Update on the International Terrestrial Reference Frame (ITRF)

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Goal & Challenge: determine locations & deformations with an improved precision, Everywhere & Anytime on Earth, to satisfy societal and science requirements

ITRF defining parameters: Origin, Scale & Orientation
Why is a Reference Frame needed?

• Precise Orbit Determination for:
  – GNSS: Global Navigation Satellite Systems
  – Other satellite missions: Altimetry, Oceanography, Gravity

• Earth Science & Societal Applications
  – Mean sea level variations
  – Hazard mitigation and tsunami warning
  – Plate motion and crustal deformation
  – Glacial Isostatic Adjustment (GIA)
  – …

• Geo-referencing applications: positioning, navigation, surveying…

• GNSS is today’s tool for all the above and for accessing the ITRF

==> Inter-Operability between GNSS is needed
But, GNSS Weaknesses for ITRF defining parameters:

- A GNSS Satellite does not “see” the Earth center of mass:
  - Geocenter components are absorbed by clock & other parameters
  - ==> Need more stable on-board clocks ($10^{-12}$), but at the satellite revolution period
  - ==> Need robust clock thermal conditions
  - ==> Add an accelerometer to each Satellite

- GNSS TRF Scale is under-determined
  - ==> Satellite antennas to be calibrated

- ITRF relies on SLR for the origin and on SLR & VLBI for the scale
ITRF Network

~ 600 sites

~ 500 GNSS sites

461 Sites North

118 Sites South
ITRF2008 Site Velocities: 
time-span > 3 yrs, ($\sigma \sim 0.1 – 1$ mm/yr)

\[ X(t) = X(t_0) + \dot{X}(t - t_0) \]
Next ITRF solution (ITRF2013)

• To be ready mid-2015
• Name might be changed to ITRF2014
• Expected Improvements & Developments:
  – Improved modeling of non-linear station motions
    • All kind of ruptures/discontinuities in the position time series
    • Seasonal signals
    • Modeling of post-seismic deformation
Position Residuals of Porto Velho, Brazil

Standard Solution

Ann+semi-ann removed

Velocity change

Horizontal: 0.2 mm/yr

Vertical: 1.7 (±0.15) mm/yr
Post-Seismic Deformation

Arequipa (Peru)
Arequipa Linear Function

Multiple velocities estimated

POST-FIT RESIDUALS

EAST (mm)

UP (mm)

AREQ 42202M005 Residuals

Lercier et al., 2014, submitted

Arequipa Parametric Model

One velocity estimated

POST-FIT RESIDUALS

EAST (mm)

UP (mm)

AREQ 42202M005 Residuals

ICG-9, Prague, 10-14 November, 2014
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)

• Publicly available:
  – IGS/GNSS observations (RINEX files) & Products
  – Geodetic/mathematical procedure to express a GNSS network in the ITRF is
  – Scientific software packages
Conclusion: Key Points

• GNSS provides high accuracy for positioning applications
• IAG/IERS provides the International Terrestrial Reference Frame (ITRF), the most accurate global RF available today;
• All GNSS positioning services rely on the ITRF availability, through IGS products;
• Implementation of GNSS-based Global, Regional & National reference frames depend & rely on the availability of the ITRF;

• ICG WG-D notes the progress of the alignment of GNSS associated reference frames to the ITRF
• ICG to acknowledge/support UN-GGIM initiative: need for UN mandate for the GGRF and its infrastructure
Geodetic Community Wishes Toward GNSS Providers

- Satellite antennas to be calibrated before launch
  ==> Ensure/improve the scale stability of the GNSS RF

- Add an accelerometer & ultra-stable clock to each GNSS satellite
  ==> Improve the geocenter determination by GNSS

- Provide data of subset of GNSS control stations to IGS for inclusion in the ITRF
  (cf. ICG-6 WG-D Recommendation)
  ==> (1) facilitate GNSS RF alignment to ITRF & 
  (2) ensure interoperability between GNSS RFs
GNSS satellite data for orbit dynamics modelling

- Surface geometry and dimensions
- Surface optical properties (or material types)
- Nominal attitude model
- Transmitted power in all signals (and direction if relevant)
- Solar panel construction information (thickness, conductivity, power draw)
- Position and power output of radiators
- Thermal properties of multi-layered insulation
More detailed list

• Structural data/drawings of the satellite, with dimensions (surface only – we don’t need the internals)
• Optical properties (reflectivity, specularity) of the surface materials
• Identification of what is covered in multi-layered insulation (MLI) or ‘thermal blankets’
• Attitude model of the satellite
• Power of all transmitted signals (note we don’t need to know anything about function of the signals, only which way they are pointed, and how much power is transmitted)
• Construction data of the solar panel (material types, thickness, conductivity, surface properties – reflectivity, specularity, emissivity, power draw from the panel)
Thank you