GGOS and the Importance of the Combination of Space Techniques

Hansjörg Kutterer
Federal Agency for Cartography and Geodesy, Germany
Content

- Combination of space-geodetic techniques
- Combination examples
- Role of GGOS
- Conclusions
Combination: State of the Art
Current ITRF approach

- **Station co-locations** are the major connection between space-geodetic techniques
- Connection mainly via GNSS

**BUT:**
- Only few co-locations
- Insufficient global distribution
- Discrepancies with local ties

*from DTRF2008 (Seitz et al.)*
## Combined parameters: Current ITRF approach

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VLBI</th>
<th>GNSS</th>
<th>SLR</th>
<th>DORIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quasar coordinates</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station positions</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Satellite orbits: GNSS</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite orbits: spherical sat.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Satellite orbits: LEO</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nutation</td>
<td>X</td>
<td>(x)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UT1-UTC, LOD</td>
<td>X</td>
<td>lod</td>
<td>lod</td>
<td>lod</td>
</tr>
<tr>
<td>Polar motion</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Geocenter</td>
<td>(X)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-degree gravity field</td>
<td>(x)</td>
<td>X</td>
<td></td>
<td>(x)</td>
</tr>
<tr>
<td>Troposphere</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Combined parameters: Further possibilities

<table>
<thead>
<tr>
<th></th>
<th>VLBI</th>
<th>GNSS</th>
<th>SLR</th>
<th>DORIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quasar coordinates</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station positions</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Satellite orbits: GNSS</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Satellite orbits: spherical sat.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Satellite orbits: LEO</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Nutation</td>
<td>X</td>
<td></td>
<td>(x)</td>
<td></td>
</tr>
<tr>
<td>UT1-UTC, LOD</td>
<td>X</td>
<td>lod</td>
<td>lod</td>
<td>lod</td>
</tr>
<tr>
<td>Polar motion</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Geocenter</td>
<td></td>
<td>(x)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Low-degree gravity field</td>
<td></td>
<td>(x)</td>
<td></td>
<td>(x)</td>
</tr>
<tr>
<td>Troposphere</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Station co-locations

- All instruments have to be located at one site together
- „Local Ties“ are necessary as additional information
- Independent of the satellites tracked by each instrument
In both cases: Vectors of „Space Tie“ are needed

- Center-of-Mass -> microwave GNSS antenna
- Center-of-Mass -> Laser retro-reflector array
General aspects of the combination

- Observational point of view: usable infrastructure with technique ties
- Mathematical point of view: need for identical or mutually transformable parameters
- Standardizational point of view: unique constants, background models, etc.
- Organizational point of view: dedicated structures, workflows, resources
Gravity: Contribution of SLR

- Mean monthly gravity field variations (w.r.t. EGM2008)
- up to degree/order 10
- 9 spherical satellites: LAGEOS-1/2, Starlette, Stella, AJISAI, Beacon-C, Blits, Larets, LARES

from Sosnica et al., 2014: „Earth Rotation and Gravity Field Parameters from Satellite Laser Ranging“. Poster presentation at the ILRS Workshop 2014, Annapolis
Gravity: SLR and GNSS

from Thaller et al., 2013:
"Earth Rotation Parameters from Satellite Techniques“. Presented at the EGU General Assembly 2013, Vienna
German DFG Research Unit FOR 584: “Earth Rotation and Global Dynamic Processes“ (Lead: J. Müller)

Here: Joint project together with DGFI and TU Munich

Integration of ERP + gravity variations + data from geophysical models

Standards and conventions!

Metadata!
Results: ERP + GFC + Geophysical models

from A. Heiker (2013): Mutual validation of Earth orientation parameters, geophysical excitation functions, and second degree gravity field coefficients.
Role of GGOS: Motivation
Role of GGOS: Terms of Reference

The vision of GGOS is

“Advancing our understanding of the dynamic Earth system by quantifying our planet’s changes in space and time.”

The mission of GGOS is

- to provide the observations needed to monitor, map and understand changes in the Earth’s shape, rotation and mass distribution
- to provide the global frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications.
- to benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built.

GGOS strongly relies on the comprehensive combination of space-geodetic techniques … … but this does not complete the job!
Five major levels of instrumentation and objects to be observed

**Level 1**: terrestrial geodetic infrastructure;

**Level 2**: LEO satellite missions;

**Level 3**: GNSS and Lageos-type SLR satellites;

**Level 4**: planetary missions and geodetic infrastructure on Moon and planets;

**Level 5**: extragalactic objects.

Consistent spatial referencing as immanent condition / contribution

Source: Plag et al. (2009)
GGOS: Present state and next steps

- Strategic plan adopted in April 2014 ⇒ Strategic focus areas
  - Geodetic information and expertise
  - Global geodetic infrastructure ⇒ Implementation plans
  - Services, standards and support
  - Communication, education and outreach
- Structural enhancement of the GGOS organization (BNO, BSP, CO) ⇒ Implementation plans
- High-level GGOS Plenary Talk at IAG Scientific Assembly 2013
- Participation in GEO, CEOS, UN GGIM
Conclusions

- Thorough combination of space techniques (and others) is the feasible key to further relevant applications of Geodesy for science and society

- Ongoing activities
  - IAG: Services, GGOS ↔ Scientific Community together with National Agencies ↔ National Level / Regional Level
  - Establishment and maintenance of geodetic observatories – meeting GGOS requirements
  - Further development and adoption of standards and metadata
  - Scientific work as well as R&D work

- Needs
  - Official High-Tech Infrastructure with better global coverage
  - Strategic Partnerships (NMAs, Space Agencies, ...)
  - Coordinated Policies
  - Sustainable Funding

Inter-governmental coordination and support ⇒ UN GGIM !!!
Thank you for your kind attention!

Contact:
Bundesamt für Kartographie und Geodäsie
Richard-Strauss-Allee 11
60598 Frankfurt

Prof. Dr.-Ing. Hansjörg Kutterer
President
hansjoerg.kutterer@bkg.bund.de
www.bkg.bund.de
Tel. +49 (0) 69 6333-226