Joint Working Group (JWG) 0.1.2.
Strategy for the Realization of the International Height Reference System (IHRS)

Summary of the Business Meetings held at IAG-IASPEI 2017 (Kobe, Japan)

Date — Monday 31 July 2017, 6:00 to 8:00 pm
Thursday 3 August 2017, 6:30 to 8:00 pm
Saturday 5 August 2017, 9:00 to 12:00 pm

Place — Joint Scientific Assembly of the International Association of Geodesy and the International Association of Seismology and Physics of the Earth's Interior (IAG-IASPEI 2017), Kobe International Convention Centre.

Attendees — D. Roman (USA), J. Ågren (Sweden), J. Huang (Canada), L. Sánchez (Germany), Y.M. Wang (USA), D. Avalos-Naranjo (Mexico), J. Mäkinen (Finland), M. Sideris (Canada), C. Tocho (Argentina), R. Barzaghi (Italy), U. Marti (Switzerland), H. Wziontek (Germany), I. Oshchepkov (Russia), H. Abd-Elmotaal (Egypt), R. Grebenitcharsky (Saudi Arabia), G. Guimaraes (Brazil), P. Dykowski (Poland), V. Grigoriadis (Greece), S. Claessens (Australia).

Topics
1) Report of activities (L. Sánchez)
2) On the standardisation of regional gravity potential determination for the realization of IHRS (J. Ågren, J. Huang), presentation + discussion
3) Interaction with the JWG 2.2.2: The 1 cm geoid experiment (Y.M. Wang)
4) The permanent tide and the International Height Reference System IHRS (J. Mäkinen)
5) Others

1) **Report of activities** (L. Sánchez)

A description of the present achievements of the JWG 0.1.2 is presented. It includes (see Annex 1):

- A summary of the JWG terms of reference to provide all meeting attendees with a homogeneous context.
- Definition of the IHRS and immediate objectives to advance in its realisation.
- Station selection for a first approximation to the International Height Reference Frame (IHRF) network.
- An inventory of the numerical experiments that are being presently performed for the computation of the potential values.

Main conclusions:

- The geodetic stations selected up to now for the IHRF reference network should be the basis for the computation of the potential values. Further changes (additional stations) may be considered without problem.
- A "centralised" computation of the potential values (like the geometric coordinates in the ITRF) is (still) complicated due to the restricted accessibility to terrestrial gravity data. In this way, it is necessary to count on national/regional gravity field modellers.
- The different numerical experiments performed up to now for the computation of potential values provide results with large discrepancies (see slides 9, 10, 11 and 12 in Annex 6).

- To reduce the discrepancies between the different computations, it is necessary to outline a basic set of standards and conventions.
- Therefore, the JWG 0.1.2. ask for the support of (see item 2):
  - IAG SC 2.2: Methodology for Geoid and Physical Height Systems (chair: J. Ågren)
  - IAG ICCT JSG 0.15: Regional geoid/quasi-geoid modelling (chair: J. Huang)

2) **On the standardisation of regional gravity potential determination for the realization of IHRS** (J. Ågren, J. Huang)

This presentation faces the two following questions (see Annex 2):

- Is it possible to identify the basic requirements to compute regional models that represent one and the same global gravity potential field?
- Does it make sense to outline a roadmap for the gravity potential modelling that standardises the procedure and minimises sources of disparity between different regional computations?

Main conclusions:

- A “standard” procedure/strategy for the computation of the potential values may not be suitable, as regions with different characteristics apply particular approaches (e.g. modification of kernel functions, size of integration caps, geophysical reductions like GIA, etc.).
- It would be very difficult to single out a certain “IHRS method” for the potential computation at the present time. This would require that the active gravity field modellers agree on this.
- The alternative is to standardise as much as possible to get as similar and compatible results as possible with the different methods. Therefore, a set of basic requirements may be identified/outlined and be applied by regional/national experts for the computation of the potential values. The choice of the computation method is up to the gravity field modeller.
- National/regional experts on geoid modelling should be involved in this task as they have the best possible data for the computation of the potential values. They have access not only to terrestrial gravity data but also to terrain models of high-resolution, GPS/levelling data, etc.
- R. Barzaghi emphasises the necessity of comparing the results obtained by different computing groups, using different methods. J. Ågren and J. Huang recommend a strong interaction with the JWG 2.2.2: The 1 cm geoid experiment, chaired by Y.M. Wang.
- Aim of JWG 2.2.2 (the 1 cm geoid experiment) is the computation and comparison of geoid undulations using the same input data and the own methodologies/software of the colleagues involved in the geoid computation. The comparison of the results should highlight the differences caused by disparities in the computation methodologies (see Item 3).
- M. Sideris points out the necessity of independent geodetic data sets for verification/validation of the potential values. He strongly recommends to make GNSS/levelling data at the IHRF stations available.
- J. Huang mentions the necessity of further studies to see if the omission errors become negligible when the remove-restore Stokes integration is performed with modified kernel functions and a proper integration cap size. This can be probably addressed in the geoid experiments over Colorado (see item 3).

- J. Ihde distributed a further contribution about the assessment of accuracy values for the potentials at the IHRF stations via e-mail (see Annex 3). Unfortunately, this document could not be discussed in this meeting because a lack of time. It should be considered in the next actions of the JWG 0.1.2.

3) **Interaction with the JWG 2.2.2: The 1 cm geoid experiment** (Y.M. Wang)

This topic was discussed in an additional splinter meeting on Thursday 3 August 2017; 6:30 to 8:00 pm (see Annex 4):

- Y.M. Wang (NGS/NOAA) agrees to provide us with terrestrial gravity data, airborne gravity, a digital terrain model, deflexions of the vertical and GPS/levelling data for an area of about 700 km2 in Colorado, USA. With these data, the different processing groups should compute potential values for some geodetic stations located in that region. Afterwards, the results obtained individually should be compared.
- At present, the airborne gravity is being measured. It is expected to get access to the complete data set by spring 2018.
- In parallel, a basic set of standards should be set up (e.g. normal gravity field, W_0 reference value, zero degree correction: $N_1 = \zeta_1 = T_1 = 0$, reference frames for heights and horizontal positions of the terrestrial gravity data, a common satellite-only GGM, etc.), see slide No. xx in Annex 4. These standards will be distributed together with the NGS/NOAA input data set.
- Initial contributors: J. Ågren, J. Huang, L. Sánchez, Y.M. Wang, I. Oshchepkov, V. Grigoriasis, S. Claessens. If somebody wants to join this experiment, please send a message to lm.sanchez@tum.de.

4) **The permanent tide and the International Height Reference System IHRS** (J. Mäkinen)

This topic was included in the agenda of the JWG 0.1.2 business meeting, but it could not be discussed because a lack of time. However, J. Mäkinen gave a detailed presentation in the Symposium G02-6. This presentation is included in this summary (see Annex 5), as it provides a clear guidance how to handle the permanent tide in the realisation of the IHRS.

Main conclusion: "*compute everything in zero-tide system, transfer to mean-tide at the very end, using simplified formulas. This will keep the computations consistent with the gravity/geoid work in zero-tide without introducing an awful amount of new transformations and corrections*" (see slide No. 2 in Annex 5).

5) **Others**

- New members of the JWG 0.1.2: Our colleagues Koji Matsuo (Geospatial Information Authority of Japan) and Hussein A. Abd-Elmotaal (Minia University, Egypt) became members of the JWG 0.1.2. They will support the IHRF activities in Japan and Africa, respectively.
- Presentations, reports and articles related to the JWG 0.1.2 are available at https://ihrs.dgfi.tum.de/. This information is also mirrored at www.ggos.org.
- The presentation "Establishing an IHRS reference station" given by G.S. Vergos and I.N. Tziavos at the Section G02-6 of the Kobe meeting is made available for the WG (see Annex 7).
- Next meeting: in the frame of the Joint Commission 2 and IGFS symposium GGHS 2018, September 17 - 21, 2018, Copenhagen, Denmark.

Annexes

1) Report on the Working Group on the Strategy for the Realization of the International Height Reference System (IHRS), L. Sánchez.
2) On standardization of regional gravity potential determination for realization of IHRS, J. Ågren and J. Huang.
3) Some remarks/considerations to the "Strategy for the Realization of the International Height Reference System (IHRS)", J. Ihde.
4) Yan Ming Wang presentation about a test area for the evaluation/comparison of potential values computed using different methods.
5) The permanent tide and the International Height Reference System IHRS, J. Mäkinen.
6) A first approximation to the International Height Reference Frame (IHRF), L. Sánchez, H. Denker, R. Pail, V. Lieb, J. Huang, D. Roman, J. Ågren, M. Amos, J. Ihde, R. Barzaghi, M. Sideris, I. Oshchepkov, D. Blitzkow, A.C.O.C. Matos, D. Piñon, D. Avalos, S.R.C. Freitas, R. Luz.
7) Establishing an IHRS reference station, G.S. Vergos and I.N. Tziavos.