Role and importance of the International Terrestrial Reference Frame (ITRF) for science and positioning applications

Zuheir Altamimi
Head of the IERS ITRF Product Center
Institut National de l’Information Géographique et Forestière
IGN, France
E-mail: zuheir.altamimi@ign.fr
UN-GGIM Objectives

• The promotion of global geospatial information to address key global challenges & to support improved decision-making;

• At the 2\textsuperscript{nd} Session of the Committee of Experts held in New York in August 2012 nine critical issues were identified, including:
  – future trends for geospatial information
  – development of a knowledge base
  – a global geodetic reference system
  – a global map for sustainable development
Background: need for a global terrestrial reference system (1/2)

• Positioning (determination of point positions or coordinates) is fundamental for
  – Earth science & Earth observation applications
  – Geospatial activities, navigation, civil engineering, agriculture, ...
  – Disaster management & reconstruction (Earthquake, Tsunami...)

• Coordinates are time dependent
  – Plate motion --> up to 10 cm/yr
  – Earthquake dislocation --> up to several meters

• To be truly useful, coordinates are (should be) expressed in a terrestrial reference system
Background: need for a global terrestrial reference system (2/2)

• Need for a global & unique/standard reference frame  --> ensure inter-operability

• GNSS is today’s best tool for positioning:
  – To support science and societal applications
  – Low-cost, easy to use, with up to few mm precision

• Need for Continuously Operating GNSS Core Stations, necessary for:
  – Access to the global reference frame
  – Variety of other geodetic & geospatial applications
What is a Reference Frame in practice?

• **Earth fixed/centred RF:** allows determination of station location/position as a function of time

• **It seems simple, but ... we have to deal with:**
  – Relativity theory
  – Forces acting on the satellite
  – The atmosphere
  – Earth rotation
  – Solid Earth and ocean tides
  – Tectonic motion
  – ...

• **Station positions and velocities are now determined with mm and mm/yr precision**
International Union of Geodesy and Geophysics (IUGG)
65 Member Countries (Adhering Bodies), 8 Associations

International Association of Geodesy (IAG)

Commission 1
Reference Frames

Commission 2
Gravity Field

Commission 3
Earth Rotation and Geodynamics

Commission 4
Positioning and Applications

Inter-Commission Committee on Theory (ICCT)

Services:
IERS
IGS
IGFS
BGI
ICET
BIPM
IAS
ILRS
IVS
IDS
ICGEM
IGeS
IDEMS
PSMSL
IBS

Global Geodetic Observing System (GGOS)

http://www.iag-aig.org
The International Terrestrial Reference Frame (ITRF)

- Established and maintained by the International Earth Rotation and Reference Systems Service (IERS)
- Numerical realization of the International Terrestrial Reference System (ITRS)
- Adopted by IAG & IUGG in 1991 & 2007 and by CGPM in 2011 for Earth science & timing applications
- Combination of VLBI, SLR, GNSS and DORIS TRFs
- Operated by the ITRS Center, hosted by IGN- France
- Based on co-location sites (see next)
- Updated every 3-5 years: ITRF88,...,2000,2005
- Current Version: ITRF2008
ITRF2008 Network

580 sites (920 stations)

492 IGS/GNSS sites

461 Sites North

118 Sites South
ITRF2008 Site Velocities:

time-span > 3 yrs, ($\sigma \sim 0.1 - 1$ mm/yr)

509 sites
Access to the ITRF and the IGS role

• Any GNSS network can easily be expressed in the ITRF using IGS products (orbit, clocks, ERP: all expressed in the ITRF)

• IGS/GNSS observations (RINEX files) & Products are publicly available

• IGS products (Orbits, Clocks and Earth Rotation Parameters) to be fixed in regional processing

• Geodetic/mathematical procedure to express a GNSS network in the ITRF is also available

• NMAs have access to scientific software packages
Processed IGS/GNSS sites, since 1994

652 sites

Time series:
Red < 5yrs (118), Blue 5-10yrs (138), Green 10-18yrs (396)
Regional & National Reference Systems/Frames

• IAG Commission 1 (Reference Frames) ==> Sub-Commission 1.3 (Regional Reference Frames):
  – EUREF/Europe: ETRS89
  – NAREF/North America: NAD83
  – SIRGAS/South America: SIRGAS
  – AFREF/Africa
  – APREF/Asia & Pacific
  – SCAR/Antarctica

• Regional Reference Frames: rely on the ITRF

• Many countries have redefined their geodetic systems to be compatible with/related to ITRF
EUREF Permanent Network (EPN)

EUREF Permanent Tracking Network
ITRF densification

ITRF2008 GNSS sites  Densification sites

Courtesy Juliette Legrand
GNSS associated reference systems/frames

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Ref. System/Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GPS (broadcast orbits)</td>
<td>WGS84</td>
</tr>
<tr>
<td>• GPS (precise IGS orbits)</td>
<td>ITRS/ITRF</td>
</tr>
<tr>
<td>• GLONASS</td>
<td>PZ-90</td>
</tr>
<tr>
<td>• GALILEO</td>
<td>ITRS/ITRF/GTRF</td>
</tr>
<tr>
<td>• COMPASS</td>
<td>CGCS 2000</td>
</tr>
<tr>
<td>• QZSS</td>
<td>JGS</td>
</tr>
<tr>
<td>• All are now aligned to the ITRF2008</td>
<td></td>
</tr>
<tr>
<td>• WGS84 ≈ ITRF at the decimeter level</td>
<td></td>
</tr>
<tr>
<td>• GTRF ≈ ITRF at the mm level</td>
<td></td>
</tr>
<tr>
<td>• σ-Position using broadcast ephemerides = 150 cm</td>
<td></td>
</tr>
</tbody>
</table>
Summary

• The ITRF
  – is more precise and accurate TRF available today
  – is the achievement of 30 years of international collaboration and investment of IAG services
  – needs to be maintained and improved over time

• GNSS and IGS publicly available products are essential in accessing the ITRF

• GNSS, regional & national reference frames rely on the availability of the ITRF

• The ITRF as a common standard ensures interoperability between geospatial information systems

• A UN-mandate for ITRF and its infrastructure?