Interim Activity Report for IAG Commission 2, The Gravity Field

by

Christopher Jekeli
Commission President

September 2005

Executive Summary

Commission 2 consists of four sub-commissions, seven projects, and six study groups, organized in the following structure:

1. Sub-Commission SC2.1: Gravimetry and Gravity Networks (president: Shuhei Okubo)
    a) Commission Project CP2.7: Gravity in South America (María Cristina Pacino)
    b) Study Group SG2.1: Comparison of Absolute Gravimeters (Leonid Vitushkin)
    c) Study Group SG2.4: Aerogravimetry and Gradiometry (Uwe Meyer)

2. Sub-Commission SC2.2: Spatial and Temporal Gravity Field and Geoid Modeling (president; Martin Vermeer)
    a) Study Group SG2.2: Forward Gravity Field Modeling Using Global Databases (Michael Kuhn)
    b) Study Group SG2.3: Satellite altimetry: data quality improvement and coastal applications (Cheinway Hwang)
    c) Inter-Commission Study Group IC-SG2.5 (Joint with ICCT): Aliasing in Gravity Field Modeling (C.C. Tscherning)
    d) Inter-Commission Study Group IC-SG2.6 (Joint with ICCT): Multiscale Modeling of the Gravity Field (Willi Freeden)

3. Sub-Commission SC2.3: Dedicated Satellite Gravity Mapping Missions (president: Pieter Visser)

4. Sub-Commission SC2.4: Regional Geoid Determination (president: Urs Marti)
    a) Commission Project CP2.1: European Gravity and Geoid (Heiner Denker)
    b) Commission Project CP2.2: North American Geoid (Marc Véronneau)
    c) Commission Project CP2.3: African Geoid (Charles Merry)
    d) Commission Project CP2.4: Antarctic Geoid (Mirko Scheinert)
    e) Commission Project CP2.5: South American Geoid (Denizar Blitzkow)
    f) Commission Project CP2.6: Southeast Asian Geoid (Bill Kearsley)

In addition, there are a number of Inter-Commission working groups and projects, as follows.

a) Inter-Commission Working Group IC-WG1 (Joint with ICCT & Commission 1):

Quality Measures, Quality Control, and Quality Improvement (H. Kutterer)

b) Inter-Commission Working Group (proposed) IC-WG2 (Joint with IGFS): Evaluation of Global Earth Gravity Models (Jianliang Huang)

c) Inter-Commission Working Group IC-WG3 (Joint with ICCT & Commission 1): Satellite Gravity Theory (Nico Sneeuw)

d) Inter-Commission Project IC-P1.1: (Joint with Commissions 1 & 3): Satellite Altimetry (Wolfgang Bosch)

e) Inter-Commission Project IC-P1.2: (Joint with Commission 1) Vertical Reference Frames: (Johannes Ihde)

f) Inter-Commission Project IC-P3.1: (Joint with Commissions 1 & 3): Global Geodynamics Project (David Crossley)

These entities have their primary affiliation as indicated and the reporting of their activities is contained in other corresponding documents.

This report covers the period of activity of the entities in Commission 2 for the year 2004. Each of the chairs of the entities was asked to summarize activities in seven general areas:

1) publications of members, including journal papers, conference papers and presentations, and bulletin reports;
2) organizations of workshops, conference sessions, group meetings;
3) participation in observation campaigns and major computational efforts;
4) other noteworthy accomplishments, including significant interaction with groups outside the Commission;
5) future plans and activities;
6) issues and concerns, and recommended improvements in the Commission.

Reporting for the Commission was organized by Sub-Commission, with entities submitting activity summaries to their corresponding Sub-Commission. Each president of a Sub-Commission then collected and submitted a brief report to the Commission President. This report then summarizes these for the Executive Committee of the IAG.

It is clear that some entities of the Commission were significantly more active than others, but most if not all made progress in their stated objectives. A large majority of entities now maintains a web page with links to publications, meetings, reports, and other items of relevance. All of these web pages can now be accessed through the main web page for the Commission (www.ceegs.ohio-state.edu/iag-commission2). Important highlights of the Commission are represented by the following.

1. The International Symposium on Gravity, Geoid, and Space Missions 2004 (GGSM2004), held in the beautiful city of Porto, Portugal, from 30 August to 3 September 2004. It was expertly organized by members of the Faculty of Science, University of Porto. GGSM2004 brought together 234 scientists from 39 countries to discuss the state-of-the-art in nine topical areas of interest to the Commission. These included gravity field modeling from satellite missions; airborne and satellite gravimetry instrumentation; regional geoid modeling; radar and laser surface mapping from

satellites; topographic data bases and gravity modeling; satellite altimetry, oceanography, and the geoid; terrestrial gravity instrumentation, networks, and geodynamics; Temporal gravity variations: modeling and measurements; and Planetary gravity fields and models. All components of the Commission were well represented at the symposium not only in terms of participants but also by attracting a total of 258 papers. A Proceedings of the Symposium was published in the form of a CD with most of the oral and poster presentations, as well as many corresponding journal-style papers. A Springer-Verlag volume of a selected number of peer-reviewed papers (approximately 55) is also being published.

2. The various geoid projects under Sub-Commission 2.4 are proceeding well for the most part, especially the European, South American, and Antarctic projects. The greatest effort at the moment pertains to the coordination of collecting, validating, and bringing consistency to existing data sets from among the many participating groups (countries and/or organizations). Details may be found in the Appendices 7-12.

3. The gravity field satellite missions, CHAMP and GRACE, have already had a profound effect on geoid modeling and time-variable gravity investigations. Significant improvements over the global standard, EGM96, have been documented (e.g., one-meter differences in parts of Africa). The identification of the intensive hydrological signal over the Amazon basin in the GRACE data was particularly convincing evidence and confirmation of the exquisite precision of these satellite data. It gives investigators much hope even further improvement and applications for the future mission GOCE and potential follow-on projects to GRACE. Extensive references and more details on the activities of the Sub-Commission 2.2 are found in Appendices 3 and 4. Another area of significant development concerns the re-tracking of satellite altimetry data. This has led to improved geoid and gravity determination in shallow waters and inland lakes (see also Appendix 4).

4. Extensive absolute gravity networks are being established in eastern Asia and the western Pacific under the auspices of the Geographical Survey Institute of Japan and several institutions of the participating countries (Appendix 1). Work is continuing to organize comparison of absolute gravimeters under the auspices of the BIPM. Further details are found in Appendix 2. Discussions are under way to bring together a wider group of investigators and scientist involved in the metrology of gravity, adding to the topic of absolute gravimetry also airborne and shipborne gravimetry, both absolute and relative, as well gravity gradiometry.

5. Additional activities were reported by entities that have a joint interest between Commission 2 and other groups within the IAG. These are contained in Appendices 13, 14, 15, and 16, and include reports from IC-P1.2:(Vertical Reference Frames), showing significant progress toward a world vertical datum; from IC-P3.1: (Global Geodynamics Project), describing activities of workshops and particular efforts to increase absolute gravimetry data collection; from IC-WG3 (Satellite Gravity Theory), which has launched a special issue of the Journal of Geodesy on satellite gravity theory and inverse problems; and from IC-SG2.6 (Multiscale Modeling of the Gravity Field), reporting on extensive

cooperation and publications with various groups in wavelet and multiscale applications. Special mention should also be made of the new International Gravity Field Service (IGFS) with which a close collaboration is expected. Details of its inauguration are found in Appendix 17. A joint working group has also been established on the evaluation of earth gravity models (Appendix 18).

A few Study Groups unfortunately have not reported significant activity. This undoubtedly is not due to apathy but rather a lack of time to coordinate and assimilate relevant studies. Nevertheless, a decision to discontinue these study groups (namely, SG2.4, IC-SG2.5) is under consideration of the Commission.

In summary, the Commission 2 appears to have survived the major re-structuring of the IAG that occurred in 2003 and is carrying on with geodetic and gravity-related activities in the high-quality tradition of the Association.

The Appendices are reports provided by the sub-commission presidents and chairs of individual entities and form a part of this report. They provide the details of activities within the sub-structure of the Commission.

Appendix 1: Report of **Sub-Commission SC2.1**, by S. Okubo
Appendix 2: Report of **Study Group SG2.1**, by L. Vitushkin
Appendix 3: Report of **Sub-Commission SC2.2**, by M. Vermeer
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Appendix 15: Report of **Inter-Commission Working Group IC-WG2.1**, by N. Sneeuw
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Appendix 17: Report of **IGFS**, by R. Forsberg
Appendix 18: Terms of Reference of **Joint Working Group**, by J. Huang

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Appendix 1

Activity Report of Sub-Commission 2.1

(Gravimetry and Gravity Networks)

Compiled by S. Okubo, President of SC 2.1

Absolute Gravity Network in East Asia and Western Pacific:
Reported by Y. Fukuda, Member of SC2.1.

Absolute gravity measurements provide nationwide fundamental basis for local and regional gravity surveys and consequently a reference for the height system of the nation as well. Moreover the absolute gravity measurements very much contribute to the studies of crustal movements, sea level changes as well as secular gravity changes due to various phenomena in and on the Earth. Therefore, to establish/enhance the absolute gravity standard station network, we have been conducting absolute gravity measurements in East Asia and Western Pacific under the collaboration with Geographical Survey Institute of Japan and several institutions of the countries. So far, using FG-5 absolute gravimeters, we successfully finished the measurements at the stations of

1) Wuhan, Shanghai, Nanning, Beijing, Kunming, Lhasa and Hong Kong in China,
2) Bandung, Yogyakarta and Cibinong in Indonesia;
3) Kuala Lumpur and Kota Kinabalu in Malysia,
4) Hsinchu in Taiwan,
5) Perth and Canberra in Australia, and
6) Syowa Station in Antarctica.

During the period of 2005-2006, we will conduct the absolute gravity measurements in Urumqi, Xi'an, Xining and Changchun in China, Pontianak in Indonesia, Chiang Mai and Bangkok in Thailand and Manila in the Philippines. Addition to these new measurements, we are also planning to reoccupy at some of the stations in Indonesia, Malysia and Australia within a few years.

Study Group 2.1.1: Study Group on Comparisons of Absolute Gravimeters
Reported by Leonid Vitushkin (Chairperson of SG 2.1.1 and CCM WGG).

A separate report is included as Appendix 2.

Gravity in South America.
Reported by M. C. Pacino (Chair of Commission Project 2.7)

The report of this Project is included in the report for Commission Project 2.5, Appendix 12.

Appendix 2

file: SG2-1-1_report_to_S_Okubo_170205.doc
BIPM, 17 February 2005

Sub-Commission 2.1
(Gravimetry and Gravity Networks)
Study Group 2.1.1
(Study Group on Comparisons of Absolute Gravimeters)

Activity report
(May 2004 – February 2005)

1. The First Joint Meeting of the SG 2.1.1 and Working Group on Gravimetry of the Consultative Committee on Mass (CCM WGG) was organized on 26-27 May 2004 at the Bureau International des Poids et Mesures (BIPM), Sevres. Twenty five participants from fourteen countries and the BIPM have attended the meeting.
The meeting discussed the problems related to metrology in absolute gravimetry and organization of the International Comparisons of Absolute Gravimeters (ICAGs) under the auspices of the CCM, BIPM and IAG.
1.1 For the first time the project of the Technical Protocol for the ICAGs was discussed. This project was developed by the Discussion Group 2 (moderator Alessandro Germak, IMGC, Italy) following the rules for the key comparisons in the frame of the Mutual Recognition Arrangement signed by the directors of the National Metrology Institutes from more than 50 countries.

1.2 The draft requirements to the sites for the regional international comparisons were prepared by Discussion Group 1 (moderator Jacques Liard, NRCan, Canada) and also discussed at the meeting. Sites in Canada, China, Finland, Luxemburg, Slovakia, Russia and USA have been proposed for regular regional comparisons and, probably, future calibrations of the absolute gravimeters.

1.3 The meeting proposed to organize the 7th ICAG (ICAG-2005) in 2005 at the BIPM. The steering committee of the ICAG-2005 was nominated. It consists of L.Vitushkin (BIPM), M.Becker (IPG DTU, Germany), O.Francis (ECGS, Luxemburg), A.Germak (IMGC, Italy), Z.Jiang (BIPM), Wangxi Ji (NIM, China).

2. The first meeting of the steering committee was held on 29 November 2004 at the IMGC (Turin, Italy). It was decided to organize the absolute measurements of the ICAG-2005 at the BIPM in September 2005 and the relative measurements (gravity

gradients, links between the sites) in July 2005. Proposals on the programme of absolute and relative (gravity gradients and links between the sites of the BIPM) measurements have been discussed.

3. The Circular Letter 1 on the ICAG-2005 was prepared by the chairman and steering committee, and distributed on 23-24 December 2004.
Currently more than 15 participants plan to take part in the absolute measurements of the ICAG-2005 at the BIPM.

4. The Circular Letter 2 on the ICAG-2005 will be distributed in March 2005. Taking into account the decisions of the institutes - members of the CCM WGG and SG2.1.1 the steering committee proposed to organize the ICAG-2005 as a pilot study.

The working documents of the 1st CCMWGG-SG2.1.1 are available for the members of CCM WGG and SG2.1.1 on the website of the BIPM www.bipm.org (see Consultative Committees; CMM; Working Group on Gravimetry).

Leonid Vitushkin
Chairman of SG 2.1.1 and CCM WGG.

Appendix 3

Activities of IAG Subcommission 2.2: Spatial and Temporal Gravity Field and Geoid Modelling

Martin Vermeer

18th March 2005

1 Reporting period

This report covers the Subcommission's history from its official creation in Sapporo, Japan in 2003.

2 Terms of Reference

The subjects of study that the Sub-commission supports and promotes can be summarized, without claim to completeness, as follows. Research work in the spatial domain concentrates on:

- Global and regional gravity modelling
- Topographic/isostatic modelling
- Downward and upward continuation problems
- Boundary value problem approaches
- Spectral techniques like (but not limited to) spherical harmonics
- Height theory and height systems
- Geodetic aspects of satellite radar altimetry

Studies in the temporal domain of the gravity field include, among others, the following:

- Tides
- The effect of postglacial land uplift
- Time derivatives of the J_n
- Short/medium term gravity change due to movements of air and water
- Anthropogenic gravity changes.

3 Steering Committee and membership

Martin Vermeer (Chair) – Finland	marti.vermeer@hut.fi
Bernard Ducarme – Belgium	bernard@ksb-orb.oma.be
Michael Kuhn – Australia	kuhnm@vesta.curtin.edu.au
Dimitrios Tsoulis – Germany... Greece	tsoulis@topo.auth.gr
Bernhard Heck – Germany	heck@gik.uni-karlsruhe.de
Zdenek Martinec – Germany	zdenek@gfz-potsdam.de
Christopher Kotsakis – Canada	kotsakis@geomatics.ucalgary.ca

As for the Subcommission's members, we have a mailing list of interested people in which no distinction is being made between full and corresponding members. These are almost 40 people that your chairman knows to be or have been active in the field of the Subcommission. During the reporting period only part of these people actually responded to the initial invitation or otherwise participated in the work.

4 Activities

4.1 Subcommission

The main activity was undoubtedly our participation in the Porto International IAG Symposium GGSM "Gravity, Geoid and Space Missions" in 2004. At this meeting, we organized a splinter meeting of the Subcommission, which was well attended.

A website has been set up:

`http://www.hut.fi/~mvermeer/IAGSC2.2.html`

but is still incomplete.

The current report includes contributions by Michael Kuhn, Dan Roman, Dimitris Tsoulis, Heiner Denker, Artu Ellmann and Frank Lemoine.

- Dan Roman of the National Geodetic Survey, Washington DC, reported on the national geoid determination effort [RWHH04], which includes airborne gravity missions in collaboration with Naval Research Lab in the seas surrounding the country.
- Dimitris Tsoulis, who is involved with a number of colleagues in finding ways of assessing available gravity field models by connecting them with known structures in the Earth's interior. This work relates to IAG Study Group 2.2, but also the the new satellite gravity missions.
- Heiner Denker, who reported [DBB+05] on the European Gravity and Geoid Project, a regional application in practice of the subject area of our Subcommission. The ambitious effort is envisaged to exploit many different data types and several different techniques, but with a focus on gravimetric-topographic geoid determination using remove-restore.

  For the first time, also satellite mission data is included: already improvements by up to 60% are seen when using GRACE data compared to the previous European geoid model EGG97, while also systematic errors are substantially less. Accurate determination of W_0will make it possible to contribute to the establishment of a new, globally defined European vertical datum.
- Artu Ellmann reported on ongoing work of the Vancouver group, on subjects like gravity field studies, e.g., the Stokes-Helmert method of solving the geodetic BVP, and the rigorous determination of orthometric heights. A number of publications are included below.
- Frank Lemoine provided a draft of an upcoming article[RLK+05] on the GRACE work also presented in Porto, where seasonal ground water variations in the Amazone and similar river basins can actually be monitored gravimetrically from space.

4.2 Scientific results

As Frank Lemoine also pointed out, the big development in the field of study covered by the Subcommission was the explosion of scientific studies prompted by the becoming available of the first CHAMP and GRACE mission results. A synthesis is represented by the publication of the combination geopotential model EIGEN-CG01C, comprising 860 days of CHAMP data, 200 days of GRACE data, and terrestrial gravimetry and satellite radar altimetry, cf.

`http://www.gfz-potsdam.de/pb1/op/grace/results/index_RESULTS.html`.

We should mention:

- The determination of ever more precise global geopotential and geoid models (e.g., [RSF+05, TBWR04])
- Their validation against, e.g., GPS and DORIS results[WH04]
- The measurement by GRACE satellite gravimetry of ground and ocean water level variations of various kinds[TBR+04]

- The validation of these measurements against hydrological and ocean circulation models [AHL04, AH05, RFC+04, RCB04, RCR+04] and satellite altimetry [CWN04]
- Other methodogical studies [HJS04, GTS05, MTGD04, CWTR04].

It appears that today, global geoid models can be robustly determined at cm-level accuracy up to harmonic degree 150, and seasonal ground water variations studied on the several-mm level on subcontinental (river basin) scales.

Let us place this in historical perspective: those scientists preparing for and planning missions like the now succesful CHAMP and GRACE — and hopefully, GOCE — have thus been amply vindicated already.

4.3 IAG Study Group 2.2

This study group, "Forward Gravity Field Modelling Using Global Databases", chairman Michael Kuhn, reported separately. This section presents his report, slightly edited. The below publications list contains references from that report. It covers the period from the creation of the group in August 2003 and does not claim completeness.

4.3.1 Primary Objectives of the SG

The primary objective of the SG is to investigate the use of different global datasets describing the Earth's mass distribution for gravity field recovery and interpretation, using forward gravity field methods (direct application of Newton's integral). Special focus is the employment of high-resolution digital elevation models as well as datasets on the structure of crust and mantle to recover high-frequency information of the Earth's gravity field. Furthermore, these data can be used to study the behaviour of gravity inside the (topographic) masses. Summarising, the SG will mainly focus on the following generic items:

- Construction of forward gravity field models using geophysical data
- Interpretation of forward gravity field modelling results
- Application of forward modelling results in gravity field determination

4.3.2 SG Membership, full members (active)

Michael Kuhn (Australia) (Chair) `M.Kuhn@curtin.edu.au`
Dimitris Tsoulis (Germany) (Vice-Chair) `tsoulis@topo.auth.gr`
Hussein Abd-Elmotaal (Egypt) `abdelmotaal@lycos.com`
Giampietro Allasia (Italy) `giampietro.allasia@unito.it`
Heiner Denker (Germany) `denker@ife.uni-hannover.de`
Thomas Gruber (Germany) `Thomas.Gruber@bv.tu-muenchen.de`
Pavel Novak (Czech Republic) `pnovak@pency.asu.cas.cz`
Spiros Pagiatakis (Canada) `spiros@yorku.ca`
Nikolaos Pavlis (USA) `npavlis@atlas.stx.com`
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4.3.4 Activities of the SG

Discussion of the terms of references: After the creation of the SG in late 2003 the group's members discussed the current terms of references as well as expressed their personal views and ideas on the subject of this SG. The result of this discussion led to the final version of the terms of references.

Installation of a web-page: A web-page of the group's activities has been created, which summarises the activities of the SG as well as a list of relevant publications. Two mirrored versions of the web-page are located at Curtin University of Technology, Perth, Western Australia, as well as Aristotle University of Thessaloniki, Greece.

Addresses:

http://www.cage.curtin.edu.au/~kuhnm/IAG_SG2.2/intex.html

and

http://users.auth.gr/~tsoulis/IAG_SG2.2/index.html.

Meeting at the GGSM2004 conference: The first meeting of the Study Group was held at the GGSM2004 Symposium in Porto, Portugal. It was open for members as well as nonmembers. The meeting had mostly two objectives:

1. Introduction of the group's members in order to present their interests. Each participant of the meeting got the possibility to give a brief introduction as well as to provide some information on his or her research area and interest in the SG.
2. How to focus the group's resources on one particular study area. An extensive and lengthy discussion took place regarding a smart use of the group's resources. The background to this point was the proposal of a more intense focus on one particular aspect of the SG, which might be an achievable goal. However, all participants are strongly encouraged to continue their own research and if possible sharing their results with the SG.

It could be seen that most participants either directly deal with forward gravity field modelling or consider it as an important/helpful tool in gravity field modelling. Two main categories of use could be identified:

1. Use of forward gravity modelling results for data smoothing in order to get better data properties (e.g. interpolation and downward continuation of gravity data).
2. Use of forward gravity modelling results for geophysical interpretations of the Earth s interior (e.g. topographic/isostatic models).

The group agreed that the development of software/algorithms in forward gravity field modelling is a suitable subject to be studied by the SG in more detail. It has been identified that most group members use an algorithm, which is somehow based on prism formulae, which is very time consuming. Therefore, this point is central for forward gravity field modelling as all studies depend on fast and reliable software algorithms. Focus should be given on different ways to obtain fast and reliable forward gravity modelling results. Briefly discussed was the approach using spherical shell elements (tesseroids) rather than prisms as well as the development of fast space domain forward modelling algorithms with an optimal way of handling the required computer memory.

5 Publications

Below we list some publications by members of the Subcommission (and others) that are relevant to the field of the Subcommission according to the Terms of Reference. The list includes the presentations at the Porto Symposium in Session 8: "Temporal gravity variations: modeling and measurements".

This reference list is also found, in richly cross-refererenced form, on the Subcommission's web site, at `http://www.hut.fi/~mvermeer/bib2html/index.html`.

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Appendix 4

Activity Report of the IAG Study Group 2.2 Forward Gravity Field Modelling Using Global Databases

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Dimitris Tsoulis (Vice-Chair) (tsoulis@mca.bv.TU-Berlin.de)
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February 2005

Period Covered

This activity report gives a summary of the work undertaken by the IAG SG 2.2 since its creation in August 2003. Importantly, it summarises only the contributions of some members. Our apologies to all whose results are omitted in this report.

Primary Objectives of the SG

The primary objective of this study group (SG) is to investigate the use of different global datasets describing the Earth's mass distribution for gravity field recovery and interpretation, using forward gravity field methods (direct application of Newton's integral). Special focus of the SG is the employment of high-resolution digital elevation models as well as datasets on the structure of crust and mantle to recover high-frequency information of the Earth's gravity field. Furthermore, these data can be used to study the behaviour of gravity inside the (topographic) masses. Summarising, the SG will mainly focus on the following generic items:

- Construction of forward gravity field models using geophysical data
- Interpretation of forward gravity field modelling results
- Application of forward modelling results in gravity field determination

Current Member List

We have to acknowledge that the background of the group's members is very different ranging from geodesy, geophysics to mathematics.

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See html addresses:
http://www.cage.curtin.edu.au/~kuhnm/IAG_SG2.2/intex.html
http://users.auth.gr/~tsoulis/IAG_SG2.2/index.html

Meeting at the GGSM2004 conference: The first meeting of the SG was held at the GGSM2004 meeting at Porto, Portugal. It was open for members as well as non-members. The meeting had mostly two objectives:

(i) Introduction of the group's members in order to present their interests. Each participant of the meeting got the possibility to give a brief introduction as well as to provide some information on his or her research area and interest in the SG.

(ii) How to focus the group's resources on one particular study area. An extensive and lengthy discussion took place regarding a *smart* use of the group's resources. The background to this point was the proposal of a more intense focus on one particular aspect of the SG, which might be an achievable goal. However, all participants are strongly encouraged to continue their own research and if possible sharing their results with the SG.

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Publications of SG members as well as others related to the SG's aim

This is a summary of publications (obtained by the chair up until the date of the report) related to the objectives of the SG published by group members as well as others.

Allasia G (2004): Recursive and parallel algorithms for approximating surface data on a family of lines or curves. In P. Ciarlini et al. (eds.): Advanced mathematical and computational tools in metrology VI, World Scientific, 2004, pp. 137—148

Baran, I., Kuhn, M., Claessens, S., Featherstone, W.E., Holmes, S.A., Vaníček, P. (submitted February 2005): A synthetic Earth gravity model specifically for testing regional gravimetric geoid determinations. Journal of Geodesy.

Denker H. (2004). Evaluation of SRTM3 and GTOPO30 terrain data in Germany. Proceed. GGSM2004, Porto.

De Rossi A (2004): Spherical interpolation of large scattered data sets using zonal basis functions. Proceedings of the sixth International Conference on Mathematical Methods for Curves and Surfaces, July 1-6, 2004, Tromsø, Norway.

Gruber C, Tsoulis D (2003) Kalibrierung des CHAMP Akzelerometers mittels der Kräftebilanzmethode, Presented at the *Geodätische Woche 2003, Hamburg, Session 5: Geodätische Aspekte neuartiger Satellitenmissionen: Gravitationsfeld, Bahnberechnung, Altimetrie, SAR, neue Sensoren*

Gruber C, Tsoulis D, Sneeuw N (2004) CHAMP kinematic orbit processing for use in gravity field determination, Oral Presentation at the Joint CHAMP/GRACE Science Meeting, Geoforschungszentrum Potsdam, July 5-8, 2004

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Kirby, J.F., and C.J. Swain (2004). Global and local isostatic coherence from the wavelet transform, *Geophysical Research Letters*, 31(24), L24608, doi: 10.1029/2004GL021569.

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Swain, C.J., and J.F. Kirby (2003). The effect of 'noise' on estimates of the elastic thickness of the continental lithosphere by the coherence method, *Geophysical Research Letters*, 30(11), 1574, doi:10.1029/2003GL017070.

Swain, C.J., and J.F. Kirby (2003). The coherence method using a thin anisotropic elastic plate model, *Geophysical Research Letters*, 30(19), 2014, doi: 10.1029/2003GL018350.

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Future Work

- The next official meeting of the SG has been scheduled for the IAG/IASPO meeting 2005, at Cairns, Australia.
- During the first meeting of the SG (during the GGSM2004 conference, Porto, Portugal) the group agreed to organise a session at the IGFS meeting at Istanbul, Turkey in 2006. Apart from being a platform for the group's members to present their actual results this session gives the opportunity to all others to present their latest research in this field. The chair is in contact with the local organising committee.
- As a main outcome of the group's meeting at Porto should be mentioned, that the SG will focus in more detail on software/algorithms used in forward gravity field modelling. Special intention will be given on different ways (other than prism integration) to obtain fast and reliable forward gravity modelling results. All SG members are encouraged to collect available information on this subject (literature research). The information will be collocated on the SG's web-page. Much information should be found in the relevant geophysical literature. After this step it will be attempted to identify suitable study areas, which can be tackled by small groups of few SG members.
- Apart from the modelling and computing issues (algorithm & software) an equally important issue is the interpretation of the obtained gravity models. As the global databases offer now a geometrical means of modelling the different mass distributions in the Earth's interior, it should be feasible to correlate different bandwidths of the available or the newly developed Earth gravity models with the potential contributions due to these fairly well known mass distributions. This line of reasoning should lead eventually to the compilation of Synthetic Earth Gravity Models for which we will possess a better understanding of their geophysical interpretation.

Appendix 5

Midterm Report

IAG Special Group 2.3: Satellite altimetry: data quality improvement and coastal applications

Chair: Cheinway Hwang,
Department of Civil Engineering, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu 300, Taiwan

1. Introduction

Coastal applications of satellite altimetry in geodesy, geophysics and oceanography have become increasingly important. However, shallow-water altimeter data are prone to errors in range itself, environmental and geophysical corrections. If shallow-water altimeter data are to be useful, the first problem on has to confront is data quality. For example, retracking waveforms of altimetry can produce improved results in altimetric applications. Retracked altimetry will be first used to improve tide modeling and in turn improve coastal gravity field modeling and determination of ocean dynamic topography. The densely distributed Geosat/GM and ERS-1/GM will be the biggest contributors to high frequency components of parameters extracted from altimeter data. Another dense data set, namely, Geosat/GM, has not been retracked for coastal applications. One of the objectives of this current SSG will be to freely provide a database of retracked ERS-1 and Geosat/GM for members interested in applications of these retracked altimeter data. Exchange of data and idea will be also encouraged to maximize the use of improved shallow-water altimeter data.

2. Current activities

1) Retracking Geosat and ERS-1 waveforms
2) Developing improved data processing techniques over shallow waters
3) Developing new theories and computational techniques for gravity modeling from satellite altimetry over shallow waters
4) Evaluation of gravity field models by means of long-term averaged single satellite altimetry crossovers (SSC), derived from altimetry of ERS 1, 2 and Geosat
5) Examination of global ocean laser altimetry in support of cal/val efforts for ICESat (40 Hz, 70 m footprint, 170 m separation). Some specific coastal, river, wetland and lake areas have been examined.

3. Current achievements of members

1) Retracked Geosat and ERS-1 waveforms and improved gravity determination from such data
2) Improved procedure of gravity anomaly computations over shallow waters
3) Calibration factors of the covariance matrices of recent gravity field models checked or corrections suggested.
4) Estimating noise level of 40 Hz laser altimetry to be about 3 cm over quiet waters. Have identified regions of specular reflection over some areas which require further analysis. Have developed several methods for elevation calibration using ocean data.

4. Future activities

1) Distributions of waveform retracking algorithms and retracked altimetry data to SG 2.3 members

2) Continue the current works on retracking, data processing and theory development
3) Organize a satellite altimetry workshop for shallow-water applications of altimetry in 2006.
4) Use of the SSC data and LLC method to explain significantly lower accuracy of recent (mostly only CHAMP-based) models for the lowest degrees and orders.
5) Continue ICESat cal/val, including coastal examinations. Recover data from areas of specular reflection.

5. Publications of members

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Appendix 6

Sub-Commission 2.3 – Dedicated Satellite Gravity Mapping Missions
Commission 2 (Gravity Field)
International Association of Geodesy (IAG)

Report 2003-2004

http:/www.deos.tudelft.nl/~pieter/IAG/sc23.htm

Pieter Visser (chair)

Activities:

- Organization of Session 1 of The International Symposium on Gravity, Geoid, and Space Missions (GGSM2004), 30 August – 3 September, 2004, Porto, Portugal (19 oral/27 poster presentations, 17 fully reviewed papers for proceedings).
- Proposal for a Joint Working Group between the International Gravity Field Service (IGFS) and IAG Commission 2 by Dr. Jianliang Huang (Geodetic Survey Division, CCRS, Nrcan, Canada) and Dr. Christopher Kotsakis (Aristotle University of Thessaloniki, Greece).

Future plans and activities:

- The sub-commission members are all actively involved in the analysis of CHAMP and GRACE data and are preparing for missions like GOCE and COSMIC (and even for GRACE and GOCE follow-ons). It is planned to monitor relevant activities and stimulate participation in workshops and conferences, and support/propose dedicated sessions.

Members:

Pieter Visser (DEOS/Netherlands, chair)
Srinivas Bettadpur (CSR/U.S.A.)
Thomas Gruber (IAPG/Germany)
Cheinway Hwang (NCKU/Taiwan)
Radboud Koop (SRON/The Netherlands)
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Appendix 7

Activity Report of Sub-Commission 2.4 "Regional Geoid Determination" for the period: August 2003 - March 2005-03-29

General organization, overview

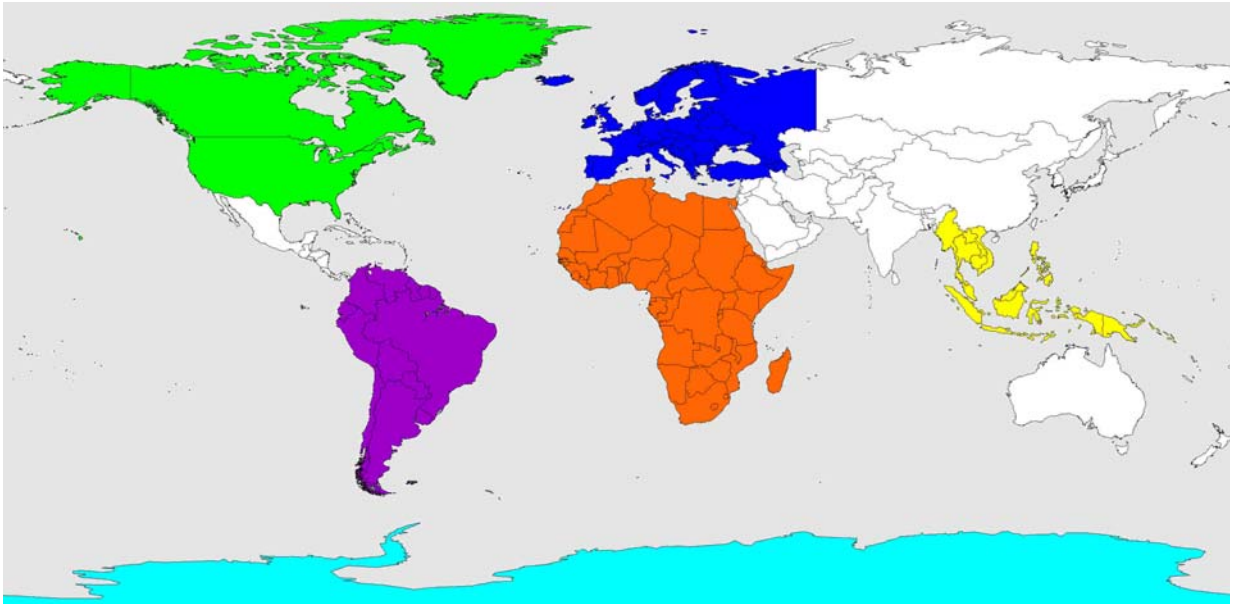
Sub-Commission 2.4 was initiated after the IUGG General Assembly in Sapporo (2003) and covers the following principal objectives:

- coordination of regional geoid projects
- comparison of methods and results, data exchange, comparison with global models
- gravimetric geoid modeling techniques and methods, available software
- GPS/leveling geoid determination:
- methods, comparisons, treating and interpretation of residuals
- common treatment of gravity and GPS/leveling for geoid determination
- geoid applications: GPS heights, sea surface topography, integration of geoid models in GPS receivers, vertical datums
- other topics: topographic effects, downward and upward continuation of terrestrial, airborne, satellite data specifically as applied to geoid modeling

The steering committee of SC 2.4 is formed by the chair and the leaders of the Sub-Commission projects:

Urs Marti	chair
Heiner Denker	CP 2.1: European Gravity and Geoid Project (EGGP)
Marc Véronneau	CP 2.2: North American Geoid Project
Charles Merry	CP 2.3: African Geoid Project
Mirko Scheinert	CP 2.4: Antarctic Geoid Project (AntGP)
Denizar Blitzkov	CP 2.5: Gravity in South America and South American Geoid
Bill Kearsley	CP 2.6: Southeast Asian Geoid

There has been no official meeting of the steering committee until now but there have been many informal contacts especially during the IAG Symposium " Gravity, Geoid and Space Missions" (GGSM2004) in Porto (August 30 - September 3 2004).
The web-site of SC2.4 can be found at http://www.swisstopo.ch/um/sc24.htm, where the reports of the projects and several other information can be found.



Areas covered by the Commission 2 Projects

Meetings, Workshops

The principal meeting of SC2.4 during the reporting period was the GGSM 2004 symposium in Porto (http://www.fc.up.pt/ggsm2004/) where session 3 "Regional Geoid Modeling" was one of the largest sessions with more than 60 oral and poster contributions. The status of some of the SC projects was presented there.
Most of the project leaders used the GGSM2004 to organize a meeting. Some other meetings of the Commission projects are the following:

CP2.1:	Feb. 2004, Milan
CP2.2:	May 2004, Montreal
CP2.3:	Dec 2003, Marrakech
CP2.4:	Sep 2003, Potsdam
	Jul 2004, Potsdam
	Jul 2004, Bremen
	Sep 2004, Herndon VA
	Dec 2004, Hanover
CP2.5:	Sep 2004, Buenos Aires

Measuring Campaigns, computational efforts

Most of the Projects are more involved in collecting available data than in measuring. Exceptions are until now only the AntGP with several activities in Antarctica and the South American project, where several gravity campaigns have been performed in various countries. Most other projects are in the stage of contacting national representatives and in collecting, testing and validating available data (mostly gravity, but also GPS/Leveling, DTM's and global models). For all projects the release of the new global geopotential models from CHAMP and GRACE and the SRTM3 digital elevation model are of enormous help and allowed the computation of some preliminary regional geoid models.

Future plans

The **European** Geoid project advances well. In 2005, a major effort will be undertaken to further update the gravity and terrain data sets, and new preliminary geoid computations will be done based on these data. The project should finish until the next IUGG General Assembly in 2007.
In **North America**, the main goal is to converge the national geoid solutions of the USA and of Canada to one single North American geoid model. Until now, some larger discrepancies are mainly caused because the two agencies do not have the same data holding. A better data exchange process between the agencies is the focus of 2005.
In **Africa,** data collection is very difficult and there still exist large data gaps which could be very efficiently filled by airborne gravimetry. One main problem is to find funding for such surveys.
The **Antarctic** Geoid Project is advancing well. One main goal is to carry out new gravity surveys and to close the polar gap. The most promising method is airborne gravimetry. A second main activity is the built-up of a gravity database for Antarctica.
In **South America,** the collection of gravity data is almost completed. Now, GPS/Leveling data is collected all over the continent in order to derive a set of geoid undulations that will be compared to the gravimetric model. A new gravimetric geoid will be computed as soon as new data sets for Ecuador and Columbia are available.
For the **Southeast Asian** Geoid project, it is rather hard to collect data. First contacts have been established with most relevant agencies in the region. In some countries, the tsunami disaster stopped much of the activities.

Some publications (see also proceedings of the GGSM2004)

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Appendix 8

European Gravity and Geoid Project (EGGP)
Status Report, February 2005

Heiner Denker (denker@ife.uni-hannover.de)

The project started with the setup of a steering committee (SC), consisting of H. Denker (Chair), J.P. Barriot, R. Barzaghi, R. Forsberg, J. Ihde, A. Kenyeres, U. Marti, I.N. Tziavos. A first meeting of the SC was held in Milan, Feb. 3-4, 2004 (kick-off meeting). During the meeting, the status and possible improvements of the European Geoid, the project structure, the input data sets, the methodology, and the time schedule were discussed. It was decided to have national correspondents/delegates from all countries as project members, which have access to the relevant data sets or are engaged in geoid computations. The primary input data sets for the geoid computation will be gravity and terrain data supplemented by a state-of -the-art global geopotential model. In addition, GPS/levelling, bathymetry, altimetry, and density data were discussed. Due to confidentiality reasons, it was decided to have only one data and computation centre within the project, which is the Institut für Erdmessung (IfE), University of Hannover. In addition, if the data owners agree, the project gravity data shall also be stored within a separate confidential data base at the Bureau Gravimétrique International (BGI), Toulouse. The confidential data base of BGI will not have any connections to the public BGI data base and will not be connected to a network. The main reason for the 2nd gravity data centre is to use the expertise of BGI in the validation and cleaning of large gravity data sets. With respect to terrain data, national models will be merged with the global models SRTM3 and GTOPO30. GPS/levelling data are collected worldwide at the International Geoid Service (IGeS) in Milan and will be made available. The general strategy for the geoid/quasigeoid calculation will be the remove-restore technique, where a global model and terrain reductions are taken into account, before applying the modelling techniques. From the discussion it turned out that IfE will start with the spectral combination and integration technique (later on IfE may also investigate other techniques, e.g., collocation or wavelets), while the Milan group intends to test the fast collocation procedure (e.g., Sansò and Tscherning, 2003). Regarding the time line, the project should finish until the next IUGG General Assembly in Perugia, 2007, and intermediate results should be generated in 2005 and 2006 (IGFS meeting in Istanbul).

After the SC meeting, the project members were approached and about 50 national delegates (project members) from most of the countries in Europe agreed to join the project. At the GGSM2004 symposium in Porto, a meeting of the project members was held and about 30 people participated. Information was given on the project organization and status. The main discussion concentrated on possible improvements of the relevant data sets. Several problem areas were identified and discussed (e.g., the Mediterranean Sea), and several project members offered their support. Furthermore, a complete project status report was presented by H. Denker at the GGSM2004 symposium (oral and poster) and will be published in the proceedings (Denker et al., 2004).

Since the start of the project, significant improvements of the gravity database were made, including new data sets for several countries, e.g., Belgium, Luxemburg, Germany, Slovenia, Switzerland, and Netherlands. Moreover, positive responses, indicating a data update in the near future, were received from Austria, the Baltic States, Croatia, France, Greece, Poland, Serbia, Russia, the Scandinavian countries, etc. In addition to this, the public domain data set from the Arctic Gravity Project became available (Forsberg and Kenyon, 2004). In addition,

the older gravity data sets were revised regarding the underlying reference systems, the target systems being ETRS (European Terrestrial Reference System), UELN (United European Levelling Network) and absolute gravity. Within the EGGP, only data which can be related without any doubts to the target reference systems will be included in the primary data base. Significant progress was also made in the collection and reprocessing of ship gravity data (Denker and Roland, 2003). The ship gravity data, collected from several institutions for the European Seas, were crossover adjusted using a bias per track error model in order to reduce instrumental and navigational errors, incorrect ties to harbour stations, and other error sources. An "original" and an "edited" data set were considered, where the edited data set excluded data affected by ship turns, data in the Red Sea, data from short tracks (< 3 points), and tracks with large crossover differences. The editing of some bad observations resulted already in an improvement of the crossover differences by a factor of two, while the crossover adjustment again reduced the crossovers by a factor of two. Before the adjustment, the RMS crossover difference is 15.5 mgal for the original and 8.4 mgal for the edited data set; the corresponding values after the adjustment are 7.0 mgal and 4.7 mgal, respectively.

Improvements were also made regarding the digital elevation models (DEMs). Switzerland has released a 1" × 1" DEM, and Austria has indicated the release of a corresponding model. However, especially in Eastern Europe and some other areas, fill-ins from global public domain databases have to be used, either because high-resolution DEMs do not exist or are not released for confidentiality reasons. For this purpose, the SRTM3 model with a resolution of 3" × 3" (JPL, 2004) and the public domain global model GTOPO30 with a resolution of 30" × 30" (LP DAAC, 2004) were investigated (Denker, 2004a). The national DEMs, augmented by the SRTM3 and GTOPO30 data will allow the creation of DEMs for entire Europe with a resolution of at least 30" × 30", which is a significant improvement compared to the previous EGG97 computation.

Regarding the global geopotential models, the CHAMP and GRACE missions have led to significant improvements in the modelling of long wavelength gravity signals. This is documented, e.g., by the accumulated formal geoid error, which does not exceed 0.01 m for spherical harmonic degrees up to about 25 for the CHAMP models (e.g., Reigber et al., 2004a) and 75 for the GRACE models (e.g., Reigber et al., 2004b). On the other hand, the limit of 0.01 m is already exceeded at degree 8 for the EGM96 model.

Updated European geoid/quasigeoid models were computed based on the new CHAMP and GRACE geopotential models (Denker, 2004b). The computations were done using the EGG97 terrestrial gravity data set as well as an updated data set (see above). All computed quasigeoid models were evaluated by GPS/levelling data from the European EUVN data set (Ihde et al., 2000) and by national campaigns. The comparisons show clearly that the long wavelength discrepancies over Central Europe almost disappear for the solutions based on the GRACE models. The largest discrepancies remain at coastal stations, especially around the Mediterranean Sea where the gravity data quality is weak. In the GPS/levelling comparisons of the European and national data sets, the RMS differences reduce up to about 60 % when using the GRACE models and up to 30 % for the solutions based on CHAMP, as compared to the previous EGG97 model relying on EGM96. In addition, the tilts, existing in EGG97, were reduced to typically below 0.1 ppm. Furthermore, with the updated solutions based on the GRACE models, accurate determinations of W_0 (reference geopotential of the vertical datum) and vertical datum unifications become possible. Thus, contributions can be made to the definition of a European Vertical Reference System (EVRS).

In summary, significant progress was made within the framework of the European Gravity and Geoid Project EGGP regarding the collection and homogenization of high-resolution gravity and terrain data. Several new data sets became available, and especially the new geopotential models from the CHAMP and GRACE missions improved the geoid/quasigeoid modelling very much. Further details on the progress made so far are documented in Denker et al. (2004).

In my opinion, the project is running well so far. In 2005, a major effort will be undertaken to further update the gravity and terrain data sets, and new geoid computations will be done based on these data.

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Appendix 9

The activities for the North American Geoid project consisted of two meetings. The first meeting was held in Montreal during the Canadian Geophysical Union annual scientific meeting back in back in May 2004 while the second meeting was held in Porto during the Geoid and Gravity conference back in September 2004. Furthermore, Natural Resources Canada's Geodetic Survey and U.S. National Geodetic Survey Division maintain channel of communication in the development of a geoid model for North America. This development is especially important for Canada because the future vertical datum for Canada (~2008) will be define by an equipotential surface and realized by a geoid model.

Latest geoid models developed in the USA and Canada are continuously compared in order to converge towards a single solution. Currently, the largest discrepancies are principally due to the facts that the two agencies do not have the same data holding. A better data exchange process is required between the two agencies. This process will be the focus for this coming year.

Appendix 10

REPORT OF COMMISSION PROJECT 2.3: AFRICAN GEOID PROJECT
(part of Sub-Commission 2.4: Regional Geoid Determination)

For the period: June 2003 - June 2005

General:

The working group on this project has not made as much progress as had been hoped. Members have found it difficult to obtain time, funds and data. Nevertheless data collection has continued and most of the BGI gravity data holding for Africa have been obtained, as well as some additional data sets for a few specific regions. Nevertheless, there are still large data gaps in many parts of Africa; particularly in those regions that have been or are in a state of conflict. Airborne gravimetry would be a very efficient way to fill these gaps, but it is difficult to find sources of funding for such surveys.

The new satellite-based data sets from Grace and from the SRTM should improve both the long wavelength and short wavelength modelling of the geoid for Africa. Time constraints have prevented much work being done with these data, but preliminary testing indicates that the SRTM30 DEM is a significant improvement over earlier 1km DEM's for Africa, and that there are significant differences between the Grace geopotential model and EGM96 (up to one metre in geoid height) over parts of southern Africa.

Publications:

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Appendix 11

Report of Commission Project 2.4 "Antarctic Geoid" (AntGP)

Mirko Scheinert
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Short Review

This group was initiated in the course of the IUGG General Assembly in Sapporo 2003 and the adoption of the new structure of the IAG. It is the first time, that within IAG a special group is dedicated to the determination of the gravity field in Antarctica. Therefore, substantial time has to be taken to get into and to deepen contacts. Because of the special conditions in Antarctica, cooperation is possible only in an interdisciplinary way, especially in the fields of geodesy, geophysics and glaciology. This is reflected in the membership of the group (cf. below).
Thus, considerable work has been done in establishing communication, in disseminating the idea of closing the gravity gap in Antarctica and in investigating what gravity (and auxiliary) datasets do already exist for Antarctica.
For communication various conferences played an important role (cf. below). At the Porto symposium (GGSM2004), a short meeting of the AntGP group could be carried out. In between, communication was maintained by circular letters. The most comprehensive report on the status of the project was given by an invited talk of M. Scheinert at the IAG International Symposium on Gravity, Geoid and Space Missions (GGSM2004) in Porto (Scheinert 2004a). This paper is due to publication in a respective Springer volume (Scheinert 2004b).
To present AntGP to a wider audience, a website has been established and will be maintained under `http://www.tu-dresden.de/ipg/antgp/antgp.html`

An important linkage could be maintained to the Scientific Committee on Antarctic Research (SCAR), which represents Antarctic sciences in a broad sense. Within the "SCAR Standing Scientific Group on GeoSciences" the "Expert Group on Geospatial Information - Geodesy" adopted a new work plan for Geodetic Infrastructure of Antarctica (GIANT) for the period 2004 - 2006. Project 3 of this work plan "Physical Geodesy" is chaired by A. Capra and co-chaired by M. Scheinert. A close linkage to SCAR is also very important envisaging the International Polar Year 2007/08, which offers unique possibilities for internationally and interdisciplinarily coordinated initiatives and thus also for geodetic-geophysical campaigns aiming at gravity surveys in Antarctica.

Specific activities have been undertaken by the AntGP members when carrying out or planning observation campaigns in Antarctica in the time period 2003 - 2005 (cf. below).

Future plans and activities

Future activities can be well defined following the "Terms of Reference". Activities of the group should be focussed in the following sense:

(a) Promotion and carrying-out of new gravity surveys in Antarctica

Here, the upcoming IPY plays an important role for the international coordination of such surveys. Airborne gravimetry is the most promising technique to close the polar gap in the global gravity data coverage. Due to the huge logistic efforts of Antarctic (and especially airborne) surveys, coordination has to be set up well in advance and on a broad (national/international) basis.

(b) Built-up of databases

An overview of already existing data is given in (Scheinert 2004b). The built-up and maintainance of Antarctic gravity databases should be supported. Within AntGP, methods and rules of data exchange have to be elaborated.

Upcoming conferences will be important to further communicate the goals of AntGP and to coordinate the work between the group members and the different communities (especially: Joint Assembly of IAG/IAPSO/IABO, Cairns 2005; Intl. Symp. on Antarctic Earth Sciences, Hobart 2006; IUGG General Assembly, Perugia 2007). It is also intended to organize a workshop dedicated to AntGP (possibly in 2006).

Membership (as of January 2005)

Active members

Mirko Scheinert (chair)	TU Dresden, Germany
Alessandro Capra	Politechnico di Bari, Italy
Detlef Damaske	BGR Hannover, Germany
Reinhard Dietrich	TU Dresden, Germany
René Forsberg	KMS Copenhagen, Denmark
Larry Hothem	USGS, USA
Wilfried Jokat	AWI Bremerhaven, Germany
Gary Johnston	Geoscience Australia
A.H. William Kearsley	University of New South Wales, Australia
Steve Kenyon	NIMA, USA
Christopher Kotsakis	University of Calgary, Canada
German L. Leitchenkov	VNIIOkeangeologia, Russia
Jaakko Mäkinen	FGI, Finland
Kazuo Shibuya	NIPR, Japan
C.K. Shum	OSU Columbus, USA
Dag Solheim	Statens Kartverk, Norway
Michael Studinger	Lamont-Doherty Earth Observatory, USA

Corresponding members

Robin Bell	Lamont-Doherty Earth Observatory, USA
Graeme Blick	LINZ, New Zealand
John Brozena	Naval Research Lab, USA
Cheinway Hwang	National Chiao Tung University, Taiwan
John Manning	University of New South Wales, Australia
Dave McAdoo	NOAA, USA

Selected conferences and workshops with participation of AntGP members

IX International Symposium on Antarctic Earth Sciences (ISAES IX)
Potsdam, Germany, September 8-12, 2003

Joint CHAMP/GRACE Science Meeting (JCG)
Potsdam, Germany, July 6-8, 2004

XXVIII SCAR Meeting and Open Science Conference (SCAR 28)
Bremen, Germany, July 25-31, 2004

IAG International Symposium "Gravity, Geoid and Space Missions" (GGSM 2004)
Porto, Germany, August 30 - September 3, 2004

NSF Workshop on Science Opportunities for a Multidisciplinary Long-Range Aircraft for Antarctic Research, Herndon VA, USA, September 27-29, 2004
co-organized by Michael Studinger, member of AntGP

Workshop Geosciences on HALO (High-Altitude and Long-Range Research Aircraft)
Hannover, Germany, December 14, 2004

Selected activities in Antarctic observation campaigns

Joint project of TU Dresden and AWI Bremerhaven (Germany) "Validation, Densification and Interpretation of Satellite Data for the Determination of the Magnetic Field, Gravity Field, Ice Mass Balance and Crustal Structure in Antarctica by Means of Airborne and Terrestrial Measurements" (PIs: R. Dietrich and W. Jokat): Antarctic campaigns in Dronning Maud Land in the seasons 2003/04 (head of field group: M. Scheinert) and 2004/05

Projects of VNIIOkeangeologia (Russia) in Antarctica (G. Leitchenkov)

Finnish Antarctic Research Programme (FINNARP): Absolute gravity measurements in Dronning Maud Land, season 2003/04 (J. Mäkinen)

Observatory programme (superconducting gravimeter and others) at Japanese Syowa station, East Antarctica (K. Shibuya)

Selected publications and presentations of members

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Appendix 12

Projects: Gravity in South America (M.C. Pacino) and South American Geoid (D. Blitzkow).
Report to Commission II: Gravity Field.

This is a joint report of "Gravity in South America" (SC2.1 - CP2.7) and "South American Geoid" (SC2.4 - CP2.5) projects. Their members are organized in a coordinated effort to develop activities related to both projects, under the coordination of Maria Cristina Pacino and Denizar Blitzkow respectively. The two projects were established as part of the Commission II: Gravity Field, in order to organize the activities of gravity measurements in the continent and to provide the necessary information for the height system in association with the geoid determination.

Gravity meeting:

The first meeting of the "Gravity in South America" project took place at the headquarters of Instituto Geográfico Militar de Argentina, during the XXII Scientific Assembly of the AAGG (Argentine Association of Geodesy and Geophysics), on September 9th, 2004, and was attended by the following members:

- M. Cristina Pacino (chairman)
- Eduardo Lauría (Argentina)
- Rubén Ramos (Argentina)
- Mauro Andrade de Sousa (Brazil)
- Wilfredo Rubio Díaz (Chile)
- Héctor Rovera (Uruguay)
- Eugen Wilderman (Venezuela)

The following objectives and actions regarding gravity measurements were approved:

- To collect and to send to Dr. M. Cristina Pacino for validation and technical evaluation, all the existent information regarding Absolute Gravity Measurements in South America, in special those performed from 1988 to 1991 by Dr. W. Torge;
- To define sites for absolute gravity determinations in order to establish a new Absolute Gravity Network in South America with a medium distance between the stations on the order of 1,000 km, with the re-observation of the existent absolute gravity stations to assure internal consistency in precision, reference system, method of measurement, etc;
- To adopt the absolute gravitymeter Micro-G Solution Inc, FG5 model, property of the Observatorio Nacional – Río de Janeiro – Brasil to perform the measurements;
- Adjust national gravity networks at a continental level;
- To maintain and to promote international relationships between National Geographic Institutes and similar Institutions;
- To apply for national and international support;
- To cooperate with the "South American Geoid" Project;
- To encourage international seminars and short courses ;

Activities accomplished:

The documents related to Absolute Gravity Measurements (1988-1991) in Venezuela, Brazil, Uruguay and Argentina were collected. Besides, several gravity stations were reoccupied in Brazil and Uruguay and a budget was approved for the reoccupation of absolute gravity stations in Argentina. In Chile it has been reported a set of new absolute measurements carried out with the support of France.

In the last two years a strong effort was carried out in order to improve the distribution of gravity information in the South American continent (Figure 1). It includes Argentina, Brazil, Chile, Colombia, Ecuador and Paraguay. Many new surveys were carried out and an intense process of validation was also carefully realized in different countries. The contribution of many organizations in South America and other countries is very much appreciated: IBGE, EPUSP and many universities and research institutes (Brazil), IGM (Chile), IGM and University of Rosario (Argentina), DISERGEMIL (Paraguay), IGAC (Colombia), IGM and INOCAR (Ecuador), GETECH (UK), NGA (USA), Dr. Goetze (Germany), IRD and BGI (France).

New Fundamental Gravity Networks were established in Chile, Ecuador and Paraguay (Figures 2 - 3). A least squares adjustment of the networks is in progress.

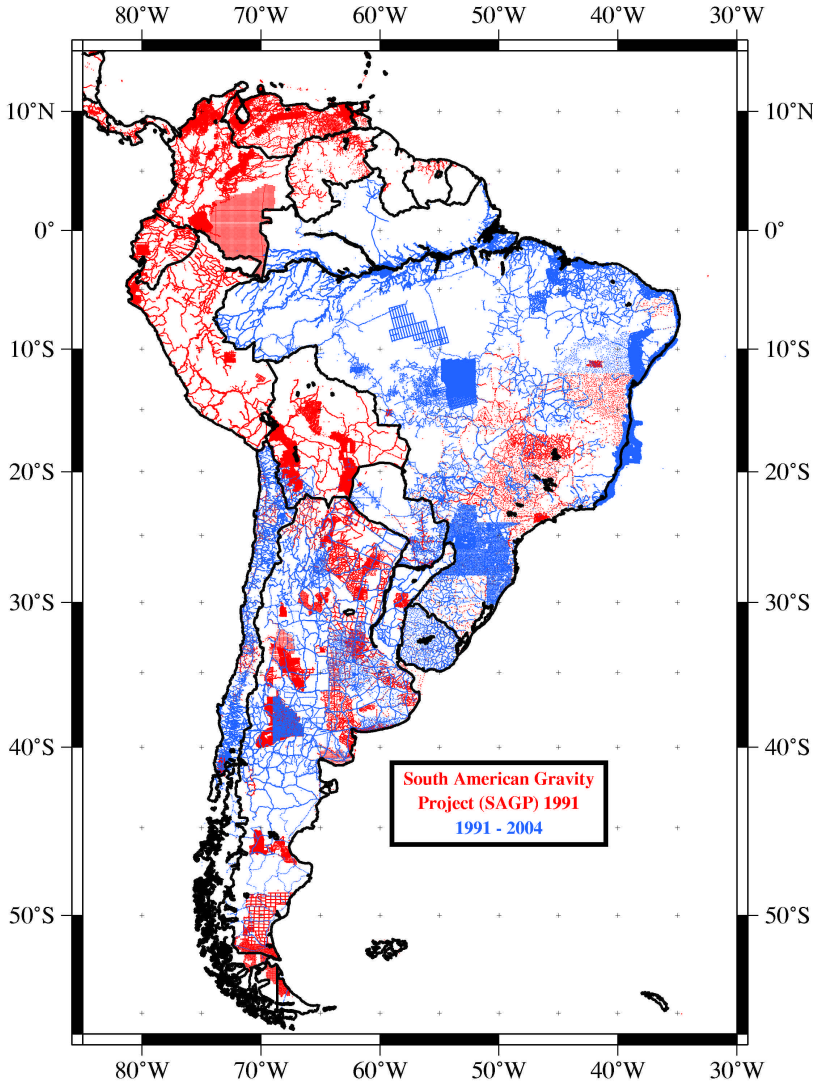

Figure 1 – Gravity data distribution in South America.

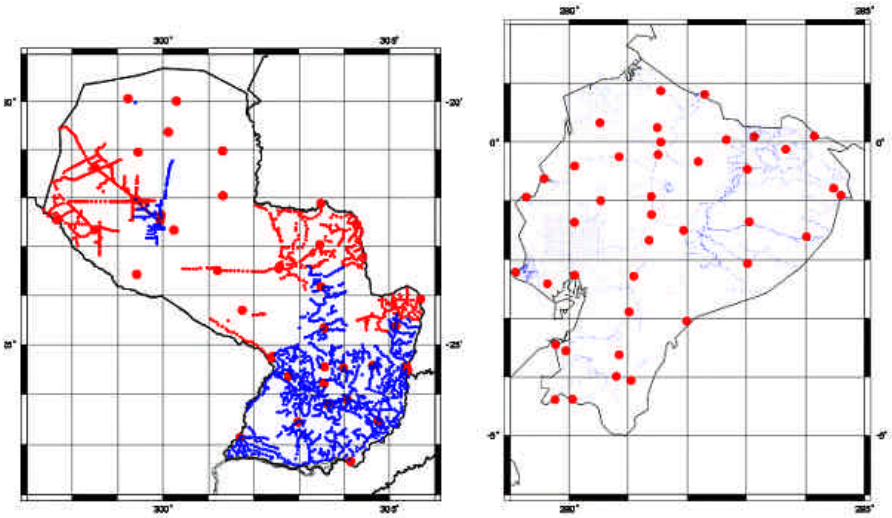

Figure 2 – Fundamental Gravity Network in Paraguay and Ecuador.

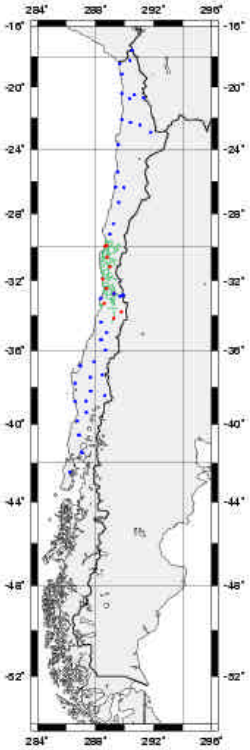

Figure 3: Fundamental Gravity Network in Chile.

<u>DTM initiative:</u>

A great effort has been done to analyse the different DTM available (DTM2002, GLOBE, GTOPO30, ETOPO2, JGP95E, TERRAINBASE, ETOPO5), with a special emphasis to Endeavour mission, Shuttle Recovery Topography Mission (SRTM). The models were compared with heights on Bench Marks (BM) derived from spirit leveling throughout Brazil and Argentina. Topographic maps have been digitized in many areas in the continent (Figure 4 - black). Special bathymetric information has been recovered from different sources in the coast of Brazil (nautical maps, profiles of specific surveys, point measurements) and Argentina (nautical maps) (Figure 4 – orange). The blue color in the figure 4 is DTM2002 and the green is SRTM.

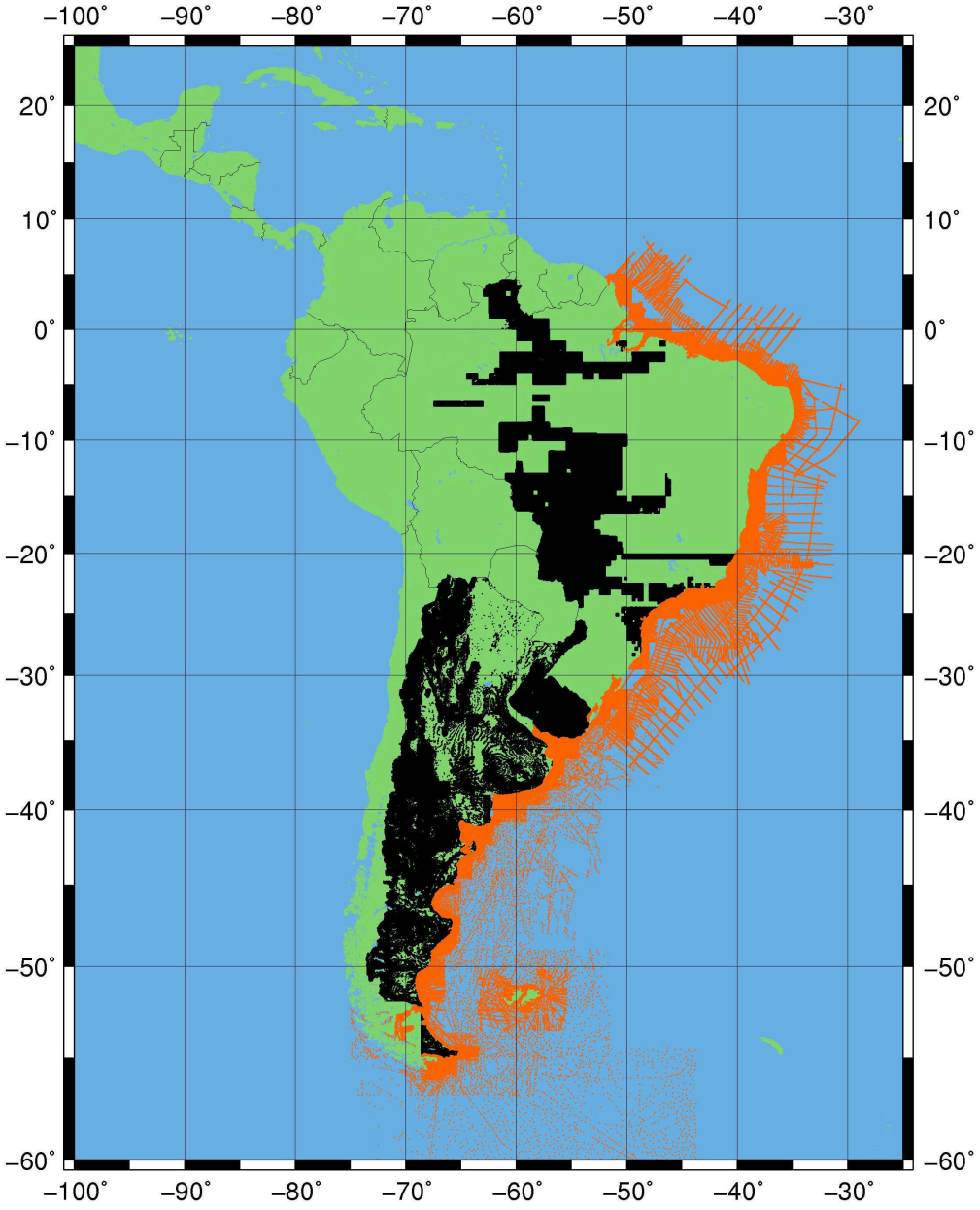

Figure 4: Distribution of different data used in the DTM.

As a result, three DTM models were generated for South America: DTM-ver1, DTM-ver2, DTM-ver3. The first one has a resolution of 1’ and was generated from data of Figure 4. The second has also a resolution of 1’. It differs from ver1because it used SRTM instead of topographic maps. The ver3 is a 30” resolution; it is SRTM only in the continent and in the ocean is DTM2002. Figure 5 represent the DTM with ver2. This important and time consuming work was carried out at EPUSP by the student Ana C. Cancorro de Matos.

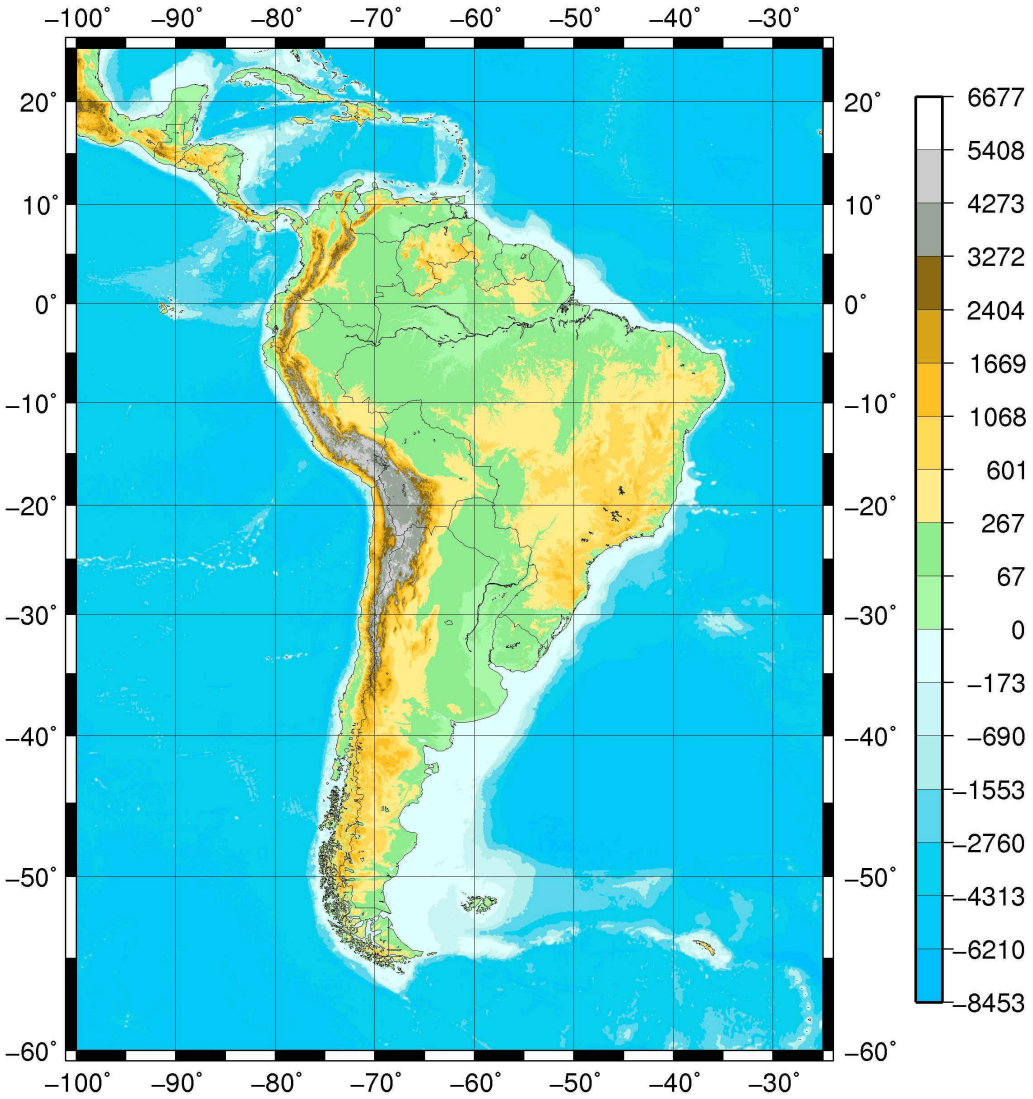

Figure 5: DTM representation (ver2).

Using ver2 of the DTM, the terrain correction and the indirect effect were estimated for South America (Figure 6).

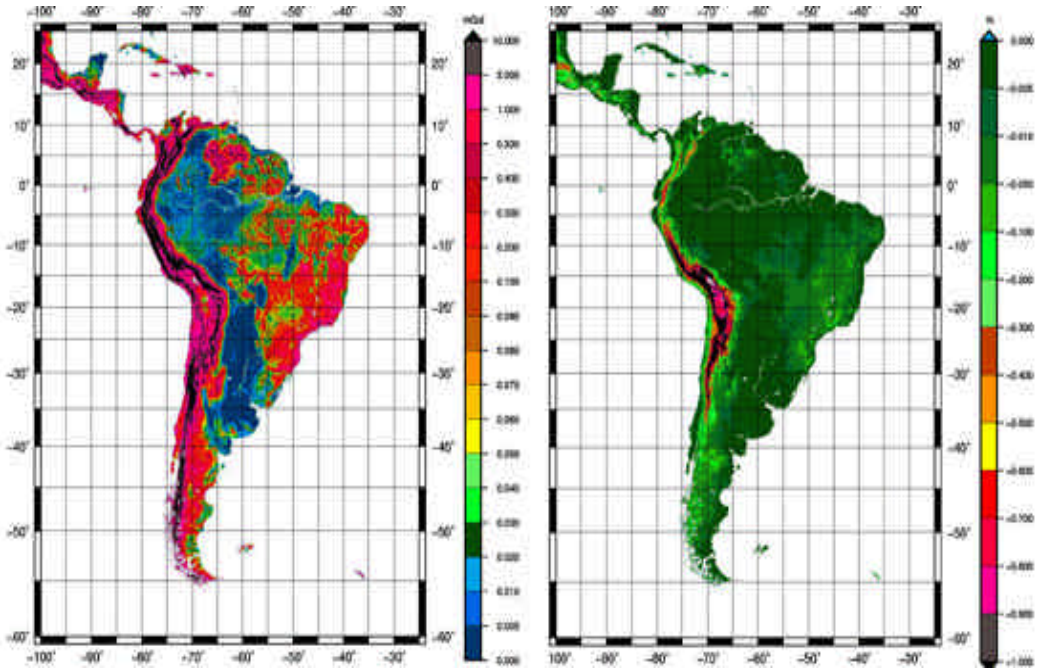

Figure 6: Terrain correction (left) and indirect effect (right).

<u>GPS/leveling:</u>

GPS/leveling stations data are being collected all over the continent to derive a set of geoid undulations that will be used for comparisons with the gravity geoid model.

<u>Geoid computations:</u>

All the above data collected, validated and organized are being used for geoid computations by numerical integration and FFT-1D. The geopotential models available, specially those from dedicated satellite missions CHAMP and GRACE, are being compared with terrestrial data. A new geoid computation will be done as soon as the new data from Ecuador and Colombia be replaced on the 5’ x 5’ mean gravity anomalies grid. The last version was derived with fft (Figure 7).

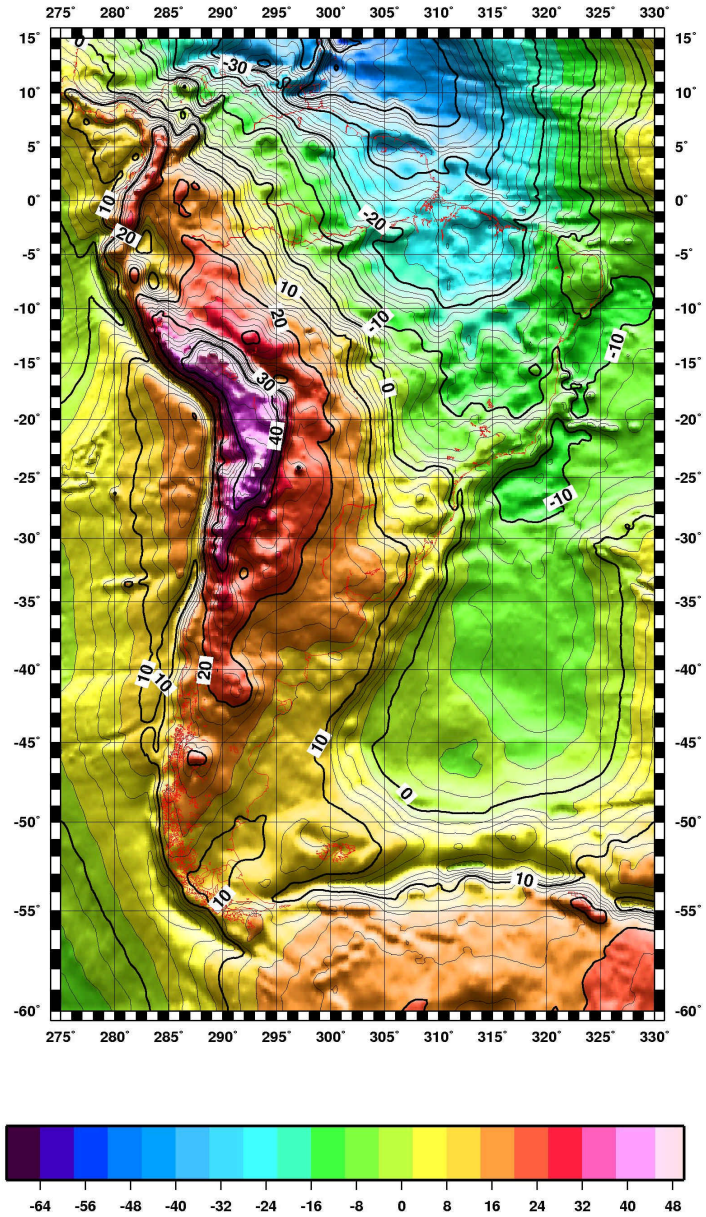

Figure 7. Geoid model computed with fft-1d – version 2004.

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Matos, A.C.C.de, Campos, I.O., Castro Jr., C.A.C., Blitzkow, D. (2004). Height analysis in Amazon área using different methods. Symposium on Gravity, Geoid and Space Missions (GGSM2004). Aug 30 – Sep 3, 2004. Porto, Portugal.

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Appendix 13

IAG Inter-Commission Project
ICP1.2 Vertical Reference Frames

Progress Report 2004

Based on the classical and modern observations, the ICP1.2 on Vertical Reference Frames shall study the consistent modelling of both, geometric and gravimetric parameters, and provide the fundamentals for the installation of a unified global vertical reference frame.
Error! Unknown switch argument.

Objectives

- To elaborate a proposal for the definition and realization of a global vertical reference system (World Height System – WHS);
- To derive transformation parameters between regional vertical reference frames;
- To establish an information system describing the various regional vertical reference frames and their relation to a world height frame (WHF).

Program of Activities

- Harmonization of globally used height data sets;
- Study of combination procedures for height data sets from different techniques;
- Study of information on regional vertical systems and their relations to a global vertical reference system for practical applications;
- Unification of regional (continental) height systems.

Activities since 2003

(1) Realization of the European Combined Geodetic Network (ECGN) as case study for further global activities (Project of EUREF - IAG SC1.3a)

ECGN is a terrestrial network for the combination of different techniques: GPS/GLONASS positioning, gravity measurements, levelling, tide gauge observations.

- 1st Call for Participation: Implementation of ECGN Stations in April 2003
- Decision about the criteria to evaluate the proposals of the 1st Call and discussion of the individual proposals in September 2003
- Information of the ECGN organizations/institutions about the status in November 2003 (http://www.ifag.de/ecgn/index.htm)
- Preparation of the 2nd Call relating methodical investigations for the combination of spatial observation data with gravity field data.

(2) European Vertical Reference System Workshop April 5-7, 2004

- Preparation of a common European Vertical Reference System (EVRS) and its relation to a WHS till 2007
- Revision of the present EVRS conventions in agreement with the WHS/WHF conventions of ICP1.2
- Realization and maintenance of the EVRS by the ECGN till 2007.

(3) Meeting of ICP1.2, August 31, 2004, Porto

Main items of the discussion were the

- view to ICP1.2 strategy
- principles for conventions, open questions
- Information of local reference frames needed for transformation in a regional and global vertical system
- importance of W_0 in the definition of a global vertical reference system, and adoption of a new number for W_0, respectively the acceptance of existing conventions,
- importance of tide gauge observations and satellite altimetry for the realization of the global vertical reference system as well as the unification of regional vertical reference frames.

Next actions

A result of the discussion of the members of ICP1.2 about the definition and realization of a global vertical reference system was the composition of two work packages.

The first work package will address

- convention and standards for a Conventional Height System, a World Height System and a World Height Frame
- relationships to the CTRS, CTRF and gravity standards
- datum realization (handling of information of the satellite altimetry, possible role of the TIGA project, mean earth ellipsoid versus W_0)

This work package will be in executed in collaboration of J. Ihde, J. Krynski (chair), J. Mäkinen and V. Vatrt.

The second work package is related to the unification of height systems and the collection and distribution of information about the different national height systems including transformation parameters. Members of the group are M. Amos, A. Kasenda, Bill Kearsly, G. Liebsch, D. Roman (chair) and Marc Veronneau.

All ICP1.2 members are asked to contribute to the work packages. Both groups shall present first results till end of March 2005.

The next ICP 1.2 meeting is planned for spring 2005 during the EGS Conference in Vienna on 24.-29.04.2005. First results of our project shall be presented on the IAG Scientific Symposium in Cairns, Australia on 22.-26 August 2005.

January 7, 2005-01-06 Johannes Ihde (Chair of IAG ICP1.2)

Appendix 14

IAG Commission 2 – The Gravity Field
Report on the Activities of the
Global Geodynamics Project (GGP)

by

David Crossley,
GGP Chairman

In 2004 the main GGP activity was the project session held at the 15th International Symposium on Earth Tides, in Ottawa, August 2-6. The associated Newsletter #14 appeared in the Fall of 2004 and was posted on the GGP website (http://www.eas.slu.edu/GGP/ggphome.html). Important points noted in the Newsletter were:

1. Station Review. We have seen the closing down of the Boulder stations (BO) due to a hardware malfunction that also required a software upgrade that has not yet been implemented. For the moment the only North America SG station still recording is in Cantley Canada, and recently we heard that this station is also in imminent danger of disappearing, unless funding can be arranged through the Geological Survey of Canada. Contrary to the NA situation, a new station has come on line in Korea, and a new installation in Taiwan is in the planning phase. We are pleased that station BH (Bad Homberg, Germany) is now providing data to GGP and the remote station in Concepcion, Chile is working well.
2. Updated GGP agreements now require a delay of no more than 6 months between members and within 1 calendar year after its collection, all reporting SG stations are required to send their data to the International Center for Earth Tides (ICET)in Brussels.
3. GGP is moving towards more timely release of earthquake (rapid sample data), see below.
4. GGP is also working out the details of collecting AG (absolute gravimeter) data at the SG station sites. The purpose if to provide AG data for (a) the calibration of the SGs, and (b) to determine the secular changes in gravity at a station so that the SH drift can better be monitored. The reason GGP is considering thi development is due to the reservations some members of the community seem to have with the current procedures for collecting absolute gravimeter data through the BGI database.

Since the August GGP Workshop, and spurred on by the very large earthquakes in Sumatra on December 26 2004 and March 28 2005, GGP has move to make raw data available online (http://www.eas.slu.edu/GGP/sumatra.html). The format for the data has been standardized as modified PRETERNA format, just as for the 1 minute data, and now about 15 datasets are available for December 2004 and January 2005. It is hoped this will be expanded in future to permit more continuous data to be sent to the IRIS (seismology)

database. Some differences of approach exists within GGP as to whether to go directly to IRIS or work through our normal ICET procedures, now managed from GFZ (Potsdam).

The special issue of the Journal of Geodynamics (vol 38, Nos. 3-5, 2004) was devoted to papers arising from the previous years' Sapporo GGP Workshop, on the occasion of the first 6 year period of GGP (1997-2003). This special issue contained 19 papers from about 60 authors. At the present time, papers are being assembled from the 2004 Earth Tides meeting and will again be published in a future issue of the Journal of Geodynamics.

The next GGP Workshop is scheduled to be held during the imminent EGU meeting in Vienna, April 2005. Issues to be addressed remain those largely on the table last year. GGP has now successfully completed its first year as an interdisciplinary project of the newly organized IAG.

Of particular interest the gravity community at large is the need to create an absolute gravity database. GGP will continue to seek a viable means to collect AG data from the SG station sites, and this should be a good point of intersection for the combined resources of GGP and Commission 2.

St. Louis,
April 11, 2005.

Appendix 15

Inter-Commission Working Group 2.1
International Association of Geodesy (IAG)

Satellite Gravity Theory

Commission 2 (Gravity Field)
&
InterCommission Committee on Theory

Report 2003-2004

Nico Sneeuw (chair)

Joint WG Meeting

During the GGSM2004 meeting, August/September 2004, Porto, Portugal, a joint meeting was organized between ICWG2.1 and the ICCT WG on Inverse Problems (chair: J Kusche). The participation level was high, about 70%. Individual members briefly presented their research plans for the next few years. This meeting can be regarded as a kick-off for both working groups. One of the main discussions at the joint meeting was about a publication plan; see below.

Special issue Journal of Geodesy

It was proposed and agreed at the joint meeting that the two WG chairs will organize a special issue of the Journal of Geodesy, dedicated to the combined areas of the two working groups. The authorship is mostly drawn from the combined WG membership, although authors from outside will participate as well. Further details:

- The Editor-in-Chief of JoG, Will Featherstone, has agreed.
- The two WG chairs will act as guest editors (though N Sneeuw is regular JoG editor already).
- To date, about 16 papers have been announced.
- Deadline for submission is end of June 2005.
- Papers will have to pass the normal editorial and review process.
- Depending on the speed of the review process, the special issue may be expected end of 2005, or rather early 2006.

Further activities

All WG members are actively involved in aspects of spaceborne gravimetry using CHAMP, GRACE, GOCE and/or future missions. In this reporting period it is too early to extensively document all publications, papers, poster presentations, etc. For the upcoming reporting timeframe it is planned to monitor relevant activities and stimulate participation in workshops and conferences, in close agreement with the chairs of SC2.3 on Dedicated Gravity Field Missions (P Visser) and the InterCommission Committee on Theory (PL Xu), to which this WG is answerable.

Members

The initial members of the working group (addresses at start of WG activities) are:

N Sneeuw (chair)	University of Calgary	Canada	sneeuw@ucalgary.ca
P Ditmar	TU Delft	Netherlands	ditmar@geo.tudelft.nl
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R Grebenitcharsky	University of Calgary	Canada	grebski@ucalgary.ca
SC Han	Ohio State University	USA	han.104@osu.edu
M Kern	TU Graz	Austria	kern@geomatics.tu-graz.ac.at
C Kotsakis	University of Calgary	Canada	ckotsaki@ucalgary.ca
J Kusche	TU Delft	Netherlands	j.kusche@citg.tudelft.nl
J Li	Wuhan University	China	jcli@wtusm.edu.cn
P Moore	Newcastle University	UK	philip.moore@ncl.ac.uk
R Pail	TU Graz	Austria	pail@geomatics.tu-graz.ac.at
N Pavlis	Raytheon ITSS Corp.	USA	npavlis@atlas.stx.com
T Peters	TU Munich	Germany	peters@bv.tum.de
H Schaub	Virginia Tech	USA	schaub@vt.edu
Y Shen	Tongji University	China	yzshen@mail.tongji.edu.cn
I Velicogna	University of Colorado	USA	isabella@colorado.edu
P Visser (ex officio)	TU Delft	Netherlands	Pieter.Visser@lr.tudelft.nl
F Wild	University of Karlsruhe	Germany	wild@gik.uni-karlsruhe.de
DN Yuan	JPL	USA	dah-ning.yuan@jpl.nasa.gov

At the GGSM2004 meeting in Porto, Portugal, Pavel Nová k (Research Institute of Geodesy, Czech Republic, pnovak@pecny.asu.cas.cz) was added to the membership. C Kotsakis has since moved to the Aristotle University of Thessaloniki, Greece. R Grebenitcharsky has moved to TU Delft, The Netherlands.

Appendix 16

Report of IAG ICCT Joint Working Group with Commission on Gravity:

JWG 5: Multiscale Modelling of the Gravity Field

Introduction

During the last decades technological progress has changed completely the observational methods in all fields of geosciences with a trend to achieve immediate results, thus reducing time and costs. A reconstruction of the gravity field from data material coming from satellite as well as airborne and terrestrial measurements requires a careful multiscale analysis of the gravity potential, fast solution techniques, and a proper stabilization of the solution by regularization. While global long-wavelength modelling can be adequately done by use of spherical harmonic expansions, harmonic splines and/or wavelets are most likely candidates for medium and short-wavelength approximation. The working group intends to bring together scientists concerned with the diverse areas of geodetically relevant wavelet theory in general and its applications. An essential field of research is the specific character of geodetic multiresolution methods used in addition or in contrary to standard spectral techniques based on spherical harmonic framework.

Objectives

- Theoretical research in the field of spherical and ellipsoidal wavelets as well as wavelet introduction and modelling on geodetically relevant surfaces (like spheroid, geoid, (actual) Earth's surface).
- Studies of harmonic wavelets in geodetic boundary-value problems (e.g., Runge-Walsh wavelets, layer potential wavelets, etc).
- Studies on spline/wavelet kernel modelling, multiscale pyramid algorithms via kernel functions known from (least squares) collocation and spline approaches, noise cancellation, least-squares adjustment and spline smoothing vs. multiscale thresholding, etc.
- Development of specific numerical methods: fast wavelet transform, tree algorithms, data compression, domain decomposition techniques, fast multipole methods, panel clustering, data transmission, etc.
- Comparison of spherical harmonic and/or wavelet modelling: Combined spectral and multiscale expansion of the gravitational potential, degree variances vs. local wavelet variances, spectral and/or multiscale signal to noise thresholding, etc.
- Investigation of different wavelet types in geodetic pseudodifferential equations (using numerical methods such as collocation, Galerkin method, least-squares approximation, etc).
- Regularization of inverse problems by multiresolution, locally reflected multiscale vs. globally reflected spectral regularization, multiscale parameter choice strategies, multiscale modelling in SST, SGG.
- Time dependent multiscale modelling in boundary value and inverse problems, numerical implementation and application to GRACE-, GOCE-data.

Members and Correspondent Members

W. Freeden, Germany (chair)

M. J. Fengler (Germany), T. Gervens (Germany), E. W. Grafarend (Germany), M. Gutting (Germany), K. Hesse (Australia), C. Jekeli (USA), W. Keller (Germany), J. Kusche (Netherlands),

D. Michel (Germany), V. Michel (Germany), J. Otero (Spain), S. Pereverzev (Austria), F. Sacerdote (Italy), F. Sanso (Italy), M. Schreiner (Switzerland), J. Schröter (Germany), W.-D. Schuh (Germany), I. H. Sloan (Australia), N. Sneeuw (Canada), L. Svensson (Sweden), C. C. Tscherning (Denmark)

Past Activities

- Oberwolfach conference on Geomathematics in May 2004, organised by W. Freeden, E. W. Grafarend, I. H. Sloan, L. Svensson.
- Presentations at several conferences:
  - 2nd CHAMP Science Meeting in Potsdam, September 2003.
  - Minisymposium about Inverse Problems at DMV Jahrestagung Rostock, September 2003.
  - Geodetic Week Hamburg, September 2003.
  - GOCE-CryoSat-Workshop at EADS Astrium in Friedrichshafen, November 2003.
  - 2nd GOCE User Workshop at ESRIN, Frascati, March 2004.
  - General Assembly of the European Geoscience Union (EGU) in Nice, April 2004.
  - Geodetic Week Stuttgart, October 2004.
  - General Assembly of the European Geoscience Union (EGU) in Vienna, April 2005.
  - SIAM Conference on Mathematical and Computational Issues in the Geosciences, Avignon, June 2005.
- Cooperation between the groups in Kaiserslauten (W. Freeden) and Munich (R. Rummel) about multiscale modelling of temporal changes of the gravitational field measured by GRACE (see: M.J. Fengler, W. Freeden, A. Kohlhaas, V. Michel, T. Peters, "Wavelet Modelling of Regional and Temporal Variations of the Earth's Gravitational Potential Observed by GRACE", submitted to Journal of Geodesy, 2005).
- Cooperation between the groups in Kaiserslautern (W. Freeden) and Stuttgart (E. W. Grafarend) in form of a joint DFG-project: Inverse Multiscale Geoid Computation (IMGC).
- Cooperation between the groups in Delft (J. Kusche) and Kaiserslautern (W. Freeden) about Wavelet Modelling of satellite data and its combination with regional terrestrial data. (see: M. J. Fengler, W. Freeden, V. Michel: "The Kaiserslautern Multiscale Geopotential Model SWITCH-03 from Orbit Perturbations of the Satellite CHAMP and Its Comparison to the Models EGM96, UCPH2002_02_0.5, EIGEN-1s, and EIGEN-2." Geophysical Journal International, Vol. 157, pp. 499-514, 2004; and: M. J. Fengler, W. Freeden, J. Kusche: "Multiscale Geopotential Solutions from CHAMP Orbits and Accelerometry." C. Reigber, H. Lühr, P. Schwintzer, J. Wickert (Eds.), Proceedings of the 2nd CHAMP Science Meeting, Springer Berlin, Heidelberg, New York, pp. 139-144, 2004.).

Literature

In addition to many papers the following books about wavelets and multiscale techniques in geosciences have been published during the last 2 years:

- W. Keller, "Wavelets in Geodesy and Geodynamics", de Gruyter, Berlin, 2004.
- W. Freeden, V. Michel, "Multiscale Potential Theory (With Applications to Geoscience)", Birkhäuser, Boston, 2004.
- "Geomathematics, Oberwolfach Conference Report No. 27/2004", in: Oberwolfach Reports, Vol. 1, No. 2, European Mathematical Society, 2004.

Planned Activities

- Organisation of a workshop "Inverse Problems in Geosciences" together with the Group of R. Rummel (Munich, Germany) and ESA representatives in Kaiserslautern in fall 2005.
- Further Email discussion and electronic exchange.
- Launch of an extended web-page for dissemination of information, expressing aims, objectives, and providing a bibliography.
- Further monitoring and presentation of activities, either of working group members or interested external individuals.

Appendix 17

Report of the International Gravity Field Service – Feb. 2005

Chairman: Rene Forsberg, Danish National Space Center
rf@spacecenter.dk

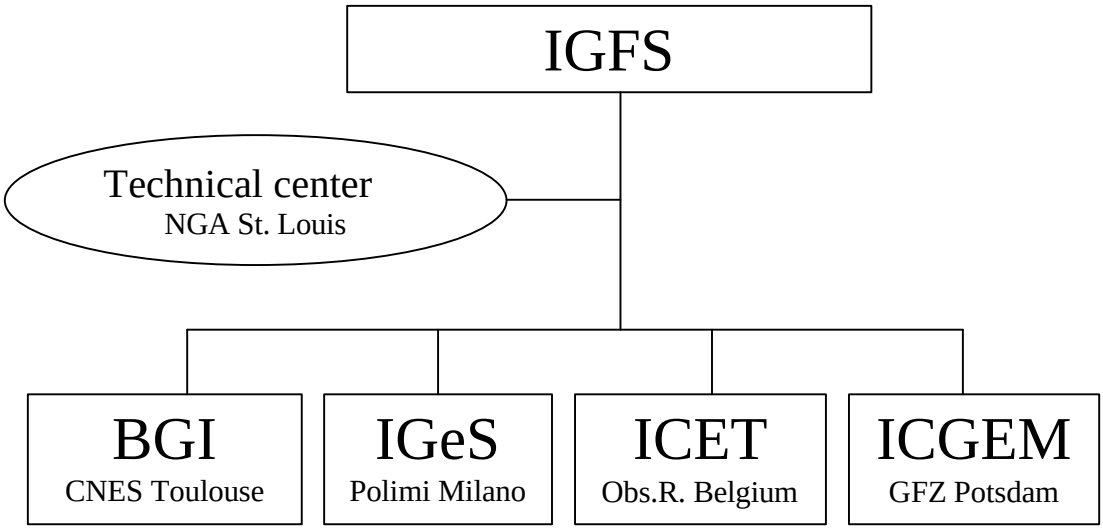
The International Gravity Field Service (IGFS) is an "umbrella service", coordinating the gravity-related services under the International Association of Geodesy (IAG). The IGFS was approved by IAG at the IUGG General Assembly in Sapporo 2003. The primary purpose of the IGFS is - in addition to the service coordination - to represent gravity field geodesy more unified in relation to other parts of geodesy, notably in connection with the IAG project GGOS – Global Geodetic Observing System. The IGFS is presently still under formation ("in statu nascendi"), and the active cooperation and communication between existing services under the IGFS umbrella could be somewhat improved. It is not presently not the idea that the IGFS should serve the scientific community directly, but focus on the inter-service coordination, aid in the data collection, establish new service elements ads required, and – to some degree – participate in outreach of more general gravity field nature.

Current structure of the IGFS

The following service entities are presently active under the IGFS umbrella:

- International Gravimetric Bureau (BGI) – *director G. Barriot*
- International Geoid Service (IGeS) – *director R. Barzagi*
- International Center for Earth Tides (ICET) – *director B. Ducarme*
- International Center for Global Earth Model (ICGEM) – *director t.b.a.*

In addition the Geodesy and Geophysics Department at National Geospatial-Intelligence Agency (NGA, *chief geodesist S. Kenyon*), serve a special role as an IGFS Technical Center, interacting both with the IGFS services and directly with the scientific community, supplementing especially BGI and IGeS activities in terms of collecting and disseminating gravity and geoid data. A proposed service to collect and provide digital terrain models (DEMs) for gravity field modelling purposes (De Montfort University, UK, *P. Berry)* is not yet operational. The activities of the IGFS is governed by an Advisory Board, consisting of the service directors, IAG representatives (*C. Jekeli, M. Sideris*) and two members of the IGFS affiliates (*D. Blitzkow and H. Denker).*



Ongoing activities of the IGFS

1st Advisory Board meeting: Nice, April 2004. Agenda and structure of the IGFS confirmed. Next advisory board planned for Cairns, August 2005.

Preparations for 1st International Symposium of the IGFS in Istanbul, Turkey, September 2006, is under way. The IGFS Symposium will partially carry on the activities of the earlier joint Gravity and Geoid symposia under the auspices of the former International Gravity and Geoid Commission. A scientific steering group has been appointed and a technical program is being prepared. The Geodetic Department of the Turkish Military Mapping Agency will be leading the local organization committee (*chairman A. Kilicoglu).*

A joint IAG Commission 2 / IGFS working group for validation of new EGM05 ultra-high resolution (n_{max} = 2160) global gravity field model (NGA/NASA) have been established. The EGM05 will likely serve as a de facto standard for global gravity field and geoid information for a long period after 2005, equivalent to the success of EGM96. The IGFS will actively support the release of regional gravity field data for various regions of the world to enhance the overall quality of EGM05.

Other main activities:
* Joint service schools: Microgravimetry school, BGI and ICET, Canary Islands, planned for fall 2005.
* Joint bulletin: Newton's Bulletin – joint electronic journal of the BGI and IGeS.
* Geoid schools: New IGeS Geoid School successfully held in Budapest, Feb. 2005 (with approx. 60 participants).

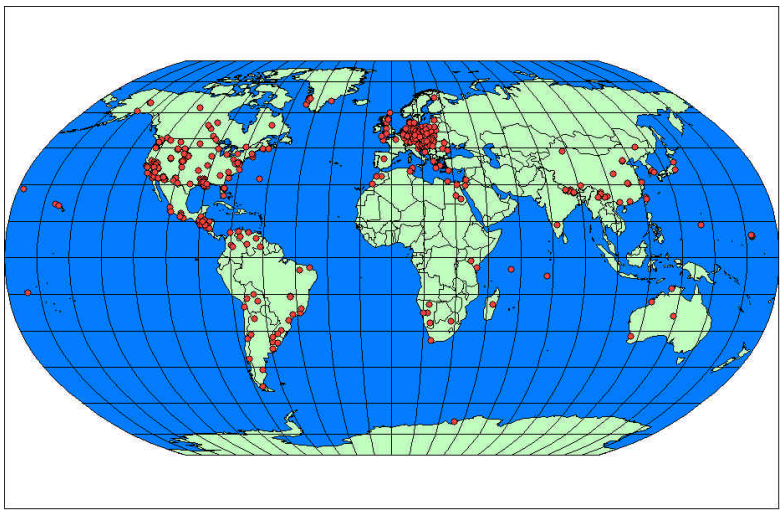
Web sites of the IGFS services:
BGI – http://bgi.cnes.fr
IGeS – http://www.iges.polimi.it
ICET – http://www.astro.oma.be/ICET
ICGEM – http://icgem.gfz-potdam.de/ICGEM/ICGEM.html

The IGFS own website has not yet been established (available a.s.a.p. at the new DNSC premises of the chairman).

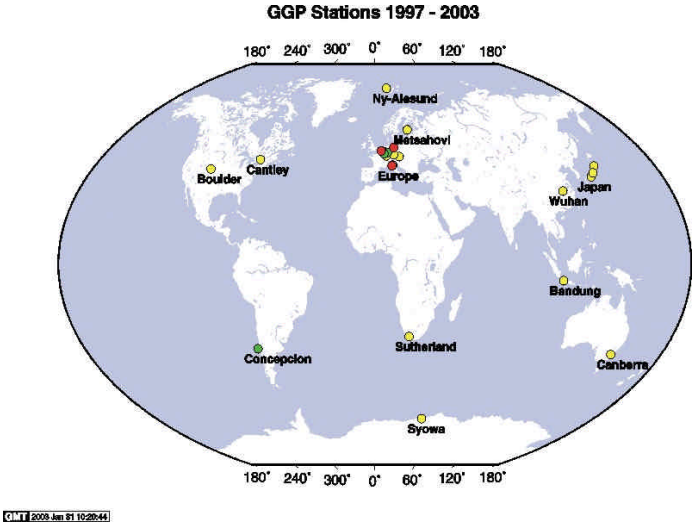
Outlook

The IGFS should in cooperation with the gravity-related services provide gravity field input, standardization and outreach to the GGOS, including such activities as

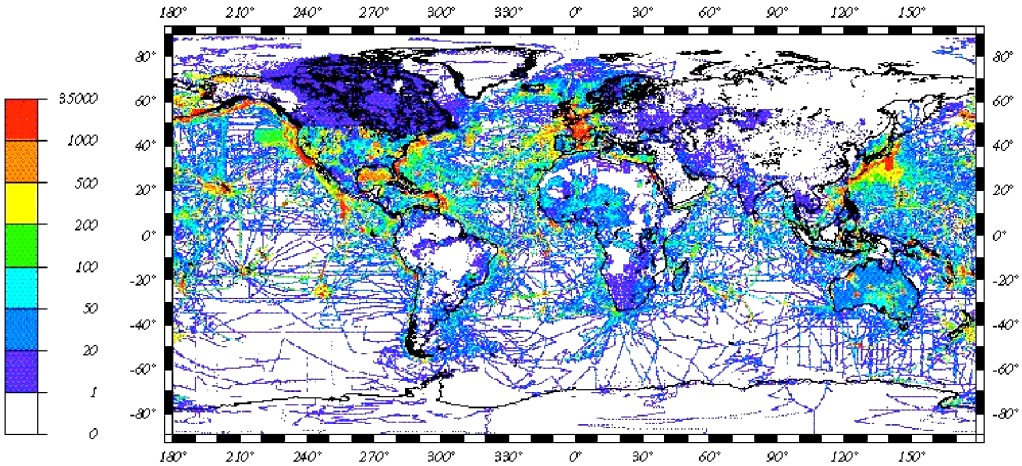
- encourage fundamental gravity field observation networks (e.g., a global absolute reference net, co-located with satellite stations and other geodetic observation techniques);
- encourage the data collection and release of marine, surface and airborne gravity data for improved global model development (e.g, EGM05);
- encourage the use of consistent standards for gravity field models across the services, and for combination of satellite and terrestrial gravity field data;
- encourage timely release of satellite gravity field data from space agencies;
- encourage establishment of new IAG service "homes" for new science applications (e.g., time-varying gravity).



Absolute gravity measurement coverage (NGA)



Coverage of superconducting gravimeters (ICET/Global Geodynamics Project)



Coverage of unclassified surface gravimetry (BGI; approx 12 mio points)

Appendix 18

Proposal for a Joint Working Group (JWG)
Between International Gravity Field Service (IGFS) and the IAG Commission 2

Evaluation of Global Earth Gravity Models

Chair: Dr. Jianliang Huang (Geodetic Survey Division, CCRS, NRcan, Canada)
Vice-chair: Dr. Christopher Kotsakis (Aristotle University of Thessaloniki, Greece)

Terms of Reference

The CHAMP and GRACE satellite gravity missions, along with the upcoming GOCE mission, are and will be mapping the Earth's gravity field with significantly increasing accuracy and spatial resolution. The data obtained from these missions are being and will be used to develop a series of new static satellite-only gravity models down to 150 – 200 km wavelength, as well as combined Earth Gravity Models (EGMs) down to about 20 km wavelength. The evaluation of such global EGMs is commonly based on comparisons with other "external" data sets that depend on the same gravity field. The various centers responsible for the development of these models routinely perform such comparisons using a variety of validation data sets such as geoid heights from GPS and leveling heights, airborne and surface gravity measurements, marine geoid heights from mean oceanographic sea surface topography models and altimetry observations, orbits from other geodetic and altimetry satellites etc.

In response to the call of having an independent and coordinated initiative for the evaluation of the new EGMs, a new Joint Working Group (JWG) has been established between IGFS and the IAG Commission 2. The main objective of the JWG is to develop standard validation/calibration procedures, and to perform the quality assessment of GRACE-, CHAMP- and GOCE-based satellite-only and combined solutions for the static Earth's gravity field. The external data sets that will be used for such purposes include mainly GPS-leveling data, airborne and surface gravity data, mean oceanographic sea surface topography models and altimetry data, orbit data from other geodetic and altimetry satellites and astro-geodetic deflection data etc.

Another equally important evaluation is with respect to temporal variation of the Earth's gravity field derived from the GRACE monthly gravity solutions. The repeated absolute/relative gravity measurements and super-conducting gravity observations provide the most accurate temporal variation on the ground. As part of the initiative, validation/calibration methods for temporal gravity variation will be explored.

Program of Activities

1. The JWG creates opportunities through communication and workshops/conferences for international cooperation to develop and propose standard methods for evaluating global EGMs using external geodetic and oceanographic data. A specific research area of interest will be the issue of how to handle the different spectral content of satellite-based global gravity field models and terrestrial gravity data.
2. The JWG defines a set of synthetic data to test the feasibility and the performance of various evaluation methods for EGMs.
3. The JWG conducts evaluation of new global EGMs.
4. The JWG explores evaluation methods for temporal gravity variation.
5. The JWG encourages active participation and contribution from its members through email contact, conferences/meetings, scientific presentations and publications.
6. A WWW site will be created to facilitate communication, information and data exchanges.

The Joint Working Group reports to IGFS and the Commission 2.

Membership:

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Dr. Min Kang Cheng, CSR, University of Texas & Austin, USA
Dr. Heiner Denker, University of Hannover, Germany
Prof. Will Featherstone, Curtin University of Technology, Australia
Dr. Rene Forsberg, National Space Centre, Denmark
Dr. Thomas Gruber, IAPG, TUM, Germany
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Dr. Jaroslav Klokocníc , Astronomical Institute of the Acad. of Sciences, Czech Republic
Dr. Christopher Kotsakis, Aristotle University of Thessaloniki, Greece
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