Contributions of Future SLR Networks to the Development of ITRF

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Global Geodetic Observing System (GGOS)

Official Component (Observing System) of the International Association of Geodesy (IAG) with the objective of:

Ensuring the availability of geodetic science, infrastructure, and products to support global change research in Earth sciences to:

- extend our knowledge and understanding of system processes;
- monitor ongoing changes; and
- increase our capability to predict the future behaviour.
GGOS consists of the following four components:

• Instrumentation - networks of observing stations, ground and space components

• Data infrastructure - communications, data centers, archive and access

• Data analysis and combination - research and analysis algorithms and processes, integrative approach

• Modeling and interpretation - observations improve models, interpretation towards improved understanding
Reference Frame

- Stable coordinate system through which we measure changes and link/integrate measurements over space (global to regional), time (decades) and rapidly evolving technologies.
- Realized by a global array of accurate, well distributed, stable set of station positions and velocities.
- Established and maintained by the global space geodetic networks.
- IAG Services provide the geodetic infrastructure necessary for observing, monitoring and modeling Earth system science and global change research,
- Scientific services form the organizational basis of GGOS.
Motivation

• Space techniques are indispensable for the development of the terrestrial reference frame and for geodetic metrology

• The current state-of-the-art does not meet science requirements due to poor area coverage and aging equipment

• To meet the stringent future requirements (e.g. GGOS), we need to design a new network and deploy modern hardware systems
• Future ITRF* should exhibit consistently and reliably accuracy and stability at the level of:

<1 mm in epoch position, and

< 0.1 mm/y in secular change

*Current performance: ~ 10 mm and ~ 1 mm/y
Why 1 mm / 0.1 mm/yr ?

For every 1 mm/yr Z-trend in the TRF origin, sea-level rates are affected by ~ 0.2 mm/yr

ITRF2005: 3.3 +/- 0.07 mm/yr

ML Rates (mm/yr)
1993-2007 = 3.33 ± 0.07 (MOG2D)
= 3.36 ± 0.10 (No IB)
First 7 years = 2.75 ±0.21 (MOG2D)
= 2.53 ±0.23 (No IB)
Last 7 years = 3.76 ±0.14 (MOG2D)
= 3.99 ±0.25 (No IB)

Beckley et al. (2007), GRL, Fig 4

Lemoine et al. (2008), EGU2008-A-11368
Multiple techniques to solve the puzzle

- High precision geodesy is very challenging
  - 0.1 mm/yr stability required for sea level monitoring
- Fundamentally different observations with unique capabilities
- Together provide redundancy, cross validation and increased accuracy for TRF
- Strength from improvement of techniques and integration of techniques

<table>
<thead>
<tr>
<th>Technique</th>
<th>VLBI</th>
<th>SLR</th>
<th>GPS</th>
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</thead>
<tbody>
<tr>
<td>Signal Source</td>
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<td></td>
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<tr>
<td>Celestial Frame UT1</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Scale</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Geocenter</td>
<td>No</td>
<td>Yes</td>
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<td>Geographic Density</td>
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<tr>
<td>Real-time</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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<tr>
<td>Decadal Stability</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
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Fundamental prerequisite: **Well-distributed, co-located network with accurate ties**
The ILRS Network

NORTH SITES: 16

SOUTH SITES: 7

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Selected SLR Stations Around the World

Hartebeesthoek, South Africa
TIGO, Concepcion, Chile
MGSLR, Greenbelt, MD USA
Matera, Italy
Riyadh, Saudi Arabia
TROs, China
Yarragadee, Australia
Tahiti, French Polynesia
Wettzell, Germany
Zimmerwald, Switzerland
MLRS, TX USA
Shanghai, China
Kashima, Japan
Future Space Geodetic Network
Network variants (32 ⇒ 8)

Next Generation NASA Networks  32 sites

Next Generation NASA Networks  24 sites

Next Generation NASA Networks  16 sites

Next Generation NASA Networks  08 sites
Simulation Results

<table>
<thead>
<tr>
<th>Network</th>
<th>3D Error [mm]</th>
</tr>
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<tbody>
<tr>
<td>8 Sites</td>
<td>1.9</td>
</tr>
<tr>
<td>16 Sites</td>
<td>1.6</td>
</tr>
<tr>
<td>24 Sites</td>
<td>1.2</td>
</tr>
<tr>
<td>32 Sites</td>
<td>1.1</td>
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</tbody>
</table>

**Network Offsets and Scale [mm]**

**Sixteen (16) Years of Data**

Network Origin and Scale Components

- Tx: Black
- Ty: Blue
- Tz: Green
- Scale: Red

Error values:
- 8 Sites: 0.13 ppb
- 16 Sites: 0.11 ppb
- 24 Sites: 0.08 ppb
- 32 Sites: 0.07 ppb
One-year Simulation Results

Relative EOP Error vs. Number of Sites

- X-pole
- Y-pole
- UT1

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Summary

• Origin and scale marginally controlled by a 24 site network; when extended to 32 sites, it approaches GGOS goals (1 mm)

• Orientation seems to be less dependent on the size of the network

• The effect of additional techniques on the quality of the TRF remains to be assessed

• Need to develop scenarios of “degradation” and “improvement” of nominal design parameters
Future Work

• We may have to consider improvement of our models, analysis techniques and our space segment (e.g. SLR targets) to improve TRF accuracy while keeping a reasonable network size to reach our goal.

• Our simulation process now runs on a faster CPU to allow a quicker turn-around of future cases (Columbia grid cluster).

• As we improve our turn-around time we plan to investigate scenarios with additional parameters varied (more satellites, different orbits, systematic errors, operational modes, etc.).