Celebrating the Centennial of the IAG in IUGG (Brussels 1919 ... Montreal 2019)

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Technical University of Munich (TUM), Germany

SIRGAS Symposium, Rio de Janeiro, Brazil, 11 – 14 November 2019
Geodesy at the beginning of the 20th century

The principal problem of geodesy around the year 1900 was the physical reference figure of the Earth. *Carl Friedrich Gauss* (1777 – 1855) described it as the surface of the oceans under calm conditions (without currents and tides), and *Johann Benedict Listing* (1808 – 1882) named it the geoid. It is an equipotential surface, to which the plumb line is always rectangular.

Deflection of the vertical
\[ \eta = (\Lambda - \lambda) \cos \varphi \]
\[ \xi = \Phi - \varphi \]

The determination of the geoid was only achievable by astronomic positioning (uncertainty at the ~ 100 m level).

Astronomic coordinates \( \Phi, \Lambda \) refer to the geoid, geodetic \( \varphi, \lambda \) to the ellipsoid.

All geodetic positioning was done in regional (mostly national) networks with coordinates in local reference systems.

Gravity measurements for determining the potential were in the initial stage.
In 1861, the retired Prussian General Johann Jacob Baeyer (1794 – 1885) called for a “Central European Arc Measurement”, and 14 States joined. In 1886, it was extended to the IGA: International Geodetic Association.

Main achievements of the project were:

1875: Meter convention (standard unit of length) Bureau International des Poids et Mesures (BIPM)
1883: Greenwich Meridian (longitude reference)
1899: International Latitude Service (ILS)
1909: Potsdam Gravity System (by pendulum)
1912: Bureau International de l’Heure (BIH)

1916: The “Arc Measurement Convention” ended and was not renewed due to World War I, but continued as IGA of neutral nations.
January 1918: The French geodesist Charles Lallemand (1857–1938) sent a draft convention for a new international geodetic association to delegates of the former IGA, which formed the basis for conferences in London and Paris 1918.

July 1919: At the constituent assembly in Brussels, Belgium, Charles Lallemand was elected President of the IUGG, and William Bowie (1872–1940), the USA representative to the former IGA, President of the Section of Geodesy.

William Bowie followed Charles Lallemand as the second IUGG President from 1933 – 1936.

May 1922: The IUGG Section of Geodesy held its constituent assembly during the first IUGG General Assembly in Rome. 59 delegates represented 23 countries: Europe 14, Africa (Egypt, Morocco) 2, Asia (Japan) 1, Australia 1, North America 3, South America 2 (Brazil, Uruguay).
1922 (Rome): Proposed activities of the Section of Geodesy

Themes:
• Observations and theories on the deflections of the vertical;
• Gravity intensity (on land and on sea);
• Isostasy;
• Earth tides;
• The shape of the geoid, and the stability of the Earth in time.

Scientific Issues:
• Density and precision of triangulation points, baselines, astronomic coordinates, etc.;
• Minimum details to be included in publications of different works;
• Choice of an international reference ellipsoid;
• Choice of a unique map projection system;
• Lines to follow or regions to explore the geoid and gravity determination;
• A bibliography of geodesy.

Publications:
• National Reports: “Travaux de la Section de Géodésie“ (existing to date);

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1922 (Rome): Triangulation (national report of Brazil)

Sta. Catarina:
National triangulation network with regional densifications.
1924 (Madrid): International Ellipsoid (Hayford Spheroid)

The computation of the Hayford spheroid included (besides those from Europe) measurements from North America and (to a lesser extent) from other continents; and it included isostatic measurements to reduce plumb line divergences.

It was the official reference ellipsoid until 1967 (GRS 67)

*John F. Hayford 1868 – 1925*
(https://de.wikipedia.org/)

**Comparison of parameters:**

<table>
<thead>
<tr>
<th></th>
<th>Bessel 1841</th>
<th>Helmert 1906</th>
<th>Hayford 1910</th>
<th>GRS 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>flattening f</td>
<td>1 : 299,15</td>
<td>1: 298,3</td>
<td>1 : 277,0</td>
<td>1 : 298,257</td>
</tr>
</tbody>
</table>
1922 – 1939: Gravity measurements

Vening-Meinesz pendulum (used e.g. on submarine Nautilus 1923-1938)

F. A. Vening-Meinesz (IAG President 1933 – 1946) with pendulum (https://de.wikipedia.org)
1946 – 1963: Re-establishment of the IAG after World War II

Dec 1945: IUGG Executive Committee meeting in Oxford, UK

July 1946: Extraordinary IUGG General Assembly in Cambridge, UK

Aug 1946: IAG Permanent Commission meeting in Paris, France

IUGG General Assembly, Oslo, Norway, 1948

Scientific structure composed of 5 sections:

- Section I: Triangulation
  - *Connection of national networks*

- Section II: Precise Levelling
  - *Atmospheric refraction; gravity reduction to the geoid*

- Section III: Geodetic Astronomy
  - *Methods for latitude, longitude and azimuth determination*

- Section IV: Gravimetry
  - *Probing the Potsdam Gravity System*

- Section V: Geoid
  - *Gravimetric global geoid (Heiskanen 1957)***
1946 – 1963: Re-establishment of the IAG: Triangulation

First important IAG project: Réseaux Européennes des Triangulations (RETrig) (European Triangulation Net)

1947: Order of the US AMS to create a unified net
1950: European Datum 1950
1951: IAG resolution for the scientific continuation, at the IUGG General Assembly in Brussels
1987: Final solution (ED87) with 8047 stations at the IUGG General Assembly in Vancouver
1946 – 1963: Re-establishment of the IAG: Geoid determination

The Columbus geoid (Heiskanen, 1957)

Figure 3.21: The generalized geoid of Uotila (1962) computed from a spherical-harmonic expansion of the fourth degree. Unit 1 meter; flattening of the reference ellipsoid $f = 1/298.24$. 
1963 – 1983: Inception of the Space Age in the IAG

IUGG General Assembly, Berkeley, USA, 1963

Fundamental change of the scientific structure:
- Section I: Geodetic Positioning (including terrestrial and spaceborne)
- Section II: Levelling and Crustal Motion (including variations in time)
- Section III: Geodetic Astronomy and Artificial Satellites
- Section IV: Gravimetry
- Section V: Physical Geodesy (more general than geoid determination)

IUGG General Assembly, Moscow, Russia, 1971

Slightly changed emphasizing space techniques and applications:
- Section I: Control Surveys (horizontal and vertical)
- Section II: Space Techniques (including VLBI)
- Section III: Gravimetry
- Section IV: Theory and Evaluation (new models and computer programs)
- Section V: Physical Interpretation (first step to geodynamics research)
Inception of the Space Age in the IAG: Satellite triangulation

Echo 1:
1960-08-12

Echo 2:
1964-01-25

PAGEOS:
1966-06-24

Wild BC4 chamber
The late 1960s: Result of the optical satellite triangulation

Global network of satellite triangulation: accuracy ±2 – 8 m (Schmid, 1974). The network provides for the first time geocentric coordinates globally.
The 1970s: Satellite Doppler measurements

Global network based on satellite Doppler measurements: accuracy at decimeter-level (~40 cm), i.e. tenfold better than the satellite triangulation.
Satellite laser ranging network in the early 1980s (Christodoulidis et al., 1984). The precision (cm-level) is tenfold better than satellite Doppler measurement.
1983 – 2003: Geodynamic research and IAG Services

IUGG General Assembly, Hamburg, Germany, 1983

Changes of structure emphasizing space techniques and a **deformable** Earth:

- **Section I:** Positioning (*general theme*)
  - Commission X: Continental Networks

- **Section II:** Advanced Space Techniques (*standing out from routine*)
  - Commission VIII: Space Techniques for Geodynamics (CSTG)

- **Section III:** Determination of the Gravity Field (*global and regional models*)
  - Commission III: International Gravity Commission (IGC)
  - Bureau Gravimétrique International (BGI)

- **Section IV:** General Theory and Methodology (*more general*)

- **Section V:** Geodynamics (*new broad research field*)
  - Commission V: Earth Tides
  - Commission VII: Recent Crustal Movements (CRCM)
  - Bureau International de l’Heure (BIH)
  - International Polar Motion Service (IPMS)
  - Permanent Service for Mean Sea Level (PSMSL)

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First ITRF: ITRF 1988, based on previous solutions of the Bureau International de l’Heure (BIH) without velocities (Boucher and Altamimi 1990)
1983 – 2003: Geodynamic research: Plate kinematics

Comparison of geodetic & geophysical plate models  
(Drewes 1991)  

Drewes (1988): APKIM1 with 3 plates  
(1991): APKIM3 with 7 plates  
(1999): APKIM9 with 12 plates

First comparison of geophysical and geodetic plate models

IUGG General Assembly, Sapporo, Japan, 2003

Completely **new structure** with Commissions instead of Sections:
- Commission I: Reference Frames *(geocentric)*
- Commission II: Gravity Field *(global and regional)*
- Commission III: Earth Rotation and Geodynamics *(in space and on Earth)*
- Commission IV: Positioning and Applications *(technical and scientific)*
- Inter-Commission Committee on Theory *(including all commissions)*
- Global Geodetic Observing System *(integrating geometry and gravimetry)*
- IAG International Scientific Services *(products for science and practice)*

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<thead>
<tr>
<th>Geometry</th>
<th>Gravity</th>
<th>Overlapping</th>
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<tr>
<td>IERS:</td>
<td>IGFS: Gravity Field</td>
<td>BIPM: Weights and</td>
</tr>
<tr>
<td>Earth Rotation</td>
<td>BGI: Gravimetry</td>
<td>Measures</td>
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<tr>
<td>ILRS:</td>
<td>ICGEM: Global Models</td>
<td>PSMSL: Mean Sea</td>
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<td>Laser Ranging</td>
<td>ISG: Geoid</td>
<td>Level</td>
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<tr>
<td>IVS:</td>
<td>IGETS: Earth Tides</td>
<td>IAS: Satellite Altimetry</td>
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<tr>
<td>VLBI</td>
<td>IDEMS: Elevation</td>
<td>(planned)</td>
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<tr>
<td>IGS:</td>
<td>Models</td>
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<td>GNSS</td>
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<td>IDS:</td>
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<td>DORIS</td>
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GGOS Consortium (1)
(Steering and Election Committee)

GGOS Coordinating Board (1)
(Decision-Making Body)

GGOS Executive Committee
(Management Board)

External Stakeholders

GGOS Coordinating Office
- Director
- Secretariat
- Outreach and User Linkage
- Web and Social Media
- Focus Area Coordination
- Manager of External Relations
- Working Group on DOIs for Geodetic Data

GGOS Bureau of Networks & Observations
- IAG Service Network Representatives (1)
- Committee on Satellite Missions
- Committee on Data and Information Systems
- Committee on Performance Simulations and Architectural Trade-Offs

GGOS Bureau of Products & Standards
- IAG Service Analysis Coordinators & Representatives (1)
- Committee on Earth System Modeling
- Committee on Essential Geodetic Variables
- Working Group on ITRS Standards for ISO TC 211
- Working Group on the Establishment of the Global Geodetic Reference Frame (GGRF)

GGOS Focus Areas
(formerly Themes)
- Unified Height System
- Geohazards
- Sea Level Change, Variability, and Forecasting
- Geodetic Space Weather Research

IERS Working Group
Site Survey and Co-location

IERS Conventions Centre
Standards and Conventions

(1) GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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Statistics (July 15, 2019, final publication in IUGG Comptes Rendus, 2020)

4919 abstracts from 103 countries  (Prague 2015: 5431 from 87 countries)
426 for IAG symposia (= 9%)
1210 for joint symposia (= 25%)
~4000 participants
  832 students (= 21%)
  84 retired (=2%)
  437 with IAG priority (11 %)
  12 from Latin America
210 symposia in total
556 oral sessions  2329 oral presentations
195 poster sessions  1875 posters
Important decisions at the IUGG/IAG General Assembly 2019

Resolutions (https://iag.dgfi.tum.de/fileadmin/IAG-docs/IAG_Resolutions_2019.pdf)

1. **The International Terrestrial Reference Frame (ITRF)** (ident. IUGG Res. 2)
   To recommend to the user community that the ITRF be the standard terrestrial reference frame for positioning, satellite navigation and Earth science applications, as well as for the definition and alignment of national and regional reference frames.

2. **Third Realization of the International Celestial Reference Frame (ICRF)**
   That the ICRF3 should be used as a standard for all future applications...

3. **Establishment of the International Height Reference Frame (IHRF)**
   To engage all countries in the IAG in order to promote and support the implementation of the IHRF (reference stations, gravimetric surveys, ...)

4. **Establishment of the Infrastructure for the International Gravity Reference Frame (IGRF)**
   Establish a set of absolute gravity reference stations on the national level; perform regular absolute gravity observations, ...

5. **Improvement of the Earth’s Rotation Theories and Models**
Important decisions at the IAG General Assembly 2019

New Inter-commission Committees:
- **Geodesy for climate research**: Climate signals in geodetic measurements; improve numerical climate models and climate monitoring systems;
- **Marine Geodesy**: Sea floor monitoring, ocean tides analysis, ocean surface (geoid, sea surface topography) studies, undersea navigation.

New IAG Project:
- **Novel concepts and Quantum Technology for Geodesy**: Atom interferometry, Laser interferometric ranging in space, optical clocks for measuring gravity potential differences (general theory of relativity).

IAG Publication Series:
- **Journal of Geodesy** will be published in *continuous article publishing* (CAP) immediately after review and acceptance (no continuous page numbers).
- **IAG Symposia Series** will be published as open access without charge for authors and readers.
- **Geodesist’s Handbook, IAG Reports** (Travaux de l’AIG) and **IAG Newsletter** are freely accessible in the IAG Home site.
Important decisions at the IAG General Assembly 2019

New Executive Committee (https://www.iag-aig.org/iag-executive-committee)

President: Z. Altamimi (France)
Vice President: R. Gross (USA)
Secretary General: M. Poutanen (Finland)
Immediate Past President: H. Schuh (Germany)
Immediate Past Secretary General: H. Drewes (Germany)
Commission 1 “Reference Frames”: C. Kotsakis (Greece)
Commission 2 “Gravity Field”: A. Jäggi (Switzerland)
Commission 3 “Earth Rotation and Geodynamics”: J. Bogusz (Poland)
Commission 4: “Positioning and Applications”: A. Kealy (Australia)
Inter-Commission Committee on Theory (ICCT): P. Pavel (Czech Republic)
Communication and Outreach Branch (COB): Sz. Rózsa (Hungary)
Global Geodetic Observing System (GGOS): B. Miyahara (Japan)
Representatives of the Services:
J. Böhm (Austria)
T. Herring (USA)
T. Otsubo (Japan)
Members at Large:
S. Costa (Brazil)
Y. Dang (China)
Conclusions and Outlook

The IAG has always been in the front of scientific and practical progress, e.g.

1875: Meter convention (Bureau International des Poids et Mesures, BIPM)

1883: Greenwich Meridian as the longitude reference (Washington 1884)

1912: Bureau International de l’Heure (BIH): Universal Time (UT)

1933: Permanent Service of Mean Sea Level (PSMSL) together with IAPSO

1963: Space techniques: Satellite triangulation, SLR, VLBI


2003: Global Geodetic Observing System: Global change research

2019: Climate research, Marine Geodesy, Quantum Technology

Thank you very much for your attention!