquake activity and earth tides). This contributes in knowing the reservoir properties, structure and long-term behaviour. The expected amplitudes are small (e.g., <1 to 100s _gal, 1 _gal=10e-8 m.s-2). We therefore use high performance and up-to-date instrumentation such as broadband seismometers and superconducting gravity meters; we also measure all other parameters that may affect the records (deformation, hydrological parameters, pressure, temperature, snow height...).

To achieve those goals, we deployed in December 2017 a network of gravimeters 3 iGrav superconducting gravimeters and 2 gPhone spring-meters), supplemented with additional instruments, such as tilt-meters, GNSS receivers (complemented with InSAR analysis), hydro-meteorological stations, snow height observation instruments, piezometers in shallow boreholes, ... In particular, In order to monitor and remove the instrumental drift and calibrate each relative gravimeter, we performed also absolute gravity measurements (FG5) at each location, and in order to increase the spatial coverage of the gravity changes, a repetition gravity network was set-up in summer 2017. Theistareykir (Northeast Iceland) is the chosen site for this unique experiment; this geothermal system is at the very beginning of its exploitation providing us with the initial mass and stress status. After being used for power production (45 MW since November 2017) all extracted fluids are re-injected at a single location. We present here the site, the infrastructure, the instruments deployed and the first results.

A remote telecommunication and operation system has also been set-up, which allows us to monitor, control and analyze recorded data from everywhere on Earth. Data are also sent via wifi and mobile phone system to the Telegrafenberg at GFZ, where we perform analysis and interpretation. Our goal is to demonstrate that we can monitor and interpret integrated high quality data for a better understanding of magmatic and hydrothermal reservoirs in order to prepare their future highly challenging exploration by drilling.

The gravity records allow us to compute Earth tide models which we present as special outcome for IGETS workshop.

Jeffrey Kennedy

USGS Arizona Water Science Center, Flagstaff

Hydro-gravity signals, from large to small

Abstract for the 1st workshop on the International Geodynamics and Earth Tide Service

Since the 1980's the USGS Southwest Gravity Program has used gravity measurements to infer changes in groundwater storage in the Southwestern US. Two recent projects using continuously-recording gravimeters highlight the wide range of studies to which the gravity method applies. First, two iGrav superconducting gravimeters and three gPhone gravimeters deployed at an artificial-recharge facility, where water infiltrates from surface basins to aquifers below, recorded perhaps the most rapid gravity increase in history while recharge was taking place: on average 3 microGal per day, sustained over several weeks. After infiltration stopped gravity began decreasing immediately at a similar rate. The long-term gravity record at the site showed clearly that the facility was operating at steady-state, with subsurface water moving efficiently away from the basins, leaving storage capacity for future recharge cycles. The continuous gravity record proved useful for identifying unsaturated-zone parameters in a MODFLOW groundwater-flow model, even more so than continuous groundwater-level records, which were influenced by factors other than groundwater recharge at the facility. Relative-gravity surveys showed that infiltrated water was accumulating preferentially to the west of the basins, with no increase in storage to the east.

A second project, using superconducting and gPhone gravimeters to record gravity changes associated with groundwater pumping, demonstrates the value of gravity data even for small signals. The instruments were located at 180 m distance from a water-supply well operated by The University of Arizona. The power spectrum of the iGrav shows a microGal-level peak at a weekly cycle, reflecting the residential nature of the University – pumping is greater during the week when classes are in session, and less on weekends. The timing of changes in gravity corresponded with changes in pumping, but the magnitude of the iGrav-measured gravity changes were larger than were suggested by a groundwater-flow model, and disagreed with measurements made using a co-located A-10 absolute gravimeter. A gPhone located at the site showed similar behavior during a later period. Analysis of the continuous records from both instruments indicate that groundwater drains slowly from storage in response to pumping variations, requiring several days or longer for the aquifer to drain, which is consistent with other hydrologic records.

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Session 1:

Meurers, B.: 10 years SG gravity time series at Conrad Observatory (Austria)

Abstract: ZAMG (Austria) operates the SG GWRC025 since 1995. After acquiring a gravity time series over 12 years at Vienna (Austria), the instrument moved to the Conrad observatory in autumn 2007. Until now, a 10 years time series is available. Unfortunately, a hardware crash in November 2013 interrupted the time series, making a complete re-installation necessary. Since March 2015, GWRC025 is in normal operation again. Calibrations were performed twice a year by co-located Jila-g/FG-5 observations and by numerous SG/CG-5 intercomparisons.

Session 2:

Meurers, B.: Can we reliably detect SG scale factor changes far below the one per mill accuracy level?

Abstract: Commonly, the SG scale factor is assumed to remain constant as long as the hardware (coil geometry) does not change (Goodkind 1999). The SG GWRC025 has been moved from Vienna to the Conrad observatory in 2007 with the sphere kept levitated during transport. Gravity at both stations differs largely due to the elevation difference of about 900 m. Indeed, the scale factor turned out to be unchanged after re-installation. However, high site noise at Vienna hampered to achieve a scale factor accuracy of better than one per mill. A hardware crash (sphere drop down, warm-up) in November 2013 made a complete re-installation necessary. Frequent calibrations performed by co-located Jila-g/FG-5 observations indicate that there might be a scale factor change of about 0.2 per mill after re-installation, which, however, is perhaps statistically insignificant. This contribution discusses, whether additional SG/CG-5 experiments may help to assess a high accurate scale factor, and tidal analyses as a way to detect scale factor changes reliably at the 0.1 per mill level.

Session 3:

Papp, G., Ruotsalainen, H., Meurers, B., Benedek, J., Leonhardt, R.: Comparison of Tilt and SG-Gravity Residuals at Conrad Observatory (Austria)

Since spring 2016 two tilt meters have been operating continuously at the Conrad Observatory (Austria): a 5.5m long interferometric water level tilt meter (iWT) built by the Finnish Geodetic Institute (FGI) and a Lippmann-type 2D tilt sensor (LTS). While iWT monitors E-W tilts, LTS provides both N-S and E-W tilt time series. We discuss tidal analyses and air pressure response and then compare the gravity residual time series from both the tilt meters and the SG. The residuals of all sensors clearly reflect the gravity/deformation effects due to short- and long-term environmental processes. Remarkable long-term signatures show a clear correlation between the tilt and SG sensor data related to snowmelt and long lasting rain.

Mikolaj, M., Reich, M. and Güntner, A.: **Uncertainty analysis of gravity time series reduction**

Abstract:

The main aim of this study is to analyze error sources related to reduction of high-precision gravity time series. To exploit the full potential of superconducting gravimeters in new emerging fields of applications such as monitoring of geothermal fields, volcanic activities or evapotranspiration measurements, the observed gravity needs to be reduced to the signal of interest. The set of required reductions mostly includes Earth and ocean tides, non-tidal ocean loading, atmosphere, and the global hydrology. However, no standard procedure indicating which specific reduction model should be used has been adopted yet. Therefore, the reductions are often computed relying on a subjective choice of input models. In order to estimate the uncertainty of the reductions mentioned above as well as their combined contribution, we considered all commonly used tidal, global hydrological, oceanic and atmospheric models. These were utilized at various test locations to cover a range of different climate zones and distances of the sites to the ocean. This allowed us to quantify the uncertainty of gravity residuals at different frequencies of interest.

Authors: Vojtech Pálinkáš, Miloš Vaľko and Jakub Kostelecký

Affiliation: Research Institute of Geodesy, Topography and Cartography, Geodetic Observatory Pecný, 25165 Ondřejov 244, Czech Republic

Pecný, station report

In November 2017, the OSG-050 has been moved to the new gravimetric laboratory at the Pecný station that is located 100 m from the former station. Among others, the new station should among allows a more accurate determination of local hydrological effects. We are presenting quantitative, qualitative and technical parameters related to the OSG-050.

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On the drift-free SG time series and comparisons of absolute gravimeters

To determine temporal gravity variations from SG time series with long term stability, repeated absolute gravity measurements at the particular site are needed. Since these absolute measurements are carried out over decades, a consistent treatment of AG data is required. Discussed are important parameters that have to be taken into account, as variable systematic errors, results at comparisons of AG, reference instrumental heights or vertical gravity gradients to achieve compatible estimates of temporal gravity variations and trends. Assuming stability of the SG over long periods, i.e. a linear instrumental drift, deviations of individual AG can be inferred from the combination of both observations. Consequently, the role of SGs in comparison/calibration of absolute gravimeters is discussed.

Self-noise correlation analysis of Superconducting Gravimeters at the J9 gravimetric observatory of Strasbourg, France

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Abstract
Knowledge of the instrumental limits and of the environmental noise level at a site is fundamental to provide limits of detection of elusive signals, like the ones coming from the deep Earth's interior. In this work we compare the observed noise levels of time-varying surface gravity from several superconducting gravimeters (SGs) that were recording in parallel at the J9 gravimetric observatory of Strasbourg (France): 4 iGrav instruments (iGrav15, iGrav29, iGrav30 and iGrav31), the iOSG-23 and the old-type compact C026 gravimeter. These noise levels are compared to the noise levels of relative spring gravimeters that were also temporarily recording at J9: the Micro-g gPhone-54, two Scintrex CG5 and a Lacoste-Romberg Earth-Tide gravimeter (ET-11). Absolute gravity measurements of the FG5#206 are also used in the noise level comparison, as well as records of a long-period STS-2 seismometer. We then apply a three-channel correlation analysis of the records of SGs in order to separate the environmental noise from the instrumental self-noise. The self-noise coherence analysis shows that the instrumental noise level of the SGs remains flat towards lower frequencies till 10^{-4} Hz. At seismic frequencies, the self-noise is well explained by a Brownian thermal noise model of a damped oscillator. Large deviations from this noise model occur when installation is not optimal. Knowledge of the damped oscillator parameters modeling the sensor response is necessary to quantify the instrumental self-noise, particularly when only one instrument is available at a site. At sub-seismic and tidal frequencies, the self-noise is increasing with the period but to a much lesser extent than the observed noise level. Observed Earth's ambient noise level at sub-seismic frequencies is hence mostly due to un-modeled geophysical processes and slightly due to instrumental limits.

The Baltic Sea tidal and ocean tidal loading models compared with earth tide tilt observations - case Lohja, Finland

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Abstract

The Baltic Sea tidal loading and some ocean tide loading (OTL) models are combined with interferometric tilt meter observations in Lohja, southern Finland. The Baltic Sea tidal loading tilt model developed by the Finnish Geospatial Research Institute of the National Land Survey of Finland is compared with Baltic Sea models included in some OTL models in the case Lohja geodynamic station. The Baltic Sea have non-tidal oscillations (seiche) and level changes, which can cause considerable loading tilts along the coastlines of the Baltic Sea. Measured loading tilt responses to loading models are presented.

Station report: OS, Onsala, Sweden

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We report on efforts to provide reduction data for AG campaigns using the SG GWR054. Instead of g-software reduction parameters the basic idea is to subtract low-pass filtered SG data (even at the the exact drop times, eventually supplemented with accelerations from a broadband seismometer). The crucial point here is to accurately determine the drift of the SG. A range of solutions from tide analysis employs different strategies that affect in particular the long-period domain. The station is located near the coast of the semi-enclosed basin of Kattegat, which urges us to carefully separate long-term effects from atmosphere and sea level.

We also report on the advantages of the OSO station, which is primarily its low gravity variations due to ground water; and the range of ancillary sensors in and around the building. A further important asset for investigations into GIA is its collocation with geodetic techniques operating at OSO within GNSS and VLBI networks, facilities that have been contributing to GIA modelling and to reference frames since 1992 and 1980, respectively.

Finally we report on the determination of the time delay of the SG's signal chain. We used a teleseismic P-wave from an antipodal event recorded by the broadband seismometer at 100 S/2, matched a numerical representation of the GGP filter and adjusted for a remaining delay. We think the timing result is precise to within 0.1 s.

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Superconducting Gravimeter (SG) Measurement in Cibinong Station (Station Report)

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Abstract

Superconducting Gravimeter (SG) is an accurate gravimeter that can measure gravity to a fraction of NanoGal. Cibinong station was in operation from November 2008 but stopped in June 2012 due to Liquid Helium supply rarity. During 3,5 years of operation, 2011-2012 data were believed to the best data with minimum gaps and error. Earth tide as the main component of SG could be analyzed that can describe gravity variation and earth tide effect near the equator. Atmospheric pressure data were also recorded as the supporting data in the station. The tidal analysis process derived 30 tidal parameters with a standard deviation of 0.0801 µGal. The tidal factor deviated 6 % from theoretical tide Wahr Dehant solid earth tide model. The SG was also used for monitoring ground water level variation, with some supporting data like ground water level and rain gauge data. Finally earthquake study was also conducted using the SG data to analyze co and post seismic gravity change. The 2012 Indian Ocean earthquakes was one of the examples. Based on these experiences, SG measurement is very important and it is believed that Cibinong station was the one and only SG station located near equator that also has strong geodynamics activities, useful for many geoscientific researches and gravity variations analysis near the equatorial zones .

Keywords: superconducting gravimeter, earth tide

IGETS-2018 title and abstract:

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Superconducting gravimeters during 2014-2018 at Metsähovi geodetic research station, Finland

The old superconducting gravimeter (SG) T020 operated continuously since August 1994. The new dual-sphere SG OSG-073 was installed in February 2014. The new instrument was installed in the same room at a distance of 3 m from T020. The two sensors were separate and side by side. The first sensor N6 has very low-noise level and a 0.02 kg sphere. The second sensor N7 is a standard iGrav™ with lightweight sphere (0.005 kg).
The OSG-073 was sent back to manufacturer for improvements in May 2015. The new iGrav-013, which is the old sensor N7, was installed in April 2016 on the floor beside the pier of former OSG-073. The operation of T020 was finished in September 2016. The common time series with T020 was 5 months. The new iOSG-022, which sensor is the modified and improved N6, was installed in December 2016 on the pier of OSG-073. The final setup was carried out in November 2017, when iGrav-013 was moved to the pier of the old T020. There are now two operating SGs at Metsähovi with a horizontal distance of 3 m.

1st IGETS Workshop 2018 Potsdam, Germany

Session 1: Station Reports

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Report on the stations Sutherland (South Africa) and Zugspitze (Germany)

Abstract:

GFZ operates the South African Geodynamic Observatory Sutherland (SAGOS) located 350 km northeast of Cape Town, South Africa, jointly with SAAO. Established in 2000, Sutherland was the first station on the African continent and had been equipped with the SG CD037 until 2008. For the continuation of the time series during a necessary upgrade, it had been substituted by the OSG 052. Since the OSG D037 returned to Sutherland in 2009, both instruments had been operated in parallel until September 2017.

The report shows analysis of the continuous time series from 2000 to 2017 including tidal analysis on the basis of ET34-ANA-V61 and reductions of non-tidal effects. Corresponding gravity residuals from parallel recordings are compared, and noise levels of the various instruments are estimated. The calibrations with absolute measurements are shown, and long-term gravity variations are interpreted with regard to hydrological effects.

In September 2017, the OSG052 was de-installed in Sutherland and sent to GWR for refurbishment and upgrade of the electronics, since it had been operated with an old GEP2. The upgraded instrument is intended to be operated at the Zugspitze Geodynamic Observatory Germany (ZUGOG) on the summit of Germany's highest peak at 3000 m in the European Alps, which is currently being set up. The report documents the recent status and describes the scientific goals in connection with the cooperation partners of the Environmental Research Station Schneefernerhaus.

1st Workshop on the International Geodynamics and Earth Tide Service (IGETS), 18-20 June 2018, Potsdam, Germany,

Contribution to Session 3:

Title: Determination of the Earth's mantle structure from low-period seismic surface waves recorded by superconducting and spring gravimeters at the Borowa Gora Observatory

Authors: Monika Wilde-Piorko[1], Przemyslaw Dykowski[1], Marcin Polkowski[2], Marcin Sekowski[1], Marek Grad[2], Jan Krynski[1]

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Abstract: The physical properties of tidal gravimetric instruments allow to record surface waves of very long periods, generated by the earthquakes. In the case of a superconducting gravimeter, periods of seismic surface waves even up to 400-500 seconds can be determined, while typical broad-band seismic sensor can measure such waves up to periods of 120-150 seconds due to its transfer function limitation. This is of great importance for Earth's structure studies, because waves of longer periods make possible studying directly deeper structure of the Earth. The seismic analysis of surface waves recorded by the iGrav-027 superconducting gravimeter and the LaCoste&Romberg G-1036 spring gravimeter are presented. The same analysis is performed for recordings of a broad-band REF-TEK 150B-120 seismometer, co-located with the iGrav-027 gravimeter, in order to validate the gravimetric results. Transfer functions of the gravimeters, in seismic bands, are calculated by a step method and included in calculations of group velocity dispersion curves. Finally, an inversion procedure is applied to the dispersion curves to calculate a distribution of shear-wave seismic velocity with depth in the upper mantle.

The McDonald Geodetic Observatory Superconducting Gravimeter

NASA is in the process of developing a new core geodetic observatory in West Texas at McDonald Observatory. The McDonald Geodetic Observatory (MGO) involves the full participation of the University of Texas at Austin, led by the Center for Space Research, and including contributions from the Jackson School of Gesociences, and the Applied Research Laboratories. New equipment will include a VLBI radio telescope, 5 new GNSS monuments and receivers, and a new Satellite Laser Ranging Station, which will run alongside the existing laser ranging station for a period of years. Work is in progress through the remainder of 2018 and 2019. The University of Texas at Austin will contribute its superconducting gravimeter (SG047) to the site, with installation planned for mid-2018. This report will summarize the development of the site and supplementary measurements including soil moisture monitoring arrays and other experiments.

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Station Report on gravity stations Wettzell and Bad Homburg (Germany), Medicina (Italy) and AGGO/La Plata (Argentina)

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Since many years, BKG operates continuously superconducting gravimeters at two stations in Germany, in Northern Italy and since December 2015 at the Argentinean German Geodetic Observatory AGGO near La Plata, Argentina. The current status of these stations is reported, giving an overview about recent activities and the characteristics of the recorded signal.

Contributions to the General Discussion

1) IGETS data and seismological services

Hartmut Wziontek[1)], S. Rosat, J.-P. Boy[2)], J. Hinderer[2)], D. Crossley[3)], Thomas Forbriger[4)]

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Already the Global Geodynamics Project (GGP) started an initiative to provide high quality data from superconducting gravimeters the seismological services IRIS/FDSN. Because of the high performance in the band below a frequency of 1 mHz, a clear benefit to the seismological community is expected. We report about the status, the process of data preparation and submission and want to discuss the future support given by IGETS.

2) Evaluation of preprocessed data provided by IGETS

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IGETS collects and distributes raw (Level 1) and preprocessed data (Level 2) and aims for a new product providing residual gravity data after reducing Level 2 gravity data for modeled tidal and non-tidal gravity variations. Independently processed time series from the University of French Polynesia and station operators are compared and evaluated, aiming for an uncertainty estimate and quality assessment.

3) Recent Progress in tidal analysis by Klaus Schüller

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A comprehensive and sustainable platform for Earth tide analysis is needed for meeting the requirements of the tidal user community and for the interpretation of the residual signal for applications in geosciences. Over the past 5 years, a considerable amount of tasks have been tackled and solved by now. These efforts led to the distribution of several major releases of the enhanced ETERNA program system for tidal analysis and prediction. An overview about major changes will be given.