Reference frames and geodetic products

Daniela Thaller

*Introductory and Refresher Course on Satellite and Lunar Laser Ranging*

*Stuttgart, Germany, October 20, 2019*
Overview

▪ **The 3 pillars of geodesy and the reference frames:**
  • Geometry – Orientation – Gravity field
  • Contributions by SLR
  • Parameters for actual ITRF generation

▪ **SLR-based products generated within the ILRS:**
  • Organizational aspects
  • Characteristics of different products
  • Examples
The 3 pillars of geodesy and the reference frames:

- Geometry – Orientation – Gravity field
- Contributions by SLR
- Parameters for actual ITRF generation

SLR-based products generated within the ILRS:

- Organizational aspects
- Characteristics of different products
- Examples
The 3 Pillars of Geodesy

**Earth geometry and kinematics:**
Shape of the Earth and its variation

**Earth orientation and rotation:**
Earth rotation and its variation

**Earth gravitational field:**
Static (mean) and variable gravity field

- Requirement for integrated estimation:
  highly accurate, homogeneous, long-term stable reference frame
The 3 Pillars of Geodesy: Relationships

Earth Orientation

Celestial Reference Frame

Terrestrial Reference Frame

EOP
The 3 Pillars of Geodesy: Relationships

Earth Orientation

Celestial Reference Frame

Terrestrial Reference Frame

SLR: Satellite orbits as „quasi-inertial“ reference frame for a short time

EOP
Reference System and Reference Frame

Reference System

Geodetic Observations

Reference Frame

REALIZATION
The 3 Pillars of Geodesy: Contributions by SLR

**Contributions by SLR:**

1. **Geometry:**
   - Coordinates of SLR stations
   - Position variations due to, e.g., plate tectonics, loading deformation
   - Scale

2. **Earth Rotation:**
   - Polar motion
   - Length of Day (LOD)

3. **Gravity Field:**
   - Geocenter
   - Low-degree harmonics of Earth’s gravity field: depending on satellites
## Parameter Space and Actual ITRF Computation

<table>
<thead>
<tr>
<th>Parameter Space</th>
<th>GNSS</th>
<th>VLBI</th>
<th>SLR</th>
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<tbody>
<tr>
<td>Station coordinates + velocities</td>
<td>XG</td>
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Parameter Space and Actual ITRF Computation: ⇒ only few parameter types are included

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### Parameter Space and Actual ITRF Computation

**No Direct combination possible; Co-location sites and Local Ties are needed**

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The 3 pillars of geodesy and the reference frames:
  • Geometry – Orientation – Gravity field
  • Contributions by SLR
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SLR-based products generated within the ILRS:
  • Organizational aspects
  • Characteristics of different products
  • Examples
The ILRS – International Laser Ranging Service

- Under the umbrella of IAG (International Association of Geodesy)
- Integrated into the IERS as one of the Technique Centers
- Organizing product generation, data/product holding, exchange between individual groups, support new developments, exchange of knowledge
The ILRS – International Laser Ranging Service

Observing Sites

Observations

Analysis Centers (AC)

AC solutions for:
- Station positions
- Earth rotation parameter
- Satellite orbits
- Troposphere parameter ...

Combination Center

Combination of all individual AC contributions to one Service solution

Data base / Data Center
ILRS Analysis and Combination Centers
ILRS Analysis Centers: Software Packages used

- A broad variety of analysis software packages used among the Analysis Centers helps to reduce the „Analysis Noise“

<table>
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<th>Software Package</th>
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<tr>
<td>ASI, Italy</td>
<td>Geodyn</td>
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<tr>
<td>BKG, Germany</td>
<td>Bernese GNSS Software, SLR development version</td>
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<tr>
<td>DGFI-TUM, Germany</td>
<td>DOGS-OC</td>
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<td>ESA</td>
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<td>EPOS</td>
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<td>GRGS, France</td>
<td>GINS / Dynamo</td>
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SLR-based Products by the ILRS

- 7-day solutions = 7-day orbital arcs

- **Satellites** used for operational products:
  - LAGEOS, LAGEOS-2:
    - Orbital height ≈ 5.800 km
  - ETALON-1/-2:
    - Orbital height ≈ 19.000 km

- **Parameters** estimated:
  - Satellite orbits
  - Station coordinates
  - Earth rotation parameters: x-/y-pole, LOD
  - Range biases for selected stations
(1) **Operational products**

- **DAILY** products (= „Rapid“ product) are due 2 days after last observation day:
  - e.g. for the DAILY orbital arc Tuesday-Monday, the product needs to be delivered on Wednesday morning (UT)
- **WEEKLY** products (orbital arc Sunday - Saturday) are due on Wednesday

(2) **Special study products:**

- Estimating range biases to investigate potential systematic errors
- Inclusion of the LARES satellite
- Estimation of low-degree gravity field coefficients
- Impact of non-tidal loading

(3) **Re-analysis for ITRF generation** (e.g. input for ITRF2020)
ILRS Analysis Statistics per Orbital Arc
(from Luceri et al., 2014)
Geodetic Products by the ILRS

- **Station coordinates:**
  - DAILY
  - WEEKLY
  - via ITRF

- **Station velocities:**
  - via ITRF

- **ERPs:**
  - DAILY
  - WEEKLY

- **Satellite orbits:**
  - WEEKLY

- **Geocenter / Gravity field:** no official ILRS product yet
ILRS DAILY Solution Series: Scale

**Scale** w.r.t. actually used ITRF (using „Core Sites“):

0.3 – 2.0 ppb

Starting point of using ITRF2014 in SLR analysis
ILRS DAILY Solution Series: Polar motion

Polar motion w.r.t. IERS Bulletin A
Thank you for your kind attention!

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Current ITRF approach

Inter-technique Combination
DORIS + GNSS + SLR + VLBI

IGN, Paris
DGFI, München
JPL, Pasadena
ITRF2014 generation: ILRS Time Line

- AC submission
- Solution check
- Combination
- 1993-2013 ILRS Release
- AC submission 2014
- Check & Combination 1983 - 2014
- ILRS FINAL CONTRIBUTION
The organization and exchange between the ILRS Analysis and Combination Centers is done within the „ILRS Analysis Standing Committee“ (formerly „Analysis Working Group“)

- Define the guidelines for product generation
- Define next steps forward by organizing Pilot Projects

Led by the 2 Analysis Coordinators:
- Erricos Pavlis (JCET, US)
- Cinzia Luceri (ASI, Italy)

Meeting usually twice per year (EGU in April; ILRS Workshop in Oct/Nov)

Participation is open for any interested people
SLR data analysis: DAILY solution series

Global 3-D WRMS w.r.t. actually used ITRF (using „Core Sites“): 5 - 10 mm

Starting point of using ITRF2014 in SLR analysis
Consistency between AC contributions

wrms of SSC residuals wrt ILRSA (yearly running average)