The Global Geodetic Observing System (GGOS) - its Role and its Activities

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Meeting at the Geospatial Information Authority of Japan (GSI)
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Japanese Institutions have been Involved in International Space Geodesy Programs since early in the Space Program

Early SLR System at Tokyo Astronomical Observatory

Prof. Yoshihide Kozai
International Association of Geodesy (IAG) Central Objective
Geodetic Observation of Earth Processes

Processes in the solid Earth: geodynamics (deformation)
- point positioning
- surface scanning
- gravity measurement

Processes in the atmosphere and hydrosphere: water cycle
- variations of the rotation
- and the gravity field
The study, understanding and modelling of the effects of global change require:

- precise, consistent and stable reference frames,
- standards and models for the three geodetic parameter groups:
  - Earth geometry and kinematics,
  - Earth gravity field and dynamics,
  - Earth orientation and rotation.

The reference frame is the basis upon which we measure change over space, time, and evolving technology.

It must fulfill the following conditions:

- One order more precise than the magnitude of the phenomena to be analysed;
- Globally consistent and reliable (high precision at any place of the Earth’s surface);
- Stable over long periods (high precision at any time).
Global Geodetic Observing System (GGOS)

- Established by the IAG in 2004 to be its Observing System
- Vision: Advancing our understanding of the dynamic Earth system by quantifying our planet’s changes in space and time to:
  - Advance Earth Science (Earth, oceans, ice, atmosphere, etc)
  - Help us better understand the processes
  - Help us make intelligent societal decisions
- Mode of Operation: Works with the IAG components (IGS, ILRS, IVS, IDS, IGFS, IERS, IAG commissions, etc.) to provide the geodetic infrastructure necessary for monitoring the Earth System and Global Change:
  - observations needed to monitor, map, and understand changes in the Earth’s shape, rotation, and mass distribution;
  - the TERRESTRIAL REFERENCE FRAME and CELESTIAL REFERENCE FRAME for measuring and consistently interpreting key global change processes;
  - Other data products that require integration among measuring techniques: Unified height systems, Unified sea level model, Natural hazard warning tools, etc
Approaches of GGOS

- Combination and integration of all available observations, methods, ...
- Combine physical measurements and geometric techniques
- Improve our understanding of the interactions in "System Earth"
Geodesy is an essential input to several of the areas of focus of the Global Earth Observation System of Systems (GEOSS).

GGOS should benefit science and society by providing the foundations upon which advances in Earth science and applications are built.
IAG Bylaws 1(d)

“The Global Geodetic Observing System works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research.”

The vision of GGOS is

“Advancing our understanding of the dynamic Earth system by quantifying our planet’s changes in space and time.”
• **Geodesy** is the science of the Earth’s shape, gravity and rotation, including their evolution in time.

• **Techniques** used to observe the geodetic properties of the Earth provide the basis for the International Terrestrial Reference Frame (ITRF).

• The ITRF is the foundation for virtually all airborne, space-based, and ground-based Earth observations, and is fundamentally important for interplanetary spacecraft tracking and navigation.

The ITRF performance requirement for sea level measurement is 1 mm reference frame accuracy and 0.1 mm/year stability (NRC 2010).

Most stringent requirement on ITRF performance is sea level

Provided through the courtesy of Prof. Bernard Minster
GLOBAL Reference Frame
(Terrestrial and Celestial)

- Basis on which we measure changes over time, space, and evolving technology
- Most stringent requirement from sea level rise, but other applications are close behind
  - “accuracy of 1 mm, and stability at 0.1 mm/yr” (a factor of 5 - 10 improvement)
- Accessibility: 24 hours/day; worldwide
  - Users anywhere on Earth can position their measurements in the reference frame
- Space Segment:
  - LAGEOS, LARES, Etalon, GNSS, DORIS to define the reference frame
- Ground Segment (Core and Co-located ground sites):
  - Global distributed network of “modern technology”, co-located SLR, VLBI, GNSS, DORIS stations locally tied together with accurate site ties
  - Dense GNSS ground station network to distribute the frame globally to the users
- Reference Frame Formulation provided by the IERS from data provided by the IAG

<table>
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<tr>
<th>VLBI</th>
<th>SLR</th>
<th>GNSS</th>
<th>DORIS</th>
<th>Vector Tie</th>
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<td><img src="image3.png" alt="GNSS" /></td>
<td><img src="image4.png" alt="DORIS" /></td>
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What does each technique provide to the Reference Frame?

- SLR: Uniquely provides Earth Center of Mass;
- VLBI: Provides EOP parameters and the connection with the Celestial Reference Frame;
- SLR and VLBI independently provide Scale
- GPS: Global coverage and density
- DORIS: Global coverage
- Gravimetry: Help interpret station dynamics
Co-located SLR, VLBI, GNSS and DORIS (where available) so that their measurements can be related to sub-mm accuracy.

Why do we need multiple techniques?

- Each technique makes its measurements in a different way and therefore each measures something a little different:
  - Terrestrial (satellite) verses celestial (quasar) reference
  - Range verses range difference measurements
  - Broadcast up verses broadcast down
  - Radio verses optical
  - Active verses passive
  - Geographic coverage

- Each technique has different strengths and weaknesses
- The combination (Co-location) allows us to take advantage of these strengths and mitigate the weaknesses
Early simulation studies showed the we needed:

- ~32 globally distributed, well positioned, new technology, co-location sites will be required to define and maintain the reference frame;
- ~16 of these co-location stations must track GNSS satellites with SLR to calibrate the GNSS orbits which are used to distribute the reference frame.

- Design Initiative, but it a major Challenge
- Will require time, significant resources, and strong international participation
- Now we recognize that it will be a combination of core and colocation sites with apple geographic distribution.

Content: main arguments for GGOS

• Goals, achievements and tools of modern geodesy
• Earth science requirements for geodesy
• Maintaining a modern society (9 societal benefit areas)
• Future geodetic reference frames
• Future Global Geodetic Observing System (GGOS)
• GGOS 2020
Structure of the Global Geodetic Observing System

GGOS (Chair: Hansjörg Kutterer, Germany)

- GGOS Consortium
  - Steering and Election Committee
- GGOS Coordinating Board
  - Decision-Making Body
  - Management Board
- GGOS Coordinating Office
  - Director
  - Secretariat
  - Outreach and User Linkage
  - Web and Social Media
  - Focus Area Coordination
- GGOS Bureau of Networks & Observations
  - IAG Service Network Representatives
  - Working Group on Satellite Missions
  - Working Group on Data and Information Systems
  - Working Group on Performance Simulations and Architectural Trade-Offs
- GGOS Bureau of Products & Standards
  - IAG Service Analysis Coordinators & Representatives
  - Working Group on ITRS Standards
  - Working Group on Earth System Modeling
- GGOS Focus Areas (formerly Themes)
  - Focus Area 1: Unified Height System
  - Focus Area 2: Geohazards Monitoring
  - Focus Area 3: Sea Level Change, Variability, and Forecasting
- IERS Working Group
  - Site Survey and Co-location
- IERS Conventions Centre
  - Standards and Conventions

IAG Commissions

IAG Services
Stations Participating in the GGOS Affiliated Network
(Call for Participation)
Present and Projected CORE Network (all 4 techniques)

Remark: Global geodetic network does not always meet GGOS requirements

- Combination of new and legacy equipment
- Unequal network distribution
- Local ties of techniques
- Still systematic observational errors
- Need for ~10 times improvement in measurement accuracy
GGOS Site Requirements Document
(http://cddis.gsfc.nasa.gov/docs/GGOS_SiteReqDoc.pdf)

- Introduction and Justification
  - What is a Fundamental Station?
  - Why do we need the Reference Frame?
  - Why do we need a global network?
  - What is the current situation?
  - What do we need?

- Site Conditions
  - Global consideration for the location
  - Geology
  - Site area
  - Weather and sky conditions
  - Radio frequency and optical Interference
  - Horizon conditions
  - Air traffic and aircraft Protection
  - Communications
  - Land ownership
  - Local ground geodetic networks
  - Site Accessibility
  - Local infrastructure and accommodations
  - Electric power
  - Site security and safety
  - Local commitment
First Geospatial UN Resolution

- Global Geodetic Reference Frame (ITRF and ICRF combination) for Sustainable Development (GGRF) resolution - No. A/69/L.53 -
- adopted by the United Nations General Assembly on 26th of Feb, 2015
- co-sponsored by 52 Member States including Japan

... first resolution recognizing the importance of a globally coordinated approach to geodesy – the discipline focused on accurately measuring the shape, rotation and gravitational field of planet Earth.

The General Assembly resolution, A Global Geodetic Reference Frame for Sustainable Development, outlines the value of ground-based observations and remote satellite sensing when tracking changes in populations, ice caps, oceans and the atmosphere over time.
Japanese submission to the GGOS Call for Participation
- Submitted by Dr S Matsuzaka (Japanese GGOS WG Chair at that time)
  and approved by GGOS Bureau in 2014

Tsukuba (VLBI+GNSS+Gravimeter)
Ishioka (VLBI+GNSS)
Aira (VLBI+GNSS)
Chichijima (VLBI+GNSS+Gravimeter)
Shintotsukawa (VLBI+GNSS+Gravimeter)
Tanegashima (SLR+GNSS)
Simosato (SLR+GNSS)
Mizusawa (VLBI+GNSS+Gravimeter)
Koganei (SLR+VLBI+GNSS)
Kashima (VLBI+GNSS)
Syowa (VLBI+DORIS+Gravimeter)
Conclusions

- Challenges in Earth observation:
  - very small but significant trends need to be monitored (plate tectonics, sea level change, global isostatic adjustment (GIA), climate change, ...)
  - very fast events (earthquakes, tsunami, land slides, ...)
- Geodesy is a fundamental tool for exploration and understanding of our planet
- Global Geodetic Observing System (GGOS) is the geodetic contribution to Earth observation (within GEOSS, the Global Earth Observing System of Systems under GEO, the Group on Earth Observations)
- GGOS provides the metrological basis (in terms of reference frames, time and frequency transfer) for a multitude of other Earth observations
- Challenges in Earth observation require a lot of geodetic expertise
- Precise data and monitoring by geodesy is needed for many other Earth sciences
- A lot of new developments (technology, e.g. application of quantum physics for geodetic measurements, new extremely precise clocks, next space missions, micro satellites für geodesy etc.) offer many new tasks (and also jobs)
Summary

• Challenging program with very important science and societal benefits
• Technologies are maturing
• Global distribution is essential; success needs the enhanced networks that will depend on partnerships
• Very large opportunity for participation in analysis and scientific research
• Need to engage young scientists and students
Thank you for your attention!

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