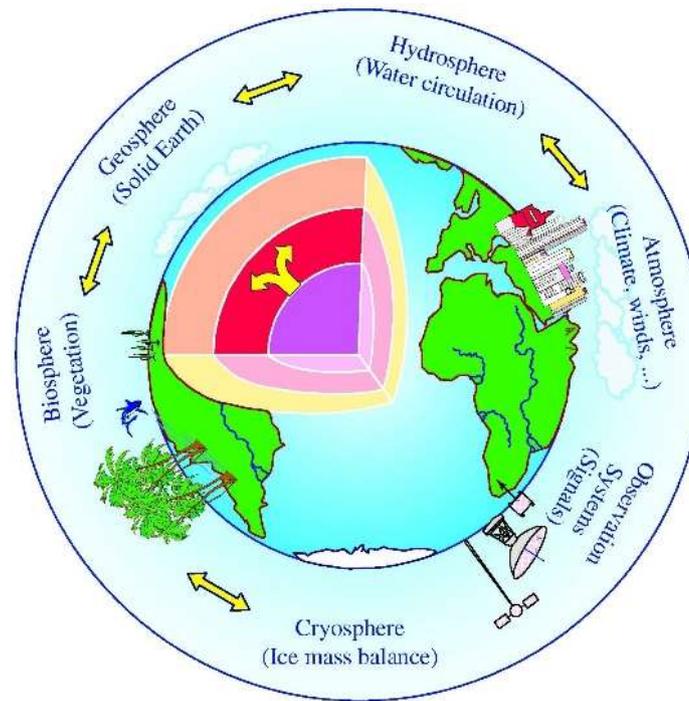


Celebrating the Centennial of the IAG in IUGG (Brussels 1919 ... Montreal 2019)



Hermann Drewes
IAG Representative to SIRGAS
Technical University of Munich (TUM), Germany

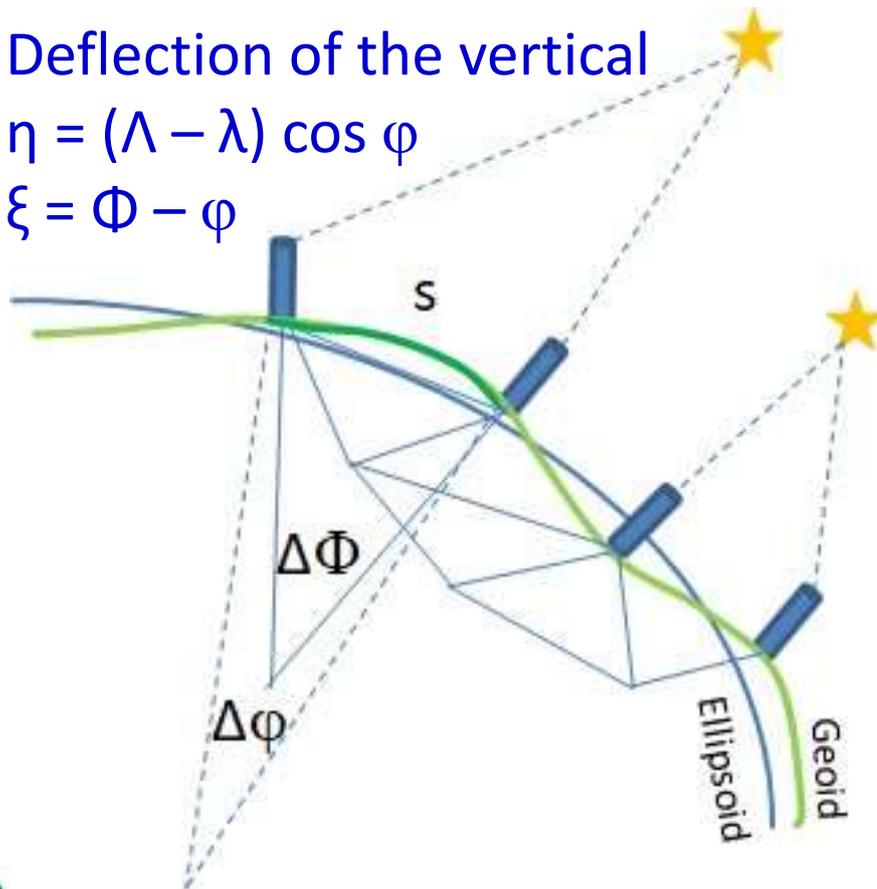
Geodesy at the beginning of the 20th century

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 Φ , Λ refer to the geoid, geodetic φ , λ 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.

Determination of the geoid by international arc measurements



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)

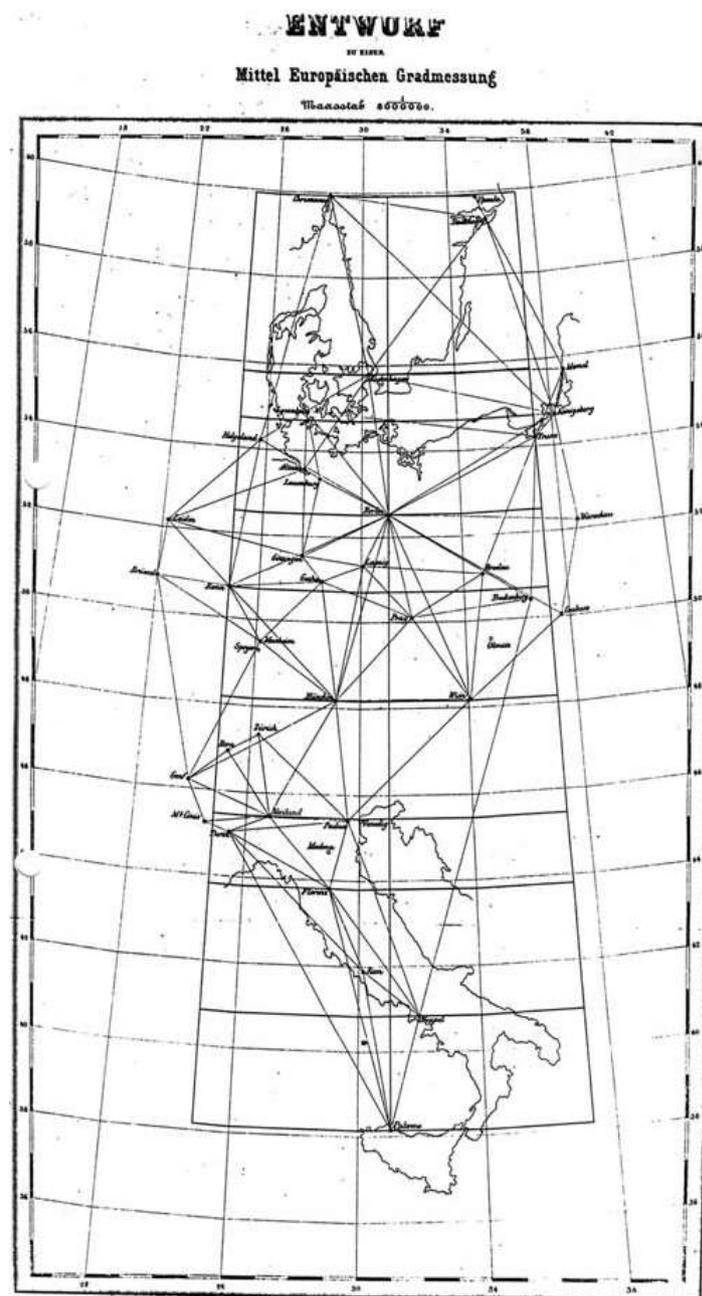
1883: Greenwich Meridian (longitude reference)

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**.



Transition to IUGG / IAG in the International Research Council



Charles Lallemand

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)	



William Bowie

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:

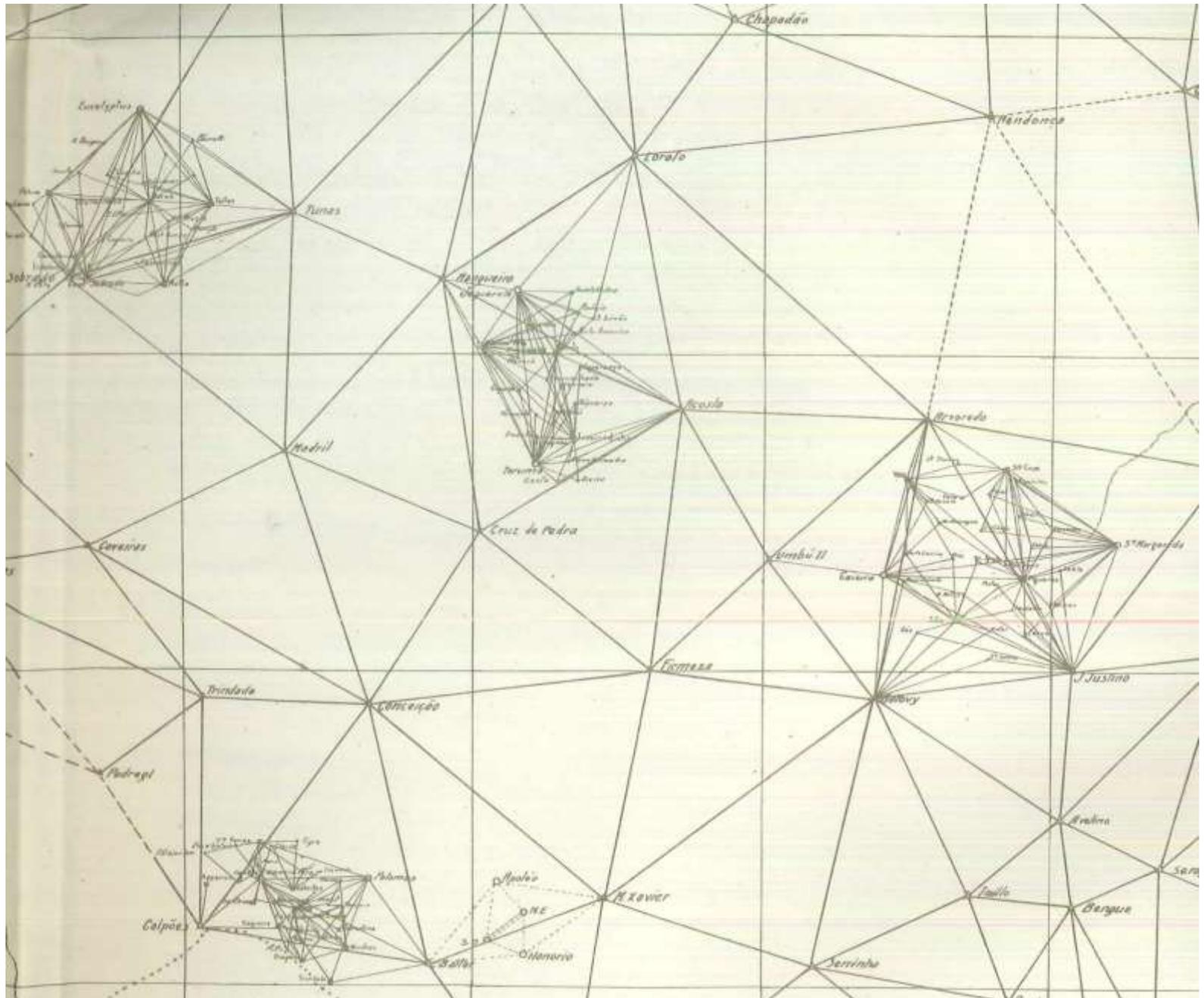
- **Density and precision of triangulation points, baselines, astronomic coordinates, etc.;**
- Minimum details to be included in publications of different works;
- **Choice of an international reference ellipsoid;**
- Choice of a unique map projection system;
- Lines to follow or regions to explore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

Publications:

- National Reports: "*Travaux de la Section de Géodésie*" (existing to date);
- Scientific papers: "*Bulletin Geodésique*" (renamed "*Journal of Geodesy*").

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)

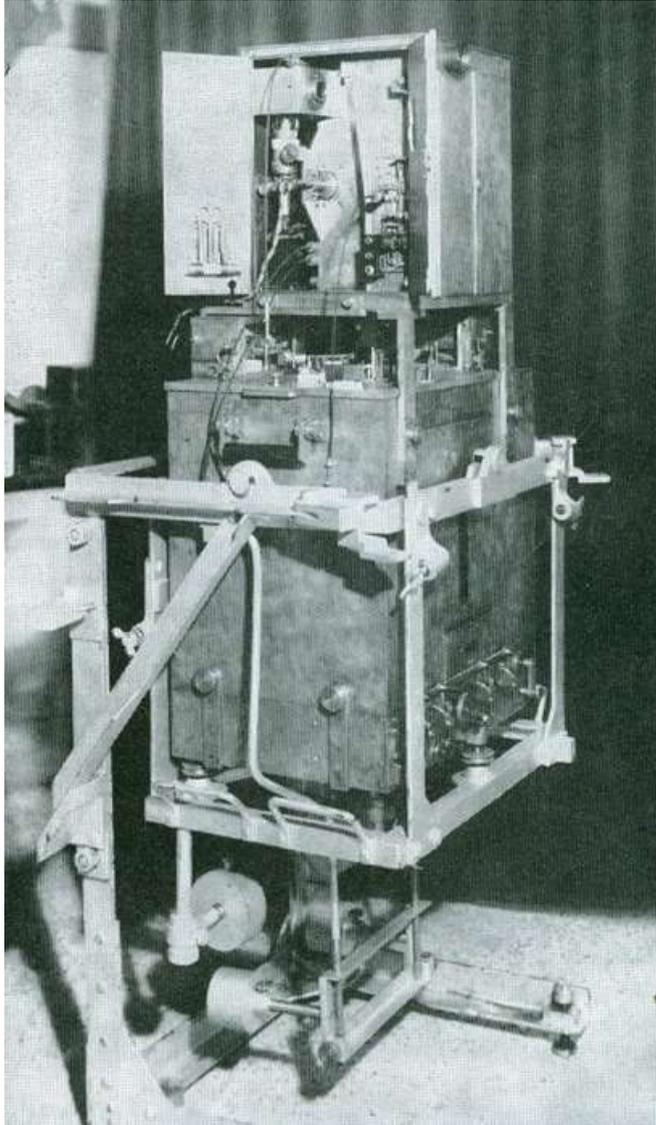
John F. Hayford 1868 – 1925
(<https://de.wikipedia.org/>)

Comparison of parameters:

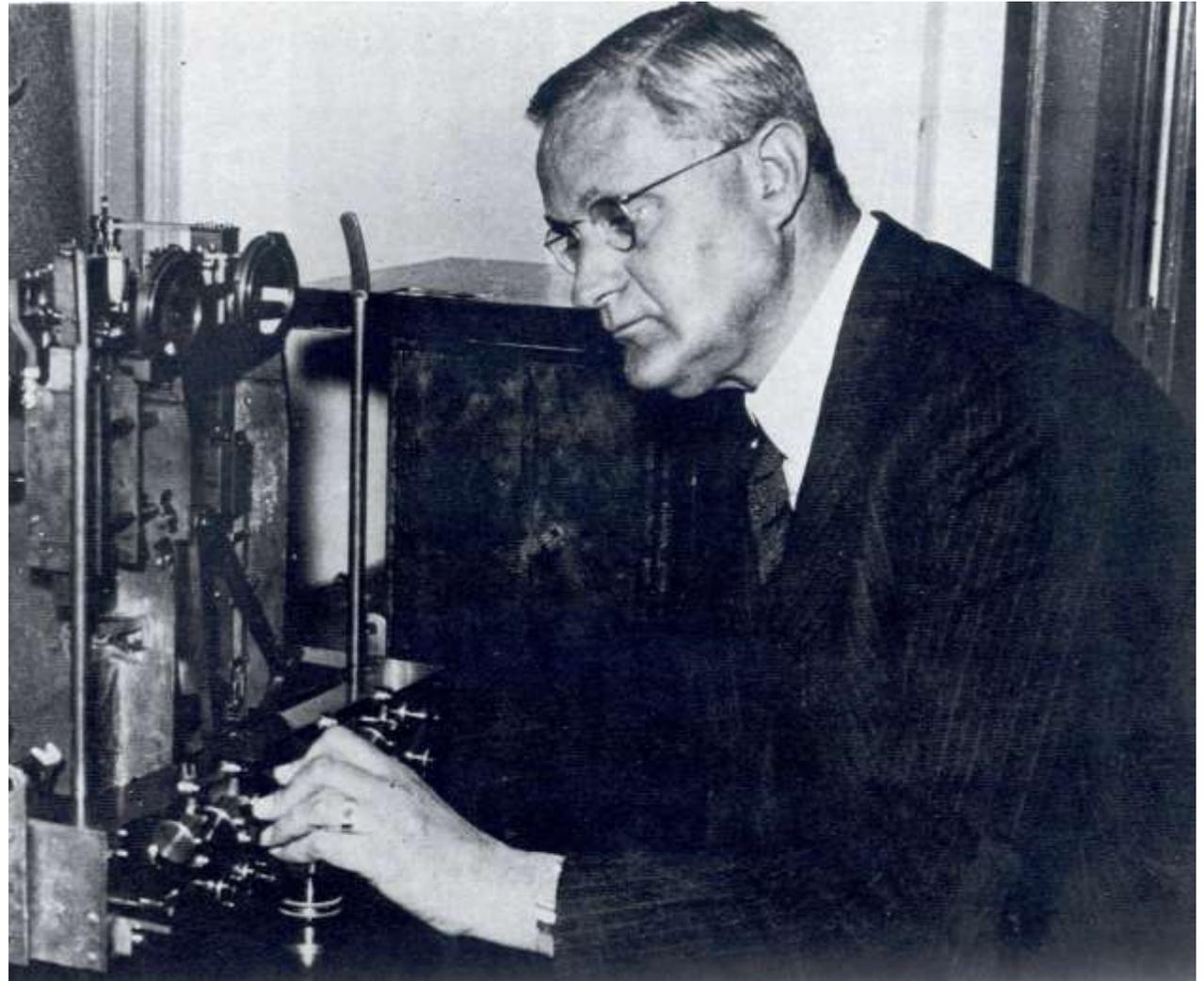
	Bessel 1841	Helmert 1906	Hayford 1910	GRS 1980
Semi-axis a:	6.377.397 m	6.378.200 m	6.378.388 m	6.378.137
flattening f:	1 : 299,15	1: 298,3	1 : 277,0	1 : 298,257

1922 – 1939: Gravity measurements

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



Vening-Meinesz pendulum



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



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

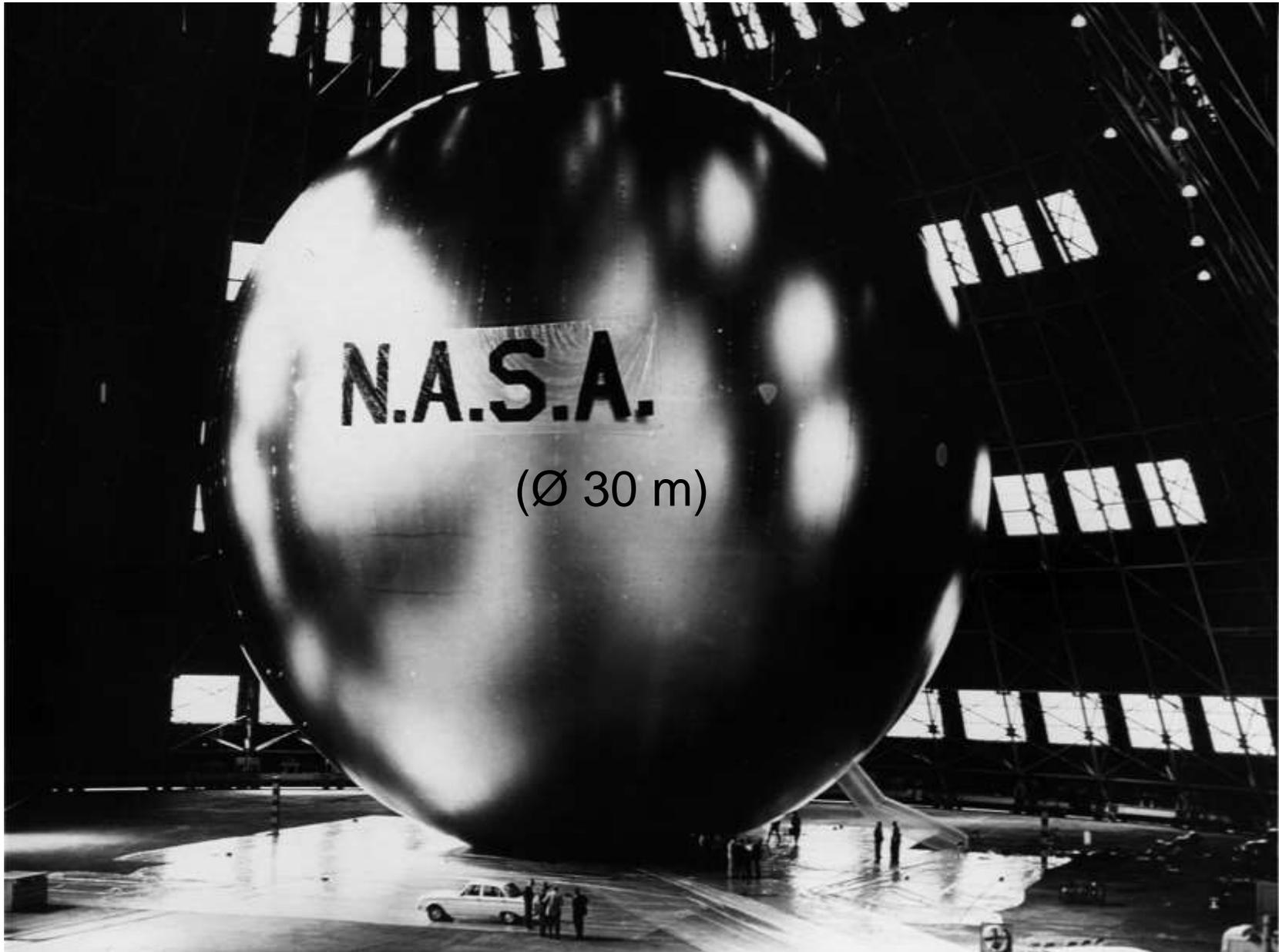
Slightly changed emphasizing space techniques and applications:

- 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*)

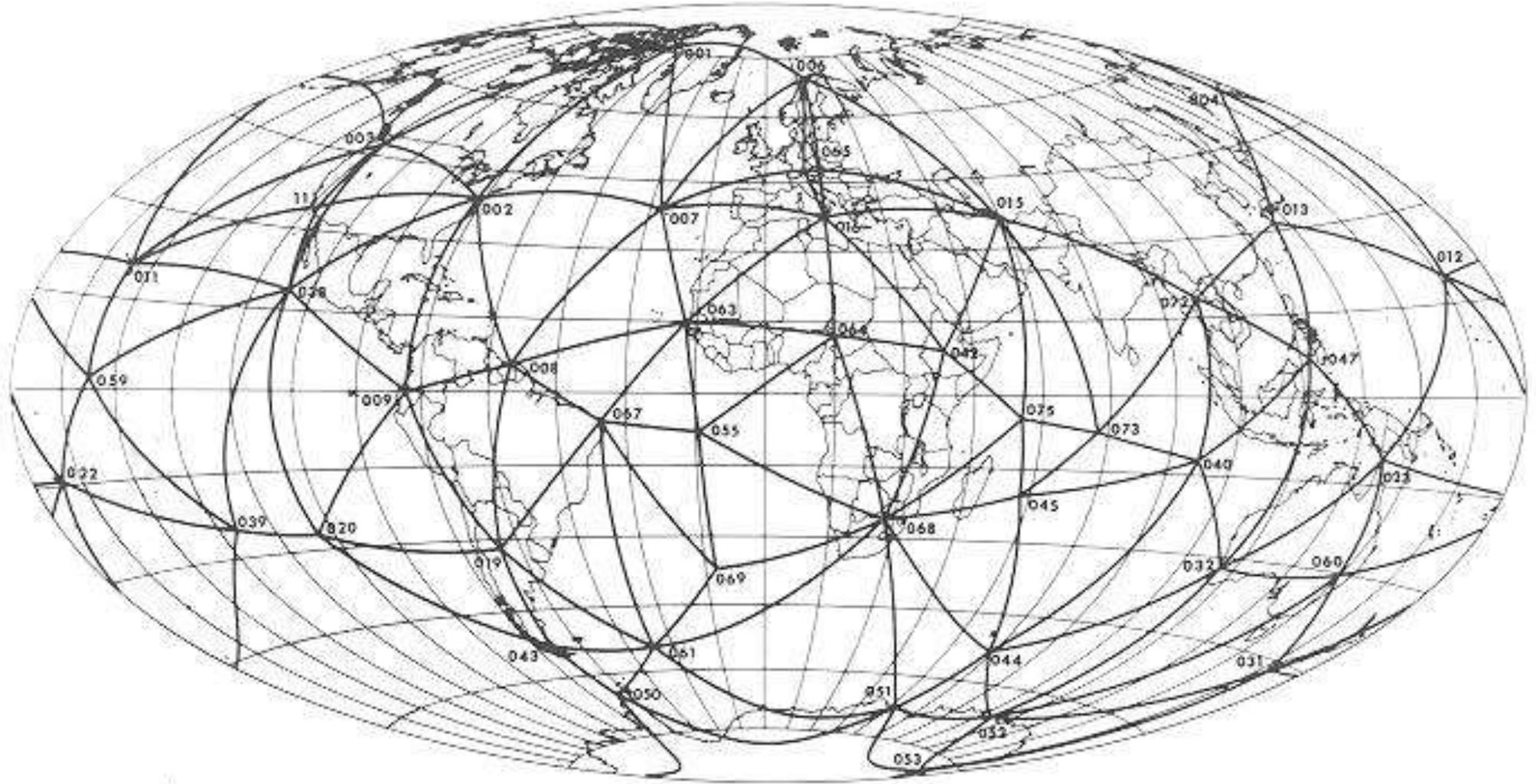
Inception of the Space Age in the IAG: Satellite triangulation

Echo 1:
1960-08-12
Echo 2:
1964-01-25
PAGEOS:
1966-06-24

Wild BC4
chamber

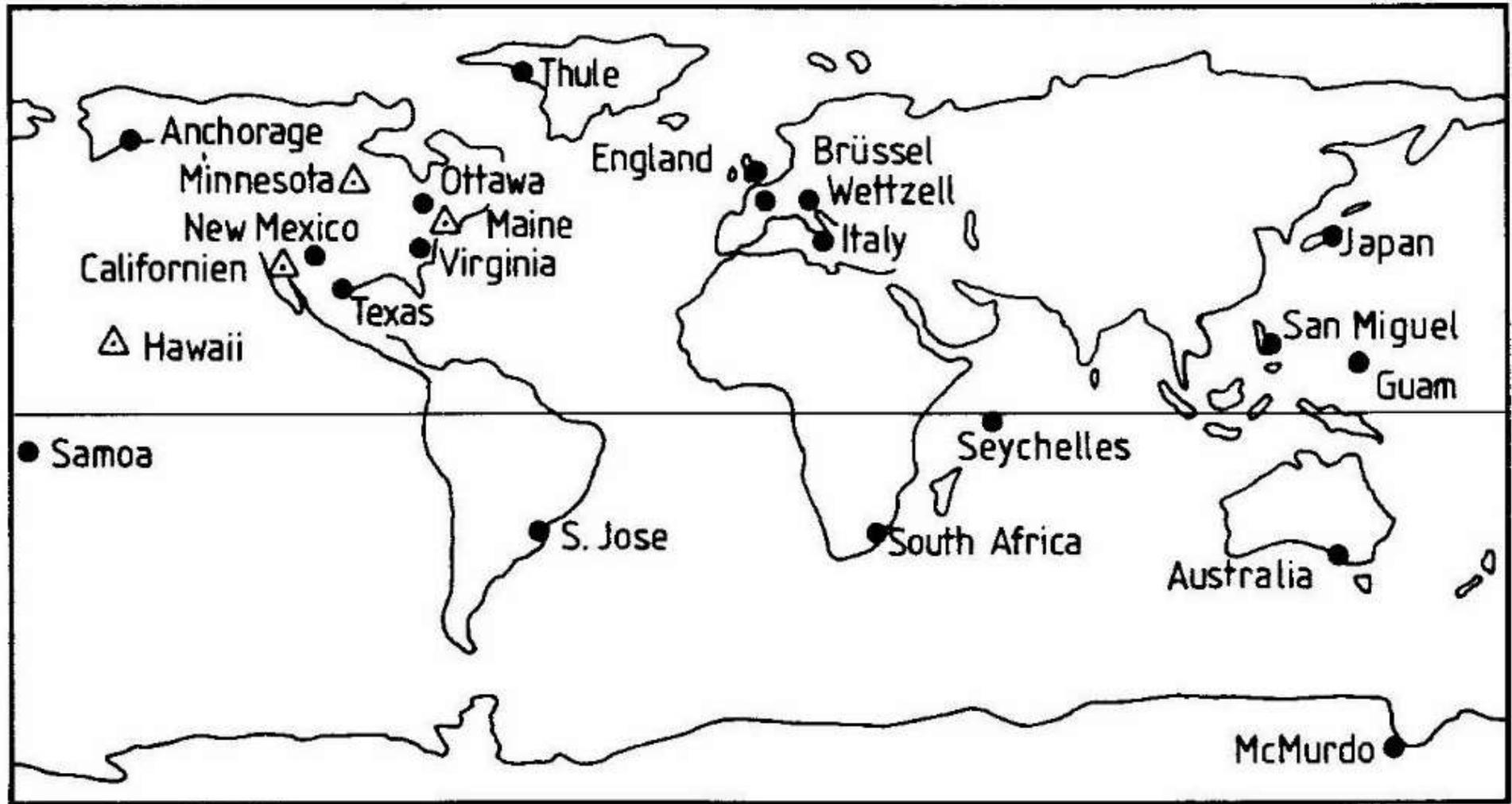


The late 1960s: Result of the optical satellite triangulation



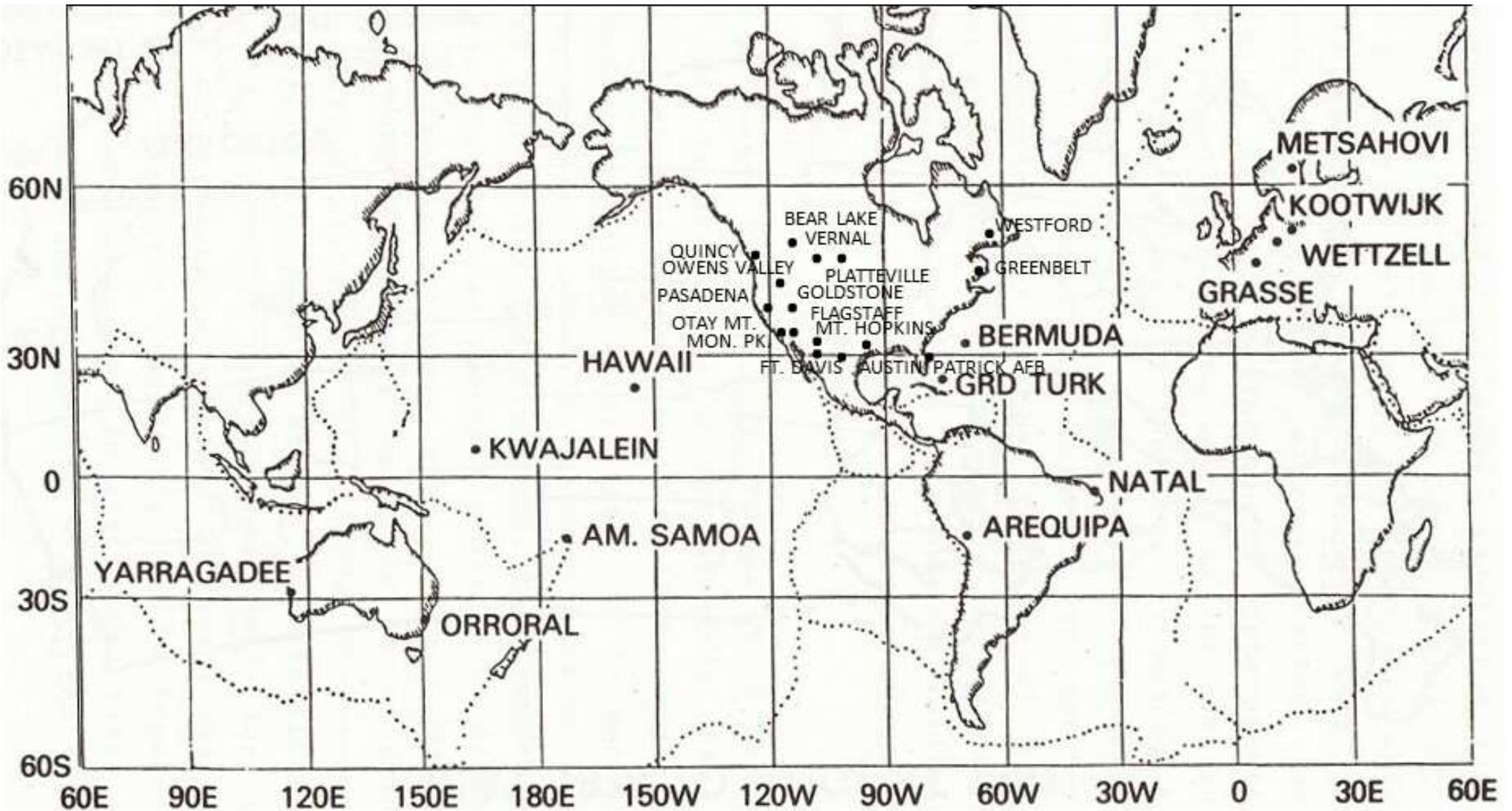
Global network of satellite triangulation: accuracy $\pm 2 - 8$ m (Schmid, 1974).
The network provides for the first time geocentric coordinates globally.

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.

The early 1980s: Satellite Laser Ranging



Satellite laser ranging network in the early 1980s (Christodoulidis et al., 1984). The precision (cm-level) is tenfold better than satellite Doppler measurement.

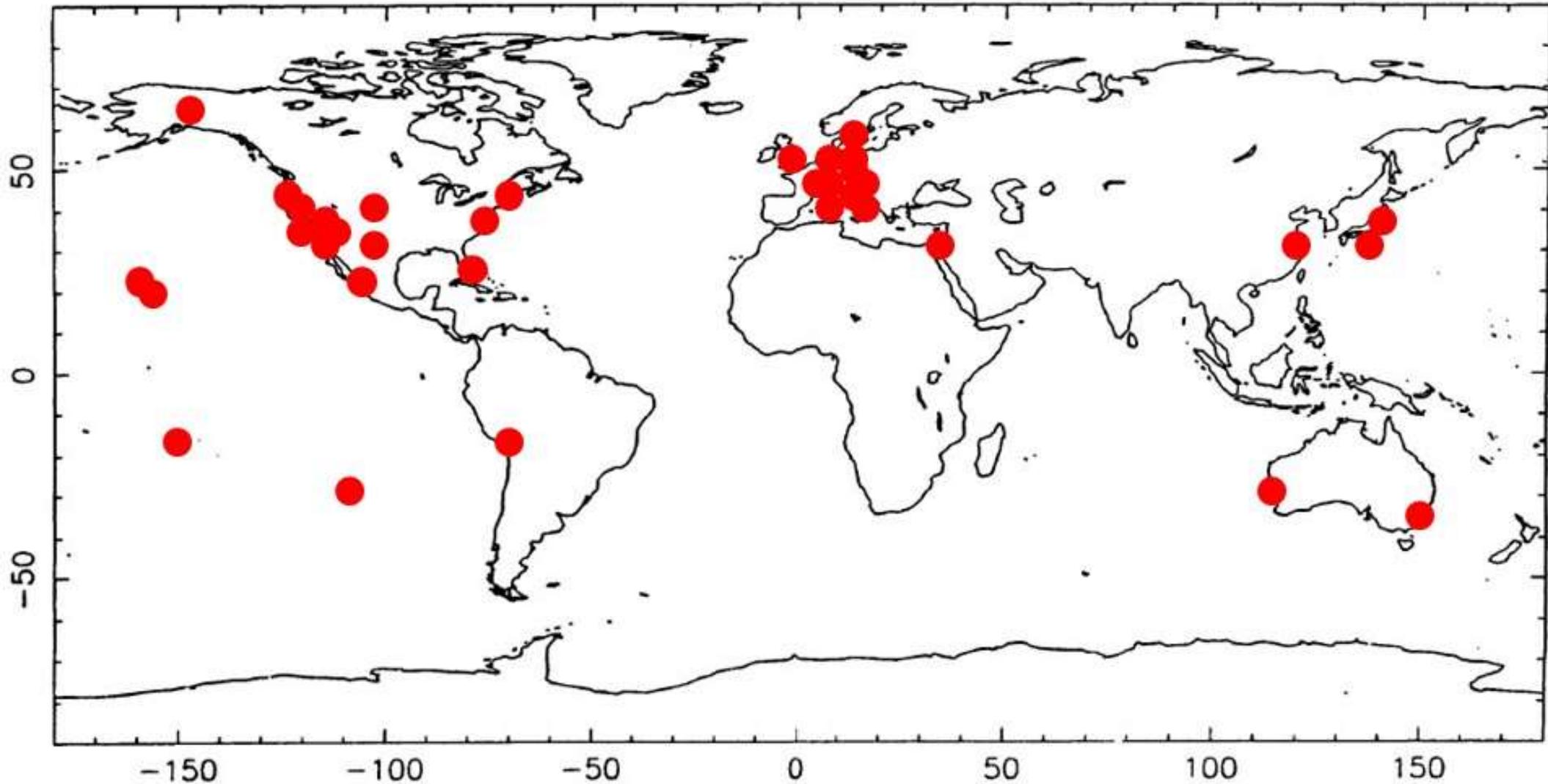
1983 – 2003: Geodynamic research and IAG Services

IUGG General Assembly, Hamburg, Germany, 1983

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

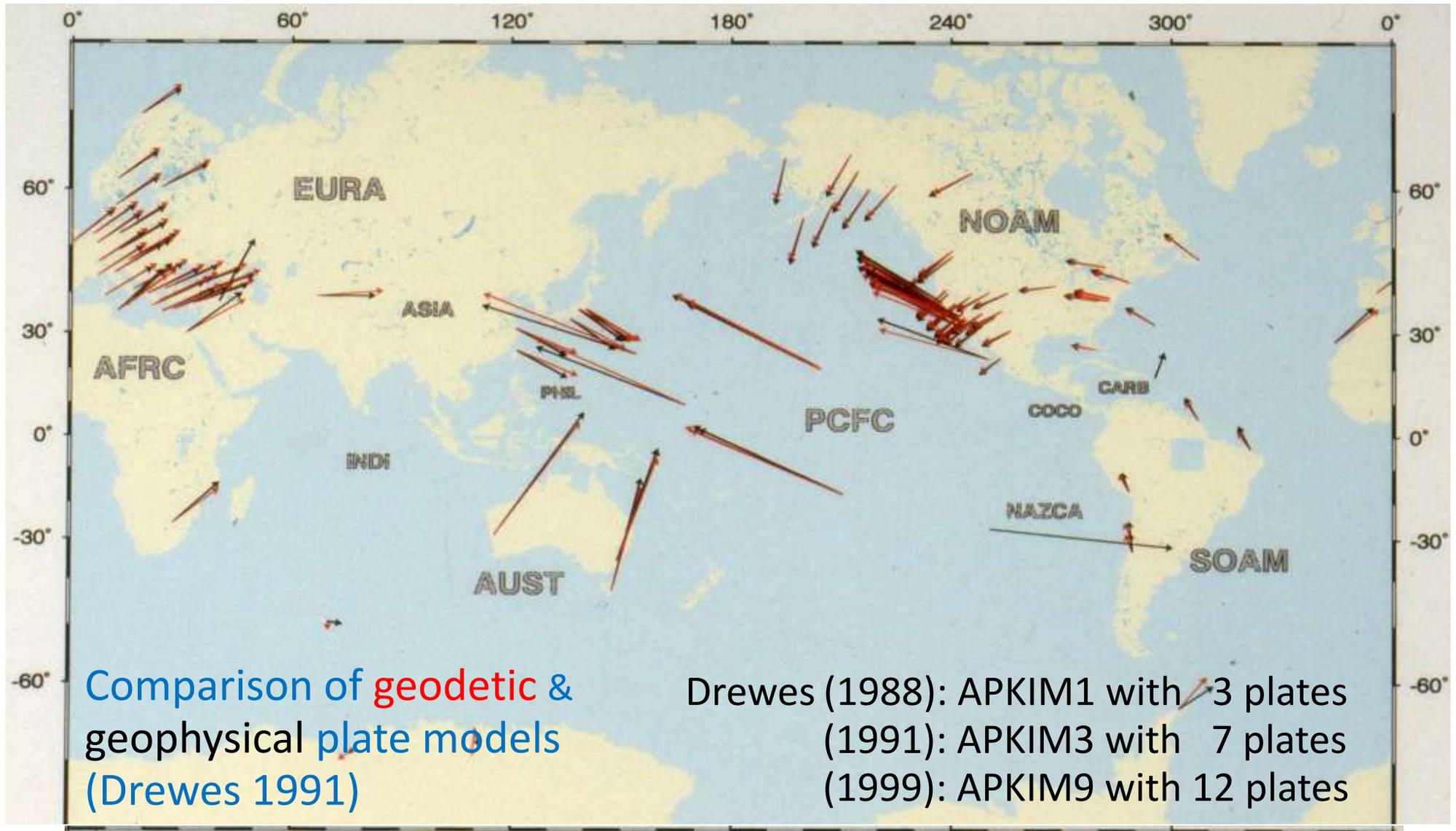
- Section I: **Positioning** (*general theme*)
 - *Commission X: Continental Networks*
- Section II: *Advanced Space Techniques (standing out from routine)*
 - *Commission VIII: Space Techniques for Geodynamics (CSTG)*
- Section III: *Determination of the Gravity Field (global and regional models)*
 - *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)*

1983 – 2003: IAG Services (Terrestrial Reference Frame)



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



First comparison of geophysical and geodetic plate models

2003 – 2019: The Global Geodetic Observing System (GGOS)

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*)

Geometry

IERS: Earth Rotation and
Reference Systems

ILRS: Laser Ranging

IVS: VLBI

IGS: GNSS

IDS: DORIS

Gravity

IGFS: Gravity Field

BGI: Gravimetry

ICGEM: Global Models

ISG: Geoid

IGETS: Earth Tides

IDEMS: Elevation Models

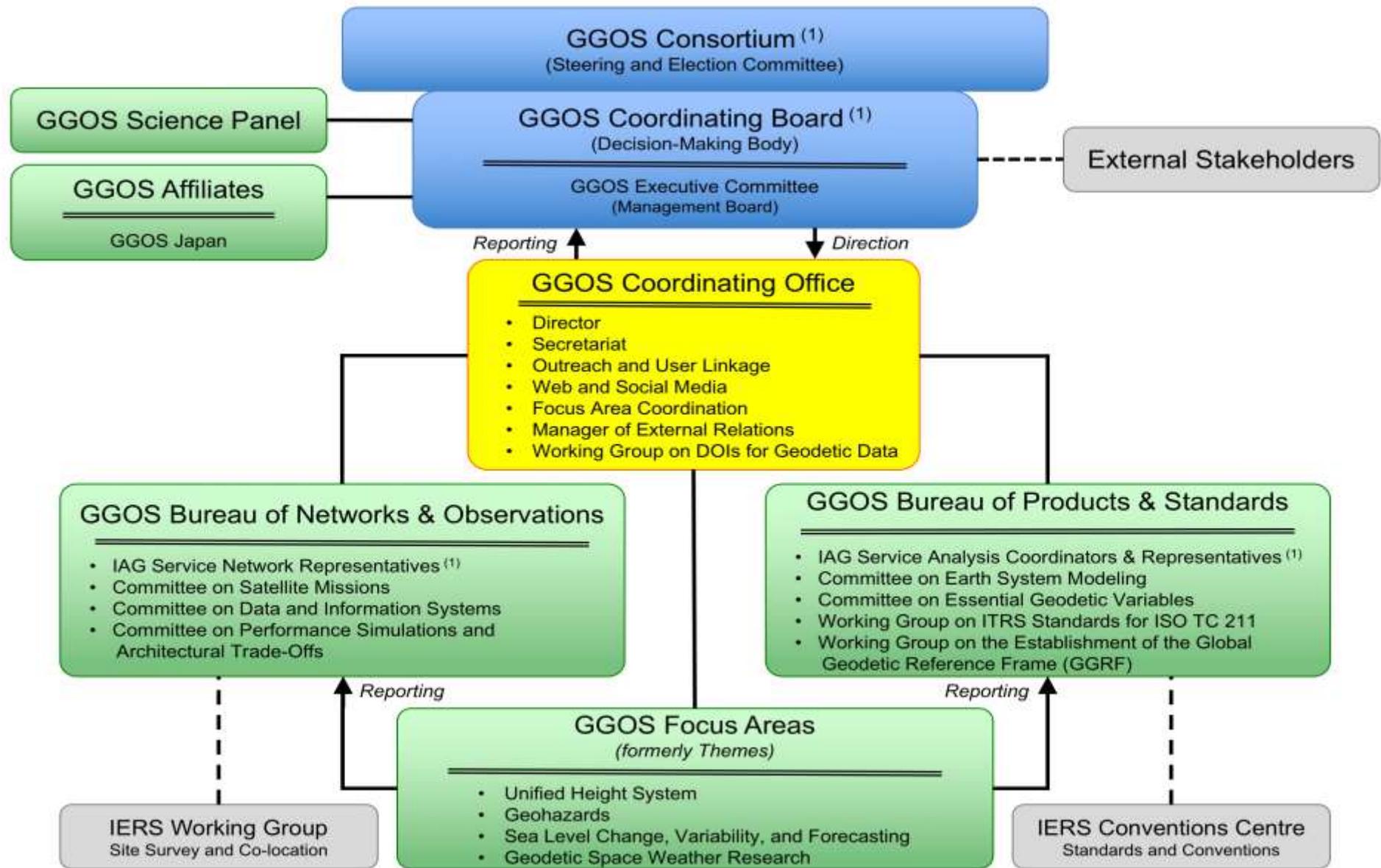
Overlapping

BIPM: Weights and
Measures

PSMSL: Mean Sea
Level

IAS: Satellite Altimetry
(planned)

2003 – 2019: The Global Geodetic Observing System (GGOS)



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



27th IUGG General Assembly
 Assemblée Générale de l'UGGI



International Union of Geodesy and Geophysics | Union Géodésique et Géophysique Internationale

IUGG Centennial | 1919-2019 | Centenaire de l'UGGI

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%) 537 (= 13 %)

1210 for joint symposia (= 25%) 715 (= 13 %)

~4000 participants 4231

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)
	S. Costa (Brazil)
	Y. Dang (China)

Members at Large:

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)

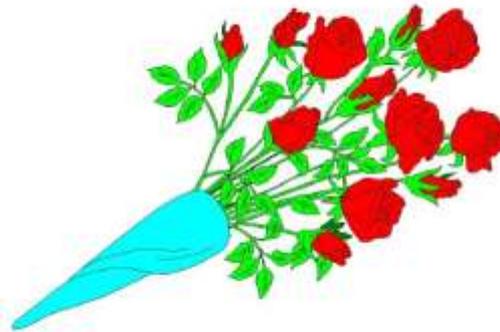
1933: Permanent Service of Mean Sea Level (PSMSL) together with IAPSO

1963: Space techniques: Satellite triangulation, SLR, VLBI

1994: International GNSS Service (IGS): Satellite orbits for all navigation

2003: Global Geodetic Observing System: Global change research

2019: Climate research, Marine Geodesy, Quantum Technology



Thank you very much for your attention!